BOONTON ELECTRONICS CORPORATION

Technical Data Package

- ☐ *Precision Impedance Instrumentation*
- ☐ *Sensitive RF Voltmeters*
- ☐ *Sensitive DC Instruments*
- ☐ *Instrumentation for High-Speed, Automatic Production*

Telephone: 201-887-5110 ■ TWX: 510-235-6747 ■ Route 287, Parsippany, N. J. – 07054

BOONTON ELECTRONICS CORPORATION

PARSIPPANY, NEW JERSEY

Model 91D Sensitive RF Voltmeter

Accurate Measurement of RF Voltage Over a Wide Range of Frequency and Amplitude

- **Voltage Range: 300 μvolts to 3 volts (to 300 volts with included 100:1 voltage divider)**
- **Frequency Range: 20 Kc to 1200 Mc (useful indication to above 2500 Mc)**
- **Basic accuracy: 3%**
- **True RMS response from 300 μvolts to 3 volts**
- **Expanded linear meter scales**
- **Linear dc output at front panel**
- **Probe internally heated for temperature stability**
- **Two voltage scales in a 1, 3, 10 Sequence and one db Scale (dbm Scale also available)**

Model 91D
Price: $750.00 with accessory kit.

Function

The Model 91D provides a broad range of accurate voltage measurements from ultrasonic frequencies through to the gigacycle region.

The frequency range of the Model 91D is conservatively specified from 20 Kc to 1200 Mc. It should be noted however that the instrument provides useful indication to beyond 2500 Mc, although accuracies in this region can not be specified since no appropriate primary standards exist for their validation.

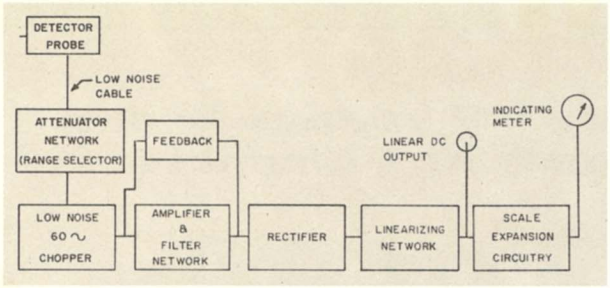
Voltages from 300 μvolts to 3 volts may be measured and this range is increased to 300 volts through use of the 100:1 voltage divider supplied with the instrument.

These capabilities render the Model 91D valuable for a great variety of functions. Beyond the usual voltage measurements and related tests in a diversity of RF circuits, the instrument is widely used in the measurement of the high-frequency characteristics of transistors and other semiconductors; for determining the frequency response of both active and passive networks; for measuring VSWR and return loss in transmission line and attenuation systems; and for determining attenuation and insertion loss of RF attenuators. Having true RMS response the Model 91D may also be used to measure harmonic distortion of RF waveforms as well as wideband noise.

The Model 91D may also be used as an RF null detector for bridge measurements.

General Description

The essential elements of the Model 91D are outlined in the block diagram of figure 1. The test probe (supplied as a standard accessory with the instrument) embodies a full-wave rectifier which converts the RF signal to a dc voltage, and provides a true RMS response without turnover or harmonic error at levels up to 30 millivolts (or 3 volts with the 100:1 voltage divider), gradually changing to peak-to-peak (calibrated in RMS) at higher amplitude levels. The probe housing is internally heated for thermal stability.



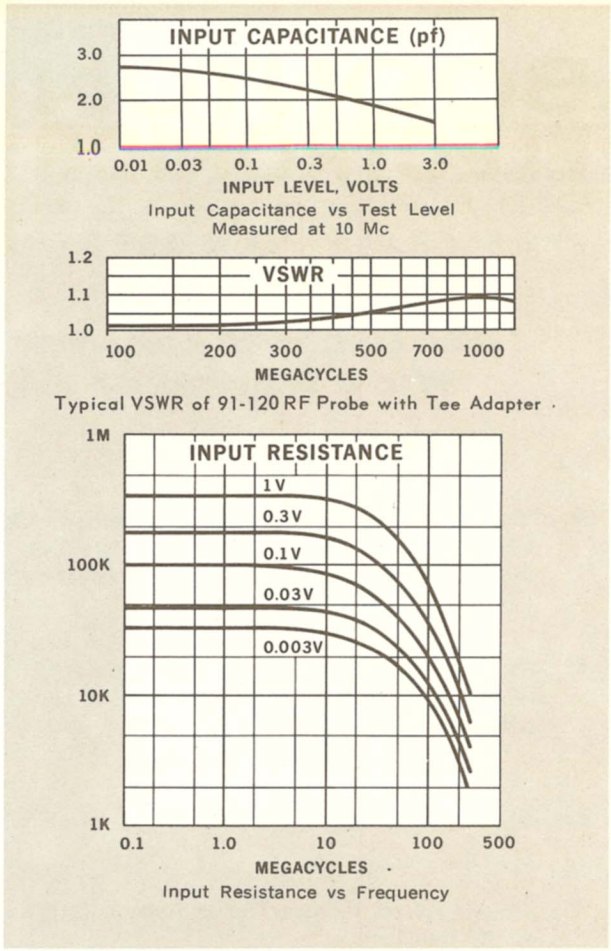
The rectified output from the probe is passed through an attenuator network (Range Selector) to a low-noise chopper where it is converted to a 60-cycle signal. This ac voltage is then amplified and again rectified. Since probe output is a non-linear function of the test signal it is passed through a linearizing network before metering.

Additional circuitry is incorporated to expand the calibrated portion of the meter scale so that the pointer range covers the greatest possible percentage of the scale for optimum readability.

Consistent with the quality of design and construction of the Model 91D, the indicating meter is a high quality, 3/4 percent mirror-knife-edge type having a tracking accuracy of 1/2 percent.

A linear dc output is available at the front panel for external monitoring or driving other instrumentation. Output is approximately 1 volt (at full scale deflection) into a 1000-ohm load.

The Model 91D is packaged as a compact, portable bench unit and in spite of its very high sensitivity, is sufficiently rugged to withstand extensive use in the laboratory or in the field.



SPECIFICATIONS

Frequency Range: 20 Kc to 1200 Mc. Useful indication to above 2500 Mc

Voltage Range: 300 microvolts to 3 volts
Measurements to 300 volts from 50 Kc to 250 Mc with 100:1 Voltage Divider (provided)

Full Scale Volts: 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, and 3

DB Range: 80 (70 in 10 db switch steps plus 10 db on meter scale)

Voltage Accuracy: 150 Kc to 100 Mc : ±3%
50 Kc to 400 Mc : ±5%
20 Kc to 1200 Mc : ±10%

Probe Capacitance With Tip (approx): Varies from 2.0 to 3.0 pf inversely with voltage

VSWR: Less than 1.2 to 1200 Mc with Tee Adapter

Waveform Response: True RMS below 0.03 volts changing to peak reading (calibrated in RMS) at higher levels. With 91-7B Voltage Divider RMS response may be extended to 3 volts

Linear DC Output: Approx. 1.0 v DC into 1000Ω load

Power Sensitivity: 0.0018 microwatt

Power Requirements: 105 to 125 v, 60 cycles, 45 watts, 210 to 250 volt, 50 cycle operation available at the extra cost of $20.00

Standard Equipment Supplied with 91D: See probe kit at right

Size: 7-1/4" w x 9-1/2" d x 11" h excluding handle

Weight: 13-1/2 lb. Shipping Weight, 18 lb.

Price: $750 (including probe kit shown)

MODEL 91DR

The Model 91DR is electrically identical to the Model 91D, but is packaged for mounting in a standard 19-inch rack. It is supplied complete with dust covers, and with the same selection of accessories as the Model 91D. Dimensions of the Model 91DR are: 7" h x 19" w x 8-3/4" d.

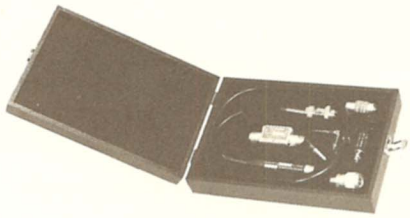
Weight: 15 lbs. **Price** $775

MODEL 91D-S5

Identical to Model 91D, except scale is calibrated in dbm. **Price:** $750.

Included Accessories

A kit of accessories, supplied as standard equipment with the Model 91D, and included in its price, contribute substantially to the versatility of measurement and convenience of operation of the instrument. These accessories are packed in a durable, well cushioned carrying case for safe storage and transportation.



		Price*
91-12D	RF Probe and 30-inch low noise cable	$50.
91-13B	Probe tip	$ 2.
91-14A	Type N Tee Adapter & 91-15A 50-ohm termination	$50.
91-6C	Unterminated Type BNC adapter	$15.
91-7B	100:1 voltage divider	$30.

*If purchased separately

Additional Accessories

(available separately at extra cost)

		Price
91-8B	50-ohm adapter	$20.
91-8B-1	75-ohm adapter	$20.
91-8B-2	93-ohm adapter	$20.
91-4C	1 Kc to 250 Mc Probe	$60.

BOONTON ELECTRONICS CORPORATION

Represented by

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 71A 1 Mc/s Capacitance/Inductance Meter

Instant, Direct-reading Measurements of Capacitance and Inductance at 1 Mc/s

- **Capacitance Measurements (Three Terminal):**
  - Range: 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS.
  - Resolution: 0.01 pF
  - Accuracy: ±1%, (see Specifications)
- **Inductance Measurements (Two Terminal):**
  - Range: 0 to 1000 μH in 7 ranges; lowest range, 1 μH, FS.
  - Resolution: 0.01 μH
  - Accuracy: ±1%, (see Specifications)
- **DC Analog Output**
  - Linearity, 0.1% of measured value +0.005% FS; provides at least 3-digit resolution on all ranges with appropriate DVM
  - Response time less than 10 ms from 0 to FS
  - Suitable for use with recorder, scope, X-Y plotter, voltage comparator, etc.
- **Particularly useful for measuring semiconductor junction capacitance**
  - Low (15 mV) test level
  - 1 Mc/s crystal controlled test signal
  - Provision for DC bias up to 200 V @ 250 mA
- **Measures over wide range of Q values; down to as low as 3 (lower with re-adjustment)**
- **Three-terminal arrangement permits remote capacitance tests**
- **Rack-mounting version also available**

The Model 71A provides precise, high resolution three-terminal capacitance measurements and two-terminal inductance measurements with the speed and convenience of a VTVM. In addition, the instrument offers an accurate dc analog of the test value.

The Model 71A operates by metering the quadrature current through the test, while ignoring the in-phase current, so that the instrument is not susceptable to errors resulting from specimen loss over a wide range of Q values. Specified accuracy applies for Q's down to 3. Devices of lower Q (to 0.1) may be measured after proper readjustment of phase.

The measuring capabilities of the Model 71A of 0 to 1000 pF and 0 to 1000 μH are each covered in 7 ranges in a 1-3-10 sequence. Capacitance or inductance is read directly from the 6-inch mirrored scale meter.

Test signal level for capacitance measurement is fixed at 15 millivolts, permitting tests on a wide variety of solid-state devices. Test level for inductance measurement is less than 1 millivolt. The highly stable test signal is crystal controlled at 1 Mc/s.

DC Bias up to ±200 volts at 250 mA may be applied through rear panel terminals to the test from an external supply. Resistance of the bias

circuit is 7Ω (which includes 3.5 ohms in the fuse); thus the bias voltage may be monitored at the rear terminals without interfering with measurements. The bias circuit is protected from overload by a 250 mA fuse.

The instrument measures only the capacitance of the test. It ignores stray impedances from the LO post to ground; thus the specimen can be connected to the terminals by coaxial cable, or a remote test fixture may be used. However, for capacitances below 10 pF, when measured remotely, adjustment of the "CABLE COMP" control is required as part of the initial zero setting of the meter. For larger values of capacitance, the series inductance of connecting cables must be taken into consideration.

The dc analog output is available at rear panel terminals. Amplitude range is from zero to either 100 or 300 millivolts for full scale, depending on the numerics of the selected range. Thus when used in conjunction with a DVM, correct numerics are automatically maintained when switching from range to range.

Linearity of the dc analog is better than 0.1% of the reading plus 0.005% of full scale; it provides exceptionally good discrimination on a DVM. Accuracy of the dc output is better than ±0.5% when standardized with the Model 71-1A Standard Capacitor (see below).

This output may be used simultaneously with the panel meter without error. In cases of rapidly changing test values or in applications where meter readout is not required, the meter may be switched off to avoid interaction resulting from a small counter EMF in the moving coil and needless wear.

In providing an accurate dc analog of the continuously measured capacitance or inductance value, the Model 71A constitutes a C or L to DC Converter and greatly facilitates many tests which previously could be made only by time consuming point-by-point balancing. For example with an oscilloscope or an X-Y Plotter, curves of such phenomena as capacitance versus voltage of voltage variable diodes may be rapidly and accurately drawn. Similarly, plots may be made of the linearity of variable capacitors or inductors, or of the tracking accuracy of a pair of variable capacitors or voltage variable diodes.

Since the response time of the dc output (from 0 to full scale) is less than 10 milliseconds, the instrument can follow rapid changes in the value of the test, or make a large number of individual measurements in an extremely short time. For example, used with a dc voltage comparator it performs high-speed go/no-go capacitance or inductance tests, or provides facilities for automatic sorting or batching.

The Model 71A may also be used as the readout device for a wide variety of capacitive or inductive transducers.

SPECIFICATIONS

Capacitance Measurements (Three-terminal):

Range, 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{3}{Q}\%\right) \text{FS} + 0.01 \text{ pF}$$

Resolution, 0.01 pF

Inductance Measurements (Two-terminal):

Range, 0 to 1000 μH in 7 ranges; lowest range 1 μH, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{6}{Q}\% + \frac{L_{\mu H}}{500}\%\right) \text{FS} + 0.01\ \mu H$$

Resolution, 0.01 μH

Test Signal:

Frequency, 1 Mc/s, crystal controlled

Level, Capacitance measurements, 15 mV;
Inductance measurements, less than 1 mV

DC Bias:

Externally supplied bias up to ±200 V may be applied at 250 mA at rear terminals; bias circuit protected from overload by 250 mA fuse

DC Analog Output:

Level, 0 to 100 mV or 0 to 300 mV depending on full scale numerics; also >1 V FS for loads >10 MΩ

Linearity, 0.1% of reading + 0.005% FS

Primary Power:

117 or 234 V (±10%), 50/60 cps: 40 watts

Physical Dimensions:

7¼" w x 10¼" d x 11" h; weight, 12 lbs; packed for shipment, 16 lbs.

Price: $735.00 FOB Parsippany, New Jersey

Model 71-1A Standard Capacitor

The Model 71-1A Standard Capacitor was designed specifically for calibrating the Model 71A. It is a highly compact standard adjusted to 100 pF ±0.25% against references traceable to the NBS. It provides for both high Q calibration and calibration for a Q of 3. (The Model 71-1A is built into the Model 71AR and is put into use by means of a front panel selector.)

Price, $50.00.

Model 71AR Rack-Mounting Capacitance/Inductance Meter

The Model 71AR provides the performance characteristics of the Model 71A in rack-mounting form. In every respect its electrical specifications are identical to those of the bench unit. In addition, the Model 71-1A Standard Capacitor is incorporated in the Model 71AR and is switched into service by a front panel selector.

Price, $810.00

BOONTON ELECTRONICS CORPORATION

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 71D Digital 1 Mc/s Capacitance/ Inductance Meter

Continuous, High-Resolution Measurements of Capacitance & Inductance at 1 Mc/s with Digital Read-out

The Model 71D is a digital read-out version of the Model 71A Capacitance/Inductance Meter, providing continuous measurements of three-terminal capacitance and two-terminal inductance at 1 Mc/s.

The capacitance and inductance capabilities of 0 to 1000 pF and 0 to 100 μH, respectively, are each covered in 3 decade ranges, with 4-digit resolution on all ranges. Range selection is manual.

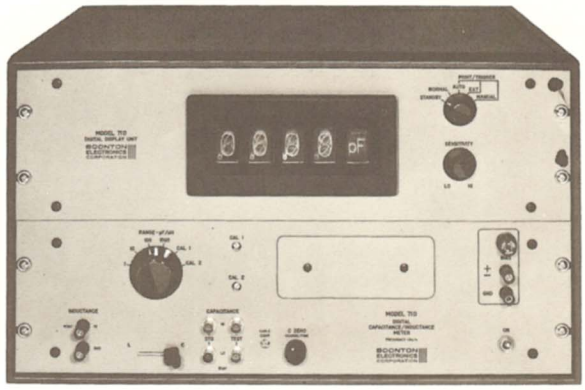
The digital display unit of the Model 71D comprises a potentiometric system with edge-lighted 4-digit read-out. In the NORMAL mode, the Model 71D is free-running, continuously measuring and displaying the test value. With the front-panel selector in the STAND-BY position, the reading is "held" regardless of the test condition) until reset to the NORMAL condition. Both free-running and triggered print-out connections are included.

An over-range indication is automatically displayed when the test value exceeds full-scale. Indication is also given to warn that tests are being attempted with the C/L selector in the incorrect position.

A 100 pF (±0.25%) capacitance standard is incorporated in the Model 71D, and is switched into use by a front panel selector. This standard provides for both high and low (Q=3) Q check.

The Model 71D is completely self contained, and comprises two rack-type units in a bench console.

Since the Model 71D measures 3-terminal capacitance, it is possible to connect the test specimen by coaxial cables or to use a remote test fixture.



SPECIFICATIONS

Capacitance Measurements (Three-terminal):

Range, 0 to 1000 pF in 3 ranges; lowest range, 10 pF, FS

Accuracy, 0.5% of reading + $\left(0.01\% + \frac{3}{Q}\%\right)$ FS + 0.001 pF

Resolution, 4 digits, all ranges

Inductance Measurements (Two-terminal):

Range, 0 to 100 μH in 3 ranges; lowest range 1 μH, FS

Accuracy, 0.5% of reading + $\left(0.5\% + \frac{6}{Q}\% + \frac{L\mu H}{500}\%\right)$ FS + 0.0002 μH

Resolution, 4 digits, all ranges

Test Signal:

Frequency, 1 Mc/s, crystal controlled

Level, Capacitance measurements, 15 mV
Inductance measurements, less than 1 mV

Q Range: Specified performance applies for Q's down to 3; to lower Q values with readjustment.

DC Bias:

External bias up to ±200 V may be applied at 250 mA at rear terminals; bias circuit protected from overload by 250 mA fuse

Reference Standard:

Model 71-1A 100 pF (±0.25%) Capacitance Standard built in; switched into use by front panel selector; provides for both high Q and Low Q (Q = 3) check.

Primary Power:

117 or 234 V (±10%), 50/60 cps: 40 watts

Availability: Fall, 1966

BOONTON ELECTRONICS CORPORATION
PARSIPPANY, NEW JERSEY

Domestic Price List
Instruments & Accessories

Effective Date: Dec. 15, 1967
Superseding issue of June 1, 1967

INSTRUMENTS

Model	Unit Price	Description
33A	$2,500.00	RF Admittance Bridge (0 to 150 pF)
33B	3,000.00	Ultra-high Conductance Resolution Admittance Bridge (0 to 5000 μmhos)
33C	2,650.00	Ultra-high Capacitance Resolution Admittance Bridge (0 to 15 pF) (Formerly 33A-S7)
33D	3,150.00	Ultra-high Capacitance and Conductance Resolution Admittance Bridge (0-15 pF; 0 to 5000 μmhos)
35A	3,000.00	Q Bridge
41A	750.00*	RF Microwattmeter
51A	2,500.00	AC Null Detector (rack mounting)
56A	495.00*	DC Null Detector
56A-S2	550.00*	DC Null Detector, 40 Megohm Input
63H	2,300.00	Inductance Bridge (5-500 KHz)
63L	2,300.00	Inductance Bridge (400 Hz-40 KHz)
63M	2,300.00	Inductance Bridge (1-100 KHz)
71A	875.00	Capacitance/Inductance Meter (1 MHz)
71A-R	950.00	Rack Mtg. Mod. 71A; includes built in Cap. Std. & Q Check
71C-R	995.00	Capacitance/Inductance Meter (100 KHz) Rack Mtg. Model; built in Cap. Std. & Q Check
71D (700A)	2,500.00	Digital Capacitance/Inductance Meter (1 MHz)
74D	1,595.00	Capacitance Bridge (100 KHz; 0.1%; dc bias; limit/norm. detector)
75C	2,200.00	Capacitance Bridge (5-500 KHz; dc bias)
75D	1,595.00	Capacitance Bridge (1 MHz; dc bias low C range; phase sensitive detector)
77B	2,300.00	Automatic Capacitance Limit Bridge (1 MHz)
77B-S1	2,300.00	Automatic Capacitance Limit Bridge (100 KHz)
91C	550.00*	RF Voltmeter (incl. Probe, Tip, 50Ω Adapter)
91C-S4	680.00*	RF Voltmeter (400 Hz operation; incl. Probe, Tip, 50Ω Adapter)
91C-S5	550.00*	RF Voltmeter (dBm scale; incl. Probe, Tip, 50Ω Adapter)
91C-S7	680.00*	RF Voltmeter (400 Hz; dBm scale; incl. Probe, Tip, 50Ω Adapter)
91H	650.00*	RF Voltmeter (incl. Probe, Tip, 50Ω Adapter)
91H-S4	780.00*	RF Voltmeter (400 Hz operation; incl. Probe, Tip, 50Ω Adapter)
91H-S5	650.00*	RF Voltmeter (dBm scale; incl. Probe, Tip, 50Ω Adapter)
91H-S7	780.00*	RF Voltmeter (400 Hz; dBm scale, incl. Probe, Tip, 50Ω Adapter)
91DA	700.00*	RF Voltmeter (incl. Probe, Tip, 50Ω Adapter)
91DA-S5	700.00*	RF Voltmeter (dBm scale; incl. Probe, Tip, 50Ω Adapter)

Complete Accessory Kit, (when purchased with any of the above RF Voltmeters) — price $125. Includes 91-6C; 91-7C; 91-14A; 91-15A; 91-18A; and storage space for Probe, Tip and 50Ω Adapter provided with each instrument.

95A	600.00*	Sensitive DC Meter

There are many special versions of instruments, designated by —S numbers, not shown. Prices of these units will be quoted on request.

50 Hz (117V or 220V) versions of all instruments available at no extra cost.
Add $50.00 for special paint.
* Add $25.00 for rack mounting version.
For prices of RF Voltmeter and Bridge Accessories see reverse side.

VOLTMETER ACCESSORIES

Model	Unit Price	Description
91-4C	$75.00	Special 1 KHz-250 MHz RF Probe
91-6C	25.00	Unterminated Adapter (BNC)
91-7C	40.00	100:1 Voltage Divider
91-8B	30.00	50Ω Adapter (BNC)
91-8B-1	30.00	75Ω Adapter (BNC)
91-8B-2	30.00	93Ω Adapter (BNC)
91-8B-3	30.00	72Ω Adapter (BNC)
91-8B-4	30.00	90Ω Adapter (BNC)
91-8B-5	30.00	95Ω Adapter (BNC)
91-8B-6	30.00	60Ω Adapter (BNC)
91-8B-7	30.00	20Ω Adapter (BNC)
91-8B-8	30.00	200Ω Adapter (BNC)
91-8B-9	30.00	52Ω Adapter (BNC)
91-12D	65.00	RF Probe**
91-12E	55.00	RF Probe for all current RF Voltmeters
91-13B	5.00	Probe Tip
91-14A	45.00	"Tee" Adapter (Type N)
91-15A	25.00	50Ω Termination for 91-14A (Type N)
91-16A	25.00	Unterminated Adapter (Type N)
91-17D	75.00	Special 1 KHz-250 MHz RF Probe**
91-18A	15.00	Accessory Storage Box
91-19B	15.00	Accessory Storage Bracket

** For replacement in Model 91DA's with Serial Numbers below 8535 only.

BRIDGE ACCESSORIES

CS	$100.00	Capacitance Standard for 74, 75, & 77 Series
TS1	5.00	Terminal Shield
33-1A	60.00	Dielectric Sample Holder for Model 33 Series
33-2A	60.00	Diode Test Jig for Model 33 Series
33-3A	60.00	Type N 50Ω Adapter for Model 33 Series
33-4A	120.00	Set of 7 work coils (with storage container) for capacitance measurement with Models 33A & 33B
33-5A	120.00	Set of 7 work coils (with storage container) for capacitance measurement with Models 33C & 33D
33-6A	120.00	Set of 7 work coils (with storage container) for inductance measurement with Models 33A & 33B
33-7A	120.00	Set of 7 work coils (with storage container) for inductance measurement with Models 33C & 33D
33-8A	40.00	Zero Conductance Standard.
33-9A	30.00	Capacitance Standard for Model 33 Series
33-10A	30.00	Conductance Standard for Model 33 Series
33-11A	30.00	Range Extending Capacitor for 33A
33-12A	25.00	Range Extending Work Coil for 33A
33-13A	15.00	Storage Case for 8 Work Coils for 33 Series
33-14A	350.00	Set of Capacitance and Conductance Standards in Storage Case for 33A
33-15A	25.00	Test Signal Attenuator for use with 33C
41-1A	160.00	Power Detector for 41A
41-2A	15.00	Power Detector Cable for 41A
63-11B	100.00	Mu Jig for use with 63H, 63L, or 63M
63-15A	100.00	Inductance Standard (1 μH)
71-1A	60.00	100 pF Capacitance Standard & Q Check for Model 71A
75-1A	25.00	Fixed 40 dB Test-Signal Attenuator for 74 & 75 Series
75-2A	230.00	Oscillator/Detector (100 KHz) for 75A
75-3A	230.00	Oscillator/Detector (465 KHz) for 75A
75-5A	120.00	Three to Two Terminal Adapter for 74, 75, & 77 Series Bridges
77-1A	120.00	Remote Test Jig for Model 77B and 77B-S1
77-2A	175.00	Capacitance Range Extender, 1 MHz for 75D & 77B
77-3A	175.00	Capacitance Range Extender, 100 KHz for 74 Series
77-5A	120.00	Capacitance Range Divider (10:1, 100 KHz) for 71C-R and 74 Series
77-4A	120.00	Capacitance Range Divider (10:1, 1 MHz) for 71A, 71A-R, 71D, 75A Series, 75D, and 77B

All prices F.O.B. Parsippany, New Jersey
State and local taxes not included.
Minimum order value, $15.00
Prices and specifications subject to change without notice.

Terms: Net 30 days

Telephone: 201-887-5110 ■ TWX: 710-986-8241 ■ Route 287, Parsippany, N. J. – 07054

2M 6 68

Printed in U.S.A.

BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 33A
RF Admittance Bridge

Precise, High-Resolution Measurements of Admittance / Impedance at 1 Mc/s to 100 Mc/s

- Capacitance Range: 0 to 150 pF *
  Basic Accuracy: 1%
  Resolution: 0.02 pF
- Conductance Range: 0 to 25,000 μmhos
  Basic Accuracy: 2%
  Resolution: 1% +0.5 μmho
- Shunt or series resistance, shunt inductance, dissipation factor, and Q may also be readily determined.
- Test Frequencies: 1, 5, 10, 20, 30, 50, and 100 Mc/s; all crystal controlled
- Operates with test signal levels as low as 1 mV; continuously adjustable up to at least 100 mV
- Low distortion test signal prevents errors resulting from turn-over effect
- DC Bias: Internal, −5 V to +100 V; external, to ±250 V

* 0 to 30 pF at 100 Mc/s

- Invaluable for measurements of semiconductor devices, including integrated circuits
- Some typical applications are:

  Capacitance and loss measurements of diodes (particularly varactors and tunnel diodes)

  Measurements of transistors (including F.E.T.'s)

  Measurements of resistors, capacitors, inductors, connectors, and transmission lines

  Determination of dielectric constants including those of thin films

  Measurement of permeability and loss of magnetic materials

GENERAL DESCRIPTION

The Model 33A is a precision admittance bridge whose ability to measure directly both capacitance and conductance at high frequencies with superb resolution and with extremely low test signal levels sets it apart from all other commercially available instruments.

Shunt inductance and both series and parallel resistance may also be measured with the Model 33A. In addition, such quantities as Q, dissipation factor, dielectric constant, and permeability may be conveniently determined.

The balance network of the Model 33A (patent applied for) was developed by John H. Mennie of Boonton Electronics Corporation. It represents an important advance in the art of rf impedance measurement.

The instrument includes a dc supply for biasing the test specimen as well as provision for external bias. An internal test signal generator supplies seven crystal controlled frequencies ranging from 1 to 100 Mc/s. These circuits, together with the RF bridge network and null detector, are packaged in a single, compact bench cabinet.

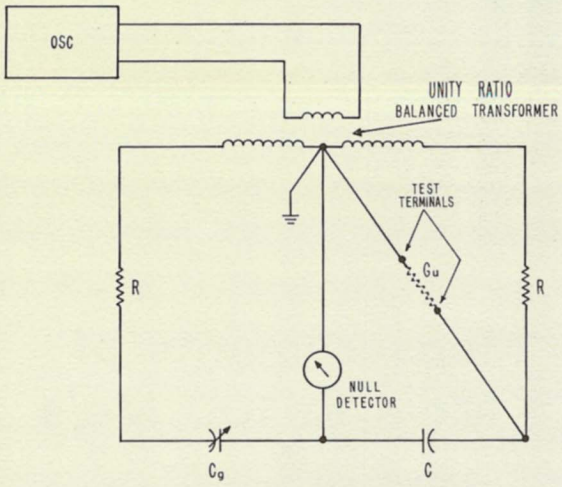


Figure 1a

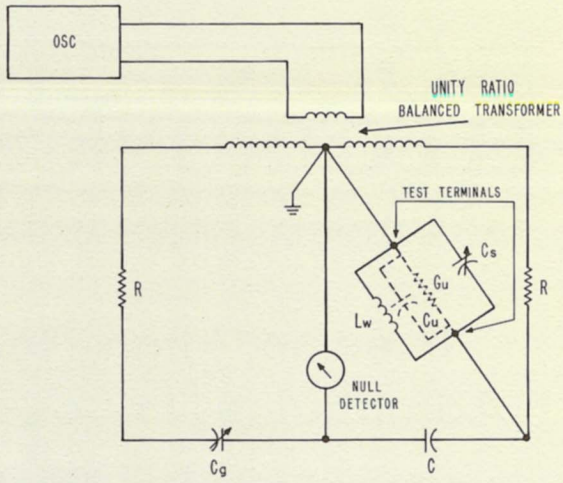


Figure 1b

Figure 1. Simplified schematics of Model 33A Bridge Circuit

BASIC BRIDGE CIRCUIT

The unique characteristics of the Model 33A are made possible by the bridge circuit, a simplified diagram of which is shown in Figure 1.

Conductance Measurement — In the configuration shown in Figure 1a, the network is balanced when:*

$$G_u = \frac{\frac{C}{C_g} - 1}{R}.$$

Thus the conductance of the test specimen, G_u, may be measured in terms of the capacitance removed from the circuit by adjustment of the calibrated air capacitor (C_g) to restore the balance of the bridge.

Capacitance Measurement — The network shown in Figure 1a measures conductance only. Addition of the resonant circuit, C_s and L_w, across the test terminals (See Figure 1b) provides means for measuring the effective capacitance of the test specimen, C_u.

When this circuit is initially brought to resonance at the test frequency, the bridge sees it only as a low value of pure conductance which can be easily balanced out when the bridge is initially zeroed.

When the specimen is placed across the test terminals, the capacitance it adds is determined from the amount of capacitance removed by adjustment of the calibrated air capacitor, C_s, to return the network to resonance, as indicated by restoring the balance of the bridge.

MODEL 33A BRIDGE CIRCUIT

In applying this basic concept to the Model 33A, the function of C_g is performed by a precision, highly stable air capacitor which is calibrated in micromhos. The helical conductance scale is effectively more than 34 inches long, providing excellent readability over the total range of zero to 25,000 micromhos.

C_s, also a precision air capacitor, serves as the main capacitance control of the Model 33A. With the arrangement of the outer "counter dial" plus the 10-to-1 vernier each picofarad occupies a full inch on the scale, again assuring excellent resolution of readout.

* For derivation of this balance equation, see Boonton Electronics Technical Report No. 21, available on request.

The inductance, L_w, in the resonant network (Figure 1b) is provided by an external inductor, or "work coil", which attaches to connector posts located on top of the cabinet. The eight work coils required for operation over the total range of the Model 33A are supplied (complete with a sturdy storage container) as standard equipment with the instrument.

In the Model 33A two additional controls are added to the simplified bridge circuit shown in Figure 1b, both of which contribute to convenience of operation. A small variable air capacitor inserted in series with C_g permits balancing out the loss of the resonant circuit so that the conductance measurements can be made from a zero reference point. Another small variable air capacitor is placed in parallel with C_s, again to permit capacitance readings from a zero reference. Front panel markings of these two adjustments are G ZERO and C ZERO, respectively (see Figure 2).

This bridge circuit provides a number of important advantages: The use of air capacitors as the variable elements provides "infinite resolution" controls, and eliminates problems of noise, wear, and frequency restriction commonly associated with even the best potentiometers.

