The HB-75 Transceiver

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Introduction

Construction of the HB-75 Transceiver shown in Figure 1 was prompted by acquisition of a mechanical filter and a LMB Heeger cabinet and chassis. This radio is a great performer. The filter is a 455 KHz lower sideband (LSB) unit, manufactured in the 1960s by a Japanese company called Kokusai. As far as I am able to determine, Kokusai filters were available from Lafayette Radio with their markings, and were used in some of their receivers. They were also used in some KW series radios built in the UK, and possibly some Japanese equipment.

Figure 1: The HB-75 Transceiver

The LMB Heeger cabinet is roughly styled and sized to match a Collins KWM-2 transceiver or a 30L-1 linear amplifier. These cabinets and matching chassis are still available, but are not cheap. I toyed with the idea of using all octal tubes and possibly a multi-band configuraton. But with the number of circuits required, physical size constraints, and limited selection of dual section octal tubes, I decided to go with a single band radio using 7 and 9 pin miniature tubes. This pretty much filled up all the available "real estate" on the chassis.

The LSB filter was designed for a nominal carrier frequency of 455 KHz. Kokusai also made a matching USB filter for the same carrier frequency. Using the LSB filter allowed construction of a single conversion radio for 75 meters, using a variable frequency oscillator (VFO) frequency 455 KHz below the desired LSB signal output. Due to some practical VFO limitations explained later, the radio covers 3.75 to 4.00 MHz. This range includes the current phone allocation for General class licenses (although I have an Extra), and the vintage radio nets I participate in are all in this range.

Power for the radio comes from an external Heathkit HP-23B supply. Because this supply's filament voltage is 12.6 VAC, various heaters in the radio are connected in series and parallel arrangements. Some of this also resulted from my supply of tubes. I have a ton of 6BA6s, and only a few 12BA6s. The Heathkit supply was also modified to provide 12 VDC to power the various relays, the digital display, and a 6 VDC regulator in the radio for the VFO's filament. I was able to squeeze a transformer and other necessary parts under the HP-23B chassis.

The front panel was painted light gray, labeled with custom designed water slide decals, and then sprayed with a matte finish. The cabinet received a similar finish.

There is more information on general homebrewing techniques used to build this radio on the button at the bottom of my home page at kg7tr.com. This includes panel and chassis decals, and custom meter scales.

From start to finish, it took about eight months of almost full time effort to complete the transceiver, including all documentation. The result is a homebrew radio that looks great inside and out, and works as great as it looks. It is very easy to set up and use.

Mechanical Layout

The LMB Heeger cabinet was obtained from a fellow ham, and was likely a hamfest find. It was a little rough, and required some cosmetic restoration. Several of the spot welds were broken, and had to be repaired with countersunk screws or metallic epoxy (aka JB Weld©). A blank front panel had been fabricated by the previous owner from .090 aluminum sheet. The matching chassis was new and completely blank.

The cabinet (LMB Heeger part number CO-1 Grey, https://lmbheeger.com/coseries.aspx) measures (in inches) 14.4 wide by 13.0 deep by 6.5 high. The matching chassis measures 13.0 wide by 11.0 deep by 1.5 high. If you are thinking of procuring this cabinet and chassis, it would be best to call the manufacturer. The website data is somewhat confusing, and it is not clear if the chassis and a front panel are included with the cabinet. In addition, there is some indication that the chassis might also be available in a 2.0 inch height.
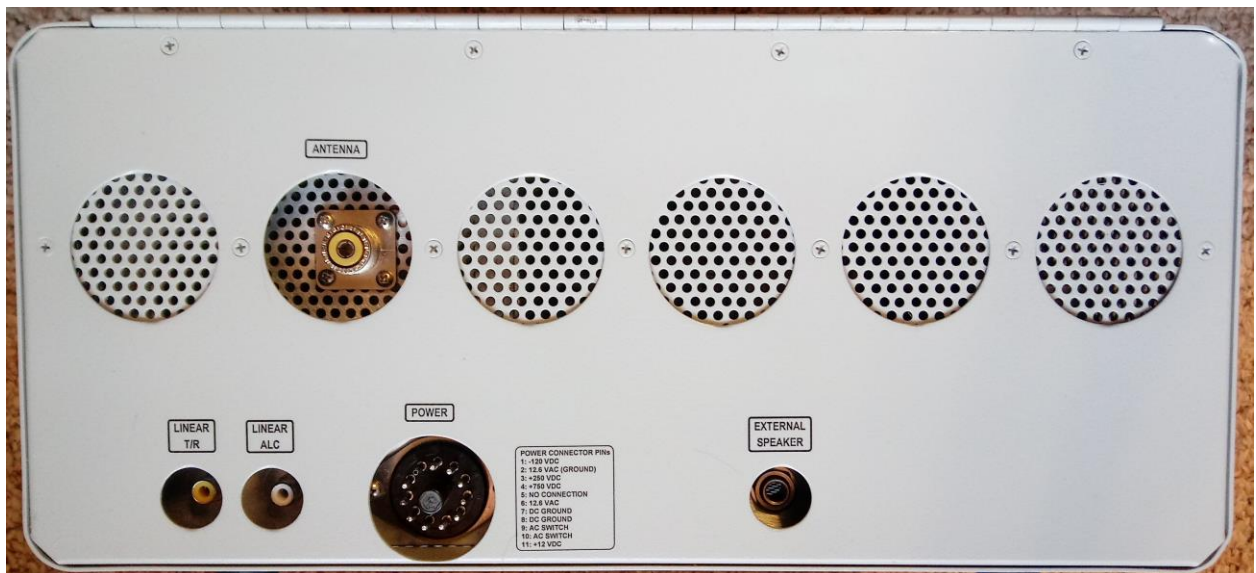

