Heathkit of the Month #110:
by Bob Eckweiler, AF6C

Figure 1: Heathkit IM−10 “Deluxe Service Bench” VTVM. The first of the Service Bench VTVM series, vertically configured with the controls below the large 6” meter. Photo courtesy of Chuck Penson - WA7ZZE.

ELECTRONIC TEST EQUIPMENT
Heathkit “Deluxe Service Bench” VTVMs.
(IM−10, IM−13, IM−28, IM−32 & IM−5228)

Introduction:
During its reign, Heathkit sold three series of vacuum-tube voltmeters (VTVMs); the familiar table-top series, an AC only audio series and a professional series. The V−1, the first of the table-top VTVMs, was the second-ever Heathkit produced. The table-top models were the topic of HotM #19[1]. featuring the V−7A. The AC VTVMs were covered in HotM #47[2] featuring the AV−3. The professional “Deluxe Service Bench” VTVMs will be covered in this article. **Table I** shows the model numbers of the three groups and the range of their production dates.

In 1961, along with a major styling change, the VTVM prefix changed from “V” to “IM” (presumably standing for: Instrument, Meter). Various meters, other than VTVMs, share the IM prefix.

The “Deluxe Service Bench” VTVM Series:
With the Radio / Television / HI-FI repair business booming in the early sixties, Heathkit decided to come out with a larger version of their VTVM for professional bench use. They dubbed their product line the “Deluxe Service Bench” (DSB) VTVMs. Altogether five versions of the DSB line were produced between 1961 and 1989. They are (in order by date) the IM−10, IM−32, IM−13, IM−28 and IM−5228. These VTVMs feature a 6” meter vs. 4½” on most of Heath’s other VTVMs. The range resistor values in the DSB meters were changed to provide a constant ratio across the seven ranges. Also, the two lowest AC voltage ranges were given separate meter scales for higher accuracy. (more on these changes will follow.)

Here is a link to the index of Heathkit of the Month (HotM) articles:
http://www.w6ze.org/Heathkit/Heathkit_Index.html

The DSB series is heavily based on the V-7. circuit. They both use the same range and function rotary switches. Newer part numbers

1. Notes begin on page 17.

HEATH VTVMs

TABLE-TOP VTVMs (14 Models)

V–1	12/47-03/49	V–5A	05/52-08/52
V–2	04/49-11/49	V–6	09/52-08/54
V–2A	11/49-12/49	V–7	09/54-08/55
V–3*	03/49-05/49	V–7A	09/55- 1961
V–4	01/50-08/50	IM–11	1961 - 1969
V–4A	09/50-08/51	IM–18	1969 - 1977
V–5	09/51-04/52	IM–5218	1977 - 1983

AC VTVMs (5 Models)

AV–1	09/51-08/52	IM–21	1961 - 1969
AV–2	09/52-08/56	IM–38	1969 - 1977
AV–3	09/56 - 1961		

PROFESSIONAL (DSB) VTVMs (5 Models)

IM–10	1961 - 1962	IM–28	1969 - 1977
IM–32	1962 - 1963	IM–5228	1977 - 1989
IM–13	1963 - 1969		

Dates prior to 1961 came from Heath ads in Radio (TV) News. Later dates are from catalogs and are approximate. *The V-3 was advertised only, it appears.

TABLE 1

for these switches appeared in 1969. Electrically the new switches are identical to their predecessors, but mechanically they have a modified flat on the shaft to accommodate push-on knobs for the “new look” and “post new look” styles of the later models. Circuit-wise, other than the DC and AC range resistors, circuit changes are minimal.

The Two New Features of the DSB VTVMs”

On all Heathkit series of VTVMs the meter ranges are set so that every two ranges is a decade increase – such as 1.5 V, 5 V, 15 V, 50 V, etc. However, the table-top VTVMs use multipliers that make the ratios between alternating ranges 3⅓ then 3 (If you multiply those numbers together you get exactly 10, a decade.) While this creates no problem when measuring DC voltages, it creates small errors when using the AC decibel scale, especially between adjacent ranges. A ten-fold change in voltage (a decade) is 20 dB. A 3.162… (the square root of ten) change of voltage is 10 dB. If the change between voltage ranges are 3 or 3⅓, that results in 9.54 dB or 10.46 dB respectively. About a half dB of error.

The problem may be corrected if the ratio between scales is changed to a constant square root of ten (3.162…) Every second range is still exactly a decade (20 dB) change, and every adjacent range is 10 dB change, but the full scale meter ranges are now approximately 1.58 V, 5 V, 15.8 V, 50 V, etc. This is corrected on the meter scale by simply stopping the “15.8” meter scale short of full-scale at 15, while the “50” scale goes to full-scale (see **Figure 2**.) If you multiply 15 by √10 [3]

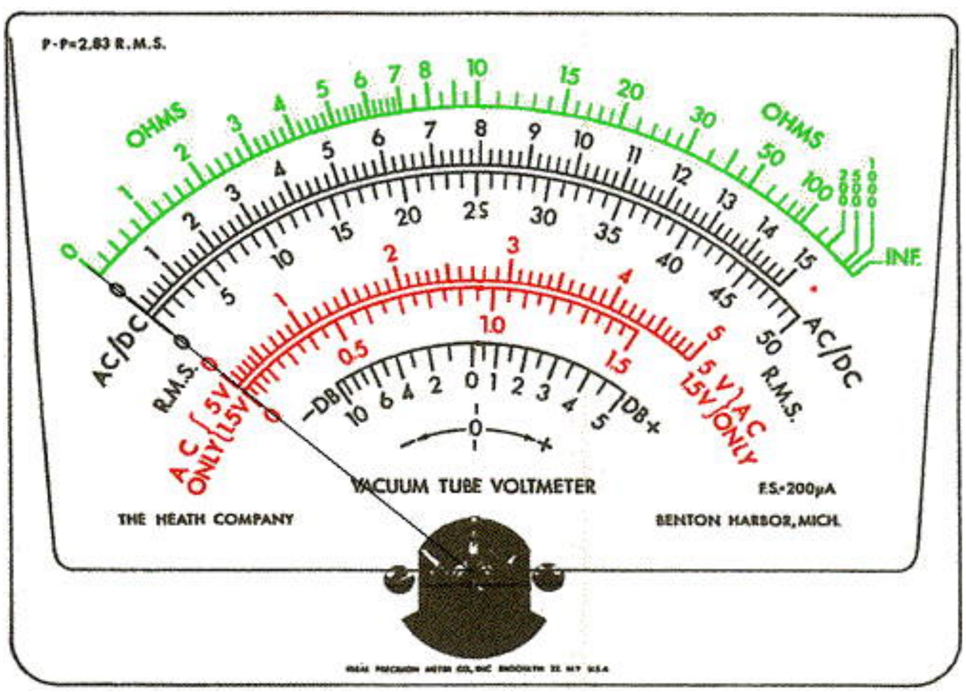


Figure 2: Drawing by author showing the seven meter scales on the Deluxe Service Bench VTVMs. Note the two black scales end so that if the upper scale were expanded it would end at 15.8. Also 15 corresponds with 47.4. See text for explanation.

you get 47.4, and the black 0–15 meter scale ends just above 47.4 on the black 0–50 scale. This makes the black dB (decibel) scale accurate with both black voltage scales. The multiplier resistors on the DSB series of VTVMs have been changed from the values used on the table-top VTVMs to provide a true √10 ratio between ranges.

The second change for the DSB series voltmeters is the addition of two additional meter scales, colored red, for the two lowest AC voltage ranges. Again refer to **Figure 2**. The rectifier used to change AC into DC in the VTVM is not linear at low voltages. This problem is ignored on the table-top VTVMs, and AC voltages will read low on the two low ranges. On the professional DSB meters those ranges are read accurately on their own two corrected red-colored scales.

This might seem a 'Catch 22' situation since voltages read on the red scales cannot be converted to dB directly on the black scale. But it is simple to use the zero control to set the pointer to the corresponding voltage on the black scale and then read the dB on the black dB scale. Just remember to re-zero the meter when done.

