A High-Performance Homebrew Transceiver: Part 3

Mixing, premixing, dual receiving, IF shift and CW offset—all these topics are covered in this description of the 40-MHz RF board.

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To many builders, the RF board in any radio is the most interesting. It includes the receive mixer, a prime component in determining the dynamic range of the receiver. The RF board in this radio also contains the transmit mixer, BFOs, premixers for LO injection, LO amplifier and the tunable noise channel. The basic radio covers 40-39 MHz; three front-end sections covering the ham bands from 160 to 2 meters are on separate panels. This RF board, part of the main panel, establishes the 40 MHz to 9 MHz transitions.

Part 1 gave a general description of the K5AM homebrew transceiver, built for serious DX work and contest operating.[1] Part 2 described the IF board.[2] The RF board described in this article is shown in Fig 1.

Features

The main features of the RF board are:

- Balanced JFET receive mixer
- Balanced MOSFET transmit mixer
- Premixing for the IF-shift circuit
- Adjustable-waveform keying circuit
- Offset oscillator for panel-adjustable CW offset
- Tunable noise channel for the noncrunching blanker

Circuit Description

A general description of the RF board has been given in Part 1. The block diagram in Fig 2 shows the arrangement of the various RF-board stages. Figures 3, 4, 5, 6, 7, 8, 9, and 10 show schematic diagrams of the different RF-board sections.

BFO

See Reference 1 for a discussion of the mixing scheme. To provide IF shift (IFS) operation, the BFOs are premixed along with the PTOs to obtain

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[1]Notes appear on page 50.

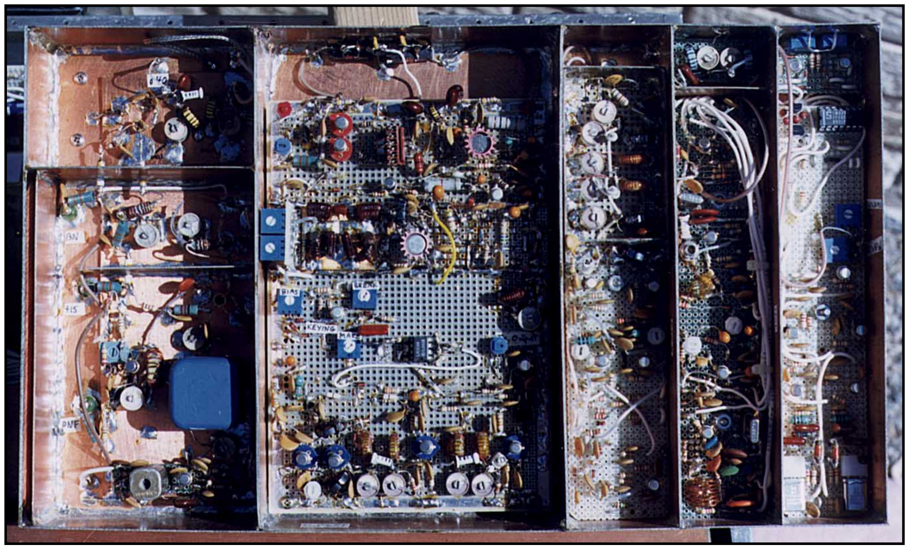


Fig 1—Top view of the RF board in the K5AM homebrew transceiver. From right to left, the sections are: the BFO, BFO mixer, PTO mixer, LO amplifier and main mixers and tunable noise channel. Several section-shielding covers have been removed for the photo.

the LO injection frequencies for the receive and transmit mixers. BFO frequencies are also routed to the AF board to provide LO injection for the product detector and balanced modulator.

The BFO circuit is shown in Fig 3. Although the BFO is tunable, a wide-range VXO circuit (with its inherent drift) was rejected in favor of a simple, adjustable crystal oscillator. A narrower tuning range results, but it is more than adequate for normal operating. For simplicity, two separate oscillators are used: one for USB/CW, the other for LSB. The components are selected to obtain the required IFS range. For normal SSB use, ±500 Hz is adequate.

The CW filters on the IF board have a center frequency of 8815.7 kHz. Thus, to provide full CW tone range for receiving, the USB oscillator must tune downward at least 800 Hz.

The circuit is somewhat unusual, as the variable tuning element is in the feedback loop. One would expect this to cause unwanted oscillator output-level changes as the BFO is tuned, but level changes also occur when pulling the crystal: The output drops with increased capacity across the crystal. With the varactor diode in the feedback loop, the feedback increases with increasing diode capacity; this counteracts the aforementioned effect. The result is much less output variation than that with the varactor across the crystal. The output is essentially constant over the range normally used in operation.

