Serial Φ3438

MODEL IM-104 Solid-State VOM

HEATHKIT®

ASSEMBLY MANUAL

Model IM-104 Solid-State VOM

HEATH COMPANY • BENTON HARBOR, MICHIGAN

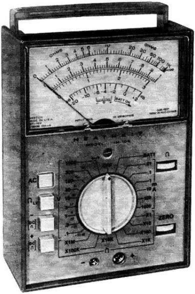
HEATHKIT

PRICE $2.00

595-1389-03

Assembly and Operation of the HEATHKIT SOLID-STATE VOM

MODEL IM-104



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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

INTRODUCTION

The Heathkit Model IM-104 VOM is a laboratory-grade instrument that is simple to operate and, at the same time, capable of a broad range of measurements. This compact multimeter gives you:

- Nine voltage ranges: 0.1 to 1000 volts. DC and ac functions use the same meter scales and Range switch positions.
- Six current ranges: 0.01 mA to 1000 mA. DC and ac functions use the same meter scales and Range switch positions.
- Seven resistance ranges: from less than 1 ohm to over 100 megohms (multiples of 10 center-scale).
- dB ranges: from –40 dB to +62 dB.
- A DC null (zero center) scale.
- A position on the Range switch to check the amplifier circuit batteries.
- A single, 24-position, continuous-rotation. Range switch with just two input sockets to serve all ranges.

AC, +DC, and –DC measurements can be quickly made, by means of the pushbutton function switches, on all voltage and current ranges. Resistance can be measured on any resistance range with either a 1.5 volt or a .085-volt test voltage. The 1.5-volt test voltage lets you check semiconductor conductance in both directions by just pressing the –DC and +DC pushbuttons. The low test voltage in the Ω $_{LV}$ position lets you measure resistance in semiconductor circuits without causing the semiconductors to conduct.

Excellent stability and accuracy are also provided. Low-drift, 1% precision resistors increase the stability of operation; and the meter circuitry, which consists of a dual-FET and a high-gain operational amplifier, provides a low temperature coefficient with no warm-up period. Basic DC accuracy of the VOM is ±2% of full scale for both voltage and current. Basic AC accuracy for both voltage and current is ±3% of full scale; and resistance measurement accuracy is ±2 degrees of arc.

Overload protection is provided in five ways: 1. The input banana socket is fused in-line. 2. On all voltage ranges and on the higher resistance ranges, the meter amplifier is protected by a pair of voltage-limiting, clamping transistors. 3. On all current ranges and on the lower resistance ranges, a pair of high-current diodes protects internal circuitry by causing the front panel fuse to open whenever an overload occurs. 4. The internal circuitry is protected against improper battery installation. 5. Reverse-parallel bypass diodes protect the meter movement. Note also that this meter will withstand a momentary application of 220 volts DC or AC **ON ANY RANGE WITH NO DAMAGE OR LOSS OF ACCURACY.**

Key features of this easy-to-use VOM are its compact size and rugged design. While it is compact enough to be easily stored in a briefcase, the 4-1/2" meter contains full-size, easy-to-read scales. All calibration controls are readily available under the "snap-on" front panel. Only commonly-used batteries are used, and the easy-to-remove rear panel makes them easy to replace. The high-impact-strength Lexan* case and the ruggedized, taut-band Weston meter movement reduce the chances of accidental damage. This high-quality VOM is sure to please you while it serves as an accurate, dependable, and attractive test instrument for laboratory, field, and bench use.

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

*Registered Trademark, General Electric Co.

PARTS LIST

Check each part against the following list. The key numbers correspond to the numbers in the Parts Pictorial (fold-out from Page 5).

To order a replacement part, use the Parts Order Form furnished with this kit. If one is not available, see "Replacement Parts" inside the rear cover of the Manual.

RESISTORS

NOTE: Resistor sizes may vary slightly from the sizes shown in the Parts Pictorial.

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
1/4-Watt, Precision				
A1	2-608-12	2	90 Ω	.25
A1	2-609-12	1	187 Ω	.25
A1	2-610-12	3	900 Ω	.25
A1	2-98-12	1	1350 Ω (1.35 k)	.25
A1	2-611-12	2	3010 Ω (3.01 k)	.25
A1	2-612-12	1	4870 Ω (4.87 k)	.25
A1	2-613-12	3	9000 Ω (9 k)	.25
A1	2-90-12	1	13 kΩ	.25
A1	2-614-12	3	16.7 kΩ	.25
A1	2-91-12	2	37.5 kΩ	.25
A1	2-615-12	1	90 kΩ	.25
A1	2-95-12	1	800 kΩ	.25
1/2-Watt				
A2	1-103	1	33 Ω, 10% (orange-orange-black)	.10
A2	1-52	1	680 Ω, 5% (blue-gray-brown-gold)	.10
A2	1-81	1	1500 Ω, 5% (brown-green-red-gold)	.10
A2	1-105	1	10 kΩ, 5% (brown-black-orange-gold)	.10
A2	1-166	1	10 MΩ, 5% (brown-black-blue-gold)	.10
A3	2-306	1	900 kΩ, 1%, precision	.25
1-Watt				
A4	2-97-1	2	4.5 MΩ	.70
3-Watt, Precision				
A5	3-8-3	1	.1 Ω	1.05
A5	3-9-3	1	.64 Ω	.75
A5	3-11-3	1	.9 Ω	.95
A5	3-12-3	1	9 Ω	.80
A5	3-10-3	1	10 Ω	.70

CONTROLS

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
A6	10-911	1	470 Ω (470 E or 470 R) control	.40
A6	10-369	1	4700 Ω (4 k7) control	.40

Controls (cont'd.)

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
A7	10-909	1	5000 Ω (5 k) control	.75
A7	10-910	1	500 kΩ control	.75
A8	10-912	2	22 kΩ (22 k) control	.40

CAPACITORS

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
B1	20-118	1	15 pF mica	.15
B1	20-173	1	20 pF mica	.20
B1	20-77	1	24 pF mica	.15
B1	20-182	1	30 pF mica	.25
B1	20-147	1	75 pF mica	.30
B1	20-180	1	445 pF mica	.50
B2	21-181	1	7.7 pF disc	.25
B2	21-176	1	.01 μF disc	.10
B2	21-82	1	.02 μF disc	.10
B2	21-95	4	.1 μF disc	.15
B2	21-140	1	.001 μF disc	.10
B3	29-14	1	.0047 μF polycarbonate	1.75
B3	27-134	1	.033 μF polyester	1.15
B3	29-15	1	.047 μF polycarbonate	1.85
B3	29-16	1	.47 μF polycarbonate	2.25
B4	31-65	1	15-60 pF ceramic variable	2.35

DIODES-TRANSISTORS-IC

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
C1	57-71	2	Silicon rectifier	.80
C2	56-89	2	GD510 diode	.20
C3	56-56	3	1N4149 diode	.20
C4	417-118	2	2N3393 transistor	.40
C5	417-186	1	2N3958 FET transistor	5.00
C6	442-39	1	IC (integrated circuit)	1.55

SWITCHES

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
D1	63-643	1	Wafer switch (brown dot)	1.00
D2	63-644	1	Wafer switch (orange dot)	1.60
D3	63-645	1	Wafer switch (red dot)	2.10
D4	63-646	1	Wafer switch (white dot)	1.35
D5	63-647	1	Wafer switch (gray dot)	1.75
D6	64-93	1	Pushbutton switch	5.00

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
CONNECTORS-SOCKETS-PLUGS				
E1	432-77	14	Flat connector	.10
E2	432-123	5	Molex* connector	.10
E3	432-144	8	IC connector	.01
E4	432-188	1	Fuseholder	.20
E5	432-189	5	Pin connector	.10
E6	432-725	14	Flat pin	.10
E7	436-38	1	Internally threaded banana socket	.65
E8	436-39	1	Banana socket/ fuseholder	.70
E9	438-47	2	Banana plug	.15
E10	439-1	1	Red test probe	.45
E11	260-1	1	Alligator clip	.10

*Registered Trademark, Molex Products Co.

HARDWARE

F1	250-56	1	6-32 x 1/4" screw	.05
F2	250-89	2	6-32 x 3/8" screw	.05
F3	250-546	2	Hex head screw	.20
F4	258-143	1	Coil spring	.05
F5	260-67	2	D battery clip	.05
F6	260-71	4	AA battery clip	.10
F7	260-72	2	Battery connector clip	.10

WIRE-TEST LEADS

	340-8	1	Bare wire	.05/ft
	341-1	1	Black test lead	.10/ft
	341-2	1	Red test lead	.10/ft
	344-50	1	Black wire	.05/ft
	344-52	1	Red wire	.05/ft
	344-53	1	Orange wire	.05/ft
	344-54	1	Yellow wire	.05/ft
	344-55	1	Green wire	.05/ft
	344-56	1	Blue wire	.05/ft

NOTE: Save one of the rubber bands from the packing materials for use in an assembly step.

MISCELLANEOUS

G1	70-10	1	Black banana plug insulator	.10
G1	70-11	1	Red banana plug insulator	.10
G2	73-21	1	Alligator clip insulator	.10
G3	73-47	1	Battery cushion	.10
G4	73-98	1	Foam gasket	.10/ft
G5	75-163	1	1-1/4" x 5/8" adhesive-backed insulator paper	.20

Miscellaneous (cont'd.)

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
G6	75-172	2	2" x 5/8" adhesive-backed insulating paper	.10
G7	75-173	1	Fuse insulator sleeve	.10
	85-1489-1	1	Front circuit board	1.15
	85-1106-1	1	Rear circuit board	1.15
	85-1236-1	1	Switch circuit board	.75
	100-1076	1	Meter and case assembly (NOTE: A Range switch shaft and two thumb-wheels are wrapped separately inside the case.)	31.00
G8	206-553	1	Fuse shield	.50
G9	206-554	1	Capacitor shield	.45
	346-44	1	Sleeving	.05/ft
	390-934	1	Label strip	.20
	391-34	1	Blue and white label	
G10	421-45	1	2-ampere fuse	.15
	597-260	1	Parts Order Form	
	597-308	1	Kit Builders Guide	
		1	Assembly Manual (See front cover for part number.)	2.00
			Solder (Additional 6' rolls of solder, #331-7, can be ordered for 25 cents each.)	

NOTE: Replacement parts for the meter and case assembly are listed on Page 75.

BATTERIES

The following batteries should be purchased at this time for use in your kit:

4 1.5-volt, AA-cell, zinc-carbon battery (NEDA 15)

1 1.5-volt, D-cell, zinc-carbon battery (NEDA 13)

Caution: Do not use alkaline batteries in this VOM.

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 a 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.

STEP-BY-STEP ASSEMBLY

Before you start to assemble this kit, read the wiring, soldering, and step-by-step assembly information in the "Kit Builders Guide."

Resistors will be called out by their resistance value in Ω, kΩ, or MΩ, and color code (where color bands are used). Use 1/2-watt resistors unless directed otherwise.

Capacitors will be called out by their capacitance value (in pF or μF) and type (disc, mica, etc.).

CIRCUIT BOARDS

START

( ) Refer to Pictorial 1-1 (fold-out from Page 5) and prepare the fourteen flat connectors as shown.

( ) Locate the two large circuit boards and position them component side up as shown.

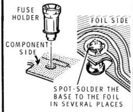
CAUTION: In the next two steps you will be directed to install flat connectors on the circuit boards. Be sure to install these connectors as shown in Detail 1-1A (fold-out from this page).

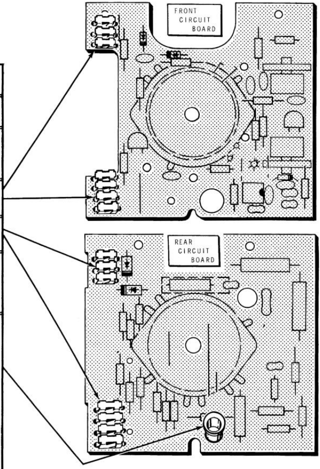
( ) Install flat connectors at locations A1 through A7 on the front circuit board (#85-1489-1).

( ) Install flat connectors at locations B1 through B7 on the rear circuit board (#85-1106-1).

NOTE: Heat the fuseholder base thoroughly before applying solder to it in the next step. Solder should flow easily onto the connection. Do not allow solder to build up above and around the connector.

( ) Install the fuseholder. Be sure it is perpendicular to the board. Then, solder its base to the foil as shown below.



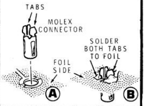


PICTORIAL 1-2

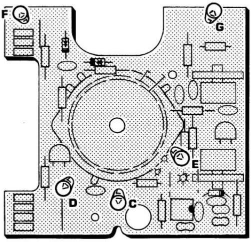
START

In the following step you will be instructed to install Molex connectors in front circuit board. Install each connector as follows:

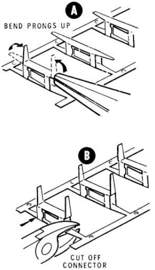
1. Push it through from the foil side as shown in A below until its tabs are against the foil.
2. Rotate the connector and align the tabs with the two foil segments.
3. Be sure the connector is perpendicular to the circuit board. Then solder the tabs to the foils as shown in B below, and by holding the tip of the soldering iron against the tab and the foil. Avoid pressure on the circuit board, as this could move the connector.



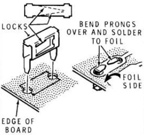
( ) Install Molex connectors at holes C, D, E, F, and G in the front circuit board.



PICTORIAL 1-3



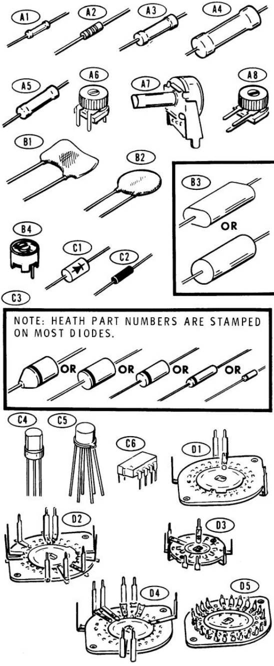
PICTORIAL 1-1



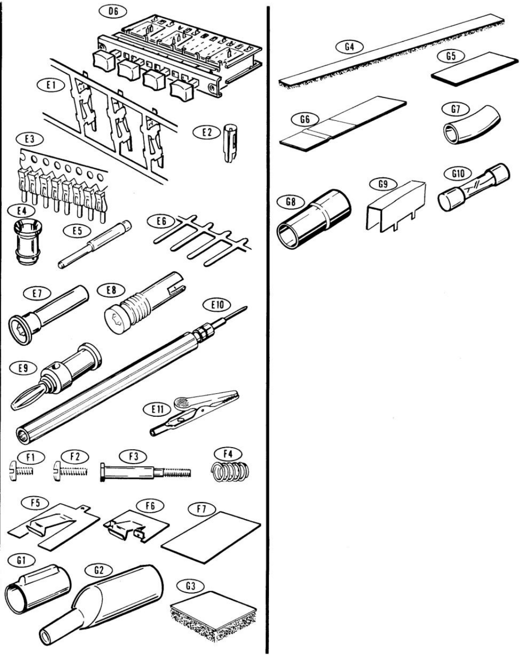
Install flat connectors as follows:

1. Insert the prongs into the circuit board holes so the locks are positioned as shown. Note the edge of the circuit board.
2. Press the connector firmly against the circuit board; then bend the prongs against the foil side of the circuit board with a screwdriver.
3. Solder the prongs to the foil.

Detail 1-1A



PARTS PICTORIAL

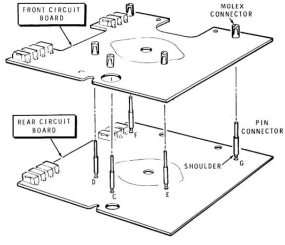


START

( ) Position the rear circuit board component side up as shown.

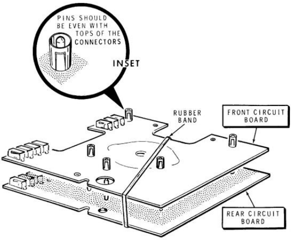
( ) Install pin connectors (the short end) in holes C, D, E, F, and G of the rear circuit board. Push each pin connector in until its shoulder is against the circuit board. Do not solder the pin connectors until instructed to do so in a later step.

( ) Assemble the two large circuit boards together by partially mounting the Molex connectors of the front circuit board onto the pin connectors of the rear circuit board. Be sure the component side of the front circuit board is up as shown.



PICTORIAL 1-4

( ) Push the two boards together as shown. Note the inset drawing. Now pick up the boards. Make sure the connectors and the boards maintain alignment with each other. Then place a rubber band (supplied in the packaging materials) around both circuit boards as shown.

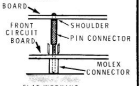


PICTORIAL 1-5

START

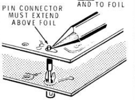
( ) Carefully turn the circuit boards over (foil side up) and position them on a flat work surface as shown.

( ) Use your fingers to press down on the two sides of the circuit boards, as shown by the arrows, until the ends of the pin connectors and the Molex connectors are flush with the working surface — as shown below. Be sure the shoulder of each pin connector remains against the component side of the rear circuit board (as indicated by the amount that each pin connector extends from the foil side of the circuit board).

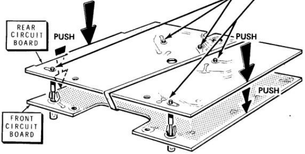


CONTINUE

In the following step you will be instructed to solder the pin connectors to the foil on the rear circuit board. Hold the tip of the soldering iron against the pin connector and the foil of the circuit board as shown below.



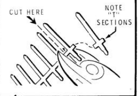
( ) Solder the five pin connectors to the foil of the rear circuit board. Use sufficient heat to make the solder flow onto the pin.



PICTORIAL 1-6

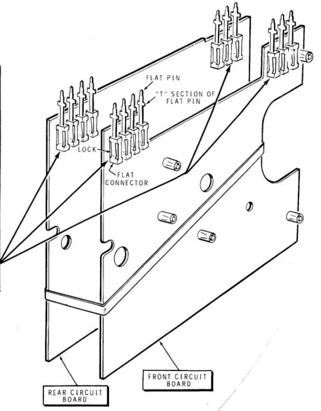
START

( ) Prepare the fourteen flat pins as shown below.



( ) Position the front and rear circuit boards as shown. Leave the rubber band in place around the circuit boards.

( ) Install a flat pin in each flat connector on the front and rear circuit boards. Push on the flat pins only until the locks of the flat connectors grip them.



PICTORIAL 1-7

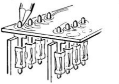
START

( ) Check to see that the end of each pin connector from the rear circuit board is even with the end of its Molex connector on the front circuit board.

