BRIDGES AND ACCESSORIES

Electro Scientific Industries
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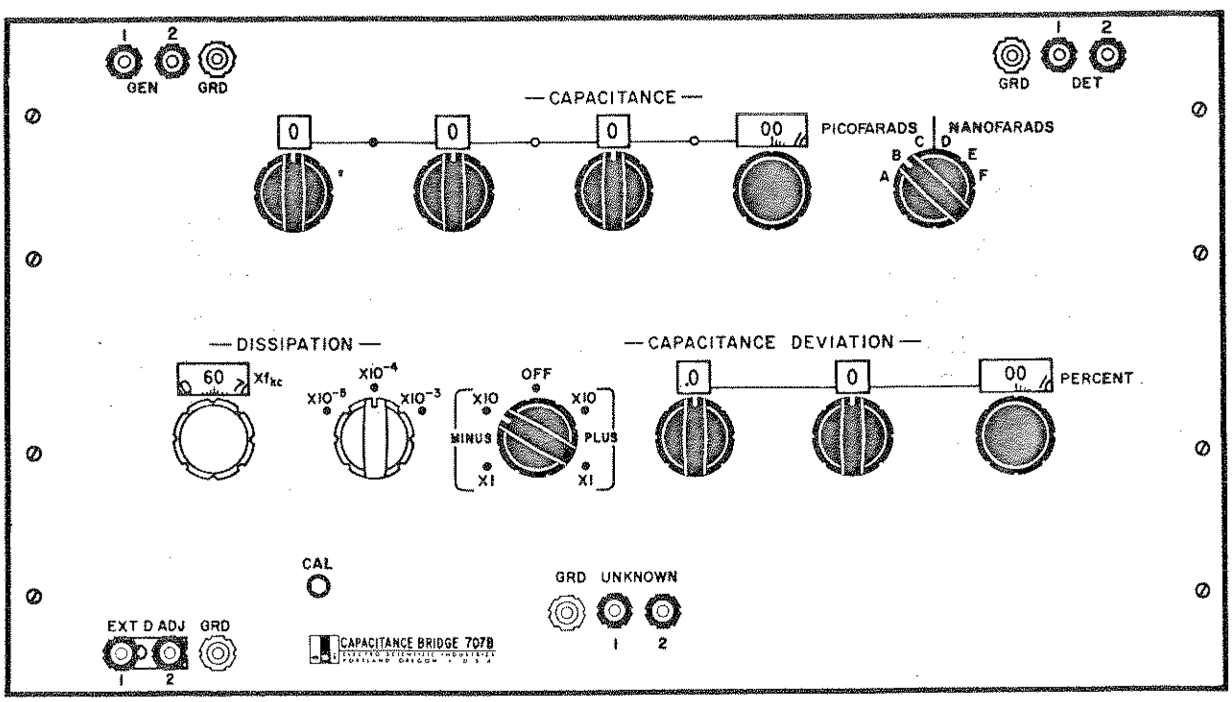
MODEL
707B

Instruction Manual

CAPACITANCE BRIDGE



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PVB® Potentiometric Voltmeter Bridge

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DEKATRAN Decade Transformer

SECTION I

GENERAL

1.1 DESCRIPTION

The ESI MODEL 707B CAPACITANCE BRIDGE is designed to measure two-terminal or three-terminal capacitors in the range from 0 to 1.2 microfarads with a resolution of 0.0001 picofarad on the lowest range. The use of a ratio transformer circuit and a hermetically sealed standard capacitor having a very low temperature coefficient of capacitance and exceptional stability assures a minimum effect from changes in room temperature, voltage, and frequency. Accuracy of the measured capacitance is referred to this one standard which can be periodically checked and adjusted to agree with a certified reference standard capacitor.

The unknown capacitor is measured in terms of the capacitance and dissipation factor of its equivalent series circuit. Capacitance is presented as an in-line reading including the decimal point and measurement unit. A deviation dial indicates the percent difference between the value of the unknown capacitor and the capacitance dial setting.

1.2 SPECIFICATIONS

Bridge circuit	Ratio transformer type comparison bridge with a single internal capacitance standard for all ranges.
Capacitance readings	
Number of ranges	6
Dial resolution	120,005 divisions full scale on any range.
Highest range	0 to 1.2 microfarads (10 picofarads per dial division)
Lowest range	0 to 12 picofarads (0.0001 picofarad per dial division)
Accuracy (at frequencies between 100 and 1000 cps)	
On the five lower ranges	± (0.01% + 1 dial division)
On the highest range	± (0.02% + 1 dial division)
Calibration adjustment	The capacitance standard can be adjusted to make the bridge agree with your certified reference standard capacitor. Since the accuracy of the transformer is essentially independent of temperature and aging effects, the adjustment of the capacitance standard simultaneously calibrates all ranges of the bridge. The ESI MODEL SC 1000 Standard Capacitor or equivalent is recommended as a reference standard.
Capacitance deviation readings	
Number of range settings	Five; (x (±10), x (±1), and OFF)
Dial resolution	12,005 divisions full scale on any range
High ranges	0 to ±12% (0.001% per dial division)

Low ranges	0 to 1.2% (0.0001% (1 ppm) per dial division)
Accuracy (at 1 kc)	± 2 dial divisions

<u>Dissipation factor readings</u>

Number of ranges	3
Dial resolution	105 divisions full scale on any range
Highest range	0 to 0.105 x frequency in kilocycles
Lowest range	0 to 0.00105 x frequency in kilocycles (0.00001 per dial division at 1 kc)
Accuracy (at 1 kc and 23°C)	$\pm (0.0001 \times \frac{C_{full\ scale}}{C_{unknown}} + 2$ dial divisions)

<u>Capacitance standard</u>

Number of capacitors	1
Capacitance value	1 nanofarad (1000 picofarads)
Type of capacitor	Three-terminal, dry nitrogen dielectric, hermetically sealed for altitude and humidity stability
Accuracy	Initially adjusted to ± 10 ppm at 23°C and 1000 cps
Stability	Long term drift should not exceed ± 20 ppm per year
Temperature coefficient	Better than ± 5 ppm/C°
Capacitance adjustment	The capacitance standard can be adjusted over a range of ± 0.03% with a resolution of better than 0.001%. This permits the bridge to be adjusted to agree with a certified reference standard capacitor.

Frequency range

100 cps to 1000 cps is the recommended range for rated accuracy. Above 1000 cps capacitance reading errors will increase as the square of the frequency, and dissipation factor errors will increase directly with frequency.

Dimensions

Width 19 in. (48.25 cm), height 10.5 in. (26.7 cm), depth 12 in. (30.5 cm).

Weight

30 lb (13.5 kg).

1.3 ACCESSORY REQUIREMENTS

To utilize the full capabilities of the MODEL 707B CAPACITANCE BRIDGE, it is necessary that an adequate generator-detector be chosen. The minimum qualifications of such a generator-detector are:

1.3.1 GENERATOR REQUIREMENTS

a) Generators that are not well isolated from ground must be coupled to the bridge through an isolation transformer.

b) The secondary and primary of the generator output transformer should be shielded from one another so that the direct capacitance between them is less than 10 pf.

c) Capacitance from the secondary of the generator output transformer to ground should be less than 50 pf.

d) The generator voltage should be adjustable from 0 to at least 100 volts for a load impedance varying between open circuit and .005 μf in parallel with 100k. A power limiting resistance of $\frac{(E_{max})^2}{4}$ should be connected in series with the generator to make sure that neither the bridge nor the detector will be damaged by excessive power.

e) Full bridge accuracy is obtained at any generator frequency between 100 cycles and 1 kilocycle. Other frequencies in the audio range may be used with reduced accuracy.

f) Maximum voltage of the generator from 1 kc up should be 350 volts. Below 1 kc, the voltage should not exceed 0.35 times the frequency in cycles per second.

1.3.2 DETECTOR REQUIREMENTS

a) The detector and its input leads should be shielded to prevent electrostatic pickup, especially from the generator.

b) It is desirable that the detector be sharply tuned to discriminate against harmonics of signal frequency, and pickup of stray signals and noise.

c) To achieve the rated, direct-reading capacitance accuracy of the bridge, the detector sensitivity should be sufficient to observe a signal of 20 microvolts or less in series with a source coupling capacitor of 1000 picofarads. To fully resolve the capacitance deviation dial resolution of 0.0001% (1 ppm) at high and low capacitances, additional detector sensitivity down to better than 1 μv is necessary.

SECTION II

OPERATING INSTRUCTIONS

2.1 GENERATOR-DETECTOR CONNECTIONS

2.1.1 GENERATOR CONNECTIONS

The upper left-hand terminals are used to connect the generator output to the capacitance bridge. Ideally the generator is rack mounted directly above the bridge and is connected to the bridge with shorting bars. However, the generator can be connected to the bridge by a twisted two-wire, shielded cable, preferably no longer than three feet. Belden 8422 is recommended. The shielding is connected to the ground terminals on the generator and bridge.

2.1.2 DETECTOR CONNECTIONS

The upper right-hand terminals are used to connect the detector to the capacitance bridge. The ESI MODEL 707B was designed for use with detector terminal 1 grounded. If the detector does not have an internal ground connection to its input, detector terminal 1 on the bridge should be connected to the GRD terminal adjacent to it. If the detector does have an internal ground connection, be sure that the grounded input terminal is connected to detector terminal 1 on the bridge. Also, make certain that there is no other connection from this terminal to ground since this will produce a stray signal input to the detector as a result of a ground loop. The detector terminal 2 must be shielded.

2.1.3 USING ESI COMPANION GENERATOR-DETECTOR MODELS

ESI companion generator-detectors such as MODELS 860B and 861A have their output and input terminals located to exactly correspond to those on the MODEL 707B BRIDGE.

2.2 MEASUREMENT SETUP

2.2.1 TWO-TERMINAL VERSUS THREE-TERMINAL CAPACITORS

The majority of capacitors are of the two-terminal type. When such a capacitor is installed in a piece of equipment or connected to a capacitance bridge, most of the capacitance will ordinarily lie within the body of the capacitor. However, a further capacitance will be associated with the stray fields between the conductors connected to the capacitor. The stray capacitance will be neither fixed nor as well defined as the capacitor itself is. It will instead vary with its surroundings. It is, therefore, a theoretical impossibility to define the capacitance of a two-terminal capacitor without first specifying its surroundings.

To eliminate the influence of the surroundings on a capacitor, it is necessary to place the capacitor within a conducting case or shield. It is then a three-terminal capacitor, the case being the third terminal. The direct capacitance between the two terminals inside the shield will then be independent of the external environment.

The connecting leads to the terminals will also have to be shielded to eliminate the influence of stray capacitances between them. Although the terminal to shield capacitance will be a function of its surroundings, it is frequently possible to place these stray capacitances so that they will not influence the circuit appreciably. This is done in the MODEL 707B by placing the terminal capacitances across the detector and a low impedance transformer ratio arm.

If a two-terminal capacitor is enclosed in a shield and one of its terminals is connected to the shield, the capacitance from the insulated terminal to the shield will still be a function of the ambient conditions. For this reason, the total capacitance cannot be defined without first defining the surroundings. If the shielded capacitance were variable, a change in capacitance could be measured very accurately. If, in fact, a switch were placed in series with the capacitor within its shield, it would provide a very accurate capacitance standard. The value of this standard would be the difference between the closed switch and open switch capacitances.

To approximate this condition, usually, the zero capacitance of the bridge is measured before connecting the capacitor to its terminals and subtracting this reading from the one obtained with the capacitor attached. Unfortunately, the stray capacitance effects around the bridge terminals will not be the same with the capacitor connected as they are with it removed. The difference between the two readings will depend upon the bridge terminal configuration and the potential of the panel, which may differ with different bridges. It is possible, however, to duplicate any bridge configuration with a test jig. The jig consists of a pair of terminals mounted on a metal panel in such a manner as to duplicate the specific bridge being used. The metal panel should extend several inches on all sides of the terminals. It should also be insulated from ground and be maintained at the same potential, relative to the terminals, as the panel of the bridge being duplicated. The zero capacitance reading to be subtracted is the value measured with the capacitor removed from the test jig, but with the test jig connected to the bridge.

Such a test jig can readily be used with a three-terminal capacitance bridge such as the 707B, to duplicate measurements made on two-terminal type bridges. No matter what test jig is used, the agreement between it and other test jigs or intended applications must be checked experimentally. There is no such thing as a "correct" test jig or terminal configuration for measuring two-terminal capacitors. The only way to agree with other measurements is to define the measurement terminal or jig configuration and duplicate it.

2.2.2 USING THE SHIELDED LEAD SET

The shielded lead set used with Model 707B Capacitance Bridge is recommended for general purpose measurements of two-terminal and three-terminal capacitors, as shown in Figure 2.2.2.

When using this lead set, be sure that it is connected to the bridge with x the three-hole shield case over all three terminals, and the ground lock screwed firmly on the GRD terminal. Note that the gold-plated binding post cap must be removed from the before the ground lock is connected.

When measuring three-terminal capacitors, connect the shield of the unknown capacitor to the shield of either test lead using a ground lead clipped to the end of the test lead shield as shown in Figure 2.2.2A.

Two-terminal capacitors can be clipped directly to the test leads or fastened to a test jig as shown in Figure 2.2.2B.

In either case, the shielding of the test leads is complete and eliminates leakage capacitance and minimizes stray ac pickup.

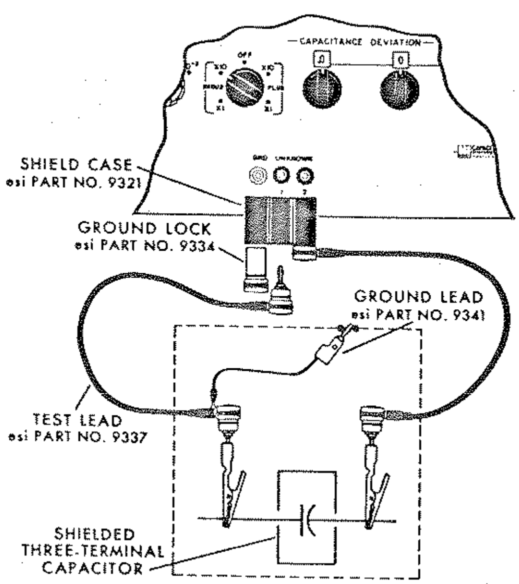


Fig. 2.2.2A

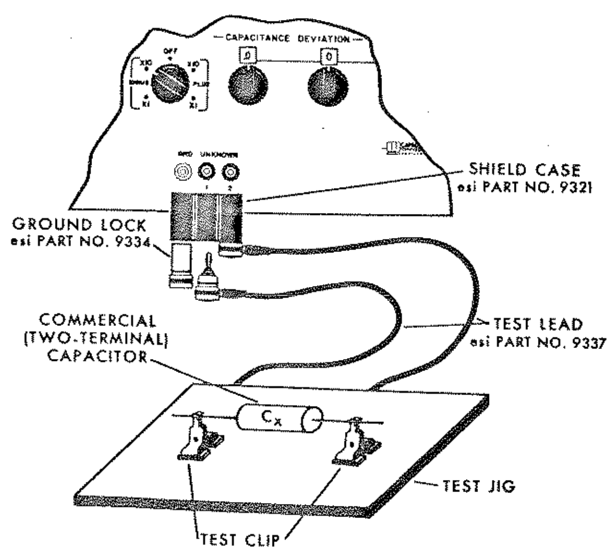


Fig. 2.2.2B

2.2.3 USING COAXIAL ADAPTERS

An adapter fitting is used with Model 707B Capacitance Bridge in order to connect the test leads to General Radio type 874 connectors. The method of using the adapters is shown in Figure 2.2.3.

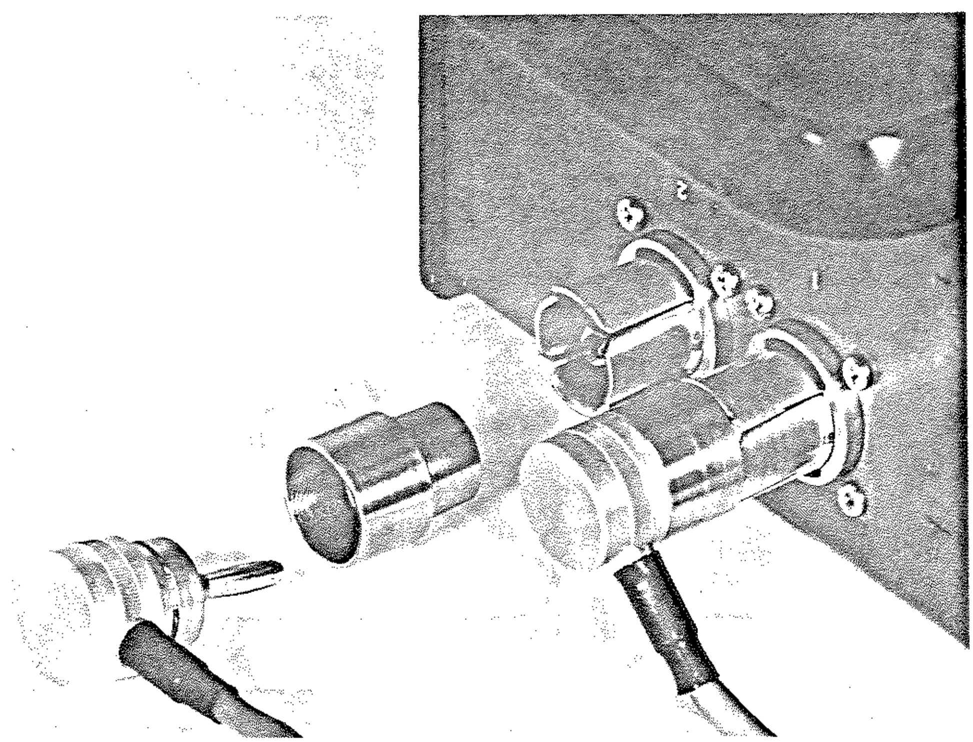


Fig. 2.2.3

2.2.4 MEASURING AC VOLTAGE APPLIED TO CAPACITOR UNDER TEST

When the bridge is balanced, UNKNOWN TERMINAL 1 is at ground potential. Therefore, the voltage between UNKNOWN 2 and GND is the same as that across the unknown capacitor. Also, since these terminals connect across a low impedance transformer winding, loading, and shielding effects are not critical.