The transmit-frequency trimpot adjustments are critical. The BFOs must be positioned at the proper points on the SSB filter passband skirt to obtain the best transmitted-audio-frequency response. The initial settings have held within 10 Hz during the last seven years of operating; no doubt, the choice of quality crystals was a factor in this happy situation.

The simple IFS circuit allows BFO tuning while receiving and automatic return to the proper frequency when transmitting. When receiving, the µIFS control line is nominally –15 V. The IF-shift control on the front panel may then vary the voltage at terminal IFS1 from 0 to –15; this tunes the varactor diode VC1 in the oscillator tank circuit. At the same time, the transistor in the IFS circuit is cut off, and the **USB XMIT SET** trimpot has no effect. When transmitting, the µIFS line shifts to zero. Now the panel IFS control has no effect, but the transistor is turned on, allowing the **USB XMIT SET** trimpot to set the BFO to the proper frequency. When the CW offset spotting button is pressed, the µIFS control line also shifts to the transmit state to ensure proper offset adjustment. The Zener diode in the IF-shift circuit is needed because the control line shifts to –15 V only approximately. In practice, the op amps on the logic board that drive the control lines provide about –14 V. According to the op-amp data sheet, only –13 V can be assumed. The Zener holds the transistor's emitter voltage below –12 V, so the control line easily keeps the transistor turned off. The 10-kΩ resistor at the IFS1 terminal provides a load to ensure conduction in the diodes. Without this resistor, one may observe floating and drifting of the bias voltage applied to the varactor diode.

BFO Mixer and Offset Oscillator

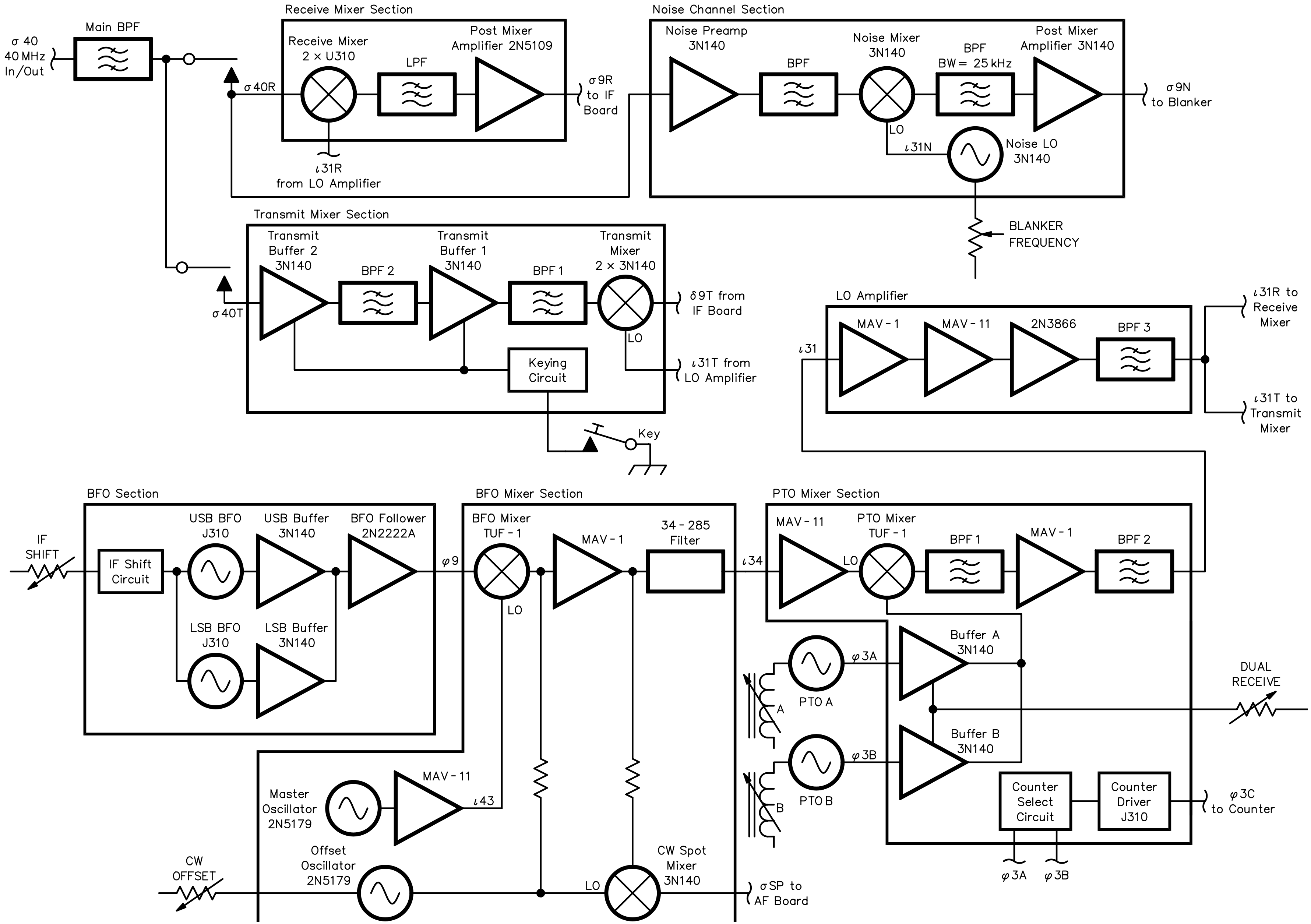
In this mixer, the BFO frequencies are mixed with the fixed 43.1-MHz master oscillator. The circuit is shown in Fig 4. The output of this mixer is nominally 34.285 MHz, shifting slightly with sideband selection and IF-shift operation. For CW-offset operation, this mixer is switched off (ignore the BFO frequencies here), and the panel-adjustable offset oscillator is used instead. Considerable temperature compensation is used to cancel the drift of the varactor diode in the offset oscillator.[3] The offset spotting mixer is enabled by the **CW SPOT** push-button on the front panel, which also enables both the normal BFO mixer and the offset oscillator. The resulting audio tone represents the actual offset; it is fed to the headphones by the AF board. A panel control sets the headphone level.

