

Heathkit of the Month:
by Bob Eckweiler, AF6C

Heathkit

Heathkit FM-4
FM Hi-Fi Tuner (including FM-1 thru FM-3B)

Introduction:

Heathkit was not only known for its amateur and test equipment, it also produced a long line of audio Hi-Fi equipment. Their HI-Fi equipment included many monaural, and later stereo, FM tuners. This article looks at Heathkit's early FM tuners from the FM-1 through the FM-4.

A Short History of Broadcast FM:

In an effort to improve the quality of broadcast radio Major Edwin Howard Armstrong developed frequency modulation (FM) in the late 30s. FM offers immunity from interference that affects the amplitude of the received signal; it also provides high fidelity at the penalty of wide bandwidth. Due to the bandwidth requirements of hi-fidelity FM, an allocation in the VHF region at 42 to 50 MC (MHz) was initially assigned by the FCC in 1940. Numerous FM broadcast stations started broadcasting in, and many FM radio sets were sold for, the 42 to 50 MC FM broadcast band.

After World War II a broadcast war broke out between Armstrong and RCA chairman David Sarnoff over the FM frequency allocation. RCA was heavily into AM broadcast and pioneering TV, and was pushing to move the FM band to a higher frequency allocation. Part of the reason was to make room for the upcoming growth in TV, but another reason may have been to impede Armstrong's growing FM broadcast business that was in direct competition with RCA's AM broadcasting. The FCC sided with RCA, (a decision that had some merit) and on June 27, 1945 the FM band was moved to 88 to 108 MC. The expense of updating a commercial FM station to the new frequency band caused many stations to shut their doors. The result was a



Fig. 1: Heathkit FM-4 Hi-Fi FM Tuner

blow to FM broadcasting that lasted for many years until home hi-fidelity once again created a demand for high audio-quality broadcasting. The setback to FM broadcast, and the drawn out litigation with RCA, bankrupted Armstrong and, along with domestic problems, drove him to suicide in 1954.

The 88 to 108 MC (actually 87.8 to 108 MC) band allows for 101 FM channels, each 200 KHz wide. The channels center on each odd tenth of a MHz (i.e. 87.9, 88.1, 88.3 MC, etc. up to 107.9 MC). Not all channels are available in all areas. Channels are selected to prevent interference in the nearby aviation and commercial bands. Nearby stations that are 10.6 and 10.8 MC apart are avoided to prevent interference with the 10.7 MHz IF used by most FM receivers.

Stereo FM broadcasting, by transmitting a multiplexed sub-carrier, was initiated on the first of June in 1961.

The Heathkit FM-1:

Heathkit introduced its first FM broadcast tuner, the FM-1 in early 1949 (Fig. 2). It has two tubes, a 14F8 "loctal" dual-triode and a 12A6 octal tetrode that only provides power rectification (more on this later). The circuit design is based on the Hazeltine-Fremodyne super-regenerative detector. This circuit overcomes a serious problem with the typical super-regenerative detector which generates interference on the received frequency that is coupled to and radiated by the antenna unless a stage of isolation is added. The Fremodyne circuit consists of an oscillator that operates a given frequency above the received signal fre-

**HEATHKIT
FM TUNER KIT**

Complete kit to assemble frequency modulation tuner. Connects to any radio to receive the new static free FM band. Easily assembled — no coils to wind, clear detailed instructions anyone can read — comes complete with tubes and all other parts — slide rule calibrated dial, 110V 60 cycle transformer operated, etc Shipping weight 6 pounds.

\$14.75

Mahogany Cabinet (extra) **\$3.75**



Fig. 4: Heathkit Cabinet for the FM-2

quency (about 22 MC is common). The received signal and the oscillator are both fed into a regenerative detector that is tune to this difference IF frequency (22 MC). Thus the Fremodyne oscillation and super-regenerative oscillator signals are not near the receive frequency and don't cause interference on the received frequency.

