OPERATING INSTRUCTIONS

P-582

TYPE P-582
CAPACITANCE BRIDGE

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manufacturers of
electronic apparatus
for science and industry

®

GENERAL RADIO COMPANY
CAMBRIDGE 39, MASSACHUSETTS, USA

975-A

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OPERATING INSTRUCTIONS

TYPE P-582
CAPACITANCE BRIDGE

(TEST SET, CAPACITANCE BRIDGE, TTU24/E)

Form 975-A
May, 1958

GENERAL RADIO COMPANY

CAMBRIDGE 39 — MASSACHUSETTS

SPECIFICATIONS

RANGE	Capacitance: 5 $\mu\mu$f to 0.011 μf Dissipation Factor: 0 to 0.11.
ACCURACY:	Capacitance, see Figure 7. Variable capacitor on x1 Range, ±0.4 $\mu\mu$f or ±0.1%, whichever is greater; on x 1/10 Range, ±0.04 $\mu\mu$f or ±0.1%, whichever is greater. Decade capacitor, ±0.1% on both ranges. Dissipation Factor: ±2% of reading ±0.0002.
OSCILLATOR:	Frequency: 400 cps ±0.25%. Output: 25 volts nominal. Distortion: less than 0.5%.
DETECTOR:	Sensitivity on amplifier alone: 10% scale deflection for 10-μv input. Sensitivity of system: x1 MULTIPLIER position, 10% deflection for 0.05 $\mu\mu$f ΔC; x1/10 MULTIPLIER position, 10% for 0.005 $\mu\mu$f ΔC. Selectivity of amplifier alone: down 56 db at 800 cps, down 64 db at 60 cps. Selectivity of amplifier and bridge transformer: down 50 db at 800 cps, down 80 db at 60 cps.
EFFECT OF IMPEDANCE TO THIRD TERMINAL (CHASSIS):	Impedance from unshielded lead to chassis shunts the oscillator, and therefore causes no bridge error. Output voltage is reduced about 50% by shunt impedance of 5 kilohms or 0.1 μf. Impedance from coaxial lead to chassis shunts the bridge transformer. On the x1 MULTIPLIER position, there is negligible effect from a shunt of 1 kilohm or 0.1 μf. On the x1/10 MULTIPLIER position, there is negligible effect from 10 kilohms or 0.01 μf.
ACCESSORIES SUPPLIED:	For connection to Type P-579 Fuel Gage Tester, two unshielded cable assemblies and one common shielded assembly; for connection to Type 03 Fuel Gage Tester, one cable harness, including termination unit assembly; general-purpose three-terminal measurements, one coaxial and one unshielded cable assembly, with Type 874 connectors. Power cord is also supplied. (Refer to paragraph 1.2.3 and Figure 18.)
POWER SUPPLY:	105 to 125 v, 50 to 60 cps. 30 watts input at 115-v line.
DIMENSIONS:	Length 22-1/2 in., height 14 in., depth 12-3/4 in., over-all including cover.
WEIGHT:	55 lb.

GENERAL RADIO EXPERIMENTER reference: Vol 32 No. 9, February 1958.

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Figure 1. Type P-582 Capacitance Bridge.

TYPE P-582

CAPACITANCE BRIDGE

Section 1

INTRODUCTION

1.1 PURPOSE. The Type P-582 Capacitance Bridge (Figure 1) is a complete, self-contained bridge system for the measurement of direct capacitance and dissipation factor. Although designed especially to check the calibration of the Type MD-1 Field Variable-Capacitance Tester (GR Type P-579), it can be used for general capacitance measurements within the ranges specified.

1.2 DESCRIPTION.

1.2.1 CONTROLS. The controls on the panel of the Type P-582 Capacitance Bridge are listed in Table 1 below.

1.2.2 CONNECTORS. The connectors on the panel of the Type P-582 Capacitance Bridge are listed in Table 2 below.

1.2.3 ACCESSORIES. Supplied with the Type P-582 Capacitance Bridge are a power cord and interconnecting cables listed in Table 3 and shown in Figure 18.

TABLE 1 - CONTROLS

Name	Type	Function
C1	Continuous rotary control	Adjusts variable capacitor.
C2	11-position selector switch	Adjusts value of decade capacitor.
MULTIPLY TOTAL C BY	2-position toggle switch	Multiplies value of C1 and C2 by 1 or 1/10, as desired.
D	Continuous rotary control	D balance adjustment; indicates unknown dissipation factor.
FINE ADJ (on C1)	Continuous rotary control	Vernier control on C1 (does not appreciably affect C1 calibration).
GAIN	Continuous rotary control	Adjusts detector gain.
POWER	2-position toggle switch	Energizes instrument.

TABLE 2 - CONNECTIONS

Name	Type	Function
COAXIAL LEAD	M-H 415607B	Connection from unknown to bridge transformer.
UNSHIELDED LEAD	M-H 415607B	Connection from unknown to oscillator.
POWER	AN3106E12S3S	Line-voltage connection.
GND	GR Type 938-P Binding Post	Connection to chassis of instrument.

TABLE 3 - ACCESSORIES

Description	Type No.	Purpose
Cable Assembly, Unshielded (A) Cable Assembly, Coaxial (B) Cable Assembly, Unshielded (C)	P582-P1-20 P582-P1-21 P582-P1-22	Connection to Type P-579 Fuel Gage Tester.
Cable Assembly, Unshielded (UN-874) Cable Assembly, Coaxial (CO-874)	P582-P2-20 P582-P2-21	General-purpose connections for three-terminal measurements.
Cable Harness (03) with Type 722-DS9-P11 Termination Unit Assembly	P582-P3-20	Connector to Type 03 Fuel Gage Tester.

Section 2
PRINCIPLES OF OPERATION

2.1 SERIES AND PARALLEL EQUIVALENTS. The Type P-582 measures series capacitance, C_s, and dissipation factor, D, as defined by the equivalent circuit of Figure 2, where $D = \omega R_s C_s$.

The formula for effective parallel capacitance, as defined by the equivalent circuit of Figure 3, is $C_p = \frac{C_s}{1 + D^2}$. The value of D is independent of the equivalent circuit used to describe the unknown. For a parallel equivalent circuit, $D = \frac{1}{\omega R_p C_p} = \omega R_s C_s$.

2.2 DIRECT AND STRAY CAPACITANCES. Almost all physical capacitors are actually three-terminal networks where two terminals are those of the capacitor and the third consists of surrounding objects, such as shield, free space, or ground. Stray capacitance from each capacitor terminals to this third terminal will affect the value of the capacitor unless provision is made to measure the capacitor by itself. The error introduced by the stray capacitance is of greatest importance when the main capacitance is small. This three-terminal system is shown in Figure 4. Here the direct capacitance between terminals 1 and 2 is C_{12}. Also present are stray capacitances C_{13} and C_{23} from each of these terminals to a third terminal. The Type P-582 Capacitance Bridge will measure C_{12} only, even though C_{13} and C_{23} may be much larger than C_{12}.

2.3 BRIDGE CIRCUIT. The basic bridge circuit is shown in Figure 5. The circuit is most easily explained if we consider the transformer a differential current detector. That is:

$$E_o = j\omega M (I_x - I_s) \tag{1}$$

where M is the mutual inductance from one primary winding to the secondary. At null the voltages on the

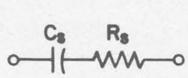


Figure 2.

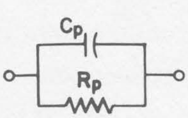


Figure 3.

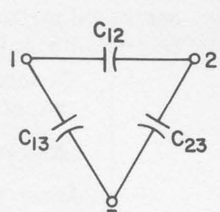


Figure 4.

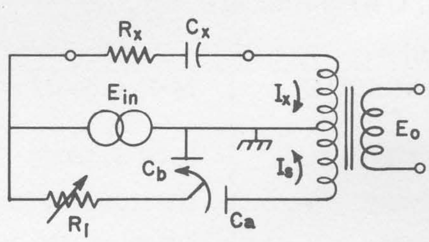


Figure 5.

primary windings are negligible because the transformer is tightly coupled. Therefore:

$$I_x = \frac{E_{in}}{Z_x} = \frac{E_{in}}{R_x + \frac{1}{j\omega C_x}} = E_{in}\frac{j\omega C_x}{1 + jD} \qquad (2)$$

and $I_s = \frac{E_{in}}{Z_s}$ where Z_s is the short-circuit transfer impedance $(\frac{1}{y_{21}})$ of the three-element T network in the standard side of the bridge.