In the Signal/One CX7, the 43.1-MHz oscillator was tuned by a varactor diode, adjustable from the front panel. This was used in conjunction with an HF (100-kHz marker) calibration oscillator—itself adjusted using WWV—to calibrate the radio on each band. This resulted in some drift, destroyed the CW-offset settings and made band changing very inconvenient. Here the oscillator is fixed; the highest-quality crystals are used in the front-end sections for each band. This results in maximum convenience and read-out accuracy within 100 Hz. An important feature is the use of 10 separate oscillators on the HF panel in lieu of a crystal switch, which can cause frequency errors, instability and even total failure.

PTO Mixer and Dual-Receive Circuit

This premixer produces the final LO-injection frequencies for the main receive and transmit mixers. The cir-

Fig 2—RF board block diagram. Terminal σ40 is the 40-MHz input/output terminal from the rear panel. When receiving, the output is at terminal σ9R. For transmitting, the input is at terminal σ9T. Potentiometers labeled in all-capital letters are front-panel controls. An explanation of the terminal designations is given in Part 2, Table 1. The control lines are provided by the logic board.



Receive Mixer Section
Noise Channel Section
Main BPF
σ 40
40 MHz
In/Out
Receive Mixer
2 × U310
LPF
Post Mixer
Amplifier 2N5109
σ 40R
σ 9R
to IF
Board
ι31R
from LO Amplifier
Noise Preamp
3N140
BPF
Noise Mixer
3N140
BPF
BW = 25 kHz
Post Mixer
Amplifier 3N140
σ 9N
to Blanker
LO
ι31N
Noise LO
3N140
BLANKER
FREQUENCY
Transmit Mixer Section
Transmit
Buffer 2
3N140
BPF 2
Transmit
Buffer 1
3N140
BPF 1
Transmit
Mixer
2 × 3N140
σ 40T
δ9T from
IF Board
LO
ι31T from
LO Amplifier
Keying
Circuit
Key
LO Amplifier
MAV - 1
MAV - 11
2N3866
BPF 3
ι31
ι31R to
Receive
Mixer
ι31T to
Transmit
Mixer
BFO Section
BFO Mixer Section
PTO Mixer Section
IF
SHIFT
IF Shift
Circuit
USB BFO
J310
USB Buffer
3N140
BFO Follower
2N2222A
LSB BFO
J310
LSB Buffer
3N140
φ9
BFO Mixer
TUF - 1
LO
MAV - 1
34 - 285
Filter
ι34
MAV - 11
LO
PTO Mixer
TUF - 1
BPF 1
MAV - 1
BPF 2
Buffer A
3N140
φ3A
PTO A
A
DUAL
RECEIVE
Buffer B
3N140
φ3B
PTO B
B
Counter
Select
Circuit
Counter
Driver
J310
φ3C
to Counter
φ3A
φ3B
Master
Oscillator
2N5179
MAV - 11
ι43
CW
OFFSET
Offset
Oscillator
2N5179
LO
CW Spot
Mixer
3N140
σSP to
AF Board

cuit is shown in Fig 5. To minimize spurious responses, three band-pass filters are used for the LO injection: two here and a third in the LO-amplifier section.

