Modifying the Collins KWM-2 for Serious CW Operation

Make this old SSB workhorse perform like it should on CW.

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The vintage Collins KWM-2 was originally marketed as a SSB mobile transceiver. While giving good SSB performance, operating CW is somewhat problematic. The KWM-2 uses an audio oscillator operating between 1450 Hz to 1750 Hz, depending on the serial number, to generate a CW signal through the balanced modulator and heterodynes it up to the transmit frequency.

To keep the KWM-2's transmit frequency tuned to the other station's transmit frequency, the KWM-2 PTO has to be tuned away from zero beat by 1750 Hz on receive. Therefore the received CW signal is a 1750 Hz tone with a corresponding 1750 Hz monitoring sidetone when transmitting CW. Essentially, the KWM-2 uses the existing SSB circuitry for transmitting CW. If the KWM-2 is retuned to receive a more desirable CW audio tone, the transmit frequency will change. The other station would be required to retune its frequency if not equipped with receive incremental tuning (RIT) or a variable beat frequency oscillator (BFO). Neither are available on a stock KWM-2. The result is a CW QSO in which each station chases each other over the band. This is not best amateur practice.

What's the Answer?

As an alternative, a carrier generated system for KWM-2 CW operation is presented. The CW modifications are split into two assemblies. First, a circuit board containing the BFO carrier oscillators and necessary switching circuits is fabricated and wired in place behind the PTO housing of the transceiver. This will be referred to as the *BFO board*. Second, an outboard chassis is built containing the keyer, zero beat indicator, sidetone oscillator and the TR circuits for use in CW mode. The chassis is placed external to the KWM-2 and connected via coaxial cables to the KWM-2 rear chassis jacks. This chassis will be referred to as the *external functions box*.

These modifications are presented here

as information for those who may wish to improve KWM-2 CW operating performance by means of BFO carrier shift. The intent is to generate true carrier CW operation and bring the received tone to 800 Hz while copying CW. These modifications do not change SSB operation of the KWM-2 transceiver. All circuit changes are reversible if it is desired to return the transceiver to its original state.

Circuit details of both the BFO board and external functions box are presented and their operation discussed. Tests and alignment procedures are included for these circuits along with the overall tests and alignment following integration into the KWM-2 transceiver.

KWM-2 Architecture

To better understand the rationale for modifying the KWM-2 to a carrier generated CW system, a brief review of an unmodified KWM-2 frequency conversion is presented. The KWM-2 heterodyne plan is shown in Figure 1. For clarity, only the mixers, product detector and balanced modulator are shown. All filters, amplifiers, and other non-relevant sections are left out.

SSB Receive Signal Flow

As an example, let's assume a sideband signal in the frequency range from 14,300.3 kHz to 14,302.7 kHz is being received. The 17,355 kHz crystal oscillator signal is mixed with the incoming signals in the receiver first mixer. IF signals out of the first mixer in the range of 3054.7 kHz to 3052.3 kHz are generated and mixed with the 2598.65 kHz PTO frequency in the receiver second mixer. Frequencies between 456.05 kHz and 453.65 kHz are generated out of the receiver second mixer and are mixed with the 456.35 kHz USB BFO signal at the product detector producing audio signals in the 300 Hz to 2700 Hz frequency range.

SSB Transmit Signal Flow

The transmit sequence of the SSB signal is followed in reverse. The 300 Hz to 2700 Hz audio baseband is mixed with the 456.35 kHz USB BFO in the balanced modulator. This signal is passed on to the first transmit mixer and mixed with the 2598.65 kHz PTO oscillator signal to produce IF frequencies in the range of 3054.7 kHz to 3052.3 kHz. These signals are sent to the second transmit mixer and mixed with the 17,355 kHz crystal oscillator to generate output sideband signal frequencies between 14,300.3 kHz and 14,302.7 kHz.

CW Receive Signal Flow

Now we come to CW operation in the

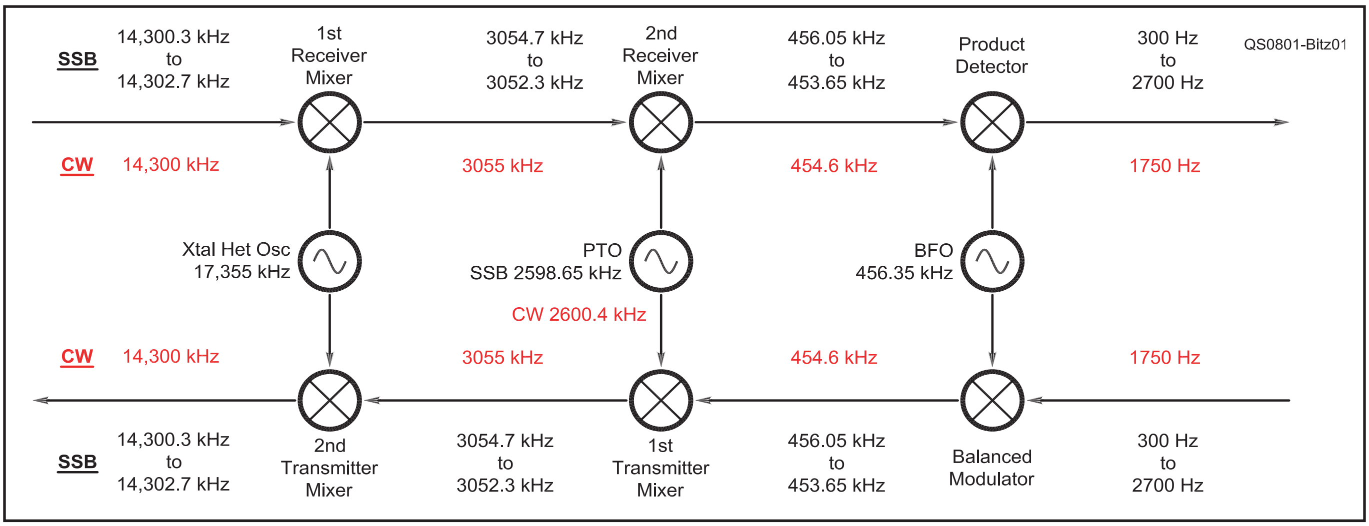

Figure 1 — The original KWM-2 frequency plan for SSB and CW modes.

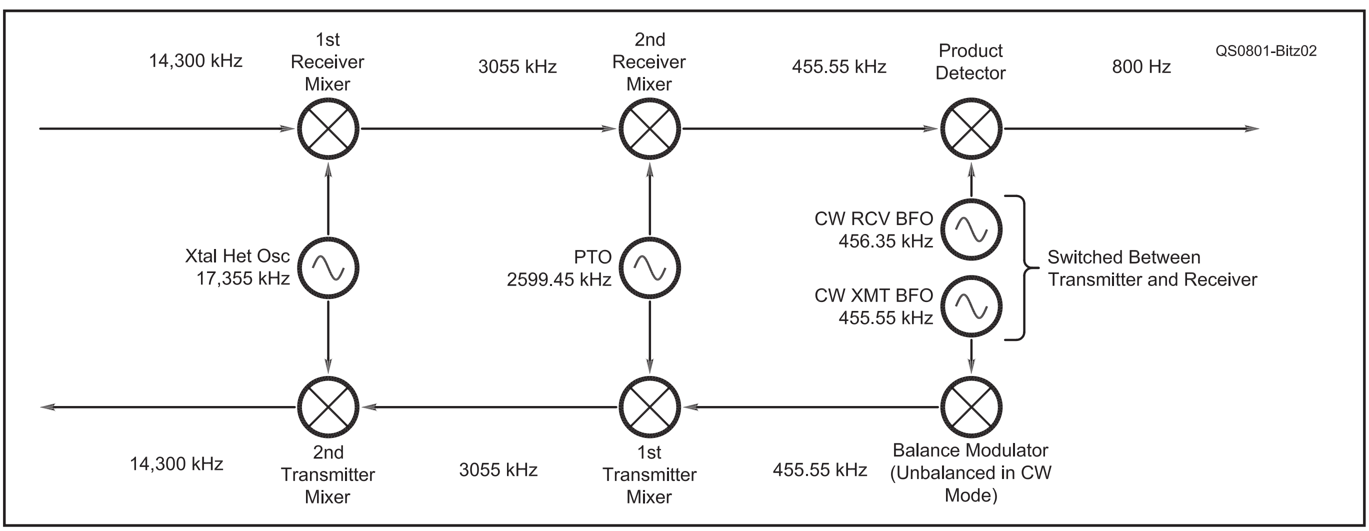

Figure 2 — Modified KWM-2 frequency plan for carrier generated CW operation.

unmodified KWM-2. Assume an incoming 14,300 kHz signal is to be received as shown in red in Figure 1. As in the phone example above, the 17,355 kHz crystal oscillator signal is mixed with the incoming signal in the receiver first mixer. A 3055 kHz IF signal is generated and mixed with the 2600.4 kHz PTO frequency in the receiver second mixer. A 454.6 kHz IF frequency is generated out of the receiver second mixer. The mixed product of this signal and the 456.35 kHz USB BFO signal at the product detector (CW uses the USB BFO crystal) produces a CW audio signal at 1750 Hz. Note that this PTO frequency of 2600.4 kHz is 1750 Hz away from the 2598.65 kHz signal when SSB operation was used.