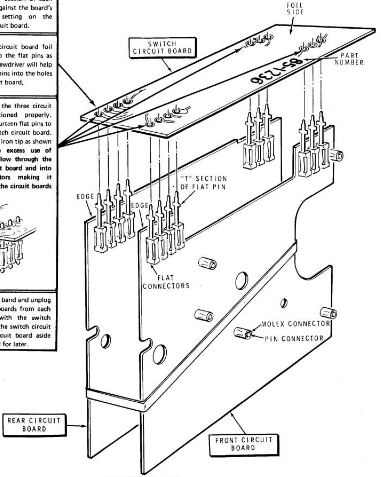
When the switch circuit board (#85-1236-1) is properly installed, it must be perpendicular to the front and rear circuit boards. The "T" section of each flat pin must be tight against the board's component side and setting on the indicated edge of the circuit board.

( ) With the switch circuit board foil side up, fit it onto the flat pins as shown. A small screwdriver will help you guide the flat pins into the holes of the switch circuit board.

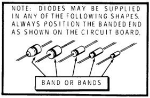
( ) Check to see that the three circuit boards are positioned properly. Then solder the fourteen flat pins to the foil on the switch circuit board. Hold the soldering iron tip as shown below. **Avoid the excess use of solder, as it can flow through the holes in the circuit board and into the flat connectors making it impossible to get the circuit boards apart.**



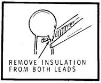
( ) Remove the rubber band and unplug the three circuit boards from each other, beginning with the switch circuit board. Set the switch circuit board and rear circuit board aside until they are called for later.



PICTORIAL 1-8



Detail 1-9A



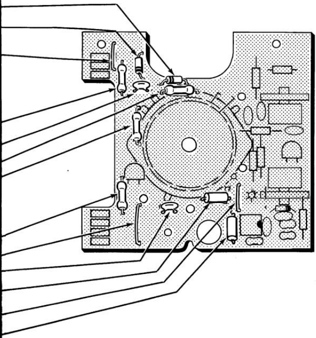
Detail 1-9B

START

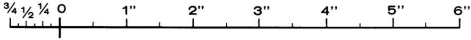
- ( ) Position the front circuit board as shown.
- ( ) 1N4149 diode (#56-56) at D4. See Detail 1-9A.
- ( ) 1N4149 diode (#56-56) at D3.
- ( ) 1" jumper. Use the bare wire supplied.

NOTE: In the following steps, bend the leads and install each precision resistor so its value can be seen after it is mounted.

- ( ) 3010 Ω (3.01 k), 1/4-watt, precision.
- ( ) .001 μF disc. See Detail 1-9B.
- ( ) 16.7 kΩ, 1/4-watt, precision.
- ( ) 37.5 kΩ, 1/4-watt, precision.
- ( ) Solder all leads to the foil and cut off the excess lead lengths.
- ( ) 1350 Ω, (1.35 k) 1/4-watt, precision.
- ( ) 1-1/4" jumper.
- ( ) .01 μF disc. See Detail 1-9B.
- ( ) 10 kΩ, 5% (brown-black-orange-gold).
- ( ) 1" jumper.
- ( ) 10 MΩ, 5% (brown-black-blue-gold).
- ( ) Solder all leads to the foil and cut off the excess lead lengths.

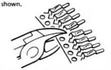


PICTORIAL 1-9



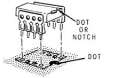
START

( ) Locate the strip of eight IC connectors. Cut this strip in half as shown.

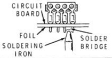


( ) Place these IC connector strips on the pins of the IC (#442-39) as shown.

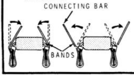
( ) Insert the pins of the IC connectors into the circuit board holes at IC1 with the pin 1 end of the IC (See Detail 1-10A) over the dot on the circuit board. Push down on the IC until the pins are all the way into their holes.

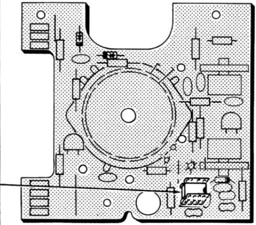


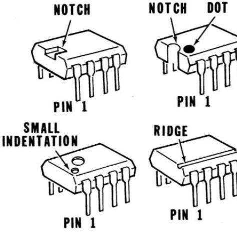
( ) Turn the circuit board over and solder the IC connector pins to the foil. If a solder bridge develops between pins, hold the circuit board in a horizontal position and melt the solder bridge from between the pins with the tip of the soldering iron as shown below.



( ) Use needle-nose pliers and remove the connecting bar from each IC strip by bending it back and forth. Be sure to bend it towards the IC the first time.



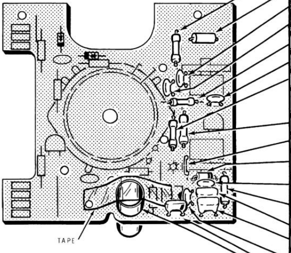




Detail 1-10A

PICTORIAL 1-10

START



( ) 37.5 kΩ, 1/4-watt, precision.

( ) 33 Ω (orange-orange-black).

( ) .1 μF disc.

( ) .1 μF disc.

( ) 800 kΩ, 1/4-watt, precision.

( ) .1 μF disc.

( ) 16.7 kΩ, 1/4-watt, precision.

( ) Solder all leads to the foil and cut off the excess lead lengths.

( ) 900 Ω, 1/4-watt, precision.

( ) 1" jumper.

( ) 1N4149 diode (#56-56) at D5. Position the banded end as shown.

( ) .1 μF disc.

( ) 13 kΩ, 1/4-watt, precision.

( ) 75 pF mica.

( ) 20 pF mica.

( ) 7.7 pF disc.

( ) 24 pF mica.

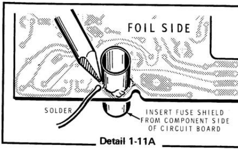
( ) Solder all leads to the foil and cut off the excess lead lengths.

( ) Lightly sandpaper the outside of the fuse shield, near the shoulder, so it will be easier to solder to.

( ) Insert the fuse shield so its shoulder is against the component side of the circuit board. Temporarily put a piece of tape over it to hold it in place.

NOTE: Heat the fuse shield thoroughly before applying solder to it in the next step.

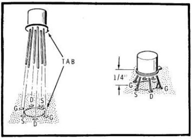
( ) Turn the circuit board over and solder the shield to the foil in several places. See Detail 1-11A. Then remove the tape.



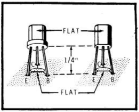
Detail 1-11A

PICTORIAL 1-11

3/4 1/2 1/4 0 1" 2" 3" 4" 5" 6"



Detail 1-12A



Detail 1-12B

START

( ) 2N3958 FET transistor (#417-186) at Q3. See Detail 1-12A. Align the tab of the transistor with the tab outline on the circuit board. Insert the proper transistor leads into the designated holes in the circuit board. Position the transistor 1/4" above the circuit board as shown. Solder all six leads to the foil and cut off the excess lead lengths.

NOTE: When you install transistors in the next two steps, mount them leaning slightly away from the switch outline, as they are shown.

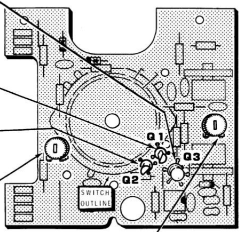
( ) 2N3393 transistor (#417-118) at Q1. Refer to Detail 1-12B and align the flat of the transistor with its flat outline on the circuit board. Then insert the E, C, and B leads into the E, C, and B marked holes in the circuit board. Position the transistor 1/4" above the circuit board. Solder all three leads to the foil and cut off the excess lead lengths.

( ) In a similar manner, install another 2N3393 transistor at Q2. Note that the flat on this transistor faces in the other direction.

NOTE: The controls installed in the next two steps are physically identical. Be sure to use the correct control in each step.

( ) 470 Ω (470 E or 470 R) control (#10-911). Solder all three pins to the foil.

( ) 4700 Ω (4 K7) control (#10-369). Solder all three pins to the foil.

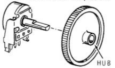


PICTORIAL 1-12

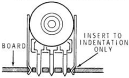
START

NOTE: The thumbwheels used in the following step are packaged inside the meter case. Use a coin to unscrew the thumbnut holding the rear panel onto the back of the meter case. Use the hexagon end of the thumbnut to slightly lift the panel; then slide the panel off toward the bottom of the case.

(✓) Mount a thumbwheel on the control shaft of each control, as shown below. Push the thumbwheel as far onto the control shaft as possible.

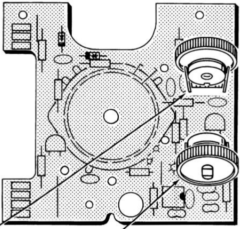


(✓) 500 kΩ control (#10-910). Press in on the sides of the control and insert the lugs through the holes in the circuit board ONLY AS FAR AS THE INDENTATIONS, as shown below. Be sure the control is perpendicular to the circuit board, and then solder all five pins to the foil.



(✓) 5000 Ω (5 k) control (#10-909). Solder all five pins to the foil.

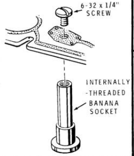
(✓) Align each thumbwheel directly over its outline on the circuit board.



PICTORIAL 1-13

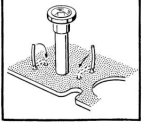
START

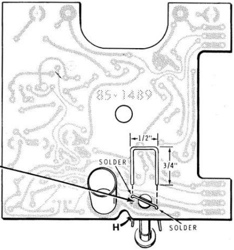
( ) Install the internally-threaded banana socket at hole H; install a 6-32 x 1/4" screw from the foil side of the circuit board. Turn the screw only finger tight, with its slot aligned with the indicated holes in the circuit board.



( ) Bend a 2" length of bare wire as shown in the Pictorial. Then install the wire ends through the indicated holes in the circuit board and place the 1/2" portion of the wire in the slot of the screw. Solder the wire to the screw head and to the two indicated locations on the foil.

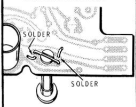
( ) Turn the circuit board component-side-up, and pass the free ends of this bare wire through the two indicated holes in the circuit board. Pull the wires tight.





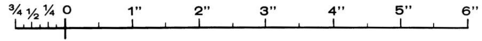
CONTINUE

( ) Solder the free ends of this bare wire to the same foil as before and cut off the excess lead lengths.



( ) After the connection cools, remove the internally-threaded banana socket and set it aside until it is called for later.

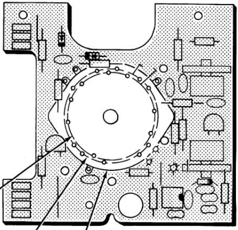
PICTORIAL 1-14



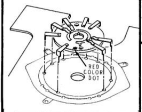
START

NOTE: When installing the wafer switches in the following steps:

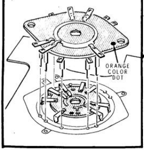
1. Select the wafer switch with the correct color dot.
2. Be sure the color dot is positioned correctly in relation to the circuit board.
3. All wafer switch pins must be pushed all the way through the circuit board holes. All pins of a switch must be on the same circle (switch outline) on the circuit board.
4. Then solder all pins of the switch to the foil. Cut off the excess switch pin length as close to the circuit board as possible.
5. Visually check for any interference or shorts between the switch lugs or other component parts.



( ) Wafer switch (#63-645) with red color dot.

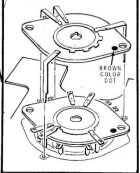


( ) Wafer switch (#63-644) with orange color dot.



CONTINUE

( ) Wafer switch (#63-643) with brown color dot.



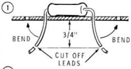
This completes the assembly of the front circuit board. Check to see that all leads are soldered to the foil and that no solder bridges exist between foils. Set the circuit board aside until it is called for later.

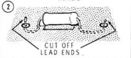
PICTORIAL 1-15

START

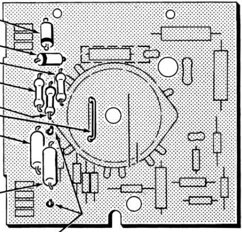
CAUTION: Avoid the excessive use of solder and cut all excess lead lengths as close to the circuit board as possible. Otherwise, the rear panel will not fit properly in the cabinet.

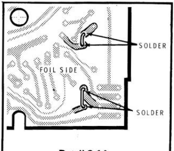
- ( ) Position the rear circuit board as shown.
- ( ) Silicon rectifier (#57-71) at D2. Position the banded end as shown.
- ( ) Silicon rectifier (#57-71) at D1. Position the banded end as shown.
- ( ) 900 Ω, 1/4-watt, precision.
- ( ) 187 Ω, 1/4-watt, precision.
- ( ) 90 Ω, 1/4-watt, precision.
- ( ) 1-1/4" jumper.
- ( ) 0.9 Ω, 3-watt, precision.
- ( ) Solder all leads to the foil and cut off the excess lead lengths.
- ( ) Install the 0.1 Ω, 3-watt, precision but do not solder. Then cut off its leads 3/4" from the foil side of the circuit board. Bend the leads and pass their free ends through the holes that have a circle around them. Position the leads as close as possible to the foil **without the leads touching the foil** (approximately 1/32" away from it).





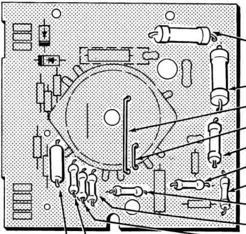
- ( ) See Detail 2-1A. Solder all four points where the leads of the 0.1 Ω resistor pass through the foil. Do not use excessive solder. Cut off the remaining lead ends on the component side of the circuit board.





Detail 2-1A

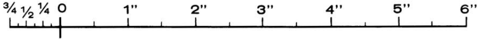
PICTORIAL 2-1



START

- ( ) 4.5 MΩ, 1-watt.
- ( ) 4.5 MΩ, 1-watt.
- ( ) 1-3/4" jumper.
- ( ) 1" jumper.
- ( ) 900 kΩ precision.
- ( ) 9000 Ω (9 k), 1/4-watt precision.
- ( ) 90 kΩ, 1/4-watt, precision.
- ( ) Solder all leads to the foil and cut off the excess lead lengths.
- ( ) 9000 Ω (9 k), 1/4-watt precision.
- ( ) 900 Ω, 1/4-watt precision.
- ( ) 90 Ω, 1/4-watt precision.
- ( ) 9 Ω, 3-watt precision.
- ( ) 10 Ω, 3-watt precision.
- ( ) Solder all leads to the foil and cut off the excess lead lengths.

PICTORIAL 2-2

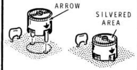


START

( ) 15 pF mica.

( ) .033 μF polyester. Be sure to position the body of the capacitor upright and within its outline on the circuit board as shown. Solder the leads to the foil.

( ) 15-60 pF ceramic variable. Position the side of the capacitor with the arrow as shown. Solder both leads to the foil and cut off any excess lead lengths.



( ) Turn the silvered area of this capacitor to the position shown.

( ) 30 pF mica.

( ) 445 pF mica.

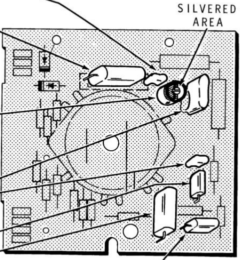
NOTE: The polycarbonate capacitors to be installed in the following steps may have either round or flat sides.

( ) .0047 μF polycarbonate.

( ) .47 μF polycarbonate.

( ) .047 μF polycarbonate.

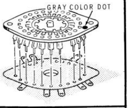
( ) Solder all leads to the foil and cut off the excess lead lengths.



PICTORIAL 2-3

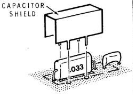
START

(✓) Switch wafer (#63-647) with gray color dot. Position the color dot as shown. Then use a pencil to maneuver each pin into its hole. Be sure all 23 pins are through the circuit board. Then solder all the pins to the foil. Cut off any excess pin lengths.

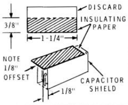


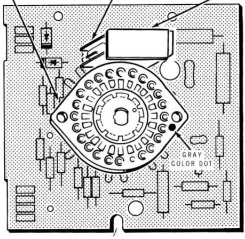
CONTINUE

(✓) Capacitor shield. Solder all four tabs to the foil as the shield is installed. Cut off the excess tab length.



(✓) Cut the 5/8" x 1-1/4" adhesive backed paper to 3/8" x 1-1/4". Remove the paper backing and press the insulating paper on the capacitor shield in the position shown.

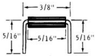




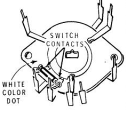
PICTORIAL 2-4

START

( ) Center a 5/16" length of sleeving on a 1" length of bare wire. Then bend both ends of the wire as shown.

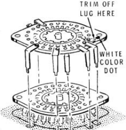


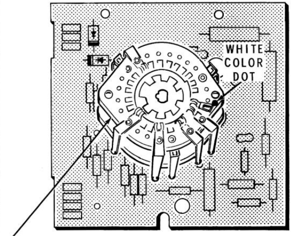
( ) Insert the ends of this wire through the indicated lugs of the wafer switch (#63-646) with the white color dot. Note the position of the color dot. Then bend the lugs down as shown in Detail 2-5A.



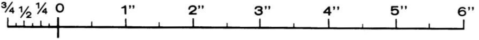
( ) Solder this wire to these lugs. Avoid the use of excess solder. If solder is allowed to flow into the switch contacts, the switch will be damaged. Cut off the excess wire lengths.

( ) Trim off the switch lug closest to the color dot. Then install this wafer switch on the circuit board. Note the position of the color dot and solder all eight pins to the foil.



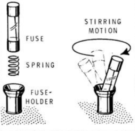


Detail 2-5A

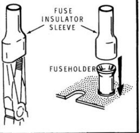


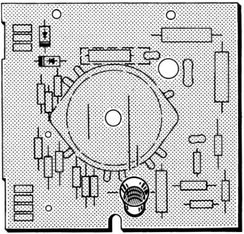
START

( ) Insert the coil spring into the fuseholder as shown below. Use the fuse to force the spring all the way down into the fuseholder; then exert a clockwise, stirring motion to lock the spring in place. Check to be sure the spring is locked by turning the circuit board upside down.



( ) Locate the fuse insulator sleeve. Push this sleeving over the end of a pair of long-nose pliers and stretch one end of the sleeving as shown. Then quickly install this sleeving over the fuseholder.





PICTORIAL 2-6

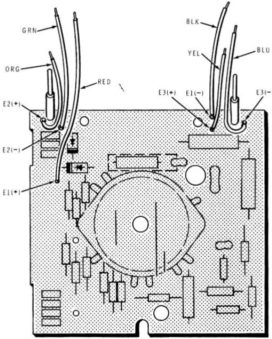
START

NOTE: When a wire is called for in a step, cut the proper color wire to the indicated length and remove 1/4" of insulation from each end. Solder one end of the wire to the foil when it is installed. The free end will be connected later.

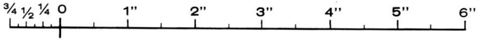
- ( ) 2-1/2" orange wire at E2 (+).
- ( ) 3" green wire at E2 (–).
- ( ) 4" red wire at E1 (+).
- ( ) 3" black wire at E1 (–).
- ( ) 2" yellow wire at E3 (+).
- ( ) 3" blue wire at E3 (–).
- ( ) Position these six wires as shown.