The dual-receive feature is very simple; it is not equal to the much more elaborate subreceivers found in some contemporary commercial radios. The two PTOs each produce an LO injection frequency, so the receiver responds to two different frequencies at the antenna. Although simple, it can be very effective in certain DX split-frequency situations. With appropriate switching and combining of the external front-end sections, it can also be used to monitor two VHF DX calling frequencies simultaneously, or an HF and a VHF frequency. Control line µD energizes the **DUAL RECEIVE** control on the front panel. This applies gain-control voltage to the PTO buffers, resulting in adjustable balance control.

This section also contains a diode switch that routes the appropriate PTO frequencies to the counter on the front panel. Signals are selected by the readout-control line βR from the logic board. The control lines µIA and µIB control the PTO buffers and thus the received signal. This allows some flexibility. For example, PTO B can be read out and tuned while listening to a signal on PTO A.

LO Amplifier

The grounded-gate balanced JFET mixer used for the receiver has LO injection applied to the JFET source ter-

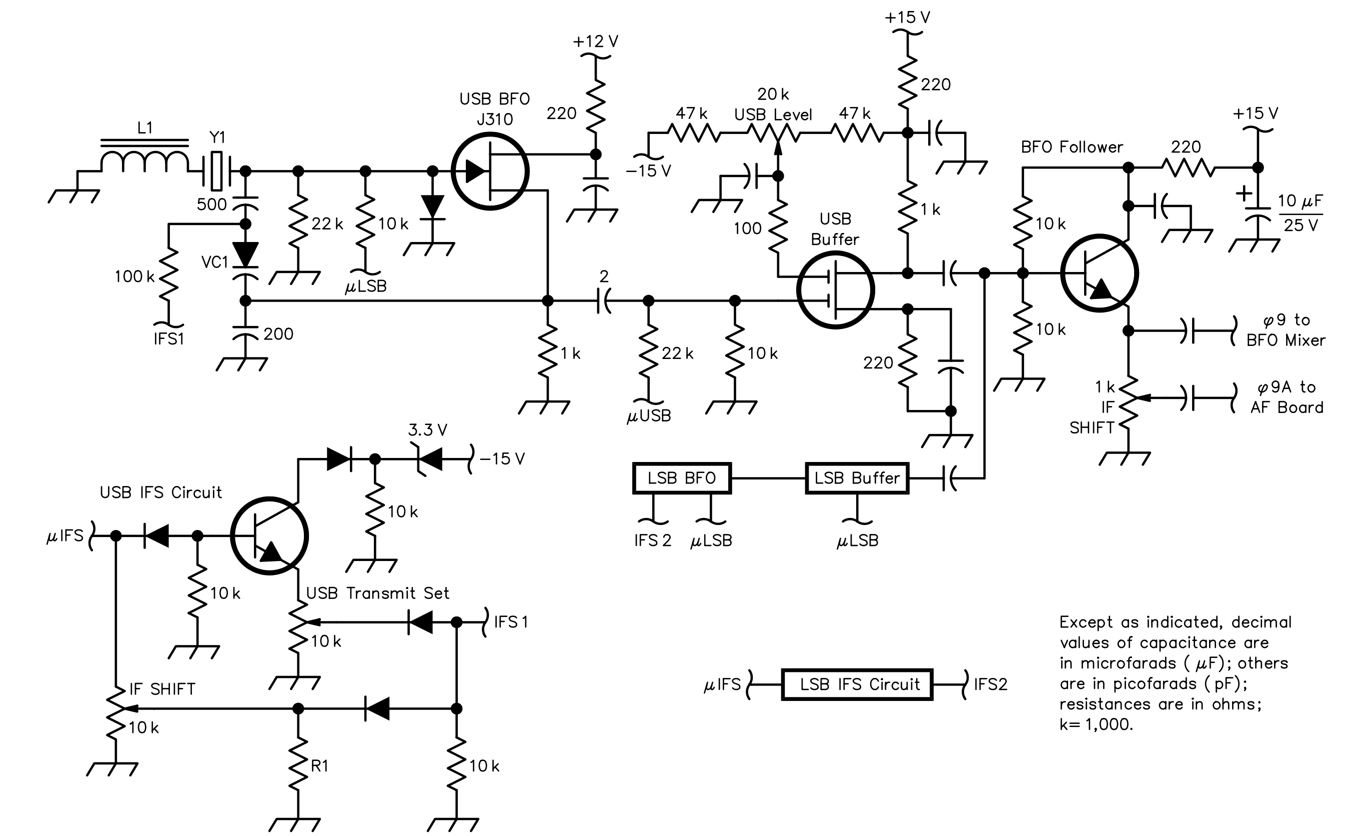


Fig 3—BFO schematic diagram. Except as noted, each resistor is a 1/4-W, carbon-film type. All trimpots are one-turn miniature types, such as Bourns type 3386; Digi-Key #3386F-nnn. (See Reference 8.) The unmarked coupling and bypass capacitors are all disc ceramic types; 1 nF in circuits above 30 MHz, 10 nF below. Also, each control and power terminal has a bypass capacitor that is not shown. Except as noted, the trimmer capacitors are Erie series 538, a sturdy 9-mm-diameter type that will withstand extensive testing and adjustment. These trimmers are available on the surplus market. (See Reference 9.) Xicon 7-mm ceramic trimmers are possible substitutes. (See Reference 10.) Except as noted, other capacitors are silver-mica types. Electrolytic capacitors are tantalum. Values of RF chokes (RFC) are given in microhenries. Potentiometers labeled in all-capital letters are front-panel controls; others are circuit-board trimpots for internal adjustment. All coils are wound with #26 enameled wire. The control signals are provided by the logic board. Some part designators differ from *QEX* style so they conform to the author's diagrams.