To measure the ac voltage being applied to the capacitor under test, connect an ac voltmeter to UNKNOWN 2 and GND terminals. It is convenient to use the single-shielded test lead set as shown in Figure 2.2.4 for this measurement.

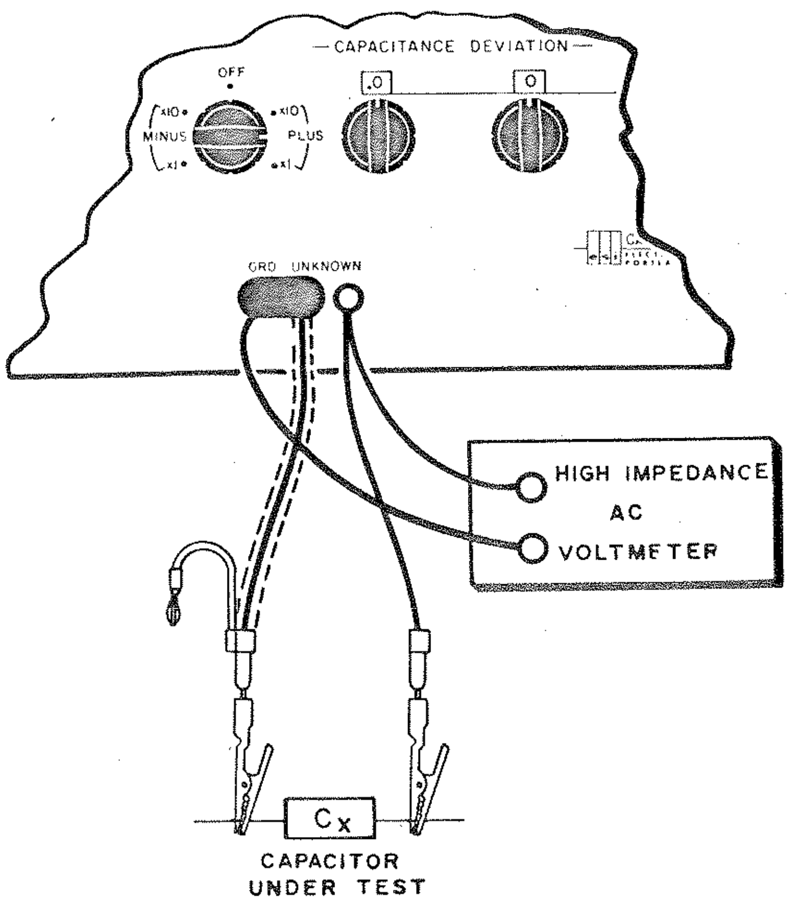


Fig. 2.2.4

2.2.5 APPLYING DC BIAS VOLTAGE TO THE CAPACITOR UNDER TEST

The circuit in Figure 2.2.5A shows the recommended connections for applying dc bias to the capacitor under test.

A battery should be used as the dc supply voltage (E). This voltage should not exceed 300 volts for protection of the Capacitance Bridge transformers and capacitors.

The resistor (R) is used to limit the dc power to the Capacitance Bridge to one watt. This protects the bridge transformer in case the capacitor under test is accidentally shorted.

The resistor (R_D) is used to control the dc bias voltage. The value of the resistor (R_L) will be determined by the dc leakage resistance of the capacitor under test (C_X) and the detector sensitivity. Adjust R_L so that the maximum dc current for the ac voltage and frequency used does not exceed that shown in the graph in Figure 2.2.5B.

The dc bias voltage can be measured by a high impedance voltmeter connected between the DET terminals.

To keep hum pickup and stray capacitances to a minimum, the components connected to the UNKNOWN 1 terminal should be shielded.

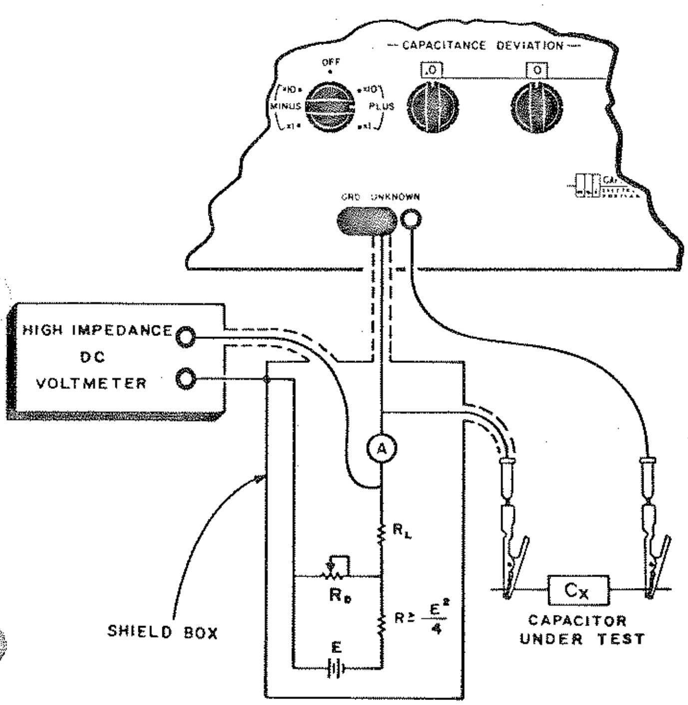


Fig. 2.2.5A

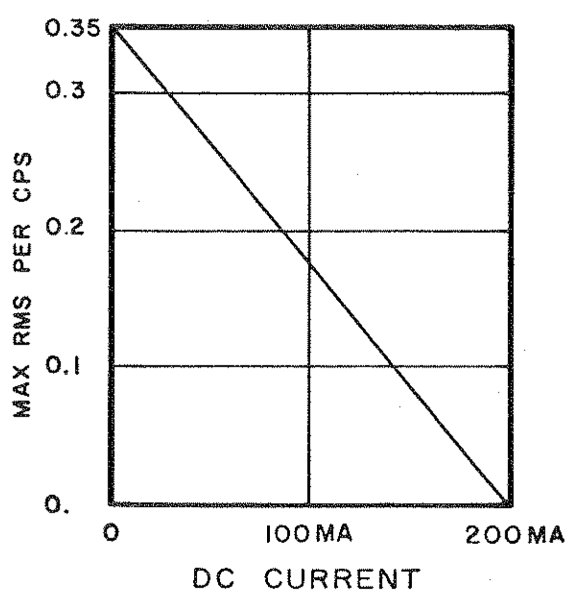
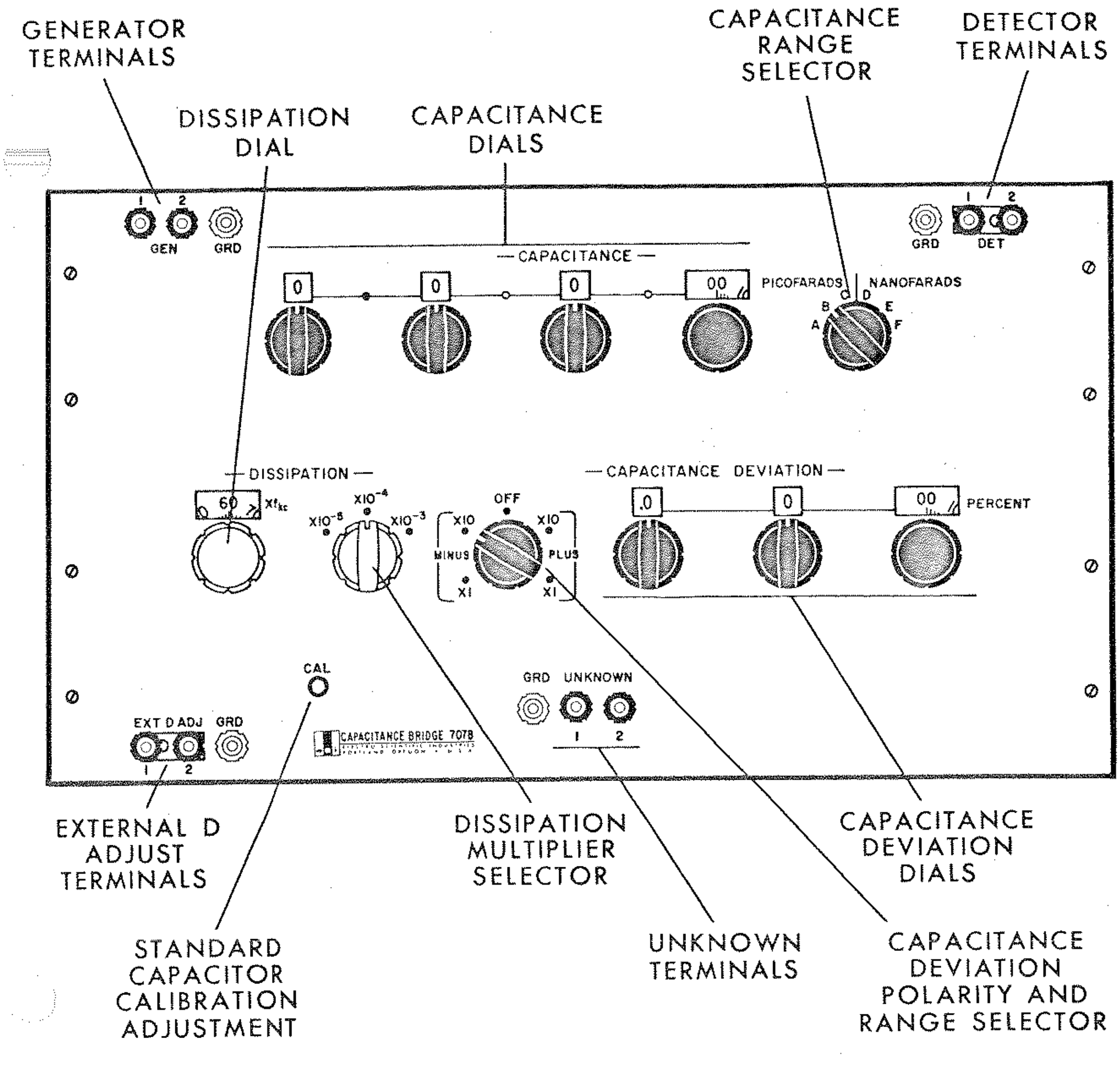


Fig. 2.2.5B



MODEL 707B PANEL CONTROLS

2.3 BALANCING AND READING

2.3.1 OPERATING CONTROLS

CAPACITANCE RANGE SELECTOR: The top, right-hand control selects from six capacitance ranges, indicates the units of measurement used, and positions the decimal point for accurate and convenient readout.

CAPACITANCE DIALS: The remaining four dials in the top row are used to determine the equivalent series capacitance value of the capacitor under test.

DISSIPATION DIAL: The bottom, left-hand dial is used to determine the dissipation factor (D) of the capacitor under test. If the operating frequency is not 1 kc, note that the dissipation factor reading includes a multiplication by the frequency in kilocycles (f_{kc}).

DISSIPATION MULTIPLIER SELECTOR: The second control from the left in the bottom row selects from three dissipation factor (D) ranges, and indicates the multiplier to be applied to the DISSIPATION DIAL reading.

CAPACITANCE DEVIATION SELECTOR: The fourth dial from the right in the bottom row selects the capacitance deviation polarity and range. When this dial is in the OFF position, the capacitance deviation dials have no effect, and the bridge is direct reading on the capacitance dials. The other four positions are used to read percent of deviation from the capacitance dial setting. Use the minus ranges for values lower than the capacitance dial setting, the plus ranges for values higher than the setting, and multiply the reading by 1 or 10 as indicated.

CAPACITANCE DEVIATION DIALS: The three dials on the right in the bottom row provide an in-line indication of the percent of difference between the value of the capacitor under test and the capacitance dial value.

2.3.2 MEASURING CAPACITANCE AND DISSIPATION FACTOR

a)	Connect an external generator and detector to the bridge.	See instructions in Section 2.1.
b)	Turn on the generator and detector and regulate the generator voltage to the lowest possible value.	DANGER HIGH VOLTAGE: The full generator output of 100 volts or more may be found on the unknown terminals. To avoid any possibility of injury always turn the generator to minimum before touching the unknown terminals.
c)	Connect the capacitor under test to the UNKNOWN TERMIALS 1 and 2.	Follow instructions in Section 2.2.
d)	Set the CAPACITANCE DEVIATION SELECTOR to the OFF position.	The CAPACITANCE DEVIATION DIALS will have no effect on the measurement now.
e)	Set the CAPACITANCE DIALS and the CAPACITANCE RANGE SELECTOR for the nominal value of the capacitor under test.	
f)	Adjust the generator output voltage to any value well below the voltage rating of the unknown capacitor.	This provides sufficient voltage for initial null search.
g)	Adjust the detector gain so that the effect of changes in the bridge setting are discernible.	
h)	Alternately adjust CAPACITANCE and DISSIPATION DIALS (and their range selectors if necessary) for a minimum indication on the detector.	If a null indication cannot be obtained, the dissipation factor (D) of the capacitor under test may be too high to measure. Refer to EXTENDED D MEASUREMENTS, paragraph 2.3.4 for recommended procedure.

i) As a null is approached, increase the generator voltage and/or the detector gain for increased sensitivity.

j) If either the CAPACITANCE or the DISSIPATION DIALS indicate less than 1/10 full scale, use the next lower capacitance or dissipation range selector setting.

k) Read the capacitance and dissipation factor on the dials.

The capacitance reading is equivalent series capacitance. To calculate other equivalent circuit values refer to Section 2.3.5.

2.3.3 MEASURING DEVIATION FROM NOMINAL CAPACITANCE

a)	Connect an external generator and detector to the bridge.	See instructions in Section 2.1.
b)	Turn on the generator and detector and regulate the generator voltage to the lowest possible value.	DANGER HIGH VOLTAGE: The full generator output of 100 volts or more may be found on the unknown terminals. To avoid any possibility of injury, always turn the generator to minimum before touching the unknown terminals.
c)	Connect the capacitor under test to the UNKNOWN TERMINALS 1 and 2.	Follow instructions in Section 2.2.
d)	Set the CAPACITANCE DEVIATION selector dial to the X10 mark in either the plus or minus range.	The polarity indicates the direction of deviation.
e)	Set the CAPACITANCE DIALS and the CAPACITANCE RANGE SELECTOR for the nominal value of the capacitor under test.	
f)	Adjust the generator output voltage to any value well below the voltage rating of the unknown capacitor.	This provides sufficient voltage for initial null search.
g)	Adjust the detector gain so that the effect of changes in the bridge setting are discernible.	

h) Alternately adjust the CAPACITANCE DEVIATION and DISSIPATION dials for a minimum reading on the detector. If the minimum is found when the CAPACITANCE DEVIATION DIALS are at 0, set the selector dial to the X10 mark on the opposite polarity and repeat.

i) As a null is approached, increase the generator voltage and/or the detector gain for increased sensitivity.

j) If either the CAPACITANCE DEVIATION or the DISSIPATION DIALS indicate less than 1/10 full scale, use the next lower CAPACITANCE DEVIATION or DISSIPATION RANGE selector setting.

k) Read the percent of deviation and the dissipation factor on the dials.

If a null indication cannot be obtained, the capacitance deviation of the capacitor under test may be too high to read. Change to the procedure of Section 2.3.2, and then calculate the deviation of the CAPACITANCE DIAL reading from its nominal value.

2.3.4 EXTENDING DISSIPATION FACTOR RANGE

The dissipation factor (D) range of the capacitance bridge can be extended by connecting an external resistor across the EXT D ADJ terminals. In connecting an external resistance the following should be considered:

a) The value of the external resistor should not exceed 10 kilohms.

b) The capacitance to ground of an EXT D ADJ resistor may affect the bridge readings. To minimize this effect the maximum capacitance from TERMINAL 2 to GND should be limited to a few hundred picofarads. Also the maximum capacitance from TERMINAL 1 to GND should be less than 100 picofarads.

The dissipation factor (D) can be calculated from the equations given below:

$$D = (D_B + R_\Omega)\ M x f_{kc} \quad \text{for } M = X10^{-5}$$

$$D = \left(D_B + \frac{R_\Omega}{10}\right) M x f_{kc} \quad \text{for } M = X10^{-4},\ X10^{-3}$$

where:

D -- Dissipation factor of unknown capacitor

D_B -- D reading of bridge in dial divisions

R_Ω -- External rheostat resistance in ohms

M -- D dial multiplier

f_{kc} -- Operating frequency in kilocycles

2.3.5 CALCULATING EQUIVALENT CIRCUIT VALUES

The 707B CAPACITANCE BRIDGE measures the capacitor connected to its UNKNOWN terminals in terms of its series equivalent circuit. This equivalent circuit consists of a capacitance in series with a resistance. The circuit values are not necessarily valid at any frequency other than the one at which the measurement was made.

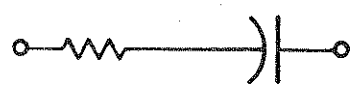
The parameters for the equivalent parallel circuit can be derived from the equivalent series circuit and they also are not necessarily valid at any frequency other than the one at which the measurement was made. The equivalent parallel circuit is obtained from the equivalent series circuit as follows:

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

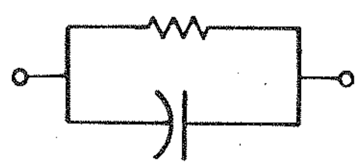
$$R_p = \frac{1}{2\pi DC_p}$$

Where:

Series equivalent circuit:



Parallel equivalent circuit:



C_s -- The value of the capacitor under test as measured by the bridge.

D -- The dissipation factor of the capacitor under test as measured by the bridge. The D of the parallel equivalent circuit will equal the D of the series equivalent circuit.

