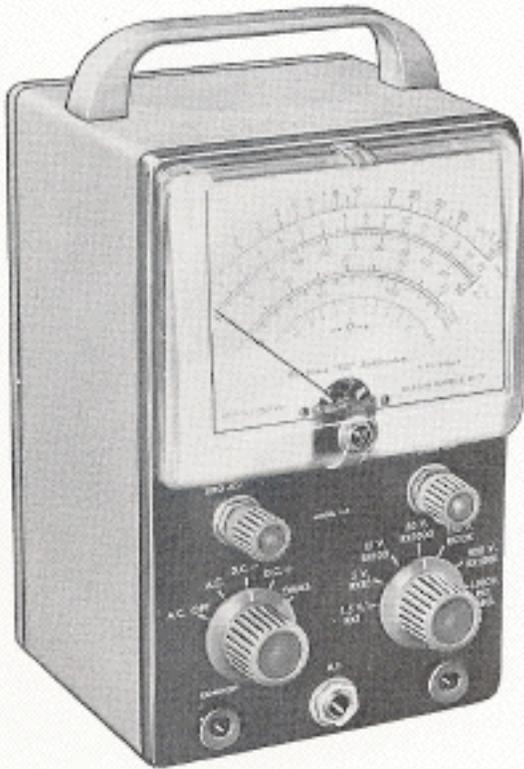


Heathkit of the Month:
by Bob Eckweiler, AF6C



The Heath V-7A
VTVM and family.



MODEL V-7A

Introduction:

A very popular older piece of Heathkit test equipment is the V-7A vacuum tube voltmeter (VTVM). The V-7A is the last of a long line of V-series VTVMs manufactured by Heath. The V series was replaced by the IM series (which includes other instruments as well as VTVMs) in the early sixties. An amateur who built a Heathkit transmitter or receiver over the years often found that a VTVM and RF probe were two of the few instruments needed to align or adjust the equipment after it was built. Thus most builder hams had a VTVM as one of their prime test instruments.

Why a VTVM?

The VTVM features a high input impedance that a standard volt-ohm meter doesn't offer. Typically the input resistance of a VTVM is 10 to 11 megohms. This high impedance creates less interaction between the circuit and the measuring device. One megohm of the input impedance is created by a resistor right at the tip of the DC test probe, helping isolate and reduce capacitance created by the test leads. This all results in more accurate readings. The high impedance of the VTVM also allows the use of special probes. One probe often required for alignment of ham gear is an RF Probe; Heath offered the 309 series RF probe as an accessory for their line of VTVMs. Let's briefly touch on the earlier Heathkit VTVMs before looking at the V-7A.

The Heathkit V-1 VTVM:

The V-1 was the first Heathkit VTVM. It was introduced in December 1947 for \$24.50. and was produced until late 1948 when the V-2 was released.

Front panel controls and jacks for the V-1 are:

Meter w/ scales:

- 0 – 1,000 Ohms (10 ohms center)
- 0 – 10 V (AC/DC)
- 0 – 30 V (AC/DC)
- 20 – +15 dB

Power Switch:

ON / OFF (toggle switch, replaced in later production by a slide switch)

Selector Switch:

AC, DC-, DC+ and OHMS

Range Switch (Five ranges):

- 3V / R x 1, 30V / R x 10,**
- 100V / R x 100, 300V / R x 1000,**
- 1000V / R x 1 MEG**

Potentiometer:

ZERO ADJUST

Potentiometer:

OHMS ADJUST

Power Indicator:

Jeweled pilot light (#47 bulb)

Input Jack:

Black banana jack **COMMON**

(Connected to chassis)

Input Jack:

1/4" Phone jack: **D.C.**

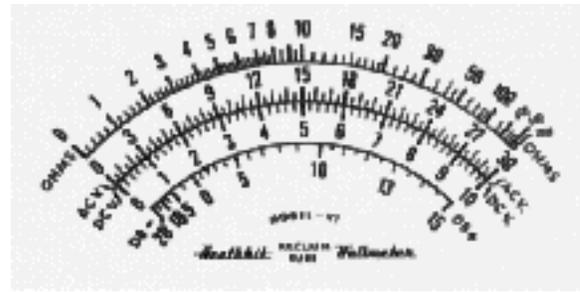
Input Jack:

Red banana jack **A.C. OHMS**

(note: Front panel nomenclature is shown in bold.)