CW Transmit Signal Flow

When the KWM-2 is switched to CW transmit, a 1750 Hz tone oscillator is connected to the balanced modulator. The balanced modulator output is heterodyned up to the transceiver output to generate a 14,300 kHz CW signal. Just as in the phone example above, the CW beat frequency on receive and the audio tone oscillator on transmit must be identical so that the KWM-2 receive and transmit frequencies are the same. Collins used this scheme to add CW capability to a transceiver primarily designed for SSB operation.

CW Options

So this being the case, why not change the tone oscillator frequency from 1750 Hz to 800 Hz? There is a flaw in this approach. The tone signal is amplified by the speech amplifier where low level distortion occurs and harmonics of the tone signal are generated. While a low level of harmonic content (around 2%) is acceptable for voice, it is not for a CW tone. The tone signal and harmonics are translated up to the 455 kHz DSB balanced modulator output. The SSB filter will not attenuate these BFO harmonic signals since they are within the filter passband. They will be heterodyned up to the output transmit frequency. The transmitted output CW signal will have sideband products spaced at 800 Hz intervals.

This seems to be the reason Collins increased the tone oscillator frequency to get around this problem. Between 1450 Hz and 1750 Hz, all tone harmonics generated within the speech amplifier and translated up to the balanced modulator output fall outside the SSB filter passband and are attenuated.

A Better Approach

To work around this somewhat inflexible condition when KMW-2 CW operation is desired, an alternate approach has been tried by others. This approach shifts the PTO frequency only when in receive mode. It essentially provides an RIT function that can move the receive frequency while not affecting the transmit dial setting of the PTO. A fabricated circuit board with the appropriate components is attached to the back of the PTO housing. A spring loaded finger from the board makes contact with a capacitor on top of the PTO housing.

This modification requires an RIT control to be mounted externally from the KWM-2 or as has been suggested, the RIT control could be installed on the front panel in place of the headphone jack. I have not read any comments regarding frequency stability of the PTO using this modification. However, there may be an effect on PTO drift. Temperature and voltage variations on the varicap diode across the PTO circuit during transmit or when switched in during receive can cause a shift in PTO frequency over time.

If one acquires a KWM-2 with a PTO that has good stability and drift characteristics, it is best not to alter it. Rather than shift the PTO, why not shift the BFO carrier frequency in the CW mode. Figure 2 shows how this might be accomplished. Using the same frequency conversion diagram approach, two BFO carrier oscillators are used instead of one. The KWM-2 USB BFO at 456.35 kHz is used on receive and an added 455.55 kHz BFO is connected in its place during transmit. The balanced modulator is unbalanced during transmit allowing the 455.55 kHz signal to be heterodyned up to the transmit frequency. Using the previous example, a received CW signal at 14,300 kHz is downconverted to 3055 kHz. Here it is mixed with the PTO tuned to 2599.45 kHz. A second IF at 455.55 kHz is mixed with the 456.35 kHz USB BFO in the product detector giving an 800 Hz CW beat note. On transmit, the external 455.55 kHz BFO is now connected to the unbalanced balanced modulator and heterodyned up to the transmit frequency of 14300 kHz. The downside of this method requires the BFO in the KWM-2 to be switched in and out of operation for both SSB and CW when the transceiver is in receive mode.

A variation on this approach uses two separate BFO carrier oscillators for CW operation leaving the KWM-2 internal BFO intact for SSB operation. A 455.0 kHz crystal oscillator positions the receive BFO carrier in the center of the 455 kHz sideband filter passband during receive, and a 454.2 kHz oscillator positions the BFO transmit 800 Hz below the 455 kHz receive frequency. Further details will be described in the CW frequency conversion plan in the next section. It is this modification that is described here and it's what I installed into my KWM-2. The crystals cut for these two

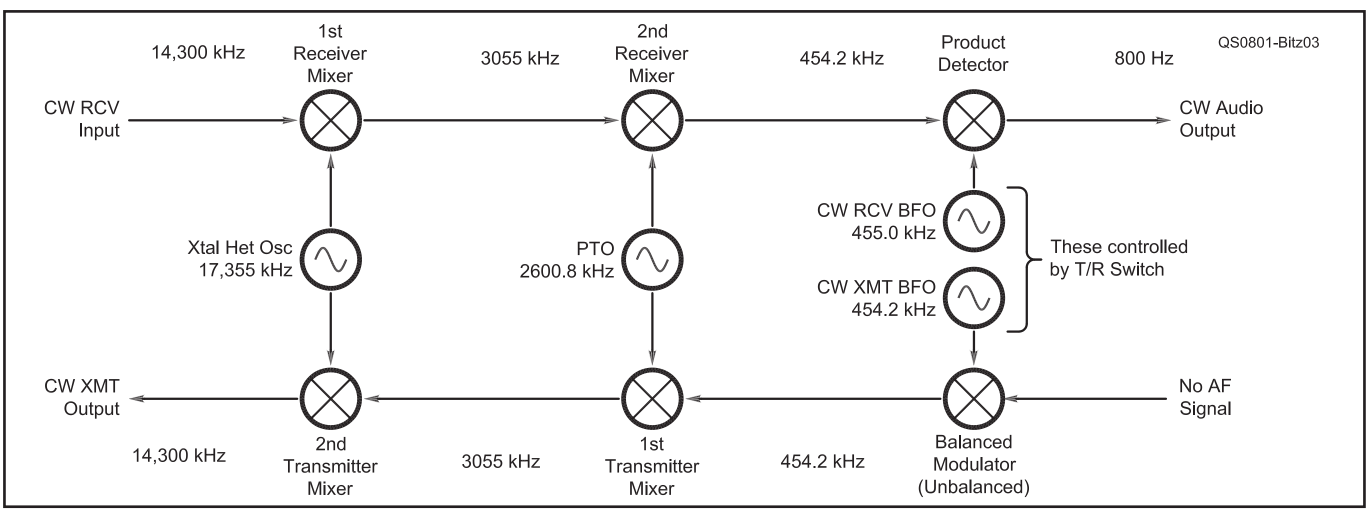

Figure 3 — Modified KWM-2 frequency plan for CW using two BFO frequencies.

frequencies are easily obtained and much cheaper than new crystals purchased direct from a crystal manufacturer.

CW Frequency Conversion Plan

The KWM-2 frequency conversion plan adds two new BFO carrier frequencies when CW operation is desired. The KWM-2 USB and LSB internal BFO carrier oscillator remains untouched when in the TUNE, LOCK, USB and LSB modes. The 1750 Hz tone oscillator is disconnected only in CW mode. Outboard CW sidetone monitoring is provided when the KWM-2 is switched over to CW operation.

The new KWM-2 heterodyne plan for CW is shown in Figure 3. Assume the transceiver is tuned to a 14,300 kHz incoming CW signal. The 17,355 kHz crystal oscillator signal is mixed with the incoming 14300 kHz signal in the receiver first mixer. A 3055 kHz IF signal is generated and mixed with the 2600.8 kHz PTO frequency in the receiver second mixer resulting in an IF frequency of 454.2 kHz. The 455 kHz BFO signal is switched to the product detector. The mixed product of the 454.2 kHz IF signal and the 455 kHz BFO signal at the product detector produces the 800 Hz audio CW tone.

As shown in Figure 3 when the transceiver is in CW transmit mode, the balanced modulator is switched to an unbalanced condition and the transmit 454.2 kHz BFO oscillator is connected. The 454.2 kHz signal is passed on to the first transmit mixer. This signal is mixed with the 2600.8 kHz PTO oscillator signal to generate an IF frequency at 3055 kHz. The 3055 kHz signal is sent to the second transmit mixer and mixed with the 17,355 kHz crystal oscillator to generate an output signal at 14,300 kHz. As a result, the received frequency at 14,300 kHz and the KWM-2 transmitting frequency are now the same.