The Heath AC series of VTVM meters all use ranges based on the square root of ten. They also don't suffer from rectifier non-linearity since the rectification is not done until after the last stage of amplification, and any non-linearity is common to all ranges and can be corrected on the meter scale. These series use 0–3.162 and 0–10 scales with the former scale ending at 3.0 (just above 9.49 on the full-scale 0–10 volt scale.)

The IM–10 "Deluxe Service Bench" VTVM:
Heathkit released the first "DSB" VTVM in the spring of 1961 and gave it the designation IM–10 (**Figure 1**). The VTVM features a 6" meter and was priced at $32.95. The IM–10 is taller then it is wide, measuring 9½"H x 6½"W x 5"D, with the meter at the top filling most of the width, with the controls below. Because of the large width there is plenty of room for the controls and they are well separated. The **ZERO ADJ**ust and **OHMS ADJ**ust controls are horizontal thumbwheels driving miniature potentiometers. These thumbwheels require an Allen wrench to install (included). Between these controls and slightly below on

IM–10 / IM 32 Front Panel Layout

Across the top:	
Meter	0 – 200 µA, 6" with 7 color scales. (Text shows scale color)
OHMS:	**0 – INF** (10 at center)
AC/DC Volts:	**0 – 15** (**R.M.S.** on AC)
	0 – 50 (**R.M.S.** on AC)
AC Volts	**0 – 5** (**R.M.S.**) range only
	0 – 1.5 (**R.M.S.**) range only
Decibels	**-10 – + 5 dB** (0 dB = 1mW into 600Ω)
Center zero:	**- | +**
Second row (L to R):	
ZERO ADJ.	Potentiometer - 10KΩ Thumbwheel
Pilot Lamp Ass'y	Red jewel - #47 bulb (located between and slightly below the Thumbwheels)
OHMS ADJ.	Potentiometer - 10KΩ Thumbwheel
Third row (L to R):	
Mode Switch:	Five-position rotary switch marked: **OFF, A.C., D.C .–, D.C. +, OHMS**
Range Switch	Seven-position rotary switch marked: **1.5 V. RX 1, 5 V. RX 10, 15 V. RX100 50 V. RX 1000, 150 V. RX 10K, 500 V. RX 100K, 1500 V. RX 1 MEG.**
Fourth row (L to R):	
A.C. OHMS	Banana Jack - Red
D.C.	¼-inch Phone Jack
COMMON	Banana Jack - Black

TABLE II

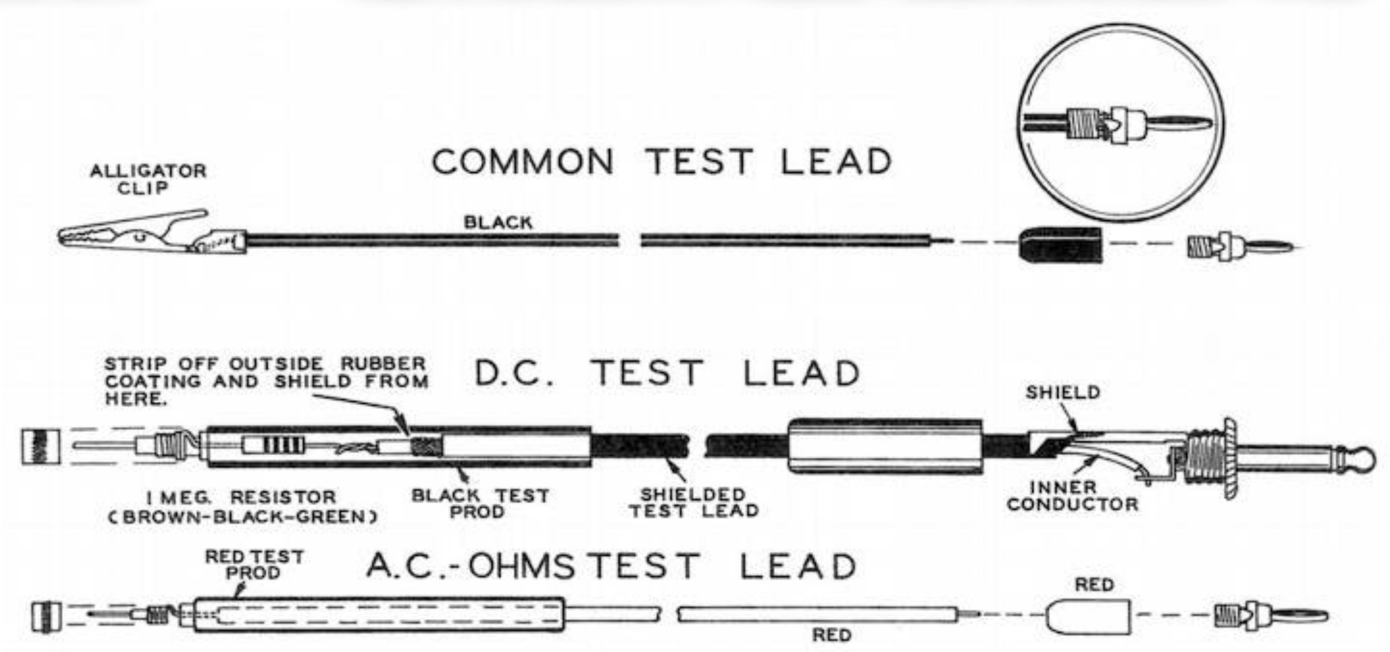


Figure 3: The three test leads supplied with the IM-10 and IM-32.

the panel is a small jeweled pilot light utilizing a #47 incandescent bulb. **Table II** shows the controls of the IM−10 (and IM−32). The AC line cord exit is at the rear of the cabinet. There are three internal calibration potentiometers, AC BAL. AC CAL. and DC CAL. The cabinet must be removed for access to these controls.

The IM−10 came with same three test leads as the V−7(A) See **Figure 3:**

- A black lead with a banana plug at one end and an uninsulated alligator clip at

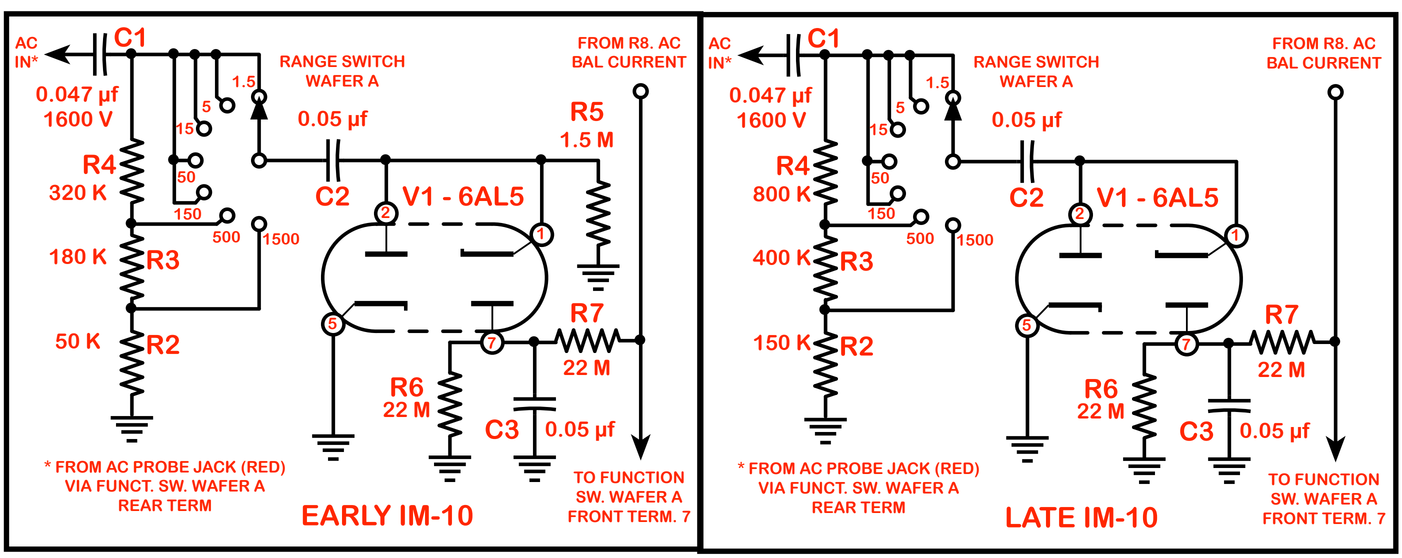


Figure 4: On the left is the early IM−10 AC rectification circuit. On the right is the later circuit which improved the input impedance, by a factor of three, to 1 megohm shunted by 30 µµf. R2, R3 and R4 values were changed and R5 was removed entirely from the circuit. The modification occurred sometime between May and July of 1961.

