Heathkit of the Month:
by Bob Eckweiler, AF6C

HEATHKIT

ELECTRONIC TEST EQUIPMENT
Heathkit IM-38
AC Vacuum Tube Voltmeter (VTVM).

Introduction:

Back in March of 2013 **Heathkit of the Month #47** discussed the Heathkit line of AC VTVMs as well as the solid state IM-5238. That article focused mainly on the late 1950s AV-3 model.

I was recently offered an IM-38 by Bill - K6WHP, and jumped at the opportunity. It has many features and improvements over the earlier AV-1, through AV-3 AC VTVMs, and I felt it warranted its own feature article.

The IM-38 AC VTVM:

The IM-38 (Figure 1), sold between 1969 and 1976, was the last Heathkit AC VTVM model before Heath switched to a solid-state design. In between the AV-3 and the IM-38, the IM-21 was offered. The IM-38 originally sold for $39.50 in kit form or $54.95 factory wired (as the IMW-38). In the Christmas 1976 catalog the IM-38 sold for $52.50, and there was no mention of the factory-built model. See Figure 4, an ad from the summer 1969 Heath catalog.

The IM-38 is a significant update from the AV-3. Most of these updates first appeared in the earlier IM-21 model. As a result, the IM-38 shares with the IM-21 an input impedance that is higher than the AV-3 by a factor of ten and also improves the ±1 dB frequency response from 10 cps - 400 kHz to 10 cps - 500 kHz on all ranges (± 2dB 10 Hz to 1MHz). Due to the increased input impedance, the 1,000 : 1 resistive input voltage divider is capacitively compensated to help improve the response at higher AC frequencies. This compensation is internally adjustable via a small trimmer capacitor.

Figure 1:Heathkit IM-38 AV Voltmeter

The ranges remain the same as on the earlier models, going from 10 mV full-scale to 300 volts full-scale in ten 1 : 3 steps. The fully-clockwise eleventh position of the range switch turns the unit off.

The IM-38 differs from the IM-21 in three aspects. First it introduces a new updated style which Chuck Penson - WA7ZZE coined “The New Look” in his book ***Heathkit Test Equipment Products***[1]. This is the light beige front panel with a darker beige cabinet, two-tone brown knobs and dark brown lettering.

The second change is in the power supply; a dual primary transformer is used so the IM-38 may be wired for 120 or 240 VAC use, negating the need for a separate export model. Surprisingly there is no fuse in the AC line.

Thirdly, the two-wire power cord was replaced with a three-wire cord that connects the chassis to AC power ground. Since the black (low side) of the voltmeter input is also connected to chassis ground, you need to be certain the low side is at ground potential if you are measuring the AC voltage of the power line. Otherwise you will be popping fuses, damaging alligator clips or test probes, possibly damaging the equipment you are measuring, or worse. Still that is likely better than touching a hot chassis, possibly resulting in electrocution.

The IM-38 and IM-21 share a different vacuum tube lineup than the AV-3. Two tubes, with three total sections, replace three tubes with five total sections. Table I shows the lineup. In the IM-21 and IM-38 models Heathkit uses higher gain pentodes to replace pairs of triodes.

The front panel layout of the IM-38 is extremely simple, containing just a 4-1/2" meter, two of the Heathkit five-way binding posts, one red and and one black, and an eleven position rotary switch. A pilot light sits behind the top center of the meter to indicate when the power is on. The rotary switch selects one of the ten meter ranges; the eleventh position (fully clockwise) turns the power off. While most devices have the off position at the fully counterclockwise position, Heathkit chose the other end, so the meter, when turned on, will first be on the highest (300 Volt) range.

Heathkit AV-3 Tube Lineup		
Tube	**Type**	**Use**
6C4	Triode	Input buffer - follower
12AT7	Dual Triode	Cascode AC amplifier
1/2 12AT7	Triode	Cathode follower
1/2 12AT7	Triode	Meter driver
Heathkit IM-38 Tube Lineup		
Tube	**Type**	**Use**
1/2 6AW8	Triode	Input buffer - follower
1/2 6AW8	Pentode	AC amplifier
6EJ7/ EF184	Pentode	Meter driver

Table I: AV-3 - IM-38 Tube Lineup Comparison

The rear of the IM-38 contains just the calibration potentiometer and the strain-relief grommet for the power cord.

