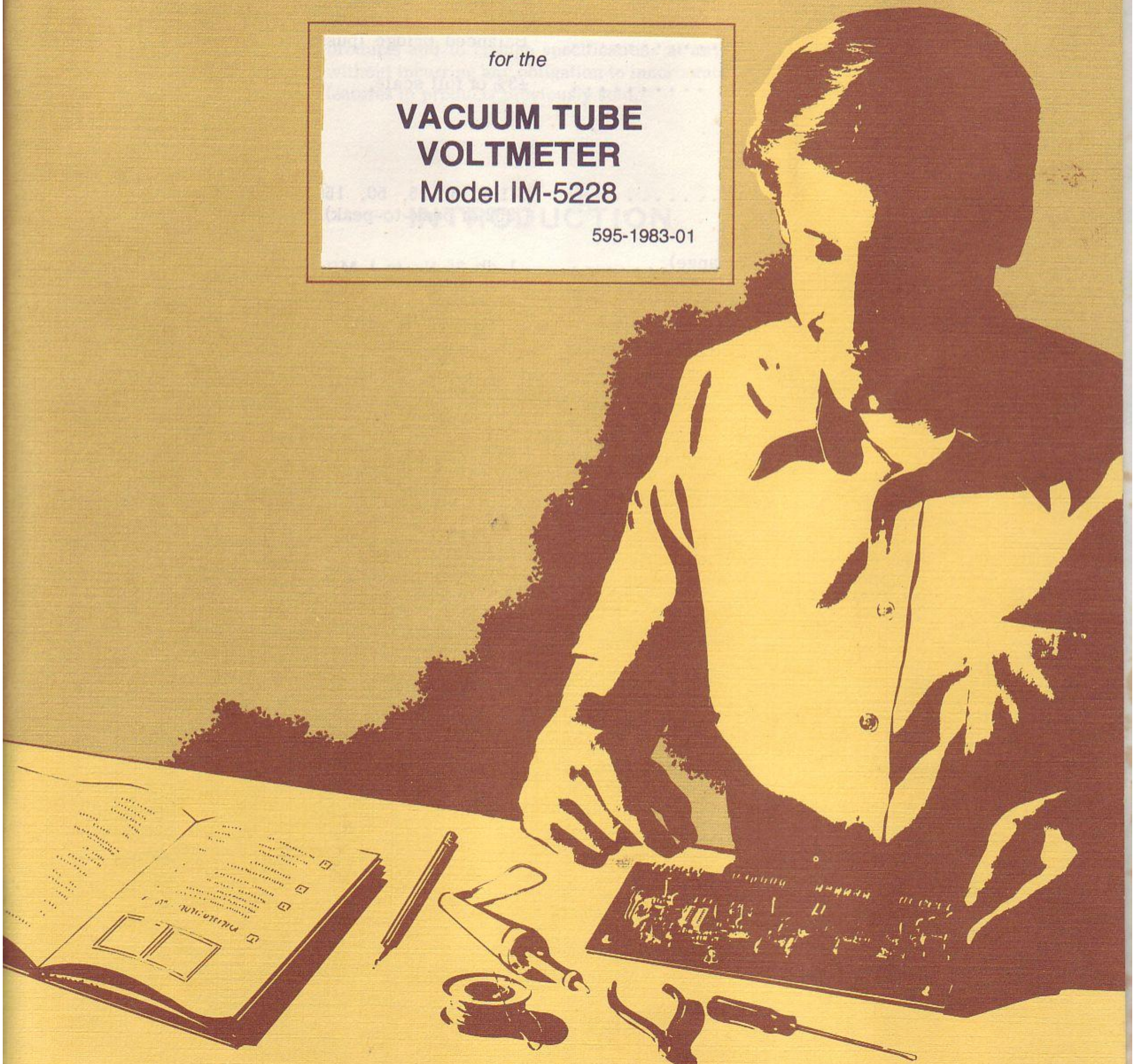
HEATHKIT® MANUAL

for the

VACUUM TUBE VOLTMETER

Model IM-5228

595-1983-01



HEATH COMPANY · BENTON HARBOR, MICHIGAN

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HEATH COMPANY
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SPECIFICATIONS

Electronic DC Voltmeter -

7 Ranges	0-1.5, 5, 15, 50, 150, 500, 1500 volts full scale; up to 30,000 volts with accessory probe.
Input Resistance	11 megohm (1 megohm in probe) on all ranges; 1100 megohms with accessory probe.
Circuit	Balanced bridge (push-pull) using twin triode.
Accuracy	±3% of full scale.

Electronic AC Voltmeter -

7 Ranges	0-1.5, 5, 15, 50, 150, 500, 1500 rms scales (.353 of peak-to-peak).
Frequency Response (5 V range)	±1 db 25 Hz to 1 MHz (600 Ω source, referred to 60 cps).
Circuit	Half-wave voltage doubler, using twin diode.
Accuracy	±5% of full scale.
Input Resistance And Capacitance	1 megohm shunted by 40 μμf measured at input terminals (200 μμf at probe tip).

Electronic Ohmmeter -

7 Ranges	Scale with 10 Ω center X1, X10, X100, X1000, X10K, X100K, X1MEG. Measures .1 Ω to 1000 megohms with internal battery.
Meter	6", 200 μa movement, polystyrene case.
Probe	Combined AC-OHMS-DC switching probe, single jack input for probe and ground connections.
Dividers	1% precision type.
Tubes-Diode	1 - 12AU7, twin triode meter bridge. 1 - 6AL5, twin diode AC rectifier. 1 - Silicon diode power supply rectifier.
Battery	1-1/2 volt, "C" cell.

Power Requirements.	105-125 or 210-250 volts, 50/60 Hz AC, 10 watts.
Cabinet Size.	5" high x 12-11/16" wide x 4-3/4" deep (overall).
Net Weight.	5 lbs.

INTRODUCTION

The HEATHKIT Model IM-5228 Vacuum Tube Voltmeter is intended for use by servicemen, engineers, and maintenance men to make accurate measurements of DC+, DC− and AC voltages, and resistance. The design is simple and rugged, yet accurate.

In this instrument, vacuum tubes are used for rectification and amplification on all measurement functions to insure good sensitivity and stability of operation. Precision resistors are used in the voltage divider networks to provide high accuracy.

The confusing tangle of test leads coming from the front panel of most VTVMs is eliminated by the use of a combination AC-OHMS-DC switching test probe and a single jack input connection for both the test probe and ground leads. The 1 megohm resistor in the probe is switched into operation when the probe switch is set on DC. This isolating resistor allows DC voltages to be measured without materially affecting AC voltages present at the test point.

Because the VTVM has a very high input impedance, the circuit in which the voltage is being measured will not be significantly loaded by the VTVM. Most nonelectronic voltmeters (VOM) have a much lower input impedance over the most frequently used ranges of test voltages. Consequently, when a VOM is used to measure voltages in high impedance circuits, the indicated voltage will be appreciably less than the actual voltage. The amplifier section enables the VTVM to accurately measure much higher resistances than can be conveniently measured with a VOM.

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

CIRCUIT DESCRIPTION

In order to obtain a better understanding of the circuit, follow the Schematic Diagram (fold-out from Page 35) while reading the Circuit Description.

The combination AC-OHMS-DC test lead of the VTVM is connected to the Function switch, which is used to connect the part of the circuit needed for any of the VTVM measurement functions. The COMMON test lead is connected to the case (ground) of the instrument.

With the Function switch in the DC+ or DC- position and the switching probe on DC, the test voltage is applied through 1 megohm resistor R1 in the probe to the Range switch, on which is a series of precision resistors, R17 through R23, arranged as a voltage divider. Depending on the position of the Range switch, a portion of this DC voltage is "picked off" and applied through resistor R12 to the input grid of the 12AU7 tube.

With the Function switch in the AC position and the test probe on AC-OHMS, an AC test voltage is applied through capacitors C1 and C2 to the 6AL5 tube (half-wave doubler circuit) where it is changed to a DC voltage which is proportional to the peak-to-peak value of the applied AC test voltage. On the higher AC ranges, a voltage divider arrangement consisting of R2, R3 and R4, is used at the input of the 6AL5 tube to insure that the AC voltage applied to the 6AL5 tube does not exceed the tube's rating. The DC voltage output of the 6AL5 tube is applied to the Range switch and then to the input grid of the 12AU7 tube, in the same way that DC test voltages are applied. The VTVM responds to peak-to-peak voltage regardless of the test voltage waveform. The AC balance control is used to "buck-out" the small amount of contact potential in the 6AL5 tube, thus eliminating residual readings on the lower AC ranges.

The ohmmeter section of the VTVM uses a 1.5 volt battery connected in series with part of the standard-resistor network (determined by the Range switch position) and the resistance to be measured. The ratio between the ohmmeter standard-resistor network and the measured resistance determines what portion of the ohmmeter battery voltage is applied to the input grid of the 12AU7 tube.

Thus, for all measurement functions, a voltage dependent upon the quantity being measured is applied to the grid of one-half of the 12AU7 twin triode. With zero voltage input to the 12AU7 balanced bridge circuit, each of its triode sections draws the same amount of cathode current and therefore each cathode is at the same voltage potential. The meter movement is connected between the cathodes of the 12AU7 tube and consequently will not deflect since both cathodes are at the same potential.

When a positive voltage (from the Range switch) is applied to one-half of the 12AU7 tube, this half of the tube draws more current than the other half, causing a difference in cathode potential between the two tube sections. Since the meter is connected between the two cathodes, a current flows through the meter movement. The meter pointer responds proportionally to this current, indicating the value of voltage or resistance being measured. The DC+ and DC- switch positions are used to reverse the meter connections between the cathodes so that current always flows through the meter in the same direction.