MOSFETs are small-signal VHF dual-gate types. Type 3N140 is used here, but any similar type may be substituted. Type NTE 221 is available from Hosfelt (Reference 11). Except where otherwise indicated, the diodes are all small-signal silicon types, such as 1N4148, and the bipolar transistors are type 2N2222A (NPN) or 2N2907A (PNP).

For clarity and to save space, LSB circuits (which are identical to the USB circuits) are indicated only as blocks. The only variation concerns the IFS panel control, which is a dual control (single shaft). The LSB section is wired so that the clockwise indicator arrow points towards ground. This is done so that the control functions the same on either sideband with respect to received audio passband.

L1—Small, molded RFC. Select, if needed, to adjust oscillator range; 1.6 µH used here.
R1—Select as needed to obtain center BFO frequency at center position of panel control. Used here: USB, none; LSB, 2.2 kΩ.
VC1—Varactor diode, nominal 33 pF. Motorola type MV2109. NTE type 614 (see Reference 11).
Y1—Fundamental crystal, USB/CW, 8816.5 kHz, type CS-1, ICM #433375-8.8165. Socket type FM-2, ICM #035007 (Reference 12).
Y2—Same as Y1, except LSB, 8813.5 kHz.

minals. It requires more LO power than other configurations. The transmit mixer also requires considerable LO power. The circuit for the amplifier that provides it is shown in Fig 6; the amplifier is operated in the linear region. The LO power for the two mixers is provided through adjustable trimpots.

Receive Mixer

The second mixer in a dual-conversion receiver is the most important single stage in the radio (see the discussion in Part 1). The circuit is shown in Fig 7. The singly balanced JFET mixer results in excellent dynamic range. The circuit is based on ideas found in a Siliconix manual.[4] There is no balance control; best mixer performance is achieved with a matched pair. A pair was selected from a batch of 10 devices. Best IMD performance and stability are obtained with the common-gate (grounded-gate) configuration.[5] In this configuration, the manufacturer suggests from +12 to +17 dBm of LO power for best performance. The dc source bias is set at 2 V, as measured at test point TP1. This dc bias is half the –4 V gate-cutoff bias of the selected JFETs; this allows full LO voltage swing without cut-off or gate conduction. The LO injection level is set for a dc reading of 1.1 V at TP2 (on a 10M Ω meter). This represents about 3.1 V P-P, or +14 dBm.