The IM-38 Meter Scale:
The IM-38 meter has three scales. Two are linear RMS voltage scales marked 0 - 3 and 0 - 10 and are arranged at a ratio of 1 : 3.16 (or more precisely 1 : √10). Thus, if the 0 - 3 scale were to be extended to the end of the 0 - 10 scale, it would end at 3.16. If you are interested in the reason for this ratio, see the separate article on dB meter scales in this issue of ***RF***. There is more to selecting meter scales than one thinks!

The third scale is the **DECIBELS** scale which goes from -12 dB to +2 dB. This scale starts at about 2 and ends at about 9.75 on the 0 - 10 scale. It could extend farther down, but the markings would quickly become too close together to read. (0 volts equals negative infinity dB). Thus Heathkit decided to stop there so the scale, across all ranges is: -52 to +52 dB.

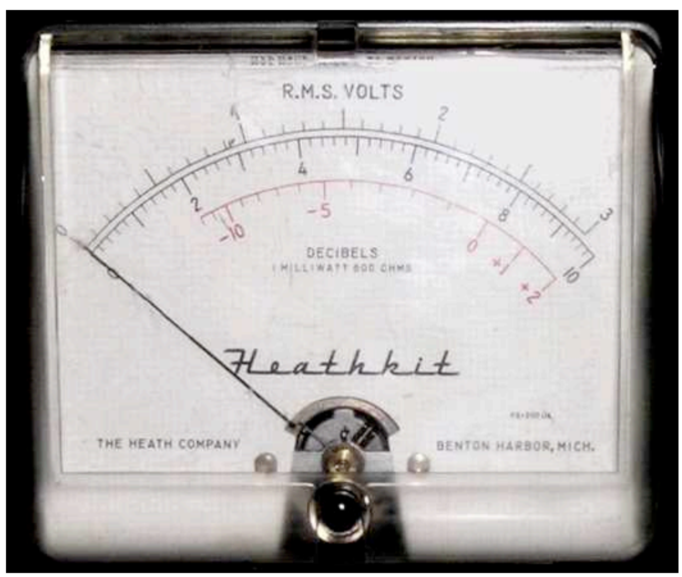


Figure 2: Meter face of a typical AC VTVM showing the three scales.

Since decibels is a ratio, zero dB has to be defined. On the IM-38 the definition is printed right on the meter face as **1 MILLIWATT 600Ω**, (0 dB = 1 mW across 600 ohms) which is a common standard for audio measurements. A simple Ohm's law calculation shows 0 dB to be equal to 0.775 volts (more precisely $\sqrt{0.6}$ volts). If you look at the meter scale (Figure 2), 0 dB occurs at the 7.75 mark on the 0 - 10 scale.

Other audio dB references exist, one being the standard VU (volume unit) which is defined as 1.228 volts into 600 ohms[2]. Another common standard, that was in use by the telephone industry for many years, is defined as 6 mW across 500 ohms. Luckily, it is easy to convert from one standard to another by simply adding or subtracting a fixed dB value. In the case of the VU, subtract 4.0 dB from the (1 mW/600Ω) reading, and in the case of the telephone standard subtract 7.78 dB from the reading.

