Heathkit of the Month:
by Bob Eckweiler, AF6C

AMATEUR RADIO - SWL
Heathkit HW-12 / HW-22 / HW-32
"*Single-Bander*" SSB Transceivers - PART II

Fig. 1 - HW-22 40-meter Transceiver

Introduction:

in the February issue of ***RF*** the *"Single Bander"* HW-12 (75 meters LSB), HW-22 (40 meters LSB) and HW-32 (20 meters USB) were the topic. These sideband only transceivers were very popular in the mid sixties; many are still on the air today. In the February article the construction, control layout and frequency scheme were discussed at length. This month the circuit will be covered.

Since the schematics are too big to publish here, a copy of the HW-22 schematic has been uploaded to our website so you can follow everything a little closer:

http://www.w6ze.org/Heathkit/Sch/hw22.pdf.

Schematics of the other *"Single Bander"s* may be available on line too, but the HW-22 is representative of the other radios and should suffice. Snippets of the schematics of the other radios may be used as needed.

Figures 5 and 6 are block diagrams of the transmitter and receiver sections (Table and figure numbers will continue from last month. If one is shown in both articles, it will retain its original number.)

Tube Line-up:

Each of the *"Single Bander"* transceivers uses 14 tubes; with the exception of V14, they each perform the same function in each radio. Five of the tubes are dual-section, so the effective tube count is 19, and even 20 on the HW-22 and HW-32 if you consider the dual function for V14 tube.

ID	Section - Tube # (Type)	Function
V1A	1/2 - 6EA8 (P)	Mic Amp
V1B	1/2 - 6EA8 (T)	Audio Follower
V2A	1/2 - 6EA8 (P)	Xmtr IF
V2B	1/2 - 6EA8 (T)	Relay Amp
V3	6AU6	Common IF Amp
V4	6AU6	Xmtr Hetro. Mixer
V5	1/2 - 6EA8 (P)	Xmtr RF Driver
V6	6GE5	RF Power Amp
V7	6GE5	RF Power Amp
V8A	1/2 - 6EA8 (P)	Rcvr RF Amp
V8B	1/2 - 6EA8 (T)	Xmtr Het. Mixer
V9	6AU6 (P)	Rcvr IF Amp
V10	6AU6 (P)	VOX Amp
V11A	1/2 - 12AT7 (T1)	Product Detector
V11B	1/2 - 12AT7 (T2)	Carrier Oscillator
V12A	1/2 - 6EB8 (P)	Rcvr Audio Out
V12B	1/2 - 6EB8 (T)	Rcvr Audio Amp
V13	6AU6 (P)	VFO
V14[1]	6BE6 (H)	VFO Follower
V14[2]	6BE6 (H)	VFO Het Osc/Mix

[1] HW-12 75-meter transceiver only
[2] HW-22 40-meter & HW-32 20-meter transceivers
Tube Type: (P) = Pentode, (H) = Heptode, T = Triode