Ahead of the receive mixer and following the transmit stages are the main 40-MHz band-pass filter and the TR relays. These are shown in Fig 10. Mixer gain is only about 3 dB. A strong

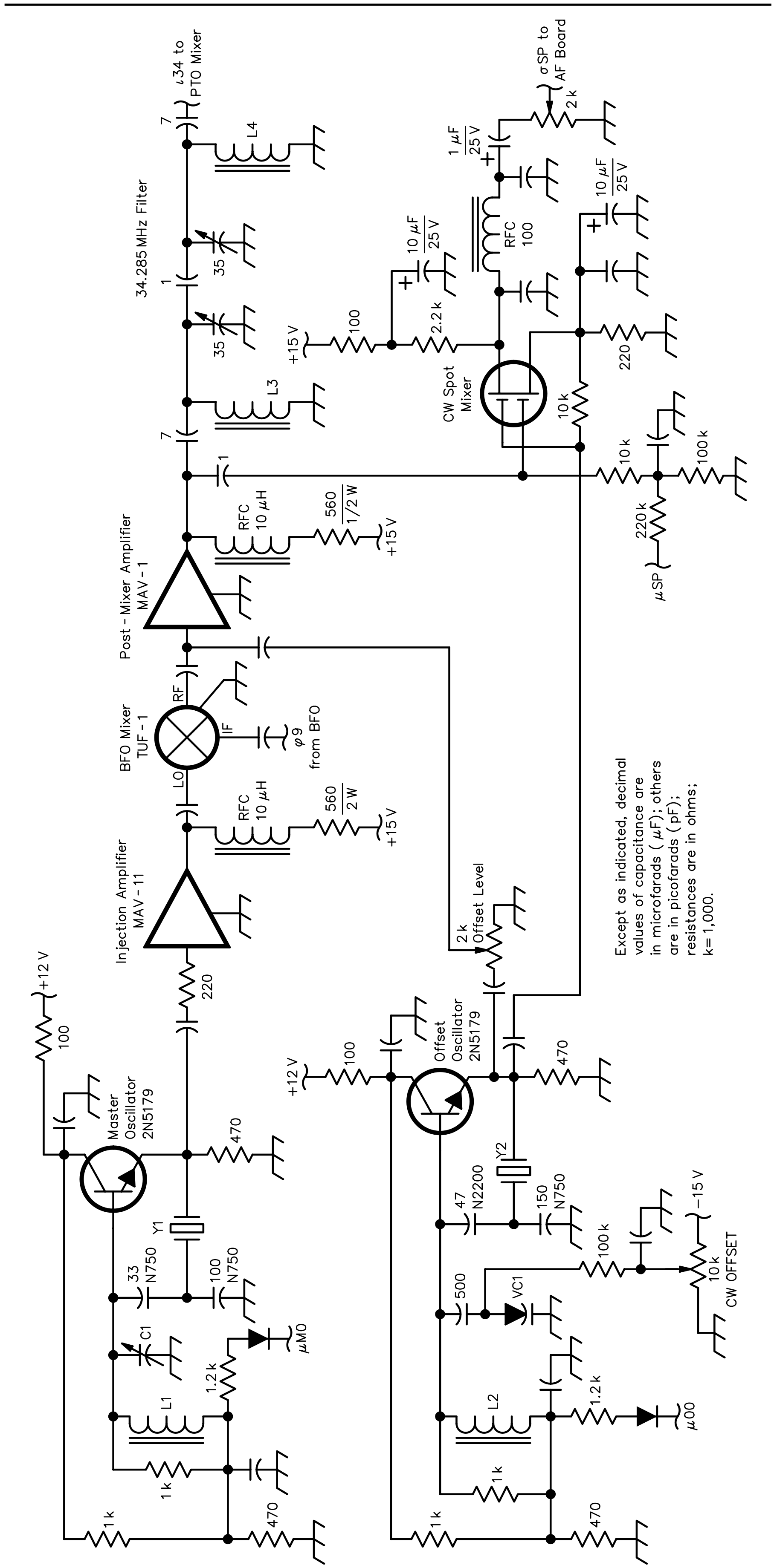


Fig 4—BFO mixer schematic diagram. For general notes on the schematics, refer to the caption for Fig 3. DBMs and MMICs may be obtained in small quantities directly from the manufacturer (Reference 13).
C1—Glass piston trimmer, 1-5 pF
L1—Master oscillator coil, 450 nH, T-37-17 powdered-iron toroidal core, 17 turns. Adjust turns to pull the crystal to the proper frequency. Compressing the winding or expanding to fill the core greatly affects the inductance. (See Reference 14.)
L2—Offset oscillator coil, 500 nH, same as L1 except 18 turns.
L3, L4—570 nH, T-37-6 powdered-iron toroidal core, 14 turns.
VC1—Varactor diode, nominal 6.8 pF. Motorola type MV2101. NTE type 610 (see Reference 11).
Y1—Master-oscillator crystal, third overtone, 43.1 MHz, type CS-1, ICM #471360-43.1 (see Reference 12).
Y2—Offset-oscillator crystal, same as Y1 except 34.2835 MHz; ICM #471360-34.2835 (see Reference 12).

bipolar amplifier follows the receive mixer. It overcomes filter losses at the input to the IF board and provides enough signal at the first IF amplifier to ensure high IF sensitivity.

