Electronic Services - Los Angeles
M12662X

GenRad

GR 1617

Capacitance Bridge

1617-0100-E

Instruction Manual

WARNING

Use of this bridge can involve exposure to potentially dangerous high voltages. For operator safety, no measurements should be attempted until the operator has read, and understands, operating procedures outlined in this manual, pages 1 through 18.

GR 1617

Capacitance Bridge

1617-0100-E

GENERAL ELECTRIC
INSTRUMENTATION & COMMUNICATION
1200 KONA DRIVE
COMPTON, CA 90220
(213) 642-5317

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Concord, Massachusetts, U.S.A. 01742
Form 1617-0100-E
August 1978
ID-2528

SPECIFICATIONS

Quantity	Frequency	Range	Accuracy
Capacitance	120 Hz internal *	0 to 0.11 F	± 1% ± 1 pF, smallest division 2 pF; residual ("zero") capacitance approximately 4 pF
		0.11 F to 1.1 F	± 2%
	40 Hz to 120 Hz external (useful down to 20 Hz with reduced accuracy)	0 to 1.1 F	Same as above with suitable generator
	120 Hz to 1000 Hz external	$0 \text{ to } 1\ F\left(\frac{100}{f_{Hz}}\right)^2$	± 1% ± 1 pF with suitable generator and precautions
Dissipation Factor	120 Hz internal or 40 Hz to 120 Hz	$0 \text{ to } 10\frac{f_{Hz}}{120}$*	± 0.001 ±0.01 C (in F) ± 2%
	120 Hz to 1 kHz	0 to 10	$\left(\pm 0.001 \pm 0.01\ C\ (\text{in F})\right)\frac{f_{Hz}}{120} \pm 2\%$*

Lead-Resistance Error (4-terminal connection): Additional capacitance error of less than 1% and D error of 0.01 for a resistance of 1Ω in each lead on all but the highest range, or 0.1Ω on the highest range.

Internal Test Signal: 120 Hz (synchronized to line) for 60-Hz model; 100 Hz for 50-Hz model. Selectable amplitude less than 0.2 V, 0.5 V, or 2 V. Phase reversible.

External Test Signal: 20 Hz to 1 kHz with limited range (see above).

Internal DC Bias Voltage and Voltmeter: 0 to 600 V in 6 ranges.

Voltmeter Accuracy: ± 3% of full scale.

Internal DC Bias Current: Approximately 15 mA maximum.

Ammeter Range: 0 to 20 mA in 6 ranges. Can detect ½-μA leakage.

Ammeter Accuracy: ± 3% of full scale.

External Bias: 800 V maximum.

Power Required: 105 V to 125 V or 210 V to 250 V, 60 Hz, 18 W maximum. Models available for 50-Hz operation.

Accessories Supplied: Four-lead and shielded two-lead cable assemblies.

Accessories Required: None for 120-Hz measurements. The Type 1311 Oscillator is recommended for measurement at spot frequencies, the Type 1310 Oscillator for continuous frequency coverage.

Mechanical Data: Flip-Tilt Case.

	Width		*Height*		*Depth*		*Net Wt*		*Ship Wt*	
Model	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	16¼	415	15	385	9	230	26	12	34†	15.5
Rack	19	485	14	355	6⅛**	160	28	13	43†	20

*120 Hz is the frequency of the internal signal for the 60-Hz model; it becomes 100 Hz in the 50-Hz model.

**Behind panel. †Estimated.

Summary of EIA and MIL Specifications on Testing Electrolytic Capacitors

Specification and Capacitor Type	*Frequency*	*AC Level*	*Accuracy* C	*Accuracy* Loss	*DC Polarizing Voltage*
MIL C—3965 C Tantalum Foil and Sintered Slug Capacitors	120±5 Hz	Less than 30% of DCWV or 1 V, whichever is smaller	2%	*R* or P.F. 2%	C—Sufficient for no reversal of polarity. *D*—"Polarized Capacitance Bridge" Sum of ac and dc shall not exceed DCWV.
MIL C—26655-B Solid Tantalum Capacitors	120±5 Hz	Limited to 1V, rms	2%	*D*, 10%	C—Max bias 2.2 V. *D*—"Polarized Bridge", 2.2-V dc max.
RS 228 Tantalum Electrolytic Capacitors	120 Hz	Small enough not to change value	±2½%	*D*, 5%	Optional
MIL C-62 B Polarized Aluminum Capacitors	120±5 Hz	Limited to 30% of DCWV or 4 V, whichever is smaller	2%	*D*, 2%	No bias required if ac voltage less than 1 V. However, if bias causes differences, measurements with bias shall govern.
RS 154 B Dry Aluminum Electrolytic Capacitors	120 Hz	Small enough not to change value	±2½%	*R* or RC	Optional; but if substantial difference occurs, rated dc should be used.
RS 205 Electrolytic Capacitors for use in Electronic Instruments	120 Hz	Small enough not to change value	±2½%	*D*	Optional

General Radio Experimenter reference, Vol. 40, No. 6, June 1966.

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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with GenRad's applicable published specifications. If within one (1) year after original shipment it is found not to meet this standard, it will be repaired or at the option of GenRad, replaced at no charge when returned to a GenRad service facility.

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THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

SERVICE POLICY

Your local GenRad office or representative will assist you in all matters relating to product maintenance, such as calibration, repair, replacement parts and service contracts.