In the FM-1 each section of a dual-ganged tuning condenser supports a single-turn loop coil. The smaller loop tuned circuit is connected to one-half of the dual-triode 14F8 which operates as an oscillator tracking 21.75 MC above the tuned frequency. The other tuned circuit tunes the incoming signal and feeds it to the second half of the 14F8 dual-triode; the oscillator signal is also coupled to the second triode, a regenerative detector for 21.75 MC that acts like a mixer, FM detector and amplifier all in one. Output from the second triode is the recovered audio. The FM-1 uses a power transformer to isolate the device from the AC line. Heathkit must have acquired a large supply of surplus 12A6 tetrode tubes as they chose to use this tube as the rectifier diode. The grids and plate are connected together and the tube is wired in a half-wave rectifier configuration.

The FM-1 came with the regenerative transformer, the tuning condenser and coil assembly both pre-built and aligned. The kit sold for \$14.75 less cabinet. A mahogany cabinet was available for \$3.75. The FM-1 has just two controls, a rotary ON-OFF switch and the tuning knob that operates a slide-rule dial. On the back, left to right, are two two-screw terminal strips and a grommet for the exiting line cord. The left-most terminal strip is for the audio output and the other is for the antenna terminals.

The Heathkit FM-2:

In the fall of 1950 Heathkit introduced the more advanced FM-2 superheterodyne FM tuner (Fig. 3). It uses eight tubes, three" loctal" (See Sidebar) and five octal. The tube lineup is shown in Table I.

The design is straight forward; the signal from the antenna is tuned and fed into a mixer. The local oscillator, tuned to track 10.7 MHz above the received signal, is also coupled to the mixer. The resulting 10.7 MHz output is ampli-

**TRUE FM FROM *Heathkit*
FM TUNER KIT**

\$22⁵⁰



The Heathkit FM Tuner Model FM-2 was designed for best possible tonal reproduction. The circuit incorporates the most desirable FM features — true FM — ready wound and adjusted coils — 3 stages of 10.7 Mc. I.F. (including limiter).

Tube lineup: 7E5 oscillator, 6SH7 mixer, two 6SH7 I.F. stages, 6SH7 limiter, two 7C4 diodes as discriminator, 6X5 rectifier.

The instrument is transformer operated making it safe for connection to any type receiver or amplifier. The R.F. coils are ready wound — mounted on the tuning condenser and the condenser is adjusted — no R.F. coils to wind or adjust.

A calibrated six inch slide rule dial has vernier drive for easy tuning. The finest parts are provided with all tubes, punched and formed chassis, transformers, condensers and complete instruction manual. Model FM-2. Shipping Wt., 10 lbs.

Fig. 3: Heathkit FM-2 Ad Circa Late 1950



Fig. 2: Heathkit FM-1 Flyer Ad Circa 1949

fied in three stages of IF; the last stage, designated the limiter, saturates on moderate signals removing any AM component. The 10.7 MHz signal from the limiter is fed into a Foster-Seeley discriminator, composed of two 7C4 diode tubes. The audio output of the discriminator is de-emphasized and fed through a volume control to the audio output terminals. The FM-2 has neither AGC nor AFC circuitry.

Function:	Tube:	Type:	Base:
Mixer	6SH7	tetrode	octal
Oscillator	7E5	triode	loctal
1st. IF Amp.	6SH7	tetrode	octal
2nd. IF Amp.	6SH7	tetrode	octal
IF Limiter	6SH7	tetrode	octal
Discriminator	7C4	diode	loctal
Discriminator	7C4	diode	loctal
FW ¹ Rectifier	6X5	rectifier	octal

¹ FW = full-wave

Table I - FM-2 Vacuum Tube Lineup

The FM-2 sold for \$22.50. Also available was a blonde birch veneer cabinet model #350 (Fig. 4) that sold separately for \$4.95. The front of the FM-2 has two controls. On the left is the ON-OFF and volume control, and on the right is the tuning control that drives a 6" slide-rule tuning dial. Between them is a pilot lamp that I could not find on the schematic. There are no connectors on the rear of the FM-2 chassis. Instead the connections are on the top of the

chassis along the rear edge. From left to right (as viewed from the back) is a two-screw antenna terminal, an AC outlet (switched with the tuner power switch), a grommet where the AC power cord exits, and another grommet that has a shielded pigtail lead, terminating in an RCA plug, that carries the audio output from the tuner.