This completes the assembly of the rear circuit board. Check to be sure that all connections are soldered, that no solder bridges exist, and that all leads and pins are cut off as close as possible on the foil side of the circuit board.

FINISH



PICTORIAL 2-7

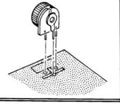


START

( ) Position the switch circuit board as shown.

( ) 4870 Ω (4.87 k), 1/4-watt, precision. Install the resistor so it is 1/8" above the circuit board. See Detail 3-1A. Solder the leads to the foil and cut off the excess lead lengths.

( ) 22 kΩ control (#10-912). Solder all three pins to the foil. Then turn this control to the full counterclockwise position (as viewed from the knob side of the control).



( ) 680 Ω, 5% (blue-gray-brown-gold).

( ) 1-1/4" jumper wire.

( ) 1" jumper wire.

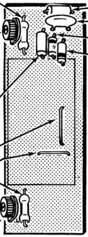
( ) 9000 Ω (9 k), 1/4-watt, precision. Install the resistor so it is 1/8" above the circuit board. See Detail 3-1A. Solder the leads to the foil and cut off the excess lead lengths.

( ) 22 kΩ control (#10-912).

( ) Solder all leads to the foil and cut off the excess lead lengths.

( ) Refer to Detail 3-1B and center the 4870 Ω resistor between the control and the flat pins.

( ) Center the 9000 Ω resistor in a similar manner.



CONTINUE

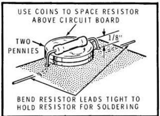
( ) 1500 Ω, 5% (brown-green-red-gold).

( ) .02 μF disc.

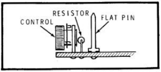
( ) GD510 diode (#56-89) at D7. Position the banded end as shown.

( ) GD510 diode (#56-89) at D6.

( ) Solder all leads to the foil and cut off the excess lead lengths.

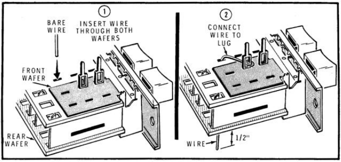


Detail 3-1A



Detail 3-1B

PICTORIAL 3-1



Detail 3-2A

START

In the following steps you will install wires on the pushbutton switch. Install each wire in the following manner. See Detail 3-2A.

1. Insert the wire into the proper hole in the front wafer.
2. Pass it down through the same hole in the rear wafer. Stop when it extends about 1/2" below this wafer.
3. Connect the upper end of the wire to the proper switch lug. The other end will be connected later.
4. Avoid excess solder. After making the connection, cut off any excess wire that extends beyond the lug.

In the following steps, "(NS)" means not to solder. "S-" with a number, such as (S-2), means to solder the connection. The number tells how many wires are to be at the connection.

( ) Position the pushbutton switch with the 6-lug side (L1, L2, etc.) up as shown.

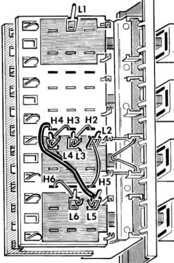
( ) 1-1/4" bare wire through holes H2. Top end to lug L3 (S-1).

( ) 1-1/4" bare wire through holes H3. Top end to lug L4 (S-1).

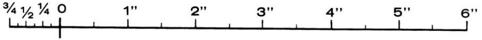
( ) 2" bare wire through holes H4. Install a 3/4" length of sleeving on the top end of the wire. Then connect the wire to lug L5 (S-1).

( ) 1-1/4" bare wire through holes H6. Top end to lug L6 (S-1).

( ) 1-1/2" bare wire through holes H5. Top end to lug L2 (NS). Position this wire away from the metal switch frame as shown.



PICTORIAL 3-2



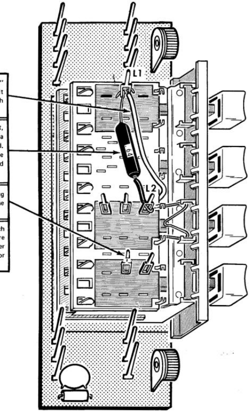
START

(✓) Connect the free end of the 2" yellow wire coming from the circuit board to lug L1 on the switch assembly (NS).

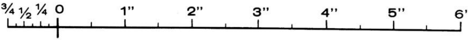
(✓) Cut both leads of a .64 Ω, 3-watt, precision resistor to 5/8" and place a 3/8" length of sleeving on one lead. Connect this lead to lug L2 on the switch (S-2). Connect the other lead to lug L1 on the switch (S-2).

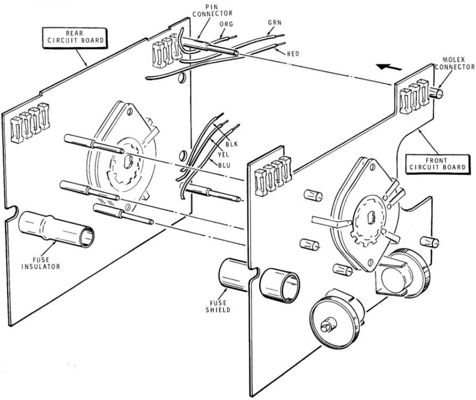
(✓) Carefully trim off the excess lug length on all six lugs above the solder connection.

This completes the assembly of the switch circuit board. Be sure all connections are soldered and that there are no solder bridges between the circuit board foils or switch lugs.



PICTORIAL 3-4



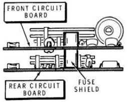


PICTORIAL 4-1

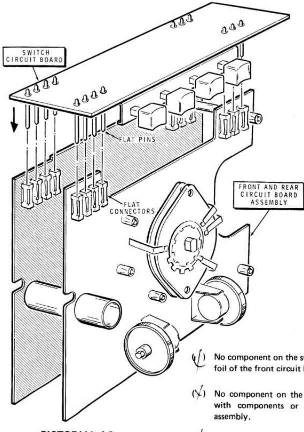
CIRCUIT BOARD COMBINATION

Refer to Pictorial 4-1 for the following steps.

(✓) Assemble the front and rear circuit boards together as shown. Guide the pins all the way into the connectors and the fuse insulator into the fuse shield. Be sure there are no solder joints on the front circuit board foil touching the switch lugs on the rear circuit board. Position the front and rear circuit boards so they are parallel as shown in Detail 4-1A.



Detail 4-1A



PICTORIAL 4-2

Refer to Pictorial 4-2 for the following steps.

( ) Set the front and rear circuit board assembly on your work bench with the fourteen flat connectors facing up as shown.

( ) Position the switch circuit board assembly as shown, with the pins over the connectors; then carefully plug the pins all the way into the connectors.

Be sure that:

( ) Each pin goes into its connector.

( ) No component on the switch circuit board touches the foil of the front circuit board.

( ) No component on the switch circuit board interferes with components or wiring on the circuit board assembly.

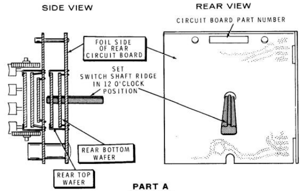
( ) The switch circuit board is at a right angle to the front and the rear circuit boards.

Refer to Part A of Pictorial 4-3 for the following steps.

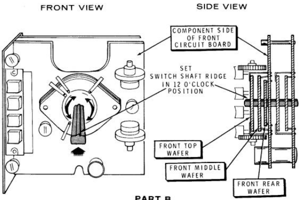
NOTE: The switch shaft used in the following steps is packaged inside the meter case.

( ) Position the circuit board assembly as shown in part A of the Pictorial.

( ) Insert the switch shaft through the center hole of the rear circuit board. Rotate the switch shaft slowly until it passes through the center hole of the rear, bottom wafer switch. Apply a slight pressure, if necessary.



PART A



PART B

PICTORIAL 4-3

( ) Continue to rotate the switch shaft until it passes through the rear top wafer switch. Then rotate the shaft one full turn and position it with the ridge at the 12 o'clock position, as shown.

( ) Carefully remove the switch shaft without disturbing the wafer switch rotors.

Refer to Part B of Pictorial 4-3 for the following steps.

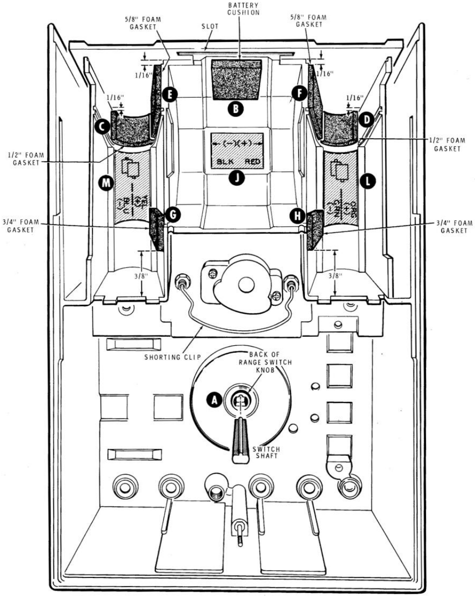
( ) Position the circuit board assembly as shown in part B of the Pictorial, and insert the shaft through the center hole of the top wafer switch.

( ) Rotate the shaft slowly with a slight pressure, until it passes through the center hole of the front, middle wafer switch.

( ) Continue to rotate the switch shaft until it passes through the center hole of the front, bottom wafer switch. Then rotate the shaft one full turn and position it with the ridge at the 12 o'clock position, as shown.

( ) Carefully press the shaft in further until it passes through the two rear circuit board wafer switches, and all five wafers are engaged by the switch shaft.

( ) Remove the switch shaft carefully without disturbing the wafer switch rotors.



PICTORIAL 4-4

CASE ASSEMBLY

Refer to Pictorial 4-4 for the following steps.

( ) Locate the meter and case assembly. Remove and discard the shorting clip between the two meter terminals, as shown.

CAUTION: In the following step, do not apply excess pressure to the back of the Range switch knob when installing the switch shaft. This could force the switch knob out of the case. If this should occur, refer to the "Case and Meter Replacement" paragraphs on Page 54 for instructions to reinstall the knob.

( ) Install the switch shaft in the switch knob at A as shown. Then turn the switch knob so the key ridge of the switch shaft is at the 12 o'clock position (toward the top of the case), as shown.

NOTE: In the following step be sure to locate the edge of the battery cushion below the slot for the case back panel.

( ) Remove the adhesive backing from the battery cushion and press the cushion in place at B in the large battery chamber.

( ) Locate the foam gasket and, using scissors, cut it into the following lengths:

1/2"	5/8"
1/2"	3/4"
5/8"	3/4"

Install these lengths of foam gasket in the meter case, as follows, in the following steps:

1. Carefully remove the protective backing.
2. Hold the foam gasket in position with your long-nose pliers at the indicated area.
3. Apply finger pressure to firmly seat the gasket in place.

( ) Place 1/2" lengths of foam gasket at C and D in the small battery chambers. Position each gasket 1/16" back from the top of the chambers, as shown.

( ) Place 5/8" lengths of foam gasket at E and F in the small battery chambers just above the 1/2" lengths, and 1/16" from the top of the chambers, as shown.

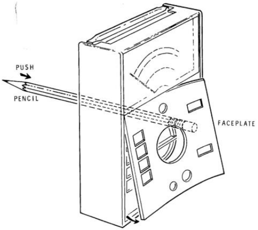
( ) Place 3/4" lengths of foam gasket at G and H in the small battery chambers. Position each 3/4" length 3/8" from the bottom of the chamber as shown.

Battery labels will be installed in the next three steps. To install a label, remove it from the common, protective backing on the label strip. Then press the label into position as directed in the step. Be sure to position it so the lettering appears as it is shown in the Pictorial.

( ) Use needlenose pliers to position the label and install the Black/Red battery label at J in the large bottom chamber.

( ) Install the Yellow/Blue battery label at M in the small battery chamber.

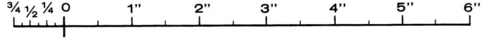
( ) Install the Orange/Green battery label at L in the small battery chamber.

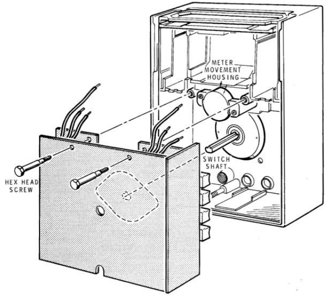


Detail 4-4A

NOTE: In the next step, you will remove the plastic faceplate from the meter case. It is normal for this faceplate to bend outward quite a ways before it springs loose.

( ) Refer to Detail 4-4A and, using the eraser end of a pencil, push carefully on the plastic faceplate to spring it outward and remove it from the meter case. Be careful not to scratch the paint backing on the faceplate.





PICTORIAL 4-5

Refer to Pictorial 4-5 for the following steps.

NOTE: If you have any difficulty getting the switch shaft through the wafers in the following step, it may be necessary to remove the circuit board assembly from the case and repeat the steps on Pages 30 and 31 that refer to Pictorial 4-3.

( ) Install the circuit board assembly in the case by carefully guiding the wafer switches onto the switch shaft. If necessary, rotate the Range switch slightly to engage the shaft with the wafer switches. The thumbwheels should be centered in their openings. If necessary, remove the circuit board assembly and reposition them for proper centering. Position the six hook up wires through the space next to the meter movement housing.

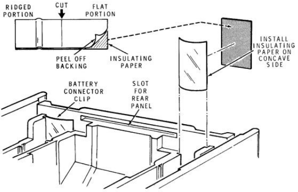
( ) Install the two hex head screws to hold the assembly in place. Tighten these two screws only finger tight.

Refer to Pictorial 4-6 (fold-out from Page 37) for the following steps.

( ) Locate the two 2" x 5/8" pieces of adhesive-backed insulating paper. Refer to Detail 4-6A and, using scissors, cut each piece at the scored line. Keep both sections of each piece.

( ) Refer to Detail 4-6A. Then remove the adhesive backing and press the flat portion of one of these insulating papers onto the concave (inner curved) side of each battery connector clip. Match the edges of the paper with the edges of the clip.

( ) Insert the battery connector clips, with the metal sides as shown, into the slots at the top of the meter case. If necessary, use the flat side of a screwdriver blade to press the clips to the bottom of the slots. Be sure the top of each clip is even with or below the slot for the rear panel.



Detail 4-6A

( ) Position the meter case as shown in Detail 4-6B (fold-out from Page 37). Then place a small piece of paper (or cardboard) over the foil of the rear circuit board to prevent solder from falling on it during the following steps.

( ) Bend the yellow wire over the paper as shown, and connect it to the indicated vertical tab of an AA battery clip (S-1). Cut off the excess wire length beyond the clip.

( ) In a similar manner, bend the blue wire over the paper and connect it to the indicated tab of an AA battery clip as shown (S-1). Cut off the excess wire length.

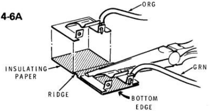
( ) Bend the orange wire over the paper as shown and connect it to the indicated tab of an AA battery clip (S-1). Cut off the excess wire length.

( ) Bend the green wire over the paper and connect it to the indicated tab of an AA battery clip as shown (S-1). Cut off the excess wire length.

( ) Carefully lift the paper away from the rear circuit board. Be sure no wire clippings fall into the meter case.

( ) Position the four AA battery clips as they are shown in Detail 4-6B (fold-out from Page 37).

( ) Remove the protective backing from one of the two ridged pieces of insulating paper.



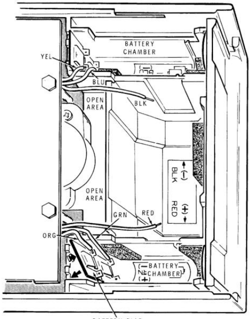
Detail 4-6C

( ) Refer to Detail 4-6C and position this piece of insulating paper and the battery clip that is connected to the green wire as shown. Then press the clip onto the insulating paper. Match the lower edge of the clip with the bottom edge of the insulating paper. Use needlenose pliers to squeeze the clip firmly onto the paper.

( ) In a similar manner, press the clip that is connected to the orange wire onto the upper half of the insulating paper, as shown. Note the position of this clip on the insulating paper.

( ) Remove the protective backing from the other ridged piece of insulating paper.

( ) In a manner similar to the steps above, press the battery clips on the blue and yellow wires onto this piece of insulating paper. Position the "blue clip" so its lower edge matches the bottom edge of the insulating paper and the yellow clip so its bottom edge is against the ridge of the insulating paper.



Detail 4-6D

( ) Refer to Detail 4-6D and install the "orange-green battery clip assembly" into the end of the battery chamber as shown. First place the assembly against the bottom of the chamber; then press it against the end of the chamber. *Position the wires as shown. Be sure the two battery clips do not touch each other.*

( ) In a similar manner, install the "yellow-blue battery clip assembly" into the other small battery chamber. *Position the wires as shown. Be sure that the two battery clips do not touch each other.*

( ) Position the excess yellow, blue, orange, and green wires in the open area around the meter housing.

Refer to Detail 4-6E for the following steps.

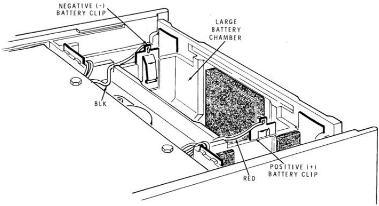
( ) Partially install a D battery clip, as shown, in the slot at each end of the large battery chamber.

( ) Connect the black wire to the negative (—) battery clip (S-1). Cut off any excess wire length. Position this wire in the notch at the side of the battery chamber.

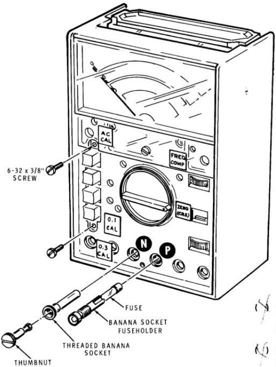
( ) Connect the red wire to the positive (+) battery clip (S-1). Cut off the excess wire length. Position this wire in the notch at the opposite side of the battery chamber.

( ) Press the two D battery clips all the way into the slots.

( ) Position the excess red and black wire in the open area around the meter housing.



Detail 4-6E



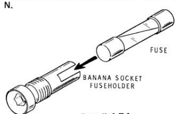
PICTORIAL 4-7

Refer to Pictorial 4-7 for the following steps.

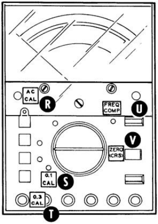
( ) Position the meter case as shown.

NOTE: The thumbnut used to hold the rear panel on the case has a hexagon socket on one end. Use this thumbnut as a tool to install the banana sockets in the next two steps.

( ) Install a threaded banana socket in the front panel at N.



Detail 4-7A



Detail 4-7B

( ) Refer to Detail 4-7A and press the fuse into the banana socket/fuseholder. Then install the socket and fuse in the front panel at P.

( ) Install a 6-32 x 3/8" screw at each end of the pushbutton switch. Tighten the screws carefully.

( ) Refer to Detail 4-7B to install the labels in the following steps.

( ) Remove the protective backing from the AC CAL (Calibrate) label, and press the label into position at R as shown.