The use of the bridge circuit minimizes any change in the voltage reading if the B+ voltage in the VTVM should vary since the resulting variation in tube conduction will occur in both triodes and, therefore, will not affect the difference in cathode potential. Also, the maximum conduction characteristics of the 12AU7 tube, as used in the VTVM circuit, are such that the voltage applied to the meter terminals cannot be large enough to damage the meter movement. This is one of the primary advantages of the VTVM circuit. The meter movement cannot be burned out by inadvertently measuring a voltage that is higher than the Range switch setting. However, if excessive voltage is applied, the pointer may be bent as it hits against the stop. Caution must also be exercised to avoid applying any test voltage to the test probe when the Function switch is set in the OHMS position. The precision resistors in the ohmmeter voltage divider network have very low power ratings and can easily be burned in this way.

The power supply of the VTVM uses a silicon diode in a half-wave rectifier circuit. An electrolytic capacitor is used for filtering the DC voltage from the power supply. The power supply provides both B+ voltage for the 12AU7 tube and positive DC "buck-out" voltage for the AC balance circuit.

PARTS LIST

NOTE: The numbers in parentheses in the Parts List are keyed to the numbers on the Parts Pictorial (fold-out from Page 9) to aid in parts identification.

To order replacement parts, use the Parts Order Form furnished with this kit. If one is not available, refer to "Replacement Parts" inside the rear cover of this Manual. Refer to the separate "Heath Parts Price List" for pricing information.

PART No.	PARTS Per Kit	DESCRIPTION
RESISTORS		
(1)1-3	1	100 Ω 1/2 watt (brown-black-brown)
1-20	1	10 KΩ 1/2 watt (brown-black-orange)
1-23	1	27 KΩ 1/2 watt (red-violet-orange)
1-27	3	150 KΩ 1/2 watt (brown-green-yellow)
1-126	1	180 KΩ 1/2 watt (brown-gray-yellow)
1-35	1	1 megohm 1/2 watt (brown-black-green)
1-38	1	3.3 megohm 1/2 watt (orange-orange-green)
1-40	1	10 megohm 1/2 watt (brown-black-blue)
1-70	6	22 megohm 1/2 watt (red-red-blue)
(2)2-24	1	90 Ω 1/2 watt precision
2-29	1	900 Ω 1/2 watt precision
2-35	1	9 KΩ 1/2 watt precision
2-50	1	10 KΩ 1/2 watt precision
2-39	1	21.62 KΩ 1/2 watt precision
2-40	1	68.38 KΩ 1/2 watt precision
2-41	1	90 KΩ 1/2 watt precision
2-86	1	150 KΩ 1/2 watt precision
2-42	1	216.2 KΩ 1/2 watt precision
2-138	1	400 KΩ 1/2 watt precision

PART No.	PARTS Per Kit	DESCRIPTION
Resistors (cont'd.)		
2-45	1	683.8 KΩ 1/2 watt precision
2-123	1	800 KΩ 1/2 watt precision
2-51	1	900 KΩ 1/2 watt precision
2-146	1	2.162 megohm 1/2 watt
2-147	1	6.838 megohm 1/2 watt precision
2-52	1	9 megohm 1/2 watt precision
(3)3-4-2*	1	9.1 Ω 2 watt precision (white-brown-gold)

*NOTE: This resistor is a 2 watt wire-wound resistor, but is the same size as a 1 watt composition resistor.

PART No.	PARTS Per Kit	DESCRIPTION
CAPACITORS		
(4)21-27	2	.005 μfd disc ceramic
23-91	1	.047 μfd 1600 V tubular
(5)23-61	2	.05 μfd 400 V tubular
(6)25-19	1	20 μfd 150 V electrolytic
CONTROLS-SWITCHES		
(7)10-57	3	10 KΩ tab-mounting control
(8)10-142	2	10 KΩ vernier control
63-500	1	Range switch
(9)63-501	1	Function switch

PART No.	PARTS Per Kit	DESCRIPTION
TUBES-LAMP-DIODE		
411-275	1	12AU7 tube
411-40	1	6AL5 tube
(10)412-36	1	Neon lamp
(11)57-27	1	Silicon diode
TERMINAL STRIPS-SOCKETS-JACK-PLUG		
(12)431-50	1	1-lug terminal strip
(13)431-5	1	4-lug terminal strip
(14)431-12	2	4-lug terminal strip
(15)431-40	1	4-lug terminal strip
(16)431-77	1	5-lug terminal strip
(17)434-15	1	7-pin tube socket
434-16	1	9-pin tube socket
(18)436-20	1	Phone jack
(19)438-28	1	Phone plug
PROBE PARTS		
(20) 253-51	1	E washer
(21) 256-15	2	1/16" x 1/8" rivet
(22) 258-53	1	Probe contact loading spring
(23) 459-46	1	Probe switch lever
(24) 459-47	1	Probe insert insulator
(25) 459-44	1	Front section of probe body
(26) 459-45	1	Center section of probe body
(27) 459-43	1	Rear section of probe body
(28) 477-11	1	Probe spike
WIRE-SLEEVING		
340-2	1	Bare wire
341-1	1	Black test lead
343-11-1	1	Shielded test lead
344-59	1	Hookup wire
346-1	1	Sleeving
METAL PARTS		
90-262-6	1	Cabinet
200-524	1	Chassis
203-351-5	1	Front panel
(29) 204-254	1	Battery bracket
204-542-6	1	Gimbal bracket
(30) 214-2	1	Battery housing cup
(31) 258-7	1	Battery spring

PART No.	PARTS Per Kit	DESCRIPTION
HARDWARE		
(32) 250-49	4	3-48 x 1/4" screw
(33) 250-116	1	6-32 x 1/4" screw (black)
(34) 250-89	7	6-32 x 3/8" screw
(35) 250-54	2	10-32 x 5/8" screw
(36) 250-155	12	#6 sheet metal screw (black)
(37) 250-68	3	#7 x 3/4" wood screw
(38) 252-1	4	3-48 nut
(39) 252-3	8	6-32 nut
(40) 252-7	5	Control nut
(41) 252-32	1	Push-on speednut
(42) 252-49	2	Thumbnut
(43) 253-2	3	#6 fiber shoulder washer
(44) 253-10	5	Control flat washer
(45) 253-19	4	#10 flat washer
(46) 254-7	4	#3 lockwasher
(47) 254-1	13	#6 lockwasher
(48) 254-4	5	Control lockwasher
(49) 255-44	2	Threaded spacer
(50) 259-1	1	#6 solder lug
MISCELLANEOUS		
54-2-24	1	Power transformer
75-30	1	Strain relief, round cord
(51)75-71	1	Strain relief, flat cord
89-23	1	Line cord
260-1	1	Alligator clip
(52)260-51	1	Alligator clip, threaded
(53)73-20	1	Alligator clip insulator, red
73-21	1	Alligator clip insulator, black
(54)261-49	4	Plastic foot
391-34	1	Identification label
407-732	1	Meter
(55)413-11	1	Neon lamp lens
(56)455-619	2	Knob bushing
462-999	2	Knob
(57)490-5	1	Nut starter
597-260	1	Parts Order Form
597-308	1	Kit Builders Guide
	1	Manual (See front cover for part number.)
		Solder

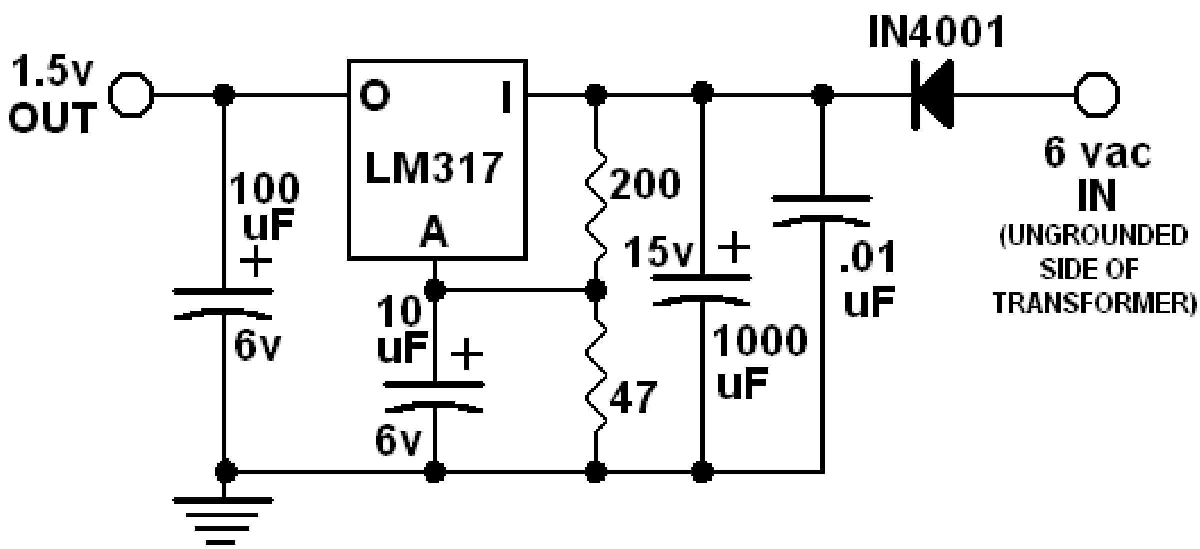
NOTE: One size C 1.5 volt flashlight battery will also be needed before the ohmmeter function of your VTVM can be used. By purchasing the battery now, you will be able to use your VTVM as soon as assembly is completed.

NOTE: Assembly instruction, pages 7 through 19 of the original manual, have been left out.

