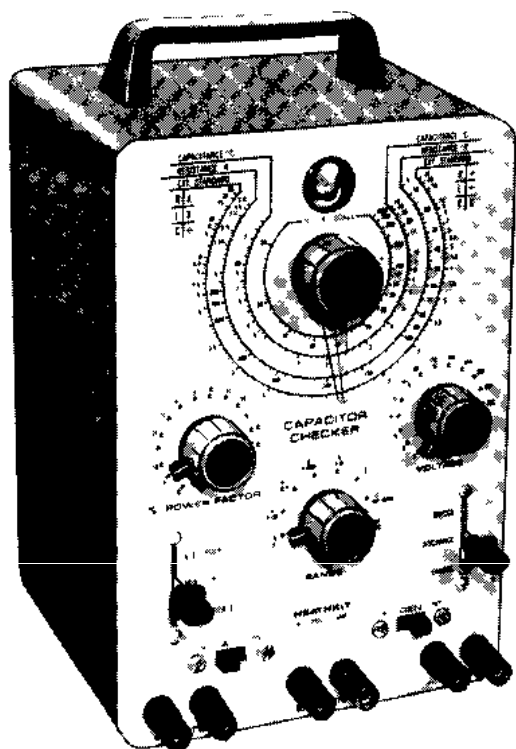


# Assembly and Operation of the



## CAPACITOR CHECKER

Model IT-28



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## SPECIFICATIONS

Test Circuit . . . . .	AC bridge, powered by an internal 60 cycle supply or by an external audio generator with 10 volts output (see Page 28, EXT. GEN.). Upper frequency limit: 10 kc.
Capacitance, 5 Ranges . . . . .	10 $\mu\text{f}$ to .005 $\mu\text{f}$ . .001 $\mu\text{f}$ to .5 $\mu\text{f}$ . .1 $\mu\text{f}$ to 50 $\mu\text{f}$ . 20 $\mu\text{f}$ to 1000 $\mu\text{f}$ . External standard (comparison bridge; maximum ratio 25:1).
Capacitor Leakage . . . . .	DC test voltages from 3 to 600 volts in 16 steps.
Resistance, 4 Ranges . . . . .	5 $\Omega$ to 5000 $\Omega$ . 500 $\Omega$ to 500 K $\Omega$ . 50 K $\Omega$ to 50 megohms. External standard (comparison bridge; maximum ratio 25:1).
Inductance Check . . . . .	External standard only.
Power Supply . . . . .	Transformer-operated, half-wave rectifier.
Power Requirements . . . . .	105-125 or 210-250 volts AC, 50/60 cycles, 30 watts.
Dimensions . . . . .	9-5/8" high x 8-5/8" wide x 5" deep.
Net Weight . . . . .	5 lbs.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

## INTRODUCTION

The HEATHKIT Model IT-28 Capacitor Checker is a general-purpose instrument designed for use by servicemen, engineers, and technicians in checking capacitors for value, leakage, shorts, and opens. The Checker may also be used to check resistance, inductance, and transformer turns ratios.

A bridge circuit and eye tube indicator are used

in making quick, accurate tests. Precision resistors and capacitors in the bridge circuit provide a high degree of accuracy and stability.

Terminals are provided on the front panel for the component under test (TEST), an external generator (EXT. GEN.), and external standard (EXT. STD.).

## CIRCUIT DESCRIPTION

Frequent reference to the small schematic diagrams in this description will prove helpful in fully understanding how the circuit functions.

The heart of the Capacitor Checker is the AC-powered bridge. Balance control R13 is used to vary the resistance of two arms of the bridge. The third arm is the standard (internal or external) and the fourth arm is the component being tested.

### BRIDGE RATIO CALCULATIONS

Referring to Figure 1, assume that  $R_x = R_s$  (any value) and that Balance control R13 is in the center of its range so that  $R_{13A} = R_{13B}$  (500  $\Omega$  each). Under this condition, with the bridge balanced and with  $R_x$  equal to  $R_s$ , the ratio of  $R_{13A}$  to  $R_{13B} = 1:1$ .

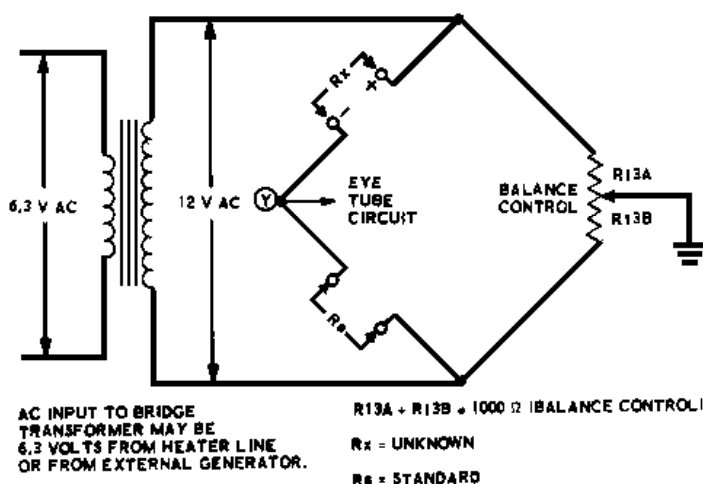


Figure 1

If  $R_x$  did not equal  $R_s$ , balance of the bridge would occur with the Balance control at some point other than the center of its range. When balance occurs with  $R_{13A} = 800 \Omega$ , then  $R_{13B} = 400 \Omega$ . The ratio is now 800/400, or 1.5:1.

When balance occurs with  $R_{13A} = 800 \Omega$ , then  $R_{13B} = 200 \Omega$ . The ratio is 800/200, or 4:1.