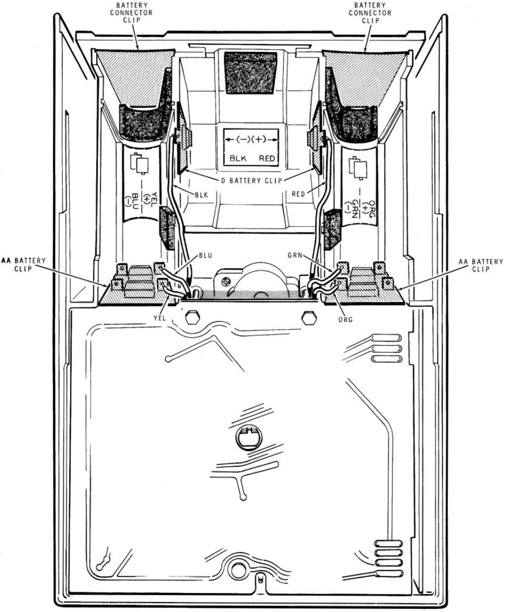
( ) In a similar manner install the 0.1 CAL label at S.

( ) Install the 0.3 CAL label at T.

( ) Install the FREQ COMP (Frequency Compensation) label at U.

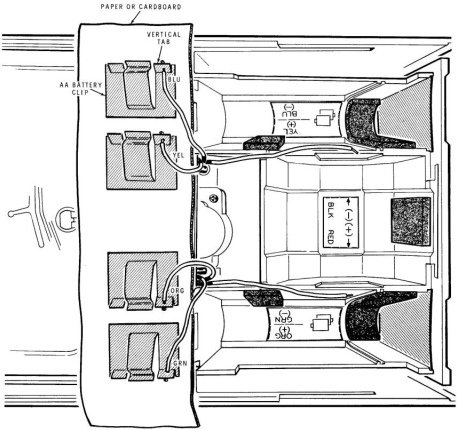
( ) Install the Zero CRS (Zero Coarse) label at V.

( ) Now turn the meter case over and carefully tighten the two hex head screws on the rear circuit board.



PICTORIAL 4-6

AA BATTERY
CLIP



Detail 4-6B

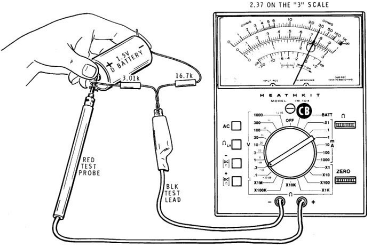
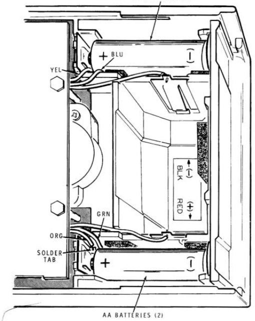

2.37 ON THE "3" SCALE
1.5V
D BATTERY
3.01k
16.7k
RED
TEST
PROBE
BLK
TEST
LEAD
HEATHKIT
AC
ZERO
OFF
BATT
X1M
X100K
X10K
X1K
X100
X10
X1

Figure 1



PICTORIAL 4-8

Refer to Pictorial 4-8 for the following steps.

( ) Position the Range switch so the pointer is at the OFF (straight up) position.

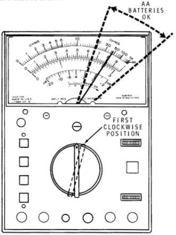
( ) Install an AA battery in the bottom position in each small battery chamber. Position the positive (+) end of each battery toward the top of the meter case.

( ) Check to be sure the green wire is positioned as shown, away from the solder tab. CAUTION: If this wire were pressed against the solder tab when the other battery is installed, the tab could cut through the wire's insulation and cause a short circuit that would damage the batteries.

( ) Check to be sure the blue wire is positioned away from the solder tab for the yellow wire.

NOTE: Be sure the green and blue wires do not move against the solder tabs when you install the batteries in the next step.

( ) Install the other two AA batteries. Position the positive (+) end of each battery toward the center of the case as shown.



Detail 4-8A

( ) Turn the meter case over and press the +DC/Ω pushbutton.

NOTE: If you can get the correct, "Battery OK," indication in the next step; turn the Range switch OFF, disregard steps 1 through 7, and proceed to "Test Lead Preparation." If you do not get the correct meter indication, perform steps 1 through 7.

( ) Rotate the Range switch to the first clockwise position. As shown in Detail 4-8A, the meter should indicate in the "Battery OK" position. If it does not:

1. Immediately return the Range switch to the straight up position.
2. Turn the meter case over.
3. Remove the top AA batteries on each side.
4. Be sure the battery clips are not touching each other.
5. Be sure the green and blue wires are not pinched against their respective solder tabs.

6. Be sure the batteries are correctly installed.

7. Repeat the step. If you still do not get a correct indication, proceed to the "In Case of Difficulty" section on Page 56. Then, after the problem is corrected, return to Page 38 and repeat the Battery OK check.

TEST LEAD PREPARATION

Refer to Pictorial 4-9 for the following steps.

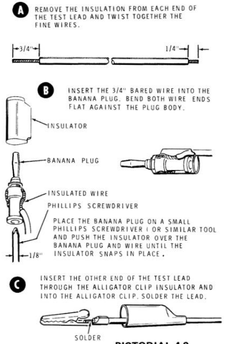
( ) Prepare the black test lead as shown. Use the black insulator to fasten the banana plug to the black test lead wires.

( ) Similarly, prepare the red test lead with a banana plug and the red insulator. However, do not install an alligator clip.

Refer to Pictorial 4-10 for the following steps.

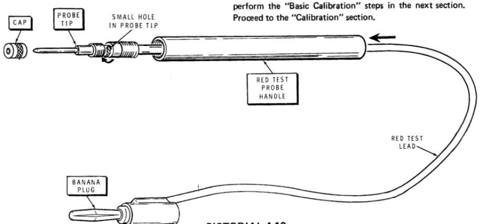
( ) Unscrew the threaded cap and the probe tip from the red test probe.

( ) Push the red test lead through the red test probe handle. Then pass the stripped end entirely through the small hole in the probe tip. Wrap the lead end around the shank of the probe tip in the direction of the arrow. Then screw the threaded cap into position on the probe tip and screw the handle onto the probe tip.

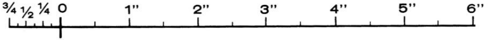


PICTORIAL 4-9

This completes the "Step-by-Step Assembly." You should have parts left over that will be used later, as well as a 3.01 kΩ and a 16.7 kΩ resistor that will only be needed if you perform the "Basic Calibration" steps in the next section. Proceed to the "Calibration" section.



PICTORIAL 4-10



CALIBRATION

This section of the Manual contains two calibration procedures. If you have access to a precision standard, proceed with the "Precision Calibration" section on Page 43. If a precision standard is not available, proceed with the following "Basic Calibration" section.

NOTE: If you desire to recalibrate the VOM at some future date, you can remove the faceplate as described in the first step on Page 54.

BASIC CALIBRATION

The accuracy of your Meter depends to a great extent upon the care and accuracy that you exercise in performing the following steps. These steps require only a minimum of equipment to calibrate the AC and DC sections of your Meter. If you do not know how to read the meter scales, refer to the instruction under "Reading the Meter" on Page 47 before proceeding with this Calibration.

If at any time you do not obtain the results called for in a step, refer to the "In Case of Difficulty" section on Page 56. Then, after the problem is corrected, return to this section and complete the calibration.

NOTE: In the following adjustments, it will be necessary to leave the faceplate off the meter case. Verify the locations of the various range-positions and plugs by temporarily laying the faceplate over the RANGE switch.

ZERO ADJUST

( ) Check the zero position of the meter pointer. If necessary, carefully turn screw CB (see Figure 1, fold-out from Page 38) to bring the pointer over the zero marks. Due to the frictionless characteristics of the movement, it is not necessary to tap the face of the meter while you turn screw CB.

DC CALIBRATION

( ) Insert a 1/8" blade screwdriver through the hole marked "0.3 CAL" (R4 on the schematic) and adjust the control to the midpoint of its rotation.

( ) Insert a 1/8" blade screwdriver through the hole marked "0.1 CAL" (R44 on the schematic) and adjust the control to the midpoint of its rotation.

( ) Turn the RANGE switch to the BATT (Battery) position. With new batteries, the meter should indicate in the "BATT OK" area of the scale. If the meter reads below this area, replace the batteries.

( ) Insert the red test lead into the "+" socket.

( ) Insert the black test lead into the "–" socket.

( ) Clip the alligator clip to the red test probe tip.

( ) Press the +DC/Ω pushbutton.

( ) Turn the RANGE switch to the 0.1 volt position.

( ) Rotate the ZERO thumbwheel all the way to the right.

( ) Insert a 1/8" blade screwdriver through the hole marked "ZERO CRS" (Zero Coarse) and adjust the control (R37 on the Schematic) for a reading of 0.55 to 0.60 on the 1.0 scale.

( ) Rotate the ZERO thumbwheel all the way to the left. The pointer should be to the left of the zero marks on the scale.

( ) Use the ZERO thumbwheel to carefully position the pointer on the zero marks.

( ) Turn the RANGE switch to the 0.3 volt position.

( ) Locate the 3.01 kΩ and 16.7 kΩ resistors and the 1.5 volt, "D battery."

Refer to Figure 1 (fold-out from Page 38) for the following steps.

( ) Twist the resistor leads together as shown for about 1/2". Then solder the twisted connection.

( ) Clip the black test lead to the soldered connection.

( ) Twist the other lead of the 3.01 kΩ resistor around the tip of the red test probe.

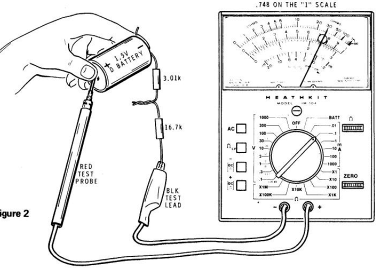


Figure 2

( ) Hold the red test probe tip to the plus (+) end and the 16.7 kΩ resistor lead to the other end of the 1.5 volt "D battery." the pointer should deflect upscale. Then use a 1/8" blade screwdriver to adjust the "0.3 CAL" control (R4 on the Schematic) for a reading of 2.37 on the 3.0 scale.

( ) Disconnect the battery and the resistors from the test leads.

( ) Turn the RANGE switch to the 0.1 mA position.

Refer to Figure 2 for the following two steps.

( ) Attach the alligator clip to one lead of the joined resistors as shown.

( ) Hold the other lead of the joined resistors to the negative (—) end of the 1.5 volt D battery and the red test probe to the positive end of the battery. The pointer should deflect upscale. Then use a 1/8" blade screwdriver to adjust the "0.1 CAL" control (R44 on the Schematic) for a reading of 0.748 on the 1.0 scale.

( ) Disconnect the test leads from the resistors and battery.

AC CALIBRATION

WARNING: Use extreme care when measuring line voltage to prevent personal shock or instrument damage.

( ) Turn the RANGE switch to the 300 volt position.

( ) Press the AC pushbutton.

( ) If you have a household appliance (waffle iron, etc.) with an AC cord that connects to two round posts on the appliance, connect your VOM test leads to, the two holes in the appliance end of the cord. Plug the cord into a line voltage outlet. If no such appliance cord is available, attach the alligator clip to a known earth ground and carefully insert the test probe into an AC wall outlet. If there is no voltage indication on one side of the outlet, try the other side. The pointer should deflect upscale.

NOTE: Successful calibration, in the following step, largely depends on whether you know or do not know the value (in AC volts) of the line voltage being measured. If you know the line voltage, proceed with the following step. If you do not know it, set the AC CAL control to the center of its rotation and disregard the next step. (Remember that this adjustment can always be "touched-up" when you have access to a known voltage.)

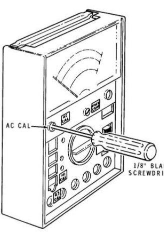


Figure 3

( ) Refer to Figure 3. Then use a 1/8" blade screwdriver and adjust the "AC CAL" control (R6 on the Schematic) so the meter indicates the line voltage in your area. (In the United States this is usually at or close to 120 VAC.)

( ) Disconnect the test leads from the line voltage outlet.

FREQUENCY COMPENSATION

NOTE 1: Accurate adjustment of the FREQ COMP (frequency compensation) trimmer capacitor requires a sine wave generator and an AC voltmeter, or an oscilloscope with a flat frequency response to approximately 1 kHz. If you do not have these instruments, disregard the following adjustments, which were approximately set during the "Step-by-Step Assembly," and proceed to "Ohms Adjustment" on Page 45. If you do have these instruments available, proceed as follows:

NOTE 2: In areas where there is significant radiation from 60 Hz power lines, fluorescent lights, etc., some oscillation of the pointer may be seen when you measure AC voltages of a frequency near 60 Hz. Varying the frequency between 40 Hz to 80 Hz may improve the measurement readability. Otherwise, assume the center of the pointer oscillation to be the correct reading.

( ) Turn the RANGE switch to the 1.0 volt position.

( ) Press the AC pushbutton.

( ) Adjust the generator output level for about 1.0 volts rms. Set the frequency to approximately 60 Hz.

( ) Connect the AC voltmeter (or oscilloscope) and your Solid-State VOM across the generator output terminals.

( ) Readjust the generator output level slightly, if necessary, to get an indication on the AC voltmeter (or oscilloscope) that will be an easy-to-refer-to reference in the following steps.

( ) Observe and remember the meter indication. This will be referred to as the "60 Hz meter indication" below.

( ) Adjust the generator frequency to approximately 1 kHz. Then readjust the generator output to the same reference as above.

( ) Adjust the FREQ COMP trimmer capacitor (C12 on the Schematic) until the VOM gives the same indication as it did above with the "60 Hz meter indication." If the previous 60 Hz indication cannot be obtained, adjust the trimmer capacitor to the center of its adjustment range.

( ) Disconnect all equipment.

( ) Turn the RANGE switch to OFF.

This completes the "Basic Calibration" of your Meter.

PRECISION CALIBRATION

The accuracy of your Meter depends to a great extent upon the care and accuracy that you exercise in performing the following steps. These steps are designed to be used with precision standard equipment to calibrate the AC and DC sections of your Meter. If you do not know how to read the meter scales, refer to the instructions under "Reading the Meter" on Page 47 before proceeding with this Calibration.

If at any time you do not obtain the results called for in a step, refer to the "In Case of Difficulty" section on Page 56. Then, after correcting the problem, return to this section and complete the calibration.

NOTE: In the following adjustments, it will be necessary to leave the faceplate off of the meter case. Verify the locations of the various range positions and plugs by temporarily laying the faceplate over the RANGE switch.

Refer to Figure 1 (fold-out from Page 38) for the following steps.

ZERO ADJUST

( ) Check the zero position of the meter pointer. If necessary, carefully turn screw CB to bring the pointer over the zero marks. Because the meter movement is frictionless, it is not necessary to tap the face of the meter while you turn screw CB.

DC CALIBRATION

( ) Turn the RANGE switch to the BATT (Battery) position. With new batteries, the meter should indicate in the "BATT OK" area of the scale. If the meter reads below this area, replace the batteries.

( ) Insert the red test lead into the "+" socket.

( ) Insert the black test lead into the "–" socket.

( ) Clip the alligator clip to the red test probe tip.

( ) Press the +DC/Ω pushbutton.

( ) Turn the RANGE switch to the 0.1 volt position.

( ) Rotate the ZERO thumbwheel all the way to the right (maximum clockwise rotation).

( ) Insert a 1/8" blade screwdriver through the hole marked "ZERO CRS" (Zero Coarse) and adjust the control (R37 on the Schematic) for a reading of 0.55 to 0.60 on the 1.0 scale.

( ) Rotate the ZERO thumbwheel all the way to the left (maximum counterclockwise rotation). The pointer should be to the left of the zero marks on the scale.

( ) Use the ZERO thumbwheel to carefully position the pointer on the zero marks.

( ) Turn the RANGE switch to the 0.3 volt position.

( ) Adjust the DC voltage standard for 0.3 volts.

( ) Connect the DC voltage standard output to the + and – sockets on the Meter.

( ) Use a 1/8" blade screwdriver to adjust the "0.3 CAL" control (R4 on the Schematic) for a full-scale reading on the 3.0 scale of the Meter.

( ) Adjust the DC voltage standard for 0.100 volt output.

( ) Turn the RANGE switch to the 0.1 position.

( ) Use a 1/8" blade screwdriver to adjust the "0.1 CAL" control (R44 on the Schematic) for a full-scale reading on the meter.

( ) Disconnect the test leads from the DC standard.

AC CALIBRATION

( ) Turn the RANGE switch to the 0.1 volt position.

( ) Press the AC pushbutton.

( ) Use a 1/8" blade screwdriver and turn the "AC CAL" control (R6 on the Schematic) fully counterclockwise.

NOTE: In areas where there is significant radiation from 60 Hz power lines, fluorescent lights, etc., the pointer may oscillate when you measure AC voltages near 60 Hz. If this occurs, try to eliminate it by using some other frequency between 40 Hz and 80 Hz. Otherwise, assume the center of the pointer oscillation to be the correct reading.

( ) Adjust the AC voltage standard for an output of 0.100 volts rms at a frequency of 60 Hz.

( ) Connect the output of the AC voltage standard to the + and – sockets on the Meter.

( ) Adjust the "AC CAL" control (R6 on the Schematic) for a full-scale reading on the meter.

( ) Turn the RANGE switch to the 10 volt position.

( ) Adjust the AC voltage standard for exactly a full-scale indication.

( ) Adjust the AC standard frequency to 10 kHz.

( ) Use a 1/8" blade screwdriver and adjust the "FREQ COMP" trimmer capacitor (C12 on the Schematic) for a full-scale indication.

( ) Adjust the AC standard frequency to 60 Hz.

( ) Turn the RANGE switch to the 3 volt position.

( ) Adjust the AC voltage standard for exactly a full-scale indication.

( ) Adjust the AC standard frequency to 10 kHz.

( ) Observe the difference in meter indication from full scale. Readjust the FREQ COMP trimmer capacitor for a meter indication halfway between the full scale and the present reading.

NOTE: The above procedure should equally divide the frequency error between the 3 volt and the 10 and 30 volt ranges.

( ) Disconnect the Meter from the AC standard.

( ) Turn the RANGE switch to OFF.

This completes the "Precision Calibration" of your Meter.

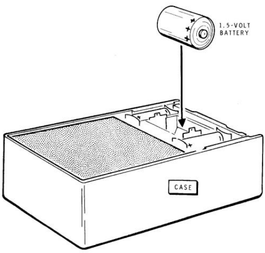


Figure 4

OHMS ADJUSTMENT

Use the following steps to check and adjust the OHMS scale on your VOM. If at any time you do not obtain the results called for in a step, refer to the "In Case of Difficulty" section on Page 56 to correct the problem.

Refer to Figure 4 for the following step.

( ) Install the 1.5-volt "D battery" in the center compartment. Be sure to observe battery polarity as shown on the label in the chamber.

