Heathkit of the Month #77:
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AUDIO HI-FI EQUIPMENT

Heathkit BC-1A
BROADCAST TUNER

Introduction:

In 1956 Heathkit had about a half-dozen Hi-Fi amplifiers in their stable. Many could be purchased bundled with the WA-P2 Monaural Preamplifier, or the preamplifier could be purchased separately. Heath was producing their third Hi-Fi FM tuner, the FM-3. The FM-3 and the later FM-3A matched the new styling of the WA-P2, a gold color low-height design, some with the vacuum tubes mounted horizontally. Both of the units measured 12-1/2" wide by 3-1/2 high by 6" deep.

While FM provided many advantages over AM for transmitting high-fidelity music, AM was still the favored mode of many teens and young adults due to the numerous AM rock-and-roll stations, and the large number of ***All-American Five*** radios in existence (See sidebar). A lot of effort was made by AM broadcasters to improve the AM fidelity to compete with the growing FM market.

Heathkit took advantage of the AM Hi-Fi trend by producing the Hi-Fi BC-1 AM Broadcast Tuner. This model was followed a year later by the BC-1A (Figure 1). Figure 2 shows an ad for the original BC-1 that appeared in the Summer 1956 Heathkit catalog. The BC-1 and BC-1A continued in the styling of the WA-P2 and FM-3 kits, with the same gold paint, low-height design and physical dimensions. The BC-1 sold for $24.50 over its year lifetime. The 1957 BC-1A sold for $25.95 and remained in production into 1960. In 1959 the FM-3A was replaced by the newly styled and more sensitive FM-4;

Fig, 1: BC-1A AM Broadcast (Hi-Fi) Tuner

shortly afterwards the AJ-20, with the same new styling replaced the BC-1A. The updated styling consisted of a black and gold front panel with vinyl covering on top and sides of the cabinet. The new cabinet was open in the rear and was about an inch taller to allow the tubes to be mounted vertically.

HI-Fi AM:

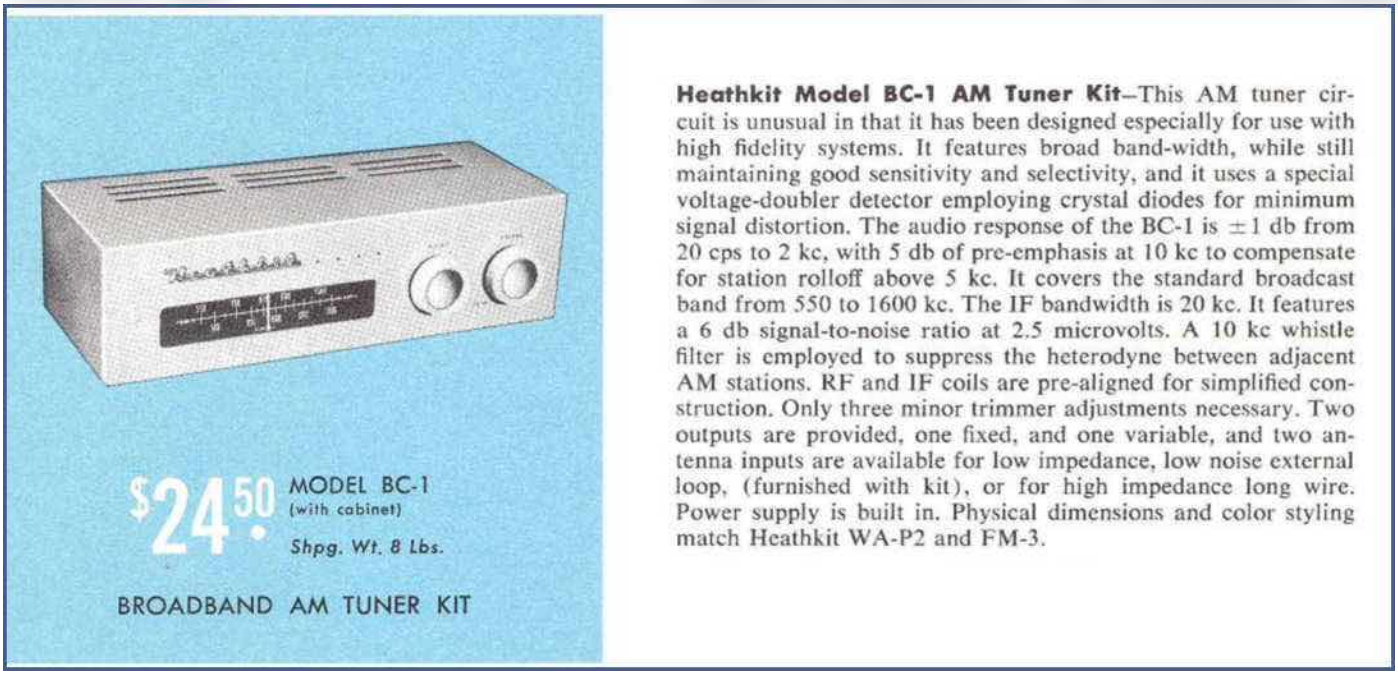
The typical *"All-American five"* tube AC/DC radio of the fifties had a bandwidth of about 10 kc*, that is 5 kc on either side of the carrier. Thus, the highest audio component that can be received is somewhat less than 5 kc. AM stations were spaced 10 kc apart. Stations in physical proximity to each other were spaced 20 kc, 30 kc or more apart to cutdown interference. However, as nighttime propagation allows signals to travel much farther, interference from stations 10 kc apart can occur. The limited bandwidth of the 5-tube AC/DC radio helps eliminate interference from stations nearby in frequency, but if the bandwidth approaches 20 kc (10 kc on either side of the carrier) both carriers can be received resulting in an annoying 10 kc beat note or whistle emanating from the speaker.