Drawings by the author.

the other, this is the common lead for all measurements and is electrically connected to the VTVM chassis.

- A red lead with a banana plug at one end and a red test probe at the other; this is the active test lead for AC voltage and ohms measurements.
- A black shielded lead with a ¼-inch phone plug at one end and a black test probe containing a 1 meg Ω series resistor at the other; this is the active test lead for DC± voltage measurements.

The test leads connect to black and red banana jacks and a ¼-inch phone jack, respectively, on the front panel of the IM−10 (and IM–32).

The IM−10 underwent an early production change involving the AC divider resistors around the 6AL5 on the schematic. Initially the IM−10 was specified to have a rather low AC measurement impedance of 320 KΩ shunted by 30 µµf [4]. The modification improved this to 1 MΩ shunted by 30 µµf, bringing it more in line with the V-7 and later table-top VTVMs[5]. The changes are shown in **Figure 4**. Whether Heathkit offered an update kit of parts for early owners is not known.

The early schematic is shown in the Fall / Winter 1961 / 1962 Heathkit catalog. Which, surprisingly, is after the circuit had been changed, as indicated by the updated AC input impedance specification. The April 1962 issue of *73 Magazine* reviews the IM−10 and also shows the early schematic[6].

The IM−10 came to market in the spring of 1961 while Heathkit was in the process of changing the style of their test equipment from Classic I to Classic II[7]. Thus the IM−10 ended up with a style unlike either of the two styles. It features wide white arcs, with black lines, marking the positions of the range and function switches, and knobs that appeared only briefly on kits (IO−30 scope and TT−1 tube tester) released in the same period. In 1962 the IM−10 was restyled in the Classic II configuration as the IM−32.

The IM−32 "DSB" VTVM:

IM−32 (**Figure 5**), is electronically almost identical to the later version of the IM−10 and matches the new Classic II style. Physically they are identical in dimensions and control layout. Rubber feet were added to the IM-32 replacing the stamped metal feet that were part of the cabinet on the IM-10, and the kit came with solder. The internal fuse

Figure 5: Heathkit IM−32 Deluxe "Service Bench" VTVM The Classic II style update of the IM−10. It was the last of the vertically oriented Bench VTVM. Photo courtesy of Sonny Clutter, www.radiolaguy.com.

Figure 6: Heathkit IM–13 Deluxe “Service Bench” VTVM In the Classic II style, and in the new horizontal format. Note calibration access holes to the right of the meter. Photo by author.

was changed to ⅛ amp slow-blow. The 1½ V C-battery was no longer included in the kit. The price remained at $32.95.

The IM–13 “Deluxe Service Bench” VTVM: After about a year, the IM–32 was replaced with the IM–13 **(Figure 6)** which is still in the Classic II style, but is laid out horizontally instead of vertically, measuring 5” H x 12¹¹/₁₆” W x 4¾” D, with the same large 6” meter on the left and the controls to the right of the meter. The ZERO ADJust and OHMS ADJust controls are no longer thumbwheels, but potentiometers with a knob-less plastic knurled shaft. The pots feature a built-in ball vernier drive making adjustment easy even with the small diameter control shaft. Another feature added to the IM–13 is front panel access to the three internal calibration controls. These can be accessed, using a small screwdriver, through three holes just to the right of the meter. In the prior models access required removing the cabinet. See **Table III** for front panel layout of the IM–13, IM–28 and IM–5228 models.

Other changes were the replacement of the 9.1Ω resistor in the ohms divider chain from a ½-watt 5% wire-wound resistor (2–48) to a 2-watt precision resistor (3B–4)[8]. An included gimbal mounting bracket allows the meter to be mounted under a bench shelf, on a vertical surface or just sitting on (or bolted to) the bench-top. The VTVM can be easily removed from the mount if it needed to be used away from the bench.

The internal fuse and holder were removed (the IM–13 and later models are not fused.) The #47 incandescent pilot lamp and jeweled assembly were replaced with a plastic lens assembly containing a neon bulb. And the power rectifier was changed from selenium (#57–22) to a silicon diode (#57–27) without the addition (or need) of any dropping resistor[9].

Another significant change was the test lead set. The three test leads were replaced by a single test probe with a ¼-inch phone plug at one end with a shielded wire and a black ground lead exiting the plug body. The black ground lead terminates with an alligator clip. The shielded lead ends in a special test probe with a flip-type switch that selects ei-

Figure 7: Top shows the new phone plug with its thicker insulation to prevent flashover at higher voltages. Below it is the standard phone plug used on the earlier VTVMs.

Figure 8: Heathkit IM−28 Deluxe “Service Bench” VTVM In the “New Look” style. It is the first of the series to use a 120/240 V primary transformer and a three-wire AC plug. Photo by author.

There was a minor change to the IM−13 specifications due to the new horizontal layout. The input capacitance (at the front panel terminal) increased from 30 to 40 pF in shunt with 1 Meg Ω, likely due to the new layout. However the cable of the shielded test lead adds about 160 pF when used.

Initially, IM−13 pricing remained at $32.95. For the first time Heath offered a factory wired version of the VTVM. The wired IMW-13 initially sold for $49.95. The prices increased to $36.50 and $56.95 respectively by 1969 shortly before the IM−13 was replaced by the IM−28.

ther **AC – Ohms** in one position or **DC** in the other. In the AC – Ohms position the tip of the test probe is directly connected to the shielded test lead, and in the DC position a 1 Meg Ω resistor is switched in series with the test probe, The front panel contains only a ¼-inch phone jack; no more red and black banana jacks. Also, a new ¼” phone plug with heavier insulation replaces the standard phone plug used on the earlier VTVMs (**Figure 7**).

The IM−28 “DSB” VTVM

In the summer of 1969 the the IM−13 was rebranded into the IM−28 (**Figure 8**). It initially sold at the same price as the recently discontinued IM−13, $36.50 in kit form and $56.95 factory wired.

The IM−28, supporting the “New Look” style, was the first of the DSB VTVMs to operate on 210 to 250 VAC as well as 105 to 125 VAC and incorporate a three-wire line cord with ground lead. Other than the dual primary power transformer the unit appears electronically identical to the IM−13 with the exception of the neon pilot lamp assembly which was replaced by an NE-2E and separate lens. The 150 KΩ resistor remains, and is used for 120 and 240 VAC.

Figure 9: The last of the “Deluxe Service Bench VTVMs. The IM−5228, sporting the “Post New Look” style and a new style meter continued in production into 1989. Photo courtesy of Chuck Penson WA7ZZE.