NOTE: If you do not know how to make a resistance measurement, refer to the section on "Resistance Measurements" on Page 49 before proceeding with this adjustment. Instructions for reading the OHMS scale are given on Page 48.

( ) Insert the red test lead into the "+" socket.

( ) Insert the black test lead into the "–" socket.

( ) Clip the alligator clip to the red test probe tip.

( ) Turn the RANGE switch to the 1000 mA position.

( ) Press the + DC/Ω pushbutton.

( ) Adjust the ZERO thumbwheel to position the pointer over the zero marks.

( ) Unclip the alligator clip from the red test probe tip.

( ) Turn the RANGE switch to the Ω x 1 position. The meter should deflect upscale.

( ) Adjust the Ω thumbwheel for a full-scale (∞, infinity) indication.

( ) Turn the RANGE switch from the Ω x 1 position through the Ω x 1M position. The pointer should remain at "∞".

( ) Turn the RANGE switch to the Ω x 10 k position.

( ) Measure the 3.01 kΩ – 16.7 kΩ joined resistors. The total, 19.71 kΩ, should be indicated (± about 2.4 kΩ).

( ) Turn the RANGE switch to the Ω x 1k and Ω x 100 positions. 19.71 kΩ (± about 2.4 kΩ) should be indicated on these ranges also.

( ) Measure only the 3.01 kΩ resistor on the Ω x 100 and Ω x 10 ranges. Depress the – DC/Ω pushbutton during one of these measurements; the resistance reading should be the same as the + DC/Ω reading.

( ) Disconnect the resistors and depress the Ω_{LV} pushbutton.

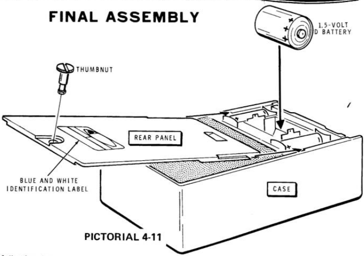
( ) Readjust the Ω thumbwheel for a full-scale (∞, infinity) indication.

( ) Turn the RANGE switch from the Ω x 1 through the Ω x 1M positions. The pointer should remain at "∞".

( ) Repeat the measurements of the previous steps (19.71 kΩ and 3.01 kΩ).

This completes the "Ohms Adjustment". Store the 3.01 kΩ – 16.7 kΩ joined resistors in a safe place for future use. They can be completely wrapped in tissue paper and stored, tightly lodged, in the area between the lower wall of the D-cell battery chamber and the meter housing.

FINAL ASSEMBLY



PICTORIAL 4-11

Refer to Pictorial 4-11 for the following steps.

NOTE: If you have not already done so, install the 1.5 volt "D battery" in the center compartment. Be sure to observe battery polarity as shown on the label in the chamber.

( ) Slide the rear panel into place on the back of the case. Be sure the panel seats properly in the side and the top slots of the case.

NOTE: The blue and white identification label that is installed in the next step shows the Model number and Production Series number of your kit. Refer to these numbers in any communications with the Heath Company; this assures you that you will receive the most complete and up-to-date information in return.

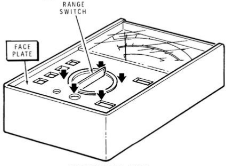
( ) Carefully peel away the backing paper from the blue and white identification label. Then press the label onto the back of the back panel in the location shown.

( ) Insert the thumbnut through the rear panel and tighten it using a coin.

Refer to Pictorial 4-12 for the following steps.

( ) Place the VOM face-up on your workbench.

( ) Lay the faceplate in position on the front of the case, with its top edge inserted into the slot at the bottom of the meter window.



PICTORIAL 4-12

( ) Starting at the top of the Range switch, and working around it, firmly press the faceplate into position. Then press in on the corners and around the edges of the faceplate to be sure it is completely seated in position.

NOTE: If you desire to check the calibration of this VOM at some future time, you can remove the faceplate by inserting the flat of a small screwdriver through the opening for the Zero thumbwheel. Then lift up on the faceplate until it snaps out.

This completes the "Final Assembly."

OPERATION

Refer to Figure 5 (fold-out from Page 53) for a description of the control and socket functions.

NOTE: Turn the RANGE switch to the OFF position when the Meter is not being used to avoid running down the batteries.

SAFETY PRECAUTIONS

You may often use your Meter to check, maintain, and repair electronic equipment which contains DANGEROUSLY HIGH VOLTAGES. Because of this danger, you should always observe the safety procedures listed below.

1. Always handle the test probe by the insulated housing only. Be careful not to touch the exposed tip.

2. When you measure high voltages, turn off the power to the equipment to be tested before you connect the test leads. If this is not possible, be very careful to avoid accidental contact with any object that could provide a ground return (circuit completion) path.

3. If it is at all possible, use only one hand when testing energized equipment. Keep one hand in your pocket or behind your back to minimize the possibility of accidental shock.

4. If possible, insulate yourself from ground while making measurements. Stand on a properly insulated floor or floor covering.

5 Before you connect the test leads for a resistance measurement, turn off the power to the equipment to be tested, and discharge any capacitors which may have stored a charge.

READING THE METER

This section of the Manual will familiarize you with the meter scales. Instructions are given, along with an example, for reading each scale. In addition, the first example for each type of reading is illustrated on the fold-out from Page 53.

AC or DC Voltage Readings

NOTE: The numbers in the "V" bracket on the RANGE switch refer to the full-scale voltages of the Meter.

.1 VOLTAGE RANGE – Read the 0 to 1 scale and move the decimal point one place to the left. For example, a reading of .7 on this range would indicate a measurement of .07 volts, as shown in Figure 6 (fold-out from Page 53).

.3 VOLTAGE RANGE – Read the 0 to 3 scale and move the decimal point one place to the left. For example, a reading of 2 would indicate a measurement of .2 volts.

1 VOLTAGE RANGE – Read the 0 to 1 scale directly. For example, a reading of .5 would indicate a measurement of .5 volts.

3 VOLTAGE RANGE – Read the 0 to 3 scale directly. For example, a reading of 2 would indicate a measurement of 2 volts.

10 VOLTAGE RANGE – Read the 0 to 1 scale and move the decimal point one place to the right. For example, a reading of .8 would indicate a measurement of 8 volts.

30 VOLTAGE RANGE – Read the 0 to 3 scale and move the decimal point one place to the right. For example, a reading of 2 would indicate a measurement of 20 volts.

100 VOLTAGE RANGE – Read the 0 to 1 scale and move the decimal point two places to the right. For example, a reading of .6 would indicate a measurement of 60 volts.

300 VOLTAGE RANGE – Read the 0 to 3 scale and move the decimal point two places to the right. For example, a reading of 2 would indicate a measurement of 200 volts.

1000 VOLTAGE RANGE – Read the 0 to 1 scale and move the decimal point three places to the right. For example, a reading of .8 would indicate a measurement of 800 volts.

Current Readings

NOTE: The numbers in the "mA" bracket on the RANGE switch refer to the full-scale currents of the Meter.

.01 mA RANGE – Read the 0 to 1 scale and move the decimal point two places to the left. For example, a reading of .7 on this range would indicate a measurement of .007 mA (7.0 μA) as shown in Figure 7 (fold-out from Page 53).

.1 mA RANGE – Read the 0 to 1 scale and move the decimal point one place to the left. For example, a reading of .6 would indicate a measurement of .06 mA.

1 mA RANGE – Read the 0 to 1 scale directly. For example, a reading of .8 would indicate a measurement of .8 mA.

10 mA RANGE – Read the 0 to 1 scale and move the decimal point one place to the right. For example, a reading of .5 would indicate a measurement of 5 mA.

100 mA RANGE — Read the 0 to 1 scale and move the decimal point two places to the right. For example, a reading of .9 would indicate a measurement of 90 mA.

1000 mA RANGE — Read the 0 to 1 scale and move the decimal point three places to the right. For example, a reading of .5 would indicate a measurement of 500 mA.

Resistance Readings

NOTE: The numbers in the "Ω" bracket on the RANGE switch are multipliers for the OHMS scale on the Meter.

Ω x 1 RANGE — Read the OHMS scale directly. For example, a reading of 20 would indicate a measurement of 20 Ω, as shown in Figure 8 (fold-out from Page 53).

Ω x 10 RANGE — Read the OHMS scale and multiply by 10. For example, a reading of 30 would indicate a measurement of 300 Ω.

Ω x 100 RANGE — Read the OHMS scale and multiply by 100. For example, a reading of 10 would indicate a measurement of 1000 Ω or 1 kΩ.

Ω x 1 K RANGE — Read the OHMS scale and multiply by 1000. For example, a reading of 30 would indicate a measurement of 30,000 Ω, or 30 kΩ.

Ω x 100 K RANGE — Read the OHMS scale and multiply by 100,000. For example, a reading of 20 would indicate a measurement of 2,000,000 Ω, or 2 MΩ.

Ω x 1 M RANGE — Read the OHMS scale and multiply by 1,000,000. For example, a reading of 10 would indicate a measurement of 10,000,000 Ω, or 10 MΩ.

DB Readings

Readings on the dB scale are explained under "Decibel Measurements" in this section.

DC VOLTAGE MEASUREMENTS

The voltage ranges provided by your Meter were selected for easy reading and convenient measuring. The low ranges (0.1 to 30) cover most measurements in transistor circuits. The higher ranges (100 to 1000) cover most measurements in tube-type, transformer-operated equipment. The 10 MΩ input resistance virtually eliminates meter loading on high impedance circuits. When the Meter is used with the Heath High Voltage Probe assembly, for 10 MΩ input resistance meters, voltages up to 30,000 volts can be measured for servicing or adjusting television or oscilloscope anode circuitry.

WARNING: Be cautious when making measurements of 20 volts or more. If you do not know the value of the voltage, assume that it is dangerous.

To measure DC voltage, depress the + DC/Ω pushbutton. Connect the black test lead from the "–" socket of the VOM to the common, or ground, side of the voltage to be measured. Connect the red test lead to the "+" socket.

If you know the approximate value of the voltage to be measured, set the RANGE switch to the next higher voltage range. If you do not know the approximate value, set the RANGE switch to the 1000 volt position. Then, with the red test probe, touch the point in the circuit where the voltage is to be measured. If the pointer moves less than 1/3 of full-scale, switch to the next lower range (several times if necessary). If the pointer deflects to the left, depress the – DC/Ω pushbutton for an upscale reading.

Null Detector

As a null detector, the VOM indicates polarity and relative difference between two voltage levels (when there is a common connection between the two voltage sources). Each small mark on the null scale (located to the left of the BATT OK scale) corresponds to approximately one millivolt on the .1 volt range.

To use the VOM as a null detector, set the RANGE switch to any one of the "1" ranges. Then press the + DC/Ω pushbutton, and rotate the ZERO thumbwheel so the pointer is over the "0" mark on the null scale. Connect the black test lead to a known reference voltage and the red test lead to the voltage you are comparing to the reference. If the pointer indicates on the left side of "0," the voltage is lower than the reference. If the pointer indicates on the right side of "0," the voltage is higher than the reference.

The null detector function may be used to measure regulation of a regulated power supply to adjust a power supply output to a reference level or to balance DC resistance bridges.

RESISTANCE MEASUREMENTS

WARNING: Before you connect the meter leads to make a resistance measurement, remove the operating power to the equipment to be tested and discharge any capacitors which may have stored a charge.

NOTE: Turn the RANGE switch to the OFF position when the VOM is not being used to avoid running down the batteries.

Resistance measurements can be made as described in the following paragraphs.

1. Zero the meter on one of the current ranges for the most accurate zeroing.

2. If you know the approximate value of the resistance, set the RANGE switch so the meter will indicate as near midscale as possible. If you do not know the approximate value, turn the RANGE switch to the X1 range; then, if the meter indicates near full scale, turn the RANGE switch to a higher (X10, X100, etc.) range.

3. The three ohms pushbuttons (Ω_{LV}, +DC/Ω, –DC/Ω) have the following characteristics:

Ω_{LV} This pushbutton activates a low voltage measuring circuit. It is especially useful for measurements in semiconductor (diodes, transistors, etc.) circuits, but it can also be used for other measurements. If you are measuring resistance in a semiconductor circuit and do not want any semiconductors to conduct and affect the resistance reading, press this pushbutton.

–DC/Ω
+DC/Ω These pushbuttons both activate a measuring circuit with a test voltage large enough to "turn on" a semiconductor. With the +DC/Ω pushbutton depressed, the test leads will have the polarity marked on the front panel. With the –DC/Ω pushbutton depressed, the polarity of the test leads will be reversed from the front panel markings.

These pushbuttons will be especially useful when you wnat to check a device that has a different resistance in each direction, such as a diode. First make the measurement with one of these pushbuttons depressed, and then press in the other one to get a reading of the resistance with the current in the other direction.

CAUTION: Your Meter can be used to check the forward and reverse resistance of low-power diodes and transistors, but use the Ω x 10 range or high only. The Ω x 1 range may cause excessive forward conduction and result in junction breakdown.

4. Press one of the three ohms (Ω) pushbuttons.

5. Be sure the test lead ends are not touching, and then adjust the "Ω" thumbwheel until the meter pointer is exactly over the full scale (∞) indication.

   When you change from Ω_{LV} to –DC/Ω or +DC/Ω, or vice versa, readjust the "Ω" thumbwheel for a full scale (∞) indication on the meter.

6. Connect the black test lead to one side of the resistance to be measured. Then touch the other side with the red test probe and read the resistance on the OHMS scale. Be sure to multiply the reading by the proper factor as shown on the RANGE switch.

NOTE: For very low resistance measurements on the Ω x 1 scale, it may be necessary to take the resistance of the VOM and test leads into account. First make sure the meter is carefully zeroed on one of the current ranges. Then switch back to the Ω x 1 scale and adjust the thumbwheel to ∞ with the test lead ends apart. Now touch the test leads together; the meter will indicate the resistance of the test leads and the internal resistance of the VOM (fuse, contacts, etc.). Subtract this reading from all subsequent readings.

AC VOLTAGE MEASUREMENTS

WARNING: Be cautious when making measurements of 20 volts or more. If you do not know the value of the voltage, assume that it is dangerous.

CAUTION: When making AC measurements in circuits with a DC voltage in excess of 500 volts, DO NOT attempt to measure any point where the instantaneous voltage (peak AC +DC) may exceed 1000 volts.

To measure AC voltages, connect the black test lead between the "–" socket and the common, or ground, side of the voltage to be measured. Connect the red test lead to the "+" socket. After zeroing the meter on a DC current range (or on one of the "1" voltage ranges), press the AC pushbutton.

If you know the approximate value of the voltage to be measured, set the RANGE switch to the next higher voltage range. If you do not know the approximate value, set the RANGE switch to the 1000 volt position. Then, with the red test probe, touch the point in the circuit where the voltage is to be measured. If the indicator moves less than 1/3 of full-scale, switch to the lower ranges.

AC Voltage Interpretation

Your Meter can measure almost any type of AC voltage. Filament voltage, power line voltage, noise voltage, or even output or gain measurements can be made quickly and accurately. It is important, however, to understand how the various types of input waveforms affect the readings and how to interpret these readings for the greatest accuracy. For this reason, the following information is presented.

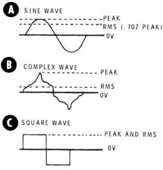


Figure 9

When a DC voltage is applied to a resistor, it produces a measurable temperature increase. If an AC voltage is applied to the same resistor and produces the same temperature increase, then the AC voltage must be producing the same amount of power. Since this power produced by the AC voltage is averaged over a period of time, it is called "mean" (or average) power. The AC voltage that produces this power is proportional to the square root of the mean power, and is called the rms (root-mean-square) voltage. AC meters are usually calibrated in rms voltage. for a sine wave (see Figure 9), the most common AC voltage waveform, the rms value of each half cycle is .707 times the peak of the waveform.

The following relationships exist for sine wave AC voltages:

rms voltage = peak voltage x 0.707
Peak voltage = rms x 1.414
Peak-to-Peak voltage = rms x 2.828
rms voltage = peak-to-peak voltage x 0.3535

If the input voltage to your Meter is an AC sine wave, the positive portion of the signal will deflect the indicator upscale.* Since the meter movement has mechanical inertia, it "averages" the current pulses and causes the indicator to show this average value. Therefore, the scales are designed to indicate the rms value of a sine wave while the meter itself is actually responding to the average value of the positive portion of the waveform. Therefore, if you suspect that the waveform being measured is not a sine wave, read the voltage with just the AC pushbutton depressed, and then read the voltage with both the AC pushbutton and the – DC/Ω pushbutton depressed. The average of these two readings will approximately reflect the rms value of the waveform being measured.

If a nonsinusoidal (not a sine wave) waveform such as a square wave, sawtooth wave, or pulse is being measured, the indicated reading on the scale must be given some special interpretation. For example, the complex waveform shown in Figure 9 contains a "spike" (peak) that may be several times as large as the average value of the waveform. Since the spike is of such short duration, the average value of the overall waveform is barely affected. On the other hand, the symmetrical square wave (a square wave having positive and negative portions of equal amplitude and time duration) shown in Figure 9 would indicate an rms value higher than its peak value. On your Meter, a symmetrical square wave having a 1.0 volt peak would indicate 0.55 volts.

Remember: Examine any nonsinusoidal waveform with an oscilloscope or a true rms meter if you want a highly accurate measurement.

*See the "AC Voltage Measuring" portion of the "Circuit Description" (Page 66).

Meter Loading

When you connect your VOM to a circuit, its input resistance and input capacitance are, in effect, placed in parallel with those parts of the circuit located between the test leads. In some cases, this can load the circuit under test and change the value of the voltage being measured.

The amount of loading presented by the input resistance of your VOM is primarily determined by the impedance of the circuit under test. Little error will be introduced through loading into any circuit with an impedance of 1 MΩ or less.

The amount of loading presented by the input capacitance of your VOM is primarily determined by the frequency of the signal under test. In low frequency circuits, you can usually disregard the effects of capacitive loading. In high frequency circuits, however, the effects of capacitive loading may considerably alter the voltage at the point of measurement.

DECIBEL MEASUREMENTS

Because the human ear does not respond to sound volume in direct proportion to sound intensity, the telephone industry adopted a logarithm-based system of measurement which more nearly matches the human hearing response. The basic unit of measurement in this system is called the "bel". The bel is mathematically expressed as:

$$\text{bel} = \log \frac{P_1}{P_2}$$

where P_1 and P_2 refer to two sound intensity levels.

Since differences as small as 0.1 to 0.3 bels are detectable by human hearing, a smaller increment of the bel, called the decibel, is more convenient to use. A decibel (dB) is 1/10 of a bel, and is mathematically expressed as:

$$\text{dB} = 10 \log \frac{P_1}{P_2}$$

where the 10 appears because a decibel is 1/10 of a bel.

The decibel system was adapted to electrical measurements in order to describe power ratios. When used in this manner, P_1 could refer to the output power and P_2 could refer to the input power of an amplifier.