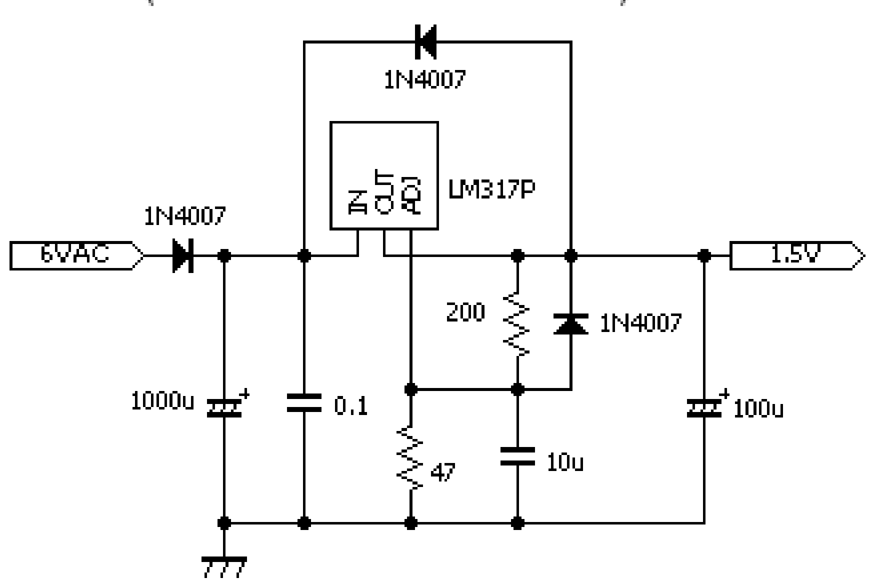
The VTVM uses a 1.5v "C" size battery for to measure resistance. The battery is inside the VTVM case and twelve screws need to be removed in order to access it. If the battery is left in the unit for a long period of time, the battery can discharge and then leak corrosive liquid inside the VTVM.

Circuits using a LM317 adjustable regulator have been employed by others in order to eliminate this battery. It gets it's power from the ungrounded side of the 6vac filament transformer used in most VTVM's. On this page are a couple of circuits for this purpose.

1.5v BATTERY ELIMINATOR CIRCUIT



1.5v BATTERY ELIMINATOR CIRCUIT
(WITH PROTECTION DIODES)



(✓) C2. Connect the lead from the marked end of the .05 μfd tubular capacitor to lug A8 of switch N (S-1). Connect the other lead to lug 4 of terminal strip Q (S-2).

(✓) Connect the free end of the wire coming from lug 3 of terminal strip B to lug C1 of switch P (S-1).

(✓) Connect the free end of the wire coming from lug 2 of terminal strip E to lug A7 of switch P (S-1).

(✓) Connect a 6" wire from lug 3 of control R (S-1) to lug B6 of switch P (S-1).

(✓) Connect a 2" wire between lugs A3 (S-1) and A5 (NS) of switch P. Use sleeving.

(✓) Connect one end of a 3-1/2" wire to lug 2 of phone jack U (S-1). Slide sleeving over this wire. Connect the other end of this wire to lug A5 of switch P (S-2).

(✓) Connect a 2-1/2" wire from lug 3 of terminal strip Q (S-3) to lug C2 of switch P (S-1).

(✓) Connect a 7-1/2" wire from lug 3 of control T (NS) to lug B7 of switch P (NS).

(✓) Connect the free end of the wire coming from lug 8 of tube socket V2 to lug B7 of switch P (S-2).

(✓) Connect a 7-1/2" wire from lug 1 of terminal strip F (S-2) to lug A9 of switch P (S-1).

(✓) Connect one end of a 6-1/2" wire to lug C1 of switch N (S-2). Insert the other end through the hole near terminal strip F and connect it to the solder lug on the battery bracket (S-1).

(✓) Connect a 5" wire from lug 1 of phone jack U (S-2) to lug B7 of switch N (S-3).

(✓) Connect a 4" wire from lug 1 of control T (NS) to lug 3 of control K (S-2).

(✓) R35. Connect a 27 KΩ (red-violet-orange) resistor from lug 3 of control J (S-2) to lug 1 of terminal strip Q (NS).

(✓) R31. Connect a 180 KΩ (brown-gray-yellow) resistor from lug 1 of control T (S-3) to lug 1 of terminal strip Q (NS).

(✓) R32. Connect a 150 KΩ (brown-green-yellow) resistor from lug 2 of control T (S-1) to lug 1 of terminal strip Q (NS).

IMPORTANT WARNING: TUBES CAN BE DAMAGED WHEN INSTALLING THEM IN THEIR SOCKETS. THEREFORE, USE EXTREME CARE WHEN INSTALLING TUBES AS WE DO NOT GUARANTEE OR REPLACE TUBES BROKEN DURING HANDLING OR INSTALLATION.

(✓) R34. Connect a 150 KΩ (brown-green-yellow) 1/2 watt resistor from lug 3 of control T (S-2) to lug 1 of terminal strip Q (S-5).

( ) Install the tubes in their appropriate socket (V1: 6AL5, V2: 12AU7).

PRELIMINARY TEST

Carefully inspect the instrument and check the arrangement of all wiring. Be sure the wiring and components are not positioned in such a way that short circuits may occur. Check all solder connections. Gently shake out all loose wire clippings, insulation, and other debris that may have accumulated during the assembly of the instrument.

NOTE: The switch lug between lugs B2 and B4 of switch P is not used.

Plug the VTVM line cord into the appropriate AC power source. Turn the Function knob to the DC+ or DC- position and the Range switch to the 1.5 V position. The tubes and pilot lamp should light after a few seconds of warmup time. When the VTVM is first turned on, the meter pointer will normally deflect to full scale and then return to, or near, the zero position. This is caused by the 12AU7 tube stabilizing during warmup. There should be some degree of ZERO ADJ control action which will permit the meter pointer to deflect over a limited range of the dial. During the preliminary test warmup, check the instrument assembly very carefully for any indication of overheating. If the VTVM does not function in the prescribed manner or if overheating occurs, turn the unit off and refer to the In Case Of Difficulty section of the manual.

Assuming that the instrument will respond in the manner indicated, it will be safe to leave it turned on to thoroughly warm up while the balance of the kit project is completed; this will consist of test probe preparation.

PREPARATION OF TEST PROBE AND LEADS

Refer to Pictorial 8 for the following steps.

NOTE: Read the remaining assembly steps up to "Test And Calibration" and familiarize yourself with the completed assembly and parts before proceeding.

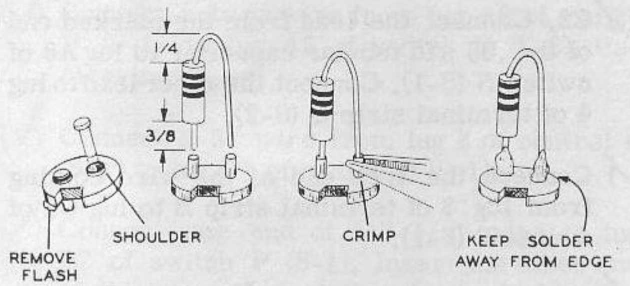
( ) Locate the probe insert insulator. If necessary, remove any "flash" or sharp edge on the insert insulator with a file or penknife.

( ) R1. Locate the two small rivets, the probe insert insulator, and the 1 megohm (brown-black-green) resistor shown in Detail 8A. Insert the rivets into the holes in the insulator so that the head of each rivet rests on the small shoulder around the hole in the insulator. Now turn the insulator over and lay it flat on the workbench.

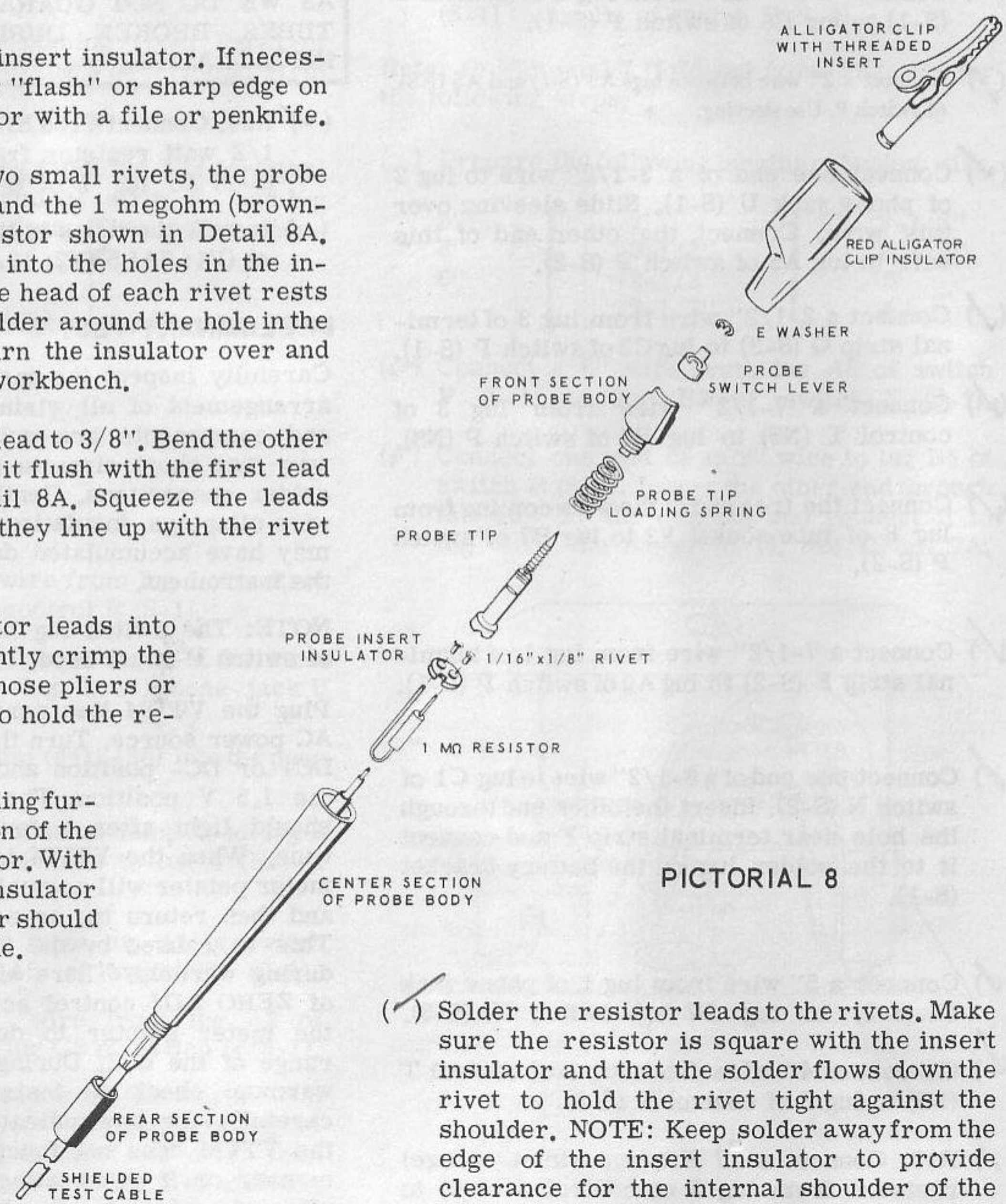
( ) Cut one resistor lead to 3/8". Bend the other lead over and cut it flush with the first lead as shown in Detail 8A. Squeeze the leads together so that they line up with the rivet holes.

