Heathkit of the Month #47:
by Bob Eckweiler, AF6C

Heathkit

Heathkit AV-3
AC Vacuum Tube Voltmeter (VTVM).

Introduction:
Heathkit manufactured many models of general purpose vacuum tube and solid-state voltmeters, both analog and digital, over the years. They all measure DC voltage and resistance as well as AC voltage. So why would Heathkit sell, and why would people want to buy, a VTVM that only measures AC voltage?

The answer lies in the large popularity of Hi-Fi and later stereo Hi-Fi equipment that started sweeping the nation in the mid-fifties. People designing and servicing audio equipment needed to measure audio voltages, and often small audio voltages. The typical general purpose VTVM has a low AC range of 1.5 volts RMS full-scale (FS), allowing measurement of audio down to about -10 dBm, or about a quarter-volt. The Heathkit AV-3 AC VTVM (Fig. 1) has a low range of 0.01 volts (10 mV) RMS FS, allowing measurement of audio down to -52 dB, or less than 2 mV. This high sensitivity allows easy measurement of preamplifier signals and even the direct output of microphones. For the ham, similar audio voltages can be found in the audio circuits of a transmitter's modulator.

While the AC VTVM has good low-voltage sensitivity, its high-voltage capability usually is limited to around 300 volts RMS FS, lower than the typical 1,500 volts FS of a regular VTVM. But then audio voltages over 300 volts (+52 dBm) are uncommon in most equipment.

The early Heathkit AC VTVM line was designed with a frequency response to cover the audio frequency range with a variation of under ±1 dB. The low frequency end was 10 cps (Hz)

Fig. 1: AF6C's Heathkit AV-3 AC VTVM

while the high end was 50 kc (kHz) and improved on later models, starting with the AV-3.

The Heathkit AC VTVM Line:
Heathkit manufactured five AC VTVM kit models over the company's lifetime; they also manufactured one advanced solid-state kit voltmeter (also available factory wired). The models along with their approximate dates of manufacture and initial selling price are shown in Table 1:

Heathkit also sold factory-wired versions of the IM-21 and IM-38 designated the IMW-21 and IMW-38. In 1962 Schlumberger purchased Daystrom (and as part of Daystrom, Heathkit). Sometime between 1969 and 1973 Schlum-

berger started selling factory wired versions of many Heathkit models under the Heath-Schlumberger name. The IMW-38 became the SM-22A, and when the IM-5238 was released Heathkit released the factory wired Heath-Schlumberger SM-3258.

Kit Models:		
AV-1	9/1951 - 8/1952	$29.50
AV-2	9/1952 - 8/1956	$29.50
AV-3	9/1956 - 1961	$29.50
IM-21	1961 - 1968	$33.95
IM-38	1968 - 1976	$39.50
IM-5238	9/1976 - 1981	$89.95
Factory Wired Models:		
IMW-21	1961 - 1968	$60.25
IMW-38	1961 - 1969	$54.95
SM-22A	1973 - 1976	$85.00
SM-5238	9/1976 - 1981	$130.00

Table 1: Heathkit AC Meters

Each of the Heathkit AC VTVM models is an improvement on the preceding model. However, until the IM-5238, they all share the same ten voltage ranges: 0.01V, 0.03 V, 0.1 V, 0.3 V, 1 V, 3 V, 10 V, 30 V, 100 V, & 300 V. The IM-5238 added two ranges of 1 mV and 3 mV to the low end.

The AV-1 and AV-2 have a ±1 dB frequency response from 10 Hz to 50 kHz. The AV-3 tops out at 400 KHz; while the IM-21 and IM-38 go up to 500 kHz (to 1 MHz at ±2 dB).

The AV-1 AC VTVM:

The AV-1 was the original AC voltmeter kit introduced in the fall of 1951 for $29.50. It has two tubes, a 6AU6 pentode voltage amplifier and a 6AT6 triode current driver to drive the meter. The input voltage is fed to a voltage divider chain composed of ten precision resistors in series that sum to 1 meg ohm. A ten-position rotary range switch selects the proper tap in the resistor chain for the correct range. The selected tap is then fed through a capacitor to the 6AU6 voltage amplifier. The output of the amplifier is AC coupled to the triode section of a 6AT6. The tube's dual diodes are not used.