TABLE IV – "Single Bander" Tube Line-up

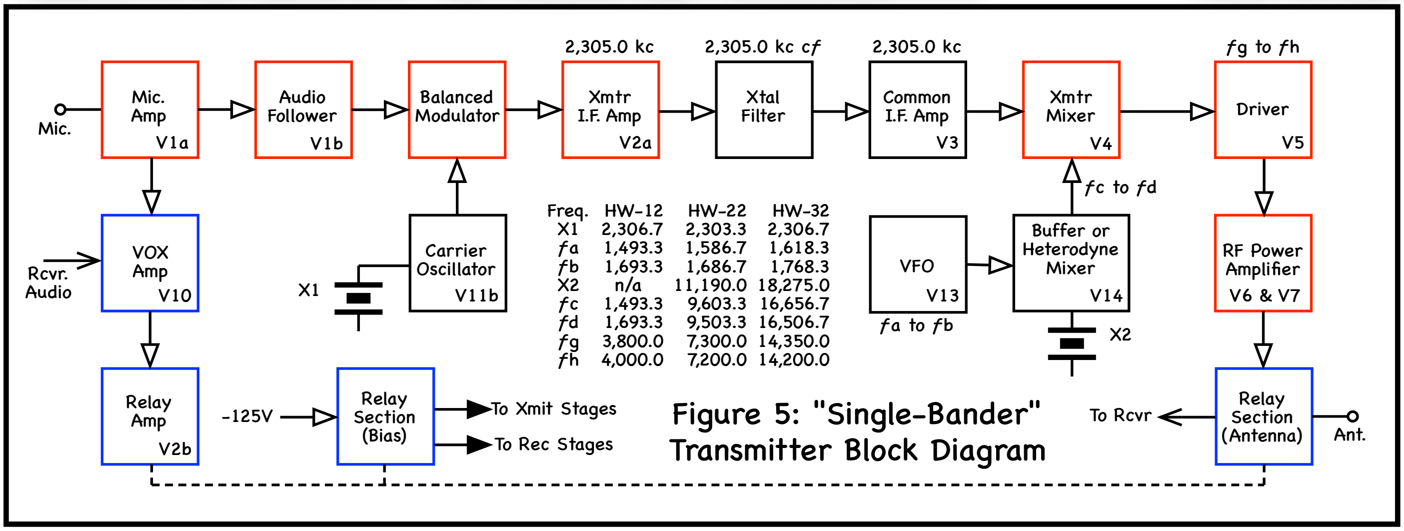

Figure 5: "Single-Bander" Transmitter Block Diagram

Circuit Description:

The circuit may be broken up into four sections - the oscillators, the transmitter, the receiver and the transmit/receive control and switching.

<u>The Oscillators</u>:

All three radios have a similar crystal controlled carrier oscillator and VFO oscillator. The HW-22 and HW-23 also have a crystal controlled heterodyne oscillator to raise the frequency of the VFO without compromising stability. All three oscillators use series-resonant crystal mode oscillators.

Carrier Oscillator (V11B):

The crystal controlled carrier oscillator uses 1/2 of a 12AT7 in a Colpitts oscillator circuit. It operates either on a frequency of 2,303.3 or 2,306.7 kc. Each frequency is 1.70 kc from the 2,305.0 kc IF frequency. The lower crystal frequency will initially create an USB signal after passing through the crystal filter; likewise, the higher crystal frequency will create an LSB signal. Feedback is supplied by the series capacitors and the signal is taken from the cathode. This oscillator provides the carrier signal to the balanced modulator on transmit, and carrier injection signal to the product detector on receive.

VFO Oscillator (V13):

A 6AU6 pentode is used to generate the VFO signal. This is also a Colpitts circuit. Since the frequency range and frequency span of the VFO is different for each of the *"Single-Bander"* radios, the capacitor values, including the variable capacitor are not identical across the line. The lower and upper range of the VFO is given in Figures 5 or 6 as *f*a and *f*b.

