

Heathkit of the Month #78:
by Bob Eckweiler, AF6C



ELECTRONIC TEST EQUIPMENT

HEATHKIT IM-17 Utility Solid-State Voltmeter

Introduction:

Over its history Heathkit sold many voltmeters. Probably most famous among them was the V7-A VTVM (vacuum tube voltmeters) which seems to appear frequently at swap meets over sixty years after it was introduced. After the V-7A was retired, Heathkit continued to make many newer VTVMs using the same circuit, but with different styles and model numbers, right up until 1989. The main changes after the V7-A seems to be the test leads and the connectors that joined them to the meter. Heathkit also produced a line of bench-style VTVMs utilizing the same V7-A circuit.

But technical progress moves on, and in the late sixties Heathkit announced an inexpensive portable solid-state voltmeter with the model number of IM-17, an "FETVM".

The IM-17 has a high-impedance input of 11-megohms for the DC voltmeter input similar to their VTVM line; but with no vacuum tubes one couldn't call this meter a VTVM so Heathkit called it a Utility Solid-State Voltmeter. The IM-17 (Figure 1) uses a small metal chassis that mounts in a polypropylene case. It was introduced late in 1967, for \$25.95 and appeared in the 1968 catalog 810/68R for \$19.95 (Figure 2). The IM-17 was produced for over ten years through most of 1977, finally selling for \$32.95.

IM-17 Specifications and Features:

The IM-17 is battery powered using a 1.5V standard 'C' cell for the ohms circuit and one 8.4V NEDA #1611 M mercury cell for the main power. Batteries were not included.



Figure 1: Later style IM-17 Solid State Utility Voltmeter

The IM-17 measures DC voltage from 1 to 1000 volts full-scale with 11 megohm input resistance in four decade ranges. The DC voltage is read on one 0-10 scale. The AC ranges are similar, except the first range is extended to 1.2 VAC full scale. The AC voltages are read on one of three meter scales. with a one-megohm input resistance shunted by $\sim 100\text{pF}$ (38 pF on the 1000 volt range). The 0 - 1.2 and 0 - 10 volt ranges each have their own individual red scale and the 100 and 1000 volt ranges are read on the same scale as the DC voltages. The need for separate scales for the lower two AC ranges is due to the nonlinearity introduced by the AC rectifier diode. The meter also has four ohm-meter scales: R x 1, R x 100, R x 10K and R x 1M.

The IM-17 has three test leads that are permanently attached to the meter, and the case has a convenient storage area for the leads. One lead is for AC-OHM measurement and is a red cable with a red probe. The second lead is for DC measurements and is a gray shielded cable with a black test probe. At inside the tip of the probe is a 1 megohm resistor that isolates the circuit under measurement from the cable capacitance. The third lead is the common lead for the other two leads and is black with an alligator clip on the end. No rubber insulation boot is provided for the clip.

**Every Man's Meter! New Portable Solid-State VOM . . .
A Thousand And One Uses . . . Lowest Cost**

- Solid-state circuit—FET input, 4 silicon transistor, 1 diode
- 4 AC voltage ranges • 4 DC voltage ranges • 4 ohm ranges • 11 megohm input on DC • 1 megohm input on AC
- 4 1/2", 200 uA meter • Battery powered • Rugged polypropylene case with self cover & handle includes storage space for test leads
- Easy-to-build circuit board construction

JUST RIGHT FOR HOMEOWNERS, hobbyists, boaters, model builders, CBer's, hams . . . even sophisticated enough for radio & TV servicing.

DOES HUNDREDS OF EVERYDAY MEASUREMENTS AT LOWEST COST. Features four ranges on AC and DC volts that measure from 1 to 1000 volts full scale . . . four resistance ranges (10 ohms center scale x1, x100, x10K, x1M) that measure from 0.1 ohm to 1000 megohms. All ranges are multi-colored. And there's an extra jack to connect accessory probes to extend its basic capabilities.