Transmit Mixer

The balanced MOSFET transmit mixer circuit is shown in Fig 8. The mixer is followed by several buffers and careful filtering. There is no impedance matching at the mixer input, since high mixer gain is not required here. The voltage level on the σ9T input line is sufficient for the mixer gates. Keeping the level from the IF board high on this line minimizes the effect of any possible carrier leakage into the circuit. The total residual hum, noise and carrier on the transmitted SSB signal is more than 65 dB down.

CW keying is accomplished in the buffer stages. The keying waveform is adjustable using two trimpots in the simple timing circuit shown in Fig 9. The make and break trimpots act independently. The bias trimpot is needed because of the variation in individual MOSFET cutoff voltages. A fixed bias level high enough to accommodate any MOSFET would result in an unwanted lag between the key closure and the start of the transmitted element. The bias is set just high enough to achieve full cutoff. The timing trimpots are set for 2- to 3-ms make and break times. To ensure the absence of key clicks, the adjustment is made while monitoring with a receiver.

Tunable Noise Channel

The noncrunching noise blanker has been described previously in *QEX*.[6] It consists of several parts. The tunable noise channel is situated here on the RF board. The noise amplifier, pulse detector, signal channel and blanker gate are located on the IF board, described in Part 2. The circuit for the tunable noise channel is shown in Fig 10. The main 40-MHz filter and the 40-MHz TR reed relays are also shown on this diagram.