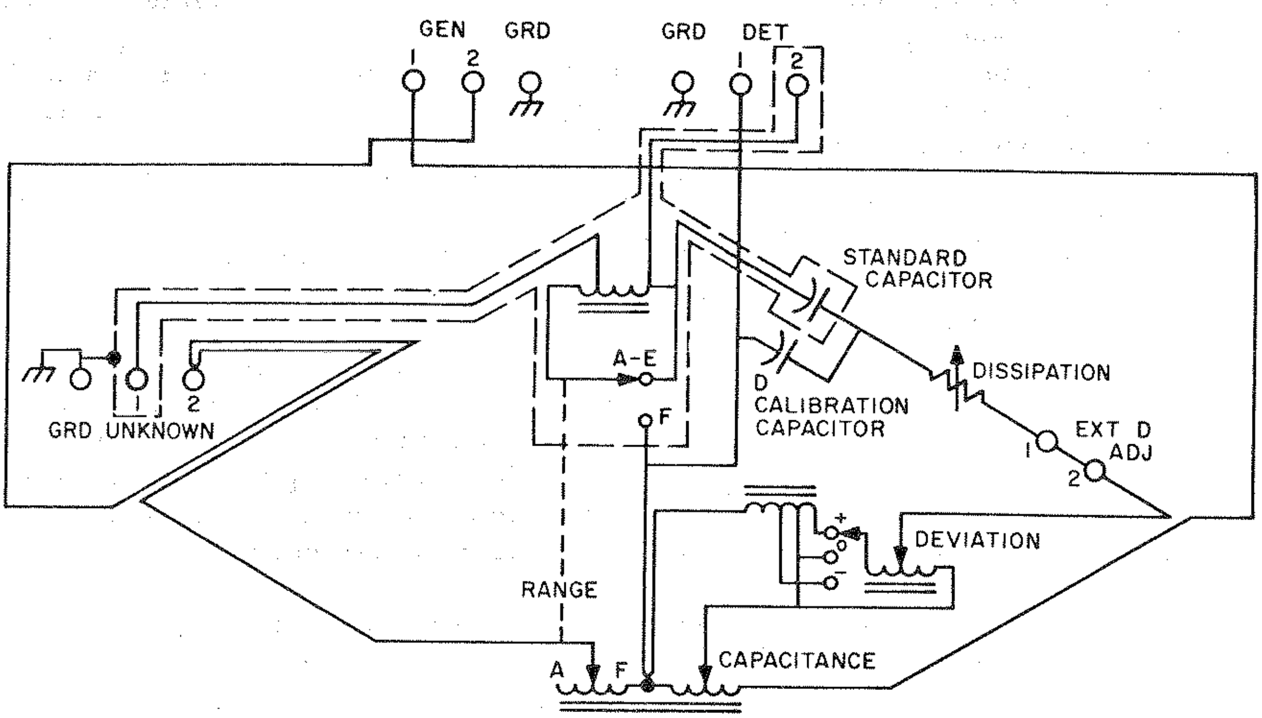
R_s -- The resistive component of the series equivalent circuit is obtained from the measured values of C_s and D as follows:

$$R_s = \frac{D}{2\pi fC_s}$$

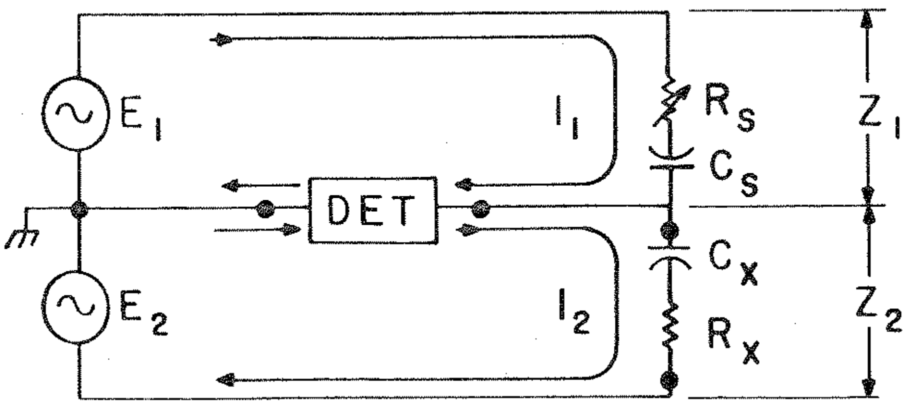
SECTION III

THEORY AND DESIGN

3.1 GENERAL THEORY



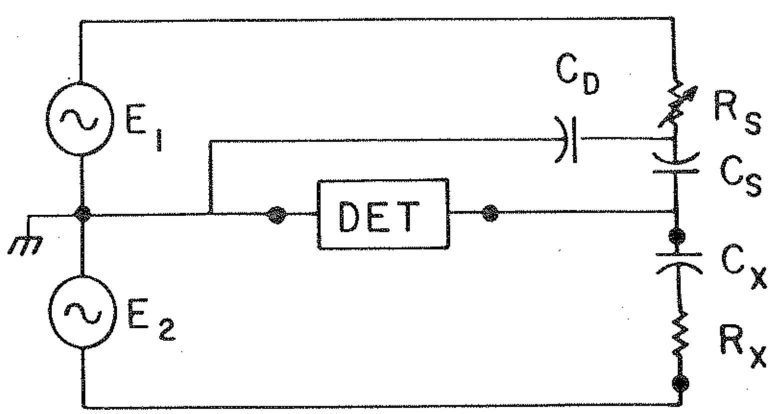
The MODEL 707B CAPACITANCE BRIDGE is basically a variable-ratio transformer type comparison bridge utilizing an external ac voltage source and null indicator. The external ac generator is connected across a precision transformer with a ratio tap connected through an external null indicator to a point between the UNKNOWN terminals and a very stable standard capacitor C_s. Therefore, each half of the transformer acts as a low impedance ac generator with separate voltage outputs (E_1 and E_2) to each bridge arm as shown in the following simplified circuit.



The unknown capacitor (C_x) is measured in terms of its equivalent series circuit (C_x and R_x). The standard capacitor (C_s) and rheostat (R_s) are build into the bridge circuit and provide a fixed capacitance and a variable resistance for obtaining the proper impedance ratio between the standard and unknown capacitors, (Z_1/Z_2).

Assume that generator voltage E_2 is fixed in magnitude and frequency while generator voltage E_1 is at the same frequency and phase but variable in magnitude by a known ratio. Then, by adjusting the value of E_1 and R_s, current flow (I_1 and I_2) of equal magnitude but opposite polarity can be obtained through the external null indicator for various values of C_x and R_x. This is essentially what occurs in the MODEL 707B CAPACITANCE BRIDGE and is commonly referred to as a "balanced bridge" or "null" condition. In the balanced bridge or null condition, the currents I_1 and I_2 through the detector will cancel each other due to their equal and opposite relationship, and the external null indicator will indicate zero current flow.

The simplified circuit on the preceeding page has been slightly modified in the MODEL 707B CAPACITANCE BRIDGE by the addition of a dissipation factor calibration capacitor (C_d). This capacitor changes the current flow in phase with the bridge resistive balance without effecting the capacitance balance. This modified circuit is shown below.



The exact value of the unknown capacitance and dissipation factor can be determined from the following equations:

$$C_x = \frac{E_1}{E_2} C_s \qquad D_x = 2\pi f (C_s + C_d) R_s$$

The CAPACITANCE dials on the MODEL 707B are represented by E_1/E_2 and are calibrated to read directly the value of the unknown capacitor. The DISSIPATION dial is represented by R_s and is calibrated to read directly the dissipation factor of the unknown capacitor (D_x).

3.2 SPECIAL FEATURES

Each of the transformer switching units is designed with an extra contact and resistor. This arrangement maintains continuity through the resistor while the switch is being rotated between adjacent steps. Without this resistor, large transient signals would occur as the switches were rotated, making it difficult to find the null quickly.

The transients would be the result of momentary open circuits if non-shorting switches were used, or from momentary short circuits if shorting type switches were used. With the extra contact and resistor, neither an open circuit nor a short circuit condition is ever encountered. The maximum effect of the resistor occurs when it appears in series between adjacent decades or in parallel with one section of a winding. This effect, however, is far smaller than a complete open circuit or short circuit.

3.3 ACCURACY CONSIDERATIONS

THREE-TERMINAL MEASUREMENT OF CAPACITANCE AND RESISTANCE IN SERIES:

When making a three-terminal measurement of a capacitor and a resistor connected in series, the effect of stray capacitance to ground from the junction between the two must be considered. When either the capacitor or the resistor, or both, are of three-terminal construction (in shield case which is not connected to either terminal), stray capacitance from the common junction to ground may be as large as 100 to 200 pf in some cases. Since part of this stray capacitance is likely to be in a dielectric material, whose loss (dissipation factor) is not negligible, the resistive component should be included in analyzing the circuit.

The circuit in Fig. 3.3A can be analyzed by making a wye-delta (T to π) transformation as shown in Fig. 3.3B. The important observation is that the stray capacitance changes the effective series resistance, while the stray conductance changes the effective series capacitance.

This effect is important in measuring a capacitor and a resistor in series to calibrate the bridge for measurements of high-loss capacitors. It is not sufficient simply to use the direct series capacitance and resistance values connected in series. The stray effects must be measured, or at least estimated, and the equivalent series values calculated.

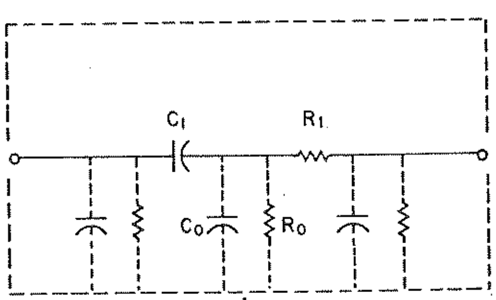


Fig. 3.3A

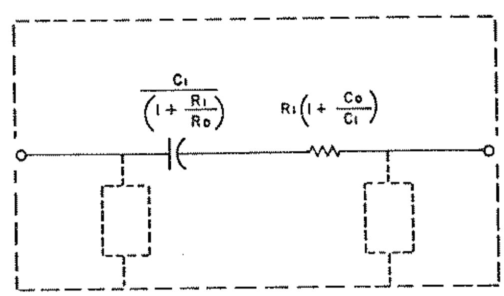


Fig. 3.3B

SECTION IV

CALIBRATION

To keep the bridge within its original specified accuracy, the calibration of the standard capacitor should be checked periodically and adjusted if necessary. Accuracy can be checked simply by making a measurement on a single certified reference standard capacitor. Note, however, that this reference standard must have unusually high accuracy since the standard capacitor in the MODEL 707B is more accurate and stable than the standard capacitors available in many standards laboratories.

4.1 EQUIPMENT REQUIRED

a) Generator and detector as used in normal bridge operation.

b) Certified reference standard capacitor, three-terminal type, nominal value 1000 pf. Must have certificate stating its value to an accuracy of ± 0.005% or better. (ESI MODEL SC 1000 or equivalent).

4.2 STANDARD CAPACITOR ERROR CHECK

a) Connect the 1000 pf reference standard capacitor to UNKNOWN terminals, using shielded lead set (see 2.2.2).

b) Set CAPACITANCE dials to 10 0 0.00 PICOFARADS (range selector in C position).

c) Balance the bridge with CAPACITANCE DEVIATION and DISSIPATION dials (see 2.3.3).

d) Subtract the setting of the CAPACITANCE DEVIATION dials from the deviation of the reference standard capacitor. The difference is the deviation of the standard capacitor in the bridge.

4.3 STANDARD CAPACITOR ADJUSTMENT PROCEDURES

There are two slightly different procedures for adjusting the standard capacitor of the MODEL 707B, depending on the type of standard capacitor trimmer control installed. On units with serial numbers lower than 734000, the adjustment is internal. On units with serial numbers higher than 734000, the adjustment is on the front panel.

4.3.1 PROCEDURE FOR UNITS WITH SERIAL NUMBERS HIGHER THAN 734000

a) Connect 1000 pf reference standard capacitor to UNKNOWN terminals with shielded leads.

b) Set CAPACITANCE dials to 10 0 0.00 PICOFARADS (range C).

c) Set CAPACITANCE DEVIATION dials to the deviation of the reference standard capacitor.

d) Adjust CAL adjustment with an Allen wrench and DISSIPATION dials for detector null.

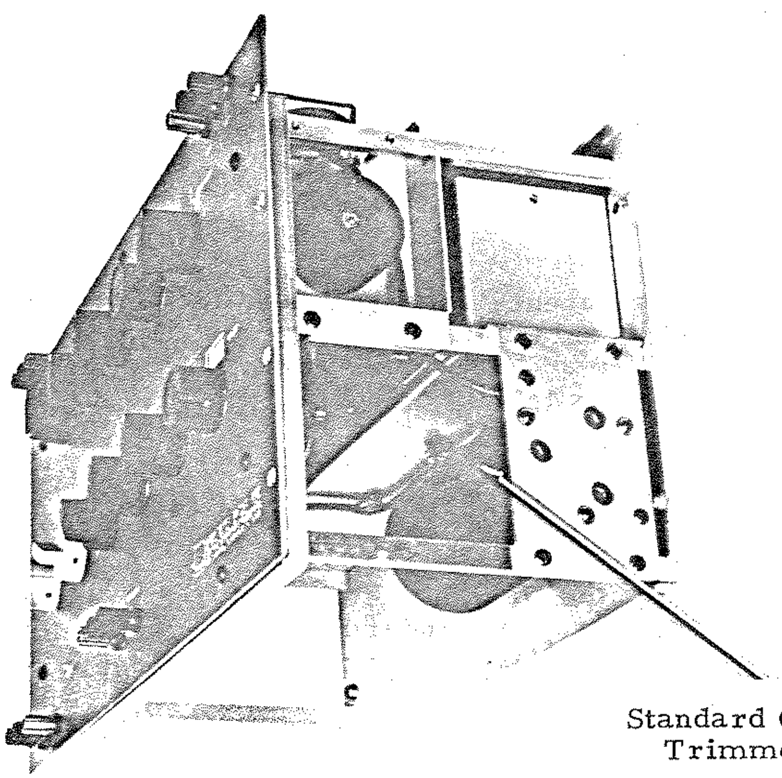


Fig. 4-1 MODEL 707B, Serial Number less than 734000

4.3.2 PROCEDURE FOR UNITS WITH SERIAL NUMBERS LOWER THAN 734000

a) Remove the bridge from its cabinet, and the dust cover from the back of the bridge. (see section 5.1.2)

b) Connect the generator to the bridge GEN terminals with a shielded pair of leads and connect the detector to the bridge with another. Be sure that DET terminal 1 is grounded at one place only, either internally in the detector or externally.

c) Connect 1000 pf reference standard capacitor to UNKNOWN terminals with shielded leads.

d) Set CAPACITANCE dials to 10 0 0 0.00 PICOFARADS (range C).

e) Set CAPACITANCE DEVIATION dials to the deviation of the reference standard capacitor.

f) Adjust standard capacitor trimmer (figure 4-1) and DISSIPATION dials for detector null.

g) Reassemble the bridge and replace it in its cabinet. Reconnect the generator and detector in the normal manner.

h) Repeat the standard capacitor error check described in section 4.2. The deviation of the standard capacitor should be less than ± 0.001%.

SECTION V

MAINTENANCE

5.1 PREVENTIVE MAINTENANCE

The following procedures should be performed periodically to insure maximum accuracy and reliability from the ESI MODEL 707B CAPACITANCE BRIDGE.

If the need for major repairs is apparent, it is recommended that the unit be sent to the factory for service and repair. Necessary repair information as well as any replacement parts will be furnished upon request. Unauthorized repairs will invalidate the instrument warranty. If the instrument is more than one year old when returned to the factory a reasonable charge may be expected for replacement parts or complete reconditioning.

5.1.1 VISUAL INSPECTION

First inspect the bridge externally for dial orientation, damaged binding posts and binding post caps, and for dirt around the binding post insulators. Next remove the dust cover as described in Section 5.1.2 and inspect the unit for possible internal defects. These defects include such things as loose or broken connections, damaged or dirty switch contacts and worn or dirty potentiometers and sliders.

5.1.2 REMOVING THE DUST COVER

Prepare a soft, clean place on which the instrument may be set. Be sure that no projections or pointed objects will be underneath the panel. See that there are no metal fillings in the area.

Remove the instrument from the rack and place it face down on the prepared surface.

Loosen the screws on the back of the instrument, and carefully slide the dust cover off.

5.1.3 CLEANING AND LUBRICATION

Clean the front panel with a soft, dry, lint free cloth being particularly careful to remove all dirt around the binding post insulators. The only internal components which require cleaning and lubricating are the potentiometers R_2 and R_5, rheostats R_{3a} and R_{3b}, and occasionally the switch decks. Clean and lubricate the slide wire potentiometers as follows:

> CAUTION: Do not use solvents on the potentiometers. Solvents can leave a residue which may affect their performance.

a) Polish the contact surfaces lightly with abrasive cloth (Crocus cloth or equivalent).

b) Remove loose particles by wiping with a Nylon Cloth.

c) Apply a liberal amount of RPM Aviation Grease #5 to the contact surface.

Clean and lubricate the dissipation factor rheostats as follows:

> CAUTION: Do not use solvents on the rheostats. Solvents can leave a residue which may affect their performance.

a) Polish contact surfaces lightly with abrasive cloth (Crocus cloth or equivalent).

b) Remove loose particles by wiping with a Nylon cloth or with a soft brush.

c) Apply a moderate amount of pure petroleum jelly to the contact surfaces.

The switch decks are carefully lubricated at the time of manufacture and are protected from contamination by the dust cover. They should rarely, if ever, need maintenance. It is recommended that they be cleaned or lubricated only if they are not making good electrical contact. If the switch decks need cleaning or lubrication, proceed as follows:

a) Apply solvent (Freon printed circuit solvent or equivalent) to the contact surfaces with a small brush or pipe cleaner.

b) Wipe surface with clean dry brush or dry with low preasure air.

c) Apply a thin coating of lubricant (Oak #2008 or equivalent) to the contact surface with a hypodermic needle.

d) Apply two drops of the same oil to each of the switch bearings and detent mechanisms.

e) Remove excess oil with a clean, dry cloth and remove all traces of lint with a soft brush.

5.1.4 REPLACING THE DUST COVER

Be sure that the interior of the dust cover is completely clear of all foreign material.