GenRad policy is to maintain product repair capability for a period of five (5) years after original shipment and to make this capability available at the then prevailing schedule of charges.

Introduction–Section 1

WARNING

To minimize electrical shock hazard, it is recommended that bias voltages be limited to 30 volts maximum. For certain applications, under proper conditions, up to 800 volts can be used.

When bias voltages greater than 30 volts are used exercise extreme care. Full bias voltage appears on panel binding posts, test leads, test fixtures and on the leads of the capacitor under test.

As the first step in the operating procedure, check that the CAPACITOR CHARGED and DANGER – BIAS ON warning lights glow as the capacitor under test becomes charged. If either warning light does not glow, turn off the bias source and bridge power immediately, and refer the bridge to properly qualified personnel for correction of the malfunction.

Capacitors remain charged after measurement. The user must follow safe procedures to assure proper discharge of capacitors after measurement.

For their safety, all personnel operating this bridge must be made aware of the potential shock hazard involved in measuring biased capacitors.

Do not leave the bridge unattended with bias applied.

1.1 PURPOSE.

The Type 1617 Capacitance Bridge, an entirely self-contained system, measures capacitance and dissipation factor of practically any capacitor, and is particulary designed to test tantalum or aluminum electrolytic capacitors at 120 Hz per MIL and EIA specification (refer to specifications).

It measures dc leakage current with a resolution of about 1 μA and in general is a good 1% capacitance bridge. It permits two-, three-, four- and even five-terminal measurements of capacitance and dielectric loss of insulating materials, cables, and transformers, even if remotely located.

1.2 DESCRIPTION.

The Type 1617 Capacitance Bridge is a modified form of the standard series-RC bridge. It operates from conventional 60-Hz power lines (50-Hz versions available), and is completely self-contained, including a 120-Hz generator, a selective detector, and a dc bias. Provisions have also been made for use of an external ac generator and dc bias supply. Accuracy is 1% between 40 Hz and 1kHz over most of the capacitance range.

To achieve the 1% accuracy over this wide capacitance range, 3- and 4-terminal connections as well as 2-terminal connections are provided. On high-capacitance ranges, where impedance is so low that leads have a significant effect on the D reading, a 4-terminal connection can be used. On low-capacitance ranges, where stray capacitance may cause a significant error in C measurement, a 3-terminal connection may be used.

Because the internally generated polarizing voltage can be as high as 600 volts, two panel lights are provided as safety features, one to indicate that the biasing switch is thrown, the other to indicate that the charge on the unknown capacitor exceeds 1 volt.

1.3 ACCESSORIES SUPPLIED.

Table 1-1 lists the accessories supplied with the Type 1617 bridge.

Table 1-1
Accessories Supplied

Quantity	*Description*	*Part Number*
1	Cable assembly for guarded measurements	1617-2200
1	Cable assembly for 4-terminal measurements	1617-2210

1.4 CONTROLS, CONNECTORS, AND INDICATORS

Table 1-2 lists and describes front-panel controls, connectors and indicators on the Type 1617 bridge.

