ASSEMBLING AND USING YOUR

Heathkit

Vacuum Tube Voltmeter
Model V-5A

THE HEATH COMPANY
BENTON HARBOR, MICH.

595-2

PRICE $1.00

HEATHKIT VTVM • • • • MODEL V-5A

SPECIFICATIONS

Power Requirements:	105-125V 50/60 Cycle AC, 10 Watts.
Cabinet Size:	7 3/8" high x 4 11/16" wide x 4 1/8" deep.
Kit Shipping Weight:	5 pounds
Meter:	$4\frac{1}{2}$" Streamlined case with 200 microampere movement.
Multipliers:	Precision type.
Tubes:	1 - 6H6 Twin triode meter bridge. 1 - 7A6 Twin diode AC rectifier.
Power Supply:	Power transformer and selenium rectifier.
Battery:	$1\frac{1}{2}$ Volt flashlight cell.
D. C. Voltmeter: 6 Ranges:	0-3, 10, 30, 100, 300, 1,000 volts full scale. With accessory probe to 30,000 Volts.
Input Resistance:	11 megohms (1 megohm in probe) on all ranges. 1,100 megohms with accessory probe.
Sensitivity:	3,666,666 ohms per volt on 3 Volt range.
Circuit:	Balanced bridge (push-pull) using twin triode.
Electronic AC Voltmeter: 6 Ranges:	0-3, 10, 30, 100, 300, 1,000 Volts full scale on linear scales reading R. M. S. (.707 of positive peak).
Circuit:	Diode with adjustable compensation.
Electronic Ohmmeter: 6 Ranges:	Scale with 10 ohms center x1, x10, x100, x1,000, x10K, x1 Meg. Measures .1 ohm to 1,000 megohms with internal battery.

Fig. 12

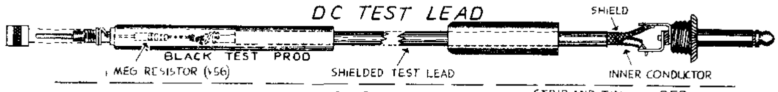


Fig. 13

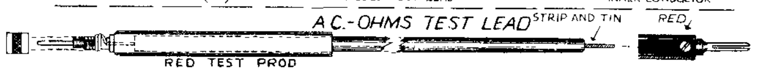


Fig. 14

(*) DC test lead. The DC test lead is made by connecting the phone plug (V41) on one end of the shielded test lead (V47). On the other end goes a small 1 megohm resistor (V56), which is then slipped inside the black test prod. See Figure 13.

(*) AC-Ohms test lead. The AC-Ohms test lead is made by connecting the red banana plug (V40) on one end of the red test lead (V46), and the red test prod (V42) on the other. Figure 14 shows the construction.

(*) Fasten the handle (O79) on the case (V112) using two 10-24 screws (O30).

(*) Push the rubber feet (O34) into the four holes in the bottom of the case. (See Figure 15.)

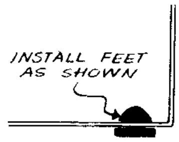


Fig. 15

(*) Slide the acorn knobs (V48) over the shafts of the zero adjust and ohms adjust controls and tighten down the small set screw in each.

(*) Turn both switches maximum counterclockwise and slide the two pointer knobs (O51) over the shafts and tighten down the small set screw while the pointer knobs are indexed properly (ie pointing correctly).

(*) Plug the 6H6 in socket E and the 12AU7 in socket A. (See warning below)

This completes the wiring of the kit and the instrument is now ready to test and calibrate.

IMPORTANT WARNING

Miniature tubes can be easily damaged when plugging them into their sockets. Therefore, use extreme care when installing them. WE DO NOT GUARANTEE OR REPLACE MINIATURE TUBES BROKEN DURING INSTALLATION.

TEST AND CALIBRATION

Check over the wiring carefully. We suggest tracing over each wire on the pictorial with a colored pencil as it is checked on the instrument. Check each solder connection. Install the tubes.

Plug the instrument into a 117 Volt 50/60 Cycle AC ONLY outlet. This instrument will not operate, and serious damage will result, if plugged into a DC outlet.

Turn the switch on and allow a minute for warm up. Set the selector switch to DC+. Check operation of zero adjust control. Turning this control should move the meter pointer to about half or ¾ scale and to zero. Set pointer to zero and check if it remains on zero when switched to DC-. If there is appreciable zero shift (more than one or 2 divisions on the scale) the tubes must be aged. First complete the initial test, however.

Turn the instrument off and make sure the mechanical zero of the meter is correct. If not, adjust as follows: Place the instrument in normal operating position. (This usually is with the rubber feet on a level surface.) Turn the black 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.

Insert the common and DC test leads. Set the selector switch to DC+ and the range switch to 3V. Connect the test leads to the calibrated flashlight cell, and adjust the DC calibrate control (See Figure 16) so the meter pointer indicates the calibration voltage on the 3V scale. The reading will be close to that shown in figure 17, ie. 30 on the 3V range means full scale is actually 3V. Therefore, 15.5 for example, is a voltage of 1.55 volts.