BATTERY POWERED TO WORK ANYWHERE . . . runs on a "C" cell and 8.4 v. mercury cell (same as used in transistor radios). Housed in a rugged, black, textured, polypropylene case with molded-in cover and handle with plenty of space for the three built-in test leads. Also features zero-adjust and ohms-adjust controls; a DC polarity reversing switch to eliminate switching leads, plus a continuous rotation 12-position function switch. Build in 3-4 hours.

Kit IM-17, 4 lbs. \$19.95

IM-17 SPECIFICATIONS—DC VOLTMETER: Four Ranges: 0-1, 10, 100, 1000 volts full scale. **Input resistance:** 1 meg. on all ranges. **Accuracy:** ±3% of full scale. **AC VOLTMETER:** Four Ranges: 0-1, 10, 100, 1000 volts full scale. **Input resistance:** 1 meg. on all ranges. **Accuracy:** ±5% of full scale. **Frequency response:** ±1 db, 10-Hz to 1MHz. **OHM-METER:** Four Ranges: Rx1, x100, x10K, x1 meg. **POWER SUPPLIES:** Ohms circuit: 1.5V "C" Cell. **Amplifier circuit:** 8.4V mercury cell (NEDA ±1011). **GENERAL:** Meter: 4 1/2", 200 uA, 100° movement. **Dimensions:** 8 1/2" W x 4 1/4" H x 7 1/4" D.



Figure 2: IM-17 Ad from 1968 Catalog showing early style

A 1/4" phone jack is also located on the panel where the test leads exit through grommets. The jack is for use with some of the accessory probes Heathkit offers for their meters. - particularly the RF Probe for measuring RF voltage and the HV probe for measuring voltages up to 30,000 volts. One must be careful that the attached probes are not shorted when using the accessory probe jack.

The accessory jack is rumored to have not been included in the early kits. However, looking at three different IM-17 manuals, the jack is shown on all schematics including the one in the November 1967 manual. The origin of the rumor might be that on early units the jack is mounted on the vertical panel; the same panel from which the test leads exit. On later units, after mid-1970, this jack was relocated to the

