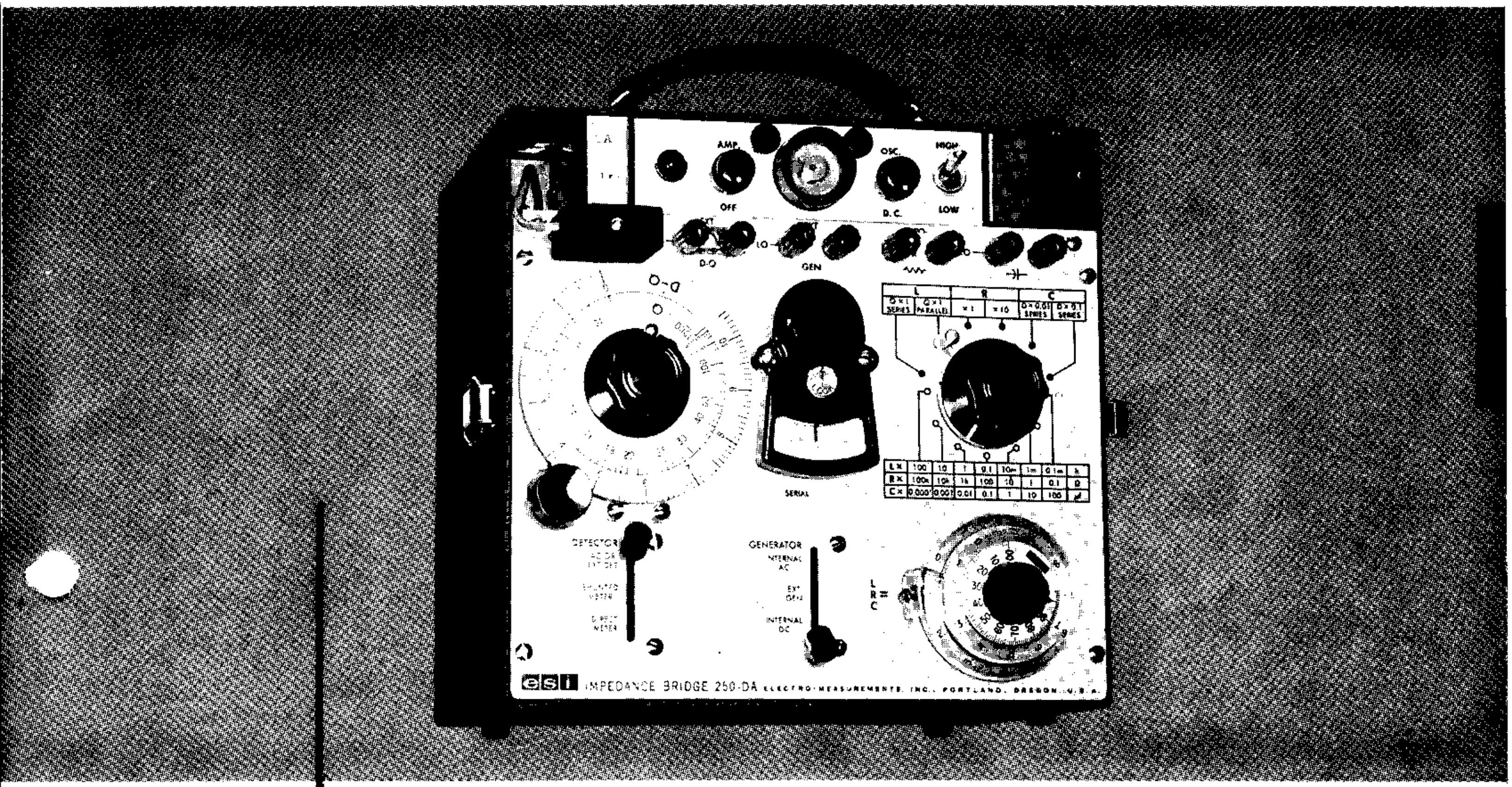
Instruction Manual

BRIDGES
AND
ACCESSORIES

Electro Scientific Industries
7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

JANUARY 1960
REPLACES OCTOBER 1959



Model 250-DA

IMPEDANCE BRIDGE

Litho in U.S.A.
©Electro Scientific Industries, Inc. 1960

INSTRUCTION MANUAL
for
MODEL 250-DA IMPEDANCE BRIDGE

CONSISTING OF:

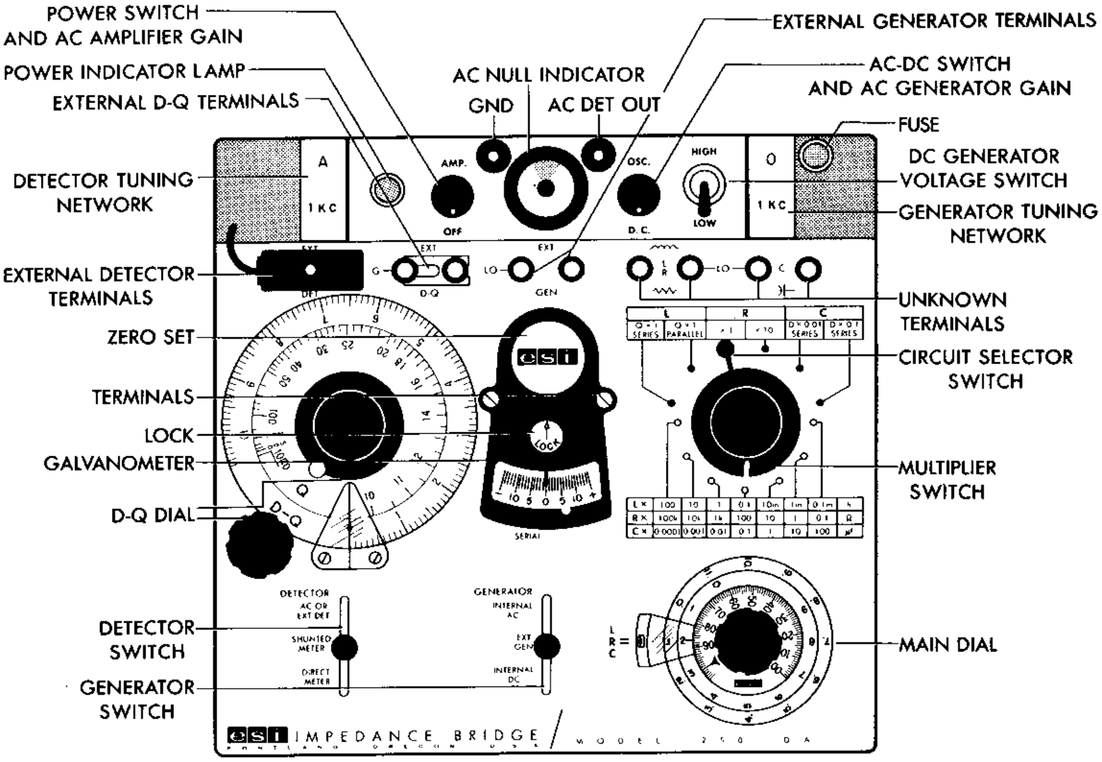
- Catalog Sheet C-16 including:
  - Introduction
  - Specifications
- Model 250-DA Impedance Bridge Instruction Manaual
- Lid Instructions From Model 250-DA Bridge

INSTRUCTION MANUAL
for
MODEL 250-DA UNIVERSAL IMPEDANCE BRIDGE

TABLE OF CONTENTS

TABLE OF CONTENTS (cont. i)

TABLE OF CONTENTS (cont. ii)



MODEL 250-DA PANEL CONTROLS

1. CONTROLS

1.1 Circuit Selector: The metal lever in the upper right-hand control group selects the bridge circuit. Panel markings indicate the circuit chosen. Two inductance measurement circuits are provided; inductors can be measured in terms of their equivalent series or equivalent parallel circuit. Two resistance multipliers are available; the X10 multiplier is included to extend the resistance range. For capacitance, two D-multipliers are provided.

1.2 Multiplier Switch: The upper right-hand black knob selects any of seven multipliers. The pointer indicates the value of the multiplier and the type of units used.

1.3 Main Dial Assembly: The lower right-hand DEKASTAT® decade resistor dial is used for reading the value of resistance, inductance or capacitance being measured. The measured value is given by the product of the DEKASTAT reading and the multiplier reading. For resistance, this product must also be multiplied by the circuit selector reading.

1.4 D-Q Dial: The reading of the large left-hand dial times the D or Q multiplier reading gives the value of D or Q at one kilocycle. At other frequencies, the D reading for C or Q reading for L series must be multiplied by the frequency in kilocycles, and the Q reading for L parallel must be divided by the frequency in kilocycles.

1.5 Unknown Terminals: An unknown capacitor is connected to the two right-hand terminals. An unknown resistor or inductor is connected to the third and fourth terminals from the right.

1.6 External Generator Terminals: The center pair of terminals are for connecting an external generator to the bridge.

1.7 External D-Q Terminals: The third and fourth terminals from the left are for attaching an external circuit element to the D-Q arm of the bridge for special measurements. The left-hand external D-Q terminal is connected to the bridge chassis.

1.8 External Detector Terminals: The upper left-hand terminals are for connecting an external detector to the bridge. The internal ac detector is connected to the bridge through these terminals by means of a shielded double banana plug.

1.9 Detector Switch: The switch in the lower left-hand corner of the bridge is for choosing the detector. In the ac or external detector position, the detector corners of the bridge are connected to the external detector terminals. In the shunted meter position, the detector corners of the bridge are connected to the galvanometer through a shunting network. In the direct meter position, the bridge is connected directly to the meter.

1.10 Generator Switch: The switch at the bottom center of the panel chooses the generator to be connected to the bridge. In the internal ac position the output of the internal generator is connected to the bridge generator corners. In the external generator position the bridge corners are connected to the external generator terminals. In the internal dc position the internal dc generator is connected to the bridge generator corners.

1.11 Galvanometer: The meter in the center of the panel is a sensitive galvanometer which is used for indicating a bridge balance. The two mounting screws are connected to the galvanometer terminals so that it may be easily connected to other external circuits. The large knob on the galvanometer can be rotated for mechanically positioning the galvanometer pointer. When the lock button is pushed in the direction of the arrow, the galvanometer suspension is rigidly supported for protection during transportation.

1.12 Power Switch and AC Amplifier Gain: The left-hand control knob on the small upper panel controls the AC detector sensitivity. The power switch for the unit is connected to the same knob. The adjacent pilot light indicates when power is supplied to the bridge.

1.13 AC - DC Switch and AC Generator Gain: The right-hand control knob on the small upper panel controls the ac generator output. In the extreme counter-clockwise position, it switches the ac generator off and the dc generator on.

1.14 DC Generator Voltage Switch: The switch on the right-hand side of the small panel provides for high and low values of dc voltage for resistance measurements. The low value gives greater sensitivity for unknown resistors below about 100 ohms, and the high position gives greater sensitivity above about 100 ohms. This switch has no effect on the ac generator.

1.15 AC Generator Tuning Network: The upper right-hand plug-in unit controls the frequency of the oscillator.

1.16 AC Detector Tuning Network: The upper left-hand plug-in unit determines the frequency response of the detector. With this network, the detector has a narrow acceptance band centered at the generator frequency. With this network removed, the detector has a flat response.

1.17 AC Null Indicator: The electron-ray-tube visual null indicator provides high sensitivity and rapid response. A null is indicated by the maximum opening of the eye.

1.18 AC Amplifier Output Terminals: The two terminals at the top of the small panel are for connecting an oscilloscope or other indicator to the output of the detector amplifier. They are in parallel with the visual null indicator. The black terminal on the left is connected to the bridge chassis. The red terminal on the right is connected through a capacito to the detector output.

1. CONTROLS (cont.)

1.19 Fuse: The fuse receptacle is located in the upper right-hand corner recess. A 1/2 amp - 3AG fuse protects the bridge. The recess is also used to store the power cord.

1.20 Power Indicator Lamp: The red lamp on the left-hand side of the small upper panel lights when power is supplied to the bridge.

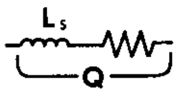
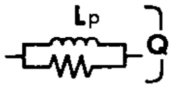
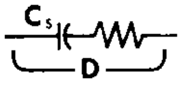
2. OPERATING INSTRUCTIONS

2.1 WHAT THE BRIDGE MEASURES

The ESI Model 250-DA Impedance Bridge measures resistance, inductance and capacitance. It also measures the dissipation factor (D) and the storage factor (Q) of inductors and capacitors.

Resistance measurements are usually made with direct current because of the increased accuracy and the lack of hum pickup and stray capacitance effects. Resistance measurements can be made using ac, but they may require external reactance compensation.

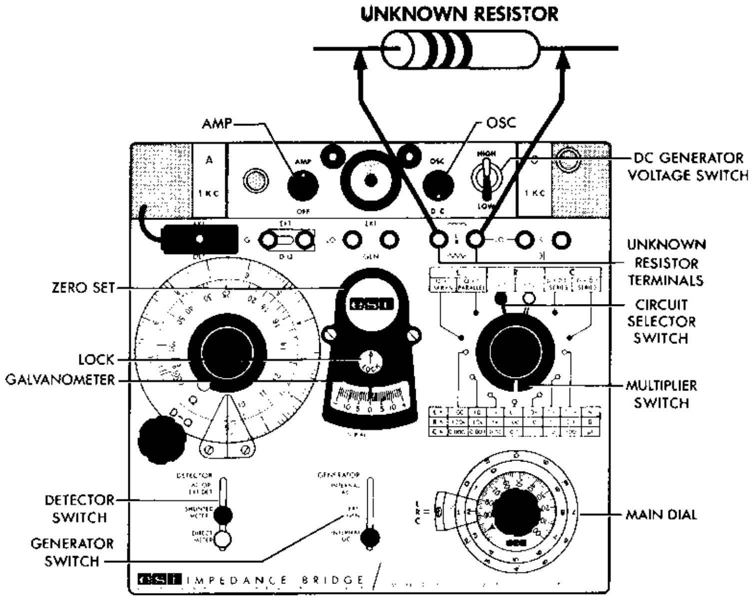
Inductance and capacitance measurements are made in terms of a simple two-element circuit with the same impedance as the unknown. The bridge dials read the values of this equivalent circuit. An equivalent series circuit is used for capacitors and low Q inductors; an equivalent parallel circuit is used for high Q inductors.

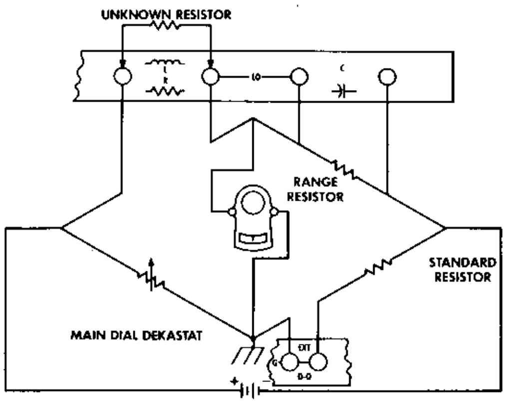
Selector Switch Setting	Equivalent Circuit	Magnitude		Frequency	D and Q		
		Range	Smallest Step On Lowest Range			Range	Smallest Division on Lowest Range
R		0 to 12 megohms	10^{-4} ohms (0.1 milliohm)	dc *			
L Series		0 to 1200 henries	10^{-4} millihenries (0.1 µh)	0.1 kc 1 kc 10 kc	Q	0 to 1.05 0 to 10.5 0 to 105	0.01 0.1 1
L Parallel		0 to 1200 henries	10^{-4} millihenries (0.1 µh)	0.1 kc 1 kc 10 kc	Q	95 to 10,000 9.5 to 1,000 0.95 to 100	non-linear scale
C Series		0 to 1200 microfarads	10^{-7} microfarads (0.1 µµf)	0.1 kc 1 kc 10 kc	D	0 to 0.105 0 to 1.05 0 to 10.5	0.001 0.01 0.1

*Resistance measurements can be made using ac, but they may require external reactance compensation.

2.2 RESISTORS

2.2.1 MEASURING RESISTORS *the* esi *way*





CONNECT UNKNOWN RESISTOR TO L-R TERMINALS	Make good contact with the terminals.
SET DC GENERATOR VOLTAGE SWITCH TO LOW	This applies approximately 10 volts to the bridge.
UNLOCK GALVANOMETER	Adjust the zero with the zero set knob if necessary.
TURN AMP CONTROL CLOCKWISE	This turns on the power supply. The red light to the left of the AMP switch should light.
TURN THE OSC CONTROL COUNTER CLOCKWISE FOR DC	This should turn off the green fluorescent screen of the visual null indicator.
SET CIRCUIT SELECTOR SWITCH TO R X 1 OR R X 10	For resistors between 1.2 and 12 megohms, use R X 10 position.
SET MAIN DIAL TO 3.000	This makes it easier to find the correct range.

2.2.1 MEASURING RESISTORS (cont.)

SET DETECTOR SWITCH TO SHUNTED METER	This makes it easier to find a rough null.
SET GENERATOR SWITCH TO INTERNAL DC	This connects the generator to the bridge.
ADJUST MULTIPLIER SWITCH FOR MINIMUM GALVANOMETER DEFLECTION	This sets the range so that the value can be found with maximum resolution on the main dial.
ADJUST MAIN DIAL FOR NULL	The detector sensitivity can be increased as null is approached by moving the detector switch to direct meter.
IF THE MAIN DIAL READING IS LESS THAN 1.200, USE THE NEXT LOWER RANGE AND READJUST THE MAIN DIAL FOR NULL	This takes advantage of the increased resolution near full scale of the dial.
FOR RESISTANCES GREATER THAN 10K SET THE DC GENERATOR VOLTAGE SWITCH TO HIGH	(WARNING: This may put 300 volts on the unknown terminals.)
THE MEASURED RESISTANCE IS THE PRODUCT OF THE READING OF THE CIRCUIT SELECTOR SWITCH, THE MULTIPLIER SWITCH, AND THE MAIN DIAL	
BEFORE DISCONNECTING THE MEASURED RESISTOR SET THE GENERATOR SWITCH TO EXT DET, THE DETECTOR SWITCH TO SHUNTED METER, AND THE DC GENERATOR VOLTAGE SWITCH TO LOW	This disconnects the generator, protects the meter and removes the high voltage from the bridge.
BEFORE LEAVING THE BRIDGE, LOCK THE GALVANOMETER AND SET THE AMP SWITCH TO OFF	This turns off the power supply and protects the galvanometer.

2.2.2 THINGS TO WATCH OUT FOR

2.2.2.1 HIGH RESISTANCE MEASUREMENTS

Care must be taken to avoid leakage resistance across the unit being measured. If an external electronic null detector is being used it may be affected by ac hum and by the hum output of the internal dc generator. In this case a battery supplying the EXT GEN terminals may be necessary. If a battery supply is used connect a protective resistor in series with it. Use a resistor of greater than $(1/4)\,(\text{battery voltage})^2$ ohms.

2.2.2.2 LOW RESISTANCE MEASUREMENTS

On the low resistance ranges the lead resistance in the unknown arm becomes significant. A correction for this resistance can be made as follows:

1. Short the test leads together at the point where they are to be connected to the unknown resistor and measure this "ZERO RESISTANCE".

2. Connect the test leads to the unknown resistor and measure the "RESISTANCE READING".

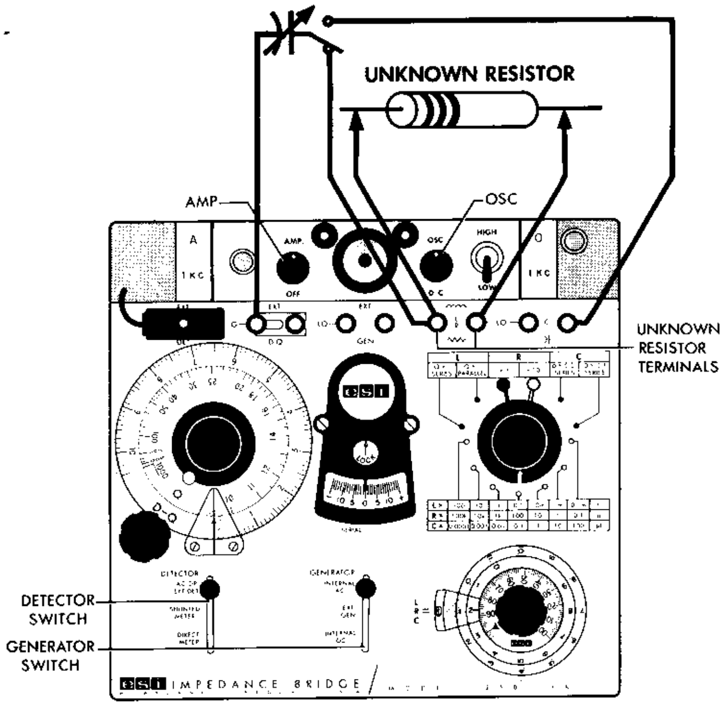
3. The "RESISTANCE VALUE" of the unknown resistor is then the "RESISTANCE READING" minus the "ZERO RESISTANCE".

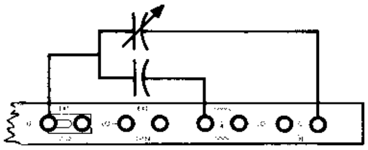
4. If the unknown resistance is to be connected directly to the terminals, the "ZERO RESISTANCE" reading can be taken by connecting a piece of heavy copper wire between the unknown resistance terminals. (#14 AWG copper wire has a resistance of about 0.00025 ohm/inch.)