Again referring to Figure 3, notice that the PTO is tuned to 2600.8 kHz. If tuned to 2600.0 kHz, the 455 kHz IF signal generated is sent to the product detector and mixed with the receive 455 kHz BFO resulting in a zero beat with the incoming signal. No 800 Hz tone generated here. To generate an 800 Hz audio tone, the KWM-2 dial setting must be retuned to set the PTO at 2600.8 kHz. This is done with the aid of an external tone decoder set at 800 Hz. The KWM-2 tuning dial is retuned below its zero beat setting (2600.0 kHz) by 800 Hz as indicated by an LED on the tone decoder output. Note that the tuning down rather than up is a consequence of the KWM-2 and S-Line PTO tuning in reverse of the tuning dial reading. As shown in Figure 3 when in CW transmit with the PTO now set at 2600.8 kHz, this signal is mixed with the transmit 454.2 kHz BFO such that the KWM-2's transmit frequency is the same as its receive frequency. In effect, the PTO frequency between transmit and receive does not change; this task is performed by shifting BFO frequency.

Required KWM-2 Circuit Modifications

Listed are changes to the KWM-2 that will retain USB, LSB, Tune and Lock functions in SSB mode while allowing the new BFO and relay circuits to be wired in to handle CW operation.

- Internal BFO carrier oscillator power is disconnected during CW operation.
- Internal BFO outputs to balanced modulator and product detector are separated.
- The internal 1750 Hz tone oscillator is disconnected only when the mode switch is in CW.
- Provision is made to unbalance the balanced modulator during CW operation.

Required BFO Board Functions

To change over to CW operation, the following circuits with specific functions are placed on the BFO board. The completed board is fitted in behind the PTO housing. All leads from this board fit through the existing hole in the KWM-2 already in place for PTO leads and cable. The circuits on the BFO board are as follows:

- Two crystal oscillators, one operating at 455.0 kHz (receive) and the other operating at 454.2 kHz (transmit).
- A level set potentiometer to adjust the transmit BFO output level. This is accessible at the top of the board.
- A solid state relay driver to handle the following TR functions:
  - switching BFO outputs between transmit and receive,
  - switching BFO power between transmit and receive,
  - switch BFO output signals between balanced modulator and product detector for both CW and SSB operation.
- A second set of relays is activated through ground closure to perform the following:
  - applies power to BFOs while in CW mode,
  - disconnects KWM-2 BFO (V11A) power when in CW position,
  - switches either BFO board outputs or internal KMW-2 BFO output between balanced modulator or product detector through relay K-3.
- Provide a filtered 12 V dc power source for the BFO board circuits and relays.

An unmodified KWM-2 operating in CW mode allows the tone oscillator output level to be adjusted through the MIC gain to keep the transmitter amplifier stages from being overdriven. When the transmit BFO on the BFO board drives the balanced modulator in an unbalanced mode directly, this control is lost, since no tone signal is available to generate CW. To get around this problem, a potentiometer controls the output level of the 454.2 kHz transmit BFO. The 455.0 kHz receive BFO and the 454.2 kHz transmit BFO outputs to the product detector and balanced modulator respectively must be switched during TR operation, requiring electrical separation of these two circuits internal to the KWM-2.

When CW mode is selected, the internal KWM-2 BFO power is disconnected. The transceiver is placed in receiving mode. Power is applied to the receive BFO on the BFO board and its output is switched to the product detector. When the transceiver is placed in transmit mode, power is switched from the receive BFO and connected to the transmit BFO. The output of the transmit BFO is connected to the balanced modulator input through a level set potentiometer for transmitter drive adjustment.

In some of the older transceivers, when CW mode is selected, the ALC is disabled and an external transmit level control allows for proper setting of the transmit drive level. This becomes difficult in the modified KWM-2 since a separate control must be brought out to the front panel. Installing this control to the front panel requires additional shielded leads and possibly a new location for the control. Cutting a hole in the front panel for this control is not practical, so another solution was found.

Rather than disable the ALC, it is used to level the transmit drive signal across the bands (this is the normal ALC mode for CW in the unmodified KWM-2). The ALC in the KWM-2 has fast attack and slow delay time constants and in CW mode can perform automatic transmit drive level control. The ALC reference is set via the transmit BFO level control on the new BFO board. The band that requires most drive is selected, in this case the 10 meter band, and the drive level is set for optimum ALC control. On the lower bands where more drive is available, the ALC will automatically back off the drive levels keeping the CW output constant.

When switching back to SSB operation, relays on the BFO board will remove power from the CW BFOs and reconnect power to the internal KWM-2 BFO. The relays will also switch the internal KWM-2 BFO between balanced modulator and product detector during TR functions. The balanced modulator will be switched back to its balanced configuration.

With limited real estate on the BFO board, the functions of a keyer, zero beat indicator, TR transfer and a tone oscillator to monitor

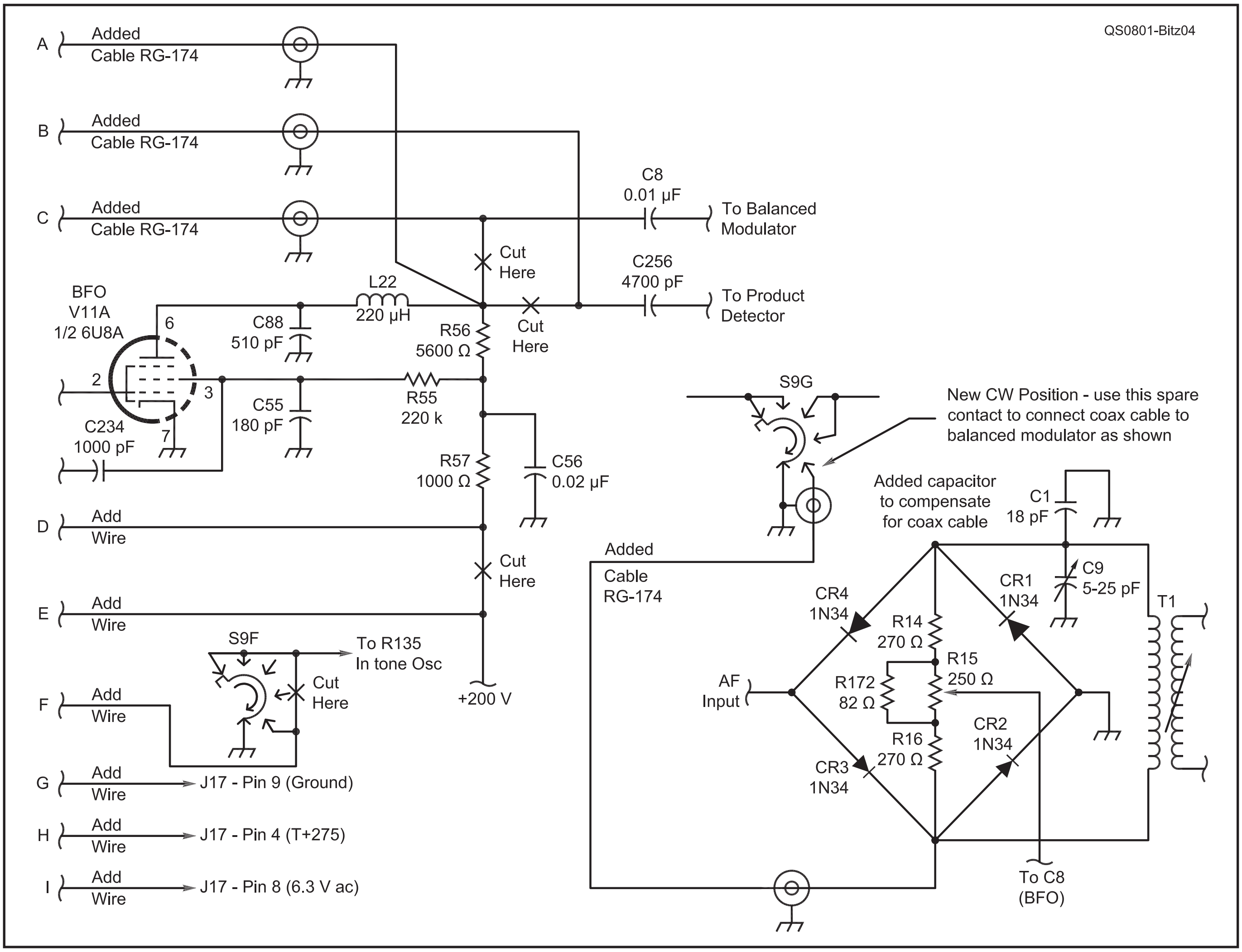

Figure 4 — Required KWM-2 circuit changes for CW modification. C1 is the only added part.