The IM−28 continued to be sold until 1977. At that time the it was selling for $59.95. The as-

IM–13 / IM–28 / IM–5228 Front Panel Layout

Left half of front panel:	
Meter	Same as in Table I
Vertically to right of meter (Top to Bottom):	
DC CAL	Access hole to pot behind panel.
AC CAL	Access hole to pot behind panel.
AC BAL	Access hole to pot behind panel.
Right half of front panel:	
First row (L to R):	
FUNCTION:	Five-position rotary switch marked: **OFF, A.C., D.C .–, D.C. +, OHMS**
RANGE:	Seven-position rotary switch marked: **1.5 V. RX 1, 5 V. RX 10, 15 V. RX100 50 V. RX 1000, 150 V. RX 10K, 500 V. RX 100K, 1500 V. RX 1 MEG.**
Second row (L to R):	
ZERO ADJ. [a]	Potentiometer - 10 KΩ w/vernier.
Pilot Lamp Ass'y	NE-2 neon lamp in amber lens.
OHMS ADJ. [a]	Potentiometer - 10 KΩ w/vernier.
Third row (centered):	
Connector	¼-inch phone jack

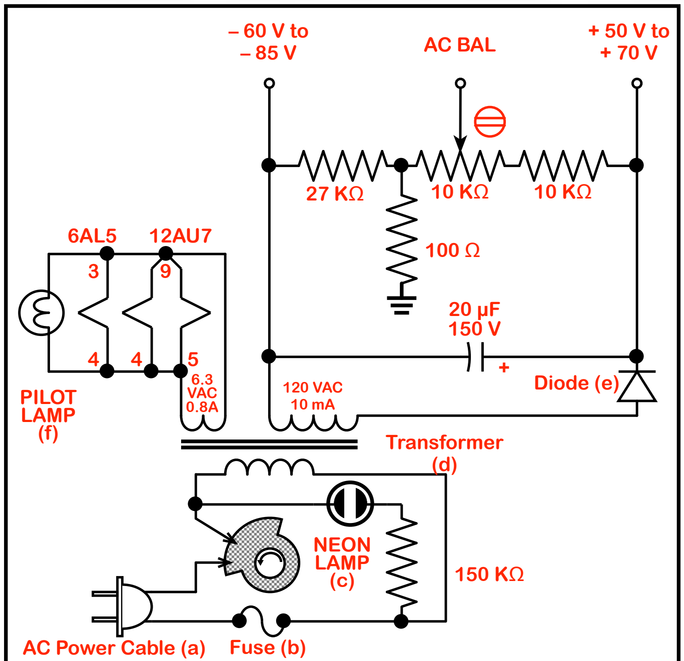
[a] On the IM–5228 …**ADJUST** is spelled out.

TABLE III

sembled model SM21A, (rebranded when Slumberger bought Heath) sold for $95.00.

The IM–5228 "DSB" VTVM

The IM–5228 VTVM, replaced the IM–28 in 1977 at the same $59.95 price as the unit it replaced. However the factory wired price of the SM–5228 increased to $100.00. The IM–5228 was designed in the "Post New Look" style **(See Figure 9)**. The IM–5228 VTVM sold for thirteen years until 1989 when Heath production was waning. In the Christmas 1987 catalog the IM–5228 price was $89.95. Circuitry remained the same as the IM–28, but the unit sports a new style meter, though the specifications and meter scales



Notes for figure 10:

a. The IM–10, IM–32, & IM–13 use a two wire power cord. The IM–28 & IM–5228 use a three wire power cord.

b. Only the IM–10 & IM–32 contain a fuse; ¼ A and ⅛ A respectively. The IM–32 fuse is slow-blow. Fuse is internal.

c. The IM–13, IM–28 & IM–5228 have a neon pilot lamp.

d. Transformers rated secondaries of 120 vac @ 10 ma and 6.3 vac at 0.8A. The IM–10, IM–32 & IM–13 use #54-2 Transformer. The IM–18, IM–5218, IM–28 and IM–5228 a use dual primary version part #54-2-24. Dual primary wiring is not shown here. See text.

e. The IM–10 & IM–32 use a (57–22) selenium rectifier. The IM–13, IM–28 & IM–5228 use a (57–27) silicon diode rectifier.

f. The IM–10 & IM–32 use a bayonet #47 6.3 V bulb mounted in a jewel lens socket.

Figure 10: The Heathkit VTVM power supply.

remain the same. The factory wired SM–5228 was discontinued in 1981. In 1981 Heath started selling the PKW–4, a wired replacement test probe for the IM–5228 (and the IM-13 & IM–28), for $10.95. The last time Heathkit is believed to advertise a VTVM is in the Christmas 1989 catalog. At that time the IM–5228 was selling for $129.95 in kit form. The PKW-4 wired replacement probe was discontinued in late 1986, last selling for $19.95.

Heathkit "DSB VTVM Circuit Description[10]:
The VTVM circuit after the V–7 hasn't been discussed before in HotM. The actual circuit since the V–7 has been pretty constant with minor changes. While the circuit descriptions that follow can describe much of the later table-top Heathkit VTVMs, The following descriptions focus on the DSB series of VTVMs. The VTVM circuit can be divided into seven sections: Power supply, meter amplifier, meter calibration circuits, DC range divider, AC range divider, ohmmeter divider and probe.

Power Supply:
Both the table-top and bench series VTVMs share the same basic circuit. They do use different power transformers, though both have the same secondary ratings. The differences are physical because the transformer used with the table-top VTVMs mount on a circuit board, and the transformer used with the DSB VTVMs mount on the chassis. The basic circuit, shown in **Figure 10,** is a simple half-wave rectifier with a solid-state diode and a 20 µF filter capacitor[11]. Surprisingly, the filter capacitor is only rated for 150 VDC which is close to the actual voltage across it [12]. The capacitor working voltage was not increased[13] even when the rectifier was changed from selenium used in the IM–10 and IM–32 (part # 57-22) to a silicon diode used in the later VTVMs (part # 57-27).

The power supply B+ and B– voltage is referenced to ground by resistors so that the power supply provides a positive voltage of + 50 to +70 V (nominally + 65 V) and a negative voltage of 60 to 85 V (nominally –75 V). these values are shown on the Heathkit schematics. Very little current is drawn by the circuit VTVM.

The power supply supports the 12AU7 amplifier tube and supplies a very small current to counter the offset contact potential created

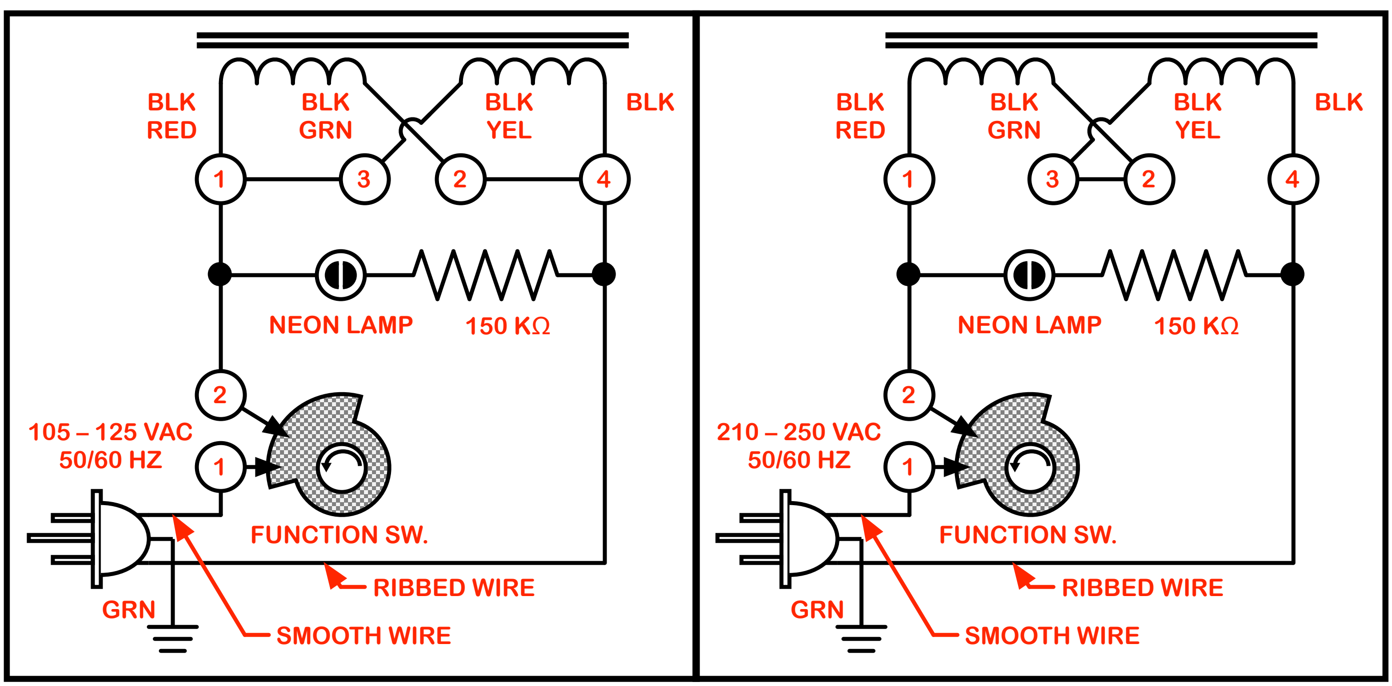


Figure 11: On the left is the primary wiring of the IM–28 and IM–5228 for 120 VAC; On the right is the primary wiring for 240 VAC. A simple wiring change is required to switch.

