

HEATHKIT[®] MANUAL

for the

FET MULTIMETER

Model IM-5225

595-1934



HEATH COMPANY • BENTON HARBOR, MICHIGAN

HEATH COMPANY PHONE DIRECTORY

The following telephone numbers are direct lines to the departments listed:

Kit orders and delivery information (616) 982-3411
Credit (616) 982-3561
Replacement Parts (616) 982-3571

Technical Assistance Phone Numbers

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YOUR HEATHKIT 90-DAY LIMITED WARRANTY

Consumer Protection Plan for Heathkit Consumer Products

Welcome to the Heath family. We believe you will enjoy assembling your kit and will be pleased with its performance. Please read this Consumer Protection Plan carefully. It is a "LIMITED WARRANTY" as defined in the U.S. Consumer Product Warranty and Federal Trade Commission Improvement Act. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

Heath's Responsibility

PARTS — Replacements for factory defective parts will be supplied free for 90 days from date of purchase. Replacement parts are warranted for the remaining portion of the original warranty period. You can obtain warranty parts direct from Heath Company by writing or telephoning us at (616) 982-3571. And we will pay shipping charges to get those parts to you . . . anywhere in the world.

SERVICE LABOR — For a period of 90 days from the date of purchase, any malfunction caused by defective parts or error in design will be corrected at no charge to you. You must deliver the unit at your expense to the Heath factory, any Heathkit Electronic Center (units of Veritechnology Electronics Corporation), or any of our authorized overseas distributors.

TECHNICAL CONSULTATION — You will receive free consultation on any problem you might encounter in the assembly or use of your Heathkit product. Just drop us a line or give us a call. Sorry, we cannot accept collect calls.

NOT COVERED — The correction of assembly errors, adjustments, calibration, and damage due to misuse, abuse, or negligence are not covered by the warranty. Use of corrosive solder and/or the unauthorized modification of the product or of any furnished component will void this warranty in its entirety. This warranty does not include reimbursement for inconvenience, loss of use, customer assembly, set-up time, or unauthorized service.

This warranty covers only Heath products and is not extended to other equipment or components that a customer uses in conjunction with our products.

SUCH REPAIR AND REPLACEMENT SHALL BE THE SOLE REMEDY OF THE CUSTOMER AND THERE SHALL BE NO LIABILITY ON THE PART OF HEATH FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING BUT NOT LIMITED TO ANY LOSS OF BUSINESS OR PROFITS, WHETHER OR NOT FORSEEABLE.

Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

Owner's Responsibility

EFFECTIVE WARRANTY DATE — Warranty begins on the date of first consumer purchase. You must supply a copy of your proof of purchase when you request warranty service or parts.

ASSEMBLY — Before seeking warranty service, you should complete the assembly by carefully following the manual instructions. Heathkit service agencies cannot complete assembly and adjustments that are customer's responsibility.

ACCESSORY EQUIPMENT — Performance malfunctions involving other non-Heath accessory equipment, (antennas, audio components, computer peripherals and software, etc.) are not covered by this warranty and are the owner's responsibility.

SHIPPING UNITS — Follow the packing instructions published in the assembly manuals. Damage due to inadequate packing cannot be repaired under warranty.

If you are not satisfied with our service (warranty or otherwise) or our products, write directly to our Director of Customer Service, Heath Company, Benton Harbor MI 49022. He will make certain your problems receive immediate, personal attention.

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Heathkit® Manual

for the

FET MULTIMETER

Model IM-5225

595-1934

Blue label. SN 01807

WARNING: TO PREVENT FIRE OR SHOCK HAZARD, DO NOT EXPOSE THIS INSTRUMENT TO RAIN OR MOISTURE.

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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PARTS

Resistors will be called out by their resistance value in Ω (ohms), $k\Omega$ (kilohms), or $M\Omega$ (megohms). Certain types of resistors will have the value printed on the body, while others will be identified by a color code. The colors of the bands and the value will be given in the steps, therefore the following color code is given for information only.

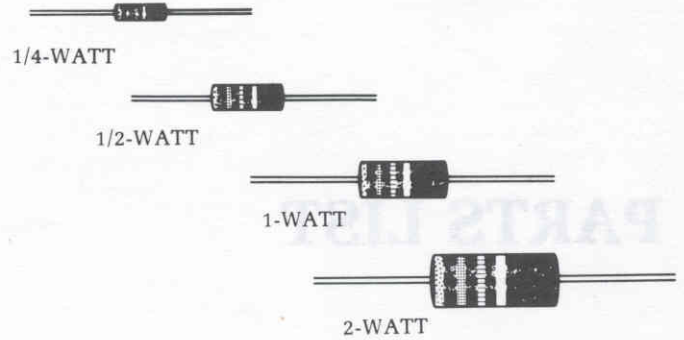
EXAMPLES:

BROWN 1
GREEN 5
ORANGE 1,000
SILVER $\pm 10\%$

$15 \times 1,000 = 15,000 \Omega$ (15,000 OHMS),
or "15 $k\Omega$ "

ORANGE 3
BLACK 0
GREEN 100,000
GOLD $\pm 5\%$

$30 \times 100,000 = 3,000,000 \Omega$ (or 3 $M\Omega$)
3 $M\Omega = 3$ MEGOHMS



RESISTOR COLOR CODE

TOLERANCE
Gold 5%
Silver 10%
No Band 20%

COLOR	1st DIGIT	2nd DIGIT	MULTIPLY BY
BLACK	0	0	1
BROWN	1	1	10
RED	2	2	100
ORANGE	3	3	1,000
YELLOW	4	4	10,000
GREEN	5	5	100,000
BLUE	6	6	1,000,000
VIOLET	7	7	10,000,000
GRAY	8	8	100,000,000
WHITE	9	9	1,000,000,000
GOLD			.1
SILVER			.01

Capacitors will be called out by their capacitance value in μF (microfarads) or pF (picofarads) and type: ceramic, Mylar*, electrolytic, etc. Some capacitors may have their value printed in the following manner:

First digit of capacitor's value: 1

Second digit of capacitor's value: 5

Multiplier: Multiply the first & second digits by the proper value from the Multiplier Chart.

To find the tolerance of the capacitor, look up this letter in the Tolerance columns.

EXAMPLES:

$151K = 15 \times 10 = 150 pF$
 $759 = 75 \times 0.1 = 7.5 pF$

NOTE: The letter "R" may be used at times to signify a decimal point; as in: 2R2 = 2.2 (pF or μF).

MULTIPLIER		TOLERANCE OF CAPACITOR		
FOR THE NUMBER:	MULTIPLY BY:	10pF OR LESS	LETTER	OVER 10pF
0	1	$\pm 0.1 pF$	B	
1	10	$\pm 0.25 pF$	C	
2	100	$\pm 0.5 pF$	D	
3	1,000	$\pm 1.0 pF$	F	$\pm 1\%$
4	10,000	$\pm 2.0 pF$	G	$\pm 2\%$
5	100,000		H	$\pm 3\%$
			J	$\pm 5\%$
8	0.01		K	$\pm 10\%$
9	0.1		M	$\pm 20\%$

*DuPont Registered Trademark

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
---------	----------------	------	-------------	-------------------

RESISTORS

NOTE: Open all resistor envelopes (marked R) before you check the resistors. Precision (1%) resistors are stamped with their value. All color coded resistors are 10% (fourth band silver) unless designated 5% (fourth band gold).

1/8-Watt

A1	2-32-11	1	200 Ω, 1%	R118
A1	2-46-11	1	400 Ω, 1%	R147
A1	2-17-11	1	5760 Ω (5.76k) 1%	R152

1/4-Watt

A2	2-608-12	2	90 Ω, 1%	R111, R115
A2	2-610-12	4	900 Ω, 1%	R109, R116, R125, R145
A2	2-678-12	1	1600 Ω (1.6k) 1%	R148
A2	2-61-12	1	2050 Ω (2.05k) 1%	R121
A2	2-718-12	2	4000 Ω (4k), 1%	R143, R144
A2	2-737-12	1	4610 Ω (4.61k) 1%	R153
A2	2-612-12	1	4870 Ω (4.87k) 1%	R123
A2	2-662-12	1	7500 Ω (7.5k) 1%	R122
A2	2-613-12	2	9000 Ω (9k) 1%	R107, R108
A2	2-615-12	1	90 kΩ, 1%	R106
A3	1-100-12	1	270 kΩ, 5% (red-violet-yellow)	R2
A2	2-738-12	1	900 kΩ, 1%	R105
A3	1-88-12	1	10 MΩ (brown-black-blue)	R3

1/2-Watt

A4	2-262	1	.505 Ω, 1%	R1
A5	1-83	1	56 Ω, 5% (green-blue-black)	R131
A5	1-175	1	120 Ω, 5% (brown-red-brown)	R126
A5	1-111	2	150 Ω, 5% (brown-green-brown)	R141, R142
A5	1-131	1	620 Ω, 5% (blue-red-brown)	R127
A5	1-96	2	750 Ω, 5% (violet-green-brown)	R101, R128
A5	1-8	3	820 Ω (gray-red-brown)	R129, R132, R139
A4	2-220	1	3162 Ω (3.162k) 1%	R124
A5	1-16	2	4700 Ω, (yellow-violet-red)	R137, R138
A5	1-20	1	10 kΩ (brown-black-orange)	R136
A5	1-126	1	180 kΩ (brown-gray-yellow)	R133
A5	1-184	1	1.2 MΩ, 5% (brown-red-green)	R135

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
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Resistors (cont'd.)

Other Resistors

A4	2-97-1	2	4.5 MΩ, 1%, 1-watt	R103, R104
A4	3-8-3	1	.1 Ω, 1%, 3-watt	R114
A4	3-11-3	1	.9 Ω, 1%, 3-watt	R113
A4	3-12-3	1	9 Ω, 1%, 3-watt	R112
A4	3-10-3	1	10 Ω, 1%, 3-watt	R117
A6	3-21-5	1	2.6 Ω, 10%, 5-watt	R102

CAPACITORS

Mica

B1	20-173	1	20 pF	C104
B1	20-199	1	36pF, 1500V	C102
B1	20-701	1	433 pF, 1%	C105

Ceramic

B2	21-3	1	10pF	C121
B2	21-56	1	470 pF	C126
B2	21-140	2	1000 pF (.001)	C115, C116
B2	21-72	2	5000 pF (.005)*	C1, C101
B2	21-95	3	.1 μF	C122, C123, C124

Electrolytic

B3	25-801	1	1.5 μF	C114
B4	25-115	1	10 μF	C125
B5	25-199	1	500 μF	C113
B5	25-241	1	1200 μF	C112

Film

B6	29-45	1	4900 pF (.0049), 1%	C106
B6	27-134	1	.033 μF, 1000V	C108
B6	29-46	1	.05 μF, 1%	C107
B6	29-47	1	.44 μF, 1%	C109

Other Capacitors

B7	27-47	5	.1 μF Mylar	C2, C111, C117, C118, C119
B8	31-36	1	8-50 pF ceramic trimmer	C103

*This part is critical to continued safety. Replace only with Heath Company part.



KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
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DIODES

C1	56-56	4	1N4149	D111, D112, D113, D114
C1	57-27	5	1N2071	D101, D102, D103, D104, D109
C1	57-65	4	1N4002	D105, D106, D107, D108

TRANSISTORS — INTEGRATED CIRCUITS (IC's)

NOTE: Transistors and integrated circuits are marked for identification in one of the following ways:

1. Part number.
2. Type number. (On integrated circuits this refers only to the numbers; the letters may be different or missing.)
3. Part number and type number.
4. Part number with a type number other than the one shown.

D1	417-118	4	2N3393 transistor	Q101, Q102, Q105, Q106
D2	417-808	2	2N3702 transistor	Q103, Q108
D2	417-809	1	2N3704 transistor	Q107
D3	417-818	1	MJE181 transistor	Q104
D4	442-617	1	UA78MGT2C IC	IC101
D4	442-618	1	UA79MGT2C IC	IC102

CAUTION: The protected CA3130S (#442-623) IC can be damaged by static electricity. DO NOT remove it from the foam pad until instructed to do so in a step.

D5	442-623	1	CA3130S IC (protected)	IC103
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CONTROLS — SWITCHES

E1	10-986	1	100 Ω control	R146
E1	10-398	2	2000 Ω (2k) control	R149, R151
E2	10-1084	1	50 k Ω control	R4
E3	10-1101	1	500 k Ω control	R134
E4	60-54	1	Slide switch	SW5
E5	63-1288	1	Rotary switch assembly	SW101
E6	64-831	1	Pushbutton switch assembly	SW1, SW2, SW3, SW4

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
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OTHER CIRCUIT COMPONENTS

F1	54-934	1	Power transformer	T1
	407-729	1	Meter	M1
F2	412-79	2	Light emitting diode (LED)	LED1, LED2
F3	421-27	1	1/16-ampere slow-blow fuse*	F1
F3	421-43	1	2-ampere quick-blow fuse	F101

CLIP — FUSE BLOCK — SOCKETS

G1	260-65	2	Fuse clip	
G2	422-1	1	Fuse block	
G3	434-230	1	8-pin IC socket	
G4	436-11	1	Red banana socket	S1
G4	436-22	1	Black banana socket	S2

TEST LEAD PARTS

H1	70-10	1	Black banana plug sleeve
H1	70-11	1	Red banana plug sleeve
H2	73-21	1	Black alligator clip insulator
H3	260-1	1	Alligator clip
H4	438-47	2	Banana plug
H5	439-7	1	Red test probe
H6	439-9	1	Collar nut

INSULATORS

J1	73-4	1	Rubber grommet
J2	73-98	3"	Foam tape
J3	75-736	1	Line cord strain relief
J4	75-738	1	1" \times 2" fish paper
J5	75-743	2	3/4" \times 1" fish paper (with hole)

HARDWARE

Hardware packets are marked to show the size of the hardware they contain (HDW #4, or, HDW #2 & #6, etc). You may have to open more than one packet to locate all the hardware of any one size (#6, for example).

#3 Hardware

K1	250-2	2	3-48 \times 5/16" screw
K2	254-7	2	#3 lockwasher

*This part is critical to continued safety. Replace only with Heath Company part.



KEY HEATH QTY. DESCRIPTION
No. Part No.

CIRCUIT
Comp. No.

KEY HEATH QTY. DESCRIPTION
No. Part No.

CIRCUIT
Comp. No.

Hardware (cont'd.)

#4 Hardware

K3	250-52	4	4-40 × 1/4" screw
K4	250-1194	2	4-40 × 1/2" "T" bolt
K5	252-15	6	4-40 nut
K6	254-9	2	#4 lockwasher
K7	254-41	4	#4 split lockwasher
K8	259-30	1	#4 solder lug

#6 Hardware

L1	250-170	2	#6 × 1/4" sheet metal screw
L2	250-274	4	6-32 × 5/16" flat-head screw
L3	250-155	10	#6 × 3/8" black sheet metal screw
L4	250-381	9	6-32 × 3/8" black screw
L5	250-1248	2	6-32 × 3/8" self-tapping screw
L6	250-1150	3	6-32 × 1/2" phillips head screw
L7	252-3	6	6-32 nut
L8	252-23	1	6-32 thumb nut
L9	252-127	4	6-32 push-on nut
L10	253-127	2	#6 flat washer
L11	254-1	5	#6 lockwasher
L12	254-33	2	#6 black lockwasher
L13	254-6	1	#6 external-tooth lockwasher
L14	255-83	2	11/16" spacer
L15	259-1	4	#6 solder lug

#8 Hardware

M1	250-1186	2	8-32 × 3/8" black screw
M2	252-4	2	8-32 nut
M3	254-2	2	#8 lockwasher

Other Hardware

M4	253-7	2	#10 fiber shoulder washer
M5	252-39	1	1/4 - 32 nut
M6	254-14	1	1/4" lockwasher
M7	254-15	2	5/16" lockwasher
M8	252-7	2	3/8 - 32 nut
M9	253-10	1	3/8" flat washer
M10	254-5	2	3/8" lockwasher
M11	253-67	2	1/16" long spacer

METAL PARTS

N1	90-1186-3	1	Cabinet top
N2	216-69	1	Trim bar
N3	203-1883-1	1	Front panel
N4	204-2233	2	Meter bracket
N5	206-1246	1	Meter shield
N6	204-2232	1	Switch bracket
N7	206-1238	1	Switch shield
N8	205-1669-1	2	Cabinet side
N9	200-1316-1	1	Cabinet bottom

LINE CORD — WIRE — SLEEVING

89-54	1	Line cord
344-54	24"	Yellow wire
344-29	42"	Blue wire
341-1	42"	Black wire
341-2	54"	Red wire
344-91	15" 10"	Brown wire
344-93	15" 10"	Orange wire
346-4	7-1/4"	Sleeving
346-21	1"	White tubing

MISCELLANEOUS

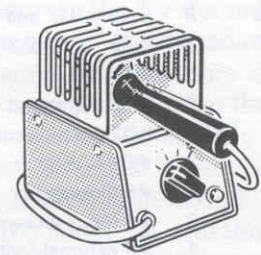
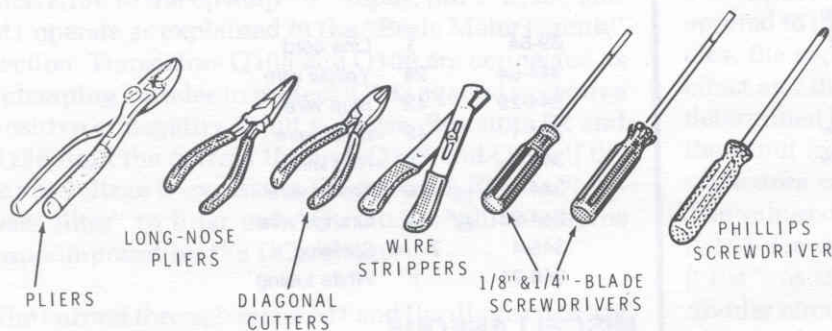
85-1875-1	1	Circuit board	
134-994	1	Harness	
211-74	1	Handle	
N10 261-34	4	Plastic foot	
N11 455-71	1	Knob bushing (large)	
N12 455-613	1	Knob bushing (small)	
N13 462-363	1	Red knob	
N14 462-951	1	Black knob	
N15 475-10	2	Ferrite bead (small)	FB4, FB5
N16 475-18	3	Ferrite bead (large)	FB1, FB2, FB3
N17 490-5	1	Nut starter	
390-1255	1	Fuse label	
390-1337	1	Model label	
391-34	1	Blue and white label	
597-260	1	Parts Order Form	
		Solder	
	1	Manual (See Page 1 for part number.)	
	1	Illustration Booklet (See Page 1 for part number.)	
	1	Schematic Diagram	



ASSEMBLY NOTES

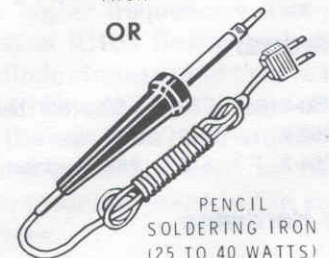
TOOLS

You will need these tools to assemble your kit.

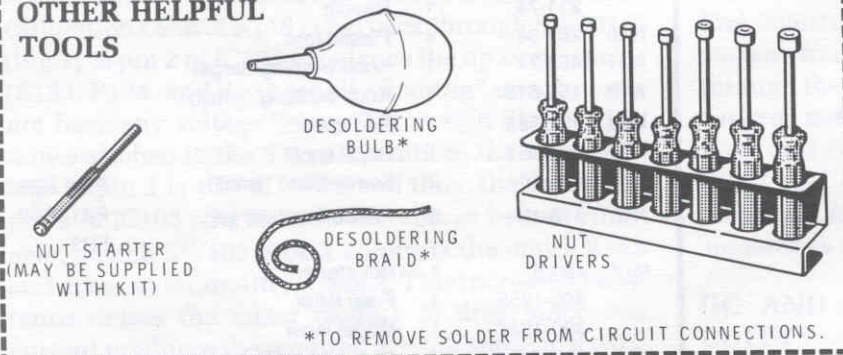


HEATHKIT
SOLDERING
IRON

OR



OTHER HELPFUL TOOLS



ASSEMBLY

1. Follow the instructions carefully and read the entire step before you perform the operation.
2. The illustrations in the Manual are called Pictorials and Details. Pictorials show the overall operation for a group of assembly steps; Details generally illustrate a single step. When you are directed to refer to a certain Pictorial "for the following steps," continue using that Pictorial until you are referred to another Pictorial for another group of steps.
3. Most kits use a separate "Illustration Booklet" that contains illustrations (Pictorials, Details, etc.) that are too large for the Assembly Manual. Keep the "Illustration Booklet" with the Assembly Manual. The illustrations in it are arranged in Pictorial number sequence.
4. Position all parts as shown in the Pictorials.
5. Solder a part or a group of parts only when you are instructed to do so.

6. Each circuit part in an electronic kit has its own component number (R2, C4, etc.). Use these numbers when you want to identify the same part in the various sections of the Manual. These numbers, which are especially useful if a part has to be replaced, appear:

- In the Parts List,
- At the beginning of each step where a component is installed,
- In some illustrations,
- In the Schematic,
- In the section at the rear of the Manual.

7. When you are instructed to cut something to a particular length, use the scales (rulers) provided at the bottom of the Manual pages.

SAFETY WARNING: Avoid eye injury when you cut off excess lead lengths. Hold the leads so they cannot fly toward your eyes.

SOLDERING

Soldering is one of the most important operations you will perform while assembling your kit. A good solder connection will form an electrical connection between two parts, such as a component lead and a circuit board foil. A bad solder connection could prevent an otherwise well-assembled kit from operating properly.

It is easy to make a good solder connection if you follow a few simple rules:

1. Use the right type of soldering iron. A 25 to 40-watt pencil soldering iron with a 1/8" or 3/16" chisel or pyramid tip works best.
2. Keep the soldering iron tip clean. Wipe it often on a wet sponge or cloth; then apply solder to the tip to give the entire tip a wet look. This process is called tinning, and it will protect the tip and enable you to make good connections. When solder tends to "ball" or does not stick to the tip, the tip needs to be cleaned and retinned.

STEP-BY-STEP ASSEMBLY

MAIN CIRCUIT BOARD

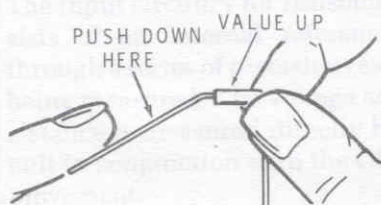
START

In the following steps, you will be given detailed instructions on how to install and solder the first part on the circuit board. Read and perform each step carefully. Then use the same procedure whenever you install parts on a circuit board.

() Position the circuit board as shown with the printed side (not the foil side) up. NOTE: Only a portion of the circuit board is shown in the following Pictorials. The small "Identification Drawing" at the top of each Pictorial shows the area of the circuit board to be assembled.

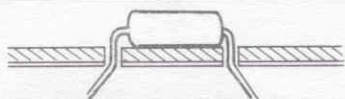
NOTE: When you install a component that has its value printed on it, position the value marking up, so it can be easily read. Diodes should be mounted with their type or part number up, if possible.

() R105: Hold a 900 k Ω , 1%, 1/4-watt resistor by the body as shown and bend the leads straight down.

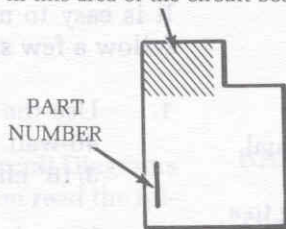


() Push the leads through the holes at the proper location on the circuit board. Resistors can be positioned either way.

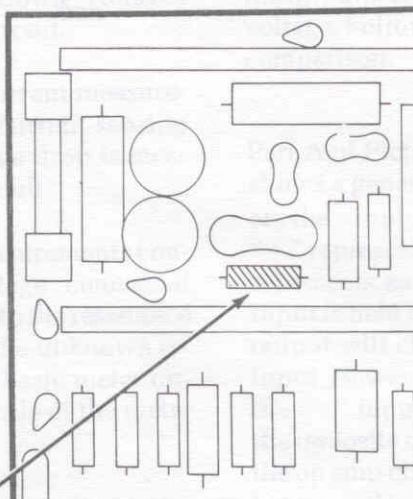
() Press the resistor against the circuit board. Then bend the leads outward slightly to hold the resistor in place.



The steps performed in this Pictorial are in this area of the circuit board.



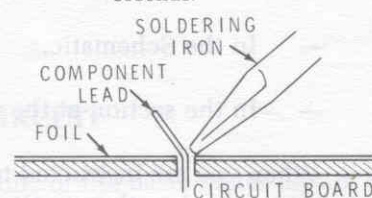
IDENTIFICATION DRAWING



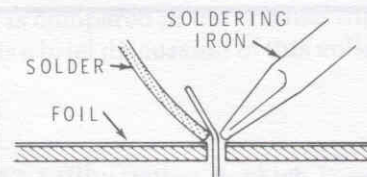
CONTINUE

() Solder the resistor leads to the circuit board as follows:

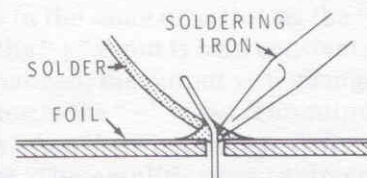
1. Push the soldering iron tip against both the lead and the circuit board foil. Heat both for two or three seconds.



2. Then apply solder to the other side of the connection. IMPORTANT: Let the heated lead and the circuit board foil melt the solder.



3. As the solder begins to melt, allow it to flow around the connection. Then remove the solder and the iron and let the connection cool.



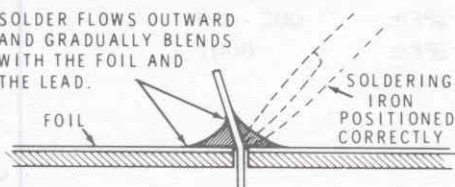
() Cut off the excess lead lengths close to the connection. WARNING: Clip the leads so the ends will not fly toward your eyes.

() Check each connection. Compare it to the illustrations on Page 11. After you have checked the solder connections, proceed with the assembly on Page 12. Use the same soldering procedure for each connection.

PICTORIAL 1-1

A GOOD SOLDER CONNECTION

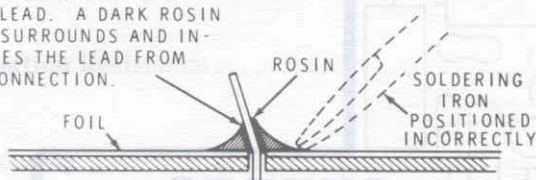
SOLDER FLOWS OUTWARD AND GRADUALLY BLENDS WITH THE FOIL AND THE LEAD.



When you heat the lead and the circuit board foil at the same time, the solder will flow evenly onto the lead and the foil. The solder will make a good electrical connection between the lead and the foil.

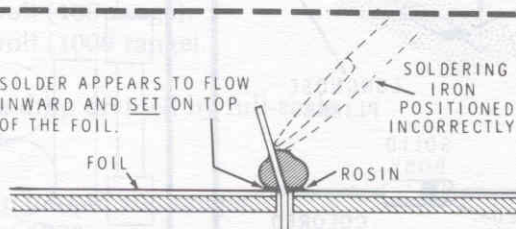
POOR SOLDER CONNECTIONS

SOLDER DOES NOT FLOW ONTO LEAD. A DARK ROSIN BEAD SURROUNDS AND INSULATES THE LEAD FROM THE CONNECTION.



When the lead is not heated sufficiently, the solder will not flow onto the lead as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder to obtain a good connection.

SOLDER APPEARS TO FLOW INWARD AND SET ON TOP OF THE FOIL.

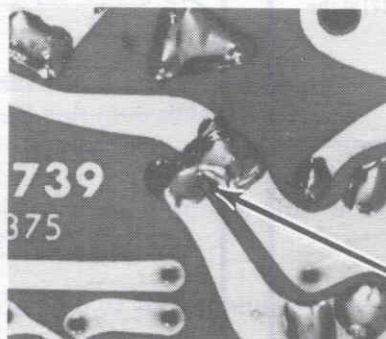


When the foil is not heated sufficiently the solder will blob on the circuit board as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder to obtain a good connection.

SOLDER BRIDGES

A solder bridge between two adjacent foils is shown in photograph A. Photograph B shows how the connection should appear. A solder bridge may occur if you accidentally touch an adjacent previously soldered connection, if you use too much solder, or if you "drag" the soldering iron across other foils as you remove it from the connection. A good rule to follow is; always take a good look at the foil area around each lead before you solder it. Then, when you solder the connection, make sure the solder remains in this area and does not bridge to another foil. This is especially important when the foils are small and close together. NOTE: It is alright for solder to bridge two connections on the same foil.

Use only enough solder to make a good connection, and lift the soldering iron straight up from the circuit board. If a solder bridge should develop, turn the circuit board foil-side-down and heat the solder between connections. The excess solder will run onto the tip of the soldering iron, and this will remove the solder bridge. NOTE: The foil side of the circuit board has a coating on it called "solder resist." This is a protective insulation to help prevent solder bridges.



A

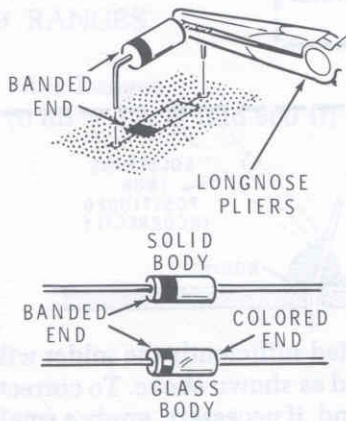
SOLDER BRIDGE

B



START

NOTE: When you install a diode, always match the band on the diode with the band mark on the circuit board. See Detail 1-2A. THE CIRCUITRY WILL NOT WORK PROPERLY IF A DIODE IS INSTALLED BACKWARDS. Grip the diode leads between the body of the diode and the bend when you bend the leads to prevent diode damage.



If your diode has a solid body, the band is clearly defined. If your diode has a glass body, do not mistake the colored end **inside** the diode for the banded end. Look for a band painted on the **outside** of the glass.

Install 1N2071 diodes (#57-27) at the following four locations.

- D103 D102
- D104 D101

Install 1N4002 diodes (#57-65) at the following four locations.