The front panel controls remained similar for the later VTVMs, though new ranges were added, until the V-7 when the on/off function was added to the selector switch, and the pilot lamp was incorporated onto a circuit board and shined through the meter bezel.

The V-1 uses three octal tubes: a 6X5 power rectifier, a 6H6 dual diode for AC to DC voltage conversion and a 6SN7 dual triode for a balanced bridge amplifier and meter driver. Two flashlight cell batteries provide 3V power for the Ohms circuitry. Resistors in the voltage divider circuits are 1% precision resulting in reasonably accurate readings for the price of the instrument. The V-1 shipping weight was 8 pounds.



Heathkit V-1 Meter Scale

The Heathkit V-2 VTVM:

The V-2 adds an additional position on the range switch that was missing from the earlier unit. Added to the voltage ranges is the 10 V range, and added to the Ohms range is the 10MΩ (10,000Ω)* range. The other difference is that the meter, though physically the same size, was improved to a more sensitive 200μA movement and the associated meter circuitry changed to accommodate it. The new range switch was marked:

Range Switch:

- 3V / R x 1, 10V / R x 10,**
- 30V / R x 100, 100V / R x 1000,**
- 300V / R x 10M, 1000V / R x 1 MEG**

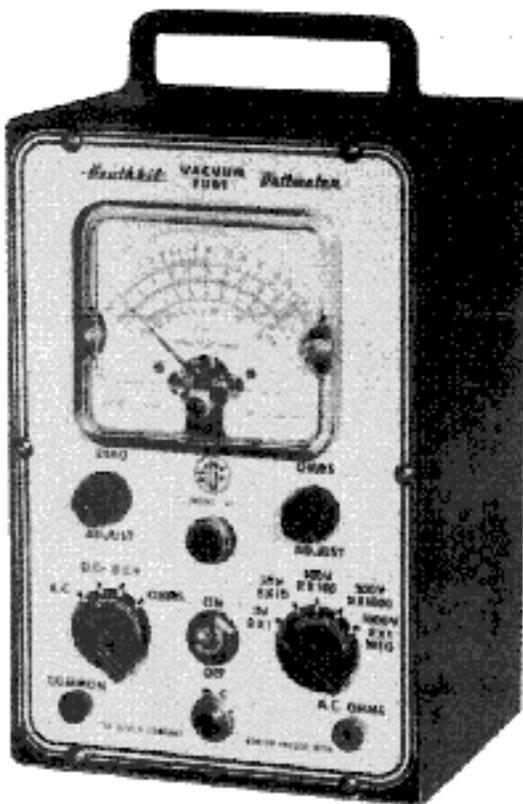
(* note: Heathkit used the designation M to symbolize 1,000, and MEG to symbolize 1 million).

The Heathkit V-3 VTVM:

In April of 1949 Heath was developing the V-3. It was supposed to be a battery operated version of the V-2 VTVM, and set to sell for \$34.50. But due to engineer problems, probably related to battery cost and life, very few, if any, were manufactured commercially. Prototypes are evidently around.

The Heathkit V-4 VTVM:

The V-4 came out in 1950 continuing at the \$24.50 price. It features a larger meter and the 6X5 rectifier tube was replaced by a (then) state-of-the-art 65 ma selenium rectifier. It also includes a modification to the 6H6 AC to DC conversion circuit. Not too long after the V-4 was released, it was replaced by the V-4A



The Original Heathkit V-1 VTVM (Late 1947)

The Heathkit V-4A VTVM:

The V4A replaced the V-4 in late 1950 or early 1951. The major change was a further modification to the AC to DC conversion circuit which actually brought the circuit back closer to the original V-1 circuit. The V-4A sold for \$23.50; a dollar less than the earlier models.