Turning the Balance control changes the values of  $R_{13A}$  and  $R_{13B}$ . When the bridge is balanced,  $R_{13A}$  times  $R_s = R_{13B}$  times  $R_x$ . Then the voltage at Y (see Figure 1) is minimum and the eye inbe opens. The bridge circuit is basically the same for all types of measurements; only the standards and the unknown values change.

### MEASURING RESISTANCE

When checking resistance,  $R_s$  becomes the resistance standard and  $R_x$  is the unknown resistance. The value of  $R_x$  is indicated on the front panel by the Balance control pointer when the bridge is balanced.

### MEASURING CAPACITANCE

#### LOWER RANGES - $C \times .0001$ and $C \times .01$

Referring to Figure 2, the standard,  $C_s$ , is a capacitor (internal or external), and  $C_x$  is the unknown capacitance being measured. As in measuring resistance, the Balance control is adjusted for balance of the bridge. At balance  $R_{13A}$  times  $X_{Cs} = R_{13B}$  times  $X_{Cx}$ . In this case,  $X_{Cs}$  is the capacitive reactance of  $C_s$  and  $X_{Cx}$  is the capacitive reactance of  $C_x$ .

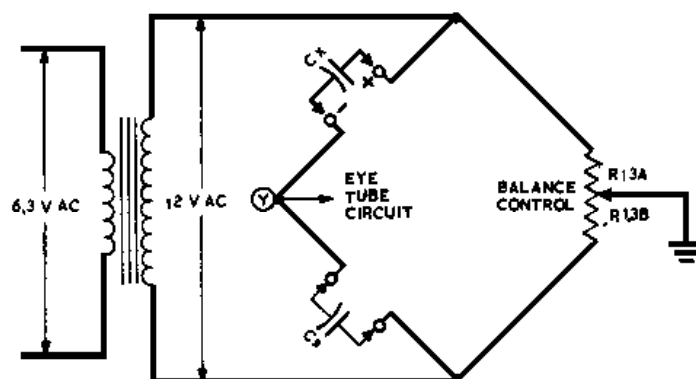


Figure 2

#### HIGHER RANGES - $C \times 1$ and $C \text{ EXT Scale}$

Capacitors are measured on the higher ranges just as described for the two lower ranges, except for electrolytics.

Since electrolytic capacitors have a certain amount of internal series resistance, it is necessary to use POWER FACTOR control R14 along with Balance control R13 to properly balance the bridge. See Figure 3. The POWER FACTOR control is used to cancel the effect of series resistance in electrolytic capacitor  $C_x$ , and is used only on the two higher ranges. The formula for finding the series resistance of an electrolytic capacitor is:

$$\text{Series Resistance} = \frac{\% \text{ PF}}{2 \pi F C}$$

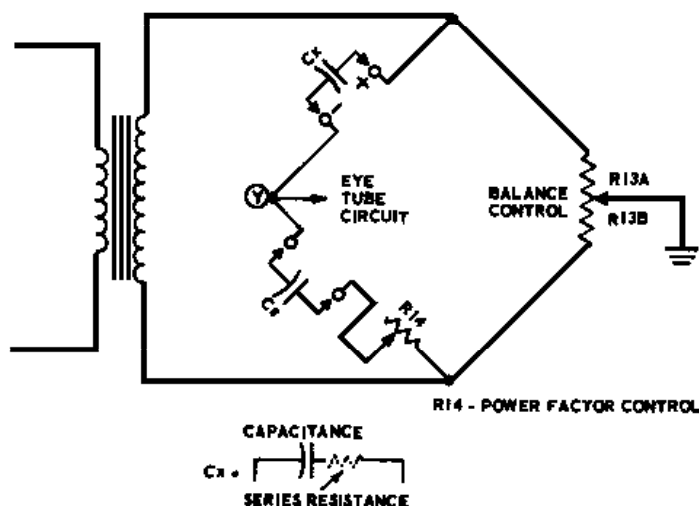


Figure 3

% PF = percent power factor

$\pi = 3.14$

F = frequency of applied voltage

C = capacity in farads

For example, the series resistance of a 2  $\mu$ fd capacitor with 5% PF at 60 cycles would equal:

$$\frac{.05}{2\pi \times 80 \times 2 \times .000001} = 66.3 \Omega$$

NOTE: The POWER FACTOR control is calibrated, using internal 2  $\mu$ fd capacitor C6 as a standard, at 60 cps. Therefore, when using an external generator at a frequency other than 60 cps, the value indicated by the POWER FACTOR control must be corrected by a factor of  $\frac{FT}{60}$ . FT is the external applied frequency.

EXAMPLE: Determine the % PF of a capacitor which measures 5% PF at 120 cps.

$$\% \text{ PF} = \text{measured } \% \text{ PF} \times \frac{FT}{80}$$

$$\% \text{ PF} = .05 \times \frac{120}{80}$$

$$\% \text{ PF} = 10\%$$

### USING THE EXTENDED SCALE

The capacitance scale is extended by adding 9000  $\Omega$  resistor R34 in series with Balance control R13. The bridge is balanced as before, using the Balance control, plus the POWER FACTOR control for electrolytics. However,

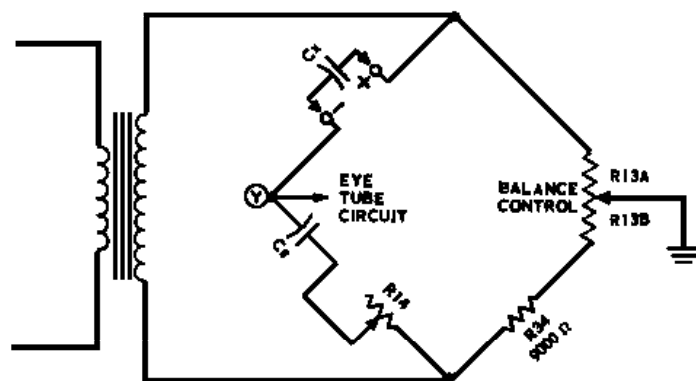


Figure 4

the ratio has now been changed due to the addition of R34. With the Balance control in the center of its range, R13A = 500  $\Omega$  and R13B = 500  $\Omega$ . Therefore, the ratio is:

$$\frac{9000 \text{ plus } 500}{500} = 19:1$$

The standard internal capacitance value is 2  $\mu$ fd, which makes the center scale reading equal to 19 times 2  $\mu$ fd, or 38  $\mu$ fd. The remainder of the "C" EXTENDED SCALE is calculated in the same way.