( ) Insert the resistor leads into the rivets and lightly crimp the rivets with long-nose pliers or diagonal cutters to hold the resistor.

NOTE: Before proceeding further, check the position of the resistor on the insulator. With the notch in the insulator facing you, the resistor should be on the left-hand side.



Detail 8A



PICTORIAL 8

( ) Solder the resistor leads to the rivets. Make sure the resistor is square with the insert insulator and that the solder flows down the rivet to hold the rivet tight against the shoulder. NOTE: Keep solder away from the edge of the insert insulator to provide clearance for the internal shoulder of the probe center section.

(✓) After the wires have completely cooled down, use pliers to bend the tabs on the phone plug over lightly to secure the black cable. Screw the two parts of the phone plug together.

This completes the phone plug assembly.

(✓) Place the black alligator clip insulator, small end first, on the black test lead.

(✓) Tin the strands of the free end of the black test lead and solder it to the alligator clip as shown.

(✓) After the solder connection has cooled, slide the insulator over the alligator clip.

TEST AND CALIBRATION

During the preparation of the test leads, the VTVM has had an opportunity to warm up thoroughly and should now be calibrated. If you wired your VTVM for 240 VAC, read that figure instead of 120 VAC in the following instructions.

Turn the instrument off and make sure that the mechanical zero position of the meter pointer is correct. If not, adjust as follows:

(✓) Turn the plastic screw on the meter face with a screwdriver while gently tapping the meter face with one finger until the pointer coincides with the zero line on the left side of the scale. Turn the instrument on again.

ZERO ADJUST

(✓) Set the Function switch to DC+.

( ) Check operation of the ZERO ADJ control. Turning this control should move the meter pointer part way up scale. Set the pointer to zero at the left side of the scale and check for zero positioning when the Function switch is changed to DC-. It should be possible to obtain a ZERO ADJ control position that will permit the meter pointer to remain stationary when switching from DC+ to DC-. If there is an appreciable zero shift of more than two divisions on the scale, it should be regarded merely as an indication that additional aging of the 12AU7 tube is required. This aging can be obtained by leaving the instrument turned on for a period of 48 hours or more, or through continued use of the VTVM with periodic calibration.

DC CALIBRATE

( ) Insert the test lead phone plug.

( ) Set the Function switch to DC+, the Range switch to 1.5 V, and the probe to DC.

( ) Connect the probe and common test leads to the flashlight battery and adjust the DC Calibrate control so that the meter pointer falls directly over the very small red dot on the meter face. Approach the red dot going up scale by turning the screwdriver control and watch the meter read 1.4 volts, and 1.5 volts, and then the red dot. As soon as the red dot is reached, stop turning the DC Calibrate control. Remember that the Range switch must be set on 1.5 V for this adjustment.

OHMS CHECK

(✓) Turn off the VTVM.

(✓) Install the battery by starting the top (+) end into the battery cup and then pulling the spring out and over the bottom (-) end. Now push the spring and the battery in so the spring, battery, and battery cup are all in line.

(✓) Turn on the VTVM and set the Function switch to OHMS and the Range switch to RX1K. Set the OHMS ADJ control for full scale (infinity).

( ) Set the probe switch to AC-OHMS (the position opposite the DC marking) and touch the probe to the common test clip. The meter pointer should drop to zero at the left end of the scale (no resistance).

AC CALIBRATE

NOTE: Your AC power line outlets may be either the 2-wire or 3-wire types. Determine which type you have and complete the appropriate AC Calibration instructions. Use the AC Calibrate With Line Cord Adapter for the 2-wire outlets and AC Calibrate Without Line Cord Adapter for the 3-wire outlets. NOTE: You must purchase a line cord adapter if you wish to plug this instrument into a 2-wire outlet.

AC Calibrate With Line Cord Adapter

(✓) Install the line cord adapter on the line cord.

(✓) Temporarily remove the phone plug from the jack.

(✓) Set the Range switch to 1.5 V and the Function switch to AC.

(✓) Adjust the AC Balance control so no movement is detected when switching from AC through DC- to DC+.

(✓) Set the Range switch to the 150 V range if you wired your VTVM for 120 VAC operation, or to the 500 V range if you wired the VTVM for 240 VAC operation.

(✓) Set the Function switch to AC.

(✓) Set the AC Calibrate control fully clockwise.

(✓) Reinsert the phone plug.

(✓) Set the switch on the test probe to AC.

(✓) Connect the test probe to one side of the AC line and then the other side. Note the lowest reading and remove the probe from the AC line.

(✓) Now connect the negative meter lead to the side of the AC line with the lowest reading. Then connect the test probe to the other side of the line.

(✓) Adjust the AC Calibrate control until the meter pointer indicates the line voltage.

(✓) Disconnect the test lead and probe.

AC Calibrate Without Line Cord Adapter

WARNING: When your power line outlet is the 3-wire, polarized type, DO NOT use the common (negative) lead of this VTVM to measure power line voltages. To do so may short circuit the power line through the common lead, the chassis, and the green line cord wire.

( ) Temporarily remove the phone plug from the jack.

( ) Set the Range switch to 1.5 V and the Function switch to AC.

( ) Adjust the AC Balance control so no movement is detected when switching from AC through DC- to DC+.

( ) Set the Range switch to the 150 V range if you wired your VTVM for 120 VAC operation, or to the 500 V range if you wired the VTVM for 240 VAC operation.

( ) Set the Function switch to AC.

( ) Set the switch on the test probe to AC.

( ) Reinsert the phone plug.

( ) Connect the test probe to the side of the AC line with the highest reading.

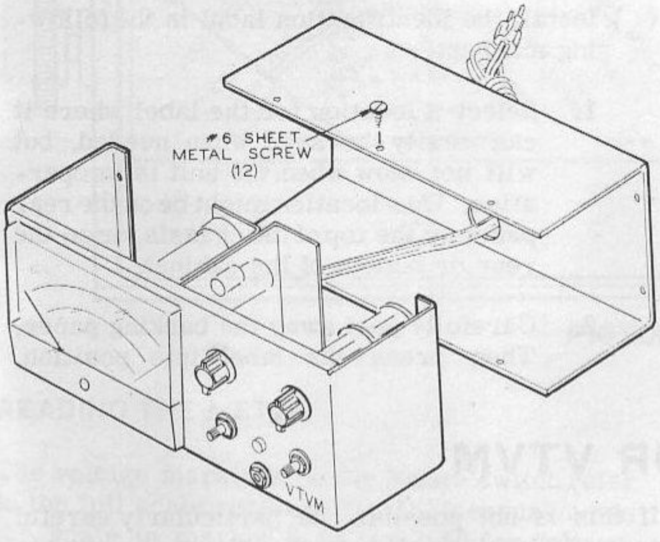
( ) Adjust the AC Calibrate control until the meter pointer indicates the line voltage.

AGING AND FINAL CALIBRATION

It is recommended that you age the tubes before final calibration by keeping the instrument turned on for a period of at least 48 hours. Final calibration should be done in the same way as the initial calibration. Careful calibration will result in a more accurate instrument. If a standard AC meter is available, it is desirable to use such an instrument to check the accuracy of the VTVM. Preferably, use a voltage near full scale on the VTVM; for instance, 140 volts or 40 volts on the 150 V or 50 V range, respectively. The DC scales may also be calibrated using a DC meter of known accuracy. One of the major advantages of kit form instrument assembly is that the kit builder becomes thoroughly familiar with the calibration procedure and is therefore capable of periodically checking VTVM operating accuracy, instead of assuming that usual factory instrument calibration is still valid.