Slip the dust cover over the bridge being careful not to touch it against the resistors. Replace the screws.

5.2 TROUBLE SHOOTING

The following procedures are designed to indicate any major abnormalities in the MODEL 707B bridge. Normally, erroneous readings will be encountered only if the toroidal wound decade transformers have been severely over-heated or if there has been physical damage to the bridge. If erroneous results are encountered, the instrument should be returned to the factory or to an authorized service facility for repairs.

5.2.1 CAPACITANCE DECADE TRANSFORMER VOLTAGE CHECKS

a) Measure the resistance of all binding posts to GND with an ohmmeter. The meter should indicate infinite resistance. Make certain there is no path from DET 1 to GND for this check.

b) Connect the generator output to the GEN terminals on the bridge.

c) Connect the bridge terminal DET 1 to the adjacent GND terminal.

d) Connect the low terminal of an ac voltmeter to the DET 1 terminal of the bridge.

e) Connect the high end of the ac voltmeter to the EXT D ADJ terminals of the bridge.

f) Set the CAPACITANCE DEVIATION polarity selector to OFF.

g) Set the DISSIPATION multiplier selector to 10^{-5}.

h) Set the CAPACITANCE range selector to C.

i) When making the following checks turn the switches slowly and watch for switch transients.

j) Set the CAPACITANCE dials to 10 0 0 00 and set the generator controls for a 10 volt reading on the meter.

k) Switch the first decade from 11 to 1 in steps of 1 while watching the meter. Each step change should produce a 1 volt change in the meter reading.

l) Leaving the first decade on 1, change the voltmeter range to 1 volt full scale and adjust the generator for a full scale reading on the meter.

m) Change the second decade to -1. The voltmeter reading should drop 0.1 volt.

n) Change the first decade to 0 and then switch the second decade from 10 to 1 in steps of 1 while watching the meter. Each step change should produce a 0.1 volt change in the meter reading.

o) Leaving the second decade on 1, change the voltmeter range to 0.1 volt full scale and adjust the generator for a full scale reading on the meter.

p) Change the third decade to -1. The voltmeter reading should drop 0.01 volt.

q) Change the second decade to 0 and then check all of the steps of the third decade. Each step change should produce a 0.01 volt change in the meter reading.

r) With the third decade on 1, change the voltmeter range to 0.1 full scale and adjust the generator for a full scale reading on the meter.

s) Change the third decade to zero and check every 10 dial divisions on the potentiometer. Each 10 divisions should produce a 0.001 volt change in the meter reading.

t) Set the CAPACITANCE range selector to B and repeat steps j through n.

u) Set the CAPACITANCE range selector to A and repeat steps j through n, except on the first decade where the voltage should be set at 1 volt instead of 10 volts. This will make the voltage readings for these steps 1/10 of those listed for range C.

5.2.2. DEVIATION DECADE VOLTAGE CHECKS

a) The voltmeter and generator remain connected as in Section 5.2.1.

b) Set the CAPACITANCE range selector to C and the DISSIPATION multiplier selector to 10^{-5}.

c) With the CAPACITANCE DEVIATION polarity and range selector off and the CAPACITANCE DEVIATION dials set to zero, set the CAPACITANCE dials to 10 0 0 00 and adjust the generator output for a 10 volt reading on the meter.

d) Change the CAPACITANCE DEVIATION polarity and range selector to +1, +10, -1, and -10. This is to check for loading effects. There should be no appreciable change in the meter reading.

e) Set the CAPACITANCE DEVIATION polarity and range selector to +10.

f) Set the first decade of the CAPACITANCE DEVIATION dials to 10 and change the deviation control from +10 to -10. The meter should read 11 volts on both +10 and -10.

5.2.3 RANGE TRANSFORMER VOLTAGE CHECKS

a) Connect the low terminal of the ac voltmeter to the DET 1 terminal and a ground terminal of the bridge.

b) Set the CAPACITANCE DEVIATION polarity and range selector on OFF and set the DISSIPATION multiplier selector on 10^{-5}.

c) Set the CAPACITANCE dials to 10 0 0 00.

d) Set and check the voltages according to the table below:

RANGE	SET VOLTAGE meter gnd-det 1 meter hi- EXT D	MEASURE VOLTAGE meter gnd-det 1 meter hi- unknown 2
A	1 volt	100 volts
B	10 volts	100 volts
C	10 volts	10 volts
D	10 volts	1 volt
E	10 volts	0.1 volt
F	10 volts	0.1 volt

5.3 PHOTOGRAPHS AND DIAGRAMS

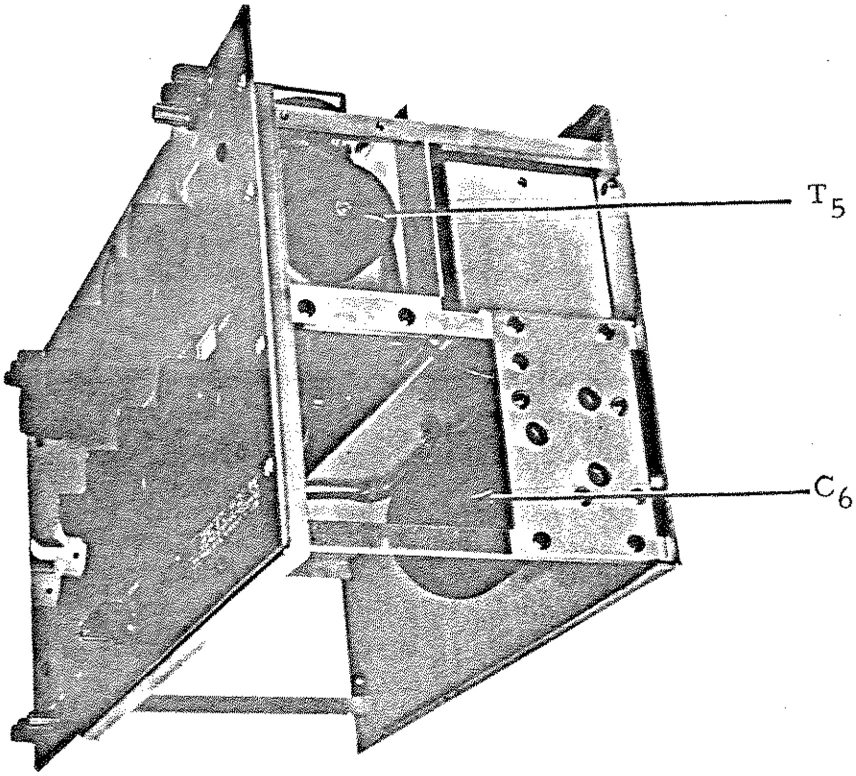


FIG. 5.3A MODEL 707B RIGHT SIDE VIEW

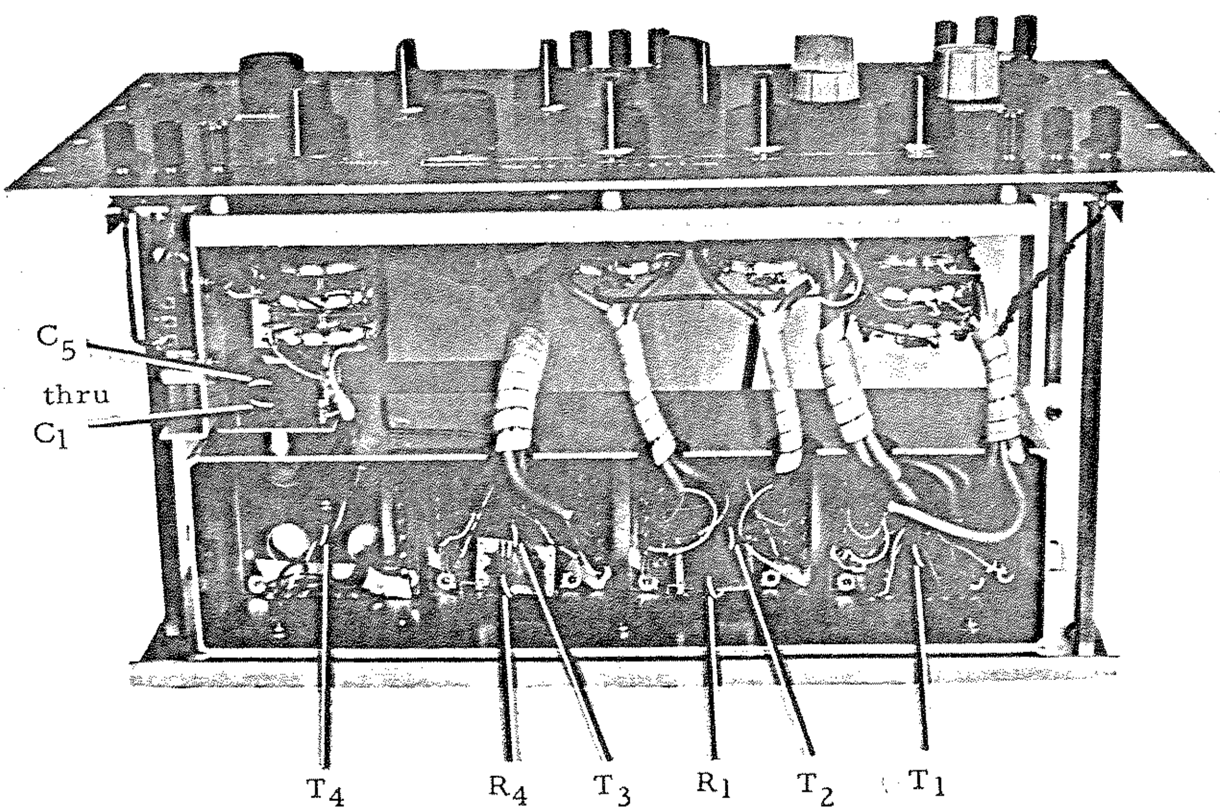


FIG. 5.3B MODEL 707B TOP VIEW

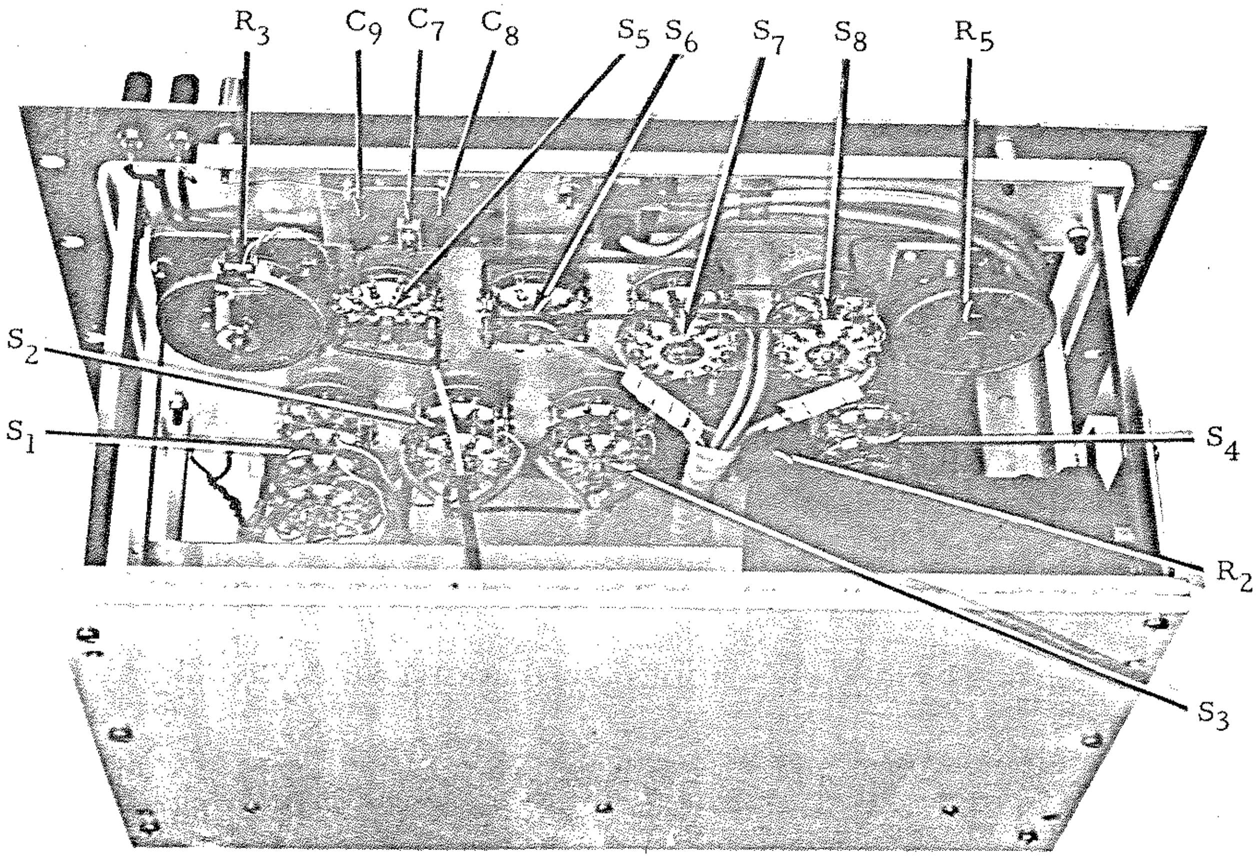
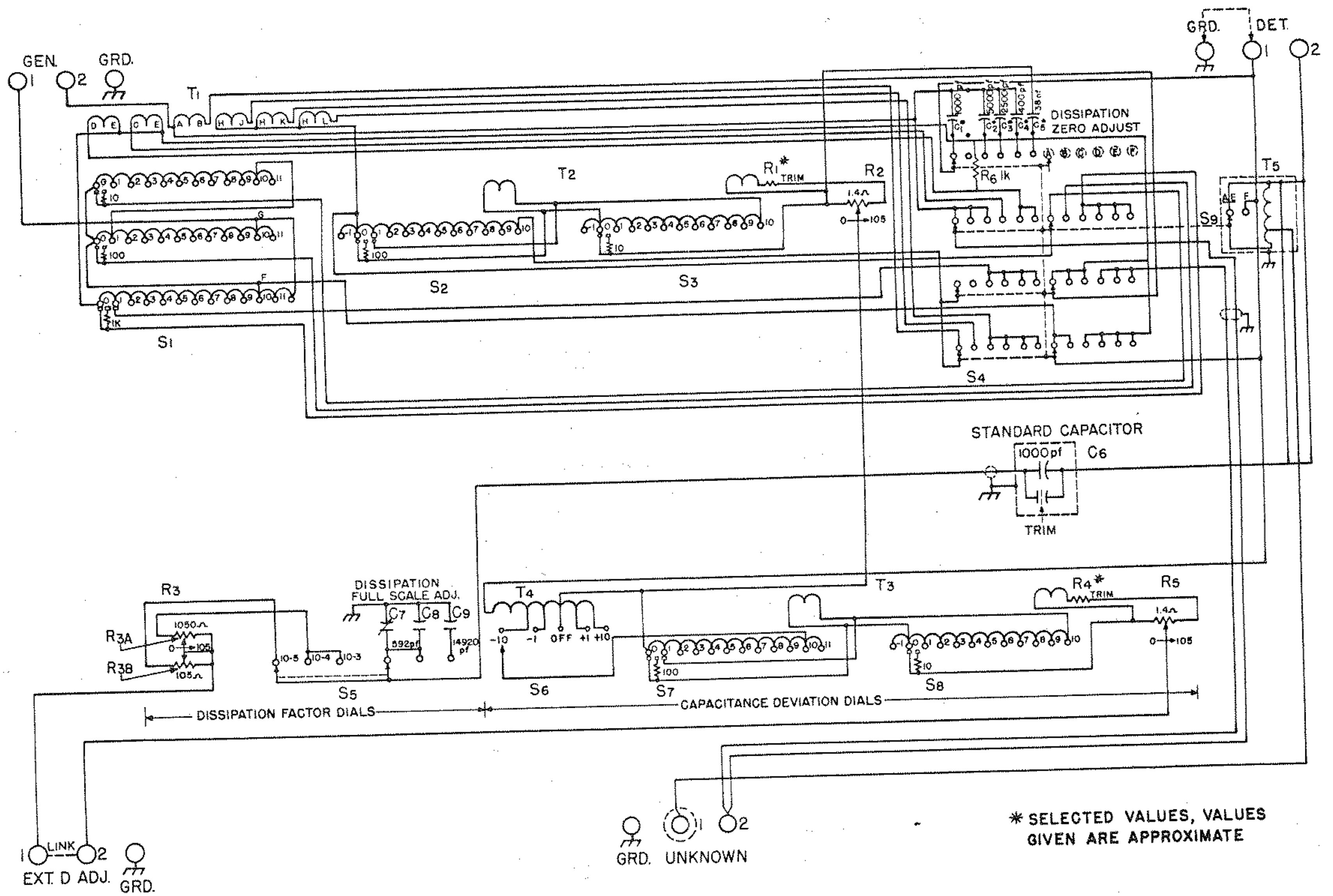