Decibels can also be used to express voltage ratios. However, extreme care must be taken to insure that the conversion to these ratios is accurate. The basis for the use of decibels to express voltage ratios is given in the following discussion.

Electrical power is mathematically expressed as:

$$P = \left(\frac{E^2}{R}\right)$$

where E refers to the circuit voltage and R refers to the circuit resistance. Therefore, decibels can be expressed for two power levels as:

$$\text{dB} = 10 \log \left(\frac{E_1{}^2/R_1}{E_2{}^2/R_2}\right)$$

Then, if R_1 and R_2 are equal in value:

$$\text{dB} = 10 \log \left(\frac{E_1{}^2}{E_2{}^2}\right)$$

$$= 20 \log \left(\frac{E_1}{E_2}\right)$$

This last example is perhaps the most common form of the equation. However, it must be clearly understood that the equation is valid only because of the assumption that R_1 and R_2 are equal.

Values used to express measurements of electrical gain or electrical attenuation would often lead to the use of some rather unwieldy numbers without the use of dB's. As an example, consider two amplifiers having voltage gains of 100 and 1000. If these two amplifiers are connected in series, their total gain would be 100 x 1000 or 100,000. Using dB's, the individual gains would be 40 dB and 60 dB. The total voltage gain would be expressed as 100 dB. Thus, the addition of dB numbers is equivalent to the multiplication of conventional numbers. Also, the subtraction of dB numbers is equivalent to the division of conventional numbers. As you can see, these properties make decibel units very convenient.

Several systems exist for defining a dB reference level that can be compared to other power levels. One of the more common power levels used as a reference is 1 milliwatt. If this reference is used, then decibels may be expressed in the unit "dBm," where the m refers to 1 milliwatt.

In audio systems (where the circuit impedance level is usually 600 Ω), 0.775 volts rms across a 600 Ω load produces 1 milliwatt of power. This is the "0 dB" point on the 1 volt range of the VOM. When you compare dB readings on different ranges, use the range factors listed on the Range switch; and add or subtract, as required, the dB factor on that position to the reading on the dB scale of the meter.

The use of decibels to express measured voltage ratios in other than 600 Ω systems is valid only if the impedance levels are equal. If the impedance levels are not equal, it is necessary to convert the readings to a power level where a valid comparison can be made. A comparative measurement of two voltage levels at the same circuit location, however, is valid since the impedance level would be the same.

One example of the use of dB scales would be to check the flatness of the frequency response of an audio amplifier. The following procedure could be used to make this check. NOTE: A low impedance, variable frequency, sine-wave signal generator should be used in these steps, with the output voltage set to .05 volts rms or higher.

1. Connect the signal generator to the input of the amplifier. If the amplifier requires a lower input level for undistorted operation, use an impedance-matching attenuator.

2. Set the signal generator frequency to the lowest frequency of interest.

3. Connect your VOM (in the same manner as for any AC voltage measurement) and the proper resistive load to the output of the amplifier.

4. Adjust the signal generator's output level to obtain the desired output voltage or power level from the amplifier. If an exact output level is not required, the signal generator may be adjusted to indicate a specific point on the dB scale: such as 0 dB, −6 dB, or +2 dB.

5. Note the indication on the meter.

6. Connect the Meter to the output of the signal generator and note the voltage.

7. Set the signal generator frequency to the next highest value of interest and, if necessary, readjust the output level of the generator to that of the previous measurement.

8. Reconnect the VOM to the amplifier's output and note the dB reading.

Repeat steps six, seven, and eight at as many frequency points as desired. Then use the recorded dB readings to express the flatness of the amplifier's response over a prescribed bandwidth.

The dB scale can also be used to:

- Examine gain versus control voltage in avc (automatic volume control) circuits.
- Measure the signal reduction in T-pad, L-pad, or other attenuator circuits.
- Measure the effect of bass or treble controls in audio circuits versus the frequency or setting.
- Examine pass-band, stop-band, and attenuator of filter networks.
- Verify the flatness of response of signal generators.

These explanations of decibel measurements cover only the basic principles of the subject. There are many fine text books that treat the subject in greater detail.

CURRENT MEASUREMENTS

CAUTION: All current measurements must be made by connecting the test leads in series with the current to be measured. Be sure that the circuit is turned off prior to connecting the leads.

To measure current, connect the black test lead between the − socket and the negative side of the circuit to be measured. Connect the red test lead between the + socket and the positive side of the circuit to be measured.

If you know the approximate value of the current to be measured, set the RANGE switch to the next higher current range. If you do not know the value of the current to be measured, set the RANGE switch to the 1000 mA range.

To measure DC currents, depress the +DC/Ω pushbutton.

To measure AC current, depress the AC pushbutton. NOTE: An erroneous reading will result if any significant DC current is present when you are making AC current measurements.

Turn the circuit on. If the pointer moves to less than 1/3 of full scale, switch to the next lower range. If the pointer moves to more than full scale (pegs), switch to the next higher range. If the pointer moves to the left, when you are measuring DC currents, depress the opposite polarity pushbutton. NOTE: When a measurement can be made on more than one range, use the most readable range.

METER ACCURACY

The meter movement is accurate to within ±1% of full scale. For DC measurements, the ±1% accuracy of the divider resistors must be added to this, resulting in an overall accuracy of ±2% of full scale. For AC measurements, the rectifier circuit contributes additional variations which result in an accuracy of ±3% of full scale. Variations in frequency response, although insignificant at low frequencies, may result in a still larger percentage of error at higher frequencies. (See "Frequency) Response" in the "Specifications," Page 60.)

Accuracy on the OHMS range depends primarily on the ±1% accuracy of the multipliers and the ±1% of the meter movement. The resulting accuracy is not readily expressed as a percentage figure because of the nonlinear OHMS scale.

NOTE: When comparing a reading on this VOM with a reading on another meter, consider that the error of the other meter may be in the opposite direction. For example, if you were comparing two meters having an accuracy of ±5%, the total difference could be as much as ±10%. Critical comparisons should only be made against certified standards.

MAINTENANCE

This section of the Manual will provide you with the information necessary to keep your Meter in peak operating condition. As with any precision instrument, periodic inspections and prompt attention to small problems will often forestall more troublesome difficulties.

TEST LEADS

Because of their constant flexing during use, the test leads should never be above suspicion when difficulties occur. Broken test leads not only cause the meter to stop functioning or respond in an erratic manner, but are potentially dangerous. If there is ever any doubt, it is best to obtain new test lead wires.

BATTERY CHAMBERS

Periodic inspection of the battery chambers inside the case may help you avoid a difficult clean-up problem because of leaking batteries. After carefully removing the battery contact clips, the battery chambers may be cleaned with a damp cloth. Avoid getting any other areas of the case wet, and allow the chambers to thoroughly dry before replacing the batteries. The contact clips should be free of oxidation and tarnish. A few strokes with a fine grade of sandpaper will usually restore the clips.

ELECTROSTATIC CHARGE

The clear plastic meter window has been treated to resist the accumulation of a static charge. However, should a static charge accumulate through repeated rubbing of the meter window, the pointer will deflect in an erratic manner on all range settings. This condition can be easily corrected by applying a small quantity of liquid dishwashing detergent to a soft cloth and wiping the surface of the meter window. DO NOT remove the meter window for this operation.

METER MOVEMENT

Because of the delicate nature of the meter movement, you should never attempt to repair the meter. Any such attempt will automatically void the standard warranty coverage of the Meter.

METER COIL

If you suspect that the meter coil has failed, you can check the continuity of the coil with another ohmmeter as follows: Never check the continuity of the meter coil directly with another ohmmeter. The amount of current that would be drawn would seriously overload and probably ruin the coil. Always use a limiting resistor having a value of at least 50,000 Ω in series with the other ohmmeter's test lead. The actual value of the resistor will depend upon the other ohmmeter's battery voltage and the setting of its range switch.

FUSE

The fuse may be replaced with a new one ordered from the Heath Company (see the "Parts List"), or with any 2-ampere, 8AG, instrument type fuse.

METER WINDOW REPLACEMENT

In the event that the meter window should ever be cracked or broken, it may be replaced as follows:

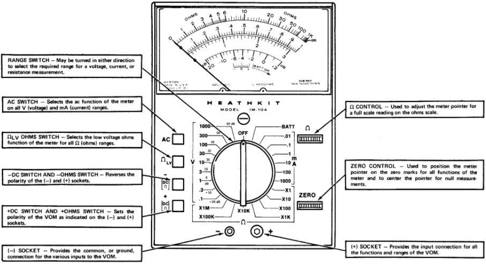


Figure 5

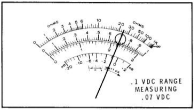


Figure 6

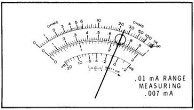


Figure 7

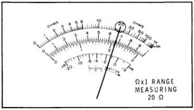


Figure 8

NOTE: Since the mechanism of the meter is delicate and sensitive to the environment, the following steps should only be performed in a dust-free room and on a firm table.

( ) Insert the flat of a small screwdriver through the opening for the ZERO thumbwheel and lift the faceplate up. Continue to lift until the faceplate snaps out. Then set the faceplate aside with its face down.

( ) Remove the two screws which hold the window in place.

( ) Carefully lift the bottom of the old window up and off of the case. Do not contact the pointer in any way.

( ) Examine the inside of the old window and observe the position of the small crank attached to the meter zero adjustment screw.

( ) Turn the zero adjustment screw to adjust the position of the crank in your new window. The position of the new crank must exactly match the position of the old crank.

( ) Insert the top edge of the new window into the case. Be sure that the rectangular areas on the top edge of the window seat into the openings inside the edge of the case. Carefully ease the window down while observing that the crank stays in alignment with its corresponding slot, and that the pointer stays in between the two ceramic stops attached to the window. Then, if everything appears to be in order, press the window into position.

( ) Use a screwdriver to turn the ZERO ADJUST screw. Be sure that the indicator can be adjusted above and below the zero mark. Then adjust the pointer directly over the zero mark.

( ) Replace the window retaining screws, but do not overtighten them.

( ) Lay the faceplate in position on the front of the case with its top edge inserted into the slot in the bottom edge of the meter window. Then, starting at the top of the RANGE switch cutout, firmly press the faceplate into position all the way around the switch. Finally, press in on the corners to be sure the faceplate is seated in position.

CASE AND METER REPLACEMENT

In the event the meter mechanism is damaged due to mechanical impact or severe electrical overload, the entire case and meter assembly must be replaced. The following procedure should be followed to replace the case and meter assembly.

NOTE: Because of the delicate nature of the meter movement, you should never attempt to repair the meter. Any such attempt will automatically void the standard warranty coverage of the meter.

( ) Turn the RANGE switch to the OFF position.

( ) Remove the thumbnut and rear panel.

( ) Remove the faceplate. Insert the flat of a small screwdriver through the opening for the ZERO thumbwheel and lift the faceplate up. Continue to lift until the faceplate snaps out. Then set the faceplate aside with its face down.

( ) Use the tool end of the thumbnut to remove the + and – sockets.

( ) Remove the two 6-32 x 3/8" screws.

( ) Remove the batteries.

( ) Carefully disengage the battery clips at each end of all three battery chambers.

NOTE: You can try to remove the battery cushions and the battery polarity labels for use in your new case. However, due to aging, these items are often difficult to remove without tearing. If necessary, refer to the "Parts List" and order replacements.

( ) Remove the calibrating resistors from below the center battery compartment if they have been stored there.

( ) Remove the handle.

( ) Remove the two hexagon-head screws that hold the circuit boards to the case.

( ) Place one hand over the back of the case to catch the circuit boards as you shake them from the case with the other hand.

( ) Remove the shaft from the RANGE switch. (This shaft may have come out with the circuit boards.)

( ) Carefully examine and memorize the fit of the RANGE switch on the inside of the case. Notice the thin white edge of the back of the knob is flush with the inside of the case.

CAUTION: Perform the next step on top of a large table since several small parts may be released and lost if care is not taken.

( ) Position the case face down on a table. Prop up one side of the case with your fingers. Then press on the RANGE switch knob from inside the case until it snaps out of its opening.

( ) STOP IMMEDIATELY and locate the two detent rollers and two detent springs (shown in Figure 10). Look on the rear of the knob and on the front of the case. If all four parts (two rollers and two flat springs) are not found, you will be unable to continue with the case replacement.

( ) Take the new case and meter assembly and place it face up on the table.

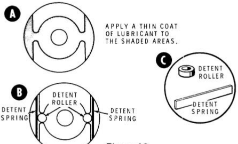


Figure 10

( ) Refer to Figure 10 and apply a thin coat of lubricant (Lubriplate or Vaseline) into the umbrella-shaped areas on both sides of the RANGE switch knob depression. Use a match or toothpick to apply the lubricant. Do not use a cotton-tipped swab, as the fibers that come loose may cause the detent mechanism to bind.

( ) Also apply a thin coat of lubricant on the inside edge of the hole and on the inside edge of the side walls of the RANGE switch knob depression. Wipe off any excess lubricant that may be on the front of the case.

( ) Carefully clean and relubricate the two springs and two rollers removed from the old assembly.

( ) Refer to Figure 10 and place the two springs and then the two rollers as shown.

( ) Position the knob and, with a steady downward pressure, rotate it until you feel both detent rollers move back against the springs and allow the knob to seat. Still holding the knob firmly, turn the case over and determine that the edge of the knob is as flush with the inside of the case as before. If not, continue to press and rotate the knob until it is.

( ) Rotate the knob one complete turn to insure that it detents properly.

( ) Turn the RANGE switch to the OFF or vertical reference position.

( ) If necessary, install the shaft into the face of the RANGE switch knob. Be sure to hold the knob against the case to prevent it from being pushed out.

( ) Install the circuit boards. Be sure that the battery clip wires do not interfere with any of the controls or prevent access for the hex head screws. If necessary, rotate the RANGE switch knob slightly until its shaft goes through the rotor wafers on both circuit boards.

( ) Install the two hexagon-head screws.

( ) Install the battery cushions in the battery chambers.

( ) Install the battery polarity labels.

( ) Install the battery clips.

( ) Install the handle.

( ) Install the calibrating resistors below the center compartment if they were stored there before.

( ) Use the tool end of the thumbnut and install the + and – sockets.

( ) Install the two 6-32 x 3/8" screws.

( ) Install the rear panel and thumbnut.

NOTE: Your meter circuits should be recalibrated for optimum performance with the new meter movement. If calibration is to be performed at this time, proceed to the "Calibration" section on Page 40. If calibration is to be performed later, proceed with the following step.

( ) Lay the faceplate in position on the front of the case with its top edge inserted into the slot in the bottom edge of the meter window. Then, starting at the top of the RANGE switch cutout, firmly press the faceplate into position all the way around the switch. Finally, press in on the corners to be sure the faceplate is seated in position.

IN CASE OF DIFFICULTY

This section of the Manual is divided into two parts. The first part, titled "General Troubleshooting Information," describes what to do about the difficulties that may occur right after your Meter is assembled.

The second part, titled "Troubleshooting Chart," is provided to assist you in servicing the Meter if the "General Troubleshooting Information" fails to clear up the problem, or if difficulties occur after your VOM has been in use for some time. The "Troubleshooting Chart" lists a number of possible difficulties that could arise along with several possible solutions to those difficulties.

Before starting any troubleshooting procedure, try to narrow the problem down to a specific area by trying the various functions of your meter. Unless you know that a specific function or position is inoperative or inaccurate, test the meter functions in the following order:

1. BATT position.
2. DC Voltage.
3. AC Voltage.
4. DC Current.
5. AC Current.
6. Resistance (Low Test Voltage, ΩLV).
7. Resistance (High Test Voltage: +DCΩ, −DCΩ).

GENERAL TROUBLESHOOTING INFORMATION

The following paragraphs deal with the types of difficulties that may show up right after your kit is assembled. These difficulties are most likely the result of assembly errors or faulty soldering. These checks will help you locate any error of this type that might have been made.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

1. Recheck the wiring. 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 builder.

2. 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 soldering section of the "Kit Builders Guide."

3. Check the values of the parts. Be sure that the proper part has been wired into the circuit, as shown in the Pictorials and as called out in the step-by-step instructions. Pay special attention to resistor and capacitor values; parts with similar values are easily interchanged.

4. Check for bits of solder, wire ends or other foreign matter which may be lodged in the wiring or between parts.

5. Check for solder bridges between circuit board foils.

6. Check the batteries. Be sure that they are fresh and making good electrical contact with the battery clips.

7. There is a chance that a resistor may have been damaged during soldering. If another ohmmeter is available, check each individual resistor. Each resistor should read very close to its marked value. These checks can be aided by consulting the "Circuit Board X-Ray Views" section of the Manual on Page 71. Be sure to remove one of the hexagon-head screws before making any resistance checks. The circuit board assembly will have to be removed from the case to make measurements on the front circuit board.

8. A review of the "Circuit Description" section on Page 65 and a study of the Schematic (fold-out from Page 73) may also help you locate a difficulty in your VOM.

Troubleshooting Chart

SYMPTOM	POSSIBLE CAUSE
Inoperative on all ranges.	1. Test lead open. 2. Fuse blown. 3. Hex head screws not tight. 4. AA batteries E2 and E3 dead. 5. Defective solder joint at fuseholder. 6. Spring out of fuseholder. 7. Shorting clip not removed from between meter posts. 8. Switch S1, S2, S3, or S6. 9. Transistors Q1 and Q2 shorted. 10. Transistor Q3 or IC1. 11. Diodes D3, D4, or D5 shorted. 12. Capacitors C33, C37, or C40 shorted. 13. Resistors R31 or R33 open. 14. Meter coil open. 15. Defective connection at B1, B2, B3, A1, A6, or A2. 16. Defective connection at Molex connector C or E. 17. Defective connection at Molex connectors F and G. 18. Open wire to AA batteries E2 and E3.
Inoperative on BATT position.	1. AA batteries E2 and E3 dead. 2. Resistors R32 or R34. 3. Switch S3. 4. Defective connections at points F or G on rear circuit board (pin connectors not soldered to foil). 5. Hex head screws not tight on rear circuit board.
Inoperative on DC voltage ranges only.	1. Defective connection at B7, B6. 2. Capacitor C31 shorted. 3. Switches S2 or S6.
Inoperative on AC voltage ranges only.	1. Capacitor C18 open. 2. Diode D7 open.
Inoperative on mA ranges only.	1. Switch S1. 2. Diode D2 shorted.