Figure 2: Rear View

I think the chassis really should have been about one inch deeper, i.e., 12 inches deep instead of 11. Ideally, you want the chassis to butt up against the back of the cabinet so that rear panel connectors can protrude enough for mate and demate action. However, with the 11 inch depth, positioning the chassis against the back of the cabinet left way too much overhang over the front panel. Note that there are no suitable chassis sizes available from Hammond or Bud that will work in this cabinet.

As it was, I ended up with a compromise position with a one inch gap between the chassis rear and the cabinet back. Large holes were punched in the cabinet back to allow my fingers to grip mating connectors. I also punched several 1.75 inch holes in the cabinet rear to provide more ventilation, and covered these with perforated aluminum sheet. The recessed connectors are visible in Figure 2, which shows the cabinet rear with the chassis installed.
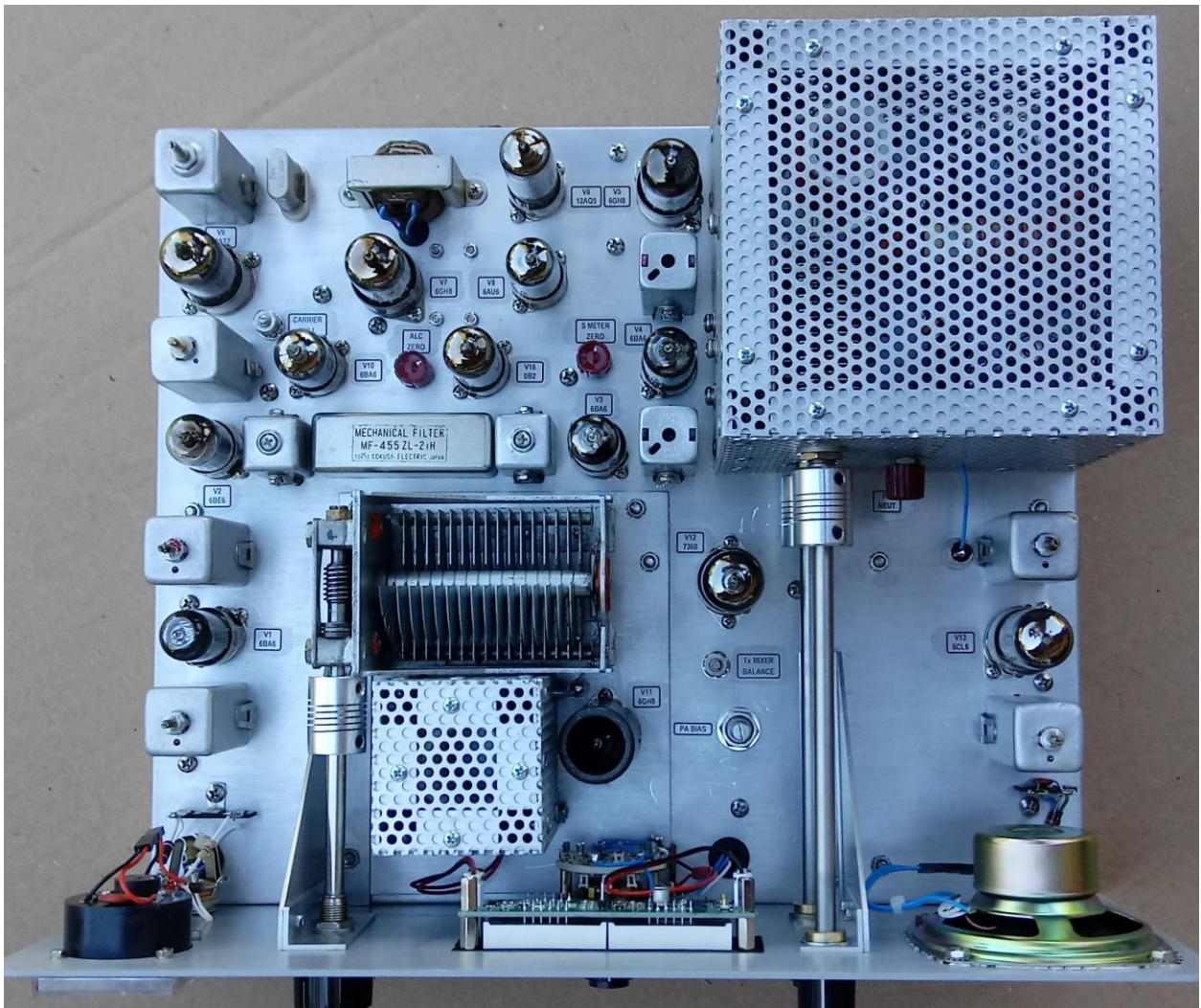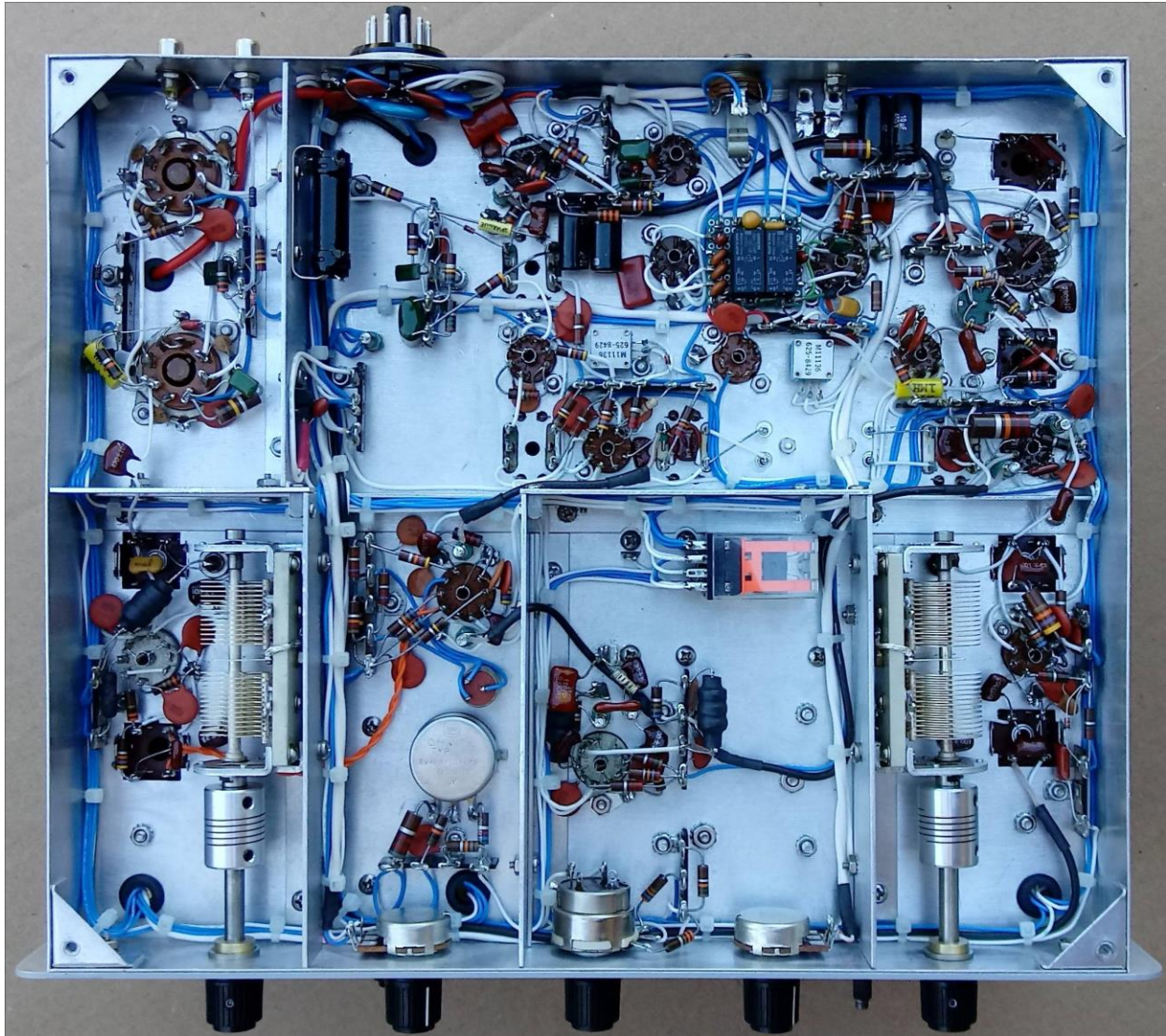

Figure 3: Transceiver Top View

Figure 4: Transceiver Bottom View

Figures 3 and 4 show the chassis top and bottom respectively. The cabinet as supplied new comes with side rails for sliding in the chassis. One of these was missing on my cabinet, so I fabricated new rails out of .062 inch angle stock. The chassis is mounted in the cabinet by four 6-32 screws that thread into PEM type nuts pressed into in the chassis corners.