2.2.3 MEASURING AC RESISTANCE *the* esi *way*

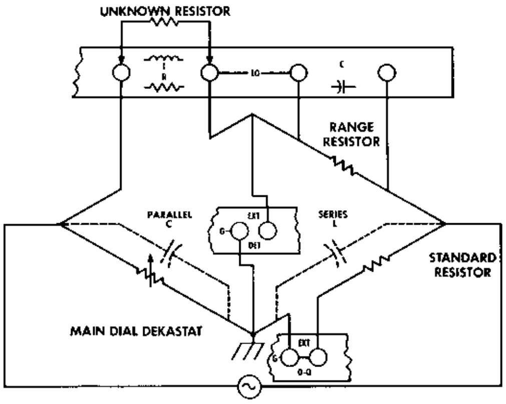
For greatest accuracy resistors should always be measured with dc. The accuracy of ac measurement will be 0.3% for one kilocycle and below over the range from one ohm to one megohm, for resistors with low reactance.

The indicated connections for the phase correction capacitor compensate for series inductance or parallel capacitance. It is impossible to separate the correction for the unknown from that for the rest of the bridge circuit.





NOTE: If the phase correction is small it may be convenient to connect a fixed capacitor to one terminal and a variable one to the other.



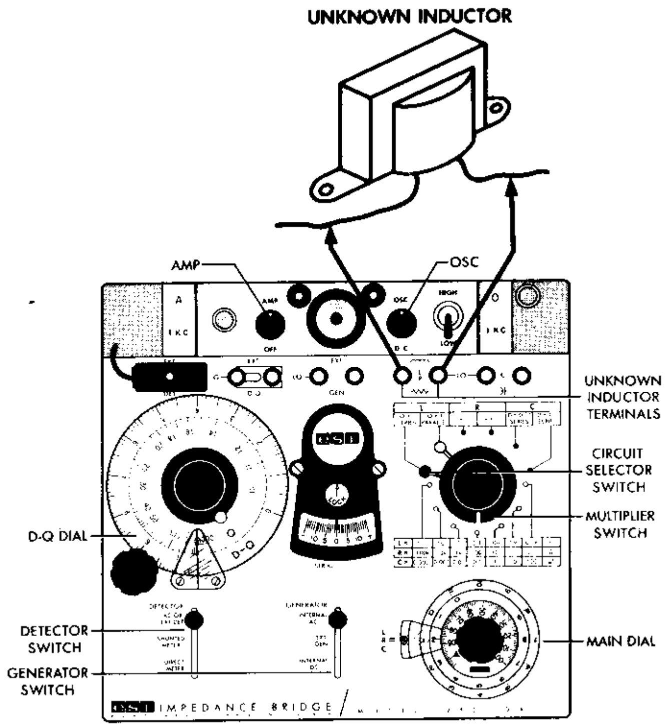
CONNECT UNKNOWN RESISTOR TO L-R TERMINALS	Make good contact with the terminals.
SET THE AMP CONTROL WITH THE DOT UP	This turns on the unit and provides medium detector sensitivity. The red light to the right of the AMP switch should light.
SET THE OSC CONTROL WITH THE DOT UP	This turns on the ac supply and provides a medium signal to the bridge. The green fluorescent screen of the visual null indicator should light.

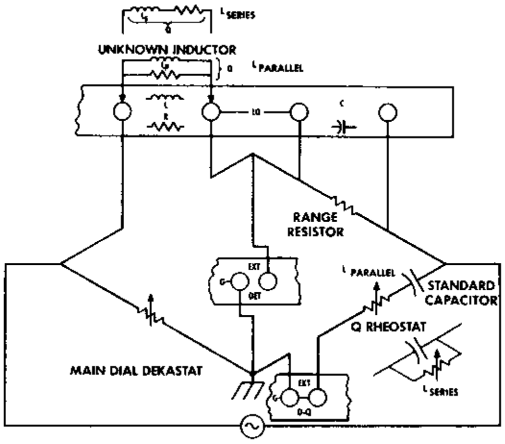
2.2.3 MEASURING AC RESISTANCE (cont.)

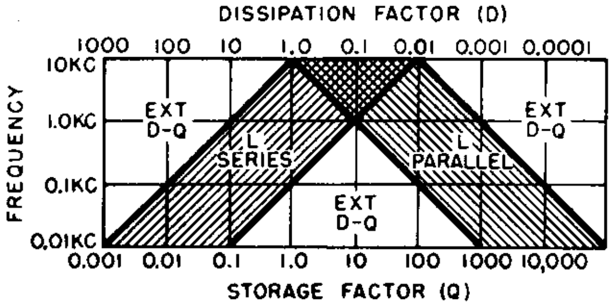
SET CIRCUIT SELECTOR SWITCH TO R X 1 OR R X 10	For resistors between 1.2 and 12 megohms, use R x 10 position.
SET MAIN DIAL TO 3.000	This makes it easier to find the correct range.
SET DETECTOR SWITCH TO AC OR EXT DET	This will connect from the bridge to the ac detector.
SET THE GENERATOR SWITCH TO INTERNAL AC	This will connect the ac supply to the bridge.
TRY TO BALANCE THE BRIDGE AS WITH DC	Usually the eye will not completely open indicating uncompensated phase shift.
CONNECT A VARIABLE CAPACITOR FROM THE EXT D-Q TERMINAL MARKED G TO THE HIGH C TERMINAL AND TRY TO OBTAIN A NULL WITH IT AND THE MAIN DIALS	Connecting the capacitor from ground to either of the generator terminals permits compensation for some of the possible equivalent circuits of the unknown.
IF A NULL CANNOT BE REACHED, CONNECT THE VARIABLE CAPACITOR BETWEEN THE EXTERNAL D-Q TERMINAL MARKED G AND THE HIGH L-R UNKNOWN TERMINAL. A NULL SHOULD BE OBTAINABLE WITH ONE CONNECTION OR THE OTHER	This permits balance over the remaining possible circuit combinations. If a non-linear element is being measured by ac, a null balance may not be possible because the bridge will not be in balance at all parts of the cycle.
THE MEASURED RESISTANCE WILL BE CORRECT FOR EQUIVALENT CIRCUITS CONSISTING OF A RESISTOR AND CAPACITOR IN PARALLEL OR A RESISTOR AND INDUCTOR IN SERIES	This is true even for fairly large values of phase shift. Resistance accuracy will be 0.3% or better for resistors between 1 ohm and 1 megohm at a frequency of 1 kilocycle or less.
BEFORE DISCONNECTING THE RESISTOR SET THE GENERATOR SWITCH TO EXT GEN	This disconnects the generator while the resistor is being removed.
BEFORE LEAVING THE BRIDGE SET THE AMP SWITCH TO OFF	This turns off the power supply.

2.3 INDUCTORS

2.3.1 MEASURING INDUCTORS the esi way





CONNECT THE UNKNOWN INDUCTOR TO THE L-R TERMINALS	Make good contact with the terminals.
TURN THE AMP CONTROL CLOCKWISE FOR POWER AND SET IT WITH THE DOT UP	This turns on the power supply. The red pilot light to the left of the AMP switch should light.
TURN THE OSC CONTROL CLOCKWISE FOR AC AND SET IT WITH THE DOT UP	This supplies ac to the bridge. The green fluorescent screen of the ac null indicator should light.
SET THE CIRCUIT SELECTOR SWITCH TO THE APPROPRIATE L CIRCUIT L_{series} for $Q<10xf_{kc}$ $L_{parallel}$ for $Q>10/f_{kc}$	
SET THE MAIN DIAL TO READ 3.000 SET THE D-Q DIAL AT MAXIMUM	These settings make it easier to find the correct range.

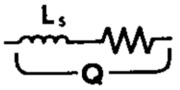
2.3.1 MEASURING INDUCTORS (cont.)

SET THE DETECTOR SWITCH TO AC OR EXT DET	This connects the detector to the bridge.
SET THE GENERATOR SWITCH TO INTERNAL AC	This connects the generator to the bridge.
ADJUST THE MULTIPLIER SWITCH FOR MINIMUM DETECTOR SIGNAL	This sets the range so that the value can be found with maximum resolution on the main dial. The AMP and OSC controls can be changed to give optimum sensitivity.
ADJUST THE MAIN DIAL AND THE D-Q DIAL ALTERNATELY FOR THE WIDEST AND SHARPEST POSSIBLE SHADOW ON THE NULL INDICATOR	If more or less sensitivity is needed, adjust the AMP control and/or the OSC control. Changing the OSC control may change the inductance of iron core inductors.
IF THE MAIN DIAL READING AT BALANCE IS LESS THAN 1.200, USE THE NEXT LOWER SETTING OF THE MULTIPLIER SWITCH AND READJUST THE MAIN DIAL FOR A NULL	This takes advantage of the increased resolution near full scale of the dial.
THE MEASURED L IS THE PRODUCT OF THE READINGS OF THE MULTIPLIER SWITCH AND THE MAIN DIAL	
AT 1 KC THE MEASURED Q IS THE PRODUCT OF THE READINGS OF THE CIRCUIT SELECTOR SWITCH AND THE D-Q DIAL. USE BLACK SCALE FOR L-SERIES USE RED SCALE FOR L-PARALLEL	FOR OTHER FREQUENCIES: MULTIPLY Q_{series} by the frequency in kc; or DIVIDE $Q_{parallel}$ by the frequency in kc
BEFORE DISCONNECTING THE INDUCTOR SET THE GENERATOR SWITCH TO EXT GEN	This disconnects the generator.
BEFORE LEAVING THE BRIDGE SET THE AMP SWITCH TO OFF	This turns off the power supply.

2.3.2 SERIES AND PARALLEL INDUCTANCE

The bridge measures a simple equivalent circuit for the impedance connected to its terminals. This equivalent circuit consists of either an inductance and resistance connected in series or a different inductance and resistance connected in parallel. The phase and magnitude of the resulting impedance are identical for both circuits. For values of Q less than 100 the series and parallel inductances differ measurably (by more than 0.01%).

WHEN THE BRIDGE MEASURES SERIES INDUCTANCE, L_s:



L_s = (range switch setting) x (main dial reading)

Q = (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$$D = \frac{1}{Q}$$

$$R_s = \frac{1}{Q} \times 2\pi f L_s$$

$$Z = 2\pi f L_s(\frac{1}{Q} + j)$$

Q and D in per unit
R_s in kilohms
f in kc
L_s in henrys
$j = \sqrt{-1}$
Z in kilohms

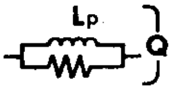
To calculate the equivalent parallel circuit:

The Q of the equivalent parallel circuit always equals the Q of the equivalent series circuit. The same is true of D.

$$L_p = (1 + \frac{1}{Q^2}) \times L_s$$

$$R_p = Q \times 2\pi f L_p$$

WHEN THE BRIDGE MEASURES PARALLEL INDUCTANCE, L_p:



L_p = (range switch setting) x (main dial reading)

Q = (D-Q multiplier setting) x (D-Q dial reading) ÷ (f_{kc})

$$D = \frac{1}{Q}$$

$$R_p = Q \times 2\pi f L_p$$

$$Z = \frac{2\pi f L_p Q(1+jQ)}{1+Q^2}$$

D and Q in per unit
R_p in kilohms
f in kc
L_p in henrys
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent series circuit:

The Q of the equivalent series circuit always equals the Q of the equivalent parallel circuit. The same is true of D.

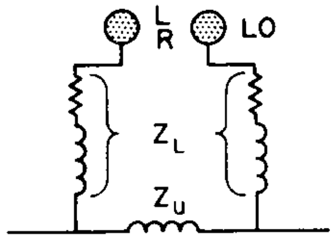
$$L_s = \frac{Q^2}{1 + Q^2} \times L_p$$

$$R_s = \frac{2\pi f L_s}{Q}$$

2.3.3 THINGS TO WATCH OUT FOR

2.3.3.1 LOW INDUCTANCE MEASUREMENTS

The bridge measures the total impedance connected to its terminals. Both the unknown inductor and its leads contribute to this impedance. The leads have some resistance and inductance, which affect the value read from the bridge.



$$Z_{measured} = Z_u + Z_L$$

Z_u - Impedance of unknown inductor

Z_L - Impedance of leads

For greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance. Closely spaced twisted leads will reduce the inductance and the pickup of stray fields.

2.3.3.2 HIGH INDUCTANCE MEASUREMENTS

In making high inductance measurements, there are two things to watch out for:

1. Be careful to avoid hum pickup.
2. Keep the stray capacitance to a minimum.

To minimize both effects keep your hands as far as possible from the inductor measured.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from the LO terminal should be shielded. See section 2.4.6 "Extended Leads".

Care should be taken to avoid coupling stray magnetic fields into the inductor being measured.

The D and Q readings on the highest L range will be in error as indicated in the specifications because of the residual capacitance of the range resistor. If accurate D or Q readings are needed the next lowest L range can be used. The L readings on the high range are accurate.

2.3.4 INDUCTANCE MEASUREMENTS WITH DC

2.3.4.1 WHEN TO USE DC

Iron core inductors are sensitive to both ac and dc current variations. Quantitative measurements of these effects can be made with the bridge.

2.3.4.2 THINGS TO WATCH OUT FOR

A. GENERAL PRECAUTIONS

Stray ac pickup may change sensitive components being measured or may give erroneous null detector readings.

The ac impedance of the dc external circuit must be greater than 2000 ohms for maximum sensitivity. If an isolating inductor is used to raise the ac impedance it may pick up stray signals or may have mutual coupling with the unknown inductor being measured. Either one may cause reading errors. Such an inductor should be well shielded magnetically and be placed to minimize its chance of interfering. For low currents isolation may be accomplished with a resistor instead of the inductor.

The parallel inductance circuit is recommended because it simplifies dc current measuring and bridge protection problems. With the series circuit the dc current divides between the bridge arms so that it is difficult to meter. The series circuit would also require a more careful analysis to avoid excessive current in any of the bridge arms.

If equivalent series inductance is required it can be easily calculated from the parallel inductance and D (See Sec. 2.3.2).

If Q is too low to be read directly, connect an external rheostat such as the ESI Model DB-655 DEKASTAT® to the EXT D-Q terminals. This extends the Q range for the L parallel circuit. Q can be calculated from the equation:

$$Q = \frac{1.592}{R_{k\Omega} f_{kc}}$$

Where:

Q - Storage factor of unknown

$R_{k\Omega}$ - External rheostat resistance in kilohms

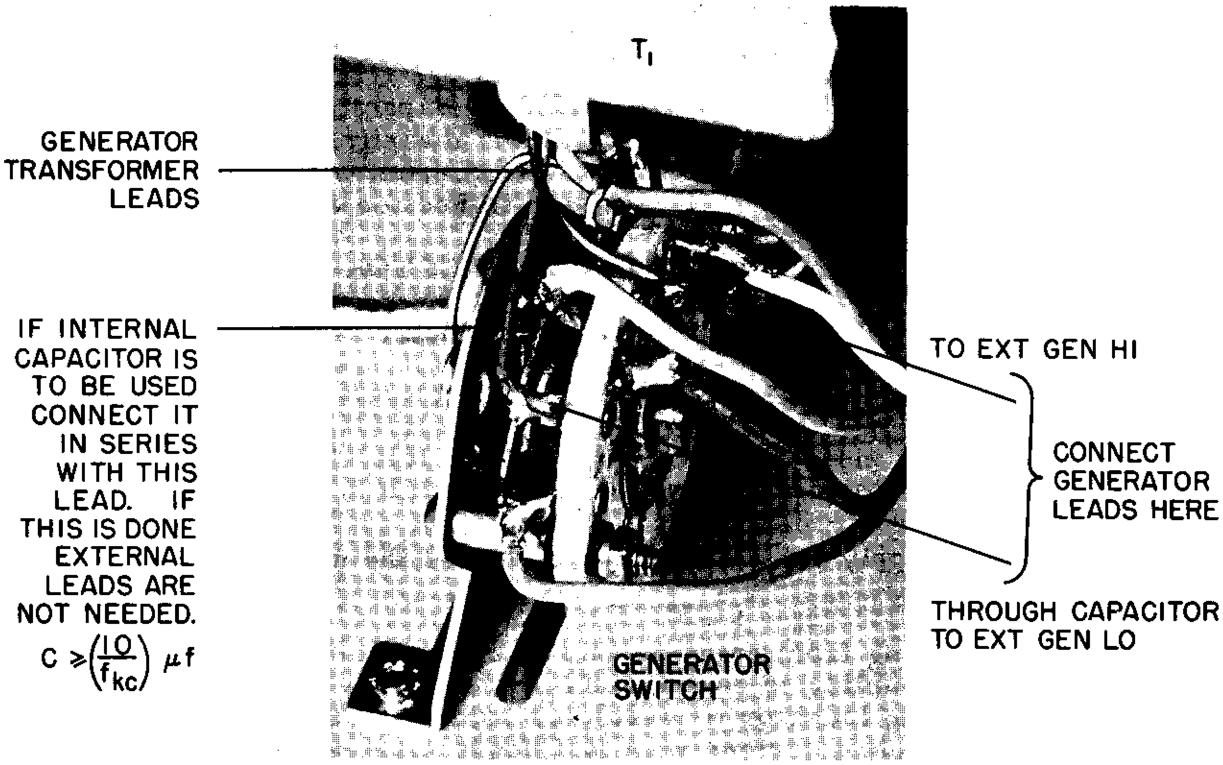
f_{kc} - Operating frequency in kilocycles

B. WITH DC SUPPLIED THROUGH THE GENERATOR TERMINALS

DC power can be supplied through the generator terminals by using an auxiliary ac generator instead of the bridge generator. This generator must be isolated from the dc power supply by a capacitor of at least $(10/f_{kc})$ µf.

2.3.4.2 THINGS TO WATCH OUT FOR (cont. i)

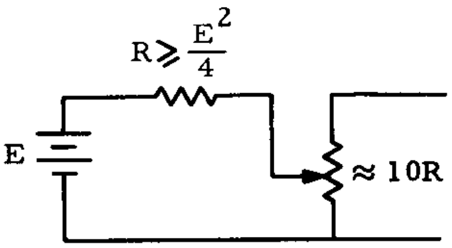
The internal bridge generator can be used as the ac source by making the special connection shown below. Bring out the generator leads. Connect one generator lead to an isolating capacitor. Connect the other side of the capacitor to the EXT GEN terminal marked LO. Connect the second generator lead to the other EXT GEN terminal. Set the generator switch to EXT GEN. It is also possible to connect the capacitor inside the bridge, in series with the generator lead. If this is done no external leads are needed, and the generator switch is set to INTERNAL AC. In either case, the capacitor should have a value of at least $(10/f_{kc})$ µf.



If this operation is repeated often it may be helpful to connect two binding posts in series with one transformer lead so that an external capacitor can be easily attached. These can be mounted between the generator and detector switches. When the capacitor is not needed the terminals can be connected by a shorting bar.

Supplying the dc signal through the generator terminal allows more current for measuring inductors below 1.2 millihenrys. With this connection the dc current is not affected by balancing the bridge. A grounded dc generator cannot be used because one of the detector terminals is grounded. Leakage capacitance and resistance from the dc source to ground will be across bridge arms and may cause significant errors.

Most line operated dc power supplies have high leakage capacitance to the ac line and enough dc leakage to be objectionable. An insulated, isolated battery is the recommended power supply. If a variable supply is needed the circuit shown below can be used. This circuit has a maximum output of one watt so it will not exceed the rating of any bridge element.



With the parallel inductance circuit the standard capacitor blocks the dc from all of the bridge arms except the inductor being measured and the range resistor. As a result the maximum allowable current will be limited by the range resistor. This current limit is shown in Section 2.3.4.3.

C. WITH DC SUPPLIED THROUGH THE DETECTOR TERMINALS

Supplying the dc signal through the detector terminals allows the use of higher current in measuring inductors above 1.2 millihenrys, but the dc current will be influenced by the main dial DEKASTAT setting.

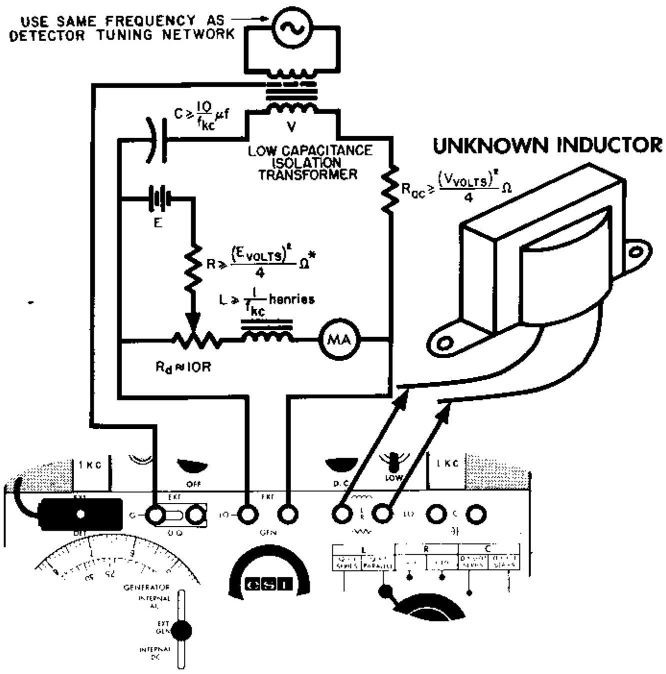
The generator circuit must be isolated by a capacitor. This will require an external generator or the connection recommended in 2.3.4.2-B.

