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On-line curator: Glenn Robb
FOUR EASY WAYS TO USE THIS CATALOG

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

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

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

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

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

@ DIVISIONS, SUBSIDIARIES. Page 4 contains brief data about equipment available from, and communications with Dymec, a Division of Hewlett-Packard Co. (see also pages 193-210), and Palo Alto Engineering Company, a subsidiary.

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

COMMUNICATING WITH HEWLETT-PACKARD
Mail: 1501 Page Mill Road, Palo Alto, California, U. S. A.
TWX: PAL AL 02.
Cable: HEWPACK

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

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

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<tr>
<td>-hp-120A</td>
<td>General laboratory and production measuring</td>
<td>DC to 200 KC</td>
<td>-</td>
<td>$450.00</td>
<td>16-18</td>
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<tr>
<td>-hp-122A</td>
<td>General laboratory and production measuring</td>
<td>DC to 200 KC — Dual trace</td>
<td>-</td>
<td>455.00</td>
<td>16-19</td>
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<tr>
<td>-hp-128B</td>
<td>General laboratory and production testing</td>
<td>DC to 300 KC — High sensitivity</td>
<td>-</td>
<td>600.00</td>
<td>20, 21</td>
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<tr>
<td>-hp-130A</td>
<td>General laboratory high frequency and TV work</td>
<td>DC to 10 MC — Plug-in vertical amplifiers</td>
<td>-</td>
<td>1,300.00</td>
<td>22, 23</td>
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<td>-hp-151/B/154A</td>
<td>Plug-ins for 150A</td>
<td>DC to 10 MC — High sensitivity</td>
<td>-</td>
<td>-</td>
<td>22, 23</td>
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<tr>
<td>-hp-162B</td>
<td>Militarized general duty oscilloscope</td>
<td>DC to 15 MC — plug-in versatility</td>
<td>-</td>
<td>1,600.00</td>
<td>24-27</td>
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<tr>
<td>-hp-162D</td>
<td>Dual trace plug-in for 160B, 170A</td>
<td>20 mv/cm, high stability</td>
<td>-</td>
<td>350.00</td>
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<tr>
<td>-hp-162F</td>
<td>Fast rise amplifier for 160B, 170A</td>
<td>0.05 v/cm, dc to 30 MC</td>
<td>-</td>
<td>145.00</td>
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<tr>
<td>-hp-162X</td>
<td>Marker generator plug-in for 160B, 170A</td>
<td>Time markers 0.1-10 usec</td>
<td>-</td>
<td>120.00</td>
<td>24-27</td>
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<tr>
<td>-hp-164C</td>
<td>Display scanner for 160B, 170A</td>
<td>Sampling unit for X-Y recording</td>
<td>-</td>
<td>300.00</td>
<td>24-27</td>
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<td>-hp-164D</td>
<td>Sweep delay generator for 160B, 170A</td>
<td>Main sweep, delayed sweep, main sweep, delayed or mixed</td>
<td>-</td>
<td>325.00</td>
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<td>-hp-170A</td>
<td>Militarized high frequency oscilloscope</td>
<td>DC to 10 MC; dual plug-in versatility</td>
<td>2,160.00</td>
<td>24-27</td>
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<tr>
<td>-hp-185A</td>
<td>Sampling oscilloscope for very fast circuits</td>
<td>DC to 1,000 MC; 5° CRT</td>
<td>-</td>
<td>2,500.00</td>
<td>28-30</td>
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<tr>
<td>-hp-187B</td>
<td>Dual trace plug-in for 150A</td>
<td>16 mv/cm to 200 mv/cm</td>
<td>-</td>
<td>1,000.00</td>
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<tr>
<td>-hp-194A</td>
<td>Oscilloscope camera for all -hp- scopes</td>
<td>-</td>
<td>-</td>
<td>460.00</td>
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## Oscillators—0.008 cps to 10 MC

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<th>Instrument</th>
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<tr>
<td>-hp-202AB</td>
<td>Audio tests</td>
<td>20 cps to 40 KC</td>
<td>1 watt/24.3 v</td>
<td>$165.00</td>
<td>36, 37</td>
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<tr>
<td>-hp-200CD</td>
<td>Subsonic through Low rf tests</td>
<td>5 cps to 600 KC</td>
<td>160 mv or 10 v/600 ohms; 20 v open circuit</td>
<td>195.00</td>
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<td>-hp-201C</td>
<td>Interpolation, frequency measurements</td>
<td>6 cps to 6 KC</td>
<td>160 mv/10 v</td>
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<td>-hp-202A</td>
<td>Driving -hp-79A</td>
<td>5 cps to 600 KC</td>
<td>3 v rms into 50 ohms</td>
<td>230.00</td>
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<td>-hp-206C</td>
<td>Telemetry, carrier current tests</td>
<td>250 cps to 100 KC</td>
<td>160 mv or 10 v/600 ohms</td>
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<td>-hp-201/2C</td>
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<td>-hp-201A</td>
<td>Low frequency measurements</td>
<td>0.068 to 1200 cps</td>
<td>28 mw or 0.1 v/4000 ohms</td>
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<td>-hp-215C</td>
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<td>1 cps to 1000</td>
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<td>-hp-224B</td>
<td>Battery operated portable, floating output</td>
<td>5 cps to 500 KC</td>
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<td>-hp-225AG</td>
<td>High power audio tests, gain measurements</td>
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<td>-hp-236A</td>
<td>High quality, high accuracy audio tests</td>
<td>20 cps to 100 KC</td>
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<td>-hp-356A</td>
<td>Audio sweep generation</td>
<td>200 mHz to 10000 Hz</td>
<td>160 mv or 10 v/600 ohms</td>
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<td>-hp-356A</td>
<td>Carrier oscillator — main tests</td>
<td>50 cps to 1000</td>
<td>3 v/600 ohms</td>
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## Voltmeters and Ammeters—DC to 1,000 MC

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<td>Wide range ac measurements; High sensitivity</td>
<td>10 cps to 4 MC</td>
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<td>High resolution, wide range ac measurements</td>
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<td>10 mohms</td>
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<td>-hp-401A</td>
<td>Battery operated portable; fast accurate, hum-free</td>
<td>1 cps to 1 MC</td>
<td>1 mv, 20 pf, 50 ohms</td>
<td>275.00</td>
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<td>-hp-405B/CR</td>
<td>Digital display of dc voltages</td>
<td>DC</td>
<td>3 digits to 999 &amp; automatic range</td>
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<td>650.00</td>
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<td>-hp-410B</td>
<td>Audio, rf, VHF measurements; ac; dc; ranges; resistances</td>
<td>DC; ac— 20 cps to 700 MC</td>
<td>1 to 300 v AC, 1 to 1,000 v DC</td>
<td>DC — 122 mohms; ac—15 mohms/1.5 pf</td>
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<td>-hp-411A</td>
<td>HF millivoltmeter</td>
<td>500 KC to 1 GC</td>
<td>10 mv to 10 v</td>
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<td>-hp-412A</td>
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<td>-hp-425A</td>
<td>Low dc voltages and current</td>
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<td>10 pf to 1 v</td>
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<td>-hp-428A/B</td>
<td>DC current measurements</td>
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<td>-hp-466A</td>
<td>AC Current Probe</td>
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<td>Converts amps to v for direct current readings on scope, VTVM</td>
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<td>-hp-467A</td>
<td>AC-to-DC converter</td>
<td>50 cps to 550 KC</td>
<td>1 to 200 v AC, 1 to 1,000 v AC</td>
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<td>-hp-462A-475A</td>
<td>Voltmeter Accessories, including Dividers, Multipliers, Shunt Resistors and Connectors</td>
<td>50 to 550 KC</td>
<td>1 to 200 v AC</td>
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<td>-hp-736AR</td>
<td>Voltmeter Calibrator</td>
<td>DC; 400 cps site wave</td>
<td>Works into 3 to 10 mohms</td>
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<td>Frequency Response Test Set</td>
<td>5 cps to 10 MC (with 2020R)</td>
<td>3 v output</td>
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<td>-hp-2212/2111</td>
<td>Voltage-to-Frequency Converter</td>
<td>10 KC/100 KC</td>
<td>0.1 to 1,000</td>
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<td>-hp-2401</td>
<td>Integrating Digital Voltmeter</td>
<td>DC</td>
<td>0.1 to 1,000</td>
<td>1 mohm</td>
<td>3,759.00</td>
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<td>-hp-2410</td>
<td>Multimeter</td>
<td>10 KC</td>
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<td>1 mohm</td>
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## Distortion, Wave Form Analyzers—20 cps to 50 KC

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<td>-hp-302A</td>
<td>Waveform analyzer</td>
<td>20 cps to 55 KC</td>
<td>Measuring range 30 µv to 300 v oscillator-tuned voltmeter</td>
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<td>-hp-330B/C/D</td>
<td>Audio distortion; AM, PM monitor</td>
<td>20 cps to 20 KC</td>
<td>Includes input amplifier, VTVM</td>
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* Rack mounted instrument available for $5.00 extra. ** Rack mounted instrument available for $10.00 extra.
### Frequency Measuring, Monitoring Equipment

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<tr>
<td>AG-100E</td>
<td>Frequency Standard</td>
<td>Establish standard frequencies; calibrate, measure time</td>
<td>6 sine 16 cps to 1 MC; 4 pulse, 16 cps to 10 KC</td>
<td>Stability 1/5° per week Timing comb</td>
<td>$925.00</td>
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<tr>
<td>AG-101A</td>
<td>1 MC Time Base</td>
<td>1 MC (fixed)</td>
<td>Stability 1/5° per week</td>
<td>$500.00</td>
<td>125</td>
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<tr>
<td>AG-103AR</td>
<td>Quartz Oscillator</td>
<td>Frequency and time standards</td>
<td>1 MC and 100 KC (fixed)</td>
<td>Stability 1/5° per day</td>
<td>$2,500.00</td>
</tr>
<tr>
<td>AG-104AR</td>
<td>Quartz Oscillator</td>
<td>Frequency and time standards</td>
<td>5 MC, 1 MC and 100 KC (fixed)</td>
<td>Stability 1/10° per day</td>
<td>$3,250.00</td>
</tr>
<tr>
<td>AG-113AR</td>
<td>Frequency Divider and Clock</td>
<td>Adjustable, standards; comparisons</td>
<td>100 KC Input</td>
<td>$2,750.00</td>
<td>122</td>
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<td>AG-114BR</td>
<td>Time Comparator</td>
<td>Time comparisons in time standards</td>
<td>Provides 0 to 999 msc delay in one msc step</td>
<td>$1,200.00</td>
<td>123</td>
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<td>AG-500BC</td>
<td>Electronic Frequency Meter</td>
<td>Rapid frequency measurements</td>
<td>3 cps to 100 KC, 180 000,000 rpm</td>
<td>9 ranges 1%, -2%, accuracy, Input 0.2 to 250 volts</td>
<td>100.00</td>
</tr>
<tr>
<td>AG-506A</td>
<td>Optical Tachometer Pickup</td>
<td>Rps and rpm measurements</td>
<td>180 to 300,000 rpm</td>
<td>Phototube and light source; output 1 v rms</td>
<td>$150.00</td>
</tr>
<tr>
<td>AG-508DA-D</td>
<td>Tachometer Generators</td>
<td>Shaft speed measurement</td>
<td>30 to 40,000 rpm</td>
<td>Output 60, 100, 120, 240 cycles/sec</td>
<td>$125.00</td>
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<tr>
<td>AG-520A</td>
<td>Nuclear Scaler</td>
<td>For counting high-rate pulses</td>
<td>Capacity 100 counts in 2 decades, 1,000,000 pps counting rate</td>
<td>100:1 divider for operation of low speed scalers</td>
<td>$700.00</td>
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<td>AG-621C, D, E Industrial Electronic Counters</td>
<td>Measure frequency, speed, elapsed time</td>
<td>1 cps to 120 KC</td>
<td>Direct reading, good accuracy, 4 or 5 place in-line or columnar readout</td>
<td>$450.00</td>
<td>99</td>
</tr>
<tr>
<td>AG-626B</td>
<td>Electronic Counter</td>
<td>Frequency, period, time interval measurements</td>
<td>10 cps to 120 KC</td>
<td>6 digit nixie stability 1/10°/week</td>
<td>$915.00</td>
</tr>
<tr>
<td>AG-623C</td>
<td>Electronic Counter</td>
<td>Frequency, period, time interval</td>
<td>10 cps to 120 KC</td>
<td>6 digit nixie stability 1/10°/week</td>
<td>$1,575.00</td>
</tr>
<tr>
<td>AG-530C</td>
<td>Electronic Counter</td>
<td>Frequency, period, time interval</td>
<td>10 cps to 120 KC</td>
<td>6 digit nixie stability 1/10°/week</td>
<td>$915.00</td>
</tr>
<tr>
<td>AG-532D</td>
<td>Electronic Counter</td>
<td>Frequency, period, time interval</td>
<td>10 cps to 120 KC</td>
<td>6 digit nixie stability 1/10°/week</td>
<td>$1,575.00</td>
</tr>
<tr>
<td>AG-537/5312</td>
<td>Transistorized Counters</td>
<td>Measures frequency, period, ratio</td>
<td>2 cps to 300 KC</td>
<td>5 digit resolution, transistorized</td>
<td>$1,175.00</td>
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<tr>
<td>AG-533C</td>
<td>Transistorized Counter</td>
<td>Measures frequency, period, ratio</td>
<td>2 cps to 120 KC</td>
<td>6 digit resolution, transistorized</td>
<td>$1,300.00</td>
</tr>
<tr>
<td>AG-537C</td>
<td>Time Interval Counter</td>
<td>Measures precise time interval</td>
<td>10 nanoseconds to 1 sec</td>
<td>7 digits, 10 ns resolution 10°/high</td>
<td>$110</td>
</tr>
<tr>
<td>AG-540C</td>
<td>Frequency Counter</td>
<td>Measure, period, measurements</td>
<td>10 cps to 10.1 MC (Freq.), 10 cps to 100 KC (Period)</td>
<td>5/10° stability, digital display tube readout</td>
<td>$2,400.00</td>
</tr>
<tr>
<td>AG-524D</td>
<td>Frequency Counter</td>
<td>Frequency, period, measurements</td>
<td>10 cps to 10.1 MC (Freq.), 10 cps to 100 KC (Period)</td>
<td>5/10° stability, decade counter readout</td>
<td>$2,150.00</td>
</tr>
<tr>
<td>AG-525, A, B, C Plug-ins for 524</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>105, 106</td>
</tr>
<tr>
<td>AG-526, A, B, C, D Plug-ins for 524</td>
<td>Video, amplifier, time interval unit, period divider, phase unit</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>105, 106</td>
</tr>
<tr>
<td>AG-547B</td>
<td>Frequency Counter</td>
<td>Frequency measurements</td>
<td>10 KC to 12.4 GC</td>
<td>Extends range of 54 to 12.4 GC</td>
<td>$850.00</td>
</tr>
<tr>
<td>AG-506A, 516B</td>
<td>Digital Recorders</td>
<td>Record counter measurements</td>
<td>Sine of counter</td>
<td>5 counts per second; 11 digit parallel entry</td>
<td>$1,325.00</td>
</tr>
<tr>
<td>AG-622C</td>
<td>Digital Recorder</td>
<td>Records kilocolumns of digital information</td>
<td>Max. 5 prints per second</td>
<td>111, 116</td>
<td></td>
</tr>
<tr>
<td>AG-550A</td>
<td>Digital Recorder</td>
<td>Digital printer for custom applications</td>
<td>Max. 8 prints per second</td>
<td>$600.00</td>
<td>117, 116</td>
</tr>
<tr>
<td>AG-570A/571B</td>
<td>Digital Clocks</td>
<td>Adds time of day information to AG-50A or 516B</td>
<td>-</td>
<td>-</td>
<td>114, 115</td>
</tr>
<tr>
<td>AG-P032</td>
<td>Harmonic Mixer</td>
<td>Beat frequency mixer</td>
<td>Extends 400 range to 18.0 GC</td>
<td>100 mw max. Input; 0.1 v min. output</td>
<td>$250.00</td>
</tr>
<tr>
<td>AG-94A</td>
<td>Harmonic Mixer</td>
<td>Beat frequency mixer</td>
<td>2 to 12.4 GC</td>
<td>100 mw max. Input; 0.5 v min. output</td>
<td>$150.00</td>
</tr>
<tr>
<td>DY-350A</td>
<td>Computing Counter</td>
<td>Measures in desired engineering units</td>
<td>-</td>
<td>Variable gate time</td>
<td>$1,830.00</td>
</tr>
<tr>
<td>DY-350E</td>
<td>Photoelectric Tachometer</td>
<td>Shaft speed measurement</td>
<td>0-10,000 rpm</td>
<td>Very low friction</td>
<td>-</td>
</tr>
</tbody>
</table>

### Regulated Power Supplies

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Primary Uses</th>
<th>Range</th>
<th>Regulation: no load to full load</th>
<th>Price</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG-711A</td>
<td>General Purpose, metered output</td>
<td>0 to 600 v dc @ 100 ma</td>
<td>± 0.5% or 1 v</td>
<td>$250.00</td>
<td>54</td>
</tr>
<tr>
<td>AG-712B</td>
<td>General Purpose, metered output</td>
<td>0 to 300 v dc @ 200 ma, blc, (fixed)</td>
<td>± 50 mv</td>
<td>$390.00</td>
<td>55</td>
</tr>
<tr>
<td>AG-715A</td>
<td>Low power klystron</td>
<td>-250 to -600 v dc</td>
<td>± 1%</td>
<td>$325.00</td>
<td>58</td>
</tr>
<tr>
<td>AG-721A</td>
<td>Low power transistors</td>
<td>0 to 30 v dc @ 150 ma</td>
<td>± 0.3% or 30 mv</td>
<td>$145.00</td>
<td>56</td>
</tr>
<tr>
<td>AG-722AR</td>
<td>High current transistors</td>
<td>0 to 40 v dc @ 2 amps</td>
<td>± 5 mv</td>
<td>$525.00</td>
<td>57</td>
</tr>
<tr>
<td>AG-723A</td>
<td>Programmed voltages for systems</td>
<td>0 to 40 v dc @ 500 ma</td>
<td>± 20 mv</td>
<td>$225.00</td>
<td>56</td>
</tr>
<tr>
<td>AG-724BR</td>
<td>Power frequency, time standards</td>
<td>24 v dc @ 100 ma 48 hr standby capacity</td>
<td>-</td>
<td>-</td>
<td>124</td>
</tr>
<tr>
<td>AG-725AR</td>
<td>Power frequency, time standards</td>
<td>24 v dc @ 100 ma 6 hr standby capacity</td>
<td>-</td>
<td>-</td>
<td>124</td>
</tr>
</tbody>
</table>

Δ Rack mounted instrument available for $15.00 less.  ■ Rack mounted instrument available for $25.00 less.  *Rack mounted instrument available for $50.00 extra.
### Square Wave, Pulse, and Digital Delay Generators

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Primary Uses</th>
<th>Frequency Range</th>
<th>Characteristics</th>
<th>Price</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>-hp 211A</td>
<td>Square wave</td>
<td>1 cps to 1 MC</td>
<td>Output -3.5 v p-p across 75 ohms and -27 v p-p across 400 ohms</td>
<td>$325.00</td>
<td>50</td>
</tr>
<tr>
<td>-hp 212A</td>
<td>Pulse</td>
<td>50 to 5,000 pps, 0.02 usec rise time</td>
<td>Pulse length 0.37 to 10 usec, output 50 v to 50 ohm load</td>
<td>$600.00△</td>
<td>51</td>
</tr>
<tr>
<td>-hp 218AR</td>
<td>Digital delay</td>
<td>—</td>
<td>Time interval 1 to 10,000 usec, adjustable in 1 sec steps</td>
<td>$2,000.00</td>
<td>52, 53</td>
</tr>
<tr>
<td>-hp 219A/B/C</td>
<td>Dual trigger, pulse, duration generators for 211A</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Frequency Range</th>
<th>Characteristics</th>
<th>Price</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>-hp 606A</td>
<td>50 KC to 45 MC</td>
<td>Output 0.1 v to 3 v into 50 ohm load, constant output impedance, versatile modulation</td>
<td>$1,350.00△</td>
<td>132, 133</td>
</tr>
<tr>
<td>-hp 608C</td>
<td>10 to 400 MC</td>
<td>Output 0.1 v to 1 v into 50 ohm load, AM, pulse, or CW modulation, Direct calibration</td>
<td>$1,100.00**</td>
<td>134, 135</td>
</tr>
<tr>
<td>-hp 608D</td>
<td>10 to 420 MC</td>
<td>Output 0.1 v to 0.5 v into 50 ohm load, AM, pulse, or square wave modulation, Direct calibration</td>
<td>$1,300.00**</td>
<td>136, 137</td>
</tr>
<tr>
<td>-hp 612A</td>
<td>450 to 1,220 MC</td>
<td>Output 0.1 v to 0.1 v into 50 ohm load, Pulse, CW or FM modulation, Direct calibration</td>
<td>$1,900.00**</td>
<td>138, 139</td>
</tr>
<tr>
<td>-hp 614A</td>
<td>800 to 2,100 MC</td>
<td>Output 0.1 v to 0.1 v into 50 ohm load, Pulse, CW or FM modulation, Direct calibration</td>
<td>$1,900.00**</td>
<td>138, 139</td>
</tr>
<tr>
<td>-hp 616B</td>
<td>1,800 to 4,000 MC</td>
<td>Output 0.1 v to 0.1 v into 50 ohm load, Pulse, CW or FM modulation, Direct calibration</td>
<td>$1,900.00**</td>
<td>138, 139</td>
</tr>
<tr>
<td>-hp 618B</td>
<td>3,000 to 7,400 MC</td>
<td>Output 0.1 v to 0.022 v into 50 ohm load, Pulse, CW, FM or square wave modulation, Direct calibration</td>
<td>$2,150.00**</td>
<td>140, 141</td>
</tr>
<tr>
<td>-hp 620A</td>
<td>7,000 to 11,000 MC</td>
<td>Output 0.1 v to 0.022 v into 50 ohm load, Pulse, FM or square wave modulation, Direct calibration</td>
<td>$2,250.00**</td>
<td>140, 141</td>
</tr>
<tr>
<td>-hp 623B</td>
<td>5,925 to 7,725 MC</td>
<td>Output 2 v to 2,220 v into 50 ohm load, Pulse, FM or square wave modulation, Direct calibration</td>
<td>$3,000.00**</td>
<td>142, 143</td>
</tr>
<tr>
<td>-hp 624C</td>
<td>8,500 to 10,000 MC</td>
<td>Output 2 v to 2,220 v into 50 ohm load, Pulse, FM or square wave modulation, Direct calibration</td>
<td>$3,150.00**</td>
<td>143, 144</td>
</tr>
<tr>
<td>-hp 625A</td>
<td>15 to 21 GC</td>
<td>Output 10 dbm to -60 dbm, Pulse, FM, or square wave modulation, Direct calibration</td>
<td>$1,800.00**</td>
<td>144, 145</td>
</tr>
<tr>
<td>-hp 628A</td>
<td>18 to 26, 26.5 to 40 GC</td>
<td>Output 10 dbm to -60 dbm, Pulse, FM, or square wave modulation, Direct calibration</td>
<td>$1,800.00**</td>
<td>144, 145</td>
</tr>
<tr>
<td>-hp 629A</td>
<td>21 to 26 GC</td>
<td>Frequency Doubler</td>
<td>$5,000.00</td>
<td>146, 147</td>
</tr>
</tbody>
</table>

### Swept Frequency Oscillators – 1 to 18.0 GC

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Frequency Range</th>
<th>Characteristics</th>
<th>Price</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>-hp 422C</td>
<td>1 to 2 GC</td>
<td>Electromagnetically swept, variable sweep width and rate, Pulse, square wave, FM and AM modulation</td>
<td>$2,000.00△</td>
<td>144, 146</td>
</tr>
<tr>
<td>-hp 462C</td>
<td>2 to 4 GC</td>
<td></td>
<td>$2,000.00△</td>
<td>144, 146</td>
</tr>
<tr>
<td>-hp 483C</td>
<td>4 to 8.1 GC</td>
<td></td>
<td>$2,900.00△</td>
<td>144, 146</td>
</tr>
<tr>
<td>-hp 486C</td>
<td>7.0 to 11.0 GC</td>
<td></td>
<td>$2,900.00△</td>
<td>144, 146</td>
</tr>
<tr>
<td>-hp 586C</td>
<td>8.2 to 12.4 GC</td>
<td></td>
<td>$2,900.00△</td>
<td>144, 146</td>
</tr>
<tr>
<td>-hp 487C</td>
<td>12.4 to 18.0 GC</td>
<td></td>
<td>$3,400.00△</td>
<td>144, 146</td>
</tr>
</tbody>
</table>

### Other Instruments and Accessories

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Primary Uses</th>
<th>Frequency Range</th>
<th>Characteristics</th>
<th>Price</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DY-33BR</td>
<td>FM Monitor</td>
<td>88 MC to 108 MC</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$1,650.00</td>
<td>210</td>
</tr>
<tr>
<td>DY-33ER</td>
<td>TV Monitor</td>
<td>2 to 83 MC</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$2,050.00</td>
<td>210</td>
</tr>
<tr>
<td>-hp 355A/B</td>
<td>Attenuator</td>
<td>DC to 100 KHz</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$1,100.00**</td>
<td>64</td>
</tr>
<tr>
<td>-hp 355A/B</td>
<td>Precision Attenuator</td>
<td>DC to 500 KHz</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$1,250.00</td>
<td>64</td>
</tr>
<tr>
<td>-hp 36A-D</td>
<td>Low Pass Filters</td>
<td>2 to 83 MC</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$60.00</td>
<td>186</td>
</tr>
<tr>
<td>-hp 450A</td>
<td>Amplifier, Stabilized</td>
<td>5 to 1,000,000</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$50.00</td>
<td>186</td>
</tr>
<tr>
<td>-hp 462X/R</td>
<td>Amplifier, Wide Band</td>
<td>100 KHz to 120 MC</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$15.00</td>
<td>86, 87</td>
</tr>
<tr>
<td>-hp 468A</td>
<td>AC Amplifier</td>
<td>10 to 100 KHz</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$25.00</td>
<td>86, 87</td>
</tr>
<tr>
<td>-hp 4C</td>
<td>Century Counters</td>
<td>1 to 10 MC</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$25.00</td>
<td>111</td>
</tr>
<tr>
<td>-hp 16</td>
<td>Cable Assemblies</td>
<td>—</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>-hp 21</td>
<td>Probes</td>
<td>—</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>-hp 40/A/B</td>
<td>Line Matching Transformers</td>
<td>5 to 600 KHz</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$60.00</td>
<td>192</td>
</tr>
<tr>
<td>-hp 478/C</td>
<td>Terminations</td>
<td>100 ohm compensated and feed-through terminations</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$17.00</td>
<td>19</td>
</tr>
<tr>
<td>-hp 497C</td>
<td>Sweep Drive</td>
<td>10° rotation to 360° revolutions</td>
<td>Accuracy ±3 KHz, ±100 ppm</td>
<td>$275.00</td>
<td>41</td>
</tr>
</tbody>
</table>

△ Rack mounted instrument available for $15.00 less. **Rack mounted instrument available for $20.00 extra. *Rack mounted instrument available for $5.00 extra.
## Microwave Equipment to 40 GC (KMC)

| Instrument | Type N Conn. | 1.2 | 2 | 3 | 3.8 | 5.8 | 8.2 | 11.5 | 15 | 20 | 30 | 35 | 40 | 45 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 150 | 180 | 200 | 250 | 300 | 350 | 400 | 500 | 700 | 1000 | 1500 | 2000 |
|------------|--------------|-----|---|---|----|----|----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Adapter, Waveguide to Coax | 529A $50 G29A $40 J29A $35 H29A $30 X29A $25 | 186 |
| Cover to choke flange | 529A $55 G29A $50 J29A $45 H29A $40 X29A $35 | 186 |
| Waveguide to waveguide | $290A $55 G290A $50 J290A $45 H290A $40 X290A $35 | 186 |
| Waveguide Noise Source | 5347A $100 G347A $95 J347A $90 H347A $85 X347A $80 | 179 |
| Low Pass Filters | X347A $120 G347A $115 J347A $110 H347A $105 X347A $100 | 179 |
| Attenuators, Fixed 3, 6, 10, 20 db | $343A $120 G343A $115 J343A $110 H343A $105 X343A $100 | 179 |
| Precision Variable | 393A $120 G393A $115 J393A $110 H393A $105 X393A $100 | 181 |
| Slotted Sections, Waveguide | $408A $150 G408A $145 J408A $140 H408A $135 X408A $130 | 191 |
| Directional Couplers, Cross Guides 20, 30 db | $409A $150 G409A $145 J409A $140 H409A $135 X409A $130 | 191 |
| Directional Couplers, Multi Hole 3, 10, 20 db | $410A $150 G410A $145 J410A $140 H410A $135 X410A $130 | 191 |
| Slotted Sections, Waveguide | $411A $150 G411A $145 J411A $140 H411A $135 X411A $130 | 191 |
| Tuner, Slidebar | 872A $150 G872A $145 J872A $140 H872A $135 X872A $130 | 187 |
| Directional Couplers, Universal | $873A $150 G873A $145 J873A $140 H873A $135 X873A $130 | 187 |
| Waveguide Phase Shifter | $874A $150 G874A $145 J874A $140 H874A $135 X874A $130 | 187 |
| Terminations, Low Power | $875A $150 G875A $145 J875A $140 H875A $135 X875A $130 | 187 |
| Terminations, High Power | $876A $150 G876A $145 J876A $140 H876A $135 X876A $130 | 187 |
| Moving Load | $877A $150 G877A $145 J877A $140 H877A $135 X877A $130 | 187 |

### Microwave Test Instruments—For coaxial and waveguide systems

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Primary Uses</th>
<th>Frequency Range</th>
<th>Characteristics</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Ap-390B Noise Figure Meter</td>
<td>Noise figure measurement, alignment</td>
<td>30 and 60 MC</td>
<td>Fast, simple, adaptable to your specific equipment</td>
<td>$715.00</td>
</tr>
<tr>
<td>-Ap-343A, 346B, 349A Noise Sources</td>
<td>Noise figure measurement, alignment</td>
<td>30 MC plus any frequencies 38 to 200 MC</td>
<td>Versatile, accurate, new convenience</td>
<td>$815.00</td>
</tr>
<tr>
<td>-Ap-346A Noise Figure Meter</td>
<td>Noise figure measurement</td>
<td>10 to 400 MC, 30/60 MC, etc.</td>
<td>Broad band, 60 ohm impedance</td>
<td>$75.00</td>
</tr>
<tr>
<td>-Ap-4152 Standing Wave Indicator</td>
<td>Continuous Noise Figure Measurement in operating Radar Systems</td>
<td>25 or 30 MC</td>
<td>Selectable Impedance 50, 100, 200 and 400 ohms</td>
<td>$75.00</td>
</tr>
<tr>
<td>-Ap-416A Ratio Meter</td>
<td>Reflection coefficient measurements</td>
<td>1,000 cps = 40 cps</td>
<td>Continuous sweep frequency presentation; accuracy ± 3%</td>
<td>$550.00</td>
</tr>
<tr>
<td>-Ap-417A VHF Detector</td>
<td>Measurement of r0 wave power</td>
<td>Depends on bolometer mount</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$400.00</td>
</tr>
<tr>
<td>-Ap-4200 Microwave Power Meter</td>
<td>Measurement of r0 wave power</td>
<td>Depends on bolometer mount</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$345.00</td>
</tr>
<tr>
<td>-Ap-431A Power Meter</td>
<td>Stabilized r0 power measurements</td>
<td>Depends on bolometer mount</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$345.00</td>
</tr>
<tr>
<td>-Ap-434B Calorimetric Power Meter</td>
<td>Measurement of r0 power</td>
<td>DC to 12.4 GC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$345.00</td>
</tr>
<tr>
<td>-Ap-437A Universal Bolometer Mount</td>
<td>Measurement of r0 power</td>
<td>DC to 12.4 GC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$345.00</td>
</tr>
<tr>
<td>-Ap-4778 Travelling-Wave Tube Amplifiers</td>
<td>Enhancement throughout</td>
<td>1 to 12.4 GC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$345.00</td>
</tr>
<tr>
<td>-Ap-7600, 7610 Dual Directional Couplers</td>
<td>Reflectometer, power measurements</td>
<td>260 to 4,000 MC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$200.00</td>
</tr>
<tr>
<td>-Ap-7461-7470 Dual Directional Couplers</td>
<td>Reflectometer, power measurements</td>
<td>260 to 4,000 MC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$200.00</td>
</tr>
<tr>
<td>-Ap-803A VHF Bridge</td>
<td>Measurement of r0, impedance, SWR</td>
<td>260 to 4,000 MC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$200.00</td>
</tr>
<tr>
<td>-Ap-805C Coaxial Slotted Section</td>
<td>Measurement of SWR</td>
<td>260 to 4,000 MC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$200.00</td>
</tr>
<tr>
<td>-Ap-806C Coaxial Slotted Section</td>
<td>Measurement of SWR</td>
<td>260 to 4,000 MC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$200.00</td>
</tr>
<tr>
<td>-Ap-807/8148 Universal Bolometer Carriage</td>
<td>Supports 810, 815, 805B Waveguide Sections</td>
<td>260 to 4,000 MC</td>
<td>0.1 to 10 MW, extreme temperature stability</td>
<td>$200.00</td>
</tr>
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DYMEC DIVISION OF hp

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

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

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

PALO ALTO ENGINEERING COMPANY

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

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

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

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(For Both Warranty and Non-Warranty Repairs)

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

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

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


**SUGGESTIONS FOR ORDERING**

Order by Model Number

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

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

**Local Technical Assistance**

Technical assistance in selecting equipment and preparing orders is available without charge from engineering representatives at authorized sales offices in the United States and in principal areas throughout the world (see inside back cover for names and addresses.) In addition, a staff of qualified engineers is maintained at offices in Palo Alto, California and Geneva, Switzerland, to supplement the services available from your local representatives.

**Shipping Methods**

Shipments to destinations within the United States and Western Europe are made directly from local factories or warehouses. Unless specifically requested otherwise, express or truck transportation is used, whichever is cheaper and most serviceable to you. Small items are sent via parcel post. If rapid delivery is needed, we will gladly ship by the more expensive methods of air freight, air express or air parcel post when specified on your order.

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Where to Send Your Order

Your order should be made out to the Hewlett-Packard Company and sent to Palo Alto, California, through your local or representative (see inside back cover) or directly, if you prefer. See additional information below if you are located outside the United States.

**Local Technical Assistance**

In addition, a staff of qualified engineers is maintained at offices in Palo Alto, California and Geneva, Switzerland, to supplement the services available from your local representatives.

**Shipping Methods**

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

**Terms**

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

**Quotations and Pro Forma Invoices**

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

**Reparis**

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

Field servicing of instruments is normally faster since transportation time to the factory is eliminated. If, however, you wish to return an instrument to the factory for repairs, recalibration, or for any other reason, please contact Customer Service, Hewlett-Packard Company, 395 Page Mill Road, Palo Alto, California, phone: D'Vernon 6-1775, before shipment for instructions. Please give model number, name, serial number, and as much other information as possible concerning the reason for return. Non-warranty repairs are made at the cost of labor and materials, plus a small service charge. See page 5 for information on warranty repairs.

**Repair Parts**

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

**Terms**

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

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FAS, CIF, C & F, etc., quotations or pro forma invoices, as well as exportation assistance, are available on request from your local authorized sales office, the Hewlett-Packard Co., Palo Alto, California, or Hewlett-Packard S. A., Geneva, Switzerland.
OTHER HEWLETT-PACKARD PUBLICATIONS AVAILABLE TO YOU ON REQUEST

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

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

HEWLETT-PACKARD JOURNAL. Published monthly by the @ R & D laboratories, the Hewlett-Packard Journal is the most widely distributed publication in electronics. It is devoted to detailed, academic discussion of new measuring approaches, most productive methods of employing test instrumentation, latest instrumentation for complex as well as routine measurements. For your free subscription simply write on your letterhead to Hewlett-Packard Journal, Hewlett-Packard Company, 1501 Page Mill Road, Palo Alto, California.
The Hewlett-Packard Company was founded in 1939 in Palo Alto, California. The first Hewlett-Packard product was a new kind of instrument — a resistance capacity audio oscillator. Hewlett-Packard pioneered the resistance capacity circuit which is now an accepted standard for test oscillator design.

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

Behind every instrument is a basic philosophy governing equipment design, manufacture, sales and service. This philosophy specifies that there shall be built into each instrument the greatest possible usefulness, accuracy, convenience, dependability and dollar value. Further, each instrument must make a contribution to the art of measurement, or it is not offered.
Consistently, Hewlett-Packard insures that these standards are met. Every effort is made to provide the best engineering staff possible, and to pursue the most up-to-date manufacturing methods.

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

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

The new Hewlett-Packard plant at Stanford Industrial Park is engineered to be the most efficient yet thoroughly livable electronic manufacturing facility known. Housing Hewlett-Packard's engineering, manufacturing and administrative headquarters, it consists of four two-story buildings and a large underground storage area, totaling approximately 400,000 square feet. Additional manufacturing and service facilities are maintained at the "old" (1954) Palo Alto plant now principally occupied by Hewlett-Packard's Dymec systems division. Other manufacturing facilities are now in operation at Loveland, Colorado (near Denver) and at Böblingen, in Germany.
The Hewlett-Packard production policy is also somewhat different from that employed elsewhere. Instruments are manufactured in "runs," and actual fabrication is preceded by careful planning to insure that all parts are available and supplied as needed to keep the runs progressing smoothly. As many as thirty runs are normally in progress simultaneously, yet production schedules are kept flexible to permit meeting special orders or unusual delivery requirements involving substantial numbers of instruments. Short delivery cycles are normally maintained. Another unique aspect of the Hewlett-Packard manufacturing process is the use of the "Product-Centered" approach as opposed to the conventional "Process-Centered" method. "Product-Centered" means that a group of people and equipment produces a given group of instruments from prefabrication through assembly, wiring and testing. This results in intimate familiarity on the part of employees with the finished instrument. It leads to a more critical self-inspection of work, a greater desire to excel, and makes possible a "hand-crafted" operation combining the best quality aspects of the "small company" approach with "big company" economies to the user.

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

Location of the plants is Palo Alto, California. Administrative, engineering, manufacturing, purchasing and personnel headquarters are at the new Stanford plant. Plants may be reached by Southern Pacific commuter train to California Avenue station (South Palo Alto), by Greyhound bus or by automobile via Bayshore Highway, U. S. 101 Alternate. Plant is approximately 25 minutes driving time from San Francisco airport, 40 minutes from downtown San Francisco.
In sales and service, Hewlett-Packard makes a particular effort to provide customers with every assistance that will make the use of its instruments more efficient and productive. Factory-trained field engineering representatives provide prompt, on-the-job consultation as well as operating and repair information. These men are constantly supplied with the latest in technical data and measurement technique, and are in almost daily contact with the plant at Palo Alto. On numerous occasions each year, members of the sales organization meet for one week at Palo Alto for new-information and retraining seminars which include not only theory but actual “field problem” measuring with its instruments and allied equipment. On additional occasions, its representatives return to the plant for special training or instruction on new instruments and measuring methods.

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

Through the years, there has come into being a definite attitude on the part of its people toward the development, manufacture and service of its instruments. This attitude is best described as a genuine and pervasive team spirit, a spirit of cooperation coupled with a common desire to excel. Its 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. Its instruments — the standard of the electronic test equipment field.
An oscilloscope is an instrument designed to display a wide variety of electrical signals on the face of a cathode ray tube. In the CRT, an electron beam, whose position is precisely controlled by horizontal and vertical deflection plates, activates the phosphor which emits light. A visible representation of the signal as a function of time is formed by moving the beam vertically in accordance with the signal while moving the beam at a uniform rate from left to right. The uniform left to right movement of the beam is controlled by applying a sawtooth voltage to the horizontal deflection plates. The simplified block diagram of Figure 1 illustrates the basic circuit functions of a typical oscilloscope.

![Figure 1. Simplified Block Diagram.](image)

**Operation**

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

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

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

**Types of Measurements**

**General**

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

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

**Pulse Testing**

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

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

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

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

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

![Figure 2. Pulse definitions.](image)

The important characteristics are as follows:

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

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

**Pulse Width**: \(t_w\) is the time between the 50% amplitude point on the leading edge and the same amplitude point on the trailing edge.

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

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

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

**Rise Time and Bandwidth**

A useful relationship \(t_r \approx \frac{0.35}{BW}\) exists between the rise time of an amplifier and its bandwidth, provided the overshoot is less than 5%, where \(t_r\) is the rise time in microseconds and BW is the bandwidth in megacycles. For example, if \(BW = 50\text{ M\ensuremath{\mu}}\text{C}\), \(t_r \approx 12\text{ nanoseconds}\).

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

\[
t_{\text{observed}} = \sqrt{\left(t_{\text{observed}}\right)^2 + \left(t_{\text{rise}}\right)^2 + \left(t_{\text{oscilloscope}}\right)^2}
\]

input pulse system oscilloscope

**Selecting an Oscilloscope**

**General**

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

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

Also of importance is the decision regarding a single channel or dual channel approach. For example, relative phase can be measured on a single channel oscilloscope by means of a staircase voltage to step the cathode ray tube picture is to be moved. (Figure 4.) In operation, many dots are present, and the pattern appears continuous.

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

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

In the low frequency area the selection involves the choice between the 120A (single channel) and the 122A (dual channel) oscilloscopes. (See pages 24-27.) In the high frequency area the choice is simply the selection of the appropriate plug-in amplifier.

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

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

**Ultra High Frequency Oscilloscope**

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

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

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

**Operation Described**

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

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

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

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

**Figure 5**

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

**High Frequency Oscilloscopes**

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

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

Model 162A Dual Trace Amplifier offers unusually high sensitivity of 20 mV/cm while providing 24 MC bandwidth in Model 170A and 14 MC in Model 160B.
Model 162F Fast Rise Amplifier utilizes full bandwidth capability of the 170A and 160B oscilloscopes. Bandwidth is 30 MC with the 170A; 15 MC with the 160B.

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

Model 166C Display Scanner provides outputs from either the 170A or 160B when plugged into second plug-in "pocket." Moseley Autograf Models 3S or 2D. A third plug-in of the 166 series is 166B Time Mark Generator which provides intensity markers at 0.1 μsec, 1 μsec, and 10 μsec intervals, accurate to ±1%. Markers are useful for checking sweep calibration and for convenient reference on scope photographs. The markers are also available to operate external circuitry.

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

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

Low Frequency Oscilloscopes

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

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

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

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

Oscilloscope Camera

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

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

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

Primary Specifications of Hewlett-Packard Oscilloscopes

| Model     | Dual Channel | Band-Width | Rise Time | Calib. Sensitivity (v/cm) | Sweep Ranges | Sweep Magnifier | Signal Delay | Sweep Delay | X-Y Output | Price      |
|-----------|--------------|------------|-----------|---------------------------|--------------|------------------|--------------|-------------|------------|------------|------------|
| 165A/175B | Yes          | 1,000 MC   | 0.4 ns    | 0.01-0.2                  | 7 ranges, 1-100 | Yes              | (1) No      | Yes         | $1,000.00  |            |
| 170A/122A | Yes          | 300 MC     | 0.016 μs  | 0.03-20                   | 7 ranges, 1-100 | Yes              | (2) Yes     | (2) Yes     | $1,295.00  |            |
| 170A/162F | No           | 150 MC     | 0.025 μs  | 0.02-20                   | 7 ranges, 1-100 | Yes              | (3) Yes     | (3) Yes     | $1,995.00  |            |
| 160B/122A | Yes          | 10 MC      | 0.035 μs  | 0.05-60                   | 6 ranges, 1-100 | Yes              | (2) Yes     | (2) Yes     | $1,995.00  |            |
| 150A/152B | No           | 300 KC     | 1.17 μs   | 0.001-50                  | Yes No No     | Yes              | No          | No          | $1,650.00  |            |
| 130B      | No           | 300 KC     | 1.75 μs   | 0.01-10                   | XS No No      | Yes              | No          | No          | $650.00    |            |
| 122A      | Yes          | 200 KC     | 1.75 μs   | 0.01-10                   | 5 μs-0.25 μs  | XS No No          | Yes         | No          | $675.00    |            |
| 120A      | No           | 200 KC     | 1.75 μs   | 0.01-10                   | 5 μs-0.25 μs  | XS No No          | Yes         | No          | $450.00    |            |

(1) Can be obtained with separate optional delay line, Model AC-14V. (2) Requires Sweep Delay Generator, Model 166D. (3) Requires Display Scanner, Model 164C.
**HP 120A/AR 200 KC OSCILLOSCOPE**
Quality Production or Lab Instrument at Low Price

**HP 122A/AR DUAL TRACE 200 KC OSCILLOSCOPE**
Big Scope Comparison Versatility at Moderate Price
Both Oscilloscopes Opposite Have These Practical Advantages:

Simple operation, easily used by non-technical personnel
Direct reading calibration, automatic trigger, automatic baseline
"Times-5" sweep expander; linear integrator for accurate sweeps
Built-in amplifier calibrator assuring accurate voltage measurements
High quality 5" cathode ray tube for sharp, clear trace
Slow sweep speeds for medical or mechanical work
Fast sweep speeds for measuring transients

And in Addition Dual Trace Model 122A/AR Offers:
Simultaneous comparison of two signals
Twin vertical amplifiers, each usable separately
Alternate and chopped presentation, differential input

Uses:
Measure complex voltages, stress, strain, vibration analysis, pressure, flow, displacement, other phenomena through proper transducers
and . . .
with \( \oplus \) 122A, also compare amplifier, filter input and output directly, use with vibration testing apparatus; study filter and amplifier characteristics

Models 120A and 122A are basically similar dc to 200 KC oscilloscopes, but Model 122A offers the added versatility of twin vertical amplifiers and dual trace operation. Both are offered in either cabinet or rack mount styles, and both represent outstanding values in multi-purpose precision instruments suitable for either laboratory or production work.

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

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

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

Accurate, Calibrated Amplifiers
\( \oplus \) 120A makes accurate voltage measurements on all types of waveforms easily because the oscilloscopes amplifiers are calibrated and accurate to within \( \pm 5\% \). A built-in calibrator accurate to within \( \pm 2\% \) quickly verifies vertical amplifier sensitivity.

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

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

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

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

“Times-5” Sweep Expander

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

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

Specifications

Models 120A/AR, 122A/AR

Sweep

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

Sweep Expand: X5 sweep expansion may be used on all ranges and expands fastest sweep to 1 μsec/cm. Expansion is from 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 50 pf shunt capacitance.

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

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

Difference Input (Model 122A only): Both input signals may be switched to one channel to give differential input on all vertical sensitivity ranges. The sensitivity switches may be set separately to allow mixing signals of different levels. Common signal rejection is at least 40 db with both switches on most sensitive range, 30 db on other ranges.

Vertical Presentation (Model 122A only): Switch selects: A ONLY, B ONLY, A-B, 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 steps to at least 100 v/cm.

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

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

General

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

Cathode Ray Tube: Light proof bezel provides firm mount for oscilloscope camera and is removed easily for quick change of filter.

Cathode Ray Tube: 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.


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, 15¾” high, 20¾” deep. Rack Mount: 19” wide, 7” high, 20-11/16” deep. 19-7/16” deep behind panel.


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

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

Data subject to change without notice.
**Voltage Divider Probes**

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

**Current Probe, Terminations**

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

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

**Low Frequency Probe**

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

**AC-115B Oscilloscope Testmobile**

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

The 115B Testmobile rolls easily on large, 4" rubber-tired wheels. Construction is of rugged ¾" chrome plated tube stock. Overall size of the cart (less oscilloscope) is 40" high x 25½/16" wide x 29" deep. It weighs only 28 lbs. and folds compactly for shipment or storage. Price, $85.00.
130B/BR 300 KC OSCILLOSCOPE

Versatile, Dependable Laboratory, Production Oscilloscope

Advantages:

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

Uses:

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

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

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

Automatic Triggering

Two circuit features contribute to the instrument's unique operating convenience. First, the oscilloscope accepts signals direct from conventional transducers without preamplification in the majority of cases. Findings are presented in a brilliant, high resolution trace visible under all lighting condi-
tions. Second, the instruments contain a “universal” automatic triggering system. Under almost all circumstances, one single preset condition provides optimum triggering. The sweep may be operated free-running when it is desired to determine the base line. A high degree of stability and freedom from horizontal jitter is maintained under all sweep conditions.

**Similar Vertical, Horizontal Amplifiers**

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

**Use as Voltmeter**

Both amplifiers on the 130B are highly stable, requiring virtually no adjustment during operation. Their gain may be standardized by an external 500 cycle 300 millivolts source. These features, together with the instrument’s precision input attenuator, make possible use of the oscilloscope as a millivoltmeter or voltmeter accurate within 5%.

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

**Specifications**

**Sweep**

- **Sweep Range:** 0.2 μsec/cm to at least 12.5 sec/cm. 21 calibrated sweeps, accurate within ±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 1/2 centimeter or more vertical deflection. Externally from 0.5 volts peak-to-peak or more.
- **Trigger Point:** Continuously adjustable from −30 to +30 volts on either positive or negative slope of external synchronizing signal, or from any point of the vertical signal presented on the screen.
- **Preset Triggering:** Switch position on sweep mode control selects optimum setting for automatic triggering.

**Input Amplifiers**

Vertical and horizontal amplifiers have same characteristics.

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

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

**Stability:** 1 mV/hr after warmup.

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

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

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

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

**Internal Calibrator:** 300 millivolts peak-to-peak ±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: 9⅜” wide, 15” high, 21⅞” deep. Rack Mount: 19” wide, 8⅜” high, 22” deep, depth behind panel 19⅜”.

**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. AC-21 series probes (see page 19).

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

*Data subject to change without notice.*
HP 150A 10 MC OSCILLOSCOPE
High Sensitivity, Dual Trace, Outstanding Scope Value

Advantages:

- Maximum usefulness, reliability
- 24 direct reading calibrated sweeps
- Automatic sweep triggering
- 0.25 μsec distortionless delay line
- Calibrated horizontal amplifier
- Plug-in vertical pre-amplifiers, single or dual trace
- Sweep magnification of 5, 10, 50 and 100 x
- Single shot sweep with lock-out
- Quick CRT interchange
- Unitized construction
- Color-coded, concentric controls, simplified and functionally grouped

Uses:

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

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

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

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

### 150A Oscilloscope

**Sweep**
- **Range:** 0.02 μsec/cm to 15 sec/cm.
- **Calibrated:** 24 calibrated sweeps in 1, 2, 3, and 10 sequence, 0.1 μsec/cm to 5 sec/cm. Accuracy within 5%.
- **Sweep Magnification:** Sweep may be expanded 5, 10, 50 or 100 times. Increases fastest sweep speed to 0.02 μsec/cm.
- **Vernier:** Permits continuous adjustment of sweep time; extends slowest sweep to 15 sec/cm.
- **Triggering:** Internally, line voltage; externally with 0.5 v or more.
- **Trigger Point:** Any positive or negative level on positive or negative slope of signal triggering sweep. 30 v/cm to -30 v/cm range for external trigger.
- **Single Sweep:** In single sweep operation, after being triggered, sweep remains locked out until reset.

**Horizontal Amplifier**
- **External Input:** Pass band dc to over 500 KC. Sensitivity range 200 mv/cm to 5 v/cm. Five calibrated ranges plus vernier.
- **Input Impedance:** 1 megohm shunted by 31 pf.

**Vertical Amplifier**
- **Main Vertical Amplifier:** Pass band dc to more than 10 MC. Optimum transient response and rise time less than 0.035 μsec.
- **Signal Delay:** 0.25 μsec delay permits viewing leading edge of signal triggering sweep.

**General**
- **Amplitude Calibrator:** 18 calibrating voltages, 0.2 mv to 100 v peak-to-peak. Accuracy within 5%. Approximately 1 KC square wave with rise and decay times approximately 1 μsec.
- **Sawtooth Output:** + 20 to -20 v sawtooth waveform.
- **Gate Output:** + 20 v signal for duration of sweep.
- **Illuminated Graticule:** Edge-lighted graticule with controlled illumination, marked in centimeter squares with 2 mm subdivisions on major horizontal and vertical axes.
- **CRT Bezel:** Provides firm mount for standard oscilloscope camera equipment; easy access to CRT.
- **CRT Plates:** Direct connection to deflecting plates via terminals in access compartment.
- **Intensity Modulation:** Terminals provided; 20 v positive signal blanks CRT at normal intensity.
- **Power Supply:** 115/230 v ± 10%, 50/60 cycles. Approximately 610 watts.
- **Cathode Ray Tube:** 5AMP mono-accelerator flat face type with 5,000 v accelerating potential. Available with P1, P2, P7 or P11 screen.
- **Dimensions:** 14" wide, 17½" high, 24½" deep.
- **Weight:** Net 83 lbs. Shipping 125 lbs.
- **Accessories Furnished:** 2—AC-21A Low Capacity Probes, 2—AC-76A BNC to binding post adaptors.
- **Price:** $150A, $1300.00 (cabinet). (Normally supplied with P2 screen. For P1 screen, specify 150A-1; for P7 screen, specify 150A-7; for P11 screen, specify 150A-11.)

**150B High Gain Amplifier**
- **Sensitivity Range:** 5 mv/cm to 50 v/cm.
- **Input Attenuator:** 12 calibrated ranges, in 1, 2 and 5 sequence, from 5 mv/cm to 20 v/cm. Vernier permits continuous adjustment between ranges.
- **Input Impedance:** 1 megohm shunted with 31 pf.
- **Pass Band:** DC to 10 MC, 0.035 μsec rise time, dc coupled. 2 cps to 10 MC, 0.035 μsec rise time, ac coupled.
- **Dual Inputs:** Two signal inputs with Type BNC. Selection of either input by panel switch.
- **Weight:** Net 4 lbs. Shipping 9 lbs.
- **Price:** $150B, $200.00.

**152B Dual Channel Amplifier**
- **Sensitivity Range:** 0.05 v/cm to 50 v/cm.
- **Input Attenuator:** 9 calibrated ranges, in 1, 2, 5 and 10 sequence, from 0.05 v/cm to 20 v/cm. Vernier.
- **Input Impedance:** 1 megohm shunted with 31 pf.
- **Pass Band:** DC to 10 MC, 0.035 μsec rise time, dc coupled. 2 cps to 10 MC, 0.035 μsec rise time, ac coupled.
- **Differential Input:** Both inputs may be switched to one channel. Common signal rejection is at least 40 db when both input attenuators are set for maximum sensitivity.
- **Electronic Switching:** By alternate sweeps or chopped at approximately 100 KC.
- **Vertical Positioning:** Channels individually adjustable.
- **Polarity of Presentation:** Pos. up or neg. up.
- **Input Connectors:** Type BNC both channels.
- **Weight:** Net 6 lbs. Shipping 10 lbs.
- **Price:** $152B, $250.00.

**153A Differential Amplifier**
- **Sensitivity Range:** 1 mv/cm to 125 v/cm.
- **Input Attenuator:** 15 calibrated ranges, in 1-2-5-10 sequence, from 1 mv/cm to 50 v/cm. Vernier.
- **Pass Band:** DC to 500 KC, dc coupled. 2 cps to 500 KC, ac coupled.
- **Input Impedance:** 2 megohms shunted with 17 pf (balanced). 1 megohm shunted with 35 pf (single-ended).
- **Common Signal Rejection:** (Balanced input only.) At least 40 db on 1 mv/cm to 30 mv/cm ranges when common mode signal does not exceed 1.5 volts. 30 db on other ranges.
- **Weight:** Net 5 lbs. Shipping 9 lbs.
- **Price:** $153A, $150.00.

**154A Voltage-Current Amplifier**
- **Sensitivity Range:** Current: 1 ma/cm to 1,000 ma/cm. Voltage: 0.05 v/cm to 20 v/cm.
- **Input Impedance:** Current channel: probe adds approx. 0.01 ohm with 16Ω shunt in series with circuit. Voltage channel: 1 megohm, 30 pf shunt.
- **Maximum Current:** AC 10 amps rms, 20 KC and above ½ amp at 1 KC; dc up to 0.5 amp has no appreciable effect.
- **Vertical Presentation:** Either voltage or current signal continuously; or voltage and current signals sampled at 100 KC or on alternate traces.
- **Weight:** Net 8 lbs. Shipping 10 lbs.
- **Price:** $154A, $430.00 (includes AC-21F Current Probe).

*Data subject to change without notice.*
MILITARIZED Oscilloscopes Offer Unique Plug-In Versatility

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

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

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

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

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

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

Important features include reliable tube-transistor cir-

*See "Environmental Specifications for hp Models 160B and 170A Oscilloscopes and Models 166A, 162A, 166D Plug-in Units" for detailed specifications. Available from Hewlett-Packard Co. or your hp representative.
circuits, regulated dc filament voltages and premium components throughout. Power transistors in efficient heat sinks ensure cool operation. Etched circuits on translucent epoxy glass simplify circuit tracing and servicing.

Specifications 160B/170A
(With 166A Auxiliary Unit plugged in.)

Sweep Generator:

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

Magnification: 7 calibrated ranges, X1, X2, X5, X10, X20, X50 and X100. Increases fastest sweep speed to 0.02 μsec/cm. Accuracy: X1, X2 and X5, ±3%; X10 and X20 ± 5% to 0.02 μsec/cm; X50 and X100, ±10% to 0.02 μsec/cm.

Triggering: Internal, power line or vertical input signal (2 mm or more vertical deflection). External (1/2 v peak-to-peak or more).

Trigger Point: Positive or negative going voltage. Trigger level of external sync signal adjustable — to +50 v.

Sawtooth Output: — +50 to +50 v.

Gate Output: +50 v pulse.

Horizontal Amplifier:

Bandwidth: dc to 1 MC.

Sensitivity: 7 ranges 0.1 v/cm to 10 v/cm. Vernier extends minimum sensitivity to 25 v/cm.

Input Impedance: 1 megohm shunted by 30 pf.

Main Vertical Amplifier:

Bandwidth Capability: 160B, dc to 15 MC.
170A, dc to 30 MC.

Calibrator:

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

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

Current: 5 ma peak-to-peak, ±3%.

Cathode Ray Tube:

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

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

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

Deflection Plate Connection: Pin type terminals.

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

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

General:

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

Color: Grey enamel in accordance with Type III Class 2 of Specification MIL-E-15000.

Dimensions: Cabinet Mount: 14½” high, 19” wide, 22½” deep. Rack Mount: 12½” high, 19” wide, 21” deep behind panel.


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

Time Axis Plug-In Units: Model 166A Auxiliary Unit (supplied with 160B and 170A, provides Z-axis input and single sweep arming input connections).

Model 166B Marker Generator (see page 27).

Model 166C Display Scanner (see page 27). Model 166D Sweep Delay Generator (see page 27).

Accessories Available:

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

Accessories Furnished:

Two AC-21A Probes, two AC-76A Adapters.

Options: 50 to 600 cps ac fan in lieu of dc fan, no extra charge.

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

Chassis Track Detented Tilting slides for rack mount, specify C99-160BR, C99-470AR, add $85.00. 160B-44-A1, 170A-44A-1 Front Cover required for drip proofing, (includes adapters; 2-UHF female to BNC male cables UG-255/U, 2-Dual Banana Plug to BNC male cables UG-1035/U, 2-UHF male to BNC female UG-273/U, 2-BNC male to BNC male cables CG-409E/U), add $75.00. (Not compatible with rack mount.)

Price:

With line filter, dc fan and Model 166A plug-in unit.

160B* (cabinet or rack mount), $1,850.00.
162A* Dual Trace Amplifier, $350.00.
162F Fast Rise Preamplifier, $145.00.
160B Time Mark Generator, $130.00.
166C Display Scanner, $300.00.
166D* Sweep Delay Generator, $325.00.
170A* (cabinet or rack mount), $2,150.00.

*Available with all tubes and transistors.

MIL approved types (extra cost option).

Data subject to change without notice.
MILITARIZED AMPLIFIERS

© 162A Dual Trace Amplifier

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

Specifications

Each Channel:

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

Vernier extends minimum sensitivity to at least 50 v/cm.

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

With 170A: dc coupled; dc to 25 MC, 0.014 µsec rise time. AC coupled; 2 cps to 24 MC.

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

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

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

Differential Input: Both input attenuators may be switched to one channel to give differential input. The input attenuators may be set separately to allow mixing signals of different levels.

Amplifier: Channel A. Amplifier Input A — Input B.

Common Mode Rejection: At least 40 db at maximum sensitivity, at least 30 db when using attenuators.

General:

Weight: Net 6 lbs.

Power: Supplied by © 160B or 170A Oscilloscope.

Accessories Available: AC-21F Current Probe, $100.00; AC-67B Feed-through Termination (for AC-21F, 2.5 KC to 30 MC), $17.50; AC-67C Compensated Termination (for AC-21F, 1.4 KC to 30 MC), $30.00; AC-21C Probe, 50:1 division, $50.00.

Price: © 162A Dual Trace Amplifier for 160B or 170A Oscilloscope, $350.00.

With all tubes and transistors MIL approved types, specify H02-162A, $395.00. (Environmental specifications are met with or without this option.)

© 162F Fast Rise Preamplifier

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

Specifications

Pass Band: With 170A: DC coupled; dc to 30 MC, 12 nsec rise time.

With 160B: DC coupled; dc to 15 MC, 23 nsec rise time.

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

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

Weight: Net 5 lbs.

Power: Supplied by © 160B or 170A Oscilloscope.

Price: © 162F, $145.00.

Data subject to change without notice.
Specifications

**Specifications**

**166B Time Mark Generator**

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

![166B Time Mark Generator](image)

**166B Time Mark Generator**

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

**166D Sweep Delay Generator**

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

![166D Sweep Delay Generator](image)

**166C Display Scanner**

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

![166C Display Scanner](image)

**166C Display Scanner**

- **Range**: 10 μsec, 1 msec, and 0.1 μsec intervals.
- **Accuracy**: ± 0.5%.
- **Output Markers**:
  - **Amplitude**: 0 to 1 volt, adjustable.
  - **Duration**: Less than 40% of marker interval.
- **Functions**:
  - **Time Marker**:
    - **Off**: Marker de-energized.
    - **Output**: Marker provided at BNC output jack.
    - **Display**: Marker provides intensity modulation on display.
  - **Intensity Modulation**:
    - **External**: Provides for normal external intensity modulation.
    - **Internal**: Connects internal time markers to display.
- **Weight**: Net 3½ lbs. Shipping 6 lbs.
- **Price**: Supplied by 160B or 170A Oscilloscope, $130.00.