The Heathkit FM-3:

In the fall of 1955 Heathkit introduced the FM-3 to replace the FM-2. The FM-3 design, again a standard superheterodyne circuit, switched to miniature 7 and 9-pin tubes. While the FM-2 has eight tubes the FM-3 has only seven tubes; however, three of those tubes are dual-section resulting in the equivalent of 10 tubes. The tube lineup is shown in Table II.

Function:	Tube:	Type:
RF Cascode Amp.	6BQ7	dual-triode
Mixer	1/2 6U8	pentode
Oscillator	1/2 6U8	triode
1st. IF Amp.	6CB6	pentode
2nd. IF Amp.	6CB6	pentode
Ratio Detector	6AL5	dual-diode
Audio Amplifier	6C4	triode
FW ¹ Rectifier	6X4	rectifier

¹ FW = full-wave

Table II - FM-3/3A Vacuum Tube Lineup

One improvement for the FM-3 is the addition of a cascode RF amplifier before the mixer. The cascode amplifier offers a high gain at a low noise level, important at VHF frequencies. The input to the RF amplifier is broadly tuned in a fixed circuit. It's signal is fed to the mixer along with the oscillator signal, and on to two high-gain stages of IF amplification. Instead of the Foster-Seeley discriminator used in the FM-2, the FM-3 uses a ratio detector which is more immune to amplitude signals. While the high gain of the two IF stages performs some limiting on large signals, limiting is not as critical when using a ratio detector which suppresses amplitude variations. Like its predecessors the tuning condensers and coils come pre-aligned.

Two features not found in the earlier FM-2 are dual audio outputs, one fixed at a low level and one amplified about 22 dB with front panel level adjustment, and the addition of AGC that reduces the gain of the cascode amplifier on strong signals.

The Heathkit FM-3 sold for \$24.50 including a metallic gold colored case. Like the FM-2 there are two controls on the front panel of the FM-3, which unlike the FM-2 is in a low-profile cabinet. Left to right are the slide rule tuning dial, the tuning control, and the OFF-ON - volume control. Internally the chassis is shock-mounted vertically with the tubes facing the rear of the cabinet. In the rear, left to right, are two RCA jacks (audio output **LO** and **HI**), the two-screw antenna terminal strip, and the power cord which actually comes out through the cabinet flange.

The Heathkit FM-3A:

After being in production for about a year Heathkit updated the FM-3 to the FM-3A in September of 1956. Most of the circuitry remained unchanged, as did the appearance, except for the B-plus distribution. Additional filtering and isolation resistors were added to

better isolate interaction between circuits. Perhaps there were some instability problems in the FM-3 that needed resolution? The FM-3A also added AGC to the first IF amplifier to improve AGC operation. Finally, a second pilot light was added to even-out the lighting of the slide-rule dial. The FM-3A sold for \$25.95.

The Heathkit CFM-3 Modification Kit:

When Heathkit updated the FM-3 to the FM-3A it offered the CFM-3 update kit for \$2.95. This kit "converts FM-3 to include major features of FM-3A."

The Heathkit FM-4:

The Heathkit FM-4 came out around 1958, replacing the FM-3A. The FM-4 is a update to the FM-3A adding new features such as a multiplexer output to allow stereo FM that was on the horizon; the FM-4 adds AFC (automatic frequency control) that limits receiver drift. The new FM tuner also features a pre-assembled, pre-aligned FM tuner (part # 110-1). The FM-4 sold for \$39.95. The multiplex output connection has no use for a few years until Heathkit released its initial multiplex adapter sometime in 1960 letting FM-4 users get ready for the upcoming Stereo FM broadcasting.

The FM-4 continues the low-profile styling of the FM-3 series, but the color scheme went from gold to black. The cabinet was included in the kit and was metal with vinyl covering. The kit could be mounted into an enclosure, such as the **Heathkit Chairside Enclosure** or a custom-built cabinet, by removing the kit's cabinet and feet; mounting holes are provided. Heathkit recommended keeping the bottom shield in place for proper operation and stability.