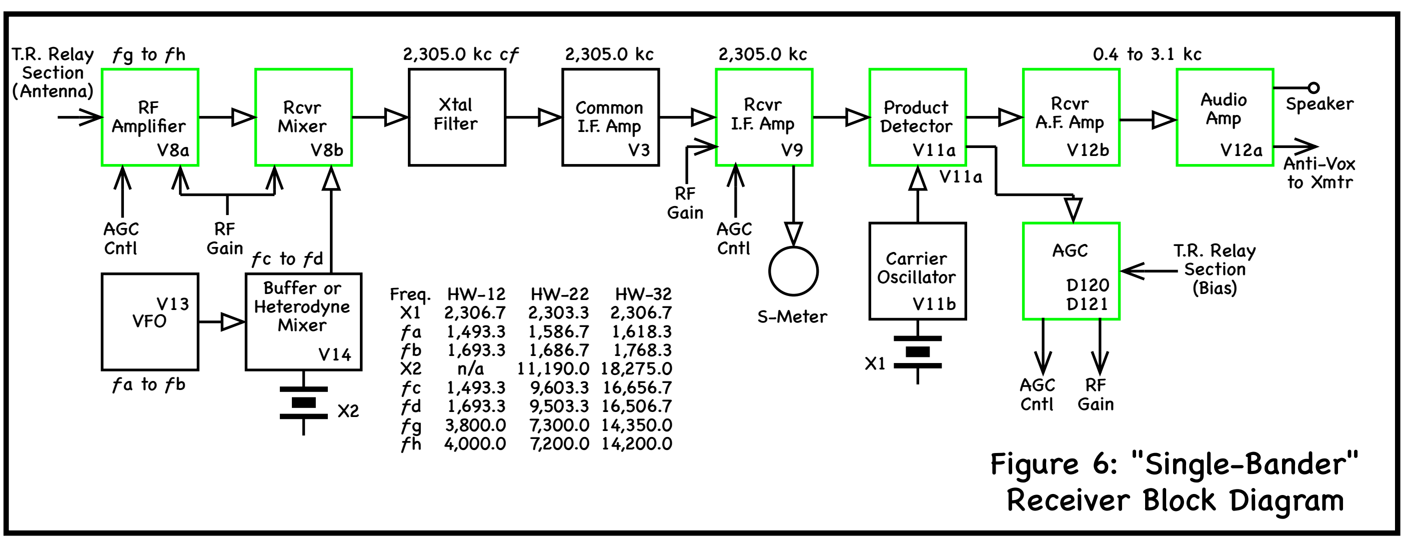

Figure 6: "Single-Bander" Receiver Block Diagram

The same coil is used in each (L5 in the HW-12 and L6 in the HW-22 and HW-32), and is temperature compensated by C130, a negative temperature coefficient capacitor. The remaining frequency determining capacitors are of the NPO type. Using a low frequency around 1,600 kc for the VFO adds to the stability, as does mounting the coil and variable capacitor on the rigid chassis instead of the circuit board.

VFO Buffer (V14) [HW-12 only]:

Since the HW-12 uses the VFO frequency as the transmitter and receiver mixer frequency directly, it does not need to be heterodyned to a higher frequency. However, to keep load changes from pulling the VFO off frequency, V14 acts as an isolation buffer in the form of a cathode follower. Evidently Heathkit wanted to use the same tube lineup for all the *"Single-Bander"s,* so a 6BE6 pentagrid tube that is used as a heterodyne oscillator and mixer in the higher frequency radios, is used as a triode cathode follower in the HW-12. The schematic of this circuit, along with the VFO oscillator, is shown in figure 7. Note that there is no connection to the plate (pin-5) of the tube; instead, the first screen grid acts as the plate. The signal from the VFO is coupled to the 1st control grid (pin-1). Since the two screen grids (pin-6) are connected internally, the second control grid (pin-7) is tied to the first one externally. In effect this creates a triode. The buffered signal appears at the cathode (pin-2) where it is fed to the receiver mixer and, after filtering (not shown in figure 7), to the transmitter mixer. Capacitor C134 is large enough to bypass any harmonics to ground while passing the fundamental frequency to the buffer.

Heterodyne Oscillator & Mixer (V14) [HW-22 & HW-32]:

In the two higher frequency radios, the VFO is raised in frequency by mixing it with the signal from a crystal oscillator. This the raises VFO frequency without introducing additional drift of any significance. V14, a pentagrid, tube (five grids), also called a heptode (seven electrodes), is a tube designed specifically as a single tube

