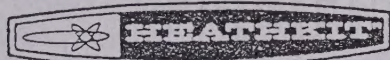


Assembly and Operation of the



DIGITAL MULTIMETER MODEL IM-1210

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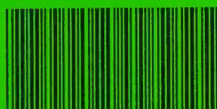
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CAUTION: TO PREVENT FIRE OR SHOCK, DO NOT
EXPOSE THIS INSTRUMENT TO RAIN OR MOIS-
TURE.

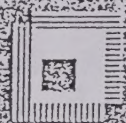
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MP MASTER



MA23877



Belle Howell Schools

ASSEMBLY MANUAL

9580

IM-1210

Digital Multimeter CONDENSED MANUAL

CONDENSED MANUAL

595-1872

PARTS LIST

Check each part against the following list. Refer to the illustration in the separate "Illustration Booklet" that corresponds to the key number on the Parts List. The parts may vary slightly from the illustrations. Any part that is individually packaged with a part number on it should be kept in its package after it is identified until you use it.

Some parts are marked with a "171-" or "172-" packaging number. These numbers are used for packaging only and do not appear in the Manual "Parts List." Save all packaging material until all parts have been located.

To order a replacement part, use the Parts Order Form furnished with this kit. For pricing information, refer to the separate "Heath Parts Price List."

Each circuit component in this kit has a Circuit Component Number (R2, C4, Q1, etc.). This is a specific number for only that one part in the kit. The purpose of these numbers, which are especially useful if a part ever has to be replaced, is to help you easily identify the same part in each section of the Manual. These numbers will appear:

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

KEY PART No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
-----------------	------	-------------	----------------------

RESISTORS

NOTE: Open all resistor envelopes (marked R) before you check the resistors. All resistors are 10% (fourth band silver) unless designated 5% (fourth band gold).

1/2-Watt

A1	1-3	2	100 Ω (brown-black-brown)	R13,R78
A1	1-193	19	180 Ω (brown-gray-brown)	R35,R36,R37, R38,R39,R41, R42,R43,R44, R45,R46,R47, R48,R49,R51, R52,R53,R67, R81
A1	1-48	5	390 Ω (orange-white-brown)	R23,R24,R26, R34,R77
A1	1-119	2	560 Ω (green-blue-brown)	R16,R65
A1	1-80	2	1200 Ω , 5% (brown-red-red)	R64,R88
A1	1-11	2	1500 Ω (brown-green-red)	R15,R18
A1	1-44	6	2200 Ω (red-red-red)	R21,R22,R33, R66,R69,R79
A1	1-18	4	5600 Ω (green-blue-red)	R25,R27, R29,R32
A1	1-116	1	6200 Ω , 5% (blue-red-red)	R56
A1	1-105	3	10 k Ω , 5% (brown-black-orange)	R31,R61,R62
A1	1-21	3	15 k Ω (brown-green-orange)	R54,R68,R93
A1	1-26	2	100 k Ω (brown-black-yellow)	R57,R58

KEY PART No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
-----------------	------	-------------	----------------------

Resistors (cont'd.)

A1	1-35	2	1 M Ω (brown-black-green)	R11,R59
A1	1-169	1	3.9 M Ω , 5% (orange-white-green)	R76
A1	1-70	2	22 M Ω (red-red-blue)	R14,R17
A1	1-139	1	100 M Ω (brown-black-violet)	R55

1-Watt

A2	1-1-1	1	470 Ω (yellow-violet-brown)	R92
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2-Watt

A3	1-13-2	1	220 Ω (red-red-brown)	R87
----	--------	---	------------------------------	-----

PRECISION RESISTORS

1/4-Watt

A4	2-670-12	1	1010 Ω (1.01k) .5%	R8
A4	2-728-12	1	9090 Ω (9.09k) .5%	R7

1/2-Watt

A5	2-19	1	9 Ω , 1%	R3
A5	2-24	1	90 Ω , 1%	R2
A5	2-83	1	200 Ω , 1%	R82
A5	2-29	1	900 Ω , 1%	R1

KEY PART QTY. DESCRIPTION
No. No.

Precision Resistors (cont'd.)

A5	2-228	1	2000 Ω (2k) 1%	R83
A5	2-38	1	20 k Ω , 1%	R84
A5	2-294	1	90.9 k Ω , .5%	R6
A5	2-54	1	200 k Ω , 1%	R85
A5	2-55	1	2 M Ω , 1%	R86

1-Watt

A6	2-98-1	1	909 k Ω , .5%	R5
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5-Watt Wire-Wound

A7	3-25-5	1	1 Ω , 1%	R4
----	--------	---	-----------------	----

CAPACITORS

Ceramic

B1	21-33	1	3.3 pF	C13
B1	21-722	1	330 pF	C1
B1	21-26	1	3000 pF (.003 μ F)	C2
B1	21-57	1	5000 pF (.005 μ F)	C8
B1	21-143	4	.05 μ F	C15,C16, C22,C25
B1	21-95	3	.1 μ F	C17,C18, C19

Mylar*

B2	27-47	1	.1 μ F	C3
B3	27-60	1	.22 μ F	C5
B3	27-61	3	.47 μ F	C9,C11,C14
B3	27-62	1	.68 μ F	C4

Electrolytic

B4	25-115	1	10 μ F	C23
B5	25-281	1	39 μ F tantalum	C12
B4	25-830	1	50 μ F	C26
B4	25-819	1	500 μ F	C24
B4	25-148	1	1000 μ F	C21

Other Capacitor

B6	29-4	2	1800 pF (1.8n) polystyrene	C6,C7
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*DuPont Registered Trademark

KEY PART QTY. DESCRIPTION
No. No.

DIODES

C1	57-27	2	1N2071	D13,D14
C1	57-65	5	1N4002	D16,D17, D18,D22, D24
C1	56-56	12	1N4149	D1,D2, D3,D4,D5, D6,D7,D8, D9,D11,D12, D25
C1	56-31	1	PS18775	D15
C1	56-620	2	15V zener	D19,D23

TRANSISTORS — INTEGRATED CIRCUITS (IC's)

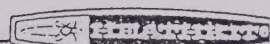
NOTE: Transistors and integrated circuits are marked for identification in one of the following ways:

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	417-235	4	2N4121 transistor	Q2,Q3, Q5,Q6
D2	417-213	2	2N5249A transistor	Q1,Q4
D3	417-801	6	MPSA20 transistor	Q8,Q9,Q10, Q11,Q12,Q16
D3	417-295	1	MPSL51 transistor	Q14
D3	417-884	2	Selected transistor	Q7,Q13
D4	417-818	1	MJE181 transistor	Q15
D5	442-39	1	LM301AN IC	IC1
D6	443-46	1	SN7402N IC	IC2
D6	443-73	1	SN7416N IC	IC8
D6	443-7	3	SN7490N IC	IC3,IC5,IC7
D7	443-36	2	SN7447N IC	IC4,IC6

CONTROLS — SWITCHES

E1	10-918	1	500 Ω control	R71
E1	10-936	1	1000 Ω (1K) control	R19
E1	10-386	3	10 k Ω control	R63,R72,R94
E1	10-390	1	20 k Ω control	R12
E1	10-385	1	50 k Ω control	R28
E1	10-941	1	100 k Ω control	R73
E1	10-828	1	1 M Ω control	R44
E1	10-989	1	5 M Ω control	R75
E2	63-1279	1	2-wafer switch	SW1
E3	63-1280	1	3-wafer switch	SW2



KEY PART No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
-----------------	------	-------------	----------------------

OTHER CIRCUIT COMPONENTS

F1	54-927	1	Power transformer	T1
	100-1686	1	Selected calibration parts consisting of the following parts. DO NOT open the envelope until instructed to do so in a step.	
			1 2000 Ω , 5% (red-black-red) 1/2-watt resistor	R91
			1 5100 Ω , 5% (green-brown-red) 1/2-watt resistor	R89
			1 Selected diode	D21
F2	421-33	1	1/4-ampere slow-blow fuse	F2
F2	421-2	1	3-ampere regular fuse	F1
F3	411-823	3	Light emitting diode (LED) display	P1,P2,P3

CONNECTOR PINS — SOCKETS — CLIP

G1	259-20	2	Straight connector pin (1 extra)
G2	432-134	13	Tapered connector pin (1 extra)
G3	434-292	6	5-pin display socket
G4	434-230	1	8-pin IC socket
G5	434-298	5	14-pin IC socket
G6	434-299	2	16-pin IC socket
G7	260-65	4	Fuse clip

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	436-11	1	Red banana jack
H4	436-22	1	Black banana jack
H5	438-47	2	Banana plug
H6	439-1	1	Red test probe

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 — in this pack — to locate all the hardware of any one size (#6, for example).

#4 Hardware

J1	250-4	1	4-40 $\times$ 3/8" screw
J2	252-2	1	4-40 nut
J3	254-9	1	#4 lockwasher

KEY PART No.	QTY.	DESCRIPTION
-----------------	------	-------------

#6 Hardware

J4	250-56	5	6-32 $\times$ 1/4" screw
J5	250-162	2	6-32 $\times$ 1/2" screw
J6	250-26	4	6-32 $\times$ 5/8" screw
J7	252-3	5	6-32 nut
J8	252-195	6	6-32 self-retaining nut
J9	254-1	6	#6 lockwasher
J10	259-1	1	#6 solder lug

Other Hardware

J11	254-15	2	5/16" lockwasher
J12	252-7	2	3/8 nut
J13	253-10	2	3/8" flat washer

LINE CORD — WIRE

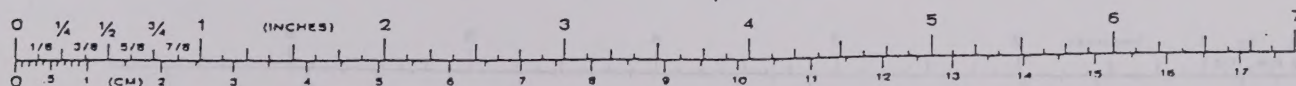
89-54	1	Line cord
340-8	39"	Baro wire
341-1	39"	Large black wire
341-2	39"	Large red wire
344-21	36"	Medium red wire
344-50	36"	Small black wire
344-51	15"	Brown wire
344-52	30"	Small red wire
344-53	24"	Orange wire
344-54	27"	Yellow wire
344-55	15"	Green wire

MISCELLANEOUS

	85-1786-1	1	Main circuit board
	85-1787	1	Display circuit board
	92-641	1	Cabinet bottom
	92-642	1	Cabinet top
	203-1783	1	Front panel
K1	204-2191	3	Angle bracket
K2	346-56	1"	Rubber tubing
K3	455-619	2	Knob bushing
K4	462-999	2	Knob
K5	490-111	1	IC puller
	390-1279	1	Model label
	390-1281	1	Calibration label
	390-1336	1	Front panel label
	391-34	1	Blue and white label
	597-260	1	Parts Order Form

Solder

1	Manual (See front cover for part number.)
---	---



INITIAL TESTS

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 40.

NOTE: In the first set of following tests (test points A through H), if you do not obtain the proper readings, 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 40.

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

() Refer to Figure 1-1 (in the "Illustration Booklet") and connect the common (-) ohmmeter lead to the anode (unbanded) end of D21. Touch the input (+) ohmmeter lead to the following points. The readings should be greater than those shown.

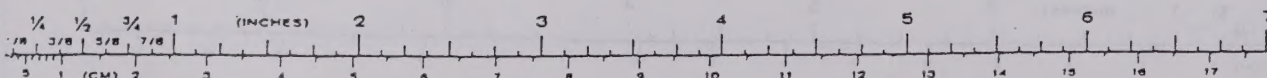
TEST POINT	READING: GREATER THAN
() A	10 K Ω
() B	1500 Ω
() C	1000 Ω
() D	50 Ω
() E	10 K Ω
() F	50 Ω
() G	1000 Ω
() H	50 Ω

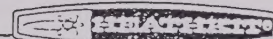
() Reverse the ohmmeter leads and touch each test point again.