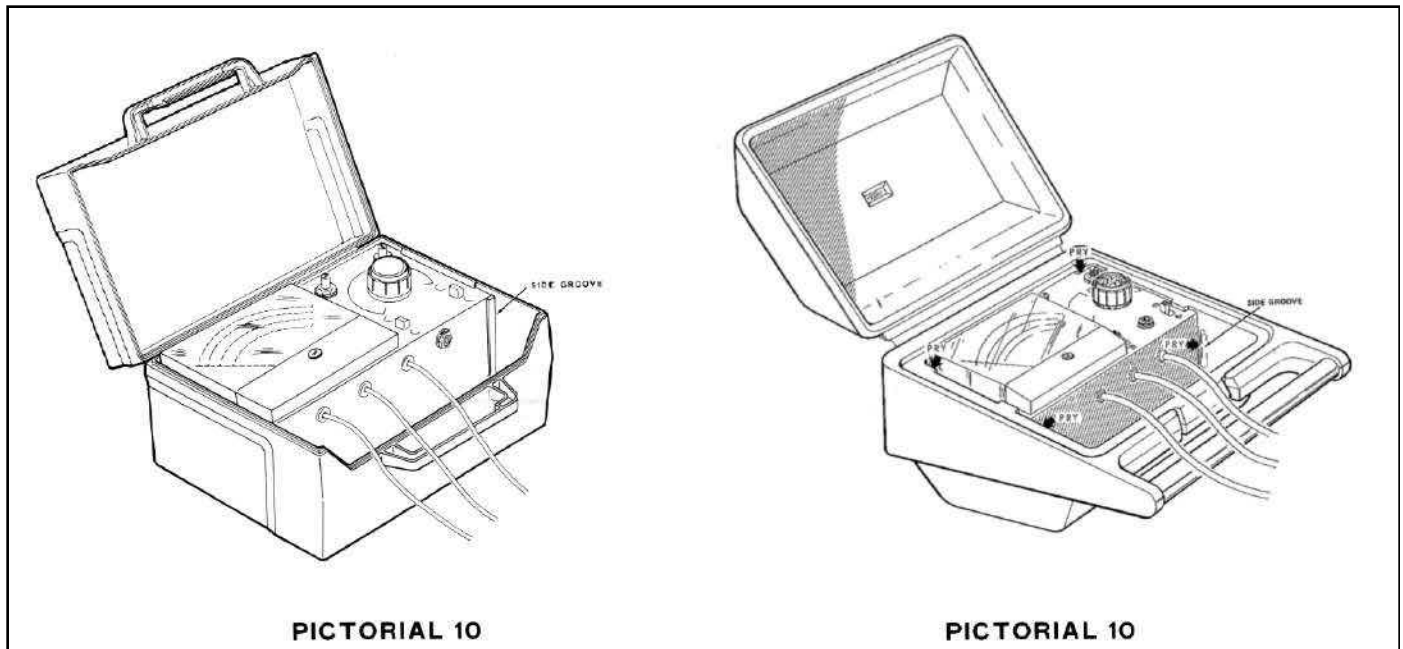


Fig. 3A: From the Nov. 1967 Manual

Fig. 3B: From a later. (1972?) Manual

top panel between the power and DC polarity slide switches.

The original IM-17 meters came with a boxy shaped black polypropylene case. Sometime around the middle of 1970 the case was changed to a more streamlined case. Evidently the new case was originally black but Heathkit switched to beige by the time the 1971 main 810/71 catalog was printed.

Figure 3A is pictorial 10 from the 11/10/1967 kit manual and figure 3B is the same pictorial from a later (possibly 1972) manual. Not only do they show the different style of cases but also the different locations for the accessory jack.

IM-17 Controls:

Table I shows the controls and connections of the IM-17 Utility Voltmeter. All the external controls and the meter mount on the horizontal panel. The front vertical panel is used for input connections.

IM-17 Construction:

Most of the components except the meter and major controls mount on a single circuit board, including the two battery holders and the large four-deck rotary switch. The board, in turn, mounts to the 'L' shaped chassis by the two large meter terminal studs and the rotary switch bushing.

Assembly involves first wiring the rotary switch. Many of these wires are open at the other end and will be attached later to the circuit board. The diode and one resistor mount to the switch. The rear switch layer has PC terminals that will attach to the circuit board. The switch is then put aside and the circuit board is assembled next. Five transistors, three PC-mount potentiometers, two battery holders, three capacitors, eight standard resistors, including one 2-watt resistor, and seven precision resistors are soldered to the board. One of the capacitors stands up vertically from the board and its other lead will be attached to the rotary switch. The switch is then attached to

Top panel from Left to Right:

Meter - 4-1/2" 200 μ A. Four scales - top to bottom:
OHMS (0 to INfinity. 10 Ω center scale, non-linear, Green color)
DC (0 - 10 linear, Black color)
AC (0 - 10 semi-linear, Red color)
AC (0 - 1.2 semi-linear, Red color)
 Remaining panel from top to bottom (Three rows):

Top Row (L to R):

ZERO adjust (potentiometer)
OHMS adjust (potentiometer)

Middle Row (centered):

Mode Range Sw. (rotary switch 12 position)
1 DC VOLTS Black text (8:30 o'clock position)
10 DC VOLTS Black text (9:30 o'clock)
100 DC VOLTS Black text (10:30 o'clock)
1000 DC VOLTS Black text (11:30 o'clock)
1.2 AC VOLTS Red text (12:30 o'clock)
10 AC VOLTS Red text (1:30 o'clock)
100 AC VOLTS Black text (2:30 o'clock)
1000 AC VOLTS Black text (3:30 o'clock)
R x 1M Green text (4:30 o'clock)
R x 10K Green text (5:30 o'clock)
R x 100 Green text (6:30 o'clock)
R x 1 Green text (7:30 o'clock)

Bottom Row (L to R):

Power **OFF - ON** (slide-switch - 3pdt)
 Accessory jack (1/4" phone jack)¹
 DC polarity **DC+ DC-** (slide-switch - dpdt)