- D108 D106
- D107 D105

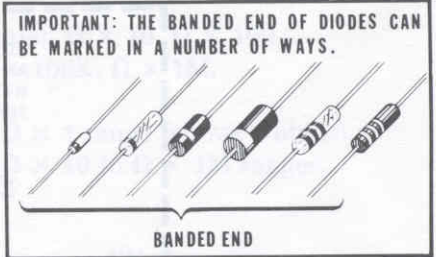
Solder the leads to the foil and cut off the excess lead lengths.

D109: 1N2071 diode (#57-27).

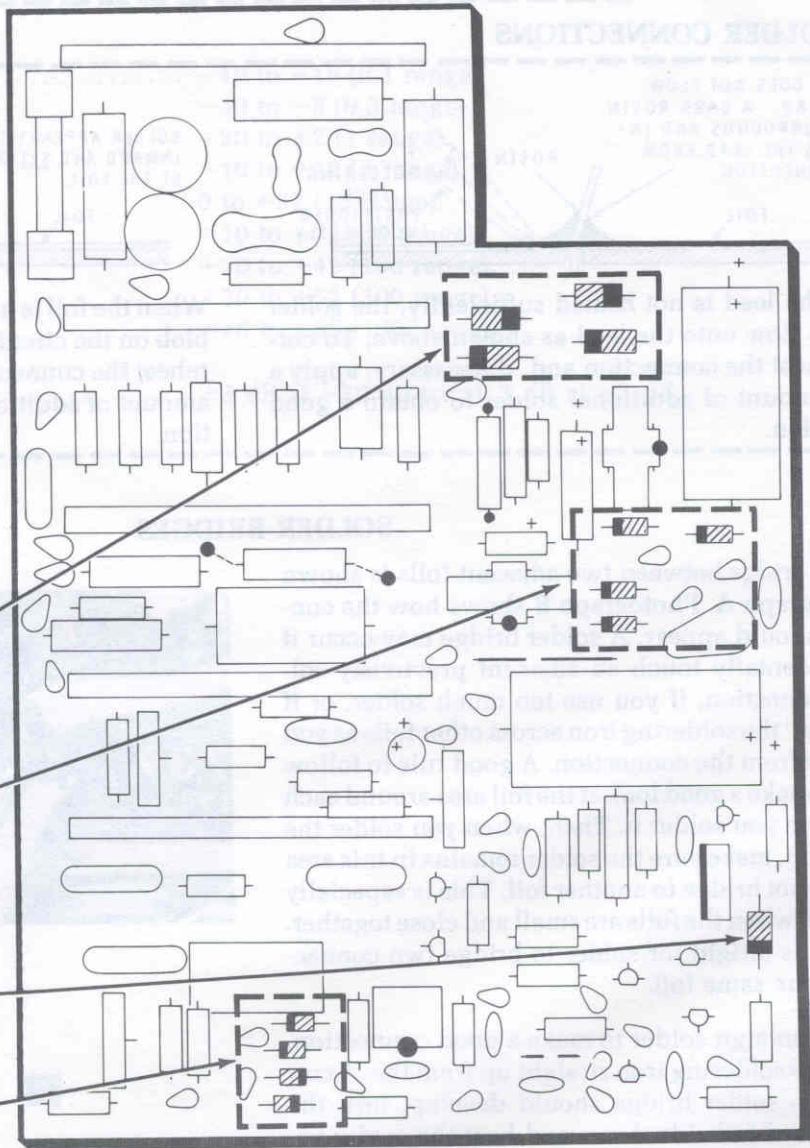
Install 1N4149 diodes (#56-56) at the following four locations.

- D113 D111
- D114 D112

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



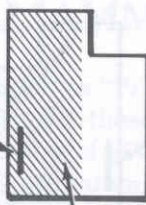
Detail 1-2A



PICTORIAL 1-2

IDENTIFICATION
DRAWING

PART
NUMBER

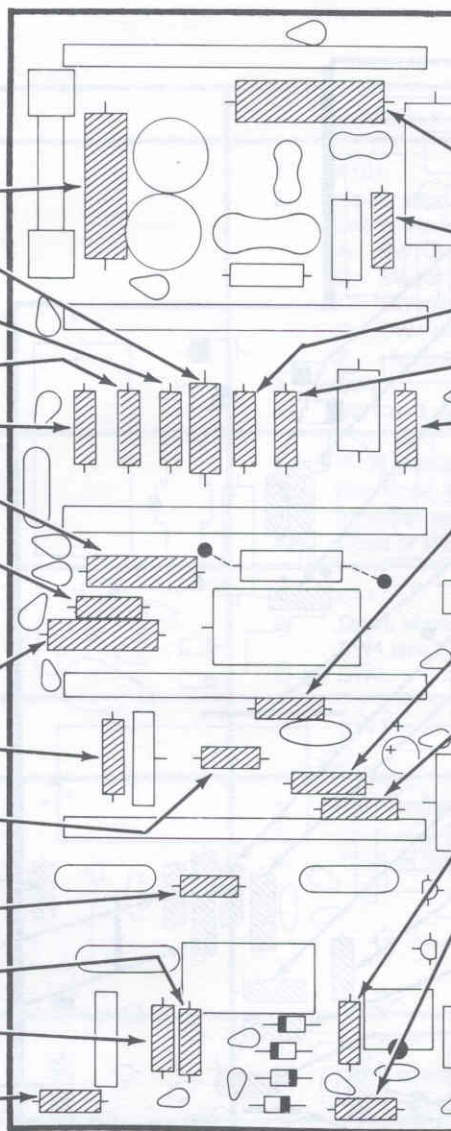


The steps performed in this Pictorial are
in this area of the circuit board.

START ↘

CAUTION: Do not confuse the Ω sign
printed on some resistors with a 0.

- () R103: 4.5 M Ω , 1%, 1-watt.
- () R112: 9 Ω , 1%, 3-watt.
- () R111: 90 Ω , 1%, 1/4-watt.
- () R109: 900 Ω , 1%, 1/4-watt.
- () R108: 9000 Ω (9k), 1%, 1/4-watt.
- () R113: .9 Ω , 1%, 3-watt.
- () R118: 200 Ω , 1%, 1/8-watt
- () Solder the leads to the foil and
cut off the excess lead lengths.
- () R117: 10 Ω , 1%, 3-watt.
- () R145: 900 Ω , 1%, 1/4-watt.
- () R135: 1.2 M Ω (brown-red-
green).
- () R133: 180 k Ω (brown-gray-
yellow).
- () R144: 4000 Ω (4k), 1%, 1/4-watt.
- () R143: 4000 Ω (4k), 1%, 1/4-watt.
- () R152: 5760 Ω (5.76k), 1%, 1/8-
watt.
- () Solder the leads to the foil and
cut off the excess lead lengths.

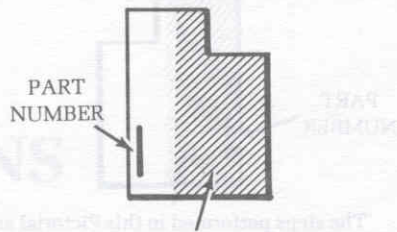


CONTINUE ↙

- () R104: 4.5 M Ω , 1%, 1-watt.
- () R106: 90 k Ω , 1%, 1/4-watt.
- () R115: 90 Ω , 1%, 1/4-watt.
- () R116: 900 Ω , 1%, 1/4-watt.
- () R107: 9000 Ω (9k), 1%, 1/4-watt.
- () R147: 400 Ω , 1%, 1/8-watt.
- () Solder the leads to the foil and
cut off the excess lead lengths.
- () R153: 4610 Ω (4.61 k), 1%, 1/4-
watt.
- () R148: 1600 Ω (1.6 k), 1%, 1/4-
watt.
- () R138: 4700 Ω (yellow-violet-
red).
- () R139: 820 Ω (gray-red-brown).
- () Solder the leads to the foil and
cut off the excess lead lengths.

PICTORIAL 1-3

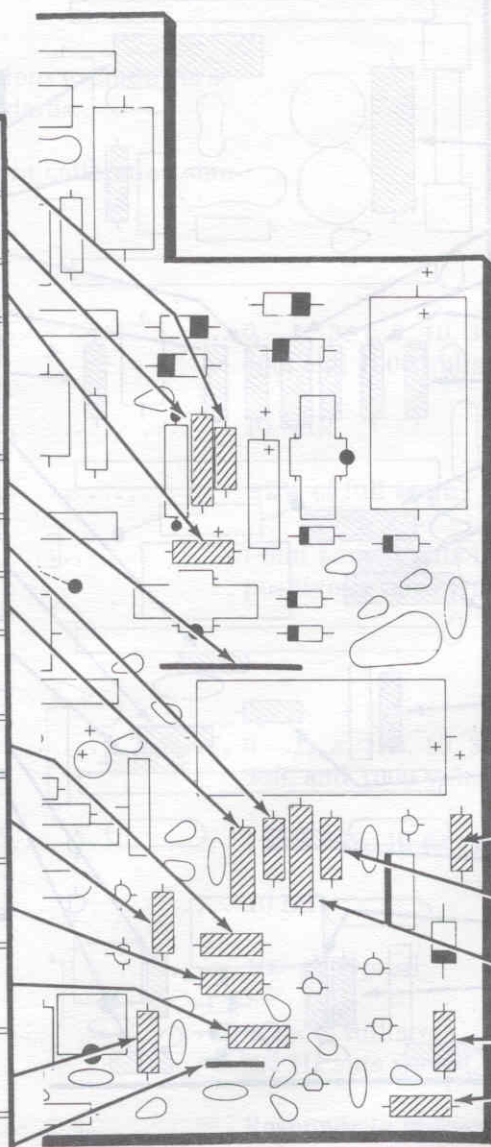
IDENTIFICATION
DRAWING



The steps performed in this Pictorial are in this area of the circuit board.

START ▾

- () R101: 750 Ω (violet-green-brown).
- () R123: 4870 Ω (4.87 k), 1%, 1/4-watt.
- () R121: 2050 Ω (2.05 k), 1/4-watt.
- NOTE: When a bare wire is called for in a step, remove all the insulation from the indicated length of the yellow wire.
- () 1-1/2" bare wire.
- () R132: 820 Ω (gray-red-brown).
- () R125: 900 Ω, 1%, 1/4-watt.
- () Solder the leads to the foil and cut off the excess lead lengths.
- () R129: 820 Ω (gray-red-brown).
- () R136: 10 kΩ (brown-black-orange).
- () R142: 150 Ω (brown-green-brown).
- () R141: 150 Ω (brown-green-brown).
- () R137: 4700 Ω (yellow-violet-red).
- () 1" bare wire.
- () Solder the leads to the foil and cut off the excess lead lengths.

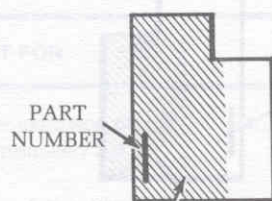


CONTINUE ▾

- () R126: 120 Ω (brown-red-brown).
- () R128: 750 Ω (violet-green-brown).
- () R124: 3162 Ω (3.162 k), 1%.
- () R131: 56 Ω (green-blue-black).
- () R127: 620 Ω (blue-red-brown).
- () Solder the leads to the foil and cut off the excess lead lengths.

PICTORIAL 1-4

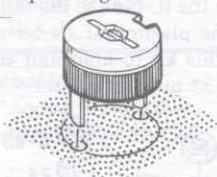


IDENTIFICATION
DRAWING

The steps performed in this Pictorial are in this area of the circuit board.

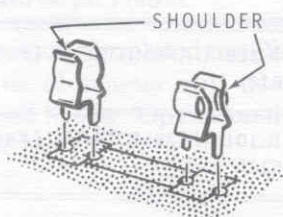
START

- () C103: 8-50 pF ceramic trimmer (#31-36). Be sure the trimmer fits within its outline. If it does not, remove it and insert its pins in the opposite holes. Solder the pins to the foil and cut off the excess pin lengths.

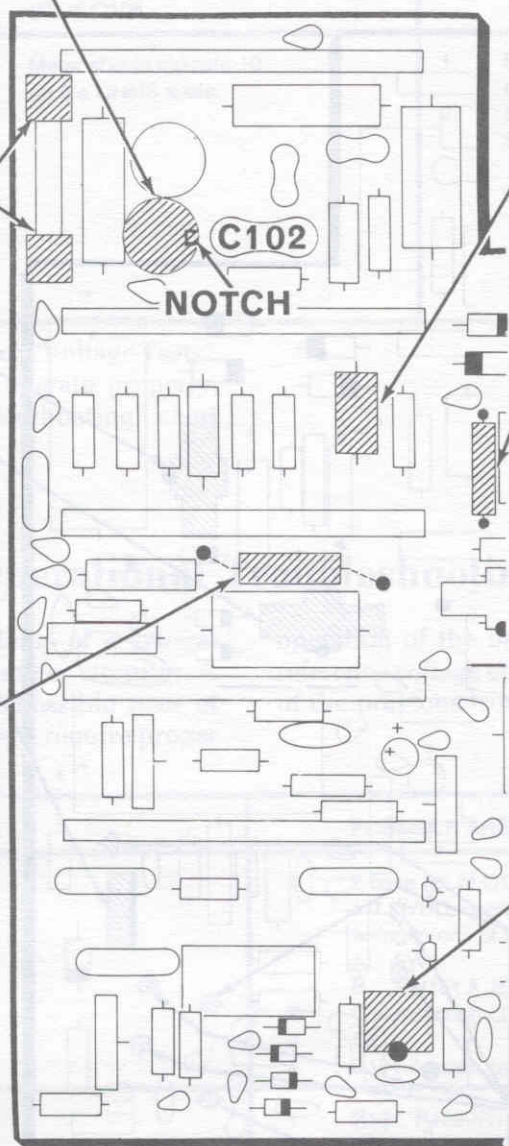
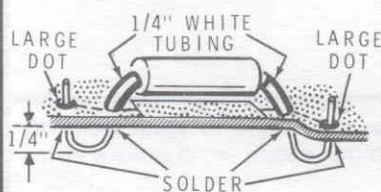


- () Turn the top of the trimmer so its notch points at C102.

- () Two fuse clips at F101. Be sure to position the shoulder of each fuse clip as shown. Push the fuse clips tight against the circuit board. Then solder the lugs to the foil.



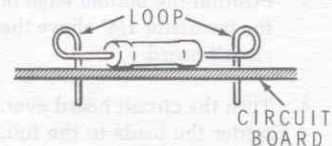
- () R114: .1 Ω , 1%, 3-watt. Place a 1/4" length of white tubing on each lead. Pass each lead down through the indicated hole in the circuit board and push the resistor down so the sleeving is against the board. The body of the resistor **must** be positioned 1/8" above the board. Then bend each lead back up through the holes with the large dots. These loops must not extend more than 1/4" below the board. Solder each lead to both of its foils and cut off the excess lead lengths on the printed side of the board.



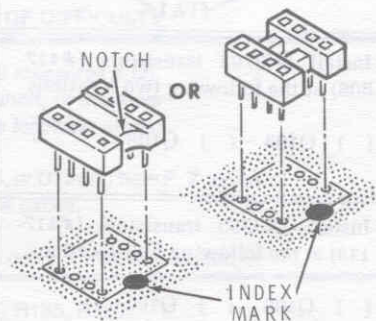
CONTINUE

- () C107: .05 μ F film. Solder the leads to the foil and cut off the excess lead lengths.

- () R122: 7500 Ω , 1%, 1/4-watt. Bend a loop in both leads of the resistor. Match the bend in the leads with the hole spacing in the circuit board. Solder the leads to the foil and cut off the excess lead lengths.

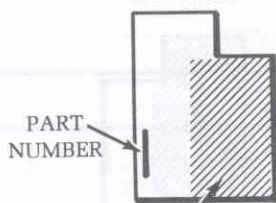


- () 8-pin IC socket at IC103. Insert the socket pins into the holes. The index mark on the circuit board should still be visible after it is installed. Solder the pins to the foil.



PICTORIAL 1-5

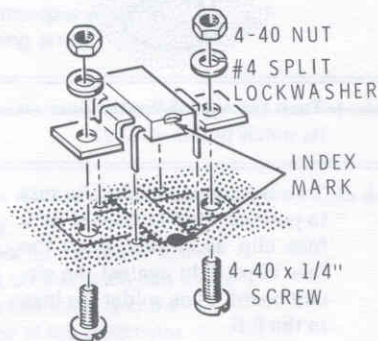
IDENTIFICATION DRAWING



The steps performed in this Pictorial are in this area of the circuit board.

CONTINUE

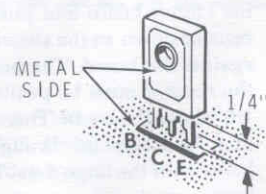
When you install the IC's in the next two steps, match the index mark on the IC with the index mark on the circuit board. Push the IC pins into their holes in the board. Secure the IC with 4-40 x 1/4" screws, #4 split lockwashers and 4-40 nuts. Then solder the IC pins to the foil. NOTE: Use the plastic nut starter supplied with this kit to hold and start 4-40 and 6-32 nuts on screws.



() IC102: UA79MGT2C IC (#442-618).

() IC101: UA78MGT2C IC (#442-617).

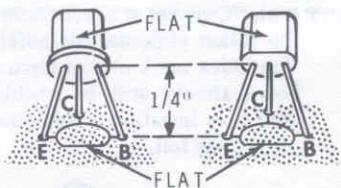
() Q104: MJE181 transistor (#417-818). Be sure its metal side is positioned as shown.



START

In the following steps, install each transistor as follows:

1. Refer to the illustration that matches the shape of the transistor you received. Then identify the E, C, and B leads.
2. Insert the leads into the corresponding E, C, and B holes in the circuit board.
3. Position the bottom edge of the transistor 1/4" above the circuit board.
4. Turn the circuit board over, solder the leads to the foil, and cut off the excess lead lengths.



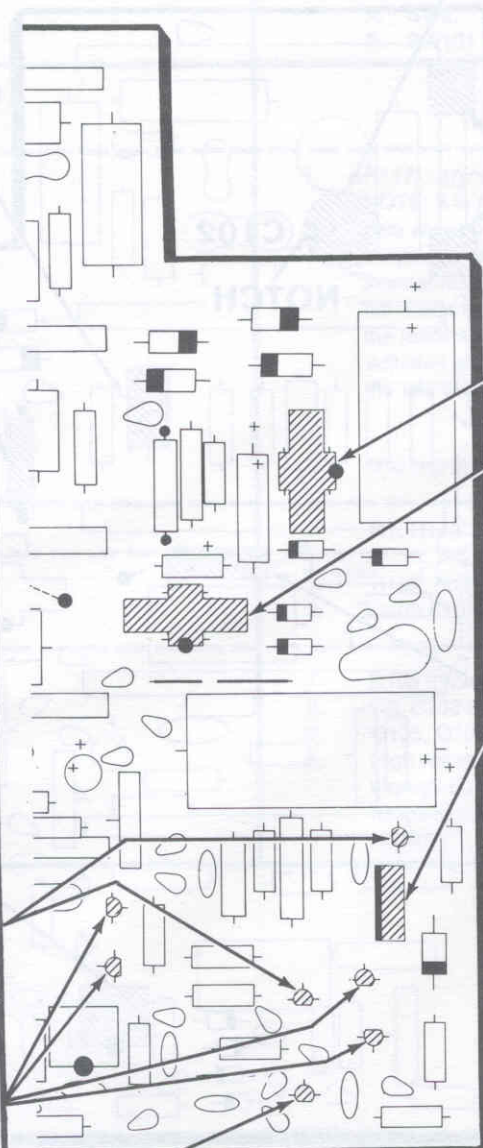
Install 2N3702 transistors (#417-808) at the following two locations.

() Q103 () Q108

Install 2N3393 transistors (#417-118) at the following four locations.

() Q106 () Q102
() Q105 () Q101

() Q107: 2N3704 transistor (#417-809).



PICTORIAL 1-6

START 
 C105: 433 pF mica.

 C104: 20 pF mica.

 C102: 36 pF mica.

 C106: 4900 pF (.0049) film.

NOTE: When you install ceramic capacitors, remove any excess coating from the leads. Use long-nose pliers to remove this coating.

REMOVE COATING
EVEN WITH
BOTTOM OF
CAPACITOR BODY

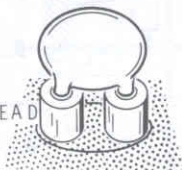

 C101: 5000 pF (.005) 1.4 kV ceramic.

 C111: .1 μ F Mylar.

 C109: .44 μ F film.

 C126, FB4, FB5: 470 pF ceramic with a small ferrite bead on each lead.

SMALL
FERRITE BEAD


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

 C116: 1000 pF (.001) ceramic.

 C123: .1 μ F ceramic.

 C117: .1 μ F Mylar.

 C118: .1 μ F Mylar.

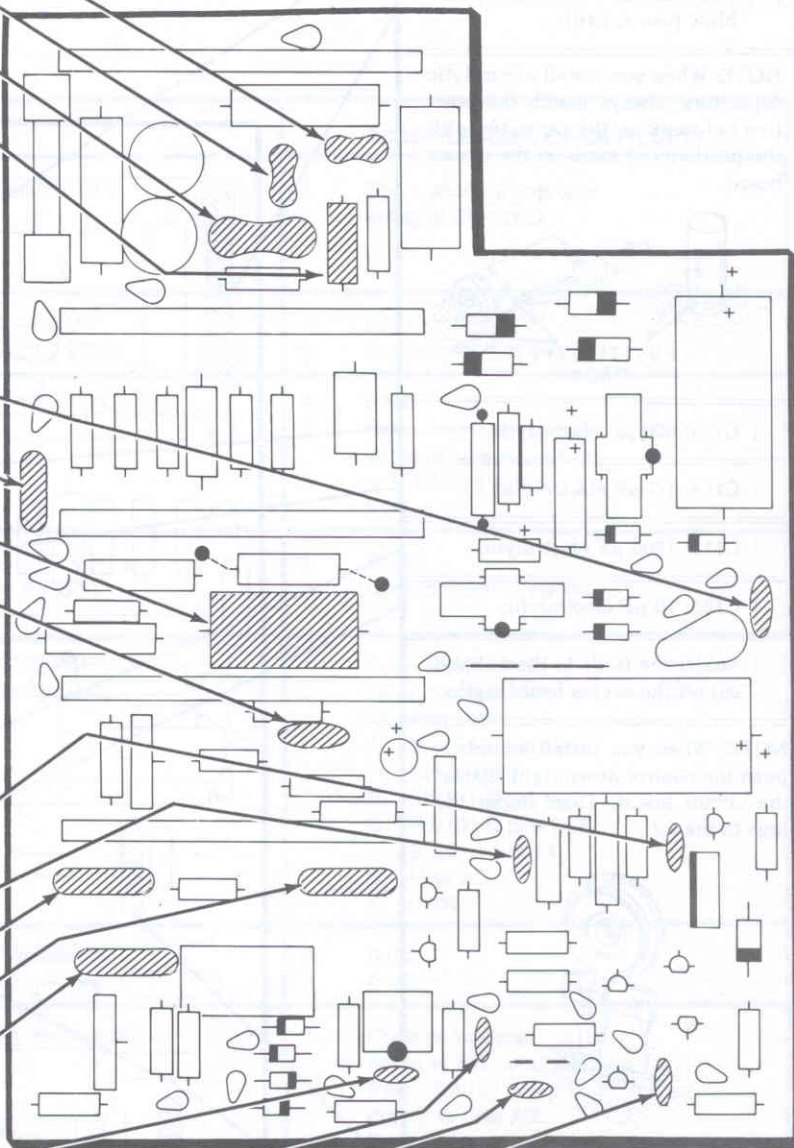
 C119: .1 μ F Mylar.

 C121: 10 pF ceramic.

 C122: .1 μ F ceramic.

 C124: .1 μ F ceramic.

 C115: 1000 pF (.001) ceramic.

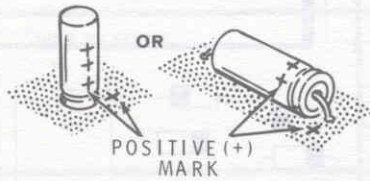
 Solder the leads to the foil and cut off the excess lead lengths.

PICTORIAL 1-7

START

() R102: 2.6 Ω , 10%, 5-watt.

() F101: Install a 2-ampere quick-blow fuse at F101.

NOTE: When you install electrolytic capacitors, always match the positive (+) mark on the capacitor with the positive (+) mark on the circuit board.



() C113: 500 μ F electrolytic.

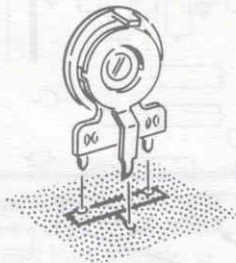
() C114: 1.5 μ F electrolytic.

() C112: 1200 μ F electrolytic.

() C125: 10 μ F electrolytic.

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

NOTE: When you install a control, push the control down tight against the circuit board. Then solder the lugs to the foil.

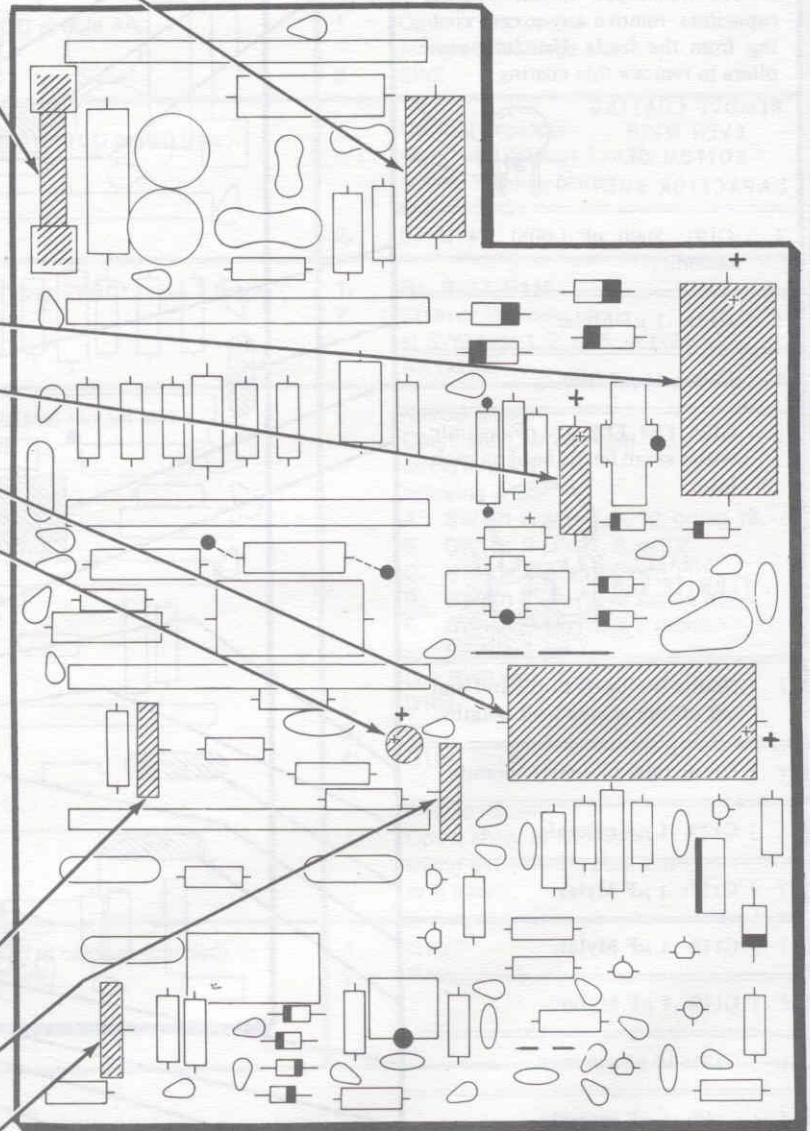


() R146: 100 Ω control (#10-986).

() R149: 2000 Ω (2k) control (#10-398).

() R151: 2000 Ω (2k) control (#10-398).

Set the circuit board aside temporarily.



PICTORIAL 1-8



ROTARY SWITCH

Refer to Pictorial 2-1 (Illustration Booklet, Page 2) for the following steps.

R134: Mount the 500 k Ω control (#10-1101) on the rear of the rotary switch (#63-1288) as follows:

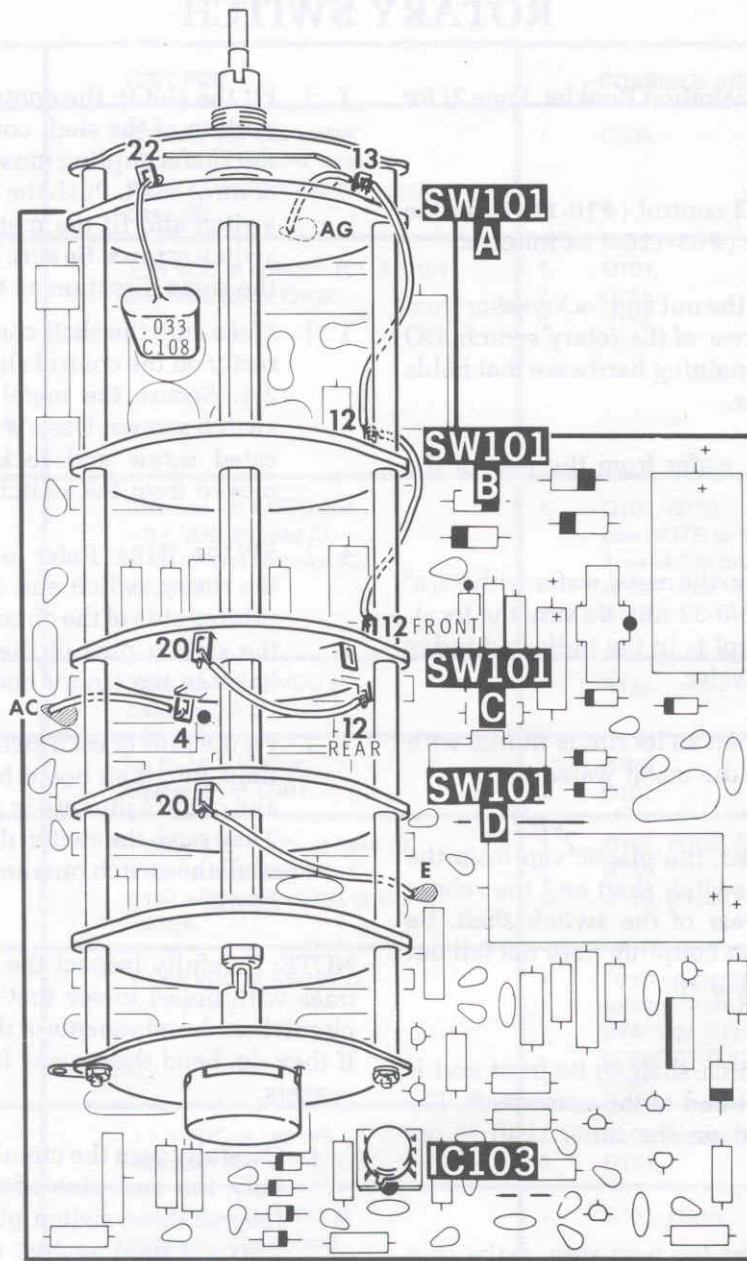
- () Remove, and save, the nut and lockwasher from each screw at the rear of the rotary switch. DO NOT loosen the remaining hardware that holds the switch together.
- () Remove the metal wafer from the rear of the rotary switch.
- () Mount the control on the metal wafer with a 3/8" lockwasher and a 3/8-32 nut. Be sure the locating tab of the control is in the indicated index hole in the metal wafer.
- () Turn the control shaft so its slot is in line with the screw holes in the metal wafer.
- () Remove and discard, the plastic^{IF ANY} cap from the front of the rotary switch shaft and the rubber washer from the rear of the switch shaft. Be careful that the shaft coupling does not fall out of the inner switch shaft.
- () Push the inner switch shaft so its front end is even with the front end of the outer shaft. The position of the flat on the inner shaft is not important.