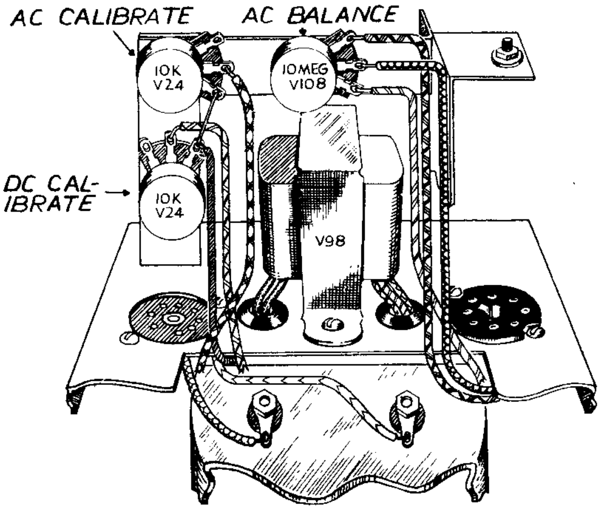


Fig. 16

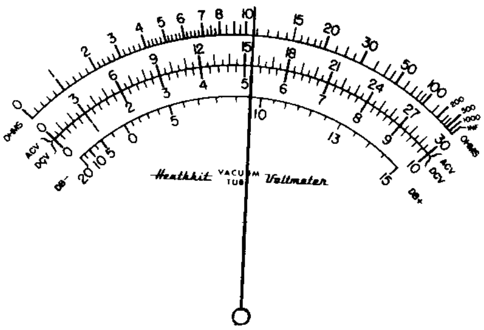


Fig. 17

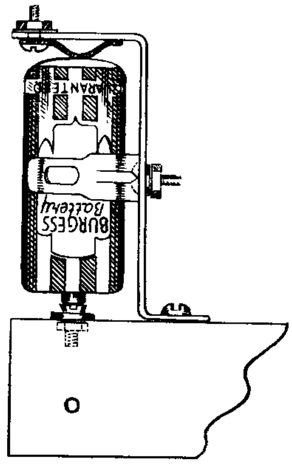


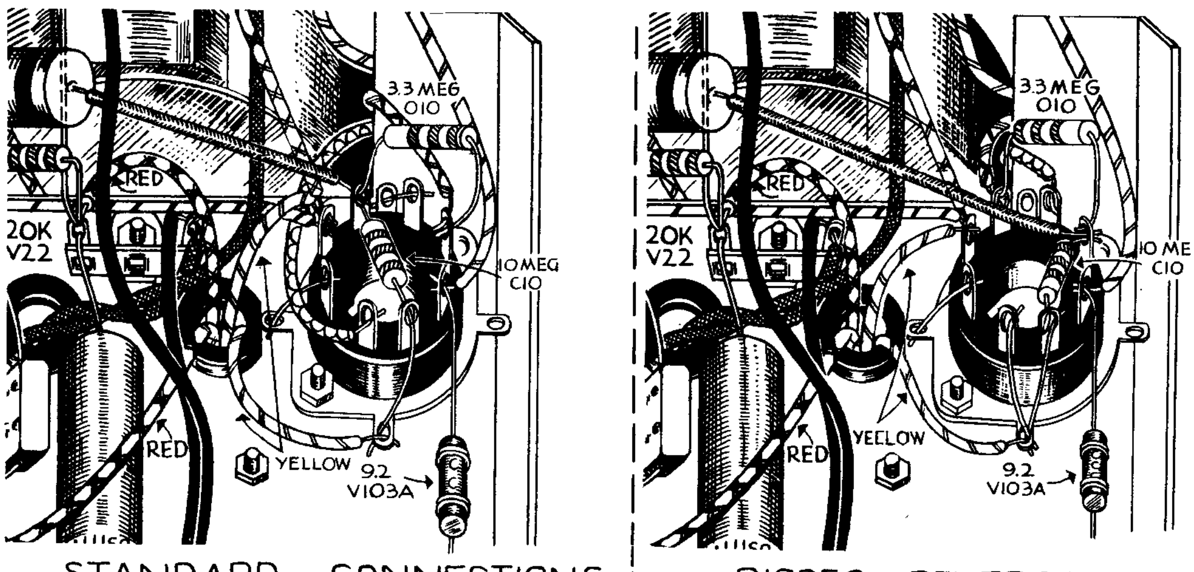
Fig. 18

Install the battery in the battery bracket as shown. Now place the instrument in the case, but leave off the rear cover. Set selector switch to ohms. Pointer should swing to about full scale. Turn ohms adjust to give full scale reading (INFinite). Insert AC ohms test lead. Touch this lead to common lead and observe pointer dropping to zero indicating short circuit (no resistance).