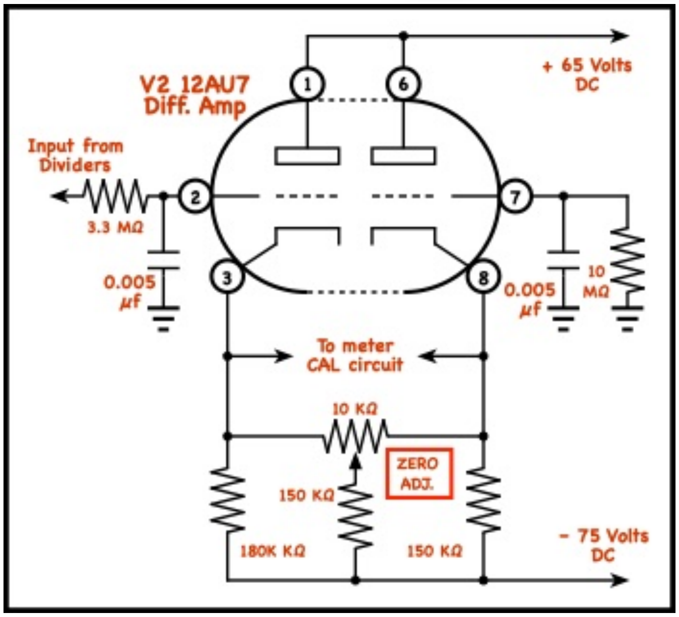


Figure 12: The meter amplifier utilizes a 12AU7 dual triode. About 1.44 volts is applied by the divider chain to give full scale deflection on the meter.

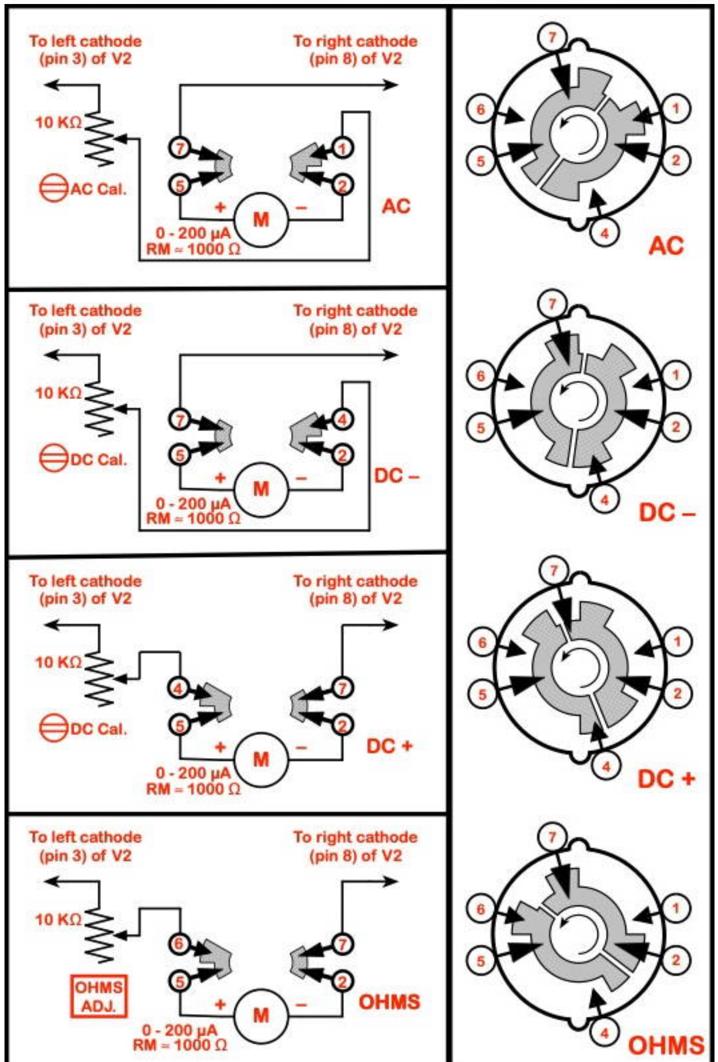


Figure 13: The meter circuit driven off of the two cathodes of the 12AU7 twin triode tube. To the right is the associated switch wafer and its connections for each of the four function positions. Controls marked with a slotted shaft end are internal controls accessible in late units through holes in the front panel. Controls shown with a box are located on the front panel.

by the 6AL5 rectifier tube used for the AC ranges. It also provides all needed filament voltage and power for the incandescent pilot lamp in the early meters.

Only the primary wiring for the IM–10, IM–32 and IM–13 are shown in **Figure 10** (the IM-13 is not fused.) A dual primary transformer, (#54-2-24) is used on the IM–28 and IM–5228 to provide 105 - 115V or 210 - 240V capability with a wiring change. (See **Figure 11**).

The early IM–10 and IM–32 VTVMs use a #47 (6.3V @150 ma) in a jeweled red pilot lamp assembly. The IM–13 uses a pre-assembled neon lamp with lens (#412-12) for its pilot light. Later DSB units, the IM–28 and IM–5228, use an NE-2E neon bulb (#412-36) that slips into a plastic lens (#413-11). The neon lamp is across the primary transformer winding in series with a 150 KΩ resistor making it brighter with 230 volt power.

Meter Amplifier:

Figure 12 shows the basic amplifier circuit. The plates of the tube are connected directly to the positive 65 V supply. The cathodes are connected through resistors and a balancing network to the negative 75 V supply. The meter is connected between the cathodes along with the necessary switching and calibration circuits; they will be discussed in the next section. With no input, both grids are at ground potential and plate current will flow