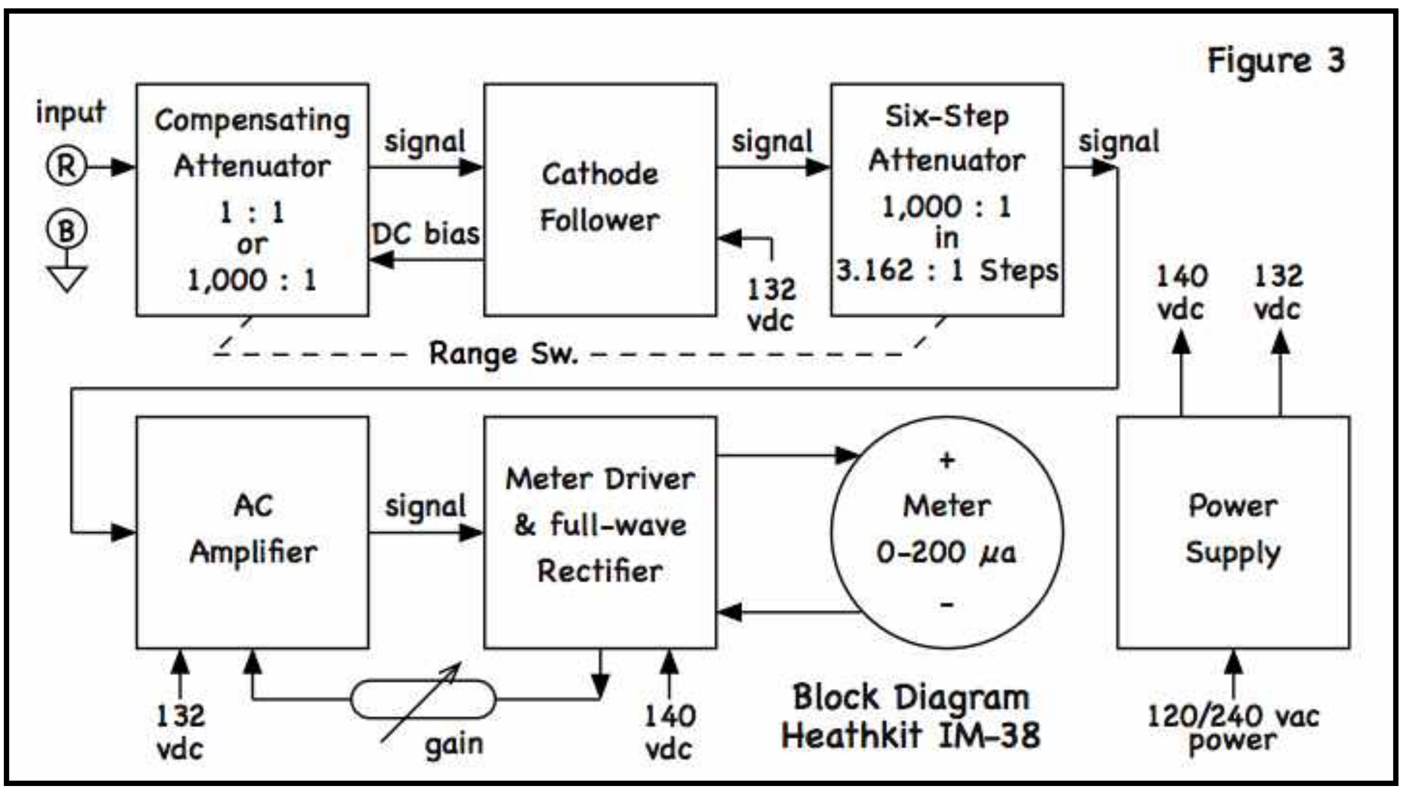
The IM-38 Circuit Description:

A schematic of the IM-38 was not available when I wrote this, however the similar IM-21 is shown as Figure 6.

Figure 3 is a block diagram of the IM-38. The power supply is a simple half-wave rectifier using a silicon diode to produce about 140 VDC. Tapped off this voltage via an RC filter network is a 132 volt supply. The 140 VDC source powers the meter driver amplifier, and the 132 VDC source powers the input cathode follower and the AC amplifier. Filament voltage for the two tubes is supplied by a winding on the power transformer. This voltage is specified as 5.5 VAC, about 13% below the 6.3 VAC standard. This reduces the space charge around the cathode, which matters little since the plate current being drawn is small; perhaps this is done to reduce hum pickup? It does reduce heat and extend the life of the tubes. The filament wiring is balanced twisted pair with a pseudo transformer center-tap, composed of two 47 Ω resistors R28 and R29 to balance the filament voltage around ground, again to reduce hum pickup.

Compensating Attenuator:

The Input binding posts connect to an attenuator. The black post connects directly to chassis ground; the red post is coupled to the attenua-



tor through a capacitor. On the ranges below 10 VAC, the signal is fed directly to to the cathode follower stage; on the ranges of 10 VAC and above the signal is divided by 1,000 before being fed to the cathode follower. The attenuator is composed of resistors R1 and R2 and capacitors C2 and C3. R1 is a 10 MΩ that sets the input resistance; it is large enough, compared to R2 (10 KΩ) that the accuracy is not compromised. Capacitor C2 and C3, along with stray capacitance form a capacitive 1,000 : 1 divider. C2 is adjustable and may be adjusted for the best frequency response. The input impedance is 10 MΩ shunted by 22 pF on the 0.01 through 3 volt ranges, and 10 MΩ shunted by 12 pF on the 10 through 300 volt ranges. This is made up mostly of stray and tube capacitances.

The low side of the attenuator is AC coupled to ground through C4, but is set to about 11 VDC by a voltage divider composed of R3 and R5. This provides DC bias for the cathode follower.