NOTE: When you perform the next step, make sure you fit the slot in the control shaft onto the **center** portion of the shaft coupling of the rotary switch. Otherwise, the control will be hard to turn and the shaft coupling can fall out. Be sure the short end of the shaft coupling remains in the hole in the inner shaft of the rotary switch as shown in the inset drawing on Pictorial 2-1 (Illustration Booklet, Page 2).

- () Fit the slot in the control shaft onto the **center** portion of the shaft coupling. The long end of the shaft coupling must fit on the outside of the control shaft. Push the metal wafer towards the switch and fit the metal wafer holes onto the switch screws. Be sure the control pins point in the same direction as the switch pins.
- () Make sure the shaft coupling is positioned correctly on the control shaft as shown in Pictorial 2-1. Secure the metal wafer onto the rotary switch screws. Use a #4 solder lug on the indicated screw and lockwashers and nuts (removed from the switch earlier).
- () SW101, R134: Refer to Detail 2-1A and mount the rotary switch and control assembly on the printed side of the circuit board. Carefully align the switch pins of the front wafer with their holes in the circuit board.
- () Fit the pins of each switch wafer, one wafer at a time, into their board holes until all the switch and control pins are in place in the board holes. Then push the switch down so the wide portion of all the switch pins are tight against the circuit board.

NOTE: Carefully inspect the rotary switch lugs (the ones with holes) to see that they do not touch any circuit board components or the spacers of the switch. If they do, bend them away from the components or spacers.

- () Carefully turn the circuit board over and solder **only** the end pins of each wafer to the foil. Inspect these switch pins to make sure all the pins are tight against the lettered side of the circuit board. If they are not, reheat the connection and push the lug tight against the board. Then solder all the remaining switch pins to the foil.
- () Solder the lugs of control R134 to the foil and cut off the excess pin lengths.



PICTORIAL 2-2



Refer to Pictorial 2-2 for the following steps.

NOTE: Each rotary switch wafer has its location lettered on the circuit board, SW101A, SW101B, etc. To make it easier to locate the switch lugs, each possible lug location (hole) is numbered, even though every hole does not have a lug.

- () C108: Insert one lead of a .033 μ F film capacitor all the way into its hole in the circuit board. Solder this lead to the foil and cut off the excess lead length.

NOTE: In the following steps, (NS) means not to solder because other wires will be added later. "S-" with a number, such as (S-3), means to solder the connection. The number following the "S" tells how many wires are at the connection.

- () Connect the other lead of the .033 μ F capacitor to rotary switch SW101A lug 22 (NS).

NOTE: When you are instructed to prepare wires, as in the next step, cut the specified color wire to the indicated length and remove 1/4" of insulation from each end.

- () Prepare the following yellow wires. The wires are listed in the order they will be used.

1-3/4"	2"
2-1/2"	3"
2"	1-1/4"

NOTE: When you connect each wire in a circuit board hole, solder the wire to the foil and cut off the excess wire length.

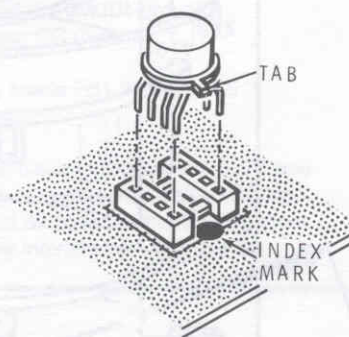
- () Connect a 1-3/4" yellow wire from circuit board hole AG (S-1) to switch SW101A lug 13 (NS).
- () Connect a 2-1/2" yellow wire between switch SW101A lug 13 (S-2) and SW101B lug 12 (NS).
- () Connect a 2" yellow wire between switch SW101B lug 12 (S-2) and SW101C front lug 12 (S-1).
- () Connect a 2" yellow wire between switch SW101C rear lug 12 (S-1) and lug 20 (S-1).

- () Connect a 3" yellow wire from circuit board hole E (S-1) to switch SW101D lug 20 (S-1).
- () Connect a 1-1/4" yellow wire from circuit board hole AC (S-1) to switch SW101C rear lug 4 (S-1).

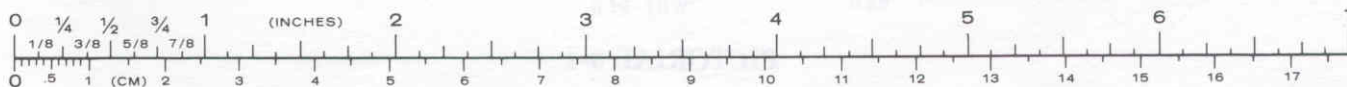
CAUTION: When you install the protected IC, be sure it does not get damaged by static electricity. Once you remove the foam pad from the IC, DO NOT let go of the IC. Install the IC as follows. Read the entire step before you pick up the IC.

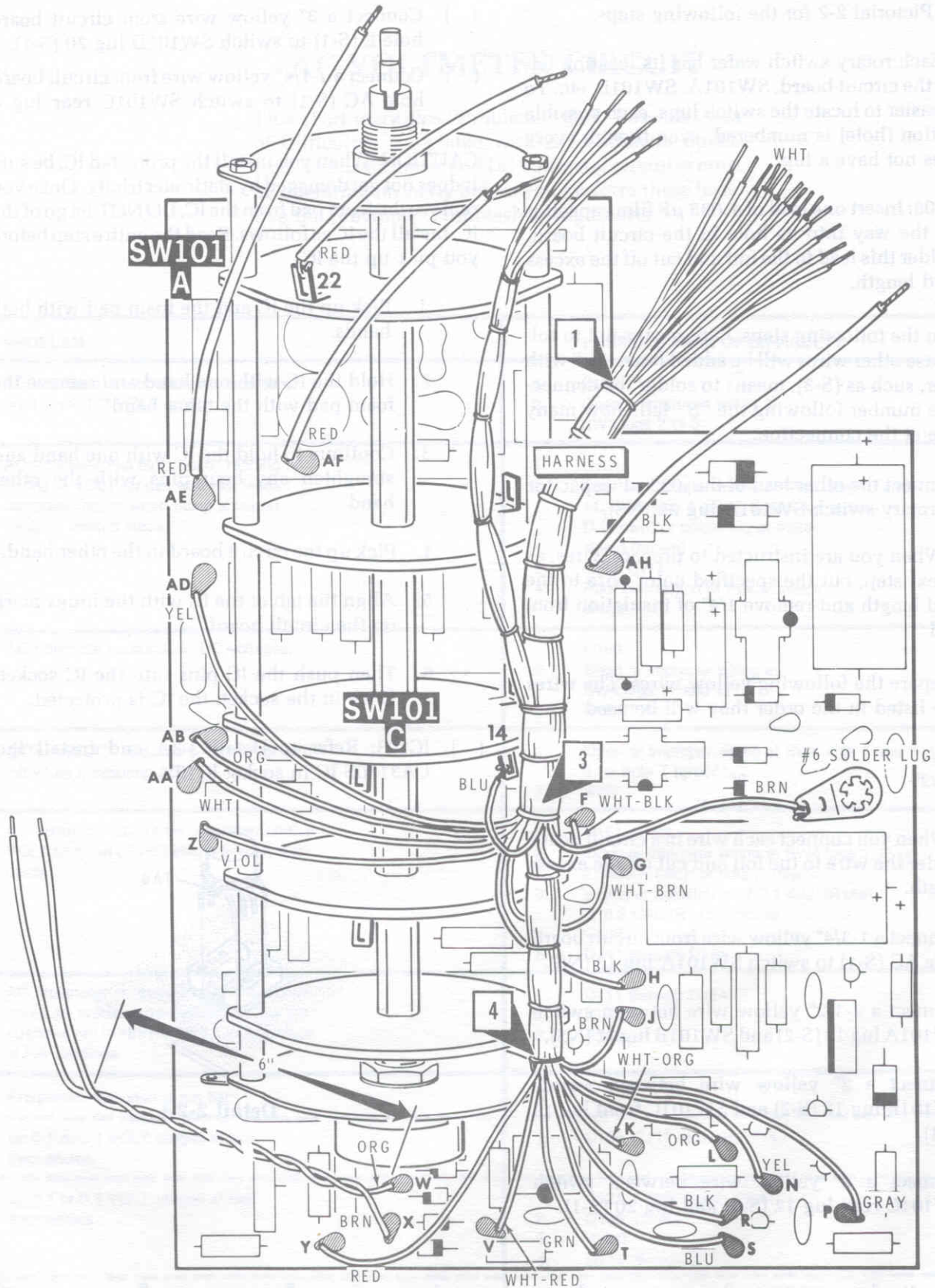
1. Pick up the IC and the foam pad with both hands.
2. Hold the IC with one hand and remove the foam pad with the other hand.
3. Continue to hold the IC with one hand and straighten any bent pins with the other hand.
4. Pick up the circuit board in the other hand.
5. Align the tab of the IC with the index mark on the circuit board.
6. Then push the IC pins into the IC socket. Once in the socket, the IC is protected.

- () IC103: Refer to Detail 2-2A and install the CA3130S IC in socket IC103.

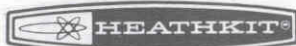


Detail 2-2A





PICTORIAL 3-1



HARNESS

Refer to Pictorial 3-1 for the following steps.

- () Straighten the harness and identify the break-outs (BO) of the harness. There is a white wire at BO#1 and BO#3.
- () Position the harness along the rotary switch (SW101) with BO#1 at the front end of the switch. The main trunk of the harness should be kept above the circuit board parallel to the spacers of switch SW101.
- () Connect the blue wire from BO#3 to switch SW101C lug 14 (S-1).
- () Connect the brown wire from BO#3 to a #6 solder lug (S-1). The solder lug will be mounted later.

Connect the harness wires from BO#3 to the circuit board holes as follows:

- () White-black wire to hole F.
- () White-brown wire to hole G.
- () Black wire to hole H.
- () Violet wire to hole Z.
- () White wire to hole AA.
- () Orange wire to hole AB.
- () Yellow wire to hole AD.

Connect the harness wires from BO#4 to the circuit board as follows:

- () Brown wire to hole J.
- () White-orange wire to hole K.
- () Orange wire to hole L.
- () Black wire to hole R.
- () Blue wire to hole S.

() Yellow wire to hole N.

() Gray wire to hole P.

() Green wire to hole T.

() White-red wire to hole V.

() Red wire to hole Y.

This completes the harness wiring to the circuit board. The remaining harness wires will be connected later.

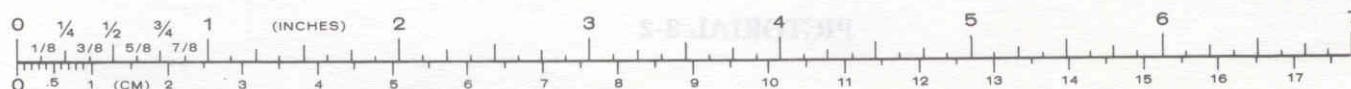
When you prepare **stranded** wire, cut the specified color wire to the indicated length and remove 1/4" of insulation from each end. Tightly twist the fine wire strands. Then melt a small amount of solder on the exposed wire ends to hold the fine wire strands together.

() Prepare the following stranded wires:

3-3/4" large red	7" large red	12-1/2" brown
5" large red	5" large black	12-1/2" orange

Connect only one end of each wire in the following six steps. Their free ends will be connected later.

- () One end of a 3-3/4" large red wire to switch SW101A lug 22 (S-2). If necessary, flatten the wire end so it will fit into the lug hole.
- () One end of a 5" large red wire to circuit board hole AF (S-1).
- () One end of a 7" large red wire to circuit board hole AE (S-1).
- () One end of a 5" large black wire to circuit board hole AH (S-1).
- () One end of an ^{12 1/2} 8-1/2" orange wire to circuit board hole W (S-1).
- () One end of an ^{12 1/2} 8-1/2" brown wire to circuit board hole X (S-1).
- () Tightly twist together the orange and brown wires to form a twisted pair for a length of 6" from the circuit board.

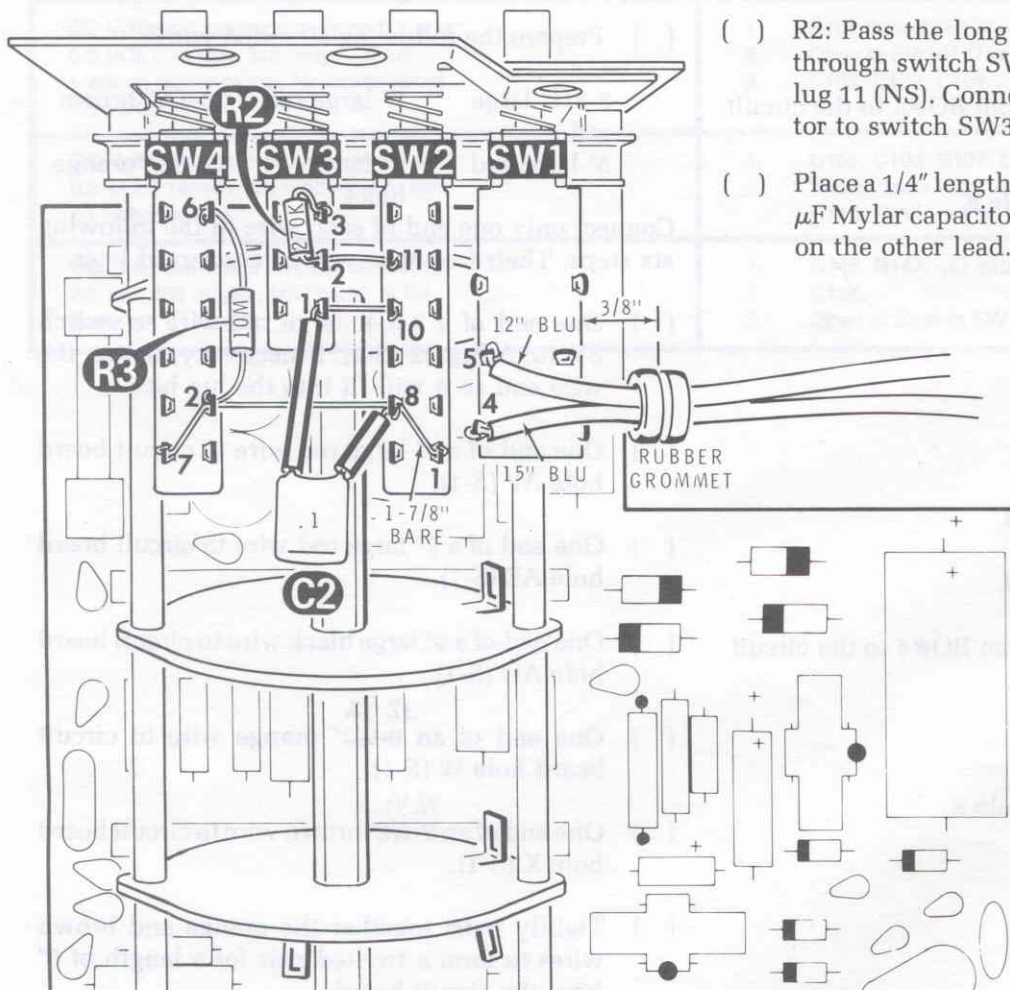


Refer to Pictorial 3-2 for the following steps.

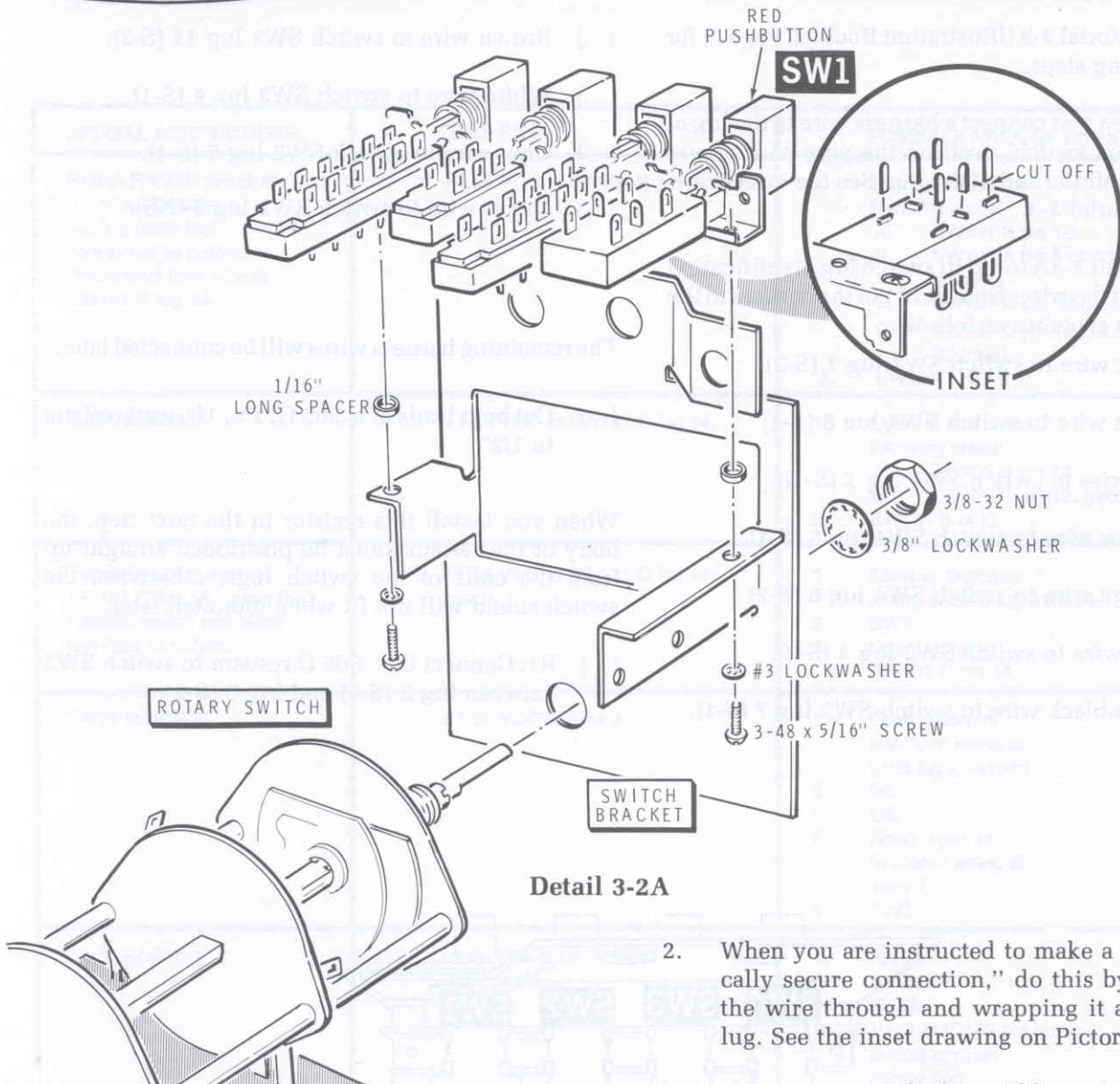
- () Locate the pushbutton switch assembly (#64-831).
- () Refer to the inset drawing on Detail 3-2A and cut off the six indicated lugs (not the ones with holes) from switch SW1 (the switch with the red pushbutton).
- () SW1, SW2, SW3, SW4: Refer to Detail 3-2A and mount the pushbutton switch assembly on the switch bracket with 3-48 × 5/16" screws and #3 lockwashers, and 1/16" long spacers. Be sure to position the switch with the red pushbutton as shown.
- () Refer to Detail 3-2A and temporarily mount the switch bracket on the rotary switch that is mounted on the circuit board. Use a 3/8" lockwasher and a 3/8-32 nut. Position the switch bracket up as shown.

NOTE: Where a wire passes through a connection and goes to another point, it will count as two wires in the solder instructions (S-2), one entering and one leaving the connection. Be sure, when you solder these connections, to apply enough heat to solder these "through wires."

- () Connect a 1-7/8" bare wire (use the yellow wire and remove all the insulation) from switch SW4 lug 7 (NS), through switch SW4 lug 2 (NS), through switch SW2 lug 8 (NS), to switch SW2 lug 1 (S-1).
- () Cut both leads of a 10 MΩ, 1/4-watt (brown-black-blue) resistor to 7/16".
- () R3: Connect this 10 MΩ resistor to switch SW4 between lug 2 (S-3) and lug 6 (NS).
- () Locate a 270 kΩ, 1/4-watt (red-violet-yellow) resistor and cut one lead to 5/8" and the other lead to 3/8".
- () R2: Pass the long lead of this 270 kΩ resistor through switch SW3 lug 2 (S-2) to switch SW2 lug 11 (NS). Connect the other lead of the resistor to switch SW3 lug 3 (NS).
- () Place a 1/4" length of sleeving on one lead of a .1 μF Mylar capacitor and a 1/2" length of sleeving on the other lead.



PICTORIAL 3-2



Detail 3-2A

() C2: Connect the lead of this capacitor with the shorter insulation to switch SW2 lug 8 (S-3). Pass the other lead through switch SW-3 lug 1 (S-2) to switch SW2 lug 10 (S-1).

() Prepare the ends of a 15" blue wire and a 12" blue wire.

NOTES:

1. When you connect a larger wire to the push-button switches, you may find it necessary to flatten the wire end with long-nose pliers so the wire end will fit into the lug hole.

2. When you are instructed to make a "mechanically secure connection," do this by inserting the wire through and wrapping it around the lug. See the inset drawing on Pictorial 3-2.

() Connect one end of a 15" blue wire to switch SW1 lug 4 (S-1). Make a mechanically secure connection. Lay the wire flat against the top of the switch. The other end will be connected later.

() Connect one end of a 12" blue wire to switch SW1 lug 5 (S-1). Make a mechanically secure connection. Lay the wire flat against the top of the switch. The other end will be connected later.

() Slide the rubber grommet onto these blue wires so the grommet is 3/8" from the indicated edge of the switch.



Refer to Pictorial 3-3 (Illustration Booklet, Page 3) for the following steps.

NOTE: When you connect a harness wire to the lug of a pushbutton switch, position the wire so it comes straight up off the end of the lug. See the inset drawing on Pictorial 3-3.

Refer to Detail 3-3A to aid in switch lug identification and connect the wires from BO#1 of the harness to the pushbutton switches as follows:

- () Black wire to switch SW4 lug 7 (S-2).
- () Green wire to switch SW4 lug 8 (S-1).
- () Red wire to switch SW4 lug 1 (S-1).
- () Yellow wire to switch SW4 lug 5 (S-1).
- () Orange wire to switch SW4 lug 6 (S-2).
- () Blue wire to switch SW3 lug 3 (S-2).
- () White-black wire to switch SW2 lug 7 (S-1).

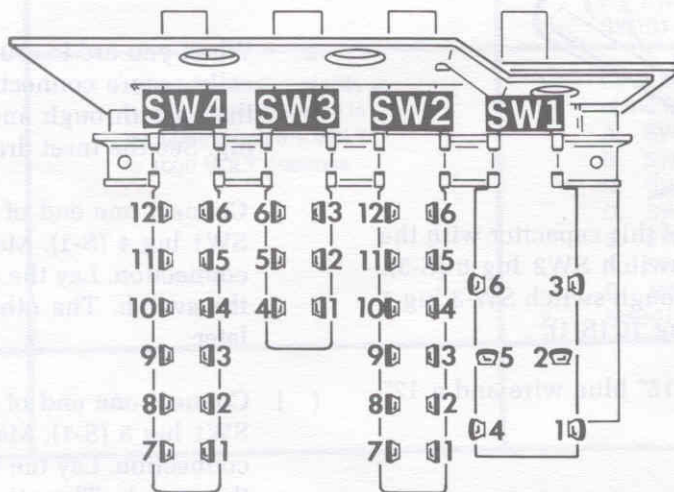
- () Brown wire to switch SW2 lug 11 (S-2).
- () White wire to switch SW2 lug 4 (S-1).
- () Gray wire to switch SW2 lug 5 (S-1).
- () Violet wire to switch SW2 lug 6 (NS).

The remaining harness wires will be connected later.

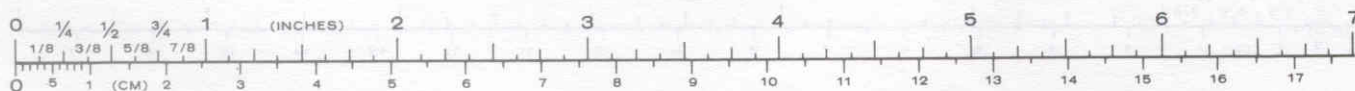
- () Cut both leads of a .505 Ω, 1%, 1/2-watt resistor to 1/2".

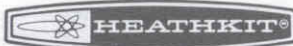
When you install this resistor in the next step, the body of the resistor must be positioned straight up from the ends of the switch lugs; otherwise, the switch shield will not fit when mounted later.

- () R1: Connect this .505 Ω resistor to switch SW2 between lug 2 (S-1) and lug 6 (S-2).



Detail 3-3A

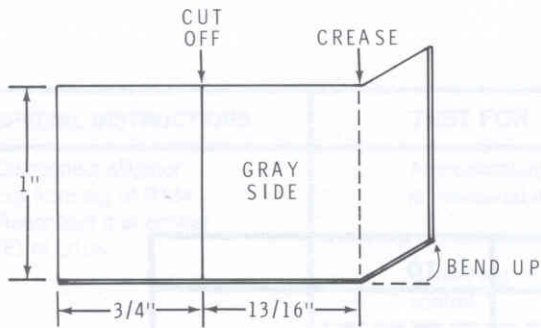




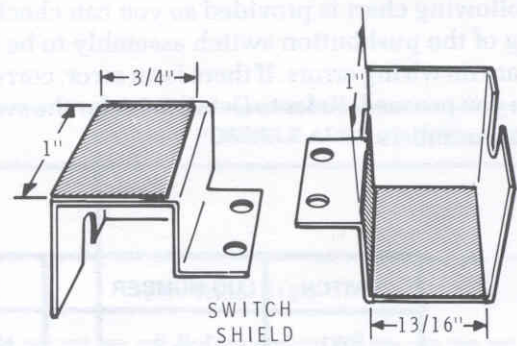
The following chart is provided so you can check the wiring of the pushbutton switch assembly to be sure there are no wiring errors. If there is an error, correct it before you proceed. Refer to Detail 3-3A for the switch and lug numbers.