In addition, this circuit avoids the complexities introduced by the use of double-shielded transformers for coupling to a grounded signal source or null detector. Their limited frequency range, low impedance, and inter-shield capacitance across the arms of the bridge all would work to the substantial detriment of the instrument's wide operating range.

The basic simplicity of both the circuit and its shielding requirements results in only small values of residual reactance which are easily compensated under all operating conditions.

Since all shunt reactances both of the test specimen and of the measuring system are completely neutralized when the bridge is balanced, their effects do not mask the equivalent conductance of the test. As a result, measurements can be made of small values of capacitance and conductance with high resolution, even with low test signal levels.

Another characteristic of this bridge circuit is that interaction between the arms of the bridge is eliminated, avoiding the annoyance and ambiguity of false nulls and sliding balance.

Mechanical linkages between the panel controls, calibrated scales, and their respective variable capacitors all have been engineered and manufactured to reduce backlash to an absolute minimum, with the result that it may be discounted from the standpoints of accuracy and resolution.

TEST SIGNAL

Since stability of the test signal frequency is vital to the accuracy of measurement, each of the seven internally supplied test frequencies is crystal controlled. Harmonic distortion of the test signal waveform is held to a minimum, eliminating errors in measurement resulting from turnover effects, a point of major importance in measurements on semiconductors.

The test signal level is continuously adjustable from a maximum of at least 100 millivolts to as low as 1 millivolt (5 millivolts at 100 Mc/s). Operation at even lower test levels is possible under some circumstances. It is important to note that adjustment of signal level has no effect whatever upon the test frequency.

The amplitude of the test signal may be measured and set to a specific level with any of the Boonton Electronics Sensitive RF Voltmeters, Model 91- Series. When the bridge is balanced with the RF Voltmeter and test specimen connected, the desired level may be accurately set. When the meter is removed and the bridge rebalanced, the test voltage returns to the pre-set level.

NULL DETECTOR AND INDICATOR

The null detector of the Model 33A is of the superhetrodyne type. The local oscillator is crystal controlled and selection of the test frequency simultaneously selects the appropriate local oscillator frequency. No further tuning is required. Gain of the null detector amplifier is adjustable at the front panel so that the optimum conditions of system noise and sensitivity can be selected. Adjustment of detector sensitivity in no way effects test signal frequency or level.

DC BIAS

An internal, regulated dc supply provides bias for the test specimen which is continuously adjustable from −5 volts to +100 volts. It may be monitored by connecting a dc meter to front panel jacks. Provision is also included for application of externally supplied bias up to ±250 volts, dc. Both the resistance and inductance of the external bias channel have been held to extremely low values so that high current tunnel diodes may be tested without oscillation.

INDUCTANCE AND RESISTANCE MEASUREMENTS

Effective shunt inductance can be readily determined with the Model 33A. By selecting a work coil which brings the bridge to balance up-scale rather than at "zero picofarads" the effective "negative capacitance" of the test sample may be measured, and the shunt inductance then computed from well established relationships, i.e., $L = 1/\omega^2 C$.

While measurements of inductance can be made with many of the work coils provided with the instrument, an additional set of coils intended specifically for this purpose is available as a separate accessory. These coils permit balancing the bridge at full capacitance scale (150 pF) at all frequencies, and provide a more convenient means for making such measurements. (see "Recommended Accessories" listings below)

The Model 33A is calibrated in micromhos which may, of course, be readily converted to ohms of parallel resistance, or to dissipation factor or Q. Series resistance may also be determined from established equations.

APPLICATIONS

The applications for the Model 33A may be divided into two basic areas: (a) precision, high resolution measurement of RF admittance on a wide range of semiconductor devices; and (b) general high frequency impedance and loss measurements on a great variety of components.

Semiconductor Measurements — The unique capabilities of the Model 33A make possible vital capacitance and loss measurements on solid state devices at high frequencies and low test levels with an accuracy and resolution that has never before been possible. In addition, a number of

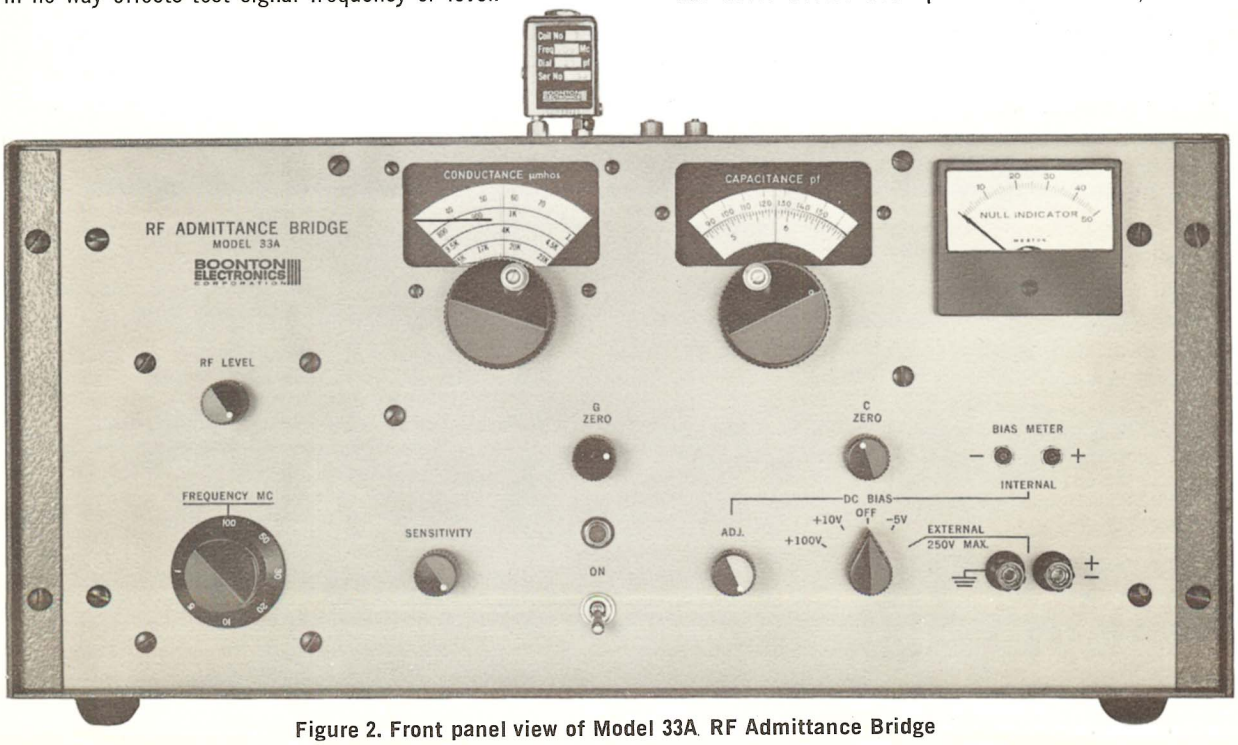


Figure 2. Front panel view of Model 33A RF Admittance Bridge

features have been incorporated which add materially to the convenience and efficiency of measurement. For example, the ability to bias the specimen over a wide range of values from a built-in regulated supply plus the facility for adjusting and monitoring this bias level at the front panel are of particular importance in tests on such voltage sensitive components as voltage variable capacitor diodes.

An important application for the Model 33A involves measurements on integrated circuits. Here, in addition to measuring the stray capacitance and the capacitance and loss of individual components on the substrate, the Model 33A is of great value in determining the effectiveness of isolation of elements, whether the circuit is constructed by either P-N junction or by dielectric isolation.

The Model 33A is also extremely useful for capacitance and loss measurements on transistors of all types (including FET's), as well as for determination of a number of h, y, and z parameters.

General RF Impedance Measurements — In impedance measurements on a wide range of high frequency components there is a distinct advantage in testing at or near the frequency at which the device is to be used, rather than measuring at low frequency and then attempting to extrapolate. Many phenomena such as skin effect and distributed capacitance are extremely difficult or impossible to detect at lower frequencies.

Typical of the components for which the Model 33A is useful are connectors, switches, resistors, capacitors, and inductors, in addition to such assemblies as high frequency attenuators, and pulse forming networks. The instrument also provides means for determination of phase and attenuation constants of cables, as well as their characteristic impedances.

The Model 33A is equally useful for a number of measurements on broad band transformers. These include determination of primary inductance, or leakage and mutual inductance, and of coupling coefficients. Since these devices are frequently quite lossy, their Q's are often too low for measurement on other types of high frequency instrumentation.

MATERIAL CONSTANT STUDIES

This bridge is a valuable tool in the study of dielectric constants. The Model 33-1A Dielectric Sample Holder is intended specifically for use with the Model 33A, and accepts sheet materials having thicknesses from a maximum of 0.13″ down to approximately 0.005″ or less. The dielectric constant is determined by comparing the capacitance of the fixture containing the sample minus fringe capacitance to the calculated capacitance of the fixture with an equivalent air gap.

The Model 33A may also be used in determining effective permeability and loss of magnetic materials, particularly of toroidal cores.

SPECIFICATIONS

Capacitance Range: 0 to 150 pF from 1 Mc/s to 50 Mc/s; 0 to 30 pF at 100 Mc/s

Capacitance Accuracy: $\pm (1\% + \frac{0.2}{L}\% + 0.05\ pF)$*

Capacitance Resolution: 0.02 pF at 100 mV test level

Conductance Range: 0 to 25,000 μmhos

Conductance Accuracy: $\pm (2\% + \frac{Qf}{1000}\% + 0.5\ \mu mhos)$**

Conductance Resolution: 0:5 μmho at 100 mV test level

Inductance Range: 0.02 μH to ∞ at 100 Mc/s

Inductance Accuracy: $\pm (1\% + \frac{10}{C}\% + 0.01\ \mu H)$***

Test Signal Frequencies: 1, 5, 10, 20, 30, 50, and 100 Mc/s; all crystal controlled; Accuracy at all frequencies, 0.01%

Test Signal Level: Continuously adjustable from 100 mV to 1 mV at all frequencies except 100 Mc/s, where minimum level is 5 mV; adjustment of test signal level does not effect frequency

DC Bias: Internal: continuously adjustable from −5 V to +100 V, dc; External: up to ±250 V, dc

Primary Power: 105/125 V, 50/60 cps, 45 watts

Price: $2,200 (including 8 work coils in storage container) FOB Parsippany, New Jersey

MODEL 33A-S7 EXTRA HIGH RESOLUTION ADMITTANCE BRIDGE

An alternate version of the Model 33A, the Model 33A-S7 provides a basic capacitance resolution of 0.002 pF over a total capacitance range of 0 to 15 pF, for those applications where the greatest possible resolution of small values of capacitance is required. In all other respects, the Model 33A-S7 is identical to the Model 33A.

The total operational range of the Model 33A-S7 is covered by seven, rather than the eight work coils for the Model 33A. These seven coils are provided as standard equipment.

SPECIFICATIONS, MODEL 33A-S7

Performance specifications for the Model 33A-S7 are identical to those for the Model 33A, with the following exceptions:

Capacitance Range: 0 to 15 pF

Capacitance Accuracy: $\pm (1\% + \frac{0.2}{L}\% + 0.005\ pF)$*

Capacitance Resolution: 0.002 pF at 100 mV test level

Inductance Range: 0.2 μH to ∞ at 100 Mc/s

Price: $2,350 (including 7 work coils in storage container) FOB Parsippany, New Jersey

* Where "L" is resonating inductance in μH
** Where "Q" is Q factor of test component and "f" is frequency in Mc/s
*** Where "C" is the resonating capacitance of the sample in pF

AVAILABLE ACCESSORIES

		Price
33-1A:	Dielectric Sample Holder	$50.00
33-2A:	Diode Test Jig	$50.00
33-3A:	Type N 50 Ω Adapter	$50.00
33-4A:†	Set of 8 work coils (with storage container) for capacitance measurement with Model 33A	$95.00
33-5A:†	Set of 7 work coils with storage container) for capacitance measurement with Model 33A-S7	$84.00
33-6A:	Set of 7 work coils (with storage container) for inductance measurement with Model 33A	$84.00
33-7A:	Set of 7 work coils (with storage container) for inductance measurement with Model 33A-S7	$84.00
33-8A:	Zero Conductance Standard with Storage Case	$35.00
33-9A:	Capacitance Standards for Models 33A and 33A-S7	$25.00
33-10A:	Conductance Standards for Models 33A and 33A-S7	$25.00
33-11A:	Range Extending Capacitors for Model 33A	Dependent on requirements
33-12A:	Range Extending Work Coils for Model 33A	$11.00
33-13A:	Storage Case for 8 Work Coils for Model 33A	$10.00
33-14A:	Set of Capacitance and Conductance Standards in Storage Case for Model 33A	$300.00

† Supplied as standard equipment with instrument

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BOONTON ELECTRONICS
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PARSIPPANY, NEW JERSEY

Model 56A
DC Null Detector

A Highly Sensitive Electronic Galvanometer Particularly Valuable for Use with DC Bridges

- Input Resistance: 10 Megohms on *all* ranges
- Voltage Capability: 1 μV to 100 V
- Current Capability: 0.1 pA to 10 μA
- 160 dB control of Sensitivity in 8 ranges
- 60 dB compression in HUNT mode for locating null
- DC output for recorder, Go/No-Go testing, or automatic control functions
- Grounded or floating input

General Description

The Model 56A is an electronic galvanometer which combines extremely high sensitivity with high input resistance, excellent stability, and unusual convenience of operation. Unlike mechanical galvanometers, the Model 56A is unaffected by mechanical shock or vibration. The instrument is particularly valuable as a null detector for use with dc bridges and potentiometers, as well as in a great variety of applications in the laboratory and in production where requirements are beyond the capabilities of even the best mechanical galvanometers.

The zero-center meter of the Model 56A permits indications of either polarity without interchanging connections or polarity switching. Scale calibrations are linear and extend from −1.0 to +1.0 relative units, (approximately ±0 μV) with the smallest calibration representing 0.05 relative units. Additional "overcalibrations" to −1.2 and +1.2 are provided to permit overlapping readings on successive ranges.

Sensitivity of the Model 56A is continuously selectable over a 160 dB range in eight decade steps plus overlapping vernier (SENS ADJ) control. Such an arrangement permits "calibrating" the scale of the instrument so that a given input level relates to a specific percentage or tolerance limit on the meter.

An electrical zero control is provided to center the pointer. However, the stability of the instrument is such that after a warm up period of about 30 minutes readjustment of the control is unnecessary, except on the most sensitive range where a slight correction may occasionally be desired. It should be noted that range switching has no effect on the zero position.

DC Output

A dc output is available at front panel terminals which (in the CAL mode) is linear with respect to the dc input. The output level is continuously adjustable from essentially zero to at least ±1 volt

for full scale deflection on all ranges. Output polarity is the same as that of the input. The dc output is useful for application to a recorder, and is especially valuable in conjunction with a dc voltage comparator (such as the Boonton Electronics Models 52B or 53A) for go/no-go testing as well as for a variety of automatic control functions.

Operating Modes

The Model 56A may be operated in either of two modes: "CAL" (calibrate) in which the meter indication is linear with respect to the dc input over the entire scale; or "HUNT" in which sensitivity is "normal" at zero but is progressively compressed, reaching 60 dB below "normal" at ± full scale to facilitate locating the null when testing components of unknown value. Mode selection is accomplished either by a front panel switch or remotely by a switch connected to receptacles at the side of the instrument. Typically, the remote selector is a foot switch which frees the operator's hands for adjustment of equipment while first coarsely locating the null in the HUNT mode, and then finding the precise point of balance in the CAL mode.

Other Characteristics

The input circuit of the Model 56A may be operated either grounded or floating. A jumper at the front input terminals grounds one side of the input when desired. With the jumper removed the input is isolated from ground by at least 200 megohms.

The instrument is packaged as a compact bench unit. An alternate version, the 56A-R, is electrically identical but is designed for mounting in a standard 19-inch rack.

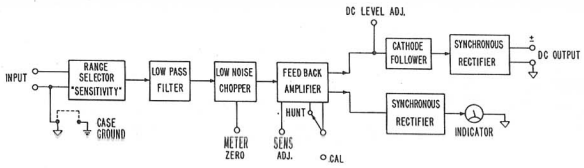

Figure 1. Block diagram, Model 56A

Theory of Operation

A block diagram of the Model 56A is shown in Figure 1. Input is made through a voltage dividing network (Range Selector) where it is attenuated as required. A low pass filter is included in the input circuit to minimize the effects of external ac pickup. The dc is then converted to ac at power line frequency by the mechanical low noise chopper.

The chopper output is applied to the high gain, feed back stabilized ac amplifier. The R/C coupling networks between amplifier stages and their associated filters are designed to peak in the 50-60 c/s region with sharp attenuation of frequencies above and below this band to reduce further the effects of spurious ac.

The metering voltage is obtained by applying the output of the ac amplifier to a synchronous rectifier which is so phased that the meter indication conforms to the polarity of the dc input. The linear dc output is derived by passing a portion of the ac amplifier output through an impedance matching cathode follower and then to a synchronous rectifier which again is phased to provide a dc voltage at the output terminals which is of the same polarity as the dc input.

SPECIFICATIONS

Voltage Capability: 1 μV to 100 V, dc

Current Capability: 0.1 pA to 10 μA, dc

Full Scale Sensitivities: (SENS ADJ. at max.)
Voltage: 10 μV to 100 V, dc
Current: 1 pA to 10 μA, dc
Power: 10^{-17} W to 10^{-3} W

Sensitivity Ranges: 8 decade ranges (calibrated in amplifier gain) of 0.01, 0.1, 1, 10, 100, 1 K, 10 K, and 100 K

Input Resistance: 10 megohms on all ranges

Noise Level: Less than 1 μV, p-p, referred to input

Zero Drift: Less than 1 microvolt after warm-up

Response Time: Approximately 1 second for full scale deflection

Modes of Operation:
Hunt: 60 dB compression
Calibrate: Indication linear with respect to dc input

Mode Switching: At front panel or by remote switch

Meter: 1.2 — 0 — 1.2 scale.

Meter Linearity: 2% of end scale, maximum error

Amplifier Gain: Continuously variable from −40 dB +100 dB

Amplifier Output: ±1.0 mA into 1000Ω; Polarity the same as input

Output Impedance: Approximately 2000 Ω

Overload Tolerance:

Range	Approximate Full Scale Voltage	Overload Voltage Tolerated	Overload Factor
0.01	100 V	1000 V	10
0.1	10 V	1000 V	100
1	1 V	1000 V	1 K
10	0.1 V	1000 V	10 K
100	0.01 V	100 V	10 K
1 K	1 mV	10 V	10 K
10 K	0.1 mV	10 V	100 K
100 K	0.01 mV	10 V	1 M

Power Requirements: 105 to 125 V, 50-60 cycles, 40 watts; 210 to 250 V operation also available

Size: 7¼" W x 9½" D x 11" H excluding handle; Model 56 A-R 19" W x 7" H x 8¾" D

Weight: 12 pounds

Price: Model 56A, $495.00; Model 56 A-R, $520.00, f.o.b., Parsippany, N. J.

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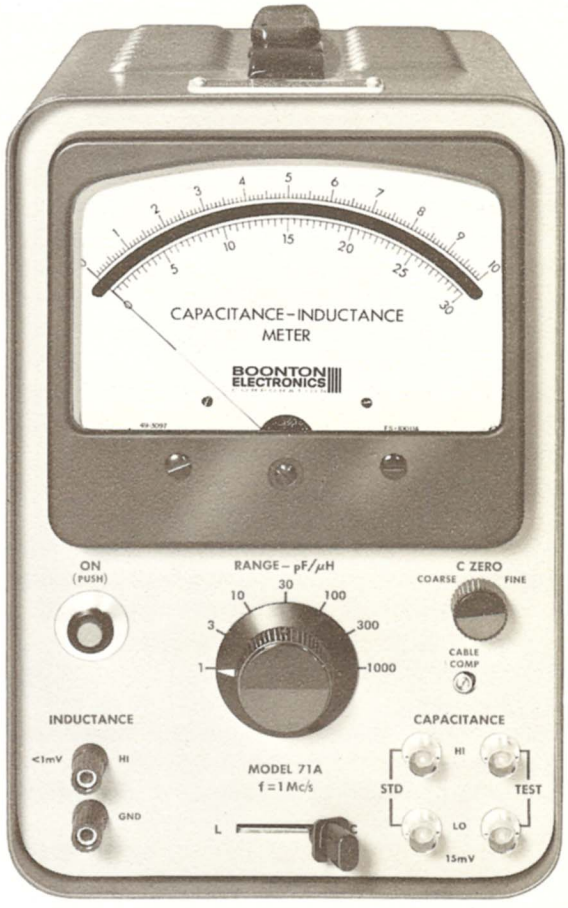
BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 71A 1 Mc/s Capacitance/Inductance Meter

Instant, Direct-reading Reading Measurements of Capacitance and Inductance at 1 Mc/s

- **Capacitance Measurements (Three Terminal):**
  - Range: 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS.
  - Resolution: 0.01 pF
  - Accuracy: ±1%, (see Specifications)
- **Inductance Measurements (Two Terminal):**
  - Range: 0 to 1000 μH in 7 ranges; lowest range, 1 μH, FS.
  - Resolution: 0.01 μH
  - Accuracy: ±1%, (see Specifications)
- **DC Analog Output**
  - Linearity, 0.1% of measured value +0.005% FS; provides at least 3-digit resolution on all ranges with appropriate DVM
  - Response time less than 10 ms from 0 to FS
  - Suitable for use with recorder, scope, X-Y plotter, voltage comparator, etc.
- **Particularly useful for measuring semiconductor junction capacitance**
  - Low (15 mV) test level
  - 1 Mc/s crystal controlled test signal
  - Provision for DC bias up to 200 V @ 250 mA
- **Measures over wide range of Q values; down to as low as 3 (lower with re-adjustment)**
- **Three-terminal arrangement permits remote capacitance tests**
- **Rack-mounting version also available**



The Model 71A provides precise, high resolution three-terminal capacitance measurements and two-terminal inductance measurements with the speed and convenience of a VTVM. In addition, the instrument offers an accurate dc analog of the test value.

The Model 71A operates by metering the quadrature current through the test, while ignoring the in-phase current, so that the instrument is not susceptable to errors resulting from specimen loss over a wide range of Q values. Specified accuracy applies for Q's down to 3. Devices of lower Q (to 0.1) may be measured after proper readjustment of phase.

The measuring capabilities of the Model 71A of 0 to 1000 pF and 0 to 1000 μH are each covered in 7 ranges in a 1-3-10 sequence. Capacitance or inductance is read directly from the 6-inch mirrored scale meter.

Test signal level for capacitance measurement is fixed at 15 millivolts, permitting tests on a wide variety of solid-state devices. Test level for inductance measurement is less than 1 millivolt. The highly stable test signal is crystal controlled at 1 Mc/s.

DC Bias up to ±200 volts at 250 mA may be applied through rear panel terminals to the test from an external supply. Resistance of the bias

circuit is 7Ω (which includes 3.5 ohms in the fuse); thus the bias voltage may be monitored at the rear terminals without interfering with measurements. The bias circuit is protected from overload by a 250 mA fuse.

The instrument measures only the capacitance of the test. It ignores stray impedances from the LO post to ground and is adjustable to be insensitive to stray impedances from the H1 post to ground. Thus the specimen can be connected to the terminals by coaxial cable, or a remote test fixture may be used. However, for capacitances below 10 pF, when measured remotely, or for extreme cases of stray loss, adjustment of the "CABLE COMP" control is required as part of the initial zero setting of the meter. For larger values of capacitance, the series inductance of connecting cables must be taken into consideration.

The dc analog output is available at rear panel terminals. Amplitude range is from zero to either 100 or 300 millivolts for full scale, depending on the numerics of the selected range. Thus when used in conjunction with a DVM, correct numerics are automatically maintained when switching from range to range.

Linearity of the dc analog is better than 0.1% of the reading plus 0.005% of full scale; it provides exceptionally good discrimination on a DVM. Accuracy of the dc output is better than ±0.5% when standardized with the Model 71-1A Standard Capacitor (see below).

This output may be used simultaneously with the panel meter without interaction. In cases of rapidly changing test value or in applications where meter readout is not required, the meter may be switched off to avoid needless wear.

In providing an accurate dc analog of the continuously measured capacitance or inductance value, the Model 71A constitutes a C or L to DC Converter and greatly facilitates many tests which previously could be made only by time consuming point-by-point balancing. For example with an oscilloscope or an X-Y Plotter, curves of such phenomena as capacitance versus voltage of voltage variable diodes may be rapidly and accurately drawn. Similarly, plots may be made of the linearity of variable capacitors or inductors, or of the tracking accuracy of a pair of variable capacitors or voltage variable diodes.

Since the response time of the dc output (from 0 to full scale) is less than 10 milliseconds, the instrument can follow rapid changes in the value of the test, or make a large number of individual measurements in an extremely short time. For example, used with a dc voltage comparator it performs high-speed go/no-go capacitance or inductance tests, or provides facilities for automatic sorting or batching.

The Model 71A may also be used as the readout device for a wide variety of capacitive or inductive transducers.

SPECIFICATIONS

Capacitance Measurements (Three-terminal):

Range, 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{3}{Q}\%\right) \text{FS} + 0.01 \text{ pF}$$

Resolution, 0.01 pF

Inductance Measurements (Two-terminal):

Range, 0 to 1000 μH in 7 ranges; lowest range 1 μH, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{6}{Q}\% + \frac{L\mu H}{500}\%\right) \text{FS} + 0.01\ \mu H$$

Resolution, 0.01 μH

Test Signal:

Frequency, 1 Mc/s, crystal controlled

Level, Capacitance measurements, 15 mV;
Inductance measurements, less than 1 mV

DC Bias:

Externally supplied bias up to ±200 V may be applied at 250 mA at rear terminals; bias circuit protected from overload by 250 mA fuse

DC Analog Output:

Level, 0 to 100 mV or 0 to 300 mV depending on full scale numerics; also >1 V FS for loads >10 MΩ

Linearity, 0.1% of reading + 0.005% FS

Primary Power:

117 or 234 V (±10%), 50/60 cps: 40 watts

Physical Dimensions:

7¼" w x 10¼" d x 11" h; weight, 12 lbs; packed for shipment, 16 lbs.

Price: $735.00 FOB Parsippany, New Jersey

Model 71-1A Standard Capacitor

The Model 71-1A Standard Capacitor was designed specifically for calibrating the Model 71A. It is a highly compact standard adjusted to 100 pF ±0.25% against references traceable to the NBS. It provides for both high Q calibration and calibration for a Q of 3. (The Model 71-1A is built into the Model 71AR and is put into use by means of a front panel selector.) **Price,** $50.00.

Model 71AR Rack-Mounting Capacitance/Inductance Meter

The Model 71AR provides the performance characteristics of the Model 71A in rack-mounting form. In every respect its electrical specifications are identical to those of the bench unit. In addition, the Model 71-1A Standard Capacitor is incorporated in the Model 71AR and is switched into service by a front panel selector. Physical dimensions are indicated on the outline drawings below. **Price,** $810.00

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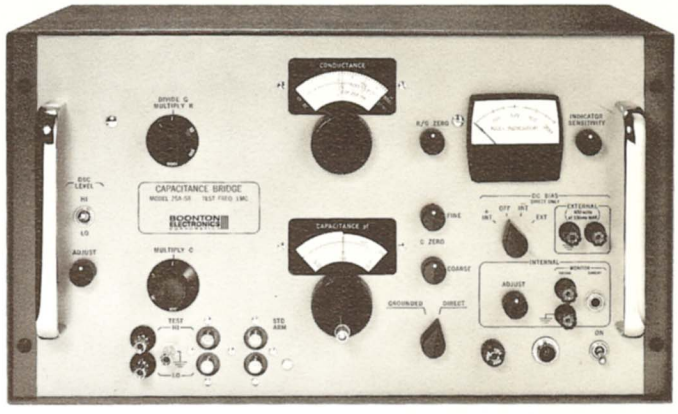
CORPORATION
PARSIPPANY, NEW JERSEY

Models 75A & 75B 1 Mc/s Capacitance Bridges

Standards of Performance For Reliable, High-Resolution Capacitance and Loss Measurements at 1 Mc/s

- Capacitance Range:
  Model 75A, 0.0002 pF to 1000 pF (Three or Two Terminal)

  Model 75B, 0.00002 pF to 1000 pF (Three Terminal only)
- Conductance Range:
  0.01 umho to 1000 umhos
- Resistance Range:
  1000 ohms to 100 megohms
- DC Bias, internal or external, in -S8 versions
- Particularly valuable for semiconductor measurements
- Low test signal levels
- Accurate measurements of extremely low Q devices



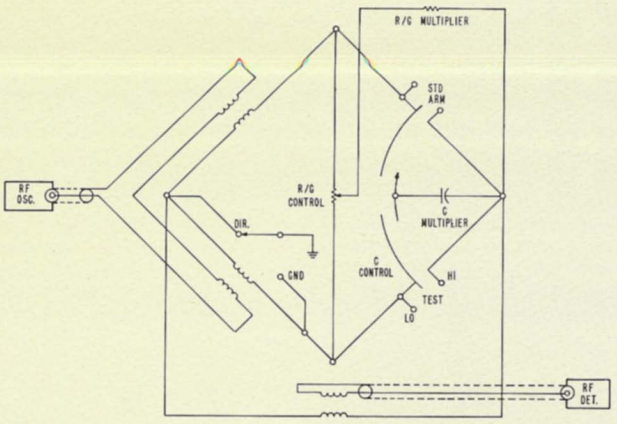
- Remote measurements via coaxial cables
- No false or sliding nulls; simple, convenient balancing; all zeroing controls vernier driven
- Completely self-contained, including bridge circuitry, oscillator, and detector
- High-resolution differential measurements

GENERAL DESCRIPTION

The Models 75A and 75B have become the industry's standards for accurate, reliable measurement of capacitance and loss at 1 Mc/s. Their ability to make high-resolution measurements down to small values of capacitance with low test signal levels, combined with the facility (in the -S8 versions) for applying dc bias to the specimen, have brought these instruments into wide use for a great variety of semiconductor tests.

High resolution, excellent long term stability, provision for use of remote test fixtures, and the ability to make differential measurements render the Models 75A and 75B particularly well suited for such investigations as temperature coefficient determination.

The wide measuring ranges, convenience of operation, and reliability of these instruments recommend them for a great number of general laboratory capacitance and loss studies.



1. Simplified Diagram, Models 75A & 75B

COMPARISON OF MODELS 75A AND 75B

The Models 75A and 75B are essentially similar except that the Model 75B is provided with an additional capacitance range which extends measurements down by one order of magnitude to 0.00002 pF. Because of its increased detector sensitivity, the Model 75B can be operated with lower test signal levels than is the case with the Model 75A, as discussed under "Test Signal" on page 3. The Model 75A measures either three or two terminal capacitance; the Model 75B measures three terminal capacitance only.

Both instruments are completely self-contained, including bridge network, 1 Mc/s test oscillator, null detector, and (in the -S8 versions) the dc bias supply. They are packaged as compact bench cabinets. Since they are built on a 19-inch chassis, they may be mounted in a standard rack when removed from the case.

CAPACITANCE MEASUREMENTS

Capacitance is read directly in pF from the main capacitance dial. The measuring range of 0.0002 pF to 1000 pF of the Model 75A is covered in four decade multiplier ranges; the Model 75B measures from 0.00002 pF to 1000 pF in five decades.

The main capacitance dial consists of a "counter" plus a 40:1 vernier which provides speed and convenience in scanning together with great accuracy of fine adjustment. This arrangement results in a capacitance scale which is effectively over 200 inches long for each range. In the case of the Model 75A on the lowest multiplier range, a single picofarad is spread across 5000 divisions; with the Model 75B set to its lowest multiplier, 0.1 pF occupies this same scale length.

CONDUCTANCE/RESISTANCE MEASUREMENTS

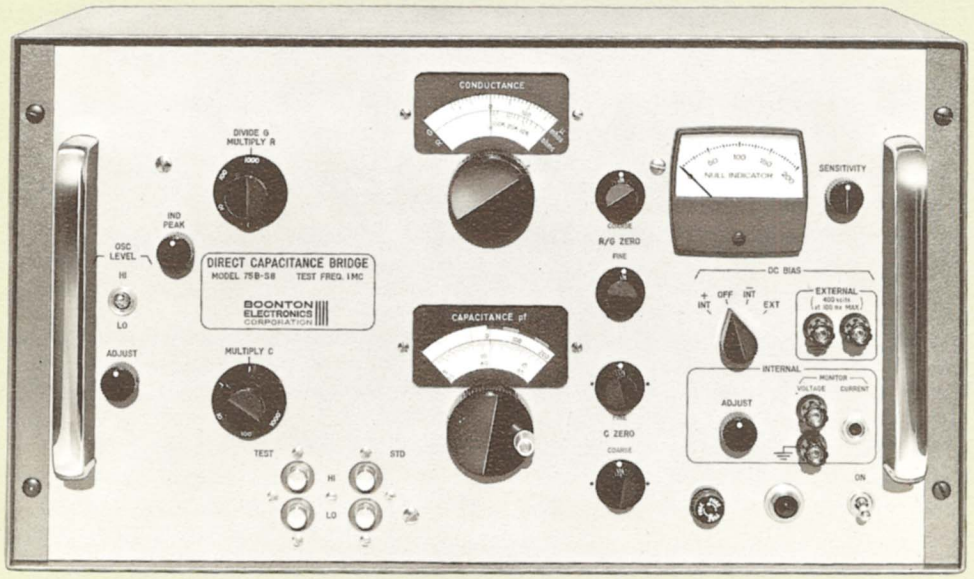
Conductance and parallel resistance are also read directly from a front panel dial. In both the Model 75A and 75B the range 0.01 μmho to 1000 μmhos (1000 ohms to 100 megohms) is covered in 4 decade steps. Since the conductance and capacitance balancing networks are independent of each other, the range setting for one has no bearing on that for the other. In addition this lack of interaction between the two arms assures convenient balancing without the annoyance and ambiguity of false nulls or sliding balance.