Since

$$Z_s = R_1(1 + \frac{C_b}{C_a}) + \frac{1}{j\omega C_a} = \frac{1 + j\omega R_1(C_a + C_b)}{j\omega C_a}, \qquad (3)$$

$$I_s = E_{in}\frac{j\omega C_a}{1 + j\omega R_1(C_a + C_b)}. \qquad (4)$$

Since at null, $E_o = 0$ and $I_x = I_s$:

$$\frac{j\omega C_x}{1 + jD} = \frac{j\omega C_a}{1 + j\omega R_1(C_a + C_b)}. \qquad (5)$$

Thus the necessary conditions for null are

$$C_x = C_a, \quad D_x = \omega R_1(C_a + C_b). \qquad (6)$$

The sum $(C_a + C_b)$ is kept constant, so that R_1 is proportional to D_x, and can therefore be calibrated directly in dissipation factor. The standard capacitor that forms the differential unit consisting of C_a and C_b is actually a 50-1100-μμf differential variable air capacitor (C1, Figure 10) and a 1000-10,000-μμf decade of silvered-mica capacitors (C2), which can be switched in to extend the capacitance range of the bridge upward. The small losses of these mica capacitors are balanced out by the resistive network consisting of resistors R2 to R9.

To extend the capacitance range downward, the turns ratio in the transformer (and thus the mutual inductance from the unknown primary winding) can be increased by a factor of 10. Thus, with the MULTIPLY TOTAL C BY switch at 1/10:

$$E_o = j\omega M(10 I_x - I_s) \qquad (7)$$

So that at null

$$\frac{10j\omega C_x}{1 + jD_x} = \frac{j\omega C_a}{1 + j\omega R_1(C_a + C_b)} \qquad (8)$$

Therefore

$$C_x = \frac{C_a}{10}, \quad D_x = \omega R_1(C_a + C_b). \qquad (9)$$

The accuracy of this turns ratio is high enough to result in negligible error.

2.4 STRAY IMPEDANCE TO CHASSIS. Stray impedance from either unknown terminal to the chassis of the instrument has negligible effect unless it is relatively low (refer to Specifications). An impedance across the oscillator merely loads down the oscillator, and this merely reduces sensitivity and eventually causes distortion.

Impedance across the transformer would have no effect if the transformer were ideal. The small effective series resistance and leakage inductance of the transformer will cause an error if the shunting impedance is low.

Because of the substantial immunity from effects of stray impedance, it is often possible to permit these strays to be actual components, and to measure the unknown while it is connected in a circuit.

2.5 OSCILLATOR. The oscillator circuit consists of a precise Wien bridge oscillator and a cathode-follower output stage. Precision frequency-determining components and more-than-usual loop gain provide high stability. A thermistor limits the amplitude of oscillation.

2.6 DETECTOR. The detector is a high-gain selective amplifier, which drives the panel meter. Two cascaded twin-T feedback circuits are used to obtain the high selectivity provided. The over-all rejection of low frequencies is enhanced by the nature of the bridge itself, whose sensitivity, from oscillator to transformer secondary, is proportional to ω^2. That is:

$$E_o = j\omega M(I_x - I_s) = -\omega^2 M\Delta C \qquad (10)$$

The meter characteristic is made nonlinear by a shunt diode to facilitate balance when the bridge is off null. When the bridge is substantially unbalanced, the panel lights indicate the direction that the standard capacitance (C1 and C2) should be varied to obtain a null.

Section 3
OPERATING PROCEDURE

3.1 INSTALLATION.

3.1.1 POWER CONNECTIONS. Connect the instrument to a 115-volt, 50-60-cycle power line by means of the power cord supplied. This cord is connected to the bridge through a watertight connector.

3.1.2 GROUNDING. A connection from a good ground to the panel terminal marked GND is generally desirable. However, if the unknown is completely shielded a ground is not necessary. If the unknown is not completely shielded, good grounding is necessary. Note that if one side of the unknown is grounded, the instrument should not be grounded. Refer to paragraph 3.3 for details on the measurement of unshielded and grounded capacitors.

3.2 MEASUREMENT OF DIRECT CAPACITANCE OF SHIELDED CAPACITOR.

3.2.1 CONNECTION TO UNKNOWN. Connect the unknown to the panel connectors marked COAXIAL LEAD and UNSHIELDED LEAD. Use coaxial lead for the connection to the COAXIAL LEAD terminal; the other lead may be shielded or unshielded. Figure 6 shows the normal setup for the measurement of a shielded component. Note that in this figure, the third terminal (the shield) is tied to the bridge chassis by means of the cable shield, so that a separate connection is not necessary.

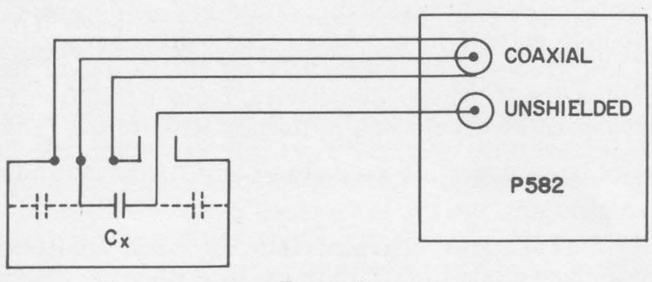


Figure 6.

Due to the nature of this three-terminal measurement, the leads used may be quite long without causing error. Note that the above connection measures only C_x, and is independent of the values of stray capacitance shown.

3.2.2 BALANCING PROCEDURE. Adjust C1, C2, the MULTIPLY TOTAL C BY switch, and the D control to bring the meter indication as near zero as possible. Detector sensitivity can be adjusted by means of the GAIN control. However, adjustment of this control is usually unnecessary, since the panel lights indicate the direction in which C1 and C2 should be adjusted when there is a substantial capacitive unbalance. A large D unbalance will not affect the light, so that if the lights are both off and the meter is upscale, an adjustment of the D dial is required.

A vernier capacitor, marked FINE ADJ, permits accurate low D measurements when the capacitance is small. The total adjustment here is about ±0.03 μμf (or ±0.003 μμf on the 1/10th range), so that the position of this control does not affect the calibration of C1.

Because of the range-extending features described in paragraph 2.3, there are two possible methods of balancing unknown capacitances from 110 to 1100 μμf: by C1, with the multiplier at 1 and C2 at zero; or by C1 and C2, with the multiplier set at 1/10. With the first method, the accuracy is 0.4 μμf or 0.1%; the second method yields an over-all accuracy close to 0.1%, just as on the 1000-11,000-μμf range.

3.2.3 COMPUTATION. The value of the unknown capacitor is C1 plus C2, plus their corrections, multiplied by 1 or 1/10 as indicated by the multiplier switch. The value of D is indicated directly on the D dial. Note that the capacitance measured is the effective series capacitance, as defined in paragraph 2.1.

One turn of the capacitance dial corresponds to 50 μμf. The value of C1 is the dial reading plus the lower of the two drums readings above and below the fixed indicating line. Each small dial division represents 0.2 μμf.

The calibration correction chart on the panel gives a correction for each 50-μμf increment of C1 and each step of C2. The correction used on C1 should be a simple interpolation (to the nearest 0.1 μμf) between the corrections for the two drum readings involved. These corrections are determined for each instrument in the General Radio laboratory.

The following is a sample calculation of capacitance where the bridge is balanced with controls set as follows:

MULTIPLY TOTAL C BY set at 1/10
C2 set at 2000

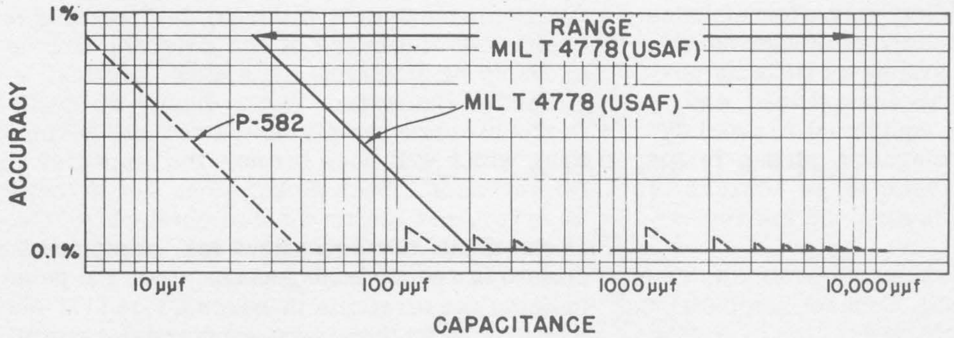


Figure 7.
Percent Accuracy
vs Capacitance Measured

C1 dial drum reads 21.4 μμf, drum between 650 and 700 μμf
C1 correction at 650 assumed to be -0.2
C1 correction at 700 assumed to be +0.1
C2 correction at 2000 assumed to be +1.1

The unknown capacitance is therefore:

C1 dial	21.4 μμf
C1 drum	+650.0
C1 correction	- 0.1
C2 setting	2000.0
C2 correction	+ 1.1
Total	2672.4 μμf

2672.4 x 1/10 = 267.24 μμf

(Since the accuracy is limited to ±0.1%, the corrections in the above calculation are of little consequence.)