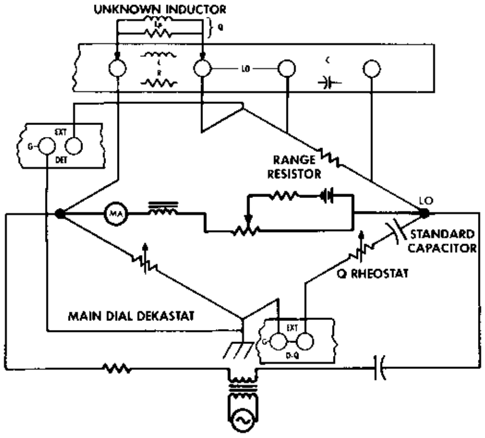
A grounded power supply can be used, since one of the detector terminals is grounded.

The problems resulting from stray ac pickup either from the ripple of a dc supply, capacitive coupling to power lines or the bridge generator, stray field pickup by the isolating inductor (if used), or inductive coupling to the unknown inductor, are much more serious with this connection because of the direct coupling to the detector.

In this circuit the current goes through the unknown inductor and the main dial DEKASTAT. It must be limited by the values given in Section 2.3.4.4. If more current is needed the range can be increased by one setting and the first DEKASTAT dial turned to zero. This will decrease the DEKASTAT resistance and increase its current rating. Because of the high resolution of the main dial DEKASTAT accurate measurements are possible even when the first dial is not used. By setting the first two dials to zero higher current is possible but only 100 divisions of resolution are left.

2.3.4.3 FOR PARALLEL INDUCTANCE MEASUREMENT WITH DC SUPERIMPOSED THROUGH THE GENERATOR TERMINALS





CONNECT AS SHOWN

E - DC VOLTAGE SOURCE

For the ac supply use an external generator or the special internal connection indicated in section 2.3.4.2 B. A detector isolating capacitor is built into the Model 250-DA Bridge.

*This limits to one watt the dc power which can be supplied to the bridge thus protecting all of the bridge circuit. With care more current and voltage can be applied. The current rating of the bridge is given in the table below. These values should never be exceeded.

RANGE	UNKNOWN INDUCTANCE**	MAXIMUM CURRENT
0.1 mh	0.1 µh to 1.2 mh	710 ma
1 mh	1 µh to 12 mh	230 ma
10 mh	10 µh to 120 mh	71 ma
0.1 h	100 µh to 1.2 h	23 ma
1 h	1 mh to 12 h	7.1 ma
10 h	10 mh to 120 h	2.3 ma
100 h	100 mh to 1200 h	250 µa

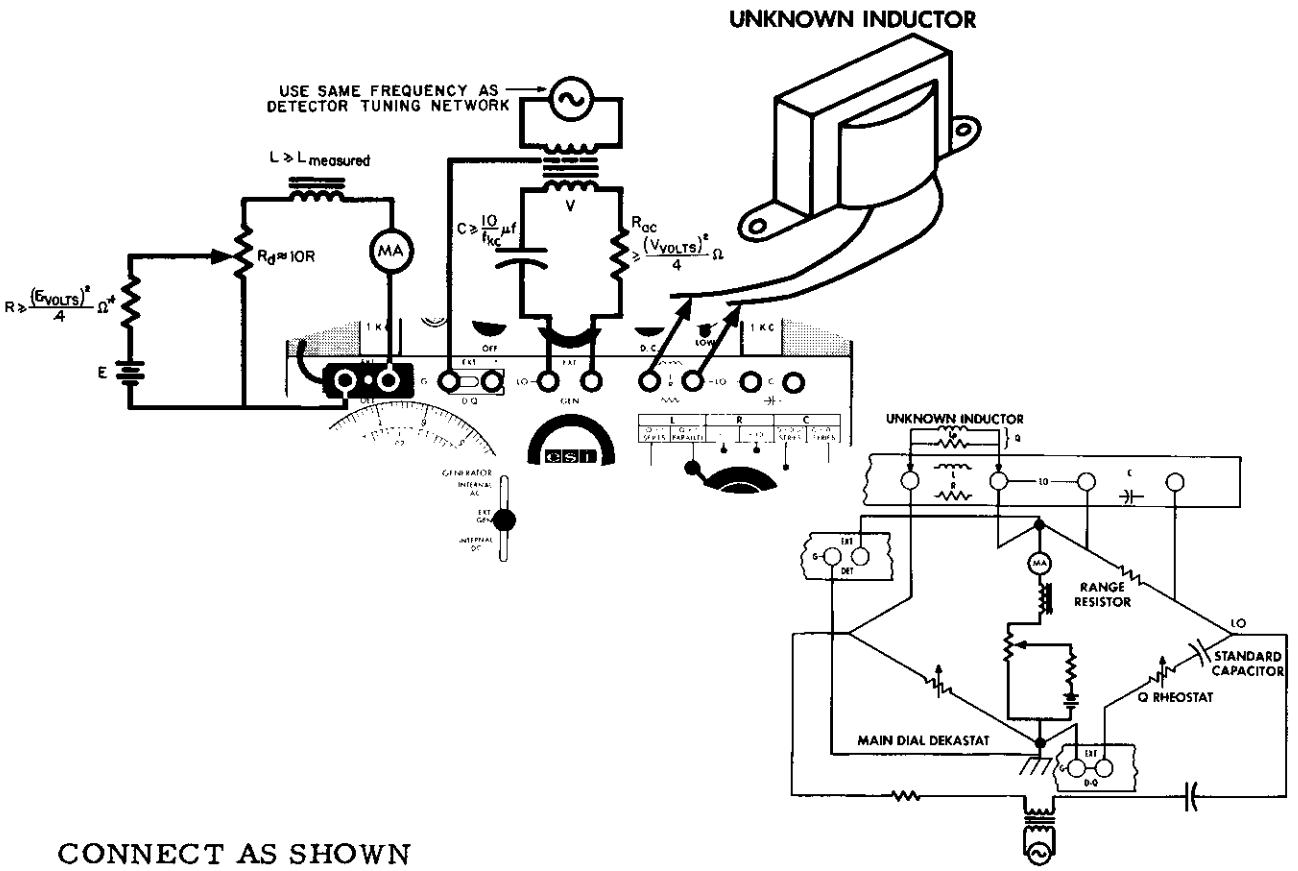
**Lower limit is one dial division

2.3.4.3 FOR PARALLEL INDUCTANCE MEASUREMENTS WITH DC SUPERIMPOSED THROUGH THE GENERATOR TERMINALS (cont.)

R	-	POWER LIMITING RESISTOR	This protects the bridge, the detector, and the unknown inductor.
L	-	ISOLATING INDUCTOR	Avoid ac pickup and coupling to the unknown. This prevents excessive generator loading. Not necessary if $R \geqslant 100$ ohms.
C	-	ISOLATING CAPACITOR	This keeps dc out of the Generator.
R_d	-	CURRENT ADJUSTING CONTROL	To set desired current.
MA	-	CURRENT MONITORING METER	To measure dc current.

MEASURE THE INDUCTANCE	See Section 2.3.

2.3.4.4 FOR PARALLEL INDUCTANCE MEASUREMENTS WITH DC SUPERIMPOSED THROUGH THE DETECTOR TERMINALS



CONNECT AS SHOWN

E - DC VOLTAGE SOURCE

For the ac supply use an external generator or the special internal connection indicated in section 2.3.4.2 B. A detector isolating capacitor is built into the Model 250-DA Bridge.

---

*This limits to one watt the dc power which can be supplied to the bridge thus protecting all of the bridge circuit. With care more current and voltage can be applied. The current rating of the bridge is given in the table below. The outer dial must be set to zero to use the "MIDDLE" dial rating. Both outer dials must be set to zero to use the "POT" dial rating. These values should never be exceeded.

RESOLUTION	DIAL	UNKNOWN INDUCTANCE**	MAXIMUM CURRENT
12,005 div	OUTER	100.0 µh to 1200 h	23 ma
1,005 div	MIDDLE	10.0 µh to 100 h	71 ma
105 div	POT	0.1 µh to 10.5 h	270 ma

**Lower limit is one division on dial which limits current on lowest range.

2.3.4.4 FOR PARALLEL INDUCTANCE MEASUREMENTS WITH DC SUPERIMPOSED THROUGH THE DETECTOR TERMINALS (cont.)

R - POWER LIMITING RESISTOR	This protects the bridge, the detector, and the unknown inductor.
L - ISOLATING INDUCTOR	Avoid ac pickup and coupling to the unknown. This prevents excessive generator loading. Not necessary if $R \geqslant (L_{h\text{-measured}})(f_{kc})$ (6) kilohms.
C - ISOLATING CAPACITOR	This keeps dc out of the Generator.
R_d - CURRENT ADJUSTING CONTROL	To set desired current.
MA - CURRENT MONITORING METER	To measure dc current.
ADJUST THE DC CURRENT AS REQUIRED	The current will vary with the setting of the main dial.
MEASURE THE INDUCTANCE	See Section 2.3.

2.3.5 AC VOLTAGE MEASUREMENT

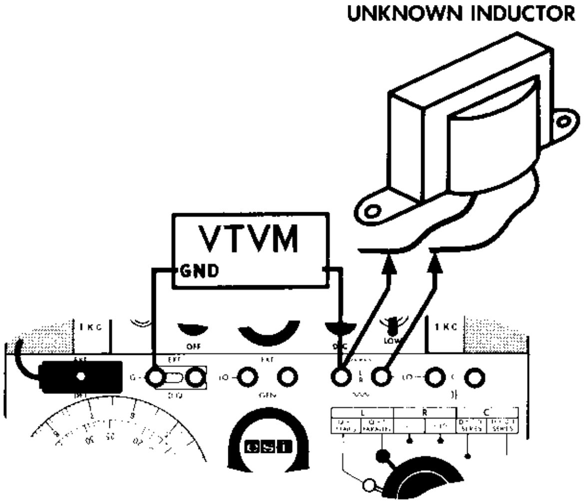
To measure the ac voltage applied to the unknown inductor:

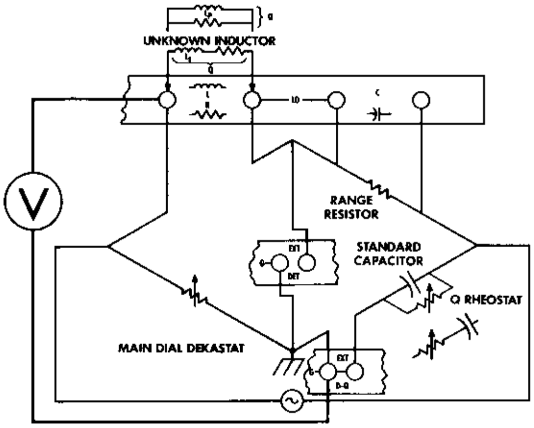
Connect the ground terminal of a high impedance ac voltmeter to the EXT D-Q terminal marked G.

Connect the input terminal of the voltmeter to the HI inductor terminal.

Balance the bridge.

Read the voltmeter. With the bridge balanced, this voltage is equal to the ac voltage across the unknown inductor, but the inductor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the meter is connected.

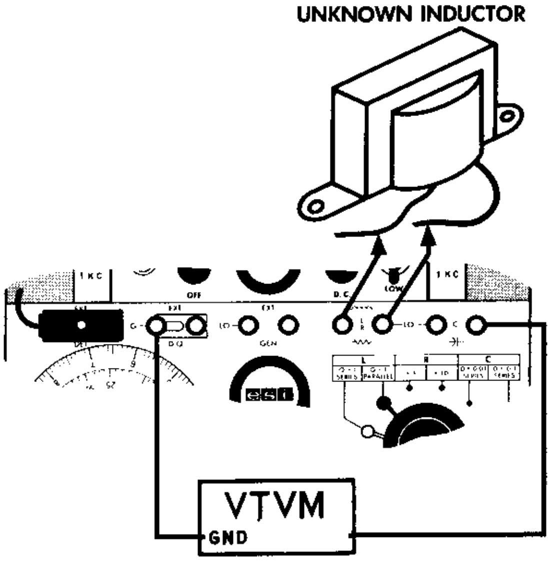


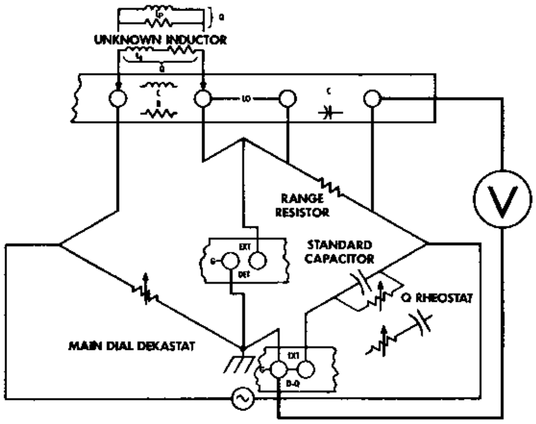


2.3.6 AC CURRENT MEASUREMENT

To measure the ac current supplied to the unknown inductor:

The ac voltage across the range resistor is proportional to the ac current through the unknown. At balance this voltage is equal to the voltage across the standard capacitor arm, which can be measured with a grounded voltmeter.





Connect the ground terminal of a high impedance sensitive ac vacuum tube voltmeter to the EXT D-Q terminal marked G.

Connect the input terminal of the voltmeter to the high unknown capacitor terminal of the bridge.

Balance the bridge using either the series or parallel inductance circuit.

Read the voltmeter. The ac current in milliamperes will be equal to the voltage read (in volts) times the multiplier M from the following table.

$$I = V \times M$$

I - current in milliamperes
V - voltmeter reading in volts
M - multiplier from table

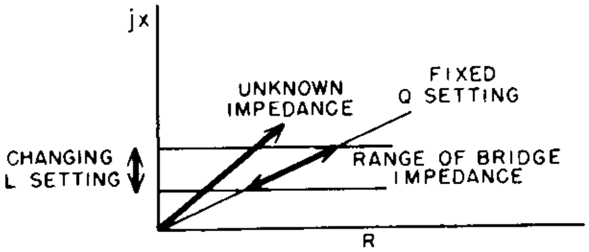
RANGE	UNKNOWN INDUCTANCE*	M
0.1 mh	0.1 μh to 1.2 mh	1000
1 mh	1 μh to 12 mh	100
10 mh	10 μh to 120 mh	10
0.1 h	100 μh to 1.2 h	1
1 h	1 mh to 12 h	0.1
10 h	10 mh to 120 h	0.01
100 h	100 mh to 1200 h	0.001

*Lower limit represents one dial division.

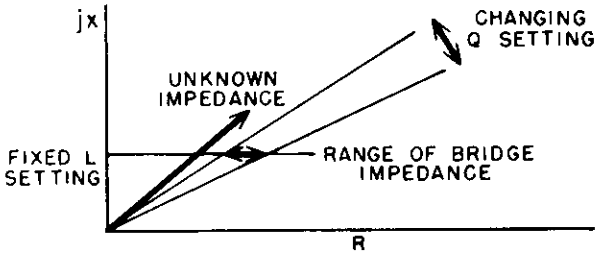
Remove the voltmeter and re-balance the bridge for the precise inductance measurement.

2.3.7 SLIDING BALANCE

WHAT IT IS



CHANGING THE L DIAL



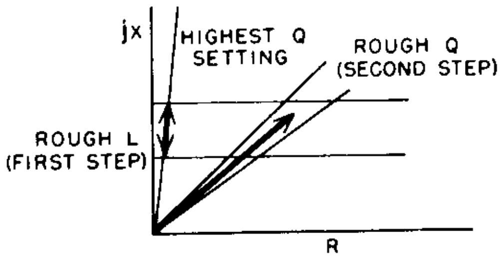
CHANGING THE Q DIAL

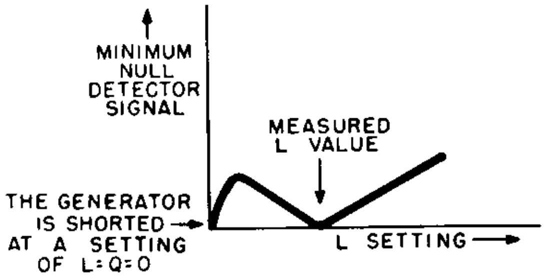
When lossy inductors are measured the nulling problem known as sliding balance will occur if the usual procedure of adjusting first one control then the other is followed. As shown in the above drawings, neither the Q dial nor the L dial will move the bridge vector toward a null directly or quickly. When Q is high there is no sliding balance because the effects of Q and L are perpendicular to each other and nulling is easy.

WHAT TO DO ABOUT IT WHEN USING ESI 250-DA BRIDGE

This problem is not too serious if the value of Q is greater than one. For lower values of Q, an external D-Q rheostat may be necessary. For low Q, the L series circuit should be used. The following approach should be used if balancing is difficult.

By a somewhat different nulling technique rapid accurate low Q measurements can be accomplished.

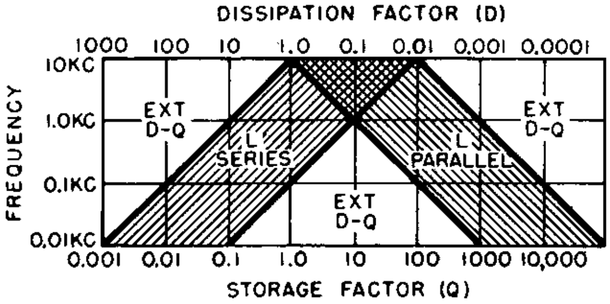




First set the Q dial to its maximum position, then set L for a detector minimum. With Q set high, L will move the impedance vector in the L direction only. The bridge null detector signal is almost exactly proportional to the difference between the unknown impedance and the impedance indicated by the bridge dial. The correct L setting will bring the impedances closer together and give minimum signal. Next set the Q dial for a minimum on the detector. This should give a good start on finding L and Q. Move L a small amount then set Q for a minimum and observe whether this minimum is better or worse than the previous one. If it is better move L another small amount in the same direction. If it is worse try the other direction. Continue moving L in small steps in one direction only while setting Q for minimum detector signal until the detector signal reaches a true null. Moving L further will make the null worse again. The null found this way is correct. A little practice will allow you to make these measurements rapidly even when Q is in the order of 0.1. When almost nulled it is often easier to move the Q dial "one wire at a time" while null seeking with the center L dial. Be careful with the L series circuit. The bridge will also indicate a null at a setting of Q = L = O because at this setting the generator is shorted.

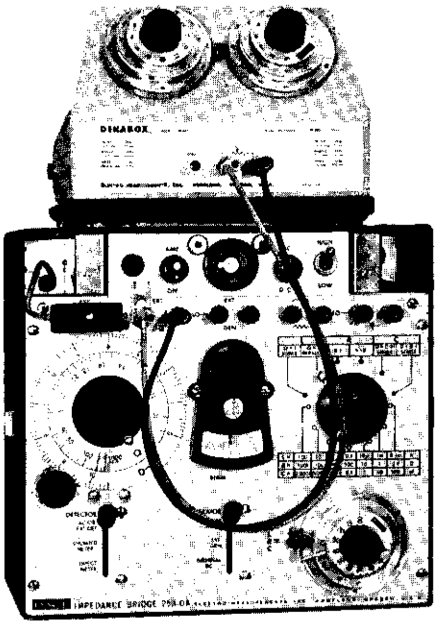
2.3.8 TO USE AN EXTERNAL Q RHEOSTAT

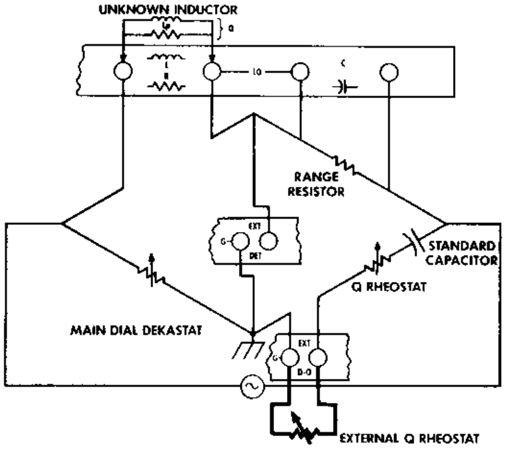
The D and Q ranges of the bridge can be extended by use of an external rheostat. The curve below shows the ranges of D and Q for which this technique is advisable.



ALWAYS SET THE CIRCUIT SELECTOR TO L PARALLEL.	This bridge circuit gives the best results for both the series and parallel bridge connections when using an external D-Q rheostat.
ALWAYS TURN THE D-Q DIAL CLOCKWISE UNTIL IT HITS THE MECHANICAL STOP AND LEAVE IT THERE DURING THE ENTIRE MEASUREMENT.	This shorts out the internal D-Q rheostat.

2.3.8.1 PARALLEL INDUCTANCE BRIDGE





REPLACE THE EXT D-Q JUMPER BY AN EXTERNAL RHEOSTAT "R".	This completes the parallel inductance circuit.
BALANCE THE BRIDGE.	Use the range switch, the MAIN DIALS and the external rheostat.

READ L_p(EQUIVALENT PARALLEL INDUCTANCE) FROM THE DIALS.