SWITCH	LUG NUMBER	PART	TO
SW1	1, 2, 3	NC*	—
	4	Blue wire	NC
	5	Blue wire	NC
	6	NC	—
SW2	1	Bare wire	SW2 lug 8
	2	.505 Ω resistor	SW2 lug 6
	3	NC	—
	4	White wire	Harness
	5	Gray wire	Harness
	6	.505 Ω resistor	SW2 lug 2
	6	Violet wire	Harness
	7	White-black wire	Harness
	8	Bare wire	SW2 lug 1
	8	Bare wire	SW4 lug 2
	8	.1 μ F Mylar	SW3 lug 1
	9	NC	—
10	Bare wire	SW3 lug 1	
11	Bare wire	SW3 lug 2	
11	Brown wire	Harness	
12	NC	—	
SW3	1	Bare wire	SW2 lug 10
	1	.1 μ F Mylar	SW2 lug 8
	2	Bare wire	SW2 lug 11
	2	270 k Ω resistor	SW3 lug 3
	3	270 k Ω resistor	SW3 lug 2
	3	Blue wire	Harness
4,5,6	NC	—	
SW4	1	Red wire	Harness
	2	Bare wire	SW2 lug 8
	2	Bare wire	SW4 lug 7
	2	10 M Ω resistor	SW4 lug 6
	3,4	NC	—
	5	Yellow wire	Harness
	6	10 M Ω resistor	SW4 lug 2
	6	Orange wire	Harness
	7	Bare wire	SW4 lug 2
	7	Black wire	Harness
8	Green wire	Harness	
9, 10, 11, 12	NC	—	

*NC = No connection

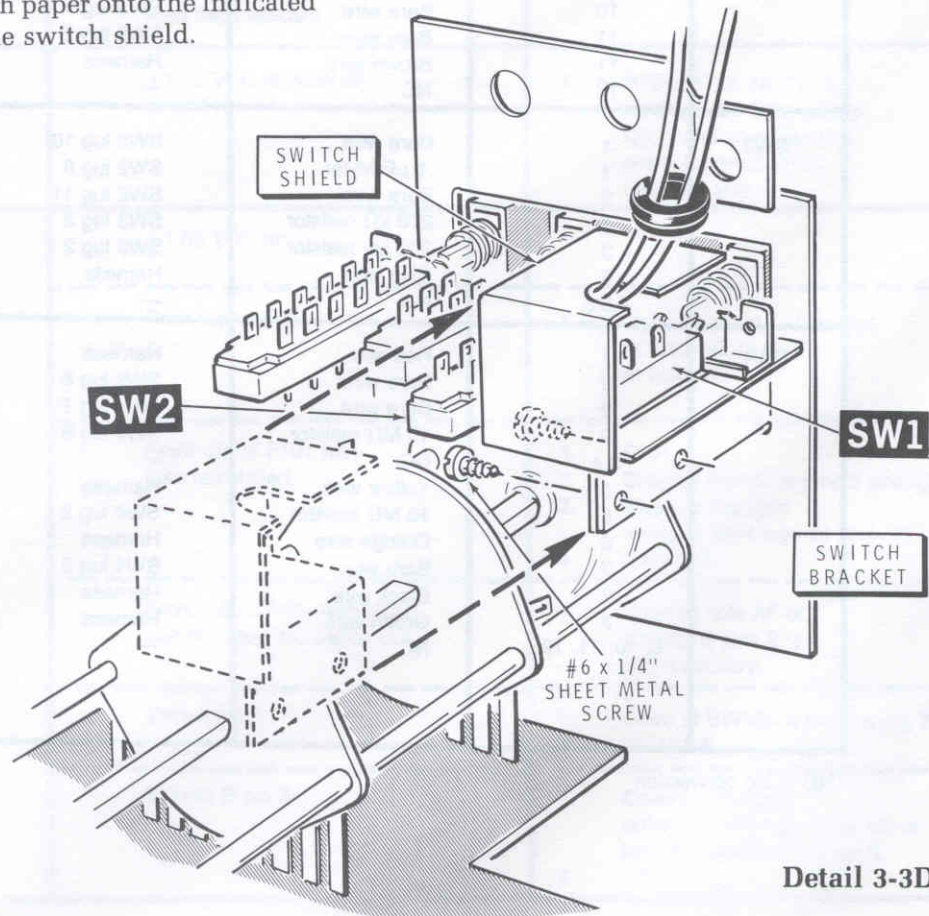


Detail 3-3B

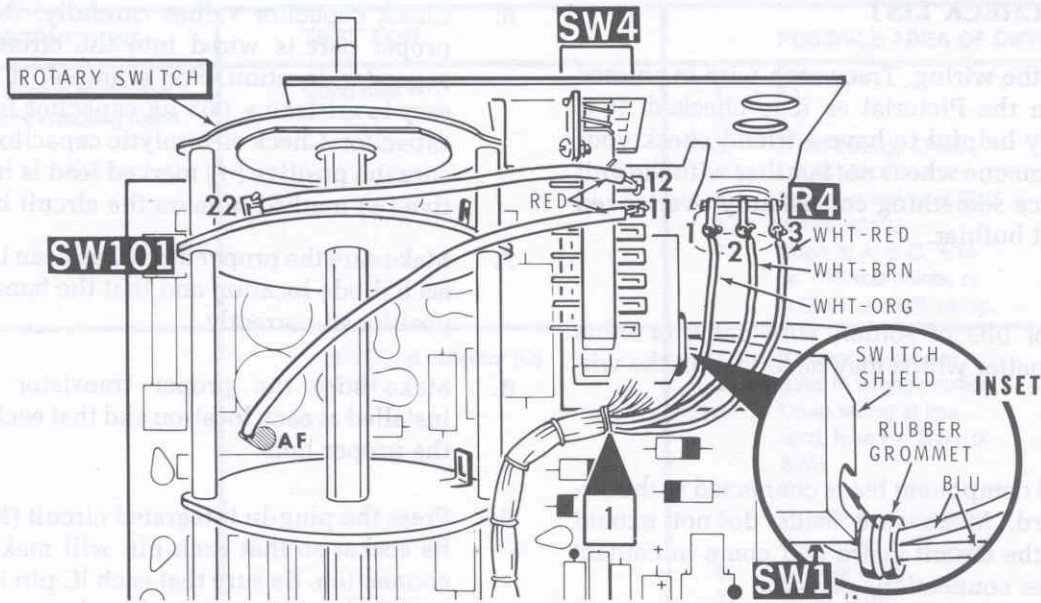
SWITCH
SHIELD

Detail 3-3C

- () Locate the 1" × 2" piece of fish paper and position its gray side up as shown Detail 3-3B. Then cut off a 3/4" × 1" piece.
- () Refer to Detail 3-3B and bend the remaining piece of fish paper to form a crease 13/16" from the indicated edge.
- () Refer to Detail 3-3C and remove the paper backing from the 3/4" × 1" piece of fish paper. Then press this piece of fish paper onto the indicated outside surface of the switch shield.
- () In the same manner, install the remaining piece of fish paper in the inside of the switch shield as shown in Detail 3-3C.
- () Refer to Detail 3-3D and slide the switch shield between switches SW1 and SW2 of the pushbutton switch assembly. Then secure the switch shield to the switch bracket with two #6 × 1/4" sheet metal screws. Hold the switch bracket so it does not bend.



Detail 3-3D



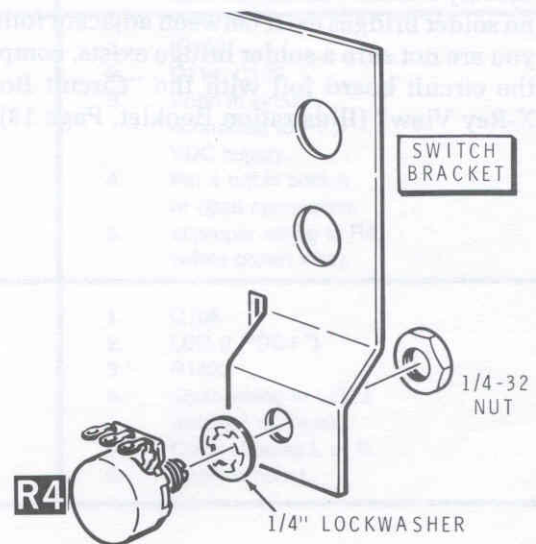
PICTORIAL 3-4

Refer to Pictorial 3-4 for the following steps.

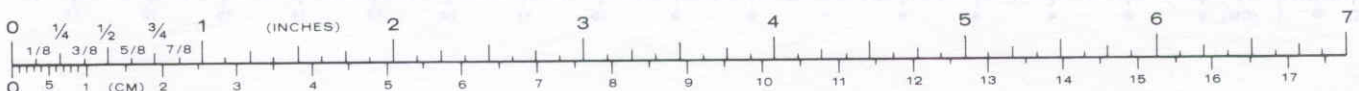
- () Loosen the nut on the front of the rotary switch and reposition the switch bracket as shown in Pictorial 3-4.
- () R4: Refer to Detail 3-4A and mount the 50 kΩ control (#10-1084) in the indicated hole in the switch bracket with a 1/4" lockwasher and a 1/4-32 nut. Position the control so its lugs are positioned as shown.
- () Connect the free end of the red wire coming from circuit board hole AF to switch SW4 lug 11 (S-1). Keep this wire tight against the top of the switch.
- () Connect the free end of the red wire coming from rotor switch SW101A lug 22 to switch SW4 lug 12 (S-1). Keep this wire tight against the top of the switch.
- () White-red wire to lug 3 (S-1).
- () Position the rubber grommet, on the blue wires coming from switch SW1, into the notch in the switch shield.
- () Twist these blue wires together to form a twisted pair. Their free ends will be connected later.

Connect the remaining wires from BO#1 of the harness to control R4 as follows:

- () White-orange wire to lug 1 (S-1).
- () White-brown wire to lug 2 (S-1).



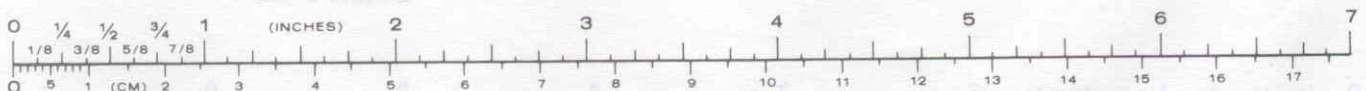
Detail 3-4A



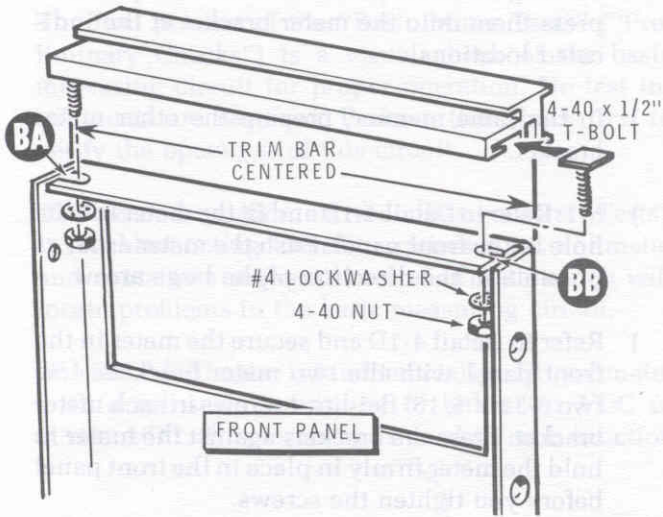
ASSEMBLY CHECK LIST

1. Recheck the wiring. Trace each wire in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the kit builder.
2. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the wiring.
3. Check all component leads connected to the circuit board. Make sure leads do not extend through the circuit board and come in contact with other connections or parts.
4. About 90% of the kits that are returned for repair do not function properly because of poor soldering. Therefore, many troubles can be corrected by careful inspection of connections to make sure they are properly soldered. Reheat any doubtful connections.
5. Closely examine the circuit board foil to see that no solder bridges exist between adjacent foils. If you are not sure a solder bridge exists, compare the circuit board foil with the "Circuit Board X-Ray View" (Illustration Booklet, Page 13).
6. Check capacitor values carefully. Be sure the proper part is wired into the circuit at each capacitor location. For example, it would be easy to mistake a $.005 \mu\text{F}$ capacitor for a $.05 \mu\text{F}$ capacitor. Check electrolytic capacitors to make sure the positive (+) marked lead is in the positive (+) marked hole on the circuit board.
7. Make sure the proper diode has been installed at each diode location and that the banded end is positioned correctly.
8. Make sure the proper transistor has been installed at each location and that each lead is in the proper hole.
9. Press the plug-in integrated circuit (IC103) into its socket so that each pin will make a secure connection. Be sure that each IC pin is properly installed in its socket and not bent out or under the IC.
10. Check each IC to make sure its tab or index mark end matches the index mark on the circuit board.
11. Check the values of the parts. Make sure the proper part has been wired into the circuit at each location. For example, a 900Ω resistor could easily be installed in place of a 9000Ω . NOTE: If a resistor appears darkened (from possible overheating during soldering) and you have an ohmmeter available, measure the resistance. (CAUTION: Once the meter movement has been wired into the kit, **be sure** you disconnect one of its leads before you make any resistance checks.)

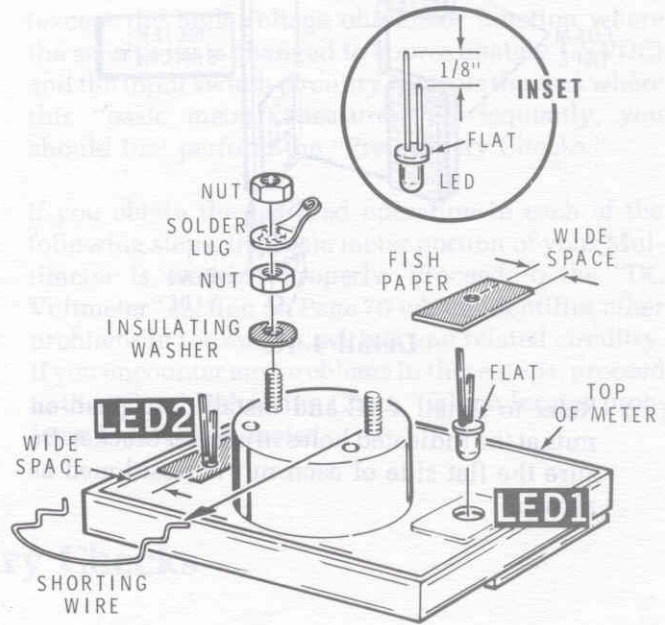
Set the circuit board assembly aside temporarily.



FRONT PANEL



Detail 4-1A



Detail 4-1B

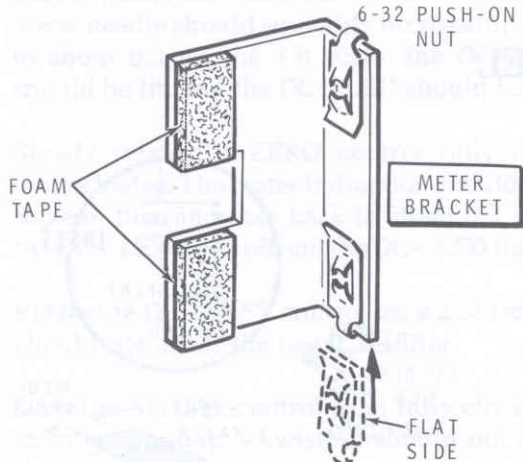
Refer to Pictorial 4-1 (Illustration Booklet, Page 3) for the following steps.

- () Place a soft cloth on your work area to keep the front panel from getting scratched.
- () Refer to Detail 4-1A and install 4-40 × 1/2" "T" bolts in slots BA and BB of the front panel with a #4 lockwasher, and a 4-40 nut. Only start the nuts on the bolts at this time.
- () Slide the trim bar onto the square heads of the "T" bolts. Position the ends of the trim bar even with the sides of the front panel and tighten the nuts on the T bolts.

Refer to Detail 4-1B for the following steps.

- () Carefully unpack the meter and position it face down on the soft cloth.
- () Remove and discard the shorting wire from between the meter bolts.
- () Remove and save both nuts, solder lug, and insulating washer from each meter bolt.

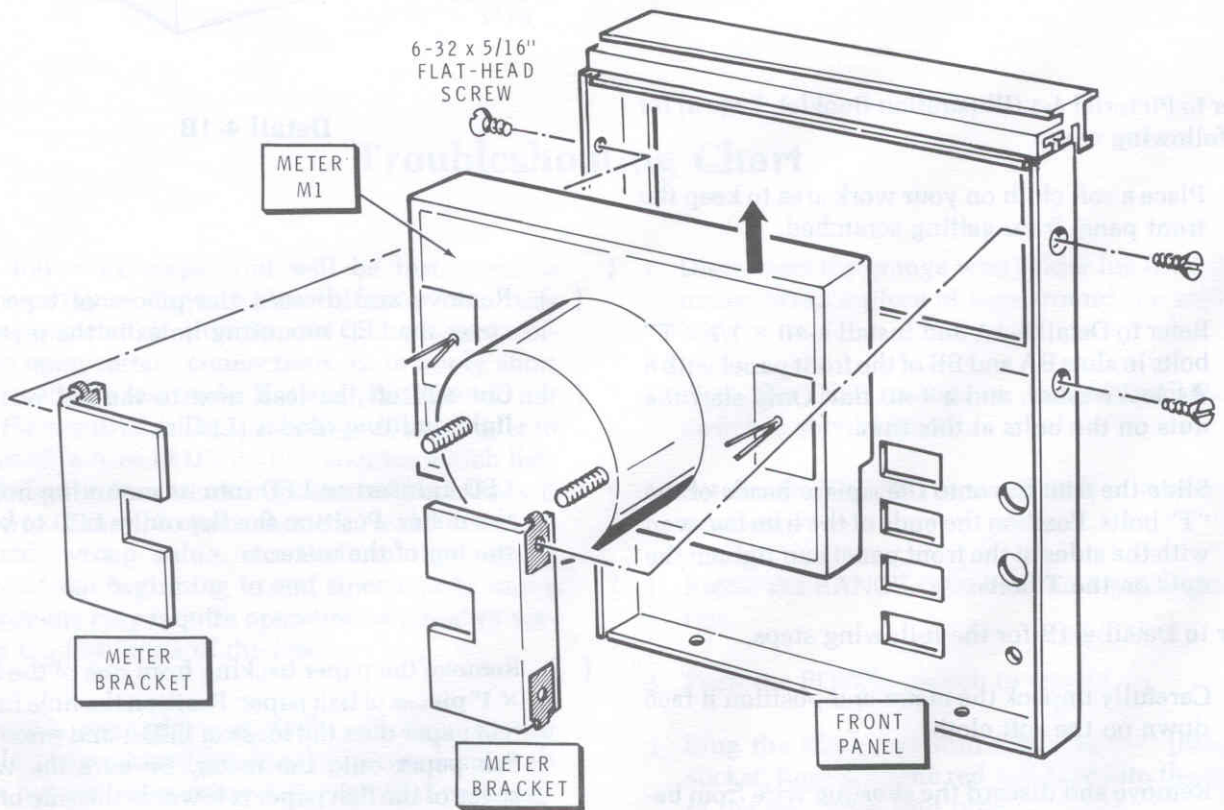
- () Remove and discard the pieces of tape that cover the LED mounting holes in the meter.
- () Cut 1/8" off the lead next to the flat on both light-emitting diodes (LED's).
- () LED 1: Insert an LED into its mounting hole in the meter. Position the flat of the LED towards the **top** of the meter.
- () Remove the paper backing from one of the 3/4" × 1" pieces of fish paper. Position the hole in the fish paper over the leads of LED 1 and press the fish paper onto the meter. Be sure the wide space of the fish paper is towards the side of the meter.
- () LED2: In the same manner, install an LED in the other hole in the meter.



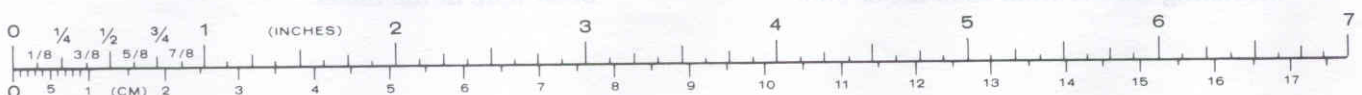
Detail 4-1C

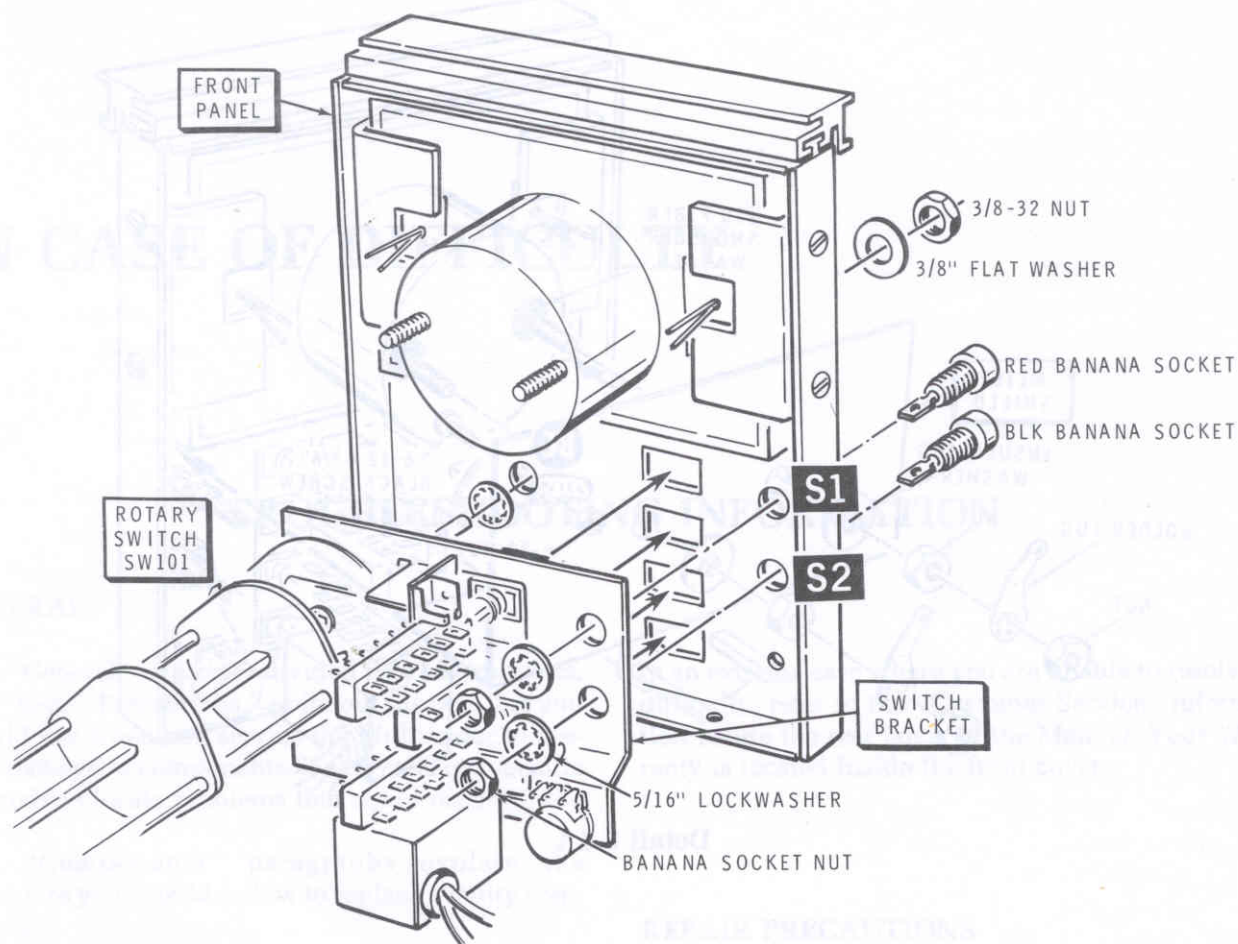
- () Refer to Detail 4-1C and install 6-32 push-on nuts at the indicated holes in a meter bracket. Be sure the flat side of each nut is positioned as shown.

- () Cut four 3/4" long pieces from the length of foam tape.
- () Refer to Detail 4-1C and remove the protective backing from two pieces of the foam tape. Then press them onto the meter bracket at the indicated locations.
- () In the same manner, prepare the other meter bracket.
- () M1: Refer to Detail 4-1D and fit the meter into its hole in the front panel. Push the meter as far as possible in the direction of the large arrow.
- () Refer to Detail 4-1D and secure the meter in the front panel with the two meter brackets. Use two 6-32 x 5/16" flat-head screws in each meter bracket. Press the brackets against the meter to hold the meter firmly in place in the front panel before you tighten the screws.



Detail 4-1D





Detail 4-1E

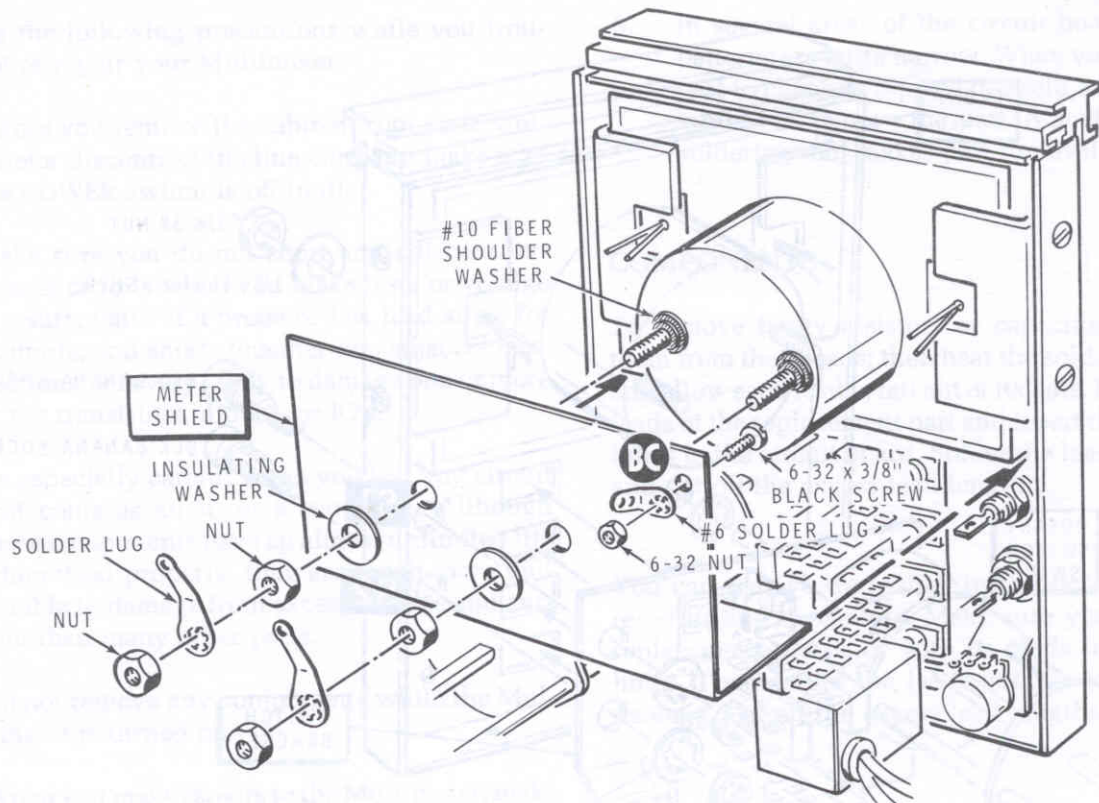
Refer to Detail 4-1E for the following steps.

- () Remove the nut from rotary switch SW101.
- () Fit the pushbutton knobs and the rotary switch bushing into their respective holes in the front panel.
- () Install a 3/8" flat washer and a 3/8-32 nut on the bushing of rotary switch SW101. Do not tighten the nut at this time.
- () S1: Install a red banana socket at S1 in the front panel and the switch bracket with a 5/16" lockwasher and the nut from the banana socket. Do not tighten the nut at this time.

- () S2: In the same manner, install a black banana socket at S2 in the front panel and the switch bracket.
- () Check to see that all four of the pushbuttons operate freely in their front panel holes. If not, move the switch bracket until the pushbuttons are centered. Then tighten the nut on the rotary switch.

NOTE: When you tighten the nuts on the banana sockets in the next step, be sure the tool you use does not slip and damage the banana sockets or adjacent parts. Do not overtighten the nuts or the sockets will be damaged.

- () Tighten the nuts on banana sockets S1 and S2.



Detail 5-1A

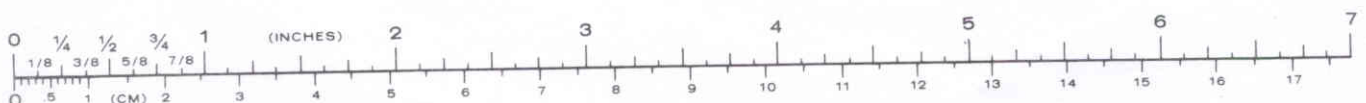
Refer to Pictorial 5-1 (Illustration Booklet, Page 3) for the following steps.

- () FB1, FB2: Pass the free end of the large black wire coming from circuit board hole AH through one hole of two large ferrite beads. Then connect this wire to banana socket S2 (S-1).
- () Pass the free end of the large red wire (coming from circuit board hole AE) through the other hole of the two ferrite beads just installed on the large black wire. Then connect this wire to banana socket S1 (S-1).
- () Place a 1" length of sleeving on each of the blue, orange, yellow, and black wires coming from BO#2 of the harness. Push the sleeving as far as possible onto each wire.

CAUTION: When you work with the LED's in the following steps, avoid bending their leads near the body of the LED, as the leads can be easily broken.

- () Refer to the inset drawing in Pictorial 5-1 and bend a small hook in the end of both leads of LED1 and LED2.
- () In the same manner, bend a small hook in the end of each of the four harness wires that have the sleeving on them.

When you connect a wire from BO#2 of the harness to the lead of an LED, bend the hook in the wire and the hook in the LED lead closed. Make these connections as small as possible so the sleeving will fit over the



connections. Solder the connection. Then after the connection has cooled, push the sleeving over the connection and tight against the rear of the meter.

- () Connect the yellow harness wire to the longer lead of LED 1 (S-1).
- () Connect the black harness wire to the shorter lead of LED 1 (S-1).
- () Connect the blue harness wire to the longer lead of LED 2 (S-1).
- () Connect the orange harness wire to the shorter lead of LED 2(S-1).

NOTE: Use a black screw and/or black lockwasher only when specifically called for in a step.

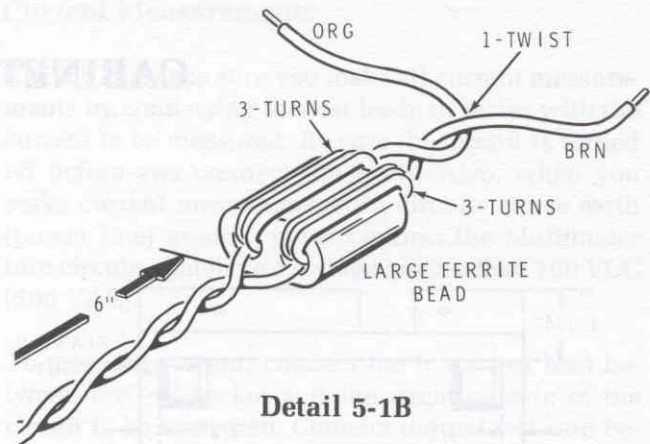
- () Refer to Detail 5-1A and install a #6 solder lug at BC on the meter shield with a 6-32 × 3/8" black screw and a 6-32 nut.

Refer to Detail 5-1A and install the meter shield on the meter as follows:

- () Place a #10 fiber shoulder washer (with the shoulder out) onto each meter bolt.
- () Carefully slip the meter shield under the wires from BO#2 of the harness and onto the meter bolts. Be sure no wires are pinched between the meter shield and the front panel.
- () Place an insulating washer (supplied with the meter) on each bolt.
- () Install and tighten a nut (supplied with the meter) onto each meter bolt. Be sure the shoulder of each fiber washer is centered in its hole of the meter shield.
- () Install a solder lug and nut (supplied with the meter) onto each meter bolt. Position the solder lugs as shown.

Refer to Pictorial 5-1 for the following steps.

- () Connect the free end of the brown wire coming from BO#2 of the harness to solder lug BC on the meter shield (S-1).