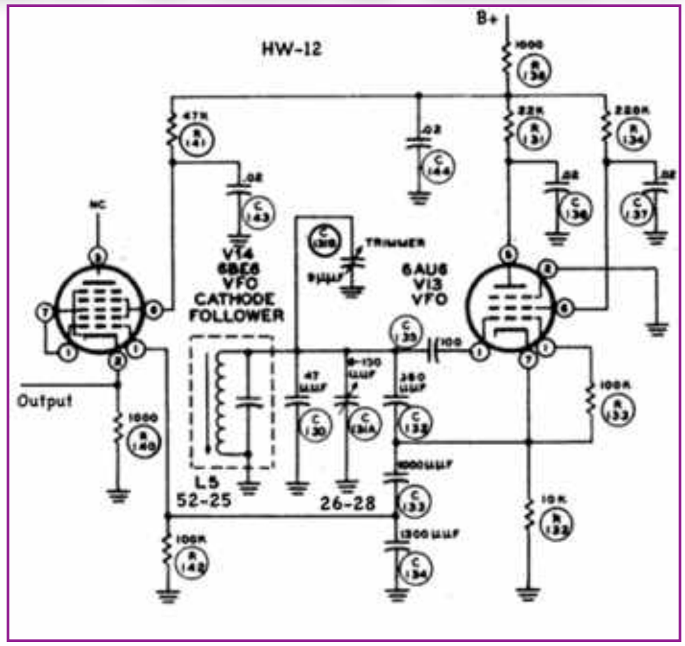

Figure 7: HW-12 (75-Meter) VFO with Buffer

that functions as an oscillator and mixer. The first grid is a control grid for the oscillator; in this case another crystal Colpitts oscillator. The second grid acts as a plate for the oscillator section; it is connected to the screen source. Since this grid is so porous, some electrons pass right through to the second section. the third grid is also a control grid. The VFO signal is coupled to it. The fourth grid, which is internally connected to the second grid, is a screen grid for the upper section, and the fifth grid is a suppressor grid to absorb any electrons bouncing off the plate. With the tube biased to a point where it is no longer linear, mixing occurs and the two frequencies, plus their sum and difference appear at the plate. L5 is broadly tuned to the difference frequency band. The heterodyne crystals are at 11,190.0 (HW-22) and 18,275.0 kc (HW-32), resulting in output frequencies between fc and fd (Fig. 5 or 6) as the VFO is tuned.

The TRANSMITTER:

Microphone Amplifier (V1A):

Audio from a high impedance microphone is amplified by V1A, the pentode section of a 6EA8. C11 removes any RF entering from the mic connection. This is a simple pentode amplifier using grid-leak biasing. Its output is fed to the MIC GAIN control. The low end of the control is AC coupled to ground so the next stage can be biased off during transmit.

AF Cathode Follower (V1B):

The triode section of the 6EA8 is a cathode follower buffer. It presents a low output impedance audio signal to the balanced modulator through C18.

Balanced Modulator (CR1 - CR4):

Mic audio from V1B is mixed with the carrier oscillator signal in the balance modulator (Figure 8). The RF carrier signal is fed across R8 to the junction of two legs of the bridge consisting of C1 & R3 and C2 & R4. When these legs are identical, the bridge is balanced and none of the carrier signal appears across transformer.- T1's primary. The CARRIER-NULL control adjusts the bridge balance, correcting for component tolerances. When audio is applied from V1B to the diode ring, it unbalances the bridge at an audio rate, causing the upper and lower sideband signals to appear across the transformer primary. In order to provide a carrier for tune-up, the TUNE LEVEL places a DC voltage across the diode ring when the FUNCTION switch is in the TUNE position, resulting in an unbalancing of the bridge, allowing a steady carrier to appear across T1.

Transmitter IF Amplifier (V2A):

V2A, the pentode section of a 6EA8, amplifies the two sideband signals from the secondary of T1 and applies them to the crystal filter. It also matches the impedance the filter needs to see for optimal performance.

Crystal Filter (Y2 - Y5):

The crystal filter passes only the desired sideband for the particular model, which is determined by the carrier oscillator crystal and whether sideband inversion occurs later in the transmitter mixer. Y2 through Y5 are matched pairs of crystals at 2,303.5 and 2,505.1 kc., which, along with L1, provide a filter response as shown in figures 8. With a carrier crystal of 2,303.3 kc (red) the filter passes only the USB signal within an audio range of 400 to 3,100 cps at the 6 dB points (shown green to yellow), which corresponds to 2,303.7 to 2,306.4 kc. Similarly, with a carrier crystal of 2,306.7 kc (purple) the filter passes only the LSB signal within an audio range of 400 to 3,100 cps, which corresponds to 2,306.4 to 2,303.7 kc. This signal is then coupled to V3, the common IF stage.