SYMPTOM	POSSIBLE CAUSE
Inoperative on Ohms ranges only.	1. D battery E1 weak or dead. 2. D battery E1 making poor contact. 3. Open wire to D battery E1. 4. Defective connection at A5 or B5. 5. Resistor R41. 6. Capacitor C32, C34, or C35 shorted. 7. Switch S1, S4, or S6.
Inaccurate dc voltage readings.	1. Check resistors R17 through R24 for wrong value. 2. Check capacitors C11 through C17 for shorted capacitor. 3. Capacitor C1, C31, C33, C36,or C37 leaky. 4. Transistor Q1 or Q2 leaky. 5. "0.1 CAL" or "0.3 CAL" misadjusted. 6. Switch S1, S5, or S6. 7. Resistor R2, R4, R35, R43, R44, or R45.
Inaccurate ac voltage readings.	1. Check capacitors C11 through C17 for open capacitor. 2. "AC CAL" or "FREQ COMP" misadjusted. 3. Switch S1, S4, or S6. 4. Diode D4, D6, or D7. 5. Resistor R5, R6, or R7. 6. Transistor Q3 or IC1. 7. AA battery E2 or AA battery E3 weak.
Inaccurate mA readings.	1. Check resistors R11 through R16 for wrong value. 2. Diode D1 or D2 leaky. 3. Switch S1.
Inaccurate ohms readings.	1. D battery E1 or AA battery E2 weak. 2. Capacitor C31 leaky. 3. Diode D1 or D2 leaky. 4. Capacitor C32, C34, or C35 leaky. 5. Resistor R41, R42, R25, or R35. 6. Transistor Q3 or IC1. 7. Capacitor C33.
Inaccurate ohms readings on X1 range only.	1. D battery E1 weak. 2. Resistor R24. NOTE: It is normal for the meter to indicate about 0.4 Ω on this scale due to the resistance of the test leads and the internal resistance of the VOM. If the meter reads more than 0.4 Ω (with the leads shorted, after being carefully adjusted at zero and ∞ on a higher range), the test leads may be defective. Also see the note on Page 49.
Ohmmeter cannot be adjusted to "∞" mark.	1. D battery E1 or AA battery E3 weak. 2. Resistor R41, R42, R25, or R35. 3. Capacitors C32, C34, or C35 leaky. 4. Diode D1 or D2.

SPECIFICATIONS

(calibrated to precision standards)

DC VOLTMETER

Nine Ranges	0–.1, .3, 1, 3, 10, 30, 100, 300, and 1000 volts full-scale.
Input Resistance	10 MΩ.
Accuracy	±2% of full-scale (meter in horizontal position).
AC Rejection	Accuracy not affected by impressed 60 Hz sine wave that has rms value two times greater than full-scale value.
Null Indicator	On 0.1, 1, 10, 100, 1000 volt ranges, meter zero level may be adjusted to center of null reference scale. Null variations of approximately 1% of full-scale can be resolved.

AC VOLTMETER

Nine Ranges	0–.1, .3, 1, 3, 10, 30, 100, 300, and 1000 volts full-scale.
Range Factor	1 to 3.162 (10 dB) per step.
Input Resistance	10 MΩ.
Input Capacity	100 pF typical.
Accuracy	±3% of full-scale. (Meter in horizontal position; 60 Hz sine wave.)
Response	Responds to the average value of 1/2 of a sine wave. Scale calibrated to indicate rms.

Frequency Response

Range	Error	Frequency
0.1 to 30	±3%	20 Hz to 20 kHz.
	±5%	20 Hz to 50 kHz.
100, 300	±3%	20 Hz to 10 kHz.
	±5%	20 Hz to 20 kHz.
1000	±3%	20 Hz to 1.0 kHz.
	±5%	20 Hz to 2.5 kHz.

DC MILLIAMMETER

Six Ranges	0–.01, .1, 1, 10, 100, 1000 milliamperes full-scale.
Voltage Drop (Approximate at full-scale)	0.100 volt (0.01 to 10 ranges). 0.150 volt (100 range). 0.350 volt (1000 range).

Insertion Resistance	Voltage drop divided by full-scale current.
Accuracy	±2% on 0.01 to 100 ranges. ±3% on 1000 range. (Meter in horizontal position.)

AC MILLIAMMETER

Six Ranges	0-0.01, .1, 1, 10, 100, 1000 milliamperes full-scale.
Voltage Drop (approximate at full-scale)	0.100 volt (0.01 to 10 ranges). 0.150 volt (100 range). 0.350 volt (1000 range).
Insertion Resistance	Voltage drop divided by full-scale current.
Accuracy	±3% on 0.01 to 100 ranges. ±4% 1000 range. (Meter in horizontal position; 60 Hz sine wave.)
Response	Responds to the average value of 1/2 of a sine wave (DC current must be negligible). Scale-calibrated to indicate rms.

Frequency Response

Range	Error	Frequency
0.01	±3%	20 Hz to 5 kHz.
0.1	±3%	20 Hz to 20 kHz.
1 to 1000	±3%	20 Hz to 50 kHz.

OHMMETER

Seven Ranges	RX1 (10 Ω center scale), RX10, RX100, RX1K, RX10K, RX100K, RX1M.
Accuracy	±3 degrees of arc on Ω x 1 range (above 2 Ω.) ±2 degrees of arc on Ω x 10 to Ω x 1M ranges. (Meter in horizontal position.)
Test Voltage (nominal)	1.55 volts on +DC/Ω and −DC/Ω ranges. 0.085 volts on Ω_{LV} range.

dB RANGES

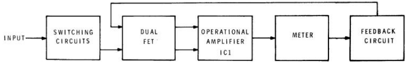
Nine Ranges (0 dB = 1 mW into 600 Ω)	−40 to −18 (0.1 range). −30 to −8 (0.3 range). −20 to +2 (1 range). −10 to +12 (3 range). 0 to +22 (10 range). +10 to +32 (30 range). +20 to +42 (100 range). +30 to +52 (300 range). +40 to +62 (1000 range).
Accuracy	±3 dB at −20 dB to ±0.3 dB at +2 dB.

GENERAL

Voltage Dividers	1% precision metal-film resistors.
Meter	4-1/2", 100 μA, 95 degree, ruggedized, taut-band movement.
Meter Protection	Will sustain a momentary overload of 220 volts AC or DC applied to any range. 2-ampere, quick-blow input fuse caused to open with overload on Ω x 1 range to Ω x 1 k range, and 0.01 to 1000 mA ranges by input clamping diodes. FET protected on 0.1 volt to 1000 volt ranges and Ω x 10 k to Ω x 1 M ranges by clamping transistors. Internal circuitry protected against improper battery installation. Meter movement protected by internal reverse-parallel bypass diodes.
Amplifier Circuit	Dual FET source followers driving operational amplifier.
Front Panel Switches	24-position, continuous-rotation RANGE switch [including battery check position BATT and OFF]. 4-position pushbutton switch: AC, Ω_{LV}, −DC/Ω, +DC/Ω.
Meter Temperature Coefficient	Maximum of ±0.2% or ±0.2 degrees of arc (whichever applies) per degree C over a range of 15 to 35 degrees C.
Operating Temperature	0 to 50 degrees C.
Storage Temperature (less batteries)	−40 to +80 degrees C.
Batteries Required	1-1.5 volt, D-cell (NEDA #13). 4-1.5 volt, AA-cell (NEDA #15).
Dimensions	4.95" wide x 6.95" high x 2.25" deep.
Weight	3 pounds (approximately), including batteries.

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.

THEORY OF OPERATION



Block Diagram
Figure 11

The principle sections of the VOM are shown in the Block Diagram of Figure 11. The input (voltage, current, or resistance) to be measured is applied to the switching and sensing circuits which provide a voltage to one of the dual FET (field effect transistor) transistors. This voltage is then coupled to one of the op-amp (operational amplifier) inputs. The output voltage of the op-amp drives the meter and the feedback circuit. A portion of this output voltage is returned to the other FET transistor and goes to the other input of the op-amp. Here it is compared to the original voltage from the switching circuits. Following is a brief discussion of this voltage comparison.

Part A of Figure 12 shows a differential op-amp. +V and −V are the battery supply voltages which power the FET transistors and the op-amp. The "+" on IC1 represents the "non-inverting" input and the "−," an "inverting" input. That is, if the "−" input is held constant and the "+" input is changed, the output will change in the same direction as the "+" input. However, if the "+" input is held constant and the "−" input is changed, the output will change in the opposite direction to the "−" input. The output of the op-amp changes when there is a voltage difference between the inputs. The amplification, "differential gain," of the op-amp is very large (100,000, for example) so that a small voltage difference between the op-amp inputs will immediately force the op-amp output to its maximum.

The manner in which this very large gain is used in the VOM is illustrated in Figure 12, Part B. Assume resistor network RF and resistor R are such that exactly 1/10 of the output voltage of the op-amp is returned to the "−" input. A voltage applied to the "+" input causes the output to change in the same direction as the "+" input while the voltage fed back to the "−" input will be 1/10 of the output. When this feedback voltage exactly equals the "+" input voltage, the output of the op-amp will stabilize at exactly 10 times the "+" input voltage. This entire circuit then is a "non-inverting" amplifier with a fixed gain of 10. The gain can be changed by varying R or RF. The advantages of this circuit are: the fixed gain of the circuit is constant over a wide input voltage range, the gain is constant over wide frequency variations, and the circuit is relatively immune to variations in supply voltage and temperature.

As shown in Figure 12, part C, the performance of the op-amp is further improved by isolating the op-amp with the two FET transistors, Q3A and Q3B. These transistors have a high input impedance (greater than 10,000 MΩ) and a low output impedance. Their low output impedance provides a stable driving point for the op-amp and their high input impedance prevents loading of the high impedance AC/DC input voltage divider in the VOM.

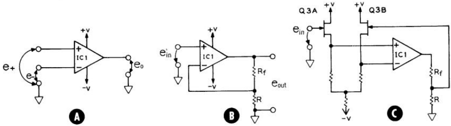
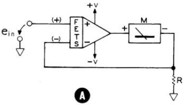


Figure 12



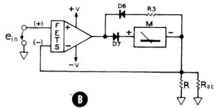


Figure 13

Part A of Figure 13 is a simplified version of Figure 12, part C, with a current meter now placed in the output circuit of the op-amp. Since the voltage across R always equals the input voltage, the current through R and M (meter movement) will be exactly proportional to the input voltage. This circuit is a "voltage-to-current converter." For a given input voltage level (0.1 volts, for example), R is adjusted until the meter deflects to full scale. The meter scale is calibrated linearly from 0 volts to a full-scale of 0.1 volts.

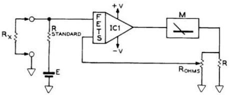


Figure 14

To measure AC inputs, the rectifier circuitry and R_{AC} are added as shown in Figure 13, part B. During the positive portions of the AC input cycles, the op-amp output current will flow through diode D7 and meter movement M to R and R_{AC}. During negative portions of the input cycles, current will flow through D6, R3, R, and R_{AC}. Thus, the meter indicates the average value of the positive portions for the AC input. (Since the meter deflects less than it would for an equivalent DC input, resistor R_{AC} is added to increase the fixed gain of this circuit. This allows AC and DC input voltages to be indicated on the same meter scale.) The meter is calibrated to indicate the rms value of the AC input.

Figure 14 shows the basic circuitry of the VOM for resistance measurements. Internal voltage source E is connected through a precision resistor (R standard) to the input. The voltage at the input is measured by the op-amp circuitry.

R_{ohms} adjusts the feedback voltage to produce exactly a full scale deflection when R_X is an infinite resistance "∞" (open circuit). If R_X is reduced to zero, the meter will then indicate zero, or no deflection. For any value of R_X between zero and ∞, the meter will deflect by an amount proportional to the ohmic value of the resistance, R_X, being measured. The meter scale is calibrated in ohms using the proportion between R_X and R-standard.

CIRCUIT DESCRIPTION

Refer to the Schematic Diagram (fold-out from Page 73) while you read this "Circuit Description." Also read the "Theory of Operation" on Page 63, for an overall description of the circuits and how op-amp (operational amplifier) IC1 is used.

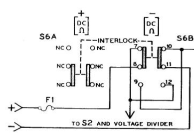


Figure 15

INPUT SWITCHING

An input (voltage, current, or resistance) to the VOM is connected through the switching circuit shown in Figure 15.

If a positive DC voltage is being measured (S6A depressed), the voltage at the "+" input is connected through fuse F1 and one side of switch S6B to S2 and the voltage divider. The ground connection of the voltage being measured is through the other side of switch S6B to the meter common ground.

When a negative DC voltage is measured (S6B depressed), the voltage at the "–" input is connected through switch S6B to S2 and the voltage divider. The ground connection for the input voltage is through fuse F1 to S6B and to the Meter common ground. This meter function is electrically the same as reversing the test lead connections. In measuring DC current the current through S6B to S2 is selected to always flow in the same direction (resulting in a positive voltage to S2). When it is used with the higher resistance test voltage, this +DC/–DC switching allows a quick comparison of forward and reverse conductance of semi-conductor junctions without reversing the test leads.

Input switching on the lower resistance test voltage range is not required since the conductance of semi-conductors in either direction is negligible at the 0.085 volts resistance testing level. It is not required when measuring AC voltage or current except as explained in "AC Voltage Measuring" on Page 66.

DC VOLTAGE MEASURING

The circuit of Figure 16 is used when you make DC voltage measurements. The capacitors shown in dashed lines are connected as shown but have no effect during DC voltage measuring. The input DC voltage is connected through the input switching circuit to R17, R18, and S1 as shown. The Range switch S1, is shown in the 1.0 volt position. With an input of exactly 1.0 volts, the voltage division of R17 through R24 produces exactly 0.1 volts at the junction of R18 and R19. This voltage is connected through S1 and R33 to Q3A. The operation of Q3A, Q3B, IC1 and M are as explained in the "Theory of Operation" section. Transistors Q1 and Q2 are connected as "clamping" diodes to protect Q3A against excessive positive or negative input voltages. R33 limits the current through Q1 and Q2 if the input voltage is excessive. C31 acts with R33 as a "low pass" filter to filter out AC voltages which may accompany the DC voltage.

The current through Meter M generates a voltage across the resistor network of R2, R4, R35, R43, R44, and R45. Exactly 0.1 volts of this voltage from the slider of calibration control R44 is fed back through position A of S5 to Q3B to balance the op-amp inputs. If switch S1 is now switched to the 3.0 volt position, the input voltage to Q3A is still 0.1 volt as before. However, switch S5 now connects the voltage at position B to Q3B. This increased feedback causes the meter reading to drop since less current is required to produce the 0.1 volt input to Q3B.

Diodes D3 and D4 protect the Meter from excessive voltage. Resistor R46 provides DC stabilization for op-amp IC1 when the differential gain of IC1 is very high.

Resistors R36 through R40 balance the inputs to IC1 to zero the meter and also allow the meter pointer to be positioned at midscale for null measurements.

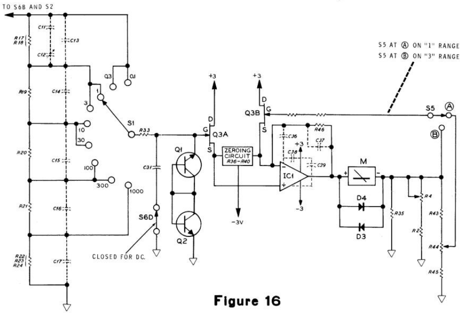

TO S6B AND S2
S5 AT Ⓐ ON "1" RANGE
S5 AT Ⓑ ON "3" RANGE
ZEROING CIRCUIT R36-R40
CLOSED FOR DC.
Q3A
Q3B
IC1
S1
S5
S6D
Q1
Q2
M
D4
D3
-3V

Figure 16

AC VOLTAGE MEASURING

The circuit of Figure 17 (fold-out from this page) is used when you measure AC voltages. C18 is now inserted between S6B and the voltage divider to block any DC portion of the input voltage and C11 through C17 become a part of the voltage divider circuit. C31 is disconnected from the circuit to prevent filtering of the AC voltage. The meter is connected into the rectifier circuit of D6, D7, and R3. R5 and R6 are added across the total feedback circuit (R2, R4, R5, R6, R35, R43, R44, and R45).

Operation of the AC circuit is similar to that for DC as follows: The input AC voltage, after passing through C18, is applied to the voltage divider circuit. At low frequencies, capacitors C11 through C17 have little effect and the voltage to R33 and Q3A is primarily determined by the resistor divider network, R17 through R24. As the input frequency increases, the impedance of the capacitors connected across the resistors decreases. Since the ratio (10:1) of the capacitors is identical to the resistor ratio, the voltage applied to R33 and Q3A remains essentially constant as the frequency changes. Thus, the voltage divider circuit is "frequency compensated." This compensation is required to cancel out any variations in the stray capacitance across each resistor in the circuit. Because of the high value of R17 and R18, the compensation across these is made variable (C12) to allow a fine adjustment for the higher frequencies.

The AC current from the output of IC1 flows alternately through D6, Meter M, D7, R3, and then to the resistor network of R2, R4, R5, R6, R35, R43, R44, and R45. Since the current through the Meter will be lower for AC voltages than for DC voltages, R5 and R6 are added to decrease the amount of feedback to Q3B. This increases the gain of the op-amp circuit. Capacitor C36 extends the amplifier bandwidth and capacitors C37, C38, and C39 provide stability at higher frequencies.

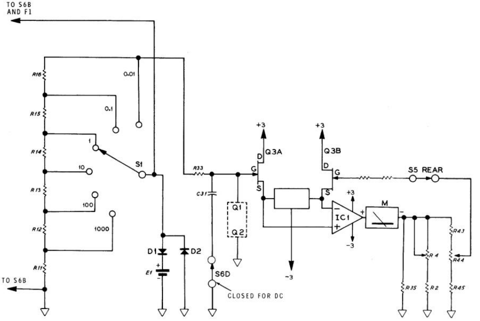


Figure 18

DC CURRENT MEASURING

Refer to Figure 18. For DC current measuring, the current to be measured flows through fuse F1, switches S6B and S1, the selected sensing resistors (in this case, R11 through R14), and then back to the circuit under test through switch S6B. This current flow generates a voltage (across the sensing resistors) directly proportional to the DC current. This voltage is applied to Q3A through the circuit of R15, R16, S2, and R33. The output current of IC1 generates a voltage across the resistance circuit of R2, R4, R35, R43, R44, and R45. This voltage is applied to Q3B through S5 rear.

Switch S6D connects C31 into the circuit, as before, to filter out any AC voltage portion of the current being measured.

Diodes D1, D2, and battery E1 form a protection circuit for the precision sensing resistors in case an over-current is applied. If the voltage at S1 becomes more positive than +2.1 volts or more negative than –0.6 volt, either D1 or D2 will be heavily forward-biased. The current through fuse F1 will increase greatly and cause F1 to open and disconnect the VOM from the test voltage. Voltage clamping transistors Q1 and Q2, although in the circuit, do not reach their clamping level.

AC CURRENT MEASURING

The AC current measuring circuit is shown in Figure 19. The current to be measured flows through the sensing resistors in the same manner as for DC current. The sensing voltage, which is proportional to the AC current, is coupled through R15 and R16 (for the example shown) to R33 and Q3A. The current path through C31 is open, as for AC voltage, to prevent filtering of the signal. The Meter, as shown, is connected into a circuit made up of D6, D7, and R3 with R5 and R6 added to increase the amplifier gain. The feedback signal to balance the op-amp circuit is coupled through S5 rear the same as for DC current.