Temporarily remove AC-ohms test lead. Set range switch to 3V, and selector to AC. Adjust AC balance control so no movement is noticed in the pointer when switching from AC through DC- to DC+. Now set range switch to 300V. Re-insert AC ohms lead. Connect AC ohms and common lead to the 117V AC line (NOTE: 117 Volt line is dangerous—proceed with due care) and adjust AC calibrate control so pointer indicates the line voltage.

It is recommended that the tubes be aged before final calibration. This is accomplished 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, preferably at a voltage near full scale indication on the VTVM, as for instance 250 Volt or 90 Volt (on the 300V or 100V scale respectively).

If, after a period of about 72 hours, the AC balance control cannot keep the pointer from moving when switching from AC through DC- to DC+ (with the range switch at 3V), the diode connections should be reversed. This should be done as shown below.



STANDARD CONNECTIONS DIODES REVERSED

FOLLOW COLOR CODING TO MAKE THE CHANGE

After final calibration, place the rear cover (V111) on the case, and install two sheet metal screws through the back and into the chassis. The instrument is now ready for use.

CIRCUIT DESCRIPTION

This instrument uses a balanced vacuum tube circuit to increase the sensitivity and provide greater flexibility. The relationship between the test voltage applied to the tube and the indicating meter current is linear over a range appreciably greater than the operating range. When a much larger test voltage is accidentally applied, the relationship ceases to be linear and the indicating meter current is limited to a value of a few times full scale current. Thus the meter movement, when used in this circuit, is protected. Repeated overloads should be avoided, however, as the pointer may be bent.

The zero adjust control balances the currents through the tubes and permits the meter to be set to zero, or partly up scale.

The calibration controls are in series with the meter and are adjusted to produce full scale reading with the proper test voltage applied to the instrument. The maximum test voltage applied to the tube is about 3 Volts. Higher test voltages are reduced by a voltage divider with a total resistance of 10 megohms. An additional resistor of 1 megohm is located in the DC test prod, which permits measurements to be made in circuits carrying R.F. with minimum disturbance of such circuits.

For AC voltages in the Audio Frequency range, a shunt fed diode is used to provide a DC voltage proportional to the peak of the applied AC voltage. This DC voltage is applied through the voltage divider to the tube, causing the meter to indicate. The AC calibrate control is used so as to obtain the proper meter deflection for the applied AC voltage. Vacuum tubes develop a contact potential voltage between tube elements. Such contact potential developed in the diode would cause a slight voltage to be present at all times. This voltage is cancelled out by bucking it with a portion of the contact potential of a second diode. The amount of bucking voltage is controlled by the AC balance control. This eliminates zero shift when switching from DC to AC.

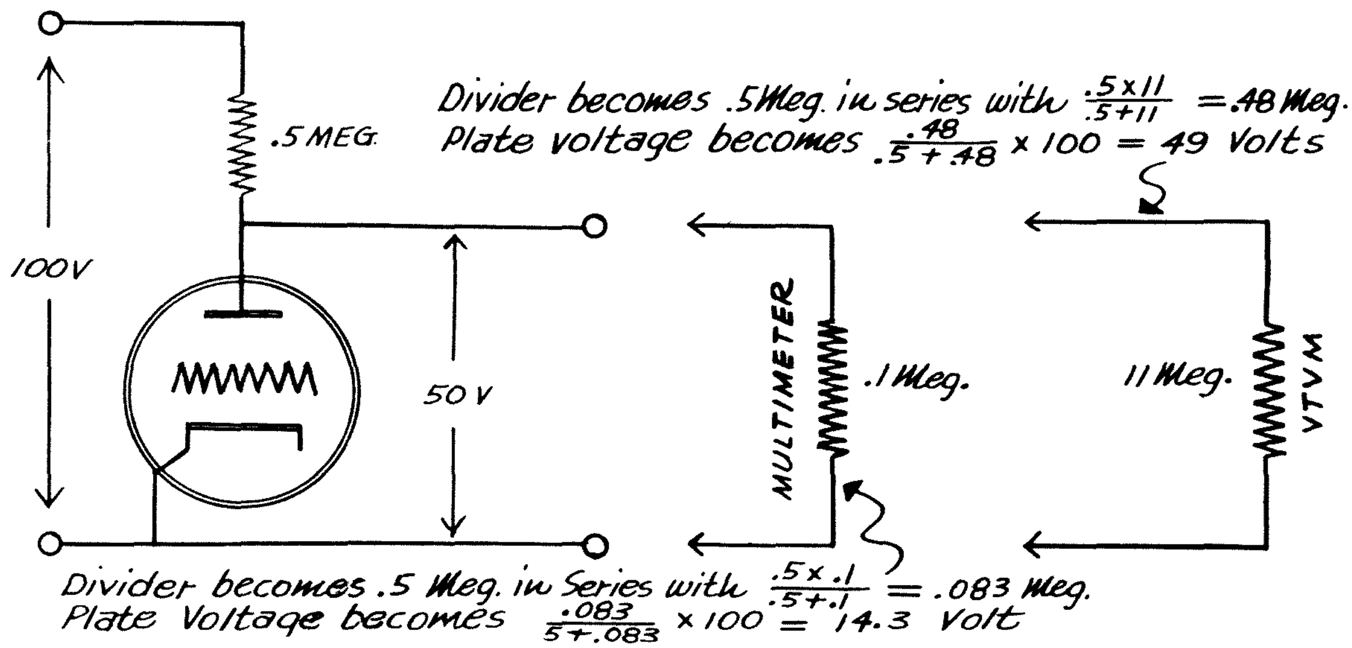
For resistance measurements, a battery is connected through a string of multipliers to the tube. The extermal resistance to be tested is connected between tube and common (chassis), forming, together with the multipliers, a voltage divider across the battery. The resultant portion of the battery voltage is thus applied to the tube causing the meter to deflect. The meter scale is calibrated in resistance.