TEST POINT	READING: GREATER THAN
() A	50 Ω
() B	50 Ω
() C	50 Ω
() D	5000 Ω
() E	50 Ω
() F	30 Ω
() G	50 Ω
() H	5000 Ω

() With either ohmmeter lead connected to the anode (unbanded) lead of D21, measure at all three prongs of the line cord, and at both of the lugs of the AC switch at the rear of the RANGE switch. The reading at each point must show infinity for any position of the FUNCTION switch.

Disconnect the meter 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 48.

PROBLEM	POSSIBLE CAUSE OF LOW READINGS
Improper reading at Point A.	1. D21. 2. Q16, C23.
Improper reading at Point B.	1. D17, D18, C21. 2. Q15, Q16.
Improper reading at Point C.	1. D19, D22. 2. C24.
Improper reading at Point D.	1. D25.
Improper reading at Point E.	1. D23, D24. 2. C26.
Improper reading at Point F.	1. D16.
Improper reading at Point G.	1. C17, C18, C19. 2. Q15, Q16, D12. 3. IC2 thru IC8.
Improper reading at Point H.	1. D15, D19. 2. C22. 3. IC1.
Improper reading at Point I.	1. D23. 2. C25. 3. IC1.
Any line cord prong or AC switch lug shows less than an infinite resistance reading.	1. T1 or fuse F2 foil areas. 2. Short near solder lug of line cord green wire. 3. Short near "120" or "240" jumpers. 4. Short to red wires at holes S or T. 5. Short near AC switch at rear of SW1. 6. Transformer T1.

OPERATIONAL CHECK

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

() Turn the ZERO ADJ, DC CAL. and CLOCK ADJ controls fully counterclockwise.

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 Figure 1-1 (in the "Illustration Booklet").

Refer to Figure 1-1 for the following steps.

() Set the front panel switches as follows:

FUNCTION OFF

RANGE 2

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."

() Plug the line cord into an AC outlet.

NOTE: In the following steps, the heavy solid portions of the displays indicate which segments should be on. The "ghosted" portions indicate the display segments that should be off.

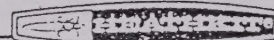
() Turn the FUNCTION switch to DCV. The display should be $\overline{0.00}$.

() Turn the ZERO ADJ control clockwise until the display is $\overline{0.00}$. (You may have to rotate the DC CAL control clockwise slightly.)

() Plug the red test lead into the "-" (black) front panel connector.

() Touch the red probe tip to the base (B) lead of transistor Q9. The display should be $\overline{1.88}$.

() Turn off the Multimeter, and unplug the line cord and test lead. Then proceed to "Final Assembly."



CALIBRATION

NOTE: New Multimeters may exhibit a small amount of calibration drift due to "burn-in" stabilization. Therefore, it is suggested that you 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, to insure optimum accuracy during use.

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

WARNING: When the line cord is connected to an AC outlet, hazardous voltages will be present at several places. These are shown by the boxed-in areas in Figure 2-1 in the "Illustration Booklet."

- () Plug in the Multimeter, turn it on, and allow it to warm up for 30 minutes. Also read the operational statements on Figure 3-1 in the "Illustration Booklet."
- () Plug the test leads into the front panel connectors (red lead to red connector; black lead to black connector).
- () Remove the cover from the Multimeter. (The screws will not come out).

Refer to Figure 2-1 for the following steps.

- () Set the ZERO ADJ, DC CAL, and CLOCK ADJ controls fully counterclockwise.
- () Set the other seven controls to their centers of rotation (slots vertical to the circuit board).

- () Set the RANGE switch to 2.
- () Set the FUNCTION switch to DCV. The display should show -1.00 . No other display segments should be lit.
- () Set the ZERO ADJ control to a display of 1.00 . (It may be necessary to rotate the DC CAL control clockwise slightly.)
- () Connect the test leads together.
- () Rotate the ZERO ADJ control until the display just shows -1.00 . Then slowly turn the control until the display just changes to 1.00 . Only a slight adjustment is needed.
- () Touch the red test probe to the DC CAL TP (test point) at the loop end of R91 (2000Ω , red-black-red). Hold the probe at the test point and rotate the DC CAL control slowly clockwise while you watch the display. The count should increase, reach a maximum, and then decrease. Rotate the control fully counterclockwise and then slowly advance it until the display shows about 20 counts less than the observed maximum. Remove the test probe from the test point.

NOTE: In the next step, if you are unable to obtain a reading of at least 1.00 , obtain the nearest possible reading with the CLOCK ADJ control. Then leave the control set at this point and proceed.

- () Turn the FUNCTION switch to OHMS and adjust the CLOCK ADJ control for a display of between 1.00 and 1.00 .

DC VOLTS CALIBRATION

NOTE: Refer to the calibration voltage value written on the label on the side of the transformer to perform the following step. Observe that the calibration voltage number has four digits, whereas the Multimeter can display only three digits. Convert the number to three digits by dropping the fourth digit if it is 4 or less, or by increasing the third digit by one if the fourth digit is 5 or more. For example:

$$1.943 = 1.94$$

$$1.946 = 1.95$$

$$2.037 = 2.04$$

If the rounded-off number is 2.00 or higher, the 2 will not be displayed in the following steps, and the "overrange" indicator will be lit:

$$2.11 = \text{'.111'}$$

() Turn the FUNCTION switch to DCV.

1. () Connect the test leads together and, if necessary, adjust the ZERO ADJ control to show 0.00 .

2. () Touch the red test probe to the DC CAL TP at the loop end of R91.

3. () Rotate the DC CAL control fully counterclockwise. Then turn it clockwise until the display matches the value of the rounded-off calibration voltage.

4. () Remove the test probe from the DC CAL test point.

() Return the RANGE switch to 2 and repeat the previous four steps one time. Then finish by leaving the RANGE switch in the 20 position.

NOTE: In the previous adjustments you "roughly" calibrated the DC voltmeter function of your Multimeter in order to perform the measurement in the next step. This measurement reflects whether the AC line voltage is high, low, or of an average value, since it has a slight effect on the DC calibration test point voltage used to calibrate your Multimeter. After you complete this measurement, you may need to apply a small correction factor to the DC calibration number for only this particular calibration for the line voltage condition at this time.

() Touch the test probe to the +V TP (bracket of Q15) and observe the reading. If the reading is less than 7.8, subtract .003 from the number on the calibration label. If the reading is greater than 8.6, add .003 to the number. If the reading was between 7.8 and 8.6, no adjustment is required. After you have added or subtracted as required, round off the result to obtain a "corrected" calibration number. Write this number down in a convenient place (not on the calibration label) for use later.

() Remove the test probe from the +V TP.

() Turn the RANGE switch to 2.

() Turn the FUNCTION switch to OHMS.

() Rotate the CLOCK ADJ control fully counterclockwise. Then turn it clockwise for a display of ' .90 .

NOTES:

1. This time, the reading must be within 5 digits (no less than ' .85 , or no more than ' .95). If you are unable to calibrate within these limits, refer to the "In Case Of Difficulty" section of the Manual. If your Multimeter is operating from a 60 Hz power line during calibration, this "infinity" (open-circuit) display will be approximately ' .90 .

2. If you calibrate your Multimeter using 60 Hz power source, recalibrate it before you use it on a 50 Hz power source. Also do not use a meter calibrated on 50 Hz on a 60 Hz power source. It will be inaccurate at the higher portions of the range.

() Turn the FUNCTION switch to DCV.

NOTE: The following procedure determines which of the two transistors in the Q1 and Q4 positions is better to use in the Q1 position to prevent Multimeter warm-up drift from showing negative at turn-on.

() Adjust the ZERO ADJ control as close as possible to the point where the display changes from -.88 to 0.00 but still shows 0.00 most of the time.

- () Disconnect the line cord.
- () Interchange the transistors at Q1 and Q4. Make sure you properly reinstall each transistor.
- () Connect the line cord and, without touching any switches or controls, observe the display. If the display is $\square.\square\square$, disregard the next step and proceed. If the display is $-\square.\square\square$, perform the next step and then proceed.

If the display obtained in the last step was $-\square.\square\square$, disconnect the line cord, interchange the transistors at Q1 and Q4 to their original positions, reconnect the line cord, and then continue with the calibration.

Due to the interaction between controls, repeat the following procedure as many times as required until each calibration display is properly obtained.

- A. Connect the test leads together and adjust the ZERO ADJ control so that the display just changes from $\square.\square\square$ to $\square.\square\square$ and then is stable at $\square.\square\square$.
- B. Turn the FUNCTION switch to OHMS and adjust the CLOCK ADJ control to show an "infinity" display between $\square.\square\square$ and $\square.\square\square$.
- C. Turn the FUNCTION switch to DCV, touch the test probe to the DC CAL TP, and adjust the DC CAL control until the display shows the "corrected" calibration number.

AC VOLTS CALIBRATION

- 1. () Set the front panel switches as follows:

FUNCTION	DCV
RANGE	2

- 2. () Touch the test probe to AC REF TP and adjust the control for a display of $\square.\square\square$.

NOTE: The display may vary between $\square.\square\square$ and $\square.\square\square$ and $\square.\square\square$. A proper adjustment will cause it to read $\square.\square\square$ most of the time.

- 3. () Remove the test probe from the AC REF TP.
- 4. () Turn the FUNCTION switch to ACV.
- 5. () Touch the test probe to the AC REF TP again and allow the display to stabilize.

NOTE: Do Not change the position of the AC REF ADJ control in the next step.

- 6. () Adjust the AC CAL control for a display of $\square.\square\square$.

NOTE: The display may vary between $\square.\square\square$, $\square.\square\square$, and $\square.\square\square$.

- () Repeat the previous six steps until you obtain the correct displays in both switch positions.

- () Remove the test probe from the AC REF TP.

OHMS CALIBRATION

- () Turn the FUNCTION switch to OHMS.

You will calibrate the five OHMS ranges in the following steps. Touch the test probe to the indicated OHMS CAL TP for each range and adjust the indicated control for a $\square.\square\square$ display. The decimal point should be at the indicated position as shown under the "Display Reading" column in the following chart.

RANGE SWITCH	OHMS CAL TP (Test Point)	CAL CONTROL	DISPLAY READING
() 200 Ω	200	200	$\square.\square\square$
() 2 K Ω	2K	2K	$\square.\square\square$
() 20 K Ω	20K	20K	$\square.\square\square$
() 200 K Ω	200K	200K	$\square.\square\square$
() 2 M Ω	2M	2M	$\square.\square\square$

() Repeat the steps in the previous chart as many times as necessary until you obtain the proper reading for each switch position.

() Turn off the Multimeter.

() Unplug the line cord.

() Install the cabinet top on the cabinet bottom. Be sure no wires are pinched between the cabinet halves.

NOTE: The built-in calibration standards provide accuracy within the specifications for your Multimeter. However, if you wish to improve the accuracy at any time, you can recalibrate your Multimeter with precision AC and DC voltage and resistance standards. The precision standards should be accurate within one-tenth of the appropriate Specifications on Page 70.

CAUTION: In the next step you will install the cabinet top. Be sure none of the controls are touched or changed.

OPERATION

DUTY CYCLE

Since the power consumption of the Digital Multimeter is very low, you may wish to leave the instrument on continuously during the daily work period. Always allow a 30 minute warmup period from a cold start to insure best accuracy. However, the Multimeter will provide serviceable accuracy after a few minutes of warmup. A "touch-up" of the ZERO control (through the front panel) may be necessary during warmup.

SAFETY PRECAUTIONS

CAUTION: Always observe basic safety rules any time you make voltage measurements. Always handle the test leads by their insulated portions and do not touch the exposed tips.