Front panel from Left to Right:

Red AC - OHMS test lead with red probe²
 Black COM test lead with alligator clip²
 Gray DC test lead with black probe²
 Accessory jack (1/4" phone jack)³

Internal Controls:

BIAS ADJust (dual ganged potentiometer)⁴
DC CALibration (potentiometer)⁴
AC CALibration (potentiometer)⁴

¹ Only on units built after mid August 1970
² Permanent test lead that exits through a grommet
³ Only on units built before mid August 1970
⁴ Mounted on the circuit board

Table I: IM-17 Controls and Connections

the board using the switch's PC mount terminals and the switch's leads are soldered to the board, as is the free end of the vertically mounted capacitor, and the circuit board is put aside.

The Chassis/Panel is assembled next. Plastic grommets are mounted where the leads exit, the accessory phone jack is installed, as are the two slide switches and two potentiometer controls. Then the meter is installed and the face is protected with cardboard. The three test leads are assembled, and run through their respective grommets. The circuit board is then placed next to the 'L' shaped chassis and they are wired together.

Finally the circuit board and chassis are attached, two final wires are soldered to the **OHMS** pot, the knob is aligned, assembled and installed, and the "blue and white" model/serial # label is attached. The unit is then calibrated prior to being fitted into the polypropylene case.

IM-17 Calibration:

After a recommended final inspection of the wiring, the controls are preset, the meter is mechanically zeroed and the batteries are installed. The power is then turned on and the internal **BIAS ADJ** is adjusted so the meter reads zero. The **ZERO** control is then checked for proper response.

Next the DC calibration is performed. With the meter on the 10 volt range the DC probe is connected to the positive terminal of the internal 1.5 battery (I hope whoever bought the kit bought a fresh battery) and the internal **DC CAL** pot is adjusted for a meter reading of 1.5 on the black 10 V scale.

The AC calibration follows. With the meter on the 1000 volt AC scale, the meter is calibrated by carefully connecting the red and black test leads to a 120 volt household outlet and adjusting the **AC CAL** pot so the meter reads 1.2, on the black scale.

Generally meters are calibrated at points where the meter is close to full-scale. These calibrations are performed in the lower 20% of the meter movement.

The **OHM** ranges aren't calibrated but checked that they can be set at full scale with the test leads open and set at zero with the test leads shorted.

The final calibration involves resetting the **BAL ADJ** pot so that it will remain calibrated as the voltage on the mercury cell starts to decline.

Circuit Description:

The circuit can be divided into two sections; the input section with its resistance divider chain and the meter amplifier circuit. The dividing line for these two sections is the protection circuit prior to the gate of the FET transistor. A schematic for the IM-17 may be found at:

<http://www.w6ze.org/Heathkit/Sch/IM-17-Sch.jpg>

DC Input Circuit:

When measuring DC voltages the shielded probe with a built-in 1 megohm resistor is utilized. The lead is directly connected to the 10 megohm divider consisting of a 9M Ω , 900K Ω , 90K Ω , and 10K Ω (9K Ω , 990 Ω and 10 Ω in series). If the 1 megohm resistor in the probe is included the four DC voltage ranges get divided by 10/11, 1/11, 1/110 and 1/1100 for the 1V, 10V, 100V and 1000V ranges respectively, resulting in a voltage of 0.91 volts full-scale for each range being applied to the protection circuit.

AC Input Circuit:

When measuring AC voltages a direct probe is used. The AC voltage is isolated through a 1.6KV rated capacitor. The lower three ranges are then connected directly to the rectifier circuit while the 1000 volt range is first divided by 10 by a 1.8M Ω and 200K Ω divider. This divider protects the rectifier diode, which is rated at 750V PRV. The rectifier is a silicon diode (1N2071) which, along with a 0.05 μ F capacitor, changes the AC voltage to a DC voltage equivalent to the peak AC voltage. At lower voltages the diode adds some nonlinearity on