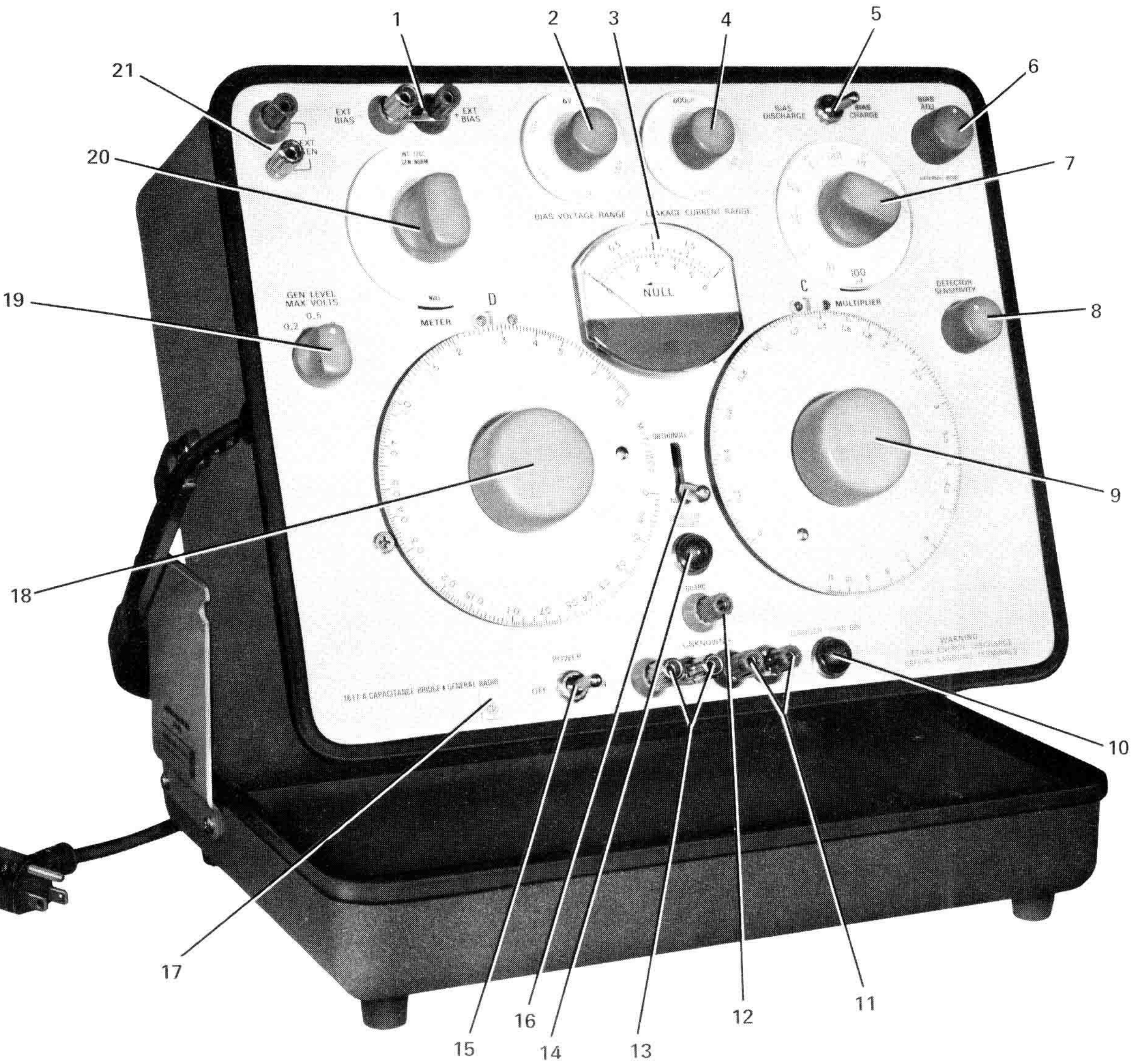


Figure 1-1. Controls, connectors and indicators.

Table 1-2

Controls, Connectors and Indicators
(See Figure 1-1)

Ref	Control	Type	Function
1	EXT BIAS	Binding-post pair, 3/4-inch spaced	Allows connection of an external dc-bias voltage of up to 800 V.
2	BIAS VOLTAGE RANGE	Six-position rotary switch	Selects internal dc bias supply and corresponding meter ranges; 2, 6, 20, 60, 200, or 600 V.
3	NULL meter	50-μA meter	Measures detector output voltage, (null), bias voltage, or leakage current as determined by function control.
4	LEAKAGE CURRENT RANGE	Six-position rotary switch	Selects leakage-current range of NULL meter when function control (20) is set to LEAKAGE CURRENT. Full-scale currents are 60, 200, or 600 μA; 2, 6, or 20 mA.
5	BIAS switch	Two-position toggle switch	Allows internal or external bias voltage to be applied to or removed from capacitor under test.
6	BIAS ADJUST	Combination switch-potentiometer	Extreme counter-clockwise position (EXTERNAL BIAS) allows application of bias from external power supply via EXT BIAS terminals. Over remainder of range, allows continuous adjustment of internal dc bias from 0 to maximum value determined by BIAS VOLTAGE RANGE control.
7	MULTIPLIER	Ten-position rotary switch	Multiplier control for capacitance dial: 100 pF; 1, 10, or 100 nF; 1, 10, or 100 μF; 1, 10, or 100 mF.
8	DETECTOR SENSITIVITY	Potentiometer control	Provides continuously adjustable detector sensitivity for bridge measurement.
9	C dial	Potentiometer control with calibrated dial	Main balance control for capacitance.
10	DANGER-BIAS ON	Incandescent lamp	Lit when BIAS switch is in CHARGE position, to warn of possible lethal energy at UNKNOWN terminals.
11	+UNKNOWN	Binding-post pair, 3/4-inch spaced	Allows connection of positive side of unknown capacitor.
12	GUARD	Single binding post	Furnishes guard voltage for 3-terminal measurements to reduce stray capacitance.
13	- UNKNOWN	Binding-post pair, 3/4-inch spaced	Allows connection of negative side of unknown capacitor.
14	CAPACITOR CHARGED	Incandescent lamp	Lit when charge on capacitor exceeds one volt.
15	POWER	Two-position toggle switch	Energizes instrument.
16	ORTHONULL	Mechanical lever	Engages Orthonull mechanism to simplify balance operation, to avoid false nulls and sliding balances with lossy capacitors (D>1).
17	Pilot Lamp	Incandescent lamp with GR monogram	Lit when POWER switch is ON.
18	D dial	Potentiometer control with calibrated dial	Main balance control for dissipation factor.
19	GEN LEVEL MAX VOLTS	Three-position rotary switch	Selects generator voltage applied to the bridge: 0.2, 0.5, or 2 V, rms. The ac voltage on the unknown capacitor will always be less.
20	Function switch	Six-position rotary switch	Selects generator source and polarity (INT NORM, INT REV, EXT NORM, or EXT REV) and meter indication (NULL, BIAS) VOLTAGE, or LEAKAGE CURRENT).
21	EXT GEN	Binding-post pair, 3/4-inch spaced	Allows connection of an external generator; 40 Hz to 1 kHz, 1 W, max.