The FM-4 Circuitry:

The FM-4 uses five miniature tubes; two are multiple-section. Missing is a rectifier tube which has been replaced by a single silicon diode. The FM-4 tube lineup is shown in Table III. The circuitry is typical of an FM superheterodyne tuner of the day. The tube count of the FM-4 drops to five, due to the pre-assembled tuner



Fig. 5: Heathkit FM-3A Catalog Ad

and a silicon rectifier diode. The FM-4 schematic is shown in figures 8a and 8b. Figure 9 shows an FM-4 ad mentioning a multiplexer.

The Tuner Circuit:

As mentioned earlier, the tuner comes pre-built and pre-aligned. The dual-triode tube, either a 6DT8 or 6AQ8, is already installed as it was used for alignment. The tuner is shielded in its own enclosure with five feedthrough terminals carrying the input and output connections. Grounding is through the tuner's case. The five terminals are: Antenna, B+, Filament, AFC and IF output. The pre-built tuner allows for a more exotic design using permeably tuned coupling and oscillator coils utilizing shorted links to improve tuning linearity. This would be hard to align without good test equipment.

Function:	Tube:	Type:
RF Amp. ¹	1/2 6DT8	triode
Mixer / Oscillator ¹	1/2 6DT8	triode
1st. IF Amp.	6AU6	pentode
2nd. IF Amp.	6AU6	pentode
3rd. IF Limiter	6AU6	pentode
Ratio Detector	2/3 6BN8	dual-diode
Audio Follower	1/3 6BN8	triode

¹ Part of pre-assembled tuner.

Table III - FM-4 Vacuum Tube Lineup

One triode section, coupled to the antenna through a bandpass filter, acts as a grounded-grid RF amplifier; the other triode section is a combination mixer and oscillator driving a 10.7 MC IF transformer. Varying the tuning control tunes the RF amplifier plate circuit as well as oscillator. these tuned circuits are aligned to track 10.7 MC apart. The oscillator circuit also contains a special diode that is reverse biased and acts as a small capacitor changing the oscillator slightly when the bias voltage is varied. This bias is controlled by the external AFC circuit.

The IF and Limiter Circuit:

The three stages of IF amplification using 6AU6 pentodes are coupled with bandpass transformers with a bandwidth of 150 KC and

10.7 MC center frequency. The third IF stage with its high plate resistor is designed as a limiter to help remove any amplitude modulated noise. The second IF also is designed to act as a limiter, but only on strong signals.

The Detector Circuit:

The FM signal at 10.7 MC is coupled to a standard ratio detector composed of the two diode sections of a 6BN8 triple-section tube. The circuit is similar to the FM-3 with the exception of the circuitry for the AGC which is not used in the FM-4. Output from the detector is filtered by a small capacitor to remove any residual IF energy and goes three places: It is directly connected through a 100KΩ isolation resistor to the multiplexer circuit. It is connected to the AFC circuit, and it is connected through a de-emphasis network to the audio output follower stage.

The AFC Circuit:

The output of the ratio detector carries not just the audio signal, but a DC component that varies with the average offset of the signal in the detector. This DC component is isolated and further filtered in an RC circuit. Its level is then set by an internal AFC potentiometer and it is fed to the tuner. If a station drifts off frequency the resulting voltage will correct the oscillator, bringing the signal back into tune. A front panel switch turns off the AFC circuit by shorting the AFC voltage to ground; you may want to disable it when tuning near a very strong signal.

The De-emphasis Circuit:

Audio being transmitted by an FM station has the higher frequency components boosted to help eliminate noise. The de-emphasis network is just a simple RC network with a 3dB point at 2.34 KHz to attenuate the higher frequencies back to their proper levels.

The Audio Follower Circuit:

The triode section of the triple-section 6BN8 tube is wired as a cathode follower. The audio from the de-emphasis circuit is fed through the volume control potentiometer to the grid of the

cathode follower. Negative feedback in the bias circuit helps linearize this stage which lowers the output impedance reducing hum and noise pickup in the cable to the amplifier. The output of the cathode follower is connected to the RCA output jack on the rear of the FM-4.