FIG. 5.3C MODEL 707B BOTTOM VIEW



MODEL 707B CIRCUIT DIAGRAM

Fig. 5.3D

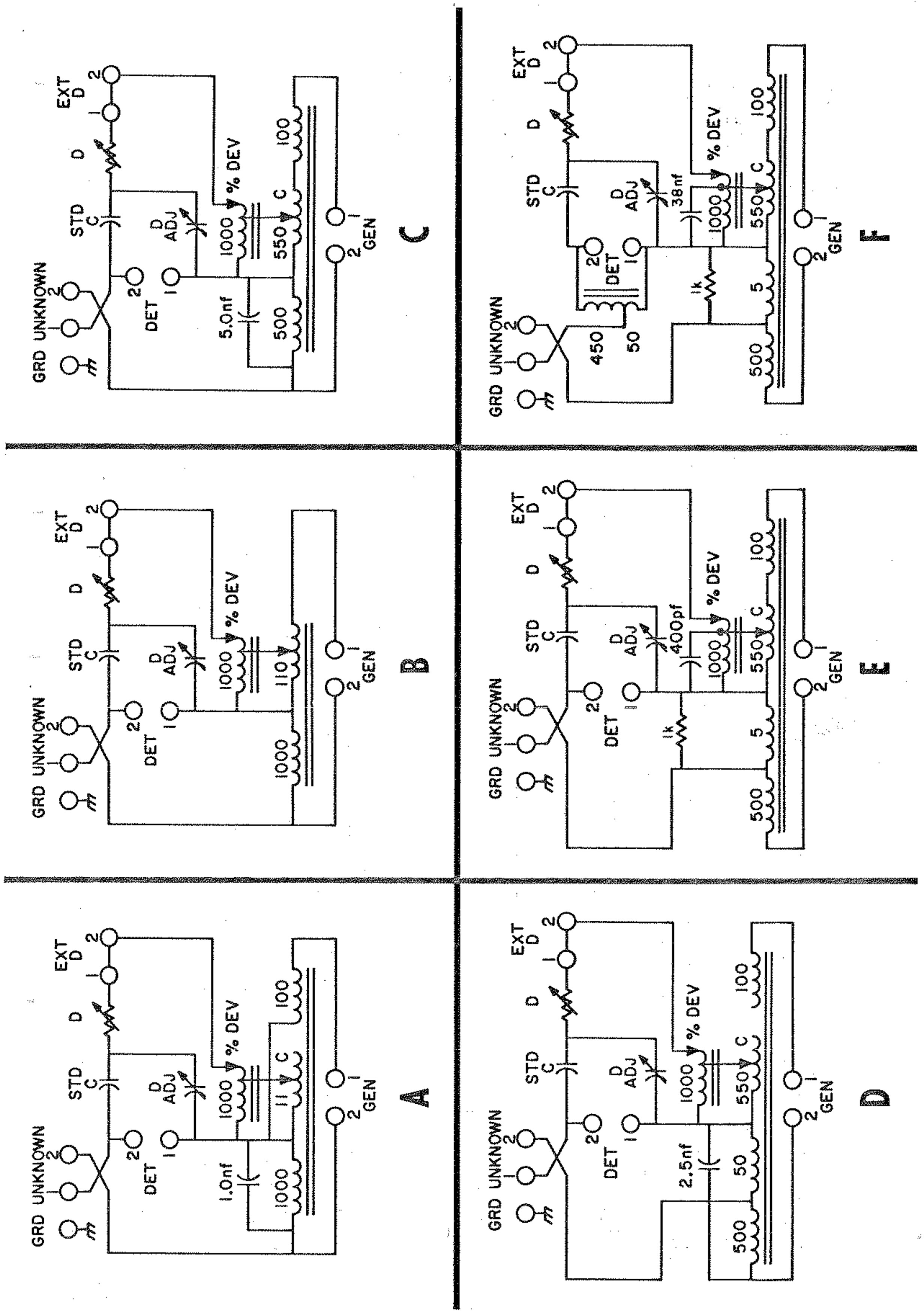


FIG. 5.3E
INDIVIDUAL CIRCUIT DIAGRAMS
FOR RANGES A - F

5.4 PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers; see list of manufacturers below. Parts recommended as spares to sustain operation in isolated locations are indicated in the recommended spare parts column.

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering parts from the factory include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

00884	ELECTRONIC FABRICATORS, INC. New York, New York
11837	ELECTRO SCIENTIFIC INDUSTRIES Portland, Oregon
56289	SPRAGUE ELECTRIC CO. North Adams, Massachusetts
84171	ARCO ELECTRONICS INC. Great Neck, New York
92993	MICRO SWITCH DIVISION OF HONEYWELL REGULATOR CO. Freeport, Illinois

Ckt Ref	Description	Mfr.	ESI Part No.	Qty Used	Recm SP
A_1	Ass'y, Transformer Box	11837	9538	1	
C_1	Capacitor, Mica, approx. 1000 pf, Selected Value	84171		1	
C_2	Capacitor, Mica, approx. 5000 pf, Selected Value	84171		1	

Ckt Ref	Description	Mfr.	ESI Part No.	Qty Used	Recm SP
C_3	Capacitor, Mica, approx. 2500 pf, Selected Value	84171		1	
C_4	Capacitor, Mica, approx. 400 pf, Selected Value	84171		1	
C_5	Capacitor, Mylar, approx. 0.038µf, Selected Value	56289		1	
C_6	Capacitor, Standard, 1000 pf	11837	7709	1	
C_7	Capacitor, Trimmer, 14-150 pf, Mfr PN 424	84171		1	
C_8	Capacitor, Mica, 350 pf ±5%, Mfr PN CM20D351J	84171		1	
C_9	Capacitor, Polystyrene 0.0147µf, Mfr PN E2453	00884			
R_1	Resistor, Selected Value, Part of Ass'y A_1	11837	*	1	
$R_{2,\ 5}$	Potentiometer, 1.4Ω	11837	7773	2	
R_3	Rheostat, Dual	11837	7775	1	
R_4	Resistor, Selected Value Part of Ass'y A_1	11837	*	1	
R_6	Resistor, Selected Value, Part of S_4				
S_1	Switch, Capacitance, 1st	11837	7714	1	
S_2	Switch, Capacitance, 2nd	11837	7715	2	
S_3	Switch, Capacitance, 3rd	11837	7214	2	
S_4	Switch, Range, Capacitance	11837	7771	1	

* Replace entire ass'y

Ckt Ref	Description	Mfr.	ESI Part No.	Qty Used	Recm SP
S_5	Switch, Range, Dissipation	11837	7772	2	
S_6	Switch, Range, Deviation	11837	7887	1	
S_7	Switch, Dev, 1st, Same as S_2	11837			
S_8	Switch, Dev, 2nd, Same as S_3	11837			
S_9	Switch, Micro, Mfr PN 111 SMI-T SPDT	92993	7848	1	
T_1	Transformer, Part of Ass'y A_1	11837	*	1	
T_2, T_3	Transformer, Part of Ass'y A_1	11837	*	2	
T_4	Transformer, Part of Ass'y A_1	11837	*	1	
T_5	Transformer	11837	7846	1	
	MISCELLANEOUS				
	Dial, 0 thru 11	11837	7809	1	
	Dial, -1 thru 10	11837	7810	3	
	Dial, Rheostat	11837	7858	3	
	Knob, Round, Blk	11837	1249	2	
	Knob, Bar, Blk	11837	1266	7	
	Knob, Round, Beige	11837	1458	1	
	Knob, Bar, Beige	11837	1460	1	

* Replace entire ass'y

Ckt Ref	Description	Mfr.	ESI Part No.	Qty Used	Recm SP
	Dial, 0.0 thru 1.1	11837	7812	1	
	Cap, Binding Post, Ins.	11837	1294	8	3
	Cap, Binding Post, Metal	11837	1296	4	2
	Binding Post	11837	1393	12	
	Window, Decimal Pt.	11837	2317	3	
	Window .485 x .75	11837	7242	5	
	Window 1.105 x .49	11837	7789	3	
	Slider, Rheostat, Dual	11837	7767	1	1
	Slider, Potentiometer	11837	6971	2	1
	Reversing drive	11837	8817	3	1
	Insulator, Binding Post, Shoulder	11837	8823	12	
	Spring, Decimal Point	11837	2345	1	1
	Cam, Decimal Point	11837	7873	1	
	Test Lead, Shielded	11837	1560	1	1
	Test Lead, Double Shielded	11837	1550	1	1
	Cover, Dust	11837	7758	1	
	Plug, Banana, double	11837	7869	3	3
	Strap, Shorting	11837	3247	1	1

Electro Scientific Industries
13900 N.W. SCIENCE PARK DRIVE • PORTLAND, OREGON 97229

BRIDGES
AND
ACCESSORIES

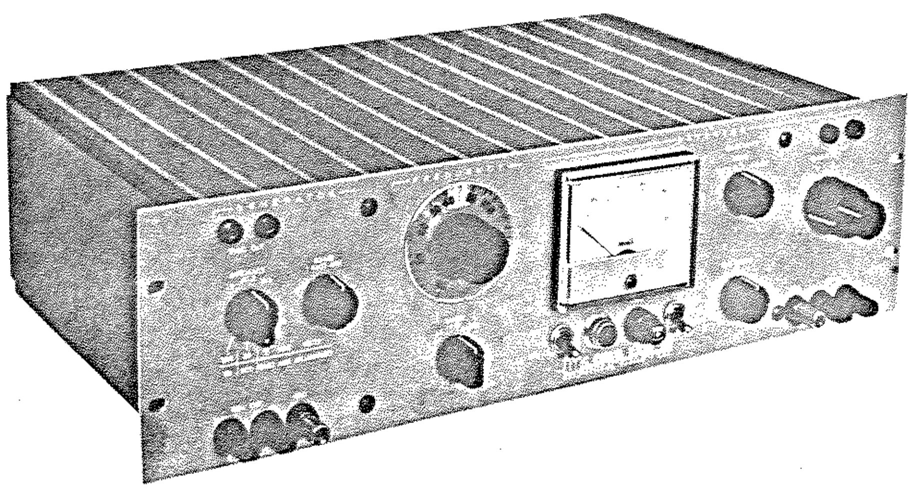
JULY 1964
REPLACES JANUARY 1963

MODEL

861A

Instruction Manual

GENERATOR DETECTOR AC



SERIAL NUMBER:__________

PART NUMBER: 9103

TABLE OF CONTENTS

1.1 DESCRIPTION

The 861A AC GENERATOR-DETECTOR consists of a variable frequency generator and low noise, high gain, tuned detector. It is designed especially for use in performing bridge measurements with state-of-the-art precision.

Among the many unique design features which contribute to the operating convenience and accuracy of this unit are:

CONTINUOUS SINGLE-CONTROL TUNING OF BOTH THE GENERATOR AND THE DETECTOR eliminates the possibility of inadvertently mis-tuning the detector with a consequent large loss of sensitivity.

POWER-LIMITED GENERATOR OUTPUT prevents accidental damage to the external circuit.

REGULATED GENERATOR AND DETECTOR POWER SUPPLIES increase stability with line voltage fluctuations.

VARIABLE GENERATOR OUTPUT IMPEDANCE permits optimum matching to a wide range of impedances for maximum system sensitivity.

GUARDED GENERATOR OUTPUT TRANSFORMER minimizes stray capacitances.

GENERATOR SYNC OUT TERMINALS supply a signal of generator frequency which is independent of output control setting or generator loading. The signal may be used to synchronize a null indicating oscilloscope or phase sensitive voltmeter or for measurement of the generator frequency.

TWO TUNED DETECTOR STAGES give maximum rejection of harmonics and other spurious frequencies.

MULTISTAGE DETECTOR LIMITING permits rapid recovery from large overloads for fastest bridge balancing.

SELECTABLE 60 db COMPRESSION OF METER READING minimizes changes in gain setting.

DET OUT TERMINALS make the detector signal available for an external meter or oscilloscope.

VARIABLE DETECTOR SELECTIVITY permits optimum balance between detector response time and spurious frequency signal rejection.

1.2 SPECIFICATIONS

1.2.1 GENERATOR

Frequency:	Continuously variable in three ranges from 20 cps to 20,000 cps.
Output Voltage:	Four ranges; 0-0.2V, 0-2V, 0-20V, and 0-200V, all with less than 2% distortion. Maximum power into a matched load is one watt.
Output Circuit:	Four output impedances; 0.04Ω, 1Ω, 100Ω, and 10KΩ. Guarded transformer with less than 50 pf guard capacitance to ground, and less than 4 pf from guarded terminal to ground.

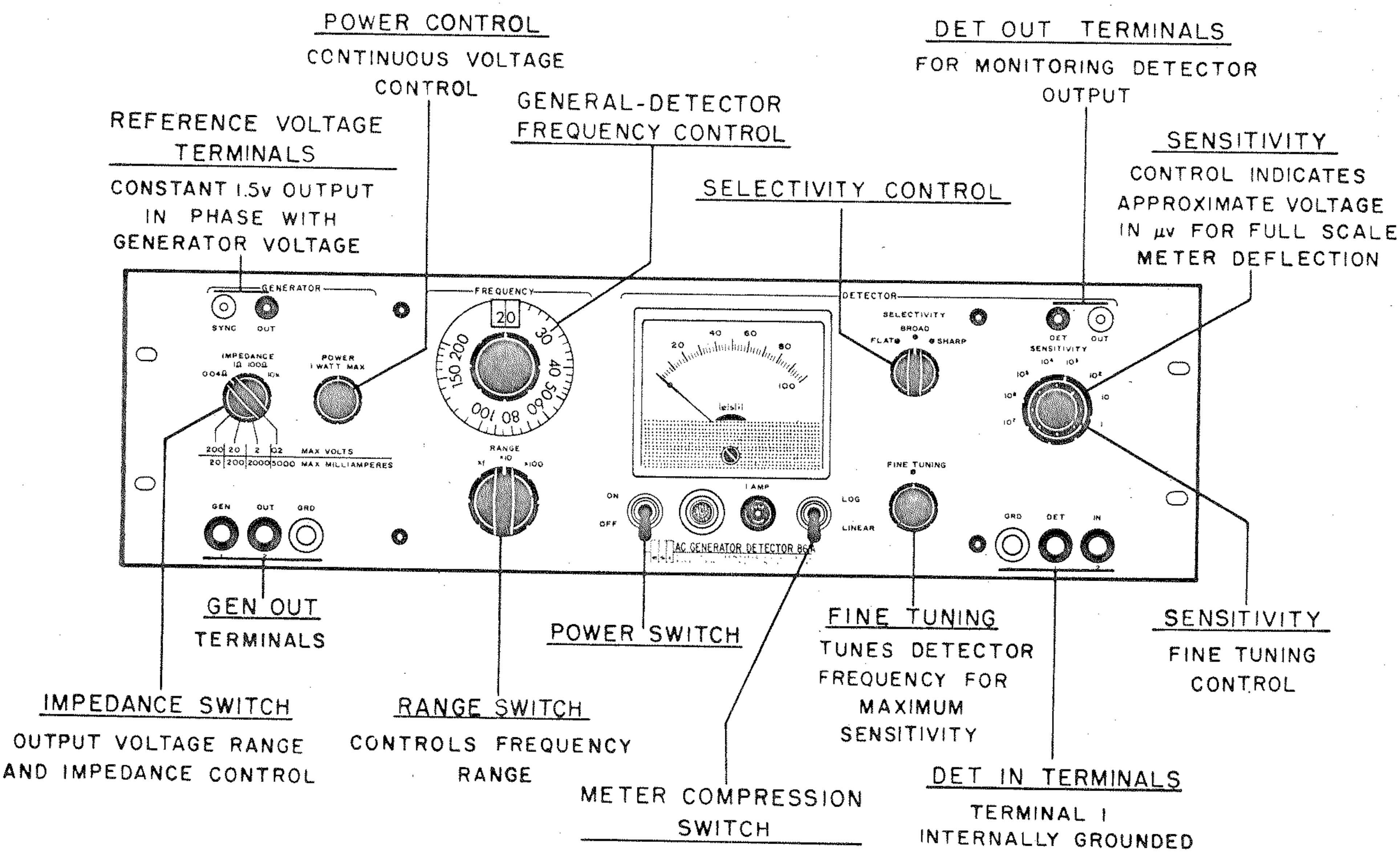
1.2.2 DETECTOR

Frequency:	Continuously variable in three ranges from 20 cps to 20,000 cps. Tuned with the generator.
Sensitivity:	Full scale deflection with one microvolt or less input signal.
Noise:	Maximum short circuit input noise voltage at 1 kc is 0.25 microvolts RMS. Typical short circuit noise is less than $\left[0.1 + 0.1\sqrt{f_{kc}}\right]$ microvolts RMS where f_{kc} is the frequency to which the detector is tuned. Maximum 1 kc open circuit noise current is 2.5 picoamperes. Typical open circuit noise current is less than $\left[1 + 0.5\, f_{kc}\right]$ picoamperes.
Input Impedance:	Approximately one megohm shunted by 80 picofarads on the most sensitive range. Capacitance reduced to less than 20 picofarads on other ranges.

Maximum Input Voltage:	200 volts RMS AC or 400 volts DC.
Indication:	3-1/2 inch rectangular panel meter. Linear mode sensitivity can be adjusted for full scale deflection with any input voltage between 1 microvolt and 100 volts. Logarithmic scale extends the range three decades beyond the linear full scale.
Selectivity:	Three positions available. Typical rejection in sharp position is 40-45 db for half and double frequency points, 50-55 db for one third and three times frequency. Ultimate high and low frequency rejection in excess of 70 db. Typical 3 db bandwidth is 7% of nominal frequency.
Overload Recovery:	Typical 1 kc. overload recovery time is less than 0.1 seconds for 10^5 overload. Amplifier overloads smoothly with no foldback (downward deflection) for any overload condition.

1.2.3 PHYSICAL

Height:	5.25 inches.
Width:	19 inches.
Depth:	11.2 inches.
Weight:	22 lbs. net 32 lbs. shipping
Power Requirements:	115/230 ±10% volts AC, 50-400 cps, 0.6 amp.


POWER CONTROL
CONTINUOUS VOLTAGE CONTROL
DET OUT TERMINALS
FOR MONITORING DETECTOR OUTPUT
GENERAL-DETECTOR FREQUENCY CONTROL
REFERENCE VOLTAGE TERMINALS
CONSTANT 1.5v OUTPUT IN PHASE WITH GENERATOR VOLTAGE
SENSITIVITY
CONTROL INDICATES APPROXIMATE VOLTAGE IN μv FOR FULL SCALE METER DEFLECTION
SELECTIVITY CONTROL
GENERATOR
SYNC
OUT
IMPEDANCE
POWER 1 WATT MAX
FREQUENCY
DETECTOR
SELECTIVITY
BROAD
FLAT
SHARP
DET
SENSITIVITY
RANGE
MAX VOLTS
MAX MILLIAMPERES
GEN
GRD
ON
OFF
1 AMP
LOG
LINEAR
FINE TUNING
IN
AC GENERATOR DETECTOR 86A
GEN OUT TERMINALS
POWER SWITCH
FINE TUNING
TUNES DETECTOR FREQUENCY FOR MAXIMUM SENSITIVITY
SENSITIVITY
FINE TUNING CONTROL
IMPEDANCE SWITCH
OUTPUT VOLTAGE RANGE AND IMPEDANCE CONTROL
RANGE SWITCH
CONTROLS FREQUENCY RANGE
METER COMPRESSION SWITCH
DET IN TERMINALS
TERMINAL 1 INTERNALLY GROUNDED

2.1 GENERAL OPERATING PROCEDURE

The following control settings should be used as a guide in the initial operation of the 861A GENERATOR-DETECTOR. Instructions for specific applications will be found in Sections 2.2 through 2.6.