The Heathkit V-5 VTVM:

The V-5 replaced the V-4A in September of 1951. Again the size of the meter was increased to 4-1/2" almost filling the width of the front panel. The cabinet itself also changed radically. Instead of a flat front panel that screws into a flange on the cabinet, the front panel, rear panel and cabinet are "formed" aluminum with rounded edges. There are no front panel screws; instead the front and rear panels and chassis are held to the cabinet by screws at the back of the cabinet, making a neater appearance and allowing the meter to fully extend from edge to edge. The jeweled pilot light remained on the front panel. Internally the tube lineup changed; the octal 6SN7 tube was replaced with the smaller miniature 9-pin 12AU7 dual triode and the 6H6 was replaced by a 7A6 dual diode in an attempt to improve AC accuracy. The 7A6 is a "loctal" based tube and has a different pin-out than the 6H6. The tube socket and socket wiring were changed to accommodate the new tube. In the Ohms circuit the two batteries (3V) were replaced with a single 1.5 volt cell, and one of the Ohms divider resistors was changed to compensate. Meter ranges remained the same as the V-2 through V4A.

The Heathkit V-5A VTVM:

The V-5A replaced the V5 in 1952. It remained on the market until replaced by the V-6 in 1954. The V5A is almost identical to the V-5 except the 7A6 AC to DC circuit tube was changed back to a 6H6, as was the tube socket and wiring.

The Heathkit V-6 VTVM:

The Heathkit V-6 VTVM came out in 1952 and remained in production until early 1955. It features a new seven-position range switch. The 1 - 3 voltage decade steps changed to 1.5 - 5

steps. The lowest range decreased to 1.5V and the largest range increases to 1,500V. The AC and DC voltage steps are now: 1.5, 5, 15, 50, 150, 500 and 1,500V. The additional step on the range switch allowed a new resistance range of R x 100K. The power supply was also beefed up slightly with a higher value filter capacitor, possibly due to the lower full scale voltage range.

The Heathkit V-7 VTVM:

The Heathkit V-7 replaced the V-6 in early 1955. The V-7 added a new feature to kit building; it is believed to be the first Heathkit to use a printed circuit board for construction. Also, for the first time since the V-1, the instrument color scheme changed. Prior to the V-7 the front panel was light gray with red nomenclature and trim lines. The V-7 has a darker gray front panel with white nomenclature, no trim lines, and a feather gray cabinet that is somewhat lighter than the gray of the front panel. Starting with the V-7 the #47 pilot lamp is located behind the top of the meter and shines through a piece of red transparent tape and the top of the plastic meter cover. Significant changes to the AC to DC conversion circuit were made including changing the tube to a 6AL5.

The Heathkit V-7A VTVM:

The V-7 was replaced by the V-7A after about one year. Of all the Heathkit VTVMs, the V-7A remained in production the longest; from 1956 into 1962. The V-7A is believed to be identical to the V-7 with the exception of the circuit board which was improved significantly over the original circuit board.

A Closer Look at the V-7A:

A closer look at the V-7A, shows it uses just two tubes, a 6AL5 dual diode and a 12AU7 dual triode. The transformer powered supply puts out about 130 VDC using a selenium rectifier and 16µF axial electrolytic capacitor. A filament winding on the transformer lights the tube filaments and the #47 pilot lamp mounted to the circuit board. Resistors across the supply

output provide a ground reference and provide negative and positive voltages to the circuits relative to common. A small DC voltage tapped from the voltage source is fed back through a very large resistance to the AC to DC converter circuit to buck the contact potential developed in the 6AL5 tube. Since the V-1 Heathkit has been changing the AC conversion circuit in almost every model. Evidently they felt the need to improve the circuit. With the V7-A the AC circuit evidently met their expectations; and it has remained the circuit used in all the future VTVMs.

