Heathkit of the Month:
by Bob Eckweiler, AF6C

AMATEUR RADIO - SWL
Heathkit GR-78
General Coverage Portable Receiver

Introduction:
Over the years Heathkit has manufactured a variety of general coverage HF receivers. A few of these have been portable units that are of solid-state construction and can run on battery power as well as off the AC mains.

In Heathkit of the Month #34 I covered the popular Heathkit GC-1(A) "Mohican" receiver. It sold from about 1960 until 1968 with an update in 1962 to alleviate some problems with the initial version. It covers from the AM broadcast band up to 32 mc. in five bands and runs on eight 'C' batteries or from an optional AC power supply. In 1967 the GC-1A sold for $89.95, and the optional XP-2 AC power supply for $9.95.

In 1969, too late for the main catalog, Heathkit introduced the GR-78 as a replacement for the "Mohican". In the 1972 catalog the GR-78 was selling for $129.95. It covers 190 to 410 kc. and from the start of AM broadcast band up to 30 mc. in six bands. The receiver is powered by a built-in 9.6-volt 500 mAh nickel-cadmium rechargeable battery that charges automatically when connected to either the AC mains or an external 12 volt source. The GR-78 remained in production until late 1976; selling for $159.95 in the Winter* 1976 catalog and for $169.95 in the Christmas 1976 catalog. It no longer appeared in the Spring 1977 catalog.

The Heathkit GR-78:
The GR-78 communications receiver, shown in Figure 1, comes in a reasonably small package for its day. It weighs 10 lbs. and measures just

Figure 1: Heathkit GR-78 Portable SW Receiver

6-1/4" high x 11-1/2" wide x 9" deep. A 6" slide-rule dial, covering the main tuning for the six bands, takes up much of the top half of the front panel with a cylindrical band-spread dial to the left and a vertically mounted S-meter to the right. Two large tuning knobs, two smaller knobs (one dual concentric) and six rocker switches make up the lower half of the front panel. The controls are listed in Table I.

The rear panel (Figure 2) is simple with only five connectors. From the rear, left to right, there is a two-screw terminal strip just left of center near the top designated **MUTE**; a two (or three) pin **120 VAC** connector, then a **12 VDC** female two-terminal Cinch-Jones type connector near the bottom; another two-screw **EXTERNAL ANTENNA** terminal strip near vertical center right and a 1/4" phone jack that is designated **PHONES.** More on some of these connectors later. On the top left rear of the radio is a multi-section telescoping antenna that can be pulled out for local reception.

There are a few things you should be aware of concerning the rear connectors. The **MUTE** terminals need to be connected together for the receiver to work. There is normally a jumper

* I often find the term 'winter catalog' confusing since winter spans two years. The winter catalog is early in the year. Heathkit also often put out a Christmas catalog near the end of the year.

Heathkit© GR-78 Front Panel Controls

Top Row - (Left to Right)

(BANDSPREAD)	Tuning Dial - Cylindrical 3" Segments - See text
(MAIN TUNING)	Tuning Dial - Ruler 6" segments - see text
RELATIVE SIGNAL	Meter - vertically mounted marked **0 - 5**

Bottom Row (Left to Right)

BANDSPREAD	Large knob - 1-1/8" dia. Single section variable capacitor
AF / RF GAIN	Dual concentric pots w/switch Power **OFF** - switch on AF Gain AF Gain - Small knob - 5/8" dia. RF Gain - Outer lever knob
LIGHT	Rocker Switch (Momentary*) **LIGHT*** - (blank)
MODE	Rocker Switch **ReCeiVe - STandBY**
CAL	Rocker Switch **CAL**ibrate - (blank) 500 kc markers
MODE	Rocker Switch **AM - CW / SSB**
AVC	Rocker Switch **AVC / MVC**
ANL	Rocker Switch **OFF / ANL**
BAND	Rotary Switch (6-position) **A, B, C, D, E, F**
MAIN TUNING	Large knob - 1-1/8" dia. Dual section variable capacitor

Table I

wire between these two connectors. A word of caution - this jumper contain the full battery voltage on it. Should the receiver touch up against some metal also touching the chassis the battery will be shorted. Since the GR-78 receivers have been around long enough to warrant a battery change, and the newer NiCAD and NiMH batteries can contain quite a wallop,

Figure 2: Rear view of the GR-78 showing the five connectors. A sixth connector has been added (neatly) to this radio. It is the BNC jack in the upper right.

this could be a fire hazard. A fuse, placed in the battery line might make a good modification.