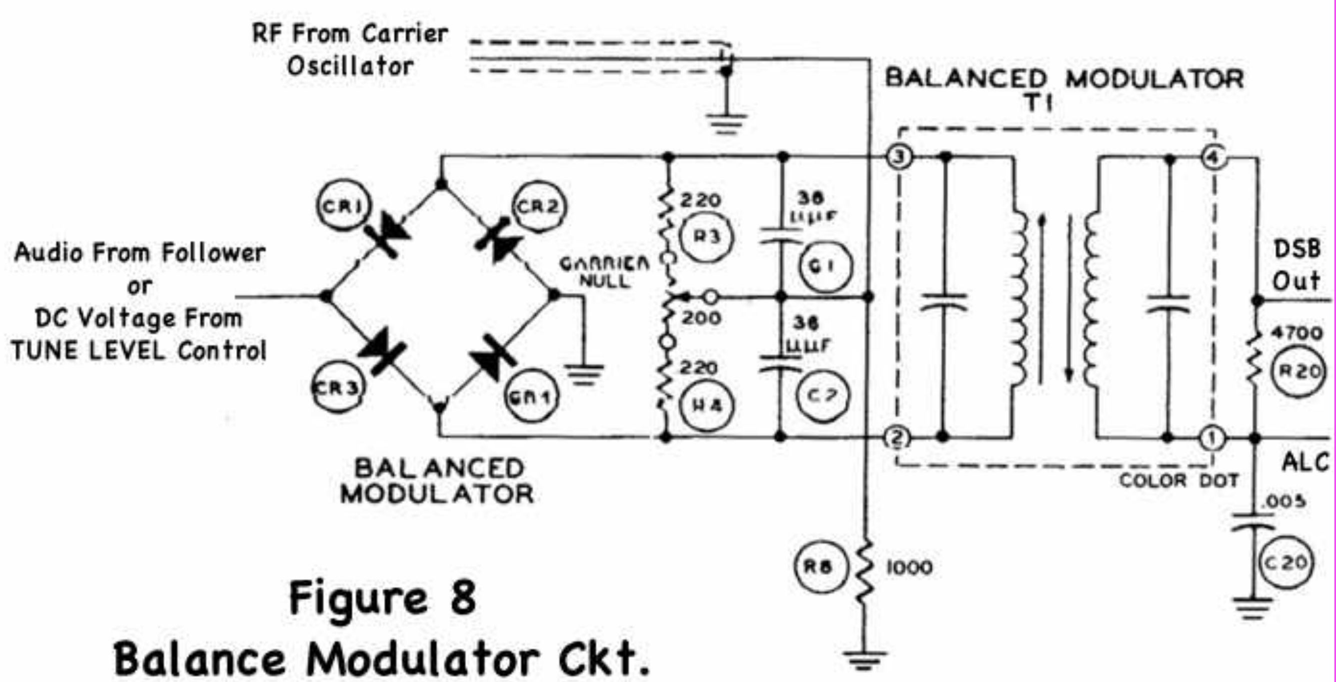

Figure 8
Balance Modulator Ckt.

The Common IF (V3 - During Transmit):
The common IF uses V3, a 6AU6 pentode, It is driven directly from the crystal filter, with R30 providing the proper load for the filter. Output is through a double tuned IF transformer, T2. This stage and the filter are used for receiving also.

Transmitter Mixer (V4):
In the transmitter mixer, another 6AU6 pentode, the transmitter IF signal and the heterodyned (or buffered in the case of the HW-12) VFO signal from V14 are mixed. Only one of the mixer products is allowed to pass the double tuned driver grid transformer L2. The heterodyne signal is coupled to the secondary of T2, along with the transmitter IF, and both are fed to the control grid of V4. On the HW-12 the sum of the two signals is passed and no sideband inversion occurs. But, on the HW-22 and HW-32 the difference between the two signals is passed. Since the sideband signal is subtracted from the higher frequency oscillator signal, sideband inversion does occur. To correct for this, the carrier oscillator crystal is selected to initially produce the other sideband.