Detail 5-1B

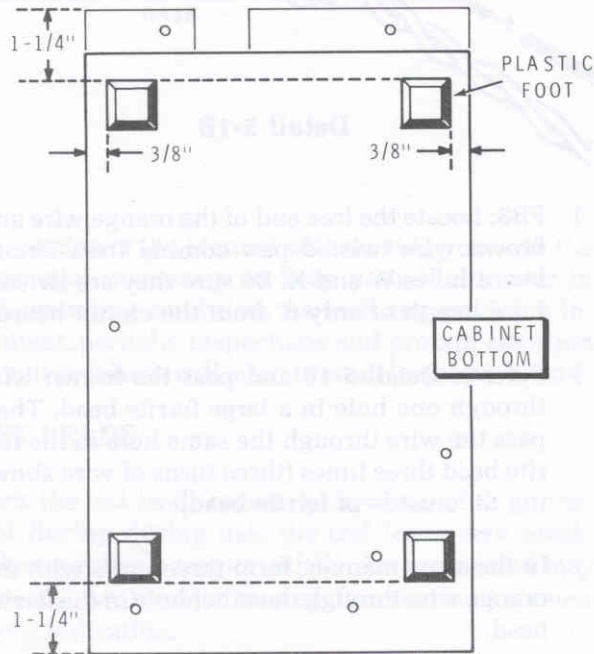
- () FB3: Locate the free end of the orange wire and brown wire twisted pair coming from circuit board holes W and X. Be sure they are twisted for a length of **only** 6" from the circuit board.
- () Refer to Detail 5-1B and pass the brown wire through one hole in a large ferrite bead. Then pass the wire through the same hole in the ferrite bead three times (three turns of wire showing on outside of ferrite bead).
- () In the same manner, form three turns with the orange wire through the other hole in the ferrite bead.
- () Twist these wires one complete twist where they come out of the ferrite bead as shown in Detail 5-1B.

Connect the free ends of these brown and orange twisted wires to the meter solder lugs as follows:

- () Orange wire to meter M1 positive (+) lug (S-1).
- () Brown wire to meter M1 negative (-) lug (S-1).
- () Prepare a 1-1/2" brown wire.
- () Connect one end of this wire to the solder lug on the rear of rotary switch SW101 (S-1).
- () Connect the other end of this brown wire to a #6 solder lug (S-1). This solder lug will be mounted later.

Set the circuit board-front panel assembly aside temporarily.

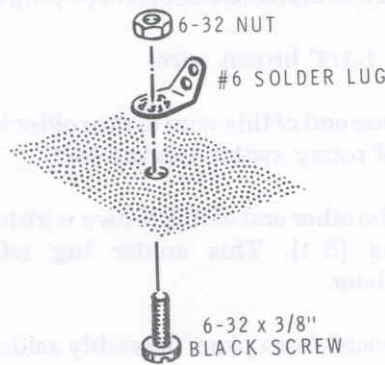
CABINET BOTTOM



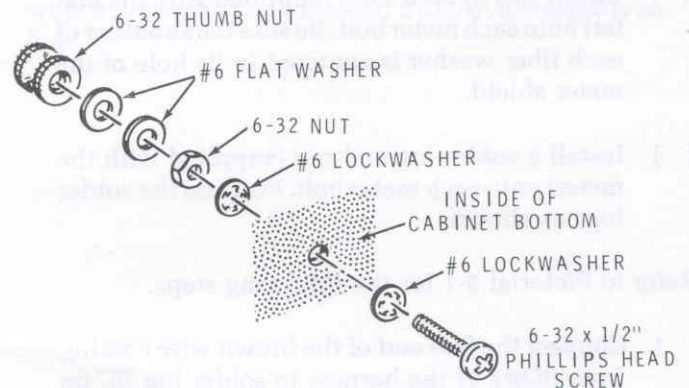
Detail 6-1A

Refer to Pictorial 6-1 (Illustration Booklet, Page 4) for the following steps.

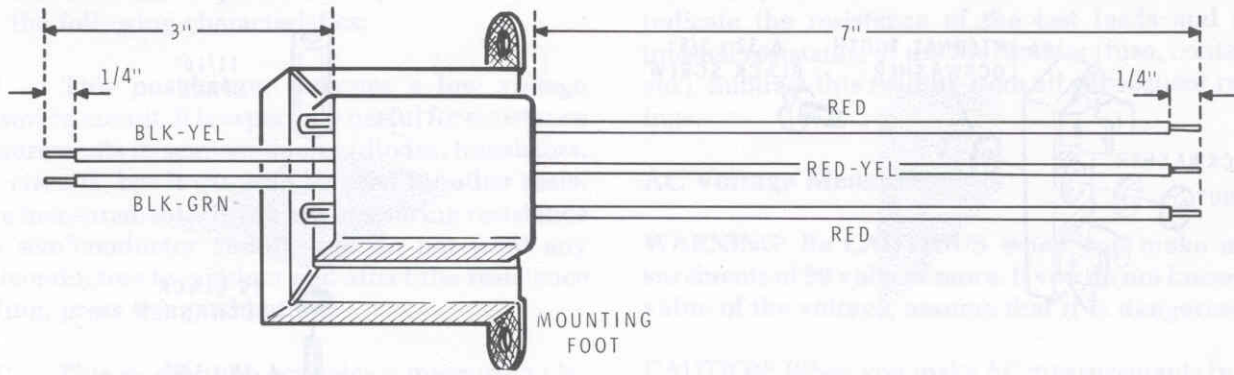
- () Refer to Detail 6-1A and remove the protective backing from the four plastic feet. Then press the feet onto the bottom of the cabinet bottom at the indicated locations.
- () Scrape or sandpaper any paint off the six areas on the top of the cabinet bottom indicated by the large arrows. This is to provide a good electrical contact between the cabinet bottom and the parts mounted at these locations.
- () Refer to Detail 6-1B and mount a #6 solder lug at CB with a 6-32 x 3/8" black screw and a 6-32 nut.
- () Refer to Detail 6-1C and mount a 6-32 x 1/2" phillips head screw at CA with **two** #6 lockwashers and a 6-32 nut. Securely tighten this hardware.
- () Install two #6 flat washers and the 6-32 thumb nut only finger tight on screw CA.



Detail 6-1B

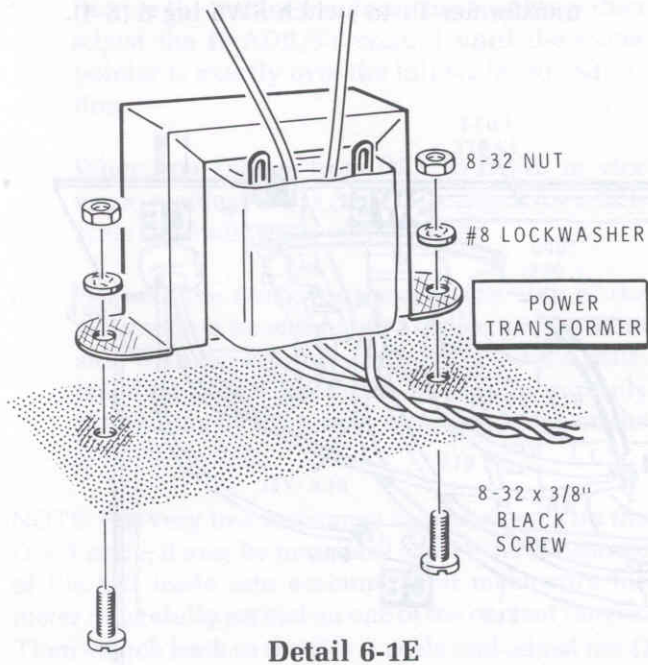


Detail 6-1C

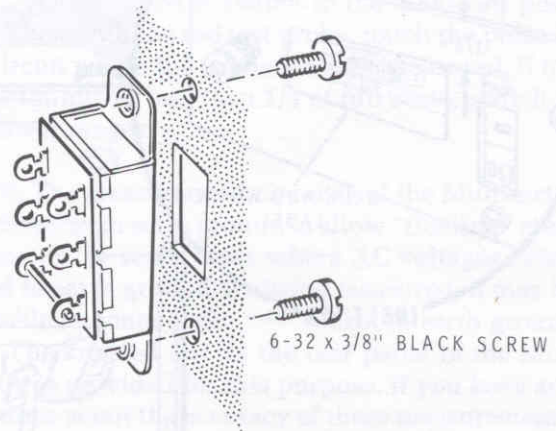


Detail 6-1D

- () Refer to Detail 6-1D and cut the leads of the power transformer (#54-934) to the indicated lengths. Measure from where the leads come out of the transformer. Remove 1/4" of insulation from each lead end. If any of the exposed lead ends do not have solder on them, melt a small amount of solder on them to hold the fine wire strands together.
- () Twist together the two red and the red-yellow wires.
- () Scrape or sandpaper any coating off both sides of each power transformer mounting foot.
- () T1: Refer to Detail 6-1E and mount the power transformer at T1 with 8-32 × 3/8" black screws, #8 lockwashers, and 8-32 nuts.
- () SW5: Refer to Detail 6-1F and mount the slide switch at SW5 with 6-32 × 3/8" black screws. Position the lugs with the wire connected between them as shown in Pictorial 6-1.

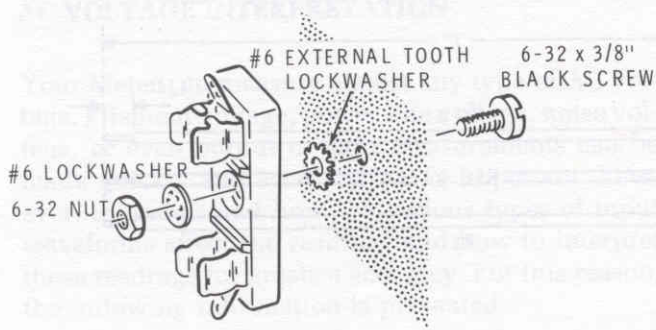


Detail 6-1E

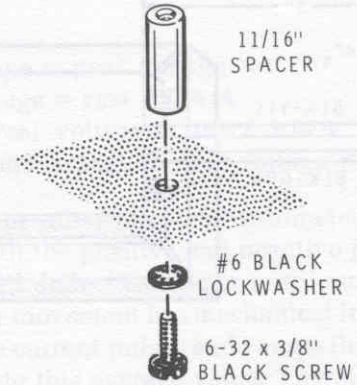


Detail 6-1F





Detail 6-1G



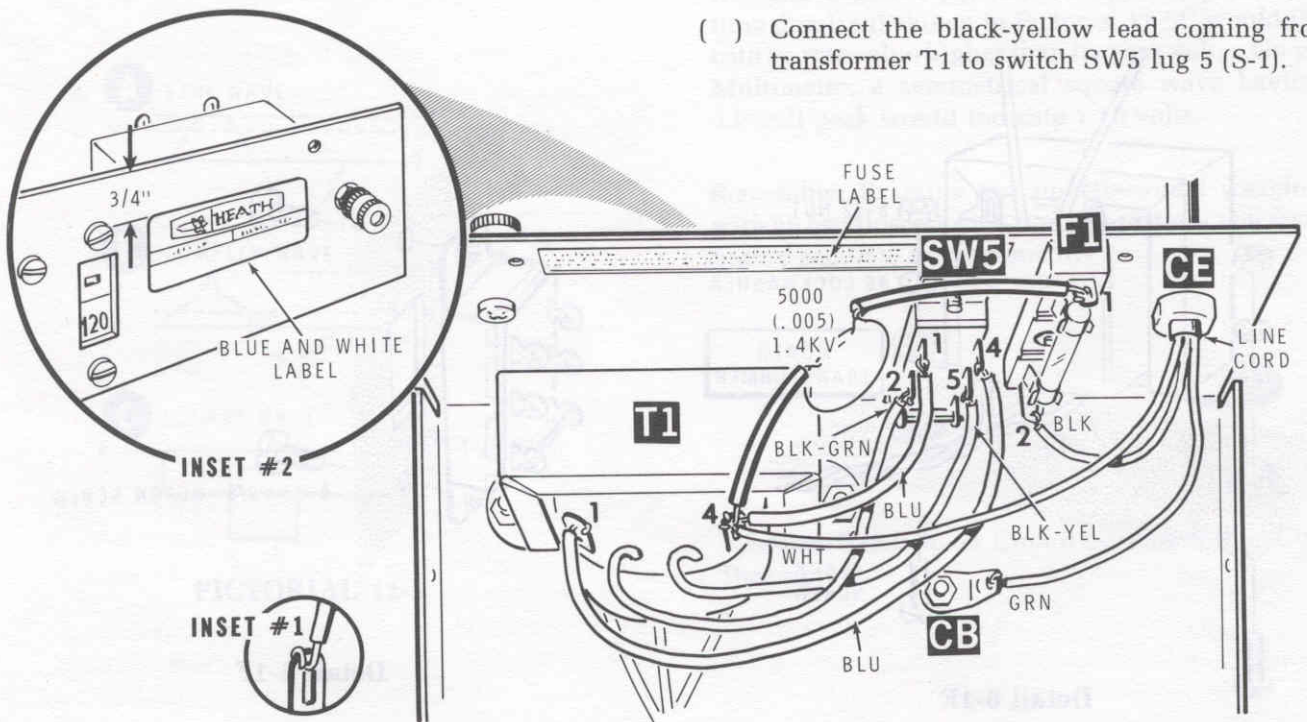
Detail 6-1H

- () Refer to Detail 6-1G and mount the fuse block at F1 with a 6-32 x 3/8" black screw, a #6 external tooth lockwasher, a #6 lockwasher, and a 6-32 nut.
- () Refer to Detail 6-1H and mount an 11/16" spacer at CC with a 6-32 x 3/8" black screw and a #6 black lockwasher.
- () In the same manner, mount an 11/16" spacer at CD.

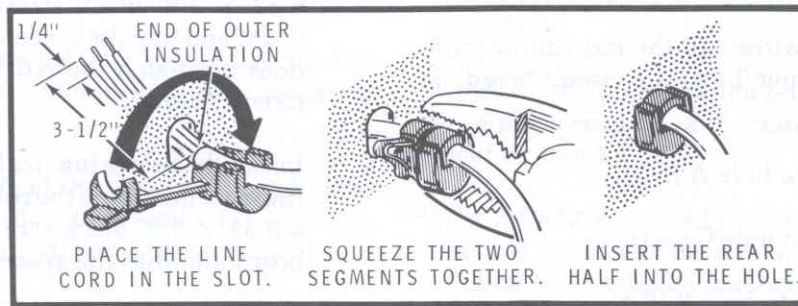
Refer to Pictorial 6-2 for the following steps.

NOTE: All the connections in this Pictorial must be "mechanically secure connections." To make a "mechanically secure connection," insert the lead or wire through the hole in the lug and wrap the lead or wire around the lug as shown in inset drawing #1 on Pictorial 6-2.

- () Connect the black-green lead coming from transformer T1 to switch SW5 lug 2 (S-1).
- () Connect the black-yellow lead coming from transformer T1 to switch SW5 lug 5 (S-1).

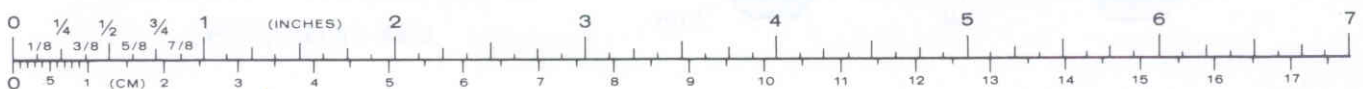


PICTORIAL 6-2



Detail 6-2A

- () Prepare a 2-1/2" blue wire and a 3-3/4" blue wire.
- () Connect a 2-1/2" blue wire from transformer T1 lug 4 (NS) to switch SW5 lug 1 (S-1).
- () Connect a 3-3/4" blue wire from transformer T1 lug 1 (NS) to switch SW5 lug 4 (S-1).
- () Locate the line cord. Refer to Detail 6-2A and carefully remove enough outer insulation to expose 3-1/2" of the inner wires. Do not cut the insulation on the inner wires. Then cut off any strings even with the end of the outer insulation.
- () Twist the fine wire ends and melt a small amount of solder on the exposed wire ends.
- () Refer to Detail 6-2A and install the line cord strain relief on the end of the outer insulation of the line cord. Then insert the end of the line cord through hole CE and install the line cord strain relief in the hole.
- () Connect the black wire of the line cord to fuse block F1 lug 2 (S-1).
- () Connect the green wire of the line cord to solder lug CB (S-1).
- () Connect the white wire of the line cord to transformer T1 lug 4 (NS).
- () Cut both leads of a 5000 pF (.005) 1.4kV ceramic capacitor to 1-1/4".
- () Place a 1" length of sleeving on each lead of this capacitor.
- () C1: Connect this capacitor from transformer T1 lug 4 (S-3) to fuse block F1 lug 1 (NS).
- () Locate the fuse label and write "1/16-ampere" "slow-blow" in the spaces provided.
- () Remove the paper backing from the fuse label and press the label on the inside of the cabinet bottom at the location shown in Pictorial 6-2.
- () F1: Install the 1/16-ampere slow-blow fuse in fuse block F1.
- () Carefully peel the paper backing from the blue and white label. Refer to inset drawing #2 on Pictorial 6-2 and press this label onto the outside rear of the cabinet bottom. Position the label 3/4" from the top edge. Be sure to refer to the numbers on this label in any communication you have with the Heath Company about this kit.
- () Set switch SW5 to match the line voltage (either 120VAC or 240VAC) used in your area.



Refer to Pictorial 7-1 (Illustration Booklet, Page 4) for the following steps.

Connect the two red wires and the red-yellow wire coming from transformer T1 to the circuit board as follows:

- () Either red wire to hole A (S-1).
- () Other red wire to hole C (S-1).
- () Red-yellow wire to hole B (S-1).
- () Loosen the nut that holds the rotary switch to the front panel.
- () Refer to the inset drawing on Pictorial 7-1 and fit the front edge of the cabinet bottom over the bottom lip of the front panel.
- () Position the twisted blue wires coming from the switch shield under the circuit board so they are between the side lip of the cabinet bottom and the spacer at D. These wires should extend from under the rear edge of the circuit board.
- () Secure the front panel to the cabinet bottom with two 6-32 × 3/8" self-tapping screws.

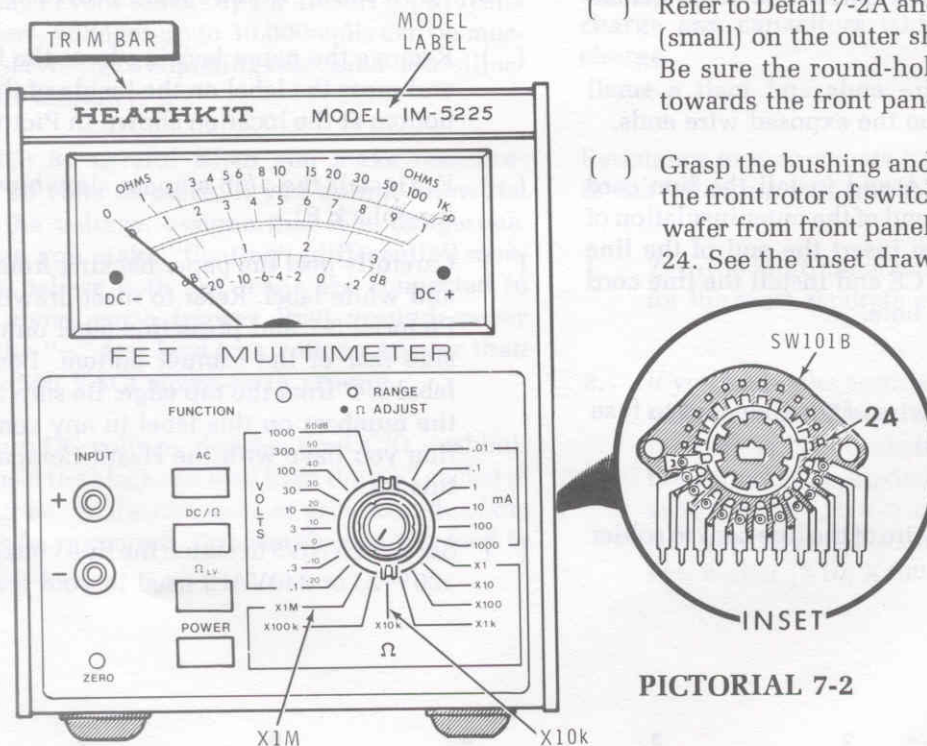
- () Install the solder lug, with the brown harness wire attached, at D, on the circuit board, with a 6-32 × 3/8" black screw through the circuit board and into the spacer. Be sure the solder lug does not touch the red lead in hole C in the circuit board.
- () Install the solder lug, with the brown wire coming from the rear of the rotary switch, at CC with a 6-32 × 3/8" black screw through the circuit board and into the spacer.
- () Tighten the nut that mounts the rotary switch to the front panel.

Connect the free ends of the twisted blue wires coming from the switch shield as follows:

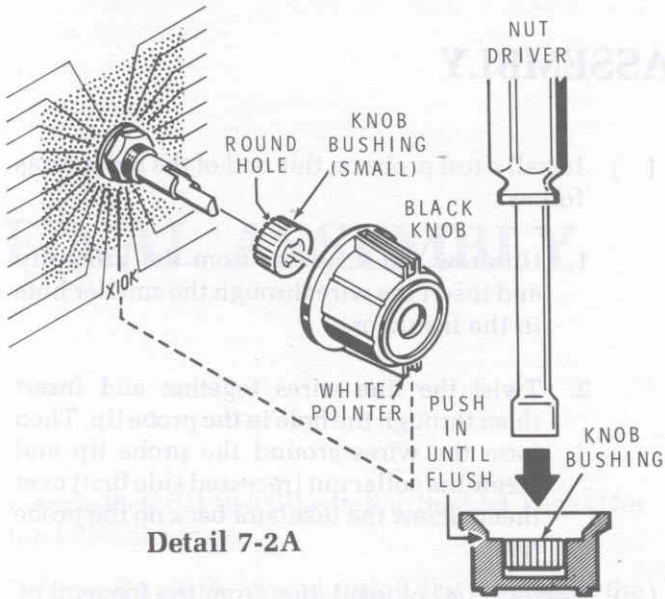
- () Shorter blue wire to transformer T1 lug 1 (S-2). Make a mechanically secure connection.
- () Longer blue wire to fuse block F1 lug 1 (S-2). Make a mechanically secure connection.

Refer to Pictorial 7-2 for the following steps.

- () Remove the backing paper from the model label and press the label in place in the space provided on the trim bar.
- () Refer to Detail 7-2A and place the knob bushing (small) on the outer shaft of the Range switch. Be sure the round-hole side of the bushing is towards the front panel.
- () Grasp the bushing and rotate it until the tab on the front rotor of switch wafer SW101B (second wafer from front panel) is in lug (hole) position 24. See the inset drawing on Pictorial 7-2.



PICTORIAL 7-2

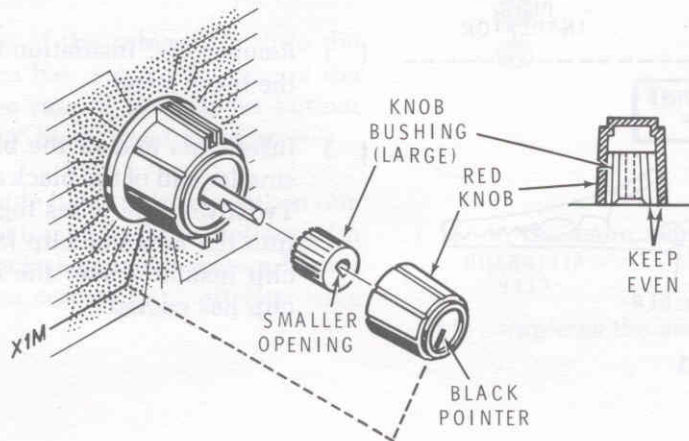


Detail 7-2A

- () Align the white pointer of the black knob **exactly** with the "X10k" line on the front panel and press the knob onto the bushing.
- () Carefully remove the knob and bushing together so the bushing **does not** move in the knob.
- () Refer to Detail 7-2A and place the knob bushing-side **up** on your work surface. Then use a nut driver, or other suitable tool, and push the bushing down into the knob until the bushing is even with the inner ledge in the knob.

- () Replace the knob on the Range switch shaft so its white pointer is in line with the X10k line on the front panel.
- () Refer to Detail 7-2B and place the knob bushing (large) on the inner shaft of the Range switch. The large-hole side must be towards the front panel.
- () Turn the bushing fully counterclockwise.
- () Align the black pointer on the red knob with the X1M line on the front panel.
- () Push the knob only part way onto the bushing.
- () Remove the red knob with its bushing together so the bushing does not turn in the knob.
- () Refer to Detail 7-2B and place the knob bushing-side **down** on your work surface. Then push knob down onto the bushing. The end of the bushing should be even with the edge of the knob.
- () Reinstall the red knob onto the inner shaft of the Range switch.

Except for the "Test Lead Assembly" and "Final Assembly", this completes the assembly of your Multimeter. Carefully check to see that all connections are soldered and that there are no wire ends touching each other or any metal parts. Shake out any solder splashes or wire clippings.

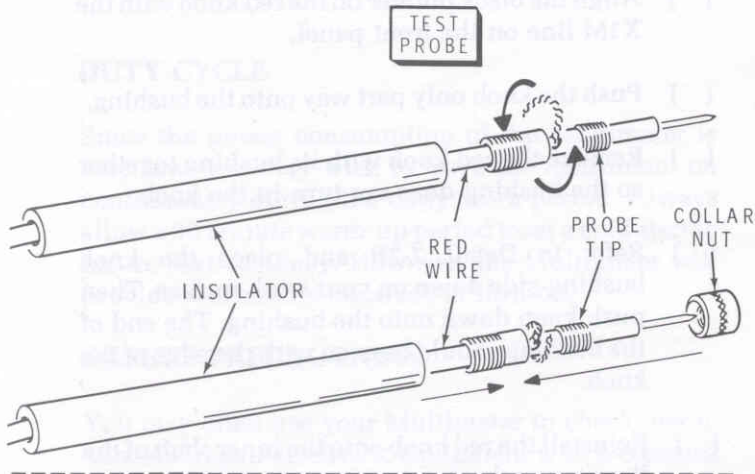


Detail 7-2B

TEST LEAD ASSEMBLY

Refer to Pictorial 8-1 for the following steps.

- () Remove 1/2" of insulation from one end of the remaining red wire.



- () Install a test probe on this end of the red wire as follows:

1. Unscrew the insulator from the probe tip and insert the wire through the smaller hole in the insulator.
2. Twist the fine wires together and insert them through the hole in the probe tip. Then form the wires around the probe tip and screw the collar nut (recessed side first) over them. Screw the insulator back on the probe tip.

- () Remove 3/4" of insulation from the free end of the red wire.

- () Insert this end of the red wire into a banana plug as shown. Then bend the wire flat against the plug body.

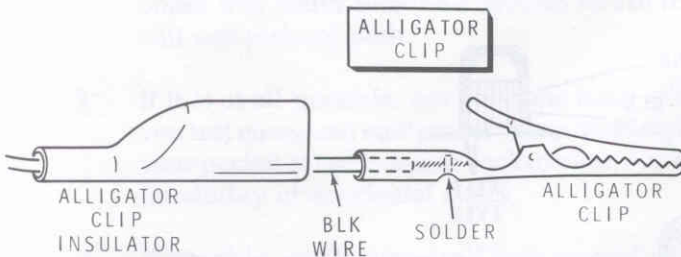
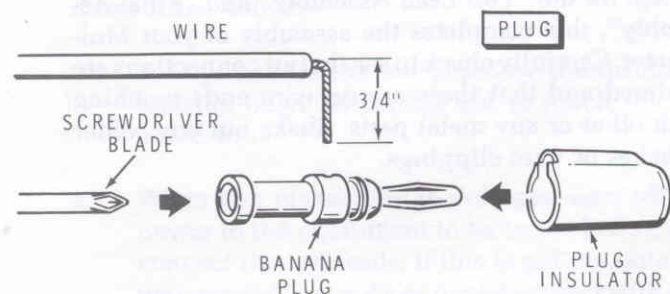
- () Place the banana plug on a small phillips screwdriver (or similar tool) and push a red plug insulator onto the plug and wire until the plug is fully seated.

- () Remove 3/4" insulation from one end of the remaining black wire.

- () In the same manner, install a banana plug and black plug insulator on this end of the black wire.

- () Remove 1/4" insulation from the "free" end of the black wire.

- () Insert this end of the black wire through the smaller end of the black alligator clip insulator. Twist the fine wires together and insert them into the alligator clip (S-1). Slip the alligator clip insulator over the alligator clip after the clip has cooled.



PICTORIAL 8-1





INITIAL TESTS

Refer to Pictorial 9-1 (Illustration Booklet, Page 5) for the location of the front panel switches and controls.

The purpose of this section is to make sure your Multimeter will not be damaged as the result of a wiring error or other difficulty.

RESISTANCE CHECKS

NOTE: DO NOT plug in the line cord until you are instructed to do so.

To perform the following steps, you will need an ohmmeter that has a 1.5 volt test voltage. Most analog ohmmeters (VOM, VTVM) have this test voltage. In addition, it should have a center-scale deflection factor (number at center of the scale) greater than 5, but less than 50. If such an ohmmeter is not available, proceed to "Operational Check" on Page 44.

NOTE: In the first set of the following tests (test points A through F), if you do not obtain the proper reading, reverse the ohmmeter test leads. (Some meters are wired differently than others). If you still do not get the proper readings, refer to "Initial Test Problems Chart" on Page 44.

CAUTION: In the following steps, use only the RX10 or the RX100 ranges of your ohmmeter. Other ranges may produce excessive current or may produce erroneously low readings.

- POWER switch out (off).
- Push the DC/ Ω switch in; the AC and Ω LV switches should be out. Set the RANGE switch to the 1000 VOLT position.
- Refer to Pictorial 9-2 (Illustration Booklet, Page 5) and connect the common (-) ohmmeter lead to the + marked end of C113. Touch the input

(+) ohmmeter lead to the following points. The readings should be greater than those shown. NOTE: Leave the test leads connected long enough to allow the test meter to stabilize.

TEST POINT	READING: GREATER THAN
<input type="checkbox"/> A	10 k Ω
<input type="checkbox"/> B	1500 Ω
<input type="checkbox"/> C	50 Ω
<input type="checkbox"/> D	100 Ω
<input type="checkbox"/> E	100 Ω
<input type="checkbox"/> F	10 k Ω

- Reverse the ohmmeter leads and touch each test point again.

TEST POINT	READING: GREATER THAN
<input type="checkbox"/> A	30 Ω
<input type="checkbox"/> B	50 Ω
<input type="checkbox"/> C	10 k Ω
<input type="checkbox"/> D	1000 Ω
<input type="checkbox"/> E	200 Ω
<input type="checkbox"/> F	10 k Ω

- With either ohmmeter lead connected to the + marked end of C113, measure all three prongs of the line cord, and at lugs 1 and 4 of the transformer. Each reading must show infinity.
- With either ohmmeter lead connected to the chassis ground (knurled nut) on the rear panel, measure the two flat prongs of the line cord (but not the round one). Each reading must show infinity. The round prong should indicate near "0" ohms.
- With either meter lead connected to chassis ground, measure lugs 1 and 4 of the transformer. Each reading must show infinity.