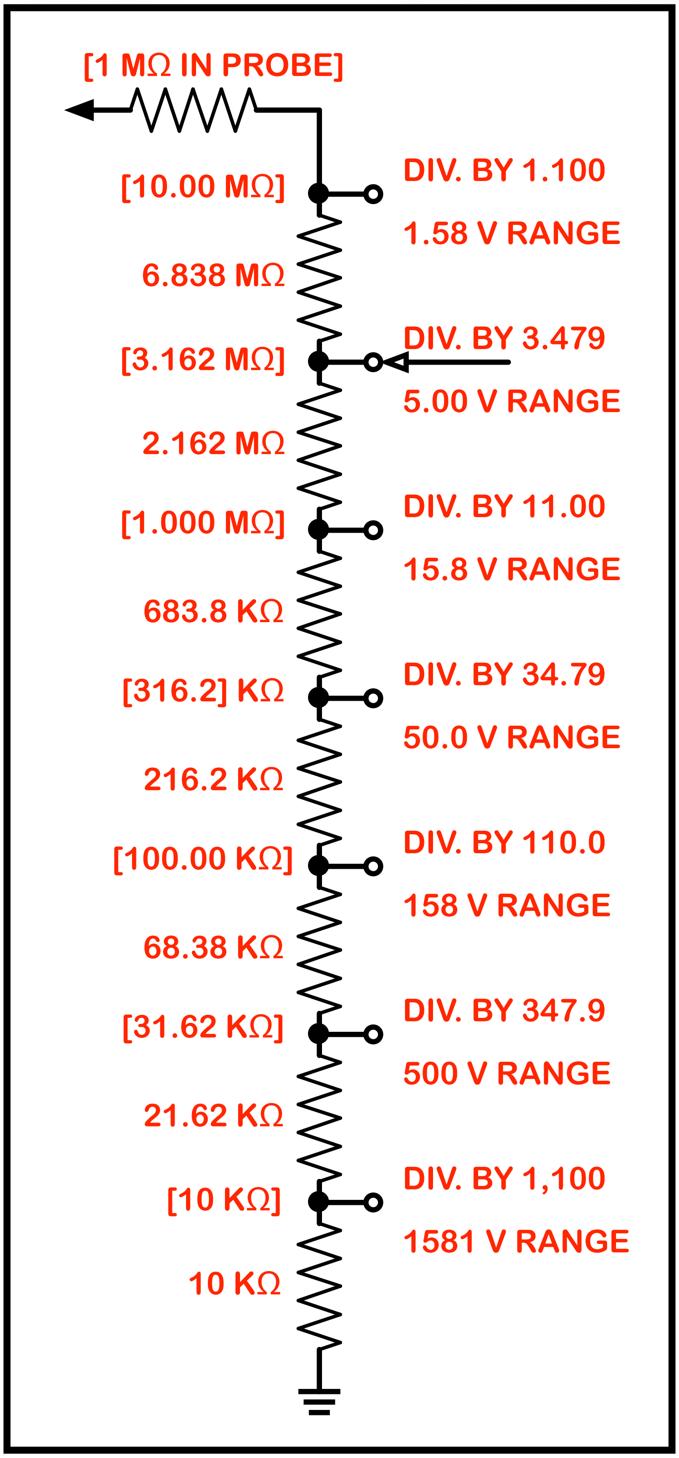


Figure 14: The DSB VTVM DC resistor divider chain with resistor values. The bracketed resistance values are the total resistance from the switch terminal to ground. Eleven million, divided by this resistance value, is the voltage division that occurs for that switch position. If full scale voltage is applied for a given range, the output voltage to the meter amplifier is 1.44 volts. On the 0 –15 black scale full-scale is actually 15.81.

in each half of the 12AU7 so that the grid to cathode voltage is about a negative 3 volts. The ZERO ADJUST control changes the cathode resistances. In balance, it is set so the voltage at each of the two cathodes are identical. The balance will happen near 45% of the control rotation since one cathode resistor is 180 KΩ and the other is 150 KΩ. This allows the control more adjustment on the up side, allowing the control to be used to set the meter to half scale so it can be used as a center-scale meter if desired. The amplifier can be thought of as a bridge circuit and the ZERO ADJUST balances the bridge.

With the function switch in DC+ or OHMS, the signal applied to the grid of the left tube section (pin 2) is positive that section draws more current and its cathode becomes more positive than the other cathode, unbalancing the bridge and sending current through the meter. With the function switch in AC or DC– the signal applied to the grid is negative resulting in the left section drawing less current and the right section drawing more. The circuit is designed so that a voltage of approximately ±1.44 volts at pin 2 will result in full scale meter deflection with the function switch in its correct position.

Meter Circuits:
Figure 13 shows the meter circuit for each of the four meter functions, AC, DC–, DC+ and OHMS.

Each circuit is the meter in series with a potentiometer. The AC CAL pot sets the AC calibration, the DC– and DC+ positions share the DC CAL pot, and the OHM ADJ. pot mounts on the front panel. It is used to set the meter to full scale with the test leads open. The FUNCTION switch selects the correct potentiometer and, when in the DC+ and OHMS position, reverses the meter leads.

DC Range Divider Circuit:

The voltage divider consists of seven resistors mounted on the range switch plus the 1 MΩ resistor in the probe. **Figure 14** is a schematic of the DC divider circuit. Some of it is also used for AC measurements.

The bracketed resistance values near each switch position give the total resistance from that position to ground. A voltage divider consists of two resistances, and the division is the total resistance divided by the resistance from the tap to ground. The total resistance is fixed at 11 MΩ (10 MΩ total in the seven dividers plus 1 MΩ in the DC probe trip.) As an example, assume the switch is at the 5 volt full-scale position. This calculates to 11 MΩ divided by 3.162 MΩ or 3.479. When 5.00 volts is applied to the tip of the probe, and the range switch is set to the 5 V range, the output is 5.00 divided by 3.479 or 1.44 volts. If you do these calculations for any of the other range positions you will end up with 1.44 volts. When the VTVM is calibrated, the DC CALIBRATE pot is adjusted so that 1.44 volts at the input to the meter amplifier results in full scale meter movement.

AC Range Divider and Rectifier Circuit:

When measuring AC voltages the input is connected to the AC rectifier circuit (Refer back to the right side of **Figure 3**) For AC ranges from 1.5 V to 150 V, the voltage to be measured is fed through C1, referenced to ground through the three resistor AC voltage divider chain and fed to the 6AL5, which is wired as a half-wave voltage doubler, producing a DC voltage approximately equal to the peak-to-peak voltage of the input AC voltage.

On positive AC peaks C2 is charged up through the left diode of the 6AL5 to the peak voltage (~1.4 times the RMS voltage.) On negative peaks the applied voltage is in series with the voltage across C2 and charges C3, through the right diode of the 6AL5, to twice the peak voltage (~2.8 times the RMS voltage.) Notice that this voltage is negative.

On the 500 and 1,500 AC volt ranges the voltages would exceed the voltage rating of the 6AL5 so they are divided down prior to reaching the tube, to correspond with a 150 volt AC input. The AC divider resistors appear to have been selected empirically for best accuracy due to the nuances of the voltage doubler circuit.

The resulting voltage is then applied to the DC range divider circuit through a 22 MΩ resistor. This divides the voltage across C3 by 3.2. Since AC voltages in the 500 and 1500 volt ranges are dropped to the 150 volt range, when the range switch is in those positions the output to the meter amplifier is taken from the 150 volt tap of the DC divider chain.

Since the V-1, Heathkit (along with many other VTVM manufacturers) has been struggling with offset on the lower AC ranges caused by contact potential in the rectifier tube. In HotM #86 [14] page 10 the solution for the V-6 is discussed. It involves knowing which diode in the twin-diode rectifier tube (6H6) has the higher contact potential, and the unit is then wired accordingly. The rectifier tube for the Heathkit V-6 came pre-aged and marked "reverse diodes" or unmarked. There were separate wiring steps depending on which your tube was.

The half-wave voltage doubler rectifier circuit used, starting with the V-7, solved the problem and allowed the AC BAL. control to balance regardless of which diode has the higher contact potential. The balance current comes from the power supply AC BAL. pot and is fed through four 22 MΩ resistors to the top of the DC range divider chain when the FUNCTION switch is in the AC position.

A separate AC CAL. potentiometer is switched in when measuring AC to allow it to be calibrated separately from the DC calibration.

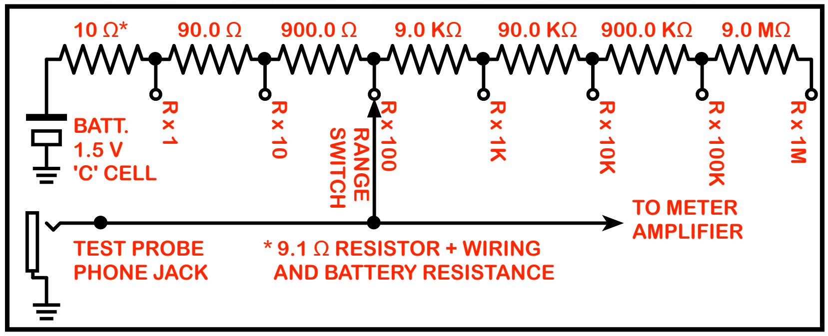


Figure 15: Schematic of the OHMS function with function switch in OHMS and Range switch in R x 100.