**Specifications**

**166C Display Scanner**

- **Delay Time**: 1 μsec to 10 sec.
- **Delaying Sweep**: 18 calibrated ranges from 2 μsec/cm to 1 sec/cm in 1, 2, 5, and 10 sequence.
- **Delay Length**: 0 to 10 cm. When delaying sweep functions in place of main sweep, setting in cm controls occurrence of main sweep. When delayed main sweep is used, setting acts as multiplier on delaying sweep setting to determine total delay time.
- **Accuracy**: ± 1% 2 μsec to 1 sec ranges; ± 3% .5, 1, 1 sec ranges.
- **Jitter**: Less than 0.01 μsec or ± 0.005% of total delay.
- **Delay Functions**:
  - **Trigger main sweep**. (b) Arm main sweep.
  - **Triggering**: Internal, power line or vertical input signal (2 mm or more vertical deflection). External, ½ volt peak-to-peak or more.
  - **Triggering Point**: Positive or negative going voltage. Trigger level of external sync signal adjustable from 10 to 30 volts.
- **Sweep Selector**:
  - **Mixed Sweep**. (b) Delaying Sweep. Brightened segment of trace indicates time relationship between delaying sweep display and main sweep display. (c) Main Sweep Delayed.
  - **Price**: 166D Sweep Delay Generator for 160B and 170A Oscilloscopes, $325.00. With all tubes and transistors MIL approved types specify H02-166D, $365.00. (Environmental specifications are met with or without this option.)

*Data subject to change without notice.*
**hp 185A 1,000 MC OSCILLOSCOPE**

Conventional Measuring Ease in Nanosecond Region

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

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

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

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

**Sampling Oscilloscope**

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

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

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

The translation is achieved by the sampling process, an approach analogous to stroboscopic light in that both simulate slowing down the "motion" for better visual perception—and both depend on repetition for a faithfully simulated signal. The sampling process, however, will operate with an aperiodic signal.
To permit study of fast pulses in great detail, and under varied trigger conditions, the 185A has a variable time delay and 4-range time scale with 6-step magnifier.

**Built-in Delay Feature**

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

**Recorder Output**

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

**Dual or Differential Input**

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

**Special, Easy-to-Use Probes**

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

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

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**Specifications**

**Model 187B Dual Trace Amplifier**

(When plugged into Model 185A Oscilloscope)

**Vertical (Dual Channel):**

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

- **Overshoot or Undershoot**: Less than 5%.

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

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

- **Input**: By means of input probe for each channel.

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

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

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

- **Price**: $1,000.00.

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**Model 185A Oscilloscope**

**Horizontal:**

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

- **Time Scale**: 4 ranges, 10, 20, 50, and 100 nsec/sec.

- **Vernier control between steps which increases speed.

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

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

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

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

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

- **Minimum Delay**: Less than 120 nsec.

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

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

- **"Sampling" Repetition Rate**: 100 KC maximum.

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

- **Trigger Input Impedance**: 10,000 ohms at panel. Capacitive coupling.

**Sync Pulse Output:**

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

- **Rise Time**: Less than 1.5 nsec.

- **Width**: Greater than 1 usec.

- **Timing**: Approximately 20 nsec after start of undelayed trace.

- **Recurrence**: One pulse per sample.

**General:**

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

- **Horizontal Output**: 0 at left to approx. 12 v at right of CRT face, source impedance 20,000 ohms. Vertical Output: approximately 2 v at bottom to -1 v at top of CRT face, source impedance 10,000 ohms.

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

- **Cathode Ray Tube**: 5 in. type 5AQP.

- **Useful Deflection**: 10 cm x 10 cm.

- **Power**: 115/230 v ±5%, 50/60 cps, approx. 250 w.

- **Dimensions**: Cabinet Mount: 14½" high, 19" wide, 22½" deep. Rack Mount: 12¼" high, 19" wide, 21½" deep behind panel.

- **Weight**: Net 75 lbs. Shipping 120 lbs.

- **Accessories Furnished**: 185A-21A Sync Probe.

- **Accessories Available**: See next page.

- **Price**: $2,000.00 (cabinet).

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*The present lack of pulse generator which can provide a pulse sufficiently fast and distortion free to serve as a waveform standard makes it difficult to specify the step response of 187B. The specified rise time of less than 0.5 nsec is that observed from a tunnel diode pulse generator and includes the rise time of the pulse generator itself, estimated at 0.2 nsec. The actual rise time of the 187B, based on its measured bandwidth (over 800 MC), is less than 0.44 nsec in case (A), less than 0.35 nsec in case (B). Data subject to change without notice.
ACCESSORIES FOR HP 185A 1,000 MC OSCILLOSCOPE, HP 187B DUAL TRACE AMPLIFIER

185A-21A Sync Probe
Furnished with the HP 185A Oscilloscope, this probe provides a convenient means for connecting synchronizing signals to the scope. The probe increases input impedance to at least 700 ohms, reduces trigger sensitivity about 6:1. Price, $31.00.

187A-76A BNC Adapter
These adapters, two of which are furnished with the HP 187B Scope, convert the signal probe of the 187B to a male BNC connector, permit viewing of signals from BNC fittings. Price, $8.00.

187A-76B Type N Adapter
This adapter converts the HP 187B signal probe to a Type N connector. It is a straight-through connection and not a cable matching termination. Price $10.00.

187A-76C 10:1 Divider
Signals as large as 20 v peak-to-peak may be observed with this divider, which increases the input impedance of the probe to 1 megohm shunted by 3 pf. The divider has an axial pin for contacting test points and will accept most other accessories. Does not fit 187B-76E 50-ohm T Connector. Price, $40.00.

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

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

908A 50-ohm Coaxial Termination
908A is a low power termination for 50-ohm transmission lines. Its SWR is 1.05 or less at any frequency, dc to 4,000 MC. Dissipation is 1/2 w. Price $35.00. (See also page 189.)

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

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

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

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

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

Data subject to change without notice.
Model 196A Oscilloscope Camera is the most convenient and versatile means yet devised for recording oscilloscope traces on either film or transparency.

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

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

Specifications

Object/Image Ratio: 1 to 0.9. Available with 1 to 1 ratio.
Lens: Wollensak 3" (75 mm) f/1.9 Oscillo-Raptar.
Focus: Factory adjusted for CRT face 5/16" behind front surface. May be adjusted for other distances.
Lens Opening: f/1.9 to f/16.
Shutter: Alphax #3. Time, Bulb, 1/100, 1/50, 1/25, 1/10, 1/5, 1/2, 1 second.
Print Size: 3¼" x 4¼". Image Area 2½" x 3-13/16" (7.3 cm x 9.6 cm).
Film: Polaroid® Land types 42, 44, 46, 46-L, 47.
Size: 13½" long, 9½" high, 10" wide. Weights: net 9 lbs., shipping 18 lbs. (32 lbs. in carrying case).
Accessories Available: @ 196A-45 Carrying Case, $40.00;
@ 196A-20 Tektronix Adapter, $4.50.
Price: $440.00.

Data subject to change without notice.
OSCILLATORS
Oscillators are among the most basic and useful of all electrical and electronic measuring instruments. They provide a convenient source of power or test voltage for almost all measurements, including frequency, gain, impedance, distortion, etc.

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

Throughout the years, the RC oscillator has become recognized as the most versatile, practical, dependable and easiest to use of all oscillator types. Hewlett-Packard pioneered and developed the RC oscillator, and is today the leader and largest manufacturer of this superior type of instrument. 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 resetting 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 RC series of oscillators includes 11 separate instruments which are essentially resistance-capacity oscillators. Collectively, they operate from 0.008 cps to 10 MC, covering the audio, subsonic, ultrasonic and low rf regions.

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

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

\[ f_0 = \frac{1}{2 \pi RC} \]

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

**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 RC 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 200CD Wide Range Oscil-
lator 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.

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

Distortion

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

Hum

Hum is defined as alternating currents appearing in the output of an oscillator as a result of power-frequency

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

Accuracy

"Overall accuracy" as applied to a variable-frequency oscillator is a general term including factors such as inherent circuit stability, mechanical stability, resettability of the tuning system, readability of the tuning dial, dial calibration, component aging, power supply variations and temperature changes. Some of these factors affect short time stability; others affect long time stability. The accuracy specification of within 2% usually given for RC oscillators includes all of these factors. (Typical long time and short time stability are shown in Figures 5 and 6.)

Description of @ Oscillators

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

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

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

![Figure 2. Distortion and Amplitude Characteristics RC Oscillator.](image)

![Figure 3. Characteristics of Frequency Determining Network.](image)

![Figure 4. Voltage Divider Circuit.](image)
This instrument is such that transient 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 nonexistent. This is of considerable convenience in low frequency work where much time is required for ordinary circuits to stabilize.

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

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

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

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

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

200S is a version of 200CD Oscillator designed to provide 3 volts into 50 ohms required by 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. 200S is also part of the 3-instrument Hewlett-Packard Voltmeter Calibration System which provides both frequency response and voltage calibration. Further details of this system appear on page 83.

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

Model 200T is a precision telemetry 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 telemetry is covered without splitting a single telemetry channel.

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

**Oscillator Output System**

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

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

Exceptional Value, Highest Quality Throughout

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

Hewlett-Packard RC oscillators have long been basic tools for making electrical and electronic measurements of precise accuracy. These world-famous test instruments give you the most compact, dependable, accurate and easy-to-use commercial oscillators available.

The @ 200 series oscillators have high stability and accurate, easily resettable tuning circuits. Low impedance operating levels together with superior insulation guarantee peak performance throughout years of trouble-free service. The instruments have wide frequency range and long dial lengths and feature an improved vernier frequency control. Operation is simplified—just three controls are required. Instruments are compact, light in weight and enclosed in a convenient, aluminum case with carrying handle. They occupy minimum bench space and are easily portable. Rack mounting is available on order.

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

This basic oscillator is a compact, convenient source of precision audio test voltages at extremely low price. Frequency coverage is 20 cps to 40 KC in four overlapping bands. The 63" effective scale length and 72 dial divisions insure accurate direct frequency setting. Output is balanced for dependable driving of transmission systems. The 200AB is ideal for amplifier testing, as a bridge voltage source, for testing transmitter modulator response, modulating signal generators, ultrasonic voltage source, driving mechanical systems, synchronizing pulse generators and making loudspeaker resonance tests. @ 200 AB, $165.00 (cabinet); @ 200 ABR, $170.00 (rack mount).

@ 200CD Wide Range Oscillator
Multi-Purpose, 5 cps to 600 KC

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 ultrasonic apparatus, carrier telephone systems, video frequency circuits, etc. Waveform purity is maintained with extremely low loads. Frequency is covered in 5 decade ranges, and accuracy is ± 2% including warmup, aging, tube changes, etc. Frequency response is ± 1 db full range. @ 200 CD, $195.00 (cabinet); @ 200 CDR, $200.00 (rack mount).
Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range</th>
<th>Calibration Accuracy</th>
<th>Output to 600 ohms</th>
<th>Recommended Load</th>
<th>Maximum Distortion</th>
<th>Max. Hum &amp; Noise</th>
<th>Input Power</th>
<th>Weight — Lbs.</th>
<th>Ship</th>
<th>Size (Inches)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>200AB</td>
<td>20 cps to 40 KC</td>
<td>± 3%</td>
<td>1 watt (24.5 v)</td>
<td>600 ohms</td>
<td>1.0%</td>
<td>70 watts</td>
<td>15</td>
<td>20</td>
<td>7 1/2 x 1 1/2 x 12</td>
<td>$165.00</td>
<td></td>
</tr>
<tr>
<td>200CD</td>
<td>5 cps to 600 KC</td>
<td>± 2%</td>
<td>160 mw (10 volts)</td>
<td>600 ohms*</td>
<td>0.5%</td>
<td>75 watts</td>
<td>22</td>
<td>27</td>
<td>7 1/2 x 11 1/2 x 14 1/2</td>
<td>195.00</td>
<td></td>
</tr>
<tr>
<td>201C</td>
<td>20 cps to 20 KC</td>
<td>± 1%†</td>
<td>3 watts (42.5 v)</td>
<td>600 ohms**</td>
<td>0.5%‡</td>
<td>75 watts</td>
<td>16</td>
<td>23</td>
<td>7 1/2 x 11 1/2 x 12 1/2</td>
<td>250.00</td>
<td></td>
</tr>
<tr>
<td>202C</td>
<td>1 cps to 100 KC</td>
<td>± 2%</td>
<td>160 mw (10 volts)</td>
<td>600 ohms*</td>
<td>0.5%§</td>
<td>75 watts</td>
<td>27</td>
<td>33</td>
<td>7 1/2 x 11 1/2 x 14 1/4</td>
<td>300.00</td>
<td></td>
</tr>
</tbody>
</table>

*Internal impedance is 600 ohms. Frequency and distortion unaffected by load resistance. Balanced output with amplitude control at 100. Use line matching transformer for other control settings. **Internal impedance approximately 600 ohms with output attenuator at 10 db or more. Approximately 75 ohms below 5,000 cps. ***Internal, non-operating controls permit precise calibration of each band. †0.5%, 60 cps to 20 KC at 1 watt output. ‡Above 5 cps. §Measured with respect to full rated output.

Frequency Response: Flat ± 1 db over instrument range. Reference level at 1 KC.

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

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

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

Data subject to change without notice.

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

Particularly designed for amplifier testing, transmission line measurements, loud speaker testing, frequency comparison and other high fidelity tests, this audio oscillator meets every requirement for speed, simplicity and pure waveform. The frequency range 20 cps to 20 KC is covered in 5 bands; response is ± 1 db full range. Output is 3 watts or 42.5 volts into 600 ohms; an attenuator adjusts output 0 to 40 db in 10 db steps and provides either low impedance or constant 600 ohm impedance. Distortion above 50 cps is less than 0.5%. © 201C, $250.00 (cabinet); © 201CR, $255.00 (rack mount).

© 202C Low Frequency Oscillator
Excellent Waveform, 1 cps to 100 KC

Model 202C brings to the low frequency spectrum the accuracy and stability you associate with audio measurements. It provides excellent waveform throughout its broad frequency range of 1 cps to 100 KC, and has unique usefulness in industrial, field or laboratory work. Model 202C is extremely convenient for vibration, stability, electro-cardiograph, electro-encephalograph and other measurements in the subsonic, audio and ultrasonic fields. Distortion is less than 0.5%, hum voltage is less than 0.1%, and recovery time is extremely short—5 seconds at 1 cps. © 202C, $300.00 (cabinet); © 202CR, $305.00 (rack mount).
202A LOW FREQUENCY FUNCTION GENERATOR

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

Advantages:

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

Use It For:

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

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

The instrument is continuously variable through 5 bands covering all frequencies from 0.008 cps to 1,200 cps. It offers exceptional stability and distortion of less than 1% over most of the band. Any of three desired waveforms—sine, square or triangular—may be instantly selected by a front panel switch. Output is high—30 volts peak-to-peak—for all three waveforms and is essentially constant over the entire frequency range.

Description

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

The triangular wave then enters a shaping circuit designed by $\&$ exclusively for this equipment. In this circuit, 12 crystal diodes modify or "shape" the peaks of the wave and provide a true sine wave. (See Figure 2B.) This sine wave has a distortion of less than 1%, and the synthesizing circuit provides virtually transient-free output even when frequency and operating conditions are rapidly varied. It is not necessary to wait long periods of time for the circuits to stabilize as is the case with conventional low frequency oscillators. The circuit inherently maintains constant amplitude over the entire frequency range.

**Special Features**

The output system of $\&$ 202A is fully floating with respect to ground and may be used to supply a balanced voltage or an output voltage with either output terminal grounded. The equipment will deliver 10 volts RMS into a load of 4,000 ohms or greater. Throughout, internal impedance is only 40 ohms. There are no coupling capacitors in the output system, and a high degree of dc balance is achieved by the special circuitry.

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

### Specifications

- **Frequency Range:** 0.008 to 1,200 cps in five decade ranges.
- **Dial Accuracy:** 2% from 1.2 to 12; 3% from 0.8 to 1.2.
- **Frequency Stability:** Within 1% including warmup drift.
- **Output Waveforms:** Sinusoidal, square, and triangular.
- **Maximum Output Voltage:** At least 30 volts peak-to-peak across rated load (4,000 ohms) for all three waveforms.
- **Internal Impedance:** Approximately 40 ohms over the entire range.
- **Sinewave Distortion:** Less than 1% on x .01, x .1, x 1, and x 10 ranges; less than 2% on x 10 range.
- **Output System:** Output is isolated from ground and either side may be grounded. Output system is direct coupled; dc level of output remains stable over long periods of time and can be adjusted to zero by a front panel control.
- **Frequency Response:** Constant within 0.2 db.
- **Hum Level:** Less than 0.05% of maximum output.
- **Sync Pulse:** 10 volts peak negative, less than 5 µsec duration. Sync pulse occurs at crest of sine and triangular wave output.
- **Power:** 115/230 v ± 10%, 50/1,000 cps, approx. 150 watts.
- **Dimensions:** Cabinet Mount: 20½” wide, 12¾” high, 14½” deep. Rack Mount: 19” wide, 10½” high, 13” deep. Also can be used with $\&$ AC-17 End Frames.
- **Weight:** Net 42 lbs. Shipping 53 lbs. (cabinet mount).
  Net 37 lbs. Shipping 52 lbs. (rack mount).
- **Accessories Available:** AC-16A Cable Assembly, $4.50, AC-16B Cable Assembly, $5.50.
- **Price:** $202A, $550.00 (cabinet); $202AR, $535.00 (rack mount).

Data subject to change without notice.

![Figure 1](image1.png)  
**Figure 1.** Oscillogram shows freedom from transients as output frequency is rapidly changed.

![Figure 2](image2.png)  
**Figure 2.** Oscillogram of (A) triangular wave applied to special $\&$ developed shaping circuit and (B) resulting true sine wave.
**650A TEST OSCILLATOR**

Fast, Accurate Tests 10 cps to 10 MC

**Advantages:**

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

Use It For:

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

The Model 650A Oscillator brings audio frequency speed, accuracy and ease of operation to higher frequency fields. Its wide frequency range, 10 cps to 10 MC, makes it ideal for a wide variety of measurements in audio, ultrasonic, video and rf bands. It is a wide-band highly-stable precision instrument which provides output flat within 1 db throughout its frequency range. Its voltage range is 0.00003 volts to 3 volts. Output impedance is 600 ohms, and, for measurements where low source impedance is desired, a 6 ohm impedance is provided by means of an output voltage divider.

**Decade Ranges, Output Voltmeter**

Like other resistance-capacitance oscillators, Model 650A is fast and easy to operate. Six decade frequency ranges provide an effective scale length of 94 inches. The tuning dial is controlled directly, or with a 6 to 1 vernier microdrive for hairline adjustment. Frequencies are read through a no-parallax illuminated window.

The output voltage is monitored by a vacuum tube voltmeter which measures the voltage at the input to the atten-
uator system. The VTVM is calibrated in volts and decibels and reads actual output voltage when the attenuators are set for zero attenuation. For other attenuator settings true output voltage is obtained by subtracting the attenuator reading from the output voltmeter reading. The output attenuator is adjustable in 10 db steps and maximum attenuation is 50 db.

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

**Output Voltage Divider**

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

![Figure 1](image)

Circuits of the Model 650A have been carefully proportioned and low temperature coefficient components have been employed to assure highest frequency stability. Output voltage will remain constant over long periods of time, despite wide variations in temperature. Distortion over the low frequency bands is kept at a minimum to increase the usefulness of the instrument for audio measurements.

**Uses**

Employing essentially the same resistance-capacitance circuit as audio oscillators (see pages 33, 34, 35 for description of resistance-capacitance principle) this wide-band, stable 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 rf and tf bridge measurements.

**Specifications**

- **Frequency Range**: 10 cps to 10 MC. Six decade bands.
- **Calibration Accuracy**: ±2%, 10 cps to 100 KC, ±3%, 100 KC to 10 MC including warmup, and ±10% line voltage variation.
- **Output**: 15 milliwatts or 3 volts into 600 ohm resistive load. Open circuit voltage is at least 6 volts.
- **Source Impedance**: 600 ohms; 300 ohms or 6 ohms when using 65A-16D Output Divider Cable.
- **Frequency Response**: Flat within ±1 db, 10 cps to 10 MC into 600 ohm resistive load.
- **Distortion**: Less than 1% from 20 cps to 100 KC. Less than 2% from 100 KC to 1 MC, approximately 5% at 10 MC.
- **Output Monitor**: Vacuum tube voltmeter monitors level at input to attenuator, in volts or db at 600 ohm level. Zero db=1 mw in 600 ohms. Accuracy ±5% of full scale reading.
- **Output Attenuator**: Output level attenuated 50 db in 10 db steps, providing continuously variable output voltage from +12 dbm to -50 dbm, 3 volts to 3 millivolts, or down to 30 microvolts with voltage divider. Accuracy ±1 db, into resistive load of 600 ohms.
- **Hum Voltage**: Less than 0.5% of output voltage with meter at full scale.
- **Power**: 115/230 v ±10%, 50/1,000 cps, 165 watts.
- **Dimensions**: Cabinet Mount: 20⅜” wide, 12⅜” high, 15” deep. Rack Mount: 19” wide, 10⅞” high, 15” deep behind panel. Also can be used with AC-17 End Frames.
- **Weight**: Net 46 lbs. Shipping 55 lbs. (cabinet mount).
  Net 37 lbs. Shipping 52 lbs. (rack mount).
- **Accessories Furnished**: 1 65A-16D Output Divider Cable.
- **Accessories Available**: AC-16A Cable Assembly, $4.50;
  AC-16B Cable Assembly, $5.50.
- **Price**: 650A, $550.00 (cabinet); 650AR, $535.00 (rack mount).

*Data subject to change without notice.*
**200J Interpolation Oscillator**

**Maximum Band Spread,**

**6 cps to 6 KC**

This ultra-precision instrument is engineered for interpolation and frequency measurements where frequencies must be known with extreme accuracy. Covering the range 6 cps to 6 KC, Model 200J offers an output of 160 mw or 10 volts into 600 ohms, or 20 volts open circuit, balanced to ground. Distortion is less than 0.5%, and frequency stability is ±0.2% or 0.2 cps. The instrument has 6 spread scale frequency ranges, and an effective scale length of 30" for maximum resettability. Calibration accuracy is ±0.1%, and frequency response is 1 db full range. Hum voltage is less than 0.1% of output, 115/230 v ±10%, 50/1,000 cps, 110 watts. Cabinet mount, 7½" wide, 11½" high, 14½" deep. Rack mount, 19" wide, 7" high, 12¾" deep behind panel. Weight: cabinet mount, net 22 lbs., shipping 27 lbs.; rack mount, net 27 lbs., shipping 37 lbs. @ 200J, $350.00 (cabinet); @ 200JR, $355.00 (rack mount).

**200T Telemetry Oscillator**

**High Stability, Resolution;**

**250 cps to 100 KC**

Model 200T provides the highest possible frequency stability in a wide range, convenient commercial audio oscillator. It is particularly useful for precise, high resolution frequency checking applications such as the evaluating of telemetering circuits, determination of carrier current equipment operation, and measurement of characteristics of sharply tuned filters. Model 200T covers frequencies 250 cps to 100 KC in 5 ranges, with good overlap between bands; output is 160 mw or 10 volts into 600 ohms, or 20 volts open circuit. Calibration accuracy ±1% long term, frequency response ±1 db full range. High stability, distortion less than 0.5% full range. Hum and noise less than 0.03% of rated output. 115/230 v ±10%, 50/1,000 cps, approx. 160 watts. Cabinet mount 18¾" wide, 9½/16" high, 11¾" deep. Rack mount 19" wide, 8¾" high, 10-15/16" deep behind panel. Weight: cabinet mount, net 27 lbs.; shipping 36 lbs.; rack mount, net 28 lbs., shipping 36 lbs. The instrument is compact, versatile, simple to operate and available in either cabinet or rack mounting. It covers IRIG (RDR) channels 1 through 18 and no channel is split by bandswitching. @ 200T, $500.00 (cabinet); @ 200TR, $505.00 (rack mount).

**233A Carrier Test Oscillator**

**Checks Systems, 50 cps to 500 KC**

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

*Data subject to change without notice.*
Fully transistorized and battery-operated, 204B Oscillator is extremely useful for both field and laboratory work. Internal heat production is small, resulting in unusually low warmup drift. Stable, accurate signals are instantly available over a frequency range from 5 cps to 500 KC.

Balanced and unbalanced loads, and loads referenced either above or below ground, can be driven by the versatile Model 204B. Its output is fully floating, isolated from power line ground and instrument chassis. Completely balanced output is easily obtained with a simple external matching network. There is excellent frequency stability even with rapidly changing loads; low impedance circuits drive the 600 ohm output effectively isolating the oscillator stage.

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

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

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

Specifications

Frequency Range: 5 cps to 500 KC, in 5 ranges. 5% overlap between ranges, vernier control.

Dial Accuracy: ±3%.

Frequency Response: ±3%, with rated load.

Output Impedance: 600 ohms.

Output: 10 milliwatts (2.5 v rms) into 600 ohms; 5 v rms open circuit. Completely floating.

Output Control: Continuously variable bridged "T" attenuator with at least 40 db range.

Distortion: Less than 1%.

Noise: Less than 0.05%, when battery operated.

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

Dimensions: Module 6-3/32" high, 5 5/8" wide, 8" deep.

Weight: Net 6 lbs. Shipping 9 lbs.

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

Price: 204B, $275.00.

Data subject to change without notice.
Hewlett-Packard offers a broad variety of signal, square wave and pulse generators for basic testing and investigation of circuits ranging from audio through the fast circuits employed in radar, DME, Tacan, computers, etc.

**Audio Signal Generators**

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

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

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

**Circuit Description**

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

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

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

@ 205AG is very low in order to permit maximum 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 @ 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 @ 205AG is very low in order to permit maximum voltage at the load. In applications where a matched source impedance is required one of two procedures should be employed.

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

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

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

**Square Wave Generator**

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

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

The 211A (page 50) provides complete coverage of all frequencies from 1 cps to 1 MC, and has a rise time of 0.02 μsec. It offers two separate outputs — a 7 volt peak-to-peak 75 ohm impedance circuit for television measurement, and a 55 volt peak-to-peak 600 ohm output for high level work.
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 212A Pulse Generator (page 51) is deliberately designed for speeding and simplifying all of these measurements. It has a direct-reading pulse length control, and 50 watts of peak pulse power. Rise time is 0.02 μsec, pulses have a "flat" top with minimum overshoot. Either positive or negative pulses may be synchronized to other equipment through built-in delay and advance sync-out circuits; accurate pulses may also be delivered at the end of a long transmission line.

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

Digital Delay Generators

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

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

Some of the instruments which the 218A becomes are:

1) **Precision dual time interval generator**, digitally calibrated from 1 to 10,000 microseconds, with synchronized time marker outputs preset to accuracy of ±0.1 microsecond, ± 0.01%. A special version of the 218A is available, providing time intervals up to 40,000 microseconds. Longer time intervals can also be generated with the standard 218A, by using an external counted frequency.

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

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

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

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

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

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

Power Supplies

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

Conventional tube circuits are the most practical means of building high voltage supplies, because of the high inverse signals encountered. Tubes are used throughout power supplies which have output voltages higher than 100 volts. The inherent advantages of the transistor are utilized.
in lower voltage supplies where transistors yield top efficiency, high current ratings, reliability and freedom from filament hum. Transistor power ratings are very carefully observed and the design of each supply is sufficiently conservative to allow high performance operation in ambient temperatures as high as 55°C.

**Performance Data**

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

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

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

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

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

**Summary of Power Supplies**

<table>
<thead>
<tr>
<th>Tube Types</th>
<th>Main Features</th>
<th>Special Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 711A</td>
<td>DC output 0 to 500 v; 100 ma max. AC output 6.3 v; 6 amp or 12.6 v, 3 amp. DC regulation 0.5%.</td>
<td>Inexpensive versatile; high voltage, low current power supply. Metered voltage and current.</td>
</tr>
<tr>
<td>Model 712B</td>
<td>DC output 0 to 500 v; 200 ma max. Regulation 0.01% at 500 v Bias supply 0 to -150 v; 5 ma max. AC -6.3 v; 10 amp max.</td>
<td>High quality, high voltage supply; particularly good transient response, regulation and stability.</td>
</tr>
<tr>
<td>Model 713B</td>
<td>Beam supply -250 v to -400 v, 35 ma max. Reflector supply 0 to -900 volts below beam supply, 10 amp max. AC 6.3 v; 1.3 amp.</td>
<td>Klystron supply, inexpensive general purpose instrument.</td>
</tr>
<tr>
<td>Transistor Types</td>
<td>DC output 0 to 30 v; 150 ma max.; metered voltage or current. Current limit feature regulation 0.3%. DC output 0 to 60 v; 2 amp max. Regulation 0.01% at 40 v continuously adjustable current limit. DC output 0 to 40 v; 500 ma max. Metered voltage or current. Current limit feature regulation 0.1%</td>
<td>Inexpensive general purpose, low voltage, low current power supply. Very low ripple and noise output. High quality, high power particularly good regulation, stability, low ripple and noise. Remote sensing.</td>
</tr>
</tbody>
</table>

| Model 721A | DC output 0 to 30 v; 150 ma max.; metered voltage or current. Current limit feature regulation 0.3%. | Inexpensive general purpose, low voltage, low current power supply. Very low ripple and noise output. High quality, high power particularly good regulation, stability, low ripple and noise. Remote sensing. |
| Model 722AR | DC output 0 to 60 v; 2 amp max. Regulation 0.01% at 40 v continuously adjustable current limit. | General purpose, medium power low voltage supply can be programmed remotely. |

![Figure 5. Output impedance vs. frequency, 722AR.](image1)

![Figure 6. Remote sensing arrangement, 722AR.](image2)

![Figure 7. Output voltage vs. current, 721A.](image3)

![Figure 8. Long term stability of 722AR.](image4)
205AG AUDIO SIGNAL GENERATOR

Six Basic Instruments Combined to Speed Gain Measurements

This Audio Signal Generator materially speeds and simplifies a variety of audio testing jobs where sizable amounts of power are required.

Two voltmeters measure input and output of the device under test. The output level is adjusted by means of the step attenuators and output impedance can be instantly changed by means of a selector switch to commonly used impedances.

Internal Impedances: Approximately 1/6 of the load impedance with zero attenuator setting. Approaches the load impedance with attenuator settings of 20 db or more.

Distortion: Less than 1% at frequencies above 30 cps.

Hum Level: The hum level is 60 db below the output voltage or 90 db below 0 dbm, whichever is the larger.

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

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

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

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

Output Attenuator: 110 db in 1 db steps.

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

Dimensions: Cabinet Mount: 20 3/4" wide, 12 3/4" high, 15 1/2" deep. Rack Mount: 19" wide, 10 1/2" high, 14" deep behind panel. Also can be used with @ AC-17 End Frames.

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

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

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

Data subject to change without notice.
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.

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

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

**Uses**

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

*Data subject to change without notice.*

## Specifications

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

**Calibration Accuracy:** $\pm 2\%$ including warmup drift.

**Output:** $\pm 15$ dbm into impedances of 50, 150 and 600 ohms. Approximately 10 volts are available into an open circuit.

**Output Impedances:** The generator has a matched internal impedance and the selection of output impedances includes 50, 150 and 600 ohms center-tapped and balanced and 600 ohms single ended.

**Frequency Response:** Better than $\pm 0.2$ db at all levels, 30 cps to 15 KC, when the output meter reading is held constant.

**Distortion:** Less than 0.1% at frequencies above 50 cps and less than 0.25% from 20 cps to 50 cps.

**Hum Level:** At least 75 db below the output signal or more than 100 db below zero level, whichever is the larger.

**Output Meter:** Calibrated in dbm and also in volts. Readability at least 0.2 db at all points above a 50% scale reading. (0 dbm equals 1 mw in 600 ohms.)

**Output Attenuators:** 111 db in 0.1 db steps. Accuracy approximately $\pm 0.1$ db.

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

**Dimensions:** Cabinet Mount: 20½” wide, 12¾” high, 14” deep. Rack Mount: 19” wide, 10½” high, 14” deep behind panel. Also can be used with AC-17 End Frames.

**Weight:** Net 57 lbs. Shipping 65 lbs. (cabinet mount).

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

**Price:** Model 206A, $800.00 (cabinet); 206AR, $785.00 (rack mount).
211A SQUARE WAVE GENERATOR

Convenient Audio, Video Testing 1 cps to 1 MC

Specifications

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

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

High Impedance Output: Negative 27 v peak across 600 ohm impedance; negative 55 v peak open circuit, zero level clamped to chassis. Rise time less than 0.1 μsec.

Amplitude Control: Low Impedance Output — potentiometer and 60 db attenuator, variable in 20 db steps.

Frequency Control: Dial calibrated “1 to 10” and decade multiplier switch. Six bands.

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, 15½” high, 14½” deep. Rack Mount: 19” wide, 8¾” high, 13½” deep behind panel.

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

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

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

1See Hewlett-Packard Application Note 17, “Square Wave and Pulse Testing.”

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 microseconds. There are two separate outputs — a 3.5 volt peak 75 ohm impedance circuit for television measurement, and a 27 volt peak 600 ohm output for high level work. The positive excursions of the output signals are clamped to chassis. Full amplitude variation is available on either output. The generator may be operated free-running or externally synchronized with either a positive going pulse or a sine wave signal of 5 volts peak minimum amplitude.

Uses

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

**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:** Referenced to sync out pulse: Delay, 0 to 100 μsec (to 2,500 pps) 0 to 50 μsec (to 5,000 pps). Advance, 0 to 10 μsec (to 5,000 pps).

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

**Dimensions:** Cabinet Mount: 20¾” wide, 12¾” high, 14½” deep. Rack Mount: 19” wide, 10½” high, 13½” deep behind panel. Also use with AC-17 End Frames.

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

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

**Price:** @ 212A, $600.00 (cabinet); @ 212AR, $585.00 (rack mount).
218AR DIGITAL DELAY GENERATOR

± 1 Count Ambiguity Eliminated in Time Interval, Pulse Generation

Advantages:

Generates time intervals 1 - 10,000 µsec
Variety of adjustable output pulses
± 0.1 µsec ± 0.001% accuracy
Crystal oscillator, dual-preset counter controls delays
Perfect slave to start pulses; no ±1 count error
New ease, speed, dependability

Uses:

Precision time interval generator for calibrating time bases, delay lines, radar ranges and precision sweep delays
1 MC dual preset counter for digital computer work
Precision variable gate generator for work with digital computers, counters
Precision double-pulse generator for pulse code modulation, resolution measurements on high speed circuits

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

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

Engineered to meet military performance requirements, the 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 218AR generates independent pulses, one at the end of each preset time interval, at times T₁ and T₂. A sync pulse is available at the time of the start pulse, T₀, or at T₁ or T₂.

See "Applications of the 218A, a Versatile General Purpose Pulse and Delay Generator." Application Note 48, available from Hewlett-Packard Company.
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 T₀ or T₁ 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 219 series plug-in units. The units and the pulse options they provide are described below.

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**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 T₀ or T₁, and pulse B at T₂. Pulse characteristics are identical to the sync output pulse of the 218AR Digital Delay Generator — approximately 50 volts positive, into an open circuit with a rise time of 0.1 µsec from a 50 ohm source. $100.00.

**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 T₀ or T₁ (as selected by a panel switch) and the leading edge of pulse B occurs at time T₂. Either positive or negative polarity is available, amplitude is variable from 0 to 50 volts into an open circuit, pulse width is variable from 0.2 to 5 µsec, and rise time is 0.06 µsec. The pulses may be delivered separately on individual cables, or on the same cable from either output connector. Output impedance and voltage are not affected by the setting of a "separate-common" switch governing the pulse outputs. Internal impedance is 50 ohms. $450.00.

Model 219C Digital Pulse Duration Unit produces a high power output pulse with digitally controlled delay and duration. Pulses may be started at T₀ and ended at T₁, or the pulse may be digitally delayed from T₀ to T₁ with duration digitally controlled from T₁ to T₂. Both polarities are available simultaneously and are continuously adjustable from 0 to 15 volts into an open circuit (from 90 ohms impedance) or 90 volts into an open circuit (from 500 ohms impedance). Rise or decay time is 0.05 µsec at 90 ohms. $350.00.

**Specifications**

**218AR Digital Delay Generator**

(Plug-in necessary to operate)

- **Time Interval Range**: (T₀ to T₁ and T₁ to T₂) 1 to 10,000 µsec. Accuracy ± 0.1 µsec ± 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, 1 v rms, 10 to 100 cps; 2 v rms, 100 cps to 10 KC. Pulse, 0 to 10 KC, positive or negative, 2 to 40 v peak. For trigger rise time of 0.05 µsec or less, delay between external trigger and T₀ is 0.25 µsec ± 0.05 µsec. Manual: Pushbutton operation. Jitter: 0.02 µsec or less.
- **Recovery Time**: 50 µsec or 10% of selected interval, whichever is larger.
- **Sync Output**: 50 v positive pulse into an open circuit, 0.1 µsec rise time (from 50 ohm source). Available at T₀, T₁, or T₂.
- **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 ± 10%, 50/60 cps, 555 watts.
- **Size**: 14" high, 19" wide, 21¼" deep behind panel. Weight 75 lbs.
- **Price**: $2,000.00.

*Data subject to change without notice.*
711A LABORATORY POWER SUPPLY

High Regulation, 0 to 500 Volts, Separate Meters

Specifications

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

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

Ripple:
Less than 1.0 mv.

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

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

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

Power:
115 volts ± 10%, 50/60 cps. Approximately 145 watts depending on load and line voltage.

Dimensions:
- Cabinet Mount: 75/8” wide, 113/4” high, 141/2” deep.
- Rack Mount: 19” wide, 7” high, 13-1/16” deep behind panel.

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

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

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

Uses

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

Data subject to change without notice.
The HP 712B Power Supply is deliberately designed to give you the finest performance obtainable plus broadest usefulness and the lowest price consistent with quality.

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

**Uses**

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

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

**Specifications**

Output Voltages:

- **DC Regulated High Voltage**: 0 to +500 v (without switching), 200 ma max. load.
- **DC Regulated Fixed Bias**: -300 v, 50 ma max. load.
- **DC Variable Bias**: 0 to -150 v, 5 ma max. load.
- **AC Unregulated**: 6.3 v, CT, 10 amps max. load.
- **Regulation**: (For constant line voltage.)
- **DC Regulated High Voltage**: Less than 50 millivolts change no-load to full-load at any output voltage. Less than 100 mv change at any voltage or current condition for ±10% line voltage variations.

DC Regulated Fixed Bias: Less than 50 millivolts change no-load to full-load.

DC Variable Bias: Regulated against line voltage changes. Internal impedance 0 to 10,000 ohms depending on bias control setting.

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

Ripple: Less than 500 microvolts.

Internal Impedance:

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

Recovery Time: Upon application of full-load: 0.1 millisecond max. Upon decrease from full load to: (a) 0 ma, 0.3 millisecond max.; (b) 25 ma, 0.1 millisecond max. Maximum transient voltage, 1 volt.

Metering:

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

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

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

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

Dimensions: Cabinet Mount: 20¾” wide, 12¾” high, 14¾” deep.
Rack Mount: 19” wide, 10¾” high, 13¾” deep behind panel.
Also can be used with HP AC-17 End Frames.


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

Data subject to change without notice.
POWER SUPPLIES

721A Transistor Power Supply

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

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

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

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

Specifications

Regulated Output: 0 to 30 volts dc; 0 to 150 ma dc.
Load Regulation: Less than 0.3% or 30 mv (whichever is greater) change from 0 to 150 ma.
Line Regulation: Less than 0.3% or 15 mv (whichever is greater) for ±10% line voltage change.
Noise and Ripple: Less than 150 µv.
Output Impedance: Less than 0.2 ohms in series with 30 ph.
Output Meter: Full scale indications of: 10 ma, 50 ma, 100 ma, 300 ma; 10 volts, and 30 volts.
Output Protection: Four step selection of maximum current: 25, 50, 100 and 225 ma.
Power: 115/230 v ±10%, 50/60 cps, 16 watts.
Weight: Net 4 lbs. Shipping 7 lbs.
Dimensions: 7" wide, 4½" high, 5¾" deep.
Price: $721A, $145.00

723A Power Supply

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

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

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

Specifications

Regulated Output: 0 to 40 volts dc; 0 to 500 ma dc.
Load Regulation: Less than 20 mv change from 0 to 500 ma.
Line Regulation: Less than 10 mv change for ±10% line voltage change.
Noise and Ripple: Less than 150 µv.
Temperature Stability: Less than 0.05%/°C or 10 mv/°C, whichever is greater.
Temperature Range: 0 to 55°C for operation within specifications.
Remote Programming: External resistance can control output voltage at the rate of 50 ohms/volt.
Output Impedance: Less than 4000 ohms in series with 20 ph.
Current Limiter: Continuously adjustable from approximately 60 to 600 ma.
Power: 115/230 v ±10%, 50/60 cycles.
Weight: Net, 12 lbs. Shipping 21 lbs.
Dimensions: 6-3/32" high, 5-1/16" wide, 11" deep.
Price: $723A, $225.00.

Data subject to change without notice.
New transistorized 722AR meets today's most demanding requirements for a well regulated dc power supply in investigations where high stability output under varying line and load conditions is essential. Model 722AR is particularly useful in applications which require high current at low voltage because it regulates over its full voltage range. For example, Model 722AR is an ideal source for furnishing power to banks of tunnel diodes.

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

Remote Sensing

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

Other Features

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

Specifications

Regulated Output: 0 to 60 volts, dc; 0 to 2 amperes, dc.
Load Regulation: Less than 5 mV change for 0 to 2 amperes change.
Line Regulation: Less than 2.5 mV change for ±10% line voltage change.
Noise and Ripple: Less than 250 µV.
Temperature Stability: Better than 0.02%/°C or 5 mV/°C, whichever is greater.
Temperature Range: 0 to 55°C for operation within specifications.
Output Impedance: DC: less than 2.5 milliohms.
AC: less than 5 milliohms in series with 4 µh.
Transient Recovery Time: Less than 200 μsec for recovery within 5 mV for change from 0 to full load or full load to 0 at any rated output or line voltage.
Output Meters: Voltage: 0 to 60 volts, one range.
Current: 0 to 2.5 amperes, one range.
Output Protection: Output current limiter continuously adjustable from approximately 100 mA to 2.1 amperes.
Cooling: Forced air.
Power: 115/230 V ±10%, 50/60 cps, 260 watts.
Weight: Net 34 lbs. Shipping 46 lbs.
Dimensions: 19" wide, 5¼" high, 12" deep.
Price: 722AR, $525.00 (rack mount).

Data subject to change without notice.
New transistorized 722AR meets today's most demanding requirements for a well regulated dc power supply in investigations where high stability output under varying line and load conditions is essential. Model 722AR is particularly useful in applications which require high current at low voltage because it regulates over its full voltage range. For example, Model 722AR is an ideal source for furnishing power to banks of tunnel diodes.

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

**Remote Sensing**

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

**Other Features**

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

**Specifications**

Regulated Output: 0 to 60 volts, dc; 0 to 2 amperes, dc.
Load Regulation: Less than 5 mV change for 0 to 2 amperes change.
Line Regulation: Less than 2.5 mV change for ± 10% line voltage change.
Noise and Ripple: Less than 250 µV.
Temperature Stability: Better than 0.02%/°C or 5 mV/°C, whichever is greater.
Temperature Range: 0 to 55°C for operation within specifications.
Output Impedance: DC: less than 2.5 milliohms.
AC: less than 5 milliohms in series with 4 µh.
Transient Recovery Time: Less than 200 µsec for recovery within 5 mV for change from 0 to full load or full load to 0 at any rated output or line voltage.
Output Meters: Voltage: 0 to 60 volts, one range.
Current: 0 to 2.5 amperes, one range.
Output Protection: Output current limiter continuously adjustable from approximately 100 mA to 2.1 amperes.
Cooling: Forced air.
Power: 115/230 V ± 10%, 50/60 cps, 260 watts.
Weight: Net 34 lbs. Shipping 46 lbs.
Dimensions: 19" wide, 5½" high, 12" deep.
Price: 722AR, $525.00 (rack mount).

*Data subject to change without notice.*
Versatile Power Source for Low-Power Klystrons

Specifications

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

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

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

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

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

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

Dimensions: Cabinet Mount: 7½" wide, 11½" high, 13½" deep.

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

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

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

Price: $715A, $325.00.

Data subject to change without notice.
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:

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

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

**Distortion Measuring Methods**

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

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

**Wave Analyzer**

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

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

**Automatic Harmonic Analysis**

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

\(\#\) Distortion Analyzers

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

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

The analyzer-oscilloscope combination is also useful for determining the nature of distortion, the presence of excessive noise and hum; or for detecting distortion caused by grid current on driving peaks.
302A WAVE ANALYZER

New, Highly Selective, Transistorized, Measures Wave Components Directly

Advantages:

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

Uses:

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

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

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

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

Simple Operation

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

Model 302A separates the input signal into its individual components so that each—the fundamental, harmonics and any intermodulation products—may be evaluated separately.

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

A frequency restorer circuit makes accurate frequency measurements possible at each component frequency of the input wave. The frequency restorer circuit supplies a sinusoidal signal at the frequency of the specific component to which the Model 302A is tuned. This signal can be measured on an electronic counter or observed on an oscilloscope. The amplitude of the restorer signal is determined by the level of the selected component. When the mode selector switch is in the normal or AFC position, the signal appears at the output terminals if the meter is indicating.

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

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

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

Specifications Model 302A

Frequency Range: 20 cps to 50 KC.
Frequency Calibration: Linear graduation 1 division per 10 cycles. Accuracy \( \pm (1\% + 5\text{ cps}) \).
Voltage Range: 30 \( \mu \text{v} \) to 300 \( \text{v} \) full scale in a 30, 100, 300 sequence. Steps of 1:3 or 10 dB. Meter range indicated by a dial mechanically linked to input attenuator. An absolute-relative switch provides for adjustment of intermediate values.
Warmup-Time: None.
Voltage Accuracy: \( \pm 5\% \) of full scale value.
Residual Modulation Products and Hum Voltage: Greater than 75 \( \text{db} \) down.
Intermediate Frequency Rejection: Intermediate frequency present in input signal rejected by at least 75 \( \text{db} \).
Selectivity: \( \pm 1/2 \) cycle b.w.—at least 3 \( \text{db} \) down
\( \pm 25 \) cycle b.w.—at least 50 \( \text{db} \) down
\( \pm 70 \) cycle b.w.—at least 80 \( \text{db} \) 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 \( \text{v} \) across 600 ohms at output terminals for full scale meter deflection. Output level control provided. Frequency response \( \pm 2\% \), 20 cycles to 50 KC. Output impedance approximately 600 ohms.
Oscillator Output: 1 \( \text{v} \) across 600 ohms at output terminals (mode selector in B.F.O.). Output level control provided. Frequency response \( \pm 2\% \), 20 cps to 50 KC. Output impedance approximately 600 ohms.

AC-97C Sweep Drive

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

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

Specifications AC-97C

Sweep Range: 50 revolutions.
Sweep Limits: Any interval from 50 revolutions to 10 degrees.
Sweep Speed: With Model 302A: 170 cps per second and 17 cps per second.
Shaft Speed: 10 rpm, 1 rpm, and neutral; quick change speed transfer without stopping. Neutral permits manual operation.
Sweep Output: 15 volts maximum. Change of output proportional to change in shaft position and zero output may be set for any shaft position. Full output may be obtained with 21/2 revolutions or with 50 revolutions of the output shaft.
Motor: Reversible synchronous capacitor type reluctance motor; may be stalled indefinitely.
Output Shaft: 1/4 inch diameter with adapter to 7/16 inch for Model 302A.
Power: 115 volts \( \pm 10\% \), 50 to 60 cps, 12 watts, running or stalled.
Mount: Mounts on front panel of Model 302A or bench stand.
Dimensions: 31/2" high, 7" wide, 51/4" deep, shaft extends 13/16" behind case.
Price: AC-97C, $275.00.

Data subject to change without notice.
330B/C/D DISTORTION ANALYZER

Accurate Distortion Readings 20 cps to 20,000 cps

Advantages:

- Blankets audio spectrum
- Measures noise as small as 100 μV
- High sensitivity, high stability
- Measures distortion as low as 0.1%
- Wide-band 20 db gain amplifier
- Oscilloscope terminals, built-in VTVM
- High-gain, wide-band amplification

Use It To Determine:

- Total audio distortion
- Voltage level, power output, gain
- Total distortion of AM rf carrier
- Noise and hum level directly
- Audio signal frequency

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

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

Model 330B Distortion Analyzer

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

The 20 db amplifier operates in conjunction with the @ R-C tuned rejection 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 voltmeter section of the equipment consists of a two-stage, high-gain amplifier, a rectifier and an indicating meter. A large amount of negative feedback is again employed to insure stability and uniform response from 10 cps to 100,000 cps. The voltmeter—which may be used as a separate instrument—responds to the average value of the applied voltage wave and is calibrated in the rms value of a sine wave.

Model 330C Distortion Analyzer

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

![Figure 1](image)

Model 330D Distortion Analyzer

The 330D is identical to the 330C except that an AM detector has been included. This detector permits the measurement of envelope distortion of an amplitude-modulated carrier. The detector covers a range of 500 KC to 60 MC and is varied by a tuning capacitor and range switch which selects one of five bands. (Detector may be switched out of circuit when audio frequencies are used.) Model 330D also includes the special VU meter employed in Model 330C. Other specifications are similar to Model 330B.

Specifications

**Distortion Measurement Range:** Any fundamental frequency, 20 cps to 20 KC.

**Frequency Calibration Accuracy:** ±2% entire range.

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

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

**Sensitivity:** Distortion levels of 0.3% are measured full scale. Levels of 0.1% readable with good accuracy.

**Distortion Meter Input Impedance:** Approximately 200,000 ohms, 40 pf shunt.

**Input Level for Distortion Measurements:** At least 1 volt rms.

**Voltmeter Sensitivity:** Full scale sensitivities of 0.03, 0.10, 0.50, 1.00, 3.00, 10.0, 30.0, 100 and 300 volts. Nine ranges spaced exactly 10 db. DB scale: -12 db to +2 db, calibrated on zero level = 1 milliwatt in 600 ohms.

**Voltmeter Frequency Range:** Model 330B, 10 cps to 100 KC; Models 330C and 330D, 10 cps to 60 KC.

**Voltmeter Accuracy:** For line voltages of nominal value ±10% (104 volts to 126 volts), Model 330B within ±3%, 10 cps to 100 KC; Models 330C and 330D within ±3%, 10 cps to 20 KC and ±6%, 10 cps to 60 KC.

**Voltmeter Input Impedance:** Approximately one megohm, 37 pf shunt.

**Noise Measurement:** Full scale reading of 300 microvolts. Noise measuring frequency range, 10 cps to 20 KC. Satisfactory readings can be made to -75 dbm.

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

**Meter Movement:** Models 330C and 330D: VU ballistic characteristics to meet F.C.C. requirements for AM, FM and TV broadcasting.

**AM Detector:** Model 330D: linear rf detector rectifies the transmitter carrier. Input circuit tunable from 500 KC to 60 MC in 5 bands. Detector distortion is negligible.

**Power:** 115/230 volt ±10%, 50/1000 cps, approximately 90 watts.

**Dimensions:** Cabinet Mount: 20 3/4" wide, 12 3/4" high, 14 3/4" deep. Rack Mount: 19" wide, 10 3/4" high, 15 3/4" deep behind panel. Also can be used with @ AC-17 End Frames.

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

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

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

*Data subject to change without notice.*
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

- **350A**, matches 500 ohm impedance.
- **350B**, matches 600 ohm impedance.

(Following apply to @ 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: 8½" wide, 5½" high, 5-5/16" deep. Rack Mount: 19" wide, 51/4" high 3¾" deep.

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

**Price**: @ 350A or 350B, $110.00 (cabinet); @ 350AR or 350BR, $115.00 (rack mount).

Data subject to change without notice.

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

355A/B Precision Attenuators

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

Specifications @ 355A

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

@ 355B same as 355A except:

- **Attenuation**: 120 db in 10 db steps.
- **Overall Accuracy**: ±0.5 db to 120 db at 1000 cps, ±1 db to 60 db below 250 MC, ±2 db to 120 db below 500 MC.
VOLTAGE, CURRENT AND RESISTANCE MEASURING EQUIPMENT

Measurement of the basic electrical quantities of voltage, current and resistance is required daily in practically every facility applying electronics. Electronic measuring instruments also are developed many precise, easy to use instruments to make electrical measurements under a wide range of conditions. Dependability and versatility are important design objectives, so that instruments can be applied with confidence even by personnel inexperienced with electronic circuits.

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

AC Voltage Measurement

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

<table>
<thead>
<tr>
<th>% Harmonic</th>
<th>True Rms Value</th>
<th>Modal 400D Indication</th>
<th>Peak Meter Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>5% 2nd</td>
<td>95.5</td>
<td>90 to 110</td>
<td>90 to 110</td>
</tr>
<tr>
<td>20% 2nd</td>
<td>88.2</td>
<td>80 to 120</td>
<td>80 to 120</td>
</tr>
<tr>
<td>50% 2nd</td>
<td>79.1</td>
<td>70 to 150</td>
<td>70 to 150</td>
</tr>
<tr>
<td>10% 3rd</td>
<td>95.0</td>
<td>90 to 104</td>
<td>90 to 104</td>
</tr>
<tr>
<td>20% 3rd</td>
<td>93.4</td>
<td>80 to 108</td>
<td>80 to 108</td>
</tr>
<tr>
<td>30% 3rd</td>
<td>89.5</td>
<td>80 to 116</td>
<td>80 to 120</td>
</tr>
<tr>
<td>50% 3rd</td>
<td>90.0</td>
<td>90 to 116</td>
<td>90 to 150</td>
</tr>
</tbody>
</table>

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

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

Figure 1.

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

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

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

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

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

DC Voltage Measurements

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

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

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

The \( \oplus \) photoconductor chopper was first employed in a very high sensitivity dc voltmeter, \( \oplus \) 425A, which has a range from 1 volt to 10 microvolts end scale. Careful attention to small sources of thermocouple voltages and galvanic action gives the very low drift of less than 4 microvolts per day. Very high input impedance is obtained by using feedback to increase the already high impedance of the meter. Calibrated shunt resistors make possible current measurements down to 10\(^{-12}\) amperes.

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

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

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

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

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

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

**Resistance Measurement**

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

**Current Measurement**

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

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

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

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

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

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

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

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

### Table 2

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

---

68
403A TRANSISTORIZED AC VOLTMETER
Compact, Battery-Operated, 1 cps to 1 MC, Portable

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

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

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

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

Data subject to change without notice.

Specifications

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

Frequency Range: 1 cps to 1 MC.

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

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

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

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

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

Dimensions: 8 1/4" wide, 5 1/2" high, 6 3/8" deep.

Weight: Net 4 3/4 lbs. Shipping 9 lbs.

Price: HP 403A, $275.00.
400D, 400H, 400L VACUUM TUBE VOLTMETERS

Highest Quality, Highest Accuracy Linear and Log Voltmeters

Advantages:

- Exceptional long-term stability
- Large voltage range, High sensitivity
- Broad 10 cps to 4 MC frequency coverage
- Two models individually calibrated to eliminate tracking error
- High 10 megohm input impedance
- Premium quality throughout; easy to service
- Usable as a stable, high gain amplifier
- Large overvoltage capacity

Uses:

- Research and Development Laboratory
- Production Test
- Communications
- Service Departments

On these pages Hewlett-Packard presents three of the industry's most widely used vacuum tube voltmeters.

Basically similar instruments, Models 400D, 400H and 400L have specific characteristics which render them suited to given applications.

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

Model 400H is an adaptation of Model 400D but offering individual meter face calibration and the extreme accuracy of 1% on an extra large 5” mirror-scale meter.

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

Individual Calibration

As indicated above, Models 400H and 400L are individually calibrated to eliminate tracking error. Scale tracking error is one of the major and inherent causes of inaccuracy in a voltmeter, but this has been eliminated, on a production basis and at no extra cost to the buyer, in these two precision HP...
The meter on each amplification channel is adjusted to its specific range, this assures highest stability and freedom from calibration change due to external conditions. The meter on each @ 400H and 400L is precisely and individually calibrated to the circuitry of that specific instrument.

**General Description**

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

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

Stability long term is such that a reduction in the Gm of the amplifier tubes to 75% of nominal value causes an error of less than 0.5%, 50 cps to 1 MC.

And even line voltage variations as high as ±10% cause negligible change.

Other features common to these three rugged @ voltmeters include a high 10 megohm input impedance preventing loading to circuits under test, generous overload protection guarding the instruments even against peaks of 600 volts, special circuitry minimizing transients during switching, premium quality construction throughout, and output circuitry permitting the voltmeters to be used as broadband, high gain amplifiers throughout their full frequency range.

1% Accuracy Model 400H

As indicated above, Model 400H is similar to Model 400D but offers 1% accuracy. Details of accuracy at various frequencies are found in the table below.

**Logarithmic Model 400L**

Designed specifically for acoustical and communications engineers, and men working with decibel measurements, Model 400L incorporates a special logarithmic meter movement. The log voltage scale plus unusually long scale length provide an instrument of maximum readability and accuracy which is a constant percentage (±2%) of reading. The decibel scale is more than 5" long, and voltage scales spread across the full scale length. The meter is mirror-backed for utmost accuracy. A range switch changes voltage sensitivity in 10 db levels. This feature, together with the 12 db scale, provides the wide overlap desirable in decibel level measurements.

**Special db-Measuring 400D and 400H**

As normally supplied, Models 400D and 400H read direct in volts and db, with the voltage scale uppermost. For greater resolution in db measuring, these instruments are available as Models 400D-db and 400H-db ($12.50 extra) with the db meter scale uppermost.

**Accessories**

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

Data subject to change without notice.

---

**Specifications**

<table>
<thead>
<tr>
<th>Voltage Range:</th>
<th>400D/DR</th>
<th>400H/HR</th>
<th>400L/LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mv to 300 v full scale, 12 ranges</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency Range:</th>
<th>10 cps to 4 MC</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Accuracy:</th>
<th>400D/DR</th>
<th>400H/HR</th>
<th>400L/LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>±2% of full scale, 20 cps to 1 MC; ±1% of full scale, 20 cps to 2 MC; ±5% of full scale, 20 cps to 4 MC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>±2% of reading or ±1% of full scale whichever is more accurate, 50 cps to 500 KC, ±3% of reading or ±2% of full scale, 20 cps to 1 MC; ±4% of reading or ±3% of full scale, 20 cps to 2 MC; ±5% of reading or ±4% of full scale, 20 cps to 4 MC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Long Term Stability:</th>
<th>Reduction in Gm of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 50 cps to 1 MC</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Calibration:</th>
<th>400D/DR</th>
<th>400H/HR</th>
<th>400L/LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reads rms value of sine wave. Voltage indication proportional to average value of applied wave.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear voltage scales 0 to 3 and 6 to 1; db scale = 12 to + 2 db. 0.8 db = 1 mw in 600 ohms.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reads rms value of sine wave. Logarithmic voltage scales 0.3 to 1 and 0.8 to 1. Linear db scale = -10 db to + 2 db. Based on 0 db = 1 mw in 600 ohms, 10 db intervals between ranges.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Impedance:</th>
<th>10 megohms shunted by 15 pf (ranges 1 to 300; 25 pf on ranges 0.001 to 0.3 v)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Amplifier:</th>
<th>Output approx. 0.15 v max. Internal impedance 50 ohms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power:</td>
<td>115/230 volts ±10%, 50/1000 cps, approx. 80 watts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimensions:</th>
<th>Cabinet Mount: 71/4&quot; wide, 11/16&quot; high, 12&quot; deep, Rack Mount: 19&quot; wide, 2 3/4&quot; high, 10 1/2&quot; deep behind panel.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Weight:</th>
<th>Net 18 lbs. Shipping 23 lbs. (cabinet mount), Net 21 lbs. Shipping 33 lbs. (rack mount)</th>
</tr>
</thead>
</table>

| Price: | ±p: 400D $250.00* **p: 400H $255.00* ** **p: 400LR $313.00* ** **p: 400L $325.00* |

* Cabinet ** Rack Mount
Specifications

Range: 0.001 to 999 volts, dc.
Presentation: 3 illuminated figures, with decimal and polarity sign.
Accuracy: Within ± 0.2% of reading, ± 1 count.
Floating Input: Permits measurement of systems operating within ± 500 volts dc of power line ground.
Ranging Time: 0.2 seconds to 2 seconds, depending on range change required.
Input Impedance: 11 megohms to dc on all ranges.
Sample Rate: Internal: Maximum, between 4 and 5 per second.
Response Time: Less than 1 second to step function.
Input Filter ac Rejection: 3 db at 1.5 cps, nominally 44 db at 60 cps.
Output: (405CR only).
   (1) 10-line decimal code for operating @ Model 561B Digital Recorder or K05-405A remote indicator.
   (2) Single-line voltage coded decimal (staircase), for operating @ Model 560A Digital Recorder, with use of the 405A-95C adapter.
   (3) A print command for @ digital recorders is issued after every sample, except when the 405CR is ranging.
Power: 115/230 volts ± 10%, 50/60 cps, 150 watts.
Dimensions: 7” high, 19” wide, 13½” deep behind panel.
Weight: Net 26 lbs. Shipping 38 lbs.
Accessories Available: @ 457A AC-to-DC Converter, see next page.
Price: @ 405BR, $850.00. @ 405CR, $925.00. (Both rack mount.)

Remarkable simplicity of use is an outstanding feature of the @ 405BR/CR Digital Voltmeters. Just touch the probe to the voltage to be measured, and the 405BR/CR automatically zero-sets itself, chooses the proper voltage range and polarity, and displays the result in bright, clear numerals, complete even to the polarity sign and decimal point. Operator errors are reduced to the vanishing point!

For repeated readings in the same voltage range, the automatic feature can be disabled and the decimal can be positioned manually.

Three digit resolution on all voltages between 1 and 1,000 volts allows the observation of very small changes, and accuracy is held to ± 0.2% of the reading on all ranges, ± 1 count. For maximum usability in various environments, the input is isolated from ground (allowing voltage difference measurements), dc input impedance is 11 megohms on all ranges, and ac rejection reaches the 3 db point at 1.5 cps.

For systems applications, the @ 405CR is offered. This instrument is similar to @ 405BR but has provision for an external sampling command and recording outputs both in ten-line decimal code and one-line staircase code, as well as a print command for operating @ 560A/561B Digital Recorders.