Cathode Follower:

V1A, the triode section of the 6AW8 tube is wired as a simple cathode follower. Plate voltage is held constant by electrolytic C5. R4, in series with the grid is for oscillation suppression. With the 11 volt bias the tube draws around 1.2 ma. The output is taken off the cathode. The stage has a voltage gain of just under one, but there is a large power gain providing isolation from the high impedance of the input. The output is capacitively coupled to the second attenuator.

Step Attenuator:

The step attenuator provides three decades of attenuation in six 10 dB steps. A resistor chain composed of six 1% resistors, R8 through R13, make up the divider. The AC voltage division at any given position of the switch is the total resistance of the resistors from that switch position to ground divided by the series resistance of six resistors, which is 31.62 KΩ. Table II shows the resulting total attenuation for each of the the six positions. Note that the first four of these attenuations are again used after the 1,000:1 attenuator is introduced for the last four range positions - 10 V, 30 V, 100 V and 300 V. This is shown in Table III.

Att. Pos.	Divider Resistor Values (ohms):		Resistor Sum from Att. Pos. to Gnd.:		Step Attenuator
1	R8 =	21,620	R8 ... R13 =	31,620	x 1
2	R9 =	6,838	R9 ... R13 =	10,000	x 3.162
3	R10 =	2,162	R10 ... R13 =	3,162	x 10
4	R11 =	683.8	R11 ... R13 =	1,000	x 31.62
5	R12 =	216.2	R12 ... R13 =	316.2	x 100
6	R13 =	100	R13 ... R13 =	100	x 316.2
Sum of the 6 Resistors					
	R8 ... R13 =	31,620			

Table II: IM-38 Step Attenuator Calculations

AC Amplifier:

After the second attenuator, the input to the AC amplifier will see an AC voltage of 0 - 10 mV on the five ranges with a ‘1’ and 0 - 9.5 mV on the ranges with a ‘3’. The AC amplifier uses the pentode half of V1, the 6AW8. This stage would have an open-loop gain of about 400 except for the regenerative feedback introduced by the cathode resistance. The gain is further reduced by feedback from the next stage. This feedback is introduced into the cathode via R18, a vari-

RANGE	1st. Attenuator	2nd. Attenuator	Total Attenuation	Total dB* Attenuation
0.01 V	x 1	x 1	x 1	-40 dB
0.03 V	x 1	x √10	x 3.162	-30 dB
0.10 V	x 1	x 10	x 10	-20 dB
0.30 V	x 1	x 10√10	x 31.62	-10 dB
1.00 V	x 1	x 100	x 100	0 dB
3.00 V	x 1	x 100√10	x 316.2	+10 dB
10.0 V	x 1,000	x 1	x 1,000	+20 dB
30.0 V	x 1,000	x √10	x 3,162	+30 dB
100 V	x 1,000	x 10	x 10,000	+40 dB
300 V	x 1,000	x 10√10	x 31,620	+50 dB

* Relative to the 1-volt range (0 dB = 0.775 Vrms).
dB meter scale is from -12 dB to +2 dB making the overall range of the instrument -52 dB to +52 dB

Table III: IM-38 Step Attenuator Calculations able resistor, which sets the overall gain of the two stages and, hence, the calibration of the meter.

Meter Amplifier and Rectifier

The next stage is another pentode amplifier. Due to the low plate resistance presented by the meter circuit it has much lower gain than the previous stage. It also has degenerative feedback in the cathode due to R26, further reducing the overall gain. R26 is bypassed by C14 to give increased gain over about 160 KHz, improving frequency response of the circuit.

Diodes X1 through X4 (germanium type 1N161) form a full-wave rectifier to provide pulsating DC to the meter. C16 smoothes the pulses from the rectification, letting the meter respond to the average DC current.

A portion of the AC signal driving the meter appears across R27. This signal is in phase with the input signal on the preceding stage, but is introduced into the cathode providing feedback. Rough calculations show the overall voltage gain of the two pentode stages to be about 62 dB open-loop. With the approximately 19 dB Heathkit specifies for the feedback, the overall gain is on the order of 43 dB, or about 1.5 volts RMS at the plate of V2.