Ohms Circuit:

GREEN OHMS SCALE	
Scale Mark	% of Full Scale
0	0.00%
1	9.09%
2	16.67%
3	23.08%
4	28.57%
5	33.33%
6	37.50%
7	41.18%
8	44.44%
9	47.37%
10	50.00%
15	60.00%
20	66.67%
30	75.00%
50	83.33%
100	90.91%
200	95.24%
500	98.04%
1000	99.01%
INF	100.00%

TABLE IV

The ohms circuit is shown in **Figure 15** and a simplified version is shown in **Figure 16**. When the FUNCTION switch is in the OHMS position a 1.5 volt 'C' battery is connected to the meter amplifier input through a resistance. This resistance is controlled by the RANGE switch. Resistances of 10 Ω, 100 Ω, 1 KΩ, 10 KΩ , 100 KΩ, 1 MΩ and 10 MΩ correspond to the Rx1, Rx10, Rx100, Rx1K, Rx10K, Rx100K and Rx1M ranges. With the test leads shorted, the ZERO ADJ. pot is set so the meter reads zero ohms. Then, with the test leads open, the OHMS ADJ. pot is set so the meter reads full-scale. When the unknown resistance is connected to the test leads it is in parallel with known resistance and battery. If the range resistance and unknown resistance are the same, the meter will read half-scale. Note that half scale is 10 on the green OHMS meter scale.. The rest of the non-linear scale is calibrated correspondingly. Note that the 10 Ω resistor is in reality 9.1 Ω. The remaining 0.9 ohms is made up by the internal battery and lead resistances. It is important to keep these resistances low and constant for best accuracy on the Rx1 range. Because the input resistance of the meter amplifier is close to infinity there is no shunt resistance allowing for high range resistances and the ability to measure resistances up to 1,000 megohms.

Table IV shows the percent of full scale on the meter for marked values on the ohms scale.

VTVM Calibration:

The calibration of the DSB VTVM is straightforward. After aging the tubes the DC zero is checked. Switching between DC– and DC+ should not cause the zero to shift after proper aging.

DC Calibration:

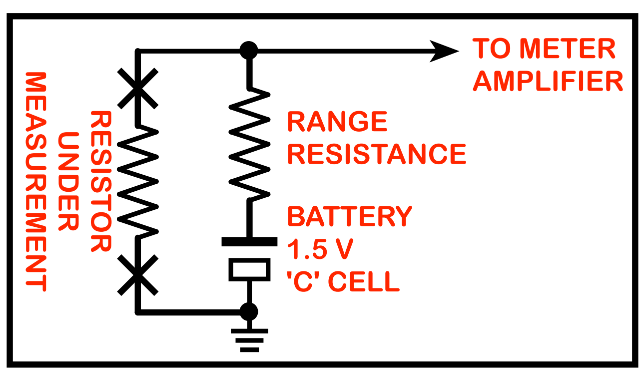


Figure 16: Simplified DSB VTVM OHMS circuit.

The IM−32, and most (if not all) Heathkit VTVMs before that model, came with a fresh carbon-zinc ‘C’ 1½ volt battery. Later models, both DSB and table-top VTVMs, required the builder to purchase a “standard” ‘C’ battery. This battery was used for DC calibration as well as in the ohms circuit. By “standard” battery Heathkit evidently meant a carbon-zinc battery. This type battery, when fresh, measures 1.55 volts. Refer back to **Figure 2** and notice the red dot just to the right of the 0 to 15 black scale. This dot corresponds to 1.55 volts. With the VTVM on the 1.5 volt range measuring DC+, properly zeroed, and the probe set to DC, the battery voltage is measured and the DC CAL. potentiometer is adjusted so the needle is over the red dot. This setting should be approached from the low side. Do not use an alkaline battery for calibration as their voltage, when fresh, is higher and varies between manufacturing processes.

AC Calibration:
Heathkit’s AC calibration relies on the accuracy of the AC line voltage. It varies a lot depending on where you are. Find an accurate AC voltmeter that you can borrow and use it to monitor your line voltage while calibrating.

Be very careful when following the Heathkit instructions. VTVMs with 3-wire plugs have their chassis connected to the AC ground. Be sure the common lead of the test probe is connected to the common side of the AC line and the probe is connected to the hot side of the AC line. If they are reversed, you’ll blow the fuse in the IM-10 or IM-32, but it will probably blow your house fuse and damage the later IM-28 or IM-5228. If they are reversedn the IM-13, if you touch the chassis of the meter and something close-by that is grounded to earth you will get a good shock, possibly fatal. A good solution is to use an isolation transformer, but be sure you are measuring the voltage after the transformer.

Once you have the voltage you are calibrating to, just measure it with the test probe (set to AC-OHMS) and adjust the AC CAL pot to the measured voltage.

Ohms Calibration:
There is no calibration for the ohms function. It relies on the precision resistors in the ohms resistor chain. They are 1% resistors and not prone to going bad. Use available known good 1% resistors to verify your meter is accuracy.

An alkaline battery is okay to use in the ohmmeter circuit (it’s just not good for calibration,) but choose a brand that is not prone to leaking; that is the most common problem found with VTVMs that use a battery in the ohms circuit. Be sure to remove the battery if you are not planning to use your meter for awhile. A removable label with the current battery information/status helps. Possible included info on label include: Meter type S/N incase label comes off; battery type; manufacturer; date installed/batt. voltage; date last checked/batt. voltage.

Accessories:
Heathkit made a few accessories for their line of VTVMs. These accessories work well with both the DSB and table-top VTVMs.

Probes:

309(A-C)	RF Probe (30 VRF, 500V DC Max)
310	10 KV HV Probe
336	30 KV HV Probe
338(B-C)	Peak-to-Peak Probe (5kc - 5 Mc)
PK-3(A)	RF Probe (90 VRF, 1KV DC Max)
PKW-4	Wired replacement probe for IM-11, IM13 and later VTVMs only.

Tube Replacements:

IMA-18-1	Solid-State replacement set for the 12AU7 and 6AL5 tubes in the later table-top and DSB VTVMs.

Modifications:

There are two modifications for the later Heathkit VTVMs that have been seen on various blogs. One involves using a replacement probe and the other is an internal power supply that provides power to the ohmmeter function, replacing the battery.

Probe Circuit Modification:

Later table-top and DSB VTVMs came with a single probe with a built in 1 MΩ resistor

Heathkit Deluxe Service Bench VTVM Line						
Item	**Early IM-10**	**Late IM-10**	**IM-32**	**IM-13**	**IM-28**	**IM-5228**
Layout	Vertical		Vertical	Horizontal	Horizontal	Horizontal
Rectifier	Selenium		Selenium	Silicon	Silicon	Silicon
Pilot Lamp	#47 Bulb 6.3V 150 ma Jeweled holder			Neon Ass'y	Neon/w Lens	Neon/w Lens
Power Xfmr	120 V Primary		120 V Primary	120 V Primary	120/240 V Primary	120/240 V Primary
Line Fuse	1/4 Amp Regular		1/8 Amp SB	none	none	none
Battery	1.55 V size "C" flashlight cell (Zinc Carbon)			Not supplied	Not supplied	Not supplied
R2	50 KΩ 1%	150 KΩ 1%	150 KΩ 1%	150 KΩ 1%	150 KΩ 1%	150 KΩ 1%
R3	150 KΩ 1%	400 KΩ 1%	400 KΩ 1%	400 KΩ 1%	400 KΩ 1%	400 KΩ 1%
R4	320 KΩ 1%	800 KΩ 1%	800 KΩ 1%	800 KΩ 1%	800 KΩ 1%	800 KΩ 1%
R5	1.5 MΩ 1%	not used	not used	not used	not used	not used
Phone Jack	DC		DC	AC/DC/Ω /COM	AC/DC/Ω /COM	AC/DC/Ω /COM
Red Jack	AC / Ω		AC / Ω	none	none	none
Black Jack	COM		COM	none	none	none
Zero Adj. & Ohms Adj.	Thumb wheel		Thumb wheel	Multiturn vernier	Multiturn vernier	Multiturn vernier
Feet	Embossed in Cabinet		Rubber	Felt stick-on	Plastic Stick-on	Plastic Stick-on
Tools Supplied	Allen Wrench		Allen Wrench Solder	Nut Starter Solder	Nut Starter Solder	Nut Starter Solder
Price Kit (Mail Order)	$32.95		$32.95	$32.95 - $36.50	$36.50	$49.95 - $129.95
Price Wired (Mail Order)	N/A		N/A	$49.95 - $56.95	$56.95*	$100 -** $120***
* Rebranded Slumberger SM-21A ** Rebranded Sulmberger SM-5228				*** The SM-5228 was discontinued after Zenith bought Heathkit in 1979		