Driver (V5):
The driver tube is a 12BY7 power pentode. It operates as a linear, tuned grid, tuned plate power amplifier. It is broadly tuned to operate over the desired band segment and no front panel tuning adjustment is provided. A small part of the RF energy from the final amplifier stage (discussed next) is fed back through a capacitive voltage divider consisting of capacitors C63, C64 and C55 to the B+ side of the plate coil L2. This voltage provides fixed neutralization for the final amplifiers.

Final Amplifier (V6 & V7):
A pair of 6GE5 “Compactron” beam-power tubes, originally designed for TV horizontal sweep deflection amplifiers, provide 200 watts of input power. The tubes are effectively in parallel with their plate, control grid and cathode connected together, and their screen grids fed by separate resistors. RF is capacitively coupled from L2 to the grids. The pi-network output

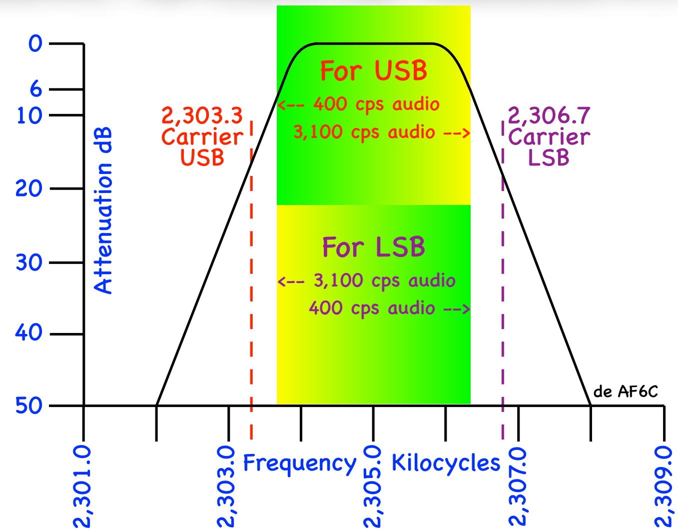

Figure 9: Filter Frequency Response (See Text)

circuit is simple since there is no band switching; L4 provides the tuning inductance. The only adjustment is the FINAL TUNE capacitor; loading is fixed by C77 for use with a 50Ω load. Low value capacitors C61 and C71, along with the circuit board trace, provide VHF oscillation suppression.

Final bias is provided through a voltage divider chain from the -130-volt power connection. The FINAL BIAS control allows setting the resting plate current to the proper value.

ALC (D70):
To help prevent the transmitter from becoming non-linear ALC (Automatic Level Control) is provided. Should the amplifier be over driven, the grid will start to draw current. This causes fluctuation in the grid voltage at the audio rate. This AC voltage is coupled through C75 and rectified by D70. The resulting negative DC voltage increases the bias on V2A (the Xmtr IF) V4 (the Xmtr mixer) and V5 (the driver), reducing their gain and bringing the final amplifier back into linearity.

<u>The RECEIVER</u>:

RF Amplifier (V8A):
When in receive mode, the antenna, and the signal from the optional 100 kc crystal calibra-

tor, if installed and turned on, are fed to the a coupling link on L3, the driver plate tuning coil. The driver plate tuning coil is also coupled to the grid of the RF amplifier V8A, the pentode section of a 6EA8. In a similar fashion the plate of the RF amplifier shares the double tuned driver grid coil L2. This eliminates the need for two additional coils and simplifies alignment.

Receiver Mixer (V8B):
V8B, the triode section of a 6EA8, acts as a simple mixer. The signal from the RF amplifier is fed to the grid; and the heterodyne signal from V14 is fed across the cathode resistor; this signal is 2,305.0 kc above or below the desired receive frequency, depending on the model. The plate signal is coupled to the common IF stage where only the output of the mixer at the 2,305.0 kc IF frequency is allowed to pass.