Operation:

Using the IM-38 is quite simple. Prior to turn-on, you should check that the meter needle is resting over zero on the voltage scales. Plastic cased meters sometimes suffer from static buildup on the plastic meter cover, causing the needle to respond to the electrostatic field. If this is the case, the needle will respond to your touching the meter face. Lightly cleaning the meter cover with a mild dishwashing solution will neutralize the static charge. If the meter needle is still not at zero, the mechanical zero should adjusted.

The unit is turned on by moving the function switch from the OFF position to the 300V division. The unit is then allowed to warm up for a few minutes; during this time the meter will move around and finally come to rest at zero.

Once warmed up, connect the test leads from the meter to the AC voltage to be measured. **Heed the fact that the black lead is directly connected to both the chassis and power-line ground.** Set the meter range switch to the position that gives a reasonable deflection of the meter needle. Read the voltage on the proper meter-scale, using the range printed on the front panel switch. To get the reading in decibels, be sure the meter needle is

[See **IM-38**, page 13]

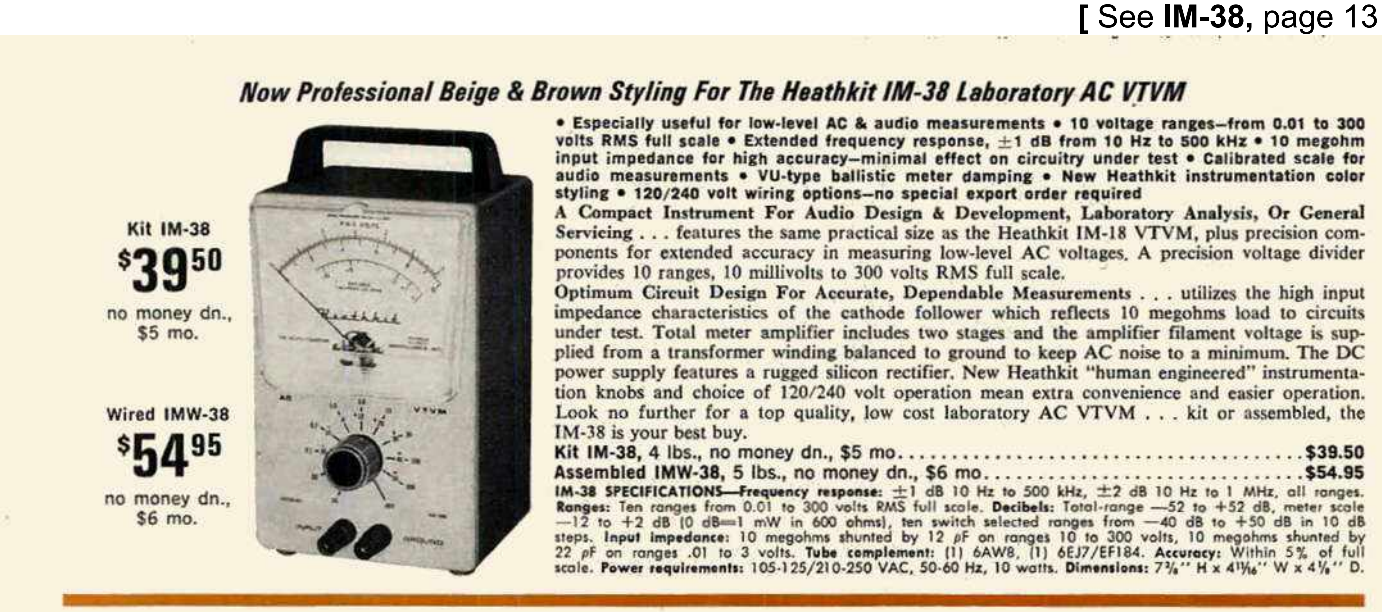


Figure 4: IM-38 Advertisement from the Summer 1969 Heathkit Catalog.