Output from the 6AT6 is AC coupled to a bridge circuit consisting of two 4.7K resistors and two crystal diodes in the legs. The 200μA meter is wired between the legs of the bridge, and is connected to a potentiometer that sets the voltmeter calibration point. The diodes are arranged so current only flows through the meter one way. The other end of the bridge is not returned to ground, but instead returns to the cathode of the 6AU6 voltage amplifier. This provides negative feedback to increase stability and control and stabilize the gain.

The power supply consists of a 117 AC primary transformer with two secondary windings. The first provides filament voltage to the tubes and the pilot lamp, and the second feeds a half-wave voltage doubler using a dual selenium rectifier. Voltage is filtered in two series pi-network RC filters. The first feeds the current amplifier and the second the voltage amplifier.

The AV-1 front panel controls are the 10 position range switch, the pilot lamp, the power on - off slide switch and dual binding posts for the input. The power cable exits from the otherwise blank cabinet rear.

The AV-2 AC VTVM:

The AV-2 (shown in Fig. 3) replaced the AV-1 the next model year (fall 1952). It continued to sell for $29.50 and is identical to the AV-1 in front panel layout, even so far as using the same meter, switches, pilot light and binding posts. The new front panel kept the earlier beige with red nomenclature color scheme, but changed the model designation. It is possible a few late AV-2 models have the later (AV-3) dark gray with white nomenclature paint.

Most of the changes are in the AV-2 circuit. The tube line-up remains the same. The meter bridge circuit was changed to a full compliment of four crystal diodes, with the meter directly connected across the bridge output. The feed-

back calibration control was changed to a 40 ohm pot located in the cathode of the 6AU6 voltage amplifier.

The power supply was changed considerably. Though the transformer is the same (54-2), one side of the filament winding is no longer grounded. Instead, the winding is shunted by two 47 ohm resistors in series, with their junction grounded. This was likely done to balance the filament voltage and reduce AC hum which can be picked up by the sensitive AC amplifiers. Also, the half-wave voltage doubler is gone, replaced by a single selenium rectifier. While the voltage developed is lower, the use of larger capacitors and a single lower resistance pi-filter result in lower ripple and less voltage drop. Due to the lower voltage, numerous resistor values were changed from the AV-1. Also optimized were some the coupling capacitors.

The AV-3 AC VTVM:

The AV-3 replaced the AV-2 in 1957. Like its predecessors it sold for $29.50, at least initially. The AV-3 is a new design, but keeps the same ranges while improving the frequency response. Externally, it also keeps the same physical size; but gone are the jeweled pilot light and off-on slide switch. The metal binding posts are now insulated red and black five-way binding posts, and the range switch has twelve positions; two positions are for off. The meter nomenclature has changed though the two scales remain identical. The top center of the meter now lights up red to indicate power on, similar to the V-7A VTVM.

The AV-3 schematic is shown in figure 4. Three tubes are used: a single 6C4 triode and two 12AT7 dual-triodes. The power supply remains unchanged from the AV-2 except for the filament requirements. The rest of the circuitry is totally new. Separate voltage dividers are used for the 0.01 V to 3 V ranges and the 10 V to 300 V ranges. When on a range above 3 volts the input is fed directly into its voltage divider, but when on a range of 3 volts and below the input is fed first into a cathode follower and then into the divider. The cathode follower converts the high input impedance into a lower impedance improving linearity

Whichever divider is selected the output goes to a 12AT7 dual triode configured as a cascode amplifier. The amplifier output is directly coupled to a buffer that uses 1/2 of the second 12AT7. and then AC coupled to other half that operates as a current amplifier driving the meter. Like the AV-2 the meter is in a bridge composed of four crystal diodes. with the meter directly across the output. However in the AV-3 the meter is damped by a 100 μF capacitor. As with earlier models the bridge return is coupled to the cathode of the voltage amplifier (in this case the cascode amplifier) through a potentiometer that sets the system gain and hence the calibration.