3.2.4 ACCURACY. The capacitance accuracy is a function of C1 and C2. The accuracy on C1 (with correction) is ±0.1% or ±0.4 μμf, whichever is greater, and the accuracy on C2 (with correction) is ±0.1%. The multiplier does not add appreciable error, so that the limiting precision is ±0.04 μμf when small capacitors are measured on the 1/10 range. (See Figure 7.)

3.3 MEASUREMENT OF UNSHIELDED COMPONENTS. If a component is unshielded, the value of capacitance depends to some extent on the geometry of the connectors and on the proximity of equipment and personnel. These effects are negligible when large capacitors are measured, but are important when the unknown is small. For precise measurement, the instrument, as well as all nearby equipment and personnel, should be grounded for such measurements.

Figure 8 shows some of the stray capacitances that must be considered in a precise measurement. If the GND terminal is connected to an external ground, C1 and C2 have no effect. However, capacitances to an ungrounded point P will have an effect.

The actual unknown is:

$$C_x + C6 + \frac{C3C4}{C3 + C4 + C5}$$

Note also that the value of C6, the capacitance between leads, depends greatly on the geometry of the connection and of the coaxial lead shield.

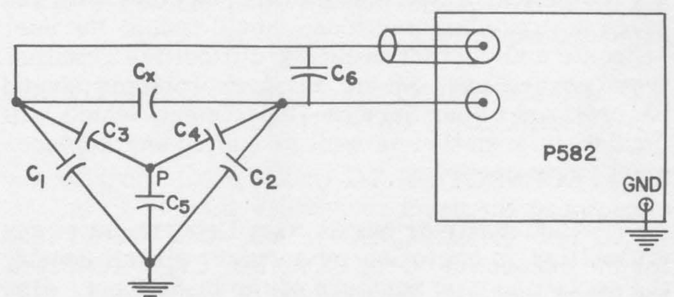


Figure 8.

3.4 MEASUREMENT OF CAPACITANCE TO GROUND. If one terminal of the unknown is grounded, the chassis of the bridge must be left ungrounded. The setup is shown in Figure 9. Capacitance from the instrument case to ground shunts the bridge oscillator and causes no difficulty. The chassis may still be used as a third terminal. If the point Q were tied to the chassis (or shield), C1 and C2 would have no effect. As drawn, the actual value of the unknown is:

$$C_x + \frac{C1C2}{C1 + C2}$$

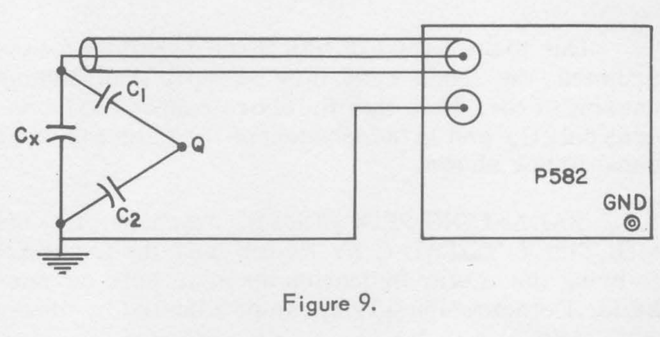


Figure 9.

3.5 PICKUP. Two types of pickup may affect balance in some instances. When unshielded measurements are made, it is desirable to expose as little as possible of the connections to the coaxial lead, and to ground the bridge and nearby equipment to avoid capacitive pickup. To avoid magnetic pickup in the bridge transformer, do not place large sources of low-frequency magnetic fields near the instrument.

Four-hundred cycle pickup could cause an error in measurement, although the frequencies of the bridge oscillator and of the external source would probably be different, and a slow "beating" would be noticed on the meter. Pickup from a 60-cycle source is troublesome mainly on the seventh harmonic (420 cps), which will pass through the amplifier with little rejection. Such pickup does not directly cause an error, but limits the null obtainable. Grounding as much nearby equipment and personnel as possible will reduce such pickup.

Section 4
SERVICE AND MAINTENANCE

4.1 GENERAL. This information, together with that given in preceding sections, should enable the user to locate and correct ordinary difficulties resulting from normal use. Major service problems should be referred to our Service Department, which will furnish information as well as supply any replacement parts needed.

When notifying our Service Department of any difficulties in operation or service, please specify the serial and type numbers of the instrument. Also give a complete report of trouble encountered and steps taken to eliminate the trouble.

Before returning an instrument or part for repair, please write to our Service Department, requesting a Returned Material Tag, which includes shipping instructions. Use of this tag will insure proper handling and identification. A purchase order covering repair of material returned should also be forwarded to avoid unnecessary delay.

4.2 CALIBRATION. If the corrections given on the calibration chart should in time be found in error, a new chart may be made. A high-precision capacitor should, of course, be used for such recalibration.

If the D scale is clearly in error, it can be adjusted by means of the eight screws on the rear of the rheostat, which deflect a cam mechanism to match the rheostat characteristic to that of the dial.

4.3 INTERNAL ADJUSTMENTS.

4.3.1 OSCILLATOR FREQUENCY ADJUSTMENT. The oscillator frequency is adjusted by means of R13, on the small etched board in the rear center of the shelf.

4.3.2 LOSS-BALANCING NETWORKS. The loss-balancing adjustments, which cancel out the small losses of the decade mica capacitor C2, are set to give a zero reading on the D dial when a good, dry air capacitor is used as the unknown. There is one adjustment for each of the four capacitors that make up the decade.