### MEASURING INDUCTANCE

Again, the bridge is balanced using Balance control R13. At balance, R13A times XLs = R13B times XLx. Here XLs = the inductive reactance of the standard, and XLx = the inductive reactance of the component being tested. An external standard must be used when measuring inductance.

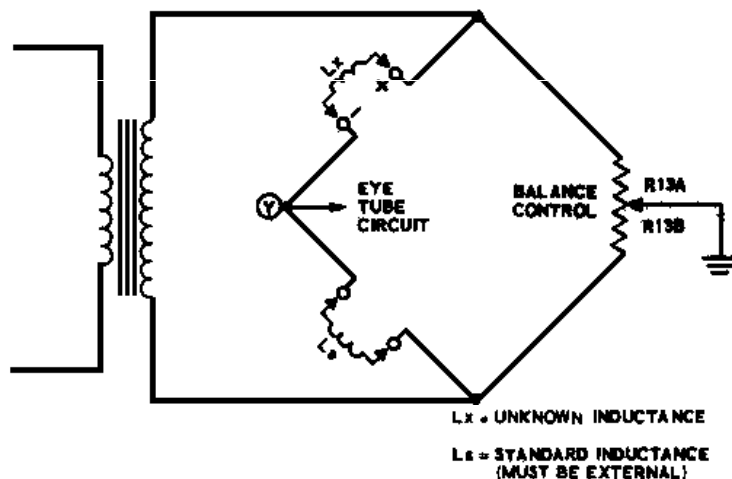
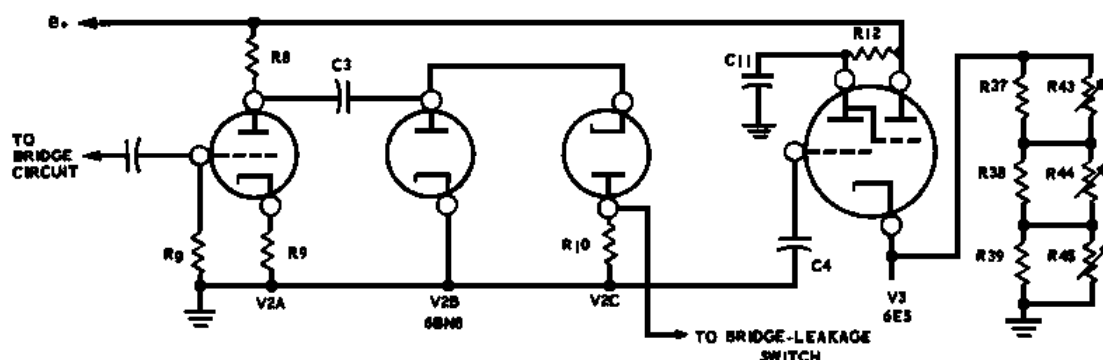


Figure 5

The AC series resistance (characteristic) of the external component should be similar to that of the test component to permit balancing, as the POWER FACTOR control is not used in the external standard circuit.

Figure 6



## EYE TUBE CIRCUIT

When the bridge circuit is not balanced, an AC signal voltage is applied from point Y of the bridge to the grid of amplifier stage V2A. The amplified signal from V2A is then applied to the voltage-doubler rectifier circuit, consisting of V2B, V2C, C3, and C4. The resulting negative DC voltage is applied to the grid of eye tube V3, closing the eye.

When the bridge is balanced, no signal is applied from the bridge to V2A. Therefore, no negative DC voltage is present at the grid of the eye tube, and the eye stays open.

## CAPACITOR LEAKAGE

### CHECKING LEAKAGE

When checking a capacitor for leakage, V2A is connected as a DC amplifier. When voltage is applied to the capacitor under test, through 10 K $\Omega$  limiting resistor R40, the capacitor charges, drawing current through grid resistor Rg of V2A. The voltage drop across this resistor causes V2A to conduct due to a positive voltage developed on its grid. This changes the voltage at the plate of V2A and at the grid of the eye tube, causing the eye to close. When the capacitor is fully charged, current ceases to flow through grid resistor Rg, and the grid voltage of V2A returns to its original value. The plate voltage of V2A also returns to its original value and the eye tube opens. This indicates a good capacitor.

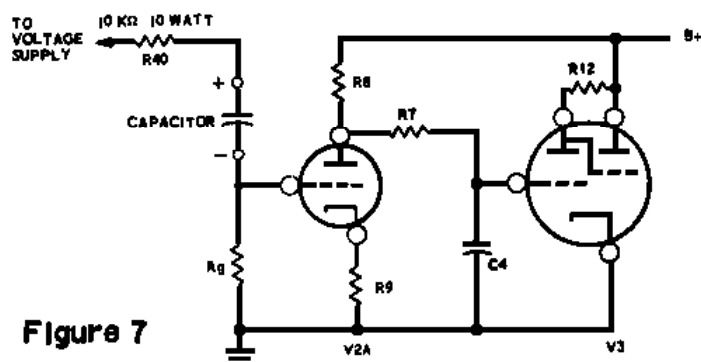


Figure 7

If the capacitor being checked is leaky or shorted, current continues to flow through grid resistor Rg, preventing the eye inbe from opening.

Calibrate controls R43, 44, and 45, connected in parallel with Type switch resistors R37, 38 and 39, are adjusted for proper grid current through Rg for different types of capacitors.

