

Heathkit of the Month:
by Bob Eckweiler, AF6C



AMATEUR RADIO EQUIPMENT
Heathkit® HM-102
RF Wattmeter.

Introduction:

Back in January 2012 (HOM #37) the line of Heathkit HF SWR bridges was covered. These devices are handy to monitor and adjust antennas for proper operation, but only give a relative indication of the power a transmitter or amplifier is outputting. The reason for this is the frequency sensitivity of the Monimatch-style pickup used to sample the forward and reflected RF energy. Since the sensitivity control has to be adjusted for each band (or even band segment) the meter cannot be accurately calibrated in RF power.

Some SWR meters, such as the Osker SWR-200, come with a sensitivity control with a 0-100 graduated dial and a separate calibration table so the sensitivity can be set and the power read on the meter. Since an expensive Bird wattmeter is specified at 5% accuracy it is reasonable to assume the Osker meter is probably 10% to 20% accurate at best; still this is not bad for the price.

By utilizing RF pickups featuring ferrite transformers, frequency dependence can be reduced to the point that the meter can read power at a



Fig 1: Heathkit HM-102 HF RF Power Meter. The HM-2102 Meter for VHF is Similar.

reasonable accuracy over a moderate span of frequencies. Such meters became readily available in the late sixties, and Heathkit produced the HM-102 “RF Power Meter” that replaced the HM-15 SWR meter in the very early seventies.

Heathkit Line of RF Wattmeters:

From 1970, until it closed its doors, Heathkit made a variety of both HF and VHF stand-alone wattmeters. They also featured RF wattmeters in their SB-634 amateur radio console. The later units featured a peak monitoring capability for reading PEP power and required power either from a battery or external power source. Table I lists the units and their features. Table II lists the prices over their years of pro-

| Part # | Began | Ended | Frequency MHz | Power Watts | Notes |
|----------|-------|-------|----------------|---------------------------|-----------------------------------|
| HM-102 | 1970 | 1981 | HF: 1.8 - 30 | 200 / 2K / SWR | |
| HM-2102 | 1973 | 1981 | VHF: 50 - 160 | 25 / 250 / SWR | |
| HM-2103 | 1973 | 1976 | HF | 200 / 1K | w/Dummy Load |
| HM-2140 | 1979 | 1983 | HF: 1.8 - 30 | 200 / 2K Fwd. (Peak read) | Dual Meter: 50 / 500 / SWR Ref. |
| HM-2141 | 1979 | 1983 | VHF: 50 - 175 | 30 / 300 Fwd. (Peak read) | Dual Meter: 10 / 100 / SWR Ref. |
| HM-9 | 1983 | 1991 | HF or 6M or 2M | 5 / 50 / SWR | Band chosen during assembly |
| HM-2140A | 1984 | 1991 | HF: 1.8 - 30 | 200 / 2K Fwd. (Peak read) | HM-2140 w/ new brown paint scheme |

TABLE I: Heathkit RF Wattmeters

| Part # | Price | Catalog | Price | Catalog | Price | Catalog | Price | Catalog |
|--|---------|-------------|----------|-------------|----------|--------------|---------|-------------|
| HM-102 | \$29.95 | Xmas 1973 | \$34.95 | Winter 1976 | \$37.95 | Spring 1977 | \$49.95 | Fall -1980 |
| HM-2102 | \$29.95 | Xmas 1973 | \$34.95 | Winter 1976 | \$37.95 | Spring 1977 | \$49.95 | Xmas 1981 |
| HM-2103 | \$59.95 | Winter 1973 | \$59.95 | Winter 1976 | - | - | - | - |
| HM-2140 | \$79.95 | Fall 1980 | \$89.95 | Xmas 1981 | \$94.95 | Spr/Sum 1982 | \$89.95 | Winter 1983 |
| HM-2141 | \$79.95 | Fall 1980 | \$89.95 | Xmas 1981 | \$94.95 | Spr/Sum 1982 | \$94.95 | Winter 1983 |
| HM-9 | \$49.95 | Xmas 1983 | \$39.95 | Fall 1985 | \$59.95 | Xmas 1989 | \$49.95 | Winter 1991 |
| HM-2140A | \$99.95 | Fall 1985 | \$129.95 | Fall 1989 | \$129.95 | Winter 1990 | \$99.95 | Winter 1991 |
| TABLE II: Heathkit RF Wattmeter Pricing | | | | | | | | |