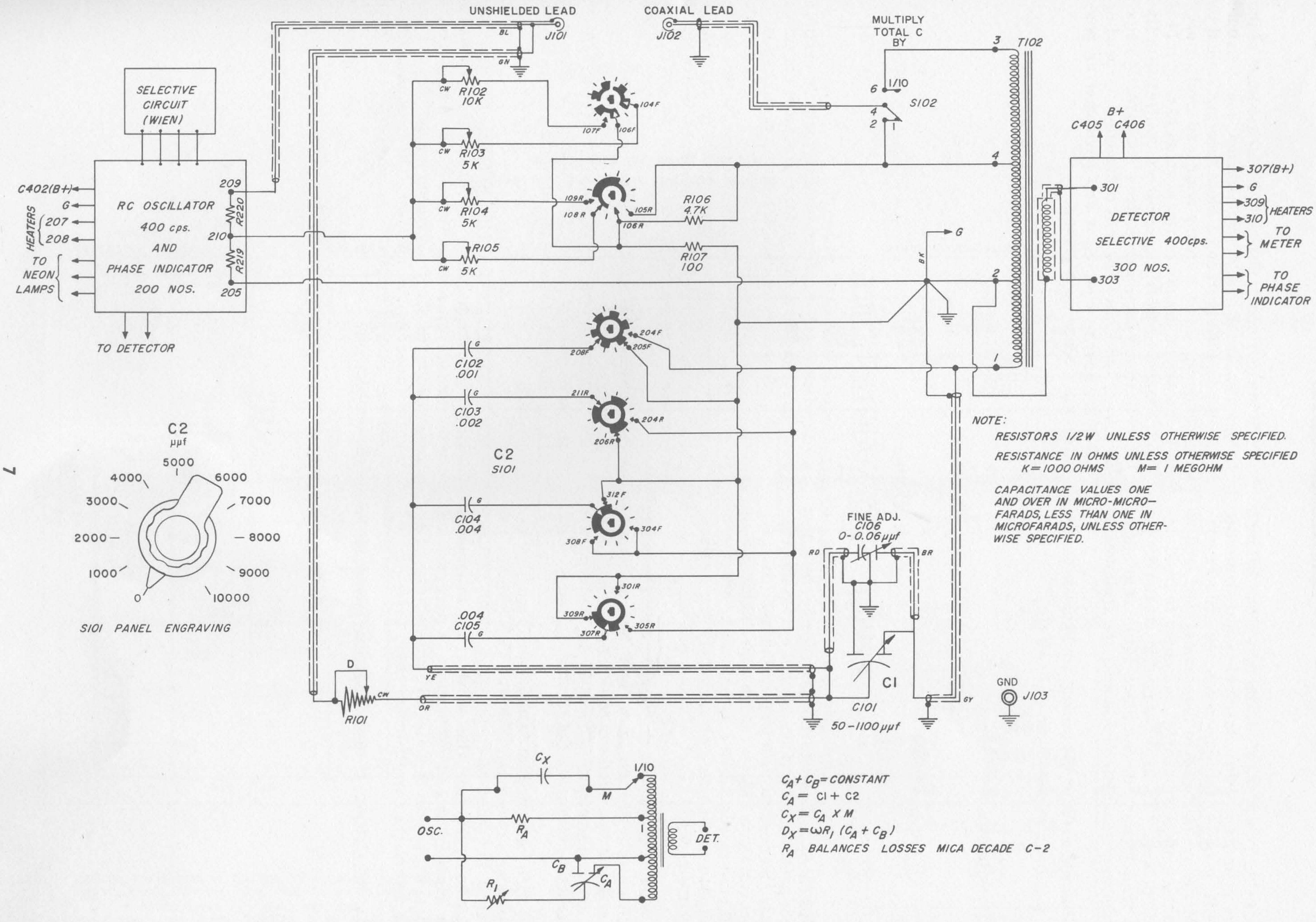


Figure 10. Schematic Diagram, P-582 Capacitance Bridge.

NOTE:

RESISTORS 1/2 W UNLESS OTHERWISE SPECIFIED.
RESISTANCE IN OHMS UNLESS OTHERWISE SPECIFIED.
K = 1000 OHMS M = 1 MEGOHM
CAPACITANCE VALUES ONE AND OVER IN MICRO- MICROFARADS, LESS THAN ONE IN MICROFARADS, UNLESS OTHERWISE SPECIFIED.

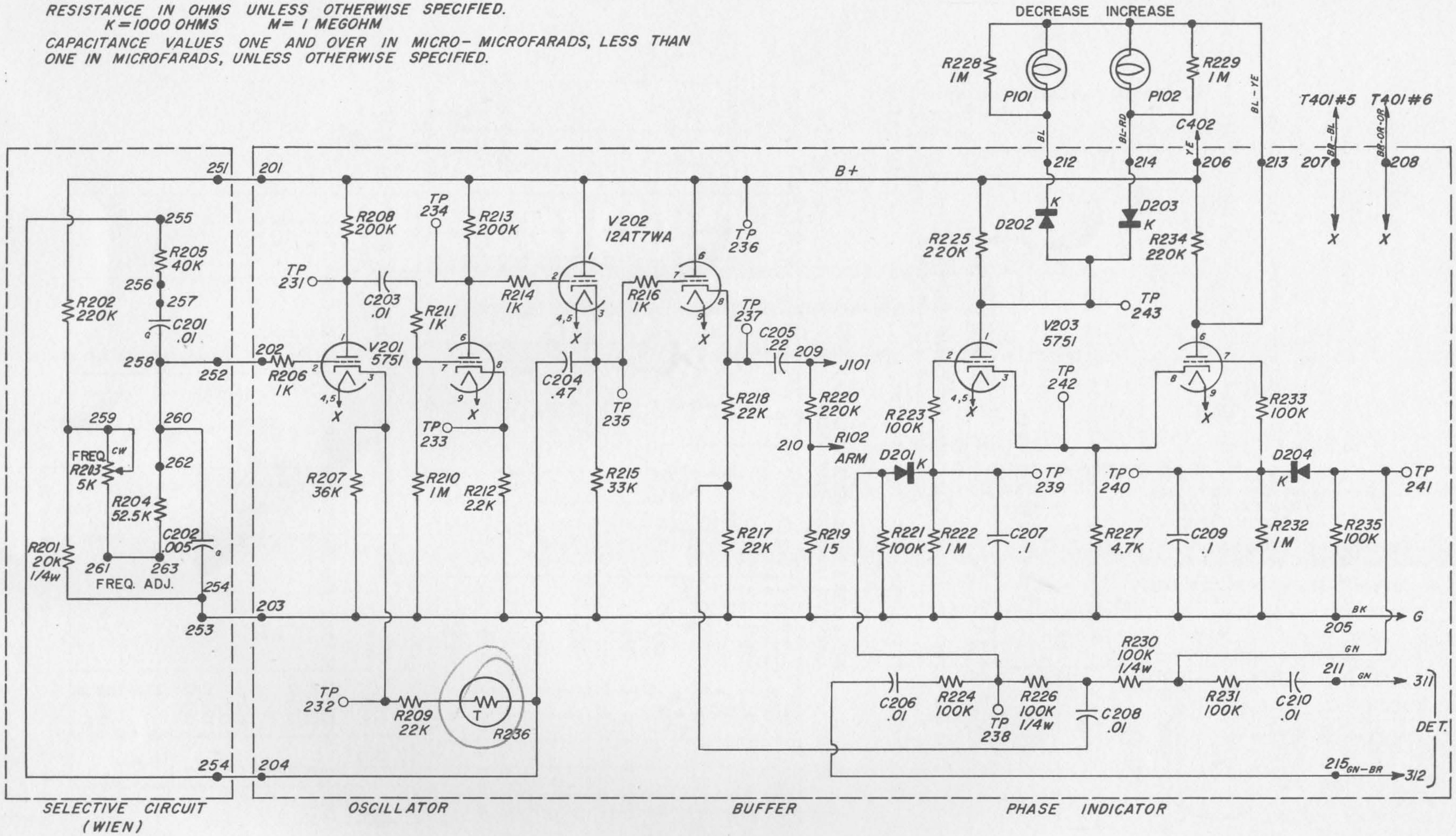


Figure 11. Schematic Diagram of Oscillator and Phase Indicator Circuit.