C1 — 18 pF ceramic capacitor.
C8 — 0.01 µF capacitor, Part of Collins KWM-2.
C9 — 5-25 pF var. capacitor, Part of Collins KWM-2.
C55 — 180 pF capacitor, Part of Collins KWM-2.
C56 — 0.02 µF capacitor, Part of Collins KWM-2.
C88 — 510 pF capacitor, Part of Collins KWM-2.
C234 — 1000 pF capacitor, Part of Collins KWM-2.
C256 — 4700 pF capacitor, Part of Collins KWM-2.
CR1-CR4 — Part of Collins KWM-2.
R14-R16 — 270 Ω resistor, Part of Collins KWM-2.
R15 — 250 Ω pot. resistor, Part of Collins KWM-2.
R55 — 220 kΩ resistor, Part of Collins KWM-2.
R56 — 5600 Ω resistor, Part of Collins KWM-2.
R57 — 1000 Ω resistor, Part of Collins KWM-2.
R172 — 82 Ω resistor, Part of Collins KWM-2.
L22 — 220 µH, Inductor, Part of Collins KWM-2.
S9F, S9G — Part of Collins KWM-2.
T1 — Part of Collins KWM-2.
V11A — Part of Collins KWM-2.

sending are placed in external functions box and interconnected to the KWM-2 through its rear apron jack connections.

KWM-2 Internal Circuit Modification Details

The first part of the CW modification procedure is to make the required internal circuit changes in the KWM-2. Modifications are made to:

- BFO V11A.
- The balanced modulator.
- Switches S9F and S9G.
- Additional leads to pick up ground, 6.3 V ac and the T+275 V line.

Figure 4 illustrates the KWM-2 circuit changes. The Collins circuit schematics parts designators are retained for ease of identification.

Bringing the +200 V dc to V11A Out to the New BFO Board

The lead to the power side of R57 located on turret E10 is cut and brought over to an empty terminal lug on turret E10 and soldered. Two wires are added; one soldered to the hot side of R57, the other to the +200 V dc lead brought over to the spare terminal lug on E10. Make these leads short and label them. For the time being they will act as markers when the leads from the BFO board are brought over for final wiring.

BFO (V11A) Output Separation from Balanced Modulator and Product Detector Inputs

This change becomes a little more complex. Locate the lug for the attachment point of L22, R56, C8 and C256 on turret E10. Cut leads to C8 and C256 off the terminal lug. There is room under the chassis to attach a small terminal strip with three lugs. The center lug is used as a ground terminal. The remaining two lugs are insulated. The terminal strip ground lug is attached to tube V15 socket mounting screw using a 4-40 nut. The lead from C8 is soldered to one of the insulated lugs and the lead to C256 is soldered to the other.

As seen in Figure 4, two coaxial cables coming from the BFO board will connect to their respective terminal lug to C8 and C256 and the third cable to the lug on E10 at which L22 and R56 join. Record the location of these connections. When the completed BFO board wires and cables come through the chassis hole for the PTO wires and cable, they can then be attached correctly.

Unbalancing the Balanced Modulator in CW Position

An unused terminal was located on the Mode switch S9G when switched to the CW position. It is fortunate that this switch terminal is a short distance from the balanced modulator circuits. To avoid BFO leakage to the surrounding circuits, a piece of RG-174 cable is used as a Faraday shield between S9G and the balanced modulator diode ring. The cable center conductor is connected to S9G spare lug (in CW position) and shield is connected to nearby ground. At the other end of the cable, only the center conductor is connected at the junction of CR2 and CR3. The cable introduces an additional capacitance of 18 pF to ground. To rebalance the balanced modulator when in SSB mode, an 18 pF capacitor is connected across the balance capacitor C9. The balanced modulator can now be rebalanced within the range of C9 and R15 for SSB operation.

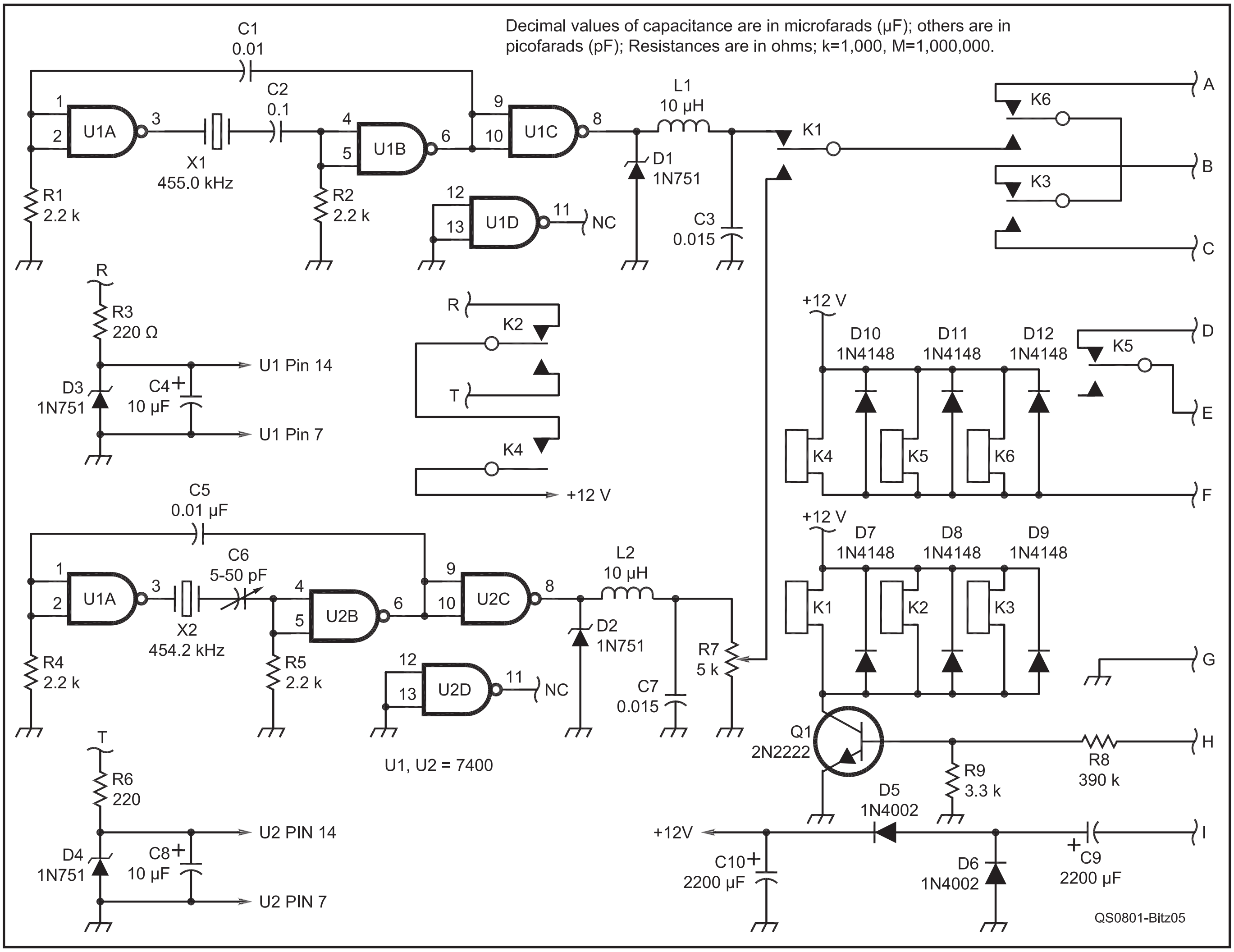

Figure 5 — Schematic diagram and parts list for new KWM-2 BFO board.