1.5 SYMBOLS, ABBREVIATIONS, AND DEFINITIONS.

Definitions for symbols used on the panel of the Type 1617 and for abbreviations used in this instruction manual are as follows:

C capacitance (see below for units)

C_s series capacitance $C_s = (1 + D^2)\, C_p$

C_p parallel capacitance $C_p = \frac{1}{1 + D^2}\, C_s$

L inductance (see below for units)

R resistance, the real part of an impedance – (see below for units)

R_s series resistance

R_p parallel resistance

X reactance, the imaginary part of an impedance

Z impedance

D dissipation factor $\frac{R}{X} = \frac{1}{Q}$

for capacitors $= \omega C_s R_s = \frac{1}{\omega C_p R_p}$

PF power factor $= \frac{R}{|Z|} = \frac{R}{\sqrt{R^2 + X^2}} = \frac{D}{\sqrt{1 + D^2}}$

ESR equivalent series resistance $= R_s = \frac{D}{\omega C_s}$

f frequency in hertz (Hz)

ω angular frequency (rad/sec) $= \omega = 2\pi f$

F farad, unit of capacitance

mF millifarad $= 10^{-3}F = 10^3 \mu F$

μF microfarad $= 10^{-6}F = 10^3 nF = 10^6 pF$

nF nanofarad $= 10^{-9}F = 10^{-3}\mu F = 10^3 pF$

pF picofarad $= 10^{-12}F = 10^{-6}\mu F = 10^{-3}nF$

Ω ohm, unit of resistance

mΩ milliohm $= 10^{-3}\Omega$

kΩ kilohm $= 10^3\Omega$

MΩ megohm $= 10^6\Omega = 10^3 k\Omega$

H henry, unit of inductance

mH millihenry $= 10^{-3}H$

μH microhenry $= 10^{-6}H$

nH nanohenry $= 10^{-9}H$

1.6 OPERATOR SAFETY.

Measurements on charged capacitors are inherently dangerous. The Type 1617 Capacitance Bridge, being a self-contained instrument, is naturally safer than a temporary clip-lead set up and all possible safety features were included in its design. The operator must follow instructions at all times to ensure safe use of the instrument.

Connect or disconnect the capacitor to be tested only when both warning lights are off. This means that bias is not applied (CHARGE-DISCHARGE switch on the DISCHARGE position) and that there is less than 1 volt across the capacitor.

Do not rely solely on the warning lights (the lamps might burn out), especially if repeated measurements are to be made; use insulated test clips, rubber gloves, and a chair insulated from the ground.

Several capacitors in the instrument itself can carry charges of lethal energy; they are safe only when both warning lights are off.

When no bias is to be applied, set the VOLTAGE/RANGE switch to 2 V, the BIAS ADJ to EXT, and the CHARGE-DISCHARGE switch to DISCHARGE. Under these conditions, an accidental change in the setting of one of the controls will not endanger the operator.

If the bridge is never going to be used with internal dc bias, the bias supply can be disabled by disconnection of the leads to pins 10 through 15 on the power-transformer plate (see Figure 6-2). If only the lower bias voltages are to be used, the higher voltages can be eliminated by disconnection of pin 12 of the power transformer and by shorting the appropriate resistor (Table 1-3).

Table 1-3

Bias Range Variation

Resistor Shorted	*Value*	*Range Eliminated*
R115	402 K	600 V
R154	140 K	200 V
R153	40.2 K	60 V
R152	14 K	20 V
R151	4.02K	6 V

Installation–Section 2

2.1 GENERAL.

2.1.1 DIMENSIONS.

The over-all dimensions for the bridge are shown in Figure 2-1.

2.1.2 ENVIRONMENTAL CONSIDERATIONS.

The Type 1617 bridge is designed to operate at ambient temperatures from 0 to 50 °C and to be stored at temperatures from -40 to +70 °C.

2.2 MOUNTING.

The Type 1617 Bridge is supplied in portable mechanical configurations. An adaptor set (P/N 0481-9759) converts the portable model to rack model. Each adaptor set contains a relay-rack panel, a hardware set, and instructions for rack mounting. A rack model can be stack mounted for bench use in combinations with other instruments.

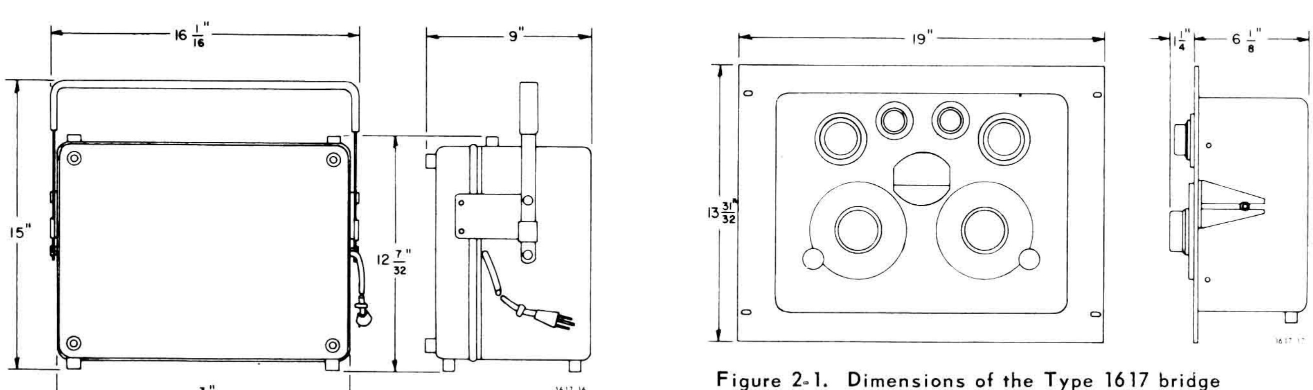


Figure 2-1. Dimensions of the Type 1617 bridge in the portable and rack models.