### LEAKAGE DISCHARGE

When the BRIDGE-LEAKAGE switch is moved from the LEAKAGE position to the DISCHARGE position, the capacitor under test is shunted to ground through resistors R40 and R36. During the resulting discharge time, a voltage is again developed at the grid of amplifier stage V2A. In turn, V2A causes a change in the grid voltage of eye tube V3, causing the eye to close. After the capacitor has discharged, the voltage on the grid of tube V2A returns to its original value and the eye tube opens.

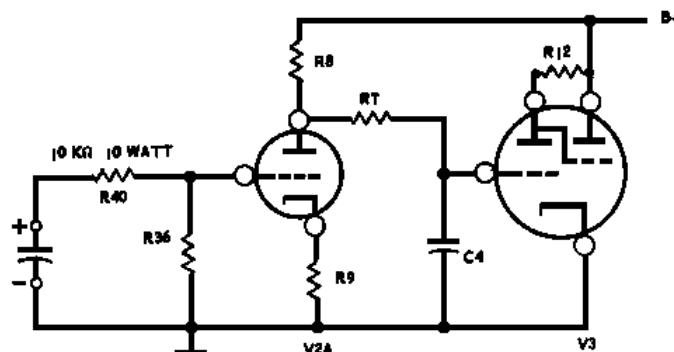
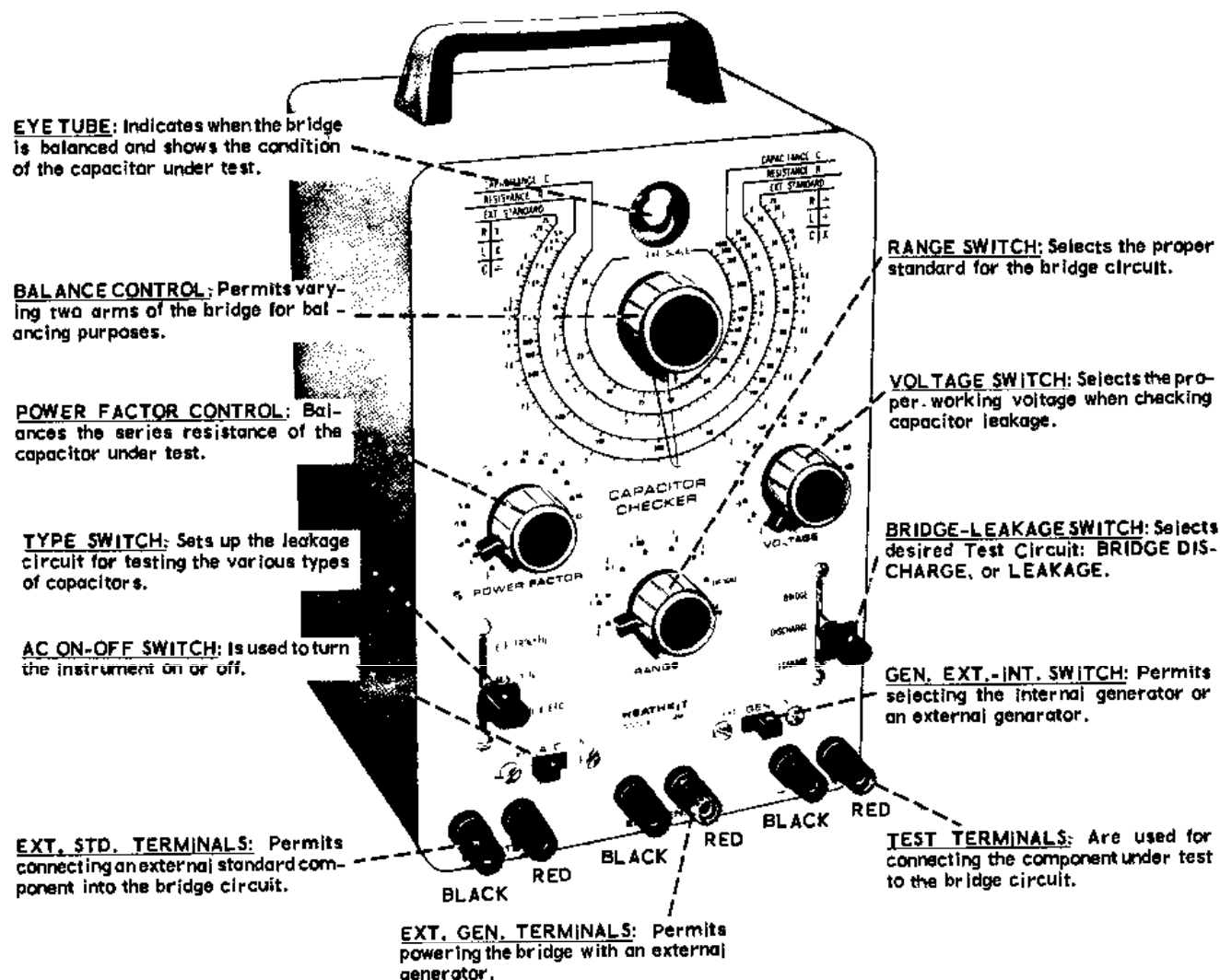


Figure 8

## POWER SUPPLY

The transformer-operated power supply uses V1 in a half-wave rectifier circuit. The fused primary circuit of the transformer is symmetrically bypassed with C9 and C10 for increased accuracy when measuring low capacitance at 60 cps. The filament circuit is effectively center tapped with R41 and R42. Capacitors C1 and C2, with resistors R1, R2, R3, R4, and R5 make up a filter-voltage divider network to provide proper DC voltages to the circuit.