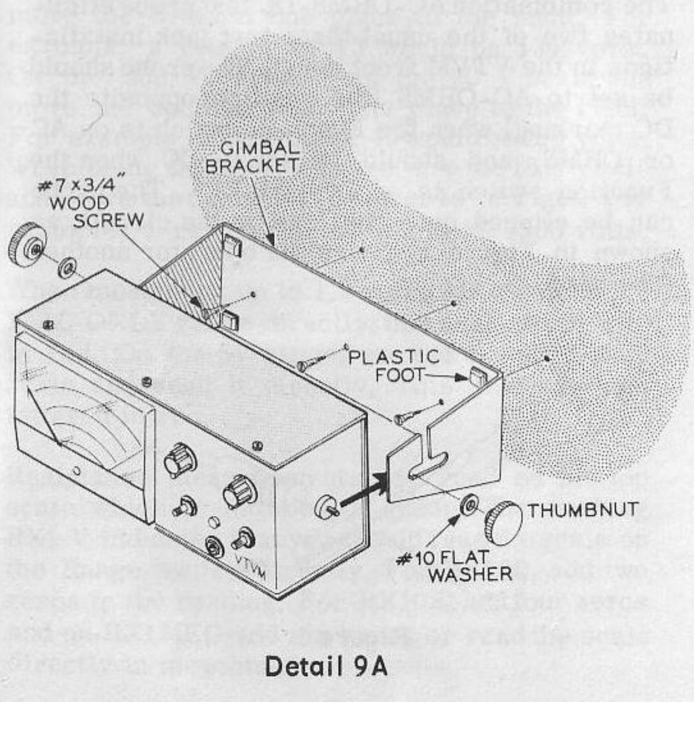
FINAL ASSEMBLY AND MOUNTING

(✓) After final calibration, place the instrument in the cabinet and secure it with twelve #6 x 3/8" sheet metal screws. See Pictorial 9.



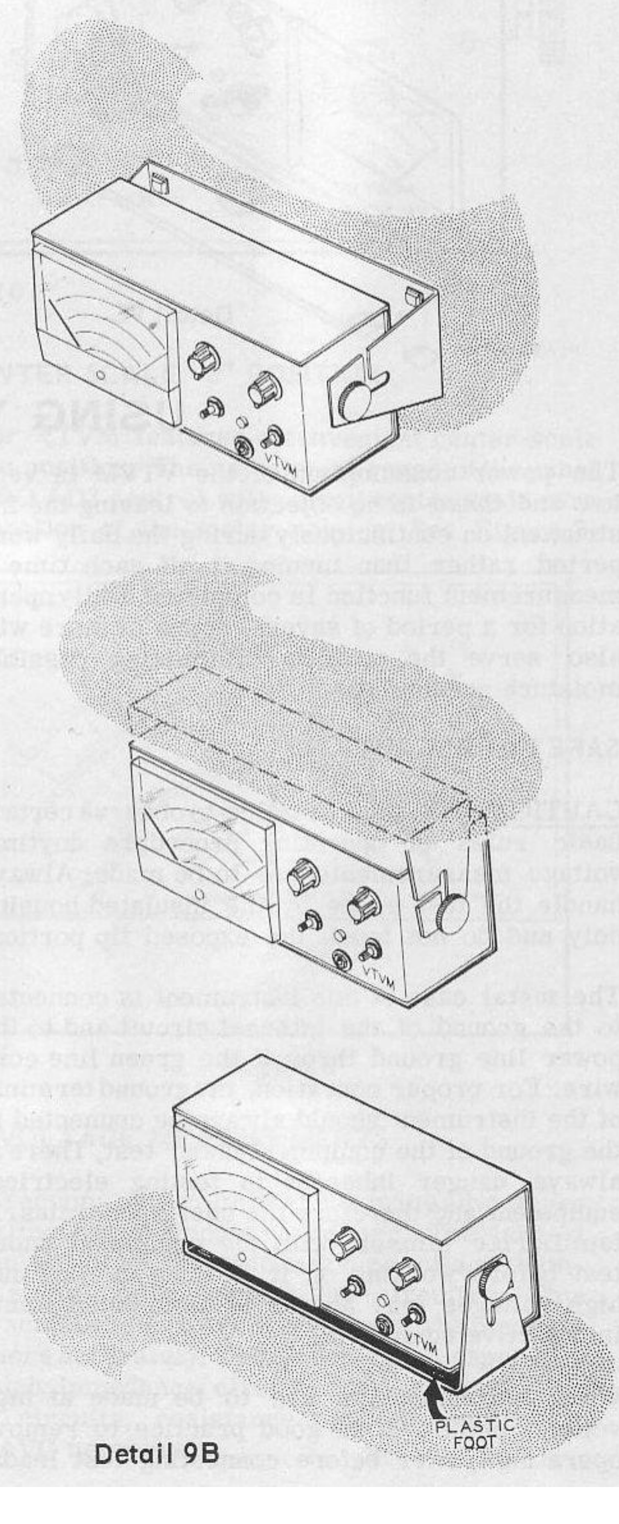
PICTORIAL 9

( ) Install the four plastic feet inside the gimbal bracket as shown in Detail 9A. Peel away the protective paper from the adhesive and press each foot into position. Be sure you position each foot properly before permitting the adhesive to contact the metal.



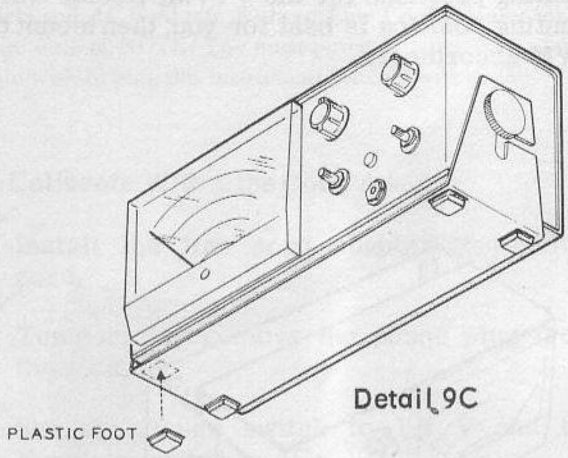
Detail 9A

Detail 9A shows the mounting of the gimbal bracket, and Detail 9B shows three possible mounting positions for the VTVM. Decide which mounting position is best for you, then mount the VTVM accordingly.



Detail 9B

If you do not wish to secure the gimbal bracket in a stationary position, the plastic feet can be applied to the bottom of the gimbal as shown in Detail 9C. The VTVM can then be set on your test bench and be moved whenever desired.



Detail 9C

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

( ) Install the identification label in the following manner:

1. Select a location for the label where it can easily be seen when needed, but will not show when the unit is in operation. This location might be on the rear panel or the top of the chassis, or on the rear or bottom of the cabinet.

2. Carefully peel away the backing paper, Then press the label into position.

USING YOUR VTVM

The power consumption of the VTVM is very low and there is no objection to leaving the instrument on continutously during the daily work period rather than turning it off each time a measurement function is completed. Daily operation for a period of several hours or more will also serve the purpose minimizing possible moisture accumulation.

SAFETY PRECAUTIONS

CAUTION: It is good practice to observe certain basic rules of operating procedure anytime voltage measurements are to be made. Always handle the test probe by the insulated housing only and do not touch the exposed tip portion.

The metal case of this instrument is connected to the ground of the internal circuit and to the power line ground through the green line cord wire. For proper operation, the ground terminal of the instrument should always be connected to the ground of the equipment under test. There is always danger inherent in testing electrical equipment and therefore the user should clearly familiarize himself with the equipment under test before working on it, bearing in mind that high voltages may appear at unexpected points in defective equipment.

When measurements are to be made at high voltage points, it is good practice to remove operating power before connecting test leads. If this is not possible, be particularly careful to avoid accidental contact with nearby objects which could provide a ground return path. When working on high voltage circuits, play safe. Keep one hand in your pocket to minimize accidental shock hazard and be sure to stand on a properly insulated floor or floor covering.

COMBINATION PROBE

The combination AC-OHMS-DC test probe eliminates two of the usual three test jack installations in the VTVM front panel. The probe should be set to AC-OHMS (the position opposite the DC marking) when the Function switch is on AC or OHMS, and should be set to DC when the Function switch is on DC+ or DC-. The probe can be clipped onto any lead in the circuit, as shown in Figure 1, giving the operator another free hand.

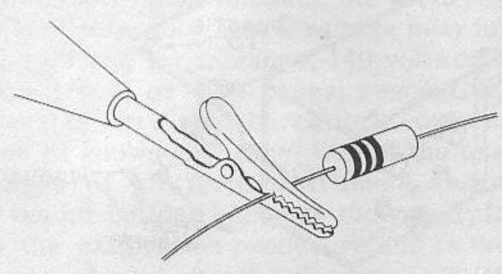
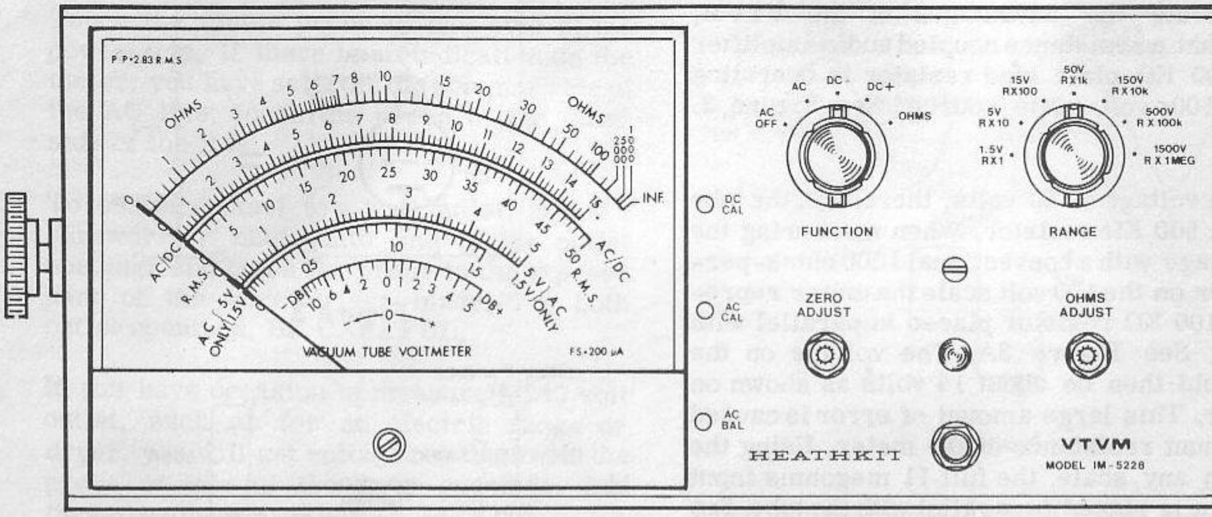