2.2.1 PORTABLE TO RACK MOUNT CONVERSION. (Figure 2-2).

To convert from portable to rack mount:

a. Open the instrument fully to its horizontal position.

b. Remove the 10-32 screws (A) that secure the instrument to the cabinet and lift the instrument out of the cabinet.

c. Remove the pivot studs (B) and lift the cabinet off the cover-and-handle assembly.

d. Attach 1/4-28 screws (C) in place of the pivot screws. Secure them with 1/4-inch lockwashers and nuts and then add a 1/4-inch flatwasher to each screw.

e. Replace the instrument in the cabinet and secure it with the 10-32 screws (A), removed earlier.

f. Attach the brackets (D) to the panel with no. 10 lockwashers and nuts; do not tighten.

g. Add a no. 10 flat washer to the top and bottom lugs, and attach the plates (E) with no. 10 lockwashers and nuts; do not tighten.

h. Place the panel over the instrument; slide the slit in each bracket over the 1/4-28 screw (C), keeping the flatwasher between the instrument and the bracket.

i. Slide the plates over the gasket, align the assembly, and tighten all nuts.

2.2.2 RACK-TO-PORTABLE CONVERSION.

To convert a rack instrument for portable use, follow the reverse procedure given in paragraph 2.2.1. The parts required for this conversion are listed in Table 2-1.

Table 2-1

Parts Required for Rack-To-Portable Conversion

Quantity	*Description*	*Part No.*
1	Handle and Bracket Assembly	1617-2010
1	Cover Assembly	4170-2086
2	Pivot Stud	4170-1000
2	Plate Nut	4170-1376
2	Spacer	4170-0700
2	Screw, No. 1/4-28, 3/8	7040-0400
4	Screw, No. 10-32, 3/8	7080-1000
4	Washer	8040-2400
2	Washer	8050-0100

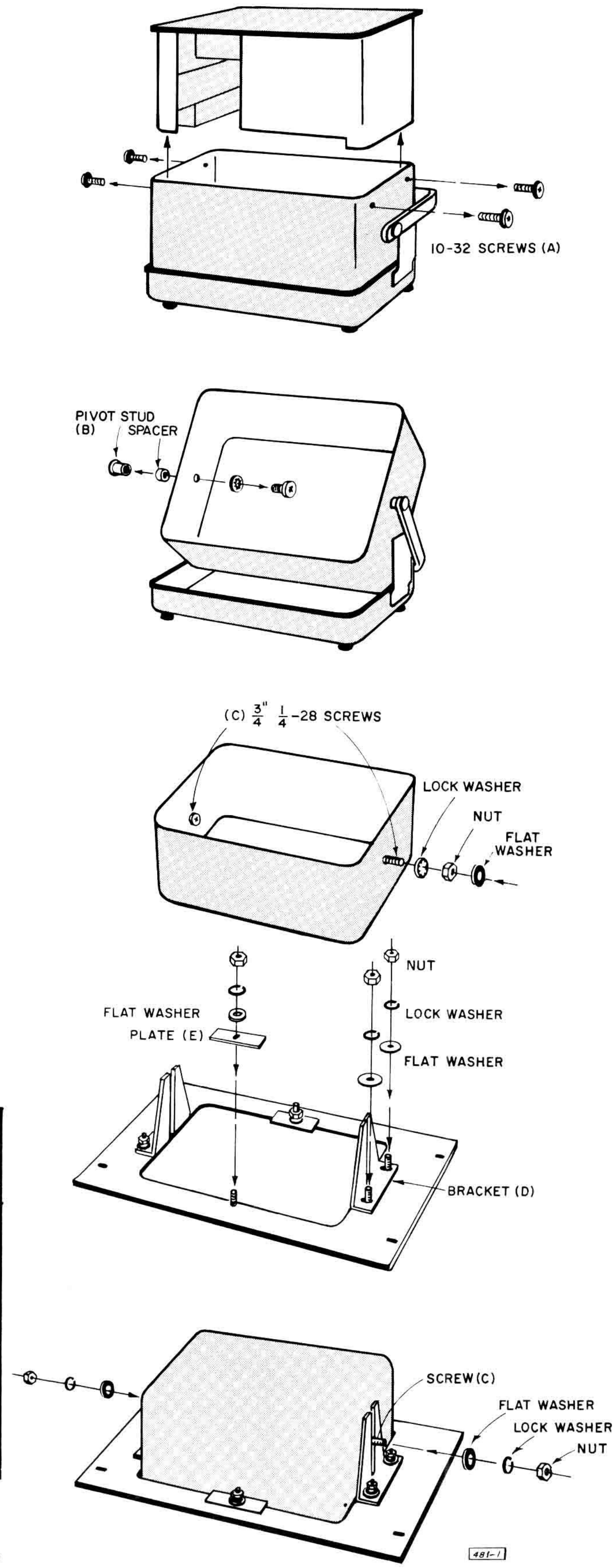


Figure 2-2. Procedure to rack mount a portable model.

2.2.3 STACK MOUNTING.

A rack model can also be stack mounted with other GR relay-rack instruments fitted with end frames for bench use. Stack-mounted accessories required for the Type 1617 are listed in Table 2-2 and mounting instructions (Form 5301-0145A) are available with the accessories.