When you make high voltage measurements, remove the power from the unit under test and then connect the test leads. If this is not possible, be careful to avoid accidental contact with nearby objects which could provide a ground return path. Keep one hand behind you to minimize accidental shock hazard and be sure to stand on a properly insulated floor or floor covering. Do not switch ranges when high voltages and high currents are at the Multimeter inputs; to do so may cause switch contact arcing.

Measurements

Refer to Figure 3-1 while you read the following information.

If the input to the Multimeter is negative, the display will show only the minus sign and decimal point (if the RANGE switch is in a position where a decimal point is used). Otherwise, the display will show values of .00 through 199.

When the OVERRANGE indicator is on, overrange values up to 1.50 (2.50) can be read directly, where the 1 stands for the overrange digit (2). Overage displays above 1.50 (2.50) are unreliable and you should switch to a higher range.

CONNECTING THE MULTIMETER

Place the FUNCTION switch in the OFF position.

Plug the line cord into an AC outlet.

Select the desired function (voltage, current, or resistance) and, if necessary, connect the test leads together and adjust the ZERO ADJ control so the display just changes from "01" to "00", and is stable at "00". Then follow the instructions according to the type of measurement to be made. NOTE: This adjustment may produce an open-input display of ".01" on the 2 VDC range. This is normal and will not produce a measurement error when the test leads are connected to a low-impedance (less than 100 k Ω) measurement point.

Always consider the loading effect of the Multimeter's one megohm input resistance when you make voltage measurements in high impedance circuits.

Start with the highest range and work down.

DC VOLTAGE MEASUREMENTS

CAUTION: 1000 VDC is the maximum DC voltage allowable between the + and - inputs on the 20, 200, and 2K ranges; and 350 volts DC is the maximum on the 2 (volt) range.

1. Set the FUNCTION switch to DCV.
2. Set the RANGE switch to 2K or the desired lower range.

CAUTION: Do not connect the black test lead to a potential greater than 1000 volts above power line (earth) ground. This could damage the Multimeter.

3. Connect the black test lead to circuit ground or to the least positive measurement point.
4. Touch the red test probe tip to the measurement point and observe the reading. If the overrange indicator lights, switch to a higher range immediately as an overload condition exists. Lower the setting of the RANGE switch until you reach the proper range. Reverse the test lead connections if the negative input indicator lights. The following table indicates the display limits for each range.

RANGE	DISPLAY RANGE	ALLOWABLE OVERRANGE
(200 Ω)	Does not function on DCV.	
2	.01 — 1.99	1.50 (2.50)
20	0.1 — 19.9	15.0 (25.0)
200	01 — 199	150 (250)
2K	.01 — 1.00 (1000)	None

AC VOLTAGE MEASUREMENTS

NOTE: When you measure AC voltage, any input other than a pure sine wave will cause an error because the AC converter is average-sensing and rms (sine wave) calibrated.

CAUTION: 700 volts rms is the maximum AC voltage allowable on the 20, 200, and 2K ranges; and 250 volts rms is the maximum on the 2 (volt) range.

1. Set the FUNCTION switch to ACV.
2. Set the RANGE switch to 2K or the desired lower range.

CAUTION: Do not connect the black test lead to a potential greater than 700 volts rms above power line (earth) ground. This could damage the Multimeter.

3. Connect the black test lead to circuit ground or to the circuit low point.

4. Touch the red test probe tip to the measurement point, and observe the reading. If the overrange indicator lights, switch to a higher range immediately as an overload condition exists. Otherwise, lower the setting of the RANGE switch until you reach the proper range. The following table indicates the display limits for each range.

RANGE	DISPLAY RANGE	ALLOWABLE OVERRANGE
(200 Ω)	Does not function on ACV.	
2	.01 — 1.99	1.50 (2.50)
20	0.1 — 19.9	15.0 (25.0)
200	01 — 199	150 (250)
2K	.01 — .70 (700*)	None

*Approximate rms value of 1000V peak.

DC CURRENT MEASUREMENTS

CAUTION: The Multimeter is fuse-protected for a 3-ampere maximum DC current on the 2K mA (or lower) range.

- Set the FUNCTION switch to DC mA.
- Set the RANGE switch to 2K or the desired lower range if it is known. 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.
- Connect the test leads in series with the circuit where current is to be measured and observe the reading. If the overrange indicator lights, switch to a higher range immediately, as an overload condition exists. Otherwise, lower the setting of the RANGE switch until you reach the proper range. Reverse the test lead connections if the negative input indicator lights. The following table indicates the display limits for each range.

RANGE	DISPLAY RANGE	ALLOWABLE OVERRANGE
(200 Ω)	Does not function on DC mA.	
2	.01 — 1.99	1.50 (2.50 mA)
20	0.1 — 19.9	15.0 (25.0 mA)
200	01 — 199	150 (250 mA)
2K	.01 — 1.99	1.50 (2.50 A)

AC CURRENT MEASUREMENTS

NOTE: When you measure AC current, any input other than a pure sine wave will cause an error because the AC converter is average-sensing and rms (sine wave) calibrated.

CAUTION: The Multimeter is fuse-protected for a 3-ampere maximum AC current on the 2K mA (or lower range).

- Set the FUNCTION switch to AC mA.
- Set the RANGE switch to 2K or the desired lower range if it is known. 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.
- Connect the test leads in series with the circuit where current is to be measured and observe the reading. If the overrange indicator lights, switch to a higher range immediately, as an overload condition exists. Otherwise, lower the setting of the RANGE switch until you reach the proper range. The following table indicates the display limits for each range.

RANGE	DISPLAY RANGE	ALLOWABLE OVERRANGE
(200 Ω)	Does not function on AC mA.	
2	.01 — 1.99	1.50 (2.50 mA)
20	0.1 — 19.9	15.0 (25.0 mA)
200	01 — 199	150 (250 mA)
2K	.01 — 1.99	1.50 (2.50 A)



RESISTANCE MEASUREMENTS

CAUTION: Be sure to turn all power off when you measure resistance in a circuit. The resistance circuits of the Multimeter are protected against the application of positive (+) DC voltages up to 350 volts. For negative (−) DC voltages or AC voltages, if sufficient current can be drawn from the circuit, the internal 3-ampere fuse will open.

1. Set the FUNCTION switch to OHMS.
2. Set the RANGE switch to the desired range.
3. Connect the test leads to the resistance to be measured and observe the reading. Raise or lower the setting of the RANGE switch until you reach the proper range. The following table indicates the display limits for each range.

RANGE	DISPLAY RANGE	ALLOWABLE OVERRANGE
200Ω	01 — 199	1.50 (250Ω)
2 kΩ	.01 — 1.99	1.50 (2.50 kΩ)
20 kΩ	0.1 — 19.9	1.50 (25.0 kΩ)
200 kΩ	01 — 199	1.50 (250 kΩ)
2 MΩ	.01 — 1.99	1.50 (2.50 MΩ)

NOTE: Since the full-scale test voltage (2.0 volts) exceeds semiconductor conduction thresholds; erroneous, low, readings may result when resistance measurements are made in circuits containing diodes or other semiconductors. If you doubt the readings, disconnect either the resistance being measured or the semiconductors in the circuit.

CAUTION: When you use the Multimeter to check diode conductance or other semiconductors, do not use the 200Ω range, as the test current (10 mA) combined with the maximum open-circuit test voltage (up to 9 volts) may damage delicate semiconductor junctions. The 2 (kΩ) or higher ranges should not produce any damage since their test currents are much lower.

IN CASE OF DIFFICULTY

WARNING: When the line cord is connected to an AC outlet, hazardous voltages are present at several places. See Figure 2-1.

CAUTION: If you ever remove the circuit board from the cabinet bottom, be sure you cover the solder lug on the green wire of the line cord with tape. This will keep the wire from accidentally causing a short circuit if you plug the Multimeter in for testing.

This section of the Manual is divided into two parts. The first part, titled "Troubleshooting and Repair

Precautions," points out the care that you should use when you service the Multimeter to prevent damage to components.

The second part, titled "Troubleshooting Procedures," calls out specific methods to locate problems that could occur and lists one or more conditions or components ("Possible Cause") that could cause each difficulty.

NOTE: Refer to the "Circuit Board X-Ray Views" on Page 78 for the physical location of parts on the circuit boards.

Troubleshooting and Repair Precautions

Observe the following precautions before you remove the cabinet from your Multimeter.

Disconnect the line cord.

Make sure the RANGE switch is in the OFF position.

1. Make sure you do not short any adjacent terminals or foils when you make tests or voltage measurements. If a probe or test lead should slip, for example, and short together two adjacent connections, it is very likely to damage one or more of the transistors, diodes, or IC's.
2. 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.
3. Do not remove any components while the Multimeter is turned on.
4. 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 should 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.

5. 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.
6. Do not flex the front panel and switch wiring repeatedly. When you service the Multimeter in this area, it is best to position the front panel forward and leave it there throughout the servicing procedure. (Unsolder the wire at C to fold the panel forward).

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 a length of bare wire. Lay the wire across the gap and solder each end to the foil. Carefully trim off any excess bare wire.



Troubleshooting Procedures

NOTE: Before you proceed, review the "Assembly Check List" on Page 27. Most problems will be found there.

If a DC voltmeter is available, proceed through the tests described in this section. Perform these tests in the following sequence:

Basic Meter Tests

DC Voltmeter Tests

AC Voltmeter Tests

DC and AC Milliammeter Tests

Ohmmeter Tests

The first portion of the "Basic Meter Tests" (Part #1) 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" (Part #2) requires a DC voltmeter and contains a sequential series of tests which will locate problems in the basic measuring circuit.

Each of the remaining sections contain procedures to identify problems and possible causes in the other circuits of the Multimeter. A DC voltmeter is required for these tests.

NOTE: As a somewhat faster technique, if you have an oscilloscope, you may wish to perform the "Waveforms" tests on Page 66 first, and then return to the other tests if necessary. To perform these tests, you will need an oscilloscope capable of the horizontal sweep and vertical sensitivity settings listed in the chart, as well as a high impedance, low capacitance probe.

Review the "Circuit Description." This may help you determine where the trouble is.

Refer to the "Circuit Board X-Ray Views," and the "Schematic" to locate the various components.

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

BASIC METER TESTS

The Digital Multimeter is, fundamentally, a DC voltmeter. This circuitry is used in each position of the Function switch, and conditioning circuits are added, if required, for each function. Consequently, you should first check the circuitry used for the basic meter function as instructed in Part #1 below.

If you obtain the indicated displays in each of these steps, the basic meter portion of your Multimeter is working properly. Proceed to the "DC Voltmeter" section which identifies other problems in the switch, wiring, and related circuitry.

If you obtain the indicated displays in the first eight steps, but the display will not count up properly in the latter steps, your Multimeter may have a problem covered by the "DC Voltmeter Tests" section, or it may simply need to be recalibrated.

If you encounter other problems in these steps, proceed to Part #2 of this section which locates problems in the basic meter.

Part #1 — Visual Inspection

Proceed through all the following steps regardless of what indications you observe. Refer to Figure 2-1 while you perform these steps.

1. Unplug the line cord.
2. Connect the black test lead between the "-" jack and the connector at hole "C." (This is not jumper C.)
3. Plug in the line cord.
4. Set the FUNCTION switch to DCV.

5. Set the RANGE switch to 2.
6. Rotate the ZERO ADJ control fully counterclockwise. The display should show $-.88$.
7. Slowly rotate the ZERO ADJ control clockwise. A point should be reached where the display changes to show 0.00 , or 0.01 , or 0.02 , etc. It may be necessary to rotate the DC CAL control approximately $1/4$ turn from the counterclockwise end to obtain this display. (Continued rotation will produce a display similar to 1.88 .)
8. Rotate the ZERO ADJ control counterclockwise and set it for a display of 0.00 .
9. Unplug the line cord.
10. Disconnect the black test lead and leave the two test leads disconnected.
11. Rotate the DC CAL control to its center of rotation.
12. Plug in the line cord.
13. Set the RANGE switch to the 200Ω position. In this position, there is no connection to the basic meter circuit input. The input filtering capacitor should charge so that the display "counts up." Observe the display while the count increases. It should increase uniformly from 0.00 to 1.50 and then change suddenly to an overrange display such as 1.88 . It may take several minutes for the count to reach overrange.
14. Set the RANGE switch to 2. The count should decrease to 0.00 in one or two seconds.