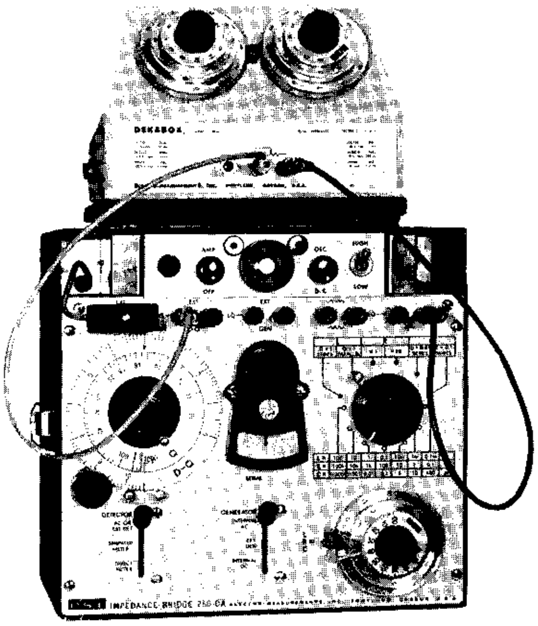
This reading does not depend on frequency.

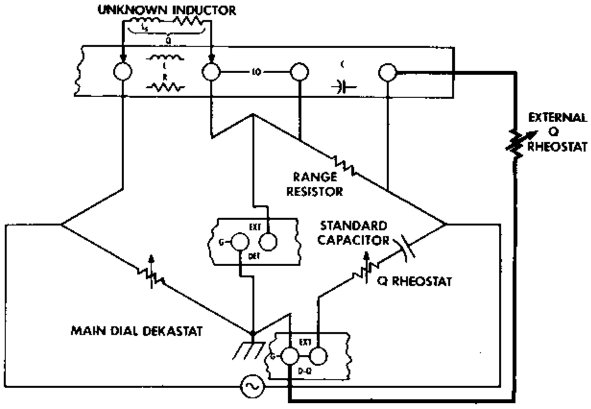
CALCULATE Q

$$Q = \frac{1.592}{f_{kc} R_{k\Omega}}$$

Q - Storage factor
f_{kc} - Frequency in kilocycles
$R_{k\Omega}$ - External D-Q rheostat resistance in kilohms.

2.3.8.2 SERIES INDUCTANCE BRIDGE





CONNECT AN EXTERNAL RHEOSTAT "R" BETWEEN THE HI "C" TERMINAL AND ANY GROUND TERMINAL.

This completes the series inductance circuit. Be sure the EXT D-Q terminals are jumpered.

BALANCE THE BRIDGE.

Use the range switch, the MAIN DIALS and the external rheostat.

READ L_s(EQUIVALENT SERIES INDUCTANCE) FROM THE DIALS.

This reading does not depend on frequency.

CALCULATE Q

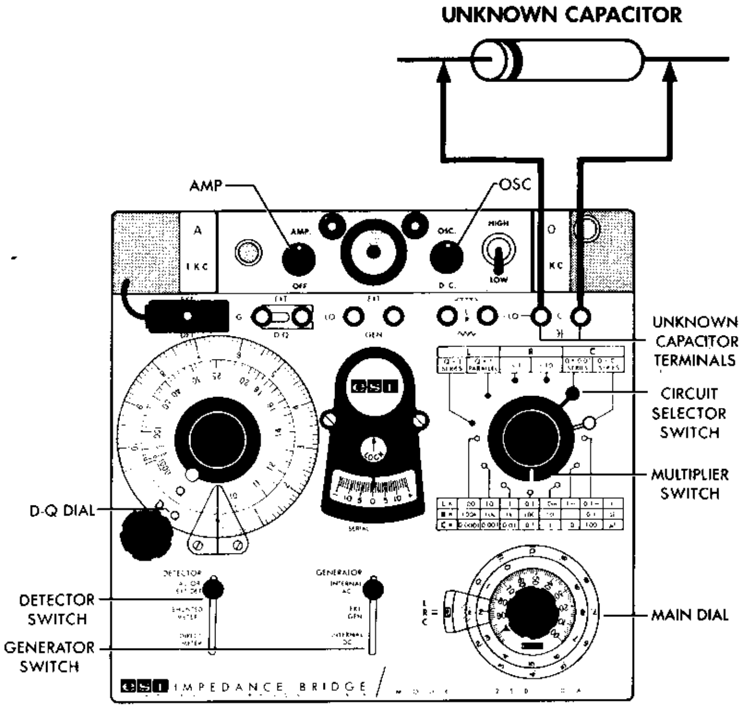
$$Q = 0.628\ f_{kc} R_{k\Omega}$$

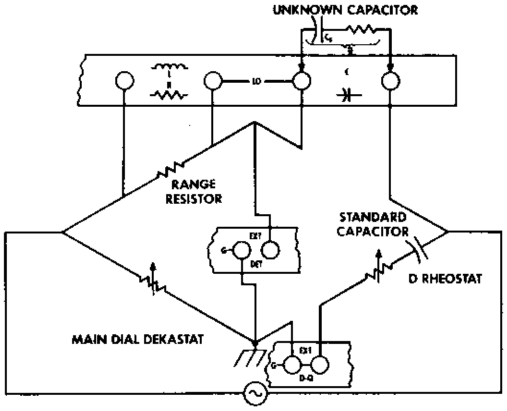
Q - Storage factor
f_{kc} - Frequency in kilocycles
$R_{k\Omega}$ - External D-Q rheostat resistance in kilohms.

Note: $L_p = \frac{1 + Q^2}{Q^2} \ L_s$

2.4 CAPACITORS

2.4.1 MEASURING CAPACITORS *the* esi *way*





CONNECT THE UNKNOWN CAPACITOR TO THE C TERMINALS

To minimize stray capacitance to ground, connect the shield or outside foil to the terminal marked LO.

TURN THE AMP CONTROL CLOCKWISE FOR POWER, AND SET IT WITH THE DOT UP

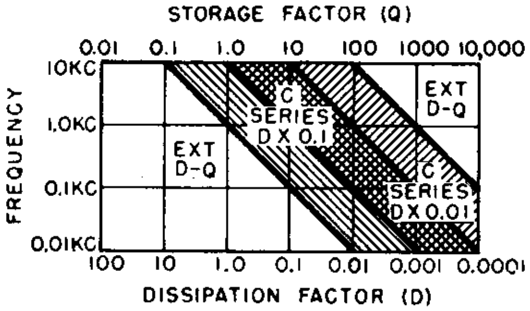
This turns on the power supply. The red pilot light to the left of the AMP switch should light.

TURN THE OSC CONTROL CLOCKWISE FOR AC, AND SET IT WITH THE DOT UP

This supplies ac to the bridge. The green fluorescent screen of the ac null indicator should light.

SET THE CIRCUIT SELECTOR SWITCH TO THE APPROPRIATE C CIRCUIT.

C_{series} Dx0.01 for $0<D<0.1xf_{kc}$
C_{series} Dx0.1 for $0.1xf_{kc}<D<1.0xf_{kc}$



2.4.1 MEASURING CAPACITORS (cont.)

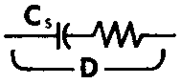
SET THE MAIN DIAL TO READ 3.000 SET THE D-Q DIAL TO READ 0	These settings make it easier to find the correct range.
SET THE DETECTOR SWITCH TO AC OR EXT-DET	This connects the detector to the bridge.
SET THE GENERATOR SWITCH TO INTERNAL AC	This connects the generator to the bridge
ADJUST THE MULTIPLIER SWITCH FOR MINIMUM DETECTOR SIGNAL	This sets the range so that the value can be found with maximum resolution on the main dial. The AMP and OSC controls can be changed to give optimum sensitivity.
ADJUST THE MAIN DIAL AND THE D-Q DIAL ALTERNATELY FOR THE WIDEST AND SHARPEST POSSIBLE SHADOW ON THE NULL INDICATOR	If more or less sensitivity is needed, adjust the AMP control and/or the OSC control.
IF THE MAIN DIAL READING AT BALANCE IS LESS THAN 1.200, USE THE NEXT LOWER SETTING OF THE MULTIPLIER SWITCH AND READJUST FOR A NULL	This takes advantage of the increased resolution near full scale of the dial.
THE MEASURED CAPACITANCE IS THE PRODUCT OF THE READINGS OF THE MULTIPLIER SWITCH AND THE MAIN DIAL	
AT 1 KC, THE MEASURED D IS THE PRODUCT OF THE READINGS OF THE CIRCUIT SELECTOR SWITCH AND THE BLACK SCALE OF THE D-Q DIAL	FOR OTHER FREQUENCIES: The measured D is the product of (CIRCUIT SELECTOR switch setting) x (D-Q DIAL reading) x (f_{kc}).
BEFORE DISCONNECTING THE CAPACITOR, SET THE GENERATOR SWITCH TO EXT GEN	This disconnects the generator.
SET THE AMP SWITCH TO OFF BEFORE LEAVING THE BRIDGE	This turns off the power supply.

2.4.2 SERIES AND PARALLEL CAPACITANCE

The bridge measures a simple equivalent circuit for the impedance connected to its terminals. This equivalent circuit consists of a capacitance and a resistance connected in series. An alternate representation of the same impedance is an equivalent circuit consisting of a different capacitance and resistance connected in parallel. The phase and magnitude of the measured impedance are identical for both circuits. For values of D greater than 0.01 the series and parallel capacitances differ measurably (by more than 0.01%).

Although the bridge measures only the equivalent series circuit of a capacitor, the values of the equivalent parallel circuit may be easily calculated.

WHEN THE BRIDGE MEASURES SERIES CAPACITANCE, C_s:



C_s = (MULTIPLIER SWITCH setting) x (MAIN DIAL reading)

D = (CIRCUIT SELECTOR reading) x (D-Q DIAL reading) x (f_{kc})

$$Q = \frac{1}{D}$$

$$R_s = \frac{D}{2\pi f C_s}$$

$$Z = \frac{D - j}{2\pi f C_s}$$

D and Q in per unit

R_s in kilohms

f in kc

C_s in microfarads

$j = \sqrt{-1}$

Z in kilohms

TO CALCULATE THE EQUIVALENT PARALLEL CIRCUIT:

The D of the equivalent parallel circuit always equals the D of the equivalent series circuit. The same is true of Q.

$$C_p = \frac{C_s}{(1 + D^2)}$$

$$R_p = \frac{1}{D} \times \frac{1}{2\pi f C_p}$$

2.4.3 THINGS TO WATCH OUT FOR

2.4.3.1 LOW CAPACITANCE MEASUREMENTS

In making low capacitance measurements, there are two things to watch out for:

1. Be careful to avoid hum pickup.
2. Keep the stray capacitance to a minimum.

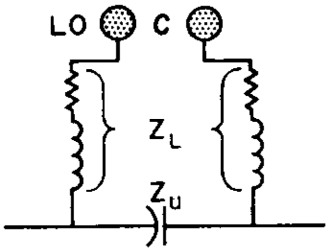
To minimize both effects, keep your hands as far as possible from the capacitor being measured.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from the LO terminal should be shielded. See section 2.4.6, "Extended Leads".

The D and Q readings on the lowest C range will be in error as indicated in the specifications because of the residual capacitance of the range resistor. If accurate D or Q readings are needed the next highest C range can be used. The C readings on the low range are accurate.

2.4.3.2 HIGH CAPACITANCE MEASUREMENTS

The bridge measures the total impedance connected to its terminals. Both the unknown capacitor and its leads contribute to this impedance. The leads have some resistance and inductance, which affect the value read from the bridge.



$$Z_{measured} = Z_u + Z_L$$

Z_u = Impedance of unknown capacitor

Z_L = Impedance of leads

For the greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance. Closely spaced twisted leads will reduce the inductance and the pickup of stray fields.

2.4.4 CAPACITANCE MEASUREMENT WITH DC

2.4.4.1 WHEN TO USE DC

Some capacitors need a polarizing voltage. For example, electrolytic and tantalytic capacitors can be damaged by the reverse polarity half-cycle of the test frequency. Even if the capacitors are not damaged, erroneous readings may result.

A polarizing voltage is not always needed in these measurements. If the ac voltage is kept at a very low value (typically below one-half volt), the capacitor will not be damaged, and the readings will be reasonably accurate.

Because of the high sensitivity of the Model 250-DA bridge, accurate measurements can be made with a very low oscillator voltage. When operating with a low oscillator voltage, be sure that the detector sensitivity is high.

2.4.4.2 THINGS TO WATCH OUT FOR

The dc should be supplied through the generator terminals. When this is done, both bridge current paths include a series capacitor. All of the dc voltage will appear across both the unknown capacitor and the standard capacitor.

Stray ac pickup may change sensitive components being measured or may give erroneous null detector readings.

The ac impedance of the external dc circuit must be less than 200 ohms for maximum sensitivity.

If D is too high to be read directly, an external rheostat such as the ESI Model DB-655 DEKASTAT®, connected to the EXT D-Q terminals can be used to extend the D range. D can be calculated by the equation:

$$D = D_{reading}\ f_{kc} + 0.628\ f_{kc}\ R_{k\Omega}$$

where:

D - Dissipation factor of unknown capacitor

$D_{reading}$ - D reading of bridge dial

$R_{k\Omega}$ - External rheostat resistance in kilohms

f_{kc} - Operating frequency in kilocycles

If the dc leakage resistance of the capacitor being measured is much greater than the resistance of the range resistor most of the dc input voltage will appear across the unknown capacitor. If the dc resistance of the unknown capacitor is known, the voltage across it will be shown by the following equation:

$$E_c = E_{in} \frac{R_c}{R_c + R_R}$$

2.4.4.2 THINGS TO WATCH OUT FOR (cont. i)

where:

E_c - DC voltage across the unknown capacitor

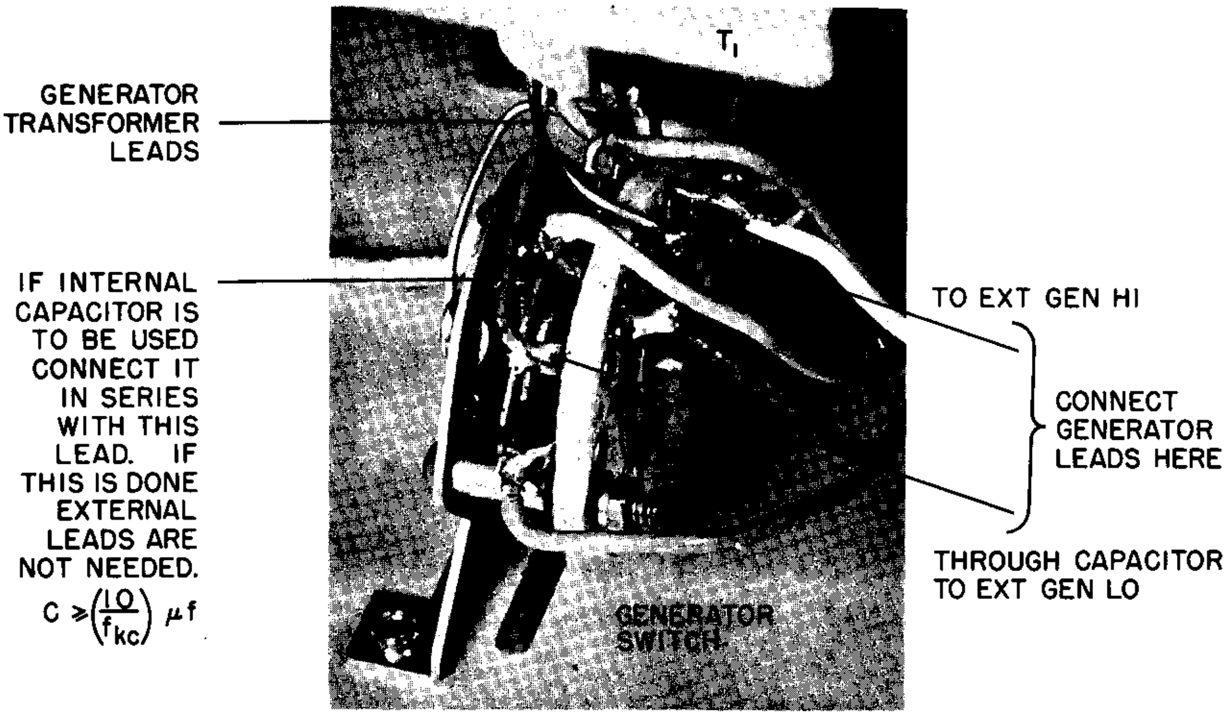
E_{in} - DC voltage at the generator terminals

R_c - DC resistance of the unknown capacitor

R_R - Resistance of the range resistor

DC power can be supplied through the generator terminals by using an auxiliary ac generator instead of the bridge generator. This generator must be isolated from the dc power supply by a capacitor of at least $(10/f_{kc})$ µf.

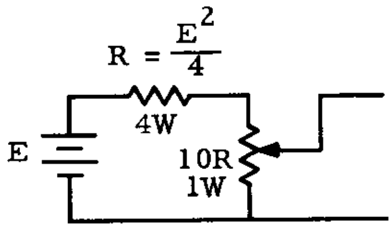
The internal bridge generator can be used as the ac source by making the special connection shown below. Bring out the generator leads. Connect one generator lead to an isolating capacitor. Connect the other side of the capacitor to the EXT GEN terminal marked LO. Connect the second generator lead to the other EXT GEN terminal. Set the generator switch to EXT GEN. It is also possible to connect the capacitor inside the bridge, in series with the generator lead. If this is done no external leads are needed, and the generator switch is set to INTERNAL AC. In either case, the capacitor should have a value of at least $(10/f_{kc})$ µf.



If this operation is repeated often it may be helpful to connect two binding posts in series with one transformer lead so that an external capacitor can be easily attached. These can be mounted between the generator and detector switches. When the capacitor is not needed the terminals can be connected by a shorting bar.

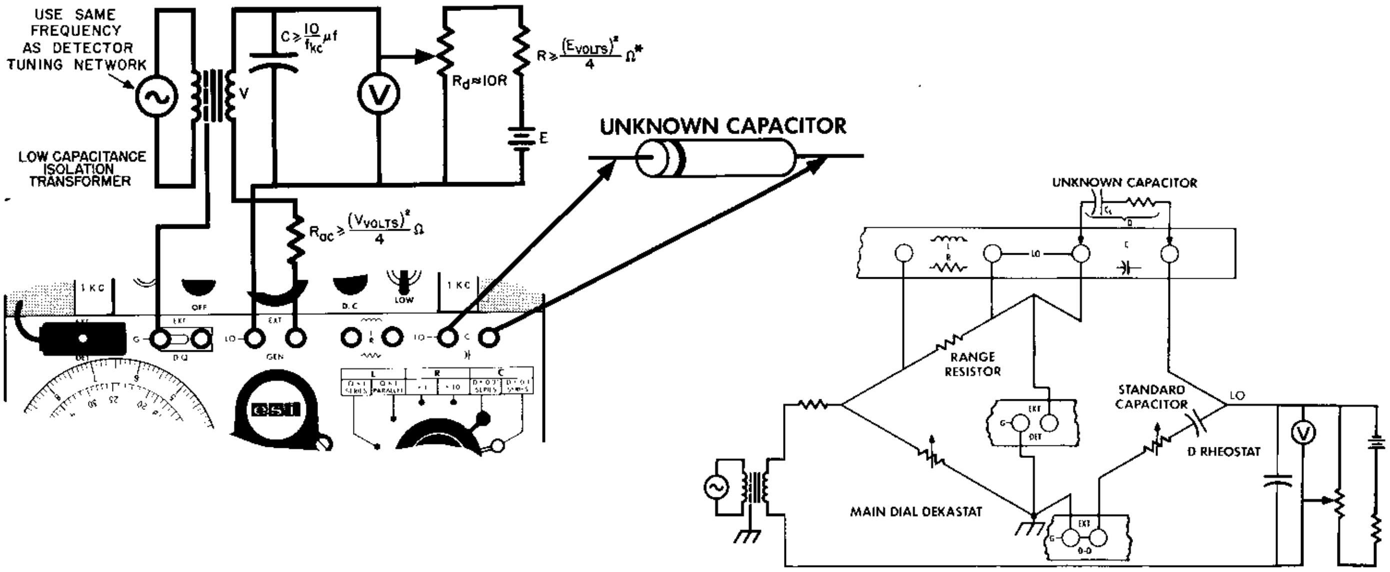
A grounded dc generator cannot be used because one of the detector terminals is grounded. Leakage capacitance and resistance from the dc source to ground will be across bridge arms and may cause significant errors.

Most line operated dc power supplies have high leakage capacitance to the ac line and enough dc leakage to be objectionable. An insulated isolated battery is the recommended power supply. If a variable supply is needed the circuit shown below can be used. This circuit has a maximum output of about one watt so it will not exceed the rating of any bridge element.



The standard capacitor is subjected to the same dc voltage as the unknown capacitor. As a result the maximum allowable voltage must be limited to the standard capacitor rating of 500 volts.

2.4.4.3 FOR PARALLEL CAPACITANCE MEASUREMENTS WITH DC SUPERIMPOSED THROUGH THE GENERATOR TERMINALS



CONNECT THE CIRCUIT AS SHOWN

A detector isolating capacitor is built into the Model 250-DA Bridge.

E - DC VOLTAGE SOURCE

A battery is recommended to avoid stray pickup and leakage. For the ac supply use an external generator or the special internal connection indicated in section 2.4.4.2 B.