Versatility, operating simplicity and reasonable price make @ 405BR/CR Automatic DC Digital Voltmeters solid investments for the laboratory, production line, or systems console.
With a dc digital voltmeter @ 457A is the ideal converter for many digital systems requiring that ac voltages be presented in digital form for entry into card punches or automatic testing systems. It can also be used with @ 405CR Digital Voltmeter and an @ 560 series Digital Recorder to provide a permanent record in printed digital form.

A frequency range from 50 cps to 500 KC is covered with conversion accuracy of ±0.75% of full scale ±1 mv. Even greater accuracy is obtained for signals under 50 KC. When Model 457A is used with @ 405BR/CR Digital Voltmeters, ac voltage measurements can be made with three-digit resolution and overall accuracy of 1% ± 2 counts from 50 cps to 500 KC. From 50 cps to 50 KC accuracy is 0.5% ± 2 counts.

Model 457A is an average-responding, rms calibrated ac-to-dc converter. Thus, a one volt rms sine wave input provides a one volt dc output.

Ranging is accomplished by input attenuation so that the output dc voltage is always between 0 and 1 volt dc. Attenuation ratios are 1:1, 10:1, 100:1, and 1,000:1 with highest rated input of 300 volts rms.

A new modular cabinet design provides easy access to the instrument chassis. The modular design facilitates stacking of instruments on the test bench. Or, if rack mounting is desired, two end brackets supplied with the instrument may be attached quickly.

**Specifications**

**Input Range:** 0 to 300 volts rms, in 4 decade ranges corresponding to 1, 10, 100, and 1,000 v rms full scale.

**Frequency Range:** 50 cps to 500 KC.

**Accuracy:** ± 0.3% ± 1 mv from 50 cps to 50 KC. ± 0.75% ± 1 mv from 50 KC to 500 KC.

**Output:** 0 to 1.0 v dc, responding to average value of ac input, with output calibrated as rms value of sine wave. Input step attenuation of 1, 10, 100, or 1,000.

**Output Impedance:** 10,000 ohms.

**Input Impedance:** 1 megohm, shunted by 30 pf.

**Power:** 115/230 volts ± 10%, 50/1,000 cps, approximately 31 watts.

**Dimensions:** 16¼” wide, 3¾” high, 13¼” deep.

**Weight:** Net: 12 lbs. Shipping 20 lbs.

**Price:** @ 457A, price on request.

*Data subject to change without notice.*
"Touch and Read" Measurement, 3 mv to 10 v, 500 KC to 1,000 MC!

**Advantages:**

- More measurements with a single instrument
- Reads rf voltage, 500 KC to 1,000 MC
- Measures millivolts at 1 GC (KMC)
- Full scale ranges 10 mv to 10 v
- Versatile probe tips for wide application
- High resolution on linear scale
- Reads in volts, decibels
- Eliminates annoying thermal drift
- Probe diodes protected against burnout

**Uses:**

- Laboratory, broadcast, production test department
- Measurements on coaxial lines
- Measurements in terminated coaxial circuits
- Accurate low-level measurements in IF strips
- Low-level measurements at vhf frequencies

Millivolt sensitivity from 0.5 to 1,000 MC, linear voltage scales and low thermal drift make the ‣ 411A RF Millivoltmeter unique among instruments of its kind.

Although Model 411A measures voltages in the region where detector characteristics are square-law, the meter scales are linear without resorting to complex, difficult to adjust, compensating networks. Two voltage scales in a 1:3 ratio are provided so that you may make most measurements in the more accurate upper two-thirds of the scale. The 1:3 ratio between voltage scales also permits a high-resolution db scale with 10 db between ranges.

Temperature compensation in Model 411A is so effective that rated performance is obtained in an ambient temperature range of 10 to 40°C, even when measuring signals as low as 3 mv.

**Figure 1. ‣ 411A Simplified Block Diagram.**
Circuit Description

Utilizing a new approach, 411A generates, by use of feedback, a low frequency sine wave whose amplitude is equivalent to that of the rf signal input. This low frequency signal is metered, indicating the magnitude of the input rf signal.

The general operation can be seen from the block diagram shown in Figure 1. The input rf is detected by a semiconductor diode, and the resulting dc signal is fed into an error detector. Any difference between it and the feedback reference is amplified and used to control the output of a modulator operating on a 100 KC carrier.

The magnitude of the 100 KC output is proportional to the magnitude of the error signal. The modulator output is fed back through the range attenuator to a second diode whose detection characteristics are closely matched to those of the rf detector. The resulting dc is used as the reference for the error detector. As long as the loop gain is high, the error will tend toward zero.

Since the two detected dc voltages are approximately equal and the detection characteristics of the diode detectors are the same, the effective amplitude of the low frequency feedback signal must be equal to that of the input rf. Thus, a measure of the amplitude of the feedback 100 KC is equivalent to a measure of the input rf regardless of any non-linearity in the detector characteristics.

Temperature compensation in Model 411A is accomplished by placing the two detector diodes in close thermal proximity in the rf probe. Even though their detection characteristics change with temperature, they change in the same manner. In this way the two diodes maintain their match over a wide temperature range.

Photoelectric Chopper

Other features offered in the 411A include an 411A-developed photoelectric chopper to eliminate contact noise, guarantee high sensitivity, and provide freedom from zero-drift; an output for galvanometer recording; accessory probe tips for use in a wide variety of circuits (for measuring on as well as at the termination of coax transmission lines), and a capacity divider increasing 411A voltage capability to 1,000 v. A coupling capacitor in the probe protects diodes from high-current transients when the probe is connected to potentials up to 300 v dc.

When measuring terminal voltages on coaxial lines it is often desirable to terminate the line with a low reflection load such as the Model 908A Coaxial Termination (see page 189).

In this application the 411A-21D Type N Tee Probe Tip is used with the 908A. Model 908A terminates the line and the "T" makes a convenient connection for the voltmeter.

![411A-21G Accessory Probe Kit. Contains probe tips to meet all measurement requirements normally encountered. See specifications for details.](image)

Figure 2. Typical input resistance for 411A-21B, 21C, 21E. For 21F, multiply 21E x 100.


50-ohm Termination: Model 908A Coaxial Termination (See page 189.)

Galvanometer Recorder Output: Proportional to meter deflection, 1 ma into 1,000 ohms at full scale deflection.

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


Weight: Net 12 lbs. (cabinet); 15 lbs. (rack). Shipping, 18 lbs. (cabinet); 28 lbs (rack).

Price: 411A, $450.00 (cabinet); 411AR, $455.00 (rack mount).

Data subject to change without notice.
410B VACUUM TUBE VOLTMETER

All-Purpose Test Instrument Measures to 700 MC

Specifications

AC Voltmeter:
- Range: 1 to 300 v full scale.
- Frequency Range: 20 cps to 700 MC.
- Frequency Response: Flat within ±1 db to 700 MC; drops off less than 1 db at 20 cps. Indications obtainable to 3,000 MC.
- Input Impedance: Input capacity 1.5 pf, input resistance 10 meg-ohms at low frequencies. At high frequencies resistance drops off due to dielectric loss.

DC Voltmeter:
- Range: 1 to 1,000 v full scale.
- Input Resistance: More than 100 megohms, all ranges.

Ohmmeter:
- Range: 0.2 ohm to 500 megohms in 7 ranges. Midscale readings of 10, 100, 1,000, 10,000, 100,000 ohms, 1 and 10 megohms.

General:
- Accuracy: ±3% of full scale, all ranges, on sinusoidal ac voltages and dc voltages. AC portion of instrument is peak-responding, calibrated in rms volts.
- Power: 115/230 v ±10%, 50/1,000 cps, 40 watts.
- Dimensions: Cabinet Mount: 7½" wide, 11½" high, 8½" deep. Rack Mount: 19" wide, 7" high, 6" deep behind panel.
- Price: @ 410B, $245.00 (cabinet); @ 410BR, $265.00 (rack mount).

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

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

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

Data subject to change without notice.
Hewlett-Packard 425A DC Microvolt-Ammeter makes measurements of extremely small dc voltages and currents without requiring expensive arrays of complex equipment, even in the presence of relatively strong ac signals.

No Mechanical Vibrator

Two important circuit aspects include very heavy ac filtering and the substitution of a photoelectric chopper developed by HP to replace the conventional error-inducing mechanical vibrator. Every known assurance of safety, accuracy and dependability has been incorporated; momentary overloads of 1,000 volts cause no damage; the pickup probe minimizes thermocouple and triboelectric effects.

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

Drift-Free Amplifier

The amplifier provides a 1 volt output for end scale deflection or a 1 ma output into 1,000 ohms to drive a potentiometer or galvanometer recorder. For driving sensitive potentiometer recorders, the 425A includes a built-in potentiometer for reducing output voltage.

Model 425A has an inherent input impedance much higher than specified and a 1 megohm resistor directly across the input insures a constant input impedance. If an unusually high input impedance is required, the input resistor can be removed to provide greater than 200 megohms input impedance.

Specifications

Microvolt-Ammeter

Voltage Range: Pos. and neg. voltages from 10 µv end scale to 1 v end scale, 11 steps, 1-3-10 sequence.
Current Range: Pos. and neg. currents from 10 µma end scale to 3 ma end scale, 18 steps, 1-3-10 sequence.
Input Impedance: Voltage Ranges: 1 megohm ± 3%. Current Ranges: Depends on range, 1 megohm to 0.33 ohm.
Accuracy: Within ± 3% of end scale. Line frequency variations ± 3 cps affect accuracy less than ± 2%.

Amplifier

Gain: 100,000 maximum.
AC Rejection: At least 3 db at 0.2 cps, 50 db at 50 cps and approximately 60 db or more above 60 cps. A power line frequency or twice power line frequency signal 40 db greater than end scale causes less than 1% error.
Output: 0 to 1 v for end scale reading, adjustable (5,000 ohm shunt potentiometer), 1 ma maximum at 1 v output.
Output Impedance: Depends on setting of output potentiometer, 10 ohms when potentiometer is set for maximum output.
Noise: Less than 0.2 µv rms (typically less than 1.2 µv p-p) referred to the input.
Drift: After 15 minutes warmup drift is less than ± 4 µv per day referred to input.

General

Power: 115/230 v ± 10%, 60 cps, 40 watts. 50 cps operation on special order.
Dimensions: Cabinet Mount: 7½" wide, 11¾" high, 12" deep.
            Rack Mount: 19" wide, 7" high, 11" deep behind panel.
Accessories Available: §§ 425A-21B, 1,000:1 Divider Probe, increases range of 425A to 1,000 volts. Division accuracy ± 2%.
§§ 425A-200B, 10,000:1 Divider Probe, increases range of 425A to 10,000 volts. Division accuracy ± 2%.
Price: §§ 425A, $500.00 (cabinet); §§ 425AR, $505.00 (rack mount).
For 50 cps power lines prefix Model No. 425B; no additional charge.

Data subject to change without notice.
Here is one compact instrument that makes all normally used dc measurements with precision and simplicity.

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

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

The 412A insures accurate readings regardless of test conditions. Input is floating and input resistance is high, thereby avoiding errors due to loading circuits or insertion of ground connections. A very high degree of ac rejection insures that readings are accurate even in the presence of ac signals.
Model 413A uses the sensitive and precise circuitry of §412A (opposite page) to provide a dc null voltmeter of outstanding stability and resolution. Model 413A has 13 zero-centered ranges, running from 1 mv to 1,000 volts end scale. The input terminals are isolated from ground, allowing operation up to 500 volts dc or 130 volts ac from ground potential.

High input impedance, (10 megohms on the most sensitive range, 200 megohms on 300 mv range and above) makes the Model 413A especially valuable in resistance bridge measurements. Accuracy of this instrument is within 2% of end scale; drift and noise are virtually imperceptible.

Because the dc null voltmeter provides an output proportional to meter deflection, §413A is useful as an indicating and control device. For instance its high voltage gain (1,000 on the 1 mv range), high stability and low noise make the §413A desirable for amplifying the output of a thermocouple in control systems. The Zero control may be used to set an arbitrary reference.

For dc voltmeter use, §413A offers high input impedance, voltage ranges from 1 mv to 1,000 volts end scale, 2% accuracy and virtually drift-free operation.

Specifications

Voltmeter:
- Ranges: Positive and negative voltages from 1 mv to 1,000 v end scale in thirteen zero-center ranges.
- Accuracy: ± 2% of end scale value.
- Input Resistance: 10 megohms on 1, 3, and 10 mv ranges.
- 200 megohms on 300 mv range.
- 1000 megohms on 1 volt range.
- 2000 megohms on 3000 mv range and above.
- AC Rejection: A voltage at power line or twice power line frequency 40 db greater than full scale affects reading less than 1%. Peak voltage must not exceed 1,500 v.
- Limits of Zero Control: Approximately ± end scale value on any range.

Amplifier:
- Voltage Gain: 0.001 to 1,000 in thirteen steps.
- Gain Accuracy: ± 1.5%.
- Gain Linearity: ± 0.2%.
- Noise: Less than 0.1% (rms) of end scale on any range.
- Output: 1 volt for end scale deflection, same polarity as input signal. End scale corresponds to 1.0 on upper scale. Maximum load current 1 ma.
- Output Impedance: Less than 2 ohms at dc.
- AC Rejection: Approximately 3 db at 1 cps, 80 db at 50 and 60 cps.
- Input Terminals: Binding posts.
- Input Isolation: Greater than 100 megohms shunted by 0.1 pf to instrument case (power line ground).
- Common Signal Rejection: May be operated up to 500 v dc, or 130 v ac above ground.
- Power: 115/230 volts ± 10%, 50/60 cps, 35 watts.
- Dimensions: Cabinet Mount: 11½” high, 7½” wide, 10” deep.
- Rack Mount: 3½” high, 19” wide, 7½” deep behind panel.
- Weight: Net 12 lbs. Shipping 17 lbs. (cabinet).
- Price: §413A, $350.00 (cabinet); §413AR, $355.00 (rack mount).

Data subject to change without notice.
**hp 428A/B CLIP-ON DC MILLIAMMETERS**

**Ultimate Measuring Ease, No Circuit Loading**

**Advantages:**
- No circuit interruption
- No circuit loading
- Measures dc in the presence of ac
- A convenient dc amplifier completely isolated from circuit being measured.

**Uses:**
- Computer testing: with quick clip-on convenience, current measurements can be made rapidly. This speed of measurement is a great advantage wherever multiple readings must be made.
- Transistor circuit analysis: with virtually no loading of the circuit under test, Model 428A/B can usefully measure current even in a low impedance emitter circuit.
- Combined measurements: by looping several wires through the jaws of the probe, the sum (or difference) of individual currents can be measured directly.
- Low frequency ac current measurements: for external metering or recorder operation a front panel output on Model 428B provides a voltage proportional to the current being measured; bandwidth is dc to 300 cps. Can be used as an isolated input dc current amplifier.

With the increased importance of current parameters in today’s development activities, 428A/B Clip-on DC Milliammeters are instrumental in saving many expensive engineering manhours. Now direct current from 0.3 milliampere to 10 amperes can be measured without interruption to the circuits involved, and without the error-producing loading of conventional methods.

For any measurement of direct current within its range, simply clamp the jaws of the 428 probe around a wire, and read!

In any application where a large number of direct current measurements must be made, Models 428A and 428B are without equal for ease and speed of operation. Their wide current range will handle most signals directly. For even greater sensitivity, several loops may be put through the probe, increasing the sensitivity by the same factor as the number of loops.

428A/B make fast, accurate measurements in circuits where the introduction of conventional current-measuring devices would alter conditions to such an extent that the desired measurement would no longer be accurate. In fact, there are some cases where conventional current-measuring methods would render the circuit inoperative. Here, too, 428A/B are fast and accurate.
Besides making current measurements directly, Models 428A/B are also valuable for measuring sums and differences of currents in separate wires. When the probe is clipped around two wires carrying current in the same direction, their sum is indicated on the meter; when one of the wires is reversed, their difference is measured. In this way, the balancing of currents is easily accomplished by making their difference equal to zero.

Models 428A and 428B are almost identical except for current measurement range. Model 428B has three more ranges than the 428A to give it full scale readings from 1 ma to 10 amperes. Another important new feature of Model 428B is an output voltage proportional to meter deflection. This adjustable or calibrated output is available at the front panel for driving recorders or making low frequency current measurements over a dc to 300 cps bandwidth. It thus makes the instrument a convenient, completely isolated dc current amplifier.

**Circuit Description**

The core of the Model 428A/B probe tip is magnetically saturated by a high frequency current produced within the instrument. Without the high frequency saturation current the direct current being measured would induce a steady magnetic flux in the core. However, the magnetic saturation periodically changes the reluctance of the magnetic circuit and varies the strength of the dc-caused magnetic flux.

Varying the dc magnetic flux induces a periodic voltage in the output coil proportional to the dc being measured. This signal is amplified and demodulated, then returned to the probe as negative dc feedback. It is this feedback signal which is metered. By keeping loop gain high and including the probe as well as the signal amplifier in the feedback loop, high levels of stability and accuracy are attained.

**Specifications**

**Current Range:**
- 428A: Full scale readings from 3 ma to 1 ampere in 6 ranges.
- 428B: Full scale readings from 1 ma to 10 amperes in 9 ranges.

**Accuracy:** ± 3%, ± 0.1 ma.

**Probe Inductance:** Less than 0.5 μh will be introduced into measured circuit.

**Probe Induced Voltage:** Less than 15 mv peak into measured circuit.

**AC Rejection:** AC with peak value less than full scale affects meter accuracy less than 2% at frequencies above 5 cycles and different from the carrier (40 KC) and its harmonics. (On 428B 10 ampere range, ac is limited to 4 amperes, peak.)

**Output:** 428B — Approx. 1.4 volts across 1400 ohms for full scale. Frequency response dc to 300 cps.

**Probe Insulation:** 500 volts, maximum.

**Probe Tip Size:** Approximately 1/2" by 9/32". Aperture diameter 3/16".

**Dimensions:** Cabinet Mount, 7 1/2" wide, 11 1/2" high, 14 1/2" deep. Rack Mount, 19" wide, 7" high, 19" deep behind panel.


**Price:**
- 428A, $500.00 (cabinet); 428AR, $505.00 (rack mount).
- 428B, $550.00 (cabinet); 428BR, $555.00 (rack mount).

Data subject to change without notice.
**hp 456A AC CURRENT PROBE**

Measures AC Current Without Direct Connection to Wire

**Specifications**

Sensitivity: 1 mv/ma ±1% at 1 KC.

Frequency Response: ±2%, 100 cps to 3 MC.
±5%, 60 cps to 4 MC.

-3 db at 25 cps and greater than 20 MC.

Pulse Response: Rise time is < 20 nsec, sag < 16%/msec.

Maximum Input: 1 amp rms; 1.5 amp peak. 100 mA above 5 MC.

Effect of dc Current: No appreciable effect on sensitivity and distortion from dc current up to 0.5 amp.

Input Impedance: (Impedance added in series with measured wire by probe.) Less than 50 milliohms in series with 0.05 ph. (This is approximately the inductance of 1 1/2 in. of hookup wire.)

Probe Aperture: 3/16" dia.

Probe Shunt Capacity: Approximately 4 pf added from wire to ground.

Distortion at 1 KC: For 1/2 amp input at least 50 db down.

Maximum at least 70 db down.

Equivalent Input Noise: < 50 μA rms (100 μA when ac powered).

Output Impedance: 220 ohms at 1 KC. Approximately +1 V dc component. Should work into load of not less than 100,000 ohms shunted by approximately 25 pf.

Power: Two Mallory Battery Co. TR 233R and one TR 234 batteries (456-0005 and 456-0006). Battery life approximately 400 hours. AC power supply optional at extra cost, 115/230 v, 50 to 1,000 cps, approximately 1 watt.

Weight: Net 3 lbs. Shipping 4 lbs.

Dimensions: 5" wide, 6" deep, 1 1/2" high. Probe cable is 5 ft. long; 2 ft. output cable terminated with dual banana plug.

Prices: @ 456A with batteries, $190.00.

@ 456A with ac supply (456A-95A) installed in lieu of batteries, $210.00. @ 456-95A AC Supply for field installation, $40.00.

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

The unique @ 456A AC Current Probe clamps around the current-carrying wire, and provides a voltage output you read on a VTVM or scope. Model 456A's 1 mA to 1 mv unity conversion permits direct readings up to 1 ampere rms. Model 456A permits measurement of ac in logic circuits, transistors and vacuum tubes since even 0.5 ampere of dc has no appreciable effect on operation. The instrument also makes possible viewing on oscilloscopes complex current waveforms with rise times up to 20 nsec, or current signals ranging from 1 ma rms to 1 ampere rms.

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

_Data subject to change without notice._
Highly accurate calibration of vacuum tube voltmeters or oscilloscopes is simple and fast with an HP VTVM Calibration System composed of Model 738AR Voltmeter Calibrator, Model 739AR Frequency Response Test Set and Model 200SR Oscillator.

**738AR Voltmeter Calibrator** is a highly stable precision voltage source, expressly designed for calibration of high impedance electronic voltmeters and oscilloscopes. It provides accurate voltage levels from 300 microvolts to 300 volts in precise pre-selected steps. Drift of dc voltage is less than 0.1% per week and less than 0.25% per week for ac voltages.

**739AR Frequency Response Test Set** provides a convenient constant-amplitude reference voltage of a variable frequency, is ideal for checking the frequency response of VTVM’s, oscilloscopes, video amplifiers and filters. Frequency response is checked by applying a constant amplitude voltage at various frequencies and noting the response of the device under test with respect to response at a reference frequency. Internal oscillator, 300 KC to 10 MC.

**200SR Oscillator** combines with the **739AR** to extend the range to frequencies as low as 5 cps.

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### Specifications

**738AR Voltmeter Calibrator**
- Voltage Range: 300 µv to 300 v, dc or ac (rms and peak-peak, 400 cps).
- Levels: Calibration voltage 300 µv to 300 v in steps of 0.3, 0.5, 1, 2 and 5 volts with multipliers of 0.001, 0.01, 0.1, 1, 10 and 100.
- Tracking voltage 0.1 to 1 v in 0.1 volt steps and 0 to 5 v in 0.5 volt steps.
- Accuracy: 300 v working voltage into attenuator, accurate within 0.1% dc and 0.25% ac, after a 30-minute warmup.
- Long-term Stability: Less than 0.1% dc drift per week, less than 0.25% ac drift per week.
- Attenuator Accuracy: Within ±0.1% or ±5 µv, whichever is larger.
- Dimensions: 19" wide, 7" high, 15" deep.
- Weight: Net 38 lbs. Shipping 75 lbs.
- Price: 738AR, $875.00 (rack mount).

**739AR Frequency Response Test Set**
- Frequency Range: 300 KC to 10 MC in 3 ranges (5 cps to 10 MC with **200SR Oscillator**).
- Frequency Response of Monitoring Circuit: Flat within ±0.5% from 10 cps to 5 MC; within ±0.5%, -1.5%, 5 cps to 10 MC. Monitoring circuit is averaBe reading.
- Dimensions: 19" wide, 7" high, 8¾" deep.
- Weight: Net 20 lbs. Shipping 28 lbs.
- Price: 739AR, $525.00 (rack mount).

**200SR Oscillator**
- Frequency Range: 5 cps to 600 KC in 5 ranges.
- Output: 3 v rms into 50 ohms.
- Dial Accuracy: ±2%.
- Frequency Response: ±1 db, 1,000 cps reference.
- Dimensions: 19" wide, 7" high, 14¼" deep.
- Weight: Net 25 lbs. Shipping 35 lbs.
- Price: 200SR, $230.00 (rack mount); 200S, $225.00 (cabinet).

**Note:** All three instruments are available in cabinet with single power cord and plug strip. Specify RO2 738A, $1,870.00.
Extend the usefulness of your present voltmeters with these precision built accessories. Make fast, accurate measurements far beyond the original range of your instruments.

In addition to the time-saving accessories shown here, AC-21F Current Probe (use with your AC VTVM or scope to measure current) and AC-21J Low Frequency Probe are offered. For details, see page 19.

452A Capacitive Voltage Divider
For 400 series and 410B. Safely measures power voltages to 25 kv. Accuracy ± 3%. Division ratio, 1,000:1. Input capacity 15 pf ± 1. Maximum voltage ratings at 60 cps, 25 kv; 100 KC, 22 kv; 1 MC, 20 kv; 10 MC, 15 kv; 20 MC, 7 kv. Usable for dielectric heating, power and supersonic voltages. Price, $125.00.

452A-95A Adapter: (Not shown.) Connects 410B to shielded connector. $25.00.

453A Capacitive Voltage Divider
For 410B Voltmeter. Increases range so transmitter voltages can be measured quickly, easily. Accuracy ± 1%. Division ratio, 100:1. Input capacity approximately 2 pf. Maximum voltage 2,000 v. For frequencies 10 KC and above. $30.00.

454A Capacitive Voltage Divider
For 400 series Voltmeters. Safely measure power line, audio, ultrasonic and rf voltages. Accuracy ± 3%. Division ratio, 100:1. Input impedance 50 megohms, resistive shunted with 2.75 pf capacity. Maximum voltage, 1,500 v. Price, $50.00.

455A Probe Coaxial “T” Connector
For 410B Voltmeter. Measures voltages between center conductor and sheath of 50 ohm transmission line. Maximum standing wave ratio 1.1 at 500 MC, 1.2 at 1,000 MC. Male and female type “N” fittings. Price $40.00.

458A Probe Coaxial “N” Connector
For 410B Voltmeter. Measure at open end of 50-ohm transmission line. (No terminating resistor.) Has female type “N” fitting. Price, $30.00.

459A DC Voltage Divider
For 410B Voltmeter. Gives maximum safety and convenience for measuring high voltages as in television receivers, etc. Accuracy ± 5%. Division ratio 100:1. Input impedance 12,000 megohms. Maximum voltage 30 kv. Maximum current drain 2.5 microamperes. Price, $50.00.

470A-470F Shunt Resistors
For 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.

<table>
<thead>
<tr>
<th>INSTRUMENT</th>
<th>MAX. CURRENT</th>
<th>MAX. VOLTAGE</th>
<th>VALUE</th>
<th>PRICE</th>
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<tr>
<td>470 F</td>
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<td>30.0 v</td>
<td>1,000 Ω</td>
<td>20.00</td>
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</tbody>
</table>

Data subject to change without notice.
AMPLIFIERS

Hewlett-Packard amplifiers cover a wide variety of measuring requirements.

General-Purpose Amplifiers

© 450A Amplifier (page 90) is a general-purpose instrument, usable wherever wide frequency range and stable gain are desired. Because of a large amount of feedback, the instrument has an extremely stable 20 or 40 db gain over a continuous frequency range of 5 cps to 1 MC. In addition, it can be used up to 3 MC with some sacrifice in gain and stability.

The new © 466A AC Amplifier (page 90) is an extremely compact, high stability instrument ideal wherever low distortion, wide frequency range and ready portability are required. It is particularly suited for increasing sensitivity of voltmeters and oscilloscopes, and for field measurements where high input impedance is required.

Distributed Amplifiers

© 460A and 460B Distributed Amplifiers (pages 86, 87) are wide-range amplifiers providing distortionless pulse amplification. They combine extremely short rise time with zero overshoot.

These instruments are employed to amplify pulses faster than 0.01 microsecond. They provide suitable output for operating scalers or coincidence devices, or investigating characteristics of pulse circuitry in nuclear work or television, uhf and vhf networks. They increase sensitivity of oscilloscopes and voltmeters and are useful for other amplification purposes up to 120 MC. Response is substantially constant down to 20 KC.

Operating Techniques

© 460A is a two stage voltage amplifier (which does not invert the input signal) with approximately 20 db gain and a rated output of 8 volts into an open circuit. This is sufficient for operating scalers, etc. For higher voltages required for cathode ray tube deflection, © 460B is recommended. This instrument is a wideband amplifier designed to supply a maximum of 125 volts peak (negative) open circuit. This is sufficient to provide full deflection on any commonly-used cathode-ray tube. One or more 460B amplifiers can be cascaded with one or more 460A amplifiers to provide a high-gain pulse amplifier with very rapid rise time and zero overshoot (see Figure 1).

Cascading Amplifiers

When cascading distributed amplifiers, consideration must be given to polarity as well as amplitude of the pulse to be amplified. Model 460B, unlike Model 460A, consists of a single stage and will invert the polarity of the applied pulse. For maximum deflection on the cathode-ray tube, the setup must be arranged so that the input to the last 460B is positive and of approximately 8 volts peak amplitude. This can be achieved by preceding the final 460B with another 460B whenever necessary.

The rise time of amplifiers in cascade is greater than that of a single amplifier by T x Vn, where n is the number of 460 amplifiers in the system and T is the rise time of one 460 amplifier (3.0 x 10^-9 seconds). In addition, the rise time of the RC combination formed by the capacity of CRT deflection plates and the internal impedance of the 460B (200 ohms) should be considered.

Traveling-Wave Tube Amplifiers

Hewlett-Packard traveling-wave tube amplifiers (pages 88, 89) are high gain broadband linear devices covering the frequency range of 1 to 12.4 GC (KMC). Besides amplifying any type rf signal in their pass band they may be used to modulate rf signals with pulses of nanosecond rise and decay time. They may also be used to frequency modulate and phase modulate rf signals. In addition they are suitable as broadband rf amplifiers for receiver and detector applications.

© 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.

© 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 © 616B) to provide a flexible 1 watt source in the 2 to 4 GC band.

Noise Consideration in Amplifiers

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

In distributed amplifiers, the noise factor is proportional to 1/√n, where n is the number of tubes in the first stage. © 460B has less internal generated noise than © 460A (460B has 13 tubes in the first stage whereas 460A has only 5). © 460B should thus be used to start a cascade chain when extremely small signals are to be examined.

© traveling-wave tube amplifiers have low noise figures but because of their extreme bandwidth they have a large theoretical thermal noise power. When cascading two amplifiers for increased power gain, the system will approach saturation due to this noise level. Cascading the amplifiers will provide a source of noise power approaching white noise for the frequency spectrum. If narrow band amplification is desired, a band pass filter may be used following the first amplifier. This will decrease the theoretical thermal noise power and increase the signal-to-noise ratio of the system.

![Figure 1. Typical cascading of 460A/B Amplifiers to give approximately 70 db gain and 125 volt pulse output.](image-url)
Wide-Band Distortion-Free Fast-Pulse Amplifiers

Advantages:

- 20 db gain — up to 90 db in cascade
- True amplification of nanosecond pulses
- Rise time 3 nsec
- No ringing or overshoot
- 125-volt open circuit output
- Response follows Gaussian curve.

Uses:

- Fast-pulse nuclear work
- TV, vhf, uhf, shf, research
- Simplifies measurement of small outputs
- 100 MC pre-amplifier for oscilloscope
- Increases VTVM sensitivity 10 times at frequencies up to 200 MC.
- General laboratory amplifier

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

460A Wide-Band Amplifier is used fundamentally to provide voltage gain, (approximately 20 db). Its companion equipment, 460B, is designed as a terminal amplifier to give maximum voltage or power output. The amplifier's ultra-short rise time of 0.003 μsec, combined with zero over-shoot, insures distortion-free amplification of pulses faster than 0.01 μsec. 460B cascaded with 460A provides linear amplification of 16 volts peak output; and with two 460B's, pulse amplification of 125 volts open circuit.

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

Operation

460A incorporates an amplifier with a very wide transmission band — approximately 200 MC. The equipment has two stages of 5 and 7 tubes, respectively.
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, exciting 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 an entrance 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.

@ 460B operates on a similar principle except that it consists of one long amplifier chain or a single stage providing maximum power and voltage output but somewhat lower gain (approximately 15 dB).

The faithfulness with which this equipment amplifies very fast pulses can be seen in Figure 1. The view at left (a) shows a 0.01 μsec pulse applied through one @ 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 @ 410B (see page 76) to increase voltmeter sensitivity up to 10 times. In this combination, accurate readings are easily made of voltages as small as 0.01 volts, at frequencies from 200 KC to 200 MC.

200-Ohm Coaxial System

Since the best interconnecting impedance level for these amplifiers is 200 ohms, @ 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 @ 410B Vacuum Tube Voltmeter. (See Specifications for details.)

Figure 1. (a) 0.01 μsec pulse through @ 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 @ 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 20 KC when operating into a matched load. Off approximately 3 db at 3 KC when operating into an open circuit (i.e. CRT plates). With @ 410B and 46A-91D: +1 dB, 200 KC to 200 MC.

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

Sinusoidal Output: Approx. 8 v peak open circuit, less than 5% distortion.

Pulse Output:

<table>
<thead>
<tr>
<th>Input Pulse</th>
<th>Maximum Output</th>
</tr>
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<tbody>
<tr>
<td>+</td>
<td>+8 v</td>
</tr>
<tr>
<td>-</td>
<td>-20 v</td>
</tr>
</tbody>
</table>

Input Impedance: 200 ohms.
Output Impedance: 300 ohms.
Noise Figure: Less than 10 dB.
Delay Characteristics: Approx. 0.01 μsec.

Rise Time: Nominally 0.003 μsec (10% to 90%). No appreciable overshoot.

Power: 115/230 v ± 10%, 50/1,000 cps, 50 watts.
Dimensions: Rack Mount: 19" wide, 5¾" high, 7" deep behind panel.
Weight: Net 12 lbs. Shipping 18 lbs.
Price: @ 460AR, $225.00.

@ 460BR*

(Same as 460A except as follows)

Gain: Nominally 15 dB into 200-ohm load.
Sinusoidal Output: Approximately 8 v peak into 200 ohms load or 16 v peak open circuit.

Output Impedance: 200 ohms.

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<thead>
<tr>
<th>Input Pulse</th>
<th>Maximum Output</th>
</tr>
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<tbody>
<tr>
<td>+</td>
<td>+8 v</td>
</tr>
<tr>
<td>-</td>
<td>-8 v</td>
</tr>
</tbody>
</table>

Input Impedance: 200 ohms.
Output Impedance: 200 ohms.
Rise Time: Nominally 0.003 μsec (10% to 90%). No appreciable overshoot.
Duty Cycle: 0.10. Higher duty cycles may be employed at sacrifice of output voltage.
Delay Characteristics: Approx. 0.015 μsec.
Noise Figure: Less than 6 db.
Price: @ 460BR, $275.00.

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

Accessories

46A-16A Patch Cord—200 ohms, 2' long. $22.50.
46A-16B Patch Cord—200 ohms 6' long. $31.50.
46A-95A Panel Jack—For 200-ohm cables, low capacitance. $5.00.
46A-95B Cable Plug—For 200-ohm systems. $5.00.
8120-004 Cable—200-ohm cable in length to specification. Per foot $2.75.
46A-95C 50-Ohm Adapter—Type N connector for coupling 50-ohm line into @ amplifiers. $17.50.
46A-95D Adapter—Bayonet sleeve for connecting @ 410B VTVM to output of 460A amplifiers. $40.00.
46A-95E Connector Sleeve—Joins 6A-95B Cable Plugs. $7.50.
46A-95F Adapter—For connecting to 5XP CRT. $9.00.
46A-95H Adapter—Type N to @ 460, 200-ohm termination. $17.50.
46A-95J Adapter—Type N to @ 460, no termination. $3.00.
46A-95K Adapter—@ 410B VTVM to @ 460, 200-ohm termination. $33.00.
46B-95A Adapter—Connects to @ 150A/AR oscilloscope plates. $35.00.

Data subject to change without notice.
Hewlett-Packard Traveling-Wave Tube Amplifiers are precision, broadband linear instruments making easily available a complete group of measurements otherwise almost unobtainable.

Traveling-Wave Tube Amplifiers were first described in 1946. But until development of this equipment, the problem of coupling broadband signals into and out of the tube was not satisfactorily solved, and the industry had no practical, dependable equipment of this type.

A 490B, 491A, 492A and 494A utilize a simple broadband coupling method employing input and output coupling helices (Figure 1). There is no mechanical connection to the inner helix, yet full energy transfer is effected. A similar helix is used for a coupled attenuator which surrounds the central portion of the tube, preventing amplified energy from causing regeneration.

**Standard TWT Amplifiers**

A 490B provides at least 10 milliwatts output, 30 db gain with noise figure of less than 25 db, excellent pulse modulation characteristics and helix modulation.

A 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 A 616A (see section on Signal...
Amplitude modulation circuitry has been specially designed for wide bandwidth (down to dc) and with internal amplification so that small modulation signals cause a large output power change. Not only does the modulation circuitry permit amplitude modulation with small input signals, but power leveling may be achieved with external elements. To complete the feedback loop, the rf output is sampled by a directional coupler, detected and then amplified to approximately 10 volts. Any tendency of the rf output to change is coupled to the modulator circuit which compensates and maintains constant rf output.

These high power TWT amplifiers utilize periodic PM focusing; they are lightweight, compact, and have low power consumption. They may be easily converted from cabinet to rack-mounting configuration merely by removing the feet and attaching brackets and a strip (supplied), so that the panel meets EIA Standards.

### Specifications

<table>
<thead>
<tr>
<th>Models</th>
<th>489A, 491C, 495A</th>
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<tbody>
<tr>
<td><strong>Model:</strong></td>
<td>489A</td>
</tr>
<tr>
<td><strong>Frequency Range:</strong></td>
<td>1-2 GC</td>
</tr>
<tr>
<td><strong>Price:</strong></td>
<td>$1,970.00</td>
</tr>
</tbody>
</table>

#### Common Specifications

- **Output Power:** For 1 mw Input: At least 1 watt.
- **Maximum rf Input:** 100 mw.
- **Small Signal Gain:** Greater than 30 db.
- **Amplitude Modulation Passband:** 10 kc to 300 kc.
- **Modulation Sensitivity:** Approx. 20 db improvement for a 20 volt pk input signal.
- **Input Impedance:** 50 ohms, SWR less than 2.
- **Output Impedance:** 50 ohms, SWR less than 2.
- **Connectors:** Type N female.
- **Front Panel Controls:** Gain.
- **Meter Monitors:** Anode, collector, helix, and cathode current.
- **Dimensions:** Cabinet: 16 1/4" wide, 13 1/8" high, 11 7/8" deep.
- **Weight:** 40 lbs.
- **Shipping Weight:** 60 lbs.

<table>
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<tr>
<th><strong>Specifications</strong></th>
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<tbody>
<tr>
<td><strong>Frequency Range:</strong></td>
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<tr>
<td><strong>Gain:</strong></td>
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<tr>
<td><strong>Output Power:</strong></td>
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<tr>
<td><strong>Noise Figure:</strong></td>
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<tr>
<td><strong>Pulse rise Decay Time:</strong></td>
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<tr>
<td><strong>Amplitude Modulation Voltage:</strong></td>
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<tr>
<td><strong>Helix Modulating Voltage:</strong></td>
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<tr>
<td><strong>Hum, Spurious Modulation:</strong></td>
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<tr>
<td><strong>Input Impedance:</strong></td>
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<td><strong>Output Internal Impedance:</strong></td>
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<tr>
<td><strong>Dimensions and Weight:</strong></td>
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<tr>
<td><strong>Power Supply:</strong></td>
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<tr>
<td><strong>Traveling-Wave Tube:</strong></td>
</tr>
<tr>
<td><strong>Price (including tube):</strong></td>
</tr>
</tbody>
</table>

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

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**Amplitude Modulation Passband:**
- **1-2 GC:** 100 kc to 300 kc
- **2-4 GC:** 200 kc to 600 kc
- **4-8 GC:** 400 kc to 1.2 MHz
- **8.2-12.4 GC:** 820 kc to 1.24 MHz

---

**Modulation Sensitivity:**
- **Approx. 20 db** improvement for a 20 volt pk input signal.
**466A AC Amplifier**

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

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

**Specifications**

- **Gain:** 20 db (x10) or 40 db (x100) ± 0.2 db at 1,000 cps.
- **Frequency Response:** ±0.5 db, 10 cps to 1 MC down 3 db or less at 5 cps and 2 MC.
- **Output Voltage:** 1.5 v rms across 1,500 ohms.
- **Output Current:** 1 ma rms maximum.
- **Noise:** 75 μv referred to input, 100,000 ohm source.
- **Impedance:** Input, 1 megohm, 15 pf shunt; output, approximately 50 ohms in series with 100 μf.
- **Distortion:** Less than 1%, 10 cps to 100 KC; less than 5% to 1 MC.
- **Power:** 115/230 v ± 10%, 50 to 400 cps, approximately 1 watt (supply normally furnished). Battery operation optional: 3 radio type mercury batteries, TR234 or equivalent, 3 required (@ #1420-0006). Battery life approximately 150 hours.
- **Size:** 6½" wide, 4½" high, 6½" deep. Weight 3 lbs.
- **Price:** @ 466A, $150.00, ac or battery operation. (Please specify.)

*Data subject to change without notice.*

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**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 0.1 MC. The instrument is resistance coupled, avoiding peaking or compensating networks. Optimum performance is obtained by clean, straightforward circuitry plus inverse feedback. Phase shift is negligible, there are no spurious oscillations or resonances, and hum is minimized by using a dc filament supply for input amplifier tubes.

**Specifications**

- **Gain:** 20 db (x10) or 40 db (x100) ± 1/8 db at 1,000 cps.
- **Frequency Response:** 40 db gain: ± ½ db, 10 cps to 1 MC; ± 1 db, 5 cps to 2 MC.
  20 db gain: ± ½ db, 5 cps to 1 MC; ± 1 db, 2 cps to 1.2 MC.
- **Stability:** ± 2%, includes line voltage variation (115/230 v ± 10%).
- **Impedance:** Input, 1 megohm, 15 pf shunt. Output, less than 150 ohms.
- **Distortion:** Less than 1%, 2 cps to 100 KC; approximately 2% above 100 KC.
- **Output:** 10 v max. into 3,000 ohm or greater load.
- **Noise Referred to Input:** 40 db gain, 40 μv; 20 db gain, 250 μv.
- **Power:** 115/230 v ± 10%, 50/1,000 cps, 50 watts.
- **Size:** 8½" wide, 5½" high, 10½" deep. Weight, 10 lbs.
- **Rack Mount:** 19" wide, 5½" high, 10½" deep (rack mount).
- **Price:** @ 450A, $160.00 (cabinet); @ 450AR, $165.00 (rack mount).
FREQUENCY AND TIME MEASURING EQUIPMENT
By means of electronic circuits, frequencies can be added, subtracted, multiplied and divided with precision. When such circuits are used in conjunction with a high quality time base, measurements of frequency and time can be made with accuracy approaching that of the time base itself.

Frequency and time measuring instruments are used in every branch of science and engineering where these quantities are considered. The complexity and precision of frequency and time measuring instruments depend largely upon their intended application.

Hewlett-Packard instruments for frequency and time measurements presented in this section of the catalog can be categorized as:

- Electronic Counters
- Transfer Oscillators
- Digital Recorders and Digital Clocks
- Electronic Frequency Meters and Tachometers
- Tachometer Instruments and Transducers

(See also pages 32 and 53)

@ equipment in these categories measures frequencies from 0 cps to 40 GC (KMC), and time intervals from 1 microsecond to 100 days with instrument stability as high as 5 parts in one hundred million per week.

@ frequency/time standard systems are described in a separate section of this catalog. See pages 118-125.

Special purpose counters and other digital equipment manufactured by Dymec division of Hewlett-Packard are described on pages 195-210.

**Electronic Counters**

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

Electronic counters and their basic characteristics are listed in Table 1.

**Frequency Measurements**

In the frequency measurement mode, an unknown frequency signal is shaped and applied to the signal gate. (See Figure 1.)

![Figure 1. Basic diagram of 524 when measuring frequencies below 10 MC.](image)

The gate is held open for a precise length of time determined by the time base generator, a crystal oscillator with high stability. The unique frequency pulses are passed to the counter circuits while the gate is open, where they are totaled and the frequency automatically displayed on the instrument, complete to the decimal point. Measurement accuracy is determined by the accuracy of the time base generator and the ± 1 count error inherent in the gate-and-count type of instrument. (See Figure 2.)

![Figure 2. Attainable counter accuracy (unshaded area).](image)

- 524C/D with 526C plugged in.

The higher the degree of refinement to which frequency measurements must be made, the greater are the performance requirements for the time base crystal oscillator.

In the case of 524 C/D counters, the internal time base is capable of performance ordinarily found only in oscillators intended for use as frequency standards. (Many 524C/D...
owners are obtaining double usefulness from their instruments by their use as a house standard.) This time base has long-term stability better than ± 5 parts in 10^6 per week, and a short-term stability of ± 3 parts in 10^6.

In terms of frequency measurement, this means, for example, that a measurement of a 100 megacycle signal (using the 524C/D Counter with the 525A, 525B or 525C converter) will be accurate within ± 8 cycles in the week following calibration, or ± 13 cycles in the second week, ± 1 count error inherent in gate-and-count type of instrument. The Journal, Volume 10, No. 3-4, discusses in detail the performance of this time base, and presents actual data for typical usage situations.

**Period Measurements**

524 counters are designed to measure the period of an unknown frequency directly. (See Figure 3.) This is particularly important for measurements at lower frequencies when the ± 1 count error becomes a seriously limiting factor. This is graphically illustrated in Figure 2.

In the period measurement mode, the unknown frequency is shaped and applied to the signal gate, holding it open for one or more periods. During that time, a standard frequency from the time base generator is applied to the counter circuits. The standard frequency pulses are totalized, and the period of the unknown signal is automatically displayed on the instrument in proper decimal notation.

The accuracy of period measurements is largely determined by the consistency with which triggering occurs at the same point on consecutive cycles of the unknown signal voltage. For a signal of given frequency, this triggering accuracy will improve as the signal-to-noise ratio improves. For a sine wave, the total possible time error from triggering can be expressed as $\frac{1}{T} E_n$, where $E_n$ is the total noise, including that from the counter circuitry, and $E_s$ is the signal.

The curves of Figure 2 for 524C/D with 526C plug-in illustrate attainable accuracy under assumed conditions of a 40 db signal-to-noise ratio for a sine wave and for measurements where the signal is a square wave. In the case of square waves (or other signals with very steep slopes) triggering error is virtually eliminated, and the factors influencing measurement accuracy again become time base accuracy and the ± 1 count ambiguity.

The curves of Figure 2 show how the 526C period multiplier unit for 524 series counters increases attainable accuracy by making possible 100, 1,000, or 10,000 period measurements. This period multiplication reduces the significance of the triggering error and the ± 1 count, in direct proportion to the multiplication factor.

**Time Interval Measurements**

Time interval measurements are similar to period measurements except that the trigger points on the signal waveform or waveforms are adjustable. This adjustment permits separate signals to be used as start and stop signals, or permits measurements to be made from one part of a waveform to another part of the same waveform. Time interval measurements can be made with 522 and 523 series counters, or with 524 series plus a 526B plug-in unit.

As in the case of period measurements, the input signals control the opening and closing of the gate, while the standard frequencies are passed to the counters as time units (Figure 4). Thus the unknown interval is measured and automatically displayed in microseconds, milliseconds or seconds. Where trigger signal noise and rise time are not deteriorating factors, the accuracy of this method is ± the accuracy of the internal time base and ± 1 count.

**Phase Angle Measurements**

524 counters in the 522, 523 and 524 series may be used for phase angle measurements. Their speed and simplicity of operation make the counters suitable for phase measurements.
on the production line as well as in the laboratory. Operating in the time interval mode, the counters measure phase difference in units of time, based on the internal standard.

For phase measurements at frequencies from 396 to 404 cps, the 526D phase unit plug-in for the 524 series counters includes a 3,600 frequency multiplier, which allows phase angle readings to be displayed directly in tenths of degrees. The accuracy of phase angle measurements with the 526D at frequencies from 1 cps to 20 KC is 

\[ \pm 0.1^\circ \pm \left( \frac{F_p - 360}{F_c} \right) \]

\[ \pm \text{time base accuracy, where } F_p \text{ is the frequency of the phase-measured signal, } F_c \text{ is the counted frequency; assuming noise 65 db below signal.} \]

\[ @ 523 \text{ and 524 series counters are probably the most accurate, convenient, wide-range phase-measuring instruments available.} \]

**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 electromechanical timers, for the longer totalizing periods encountered in nuclear work.

**Ratio Measurements**

The ratio \( f_1/f_2 \) may be measured with @ counters by using \( f_1 \) to open and close the signal gate, and counting \( f_2 \) while the gate is open. With proper transducers, ratio measurements may be extended to any phenomena which may be represented by frequencies or pulse rates within the range of the counter.

Ratio measurement accuracy is determined by the same factors as period measurement accuracy: the consistency of triggering by the lower input frequency (opening and closing the gate) and the inherent error of \( \pm 1 \) count of the higher frequency. As with period measurements, the 526C period multiplier can be used to reduce the error by extending the number of periods of the lower frequency over which the measurement is made. For each factor of ten that the measurement is extended, the trigger error is decreased by a factor of ten.

**Transfer Oscillators**

Direct frequency measurements with @ electronic counters may be made up to 510 MC (524 series counter with @ 525 Frequency Converter unit). Hewlett-Packard Model 540B transfer Oscillator makes it possible to extend frequency measurements to 12.4 GC(KMC) and beyond, with electronic counter accuracy. Figure 5 graphs the frequency coverage possible with the @ 524 counter, 525 series plugins, 540 transfer oscillators and accessory equipment.

@ 540B employs a highly stable 100 to 220 MC oscillator generating harmonics to at least 12.4 GC. The instrument contains a broadband mixer system, an amplifier and an oscilloscope for comparison of these frequencies with the unknown. Recently developed untuned mixers and an excellent vernier tuning system make it a simple matter to obtain zero beat, at which time the fundamental frequency is measured with the 524/525B combination. A harmonic generator is also included which may be used to drive external traveling wave amplifiers and waveguide mixers for extending measurements considerably above X-band. @ Application Notes 2 and 21 describe equipment and techniques for making frequency measurements to 40 GC.

For detailed information on @ 540B, refer to pages 112, 113.

**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 three types of digital recorders, Models 560A, 561B and 562A.

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.

![Figure 5. Frequency measuring range, @ 524C/D and accessory equipment.](image-url)
Hewlett-Packard 561B Digital Recorder has the same printing capabilities as the 560A, but utilizes a 10-line code. Since input information may be in the form of contact closures or voltage changes, the 561B is appropriate for many uses.

Model 562A is a transistorized digital recorder utilizing 4-line BCD code. In addition to its use as an output device for transistor counters, it is especially suitable for applications with various data handling systems where BCD code is employed. Special models may be obtained for operation from 10-line code. The 562A is similar in printing capabilities to the 560A and 561B.

Application Note 32 describes all interconnections between digital recorders and counters, including the use of dual-input couplers. It also tabulates the print wheels carried as stock items.

For custom systems and special applications, the 565A Digital Printer is available. This printer is mechanically similar to the printing mechanisms in the 560A and 561B Digital Recorders. For maximum adaptability with the input and control systems encountered, and for simplifying field maintenance, all connections (commutators, brushes, clutch solenoid, print wheel solenoids, etc.) are made through connectors at the rear of the 565A.

More detailed information on Models 560A, 561B, 562A and 565A will be found on pages 114-117.

**Digital Clocks**

570A and 571B Digital Clocks mount in the left-hand side of the 560A and 561B Digital Recorders. These clocks add time of day information to other recorded data, and can control rates at which measurements are made. The clocks indicate time to 23 hours, 59 minutes, and 59 seconds in an in-line display, and can establish precise print rates of 1/sec, 6/min, 1/min, 1/hour, or 1/hour. Independent contact closures at the selected intervals are provided for operation of other external equipment.

**Electronic Frequency Meters**

Instead of counting each input pulse directly, the 500B Frequency Meter responds to the rate of input pulses for frequency measurement applications which require an analog presentation.

Frequency is indicated on a meter, and scale expansions of x3 and x10 are provided. The instrument is equipped with an output for driving potentiometer strip charts, X-Y recorders and galvanometer recorders requiring up to 1 milliampere.

The 500B also provides, on any given range, a constant energy output pulse whose repetition frequency is determined by the rate of input pulses. This output may be used for stroboscopic purposes, and is especially useful for measuring or recording the characteristics of FM deviation.

Model 500B is described on pages 96 and 97.

**Tachometry Instruments**

Tachometry equipment includes transducers (which convert mechanical motion into electrical pulses) and tachometer indicators (which measure the rate of these pulses).

508 series Tachometer Generators are low-torque, compact units for measuring shaft speed. The pulse output from these generators may be used by any counter or frequency meter. Useful shaft speed range is 15 to 40,000 rpm. The four models available in the 508 Tachometer Generator series are described in detail on page 96.

Another transducer, Model 506A Optical Tachometer Pickup, uses a light source and phototube receiver to generate electrical pulses corresponding to shaft rotation rate. This optical method does not load the machinery under test. It can be used over a wide range of speeds from 180 to 300,000 rpm. Even this range may be extended by relatively simple techniques.

Detailed data on the 506A may be found on page 98. Tachometer indicators measure transducer-produced electrical pulses, and display this information in units of shaft speed. Tachometer system accuracy depends largely upon these indicators.

Hewlett-Packard indicators include frequency meters and electronic counters. The frequency meters respond to the rate of input pulses; the counters directly count each input pulse. Frequency meters have the necessary accuracy for many industrial applications. Electronic counters are capable of a much higher degree of precision, and are suitable for the most exacting design applications. Any electronic counter will operate with all tachometer transducers for speed measurement.

500C Electronic Tachometers are similar to 500B Frequency Meters described above, except that calibration is in rpm instead of cps. A detailed description of Model 500C appears on pages 96 and 97.

**Digital Delay Generators**

218A Digital Delay Generator is a unique instrument providing two independent delays adjustable from 1 microsecond to 10,000 microseconds in steps of 1 microsecond. Model 218A and associated plug-in units provide an extremely versatile system for generating or measuring time intervals with very high accuracy. Details of Model 218A and related plug-ins appear on pages 52 and 53.
**HP 500B/C ELECTRONIC FREQUENCY METER**

Measures Frequency of ac Voltages as High as 100 KC

**Advantages:**
- Wide frequency range
- Accurate
- Good sensitivity
- Accuracy independent of line voltage changes and tube characteristics
- Nine convenient scale ranges
- Expanded scale feature
- Output pulse provision

The Model 500B directly measures the frequency of an alternating voltage from 3 cps to 100 KC. It is suitable for laboratory and production measurements of audio and supersonic frequencies, or for direct tachometry measurements with a transducer such as HP 508A 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 this instrument is available as HP 500C with scale calibration in rpm. (See opposite page, and page 98.)

The frequency meter consists of a wide band amplifier, a Schmitt trigger, a constant current source, a current switching tube, a phantastron and an output meter. The Schmitt trigger is used to trigger the current switching tube in accordance with the rate of input pulses. A phantastron controls the "on" time of the switching tube during which time the plate current is directed to the output meter. The circuit is designed so that each pulse of charging current has the same energy making the meter reading proportional to the number of pulses per second, and hence proportional to the frequency of the input signal.

**Use It To Measure:**
- Beat frequency between two rf signals
- Crystal frequency deviation
- Audio frequencies
- Speed of rotating machinery
- Oscillator stability
- Frequency modulation
Independent of Signal Voltage Waveform

Readings are not affected by variations of input signal level or power line voltage. The frequency meter will count sine waves, square waves or pulses and will indicate the average frequency of random events. Provision is made for checking the calibration against power line frequency and to operate a recorder for a continuous frequency record or X-Y plot.

Expanded Scale Feature

Any 10% or 30% portion of a selected range may be expanded to full meter scale.

In practice, this means that for repetitive or differential type measurements the meter can be set for expanded scale readings and left in this position to better observe small fluctuations in readings. The expanded scale permits accurate measurement of small frequency changes.

Pulse Output

A pulse output synchronous with each input pulse is made available on the front panel. This output provides uniform pulses which can be used to measure the FM component of the input signal or to sync a stroboscope or an oscilloscope.

The output pulse could be used, for example, in conjunction with a stroboscope for observation of the various parts of a gear train when checking for the presence of vibration or torsion.

Specifications @ 500B

Frequency Range: 3 cps to 100 KC; nine ranges in a 10, 30, 100 sequence.

Expanded Scale: Allows any 10% or 30% portion of a selected range to be expanded to full meter scale.

Input Voltage: Sensitivity: 0.2 volts rms minimum for sine waves, 1.0 volt peak minimum for pulses.

Accuracy: Unexpanded Scale, better than ± 2% full scale value of range selector setting. Line voltage variations of nominal ± 10% affect reading less than ± 1/2%.

Expanded x3 Scale, (differential measurements of 30% or less), better than ± 1 1/2% of range switch setting. Line voltage variations of ± 10% affect reading less than ± 1/2%.

Expanded x10 Scale, (differential measurements of 10% or less), better than ± 3/4% of range switch setting. Line voltage variations of ± 10% affect reading less than ± 1/4%.

Output Linearity: (Relation of input frequency to output current at the external meter jack.) On 100 KC range: within approximately ± 1/4% of full-scale value. On all other ranges: within approximately ± 1/10% of full-scale value.

Self-Check: Allows calibration of internal constant current source and check against 60 cps line frequency.

Recorder Output: 1 ma for full scale deflection into 1400 ± 100 ohms.

Pulse Output: To trigger stroboscope, etc., in synchronism with input signal; to measure FM.

Photocell Input: Phone jack on panel provides bias for Type 1P41 Phototube. Allows direct connection of @ 506A Optical Tachometer.

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

Dimensions: Cabinet Mount: 71/2” wide, 11 1/2” high, 14 1/4” deep. Rack Mount: 19” wide, 7 1/8” high, 12 1/4” deep.


Accessories Available: @ 500A Optical Tachometer Pick-up, $150.00. @ 508A/B/C/D Tachometer Generators, $125.00 each. @ AC-LA/B Dual Rack Panel (page 194).

Price: @ 500B, $300.00 (cabinet); @ 500BR, $305.00 (rack mount).

Data subject to change without notice.

Figure 1. Tachometry measurements with @ 500C and 506A.

hp 500C Electronic Tachometer Indicator

Model 500C Electronic Tachometer Indicator is identical in construction and circuitry to @ 500B, but is calibrated in rpm for greater convenience in tachometry applications.

Specifications @ 500C

Circuit and Construction same as @ 500B except for meter calibration.

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

Price: @ 500C, $300.00 (cabinet); @ 500CR, $305.00 (rack mount).
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 electronic counters and frequency meters.

The 508A Tachometer Generator produces 60 output pulses per shaft revolution. Thus when it is connected to an indicating instrument calibrated in cps, speeds are automatically recorded in rpm. The relationship between output voltage and shaft speed is virtually linear up to 5,000 rpm, making practical oscilloscope presentation of shaft speed as a function of time for analyzing clutches, brakes or acceleration rates.

508B, C, and D are identical to 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 Voltage: Greater than 0.2 v rms over shaft speed range.
Drive Shaft: 1/8” diameter; projects 39/32”.
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 31/2” wide x 31/4” deep.
Price: 508A/B/C/D, $125.00 each.

506A Optical Tachometer Pickup

Model 506A is a light source and photocell for use as a transducer with instruments such as 521 series Electronic Counters, 500B Electronic Frequency Meter and 500C Electronic Tachometer Indicator. The instrument will measure very high speeds—up to 300,000 rpm—and will measure speed of moving parts which have small energy or cannot be connected mechanically to measuring devices.

Operation of the transducer is extremely simple. The part to be measured is prepared with alternate reflecting and absorptive surfaces. Light from the light source is interrupted by rotation of the part; the interrupted reflected light is picked up by the phototube and converted into electrical impulses.

Specifications

Range for Direct Reading:
- with 521 Series, 1 to 5,000 rps.
- with 500B, 3 to 5,000 rps.
- with 500C, 180 to 300,000 rps.

Lower speed may be measured by using a multisegment reflector.

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

Light Source: 21 candlepower, 6 volt automotive bulb.
Phototube: Type 1P41.
Phototube Bias: +70 to +90 volts dc (supplied by 500B/C, 521).

Accessories Available: 56A-16B Adapter Cable (connects 506A to 522B Counter), $40.00.
Price: 506A, $150.00.

Data subject to change without notice.
The Hewlett-Packard 521 Series Electronic Counters are rugged, versatile instruments for production, processing and laboratory applications.

521 Series Counters measure frequency and speed, and count events occurring at random within a selected period of time. With proper transducers converting mechanical into electrical phenomena, the instruments measure weight, pressure, temperature and other quantities which can be related to frequency.

**Digital Recorder Operation**

Versatile 521 Series Counters may be adapted easily to operation of 560A or 561B Digital Recorders (see pages 114, 115) with the installation of a kit. This kit can be installed by the factory before shipment (slight extra charge), or can be purchased for field installation later.

<table>
<thead>
<tr>
<th>Model</th>
<th>521A</th>
<th>521C</th>
<th>521D</th>
<th>521E</th>
<th>521G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Frequency</td>
<td>120 KC*</td>
<td>120 KC*</td>
<td>120 KC*</td>
<td>120 KC*</td>
<td>1.2 MC</td>
</tr>
<tr>
<td>Count Presentation</td>
<td>4 places, neon</td>
<td>5 places, neon</td>
<td>4 places, in-line</td>
<td>5 places, in-line</td>
<td>5 places, neon</td>
</tr>
<tr>
<td>Gate Time</td>
<td>0.1, 1 sec</td>
<td>0.1, 1 sec</td>
<td>0.1, 1 sec</td>
<td>0.1, 1 sec</td>
<td>0.1 sec</td>
</tr>
<tr>
<td>Power</td>
<td>150 watts, 200 w with Xtal time base</td>
<td>215 watts with 155 watts, 205 w with Xtal time base</td>
<td>215 watts with 160 watts, 210 w with Xtal time base</td>
<td>140 watts, 210 w with Xtal time base</td>
<td></td>
</tr>
<tr>
<td>Price (cabinet)</td>
<td>$475.00</td>
<td>$650.00</td>
<td>$750.00</td>
<td>$950.00</td>
<td>$700.00</td>
</tr>
<tr>
<td>Price (rack mount)</td>
<td>$480.00</td>
<td>$655.00</td>
<td>$755.00</td>
<td>$955.00</td>
<td>$705.00</td>
</tr>
</tbody>
</table>

*220 KC optional, add $35.00.
*Add $45.00 for 560 or 561 Digital Recorder operation (561 with 521D/E only).
*Crystal Time Base, standard equipment in 521C and 521E, optional for 521A, 521D and 521G, add $100.00.
*Binary Coded Decimal Output (1-2-4-8) compatible with Dymec equipment, add $130.00 for 521A, $145.00 for 521C, G; $120.00 for 521D, $135.00 for 521E; prefix model with H60, i.e., H60-521A.