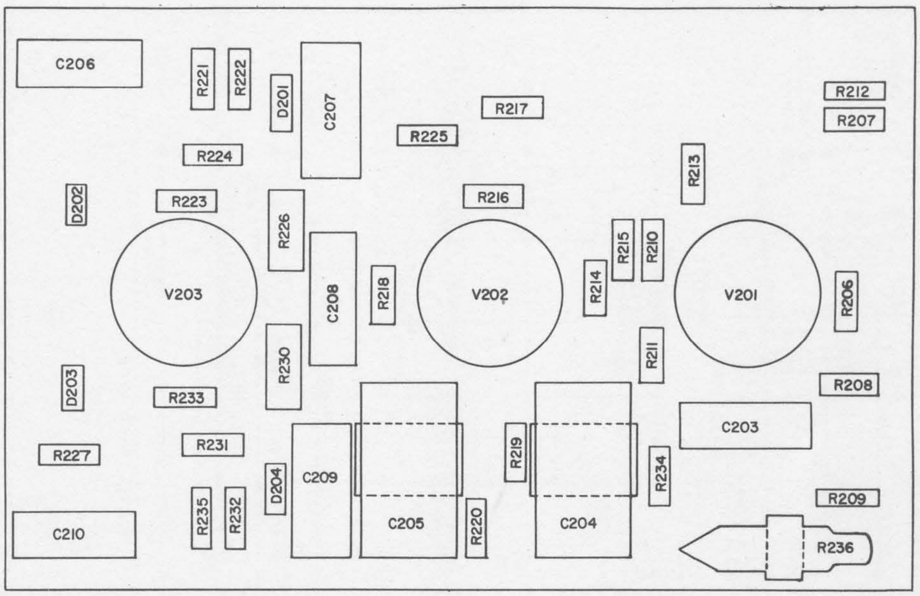


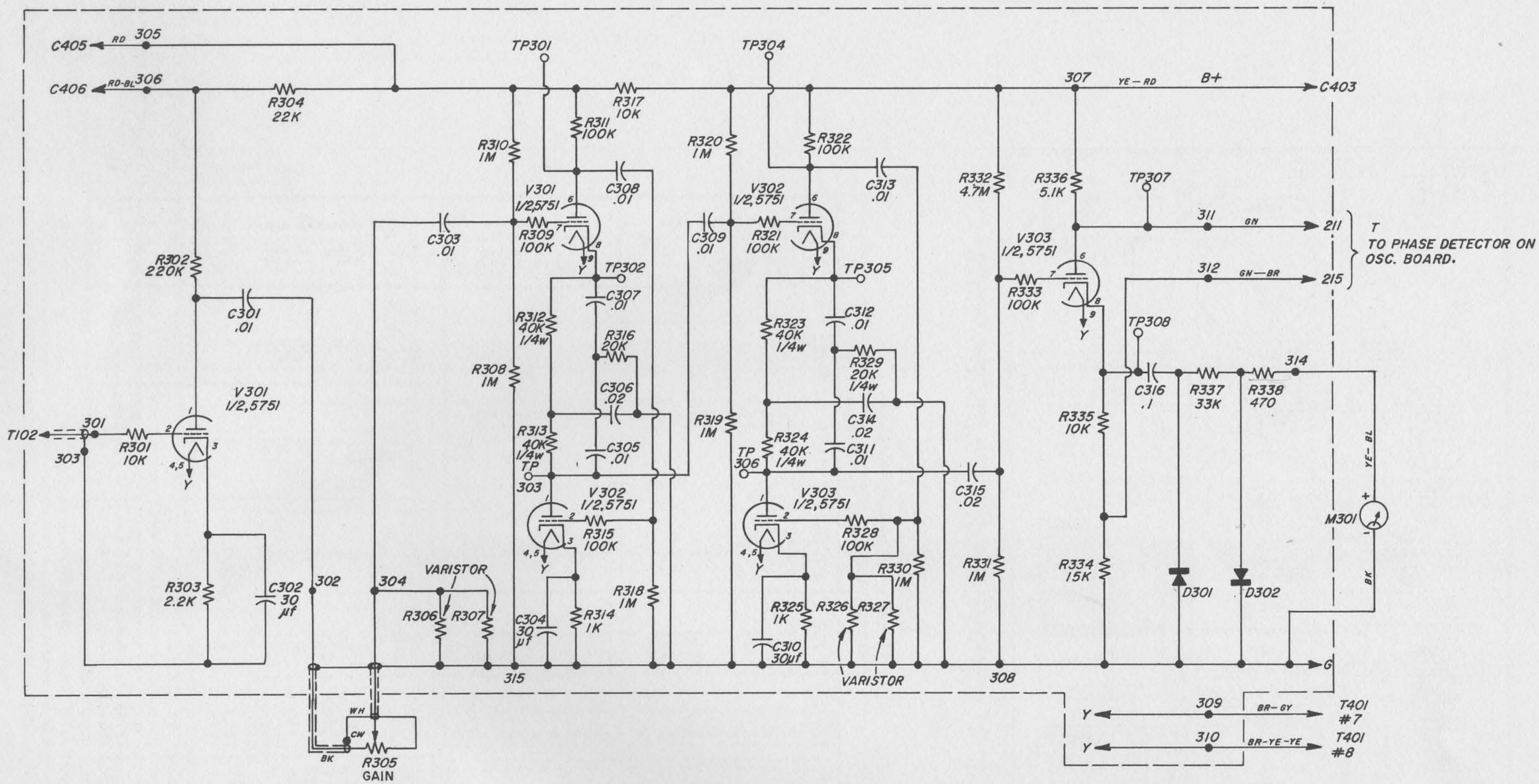
Figure 12. Tube and Component Layout, Oscillator and Phase Indicator Circuit.

OSCILLATOR & PHASE INDICATOR BOARD
TEST VOLTAGES AND RESISTANCES

TUBE (TYPE)	PIN	TEST POINT	VOLTS DC	VOLTS AC (RMS)	RES TO GND
V201 (5751)	1	TP231	150	1	200 k
	2		25*	15	75 k
	3	TP232	25	15	40 k
	4		75	0	60 k
	5		75	0	60 k
	6	TP234	150	30	200 k
	7		0*	1	1 M
	8	TP233	1.5	0.5	2.2 k
	9		75	6.3	60 k
V202 (12AT7WA)	1	TP236	300	0	0
	2		150	30	200 k
	3	TP235	150	30	30 k
	4		75	0	60 k
	5		75	0	60 k
	6	TP236	300	0	0
	7		150	30	35 k
	8	TP237	150	30	40 k
	9		75	6.3	60 k

TUBE (TYPE)	PIN NO.	TEST POINT	VOLTS DC † Balance	INCREASE C Lit	DECREASE C Lit	VOLTS AC (RMS)	RES TO GND
V203 (5751)	1	TP243	150	160	110	1	170 k
	2††	TP239	4	2	6	0	75 k
	3	TP242	5	6	6	0	5 k
	4		50	75	50	0	60 k
	5		50	75	50	0	60 k
	6	Term. 213	150	110	160	1	170 k
	7††	TP240	4	6	2	0	75 k
	8	TP242	5	6	6	0	5 k
	9		50	75	50	6.3	60 k
			VOLTS AC †				
		TP238	3.0	1.4	4.7		70 k
		TP241	3.0	4.7	1.4		70 k

For notes see page 11.



NOTE:

RESISTORS 1/2 W UNLESS OTHERWISE SPECIFIED.
RESISTANCE IN OHMS UNLESS OTHERWISE SPECIFIED.
K=1000 OHMS M=1 MEGOHM
CAPACITANCE VALUES ONE AND OVER IN MICRO-MICROFARADS, LESS THAN ONE IN MICROFARADS, UNLESS OTHERWISE SPECIFIED.

Figure 13. Schematic Diagram of Detector Circuit.

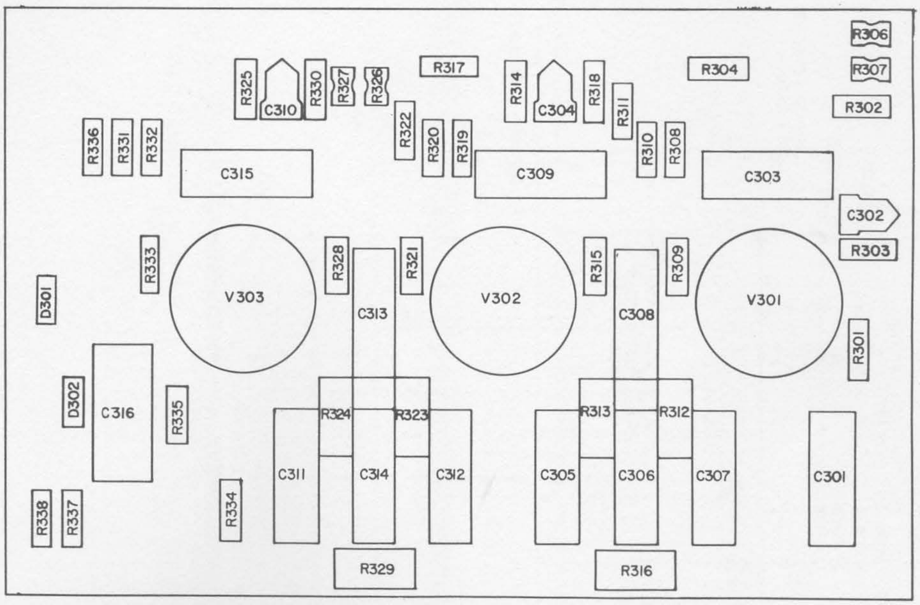


Figure 14. Tube and Component Layout, Detector Circuit.

DETECTOR CIRCUIT BOARD
TEST VOLTAGES AND RESISTANCES

TUBE (TYPE)	PIN	TEST POINT	VOLTS DC	VOLTS AC (RMS) † Balance	INCREASE C Lit	DECREASE C Lit	RES TO GND
V301 (5751)	1		120	-	-	-	250 k
	2		0	-	-	-	1 k
	3		1.5	-	-	-	2 k
	4		75	3	3	3	40 k
	5		75	3	3	3	40 k
	6	TP301	200	0	1.5	1.5	1 M
	7		120	0	0.7	0.7	600 k
	8	TP302	140	0	0.7	0.7	∞
	9		75	3	3	3	40 k
V302 (5751)	1	TP303	200	0	10	10	∞
	2		0	0	1	1	1.1 M
	3		1.5	-	-	-	750
	4		75	3	3	3	40 k
	5		75	3	3	3	40 k
	6	TP304	200	0	10	10	100 k
	7		120	0	10	10	600 k
	8	TP305	140	0	8	8	∞
	9		75	3	3	3	40 k
V303 (5751)	1	TP306	60	0	10	10	∞
	2		0	0	0.5	0.5	110 k
	3		1.0	-	-	-	1 k
	4		75	3	3	3	40 k
	5		75	3	3	3	40 k
	6	TP307	275	0	7	7	5 k
	7		25	0	10	10	1 M
	8	TP308	50	0	10	10	25 k
	9		75	3	3	3	40 k

NOTES

A-C voltages were measured with a GR Type 1803-B Vacuum-Tube Voltmeter. Values are rms for sinusoidal waveforms.