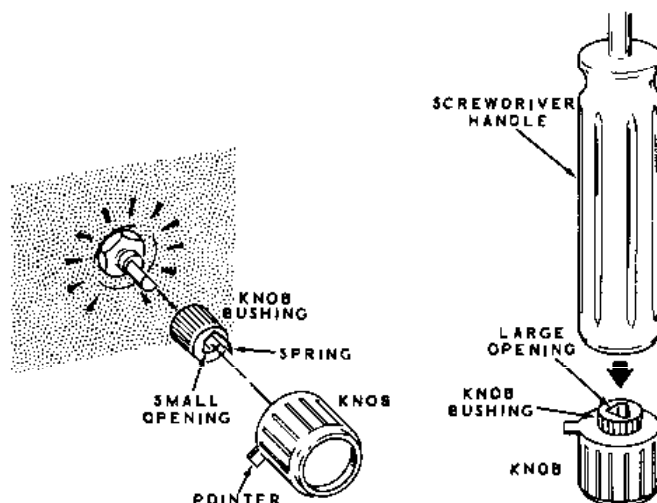
PICTORIAL 12

Refer to Pictorial 12 and Detail 12A for the following steps.

**NOTE:** The knobs supplied with this kit use knob bushings that provide permanent positive gripping without the use of setscrews. In the following steps you will install a knob on each of the four shafts as shown in Pictorial 12 and Detail 12A. Perform these steps carefully since it is very difficult to remove a knob bushing from a knob once it is fully inserted.

Each knob will be made to align with particular panel markings. Whenever you remove a knob, be sure to replace it on the same shaft.

( ) Push a knob bushing part way onto each of the Voltage switch, Range switch and Power Factor control shafts. Then turn all shafts to their full counterclockwise position.



Detail 12A

## TEST AND CALIBRATION

### TESTING

If any of the following steps do not produce the desired results, turn the instrument OFF and refer to the In Case Of Difficulty section.

Make sure the line cord is plugged into an outlet of the proper voltage. Turn the instrument on by moving the AC slide switch to the ON position. After a few seconds for warmup, the eye tube should have a green glow and the filaments of the 3 tubes should be lit.

Set the controls to the following positions.

<u>CONTROL</u>	<u>POSITION</u>
( ) BRIDGE-LEAKAGE	BRIDGE
( ) GEN.	INT.
( ) Type switch	Any
( ) VOLTAGE	3
( ) POWER FACTOR	0
( ) RANGE	*

\*For positions R X1 through C X1, the eye tube should be closed with the Balance control in any position except maximum clockwise. The tube should be open when the Balance control is maximum clockwise. Position the Balance control maximum clockwise and with your finger touch the negative TEST terminal. The eye tube should tend to close when the RANGE switch is in positions R X100 through C X.01.

( ) Set the RANGE switch to C EXT. SCALE. In this position, the eye tube should be closed regardless of the Balance control position.

( ) Now set the RANGE switch to EXT. STD. In this position, the eye tube should be open regardless of the Balance control position. As before, touching the negative TEST terminal or the red EXT. STD. terminal should close the eye tube.

( ) Switch the GEN. switch to EXT. position. The eye tube should remain open regardless of the RANGE switch or Balance control positions.

### VOLTAGE TEST

( ) Connect a voltmeter (VTVM or 1000  $\Omega$ /volt) to the TEST terminals. Set the voltmeter to read high DC+. Set the BRIDGE-LEAKAGE switch in LEAKAGE position and the TYPE switch to ELECTROLYTIC. Now turn the VOLTAGE switch through its 16 positions. The voltmeter reading should be essentially the same as the VOLTAGE switch indications.

### BRIDGE CALIBRATION

Connect the 200  $\Omega$  1% precision resistor to the TEST terminals. Set the RANGE switch to the R X1 and the BRIDGE-LEAKAGE switch to the BRIDGE. position. Set the GEN. switch to INT. Push a knob bushing onto the BALANCE CONTROL shaft, and adjust the shaft very carefully for maximum opening of the eye tube. Position the pointer knob so the pointer index line is straight down and is over the "1" at the center of the EXTERNAL STANDARD scale. Push the knob partially onto the bushing. As before, remove the knob and bushing together, fully insert the bushing into the knob, and replace the pointer knob on its shaft.

( ) Remove the 200  $\Omega$  resistor and keep it for future calibration checks.

### LEAKAGE CALIBRATION

There are two calibration procedures which can be used; the first without and the second with a milliammeter. The first is quite satisfactory, however, the second procedure will provide greater accuracy.

#### CALIBRATION WITH NO MILLIAMMETER

1. Turn the instrument on, and allow it to warm up.
2. Connect a 100 K $\Omega$  (brown-black-yellow) resistor across the TEST terminals.
3. Set the controls as follows:  
VOLTAGE -- 300 volts.  
Type -- ELECTROLYTIC.  
BRIDGE-LEAKAGE -- LEAKAGE.

4. Adjust the eye tube to "just closed" with the top (AD) calibrate control.
5. Move the BRIDGE-LEAKAGE switch to DISCHARGE and remove the 100 K $\Omega$  resistor.
6. Connect a 1.5 megohm (brown-green-green) resistor across the TEST terminals.
7. Set the controls as follows:  
VOLTAGE -- 25 volts.  
Type -- MIN, 'LYTIC.  
BRIDGE-LEAKAGE -- LEAKAGE.
8. Adjust the eye tube to the "just closed" position with the bottom (AB) calibrate control.
9. Set the controls as follows:  
VOLTAGE -- 3 volts.  
Type -- PAPER.  
BRIDGE-LEAKAGE -- LEAKAGE.
10. Adjust the eye tube to "just closed" position with the center (AC) calibrate control.
11. Return the BRIDGE-LEAKAGE switch to DISCHARGE and remove the 1.5 megohm resistor from the Test terminals.
7. Reduce the VOLTAGE switch setting and rotate the 2 megohm control until the meter reads 15  $\mu$ a.
8. Adjust the eye tube to the "just closed" position with the bottom (AB) calibrate control.
9. Set the controls as follows  
Type -- PAPER.  
BRIDGE-LEAKAGE -- LEAKAGE.
10. If necessary, reduce the VOLTAGE switch setting, and increase the 2 megohm control until the meter reads 2  $\mu$ a.
11. Set the eye tube to the "just closed" position with the center (AC) calibrate control.