Disconnect the ohmmeter leads and proceed to "Operational Check."

Initial Test Problems Chart

If you cannot find your problem in the following chart, proceed to "In Case of Difficulty" on Page 59.

PROBLEM	POSSIBLE CAUSE OF LOW READINGS
Improper reading at point A	<ol style="list-style-type: none"> 1. D105, D106. 2. C112. 3. IC101. 4. Q101 thru Q104.
Improper reading at point B	<ol style="list-style-type: none"> 1. IC101, IC103. 2. Q101, Q102, Q107. 3. R124. 4. C122.
Improper reading at point C	<ol style="list-style-type: none"> 1. D107, D108. 2. C113. 3. IC102.
Improper reading at point D	<ol style="list-style-type: none"> 1. IC102, IC103. 2. Q101, Q102, Q108. 3. Wiring to control R4. 4. C114, C123.
Improper reading at point E	<ol style="list-style-type: none"> 1. IC103. 2. D111 thru D114.
Improper reading at point F	<ol style="list-style-type: none"> 1. C101. 2. Improper wiring at front panel.
Any line cord prong or transformer lug shows less than an infinite resistance reading.	<ol style="list-style-type: none"> 1. T1 or fuse F1 wiring. 2. Short in wiring to SW1 or SW5. 3. Transformer T1.

OPERATIONAL CHECK

- () Set the three circuit board controls to their centers of rotation (slot vertical to circuit board). Use a small-bladed (1/8" wide) screwdriver.

WARNING: When the line cord is plugged in, full AC line voltage is present at several points in the Multimeter. Be careful that you do not touch these areas. See Pictorial 9-2 (in the "Illustration Booklet").

Refer to Pictorial 9-2 for the following steps.

- () Set the front panel controls and switches as follows:

ZERO CCW end.
 Ω ADJUST Center of rotation.
 RANGE 1000 VOLT.
 DC/ Ω In.
 AC Out.
 Ω LV Out.
 POWER Out (off).

NOTE: If you do not get the proper results in the following steps, immediately unplug the line cord and proceed to "In Case of Difficulty" on Page 59.

- () Plug the line cord into the AC outlet.
- () Push the POWER switch in (ON). The meter needle should deflect to the right, but not past full scale. The DC- LED should be lit.
- () Rotate the ZERO control fully clockwise. The meter needle should drop to 0 and then deflect back up scale. Both LED's should be lit near 0 and then just the DC+ LED.
- () Turn off the Multimeter, and unplug the line cord. Then proceed to "Calibration".



CALIBRATION

WARNING: Hazardous voltages are present at several places inside the Multimeter when the line cord is connected. In the following steps, make sure you do not touch any bare wires, fuses, transformer lugs, etc. The boxed-in areas in Pictorial 9-2 (Illustration Booklet, Page 5) show the hazardous voltage areas.

NOTE: New Multimeters may exhibit a small amount of calibration drift due to "burn-in" stabilization. Therefore, you should recalibrate your Multimeter after an initial period of use; one month, for example. You may also wish to regularly recalibrate your Multimeter at three to six-month intervals or as required for maximum accuracy.

If in any of the following steps you do not obtain the indicated results, refer to the "In Case of Difficulty" section on Page 59. Locate and repair any problem before you continue with the calibration.

This section of the Manual contains two calibration procedures. If you have access to precision standards, proceed to "Precision Calibration" on Page 48.

To perform the calibration with precision standards, you will need the following equipment:

1. A DC voltage standard that provides 0.1 VDC and 0.3162 VDC with an accuracy better than $\pm 0.2\%$.
2. An AC voltage standard that provides 0.1 VAC rms, 1.0 VAC rms, and 10 VAC rms with an accuracy better than $\pm 0.3\%$. The output must be a low-distortion sine wave that covers a frequency range of 80 Hz to 100 kHz.

If precision standards are not available at this time, proceed with the following "Basic Calibration" section.

BASIC CALIBRATION

The accuracy of your Multimeter depends to a great extent upon how carefully and accurately you perform the following steps. These steps require only a minimum of equipment to calibrate the AC and DC sections of your Multimeter. If you do not know how to read the meter scales, refer to "Reading the Meter" on Page 52 before you proceed with the Calibration.

NOTE: During calibration, adjustment of the calibration controls generally produces only small changes in the needle position. You may find it necessary to gently tap the meter face to obtain the full change in the movement of the needle.

- () Adjust the mechanical zero (directly under the meter) to position the needle at the zero marks.
- () Remove the cover from the Multimeter if it is not already off.
- () Plug in the Multimeter.
- () Push the POWER switch on (in) and allow a warm up period of 30 minutes. Also, read the operational statements on Pictorial 11-1 in the "Illustration Booklet" on Page 6.

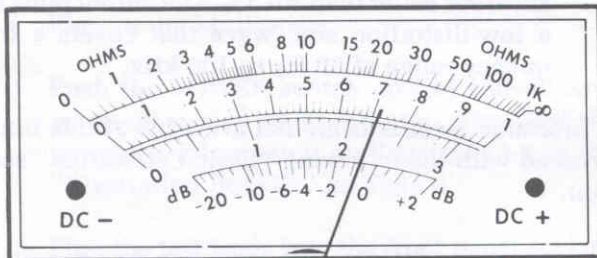
- () Plug the test leads into the front panel sockets (red lead to + socket; black lead to - socket).

Refer to Pictorial 9-2 (Illustration Booklet, Page 5) for the following steps.

- () Set the three circuit board controls to their centers of rotation (slots vertical to the circuit board).

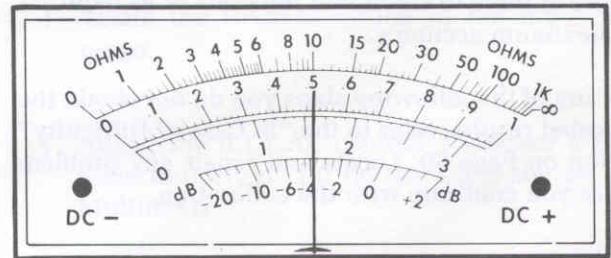
DC CALIBRATION

- () Push the DC/ Ω switch in. (The AC and Ω LV switches should be out.)
- () Connect the black test lead alligator clip to the red test lead probe tip.
- () Rotate the RANGE switch to the 0.1 VOLTS position.
- () Using a 1/8" screwdriver, carefully adjust the ZERO control for a minimum ("null") reading at zero.
- () Rotate the RANGE switch to the 3 VOLT position.
- () Separate the test leads and touch the red test probe tip to the -TP test point (front looped end of R122). The needle should deflect to near 2 on the 3 range and the DC- LED should be lit.
- () Adjust the 0.3 CAL control (R149) for an indication of -2.23 as shown in Pictorial 9-3.
- () Remove the test probe tip from the -TP test point.
- () Rotate the RANGE switch to the 10 VOLT position.
- () Touch the test probe tip to the +TP test point (other looped end of R122). The needle should deflect to near .5 on the 1.0 scale and the DC+ LED should be lit.
- () Adjust the 0.1 CAL control (R146) for an indication of +5.00 as shown in Pictorial 9-4.
- () Remove the test probe tip from the +TP test point.



-TP CALIBRATION POINT OF -2.23

PICTORIAL 9-3



+TP CALIBRATION POINT OF +5.00

PICTORIAL 9-4

AC CALIBRATION

Since the adjustment range of the AC CAL control (R151) is quite narrow, a highly accurate AC source is required to make this adjustment effective. Setting this control to the center of its rotation provides sufficient accuracy. However, if a precision AC source is available, use the adjustment procedure of the "Precision Calibration" section on Page 48.

Notes:

1. Accurate adjustment of the FREQ COMP (frequency compensation) trimmer capacitor (C103) 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 and proceed to "Ohms Check" on Page 49. If you do have these instruments available, perform the following steps.
 2. In areas where there is significant radiation from 60 Hz power lines, fluorescent lights, etc., you may see some oscillation of the pointer when you measure AC voltages of a frequency near 60 Hz. Using a frequency near 80 Hz will improve the measurement readability. See "External Interference" on Page 52.
- () Turn the RANGE switch to the 1.0 volt position.
- () Push the AC switch (in).

NOTE: With the AC switch in, both the DC+ and the DC - indicators are lighted.

- () Adjust the generator output level for about 1.0 volts rms (2.8 on an oscilloscope peak-to-peak). Set the frequency to approximately 80 Hz.
- () Connect the AC voltmeter (or oscilloscope) and the Multimeter 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 easy to refer to in the following steps.
- () Observe and remember the Multimeter indication. This will be referred to as the "80 Hz meter indication" below.
- () Adjust the generator frequency to approximately 1 kHz. Then, readjust the generator output to the same reference on the AC voltmeter, or oscilloscope, as before.
- () Adjust the FREQ COMP trimmer capacitor (C103) until the Multimeter gives the same indication as it did above with the "80 Hz meter indication." If the previous 80 Hz indication cannot be obtained, adjust the trimmer capacitor as close as possible to the 80 Hz indication point.
- () Disconnect all equipment.

This completes the "Basic Calibration" of your Multimeter.

Proceed to "Ohms Check" on Page 49.

PRECISION CALIBRATION

The accuracy of your Multimeter depends to a great extent upon how carefully and accurately you perform the following steps. Use these steps with precision standard equipment to calibrate the AC and DC sections of your Multimeter. If you do not know how to read the meter scale, refer to "Reading the Meter" on Page 52 before you proceed.

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 59. Then, after you correct the problem, return to this section and complete the calibration.

NOTE: During calibration, adjustment of the calibration controls generally produces only small changes in the needle position. You may find it necessary to gently tap the meter face to obtain the full change in the movement of the needle.

- Adjust the mechanical zero (directly under the meter) to position the needle at the zero marks.
- Remove the cover from the Multimeter if it is not already off.
- Plug in the Multimeter.
- Push the POWER switch on (in) and allow a warm-up period of 30 minutes. Also read the operation information on Pictorial 11-1 in the "Illustration Booklet" on Page 6.
- Plug the test leads into the front panel sockets (red lead to + socket; black lead to - socket).
- Connect the black test lead alligator clip to the red test lead probe tip.
- Rotate the RANGE switch to the 0.1 VOLTS position.
- Using a 1/8" screwdriver, carefully adjust the ZERO control for a minimum ("null") reading at zero.
- Rotate the RANGE switch to the 0.3 VOLT range.
- Adjust the DC voltage standard to 0.3162 volts.
- Connect the DC voltage standard to the Multimeter inputs.
- Adjust the 0.3 CAL control (R149) for a full-scale indication (1.0 on the 1.0 scale) on the Multimeter.
- Adjust the DC standard to 0.100 volts.
- Rotate the RANGE switch to the 0.1 VOLT range.
- Adjust the 0.1 CAL control (R146) for a full-scale indication (1.0 on the 1.0 scale) on the Multimeter.
- Disconnect the DC standard from the Multimeter.

Refer to Pictorial 9-2 (Illustration Booklet, Page 5) for the following steps.

- Set the three circuit board controls to their centers of rotation (slots vertical to the circuit board).

DC CALIBRATION

- Push the DC/ Ω switch in. (The AC and Ω LV switches should be out).

AC CALIBRATION

- Turn the RANGE switch to the 0.1 VOLT position.
- Push the AC switch (in).

NOTE: With the AC switch in, both the DC+ and the DC- indicators are lighted.



- () Use a 1/8" screwdriver and turn the "AC CAL" control (R151) 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. Using a frequency near 80 Hz will improve the measurement readability.

- () Adjust the AC voltage standard for an output of 0.100 volts rms at a frequency near 80 Hz.
- () Connect the output of the AC voltage standard to the Multimeter inputs.
- () Adjust the "AC CAL" control for a full-scale indication (1.0 on the 1.0 scale) on the Multimeter.
- () Turn the RANGE switch to the 1.0 VOLT position.
- () Adjust the AC voltage standard to produce exactly a full-scale indication on the Multimeter.
- () Adjust the AC voltage standard frequency to 100 kHz.
- () Use an alignment tool or a 1/8" blade screwdriver and adjust the "FREQ COMP" trimmer capacitor (C103) for a full-scale indication.
- () Adjust the AC standard frequency near 80 Hz.
- () Turn the RANGE switch to the 10 VOLT position.
- () Adjust the AC voltage standard for exactly a full-scale indication on the Multimeter.
- () Adjust the AC standard frequency to 100 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 1 VOLT and the 10 VOLT ranges.

- () Disconnect the Multimeter from the AC standard.

This completes the "Precision Calibration" of your Multimeter.

Proceed to "Ohms Check."

OHMS CHECK

Use the following steps to check the OHMS scale on your Multimeter. 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 59 to correct the problem.

Refer to Pictorials 9-1 and 9-2 (Illustration Booklet, Page 5) for the following steps.

NOTE: Instructions for reading the OHMS scale are given on Page 53. If you do not know how to make a resistance measurement, refer to "Resistance Measurements" on Page 54 before you proceed with this adjustment. All meter indications should be within the accuracy specifications of the instrument.

- () Plug the red test lead into the red "+" socket.
- () Push the DC/ Ω switch in.
- () Rotate the RANGE switch to the 1000 mA position.
- () Readjust the front panel ZERO control, if required.
- () Turn the RANGE switch to the $\Omega \times 1$ position. The needle should deflect upscale.
- () Adjust the Ω ADJUST control for a full-scale (∞ , infinity) indication.
- () Rotate the RANGE switch from the $\Omega \times 1$ position through the $\Omega \times 1M$ position. The pointer should remain at " ∞ ."

- () Turn the RANGE switch to the $\Omega \times 10k$ position.
- () Carefully touch the test probe tip to SW101C pin 1 (nearest the edge of the circuit board).
- () Disconnect the test probe tip and press the ΩLV pushbutton.
- () Readjust the Ω ADJUST for a full-scale (∞ , infinity) indication.

You should obtain the following meter indications at the indicated RANGE switch positions.

RANGE SWITCH POSITION	METER INDICATION
$\Omega \times 10k$	1
$\Omega \times 1k$	10
$\Omega \times 100$	100
$\Omega \times 10$	1k

- () Turn the RANGE switch from the $\Omega \times 1$ through the $\Omega \times 1M$ positions. The pointer should remain at " ∞ ."
- () Turn the RANGE switch to the $\Omega \times 10 k$ position.
- () Repeat the measurements of the previous steps at SW101C lug 1.
- () Push the POWER switch to off (out).
- () Disconnect the test lead.
- () Disconnect the line cord from the AC outlet.

This completes the "Ohms Check." Proceed to "Final Assembly."

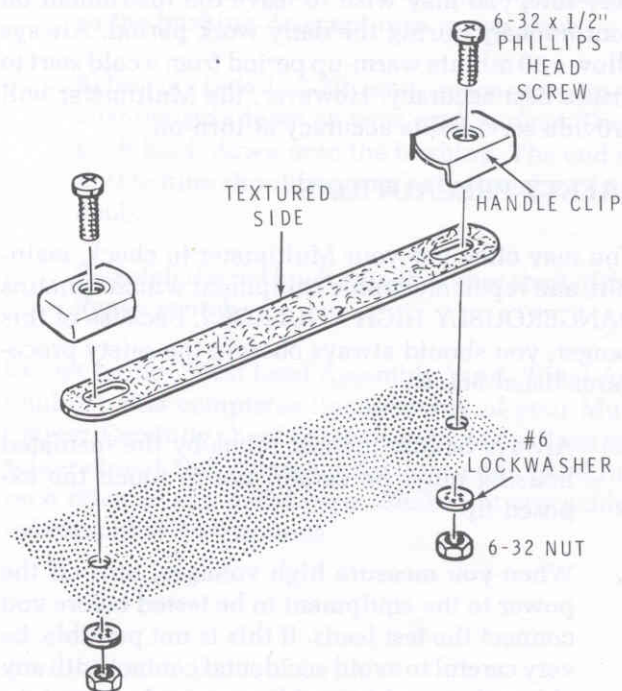


FINAL ASSEMBLY

Refer to Pictorial 10-1 (Illustration Booklet, Page 5) for the following steps.

Refer to Detail 10-1A and install the handle on the cabinet top as follows:

- () Insert a 6-32 \times 1/2" phillips head screw in one of the handle clips, in the hole at one end of the handle, and one of the holes in the cabinet top. Be sure the textured side of the handle is up.
- () Loosely secure the screw with a #6 lockwasher and a 6-32 nut.
- () In the same manner, install the other handle clip at the other hole in the handle and cabinet top.
- () Position the handle clips so they are aligned with each other, from front to rear and from side to side. Then tighten the handle hardware.
- () Fit the front edge of the cabinet top into the groove in the trim bar. Secure the rear of the cabinet top to the rear of the cabinet bottom with two #6 \times 3/8" black sheet metal screws.
- () Install a cabinet side (textured side out) on one side of the cabinet top and cabinet bottom with four #6 \times 3/8" black sheet metal screws. Do not tighten any of the screws until all four have been installed.



Detail 10-1A

- () In the same manner, install the other cabinet side.

This completes the assembly of your Multimeter.

OPERATION

Refer to Pictorial 11-1 (Illustration Booklet, Page 6) for a description of the control and input functions.

DUTY CYCLE

Since the power consumption of the Multimeter is very low, you may wish to leave the instrument on continuously during the daily work period. Always allow a 30 minute warm-up period from a cold start to insure best accuracy. However, the Multimeter will provide serviceable accuracy at turn-on.

SAFETY PRECAUTIONS

You may often use your Multimeter 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 you test 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.

EXTERNAL INTERFERENCE

Stray AC and RF (radio frequency) fields that affect measurements, can usually be reduced or eliminated by one of the following:

- A. Use twisted and as short as possible input leads.
- B. Use inner-wire shielded cable for input leads. Connect the shield to the rear panel (earth) ground screw.
- C. For voltage measurements, a 10 k Ω to 1 M Ω resistor can be connected across the input terminals. However, this may tend to load high impedance circuits.

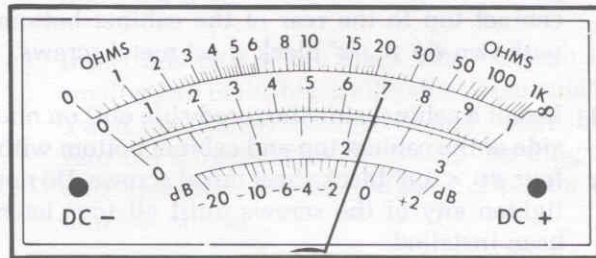
READING THE METER

This section of the Manual will familiarize you with the meter scales. Instructions are given for reading each scale.

AC or DC Voltage Readings

NOTE: The numbers in the "Volts" bracket on the Range switch refer to the full-scale voltages of the Multimeter.

.1 VOLT 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 Pictorial 11-2.



0.1 VOLT RANGE INDICATING 0.07 V

PICTORIAL 11-2

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

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

10 VOLT 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 VOLT 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 VOLT 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.

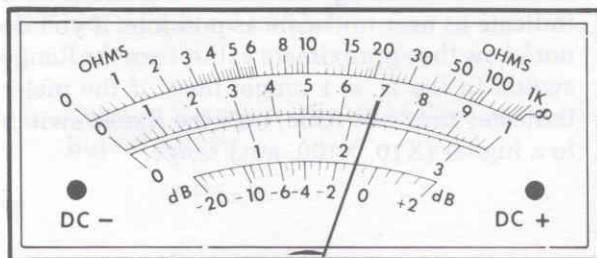
300 VOLT RANGE — Read the 0-to-3 scale and move the decimal point two places to the right. For example, a reading of 2 would indicate a measurement of 200 volts.

1000 VOLT 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 Multimeter.

.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 ($7.0 \mu\text{A}$) as shown in Pictorial 11-3.



0.01 mA RANGE INDICATING 0.007 mA

PICTORIAL 11-3

.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 ($60 \mu\text{A}$).

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.

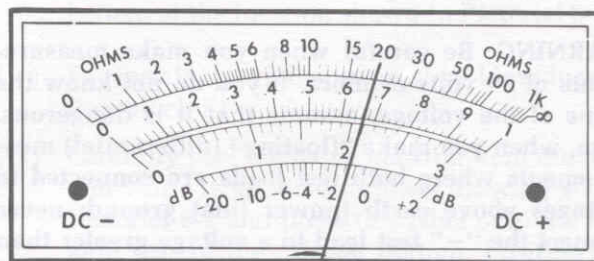
100 mA RANGE — Read the 0-to-1 scale and move the decimal point two places to the right. For example, a reading of .9 would indicate a measurement of 90 mA.

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 of the Multimeter.

Ω × 1 RANGE — Read the OHMS scale directly. For example, a reading of 20 would indicate a measurement of 20 Ω, as shown in Pictorial 11-4.



Ω × 1 RANGE INDICATING 20Ω

PICTORIAL 11-4

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

Ω × 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.

$\Omega \times 1 \text{ k}$ 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 k Ω .

$\Omega \times 100 \text{ k}$ 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 M Ω .

$\Omega \times 1 \text{ M}$ 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 M Ω .

MAKING MEASUREMENTS

DC Voltage Measurements

The voltage ranges on your Multimeter provide 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 M Ω input resistance virtually eliminates measurement loading on high impedance circuits. When the Multimeter is used with the Heath High Voltage Probe assembly for 10 M Ω input resistance meters, voltages up to 30,000 volts can be measured for servicing or adjusting television or oscilloscope anode circuitry.

WARNING: Be careful when you make measurements of 20 volts or more. If you do not know the value of the voltage, assume that it is dangerous. Also, when you make “floating” (differential) measurements where both test leads are connected to voltages above earth (power line) ground; never connect the “-” test lead to a voltage greater than 700 VDC (500 VAC) above earth ground.

To measure DC voltage, depress the DC/ Ω pushbutton. Connect the black test lead from the “-” socket of the Multimeter 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).

The “auto-polarity” function of the Multimeter always indicates the proper polarity of the voltage being measured as indicated by the DC+ and DC- LED indicators. If the DC+ LED indicator is lighted, the voltage at + input socket is positive with respect to the voltage connected to the - input jack. Conversely, if the DC- indicator is lighted, the voltage at the input is negative.

For low level inputs, both the DC+ and DC- indicators will be lighted. As the input increases to above 5% of full scale, one lamp will be bright and the other will be very dim or off.

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.

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

1. Zero the Multimeter 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 $\Omega \times 1$ range; then, if the meter indicates near full scale, turn the Range switch to a higher (X10, X100, etc.) range.



3. The two “ohms” pushbuttons (DC/ Ω ; Ω LV) have the following characteristics:

Ω LV — This pushbutton activates a low voltage measuring circuit. It is especially useful for resistance measurements in semiconductor (diodes, transistors, etc.) circuits, but it can also be used for other resistance 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 — This pushbutton activates a measuring circuit with a test voltage large enough to “turn on” a semiconductor. When you want to check a device that has a different resistance in each direction, such as a diode; make the measurement, then reverse the test lead connections. The polarity of the test voltage is positive at the “+” socket as shown by the DC+ indicator being lighted.

CAUTION: You can use your Multimeter to check the forward and reverse resistance of low-power diodes and transistors, but make sure you use the $\Omega \times 10$ range or higher **only**. The $\Omega \times 1$ range may cause excessive forward conduction and result in junction breakdown.

4. Press one of the ohms (Ω) pushbuttons.
5. Be sure the test lead ends are not touching; then adjust the Ω ADJUST control until the meter pointer is exactly over the full-scale (∞) indication.

When you change from Ω LV to DC/ Ω , or vice versa, readjust the Ω ADJUST control 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 $\Omega \times 1$ scale, it may be necessary to take the resistance of the test leads into account. First make sure the meter is carefully zeroed on one of the current ranges. Then switch back to the $\Omega \times 1$ scale and adjust the Ω ADJUST control to ∞ with the test lead ends apart.

Now touch the test leads together; the meter will indicate the resistance of the test leads and any internal resistance of the Multimeter (fuse, contacts, etc.). Subtract this reading from all subsequent readings.

AC Voltage Measurements

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

CAUTION: When you make AC measurements in circuits with a DC voltage in excess of 500 volts, **DONOT** attempt to measure any point where the instantaneous voltage (peak AC + DC) may exceed 1400 volts. Also, when you make “floating” (differential) measurements where both test leads are connected to voltages above earth (power line) ground; never connect the “-” test lead to a voltage greater than 500 VAC (700 volts PEAK) above earth ground.

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 you zero the Multimeter on a DC current range, press the AC pushbutton. NOTE: With the AC pushbutton in, both the DC+ and DC- indicators are lighted.

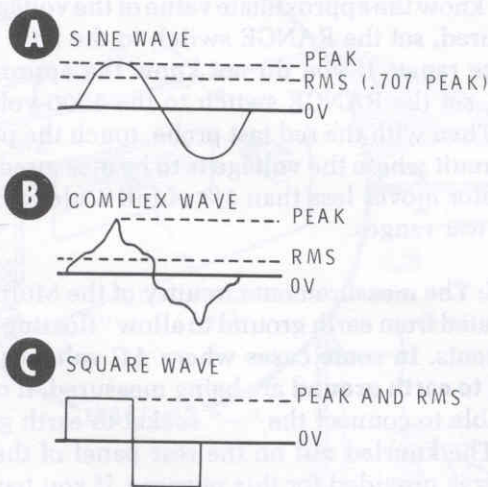
If you know the approximate value of the voltage to be measured, set the RANGE switch to the next higher voltage range. If you do not know the approximate value, set the RANGE switch to the 1000-volt position. Then with the red test probe, touch the point in the circuit where the voltage is to be measured.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

NOTE: The measurement circuitry of the Multimeter is isolated from earth ground to allow “floating” measurements. **In some cases where AC voltages referenced to earth ground** are being measured, it may be desirable to connect the “-” socket to earth ground also. The knurled nut on the rear panel of the Multimeter is provided for this purpose. If you have any questions about the accuracy of these measurements, momentarily connect a wire between the “-” socket and this earth (chassis) ground point to determine if this has an effect on your measurement. **Be sure** to remove this connection after you complete your measurements.

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 greatest accuracy. For this reason, the following information is presented.

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 Pictorial 11-5A), the most common AC voltage waveform, the rms value of each half cycle is .707 times the peak of the waveform.



PICTORIAL 11-5

The following relationships exist for sine wave AC voltages:

$$\text{rms voltage} = \text{peak voltage} \times 0.707$$

$$\text{Peak voltage} = \text{rms} \times 1.414$$

$$\text{Peak-to-Peak voltage} = \text{rms} \times 2.828$$

$$\text{rms voltage} = \text{peak-to-peak voltage} \times 0.3535$$

If the input voltage to your Multimeter is an AC sine wave, both the positive and negative portions of the signal will deflect the meter needle upscale.* Since the meter movement has mechanical inertia, it "averages" the current pulses and causes the meter needle to indicate 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 each portion of the waveform.

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 Pictorial 11-5B 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 Pictorial 11-5C would indicate an rms value higher than its peak value. On your Multimeter, a symmetrical square wave having a 1.0-volt peak would indicate 1.10 volts.

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

* See the Basic Meter Circuit portion of the "Circuit Description."



Meter Loading

When you connect your Multimeter 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 Multimeter 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 $1\text{ M}\Omega$ or less.

The amount of loading presented by the input capacitance of your Multimeter 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

The dB scale can 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.
- Check the flatness of the frequency response of audio amplifiers.

Current Measurements

CAUTION: Make sure you make all current measurements by connecting the test leads in **series** with the current to be measured. Be sure the circuit is turned off before you connect the leads. Also, when you make current measurements in circuits above earth (power line) ground, never connect the Multimeter into circuits that have a voltage greater than 700 VDC (500 VAC).

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. The “auto-polarity” function of the Multimeter always indicates the proper polarity of the current being measured as indicated by the DC+ and DC- LED indicators. If the DC+ indicator is lighted, the current **into** the “+” input socket is positive. Conversely, if the DC- indicator is lighted, the current **into** the “+” socket input is negative.

For low level inputs, both the DC+ and DC- indicators will be lighted. As the input increases to above 5% of full scale, one lamp will be bright and the other will be very dim or off.

To measure AC current, depress the AC pushbutton. Turn the circuit on. If the pointer moves to less than 1/3 of full scale, switch to the next lower range.

NOTE: Use the highest possible range that produces the resolution you require since this inserts the smallest amount of resistance into the circuit to be measured.

MAINTENANCE

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

TEST LEADS

Check the test leads regularly. Because of their constant flexing during use, the test leads may break. Broken test leads are potentially dangerous and may cause the Multimeter to stop functioning or cause erratic indication.

ELECTROSTATIC CHARGE

The clear plastic meter window is treated to resist the accumulation of a static charge. However, if a static charge accumulates through repeated rubbing of the meter window, the pointer will deflect in an erratic manner on all range settings. To correct this condition, apply a **small** quantity of liquid dishwashing detergent to a soft cloth and wipe the meter window. **DO NOT** remove the meter window to clean it.

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 Multimeter.

METER COIL

CAUTION: Never check the continuity of the meter coil **directly** with another ohmmeter. The amount of current that would be drawn would seriously overload the coil and probably ruin it. Always use a limiting resistor with 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 on the other ohmmeter's battery voltage and the setting of its range switch.

FUSE

The circuit protection fuse (F101) may be replaced with a 2-ampere, quick-blow, 3AG instrument-type fuse.



IN CASE OF DIFFICULTY

TROUBLESHOOTING INFORMATION

GENERAL

This "General" section is divided into several parts. The "Repair Precautions," point out the care that you should use when you service the Multimeter to prevent damage to components. It also calls out specific methods to locate problems that could occur.

The "Components" paragraphs explain the procedure you should follow to replace a faulty component.

The "Foil Repair" paragraph tells you how to repair a broken foil on the circuit board.

The five remaining parts of the "In Case of Difficulty" section (listed below) contain tests and troubleshooting charts to help you identify specific problems. The tests and charts list the conditions or components that could cause each problem.

Each of these sections cover one of the five major meter circuits. You should proceed through each section in the following sequence. It is necessary that the basic meter circuit perform properly before you proceed to the DC voltmeter circuit, etc.