The chassis is made from .050 inch soft aluminum, which is not sturdy enough for a SSB radio that requires a mechanically stable analog VFO. So a sheet of .062 tempered aluminum was added under the VFO components as can be seen in Figure 3. The VFO coil is mounted to this plate inside a shield made from .062 perforated sheet and angle stock. The power amplifier (PA) components at the rear are housed in a 5 inch cube made the same way. It is shown in Figure 5. To further beef up things topside, angle brackets run from the front panel to the chassis to prevent flexing.
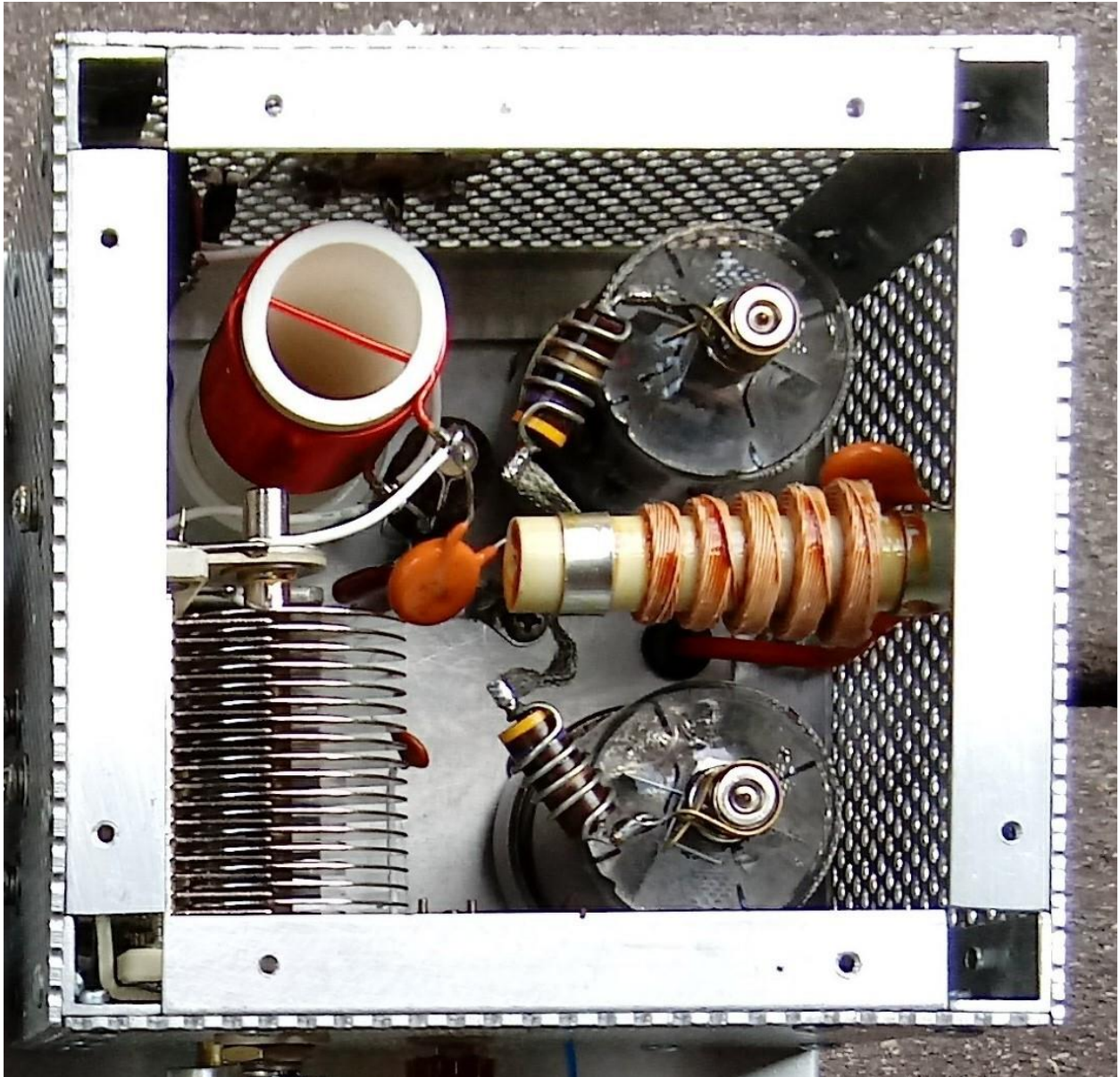
Figure 5: Interior of PA Cage

To finish off the mechanical assembly, an array of shields is mounted underneath the chassis, as can be seen in Figure 4. These are made from .062 tempered sheet and .5 inch angle stock. Some are fastened to a strip of .5 inch angle stock that runs across the chassis width at about the centerline. The end result of all these mechanical features is a radio that is quite stout. There is almost no change in VFO frequency when the cabinet is moved around.

