

Assembly  
and  
Operation  
of the



VACUUM TUBE  
VOLTMETER

MODEL IM-18



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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 megohms (1 megohm in probe) on all ranges; 1100 megohms with accessory probe.
Circuit, . . . . .	Balanced bridge (push-pull) using twin triode.
Accuracy, . . . . .	±3% full scale.

### Electronic AC Voltmeter-

7 rms Ranges, . . . . .	0-1.5, 5, 15, 50, 150, 500, 1500 volts full scale (353 of peak-to-peak).
7 Peak-to-Peak Ranges, . . . . .	0-4, 14, 40, 140, 400, 1400, 4000 volts full scale.
Frequency Response (5 V range), . . . . .	±1 db 25 cps to 1 mc (600 $\Omega$ source).
Accuracy, . . . . .	±5% full scale.
Input Resistance And Capacitance, . . . . .	1 megohm shunted by 35 $\mu$ f (measured at input terminals).

### Electronic Ohmmeter-

7 Ranges, . . . . .	Scale with 10 $\Omega$ center X1, X10, X100, X1000, X10K, X100K, X1MEG. Measures .1 $\Omega$ to 1000 megohms with internal battery.
Meter, . . . . .	4-1/2", 200 $\mu$ a movement, polystyrene case.
Probes, . . . . .	Combined AC-OHMS-DC switching probe, single jack input for probe and ground connections.
Dividers, . . . . .	1% precision type.
Tubes, . . . . .	1 - 12AU7, twin triode meter bridge. 1 - 6AL5, twin diode AC rectifier.



Battery, . . . . .	1-1/2 volt "C" cell.
Power Requirements, . . . . .	105-125 or 210-250 volts, 50/60 cps AC, 10 watts.
Cabinet Size And Finish, . . . . .	7-3/8" high x 4-11/16" wide x 4-1/8" deep.
Net Weight, . . . . .	3-1/2 lbs.

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

## INTRODUCTION

The HEATHKIT Model 1M-16 Vacuum Tube Voltmeter is intended for use by servicemen, engineers, and maintenance men to make accurate measurements of DC+, DC-, AC rms and peak-to-peak voltages, plus resistance. The design is simple and rugged, yet accurate.

The instrument employs vacuum tubes 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 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 component voltages to be measured separately, even when high frequency AC voltages are present at the test point.

The VTVM has a very high input impedance (11 megohms on DC and 1 megohm shunted by 35  $\mu$ mf on AC). Consequently, 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 of the VTVM also 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

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 VTVM circuit needed for a specific measurement function. 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 the 1 megohm resistor in the probe to the Range switch, which is a series of precision resistors arranged as a voltage divider. Depending on the position of the Range switch, a portion of this DC voltage is "picked off" and applied 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 to the 6AL5 tube (half-wave doubler circuit) where it is changed to a DC voltage which is proportional to the applied AC test voltage. On the higher AC ranges, a voltage divider arrangement 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. A capacitor is used at the output of the 6AL5 to hold the applied pulsating DC voltage at its peak value, so that the VTVM responds 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 voltage divider network (determined by the Range switch position) and the resistance to be measured. The ratio between the ohmmeter voltage divider network resistors and the measured resistance determines what portion of the ohmmeter battery voltage is applied to the input grid of the 12AU7 tube.