Part #2 — Sequential Tests

In the following steps, you will be instructed to observe the display and monitor certain circuit voltages with a voltmeter. You may also be instructed, in the

"Special Instructions" column, to open certain jumpers on the circuit board, or to apply short circuits with the test leads to component or IC leads while you measure circuit voltages or voltage changes. If at any point you do not obtain the required display, voltage, or voltage change, refer to the "Possible Cause" column which lists possible faulty components (circuits). Check the part referred to. It may be open, shorted, "leaky," 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 (Q12, R19, jumper B; 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" for IC basing diagrams and a cross reference table of manufacturers' numbers.

NOTE: Some of the circuits use the same type IC's as other circuits. An IC or display digit believed to be faulty can often be interchanged with one known to be good. When you remove and install an IC, be sure that you first unplug the line cord.

() Set the FUNCTION switch to DCV.

() Set the RANGE switch to 2.

() Connect the voltmeter common (ground) lead (not the Multimeter common lead) to the end of R4 (1.0Ω) at the center wafer of the RANGE switch.

() Refer to Figure 2-1 and plug the red test lead of the Multimeter into the "-" lead connector. Then plug the black test lead into the red test lead as shown.



SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
None.	Check fuse F2.	1. F2. 2. T1. 3. D17, D18, D22, D24. 4. C21, C24, C26. 5. Short at "AN," +27, +8.2, +5.0, or -30 volt points; or at D25; or leads 1 thru 7 of T1; or at "120" or "240" jumper wires; or holes S, T, U, V. 6. Q15, Q16. 7. C17, C18, C19. 8. IC2 thru IC8. 9. D21.
None.	+27 VDC at cathode (banded) end of D22.	1. Unit not plugged in. 2. Open wiring at line cord or holes U or V. 3. F2. 4. "120" or "240" jumper wires open. 5. T1 wiring at holes 1,2,3,4,7, or 8. 6. AC switch at rear of SW1; open wiring at switch or holes S or T. 7. D22. 8. C24. 9. T1. 10. D19, D22, C22, or C23. 11. Open at hole B or jumper wires. 12. Short at 6.2-volt point, or in circuitry connected to +15-volt supply.
None.	+8.2 VDC at cathode (banded) end of D17 and D18.	1. T1 wiring at holes 5 or 6. 2. D17, D18. 3. C21. 4. T1.
None.	+6.2 VDC at B (base) of Q16.	1. R88. 2. D21. 3. C23.
None.	+5.0 VDC at pin 14 of IC8.	1. Q15 or Q16. 2. C17, C18, C19, C23. 3. Short in circuitry connected to +5-volt supply.
None.	+9.1 VDC at cathode (banded) end of D25.	1. D25.

SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
None.	Decimal point lit at P3 (left) digit; and +2.8 VDC at AN on display board.	1. D16. 2. Open at AN, P3P, or pins of P3. 3. P3. 4. Wiring at SW2. 5. Open at hole R or short to P3P. 6. SW2. 7. R81.
None.	+15 VDC at cathode (banded) end of D15.	1. R79, R87. 2. D7, D15, D19. 3. C22. 4. Q7, Q13, IC1. 5. Short in circuitry connected to +15 volt supply.
None.	-30 VDC at anode (unbanded) end of D24.	1. D24. 2. C26.
None.	-15 VDC at pin 4 of IC1.	1. R92. 2. D8, D23. 3. C25. 4. Short in circuitry connected to -15 volt supply.
Remove IC2, IC3, IC5, and IC7. Be sure to disconnect the line cord first.	11 lights in P3 (left) digit. (Only these segments should be lit.)	1. Open at P3B, P3C, P3F, or pins of P3. 2. R35, R36, R37. 3. IC8-D, -E, or -F. 4. IC4, IC6, or Q12. 5. P3.
Carefully short pin 3 of IC4 with the red test probe tip.	8 lights in P1 (right) digit.	1. P1A thru P1G, or pins of P1. 2. R46 thru R53. 3. IC4. 4. P1. 5. Open test lead.
Carefully short pin 3 of IC6 with the red test probe tip.	8 lights in P2 (center) digit.	1. P2A thru P2G, or pins of P2. 2. R38 thru R45. 3. IC6. 4. P2.
Reinstall IC3 and IC5. IC2 and IC7 are still removed. Remove IC8.	Pin 2 and 3 of IC3 and IC5 measure more than +4.0 VDC.	1. R69. 2. IC3, IC5.



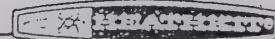
SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
Reinstall IC8. IC2 and IC7 are still removed. Connect black test lead clip to jumper B.	Pin 2 of IC8, and pins 2, 3, 6, 7, and 10 of IC3 and IC5 measure less than +0.8 VDC.	1. R68. 2. C16. 3. IC8-A. 4. Open test lead or "-" jack wiring.
Open jumper A. IC2 and IC7 are still removed. Black test lead is still connected to jumper B.	Each time you momentarily touch the red test probe tip to pin 14 of IC3, the display count should increase in digits P1 and P2 from 00 to 99 and repeat. Count increases may be just one, or several at a time. Continue this until you have seen a 0 thru 9 digit light in both P1 and P2 at least once. After satisfactory results, substitute IC7 in the IC5 location and repeat the test.	1. IC3 or IC5. (Try substitution with IC7). 2. IC4 or IC6. (Confirm by reversing).
Close jumper A. IC2 and IC7 are still removed. Black test lead is still connected to jumper B. Be sure the Clock Adj control is fully CCW.	Momentarily touch the red test probe tip to the B (base) of Q10. Display should show 11.88 after the test probe short is removed.	1. Q9, R26, or D6; if C (collector) of Q9 measures less than +4.5 VDC. 2. Q10, R28, R29, or open jumper wire; if C (collector) of Q10 measures more than +0.5 VDC before probe short is applied. 3. Q10, D2, D3, R27, or C6; if C (collector) of Q10 does not exceed +3.0 VDC when probe short is applied. 4. Q11, D4, D5, R32, or C7; if C (collector) of Q11 does not initially measure less than +0.5 VDC and then does not exceed +3.0 VDC when probe short is applied to its B (base). 5. R31, C6, or C7. 6. Jumper A. 7. Foils in Q9, Q10, Q11 (clock) circuitry.
Reinstall IC7. IC2 is still removed. Black test lead is still connected to jumper B.	Display shows only decimal point at P3. (No other segments should be lit.)	1. IC4, IC6, IC7, or IC8. 2. Q12. 3. Short in R33, Q12 associated foils.

SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
Remove black test lead clip from jumper B. IC2 is still removed.	Jumper B measures +1.9 VDC, and display changes as Clock Adj control is rotated CW and then back to CCW end.	1. Jumper B measures less than +0.8 VDC: A. R64, R66, R67. B. C15. C. Jumper B. D. IC8. 2. Jumper B measures more than +3.0 VDC: A. R65. B. D12. C. C15. D. IC8. 3. C16 or R68.
Reinstall IC2. Remove Q1 and Q4. Set Zero Adj control to center of rotation (slot perpendicular to board).	AT IC2: Pin 1 measures more than +3.0 VDC. Pin 14 measures +5.0 VDC. Pin 7 measures 0 VDC.	1. IC2. 2. Jumper F or R19 if pin 2 of IC2 measures more than +1.0 VDC. 3. Q5, Q6, R17, or R18 if E (emitter) of Q6 measures less than +14 VDC.
Same as above.	C (collector) of Q9 and Q11 measures less than +0.8 VDC.	1. Q9. 2. D6. 3. R21, R22, or R25.
Same as above.	No lights in P3 (left) digit.	1. P3G or pins of P3. 2. R33, R34. 3. Q12. 4. IC7. 5. P3.
Q1 and Q4 are still removed. Connect black test lead to jumper B.	Momentarily open jumper F. Display should change from EEEE to EEEE . The display will flicker. Closing jumper F should then have no effect. NOTE: To double check or re-establish this condition: momentarily remove test lead from jumper B; then momentarily open jumper F.	1. IC2. 2. IC7.
Same as above.	More than +2.0 VDC at E (emitter) connector of Q4, and pin 4 of IC2 measures approximately 0.7 volts higher.	1. Jumper D. 2. D1. 3. R16. 4. Open at Q4.



SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
Same as above.	At IC2: Pin 12 measures less than +1.0 VDC. Pin 13 measures more than +3.0 VDC. Pin 10 measures less than +0.8 VDC.	1. Jumper E or R19. 2. IC2. 3. Q2, Q3, R14, or R15; if E (emitter) of Q3 measures less than +14 VDC.
Same as above.	Momentarily open jumper E. Display should change from 'LEF' to 'LEB', 'LEB', or 'LEB'. Closing jumper E should then have no effect. NOTE: To double check or re-establish this condition, refer to NOTE three tests back, and repeat "Test" operations from that point.	1. IC2. 2. R21, R22, R23, R25.
Same as above.	B (base) of Q8 measures +0.7 VDC.	1. Jumper C. 2. R23, R24. 3. Q8.
Q1 and Q4 are still removed. Be sure jumpers E and F are closed. Remove the test lead from jumper B.	B (base) connector of Q4 measures: 1. Less than +1.0 VDC and changes to more than +14 VDC when jumper B is again shorted. 2. Drops to less than +0.1 VDC when jumper E is then opened.	1. Q8. 2. R12, R13. 3. C4. 4. Q7. 5. R23, R24.
Q1 and Q4 are still removed. Be sure jumper E and F are closed. (They will not be opened again.) Remove test lead from jumper B.	S (source) of Q7 measures less than +2.0 VDC.	1. Q7. 2. C4. 3. R12.
Same as above.	C (collector) of Q3 and Q6 measures between +0.3 and +1.0 VDC.	1. Q6/jumper F circuit; or Q3/jumper E circuit.

SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
Remove black test lead from "-" jack. Connect black test lead clip to 2M TP (looped end of R86). Be sure Zero Adj control is centered (slot perpendicular to board).	Touch plug end of black test lead to C (collector) connector of Q4. C (collector) of Q6 should measure more than +2.5 VDC.	1. Q5, Q6. 2. R17, R18. 3. R86: if using 200 K TP causes change at Q6. Confirm R86 with ohmmeter. 4. Q4.
Same as above.	Touch plug end of black test lead to C (collector) connector of Q1. C (collector) of Q3 should measure more than +2.5 VDC.	1. Q2, Q3. 2. R14, R15. 3. Q1.
Install either Q1 or Q4 in Q4 position. Remove black test lead clip from 2M TP, and set aside for use later. Rotate Zero Adj control to CCW end.	Rotate Zero Adj control slowly CW. Display should change from $\Xi.55$ to show any number, such as 11.35 .	1. Q4. Confirm by substitution with remaining uninstalled transistor.
Install remaining Q1/Q4 transistor at Q1. Hold red test probe tip to E (emitter) connector of Q1. Rotate Zero Adj control to CCW end.	Rotate Zero Adj Control slowly CW. Display should change from $\Xi.55$ to 8.00 and then increase with further rotation. It may be necessary to rotate the DC CAL control approximately 1/4 from CCW end to obtain 8.00 display. Leave Zero Adj control set to show 8.00 .	1. Q1.
None.	DC CAL TP (looped end of R91) measures +1.8 VDC.	1. R89, R91.
Clip black test lead to orange wire at SW1 M22. (This wire should run to hole D on board.) Rotate Range switch to "200 Ω " position.	Touch black test lead plug to DC CAL TP. Display count should increase. Opening connection should result in slow increase in display count. Touching plug to "-" jack should cause display to quickly return to $\Xi.00$.	1. R11. 2. C3. 3. Hole D. 4. Wiring at SW1F, SW1M, SW2F, or SW2M.