USING THE VTVM

NOTE: As the heaters are operated at a low temperature, the tube life is extremely long. The power consumption is very low. We therefore recommend that this instrument be turned on at the same time as the soldering iron for instance, and left on until the work is done. This will result in very stable operation, and the slight amount of heat generated inside the cabinet will keep the instrument free from moisture in humid climates.

The VTVM has many advantages over the non-electronic volt-ohmmeters. The greatest advantage is the high input resistance. This enables much more accurate readings to be obtained in high impedance circuits, such as resistance coupled amplifiers, oscillator grid circuits and AVC networks.

To illustrate this, let us assume a resistance coupled audio amplifier with a .5 megohm plate load resistor, operating with a 100 Volt plate supply. Let us also assume that the plate voltage is 50 Volts and that, therefore, the tube acts as a .5 megohm resistor. Measuring the plate voltage with a conventional 1,000 ohm per volt instrument on the 100 Volt scale, the meter can be considered a 100,000 ohm (.1 megohm) resistor in parallel with the tube. The voltage on the plate is then about 14 Volts and is shown as such by the meter. This is due to the shunt resistance of the low resistance meter. Using the VTVM on any scale setting, the full 11 megohms is placed in parallel with the tube. The voltage on the plate is then about 49 Volts or 2% lower than the normal operating voltage. Thus accurate reading can only be obtained with the high resistance provided by a VTVM.



An understanding of the characteristics of your instrument will result in greater satisfaction through proper use.

DC VOLTAGE

To measure DC voltage with the VTVM, connect the common (black) lead to the common or "cold" side of the voltage to be measured. Set the selector switch to DC+ or DC- as required, and set the range switch to a range greater than the voltage to be measured, if known. If unknown, set to 1,000 Volts. With black test prod, touch other or "hot" side of the voltage to be measured. If pointer moves less than one-third of full scale, switch to the next lower range.

AC VOLTAGE

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 selector switch to AC, and set the range switch to a range greater than the voltage to be measured, if known. If unknown, set to 1,000 Volts. With red test prod, touch other or "hot" side of the voltage to be measured. If pointer moves less than one-third of full scale, switch to the next lower range.

The Heathkit is an extremely 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 AC prod when on the lower ranges. Zero should be set with the AC prod shorted to the common clip.

RESISTANCE

To measure resistance with the VTVM, connect the common (black) lead to one side of the resistor to be measured. Set the selector to ohms, and set the range switch to such a range that the reading will fall as near to mid-scale as possible. Set the ohms adjust control so the meter indicates exactly full scale (INF. on ohms scale). Then touch the red test prod to the other side of the resistor to be measured. Read resistance on ohms scale and multiply by the proper factor as shown by the range switch setting.

NOTE: Although batteries are used to measure resistance, the indication is obtained through the electronic meter circuit, and therefore, the instrument must be connected to the AC power line and tuned on.

CAUTION: Never leave the instrument on ohms, as it greatly shortens the life of the ohmmeter battery.

USING THE VTVM DECIBEL SCALE

Because the human ear does not respond to volume of sound in proportion to signal strength, a unit of measure called the "bel" was adopted. The "bel" is more nearly equivalent to human ratios. Normally the reading is given in 1/10 of a "bel" or "decibel."

Various signal levels are adopted by various manufacturers as standard or "O" decibels.

The Heathkit VTVM DB scale uses a standard of 6 milliwatts into a 500 ohm line as "O" decibels. This corresponds to 1.73 VAC on the 0-10 scale. From this figure, the various AC ranges of the VTVM may be converted to db by the following chart

AC VOLTS SCALE	DECIBEL SCALE
0-3V	Subtract 10 db from reading
0-30V.	Add 10 db to the reading
0-100V.	Add 20 db to the reading
0-300V	Add 30 db to the reading
0-1000V	Add 40 db to the reading