**FOR ALL MODELS**

**Accuracy:** ±1 count ± time base accuracy (approx. ±0.1% with line frequency, ±0.01% with Crystal Time Base).

**Input Requirements:** 0.2 v rms minimum or output from 1P41 Phototube (or equal). Phototube bias provided at "PHOTOTUBE" jack; 0.5 v rms required at frequencies above 120 KC with 220 KC option. Attenuator reduces sensitivity to 0.5 v rms to overcome noise.

**Input Impedance:** Approximately 1 megohm, 50 pf shunt (500,000 ohms on "PHOTOTUBE" jack).

**Manual Gate:** Controlled by "Count" switch or external contacts.

**Display Time:** Variable from gate time to approximately 15 seconds; or display can be held indefinitely.

Reads In: Directly in cps or rps or in cps or rpm with 506A or 508A Tachometer Accessories.

**Self Check:** Counts 50/60 cps line frequency for any selected gate time; 10 KC with Crystal Time Base.

**External Standard:** Can be operated from any multiple of 10 cps, 10 cps to 100 cps.

**Size:** Rack Mount: 19" wide, 8 3/4" high, 14 1/2" deep behind panel.

**Weight:** Cabinet Mount: Net 28 lbs. Shipping 41 lbs. Rack Mount: Net 28 lbs. Shipping 35 lbs.

**Accessories Provided:** @ AC-16D Cable Assembly, 44" RG-58/U cable terminated one end with 358-U Type BNC connector.

**Accessories Available:** @ Model 506A Optical Tachometer Pickup, $150.00. @ Model 508 Series Tachometer Generators, $125.00 each.

Data subject to change without notice. Prices f.o.b. factory.
522B ELECTRONIC COUNTER

Versatile, Low Cost Precision Counter Covers 10 cps to 120 KC

Advantages:
- Measures frequency, period, or time
- High stability
- High quality, low cost
- Easily used by anyone
- Direct, automatic readings

Use To Measure:

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

Time Interval, Period:
- Elapsed time between impulses
- Pulse lengths
- Shutter speeds
- Projectile velocity
- Relay operating times

This all-purpose Hewlett-Packard counter is used in an ever-increasing variety of manufacturing and research measurements.

The 522B counter offers the convenience of frequency, period and time interval measurement over a broad frequency range. Results are displayed automatically in direct reading form—either in cps, KC, seconds or milliseconds. Unskilled personnel can use the equipment immediately—no training or technical background is necessary.

Specifications

Frequency Measurement:
- Range: 10 cps to 120 KC. (220 KC at slight extra charge).
- Accuracy: ± 1 count ± time base accuracy.
- Stability: 10 parts per million per week or better. May be standardized against WWV.
- Registration: 5 places. Output pulse available to actuate trigger circuit for mechanical register to provide increased count capacity.
- Input Requirements: 0.2 volt rms minimum. Input is direct-coupled.
- Input Impedance: Approx. 1 megohm, 50 pf shunt.
- Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds. May be extended to any multiple of one or ten seconds by manual control.
**General:**

**Dimensions:** 14½'' deep. Rack: 19'' wide, 10½'' high, 13½'' deep behind panel. Can be used with (rack mount).

**Weight:** Net 49 lbs. Shipping 60 lbs. (cabinet mount).

**Accessories Available:** 125-UG273/U uhf-BNC Adapters, $2.50. AC-16K Video Cable Assembly, $6.50; AC-16D Video Cable Assembly, $3.50.

**Price:** $520A, $700.00 (cabinet); $520AR, $685.00 (rack mount).

*Data subject to change without notice.*

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**Trigger Amplitude:** Approx. 1 volt peak.

**Features:**

- (a) Operates with $508 Series Tachometer Generators: $506A Optical Tachometer Pickup.
- (b) Operates with $520A Decade Scaler for high speed nuclear scaling. (See alongside.)
- (c) Measures frequency ratios.
- (d) Makes time interval measurements with externally applied standard frequency.
- (e) Operates as electronic stop watch with manual start, stop and reset.
- (f) Totallizes events to 99,999.
- (g) Operates as a secondary frequency standard providing precise rectangular output voltages at 1, 10, 100 cps; and 1 and 10 KC sine wave. Amplitude, approximately 1 volt peak.

**Power:**

- 115/230 v ± 10%, 50/60 cps, 205 watts.
- Dimensions: Cabinet Mount: 20½ '' wide, 12½'' high, 14½'' deep. Rack Mount: 19'' wide, 10½'' high, 13½'' deep behind panel. Can be used with $AC-17$ End Frames.

**Weight:** Net 50 lbs. Shipping 61 lbs. (cabinet mount). Net 45 lbs. Shipping 58 lbs. (rack mount).

**Accessories Furnished:** 2 AC-16D Cable Assemblies.

**Price:** $522B, $915.00 (cabinet); $522BR $900.00 (rack mount).

For 220 KC operation, add $35.00. For use with $560A Digital Recorder ($522B-95A installed), add $45.00. For BCD (1-2-2-4) output (compatible with Dymec instruments) add $180.00, prefix Model Number with H60 when ordering.

---

**Model 520A** makes possible quantitative measurement of extremely fast circuit pulses or nuclear parameters. The instrument is an aperiodic counter which operates at input rates of 10 MC and will resolve two sharp pulses spaced only 0.1 μsec apart.

The resolution capacity of the High Speed Decade Scaler makes it especially suitable for operation with scintillation counters. Since it provides an output pulse for every one hundred input pulses, its output may be connected to a conventional 100 KC counter to record large numbers of occurrences. This feature makes the $520A$ useful for measurement of frequencies up to 10 MC in applications where the accuracy of the last two places is unimportant.

---

**Specifications**

**Required Input Polarity:** Positive pulses only.

**Amplitude:** 5 volts minimum. 30 volts maximum. 10 volts minimum for maximum counting rate.

**Required Rate of Rise:** 10 volts per μsec, minimum.

**Input Impedance:** 5,000 ohms. UHF connector.

**Resolving Time:** Two pulses, 5 to 30 volts peak: 0.1 μsec. Three pulses, 5 to 30 volts peak: 0.2 μsec 1st to 3rd pulse. Maximum continuous uniform rate: 10³ counts/sec. No lower limit on counting rate.

**Counting Capacity:** 100 counts in two decades, count indicated by two meters (0-90 and 0-9). Pushbutton resets both meters to zero.

**Output:** Positive or negative triangular pulse, approximately 35 volts amplitude and approximately 5 μsec wide at base. Rise time approximately 1 μsec. UHF connector.

**Output Impedance:** Operates into 5,000 ohms or more.

**Power:** 115 v ± 10%, 50/60 cps, 205 watts.

**Dimensions:**
- Cabinet Mount: 20½'' wide, 12½'' high, 14½'' deep. Rack Mount: 19'' wide, 10½'' high, 13½'' deep behind panel. Can be used with $AC-17$ End Frames.
- Weight: Net 49 lbs. Shipping 60 lbs. (cabinet mount). Net 41 lbs. Shipping 56 lbs. (rack mount).
- Accessories Available: 125-UG273/U uhf-BNC Adapters, $2.50. AC-16K Video Cable Assembly, $6.50; AC-16D Video Cable Assembly, $3.50.
- Price: $520A, $700.00 (cabinet); $520AR, $685.00 (rack mount).

*Data subject to change without notice.*
523C/D ELECTRONIC COUNTERS

Measures Period, Time or Frequency 10 cps to 1.2 MC

Advantages:
- Direct frequency, period or time interval readings
- Highest quality, broad applicability, yet moderate cost
- Basic accuracy ± 1 count; stability 2 ppm per week
- Color-coded panel simplifies use by non-technical personnel
- Pulse output for Z-axis oscilloscope modulation

Use To Measure:

Totalizing:
- Production quantities
- Nuclear scaling
- Frequency
- Rps and rpm
- Oscillator stability
- Repetition rates
- Weight, pressure and temperature

Time Interval, Period:
- Phase delay, phase angle
- Time between impulses
- Pulse length, shutter speeds
- Projectile velocity
- Relay operating times
- Precise event timing
- Interval stability
- Frequency ratios
- Very low frequencies
- Power line frequencies

Model 523C is a broadly useful and popular electronic counter that measures frequency, period, time interval, phase delay, random events and ratios. It also totalizes electrical events, periodic or random.

Operation of the 523C is simple, fast and accurate. Measurements are made automatically and readings are displayed in direct numerical form with automatic decimal point. Controls are logically arranged and are color-coded for simple operation even by non-technical personnel.

Frequency Measurements

Typical frequency measurements with the 523C include oscillator and signal generator calibration and stability checks, measurement of telemeter and carrier frequencies, pulse repetition frequencies, test frequencies for narrow bandwidth circuits and rates of random pulses.

Period, Time Interval

Accuracy and resolution of the 523C make possible precise period measurements of power line voltages, test signals used in low frequency work and subsonic signals in general. Time for one cycle may be measured, or average time per cycle for 10 periods may be obtained. Time may be measured in terms of internal or external standard frequencies.

Model 523C is ideally suited to such time interval measurements as pulse length, pulse spacing, ballistic measurements, shutter speeds and relay operating times. Time interval between any two events (represented by electrical
pulses), from 1 µsec to 10^4 seconds are measured and indicated directly in µsec, milliseconds, or seconds. For normalized or measurements in other than time units, external frequencies may be counted. Separate start and stop channels are provided and each channel has trigger level and slope controls.

Pulses, generated whenever trigger level and slope conditions are met, may be used for intensity-modulating an oscilloscope to identify the time interval measurement or for triggering auxiliary equipment.

**Phase Measurements**

Sensitivity and stability of the discriminator circuits make possible phase delay measurement with greatly improved accuracy. Accuracy of zero level determination makes the 523C ideal for phase measurements.

Phase delay is measured directly in µsec, milliseconds or seconds. Phase angle may be measured in degrees or 1/100000 δ F, instead of the internal standard.

**Measuring Other Quantities**

*® optical and magnetic type speed transducers used with the 523C make possible highly accurate automatic speed measurements of jet engines, supercarriers, centrifuges, etc.

The 0.7 µsec resolving time of the 523C is well suited to nuclear measurements; i.e., totaling or random rates.

Ratio measurements may involve any phenomena which can be represented by electrical impulses in the proper frequency range. The measurement of ratio provides increased accuracy in many measurements and is especially useful in certain control applications.

Transducers, available from various manufacturers, permit measurement of speed, acceleration, displacement, force, pressure, temperature, flow, and other physical variables.

The 523C can be furnished with internal circuitry and output jack for operating the *®* Digital Recorders. Eleven columns of data can be printed by the Digital Recorders at rates up to five lines per second. Since only six columns are required for recording from the 523C, information from other counters, digital voltmeters or digital clocks may be recorded in the remaining columns.

### 523D Electronic Counter

523D Electronic Counter is identical to 523C except that registration is by 6 neon indicators.

### Specifications 523C/D

**General:**

Registration: 523C, six in-line digital display tubes; 523D, six decimal places each indicated by lighted numbers.

Stability: 2/1,000,000 per week.

Display Time: Variable from approximately 0.1 to 10 seconds; display can be held indefinitely if desired.

Self Check: Automatic count of internal 100 KC and 1 MC.

**Frequency Measurement:**

- **Range:** 10 cps to 1.2 MC.
- **Accuracy:** ± 1 count ± time base accuracy.
- **Input Sensitivity:** 0.1 volt rms; adjustable; 150 volts rms maximum input.
- **Input Trigger Level:** −300 volts to +300 volts; adjustable, either positive or negative slope.
- **Input Impedance:** Approx. 1 megohm, 50 pf shunt.
- **Gate Time:** 0.001, 0.01, 0.1, 1, 10 seconds.
- **Reads In:** Kilocycles; automatic decimal point.

**Period Measurement:**

- **Range:** 0.00001 cps to 100 KC.
- **Accuracy:** ± 3% ± 1 count ± time base accuracy (one period).
- **Input Impedance:** Approx. 1 megohm, 50 pf shunt.
- **Input Requirements:** 0.1 v rms minimum; direct coupled.
- **Measurement Period:** 10 cycles, 50 or 100 cycles.
- **Standard Frequency Counted:** 1 cps, 10 cps, 100 cps, 1 KC, 10 KC, 100 KC, 1 MC, external frequency.
- **Reads In:** Seconds, msec, µsec, automatic decimal.

**Time Interval Measurement:**

- **Range:** 1 microsecond to 10^6 seconds.
- **Accuracy:** ± 1 count ± time base accuracy.
- **Input Impedance:** Approx. 1 megohm, 50 pf shunt.
- **Input Requirements:** 0.1 v rms minimum; direct coupled.
- **Start and Stop Outputs:** 5 µsec duration and ±20 v peak, for oscilloscope intensity modulation.
- **Trigger Level:** Both channels, ±300 volts, either slope.
- **Standard Frequency Counted:** 1, 10, 100 cps, 1, 10, 100 KC, 1 MC, external.
- **Reads In:** Seconds, msec, µsec, automatic decimal point.

**Phase Measurement:**

- **Range:** 1 cps to 20 KC, dc coupled; 30 cps to 20 KC, ac coupled.
- **Input Voltage:** 5 to 10 v rms, pure sinusoidal signal.
- **Accuracy:** ± 0.1° (360° f0 f0)
- **Other Data Measurement:** Displays f0/f0 or 10f0/f0 as an integer, with accuracy of ± 1.
- **f0:** 10 cps to 1.2 MC.
- **f0:** ±0.0001 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 2/100 per week.

**External Standard:** 100 KC can be applied.

**Power:** 115/250 v ±10%, 50/60 cps, approx. 350 watts.

**Size:** Cabinet: 19” wide, 11 1/2” high, 18 5/8” deep. Rack Mount: 19” wide, 8 1/4” high, 16” deep behind panel.

**Weight:** 48 lbs. Shipping weight approx. 85 lbs.

**Accessories Furnished:** 2 @ AC-10K Cable Assemblies.

**Price:** 523C, $1,575.00 (cabinet), 523CR, $1,550.00 (rack mount). 523D, $1,310.00 (cabinet), 524DR, $1,285.00 (rack mount). For BCD (1-2-2-4) output add $135.00. For @ 561B (523C/CR only) or 560A Digital Recorder output add $45.00.

Data subject to change without notice.
Advantages:
Direct, instantaneous automatic readings
Easily used by non-technical personnel
Bright, big-numbered readout
Resolution 0.1 microseconds
Stability 5/100,000,000/week
Standardize with WWV
Available for printer operation
High sensitivity, high impedance
Extreme reliability
No calculation or interpolation
Automatic decimal point
Highest quality construction
Military design

Here is the electronic counter that provides extremely versatile frequency, time interval or period measuring coverage. You buy the basic 524C/D Counter with selected 525 or 526 series Plug-In Units covering your exact present requirements; later you can add other inexpensive plug-ins to increase the usefulness of the instrument. Still wider usefulness may be obtained by using the 524C/D in conjunction with 540B Transfer Oscillator for frequency measurements to 12.4 GC, and above (see page 112) and digital recorders for a permanent, printed record of measurements.

Great Versatility
The moderately priced 524C/D gives you more range, simplicity, usefulness and reliability than any group of instruments with comparable range ever offered. With this one all-purpose equipment, you measure transmitter and crystal oscillator frequencies, electrical, electronic and mechanical time intervals, phase angles, pulse lengths and repetition rates or frequency drift. You make high accuracy ballistics time measurements or high resolution tachometry measurements. The instrument also serves as a house frequency standard for many users, with a long-term stability of 5 parts in 10^8 per week. It is simple to operate and readily used by non-technical personnel.

Basic Counter Details
In the basic 524C Counter (without Plug-In Units) frequency from 10 cps to 10.1 MC is read over 5 selected gate

*With 540B Transfer Oscillator.
times — 0.001, 0.01, 0.1, 1 and 10 seconds. Display time is variable, counts are automatically reset, and action is repetitive. Low frequencies (below approximately 300 cps) are more accurately measured by determining the period of one or ten cycles. Here the unknown frequency operates the gate and the internal standard frequency is applied to the counter. Thus the duration of a low frequency cycle is measured in time units. A 10-cycle sample may also be taken to improve accuracy. The result is determined automatically and presented in direct reading form with automatic illuminated decimal point.

\[ \text{Model 524D is identical electrically with the } \text{524C, but has 8-decade numerical readout using the widely accepted neon indicators instead of inline readout. Model 524D offers the same time-saving convenience of direct instantaneous, automatic readings without calculation or interpolation, but is priced slightly lower than the Model 524C.} \]

\[ \text{Addition of } \text{525 and 526 series Plug-In Units will extend any } \text{524 Counter's frequency range to 510 MC, provide increased sensitivity, and make available uniquely flexible time interval and phase angle measurements.} \]

\[ \text{This instrument extends the Counter's 10 MC direct-reading range in decade steps through 100 MC. It maintains counter accuracy throughout the range. It provides additional amplification to increase sensitivity. A tuned input circuit simplifies determining the correct frequency range and rejects harmonics and spurious signals.} \]

\[ \text{Similar to 525A, this unit extends the counter's range from 100 MC to 220 MC in 10 MC steps, at the same time preserving the high accuracy of the basic counter. It maintains the same high sensitivity 0.2 volt minimum input throughout its range, and includes a wavemeter for determining the proper frequency decade range.} \]

\[ \text{Counter accuracy is extended over the wide range of 100 MC to 510 MC with this new heterodyne converter. Sensitivity is 100 mv over its range; it may also be used to increase counter sensitivity to 20 mv from 50 KC to 10.1 MC.} \]

\[ \text{526A Video Amplifier. This equipment increases the counter's 10 cps-to-10 MC sensitivity to 10 millivolts for frequency measurement at low power levels. A special probe assembly simplifies remote pickup at high impedance levels. An oscilloscope output terminal allows visual monitoring of the input waveform.} \]

\[ \text{This instrument measures intervals from 1.0 } \mu \text{sec to 100 days with maximum accuracy of } 0.1 \mu \text{sec } \pm \text{ time base accuracy. Intervals are read direct in seconds, milliseconds or microseconds. Start and stop triggering is performed in either common or separate channels, and may be accomplished through the use of positive or negative going waves. Trigger voltage levels are continuously adjustable from } -192 \text{ to } +192 \text{ volts.} \]

\[ \text{Designed for precise phase angle measurements, the new 526D covers the range from 1 cps to 20 KC, reading in time units with resolution to } 0.1 \mu \text{sec. For measurements from 396-404 cps, this unit is designed to give phase angle readings directly in tenths of degrees.} \]

\[ \text{At nominal additional charge, Model 524C or 524D Electronic Counters can be modified to provide the following output signals:} \]

2. A 10-line code decimal output for operation of the 561B Digital Recorder. (524C only.)
3. A 4-line (1-2-2-4) binary coded decimal output for connection to data processing equipment.

Models 561B and 560A (page 114, 115) are 11-column recorders which are slaves to the counter and print the counter reading at rates up to 5 per second.

\[ \text{Specifications} \]

\[ \text{524C/D Electronic Counter} \]

\[ \begin{align*}
\text{Basic Unit, for Frequency Measurements, 0 cps to 10.1 MC} \\
\text{Frequency Measurement: (without plug-in units).} \\
\text{Range: } 10 \text{ cps to } 10.1 \text{ MC.} \\
\text{Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds or manual control.} \\
\text{Accuracy: } \pm 1 \text{ count } \pm \text{ time base accuracy (see page 92).} \\
\text{Reads In: Kilocycles; decimal point automatically positioned.}
\end{align*} \]
Period Measurement: (without plug-in units).

Range: 0 cps to 100 KC.

Gate Time: 1 or 10 cycles of unknown.

Accuracy: \( \pm 0.3\% \) (measurement one period).*

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

Reads In: Seconds, milliseconds or microseconds; decimal point automatically positioned.

General:

Registration: 524C, 8 digital display tubes; 524D, 8 numbered columns; 99,999,999 maximum display.

Stability: 3/10° short term; 5/10° per week. May be standardized against broadcast standards or used with external 100 KC or 1 MC primary standard.

Display Time: Variable 0.1 to 10 seconds in steps of gate time selected. Display can be held indefinitely.

Output Frequencies: Secondary standard frequencies available at front panel: 10 cps, 1 KC rectangular; 100 KC positive pulse; 10 MC sine wave. (Stability above.)

Self Check: Panel control provides automatic count of internal standard 100 KC and 10 MC frequencies to assure proper operation of counter.

Input Voltage: 1 v rms minimum 1.5 v peak. Rise time 0.2 sec max.

Input Impedance: Approx. 1 megarohm, 40 pf shunt.

External Standard: 100 KC or 1 MC signal from external primary standard can be applied to unit for highest accuracy. 2 volts rms required. Input impedance nominal 470K, 40 pf shunt capacitance.

Power: 115/230 v \( \pm 10\% \), 50/60 cps, 600 watts.

Dimensions: Cabinet Mount: 20" wide, 21 3/4" high, 19 1/2" deep.

Rack Mount: 19" wide, 19 3/4" high, 17" deep.


Accessories Furnished: 1 AC-16K Cable Assembly.

Accessories Available: 524B-16P ($50.00) and 524B-16Q ($20.00).

Test Cable Sets for shortest standard 100 MC to 510 MC. As converter for counter, 100 MC to 10.1 MC. As amplifier for counter, 10 MC to 10.1 MC. Direct connection for 0 to 100 MC.

Price: @ 524C, $2,400.00. @ 524D, $2,150.00. Modified to operate @ 560A, add $75.00. Modified to provide BCD output (1-2-2-4) @ 561B only, add $130.00. Rack mount models available.

### 525A Frequency Converter Unit

**For Frequency Measurement. 10 cps to 100 MC.**

Plugged into @ 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 indicates on converter selector switch labeled 0, 10, 20 ... 50; next 7 indicated by counter.

Input Voltage: 0.1 v rms minimum, 10 cps to 10.1 MC; 10 v rms minimum, 10.1 MC to 100 MC.

Input Impedance: Approx. 1 megarohm shunted by 40 pf, 10 cps to 10 MC; approx. 50 ohms, 10 MC to 100 MC.

Level Control: Tuning eye aids frequency selection; indicates correct voltage level adjustment.

Weight: Net 5 lbs. Shipping 8 lbs.

Price: @ 525A, $250.00.

### 525B Frequency Converter Unit

**For Frequency Measurement. 100 MC to 220 MC.**

Plugged into @ 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, 10, 20, ... 20, 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: @ 525B, $300.00.

### 525C Frequency Converter Unit

**For Frequency Measurement. 100 MC to 510 MC.**

Plugged into @ 524.

Range: As converter for counter, 100 MC to 510 MC. As amplifier for counter, 50 KC to 10.1 MC. Direct connection for 0 to 100 MC.

Accuracy: Retains accuracy of 524 Counter.

Registration: 9 places; first two places indicated on converter dial, next 7 displayed by counter.

*See pages 92-95 for a discussion of counter accuracy considerations.

Input Voltage: 20 mv rms minimum, 50 KC to 10.1 MC; 100 mv rms minimum, 100 MC to 510 MC.

Input Impedance: Approximately 700 ohms, 50 KC to 10.1 MC. Approximately 50 ohms, 100 MC to 510 MC.

Level Control: Meter aids frequency selection; indicates relative voltage level.

Weight: Net 6 1/2 lbs., shipping 11 lbs.

Price: @ 525C, $425.00.

### 526A Video Amplifier Unit

**For Frequency Measurement. 10 cps to 10.1 MC high sensitivity.**

Plugged into @ 524.

Range: 10 cps to 10.1 MC.

Accuracy: ± 1.0% standard frequency counted, ± 1.5% base accuracy.

Input Voltage: 1 v peak minimum, 100 MC to 510 MC.

Input Impedance: Approx. 50 ohms shunted by 40 pf.

Trigger Slope: Positive or negative on start and/or stop channels.

Trigger Amplitude: Both channels continuously adjustable from -0.192 to +0.192 v.

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

Reads In: Seconds, milliseconds, or microseconds; decimal point automatically positioned.

Weight: Net 5 lbs. Shipping 8 lbs.

Price: @ 526A, $200.00.

### 526B Time Interval Unit

**For Time Interval Measurement.**

Plugged into @ 524.

Range: 1 psec to 10^15 seconds.

Accuracy: ± 1.0% standard frequency counted, ± 2.5% base accuracy.

Input Voltage: 200 mv rms minimum, 100 MC to 10.1 MC.

Input Impedance: Approx. 1 megarohm shunted by 40 pf.

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 -0.192 to +0.192 v.

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

Reads In: Seconds, milliseconds, or microseconds; decimal point automatically positioned.

Weight: Net 5 lbs. Shipping 8 lbs.

Price: @ 526B, $200.00.

### 526C Period Multiplier Unit

**For Frequency Measurement.**

Plugged into @ 524.

Range: 0 to 100 KC.

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

Accuracy: ± 1 count ± 0.3% of full scale.

(See 524 General Specifications).

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

Reads In: Seconds, milliseconds, or microseconds.

Input Voltage: 1 v rms minimum.

Input Impedance: 1 megarohm, 40 pf shunt.

Weight: Shipping 8 lbs.

Price: @ 526C, $225.00.

### 526D Phase Unit

**For Phase Comparisons.**

Plugged into @ 524.

Range: Phase angle, 0-360° lead or lag

Frequency Range: 1 cps to 20 KC.

Reads In: Seconds, milliseconds, microseconds; \( \times 3600 \) multiplier provides readings direct in tenths of degrees for signals 396-404 cps.

Accuracy: \( \pm 0.1^\circ \pm \frac{\pm}{F_0} \times 360^\circ \), where \( F_0 \) is frequency of phase measured signal, \( F_0 \) is counted frequency; assuming noise 65 db below signal and negligible counted frequency error.

Input Voltage: 5 to 120 volts rms.

Input Impedance: Approximately 1 megarohm, 80 pf shunt.

Weight: Net 7 lbs. Shipping 15 lbs.

Price: @ 526D, $750.00.

Data subject to change without notice.
An integrated development program combining new advances in component development and broad innovations in instrument layout and design has made possible a whole new family of precision frequency and time measuring devices. These solid-state instruments provide:

1. **Display storage** — making readings possible even while a count is in progress.
2. **Faster repetitive counts** — display time is no longer limited to an integral multiple of the gate time.
3. **Solid-state circuits** — with low heat dissipation and reliable operation from -20° to +65°C.
4. **Positive frequency division** — giving maximum reliability to all gate times.
5. **Multiple period average** — improving period measurement accuracy, even for noisy signals.
6. **Plug-in modules** — for clean design and easy serviceability.
7. **Compact, stackable cabinets** — only 3½ inches of rack space required.

Behind these instruments stand Hewlett-Packard's years of experience as the world's leading manufacturer of precision frequency and time measuring equipment.

We believe the new counters are the finest of their type available. They combine operational utility and rugged serviceability with true functional beauty. They are compact, light, have low power consumption and can operate over a wide temperature range without degradation of performance. Plug-in module construction increases instrument versatility, simplifies maintenance, and helps assure uniform high quality.

**New HP Counters**

Two basic counters give maximum counting rates of 1.2 MC and 300 KC with choice of either column or in-line readout. Measurements of frequency, period, ratio and total count are made with typical electronic counter precision. (Counter accuracy considerations are discussed in detail on pages 92-95 of this catalog.) Input sensitivity is adjustable to a maximum of 0.1 volts rms.

Conservative design features, such as the use of decade dividers in the gate generating circuits, greatly improve operational stability. This positive-action frequency division combined with front panel self-check provisions gives confidence in readings at every position of the function selector switch.

Dual use of decade dividers in these counters permits multiple period average measurements as a standard feature, increasing measurement accuracy in proportion to the multiplication factor.

Display storage provides a continuous visual display even while the instrument is totaling a new count. Only if the new count differs from the previous count will the display change, in which case it will shift directly to the new reading. For most repetitive measurements, this feature will improve readability. For appropriate applications, storage may be disabled by a rear panel switch.

Display time is controllable from approximately 0.2 seconds to 5 seconds and is not limited by the gate time. For 1- and 10-second gates, this substantially increases the possible rate of sampling over units whose minimum display time is equal to the length of the selected gate.

Output in four-line BCD code (1-2-2-4) is available for system use or operation of output devices such as the @ 562A Digital Recorder (see page 204). Dymec Division equipment compatible with these counters and with many other types of output recorders is described on page 204 of this catalog.

The extremely clean and compact design is shown in figure 1. Occupying just 3½ inches of rack space, these counters are light, have low power consumption and can operate over a temperature range of -20° to +65°C.

**10 Nanosecond Time Interval Counter**

This remarkable instrument measures time intervals from 10 nanoseconds to 0.1 seconds with 10 nanosecond resolution. Readout is direct in microseconds from neon columns. The @ 5275A Time Interval Counter has storage display and electrical readout features similar to the counters described above. The same clean, compact packaging is also used.

The 5275A is ideally suited for precise digital measurements of the time interval between two events which can be represented by suitable electrical pulses. (See page 110 for trigger specifications.) It is designed to be equally at home in the system console or the research laboratory.

Time interval measurement accuracy is ±1 count, ± the time base accuracy. The @ 101A 1 MC Oscillator is recommended as the time base for the @5275A, where a house standard of suitable stability is not available. @ 101A is a transistorized version of the same proven oscillator used as the time base in the @ 524C/D Counters. The long-term stability of this oscillator is 5 parts in 10⁸ per week. Sufficient output power is available to drive as many as 20 @ 5275A's.

A complete description of this oscillator can be found on page 125.
New Ease of Operation, Measure Frequency, Period, Ratio; Fully Transistorized

Advantages:

Reliable service; rugged and compact packaging
More accurate low frequency measurements, with multiple period averages
Low-level measurements without accessories; 0.1 volt sensitivity
Operational flexibility and reduced operator errors with display storage
Minimum bench or rack space, with new modular cabinets.
Low heat dissipation and power consumption, with solid-state components
Higher sampling rates; "inactive" time no longer an integral multiple of gate time

Major improvements in operating convenience and outstanding reliability with all solid-state components, are important features of the new Hewlett-Packard family of transistor counters.

Two basic counters give maximum counting rates of 300 KC and 1.2 MC, with a choice of column or in-line readout. Just 3½" high, the unique cabinet design makes these instruments suitable either for bench use or rack mounting. The front panel has input attenuation control, display control, reset button and function switch. In the rear are the storage disable switch, external standard input jack (which permits the use of an external oscillator as the counter time base) and recorder output jack (optional).

Conservative design features, such as the use of decade dividers in the gate generating circuits, greatly improve operational stability and reduce calibration problems. Dual use of these same decade dividers permits multiple period average measurements, with its resultant increase in accuracy, as a standard feature. Careful component choice makes these transistor counters operable in ambient temperatures from -20 to +65°C. Self-check is provided for both frequency and period measurement modes.

### Display Storage

The unique display storage feature of these new counters provides a continuous visual readout of the most recent measurement even while the instrument is gated for a new count. If the new count differs from the "stored" count, the display will shift to the new reading directly. The counter’s "inactive time" (when it is not making a new measurement) is completely adjustable from 0.2 to 5.0 seconds and is independent of gate time. This permits a higher sampling rate than is possible with many other counters.

Four-line BCD code output (extra cost option) with assigned weights of 1-2-2-4 is available for systems use or the operation of output devices such as the @ 562A Digital Recorder. (See page 116, 117.) Output impedance is 100 ohms for each line; "0" state is indicated by -24 volts, "1" state by -1 volt.

<table>
<thead>
<tr>
<th>Counter</th>
<th>Max. Counting Rate</th>
<th>Registration</th>
<th>No. of Digits</th>
<th>Display</th>
<th>Input</th>
<th>Time Base</th>
<th>Period Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sensitivity</td>
<td>Impedance</td>
</tr>
<tr>
<td>5212A</td>
<td>300 KC</td>
<td>Column</td>
<td>5</td>
<td></td>
<td></td>
<td>0.1 v rms</td>
<td>1 megohm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sine wave</td>
<td>shunted by 50 pf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 v neg</td>
<td>pulse, 2.0 µs min.</td>
</tr>
<tr>
<td>5512A</td>
<td>300 KC</td>
<td>In-Line</td>
<td>5</td>
<td></td>
<td></td>
<td>0.1 v rms</td>
<td>1 megohm</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>sine wave</td>
<td>shunted by 50 pf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 v neg</td>
<td>pulse, 2.0 µs min.</td>
</tr>
<tr>
<td>5232A</td>
<td>1.2 MC</td>
<td>Column</td>
<td>6</td>
<td></td>
<td></td>
<td>0.1 v rms</td>
<td>1 megohm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sine wave</td>
<td>shunted by 50 pf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 v neg</td>
<td>pulse, 0.2 µs min.</td>
</tr>
<tr>
<td>5532A</td>
<td>1.2 MC</td>
<td>In-Line</td>
<td>6</td>
<td></td>
<td></td>
<td>0.1 v rms</td>
<td>1 megohm</td>
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<td></td>
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<td></td>
<td>sine wave</td>
<td>shunted by 50 pf</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 v neg</td>
<td>pulse, 0.2 µs min.</td>
</tr>
<tr>
<td>Frequency Measurement</td>
<td>Ratio Measurement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-----------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td><strong>Accuracyn</strong></td>
<td><strong>Reeds In</strong></td>
<td><strong>Gate Time</strong></td>
<td><strong>Reads</strong></td>
<td><strong>Range</strong></td>
<td><strong>Accuracy</strong></td>
<td><strong>Power</strong></td>
</tr>
<tr>
<td>2 cps to 300 KC</td>
<td>±1 count</td>
<td>KC with</td>
<td>10, 1, 0.1, 0.01</td>
<td>(f&lt;sub&gt;1&lt;/sub&gt;/f&lt;sub&gt;0&lt;/sub&gt;) x period multiplier</td>
<td>100 cps to 300 KC</td>
<td>±1 count of f&lt;sub&gt;0&lt;/sub&gt; ± trigger error of f&lt;sub&gt;1&lt;/sub&gt;</td>
<td>115/230 V ± 10%</td>
</tr>
<tr>
<td></td>
<td>±1 count</td>
<td>positioned decimal</td>
<td>sec</td>
<td></td>
<td>(1 V rms into 100 ohms)</td>
<td>f&lt;sub&gt;0&lt;/sub&gt;</td>
<td>16%/wide, 3/4 high</td>
</tr>
<tr>
<td>2 cps to 300 KC</td>
<td>±1 count</td>
<td>KC with</td>
<td>10, 1, 0.1, 0.01</td>
<td>(f&lt;sub&gt;1&lt;/sub&gt;/f&lt;sub&gt;0&lt;/sub&gt;) x period multiplier</td>
<td>100 cps to 300 KC</td>
<td>±1 count of f&lt;sub&gt;0&lt;/sub&gt; ± trigger error of f&lt;sub&gt;1&lt;/sub&gt;</td>
<td>115/230 V ± 10%</td>
</tr>
<tr>
<td></td>
<td>±1 count</td>
<td>positioned decimal</td>
<td>sec</td>
<td></td>
<td>(1 V rms into 100 ohms)</td>
<td>f&lt;sub&gt;0&lt;/sub&gt;</td>
<td>16%/wide, 3/4 high</td>
</tr>
<tr>
<td>2 cps to 1.2 MC</td>
<td>±1 count</td>
<td>KC with</td>
<td>10, 1, 0.1, 0.01</td>
<td>(f&lt;sub&gt;1&lt;/sub&gt;/f&lt;sub&gt;0&lt;/sub&gt;) x period multiplier</td>
<td>100 cps to 1.2 MC</td>
<td>±1 count of f&lt;sub&gt;0&lt;/sub&gt; ± trigger error of f&lt;sub&gt;1&lt;/sub&gt;</td>
<td>115/230 V ± 10%</td>
</tr>
<tr>
<td></td>
<td>±1 count</td>
<td>positioned decimal</td>
<td>sec</td>
<td></td>
<td>(1 V rms into 600 ohms)</td>
<td>f&lt;sub&gt;0&lt;/sub&gt;</td>
<td>16%/wide, 3/4 high</td>
</tr>
<tr>
<td>2 cps to 1.2 MC</td>
<td>±1 count</td>
<td>KC with</td>
<td>10, 1, 0.1, 0.01</td>
<td>(f&lt;sub&gt;1&lt;/sub&gt;/f&lt;sub&gt;0&lt;/sub&gt;) x period multiplier</td>
<td>100 cps to 1.2 MC</td>
<td>±1 count of f&lt;sub&gt;0&lt;/sub&gt; ± trigger error of f&lt;sub&gt;1&lt;/sub&gt;</td>
<td>115/230 V ± 10%</td>
</tr>
<tr>
<td></td>
<td>±1 count</td>
<td>positioned decimal</td>
<td>sec</td>
<td></td>
<td>(1 V rms into 600 ohms)</td>
<td>f&lt;sub&gt;0&lt;/sub&gt;</td>
<td>16%/wide, 3/4 high</td>
</tr>
</tbody>
</table>

*For a detailed discussion of electronic counter accuracy considerations, see pages 92-95 of this catalog.
HP 5275A TIME INTERVAL COUNTER

10 Nanoseconds to 0.1 Seconds; Compact, Solid-State Construction

Specifications

Range: 10 nanoseconds to 0.1 seconds.

Resolution: 10 nanoseconds.

Accuracy: ± 10 nanoseconds, ± time base accuracy.

Time Base: External 1 MC required. (See page 125, description of 501A).

Registration: 7 places, direct digital presentation in neon columns.

Read In: Microseconds, with decimal point.

Input Requirements: Start and stop trigger pulses through separate channels.

Input Impedance: 50 ohms.

Minimum Trigger Pulse: 3.0 volts peak, 1.0 volt per nanosecond rise, 5 nsec width at 50% point.

Trigger Polarity: Selectable, positive or negative, for each channel independently.

Reset: Manual from front panel, or remote through rear-mounted terminal.

Standard Frequency Counted: 100 MC.

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

Operating Temperature Range: —20°C to +65°C.

Dimensions: 19” wide, 5½” high, 11½” deep. Weight 15 lbs.


Price: 5275A. Price on request.

Data subject to change without notice.

Information previously unavailable in digital form can now be measured with electronic counter precision and simplicity with the new 5275A Time Interval Counter. 10-nanosecond resolution is achieved in automatic measurements over the full range of the instrument. The counted frequency is 100 MC, obtained from an external 1 MC standard by a 100 to 1 multiplying circuit within the 5275A.

5275A is ideally suited for precise digital measurements of very short time intervals between events that can be represented by suitable electrical pulses. Applications include explosive burning rates, speed and acceleration timing of test vehicles in free-flight wind tunnels, and nuclear measurements.

101A Oscillator (page 125) has been specifically designed for use with Model 5275A Time Interval Counter and is capable of supplying the time base for as many as 20 instruments at one time. Using one time base for several counters conserves rack space and reduces system cost.

A 4-line BCD output (optional) permits direct connection to many computers, or may also be used to drive the 562A Digital Recorder (pages 116, 117). Other output devices . . . typewriters, card punches, tape punches, magnetic recorders, etc. . . . may be operated through standard output couplers manufactured by Dymec, a division of Hewlett-Packard. (See page 204.)
Three dependable, convenient AC-4 Decade Counters are offered, with maximum counting rates of 120 KC, 220 KC, and 1.2 MC. Specific characteristics of each decade are given in the table below. Each is of improved design providing high reliability and staircase output voltage for remote register or driving 560A Digital Recorder. Units may be cascaded for any count capacity; they may be used to totalize, or as scale-of-10 dividers with remainder indicated. Readout is provided by neon lighted numerals.

On special order, any Model AC-4 Decade Counter can be supplied with a 4-line binary coded (1-2-2-4) decimal output for direct connection to comparators, 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 $42.00 and $77.00, respectively.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>AC-4C</th>
<th>AC-4G</th>
<th>AC-4E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Counting Rate:</td>
<td>220 KC</td>
<td>120 KC</td>
<td>1.2 MC</td>
</tr>
<tr>
<td>Double Pulse Resolution:</td>
<td>4 µsec</td>
<td>7 µsec</td>
<td>0.7 µsec</td>
</tr>
<tr>
<td>Driving Voltage:</td>
<td>-50 v pulse</td>
<td>-80 v pulse</td>
<td>-20 v pulse</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.2 µsec rise time</td>
</tr>
<tr>
<td>Output Voltage:</td>
<td>-80 v pulse</td>
<td>-80 v pulse</td>
<td>-80 v pulse</td>
</tr>
<tr>
<td>Reset:</td>
<td>To zero: open base pin connection or apply +90 volt pulse 5 µsec duration.</td>
<td>To zero: open base pin connection or apply +90 volt pulse 5 µsec duration.</td>
<td>To zero: open base pin connection or apply +90 volt pulse 5 µsec duration.</td>
</tr>
<tr>
<td>Display:</td>
<td>Illuminated numerals in a column.</td>
<td>Illuminated numerals in a column.</td>
<td>Illuminated numerals in a column.</td>
</tr>
<tr>
<td>Output Code:</td>
<td>Staircase voltage + 135 volts at count of zero, + 55 volts at count of nine.</td>
<td>Staircase voltage + 135 volts at count of zero, + 55 volts at count of nine.</td>
<td>Staircase voltage + 135 volts at count of zero, + 55 volts at count of nine.</td>
</tr>
<tr>
<td>Mounting:</td>
<td>12 pin male plug.</td>
<td>12 pin male plug.</td>
<td>12 pin male plug.</td>
</tr>
<tr>
<td>Power:</td>
<td>+ 300 v at 18 ma</td>
<td>+ 300 v at 15 ma</td>
<td>+ 300 v at 30 ma</td>
</tr>
<tr>
<td></td>
<td>6.3 v ac at 1.2 amp.</td>
<td>6.3 v ac at 1.2 amp.</td>
<td>6.3 v ac at 1.2 amp.</td>
</tr>
<tr>
<td>Price:</td>
<td>$77.00</td>
<td>$42.00</td>
<td>$95.00</td>
</tr>
</tbody>
</table>

*Model AC-4D-15 and modification kit is available as a replacement for the AC-4D in hp-5238 Electronic Counters. Price $100.00.*
**540B TRANSFER OSCILLATOR**

Measure Frequency to 18 GC (KMC) with Electronic Counter Accuracy

**Advantages:**

- Extends frequency counter accuracy to microwave region
- Measures to 18 GC (KMC) with new fixed tuned mixers
- Permits measurement of pulsed, FM, CW, AM or noisy signals
- Provides multiple check for positive accuracy
- Measures FM deviation
- Includes self-contained oscilloscope
- Circuit elements usable separately
- Simple to use, compact, eliminates complex set-ups

**Uses:**

- Fast, accurate determination of CW and AM signal frequencies
- Measuring center frequency or deviation range of FM signals
- Measuring frequency in presence of high noise levels
- High accuracy measurements of pulsed signals

Use of 540B Transfer Oscillator with counters, frequency converters and fixed tuned mixers permits measurements far into the microwave region with accuracy and simplicity otherwise available only at much lower frequencies. Model 540B contains a highly stable 100 to 220 MC oscillator generating harmonics to at least 12.4 GC (KMC) for comparison. Comparison is made by means of a broadband, untuned, diode mixer system, amplifier and oscilloscope, all within the instrument. In addition, the built-in harmonic generator provides signals for driving external amplifiers and mixers for measurements above 12.4 GC.*

Combined with an 524 series Counter with 525B Frequency Converter plug-in, the 540B extends the 524's range to 12.4 GC. With the new P932A Harmonic Mixer, simple, accurate measurement is available to 18 GC.

In operation, with approximate signal frequency known, the 540B is tuned until one of its harmonics beats with the unknown. The multiplying factor is noted. The transfer oscillator frequency is then measured directly on the 524 Counter. The 524 frequency reading, times the multiplying factor, gives the frequency of the unknown signal. When the signal frequency is totally unknown, a convenient calculation employing two or more harmonics is used to determine the multiplying factor.

In measuring carrier frequency of pulsed signals, an external oscillosynchrscope is used to display the detected pulse. Zero beat appears as horizontal lines across the pulses when

*The use of external traveling wave amplifiers and waveguide mixers for measurements in P, K and R bands (12.4 to 40 GC) is described in Application Note No. 2, available on request.
the oscillator is tuned to an exact sub-multiple. Video amplifier frequency response controls can be used to simplify this procedure.

In working with noisy or AM signals, the 540B's response can be narrowed to obtain a more accurate indication of zero beat.

In signals with appreciable FM, the 540B's oscilloscope presents a characteristic pattern pin-pointing upper and lower frequency deviation limits. If FM deviation is present, center frequency may also be determined.

P-Band Measurements

The P932A Harmonic Mixer mounts directly in the waveguide system and operates with either the 540A or 540B, mixing generated harmonics with the unknown waveguide frequency. The mixer's beat frequency output is applied to the 540. The measuring procedure is the same as the procedure using the 540's internal mixer.

An earlier Transfer Oscillator, Model 540A is widely used for making measurements to 5 GC. The P934A Harmonic Mixer operates from 2 to 12.4 GC, and extends the range of the 540A from 5 GC to 12.4 GC. Both the 934A and P932A are fixed tuned.

Accuracy

The system's accuracy approaches that of the electronic counter on clean CW signals. On pulsed signals, accuracy is governed by carrier frequency and pulse length. On noisy or intense AM signals, the transfer oscillator system with 540B often provides the only means of accurate measurement. Overall system accuracy is greater than 10 times that of the best microwave wavemeters. A direct-coupled reactance control circuit in the 540B allows the oscillator to be locked at a sub-multiple of the measured frequency when it is desirable to measure automatically or record drift characteristics of microwave signal sources.

Quality Features

Each of the circuit elements of 540B may be used separately by shifting front panel patch cords. Controls are provided for coarse and fine mechanical tuning. There also is an electrical vernier with range approximately ± 125 parts per million. The video amplifier has both gain and bandwidth controls. Horizontal input to the internal oscilloscope is power line frequency with phase control, or external signals from 20 cps to 3 KC.

Specifications, Model 540B

General

Frequency Range: 10 MC to 12,400 MC.
Input Signal: CW, FM, AM or pulse.
Input Signal Level: Varies with frequency and individual crystals. (See chart.)

Accuracy: CW: Approximately 1/10,000,000 or better.

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.
Output: Approximately 2 v into 50 ohms.

Amplifier

Gain: Adjustable, Maximum 40 db or more.
Bandwidth: Variable. High Frequency: 3 db point adjustable approximately 1 KC to 2 MC. Low Frequency: 3 db point switched from 100 cycles to below 10 KC. Adjustable to above 400 KC.
Output: 1 v rms maximum into 1,000 ohms.

Oscilloscope (Self-Contained)

Frequency Range: 100 cps to 200 KC.
Vertical Deflection Sensitivity: 5 mv rms per inch at mixer output.
Horizontal Sweep: Internal, power supply frequency with phase control, or external (connection at rear) with 1 v per inch, 20 cps to 3 KC.

Miscellaneous

Size: Cabinet Mount: 20½” wide, 12½” high, 15¼” deep. Rack Mount: 19” wide, 10½” high, 14½” deep behind panel.
Power Supply: 115/230 v ± 10%, 50/1,000 cps, approximately 110 w.

Auxiliary Equipment:

524 Electronic Counter, (see pages 104-106).
525B Frequency Converter, $300.00.
Price: 540B, $850.00 (cabinet); 540BR, $835.00 (rack mount). 540B mixer [2 to 12.4 GC (KMC)] available for use with 540A; specify Model 934A, $150.00; P932A Mixer (12.4 to 18 GC) for use with 540A and 540B, $250.00.

Data subject to change without notice.
Advantages:

- Controllable by electronic or electro-mechanical devices
- 11-digit parallel entry; primary and supplementary data can be recorded simultaneously
- High speed printing rate up to 5 lines/sec.; uses folded or standard roll paper and standard typewriter ribbon
- Analog output for strip-chart or X-Y recorder (560A)

Uses:

- Recorder for frequency counters, digital voltmeters
- Recording of time functions
- Digital to analog converter for strip-chart recording
- Test, calibration, check-out of telemetering systems
- Monitoring, final tabulation and plotting of tests
- Investigating drifts in systems and equipment

The HP 560 series Digital Recorders, although specifically designed for use with electronic counters and voltmeters, are extremely versatile and useful in a wide variety of applications.

Basically, the recorders consist of a motor-driven print mechanism with inked ribbon, printing paper, eleven identical number wheels and eleven circuits which position the number wheels according to the count appearing on an associated electronic counter.

Both Models 560A and 561B have a printing speed of five, 11-digit lines per second. The 11-digit line allows secondary or coding data to be entered simultaneously with primary data. Since each recorder is literally a slave to its associated input, the recorder accuracy is the same as the accuracy of the data gathering input.

Operation—Model 560A

In normal electronic operation, the 11 number wheels are locked in position while the counter is counting. At the end of each counting period, the staircase voltage generated during the count by each decade in the counter comes to rest on the step or voltage level corresponding to the digit displayed by that decade. Each staircase voltage step is sent to the recorder along with a print command pulse which occurs at the end of the count period.
The principle of operation is as follows: When a print command is received, the clutch engages, turning the number wheels. Each number wheel turns until its armature contacts a voltage which is negative with respect to the cathode of a tube. A negative voltage on the grid of the tube de-energizes the solenoid and drops the pawl, thus stopping the number wheel in the appropriate position.

### Specifications—Model 561B/BR

Same as 560A except:

- **Column Capacity:** 11 columns.
- **Input:** Decimal code, 10 lines plus 2 lines for blank and asterisk for each column.
- **Driving Source:** 561B recorder kits installed. (See Counter specifications.) 561B Digital Voltmeter. (See Voltmeter specifications.) Stepping Switches, Relays, Beam Switching Tubes, contact closure, or —15 to —100 volt connected to appropriate number wire. Operates from 10-line coded systems.
- **Print Command:** ±15 volts peak or more, 10 μsec minimum width, or external contact closure. Manually controlled by a momentary contact toggle switch. Print commands during scan and print action have no effect.
- **Power:** 115/230 v ±10%, 50/60 cps, approximately 75 watts. 4 prints/sec maximum on 50-cycle lines. For 50-cycle operation retaining 5 prints/sec specify, H03 561B (cabinet); H03 561BR (rack), add $5.00. With 571B Digital Clock installed specify E01 561B (cabinet), E01 561BR (rack), add $950.00.
- **Price:** $561B, $1,150.00 (cabinet); $561BR, $1,350.00 (rack mount).

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**570A/571B Digital Clocks**

Models 570A and 571B Digital Clocks mount in the left-hand side of 560A and 561B Digital Recorders, respectively. These clocks provide time-of-day information for addition to other recorded data, and can control rates at which measurements are made.

Time is indicated in a 23-hour, 59-minute, 59-second arrangement; display is by bright, in-line indicator tubes with all time digits available for printing.

For maximum flexibility, two operating modes are provided. In the first, 570A or Dymec digital counters, digital voltmeters or other external equipment initiate print commands; time is printed along with primary data. In the second mode, (for long-term tests which require infrequent readings) the Digital Clocks determine the rate at which readings are made. Sampling intervals are selected on a front panel switch offering sampling rates of 1/second, 6/minute, 1/minute, 6/hour, 1/hour. Models 570A/571B operate from an internal or external time base.

- **570A (fits 560A/AR),** $1,050.00.
- **571B (fits 561B/BR),** $950.00.

*Data subject to change without notice.*
562A DIGITAL RECORDER

Flexible Data Input With Information Storage

Advantages:

Permits increased rate of data collection with information storage; 2 millisecond data transfer
Parallel entry 4-line BCD input
Versatile operation; converts to other codes with plug-in cards; can operate with different codes on separate wheels
Reliable, low maintenance operation with transistorized construction
Dual input provision to permit simultaneous printing from two unsynchronized data sources.

Uses:

Record readings of \( \odot \) Transistor Counters
Provide permanent record of readings in specialized systems
Record output from two devices.

Hewlett-Packard Model 562A Digital Recorder is a transistorized electro-mechanical device providing a printed record of digital data from any of a number of sources. Parallel data entry and low-inertia moving parts allow printing rates as high as 5 lines per second, each line containing up to 11 digits. 12 digit capacity is available on special order. Model 562A uses the same fast mechanical system pioneered by \( \odot \) in Models 560A and 561B Digital Recorders.

Data Storage

A unique data storage feature allows the driving source to transfer its data to Model 562A in 2 milliseconds. As soon as this data transfer is completed, the driving source is released to gather more information. Reducing the time that the driving source must hold a reading makes possible a higher rate of data collection.

Although designed primarily for use with the new family of \( \odot \) Transistor Counters, Model 562A is extremely flexible, and can be used in a wide variety of individual and system applications.

Data Entry

Standard input for Model 562A is parallel-entry 4-line BCD code (1-2-2-4). Data enters the unit through two rear-mounted 50-pin connectors. Internal plug-in connectors route the information to any desired sequence of print wheels. A separate storage binary unit is associated with each individual print wheel. On print command each storage binary unit
assumes the condition of the decade counting unit (or other driving source) connected to it. This data transfer takes place in 2 milliseconds, after which time the driving source is free to accumulate additional information.

The storage binary unit for each column is mounted on a plug-in card with a resistor matrix, which translates the stored data into positioning information for the print wheels. Normally, Model 562A is equipped to translate 1-2-2-4 BCD, but other 4-line codes are accommodated simply by substituting plug-in cards. 10-line code operation is also available by card substitution and the mounting of additional input plugs. However, information storage is not available for 10-line data.

Since each print wheel operates with its own plug-in card, different input codes may be used for separate wheels. For further flexibility, @ 562A is available with dual input coupling to print data simultaneously from two unsynchronized sources.

In addition to the standard print wheels which have numerals '0' through '9,' a minus sign and a blank, a wide variety of special character wheels may now be obtained from stock.*

### Specifications

**Accuracy:** Identical to input device used.

**Printing Rate:** 5 lines/second maximum.

**Column Capacity:** To 11-columns (12 available on special order).

**Print Wheels:** 12 position, numerals 0 through 9, a minus, and a blank. Other symbols available.*

**Driving Source:** Parallel entry 4-line BCD, 1-2-2-4. Other codes available. Source reference voltages establish “0” and “1” states, which may be 100 v above or below ground. “1” state 4 to 75 volts above reference. Driving power approx. 30 mA into 270,000 ohms.

**Print Command Signal:** Positive or negative pulse, 20 msec or greater in width, 6 to 20 volts.

**Hold Signal:** -7 v to +15 v and +15 v to -7 v (2 signals).

**Transfer Time:** 2 ms.

**Paper Required:** Standard 3” roll or folded paper.

**Line Spacing:** Single or double, adjustable.

**Power Requirement:** 115/230 v ± 10%, 50/60 cps, (4 prints/sec maximum at 50 cps).

**Dimensions:** Cabinet: 20½” wide, 12½” high, 18½” deep. Rack: 19” wide, 10½” high, 16½” deep behind panel.

**Weight:** Cabinet: Net 35 lbs. Shipping 70 lbs. (approx.)

Rack: Net 30 lbs. Shipping 65 lbs. (approx.)

**Price:** @ 562A/562AR, on request.

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@565A Digital Printer

Model 565A is a fast eleven-column Digital Printer designed specifically for use in custom systems. It is mechanically similar to the printing mechanisms in @ 560/561/562 Digital Printers.

Model 565A is useful as an output device in computer and data handling systems, as well as other systems involving electronic counters, mechanical counters with an electrical output, stepping switches, relays, beam switching tubes and other digital devices.

Because of the variety of performance characteristics encountered by designers of custom systems, the methods employed to drive Model 565A Digital Printer can vary considerably. For maximum compatibility with the input and control systems encountered, and for simplified field maintenance, all connections are made through connectors at the rear of the instrument.

### Specifications

**Number of Columns:** 11.

**Data Entry:** Parallel entry to all columns. One line required for each position of each print wheel to be operated.

**Maximum Print Rate:** 3 lines/sec.

**Standard Characters:** 0 through 9, minus sign (–), blank. Dimensions: approximately 0.085” wide, 0.100” high. Column spacing: ½”. Line spacing: 5/32” single space; 5/16” double space.

**Print Wheel Position:** Controlled by electromagnetically operated pawls. Wheel position sensed through brush and commutator associated with each print wheel. Maximum commutator current 1 ma. Note: Circuitry for sensing wheel position and operating pawl magnets not included in printer mechanism.

**Controls:** (1) Front panel POWER switch with pilot light.

(2) Front panel RECORD switch with pilot light. Has momentary position for manual print command.

**Power Requirements:** Motor: 115 v ±10%, 60 watts, 50/60 cps (4 prints/sec maximum at 50 cps). Clutch solenoid: 240 volts dc ± 10%, 75 ma (operates for approximately 15 msc to initiate printing cycle).

**Pawl Magnets:** 5.8 volts dc ± 10%, 15 ma (operate when needed during printing cycle).

**Dimensions:** Front panel: 9½” high, 8½” wide, 9½” deep behind panel.

**Weight:** Approximately 15 lbs.

**Accessories Furnished:** @ 565A-95A Mounting Tracks and Guides. @ 560A-95N Service Kit, contains machine oil, moly oil and type cleaner. 1 packet 1052-24 folded paper tape. 1 1056-6 inked ribbon.

**Accessories Available:** 125-125 36 pin plug, 1 required, $4.25. 125-125 50 pin plug, 3 required, $5.25 each. @ 560A-95N Service Kit, $3.50. 1056-6 inked ribbon, $3.50. @ 565A-131A folded paper tape, 24 packet carton, $20.00.

**Price:** @ 565A Digital Printer, $640.00 each in quantities of 1 to 9; $620.00 each in quantities of 10 to 24; $600.00 each for 25 or more. For 115 v 50 cps operation with 5 prints/sec capability specify H27-565A, $655.00 each in quantities of 1 to 9; $635.00 each in quantities of 9 to 24; $608.00 each for 25 or more. For 230 v 50 cps operation with 5 prints/sec capability specify H24-565A, $655.00 each in quantities of 1 to 9; $632.00 each in quantities of 9 to 24; $610.00 each for 25 or more.

*Others available on special order.

Data subject to change without notice.
The accuracy with which frequency and time intervals may be measured or generated is of vital importance in basic research and in the development, production and maintenance of modern systems and associated instrumentation.

In order to provide the performance required in satellite and missile operations, single sidereal and time-coded communication, precise navigation systems and similar applications, Hewlett-Packard places major emphasis on the development of high-performance frequency and time standard systems.

Accuracy in the Broad Sense

While accuracy may be the primary concern, the degree to which a high-accuracy system is useful is a direct function of system reliability. For this reason, increased accuracy and increased reliability are considered inseparable major design objectives at Hewlett-Packard.

The absolute accuracy which you can achieve and maintain with @ systems depends not only upon equipment performance, but also on (1) the accuracy of the reference used and (2) the techniques of comparison and adjustment employed.

By careful use of suitable comparison methods, coupled with adequate record-keeping and necessary adjustment, the user may establish and maintain high system accuracy based on the broadcast standards. Two proven comparison techniques available to the user are discussed below.

Necessary equipment characteristics provided by Hewlett-Packard systems are: (1) suitable oscillator stability, (2) high-accuracy comparison capability, (3) reliability and (4) operational simplicity.

Oscillator Stability

Improved long-term stability directly increases the permissible time between oscillator adjustments required to maintain a given absolute accuracy. If an oscillator exhibits long-term stability of \( \pm 5 \) parts in \( 10^6 \) per day, for example, adjustments at twenty-day intervals will permit the user to maintain accuracy of \( \pm 5 \) parts in \( 10^6 \); if long-term stability were \( \pm 5 \) parts in \( 10^9 \) per day, adjustments at two-day intervals would be required for the same accuracy.

Long-term stability of Hewlett-Packard quartz oscillators is conservatively rated at \( 5 \) parts in \( 10^6 \) per day and the user may usually expect performance which is substantially better than specification. Such performance results from (1) the use of carefully tested, high-quality crystals, (2) precise control of oven temperature, (3) circuitry which has proven, inherent stability, and (4) AGC action which maintains crystal dissipation level at less than \( \frac{1}{2} \) micro-watt. Careful attention to other details such as shock and vibration isolation, shielding, load isolation, and effects of supply voltage variation are also contributing factors.

The crystal operating level chosen provides the best compromise between long-term stability and short-term stability. The short-term stability specification for the @ 103AR, for example, is \( \pm 5 \) parts in \( 10^6 \), and this specification is based on the average of the frequency over one-second intervals. This specification includes effects of variations in ambient temperature from 0-50°C, variations in dc supply voltage from 22-30 v, variations in load impedance from a few ohms to several hundred ohms, and other variations in environmental conditions. As a result, the user can usually expect short-term stability on the order of one part in \( 10^6 \) (averaged over one second) when the oscillator is operating under normal laboratory conditions. (See Figure 1.)

Spectral Purity

For applications which require extreme spectral purity, @ 104AR is offered. This oscillator is similar to Model 103AR, but has an additional 5 megacycle output which can provide a spectrum only a few cycles wide when multiplied to the gigacycle region.

Comparison Methods

For High Accuracy

I. Frequency Standards

a. Time Comparison Method

Frequency standards may be calibrated and monitored by means of time comparisons with broadcast standard time signals as shown in Figure 2. Transmissions from WWV (WWVH, MSF, JJY or any other station transmitting precise time signals) are received and their "time ticks" are connected to the vertical input of the oscilloscope. The @ 115BR Frequency Divider and Clock derives "local ticks" from the output frequency of the 103AR Quartz Oscillator. The "local ticks" are used to trigger the oscilloscope.

At the beginning of a test, the "time ticks" and "local ticks" may be as much as \( \frac{1}{2} \) second apart. By successive adjustment of the 115BR or the 114BR, (see pages 122, 123) and oscilloscope sweep speed, a reference condition is established in which the time between the two ticks is very short and is accurately known. The amount by which the TIME REFERENCE control must be adjusted to re-establish
b. Frequency Comparison Using VLF Transmissions

Since vlf transmissions are virtually free of the propagation problems encountered with hf signals, an alternate method for calibration of frequency standards is based on frequency comparisons with the vlf standard stations such as NBA and WWV. By this method, comparison accuracy of one part in $10^9$ may usually be achieved in less than one hour. Tests conducted for longer periods will increase the comparison accuracy proportionally. equipment for vlf comparison is shown in Figure 3.

Output from the 113BR Clock is used to start the time interval counter and the next cycle of the vlf carrier is used as the "stop" signal. Trigger level and slope controls on the time interval counter permit selecting given and repeatable points on the start and stop signals. The resulting time-interval readings are printed by the 560A Digital Recorder and continuously plotted on a strip chart recorder using the 560A analog output. This analog record gives the relative time drift of the oscillator under test compared to the vlf carrier. From the time drift record, the user may determine frequency error and rate of frequency drift for his oscillator.

2. Time Standards

Maintenance of maximum time accuracy generally requires that oscillator frequency be maintained within close limits by some method such as those discussed above. In addition a suitable technique is required for synchronizing time signals from the system. The method most commonly employed for time synchronization of widely separated clocks is one-way transmission of time signals using hf propagation. Time signals carried by the standard broadcasts from WWV, WWVH and others are locked to the frequency of the transmissions and may be used to synchronize the time standard with national standards.