R - POWER LIMITING RESISTOR

$$R = \frac{(E_{volts})^2}{4} \text{ ohms}^*$$

This protects the bridge in case the unknown terminals are shorted.

R_D - VOLTAGE ADJUSTING CONTROL

This sets the dc voltage.

CONNECT THE METER "V" IN PARALLEL WITH THE DC SUPPLY

This meter reads the dc voltage of the unknown capacitor. The impedance of most meters is high enough so that they will not load the dc supply.

*This limits the dc power that can be supplied to the bridge to one watt to protect all of the bridge circuit in case the unknown capacitor is accidentally shorted. The maximum dc supply should not exceed 300 volts for the protection of the standard capacitor.

2.4.4.3 FOR PARALLEL CAPACITANCE MEASUREMENTS WITH DC SUPERIMPOSED THROUGH THE GENERATOR TERMINALS (cont.)

ADJUST THE DC VOLTAGE AS REQUIRED	For low leakage capacitors the voltage across the unknown capacitor will be equal to the voltmeter "V" reading.
MEASURE THE CAPACITANCE	See section 3.3.4

2.4.5 AC VOLTAGE MEASUREMENT

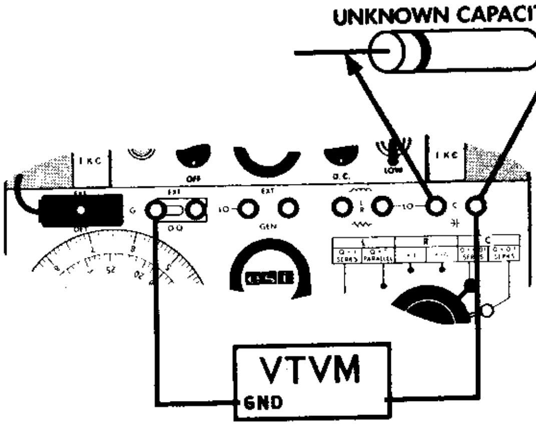
To measure the ac voltage applied to the unknown capacitor:

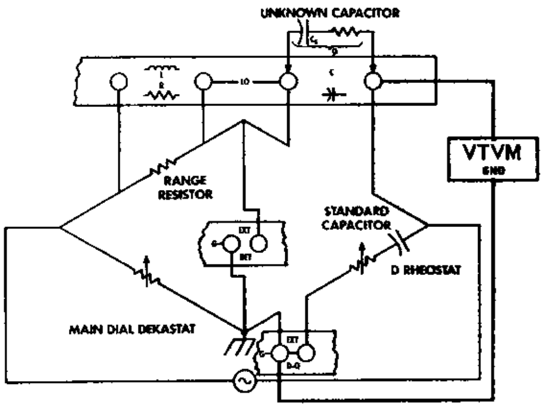
Connect the ground terminal of a high impedance ac voltmeter to the EXT D-Q terminal marked G.

Connect the input terminal of the voltmeter to the high unknown capacitor terminal of the bridge.

Balance the bridge.

Read the voltmeter. With the bridge balanced, this voltage is equal to the ac voltage across the unknown capacitor, but the capacitor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the meter is connected.





2.4.6 EXTENDED LEADS

Sometimes it is necessary to use extended leads. This can be done easily without causing error in the measurement.

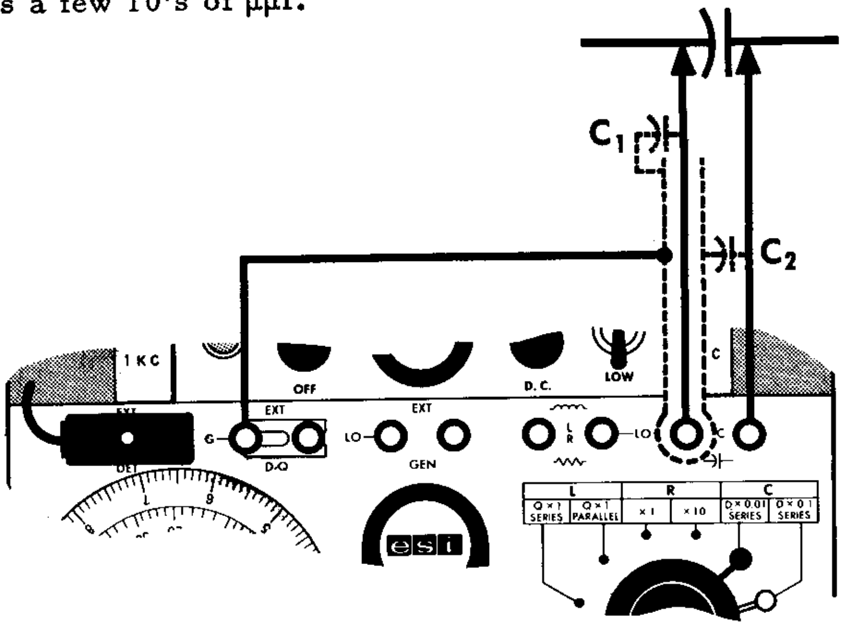
Connect a shielded lead to the unknown C terminal marked LO.

Connect the shield of this lead to the EXT D-Q terminal marked G.

Connect an ordinary clip lead to the high unknown C terminal.

The capacitance between the shield and the LO unknown C terminal is now across the detector. This keeps it from causing any error. If this stray capacitance is greater than 500 μμf, it may reduce the detector sensitivity.

The stray capacitance from the unshielded lead to ground is across the standard capacitor arm of the bridge. Since the standard capacitor is 100,000 μμf, the stray capacitance will not cause significant errors unless it exceeds a few 10's of μμf.

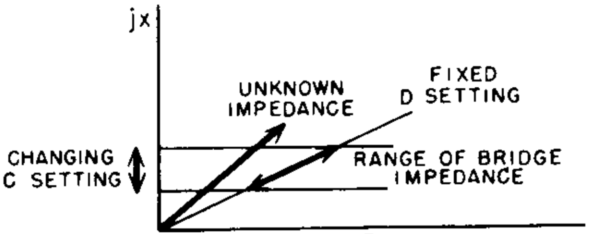


C_1: Capacitance from LO C terminal to ground

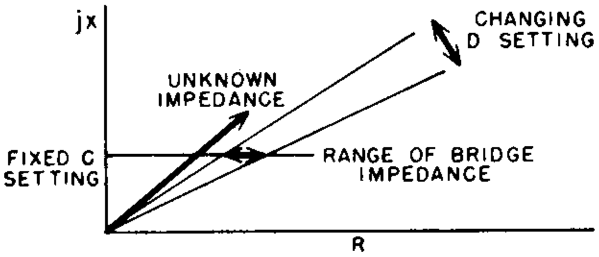
C_2: Capacitance from unshielded conductor to ground

2.4.7 SLIDING BALANCE

WHAT IT IS



CHANGING THE C DIAL



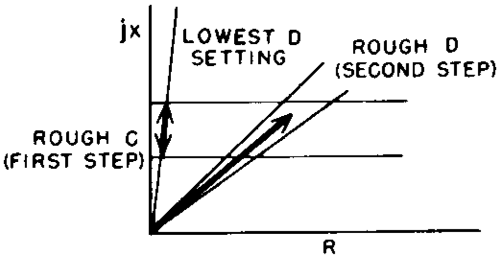
CHANGING THE D DIAL

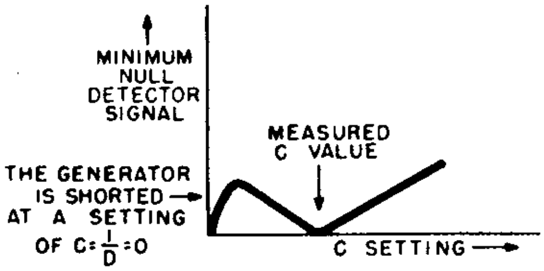
When lossy capacitors are measured the nulling problem known as sliding balance will occur if the usual procedure of adjusting first one control then the other is followed. As shown in the above drawings, neither the D dial nor the C dial will move the bridge vector toward a null directly or quickly. When D is low there is no sliding balance because the effects of D and C are perpendicular to each other and nulling is easy.

WHAT TO DO ABOUT IT WHEN USING ESI 250-DA BRIDGE

This problem is not too serious if the value of D is less than one. For higher values of D an external D-Q rheostat may be necessary. For high D, the C parallel circuit should be used. (see 2.4.8) The following approach should be used if balancing is difficult.

By a somewhat different nulling technique rapid accurate high D measurements can be accomplished.

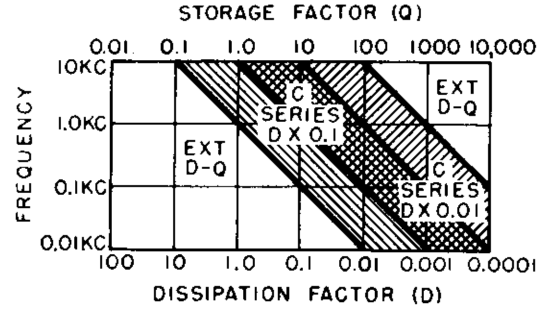




First set the D dial to its minimum position, then set C for a detector minimum. With D set low, C will move the impedance vector in the C direction only. The bridge null detector signal is almost exactly proportional to the difference between the unknown impedance and the impedance indicated by the bridge dial. The correct C setting will bring the impedances closer together and give minimum signal. Next set the D dial for a minimum on the detector. This should give a good start on finding C and D. Move C a small amount then set D for a minimum and observe whether this minimum is better or worse than the previous one. If it is better move C another small amount in the same direction. If it is worse try the other direction. Continue moving C in small steps in one direction only while setting D for minimum detector signal until the detector signal reaches a true null. Moving C further will make the null worse again. The null found this way is correct. A little practice will allow you to make these measurements rapidly even when D is in the order of 10. When almost nulled it is often easier to move the D dial "one wire at a time" while null seeking with the center C dial. Be careful with the C parallel circuit. The bridge will also indicate a null at a setting of $C = \frac{1}{D} = O$ because at this setting the generator is shorted.

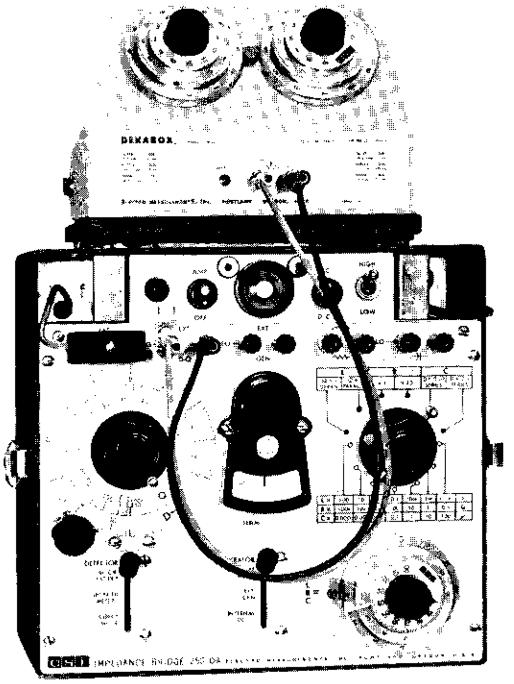
2.4.8 TO USE AN EXTERNAL D-Q RHEOSTAT

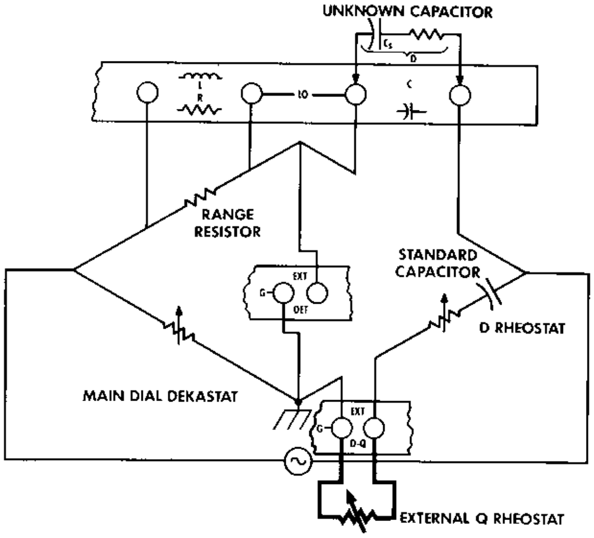
The D and Q ranges of the bridge can be extended by use of an external rheostat. The curve below shows the ranges of D and Q for which this technique is advisiable.



SET THE CIRCUIT SELECTOR TO C SERIES	This bridge circuit can be used for both series and parallel connections when using an external D-Q rheostat.

2.4.8.1 SERIES CAPACITANCE BRIDGE





REPLACE THE EXT D-Q JUMPER BY AN EXTERNAL RHEOSTAT "R".	This completes the capacitance circuit series.
BALANCE THE BRIDGE.	Use the range switch, the MAIN DIALS and the external rheostat.
READ C_s (EQUIVALENT SERIES CAPACITANCE) FROM THE DIALS.	This reading does not depend on frequency.

CALCULATE D

$$D = 0.628\, f_{kc} R_{k\Omega} + \frac{D_{dial\ reading}}{f_{kc}}$$

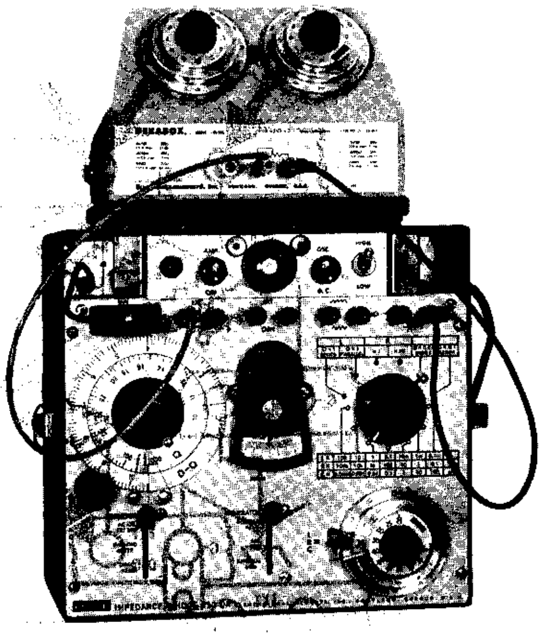
D - Dissipation factor in per unit

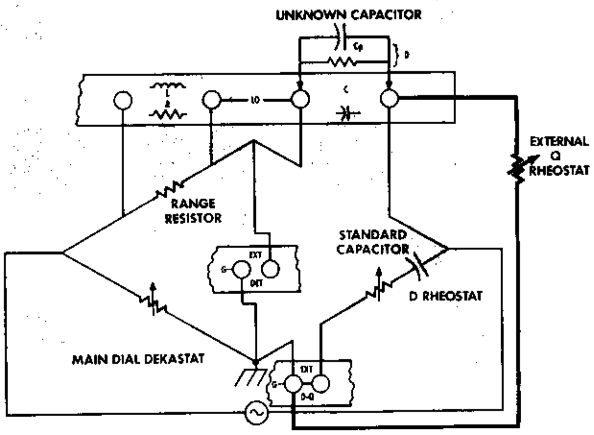
f_{kc} - Frequency in kilocycles

$R_{k\Omega}$ - External D-Q rheostat resistance in kilohms.

D_{dial} - D-Q dial reading in divisions

2.4.8.2 PARALLEL CAPACITANCE BRIDGE



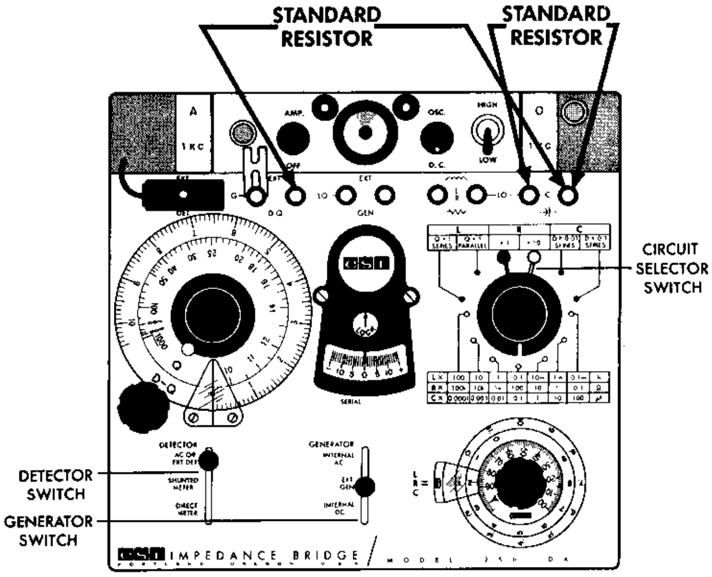


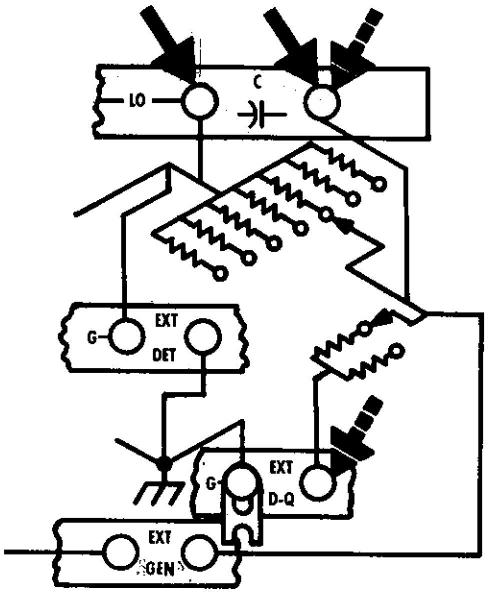
CONNECT AN EXTERNAL RHEOSTAT "R" BETWEEN THE HI "C" TERMINAL AND THE EXT D-Q TERMINAL MARKED G.	This completes the parallel capacitance bridge.
TURN THE D-Q DIAL COUNTER-CLOCKWISE UNTIL IT HITS THE MECHANICAL STOP AND LEAVE IT THERE DURING THE ENTIRE MEASUREMENT.	This shorts the internal D-Q rheostat.
BALANCE THE BRIDGE.	Use the range switch, the MAIN DIALS and the external rheostat.
READ C_p (EQUIVALENT PARALLEL CAPACITANCE) from the dials.	This reading does not depend on frequency.
CALCULATE D $D = \frac{1.592}{f_{kc}R_{k\Omega}}$	D - Dissipation factor in per unit f_{kc} - Frequency in kilocycles $R_{k\Omega}$ - External D-Q reheostat resistance in kilohms.

$$C_p = \frac{C_s}{(1 + D^2)}$$

2.5 USING BRIDGE ELEMENTS *the* **esi** *way*

2.5.1 STANDARD RESISTORS





Set circuit selector to R.

Set range as desired.

Set to EXT-GEN and EXT-DET.

Open EXT D-Q Jumper to disconnect chassis.

Connect between C terminals:

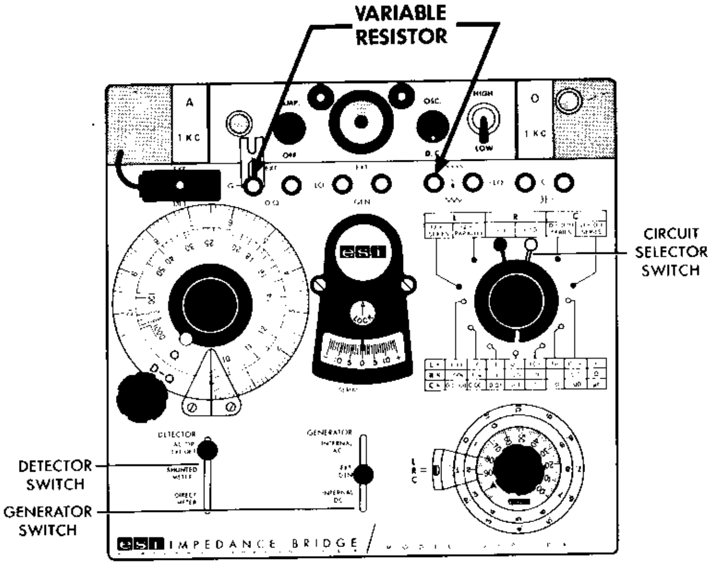
RANGE-Rx	100k	10k	1k	100	10	1	0.1
STANDARD RESISTOR	1meg	100k	10k	1k	100	10	1

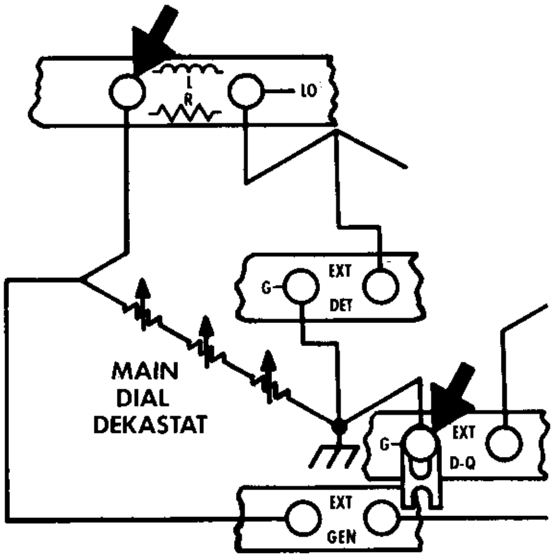
Or between right hand terminals of C and EXT D-Q:

RANGE-Rx	1	10
STANDARD RESISTOR	10k	1k

2.5 USING BRIDGE ELEMENTS (cont. i)

2.5.2 DEKASTAT® VARIABLE RESISTOR





Set circuit selector to R.

