Heathkit FM-3 Assembly Manual

Introduction

Although low in price, the Heathkit FM-3 FM Tuner is soundly engineered and is capable of high sensitivity and stable performance. Careful chassis layout, straightforward circuit design and specially selected components contribute to this result.

Two outputs are provided, one at low level which is not affected by the volume control on the tuner, and the other at high level which is controllable. Thus, the tuner can be used with high gain high fidelity systems which have a level set control on the input, such as the Heathkit WA-P2 Preamplifier, or with any amplifier by using the high level controllable output.

Good performance can be obtained by connecting high level output to transformer operated portable phonograph players which have an extra input connection provided or radio and TV sets which have phono inputs. Practically any transformer operated radio or TV set can be modified for use as an amplifier and any competent serviceman can make this addition at a nominal charge. The tuner must not be operated with AC-DC equipment. See instructions under "Installation" in back of manual.

For best performance, the tuner should be used with a high fidelity type of system, since it is only with a wide range system that the full benefit of FM can be realized. The advantage of FM over AM reception will be readily apparent with any type of amplifier, however.

Circuit Description

The Heathkit FM-3 FM Tuner is a seven tube, AC operated superheterodyne receiver employing high gain tubes in all RF circuitry. Careful layout of the components allows this high gain to be realized without troublesome instability.

A high gain cascode type radio frequency (RF) amplifier is used ahead of the tuner to increase the overall gain of the receiver and to reduce oscillator and other RF leakage to the antenna. A 6BQ7A twin triode tube is employed in this circuit, connected in an unconventional manner. Incoming signal is first applied to the antenna coil, the purpose of which is to match the antenna impedance (300 Q) to the tube input impedance and to tune this input to the FM broadcast band.

This coil is "broadbanded" to tune the entire FM band at once by using a low value resistor and condenser across the coil. Automatic Gain Control (AGC) is used on the 6BQ7A input grid, so it is necessary to feed the signal from the coil to the grid through a 47 uuf condenser which will pass the high frequency RF, but will block the Direct Current (DC) from the antenna coil.

The first half of the 6BQ7A tube acts as a conventional triode voltage amplifier. Its plate load is made up of the plate resistance of the second half of the tube which is in series with the first and the 10 K resistor connected to B+ (high voltage DC). Voltage amplified by the first half of the tube is connected through a neutralizing choke to the cathode of the second half, causing it to swing by approximately the same amount. The neutralizing choke is made to be resonant with the circuit and tube capacity in the middle of the FM band, which gives added gain to the stage and prevents oscillation. Gain in the second half of the tube is accomplished by effectively tying the grid to ground through a .001 ufd condenser and isolating the grid from the cathode with a 470 K resistor. Thus, the grid remains at a fixed potential while the cathode voltage is varied, causing the tube to act as though the grid potential were changing. Operation is much the same as a grounded grid amplifier. Loading for the second half of the 6BQ7A is provided by a 10 K resistor tied to B+ and this load is tuned through a 3.3 uuf condenser to the RF coil on the tuning condenser assembly. The main advantage of this circuit is that high gain, equivalent to that of a pentode, can be obtained at a much lower noise figure.

Signal from the RF amplifier and RF coil on the tuning assembly is coupled to the 6U8 pentode grid through a 47 uuf condenser and the signal is amplified. The triode section of the 6U8 is used as an oscillator of the standard Hartley type. Since the oscillator and RF signals are both present in the tube, they mix in such a manner that the sum and difference of the two frequencies are present at the output of the pentode, as well as the RF and oscillator signal.

The oscillator frequency is selected so it is always 10.7 megacycles (mc) higher than the frequency of the RF section. Therefore, the difference will always be 10.7 mc. It is to this frequency that the intermediate frequency (IF) transformers are tuned. This function of changing frequencies is known as the Superheterodyne Principle. Improved selectivity and gain is obtained due to the fixed tuned IF transformers, which are designed to give optimum performance at one frequency only.

Amplification of the IF signal takes place in the first 6CB6 stage. The first IF transformer passes the 10.7 mc signal and rejects almost all unwanted signals. This signal is connected to the grid of the 6CB6 tube. The signal is boosted or amplified by the tube and fed to the second IF transformer, which is connected to the plate circuit of the 6CB6. Any residual unwanted signal that might remain is eliminated by this transformer. Exactly the same thing happens in the second 6CB6 IF stage. Additional amplification takes place and the signal is passed on to the ratio detector transformer which is connected to the plate of the tube.

Detection of an FM signal involves a different principle than that used for AM demodulation, due to the different nature of the transmitted signal. Amplitude Modulation (AM) refers to a carrier signal whose amplitude or strength is varied at a rate depending on the frequency of the modulating intelligence and whose height depends on the relative volume or loudness of the audio, the carrier frequency remaining constant. For FM, the carrier amplitude is held constant and the carrier frequency varies on both sides of the center frequency at a rate determined by the modulating frequency and a frequency swing proportional to the volume of the modulating sound.

Thus it is apparent that any amplitude variations on an FM signal contribute nothing to the detected audio and so amplitude variations can be clipped off in the IF stages or cancelled out in the detector, which is done in the Heathkit FM-3. Random noise, ignition pulses from gasoline engines and electric motors and static from electrical storms are all forms of amplitude modulation which come through an AM receiver as interference but are eliminated or substantially reduced in an FM receiver due to its AM suppressing action. Hence, the quiet performance of FM which makes it so ideal for high fidelity listening.