This method of synchronization requires precise knowledge of propagation time length between the standard broadcast transmitter and the local receiver. From longitude and latitude data, the great circle distance can be calculated and from this, groundwave propagation time is easily determined. The next step is to calculate propagation times for a given mode skywave signal. These calculations are simplified by published curves for assumed layer heights and propagation modes.

Once propagation time is known, the 113BR Clock is set to agree with the time information contained in the standard broadcast transmissions. Corrections, as required, can then be made to the Quar'll Oscillator and to the 113BR Clock itself to maintain the required time accuracy.

Today, information bandwidth characteristics have limited the use of vlf for time-of-day information and for time comparison measurements.

Reliability and Fail-Safe Operation

It is important to minimize downtime of a frequency or time standard but, far more important, the accuracy which may be attained in the system is directly dependent upon continuity of operation. Further, the system must be fail-safe to prevent the accumulation of insidious frequency or time errors. Hewlett-Packard frequency and time

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*b* For a complete discussion of vlf frequency comparison measurements with laboratory equipment, Application Note 50 is now available from Hewlett-Packard upon request.

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See NBS Technical Note No. 22, "Precise Time Synchronization of Widely Separated Clocks" by A. H. Morgan.
standards employ simplified, optimized designs which display a high order of inherent dependability. Premium components are used with substantial derating to provide large safety margins. Development has been considered complete only when all component values have been optimized and rigid environmental tests have been passed. Before release for production, pilot run quantities of each type of instrument must pass independent evaluations, generally including additional environmental testing to commercial as well as military specifications. Testing prior to shipment is a meticulous, unhurried procedure which continues until performance significantly better than specification has been clearly established.

Fail-safe operation results mainly from three Hewlett-Packard equipment characteristics: (1) The Standby Power Supply employs a standby battery to provide continued operation in event of line failure, (2) Dividers used in Quartz Oscillators and in the 113BR Frequency Dividers and Clocks will not respond to spurious signals, and (3) Output from the dividers will stop and remain stopped upon any interruption of driving signal or supply power.

Power Supply Considerations

Interruptions in primary power to any quartz oscillator can cause serious changes in output frequency. In addition, if the power interruption is of sufficient length, cooling causes strains in the crystal which result in an increased aging rate. The new aging cycle thus incurred may last for days or even weeks, since the strains can be relieved only with time at the proper operating temperature. Since the accuracy attained in time comparison measurements is directly dependent upon the length of time over which the measurements are made, power interruptions to comparison equipment, such as the Frequency Divider and Clock, are also undesirable.

Hewlett-Packard Standby Power Supplies operate over wide ranges of ac line voltage and frequency and supply regulated dc to operate the Quartz Oscillator and Frequency Divider and Clock. These supplies are designed to operate with standby batteries which assume the load immediately without switching or undesirable transients whenever ac line power fails. When line power is restored, the supplies immediately reassert the load and automatically recharge the standby batteries. Alarm systems include local indication of operating conditions and provisions for remote alarms.

Fail-Safe, Regenerative Dividers

To assure the user that output signals can neither gain or lose time with respect to the driving source, Frequency and Time Standard Systems utilize regenerative frequency dividers of a non-self-starting design with simple push button starters. Small gains or losses of time, which could be difficult to detect, would not only degrade accuracy of generated time signals but would also impair the accuracy of comparisons utilizing those signals.

Sharp tuning makes regenerative dividers virtually insensitive to noise bursts or other spurious signals which would cause pulse counters or phasotron dividers to "gain" in time. Since properly designed regenerative dividers have no output in the absence of an input signal, the presence of output from a regenerative divider of the non-self-starting type is a positive indication that the divider output has not "lost" time with respect to the driving signal.

Operational Simplicity

For convenience and speed in making time comparisons, both the 113BR Frequency Divider and Clock and the 114BR Time Comparator are calibrated directly in milliseconds and microseconds. Controls on all system components are simple and clearly identified. Front panel meters facilitate monitoring important voltages and currents in the system.

To simplify oscillator frequency adjustments, the fine frequency controls on quartz oscillators are calibrated directly in parts in 10^10 frequency change. The time indicated by the 113BR Clock may be reset without affecting the position of time signals generated by the system.

Use of the specially designed standby power supplies and associated standby batteries eliminates concern over operating problems such as line voltage variations and power interruptions.

Frequency and Time Standard systems are well suited for use in sea-going vessels, aircraft and trucks, as well as for general laboratory and field use. They are characterized by small size, moderate weight, low power requirements, extended standby operation and ability to withstand a wide range of environmental conditions.

Systems Concept

Since most users prefer to have one company assume overall responsibility for a frequency and time standard system, Hewlett-Packard has developed systems capability suited to the most exacting requirements. Maintains large, well equipped research, development and manufacturing facilities in order to meet stringent requirements in performance, quantity and delivery time. This program is supported by the Precision Components Division which provides quartz crystal research and production, and by the Quality Assurance Department which includes such services as components evaluation and environmental test.

The instruments described in the following pages constitute an integrated family of precision devices which may be combined with other Hewlett-Packard and Dyniec (a division of Hewlett-Packard) instruments to meet a wide variety of requirements.
103AR and 104AR Quartz Oscillators make possible improved accuracy in Primary Frequency and Time Standard systems because they provide increased stability, maximum reliability and are easy to adjust.

Long-term stability of 103AR and 104AR is conservatively rated at 5 parts in 10¹⁰/day. Short-term stability, specified as 5 parts in 10¹⁰* includes effects of variations in supply voltage, load resistance, ambient temperature and other environmental conditions. Models 103AR and 104AR typically display short-term stability of one part in 10¹⁰ when operated in a reasonably constant environment.

Model 103AR provides two sinusoidal output signals, 1 MC and 100 KC, from a low source impedance at a power level well suited for distribution over 50-ohm systems. A separate 100 KC output is available for driving 113BR Frequency Divider and Clock for time comparison measurements and for generating time signals.

Proportionally-controlled double ovens house the crystal and all critical frequency-determining elements and maintain their temperature constant within a few hundredths of a degree. Crystal dissipation level is kept constant at less than 1/4 microwatt by AGC action. Frequency changes due to variations in supply voltage and load impedance are virtually eliminated as a result of internal voltage regulation and excellent buffering.

Completely transistorized, 103AR and 104AR Quartz Oscillators are compact and rugged, withstand severe environmental conditions and operate for extended periods from standby batteries of moderate size.

Model 104AR has the same high stability as 103AR and in addition provides a 5 MC output of extreme spectral purity. Spectra only a few cycles wide in the gigacycle region may be obtained by multiplication of this 5 megacycle output.

*Averaged over 1 second intervals.
113BR FREQUENCY DIVIDER AND CLOCK

Increased Accuracy From Frequency/Time Standards

Specifications

Input Frequency: 100 KC for solar time, input bandwidth ± 300 cps. 100.3 KC for sidereal time, on special order.

Accuracy: 1) Accuracy of output pulse and sine-wave signals determined by accuracy of input frequency. 2) Time reference dial linearity ± 10 psec.

Input Voltage: 0.5 to 5 volts rms.

Input Impedance: 300 ohms nominal.

Tick Pulse Output, positive: 1 pps with amplitude of 10 volts or more into minimum recommended load impedance of 4,700 ohms and 200 pf. Rise time, 2 psec maximum; duration 20 psec minimum; jitter 1 psec maximum. Rear BNC connector.

Tick Pulse Output, negative: 1 pps with amplitude of 10 volts or more into minimum recommended load impedance of 1 Megohm and 100 pf. Rise time, 2 psec maximum; duration 20 psec minimum; jitter 1 psec maximum. Front BNC connector.

Auxiliary Pulse Output, 1 pps: At least 2 volts positive into minimum recommended load of 50 ohms and 1,000 pf. Rise time, 1 psec maximum; duration 200 psec; jitter, 1 psec maximum. Rear BNC connector.

Auxiliary Pulse Output, 1,000 pps: At least 4 volts positive into minimum recommended load of 1,000 ohms and 1,000 pf. Rise time, 2 psec maximum; duration 20 psec minimum; jitter, 1 psec maximum. Rear BNC connector.

Auxiliary Output: 100, 10 and 1 KC sinusoidal, 0.25 volts rms, min. Source Impedance 1,200 ohms nominal. Front panel BNC connectors.

Time Reference: Continuously adjustable. Directly calibrated in 10 microsecond increments on dial and in milliseconds on mechanical counter.

Frequency Divider: Manually starting, regenerative type, fail-safe.

Effect of Transients: Will not gain or lose time because of: 1) ± 500 volt step function on 100 KC input. 2) 0 to ± 50 volt pulses, 0 to 300 pps, 1 to 10 psec duration on 100 KC input. 3) ± 4 volt step in 26 v dc input.

Clock Mechanism: 24-hour dial; minute hand adjustable in 1 minute steps; second hand continuously adjustable. Manual start. Front panel adjustment of clock hands does not affect tick output. (12-hour dial on special order.)

Monitor Meter: Ruggedized meter and selector switch on front panel for checking supply voltage, divider operation (100 KC, 10 KC, 1 KC) and total clock current.

Increased accuracy from frequency and time standard systems is possible by use of the new 113BR Frequency Divider and Clock. Precise comparisons between local standards and hf or vlf broadcasts based on national standards of time and frequency may be made simply and conveniently. Model 113BR also generates precise, adjustable time signals with accuracy determined by the driving oscillator.

Use of the 113BR simplifies recording drift rates, determining time or frequency differences in widely separated systems and permits adjustment of systems for maximum accuracy. By averaging out the effect of hf propagation path errors, use of the 113BR can reduce comparison error to a few parts in 10^10 within several days. Model 113BR also simplifies vlf comparisons, especially where ICW transmissions are involved.

The optical gating system (no contacts, no wear; cannot add jitter) and a directly-calibrated, precision phase shifter make possible the unique accuracy of the 113BR and provide time comparison capability of ± 10 microseconds, where signal conditions permit.

Fail-safe dividers and clock motor reduce the possibility of error, since (1) neither dividers nor motor can respond to spurious signals, (2) interruptions in driving signal or supply power stop all outputs.

Model 113BR is fully transistorized and meets performance requirements of MIL-E-16400.

Power Required: 22-30 v dc, approximately 2 watts. Recommended supply 724BR, 725AR.

Dimensions: 19" wide, 7" high, 19½" deep behind panel.

Weight: Net 10 lbs. Shipping approximately 21 lbs.

Accessories Furnished: @ 113A-16E Cable, 6 ft. long, connects 113BR to 724BR or 725AR Standby Power Supply.

Price: @ 113BR, $2,750.00.

Data subject to change without notice.
The new @114BR Time Comparator provides additional speed and flexibility in making time comparisons between stable oscillators and standard time signal transmissions such as those from WWV. Model 114BR is an auxiliary unit used in conjunction with the @113BR Frequency Divider and Clock and an oscilloscope in primary frequency or time standard systems. If time signals generated by the @113BR Frequency Divider and Clock are to be used with computers or for system timing signals or similar purposes, the 114BR provides a method of making time comparisons without disturbing outputs from the 113BR.

The @114BR Time Comparator consists of an adjustable preset digital delay generator, a sweep generator and a marker generator. An oscilloscope such as @120AR is used as an indicator. All critical controls on the 114BR are detented selector switches, and time markers are automatically adjusted to sweep speed. As a result, time comparison by means of the 114BR is simple and fast. Adjustment of the 114BR will not affect operation of the frequency or time standard in any way.

The time difference between the received one-per-second standard time signal and the tick output from the @113BR can be resolved to ±10 microseconds, where signal conditions permit. The data thus accumulated over a period of days, weeks or months may be used to determine the long-term drift of the stable frequency source or for time checks in time standard systems.

Specifications

- **Sweep Delay Range:** 0 to 999 msec in 1 msec steps with direct reading, in-line front panel switches.
- **Sweep Output:** 1,000, 100, 10, or 1 msec duration as selected by front panel switch. Sweep may be delayed from 0 to 999 msec in 1 msec steps with direct reading front panel switches. Amplitude 1 volt peak-to-peak, dc coupled. Front panel vernier horizontal position control provides fine adjustment of dc level. Recommended display unit, @120A/AR Oscilloscope.
- **WWV Tick Output:** WWV Tick, gated at 1-second intervals to provide stable baseline for intensity markers between ticks, appears at VERTICAL AXIS BNC connector on front panel.
- **Z-Axis Output:**
  - **Intensity Markers:** Marker intervals automatically adjusted to 1/10 of the sweep duration; length automatically adjusted with sweep time. Markers may be switched on or off by front panel switch.
  - **Unblanking Voltage:** 10 KC unblanking square wave synchronized with standard frequency for interpolation to 10 psec or better. Amplitude 40 volts peak-to-peak.
  - **Input Requirements:** 1 KC positive pulses from @113BR; 1 pps positive pulses from @113BR: WWV Tick, 0.1 to 10 volts peak-to-peak to BNC connector on rear.
  - **Self Check:** Each digit of delay setting may be checked by means of front panel pushbutton.
- **Power Requirements:** 115/230 ± 10% volts ac, 50-1,000 cps; approximately 7 watts.
- **Dimensions:** 3½” high, 19” wide, 13½” deep overall, 11½” deep behind panel, including cable allowance.
- **Weight:** Net, approximately 11 lbs.
- **Accessories Furnished:** @114BR-16A power cable, 6 feet long, with NEMA line plug; @114BR-16B Z-axis cable, 3 feet long; @114BR-16C Horizontal axis cable, 6½” long; @114BR-16D Vertical axis output cable, 10” long.
- **Price:** @114BR, $1,200.00 (rack mount).

Data subject to change without notice.
Standby Power Supplies, Models 724BR and 725AR, improve performance and reliability of frequency and time standard systems by assuring continued operation in the event of ac line power failure. Also, with these standby supplies you can use a standard at various locations, since the system can be kept in operation for extended periods during transport.

Models 724BR and 725AR are completely automatic, solid-state supplies specially designed to power the 113BR Frequency Divider and Clock and 103AR or 104AR Quartz Oscillators. These supplies are designed to operate with standby batteries. The standby battery is kept charged and instantly assumes the load, without switching, in case of ac failure. When line power is restored the supply reasserts the load and automatically recharges the battery.

After a week of operation 724BR provides a minimum of 48 hours standby operation at an average temperature of 25°C for an 113BR Frequency Divider and Clock. Under similar conditions, Model 725AR provides at least six-hour standby operation. A switch at the rear of the 724BR increases standby period at least 50%.

Output is voltage-regulated and current-limited, eliminating the need for output fuses. Operating aids include alarm lamps, contacts for remote alarms and connectors for additional standby batteries.

Both supplies will withstand severe environmental conditions. Model 724BR is equipped with heavy-duty chassis tracks. Models can be supplied to meet performance requirements of MIL-E-16400, Class 4.

*724AR, required for operation with 113AR Frequency Divider and Clock, available on special order.


**HP 100E FREQUENCY STANDARD**

5/10⁸ Stability, Multiple Outputs
For Test, Production or Lab Use

Good stability and the versatility of a wide variety of outputs are offered by the HP 100E Frequency Standard.

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

A particularly useful feature of 100E is a timing comb providing output pips at 100, 1,000, and 10,000 µsec intervals to simplify sweep and time interval measurements.

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

### Specifications

**Stability:** Short term ± 5 parts in 10⁸. Long term ± 5 parts in 10⁸ 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. 500 ohms, 10 cps, 100 cps, 1 KC and 10 KC.

**Distortion:** 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. Horizontal sensitivity adjustable approx. 2 v rms/inch. Horizontal bandwidth approx. 20 cps to 150 KC.

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

**Power:** 115/230 v ± 10%, 50/1,000 cps, 140 watts.


**Weight:** Net: Approximately 10 lbs. Shipping: 53 lbs.

**Price:** $100E, $925.00 (cabinet); $100ER, $900.00 (rack mount).

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**HP 101A 1 MC OSCILLATOR**

5/10⁸ Stability For Electronic Counter Time Base

Designed specifically to be the time base for HP 5275A Electronic Time Interval Counters, the high precision capabilities and low cost of HP 101A make it useful for many other applications as well. This 1 MC oscillator can be used directly to obtain increased accuracy from counters such as HP 523C/D. An optional 100 KC output is available for use with counters such as HP 524B, FR-38U, AN-USM-26, and for other suitable applications.

Model 101A provides an output of at least 1 volt into a 50 ohm load, sufficient to drive a number of electronic counters. Model 101A has a long-term stability of 5 parts in 10⁸ per week and is a transistorized version of the proven oscillator used in HP 524C/D Electronic Counters and HP 100E Frequency Standard.*


### Specifications

**Stability:** Short term, ± 5 parts in 10⁸. Long term, ± 5 parts in 10⁸ per week.

**Output Frequencies:** Sinusoidal, 1 MC (100 KC optional), BNC connectors.

**Output Voltages:** 1 v rms minimum into 50 ohm load.

**Source Impedance:** Approx. 15 ohms.

**Distortion:** Less than 4% into rated load.

**Oven Temperature Indicator:** Front panel dial thermometer.

**Frequency Adjustment:** Front panel screwdriver adjustment with range of approximately 1 part per million for calibration from primary standards.

**Power:** 115/230 v ± 10%, 50/1,000 cps, approx. 9 watts average.

**Dimensions:** 5 1/4" high, 16 3/4" wide, 11 1/2" deep behind panel.

**Weight:** Net: Approximately 10 lbs. Shipping: 53 lbs.

**Price:** $101A, $500.00.

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 40,000 MC. Each generator incorporates every basic requirement listed above and is designed so that both frequency and power output are direct reading. This assures utmost convenience and accuracy for all kinds of measurements, including receiver sensitivity, selectivity or rejection, signal noise ratio, gain-bandwidth characteristics, conversion gain, antenna gain, transmission line characteristics; or for driving bridges, slotted lines, filter networks, etc.

Oscillator Types

Signal generators can be divided into three different groups according to their oscillator circuit design. Signal generators in Group I have master oscillator-power amplifier circuits, those in Group II have reflex klystrons in external cavities, and the signal generators in Group III utilize broadband crystal harmonic generators with low conversion loss to provide rf power at twice the driving frequency. Table 1 shows the important characteristics of these units. Figures 1, 2 and 3 show the basic circuit diagram of each group. Tubes for the oscillator section of signal generators are carefully selected for optimum performance over the range of each generator.

Group I signal generators (except 612A) are capacitively tuned, and Group II signal generators (including 612A) are tuned by adjusting a shorting element that tunes the cavity resonator associated with the oscillator tube. Group III generators depend on the driving generator for tuning and frequency accuracy.

A number of special-purpose signal generators using techniques similar to those of instruments are manufactured by Dynec, a division of Hewlett-Packard. See page 209 for specifications.

Modulator Section

Hewlett-Packard generators, in addition to CW emission, also provide amplitude and frequency modulated output. The type of amplitude modulation (pulse, square-wave or sine wave) varies with each signal generator, and is described in detail in Table 1.

Group II signal generators include internal pulse circuitry which is used for pulse modulation. Considerable care has been taken to achieve a modulating pulse that has good waveform and does not undergo deterioration in

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[Table I. Characteristics of Signal Generators.

<table>
<thead>
<tr>
<th>Group</th>
<th>Generator</th>
<th>Frequency Range (MC)</th>
<th>Frequency Accuracy</th>
<th>Calib. Output Range</th>
<th>Output Accuracy</th>
<th>Max. SWR of Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>604A</td>
<td>0.05 - 65</td>
<td>±1%</td>
<td>0.1 μV to 3 V</td>
<td>±1 db</td>
<td>1.2</td>
</tr>
<tr>
<td>I</td>
<td>608C</td>
<td>10 - 40000</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.2</td>
</tr>
<tr>
<td>I</td>
<td>608D</td>
<td>10 - 40000</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.2</td>
</tr>
<tr>
<td>I</td>
<td>612A</td>
<td>400 - 1,320</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.2</td>
</tr>
<tr>
<td>I</td>
<td>614A</td>
<td>800 - 2,100</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.2</td>
</tr>
<tr>
<td>II</td>
<td>616B</td>
<td>1,800 - 4,200</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>II</td>
<td>618B</td>
<td>2,800 - 7,600</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>II</td>
<td>620A</td>
<td>7,000 - 11,800</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>II</td>
<td>624A</td>
<td>10,000 - 15,500</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>II</td>
<td>628A</td>
<td>15,000 - 21,000</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>II</td>
<td>632A</td>
<td>18,000 - 26,500</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>II</td>
<td>638A</td>
<td>26,500 - 40,000</td>
<td>±1%</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>1.8</td>
</tr>
<tr>
<td>III</td>
<td>938A</td>
<td>18,000 - 26,500</td>
<td>That of driving source</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>Depends on Driving Source</td>
</tr>
<tr>
<td>III</td>
<td>960A</td>
<td>26,500 - 40,000</td>
<td>That of driving source</td>
<td>±13 to -127 dbm</td>
<td>±1 db</td>
<td>Depends on Driving Source</td>
</tr>
</tbody>
</table>
the modulating system. Spurious FM, AM and harmonic content have been kept to a minimum by incorporating well regulated power supplies, good circuit design and excellent construction techniques.

Frequency modulation with variable amplitude and phase is generated internally in signal generators of Group II. The particular type of FM varies with the instrument and may be generated by power line voltage, by a sawtooth generator (40-4000 cps) or by a 1000 cps modulator. In addition, signal generators in Group II (except 614A and 616B) can be frequency modulated by signals applied to a front panel jack. These FM features are achieved by taking advantage of the voltage-tuning characteristics of reflex klystrons.

External Modulation Techniques

There are many cases where it is desirable to modulate a signal generator with external signals. The type of modulation used must be applied to the generator in such a way as not to detract from the stability or accuracy of generation. Further, incidental or spurious modulation should not be introduced. Certain precautions, different for different signal generators, should be observed when applying external modulation.

Almost any type of amplitude modulation may be applied to 606A, 608C/D and 612A (which employ master oscillator-power amplifier circuits) as long as the modulation bandwidth of the particular instrument is not exceeded.

All modulation in the 606A and 608C/D is accomplished in the amplifier section, and either sine wave, pulse or square wave modulating voltage can be employed. Because the amplifier section of the 608C/D employs a grounded grid circuit, the power is not completely cut off between pulses. The reduction in power output between the time the pulse is on and off is better than 20 db since interelectrode capacity provides some coupling even though the tube is cut off.

In the Model 612A, provision is made for applying pulse and square wave modulation directly to either the oscillator or the amplifier section. When modulation is applied to the oscillator section the signal is completely cut off between pulses. It is advisable to apply only square waves or pulses for amplitude modulation to the oscillator section. Other types of modulation should be applied to the amplifier section, the bandwidth limitation of which is 5 MC. The types of modulation employed (with due consideration to above restrictions) will not seriously affect the stability or spurious signal content.

There is no provision for FM modulation in Models 606A, 608C/D and 612A signal generators.

In Group II generators utilizing klystron oscillators, it is desirable to use pulse or square wave modulation of sufficient magnitude to completely cut off the generator between pulses. This is necessary to eliminate spurious signals and harmonics. If a square wave generator is not available, a high voltage sine wave may be used. The use of this sine wave will tend to overload the modulator and the sine wave will become heavily clipped — thus applying an approximation of a square wave to the oscillator. Since the grids of the modulator tubes are ac coupled, high level signals drawing grid current will develop a clamp voltage on the grid of the tube. Damage to tubes is thus prevented. The amplitude of the modulating voltages should be approximately 50 volts.

Models 618B, 620A, 626A, and 628A, in addition to external amplitude modulation, have provision for external frequency modulation. Modulation capability depends on the reflex klystrons in each individual generator, and magnitude of the applied modulating voltage should be limited so that the reflector will not be swept into undesired oscillating modes.

Output Section

The output sections of @ generators are designed to achieve high monitor accuracy, high attenuator accuracy and to minimize mismatch between generator and load.

In Models 606A, 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 @ generators, accuracy is maintained through use of a thermistor bridge. In these instruments, drift compensating networks are employed to reduce zero drift and sensitivity variations with ambient temperature changes.

Attenuators in the output systems are the waveguide-beyond-cutoff type, (except @ 606A, 626A and 628A), and
operate on magnetic coupling for the lowest order mode. This type of attenuator is characterized by linear relation between the attenuation (in db) and displacement (in length units) of the coupling elements. The linear relationship holds except for approximately the first 7 db of attenuation. As long as the attenuator waveguides are well below cutoff, the attenuation will be independent of frequency and will be dependent only upon tube size and type of coupling employed. Attenuator waveguides are accurately sized, and this, in conjunction with magnetic coupling assures that once the relation between attenuator movement and attenuation in db becomes linear, it will stay linear down to the lowest value desired.

Thus accurate measurements are easily obtained whether working into a standard 50-ohm load or into a load adjusted to match exactly with generator characteristics.

Sources of Error

Harmonic Content: In 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 360 or 362A low pass filters (page 180) between the signal generators and equipment following the generator.

Power Loss Due to Mismatch: Another source of error in determining power output is mismatch between a signal generator output impedance and the instrument following the generator. Hewlett-Packard generators have an output impedance of 50 ohms which matches the nominal impedance of most cables and connectors. The deviation of output impedance from 50 ohms is designated Standing Wave Ratio (SWR) and it is less than 2.5 for all signal generators. With a knowledge of the value of SWR of both generator and load, the limits of the power loss can be calculated. It is necessary to know the phase of the reflection coefficient to determine the exact power loss.

A typical setup for making measurements on signal generators is shown in Figure 4. To determine the amount of error due to mismatch, the values of SWR of the signal generator and the load should be measured. Maximum and minimum power loss is then obtained by substituting the values of SWR in the equation below:

\[ P_{\text{max}} = 20 \log \left( \frac{\sqrt{\sigma_x \sigma_L} + \frac{1}{\sqrt{\sigma_x \sigma_L}}}{2} \right) - 6 \text{ db} \]

And

\[ P_{\text{min}} = 20 \log \left( \frac{\sqrt{\sigma_x \sigma_L} - \frac{1}{\sqrt{\sigma_x \sigma_L}}}{2} \right) - 6 \text{ db} \]

Where \( \sigma_x \) = SWR of signal generator
Where \( \sigma_L \) = SWR of device under test

Note: These losses are with respect to the maximum available power output.

(Calibration of the signal generator.)

\[ \text{POWER LOSS CURVES} \]

(Solid lines indicate \( P_{\text{max}} \); broken lines \( P_{\text{min}} \). (Courtesy Sperry Gyroscope Co.)

Figure 4. Typical setup for making measurement on Signal Generators.

The Model 606A output attenuator is a series of 4 resistive \( \pi \) networks switched with cam-controlled micro-switches for a total of 120 db range. It is similar to the Model 355A/B vhf attenuators on page 64.

Models 626A and 628A employ rotary waveguide attenuators which have an extremely flat frequency response. These attenuators are similar to 382A Waveguide Attenuators (page 180).

Signal generator output impedance is held close to 50 ohms by utilizing pads in the attenuator and output connectors. This type of output system has certain advantages which contribute greatly to the accuracy and usefulness of a signal generator. The monitoring circuit sets a reference calibration level and also serves as a continuous monitor on the oscillator level. Changes of oscillator level due to loading, etc., are immediately apparent. At any level the maximum available power from the generator can be determined quickly and accurately from monitor readings and attenuator settings. It is not necessary to return the output to a high level for monitoring.

\$\$ generators are calibrated in terms of their maximum available power.
These formulas can be drawn up in chart form as shown in Figure 5. As an example, let it be assumed that on a measurement the attenuator setting is —30 dbm, the SWR of the generator is 1, and the SWR of the load is 3. Then using the above formulas or chart, it can be shown that $\eta_{max}$ equals 1.28 db, and $\eta_{min}$ equals 1.28 db. Here it should be noted that because the generator is matched, the ambiguity of error is eliminated and power loss can be calculated exactly.

Assuming the same data as before with the exception that the generator has an SWR of 1.5, it can be shown that $\eta_{max}$ equals 2.28 db, and $\eta_{min}$ equals 0.52 db. In this last example the power actually being delivered to the load lies somewhere between —30.52 dbm and —32.28 dbm. Without further information concerning the relative phase of the reflection coefficients, it is impossible to obtain this value more accurately. With some form of tuner, the load may be matched to the generator. Then the attenuator reads accurately as maximum power is transmitted to the load. For most measurements, it will be found that an average value of the power loss will adequately meet the accuracy requirements.

**Loss in Cables:** Another source of error in power output determination is loss in the cables connecting the generator to the load. This loss may become significant, particularly at higher frequencies. To minimize this error, generators which may be most affected by cable loss, (614A, 616B, 618B and 620A) are calibrated in terms of power at the end of the 6 ft. cable which is furnished with the generator. If cables of different lengths are used, consideration should be given to the differences in attenuation presented by such cables. Nominal attenuation for several different types of cables is shown in Figure 6.

**606A HF Signal Generator**

The Model 606A High Frequency Signal Generator (pages 132, 133) has been specially designed for new convenience and accuracy in hf measurements. It features feedback circuitry around the power amplifier section of the generator which provides constant output levels on all bands and at any frequency within a band. This eliminates the tedious, error-producing retuning and resetting of output power levels normally found in generators of this type. Furthermore the feedback circuitry is wide band so that a constant modulation level is obtained with negligible envelope distortion, even up to 100% modulation. Output is high and is continuously adjustable from 0.1 microvolts to 3 volts into 50 ohms.

Covering the high frequency spectrum (which includes the 30 and 60 megacycle radar IF bands) the new 606A is exceptionally useful in driving bridges, antennas and filters, and measuring gain, selectivity, and image rejection of receivers and hf circuit elements.

Output is constant within $\pm$ 1 db over the full frequency range and is adjustable from $+\ 20$ dbm (3 volts rms) to $-110$ dbm (0.1 microvolts rms). No level adjustments are required during operation; the instrument has a minimum of controls and high accuracy results are assured because of the constant internal impedance.

The 606A may be modulated by sine waves and complex wave forms from dc to a maximum of 20 KC with the percentage modulation indicated on an internal meter. An internal crystal calibrator circuit provides check points at 100 KC and 1 megacycle intervals with errors of less than 0.01% to insure maximum accuracy of frequency setting.

**New 938/940A Frequency Doubler Sets**

The new 938A/940A Frequency Doubler Sets (pages 146, 147) extend the Hewlett-Packard signal generator range up to 40 GC (KMC). These versatile frequency doubler sets consist of broadband crystal harmonic generators with low conversion loss to provide up to 1 milliwatt of power throughout the frequency range from 18 to 40 GC.

In each frequency doubler set, a broadband crystal harmonic generator is suitably mounted in a waveguide flange and is provided with an input matching section so that input drive power may be applied directly to the crystal element. Signal generators in the 9 to 20 GC range supply power to this input flange and thence to the crystal element which generates harmonics with very low conversion loss. The desired second harmonic signal is separated from higher harmonics by use of a low pass filter which follows the harmonic generation section. This low pass filter is specifically designed for broad stop band characteristics and is similar to the Models K/R362A (page 186).

To provide accurate attenuation capabilities and true signal generator action, a 100 db dual rotary vane attenuator follows the low pass filter. This attenuator allows the desired rf power to be reduced 100 db and results in convenient power setting for many measurements.

![Figure 6. Attenuation vs. frequency curves for several cables.](image-url)
A power monitor section consists of a meter calibrated in dbm which responds to the harmonic generation crystal current. This meter provides for monitoring the rf output power level within ± 1.5 db to ± 3 db, depending on the frequency range involved. The power monitor is set to the desired reference by using the level attenuators in the driving source.

Model 938A/940A Frequency Doubler Sets are specially designed to be driven with 626 or 628A Signal Generators and, since their conversion loss is between 17 and 18 db, output power typically runs between 0.5 milliwatts and 1 milliwatt when these driving signal generators are run at full output. Furthermore, since the doubler sets are broadband devices they will convert swept frequency signals as well as CW to higher frequencies. Thus Models 686C and 687C BWO Sweep Oscillators may also be used as the driving source. This capability provides for extremely useful swept frequencies in the 18 to 40 GC frequency range.

Modulation characteristics of the driving source are preserved and the doubler set output may be CW, pulse modulated, square wave modulated or frequency modulated.

Swept frequency output, of course, gives the capability of making reflectometer measurements in K and R bands hitherto not possible because of a lack of swept sources in the 18 to 40 GC range.

**Sweep Oscillators**

In addition to precision signal generators, offers six sweep oscillators covering the frequencies in the range 1.0 to 18.0 GC. These oscillators have voltage-tuned backward wave tubes which generate CW and swept frequencies with a wide variety of modulation capabilities. Most provide high output levels of at least 10 milliwatts (50 milliwatts for the 682C, 5 mw for the 687C) into a matched load. The rf output frequency sweeps linearly with time and both the desired frequency sweep, Δf, as well as the rate of change of frequency are selectable individually in direct reading switch positions on the front panel. The rf output frequency may be swept slowly

Swept frequency techniques are usable for a wide variety of waveguide instrument and component testing. The @ pioneered reflectometer system (pages 172, 173), depends on swept frequency sources for its fast, wide band presentation of SWR measurements. These swept frequency test techniques are used extensively in the Hewlett-Packard waveguide testing department for both speedy and comprehensive tests on all microwave components. X-Y recorder plots of SWR and of attenuation versus frequency are just two of the typical measurements made. Reflectometer techniques assure that no hidden spurious responses will slip through unnoticed on a microwave component. Band insertion loss tests on flap attenuators, for instance, assure that the attenuation versus frequency curve does not go out of specification.

Sweep frequency generators are used extensively in the microwave development laboratories for broadband, "quick look" information on the new components under development. They eliminate many of the tedious point-by-point measurements previously required in a waveguide component development program.

**Level Output From Sweep Oscillators**

A new feature of the "C" series of sweep oscillators, which contributes to their general usefulness, is a simple open loop control system which maintains the rf output nearly constant. This practical system varies the anode voltage of the backward wave tube in accordance with the changing helix voltage so that the typical rf output variations of the backward wave oscillator are removed. Only the minor variations, which are usually less than ± 1.5 db are left. The curves in Figure 7 show the effectiveness of this inexpensive control system in a typical @ 682C.

Models 686C and 687C are additionally useful now with the introduction of the 938/940A frequency doubler sets, since their output power is sufficient to provide up to 1/2 milliwatt output from the frequency doubler sets in the 18 to 36 GC region. For maximum power output to drive the doubler sets at best efficiency, a front panel switch on the 686C and 687C permits the open loop leveler to be turned off. A cathode current control further provides for reducing cathode current of the backward wave oscillator tube when the full output is not required.

The new backward wave oscillators feature a direct connection to the backward wave tube grid which can provide extremely fast rf rise and decay times for many fast pulse requirements. Typical rise times on the order of 50 nanoseconds and decay times on the order of 100 nanoseconds may be obtained by the use of this external modulation capability. Using this external modulation allows extremely narrow pulses to be generated.

![Figure 7. Typical output characteristics of @ 682C.](image-url)
Advantages:
Wide range. Includes 30 and 60 MC IF bands
Constant output level
Constant modulation level
Wide modulation capabilities
3 volt output into 50 ohms
Crystal calibrator insures exact frequencies
Low envelope distortion

Uses:
Measuring receiver and IF circuit gain, selectivity and image rejection
Driving bridges, antennas, filters
Measuring harmonic distortion of AM receivers

Here in the HP 606A is the most convenient and versatile signal generator ever manufactured. Its wide frequency and output range and excellent modulation characteristics fit the HP 606A for many measurements.¹

Constant Output—Modulation
A feedback circuit maintains both output level and percent modulation essentially constant over the entire frequency range. Thus, it is usually unnecessary to readjust either the output level or modulation controls when conducting measurements at various frequencies. Even the output level can be varied without seriously affecting percent modulation. Another advantage provided by the feedback circuit is the reduction of envelope distortion during modulation.

Low Distortion
Because envelope distortion is low, overall distortion measurements may be made on high-fidelity AM receivers by applying the HP 606A output to the receiver's antenna terminals (see Figure I).

Broad Modulation Bandwidth
HP 606A may be modulated with signals from dc to 20 KC, by square waves and other complex signals. Square wave

and pulse modulation of the carrier permit examination of the overall transient and pulse response of receivers. Such modulation characteristics permit tone-burst modulation and remote programming as well as the more conventional applications.

**Specifications**

**Frequency Range:** 50 KC to 65 MC in six bands:
- 50 - 170 KC
- 165 - 560 KC
- 530 - 1800 KC

**Frequency Accuracy:** Within ± 1%.

**Frequency Calibrator:** Crystal oscillator provides check points at 100 KC (useful to 6 MC), and 1 MC intervals (useful to 65 MC) accurate within 0.01% from 0° to 50° C.

**RF Output Level:** Continuously adjustable 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 1.1 on 0.3 volt range; on 1 v and 3 v ranges, less than 1.1 to 20 MC and less than 1.2 to 65 MC. BNC output connector mates with UG-88A/B/C/D.

**Spurious Harmonic Output:** Less than 3%.

**Leakage:** Negligible; permits receiver sensitivity measurements down to at least 0.1 microvolt.

**Amplitude Modulation:** Continuously adjustable from 0 to 100%. Indicated by a panel meter. Modulation level is constant within ± 0.5 db regardless of carrier frequency and output level changes.

**Internal Modulation:** 0 to 100% sinusoidal modulation at 400 cps ± 5% or 1,000 cps ± 5%. Internal modulation voltage appears at modulation jack.

**Modulation Bandwidth:** DC to 20 KC maximum, depends on carrier frequency, f, and percent modulation as shown in the following table:

<table>
<thead>
<tr>
<th>Max. Mod.</th>
<th>30% Mod.</th>
<th>70% Mod.</th>
<th>Squarewave Mod.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>0.06 f,</td>
<td>0.09 f,</td>
<td>0.03 f, (3 KC max)</td>
</tr>
</tbody>
</table>

**External Modulation:** 0 to 100% sinusoidal modulation dc to 20 KC. 4.5 volts peak produces 100% modulation at modulating frequencies from dc to 20 KC. Input impedance is 600 ohms. May also be modulated by square waves and other complex signals.

**Envelope Distortion:** At output levels of 1 v or less, less than 1% at 30% modulation, less than 3% from 0 to 70% modulation using internal 400/1,000 cps source.

**Modulation Meter Accuracy:** Within ± 5%, 0 to 90%.

**Incidental FM:** At 1 v or less output and 30% amplitude modulation: 0.00257 or 100 cps, whichever is greater.

**Spurious FM:** Less than 0.0001% or ± 20 cps, whichever is greater.

**Spurious AM:** Hum and noise sidebands are 70 db below carrier down to thermal level of 50-ohm output system.

**Frequency Drift:** Less than 0.005% or 5 cps, whichever is greater, for a 10-minute period after warmup or restabilization at frequency of use.

**Power:** 115/230 v ± 10%, 50 to 1,000 cps, 135 watts.

**Dimensions:** Cabinet Mount: 20 1/2" wide, 12 1/2" high, 14 1/4" deep. Rack Mount: 19" wide, 10 1/4" high, 13 3/4" deep behind panel.

**Weight:** Net 46 lbs. Shipping 57 lbs. (cabinet mount).
Net 43 lbs. Shipping 58 lbs. (rack mount).

**Accessories Available:** 606A-34A Output Termination with 50 ohms termination, 5 ohms termination (10:1 voltage division), and IRE standard dummy antenna (10:1 voltage division). $70.00.

**Price:** 606A, $1,350.00 (cabinet); 606AR, $1,335.00 (rack mount).

(Data subject to change without notice.)
608C/D VHF SIGNAL GENERATORS

Finest Tools Available for Measurements 10 to 480 MC

Advantages:

- Wide range, direct calibration
- Convenient operation
- Incidental FM less than 1 KC
- Drift less than 0.005%
- High power output
- Microsecond pulsing
- Broad modulation capabilities

Hewlett-Packard 608C/D are designed as broadly applicable vhf signal generators. They offer the highest stability attained in production equipment of their type. There is almost a complete absence of incidental FM (less than 1 KC for the 608D) and frequency drift is held low despite line voltage variations. This performance is possible because of the master oscillator output amplifier construction and close filament regulation of the tubes.

Premium Quality 608D

Output of the 608D is calibrated from 0.1 μv to 0.5 v throughout the frequency range of 10 to 420 MC. A built-in crystal calibrator provides accurate frequency check points in 1 and 5 MC steps throughout range. Modulation capabilities are extremely broad allowing pulse and transient testing of vhf receivers. At the same time, envelope distortion, incidental FM and drift are kept low so that measurements of high-slope narrow band circuits are accurate and reliable. Low incidental FM is the result of using a buffer amplifier between the master-oscillator and power amplifier. Pulses as short as 1 μsec are available at rf output frequencies above 100 MC. Percentage modulation is read directly on the front panel meter.

Uses:

- Testing and aligning vhf communications receivers
- Measuring gain, sensitivity, selectivity, image rejection of receivers, IF amplifiers, broadband amplifiers, and other vhf equipment
- Driving bridges, slotted lines, antennas, filter networks, etc.

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An important feature of the 608 series is the mechanical design and construction employed throughout. Aluminum castings and cabinets reduce weight at no sacrifice in strength or ruggedness. Circuitry is clean and accessible. Dial, capacitor, and turret drives are all precision built and ball-bearing equipped. Variable capacitors are specially manufactured by and feature electrically welded Invar low temperature steel plates to minimize drift. Sealed transformers are used throughout, and construction is militarized.

**Specifications**

**608C vhf Signal Generator**

The 608C is a high power, stable, and highly accurate vhf signal generator for general laboratory and field use. Utilizing a master oscillator-power amplifier circuit, Model 608C provides 1 volt maximum output and a broad frequency coverage of 10 to 480 MC. It 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 608D, rf leakage is negligible, and the rf attenuator is calibrated to 0.1 µv.

608C is especially suited for measurements of gain, selectivity, sensitivity or image rejection of receivers, IF amplifiers, broadband amplifiers and other vhf equipment. It also provides ample output for driving bridges, slotted lines, transmission lines, antennas, filter networks, and other circuits operating in the vhf band.

**608A-16D**

Terminated Output Cable, 608A-16D, is designed for use with 608D and 608C vhf Signal Generators. It provides an accurate termination which may be directly connected to the point of a circuit at which the signal voltage is to be injected.

Another accessory, the 608A-95A Fuseholder is particularly useful for these signal generators when tests on transceivers are being made. The Fuseholder protects the output attenuator of the signal generator should the transmitter be keyed while the 608 is connected to the antenna.

**Accessories**

- 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.
- Retestability: Better than ± 0.1% after warmup.
- Crystal Calibrator: Provides frequency check points every 1 MC (useful to 270 MC) or 5 MC over the range of the instrument. Headphone jack provided for audio frequency output (headphones not included). Crystal frequency accuracy better than 0.01% at normal ambient temperatures.

**Data subject to change without notice.**
612A UHF SIGNAL GENERATOR

All-Purpose Uhf Signal Generator 450 to 1230 MC

Advantages:

Output 0.5 v over full range
Uhf-TV modulation characteristics
Direct calibration
CW, AM and pulse output
Low incidental FM
Constant internal impedance
Microsecond pulsing
No charts or interpolation

Use To:

Measure gain, selectivity, sensitivity
and image rejection of receivers and amplifiers
Drive bridges, slotted lines, antennas
and filter networks
Test uhf-TV equipment under actual
modulation conditions

Here is an all-purpose, precision signal generator particularly designed for utmost convenience and applicability in measurements throughout the important uhf-TV frequency band. It is ideally suited for measurements in uhf television broadcasting, studio-transmitter links, public service communications, citizen's radio, marine communication systems, and aeronautical radio-navigation networks. In the laboratory it is also a convenient power source for driving bridges, slotted lines, antennas and filter networks.

MO-PA Circuit

The master oscillator-power amplifier circuit in 612A provides a high output power of 0.5 v into 50 ohms over the full frequency range of 450 to 1,230 MC. There is very low incidental FM (less than 0.002% at 30% AM) and excellent modulation capabilities by all frequencies from 20 cps to 5 MC. The instrument may be modulated internally or externally, amplitude modulated, or pulse modulated (good rf pulses 0.2 μsec or longer). Pulse modulation may be applied to the amplifier, or direct to the oscillator when high on-off
signal ratios are required. (Signal may be completely cut off during pulses.) A dc restorer circuit allows modulation up or down from preset level to simulate TV modulation characteristics accurately. The large, easily read percentage modulation meter responds to peak value, indicating degree of pulse modulation.

**Advanced Design**

The oscillator-amplifier circuit in @ 612A employs high frequency pencil triodes in a cavity-tuned circuit for precise tracking over the entire band. The tuned cathode, tuned-plate oscillator drives a double-tuned power-amplifier of 15 MC bandwidth. (This circuitry produces the high modulation percentages to 5 MC and minimum incidental FM which characterize the instrument.)

Non-contacting cavity plungers are die cast to precise tolerances, then injection molded with a plastic filler for optimum Q. The frequency drive is a direct screw-operated mechanism, free from backlash. A waveguide beyond cutoff piston attenuator and crystal monitor circuit are used to insure accurate, reliable output down to 0.1 µV. The attenuator is calibrated over a range of 131 db. It has been carefully designed to provide a constant impedance versus frequency characteristic. The SWR of the output system is less than 1.2 over the complete frequency range when used into a 50 ohm impedance.

![Block diagram, @ 612A Signal Generator.](image)

The @ 612A covers the 450 to 1,230 MC band in one continuous range. The tuning dial has an expanded scale that covers 15 inches and is calibrated every 5 megacycles. The dial can be read to approximately 1 megacycle and is accurate within 1%.

**Specifications**

- **Frequency Range:** 450 to 1,230 MC in one band. Scale length approximately 15 inches.
- **Calibration Accuracy:** Within ±1%. Retestability better than 5 MC at high frequencies.
- **Output Voltage:** 0.1 µv to 0.5 v into 50 ohm load. Calibrated in volts and dbm (0 dbm = 1 mw).
- **Output Accuracy:** ± 1 db, 0 to −127 dbm over entire frequency.
- **Internal Impedance:** 50 ohms. Maximum SWR 1.2.
- **Leakage:** Negligible. Permits receiver sensitivity measurements down to 1 µV.
- **Amplitude Modulation:** 0 to 90% at audio frequencies, indicated by panel meter. Accuracy, ±10% of full scale, 30% to 90% modulation.
- **Incidental FM:** Less than 0.002% for 30% AM.
- **Internal Modulation:** 400 cps and 1,000 cps ± 10%. Envelope distortion less than 2% at 30% if modulation.
- **External Modulation:** 20 cps to 5 MC. Above 470 MC, 2 v rms produces 85% AM at modulating frequencies up to 1 MC; at least 40% AM at 5 MC. Modulation may be up or down from the carrier level or symmetrical about the carrier level. Positive or negative pulses may be applied to increase or decrease rf output from the carrier level.
- **Pulse Modulation:** Pulse 1, (pulse applied to amplifier) positive or negative pulses, 4 to 40 v peak produce an rf on-off ratio of at least 20 db. Minimum rf output pulse length, 0.2 µsec.
  - Pulse 2, (pulse applied to oscillator) positive or negative pulses, 4 to 40 v peak. No rf output during off time. Minimum rf output pulse length, 1.0 µsec.
- **Power:** 115/230 v ± 10%, 50/1,000 cps, 215 watts.
- **Dimensions:** Cabinet Mount: 13½" wide, 16½" high, 21½" deep. Rack Mount: 19" wide, 14" high, 20½" deep behind panel.
- **Weight:** Net 57 lbs. Shipping 69 lbs. (cabinet mount). Net 57 lbs. Shipping 93 lbs. (rack mount).
- **Accessories Available:** AC-16F rf Cable Assembly, $15.00; AC-16K Video Cable Assembly, $5.50; 360B Low Pass Filter (may be used where harmonic output must be reduced to a minimum, as in slotted line measurements), $60.00.
- **Price:** @ 612A, $1,300.00 (cabinet); @ 612AR, $1,320.00 (rack mount).

Data subject to change without notice.
**614A/616B UHF SIGNAL GENERATORS**

Direct Reading, Direct Control 800 to 2,100 MC, 1.8 to 4.2 GC (KMC)

**Advantages:**
- Direct frequency control
- Direct voltage readings
- CW, FM or pulsed output
- Variable pulse rate
- Synchronized pulsing
- Wide frequency range
- High stability
- Rugged, compact, dependable

**Use To Measure:**
- Receiver sensitivity
- Signal-to-noise ratio
- Conversion gain
- Standing wave ratios
- Antenna gain
- Transmission line characteristics

Ease of operation, direct reading without calibration charts, one-dial frequency control, high stability, accuracy and broad frequency coverage—all are outstanding advantages of these two widely-used @ signal generators.

@ 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.

@ 616B gives complete coverage of frequencies from 1.8 to 4.2 GC, has constant internal impedance with less than 1.8 SWR, and output accuracy of ± 1.5 db from -7 dbm to -127 dbm.

On both instruments, operation is extremely simple. Carrier frequency is set and read directly on the large tuning dial. No voltage adjustments are necessary during operation because of the coupling device which causes oscillator repeller voltage to track frequency changes automatically. Oscillator output is set and read directly on a simplified dial. Output may be continuous or pulsed, or frequency modulated at power supply frequency. Pulse modulation may be provided externally or internally. Internal pulsing may be synchronized with either positive or negative external pulses, or sine waves.

The oscillator portion of both the @ 614A and 616B consists of a reflex klystron in an external coaxial resonator. Frequency of oscillation is determined by a movable plunger which varies the resonant frequency of the resonator. Oscillator output is monitored by a temperature-compensated ther-
mistor bridge circuit which is virtually unaffected by ambient temperature conditions. Voltage output is read directly on the scale. A logging scale on the frequency dial provides a readability of 0.01%.

A piston attenuator in the power monitor circuit is mechanically coupled to the cursor of the output attenuator dial to compensate for variations in klystron output as frequency is changed. Output power is passed through another identical piston attenuator which is linear over a range of 120 db or more.

Because of their wide range and great stability, @ 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 0.03% frequency change.

**Attenuator Range:** 0 dbm to −127 dbm (0.223 v to 0.1 µv) calibrated directly in volts and dbm.

**Attenuator Accuracy:** ± 1 db from −10 dbm to −127 dbm.

**Output Power:** At least 0.5 mw.

**Internal Impedance:** 50 ohms. SWR less than 1.6.

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

**Dimensions:** Cabinet Mount: 17 1/4” wide, 13½” high, 13 1/2” deep. Rack Mount: 19” wide, 14” high, 12½” deep behind panel.

**Weight:** Net 58 lbs. Shipping 79 lbs. (cabinet mount). Net 59 lbs. Shipping 80 lbs (rack mount).

**Accessories Furnished:** 1 AC-16F rf Cable Assembly.

**Accessories Available:** 360D Low Pass Filter, $50.00. AC-16K Video Cable Assembly, $6.50.

**Price:** @ 614A, $1,950.00 (cabinet); @ 614AR, $1,970.00 (rack mount).

@ 616B

**Frequency Range:** 1.8 to 4.2 GC (KMC), directly calibrated.

**Frequency Calibration Accuracy:** ± 1%.

**Frequency Stability:** 0.005%/°C change in ambient temperature; line voltage changes of ± 10 v cause less than 0.03% frequency change.

**Output Range:** 1 millivolt or 0.223 v to 0.1 µv (0 dbm to −127 dbm). Directly calibrated in microvolts and dbm; continuously monitored.

**Attenuator Accuracy:** Within ± 1.5 db from −7 dbm to −127 dbm without correction charts.

**Internal Impedance:** 50 ohms, nominal. SWR less than 1.8.

**Modulation:** Internal or external pulse or FM.

**Internal Pulse Modulation:** Repetition rate variable from 40 to 4,000 per second; pulse length variable from 1 to 10 µsec; and delay variable from 3 to 300 µsec (between synchronizing signal and rf pulse).

**External Pulse Modulation:** Pulse requirements: Amplitude from 40 to 70 v positive or negative, width 1 µsec to 2,500 µsec. May be square wave modulated.

**Trigger Pulses Out:** (1) Simultaneous with rf pulse. (2) In advance of rf pulse, variable 3 to 300 µsec. (Both approx. 1 µsec rise time, amplitude 10 to 50 v.)

**External Sync Pulse Required:** Amplitude from 10 to 50 volts of either positive or negative polarity and 1 to 20 µsec width. May also be synchronized with sine waves.

**FM Modulation:** Oscillator frequency sweeps at power line frequency. Phasing and sweep range controls provided. Maximum deviation approximately ± 3 MC.

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

**Dimensions:** Cabinet Mount: 17¼” wide, 13½” high, 13¼” deep. Rack Mount: 19” wide, 14” high, 12½” deep behind panel.

**Weight:** Net 58 lbs. Shipping 82 lbs. (cabinet mount). Net 59 lbs. Shipping 80 lbs (rack mount).

**Accessories Furnished:** 1 AC-16F rf Cable Assembly.

**Accessories Available:** 360D Low Pass Filter, $50.00. AC-16K Video Cable Assembly, $6.50.

**Price:** @ 616BR, $1,970.00 (cabinet); @ 616B, $1,950.00 (rack mount).

Data subject to change without notice.

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Figure 1. Block diagram, @ 614A/616B Signal Generator.
**Advantages:**
- Direct reading frequency control
- Direct output voltage control
- Internal FM, CW, pulsed or square wave modulation
- Broad pulsing capabilities
- Wide frequency range
- High stability, high accuracy
- Sturdy, compact, precision built

**Use To Measure:**
- Receiver sensitivity
- Selectivity or rejection
- Signal-to-noise ratio
- Conversion gain, SWR
- Antenna gain
- Transmission line characteristics

Hewlett-Packard 618B and 620A shf Signal Generators bring the simple yet versatile operation and the varied pulsing capabilities of 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 618B and 620A have a saw-tooth voltage variable from 40 to 4,000 cps 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 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 developed coupling device which causes oscillator repeller voltage to track frequency changes automatically. RF output is also set and read directly; no calibration charts are needed either for voltage or frequency control or determination. A logging scale on the frequency dial permits you to reset frequencies within 0.1%.

**Reflex Klystron Oscillator**

The 618B and 620A Generators both feature oscillators of the reflex klystron type, with external resonant cavity. Oscillator frequency is determined by a movable plunger which varies the length of the cavity. Oscillator output is monitored by a temperature-compensated thermistor bridge circuit. This circuit operates virtually unaffected by ambient temperature conditions. Identical piston attenuators couple power to the monitor and output terminal. The power monitor attenuator is linked to the output attenuator cursor to compensate for klystron output variation as frequency is changed.

Models 618B and 620A are designed to be the most broadly useful, accurate and dependable signal generators available in their frequency ranges. Their high stability, broad frequency coverage, precision accuracy and varied pulsing capabilities make them ideal for virtually all measurements requiring precisely known and controllable shf signals. They are sturdily built of the best components, many parts being specially manufactured for or by Hewlett-Packard. Circuitry is clean and accessible. The generators are designed for years of dependable service with little or no maintenance.

**Specifications**

### ☞ 618B

- **Frequency Range:** 3,800 to 7,600 MC covered in a single band. Repeller voltage automatically tracked and proper mode automatically selected.

- **Calibration:** Direct reading. Frequency calibration accuracy better than 1%.

- **Frequency Stability:** Frequency variation less than 0.006% per degree centigrade change in ambient temperature. Line voltage change of ± 10 volts causes less than 0.02% frequency change.

- **Output Range:** 1 milliwatt or 0.223 volt to 0.1 microvolt (0 dbm to -127 dbm) into 50 ohms. Directly calibrated in microvolts and db (coaxial Type N connector).

- **Output Accuracy:** Within ± 2 db from -7 dbm to -127 dbm into 50 ohms.

- **Internal Impedance:** 50 ohms nominal. SWR less than 2.

- **Modulation:** Internal or external pulse, FM, square wave.

- **Internal Pulse Modulation:** Repetition rate variable from 40 to 4,000 pps, pulse width variable 0.5 to 10 μsec.

- **Sync Out Signals:** (1.) Simultaneous with rf pulse—positive (2.) In advance of rf pulse—positive, variable 3 to 300 μsec. (Better than 1 μsec rise time and 25 to 100 volts amplitude into 1,000 ohm load.)

- **External Synchronization:** (1.) Sine wave: 40 to 4,000 cps, amplitude 5 to 50 volts rms. (2.) Pulse signals: 0 to 4,000 pps and 5 to 50 volts amplitude, both positive and negative, pulse width 0.5 to 5 μsec, rise time 0.1 to 1 μsec.

- **Internal Square Wave Modulation:** Variable 40 to 4,000 cps, controlled by 'pulse rate' control.

- **Internal Frequency Modulation:** Saw-tooth sweep rate adjustable between 40 to 4,000 cps. Frequency deviation up to ± 3 MC.

- **External Pulse Modulation:** Pulse requirements: amplitude from 20 to 70 volts positive or negative, width 0.5 to 2,500 μsec.

- **External Frequency Modulation:** Provides capacitive coupling to repeller of klystron. Max. deviation approx. ± 5 MC.

- **Power:** 115/230 v ±10%, 50/60 cps, 250 watts.

- **Dimensions:** Cabinet Mount: 17½" wide, 14½" high, 19½" deep. Rack Mount: 19" wide, 14" high, 17½" deep behind panel.

- **Weight:** Net 95 lbs. Shipping 118 lbs. (cabinet mount).

- **Accessories Furnished:** 1 AC-16Q rf Cable Assembly.

- **Accessories Available:** AC-16K Video Cable Assembly, $6.50.

- **Price:** ☞ 618B, $2,250.00 (cabinet); ☞ 618BR, $2,270.00 (rack mount).

### ☞ 620A

(Same as ☞ 618B except as follows:)

- **Frequency Range:** 7,000 to 11,000 MC covered in a single band. Repeller voltage automatically tracked and proper mode automatically selected.

- **Output Range:** 1.0 milliwatt or 0.223 volt to 0.1 microvolt (0 dbm to -127 dbm) into 50 ohms. Directly calibrated in microvolts and db (coaxial Type N connector).

- **Output Accuracy:** Within ± 2 db from -7 dbm to -127 dbm; within ± 3 db from 0 to -7 dbm, at panel connector, terminated in 50 ohm load.

- **Price:** ☞ 620A, $2,250.00 (cabinet); ☞ 620AR, $2,270.00 (rack mount).

Data subject to change without notice.
**626A/628A SHF SIGNAL GENERATORS**

Direct Reading, High Power 10 to 15.5 GC (KMC), 15 to 21 GC

**Advantages:**
- Direct reading frequency control
- Direct reading output control
- 10 mw output over full range
- CW, FM or pulsed output
- Internal square wave modulation
- Broad pulsing capabilities
- Low internal SWR
- High stability, high accuracy
- Sturdy, compact, precision-built

With @ 938/940 Frequency Doubler Sets operates to 40 GC (KMC).

**Use To Measure:**
- Receiver sensitivity
- Selectivity or rejection
- Signal-to-noise ratio
- Conversion gain, SWR
- Antenna gain
- Transmission line characteristics

Here are two @ signal generators which extend the measuring versatility, convenience and accuracy of @ vhf signal generators to 21 GC (KMC). The @ 626A covers frequencies 10,000 to 15,500 MC, and the @ 628A covers frequencies 15,000 to 21,000 MC.

In design and operation, the instruments are similar to @ generators for lower frequency ranges. Operation is very simple. Carrier frequency in MC is set and read directly on the large tuning dial. No voltage adjustment is necessary during tuning because repeller voltage is tracked with frequency changes automatically. Oscillator output is also set and read directly, and no frequency correction is necessary throughout operating range. A frequency logging scale permits frequency to be reset within 0.1%.

The high power output of these signal generators makes them ideally suited for driving @ 938A and 940A Frequency Doubler Sets (18 to 26.5 GC and 26.5 to 40 GC respectively). These Doubler Sets (see pages 146, 147) retain the modulation of the driving source and have accurate power monitors and attenuators.

**Versatile Modulation**

Both @ 626A and 628A offer internal and external pulse modulation as well as internal squarewave 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, 626A/628A.**

Figure 1 shows the basic circuits of the 626A/628A signal generators. The reflex klystron oscillator is tuned by a plunger driven by the direct-reading frequency dial and control. Repeller voltage is automatically tracked so that correct operating potentials are maintained over the entire frequency range. Klystron output is introduced into a power monitoring directional coupler through an attenuator which is adjusted to provide a fixed reading on the power monitoring meter. The directional coupler provides uniform coupling over the entire frequency range. A rotary attenuator which follows the coupler assures high accuracy and stability because the attenuation is governed by a precise mathematical law related to the angular rotation of the attenuator. The conductivity of the attenuating film does not affect the attenuation; thus the output of the generator is independent of humidity, temperature or the effects of long term aging. The attenuator also provides low SWR over the complete frequency range. On both 626A and 628A, the output connector is waveguide. Adapters furnished permit the instruments to be connected to WR-42, WR-62 or WR-90 waveguide. Thus the generators can be employed with all EIA (RETMA) guides suitable for the 10 to 21 GC range.

**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 pw. (+10 dbm to −90 dbm, 0 dbm = 1 mw.) Attenuator dial directly calibrated in output dbm. SWR less than 2.5 at +10 dbm; 1.2 at 0 dbm and lower.

**Output Monitor Accuracy:** Better than ± 1 db.

**Output Attenuator Accuracy:** Better than ± 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:** Positive 20 to 50 volts peak into 1,000 ohm load. Better than 1 μsec rise time.

1. Simultaneous with rf pulse.
2. In advance of rf pulse, variable 3 to 300 μsec.

**External Synchronization:** (1) Sine wave, 40 to 4,000 cps, amplitude 5 to 50 volts rms.
(2) Pulse signals 0 to 4,000 pps, 5 to 50 volts amplitude, positive or negative. Pulse width 0.5 to 5 μsec. Rise time 0.1 to 1 μsec.

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

**Dimensions:** Cabinet Mount: 17” wide, 14” high, 15” deep. Rack Mount: 19” wide, 14” high, 12-13/16” deep behind panel.

**Weight:** Net 65 lbs. Shipping 83 lbs.

**Accessories Furnished:** 626A (a) MX 29214 Waveguide Adapter, WR-75 to WR-90 guide. (b) MP 292A Waveguide Adapter, WR-75 to WR-62 guide. 628A (a) NP 292A Waveguide Adapter, WR-51 to WR-62 guide. (b) NK 292A Waveguide Adapter, WR-51 to WR-42 guide.

**Accessories Available:** AC-16K Video Cable Assembly, $6.50. For 626A: M362A Low Pass Filter, $350.00. For 628A: N362A Low Pass Filter, $350.00.