The Power Supply:

The FM-4 uses a power transformer with two secondary windings and a 120 VAC primary. Silicon diodes were just coming on the market in quantity and at reasonable prices in 1958. The FM-4 uses a single R200 200PRV 200 ma diode in a half wave rectifier circuit. The FM-2 and FM-3 series all used a tube full-wave rectifier circuit. The half-wave circuit requires better filtering, but Heathkit evidently decided the cost of an additional diode was more than the cost of adding higher capacitance and more RC filtering to the B-plus power supply. The FM-3A utilizes three 20µF filter capacitors, while the FM-4 uses one 100µF, two 40µF and one 20µF filter capacitors. The FM4's half-wave rectifier produces about 135 volts DC. A filament winding on the transformer supplies 6.3 VAC to the five tubes. The filament circuit contains choke coils and capacitors to isolate the tube filaments.

The FM-4U FM Tuner:

Heathkit also made the FM-4U FM tuner for the European market. This tuner has a multiply-tapped transformer primary to allow



Fig. 6: Heathkit's European FM-4U

operation on 105, 125, 205, 225 and 245 VAC @50/60 cps. The circuitry is very different than the American FM-4; an EZ80 (6V4) rectifier tube is used instead of the silicon diode. An EM84 (6FG6) tuning indicator tube is included, and no AFC is provided. Physically, the FM-4U (Fig. 6) looks nothing like its American namesake.

The AJ-31 FM Tuner:

In 1961 Heathkit introduced the AJ-31 FM Tuner for \$39.95. It replaced the FM-4 and was part of a newly styled series of audio hi-fi equipment which included the AJ-21 AM Tuner, AJ-11 AM/FM Tuner, and a large contingency of other similarly styled tuners and amplifiers of different prices and performance levels. I couldn't find a schematic of the AJ-31 to see how much had changed from the FM-4; however the tube lineup was similar, as was the physical layout except for the tuner which now supports a triple-triode 6GY8 tube and is mounted differently to the chassis. The AJ-31

Now Enjoy FM in Stereo!

AC-11A
\$32.50

Kit Form or Factory Assembled

- + Use with any FM tuner having multiplex output
- + Built-in power supply
- + Easy to build
- + Color styled to match Heathkit tuners
- + Measures only 3 3/8" H x 3 1/2" W x 9 7/8" D

Kit AC-11A (black case) ...	\$32.50
no money down, \$5 mo.	
Kit AC-11B (luggage tan case) ...	\$32.50
no money down, \$5 mo.	
Assembled ACW-11A ...	\$56.25
no money down, \$5 mo.	
Assembled ACW-11B ...	\$56.25
no money down, \$5 mo.	

FM STEREO CONVERTER ...

Kit Form or Factory Assembled

With the AC-11 converter you can receive stereo FM programs from any good quality FM tuner with multiplex output. Compact and easy to assemble! ... has 3 tubes, built-in fused power supply and prealigned coils. A balanced-diode detector assures low distortion and controlled signal matrixing gives maximum separation of channels for true stereo. Features separation control, and cathode follower outputs. Frequency response is 50 cps to 15 kc with built-in de-emphasis. Color styled to match deluxe or economy Heathkit tuners. Order with your Heathkit tuner today! Connecting cables included. 4 lbs.

Fig. 7: Heathkit AC-11A Stereo Multiplexer Converter

front panel controls are the same and located in the same position as the FM-4.

Compatible Multiplexers:

The FM-4 and later monaural FM tuners came with a multiplexer output in preparation for the June 1961 introduction of stereo FM transmitting. Heathkit made two multiplexers that worked with the FM-1, the MX-1 and later the \$32.50 AC-11 Multiplexer (Fig. 7). Interestingly, the AC-11 came in two versions, the AC-11A, which was black in color to match the FM-4 and the AC-11B which was tan in color to match the AJ-31, AJ-11 and AJ-32 Deluxe AM/FM Tuner.