The 12AU7 is wired as a balanced differential amplifier. The plate of both triode sections are connected together and to a B+ voltage of about 60 volts. The cathodes are each connected through current limiting resistors to each end of a balance potentiometer whose wiper goes to a B- voltage of -75V. The meter is connected between the two cathodes. Depending on the function switch setting, (AC, DC or OHMS), a different calibration potentiometer is switched in series with the meter. The meter leads are also reversed by the function switch between the AC, DC- and DC+, Ohms settings. The grid of one triode is grounded through a large resistance while the voltage to be measured is applied to the other grid. Bias is provided by the voltage on the cathodes. Since no grid-bias resistor is needed the input impedance to this stage is extremely high. When there is no voltage to be measured the currents in the two triode sections balance and the meter remains at zero, assuming the balance control is properly set. Full meter deflection results when about 1.36 DC volts is applied to the grid. This type of differential amplifier is linear so the meter responds in a linear fashion to the applied voltage. The tube limits the maximum current through the meter, protecting it if improper voltages are applied to the VTVM input.

DC Circuit Operation:

In the DC modes a series of precision 1% resistors make up a voltage divider chain. The sum

of the series resistors is 10 M Ω . An additional 1 M Ω resistor, located in the test probe, is also in series with the voltage. As the range switch is switched to higher voltage settings the voltage going to the 12AU7 is tapped further down the 10 M Ω resistive divider chain. As an example, when on the 15V range the tap is 9 M Ω down the chain (plus the 1 M Ω in the probe). Thus the input voltage reaching the 12AU7 grid is 1/11 of the input voltage. Assuming 15 volts is applied to the VTVM input, the voltage on the grid is 1/11 (0.0909) of 15 volts or 1.36 volts. Other DC ranges operate similarly.

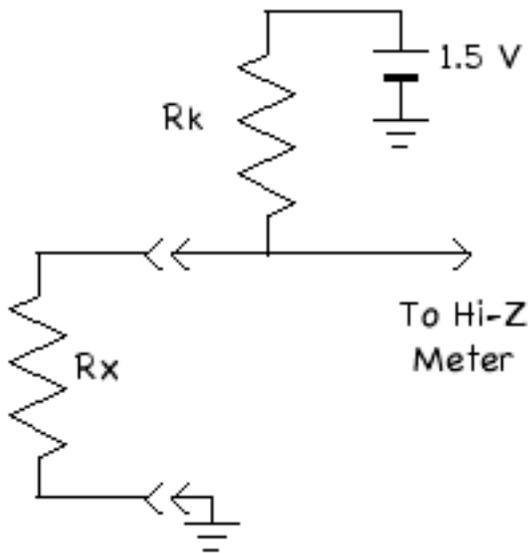
AC Circuit Operation:

Earlier Heath VTVMs offered high DC impedance (~6 M Ω) on their AC ranges. This is not the case on the V-7A. When Heathkit changed the AC to DC tube from the 6H6 to the smaller 7-pin miniature 6AL5 tube they had to limit the voltage going to the tube. The AC input resistance dropped to about 1.5 M Ω with the addition of a separate voltage divider to reduce the voltage on the tube when in the 500 and 1,500 volt ranges. The 6AL5 twin diode is wired as a voltage doubler. Its output corresponds to the peak-to-peak of the AC voltage. The output is then fed to the same voltage divider chain as used for DC. However the 500 and 1,500 VAC ranges are tapped at the same point as the 150 range because of the earlier divider. A separate calibration control sets the AC calibration. The meter has separate scales for both RMS AC volts and Peak-to-Peak AC volts.

Ohms Circuit Operation:

The Ohms operation relies on the extremely high input impedance of the 12AU7 differential amplifier. For all practical purposes it can be considered infinite at DC since it is biased so no grid current flows. Operation is rather simple. The internal 1.5 volt battery is connected across a voltage divider made up by a known resistance R_k selected by the range switch and the unknown resistance R_x. The output of the voltage divider is fed to the 12AU7 amplifier. When the resistance being measured is infinite (open), the full battery voltage is applied to the

tube and the meter reads full scale. When the resistance is zero (shorted) no voltage is applied to the tube and the meter reads zero. And when the resistance being measure is the same as the known resistance the meter reads half-scale. The readings are not linear so the Ohms scale on the meter face is marked accordingly. By adjusting the zero control with the meter leads shorted and the Ohms control with the meter leads open the accuracy can be quite good when using the correct meter scale.