#### LEAKAGE REFERENCE CHECK

Due to component tolerances and line voltage variations, it is usually not possible to draw 2 ma from the power supply on the 25 volt setting of the VOLTAGE switch. To determine the degree of closure of the eye tube under short conditions, set the VOLTAGE switch to 25, BRIDGE-LEAKAGE switch to LEAKAGE, and the Type switch to ELECTROLYTIC. Momentarily short the TEST terminals with a screwdriver and observe the eye tube. The size of the opening remaining should be mentally retained as an indication of short conditions on the 25 volt setting only. The 50 volt position should completely close the eye. NOTE: A completely shorted capacitor will be detected during the value test (Bridge Circuit). It is not recommended that the leakage test be performed on a capacitor known to be shorted since possible damage to the power supply could occur.

#### EYE TUBE POSITIONING

With the BRIDGE-LEAKAGE switch in the BRIDGE position, rotate the Balance control for a very narrow opening of the eye tube. Next rotate the eye tube in its mounting clip until the eye tube opening is vertical.

Install the cabinet using two 6-32x3/8" screws. The screws are placed through the rear of the cabinet and into the speednuts in the rear chassis flange.

#### CALIBRATION WITH A MILLIAMMETER

1. Connect the meter in series with a 2 megohm control (not supplied) across the TEST terminals.
2. Turn the instrument on and allow it to warm up.
3. Set the controls as follows:  
VOLTAGE -- 50 volts.  
Type -- ELECTROLYTIC.  
BRIDGE-LEAKAGE -- LEAKAGE.
4. Adjust the 2 megohm control until the meter reads 2 ma.
5. Adjust the eye tube to the "just closed" position with the top (AD) calibrate control.
6. Set the controls as follows:  
TYPE -- MIN, 'LYTIC.  
BRIDGE-LEAKAGE -- LEAKAGE



## OPERATION

Pictorial 12 (on Page 22) explains the eye tube, and front panel controls and terminals.

**CAUTION:** The circuit ground and the case of this instrument are both connected to the power line ground through the green wire of the line cord. Always connect the ground test lead of this device to the chassis, or ground, of the circuit being tested or measured.

**NOTE:** It is always best to connect the component under test directly to the TEST terminals. Long test leads may pick up stray AC fields and give inaccurate readings. If test leads must be used, keep them as short as possible.

### RESISTANCE MEASUREMENT

Connect the unknown resistance to the TEST terminals. Set the RANGE switch to one of the "R" multipliers. The GEN. switch should always be in INT. position on all tests unless an external generator is used. The Type, VOLTAGE, and POWER FACTOR controls are not used in this test. Set the BRIDGE-LEAKAGE switch to the BRIDGE position. Adjust the Balance control for maximum eye tube opening. Read the resistance indicated by the Balance control pointer on the "R" scale and multiply by the RANGE switch setting.

### CAPACITANCE MEASUREMENT

#### Lower Ranges-X .0001 And X .01

Connect the unknown capacity to the TEST terminals. The VOLTAGE switch is not used in this test.

Set the Type switch to its lower position, this position is for paper, mica, ceramic, glass, and any other small value capacitors. The RANGE switch should be in either the C X.0001 or C X.01 position, depending on the size of the capacitance under test. Set the BRIDGE-LEAKAGE switch to the BRIDGE position and adjust the Balance control for eye tube opening. Read the value of the capacitance on the "C" scale and multiply by the RANGE switch setting.

**NOTE:** To obtain sharper eye tube indications when measuring small capacitance values, connect an external generator to the EXT. GEN. terminals and set the GEN. switch to EXT. position. Set the generator to 1000 cps.

#### High Range - X1, Extended Scale

**WHEN CHECKING ELECTROLYTIC CAPACITORS IT IS ESSENTIAL THAT POLARITY BE OBSERVED.** The positive (+) lead of the capacitor should be connected to the positive (red) binding post, and the negative (-) lead to the negative (black) binding post of the TEST terminals. The VOLTAGE switch is not used in this test.

Set the Type switch to either the MIN. LYTIC or ELECTROLYTIC position, depending on the capacitor under test. **NOTE:** A MIN. LYTIC (miniature electrolytic) can be distinguished from an electrolytic by its high capacitance, low working voltage and small physical size. Miniature electrolytics are usually encased in ceramic or plastic and are completely sealed. Adjust the Balance control and the \*POWER FACTOR control for the widest opening of the eye tube. Read the capacitance on the "C" scale or EXTENDED scale, depending on the RANGE switch setting. The capacitance is read at so much (%) power factor. For example: 40  $\mu$ fd at 6% power factor.

\*Power Factor is the measure of the energy loss in an imperfect capacitor. In filter applications, a higher power factor decreases the effective capacity so that the effective capacity at 20 PF (Power Factor) is 96% of the measured capacity. At 30% PF, the effective capacity is decreased to 95%. While at 50% PF, the effective capacity is decreased to 67% of the measured capacity.

A significant point of the capacitor test, well worth remembering, is that a capacitor which will not balance on any of the ranges but allows the eye tube to open on the low end of the low range, is an open capacitor. A capacitor which allows the eye to open on the high end of the high range is a shorted capacitor. In either case, there is no reason to carry the test any further.

## LEAKAGE TEST

After the capacitor value has been determined, a leakage test for quality can be made. Set the VOLTAGE switch to the voltage rating of the capacitor (the four voltage positions below 25 volts are to be used for miniature electrolytics only), which is usually printed on the capacitor itself. Push the BRIDGE-LEAKAGE switch to the LEAKAGE position and observe the action of the eye tube. A sudden closing and then return to normal shadow angle indicates a satisfactory capacitor. A partially closed eye or fluttering condition would indicate an intermittent condition. If the eye stays closed the capacitor is leaky.