**Price:** 626A or 628A, $3,400.00 (cabinet). 626AR or 628AR, $3,420.00 (rack mount).
Electronic Sweeping for Simple, Comprehensive Full-Band Measurements

Advantages:
- Electronic sweep
- 1 to 18 GC (KMC)
- Simple to operate, direct reading
- Continuously adjustable sweep width and rate
- 10 mw output minimum
- Frequency sweep linear with time
- Slow sweep for mechanical recorders; fast sweep for non-flickering oscilloscope presentation
- Single sweep manually started or externally triggered
- External FM or AM modulation

Hewlett-Packard offers six backward-wave sweep oscillators that eliminate sweep motors, tuning plungers, previous range limitations and mechanical problems ... and cover all or part of a given band with a simple, flexible, broadly adjustable, quiet electronic sweep!

With these instruments, you have complete freedom of sweep combination—both sweep width and rate of change of frequency (sweep rate) are independently controlled and direct reading. CW or swept rf frequencies may be obtained over any part of the range; sweep width may be adjusted instantly without interrupting operation. The full range can be covered in periods slow enough for high resolution mechanical recording or fast enough for flickerless oscilloscope presentations (see Specifications). Sweep rate is adjustable in nine steps over various ranges as indicated under Specifications.

Linear Frequency Sweep

A unique means is used to achieve a swept frequency that is a linear function of time. Output frequency of a backward wave oscillator tube is an exponential function of the voltage applied to its helix, so by making the sweep voltage applied to the helix the proper exponential function of time, a frequency sweep results which is linear.
For greatest convenience the sweep may be operated recurrently, triggered manually by means of a pushbutton or by an externally generated voltage for operation of the instrument in synchronism with other equipment. To facilitate oscilloscope and mechanical recordings, a 20 volt peak saw-tooth sweep voltage concurrent with the frequency sweep is supplied at a front panel connector. This saw-tooth sweep voltage has a fly-back so short that no blanking signal is required during oscilloscope retake.

**Broad Modulation Capabilities**

In addition to their swept frequency output, the oscillators may be internally or externally AM modulated, externally pulse modulated and externally FM modulated.

**Internal amplitude modulation** is produced by a square wave variable 400 to 1,200 cps. During modulation, peak power is the same as the unmodulated cw output.

**External amplitude modulation** is produced by a signal applied to the backward wave oscillator through a built-in amplifier. Pass band of this amplifier is dc to 300 KC, and -20 volts or more reduces the output level from rated to zero.

**Pulse modulation** is also available. In this case there is no output from the instrument except during the pulse. The peak pulse power will be equal to the cw level if the input pulse is 10 volts peak or larger. Pulses up to 5 milliseconds long may be used for this modulation.

**Frequency modulation** is achieved by varying with externally generated signals the voltage supplied to the helix of the backward wave tube. These signals are capacitively coupled to the helix modulator. When FM'd externally in this manner, the instrument's frequency deviation is both above and below the frequency set on the main tuning dial.

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**Specifications**

<table>
<thead>
<tr>
<th>Model</th>
<th>Freq. (KMC)</th>
<th>Sweep Range</th>
<th>RF Sweep Rate of Change</th>
<th>Sweep Time</th>
<th>Output Power Variation</th>
<th>Residual FM</th>
<th>Spurious Signal</th>
<th>Output Connector</th>
<th>Price</th>
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<tbody>
<tr>
<td>482C</td>
<td>1 - 2</td>
<td>1.1 MC to 1.1 GC, seven steps, continuous control between steps</td>
<td>0.0136 sec to 138 sec for full band sweep, determined by sweep range and rate</td>
<td>Less than ± 1.5 dB over entire frequency range</td>
<td>Less than 50 KC pk</td>
<td>Less than -20 dB</td>
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<td>2 - 4</td>
<td>2.1 MC to 2.1 GC, seven steps, continuous control between steps</td>
<td>0.0136 sec to 135 sec for full band sweep, determined by sweep range and rate</td>
<td>Less than ± 1.5 dB over entire frequency range</td>
<td>Less than 100 KC pk</td>
<td>Less than -20 dB</td>
<td>Type N (Female)</td>
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<td>4 - 8.1</td>
<td>4.1 MC to 4.1 GC, seven steps, continuous control between steps</td>
<td>0.0136 sec to 135 sec for full band sweep, determined by sweep range and rate</td>
<td>Less than ± 1.5 dB over entire frequency range</td>
<td>Less than 200 KC pk</td>
<td>Less than -20 dB</td>
<td>Type N (Female)</td>
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<td>485C</td>
<td>8.2 - 12.4</td>
<td>4.4 MC to 4.4 GC, seven steps, continuous control between steps</td>
<td>0.0136 sec to 135 sec for full band sweep, determined by sweep range and rate</td>
<td>Less than ± 1.5 dB over entire frequency range</td>
<td>Less than 200 KC pk</td>
<td>Less than -30 dB</td>
<td>Type N (Female)</td>
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<tr>
<td>487C</td>
<td>12.4 - 18</td>
<td>6 MC to 6 GC, seven steps, continuous control between steps</td>
<td>0.0136 sec to 135 sec for full band sweep, determined by sweep range and rate</td>
<td>Less than ± 1.5 dB over entire frequency range</td>
<td>Less than 200 KC pk</td>
<td>Less than -30 dB</td>
<td>Type N (Female)</td>
<td>$3,085.00</td>
<td></td>
</tr>
</tbody>
</table>

*With leveler operating.*

**For All Models:**

**Sweep Mode:** Recurrent; externally triggered; manually triggered. RF frequency sweep is linear with respect to time and is downward from frequency dial setting.

**Sweep Output:** ± 20 volt (approx.) peak sawtooth provided concurrently with swept rf output for recorder and oscilloscope sweeping. Source impedance approximately 10,000 ohms and 20 pf in parallel.

**Power Output:** 10 milliwatts or greater into load (50 ohms for Type N output) having an SWR of 1.25 or less. Output continuously adjustable to zero.

**Maximum SWR:** 3 or less for 687C, 2.5 or less for other models.

**Dial Accuracy:** ± 1%.

**Residual AM:** Less than -40 db.

**Modulation:**

**Internal AM:** Square wave modulation continuously adjustable from 400 - 1200 cps; output peak rf output power is within 1 db of the cw setting.

**External AM:** Direct coupled dc to 500 KHz; -20 volts or more reduces rf output level from rated cw output to zero. Input impedance: 75 ohms.

**External FM:** Approximately 150 volts peak-to-peak required to modulate full frequency range of instrument. 10 cps to 60 cps. Modulating voltage must be decreased with modulating frequencies higher than 60 cps. Input impedance: 45,000 ohms shunted by 100 pf; ac coupled.

**External Pulse:** ± 10 volts or greater pulse required; 5 milliseconds maximum pulse length. Peak rf pulse level within 1 db of cw setting. Pulse rise and decay times less than 1 usec. Input impedance: 350,000 ohms shunted by 25 pf; ac coupled.

**Power:** 115-230 volts ± 10%, approximately 340 watts.

**Dimensions:** Width 20 - 9/16", height 12 1/2", depth 18" (cabinet mount). Width 19", height 10 1/2", 16 1/2" deep behind panel (rack mount).

**Weight:** Net 105 lbs. Shipping 134 lbs. (cabinet mount). Net 104 lbs. Shipping 133 lbs. (rack mount).
Now! Generate Precise Signals to 40 GC (KMC) with New Doublers!

Advantages:

Cover 18 to 40 GC (KMC) with accuracy, versatility, simplicity

Increases usefulness of 9 to 20 GC signal generators

Versatile output capability identical to driving source

Use with swept signal sources, signal generators, klystrons

Convenient, economical, reliable signal generation to 40 GC (KMC) is possible with the new @ 938A/940A Frequency Doubler Sets used in conjunction with a wide variety of existing signal sources or one of the dependable, bench-proven @ signal generators or sweep oscillators listed in this catalog.

@ Model 938A supplies power from 18 to 26.5 GC when driven by a 9 to 13.25 GC source; @ Model 940A supplies power from 26.5 to 40 GC when driven by a 13.25 to 20 GC source.

The 938A and 940A have the same output versatility as the driving source. These broadband instruments accept CW, pulsed or swept input signals from signal generators, swept signal sources or klystrons.

Each contains a broadband crystal-harmonic generator, plus a dual rotary vane attenuator, for generating and accurately setting the output level 0 to —100 db. Output power depends on input power and is typically 0.5 to 1.0 mw when the driving source is an @ 626A or 628A Signal Generator or an @ 686C or 687C Sweep Oscillator. (See paragraph on Swept Frequency Output, next page.) Output power is known, even though an uncalibrated signal source is used, since the output monitor is accurate to ±2 db.

Typical of the output versatility of these Frequency Doubler sets is the fact that an @ 938A driven by an @ 626A will provide CW output, pulse modulated output with a repetition rate from 40 to 4,000 pps, square wave modulated...
Specifications

Model 938A Frequency Doubler Set

Frequency Range: 18-26.5 GC (KMC).
Conversion Loss: Less than 18 db at 10 mw.
Output Power: Depends on input power supplied. Approx. 0.5 to 1.0 mw when used with typical Model 626 Signal Generator.
Saturation Output Power: 3 mw.
Input Power Required: 10 mw design center.
Maximum Input Power: 100 mw.
Output Monitor Accuracy: ± 1 db.
Output Attenuator Accuracy: ± 2% of reading or ± 0.2 db whichever is greater.
Attenuator Range: 100 db.
Output SWR: Approx. 2:1 at full output. Less than 1.5 with attenuator set to 10 db or more attenuation.
Input Flange: M-Band flat cover flange for WR-75waveguide.
Output Flange: UG-595/U flat cover flange for WR-42 waveguide.
Dimensions: 5” high, 19” wide, 18” deep.
Weight: Net 20 lbs. Shipping 26 lbs.
Price: $938A, $1,500.00.
Complementary Equipment: Model 626A Signal Generator, Models 686C and 687C Electronic Sweep Oscillators.

Model 940A Frequency Doubler Set

Frequency Range: 26.5 to 40 GC.
Conversion Loss: Less than 18 db at 10 mw input.
Output Power: Depends on input power supplied. Approximately 0.5 mw when used with typical Model 626A and 628A Signal Generators.
Saturation Output Power: 2 mw.
Input Power Required: 10 mw design center.
Maximum Input Power: 100 mw.
Output Monitor Accuracy: ± 1 db.
Output Attenuator Accuracy: ± 2% of reading or ± 0.2 db whichever is greater.
Attenuator Range: 100 db.
Output SWR: Approx. 2:1 at full output. Less than 1.5 with attenuator set to 10 db or more attenuation.
Input Flange: N-Band flat cover flange for WR-51 waveguide.
Output Flange: UG-599/U flat cover flange for WR-28 waveguide.
Dimensions: 5” high, 19” wide, 18” deep.
Weight: Net 20 lbs. Shipping 26 lbs.
Price: $940A, $1,500.00.
Complementary Equipment: Model 626A and 628A Signal Generators, 687C Electronic Sweep Oscillator.

Data subject to change without notice.
Hewlett-Packard microwave test equipment is designed to provide a complete set of high-quality, low-cost instruments for measurement of microwave parameters including power, impedance, noise figure, attenuation, and frequency. In addition to a wide variety of coaxial slotted lines, bridges, detectors, mounts, etc., the equipment includes complete instrumentation in the waveguide field. Each instrument has been designed for broad band coverage, high stability, broadest applicability, convenient size, and simplest possible operation. Highest quality metals, alloys, components and dielectrics have been used in construction; and utmost care is taken during manufacture. All units are thoroughly tested before leaving the factory and are warranted to conform with, or exceed, specifications.

Letter Designations

Model numbers of @ waveguide components are normally preceded by a prefix letter. This letter designates the waveguide size and frequency band of the instrument. Each @ waveguide instrument of a given band will have this same prefix in its model number. Eleven designator prefixes are used:

<table>
<thead>
<tr>
<th>Waveguide Size</th>
<th>Designator Prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 3&quot; x 1 1/2&quot;</td>
<td>A</td>
</tr>
<tr>
<td>G 2&quot; x 1</td>
<td>B</td>
</tr>
<tr>
<td>H 1 1/2&quot; x 3/4&quot;</td>
<td>C</td>
</tr>
<tr>
<td>T 1 1/2&quot; x 1 1/4&quot;</td>
<td>D</td>
</tr>
<tr>
<td>X 1 1/2&quot; x 1 1/2&quot;</td>
<td>E</td>
</tr>
<tr>
<td>M 1&quot; x 1 1/2&quot;</td>
<td>F</td>
</tr>
<tr>
<td>N 1&quot; x 5/8&quot;</td>
<td>G</td>
</tr>
<tr>
<td>K 1&quot; x 1/4&quot;</td>
<td>H</td>
</tr>
<tr>
<td>R 7/16&quot; x 3/4&quot;</td>
<td>I</td>
</tr>
<tr>
<td>P 7/32&quot; x 1/4&quot;</td>
<td>J</td>
</tr>
</tbody>
</table>

Thus, an @ 370 Fixed Waveguide Attenuator designed for use with 3" x 1 1/2" guide is designated S370. The same instrument designed for the 7/32" x 1/4" 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 @ microwave elements, the suffix letter indicates specific attenuation or coupling factors. Six designator letters are used:

- “A” 3 db
- “B” 6 db
- “C” 10 db
- “D” 20 db
- “E” 30 db
- “F” 40 db

Thus, the 20 db coupling version of @ 750 Cross-Guide Coupler will be designated as @ 750D.

The model of the 750 built for 1 1/2" x 1 1/4" waveguide systems will, of course, have the size prefix designer “X.” Therefore, the complete model number of a 750 series Coupler with 20 db coupling for use with 1 1/2" x 1 1/4" equipment is @ X750D Cross-Guide Coupler. Use of this prefix and suffix code will simplify and speed inquiries and ordering.

Flanges

All @ 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, @ 290A Cover to Choke Flange Adapters may be used.

K band (18 to 26.5 GC) and R band (26.5 to 40.0 GC) waveguide equipment is normally supplied with rectangular flanges. However, when specified, circular flanges may be obtained on most K- and R-band instruments at no extra charge.

Waveguide Equipment

Hewlett-Packard Broad Band Waveguide Instruments are based on a time-proven design approach. The fundamentals of this concept are:

1. Each instrument is of simplest construction consistent with its basic function and covers the entire frequency range of its waveguide size.
2. An integrated set of instruments is available for each commonly used waveguide frequency from S to R band.
3. Simple mechanical design, incorporating novel electrical circuitry, insures high accuracy, stability, and quality, and yet makes possible quantity production at low cost.

With @ 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 @ waveguide line. You are assured maximum operating flexibility, efficiency, convenience, and economy.

Power, Impedance, Noise Figure Measurements

General information and techniques for the use of Hewlett-Packard microwave test equipment in making power measurements are presented on pages 151 to 153. A similar discussion concerning microwave impedance measurements appears on pages 163 to 165. A discussion on noise figure measurements appears on page 176. Instruments appropriate to each type of measurement are shown on the pages immediately following the discussion of that type of measurement.

Attenuation Measurement

Attenuation measurements are made by a number of different methods such as power ratio or either RF or IF substitution. In the power ratio method the signal source is connected to a detector mount through a length of lossless transmission system in which place the unknown attenuator may be substituted. A reading is obtained on the output indicator with a section of lossless line in the circuit. The lossless line is then replaced by the attenuator being measured. The power attenuation at the output indicator is a measure of the attenuation. This measurement requires first, that the low of the detector be known over the complete frequency range of the measurement; and second, that reflection effects in the system be essentially the same both with and without the attenuator.

The type of detecting equipment used will depend on the range of the attenuation measurement. A range of attenuation measurement up to 30 to 40 db can be achieved with a detector mount employing a barretter, and @ 415B Standing Wave Indicator (high sensitivity, tuned voltmeter). In this case, the signal source must be modulated, and the RF power level must be kept below 200 microwatts for square law detector characteristics. The attenuation in decibels may be read directly from the Model 415B.

To eliminate effects of reflections between generator and attenuator, and attenuator and load, it is desirable to
use pads. Pads should be well matched to the transmission system. The homodyne method permits measuring attenuation as high as 100 db. In this system a signal generator furnishes local oscillator power to a mixer and at the same time drives a TWT amplifier which is modulated to produce an offset frequency. The offset frequency is fed through the attenuator to be measured, and combined with the local oscillator frequency. The difference frequency is amplified in a tuned amplifier and applied to an indicating meter. Be-ween pads. Pads should be well matched to the transmission system.

RF substitution depends on substituting an RF attenuator of unknown characteristic for the unknown. For instance, a signal generator attenuator may be used. When using this method the output of the signal generator is fed to the attenuator being measured and then into the detector. The attenuator being measured is removed, and a reading is obtained upon the detector. The setting of the signal generator attenuator is noted. The attenuator is then inserted, and the signal generator output is adjusted to obtain the same reading as before. The difference between the signal generator attenuator settings is the attenuation of the attenuator in db. Since the detector is always operated at the same level, detector law is no problem. The attenuator measurement may similarly be performed with an 382A Precision Attenuator and a signal source.

The IF substitution method offers the highest accuracy in attenuation measurements since its substitution standard is a precise 30 MC cutoff attenuator. The power change caused by removing the unknown RF attenuator is replaced by change of the precision IF cutoff attenuator in the IF stage of the detecting microwave receiver.

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.

RF substitution depends on substituting an RF attenuator of known characteristic for the unknown. For instance, a signal generator attenuator may be used. When using this method the output of the signal generator is fed to the attenuator being measured and then into the detector. The attenuator being measured is removed, and a reading is obtained upon the detector. The setting of the signal generator attenuator is noted. The attenuator is then inserted, and the signal generator output is adjusted to obtain the same reading as before. The difference between the signal generator attenuator settings is the attenuation of the attenuator in db. Since the detector is always operated at the same level, detector law is no problem. The attenuator measurement may similarly be performed with an 382A Precision Attenuator and a signal source.

The IF substitution method offers the highest accuracy in attenuation measurements since its substitution standard is a precise 30 MC cutoff attenuator. The power change caused by removing the unknown RF attenuator is replaced by change of the precision IF cutoff attenuator in the IF stage of the detecting microwave receiver.

Characteristic Impedance

The value of the characteristic impedance of a cable can be computed from impedance measurements made with a bridge such as 803A VHF Bridge (page 174). Suggested procedure is as follows:

At some specific frequency, measure the input impedance to the line with the output end of the line open. At the same frequency, measure the input impedance of the line with the output end shorted. Then compute the characteristic impedance with the formula:

\[ Z_0 = \frac{V}{Z_{(op)} Z_{(sh)}} \]

where \( Z_0 \) = characteristic impedance

\[ Z_{(op)} = \text{input impedance with output end open} \]

\[ Z_{(sh)} = \text{input impedance with output end shorted} \]


Another useful method of determining characteristic impedance in a coaxial cable is through the measurements of two constants of the cable—capacitance and velocity of propagation. The characteristic impedance is then computed as follows:

\[ Z_0 = 101,000 \frac{V}{C} \]

where \( Z_0 \) = characteristic impedance

\[ V = \text{velocity of propagation} \]

\[ C = \text{capacity in pf/foot} \]

The suggested procedure is as follows:

1. Measure cable capacitance at low frequencies with a standard capacitance bridge.
2. Measure velocity of propagation at some frequency (above 50 MC to prevent "skin effect" errors).
3. Substitute the values of capacitance and velocity of propagation in the formula:

\[ Z_0 = \frac{101,000 \frac{V}{C}}{\text{characteristic impedance}} \]


Figure 1. Suggested instrument arrangement for measuring small values of cable attenuation. Unknown cable is placed between slotted line and short.

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:

\[ V = \frac{f_1 f_2}{2 f_1 - f_2} \]

where \( L = \text{cable length in feet} \)

\( f_1 = \text{recorded frequency} \)

\( K = \frac{2 f_1}{f_2 - f_1} \)

3. Substitute the values of capacitance and velocity of propagation in the formula:

\[ Z_0 = \frac{101,000 \frac{V}{C}}{\text{characteristic impedance}} \]

In the microwave region, power measurements are considered to be more basic than current or voltage measurements. This is because power is invariant with position of measurement, while current and voltage (because of the distributed nature of the transmission system at these frequencies) are not.

In the power range up to 10 milliwatts, power measurements are customarily made by use of temperature-sensitive elements, such as bolometers. A bolometer is an element which converts rf power to heat, which in turn varies the resistance in proportion to the temperature change of the element. Bolometers are normally used in a bridge configuration which allows the change of resistance in the bolometer to be determined by external audio or dc techniques. Unbalanced bridge configurations are used occasionally. However, the more accurate bridges use ac substitution techniques which allow the resistance of the bolometer to remain at a fixed value (100 or 200 ohms) at all values of rf power. The audio power, which is removed to rebalance the bridge and keep the bolometer resistance constant, is a measure of the rf power being applied.

In the range above 10 watts, power measurements are generally made using calorimeter techniques. Either a dry calorimeter or a water flow calorimeter is usually used.

Between these low and high power ranges, measurements can be made using attenuators and low power bolometers. However, these measurements are somewhat clumsy and inaccurate.

The 434A Calorimetric Power Meter makes direct, convenient and accurate measurements in the 10 mw to 10 watt range. This unique oil flow calorimeter fills the need for a convenient measuring device having high accuracy and wide bandwidth.

Conventional Bridge Techniques

Bolometers used for microwave measurements are of two general types: barretters—metallic wire or film in which the temperature coefficient of resistance is positive, and thermistors—semi-conductor material in which the temperature coefficient is negative. Both barretters and instrument fuses are used as positive temperature coefficient bolometers. Barretters consist of a short length of very fine platinum wire suitably encapsulated. Negative temperature coefficient bolometers (thermistors) consist of a small bit of semi-conductive material suspended between two fine wires.

In general, barretters are delicate, and readily burned out by too much power. Even if the overload is insufficient to burn out a barretter, it may still increase its cold resistance to the point where a self-balancing bridge meter cannot be zero set. Thermistors are much more rugged. Although they are rated at 25 mw maximum, they generally burn out at about 400 mw and their characteristics change only slightly, if at all, upon overload.

The bolometer element is used in conjunction with a power meter such as the 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. The self-balancing bridge uses the external bolometer element (a non-linear resistor) as one of the bridge arms. A high gain amplifier is connected across the bridge as a detector, and the output of the same amplifier is connected as the driving source for the bridge. With sufficient gain, the bridge oscillates and audio power is furnished at an amplitude such that the bridge is almost balanced. When the rf power is applied to the element, the amplitude of oscillation decreases an amount necessary to maintain the element’s resistance constant. This audio power decrease is equal to that power added by the rf source and can be read on the voltmeter which is calibrated in power units.
bolometer mounts have been designed for both coaxial and waveguide systems at frequencies between 10 MC and 40.0 GC (KMC). These mounts are extremely simple to use, have low SWR, and may be used with @ 430C Power Meter to provide direct reading measurements. bolometer mounts may be classified according to the type of bolometer element employed—thermistor, or barretter—and whether the mount is untuned (broadbanded) or tunable.

fixed tuned thermistor mounts are exceptionally broad band bolometers. Model 477B Coaxial Thermistor Mount (page 160) covers the frequency range of 10 MC to 10 GC, while @ 487B (waveguide series, page 162) are available from 2.6 to 40.0 GC. No tuning is required and an extremely low SWR is maintained throughout frequency bands.

Model 485B Detector Mounts (page 161) employ a single tuning control to match the applicable waveguide to a barretter power detection element. In general, their SWR is less than 1.25 over the rated frequency range when using barretters. This provides an excellent match to the rf line and very low mismatch losses.

@ 476A Universal Bolometer Mount (page 160) is a fixed tuned bolometer in the frequency range from 10 to 1,000 MC. The bolometer element consists of 8.25 ma fuses.

In general, squarewave or pulse modulated power can be measured accurately with either a barretter, fuse, or thermistor, subject to certain limitations which depend upon the characteristics of the bolometer elements in conjunction with the bridge oscillator. However, in @ 430C Power Meter, these limitations are not serious.

New Temperature Compensated Power Bridge

Conventional bolometer bridge techniques have a serious limitation in the lower power sensitivity regions because of thermal drift in the mount itself. Since the bolometer is a temperature sensitive element, power of all types, including ambient temperature change, causes a resistance change in the mount. In fact, typical power sensitivity of a thermistor mount to temperature change is such that 0.005° Centigrade is approximately equivalent to 1 micro watt. Such a high temperature sensitivity seriously limits the low power sensitivity unless special techniques are employed.

The new @ 431A Temperature Compensated Power Meter (pages 156, 157) represents a significant advance in stability and accuracy in power measurements. The power meter utilizes a dual bridge, temperature-compensated circuit arrangement which allows power measurements to be made down to a full scale sensitivity of 10 microwatts. Operation is essentially drift-free.

Under laboratory conditions, for instance, long-term drift on the most sensitive range of 10 microwatts full scale, is typically 1 or 2 microwatts per 4 hour period. This extreme stability makes for a truly satisfying power measurement in the high sensitivity region and opens a new area of convenience to power meter users. Furthermore, power up to 10 milliwatts may be measured directly on the same bridge.

Time savings on zero setting alone are appreciable and further time savings are made by providing that the zero set be carried over for all power ranges. Previous conventional bridge techniques required that new zeroing be done whenever the power range switch was turned to a different range.

Operation of the temperature compensated power meter depends on the use of two identical thermistor bridges. Thermally sensitive elements, the thermistors, are located in close thermal proximity to each other, but one element is placed so that it absorbs rf power from a transmission line while the other element is free from any rf influence. Special mount design and thermistor mounting procedures provide the nearly identical thermal environment, the coupling of rf power to one thermistor and the shielding of the other.

An increase or decrease of ambient temperature tends to change the operating resistance of both thermistors. The unbalance, sensed by the temperature compensating thermistor bridge, is amplified and in turn reduces the audio power applied to both bridges, keeping both in balance. Thus, as long as the temperature sensitivity of the two thermistors' tracks with temperature, and they are both maintained in close thermal proximity, temperature effects are essentially cancelled out. The rf power applied to the rf mount, however, reduces the audio power drive to both bridges and, to maintain the temperature compensating bridge in balance, a dc power is supplied from the electronics of the power meter. It is this dc power which is metered to indicate the rf power input. One feature of this bridging system is that both bolometer elements are maintained in a balanced condition, and since they are identical thermally there is a 1 to 1 translation between the rf power supplied to the rf bridge and the dc rebalance power supplied to the compensating bridge. Thus, both elements are maintained at the same impedance over all power ranges. One of the advantages obtained from operating both bridges in a balanced condition is that 10 milliwatts of rf power can be measured. This is not true of some temperature compensated power meters which utilize an unbalanced bridge as the metering drive.

The 431A features a "zero carry over" which means that the power meter may be balanced on the lowest range of 10 microwatts, and as the range is switched upward to 10 milliwatts no re-zoning need be done.

High accuracy is realized in this meter by careful attention to switching resistors and bridge determining resistors. In addition, terminals are provided on the rear of the unit for a dc calibration input to calibrate the mounts with precise dc standards for even higher accuracy. For better readability commensurate with the increased accuracy that can be obtained with precise dc calibration, a recorder output is provided. A 3 or 4 digit digital dc voltmeter may be connected to the recorder.
output and, in combination with precise dc calibration, improves resolution and accuracy of power measurements. Hence, Model 431A provides an extremely convenient automatic balancing bridge with excellent readability for use in Standards laboratories.

The special bridge balancing arrangement in Model 431A achieves a new convenience in pulsed power measurements. Conventional bridges respond to the audio drive voltage and mathematically convert this to indicate power. At low repetition rates the bridge tends to follow the rf modulation, with the meter responding to average voltage rather than average power. Since Model 431A meters a dc rebalance voltage proportional to power, true power averaging is obtained on amplitude modulated rf waves.

A special series of coaxial and waveguide thermistor mounts has been designed for use with this temperature-compensated power meter, and these mounts must be used because of the inherent thermal matching problems in the mounts. These mounts are presently available in coax and X-band. The Model 478A (page 157), which covers the frequency range from 10 megacycles to 10.5 GC, is an extremely compact thermistor mount which contains both thermistor elements in close thermal contact. It utilizes a dual set of rf thermistors, each operating at 100 ohms so that it presents 200 ohms to the temperature compensated power meter while presenting 50 ohms to the rf line. The compensating elements are constructed in a similar manner.

A second temperature compensated mount, Model X486A (page 157), is available in X-band waveguide, which covers the frequency range from 8.2 to 12.4 GC. Other waveguide mounts from 2.6 to 40 GC are being made available. Write for information.

10 mw to 10 Watts

The Model 434A Calorimetric Power Meter (see pages 154, 155) automatically measures average power from 10 milliwatts to 10 watts. The instrument operates from dc to 12.4 GC. The operator simply connects the source to the 434A and reads the power. Power above 10 watts may be measured by reducing it to the range of the 434A with calibrated attenuators or directional couplers.

Model 434A is ideally suited for highly accurate measurements because its overall accuracy is 5% which includes rf efficiency and substitution error. Also, it allows direct measurement of intermediate powers and thus eliminates the error in the power reducing attenuator which is required in bolometer techniques.

The Model 434A, shown simplified in Figure 3, consists of a self-balancing bridge which has identical temperature-sensitive resistors (gauges) in two legs, an indicating meter and two load resistors, one for the unknown input power and one for the comparison power. The input load resistor and one gauge are in close thermal proximity so that heat generated in the input load resistor heats the gauge and unbalances the bridge. The unbalance signal is amplified and applied to the comparison load resistor which is in close thermal proximity to the other gauge so that the heat generated in the comparison load resistor is transferred to its gauge and nearly rebalances the bridge.

The meter measures the power supplied to the comparison load to rebalance the bridge. The characteristics of the gauges are the same and the heat transfer characteristics from each load are the same, so the power dissipated in each load is the same, and the meter may be calibrated directly in input power.

To provide swift balancing, an efficient heat transfer from the loads to the temperature gauges is accomplished by immersing the components in an oil stream. This gives full scale deflection in less than 5 seconds.

The power measurement is accurate, because the flow rates through the two heads are the same and the head characteristics are the same. To insure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger prior to entering the heads.

The accuracy of Model 434A is one of its unique attributes. Since the power meter represents the most accurate method available for measuring high-frequency power the 434A may find much use as a laboratory standard power meter. Nominal accuracy is 5%. However, higher accuracies can be achieved by employing techniques to minimize frequency and impedance mismatch effects.

![Figure 3. Simplified diagram, 434A Calorimetric Power Meter.](image)
434A CALORIMETRIC POWER METER

Just Connect, Read Power 10 mw to 10 Watts

Advantages:
- Simplest power measurements, 10 mw to 10 watts, dc to 12.4 GC (KMC)
- No barretter or thermistor needed
- No external terminations or plumbing
- Compact, entirely self-contained
- Direct reading in watts and DBW

Stated simply, the 434A Calorimetric Power Meter offers you this:

The fastest, easiest means yet devised to measure powers accurately from 10 milliwatts to 10 watts between dc and 12.4 GC (KMC).

With the new 434A, measurement is literally as simple as connecting to a 50 ohm type N front panel terminal and reading power directly. The instrument has only two simple front panel controls, and is ideal for use by non-technical personnel.

Model 434A fills the important range between bolometer-type microwave power meters such as 431A (pages 156,157) and conventional calorimeters whose lower range is approximately 10 watts. But unlike previous cumbersome and costly equipment suggested for its range, the 434A is completely self-contained and requires no external detectors or plumbing of any type.

Rapid Response Time

Model 434A employs a self-balancing bridge and a high-efficiency heat transfer system to and from an oil stream to
provide a full scale response time of 5 seconds or less. This fast reaction, a fraction of the response time needed by ordinary calorimeters, means the 434A quickly follows small adjustments in input tuning circuits. Further, the use of twin power sensitive elements in one oil stream plus a feedback system makes the accuracy virtually independent of variations in oil flow rate or ambient temperature, and prevents fluctuations because of changes in oil temperature.

Circuit Description

Basically the Model 434A consists of a self-balancing bridge which has identical temperature-sensitive resistors (gauges) in two legs, an indicating meter and two load resistors, one for the unknown input power and one for the comparison power. The input load resistor and one gauge are in close thermal proximity so that heat generated in the input load resistor heats the gauge and unbalances the bridge. The unbalance signal is amplified and applied to the comparison load resistor which is in close thermal proximity to the other gauge so that the heat generated in the comparison load resistor is transferred to its gauge and nearly rebalances the bridge.

The meter measures the power supplied to the comparison load to rebalance the bridge. The characteristics of the gauges are the same and the heat transfer characteristics from each load are the same, so the power dissipated in each load is the same, and the meter may be calibrated directly in input power.

The power measurement is accurate, because the flow rates through the two heads are the same and the oil enters the heads at nearly the same temperature. To insure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger just prior to entering the heads. Identical flow rates are obtained by placing all elements of the oil system in series.

Specifications

Input Power Range: Seven meter ranges. Full-scale readings of 0.01, 0.03, 0.1, 0.3, 1.0, 3.0 and 10 watts. Meter scale also calibrated from -10 to 0 DBW, providing continuous readings from -30 to +10 DBW. Power range can be extended upward with attenuators or directional couplers.

Peak Input Power: 1 kilowatt, maximum.

Frequency Range: DC to 12.4 GC (KMC).

DC Input Impedance: 50 ohms ± 5 ohms at type N input jack.

Input SWR: DC to 5 GC, less than 1.3, 5 to 12.4 GC, less than 1.5.

Meter Response Time: Less than 5 seconds for full scale deflection.

Internal Calibrator: 100 mw dc ± 1% into 45 to 55 ohms.

Accuracy: Within ± 5% of full scale. Includes dc calibration and rf termination efficiency but not mismatch loss. Greater accuracy can be achieved through appropriate techniques.

Estimated Attainable Accuracy:

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Upper Ranges</th>
<th>Two Lowest Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>½%</td>
<td>2%</td>
</tr>
<tr>
<td>0 to 1 GC</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>1 to 4 GC</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>4 to 10 GC</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>10 to 12.4 GC</td>
<td>4%</td>
<td>5%</td>
</tr>
</tbody>
</table>

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, 14" deep. Rack Mount: 19" wide, 10½" high, 13½" deep behind panel.

Weight: Net 49 lbs. Shipping 60 lbs. (cabinet mount).

Net 44 lbs. Shipping 59 lbs. (rack mount).

Price: $434A, $1,600.00 (cabinet); $434AR, $1,585.00 (rack mount).

Data subject to change without notice.
431A POWER METER

New Accuracy and Temperature Stability; Power Measurements 1 \( \mu \text{w} \) to 10 mw

Advantages:

- Drift less than 2 \( \mu \text{w} \) per degree Centigrade for a wide temperature range
- \( \pm 3\% \) accuracy on all ranges. Even greater accuracy using simple external calibration procedures
- One zero setting for all ranges
- Extremely easy to operate
- Grounded recorder output
- Portable operation (with optional battery pack)

Continual zero-setting is a thing of the past... even on the 10 \( \mu \text{w} \) range, with the new @ 431A Power Meter. A drift stability of less than 2 microwatts per °C means that in typical laboratory environments one zero setting will hold for hours. In addition, only one zero adjustment is needed to calibrate the 431A for all ranges! Even in less favorable environments only occasional adjustment is necessary.

The extreme temperature stability of this instrument makes possible (and usable) an additional sensitivity of 10 db over previously available equipment. Full scale readings of 10 \( \mu \text{w} \) to 10 mw are covered in 7 ranges. The meter face is also calibrated in dbm with 5 db between ranges. Direct-reading accuracy is \( \pm 3\% \) of full scale.

Newly-designed temperature-compensated thermistor mounts are required for operation with the @ 431A. The new @ 478A Coaxial Mount covers 10 MC to 10 GC (KMC) and the new 486A Waveguide Mount is being made available for the various waveguide bands.

Microwave standards measurements can be made to high accuracy and resolution with the Model 431A by using the automatic bridge as a transfer device. A dc calibration input jack permits precise dc calibration of the thermistor mount. The grounded output jack will then drive an appropriate digital voltmeter for increased resolution.

The @ 431A also has an optional rechargeable battery pack which will give up to 24 hours of completely portable operation.
operation. A front panel control selects ac operation with trickle-charge, battery operation, or battery charge alone.

Circuit Description

Two balanced bridges are employed in the @ 431A. One arm of each is a temperature-sensitive element. The thermistor units are in close thermal proximity in the dual mount. One bridge is made sensitive to a combination of rf power, audio power, and power supplied by ambient temperature change. The other bridge element is made sensitive to audio, temperature, and dc power. By suitable design of the ther- mistor mounts, the thermal characteristics are made virtually identical. In this way, dc power in one bridge is made equal to rf'power in the other. The dc power is metered. Both bridges are continuously maintained in a balanced condition so both thermistor elements have similar heat transfer characteristics at all times.

This unique circuit approach gives a self-balancing device for both rf power and temperature changes, with all critical components located within a feedback loop. If thermistors and mounts were available that tracked identically with temperature, no zero setting would ever be necessary. The new @ 478A and 486A dual thermistor mounts use extremely high heat-conductivity metals and selected thermistors for exceedingly close tracking, even in the presence of thermal shocks.

Specifications

@ 431A

Power Range: 7 ranges. Full scale readings from 10 μw to 10 mw. Also calibrated in dbm from -30 dbm to +10 dbm.
Accuracy: ±3% of full scale on all ranges.
Overall Thermal Drift: Less than 2μw/°C (includes meter and @ 478A/486A mounts).
Operating Impedance: 100 or 200 ohms, negative, for operation with @ 478A/486A.
Recorder/Voltmeter Output: Phone jack on rear with 1 ma into maximum of 2,000 ohms.
Calibration Input: Binding posts on rear for calibration of bridge with precise dc standards.
Power: 1½ watts, 115/230 v ± 10%, 50-1,000 cps.
Dimensions: 7½” wide, 6½” high, 12½” deep.
Weight: Net, approximately 10 lbs.
Accessories Furnished: 5-foot interconnection cord for @ temperature-compensated thermistor mounts.
Accessories Available: Rechargeable battery pack.
Price: @ 431A, $345.00.

@ 478A WAVEGUIDE THERMISTOR MOUNT

X-band power measurements can now be made with high accuracy and new operating convenience. New @ 486A is a temperature-compensated 1 μw sensitivity mount containing two thermistor elements in a mounting scheme providing very similar thermal environments. Extremely close temperature tracking is achieved, even with the application of thermal shocks, making the instrument remarkably free from drift.

Model 486A covers X band, with no tuning required. Temperature-compensated waveguide mounts for other bands are also being made available. Request latest price and delivery information.

Specifications

@ 486A with @ 431A

Frequency Range: 8.2 to 12.4 GC.
SWR: Less than 1.5.
Power Range: 1 μw to 10 mw.
Elements: Two permanently installed 100-ohm negative temperature coefficient thermistors.
Waveguide Size: 1 x ½ inches.
Price: @ 486A, $145.00.

Data subject to change without notice.
430C MICROWAVE POWER METER
Direct, Automatic, Instantaneous Pulsed or CW Power Readings

Advantages:
Reads direct in dbm or mw; no tedious calculations
Wide power range; nominal range extendable with directional couplers and attenuators
Automatic operation; usable with many different bolometers

Uses:
Instantaneous microwave power measurements, pulsed or CW
Use on waveguide or coaxial system

This Microwave Power Meter gives you instantaneous rf power readings direct in dbm or mw—and completely eliminates tedious computation and troublesome adjustments during operation. The instrument may be used at any frequency for which there are bolometer mounts—and measurements are entirely automatic.

In measuring power, 430C uses either a negative or positive temperature coefficient bolometer at 100 or 200 ohm levels. Power is read direct in milliwatts, 0.01 to 10 mw, or in dbm from -20 to +10. Higher powers may be measured by adding attenuators such as 370, 380 or 382A series to the system. Directional couplers such as 750 or 752 may also be used to sample energy.

When used in an appropriate bolometer mount, instrument fuses are generally satisfactory for measuring CW, pulsed, square- or sine-wave modulated power at frequencies up to 4 GC (KMC). Barretters and thermistors can be used for these measurements at much higher frequencies; up to 12.4 GC for barretters (in mounts) and up to 40.0 GC for certain thermistors.

Hewlett-Packard waveguide bolometer mounts for the 430C are available covering, collectively, the frequency spectrum from 2.6 to 40.0 GC. Each bolometer mount covers a
complete waveguide band. In addition, three coaxial bolometer mounts cover the frequency spectrum from 10 MC to 10 GC. Model 430C Microwave Power Meter will furnish dc bias current for all bolometer mounts which require up to 16 ma bias current. Fine as well as coarse control of the bias current permits exact balancing of the bolometer element in the bridge over wide range ambient temperature variations.

**Circuit Description**

@ 430C consists of an audio bridge, one arm of which is a power-sensitive element. The bridge is initially balanced with no rf power in the element. As rf power is applied, the equivalent in audio power is automatically removed, so the bridge remains in balance. The change in audio power level indicates directly on a VTVM calibrated to show rf power in the sensitive bridge arm.

**Specifications @ 430C**

Power Range: 5 ranges, front panel selector. Full scale readings of 0.1, 0.3, 1, 3 and 10 mw. Also continuous readings from -20 to +10 dbm. (0 dbm = 0.001 watt). Power range may be extended with attenuators or directional couplers.

External Bolometer: Frequency range depends on bolometer mount. Bolometers can operate at resistance levels of 100 or 200 ohms and can have positive or negative temperature coefficients. Any dc bias current up to 16 ma is available for biasing positive or negative temperature coefficient bolometers. DC bias current is continuously adjustable and independent of bolometer resistance and power level range.

Suitable bolometers are:

Instrument fuses: @ G-28A 1/100 amp fuse.
Barretters: Sperry 821, Narda N821B or N610B, PRD 610A, 614, 617 or 631C.

Accuracy: ± 5% of full scale reading.

Power: 115/230 v ± 10%, 50/1,000 cps, 90 watts.

Dimensions: Cabinet Mount: 7½” wide, 11½” high, 14½” deep. Rack Mount: 19” wide, 7” high, 13½” deep behind panel.

Weight: Net 14 lbs. Shipping 19 lbs. (cabinet mount).
Net 18 lbs. Shipping 30 lbs. (rack mount).

Accessories Available: AC-16K Video Cable Assembly, $6.50; AC-16D Cable Assembly, $3.50.

Price: @ 430C, $250.00 (cabinet); @ 430CR, $255.00.

(rack mount).

Data subject to change without notice.
477B Thermistor Mount

This thermistor mount provides full frequency coverage 10 MC to 10 GC with SWR of less than 1.5. It requires no tuning, and employs long time-constant elements assuring measurement accuracy even for low duty cycle pulses. The instrument is not susceptible to burnout even at power levels as high as 1 watt.

477B is designed for use with the 430C Microwave Power Meter and can also be used with other bolometer bridges providing negative temperature coefficient operation at the 200 ohm level. Approximately 13 ma of bias is required.

Specifications

- Frequency Range: 10 MC to 10 GC (KMC).
- SWR: Less than 1.5 (less than 1.3—50 MC to 7 GC).
- Power Range: 0.01 to 10 mw (with 430C Microwave Power Meter).
- Element: 200 ohm, negative temperature coefficient thermistor included.

Accessories Available: AC-16K Video Cable Assembly, $6.50.

Price: @ 477B, $75.00.

476A Universal Bolometer Mount

Used with 430C Microwave Power Meter, this universal bolometer mount measures power from 10 to 1,000 MC and gives instantaneous, automatic power readings from 0.02 to 10 milliwatts. No tuning or adjustment is necessary. Higher powers may be measured by use of attenuators and directional couplers in conjunction with Model 476A. SWR is low, and reflected power is less than 0.1 db under most conditions.

Specifications

- Nominal Impedance: 50 ohms.
- Maximum SWR: Less than 1.15, 20 to 500 MC.
  Less than 1.25, 10 to 1,000 MC.
- Maximum Power: 10 milliwatts.
- Bolometer Element: Four 8.25 ma instrument fuses, specially selected and treated. (@ G-28B.)
- Accessories Available: AC-16F RF Cable Assembly, $15.00; AC-16K Video Cable Assembly, $6.50.
- Price: @ 476A, $85.00.

Data subject to change without notice.
Hewlett-Packard offers three basic 485 series Mounts, each ideally designed for its function and frequency range.

S485A, 2.6 to 3.95 GC (KMC), is offered in the S band range only. This instrument uses a Sperry 821 or Narda N821 barretter and requires no tuning. SWR is less than 1.35 over the entire waveguide band.

485B series, for higher waveguide frequencies (3.95-12.4 GC), is tuned by a variable short adjustable to SWR of less than 1.25 full range. For power measurements this results in a reflection loss of less than 0.1 db. 485B Mounts employ either a Sperry 821 or Narda N821 barretter. Or, for maximum sensitivity a 1N21 or a 1N23 silicon crystal may be used. Detector elements can be quickly interchanged.

485D Waveguide Barretter Mounts are available in S, G, and J bands covering 2.6 to 8.2 GC. These instruments are supplied with factory-installed 821-type barretters tested for SWR, frequency response and square-law characteristics. Sensitivity is 0.2 v/mw, SWR ranges from 1.35 to 1.5, response is \( \pm 1 \text{ db} \) and variation from square-law characteristic is less than \( \pm 0.5 \text{ db} \). No tuning required. AC-60K Barretter Matching Transformer is required to interconnect the 485D with 416A Ratio Meter (pages 172, 173).

All models have BNC output connectors mating with UG88/U plugs.

---

**Specifications**

<table>
<thead>
<tr>
<th>Model</th>
<th>Maximum SWR</th>
<th>Frequency Range GC (KMC)</th>
<th>Waveguide Size (in.)</th>
<th>Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S485A</td>
<td>1.25</td>
<td>2.60 - 3.95</td>
<td>3 x 1/2</td>
<td>4 x 1/4</td>
<td>$445</td>
</tr>
<tr>
<td>G485B</td>
<td>1.25</td>
<td>3.95 - 6.85</td>
<td>2 x 1</td>
<td>4 x 1/4</td>
<td>95.0</td>
</tr>
<tr>
<td>J485B</td>
<td>1.25</td>
<td>6.85 - 8.20</td>
<td>1/2 x 3/4</td>
<td>7/8</td>
<td>90.0</td>
</tr>
<tr>
<td>S485B</td>
<td>1.25</td>
<td>7.05 - 10.0</td>
<td>1/2 x 3/4</td>
<td>6/8</td>
<td>65.0</td>
</tr>
<tr>
<td>X485B</td>
<td>1.25</td>
<td>8.20 - 12.4</td>
<td>1 x 1/2</td>
<td>8</td>
<td>75.0</td>
</tr>
<tr>
<td>G485D</td>
<td>1.5</td>
<td>8.20 - 12.4</td>
<td>1 x 1/2</td>
<td>8</td>
<td>75.0</td>
</tr>
<tr>
<td>J485D</td>
<td>1.5</td>
<td>8.20 - 12.4</td>
<td>1/2 x 3/4</td>
<td>4/8</td>
<td>170.0</td>
</tr>
</tbody>
</table>

*Detector not supplied. SWR increases to 1.5 at 5.2 GC. All models accept either barretter or crystal except -hp. S485A, which employs barretter only.

*From 5.2 to 7.5 GC. Increases to approximately 2.0 at 8.2 GC.

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**Figure 1.** Typical SWR vs. Frequency, 485, when used with barretter.
**487 WAVEGUIDE THERMISTOR MOUNTS**

Low SWR, No Tuning. Covers Full Waveguide Frequency Range

Hewlett-Packard 487 series Waveguide Thermistor Mounts are dependable, accurate and convenient instruments that materially simplify setups and save operator time in microwave power measurement.

Series 487 instruments collectively cover all frequencies from 2.6 to 40.0 GC (KMC).

Each 487 series mount covers the full frequency range of its waveguide band and requires no tuning. The long time constant of the mount makes it ideal for measuring average power of low duty cycle pulses. Since thermistors have inherent overload protection, and since the majority of power is reflected during overload conditions, burnouts are virtually impossible.

Model 487 mounts are equipped with cover flanges and BNC output connectors. They are designed for use with microwave power meters such as @ 430C or other instruments responsive to negative temperature coefficient bolometers operating at the 100 or 200 ohm level.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Maximum Power</th>
<th>Maximum SWR</th>
<th>Frequency Range</th>
<th>Fits Waveguide Size (in.)</th>
<th>Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>5.40 - 3.95</td>
<td>3 x 1 1/2</td>
<td>2 1/4</td>
<td>$110.00</td>
</tr>
<tr>
<td>G487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>3.95 - 5.85</td>
<td>2 x 1</td>
<td>2 1/4</td>
<td>95.00</td>
</tr>
<tr>
<td>J487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>5.3 - 8.2</td>
<td>1 1/2 x 1/4</td>
<td>1/4</td>
<td>90.00</td>
</tr>
<tr>
<td>H487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>7.06 - 10.0</td>
<td>1 1/2 x 1/4</td>
<td>1 5/16</td>
<td>80.00</td>
</tr>
<tr>
<td>X487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>8.2 - 12.4</td>
<td>1 1/2 x 1/4</td>
<td>1 3/16</td>
<td>75.00</td>
</tr>
<tr>
<td>K487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>10.0 - 15.0</td>
<td>0.850 x 0.475</td>
<td>15/16</td>
<td>110.00</td>
</tr>
<tr>
<td>P487B</td>
<td>10 mw</td>
<td>1.5</td>
<td>12.4 - 18.0</td>
<td>0.702 x 0.391</td>
<td>13/16</td>
<td>110.00</td>
</tr>
<tr>
<td>R487B</td>
<td>10 mw</td>
<td>2.0</td>
<td>26.5 - 40.0</td>
<td>0.380 x 0.220</td>
<td>1 3/4</td>
<td>225.00</td>
</tr>
</tbody>
</table>

Thermistor: Permanently installed 100-ohm negative coefficient thermistor. (K487C and R487B use 200-ohm thermistors.)

Thermistor Time Constant: Approximately 1 second when cooling on an open circuit.

Accessories Available: AC-16K Cable Assembly, $6.50.

K and R-band units with UG425/U and UG381/U flanges are available; specify K487BC or R487BC.

Data subject to change without notice.
Of all the possible measurements to be made in design and production, probably the most important is impedance. With distributed parameters impedance varies with the position of measurement. Hence all impedance measurements must be referred to some reference plane. Since impedance determines reflected energy caused by the load, information concerning a load can often best be obtained by determining the magnitude of the reflection coefficient.

The value of the reflection coefficient can be determined by using a slotted section of a transmission line and measuring the standing wave ratio, (ratio of maximum to minimum voltage in the system feeding the load). It also can be measured directly with a reflectometer by sampling the incident and reflected waves and obtaining their ratio which is equal to the reflection coefficient. The reflectometer method will be explained following the discussion of the slotted line.

**Slotted Line Measurements**

A typical setup for making slotted line measurements is shown in Figure 1. The transmission system contains the incident wave and a reflected wave which is proportional to the mismatch of the load. These two waves will alternately cancel and add, setting up a standing wave pattern along the line. By inserting a probe into the slotted section and sliding it along the line the resultant voltage pattern may be measured. The usual practice is to amplitude modulate the signal source and to use a crystal or bolometer to detect the rf at the probe. The detected output of the probe is connected to a high sensitivity, tuned voltmeter, such as HP 415B Standing Wave Indicator. Using this procedure, the SWR and the position of maxima and minima of the load can be determined. The load is then replaced by a short circuit and the shift of the minimum is recorded. By entering this information on a Smith Chart, the measured impedance can be transformed back to the point of interest. In this way, one can determine the value of the reflection coefficient and the impedance in magnitude and phase.

**Slotted Line Techniques**

In measuring with this setup there are several places where errors may occur. A proper operating technique will eliminate or minimize these errors. Errors may arise from the following causes: probe loading, generator mismatch, detector characteristics, harmonics, FM, and other spurious signals.

Harmonics and spurious signals should be minimized by use of low pass filters such as Hewlett-Packard 360 and 362A series (page 186). Proper modulation techniques are explained in the signal generator section of this catalog (pages 127-147). Of special importance is the fact that modulation should not be attempted by very short pulses or poor quality square waves. When modulating klystrons in such a manner the resulting FM tends to obscure the maxima of the standing waves. To avoid FM, modulation of klystron signal sources should be by square wave.

Since the ratios of different voltage levels are being measured with slotted lines, it is essential that the detection follow the same law for all levels. If barretters are operated at levels less than 200 microwatts and crystals at power levels of less than 20 microwatts, characteristics are closely square law. It is for this condition that the HP 415B meter scale is calibrated. This condition will be adequately met in the setup shown in Figure 1 (for standing wave ratios of 10 to 1 or less), if the probe coupling is reduced to a point where the standing wave minimum is 5 to 10 db above the system noise level.

The sampling probe will extract some power from the line to supply the indicating devices and in addition will set up reflections in the line from the probe itself. Both errors become greater as the probe insertion is increased. It is therefore important in slotted line measurement to keep the probe penetration at a minimum.

The power extraction by the probe can be explained by considering the probe as admittance shunting the line. This admittance is kept small by coupling as loosely as possible (small penetrations) and by using a high sensitivity detector in conjunction with a source output of one milliwatt or more. If the coupling between the probe and the line is not small, shunt admittance introduced by the probe will cause the measured SWR to be lower than the true SWR (as shown in Figure 2) and will shift both the maximum and the minimum from their natural position.

![Figure 1. Typical setup for impedance measurements.](image-url)
wave ratios (2 or less). In this case, gives rise to reflections from the probe into the slotted section towards the generator. If the generator under these conditions, the phase of its reflected is changed and errors result. The detecting equipment should have high sensitivity, as does the 417A VHF Detector which is designed primarily to be used with Model 803A Bridge.

The bridge is basically an unbalanced device, and in many cases it is desirable to measure balanced systems. This can be accomplished by the use of a balun. A half wavelength balun is equivalent to a 4 to 1 impedance transformer. Hence, impedances measured at the input of the balun should be multiplied by 4 to obtain the actual impedance.

**Reflectometer Measurements**

The reflectometer is the most useful impedance measuring technique for fast, comprehensive production measurements. The reflectometer will indicate magnitude of impedance but will not provide phase information as will a slotted line measurement. However, in the typical production situation an SWR measurement alone is quite adequate, and phase information is not needed.

**Impedance Measurements With VHF Bridge**

Below 500 MC, slotted sections become exceedingly long, and other techniques for impedance measurements are more desirable. For these frequencies, Model 803A VHF Bridge is ideal. (See Figure 3.)

The VHF bridge provides a convenient means of measuring impedances, reading directly both magnitude and phase angle. The bridge is operated simply by tuning two controls until a sharp null is obtained. At the null, one dial reads unknown impedance in ohms and the other dial shows phase angle.

Because of the null nature of the measurement, the voltages measured are very small. Therefore, to avoid any effects from extraneous voltages, lines connected to the bridge should be adequately shielded. The signal source supplying this bridge should be capable of delivering several milliwatts of power for a well defined sharp null to be observed. The detecting equipment should have high sensitivity, as does the 417A VHF Detector which is designed primarily to be used with Model 803A Bridge.

The bridge is basically an unbalanced device, and in many cases it is desirable to measure balanced systems. This can be accomplished by the use of a balun. A half wavelength balun is equivalent to a 4 to 1 impedance transformer. Hence, impedances measured at the input of the balun should be multiplied by 4 to obtain the actual impedance.

**Reflectometer Measurements**

The reflectometer is the most useful impedance measuring technique for fast, comprehensive production measurements. The reflectometer will indicate magnitude of impedance but will not provide phase information as will a slotted line measurement. However, in the typical production situation an SWR measurement alone is quite adequate, and phase information is not needed.

With the availability of the 938/940 Frequency Doubler Sets (see pages 146, 147) which are capable of providing swept frequency rf power in K and R bands, reflectometer capabilities are extended to 40 GC (KMC). A typical reflectometer setup is shown in Figure 4. This arrangement determines the magnitude of the reflection coefficient by using two directional couplers to sample the incident power to a load and the reflected power. The couplers drive detectors which are connected to a 1,000 cycle ratio meter (416A, pages 172, 173) where a ratio measurement is made. Since the 416A is calibrated for square law detectors the resultant ratio of the two sampled powers is indicated directly as reflection coefficient on a front panel meter. Model 416A also provides a dc output to an X-Y recorder for making permanent records.

The reflectometer method is most practical for measuring reflection coefficients up to approximately 0.5 (SWR of 3.0). When used with swept frequency techniques and calibrated with a fixed short circuit at 100% reflection, accuracies of approximately ± .02 may be obtained for reflection coefficients of 0.1 (SWR of 1.22). For reflection coefficients of 0.4 (SWR of 2.3) accuracies of approximately ± .04 may be obtained. The potential accuracy of the reflectometer, however, is greatest at low SWR's when used at a fixed frequency. A rather simple calibration procedure, using a slide screw tuner, a moving load, and a sliding short circuit, cancels out ambiguity caused by the reverse
coupler directivity. Under ideal conditions errors of less than ± .005 in reflection coefficient are attainable; this is equivalent to a slotted line measurement in a line with a residual SWR of 1.01.

Reflectometers are available to measure reflection coefficients rapidly and with good accuracy in all waveguide frequencies, as well as for a wide frequency range in coaxial cable systems.

The table below lists the required components needed to set up a reflectometer in any given frequency range, both coaxial and waveguide. In the K and R band frequency regions some overlap of driving generators is required.

Although electronically swept RF sources provide faster measurements, they are not an absolute necessity. Very satisfactory measurements may be made with any manually-tuned signal source and an X-Y recorder at the output of the ratiometer. It is only necessary to sweep manually through the entire range to get a plot of reflection coefficient. In the frequency range from 36 to 40 GHz for instance, the 628A Signal Generator may be used in a manual sweep mode.

A series of Application notes is available on request to provide detailed information on certain microwave measurements, techniques; for instance #21 Microwave Standards Prospectus, #27 Basic Microwave Measurements, #38 Microwave Measurements for Calibration Labs, and #39 Standards Calibration Procedures.

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Table I. Equipment for reflectometer systems, coaxial and waveguide, using 416A Ratio Meter

<table>
<thead>
<tr>
<th>COAXIAL</th>
<th>DETECTOR TWO REQUIRED</th>
<th>FORWARD DIRECTIOAL COUPLER</th>
<th>REVERSE DIRECTIOAL COUPLER</th>
<th>WAVEGUIDE TO COAX ADAPTER</th>
<th>SIGNAL SOURCE</th>
<th>ADJUSTABLE SHORT</th>
<th>SLIDE SCREW TENSION</th>
<th>MOVING LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>216 - 450 MC</td>
<td>476A</td>
<td>764D</td>
<td>Weinstechel</td>
<td>50 - 10</td>
<td>606C 10 - 480 MC</td>
<td>612A  450 - 1220 MC</td>
<td>872A</td>
<td>906A</td>
</tr>
<tr>
<td>450 - 945</td>
<td>476A</td>
<td>765D</td>
<td>Weinstechel</td>
<td>50 - 10</td>
<td>612B  2 - 3.12 GC</td>
<td>872A</td>
<td>906A</td>
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<td>940 - 1975</td>
<td>420B (matched)</td>
<td>765D</td>
<td>Weinstechel</td>
<td>210 - 10</td>
<td>683C  2 - 4 GC</td>
<td>872A</td>
<td>906A</td>
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<td>1920 - 4000</td>
<td>420B (matched)</td>
<td>763D</td>
<td>Weinstechel</td>
<td>210 - 10</td>
<td>683D  5 - 8.1 GC</td>
<td>872A</td>
<td>906A</td>
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<tr>
<th>WAVEGUIDE</th>
<th>BAND</th>
<th>G26B</th>
<th>G752D (20 db)</th>
<th>G752C (10 db)</th>
<th>G262A</th>
<th>684C  4 - 8.1 GC</th>
<th>872A</th>
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<tr>
<td>S - 2.6 - 3.95 GC</td>
<td>26B (matched)</td>
<td>G262D</td>
<td>G752D (10 db)</td>
<td>G752C (10 db)</td>
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<td>G - 3.95 - 5.85</td>
<td>485D</td>
<td>G752D (20 db)</td>
<td>G752C (10 db)</td>
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<td>906A</td>
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<td>J - 5.3 - 8.2</td>
<td>485D</td>
<td>J152D (20 db)</td>
<td>J152C (10 db)</td>
<td>J282A</td>
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<td>906A</td>
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<tr>
<td>H - 7.05 - 10.0</td>
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<td>H752D (20 db)</td>
<td>H752C (10 db)</td>
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<td>M752C (10 db)</td>
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<td>P - 12.4 - 18.0</td>
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<td>P752C (10 db)</td>
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<td>686C  8.2 - 12.4 GC</td>
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<tr>
<td>K - 18.0 - 26.5</td>
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<td>K752D (20 db)</td>
<td>K752C (10 db)</td>
<td>J282A</td>
<td>686C  8.2 - 12.4 GC</td>
<td>872A</td>
<td>906A</td>
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<tr>
<td>R - 26.5 - 40.0</td>
<td>R422A (matched)</td>
<td>R752D (20 db)</td>
<td>R752C (10 db)</td>
<td>J282A</td>
<td>686C  8.2 - 12.4 GC</td>
<td>872A</td>
<td>906A</td>
<td></td>
</tr>
</tbody>
</table>

1Requires AC-60K Barretter Matching Transformer.
2764D - 767D are dual directional couplers, only one required.
Supplementary equipment for greater convenience: Oscilloscope, long persistence CRT. @ Models 120A, 122A or 120B with P-7 phosphor.
X-Y Recorder, F. L. Moseley Model 2D.
415B STANDING WAVE INDICATOR

Reads Direct in SWR and db

Specifications

Frequency: 1,000 cps ± 2% (315 to 2020 cps on special order).
Sensitivity: 0.1 μV at a 200 ohm level for full scale deflection.
Noise Level: Less than 0.03 μV ref. to input operated from a 200 ohm resistor.
Amplifier Q: 25 ± 5.
Calibration: Square law. Meter reads SWR, db.
Range: 70 db. Input attenuator provides 60 db in 10 db steps.
Accuracy ± 0.1 db per 10 db step. Cumulative error ± 0.2 db max.
Scale Selector: "Normal," "Expand," and "—5 db."
Meter Scales: SWR: 1–4; SWR: 5–10; Expanded SWR: 1–1.3; db: 0–10; Expanded db: 0–2.
Gain Control: Adjusts to convenient reference level, Range at least 10 db.
Input: "Bolo" (200 ohms). Bias provided for 8.7 ma bolometer or
1/100 amp. use; or 4.3 ma low current bolometer.
"Crystal." 200 ohms for crystal rectifier.
"200,000 ohms." High impedance for crystal rectifier as null detector.
Output: Jack for recording milliammeter having 1 ma full scale
deflection, internal resistance of approx. 1,500 ohms.
Power: 115/230 v ± 10%, 60 cps (other frequencies available on request), 55 watts.
Dimensions: Cabinet Mount: 7½" wide, 11½" high, 12½" deep.
Rack Mount: 19" wide, 7" high, 11" deep behind panel.
Accessories Furnished: 1 41A-16E Cable Assembly.
Accessories Available: Plug-in Filters (specify frequency); 415B 42B (315-700 cps), $60.00, 415B-42C (700-2020 cps), $50.00.
AC-16K Video Cable Assembly, $6.50. AC-16D Cable Assembly, $3.50.
Price: @415B, $200.00 (cabinet); @415BR, $205.00 (rack mount).