duction from my factory catalog collection. Often a kit was reduced for a short period on special. At times the price would be listed like: *\$99.95 was \$129.95 in [the previous] catalog.*

Heathkit HM-102 (HF) RF Power Meter:

The HM-102 is shown in Figure 1. It is a small self-powered unit measuring 5-1/4 W x 5-1/16 H x 6-1/2 D and weighing 2-1/2 pounds. The HM-102 paint scheme is the green and gray motif of the original SB amateur line as are the knobs and panel lettering, making it a match for use with any of the early SB transmitter receiver pairs or transceivers up to the SB-104.

The impedance sensor module, designed for 50Ω, can be removed from the back of the cabinet and located externally closer to the antenna feedline. An approximately six-foot, permanently wired, cable connects the sensor with the cabinet. Room is provided within the cabinet to stow the wire should you wish to leave the sensor module installed in the case.

The HM-102 has two power ranges that measure 200 watts and 2,000 watts full scale. It also measures SWR on a scale that goes from 1:1 to 3:1.

The front panel has two controls as well as a large, but unlit, meter. The left control is a three-position rotary switch marked **SWR, 2000, 200** that selects the SWR mode or one of two full-scale RF power levels. The second control is a potentiometer with a switch that is activated by pulling out on the knob. This control is marked **PULL TO SET - SWR SENSitivity**.

The rear panel (Figure 2) is part of the removable sensor module. It has two SO-239 UHF connectors marked **INPUT** and **OUTPUT** and a slide switch marked **CALibrate - NORMAL**. There are also two holes allowing access to two adjustments inside on the circuit board. These are marked with their schematic parts nomenclature **C-4** and **R-6**. A piece of insulated cardboard covers the holes between calibration periods. There is a space below the sensor module when it is installed in the cabinet. This space is for stowing the cable connecting the module with the cabinet circuitry.



Fig 2: HM-102 Rear View. The sensor chassis may be removed for remote operation

HM-102 Assembly:

Assembly of the HM-102 is divided into four sections: Circuit board assembly; Remote chassis assembly, Cabinet assembly and Cabinet wiring. This encompasses nine pages in the manual.

Most of the RF components mount on the single printed circuit board (PCB). This is stuffed first with fixed resistors, capacitors and the three 1N295 diodes (germanium 40V 50 ma). Next the pre-wound toroid coil is mounted using an eyelet that fits through the toroid center hole and is soldered to the foil side of the PCB. Later the lead between the input and output coax connectors will pass through this eyelet and the center of the toroid. Finally three controls are soldered to the circuit board; they are the CAL - NORM slide switch **S1**, the **SWR NULL** variable capacitor **C4** and the **POWER CALIBRATE** trimpot **R6**. Once the board is completed the five-wire cable is attached to the board. A ferrite bead is placed on each lead before it is soldered to the board.

Remote chassis assembly involves mounting the SO-239 coax connectors and metal stand-offs to hold the circuit board, mounting the circuit board and some simple wiring between the two coax connectors on the remote chassis. The five-wire cable is then passed through a hole in

the remote chassis cover, a Heyco strain relief is attached and the cover is assembled to the remote chassis.

Cabinet assembly starts with the mounting of feet and a solder lug, followed by the front panel controls and meter. The other end of the five-wire cable from the remote sensor chassis assembly is attached to the cabinet using a cable clamp.