Early Heathkit GR-78s came with a two-prong AC connector and a two-wire power cord. Later, a three-prong connector was used along with a three wire AC cable. Heathkit had a Bulletin (GR-78-5, dated April 16, 1975) for this modification as it related to hum in the GR-78. It involved other component changes as well. The bulletins are available online (See Links).

The female DC 12V connector is rated for 12 - 15 VDC and mates with a two pin (round) Cinch-Jones male connector. The socket on the rear of the GR-78 is setup to accept locking arms available on this connector,. One word of caution is that if the other end is connected to a car battery or such and the plug is not connected to the radio, live 12V can appear on one of the male pins. Be sure to fuse any DC cable you make up to the 12 VDC connector for this radio. My notes show this connector to be a Cinch-Jones 302H-CCTL available from Mouser. Please confirm before ordering one. Should you wire the polarity wrong on the DC cable, the input is diode protected.

The GR-78 is a reasonably sensitive receiver. It uses 15 transistors including 5 MOSFETs. It is single conversion on bands 'A' through 'E' with

Heathkit© GR-78 Band Table

Main Tuning Scales (Top to Bottom)

BAND	F_{LOW}	FHI
'A'	< 0.19 -	> 0.41 mc. in 22 10 kc divs.
'B'	< 0.55 -	> 1.35 mc. in 16 50 kc divs.
'C'	< 1.30 -	> 3.00 mc. in 34 50 kc divs.
'D'	< 3.00 -	> 7.50 mc. in 45 0.1 mc divs.
'E'	< 7.50 -	> 18.50 mc. in 22 0.5 mc divs.
'F'	< 18.00 -	> 30.00 mc. in 24 0.5 mc divs.

Amateur Bandspread (Top to Bottom)

80 M	< 3.50 -	3.60 mc. in 10 10 kc divisions
80 M	< 3.60 -	3.70 mc. in 10 10 kc divisions
80 M	< 3.69 -	3.80 mc. in 11 10 kc divisions
75 M	< 3.78 -	3.90 mc. in 12 10 kc divisions
75 M	< 3.87 -	4.00 mc. in 13 10 kc divisions
40 M	< 6.75 -	7.50 mc. in 15 50 kc divisions
20 M	< 13.55 -	14.50 mc. in 19 50 kc divisions
15 M	< 21.00 -	21.50 mc. in 10 50 kc divisions
10 M	< 27.50 -	30.00 mc. in 5 500 kc divisions

SWL Bandspread (Top to Bottom)

49 M	< 6.00 -	6.5 mc. in 10 50 kc divisions
31 M	< 9.50 -	9.8 mc. in 6 50 kc divisions
25 M	< 11.45 -	12.0 mc. in 12 50 kc divisions
19 M	< 14.40 -	15.5 mc. in 11 100 kc divisions
16 M	< 16.30 -	18.0 mc. in 17 100 kc divisions
13 M	< 21.45 -	22.0 mc. in 11 50 kc divisions
11 M	< 25.00 -	26.5 mc. in 15 100 kc divisions

Table II

an IF of 455 kc., and dual conversion on band "F" with a first IF of 4.034 mc. It uses four 455 kc. ceramic filters for IF selectivity and no IF transformers making IF alignment simple. The MOSFETS are used in the RF amplifier, mixer, local oscillator, IF amplifier - second mixer and product detector. All the bipolar transistors are silicon types except for the two complementary audio output transistors (2N2430 NPN and 2N2431 PNP).

Band Coverage:

The main tuning covers six bands. The 'A' band covers 190 kc. to 410 kc. A gap from 410 kc to 510 kc. exists between bands 'A' and 'B' to provide a buffer for the 455 kc IF frequency. The actual band ranges and the printed nomenclature are shown in table II.

Two separate band-spread dial labels are supplied for the band-spread drum. One if your

Figure 3: NiCad battery from Heathkit GR-78 radio. The forty-year-old battery actually charged up on the bench but quickly swelled after a few charge cycles pushing out the bottom of the case and failing internally.