Block Diagram Circuit Description

The block diagram of the transceiver is shown in Figure 6. Similar to my Octal Tribander transceiver, the HB-75 uses independent tuned circuits for the receiver front end and the transmitter driver, instead of sharing them as was typical in a lot of the old commercial

transceivers. It takes a few additional parts and requires an extra tuning control, but I find it less trouble to do it this way. Starting at the lower left of the diagram, the antenna jack is connected to a T/R relay. In the receive (Rx) mode the antenna is routed to an input LC circuit that feeds the grid of RF amplifier V1. The output of V1 is run through another LC circuit and then on to mixer V2. The LC circuits are tuned by a dual section variable capacitor brought out to the front panel as the Rx PRESELECTOR control.
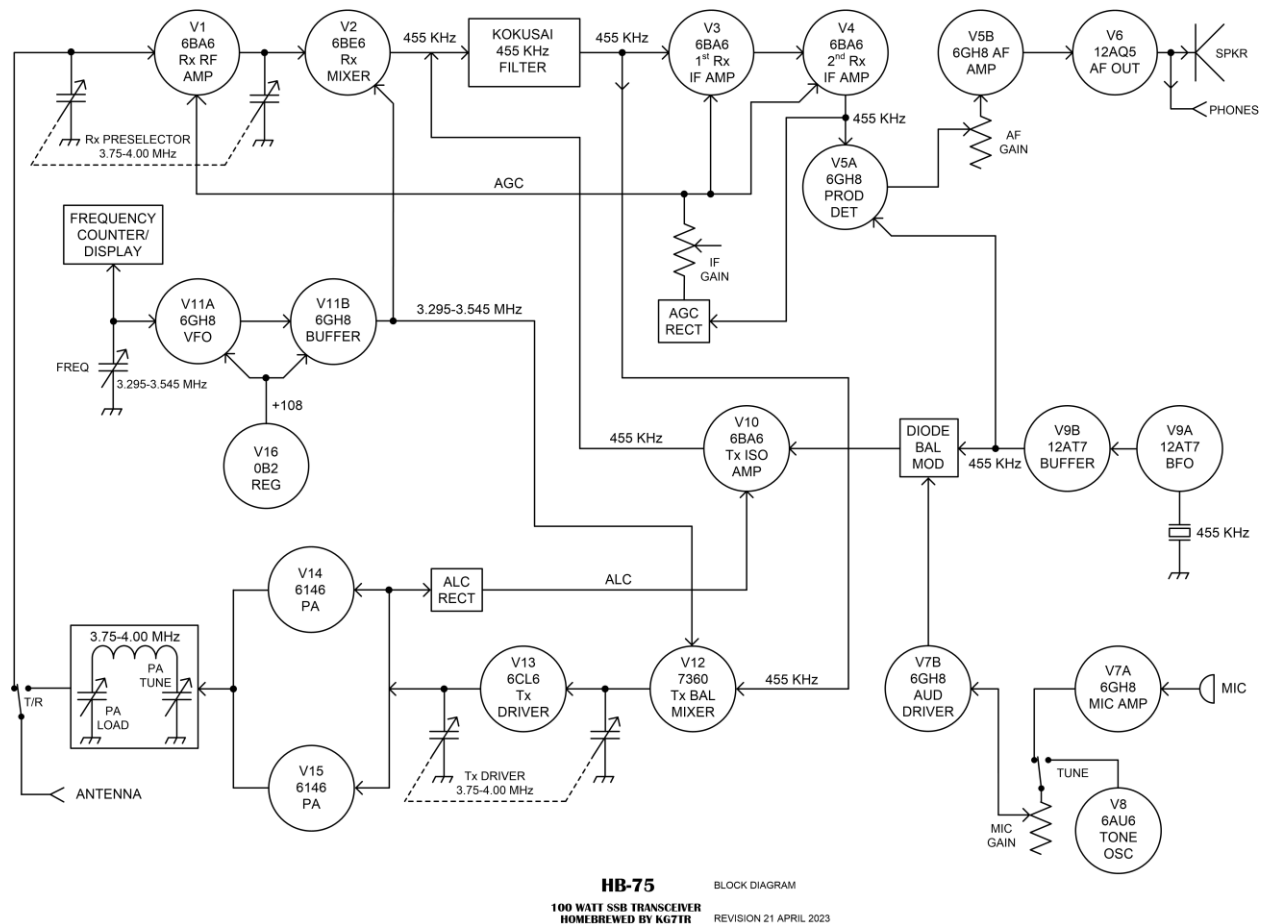
Figure 6: Transceiver Block Diagram

V2 is a pentagrid mixer that, in the receive mode, combines the amplified RF from V1 with a VFO injection voltage from V11B. The injection frequency is 3.295 to 3.545 MHz. When subtracted from the incoming signal of 3.75 to 4.00 MHz, a .455 MHz LSB intermediate frequency (IF) signal results. The 455 KHz signal at the plate of V2 is applied to the mechanical filter through a matching transformer. The primary of this transformer is also connected to the plate of transmit (Tx) isolation amplifier V10, which applies a double sideband (DSB) signal to the filter in the transmit mode.