The cabinet wiring involves wiring up the five-wire cable, the controls and the meter. Three 0.001 µf and one 0.005 µf bypass capacitors are also installed, completing the total assembly.

HM-102 Calibration:

Calibration consists of first setting the mechanical zero adjust on the meter. Next RF is applied through the wattmeter to an accurate 50Ω dummy load. The SWR NULL trimmer capacitor, C-4, is then adjusted with a non-metallic screwdriver for minimum reflected power on the meter, increasing SENSitivity and power as needed. A perfect null is the ideal outcome.

Next the power circuit is calibrated. The HM-102 includes some internal circuitry to produce a frequency dependent calibration standard valid on the 40 meter band. When the sensor switch is set in the CAL position, the wattmeter reads accurately. However this is only valid on 40-meters. If your radio transmits on 40 meters it is a simple matter to apply a reasonable power into the meter, note the setting with the switch in the CAL position, move the switch to the NORM position and adjust the power calibrate trimpot for the identical meter reading. This holds for all bands. Heathkit also offers another way to calibrate the meter if a 40-meter transmitter is not available. It requires an RF voltmeter or a VTVM with an RF probe.

HM-102 Circuit Description:

The HM-102 circuit is straight forward, but it may seem more complex due to the way the schematic (Figure 6) is drawn.

Components C7, C8, D1, R5 and C9 make up an RF voltmeter. These components look like



Fig. 3: Christmas 1973 Catalog Ad for the Heathkit HM-102.

they are connected to other components but those are all grounds. The output of this RF voltmeter goes to pin 1 of the CALibrate switch S1. On 40 meters this circuit produces about 7 volts DC when 100 watts is present on the wire passing through L1. The meter, which I assume to be 100 μ a full-scale, is scaled by R5 to read full scale with 9V at the cathode of D1 with the meter in the CAL position and 200 watts selected. Seven volts corresponds to 100 watts on the non-linear scale of the meter assuming 9 volts is full scale. This circuit is just used for a calibration source and plays no purpose during day-to-day operation of the power meter.

The SWR and power circuit consists of L1, C12, C4, C1, C13, R7, and R2. The additional components for detecting reflected power are D2, C2, R1 and C3. The additional components for detecting forward power are D3, C5, R4 and C6. L1 inductively picks up energy from the flowing RF. It is reasonably frequency independent; but the addition of R2 across the coil reduces the Q of L1 further making it frequency independent across the HF bands.

C12, C4 along with C1 and C13 provide a small voltage to the center tap of L1. This voltage corrects for capacitive anomalies in L1. It is in phase with one winding and out of phase with the other. With no SWR (reflected power) on the line, C4 can be adjusted to null out the voltage appearing on the left half of L1. Each side of L1 is rectified by a diode (D2 and D3) filtered by a capacitor (C2 and C5) and decoupled by an RC network (R1, C3 and R4, C6) The result is that forward power produces a relative voltage on terminal B and any reflected power produces a relative voltage on terminal C. These voltages are relatively frequency independent unlike those in the earlier SWR bridges.

Both of these voltages are fed to the SWR meter section, where they are selected by the pull out switch on the sensitivity pot, but the forward voltage is also fed through the POWER CALIBRATE trimpot (R6) on the circuit board to R8

which scales the voltage to read correctly on the meter when in the 200 watt position. In the 2000 watt position an additional resistor, R9 is placed between the meter and R8 further scaling the meter to respond to a full scale of 2000 watts.

The cabinet circuitry is rather straightforward. In the SWR position, when the SENSitivity control is pulled out the forward power is connected through the control to the meter and when the control is pushed in the reflected power is connected. In the 200 position the 200 watt output from the sensor (Pin F) is connected to the meter and in the 2000 position the 2000 watt output from the sensor (Pin G) is connected to the meter. C15 thru C18 bypass any stray RF to ground.