Some AM stations were licensed allowing them to transmit at up to 30 kc bandwidth when AM

° **Why kc Instead of kHz?**

A good question. I try to write using the nomenclature used in the Heathkit manual. Hertz (Hz) replaced cycles per second (cps) in the early 1960s. Here is a quick reference:

cps	= cycles [per second]	= Hz	= Hertz
kc	= kilocycles [per second]	= kHz	= kilohertz
mc	= megacycles [per second]	= mHz	= megahertz



Heathkit Model BC-1 AM Tuner Kit—This AM tuner circuit is unusual in that it has been designed especially for use with high fidelity systems. It features broad band-width, while still maintaining good sensitivity and selectivity, and it uses a special voltage-doubler detector employing crystal diodes for minimum signal distortion. The audio response of the BC-1 is ±1 db from 20 cps to 2 kc, with 5 db of pre-emphasis at 10 kc to compensate for station rolloff above 5 kc. It covers the standard broadcast band from 550 to 1600 kc. The IF bandwidth is 20 kc. It features a 6 db signal-to-noise ratio at 2.5 microvolts. A 10 kc whistle filter is employed to suppress the heterodyne between adjacent AM stations. RF and IF coils are pre-aligned for simplified construction. Only three minor trimmer adjustments necessary. Two outputs are provided, one fixed, and one variable, and two antenna inputs are available for low impedance, low noise external loop, (furnished with kit), or for high impedance long wire. Power supply is built in. Physical dimensions and color styling match Heathkit WA-P2 and FM-3.

Fig, 2: BC-1 AM Broadcast (Hi-Fi) Tuner from the 1956 Heathkit Summer catalog

hi- fidelity was under development, though 20 kc was the practical limit.

Heathkit's HI-Fi AM:

The BC-1(A) offered some innovative features in its day, and Heathkit commented heavily about specifications, AM high-fidelity theory and circuit description in the manual. The BC-1(A) is capable of of a -3dB bandwidth of over 9 kc. This is a lot higher response than one would normally hear on a simple desktop AM radio. That makes the BC-1(A) sound reasonably good on your hi-fi system when listening to a wide-band AM transmitter. The problem of stations 10 kc away, which might not be heard in the daytime, causing interference at night when propagation expands was also addressed. The GC-1(A) solves the problem for weak adjacent stations by using a 10 kc filter that sharply eliminates the beat note or "whistle" an adjacent carrier would cause, when receiving the desired station. However, should the interfering station be strong enough that its sideband interferes severely with the sideband of the station being listened to, then annoying interference will be heard. Heathkit provided an extra resistor that could be installed to reduce the bandwidth if interference is too severe. Installing it reduces the bandwidth and fidelity for the AM received signal. The later AJ-20 also offers this feature, but it is selected by moving a slide-switch instead of removing the cabinet, warming-up the soldering iron and adding another component - one probably misplaced by this time.