The Common IF (V3 - During Receive):
The common IF is used for both transmit and receive. It consists of the crystal filter, followed by an IF amplifier using a 6AU6 pentode and a double-tuned coupling transformer T2. The crystal filter is centered around the 2,305.0 kc IF frequency, and was discussed under the transmitter section. The filter is just wide enough to pass an SSB signal. On receive, T2 acts only as a single tuned circuit and the IF signal is capacitively coupled from the plate of V3 to the receiver IF stage, V9.

The Receiver IF (V9)
The receiver IF is the second stage of IF amplification using a 6AU6 pentode. This is a typical IF stage and the amplified IF signal is fed through a double-tuned IF transformer to the grid of V11A, the product detector

The Product Detector (V11A)
The product detector is another mixer; it uses a triode section of a 12AT7, V11A. It recovers the audio from the IF signal fed to the grid by beating it against the carrier oscillator signal which is coupled across the cathode resistor R112. If the IF signal is the correct sideband and tuned properly, the difference between these two signals is a reproduction of the transmitted audio. The unwanted higher frequency mixer components are bypassed to ground through C111 and C112.

The Receiver 1st Audio (V12B)
The first audio stage is a common class A triode audio amplifier. It amplifies the audio and passes it to the audio power amplifier. This stage also provides an AVC (automatic volume control) voltage to the AVC circuit (discussed later).

The Receiver AF Output Amp (V12A)
The audio from the previous stage is amplified in a class A power stage, and transferred via the audio output transformer, T4, to an external 8Ω speaker. The cathode circuit is a bit unusual; R120 develops bias for the tube while C120 rolls off the low frequencies below 160 cps. The choke coil (RFC-120) presents a higher impedance to the higher frequency audio components, which are then fed back to V12B providing degenerative feedback, canceling the higher frequency audio components, some of which may be noise.

AVC Circuit (D120 & D121)
The AVC (Automatic Volume Control) circuit, also sometimes referred to as AGC (Automatic Gain Control) reduces the gain of the RF amplifier, receiver IF and the audio output stage when a strong signal is received. A sampling of the received signal, isolated by R128, is coupled to two crystal diodes (D120 and D121) that, in conjunction with C121 and C88, form a negative voltage doubling rectifier. C121 charges quickly, providing fast gain reduction, while C88 discharges slowly providing delayed recovery for proper SSB reception. The AVC voltage is fed to the RF amplifier directly, while lower voltages are tapped off to control the receiver IF and 1st audio stages. This divider string is returned to the cathode of the 1st audio stage, providing a slight positive voltage during weak reception, canceling and AVC action due to noise and improving the weak signal sensitivity. As part of the transmit - receive

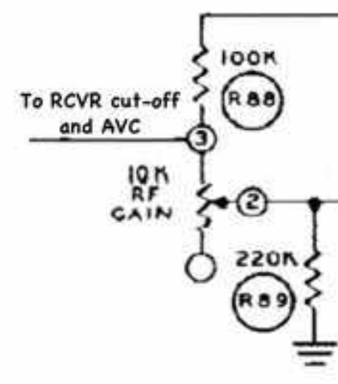

Figure 10
TR Bias Relay
(Receive)

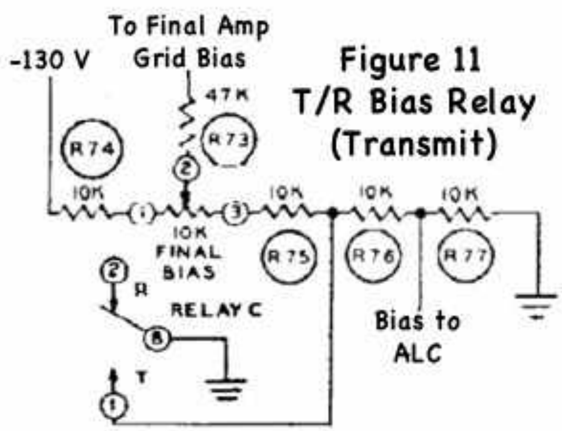

Figure 11
T/R Bias Relay
(Transmit)

switching circuitry, to be discussed next, a high negative voltage is applied to the AVC line during transmit, effectively cutting these three stages off.