HM-102 Operation:

Operation of the HM-102 is simple. It is connected in the transmission line where you want to measure RF power. This is usually in the feed line to your antenna or dummy load. Once installed the power can be read on the meter. In the 2000 position the meter is read on the top scale (2 KW FS) and in the 200 position the meter is read on the middle scale (200 W FS).

To measure SWR the switch is placed in the SWR position and with an RF carrier the SENSitivity control is pulled out and adjusted for a full-scale reading. The control is then carefully pushed in so as not to change the pot setting and the SWR is read on the bottom scale.

Heathkit HM-2102 (VHF) RF Power Meter:

In 1973, a few years after Heathkit introduced the HM-102 it introduced the HM-2102, a VHF version. Physically it is identical in size and weight to the HF model. It differs in power capability, having full-scale ranges of 25 and 250 watts. These ranges are more practical to the average VHF operator than the higher ranges. The SWR capability remains, and, like the HM-102 it is designed for 50 Ω feedline. UHF connectors are used and the sensor module may also be placed remotely to the main cabinet.

The circuit of the HM-2102 VHF wattmeter is the same as the HM-102 HF unit with the obvious exception of the component values. The ferrite inductor, and the scaling resistors and capacitors have been selected for the higher frequency range and the lower power measuring levels. A few bypass capacitors, not needed at the VHF range, are also absent.

Heathkit HM-2103 (HF) Dummy Load:

The HM-2103 is a 1KW air-cooled dummy load with a built-in power meter. This is more a test bench instrument than an amateur accessory. The HM-2103 was short lived appearing in 1973 and vanishing in early 1976.

The circuit for the power meter part of the dummy load is identical to the HM-102 with the exception of the forward SWR output which is not needed. Neither is the reflected SWR output except when nulling the bridge. Thus it is connected to the meter in the **LAMP TEST** position of the function switch and used during the calibration procedure. The power circuit varies only in the scaling resistor used for 1 KW instead of 2 KW. The 200 watt scaling resistor remains the same.

The dummy load section uses a fixed 50Ω carbon resistor element rated for 175 watts continuous, 500 watts for 5 minutes and 1,000 watts for 2.5 minutes. A power dissipation rating curve is included in the manual for other



Figure 4 Heathkit HM-2141 Dual Meter VHF Wattmeter. The HM-2140 HF model is similar. The HM-2140A sports a brown motif to match the later Heathkit ham gear; otherwise it is unchanged.

Photo courtesy of Allen Wooten - WD4EUI

powers. An over-temperature sensor lights a lamp to warn of excessive dissipation. The lamp is powered by a standard 9-volt battery (NEDA 1604). A **LAMP TEST** position on the function switch allows testing the lamp and battery. The only function of the battery is to operate the lamp during an over-temperature condition.

Heathkit HM-2140 & HM-2141 RF Wattmeters:

In 1979 Heathkit improved its HF and VHF power meters adding peak reading capability. The result was the HM-2140 power meter for HF and the HM-2141 power meters for VHF. These meters are physically identical with each other measuring 7-1/8 W x 4-1/8 H x 6-1/8 D and weigh 4 pounds. Each has two separate meters on the front panel. One indicates forward RF power and the other reflected power. The meters also can measure average power.

When using the PEP feature a source of power is required; however the regular readings will function without power. Power may be provided by an internal 9-volt battery (NEDA 1604) or an external 9-volt DC source such as the recommended PS-2350 AC Adapter. Also, the GRA-43-1 adapter was mentioned in the early manuals. This AC adapter was part of the GR-43 Zenith-clone radio Heathkit sold. These meters remained on the market until 1983 when the HM-2141 VHF meter was dropped and the HM-2140 meter was replaced by the HM-2140A meter.

Heathkit HM-2140A RF Wattmeter:

With the color scheme change from the green and gray SB series of amateur gear to the brown color scheme of the later amateur gear, Heathkit updated the HM-2140 to the HM-2140A which for all practical purposes is the same device in new clothes. Some small circuit changes may have been made, but the schematics appear identical.