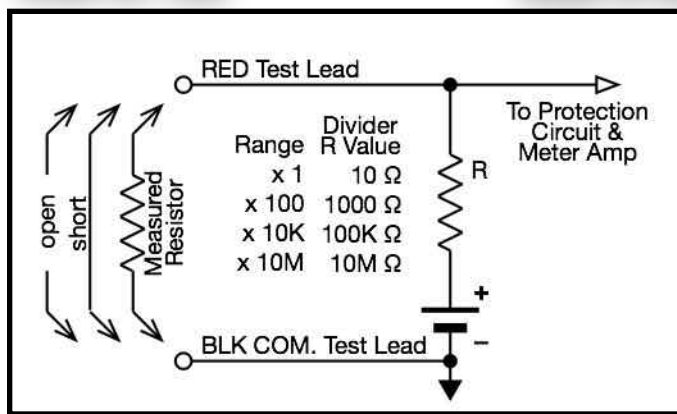


Figure 4: OHM Divider Circuit (Simplified)

the two lower ranges which are compensated for by using different meter scales for those ranges. The AC voltage is then applied through a resistor to the same voltage divider chain used for DC. The resistor provides rough conversion from peak to RMS voltage. The same divider range is used for both the 100 and 1000 volt AC ranges since the latter was already divided by 10. The result is a full-scale voltage of around 0.91 volts for each range being applied to the protection circuit. The bias circuit (discussed later) slightly forward-biases D1 to allow AC measurements near zero.

OHM Circuit:

Figure 4 shows a simplified schematic of the ohm circuit. The 1.5 volt battery in series with the 9.1Ω resistor is switched-in in place of the 10Ω at the low end of the divider chain. The

Measured Resistance	% Full Scale	Measured Resistance	% Full Scale
0	0.00	50	0.83
1	0.09	100	0.91
2	0.17	200	0.95
5	0.33	500	0.98
10	0.50	1000	0.99
20	0.67	OPEN	1.00

TABLE II: % Meter Full Scale for Different Measured Resistances

additional 0.8 ohms is made up by the internal resistance of the battery when supplying the needed current for the R x 1 measurement; at higher ranges the 0.8Ω is insignificant. The value of R in figure 4 depends on the ohms scale selected. It is 10Ω, 1KΩ, 100KΩ or 10 MΩ for the R x 1, R x 100, R x 10K and R x 1M ranges respectively. Notice that if the test leads are open (infinite resistance), the voltage to the protection circuit is 1.5 volts. The OHM adjust pot controls the gain of the meter amplifier (yet to be covered) when on an ohms range, and it is adjusted so the 1.5 volts causes the meter to read full scale. Now, if the test leads are shorted together (zero resistance) the voltage at the protection circuit is zero. On the R x 1 range R in figure 4 is 10 ohms. Now, if a 10Ω resistance is placed between the test leads then a voltage divider is created between R and the test resistance. Since the two resistors are identical the voltage to the protection circuit is 0.75 volts which will result in the meter moving to half scale. On the meter's ohms scale, half scale is 10. Values for resistances between 1 and 1000 are given in table II. This is valid for all scales by applying the proper scale multiplier.

Protection Circuit and Meter Amplifier:

The IM-17 uses four NPN silicon transistors and a junction FET (Field Effect Transistor). After the divider chain, the voltage goes through a simple protection circuit to the gate of the FET which controls a balanced bridge meter amplifier. The protection circuit consists