R1, R2 — 2.2 kΩ, ⅛ W resistor.
R3, R6 — 220 Ω, ½ W resistor.
R4, R5 — 2.2 kΩ, ⅛ W resistor.
R7 — 5 kΩ pot.10 turn trimpot, PCB mount resistor.
R8 — 390 kΩ, ½ W resistor.
R9 — 3.3 kΩ, ⅛ W resistor.
C1, C5 — 0.01 µF, 50 V dc capacitor.
C2 — 0.1 µF, 50 V dc capacitor.
C3, C7 — 0.015 µF, 50 V dc capacitor.
C4, C8 — 10 µF, 25 V dc electrolytic capacitor.
C6 — 5-50 pF variable, miniature PC mount capacitor.
C9, C10 — 2200 µF, 25 V dc electrolytic capacitor.
L1, L2 — 10 µH, 100 mA molded, inductor.
D1-D4 — 1N751, 5.1 V, 400 mW Zener.
D5, D6 — 1N4002, 100 PIV. 1A rectifier.
D7 - D12 — 1N4148, 75 PIV 30 mA, signal diode.
Q1 — 2N2222, NPN transistor.
U1, U2 — 7400 quad two input NAND integrated circuit.
K1-K3, K5, K6 — SPDT relay, 12 V dc, 30 mA Coil, 10 A @ 120 V ac contacts. RadioShack, 275-248.
K4 — SPST reed relay, 12 V dc, 11 mA coil, 0.5 A @ 125 V ac contacts. RadioShack, 275-233.
X1 — 455.0 kHz crystal, Surplus Sales of Nebraska.
X2 — 454.2 kHz crystal, Surplus Sales of Nebraska.

Obtaining a Switched Ground for the BFO Board Relays

The 1750 Hz tone oscillator is not used in CW position, allowing the lead between S9F TUNE and LOCK and the CW position to be cut. This frees up this terminal lug when S9F is in CW position. A temporary wire is soldered to this lug and labeled.

Remaining Connections from the KWM-2 Required for BFO Board Operation

Three more short wires are added as markers for later connection between the BFO board and J17. The first wire is labeled GND and soldered to J17, pin 9. The second is labeled T+275 V dc and soldered to J17, pin 4. This connection supplies +275 V dc to various circuits internal to the KWM-2 during transmit only. The third wire is labeled 6.3 V ac and soldered to J17, pin 8.

BFO Board Circuit Details

The second part of the CW modification procedure is to build the BFO circuits and controls necessary for both CW operation and switching capability between CW and SSB operation. These circuits and their power supply are built on a circuit board mounted behind the PTO housing. The board is mechanically and thermally isolated from the PTO housing.

The BFO board contains the following groups of circuits, as shown in Figure 5 and 6. There are two switched BFOs, a 455.0 kHz receive BFO and a 454.2 kHz transmit BFO. There are two groups of relays. One group is activated through transistor switch Q1. The other group is activated through a ground closure from switch S9F in the KWM-2. A half-wave voltage doubler provides +12 V dc from the 6.3 V ac in the KWM-2. Each BFO has its own regulated 5 V Zener supply.

The KWM-2 BFO output signal amplitude is typically 2.8 V_{PP} ±0.4 V_{PP}. The signal amplitude from the CW carrier BFOs must be in the same range as that of the BFO (V11A) in the KWM-2. While there are a number of different oscillator circuits available, the simplest oscillator chosen for reasonable stability, and the required output level, is provided by TTL quad NAND gates. As shown in Figure 5, each IC gate is powered through its own dedicated +5 V dc regulator. The unused fourth gate in the quad has its inputs grounded to prevent its inadvertent operation. The oscillator square wave signal is passed through a low pass filter. If one wishes, several more filter sections could be added to clean up the sine wave, but it was found that a single filter section is adequate. The 5 V zener across the third gate output of each oscillator preceding the filter acts as a snubber limiting the switching transient from exceeding 5 V from the filter inductor. Potentiometer R7 controls the transmit gain from the BFO during CW transmit operation. It is mounted on the circuit board to be accessible during alignment. Constant transmitter output amplitude during CW operation is maintained over the five bands by the level set by R7 in conjunction with the KWM-2 ALC.

All relays in Figure 5 are shown in the unpowered state. When power is applied to the KWM-2 and the mode switch is in the SSB position during receive, K5 relay contacts on the external BFO board connect +200 V dc to the BFO (V11A) in the KWM-2. Relay contacts K3 and K6 likewise connect the BFO (V11A) output in the KWM-2 to the product detector. SSB signals can be received on the transceiver. When the transceiver is switched to transmit while in SSB mode and PTT or VOX is activated in the KWM-2, the T+275 line is switched in. This activates relays K1, K2 and K3 on the CW carrier BFO board. Since K4, K5 and K6 have not been activated, no power has been applied to the BFO board's CW BFOs. Power is still connected to the KWM-2 BFO (V11A) but its output is switched over to the balanced modulator through the contacts of K3. Even though K1 and K2 have been powered, no voltage appears across U1 and U2 since contacts of K4 are still open. The KWM-2 is now in the SSB transmit mode.

Again referring to Figure 5, the KWM-2 is placed in CW mode and switched back to receive. Relays K1, K2 and K3 on the carrier BFO board are now deactivated. Power is applied to relays K4, K5 and K6 when in CW mode. Power is applied to the CW receive BFO U1 through the closure of K4. K5 disconnects power to the KWM-2 BFO (V11A) and connects the external CW receive BFO (U1) through the NC contacts of K1. K6, having been activated, routs the CW receive BFO signal through the NC contacts of K3 connecting the BFO output to the product detector in the KWM-2. This puts the KWM-2 in CW receive mode. Switching the KWM-2 over to the transmit mode, relays K1, K2 and K3 are again activated. K2 transfers power from the CW receive BFO over to the CW transmit BFO. K4 is still closed. While K1 and K6 remain activated and K3 now activated in transmit, the CW transmit BFO signal through R7 is connected to the balance modulator in the KWM-2. Recall that in the CW mode, the balanced modulator is unbalanced.

Note that the capacitor in series with the 455.0 kHz crystal is fixed while the one in

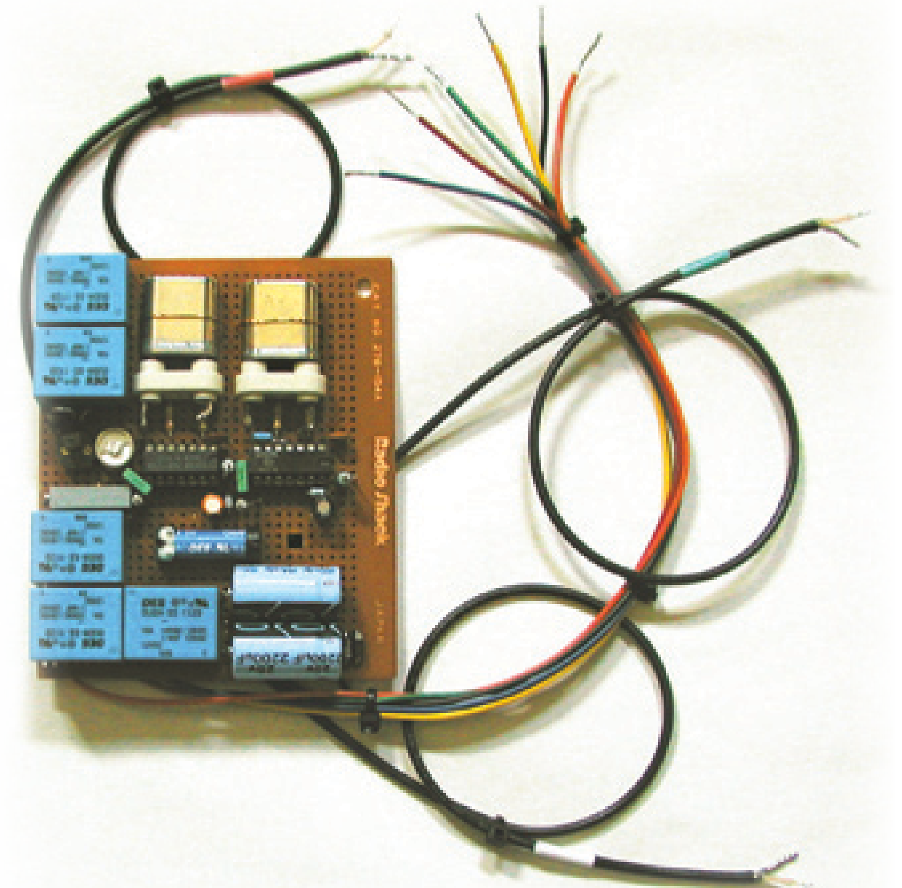

Figure 6 — Photo of the new KWM-2 BFO board.

series with the 454.2 kHz is variable. The particular 455.0 kHz crystal chosen was within tens of Hz of 455; therefore a variable capacitor was not required. However, the 454.2 kHz crystal was low by 120 Hz and it was swung up to 454.2 kHz with the series variable capacitor in its circuit. If surplus crystals are used, it is the luck of the draw concerning how far the crystal can be pulled in frequency. Purchasing a pair of new crystals can be expensive.

A voltage doubler operates off the 6.3 V ac heater supply. The doubler output provides +12 V dc to the relays and to the two +5 V dc regulators that power the BFO oscillators, U1 and U2.