Building the Kit:

Being one of the first kits to use a printed circuit board, a part of the typically excellent Heathkit manual is dedicated to proper printed circuit soldering techniques. Construction starts with the range switch; its numerous resistors are wired first. These components mount directly to the switch and not on the circuit board. Next the controls, jacks and switches are mounted to the front panel, and the wiring between front panel components is added. Then the circuit board is filled with its various components. Conventional miniature tube sockets are used; the solder lugs of the sockets are placed through one large hole for each socket and bent over and soldered to the appropriate spot on the circuit board. Evidently Heath was either getting rid of their existing sockets or PC tube sockets were not readily

available at that time. A prefabricated wiring harness is then installed between the circuit board and the front panel. The bracket that supports the circuit board, part of the battery holder, the line cord and the front panel to the cabinet is installed next, along with the meter. This bracket is attached by the meter screws to the front panel. An additional small "Z" bracket goes under a third meter screw, the other end holding the circuit board and one leg of the small power transformer. Finally the test leads are assembled. Cabinet assembly is done after checkout, burn-in and calibration are completed.

Calibration:

DC calibration relies on a voltage of a fresh carbon-zinc battery being 1.55 volts. The battery is used to set the DC calibration point on the 1.5 volt scale. The remaining scales rely on the precision resistors for their calibration. AC calibration relies on measuring the AC line voltage and it being 117 VAC. No ohms calibration is necessary since the accuracy is determined by the precision resistors and proper setting of the zero and ohms adjust controls on the front panel. Heathkit specifies accuracies of 3% on DC and 5% on AC.

Operation:

Measuring voltage is very straight forward. Set the range to the desired position. If the voltage is unknown set it to the highest range and work down. The function switch selects the proper mode: AC, -DC or +DC. In AC the meter scales can be read in RMS volts, peak-to-peak volts or dBm relative to 1 mW into 600Ω. The VTVM can measure AC at frequencies from 42 Hz to over 7 MHz (600 Ω), but the low impedance can affect measurements in critical circuits. The reason Heathkit was not concerned with lowering the AC input impedance is because true RF measurements should be used using an RF probe such as the Heathkit 309-C. This probe allows more accurate RF measurements and is a required piece of test equipment for many transmitter and receiver adjustments. The 309-C sold for \$3.50 in the days of the V-7A.

Ohms operation requires first selecting the desired Ohms range; choose a range that results in a reading near mid-scale for best accuracy. Connect the common lead to one side of the resistance to be measured. Set the Ohms adjust so the meter reads full scale; If full scale cannot be reached chances are the battery needs replacement. Now touch the meter probe to the common meter lead and set the zero adjust so the meter reads zero. Finally touch the meter probe to the other side of the resistance and read the resistance on the Ohms scale on the meter.

Restoring a V-7A:

Heathkit V-7A voltmeters may be found at swap meets and flea markets at a reasonable price. Even in today's digital world they make an excellent test bench item. Current draw is low so they won't run up your electric bill if left on for a few hours. Their immunity to RF fields is valuable when working on moderate power RF devices. Thus the V-7A is a Heathkit worth restoring.