Comments:

I have no idea how I acquired my FM-4; I believe it appeared in the mid-to-late sixties. It was used on and off back then and was later modified to allow me to analyze some of the TV scrambling techniques in the days of the infamous scrambled "Channel 52" in the Southern California area! The tuner has sat quietly in a closet for many years since the early 70s until I started this article. My FM-4 needs to be put back into its stock configuration. (No chassis modifications were made so it should be easy to do.) The chassis and tube shields have accumulated that white powder that sometimes accumulates on old chassis parts. (Anyone have a good cleaning technique for that?) Before I modified it I did make sure it was operating properly and it sounded good feeding into one channel of my Heathkit AA-32 stereo amplifier.

A few short years after the AJ-31 replaced the FM-4, Heathkit was moving their popular stereo equipment to all solid-state designs. Many top-of-the line units were complete receivers that contain FM, and often AM, tuners, preamplifiers and a stereo power amplifier in one integrated package. Heathkit stereo products were known for their quality and competitive cost. Many of the audio Heathkits were available factory wired at a moderate cost increase for the audiophile who didn't want to build one from a kit.

SIDEBAR:

What is a "Loctal" Tube?

Most hams are familiar with octal tubes. Their base, usually black bakelite, has eight pins, all of the same thickness and evenly spaced around a keyed non-conductive center post. Occasionally one or more pins are missing for electrical isolation; this is most common on rectifiers, such as the 5U4 which only has five of the eight octal pins.

Loctal tubes have the same pin spacing as octal tubes however the pins are thinner. The base shell is made of metal as is the center post which is not only keyed but has a groove that mates with a locking ring in the tube socket to "lock" the tube in place (hence the name "Loctal", pronounced "Lock-tell"). The center post is also an electrical connection to the tube - most often the base shield.

Loctal tubes were developed by Sylvania for use in high vibration environments, most notably car radios. Philco was a major employer of loctal tubes in its radios.

Removing loctal tubes from their sockets can be difficult if the proper technique is not known. On the side of the base of a loctal tube is a mark or dimple. Pushing the tube towards the side that has that mark will cause it to unlock and be easily removed.

Loctal tubes usually have numbers starting with either 7 or 14. While this starting number normally designates filament voltage, these loctal tubes run at 6 and 12 volts; however, as they are designed for automotive use where voltages run closer to 7 and 14 volts when the battery is being charged, they are designed to handle the higher filament voltages as well.