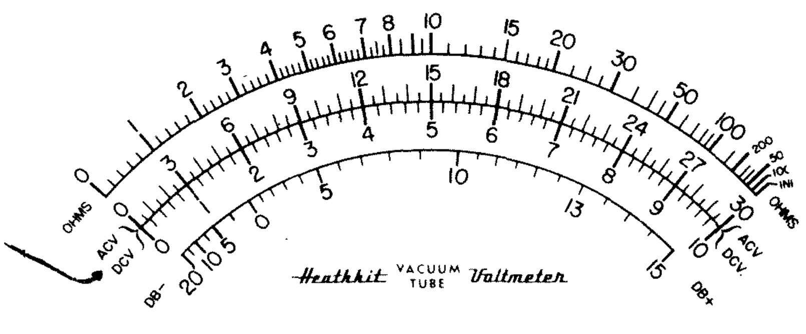
As the decibel is a power ratio or voltage ratio, it may be used as such without specifying the reference level. Thus for instance, a fidelity curve may be run on an amplifier by feeding in a signal of variable frequency but constant amplitude. At a reference frequency of say 400 cycles, adjust input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

NOTE: When measuring complex AC wave shapes, such as ripple, hum, distorted and square waves, the indication is 70% of the positive peak.

READING THE METER SCALE

The voltage markings on the range switch refer to the FULL SCALE reading. The scale is marked 0-10 and 0-30 for voltage. On the 3 Volt range, read the 0-30 scale and drop the zero. On the 10 Volt range, read the 0-10 scale directly. On the 30 Volt range, read the 0-30 scale directly. On the 100 Volt range, read the 0-10 scale and add one zero. On the 300 Volt range, read the 0-30 scale and add one zero. On the 1,000 Volt range, read the 0-10 scale and add two zeros.

NOTE: This marking does not mean that the upper scale indicates ACV and the lower scale DCV. Rather, it means that either scale will read ACV or DCV, depending on the setting of the selector switch.



The resistance marking or ohms scale refers to the lowest resistance range (Rx1). For the other ranges, add the proper number of zeros (add two zeros for Rx100, add four zeros for Rx10K, add six zeros for Rx1 Meg). On the Rx1 Meg range, the scale can also be considered to read directly in megohms.

ACCURACY

The accuracy of the meter movement is within 2% of full scale, which means that, for instance on the 1000 Volt range the accuracy of the movement will be within 20 Volts at any point on the scale. On DC, the accuracy of the multiplier (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 accuracy of within 5% of full scale.

The accuracy on the ohms ranges depends on the meter accuracy, the ohms multiplier accuracy (including the internal resistance of the batteries), and the stability of the battery voltage. On the Rx1 scale, the internal resistance of the batteries and the battery voltage both vary as 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 ranges, the accuracy depends practically on the multipliers, which are 1%, and the meter movement accuracy. Because of the non-linear ohms scale, the resulting accuracy is not readily expressed in a percentage figure, but the greatest accuracy is obtained at mid-scale readings.

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

IN CASE OF DIFFICULTY

1. Recheck the wiring. Most cases of trouble result from wrong or reversed connections. Often having a friend check the wiring will reveal a mistake consistently overlooked.

2. Check the tubes.

   The possibility exists that a perfectly balanced tube will not permit Zero center adjustment on either DC+ or DC-. Then add 1000 ohms or more in series with either 12AU7 cathodes and the Zero adjust control.

3. If the pointer swings full scale to the right and stays there with switch set to DC+, check for an open circuit or high resistance connection somewhere between the grid pin #2 of the 12AU7 and ground. This might be due to a wrong connection to the selector switches, a poor connection, or possibly an open resistor.

   If the instrument does not operate on any function, a check of the power supply, and the 12AU7 and its associated meter circuit is suggested.

   If the instrument only fails to function on AC measurements, then a check of the 6H6 and its associated circuits should be made.

   If the instrument only fails to function on ohms, the difficulty will probably be due to the battery (make certain the battery is making good contact in the bracket) or the ohms multipliers.

   Proper operation on DC should first be secured before an attempt is made to use the instrument on AC or ohms.

4. Check the operating voltages. The following voltages are measured to chassis: Pin #1 or #6 on 12AU7 tube or + lug on rectifier 40-70 Volts positive. Negative lug on rectifier 60-100V negative. Pin 2 of 6H6 and pin 9 of 12AU7, 5-6V AC.

5. Check continuity through the DC test cable. Make certain that the shielding is not shorted to center conductor.

SERVICE

In event continued operational difficulties of the completed instrument are experienced, may we remind you that the Heath Company has provided a technical consultation service. Every effort will be made to assist you through correspondence. We emphasize that in all correspondence this instrument should be referred to as the Model V-5A VACUUM TUBE VOLTMETER.

The facilities of the Heath Company Service Department are also available. Your instrument may be returned for inspection, repair, and calibration for a service charge of $ 3.00 plus the cost of any additional material that may be required. This service policy applies only to completed instruments constructed in accordance with the instructions as stated in the manual. Instruments that are not completed or instruments that are modified will not be accepted for repair. Instruments showing evidence of acid core solder or paste fluxes will be returned not repaired.

The Heath Company is willing to offer its utmost cooperation to assist you in obtaining proper operation of your instrument. The repair service is available until one year from the date of purchase.