TABLE V: Shows the changes between models of the DSB line that is switched in series with the probe tip when measuring DC± and switched out when measuring AC or OHMS. If the probe is lost or damaged a replacement probe may be hard to find and building one may be a challenge. Someone, (rumored to be a Heath employee), found a way to use a standard test probe connected via coax to the a phone plug, and a way to rewire the existing function switch so that a 1 MΩ resistor will automatically be switched in, internally to the meter, when the function switch is in either DC– or DC+.

From afar this seems a great idea, and one has to wonder why Heathkit didn't think of it. One guess is that the supposed Heathkit employee worked in sales and not engineering. The resistor is at the tip of the probe for one purpose only. It isolates the DC point under test from the stray capacitance of the cable and VTVM circuitry. This added capacitance may change the operation of the circuit, especially in higher frequency circuits, giving false readings. I highly recommend not to do this modification.

<u>Battery Elimination Modification</u>:

Many Heathkit VTVMs have been damaged by leaky batteries. There are a few modifications that involve rectifying some of the filament voltage and using a 1.5 VDC regulator circuit to supply voltage in place of the battery. This idea is appealing, but the circuits, so far seem, to be lacking. They take their power from the filament winding of the transformer, and if the VTVM uses an incandescent pilot lamp the filament winding is already being taxed. Perhaps replacing the lamp with an LED #47 replacement might ease the current drain. The Heathkit Deluxe Service Bench VTVMs (especially the later three) have ample room to add another transformer and regulator to provide the 1.55 DC voltage. The design should have a DC internal resistance of 0.9Ω to combine with the 9.1Ω

Final Words:

One may wonder what value a DSB VTVM is with all today's fancy digital instruments? They are rugged and do their job well. They are low power devices so you can leave them on for long periods without running up the electric bill. Once warmed up they are stable and the zero holds well.

The 11 MΩ impedance on DC provides isolation and more accurate readings up to the 500 V range. Above 150 V a 10X probe, like the Heathkit 310 HV probe can be used to increase the input impedance to 110 MΩ.

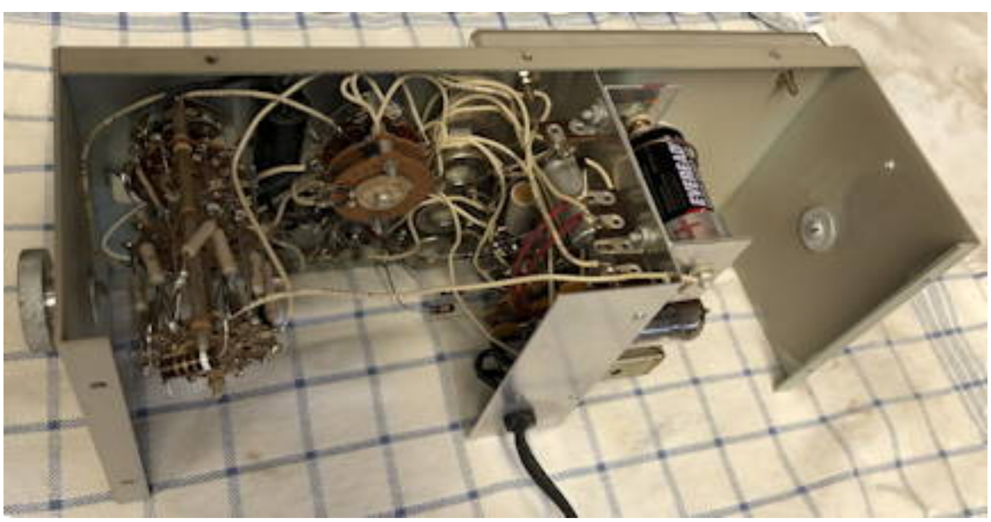


Figure 16: An internal view of the IM-28. On the left is the range switch. To its right is the function switch. Right of that are three potentiometers mounted vertically that can be accessed through holes in the front panel to allow calibration without removing the cover. To their right is the chassis. Partially visible on the top of the vertically mounted chassis are the power transformer, battery and the 12AU7 vacuum tube. Photo by author.

Schematics are available online (See notes.) Table V shows the differences between the the Deluxe Service Bench VTVM models.

This article originally was going to cover the V-7 and later table-top as well as the DSB VTVMs but it just got too long. Thus a full rewrite was started, and the article was not ready for the December issue of RF.

Acknowledgements:

The Heathkit electronics community is a large and enthusiastic group that is willing to help others with their projects. This article would not have been possible without the support of this community.

Here is a list of people who helped in this effort and others over the past few years, by providing information from their manuals, actual manuals, photos, part number information, proof reading, answers to my questions, and over-all moral support. The problem with these lists is I usually leave out a person or two who should be included; not on purpose, just due to my forgetfulness:

C. E. "Sonny" Clutter, (The Radiola Guy)
Eugene Colton - AF9O
Steve Gladstein - N8FH
Keith Greenhalgh
Nicholas Haban - AF6CF
Gary Harmon Jr. - K5JWK
Bob Koller - KG7EMO
Dave Lien - W6OVP (W7DAL)
Bob Meister - WA1MIK
Chuck Penson - WA7ZZE (See note 7)
Phil Phinizy - K6WHP
Richard Post - KB8TAD
Bill Robbins - WA8CDU
Santos e Silva
Dave Somes - WB6TFC
Gerhard Wagner - DF1DA

73, from AF6C

Notes:

1. https://www.w6ze.org/Heathkit/Heathkit_019_V7a.pdf
2. https://www.w6ze.org/Heathkit/Heathkit_047_AV3.pdf
3. The radical sign before a number signifies the square-root. √10 means "the square-root of ten".
4. As specified in the May 1961 Heathkit catalog. Page 34.
5. The table-top AC voltmeter input impedance, starting with the V−7, is 1 MegΩ shunted by 35 to 40 µµf.
6. ***73 Builds and Tests the Heathkit IM-10 VTVM*** by Donald A. Smith - W3UZN (April 1962 issue).
7. In his book: ***Heathkit Test Equipment Products*** Chuck Penson defines six different styles Heathkit used for their test equipment from 1947 - 1990. They are: Pre-Classic, Late Pre-Classic, Classic I, Classic II, New Look and Post New Look. See the book for details. The book and his others are available at: https://wa7zze.com
8. When Heath computerized its part #s 3B-4 changed to 3-4-2.
9. For those who believe you must add a series resistor when switching from selenium to silicon, Heathkit didn't, the slight increase in voltage only improves efficiency.
10. Full schematics of the DSB VTVMs are available at: https://www.w6ze.org/Heathkit/DSB/DSB.html
11. Table-top VTVMs used a16 µf electrolytic filter capacitor.
12. In at least one Heath VTVM I've measured more than 150 volts across the filter capacitor at a high 125 V line voltage. But see the next note.
13. Though I've worked many Heathkit VTVMs, and I replace the filter capacitor with a higher voltage one as a habit. I have yet to find one of the original capacitors non-functioning, out of tolerance or even with notable leakage. This power supply produces only a small current and is not taxed.
14. https://www.w6ze.org/Heathkit/Heathkit_086_V6RebuildII.pdf

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

Thanks - AF6C

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any notes you'd like to make.