Data subject to change without notice.

The 415B is designed for use with @ slotted lines and detector mounts for the measurement of standing wave ratio or as a null detector for bridge measurements. Consisting of a high gain amplifier with very low noise level, the instrument operates at a fixed audio frequency and presents amplifier output on a square law calibrated meter reading direct in SWR or db. Features include a 5 db attenuator to allow all measurements to be made in the more readable upper portion of the meter scale, an expanded SWR scale for accurate measurements of very flat systems, and a recorder output terminal for making permanent SWR records. A simple gain control adjusts the instrument to a convenient level.

Input Arrangements

Three input arrangements are provided. A switch selects
(1) a 200 ohm termination with bias of 4.3 or 8.7 ma for bolometers, (2) an unbiased 200 ohm termination for crystals, (3) a 200,000 ohm load for null measurements. A jack and monitor cable are provided for connecting an external milliammeter to measure bolometer current.

The instrument is normally supplied for operation at 1,000 cps. However, on special order it is available equipped for operation at any filter frequency from 315 to 2,020 cps (should not be harmonically related to power line frequency). Units for converting the 415B to operation at any frequency in the above range can be obtained at nominal charge and installed in the field.
The 805 Slotted Line incorporates a different structural design with precision manufacture, resulting in an instrument of unvarying accuracy for the measurement of microwave circuits.

This instrument employs two parallel planes and a rigid central conductor, offering important advantages over the standard slotted section.

For example, the parallel planes are rigid; insuring greater accuracy and a rigid probe carriage. The central conductor is proportionately larger and more rigid, with less tendency to bow. Depth of probe penetration is inherently less critical, and carriage inaccuracies are minimized. Leakage is also low because the effective slot opening is small. SWR of the basic section is less than 1.02.

The probe circuit is tunable 500 to 4,000 megacycles. Depth of probe penetration can be quickly and easily adjusted.

Two versions of the 805 are offered; the 805C, provided with Type N connectors, and the 805D with connectors suitable for mating to RG44/U stub supported coaxial cable.

Basic slab sections of 805C/D and 872A Coaxial Slide Screw Tuners (see page 187) are identical. Two connectors can be eliminated when flattening a coaxial system by mounting both an 805C or D and 872A on one slab section. In this arrangement, the lower frequency limit becomes approximately 1,000 MC.

Specifications

805C

Frequency Range: 500 MC to 4,000 MC (minimum frequency determined by usable length of 14½ inches).

Characteristic Impedance: 50 ohms. (For use with any 50 ohm cable using Type N connector.)

Connectors: Type N. (One male; one female.) Special fittings designed to mate with Type N connectors, provide a minimum SWR. Connectors compensated so that either end may be connected to the load.

Residual SWR: 1.04.

Calibration: Metric, calibrated in cm and mm. Vernier permits reading to 0.1 mm.

Detector Probe: Tunable probe provided for entire frequency range. Detector element may be 1N21B crystal (supplied with instrument), Sperry 821 barretter, Narda N821 barretter, or selected 1/100 amp. instrument fuse.

Weight: Net 18 lbs. Shipping 30 lbs.

Accessories Furnished: 1 803A-76G shorting plug; 1 8A-76H shorting jack.

Accessories Available: AC-16F rf Cable Assembly, $15.00; 475B-34V Barretter Adapter, $2.00; AC-16K Cable Assembly, $6.50; 8A-45 Carrying case 29" long, 9½" high, 9½" wide, $65.00.

Price: 805C, $525.00.

805D

Characteristic Impedance: 46.3 ohms. For use with RG 44/U stub supported coaxial cable. 3/8" outside diameter.

Connections: (One male, one female UG 45/U and UG 46/U.)

Residual SWR: 1.02.

Accessories Furnished: 1 8B-76G shorting plug.

Accessories Available: 8B-76H shorting jack, $6.00; AC-16K; 475B-34V; 8A-45, as described above.

Price: 805D, $600.00.

(Other specifications same as 805C)

Data subject to change without notice.
809B/814B UNIVERSAL PROBE CARRIAGES

Low Cost, Precision Tools for Microwave Readings to 40 GC (KMC)

Advantages:
Universal mounting for different slotted sections
Slotted sections interchange in 30 seconds
Broad usefulness, 3 to 40 GC (KMC)
809B carriage operates with waveguide or coaxial sections
Precision accuracy, highest stability
Simple operation, compact, low cost

Use To Measure:
Characteristics of rf waveguide systems or coaxial transmission lines
Standing wave magnitude and phase
Impedance
System flatness, connector reflection
Degree of antenna match
Percent of transmitted or reflected power

Models 809B and 814B Universal Probe Carriages are precision-built mechanical assemblies designed to operate, respectively, with 810B series and 815B series slotted sections. The combination of 809B Carriage and 810B series sections covers 3.95 to 18.0 GC. Model 814B Carriage and 815B series sections cover 18.0 to 40.0 GC.

These Universal Probe Carriages greatly simplify measurements involving a number of waveguide bands, and eliminate the cost of a special probe for each band. There is an appreciable saving on engineering time since waveguide sections can be interchanged in seconds. Manufacture of both carriages is of highest quality throughout to assure maintenance-free service, positive mechanical positioning of interchangeable waveguides, and precise installation of the mating probes (see pages 170, 171). 809B has a vernier scale permitting readings to 0.1 mm and provision for mounting a dial gauge for greater accuracy. 814B has a dial indicator which may be read directly to 0.01 mm.

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
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 GC.
Slope and Irregularities: 1.01 SWR.
Residual SWR: Less than 1.01.
Waveguide Size: 3” x 1 1/4”.
Length: 12 1/4”.
Price: @ S810A, $450.00.

806B Coaxial Slotted Section

Carriage: Fits @ 809B Universal Probe Carriage.
Frequency Range: 3 to 12 GC.
Connections: Type N, one male, one female. Special fittings provide minimum SWR. Either end may be connected to load. Includes shorting connectors, male and female, for phase measurements.
Residual SWR: Less than 1.04, 3 to 8 GC.
Approximately 1.06, 8 to 10 GC.
Approximately 1.1, 10 to 12 GC.
Pickup Error: Probe pickup variation along line is less than 0.1 db except at extreme ends where variation is less than 0.4 db.
Length: 10”.
Price: @ 806B, $200.00.

814B Universal Probe Carriage

Carriage: Mounts all @ 815B Waveguide Slotted Sections.
Probe Required: @ 446B Untuned Probe (see pages 170, 171).
Probe Travel: 4 centimeters.
Calibration: Metric. Dial indicator reads direct to 0.01 mm.
Accuracy: SWR of 1.02 can be read.
Dimensions: 6 1/4” long, 6 3/4” wide, 6 1/4” high.
Price: @ 814B, $225.00.

810B/815B Slotted Sections

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range GC</th>
<th>Fits</th>
<th>Overall Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>G810B</td>
<td>3.95-5.85</td>
<td>2 x 4</td>
<td>10 1/4</td>
<td>$125.00</td>
</tr>
<tr>
<td>J810B</td>
<td>5.20-8.20</td>
<td>1 1/2 x 4</td>
<td>10 1/4</td>
<td>110.00</td>
</tr>
<tr>
<td>H810B</td>
<td>7.05-10.00</td>
<td>1 1/2 x 4</td>
<td>10 1/4</td>
<td>110.00</td>
</tr>
<tr>
<td>X810B</td>
<td>8.30-12.00</td>
<td>1 1/2 x 4</td>
<td>10 1/4</td>
<td>90.00</td>
</tr>
<tr>
<td>M810B</td>
<td>10.6-18.0</td>
<td>2 1/2 x 6 1/2</td>
<td>10 1/4</td>
<td>130.00</td>
</tr>
<tr>
<td>P810B</td>
<td>12.4-18.0</td>
<td>2 1/2 x 6 1/2</td>
<td>10 1/4</td>
<td>130.00</td>
</tr>
<tr>
<td>K815B</td>
<td>18.0-26.5</td>
<td>5 x 1 1/2</td>
<td>10 1/2</td>
<td>265.00</td>
</tr>
<tr>
<td>R815B</td>
<td>26.5-40.0</td>
<td>5 x 1 1/2</td>
<td>10 1/4</td>
<td>265.00</td>
</tr>
</tbody>
</table>

Discontinuity due to slot results in SWR of less than 1.01. Slope and irregularities: 1.01 SWR.

Data subject to change without notice.
**420A Crystal Detector**

420A couples a Type N coaxial line to a modified 1N26 silicon diode for the detection of rf signals from 10 MC to 12.5 GC (KMC). Careful engineering and construction keep SWR low and give a flat frequency response over the three-decade frequency range. The polarity of the output signal is negative.

**Specifications**

- **Frequency Range:** 10 MC to 12.5 GC.
- **Sensitivity:** Approximately 0.1 v/mw.
- **Frequency Response:** ± 3 db.
- **Maximum SWR:** 5.
- **Input Connector:** Type N Male.
- **Detector Unit:** Modified 1N26 crystal and video resistor, installed.
- **Output Connector:** BNC Female.
- **Size:** 3/4" diameter, 3" long; shipping weight 1 lb.
- **Price:** $420A, $50.00.

**420B Coaxial Reflectometer**

Model 420B is similar in construction to the 420A but is designed specifically for applications where good square-law characteristics are desired. The 420B contains a video load resistor selected to give optimum square-law response. For use in reflectometer systems the 420B is available in matched pairs. A matched pair of 420B's have identical individual specifications but the differences in frequency response and deviations from square-law combined are held within ± 2 db for the pair over the 1 to 4 GC range.

**Specifications**

Same as Model 420A except:
- **Frequency Response:** Single unit same as 420A. Pairs matched within ± 1 db from 1 to 4 GC.
- **Square-law Characteristics:** ± 1 db maximum variation from square-law over 1 to 4 GC and 0 to -40 dbm.
- **Matched Pairs:** Difference in frequency response and square-law characteristics combined (excluding basic sensitivity) do not exceed ± 2 db for the pair.
- **Detector Unit:** Selected crystal with matched video load, factory installed.
- **Price:** $420B, $75.00. Matched pair, $150.00.

**421A Crystal Detectors**

These crystal detectors are accurate square-law devices for waveguide systems from H through P band, 7 to 18 GC. Each detector employs a crystal and video load resistor selected for optimum square-law characteristics. Models 421A are broadband instruments which have a flat frequency response and low SWR over the full waveguide band. Since tuning is unnecessary, measurements may be made at different frequencies rapidly. For reflectometer applications Model 421A Crystal Detectors are available in matched pairs.

**Specifications**

- **Sensitivity:** Approximately 0.05 v/mw.
- **SWR:** 1.5 maximum.
- **Frequency Response:** ± 2 db.
- **Square-law Characteristics:** ± 1 db from 0 to -40 dbm.
- **Detector Unit:** Modified 1N26 crystal and video resistor, installed.
- **Matched Pairs:** Differences in frequency response and square-law characteristics combined (excluding basic sensitivity) do not exceed ± 2 db for the pair.
- **Price:** H421A $95.00, X421A $75.00, M421A $125.00, P421A $150.00.

**422A Crystal Detectors**

These new crystal detectors for K and R band waveguide systems (18 to 40 GC) combine high sensitivity and flat frequency response with accurate square-law characteristics. High sensitivity is obtained by mounting an @-developed silicon diode within the waveguide, and flat response is achieved by making the resonant frequency high. The crystal is mounted at the end of a tapered section of waveguide which matches the crystal to the waveguide impedance to keep SWR low over the entire waveguide band. Models 422A are furnished with an @ AC-67D Feed-Through Termination consisting of a shunt resistor selected for optimum square-law characteristics. This termination may be removed for greater sensitivity.

Model 422A Detectors are available in matched pairs for reflectometer systems. Differences in frequency response plus square-law characteristics (excluding basic sensitivity) do not exceed ± 2 db in a matched pair.

**Specifications**

- **Sensitivity:** 0.05 v/mw.
- **SWR:** 2.5 maximum.
- **Frequency Response:** ± 2 db.
- **Square-law Characteristics:** ± 1 db from -3 to -40 dbm.
- **Maximum Power:** 100 mW.
- **Prices:** K422A (18 to 26.5 GC), $200.00.
- Matched pair, $420.00.
- R422A (26.5 to 40 GC), $200.00.
- Matched pair, $420.00.

Data subject to change without notice.
SLOTTED LINE PROBES, DETECTORS

440A Detector Mount
A simple, easily used instrument for detecting rf energy in coaxial or waveguide systems. In coaxial use it covers all frequencies 2.4 to 12.4 GC(KMC). Uses either 1N21 or 1N23 silicon crystal, 1/100 ampere instrument fuse or Sperry 821 barretter. Simple single stub tuning. Type N rf input connector. BNC output jack. With @ 442B (below) becomes sensitive, easily tuned detector for slotted waveguide sections. (Detector element not furnished as part of instrument.) @ 440A, $85.00.

442B Broadband Probe
@ 442B is designed to be used with the 810 series of slotted waveguide sections, the 806B Coaxial Slotted Line and the 809A Universal Probe Carriage. The probe consists of a small antenna and housing which samples the rf field in the slotted section. Sampled rf appears at a female Type N connector, permitting connection to a receiver, spectrum analyzer or other equipment. Probe penetration is variable and the probe can be locked in place with a friction-type locking ring. Spurious resonances are prevented by poly-iron inserts and the antenna probe is shielded.

A sensitive detector for slotted line measurements is formed when the 442B is used with the 440A Detector Mount. @ 442B, $40.00.

444A Untuned Probe
Model 444A Untuned Probe consists of an antenna and crystal detector in a convenient housing which mounts in an 809B Universal Probe Carriage. Probe penetration into a slotted section can be varied quickly and easily, and a locking ring fixes penetration. The detector is located near the rf pickup, minimizing residual reactances. Hence the instrument has high sensitivity and flat response over a wide range of frequencies from the middle of S-band through P-band. Poly-iron inserts damp spurious resonances.

Specifications
Frequency Range: 3 to 18 GC.
Output Connector: BNC.
Detector: Modified 1N26 Silicon Diode installed.
Replacement Detector: @ 444A-25E crystal.
Price: @ 444A, $40.00.

446B Untuned Probe
Model 446B is a broad band detector and probe which covers K and R-band waveguide frequencies without tuning. It is designed for use with @ 814B Universal Probe Carriage and K and R-band 815B Waveguide Slotted Sections. The detector is a modified 1N53 silicon diode mounted in a housing carefully designed to eliminate spurious resonances. Penetration of the probe into the waveguide is quickly and easily adjusted.

Specifications
Frequency Range: 18 to 40 GC.
Detector: Modified 1N53 silicon diode, installed.
Mounts in: 814B Universal Probe Carriage.
Price: @ 446B, $145.00.

Data subject to change without notice.
Ease and Accuracy for Reflection Coefficient Measurements

Advantages:

Makes waveguide reflection coefficient measurements practical

Allows continuous swept-frequency oscilloscope presentation

Eliminates amplitude-variation error

Operates accurately over 20/1 incident power level range

Simplifies reflectometer setups for faster production checks, wide band system alignment and laboratory investigation

Use For:

Fast reflection coefficient measurements over broad frequency range

SWR measurement independent of rf power level

Reflection coefficient measurements with a reflectometer setup are recognized as an ideal method of evaluating waveguide system performance. The reflectometer setup can save engineering time by eliminating tedious SWR measurements with slotted lines, and when driven by a swept oscillator (such as HP 682C-687C Electronic Sweep Oscillators, pages 144, 145), such setups make possible direct and continuous oscilloscope presentation of reflection coefficient over a wide frequency range.1

The HP 416A Ratio Meter eliminates the two major drawbacks heretofore present in the reflectometer setup by eliminating adjustments to correct for source amplitude variations and eliminating necessity for measuring separately the forward and reverse power.

HP 416A automatically combines forward and reverse signals and displays their ratio directly, irrespective of amplitude variations.

The instrument also is an excellent standing wave indicator for conventional slotted line measurements, and in this application again eliminates the inconvenience of adjustments due to power source amplitude variations.

1 See HP Application Note 42, "Applications of the 416A Ratio Meter."
Reflectometer Setup

Arrangement of a typical reflectometer setup with Model 416A Ratio Meter is shown in Figure 1. (See pages 163-165 for further details in table “Equipment Required for Waveguide for Reflectometer Systems, Coaxial and Waveguide.”) This setup provides continuous and direct oscilloscope presentation of the reflection coefficient of an unknown load at varying frequencies. A swept oscillator supplies power through directional couplers mounted back-to-back. One coupler samples forward power, the other reverse or reflected power. Both couplers are terminated in waveguide detector mounts such as Model 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.](image)

Simple Operation

The Model 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 Model 916 (see page 190) may be employed to establish 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 Model 870A (see page 187) to compensate for the small directivity deficiency of Model 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: 19½” wide, 10½” high, 14” deep behind panel.


Accessories Available: AC-16K Video Cable Assembly, $6.50. AC-60K Barretter Matching Transformer, $80.00.

Price: Model 416A, $550.00 (cabinet); Model 416AR, $535.00 (rack mount).

AC-60K Matching Transformer

This instrument consists of two step-up transformers and appropriate bias circuitry for impedance matching between Model 485 series Barretter Mounts and the Model 416A Ratio Meter. Designed specifically for reflectometer application, Model 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 4½” x 4”, and is 3½” high. Weight is 2 lbs. The instrument is supplied with three cable assemblies for connection to Model 416A. $80.00.

Data subject to change without notice.
Model 803A VHF Bridge provides direct impedance measurements in the VHF range. It measures impedance by sampling the electric and magnetic fields in a transmission line. Two attenuator systems are controlled simultaneously. One responds to the electric field in the transmission line, and the other responds only to the magnetic field in the transmission line. The combination is adjusted for equal output from each attenuator. These two signals are applied to opposite ends of a transmission line. Phase is determined by finding their point of cancellation. (See diagram.) This method effectively overcomes the narrow frequency limitations of conventional bridges, and permits 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 ±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**

### @ 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:**
- Impedance magnitude, better than ± (3 + (F/500)) \%.
- Phase angle better than ± (3 + (F/100)) degrees.

Charts are provided with each instrument so that impedance readings may be corrected to better than ± 2% and phase angle to better than ± 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. (@ Model 608C vhf Signal Generator, pages 134, 135, is ideal for this purpose.)

**RF Detector:** Requires a well-shielded vhf receiver of good sensitivity. (@ Model 417A vhf Detector is designed for this use.)

**Dimensions:**
- Cabinet Mount: 14¼" wide, 15¼" high, 9" deep.
- Weight: Net 28 lbs. Shipping 39 lbs.

**Accessories Furnished:** 1 803A-16D Cable Assembly; 1 803A-16E Cable Assembly; 1 803A-76G Shorting Plug.

**Price:** @ 803A, $900.00.

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This @ instrument is a super-regenerative (AM) receiver covering all frequencies between 10 and 500 MC in 5 bands. Designed for use with the @ 803A Bridge, Model 417A provides a high sensitivity of approximately 5 microvolts over the entire frequency band. It is designed for fast, simple operation, and has a single, convenient frequency control directly calibrated in megacycles.

The instrument is thoroughly shielded and is suitable for general laboratory use, including the determination of approximate frequency, noise, interference, etc. It is lightweight for portability, sturdily built, and compact to occupy a minimum of bench space.

**Specifications**

### @ 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 ± 10%, 50/60 cps, 35 watts.

**Dimensions:** Cabinet Mount: 9¼" wide, 12½" high, 9" deep.

**Weight:** Net 18 lbs. Shipping 31 lbs.

**Accessories Available:**
- AC-16B Cable Assembly, $5.50;
- AC-16K Cable Assembly, $6.50;
- 803A-16E Input Cable Assembly, $9.00.

**Price:** @ 417A, $400.00.

*Data subject to change without notice.*
In microwave communications, the weakest signal that can be detected is usually determined by the amount of noise added by the receiving system. Thus, any decrease in the amount of noise generated in the receiving system will produce an increase in the output signal-to-noise ratio equivalent to a corresponding increase in received signal. From a performance standpoint, an increase in the signal-to-noise ratio by reducing the amount of noise in the receiver is more economical than increasing the received signal level by raising the power of the transmitter. For example, a 5 db improvement in receiver noise figure is equivalent to increasing the transmitter power by 3:1.

The noise appearing at the output of a receiver or an amplifier is the sum of the noise arising from the input termination (source) and the noise contributed by the receiver or amplifier itself. The noise factor is the ratio of the actual output noise power of the device to the noise power which would be available if the device were perfect and merely amplified the thermal noise of the input termination rather than contributing any noise of its own. Noise figure is noise factor expressed in db.

The noise figure of a receiver may be measured by using a signal generator input and an output power (square law) detector. However, this method is time consuming and has the added disadvantage that the effective power gain-bandwidth characteristics of the device must be determined. Moreover, the available signal power may be difficult to determine accurately at the low levels involved.

Automatic noise figure measurements utilizing standard broadband noise sources which supply a noise spectrum of known power, flat with frequency, overcome the drawbacks of the signal generator method. At intermediate and low radio frequencies temperature limited diodes are suitable as excess noise sources, while at microwave frequencies gas discharge tubes in suitable waveguide sections are both accurate and reliable. Hewlett-Packard Noise Figure Meters utilize the noise source technique.

Automatic noise figure measurements with Hewlett-Packard Noise Figure Meters depend upon the periodic insertion of a known excess noise power at the input of the device under test. Subsequent detection of the noise power in later IF stages of the device results in a pulse train of two power levels. The power ratio of these two levels contains the desired noise figure information. For instance, in the simplified diagram of Figure 1, the various contributions of noise power to the output pulse ratio are shown.

\[ F = \left( \frac{T_b - T_s}{T_0} \right) \left( \frac{N_s - N_i}{N_i} \right) \]

Note that the gain-bandwidth factor (GB) has disappeared.

Finally

\[ F_{db} = 10 \log \left( \frac{T_i}{T_s} \right) - 10 \log \left( \frac{N_i}{N_s} \right) \]

The first term is a known quantity and expressed in db of excess noise ratio. For an argon discharge excess noise ratio is 15.2 db:

Then:

\[ F_{db} = 15.2 - 10 \log \left( \frac{N_i}{N_s} \right) \]

Thus the ratio \( N_s / N_i \) contains the desired noise figure information. Hewlett-Packard Models 340B, 342A, and 344A Noise Figure Meters measure noise figure as a function of this ratio.

Model 340B requires a 30 or 60 megacycle input from the device under test. Input circuitry of the 342A features a vhf converter which provides for 5 input frequencies: 30, 60, 70, 105 and 200 megacycles.

The new @ 344A transistorized Noise Figure Meter has been specifically designed for radar system applications where time-shared noise figure measurements are extremely important to assure that radar sets are operating at peak performance. Sensitivity has been made very high to permit noise sources to be decoupled by as much as 20 db from the main transmitter line. Alarm circuitry for remote indication of excessive noise figure, as well as remote metering of noise figure, is available in the 344A.

Hewlett-Packard noise sources are available for all frequencies between 10 megacycles and 18,000 megacycles to allow measurements on all rf devices in this range. Sources have been specifically designed for very low fired and unired SWR to lower coupling ambiguities of the excess noise ratio into the device under test. Waveguide sources have been loaded with resonance suppressing polystyrene loads to eliminate high SWR at points in the band caused by the insertion of the noise tube in waveguide.

For further information on automatic noise measurements, write for Journal Vol. 9, No. 5 and Vol. 10 No. 6-7. Application Note #43 describes radar system noise measurements.
Continuous noise figure measurement on operating radars is simple and reliable with the 344A Noise Figure Meter. Usable with radar receivers in any rf range for which noise sources are available, the 344A permits optimizing the noise figure during operation because of its fast meter response. High sensitivity permits decoupling the noise source up to 20 db from the main transmitter line to minimize degradation of the system.

Model 344A is used with a remote modulator (such as 344A-78A Modulator pictured) and noise source so that high voltage slip-rings are unnecessary. During radar scan the 344A termination is passive, to eliminate spurious reflections appearing as targets. Designed for pulse rep rates of 90 to 500 pps, the 344A may also be used with high resolution, high prf radar sets at rates up to 3,000 pps by employing sampling techniques.

This automatic instrument is transistorized, compact, rugged and militarized for reliability. Optional alarms indicate noise figure above pre-set level or failure in noise source current.

Data subject to change without notice.

Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Frequency:</td>
<td>25 or 30 MC as specified</td>
</tr>
<tr>
<td>Bandwidth:</td>
<td>1 MC</td>
</tr>
<tr>
<td>Input Sensitivity:</td>
<td>Requires 35 db ± 5 db of gain between the noise source and 344A input.</td>
</tr>
<tr>
<td>Input Impedance:</td>
<td>75 ohms nominal. Passive termination during radar scan time.</td>
</tr>
<tr>
<td>Return Loss:</td>
<td>20 db from 20 to 40 MC. (During radar scan time.)</td>
</tr>
<tr>
<td>Accuracy:</td>
<td>± 1/2 db, 0 to 12 db; ± 1 db, 12 to 20 db. Does not include excess noise accuracy.</td>
</tr>
<tr>
<td>Repetition Rate:</td>
<td>Any rate from 90 to 500 pps as specified. (Techniques available for operation above 500 pps.)</td>
</tr>
<tr>
<td>Acceptable Repetition Rate Variation:</td>
<td>Specified rate ± 25%</td>
</tr>
<tr>
<td>Measurement Duty Cycle:</td>
<td>0.075 minimum (measurement time/repetition period)</td>
</tr>
<tr>
<td>Total Duty Factor:</td>
<td>0.075 + (100 nsec) (prf)</td>
</tr>
<tr>
<td>Noise Figure Alarm:</td>
<td>[Optional] Front panel lamp indicates when noise figure exceeds preset value. Contact closure for remote alarm.</td>
</tr>
<tr>
<td>Output:</td>
<td>100 mA into 2,000 to 3,000 ohms at full scale meter reading for remote metering.</td>
</tr>
<tr>
<td>Remote Modulator Operation:</td>
<td>Maximum separation depends on total resistance between modulator and Noise Figure Meter. The trigger path must be less than 15 ohms, the dc supply and ground path must be less than 0.5 ohm.</td>
</tr>
<tr>
<td>Modulator Output:</td>
<td>Sufficient to fire any 344A gas-discharge noise source through 6 ft. cable.</td>
</tr>
<tr>
<td>Temperature Range:</td>
<td>0 to 52° C.</td>
</tr>
<tr>
<td>Humidity:</td>
<td>95%</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>Rack mount: 19&quot; wide, 5 3/4&quot; high, 10 7/8&quot; deep including cable allowance. Modulator: 4 3/4&quot; wide, 3 3/4&quot; high, 4 1/2&quot; deep.</td>
</tr>
<tr>
<td>Power:</td>
<td>115 volts ± 10%, 50 to 1,000 cps, 20 to 40 watts depending on noise source and duty cycle. Mating connector: MS-3106R-10SL-3S.</td>
</tr>
<tr>
<td>Price:</td>
<td>$1,600.00 including one 344A-78A Modulator. (Depends on options and modifications.) $250.00 each.</td>
</tr>
</tbody>
</table>

(Not available in Western Europe.)
Direct-Reading Automatic Instrument Speeds Noise Figure Measurements

Advantages:

- Gives direct noise figure readings while equipment is being operated
- Cuts receiver alignment time to minutes
- Completely automatic measurement
- Easily used by non-technical personnel
- No periodic recalibration needed
- Fast response; ideal for recorder operation

Receiver and component alignment jobs that once took skilled engineers a full hour are now done in 5 minutes by a semi-skilled worker. Receiver noise figure can often be improved over the best adjustment previously possible. For instance, a 3 dB improvement in receiver noise figure is equivalent to doubling transmitter output. Since accurate alignment is easy, equipment is better maintained and peak performance enjoyed regularly.

Above are some of the time-saving, cost cutting advantages of Hewlett-Packard noise figure measuring equipment, Models 340B and 342A, plus a variety of coaxial and waveguide noise sources.

Model 340B Noise Figure Meter, when used with an noise source automatically measures and continuously displays the noise figure of IF or rf amplifiers tuned to 30 or 60 MC and of radar or microwave receivers with intermediate frequencies of 30 and 60 MC. Collectively, noise sources cover frequencies from 10 MC to 18 GC (KMC).

These Noise Sources are described and specifications given on page 179.

Five-Frequency Operation

Model 342A Noise Figure Meter is similar to Model 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 output is connected to the 340B or 342A. The Noise Figure Meter pulses the gas discharge tube. When the tube is ignited the noise level is that of the receiver plus the discharge tube. When the tube is off, the noise level is that of the receiver and its termination. The Noise Figure Meter automatically compares these two conditions and presents noise figure directly on a front panel meter. Rate of response is such that changes in noise figure are constantly indicated on the meter.

Noise Sources
- 343A VHF Noise Source. Specifically for IF and rf amplifier noise measurement, a temperature-limited diode source with broadband noise output from 10 to 600 MC.
- 345B IF Noise Source. Operates at either 30 or 60 MC, as selected by a switch. Another selector permits matching 50, 100, 200 and 400 ohm impedances.
- 347A Waveguide Noise Source. Argon gas discharge tubes mounted in waveguide sections. For all frequencies 2.6 through 18.0 GC, provide uniform noise throughout range; maximum SWR 1.2.
- 349A UHF Noise Source. Argon discharge tubes providing 15.2 db excess noise for automatic noise figure readings on scatter communications receivers, L-band radars, parametric amplifiers, or other devices 400 to 4,000 MC. Also available with 18.2 db excess noise.

Specifications
340B Noise Figure Meter
Frequency Range: Depends on noise source used.
Noise Figure Range: 3 to 30 db, indication to \( \infty \) with Waveguide Noise Source. 0 to 15 db, indication to \( \infty \) with IF Noise Source.
Zero Offset: Permits low values to be read on sensitive external meter.
Accuracy (excluding source accuracy): \( \pm 0.5 \) db, 10 to 25 db; \( \pm 1 \) db, 3 to 10 db; 25 to 30 db with Waveguide Noise Source. \( \pm 0.5 \) db, 0 to 15 db with IF Noise Source.
Input Requirements: -60 dbm to -10 dbm (noise source on). Corresponds to system gain before 340B of approximately 40 to 90 db with 347A or 349A noise source; approximately 50 to 100 db with 343A or 345B noise source.
Input Frequency: 30 and 60 MC. Other frequencies between 10 and 70 MC on special order.
Bandwidth: 1 MC minimum.
Input Impedance: 50 ohms, nominal.
A/C Output: Nominally 0 to \(-6\) volts from rear binding posts.
Recorder Output: Maximum of 1 ma into maximum of 2,000 ohms to operate a recorder or remote meter.
Power Input: 115/230 v, \( \pm 10\% \), 50/60 cps, 185-435 watts depending on line voltage and noise source.
Power Output: Sufficient to operate 347A, 349A, 345B, or 343A Noise Sources.
Dimensions: Cabinet Mount: 203/8" wide, 123/4" high, 141/8" deep. Rack Mount: 19" wide, 101/2" high, 137/8" deep behind panel.
Weight: Cabinet Mount: Net 40 lbs. Shipping 51 lbs.
Rack Mount: Net 34 lbs. Shipping 49 lbs.
Accessories Furnished: @340A-16A, 6' cable connects @340B to an @347A or 349A Noise Source.
Price: @340B, $715.00 (cabinet); @340BR, $700.00 (rack mount). Add $25.00 for special frequencies between 10 and 60 MC. (Not available in Western Europe.)

342A Noise Figure Meter
(Same as 340B except as shown below)
Input Frequency: 30, 60, 70, 105 and 200 MC. 30 MC plus any four frequencies between 38 and 200 MC on special order. Frequency selector switch.
Price: @342A, $815.00 (cabinet); @342AR, $800.00 (rack mount). (Not available in Western Europe.)

343A VHF Noise Source
Frequency Range: 10 to 600 MC.
Excess Noise: 5.2 \( \pm 0.1 \) db, 10 to 200 MC.
Source Impedance: 50 ohms, SWR less than 1.1, 10 to 400 MC; less than 1.3, 400 to 600 MC.
Dimensions: 2%" wide, 2%" high, 5" deep.
Weight: Net \( \frac{3}{4} \) lb. Shipping 2 lbs.
Price: @343A, $100.00.

345B IF Noise Source
(Same as 343A except as shown below)
Price: @345B, $100.00. Add $25.00 for special frequencies.

347A Waveguide Noise Source

<table>
<thead>
<tr>
<th>Model</th>
<th>Range, GC (kMC)</th>
<th>Excess Noise, db</th>
<th>Approx. Length</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S347A</td>
<td>2.6 - 3.95</td>
<td>15.2 ( \pm 0.5 )</td>
<td>22 1/4&quot;</td>
<td>$500.00</td>
</tr>
<tr>
<td>G347A</td>
<td>3.95 - 5.85</td>
<td>15.2 ( \pm 0.5 )</td>
<td>19&quot;</td>
<td>$285.00</td>
</tr>
<tr>
<td>J347A</td>
<td>5.3 - 8.2</td>
<td>15.2 ( \pm 0.5 )</td>
<td>19&quot;</td>
<td>$250.00</td>
</tr>
<tr>
<td>H347A</td>
<td>7.05 - 10</td>
<td>15.2 ( \pm 0.5 )</td>
<td>16&quot;</td>
<td>$225.00</td>
</tr>
<tr>
<td>X347A</td>
<td>8.2 - 12.4</td>
<td>15.2 ( \pm 0.5 )</td>
<td>14 1/4&quot;</td>
<td>$200.00</td>
</tr>
<tr>
<td>P347A</td>
<td>12.4 - 18</td>
<td>15.2 ( \pm 0.5 )</td>
<td>14 1/4&quot;</td>
<td>$250.00</td>
</tr>
</tbody>
</table>

SWR all models, fired or unfired, 1.2 max., less than 1.1 average.

349A UHF Noise Source
Frequency Range: 400 to 4,000 MC; wider with correction.
Excess Noise: 15.2 \( \pm 0.5 \) db, including insertion loss
SWR: Up to 2,600 MC: less than 1.35 (fired); less than 1.5 (unfired)
2,600 to 3,000 MC: less than 1.5 (fired); less than 1.5 (unfired)
3,000 to 4,000 MC: less than 2.0 (fired); less than 3.0 (unfired)
(Source terminated in coaxial load with less than 1.05 SWR.)
Dimensions: 13" long, 3/4" wide, 2" high.
Weight: Net approximately 314 lbs. Shipping 6 lbs.
Price: @349A, $325.00.

Data subject to change without notice.
### 382A Waveguide Attenuators

Operation of these direct-reading precision attenuators depends on mathematical law instead of the resistivity of attenuating material. Accurate, stable attenuation from 0 to 50 db is assured full range, despite varying temperature and humidity conditions. The instruments feature high power handling capacity and large, easily read dials. Insertion loss at zero setting is less than 1 db, and SWR is less than 1.15. Accuracy is \( \pm 0.1 \) db, whichever is greater, including both calibration and frequency error.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range (MC)</th>
<th>Capacity</th>
<th>Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>G382A</td>
<td>3.95 - 5.95</td>
<td>15</td>
<td>31 1/8</td>
<td>$500.00</td>
</tr>
<tr>
<td>C382A</td>
<td>4.7 - 7.0</td>
<td>10</td>
<td>23 1/4</td>
<td>$800.00</td>
</tr>
<tr>
<td>J382A</td>
<td>6.3 - 8.2</td>
<td>10</td>
<td>25</td>
<td>$375.00</td>
</tr>
<tr>
<td>H382A</td>
<td>7.0 - 10.0</td>
<td>10</td>
<td>19-15/16</td>
<td>$350.00</td>
</tr>
<tr>
<td>X382A</td>
<td>8.7 - 17.4</td>
<td>10</td>
<td>15%</td>
<td>$775.00</td>
</tr>
<tr>
<td>M382A</td>
<td>10.0 - 15.0</td>
<td>10</td>
<td>15</td>
<td>$300.00</td>
</tr>
<tr>
<td>F382A</td>
<td>12.4 - 18.0</td>
<td>5</td>
<td>12 1/4</td>
<td>$275.00</td>
</tr>
<tr>
<td>K382A</td>
<td>18.0 - 26.5</td>
<td>2</td>
<td>7 5/8</td>
<td>$475.00</td>
</tr>
<tr>
<td>R382A</td>
<td>26.5 - 40.0</td>
<td>1</td>
<td>7 1/2</td>
<td>$500.00</td>
</tr>
</tbody>
</table>

For all models: Calibrated range, 0 to 50 db. Phase shift, less than 3° variation from 0 to 50 db. Attenuation at zero setting, less than 1 db.

Data subject to change without notice.

### 393A/394A Coaxial Attenuators

These multi-purpose instruments provide a convenient means of obtaining accurate attenuation in high power co-axial systems in the 500 to 1,000 MC range (393A) and the 1,000 to 2,000 MC range (394A). They are designed to provide precise, continuously variable attenuation as high as 120 db. Good directivity in the 10 to 40 db range makes the instruments valuable for directional coupler power sampling in high power systems, or for variable isolated coupling of local oscillators in mixer applications.

Dials are direct-reading over the full frequency range. Two low power loads are furnished (3908A) for operating levels up to 0.5 watts.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>393A</th>
<th>394A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>500-1,000 MC</td>
<td>1,000-2,000 MC</td>
</tr>
<tr>
<td>Attenuation or Coupling</td>
<td>0 - 120 db, continuously variable</td>
<td>0 - 120 db, continuously variable</td>
</tr>
<tr>
<td>Accuracy (between matched generator and load)</td>
<td>( \pm 0.1 ) db or ( \pm 1 ) % of dial value, whichever is greater</td>
<td>( \pm 0.1 ) db or ( \pm 2 ) % of dial value, whichever is greater</td>
</tr>
<tr>
<td>Nominal Impedance</td>
<td>50 ohms</td>
<td>50 ohms</td>
</tr>
<tr>
<td>SWR</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Directivity (dial setting: 15-40 db, loads less than 1.05 SWR)</td>
<td>15 db</td>
<td>10 db</td>
</tr>
<tr>
<td>Maximum Voltage</td>
<td>500 volts, peak</td>
<td></td>
</tr>
<tr>
<td>Average Power</td>
<td>0.5 watts (with furnished loads)</td>
<td></td>
</tr>
<tr>
<td>Maximum Average Power</td>
<td>200 watts (requires external high-power loads)</td>
<td></td>
</tr>
<tr>
<td>Size and Weight</td>
<td>5 1/2* x 12 x 2 3/4* 6 lbs.</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>$420.00</td>
<td>$420.00</td>
</tr>
</tbody>
</table>
370 Fixed Waveguide Attenuators

These attenuators are waveguide sections providing fixed amounts of attenuation. They are useful in reducing power flowing in a waveguide system, reducing reflection of loads or sources, or isolating parts of a waveguide system. They consist of rectangular waveguide sections containing a rigidly mounted resistive strip. The resistive strip has been carefully designed to keep SWR low and attenuation constant over the full waveguide band. Accuracy over the band is within ± 20% of the nominal attenuation.

372 Precision Attenuators

Model 372 Precision Attenuators are rugged, ultra-dependable, broad band instruments, which remain precisely calibrated regardless of humidity, temperature or other ambient conditions—or aging of the instrument. Models with either 10 or 20 db of attenuation are offered. (See table.) Calibration within ± 0.1 db may be obtained at 10 points across the band. (Extra cost option.) SWR is 1.05:1; mean attenuation is within ± 0.4 db (± 0.7 db for K and R-bands) from nominal; variation across band is less than ± 0.5 db from mean.

375A Variable Flap Attenuators

Variable flap attenuators provide a simple, convenient means of adjusting waveguide power level, or isolating source and load. They consist of a slotted section in which a matched resistive strip is inserted a variable amount. The degree of strip penetration determines attenuation. A dial shows average reading over the frequency band, and a dust cover with shielded braid reduces external radiation and eliminates hand capacity effects. Attenuation is variable 0 to 20 db. Dial calibration is accurate within ± 1 db from 0 to 10 db, ± 2 db from 10 to 20 db.

S380A Calibrated Variable Attenuator

Model S380A, for setting exact power level or measuring attenuation, consists of a waveguide section with an attenuating plate parallel to the narrow face of the waveguide. A micrometer adjustment moves the plate across the waveguide, increasing attenuation from 0 to 10 db. Maximum average power is 1 watt, peak power 1 kilowatt; frequency range 2 to 60 Gc (KMC), insertion loss less than 0.5 db. Calibration accuracy is ± 0.3 db at 3 Gc. Calibration for other frequencies available on request. Price $260.00.

Specifications, 370, 372, 375 Attenuators

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>370A</td>
<td>1.0</td>
<td>12</td>
<td>$100.00</td>
<td>372</td>
<td>2.4 - 3.95</td>
<td>10/20</td>
<td>3 x 1/2</td>
<td>2</td>
<td>375A</td>
<td>2.0</td>
<td>14/16</td>
</tr>
<tr>
<td>372</td>
<td>1.0</td>
<td>10/20</td>
<td>85.00</td>
<td>372</td>
<td>3.95 - 5.85</td>
<td>10/20</td>
<td>3 x 1/2</td>
<td>2</td>
<td>375A</td>
<td>2.0</td>
<td>14/16</td>
</tr>
</tbody>
</table>

Maximum SWR 1.15 for all models. (Note: Model number suffix indicates db attenuation of 370 and 372 series attenuators. Suffix "A" 3 db. Suffix "B" 6 db. Suffix "C" 10 db. Suffix "D" 20 db. Model 372's are available in 10 and 20 db models only. K and R-band units are available with circular flanges (UG-425/U for K-band, UG-381/U for R-band). Specify by adding suffix "C" to model number; i.e., X370CC is a 10 db attenuator with UG-381/U flanges for 26.5 to 40 Gc range.

Data subject to change without notice.
**532/536A FREQUENCY METERS**

**Precision General-Purpose Meters for Lab or Production Use**

## Specifications

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Overall Accuracy (%)</th>
<th>Frequency Range GC (KMC)</th>
<th>Dial Calib. Accuracy (%)</th>
<th>Calibration Increment (MC)</th>
<th>Max. Temp. Coefficient % per °C</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>536A</td>
<td>0.14</td>
<td>1.4 (coax)</td>
<td>0.10</td>
<td>1</td>
<td>0.0016</td>
<td>$500.00</td>
</tr>
<tr>
<td>G532A</td>
<td>0.065</td>
<td>3.95 - 5.85</td>
<td>0.033</td>
<td>2</td>
<td>0.0012</td>
<td>$325.00</td>
</tr>
<tr>
<td>J532A</td>
<td>0.065</td>
<td>5.30 - 8.20</td>
<td>0.033</td>
<td>2</td>
<td>0.0012</td>
<td>$300.00</td>
</tr>
<tr>
<td>H532A</td>
<td>0.075</td>
<td>7.05 - 10.0</td>
<td>0.040</td>
<td>2</td>
<td>0.0015</td>
<td>$250.00</td>
</tr>
<tr>
<td>X532B</td>
<td>0.080</td>
<td>0.20 - 12.4</td>
<td>0.050</td>
<td>5</td>
<td>0.0010</td>
<td>$175.00</td>
</tr>
<tr>
<td>M532A</td>
<td>0.085</td>
<td>10.0 - 15.0</td>
<td>0.053</td>
<td>5</td>
<td>0.0012</td>
<td>$275.00</td>
</tr>
<tr>
<td>P532A</td>
<td>0.100</td>
<td>12.4 - 18.0</td>
<td>0.068</td>
<td>5</td>
<td>0.0012</td>
<td>$210.00</td>
</tr>
<tr>
<td>K532A</td>
<td>0.110</td>
<td>18.0 - 24.5</td>
<td>0.077</td>
<td>10</td>
<td>0.0013</td>
<td>$280.00</td>
</tr>
<tr>
<td>R532A</td>
<td>0.120</td>
<td>24.5 - 40.0</td>
<td>0.083</td>
<td>10</td>
<td>0.0017</td>
<td>$300.00</td>
</tr>
</tbody>
</table>

K and R band models available with circular flange adapters; specify K532AC and R532AC respectively.

*Because of the wide frequency range of the J532A, frequencies from 7.6 to 8.2 GC can excite the \( TE_{112} \) mode when the dial is set between 5.3 and 5.6 GC.

Data subject to change without notice.

Model 532 and 536A Frequency Meters are wide band, direct reading instruments offering quality construction, convenience and outstanding value at low cost. Frequency is read directly in GC (KMC) with high accuracy as indicated on the adjoining table. No interpolation or charts are required. Overall accuracy includes a temperature variation of \( \pm 10^\circ \) C from 23° C and \( \pm 0.02\% \) for 0 to 100% humidity change.

The instrument comprises a special section mounting a high Q resonant cavity tuned by a choke plunger. No sliding contacts are used, and the waveguide section transmits virtually full power at resonance. A 1 dB or greater dip in output indicates resonance. Tuning is by a precision lead screw, spring-loaded to eliminate backlash. Readability is enhanced by a long, effective spiral scale length and a scale calibrated in small frequency increments. For example, Model X532B has an effective scale length of 77" and is calibrated in 5 MC increments. Resettability is 0.01% (1 MC at 10 GC).

For measurements of 1 to 4 GC on coaxial circuits, \( \Phi \) 536A Coaxial Frequency Meter is offered. Specifications of this high resolution, broadband, direct reading instrument are listed in the table.
For power monitoring, mixing and power sampling with tightly controlled coupling, new 760D/761D Dual Directional Couplers offer very broad band coverage of the vhf-uhf frequencies. Model 760D covers 250-1,000 MC; Model 761D, 1 to 4 GC (KMC). High directivity and flat frequency response make these units ideal for reflectometer systems.

With a power capacity of 50 watts CW and 10 kw peak, and low insertion loss, 760D/761D Couplers can be installed permanently in coaxial systems for power monitoring. Since they are dual devices, the power meter or detector may be connected to either the "incident" or "reflected" terminals to simplify maximizing forward power.

Compact size and rugged aluminum construction add to the usefulness of these instruments.

**764D/767D Dual Directional Couplers**

Similar specifications are available in single octave coverage in the 764D/767D Couplers. Four instruments collectively cover frequencies from 216 to 4,000 MC for applications requiring less bandwidth.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range</th>
<th>Mean Coupling</th>
<th>Coupling Variation</th>
<th>Directivity (minimum)</th>
<th>Primary SWR (max)</th>
<th>Secondary SWR (max)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>760D</td>
<td>250 - 1,000 MC</td>
<td>20 ± ½ db</td>
<td>± ½ db</td>
<td>35 db</td>
<td>1.20</td>
<td>1.25</td>
<td>$200.00</td>
</tr>
<tr>
<td>761D</td>
<td>1 - 4 GC (KMC)</td>
<td>20 ± ½ db</td>
<td>± ½ db</td>
<td>30 db</td>
<td>1.25</td>
<td>1.30</td>
<td>185.00</td>
</tr>
<tr>
<td>764D</td>
<td>216 - 450 MC</td>
<td>20 ± ½ db</td>
<td>± 1 db</td>
<td>30 db</td>
<td>1.10</td>
<td>1.20</td>
<td>160.00</td>
</tr>
<tr>
<td>765D</td>
<td>450 - 945 MC</td>
<td>20 ± ½ db</td>
<td>± 1 db</td>
<td>30 db</td>
<td>1.15</td>
<td>1.20</td>
<td>160.00</td>
</tr>
<tr>
<td>766D</td>
<td>940 - 1,975 MC</td>
<td>20 ± ½ db</td>
<td>± 1 db</td>
<td>26 db</td>
<td>1.20</td>
<td>1.30</td>
<td>150.00</td>
</tr>
<tr>
<td>767D</td>
<td>1.9 - 4.0 GC</td>
<td>20 ± ½ db</td>
<td>± 1 db</td>
<td>26 db</td>
<td>1.25</td>
<td>1.50</td>
<td>150.00</td>
</tr>
</tbody>
</table>

Power handling capacity: all couplers 50 watts CW, 10 kw peak.
Type N connectors throughout. All couplers include 803A-766 Shorting Plug for reflectometer calibration.

*Data subject to change without notice.*
Easy-to-Use, Precision Couplers Simplify Waveguide Measurements

Directional couplers such as § 752 and § 750 are important tools in waveguide measurements. They may be used to monitor power, measure reflections, mix signals or isolate signal sources or wavemeters.

Ideally, power flowing in one (the forward) direction of the main guide is coupled to the output of the auxiliary guide while power flowing in the other (reverse) direction is not coupled to the output of the auxiliary guide. The ratio, expressed in db, of forward power in the main guide to the power out of the auxiliary guide is the "coupling factor." Example: 20 db coupling means a ratio of powers of 100:1.

In practice, some reverse power in the main guide is coupled to the output of the auxiliary guide and the ratio, also in db, of the powers out of the auxiliary guide from equal forward and reverse powers in the main guide is the coupler's "directivity."

§ 752 Multi-Hole Couplers

In this § Coupler, the broad faces of two waveguides are joined together. Coupling is obtained from a series of graduated holes. (Figure 1.) These holes are accurately machined along the broad faces of the waveguides. Power flowing down the primary guide couples through the holes, exciting waves which propagate in both directions in the auxiliary. Directivity is explained by reference to the two-aperture coupler. (See Figure 2.) The coupling holes are spaced 1/4 wavelength apart, and thus waves traveling in the reverse direction are out of phase and cancel each other. Waves traveling in a forward direction reinforce each other. The power coupled into the auxiliary arm by a wave traveling in the main guide in the opposite direction is absorbed by a resistive termination.

The auxiliary guide of Model 752 is terminated in a low reflection load at one end and in a precision cover flange at the other end. Detection of power in the auxiliary arm can be achieved readily by connecting a crystal detector or bolometer mount to the open end.

Figure 1. Construction, § 752 Directional Couplers.

Figure 2. Cross-section, two-aperture coupler.
752 has an overall directivity of better than 40 db (including reflection from built-in termination and flange) over the entire range of the guide. The coupling factors are 3, 10, and 20 db; accuracy of mean coupling level is ± 0.4 db (± 0.7 db for K and R band instruments) and frequency sensitivity of coupling is ± 0.5 db over the waveguide frequency range.

![Typical Overall Coupler Directivity](image1.png)

**Figure 3.** Characteristics, 752 Coupler - 10 db model.

**Uses and Advantages**

Because of its high directivity (Figure 3) this equipment is particularly suited for measurement of very small reflections, for rapidly adjusting transmission line flatness over the entire frequency range of the guide or for broadband reflectometer applications. (See pages 163-165 for discussion of reflectometer measurements.) With Model 752, a single oscilloscope presentation of SWR vs. frequency is easily made. In this operation, output of the auxiliary arm of the coupler is detected, amplified and applied to the vertical plates of the oscilloscope tube. The frequency applied to the system is swept and a voltage proportional to this frequency is applied to the horizontal plates of the oscilloscope. The resulting trace is a plot of reflection vs. frequency.

**750 Cross-Guide Couplers.** For many applications the precision multi-hole coupler is not required. An inexpensive and compact instrument suited to numerous laboratory tests is **750 Cross-Guide Coupler.**

It consists of two waveguide sections joined at right angles across their broad faces. Coupling factors of 20 or 30 db are available and connections may be made to both ends of the main and auxiliary guides. This provides a "four-terminal" network of maximum usefulness and versatility. The unit is well suited for power monitoring, for isolation and mixing powers.

**Specifications**

**750 Multi-Hole Couplers**

<table>
<thead>
<tr>
<th>Model</th>
<th>Coupling (db)</th>
<th>Frequency Range GC (KHz)</th>
<th>Waveguide Size (in.)</th>
<th>Physical Size (in.)</th>
<th>Shipping Weight (lbs.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S750D</td>
<td>20</td>
<td>2.4 - 3.95</td>
<td>3 x 1/2</td>
<td>9 x 9</td>
<td>18</td>
<td>$150.00</td>
</tr>
<tr>
<td>S750E</td>
<td>30</td>
<td>2.4 - 3.95</td>
<td>3 x 1/2</td>
<td>9 x 9</td>
<td>18</td>
<td>$150.00</td>
</tr>
<tr>
<td>G750D</td>
<td>20</td>
<td>3.75 - 5.85</td>
<td>2 x 1</td>
<td>4 x 6</td>
<td>7</td>
<td>120.00</td>
</tr>
<tr>
<td>G750E</td>
<td>30</td>
<td>3.75 - 5.85</td>
<td>2 x 1</td>
<td>4 x 6</td>
<td>7</td>
<td>120.00</td>
</tr>
<tr>
<td>J750D</td>
<td>20</td>
<td>4.85 - 8.20</td>
<td>1 1/4 x 3/8</td>
<td>5 x 5</td>
<td>4</td>
<td>85.00</td>
</tr>
<tr>
<td>J750E</td>
<td>30</td>
<td>4.85 - 8.20</td>
<td>1 1/4 x 3/8</td>
<td>5 x 5</td>
<td>4</td>
<td>85.00</td>
</tr>
<tr>
<td>M750D</td>
<td>20</td>
<td>7.06 - 10.0</td>
<td>1 3/4 x 3/8</td>
<td>4 x 3</td>
<td>3</td>
<td>75.00</td>
</tr>
<tr>
<td>M750E</td>
<td>30</td>
<td>7.06 - 10.0</td>
<td>1 3/4 x 3/8</td>
<td>4 x 3</td>
<td>3</td>
<td>75.00</td>
</tr>
<tr>
<td>H750D</td>
<td>20</td>
<td>8.2 - 12.4</td>
<td>2 x 2</td>
<td>3 x 3</td>
<td>2</td>
<td>60.00</td>
</tr>
<tr>
<td>H750E</td>
<td>30</td>
<td>8.2 - 12.4</td>
<td>2 x 2</td>
<td>3 x 3</td>
<td>2</td>
<td>60.00</td>
</tr>
</tbody>
</table>

**752 Multi-Hole Couplers**

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency GC (KHz)</th>
<th>Fits Waveguide Size (in.)</th>
<th>Mean Coupling Accuracy (db)</th>
<th>SWR Main Guide</th>
<th>Average Power Aux. (w)</th>
<th>A</th>
<th>Length (in.)</th>
<th>C</th>
<th>D</th>
<th>Shipping Weight (lbs.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2.4 - 3.95</td>
<td>3 x 1/2</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.4</td>
<td>48</td>
<td>48</td>
<td>40</td>
<td>$250.00</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>3.75 - 5.85</td>
<td>2 x 1</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.2</td>
<td>33</td>
<td>34</td>
<td>34</td>
<td>250.00</td>
<td></td>
</tr>
<tr>
<td>J*</td>
<td>5.85 - 8.2</td>
<td>1 1/4 x 3/8</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.1</td>
<td>26.5</td>
<td>25-1/16</td>
<td>25-1/16</td>
<td>160.00</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>7.06 - 10.0</td>
<td>1 3/4 x 3/8</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.1</td>
<td>18</td>
<td>17/8</td>
<td>17/8</td>
<td>160.00</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>8.2 - 12.4</td>
<td>1 x 1/2</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.0</td>
<td>16-1/16</td>
<td>15-1/16</td>
<td>15-1/16</td>
<td>160.00</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>10 - 15</td>
<td>8 x 0.475</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.0</td>
<td>16-1/16</td>
<td>15-1/16</td>
<td>15-1/16</td>
<td>160.00</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>12.4 - 18.0</td>
<td>2 x 2</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.0</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>160.00</td>
<td></td>
</tr>
<tr>
<td>K1</td>
<td>18.0 - 26.5</td>
<td>1 1/4 x 1/2</td>
<td>± 0.4</td>
<td>1.1, 1.05</td>
<td>2</td>
<td>0.0</td>
<td>12-1/16</td>
<td>11-1/16</td>
<td>11-1/16</td>
<td>160.00</td>
<td></td>
</tr>
<tr>
<td>K2</td>
<td>30.0 - 40.0</td>
<td>1 3/4 x 1/2</td>
<td>± 0.7</td>
<td>1.1, 1/2</td>
<td>1/2</td>
<td>0.0</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>160.00</td>
<td></td>
</tr>
</tbody>
</table>

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.
5. *J752 couplers operate to 5.2 GC with reduced performance.

**Data subject to change without notice.**
281A Waveguide-Coax Adapter, for convenient transmission between waveguide and coax systems. Power may be fed in either direction. SWR less than 1.25 over full range of each adapter. Probes with low-loss dielectric sheath transform waveguide impedance into coax cable impedance. Type N and plain AN flange connections.

290A Cover to Choke Flange, a short waveguide section with precision cover flange on one end, choke flange on the other. Simulates actual operating conditions when inserted between waveguide test equipment and choke flange system having a non-precision cover flange.

292A Waveguide to Waveguide Adapter, tapered lengths of waveguide to connect a given size waveguide to the next size larger or smaller. Five models provide band interchange as indicated on chart. Prefix letters indicate band mating.

281A/290A/292A ADAPTERS, 360/362A LOW PASS FILTERS

<table>
<thead>
<tr>
<th>281A Adapters</th>
<th>290A Adapters</th>
<th>Frequency Range GC(KMC)</th>
<th>Fits Waveguide Size (in.)</th>
<th>292A Adapters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Price</td>
<td>Model</td>
<td>Price</td>
<td>Length (in.)</td>
</tr>
<tr>
<td>S281A</td>
<td>$50.00</td>
<td>G290A</td>
<td>$55.00</td>
<td>2</td>
</tr>
<tr>
<td>G281A</td>
<td>40.00</td>
<td>G290A</td>
<td>55.00</td>
<td>2</td>
</tr>
<tr>
<td>J281A</td>
<td>35.00</td>
<td>J290A</td>
<td>40.00</td>
<td>1 1/2</td>
</tr>
<tr>
<td>H281A</td>
<td>30.00</td>
<td>H290A</td>
<td>35.00</td>
<td>1 3/4</td>
</tr>
<tr>
<td>X281A</td>
<td>25.00</td>
<td>X290A</td>
<td>20.00</td>
<td>1 1/2</td>
</tr>
</tbody>
</table>

*SWR 1.30 from 5.3 to 5.5 GC.

360 Low Pass Filters, eliminate harmonics, permit transmission of energy at a single known frequency, 700 to 4,100 MC. No spurious responses up to 3 times cut-off frequency. Type N fittings.

Cut-Off Frequency: Model 360A, 700 MC; 360B, 1,200 MC; 360C, 2,200 MC; 360D, 4,100 MC.
Insertion Loss: Not over 3 db throughout pass band.
Rejection: 50 db or more attenuation at 1.25 x (Cut-Off Frequency).
Nominal Impedance: 50 ohms through pass band. Should be matched for optimum performance.
SWR: Less than 1.5:1 to within 100 MC of cut-off for 360A and 360B; 200 MC of cut-off for 360C; 500 MC of cut-off for 360D.

Physical Dimensions:
<table>
<thead>
<tr>
<th>Model No.</th>
<th>360A</th>
<th>360B</th>
<th>360C</th>
<th>360D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Overall</td>
<td>10 1/8</td>
<td>7-1/4</td>
<td>10-1/2</td>
<td>10-1/4</td>
</tr>
<tr>
<td>Outer Diameter</td>
<td>5/8</td>
<td>5/8</td>
<td>5/8</td>
<td>5/8</td>
</tr>
<tr>
<td>Center Line to Male End</td>
<td>2 5/16</td>
<td>2 5/16</td>
<td>2 5/16</td>
<td>2 5/16</td>
</tr>
<tr>
<td>Center Line to Female End</td>
<td>2 1/4</td>
<td>2 1/4</td>
<td>2 1/4</td>
<td>2 1/4</td>
</tr>
</tbody>
</table>

Accessories Available: AC-12F RF Cable Assembly, $15.00; AC-16C RF Cable Assembly, $38.00.
Price: @ 360A/B, $50.00; @ 360C/D, $50.00.

362A Waveguide Low Pass Filters, eliminate harmonics, permit transmission of energy at a single frequency, 8.2-40 GC(KMC).

<table>
<thead>
<tr>
<th>Model</th>
<th>Pass Band (GC)</th>
<th>Stop Band (GC)</th>
<th>Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>X362A</td>
<td>8.2 - 12.4</td>
<td>16 - 37.5</td>
<td>5-1/32</td>
<td>$325.00</td>
</tr>
<tr>
<td>M362A</td>
<td>10 - 15.5</td>
<td>19 - 47</td>
<td>4-15/32</td>
<td>350.00</td>
</tr>
<tr>
<td>P362A</td>
<td>12.4 - 18</td>
<td>23 - 54</td>
<td>3-11/16</td>
<td>350.00</td>
</tr>
<tr>
<td>N362A</td>
<td>15 - 21</td>
<td>27 - 63</td>
<td>3-1/16</td>
<td>350.00</td>
</tr>
<tr>
<td>R362A</td>
<td>26.5 - 40</td>
<td>47 - 120</td>
<td>1-21/32</td>
<td>385.00</td>
</tr>
</tbody>
</table>

SWR (pass band): 1.5.
Pass Band Insertion Loss: Less than 1 db (1.5 db for R362A).
Stop Band Rejection: At least 40 db.
Flange: Flat cover.

Data subject to change without notice.
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

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency (GHz)</th>
<th>Accuracy</th>
<th>Insertion Loss</th>
<th>Loss Variation with Phase Setting</th>
<th>Max. Average Input Power</th>
<th>Approx. Length</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>J885A</td>
<td>5.3 - 6.2</td>
<td>$3^\circ$</td>
<td>2 db max.</td>
<td>0.4 db max.</td>
<td>10 watts</td>
<td>28&quot;</td>
<td>$550.00</td>
</tr>
<tr>
<td>X885A</td>
<td>8.2 - 12.4</td>
<td>$2^\circ$</td>
<td>2 db max.</td>
<td>0.4 db max.</td>
<td>10 watts</td>
<td>18 1/2&quot;</td>
<td>$425.00</td>
</tr>
<tr>
<td>P885A</td>
<td>12.4 - 18.0</td>
<td>$4^\circ$</td>
<td>3 db max.</td>
<td>0.5 db max.</td>
<td>5 watts</td>
<td>12 1/2&quot;</td>
<td>$600.00</td>
</tr>
</tbody>
</table>

All models, SWR (maximum): 1.35. For small phase differences accuracy is as tabulated or 10%, whichever is less.