NOTE: Before returning this unit, be sure all parts are securely mounted. Attach a tag to the instrument giving name, address and trouble experienced. Pack in a rugged container, preferably wood, using at least three inches of shredded newspaper or excelsior on all sides. Do not ship in original carton only as this carton is not considered adequate for safe shipment of the completed instrument. Ship by prepaid express, if possible. Return shipment will be made by express collect. Note that a carrier cannot be held liable for damage in transit if packing, in his opinion, is insufficient.

Prices are subject to change without notice. The Heath Company reserves the right to change the design without incurring liability for equipment previously supplied.

BIBLIOGRAPHY

Many excellent articles on the construction and use of vacuum tube voltmeters have appeared in radio magazines. A few are:

RADIOCRAFT, June, 1945, Electronic Ohmnichecker
RADIO NEWS, January, 1947, Home Constructed VTVM
RADIO NEWS, July, 1946, Vacuum Tube Voltmeter
RADIO NEWS, November, 1945, Electronic Volt-ohmmeter
RADIO NEWS, February, 1946, Universal Test Instrument
RADIOCRAFT, May, 1945, Practical VTVM
VACUUM TUBE VOLTMETERS, A Book by John F. Rider

RF TEST PROBE KIT

A test probe in kit form for use in measuring RF voltages of up to about 20 Volts is available for $5.50. The kit contains all parts necessary for the construction of the probe, including 1N34 crystal detector, condensers, resistor, cable and connectors. This probe and cable is simply plugged into the instrument in place of the regular DC test probe assembly and the voltage is read on the lower regular DC ranges.

Order No. 309 RF Test Probe Kit—$5.50

TELEVISION TEST PROBE KIT

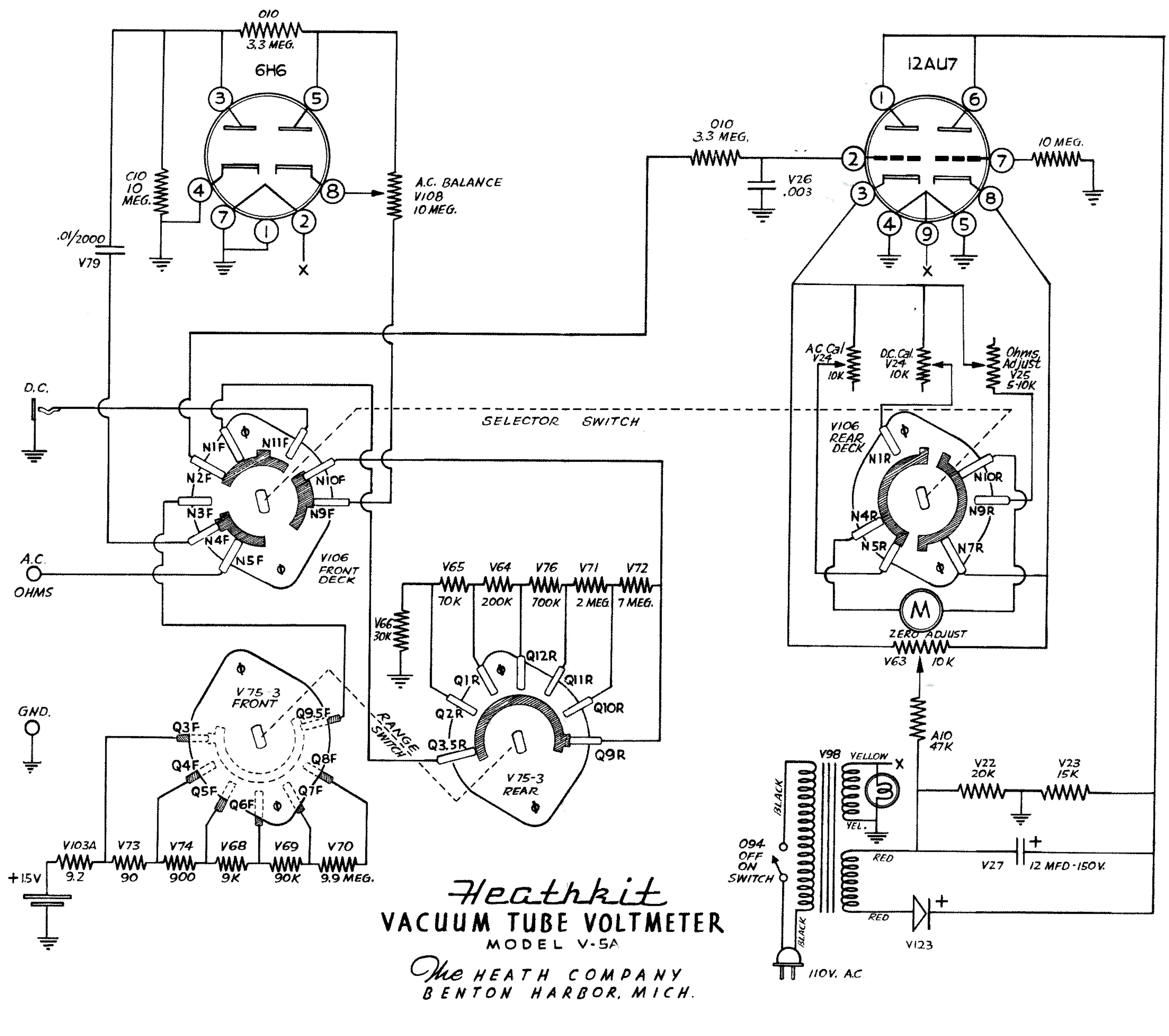
A 30,000 volt test probe in kit form for use in testing the high DC voltage in Television receivers is available for $5.50. The kit contains all parts necessary for the construction of the probe, such as the precision multiplier of 2% accuracy, the molded red and black body and handle, the connectors and the cable. This probe and cable is simply plugged into the instrument in place of the regular DC test probe and with the range switch set at 300 volt, 0 - 30,000 volts is read on the 0 - 30 scale. With range switch set a 100 volt or 30 volt, the instrument reads 0 - 10,000 volts on the 0 - 10 scale and 0 - 3,000 volts on the 0 - 30 scale.