Turn the AC line switch on.

To achieve maximum stability, allow 15 minutes for warmup.

Set the output IMPEDANCE switch to the desired position.

The optimum output impedance is determined by the external circuit configuration. To attain maximum power transfer, match the generator output impedance to the external circuit impedance. A table of the maximum short circuit currents and open circuit voltages available at each switch position will be found on the front panel adjacent to this switch.

Rotate the output POWER control fully clockwise.

If desired, this control may be rotated counterclockwise to reduce the output voltage.

Set the SELECTIVITY control to the SHARP position.

This position provides the maximum rejection of noise and harmonics. If a faster response time is desired, particularly when operating at lower frequencies, this control may be adjusted to either the broad or flat position. For typical frequency response characteristics in each of these positions, see Section 3.4.

Set the FINE TUNING control to the dot marking on the panel.

This control adjusts the detector to the exact generator frequency. Normally it may be left in its center position. However, to obtain the ultimate sensitivity for critical measurements, this control should be rotated to the position giving the maximum detector meter deflection at each operating frequency.

Turn the LOG-LINEAR SWITCH to the LOG position.

With the switch in this position the meter will read three decade ranges above the linear range without readjusting the sensitivity controls. Normally this will be the most convenient mode of

operation. However, to obtain the maximum detector sensitivity, or to use the detector for deflection type measurements, this switch should be in the linear position.

Turn the inner knob of the SENSITIVITY control fully clockwise. Turn the outer knob to 10^5. With these settings the meter deflection will be visible as a null is approached.

The inner control knob provides a continuous control of the detector sensitivity over a 20:1 range, and is most useful when making deflection type measurements. Normally it will be left at the extreme clockwise or maximum sensitivity position.

The outer control knob changes the sensitivity in approximate decade steps. With the continuous control at its maximum position and the LOG-LINEAR SWITCH in the linear position, the order of magnitude of the full scale sensitivity in microvolts is indicated by the panel engraving.

2.2 BRIDGE CONNECTIONS

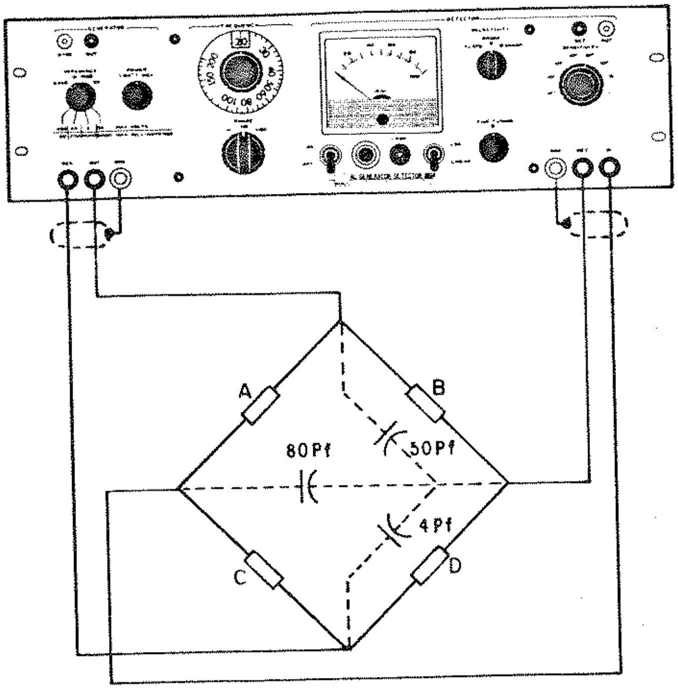


FIG. 2.2

Connect the generator output to the ungrounded corners of a bridge as shown in Fig. 2.2.

Terminal 1 is the guarded terminal with approximately 4 pf* shunt capacitance to ground. Terminal 2 has approximately 50 pf* to ground and should be placed across the bridge arm on which this capacitance will have the least effect.

Connect the detector input to the bridge as shown also in Fig. 2.2.

Terminal 1 is internally grounded. Terminal 2 has approximately 80 pf* shunt capacitance to ground.

For highest accuracy be sure that both the generator and the detector leads are shielded and that the bridge is grounded at one point only.

More detailed information regarding shielding and grounding will be found in Section 2.6.

* Plus lead capacitance

2.3 CONNECTIONS FOR VOLTAGE DIVIDER CALIBRATION

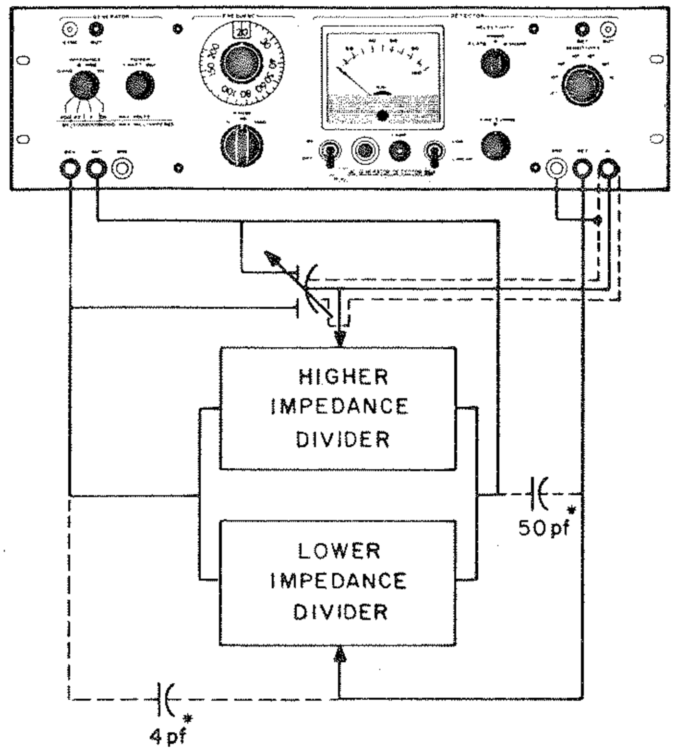


FIG. 2.3

Connect the dividers to the GEN OUT and DET IN terminals as shown in Fig. 2.3. (Note: DET 1 terminal is internally grounded.)

Normally it will be necessary to make a phase compensation between the two dividers. This is most easily accomplished by connecting a differential capacitor (50 pf approximate value) in the circuit as shown. This capacitor should be adjusted for a minimum reading on the null indicator.

Compare the calibrated divider settings to the readings on the divider being checked.

See Section 2.1 for null balance procedure.

For highest accuracy be sure that both the generator and the detector leads are shielded and that the circuit is grounded at one point only.

More detailed information regarding shielding and grounding will be found in Section 2.6.

* Plus lead capacitance

2.4 CONNECTIONS TO EXTERNAL INSTRUMENTS

2.4.1 OUTPUT JACKS

Two sets of special output jacks have been provided on the Model 861A to attain maximum utility of the instrument.

The SYNC OUT terminals provide a reference voltage at the generator frequency. This voltage has a constant amplitude of about 1.5 volts, and is unaffected by the setting of the generator output controls or the load connected to the generator. The output impedance is approximately 10 kilohms.

The DET OUT terminals provide an ac output signal with a voltage of about 8 volts RMS corresponding to a full scale linear meter deflection. The internal impedance of this voltage is less than 1 kilohm. A linear output up to at least 10 volts is available when the external loading is greater than 10 kilohms. This output is not affected by the position of the LOG-LINEAR switch.

Some suggested applications for these outputs are listed in the following instructions.

2.4.2 ELLIPTICAL (LISSAJOUS) CRO PATTERNS

To obtain an elliptical presentation on a cathode ray oscilloscope, connect the DET OUT terminals to the CRO vertical input, and the SYNC OUT terminals to the CRO horizontal input by means of shielded cable, as shown in Fig. 2.4.2.

The bridge may now be balanced in the normal manner. As a null is approached, the pattern should collapse to a horizontal, straight line, or a band if nonsynchronous noise components are present. A null adjustment should result in a minimum pattern width with no tilt from the horizontal axis.

The ellipse pattern is a desirable means of observing the output signal because it readily indicates the relative phase of the null, and also the separation of the fundamental null frequency from its harmonic components and noise frequencies. For this reason a greater selectivity can be achieved with a CRO than with the meter.

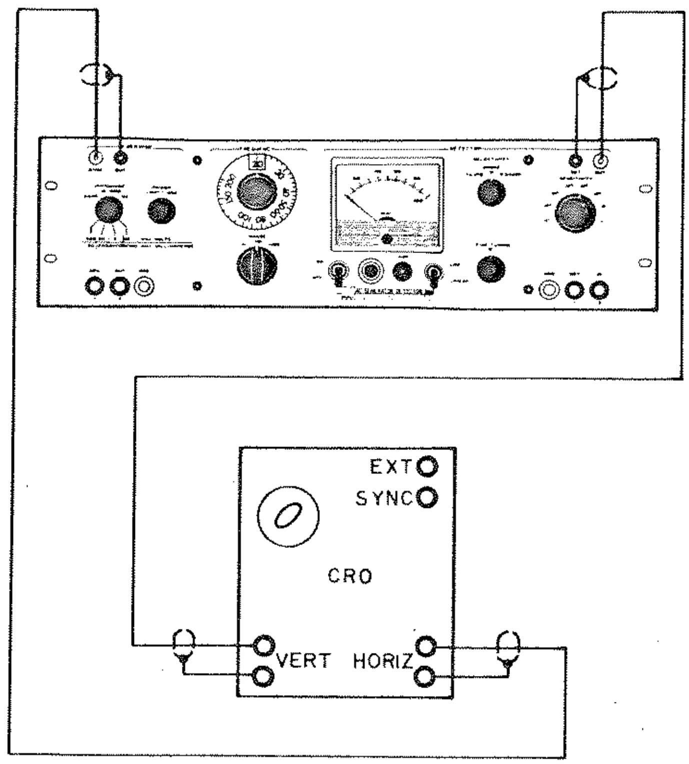


FIG. 2.4.2

2.4.3 SINUSOIDAL CRO PATTERNS

To obtain a sinusoidal presentation on an oscilloscope, connect the DET OUT terminals to the vertical input on the scope, and the SYNC OUT terminals to the CRO external sync terminals as shown in Fig. 2.4.3.

By using the external sync terminals on the CRO, the pattern will have horizontal stability even at null. The pattern will show phase reversal as a null is passed and the effects of individual bridge or divider controls can be easily separated.

2.4.4 REMOTE METER INDICATOR

A remote meter may be used by connecting it to the DET OUT terminals. A suitable instrument for this purpose would be a 10 to 30 volt AC voltmeter with an impedance of at least 1000 ohms per volt. The output will be linear to slightly over 10 volts, and will be limited to approximately 30 volts at which value the amplifier reaches saturation.

If a phase sensitive voltmeter is used, its reference voltage may be taken from the SYNC OUT terminals, as shown in Fig. 2.4.4. The detector FINE TUNING control can be used to produce a change in the phase angle of the signal as much as 150° or more at the DET OUT terminals. The change in phase angle results in some loss in gain.

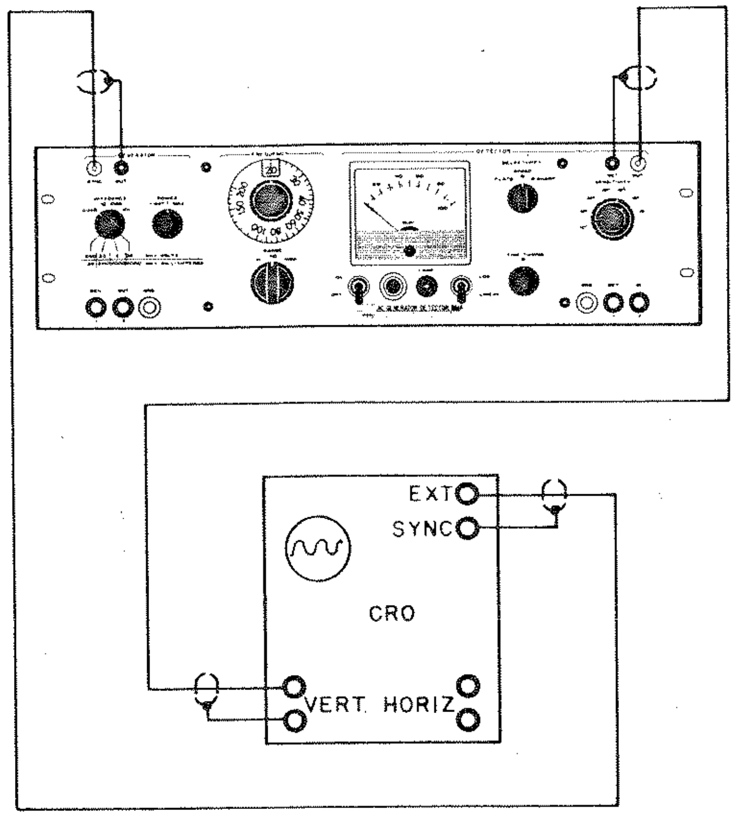


FIG. 2.4.3

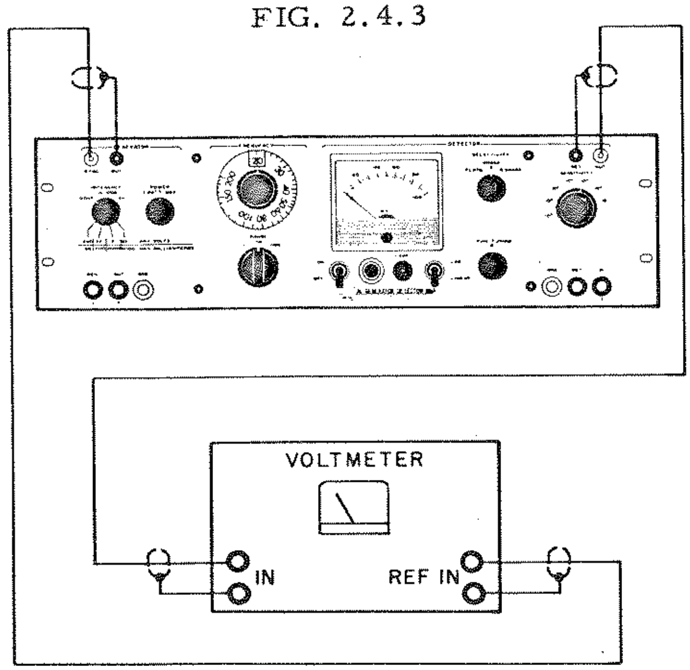


FIG. 2.4.4

2.4.5 HIGH ACCURACY FREQUENCY ADJUSTMENT

If it is desired to adjust the generator frequency more exactly than is possible with direct dial calibrations, the SYNC OUT terminals will provide a convenient source of voltage. This voltage may be used either with a direct reading frequency meter, or to provide a Lissajous pattern referred to a standard frequency source, as shown in Fig. 2.4.5.

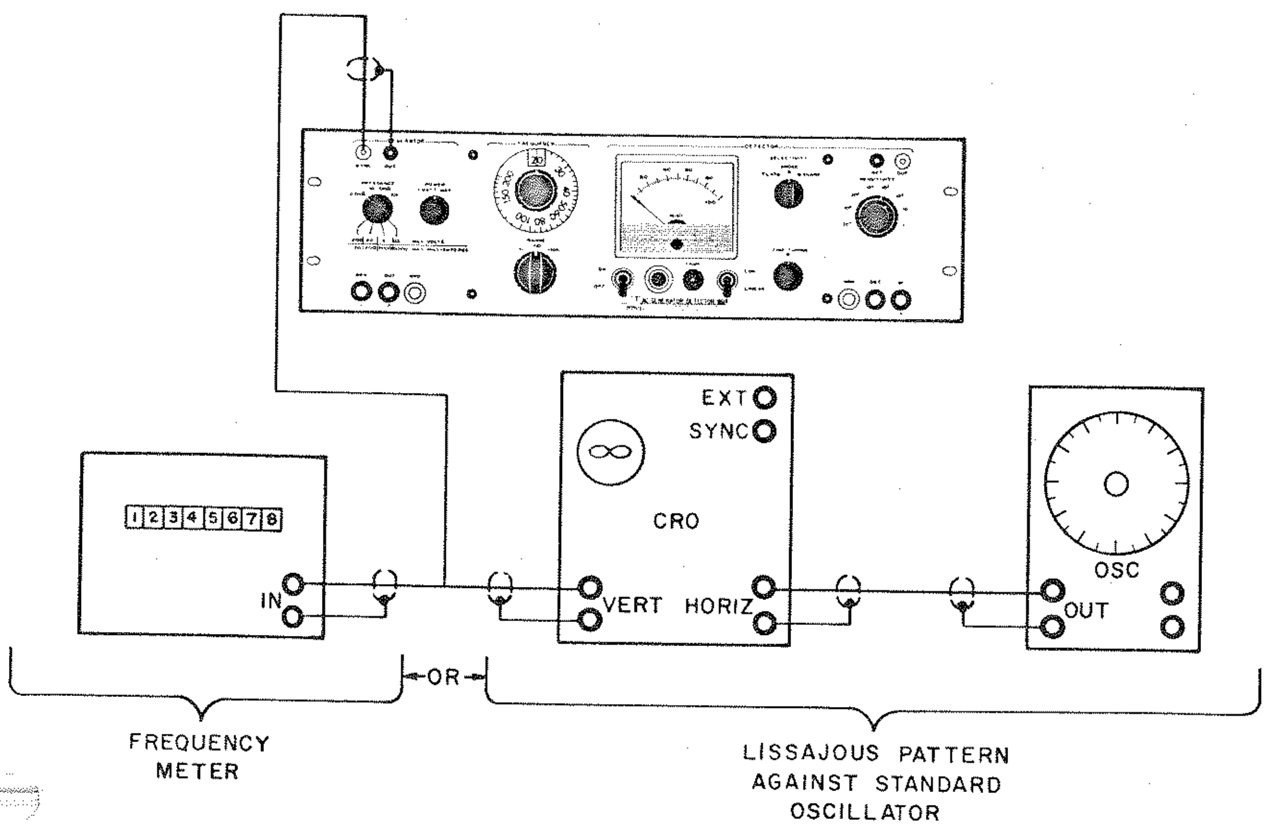


FIG. 2.4.5

2.5 MISCELLANEOUS APPLICATIONS

2.5.1 HIGH GAIN AMPLIFIER

The 861A detector may be used as a high gain, low noise amplifier. The amplifier may be operated in either the tuned or untuned mode.