NOTE: The eye may not open on some electrolytics, especially large electrolytics. This does not always mean the capacitor is shorted. Refer to the Capacitor Current section which follows.

After the leakage test, return the BRIDGE-LEAKAGE switch to the DISCHARGE position. When the eye tube opens, the capacitor under test is discharged and safe to handle.

## CAPACITOR CURRENT

The eye will close when approximately 2 milliamperes of direct current are drawn through the test circuit when checking electrolytic capacitors. Approximately 15 microamperes of current are required to close the eye when checking miniature electrolytics, and approximately 2 microamperes are required when checking paper, mica, etc., capacitors.

Some electrolytic capacitors may allow 2 milliamperes of current to go through them and still be satisfactory. In this case, the eye will not open, showing the capacitor to be leaky or shorted. Leakage current is calculated with the following formula:  $I = K \times C + .3$

$I$  = milliamperes of maximum current through the capacitor.

$C$  = capacitance in  $\mu\text{fd}$ .

$K$  = constant relative to the voltage rating of the capacitor, as follows:

3 to 100 volts	$K = .01$
101 to 250 volts	$K = .02$
251 to 350 volts	$K = .025$
351 to 450 volts	$K = .04$

EXAMPLE: 40  $\mu\text{fd}$  capacitor rated at 450 volts.

$$I = K \times C + .3$$

$$I = .04 \times 40 + .3$$

$$I = 1.6 + .3$$

$$I = 1.9 \text{ milliamperes.}$$

## EXTERNAL STANDARD SCALES

Connect a component of known value to the EXT. STD. terminals. If the component to be tested is a resistor, then the EXT. STD. component must be a resistor; for checking capacitors, the EXT. STD. component must be a capacitor, etc; for checking inductance, use a coil of known value as the external standard. Set the RANGE switch to EXT. STD. and the BRIDGE-LEAKAGE switch to BRIDGE. Adjust the Balance control for eye tube opening. When measuring resistance or inductance and the pointer is on the left side of the scale, multiply the value of the EXT. STD. component by the pointer reading on the EXT. STD. scale. If the pointer is on the right side of the scale, divide the EXT. STD. component by the pointer reading.

When measuring capacitance, divide the value of the EXT. STD. component by the pointer reading when the pointer is on the left side; multiply the value of the EXT. STD. component by the dial reading when the pointer is on the right side.

To improve accuracy when checking small capacitance values, connect a generator to the EXT. GEN. terminals and push the GEN. switch to the EXT. position. Set the generator at 1000 cps and set the RANGE switch to EXT. STD. Balance the bridge for eye tube opening indication. If the pointer does not read "1" (center of scale), add capacitance to the appropriate terminals (TEST or EXT. STD.) until the pointer is at center scale with the bridge balanced. This capacitance should be left on the terminals when checking small value capacitances on the EXT. STD. scale.

NOTE: When measuring inductance, an external standard must be used as no internal inductance is provided. The external standard inductance should have characteristics similar to those of the inductance being measured. Multiply for pointer readings on the left side of the scale

and divide for readings on the right side of the scale.

## MEASURING TRANSFORMER TURNS RATIO

Connect either pair of leads (primary or secondary) to the TEST terminals and the other pair to the EXT. STD. terminals. (Interchanging the primary and secondary leads only results in reading the ratio on the other side of the scales.) Set the RANGE switch to EXT. STD. and adjust the Balance control for eye tube opening. Read the TURNS RATIO directly on the EXTERNAL STANDARD scale.

Polarity is important when measuring turns ratio, due to transformer action. That is, a signal appearing in one winding will also appear in the other winding. If eye tube opening cannot be obtained, reverse the leads of one winding.

In some cases, the ratio may be misleading. This is due to the non-loaded condition of the transformer under test. For example, the filament winding of a transformer might show up as something other than 16:1. Assuming the primary winding is 117 volts and the filament winding is 6.3 volts, the turns ratio is equal to the primary

voltage (117 volts) divided by the secondary filament winding voltage (6.3 volts), which is approximately equal to 16:1.

## EXT. GEN.

An external generator may be used for checking components at frequencies other than internal 60 cps. Any audio generator capable of delivering 2 volts or more to the EXT. GEN. terminals at the desired frequency may be used. A larger signal voltage will give a sharper null indication on the eye tube.

The maximum voltage that should be applied to the EXT. GEN. terminals is 6 volts, measured with the Capacitor Checker operating. The unloaded external generator voltage may be as high as 10 volts, but the very low impedance of this circuit permits a heavy current to be drawn, which results in a large voltage drop. The frequency limit of this circuit is 10,000 cps.

A point to remember, when using this instrument, is that the greatest error will occur at the ends of the scales. Therefore, for greatest accuracy, use the range that will give a null indication on the eye tube nearest center scale.

## IN CASE OF DIFFICULTY

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the constructor.
2. It is interesting to note that about 90% of the kits that are returned for repair, do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure that they are soldered as described in the Proper Soldering Techniques section of this manual.
3. Make sure that all tubes light up properly.
4. Check the tubes with a tube tester or by substitution of tubes known to be good.
5. Check the values of the component parts. Be sure that the proper part has been wired into the circuit, as shown in the pictorial diagrams and as called out in the wiring instructions.
6. Check for bits of solder, wire ends or other foreign matter which may be lodged in the wiring beneath the chassis.
7. If, after careful checks, the trouble is still not located and a voltmeter is available, check voltage readings against those found on the Schematic Diagram. NOTE: All voltage readings were taken with an 11 megohm vacuum tube voltmeter. Voltages may vary as much as 10% due to line voltage variations.
8. A review of the Circuit Description will prove helpful in indicating where to look for trouble.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the Service and Warranty section of the "Kit Builders Guide", and to the "Factory Repair Service" information on Page 31 of this Manual.