THEORY OF OPERATION

A simplified diagram of the Models 75A and 75B is shown in figure 1.

Bridge Circuit

The bridge is a modified Young circuit. The output from the 1 Mc/s oscillator is applied to the bridge input transformer through a low impedance link coupling. The secondary of the input transformer is an integral part of the bridge network, providing effectively two generators with a common ground which produce signals that are equal in amplitude and opposite in phase. The low impedance of the secondary minimizes the effects of shunt capacitance. And with the extremely tight coupling between the two secondary windings, loading effects on one side affect the other side **equally.** Thus capacitance from the LO post to ground has negligible influence on the balance of the bridge.



2. Front Panel View, Model 75B-S8

Any capacitance from the HI post to ground is shunted across the detector where its only practical effect is a reduction of detector sensitivity.

As a result of this arrangement only the capacitance between the HI and LO posts has significant effect on the balance condition of the bridge, permitting measurements which are essentially unaffected by impedances from either side of the test to ground

The main balance control is a variable differential air capacitor built to the most exacting standards to assure maximum stability. Use of a differential capacitor also contributes to the overall bridge stability since the capacitive elements in each arm are subjected to identical thermal conditions.

The unique design and construction of the mechanical linkage connecting this capacitor to its associated dial hold backlash to negligible proportions, permitting full advantage to be taken of the high resolution capabilities of these bridges.

Capacitance range multiplication is accomplished by selectively inserting one of the multiplier capacitors in series between the main balance capacitor and the high post. These range multipliers are stable variable air capacitors which are adjusted to accuracies of 0.1 percent or better.

The conductance control is an infinite resolution potentiometer connected between the standard and test arms of the bridge, with its center arm connected to the high post. The conductance range is multiplied by switching one of the G multiplier resistors in series between the center arm of the potentiometer and the high post. These resistors are characterized by excellent thermal stability and low capacitance so that their insertion in the bridge network has no practical effect on bridge stability or capacitance accuracy.

Test Oscillator

The internal test oscillator is of the series-fed Hartley type and generates a 1 Mc/s signal whose frequency is accurate to ±1 percent. Since the bridge circuit is not of the resonant type, accuracy of measurement is not dependent upon the test frequency. Frequency variations within the specified ±1 percent have no effect on bridge performance; were greater variations to occur, the only influence would be a decrease in sensitivity.

A tuned filter at the oscillator output provides harmonic suppression. The entire oscillator assembly is carefully shielded to prevent spurious interaction with other stages of the instruments.

The test level is continuously adjustable from 3 volts down to approximately 20 millivolts. In the Model 75B, with its increased sensitivity, it is possible to make measurements with considerably lower test levels. A 40 dB pad is provided as a standard accessory with the Model 75B, permitting operation with signal levels down to approximately 1 millivolt.

The wide range of control over the test signal level is valuable for measurements on such devices as diodes and transistors, where low test levels are usually required in order to obtain a clearly defined null on bridge balance, as well as in cases where measurements are made on components whose capacitance varies with the test signal voltage.

The test signal level may be continuously monitored (between the LO terminal and ground) without affecting the accuracy of test results. A Sensitive RF Voltmeter such as one of the Boonton Electronics Model 91 series is recommended for this purpose.

Detector

The primary of the bridge output transformer is connected by link coupling to the detection corners of the bridge.

The high gain, 3 stage IF-type detector is tuned at 1 Mc/s but provides sufficient band width that oscillator variations within the specified ±1% do not effect the system sensitivity. The detector output is rectified to provide both the null indictating signal and negative bias to the detector amplifier stages. This bias serves as AGC, providing little or no suppression when the bridge output is very low, but causes increasing compression as the unbalance voltage rises. Thus even large unbalance signals are on-scale on the null indicator, while full sensitivity is available near null for locating the precise point of balance.

DC BIAS (MODELS 75A-S8 AND 75B-S8)

In the -S8 versions of these instruments provision is included for applying dc bias to the test specimen either from the internal bias supply or from an external source. The internally supplied bias is continuously adjustable from −6 to +110 volts; external dc bias up to ±400 volts at 100 mA may be applied through front panel terminals. Connectors are provided on the front panel so that the internal bias voltage and current may be conveniently monitored.

REMOTE MEASUREMENTS

The three terminal arrangement of these bridges permits locating the test specimen remotely from the TEST terminals, since the bridges are essentially insensitive to impedances from either side of the test to ground. As a result, the capacitance of the connecting cables can be ignored, and errors resulting from changes in cable position or cable temperature are eliminated. The characteristics of the specimen alone may be accurately measured even when the specimen and connection system are exposed to wide temperature variations, to vibration, or to other extreme environmental conditions.

DIFFERENTIAL MEASUREMENTS

The standard arm of the bridge is accessible through BNC connectors at the front panel so that external standards or balancing capacitors may be attached. Thus these bridges may be used for comparison or differential measurements. This is particularly valuable for temperature coefficient studies, where the differential sensitivity of the lowest multiplier range can be used for capacitors having values up to approximately 1000 pF. In the case of the Model 75A, resolution for temperature coefficient measurements is of the order of ± (0.0001% of nominal capacitance +0.0002 pF) or 1 ppm/°C for values above 200 pF. For the Model 75B, resolution of such measurements is of the order of ± (0.0001% of nominal +0.00002 pF) or 1 ppm/°C for values above 20 pF.

AVAILABLE ACCESSORIES

Model CS- Capacitance Standards — Precision standards for checking accuracy or calibrating three terminal capacitance bridges, or for use as highly stable references for temperature coefficient measurements or other comparison studies; available in any value from 0.01 pF to 1000 pF; frequency range, 1 Kc/s to 1 Mc/s; basic accuracy, 0.1%; calibrated against references directly traceable to National Bureau of Standards. **Price** $75.00

Model 77-2A Range Extender — Precision ratio network attaches to test terminals of the bridge to multiply capacitance readings by exactly 1000, up to a practical limit of approximately 0.1 μF; extends conductance range to 1 mho, and resistance range to 1 ohm; all biasing facilities retain full function. Particularly valuable for measuring forward-bias, low-impedance parameters of semiconductor diodes. **Price** $150.00

SPECIFICATIONS, MODELS 75A & 75A-S8

Capacitance Measurements: 0.0002 pF to 1000 pF in 4 decade ranges; 2 or 3 terminal measurements.

Multiplier	C Range, pF	Smallest Division, pF	Accuracy
1.0	100 to 1000	0.2	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.5 pF) 3-terminal $\pm(0.25\% + \frac{1000}{R_p}$ pF + 1.0 pF) 2-terminal
0.1	10 to 100	0.02	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.02 pF) 3-terminal $\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.5 pF) 2-terminal
0.01	1 to 10	0.002	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.005 pF) 3-terminal $\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.5 pF) 2-terminal
0.001	0.05 to 1	0.0002	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.001 pF) 3-terminal
0.001	0 to 0.05	0.0002	$\pm(2\% + \frac{1000}{R_p}$ pF + 0.0002 pF) 3-terminal

Where R_p is the equivalent parallel resistance of the test in ohms.

Conductance Measurements: 0.01 μmho to 1000 micromhos in 4 decade ranges.

Divider	G Range	Accuracy
1	100 to 1000 μmhos	$\pm(10\% + \frac{Q}{500}\% + 10\ \mu$mhos)
10	10 to 100 μmhos	$\pm(10\% + \frac{Q}{500}\% + 1\ \mu$mho)
100	1 to 10 μmhos	$\pm(10\% + \frac{Q}{500}\% + 0.1\ \mu$mho)
1000	0 to 1 μmho	$\pm(10\% + \frac{Q}{500}\% + 0.01\ \mu$mho)

Resistance Measurements: 1000 ohms to 100 megohms in 4 decade ranges.

Multiplier	R Range	Accuracy
1	1K to 10K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^3}\%)$
10	10K to 100K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^4}\%)$
100	100K to 1 megohm	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^5}\%)$
1000	1 megohm to ∞	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^6}\%)$

Where R is the measured resistance in ohms.

Test Signal:
Frequency, 1 Mc/s ±10 Kc/s, internally supplied.
Level, Continuously adjustable from approximately 20 mV to 4 V.

DC Bias (in —S8 versions only):
Internal, Continuously adjustable from —6 V to +110 V.
External, up to ±400 V, dc, @ 100 mA.

Primary Power: 105 to 125 V, 50/60 c/s; 30 W.

Physical Specifications:
Dimensions: 11¼" h x 19½" w x 12¾" d over-all, in cabinet.
10½" h x 19" w x 10⅛" d behind panel, rack mounted.
Weight: 32 lbs, in cabinet.
25 lbs, rack.

Price, Model 75A, $1250.00; Model 75A-S8 (with dc bias), $1325.00.

SPECIFICATIONS, MODELS 75B & 75B-S8

All specifications for the Models 75B and 75B-S8 are identical to those for the Models 75A and 75A-S8, with the following exceptions:

Capacitance Measurement: 0.00002 pF to 1000 pF in 5 decade ranges; 3 terminal only.

Multiplier	C Range, pF	Smallest Division, pF	Accuracy
1.0	100 to 1000	0.2	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.5 pF)
0.1	10 to 100	0.02	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.02 pF)
0.01	1 to 10	0.002	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.005 pF)
0.001	0.05 to 1	0.0002	$\pm(0.25\% + \frac{1000}{R_p}$ pF + 0.001 pF)
0.001	0 to 0.05	0.0002	$\pm(2\% + \frac{1000}{R_p}$ pF + 0.0002 pF)
0.0001	0 to 0.1	0.00002	$\pm(2\% + \frac{1000}{R_p}$ pF + 0.00005 pF)

Where R_p is the equivalent parallel resistance of the test in ohms.

Test Signal Level: Internally supplied 1 Mc/s test signal continuously adjustable from approximately 20 mV to 4 V; with 40 dB pad, supplied as standard accessory, test signal level is adjustable from 0.2 mV to 40 mV.

Price: Model 75B, $1500.00; Model 75B-S8 (with dc bias), $1575.00.

BOONTON ELECTRONICS CORPORATION

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

MODEL 75C
VARIABLE FREQUENCY DIRECT CAPACITANCE BRIDGE

VARIABLE FREQUENCY BRIDGE FOR COMPONENT ANALYSIS (5-500KC)

CAPACITANCE RANGE:
200 μpf to 1000 pf

CONDUCTANCE RANGE:
0.001 to 1000 μmhos

FREQUENCY RANGE:
5 KC to 500 KC

INTERNAL D.C. BIAS

BUILT-IN DET & OSC

DIRECT CAPACITANCE (3 TERMINAL) BRIDGE

APPLICATIONS

- Capacitors from 200 μpf to 1000 pf can be measured accurately over the test frequency range of 5 KC to 500 KC. The test signal level is continuously variable from below 1 millivolt to 3 volts.
- The direct-capacitance method of measurement is used by the 75C to obtain precise values in areas where stray capacitance becomes important and other measuring techniques impractical. Typical examples of direct-capacitance measurements are: capacitance measurement between control grid and plate of a tube, capacitance measurement between two conductors in a multiconductor cable, capacitance measurement between a single conductor and its shield, capacitance measurement between any two conductors of a printed circuit, and capacitance measurement between the windings of transformers.
- Resistors from 1000 ohms to 1000 megohms can be measured, and resistor performance can be analyzed through the test frequency range of 5 KC to 500 KC.
- Dielectrics can be inspected to determine characteristics throughout the test frequency and test signal level ranges.
- At low test signal levels, capacitance and conductance characteristics of semiconductors can be investigated through the variable frequency range of 5 KC to 500 KC, with the availability of internal d-c bias from -5 volts to +100 volts.
- Remote measurements of capacitance can be made with extended coaxial cables.
- The capacitance and conductance of dielectric solutions can be investigated through the variable frequency range.
- Complex networks can be checked to determine the equivalent capacitance and conductance over the test frequency range.

GENERAL DESCRIPTION

The Model 75C is a versatile, direct-capacitance (three terminal) bridge with a measuring frequency CONTINUOUSLY ADJUSTABLE from 5 KC to 500 KC. The Wien bridge oscillator, multistage tuned detector, and power supply are self-contained, eliminating the necessity of using additional equipment. The 75C is a portable, precision instrument for the measurement of direct capacitance. The bridge, using the direct capacitance measuring technique, is insensitive to stray ground capacitance. This feature is extremely important when measuring a small capacitance where the stray capacitance to ground may be large compared to the value being measured. The Model 75C Capacitance Bridge utilizes the three terminal circuit as described by C. H. Young.*

CAPACITANCE RANGE: The range of measurement for the Model 75C is from 200 μpf to 1000 pf. A multiplier switch provides full scale ranges of 1, 10, 100 and 1000 pf. Precision of readability for all values between 0.1 pf and 1000 pf is 0.1% to 0.01% depending on dial setting.

CONDUCTANCE RANGE: The CONDUCTANCE dial is calibrated in conductance and parallel resistance with ranges covering 0.001 micromho to 1000 micromhos and 1000 ohms to 1000 megohms. The capacitance and conductance adjustments are largely independent of each other. This feature allows easier adjustment under a wide variety of test conditions and also prevents false nulls which can occur with a sliding balance.

TEST FREQUENCY: Test frequency is continuously variable from 5 KC to 500 KC. Frequency accuracy is ±5%.

TEST VOLTAGE LEVEL: The test voltage level can be varied from below 1 millivolt to approximately 3 volts. An external r-f voltmeter may be connected between the LO TEST post and the GND post to read the level of the test voltage. Control of the test voltage is essential in measuring the capacitance of non-linear devices such as diodes, transistors, vacuum tubes, HI-K material, etc. With this type of component, low test voltages are often required to obtain a sharp null in bridge balance. In some instances the capacitance of the component varies with the level of the test voltage.

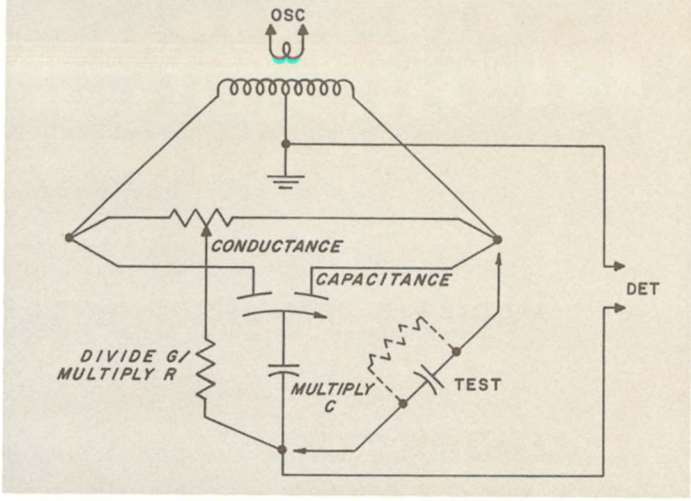
REMOTE TESTING: In addition to the regular test binding posts, BNC coaxial receptacles are provided to facilitate the connection of coaxial test leads for measuring DIRECT capacitance at locations remote from the bridge.

D.C. BIAS: D.C. Bias provision is standard for the Model 75C. The bias range is from −5 volts to +100 volts for application to the specimen under test. The Bias provision is of particular usefulness in the measurement of the voltage variable capacitor, and this feature also finds application in measurements on diodes, transistors and other non-linear devices.

THE STANDARD ARM: The standard arm of the bridge has been made available at BNC receptacles located on the front panel. Standards or balancing capacitors may be connected at these receptacles, and the instrument used as a comparison bridge. Measurement of the temperature coefficient of capacitors can also be made using the differential sensitivity of the X .001 multiplier for values up to approximately 1000 pf. The sensitivity and readability for temperature coefficient measurements is of the order of ±0.0001% of nominal capacitance +0.0002 pf, or 1 PPM/°C for values above 200 pf.

*C. H. Young "Measuring Interelectrode Capacitance" published in "Bell Labs. Record", Dec. 1946.

SIMPLIFIED SCHEMATIC DIAGRAM
MODEL 75C CAPACITANCE BRIDGE



SPECIFICATIONS

CAPACITANCE RANGES:

Multiplier	Capacitance Range	Smallest Division	Accuracy†*
1	100 to 1000 pf	0.2 pf	$\pm$ (0.25% + $\frac{1000}{Rp}$ pf + 0.2 pf)
.1	10 to 100 pf	0.02 pf	$\pm$ (0.25% + $\frac{1000}{Rp}$ pf + 0.02 pf)
.01	1 to 10 pf	0.002 pf	$\pm$ (0.25% + $\frac{1000}{Rp}$ pf + 0.005 pf)
.001	0.05 to 1 pf	0.0002 pf	$\pm$ (0.25% + $\frac{1000}{Rp}$ pf + 0.001 pf)
.001	0 to 0.05 pf	0.0002 pf	$\pm$ (2% + $\frac{1000}{Rp}$ pf + 0.0002 pf)

*Where Rp is the equivalent parallel resistance of the test in ohms.

CONDUCTANCE RANGES:

Divider	Conductance Range	Accuracy†
1	100 to 1000 μmhos	$\pm$ (10% + $\frac{Q}{500}$ % + 10 μmhos
10	10 to 100 μmhos	$\pm$ (10% + $\frac{Q}{500}$ % + 1 μmho)
100	1 to 10 μmhos	$\pm$ (10% + $\frac{Q}{500}$ % + 0.1 μmho)
1000	0.1 to 1 μmho	$\pm$ (10% + $\frac{Q}{500}$ % + 0.01 μmho)
10,000	0 to 0.1 μmho	$\pm$ (10% + $\frac{Q}{500}$ % + 0.001 μmho)

RESISTANCE RANGES:

Multiplier	Resistance Range	Accuracy†‡
1	1K to 10K	$\pm$ (10% + $\frac{Q}{500}$ % + $\frac{R}{10^3}$ %)
10	10K to 100K	$\pm$ (10% + $\frac{Q}{500}$ % + $\frac{R}{10^4}$ %)
100	100K to 1 megohm	$\pm$ (10% + $\frac{Q}{500}$ % + $\frac{R}{10^5}$ %)
1000	1 megohm to 10 megohms	$\pm$ (10% + $\frac{Q}{500}$ % + $\frac{R}{10^6}$ %)
10,000	10 megohms up	$\pm$ (10% + $\frac{Q}{500}$ % + $\frac{R}{10^7}$ %)

‡Where R is resistance of the test in ohms.
†At HI and LO TEST binding posts only.

TEST FREQUENCY: Continuously variable from 5 KC to 500 KC.

TEST VOLTAGE LEVEL: Continuously variable from below 1 millivolt to approximately 3 volts.

POWER REQUIREMENTS: 105-125 volts, 50-60 cycles, 65 watts. 200-240 volts, 50-60 cycle operation available.

DIMENSIONS: 19½" wide x 13" high x 14⅞" deep case mounted. Rack mounting available at no extra cost. Weight: 39 lbs.

CAPACITANCE STANDARDS: Three-terminal Capacitance Standards, particularly useful for checking the accuracy of the Model 75C Capacitance Bridge, are available in any value from 0.01 pf and 1000 pf. Price: $75 each. The Capacitor Standards are ruggedly housed, electrically stable and highly accurate.

PRICE: $1900 f.o.b. Parsippany, New Jersey.

Specifications and Prices subject to change without notice.

BOONTON ELECTRONICS CORPORATION

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 71A 1 Mc/s Capacitance/Inductance Meter

Instant, Direct-reading Measurements of Capacitance and Inductance at 1 Mc/s

- **Capacitance Measurements (Three Terminal):**
  - Range: 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS.
  - Resolution: 0.01 pF
  - Accuracy: ±1%, (see Specifications)
- **Inductance Measurements (Two Terminal):**
  - Range: 0 to 1000 μH in 7 ranges; lowest range, 1 μH, FS.
  - Resolution: 0.01 μH
  - Accuracy: ±1%, (see Specifications)
- **DC Analog Output**
  - Linearity, 0.1% of measured value +0.005% FS; provides at least 3-digit resolution on all ranges with appropriate DVM
  - Response time less than 10 ms from 0 to FS
  - Suitable for use with recorder, scope, X-Y plotter, voltage comparator, etc.
- **Particularly useful for measuring semiconductor junction capacitance**
  - Low (15 mV) test level
  - 1 Mc/s crystal controlled test signal
  - Provision for DC bias up to 200 V @ 250 mA
- **Measures over wide range of Q values; down to as low as 3 (lower with re-adjustment)**
- **Three-terminal arrangement permits remote capacitance tests**
- **Rack-mounting version also available**

The Model 71A provides precise, high resolution three-terminal capacitance measurements and two-terminal inductance measurements with the speed and convenience of a VTVM. In addition, the instrument offers an accurate dc analog of the test value.

The Model 71A operates by metering the quadrature current through the test, while ignoring the in-phase current, so that the instrument is not susceptable to errors resulting from specimen loss over a wide range of Q values. Specified accuracy applies for Q's down to 3. Devices of lower Q (to 0.1) may be measured after proper readjustment of phase.

The measuring capabilities of the Model 71A of 0 to 1000 pF and 0 to 1000 μH are each covered in 7 ranges in a 1-3-10 sequence. Capacitance or inductance is read directly from the 6-inch mirrored scale meter.

Test signal level for capacitance measurement is fixed at 15 millivolts, permitting tests on a wide variety of solid-state devices. Test level for inductance measurement is less than 1 millivolt. The highly stable test signal is crystal controlled at 1 Mc/s.

DC Bias up to ±200 volts at 250 mA may be applied through rear panel terminals to the test from an external supply. Resistance of the bias

circuit is 7Ω (which includes 3.5 ohms in the fuse); thus the bias voltage may be monitored at the rear terminals without interfering with measurements. The bias circuit is protected from overload by a 250 mA fuse.

The instrument measures only the capacitance of the test. It ignores stray impedances from the LO post to ground; thus the specimen can be connected to the terminals by coaxial cable, or a remote test fixture may be used. However, for capacitances below 10 pF, when measured remotely, adjustment of the "CABLE COMP" control is required as part of the initial zero setting of the meter. For larger values of capacitance, the series inductance of connecting cables must be taken into consideration.

The dc analog output is available at rear panel terminals. Amplitude range is from zero to either 100 or 300 millivolts for full scale, depending on the numerics of the selected range. Thus when used in conjunction with a DVM, correct numerics are automatically maintained when switching from range to range.

Linearity of the dc analog is better than 0.1% of the reading plus 0.005% of full scale; it provides exceptionally good discrimination on a DVM. Accuracy of the dc output is better than ±0.5% when standardized with the Model 71-1A Standard Capacitor (see below).

This output may be used simultaneously with the panel meter without error. In cases of rapidly changing test values or in applications where meter readout is not required, the meter may be switched off to avoid interaction resulting from a small counter EMF in the moving coil and needless wear.

In providing an accurate dc analog of the continuously measured capacitance or inductance value, the Model 71A constitutes a C or L to DC Converter and greatly facilitates many tests which previously could be made only by time consuming point-by-point balancing. For example with an oscilloscope or an X-Y Plotter, curves of such phenomena as capacitance versus voltage of voltage variable diodes may be rapidly and accurately drawn. Similarly, plots may be made of the linearity of variable capacitors or inductors, or of the tracking accuracy of a pair of variable capacitors or voltage variable diodes.

Since the response time of the dc output (from 0 to full scale) is less than 10 milliseconds, the instrument can follow rapid changes in the value of the test, or make a large number of individual measurements in an extremely short time. For example, used with a dc voltage comparator it performs high-speed go/no-go capacitance or inductance tests, or provides facilities for automatic sorting or batching.

The Model 71A may also be used as the readout device for a wide variety of capacitive or inductive transducers.

SPECIFICATIONS

Capacitance Measurements (Three-terminal):

Range, 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{3}{Q}\%\right) \text{FS} + 0.01 \text{ pF}$$

Resolution, 0.01 pF

Inductance Measurements (Two-terminal):

Range, 0 to 1000 μH in 7 ranges; lowest range 1 μH, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{6}{Q}\% + \frac{\text{L}\mu\text{H}}{500}\%\right) \text{FS} + 0.01\ \mu\text{H}$$

Resolution, 0.01 μH

Test Signal:

Frequency, 1 Mc/s, crystal controlled

Level, Capacitance measurements, 15 mV;
Inductance measurements, less than 1 mV

DC Bias:

Externally supplied bias up to ±200 V may be applied at 250 mA at rear terminals; bias circuit protected from overload by 250 mA fuse

DC Analog Output:

Level, 0 to 100 mV or 0 to 300 mV depending on full scale numerics; also >1 V FS for loads >10 MΩ

Linearity, 0.1% of reading + 0.005% FS

Primary Power:

117 or 234 V (±10%), 50/60 cps: 40 watts

Physical Dimensions:

7¼" w x 10¼" d x 11" h; weight, 12 lbs; packed for shipment, 16 lbs.

Price: $735.00 FOB Parsippany, New Jersey

Model 71-1A Standard Capacitor

The Model 71-1A Standard Capacitor was designed specifically for calibrating the Model 71A. It is a highly compact standard adjusted to 100 pF ±0.25% against references traceable to the NBS. It provides for both high Q calibration and calibration for a Q of 3. (The Model 71-1A is built into the Model 71AR and is put into use by means of a front panel selector.)
Price, $50.00.

Model 71AR Rack-Mounting Capacitance/Inductance Meter

The Model 71AR provides the performance characteristics of the Model 71A in rack-mounting form. In every respect its electrical specifications are identical to those of the bench unit. In addition, the Model 71-1A Standard Capacitor is incorporated in the Model 71AR and is switched into service by a front panel selector.
Price, $810.00

BOONTON ELECTRONICS CORPORATION

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Models 77B & 77B-S1 Automatic Capacitance Limit Bridges

Precision Three-Terminal Capacitance Limit Bridges for High-Speed, Automatic Go/no-go Testing.

- Capacitance Measurements:
  Model 77B (1Mc/s)
  Automatic Mode, 0.001 pF to 1000 pF
  Manual Mode, 0.0001 pF to 1000 pF
  Basic Accuracy, 0.25%

  Model 77B - S1 (100 Kc/s)
  Automatic or Manual Mode, 0.001 pF to 1000 pF
  Basic Accuracy, 0.1%

- Inductance Measurements:
  Model 77B (1 Mc/s)
  Automatic or Manual Mode, 25 μH to ∞
  Basic Accuracy, 0.25%

  Model 77B-S1 (100 Kc/s)
  Automatic or Manual Mode, 2.5 mH to ∞
  Basic Accuracy, 0.1%

- Conductance Measurements:
  Manual only, 0 to 1000 μmhos

- Resistance Measurements:
  Manual only, 1000 Ω to 100 MΩ

- Capacitance and inductance measurements wholly independent of the loss of the specimen

- Tolerance limits continuously adjustable from $\pm$0.0005 pF to $\pm$200 pf;

- Dual-limit test time, approximately 50 milliseconds

- Visual and electrical test decision outputs

- Three-terminal arrangement permits remote measurements

- Internally supplied DC bias continuously adjustable from $-$6 to $+$150 V; external bias to $\pm$400 V

- Internally supplied, crystal controlled test signal continuously variable from 250 mV down to 1 mV

- No false or sliding nulls; simple, convenient balancing; all zeroing controls vernier driven

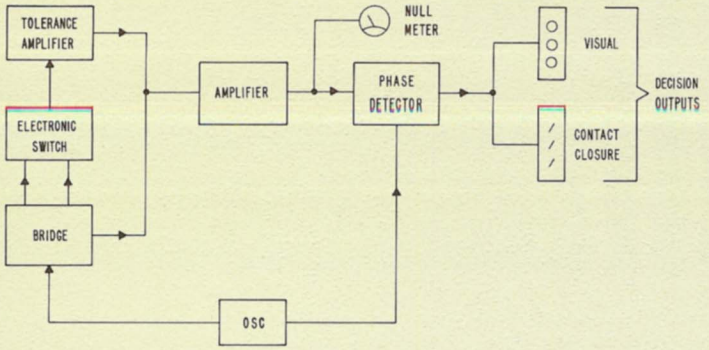

Figure 1 Block diagram of the Models 77B & 77B-S1

GENERAL DESCRIPTION

The Models 77B and 77B-S1 bring the precision and high resolution of meticulous bridge measurements to automatic high-speed dual or single limit capacitance testing. The two instruments are essentially similar except for test frequency, the Model 77B operating at 1 Mc/s and the Model 77B-S1, at 100 Kc/s.

In the automatic mode any nominal value from 0.001pF to 1000 pF and any tolerance from ±0.0005pF to ±200 pF may be programmed for rapid go/no-go capacitance tests. Automatic inductance limit tests may be made with nominal values programmable from 25 microhenries to infinity (from 2.5 millihenries in the Model 77B-S1); inductance limits are continuously adjustable from 0 to at least ±20% of nominal. Test decision outputs are provided in visual form by indicator lamps as well as in electrical form for actuation of external equipment.

In the manual mode the instruments operate as conventional laboratory bridges, providing direct reading measurements of capacitance, parallel resistance, and conductance. Inductance may also be determined by simple computation.

The test signal is internally supplied and is continuously adjustable from 250 millivolts to 15 millivolts for limit testing and to 1 millivolt for manual measurements.

Both the 1 Mc/s test oscillator of the Model 77B and the 100 Kc/s generator of the Model 77B-S1 are crystal controlled.

Test specimens may be biased either by the internal regulated dc supply whose output is continuously adjustable from −6 to +150 volts or by an external supply up to ±400 volts.

The three terminal arrangement permits remote measurements since the bridge is essentially insensitive to impedances from either side of the test to ground. The test specimen may be connected to the bridge by coaxial cables without incurring errors due to cable capacitance.

The standard arm of the bridge is accessible by means of front panel BNC connectors so that external standards or balancing capacitors may be attached. Thus these instruments may be used as comparison bridges or for differential measurements.

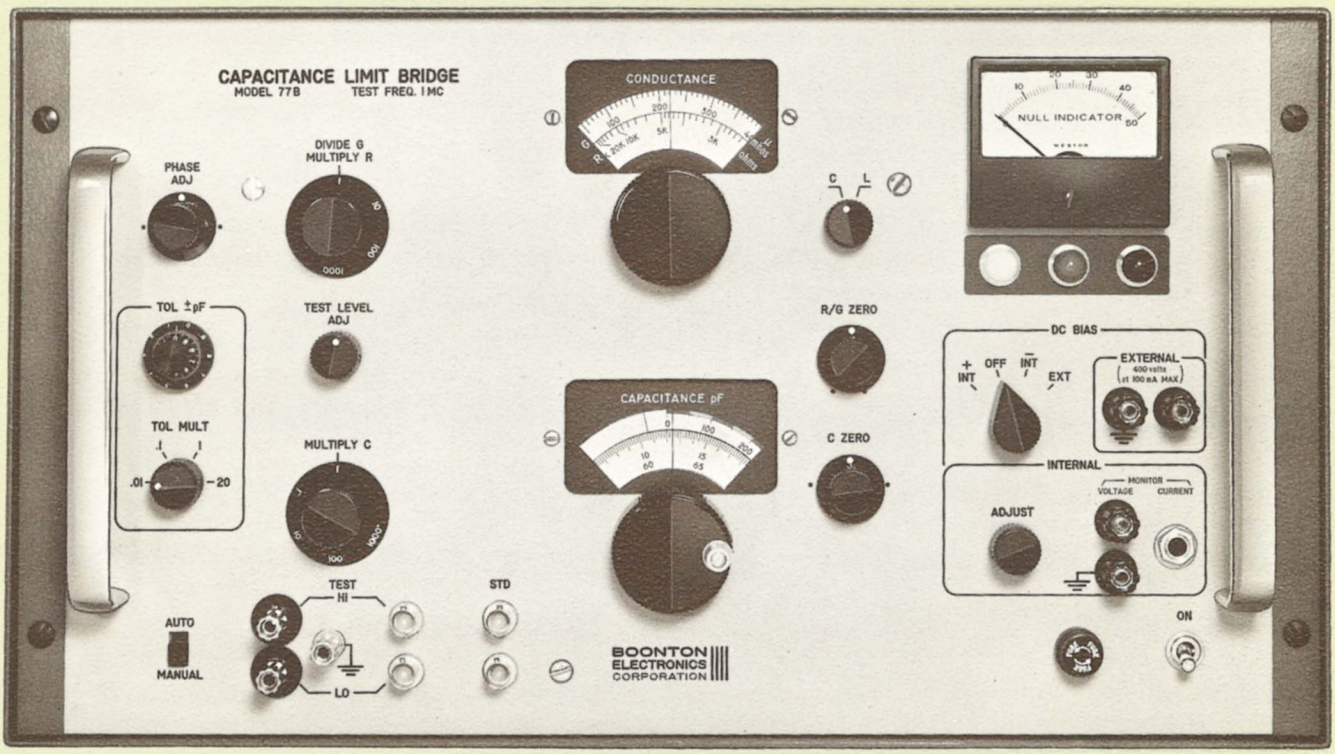

Figure 2. Front panel view of Model 77B

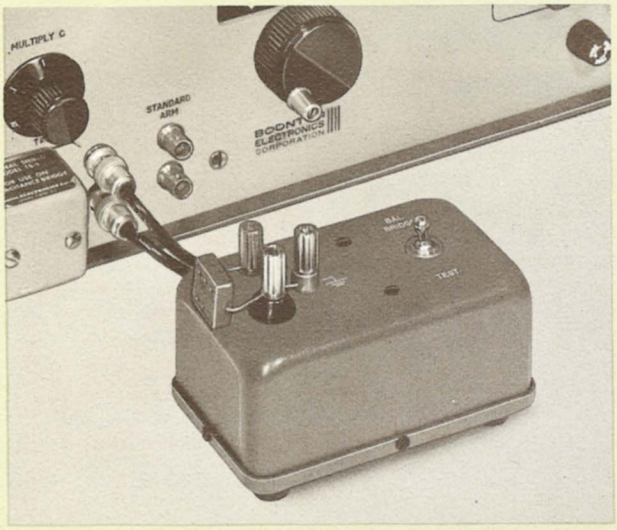

Figure 7. The Range Extender connects conveniently to the test terminals of the bridge to increase the instrument's range of measurement.