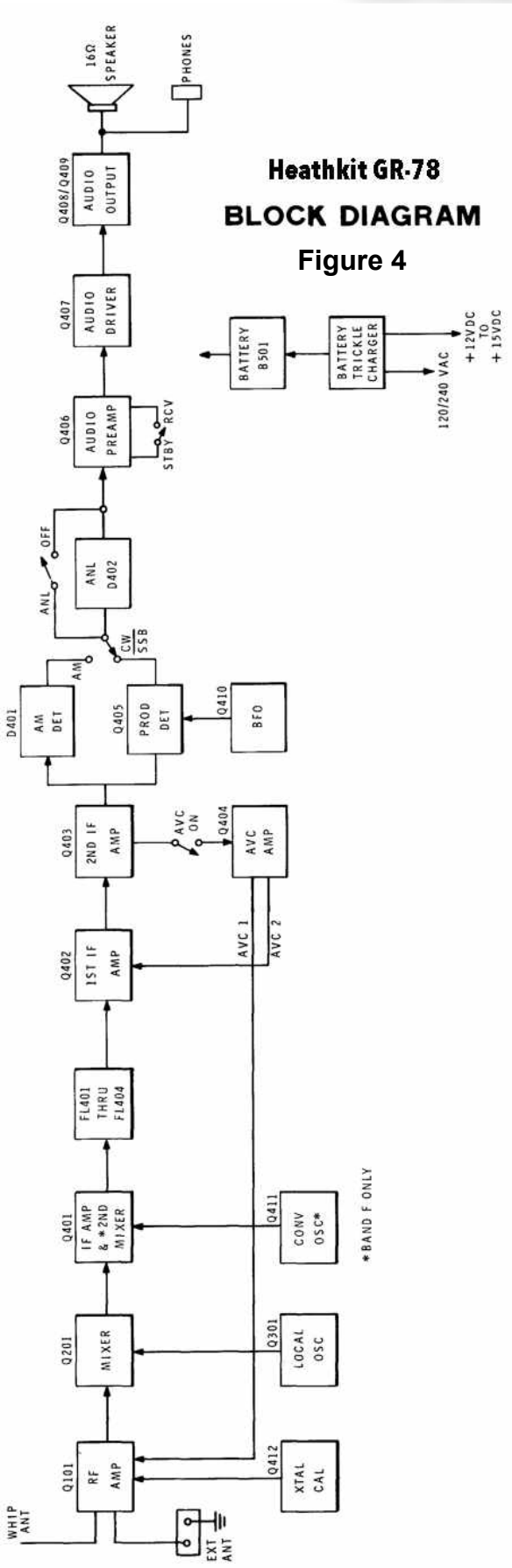
interest lies in shortwave listening and one if you are using the radio for amateur operation. The radio is assembled using one or the other. These are also shown in Table II.

The NiCad Battery:

The battery supplied with the radio is manufactured by General Electric (Part #42B905JD14-G2), and is no longer available. It is 9.6 volts (eight cells) and rated at 500 mAh. It is cylindrical in shape and is 3-9/16" long by 1-7/16" in diameter. Three wires leave the battery, a black common wire, a red 9.6V wire and a white 4.8V wire connected between the fourth and fifth cell (center tap). The Heathkit part number for this battery is 418-23 (See figure 3).

The battery is required to operate the radio. External power from either the AC-line or an external 12 to 15 volt DC power source only trickle charges the radio's battery. The radio requires 40 mA from the battery with the radio on and the volume down to zero. At 50 mW of audio the drain is 65 mA; it is significantly higher at full volume of 300 mW. Meanwhile the trickle current charging the battery is only 22 mA when plugged into the AC-line, or 15, 25, or 35 mA when plugged into a DC source of 12, 13.5, or 15 VDC respectively. Thus the battery will discharge with the radio on even when plugged into external power. Operating time with a fully charged battery is specified as 8 hours at normal volume level without any external power. The Heathkit GR-78 specifications state *"A full battery charge will be maintained if the receiver is connected to an external power source and used an average of 8 hours daily at normal listening level."* In other words the radio can be operated for 8 hours with external power and charged the remaining 16 hours to bring the battery back up to its fully charged state.

When the radio first came into my possession the battery was dead. It was removed and charged using at a constant voltage of 1.25 volts per cell with the current limited to 25 mA. To my total surprise the battery charged up and



seemed to hold its charge, so it was optimistically put back in the radio. The radio played for a few days, recharging when plugged into an AC outlet. Then suddenly the battery showed all the signs of failing. When the radio was opened up the battery had swollen, pushing a the battery case bottom open exposing one cell.

No physically similar replacement battery could be found so two battery sets were made, each containing four AA sized NiMH batteries. They were wired in series, with a third wire attached to the center-tap. The two packs were taped together and mounted in the same place as the original cylindrical battery using some velcro tape and a heavy tie-wrap through the holes that originally held the battery clamps. The new battery has significantly more mAH than the original battery, allowing longer playing time but also longer charging time.