Figure 1



PICTORIAL 10

READING THE METER

The voltage markings on the Range switch refer to the full scale reading. For DC measurements the scale is marked 0-15 and 0-50 for voltage. This scale is also used on AC except for the 1.5 V and 5 V ranges. For 1.5 volts DC read the 15 V scale and move the decimal one place to the left. For example, a reading of 8 would be .8 volt. For 5 volts DC read the 50 V scale. For example, a reading of 40 would be 4 volts. On the 15 V range, read the 0-15 V scale directly. On the 50 range, read the 0-50 V scale directly. On the 150 V range, read the 0-15 V scale and move the decimal one place to the right. For example, a reading of 13 would be 130 volts. On the 500 V range, read the 50 V scale and move the decimal point one place to the right. For example, a reading of 40 would be 400 volts. When using the 1500 V range, use the 15 V scale and move the decimal two places to the right. For example, a reading of 12 would be 1200 volts.

When measuring up to 1.5 volts AC, read the 1.5 V AC ONLY range directly; this scale is lettered in red. On the 5V range, use the 5 V AC ONLY scale and read it directly. This scale is also lettered in red.

Resistance measurements are read on the top scale which is lettered in green. The marking RX1 V indicates that you should read the scale on the Range switch directly. For RX100, add two zeros to the reading. For RX10K, add four zeros and on RX1MEG add six zeros or read the scale directly in megohms.

CENTER SCALE "0" POSITION

Your VTVM features a convenient center scale zero position. The adjustment range of the panel ZERO ADJ control will permit center scale zero deflection of the meter pointer. See Figure 2.

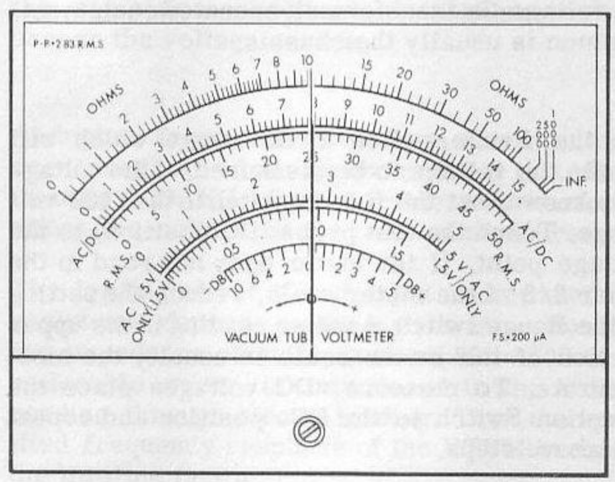


Figure 2

DC VOLTAGE MEASUREMENTS

The vacuum tube voltmeter has many advantages over the nonelectronic voltmeter. The largest advantage is its ability to measure voltages without significantly loading the circuitry. This characteristic enables the voltage to be measured more accurately. This is desirable, expecially in high impedance circuits such as oscillator grid circuits, resistance coupled amplifiers, and AVC networks.

To illustrate the advantages of the VTVM, assume that a resistance coupled audio amplifier with a 500 KΩ plate load resistor is operating from a 100 volt plate source. See Figure 3.

The plate voltage is 50 volts, therefore, the tube acts as a 500 KΩ resistor. When measuring the plate voltage with a conventional 1000 ohms-per-volt meter on the 100 volt scale the meter represents a 100 KΩ resistor placed in parallel with the tube. See Figure 3A. The voltage on the plate would then be about 14 volts as shown on the meter. This large amount of error is caused by the shunt resistance of the meter. Using the VTVM on any scale, the full 11 megohms input resistance is placed in parallel with the tube. See Figure 3B. The voltage on the plate is then about 49 volts or 2% lower than the normal operating voltage. Thus, more accurate readings can be obtained only with the high resistance provided by an electronic voltmeter.

To measure +DC voltages, connect the common (black) test lead to the "cold" (common) side of the voltage. In transformer operated equipment, common is usually the chassis.

Set the Range switch to the range which will handle the voltage to be measured. If the voltage is unknown, set the Range switch to the 1500 volt range. Touch the test probe (DC position) to the voltage point. If the meter does not read in the upper 2/3 of the meter scale, reduce the setting of the Range switch. A meter reading in the upper portion of the meter scale is usually the most accurate. To measure -DC voltages place the Function Switch to the DC- position and repeat the above steps.

The voltage ranges provided by the VTVM were selected for the greatest ease in reading and for convenience in making voltage measurements. The 1.5 V, 5 V, and the 15 V ranges will be very handy for bias and filament voltage measurements. The 50 V and 150 V ranges will be handy, and used most often, when checking AC-DC type equipment. The 500 V range will be used most when measuring B+ voltages in transformer operated equipment.

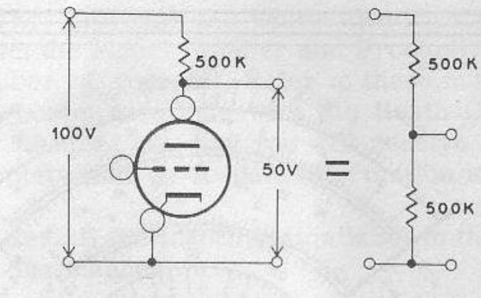


Figure 3

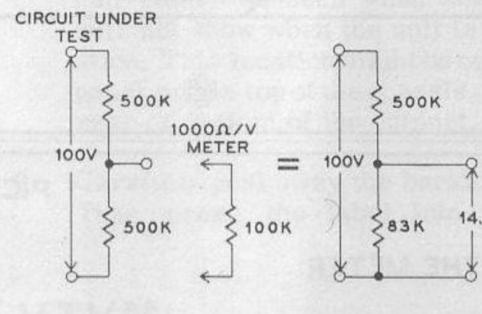


Figure 3A

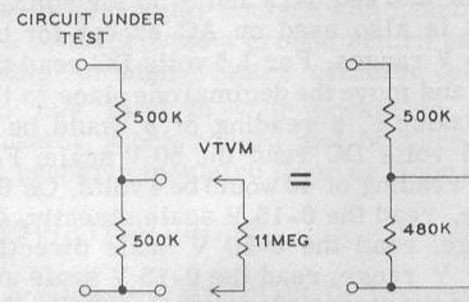


Figure 3B

AC VOLTAGE MEASUREMENTS

WARNING: When your power line outlet is the 3-wire, polarized type, DO NOT use the common (negative) lead of this VTVM to measure power line voltages. To do so may short circuit the power line through the common lead, the chassis, and the green line cord wire.

Power Line Measurements

1. Set the Function switch to AC, the range switch to 150 V, and the meter probe to AC.

2. Move the meter common lead out of the way, as it will not be used.

3. Touch the meter probe to one side of the power line. If there is no indication on the meter, you have selected the common side of the AC line; touch the probe to the other side of the line.

4. To obtain contact to a wall outlet, insert a screwdriver blade into one of the outlet openings and touch the probe to the exposed part of the screwdriver blade. Try both outlet openings. BE CAREFUL.

5. If you have occasion to measure a 240 volt outlet, such as for an electric range or dryer, you will get voltage readings with the probe at two of the three openings. Add these readings together.

Other AC Voltage Measurements

To measure AC voltage with the VTVM, connect the common (black) lead to the common or "cold" side of the voltage to be measured. Set the Function switch to AC and set the Range switch to a range greater than the voltage to be measured, if known. If unknown, set it to 1500 V. With the test probe in the AC position, touch the point in the circuit at which the voltage is to be measured. If the meter moves less than 1/3 of full scale, switch to the next lower range. The maximum AC voltage that can be safely measured with your VTVM is 1500 volts, and this limit must not be exceeded. The meter scale of the VTVM is calibrated in rms.

AC voltage readings are obtained by rectifying the AC voltage and applying the resulting DC voltage to the VTVM circuitry. The rectifier circuit is a half-wave doubler and the DC output is proportional to the peak-to-peak value of the applied AC.

For sine wave voltages, the rms value is .35 times the peak-to-peak value. For complex waveforms this ratio does not necessarily hold true, and may vary from practically zero for thin spikes to .5 for square waves. See Figure 4.

For sine wave voltages over 5 volts, the rms value is read on the same scale as a DC voltage. When using the 1.5 volt and 5 volt ranges, the 1.5 and 5 volt AC scales should be read.