The available linear output voltage at the DET OUT TERMINALS will be at least 10 volts into a 10 kilohm load, and will have a source impedance of approximately 200 ohms. The maximum available gain will be approximately 10^7.

When the detector is used as an amplifier the log-linear switch should be in the log position to keep the meter on scale with input overloads. This will not affect the amplifier output circuit.

2.5.2 WAVE ANALYZER

The 861A detector may also be used to determine the frequency spectrum of an audio signal. Typical variations in gain with frequency are shown in Section 3.4. For a more accurate measurement, the detector may be calibrated at each frequency. The following circuit is suggested when this calibaration is desired.

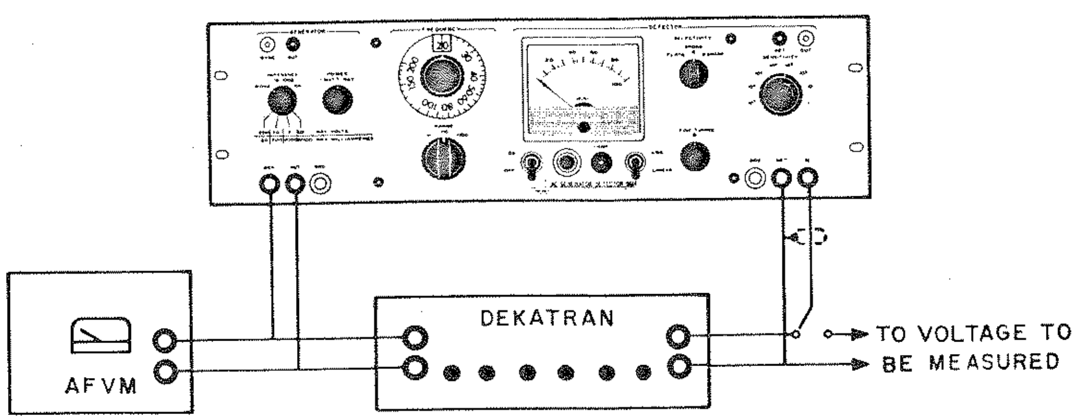


FIG. 2.5.2

The typical bandwidth at 3 db down is 7% of the center frequency, with a half and double frequency rejection of 40-45 db.

2.6 OPERATING PRECAUTIONS

2.6.1 GENERAL

Circuits which require the use of an 861A will normally demand special caution in shielding and grounding external equipment to assure reliable results. Stray capacitance and common impedance coupling of signals between the generator and detector circuits can produce an apparent null at a point considerably removed from the true null. In addition, any high level spurious signals - such as the line frequency and its harmonics - may produce undesirable amplifier overloading with consequent desensitization and modulation products, despite the highly selective amplifier characteristics.

2.6.2 SHIELDING

To prevent the introduction of electrostatically coupled stray signals, both the generator and detector connections must be completely shielded. A convenient and highly effective method of making these connections with a minimum stray capacitance to ground is by means of shorting links (ESI Part Number 3248) and shield covers (ESI Part Number 7307).

If circuit requirements dictate the use of longer connections, shielded cables with shield caps, extending completely over the terminals to the front panel, may be used. The cable should be of the type having low leakage through the shield braid. Double conductor shielded cable may be used for both the generator and detector connections. If, however, it is desired to retain the benefits of the guarded Generator output circuit, a concentric double shield or tri-axial cable should be employed with the inner conductor connected to terminal 1, the inner shield connected to terminal 2, and the outer shield connected to the ground terminal.

2.6.3 GROUNDING

To reduce the possibility of common impedance coupling the active measuring circuit should be grounded at one point only. Terminal 1 of the detector input is internally grounded to the chassis. It may be preferable to provide this ground lead independent of the shield, such as by the use of a two-conductor shielded, or tri-axial shielded cable.

When operating at power line frequency or its harmonics, special attention must be directed to the grounding. To provide greater flexibility, the 861A chassis is isolated from the power line ground. If external line operated equipment is connected to the SYNC OUT or DET OUT terminals, a ground connection will most likely be established by this path. If no external equipment is used, it may be found helpful to connect an external ground to the 861A chassis. As with the measurement circuit, multipath grounding should be avoided.

3.1 DETECTOR CIRCUIT DESCRIPTION

The detector is a high gain audio amplifier, continuously tunable from 20 cycles to 20 kilocycles in three bands. It employs four amplifier stages with shunt limiting between each stage to insure fast recovery from large overloads. Two tuned stages are used for very high rejection of any signals with other than the desired frequency. The detector block diagram is shown in Fig. 3.1.

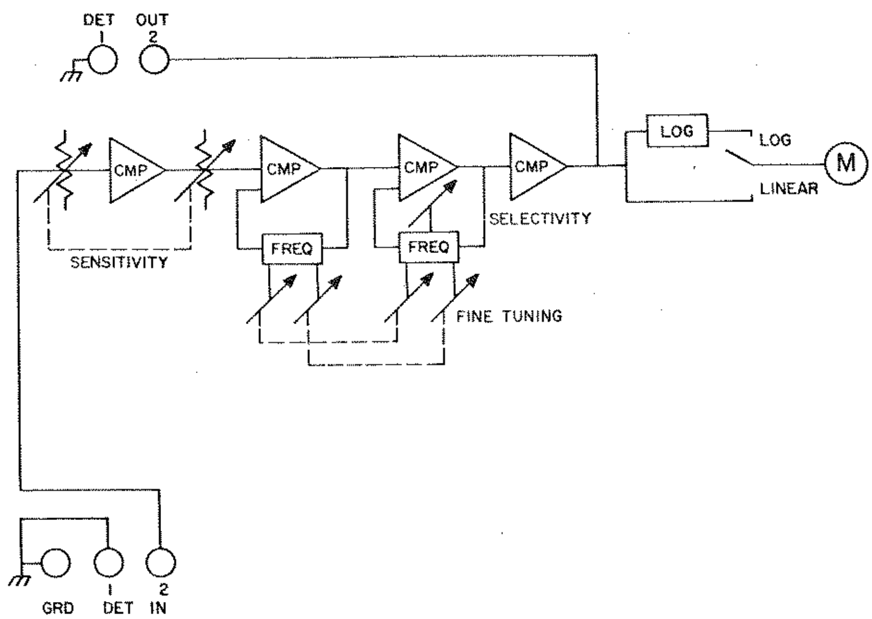


FIG. 3.1

The input signal, after passing through the input attenuator, is amplified by a low noise, cascode amplifier stage. Next it passes through the interstage attenuator to the first tuned amplifier stage. This consists of a pentode amplifier direct-coupled to a cathode follower output. The negative feedback loop for this stage consists of a tunable frequency rejection network (described in Section 3.3). The signal is further amplified by an identical tuned stage and by the output amplifier, after which it is applied to the detector output terminals and to the meter rectifier. A network in the DC meter circuit provides selection of either compressed or linear presentation of the reading.

3.2 GENERATOR CIRCUIT DESCRIPTION

The generator is composed of a variable frequency oscillator, a power amplifier, and an impedance matching output network. The block diagram is shown in Fig. 3.2

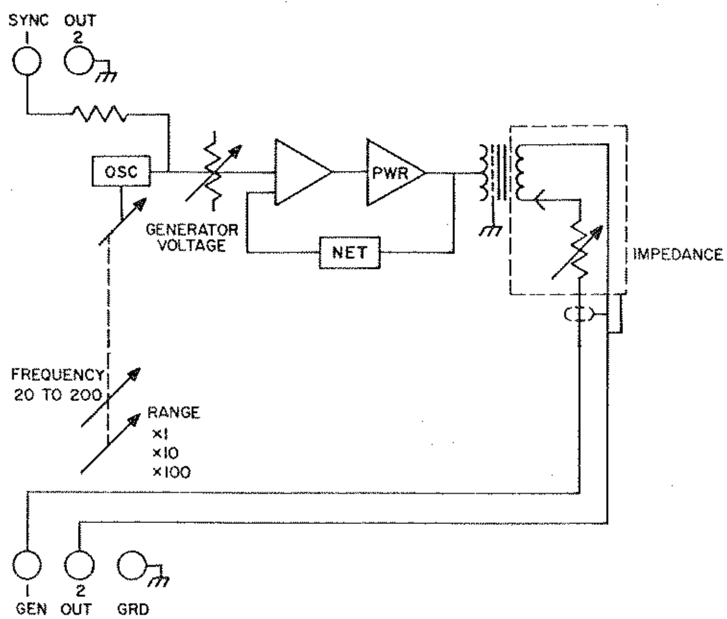


FIG. 3.2

The oscillator is a pentode-cathode follower pair, similar to that used in the detector. Positive cathode-to-cathode feedback is used to cause the circuit to oscillate. The frequency of this oscillation is determined by a tunable rejection network in a negative feedback loop from the output cathode to the pentode grid. A parallel negative feedback loop contains a temperature compensated thermistor network to stabilize the oscillator amplitude.

The power amplifier consists of a triode amplifier, direct-coupled to a split load phase inverter, followed by a push-pull pentode output stage. Overall negative feedback from a tertiary winding of the output transformer to the cathode of the input triode is utilized to reduce distortion.

The output transformer is of a special double shielded design. It minimizes the stray coupling between the amplifier and external circuit elements. A tapped secondary winding permits the selection of an optimum output impedance level for the particular measurement being performed. Associated with each tap is a shielded power limiting impedance to protect the external load elements.

3.3 TUNING NETWORK

The variable frequency tuning network employed in both the detector and generator portions of the 861A is of a unique design which makes it possible to cover a 10 to 1 frequency range by means of a single resistive divider. A simplified diagram of this network is shown in Fig. 3.3A.

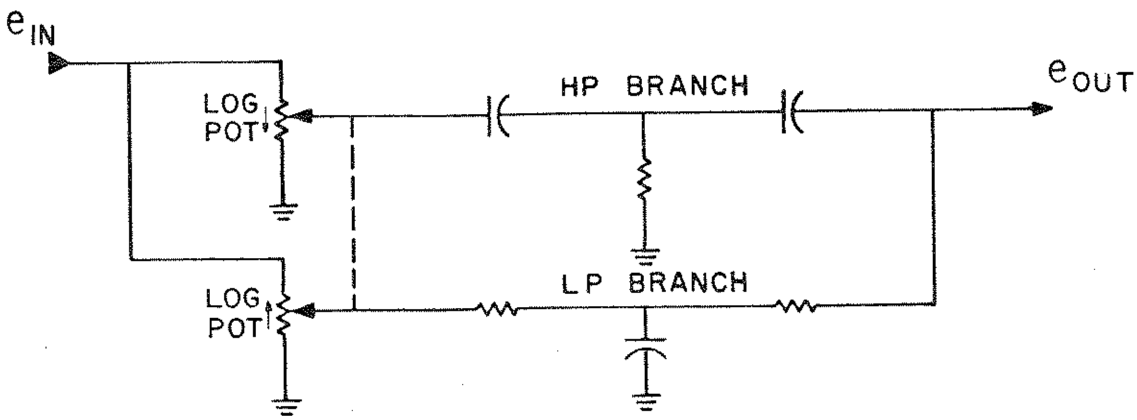


FIG. 3.3A

For clarity, the tuning attenuators have been shown as a pair of ganged, logarithmic resistive dividers. In the actual circuit, a center tapped, linear potentiometer is resistance loaded to produce a very close approximation to this configuration.

An analysis of this circuit will show that if the product of the ratios of the high pass and low pass branch attenuators is made constant over the tuning range - as would be achieved with the logarithmic attenuators - a perfect null will be obtainable over the entire tuning range. For example, the ratios at the top, geometric mean, and bottom frequencies of any range are as follows:

FREQUENCY	HIGH PASS RATIO	LOW PASS RATIO	RATIO PRODUCT
TOP	0.1	1	0.1
MEAN	0.31	0.31	0.1
BOTTOM	1	0.1	0.1

To obtain the changes in tuning range, the three capacitors in the high pass and low pass branches are switched in decade increments.

Since this network produces a null at the tuned frequency, it must be employed in a negative feedback circuit to achieve the desired peaked response. A simplified diagram of the operational amplifier type circuit is shown in Fig. 3.3B.

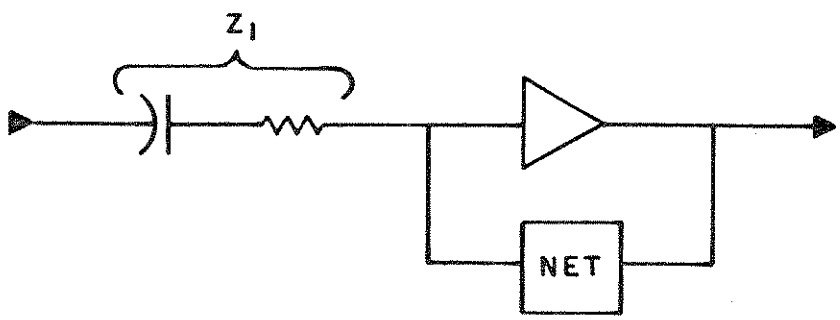


FIG. 3.3B

One unique feature of this circuit is that if the input impedance Z_1 is properly proportioned with respect to the network parameters, the response curve will be symmetrical about the center frequency. It will continue to fall indefinitely at both the high and low frequencies with a 6 db per octave rate. This is illustrated in the typical frequency response curves shown in Section 3.4.

3.4 TYPICAL OPERATING PERFORMANCE CURVES

The following curves describe graphically some of the more important operating characteristics of the 861A Generator-Detector.

3.4.1 FREQUENCY RESPONSE

Frequency response plots with the detector tuned to 100 cps, 1 kc, and 10 kc are shown in Fig. 3.4.1. It will be noted that there is only one curve for the FLAT position of the selectivity control. The reason for this is that the detector is untuned when the selectivity control is in the FLAT position, therefore, the same curve applies for all frequencies. The peak response for each range is given by the set of gain variation curves at the top of the graph.

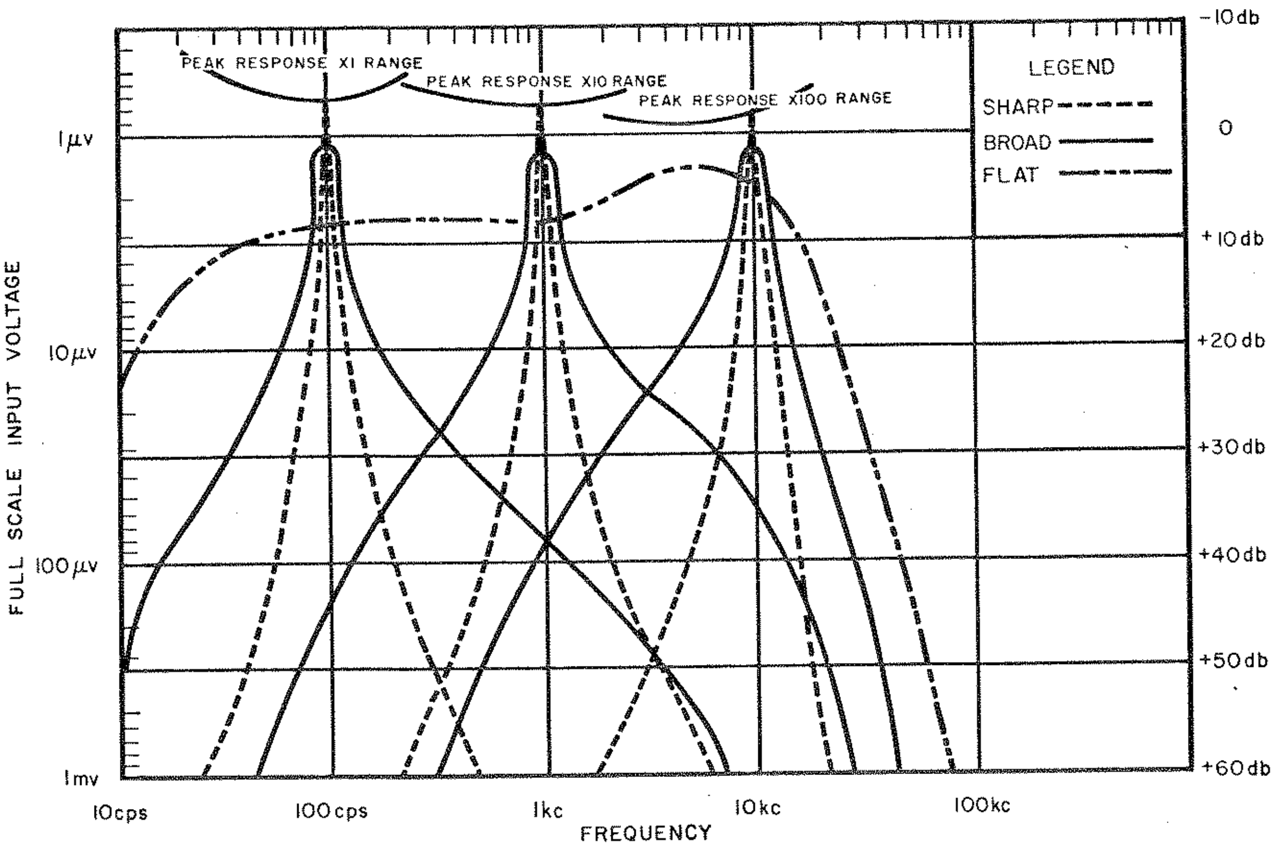


FIG. 3.4.1

3.4.2 NOISE VOLTAGE AND CURRENT

Equivalent input noise voltage and noise current variations over the tuning range are shown for the detector in Fig. 3.4.2. The increase in noise at the higher frequencies is caused principally by the increased bandwidth since the bandwidth is essentially a constant percentage of the frequency to which the detector is tuned.