- () Set the RANGE switch to 2.

Clip the black test lead to SW1 M22, as before. Then use the test lead plug as a probe and perform the following calibration test:

1. Rotate the DC CAL control fully counterclockwise, touch the plug to the DC CAL TP, and slowly rotate the DC CAL control clockwise while you observe the display. The count should increase, reach a maximum, and then decrease. Rotate the control fully counterclockwise and then slowly advance it until the display shows 20 counts less than the observed maximum.
2. Rotate the CLOCK ADJ control fully counterclockwise, touch the plug to the + VTP (heat-sink bracket of Q15), and adjust the Clock Adj control until the display shows 1.00.
3. Touch the plug to the "-" jack, and adjust the Zero Adj control to show 0.00.
4. Touch the plug to the DC CAL TP. Then rotate the DC CAL control fully counterclockwise and then clockwise to show a display of 1.00.
5. Repeat steps 2, 3, and 4 until the proper display is obtained for each step.

If you got the proper results in the above adjustments, the basic meter circuit is now functioning properly. This indicates that any problem encountered in the troubleshooting charts has now been corrected. You should now return to the "Calibration" section. However, if you have obtained the proper results in the

above procedures, but are still 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.

If you have completed the Basic Meter Tests, but your Multimeter still does not operate properly, you may do one of the following:

1. Repeat the Basic Meter Tests; perhaps having someone observe the tests with you in the event you overlooked something.
2. Perform the "Waveforms" test which is a faster troubleshooting technique.
3. Contact a Heathkit Electronic Center or the factory for further assistance, or for service of your Multimeter.

NOTE: The following problems that can affect accuracy, linearity, or stability of the basic meter circuit, are not covered in this troubleshooting procedure. The causes of these problems may be identified by inspection, ohmmeter measurement, or substitution of parts.

Wrong value or defective resistors: R11, R12, R13, R15, R16, R18.

Open Capacitors: C5, C15, C17, C18, C19, C22, C23, C25.

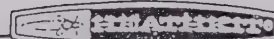
"Leaky" Components: C4, Q1, Q4, D1.

Shorted or "leaky" diodes: D2, D3, D4, D5.

DC VOLTMETER TESTS

The chart in this section locates problems in the switch wiring of SW1 and SW2. A series of problems is listed with "possible causes" for that problem. The tests require proper operation of the basic meter circuit as determined by the tests of the previous troubleshooting charts.

PROBLEM	POSSIBLE CAUSES
DC voltmeter is inoperative (reads "00") on all ranges.	1. Open at holes A or C (or associated wiring). 2. F1. 3. Wiring at "+" jack, or at SW1F, SW1M, or SW2F. 4. SW1 or SW2.
DC voltmeter reads properly on "2" ranges, but shows overrange on higher ranges for inputs above 2 VDC.	1. R5, R6, R7, R8. 2. Wiring at (or between) SW2F and SW2M.
DC voltmeter reads properly on "2" range, but reads low or "00" on higher ranges.	1. C1, C2. 2. Wrong value at R5 thru R8.
Decimal point does not light or is not positioned properly.	1. P2P, P3P, or pins of P2 or P3. 2. R81. 3. Wiring at SW2R.
DC voltmeter is inaccurate (when compared to precision standards): ----- At full-scale readings only. ----- At low readings only. ----- At any reading.	1. Q1, Q4, Q7. 2. C4. 3. Improper adjustment of R28. 1. Q7. 2. D1. 3. R11, R16. 4. Improper adjustment of R19. 5. C3. 1. R5 thru R8. 2. Improper adjustment of R12 or R19. 3. DC CAL TP in error.
Voltmeter reading is erratic or "noisy."	1. C3, C5, C12. 2. DC CAL control misadjusted.
DC voltmeter has excessive zero drift.	1. Q1 and Q4 not properly installed per "Calibration" procedure. 2. IC2. 3. Q2, Q3, Q5, Q6, Q7. 4. R19.



AC VOLTMETER TESTS

The tests in this section are divided into two parts.

The tests in Part 1 verify the AC/DC Converter circuitry and are similar to the Basic Meter Tests in that you must follow them in sequence. A DC voltmeter is required.

The chart in Part 2 locates problems in the wiring and circuitry of SW1 and SW2, and lists a series of problems and "possible causes" of these problems.

Part 1 — AC/DC Converter Tests

- () Plug the black test lead into the "+" jack.
- () Set the Function switch to ACV.
- () Set the Range switch to 2.
- () Connect the black test lead clip to the AC Ref TP (rear lug of R94).

SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
None.	Front lead of R54 (near F1) measures from zero to more than +2.0 VDC as AC Ref Adj control is rotated from CCW end to CW end. Reset to CCW end.	1. R93, R94. 2. Open at hole F (or associated wiring). 3. Open or improper wiring at SW1F or SW1M.
Remove IC1. Black test lead is still connected to R94.	S (source) of Q13 measures between 0 VDC and +1.0 VDC	1. D7, D8. 2. R55, R56. 3. Q13.
Same as above.	S (source) of Q13 "fluctuates" as R94 is quickly rotated CW and CCW. Reset to CCW end.	1. R54, R55. 2. C8.
Reinstall IC1. Be sure AC Cal control is set at center (slot perpendicular to board). Black test lead is still connected to R94.	At IC1: Pin 7 measures +15 VDC. Pin 4 measures -15 VDC. Pin 6 measures less than +1.0 VDC.	1. IC1. 2. R59. 3. C13, C14.

SPECIAL INSTRUCTION	TEST	POSSIBLE CAUSES
Same as above.	Voltage at cathode (banded) end of D9 increases from less than +0.1 VDC to more than +2.0 VDC as AC Ref Adj control is rotated CW. Leave control set at this +2.0 VDC.	1. D9. 2. C12. 3. IC1.
Same as above.	Voltage at anode (unbanded) end of D11 is approximately -2.0 VDC.	1. D11. 2. R61, R62.
Same as above.	Voltage at rear lug of AC Cal control remains near zero as AC Ref Adj control is rotated from CCW end to center (slot vertical).	1. R61, R62, R63. 2. C14.
Same as above.	Display count increases as AC Ref Adj control is rotated CW from CCW end.	1. R57, R58. 2. C9, C11. 3. Open at hole E (or associated wiring). 4. Wiring at SW1-2F. 5. SW1.
None.	AC/DC converter cannot be calibrated per "Calibration" section.	1. R57, R58, R63, R93, R94. 2. C9, C11.

Part #2 — AC Voltmeter Operation.

This chart identifies problems (and "possible causes" of problems) associated with AC Voltmeter operation; and requires operation of the basic meter, AC/DC converter, and DC voltmeter circuitry, as determined by the previous troubleshooting procedures. Make sure these circuits are operating before you proceed with the following troubleshooting chart.

PROBLEM	POSSIBLE CAUSES
Using the 2 VAC range, AC voltmeter is inaccurate (when compared with precision standards) at 50/60 Hz: At full-scale readings only. At low readings only. At any reading.	1. Q13. 2. IC1. 3. D7, D8. 4. C9, C11. 1. C12, C14. 2. D9, D11. 1. Improper adjustment of R63. 2. R59, R61, R62. 3. C14.
Frequency response is not "flat" on 2 VAC range: At low frequencies. At high frequencies.	1. C8, C9, C11, C12, C14. 2. R54, R55. 1. C13. 2. IC1. 3. R54.
Frequency response is not flat on higher AC voltmeter ranges.	1. C1, C2.

DC AND AC MILLIAMMETER TESTS

This chart identifies problems that affect the DC and AC milliamper function of these problems in the switch wiring and circuitry of SW1 and SW2. The basic meter and AC/DC converter circuitry must operate properly as determined by the tests in the previous troubleshooting charts.

PROBLEM	POSSIBLE CAUSES
Milliammeter is inoperative (reads 00 or overrange) on all or any DC and/or AC range.	1. Wiring at SW1F, SW1M, SW2F, or SW2M. 2. R1, R2, R3, R4.
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 70).	1. R1 thru R4. 2. Wiring at SW2.
Fuse F1 blows.	1. F1. 2. Wiring at SW1 or SW2.

OHMMETER TESTS

The tests in this section are divided into two parts. The tests in Part 1 locates problems in the operation of the Ohmmeter Current Source circuitry of Q14. A DC voltmeter is required.

The chart in Part 2 lists a series of problems and "possible causes" of problems in the wiring of SW1 and SW2; and requires that the basic meter circuit operate properly as determined by the previous troubleshooting charts.

Part #1 — Ohmmeter Current Source

() Set the Function switch to OHMS.

() Set the Range switch to 200Ω.

- () Plug the black test lead into the “-” jack.
- () Be sure each ohmmeter calibration control (R71 thru R75) is at its center of rotation (slot perpendicular to board).

SPECIAL INSTRUCTIONS	TEST	POSSIBLE CAUSES
Clip the black test lead to C (collector) of Q14.	B (base) of Q14 measures between +6.5 and +9.5 VDC.	1. D15 (remove Q14 to verify). 2. R79. 3. Q14.
Same as above.	E (emitter) of Q14 measures 0.7 VDC more than B (base).	1. R71, R77. 2. Q14. 3. Open at hole G or M (or associated wiring). 4. Wiring at SW2R.
Clip black test lead to the anode (unbanded) end of D13.	C (collector) of Q14 measures approximately +1.6 VDC and varies with setting of R71.	1. D13, D14. 2. Q14. 3. R77, R78.
Clip the black test lead to the cathode (banded) end of D13.	Display count reads 00 and quickly (in less than one second) increases to an overrange display (Ex: 1.99) when black test lead is unplugged from “-” jack. Make sure you plug the black test lead back in.	1. D13. 2. Open at hole N (or associated wiring). 3. Wiring at SW1F or SW1M. 4. SW1.
Same as above.	Voltage at C (collector) of Q14 should not exceed -1.0 VDC when you momentarily touch black test lead plug to anode (unbanded) end of D23.	1. D14.

Part #2 — Ohmmeter Operation Tests

The tests in this section require that the basic meter and ohmmeter current source circuitry operate properly as determined by the previous troubleshooting charts.

PROBLEM	POSSIBLE CAUSES
Ohmmeter current source operates properly, but Multimeter cannot be calibrated on 200 Ω range.	1. R71, R77, R78, R82.
Ohmmeter cannot be calibrated on: ----- 2 k Ω range. ----- 20 k Ω range. ----- 200 k Ω range. ----- 2 M Ω range.	----- 1. R72, R83. 2. Open at hole H (or associated wiring). 3. SW2R. ----- 1. R73, R84. 2. Open at hole J (or associated wiring). 3. SW2R. ----- 1. R74, R85. 2. Open at hole K (or associated wiring). 3. SW2R. ----- 1. R75, R76, R86. 2. Open at hole L (or associated wiring). 3. Q14. 4. D14. 5. High resistance leakage between foils in R75/R76/Q14 circuitry, possibly due to high humidity. 6. SW2R.



PROBLEM	POSSIBLE CAUSES
Ohmmeter is inaccurate (when compared with precision standards) on: 200 Ω range.	1. R82. 2. R71 improperly adjusted. 3. Faulty test leads. 4. F1 wrong. 5. SW1.
2 k Ω , 20 k Ω , or 200 k Ω ranges.	1. R83, R84, or R85 respectively. 2. R72, R73, or R74 improperly adjusted.
2 M Ω range.	1. R86. 2. R75 improperly adjusted. 3. Q14. 4. D14. 5. High resistance leakage between foils in R75/R76/Q14 circuitry, possibly due to high humidity.

WAVEFORMS

NOTE: Before you proceed with the "Waveforms" tests, make sure the power supply circuits operate. The following checklist verifies operation of each power supply using a DC Voltmeter. Voltages may vary $\pm 20\%$. If you encounter any difficulty, refer to the first ten steps of the "Basic Meter Tests" on Page 50 to identify problems of improper operation of these power supply circuits. After completing this checklist, proceed with the remaining portion of the "Waveforms" tests.