Table 2-2

Stack-Mounting Accessories Required

Quantity	*Part Number*	*Description*
1	5310-9682	End-frame set
1	5310-3301	Hardware Set

2.3 POWER CONNECTION.

2.3.1 GENERAL.

Use the attached three-wire power cord to connect the bridge to a source of power as indicated on the tag located on the cabinet beneath the power cord (Figure 2-3). The long cylindrical pin (ground) is connected directly to the metal case of the instrument, hence to the EXT GEN ground connector and -UNKNOWN ground connector on the front panel.

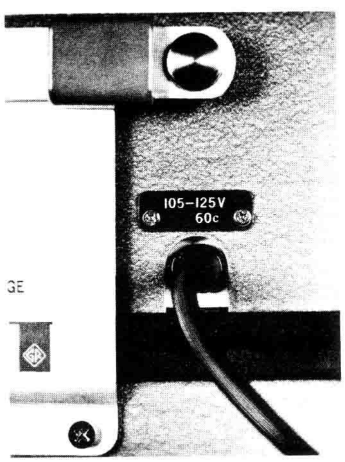


Figure 2-3. Indication of the source of power to be used.

2.3.2 115-VOLT LINE.

Power required is 105 to 125 V, 50 or 60 Hz (depending on model of bridge), 18 W. An input plate for 115-V operation, P/N 5590-0700, is used for 60-Hz models; P/N 5590-1163 for 50-Hz models. It attaches to the cabinet beneath the power cord by means of two 4-40 x 3/16 screws with attached lockwashers, P/N 7090-4030. On the terminal plate of the power transformer (Figure 6-2), terminal 1 is connected to terminal 3 and terminal 2 to terminal 4. Fuses for F501 and F502 are 0.2 A, P/N 5330-0600 each (Figure 6-13).

2.3.3 230-VOLT LINE.

Power required is 210 to 250 V, 50 or 60 Hz (depending on model of bridge), 18 W. An input plate for 230-V operation, P/N 5590-1667, is used for 60-Hz models; P/N 5590-1666 is used for 50-Hz models. It attaches to the cabinet beneath the power cord by means of two 4-40 x 3/16 screws with attached lockwashers, P/N 7090-4030. On the terminal plate of the power transformer, terminal 2 is connected to terminal 3. Fuses for F501 and F502 are 0.1 A, P/N 5330-0400 each (Figure 6-13).

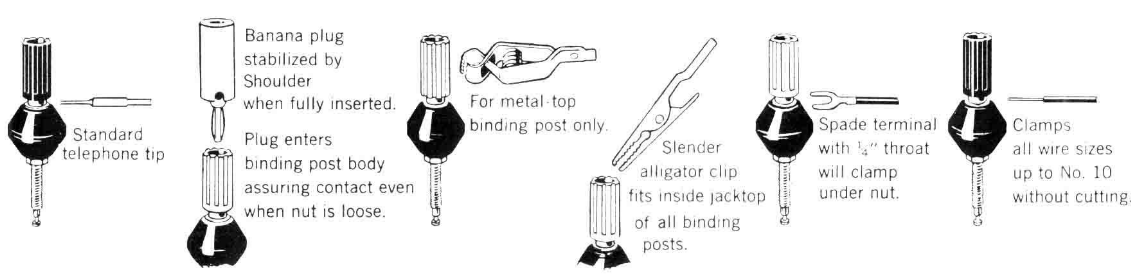
2.3.4 CONNECTIONS.

The EXT GEN, EXT BIAS and UNKNOWN terminals are standard 3/4-inch-spaced binding posts which accept banana plugs, standard telephone tips, alligator clips, crocodile clips spade terminals and all wire size up to number ten.

Two plug-in cable assemblies are supplied with the bridge expressly for the UNKNOWN terminal.

The two-cable assembly (Figure 3-2) has a shielded positive terminal. The shield is connected to the guard and the two positive and the two negative terminals are linked internally. It should be used for three-terminal measurements (refer to paragraph 3.1).

The four-cable assembly (Figure 3-3) is used for four terminal measurements (refer to paragraph 3.1). The cables of both assemblies are terminated in clip leads in an insulated rubber sleeve.



Methods of connection to the measurement terminals.

Operation – Section 3

WARNING

It is possible to apply lethal voltage across a capacitor by means of this bridge. The energy stored in the unknown capacitor, and even in the internal capacitor, can be extremely dangerous to the operator; please follow the instructions carefully.

Never connect or disconnect anything at the UNKNOWN terminals unless the BIAS CHARGE-DISCHARGE switch is on DISCHARGE and the two warning lamps are off.

When no bias voltage is applied, set the VOLTAGE RANGE switch to 2 V, the BIAS ADJ to EXT and the BIAS CHARGE-DISCHARGE switch to DISCHARGE.

When operating the bridge at high voltage level, use every possible precaution to avoid contact with the UNKNOWN terminals, or the positive terminal of the capacitor under test.

3.1 CONNECTION OF THE UNKNOWN CAPACITOR.

3.1.1 GENERAL.

The panel of the Type 1617 Capacitance Bridge offers five separate terminals at which to connect the unknown. There are two current terminals, two potential terminals and one guard terminal; two shorting links are also provided Figure 3-1. This array permits two-, three-, four-, and five-terminal measurements, as dictated by the value of the unknown and its location.