INDUCTANCE MEASUREMENTS

Equivalent parallel inductance can be measured on the Model 77B over a range from 25 microhenries to infinity, and, on the Model 77B-S1, from 25 millihenries to infinity. By turning the C/L selector to L, which reverses connections to the main conductance potentiometer, and connecting the specimen to the Standard Arm, the inductance is measured in terms of its resonating capacitance. Conversion from the capacitance reading to the effective parallel inductance is accomplished by simple computation, as detailed in the instrument's instruction book.

In the "L" Mode, either Manual or Automatic operation is available. Limit values are adjustable up to at least ±20% of nominal over the instrument's total inductance range.

AVAILABLE ACCESSORIES

Model CS- Capacitance Standards — Available in any value from 0.01 pF to 1000 pF; Basic accuracy, 0.1%; designed for operation from 1 Kc/s to 1 Mc/s; calibrated against references traceable to National Bureau of Standards. **Price $75.00**

Model 77-1A Remote Test Fixture — Convenient test fixture connects to the TEST terminals of the bridge by coaxial cables; green, amber, and red lamps on jig duplicate front panel decision outputs; supplied complete with connecting cable for decision outputs and both magnetic and spring-loaded holders for components. **Price $100.00.**

Model 77-2A Range Extender — Precision ratio network attaches to test terminals of bridge to increase capacitance range to 0.1 μF, conductance range to 1 mho, resistance range to 1 ohm, and inductance range to 0.25 μH. Bridge accuracy is effectively unchanged and all biasing facilities are unaffected. The Model 77-2A is for use with the Model 77B in the MANUAL mode only. **Price $150.00**

Model 77- 3A Range Extender — Identical to the Model 77-2A except intended for use with 100 Kc/s bridges; used with Model 77B-S1, extends capacitance range to 1 μF, conductance range to 1 mho, resistance range to 1 ohm, inductance range to 2.5 μH; for MANUAL MODE only. **Price $150.00**

SPECIFICATIONS, MODEL 77B

Capacitance Measurement:

Range: Limit Mode, 0.001 pF to 1000 pF (to 1200 pF with max. limit)

Manual mode, 0.0001 pF to 1000 pF

Multiplier	Capacitance Range	Resolution	Accuracy, Manual	Accuracy, C Nominal (Automatic)
1.0	100 to 1000 pF	0.2 pF	$\pm[0.25\% + \frac{1000}{R_p}\text{ pF} + 0.5\text{ pF}]$	$\pm[(0.25 + \frac{3}{Q})\% + 0.5\text{ pF}]$
0.1	10 to 100 pF	0.02 pF	$\pm[0.25\% + \frac{1000}{R_p}\text{ pF} + 0.02\text{ pF}]$	$\pm[(0.25 + \frac{3}{Q})\% + 0.05\text{ pF}]$
0.01	1 to 10 pF	0.002 pF	$\pm[0.25\% + \frac{1000}{R_p}\text{ pF} + 0.005\text{ pF}]$	$\pm[(0.25 + \frac{3}{Q})\% + 0.005\text{ pF}]$
0.001	0.05 to 1 pF	0.0002 pF	$\pm[0.25\% + \frac{1000}{R_p}\text{ pF} + 0.001\text{ pF}]$	$\pm[(0.25 + \frac{3}{Q})\% + 0.001\text{ pF}]$
0.001	0 to 0.05 pF	0.0002 pF	$\pm[2\% + \frac{1000}{R_p}\text{ pF} + 0.0002\text{ pF}]$	$\pm[(2 + \frac{2}{Q})\% + 0.0001\text{ pF}]$
0.0001	0 to 0.1 pF	0.0001 pF	$\pm[2\% + \frac{1000}{R_p}\text{ pF} + 0.00005\text{ pF}]$	———

* Where R_p is the equivalent parallel resistance of the test in ohms.

Inductance Measurement:

Range: Both Limit and Manual Mode, 25 μH to ∞

C MULTIPLIER	Inductance Range	Accuracy, Manual	Accuracy of L Nominal (Automatic)
1	25 μH to 250 μH	$\pm(0.25 + \frac{L}{\ }\ + \frac{4000\,L}{R_p})\%$	$\pm(0.25 + \frac{3}{Q} + \frac{L\mu H}{500})\%$
0.1	250 μH to 2.5 mH	$\pm(0.25 + \frac{L}{10} + \frac{4000\,L}{R_p})\%$	$\pm(0.25 + \frac{3}{Q} + \frac{L\mu H}{500})\%$
0.01	2.5 mH to 25 mH	$\pm(0.25 + \frac{L}{50} + \frac{4000\,L}{R_p})\%$	$\pm(0.25 + \frac{3}{Q} + \frac{LmH}{50})\%$
0.001	25 mH to 250 mH	$\pm(0.25 + \frac{L}{250} + \frac{4000\,L}{R_p})\%$	———
0.0001	250 mH to ∞	$\pm(2.00 + \frac{L}{1000} + \frac{4000\,L}{R_p})\%$	———

** Where L = millihenries
R_p = ohms of parallel resistance

(Specifications continued next page)

Since the phase of the tolerance voltage alternates 180°, the result is the same as though the programmed capacitance limit value were switched first into the standard arm and then into the test arm of the bridge with the capacitance limit value "synthesized" electronically it is possible to program tolerances remotely without the use of external capacitors or complicated mechanical linkages; complex "zoning" of components may be readily accomplished.

The process of limit testing may be explained by considering the following example: Assume that 100 pF capacitors are to be tested to ±5%. The nominal value is established by setting the MULTIPLIER C selector to X1 and the main capacitance control to exactly 100 pF. The tolerance adjustment is set to ±5 pF.

Let us also assume that a specimen placed in the test fixture has an actual value of 93 pF. The tolerance amplifier applies a signal to the detector, equivalent to the addition of 5 pF to the **Standard Arm** for a total of 105 pF. With only 93 pF in the **Test Arm,** the bridge does not reach balance, the phase of the bridge output does not reverse, and the phase-sensitive detector issues a "Low" decision to the indicating circuitry. During the second half of the test cycle, output from the tolerance amplifier is equivalent to the addition of 5 pF to the **Test Arm** for a total of 98 pF, which still does not balance the bridge, and again a "Low" decision is issued.

If the actual value of the test sample were greater than 105 pF, the process would be the same, except that the bridge would pass through and beyond balance (and the phase of the bridge output would reverse) for **both** halves of the test cycle and the "High" indicator would remain lighted during the full cycle.

For a test specimen having a capacitance within the limits of 95 and 105 pF, with the 5 pF tolerance value added to the standard arm, the bridge would not reach balance and there would be no phase inversion. But with the 5 pF added to the Test Arm, the bridge would pass **through** balance for a "High" decision.

When the decision output of the phase sensitive detector shifts from "High" to "Low" on each successive half cycle, special circuitry disables the "High" and "Low" indicators, activating only the "Go" indicator. The complete dual-limit test cycle requires only 0.05 second.

Both the accuracy and resolution of nominal-value programming are comparable to the instrument's measuring capability, as specified on page 6. Limit values from ±0.0005 pF to ±200 pF may be set with resolution of 0.0001 pF or 1%, whichever is greater.

Test results are indicated by red, yellow, and green panel lamps representing "High," "Low," and "Go" decisions, respectively. Three contact closures (one for each test result) with floating common connection are provided at a rear panel. A sample of the 6.3 V, line frequency, filament voltage to each of the three indicating lamps is also provided at this panel. These electrical and continuity contacts may be used simultaneously for remote indications, for control of external equipment, for data logging, etc.

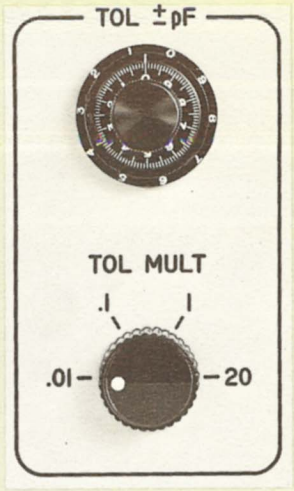

Figure 4. Tolerance limits, set at front panel controls, are continuously adjustable from zero to ±200 pF.

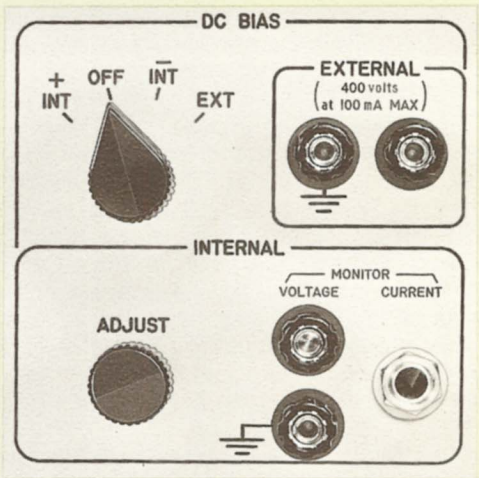

Figure 5. Detail of front panel showing dc bias controls. Provision for both internal and external dc bias is standard on both the Model 77B and Model 77B-S1.

Figure 6. The Model 77-1A Remote Test Jig is available as a separate accessory. See page 5 for details.

The Models 77B and 77B-S1 (including bridge and limit circuitry, test oscillator, null detector, bias supply, and decision outputs) are packaged as single bench type units. When removed from its case, they may be mounted in a standard 19-inch rack.

THEORY OF OPERATION

A simplified block diagram of the Models 77B and 77B-S1 is shown in Figure 1.

Bridge Circuit — The basic bridge network is a modified Young circuit, essentially similar to that used in the Boonton Electronics Models 75A and 75B 1 Mc/s Capacitance Bridges. The main capacitance balance control operates a variable differential air capacitor. Use of a differential air capacitor here contributes to the overall bridge stability since the capacitive elements in each arm are subjected to identical thermal conditions.

Great care is taken in the design of the main balance capacitor, in its metallurgy, in the fabrication and assembly of its parts, and in its final adjustment to assure the highest degree of accuracy and stability within the limits of the state of the art. The unique design and construction of the mechanical linkage between this capacitor and its associated dial hold back-lash to a minimum, permitting full advantage to be taken of the excellent resolution capability of the bridge.

The capacitance range selector (MULTIPLY C) comprises a network of precisely adjusted, gold plated invar capacitors. The conductance control (calibrated also in parallel resistance) is a specially selected long-life potentiometer.

Since the capacitance and conductance balancing networks are essentially independent of each other, the range setting for one parameter has no bearing on the setting of the other. In addition, this lack of interaction between the capacitance and conductance arms assures convenient, straightforward balancing without the annoyance or ambiguity of false nulls or "sliding" balance.

Phase Sensitive Null Detector — An outstanding feature of these bridges is the phase sensitive null detector. A portion of the test signal is applied to the detector to establish the reference voltage. Just as the bridge passes through balance, the phase of the bridge output abruptly shifts 180 degrees. Thus the bridge output either adds to (or subtracts from) the reference voltage depending on whether the capacitance of the **TEST** arm is greater or less than that of the **STANDARD** arm. At the precise point of balance, there is no output from the bridge and only the reference voltage is present in the detector.

The detector senses which of the three conditions exists and issues signals which actuate the appropriate decision-output relays.

Since the conductive (resistive) component of the test is 90 degrees out of phase with the capacitive (inductive) component, **its influence on the phase sensitive detector is negligible. Thus, capacitance tests are substantially independent of the loss of the specimen.** In practice this means that go/no-go capacitance or inductance tests may be made on specimens having widely differing losses without readjustment of the conductance control.

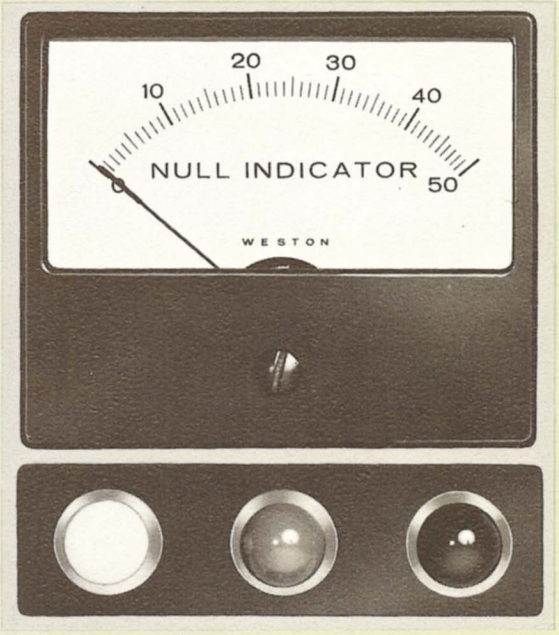

Figure 3. Detail of front panel showing null indicator and visual decision output lamps. Decision outputs in electrical form are available at rear panel terminals.

It should be noted that the Models 77B and 77B-S1 are also equipped with a conventional amplitude-sensitive null detector, permitting conductance/resistance measurements in the MANUAL MODE.

Manual Operation — With the mode selector set to MANUAL the models 77B and 77B-S1 are laboratory bridges of truly outstanding resolution.

In this mode the bridge is balanced and readings are taken in the conventional fashion. However, the phase sensitive detector provides a far more precise null indication than does a traditional amplitude-sensitive detector, particularly when working with low test signal levels; one may go from null (indicated by toggling of **both** Red and Yellow indicator lamps) to unmistakable "off balance" on either side (indicated by lighting of the red or yellow lamp alone) by turning the capacitance balance control **as little as 1/10 minor scale division.**

Automatic Limit Testing — With the mode selector switched to the AUTOMATIC position, the nominal is programmed by setting the MULTIPLIER C and main capacitance control for the desired value. Tolerance limits are established by adjusting a continuous control plus a four-position multiplier.

The electronic switch operating at line frequency samples the test signal voltage alternately at the standard arm and the test arm of the bridge, producing a voltage whose phase shifts 180° for each half switching cycle. This voltage is applied via the "Tolerance Amplifier" to the detector. The tolerance amplifier adjusts this signal level (by settings of the tolerance controls) to equal the unbalance voltage as seen by the detector that would be created in the bridge by a capacitance of the value of the programmed limit.

SPECIFICATIONS (Continued)

Conductance Measurement:

Range: Manual only; Range, 0 to 1000 μmhos

Divider	Conductance Range	Accuracy	Resolution
1	100 to 1000 μmhos	$\pm(10\% + \frac{Q}{500}\% + 10$ μmhos)	10 μmhos
10	10 to 100 μmhos	$\pm(5\% + \frac{Q}{500}\% + 1$ μmho)	1 μmho
100	1 to 10 μmhos	$\pm(5\% + \frac{Q}{500}\% + 0.1$ μmho)	0.1 μmho
1000	0 to 1 μmho	$\pm(5\% + \frac{Q}{500}\% + 0.01$ μmho)	0.01 μmho

Resistance Measurement:

Range: Manual mode only; 1000 Ω to 100 M Ω

Multiplier	Resistance Range	Accuracy†	Resolution
1	1 K to 10 K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^3}\%)$	$\frac{R}{10^3}$
10	10 K to 100 K	$\pm(5\% + \frac{Q}{500}\% + \frac{R}{10^4}\%)$	$\frac{R}{10^4}$
100	100 K to 1 M Ω	$\pm(5\% + \frac{Q}{500}\% + \frac{R}{10^5}\%)$	$\frac{R}{10^5}$
1000	1 M Ω to ∞	$\pm(5\% + \frac{Q}{500}\% + \frac{R}{10^6}\%)$	$\frac{R}{10^6}$

† Where R is the measured resistance in ohms

Test Signal:

Frequency: 1 Mc/s (±200 c/s) crystal controlled
Level: Continuously adjustable from 1 mV to 250 mV

DC Bias:

Internal: Continuously adjustable from —6 V to +150 V
External: Up to ±400 V @ 100 MA

LIMIT MODE

Tolerance:

Range: ±0.0005 pF to ±200 pF, continuously adjustable
Resolution of Limits: 1% of limit or 0.0001 pF, whichever is greater

Test Time:

Approx. 0.05 sec.

Test Decision Outputs:

Visual: Green, red, and amber panel lamps indicating "Go", "High", and "Low", respectively
Electrical: Sample of Indicator lamp filament voltages (6.3 V @ line frequency) at rear terminals
Continuity: Relay contact closures in conformance with test decision at rear terminals

Primary Power:

105-130 V, 60 c/s
105-130 V, 50 c/s
210-260 V, 60 c/s
210-260 V, 50 c/s
} As specified

Physical Characteristics:

Overall (in cabinet): 11¼" h x 19½" w x 12¾" d
Without Cabinet (for rack mounting): 10½" h x 19" w x 10⅛" d
Weight (with cabinet): 35 lbs.
Weight (without cabinet): 25 lbs.

Price:

Model 77B, $2,000.00 FOB Parsippany, New Jersey

SPECIFICATIONS, MODEL 77B-S1

All Specifications for the Model 77B-S1 are identical to those of the Model 77B with the following exceptions:

Capacitance Measurement:

Range: Both Limit and Manual Modes: 0.001 pF to 1000 pF

Multiplier	Capacitance Range	Resolution	Accuracy, Manual	Accuracy, C Nominal (Automatic)
1.0	100 to 1000 pF	0.2 pF	$\pm(0.1\% + \frac{1000}{R_p}$ pF + 0.2 pF)	$\pm[(0.1 + \frac{3}{Q})\% + 0.2$ pF]
0.1	10 to 100 pF	0.02 pF	$\pm(0.1\% + \frac{1000}{R_p}$ pF + 0.05 pF)	$\pm[(0.1 + \frac{3}{Q})\% + 0.05$ pF]
0.01	1 to 10 pF	0.002 pF	$\pm(0.1\% + \frac{1000}{R_p}$ pF + 0.01 pF)	$\pm[(0.1 + \frac{3}{Q})\% + 0.01$ pF]
0.001	0.05 to 1 pF	0.0002 pF	$\pm(0.1\% + \frac{1000}{R_p}$ pF + 0.002 pF)	$\pm[(0.1 + \frac{3}{Q})\% + 0.002$ pF]
0.001	0 to 0.05 pF	0.0002 pF	$\pm(2\% + \frac{1000}{R_p}$ pF + 0.0002 pF)	$\pm[(2 + \frac{2}{Q})\% + 0.0002$ pF]

* Where R_p is the equivalent parallel resistance of the test in ohms.

Inductance Measurement:

Range: Both Limit and Manual Mode, 2.5 mH to ∞

C MULTIPLIER	Inductance Range	Accuracy, Manual	Accuracy of L Nominal (Automatic)
1.0	25 μH to 250 μH	$\pm(0.1 + \frac{L}{10\text{ K}} + \frac{40\text{ L}}{R_p})\%$	$\pm(0.1 + \frac{3}{Q} + \frac{\text{LmH}}{100})\%$
0.1	250 μH to 2.5 mH	$\pm(0.1 + \frac{L}{40\text{ K}} + \frac{40\text{ L}}{R_p})\%$	$\pm(0.1 + \frac{3}{Q} + \frac{\text{LmH}}{500})\%$
0.01	25 mH to 25 mH	$\pm(0.1 + \frac{L}{200\text{ K}} + \frac{40\text{ L}}{R_p})\%$	$\pm(0.1 + \frac{3}{Q} + \frac{\text{LmH}}{2500})\%$
0.001	25 mH to ∞	$\pm(0.1 + \frac{L}{1\text{ M}} + \frac{40\text{ L}}{R_p})\%$	———

** Where L = millihenries
R_p = ohms of parallel resistance

Test Signal:

Frequency: 100 Kc/s (±20 c/s), crystal controlled
Level: Continuously adjustable from 1 mV to 250 mV

Price:

Model 77B-S1, $2000.00 FOB Parsippany, New Jersey

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Printed in U.S.A.

BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 63-11B
Mu Jig

A Test Fixture for Convenient, Rapid Measurement of Permeability and Q of Toroidal Cores

General Description

The Model 63-11B MU JIG is a demountable test fixture which provides means for making rapid, accurate, reproducible measurements of permeability and Q of any type or size of toroidal core within the size limitations of 1.9 O.D. x 0.27" I.D. for heights up to 0.31", and 0.5" I.D. for heights to 0.58".

The MU JIG is intended for use with the Boonton Electronics Model 63H Inductance Bridge and is based upon work by the National Bureau of Standards. It consists essentially of a seven turn toroidal coil whose windings may be opened to accept the test core by unplugging the top half of the fixture.

The test jig plugs directly into the terminals of the Model 63H or may be operated at a distance from the bridge as long as reasonable care is taken to keep lead capacitance low and **(even more important)** constant during measurements.

Theory of Operation

The MU JIG represents a considerable departure from traditional methods of measuring permeability. The conventional technique involved winding sufficient turns on the test core to approximate a uniform current sheet condition. The inductance of this coil was then compared to the calculated inductance of an equivalent air core coil (assuming a thin, current sheet) or by winding an identical coil on a core of the same geometry as the test core, but made from a low loss, unity permeability material, i.e. polystyrene, etc. The inductance of both coils was then measured and the permeability derived from the ratio. A major defect of this method lay in the fact that flux leakage was neglected, as was any departure from the assumed true current sheet condition.

A means for overcoming these sources of error was suggested by Danielson and Harrington* from whose investigations the following equations are derived:

$$\text{Permeability } (\mu) = \frac{L_m - L_o}{L_c} + 1$$

where L_m = Inductance of fixture containing test core

L_o = Inductance of fixture without core

L_c = Calculated inductance of air core (with seven turns. See formula below)

$$L_c = 0.0117\ h\ N^2 \log_{10}\left(\frac{d_2}{d_1}\right) \text{ (microhenries)}$$

where N = Number of turns (7)

h = Height of core in inches

d_1 = Inside diameter of core

d_2 = Outside diameter of core

In practical application the inductance differential of the test fixture with and without the test core is submitted to the above computation to determine the permeability. It should be noted that once L_c is derived for a given core configuration, the value will be a constant, and for that configuration subsequent permeability measurements become a simple direct process.

Core loss (Q) may be obtained from the expression:

$$Q_c = \frac{\omega\,(L_m - L_o)}{R_m - R_o}$$

where ω = 2π x test frequency

R_o = Resistance of fixture without core

R_m = Resistance of fixture with core in position

Additional Considerations

At 10 Kc/s inductance of the MU JIG is typically 0.8 μH; series resistance is 0.05 ohm. At 500 Kc/s inductance is 0.8 μH and series resistance is 0.10 ohm.

Used with the Model 63H Inductance Bridge (see specification sheet attached) tests may be made over a frequency range from 5 Kc/s to 500 Kc/s**. The Model 63H's ability to measure the lower values of inductance (down to 2 x 10^{-10} henry) and its excellent resolution (of the order of 0.01%) permit determination of permeability values as low as 2 or 3. At the other end of the scale, values as high as 100,000 may also be measured.

An important feature of the Model 63H in this application is that the current in the test fixture is essentially independent of the balance condition of the bridge for a given range of measurement. It may be conveniently measured with a standard sensitive electronic a-c meter. Once set to a desired level, the value of excitation current is not altered by balancing the bridge during subsequent inductance and resistance measuring operations. This is particularly important for many of the ferrite materials whose permeability varies widely with the coil excitation current.

The stability of the Model 63H bridge is excellent, and long term studies, such as those required for temperature coefficient determination may be made with confidence.

Price of the MU JIG is $100.00

* See "A Technique for Reducing Errors in Permeability Measurements with Coils" B. L. Danielson and R. D. Harrington, Proc. of L. R. E., Vol. 48, No. 3; March 1960; pp 365-366.

** Tests may be made at 1 Kc with Boonton Electronics Model 63M or 63B Inductance Bridges.

BOONTON ELECTRONICS CORPORATION

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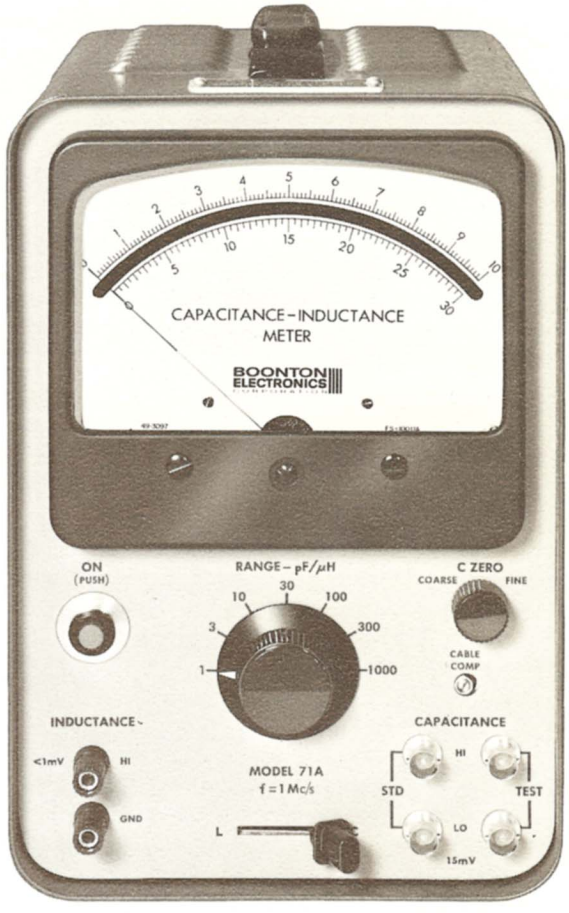
BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 71A 1 Mc/s Capacitance/Inductance Meter

Instant, Direct-reading Measurements of Capacitance and Inductance at 1 Mc/s

- **Capacitance Measurements (Three Terminal):**
  - Range: 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS.
  - Resolution: 0.01 pF
  - Accuracy: ±1%, (see Specifications)
- **Inductance Measurements (Two Terminal):**
  - Range: 0 to 1000 μH in 7 ranges; lowest range, 1 μH, FS.
  - Resolution: 0.01 μH
  - Accuracy: ±1%, (see Specifications)
- **DC Analog Output**
  - Linearity, 0.1% of measured value +0.005% FS; provides at least 3-digit resolution on all ranges with appropriate DVM
  - Response time less than 10 ms from 0 to FS
  - Suitable for use with recorder, scope, X-Y plotter, voltage comparator, etc.
- **Particularly useful for measuring semiconductor junction capacitance**
  - Low (15 mV) test level
  - 1 Mc/s crystal controlled test signal
  - Provision for DC bias up to 200 V @ 250 mA
- **Measures over wide range of Q values; down to as low as 3 (lower with re-adjustment)**
- **Three-terminal arrangement permits remote capacitance tests**
- **Rack-mounting version also available**



The Model 71A provides precise, high resolution three-terminal capacitance measurements and two-terminal inductance measurements with the speed and convenience of a VTVM. In addition, the instrument offers an accurate dc analog of the test value.

The Model 71A operates by metering the quadrature current through the test, while ignoring the in-phase current, so that the instrument is not susceptable to errors resulting from specimen loss over a wide range of Q values. Specified accuracy applies for Q's down to 3. Devices of lower Q (to 0.1) may be measured after proper readjustment of phase.

The measuring capabilities of the Model 71A of 0 to 1000 pF and 0 to 1000 μH are each covered in 7 ranges in a 1-3-10 sequence. Capacitance or inductance is read directly from the 6-inch mirrored scale meter.

Test signal level for capacitance measurement is fixed at 15 millivolts, permitting tests on a wide variety of solid-state devices. Test level for inductance measurement is less than 1 millivolt. The highly stable test signal is crystal controlled at 1 Mc/s.

DC Bias up to ±200 volts at 250 mA may be applied through rear panel terminals to the test from an external supply. Resistance of the bias

circuit is 7Ω (which includes 3.5 ohms in the fuse); thus the bias voltage may be monitored at the rear terminals without interfering with measurements. The bias circuit is protected from overload by a 250 mA fuse.

The instrument measures only the capacitance of the test. It ignores stray impedances from the LO post to ground; thus the specimen can be connected to the terminals by coaxial cable, or a remote test fixture may be used. However, for capacitances below 10 pF, when measured remotely, adjustment of the "CABLE COMP" control is required as part of the initial zero setting of the meter. For larger values of capacitance, the series inductance of connecting cables must be taken into consideration.

The dc analog output is available at rear panel terminals. Amplitude range is from zero to either 100 or 300 millivolts for full scale, depending on the numerics of the selected range. Thus when used in conjunction with a DVM, correct numerics are automatically maintained when switching from range to range.

Linearity of the dc analog is better than 0.1% of the reading plus 0.005% of full scale; it provides exceptionally good discrimination on a DVM. Accuracy of the dc output is better than ±0.5% when standardized with the Model 71-1A Standard Capacitor (see below).

This output may be used simultaneously with the panel meter without error. In cases of rapidly changing test values or in applications where meter readout is not required, the meter may be switched off to avoid interaction resulting from a small counter EMF in the moving coil and needless wear.

In providing an accurate dc analog of the continuously measured capacitance or inductance value, the Model 71A constitutes a C or L to DC Converter and greatly facilitates many tests which previously could be made only by time consuming point-by-point balancing. For example with an oscilloscope or an X-Y Plotter, curves of such phenomena as capacitance versus voltage of voltage variable diodes may be rapidly and accurately drawn. Similarly, plots may be made of the linearity of variable capacitors or inductors, or of the tracking accuracy of a pair of variable capacitors or voltage variable diodes.

Since the response time of the dc output (from 0 to full scale) is less than 10 milliseconds, the instrument can follow rapid changes in the value of the test, or make a large number of individual measurements in an extremely short time. For example, used with a dc voltage comparator it performs high-speed go/no-go capacitance or inductance tests, or provides facilities for automatic sorting or batching.

The Model 71A may also be used as the readout device for a wide variety of capacitive or inductive transducers.

SPECIFICATIONS

Capacitance Measurements (Three-terminal):

Range, 0 to 1000 pF in 7 ranges; lowest range, 1 pF, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{3}{Q}\%\right) \text{FS} + 0.01 \text{ pF}$$

Resolution, 0.01 pF

Inductance Measurements (Two-terminal):

Range, 0 to 1000 μH in 7 ranges; lowest range 1 μH, FS

Accuracy,

$$0.5\% \text{ of reading} + \left(0.5\% + \frac{6}{Q}\% + \frac{L_{\mu H}}{500}\%\right) \text{FS} + 0.01\ \mu H$$

Resolution, 0.01 μH

Test Signal:

Frequency, 1 Mc/s, crystal controlled

Level, Capacitance measurements, 15 mV;
Inductance measurements, less than 1 mV

DC Bias:

Externally supplied bias up to ±200 V may be applied at 250 mA at rear terminals; bias circuit protected from overload by 250 mA fuse

DC Analog Output:

Level, 0 to 100 mV or 0 to 300 mV depending on full scale numerics; also >1 V FS for loads >10 MΩ

Linearity, 0.1% of reading + 0.005% FS

Primary Power:

117 or 234 V (±10%), 50/60 cps: 40 watts

Physical Dimensions:

7¼" w x 10¼" d x 11" h; weight, 12 lbs; packed for shipment, 16 lbs.

Price: $735.00 FOB Parsippany, New Jersey

Model 71-1A Standard Capacitor

The Model 71-1A Standard Capacitor was designed specifically for calibrating the Model 71A. It is a highly compact standard adjusted to 100 pF ±0.25% against references traceable to the NBS. It provides for both high Q calibration and calibration for a Q of 3. (The Model 71-1A is built into the Model 71AR and is put into use by means of a front panel selector.)
Price, $50.00.