The output of the mechanical filter is applied, through another matching transformer, to the grid of V3 and the deflection plates of V12. V3 functions as an IF amplifier for the receive mode, while V12 functions as a mixer for the transmit mode. The output of V3 is fed to V4, an IF amplifier whose output goes to V5, the product detector and audio amplifier. The output of V4 is also rectified to generate the Rx AGC voltage. This voltage is fed to V1, V3 and V4, and

holds the audio output level virtually constant once a threshold of approximately a microvolt of RF at the antenna is exceeded. Negative bias from the IF GAIN control is added to the AGC voltage to control overall gain.

V5A (triode section) serves as a product detector, with 455 KHz LSB IF signal applied to its grid and 455 KHz BFO fed to its cathode. Audio is recovered and filtered at the plate, and then coupled to the AF gain control. From here it goes to the grid of V5B (pentode section), where it is amplified and fed to V6, the audio output amplifier. Output of this stage is transformer coupled to the internal speaker. The output can also be connected to external headphones or an external speaker.

For the transmit mode, audio from the microphone is amplified by V7A (pentode section), and then applied to the mic gain control through normally closed (NC) relay contacts when the front panel function switch is in the in the PTT or MOX position. When this switch is in the TUNE position, the relay is energized. This turns on V8 tone oscillator and applies its output to the MIC GAIN control. The signal at the wiper of the MIC GAIN control is applied to the grid of V7B (triode section), which is a cathode follower. Its low impedance output is coupled to the diode balanced modulator.

V9 is a dual triode that generates a 455.200 KHz crystal controlled signal used for Rx BFO and Tx carrier functions. V9A is the crystal oscillator, with its output applied to V9B, a buffer/amplifier that provides a low impedance output signal for the balanced modulator and product detector circuits. Using a frequency of 455.200 KHz sets the Rx BFO and Tx carrier at the correct point in the filter bandpass to taper off the audio response below 300 Hz.

V11A (pentode section) serves as a stable Colpitts oscillator whose output varies from 3.295 to 3.545 MHz. Output from the cathode of the pentode section is coupled to the grid of V11B (triode section), which is a cathode follower. Output of this follower is coupled to V2 and V12. V16 provides regulated B+ voltage to both sections of V11. In addition, regulated 6 VDC is applied to the filaments of this tube from an onboard regulator. This VFO has exceptional overall stability.

The balanced modulator is a ring diode type using four silicon diodes. Its double sideband output, absent the carrier, is transformer coupled to the grid of isolation amplifier V10. The output of V10 is coupled to the input of the mechanical filter through the same transformer used by V2 (the plates of these two tubes are connected together). In Tx mode the filter removes the unwanted upper sideband from the balanced modulator DSB signal, leaving only a LSB signal at its output.

V12 is a balanced mixer for the transmit function. The 455 KHz LSB signal is applied to its deflection plates, while the VFO signal is applied to its signal grid. The balancing action of this tube combined with the output LC circuit eliminate all unwanted signals (in particular the VFO signal), such that only the desired 3.75 to 4.00 MHz LSB signal remains. This is coupled to the grid of V13, where it is amplified to a level suitable for driving the PA grids. The output of V13 is also filtered by a LC circuit and coupled into the grids of V14 and V15. The LC circuits at the input and output of V13 are tuned by a dual section variable capacitor brought out to the front panel as the Tx DRIVER control.

PA tubes V14 and V15 are connected in parallel and amplify the SSB signal from the driver to 100 watts PEP. Their output is coupled through a pi network to the antenna through contacts on the T/R relay. The pi network is tuned by variable capacitors brought out to the front panel as the PA TUNE and PA LOAD controls.

If the PA tubes are over driven such that grid current flows, this signal is rectified to produce a negative ALC voltage that is applied to the grid of V10. The negative voltage reduces the gain of V10 to help prevent over drive conditions. A rear panel connector also allows ALC from a linear amplifier to be applied to V10.

A small pickup wire is mounted next to the VFO coil. This signal is sent to the digital frequency counter/readout, where a programmed 455.200 KHz IF offset produces the correct output frequency display.

Transmit/Receive changeover is provided by three internal relays that primarily switch B+, grid block bias and the antenna between Rx and Tx circuits. Other relay switching is used to mute Rx or Tx audio, switch the meter between modes, and key an external linear amplifier. As mentioned previously, the plates of V2 and V10 are connected together and fed through a common transformer primary. The secondary of this transformer feeds the input of the mechanical filter. Constant B+ is applied to the plates of these tubes, but their screen voltages are switched between the Rx/Tx modes. Without screen voltage, the affected tube is effectively turned off.

Additional Circuit and Construction Notes

A full schematic diagram of the HB-75 is available on the respective page at kg7tr.com, and should be referred to in this discussion. This information supplements the basic circuit descriptions provided in the previous section.

The only RF inductors I elected to label as transformers are T1 and T2. These are KTran type IF transformers with tuned primary and secondary coils. The rest of the RF coils are labeled with "L" reference designators, even if they have two coupled windings (e.g., L1, L3, L4, L7 and L10). For these, only one winding is resonated, so I called them coils.