Set main dial DEKASTAT as desired.

Set to EXT-GEN and EXT-DET.

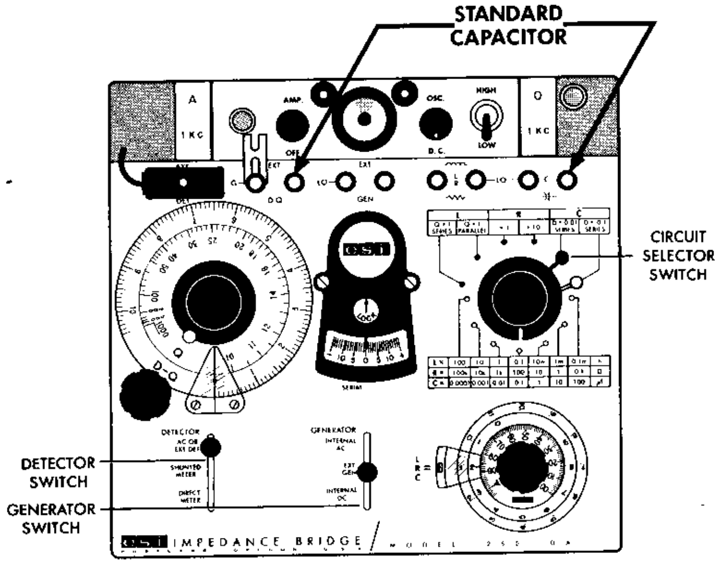
Open EXT D-Q Jumper to disconnect chassis.

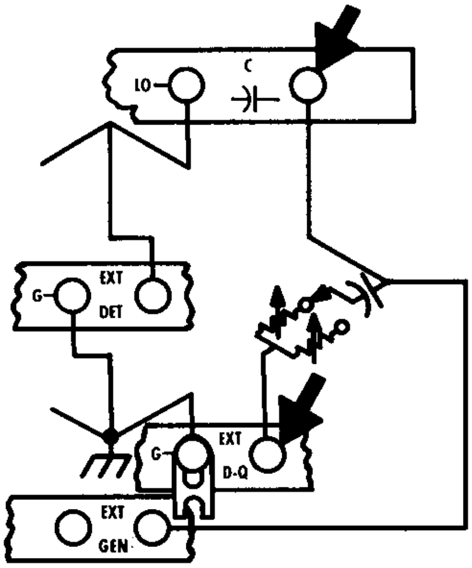
Connect between left hand terminals of R and EXT D-Q.

Resistance in Kilohms is DEKASTAT reading.

2.5 USING BRIDGE ELEMENTS (cont. ii)

2.5.3 STANDARD CAPACITOR





Set circuit selector to C.

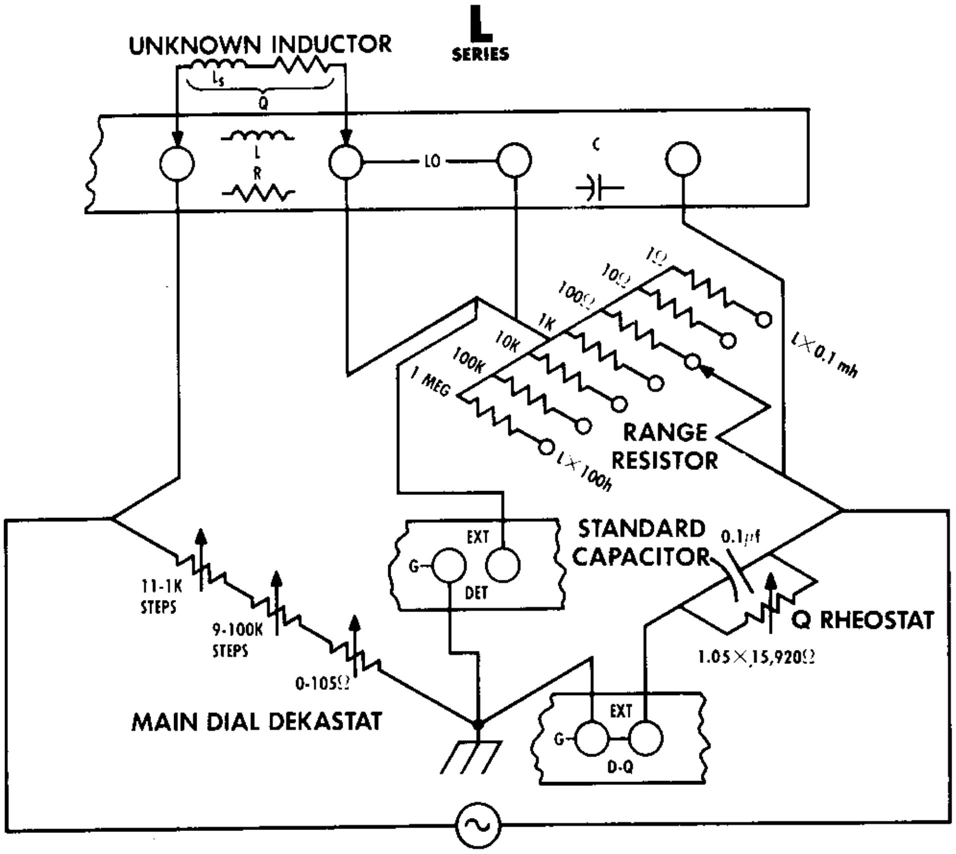
Set D-Q dial as desired.

Set to EXT-GEN and EXT-DET.

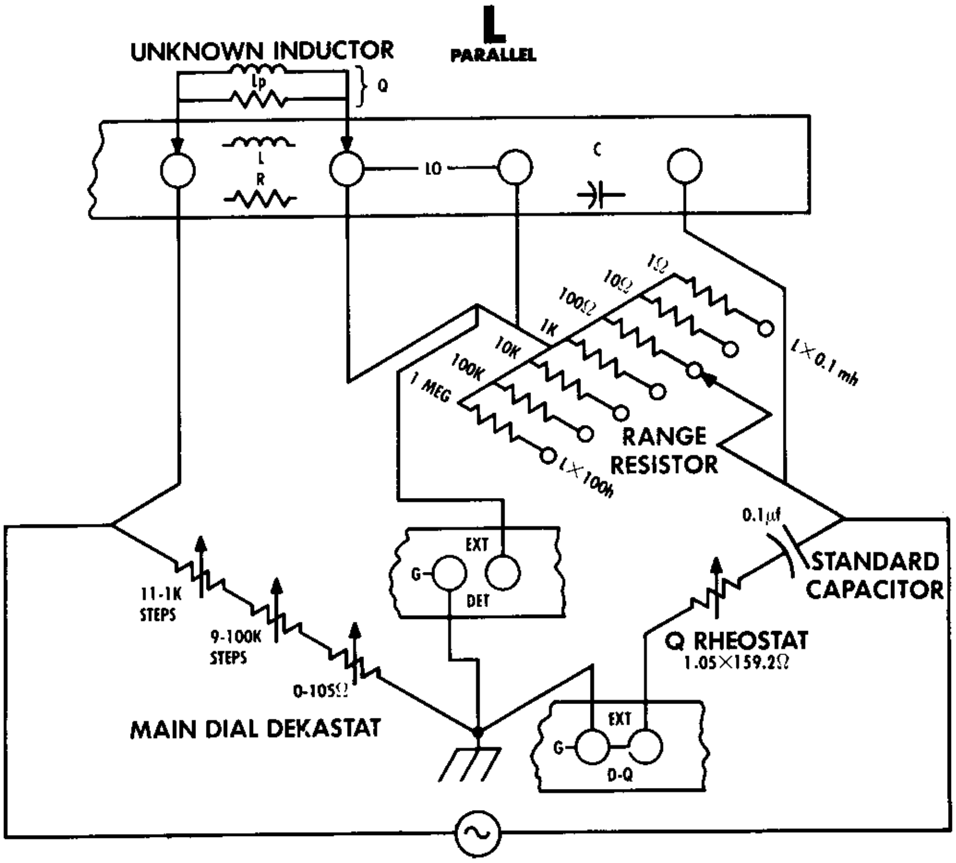
Open EXT D-Q Jumper to disconnect chassis.

Connect between right hand terminals of C and ungrounded EXT D-Q terminal.