3.1.2 LOW-VALUED CAPACITORS.

In this range (less than 10 nF), since shunt stray capacitance is apt to introduce an important error, three-terminal connections should be made. The supplied plug-in cable assembly (P/N 1617-2200) achieves this connection simply (Figure 3-2). The linkage of the positive and the negative terminals is achieved internally in the assembly. It can also be done as follows: Connect the inner conductor of a shielded cable to either positive terminal, the shield of the cable to the guard terminal, and any clip lead to either negative terminal (both positive and negative terminals should be linked). Then connect the unknown at the end of the two cables and proceed with the measurement.

Figure 3-1. UNKNOWN and GUARD terminals on the bridge.

The residual ("zero") of the bridge (i.e., the reading of the C dial when the bridge is balanced while on the lowest range with the unknown disconnected) is to be subtracted from the C reading. It is small (about 4 pF) and can be considered negligible on the other ranges.

3.1.3 MEDIUM-VALUED CAPACITORS.

Capacitance measurements in this range (about 10nF to 100μF) are not appreciably affected by shunt capacitance or series impedances, unless the leads are more than a few feet long. Therefore, most any type of clip leads may be used although the two-lead cable assembly supplied, P/N 1617-2200, is particularly convenient.

If the leads are very long, the lower capacitance values should be connected with a guarded, shielded cable and the higher values should use a four-lead connection (see paragraph 4.5.1).

NOTE

In 2- and 3-terminal measurements, when the assembly is not used, the bridge will not balance unless the shorting links are connected.

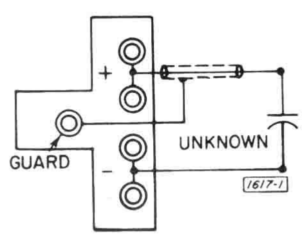


Figure 3-2. Schematic of the 3-terminal connection (guarded), using the two-lead plug-in assembly (P/N 1617-2200).

3.1.4 HIGH-VALUED CAPACITORS.

For the range 100μF to 10mF of capacitance, the lead impedance might introduce a sizeable D error in a two-terminal measurement. For example, 100μF measured with the supplied two-lead cable assembly at 120 Hz gives a D reading higher than the actual value by 0.005.

Four-terminal measurements are necessary for better D accuracy. The bridge connection is made convenient with the supplied cable assembly (P/N 1617-2210). When a four-lead connection is made to a capacitor (Figure 3-3), the bridge will measure the effective capacitance and loss of the impedance between the junction of the two positive leads and the junction of the two negative ones. In effect, the unknown starts where it becomes two-terminal. Figure 3-4 shows different types of four-terminal connections, the effective impedance measured by the bridge being from A to B.

NOTE

Disconnect the shorting links when making four-terminal measurements.

3.1.5 VERY HIGH VALUED CAPACITORS.

Four-terminal connections should be used on very large capacitors (10 mF to 1 F) not only to avoid large D errors due to lead resistance, but also to avoid capacitance errors caused by lead inductance.

While a four-lead connection removes the effect of the resistance and self-inductance of each lead, some care must be used to avoid mutual inductance between the outer two ("current") leads and the inner two ("potential") leads; see Figure 3-5. Mutual inductance here causes an induced voltage that increases the effective value of the unknown. This mutual inductance can be greatly reduced by twisting together either the two outer leads or the two inner leads as shown in Figure 3-6.

This precaution against mutual inductance is also important when lower capacitance is measured at higher frequencies, because the error is a function of $\omega^2 MC_x$, where M is the total mutual inductance. There is always some mutual inductance present at the bridge terminals and this limits the range of the bridge at higher frequencies.

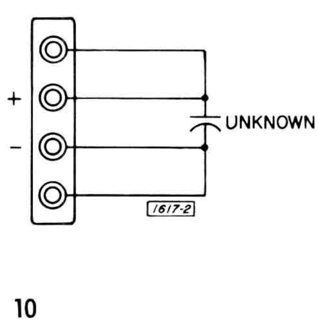


Figure 3-3. A 4-terminal connection using the four-lead plug-in assembly.

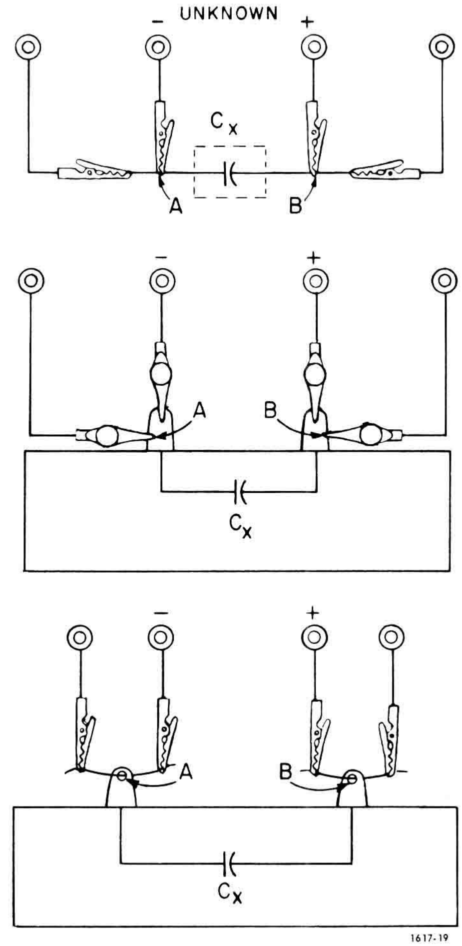


Figure 3-4. Different types of 4-terminal connections. The unknown is measured from A to B.