1. Basic Meter Tests.
2. DC Voltmeter Circuit
3. AC Voltmeter Circuit
4. Ohmmeter Tests
5. DC and AC Milliammeter Circuit

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.

REPAIR PRECAUTIONS

Before you proceed, review the "Assembly Check List" on Page 30. Most problems are caused by the assembly errors listed in these checks. A review of the "Circuit Description" on Page 84 may also help you locate a problem. Refer to the "Circuit Board X-Ray View" (Illustration Booklet, Page 13) and the Schematic to locate circuit components.

WARNING: When the line cord is connected to an AC outlet, hazardous voltages are present at several places. See Pictorial 9-2 (Illustration Booklet, Page 5).

CAUTION: If you ever remove the circuit board from the chassis, be sure you cover the transformer and the fuse wiring with a cloth; or be very careful to keep the chassis and circuit board assemblies separated. This will keep you from accidentally causing a short circuit if you plug the Multimeter in for testing.

Observe the following precautions while you troubleshoot or repair your Multimeter:

1. Before you remove the cabinet from your Multimeter disconnect the line cord and make sure the POWER switch is off (out).
2. Make sure you do not short any adjacent terminals or foils when you make tests or voltage measurements. If a probe or test lead slips, for example, and shorts together two adjacent connections, it is very likely to damage one or more of the transistors, diodes, or IC's.
3. Be especially careful when you test any circuit that contains an IC or a transistor. Although these components have an almost unlimited life when used properly, they are much more vulnerable to damage from excess voltage and current than many other parts.
4. Do not remove any components while the Multimeter is turned on.
5. When you make repairs to the Multimeter, make sure you eliminate the cause as well as the effect of the trouble. If, for example, you find a damaged resistor, be sure you find out what damaged the resistor. If the cause is not eliminated, the replacement resistor may also become damaged when you put the Multimeter back into operation.
6. In several areas of the circuit boards, the foil patterns are quite narrow. When you unsolder a part to check or replace it, avoid excessive heat while you remove the part. A suction-type desoldering tool makes part removal easier.

COMPONENTS

To remove faulty resistors or capacitors, first clip them from their leads; then heat the solder on the foil and allow each lead to fall out of its hole. Preshape the leads of the replacement part and insert them into the holes in the circuit board. Solder the leads to the foil and cut off the excess lead lengths.

You can remove transistors in the same manner as resistors and capacitors. Make sure you install the replacement transistor with its leads in the proper holes. Then solder the leads quickly to avoid heat damage. Cut off the excess lead lengths.

FOIL REPAIR

To repair a break in a circuit board foil, bridge solder across the break. Bridge large gaps in the foil with bare wire. Lay the wire across the gap and solder each end to the foil. Carefully trim off any excess bare wire.



BASIC METER TESTS

The first portion of the “Basic Meter Tests” (“Preliminary Checks”) is a visual check of the basic measuring circuit for proper operation. No test instruments are required. Perform this check first to verify the operation of this circuit.

The second portion of the “Basic Meter Tests” (“Troubleshooting Chart”) requires a DC voltmeter and contains a sequential series of tests which will locate problems in the basic measuring circuit.

The FET Multimeter is fundamentally a DC voltmeter with a full-scale sensitivity of either 0.1 VDC or 0.3162 VDC. This circuitry is used in each function

(except the high voltage ohmmeter function where the sensitivity is changed to approximately 1.5 VDC) and the input switch circuitry controls the area where this “basic meter” measures. Consequently, you should first perform the “Preliminary Checks.”

If you obtain the required operation in each of the following steps, the basic meter portion of your Multimeter is working properly. Proceed to the “DC Voltmeter” section on Page 70 which identifies other problems in the switch, wiring, and related circuitry. If you encounter any problems in these steps, proceed to the “Troubleshooting Chart,” which locates problems in the basic meter.

Preliminary Checks

- () Disconnect the orange wire solder lug from the “+” meter bolt. Wrap a piece of tape around the solder lug.
- () Plug the red test lead into the “-” (black) socket.
- () Plug the black test lead into the back of the red test lead plug.
- () Push the DC/ Ω switch in; the AC and Ω LV switches should be out.
- () Rotate the RANGE switch to the 1 VOLT position.
- () Plug the line cord into an AC outlet.
- () Clip the black test lead alligator clip to the base (B) of Q108.
- () Push the POWER switch in (ON). Both the DC+ and DC- LED’s should be lighted.
- () Carefully touch the test probe tip to the collector (C) lead of Q107. The DC- LED should go out.
- () Momentarily disconnect the line cord from the AC outlet and move the black test lead alligator clip to the emitter of Q105. Reconnect the line cord.
- () Rotate the front panel ZERO control fully counterclockwise. Only the DC- LED should be lighted.
- () Rotate the ZERO control clockwise. At some point, the DC+ LED should start to glow and then light. Additional rotation should cause the DC- LED to become dim and then go off.
- () Rotate the ZERO control to the center of the range where both the DC+ and DC- LED’s are equally lighted.
- () Carefully touch the solder lug removed from the meter to its meter terminal. The meter indication should be near zero. If so, momentarily disconnect the line cord from the AC outlet and reconnect the solder lug to the meter. Then reconnect the line cord.

- () Slowly rotate the ZERO control clockwise. The meter needle should smoothly increase upward to about 0.3 on the 1.0 scale, the DC+ LED should be lit, and the DC- LED should be off.
- () Slowly rotate the ZERO control fully counterclockwise. The meter indication should drop to zero, then increase back to about 0.3 while the DC+ LED turns off and the DC- LED lights.
- () Rotate the Ω ADJUST control back and forth. It should not affect the meter reading.
- () Vary the AC CAL control from fully clockwise to fully counterclockwise. It should not affect the meter indication.
- () Vary the positions of the 0.1 CAL and 0.3 CAL controls. They both should affect the meter indication.
- () Recenter the 0.1 CAL, 0.3 CAL, and AC CAL controls.
- () Reset the ZERO control to zero (null).
- () Disconnect the test leads.
- () Rotate the RANGE switch to the 3 VOLT position.
- () Plug the red test lead into the "+" (red) socket.
- () Carefully touch the test probe tip to the base (B) of Q101. The meter should deflect to near center-scale and the DC+ indicator should be lighted. Remove the probe tip from Q101.
- () Push the POWER switch to off (out).
- () Disconnect the test lead.

This completes the "Preliminary Checks." If you did not obtain all correct indications, proceed to the "Troubleshooting Chart." If you did obtain all the correct indications, proceed to "DC Voltmeter Tests" on Page 70.

Troubleshooting Chart

In the following steps, you will be instructed to monitor certain voltages with a voltmeter. You may also be instructed, in the "Special Instructions" column, to open certain connections, or to apply short circuits with the test leads. If at any point you do not obtain the required voltage or voltage change, refer to the "Possible Area of Difficulty" column which lists possible faulty circuits or components. Check the part referred to. It may be open, shorted, "leak," installed backward, wrong value, etc. Perform the tests in sequence from beginning to end since results in the later portions may require operation of circuitry verified in the first parts of the test.

Whenever a particular part (Q103, R4, hole AF; for example) is mentioned as a possible cause, inspect all foils or jumper wires associated with that part carefully for open or short circuits.

Refer to the "Semiconductor Identification Chart" on Page 89 for IC basing diagrams and transistor basing.

- () Disconnect the orange wire solder lug from the meter. Wrap a piece of tape around the solder lug.
- () Push the DC/ Ω switch in; the AC and Ω LV switches should be out.
- () Set the Ω ADJUST control (R134) at center of rotation.
- () Rotate the RANGE switch to the 3 VOLT position.
- () Push the POWER switch to on (in).
- () Plug the black test lead into the "-" (black) socket; then plug the red test lead into the rear of the black test lead plug.
- () Connect the voltmeter common (ground) lead to the "+" marked end of capacitor C113.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
WARNING: Unplug Multimeter line cord before checking fuse.	Good fuse F1.	<ol style="list-style-type: none"> 1. F1. 2. T1. 3. D105 through D106. 4. C1, C112, C113. 5. Improper wiring of SW5. 6. IC101, IC102. 7. Short at A or C, +14 or -15 volt points; or in SW1 or SW5 wiring.
None	+14 VDC at collector (C) of Q104.	<ol style="list-style-type: none"> 1. Unit not plugged in. 2. SW5 in wrong position. 3. Open wiring at line cord, fuse F1, SW1 or SW5. 4. F1. 5. T1 wiring at lugs 1 or 4, or holes A, B, or C. 6. SW1 or SW5. 7. D105, D106. 8. C112. 9. IC101. 10. Q103, Q104.
None	-15 VDC at pin 4 of IC102.	<ol style="list-style-type: none"> 1. D107, D108. 2. C113. 3. IC102.
None	+7.0 VDC at pin 7 of IC103.	<ol style="list-style-type: none"> 1. IC101, IC102. 2. R121, R122, R123. 3. C122. 4. Short in circuitry connected to +7.0 VDC supply. 5. Pin 7 not in socket or open connection.
None	-7.0 VDC at pin 4 of IC103.	<ol style="list-style-type: none"> 1. IC102. 2. C114, C123. 3. Short in circuitry connected to -7.0 VDC supply. 4. Pin 4 not in socket or open connection. 5. Improper wiring to R4 (white-brown wire).
Connect the alligator clip to the base (B) of Q108.	-1.7 VDC at collector (C) of Q108 and "DC+" indicator lighted.	<ol style="list-style-type: none"> 1. Q108. 2. LED 2 ("DC+"). 3. R142. 4. Open wiring to LED 2 (orange) or (blue). 5. Open at holes L or S. 6. Short at hole L.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Connect the alligator clip to the base (B) of Q108. Then touch red test probe tip to collector (C) of Q108.	"DC+" indicator should turn off.	1. Open at hole AH, open test lead, or connection at "-" socket.
Same as above.	+1.7 VDC at collector (C) of Q107 and "DC-" is lighted.	<ol style="list-style-type: none"> 1. Q107. 2. LED 1 ("DC-"). 3. R141. 4. Open wiring to LED 1 (yellow) or (black). 5. Open at holes N or R or long jumper wire. 6. Short at hole N.
Disconnect the alligator clip.	_____	_____
Using a small-bladed screwdriver, carefully short the base (B) and collector (C) leads of Q108.	<p>"DC+" indicator turns off.</p> <hr style="border-top: 1px dashed black;"/> <p>Screwdriver blade measures -0.6 VDC.</p>	<ol style="list-style-type: none"> 1. Q108. 1. C124. 2. Improper wiring at hole T (green) or SW4 lug 8. 3. Short at hole T. 4. SW4.
Using a small-bladed screwdriver, carefully short the base (B) and collector (C) leads of Q107.	"DC-" indicator turns off.	1. Q107.
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>CAUTION: Do not allow the test probe tip to also touch the metal case of IC103.</p> </div> <p>Carefully touch the red test probe tip between pins 2 and 3 of IC103 so that it touches both leads. Then rotate the ZERO control from fully counterclockwise to fully clockwise.</p>	At the counterclockwise end, only the DC- indicator should be on. At the clockwise end, only the DC+ indicator should be on. Leave the control set to fully clockwise.	<ol style="list-style-type: none"> 1. IC103. 2. R4, R137, R138, or R139. 3. Open at holes, G, K, or V. 4. Open or improper wiring to Zero control (white-orange, white-brown, or white-red). 5. C121. 6. Pin 1, 5, 6, or 8 of IC103 not in socket or open connection. 7. Short at pins 1, 5, or 8 or IC103.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Connect the alligator clip to the center lug of the Ω ADJUST control (R134) on the rear of SW101.	Pin 6 of IC103 should measure more positive than +4 VDC.	<ol style="list-style-type: none"> 1. IC103. 2. R139. 3. Open at the center lug of R134.
Same as above.	Voltage at cathode (banded) end of D114 should measure approximately 1.1 VDC less positive than at pin 6 of IC103.	<ol style="list-style-type: none"> 1. D113, D114. 2. Short at hole W.
Same as above.	Voltage at orange wire solder lug (taped) should measure same as above.	<ol style="list-style-type: none"> 1. Open at hole W. 2. Open or improper wiring (orange).
Same as above.	Approximately 1/6 of the voltage above should be measured at: SW101 E lug 2 and lug 10.	<ol style="list-style-type: none"> 1. R144, R145, R146, R147. 2. Short in circuitry connected to SW101 E pins 2 and 10. 3. SW101 not in 3 VOLT position. 4. Open at SW101 D pins 8 or 9 (rear). 5. SW101 E. 6. C119.
	Anode (unbanded) end of D112.	<ol style="list-style-type: none"> 1. D111, D112. 2. Short at hole X.
	Brown wire solder lug of meter.	<ol style="list-style-type: none"> 1. Open at hole X. 2. Open or improper wiring (brown).
	SW4 lug 1 (red wire).	<ol style="list-style-type: none"> 1. R151, R152. 2. Short or open at hole Y. 3. Open or improper wiring (red). 4. SW4.
Same as above. Then rotate ZERO control fully counterclockwise.	Pin 6 of IC103 should measure more negative than -4.0 VDC.	<ol style="list-style-type: none"> 1. IC103.
Same as above.	Brown wire solder lug of meter should measure about 1.1 volts less negative than pin 6 of IC103.	<ol style="list-style-type: none"> 1. D111, D112.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Disconnect alligator clip from lug of R134. Reconnect it at emitter (E) of Q105.	Approximately -0.05 VDC is measured at:	
	Center lug of Ω ADJUST control.	1. R133, R134.
	Pin 2 of IC103.	1. R134. 2. Pin 2 or 3 of IC103 not in socket or open connection. 3. Short in R133 to R135 circuitry.
	SW101 D pins 2 and 3.	1. R135. 2. Open or short in circuitry connected to SW101 D pins 2 and 3. 3. SW101 D.
Leave alligator clip connected to Q105. Reconnect orange wire solder lug to meter.	Meter reads upscale. Rotating ZERO control fully clockwise causes meter indication to go to zero smoothly and then back upscale.	1. Meter M1. 2. IC103. 3. C121.
Disconnect alligator clip from Q105. Unplug both test leads from "-" socket.	+1.55 VDC at base (B) of Q101.	1. R124, R125. NOTE: If resistors are OK, remove Q101 and complete this chart. Reinstall Q101 after last step.
Plug black test lead into "+" socket. Connect alligator clip to base (B) of Q101. Remove F101. Push AC switch in.	+1.55 VDC at:	
	Rear clip of F101.	1. Open wiring at "+" socket or hole AE; or short at hole AE.
	Front clip of F101 with fuse reinstalled.	1. F101. 2. Short at SW101 A pins 2 and 22. 3. Short or improper wiring at SW4 lugs 11 and 12. 4. SW101 A.
	Front clip of F101 with DC/ Ω switch in and AC switch out.	1. Short at hole AF or SW101 B pins 2, 3, and 4 circuitry.
	SW4 lug 12.	1. Open at SW101 A pin 2 or lug 22. 2. SW101 A.
SW101 B pin 3.	1. Open or improper wiring at SW4 lugs 11 or 12, or hole AF; or SW101 B pin 3. 2. SW4.	

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Rotate RANGE switch to 0.3 VOLT position, leaving black test connected as before. Disconnect blue wire at SW101 C lug 14.	+1.55 VDC at SW101 B pin 3.	<ol style="list-style-type: none"> 1. Short in one of the following areas: <ol style="list-style-type: none"> A. SW101 B pin 12. B. SW101 A pin 8 or 13, or hole AG. C. SW101 C pin 12 (front). D. SW101 C pin 12, 14 or 20 (rear). 2. SW101 A, B, or C.
Same as above.	+1.55 VDC at SW101 C lug 14.	<ol style="list-style-type: none"> 1. Open at one of the following areas: <ol style="list-style-type: none"> A. SW101 B pin 12. B. SW101 C pin 12. (rear). 2. SW101 B or C.
Reconnect blue wire to SW101 C lug 14. Leave the RANGE switch and black test lead as before.	+1.55 VDC at SW101 C lug 14 (rear).	<ol style="list-style-type: none"> 1. Short or improper wiring at SW3 lug 3 (blue). 2. SW3. 3. Open wiring to SW101 C pin 14.
Same as above.	+1.51 VDC at hole J.	<ol style="list-style-type: none"> 1. Open, short, or improper wiring at SW3 lug 2 (brown). 2. R2. 3. C2. 4. Short, open or Improper wiring at hole J. 5. SW3.
Same as above.	Meter should be "pegged" at full scale.	<ol style="list-style-type: none"> 1. IC103. 2. Meter M1. 3. R136. 4. Pin 3 of IC103 not in socket or open connection. 5. Q105, Q106.
Same as above.	+0.16 VDC at SW101 B pins 5 and 6.	If greater than +0.16 VDC: <ol style="list-style-type: none"> 1. C102, C103, C104. 2. Open in R105, R106, R107, R116, R115, R117, SW101 D pins 5 or 8 (front) circuitry. 3. Short or improper wiring at SW2 lug 4. <hr style="border-top: 1px dashed black;"/> If less than +0.16 VDC: <ol style="list-style-type: none"> 1. C105. 2. R105. 3. Short at SW101 B pins 1, 5, or 6.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Rotate RANGE switch to 3 VOLT position. Leave the black test lead as before.	+0.16 VDC at pin 3 of IC103.	<ol style="list-style-type: none"> 1. Open at SW101 B, pins 5 or 6; SW101 C lug 20 (rear); or SW101 D lug 10 (front). 2. SW101 B, C, or D.
Same as above.	Meter should be reading near center scale.	<ol style="list-style-type: none"> 1. Open at SW101 D pin 12 (rear). 2. SW101 D.
Same as above.	0.3 CAL (R149) can calibrate meter to 1.55 on the 3 scale.	<ol style="list-style-type: none"> 1. R143, R144, R148, R149, R153. 2. C126. 3. Short at SW101 E pin 1. 4. SW101 E. 5. M1.
Rotate RANGE switch to 10 VOLT position.	Meter should be reading between .1 and .2 on 1.0 scale. 0.1 CAL (R146) can calibrate meter to 0.155 on the 1.0 scale.	<ol style="list-style-type: none"> 1. Open connection at SW101 E pin 1. 2. C126. 3. R145, R146, R147.
Disconnect alligator clip for Q101. Connect alligator clip to rear of "-" socket (shorting Multi-meter input.) Rotate RANGE switch to 0.1 VOLT position.	Meter needle can be set to zero using ZERO control.	<ol style="list-style-type: none"> 1. Open connection in one of the following areas: <ol style="list-style-type: none"> A. SW101 A pins 2 or 22. B. SW101 B pins 2 or 12. C. SW101 C pin 12 (rear). D. SW101 D pin 8 (front). E. SW101 D pin 9 (rear). F. SW101 E pin 1 (front). 2. SW101 A, B, C, or D.
Same as above.	Meter needle should stay at zero as RANGE switch is rotated through 0.1 VOLT to 1000 VOLT positions.	<ol style="list-style-type: none"> 1. Open connection in one of the following: <ol style="list-style-type: none"> A. SW101 A pin 2 or lug 22. B. SW101 B pins 7, 8, 9, 10, or 11. C. SW101 C lugs 14 or 20 (rear). D. SW101 D pins 8 or 10 (front). E. SW101 D pins 9 or 12 (rear). F. SW101 E pins 1 or 2 (front). G. SW101 E pin 1 (rear). 2. SW101.
Reinstall Q101 if it was removed earlier.		



If you obtained the proper results in the preceding tests, the basic meter circuit is now functioning properly. This indicates that any problem encountered in the troubleshooting charts has now been corrected. However, if you have obtained the proper results in the preceding tests, but are unable to calibrate your Multimeter, the problem may be in the wiring and circuitry of the Function or Range switches. Problems in these (and related) areas may be located in the remaining Troubleshooting sections.

NOTE: The following problems that can affect accuracy, linearity, or stability of the basic meter circuit are not covered in this testing procedure.

1. Wrong value or defective resistors (R4, and R137 through R142.).
2. Open capacitors (C114, C117 through C124, and C126).
3. "Leaky" components (C114, C121, C124, C126, Q105, and Q106).
4. Shorted or "leaky" diodes (D111 through D114).

You may identify these problems by inspections, ohmmeter measurement, or substituting parts.

TROUBLE AREA OR SYMPTOM	You may identify these problems by inspections, ohmmeter measurement, or substituting parts.
<p>1. Meter does not read zero.</p> <p>2. Meter does not read properly in all ranges.</p> <p>3. Meter does not read properly in some ranges.</p> <p>4. Meter does not read properly in some functions.</p>	<p>Check for correct zero adjustment.</p> <p>Check for correct range setting.</p> <p>Check for correct function setting.</p> <p>Check for correct range setting.</p> <p>Check for correct function setting.</p>
<p>1. Meter does not read properly in some ranges.</p> <p>2. Meter does not read properly in some functions.</p> <p>3. Meter does not read properly in some functions.</p>	<p>Check for correct range setting.</p> <p>Check for correct function setting.</p> <p>Check for correct range setting.</p>
<p>1. Meter does not read properly in some ranges.</p> <p>2. Meter does not read properly in some functions.</p> <p>3. Meter does not read properly in some functions.</p>	<p>Check for correct range setting.</p> <p>Check for correct function setting.</p> <p>Check for correct range setting.</p>
<p>1. Meter does not read properly in some ranges.</p> <p>2. Meter does not read properly in some functions.</p> <p>3. Meter does not read properly in some functions.</p>	<p>Check for correct range setting.</p> <p>Check for correct function setting.</p> <p>Check for correct range setting.</p>

DC VOLTMETER CIRCUIT

The chart in this section locates problems of a general nature in the circuitry and in the wiring of SW101. A series of "Problems" is listed with "Possible Area of Difficulty" for that problem. The basic meter circuit must operate properly before you perform these tests. See the previous "Troubleshooting Charts."

PROBLEM	POSSIBLE AREA OF DIFFICULTY
DC Voltmeter is inoperative or reads zero on any or all ranges.	<ol style="list-style-type: none"> 1. Open at holes AE, AF, AH, J, W, or X. 2. F101. 3. Open or shorted wiring at "+" socket SW101 A, SW101 B, SW101 C, SW3, or SW4. 4. R2. 5. C2.
DC Voltmeter reads properly on 0.1 and 0.3 VOLT, ranges, but "pegs" at full scale on higher ranges for inputs above 0.3 VDC.	<ol style="list-style-type: none"> 1. R103 through R107, R115, R116, R117. 2. Open in SW101 D or E circuitry. 3. C102, C103, C104.
DC Voltmeter reads properly on 0.1 and 0.3 VOLT ranges, but reads low or zero on higher ranges.	<ol style="list-style-type: none"> 1. C105, C106, C107, C109. 2. Wrong value at R103 through R107, R115, R116, or R117.
DC Voltmeter reads properly on 0.3, 3, 30, and 300 ranges, but "pegs" at full scale on "1" ranges.	<ol style="list-style-type: none"> 1. R146, R147. 2. C126. 3. Open or short in SW101 E circuitry.



PROBLEM	POSSIBLE AREA OF DIFFICULTY
DC Voltmeter is inaccurate when compared to precision standards:	
At full scale readings only.	<ol style="list-style-type: none"> 1. Q105, Q106. 2. D111 through D114. 3. M1. 4. IC103. 5. R139.
At low readings only.	<ol style="list-style-type: none"> 1. Improper adjustment of M1 mechanical zeroing adjustment. 2. Improper adjustment of Zero control (R4). 3. Q107, Q108. 4. LED1, LED2. 5. R141, R142. 6. IC103. 7. M1.
At any reading.	<ol style="list-style-type: none"> 1. R103 through R107, R115 through R117. 2. C2, C102 through C107, C109. 3. Improper adjustment of 0.1 CAL (R146), 0.3 CAL (R149) or Zero (R4). 4. +TP or -TP test points in error.
DC Voltmeter reading is erratic; reads AC voltages on DC function, or is sensitive to nearby AC or RF sources. (Shielded cable or twisted and short input leads do not help).	<ol style="list-style-type: none"> 1. C1, C2, C117 through C123, C126. 2. IC103. 3. Q105, Q106. 4. Open or improper wiring at SW3, hole D solder lug (brown), meter shield solder lug (brown), or hole H (black), or SW101 ground at spacer CC (brown). 5. Ferrite beads FB1 through FB5 cracked. <p>NOTE: Erratic meter indications due to RF and AC fields can be reduced by making the input leads as short as possible and twisting them. See "External Interference" on Page 52.</p>
DC Voltmeter has excessive zero drift.	<ol style="list-style-type: none"> 1. IC103. 2. C2. 3. Q105, Q106. 4. R4, R137, R138.

AC VOLTMETER CIRCUIT

This chart identifies "Problems" and "Possible Area of Difficulty" associated with AC Voltmeter operation. The basic meter and DC voltmeter circuitry must be operating properly before you perform these tests. See the previous "Troubleshooting Charts."

PROBLEM	POSSIBLE AREA OF DIFFICULTY
AC Voltmeter is inoperative (reads zero) on 0.1 and 0.3 VOLT ranges.	<ol style="list-style-type: none"> 1. C108. 2. Open or improper wiring at SW3 lugs 2 or 3.
AC Voltmeter has high "zero" reading on .1 and .3 VOLT ranges with test leads disconnected; or when using shielded cable or twisted leads.	<ol style="list-style-type: none"> 1. C101. 2. Open or improper wiring at SW2 lugs 10 and 11; SW3 lugs 1 and 2; solder lug at hole D (brown) or solder lug at meter shield (brown). 3. SW2, SW3. 4. Poor connection of Power switch shield.
AC Voltmeter responds to DC voltages.	<ol style="list-style-type: none"> 1. C108. 2. Short or improper wiring at SW4 lugs 11 and 12. 3. SW101 A.
DC+ and DC- indicators "flicker" or turn off when measuring AC.	<ol style="list-style-type: none"> 1. Open or improper wiring at SW4 lugs 7 and 8; or hole T (green). 2. SW4.
AC Voltmeter cannot be calibrated on 0.1 VOLT range at 80 Hz using precision standards.	<ol style="list-style-type: none"> 1. R151, R152. 2. Open or improper wiring at SW4 lugs 1, 2, or 7; hole F (red); or hole H (black). 3. Improper adjustment of 0.1 CAL (R146) or 0.3 CAL (R149) controls. 4. C108. 5. D111 through D114.
AC Voltmeter is inaccurate (when compared to precision standards) at low frequencies (40 to 100 Hz) on 0.1 VOLT range at low readings.	<ol style="list-style-type: none"> 1. D111 through D114. 2. IC103. 3. R139.
Frequency response is not flat:	
on 0.1 or 0.3 VOLT ranges at low frequencies.	<ol style="list-style-type: none"> 1. C108, C117 through C119.
on 0.1 or 0.3 VOLT ranges at high frequencies.	<ol style="list-style-type: none"> 1. C121, C122, C123, C126. 2. Q105, Q106. 3. IC103. 4. D111 through D114.
Frequency response is not flat on higher ranges.	<ol style="list-style-type: none"> 1. Improper adjustment of C103. 2. C102 through C107, C109.

OHMMETER TESTS

The tests in this section are divided into two parts. The "Voltage Tests" locate problems in the ohmmeter reference voltage source, SW101 and SW2 circuitry. A DC voltmeter is required.

The chart in the "Operational Troubleshooting" on Page 77 identifies "Problems" and "Possible Area of Difficulty" associated with ohmmeter operation. The basic meter circuit, DC voltmeter, and AC voltmeter must be operating properly before you perform the following tests. See the previous "Troubleshooting Charts."

Voltage Tests

- Push the DC/ Ω switch in; the AC and Ω LV switches should be out.
- Set the Range switch to the 3 VOLT position.

NOTE: If the base (B) voltage of Q101 measures within 10% of +1.55 VDC and the base (B) voltage of Q102 measures within 0.1 VDC of this voltage, proceed directly to the test marked with a ★ on Page 74, and proceed from that point.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Plug black test lead into "-" socket. Connect alligator clip to collector (C) of Q101.	+15 VDC at collector (C) and emitter (E) of Q103 and base (B) of Q104. Base (B) of Q103 should measure 0.7 VDC less positive than emitter (E).	1. R126, R127. 2. Q103. NOTE: If Q103 is defective, check for a short in one of the following areas: A. SW2 lugs 4, 5, or 6. B. Hole P (gray). C. Hole AA (white). D. Hole Z (violet). E. SW101 D pins 1 and 5 (front).
Same as above.	Emitter (E) of Q104 should measure 0.7 VDC less positive than base (B).	1. Q104.
Same as above.	Cathode (banded) end of D109 should measure 0.6 VDC less positive than emitter (E) of Q104.	1. D109.
Same as above.	More than +10 VDC at base (B) of Q103.	1. R131, R132. 2. Short or improper wiring at SW2 lugs 2 or 5; or hole P (gray). 3. SW2.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Same as above.	Collector (C) and emitter (E) of Q102 should measure 0.7 VDC less positive than base (B).	1. Q102.
Disconnect the alligator clip from Q101. Use long-nose pliers (or a loose alligator clip) and short the base (B) to the emitter (E) of Q101. Use care not to short to the collector (C) lead.	+15 VDC at collector (C) of Q101 and base (B) of Q102.	1. Q101. 2. C115. 3. R126.
Same as above.	Between +0.4 VDC and -0.4 VDC at base (B) of Q102 and collector (C) of Q103.	1. Q102, Q103. See NOTE in "Possible Area of Difficulty" column of first "Test" in this Chart. 2. C116.
Same as above.	More than +10 VDC at collector (C) of Q102.	1. R128.
Disconnect short from Q101.	Up to +0.9 VDC at emitter (E) of Q101.	1. R129. 2. Q101.
None.	+1.55 VDC $\pm 10\%$ at base (B) of Q101 and base (B) of Q102 within ± 0.1 VDC of this voltage.	1. Q101, Q102, Q104. 2. R132. 3. C115, C116.
None. ★	+1.55 VDC at SW101 D pin 1 (front).	1. Open or improper wiring at hole P (gray); SW2 lugs 5 or 6; hole Z (violet), or SW101 D lug 1. 2. SW2.
None.	+1.3 VDC at cathode (banded) end of D103.	1. D101 through D104. 2. R101.
None.	Less than +0.5 VDC at cathode (banded) end of D104.	1. D103, D104.