The installation of the BFO board behind the PTO is shown in Figure 7, while Figure 8 shows it in final position.

The External Functions Box Circuit Details

In the unmodified KWM-2 operating CW, the 1750 Hz audio tone also provides the functions of a CW transmit sidetone monitor and activates VOX relays for transfer from receive to transmit. The keying function cuts off the audio stage into the balanced modulator when in CW mode under key up and turns it on during key down.

For the carrier generated CW modification being described, the former functions are rendered inoperative. Therefore to augment the KWM-2 CW modifications, circuit functions that cannot be incorporated into the BFO board itself are housed in the separate chassis and connected to the KWM-2 via its rear chassis connectors.

The circuits performing these functions are shown in Figures 9 and 10. The NE567 (U1) is a popular IC employed as a "tuning aid." Its frequency is preset to 800 Hz by means of R8. When the KWM-2 receiver audio frequency reaches 800 Hz, the decoder output at pin 3 transitions from high to low turning on LED D4. Potentiometer R4 adjusts the input audio signal level into the decoder. A +5 V Zener provides regulated voltage for the NE567. A TUNE switch on the external functions box turns on a delay controlled relay Q1 and K1 supplying power to the NE567 for approximately 45 seconds. After "zero beat" is established in receive, the KWM-2 is tuned on the low side of zero beat until LED D4 is illuminated. It is long enough for the tuning to be set to 800 Hz before the decoder is turned off. Otherwise, the LED will be blinking on and off to the cadence of the CW signal being received during the entire QSO.

U2 is a CD4011 quad NAND gate. The first three sections act as a contact debouncer; the fourth gate is configured as an inverter. The contact debouncer output is connected to the keying circuit Q2 and Q3, the TR keyed switch U2D, Q4 and Q5 and the sidetone generator U3. When the key is down, the following actions occur:

- The tone oscillator is turned on,
- Q2 and Q3 conduct turning KWM-2 RF output on,
- Q4 and Q5 conduct switching the KWM-2 from receive to transmit in the CW mode.

An adjustable delay circuit is incorporated into the output of Q4 to prevent instant switching back to receive before the CW message is completed. This is a similar function to VOX delay during SSB operation.

A plug-in wall outlet power supply module rated for 12 V dc at 500 mA is adequate to power the circuits. The module output line plug is connected to its mating chassis jack, J1. A 1000 μF capacitor provides additional power supply ripple filtering.

The circuits in the external functions box represent a minimum set of functions for the successful CW modifications to the KWM-2. There are a number of possible improvements that are left to the experimenter. These include:

- Incorporation of a sine wave tone generator for monitoring keying. This produces a less harsh tone while monitoring CW signals. If preferred, the sidetone generator frequency can be made variable or preset to 800 Hz.
- The inclusion of a narrow CW receive filter (DSP or analog) with its own AF power amplifier to drive the KWM-2 external speaker. Included would be a switching arrangement to bypass the CW filter when operating SSB. Include a sampling of the CW filter output into the tone decoder for easier 800 Hz tuning in crowded band conditions.
- The simple LED tuning indicator can be replaced with a LED bar graph display and its drive circuits, allowing a more precise alignment for the 800 Hz tuning signal indicator.
- The CW sidetone generator in the external functions box can be eliminated if a keyer is available with its own sidetone generator.
- In the same manner, the contact debouncing circuit can be eliminated in the exter-

Figure 7 — Photo of the new KWM-2 BFO board being installed behind PTO. Cooling fans were added as a part of another project.

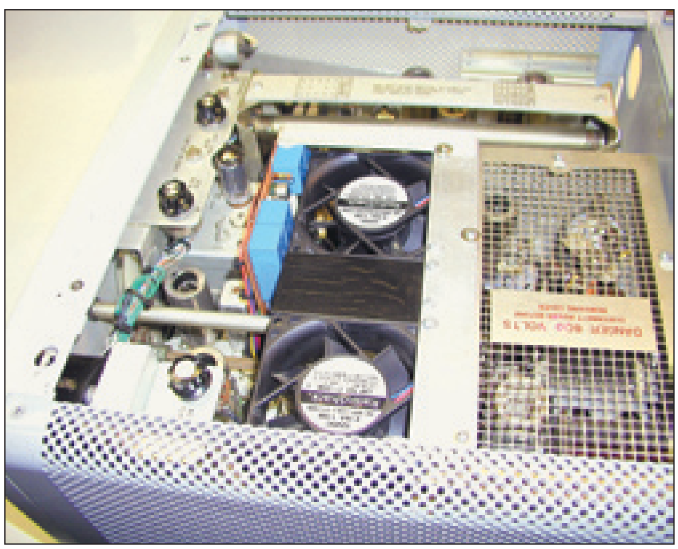

Figure 8 — Photo of the new KWM-2 BFO board in place behind PTO.

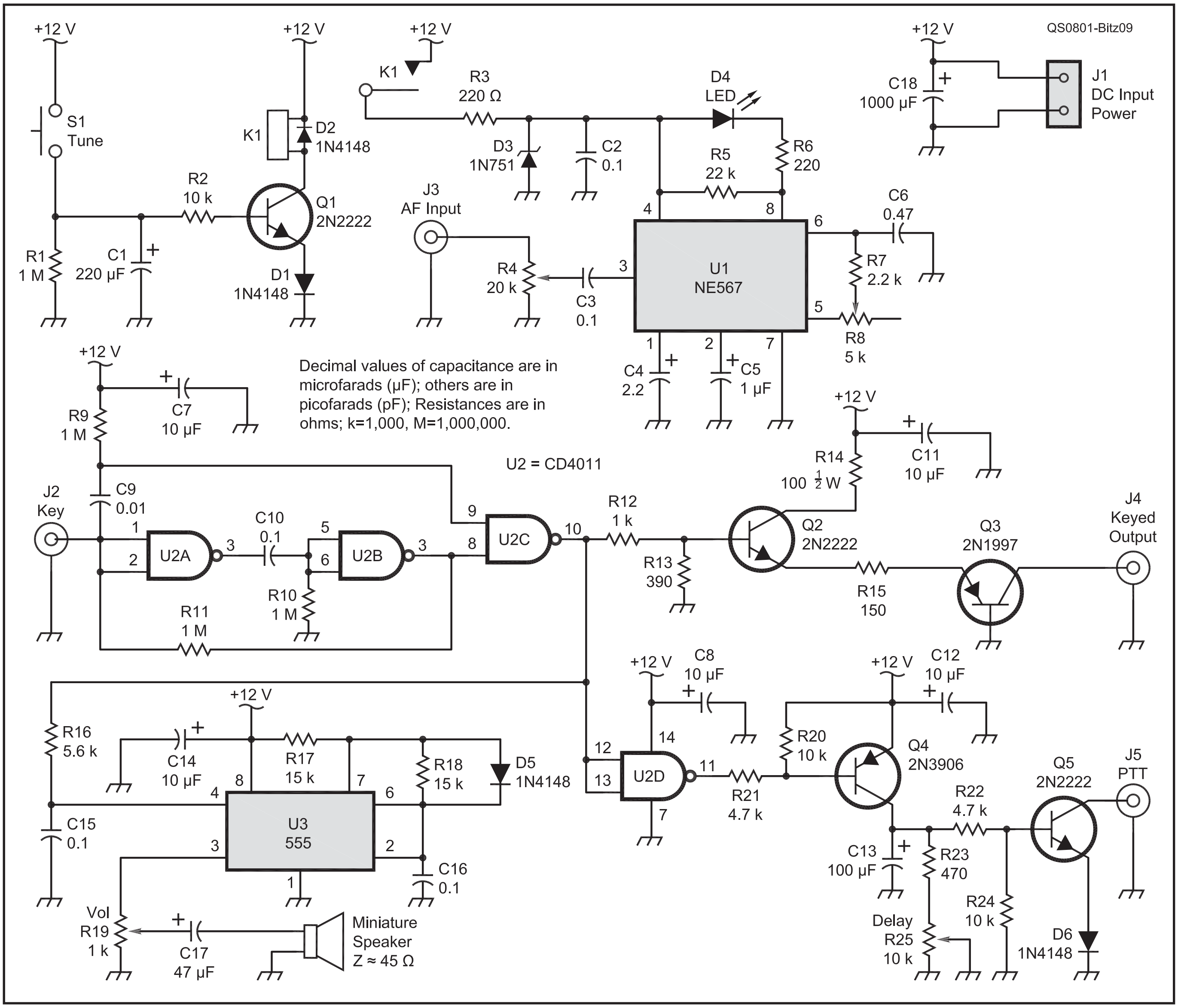

Figure 9 — Schematic diagram and parts list of external functions box.