*Data subject to change without notice.*
**910A/B Low Power Termination**

Model 910 is designed for terminating waveguide systems operating at average powers of about 1 watt. The terminations are carefully designed to absorb virtually all of the applied power and assure a low SWR. They may be used wherever a matched load is required, as in the measurements of reflection, discontinuities or obstacles in waveguide systems. They are also for use with directional couplers or hybrid tees.

**912A High Power Termination**

This termination is similar to Model 910A but is designed for waveguide systems operating at high powers. Since these terminations readily absorb large amounts of power, they are useful as dummy loads in testing vacuum tube characteristics, transmitter output, etc. Model 912A Terminations contain a high loss material which absorbs power and is carefully tapered to keep SWR low. Power is dissipated by cooling fins. When the termination is operated at 50% or more of rated power, fins should be forced-air cooled.

**908A Coaxial Termination**

Model 908A is a low reflection load for terminating 50 ohm coaxial systems in their characteristic impedance. From dc to 4,000 MC, its SWR is less than 1.05, facilitating use in terminating coaxial devices during most SWR measurements, or as a production line impedance standard.

908A is also a useful accessory for the 918A 1,000 MC Oscilloscope and 411A RF Millivoltmeter. When used with the T adapters available for those instruments, it allows the observation of waveforms or the measurement of voltage at the end of a cable with Type N fittings.

**Specifications**

- **Impedance**: 50 ohms.
- **SWR**: Less than 1.05.
- **Frequency Range**: DC to 4,000 MC.
- **Power Rating**: 1/2 watt.
- **Connector**: Type N male.
- **Size**: Length 2".
- **Weight**: 3 oz.
- **Price**: $35.00.

---

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. SWR</th>
<th>Average Power Watts</th>
<th>Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S910A</td>
<td>1.04</td>
<td>2</td>
<td>10 1/4</td>
<td>$75.00</td>
</tr>
<tr>
<td>G910A</td>
<td>1.04</td>
<td>2</td>
<td>6 1/2</td>
<td>$65.00</td>
</tr>
<tr>
<td>C910A</td>
<td>1.02</td>
<td>2</td>
<td>8 5/16</td>
<td>75.00</td>
</tr>
<tr>
<td>J910A</td>
<td>1.02</td>
<td>1</td>
<td>8 3/16</td>
<td>45.00</td>
</tr>
<tr>
<td>H910A</td>
<td>1.02</td>
<td>1</td>
<td>5</td>
<td>40.00</td>
</tr>
<tr>
<td>X910B</td>
<td>1.02</td>
<td>1</td>
<td>6 1/2</td>
<td>35.00</td>
</tr>
<tr>
<td>P910A</td>
<td>1.02</td>
<td>1</td>
<td>4 1/4</td>
<td>40.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. SWR</th>
<th>Average Power Watts</th>
<th>Length (in.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S912A</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
<tr>
<td>G912A</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
<tr>
<td>C912A</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
<tr>
<td>J912A</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
<tr>
<td>H912A</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
<tr>
<td>X912B</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
<tr>
<td>P912B</td>
<td>1.1</td>
<td>100</td>
<td>15 1/4</td>
<td>$200.00</td>
</tr>
</tbody>
</table>

*Data subject to change without notice.*
WAVEGUIDE, COAXIAL 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 \( \frac{1}{2} \) 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

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range GC(KMC)</th>
<th>Fits Waveguide Size (in.)</th>
<th>Overall Length (in.)</th>
<th>Average Power (watts)</th>
<th>Shipping Weight (lbs.)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>914A</td>
<td>2.60 - 3.95</td>
<td>3 x ( \frac{1}{2} )</td>
<td>25%</td>
<td>2</td>
<td>21</td>
<td>$100.00</td>
</tr>
<tr>
<td>914A</td>
<td>3.95 - 5.85</td>
<td>2 x 1</td>
<td>17%</td>
<td>2</td>
<td>10</td>
<td>75.00</td>
</tr>
<tr>
<td>914B</td>
<td>5.30 - 8.0</td>
<td>1/2 x 3/4</td>
<td>15%</td>
<td>2</td>
<td>9</td>
<td>70.00</td>
</tr>
<tr>
<td>914C</td>
<td>7.05 - 10.0</td>
<td>1/4 x 5/8</td>
<td>11%</td>
<td>1</td>
<td>4</td>
<td>60.00</td>
</tr>
<tr>
<td>914D</td>
<td>8.20 - 12.4</td>
<td>1 x ( \frac{1}{2} )</td>
<td>10%</td>
<td>1</td>
<td>3</td>
<td>50.00</td>
</tr>
<tr>
<td>914E</td>
<td>10.15 - 15.0</td>
<td>0.5 x 0.475</td>
<td>8%</td>
<td>1</td>
<td>1</td>
<td>45.00</td>
</tr>
<tr>
<td>914F</td>
<td>12.4 - 18.0</td>
<td>0.703 x 0.391</td>
<td>9%</td>
<td>( \frac{1}{2} )</td>
<td>1</td>
<td>55.00</td>
</tr>
<tr>
<td>914G</td>
<td>18.0 - 26.5</td>
<td>0.500 x 0.250</td>
<td>8%</td>
<td>( \frac{1}{2} )</td>
<td>1</td>
<td>250.00</td>
</tr>
<tr>
<td>914H</td>
<td>26.5 - 40.0</td>
<td>0.360 x 0.220</td>
<td>7%</td>
<td>( \frac{1}{2} )</td>
<td>1</td>
<td>250.00</td>
</tr>
</tbody>
</table>

*Circular flanges (UG-425/U for K-band, UG-381/U for R-band) are available. Specify K914BC or R914BC respectively.

916 Standard Reflections

Model 916 Standard Reflections are precision loads used to set up exact reflections for standardizing SWR measuring setups.

The instruments consist of a precision machined aluminum casting whose inside wide dimension is the same as that of a standard X-band waveguide but whose inside narrow dimension is reduced by the exact amount necessary to establish the required power reflection at the junction of the waveguide.

Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Nominal Reflection Coefficient</th>
<th>Accuracy (Reflection Coefficient)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>X914B</td>
<td>0.05</td>
<td>±0.0025</td>
<td>$125.00</td>
</tr>
<tr>
<td>X914C</td>
<td>0.10</td>
<td>±0.0035</td>
<td>$125.00</td>
</tr>
<tr>
<td>X914D</td>
<td>0.15</td>
<td>±0.0045</td>
<td>$125.00</td>
</tr>
<tr>
<td>X914E</td>
<td>0.20</td>
<td>±0.0075</td>
<td>$125.00</td>
</tr>
</tbody>
</table>

*X916A is replaced by the X916B (see table opposite).
Waveguide Size: 1" x \( \frac{1}{2} \)", OD flat cover flanges.
Frequency Range: 8.2 to 12.4 GC(KMC).
Dimensions: 1\% x 13/8 x 8 7/8" long.
Weight: Shipping 2 lbs.

906A Coaxial Load

906A Sliding Coaxial Termination is a movable, low reflection load for terminating 50-ohm systems in their characteristic impedance. The load moves at least \( \frac{1}{2} \) wavelength at its lowest rated frequency, to reverse the phase of the reflection and separate it from other reflections in a system. Model 906A includes adapters for Type N male or female connectors, and features a movable center conductor which assures proper seating in the mating conductor. An attractive storage case is provided.

Specifications

<table>
<thead>
<tr>
<th>Frequency Range: 1 to 12.4 GC(KMC).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load SWR: Less than 1.05.</td>
</tr>
<tr>
<td>Power Rating: 1 watt.</td>
</tr>
<tr>
<td>Travel: Greater than ( \frac{1}{2} ) wavelength at 1 GC.</td>
</tr>
<tr>
<td>Size: ( \frac{3}{4} )&quot; diameter, 31&quot; long.</td>
</tr>
<tr>
<td>Weight: Net weight, 2 lbs.</td>
</tr>
<tr>
<td>Price: @ 906A, price on request.</td>
</tr>
</tbody>
</table>

Data subject to change without notice.
**920 Adjustable Shorts**

Adjustable shorts are convenient instruments for introducing a variable element in waveguide systems. In conjunction with a slotted section, they can be used to provide a variable short-circuit reference point. With a waveguide tee section, they can form a stub-transformer or tuner providing variable reactance. They may also be used as a convenient tuner for crystal or bolometer mounts.

Mechanically, 920A Shorts are a waveguide section containing a movable low-loss contacting finger wiper.* Position of the short is varied by a fine tuning control.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Approx. Length (in)</th>
<th>Frequency Range GC (KMC)</th>
<th>Fits Waveguide Size (in)</th>
<th>Shipping Weight (lbs)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>920A</td>
<td>10-7/16</td>
<td>2.20 - 3.95</td>
<td>2 x 1/2</td>
<td>10</td>
<td>$150.00</td>
</tr>
<tr>
<td>921A</td>
<td>7-13/16</td>
<td>3.95 - 5.86</td>
<td>2 x 1</td>
<td>4</td>
<td>$125.00</td>
</tr>
<tr>
<td>922A</td>
<td>6</td>
<td>5.30 - 6.20</td>
<td>1 1/4 x 3/4</td>
<td>2</td>
<td>$100.00</td>
</tr>
<tr>
<td>923A</td>
<td>4 1/4</td>
<td>7.05 - 10.00</td>
<td>1 1/4 x 3/4</td>
<td>2</td>
<td>$75.00</td>
</tr>
<tr>
<td>924A</td>
<td>4 1/4</td>
<td>8.20 - 12.4</td>
<td>1 x 11/16</td>
<td>2</td>
<td>$75.00</td>
</tr>
<tr>
<td>925A</td>
<td>4 1/4</td>
<td>10.0 - 15.0</td>
<td>.850 x .475</td>
<td>2</td>
<td>$75.00</td>
</tr>
<tr>
<td>926B</td>
<td>5/8</td>
<td>12.4 - 18.0</td>
<td>.702 x .391</td>
<td>2</td>
<td>$125.00</td>
</tr>
<tr>
<td>927A/BC**</td>
<td>6/1</td>
<td>18.0 - 24.5</td>
<td>.500 x .350</td>
<td>2</td>
<td>$155.00</td>
</tr>
<tr>
<td>928A/BC**</td>
<td>4/1</td>
<td>26.5 - 40.0</td>
<td>.360 x .220</td>
<td>2</td>
<td>$155.00</td>
</tr>
</tbody>
</table>

*In the P, K, and R bands a choke-type short is employed. Position of the choke is varied by a micrometer adjustment.

**Also available with circular flanges, UG-425/U for K-band, UG-381/U for R-band, specify K920BC or R920BC.

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**X930A Shorting Switches**

The X Waveguide Shorting Switch is a time-saving means of establishing a removable short-circuit in a waveguide system. It is especially useful in power measuring setups where it can temporarily interrupt the power flowing into a bolometer mount for zero-setting a Microwave Power Meter such as the 430C. It can also be used to establish a reference reflection coefficient of 1.00 for calibrating Ratio Meters such as the 416A. The low insertion loss and SWR of the X930A make it adaptable to nearly all measuring applications of this type.

### Specifications

**SWR:** Less than 1.02 in "open" position; greater than 125 in "short" position.

**Insertion Loss:** Less than 0.05 db in "open" position.

**Waveguide:** 1" x 1/2", RG-52/U; Flanges UG-39/U.

**Frequency Range:** 8.2 to 12.4 GC (KMC).

**Length:** 3 - 11/16".

**Shipping Weight:** Approximately 2 lbs.

**Price:** X930A, $160.00.

*Data subject to change without notice.*
**ACCESSORIES**

**AC-60A/B Line Matching Transformers**

Model AC-60A is specifically designed to connect a balanced system to 200 series audio oscillators, 400 series vacuum tube voltmeters, or similar equipment, for carrier current or other measurements between 3 and 600 KC. With 200CD it provides fully balanced 135 or 600 ohm output with attenuator in use. With an 400 it provides voltage measurements on either a 135 or 600 ohm balanced line without grounding one side, and permits bridging or terminated voltage measurements on both 135 and 600 ohm lines. Maximum level + 22 dbm. Shipping weight 2 lbs. $60.00.

Model AC-60B is similar to the AC-60A except that it is for use in audio systems, being specifically designed for connecting 330 Noise and Distortion Analyzer to a balanced line. Frequency range is 20 cps to 45 KC, maximum level is + 15 dbm. Shipping weight 6 lbs. $80.00.

**AC-10C/D Binding Posts**

Designed by @, 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), $0.40; AC-10D (red), $0.40.

**AC-54 Insulators**

These binding post insulators are of four standard designs. All insulators are 3/4" thick. Holes are spaced 3/4" apart, have a minimum diameter of 0.190" and a 7/8" taper. AC-54C and AC-54G are made of nylon, others are poly- styrene. Black only. AC-54E, F, G and H are similar, respectively, to AC-54A, B, C and D, but have locating pins to prevent the bodies of the AC-10 Binding Posts from turning.

**24 Waveguide Stand**

Model 24 Waveguide Stands are cast and machined from aluminum alloy. They are designed for 25 Waveguide Clamps and lock the clamps at any height from 2 3/4" to 5 1/4". Model 24 is 2 1/2" high and its base measures 4 3/4" in diameter. $3.00 each.

**25 Waveguide Clamps**

These clamps consist of a rubber molding with a steel insert. They are offered in 8 sizes to fit waveguide equipment covering frequencies from 2.6 to 40.0 GC (KMC). They are designed for use with 24 Waveguide Stand, and when mounted in the Stand can be adjusted upward or downward to conform with a waveguide setup. When ordering, specify waveguide size. Model S25, 3" x 1 1/8"; Model G25, 2" x 1 1/8"; Model J25, 1 1/2" x 5/4"; Model H25, 1 1/4" x 3/8"; Model X25, 1" x 1 1/2"; Model P25, .702" x .591"; Model K25, .500" x .250"; Model R25, .360" x .220". $2.50 each.

**AC-76A BNC-to-Binding-Post Adapter**

This adapter mates with a BNC receptacle, providing an easy method of connecting clip leads, banana plugs or wires to instruments having BNC receptacles. The nylon ferrule of the center conductor binding post is colored red; the other ferrule is black. Spacing between the banana jacks is 3/4", $5.00 each.

Data subject to change without notice. Prices f.o.b. factory. Quantity discount prices on request.
AC-16A Cable Assembly. Equipped with two dual banana plugs, this assembly is a section of RG-58C/U 50 ohm coaxial cable measuring 44 inches overall. Plugs are for binding posts spaced $\frac{3}{4}$ inch between centers. Each, $4.50.

AC-16B Cable Assembly. Identical with AC-16A except has dual banana plug ($\frac{3}{4}$ inch center) on one end and UG-88/U Type BNC male connector on other end. Length overall, 45 inches. Each, $5.50.

AC-16C Cable Assembly. This cable consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on one end with UG-21B/U Type N male connector and UG-23B/U Type N female connector at opposite end. For use at frequencies below 4,000 MC. Each, $13.00.

AC-16D Cable Assembly. This cable consists of 44 inches of RG-58C/U 50 ohm coaxial cable terminated on one end only. Termination is UG-88/U Type BNC male connector. Each, $3.50.

AC-16E Cable Assembly. A short cable of 9 inches length consisting of RG-58C/U 50 ohm coaxial cable terminated on both ends with UG-88/U Type BNC male connectors. Each, $5.50.

AC-16K Cable Assembly. This cable consists of 4 feet of RG-58C/U 50 ohm coaxial cable terminated on each end with UG-88/U Type BNC male connectors. Each, $6.50.

AC-16F Cable Assembly. For use at frequencies below 4,000 MC. Consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on each end with UG-21B/U Type N male connectors. Each, $15.00.

AC-16Q Cable Assembly. For use at frequencies above 4,000 MC. Consists of 6 feet of specially treated RG-9A/U 50 ohm coaxial cable terminated on each end with UG-21D/U Type N male connectors. The cable is designed for low SWR in the 4,000 to 12,400 MC range. Each, $18.50.

AC-16S Test Leads. Dual banana plug to alligator clips. Five feet long, one red lead, one black lead. Each, $7.50.

AC-16T Test Lead. Dual banana plug to probe and alligator clip. Five feet long. Each, $10.00.

Prices f.o.b. factory.

Data subject to change without notice.
Most HP instruments are available either factory mounted in portable cabinets or ready for mounting in standard EIA modular relay racks. Basic dimensions are indicated below. Rack-mounting models are also available with telescoping slides at slight additional cost.

**EIA Modular (Rack) Mounting**

![EIA Modular (Rack) Mounting Diagram]

In addition, most rack-mounting HP instruments which have 10 1/2" by 19" panels may be quickly converted to bench use by installing the instrument in an HP AC-44 Cabinet or by attaching HP AC-17 End Frames.

**HP AC-2A/B Dual-Mounting Modular Adapter**

HP instruments which are normally supplied with either 7" x 19" control panels (for standard EIA modular mounting) or 9.875" x 7" panels (for small portable cabinets) can also be mounted side-by-side in HP AC-2A/B Adapter Panels. These panels measure 10.5" high x 19" wide. Thus instead of the 14" height of two conventional 7" high rack mount instruments, the same two HP instruments in "cabinet" configuration can be rack-mounted side by side at a height saving of 3.5".

**New Instrument Packaging**

Beginning with the calendar year 1961 many new HP instruments will be packaged according to a system derived from EIA Standard SE-102. The basic intent of this system is to provide a new degree of versatility in mounting, as well as improve compactness and interior accessibility.

These trim, efficient-looking new instruments are ideal for bench use, either singly or stacked; they are easily rack-mountable, either with or without extension slides; and they are conveniently portable for field applications.

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*Electronics Industries Association (formerly RETMA).*

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These instruments fall into two classes:

1. Those units which, by reason of control panel area, volume, and thermal dissipation, lend themselves to the full EIA rack width. This class is directly mountable in racks through the addition of the two brackets and a filler-strip which are provided. Or, if preferred the included feet and tilt-stand may be attached for bench use. See Figure 1.

2. Those units which dictate a greater height-to-width ratio than the first group, but do not justify the full rack width. A convenient 6-31/32" high modular adapter (HP AC-146A) is available for mounting these units in racks. See Figures 2A and 2B. These modular adapters can also be used for combining instruments neatly on the bench, merely by attaching the feet provided.

The HP AC-146A Modular Adapter is supplied with two partitions so that three instruments 5 1/2" wide or two instruments 7" wide may be placed side by side.

Any unused space in the Modular Adapter may be converted into a convenient storage compartment by adding one or more standard accessory drawers.

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*Figure 1. Rack Mounting Instrument.*

Mounting brackets detach and feet are added for bench use.

*Figure 2A. AC-146A Modular Adapter with two partitions for instruments 5 1/2 inches wide.*

*Figure 2B. AC-146A Modular Adapter with one partition for instruments 7 inches wide.*
Programmable Systems for Data Handling, Component Testing, Automatic Measurement and Control Applications

Dymec's digital instrumentation design concepts based upon "off-the-shelf" building-block modules provide reliable, inexpensive systems to quickly meet your exact requirements. Units are available to accept input signals from most types of transducers. Output information is available on punched cards or tape, typewritten or printed record, or visual display as required for most convenient analysis and handling.

RF and Microwave Checkout Equipment for Production, Maintenance, Field Support

Program controlled doppler radar simulators, signal generators, receiver testers and complete system check-out devices are designed and built by Dymec to prove operational readiness of missiles, satellites, ground support and airborne systems. Hewlett-Packard- and Dymec-developed advanced engineering techniques for signal generation, modulation, frequency control and attenuation are combined to provide reliability and accuracy.

Special Purpose Instruments for Test, Measurement and Performance Monitoring

Dymec digital and RF system building-blocks are available to you for specialized applications. In addition, Dymec produces a variety of special-purpose test sets and broadcast monitors for performance monitoring. These devices, described on the following pages, feature the same high reliability and economy available in "off-the-shelf" Dymec and Hewlett-Packard equipment.
DYMÉC DIGITAL SYSTEMS

Engineered Assemblies of "Building-Block" Units
Assure Economical, Reliable Data Handling Systems

Dymec builds digital systems for automatic data logging, component testing, missile/aircraft checkout, and many other applications. Building-block assembly and a unique digitizing method provide high accuracy and design flexibility at minimum cost.

Size, cost and complexity of a Dymec system depend on the functions to be performed. A simple data processing system may include only a digital voltmeter, a coupler/translator, and a tape punch or electric typewriter. Total cost—a few thousand dollars. A more elaborate system, such as an automatic component test set, may include automatic scanning, programming, multiple measuring devices, buffer storage, tolerance comparators and high speed output recording equipment. Total cost—depends on requirements.

In every case, Dymec will provide you with a system to meet your specific needs.

Elements of Dymec Systems

Essential elements of a Dymec digital system are shown in the diagram below. Basic system elements are (1) input scanner, (2) programmer, (3) digital voltmeter or analog-to-digital converter, (4) output coupler/translator, and (5) recorder. All or any combination of these elements may be included for your individual system, depending on the exact measurements to be made.

Dymec Input Scanners accept one or more assorted electrical inputs in the form of dc or ac voltage, current, resistance, time or frequency.

Dymec Digitizing Equipment will count an input frequency directly, or convert an input voltage, current or resistance to a precisely proportional frequency which can then be counted. Dymec systems provide accurate and versatile data processing because all inputs are converted to frequency to take advantage of the inherent accuracy provided by any of a wide range of Dymec or standard counters.

Dymec Output Coupler/Translators receive information from counters and other digitizing equipment and translate it to the proper form for direct recording.

Output Devices such as remote Digital Displays and Digital Comparators are also supplied.

Recorders, including electric typewriters, printers or adding machines, tape and card punches and magnetic devices are available with Dymec systems.

Programming of system operation is done by built-in circuitry in standard Dymec system counters and scanners. For more complex operations, custom programmers are designed and furnished.

Elements of Dymec Automatic Digital Systems for Data Handling. Other systems for component testing and various measurement and control functions are assembled from the same basic building-block components.
Dymec Digital Systems will measure and process any information which can be transduced into an electrical quantity. Input information can correspond to temperature, pressure, speed, size, volume, position, or virtually any measuring parameter. The desired data, after being digitized within the system, can be recorded on a printer, typewriter, punched paper tape or cards, or magnetic tape for efficient handling and analysis. Local or remote visual displays are also available for conveniently monitoring system measurements. The Dymec system may include programming to control automatically such factors as speed and sequence of data accumulation. Because problems of data handling and recording are seldom identical, most Dymec systems are tailored to the specific use. The two typical systems shown below are indicative of the approach used for data handling applications.

A Simple, General-Purpose Data Recording System

Digital records of voltage variation can be maintained accurately and reliably with the simple digital system shown in Figures 1 and 1A. Consisting of only four building-block instruments, the system accepts a dc input voltage, digitizes the value, translates the digital information and couples it to a tape punch or printer to obtain a permanent record. Using Dymec's proven voltage-to-frequency converter and a standard counter as the digitizing element, the system provides accurate measurements essentially unaffected by input noise. By appropriate choice of building blocks, the system can provide four-or-five digit resolution with overall accuracy to within 0.02%. Additional building blocks can be added to permit accumulation of data from more than one input, recording of other information such as time with measured data, and programming of the measurement and recording sequence. Price of the basic DY-5552 system, including voltage-to-frequency converter, counter, output coupler, cabinet, and tape punch is about $3,600.00.

Data Logging System with Automatic Totalizing

In many applications, records are needed not only on the variations in magnitude of a variable but also on the accumulated value of the variable over a specific time interval. A typical example of this is in rocket engine tests where both total thrust developed and variation of thrust with time are important. A simple logging system based on the integrating capability of the Dymec voltage-to-frequency converter provides both of these desired results automatically and accurately.

In such an application, Figures 2 and 2A, a varying dc voltage proportional to the rocket engine's thrust is developed by a force transducer and applied to a Dymec voltage-to-frequency converter. Two counters are connected across the converter output. One samples the converter frequency output for short intervals so that the thrust vs. time curve can be derived. The other counter accumulates the total number of pulses generated by the voltage-to-frequency converter during the test to indicate the total thrust developed during the burning interval. A digital printer provides a record of thrust variations during the test; when the test is completed the printer records the stored reading on the totalizing counter. Cost of this straight-forward system, including voltage-to-frequency converter, two counters, printer, and cabinet, is less than $4,500.00.
Examples of
DYMEC DIGITAL SYSTEMS

Automatic Component Testing

By automatically measuring and recording component values, Dyimec component testing systems provide important time and money savings for manufacturers and users of electronic components. Human errors are eliminated, high measuring accuracies are easily achieved and component test rate is sharply increased. Using the same "building-block" approach as for simple data logging systems, automatic component test sets can be programmed to make a wide variety of tests and measurements on resistors, capacitors, diodes and other basic electrical components.

The system shown here is one of two designed for reliability studies on large numbers of components. Up to 200 individual components are mounted on etched-circuit boards which are inserted into the test set. Test voltages and currents, and GO/NO GO limits are set manually, and the desired testing sequence is programmed on the control panel. The complete test sequence is then performed automatically at the rate of about one component per second. Both measured data and pre-established identification data are recorded on punched cards.

Component testing systems utilizing similar techniques can automate production test and incoming inspection activities of any component manufacturer or user.

Digital Control System Automates Rolling Mill

High measurement accuracy, simple operation and convenient handling of output data are key reasons why Dyimec Digital Systems are used in process control installations. Since Dyimec systems are assembled from modular units, individual requirements of each installation can be met quickly without excessive costs for special engineering.

A typical application of Dyimec digital techniques in a process control system is shown here. The Dyimec equipment assists in computer control of rolling mill operations by automatically providing net weight in digital form for each steel billet passing over a weighing table. The digital information is supplied to a computer that determines which rolling mill the billet must pass through to meet predetermined size requirements. Combined dc voltage output of load cells in the weighing table is converted to frequency in a Dyimec voltage-to-frequency converter. A zero offset feature included in the voltage-to-frequency converter automatically subtracts the tare weight of the table from the gross weight information supplied by the load cells. The frequency output of the converter is counted by a Dyimec computing counter to provide an output reading directly in net weight. The weight information is supplied to the control computer and also printed on paper tape with a record of the time the measurement was made.

The systems shown here are working examples of the hundreds of Dyimec package combinations possible to meet your needs for data logging, component testing, system checkout, and process control. Ask Dyimec or a Dyimec representative to show you how these "designed-for-systems" units can be assembled to meet your needs.
Dymec data handling systems will accept electrical inputs in the form of dc voltage, ac voltage, frequency, time interval or period, resistance, and current. Up to 100 inputs are accommodated by standard system components; specially engineered input devices can be provided when more inputs are needed. Output information is furnished in any format needed for visual display or for operation of tape punches, card punches, digital printers, electric typewriters, or magnetic tape recorders.

Any desired measurement sequence can be programmed into the system. In addition, Dymec systems can be programmed to provide necessary scaling, normalizing and ranging of measured quantities.

**Input Types and Ranges**

- **DC Voltage**: From a few millivolts to 1000 volts or higher.
- **AC Voltage**: From a fraction of a volt to 500 volts rms, 20 cycles to 100 KC or more.
- **Frequency**: DC to 10 megacycles or more.
- **Time Interval or Period**: From less than a nanosecond to 100 days.
- **Resistance**: Fractions of an ohm to 100 megohms or more.
- **Current**: From 10⁻⁹ amperes to 10 amperes or more.

**Programmable Functions**

- **Scaling**: Separate multiplying factor can be supplied for each measurement to provide digital readings in desired measuring units. (psi, gpm, rpm, etc.)
- **Scale Expansion**: Zero offset provides high measurement resolution by utilizing full accuracy of voltage-to-frequency converter on each range.
- **Ranging**: Measuring equipment can be set automatically to desired range for each channel measured.
- **Normalizing**: Separate multiplying factor can be supplied for each channel to equate all measurements to some par value.
- **Sequence**: Channels can be measured in any desired sequence or omitted from any measurement cycle.

**Other Features**

- **Polarity**: Automatic indication of positive or negative input.
- **Channel Identification and Auxiliary Data**: Channel identification codes are automatically generated and recorded with each measurement. Additional manually entered data may be recorded simultaneously.
- **Interlocked Operation**: System building blocks are synchronized to conserve time and assure reliability.
- **Input Connections**: Convenient-access input connectors accept any electrical input given above including very low level input signals.

**DY-2901/2/3/4 Input Scanners**

Major savings in equipment costs are obtained by connecting up to 100 inputs to a single set of digitizing equipment with DY-2901/2/3/4 Input Scanners. Model DY-2901 scanner accepts up to 25 inputs, and Models DY-2902/3/4 scanners may be added and operated in combination as slave scanners. Expansion capability of the DY-2901 lets you add more channels as needed, if fewer than 100 inputs are connected initially. Built-in programming in the DY-2901/2/3/4 gives you additional savings in system cost. Channels to be measured are selected by front-panel push buttons, and an internal pin board selects the desired sequence and timing of the measurement cycle. Scanning sequence can be controlled manually or automatically, and the scanning cycle can be initiated locally or remotely.

Accurate and dependable operation, even with very low level inputs, is assured by high quality features such as gold-plated stepping switch terminals and premium-quality connectors for input signal connections.

**Brief Specifications**

**Scanning Modes**

1. Continuous
2. Single 25-point cycle
3. Manual step
4. External step

**Scanning Rate**: Controlled by the measuring/recording equipment through a fully closed loop interlocked operation or manual command. Programmable delay circuit allows for stabilization of amplifiers and ac measuring devices in system.

- **Inputs**: Accepts types and ranges of inputs indicated at left. Any combination of input types and ranges may be used.
- **Scanner Advance**: Steps to next programmed channel automatically on command.
- **Stepping Switch Levels For**
  - Floating Signal pairs and shield
  - Control of channel identification lamp on front panel
  - Scan-control circuit
  - External programmer or internal pin board
  - Programmed delay of read command
- **Plug-in boards which provide channel identification codes to the system**

**Dimensions**: 19" wide x 2" high x 16½" deep. (Excluding connectors.)

**Price**: Typically $1950.00 for DY-2901 master, $1750.00 for DY-2902/3/4 slave units, depending on application.
Advantages:

- **Provides** accurate, inexpensive digital voltmeter with any gated counter.
- **Inherent** noise averaging characteristic assures accuracy, even in presence of noise or hum.
- Converting voltage to frequency provides high accuracy, good resolution in digital system applications.
- Operating principle permits direct integration of input to measure "area under the curve."

Models DY-2210 and DY-2211AR/BR Voltage-to-Frequency Converters are all-electronic measuring instruments which average out noise or hum on the input to provide high accuracy voltage measurements at lower cost than with other conversion techniques.

An input dc voltage is converted to a proportional frequency of constant amplitude, which is applied to a gated electronic counter. The counter provides a direct digital indication of the input analog voltage.

Voltage-to-frequency converters are useful both individually and as a basic building block for digital systems. On an individual basis they are used with any electronic counter to provide an inexpensive digital voltmeter. As part of a digital system they convert the electrical input into a precisely proportional frequency which is easy to count with proven and inexpensive electronic techniques. The combination of a voltage-to-frequency converter and electronic counter is an all-electronic digitizing method which is accurate, has high resolution, and is compatible with all types of display and recording equipment.

All three Dymec voltage-to-frequency converters operate on the basic principle of continuously integrating the applied input voltage to produce an output frequency always instantaneously proportional to the input. The output frequency is sampled over a precisely controlled counter gate time to provide a digital measure of the input voltage.

Models DY-2210 and DY-2211AR have full scale frequency output of 10 KC to provide four-digit resolution when used with a 1 second counter gate, or three-digit resolution with a 0.1 second gate. Model DY-2211BR has full scale output of 100 KC to provide an additional digit of resolution.

The integration principle of Dymec voltage-to-frequency converters provides two major advantages over other types of analog-to-digital conversion. First, because applied voltage is measured for a discrete time interval, as determined by the counter gate time, the reading obtained is an average rather than an instantaneous value. The reading is therefore largely independent of noise or hum level on the applied signal. A second major advantage of integration is that a record of total input voltage (integral of voltage with respect to time) can be obtained in addition to the usual record of input variations.

**Brief Specifications**

<table>
<thead>
<tr>
<th>Range</th>
<th>DY-2210/2210R</th>
<th>DY-2211AR/BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Positive or</td>
<td>0 - 1</td>
<td>0 - 1</td>
</tr>
<tr>
<td>Negative)</td>
<td>0 - 10</td>
<td>0 - 10</td>
</tr>
<tr>
<td>Output Frequency</td>
<td>0 - 100</td>
<td>0 - 1000</td>
</tr>
<tr>
<td>Accuracy:</td>
<td>0 - 1000</td>
<td>0 - 1000</td>
</tr>
<tr>
<td>Dimensions:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabinet:</td>
<td>7 1/4&quot; wide, 11 1/4&quot; high, 11 1/2&quot; deep.</td>
<td>2211AR 0 - 10 KC</td>
</tr>
<tr>
<td>Rack:</td>
<td>19&quot; wide, 3 - 15/32&quot; high, 10 - 3/16&quot; deep</td>
<td>2211AR 0.0%</td>
</tr>
<tr>
<td>Net Weight:</td>
<td>15 lbs.</td>
<td>19 1/2&quot; deep</td>
</tr>
<tr>
<td></td>
<td>26 lbs.</td>
<td></td>
</tr>
<tr>
<td>Price:</td>
<td>DY-2210, $660.00 (cabinet)</td>
<td>DY-2211AR/BR</td>
</tr>
<tr>
<td></td>
<td>DY-2210R, $650.00 (rack)</td>
<td></td>
</tr>
</tbody>
</table>

*Available at extra cost.

†Accuracy is affected by frequency and accuracy of calibration, line voltage variations, temperature changes, and accuracy of multi-range input attenuators. Figures given are typical of performance under normal operating conditions.

Accuracy is affected by frequency and accuracy of calibration, line voltage variations, temperature changes, and accuracy of multi-range input attenuators. Figures given are typical of performance under normal operating conditions.
Voltage to Frequency Converters ■ Digital Voltmeters

**DY-2401 Integrating Digital Voltmeter**

Range and Sampling Rate Programmable for Systems Flexibility.
Input Guard Circuitry Gives High Common Mode Rejection.
Automatic Noise Averaging Through Integration

New Model DY-2401 Integrating Digital Voltmeter provides more measuring convenience, greater measurement capability, and higher realizable accuracy in systems than any previously available digital measuring instrument.

A unique measurement advantage of the DY-2401 is that it reads the average value of voltage applied over a definite, selected sample period. This is especially important since it helps to increase accuracy in system use where noise and hum pick-up are likely to be encountered.

Range, sample period and sample rate of the DY-2401 are externally programmable by contact closures to assure maximum flexibility in system applications.

The DY-2401 is also an extremely versatile laboratory instrument. Its high accuracy and contact-closure control features assure a high order of flexibility in bench set-ups.

Applications of the DY-2401 are even further extended by the dual nature of the instrument which is actually two instruments combined in a single package. A voltage-to-frequency converter similar to those described on the opposite page converts the applied analog voltage to a precisely proportional frequency which is counted by a transistorized 300 KC electronic counter. The DY-2401 becomes a standard multi-purpose 5-digit electronic counter simply by setting the convenient front panel control to FREQ.

Input guard circuitry greatly reduces the effect of common mode ac pick-up between the signal source and the DY-2401. Both the input signal pair and the guard circuit may be operated at up to 500 volts above chassis ground to permit measurements referenced above instrument ground.

Over-ranging measurements of up to 300% of nominal full-scale value can be made on all but the highest voltage range. The input circuit is automatically opened when the input voltage exceeds 3500% of full scale to prevent damage to the digital voltmeter.

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**Brief Specifications, DY-2401**

- **DC Voltage Ranges:** ±0.1, 1, 10, 100, 1,000 volts nominal full scale. Over-ranging capability to 500% of nominal f.s. on all but 1,000 volt range.
- **Overall Accuracy:** 0.05% nominal. (See DY-2401 Engineering Data Sheet for detailed accuracy specifications.)
- **Stability:** Better than 0.01% /day, 1 v range and above.
- **Input Impedance:** 1 megohm on 1 v and higher ranges, 100,000 ohms on 0.1 v range.
- **Sampling Period:** 10 ms, 100 ms, 1 sec (crystal determined), or manual by local or remote control.
- **Sampling Rate:** Externally programmable to 100/sec with 10 ms sampling period to 8.8/sec with 100 ms sample period. Display time adjustable 100 ms to 8 sec, or continuous until manual reset.
- **Display:** 5-digit In-Line Nixie plus Polarity Indicator. Range and Sampling Period Controls determine decimal point position.
- **Output:** Binary-Coded-Decimal for each digit; two lines for polarity indication; one line for each range and operating mode.
- **Power Supply:** 115/230 v ±10%, 50/60 cps, 200 watts.
- **Dimensions:** Rack Mount: 19" wide, 7" high, approx. 16½" deep.
- **Weight:** Net 40 lbs, shipping 60 lbs. (Approx.)
- **Price:** Model DY-2401, $3,750.00.

**DY-2410 Multi-Converter**

Model DY-2410 converts ac, volts, resistance, and dc volts to a proportional dc voltage with 1 volt nominal full-scale output. Function and range are selected by illuminated front panel pushbuttons. The instrument also features complete external selection of function and range by contact closures. All measurement circuits are floating and guarded for rejection of common mode ac pick-up. Programmable dc attenuator optionally available for measuring dc voltages with DY-2210/2211. Attenuator not needed if DY-2410 is used with DY-2401.

**Brief Specifications, DY-2410**

- **AC-to-DC:**
  - **Input Ranges:** 0.1, 1, 10, 100, 1,000 (usable to 750 v absolute peak) volts rms nominal full scale. 100% over-ranging capability except on 1,000 v range.
  - **Accuracy:** ±0.04% of reading ±0.1% of nominal full scale over inputs of 20 cps to 50 KC, and 1 mv to 500 volts rms; ±0.05% of reading ±0.1% of nominal full scale over inputs of 50 KC to 100 KC, and 1 mv to 100 volts rms.
  - **Resistance-to-DC:**
    - **Input Ranges:** 100, 1,000, 10,000, 100,000 ohms.
    - **Accuracy:** ±0.04% of reading ±0.01% of nominal full scale.
- **Price:** Model DY-2410, $1,975.00, optional attenuator $200.00.
DYMEC DIGITIZING DEVICES

- Automatically translates Digital Data to Desired Measurement Units (psi, gpm, fps, etc.)
- Variable gate-time provides computing function to furnish data in most usable form.
- Dual inputs permit ratio measurements.
- Numerous options and simple modifications reduce system costs.

COMPUTING COUNTER DY-2500

Pulse rate information from transducers or voltage-to-frequency converters is counted and displayed in any desired measuring units by the DY-2500 Computing Counter. For example, rotational speed can be measured and read directly in rpm or rps. Information on flow, volume, or pressure can also be read directly in desired units such as gallons per minute or psi. With data supplied in standard engineering units, subsequent handling is simplified and transcribing errors are eliminated.

The DY-2500 is particularly well suited for measuring rotational rate or speed in conjunction with the DY-2504 Photoelectric Tachometer or other tachometer generators manufactured by Dymec and Hewlett-Packard. For measuring other analog quantities, the DY-2500 is often used with a Dymec Voltage-to-Frequency Converter and a suitable transducer.

Visual and Electrical Readouts

The DY-2500 provides visual readout plus electrical outputs to drive digital recorders such as the @560A. With auxiliary Dymec units, the output of the DY-2500 can be coupled to other recording devices such as tape punches, card punches or typewriters.

Variable Gate-Times

Application of the DY-2500 is more flexible than that of standard electronic counters which have a limited selection of gate times in decimal ratios of one second. The DY-2500 gate time is adjustable by front panel controls in unit steps of one from 00001 to 99999. For systems applications, the counter gate time can be externally programmed by providing decade contact closures to the front-panel receptacle. Thus, the reading for each input channel to the system can be recorded in the appropriate measuring units, or normalized. Only a simple preliminary computation is needed to determine the proper setting of the front panel controls to provide output information in the desired engineering units.

Brief Specifications

Range: Input A: 1 cps to 120 KC (220 KC optional), Input B: 1 cps to 10 KC (used for ratio measurements or external time base).

Multiplier Dials: DY-2500-4: Four multiplier dials, adjustable in steps of 1 from 0001 to 9999. Using internal time base, multiplier adjusts the gate time from 0.0001 seconds to 0.9999 seconds in 0.0001-second increments.

Optional gate times are: 0.001 to 9.9999 seconds in 0.001-second increments, or 0.01 second to 99.9999 seconds in 0.01-second increments.

DY-2500-5: Five multiplier dials, adjustable in steps of 1 from 00001 to 99999. Using internal time base, multiplier adjusts gate time from 0.0001 second to 0.99999 seconds in 0.0001-second increments.

Optional gate time is .001 second to 99.9999 seconds in .001-second increments.

Outputs: Staircase and BCD.


Dimensions: Cabinet Mount: 2034" wide, 12½” high, 14½” deep. Rack Mount: 19” wide, 10½” high, 14½” deep.

Weight: Cabinet Mount: 50 lbs. net, shipping weight 95 lbs. Rack Mount: 45 lbs. net, shipping weight 90 lbs.

Price: DY-2500-4, cabinet mount, $1350.00; rack mount, $1330.00. DY-2500-5, cabinet mount, $1425.00; rack mount, $1405.00. See DY-2500 Data Sheet for complete list of options, detailed specifications and prices.
Computing Counters

Typical of special-purpose computing counters using DY-2500 Techniques.

Speeds, Simplifies Measurement of Telemetering Sub-Carrier Signals.

The DY-2503BR is typical of the special-purpose counters which Dymec can furnish by using the basic principle of the DY-2500 Computing Counter. In this case the front panel push-buttons simply select a predetermined gate time calculated to provide a reading in percent of period of any one of 18 IRIG (RDB) channel mid-band frequencies. Model 2503BR also provides the flexibility of front panel gate time selector dials so that the counter can be used for other applications or for measuring other than the standard RDB channels.

**Brief Specifications**

- Generally comparable to DY-2500. Measures 1 cps to 100 KC.
- DY-2503BR also measures (1) input signals for gate times of .0001 to 0.9955 seconds in 0.0001 second intervals, plus fixed times of 1 and 10 seconds, (2) period for 1 to 9999 periods of input signal and (5) ratio from 1 to 9999.
- Price: DY-2503BR (rack mount), $1,950.00.

Computing Counters for Individual Applications

Dymec manufactures large or small quantities of variable or fixed gate counters similar to the DY-2500 for specific measurement requirements. The measuring system shown below, and the DY-2503BR special-purpose counter described above are typical of requirements met in the past. Dymec's field engineers or your Dymec engineering representative will be glad to discuss your individual application.

**PHOTOELECTRIC TACHOMETER**

DY-2504A

- Shaft rotational speed from 0 rpm to 10,000 rpm, and accumulated shaft rotation can be measured easily and accurately with the DY-2504A Photoelectric Tachometer. Low friction and low moment of inertia of the DY-2504A assure extremely light loading of the driving shaft to provide rapid response to speed changes, even with low input torque.

- Rotational speeds are measured by counting the number of pulses produced by the tachometer within a specified time interval. Accumulated shaft rotation is determined by counting the total number of pulses from a specified starting point. (Several options are available to provide from 60 to 360 constant amplitude and duration pulses for each shaft rotation in either direction.)

**Brief Specifications**

- Output Pulses per Revolution: 60, 100, 120, 180, 200, 360
- Speed Range: 0 to 10,000 rpm
- Resolution: ±1 to ±6 degrees.
- Size: Cylindrical case, 3¾" long, 3¾" diameter; ¾" dia. 1" long, flanged shaft.
- Weight: Approximately 1¾ pound.

**DIGITAL CLOCK**

DY-2508A

- Accurate time information in seconds, minutes and hours is provided by the DY-2508A Digital Clock. The instrument provides both an easily read in-line visual readout and multiple electrical contacts to drive standard data recording devices. This permits precise time information to be recorded along with data from any Dymec or Hewlett-Packard electronic counter or digital voltmeter. Time information from the DY-2508A is also used for programming system functions.

- Time signals can be obtained from line-frequency or optional crystal-controlled time bases, or from external sources. Numerous options are available to meet individual requirements for accuracy, number of outputs, and type of output code (staircase, ten-line, BCD). Price range is typically $1,600.00 to $2,000.00, depending on options selected.
DIGITAL SYSTEM OUTPUT DEVICES

Output information from Dymec Digital Systems may be in any form desired for fast, convenient handling and analysis of data. Dymec's flexible output couplers will operate electric typewriters or digital printers where a written record only is needed; or they will drive card or tape punches where data is to be entered into a computer or transmitted to a remote location for further processing. Display panels are also available for convenient visual readout. For control applications, output data can be compared against predetermined or programmed HI-LO limits to furnish GO/NO-GO signals. In most cases a combination of output handling devices can be operated simultaneously.

Output Couplers and Accessories. Five standard output couplers are used in Dymec systems to meet the many code and format requirements of different output devices. They provide the necessary translations and conversions to operate typewriters, digital printers, card punches or tape punches, and accessory devices such as visual readouts and comparators.

Model DY-2540 Coupler transfers information from parallel four-line binary data sources to serial-entry recorders. Up to 50 digits of information can be accepted from as many as six sources by one DY-2540 Coupler. More digits and data sources can be accommodated by using additional couplers connected on a master/slave basis. Two recording devices normally can be operated simultaneously even though they require different codes. Price of the DY-2540 Coupler depends on the number of inputs and outputs, code and format, and on the programming desired. Prices range typically from $1,200.00 to $2,500.00.

Model DY-2542 Tape Punch Set electronically scans and transfers information from a digitizing device to punched paper tape at a rate of up to 60 characters per second. Model DY-2542 operates from a staircase voltage input (one-line) and provides any 5-, 6-, or 7-level perforating code to the tape punch. Price of the DY-2542 Tape Punch Set including coupler, power supply and punch is typically $5,000 to $5,500. Exact price depends on code, format, and number of punch levels.

Model DY-2512 Card Punch Coupler transfers information from any digitizing device with one-line (staircase voltage) output to an IBM Model 523 Summary Card Punch. Up to eight digits of identification data can be manually pre-set for entry onto cards along with the data from digitizing equipment. Price of the DY-2512 Card Punch Coupler is typically $3,000. Exact price depends on the nature of the digitizing device from which information is transferred.

Model DY-2513A Counter Scanner automatically scans and transfers staircase voltage information from any combination of up to six digital data sources to a single digital recorder such as the 350A, or to a DY-2512 Card Punch Coupler. Six digits of counter information plus a channel identifying number are supplied to the recording device. Front panel switches permit selection of the data sources to be recorded or omitted during the scanning cycle. Price of the DY-2513A is typically $2,500.00, depending on type and number of data sources scanned.

Model DY-2530 Binary/Decimal Register serves two functions. It serves as a buffer/storage unit and also translates and couples data from parallel binary voltage input sources to parallel-entry recorders, comparators, and visual readouts. The storage feature permits the Model DY-2530 to receive, store and translate measurement data before sending it to the recording and handling equipment. A single DY-2530 transfers up to seven digits of four-line information from a counter or other data source to card punches or parallel entry digital printers. Price of the DY-2530 Binary/Decimal Register is typically from $695.00 to $1,435.00, depending on the number of digits to be transferred.

Model DY-2532A Digital Comparator automatically compares six digits of measured data against pre-selected HI-LO tolerance limits. Dual concentric switches on the front panel are individually set for each of the six digits compared. "HI," "LO," or "GO" condition is indicated on panel lamps. Corresponding relay contact closures control external equipment or convey the information to a recorder. The DY-2532A may be used separately or plugged into the front panel of the DY-2530 to save front-panel space. Price of the DY-2532A is $550.00 for mounting in DY-2530; $565.00 for rack mounting.

Model's DY-2533 and DY-2536 One-Line Digital Displays visually monitor measured data. DY-2533 uses long-life Nixie tubes; DY-2536 uses projection-type incandescent lamp indicators. Price of the DY-2533 is $250.00 for five-digit display; additional digits are $40.00 each. Price of the DY-2536 is $275.00 for five-digit display; additional digits are $40.00 each.

Model DY-2538 Programmed Digital Comparator is used with the DY-2530 for comparison of digital measurements against any one of five sets of automatically selectable pre-set tolerance limits. The desired set of limits against which each measurement is compared is individually selected by external programming equipment such as the DY-2901 Input Scanner. Price of the DY-2538 is $1,350.00.

Prices F. O. B. Factory, Palo Alto, California. All data subject to change without notice.

Model DY-2532A Digital Comparator mounted in Model DY-2530 Binary/Decimal Register.
DYMEC RF CHECKOUT EQUIPMENT

For Missile, Satellite and Airborne Electronic Systems, Radar and Communications Equipment

- Production and field testing, as well as performance monitoring is speeded and simplified by using Dymec's advanced techniques for programmed measurements.
- Dymec radar simulators evaluate operational readiness of missile and ground-based radar equipment by precisely duplicating signals encountered under actual operating conditions.
- Dymec's programmed signal generators provide rapid evaluation of complex airborne electronic countermeasures equipment, minimizing downtime of aircraft and the probability of unsuccessful missions.
- Dymec test sets allow rapid checkout and alignment of microwave communication systems to increase efficiency and increase in-service time.
- The advanced engineering techniques continually under development in Hewlett-Packard laboratories are uniquely available to Dymec for incorporation into equipment designed for specific system requirements.

Test Sets. Complete facilities for test and maintenance of radar and microwave communication systems are provided by Dymec's compact, easy to operate test sets. A simple self-contained system in itself, each microwave test set includes coordinated instrumentation for generating microwave signals, measuring power level and frequency of transmitted and received signals, and modulating the microwave carrier to simulate actual system operation. Four standard microwave test sets and a high power signal generator are described in this catalog. Comparable devices can be designed and delivered in any quantity required to meet individual system needs.

System Building-Blocks. Many special-purpose microwave components are available to meet requirements for automatic control and programming of microwave test conditions such as frequency, power level, and modulation. In addition to its own proprietary skill and know-how, Dymec has available for its use the broad experience in microwave techniques of the Hewlett-Packard Company.

Special-Purpose Instruments. Broadcast monitors and sweep generators are typical of the individual instruments available from Dymec for specialized test and measurement requirements. Utilizing the wide range of Hewlett-Packard general-purpose instrumentation as a base, Dymec can provide small or large quantities of individual instruments specially adapted for a given measuring task.

Radar Simulators. A typical Dymec radar simulator system is shown at right. Designed to speed and simplify factory and field testing of CW-Doppler radar equipment, the DY-5130 system simulates relative range, direction and velocity of a target. The signal generator portion of the system may also be used to provide other test signals. Techniques used in this and other complex radar simulators are described on the following pages. They indicate the diversity of Dymec system engineering capability for resolution of problems in the general field of rf and microwave system design, development, and manufacturing.

Automatic System Checkout Equipment. Dymec's capability in the digital data handling field, when coupled with its advanced rf and microwave measuring techniques, makes possible creation of fully automatic equipment for complete system checkout. Dymec's experience in the design and manufacture of both simple and complex systems covers the spectrum from low rf frequencies through all microwave bands to 40 GC and above. Frequently, Dymec can adapt its own off-the-shelf digital devices and standard Hewlett-Packard instruments to meet exacting system needs, thereby providing economy, reliability and expedited delivery of specialized measurement systems.
A solid background in basic engineering techniques developed at Hewlett-Packard and Dymec provides a sound base for designing and building numerous special-purpose rf test and measurement systems. Here are brief descriptions of some of the specialized techniques pioneered or refined by Dymec, with examples of how they are used in test systems components.

**Simulation of Doppler Effect.** Modern FM, CW and pulsed doppler radar systems extract valuable information from doppler shift of the returned signal. Through the use of serrodyne modulation techniques, Dymec provides stable test signals to monitor and maintain such equipment. Frequency offset, simulating a doppler shift, is accomplished by applying a sawtooth voltage, precisely controlled in frequency, to a traveling-wave tube helix. Clean spectrums with offsets of up to 500 KC have been obtained without difficulty.

The DY-2222 Sawtooth Generator is a typical system building block for serrodyne modulation of TWT amplifiers. It provides a signal for generating doppler offset frequencies from 5 CPS to 500 KC. In addition, it allows the offset frequency to be modulated for simulation of acceleration effects.

**Frequency Stabilization and Control.** An efficient technique for increasing radar and communication range depends upon coherent detection and employs extremely stable frequency sources. Dymec has developed both open and closed-loop frequency generation and stabilization circuits for testing such coherent systems. The DY-5156 Microwave Signal Generator, for example, provides high frequency stability over extended periods through a temperature range of 40 to 100°F. In a similar system, residual FM has been held to less than 10 KC. Dymec also can provide generators incorporating a cavity or crystal reference where extremely high stability is required.

Dymec has also developed simple methods for assuring high frequency accuracy in generated signals. One technique which has proven reliable and economical utilizes continuously visual comparison of the generated frequency against a crystal reference. Retestability and accuracy are limited only by the accuracy of the crystal oscillator reference. In the DY-5156 Microwave Signal Generator, this straightforward method of adjustment provides tuning accuracy of one part in 10⁶ for eight discrete frequencies in X-band.

**DY-5156 Microwave Signal Generator is typical of Dymec radar beacon performance evaluation equipment. It provides two phase-coherent signals with precisely controlled frequency separation. A third output frequency, the arithmetic average of the two generated frequencies, is also provided. The system features low residual FM, high frequency stability, and a high degree of retsetability.**

**DY-2222 Sawtooth Generator provides a precision output for serrodyne modulation of TWT amplifiers. High linearity and low flyback time assure accurate simulation of doppler shift.**
Proven techniques assure reliability, economy, performance

Programmable Frequency Control for Voltage Tuned Oscillators. In providing stimuli for automatic checkout of wide-band equipment such as countermeasures receivers, microwave components, and for RF interference and vulnerability checking, rapid, programmable tuning of RF signals is required. Often, the use of digital techniques improves the efficiency and utilization of such checkout equipment. Vacuum tube oscillators such as backward wave oscillators, klystrons, or voltage-tuned magnetrons are operated from Dymec programmable power supplies to provide signal sources capable of rapid setting to any required frequency within their range. A typical BWO frequency control unit provides a stable (+0.1%) control voltage over the range of 150 to 1500 V dc. Since this unit has a built-in reference, it can be accurately programmed externally by potentiometers or relay-selected resistances (as well as by external reference voltages). The control unit has a response range up to 10 KC to provide rapid and precise changes in BWO frequency with simultaneous wide-range frequency modulation.

Programmable Output Levels. For automatic sensitivity testing of complex receivers, Dymec has manufactured a number of programmable waveguide attenuators for accurately adjusting signal levels to predetermined values. Using high precision rotary vane attenuators as the basic element, Dymec provides both mechanical and servo shaft positioning devices to remotely or automatically control signal levels within a checkout system.

In a typical programmable attenuator, the amount of attenuation can be remotely changed through as many as seven preset positions. Full accuracy of the dial is retained to ±2% or 0.1 dB over a 50 dB range or, by combining two attenuators in one assembly, over a 100 dB range. Units are provided for all waveguide bands from 4 to 40 GC (KMC). Attenuator position can be controlled by local or remote pushbutton or contact closure, with each new position reached within 3 seconds. Other Dymec programmable attenuators utilize a servomotor drive to provide continuous control of attenuator position. An average slewing rate of 20 dB per second can be achieved. Programming is by remote potentiometer or analog voltage control. Transistor servo amplifiers are used for high efficiency and reliability.

DY-5065, a typical Microwave Doppler Simulator, provides up to 1 watt CW output power, provides continuous output power monitoring, and has a very high degree of phase stability between two independent output signals generated to simulate doppler effect.
Constant Output Level from Microwave Signal Sources.
For meaningful tests of many complex microwave systems, the output level from the test generator must be held constant over a wide range of frequencies and environmental conditions. To meet such requirements, Dymec provides power leveling devices which can maintain a constant output power level from any source providing a peak power output of 0 dBm or more in waveguide bands from 4 to 12 GC (KMC). A typical unit, the DY-5676, is simply inserted between the signal source and the load to provide constant power to the load, even through source variations of up to 40 dB. Automatic level control can also be incorporated directly in Dymec signal generators.

Constant Monitoring of Power Output. The techniques used for automatic control of output power level are also applicable to constant monitoring of output power. The attenuator in an automatic leveller rotates as a function of the peak pulse power input. Therefore, by calibrating the attenuator in terms of power level rather than attenuation, essentially the same device is a constant power monitor. With appropriate directional couplers and fixed attenuators to control the level of applied power, a 50 dB range of power variation can be monitored for frequency modulated, amplitude modulated and square-wave modulated signals, as well as for pulse modulated signals with pulse widths as narrow as 0.25 microseconds. Frequency sensitivity is typically less than ± 1 dB over X band, and even less at lower frequencies. Provision can be made for an analog voltage output proportional to the power level in order to operate an output meter, recorder, or other monitoring device.

DY-2301 Programmable Waveguide Attenuator provides 3 preset values of attenuation at any points within 50 dB overall range. Attenuator may be actuated by local or remote pushbuttons, or by remote contact closure. Unit provides SWR less than 1.15 and phase shift less than 3° over entire range. Units can be supplied in frequency range from 3.95 to 12.4 GC.

DY-6190 Pulse-Doppler Radar Simulator is comprised of many standard Dymec rf system building blocks. System operates from 2 to 4 GC with output variable from 0 to −80 dBm. Amplitude, pulse, noise or phase modulation may be used. Similar systems have been built to meet specific needs of major radar systems.

Constant power level is accurately maintained with DY-5676 Microwave Leveler. Servo-motor drive automatically inserts or removes attenuation as output level of source varies. Attenuator unit is mounted directly in waveguide transmission system between source and load. Control unit may be mounted at any convenient location.
MICROWAVE TEST SETS SIGNAL GENERATORS

For Faster, More Convenient Test and Maintenance of Microwave Systems

By combining several basic instruments into a single compact unit, Dymec Microwave Test Sets and Signal Generators provide faster and more economical test and maintenance for microwave systems. Each test set provides an efficient signal generator, accurate power and frequency meters, and a precision attenuator for maximum convenience in making receiver and transmitter measurements. The standard test sets and signal generator described here meet a wide range of test and measurement needs. Small or large quantities of comparable instruments can be provided to meet specialized or unusual requirements.

Model DY-623B SHF Test Set operates in the commercial and government communications bands between 5925 and 7725 MC. It is a compact unit for measuring receiver sensitivity and selectivity as well as transmitter frequency and power level. The DY-623B is particularly suitable for use with communications, control and video microwave systems.

Model DY-624C X-Band Test Set generates and monitors frequencies from 8,500 to 10,000 MC. It is particularly suitable for use with communications, control and video microwave systems.

Model DY-624C X-Band Test Set provides all features of the DY-624C, and in addition has a higher output power, making it particularly suited for testing radar transmitters and receivers where greater isolation between the equipment and the test set is required.

Model DY-5636 H-Band Test Set operates from 7125 to 8,400 MC to cover the important microwave relay communications band. Its provisions for transmitter power and frequency monitoring, along with received signal simulating facilities, make it particularly convenient for testing complete communications systems.

**SPECIFICATIONS:**

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<td>800–10,000 MC</td>
<td>0 to 35 db</td>
<td>20%4/5&quot; wide, 1/16&quot; high, 1/25&quot; deep</td>
<td>57 lbs.</td>
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<td>19&quot; wide, 13/16&quot; high, 1/2&quot; deep</td>
<td>84 lbs.</td>
<td>94 lbs.</td>
<td>$2,250.00</td>
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<td>8500–10,000 MC</td>
<td>8500–10,000 MC</td>
<td>0 to 35 db</td>
<td>19&quot; wide, 13/16&quot; high, 1/2&quot; deep</td>
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<tr>
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<td>7125–8400 MC</td>
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<td>0 to 25 db</td>
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<td>76 lbs.</td>
<td></td>
<td>$4,475.00</td>
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*Please request Engineering Data Sheets for full specifications.

Prices F. O. B. Factory, Palo Alto, California.

All data subject to change without notice.
Dymec broadcast monitors are compact packaged instruments specially designed to meet FCC requirements for monitoring FM and TV transmitters. Instruments are designed for continuous service at transmitter installations.

**Model DY-335ER** for vhf and uhf TV has three panel meters to show visual and aural carrier frequency, and percent modulation. A peak modulation indicator lamp is also mounted on the front panel. There is also provision for remote indicating meters, remote peak modulation indicating lamp, and a demodulated signal for measuring AM and FM noise levels, frequency response and distortion of the aural transmitter, and for continuous program monitoring. Price is $2,700.00.

**Model DY-335BR** for FM has two panel meters to show carrier deviation and percentage of modulation, with a lamp to indicate peak modulation. Provisions are made for operation of a remote modulation meter and a remote indicator lamp. Price is $1,550.00.

**Models DY-207A and DY-2200AR Audio Sweep Oscillators** cover their full frequency ranges in a single dial sweep to provide a convenient method for full range response tests.

**Model DY-207A** covers the 20 cps to 20 KC frequency range. It is particularly useful for testing response of audio circuits and devices such as amplifiers, transformers, and speakers. Amplitude variation is less than ±3% over the full range; sweep time can be as little as 20 seconds. The oscillator is available with a motor drive and/or accessory potentiometer to facilitate automatic testing with oscilloscope or X-Y recorder presentation of the test results. Price is $325.00 (Cabinet), $330.00 (Rack). Add $65.00 for accessory potentiometer; add $300.00 for motor drive and potentiometer.

**Model DY-2200AR** covers the 5 cps to 5 KC frequency range. Full range can be swept in as little as 10 seconds with output constant within ±1 db. The DY-2200A is particularly suitable for rapid testing of servo and vibration systems. Price is $585.00 (Rack); add $65.00 for accessory potentiometer.

For Continuous Monitoring of FM and TV Transmitters

Audio Sweep Oscillators

FOR ADDITIONAL INFORMATION

Engineering Data Sheets with descriptive information and complete technical specifications are available on all products listed in this catalog. Copies may be obtained from Dymec or your Dymec/HP Engineering Representative.

Your Dymec Representative will also be glad to discuss your needs for special instrumentation and instrumentation systems, and to forward your requirements to Dymec to obtain a quotation or engineering proposal.

How to order DYMEC Products:

All orders should be addressed to:

DYMEC,
395 Page Mill Road
Palo Alto, California.

Please do not include Dymec products on purchase orders for Hewlett-Packard instruments. Placement of separate purchase orders for HP and Dymec will assure faster handling and avoid unnecessary delay.

Prices F. O. B. Factory, Palo Alto, California.
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