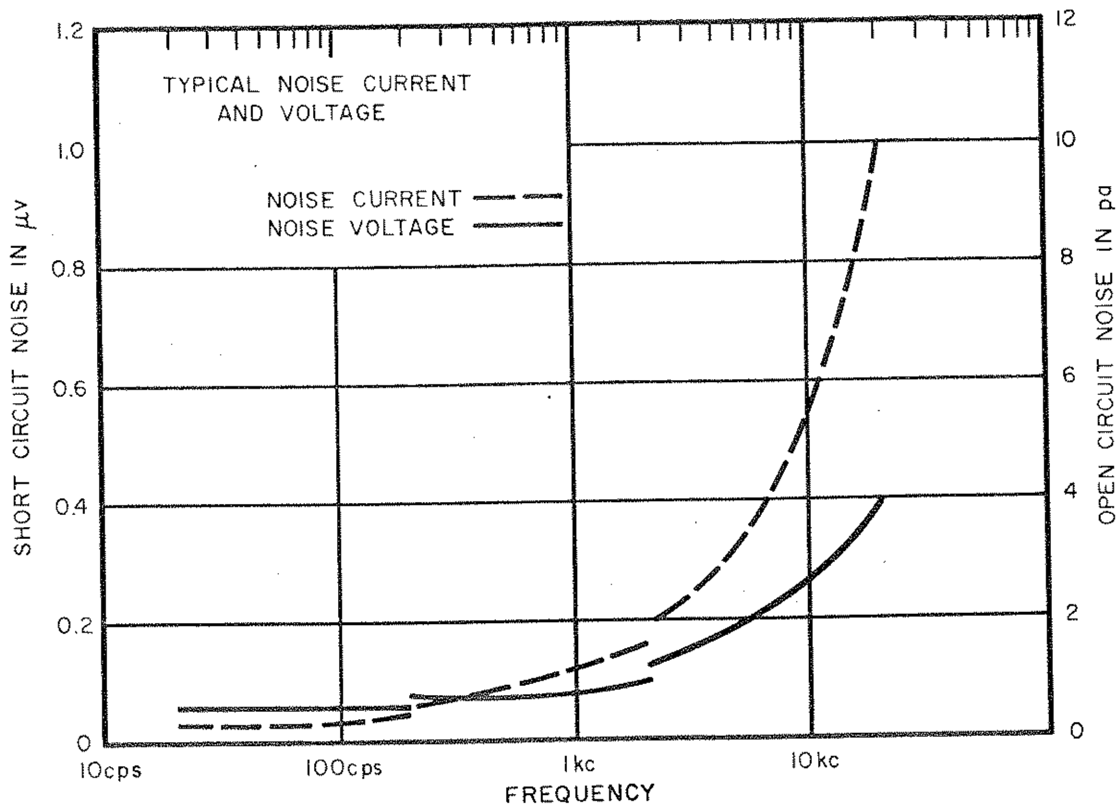


FIG. 3.4.2

3.4.3 NOISE POWER

Typical variations in the 1 kc detector equivalent input noise power over a wide range of source impedances is shown in Fig. 3.4.3. It may be noted from this curve that the noise power essentially reaches the theoretical limit for a 100 cycle equivalent noise bandwidth over several decades of source impedances.

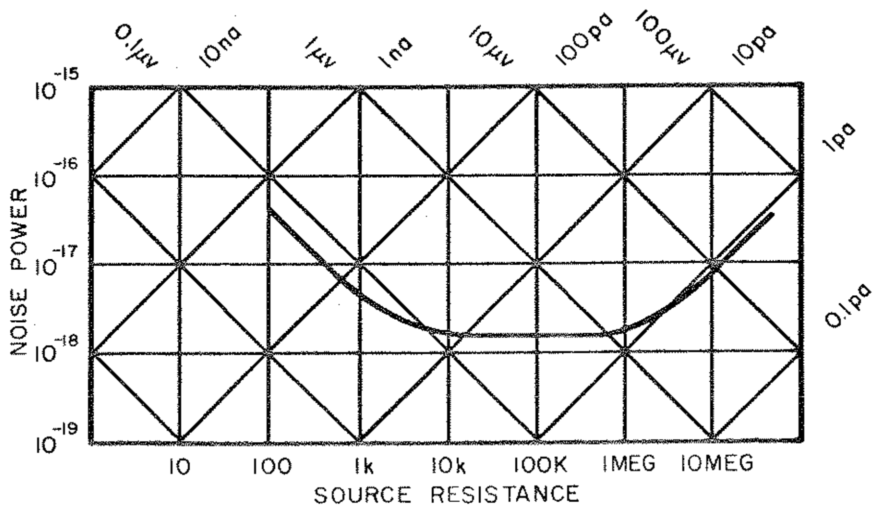


FIG. 3.4.3

3.4.4 AMPLITUDE RESPONSE

Characteristic amplitude response of the detector meter is shown in Fig. 3.4.4 for both the linear and the logarithmic modes of operation. As this curve illustrates, a detectable change in the deflection of the meter occurs for input signals of over a thousand times the normal linear full scale reading when used in the log position.

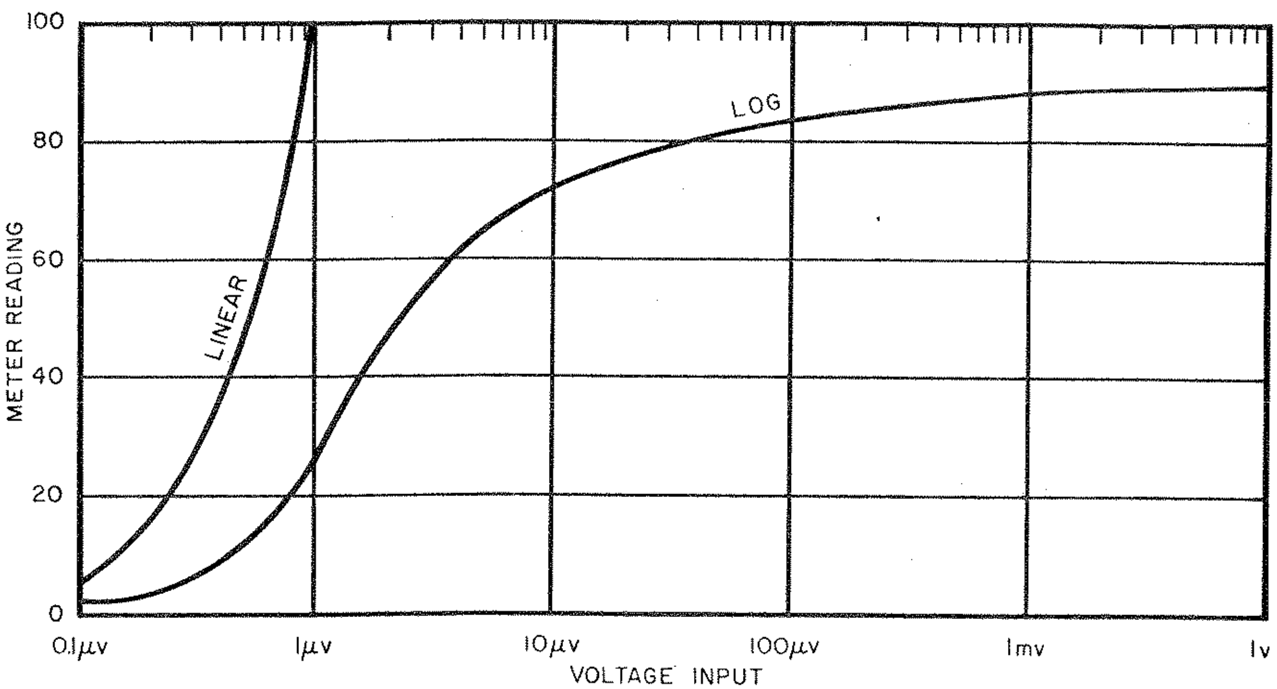


FIG. 3.4.4

3.4.5 GENERATOR OUTPUT

Typical variations in the generator output voltage and current over the tuning range are shown in Fig. 3.4.5.

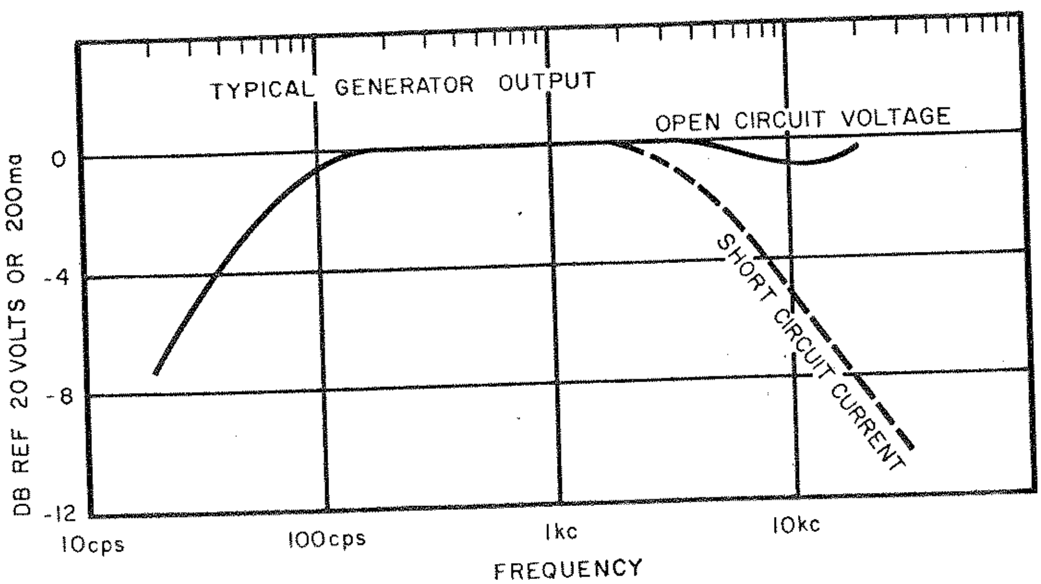


FIG. 3.4.5

4.1 TROUBLE SHOOTING

4.1.1 GENERAL

This instrument has been designed to give trouble free service with a minimum of maintenance required. If, however, it should be necessary to correct any difficulties which might arise, the following section should provide maintenance personnel with sufficient information to effect the required corrective action. It will be assumed that maintenance personnel are familiar with the operating instructions and theory of operation as contained in Sections II and III.

In the event of unusual difficulties which cannot be defined by service personnel, please write or phone the factory or nearest field representative, giving the model and serial number of the instrument, the nature of the trouble, and any test procedures used to isolate the probable cause.

4.1.2 REMOVAL OF THE COVER

The instrument cover may be removed by taking out the two screws located on the rear portion and pulling the cover straight back. Caution must be exercised not to strike any of the tubes or other components during the removal or replacement of the cover.

4.1.3 TUBE REPLACEMENT

It is probable that the majority of service required will be replacement of the vacuum tubes. Only three tube types are used in this instrument, 4 - 6BM8/ECL82, 4 - 6BL8/ECF80, and 1 - 7308. Normally any standard commercial vacuum tube may be used without special matching or testing required. It may be found, however, that there is some variation in the noise level with different tubes, and for the most critical applications it may be desired to select a tube for the lowest possible

short circuit noise level. The tube contributing principally to the noise level is the type 7308, V_1. In the event that this tube type is not immediately available, it may be replaced directly by either a type 6922 or 6DJ8. Although these latter tubes are electrically identical, they are somewhat more susceptable to mechanical vibrations.

The type 6BL8, V2, may, on rare occasions, contribute some excess noise. This may be determined by observing the noise level with the sensitivity range and vernier controls both in their counterclockwise position. This tube may then be interchanged with the similar types found in V3, V4, and V6 to yield the minimum noise level.

4.1.4 VOLTAGE MEASUREMENTS

Typical voltage measurements are indicated on the circuit diagrams for the generator and detector.

The DC voltages are all referenced to the chassis potential and are measured with a standard 11 megohm input impedance vacuum tube voltmeter. The measured readings should agree with those shown on the diagram within ±10%. All DC voltages are measured with the detector sensitivity and generator power controls in their minimum positions.

The AC voltages are measured with a sensitive 10 megohm input impedance AC vacuum tube voltmeter, and are all referenced to chassis potential. Because of the difficulty of thoroughly shielding the test probe when making these measurements, it is desirable to monitor the detector output with an oscilloscope to insure that the stray coupling thus introduced is not causing spurious oscillations, or that the added capacitance of the test lead is not appreciably loading any high impedance circuits.

An alternative and generally preferable method of avoiding spurious oscillations in AC signal tracing is to insert a voltage of the appropriate value at the particular test point, and observe the output voltage with a meter connected to the DET OUT terminals. To prevent undue loading of this test signal, it must be derived from a low impedance source. A convenient method for obtaining this voltage is to use a Dekatran® Decade Voltage Divider driven from a low impedance oscillator. The measured AC voltage reading should be within ±25% of those indicated on the circuit diagram.

4.1.5 REPAIR OF PRINTED CIRCUIT ASSEMBLIES

The printed circuit boards employed in this instrument have been carefully designed and manufactured to give long, reliable performance. If it should become necessary to replace any components, the following procedure is suggested.

It is recommended that a soldering iron of approximately 50 watts, with a small, well tinned tip be used. To avoid delaminating the copper conductor from the board, apply the iron for the shortest possible length of time.

To remove components with wire leads, such as resistors or capacitors, heat the component leads on the copper conductor side of the circuit board. Always apply the tip of the iron to the component lead rather than directly to the copper conductor. See Fig. 4.1.5. Pull gently on the lead from the component side with a pair of pliers or other small instrument hooked under the bent lead.

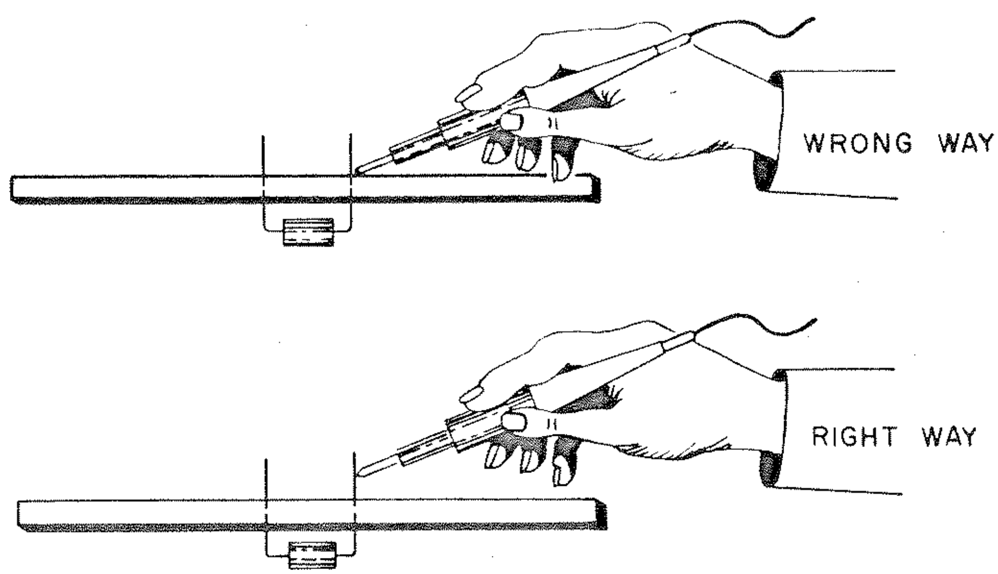


FIG. 4.1.5

To remove multiterminal devices such as tube sockets, heat each terminal in succession and lift only slightly. It will be necessary to repeat this procedure several times before the component can be removed. NOTE: Special attachments are made for soldering irons for removing multiterminal devices.

After the component has been removed, quickly reheat the solder and insert the point of an awl into the hole from the conductor side. If it is necessary to clean the copper conductor before resoldering, use some fine sandpaper or gently scrape with a knife.

To repair a break in the copper conductor, place a short piece of tinned copper wire across the break, and solder on each side. The wire should overlap the break by at least 1/4 inch on each side.

When replacing components, use only the best quality rosin core solder with no other fluxes. Bend the component leads to fit the hole spacing, and insert them in the board. (All hole centers are 3/4" for 1/2 and 1 watt resistors.) Do not force the component leads into the holes. Redrill the holes with an appropriately sized drill if the leads cannot be inserted easily. Holding the component tight against the assembly board, apply the soldering iron to the component lead on the copper side of the board and resolder. If the component is a semiconductor device, it is recommended that the lead be held on the component side with a pair of long nose pliers to act as a heat sink.

After finishing the soldering operation, clean off the excess flux with some noncorrosive solvent such as alcohol or Freon. If desired the repaired area may be protected by applying a small quantity of an insulating varnish.

4.1.6 TRIMMER RESISTOR ADJUSTMENTS

It may be noted from the circuit diagrams that there are several trimmer resistors in the circuit. These trimmers are for initial factory adjustment, and should not be touched during normal maintenance. If, however, any parts associated with these trimmers require replacement, one of the following adjustments may be necessary to restore proper performance.

CIRCUIT	FUNCTION	ADJUST FOR
R_{33}	Detector gain	Full scale meter deflection at 5 kc with 1 microvolt input signal.

CIRCUIT	FUNCTION	ADJUST FOR
R_{84}	Oscillator amplitude	1.2-1.5 volts output at SYNC OUT terminals. For minimum distortion, use setting providing amplitude slightly in excess of that required for reliable oscillation over entire frequency range.
R_{90}	Generator output	Open circuit generator output of 20 volts at 1 kc with 100 ohms output impedance.
R_{106}	Generator high voltage regulator	250 volts DC at regulator output.
R_{112}	Detector high voltage regulator	250 volts DC at regulator output.
R_{115}	Detector filament filter	6.2 volts DC at filter output.