C1 — 220 µF, 50 V dc capacitor.
C2, C3, C10, C15, C16 — 0.1 µF, 50 V dc capacitor.
C4 — 2.2 µF, 15 V dc electrolytic capacitor.
C5 — 1 µF, 15 V dc electrolytic capacitor.
C6 — 0.47 µF, 50 V dc capacitor.
C7, C8, C11, C12, C14 — 10 µF, 25 V dc electrolytic capacitor.
C9 — 0.01 µF, 50 V dc capacitor.
C13 — 100 µF, 25 V dc electrolytic capacitor.
C17 — 47 µF, 25 V dc electrolytic capacitor.
C18 — 1000 µF, 25 V dc electrolytic capacitor.
D1, D2, D5, D6 — 1N4148, 75 PIV, 30 mA, small signal diode.
D3 — 1N751, 5.1 V, 400 mW, Zener diode.
D4 — LED (red), (RadioShack 276-330).
J1 — Power connector, (RadioShack, 274-1576).
J2-J5 — RCA type phono jack.
K1 — SPST reed relay, 12 V dc, 11 mA coil, 0.5 A, 125 V ac contacts, (RadioShack 275-233).
Q1, Q2, Q5 — 2N2222 NPN transistor.
Q3 — 2N1997 (NTE100 equivalent), PNP transistor.
Q4 — 2N3906 PNP Transistor.
R1, R9-R11 — 1 MΩ, ⅛ W resistor.
R2, R20, R24 — 10 kΩ, ⅛ W resistor.
R3, R6 — 220 Ω, ½ W resistor.
R4 — 20 kΩ pot.10 turm trimpot, PCB mount resistor.
R5 — 22 kΩ, ⅛ W resistor.
R7 — 2.2 kΩ, ⅛ W resistor.
R8 — 5 kΩ pot.10 turm trimpot, PCB mount resistor.
R12 — 1 kΩ, ⅛ W resistor.
R13 — 390 Ω, ⅛ W resistor.
R14 — 100 Ω, ½ W resistor.
R15 — 150 Ω, ½ W resistor.
R16 — 5.6 kΩ, ⅛ W resistor.
R17, R18 — 15 kΩ, ⅛ W resistor.
R19 — 1 kΩ chassis mount potentiometer.
R21, R22 — 4.7 kΩ, ⅛ W resistor.
R23 — 470 Ω, ⅛ W resistor.
R25 — 10 kΩ chassis mount potentiometer.
U1 — NE567 tone decoder integrated circuit.
U2 — CD4011 quad two input NAND integrated circuit.
U3 — 555 timer integrated circuit.
S1 —NO pushbutton switch, (RadioShack, 275-609).
Speaker — Miniature 45 Ω coil intercom speaker, Tektone SK004 or equivalent.

nal functions box if a keyer has its own internal contact debouncing capability.

Tests and Alignment

A minimum test equipment list for the following test and alignment steps are:

- Two digital voltmeters (DVM).
- A dummy load with a calibrated 50 Ω RF tap.
- Dual-trace oscilloscope with 100 MHz bandwidth.
- A good signal generator, HP 8640B or equivalent.
- An audio generator.
- Two frequency counters capable of measuring frequency up to 50 MHz.
- A two tone audio generator.
- A pulsed keyer.
- Two 0-30 V variable dc power supplies.
- A 275 V dc power supply.

Caution. While performing any testing on this, or any other equipment using high voltages, always use proper safety procedures. These voltages can be lethal.

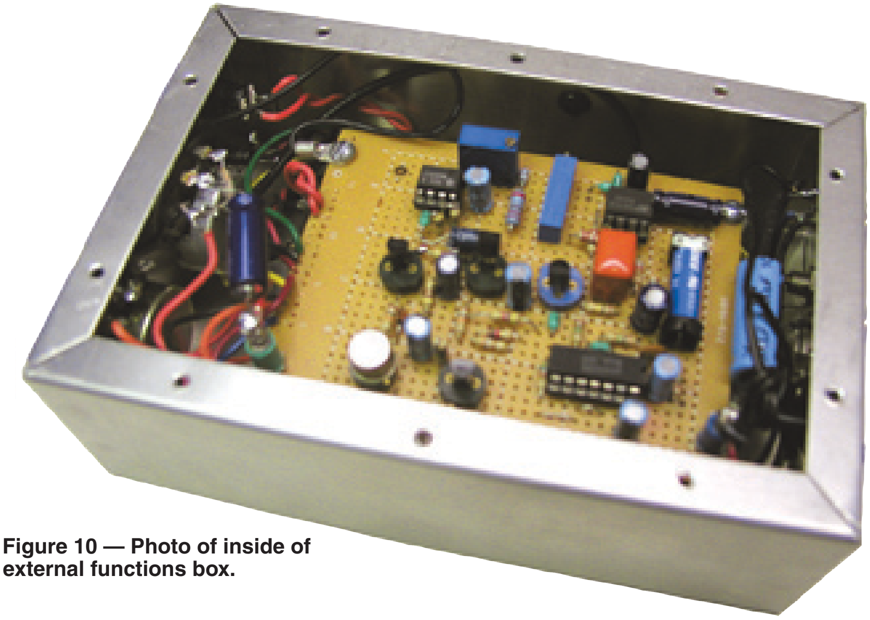

Figure 10 — Photo of inside of external functions box.

KWM-2 Initial Checks

After circuit changes are made to the KWM-2, it is necessary to temporarily reconnect these circuits to verify that the original functions have not been compromised. Reconnect the balanced modulator and product detector lines to the BFO (V11A) output together by means of short clip leads. Also reconnect the +200 V dc power to the BFO (V11A) plate circuit by means of a short clip lead. Connect the dummy load to the KWM-2 ANTENNA jack. Connect the dummy load RF tap to a scope or RF voltmeter. Apply power to the KWM-2. Set the band switch to 20 meters. Check for normal receive functions.

If there are no adverse effects from the changes, then switch to TUNE, then LOCK and check for full RF output power. If there are no problems here, turn mode switch to LSB and rotate the MIC GAIN all the way off until the switch clicks. Since changes were made to the balanced modulator, chances are that carrier balance has to be restored. Measure the RF carrier level on the scope or RF voltmeter. Switch to USB and measure the RF level. If the RF levels are not minimum and are different between USB and LSB, then rebalance the balanced modulator. Switch between USB and LSB and adjust for minimum level by means of R15 and C9 in the KWM-2. Switch the transceiver back to RECEIVE upon completion.

Turn POWER off. Attach a dc voltmeter to the wire connected to J17, pin 4. Attach an ac voltmeter to the wire connected to J17, pin 8. Turn POWER back on and place the KWM-2 in CW mode. Place the transceiver back into transmit. There should be no 1750 Hz audio tone from the KWM-2 speaker while the key is down. The balanced modulator is now in the unbalanced mode. There should be carrier signal seen at the transceiver RF output (remember that the MIC GAIN is still off). Check for +275 ±10 V dc at the end of the wire attached to J17 pin 4 and 6.3 ±0.5 V ac on J17, pin 8. This completes the checks on the changes made to the KWM-2. Turn POWER off, remove clip leads and disconnect the test equipment.

The BFO Board Checkout

Next, the completed BFO board is tested prior to installation into the KWM-2. Attach a clip lead to the K4, K5 and K6 ground line out of the board. Connect the T+275 line out of the board to a lab power supply set at +275 V dc and insulate connections. Connect the board power supply to a 6.3 V ac source. Power up the board but leave T+275 line unpowered and the K4, K5 and K6 line ungrounded. Approximately +12 V should be measured at the voltage doubler power supply output. Check for relay closure across contacts of K5 on the board (D and E in Figure 5). Verify continuity between the BFO plate line and the product detector output at the BFO board (A and B in Figure 5).

Connect the ground end of K4, K5 and K6 to ground, activating these three relays. With an ohmmeter verify that the normally closed contacts of K5 are now open. Verify +5 V dc is measured on pin 14 of U1 and no voltage is measured on pin 14 of U2. Verify that a 2.8 ±0.4 Vpp 455 kHz signal is measured at the product detector output of the board (B in Figure 5). Check that there is no BFO signal to the line going to the KWM-2 BFO plate (A in Figure 5). Apply power to the T+275 line activating relays K1, K2 and K3. Verify +5 V dc is measured on pin 14 of U2 and no voltage is measured at pin 14 of U1. Reminder: caution — there is +257 V dc shock hazard here! A 454.2 kHz signal should be seen at the balanced modulator output of the board (C in Figure 5). The output voltage should change between 2.8 +/-0.4 Vpp and zero as R7 is adjusted over its full range. Again, check that there is no BFO signal to the line going to the KWM-2 BFO plate (A in Figure 5). This completes the checkout of the BFO board.