The Heathkit IM-21 AC VTVM:

In 1961 the AV-3 was replaced by the $33.95 IM-21. The IM-21 front panel layout is close the AV-3 and is painted in the sixties dark and light gray with red accents style. The meter is a different part, boasting VU damping response. The range switch is now 11 positions, with an OFF position fully clockwise next to the 300 volt range. Thus when you first turn it on you are on the least sensitive range; this was probably done to prevent the meter being turned on to a low range when hooked to a high voltage. The IM-28 size is identical to earlier units; but one nice new feature is that the calibration control is now accessible on the back of the unit.

While the block diagram of the IM-21 is similar to previous units, the circuit is completely changed. The IM-21 has two tubes, a dual section 6AW8 triode-pentode and a 6EJ7 pentode. The input section has been upgraded so a cathode follower circuit (the triode section of the 6AW8) is in the circuit on all ranges. This allows a much higher input impedance of 10 meg ohms. In the 0.01 volt through 3 volt range the input is directly coupled to the cathode follower, but in the higher ranges the signal is first attenuated in a 1000:1 (60 dB) AC com-

pensated voltage attenuator. This allows much better frequency response along with the higher input impedance. The output of the follower goes to the range switch and on to the second half of the 6AW8, which is the voltage amplifier. The output is coupled to the current meter amplifier. Like the earlier units the meter is in a crystal diode bridge with the meter directly across the output of the bridge; and as before the bridge return is fed back to the cathode of the voltage amplifier.

The power supply uses the same transformer that was used in the original AV-1 (and probably many other Heathkits). This power supply is similar to the earlier units, but with a different filtering scheme using a three section can capacitor: 80, 40, 20 uF all at 150 V. Unfortunately these multi-section can capacitors are hard to find in today's market if you are restoring and need a new one.

The Heathkit IM-38 AC VTVM:

The last of the Heathkit vacuum tube AC voltmeters is the IM-38. It was introduced in 1968 for $39.50; in the fall of 1976 it sold for $52.50 (See figure 2 ad). It is identical to the IM-21 except for the paint scheme and a new dual primary power transformer that allows the kit to be wired for 120 or 240 VAC power. Thus the kit can be exported without having to produce a separate export model with a different transformer.

The Heathkit IM-5238 Solid State AC Voltmeter:

The final AC voltmeter produced by Heathkit was the IM-5238 (Fig. 5) which was introduced in 1976 and continued in production into 1981. With the release of the IM-5238 Heathkit presented a whole new solid-state device. Perhaps the IM-5238 will be the subject for a future Heathkit article? It is a much more advanced AC audio voltmeter with numerous features not offered on earlier units. The IM-5238 has two additional high-sensitivity scales of 1 mV and 3 mV full-scale. And, while the earlier units had linear voltage scales (which made the dB scales logarithmic), this unit has two functions that

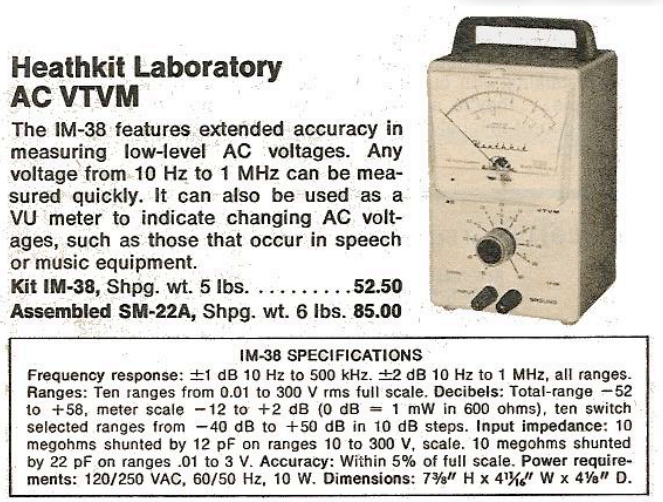


Fig. 2: IM-38 Ad - Winter 1976 Factory Catalog

allow you to select a linear voltage or linear dB scale readout. Additionally, the IM-5238 has numerous special outputs: One is a one-volt peak, full-scale AC output that can be used to drive a frequency counter. It also has a DC voltage output of 0 - 1 volt full-scale, that is proportional to the input voltage, as well as a DC voltage output of 0 - 3 volts full-scale, that is proportional to the log of the input voltage. These latter two outputs can drive a strip chart recorder or other data gathering device for production testing.