GR-78 Circuit Description:

The GR-78 circuitry is mostly that of a typical receiver circuit. The schematic is too large to include in this article; It can be found online (See Links). Instead, the block diagram is included as figure 4.

GR-78 RF and Mixer Stages:

The RF section is constructed on four separate circuit boards, each with one, two or three band-switch wafers mounted to the board. The four circuit boards plug into a mother-board and are stacked so that a single band-switch shaft passes through all their wafers. The four boards are the Antenna Switch Board, the RF Switch Board, the Mixer Switch Board and the Oscillator Switch Board.

The Antenna Switch Board, has two switch wafers. One wafer connects the lead from either the attached whip antenna or external antenna connector to a tap on one of the six antenna band coils. The switch also grounds the tap to all the antenna coils not in use. The second wafer section connects the output of the selected band coil to the next stage. Each coil can be tuned by a slug and each coil is shunted by a trimmer capacitor. These coils and trimmers are mounted on the small circuit board. The selected coil is also shunted by the first section of the main tuning capacitor, tuning the selected circuit as the main tuning dial is moved.

The RF Switch Board contains the RF amplifier that uses an RCA 40673 dual-gate MOSFET. The signal from the antenna switch board is coupled to one gate of the FET. An external AVC voltage is fed to the second gate to reduce the gain on strong signals. The FET drain circuit has tuned circuits that use two switch wafers and operate the same as the previous board. A second section of the external main tuning capacitor shunts and tunes the selected coil.

The Mixer Switch Board uses an RCA 40604 dual-gate MOSFET to mix the signal from the RF amplifier and the local oscillator to produce the signal at the IF frequency. The signal from the RF amplifier switch board is fed to one gate of the transistor. The second gate is fed by the local oscillator signal. The output signal is the difference between the two frequencies, which is 455 KHz on bands “A” through “E” and 4,034 KHz on band “F”. The output is tuned by one of two coils; bands “A” through “E” use a 455 KHz coil, and band “F” uses a 4,034 KHz coil. This switching is done by the single switch wafer on this board. However this wafer has a rear section that switches on power to the conversion oscillator when receiving band “F”. A trap is connected to the output of the mixer on bands “A” through “E” to remove a spurious signal near 5.5 MHz. Output from the mixer switch board is fed to the first IF amplifier.

The Oscillator Switch Board provides the heterodyning frequency to the previously mentioned mixer board. This oscillator tunes 455 KHz ABOVE the tuned frequency on bands “A” through “D”, 455 KHz BELOW the tuned frequency on band “E” and 4,034 KHz ABOVE the tuned frequency on band “F”. The oscillator circuit is of the Hartley type and uses an RCA 40468 single-gate MOSFET. Six oscillator coils mount on the board, each with a tap partway

down the coil for feedback; the low end of all the coils are connected in common. Three switch decks mount on the board; one selects the tap on the band oscillator coil being used, the second selects the top of that same coil while shorting all the unused coils. The third switch deck switches in a different capacitor for each band. This capacitor is placed in series with the third section of the main tuning capacitor effectively setting its range. A single band-spread tuning capacitor is in parallel with this section of the main tuning capacitor providing the band-spread function.

GR-78 IF Stages:

A large Receiver Circuit Board contains the rest of the GR-78 circuitry except for the components that mount directly to the chassis. There are three stages of IF. The initial stage uses a 40673 dual-gate MOSFET. On bands "A" through "E" it operates as a 455 KHz amplifier; on band "F" it operates as a second mixer providing double conversion. The signal from the RF mixer stage is fed to one gate of the MOSFET. On bands "A" through "E" the second gate is DC biased for proper operation. On band "F" a 3,579 KHz is superimposed on this gate and mixes with the 4,034 KHz IF frequency to produce 455 KHz as well as other mixer components. However only the 455 KHz component makes it through the four ceramic 455 KHz filters that are connected in series.

The output from the filters is amplified in the 'first' IF stage which uses a silicon bipolar 2N3694 transistor. Bias for this stage comes from the AVC amplifier, reducing the gain on strong signals. As the gain is reduced, the emitter voltage becomes less positive. This change in voltage is measured by the signal strength meter. A potentiometer sets the zero point meter voltage.

The 'second' IF stage also uses a 2N3694 transistor. This stage operates at a fixed gain. The output of this stage is fed to an AM detector, a product detector and the AVC circuits.