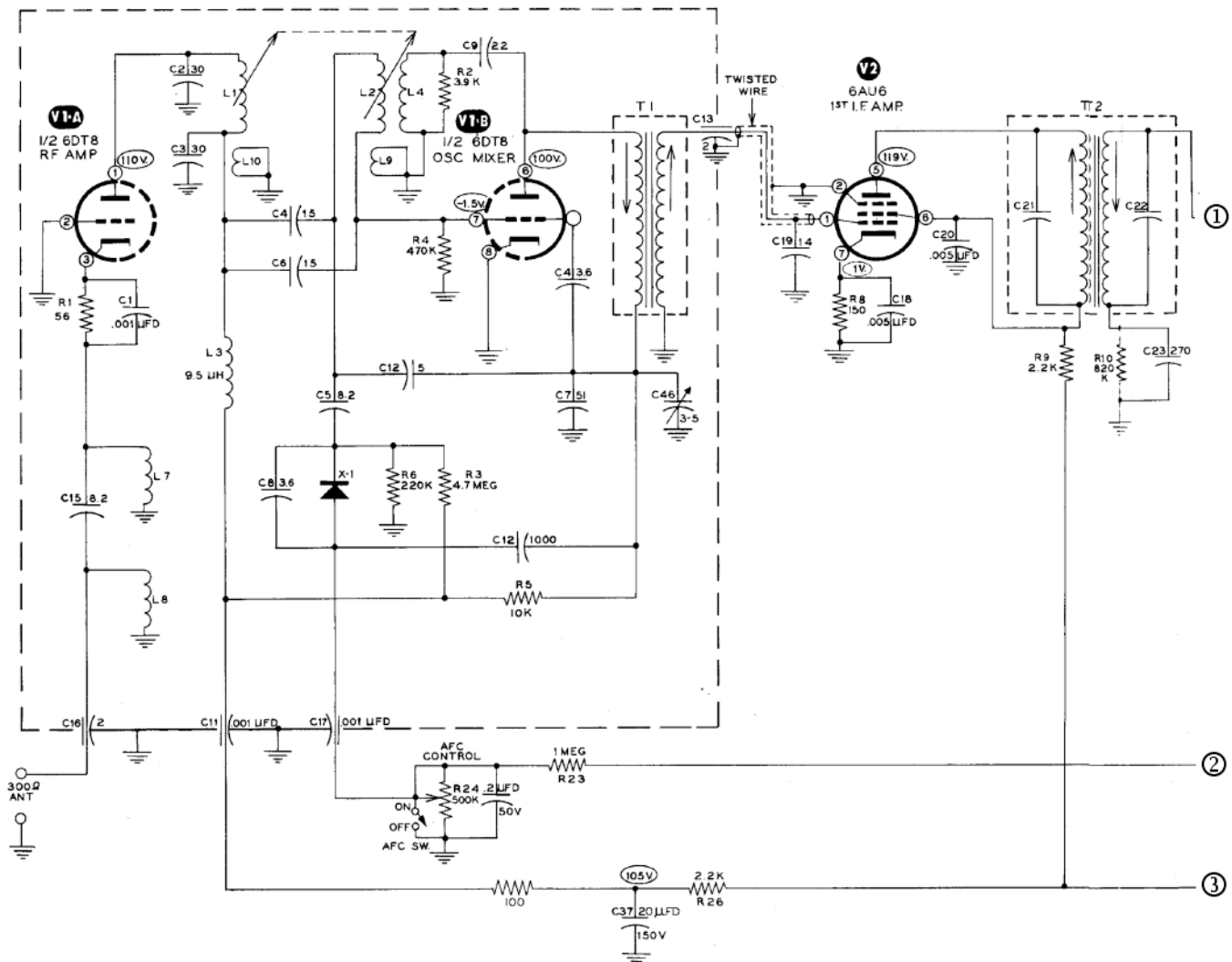
73, from AF6C



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

Thanks - AF6C

This article originally appeared in the January 2013 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.



HEATHKIT F M TUNER
MODEL FM-4

NOTE: ALL DC VOLTAGES TAKEN TO CHASSIS WITH A HEATHKIT VACUUM TUBE VOLTMETER.
ALL VOLTAGES MAY VARY ±10% FROM INDICATED VOLTAGES.
VOLUME AND TUNING CONTROLS FULL CLOCKWISE.
ANTENNA TERMINALS SHORTED.
AFC SWITCH IN OFF POSITION.
ALL CAPACITORS MARKED IN μF UNLESS OTHERWISE INDICATED.
ALL RESISTORS ARE 1/2 WATT UNLESS SPECIFIED OTHERWISE.
C16, C11, C13, C16 AND C17 ARE FEED THROUGH CAPACITORS.
ARROWS ↑ AT TRANSFORMERS T1, T2, T3, AND T4 INDICATE TOP SLUGS.

Figure 8A FM-4 Schematic
Page 1 of 2

**QUALITY FM PERFORMANCE . . .
WITH PROVISION FOR
MULTIPLEX STEREO**

**FM-4
\$39.95**

Bring the magic of FM programming into your home with this low cost, easy to assemble Heathkit FM Tuner. A multiplex adapter output jack makes the FM-4 instantly convertible to stereo by plugging-in the style-matched MX-1 FM Multiplex Adapter kit (below). Design features include: better than 2.5 microvolt sensitivity for reliable fringe area reception; automatic frequency control (AFC), eliminating station "drift"; flywheel tuning for fast, effortless station selection; and pre-wired, prealigned and pretested, shielded tuning unit for easy construction and dependable performance of finished kit. The clean-lined design will enhance the appearance of any room of your home. 8 lbs.