- () +27 VDC at cathode (banded) end of D22.
- () +8.2 VDC at cathode (banded) end of D17.
- () +6.2 VDC at B (base) of Q16.
- () +5.0 VDC at pin 14 of IC8.
- () +15 VDC at cathode (banded) end of D15.
- () -30 VDC at anode (unbanded) end of D24.
- () -15 VDC at pin 4 of IC1.

The "Waveforms" test section is used to verify various waveforms in the basic meter circuit of the Multimeter. Each numbered step corresponds to the same numbered location and illustration shown on the Schematic.

If you complete a step and do not obtain the indicated waveform, this suggests that either the indicated IC(s) is defective, or there is a problem in the associated circuitry.

NOTE: Each waveform generally requires that all previously indicated waveforms have been verified. Therefore, you must follow the steps in sequence, starting at Waveform I.

To check for the presence of the various waveforms, you will need:

1. A DC-coupled oscilloscope with vertical calibration from 0.5 volts/centimeter to 10 volts/centimeter, and a time base (horizontal) calibrated at 2 milliseconds/centimeter.

NOTE: The waveforms correspond to 60 Hz operation and thus repeat at a 16.7 millisecond rate. For 50 Hz operation, the waveforms will have a similar appearance, but will repeat at a 20 millisecond rate.

2. A high-impedance (10 megohm suggested), low-capacitance probe.

To prepare the Multimeter for the waveform tests:

1. Unplug the line cord.
2. Plug the black test lead into the "+" jack. Connect the test lead clip to the DC CAL TP (looped end of R91).
3. Set the Function switch to DC V.
4. Set the Range switch to 2.
5. Connect the oscilloscope ground (common) to the end of R4 (1.0Ω) at the middle wafer of the Range switch (SW2).
6. Reconnect the line cord.

At each waveform step, perform each of the following steps:

1. Adjust the oscilloscope for the designated voltage setting for the waveform to be observed. Adjust the DC vertical position ("zero") level to some convenient level. (NOTE: The dot on the left edge of each waveform indicates the DC "zero" level to which it is referenced.)
2. Connect or touch the oscilloscope probe to the indicated test point.
3. Adjust the triggering controls of the oscilloscope to obtain the proper presentation.
4. If you obtain the proper waveform, proceed to the next step. If it is not obtained, disconnect the Multimeter line cord, and make sure the test connections are correct. If they are, refer to the information provided in the "Comments" column to determine what circuit areas should be inspected.

WAVE-FORM	OSCILLO-SCOPE VERTICAL SETTING (V/cm.)	TEST POINT LOCATION	COMMENTS
I	10	Cathode (banded) end of D25	Confirms D25/T1 circuitry.
IA	2	Pin 3 of IC8	Confirms pin 3 circuitry.
II	1	Pin 6 of IC2	Confirms IC8-B, IC8-C, and jumper B circuitry.
III	2	Pin 2 of IC3	Confirms IC8-A and IC3, IC5, and IC7 reset circuitry.
IV	0.5	B (base) of Q8	"High lighted" (darker) area confirms jumper C circuitry. (Although waveform must go "low," duration of this "low" depends on input level.)
V	1	B (base) of Q1	Presence of any "ramp" confirms Q8 circuitry; linearity of "ramp" confirms Q7 circuitry. (Duration/amplitude of "ramp" depends on input level.)
VI	1	Pin 2 of IC2	Confirms Q4, Q5, Q6, jumper F, IC2-A, IC2-B, jumper D, and D1 circuitry. (DC level between pulses varies with setting of Zero Adj control, R19.)
VII	1	Pin 12 of IC2	Confirms Q1, Q2, Q3, jumper E, IC2-C, and IC2-D circuitry. (DC level between pulses varies with setting of R19.)
VIII	0.5	B (base) of Q9	Confirms Q9 input circuitry.
IX	1	Pin 14 of IC3	Confirms Q9, Q10, Q11 (clock), and jumper A circuitry.
X	1	Pin 14 of IC5	Confirms IC3 circuitry.
XI	1	Pin 1 of IC7	Confirms IC5 circuitry.
XII	1	Pin 11 of IC8	Confirms part of IC7 circuitry.
XIII	1	Pin 4 of IC4	Confirms part of IC7 circuitry.

() - Move the black test lead clip to +V TP (heatsink bracket of Q15).

XIV	1	Pin 9 of IC8	Confirms remaining part of IC7 circuitry.
XV	2	"AN" foil on display board	Confirms D16 and "AN" circuitry.

1. Repeat the "Waveforms" section tests in the event you overlooked something.
2. Proceed to the "Basic Meter Tests" section, a point-by-point troubleshooting technique to locate problems in this circuitry. A DC voltmeter is required for these tests.

If you have completed all waveform steps and have obtained each waveform, your basic meter circuit appears to be working properly. Now proceed to the "Calibration" section. However, if you have obtained

Maximum Input.....3 amperes into AC or DC mA, and Ohms (fuse protected). 700 VAC rms into Volts (except 2V range; 250 VAC rms). 1000 VDC into Volts (except 2V range; 350 VDC). “—” input may be floated 1000 VDC (700 VAC) above earth ground.

Resolution (Low Range)	Volts: 10 mV. Current: 10 μ A. Ohms: 1 ohm.
Display	2-1/2 digit, 7-segment, planar, LED (light emitting diode) with overrange and negative-input indicators.
Accuracy (Full Scale, ± 1 Digit)	DC volts: $\pm 1\%$. DC current: $\pm 1.5\%$. AC volts: $\pm 1.5\%$. AC current: $\pm 2\%$. Ohms: $\pm 1.5\%$.
Input Impedance	1 megohm on all voltage ranges. 2.1-volt drop maximum on current ranges (except 2.5-volt drop on 2,000 mA range).
Sample Rate	Line frequency.
Display Settling Time	Less than 1.0 seconds on DC volts and DC current, and less than 3.0 seconds on AC volts, AC current, and ohms; to within 5 counts.
Power Requirements	100-135 VAC, 200-270 VAC 50/60 Hz, 8 watts.
Fuse Requirements	Input: 3AG, 3-ampere. Line: 3AG, 1/4-ampere slow-blow. (1/8-ampere slow-blow for 240 VAC).
Dimensions (overall)	3.00" H x 8.69" W x 10.54" D. (7.62 cm high, 22.07 cm wide, 26.77 cm deep).
Weight	3.3 pounds (1.5 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 Diagram and the Block Diagram (in the "Illustration Booklet") while you read the following description.

GENERAL

Selected inputs of voltage, current, or resistance to be measured, are directed through the contacts of the Function switch and through the scaling networks of the Range switch to the input of an A-to-D (analog-to-digital) converter. Inputs other than DC are directed through conversion circuits. The results of switching, scaling, and conversion is that all inputs are converted to a proportional DC voltage level acceptable to the A-to-D converter. Full-scale input voltage to the A-to-D converter is +2 volts DC, regardless of the selected function or range, and allows overrange operation to a maximum of +2.5 volts DC.

The analog-to-digital converter uses a monopolar (single-slope) ramp technique to convert the input DC voltage to a control signal during a linearly proportional time period. This time period allows a temperature-compensated, high-stability, "clock" oscillator circuit to generate pulses. The number of pulses allowed is thus directly proportional to the DC input level. After passing through counting and decoding circuitry, the number of pulses from the clock oscillator is displayed on a digital display.

For voltage measurements, if the input exceeds 2 volts DC, it is scaled down to the 2-volt level by the Range switch before it enters the A-to-D converter. AC voltages, after any required scaling, are converted to +DC by an average-sensing, rms-calibrated operational rectifier circuit.

When DC current is measured, a precision resistor is placed in shunt with the input to the A-to-D converter. For AC current, the shunt resistor is placed across the input to the AC converter. The AC voltage developed across the shunt resistor is thus measured, and applied to the input of the A-to-D converter.

Resistance is measured by routing one of several calibrated constant currents through the unknown resistance. The voltage drop developed across the unknown resistance is applied through the input to the A-to-D converter.

Timing for the conversion and display circuit is controlled by the cyclic rate of the AC line frequency. The display is illuminated only during the positive portions of a half-wave rectified voltage, and the A-to-D converter is off, with no clock oscillator pulses being generated during this time. During the low-level portion of the rectified voltage, when the display is not illuminated, a pulse is generated to reset the counting circuitry to zero. Then the clock oscillator is turned on and its output pulses are counted. The pulse count is routed to the decoder circuitry and applied to the display before the next half-wave positive voltage disables the oscillator and lights the display.

The total measurement (counting) and display time is approximately equally divided, and both occur in 16.7 milliseconds for the 60 Hz line frequency, and in 20 milliseconds for a 50 Hz line frequency. The on-off operation of the display is not visible, so the display appears to be on constantly.

When a negative input is applied for DC voltage or current, a negative indicator is lighted during the display time, while it blanks the other digits of the display.

Since all inputs being measured are converted to a zero to +2 volt DC level, which is applied to the A-to-D converter, the operation of this "basic meter circuit" will be described first. The scaling, ranging, and other converter circuits will be described in later sections.

BASIC METER CIRCUIT

Ramp and Control Circuitry

To describe the operation of the basic meter circuit, we will assume that a +1.0 volt DC voltage from any of the input scaling or conversion circuits is applied to the emitter of Q1 (R11 and C3 provide noise filtering).

During time T1 of waveform I (see Figure 4-1), the digital display of any previously measured value is lighted by current flow through D16 to the display digits. A half-wave voltage, which is also positive during this time, is applied to the R64, R65, and D12

network at the input (pin 3) of IC8-B. D12 clamps this waveform to the +5-volt level, and R64 limits current through D12. Amplification of IC8-B and IC8-C, along with the positive feedback action of C15, squares this waveform at the output (pin 6) of IC8-C to that shown in waveform II. The positive portion (a digital logic "high"), is applied through jumper B to pins 6 and 8 of IC2. This performs several functions:

- a. The high at pin 6 forces pin 4 (and pin 3) low. This low at pin 3, along with a low at pin 2 (through part of R19), forces the output at pin 1 and pin 5 to be high.
- b. The high at pin 1, applied through R21 to Q9, turns on Q9 and prevents the clock from generating any pulses.
- c. The high at pin 1 is coupled through R33 to the base of Q12, but has no effect at this time.
- d. The low at pin 4 is coupled to pin 14 of IC7, but has no effect at this time.
- e. The low at pin 4 is below the conduction point of D1, and allows the emitter of Q4 to be "grounded" through R16.
- f. The high at pin 8 forces pin 10 (and pin 11) low. This low at pin 11, along with a low at pin 12 (through part of R19), forces the output at pin 13 and pin 9 to be high.
- g. The high from IC8-C and jumper B, couples through R24 and jumper C, and turns Q8 on. Q8 shunts all current from Q7 to ground and insures that C4 is discharged. Q7 is a FET (field-effect transistor) and, as connected to R12, functions as a constant current source.

At the end of time t_1 , the output of IC8-C goes low:

- a. This high-to-low transition, coupled through C16, forces the output of IC8-A high. This, applied to IC3, IC5, and IC7 at pins 2 and 3; clears all of their outputs (pins 8, 9, 11 and 12) to low. After a short period, C16 charges, through current flow out of pin 1 of IC8-A, returning pin 1 high. The output of IC8-A returns low, enabling the counters for this measurement. See waveform III.

- b. The low at pin 6 of IC8-C, along with the low at pin 10 of IC2-C, removes the base current from Q8 and allows it to turn off (waveform IV). The constant current from the Q7 circuit now charges C4 to produce a linearly-increasing voltage (ramp). (See waveform V)

NOTE: This high-to-low transition from the output of IC8-C does not affect the output voltages of IC2-A, B, C, and D, since these require a low-to-high change in their inputs to affect the outputs.