D-C voltages were measured with a GR Type 1803-B VTVM. A 20,000 ohm/volt meter may be used except at high-impedance points, designated by *.

Resistances may be measured with any good ohmmeter. Turn power off and ground B+ (term 206 and 207).

Terminal 206 B+ input voltage 300 v.

Terminal 207 B+ input voltage 300 v.

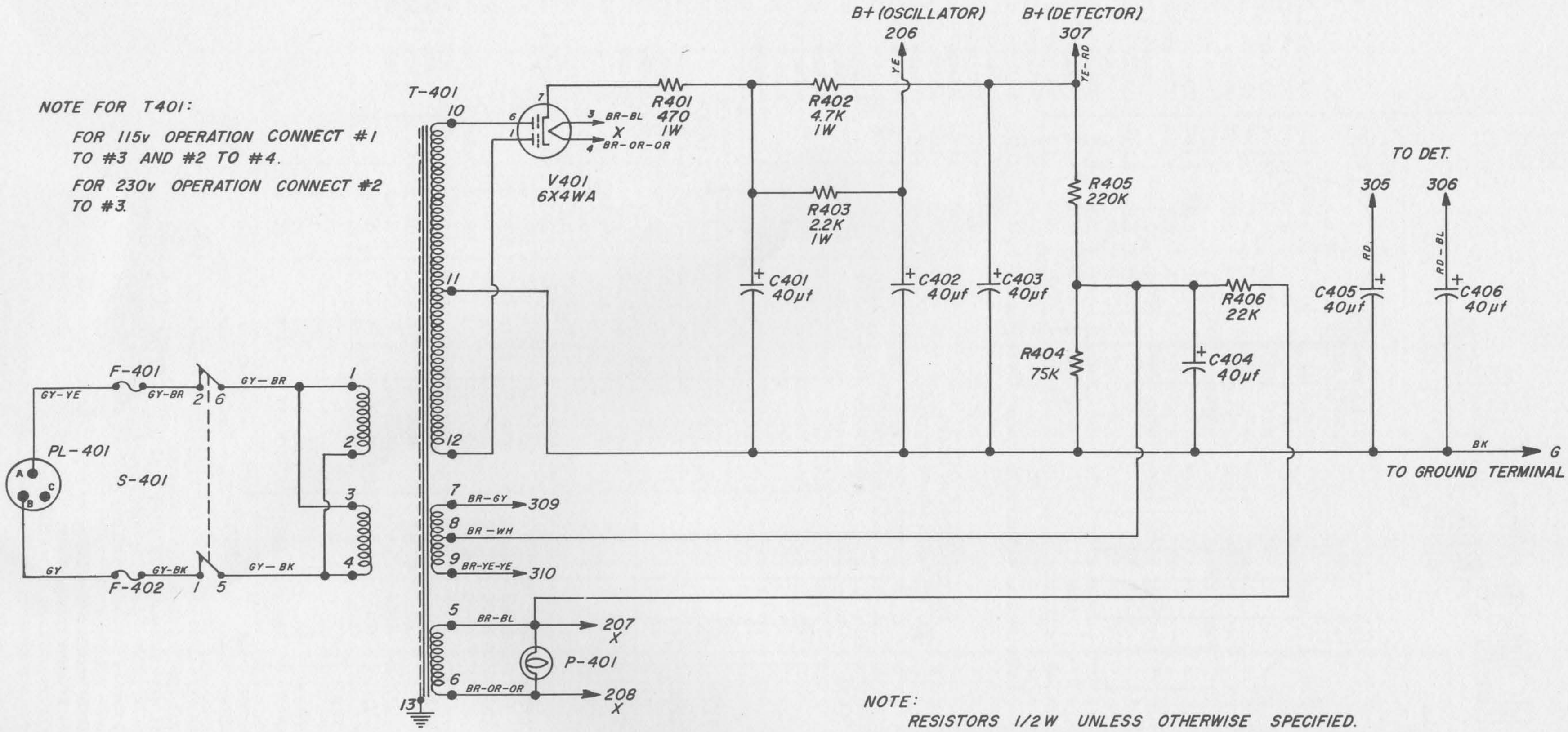
† - Voltage is dependent on bridge balance.

†† - 100-k resistor between TP239 and pin 2, and between TP240 and pin 7.

NOTE FOR T401:

FOR 115v OPERATION CONNECT #1 TO #3 AND #2 TO #4.

FOR 230v OPERATION CONNECT #2 TO #3.



NOTE:

RESISTORS 1/2 W UNLESS OTHERWISE SPECIFIED.

RESISTANCE IN OHMS UNLESS OTHERWISE SPECIFIED.
K=1000 OHMS M= 1 MEGOHM

CAPACITANCE VALUES ONE AND OVER IN MICRO-MICROFARADS, LESS THAN ONE IN MICROFARADS, UNLESS OTHERWISE SPECIFIED.

Figure 15. Schematic Diagram of Power Supply Circuit.

Section 5
PARTS LIST

					PART NO. (NOTE A)
RESISTORS (NOTE B)	R101	3550 to 3700			433-406
	R102	10 k	±10%		POSW-3
	R103	5 k	±10%		POSW-3
	R104	5 k	±10%		POSW-3
	R105	5 k	±10%		POSW-3
	R106	4.7 k	±5%	1/2w	REC-20BF
	R107	100 k	±5%	1/2w	REC-20BF
	R201	20 k	±1%	1/4w	REF-65
	R202	220 k	±5%	1/2w	REC-20BF
	R203	5 k	±10%		POSW-3
	R204	52.5 k	±1/4%		510-390
	R205	40 k	±1/4%		510-390
	R206	1 k	±5%	1/2w	REC-20BF
	R207	36 k	±5%	1/2w	REC-20BF
	R208	200 k	±5%	1/2w	REC-20BF
	R209	22 k	±5%	1/2w	REC-20BF
	R210	1 M	±5%	1/2w	REC-20BF
	R211	1 k	±5%	1/2w	REC-20BF
	R212	2.2 k	±5%	1/2w	REC-20BF
	R213	200 k	±5%	1/2w	REC-20BF
	R214	1 k	±5%	1/2w	REC-20BF
	R215	33 k	±5%	1/2w	REC-20BF
	R216	1 k	±5%	1/2w	REC-20BF
	R217	22 k	±5%	1/2w	REC-20BF
	R218	22 k	±5%	1/2w	REC-20BF
	R219	15	±5%	1/2w	REC-20BF
	R220	220 k	±5%	1/2w	REC-20BF
	R221	100 k	±5%	1/2w	REC-20BF
	R222	1 M	±5%	1/2w	REC-20BF
	R223	100 k	±5%	1/2w	REC-20BF
	R224	100 k	±5%	1/2w	REC-20BF
	R225	220 k	±5%	1/2w	REC-20BF
	R226	220 k	±1%	1/4w	REC-65
	R227	4.7 k	±5%	1/2w	REC-20BF
	R228	1 M	±5%	1/2w	REC-20BF
	R229	1 M	±5%	1/2w	REC-20BF
	R230	100 k	±1%	1/4w	REF-65
	R231	100 k	±5%	1/2w	REC-20BF
	R232	1 M	±5%	1/2w	REC-20BF
	R233	100 k	±5%	1/2w	REC-20BF
	R234	220 k		1/2w	REC-20BF
	R235	100 k	±5%	1/2w	REC-20BF
	R236				1605-41
	R301	10 k	±5%	1/2w	REC-20BF
	R302	220 k	±5%	1/2w	REC-20BF
	R303	2.2 k	±5%	1/2w	REC-20BF
	R304	22 k	±5%	1/2w	REC-20BF
	R305	1 M	±20%		POSC-7
	R306	Varistor			P-582-42