Model 71AR Rack-Mounting Capacitance/Inductance Meter

The Model 71AR provides the performance characteristics of the Model 71A in rack-mounting form. In every respect its electrical specifications are identical to those of the bench unit. In addition, the Model 71-1A Standard Capacitor is incorporated in the Model 71AR and is switched into service by a front panel selector.
Price, $810.00

BOONTON ELECTRONICS CORPORATION

TELEPHONE: 201-887-5110 ■ TWX: 510-235-6747 ■ ROUTE 287 AT SMITH ROAD, PARSIPPANY, N. J. — 07054

BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 74D Capacitance Bridge

100 Kc/s Wide Range Capacitance Bridge Providing Two or Three Terminal Measurements with a Basic Accuracy of 0.1 Percent

- Capacitance range: 0.0002 pF to 110,000 pF
- Conductance range: 0.001 μmho to 1000 μmhos
- Resistance range: 1000 ohms to 1000 megohms
- Remote measurements with three terminal (direct) operation; conventional two terminal (grounded) operation also provided
- No false or sliding nulls; simple, convenient balancing; all zeroing controls vernier driven
- Test signal internally supplied; continuously adjustable from 4 volts down to 1 millivolt

- Excellent stability; negligible warm-up drift
- DC bias internally supplied; connection for external bias
- Limit mode for go/no-go testing
- Operable as comparison bridge

General

The Model 74D, successor to the popular Model 74C, is a true "state-of-the-art" capacitance bridge providing capacitance measurements over broad ranges, under a wide variety of test conditions, and with a degree of accuracy not previously available. The instrument is completely self-contained, including bridge circuitry, 100 Kc/s test oscillator, detector, dc bias source, and related power supplies, all in a single, compact bench cabinet. (The Model 74D is built on a 19-inch chassis and may be mounted in a standard rack when removed from its cabinet.)

Capacitance Measurement

Five decade capacitance ranges plus a selector switch that connects from one to 10 internal precision mica capacitors to the standard arm provide continuous measurement from 0.0002 pF to 110,000 pF (an increase by a factor of 10 over the Model 74C). Basic accuracy of capacitance measurement is 0.1 percent (see Table of Specifications).

In spite of the unusually broad capacitance range of the Model 74D, readability is excellent even down to the smallest measurable values. For example, on the lowest capacitance range (0 to 1 pF) the

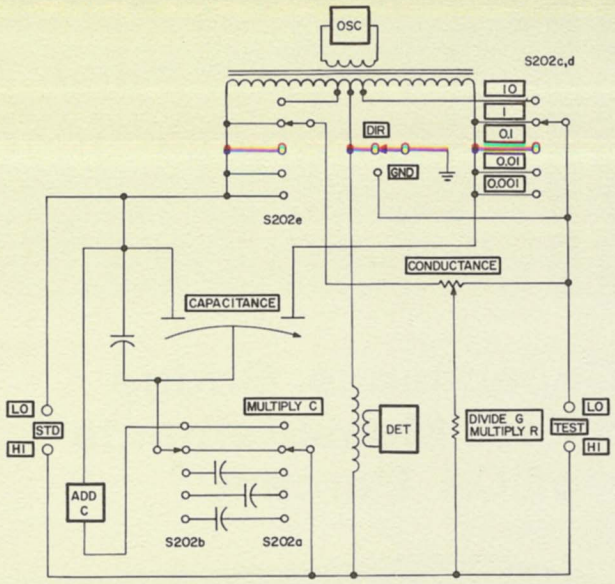


Figure 1. Simplified schematic of Model 74D

single picofarad is spread over 5000 divisions on a scale effectively more than 200 inches long. The combination of the "counter" dial and 40:1 vernier provides convenience and speed in scanning together with great accuracy of fine adjustment.

Conductance and Resistance Measurements

The conductance dial of the Model 74D is also calibrated in parallel resistance. Five decade ranges provide measurements continuously from 0.001 μmho to 1000 μmhos and from 1000 ohms to 1000 megohms. Since the conductance and capacitance balancing networks are essentially independent of each other, the range setting for one parameter has no bearing on the setting of the other. In addition, this lack of interaction between the capacitance and conductance arms assures convenient, straightforward balancing without the annoyance of false nulls or sliding balance.

Bridge Circuitry

A simplified schematic of the Model 74D is shown in Figure 1. The bridge is a modified Young circuit in which both the main capacitance balance control and the capacitance zero control are variable differential air capcitors. Use of differential air capacitors contributes to the overall bridge stability since the capacitive elements in each arm are subjected to **identical** thermal conditions. This would not necessarily be the case were two separate components used.

Great care is taken in the design of the main differential capacitor, in its metallurgy, in the fabrication and assembly of its parts, and in its final adjustment to assure the highest degree of accuracy and stability within the limits of the state of the art. The unique design and construction of the mechanical linkage between this capacitor and the dial hold back-lash to a minimum, permitting full advantage to be taken of the resolution capability of the bridge.

The range selector **("Multiply C")** comprises a network of highly stable air capacitors which are adjusted to an accuracy of better than 0.1 percent

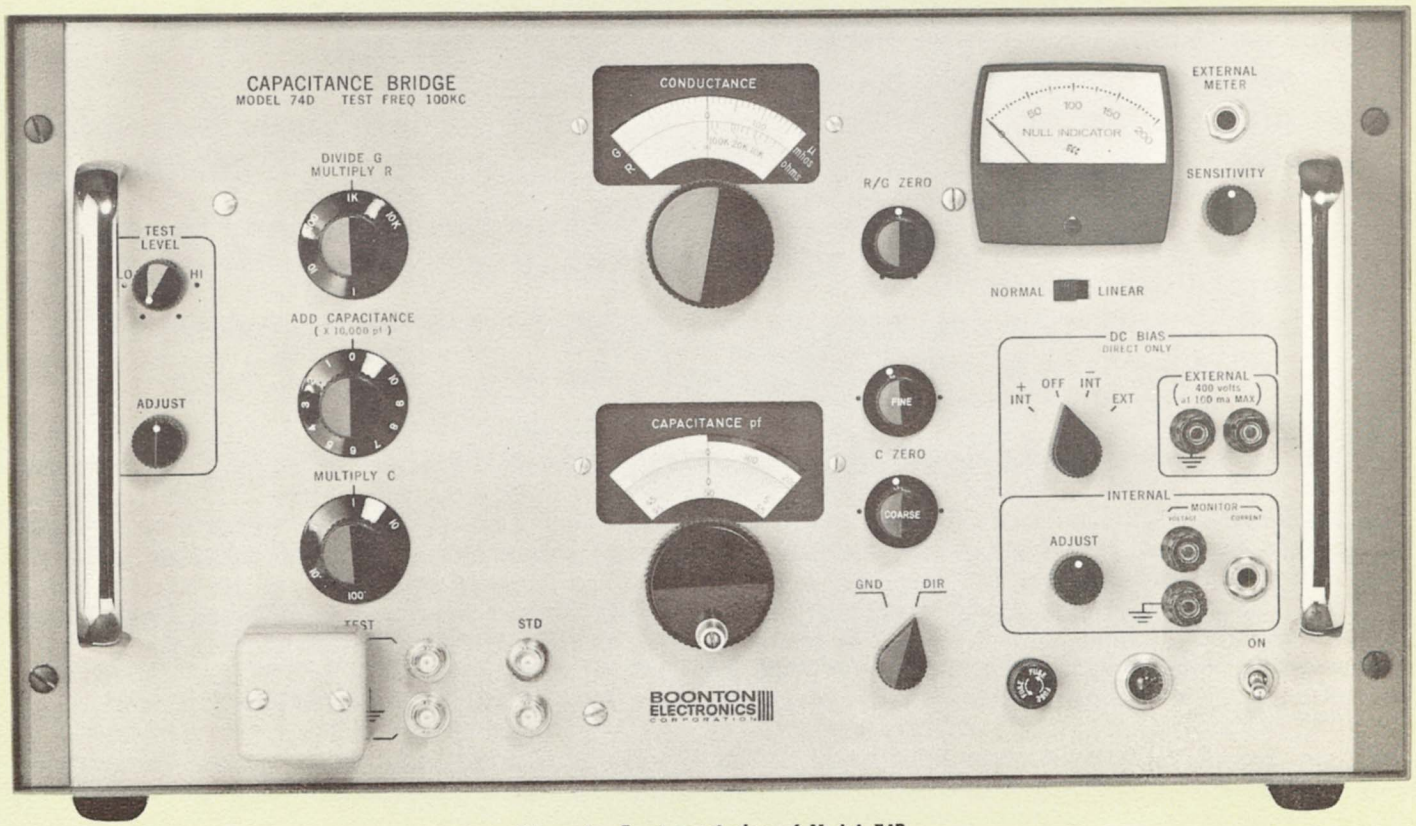


Figure 2. Front panel view of Model 74D

BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 74D Capacitance Bridge

100 Kc/s Wide Range Capacitance Bridge Providing Two or Three Terminal Measurements with a Basic Accuracy of 0.1 Percent

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- No false or sliding nulls; simple, convenient balancing; all zeroing controls vernier driven
- Test signal internally supplied; continuously adjustable from 4 volts down to 1 millivolt

- Excellent stability; negligible warm-up drift
- DC bias internally supplied; connection for external bias
- Limit mode for go/no-go testing
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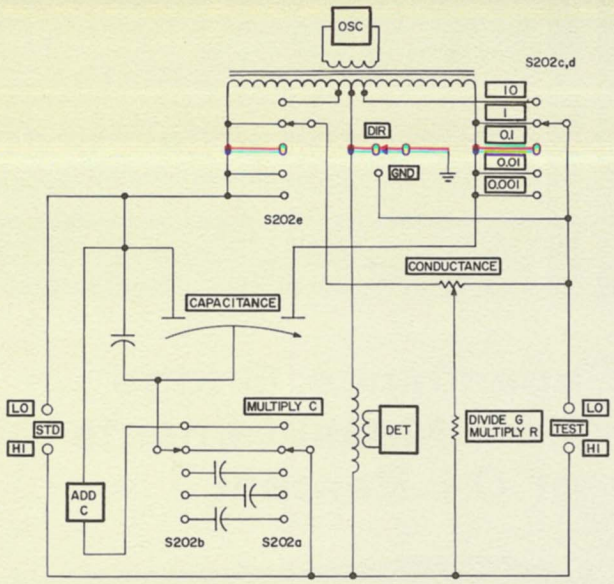
The Model 74D, successor to the popular Model 74C, is a true "state-of-the-art" capacitance bridge providing capacitance measurements over broad ranges, under a wide variety of test conditions, and with a degree of accuracy not previously available. The instrument is completely self-contained, including bridge circuitry, 100 Kc/s test oscillator, detector, dc bias source, and related power supplies, all in a single, compact bench cabinet. (The Model 74D is built on a 19-inch chassis and may be mounted in a standard rack when removed from its cabinet.)

Capacitance Measurement

Five decade capacitance ranges plus a selector switch that connects from one to 10 internal precision mica capacitors to the standard arm provide continuous measurement from 0.0002 pF to 110,000 pF (an increase by a factor of 10 over the Model 74C). Basic accuracy of capacitance measurement is 0.1 percent (see Table of Specifications).

In spite of the unusually broad capacitance range of the Model 74D, readability is excellent even down to the smallest measurable values. For example, on the lowest capacitance range (0 to 1 pF) the



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Bridge Circuitry

A simplified schematic of the Model 74D is shown in Figure 1. The bridge is a modified Young circuit in which both the main capacitance balance control and the capacitance zero control are variable differential air capcitors. Use of differential air capacitors contributes to the overall bridge stability since the capacitive elements in each arm are subjected to **identical** thermal conditions. This would not necessarily be the case were two separate components used.

Great care is taken in the design of the main differential capacitor, in its metallurgy, in the fabrication and assembly of its parts, and in its final adjustment to assure the highest degree of accuracy and stability within the limits of the state of the art. The unique design and construction of the mechanical linkage between this capacitor and the dial hold back-lash to a minimum, permitting full advantage to be taken of the resolution capability of the bridge.

The range selector **("Multiply C")** comprises a network of highly stable air capacitors which are adjusted to an accuracy of better than 0.1 percent

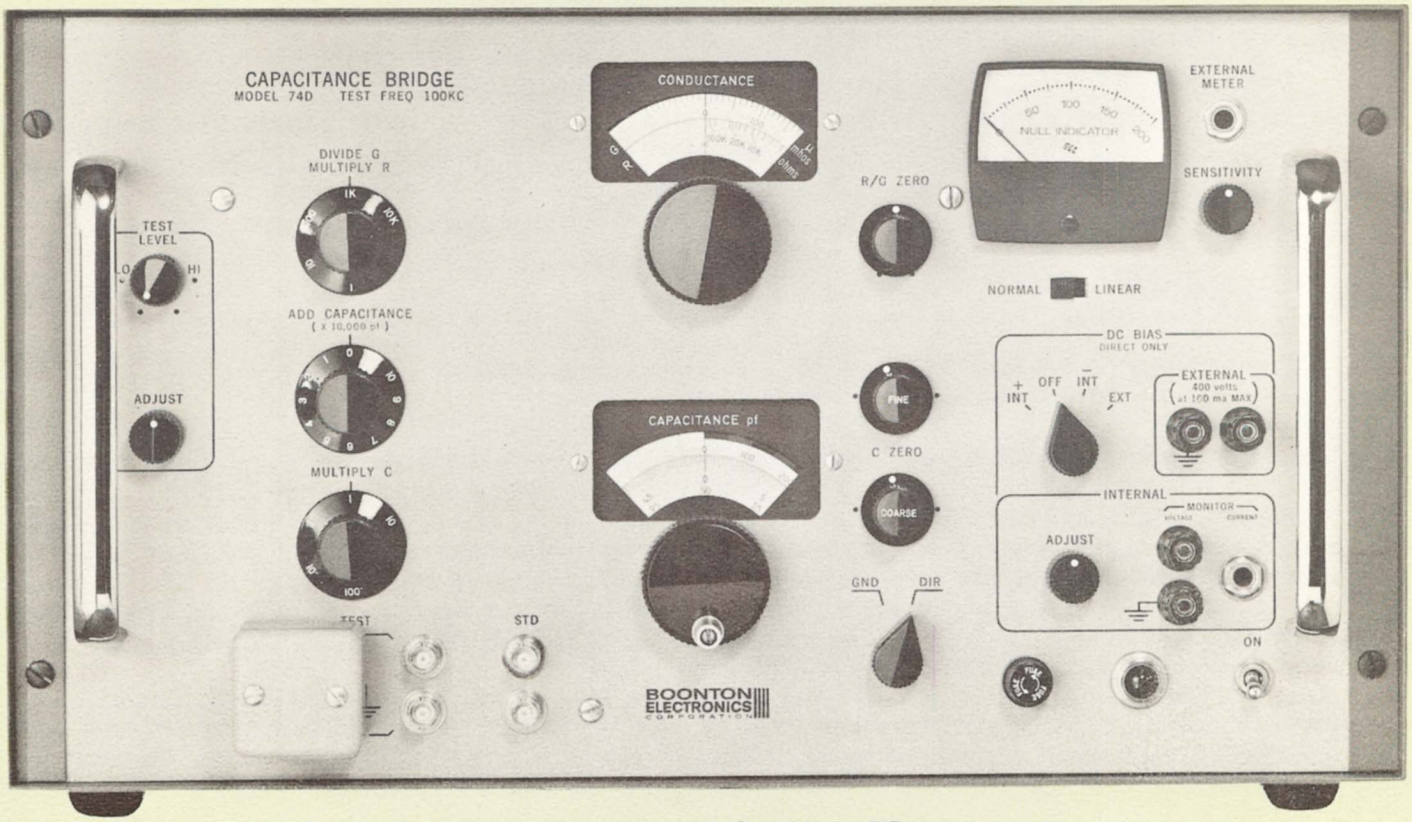

Figure 2. Front panel view of Model 74D

Test Signal

The level of the internally supplied test signal is continuously adjustable from 4 volts down to approximately 1 millivolt, and may be conveniently measured with a Sensitive RF Voltmeter such as one of the Boonton Electronics Corp. 91 Series. With the three terminal arrangement of the Model 74D, the test signal level may be continuously monitored (between the "LO" terminal and ground) during successive measurements without affecting the accuracy of test results.

Accuracy of the test frequency is 1 percent. (It should be noted that the precision of the test frequency is rarely critical and in the great majority of cases frequency variations within this specification have no measurable effect on the accuracy of measurement. In the unusual circumstance where greater precision of frequency is required, a counter may be used to monitor the test signal and to adjust it more accurately.

The wide range of control over the test signal level is valuable for measurements on such non-linear devices as diodes and transistors, where low test levels are usually required in order to obtain a clearly defined null on bridge balance, as well as in cases where measurements are made on components whose capacitance varies with the test signal voltage.

Total distortion of the test signal generator output is 35 db or more below the fundamental. This is an important consideration when measurements are to be made on non-linear devices such as diodes, since asymmetry of the wave form would result in readings that would differ depending on the polarity in which the component is connected to the test terminals.

DC Bias

An internal dc supply provides a voltage which is continuously variable from +110 volts to −7 volts for biasing the test specimen when making direct (three terminal) measurements. This bias voltage may be monitored by connecting an external meter to front panel jacks. Provision is also included for application of an externally supplied bias up to ±400 volts at 100 milliamperes. The dc bias feature is of special importance for measurements of a number of voltage sensitive devices such as voltage variable capacitors.

Remote Measurements

In addition to the regular test binding posts, BNC receptacles at the front panel allow connection of coaxial cables for remote measurements. In the Three Terminal (Direct) Mode the bridge is essentially insensitive to impedances from either side of the test to ground. Thus the capacitance of the connecting coaxial cables can be ignored, and errors resulting from changes in cable position or cable temperature are eliminated. As a result the capacitance (or changes in capacitance) of the test specimen alone may be accurately measured even when the specimen and connection system are exposed to wide variations in temperature, to vibration, or to other extreme environmental conditions.

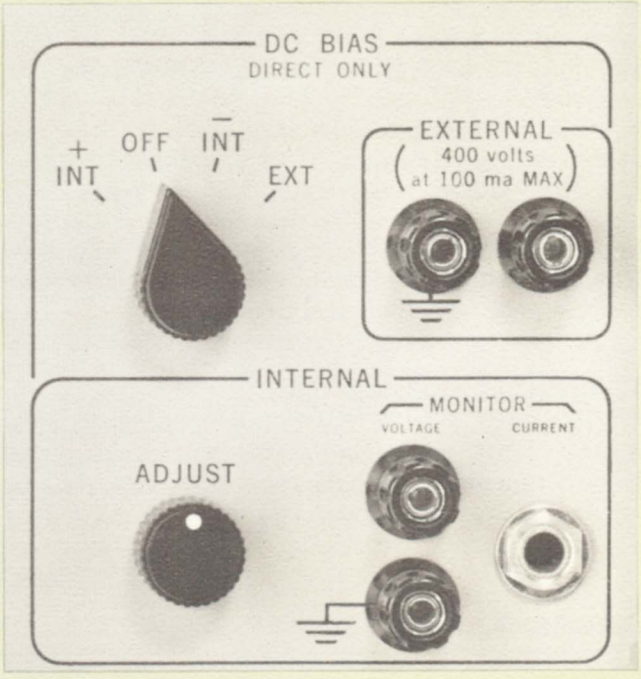

Figure 3. Detail of front panel showing dc bias controls. Internal dc bias supply is standard on all Model 74D's. Both bias voltage and current may be metered at panel connectors.

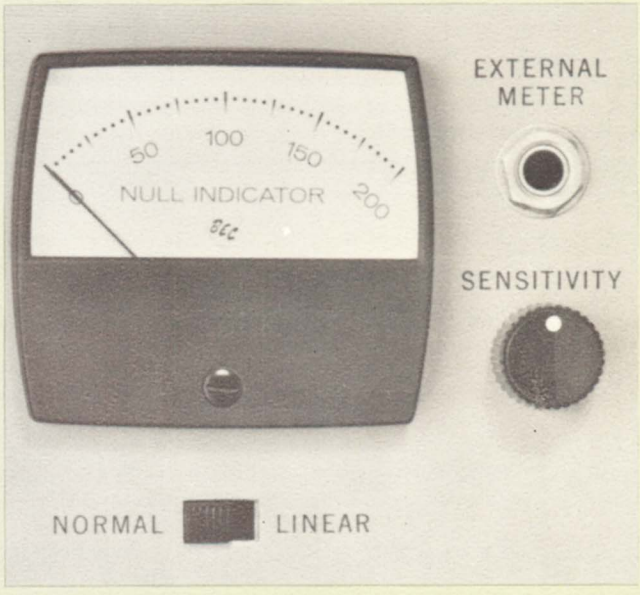

Figure 4. Detail of front panel showing null indicator. In the "Linear" mode, metering current and meter readings are directly proportional to bridge unbalance so that the meter can be "calibrated" to read directly in percent of deviation from a nominal capacitance value for go/no-go testing. The "External Meter" jack permits remote monitoring, or use of a relay type meter for actuation of associated equipment.

Limit (Go/no-go) Operation

An unusual feature of the Model 74D is the ability to switch from "Normal" to "Linear" operation, per-

mitting use of the instrument as a capacitance limit bridge. A front panel switch disables the AGC circuit in the detector so that the null metering current becomes directly proportional to the capacitance or conductance unbalance. Thus the null indicator reading represents a given percent of deviation from the nominal value, and go/no-go tests may readily be made. The metering current is also brought out to a panel jack permitting use of a relay type meter for actuation of external equipment in conformance with limit test decisions.

Comparison Measurements

The standard arm of the bridge is accessible by means of BNC connectors at the front panel so that external standards or balancing capacitors may be attached. Thus the Model 74D may be used as a comparison bridge or for differential measurements such as the temperature coefficient of capacitors. With the differential sensitivity of the X 0.001 multiplier, the resolution of temperature coefficient measurements is in the order of 1 part per million for values above 200 pF.

Stability

After one hour warm-up, drift of true capacitance in the Model 74D is typically less than 0.001 pF for a 24-hour period. This excellent stability is particularly important for studies of extended duration, such as those involving determination of temperature coefficient. Freedom from drift is important, too, for limit operations since it permits setting up the bridge to a given capacitance and making go/no-go tests over a length of time with the assurance that the nominal value setting has not shifted.

SPECIFICATIONS

Capacitance Ranges:

Multiplier	Cap. Range	Smallest Division	Direct	Grounded
10	10,000 pF to 110,000 pF	2 pF	± (0.25% + 2 pF)	± (0.25% + 2 pF)
10	1000 pF to 10,000 pF	2 pF	± (0.1% + 2 pF)	± (0.1% + 2 pF)
1	100 pF to 1000 pF	0.2 pF	± (0.1% + 0.2 pF)	± (0.1% + 0.5 pF)
0.1	10 pF to 100 pF	0.02 pF	± (0.1% + 0.05 pF)	± (0.1% + 0.5 pF)
0.01	1 pF to 10 pF	0.002 pF	± (0.1% + 0.01 pF)	± (0.1% + 0.5 pF)
0.001	0.05 pF to 1 pF	0.0002 pF	± (0.1% + 0.002 pF)	± (0.1% + 0.5 pF)
0.001	0 to 0.05 pF	0.0002 pF	± (2.00% + 0.0002 pF)	

Conductance Ranges:

Divider	Cond. Range	Accuracy
1	100 to 1000 μmhos	$\pm (10\% + \frac{Q}{500}\% + 10\ \mu\text{mhos})$
10	10 to 100 μmhos	$\pm (5\% + \frac{Q}{500}\% + 1\ \mu\text{mho})$
100	1 to 10 μmhos	$\pm (5\% + \frac{Q}{500}\% + 0.1\ \mu\text{mho})$
1K	0.1 to 1 μmho	$\pm (5\% + \frac{Q}{500}\% + 0.01\ \mu\text{mho})$
10K	0 to 0.1 μmho	$\pm (5\% + \frac{Q}{500}\% + 0.001\ \mu\text{mho})$

Resistance Ranges:

Multiplier	Resistance Ranges	Accuracy
1	1K to 10K ohms	$\pm (10\% + \frac{Q}{500}\% + \frac{R}{10^3}\%)$
10	10K to 100K ohms	$\pm (5\% + \frac{Q}{500}\% + \frac{R}{10^4}\%)$
100	100K to 1 megohm	$\pm (5\% + \frac{Q}{500}\% + \frac{R}{10^5}\%)$
1K	1 megohm to 10 megohms	$\pm (5\% + \frac{Q}{500}\% + \frac{R}{10^6}\%)$
10K	10 megohms to ∞	$\pm (5\% + \frac{Q}{500}\% + \frac{R}{10^7}\%)$

TEST FREQUENCY: 100 Kc with self-contained oscillator and detector; accuracy of test frequency, ±1%

TEST SIGNAL LEVEL: Continuously adjustable from 1 mV to 4 V

DC BIAS: Internally supplied; continuously adjustable from +110 V to −7 V; external bias up to ± 400 V at 100 mA

"LINEAR" OPERATION: Selected by front panel slide switch; null indicator current and meter reading directly proportional to bridge unbalance; full scale capacitance deviation limits: max., 4000 pF; min., 0.002 pF

POWER REQUIREMENTS: 105-125 V, 50-60 cps; 30 watts (210-240 V, 50-60 cps version also available at no additional cost)

PHYSICAL SPECIFICATIONS: 19½" w x 10¾" h x 11¼" d in cabinet; with cabinet removed, mounts in standard 19" rack; weight 35 lbs

PRICE: $1350, FOB Parsippany, New Jersey

BOONTON ELECTRONICS CORPORATION

ROUTE 287 AT SMITH ROAD, PARSIPPANY, N. J. — 07054
TELEPHONE: 201-887-5110
TWX: 510-235-6747

BOONTON ELECTRONICS CORPORATION
PARSIPPANY, NEW JERSEY

Model 63H Inductance Bridge

Precise Measurements of Inductance to Low Values Over a Frequency Range from 5 Kc/s to 500 Kc/s

- Inductance Range: 0.0002 μH to 110 mH
- Basic Accuracy: 0.25%
- Basic Resolution: 0.01%
- Resistance Range: 0.0002 ohm to 11,000 ohms
- Test signal continuously adjustable from 5 Kc/s to 500 Kc/s
- Maximum open-circuit test signal level: 3 V
- Test current independent of balance condition of bridge
- Completely self-contained, including test signal oscillator and null detector
- Outstanding stability
- No false or sliding nulls

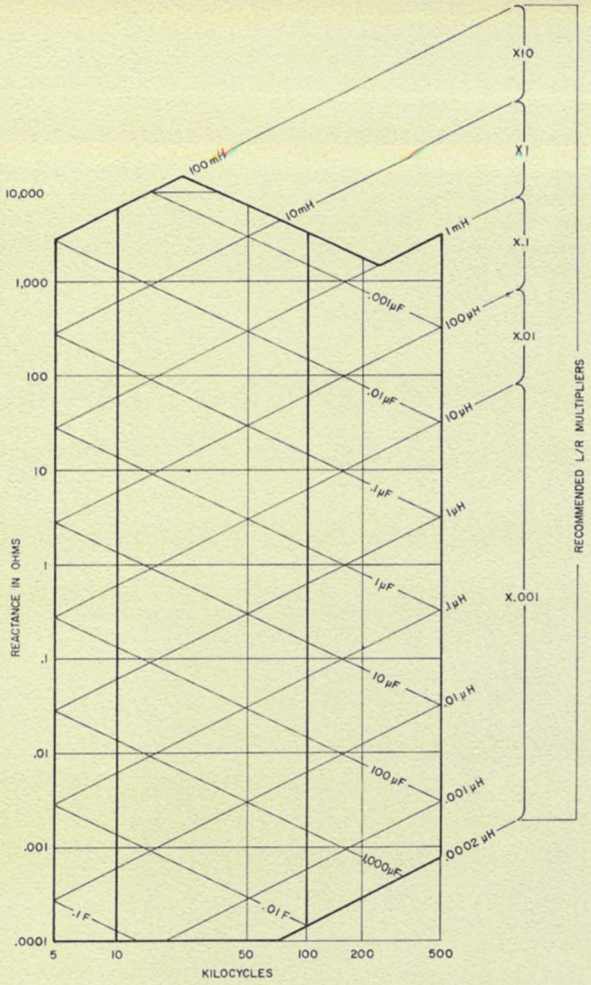

Figure 1. Diagram of the operational range of the Model 63H

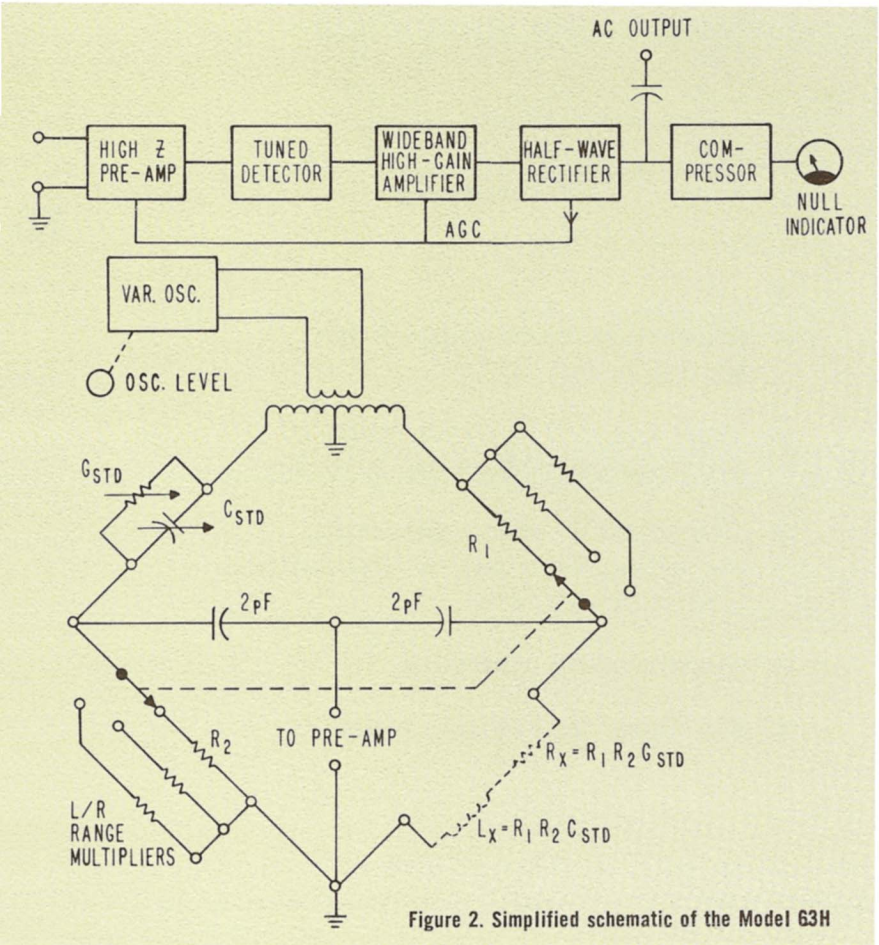

Figure 2. Simplified schematic of the Model 63H

General Description

The Model 63H is a highly advanced bridge which provides direct reading measurements of series inductance down to low values with fractional percentage accuracy, and under an unusually broad range of test conditions. The instrument also provides direct reading measurements of series resistance. The operational range of the Model 63H is shown in the diagram of Figure 1. Inductance and resistance ranges are covered in five multiplier steps; the frequency range is covered in two decades.

The instrument is completely self-contained, including bridge circuitry, variable frequency test oscillator and detector, null indicator, and power supplies. It is packaged as a single, compact bench cabinet. Built on a 19 inch chassis, the Model 63H may be installed in a standard relay rack when the cabinet is removed.

Bridge Circuit

The Model 63H embodies a modified Maxwell circuit (see simplified schematic of Figure 2). The test signal generator and null detector are coupled to the bridge by a technique which constitutes a particularly practical approach to the design of a Maxwell circuit whose capabilities for precision measurements extend over wide ranges of inductance and test frequencies. The two sides of the bridge are driven 180 degrees out of phase by a well balanced low impedance transformer. This permits detection of the balance condition by coupling the detector to the high corners of the bridge through two small, carefully balanced capacitors.

It is characteristic of this bridge circuit that the inductance and resistance arms act independently of each other. By eliminating interaction between the two arms the annoyance and ambiguity of false or sliding nulls are avoided.

Since the bridge is of the non-resonant type, the precision of frequency setting is not critical to the accuracy of measurement. Bridge accuracy is determined primarily by the balancing controls, the precision resistors in the range selector, and the silvered mica capacitors comprising the inductance decade. All of these components are adjusted to better than 0.1% accuracy.

Great care has been taken in both the electrical and mechanical design of the Model 63H to compensate or eliminate the sources of residual error that commonly restrict the accuracy of measurement of bridges operating at these frequencies, providing true "state of the art" precision and stability. Inductance drift in the instrument is typically less than 0.01% after 90 minute warm up.