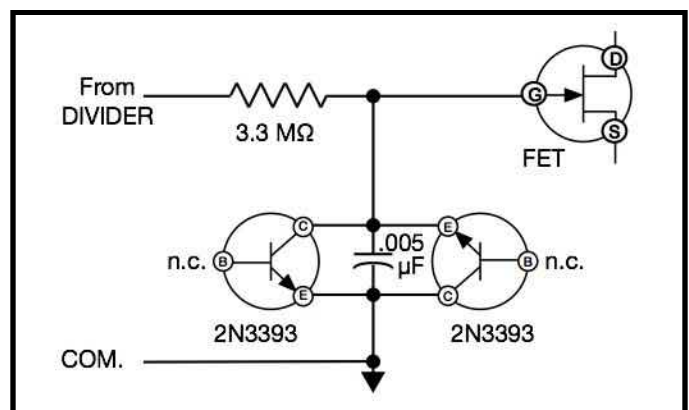


Figure 5: Protection Circuit

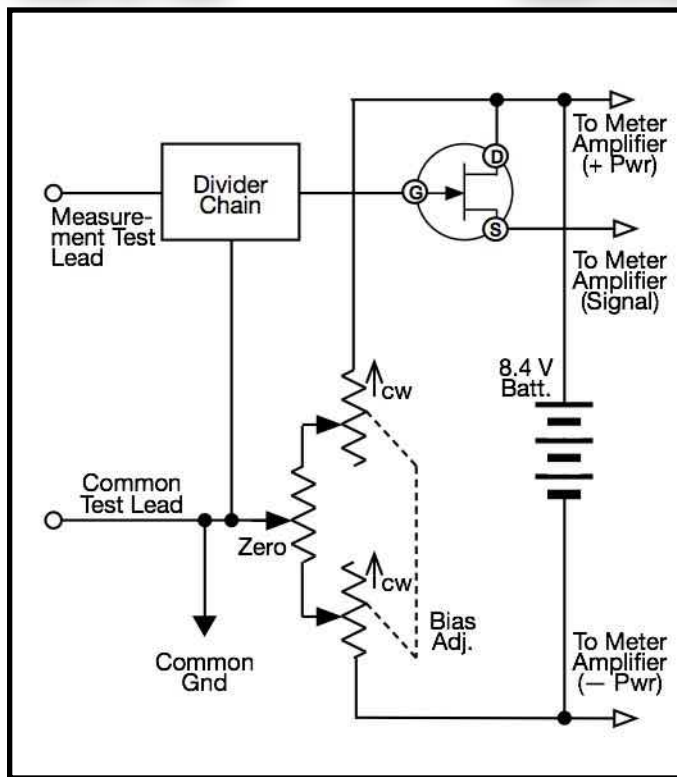


Fig. 6: FET Bias Adjustment Circuit

of a 3.3 megohm series resistor followed by back-to-back silicon transistors from the FET gate to common. See figure 5.

The 3.3 MΩ resistor, while a large value, is small compared to the high input resistance of the FET; and attenuation is corrected when the meter amp is calibrated. The transistors, with their base connection open, act as zener diodes with a rough breakdown voltage of 25 volts (V_{CEO}). Should excessive voltage reach the 3.3 MΩ resistor one of the transistors will clamp the voltage, depending on the voltage polarity. The capacitor slows any sharp voltage pulses until the transistors can conduct.

The FET acts as a follower with very high input resistance and low output resistance effectively isolating the divider from the meter amp. Zero is established by applying the proper

bias to the FET's gate. To do this the ZERO pot and the internal BIAS ADJ pot set the ground reference for the divider chain, which in turn sets the bias voltage on the FET relative to the source lead. The front panel ZERO pot provides a fine adjustment and the internal BIAS ADJ. dual ganged pot provides a coarse adjustment. Figure 6 shows a simplified schematic of the circuit excluding the protection circuit.

The meter amplifier consists of two 2N3393 silicon transistors in a bridge circuit (See Figure 7 for a simplified circuit diagram). Q3 is biased to have about 4.5 volts on its emitter. With the BIAS ADJ. and ZERO controls set properly and no input, the FET is conducting about 0.25 mA resulting in about 4.5 volts on the emitter of Q2. The meter will then have the same voltage on both terminals and read zero. The ZERO control may be adjusted a bit to compensate for any component tolerances to make the meter read zero. Now, when an additional positive voltage appears on the gate of the FET, it conducts more and Q2 draws more current making the meter read positive as the