The *All American Five* AC/DC Radio

In the 50s most US households had an All-American Five AC-DC radio. They came in many forms, but the circuit was pretty much identical with an optional pilot lamp the major circuit difference. The ***Five*** in the name refers to the use of five vacuum tubes.The radios came with plastic, or sometimes, wood cases as the chassis could be at 120 VAC depending on how the non-polarized plug was inserted in the wall. Thus, no bare metal showed.

Early on, these radios used the same five octal tube lineup, but soon switched to the more compact miniature 7-pin tubes:

TUBE FUNCTION	OCTAL	7-PIN
Mixer-Oscillator.	12SA7	12BE6
IF amplifier	12SK7	12BA6
Diode Detector/AVC/1st audio amp	12SQ7	12AV6
Audio Output Amplifier	50L6	50C5
Rectifier.	35Z5	35W4

The first two digits of the tube number is the filament voltage. The filaments are all rated at 150 mA and are wired in series for 121 VAC ± 10%, easily in the range of the typical 110 to 120 VAC power line voltage. B+ voltage was derived directly from rectifying the AC line voltage, producing about 150 VDC of B+.

The BC-1(A) has no amplifier or headphone output so it can't be used stand-alone. It does offer two separate outputs, one controlled by a the front panel volume control and one that has a fixed output so as not to compete with the volume control on the preamplifier or amplifier. The fixed output is higher in impedance than the volume controlled one which is driven by a cathode follower. This means you may use much longer leads from the volume controlled output than the fixed output. These outputs are at line level for connecting to the input of a hi-fi amplifier.

Assembly:

The kit is assembled using point-to-point wiring; there is no printed circuit board. Five tube sockets, the three-section tuning capacitor, two IF transformers, solder terminal strips and lugs and rubber grommets are installed on the vertical chassis. Four delicate coils will be mounted as they get wired.

After a short soldering tutorial is given in the manual, wiring begins. The wiring is done in sections; first the filament wiring is completed, except for the pilot lamps. Next the RF amplifier is wired, leaving connections that go to points off the chassis unconnected. The B+ distribution wiring is then completed, followed by the oscillator-mixer stage, and the IF amplifier stage. Finally the detector, with its crystal diodes, the audio cathode follower and whistle filter are wired. After each of these sections is completed, the manual instructs the builder to *"Clean out clippings and solder splashes, and carefully check for short circuits and defective connections."*

The power transformer is mounted to the left end-bracket and the bracket to the chassis. The right-end bracket mounts to the chassis next. The bracket to chassis mounting is through soft rubber grommets for vibration isolation. The power transformer leads are connected to the chassis. The front dial-plate is then mounted along with the volume control. Connectors are mounted to the ventilated rear panel and this assembly is attached and wired.

The tuning dial-drive is assembled and mounted to the dial-plate and the tuning dial is strung so the tuning capacitor turns when the dial-drive is turned, and the dial pointer moves along the bottom edge of the dial-plate. Then the pilot lamp sockets are installed.

The BC-1 and BC-1A both have dual antenna inputs. One allows the attachment of a long-wire antenna, and the other a loop antenna. Heathkit supplied the parts and cable to build a shielded broadcast loop antenna that gives optimal performance for the AM tuner (see Figure 3). This loop can be mounted on the wall behind the radio. If mounted as a circle it measures a vast 3'10" in diameter, and if mounted as a stadium (as shown in figure 3) some of its typical measurements are given in table I. The