The excellent scale readability of the Model 63H allows full advantage to be taken of the instrument's capability for high precision and resolution. The combination of the outer "counter dial" and inner 20-to-1 vernier (see Figure 3) displays the total inductance measuring range across a scale effectively more than 850 inches long. This dial arrangement also enables convenient rapid scanning to locate the null, as well as accurate fine adjustment to achieve precise balance.

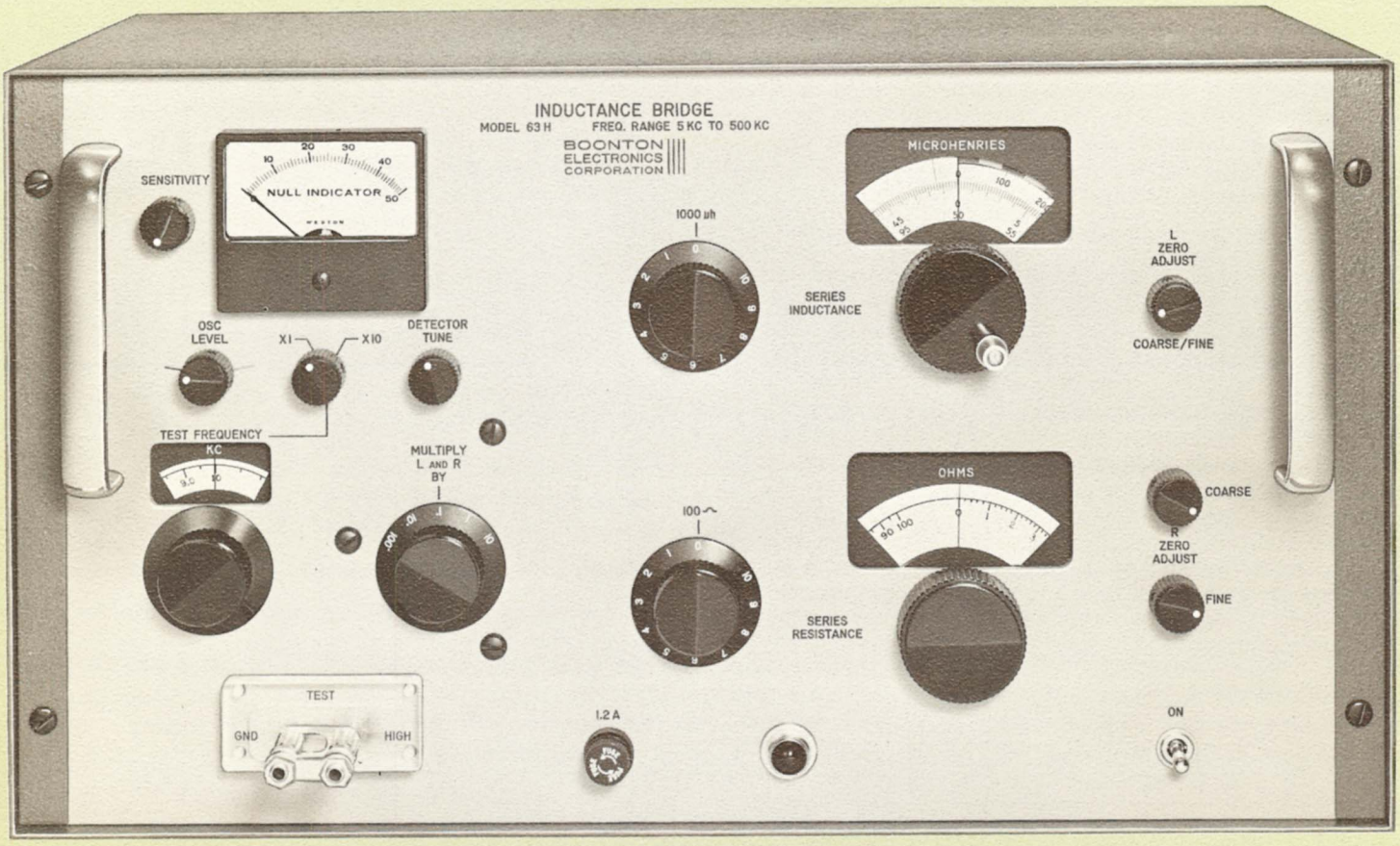

Figure 3. Front panel view of the Model 63H

Null Detector

As shown in figure 2, the null detector is coupled to the bridge at the high corners through two balanced capacitors. The untuned high impedance preamplifier prevents bridge loading and contributes to the overall system sensitivity. Adjustment of the tuned detector is independent of the test signal generator control.

Frequency response of the final wide band detector amplifier is essentially flat over the total frequency range of the instrument. It has a maximum gain of 65 db giving a total detector system gain of approximately 105 db.

Output from the wide band amplifier is passed through a half wave rectifier, compressed, and then metered. System sensitivity is further enhanced by use of a 50 microampere taut band meter for null indication.

The ac component of the rectified output from the wide band amplifier is also available at a rear jack for connection of an oscilloscope or other ac indicator.

Test Signal

The internal test signal oscillator is continuously adjustable in frequency from 5 Kc/s to 500 Kc/s. Accuracy of frequency setting is 3%. As stated above, in this bridge circuit precision of test frequency setting is not critical to the accuracy of measurement. In the rare circumstance in which more accurate frequency adjustment is required, the test signal may be monitored with a counter and set more precisely.

The test signal level is continuously adjustable by means of a front panel control and may be monitored at the test terminals with a high impedance electronic voltmeter. Maximum open circuit level is 3 volts. Test current may also be monitored by means of a "clamp-on" type probe and a sensitive ac voltmeter.

The test current is independent of the balance condition of the bridge, a fact of considerable importance in applications involving such components as ferrite cores, since their permeability varies with the level of excitation current. Were the test current to change from the known level during balancing, meaningful measurements would be impossible.

A dc current may be superimposed on the test signal if desired.

APPLICATIONS

Inductance and Loss

There is a distinct advantage in measuring the inductive characteristics of a component at or near the frequencies at which it is to be used rather than measuring at a low frequency and attempting to extrapolate. Such phenomena as skin effect, distributed capacitance, changing permeability, and loss factors are not detectable at low frequencies (1 Kc for example). At the frequencies over which the Model 63H operates, however, these effects can be accurately measured,

and operating characteristics at higher frequencies may be realistically computed. This applies not only to inductors, but particularly to such components as resistors, (even so-called "non-inductive" types), switches, connectors and connection systems, terminations, and other sources of residual inductance.

Temperature Coefficients

The accuracy, high resolution, and excellent stability of the Model 63H make it especially valuable for temperature coefficient studies. The lead inductance of the connecting cables can be "zeroed out" so that the specimen can be located in an environmental chamber during the tests without incurring significant error (so long as reasonable care is taken to control the effects of lead capacitance or changes in lead capacitance). These same features suit the Model 63H for monitoring the progress of temperature and humidity cycling of inductors, and permit accurate observation of retrace during successive stabilizing cycles until the required characteristics are achieved.

Transformers

The Model 63H is particularly well suited for a number of tests involving transformers, especially rf, if, and broad band types. Measurements of primary inductance, leakage inductance, mutual inductance, and coupling coefficient may readily be made. Since the Q of these devices is often low, the ability of the Model 63H to measure small values of inductance, plus its high frequency capability permit measurements that are difficult, if not impossible, with other instruments. In addition the high resolution of the Model 63H enables detection of shorted turns in these transformers, even when the defect involves only a few turns.

Permeability

The Model 63H provides a convenient and accurate means for determining the permeability and Q of toroidal cores. The high resolution of the instrument permits detection of small permeability differentials resulting from variations in processing and design, and this coupled with excellent stability also allows reliable, reproducible measurements of temperature coefficient.

Permeability Test Fixture

The Boonton Electronics Model 63-11B MU JIG is an accessory test fixture specifically designed for measurements on toroidal cores. It consists essentially of a seven-turn coil whose windings may be opened to accept the test specimen. It may be either plugged directly into the test terminals of the instrument or operated at a distance from the bridge (as long as reasonable care is taken to minimize the capacitance effect of the connecting cable). The measured inductance and series resistance, first with and then without the sample core, are submitted to simple, well established computation, to yield the permeability or Q. Of particular importance where ferrite cores are involved is the fact that the test current through the MU JIG (and hence the permeability value) does not vary as the bridge is brought to balance.

SPECIFICATIONS

Inductance Measuring Range: 0.0002 μH to 110 mH in 5 steps as follows:

Multiplier	Inductance Range	Resolution of Inductance Reading
10.0	0 to 110 mH	.01% +2.0 μH
1.0	0 to 11 mH	.01% +0.2 μH
0.1	0 to 1100 μH	.01% +0.02 μH
0.01	0 to 110 μH	.01% +0.002 μH
0.001	0 to 11 μH	.01% +0.0002 μH

Inductance Measuring Accuracy: $0.25\% + \frac{300}{C}\% + 0.0002\ \mu H$, where C is the resonating capacitance in pF of the test inductor at the frequency of test.

Series Resistance Measuring Range: 0.0002 ohm to 11K ohms in five ranges as follows:

Multiplier	Series Resistance Range	Accuracy
10.0	0 to 11K Ω	$3\% + \frac{Q}{25}\% + 2\ \Omega$
1.0	0 to 1,100.0 Ω	$3\% + \frac{Q}{25}\% + 0.2\ \Omega$
0.1	0 to 110.0 Ω	$3\% + \frac{Q}{25}\% + 0.02\ \Omega$
0.01	0 to 11.0 Ω	$3\% + \frac{Q}{25}\% + 0.002\ \Omega$
0.001	0 to 1.1 Ω	$3\% + \frac{Q}{25}\% + 0.0002\ \Omega$

Frequency Range: 5 Kc/s to 500 Kc/s with internal oscillator and detector.

Frequency Accuracy: $\pm$ 3%

Frequency Stability: Approximately 0.5% after 30 minute warm-up.

Max. AC Test Level: Approximately 3.0 V, RMS, open circuit.

Power Requirements: 105 to 125V, 50-60 cps, 60 watts, or 210 to 250 volt, 50-60 cps, as specified.

Size: 19-1/4" w x 10-3/4" h x 11-1/4" d; case mounted. (Also available for 19-inch rack mounting.) Weight, approx. 35 lbs.

Price: $1,995 F.O.B. Parsippany, New Jersey.

OTHER BOONTON ELECTRONICS INDUCTANCE BRIDGES

Model 63L: Measures inductance from 0.02 μH to 11 H; resistance from 0.002 ohm to 110 K ohms; test frequency continuously adjustable from 400 cps to 40 Kc/s. **Price:** $1,995.

Model 63M: Measures inductance from 0.002 μH to 1.1 H; resistance range same as **Model 63L;** test frequency continuously adjustable from 1 Kc/c to 100 Kc/s. **Price:** $1,995.

Except for measuring ranges and test frequencies, the **Models 63L** and **63M Inductance Bridges** offer performance features similar to those of the **Model 63H.**

BOONTON ELECTRONICS CORPORATION

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 52B DC Voltage Comparator

APPLICATIONS

Go/no-go bridges

Automatic test systems

Process control

Warning systems

Ground support equipment

FEATURES

Solid state circuitry

Differential input

Input resistance greater than 10,000 megohms

Decision memory

Manual and triggered operation

Variable sampling rate

Free from drift and necessity of calibration

The Model 52B is a high performance dc voltage comparator intended for manual and high speed test processing.

Essentially, this unit accepts inputs of any parameter which can be reduced to a dc voltage, and compares this unknown voltage to externally provided "high" and "low" limit references. If the unknown lies between the limits, a "go" output is formed. If it is outside the reference defined tolerance zone, a "no-go" output of either "high" or "low" is produced. The comparator performs this type of testing at a high rate of speed, to a high degree of precision, and without human error or fatigue factors.

The unique features of extremely high input impedance, floating differential input and relative immunity from source-impedance effects, permit this comparator to be utilized, without design limitations heretofore associated with this type of instrument.

Cognizant of tie-in problems encountered with mechanical equipment, and automated test systems, a "triggered" mode of operation, together with logic level indications of "test completion" and test results has been provided in addition to the conventional relay contact outputs.

Intrinsic design reliability, conservative de-rating practices, quality components and rugged modular construction have been combined to provide a unit commensurate with the demands of high speed production line testing, and other usages requiring long periods of unattended operation.

Serviceability has been optimized through the use of plug-in logic cards, a modular, self-contained power supply, and complete accessibility to all test points and components.

SPECIFICATIONS

Inputs:

Comparator accepts unknown dc voltage at "Input" and reference voltages at "REF." or "REF. HI" and "REF. LO," as indicated below in Block Diagram.

"REF. HI" and "REF. LO" are used if the unknown input is to be compared to individual high and low voltage limits.

"REF." is used if the unknown input is to be compared to a single voltage reference.

Max. Permissible Voltages

"Input" to REF. HI or REF. LO: ±35 V dc
"Input" to REF.: ±200 V dc
"Input" REF. HI, REF. LO, or "REF" to Common: ±200 V dc

Input Resistance:

Differential: Input current less than 10^{-10} amp. for input signals less than 100 mV.

Input resistance: 2 Meg (Constant) for differential signals greater than 500 mV.

Common Mode: Resistance measured from any input to common $=10^{10}$ ohm min.

Operating Differential & Stability:

500 μV, max.

Decision Outputs:

	HI	GO	LO
Visual	Red Lamp	Green Lamp	Yellow Lamp
Continuity	Mercury Wetted relay, 2 A, 500 V, 100 VA, max		
Logic	—10V/5.1K	—10V/5.1K	—10V/5.1K

Speed:

Reference sampling rate adjustable from 2 to 20 tests per second. Delay time from receipt of "Trigger" signal to issue of tests —50 ms to 500 ms.

Modes of Operation:

Manual — Comparator interrogates inputs and displays decision continuously. Outputs follow change in input or references.

Triggered — Comparator interrogates inputs upon receipt of "Trigger" (Start Test) signal. At end of interrogation time, which is a function of sampling rate, comparator displays decision. Decision remains "clamped" until receipt of next "Trigger" signal. In Triggered mode, sampling drive (continuity to common) can force "REF-LO" sampling. Without this drive "REF-HI" will be sampled.

Controls:

Power: on/off

Sampling Rate: 2 to 20 tests per second

Mode Selection: manual/triggered

Test Complete Signal — Mercury wetted relay contacts

Start Test Signal — External Contact Closure (drives internal relay)

Weight: Size:

25 lbs 3½" x 19" Panel 17" x 14" Chassis

Finish:

Panel — light gray, semi-gloss
Chassis — yellow iridited cadmium

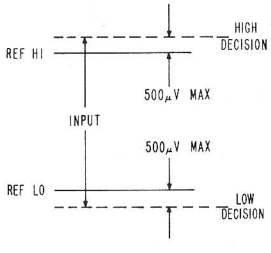
Power Requirements:

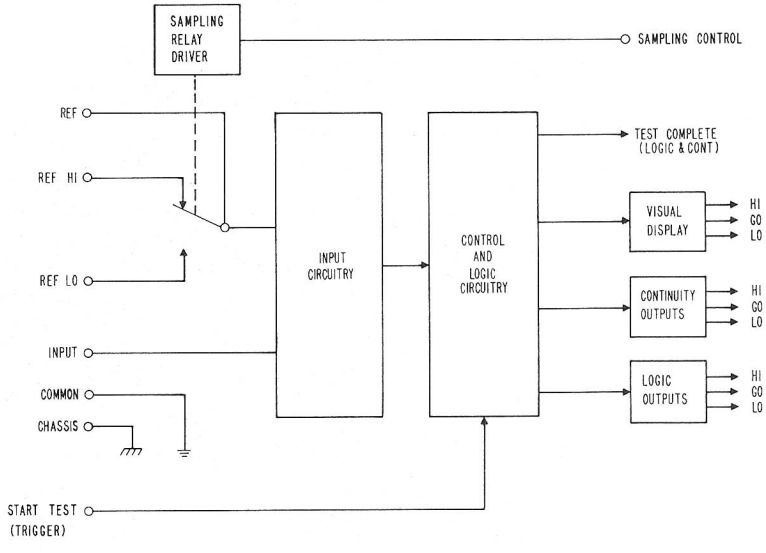
105-125 V, 50-60 c/s; 0.5 A.

Enclosure:

Optional at extra cost

Block Diagram





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Printed in U.S.A.

BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Models 53A & 53B
Miniature
DC Voltage Comparators

Sensitive, Reliable DC Comparators for a Wide Variety of Industrial and Military Control Functions

- Sensitivity, 500 microvolts
- Repeatability, 50 microvolts
- Both latch and over-ride functions provided
- Relay Contact and logic level outputs

General Description

The Models 53A and 53B are highly compact, solid state instruments which continuously compare two voltages (Va and Vb) and provide decision outputs indicating either Va > Vb or Vb > Va. They are also useful as voltage cross-over detectors and ultra-sensitive relays.

The two models are identical, except that the Model 53A operates from 60-cycle power while the Model 53B is designed for 400-cycle operation.

The basic elements of these instruments are indicated on the accompanying block diagram.

The chopper samples Va and Vb at a 60-cycle rate (or a 400-cycle rate in the Model 53B). The output of the chopper is amplified and then passed to the logic circuitry where it is synchronously strobed to provide decisions in the form of both logic level and contact switching.

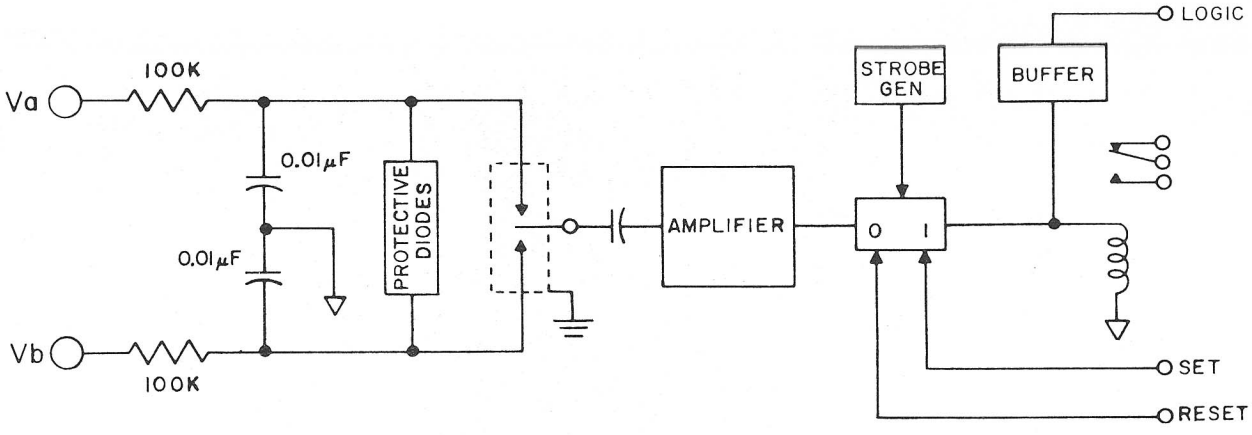
In addition to continuous comparison, the following functions are available.

Operating Modes

Simple continuity connections at the base of the comparator provide "latching" of the comparator. In this circumstance, as soon as Va exceeds Vb (or the converse, depending in the connections) the comparator issues the appropriate decision output, but remains latched in that condition until the Latch connection is removed, even if the value of Va should fall below Vb.

It is possible to simulate decisions of either Va > Vb or Vb > Va in the absence of Va and Vb. This is convenient for testing the operation of associated circuitry and equipment.

The Models 53A and 53B are useful for a wide variety of industrial and military control functions, including process control, voltage calibration, null detection, automatic ranging, and alarm control.



BLOCK DIAGRAM — 53A & 53B

LATCH: Va > Vb: Ground RESET
Vb > Va: Ground SET

OVER-RIDE CONTROL: Forced indication of Va > Vb: apply +10v, 0.3 mA, dc, to SET
Forced indication of Vb > Va: apply +10v, 0.3 mA, dc, to RESET

Sensitivity:	500 μV
Repeatability of Trip Point:	50 μV
Response Time:	53A: 9-17 milliseconds 53B: 1.25-2.50 milliseconds
Input Time Constant:	1 millisecond
Maximum Allowable Input Potentials	
Differential:	200 volts
With Respect to Case or Common:	± 100 volts
Decision Outputs:	
Voltage:	Va >Vb, +10v, dc, through 6.1K Vb >Va, approx. +3v, dc, max
Continuity:	Relay contacts (SPDT); 1 amp, resistive; 28v, dc
Terminal Connections:	14 pin Plug-in; mates with Cinch-Jones 14RS-1
Operating Temperature:	—20° C to +60° C
Enclosure:	Dust Cover
Dimensions:	2¼" w x 2⅛" d x 4" h
Weight:	1 lb.
Primary Power:	53A — 105-125v, 60 s/c; 3 W 53B — 105-125v, 400 c/s; 3 W
Price:	53A or 53B, $275.00

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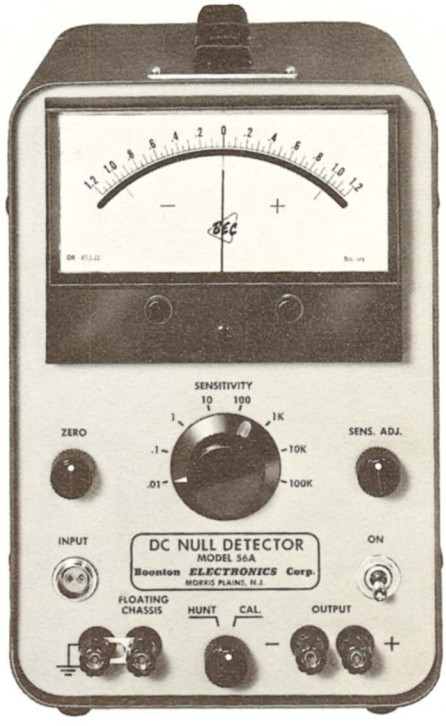
BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model 56A
DC Null Detector

A Highly Sensitive Electronic Galvanometer Particularly Valuable for Use with DC Bridges

- Input Resistance: 10 Megohms on *all* ranges
- Voltage Capability: 1 μV to 100 V
- Current Capability: 0.1 pA to 10 μA
- 160 dB control of Sensitivity in 8 ranges
- 60 dB compression in HUNT mode for locating null
- DC output for recorder, Go/No-Go testing, or automatic control functions
- Grounded or floating input



General Description

The Model 56A is an electronic galvanometer which combines extremely high sensitivity with high input resistance, excellent stability, and unusual convenience of operation. Unlike mechanical galvanometers, the Model 56A is unaffected by mechanical shock or vibration. The instrument is particularly valuable as a null detector for use with dc bridges and potentiometers, as well as in a great variety of applications in the laboratory and in production where requirements are beyond the capabilities of even the best mechanical galvanometers.

The zero-center meter of the Model 56A permits indications of either polarity without interchanging connections or polarity switching. Scale calibrations are linear and extend from -1.0 to $+1.0$ relative units, (approximately 10 μV) with the smallest calibration representing 0.05 relative units. Additional "overcalibrations" to -1.2 and $+1.2$ are provided to permit overlapping readings on successive ranges.

Sensitivity of the Model 56A is continuously selectable over a 160 dB range in eight decade steps plus overlapping vernier (SENS ADJ) control. Such an arrangement permits "calibrating" the scale of the instrument so that a given input level relates to a specific percentage or tolerance limit on the meter.

An electrical zero control is provided to center the pointer. However, the stability of the instrument is such that after a warm up period of about 30 minutes readjustment of the control is unnecessary, except on the most sensitive range where a slight correction may occasionally be desired. It should be noted that range switching has no effect on the zero position.

DC Output

A dc output is available at front panel terminals which (in the CAL mode) is linear with respect to the dc input. The output level is continuously adjustable from essentially zero to at least ± 1 volt

for full scale deflection on all ranges. Output polarity is the same as that of the input. The dc output is useful for application to a recorder, and is especially valuable in conjunction with a dc voltage comparator (such as the Boonton Electronics Models 52B or 53A) for go/no-go testing as well as for a variety of automatic control functions.

Operating Modes

The Model 56A may be operated in either of two modes: "CAL" (calibrate) in which the meter indication is linear with respect to the dc input over the entire scale; or "HUNT" in which sensitivity is "normal" at zero but is progressively compressed, reaching 60 dB below "normal" at ± full scale to facilitate locating the null when testing components of unknown value. Mode selection is accomplished either by a front panel switch or remotely by a switch connected to receptacles at the side of the instrument. Typically, the remote selector is a foot switch which frees the operator's hands for adjustment of equipment while first coarsely locating the null in the HUNT mode, and then finding the precise point of balance in the CAL mode.

Other Characteristics

The input circuit of the Model 56A may be operated either grounded or floating. A jumper at the front input terminals grounds one side of the input when desired. With the jumper removed the input is isolated from ground by at least 200 megohms.

The instrument is packaged as a compact bench unit. An alternate version, the 56A-R, is electrically identical but is designed for mounting in a standard 19-inch rack.

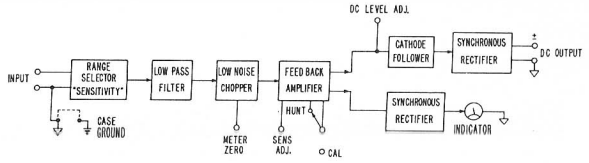


Figure 1. Block diagram, Model 56A

Theory of Operation

A block diagram of the Model 56A is shown in Figure 1. Input is made through a voltage dividing network (Range Selector) where it is attenuated as required. A low pass filter is included in the input circuit to minimize the effects of external ac pickup. The dc is then converted to ac at power line frequency by the mechanical low noise chopper.

The chopper output is applied to the high gain, feed back stabilized ac amplifier. The R/C coupling networks between amplifier stages and their associated filters are designed to peak in the 50-60 c/s region with sharp attenuation of frequencies above and below this band to reduce further the effects of spurious ac.

The metering voltage is obtained by applying the output of the ac amplifier to a synchronous rectifier which is so phased that the meter indication conforms to the polarity of the dc input. The linear dc output is derived by passing a portion of the ac amplifier output through an impedance matching cathode follower and then to a synchronous rectifier which again is phased to provide a dc voltage at the output terminals which is of the same polarity as the dc input.

SPECIFICATIONS

Voltage Capability: 1 μV to 100 V, dc

Current Capability: 0.1 pA to 10 μA, dc

Full Scale Sensitivities: (SENS ADJ. at max.)
Voltage: 10 μV to 100 V, dc
Current: 1 pA to 10 μA, dc
Power: 10^{-17} W to 10^{-3} W

Sensitivity Ranges: 8 decade ranges (calibrated in amplifier gain) of 0.01, 0.1, 1, 10, 100, 1 K, 10 K, and 100 K

Input Resistance: 10 megohms on all ranges

Noise Level: Less than 1 μV, p-p, referred to input

Zero Drift: Less than 1 microvolt after warm-up

Response Time: Approximately 1 second for full scale deflection

Modes of Operation:
Hunt: 60 dB compression
Calibrate: Indication linear with respect to dc input

Mode Switching: At front panel or by remote switch

Meter: 1.2 — 0 — 1.2 scale.

Meter Linearity: 2% of end scale, maximum error

Amplifier Gain: Continuously variable from -40 dB +100 dB

Amplifier Output: ±1.0 mA into 1000Ω; Polarity the same as input

Output Impedance: Approximately 2000 Ω

Overload Tolerance:

Range	Approximate Full Scale Voltage	Overload Voltage Tolerated	Overload Factor
0.01	100 V	1000 V	10
0.1	10 V	1000 V	100
1	1 V	1000 V	1 K
10	0.1 V	1000 V	10 K
100	0.01 V	100 V	10 K
1 K	1 mV	10 V	10 K
10 K	0.1 mV	10 V	100 K
100 K	0.01 mV	10 V	1 M

Power Requirements: 105 to 125 V, 50-60 cycles, 40 watts; 210 to 250 V operation also available

Size: 7¼" W x 9½" D x 11" H excluding handle; Model 56 A-R 19" W x 7" H x 8¾" D

Weight: 12 pounds

Price: Model 56A, $495.00; Model 56 A-R, $520.00, f.o.b., Parsippany, N. J.

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BOONTON ELECTRONICS
CORPORATION
PARSIPPANY, NEW JERSEY

Model CS- Three-Terminal Capacitance Standards

Precision Capacitance Standards for Checking Accuracy of Three-Terminal Capacitance Bridges

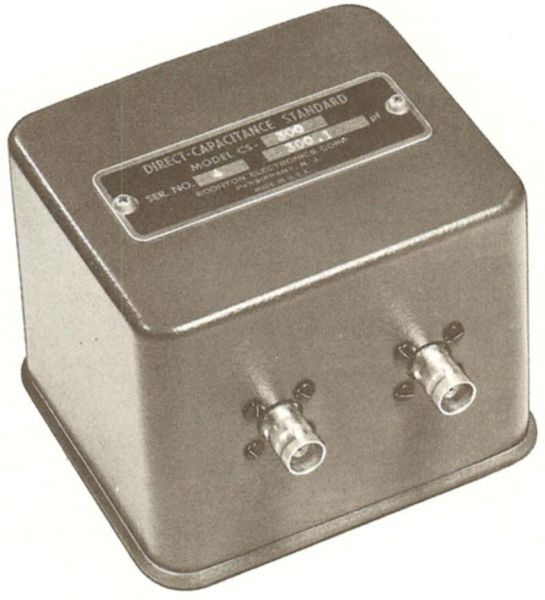
- Basic Accuracy, 0.1%
- Capacitance Values Available from 0.01 pf to 1000 pf
- Excellent Electrical Stability
- Rugged Mechanical Construction
- Calibrated against references certified by NBS

The Model CS- Capacitance Standards are convenient, reliable references for calibrating or checking the accuracy of three terminal capacitance bridges. Also, when connected to the standard arm of the bridge, they provide means for high-resolution comparison measurements.

These capacitance standards are designed for use over a frequency range from 1 Kc/s to 1 Mc/s, and are available in any value from 0.01 pF to 1000 pF. Standards having values of 1 pF or greater are adjusted to a basic accuracy of better than 0.1%; standards of smaller values are adjusted to basic accuracies better than 0.3%. In all cases certification is furnished which includes the actual measured value of the standard as well as the measured temperature coefficient. Accuracies of the references employed for calibration are certified directly by the National Bureau of Standards.

The Model CS- Capacitance Standards are characterized by low series inductance and low stray capacitance from each terminal to case ground to minimize loading effects. The capacitive elements of the standards are subjected to extensive heat cycling to assure the greatest possible thermal stability.

These standards are packaged in sturdy metal containers for mechanical protection and are equipped with BNC terminals for connection by coaxial cables to the bridge.



MODEL CS-
Three-Terminal Capacitance Standards

SPECIFICATIONS

Frequency Range: 1 Kc/s to 1 Mc/s

Capacitance Values Between:	Accuracy	Approximate Temp. Coefficient
100-1000 pf	± (0.1% + 0.1 pf)	± 30 PPM/°C
10-99.9 pf	± (0.1% + 0.01 pf)	± 30 PPM/°C
1-9.9 pf	± (0.1% + 0.004 pf)	± 30 PPM/°C
0.01-0.999 pf	± (0.3% + 0.0004 pf)	± 80 PPM/°C

Price $75.00

Please Note: Boonton Electronics Corporation produces a line of capacitance measuring instruments which are outlined on the reverse side of this sheet. Full details on any are available from your local Boonton Electronics Sales Engineering Representative, or by contacting the factory directly.

1 Mc/s Capacitance/ Inductance Meter
Model 71A

Quick, convenient, direct reading, 3-terminal (direct) measurements of capacitance and 2-terminal (grounded) measurements of inductance. Internally supplied 1 Mc/s test signal. Operates with low test signal level for semiconductor measurements. Linear meter scales. Linear dc output proportional to capacitance or inductance reading for digital display, data logging, or for actuation of materials handling equipment. Extremely valuable for go/no-go capacitance or inductance testing.

Capacitance Measurements: 0 to 1000 pF in 7 ranges; accuracy, ±1% fs; Resolution, 0.01pF

Inductance Measurement: 0 to 1000 μH in 7 ranges; accuracy, ±1% fs; Resolution, 0.01μH

Test Signal: Frequency, 1 Mc/s, crystal controlled; level: 15 mV for capacitance measurements; less than 1 mV for inductance measurements

Q Range: Specified accuracies apply for test specimens having Q's of 3 or more; slightly reduced accuracy for Q's of lower value

DC Output Voltage: 0 to 100 mV or 0 to 300 mV, depending on numerics of full scale. Also 1 V fs for loads > 10 MΩ

Price: $735.00

100 Kc/s Capacitance Bridge
Model 74D

Completely self-contained 3-terminal bridge for precision measurement of capacitance and conductance over very broad ranges; excellent stability with negligible warm-up drift. "Linear" mode for limit operation for go/no-go testing. Provision for use as comparison bridge. Test signal level adjustable to low values for semiconductor testing. 3-terminal arrangement permits use of remote test jig without lead capacitance problems; 2-terminal operation also provided. Balancing simple and convenient, with no false or sliding nulls. Internally supplied dc bias. Vernier capacitance dial provides scale effectively 15 feet long.