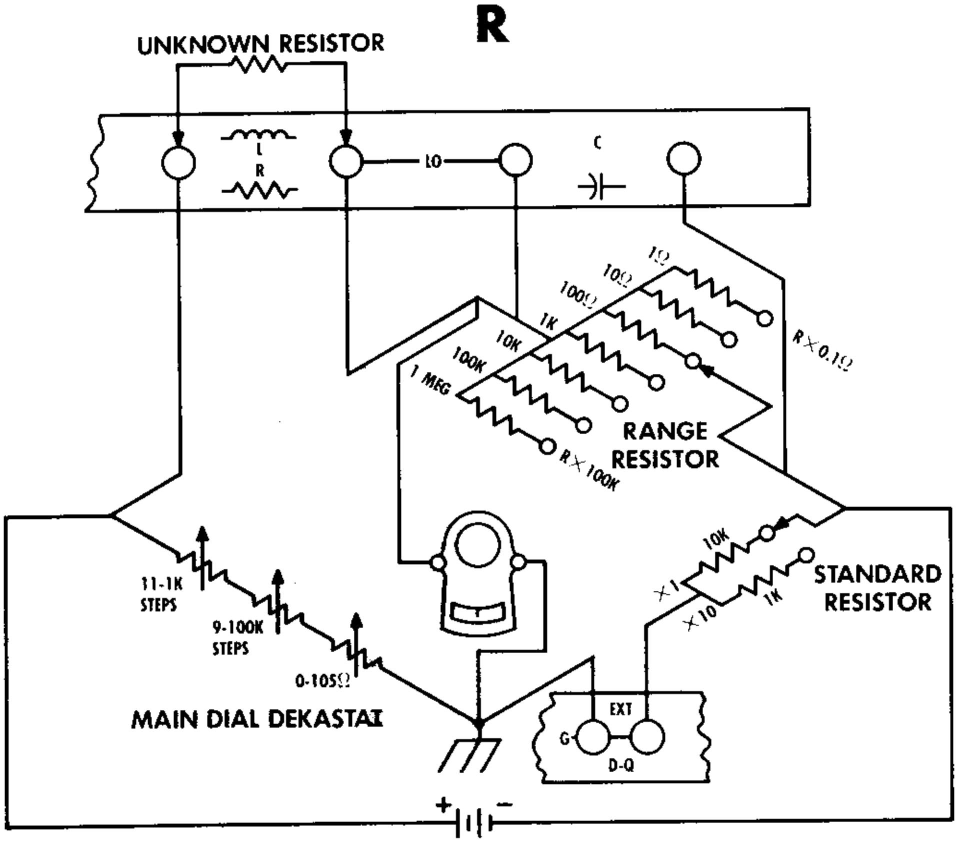
3. CIRCUIT DIAGRAMS



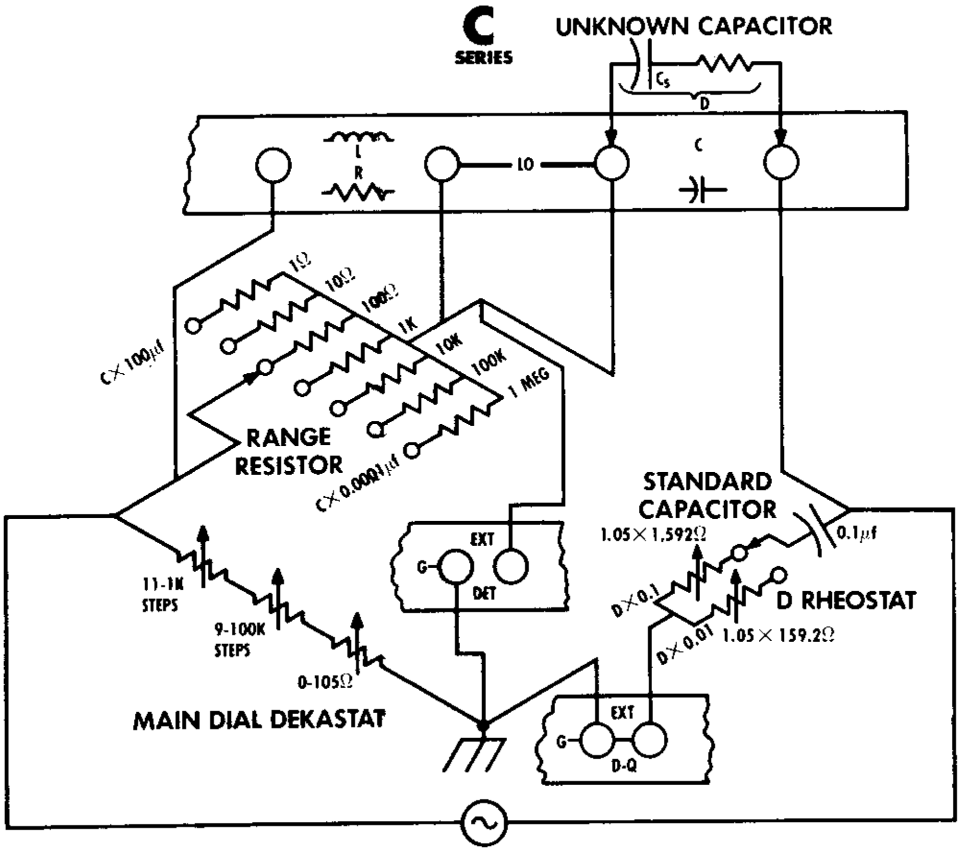
3.1 SERIES INDUCTANCE BRIDGE



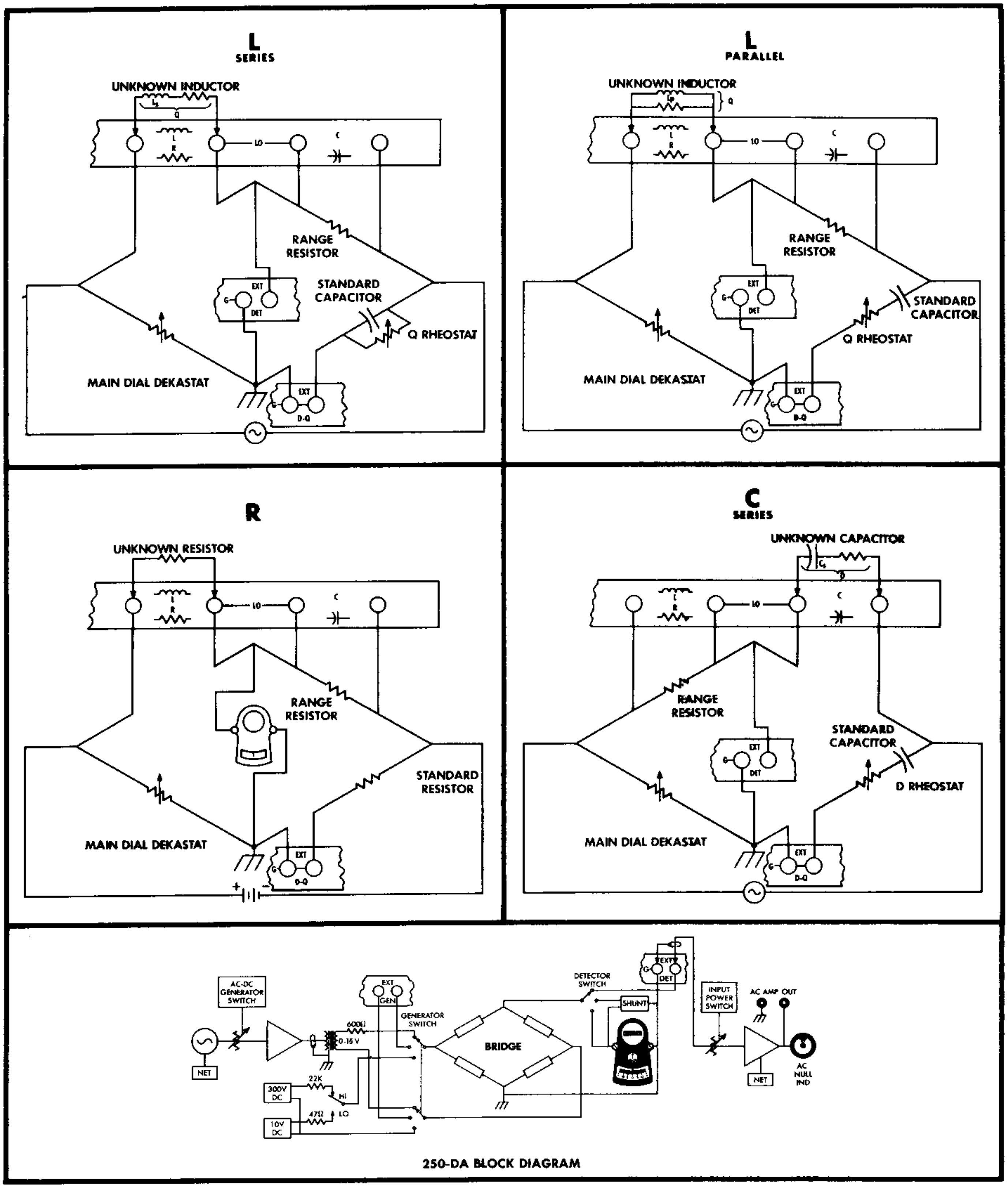
3.2 PARALLEL INDUCTANCE BRIDGE



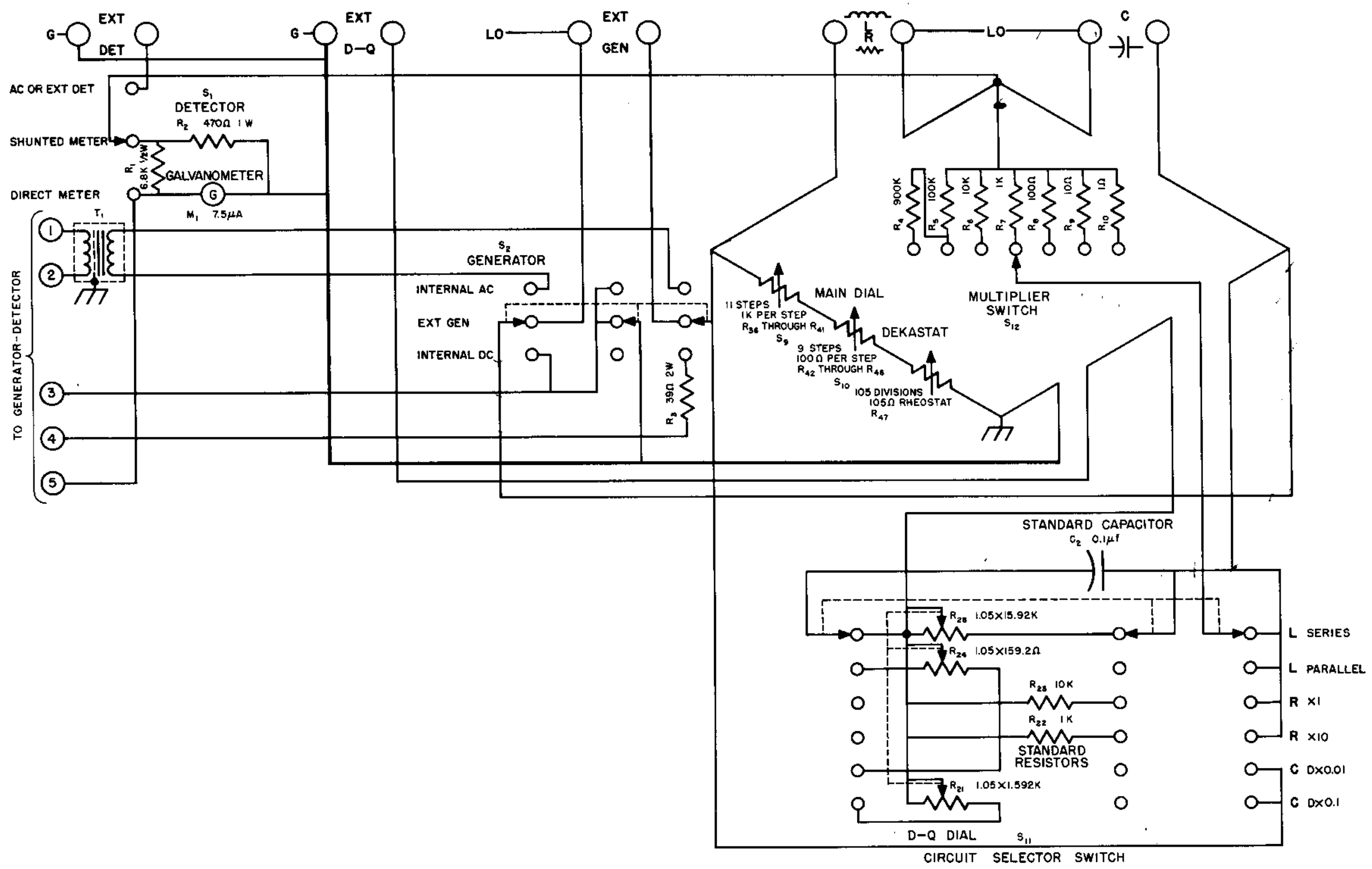
3.3 RESISTANCE BRIDGE



3.4 SERIES CAPACITANCE BRIDGE



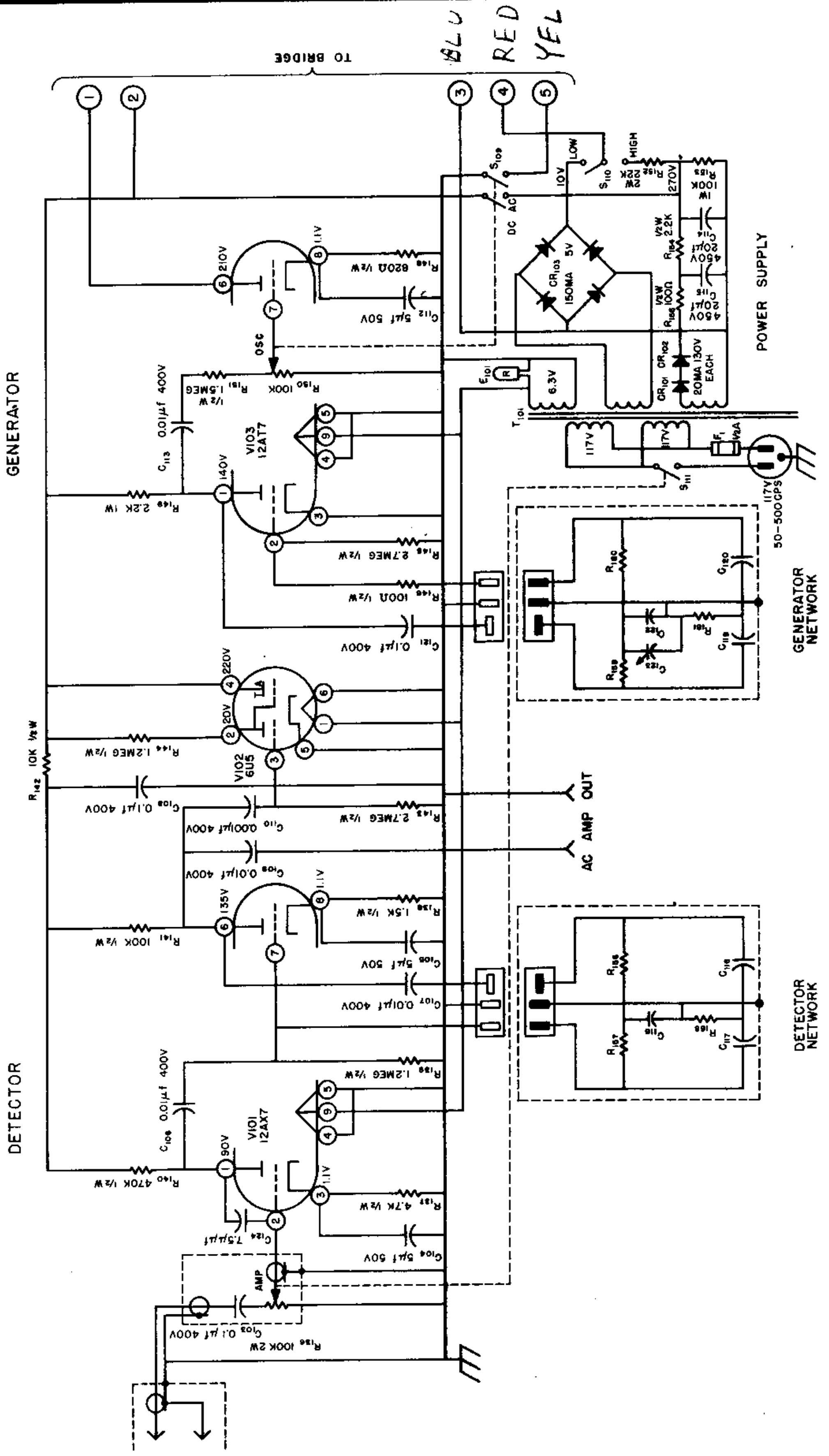
3.5 BASIC CIRCUITS



3.6 BRIDGE CIRCUIT DIAGRAM

3.6 BRIDGE CIRCUIT DIAGRAM (cont.)

				esi Part No.
RESISTORS				
R_1	6.8 K	±10%	1/2 W	
R_2	470 Ω	±10%	1 W	
R_3	39 Ω	±10%	2 W	
R_4	900 K	±0.1%	1/2 W	
R_5	100 K	±0.05%	1/2 W	
R_6	10 K	±0.05%	1/2 W	
R_7	1 K	±0.05%	1/2 W	
R_8	100 Ω	±0.05%	1/2 W	
R_9	9.996 Ω	±0.05%	1/2 W	
R_{10}	0.996 Ω	±0.25%	1/2 W	
R_{21}	1.67 K	±1%	7.5 W	4239
R_{22}	1 K	±0.05%	1/2 W	
R_{23}	10 K	±0.05%	1/2 W	
R_{24}	0 - 166 Ω	±1%	7.5 W	4237
R_{25}	0 - 16.750 K	±1%	7.5 W	4236
R_{36}	1 K	±0.05%	1/2 W	
R_{37} thru R_{41}	2 K	±0.05%	1/2 W	
R_{42}	100 Ω	±0.05%	1/2 W	
R_{43} thru R_{46}	200 Ω	±0.05%	1/2 W	
R_{47}	0 - 105 Ω	±1%	2 W	4376
CAPACITORS				
C_2	99,880 μμf	±0.1%		4092
SWITCHES				
S_1	DETECTOR switch			4357
S_2	GENERATOR switch			4357
S_9	LRC 1st decade switch			5633
S_{10}	LRC 2nd decade switch			5634
S_{11}	CIRCUIT SELECTOR switch			4324
S_{12}	LRC MULTIPLIER switch			1221
METER				
M_1	7.5 μa-0-7.5 μa			4330



3.7 GENERATOR-DETECTOR CIRCUIT DIAGRAM

3.7 GENERATOR-DETECTOR CIRCUIT DIAGRAM (cont.)

RESISTORS

				esi Part No.
R_{136}	100 K	linear pot		3958
R_{137}	4.7 K	±10%	1/2 W	
R_{138}	1.5 K	±10%	1/2 W	
R_{139}	1.2 meg	±10%	1/2 W	
R_{140}	470 K	±10%	1/2 W	
R_{141}	100 K	±10%	1/2 W	
R_{142}	10 K	±10%	1/2 W	
R_{143}	2.7 meg	±10%	1/2 W	
R_{144}	1.2 meg	±10%	1/2 W	
R_{145}	2.7 meg	±10%	1/2 W	
R_{146}	100 Ω	±10%	1/2 W	
R_{148}	820 Ω	±10%	1/2 W	
R_{149}	22 K	±10%	1 W	
R_{150}	100 K	linear pot		3958
R_{151}	1.5 meg	±10%	1/2 W	
R_{152}	22 K	±10%	2 W	
R_{153}	100 K	±10%	1 W	
R_{154}	2.2 K	±10%	1/2 W	
R_{155}	100 Ω	±10%	1/2 W	

CAPACITORS

C_{103}	0.1 µf	±20%	400 V	1429
C_{104}	5 µf	electrolytic	50 V dc	
C_{105}	5 µf	electrolytic	50 V dc	
C_{106}	0.01 µf	±20%	400 V	
C_{107}	0.01 µf	±20%	400 V	
C_{108}	0.1 µf	±20%	400 V	
C_{109}	0.01 µf	±20%	400 V	
C_{110}	1000 µµf	±20%	500 V	
C_{112}	5 µf	electrolytic	50 V dc	

				esi Part No.
C_{113}	0.01 µf	±20%	400 V	
C_{114}	20 µf	electrolytic	450 V dc	1425
C_{115}	20 µf	electrolytic	450 V dc	1425
C_{124}	7.5 µµf	±20%		

TRANSFORMERS

T_{101}	Power transformer assembly			3932

SWITCHES

S_{109}	OSC - DC switch			3958
S_{110}	HIGH-LOW DC switch			3963
S_{111}	Power switch			3958

TUBES

V101	12AX7 or equiv			1804
V102	6U5 or equiv			1803
V103	12AT7 or equiv			5276

RECTIFIERS

CR_{101}		20 ma	230 V	2535
CR_{102}		20 ma	230 V	2535
CR_{103}		150 ma	25 V	3981

LAMPS

E_{101}	Pilot Lamp	6-8 V		1800

FUSES

F_1	Fuse, 3 AG	1/2 a	250 V	1802

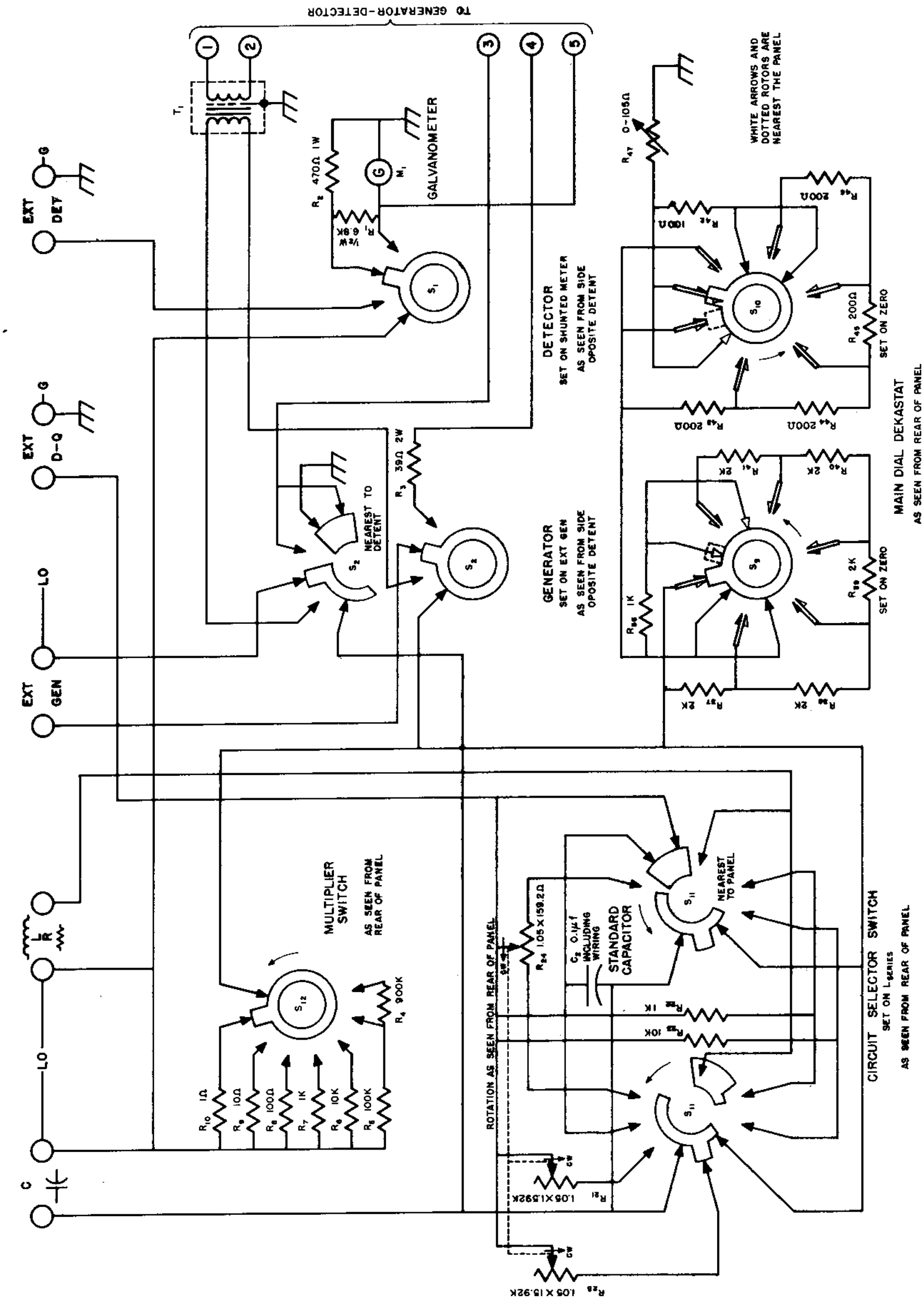
DETECTOR TUNING NETWORK*

Frequency:	0.1 kc	0.4 kc	1 kc	10 kc
R_{156}	195 K	178 K	167 K	167 K
R_{157}	195 K	178 K	167 K	167 K
R_{158}	62 K	70 K	70 K	58 K
C_{116}	0.01 µf	2500 µµf	1000 µµf	100 µµf
C_{117}	0.01 µf	2500 µµf	1000 µµf	100 µµf
C_{118}	0.02 µf	5000 µµf	2150 µµf	200 µµf

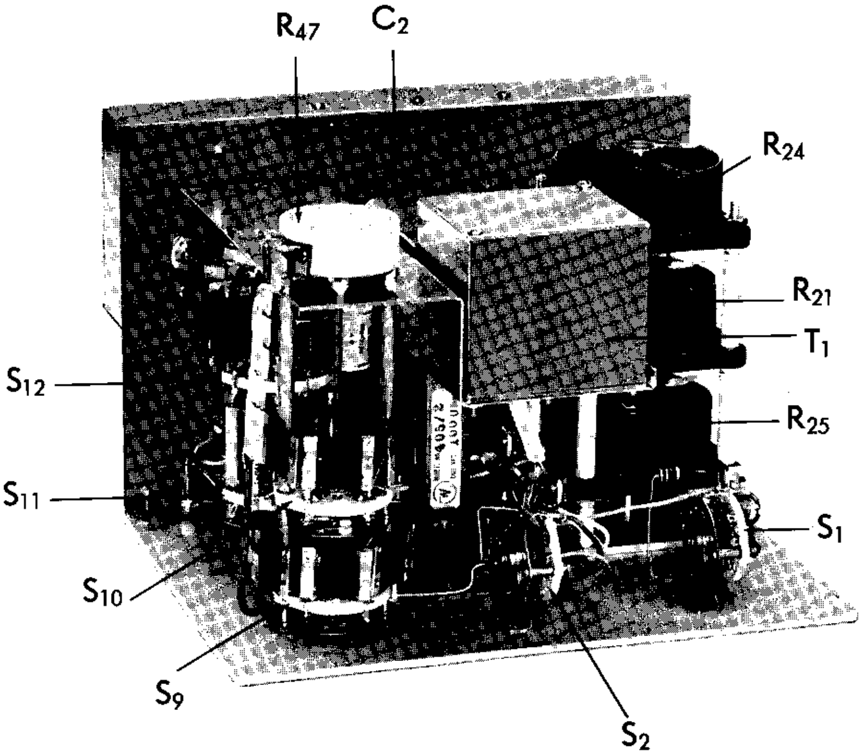
GENERATOR TUNING NETWORK*

Frequency:	0.1 kc	0.4 kc	1 kc	10 kc
R_{159}	185 K	172 K	172 K	180 K
R_{160}	185 K	172 K	172 K	180 K
R_{161}	58 K	58 K	58 K	43.5 K
C_{119}	0.01 µf	2500 µµf	1000 µµf	100 µµf
C_{120}	0.01 µf	2500 µµf	1000 µµf	100 µµf
C_{122}	0.025 µf	5000 µµf	2000 µµf	200 µµf
C_{123}		110 - 580 µµf	110 - 580 µµf	9 - 180 µµf

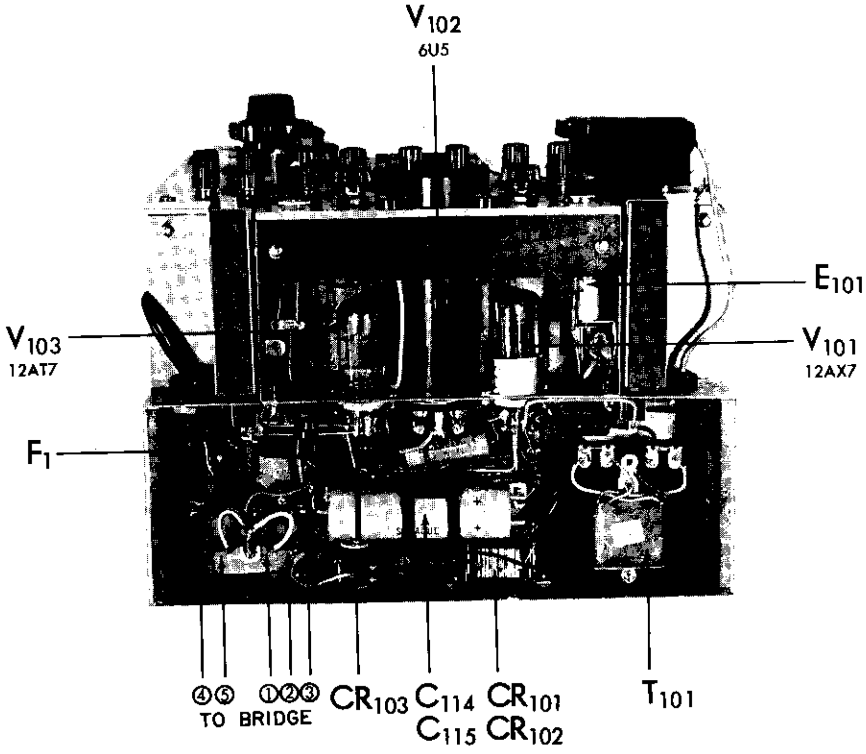
* Approximate values. Actual values adjusted for proper frequency and gain.



3.8 BRIDGE WIRING DIAGRAM



3.9 BRIDGE PARTS PLACEMENT



3.10 GENERATOR-DETECTOR PARTS PLACEMENT

RANGE RESISTORS

Safe Power limited to 1/2 watt per resistor

Resistance in Ohms	Max Voltage in Volts	Max Current in Milliamperes
1	0.71	710.00
10	2.30	230.00
100	7.10	71.00
1,000	23.00	23.00
10,000	71.00	7.10
100,000	230.00	2.30
1,000,000	250.00	0.25

D-Q RHEOSTATS

Safe power limited to 7 watts into total resistance

Resistance in Kilohms	Maximum Resistance in Ohms	Max Voltage in Volts	Max Current in Milliamperes
D-Q reading x 0.0159	167	35	210
D-Q reading x 0.159	1,670	110	68
D-Q reading x 1.59	16,700	350	21

STANDARD RESISTOR

Safe power limited to 1/2 watt

Resistance in Ohms	Max Voltage in Volts	Max Current in Milliamperes
1,000	23	23
10,000	71	7.1

MAIN DIAL RHEOSTAT

Safe power limited to 1/2 watt per step

Decade	Resistance in Ohms	Max Voltage in Volts per step	Max Current in Milliamperes
First	1000 Ω steps	23	23
Second	100 Ω steps	7.1	71
Rheostat	0 - 105	28 at max	270

5. CONVENIENT AUDIO FREQUENCY UNITS

For measurement and calculation in the audio frequency range the conventional electrical units are often inconvenient. A consistent set of units can be chosen so that the numerical values commonly encountered will be more practical while at the same time the equations used in calculations will not require any troublesome conversion constants. If either set of units listed below is followed consistently, the equations used for calculations will be unaltered. For example, $E = IR$ holds true equally well with E in volts, I in amperes, and R in ohms; or with E in volts, I in milliamperes and R in kilohms.

Function	Conventional Units	Convenient Audio Frequency Units
ω	radian/sec = $2\pi f_{cps}$	kiloradian/sec = $2\pi f_{kc}$
f	cps	kc
t	second	millisecond
C	farad	microfarad
Z, R and X	ohm	kilohm
L	henry	henry
I	ampere	milliamp
E	volt	volt
P	watt	milliwatt
Q and D	per unit ratio	per unit ratio

6. SERVICING AND REPAIR

NOTE! Unnecessary disassembly of the bridge may cause additional trouble instead of correcting existing trouble. Most of the bridge components can be checked without removing the chassis from the case.

If possible, the instrument should be returned to the factory or to an authorized service facility if trouble is suspected. If this is impractical the following procedure is recommended.

6.1 PRELIMINARY CHECKING

1. Check the panel controls to insure that they are positioned according to instructions covering the specific measurement being performed. It has been found in many cases that failure to obtain a bridge balance has been due to the wrong position of one or more of the panel controls.

2. Check connections between the bridge binding posts and the part under measurement. What appears to be an intermittent condition inside the instrument may be merely a poor outside connection.

3. When capacitor measurements of less than 100 μμf are made, be sure to consider zero capacitance of the bridge.

4. If the bridge cannot be balanced when measuring capacitance, check the capacitor under measurement for defects. It may be shorted or open.

5. If a resistor is being measured, be sure it is not open.

6.2 CHECKING PROCEDURE

NOTE: The bridge operator must acquire a knowledge of abnormal outside conditions that are reflected in unsatisfactory bridge operation so that tampering with the bridge will be avoided.

When it has been ascertained that the difficulty is not due to outside causes, the following procedures should be followed in conjunction with the trouble shooting chart. The measurements described in 6.2 should be made without removing the bridge chassis from the case.

CAUTION: Unqualified personnel must not tamper with the bridge. Unauthorized repairs will invalidate our warranty. If the tests outlined in the following paragraphs indicate the need for major repairs, our Service Department will be glad to furnish necessary repair information as well as any replacement parts. If the instrument is more than one year old, a reasonable charge may be expected for replacement parts or for complete reconditioning if the instrument is returned to the factory.