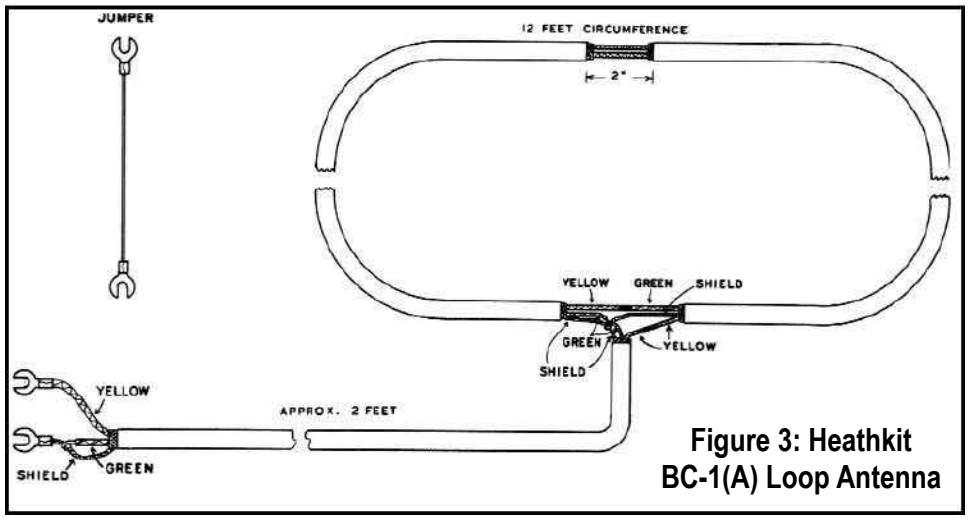


Figure 3: Heathkit BC-1(A) Loop Antenna

Width	Height
3' 10"	3' 10"
4' 0"	3' 6"
4' 4"	3' 1"
4' 6"	2' 8"
4' 9"	2' 2"
5' 0"	1' 9"
5' 4"	1' 4"

Measurements rounded to nearest inch,

Table 1: Loop Measurements

audio cable for the connection between the tuner and the preamp is assembled next.

Initial resistance checks are then made, the tubes and lamps are installed, and with the loop antenna attached, power on checkout is performed, followed by alignment. And finally the front panel, trim, fragile dial plate and knobs are installed along with the cabinet shell and ventilated bottom plate.

Alignment:
Heath states that satisfactory alignment may be accomplished without test equipment. The IF transformers and other coils come from the factory pre-calibrated. Alignment of the trimmer capacitors can be done without need of any test equipment as long as there is a local broadcast station near 1400 kc. Alignment involves adjusting the oscillator trimmer until the broadcast station is tuned in at its proper dial frequency; then the mixer and antenna trimmers are adjusted for the clearest signal. This will get the tuner reasonably well aligned.

The "whistle filter" also must be aligned for maximum performance. It is accomplished by tuning between two close-by signals near the high end of the AM band so you hear the 10 kc beat-note between the two AM carriers. The filter coil is then adjusted for minimum whistle.

If a signal generator and VTVM are available, the manual gives instructions for a full RF alignment, including IF stages. If an audio signal generator is also available the "whistle filter" can be more accurately aligned.

ID #	Part #	Description	Purpose
V1	6BA6	Pentode	RF Amplifier
V2	6BE6	Heptode (Pentagrid)	Mixer - Osciillator
V3	6BA6	Pentode	IF Amplifier
V4A	½ 12AU7	Triode	"Whistle Filter - 10 kc"
V4B	½ 12AU7	Triode	Cathode Follower
V5	6X4	Dual Diode	Full-Wave Power Rectifier
M1	HD2257	Crystal Diode (56-4)	Voltage Doubling Detector
M2	HD2257	Crystal Diode (56-4)	Voltage Doubling Detector

Table 2: Tube and Diode Lineup

Circuit Description:
The BC-1(A) uses a single-conversion superheterodyne circuit. It has five tubes including a the rectifier tube; one of the tubes is dual-section. Two crystal diodes are used for the detector. The tube lineup is shown in Table II. Since the superheterodyne circuit has been discussed before, only the more exotic aspects of the circuitry will be discussed.

RF Amplifier:
Unusual in AM radios, the BC-1(A) utilizes an RF amplifier before the mixer. The amplifier is gang-tuned along with the oscillator and mixer sections by a three-section variable capacitor. The top of the amplifier's input coil is capacitively coupled to the long-wire antenna input. A low impedance winding on the coil is designed to match the external loop antenna. The RF stage produces added gain and decoupling between the antenna and mixer circuits. Some added selectivity is also a benefit. The gain of this stage is controlled by the AVC (Automatic Volume Control) voltage derived from the detector circuit.