					PART NO. (NOTE A)
RESISTORS (NOTE B)	R307	Varistor			P-582-42
	R308	1 M	±5%	1/2w	REC-20BF
	R309	100 k	±5%	1/2w	REC-20BF
	R310	1 M	±5%	1/2w	REC-20BF
	R311	100 k	±5%	1/2w	REC-20BF
	R312	40 k	±1%	1/4w	REF-65
	R313	40 k	±1%	1/4w	REF-65
	R314	1 k	±5%	1/2w	REC-20BF
	R315	100 k	±5%	1/2w	REC-20BF
	R316	20 k	±5%	1/2w	REC-20BF
	R317	10 k	±5%	1/2w	REC-20BF
	R318	1 M	±5%	1/2w	REC-20BF
	R319	1 M	±5%	1/2w	REC-20BF
	R320	1 M	±5%	1/2w	REC-20BF
	R321	100 k	±5%	1/2w	REC-20BF
	R322	100 k	±5%	1/2w	REC-20BF
	R323	40 k	±1%	1/4w	REF-65
	R324	40 k	±1%	1/4w	REF-65
	R325	1 k	±5%	1/2w	REC-20BF
	R326	Varistor			P-582-42
	R327	Varistor			P-582-42
	R328	100 k	±5%	1/2w	REC-20BF
	R329	20 k	±1%	1/4w	REF-65
	R330	1 M	±5%	1/2w	REC-20BF
	R331	1 M	±5%	1/2w	REC-20BF
	R332	4.7 M	±5%	1/2w	REC-20BF
	R333	100 k	±5%	1/2w	REC-20BF
	R334	15 k	±5%	1/2w	REC-20BF
	R335	10 k	±5%	1/2w	REC-20BF
	R336	5.1 k	±5%	1/2w	REC-20BF
	R337	33 k	±5%	1/2w	REC-20BF
	R338	750	±5%	1/2w	REC-20BF
	R401	470	±5%	1w	REC-30BF
	R402	4.7 k	±5%	1w	REC-30BF
	R403	2.2 k	±5%	1w	REC-30BF
	R404	75 k	±5%	1/2w	REC-20BF
	R405	220 k	±5%	1/2w	REC-20BF
	R406	22 k	±5%	1/2w	REC-20BF
	C101	50-1100μμf			722-S67-2
	C102	0.001	±0.1%		505-S11-2
	C103	0.002	±0.1%		505-S12-2
	C104	0.004	±0.1%		505-S14-2
	C105	0.004	±0.1%		505-S14-2
	C106	0-0.06μμf			846-407
	C201	0.01	±0.5%		505-S17
	C202	0.005	±0.5%		505-S15
	C203	0.01	±10%	500dcwv	COM-1B

					PART NO. (NOTE A)
CAPACITORS (NOTE C)	C204	0.47	±10%	200dcwv	COW-16
	C205	0.22	±10%	200dcwv	COW-25
	C206	0.01	±10%	500dcwv	COM-1B
	C207	0.01	±10%	100dcwv	COW-17
	C208	0.01	±10%	500dcwv	COM-1B
	C209	0.1	±10%	100dcwv	COW-17
	C210	0.01	±10%	500dcwv	COM-1B
	C301	0.01	±10%	500dcwv	COM-18
	C302	30		6dcwv	P-582-43
	C303	0.01	±10%	500dcwv	COM-18
	C304	30		6dcwv	P-582-43
	C305	0.01	±1%	500dcwv	COM-1F
	C306	0.02	±1%	300dcwv	COM-1F
	C307	0.01	±1%	500dcwv	COM-1F
	C308	0.01	±1%	500dcwv	COM-1B
	C309	0.01	±10%	500dcwv	COM-1B
	C310	30		6dcwv	P-582-43
	C311	0.01	±1%	500dcwv	COM-1F
	C312	0.01	±1%	500dcwv	COM-1F
	C313	0.01	±10%	500dcwv	COM-1B
	C314	0.02	±1%	300dcwv	COM-1F
	C315	0.02	±10%	500dcwv	COM-1B
	C316	0.1	±10%	200dcwv	COW-16
	C401	40		400dcwv	P-582-44
	C402	40		400dcwv	
	C403	40		400dcwv	P-582-44
	C404	40		400dcwv	
	C405	40		400dcwv	P-582-44
	C406	40		400dcwv	
	D201	CRYSTAL DIODE			1N126
	D202	CRYSTAL DIODE			1N126
	D203	CRYSTAL DIODE			1N126
	D204	CRYSTAL DIODE			1N126
	F401	FUSE, 0.5 amp Slo-Blo			FUF-1
	F402	FUSE, 0.5 amp Slo-Blo			FUF-1
	M1	METER			MEDS-85
	P201	PILOT LAMP			NE-51
	P202	PILOT LAMP			NE-51
	P401	PILOT LAMP, Mazda #44			2LAP-939
	S101	SWITCH			SWRW-166
	S102	SWITCH			SWT-320,NP
	S401	SWITCH			SWT-333,NP
	T102	TRANSFORMER, Bridge			345-472
	T401	TRANSFORMER, Power			485-493
TUBES	V201	5751		V302	5751
	V202	12AT7WA		V303	5751
	V203	5751		V401	6X4WA
	V301	5751			

NOTES:

(A) Type designations for resistors and capacitors are as follows:

COM - Capacitor, mica
COW - Capacitor, wax
POSC - Potentiometer, composition
POSW - Potentiometer, wire-wound
REC - Resistor, composition
REF - Resistor, film

(B) All resistances are in ohms except as otherwise indicated by k (kilohms) or M (megohms).

(C) All capacitances are in microfarads except as otherwise indicated by μμf (micromicrofarads).

When ordering replacement components, be sure to include complete description as well as Part Number. (Example: R85, 51k ±10%, 1/2w, REC-20BF.)

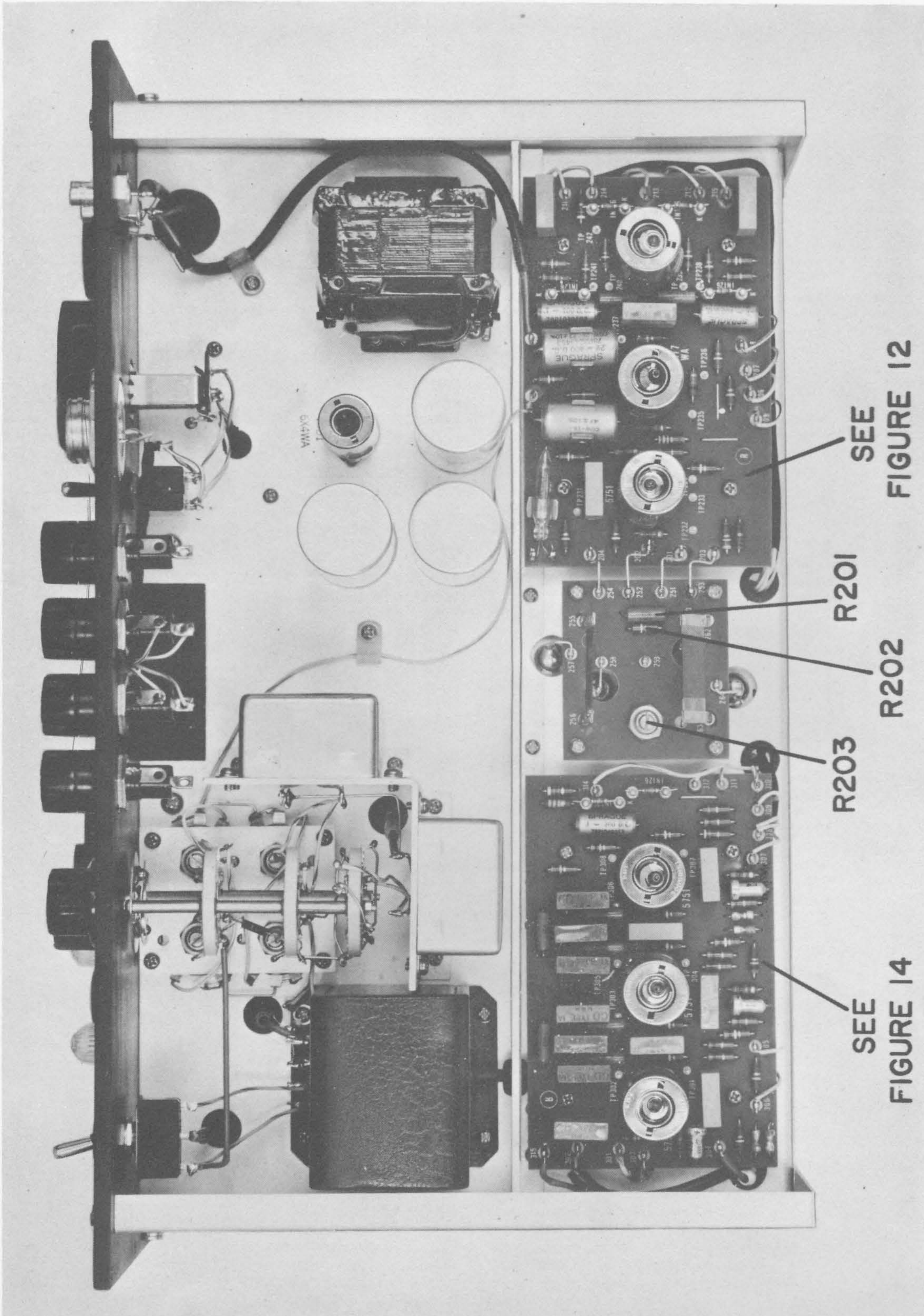


Figure 16. Top Interior View.