6.2.1 TEST EQUIPMENT AND TOOLS

TOOL OR TEST EQUIPMENT	TYPICAL MODEL	USE
Wheatstone Bridge	esi Model 230-R	For accurate resistance measurements
Multimeter	Simpson Model 260	For voltage and resistance checking
Oscilloscope (frequency and voltage calibrated)	Tektronix Model 533 with the Model B or C plug-in	For checking generator output
Laboratory Resistance Standard	esi Model RS-624	For checking accuracy of resistance readings
Laboratory Capacitance Standard	General Radio Model 1409-T Standard Capacitor, 0.1 µf	For checking accuracy of capacitance and inductance readings
Screw driver		For removing bridge from case
Allen-head wrenches	No's 8 and 10, hexagon	For loosening or tightening setscrews

6.2.2 TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	PROCEDURE
Bridge inoperative for dc measurements	D-Q jumper removed	Replace D-Q jumper
	Galvanometer locked	Unlock galvanometer
	Defective dc generator	Test dc generator for proper voltage
	Faulty wiring; galvanometer will not come to zero	Check wiring to be sure that no short circuits exist and that exposed wiring does not touch the metal cabinet
	Faulty switch	Check all switches for proper contacts and operation

6.2.2 TROUBLE SHOOTING CHART (cont. i)

SYMPTOM	PROBABLE CAUSE	PROCEDURE
Bridge inoperative for dc measurements (cont.)	Open, shorted, or defective resistor	Test resistors R-1 through R-10 and R-22, R-23 for open and shorted circuits and rated values
	Faulty LRC decade-rheostat	Check R-11 through R-20 and R-26 for continuity and for accuracy of resistance values corresponding to settings of the LRC dial
	Defective galvanometer	Check galvanometer for proper operation
Bridge inoperative for ac resistance measurements	D-Q jumper removed	Replace D-Q jumper
	Detector unplugged	Plug detector into EXT DET terminals
	Defective ac generator	Test ac generator for proper voltage
	Faulty switch	Check all switches for proper contact and operation
	Open, shorted, or defective resistor	Test resistors R-4 through R-10, R-22, and R-23 for open and shorted circuits and for rated values
Bridge inoperative for inductance and capacitance measurements	Replace D-Q jumper	Replace D-Q jumper
	Unlock galvanometer	Plug detector into EXT DET terminals
	Defective ac generator	Test ac generator for proper voltage
	Faulty switch	Check all switches for proper contacts and operation

6.2.2 TROUBLE SHOOTING CHART (cont. ii)

SYMPTOM	PROBABLE CAUSE	PROCEDURE
Bridge inoperative for inductance and capacitance measurements (cont.)	Open, shorted, or defective resistor	Check resistors R-4 through R-10 and R-21, R-24 for open and shorted circuits, and for rated values
	Faulty LRC decade-rheostat	Check R-11 through R-20 and R-26 for continuity and for accuracy of resistance values corresponding to settings of the LRC dial
	Faulty capacitor C-2	Check capacitor C-2 for an open or shorted circuit, for leakage, and for proper value
Readings inaccurate	Rheostat improperly calibrated	Recalibrate LRC decade-rheostat R-11 through R-20 and R-26. Also D and Q rheostats R-21, R-24 and R-25
Power indicator lamp fails to light	No ac line voltage	Trace failure in ac power source
	Null-amplifier gain control knob is not positioned correctly	Reset control knob so white dot is at OFF when control shaft is at extreme left position
	Fuse defective	Replace with 1/2 amp fuse
	Power indicator lamp burned out	Replace with No. 47 bulb
	AC power switch defective	Check and replace if necessary
	Power cable defective	Repair or replace cable
	Power transformer defective	Check for continuity of filament winding; replace transformer if necessary

6.2.2 TROUBLE SHOOTING CHART (cont. iii)

SYMPTOM	PROBABLE CAUSE	PROCEDURE
Line fuse blows instantly when power switch is turned ON	Defective filter capacitors	Check capacitors C_{114} and C_{115} for possible short to ground; replace if necessary
	Defective rectifier	Check all rectifiers for possible short to ground; replace if necessary
	Power transformer defective	Check windings for possible short circuit; replace if necessary
Some tube filaments fail to light	Tubes defective	Check continuity of filaments; replace defective units
	Broken filament lead	Check circuit continuity and repair if necessary
Failure of 10 volt (dc) supply	Defective selenium rectifier (CR_{103})	Check forward and back resistance of rectifier; replace if necessary
	Defective 10 volt transformer winding	Check continuity of 10 volt winding; replace transformer if necessary
Failure of 270 volt (dc) supply	Defective filter capacitors	Check capacitors C_{114} and C_{115} for possible short circuit to ground; replace if necessary
	Defective selenium rectifiers (CR_{101} and CR_{102})	Check forward and back resistance of rectifiers; replace if necessary
	Open transformer winding	Check continuity of high voltage transformer winding; replace transformer if necessary
No dc generator output	Wrong switch setting used	Recheck switch positions
	Defective switches	Check switch continuities; replace if necessary

6.2.2 TROUBLE SHOOTING CHART (cont. iv)

SYMPTOM	PROBABLE CAUSE	PROCEDURE
Failure to see green target on visual null indicator	No plate or target voltage	Check power supply; see above
	Defective tube	Replace 6U5
Failure to see null signal on visual null indicator	Null amplifier defective	Plug headphones in pin jacks and listen for amplifier signal; if none, see below
	Defective generator	Check generator output
	Defective tube	Replace 6U5
	Defective input cable	Check continuity of all leads including shield, repair as found necessary
	Defective bridge circuit	Check all circuits associated with instrument; correct as necessary
Detector input signal is not amplified	Defective amplifier tube	Replace 12AX7
	No plate voltage	Check associated circuits for open resistors (R_{140}, R_{141}, R_{142}) or short circuited capacitor (C_{106}, C_{108}, or C_{124}); replace any defective components
		Remove amplifier plug-in peaking unit; if amplifier resumes operation, check plug-in unit for possible short to ground
		Check power supply; see above
	Open cathode circuit	Check all cathode circuit components (R_{137}, R_{138}, C_{104} and C_{105}); replace any defective components
	Defective input wiring or control potentiometer	Check input circuitry and continuity of R_{136}

6.2.2 TROUBLE SHOOTING CHART (cont. v)

SYMPTOM	PROBABLE CAUSE	PROCEDURE
Failure to oscillate	Defective tube	Replace 12AT7
	No plate voltage	Check power supply; see above. Check resistor R_{149}; replace if defective
	Defective plug-in oscillator unit	Check values of all components in plug-in unit; replace any defective ones
		Check for possible shorts in plug-in unit
Failure to amplify oscillator signal	Defective tube	Replace 12AT7
	Open cathode circuit	Check R_{148}; replace if defective
	Defective input circuit	Check R_{151}, C_{113} and control potentiometer R_{150}; replace any defective component
	No plate voltage	Check power supply; see above
		Check continuity of primary winding of T_1; replace T_1 if necessary
No generator output	Defective coupling transformer	Check continuity of secondary of T_1 and associated wiring; replace transformer if necessary
Output signal off frequency	Oscillator network out of adjustment	Readjust C_{123} to give correct frequency

6.2.3 CHECKING THE DC GENERATOR

Set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	INTERNAL DC
CIRCUIT SELECTOR switch	C series D X 0.01
HIGH C TERMINAL	Connect negative lead of voltmeter
HIGH L-R TERMINAL	Connect positive lead of voltmeter

Check the voltage indicated by the voltmeter:

DC GENERATOR VOLTAGE SWITCH	APPROX. VOLTS 	SCALE ON 20,000 Ω/V VOLTMETER
HIGH	300	1000 V
LOW	10	50 V

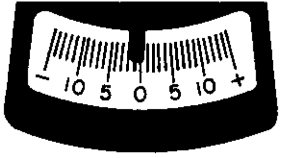
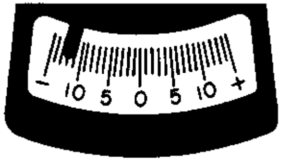
6.2.4 CHECKING THE GALVANOMETER

Set the controls as follows:

CONTROL	SETTING
CIRCUIT SELECTOR switch	R X 1
MULTIPLIER switch	R X 100 K
GENERATOR switch	EXT GEN
DETECTOR Switch	SHUNTED METER
MAIN DIAL	0
AMP control	With dot up
OSC control	To dc (extreme counter clockwise position)
DC GENERATOR VOLTAGE switch	LOW
GALVANOMETER	Unlock and zero the galvanometer
GENERATOR switch	INTERNAL DC

6.2.4 CHECKING THE GALVANOMETER (cont.)

The meter readings should then be approximately as indicated in the chart below:

DETECTOR SWITCH SETTING	APPROXIMATE DEFLECTION
SHUNTED METER	
DIRECT METER	

6.2.5 CHECKING THE AC GENERATOR

Set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	INTERNAL AC
CIRCUIT SELECTOR switch	L - Series
D-Q DIAL	Completely counter clockwise (setting below D-Q = 0)
EXT DET terminals	Remove the plug
EXT D-Q terminals	Remove the shorting bar. Connect an oscilloscope to the EXT D-Q terminals with the ground of the oscilloscope connected to the terminal marked G

The oscilloscope pattern for the one kilocycle generator tuning network should be a reasonably good 1000 cycle sine wave. The peak-to-peak amplitude should be about 40 volts with the OSC control full clockwise. A small amount of distortion can be tolerated because of the high harmonic rejection of the tuned detector.

6.2.6 CHECKING THE AC DETECTOR

Set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	INTERNAL AC
CIRCUIT SELECTOR switch	L - SERIES
MULTIPLIER switch	L X 100 h
MAIN DIAL	0
OSC control	Completely clockwise
D-Q DIAL	Completely counter clockwise (setting below D-Q = 0)

Check the values in the following table:

MAIN DIAL SETTING	AC NULL IND. OPENING
0.000	 Completely Open
0.300	 Approximately Closed

6.2.7 CHECKING THE RANGE RESISTORS

Set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	EXT GEN
CIRCUIT SELECTOR switch	C SERIES D X 0.01
AMP control	Extreme counter clockwise position (off)
L-R TERMINALS	Connect ohmmeter test leads

6.2.7 CHECKING THE RANGE RESISTORS

Check the values in the following table:

MULTIPLIER SWITCH READING RX	OHMMETER READING
100 K	1 Megohm
10 K	100 K
1 K	10 K
100 Ω	1 K
10 Ω	100 Ω
1 Ω	10 Ω
0.1 Ω	1 Ω

6.2.8 CHECKING THE STANDARD RESISTORS

Set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	EXT GEN
CIRCUIT SELECTOR switch	R X 1
C HIGH TERMINAL; EXTERNAL D-Q TERMINAL MARKED G. (D-Q shorting bar must be in position.)	Connect ohmmeter test leads

Check the values in the following table:

CIRCUIT SELECTOR SWITCH SETTING	OHMMETER READING
R X 1	10 K
R X 10	1 K

6.2.9 CHECKING THE MAIN DIAL DEKASTAT®

Set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	EXT GEN
CIRCUIT SELECTOR switch	R X 1
L-R HIGH TERMINAL; EXTERNAL D-Q TERMINAL MARKED G. (D-Q shorting bar must be in position.)	Connect ohmmeter test leads

The ohmmeter reading in kilohms should agree with the MAIN DIAL setting.

6.2.10 CHECKING THE D-Q RHEOSTATS

6.2.10.1 To check R_{25} set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	EXT GEN
CIRCUIT SELECTOR switch	L - SERIES
MULTIPLIER switch	100 h
D-Q DIAL	10
C HIGH TERMINAL, EXT D-Q TERMINAL MARKED G. (shorting bar must be in position)	Connect ohmmeter leads

The ohmmeter should read about 16 K.

6.2.10.2 To check R_{24} and R_{21}, set the controls as follows:

CONTROL	SETTING
DETECTOR switch	AC OR EXT DET
GENERATOR switch	EXT GEN
AMP control	Dot up
OSC control	Dot up
MULTIPLIER switch	C X 0.1 µf Be sure to use this setting
C TERMINALS	Decade resistor in series with 0.1 µf standard capacitor

To check R_{24}, set the CIRCUIT SELECTOR switch to C SERIES D X 0.01. The resulting D-Q DIAL readings should be as follows:

RESISTANCE IN SERIES WITH 0.1 µf CAPACITOR	D-Q DIAL READING
18 Ω	1.0
82 Ω	5.0
161 Ω	10.0

To check R_{21}, set the CIRCUIT SELECTOR switch to C SERIES D X 0.1. The resulting D-Q DIAL readings should be as follows:

RESISTANCE IN SERIES WITH 0.1 µf CAPACITOR	D-Q DIAL READING
161 Ω	1.0
798 Ω	5.0
1594 Ω	10.0

If these tests indicate possible defects in the D-Q rheostat, remove the bridge from the case, disconnect the rheostat and check the resistance values individually.

6.2.11 CHECKING THE STANDARD CAPACITOR

Check the standard capacitor by measuring a capacitor of known value. We recommend the 0.1 μf standard capacitor listed in 6.2.1. If this test indicates that the standard capacitor is unsatisfactory, remove the bridge from the case. Disconnect the standard capacitor and check it with a capacitance bridge. (The esi Model 270 Capacitance Bridge is recommended.) The value should be 99,880 μμf ±0.1%.

6.3 REMOVING THE CHASSIS FROM THE CASE

6.3.1 REMOVING THE CHASSIS

Prepare a soft, clean place to set the instrument. Be sure that no projections or pointed objects will be underneath the bridge panel. See that there are no metal filings near the exposed wiring and parts of the bridge; filings which accidentally get into the chassis can cause short circuits. Loosen the four panel screws, lift out the chassis and place it carefully on the prepared surface with the panel down.

6.3.2 REPLACING THE CHASSIS

Be sure that the interior of the case is thoroughly clean. Position the bridge in the case. Replace the panel mounting screws and tighten them in place.

6.4 REPAIRING THE BRIDGE

Repairs are limited to mechanical adjustment and replacement of parts. When trouble shooting indicates that a component is defective, replace that component.

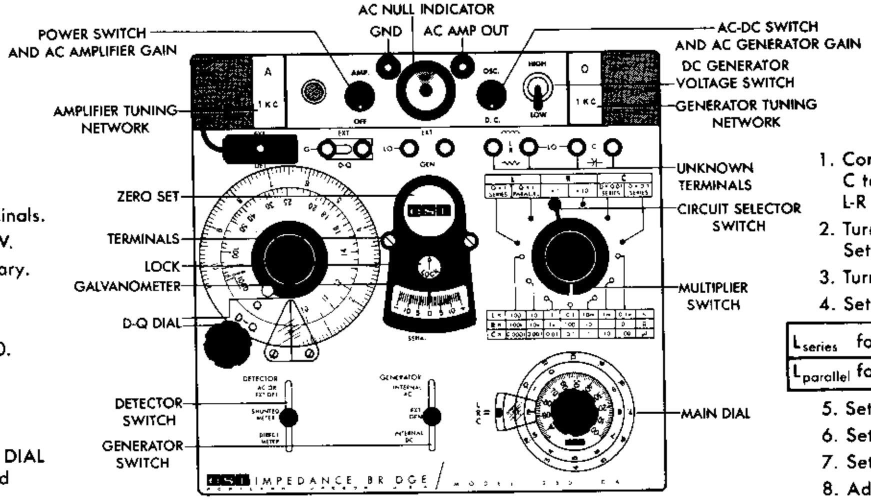
esi

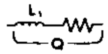
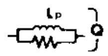
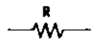
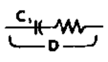
Universal Impedance Bridge

MODEL 250 DA

DC RESISTANCE MEASUREMENTS

1. Connect the UNKNOWN RESISTOR to the L-R terminals.
2. Set the DC GENERATOR VOLTAGE switch to LOW.
3. Unlock the GALVANOMETER and ZERO if necessary.
4. Turn the AMP control clockwise for power.
5. Turn the OSC control counter-clockwise for dc.
6. Set the CIRCUIT SELECTOR switch to Rx1 or Rx10.
7. Set the MAIN DIAL to 3.000.
8. Set the DETECTOR switch to SHUNTED METER.
9. Set the GENERATOR switch to INTERNAL DC.
10. Adjust first the MULTIPLIER switch then the MAIN DIAL for minimum galvanometer deflection. If increased sensitivity is needed set the DETECTOR switch to DIRECT METER.
11. The MEASURED RESISTANCE is the product of the readings of the CIRCUIT SELECTOR switch, the MULTIPLIER switch and the MAIN DIAL.
12. For resistances greater than 10K set the DC GENERATOR VOLTAGE switch to HIGH. (WARNING: This may put 300 volts on the unknown terminals.)
13. Set the GENERATOR switch to EXT GEN and the DETECTOR switch to SHUNTED METER before disconnecting the MEASURED RESISTOR.
14. LOCK the GALVANOMETER and set the AMP switch to OFF before leaving the bridge.



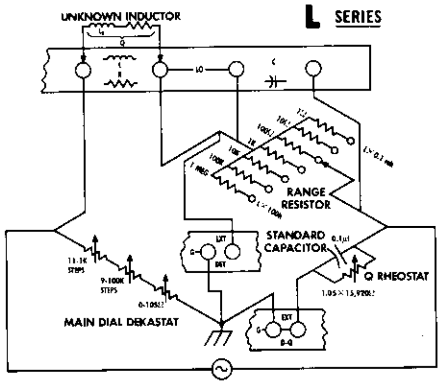
SELECTOR SWITCH SETTING	EQUIVALENT CIRCUIT	CONVERSION EQUATIONS
L Series		$L_p = L_s \cdot \left(1 + \frac{1}{Q^2}\right)$ $D = \frac{1}{Q}$
L Parallel		$L_s = L_p \cdot \left(\frac{Q^2}{1+Q^2}\right)$ $D = \frac{1}{Q}$
R		$G = \frac{1}{R}$
C Series		$C_p = C_s \cdot \left(\frac{1}{1+D^2}\right)$ $Q = \frac{1}{D}$

AC CAPACITANCE AND INDUCTANCE MEASUREMENTS

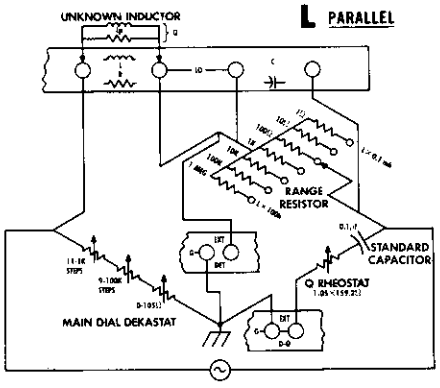
1. Connect the UNKNOWN CAPACITOR to the C terminals or the UNKNOWN INDUCTOR to the L-R terminals.
2. Turn the AMP control clockwise for power. Set the dot up.
3. Turn the OSC control clockwise for ac. Set the dot up.
4. Set the CIRCUIT SELECTOR switch to L or C.

L_{series} for $Q<10xf_{kc}$	C_{series} Dx0.01 for $0<D<0.1xf_{kc}$
$L_{parallel}$ for $Q>10/f_{kc}$	C_{series} Dx0.1 for $0.1xf_{kc}<D<1.0xf_{kc}$

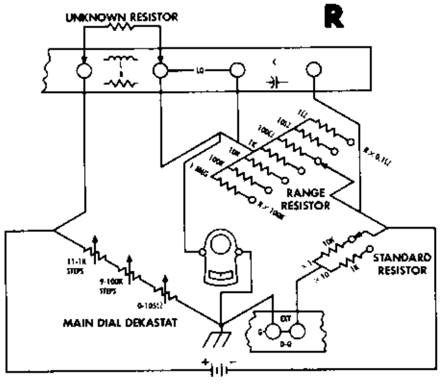
5. Set the MAIN DIAL to 3.000.
6. Set the DETECTOR switch to AC OR EXT DET.
7. Set the GENERATOR switch to INTERNAL AC.
8. Adjust first the MULTIPLIER switch then the MAIN DIAL and D-Q DIAL for the widest and sharpest possible shadow. If more or less sensitivity is needed adjust the AMP control and/or the OSC control.
9. The MEASURED CAPACITANCE or MEASURED INDUCTANCE is the product of the readings of the MULTIPLIER switch and the MAIN DIAL.
10. At 1 kc the MEASURED D or Q is the product of the readings of the CIRCUIT SELECTOR switch and the D-Q dial. For other frequencies: Multiply D and Q_{series} by the frequency in kilocycles, or divide $Q_{parallel}$ by the frequency in kilocycles.
11. Set the GENERATOR switch to EXT GEN and the DETECTOR switch to SHUNTED METER before disconnecting the MEASURED CAPACITOR or INDUCTOR.
12. Set the AMP switch to OFF before leaving the bridge.



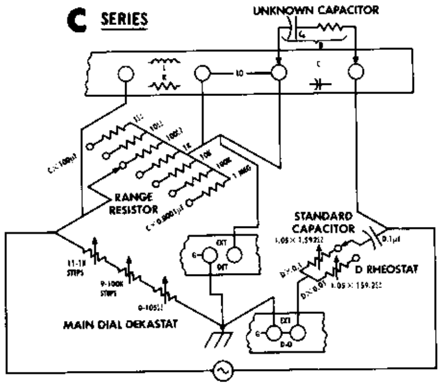
L SERIES



L PARALLEL



R



C SERIES

esi 7524 S.W. MACADAM • PORTLAND 19, OREGON