The only alignment needed for the IF section are the two coils on the mixer switch board (one at 455 KHz for bands "A" through "E" and one at 4,034 KHz for band "F".

The 3,579 KHz conversion oscillator for the second mixer is crystal controlled using an inexpensive TV color-burst crystal and a 2N3694 transistor. Power for this oscillator is only applied when the receiver is on band "F".

AVC Circuits:

To prevent stages from being overdriven when receiving strong signals The RF amplifier and the 'first' IF stage reduce their gain in response to an AVC (Automatic Volume Control) voltage. Actually two separate AVC voltages are created since the two controlled stages use different types of semiconductor devices.

AVC voltage for the RF stage is developed by a a pair of diodes that rectify and double the signal voltage developed at the collector of the last IF stage. This voltage is biased for correct no-signal gain and fed to one gate of the RF amplifier MOSFET. This negative-going voltage reduces the gain of the RF stage, depending on the level of the received signal. An RC circuit on the mother board sets the AVC timing.

AVC for the 'first' IF stage is developed by the AVC amplifier. The signal from the final IF stage is coupled to the base of a 2N3694 transistor. This stage is biased near cutoff so that the signal is rectified. A DC voltage is developed across the collector resistor and filtered. This positive voltage is used to provide bias to the IF stage. As the level of the received signal increases the bias voltage to the first IF stage is reduced reducing the gain.

A front panel switch disconnects the output of the 'second' IF from the AVC circuits when **MVC** (Manual Volume Control) is selected.

Detector Stages and BFO:

The signal from the 'second' IF amplifier is also sent to the two detectors. AM is detected by a

1N191 small signal germanium diode and a capacitor to remove the rectified IF component.

CW and SSB are detected by a product detector that uses an RCA 40673 dual-gate MOSFET. The signal to be detected is coupled via a small capacitor to one of the gates. The other gate receives a signal from the BFO (Beat Frequency Oscillator). The output of the product detector is filtered to remove all but the audio components.

A front panel **AM - CW/SSB** switch selects which detector output is fed to the next stage. When CW/SSB is selected power as also applied to the BFO.

The BFO is a Colpitts oscillator operates on a frequency of 455 KHz. Other than the internal coil slug it has no external frequency adjustment. The IF is wide enough that the user needs only to tune to the desired sideband or CW pitch. The Colpitts oscillator provides a quite stable BFO signal right from when it is activated by the AM - CW/SSB switch.

Automatic Noise Level (ANL) Stage:

Audio is routed from the selected detector through the ANL circuit. The ANL circuit consists of a diode that is forward biased. The audio is then passed through the diode and any large pulses cutoff the diode removing them from the audio. When the **ANL** switch is in the off position the audio is routed around the diode through a 0.22 µF coupling capacitor.

Audio Frequency Amplifier Stages:

Audio is then routed through the **AF GAIN** control and capacitively coupled to the audio preamplifier. The two stages of pre-amplification consist of an NPN 2N3392 transistor and a PNP X29A829 transistor, both silicon bipolar types. They are directly coupled together and directly couple to the audio output stage that consists of 2N2430 (NPN) and 2N2431 (PNP) complementary pair. This circuit, with its DC coupling, and no need for an output transformer to drive a speaker, provides low distortion audio to the speaker. Audio is also fed back to the emitter of the first audio stage reducing gain and improving linearity. The speaker output is coupled through a 100 µF electrolytic capacitor to the built-in 16 ohm speaker. An ear phone jack is also provided. Bias for the base of the first audio stage is obtained by a voltage divider from the 9.6 volt line. It first passes through the **RCV - STBY** switch which is in series with the **MUTE** terminals on the rear of the receiver. (The MUTE terminals must be connected together for the radio to operate). Should the terminals be open or the RCV - STBY switch be in standby no voltage reaches the voltage divider and the stage remains biased off, muting the receiver.

Battery Charging Circuit:

Figure 5 is a representative schematic of the GR-78 charging circuit. When AC is supplied to the radio it is stepped down by a small transformer to around 6 volts. One lead of the secondary winding is connected to the center-tap of the battery. The other lead goes to two diodes so that on a positive half-cycle of the AC one-half of the batteries are being charged and on the negative-half cycle the other half of the batteries are being charged. The transformer has a dual primary and may be wired for 120 or 240 VAC 50/60 cycle operation.