NOTE: In the next test, a short circuit to ground at SW101 D pin 5 (front) may damage the ohmmeter reference voltage source. If you have an ohmmeter, measure for a short circuit at SW101 D pin 5 (front) with the range switch in the $\Omega \times 100$ position and

with the POWER switch off (out). If you do not have an ohmmeter, press the POWER switch to off (out) before performing the tests' special instructions. Then turn the power switch on; but be prepared to turn it off **immediately** if the voltage measurement is zero.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Rotate RANGE switch to $\Omega \times 100$ position. Ignore any meter reading until otherwise instructed.	+1.55 VDC at SW101 D pin 5 (front).	1. Open, short, or improper wiring at SW101 D.
Same as above.	Greater than 1.3 VDC at SW101 C pin 7 (front).	1. R117. 2. Open or short at switch.
Same as above.	Greater than +1.3 VDC at hole AA.	1. R118. 2. Open, short, or improper wiring at hole AA (white) or SW2 lugs 4 or 5. 3. SW2.
Same as above.	Greater than +1.4 VDC at SW101 C pin 8 (front).	1. R115. 2. Open or short at switch.
Rotate the RANGE switch to the $\Omega \times 1$ position.	Greater than +1.4 at SW101 C pin 12 (front).	1. Open at SW101 C. 2. Short in one of the following areas: A. SW101 C pin 12 or lug 20 (rear). B. SW101 B pin 12. C. SW101 B pins 2, 8, 9, 10, or lug 13. D. Hole AG. E. D104.
Same as above.	+1.55 VDC at cathode (banded) end of D104.	1. R102. 2. D103.
Same as above.	Meter reading above half scale.	1. Open or improper wiring at SW101 C pin 12 (rear); SW101 D pin 1 (front); or hole AG. 2. R153.
Same as above.	0 VDC at SW101 D pins 2 or 3 rear.	1. SW101 D.
Same as above.	Voltage at "+" marked end of C125 is equal or greater than +1.55 VDC.	1. C125. 2. Short or improper wiring at hole E; SW101 D pins 9 or 12, or lug 22; or hole F (white-black); or SW7.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Same as above.	+1.55 VDC at hole J, and meter pointer can be adjusted to full scale using Ω ADJUST control.	<ol style="list-style-type: none"> 1. R133, R134, R135, R153. 2. C117, C118, C119, C125.
Push Ω LV switch in. RANGE switch is still in the $\Omega \times 1$ position.	+1.55 VDC at hole AA.	<ol style="list-style-type: none"> 1. Open or improper wiring at SW2 lugs 4 or 5. 2. SW2.
Same as above.	0 VDC at SW101 D lug 20 (rear).	<ol style="list-style-type: none"> 1. Open or improper wiring at SW2 lugs 7 or 8; or hole F (white-black), or SW101 D. 2. SW2.
Same as above.	0.078 VDC at SW101 C pin 7 (front).	<ol style="list-style-type: none"> 1. R1, R117, R118. 2. Open or improper wiring at SW2 lugs 1, 2, or 6; or hole AA (white)
Adjust Ω ADJUST to position needle at " ∞ " mark. Ω LV switch is still pushed in. Then rotate RANGE switch through the $\Omega \times 1$ to Ω 1M positions.	Needle should remain at the " ∞ " mark.	<p>Needle drops:</p> <ol style="list-style-type: none"> 1. Open, short, or improper wiring in one of the following areas: <ol style="list-style-type: none"> A. SW101 A pins 8, 9, 10, or lug 13. B. SW101 B pins 1, 2, or 12. C. SW101 C pin 12 (front). D. SW101 C pin 12 or lug 14 (rear). E. SW101 D pins 1 or 5 (front). F. SW101 E pin 1. G. SW2 pins 10 or 11. 2. D104. 3. C2. 4. Q105, Q106. <p>Needle raises:</p> <ol style="list-style-type: none"> 1. Open, short, or improper wiring at SW101 D pins 2, 3, or 8 (rear).
Rotate RANGE switch to $\Omega \times 100$. Push DC/ Ω switch in. Connect black test lead to collector (C) of Q101.	+2.1 VDC at cathode (banded) end of D103.	<ol style="list-style-type: none"> 1. D103. 2. R102.

SPECIAL INSTRUCTIONS	TEST FOR	POSSIBLE AREA OF DIFFICULTY
Disconnect alligator clip from Q101, and connect it to cathode (banded) end of D104. Rotate RANGE switch to $\Omega \times 1$.	Meter indication of approximately 2.6 Ω .	1. R102. 2. Q104.
Unplug black test lead from "-" socket. Rotate the RANGE switch to the 3 VOLT position.	DC+ indicator should turn off when black test lead plug is touched to collector (C) of Q108.	1. D104.
Disconnect the black test lead. Plug the red test lead into the "+" socket. Rotate the RANGE switch to the $\Omega \times 1K$ position. Adjust the meter needle to the " ∞ " mark using the Ω ADJUST control. Then touch the test probe tip to SW101 C pin 1 (front).	Meter should indicate 10 on the OHMS scale.	1. R108 through R114 open or wrong value. 2. Short or open near SW101 C pins 1 through 6.

If you have completed the Ohmmeter "Voltage Tests" but the ohmmeter still does not operate properly, proceed to the "Operational Troubleshooting" chart below.

Operational Troubleshooting

The following charts locate problems of a general nature in the operation of the ohmmeter circuitry. A series of problems is listed with "Possible Area of Difficulty" for that problem. The tests require proper

operation of the basic meter circuit, the ohmmeter reference voltage circuit, and the wiring and circuitry of the previous troubleshooting charts.

PROBLEM	POSSIBLE AREA OF DIFFICULTY
Ohmmeter is inoperative (reads zero) on any or all ranges on DC/ Ω .	1. If base (B) of Q102 measures 1.55, ± 0.1 VDC, open, short, or improper wiring in one of the following areas: A. SW2. B. SW101 A, B, C, or D (front) hole P, Z, or AA. 2. Q101 through Q104 circuit. 3. C2. 4. D104 if reads zero on $\Omega \times 10K$ and higher.
Ohmmeter "pegs" at full scale and can not be adjusted to " ∞ " mark on DC/ Ω .	1. R101, R133, R134, R135, R153. 2. C117, C118, C119, C125. 3. Open, short or improper wiring at SW101 D (rear). 4. Q101 through Q104 circuit. 5. IC103. 6. D101 through D104.

PROBLEM	POSSIBLE AREA OF DIFFICULTY
Ohmmeter can be adjusted to "∞" mark but does not read a resistance at the input on DC/Ω.	<ol style="list-style-type: none"> 1. F101. 2. R2, R103 through R107, R115 through R117, R136. 3. Open in SW101 B, C, or D.
Ohmmeter cannot be adjusted to "∞" mark on ΩLV.	<ol style="list-style-type: none"> 1. Improper adjustment of 0.1 CAL (R146) or 0.3 CAL (R149). 2. Open, short, or improper wiring in one of the following areas. <ol style="list-style-type: none"> A. SW2. B. SW101 D.
Ohmmeter is inaccurate when compared to precision standards on:	
Ω × 1 position (DC/Ω and ΩLV).	<ol style="list-style-type: none"> 1. R117. $10^{-3}W$ 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 Multimeter. If the meter indicates 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. 2. Q101, Q102, or Q104.
Ω × 1 position (ΩLV only).	<ol style="list-style-type: none"> 1. R1, R118.
Ω × 10 through Ω × 1K.	<ol style="list-style-type: none"> 1. R107, R115, R116. 2. D103, D104.
Ω × 10K through Ω × 1M.	<ol style="list-style-type: none"> 1. R103 through R106. 2. C2, C102 through C106. 3. Q105, Q106. 4. High resistance leakage in R103 through R105, R136, Q105, Q106, or IC103 circuitry; possibly due to high humidity.

DC AND AC MILLIAMMETER CIRCUIT

The following chart identifies "Problems" and "Possible Area of Difficulty" of these problems in the switch wiring and circuitry of SW101 and SW4 that affect the DC and AC Milliammeter function. The basic meter, DC voltmeter, and AC voltmeter circuitry must operate properly before you proceed to the following chart. See the previous "Troubleshooting Charts."

PROBLEM	POSSIBLE AREA OF DIFFICULTY
Milliammeter is inoperative (reads zero) on any or all DC ranges.	<ol style="list-style-type: none"> 1. F101. 2. Open, short, or improper wiring in one of the following areas: <ol style="list-style-type: none"> A. SW101 B pins 2 or 8, or lug 13. B. SW101 C pins 1 through 6, or pin 12 (front). C. SW101 C pin 4 or lug 14 (rear). D. SW4 pins 5 or 6. E. Holes AC, AG, AB (orange), or AD (yellow). 3. SW2. 4. SW101 B, or C.
Milliammeter "pegs" at full-scale on all DC ranges.	<ol style="list-style-type: none"> 1. R108 through R114. 2. Short near SW101 C (front). 3. Improper wiring of R114. 4. Open or short at SW101 E pin 1.
Milliammeter is inoperative (reads zero) on all AC ranges.	<ol style="list-style-type: none"> 1. C111. 2. Open, short, or improper wiring at SW4 pins 5 or 6. 3. SW4.
Milliammeter reads DC current on AC ranges.	<ol style="list-style-type: none"> 1. C111.
Milliammeter reading is inaccurate (when compared to precision standards) on any range. NOTE: Be sure to consider the effects of the insertion voltage drop when you use your Multimeter or check it for accuracy. (See "Specifications" on Page 80.)	<ol style="list-style-type: none"> 1. R3, R108 through R114. 2. Short near SW101 C (front). 3. Open at SW101 D lug 20, or hole E.
Milliammeter requires a long time to "zero" after AC input is removed.	<ol style="list-style-type: none"> 1. R3. 2. Open or improper wiring at SW4 lugs 1 or 2. 3. SW4.
F101 "blows."	<ol style="list-style-type: none"> 1. F101. 2. D101 through D104. 3. Short near SW101 A pins 2, 9, or 10.



SPECIFICATIONS

NOTE: All "Accuracy" specifications exclude the accuracy of calibration standards.

The accuracy of the built-in calibration standards is within $\pm 5\%$.

DC VOLTMETER

Nine Ranges	0 - .1, .3, 1, 3, 10, 30, 100, 300, and 1000 volts full-scale.
Input Resistance	10 M Ω .
Accuracy	$\pm 2\%$ of full scale.
Auto Polarity	Front panel lights indicate positive or negative input.

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 M Ω .
Input Capacity	100 pF typical.
Accuracy	$\pm 3\%$ of full scale (60 Hz sine wave).
Response	Responds to the average value of a full-wave rectified sine wave. Scale calibrated to indicate rms.

Frequency Response	Range	Error	Frequency
	0.1 - 300	±3%	10 Hz to 100 kHz.
	1000	±3%	10 Hz to 50 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.

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% on 1000 range
 (60 Hz sine wave).

Response Responds to the average value of a full-wave rectified sine wave. Scale calibrated to indicate rms.

Frequency Response	Range	Error	Frequency
	0.01 - 10	±3%	10 Hz to 100 kHz.
	100 - 1000	±3%	10 Hz to 50 kHz.

OHMMETER

Seven Ranges	$\Omega \times 1$ (10 Ω center scale), $\Omega \times 10$, $\Omega \times 100$, $\Omega \times 1K$, $\Omega \times 10K$, $\Omega \times 100K$, $\Omega \times 1M$.
Accuracy	± 3 degrees of arc on $\Omega \times 1$ range (above 2 ohms). ± 2 degrees of arc on $\Omega \times 10$ to $\Omega \times 1M$ ranges.
Test Voltage (nominal)	1.55 volts on DC/ Ω . 0.078 volts on ΩLV .

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

Meter	4-1/2", 200 μ A 100-degree movement.
Input Overload Protection	Will sustain 700 VAC (1000 VPK) or 1000 VDC on 1-volt to 1000-volt ranges. Will sustain 220 VAC or 300 VDC on any other range. 2-ampere, quick-blow input fuse caused to open with overload on $\Omega \times 1$ range, to $\Omega \times 1k$ range, and 0.01 to 1000 mA ranges by input clamping diodes. Measurement circuitry on 0.1 volt and 0.3 volt ranges protected by clamping transistors.
Front Panel Controls	24-position, continuous-rotation Range switch with concentric ohmmeter full-scale adjustment control. 4-position pushbutton switch: AC, DC/ Ω , Ω LV, Power (On/Off).
Meter Temperature Coefficient	Maximum of $\pm 0.1\%$ or ± 0.1 degrees of arc (whichever applies) per degree C over a range of 10 to 40 degrees C (50° to 104°F).
Operating Temperature	0 to 50 degrees C (32° to 122°F).
Storage Temperature	-40 to +70 degrees C (-40° to +158°F).
Dimensions (Overall)	5-3/4" wide \times 6-7/8" high \times 11-1/4" deep (14.61 \times 17.46 \times 28.56 cm).
Weight	5-3/4 pounds (2.61 kg).

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

CIRCUIT DESCRIPTION

Refer to the Schematic (fold-in) and Circuit Diagrams (in the "Illustration Booklet") while you read the following description.

The measurement circuitry of the Multimeter consists of input circuitry and a basic meter circuit.

The input circuitry for DC and AC voltage measurements consists of a voltage divider network and associated components which scale down voltages above the range of the basic meter circuit.

The input circuitry for DC and AC current measurements consists of a series of precision current-sensing resistors whose current-related voltage drop is measured directly by the basic meter circuit.

The input circuitry for resistance measurements consists of an internal reference voltage connected through a series of precision resistors to the resistance being measured. The voltage across the unknown resistance is measured directly by the basic meter circuit in conjunction with the Ohms scale of the meter movement.

Since all inputs are measured directly or indirectly by the basic meter circuit, the manner in which it operates will be described first to simplify the description of how the measurements are made by the Multimeter as a whole.

BASIC METER CIRCUIT

The principle sections of the basic meter circuit are shown in the block diagram (Illustration Booklet, Page 7). The input to be measured is applied to one of the FET-input op amp (operational amplifier) inputs. The output of the op amp drives the meter and the feedback circuitry. A portion of this output, as a proportional voltage, is returned to the other input of the op amp. Here, it is compared to the original input voltage. Following is a brief discussion of this voltage comparison.

Part A of Pictorial 12-1 (Illustration Booklet, Page 7) shows a generalized differential op amp. $+V$ and $-V$ are the supply voltages which power the op amp. The " $+$ " represents a "non-inverting" input and the " $-$ " represents an "inverting" input. That is, if the " $-$ " input is held constant and the " $+$ " input changes, 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 immediately force the op amp output to its maximum.



The manner in which this type of amplifier is used in the basic meter circuit is illustrated in Pictorial 12-1, Part B. Assume resistor network R_F 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 is a “non-inverting” amplifier with a fixed gain of 10. The gain can be changed by varying either R or R_F . 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 Pictorial 12-1, Part C, the performance of the op amp can be further improved by adding two field-effect transistors (FET's). (These are internal to IC103.) These transistors provide a very high input impedance and a low output impedance. This low output impedance provides a stable driving point for each input of the op amp and the high input impedance minimizes loading of any high impedance circuitry (such as from the input circuitry in the Multimeter).

Part D of Pictorial 12-1 is a simplified version of Part C, with a current meter now placed in the output circuit of the op amp. Since the voltage across R_F must always equal the input voltage, the current through R_F , and M1 (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 volt, for example), R_F is adjusted until the meter deflects to full scale. The meter scale can then be calibrated linearly from 0 volt to a full scale of 0.1 volt, and is independent of any circuitry which may be in series with M1 since circuit current, not voltage drop, is being “monitored” by R_F .

To automatically produce an up-scale indication on meter M1 for either positive or negative input voltages, meter M1 is incorporated into a full-wave rectifier circuit as shown in Part E of Pictorial 12-1. For positive input voltages, current flows from the op amp output through D113, D114, and then through both M1 and R144 (and also through R143) to R_F . For negative inputs, current flows into the op amp output

from D111, D112, from R143 and M1 (and also through R144). Note that in both cases, current flows through M1 (I_M) in the same direction (from + to -).

Since meter M1 always deflects upscale, regardless of input polarity, the Q107, Q108 circuitry of part E has been added to indicate actual input polarity. For an input voltage near zero, the op amp output is also near zero. Since neither Q107 or Q108 is thus biased on, both the DC+ LED (light-emitting diode) and the DC- LED are lighted. For higher positive inputs, the op amp output goes positive. This biases Q107 on, shunting current away from the DC- LED and turning it off. Q108 is still off and the DC+ LED is still lighted. For negative inputs, Q108 is biased on and current is shunted away from the DC+ LED leaving the DC- LED lighted.

This circuit can measure AC directly since meter M1 is deflected upscale for both the positive and negative portions of an AC waveform. However, since the average current for a sine wave is only 63.7% of its peak current and the rms (root-mean-square) value is at 70.7%, the gain (sensitivity) of the circuit must be increased by approximately 11% so that this average-responding circuit will indicate the correct rms value ($70.7/63.7 = 111\%$). This is accomplished by switching R_{AC} into the circuit, requiring 11% more current through meter M1 to balance the inputs of the op amp. At the same time, the polarity indicator circuitry of Q107, Q108 is deactivated by shorting both transistor inputs to ground. This short is “decoupled” from the op amp by R139. Now, neither transistor can be biased on, and both LED's remain on.

Part F of Pictorial 12-1 is similar to the circuitry of Part D to illustrate the operation of the basic meter circuit for resistance measurements. Here, a simplified diagram of the input circuitry is also shown.

R_{OHMS} is used to adjust the feedback so that “E” produces exactly a full-scale deflection when the input is open-circuited (R_X equals infinity, “ ∞ ”). 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 an amount proportional to the ohmic value of the resistance, R_X , being measured. In particular, when $R_X = R_{STANDARD}$, meter M1 deflects to exactly center-scale. The meter scale is then further calibrated in ohms using the mathematical relationship resulting from the division of E between R_X and and $R_{STANDARD}$.

DC VOLTAGE MEASURING CIRCUITRY

Pictorial 12-2 (Illustration Booklet, Page 8) illustrates the Multimeter circuitry for DC voltage measurements.

The capacitors shown in dashed lines are connected as shown but do not affect DC voltage measuring. The input DC voltage is connected through the input switching circuit of SW101 A and SW4 to R103 and R104 as shown. Range switch SW101 B is shown in the 1.0 volt position. With an input of exactly 1.0 volts, the voltage division of R103 and R104, R105, R106, R107, R116, R115, and R117 produces exactly 0.1 volts at the junction of R104 and R105. This voltage is connected through SW101 B, SW101 C, R2 and then R136 to the op amp "+" input, pin 3. IC103 and M1 operate as explained in the "Basic Meter Circuit" section. Transistors Q105 and Q106 are connected as "clamping" diodes to protect IC103 against excessive positive or negative input voltages. Resistors R2 and R136 limit the current through Q105 and Q106 if the input voltage is excessive. C2 acts with R2 as a "low-pass filter" to filter out AC voltages which may be superimposed on the DC voltage.

The current through meter M1 and the diode circuitry generates a voltage across the resistor network of R145 through R149, (switched in by SW101 D) and R153. Exactly 0.1 volts of this voltage from the arm of calibration control R146 is fed back through SW101 E (lug 1) to pin 2 of IC103 to balance the op amp inputs. (R133, R134, and R135 are all "floating" and thus, do not have any voltage "drop.") If switch SW101 B is now switched to the 3.0 volt position, the input voltage to pin 3 is still 0.1 VDC and thus, the voltage to pin 2 of IC103 still must be 0.1 volt as before. However, switch SW101 E now connects the entire R145 and associated circuitry to pin 2. This increased resistance causes the meter reading to drop since less current produces the required 0.1 volt input to IC103, SW101 E alternates between lug 1 and lug 2 for each position of the Range switch.

Resistors R137, R4, and R138 balance the internal circuitry of IC103 to zero the meter when the input is zero.

Resistor R139 and capacitor C124 are a low-pass filter to eliminate any transient flicker in the DC+ and DC-LED's.

AC VOLTAGE MEASURING CIRCUITRY

The circuit shown in Pictorial 12-3 (Illustration Booklet, Page 9) is used when AC voltages are measured. C108 is now inserted between SW101 A and the voltage divider to block any DC portion of the input voltage and C102 through C107, and C109 may be considered as part of the voltage divider circuit. C2 is disconnected from the circuit to prevent filtering of the AC voltage and R2 is shorted out of the circuit. R151 and R152 are added across the total feedback circuit (R145 through R149, and R153) to lower the overall resistance, as previously discussed in the "Basic Meter Circuit" section.

Operation of the AC circuit is similar to that for DC. The input AC voltage, after passing through C108, is applied to the voltage divider circuit. At low frequencies, the capacitors in the divider circuit have little effect and the voltage to R136 and IC103 is primarily determined by the resistors in the divider network. As the input frequency increases, the impedance of the capacitors connected across the resistors decreases. The values of the capacitors are such that the input to IC103 for each range remains essentially constant ("flat") as the frequency changes. Thus, the voltage divider circuit is "frequency compensated." Because of the high values of R103 and R104, and the possibility of variations in stray capacitance, the compensation across these is made variable (C103) to allow a fine adjustment for the higher frequencies. The AC current from the output of IC103 flows alternately through the meter and diode circuitry and then to the resistor network of R145 through R153. Capacitors C121 and C126 extend the amplifier bandwidth. The Q107 and Q108 circuits are deactivated by SW4. SW101 E alternates the feedback point in the same manner as for DC voltages.

DC AND AC CURRENT MEASURING CIRCUITRY

Refer to Pictorial 12-4 (Illustration Booklet, Page 10). For both DC and AC current measurements, the current to be measured flows through fuse F101, switches SW101 A and SW101 C (front), the selected sensing resistors (in this case, R108 through R114) and then back to the circuit under test. This current flow generates a voltage (across the selected sensing resistors) directly proportional to the current. This voltage is coupled through SW4 (for DC) or C111 (for



AC) to SW101 C (rear) and then via the R2 and C2 circuitry, to IC103. Resistor R3 provides a DC discharge path for C111 when AC current is measured. The balance of the circuitry (R2, C2, IC103, etc.) functions identically to that described for DC and AC voltage measuring circuitry. SW101 E is always connected to lug 1 for the “mA” ranges.

Diodes D101 to D104 and resistors R101 and R102 form a protection circuit for the precision sensing resistors in case an over-current is inadvertently applied. This circuit is connected in for all current ranges. If the voltage at the junction of D103 and D104 becomes more positive than +2.1 volts, or more negative than -0.7 volts, either D103 (along with D101 and D102) or D104 will be heavily forward biased. The current through fuse F101 and R102 will increase greatly and cause F101 to open (when the current exceeds 2 amperes) and disconnect the Multimeter from the circuit. Voltage clamping transistors Q105 and Q106 provide protection at IC103.

RESISTANCE MEASURING CIRCUITRY

Low Test Voltage (Ω LV)

Pictorial 12-5 (Illustration Booklet, Page 11) is the schematic of the low-test voltage ohmmeter circuit. The network of E_{REF} , R118, and R1, in conjunction with R117, as shown in Part 1 of Pictorial 12-6 provides a low test voltage of 0.078 VDC with an equivalent source impedance of 10.0 Ω . This equivalent circuit is shown in Part 2 of Pictorial 12-6.

As shown, the 0.100 VDC (which corresponds to full-scale deflection) produced at the arm of R146 is fed back to the top of R133 by SW101 E lug 1 for the Ω ranges. R134 is then adjusted so the voltage at pin 2 of IC103 is equal to the actual low-test voltage applied to pin 3 through SW101 C (rear) and R2 and R136 when the Multimeter input is open-circuited. The “slider” of the Range switch is also connected to the Multimeter input.

When an unknown resistance is connected to the Multimeter input, the ohmmeter test voltage is divided between the unknown resistance and the 10 Ω /0.078 VDC equivalent circuit. The portion of the voltage across the unknown resistance is then measured by the basic meter circuit as previously described. This voltage is displayed as a resistance value on the Ohms scale of the meter movement. As the Range switch is rotated to higher ranges, the “standard” resistor increases by a power of 10 (100, 1000, etc.).

As shown, the D101 through D104 circuitry is connected in the circuit by SW101 A for the ranges up to $\Omega \times 1K$ to protect the precision resistors. For higher ranges, the precision resistors have a high enough resistance value that they cannot be overloaded by voltages normally encountered. IC103 on these higher ranges is protected by the R2, R136 and Q105, Q106 circuitry. Capacitors C117, C118, and C119 bypass the high-impedance R133, R134, and R135 circuitry.

High Test Voltage (DC/ Ω)

The high-test voltage ohmmeter circuit is shown in Pictorial 12-7 (Illustration Booklet, Page 12). The operation of this circuit is similar to the circuit previously described for Ω LV, except that the internal reference voltage is now 1.55 VDC and the R145 through R149 circuit is “floated” with SW2 open, producing a full-scale sensitivity of approximately 2.0 VDC at the top of R153. This is then divided by the R133 through R135 circuit as before to balance the op amp inputs. C125 stabilizes the feedback circuit to prevent oscillation.

OHMMETER REFERENCE VOLTAGE CIRCUIT

The ohmmeter reference voltage circuit consists of transistor Q101 through Q104 and associated components. The divider circuit (R124 and R125) produces approximately 1.55 VDC at the base of Q101. Q101 and Q102 form a differential amplifier and the R129 current is divided between them. If the input at the base of Q102 tends to decrease (be less than the voltage at base of Q101), the portion of the current through Q101 increases. This provides higher forward bias to Q103, and thus Q104, to raise the voltage back up. A similar, but opposite, action occurs if the voltage at the base of Q102 tends to rise. This circuit regulation keeps the 1.55 VDC at the base of Q102 very stable.

Overload protection in this circuit (in addition to the D101 through D104 circuitry) is provided by D109 for high positive overloads, and by current limiting of R131 for high negative overloads.

POWER SUPPLIES AND BUILT-IN CALIBRATION VOLTAGES

The power supply consists of transformer T1, diodes D105 through D108, filter capacitors C112 and C113, positive and negative integrated circuit regulators (IC101 and IC102), and associated circuitry.

The power transformer has a dual primary winding and the Multimeter can be operated on either 120 or 240 volts by setting switch SW5 to the proper position.

The output of the transformer is rectified and filtered, producing about ± 14 volts DC. The IC regulators

(IC101 and IC102) regulate these voltages to ± 7 volts by resistor network R121, R122, and R123. These regulators control the output voltages by maintaining the voltage at pin 3 of IC101 (+TP) at close to +5.00 VDC and the voltage at pin 2 of IC102 (-TP) at close to -2.23 VDC. Since these are maintained within $\pm 5\%$, they provide fairly accurate calibration references.

These regulators, through internal circuitry, provide short-circuit (and thermal overload) protection.

C122 provides transient filtering on the +7 VDC supply while C114 and C123 filter the -7 VDC supply.

Ferrite beads, FB1 through FB5, reduce the susceptibility to RF pickup.

SEMICONDUCTOR IDENTIFICATION CHART

HEATH PART NUMBER	MAY BE REPLACED WITH	CIRCUIT COMPONENT NUMBER	BASING DIAGRAM	
56-56	1N4149	D111, D112, D113, D114	A	<p>A IMPORTANT: THE BANDED END OF DIODES CAN BE MARKED IN A NUMBER OF WAYS.</p> <p>BANDED END</p>
57-27	1N2071	D101, D102, D103, D104, D109		
57-65	1N4002	D105, D106, D107, D108		
417-118	2N3393 <i>50016</i>	Q101, Q102, Q105, Q106	B	<p>B</p> <p>EMITTER OR EMITTER BASE BASE COLLECTOR COLLECTOR</p>
417-808	2N3702 <i>50019</i>	Q103, Q108		
417-809	2N3704 <i>50015</i>	Q107		
417-818	MJE181 <i>5500</i>	Q104	C	<p>C</p> <p>METAL UP BASE COLLECTOR EMITTER</p>
442-617	UA78MGT2C	IC101	D	<p>D</p> <p>INPUT 1 4 COMMON COMMON 2 3 CONTROL OUTPUT</p> <p>TOP VIEW</p>
442-618	UA79MGT2C	IC102	E	<p>E</p> <p>COMMON 1 4 INPUT INPUT 2 3 OUTPUT</p> <p>TOP VIEW</p>
442-623	CA3130S <i>SK3568</i>	IC103	F	<p>F</p> <p>+V OUTPUT COMPENSATION 8 7 6 5 OFFSET NULL TAB OFFSET NULL AND COMPENSATION 1 2 3 4 -V AND CASE INV INPUT NON INV INPUT</p> <p>TOP VIEW</p>

FOR PARTS REQUESTS ONLY

- Be sure to follow instructions carefully.
- Use a separate letter for all correspondence.
- Please allow 10 - 14 days for mail delivery time.

DO NOT WRITE IN THIS SPACE

INSTRUCTIONS

- Please print all information requested.
- Be sure you list the correct **HEATH** part number exactly as it appears in the parts list.
- If you wish to prepay your order, mail this card and your payment in an envelope. Be sure to include 10% (25¢ minimum, \$3.50 maximum) for insurance, shipping and handling. Michigan residents add 4% tax. Total enclosed \$ _____
- If you prefer COD shipment, check the COD box and mail this card. COD

NAME _____
 ADDRESS _____
 CITY _____
 STATE _____ ZIP _____

The information requested in the next two lines is not required when purchasing nonwarranty replacement parts, but it can help us provide you with better products in the future.

Model # _____ Invoice # _____
 Date Purchased _____ Location Purchased _____

LIST HEATH PART NUMBER	QTY.	PRICE EACH	TOTAL PRICE

TOTAL FOR PARTS	
HANDLING AND SHIPPING	
MICHIGAN RESIDENTS ADD 4% TAX	
TOTAL AMOUNT OF ORDER	

SEND TO: **HEATH COMPANY**
 BENTON HARBOR
 MICHIGAN 49022
ATTN: PARTS REPLACEMENT

Phone (Replacement parts only): 616 982-3571

THIS FORM IS FOR U.S. CUSTOMERS ONLY
 OVERSEAS CUSTOMERS SEE YOUR DISTRIBUTOR

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CUT ALONG DOTTED LINE

CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of the defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor
MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit? — Self-Service? — Construction? — Operation? — Call or write for assistance. you'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase and invoice number.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit COD for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment. Do not include the kit Manual.) Place the equipment in a strong carton with at least **THREE INCHES** of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022



HEATH COMPANY • BENTON HARBOR, MICHIGAN
THE WORLD'S FINEST ELECTRONIC EQUIPMENT IN KIT FORM

LITHO IN U.S.A.