Here are some points to look for when choosing a flea market acquisition: First, check the integrity of the meter and look for cracks or scratches on the meter face. Static buildup on the meter can cause the meter to appear erratic even when the device is off and the meter is in good shape. A little dishwasher detergent wiped on the meter face should clear it up. Be sure the meter returns to the same point each time it is deflected and that the manual meter zero control can bring the pointer to the meter scale zero mark. If you can peek inside the unit, make sure the battery has not leaked and corroded the cup or spring. The positive contact is just a #6-32 bolt and can be replaced. Finally check the 6AL5 tube and adjoining circuitry for damage that could be caused by measuring high AC voltages in the wrong range position. Finally check the 9.1 ohm resistor on the back of the range switch. This often gets damaged if the meter is used to measure voltage when in the **OHMS** position. It is a standard value resistor and is easy to replace. If it is damaged, check the other resistors in the ohms chain for

possible damage; usually the 9.1 ohm resistor acts as a fuse and protects the other resistors.

When restoring a V-7A, first check and replace the line cord if it shows damage or wear. Remember that the VTVM **COMMON** lead is connected to the VTVM chassis so if you use a modern 3-wire grounded cord you are connecting the common lead to power ground! Next replace the 16 μ F electrolytic in the power supply; it is a cheap part and probably is not up to snuff after 50 years or so. You'll probably only find a 20 or 22 μ F today, which will work fine. Also check, and preferably replace, the 0.01 μ F 1600V tubular capacitor used in the AC circuit. You don't want this capacitor to be leaky if you are measuring high AC voltages. Be sure the battery holding spring and cup are clean and provide good contact. Put in a new flashlight battery and mark the date on a label and attach it to the unit; leaky batteries can do a lot of damage. Check and replace the tubes if necessary, making sure their pins are straight and clean.

Proper operation of the switches is important for stable readings. The two wafer switches (range and function) have silver plated contacts. The switch contact surfaces should clean up using a good brand of switch contact cleaner. Take your time and be careful not to over extend any of the spring contacts. Check that none of phenolic wafers are cracked or broken. If you use abrasives to clean the contacts you are just wearing away the silver and assuring additional trouble in the future. Check, and tighten if necessary, the switch hardware. Loose switch hardware, especially the long rods, cause misalignment and intermittent switch operation.

When the VTVM is turned on to the AC position. The meter should swing down scale then up towards full scale and, after the tubes warm up, return to the low end of the scale. Make sure the meter can be zeroed with the front panel ZERO ADJ. and that the OHMS ADJ. al-

lows the meter to reach full scale in the OHMS function position.

Do a preliminary calibration using the procedure from the manual and check that the meter operates properly. If it does, let it sit on for 24 hours and repeat the calibration. You now have a viable piece of test equipment. If you can find a 309-C RF probe add it to your instrument accessories. If you can't, they are easy to build.

Heath VTVM Accessories and Spares:

Over the years Heathkit made a series of probe kits and other accessories for their line of VTVMs. Here are the major players:

1. 309, 309-A, 309-B, 309-C RF Probe (309C \$3.50 - 1956) (In later years the probe was replaced by the PK3 around 1975).
2. 310 10KV High Voltage Probe (310 \$4.50 - 1949)
3. (Replaced by the 336 probe).
4. 336 30KV High Voltage Probe (336 \$4:50 - 1956)
5. 338, 338-A 338-B 338-C Peak-to-Peak Probe (338-C \$5.50 - 1956).
6. IM-8-1 Solid State vacuum tube replacements. A set of two metal cans that plug into the 6AL5 and 12AU7 tube sockets and turn the Heathkit VTVMs (starting with the V-7) into a solid state voltmeter with instant on capability. The 12AU7 plug-in uses four FETs and the 6AL5 plug-in uses two special silicon diodes. (IM-8-1 \$17.95 - 1976).

A circuit board repair kit and a replacement meter cover were also available.

In Closing:

The V7, V7-A and later model Heathkit VTVMs make a fine piece of test equipment that is worth having if you dabble at all in the field of electronics. Don't turn down an older, less refined, V1 - V6A VTVM if one is offered either. To give some idea of the versatility of the VTVM, Heathkit was still selling the IM-5228, a bench model VTVM based almost totally on the V-7A circuit, until 1990, shortly before they went out of the kit manufacturing business.

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73, from AF6C



Remember if you come across any old Heathkit Manuals or Catalogs that you do not need, please pass them along to me.

Thanks - AF6C

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