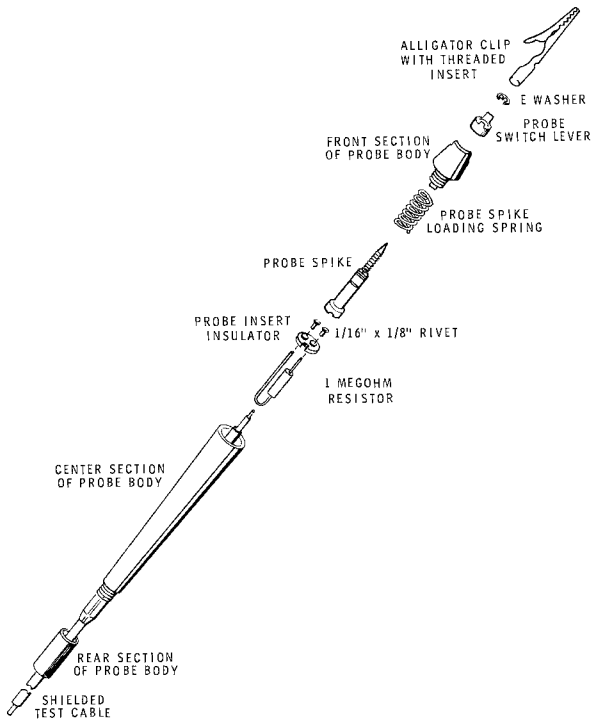
Thus, for all measurement functions, a voltage dependent upon the quality being measured is applied to the grid of one-half of the 12AU7 twin triode. With zero voltage input to the 12AU7 bal-

anced 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 eliminates 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 characteristic of the 12AU7 tube, as used in the VTVM circuit, is 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 out in this way.

The power supply of the VTVM uses a silicon rectifier 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.



**PICTORIAL 7**

## TEST AND CALIBRATION

During the preparation of the test leads and cabinet, the VTVM has had an opportunity to warm up thoroughly and should now be calibrated.

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

(✓) 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 through 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 46 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 to lug 1 on the rear wafer of the Range switch (the point to which the blue cable wire is connected in Pictorial 4).

(,) 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

( ) Set the Function switch to OHMS. 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 scale (no resistance).

### AC CALIBRATE

NOTE: Your AC power line outlets may be either 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.

#### AC Calibrate With Line Cord Adapter

CAUTION: Do not allow the green wire on the line cord adapter to be grounded in any way, or to touch any part of the VTVM. A good way to prevent this is to put a piece of tape over the spade lug on the end of the green wire.

- ( ) 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.
- ( ) 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.

### AC CALIBRATE WITHOUT LINE CORD ADAPTER

CAUTION: Do NOT use the common (negative) lead of the VTVM when measuring power line voltages. This lead is already connected to the circuit ground and to the power line ground. If the common lead should contact the "hot" side of the power outlet, the power line will be short-circuited. Connect ONLY the meter probe, set on AC, to the power line.

- ( ) 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.

### AGING AND FINAL CALIBRATION

- ( ) 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 to check the accuracy of the VTVM. Preferably, use a voltage near full scale on the VTVM as 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.

After final calibration, place the instrument in the cabinet and secure it with two 6-32 x 3/8" sheet metal screws. The instrument is now ready for use. The power consumption of the VTVM is very low and there is no objection to leaving the instrument on continuously 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 of minimizing possible moisture accumulation.

# TROUBLESHOOTING CHART

## 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 (black lead to black-red lead).
2. If pilot lamp and tube filaments do not light, check voltage between the yellow leads of power transformer (5-6 volts AC).
3. Check voltage between each end of electrolytic capacitor and ground. Correct voltages are shown on the Schematic.
4. Check the 12AU7 tube.

## INABILITY TO OBTAIN DC BALANCE

1. Check the 12AU7 tube for an unbalanced condition (Substitution).
2. Check the two .005 capacitors C5 and C6 (Pins 2 and 7 of the 12AU7).
3. Check the components in the cathode circuits of the 12AU7 tube (Pins 3 and 6). These circuits include the ZERO ADJ control, R1, R33, R34, and R35.
4. Check Range switch assembly carefully.

## AC INOPERATIVE

1. Check the 6AL5 tube.
2. Check C2, .047  $\mu$ fd 1600 volt, and the two .02  $\mu$ fd capacitors, C3 and C4.
3. Check Function switch assembly carefully.

## AC BALANCE

1. Disconnect test leads from instrument before adjusting the AC Balance control as directed in the manual.
2. 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 C4.
2. Check the 6AL5 tube.
3. Check the AC Calibrate control, R3, NOTE: With the test lead plug inserted, there may be a residual reading. This is due to stray AC pickup in the test leads. Readings on the two lower AC ranges will normally be low.