Order No. 336 TV High Voltage Probe Kit—$5.50

V-5A VACUUM TUBE VOLTMETER PARTS LIST

Part No.	Parts Per Kit	Description
Resistors		
V103A	1	9.2 Ohm Precision
V73	1	90 Ohm Precision
V74	1	900 Ohm Precision
V68	1	9K Ohm Precision
V66	1	30K Ohm Precision
V65	1	70K Ohm Precision
V69	1	90K Ohm Precision
V64	1	200K Ohm Precision
V76	1	700K Ohm Precision
V71	1	2 Megohm Precision
V72	1	7 Megohm Precision
V70	1	9.9 Megohm Precision
V23	1	15K
V22	1	20K
A10	1	47K
V56	1	1 Megohm
O10	2	3.3 Megohm
C10	2	10 Megohm
Condensers		
V26	1	.003 MFD
V79	1	.01 MFD 2,000 Volt
V27	1	12 MFD 150 Volt
Controls		
V24	2	10K Ohms (AC & DC calibrate)
V25	2	10K Ohms (Ohms & Zero Adjust)
V108	1	10 Megohm (AC balance)
Switches		
V106	1	Selector
V75-3	1	Range
O94	1	SPST Slide
Sockets--Terminal Strips--Jacks--Fiber Washers		
V113	1	Miniature Socket (9 pin)
V122	1	Octal Sockett
O52	1	Pilot Light Socket
O40	1	Pilot Light Nut
O41	1	Pilot Light Bushing
O42	1	Pilot Light Jewel
S32	1	2 Lug Terminal Strip
V77R	1	Banana Jack (red)
V77B	1	Banana Jack (black)
M28	2	Banana Jack Inserts
K17	1	Phone Jack
BE22	1	¼ Fiber Sholder Washer #8
O27	1	9/64 Plain Fiber Washer
Tubes--Lamp		
V31	1	6H6 Tube
V121	1	12AU7 Tube
O39	1	#47 Pilot Lamp

Part No.	Parts Per Kit	Description
Hardware		
G31	2	4-40 x ¼ Screws
MT12	2	4-40 Nuts
SW34	2	3-48 x ¼ Screws
SW35	2	3-48 Nuts
O31	10	6-32 x 3/8 Screws
K43	1	6-32 x ½ Flat Head Screws
O102	2	#6 x 3/8 Sheet Metal Screws
O30	2	10-24 x 3/8 Handle Screws
S22	10	6-32 Nuts
O33	8	Control Nuts
TS72	11	#6 Lockwashers
O101	8	Control Lockwashers
O28	5	Control Nickel Washers
O44	2	Speednuts for Jacks
O37	2	Solder Lugs
O35	3	3/8 Grommets
O34	4	Rubber Feet
V114	1	Battery Spring Clamp
V117	1	Control Mtg. L Bracket (Long)
V118	1	Control Mtg. L Bracket (Short)
V119	1	Battery Mtg. Z Angle Bracket
Wire--Plugs--Prods--Clips		
O77	1	Roll Hookup Wire
O81	1	Length Spaghetti
V46	1	Length Red Test Lead 3 Ft.
V45	1	Length Black Test Lead 3 Ft.
V47	1	Length Shielded Test Lead 3 Ft.
O78	1	Line Cord
V40	1	Red Banana Plug
V39	1	Black Banana Plug
V41	1	Phone Plug
V42	1	Red Test Prod
V43	1	Black Test Prod
V44	1	Alligator Clip
V124	1	Battery Base Clip
Miscellaneous		
V48	2	Acorn Knobs
O51	2	Pointer Knobs
V49C	1	200 Microamp. Meter
M39	1	Flashlight Cell (Calibrated)
V123	1	Selenium Rectifier
V98	1	Power Transformer
V116	1	Chassis
O79	1	Handle
V110	1	Front Panel
V111	1	Rear Cover
V112	1	Case