As the ramp voltage at C4 increases, during the time t_2 , it reaches a point where the base-emitter junction of Q4 turns on. Q1 cannot turn on yet, since its emitter is held positive by the input voltage, +1.0 volts. The current increase through Q4 is applied to the high gain (Q5, Q6) circuit, which quickly produces a voltage increase across the related portion of R19. When this voltage reaches a level sufficient to be a "high" at pin 2 of IC2-A (coupled through jumper F):

- a. The output at pin 1 goes low. This low, coupled to pin 5, along with the low at pin 6, allows the output at pin 4 to go high. The high at pin 4, coupled through D1, forces the emitter of Q4 positive; turning off the Q4, Q5, and Q6 circuit. The resulting low transition at pin 2, however, does not effect the output voltages of IC2-A, IC2-B. This short low-to-high-to-low pulse at pin 2 of IC2, as shown in waveform VI, is the start pulse.
- b. The low at pin 1, along with the low at pin 10 of IC2-C, removes base current from Q9 (waveform VII). This allows the Q10, Q11 clock circuit (described later) to generate pulses to the counting circuits of IC3, IC5, and IC7.
- c. The low-to-high transition at pin 4 of IC2, coupled to pin 14 of IC7, causes pin 12 to go high. The significance of this will be explained later. (It is associated with the negative sign.)

The ramp voltage at C4 continues to increase during time t_1 until it is sufficient to turn on the base-emitter junction of Q1. Notice that this voltage, approximately +1.7 volts, is equal to the sum of the base emitter junction voltage of Q1 (approximately the same as for the start voltage at Q4), plus the input voltage (+1.0 volts).

As Q1 turns on, the increase in current through it is applied to the high gain (Q2, Q3) circuit; quickly producing a voltage increase across the related portion of R19. When this voltage reaches a level sufficient to be a "high" at pin 12 of IC2-D (coupled through jumper E):

- a. The output at pin 13 goes low. This, coupled to pin 9, along with the low at pin 8; allows the output at pin 10 to go high. The high at pin 10, coupled through R23, turns Q8 on and discharges the ramp voltage on C4. The decrease in the base voltage of Q1, turns it and the Q2, Q3 circuitry off. This short low-to-high-to-low pulse at pin 12 of IC2, as shown in waveform VIII, is the stop pulse.
- b. The high at pin 10, coupled through R22, turns Q9 on. This forces the clock circuit off, inhibiting any further pulses from being accumulated in the counting circuitry.

During the t_2 time between the occurrences of the start and stop pulses, the Q10, Q11 clock circuitry has generated 100 pulses (as shown in waveform IX), and applied them to the IC3, IC5, and IC7 counting circuitry.

When a negative voltage (-0.1 volts, for example) is applied to the basic meter circuit input, the following sequence occurs:

- a. As the ramp voltage increases, during t_2 , Q1's base is turned on prior to Q4 being able to turn on. This generates a stop pulse. Since Q1 "clamps" the ramp below the turn-on point of Q4, no start pulse is generated.
- b. The occurrence of a stop pulse, similar to normal (positive input) operation, causes the ramp to be discharged through the switching action of IC2-C and IC2-D. This action also forces the clock to be off.

- c. Since no start pulse occurs, pin 1 of IC2-A stays high. Pin 14 of IC7 is thus not pulsed and results in pin 12 of IC7 staying low.
- d. With pin 1 of IC2-A high, and pin 12 of IC7 low, the base-emitter junction of Q12 is biased on through R33. As described later, this will cause the negative input indicator to be lighted during the display period.

After the occurrence of any stop pulse, the IC2 circuitry remains in that state (time t_1) throughout the remainder of the measurement period.

Clock Circuitry

During the t_2 time, between the occurrences of the start and stop signals, the pulses counted are generated by the clock circuit, which is basically a "multivibrator."

When the start pulse occurs, Q9 turns off and its collector is pulled to +5 volts by R26. Then current flow through R31 turns Q11 on. The collector of Q11, previously held at about +0.7 volts by the drop across D6, now drops to near zero. This voltage change, also at the junction of C7, D4; is coupled through C7 to create a negative voltage at the base of Q10. Q10, previously biased on by R28, R29; now turns off. Its collector; and the junction of C6, D2; goes positive. Current flow through R27 and C6 to Q11's base keeps it turned on. The negative voltage at the base of Q10 is charged positive through R28 and R29 to the point where Q10 turns on. When Q10 turns on, the resulting voltage drop at D2/C6 is coupled through C6 and creates a negative voltage at the base of Q11 which turns it off. The resulting rise at C7/D4 is coupled through C7 and insures that Q10 is on again. Note that during this second cycle, D6 cannot limit the positive level that the collector of Q11 may rise to, since the collector must exceed +5 volts before D6 can conduct. When the collector of Q11 exceeds a logic high level at the input of IC3 (pin 14), a count is registered in IC3. This cross-coupled operation through C6 and C7 continues to alternately turn Q10 or Q11 off. Each time Q11 turns off, a count is registered in IC 3 (and the other counting circuitry).

When the stop pulse occurs, Q9 is again turned on. This removes the base charging current through R31. It also causes D6 to clamp the signal to the counting

circuitry. This clamping action prevents any noise pulses from affecting the count during the display mode. It also prevents the initially short-period clock pulse from being registered, which occurs when the input is near 0 volts and the start-to-stop pulse time duration is very short. The action of D6 thus eliminates this first short pulse and allows a more accurate Zero Adjustment setting. Diodes D2 through D5 provide temperature compensation.

Counting and Display Circuitry

At the beginning of each measurement time, the BCD (binary-coded decimal) output (pins 8, 9, 11 and 12) of counters IC3, IC5, and IC7 are "cleared" to logic low. When the start signal occurs, and clock pulses are generated, each "units" clock pulse is counted by IC3. The "units" count at the outputs of IC3 is decoded by IC4 which, upon later presence of display power, will display that number on digit P1. When ten pulses are received the pin 11 output goes low, pulsing the input of IC5. IC5 counts each "tens" pulse. The "tens" counts of IC5 is decoded by IC6 which will be displayed on digit P2. When 100 pulses are received, the pin 11 output of IC5 goes low, pulsing the input of IC7. For counts between 100 and 199, the pin 9 output of IC7 goes high, resulting in a low at the outputs of IC8-E and IC8-F which forms a "1" on digit P3. When the count exceeds 199, pin 9 of IC7 again goes low, and pin 8 goes high. This, through IC8-D, will then allow the overrange indicator to be lit in digit P3.

The preceding actions occur for positive input voltages to the basic meter circuit from 0 volts to +2.5 volts DC. Inputs which greatly exceed the measurement capability of the basic meter circuit, allow the clock to generate pulses during the entire measurement period with no stop pulse occurring. In this situation, the maximum number of pulses that can occur is limited to approximately 290 counts displayed as 199 (overrange plus 90 counts).

For negative input voltages, as previously described, Q12 is biased on with pin 12 remaining low due to the absence of a start pulse. This will allow a "-" to be lighted in P3 during the display period. In addition, the low at the pin 4 inputs to IC4 and IC6, functioning as blanking controls, will prevent digits P1 and P2 from lighting during the display period.

At the end of time t_4 , which follows each measurement, the display voltage through D16 is applied to the display digits. If a segment of a digit is intended to be lit during the display period, the appropriate output of IC4, IC6, or IC8, or the collector of Q12 will be low. As the display voltage increases; current will flow through each digit anode (common connection), through the segment and its related current-limiting resistor (R34 through R53), and then to the low output to ground. In addition, depending on the Range switch setting, the decimal point of digit P2 or P3 is lighted through R81.

Power Supplies and Calibration Standards

The power supply circuitry which powers the basic meter circuitry and the other circuitry of the Multimeter, is derived from the secondary windings of T1 which also provide voltage calibration standards.

The AC secondary voltage at the red transformer lead serves several purposes:

- a. During its positive portion, the voltage is rectified through D22 to charge C24 to approximately +27 VDC. The voltage drop across R87 to D19 provides a regulated +15 VDC supply which is filtered by C22. Likewise, the voltage drop across R88 to D21 provides a regulated +6.2 VDC which is filtered by C23. The zener voltage of D21; in conjunction with the voltage divider network of R89, R91; provides a precision, factory-measured, DC calibration voltage.

- b. Also, during the positive portion, the voltage is rectified by D25 to resistors R93 and R94. These half-wave pulses have a known ratio between the average DC value, as measured on the DC voltmeter, and the AC value, as measured on the average-responding, rms-calibrated, AC voltmeter of the Multimeter. With this known ratio, and with a calibrated DC voltmeter, the AC voltmeter can be calibrated. This voltage from D25 is also coupled to the IC8-B, C, A circuitry which, as discussed before, signals the basic meter circuitry to perform a measurement cycle.
- c. During the negative portions, the voltage is rectified by D24 and charges C26 to approximately -30VDC. The voltage drop across R92 to D23 provides a regulated -15 VDC, which is filtered by C25.

The voltage of the blue and blue/yellow winding is full-wave rectified by D17 and D18 to charge C21 to approximately +8.2 VDC. This voltage is used during calibration as the +V TP (test point) to indicate the approximate level of line voltage. This determines whether a slight correction to the DC calibration voltage is required. The regulated +6.2 VDC is applied to the Q15, Q16 Darlington circuit which forces the voltage at the emitter of Q15 to be regulated at approximately +5 VDC. The +5 VDC source is filtered by C17, C18, and C19.

During the positive portion of the AC voltage at the blue wire, which is positive at the same time as the voltage at the red wire, current flow through D16 powers the display digits P1, P2, and P3.

The primary winding of power transformer T1 may be wired for a source voltage of either 120 volts or 240 volts AC, 50 or 60 Hz.

Precision resistor standards on the circuit board; R82, R83, R84, R85 and R86; permit full-scale calibration of the Multimeter ohms ranges.

The following descriptions tell how the previously described basic meter circuit is used with the Range and Function switches, and other conversion circuitry.

CONVERSION CIRCUITRY

AC Converter

The AC converter; which consists of Q13, IC1, and their associated components; functions as an operational amplifier precision-rectifier. The overall gain of the converter is such that the average rectified voltage of a sine-wave input will produce an output DC voltage equal to the rms value of the applied AC voltage.

Capacitor C8 prevents DC from entering the converter, while diodes D7 and D8 are protection diodes which clamp any excessive input voltage for safe operation of the gate terminal of Q13. R54 limits peak current through D7 and D8, and R55 references the very high input resistance of Q13 to ground. Signals applied to the AC converter are thus coupled through C8 to Q13. Q13 functions as a source follower which provides very low loading of the Range switch circuitry voltage and applies it directly to the non-inverting input of IC1.

In the IC1 circuitry, R59 feeds back any DC voltage at the output of IC1 to stabilize the DC operating point of IC1. C13 controls the high frequency response of IC1. C12 blocks the DC output voltage of IC1 from the rectifier circuitry.

During the negative portion of the input signal, the output voltage of C12 is coupled through D11 and R61 to R63. During the positive portion, the output of C12 is coupled through D9 and R62 to R63. Since the internal gain of IC1 to any voltage difference at its inputs is very high, the combined portions of the AC signal at R63, coupled through C14 to the inverting input of IC1, is forced to be equal to the input signal. The ratio of the total value of R62 plus R63, to the value of R63, sets the gain of this circuit to approximately 3. The positive voltage at the output of D9 is filtered by the R57, R58, C9, and C11 circuit, resulting in a DC voltage at C9 which is proportional to the AC input signal. R63 is adjusted so that with 2.0 volts rms applied, +2.0 volts DC is developed at C9. This voltage is then measured by the basic meter circuit.