Mixer / Oscillator:
This is a standard AM mixer oscillator circuit with the oscillator tracking 455 kc above the received frequency. The gain of the mixer is also controlled by the AVC voltage.

IF Amplifier:
The heterodyned 455 kc signal from the mixer is coupled through the first IF transformer. This transformer is different than ones used on standard AM radios. It is wide-band due to the primary and secondary windings being over-coupled. This produces a bandwidth about twice that of a normally coupled IF transformer with very steep skirts. It also produces a response that is double peaked (Figure 4A) which would result in linearity problems across the wanted bandwidth unless compensated for. This compensation is provided by the output IF

transformer which has a more peaked gain and thus fills in the valley making the response along the top flatter (Figure 4B).

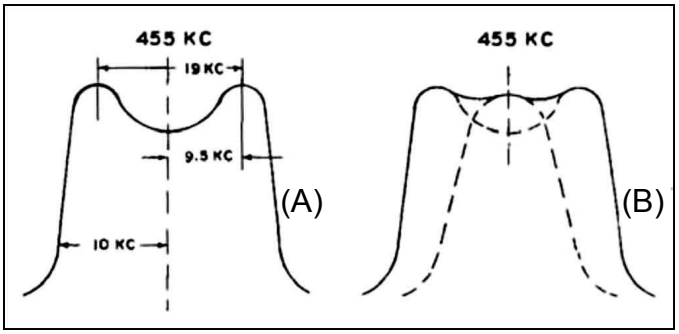


Figure 4: IF Response from BC-1(A) Manual

Crystal Detector:

Radios in the *All-American Five* class use a diode section of the audio tube to half-wave detect the AM modulation. The BC-1(A) instead uses a full-wave voltage (and frequency) doubling circuit. This circuit is very similar to the voltage doubling circuits used in many power supplies (except the power handled and capacitance needed are magnitudes lower). Just like the 60 cps power frequency gets doubled to 120 cps in such a circuit, the carrier frequency is doubled to 910 kc. The higher carrier frequency makes it easier to filter out without affecting the higher audio frequencies. The detector diodes are arranged so the output is a negative DC voltage with the high fidelity AM riding atop.

AVC:

The negative voltage from the detector is coupled through a 2.2 MΩ resistor and filtered by a 0.01 µF capacitor to the grid of the IF stage. Similarly, this AVC voltage is coupled to the grid of the mixer stage by 3.3 MΩ and 0.05 µF. The signal to the mixer grid is also fed to the RF amplifier by an additional 1 MΩ and 0.01 µF network. The stronger the signal carrier the more negative this voltage is which lowers the gain of the three stages, helping keep the volume the same independent of signal strength.

"Whistle Filter" and HF Compensation:

The audio detector is AC coupled to the "whistle filter" through a compensating circuit composed of two 1 MΩ resistors and a 150 pF capacitor (See figure 5). At low frequencies, the reactance of the capacitor is high with respect to the parallel 1 MΩ resistor, and the two 1 MΩ resistors create a voltage divider of 2 (-3 dB). However at about 1 kc the reactance of 150 equals approximately 1 MΩ and the gain increases by about -1.8 dB, and at 5 kc and 10 kc this gain is -0.7 and -0.4 dB respectively. Thus the higher frequencies are boosted. This helps correct for the broadcast station rolloff at higher audio frequencies.

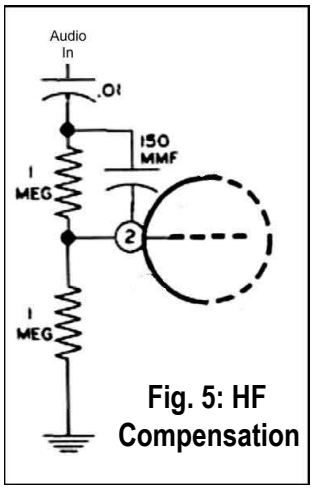


Fig. 5: HF Compensation

The first section of the 12AU7 is a bridge-tee notch filter. It has a very sharp notch at 10 kc removing or reducing any 10 kc whistle resulting from the beating of an adjacent carrier with the desired signal's carrier. Output from the filter is isolated by a 0.05 µF capacitor and appears at the **FIXED OUTPUT** RCA jack on the rear panel. Audio from the whistle filter is also connected to the second section of the 12AU7 through the volume control. This 12AU7 section is wired as a cathode-follower, producing a low impedance output that is connected to the **VARIABLE OUTPUT** connector RCA jack. The BC-1A schematic is shown in Figure 6.