## REPLACEMENT PARTS PRICE LIST

To order parts, use the Parts Order Form furnished with this kit. If Parts Order Form is not available, refer to Replacement Parts in the Kit Builders Guide.

PART No.	PRICE Each	DESCRIPTION
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### RESISTORS

1-3	.10	100 $\Omega$ 1/2 watt
1-119	.10	560 $\Omega$ 1/2 watt
1-7	.10	680 $\Omega$ 1/2 watt
1-8	.10	820 $\Omega$ 1/2 watt
1-9	.10	1000 $\Omega$ 1/2 watt
1-44	.10	2200 $\Omega$ 1/2 watt
1-16	.10	4700 $\Omega$ 1/2 watt
1-20	.10	10 K $\Omega$ 1/2 watt
1-25	.10	47 K $\Omega$ 1/2 watt
1-26	.10	100 K $\Omega$ 1/2 watt
1-29	.10	220 K $\Omega$ 1/2 watt
1-35	.10	1 megohm 1/2 watt
1-36	.10	1.5 megohm 1/2 watt
2-83	.25	200 $\Omega$ 1/2 watt 1% precision
2-35	.20	9000 $\Omega$ 1/2 watt 1% precision
2-38	.20	20 K $\Omega$ 1/2 watt 1% precision
2-55	.20	2 megohm 1/2 watt 1% precision
1-5-1	.10	22 K $\Omega$ 1 watt
1-18-2	.20	33 K $\Omega$ 2 watt
1-10-2	.20	47 K $\Omega$ 2 watt
3-7-10	.30	10 K $\Omega$ 10 watt wire-wound

### CAPACITORS

20-2	.15	200 $\mu$ f molded mica
21-71	.15	.001 $\mu$ f disc ceramic 1400 V
27-69	1.50	.02 $\mu$ f Mylar
23-59	.20	.05 $\mu$ f tubular
23-28	.20	.1 $\mu$ f tubular
23-56	.40	.5 $\mu$ f tubular
27-58	2.40	2 $\mu$ f Mylar
25-41	1.00	40 $\mu$ f 350 V electrolytic
27-47	.20	.1 $\mu$ f Mylar

### CONTROLS-SWITCHES

10-56	.35	100 K $\Omega$ tab-mount control
11-101	1.55	1000 $\Omega$ control, wire-wound
60-1	.15	SPST slide switch
60-2	.25	DPDT slide switch
62-15	2.10	3-position lever switch
62-16	1.90	3-position lever switch
63-503	2.40	16-position rotary switch
63-504	1.30	8-position rotary switch

PART No.	PRICE Each	DESCRIPTION
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### TUBES-TRANSFORMERS

411-128	1.60	6BN8 tube
411-120	2.85	6E5 tube
411-156	1.25	6AX4 tube
51-80	1.75	Bridge transformer
54-34-24	5.00	Power transformer

### CONNECTORS-TERMINAL STRIPS-SOCKETS

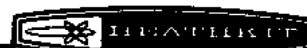
100-16-2	.10	Binding post cap, black
100-16-18	.10	Binding post cap, red
427-3	.15	Binding post base
431-1	.10	Dual-lug terminal strip
431-12	.10	3-lug terminal strip
431-11	.10	5-lug terminal strip
431-16	.10	2-lug terminal strip
434-31	.10	Octal socket
434-12	.35	6-pin tube socket
434-77	.15	9-pin tube socket

### METAL PARTS-KNOBS

90-414	5.00	Cabinet
200-525	.65	Chassis
203-250-2	1.25	Front panel
462-97	.10	Lever switch knob
455-50	.10	Knob bushing
462-245	.25	Knob
462-253	.55	Pointer knob

### HARDWARE

250-2	.05	3-48 x 5/16" screw
250-18	.05	8-32 x 3/8" screw
250-26	.05	6-32 x 5/8" screw
250-48	.05	6-32 x 1/2" screw
250-89	.05	6-32 x 3/8" screw
250-83	.05	#10 sheet metal screw
252-1	.05	3-48 nut
252-3	.05	6-32 nut
252-4	.05	8-32 nut
252-7	.05	Control nut
252-22	.05	Speednut
253-9	.05	#8 flat washer
253-10	.05	Control flat washer
254-7	.05	#3 lockwasher
254-1	.05	#6 lockwasher
254-2	.05	#6 lockwasher



<u>PART</u> <u>No.</u>	<u>PRICE</u> <u>Each</u>	<u>DESCRIPTION</u>
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**Hardware (cont'd.)**

254-5	.05	Small control lockwasher
254-4	.05	Control lockwasher
255-1	.05	1/8" spacer
255-13	.05	1/4" spacer
259-1	.05	#6 soldering
259-2	.05	#8 soldering
206-2	.10	Mounting clip

**INSULATORS-WIRE**

73-1	.10	Grommet
75-17	.10	Binding post insulator
75-30	.10	Strain relief, round cord
75-71	.10	Strain relief, flat cord
89-23	.75	Line cord
134-36	1.05	Wire harness
344-59	.05/ft	Hookup wire

<u>PART</u> <u>No.</u>	<u>PRICE</u> <u>Each</u>	<u>DESCRIPTION</u>
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**MISCELLANEOUS**

207-53	.20	Tube retaining clamp
211-15	.20	Handle
261-9	.05	Rubber foot
421-20	.30	1/2 ampere slow-blow fuse
422-1	.25	Fuseholder
432-27	.40	Line cord adapter
331-6	.15	Solder
490-5	.10	Nut starter
	2.00	Manual (See front cover for part number.)

The above prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from an authorized Service Center or Heathkit Electronic Center to cover local sales tax, postage and handling. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties and rates of exchange.