Ohms Converter Constant-Current Source

Transistor Q14, in conjunction with D15 and R71 through R77, comprise a five-decade constant current source ranging from 10 mA down to 1 μ A. The circuit operates as follows:

Current flow through D15 and R79 sets the base of Q14 at a fixed voltage below the +15 volt supply. On the 200 Ω range, for example, current through R71 and R77 (also referenced to +15V) flows through the emitter to the collector of Q14, through R78 and D13 to the Range switch (SW2), and then to the applied resistance being measured. If the current through R71 and R77 tends to decrease; the voltage drop across them, plus the emitter-base voltage of Q14; is less than the voltage drop across D15. This voltage difference forward-biases Q14 and turns Q14 on, increasing the current flow. A current increase is countered by an opposite action. The adjustment of R71 is such that this constant current is set to precisely 10 mA. For any resistance being measured between zero and 200 Ω , the voltage across it increases from zero to +2.0 volts DC. This voltage is then measured by the basic meter circuit.

Similarly, R72 is adjusted to produce a constant current of 1 mA; R73 produces 100 μ A; R74 produces 10 μ A, and R75 (with R76) produces 1 μ A.

Diodes D13 and D14 protect the current source output to prevent damage to the circuit. If the input leads are inadvertently connected across a high positive voltage source, D13 is reverse-biased and blocks the over-voltage. If the applied voltage is negative, D13 and D14 are forward-biased with D14 clamping the collector of Q14 to less than -1.0 volts. R78 limits peak current through D14 and results in the input fuse, F1, opening if the current exceeds three amperes.

INPUT RANGE AND FUNCTION SWITCHING

DC Voltage

When a DC voltage is being measured, it is routed through the "+" input jack to lug 1 on wafer 1 of SW1 and through the switch contacts to lug 3. The voltage is then applied to a voltage divider network on switch SW2 that consists of precision resistors R5 through

R8. A DC voltage developed across each "tap" on this divider, proportional to the input voltage for that range, is routed through SW1 and SW2 contacts to the A-to-D converter input.

AC Voltage

AC voltage is routed in the same manner as DC voltage, through the input switching until it passes through the voltage divider network, where a proportionate voltage is developed. This scaled AC voltage is then applied to the AC converter through the lugs of SW1M. The DC output of the AC converter is routed through lugs 3 and 22 of SW1M to the A-to-D converter input.

DC Current

DC current is applied to the "+" jack and, after passing through contacts of switch SW1F, the current is routed to lug 11 of SW2F. Current then passes through a shunt resistor (R1 through R4) selected by Range switch SW2. A voltage is developed across the selected shunt. This DC voltage is then coupled through SW1F to the A-to-D converter input.

AC Current

AC current is directed through the Function switch contacts and into the shunt resistors of switch SW2 where a proportional voltage is developed, as in the case of the DC current. The AC voltage developed across a shunt resistor is applied to the AC converter in the same manner as for AC voltages previously described. The resultant DC voltage is routed to the input of the A-to-D converter.

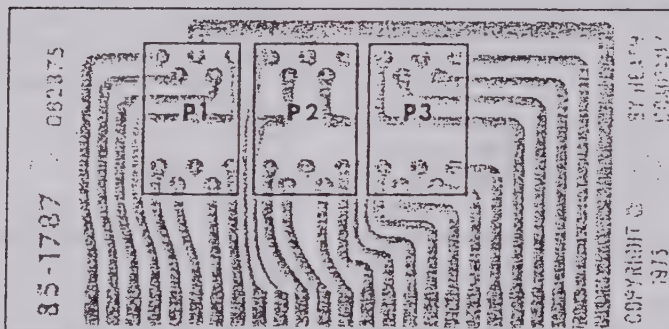
Resistance

The unknown resistance to be measured is connected through lugs of SW1F to the constant current source transistor, Q14. Depending on the ohms range selected by SW2, the proper constant current then passes through the unknown resistance and develops a voltage that is proportional to the value of that resistance. This voltage is then coupled through lugs of SW1M to the A-to-D converter input.

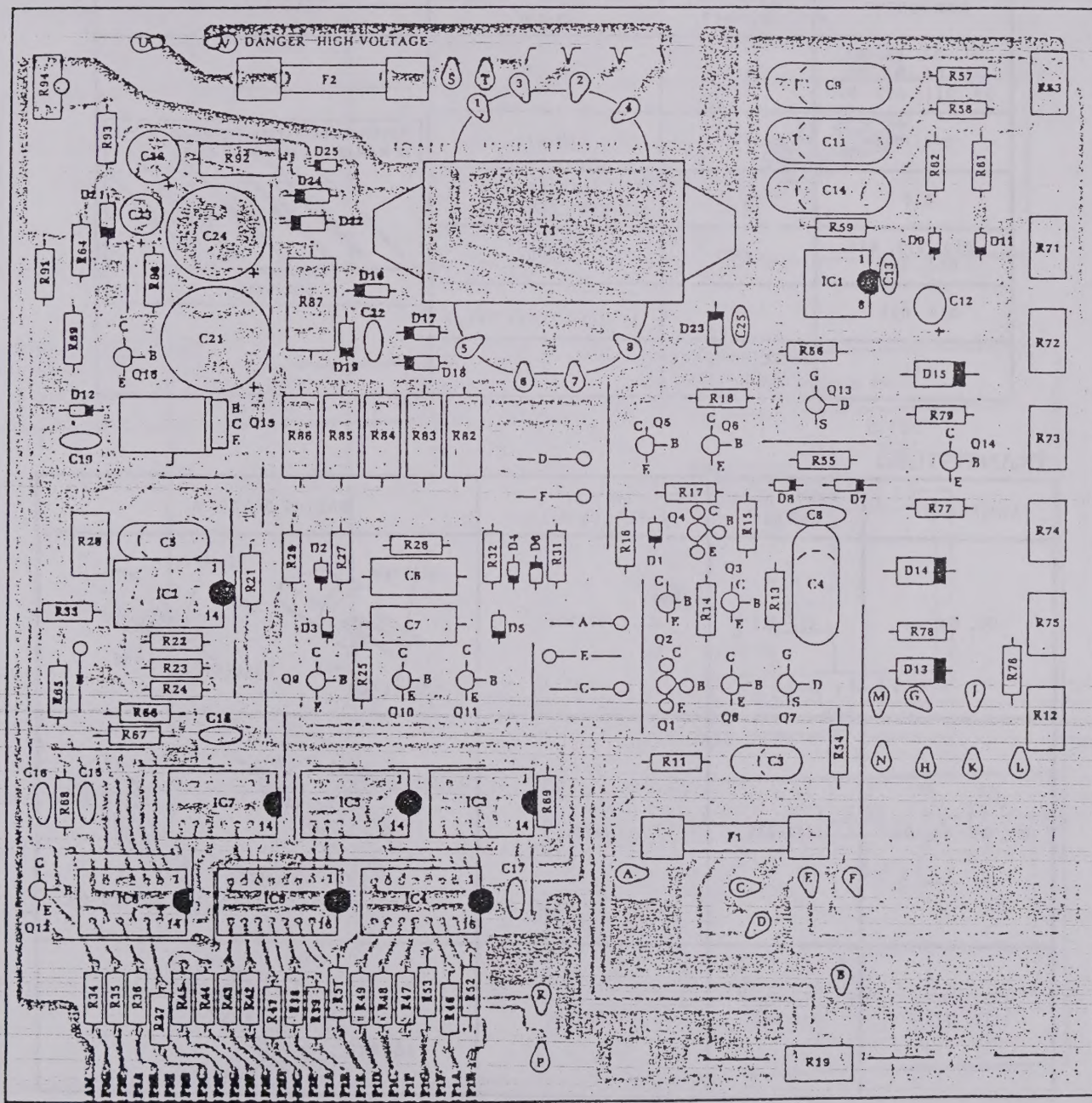
CIRCUIT BOARD X-RAY VIEWS

NOTE: To find the PART NUMBER of a component for the purpose of ordering a replacement part:

- A. Find the circuit component number (R5, C3, etc.) on the X-Ray View.
- B. Locate this same number in the "Circuit Component Number" column of the "Parts List."
- C. Adjacent to the circuit component number, you will find the PART NUMBER and DESCRIPTION which must be supplied when you order a replacement part.



(Viewed from foil side)



(Viewed from component side)

SEMICONDUCTOR IDENTIFICATION CHARTS

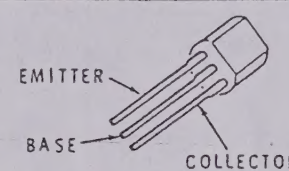
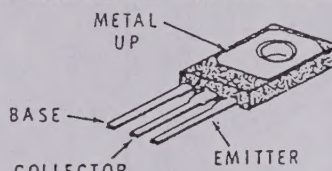
DIODES

COMPONENT	HEATH PART NUMBER	MAY BE REPLACED WITH	LEAD DIAGRAM
D1, D2, D3, D4, D5, D6, D7, D8, D9, D11, D12, D25	56-56	1N4149	IMPORTANT: THE BANDED END OF DIODES CAN BE MARKED IN A NUMBER OF WAYS. BANDED END
D13, D14	57-27	1N2071	
D15	56-31	PS18775 6.8-VOLT ZENER, 20mA	
D16, D17, D18, D22, D24	56-65	1N4002	
D19, D23	56-620	15-VOLT ZENER, 17mA	
D21	SELECTED (PART OF 100-1686)		

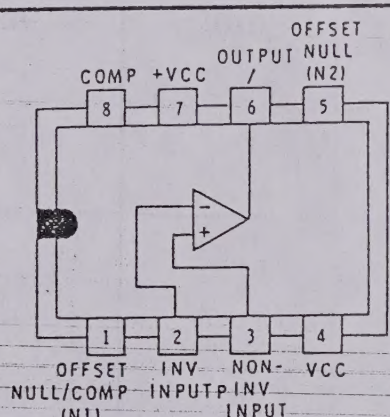
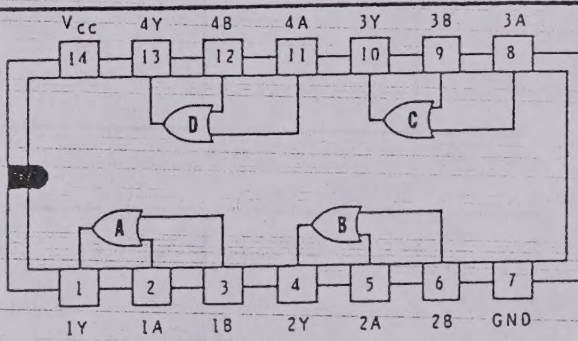
TRANSISTORS

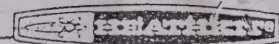
COMPONENT	HEATH PART NUMBER	MAY BE REPLACED WITH	BASING DIAGRAM
Q1, Q4	417-213	2N5249A	
Q2, Q3, Q5, Q6	417-235	2N4121	
Q7, Q13	417-884	SELECTED	

Transistors (cont'd.)

COMPONENT	HEATH PART NUMBER	MAY BE REPLACED WITH	BASING DIAGRAM
Q8, Q9, Q10, Q11, Q12, Q16	417-801	MP5A20	
Q14	417-295	MP5L51	
Q15	417-818	MJE181	

INTEGRATED CIRCUITS

COMPONENT	HEATH PART NUMBER	MAY BE REPLACED WITH	BASING DIAGRAM (VIEWED FROM TOP)
IC1	442-39	301A	
IC2	443-46	7402	



Integrated Circuits (cont'd.)

COMPONENT	HEATH PART NUMBER	MAY BE REPLACED WITH	BASING DIAGRAM (VIEWED FROM TOP)
IC3, IC5, IC7	443-7	7490	
IC4, IC6	443-36	7447	
IC8	443-73	7416	

Display

P1 P2 P3	411-823	FND507	TOP VIEW PIN 1.... Segment E 2.... Segment D 3.... Common Anode 4.... Segment C 5.... DP 6.... Segment B 7.... Segment A 8.... Common Anode 9.... Segment F 10... Segment G
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MP MASTER



MA23877