Capacitance Measurement: 0.0002 pF to 110,000 pF; accuracy, ±0.1%; resolution, 0.0002 pF

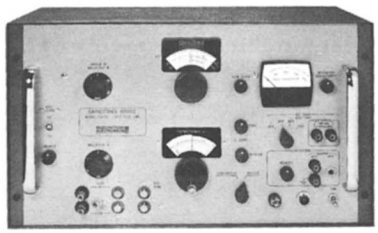
Conductance Measurement: 0.001 μmho to 1000 μmhos; accuracy, ±5%;

Test Signal: Internally supplied; 100 Kc/s; level continuously adjustable from 1 mV to 4 V

DC Bias: Internal, —5 V to +110 V; External, up to ±400 V

Price: $1,350.00

1 Mc/s Capacitance Bridges
Models 75A and 75B



These precision capacitance bridges having test frequency of 1 Mc/s as required by many MIL SPECS have become the standard of the semiconductor and capacitor industries. 3-terminal (direct) arrangement eliminates errors resulting from lead capacitance to ground. High stability permits differential capacitance measurements. Main C balance control is zero-back lash vernier providing scale effectively 15 feet long. DC bias supply available in — S8 versions.

Model 75A

Capacitance Measurement: 0.0002 pF to 1000 pF; accuracy, ±0.25%; resolution, 0.0002 pF

Conductance Measurement: 0.01 μmho to 1000 μmhos; accuracy, ±5%

Operating Mode: 3-terminal (direct), or 2-terminal (grounded)

Test Signal: Built-in 1 Mc/s test oscillator-detector; level adjustable from 20 mV to 3 V

DC Bias: (—S8 version only); internal, continuously adjustable from —5 to +125 V; external, to ±400 V, 100 mA, max.

Prices: Model 75A, $1,250.00. Model 75A-S8, $1,325.00

Model 75B

Capacitance Measurement: 0.00002 pF to 1000 pF; accuracy, ±0.25%; resolution, 0.00002 pF

Conductance Measurement: 0.01 μmho to 1000 μmhos; accuracy, ±5%

Operating Mode: 3-terminal (direct) only

Test Signal: Built-in 1 Mc/s test oscillator-detector; level adjustable from 1 mV to 3 V

DC Bias: (—S8 version only); internal, continuously adjustable from —5 to +125 V; external, to ±400 V, 100 mA, max.

Price: Model 75B, $1,500.00. Model 75B-S8, $1,575.00

Variable Frequency Capacitance Bridge
Model 75C

Versatile 3-terminal bridge having test frequency continuously adjustable from 5 Kc/s to 500 Kc/s. Permits determination of effects of frequency upon test. Includes built-in dc bias supply. Provides performance characteristics and convenience of operation similar to Model 75A 1 Mc/s bridge (see above).

Capacitance Measurement: 0.0002 pF to 1000 pF; accuracy, ±0.25%; resolution, 0.0002 pF

Conductance Measurement: 0.001 μmho to 1000 μmhos; accuracy, ±5%; resolution, 0.01 μmho

Test Signal: Internally supplied; continuously adjustable in frequency from 5 Kc/s to 500 Kc/s; level adjustable from below 1 mV to 3 V

DC Bias: Internal only; continuously adjustable from —5 V to +100 V

Price: $1,900.00

1 Mc/s Capacitance Limit Bridge Model 77B

True dual-limit capacitance tests over a wide range of nominal values and tolerances. Issues test decision outputs visually as well as in form for actuation of materials handling equipment or data logging. With tolerance limits adjusted to ±0%, Model 77B is useful as extremely high resolution laboratory type capacitance bridge. Inductance measurements also possible. 3-terminal (direct) operation. Built-in dc bias supply.

Capacitance Measurement: 0.0001 pF to 1000 pF (1200 pF with max. limit); accuracy, ±0.25%; resolution, 0.0001 pF

Conductance Measurement: Manual only; range, 0 to 1000 μmhos; accuracy, ±5%

Tolerance Range: Continuously adjustable from ±0.0005 pF to ±200 pF; limit resolution, 1% of setting.

Test Signal: Internally supplied; 1 Mc/s, crystal controlled; level adjustable from 1 mV to 250 mV

Test Time: Approximately 0.05 second.

Decision Output: Green, red, and amber panel lamps indicating "Go", "High", and "Low", respectively; continuity contacts at rear panel in conformance with test decisions; sample of indicator-lamp filament voltages at rear panel

DC Bias: Internal, continuously adjustable from —5 V to +125 V; external, to ±400 V, 100 mA max.

Price: $2,000.00

RF Admittance Bridge
Model 33A

Precise, high resolution measurement of capacitance and loss at high frequencies and with low test signal levels. Shunt inductance, series and shunt resistance, dissipation factor, and Q may also be readily determined. Built-in dc bias supply with provision for external bias. Particularly useful for semiconductors and integrated circuits.

Capacitance Measurement: 0 to 150 pF; to 30 pF at 100 Mc/s; accuracy, ±1%; resolution .02 pF

Conductance Measurement: 0 to 25,000 μmhos; accuracy, ±2%; resolution, 0.5 μmho

Test Signal: 7 internally supplied crystal controlled frequencies of 1, 5, 10, 20, 30, 50, and 100 Mc/s; level continuously adjustable from 0.1 V down to as low as 1 mV

DC Bias: Internal, continuously adjustable from —5 to +100 V; external, to ±250 V

Price: $2,000.00

Ultra High Resolution RF Admittance Bridge
Model 33A-S7

Capacitance measurements with resolution of 0.002 pF over capacitance range of 0 to 15 pF for applications where the utmost resolution of small values of capacitance is required. Otherwise identical to Model 33A.

Price: $2,134.00

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BOONTON ELECTRONICS
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PARSIPPANY, NEW JERSEY

Models 85B & 85C
RF Distortion Meters
& Voltmeters

Model 101B
UHF Grid Dip Meter
(on reverse side)

Models 85B & 85C . . . Convenient Measurement of Harmonic Distortion in RF Signals

GENERAL DESCRIPTION

The Models 85B and 85C provide means for convenient, accurate, and rapid determination of the total harmonic content of rf carriers. They are also valuable as sensitive broad band rf voltmeters. The two instruments differ only in their respective fundamental frequency ranges as indicated on the table of specifications.

These Distortion Meters function by comparing the total rf signal level to the level of the signal with the fundamental removed. The total signal level is measured by the incorporated sensitive broad band rf voltmeter to establish a reference point. The harmonic level is then determined by a second measurement, this time with the fundamental suppressed by a series resonant bridge network. The relative harmonic level (expressed in db) is obtained simply by subtracting the first reading from the second.

The series resonant bridge circuit is capable of at least 60 db suppression of the desired fundamental while providing almost perfect transmission of the harmonic content up to 200 Mc, and with approximately 4 db attenuation at 300 Mc.

Since the full wave detector of the voltmeter section operates in the square law region during harmonic measurements, readings are proportional to the TRUE RMS value of the harmonic content.*

The voltmeter section consists essentially of a solid-state rectifier probe plus a high gain, highly stable chopper type dc amplifier whose output is metered in both volts and db.

As rf voltmeters, the Models 85B and 85C are capable of accurate, reliable voltage measurements over wide ranges of frequency and input level; they provide operational characteristics essentially identical to those of the Boonton Electronics Model 91C RF Voltmeter.

As distortion meters, the Models 85B and 85C are particularly valuable for monitoring harmonic level during adjustments of circuit parameters in oscillators and amplifiers (grid bias, plate voltage, inter-stage impedance, output coupling and feed back, for example). In addition to use in design, development, and production testing of signal generators, transmitters, and allied equipment, these instruments provide convenient means for determining harmonic distortion in video systems and broad band transformers, as well as for checking high frequency bias sources in magnetic tape equipment.

Both the 85B and 85C are supplied complete with a 91-12E RF Probe, 91-13B Probe Tip, and 91-8B 50 ohm Adapter for RF Voltmeter use. (Note: To obtain specified accuracy of rf voltage measurement from approximately 100 Mc to approximately 600 Mc, the 50 ohm Adapter supplied with

*Ref: **Electronic Measurements;** F. E. Terman and J. M. Pettit; McGraw-Hill, 1952; p. 247.

the equipment should be used. For measurements beyond 600 Mc the 91-14A Tee Connector and 91-15A 50 ohm Termination are required and are available separately).

For other accessories which extend the range of rf voltage measurement of this equipment, consult your local Boonton Electronics Sales Engineering Representative, or write directly to the address on the reverse side of this sheet.

SPECIFICATIONS

DISTORTION MEASUREMENT

Fundamental Frequency Range: 85B: 1.0 Mc to 100 Mc
85C: 0.1 Mc to 6 Mc

Distortion Sensitivity: 60 db below 1 volt fundamental

Harmonic Range: Essentially no loss of harmonic content to 200 Mc; approximately 4 db down at 300 Mc

Distortion Measuring Accuracy: 2 db

Input Impedance: Approximately 50 ohms

Input: BNC connection provided

RF VOLTAGE MEASUREMENT

Voltage Capability: 1 millivolt to 3 volts

Full Scale Ranges: 0.003, 0.01, 0.03, 0.1, 0.3, 1, & 3 volts

Frequency Range: 20 Kc to 1200 Mc**; useful indications beyond 2500 Mc.

Voltage Measuring Accuracy: 5% FS from 50 Kc to 400 Mc
10% FS from 20 Kc to 1200 Mc**

VSWR: 1.2 max.

Input: High impedance RF Probe, Probe Tip, and 50 ohm Adapter supplied

COMMON SPECIFICATIONS

Primary Power: 105-125 volts; 55-65 cps; 30 watts

Dimensions: 14" w x 7" h x 7" d, overall

Weight: 17 lbs., Net. Shipping Weight, 27 lbs.

Price: $900 FOB Parsippany, N. J.

**With appropriate accessory. See text.

Model 101B . . . A Versatile UHF Meter Operating from 300 Mc to 1000 Mc

Functions

- **Tuned Circuit Resonance Indicator**
- **Absorption Type Frequency Meter**
- **Relative Field Strength Indicator**
- **Modulated Signal Detector**
- **CW or Modulated Signal Generator**
- **Marker Generator**
- **Oscillating Detector for Precision Frequency Determination**

The Model 101B is a compact, portable UHF meter that performs a broad range of functions. It may be operated as a grid dip meter for locating resonance frequencies of passive networks; as an absorption type frequency meter for measuring the frequency of an active circuit; or as a relative field strength meter for detecting changes in level of active circuits. Means are provided for precision frequency comparison and determination by the beat method.

The Model 101B may also be used as a source of calibrated variable-frequency signal power having either modulated or CW carrier. Internal modulation of 120 cps is provided to approximately 30%, or external modulation may be introduced if desired.

The Model 101B consists essentially of an indicator unit and an active UHF probe. The instrument incorporates a unique series-tuned circuit which is capable of efficient operation in the UHF region from 300 Mc to 1000 Mc. This circuit accommodates much higher values of external coupling inductance than would normally be used in oscillators at these frequencies. Band switching thus may be done with plug-in coils of practical size that permit adequate coupling to test circuits.

Model 101 B
Price: $385.00

Specifications

Frequency Range Coils: 300 Mc to 1000 Mc, with three plug-in coils: 300-425 Mc, 425-650 Mc, 650-1000 Mc

Frequency Accuracy: 2% (Dial individually calibrated)

Modulation: Internal modulation to approximately 30%, 120 cps, AM. Phone jack for applying external modulation.

Tube Types: One type 6F4 Oscillator — One type 0B2 Regulator — One type 6 X4 Rectifier

Power Supply: 115 Volts 50/60 cps, 30 Watts

Dimensions: Probe—3½″ x 2⅞″ x 2½″—Indicator Unit — 6″ x 5″ x 9″

Weight: 8 lbs. — Shipping Weight, 9 lbs.

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PARSIPPANY, NEW JERSEY

Model 91C Sensitive RF Voltmeter

A Reliable, Economical Meter for RF Voltage Measurements Over a Wide Frequency Range

- **Voltage Capability:**
  1 mV to 300 V*
- **Accuracy and Frequency Capability:**
  5% fs from 50 Kc/s to 400 Mc/s
  10% fs from 20 Kc/s to 1200 Mc/s*
  Useful indications beyond 4000 Mc/s*
- **True rms response up to 3 V***
- **VSWR less than 1.2 at 1200 Mc/s***
- **High Input Impedance**

*With appropriate accessory

General Description

The Model 91C is a practical, economical instrument for rf voltage measurements where the ultimate in sensitivity and precision is not required. The Model 91C provides reliable, highly reproducible measurements from 20 Kc s to 1200 Mc s, and useful relative measurements (for null and peak indications for example) to beyond 4000 Mc s. (For measurements beyond approximately 600 Mc s, the accessory Model 91-14A Tee Adapter and 91-15A 50-ohm Termination are required and should be ordered as separate items. See Recommended Accessory listings on reverse side.) The Model 91C provides true rms response with input levels up to 30 millivolts (to 3 volts with accessory 100:1 Voltage Divider). The instrument is characterized by high input impedance (see curves of Figure 2), excellent stability, and low noise.

Two voltage scales (calibrated 1 to 3 and 3 to 10) display the seven ranges of sensitivity. A dB scale calibrated 0 to 11 is also provided. A dBm (50 ohm) scale may be selected as an alternate version at no additional cost.

Standard equipment supplied with the Model 91C includes: an RF Probe with specially designed low noise cable and connector assembly; Probe Tip with alligator-clip grounding lead; and a 50 ohm BNC Adapter.

Theory of Operation

As shown in Figure 1, the Model 91C consists essentially of a detector probe and a highly sensitive, stable, chopper type dc amplifier, and a voltmeter.

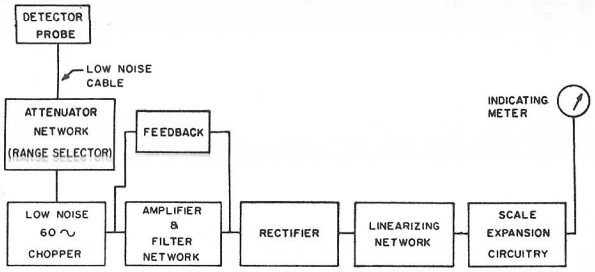
The RF Probe embodies a full-wave diode rectifier which provides **true rms** response at input levels up to approximately 30 millivolts. As the input voltage increases beyond this level, response gradually approaches peak-to-peak (calibrated on the meter scale in rms). The full-wave rectification provided by the diode detector eliminates the possibility of errors resulting from turnover effect.

The rectifier output from the probe, after passing through an attenuator network (range selector), is converted to 60 cycle ac by a low noise chopper. It is then fed to the feed back stabilized amplifier. The 60 cycle output from the amplifier is rectified by a voltage doubler and passed through a diode network to convert the non-linear response of the rf probe to a linear current suitable for metering.

Applications

In addition to voltage measurements and related tests in a variety of rf circuits, the Model 91C is valuable for such applications as the measurement of high frequency characteristics of transistors and other semiconductor devices; determining the frequency response of both active and passive networks; measurement of VSWR and return loss in transmission lines and attenuator systems; measurement of broad band noise; and proper alignment of rf filters, in addition to determining their characteristics.

Boonton Electronics has prepared a publication, "RF Voltmeter Applications" which details various measuring techniques of these versatile instruments. Copies are available, free of charge, from our Sales Engineering Representative in your area or by writing directly to the address on the reverse side.



SPECIFICATIONS

Full Scale Volts: 3 mV to 3 V; 7 ranges in a 3-10-30 sequence

Voltage Measuring Range: 1 mV to 3 V (to 300 V with accessory 100:1 Voltage Divider)

Frequency Range: 20 Kc/s to 1200 Mc/s; useful indications to beyond 4000 Mc/s (Note: accessory 91-14A Tee Adapter and 91-15A 50 Ω Termination required for measurements beyond 600 Mc/s)

Accuracy: 5% from 50 Kc/s to 400 Mc/s; 10% from 20 Kc/s to 1200 Mc/s

Noise: Sensibly zero on all ranges

DB Range: 70 dB (60 dB in 10 dB switch steps plus 10 dB on meter scale)

Waveform Response: True rms with input levels up to 30 mV (or 3 V with accessory 100:1 Voltage Divider); gradually changes to peak-to-peak reading (calibrated in rms) at higher levels

Crest Factor: 42 to 1.4, depending on input level

Power Sensitivity: 0.02 microwatt, max.

VSWR: Less than 1.2 up to 600 Mc/s with 91-8B 50 Ω Adapter; less than 1.2 up to 1200 Mc/s in 50 Ω system with 91-14A Tee Adapter and 91-15A 50 Ω Termination

Standard Equipment: Model 91C is supplied with the following accessories which are included in the price of the instrument: 91-12E RF Probe with low noise cable and connector assembly; 91-13B Probe Tip; 91-8B 50 Ω BNC Adapter (different impedance values available on request at no extra cost)

Primary Power: 105/125 V, 60 c/s; 35 watts; 210/250 V, 50 c/s available at no extra cost

Mechanical Specifications: 7-1/4" w x 10-1/4" d x 11" h (excluding leather carrying handle); net weight, 12 lb.; packed for shipment, 16 lbs.

Model 91C: 117 v, 60 c/s only, $495.00

Model 91C-S4: 117 v, 50 to 400 c/s, $625.00

Model 91C-S5: 117 v, 60 c/s only, with dbm scale; $495.00

Model 91C-S7: 117 v, 50 to 400 c/s, with dbm scale; $625.00

For rack mounted versions of above, add $25.00

OTHER BOONTON ELECTRONICS RF VOLTMETERS

Model 91H: Voltage capability, 100 μV to 300 V; frequency capability, 20 Kc/s to 1200 Kc/s, with uncalibrated response beyond 4000 Mc/s; Basic accuracy, 3%. Price, $595.00

Model 91DA: With basic accuracy of 2%, this is the most accurate RF Voltmeter commercially available; voltage capability, 300 μV to 300 V; frequency capability, 20 Kc/s to 1200 Mc/s, with uncalibrated response beyond 4000 Mc/s. Price, $650.00

Full technical details available on request.

All prices FOB, Parsippany, N. J., and do not include applicable federal, state, or local taxes. Prices and specifications subject to change without notice.

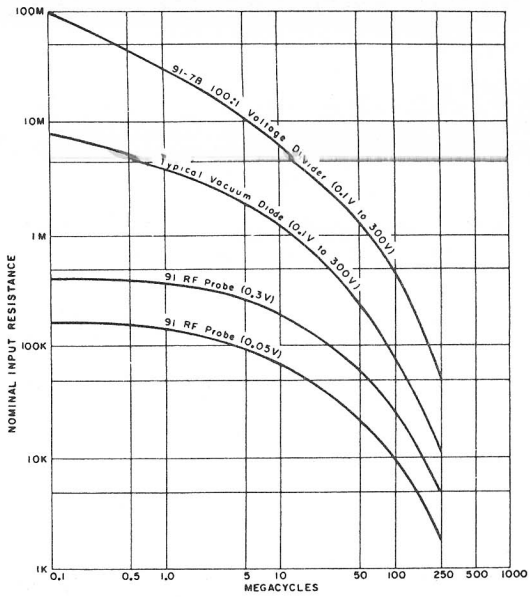


Figure 2. Input resistance, 91-12E RF Probe

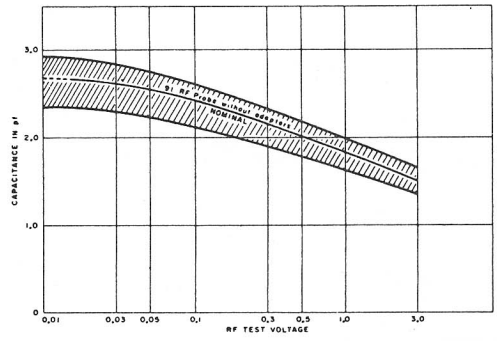


Figure 3. Input capacitance vs. test level (Measured at 10 Mc)

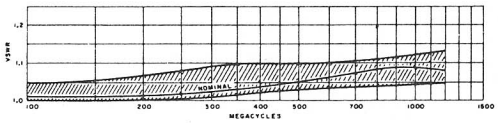


Figure 4. Typical VSWR of 91-12 RF Probe with 91-14 type "N" Tee Adapter terminated in a 91-15 50Ω Termination

Model No.	Description	Price
91-4C	RF Probe for low frequency (1 Kc to 250 Mc) operation	$65.00
91-6C	Unterminated BNC adapter	$20.00
91-7C	100:1 Voltage Divider; attenuates input signal by factor of 100 (±1%); permits measurement of amplitudes up to 300 v; increases range of RMS response to 3 v. Frequency range, 50 Kc to 700 Mc	$35.00
91-14A	Type N Tee Connector; permits connection into 50 Ω coaxial line; required for measurements within specified accuracy beyond 600 Mc; VSWR less than 1.2 at 1200 Mc	$35.00
91-15A	50 Ω Termination; required for use with 91-14A	$25.00
91-16A	Unterminated Type N Adapter	$20.00

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BOONTON ELECTRONICS
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PARSIPPANY, NEW JERSEY

Model 91DA Sensitive RF Voltmeter

A Sensitive Wide Band Voltmeter with a Basic Accuracy of 2 Percent

- Voltage Range: 300 μvolts to 300 volts*
- Frequency Range: 20 Kc to 1200 Mc* (useful indication above 2500 Mc)
- True RMS response from 300 μvolts to 3 volts*
- Expanded linear meter scales
- Linear dc output at front panel
- Jitter on most sensitive range less than 2% FS
- Two voltage scales in a 1, 3, 10 sequence and one db scale (dbm scale also available)

Model 91DA Price: $650.00

Function

The Model 91DA provides a broad range of accurate voltage measurements from ultrasonic frequencies through to the gigacycle region.

The frequency range of the Model 91DA is conservatively specified from 20 Kc to 1200 Mc. It should be noted however that the instrument provides useful indication beyond 2500 Mc, although accuracies in this region can not be specified since no appropriate primary standards exist for their validation.

Voltages from 300 μvolts to 3 volts may be measured and this range is increased to 300 volts through use of the 100:1 Voltage Divider.

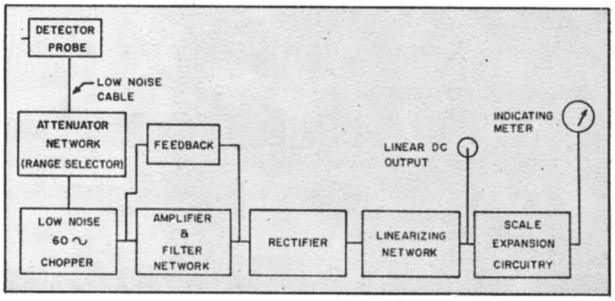
*Appropriate accessory required; see reverse side.

These capabilities render the Model 91DA valuable for a great variety of functions. Beyond the usual voltage measurements and related tests in a diversity of RF circuits, the instrument is widely used in the measurement of the high-frequency characteristics of transistors and other semiconductors; for determining the frequency response of both active and passive networks; for measuring VSWR and return loss in transmission line and attenuation systems; and for determining attenuation and insertion loss of RF attenuators. Having **true RMS** response, the Model 91DA may also be used to measure harmonic distortion of RF waveforms as well as wideband noise.

The Model 91DA is also valuable as an RF null detector for bridge measurements and analogous circuits.

General Description

The essential elements of the Model 91DA are outlined in the block diagram of figure 1. The test probe (supplied as a standard accessory with the instrument) embodies a full-wave rectifier which converts the RF signal to a dc voltage, and provides a **true RMS** response without turnover or harmonic error at levels up to 30 millivolts (or 3 volts with the 100:1 Voltage Divider), gradually changing to peak-to-peak (calibrated in RMS) at higher voltage levels. The probe housing is internally heated for thermal stability.



The rectified output from the probe is passed through an attenuator network (Range Selector) to a low-noise chopper where it is converted to a 60-cycle signal. This ac voltage is then amplified and again rectified. Since probe output is a non-linear function of the test signal it is passed through a linearizing network before metering.

Additional circuitry is incorporated to expand the calibrated portion of the 6-inch meter scale so the pointer range covers the greatest possible percentage of the scale for optimum readability.

Consistent with the quality of design and construction of the Model 91DA, the indicating meter is a high quality, 3/4 percent mirror-knife-edge type having a tracking accuracy of 1/2 percent.

A linear dc output is available at the front panel for external monitoring or driving other instrumentation. Output is approximately 1 volt (at full scale deflection) into a 1000-ohm load.

The Model 91DA is packaged as a compact, portable bench unit and in spite of its very high sensitivity, is sufficiently rugged to withstand extensive use in the laboratory or in the field.

SPECIFICATIONS

Frequency Range: 20 Kc to 1200 Mc. Useful indication above 2500 Mc

Voltage Range: 300 microvolts to 3 volts
Measurements to 300 volts from 50 Kc to 700 Mc with 100:1 Voltage Divider

Full Scale Volts: 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, and 3

DB Range: 80 (70 in 10 db switch steps plus 10 db on meter scale)

Voltage Accuracy: 150 Kc to 100 Mc : ±2% (from 60° F to 100° F.)
50 Kc to 400 Mc : ±5%
20 Kc to 1200 Mc : ±10%

Noise: Indicator unrest is less than 2% FS on most sensitive (1 mv FS) range; sensibly zero on all other ranges.

Probe Capacitance With Tip (approx): Varies from 1.5 to 3.0 pf inversely with voltage

VSWR: Less than 1.2 to 1200 Mc with Tee Adapter

Waveform Response: True RMS below 0.03 volts changing to peak reading (calibrated in RMS) at higher levels. With 91-7C Voltage Divider RMS response may be extended to 3 volts

Crest Factor: 140 to 2, depending on input level

Linear DC Output: Approx. 1.0 v DC into 1000Ω load

Power Sensitivity: 0.0018 microwatt

Power Requirements: 105 to 125 V, 60 cycles, 45 watts; 210 to 250 V, 50 cycle operation available at extra cost of $20.00

Standard Equipment Supplied with 91DA: 91-12D RF Probe; 91-13B Probe Tip

Size: 7-1/4" w x 9-1/2" d x 11" h excluding handle

Weight: 13-1/2 lb. Shipping Weight, 18 lb.

Price: $650

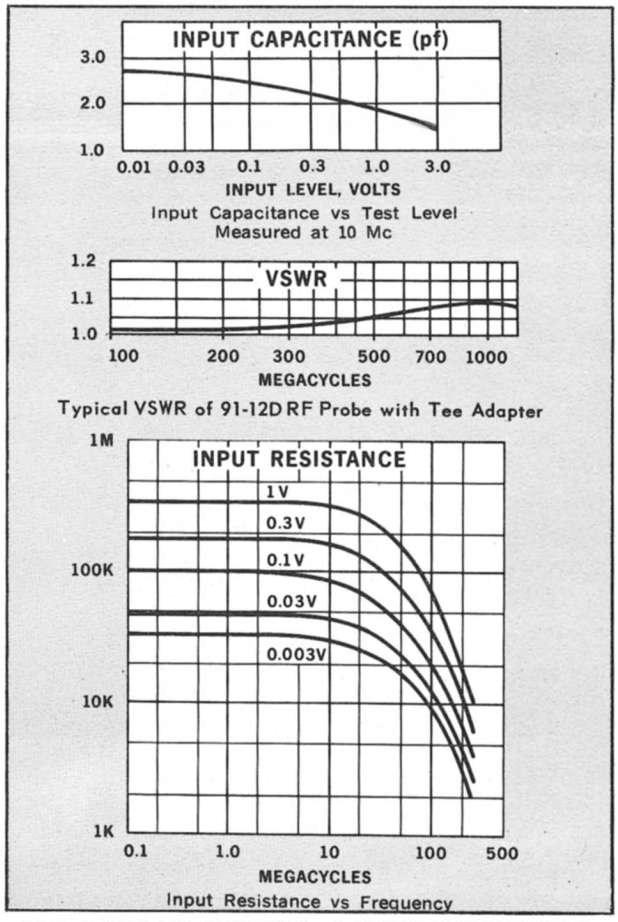
MODEL 91DA-R

The Model DA-R is electrically identical to the Model 91DA, but is packaged for mounting in a standard 19-inch rack. It is supplied complete with dust covers, and with the same selection of accessories as the Model 91DA. Dimensions of the Model 91DA-R are: 7" h x 19" w x 8-3/4" d.

Weight: 15 lbs. **Price** $675

MODEL 91DA-S5

Identical to Model 91DA, but with dbm (50Ω) scale. **Price,** $650



RF VOLTMETER ACCESSORIES

The following accessories are available for use with the Model 91DA, and should be ordered as separate items:

Model No.	Description	Price
91-6C	Unterminated BNC Adapter	$20.00
91-7C	100:1 Voltage Divider; attenuates input signal by factor of 100 (±1%); permits measurement of up to 300 v; increases range of RMS response to 3 v; frequency range, 50 Kc to 700 Mc	$35.00
91-8B	50 ohm BNC Adapter; permits measurements up to 600 Mc in 50 ohm system; VSWR less than 1.2 up to 600 Mc; other impedances available at same price	$25.00
91-12D*	RF Detector Probe with low noise cable and connector assembly; internally heated for thermal stability; frequency range, 20 Kc to 1200 Mc	$50.00
91-13B*	Probe Tip; permits convenient connection to signal source up to approx. 100 Mc	$3.00
91-14A	Type N Tee Connector permits connection into 50 ohm line; required for measurements within specified accuracy above approx. 600 Mc; VSWR less than 1.15 to 1000 Mc, less than 1.2 at 1200 Mc	$35.00
91-15A	Type N 50 ohm termination; required for use with 91-14A Tee Connector when making terminated measurements	$25.00
91-17D	RF Detector Probe with low noise cable and connector assembly; frequency range, 1 Kc to 250 Mc;	$65.00
91-18A	Storage container for the following accessories: 91-12D, 91-13B, 91-14A, 91-15A, 91-6C, and 91-7C	$10.00

*Supplied as standard equipment with Model 91DA and included in price; may also be ordered separately.

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ACCESSORIES FOR RF VOLTMETERS

ACCESSORIES FOR RF VOLTMETERS

Listed below are **current** versions of accessories designed specifically for use with recent models of Boonton Electronics RF Voltmeters. Where indicated, they are supplied as standard equipment with the Voltmeter and are included in its published price. All are also available separately as replacements or spares, or to up-date older instruments.

In cases where accessories are to be used with earlier models of RF Voltmeters (generally, 91D's with serial numbers below 4703, 91CA's earlier than serial number 2661, and 91C's below 3809), please consult your local Boonton Electronics Sales Engineering Representative, since in some cases the current versions of accessories are not directly interchangeable with their respective predecessors.

RF PROBES

These solid state detector probes provide measurements over broad ranges of frequency and signal level. All offer **true RMS** response without turn-over errors for inputs up to 30 millivolts, beyond which waveform response gradually approaches peak-to-peak (calibrated on the meter scale in RMS). Input impedance of these probes is unusually high for devices of this type (See Figure 1). Measurements up to 3 volts may be made with these probes, and up to 10 volts ac may be applied without causing damage. The high-frequency probes are dc protected to 400 volts; the low frequency models are dc protected to 200 volts.

The probes are supplied complete with a 30-inch shielded cable and connector assembly. The cable is of special low noise design so that development of voltage as the cable is flexed or moved is reduced as far as the state of the art permits.

Model No.	For Use With	Description and Price
91-4C	91C, 91CA, 91H	1 Kc to 250 Mc Probe; **Price:** $65.
91-12D*	91DA	20 Kc to 1200 Mc Probe; uncalibrated response beyond 4000 Mc; internally heated for thermal stability; **Price:** $50.
91-12E†	91C, 91CA, 91H	20 Kc to 1200 Mc Probe; uncalibrated response beyond 4000 Mc; **Price:** $45.
91-17D	91DA	1 Kc to 250 Mc Probe; **Price:** $65.

The following accessories are usable with all current Boonton Electronics RF Voltmeters

91-6C	Unterminated Type BNC Adapter; **Price:** $20.	
91-7C	100:1 Voltage Divider; attenuates input signal by factor of 100 (± 1%), permitting measurements of signal levels up to 300 volts; extends range of RMS response of Probe to 3 volts; frequency range, 50 Kc to 700 Mc. **Price:** $35.	
91-8B†	50 ohm BNC adapter; VSWR less than 1.2 at 600 Mc. (Other impedance values available at same price); **Price:** $25.	
91-13B*†	Probe Tip, provides convenient means for connection to signal sources lower in frequency than approximately 250 Mc; includes grounding lead with alligator clip; shielded for minimum rf pick up. **Price:** $3.	
91-14A	Type N Tee Connector; permits connection of probe into 50 ohm line; required for measurements within specified accuracy beyond 600 Mc; VSWR in 50 ohm system less than 1.15 to 1000 Mc, less than 1.2 at 1200 Mc (see Figure 2b on reverse side). **Price** $35.	
91-15A	50 ohm termination required for use with 91-14A Tee adapter; **Price:** $25.	
91-16A	Unterminated Type N Adapter; **Price:** $20.	