Perhaps a more in-depth article on the HM-2140, HM-2140A and HM-2141 meters are in order in a future HOM article.



Fig. 5: Heathkit HM-9 QRP Wattmeter
 Be aware that the HM-9 could be wired for one of three bands: HF, 6-Mtrs or 2-Mtrs.
Photo courtesy of - KC8RP

Heathkit HM-9 RF Power Meter:

In the early 1980s Heathkit was producing a series of QRP amateur transceivers, the HW-7, 7A, 8 and HW-9, which are still popular today. By the time Heathkit got to the HW-9 they decided to also manufacture a QRP RF power meter. Thus the HM-9 power meter came into existence.

To enhance sales of the HM-9, Heathkit designed it to be not just an HF QRP meter but also a VHF meter. In truth the kit contains the components to assemble the meter to cover either the HF band (1.8 - 30 MHz), the six-meter band (50 - 54 MHz) or the two-meter band (144 - 148 MHz). When completed the meter works only on the chosen frequency range. Full scales of 5 watts and 50 watts can be front panel selected as can the SWR mode.

The HM-9 uses the same basic circuit as the HM-102 and other power meters. The RF transformer, eight of the capacitors and four of the resistors are selected among different supplied values depending upon which range you choose the meter to be wired for.

Conclusion:

I've used the HM-102 and found it agrees with my Bird wattmeter within a few percent on the bands I operate. The meter is most accurate

when feeding a 50 ohm resistive load. Of course it matches the style of the SB-301/401 pair that was my main radio, built in the late sixties, and became a spare for my newer used TS-440SAT, bought from club member Kei Yamachika - W6NGO (SK). Recently an ICOM IC-7600 became my newest radio.

Acknowledgements:

Over the years of writing these articles, I've met some great fellow Heathkit aficionados who have helped me make these article possible. Four I'd really like to thank at this time are: **Allen Wooten WD4EUI** who contributed the HM-2141 photo and others previously (http://wd4eui.com/Amateur_Radio.html). **Richard Pestinger - KC8RP** (<http://www.pestingers.net/heathkit.htm>) who provided the HM-9 photo. Former club member **Jim Tripp - WA6DIJ** who moved about the time that I joined and continues to send me great Heathkit tidbits (<http://www.antiqueradiomuseum.org/>). And finally, but very importantly, **Dave Somes - WB6TFC** who sent me a few pounds of Heathkit manuals that I have been going through and will be using to feature upcoming articles.

Also I'd like to acknowledge my good friend **Mark Bender - KD6NOT**, for passing along an HM-102 to me; with a manual no less! I had been meaning to do an article on it and its relatives for a while, but life kept stepping in the way with higher priorities - the reason the *Heathkit of the Month* has been missing on and off for the past half-a-year.