Fig. 9: Heathkit FM-4 Ad from May 1960 Issue of Hi-Fi Stereo Magazine

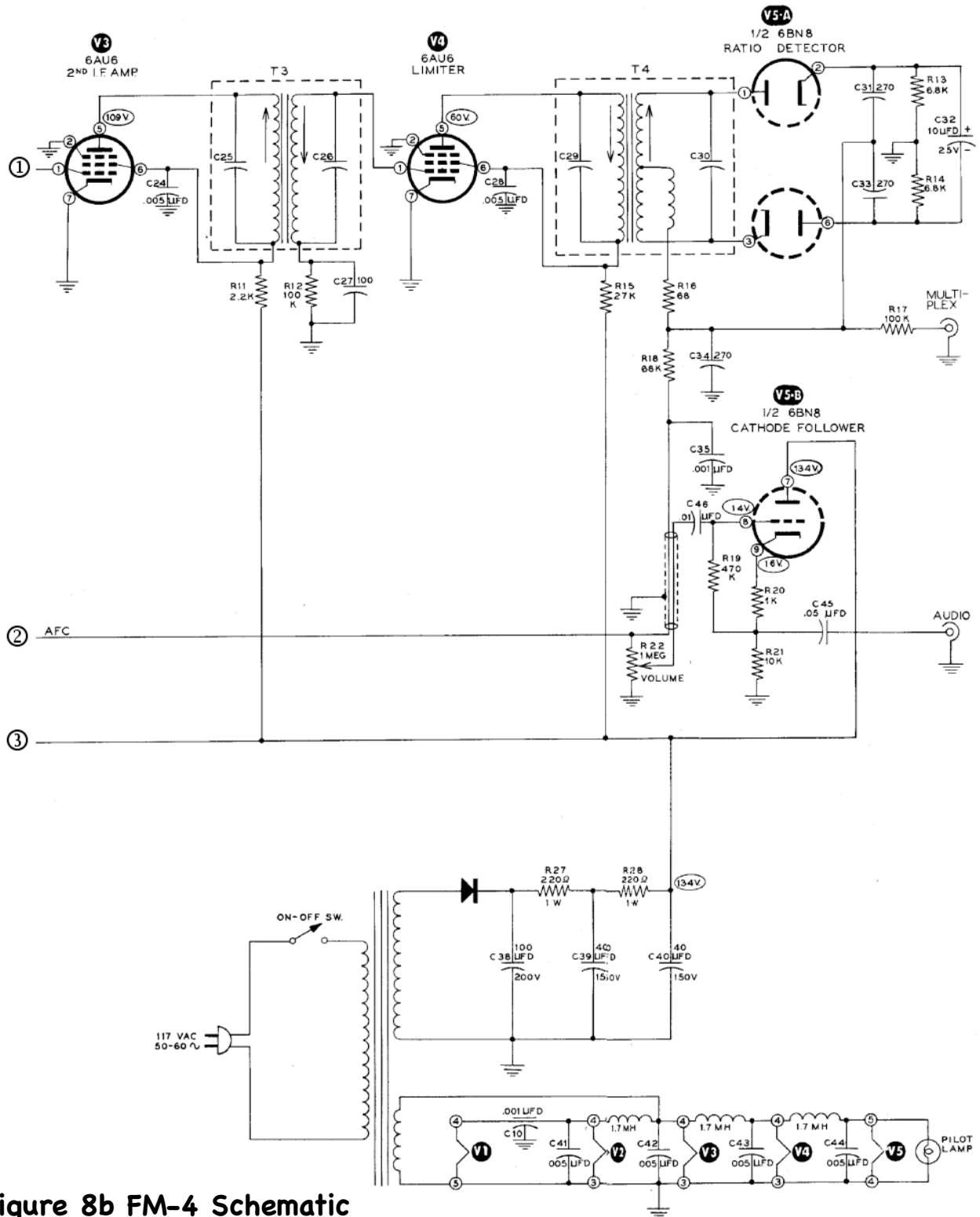


Figure 8b FM-4 Schematic