TRANSMIT/RECEIVE Switching:

T/R Relay:

A 3-pole relay controls whether the transceiver is in transmit or receive mode. One of the poles switches the antenna between the RF amplifier during receive, and the pi-network during transmit. The second section controls an external contact that is open during receive and grounded during transmit, allowing the user to switch an amplifier or use otherwise as desired. The third contact switches the bias on various stages, biasing them heavily off when they are not in use. The relay is controlled either by the VOX (Voice Operated Xmit) circuit or the PTT (Push-to-Talk) circuit, depending on the setting of the front panel FUNCTION switch.

A resistor divider chain from the -130-volt power connection to ground, consisting of R88, the RF gain control and R89, provides bias to the receiver mixer and the low end of the receiver AVC line (Figure 9). During receive, the wiper of the RF GAIN control is grounded, and the bias voltage on the receiver cut-off bias line is determined by the position of that control. The line goes to the low end of the AVC circuit adding to any AVC created bias, and the gain of V8A, V9 and V12A decrease as the pot is turned CCW. On transmit the ground is removed from the RF GAIN control and the RCVR cut-off line bias jumps to negative 90 V. This voltage is added to the low end of the AVC line forcing all the tubes affected by the AVC into cutoff. This line also directly biases off V8B, the receiver mixer stage, effectively turning the receiver off.

Another resistor voltage divider chain from the -130-volt power connection to ground consists of R74, the final bias potentiometer, R75, R76 and R77 (Figure 10). This places a large bias on the ALC controlled stages as well as the final amplifier and mic audio follower, forcing them into cutoff. When the relay activates, the junction of R75 and R76 is brought to ground potential, restoring normal operating bias on the finals, and other transmitter stages, switching the radio to transmit.

Relay Amplifier (V2B):

The T/R relay is controlled by the relay amplifier. V2B, the triode section of a 6EA8, is normally biased off by the negative voltage from the VOX DELAY control. When the FUNCTION switch is in TUNE the grid is grounded and current flows in the tube causing the relay to activate. If the FUNCTION switch is in the PTT or VOX positions, pressing the PTT microphone switch also grounds the grid of V2B, causing the relay to activate.

VOX Amplifier (V10):

Pentode V10, a 6AU6 pentode, is normally biased on. A large plate resistance results in the plate voltage being very low. In the PTT position the control grid is grounded keeping the tube from responding to any input. When the FUNC-

TION switch is moved to the VOX position the ground is removed from the grid and capacitor C105 is switched into the circuit. When microphone audio is present at the plate of the mic amplifier (V1A) it is coupled to the grid of the VOX amplifier. The negative audio peaks reduce the current flow in the tube causing the plate voltage to rise at each peak. The high plate voltage fires the neon bulb, sending a pulse to the grid of the relay amplifier, causing the relay to close. This pulse also charges C105 which holds the relay amplifier tube on and the relay closed. After a delay, determined by the bias set by the VOX DELAY control, C105 discharges and the relay opens, switching to receive.

ANTI-VOX (D100):

Receive audio, from the plate of the audio output amplifier (V12A), is rectified by diode D100. The resulting positive voltage is filtered and fed to the wiper of the VOX control. This positive voltage bucks any negative voltage that the microphone picks up, preventing speaker audio from tripping the relay. The VOX control is a single control that not only adjusts the anti-VOX, but also, since it acts as a voltage divider to the mic audio reaching V12A, acts as a sensitivity control for the VOX.

Comments:

The HW-12/22/23 became popular for mobile operations as well as use in the shack. If 100 watts mobile wasn't enough power, these transceivers could be used with the Heathkit HA-14 mobile Kompact® Kilowatt 1–KW PEP amplifier (HOM #58).

73, from AF6C

This article originally appeared in the June 2016 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