When 12 - 15V DC is applied to the radio, the negative terminal is connected directly to the battery negative lead and the positive lead is connected via a diode for polarity protection, a

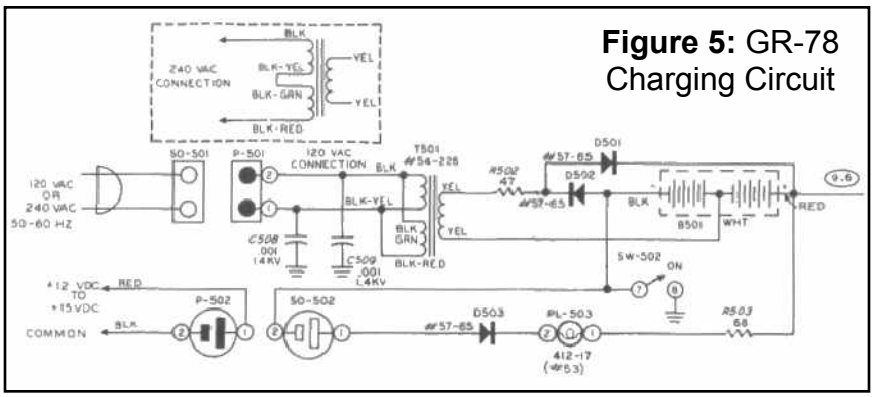


Figure 5: GR-78 Charging Circuit

#53 pilot lamp; as a compensating resistor and a 22Ω current limiting resistor to the battery's positive terminal. The lamp is internal and barely lights, but tends to increase in resistance as the current through it increases.

One unusual aspect of the 12 volt charging system is that the radio power switch is between the negative battery terminal and common. So, if the 12 volt charging source and the receiver share the same common, the power switch is shorted out and the radio is on regardless of the position of the **OFF-ON** switch!

Two tiny "grain-of-wheat" lamps light the tuning dials, but only when the momentary **LIGHT** rocker switch is held on; this is obviously done to save battery life.

Crystal Calibrator:
When the front panel **CALibrate** switch is activated power is fed to a 500 KHz crystal oscillator. Output of the oscillator is lightly coupled to the input of the RF oscillator stage, producing marker signals every half megacycle to provide markers for the tuning dial.

My GR-78 Experiences:
The GR-78 is rather new in my Heathkit stable, at least as a functioning unit. As mentioned earlier, the battery seemed to charge up but quickly failed. While I looked for an exact replacement and then a substitution, it sat on the shelf looking nice but not useable. Now it is in need of a good alignment, and the "F" band oscillator is intermittent, so it will need to be brought up to snuff after the workbench clears of some non-Heathkit items.

Heathkit released ten technical notes on the GR-78 between early 1970 and early 1984 (these are available online - see links). Some of these have already been done; the receiver came with a Heathkit factory repair sticker inside. Three of these modifications specifically address "F" band issues. The most noticeable factory modification I've noticed is the change to a three wire power cord. Both the two and three wire power cords are hard to find today. The 2-wire cord is the same cord as supplied with the SB-301 and SB-401; it is Heathkit part #89-3; the mating chassis connector is part #432-4. The 3-wire power cord used on the later GR-78 is the same cord as supplied with the SB-303 part #89-30; the mating chassis connector is part #432-76. A few other factory mods have been made, but many I have not checked out yet.

In order to save space and money, Heathkit compromised the band-spread function on this radio. The single section band-spread variable capacitor only tunes the oscillator section so sensitivity drops as you move from the set position since the RF and mixer stages do not track.

Ken - W6HHC passed this radio on to me. He got it from OCARC club member Joe Quick - KE6ZMG at the "Watson Radio Club" breakfast, who got it from a neighbor. Ken knew my interest in Heathkits and thought this radio would make a good subject for a Heathkit of the Month article.

I'd like to thank Joe and also again Gene - AF9O who passed along the 1969 catalog that covers all the Heathkit station equipment I bought back when I was just getting on the air after college.

73, from AF6C

This article originally appeared in the December 2014 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.

Thanks - AF6C

Links:

A partial copy of the manual is available here (PDF):
http://tubularelectronics.com/Heath_Manual_Collection/Heath_Manuals_G/GR-78/gr-78.pdf
GR-78 schematic is available at:
http://www.k7jrl.com/pub/manuals/hk/www.tech-systems-labs.com/schematic/GR78.jpg
GR-78 tech notes are available at:
http://www.w6ze.org/Heathkit/TN/GR-78.pdf