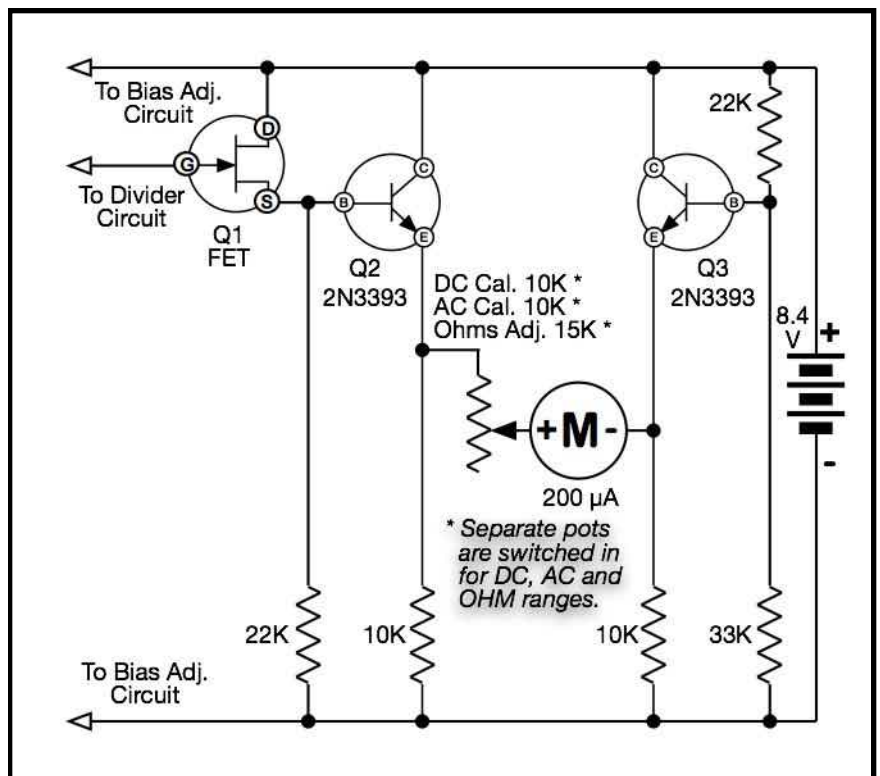


Fig. 7: Meter Amplifier Circuit

emitter goes more positive. In the case of negative DC voltage the meter will move downscale. Not shown in Figure 7 is a polarity switch that functions only on DC ranges. The switch reverses the meter terminals for measuring negative DC voltages without the need to swap leads and possibly make the chassis hot. This switch, and separate calibration pots, are switched in by the range switch for the AC and DC ranges, and the external OHM control is switched in for the OHM ranges.

Power comes from the two batteries. A three pole switch controls the power. In the ON position the two batteries are connected to the circuit. In the OFF position the batteries are disconnected and a short is placed across the meter to protect it. (See Meter Protection sidebar.)

The IM-5217 Solid-State Portable VOM:

The IM-17 stopped production in late 1977. It was over a year before Heathkit introduced a replacement, the IM-5217 selling for \$44.95. This meter has many improvements over the older meter. Table III lists the differences I've discovered so far. Of significance is the new DC and AC ranges (1.5 DC/1.7 AC, 15, 150 and 500 V), the replacement of the mercury cell with two 9-volt batteries, and use of a more sensitive meter. Also the meter uses a single, unshielded, test probe for DC, AC and Ohms. The IM-5217 remained in production until 1987. At the end it was selling for \$49.95.

IM-17 vs. IM-5217 Calibration:

The older IM-17 with its 1 (1.2 on AC), 10, 100, 1000 volt ranges make simple yet accurate calibration a problem. The calibration procedure offered by Heathkit uses the 1.5 volt battery for DC calibration and the 120 VAC line voltage for AC calibrations. These calibrations are done on the 10 VDC and 1000 VAC ranges, and the calibration point is in the lower 1/5 of the meter scale. Thus any slight error in calibration is magnified about five-fold near meter full-scale. The IM-5217 uses a 1.5 VDC and 150 VAC range for calibration, both in the upper fifth of the meter scale, resulting in more accurate calibration.