Conclusion:

I currently own an AV-2 and AV-3. The AV-3 I picked up many years ago, the AV-2 was acquired recently from a friend. Both required replacement of their power supply filter capacitors. Originally these were both Heathkit part # 25-7 dual 20 µf 150 VDC electrolytic capacitors, a part that is unobtainable today. They were replaced by two axial lead capacitors of the same rating. Due to the small side of today's components, they fit in the space of the old single unit. I also ended up changing some of the paper capacitors with later style mylar ones. Interestingly the AV-2 input capacitor had been changed from 0.05 µf at 600V to 0.47 µf at 250V. I plan to order the right capacitor and replace it when I make my next order with Digi-Key, Mouser or Allied Electronics. Axial leaded capacitors are getting harder to find and carry a price penalty over radial leaded capacitors.

The AV-3 has been used numerous times for aligning radios, often measuring the audio voltage across the speaker while aligning the IF. Because of the higher sensitivity the audio volume can be kept at a much lower level making the modulation tone from the signal generator much less annoying. While a dummy load can be used instead of a speaker, it helps to hear the quality as well as volume of the signal.

73, from AF6C

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C

This article originally appeared in the March 2013 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

SPECIFICATIONS:

Range, RMS Full Scale..0-.01, .03, .1, .3, 1, 3, 10, 30, 100, 300
Decibels, Total.....-52 DB to +52 DB (0 DB 1 MW-600 Ohms)
Input Impedance.....1 Megohm at 1 KC
Tube Complement.....1—6AU6, 1—6AT6
Accuracy.....± 5% or Better
Power Requirements.....105-125 VAC, 50-60 CPS, 10 Watts
Dimensions.....7⅜" High, 4-11/16" Wide, 4⅛" Deep

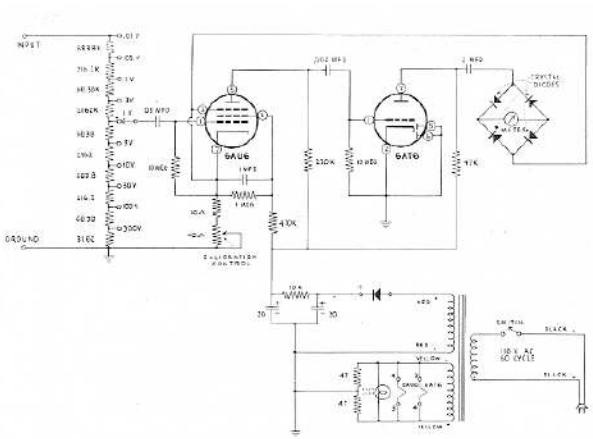


Fig. 3: AV-2 AC VTVM listing from *Heathkits for 1956* catalog

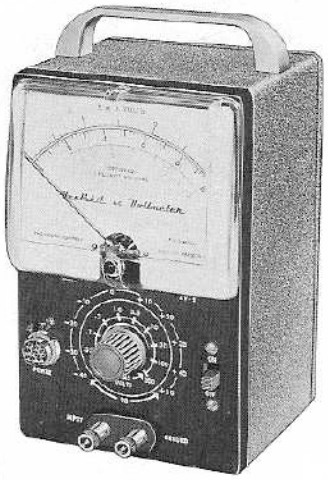
HEATHKIT

AC VACUUM TUBE voltmeter KIT

features

- *Precision voltage divider resistors.*
- *Measures as low as 1 millivolt at high impedance.*
- *Feedback type circuit for maximum stability and frequency response.*
- *Transformer operated, minimum residual hum.*
- *AC volts and DB ranges set by one switch adjustment.*
- *Full wave meter bridge (4 Germanium Diodes).*