A Ratio Detector is used to demodulate the FM signal in this tuner. The two halves of a 6AL5 duo-diode are connected in a series fashion through the ratio detector transformer. Connections to the tube are indicated on the schematic diagram. Contrary to usual practice with the somewhat better known discriminator type of detector, one winding of the transformer secondary is connected to a diode plate, while the other is connected to the cathode of the remaining diode. The remaining plate and cathode are connected to a balanced resistance network and an electrolytic condenser. When IF signal is present at 10.7 mc, a reference DC voltage is established at the condenser. Frequency deviations from the 10.7 mc center result in positive or negative current variations depending on direction of frequency swing. These variations are taken out as audio voltage from a tap at the center of the transformer secondary. An RF reference for this secondary is furnished by a third winding, which sets up the phase relationships necessary for FM detection. Amplitude modulation of all types will be applied to both diodes at the same time with a resulting increase in average current drawn through the two diodes. Voltage surges of this type are absorbed by the reference electrolytic condenser previously mentioned and are thus cancelled out. A certain amount of unbalance will always be present in the circuit however, so some response to noise will be evident when listening to weak signals.

Audio from the tap on the transformer secondary is passed through a 68 ohm resistor and a 270 uuf condenser network to bypass all remaining IF energy to ground, leaving only pure audio signal. Next, this signal is passed through a 68 K resistor and a .001 ufd condenser network, which comprises the "de-emphasis" network required to restore the audio to a "flat" response. High frequency "pre-emphasis" is used at the transmitter to keep low frequency deviation down and to improve signal to noise ratio at the receiver. "De-emphasis" at the receiver attenuates high audio frequencies at the same rate as the pre-emphasis at the transmitter and the resulting response is "flat." Most noise picked up by and generated in the receiver falls in the high audio frequency range and this noise is attenuated by the de-emphasis network at the same time as the audio is flattened out.

Signal from the de-emphasis network is connected to the volume control, which is a fixed resistor with a sliding tap. By moving the position of the tap it is possible to select any desired portion of the entire signal appearing across the fixed terminals of the control. The low level fixed amplitude signal is taken out of the fixed resistance terminals of the control and so the control has no effect on this output. Output from the variable tap is connected through a condenser to the grid of the 6C4 audio amplifier.

Conventional circuitry is used in the 6C4 stage which is wired as a standard resistance-capacity coupled amplifier. An unbypassed cathode bias resistor is used and this resistor reacts with the cathode circuit to provide bias for the tube. Although stage gain is reduced by not using a bypass condenser, noise and distortion are reduced even more because of the current feedback introduced by the unbypassed cathode resistor. A low value of plate load resistance is used (47 K) to keep output impedance low. This is desirable in order to reduce hum pickup in the interconnecting audio cable and to minimize high frequency loss.

In order to avoid distortion, loss of gain and overload, it is necessary to "bias" the tubes in an RF or audio amplifier in some manner. This term refers to application of a negative potential on the grid of a tube in respect to the cathode. If the grid (the tube control element) is at the same potential as the cathode (the heated electron emitting element), an applied signal voltage will cause the grid to draw current since the grid and cathode form a rectifier, or diode, under these conditions. When grid current is drawn, the portion of the waveform involved is clipped off or distorted by the diode action. In most cases, this is very undesirable and bias is applied to the grid so that signal voltage can be varied without swinging the grid potential positive in respect to the cathode. A number of methods can be used to obtain a negative voltage on the grid, two different methods being used in the FM-3. The 6BQ7A, 6CB6, and 6C4 employ cathode bias, where the current drawn by the tube is passed through a resistor in the cathode circuit, causing the cathode to become positive in respect to ground. Since the grid is tied to ground through a resistor or an IF transformer, the cathode will be positive in respect to the grid, which is the same as making the grid negative in respect to the cathode.

Contact bias is used in the 6U8 stage. If the cathode of a tube is tied directly to circuit ground and the grid returned to ground through a high resistance, a very small amount of current will be drawn by the grid. This current will be limited by the resistor however, and a slight negative voltage will appear at the grid. Biasing in this manner is useful where cathode impedance must be kept low and the signal level is low.

AGC (automatic gain control) action is obtained by feeding the negative DC voltage developed at the GAL5 ratio detector back to the 6BQ7A RF amplifier grid through an isolating network consisting of a 330 K resistor and a .01 ufd condenser. This network filters out all RF, IF and audio energy, preventing interaction between the input and output stages of the tuner. The DC voltage developed at the 6AL5 is proportional to the incoming signal strength and so is useful as a gain controlling voltage. when the voltage, or bias, at the grid of a tube is increased in a negative direction, the gain will be reduced. Thus, the stronger the signal, the less sensitive the set becomes, which tends to keep the audio level relatively constant and prevent overloading when tuned to very strong signals.

Power for the receiver is obtained from the power supply, which involves the power transformer, the 6X4 tube and the electrolytic filter condenser. The transformer supplies filament voltage for all tubes and high AC voltage to the plates of the rectifier. The rectifier action is exactly the same as that taking place in the 6AL5 diode detector described above. The output voltage is a series of positive pulses, one for each half of the 60 cycle line waveform. The voltage applied to the tubes must be free of these pulses, or ripple, or only a loud buzz will be evident from the speaker system. It is for this reason that the high capacity filter condenser is used. The first section of the condenser charges to the voltage from the 6X4 tube. When the tube is not conducting, the condenser starts to discharge through the load presented by the other tubes in the receiver. However, the next positive charge takes place before the condenser has time to discharge fully, so the voltage is smoothed out somewhat.

Final filtering action takes place in the second section of the filter condenser. This section is isolated from the first by a 1000-ohm resistor which tends to help smooth the voltage because it resists current variations in the filter circuit. The second section of the condenser smooths out any variations passed by the first part of the condenser and the voltage output is "pure" direct current (DC).

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