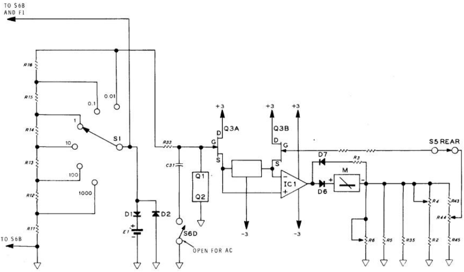


Figure 19

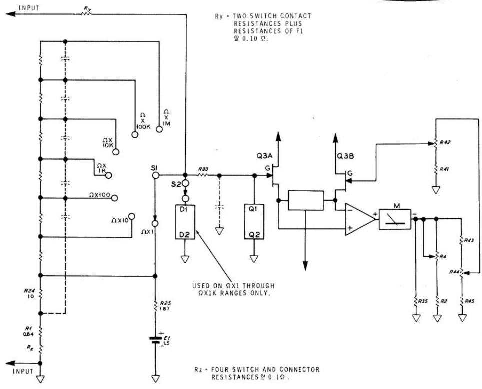


Figure 20

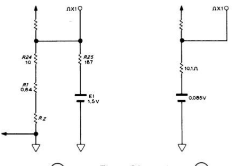


Figure 21

RESISTANCE MEASURING

Low Test Voltage Circuit (Ω_{LV})

Figure 20 is a simplified schematic of the low test voltage ohmmeter circuit. The network of E1, Rz, R1, R24, and R25, as shown in Part A of Figure 21, provides a low test voltage of 0.085 volts, as shown in Part B of Figure 21. It has an equivalent source resistance of 10.1 Ω as shown.

The 0.1 Ω portion of the 10.1 Ω effectively cancels out the effect of Ry at midscale. The ohmmeter circuit functions in the same manner as described in the "Theory of Operation" section. If there is an open circuit between the Meter inputs, the 0.085 volts at the junction of R24, R25 will be coupled through S1 and R33 to Q3A. The output current through the meter generates a voltage across the resistance network of R2, R4, R35, R41, R42, R43, R44, R45. The Ω control on the front panel, R42, is used to adjust the feedback to Q3B until the meter is deflected to full scale (the ∞ mark). When some resistance is connected between the meter inputs, the voltage at the junction of R24 and R25 is reduced. This lower voltage results in less deflection of the meter. The scale, being calibrated in ohms, relates the lower deflection to the resistance value connected between the inputs. As switch S1 is moved to high positions (such as Ω x 10 and Ω x 100), the resistance between the junction of R24 and R25, and S1 is increased. Each of these total resistances, formed by R17 through R24, is a multiple of 10 Ω (100 Ω, 1000 Ω) and produces the higher ohms ranges of the Meter. As shown in Figure 20, D1 and D2 protect the lower ohms ranges if the Meter should be connected to a test circuit with the power turned on. Similarly, Q1 and Q2 protect the gate of Q3A on the higher ohms ranges.

High Test Voltage Circuit

The high test voltage ohmmeter circuit is shown in Figure 22. This circuit is identical to the low test voltage circuit except: RZ, R1, and R25 have been removed and E1 is directly connected through R24 to S1; the 0.1 Ω internal resistance of the battery cancels the effect of RY; an open circuit at the meter inputs allows the full 1.5 volts of E1 to be applied to Q3A; and the network of R2, R4, R43, R44, and R45 at the op-amp output is disconnected to decrease the gain of the op-amp circuit. Operation of the ohmmeter, D1, D2, Q1, and Q2 is the same as for the low test voltage circuit.

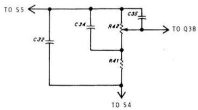


Figure 23

OHMMETER CONTROL BYPASSING

The three capacitors, C32, C34, and C35, shown in Figure 23 provide ac bypassing around resistors R41 and R42. Otherwise, because of connections in the op-amp output circuit and the close proximity of parts, circuit oscillation could result.

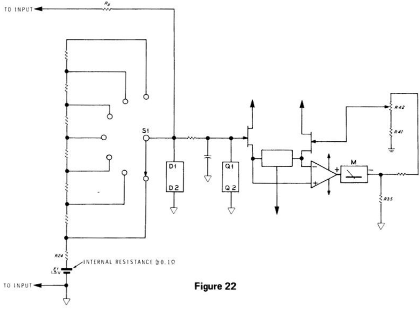


Figure 22

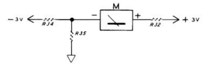


Figure 24

BATTERY TEST CIRCUIT

When the RANGE switch is turned to the BATT position meter M is connected into the circuit as shown in Figure 24.

Resistor R35 is shown but may be considered an open circuit; little current flows through it. The total meter current is about 80 μA, which corresponds to approximately the middle of the BATT OK area on the meter scale.

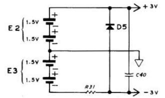


Figure 25

BATTERY REVERSE-POLARITY PROTECTION

The power sources for Q3A, Q3B, and IC1 are shown in Figure 25.

The op-amp is protected if the batteries should ever be installed backwards. As shown, diode D5 is normally reverse-biased and will not conduct. The meter circuit current under normal conditions is quite small, and little voltage is lost across resistor R31. If one or two batteries are installed backwards, the meter circuit will not work properly, but no damage will result. However, if three or all four batteries are installed backwards, damage to the circuit might result. However, diode D5 is then forward biased and will short out this improper voltage. R31 will limit the current through D5 to a safe value. If this condition is allowed to exist for some time, the battery voltage will be depleted. C40 provides a high frequency bypass to the positive and negative 3-volt supplies.

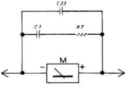


Figure 26

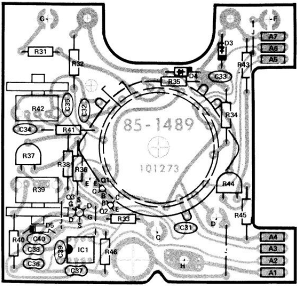
METER COMPENSATION

For AC signals, the meter movement inductance can have a slight effect on the meter feedback circuit impedance. Figure 26 shows C1 and R7 placed across the meter which, theoretically, makes the circuit equivalent to a pure resistance. Capacitor C33 acts as a high frequency bypass for very fast rise-time signals and prevents circuit oscillation due to the close proximity of parts to IC1.

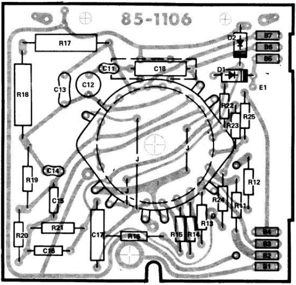
CIRCUIT BOARD X-RAY VIEWS

NOTE: To determine the value (20 kΩ, .02 μF, etc.) of one of these parts, you may proceed in either of the following ways.

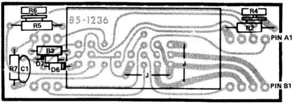
1. Refer to the place where the part is installed in the Step-by-Step instructions.
2. Note the identification number of the part (R-number, C-number, etc.). Then locate the same identification number, next to the part on the Schematic. The value, or "description" of the part will be near this number.



FRONT CIRCUIT BOARD
(Viewed from foil side)

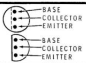
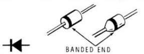
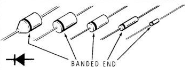
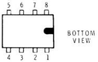


REAR CIRCUIT BOARD
(Viewed from foil side)



SWITCH CIRCUIT BOARD
(Viewed from foil side)

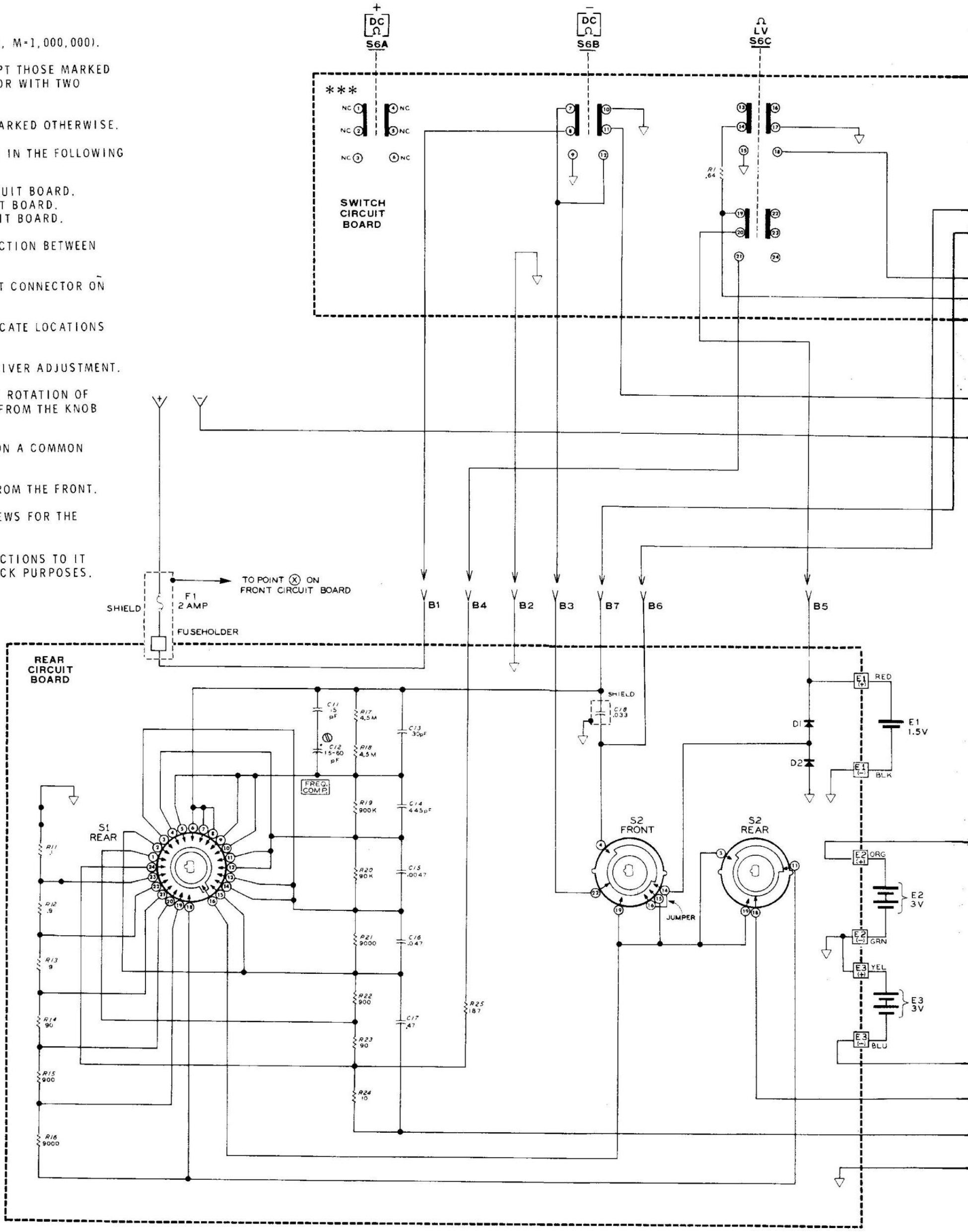
Diode and Transistor Reference Chart

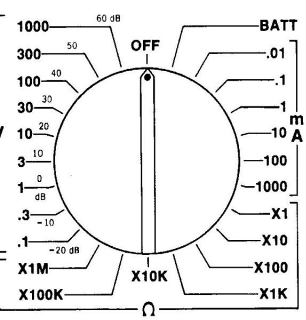
COMPONENT	HEATH PART NUMBER	FUNCTION OF PART	MAY BE REPLACED WITH	BASE DIAGRAM (BOTTOM VIEW)
Q1, Q2	417-118	OVERLOAD PROTECTION	2N3393	
Q3A, Q3B	417-186	DUAL FET, SOURCE FOLLOWER	2N3958	
D1, D2	57-71	OVERLOAD PROTECTION	"SEMI-CON" S-5A05	
D3, D4	56-56	METER PROTECTION	IN4149	
D5	56-56	BATTERY POLARITY PROTECTION	IN4149	
D6, D7	56-89	METER RECTIFIER	GENERAL INSTRUMENT GD-510	
IC1	442-39	OPERATIONAL AMPLIFIER	NATIONAL LM301AN	

NOTES:

1. RESISTOR VALUES ARE IN OHMS (K=1,000, M=1,000,000).
2. ALL RESISTORS ARE 1% PRECISION EXCEPT THOSE MARKED WITH AN ASTERISK (*), WHICH ARE 5%, OR WITH TWO ASTERISKS (**), WHICH ARE 10%.
3. CAPACITOR VALUES ARE IN µF UNLESS MARKED OTHERWISE.
4. RESISTOR AND CAPACITOR NUMBERS ARE IN THE FOLLOWING GROUPS:

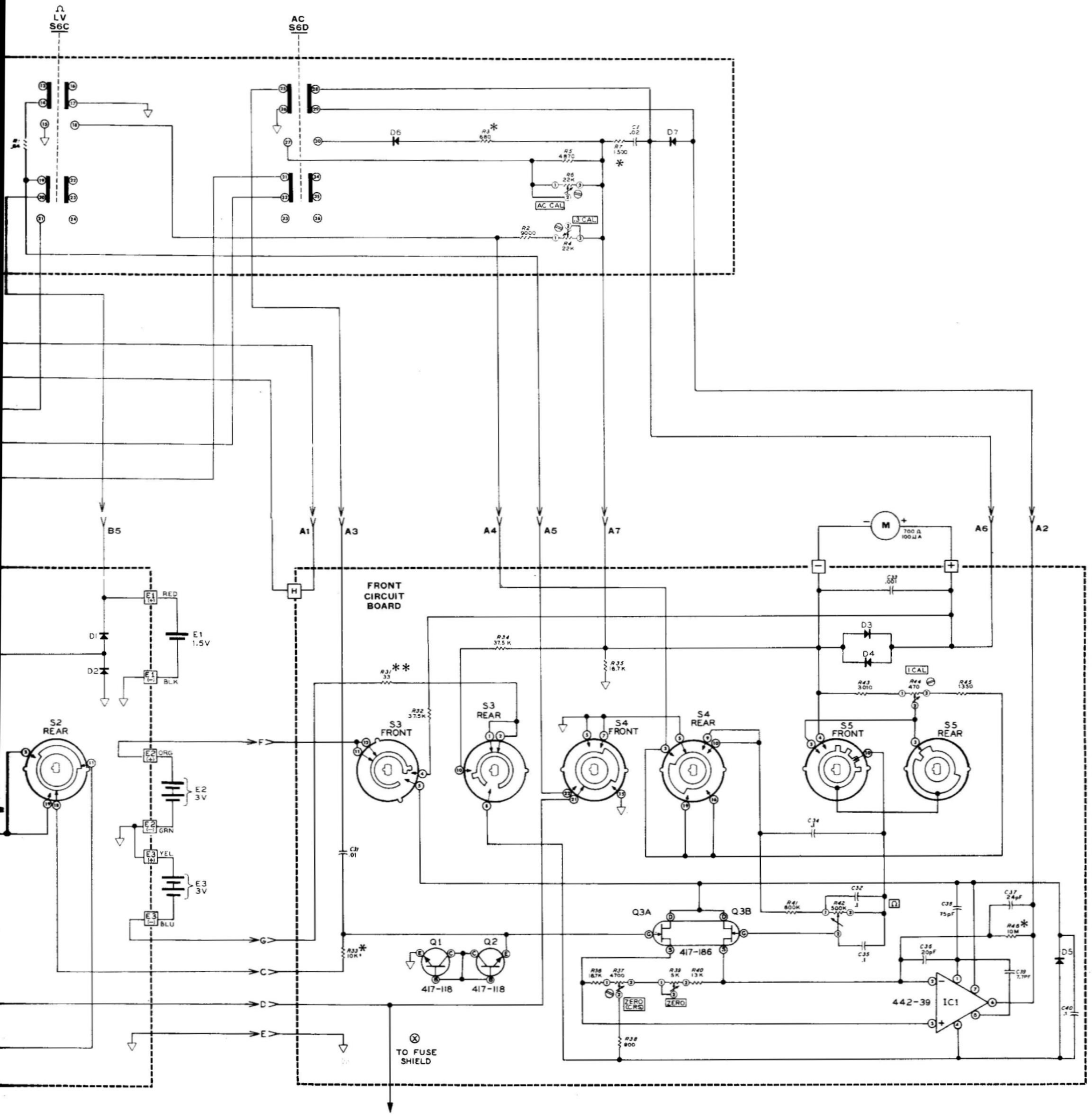
   1 - 10 PARTS ON THE SWITCH CIRCUIT BOARD.
   11 - 30 PARTS ON THE REAR CIRCUIT BOARD.
   31 - 50 PARTS ON THE FRONT CIRCUIT BOARD.
5. ➔➤ THIS SYMBOL INDICATES A CONNECTION BETWEEN CIRCUIT BOARDS.
6. ➤— THIS SYMBOL INDICATES A SOCKET CONNECTOR ON THE FRONT PANEL.
7. ☒ LETTERS OR SYMBOLS IN A BOX INDICATE LOCATIONS ON THE CIRCUIT BOARDS.
8. ⊖ THIS SYMBOL INDICATES A SCREWDRIVER ADJUSTMENT.
9. ← THIS SYMBOL INDICATES CLOCKWISE ROTATION OF CONTROLS OR ADJUSTMENTS AS VIEWED FROM THE KNOB END OF THE SHAFT.
10. SWITCHES S1 THROUGH S5 ARE GANGED ON A COMMON SHAFT.
11. ALL SWITCHES ARE SHOWN AS VIEWED FROM THE FRONT.
12. REFER TO THE CIRCUIT BOARD X-RAY VIEWS FOR THE PHYSICAL LOCATION OF PARTS.
13. *** THIS SWITCH HAS NO WIRING CONNECTIONS TO IT AND IS USED ONLY FOR SWITCH INTERLOCK PURPOSES.





RANGE SWITCH

SCHEMATIC OF THE HEATHKIT® SOLID-STATE VOM MODEL IM-104



LV
S6C
AC
S6D
D6
D7
AC CAL
LS CAL
B5
A1
A3
A4
A5
A7
A6
A2
M
700 Ω
100 µA
FRONT
CIRCUIT
BOARD
E1
1.5V
RED
BLK
D1
D2
D3
D4
S2
REAR
S3
FRONT
S3
REAR
S4
FRONT
S4
REAR
S5
FRONT
S5
REAR
I CAL
E2
3V
ORG
GRN
E3
3V
YEL
BLU
Q1
Q2
417-118
417-118
Q3A
Q3B
417-186
ZERO
ZERO (CRS)
442-39
IC1
D5
TO FUSE
SHIELD

HEATH
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