*Supplied as standard equipment with Model 91DA, and included in price
†Supplied as standard equipment with Models 91C and 91H, and included in price.

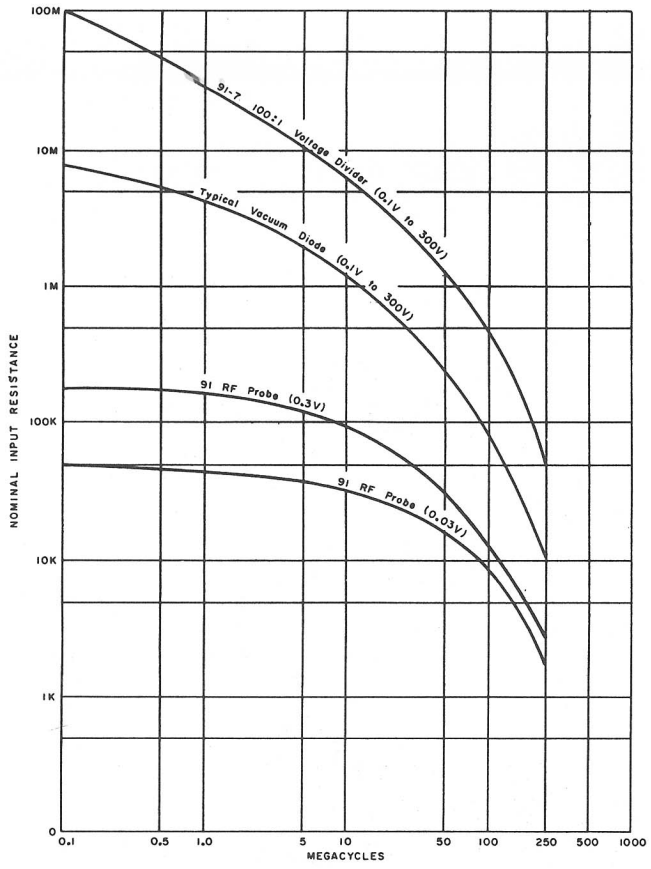

Figure 1a. Input Resistance, 91-12D RF Probe

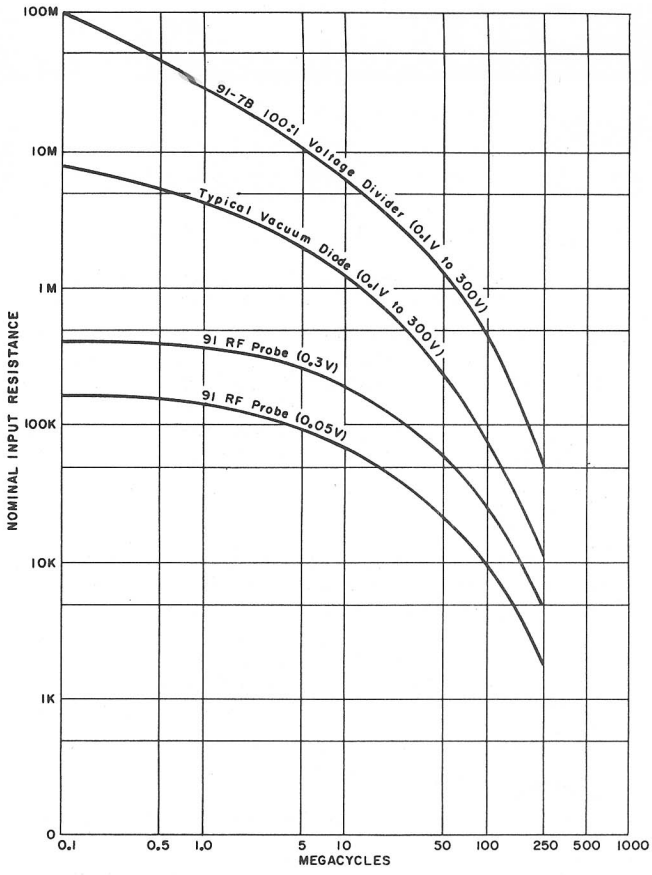

Figure 1b. Input Resistance, 91-12E RF Probe

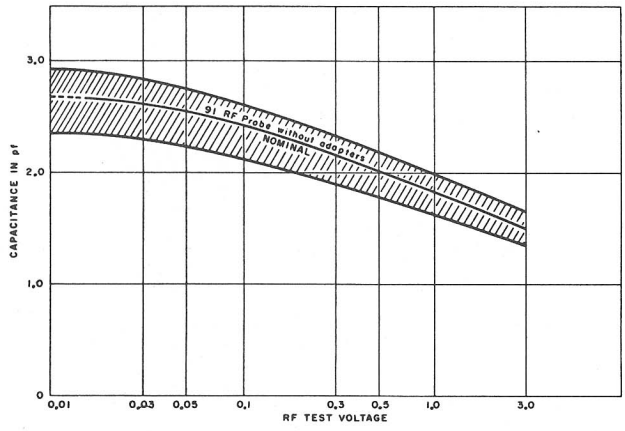

Figure 1c. Input Capacitance vs Test Level of 91-12 RF Probes Measured at 10 Mc

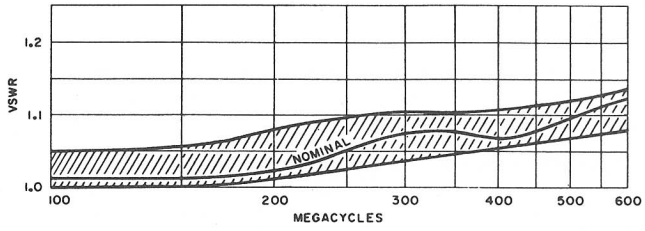

Figure 2a. Typical VSWR of 91-12 RF Probes with 91-8 50 ohm Adapter

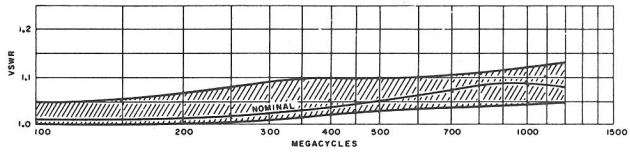

Figure 2b. Typical VSWR of 91-12 RF Probes with 91-14 Type N Tee Adapter Terminated by 91-15 50-ohm Termination

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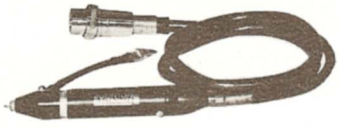
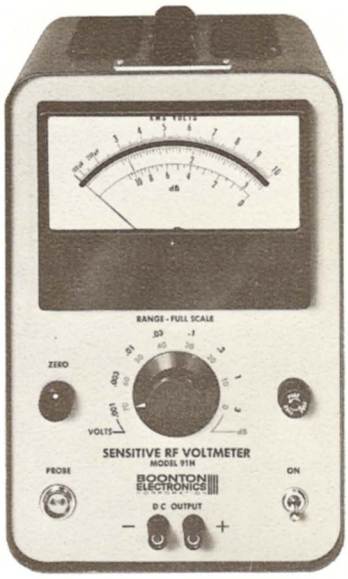
Model 91H Sensitive RF Voltmeter

An Accurate, Broadband Voltmeter Capable of Measuring Unusually Low Signal Levels

- **Voltage Capability: 100 μV to 300 V***
- **Basic Accuracy, 3%**
- **Calibrated response to 1200 Mc/s; Useful indications beyond 4000 M/cs***
- **Exceptionally low noise**
- **True rms response up to 3 V***
- **VSWR Less than 1.2 at 1200 Mc/s***
- **High Input Impedance**
- **Linear dc output**

* With appropriate accessory





General Description

The Model 91H is a highly sensitive voltmeter for measurement of signal levels from 3 volts[1] down to 100 microvolts and over a frequency range from the low radio frequencies into gigacycle region. The instrument provides true rms response with input levels up to 30 millivolts,[2] and is characterized by high input impedance, excellent stability, and low noise.

The calibrated frequency range of the Model 91H extends from 20 Kc/s to 1200 Mc/s. However, it should be noted that the instrument provides uncalibrated response for relative measurements (such as detecting peaks or nulls) beyond 4000 Mc/s. (Note: for operation beyond approximately 600 Mc/s, use of the accessory Model 91-14A Tee Adapter and Model 91-15A 50 ohm Termination is required and should be ordered as separate items; see accessory listing on reverse side.)

Two meter scales (calibrated 1 to 3 and 3 to 10) display the eight ranges of sensitivity. Subcalibrations of 100 microvolts and 200 microvolts are provided on the most sensitive range. A db scale calibrated 0 to 11 is also included. A dbm (50 ohm) scale may be selected as an alternate version at no additional cost.

Standard equipment supplied with the Model 91H includes: an RF Probe with specially designed low noise cable and connector assembly; Probe Tip with alligator-clip grounding lead; and a 50 ohm BNC adapter.

DC Output

A dc output is available at front panel terminals which is proportional to the meter reading. Jumper connections at a rear terminal board provide an output suitable for either display on a digital voltmeter (in which case the output may be adjusted for any full scale value from zero to 100 millivolts or 300 millivolts, depending on the numerics of the voltage range) or for application to a recorder (in which case the full scale output level is adjustable to any value from zero to 300 millivolts). Output resistance is 0 to 40 K, depending on output level.

Theory of Operation

The Model 91H comprises essentially a detector probe and a highly sensitive, stable, chopper type dc amplifier, and a voltmeter (see block diagram of Figure 1).

The RF Probe consists of a full wave diode rectifier which provides **true rms** response at input levels up to approximately 30 millivolts. As the input voltage increases beyond this level, response gradually approaches peak-to-peak (calibrated on the meter scale in rms).

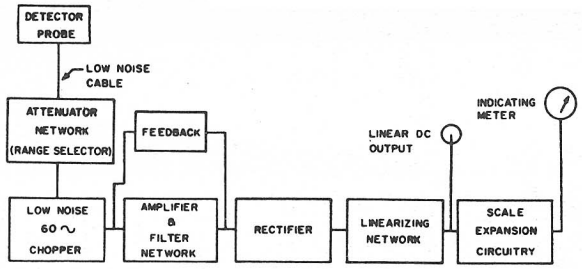
The rectified output from the probe, after passing through an attenuator network (range selector), is converted to 60 cycle ac by a low noise chopper. It is then fed to the narrow band feed back stabilized amplifier. The 60 cycle output from the amplifier is rectified by a voltage doubler and passed through a diode network to convert the non-linear response of the RF Probe to a linear current suitable for metering.

Great care has been taken in the design and construction of the Model 91H to hold noise, hum, and other sources of spurious deflection to a minimum. Jitter of the indicating needle on the most sensitive range (1 millivolt fs) is less than 2% fs, and sensibly zero on all other ranges. The probe cable of the Model 91H is of special low noise construction, and on the most sensitive range even vigorous flexing causes only momentary minor deflections.

Applications

The extremely high sensitivity and broad frequency range of the Model 91H suit the instrument for a great variety of rf measuring functions. Beyond the usual voltage measurements and related tests in a variety of rf circuits, the Model 91H is valuable for such applications as the measurement of high frequency characteristics of

[1] To 300 volts with accessory 100:1 Voltage Divider
[2] To 3 volts with accessory 100:1 Voltage Divider



transistors and other semiconductor devices; determining the frequency response of both active and passive networks; measurement of VSWR and return loss in transmission lines and attenuator systems; determining the harmonic content of rf signals; measurement of broad band noise; and proper alignment of rf filters, in addition to determining their characteristics.

Boonton Electronics has prepared a publication, "RF Voltmeter Applications", which details various measuring techniques of these versatile instruments. Copies are available, free of charge, from our Sales Engineering Representative in your area or by writing directly to the address below.

Specifications

Full Scale Volts: 1 mV to 3 V; 8 ranges in a 1-3-10 sequence

Voltage Measuring Range: 100 μV to 3 V (to 300 V with accessory 100:1 Voltage Divider)

Frequency Range: 20 Kc/s to 1200 Mc/s; useful indications beyond 4000 Mc/s (Note: accessory Tee Adapter required for measurements beyond 600 Mc/s).

Accuracy:

3% from 150 Kc/s to 100 Mc/s
5% from 50 Kc/s to 150 Kc/s and from 100 Mc/s to 400 Mc/s
10% from 20 Kc/s to 50 Kc/s and from 400 Mc/s to 1200 Mc/s

On most sensitive (1 mV, FS) range:
5% from 150 Kc/s to 100 Mc/s
10% from 50 Kc/s to 150 Kc/s and from 100 Mc/s to 400 Mc/s
15% from 20 Kc/s to 50 Kc/s and from 400 Mc/s to 1200 Mc/s

Noise: Indicator unrest is less than 2% fs on most sensitive (1 mV fs) range; sensibly zero on all other ranges

DB Range: 80 dB (70 dB in 10 dB switch steps plus 10 dB on meter scale)

Waveform Response: True rms with input levels up to 30 mV (or 3 V with accessory 100:1 Voltage Divider); gradually changes to peak-to-peak reading (calibrated in rms) at higher levels

Crest Factor: 420 to 1.4, depending on input level

Power Sensitivity: 0.0002 microwatt, max.

VSWR: Less than 1.2 up to 600 Mc/s with 50 Ω Adapter; less than 1.2 up to 1200 Mc/s in 50 Ω system with Tee Adapter and 50 Ω Termination

Linear DC Output: Proportional to meter reading; DVM mode, full scale values continuously adjustable from 0 to 100 mV or 300 mV, depending on range numerics; REC mode, full scale value continuously adjustable from 0 to 300 mV for all ranges; Output resistance, 0 to 40 k, depending on output level.

Standard Equipment: Model 91H is supplied with the following accessories which are included in the price of the instrument: 91-12E RF Probe with low noise cable and connector assembly; 91-13B Probe Tip; 91-8B 50 Ω BNC Adapter (different impedance values available on request at no extra cost)

Primary Power: 105-125 V, 60 cps; 35 watts;
for special power requirements see below.

Mechanical Specifications: 7-1/4" w x 10-1/4" d x 11" h (excluding leather carrying handle); net weight, 12 lb.; packed for shipment, 16 lbs.

Prices:

Model 91H: 105 V to 125 V, 60 c/s only*, $595.00
Model 91H-S4: 105 V to 125 V, 50 to 400 c/s, $725.00
Model 91H-S5: Same as 91H, with dBm scale*, $595.00
Model 91H-S7: Same as 91H-S4, with dBm scale, $725.00

* Models for 105 V to 125 V, 50 c/s only and 210 V to 250 V, 50 c/s only are available at the same price.

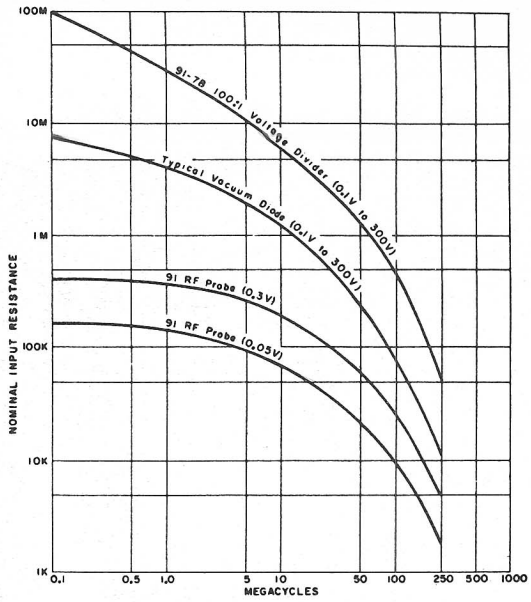


Figure 2. Input resistance, 91-12E RF Probe

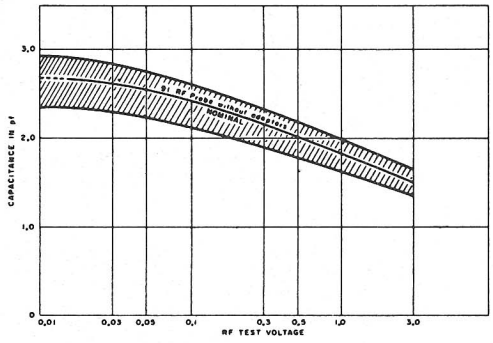


Figure 3. Input capacitance vs. test level (Measured at 10 Mc)

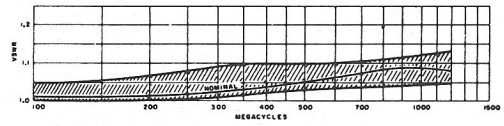


Figure 4. Typical VSWR of 91-12 RF Probe with 91-14 type "N" Tee Adapter terminated in a 91-15 50Ω Termination

Available Accessories: The following accessories are available for use with the Model 91H, and should be ordered as separate items:

Model No.	Description	Price
91-4C	RF Probe for low frequency (1 Kc to 250 Mc) operation	$65.00
91-6C	Unterminated BNC adapter	$20.00
91-7C	100:1 Voltage Divider; attenuates input signal by factor of 100 (±1%); permits measurement of amplitudes up to 300 v; increases range of RMS response to 3 v. Frequency range, 50 Kc to 700 Mc	$35.00
91-14A	Type N Tee Connector; permits connection into 50 Ω coaxial line; required for measurements within specified accuracy beyond 600 Mc; VSWR less than 1.2 at 1200 Mc	$35.00
91-15A	50 Ω Termination; required for use with 91-14A	$25.00
91-16A	Unterminated Type N Adapter	$20.00

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PARSIPPANY, NEW JERSEY

Model 95A Sensitive DC Meter

Versatile, Reliable DC Microvolt/Microammeter

Extremely Wide Range
Voltage: 1 μv to 1000 V
Currents: 0.1 μμa to 1 amp.

Simplicity of Range Switching and Meter Reading

Constant Input Resistance of 10 Megohms on all Voltage Ranges.

Floating Input

Fast Response

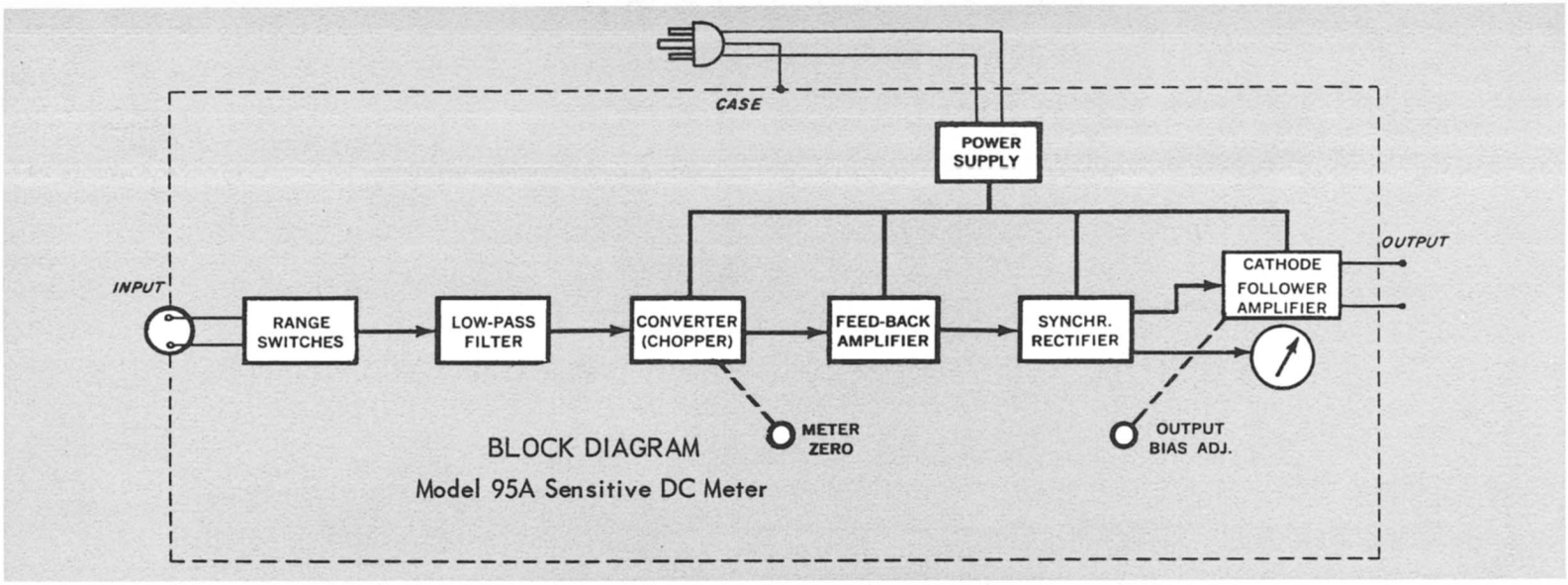
Low Drift

Amplifier Output at Front Panel

Price $550

Printed in U.S.A.

Sensitive RF Voltmeters / Sensitive DC Voltmeters / DC Null Detectors / RF Admittance Bridges
Capacitance & Inductance Bridges / RF Distortion Meters / UHF Grid Dip Meters / Automatic Test Equipment



BLOCK DIAGRAM

Model 95A Sensitive DC Meter

GENERAL DESCRIPTION

The Model 95A Sensitive DC Meter is a sensitive wide range combination voltmeter, ammeter and amplifier. A unique multiplex range switching system permits rapid selection of any of the 42 voltage or current ranges and displays in large lighted windows the full scale value and unit of measure of the range in operation. This range switching system makes for easy operation and instant recognition of the scale in use thereby reducing the incidence of errors of interpretation. The range of measurements, 1 μvolt to 1000 volts and 0.1 $\mu\mu$a to 1 ampere, it is believed, is the greatest of any commercially available instrument.

CIRCUIT

The instrument is a stable, high gain, feedback, ac amplifier operating from the output of a low noise chopper. A synchronous output rectifier consisting of a transistor switching circuit driven in phase with the input chopper produces a dc output current proportional in amplitude and identical in polarity to the input voltage. A zero center meter indicates positive to the right and negative to the left. The input voltage is applied to the chopper through a switching system which either attenuates the input voltage or varies the gain of the amplifier. Current ranges are provided by internally shunting the input with an appropriate resistance and then reading the voltage drop across this resistance in terms of current calibration. A meter ZERO ADJ control is provided; however, after a 30 minute warm-up normally there is no need to reset the zero when changing sensitivity ranges. An exception to this is the most sensitive range where some correction may be needed, particularly when thermals or residual voltages are present in the test circuit.

FLOATING INPUT

The input circuit may be operated either grounded or floating. A jumper across the terminal posts at the bottom left of the front panel connects the input circuit to the panel for grounded operation. When the jumper is removed the input circuit floats a minimum of 500 megohms above ground.

CONSTANT INPUT RESISTANCE

The input resistance of the Model 95A is held to a constant 10 megohms on all voltage ranges. This frees the Model 95A of a range switching error which is inherent in all meters that have their input resistance varying with range. By presenting a constant load to a high resistance source the Model 95A can be switched from range to range without changing the voltage at the source.

The output of the synchronous rectifier is also applied to a cathode follower where separate gain and bias controls give complete flexibility in the control of the output gain and reference level without interacting with the internal meter. This feature allows the high sensitivity of the Model 95A to be used in conjunction with a variety of recording or control devices.

SPECIFICATIONS

VOLTAGE RANGE: $\pm$1.0 microvolt to 1,000 volts dc

CURRENT RANGE: $\pm$0.1 $\mu\mu$a (10^{-13}) to 1.0 ampere dc

INPUT RESISTANCE:

Voltmeter: 10 megohms all ranges

Ammeter: 1.0 $\mu\mu$a to 100 $\mu\mu$a Range: 10 megohms

300 $\mu\mu$a: 3.33 megohms	1 μa: 1K ohms
1 mμa: 1.0 megohms	3 μa: 333 ohms
3 mμa: .333 megohms	10 μa: 100 ohms
10 mμa: 100K ohms	30 μa: 33.3 ohms
30 mμa: 33.3K ohms	100 μa: 10 ohms
100 mμa: 10K ohms	300 μa: 3.33 ohms
300 mμa: 3.33K ohms	1 ma to 1a: 1.0 ohm

FULL SCALE SENSITIVITIES:

Voltage: $\pm$10 microvolts to 1,000 volts dc

Current: $\pm$1.0 micromicroampere to 1 ampere

ACCURACY:

Voltmeter: $\pm$3% of Full Scale

Ammeter: $\pm$4% of Full Scale

RANGES:

Voltmeter: 17 Ranges 1,3,10,30 etc. sequence

Ammeter: 25 Ranges 1,3,10,30 etc. sequence

NOISE: 1 μv PP (approx.) referred to input

DRIFT: less than $\pm$2 μv after 30 minute warm up referred to input.

BANDWIDTH: 1 cycle at 3 DB

RESPONSE TIME: Approx. 1 Sec. to 90% of Full Scale

60 CYCLE REJECTION: greater than 60 DB

METER: Zero center with mirror scale

RESISTANCE FROM INPUT CIRCUIT TO CASE: 500 megohms minimum

AMPLIFIER: Gain 100,000 maximum

OUTPUT: 0 to $\pm$1.0 volt into 1,000 ohm load polarity same as applied Input. Output is continuously adjustable.

OUTPUT IMPEDANCE: Approximately 400 ohms.

RACK MOUNTING: Also available, the 95A-R on a 5¼ x 19' rack panel. Extends 8¾' behind panel. Price $575.

POWER REQUIREMENTS: 105 to 125V, 50-60 cycles, 40 watts.
210 to 250V, 50-60 cycles (Special)

SIZE: 7½W x 9½D x 11H excluding handle

WEIGHT: 17 lbs. packed.
Approx. 22 lbs. packed (rack mounted)

SUPPLIED WITH: 4 ft. shielded test leads terminated in insulated clips.

PRICES: Model 95A, $550.00
Model 95A-R (Rack mounting version), $575.00

All prices shown are FOB Parsippany, N.J. Prices do not include applicable federal, state, or local taxes. Prices and specifications are subject to change without notice.

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CORPORATION
PARSIPPANY, NEW JERSEY

MODEL 97A
DC Voltmeter-Amplifier

MODEL 98A
Differential DC Voltmeter-Amplifier
(on reverse side)

MODEL 97A DC VOLTMETER-AMPLIFIER

SPECIFICATIONS

Full Scale Ranges: 0.3, 1.0, 3.0, 10, 30, 100, 300 mv
1.0, 3.0, 10, 30, 100, 300, 1000 v

Accuracy: 3% of full scale on all ranges

Input Impedance:
100 megohms on 10 millivolt range & above
30 megohms 3 millivolt range
10 megohms 0.3 and 1 millivolt range

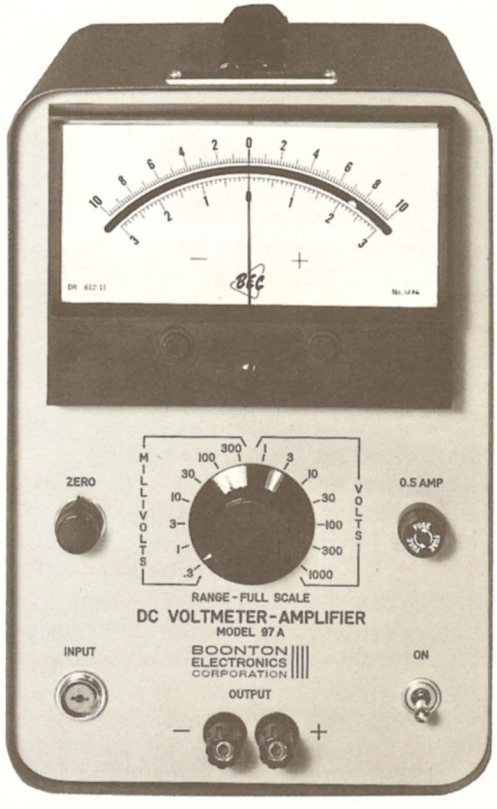
Amplifier Gain: 70 db

Output Impedance: 1200 ohms (approx)

Output Capability: ±0.5 milliampere across 1500 ohms or ±1 v unloaded

Zero Drift: (after warmup) less than 10 microvolts

Power Requirements: 117 volts, 60 cycles, 30 watts. 50 cycle units on special request.



Price: [redacted] **$425.00**

The Model 97A is a sensitive dc voltmeter offering high input impedance, excellent stability, and unusual convenience of operation at moderate cost. The instrument is also useful as a stable high-gain dc amplifier for general laboratory applications.

Fourteen overlapping voltage ranges provide measurements from 10 microvolts to 1000 volts. The six-inch mirror scale indicating meter is zero-centered, permitting measurements of either polarity without need for a polarity reversing switch or for interchanging test leads.

The input of the Model 97A is overload protected and accidental application of up to 1500 volts will not damage the instrument, even on the most sensitive range. Recovery from overload is virtually instantaneous.

The dc input to the Model 97A is passed through a low noise chopper and then amplified by a narrow band high gain ac amplifier. Thus, the drift and other instabilities frequently associated with high gain dc instruments are greatly minimized. The rectified amplifier output is available at front panel binding posts and may be used simultaneously with the indicating meter without interaction.

As an amplifier, the Model 97A has a maximum gain of 70 db and is capable of providing ±0.5 milliampere into a 1500-ohm load. An output bias control allows the adjustment of output to any current from 0 to 0.6 milliampere with zero input condition.

The Model 97A is supplied with a pair of thirty inch shielded clip leads.

Model 98A Differential DC Voltmeter-Amplifier

SPECIFICATIONS

Full Scale Ranges: 0.3, 1.0, 3.0, 10, 30, 100, 300 mv
1.0, 3.0, 10, 30, 100, 300, 1000 v

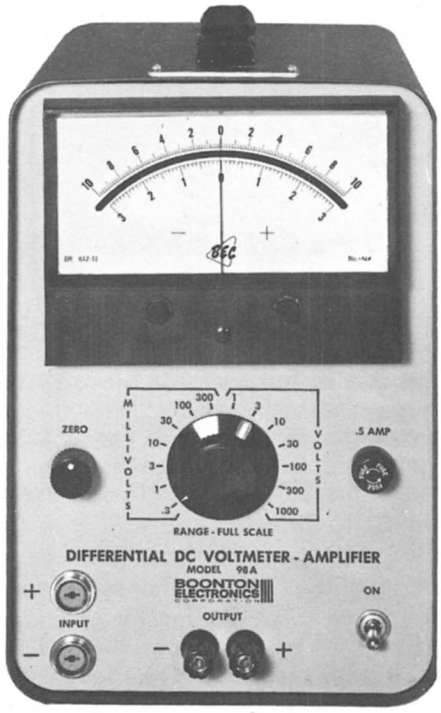
Accuracy: 3% of full scale on all ranges

Input Impedence:

Differential Input Resistance	Neg. or pos. Term. to Gnd. (in megohms)	Neg. to pos. Term. (in megohms)
0.3 mv range	27	9
1.0 mv range	27	9
3 mv range	30	27
10 mv range	40	75
30 mv range	49	98
100 mv to 1000 V range	50	100

Two Terminal Input Resistance	(Neg. terminal grounded)
0.3 mv range	8 megohms
1 mv range	8 megohms
3 mv range	20 megohms
10 mv range	40 megohms
30 mv to 1000 V range	50 megohms

DC Common Mode Rejection: greater than 80 db
60 Cycle Rejection: Better than 60 db
Amplifier Gain: 70 db
Output Impedance: 1200 ohms (approx)
Output Capability: ±0.5 ma into 1500 ohms, or ±1.5 v unloaded
Zero Drift: Less than 10 μv after warmup
Power Requirements: 117 volts; 60 cycles; 30 watts; 50 cycle units on special request



Price [redacted] **$495.00**

The Model 98A Differential DC Voltmeter-Amplifier is a three terminal instrument designed for dc measurements over the range of 10 microvolts to 1000 volts.

The three terminal feature permits the instrument to be used for voltage measurements above ground or to be operated as a differential voltmeter to measure small differences between relatively large dc voltages. Also the instrument is ideal for comparing or adjusting critical voltages against reference sources such as a standard cell, or for measuring the voltage variations of highly regulated dc power supplies.

The Model 98A may also be used as a conventional two terminal dc voltmeter when the negative input is grounded.

The six-inch mirror scale indicating meter is zero-centered. Thus, measurements of either polarity may be made without polarity switching or interchanging test leads.

The high input impedance of the Model 98A is achieved by means of special break-before-make, low noise chopper circuitry, plus a high input resistance voltage divider. The chopper output is amplified by a stable, high-gain feedback ac amplifier, then synchronously rectified to provide voltage indications of a magnitude and polarity proportional to those of the test voltages. Thus, the instabilities usually associated with dc amplification are avoided.

As a sensitive, highly stable dc amplifier, the Model 98A has a maximum gain of 70 db and is capable of providing ± 0.5 ma into a 1500-ohm load. An output bias control in the instrument allows the adjustment of output to any current between 0 and 0.6 ma with zero dc input condition.

The amplifier output is available at front panel binding posts for external use. This output is usable simultaneously with the indicating meter without interaction.

A protective circuit at the attenuator output guards the instrument from accidental overload. Voltages as high as 1500 volts may be accidentally applied to the Model 98A input without causing damage to the equipment and with rapid recovery.

The Model 98A is supplied complete with a pair of thirty inch shielded clip leads.

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