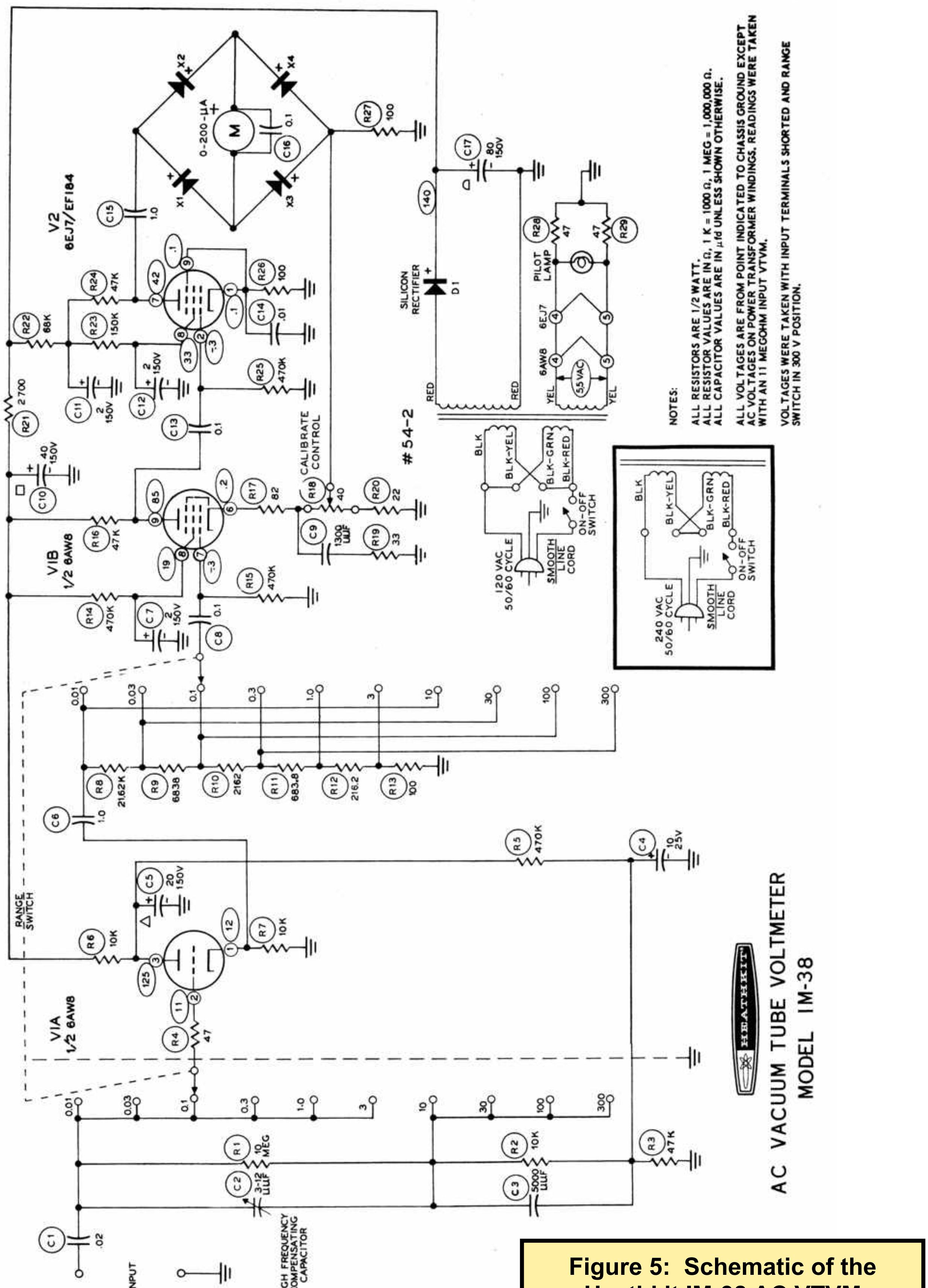


Figure 5: Schematic of the Heathkit IM-38 AC VTVM

on a range that puts it on the red dB scale; then read the dB from the schedule. Finally, add or subtract the dB value given on the current range-switch position.

Comments:

I'd like to apologize for being lax in putting out this column monthly. A family situation has required a lot of my time; I'm also currently involved with two other high-priority projects that are consuming a lot of my spare time.

Several people have written, asking that I cover the Heathkit Single Bander transceivers. Yes, I have managed to acquire enough information to get started on that project but it's still a few months off. It appears Heath did some unusual things when designing these transceivers. They do not follow the scheme used in the SB line produced over the same time period.

I also have a few kits I have yet to do including the first (and only) Heathkit TV I built - the GR-104 circa 1966; also the IM-4180 FM Deviation Meter; the simple SK-107 Stereo Synthesizer; and more.

Notes:

1. *Heathkit Test Equipment Products* by Check Penson - WA7ZZE. Available from Amazon.com $19.95
2. VU meters also have specified weighting and dampening factors for the meter movement.

73, from AF6C

This article originally appeared in the December 2015 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

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

Be sure to update>   Thanks - AF6C