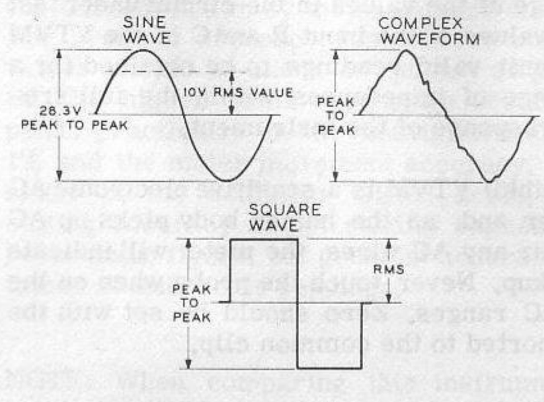


Figure 4

When connecting the VTVM to the circuit under test, the VTVM input resistance R and input capacitance C are effectively placed in parallel with the voltage source. This may change the actual voltage to be measured through loading.

At low frequencies, such as the power line frequencies of 50 or 60 cps, the effects of capacitance loading may usually be disregarded and thus the loading by the VTVM may be considered the same as connecting a 1 megohm resistor across the voltage source.

At higher frequencies, the capacitor reactance decreases. At 10 kc for example, it is approximately 170 KΩ. Such a value may seriously affect the voltage at the point of measurement.

The loading effect of both input capacitance and resistance depends on the source impedance. In low impedance circuits, such as 50 to 600 Ω, no noticeable error is introduced in the voltage reading through circuit loading. Then the specified frequency response of the VTVM becomes the limiting factor.

As a general rule, it should be kept in mind that frequency response and loading may affect the accuracy of the voltage reading obtained. Consider the resistive loading of 1 megohm regardless of frequency, and the capacitive loading effect at the frequency involved. The actual capacitance of the instrument and the leads may also affect the tuning of low capacitance resonant circuits.

Knowledge of the values in the circuit under test and the values of the input R and C of the VTVM will permit valid readings to be obtained for a wide range of impedances within the full frequency response of the instrument.

The Heathkit VTVM is a sensitive electronic AC voltmeter and, as the human body picks up AC when near any AC wires, the meter will indicate this pickup. Never touch the probe when on the lower AC ranges. Zero should be set with the probe shorted to the common clip.

RESISTANCE MEASUREMENTS

To measure resistance with the VTVM, connect the common (black) lead to one side of the resistor or circuit to be measured. Set the Function switch to OHMS and set the Range switch to such a range that the reading will fall as near mid-scale as possible. Set the OHMS ADJ control so the meter indicates exactly full scale (infinity on ohms scale) with the test lead (AC position) not connected to a resistor or circuit. Then touch the test prod to the other side of the resistor or circuit to be measured. Read resistance on OHMS scale and multiply by the proper factor as shown on the Range switch settings.

NOTE: Although a battery is used to measure resistance, the indication is obtained through the electronic meter circuit and therefore the VTVM must be connected to the AC power line and turned on. Establish the habit of never leaving the instrument set in the OHMS position as this could greatly shorten the life of the ohmmeter battery, particularly if the test leads are accidentally shorted together when lying on the service bench.

DECIBEL SCALE

The human ear does not respond to the volume of sound in proportion to voltage or power level, therefore, a unit of measure called the "bel" was adopted. The "bel" is more nearly equivalent to human hearing ratios. Normally the reading is given in 1/10 of a "bel" or a "decibel" (db). Different reference points for "0 db" have been adopted for various purposes. The trend in recent years is to use 1 milliwatt in a 600 Ω load as the 0 db reference, particularly for audio work. This is equal to .774 volt.

On the VTVM, the meter pointer position that corresponds to 0 db is 7.74 on the 0-15 scale. Due to the special calibration used on the 1.5 V and 5 V AC scales, slight inaccuracies will be introduced into the db reading when making decibel measurements with the Range switch in the 1.5 V and 5 V positions.

The resistance values of the voltage divider were chosen so that each progressive setting of the Range switch represents a change of 10 db. For example, if the signal voltage at the input of an amplifier read 0 db in the 1.5 volt position and the output voltage read 0 db in the 15 volt position it would indicate that the amplifier has a gain of 20 db.

Since the decibel is a current, voltage, or power ratio, it may be used as such without specifying the reference level. A fidelity curve may be run on an amplifier by feeding in a signal of variable frequency but constant amplitude. At a reference frequency of 400 cps adjust the input voltage for a convenient indication, 0 db for instance, on the VTVM connected to the output. As the input frequency is varied, the output variation may be noted directly in db above and below the specified reference level.

ACCURACY

The accuracy of the meter movement is within 2% of full scale which means that on the 1500 V range, for instance, the accuracy of the movement will be within 30 volts at any point on the scale. On DC, the accuracy of the multipliers, 1%, may be additive, resulting in an accuracy of within 3% of full scale.

On AC, the accuracy of the rectifier circuit contributes variations which result in an accuracy of within 5% of full scale.

The accuracy on the OHMS range depends on the meter accuracy, the ohms multiplier accuracy (including the internal resistance of the battery) and the stability of the battery voltage. On the RX1 scale, the internal resistance of the battery and the battery voltage both vary as a result of the current drawn by the resistance under test. For greatest accuracy, tests on low resistance values should be made as quickly as possible. On the higher ohms range, the accuracy depends practically on the multipliers which are 1% and the meter movement accuracy, 2%. Because of the nonlinear OHMS scale, the resulting accuracy is not readily expressed in a percentage figure, but greatest accuracy is obtained at mid-scale readings.

NOTE: When comparing this instrument with another VTVM, consider that the accuracy of the other instrument may deviate in the opposite direction. Therefore, when comparing two instruments of 5% accuracy, the total difference may be 10%. Critical comparisons should only be made against certified laboratory standards.

IN CASE OF DIFFICULTY

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the constructor.

2. It is interesting to note that about 90% of the kits that are returned for repair do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure that they are soldered as described in the Proper Soldering Techniques section of this manual.

3. Make sure the tubes light up properly.

4. Check the tubes with a tube tester or by substitution of tubes known to be good.

5. Check the values of the parts. Be sure that the proper part has been wired into the circuit, as shown in the pictorial diagrams and as called out in the wiring instructions.

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

7. If, after careful checks, the trouble is still not located and a voltmeter is available, check voltage readings against those shown on the Schematic Diagram. NOTE: All voltage readings were taken with an 11 megohm input vacuum tube voltmeter. Voltages may vary as much as 10%.

8. A review of the Circuit Description will prove helpful in indicating where to look for trouble.

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

Troubleshooting Chart

DIFFICULTY	POSSIBLE CAUSE
Completely inoperative.	1. Make sure that power is being applied to the instrument. This may be measured across the primary winding of the power transformer. Be SURE to connect together the common side of the circuits of the measuring meter, the measured meter and the power line. 2. The tube filaments do not light. Check voltage between the yellow leads of power transformer (5-6 volts AC). 3. Check the voltage between each end of the electrolytic capacitor and ground. Correct voltages are shown on the Schematic. 4. Check the 12AU7 tube.
Inability to obtain DC balance. (Changes zero indication when switching from DC+ to DC-.)	1. Check the 12AU7 tube for an unbalanced condition (substitution). 2. Check the 10 megohm resistor, R16 (brown-black-blue). 3. Check the two .005 μfd capacitors, C4 and C5, in the grid circuits of the 12AU7 tube (Pins 2 and 7). 4. Check the components in the cathode circuits of the 12AU7 tube (Pins 3 and 8). These circuits include the ZERO ADJ control (R33) R31, R32, and R34. 5. Check the Range switch assembly carefully.
AC inoperative.	1. Check the 6AL5 tube. 2. Check C1, .047 μfd 1600 volt, and the two .05 μfd capacitors, C2 and C3. 3. Check the Function switch assembly carefully.
AC balance.	1. Disconnect the test leads from the instrument before adjusting the AC Balance control as directed earlier in the manual. It is imperative that DC balance be obtained before this adjustment is made.
Inaccurate AC readings. (The inability to obtain AC calibration.)	1. Check capacitors C2, C3, and C6. 2. Check the 6AL5 tube. 3. Check the AC Calibrate control, R14. NOTE: With the test lead plug inserted, there may be a residual reading. This is due to stray AC pickup in the test leads. 4. Check the Range switch for proper assembly.

DIFFICULTY	POSSIBLE CAUSE
Inaccurate DC readings.	1. Check the DC Calibrate control, R15. 2. Check the resistor in the test probe. Make sure that it is not being grounded. 3. Check the Range switch for proper assembly.
Ohms inoperative.	1. Check the OHMS ADJ control, R13 for the correct value. 2. Check the Range switch for proper assembly.
Ohms inaccurate.	1. Check the battery (substitution). 2. Check the value of all resistors on the Range switch which have a value beginning with the number "9". (The 9.1 Ω resistor, R30, should receive special attention.) NOTE: The ohms section of the VTVM is not intended for use as a standard. Where a great degree of accuracy is required, a bridge should be used.

MAINTENANCE

METER

Because of the delicate nature of the meter movement, no attempt should be made to repair the meter. Such attempts would automatically void the standard warranty coverage of the meter itself.

ELECTROSTATIC CHARGE

The polystyrene meter cover has been treated to resist an accumulation of static electricity. However, should a static charge accumulate through repeated polishing or cleaning of the meter cover, the pointer will deflect in an erratic manner, regardless of whether the instrument is turned off or on. This condition can be corrected quickly. Apply a small quantity of liquid dishwashing detergent to a clean, soft cloth and wipe the surface of the meter cover. The accumulated electrostatic charge will immediately disappear. It is not necessary to remove the cover for this correction.

CHECKING METER COIL CONTINUITY

ALWAYS use a resistor of at least 10 KΩ in series with the meter movement and the ohmmeter test leads when checking for meter coil continuity. If this resistor is not used to reduce the current, the meter movement will probably be seriously damaged.

TEST LEADS

Because of their constant flexing during use, the test leads are not above suspicion, especially when the VTVM has been in use for several years. Erratic or improper DC voltage measurements can sometimes be caused by a fault in the shielded test lead or in the connection of the 1 megohm isolating resistor used in the test probe.