The dual section variables for the Rx RF amplifier and the Tx driver have 100 pf "padder" capacitors in series. This was done to increase the bandspread range of the variables, such that it is not possible to accidently tune them to the VFO frequency.

When bread boarding some of the 455 KHz circuits, I was unable to make usable, high-Q inductors using toroid coils. So I had to go to my junk box of slug tuned coils and old IF transformers, and cobble together suitable parts. And it seems that such vintage inductors and IF transformers are not readily available on the internet, or are ridiculously priced when they are. Maybe there are ferrite or powdered iron toroid or pot cores that would yield Qs similar to the vintage slug tuned coils with their universal windings and Litz wire. But I didn't really see anything in Amidon's data sheets. As it turned out, the only toroids used are L3 and L4 at the input and output of the filter. These are wound on FT-43A forms. They are essentially impedance matching transformers. Their Q is not great, but selectivity is not important here, and there is ample gain in the receiver and transmitter paths such that they work just fine. Most of the coil cans came from junked TVs that my dad used to have in the basement. .75 inch square holes were punched in the chassis to mount them. Some required fastening spring clips to their sides so they could be snapped to the chassis. For the KTran units, I made a drill template for their complex footprint. My digital inductance meter was indispensable for finding the right coils in the junk box to make this radio. And at the end of the day, using slug tuned coils helped make the experimentation and alignment go smoothly.

Like most of my homebrew radios, the VFO components were from an old ARC-5 transmitter. As it turned out, the ARC-5 coil I used has about 2.4 μH of inductance when sheilded, and only produced a useful bandspread of about 250 KHz within the required range

using the matching ARC-5 variable capacitor. In order to increase the bandspread, I would have had to increase its inductance by adding turns to its winding. Although the rest of the tuned circuits in the radio can cover the whole 3.5 to 4.0 MHz range, I didn't feel like messing with the VFO coil. As built, it is very difficult to remove the shield and experiment. So I ultimately decided that coverage from 3.75 to 4.00 MHz would be good enough. I also learned that putting a bypassed, 680 ohm resistor in the cathode of the triode section of V11greatly reduced the plate current through it, on the order of 10 ma. This hardly reduced the output level at all, and made the tube run a lot cooler. It also allowed V16 to run at a lower current. I subsequently applied this lesson learned to the VFO in my 75S-2B receiver.

To avoid using relays to switch the Rx and Tx signals around the filter, I came up with the idea of using a common coil, L3, to feed V2's output into the filter in receive, and V10's output in transmit. The plates are fed a hard +250 volts in either mode, but the screens are switched to achieve the required Rx or Tx function. This worked great. The tuning of L3 is so broad that there is negligible difference in resonance between the two modes. Similarly, at the output of the filter, L4 is able to feed both V3 and V12 with no difference in resonance during switching.

The receiver AGC circuit is similar to my 75S-2B receiver, and the Collins 75S-3. A single 1N4148 at the high end of T2's secondary does the rectification, with the AGC voltage appearing at the bottom of T2's secondary. A small DC bias is applied to the cathode of this diode through the voltage divider formed by the 220k and 4.7k resistors. This bias sets the AGC threshold to about one microvolt at the antenna. This is called "delayed AGC".

The 455 KHz oscillator is copied from the Eldico T-102 transmitter. My T-102 has been extensively modified, and is another whole story. At any rate, L5 was scavenged from it, and the circuit works well in the HB-75 application. The carrier frequency for the filter is specified as "455 kc" on the 1968 data sheet that came with it. Testing showed that the optimum frequency actually needs to be 455.200 KHz in order to taper off the audio response below 300 Hz. As luck would have it, I had a 455 KHz crystal with a mid-1960s date code that had aged enough in the right direction to oscillate at exactly 455.200 KHz by adjusting L5. And since the digital display offset cannot be set in less than .100 KHz increments, this all worked out quite well.

Transmit/Receive switching is accomplished by relays K1, K2 and K4. They are energized from +12 VDC by grounding the push to talk (PTT) line. Their operation is explained below:

- K1A switches +250 VDC B+ between several Rx or Tx circuits.
- K1B switches the meter between S meter and ALC meter functions, when the meter switch is in the S/ALC position.
- K1C grounds the LINEAR T/R jack on the chassis rear in the Tx mode.
- K1D switches grid block bias between Rx or Tx circuits.
- K2 grounds the high end of MIC GAIN control R6 in the Rx mode to keep Tx audio from getting through the Tx circuits and into the filter, where it could interfere with desired receive signals. In the Tx mode, K2 grounds the grid of V6 to eliminate an annoying pop in the speaker when switching back to the Rx mode. A large capacitor across K2's coil delays release of this ground until all other relays have changed over. The diode in series with it prevents the capacitor from discharging into any other relay coils.
- K4 switches the antenna between receive and transmit circuits.