## INACCURATE DC READINGS

1. Check the DC calibrate control, R4.
2. Check resistor in the test probe. Make sure that it is not being grounded.

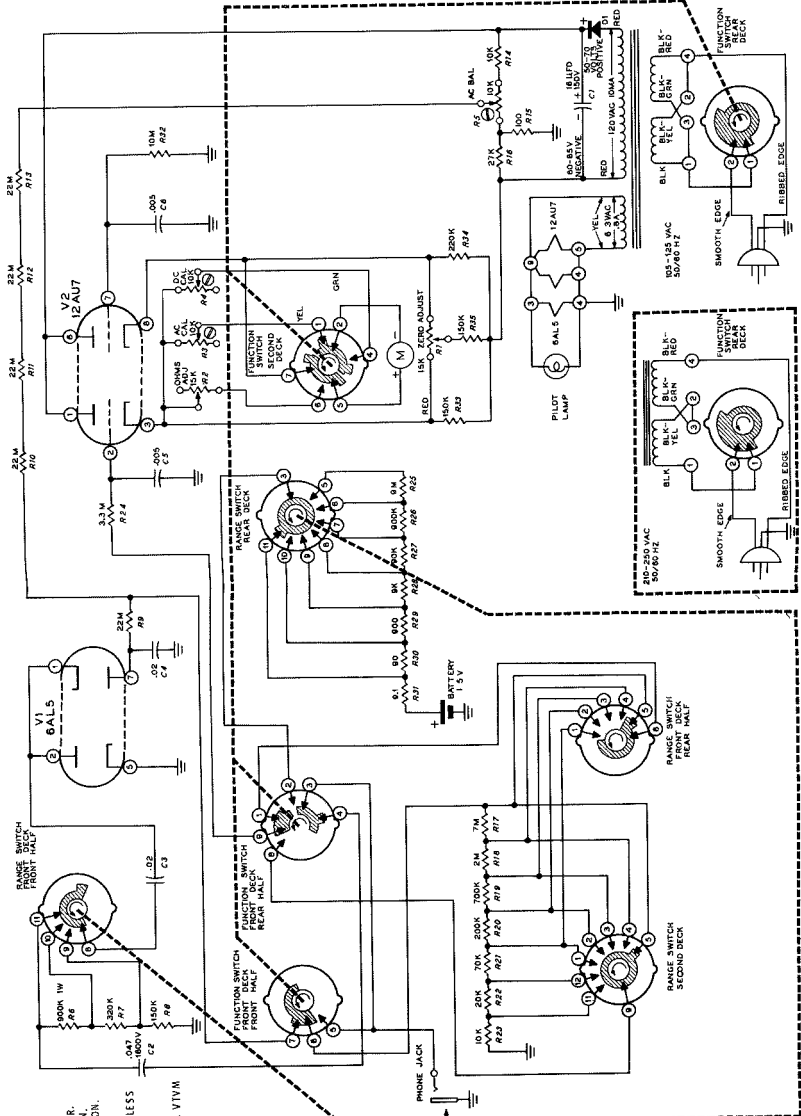
## OHMS INOPERATIVE

1. Check the OHMS ADJ control, R2, for correct value.
2. Check Range switch for proper assembly.
3. Check the battery.

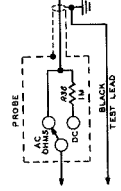
## OHMS INACCURATE

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  $\Omega$  R31 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.





- NOTES:
1. ALL SWITCHES VIEWED FROM REAR.
  2. RANGE SWITCH IN 1.5V POSITION.
  3. FUNCTION SWITCH IN AC POSITION.
  4. ALL RESISTOR VALUES IN OHMS UNLESS SPECIFIED.
  5. ALL RESISTOR VALUES IN OHMS UNLESS SPECIFIED.
  6. Ⓢ INDICATES SCREWDRIVER ADJUSTMENT.
  7. ALL VOLTAGES MEASURED WITH A VTVM OR 20,000 OHMS/VOLTMETER



**SCHEMATIC OF THE  
HEATHKIT®  
VTVM  
MODEL IM-18**