IM-17 vs. IM-5217		
Item	IM-17	IM5217
Accessory Jack:	YES	NO
Meter Power:	8.4V Hg Cell	Two 9V batts.
Ohms Power	C-cell	[same]
DC Ranges:	1, 10, 100, 1000 VDC	1.5, 15, 150, 500 VDC
DC Input Resistance:	11 Meg Ω	10 Meg Ω
AC Ranges:	1.2, 10, 10,0 1000 VAC	1.7,15,150, 500 VAC
AC Input Resistance:	1 Meg Ω	[same]
Ohm Ranges:	Rx1, Rx100, Rx10K, Rx1M	[same]
Freq. Response:	\pm 1dB 10Hz to 1 MHz	[same]
Meter:	4-1/2" 200 μ A	4-1/2" 100 μ A
Test Leads:	2 + Common	1 + Common
FETs/BJTs/Diodes:	1 / 4 / 1	2 / 2 / 1

Table III

When calibrating the IM-17, you may want to borrow a calibrated meter and a voltage source and calibrate the meter near the top of one of the ranges.

Summary:

The IM-17 is a handy meter to use for simple tasks around the ham shack, house or car. While it lacks some of the bells and whistles of more expensive meters, it is portable and reasonably rugged. Unfortunately, the SoCal ozone seems to do quick work of the brown polypropylene case the later IM-17 came with, causing it to disintegrate. Perhaps this is not common in other parts of the world, but my ID-29, which uses the same style case, fell apart. The later blue-style cases seem to standup better.

Coming Up:

It's time write about another amateur radio product. There has been a lot of discussion on the HG-10, and HG-10B External VFOs on a

Heathkit user group. External VFOs were used by many hams in years past after they moved up from the novice license and no longer needed to be crystal controlled. The Heathkit VF-1 was the first VFO and so it should be included too.

It might take an extra month to get this article out due to my current workload. We shall see.

I'd also like to do a book review of Chuck Pen-son WA7ZZE's first book **HEATHKIT - A Guide to the Amateur Radio Products**. This is a very informative book packed with information on the numerous ham products offered over the years. If you find a copy, latch onto it. They are hard to find, even after a second printing. Chuck's later book **Heathkit Test Equipment Products** was reviewed in the July 2013 issue of *RF*.

73, from AF6C



Meter Movement Protection:

Meter movements are delicate, yet are often treated to rough handling during shipping, and use - especially in portable equipment. Sensitive meters are normally shipped with their meter terminals shorted with a wire clip. The reason is that, should the meter be jarred and the movement swing, the meter coil moves in the permanent magnetic field that is part of the meter movement. Without the short a small voltage is produced on the terminals. However, if the meter is shorted, current flows in the meter which in-turn produces an opposing magnetic field damping the meter so it moves significantly less for a given jarring. This helps protect the meter movement from damage. In the IM-17 one of the sections of the power switch shorts the meter terminals together when in the off position to help protect the meter movement.

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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The NEDA #1611 M 8.4 V Mercury Cell:

Mercury cells have some traits that made them very good for use in watches, hearing aids and portable instruments like the IM-17. They have a long shelf life of more than ten years, they are less likely to leak than zinc carbon batteries and they maintain a more steady voltage as they are discharged due to use.

Unfortunately mercury is a toxic metal and a lot of it was ending up in the landfill due not only to mercury cells, but also because mercury was added to other types of batteries too. In 1996 Congress passed the **Mercury-Containing and Rechargeable Battery Management Act (the Battery Act; Public law 104-142)** and almost overnight mercury batteries became unobtainable. The NEDA #1611 (without the 'M') was also available as a zinc carbon battery. Evidently purchasers of the IM-17 were having trouble finding the mercury cells, so shortly after introduction, Heathkit included a sheet informing people where to purchase these batteries. The sheet also stated: **In an emergency a 9 volt zinc carbon battery (also NEDA #1611) can be used, but the result will be shortened battery life, excessive "zero" drift and possible battery contact problems.** Today the battery is still available as an alkaline NEDA #1611 A (Exell 206A) Unfortunately, the battery sells for between \$20 and \$25 which is right around the price of the kits when they were first introduced.