ACCESSORY PROBES

HIGH VOLTAGE TEST PROBE

A high voltage test probe is available from the Heath Company. This probe will permit VTVM DC measurements up to 30,000 volts, which covers the range of flyback power supply voltages commonly encountered in TV receivers. This probe consists of a red molded housing with a black molded handle. It contains a 2% precision 1090 megohm resistor and provides a DC range multiplication factor of 100 for 11 megohm input VTVMs.

RF TEST PROBE

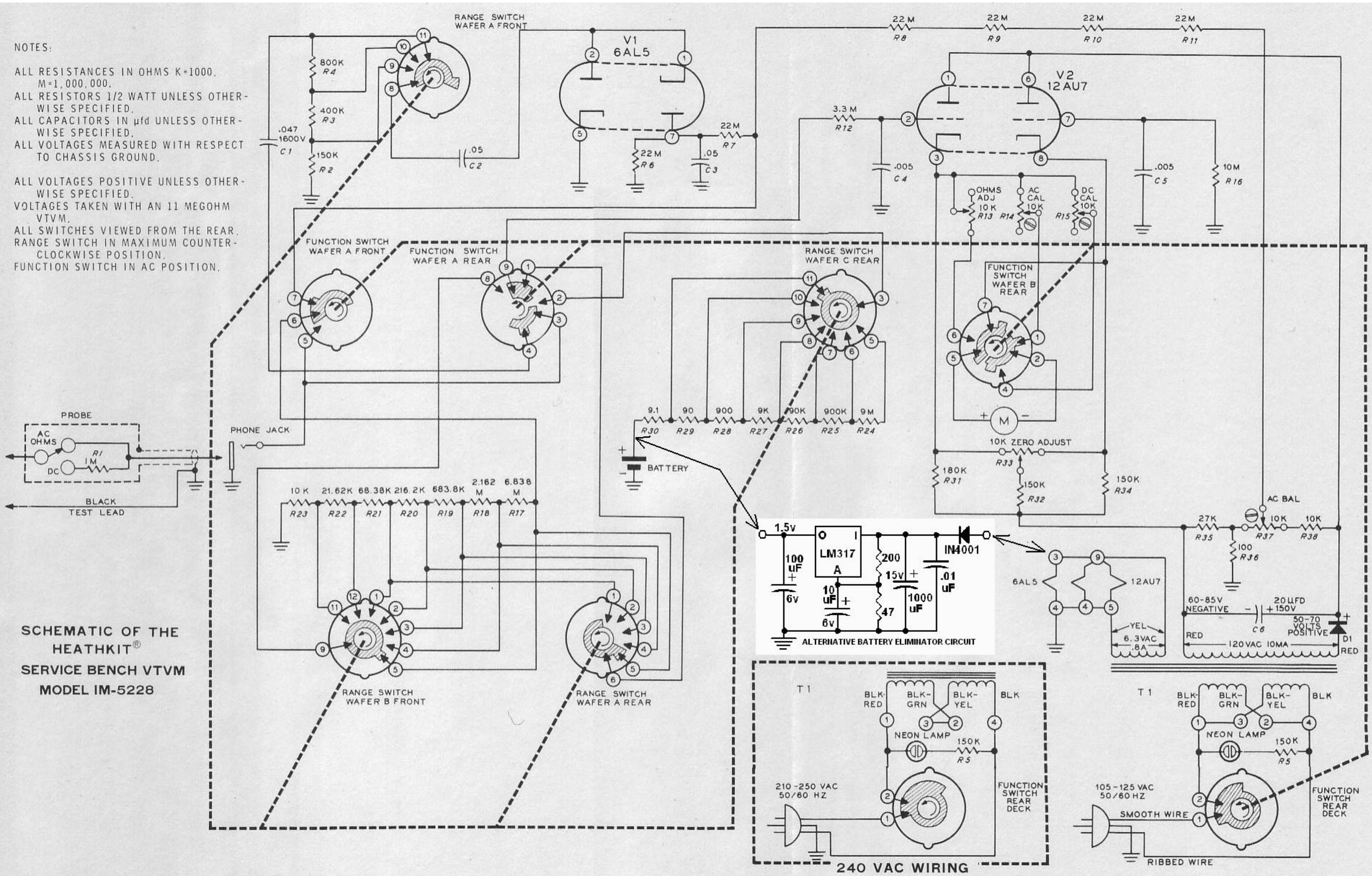
An RF test probe is available from the Heath Company. This probe will permit VTVM usage for RF measurements up to 30 volts; its response is substantially flat from 1000 cps to 100 mc. A built-in isolating capacitor permits a DC voltage range of up to 500 volts. It uses a printed circuit board for easy assembly and its housing is of polished aluminum with polystyrene insulation.

SCHEMATIC OF THE HEATHKIT® SERVICE BENCH VTVM MODEL IM-5228

NOTES:

ALL RESISTANCES IN OHMS K=1000, M=1,000,000.
ALL RESISTORS 1/2 WATT UNLESS OTHERWISE SPECIFIED.
ALL CAPACITORS IN µfd UNLESS OTHERWISE SPECIFIED.
ALL VOLTAGES MEASURED WITH RESPECT TO CHASSIS GROUND.

ALL VOLTAGES POSITIVE UNLESS OTHERWISE SPECIFIED.
VOLTAGES TAKEN WITH AN 11 MEGOHM VTVM.
ALL SWITCHES VIEWED FROM THE REAR.
RANGE SWITCH IN MAXIMUM COUNTER-CLOCKWISE POSITION.
FUNCTION SWITCH IN AC POSITION.



NOTES:

ALL RESISTANCES IN OHMS K=1000, M=1,000,000.
ALL RESISTORS 1/2 WATT UNLESS OTHERWISE SPECIFIED.
ALL CAPACITORS IN μfd UNLESS OTHERWISE SPECIFIED.
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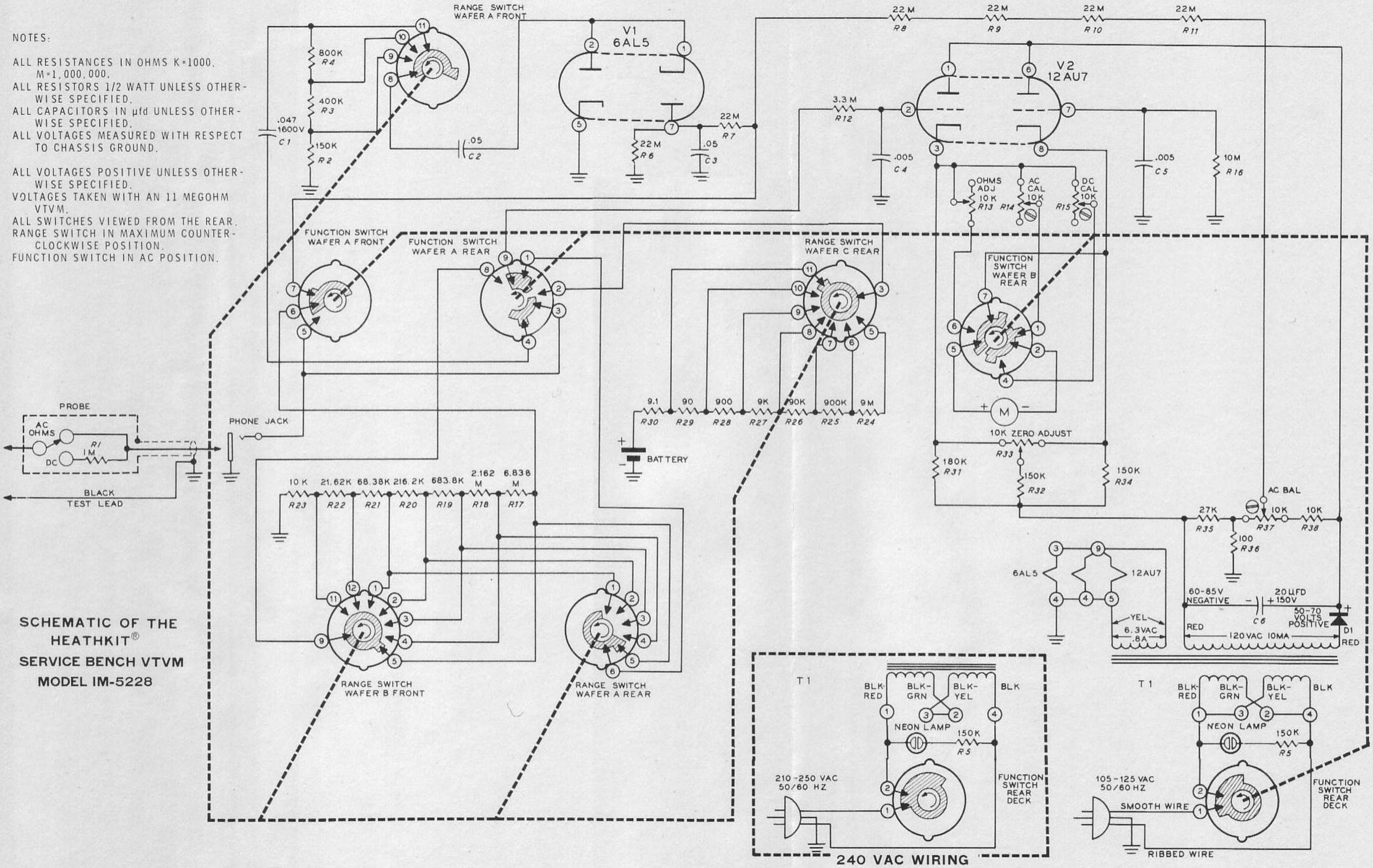

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