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VACUUM TUBE VOLTMETER

MODEL V-5A

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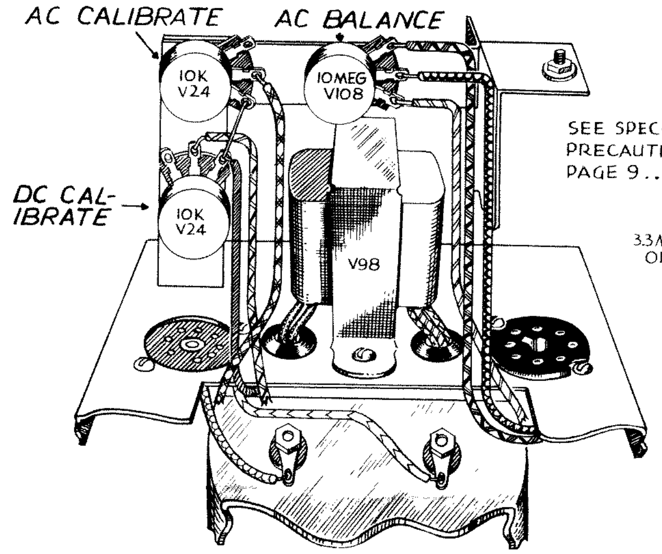

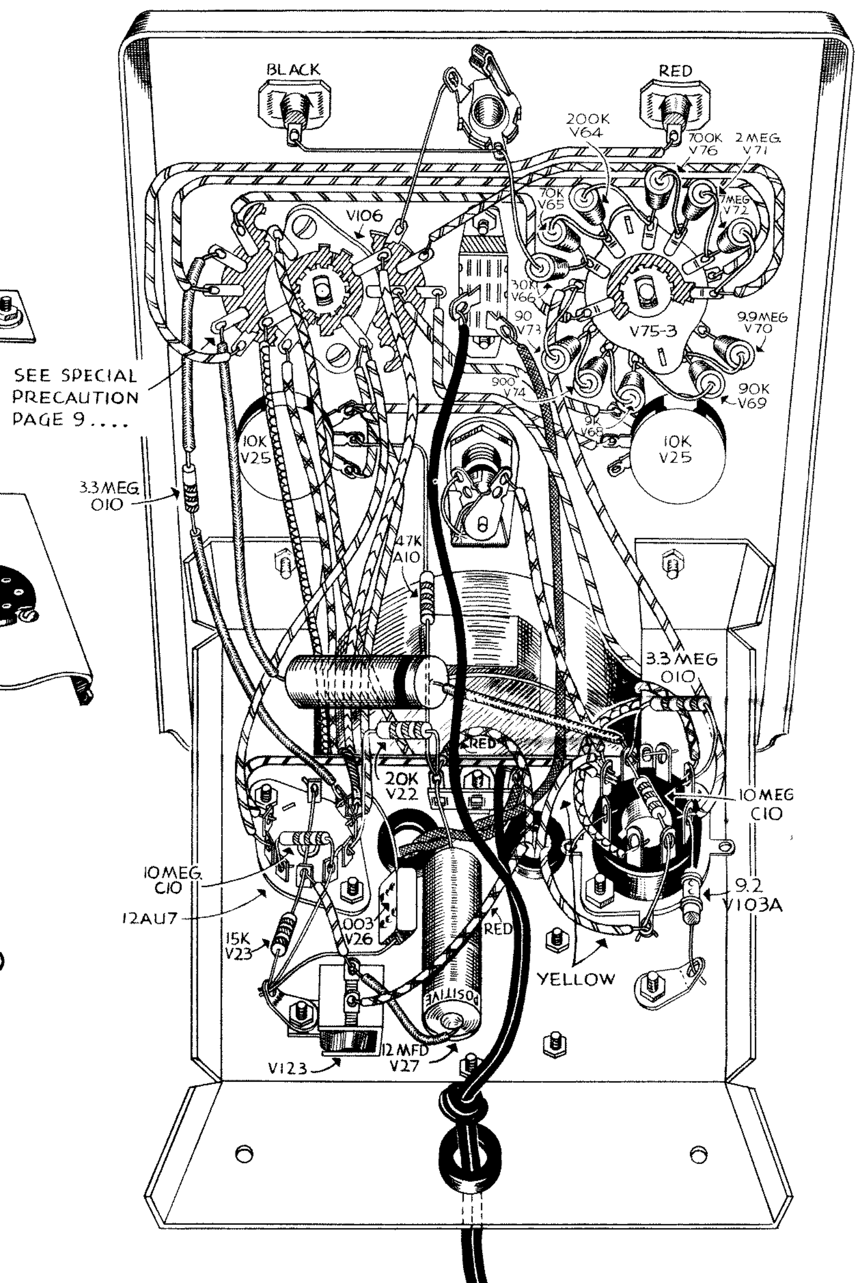

PICTORIAL 4

WIRING OF COMPLETED
INSTRUMENT....