Here is the instrument to take up the slack where your general purpose VTVM becomes a little inadequate. Designed specifically for extreme sensitivity, Model AV-2 will accurately measure those very low AC voltages encountered in audio devices. The wide DB range and flat frequency response simplify those important input-output comparison measurements. Excellent as an output meter for determining the frequency response of your audio amplifier and the gain of each individual stage. Use it to measure the output of microphones and phono pickups, the ripple voltage in filter circuits and as a sensitive null detector. The AV-2 AC VTVM is ideal as a companion to the popular Heathkit V-7A VTVM not only in the service field but also in experimental laboratories, hobby shops and in any application where high AC sensitivity is required.



MODEL AV-2

$29.50

SHPG. WT. 5 LBS.

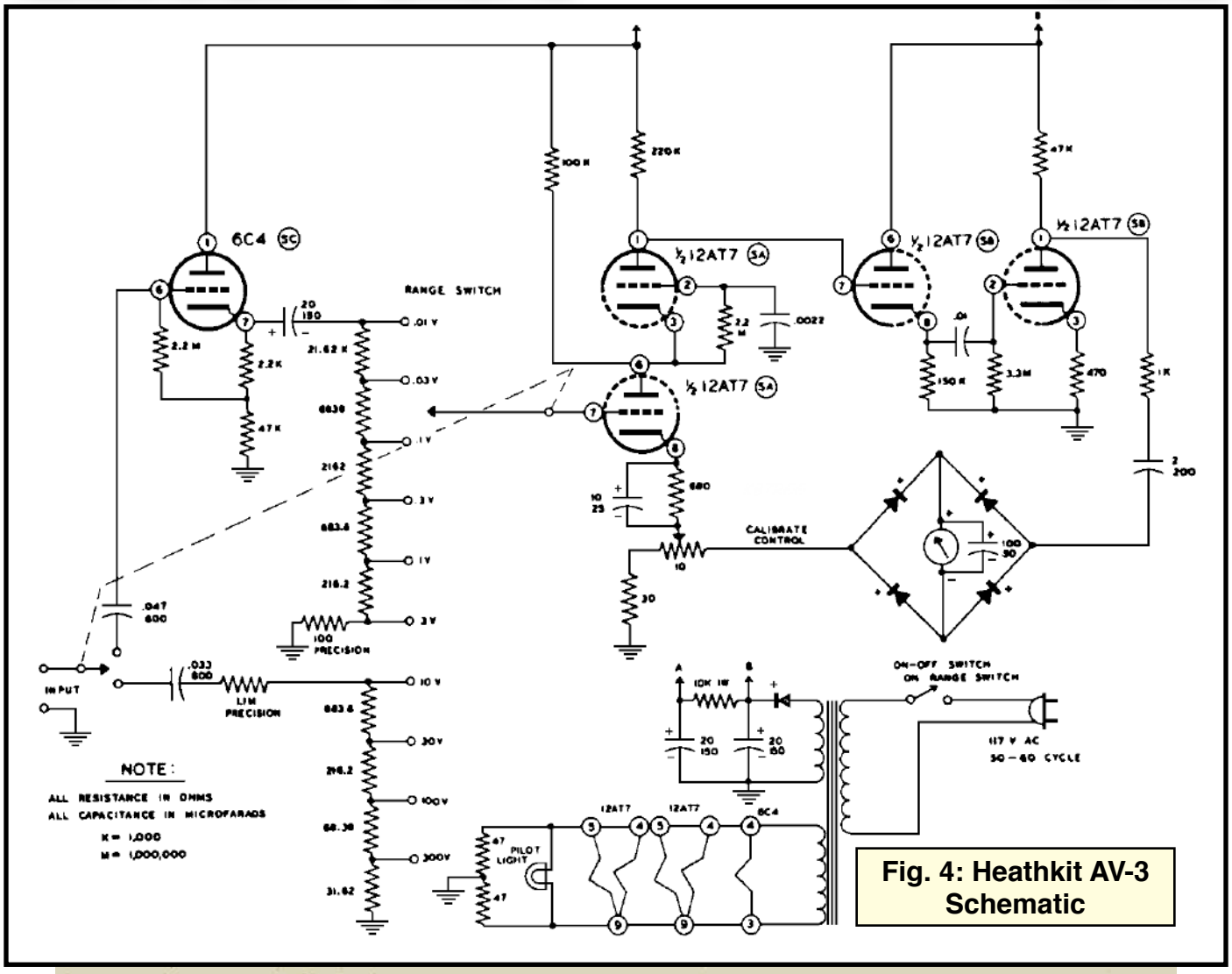


Fig. 4: Heathkit AV-3 Schematic

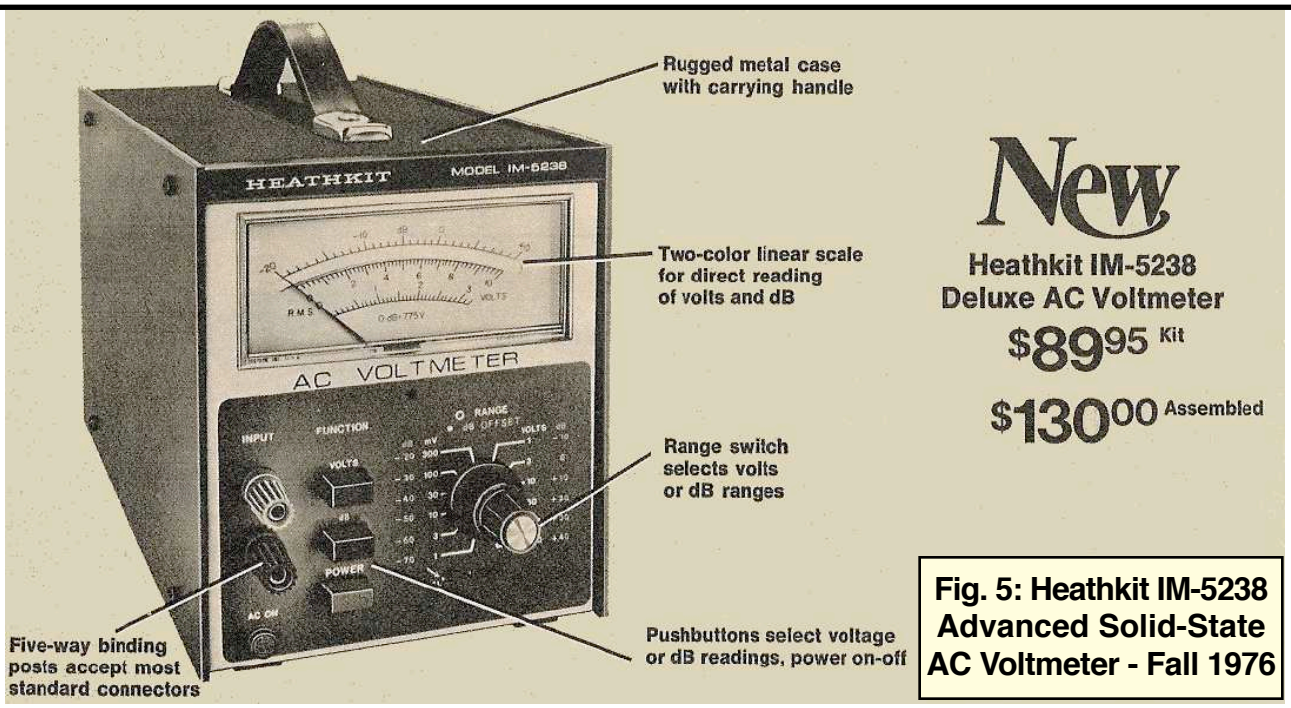


Fig. 5: Heathkit IM-5238 Advanced Solid-State AC Voltmeter - Fall 1976