73, from AF6C

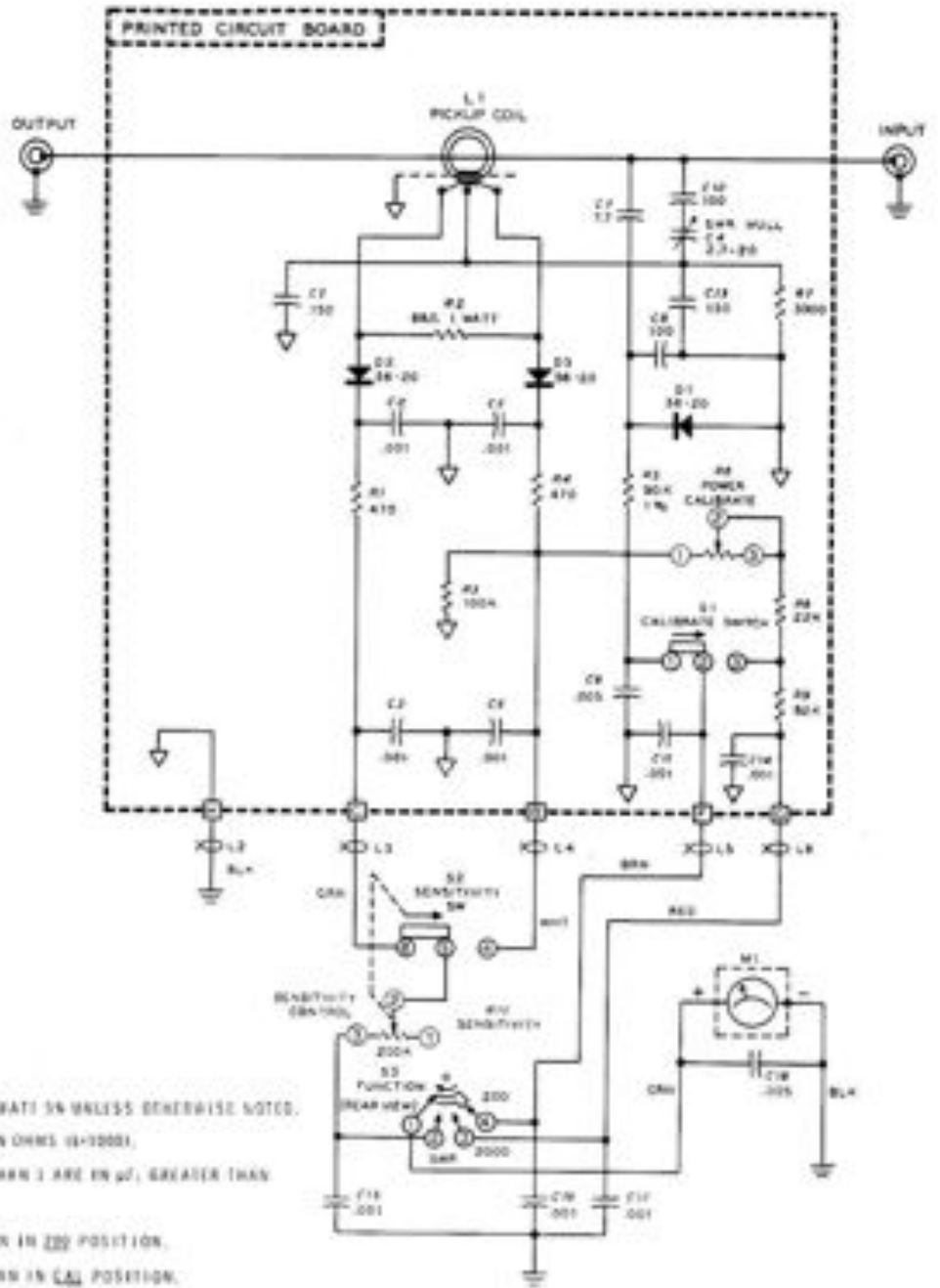


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Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C

Figure 6: Heathkit HM-102 Schematic



- NOTES:
1. ALL RESISTORS ARE 1/2 WATT 5% UNLESS OTHERWISE NOTED. RESISTOR VALUES ARE IN OHMS (Ω)-1000Ω.
 2. ALL CAPACITORS LESS THAN 1 ARE IN pF, GREATER THAN 1 ARE IN μF.
 3. FUNCTION SWITCH SHOWN IN 200 POSITION.
 4. CALIBRATE SWITCH SHOWN IN CAL POSITION.
 5. SENSITIVITY SWITCH SHOWN PUSHED IN.
 6. ▽ THIS SYMBOL INDICATES CIRCUIT BOARD COMMON.
 7. ≡ THIS SYMBOL INDICATES CHASSIS GROUND.
 8. □ THIS SYMBOL INDICATES AN EXTERNAL CONNECTION TO THE CIRCUIT BOARD.
 9. ⊗ THIS SYMBOL INDICATES A FERRITE BEAD.

SCHEMATIC OF THE HEATHKIT®
RF POWER METER
MODEL HM-102