The External Functions Box Checkout

The next tests are performed on the completed external functions box. Apply power to the chassis. With a dc voltmeter at pin 4 of U1, push the TUNE pushbutton; 5 V dc should appear at U1 pin 4 for approximately 45 seconds. Connect an audio generator to AF INPUT J3. Adjust for a 1 Vpp audio signal. Place the scope probe at pin 3 of U1 and adjust R4 for a 0.1 V_{PP} signal. Set the AF generator to 800 ±10 Hz and adjust the tone frequency potentiometer R8 until the LED lights. Rock the AF generator frequency above and below 800 Hz and readjust R8 as necessary to assure that the capture range is fairly symmetrical on each side of 800 Hz.

Connect a 4.7 kΩ resistor between KEYED OUTPUT J4 and a –30 V dc supply. Connect a 4.7 kΩ resistor between PTT J5 and a +15 V dc supply. Connect a key to KEY jack J2. Turn the SIDETONE VOLUME (R19) so that a tone is heard through the speaker mounted in the external functions box. With key up, no audio output should be heard through the speaker, –30 V dc should be measured at J4 and +15 V dc at J5. Lock the key down and confirm that voltages across J4 and J5 drop close to 0 V. A tone of around 500 Hz should be heard from the sidetone monitor speaker. Check the TR delay from key down to key up. The delay should be variable from 0.2 to 2 seconds through adjustment of R25. If the key is a semiautomatic key, generate a series of dots while observing the output at J4. The CW pulses must be free of any contact bounce. This completes the checkout and adjustments on the external functions box.

The Modified KWM-2 Checkout

Carefully mount and wire the carrier BFO board into the KWM-2. The following connections are made between the external functions box and the KWM-2 rear connections. Connect a short coax cable between KEYER OUTPUT and the transceiver KEY jack. Connect another short coax cable between PTT and the transceiver PTT jack. Connect a coax Y to the transceiver's SPEAKER jack. Connect one side of the Y to the transceiver speaker. The other side is connected via a short coax cable to AF INPUT on the external functions box. Connect a key to the KEY input of the external functions box.

Connect the dummy load to the ANTENNA jack of the KWM-2. Connect a scope to the dummy load RF tap through a 50 Ω termination at the scope. Power is applied to the external functions box and to the KWM-2 transceiver. Set the transceiver on the 20 meter band and tune it up in LOCK mode. The output RF power level should be approximately 100 W. Switch the transceiver to SSB mode. Connect a two tone generator into the transceiver MIC input; a two tone test pattern should appear on the scope. Switch between USB and LSB and verify that the test patterns are the same and their peak to peak voltage is close to the peak to peak RF voltage seen in LOCK mode.

Switch the KWM-2 back to RECEIVE mode. Set the signal generator to 14.3 MHz and lock it to its internal reference so that it does not drift. Disconnect the coax from the dummy load and connect it to the signal generator. Do *not* put the transceiver in transmit mode; this will blow out the precision attenuator in an expensive signal generator! Tune the KWM-2 in USB or LSB receive mode until a beat note is heard from the signal generator set at 14.3 MHz. Reduce the generator signal level amplitude using its precision attenuator until the received signal is just barely discernible. The signal generator level should be in the –120 to –130 dBm range. Switch to the opposite sideband and repeat. This procedure verifies that the modifications made did not affect KWM-2 performance in SSB mode.

Disconnect the cable from the signal generator and reconnect it to the dummy load. Switch over to CW mode and tune up the transceiver in transmit mode. Key down can now be used to tune the transceiver for maximum RF output since the internal transmit BFO generates the direct carrier rather than using one generated by a tone. The RF output should return to the 100 W range. The scope should display a steady carrier. At the same time, a steady 500 Hz tone should be heard from the sidetone generator via the speaker in the external functions box.

Turn the transceiver MIC GAIN all the way down. Generate a series of dots with the key and observe the keying waveshape. If the leading edge of the keyed pulse has a large leading edge transient, then the CW transmit BFO output drive is too high. The high drive level saturates the linear amplifiers and affects the response time of the ALC. The drive level must be reduced by R7 on the BFO board inside the KWM-2. Since the drive level amplitude decreases as the frequency increases, a starting place for R7 adjustment is the 10 meter band. Set the KWM-2 to 10 meters and tune for maximum output. Key the transmitter by sending a series of dots and observe the CW waveform on the scope. In order to facilitate the adjustment, a small battery operated pulser was built to replace the key for dot generation.

Adjust the drive level to eliminate the large leading edge transients. The transceiver can be tuned up on the other bands to verify elimination of leading edge transients. The MIC GAIN must be turned down completely during CW keying; otherwise a notch will appear within the CW waveform, a KWM-2 peculiarity.

Switch the KWM-2 back to receive mode. Set the signal generator back to 14.3 MHz and lock it to its internal reference so that it does not drift. Disconnect the coax from the dummy load and connect it to the signal generator. Tune the KWM-2 in CW receive mode until a beat note is heard from the signal generator set at 14.3 MHz. A beat note will be heard on either side of zero beat since the received signal is centered in the 455 kHz IF passband. Reduce the signal level amplitude out of the generator using its precision attenuator until the received signal is just barely discernible out of the transceiver. The level should be in the –120 to –130 dBm range. This procedure verifies that the CW modifications in the KWM-2 are performing as designed.

With the KWM-2 still in CW receive mode and tuned to the 14.3 MHz signal, zero beat on the received signal. Push the TUNE button on the external functions box and tune the KWM-2 on the low side of zero beat. The received audio beat note will increase in frequency as it approaches 800 Hz. When the beat note is within the capture range of the decoder, the LED indicator will light. As you tune beyond this point, the LED will go out. Tune back until the LED comes on again. Leave the KWM-2 tuning set at this frequency. Disconnect the signal generator and reconnect the transceiver antenna back to the dummy load. With the scope still connected to the dummy load RF tap and key down condition, tune the KWM-2 for nominal RF output. Key up and switch the RF tap coax cable from scope to frequency counter. Key down again and the KWM-2 transmit frequency should read 14.3 MHz ±30 Hz. This test verifies that the transmitted signal received and the KWM-2 transmitted signal is within ±30 Hz of each other.

Checking for Undesired Signals on the Modified KWM-2

With the completion of the checkout tests, a search should be made on the modified KWM-2 transceiver for any new spurious signals appearing within the receiver passband while in CW mode. There is always a possibility that mixer products or BFO leakage may produce unwanted signals as a result of the new wiring. On my modified KWM-2, four signals were found within the 3.5 MHz to 28.7 MHz bands. Very low level signals were found at 3.63 MHz, 7.28 MHz, 28.21 MHz and 28.67 MHz while in CW mode. For comparison, several unwanted low signal level spurious signals were also found in my original Collins 75S-3 receiver within the same frequency coverage.

A spectrum analyzer was used to view the transmitted output spectra of the modified KWM-2 in CW mode. The transmitted CW signal was displayed along with the harmonics. No other signals appeared as the transmitter was tuned over each of the 200 kHz band segments. The harmonic output met the specification of –40 dBc. No close-in sideband frequencies were observed around the CW signal in any of the bands.

Some Additional Comments

If a change of audio tone is desired for CW reception, the frequency difference between BFO frequencies can be made smaller. For example, keeping the receive BFO frequency at 455.0 kHz, the transmit BFO frequency can be changed from 454.2 kHz to 454.5 kHz. A 500 Hz audio CW tone is generated if that is preferred.

While TTL oscillator circuits and relays are used in this author's BFO board, other solid state oscillator circuits can be tried. Perhaps some of the relay switching could be performed with solid state devices instead of relays. This BFO board had pre-etched pads and used some point-to-point wiring. There is no reason why one cannot come up with a double sided PC board layout to mount the components for a nice clean package, if desired.

Conclusion

Although the modifications presented do not bring the Collins KWM-2 up to par with all the features of more modern CW capable transceivers, it does provide better operating compatibility with these transceivers and makes for easier CW operation. The main advantage of this approach is that no changes are required in the PTO, maintaining its original frequency stability. SSB operation has been preserved and the CW transmitted signal can be set within ±30 Hz of the received station frequency. In addition, the received 800 Hz CW audio tone is easier to copy than the tone of an unmodified KWM-2.

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