BC-1 – BC-1A Differences:

Whenever Heathkit updates a kit, people become curious as to what changes were actually made. Thanks to Chuck Penson, author of two excellent Heathkit books: *Heathkit Test Equipment Products* and *Heathkit: A Guide to the Amateur Radio Products*, I obtained the manual for the BC-1 to compare to my BC-1A** manual. I spent some time looking for the differences. The most significant and major difference is that the BC-1A adds a second pilot light, pilot lamp socket and mounting hardware to better illuminate the glass frequency scale.

This requires a new metal dial plate. Electronically the two tuner circuits remain identical to the last detail. Other differences are that four fasteners were changed from 6-32 x 3/8" bolts with lock washers and nuts to #6 sheetmetal screws. This probably was not a cost savings move as much as done to eliminate the need to put nuts and lock washers on in tight spaces. Other new parts include an improved shaft bushing for the tuning control and a new siding dial pointer (Different color?). The other change also involves the dial illumination, two lengths of 3/8" sleeving were provided to cover part of the two pilot lamps to remove direct glare from the filaments. Heathkit offered an upgrade kit, the C-BC-1 for $2.95. It *"Converts the BC-1 to include major features of BC-1A"*.

BC-1A Operation:

There is not too much to installing and operating the BC-1A other than the antenna. Though the BC-1(A) includes input for a long-wire antenna, it recommends the supplied loop be used. Getting the loop antenna oriented correctly for best reception as well as looking somewhat aesthetically pleasing, probably posed a serious problem for many families.

Other than the antenna, one must only provide AC power to the tuner, and connect the included cable, that was built during construction of the kit, between the tuner and your preamplifier, or directly to an amplifier that has a preamp built in. It may be connected either to a **TUNER** or **AUX.** input. Use of the variable or fixed output depends on the preferences of the user and how their hi-fi is set up.

The Leftover 27 KΩ Resistor:

When finished with your BC-1 or BC-1A kit you will discover you have part left over, a 27 KΩ 1/2 watt resistor part #1-23. On page 36 of the 40-page manual the reason for this resistor is explained. It is installed across the primary of the first IF transformer if you find yourself in a location where adjacent channel interference is a problem. Such a location might be near a powerful AM station or worse, near more than one of them. The wide bandwidth of the BC-1(A) makes it more susceptible to interference from strong adjacent stations. If this problem becomes serious the 27 KΩ resistor may be installed across the primary of the first IF transformer loading it and reducing its bandwidth. This should eliminate the adjacent channel interference at the cost of fidelity in the tuner.

Interestingly, the AJ-20 and AJ-21 AM Hi-Fi tuners that followed the BC-1A has this resistor wired into the kit, and it can be switched in or out with a front panel switch at the listener's discretion.

Conclusion:

I have to admit I've never owned, nor do I ever remember seeing in real life, a BC-1 or BC-1A tuner. However, I've been looking for a hi-fi AM tuner to accompany my AJ-14 and AA-14 stereo that sit on the ham shack bookshelf. While I prefer a solid-state tuner, I'm currently researching other Heathkits too (Heathkit never built a solid-state AM-only tuner). However it's on the back burner with a bunch of other tasks needing to be accomplished. Still it would be nice to be able to listen to AM radio now and then in the ham shack when the bands die.

73, from AF6C

Remember if you come across any old Heathkit Manuals or Catalogs that you do not need, please pass them along to me.

Thanks - AF6C

*This article originally appeared in the September 2017 issue of **RF**, the newsletter of the Orange County Amateur Radio Club - WWW.W6ZE.ORG*

** I'd especially like to thank Patrick Diederichs - AL7EW who passed along the BC-1A manual I used in writing this article, along with bunch of other manuals. Perhaps some will also be the start of future articles.