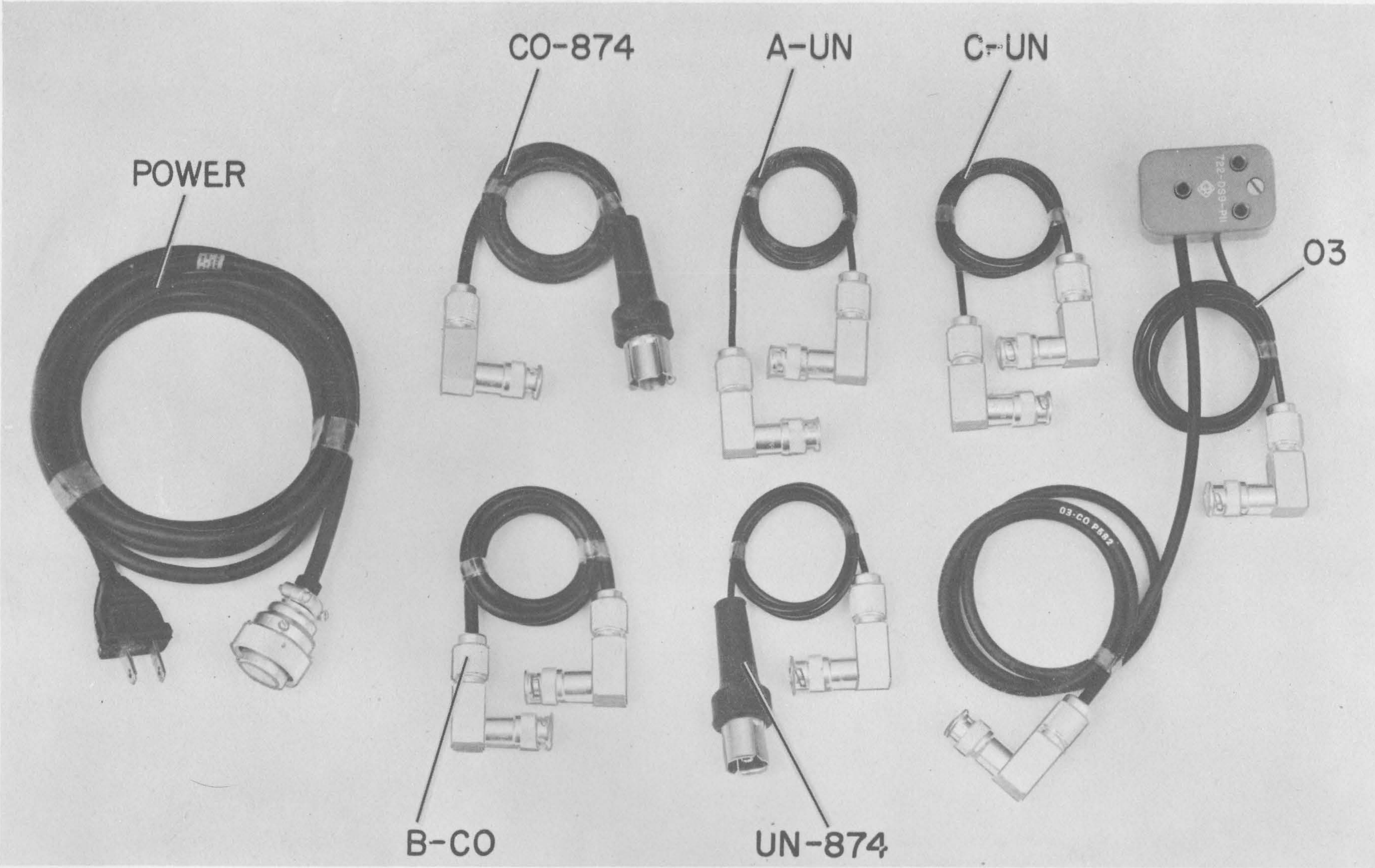


Figure 18. Power and Interconnecting Cables
Supplied with P-582 Capacitance Bridge.

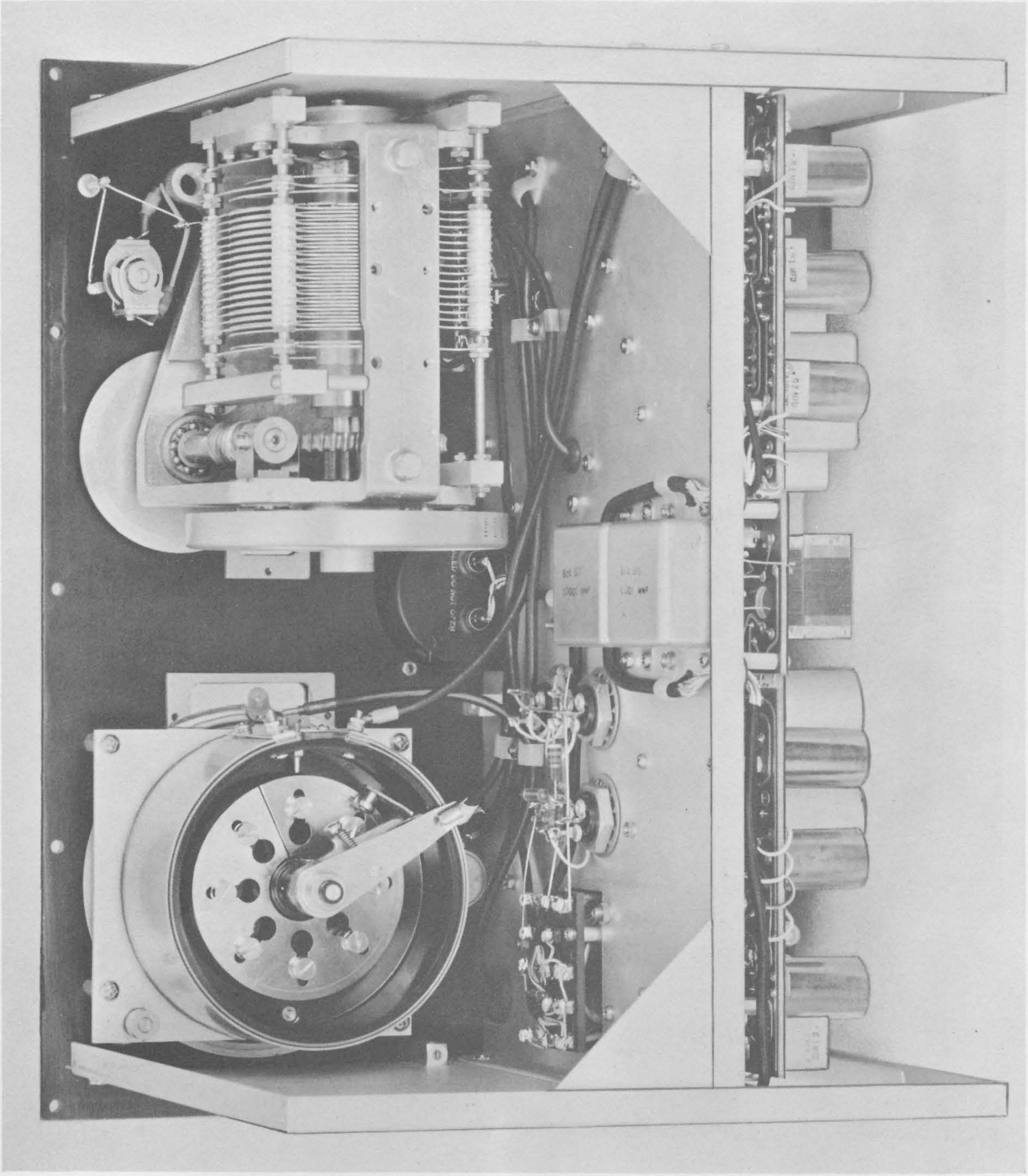


Figure 17. Bottom Interior View.