To eliminate a pop in the speaker when switching to transmit, a negative voltage is applied to the receiver AGC bus the instant the PTT line is grounded. In order to work, this must happen before any relays change state. It is accomplished by the .47 µf capacitor and two diodes

connected to the PTT line. In Rx, the capacitor charges up to about 11 volts because one end is connected to +12 VDC and the other end is grounded through the diode whose cathode is connected to ground. As soon as the PTT line is grounded, the left end of this capacitor becomes negative with respect to ground. This voltage is applied to the AGC line through the other diode, and effectively mutes the receiver instantly.

Relay K3 is energized when the TUNE function is selected. One set of contacts grounds the cathode circuit of tone oscillator V8, turning it on. The other set switches the input to MIC GAIN R6 from the output of V7A to the output of V8. A voltage divider (24k and 36k resistors) in the plate circuit of V8 reduces the audio voltage to an equivalent microphone level for tune up.

The balanced modulator is a standard circuit used in several of my homebrew radios, as well as many commercial rigs. Trimmer C7 is mounted on the side of the chassis next to L10. It was added later (after the new crystal was installed), and is not shown in Figure 4. Adjusting C7 and R7 provides carrier suppression greater than 50 dB. L10 was a junk box find, and tunes very broadly. I think it might have been an oscillator coil from an old broadcast band radio. The slug or the value of the resonating 620 pf capacitor do not have a whole lot of effect. I mainly needed a coil like this to simultaneously couple both the output of the balanced modulator and ALC voltage into the grid of V10.

The V12 Tx balanced mixer circuit was cloned from various circuits found in the ARRL handbooks. It provides good conversion gain, and effectively nulls out the VFO signal from its output. I have come to the conclusion that the secret to balanced modulators and balanced mixers lies in the output LC tank circuit. Diode circuits are low impedance, and seem to work best with low L/C ratios, whereas tube circuits are high impedance, and need high L/C ratios with bifilar windings. L7 was another junk box find, and had a bifilar winding. It may have been from a television set's 4.5 MHz sound IF ratio detector. I added a secondary winding to couple to V13, with a 22 pf parallel capacitor across it that allowed resonance with C3A. Because of layout constraints, L7 had to be located a few inches from the plates of V12. So a twisted pair of wires was used to make the connections, and this works just fine. One thing I did notice is that, just as RCA advises, V12 is indeed very sensitive to magnetic fields around it. Using a metal screwdriver to adjust R5 causes the balance to shift when the screwdriver is removed. This is very apparent if the screwdriver happens to have a magnetic tip!

The ALC circuit is the same as my other homebrew transmitters, and is copied from the Heathkit SB series of radios. As the PA grids begin to draw current due to being overdriven, these current pulses are rectified and generate a negative ALC voltage that reduces the gain of V10.

Turning to the metering circuit, in the PLATE position of the METER switch the meter measures the voltage at the cathodes of the PA tubes, which are connected to ground through a one ohm shunt resistor. Thus, a cathode current of 250 ma will produce 250 mv of voltage across the resistor. This voltage is scaled to the meter sensitivity by the 4.7k resistor in series with it.

In the S/ALC position of the METER switch, there are two voltages to measure. In the Rx mode, the voltage at the cathode of V3 decreases as signal strength and AGC voltage increase. In the Tx mode, the voltage at the cathode of V10 decreases as ALC voltage increases. Relay contacts at K1B switch the appropriate voltage into the meter circuit. The voltages are compared by the meter to a fixed reference voltage set by R4. In the Rx mode, this pot sets the reference voltage equal to the zero signal voltage at the cathode of V3, so that the meter reads zero. This setting is unchanged for the Tx mode. In Tx, R3 is used to set the zero signal voltage at the

cathode of V10 to equal that already set by R4. With this configuration, only a single set of relay contacts is required to switch between Rx and Tx metering. The 9.1k resistor in the circuit sets the sensitivity of the S meter so that S9 occurs at half scale deflection. The diode and 270 ohm resistor provide compression at the higher readings so that the meter can read up to +40 dB over S9 without pegging past full scale. The ALC meter has no specific calibration. Its main purpose is to show when V10 is being hit with ALC voltage.

The driver and PA circuits are conventional, and very similar to my other radios. PA NEUT capacitor C6 provides out of phase feedback to neutralize the PA grid to plate capacitance. It is adjusted so that plate current dip and maximum power output occur at the same setting of C4, when tuned into a dummy load.

The filaments are wired in series and parallel arrangements as required to work from a 12.6 VAC source. V12 and V13 have non-standard filament currents (350 ma and 650 ma respectively), so it was necessary to connect V10 and V12 filaments in parallel to make it all work out.

K2 and K3 are small signal relays with special alloy contacts for switching low level signals. They are contained in 16 pin DIP packages. These packages are plugged into sockets on a prototype circuit board so they can be changed if required. The proto board also allowed mounting a lot of other miscellaneous parts and connections that would have been difficult to wire up on terminal strips. I called the whole thing a relay module, which is seen towards the chassis rear in Figure 4. The schematic of all these circuits is shown on sheet 3 of the schematic diagram.