NOTE

The ranges indicated in the above paragraphs are quite arbitrary and are intended only as guides. The type of connection used for a given capacitance might also depend on the length of the leads, and the D and C accuracies desired.

3.2 CAPACITANCE MEASUREMENT PROCEDURE – INTERNAL GENERATOR.

3.2.1 NO BIAS APPLIED.

To measure an unknown capacitor with no bias applied proceed as follows:

Safety measures:

Place the BIAS CHARGE-DISCHARGE switch at DISCHARGE.

Set BIAS ADJ to EXT BIAS (EXT BIAS terminals must be shorted).

Set the BIAS VOLTAGE RANGE switch to 2 V.

a. Connect the bridge to the line and turn POWER on.

b. Connect the unknown capacitor (refer to paragraph 3.1).

c. Set the function switch to INT 120C* either NORMAL or REVERSE.

d. Select the maximum AC voltage desired on GEN LEVEL MAX VOLTS.

e. Turn the DETECTOR SENSITIVITY counterclockwise (minimum sensitivity).

f. If the approximate value is known, set the MULTIPLIER switch accordingly.

g. Increase the sensitivity (DETECTOR SENSITIVITY clockwise) to give an upscale deflection.

h. Adjust the C and D dials to obtain a minimum deflection on the NULL meter. Repeat this process until the best null for the highest feasible sensitivity is obtained.

NOTE

When the D of the unknown is greater than one, use the Orthonull® (ganging the C and D dials) will avoid false nulls and speed the balance.

i. Multiply the C-dial setting by the MULTIPLIER setting to obtain the capacitance of the unknown.

j. Read the dissipation factor directly on the D dial.

3.2.2 BIAS APPLIED. **WARNING – See Page 9.**

To measure an unknown capacitor with bias applied, proceed as follows:

a. Move the BIAS CHARGE-DISCHARGE switch to DISCHARGE.

b. Connect the bridge to the line and turn POWER on.

c. Connect the unknown (refer to paragraph 3.1).

d. Set the function switch to BIAS VOLTAGE.

e. Set BIAS VOLTAGE RANGE switch on the desired range.

f. Move the BIAS CHARGE/DISCHARGE switch to CHARGE. DANGER-BIAS ON lamp must glow.

g. Adjust the BIAS ADJ knob until the meter reads the desired voltage (do not exceed the rating of the unknown).

h. Proceed with step c through j of paragraph 3.2.1.

i. Throw the CHARGE/DISCHARGE switch on DISCHARGE before disconnecting the unknown.

3.2.3 RANGE AND ACCURACY.

With the internal generator, the C accuracy is ±1% ±1 pF from 0 to 0.11 F. The residual ("zero of the bridge") to be subtracted from the reading is approximately 4 pF. From 0.11 to 1.1 F, the accuracy becomes ±2%. The D accuracy (±0.001 ±0.01 C in F ±2%) depends on C. This naturally assumes that the correct connections (refer to paragraph 3.1) have been used to minimize errors.

*The notation C (cycles per second) is equivalent to Hz (hertz).

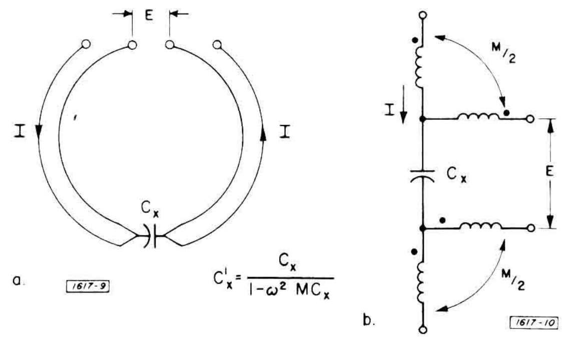


Figure 3-5. When "current" and "potential" leads form concentric loops (left), the resulting mutual inductance (right) affects the value of the capacitance being measured.

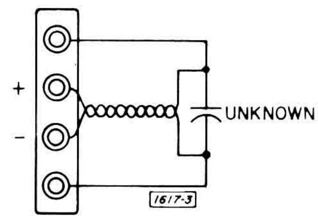


Figure 3-6. Reduction of the effect of mutual inductance in the leads.

When bias voltage is applied, the accuracy specifications are the same, but the sensitivity of the bridge is lessened by the impedance of the internal capacitor always across the bias supply (refer to paragraph 5.5).

3.3 LEAKAGE CURRENT MEASUREMENT.

3.3.1 GENERAL.

The leakage current through capacitors of most types is a function of time. A common practice for many types of capacitors is to use the value obtained after voltage is applied for two minutes, but other soaking times are also used so that this parameter should be specified.

The current measuring range of the Type 1617 is limited to 60-μA to 20-mA, full scale; 0.5 μA can be resolved. This range is sufficient for most aluminum capacitors and some tantalum types. An external microammeter may be used for lower leakage currents (refer to paragraph 4.2). The available current from the internal power supply limits the maximum to about 15 mA. An external power supply and meter should be used if the leakage is higher than this.

3.3.2 MEASUREMENT PROCEDURE.

The procedure is as follows:

a. Perform steps a through g of paragraph 3.2.2.

b. Set the function switch to LEAKAGE CURRENT.