The MOSFET noise preamplifier, with its high input impedance, taps

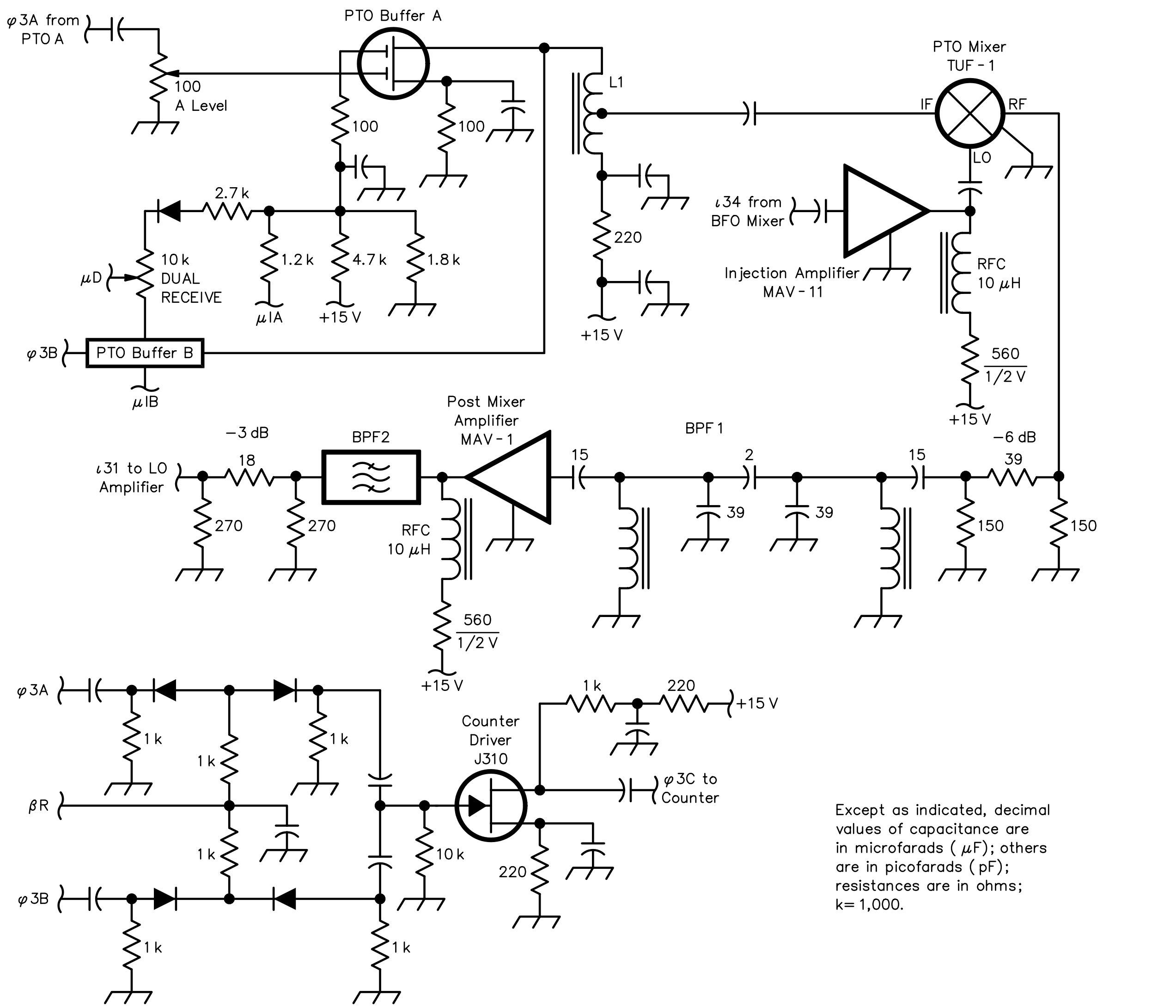


Fig 5—PTO mixer schematic diagram. For general notes on schematics, refer to the caption for Fig 3.

BPF1, BPF2—Band-pass filter, bandwidth 2 MHz, center 30.685 MHz. The coils are each 520 nH, T-37-10 powdered-iron toroidal core, 13 turns. Formulas predict 14.4 turns, but coils on these cores often have more inductance than indicated by the manufacturer's data. Adjust turns for proper inductance before assembly and again in-circuit with a sweep generator.

L1—FT-37-43 ferrite toroidal core, 12 turns, tap 3 turns from low end.

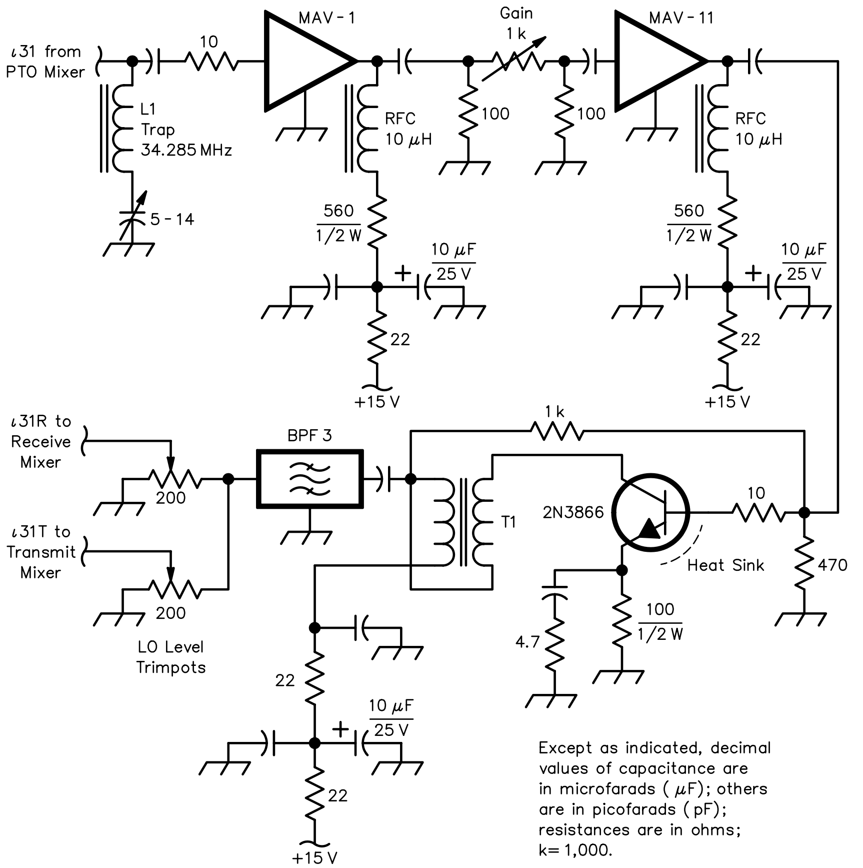
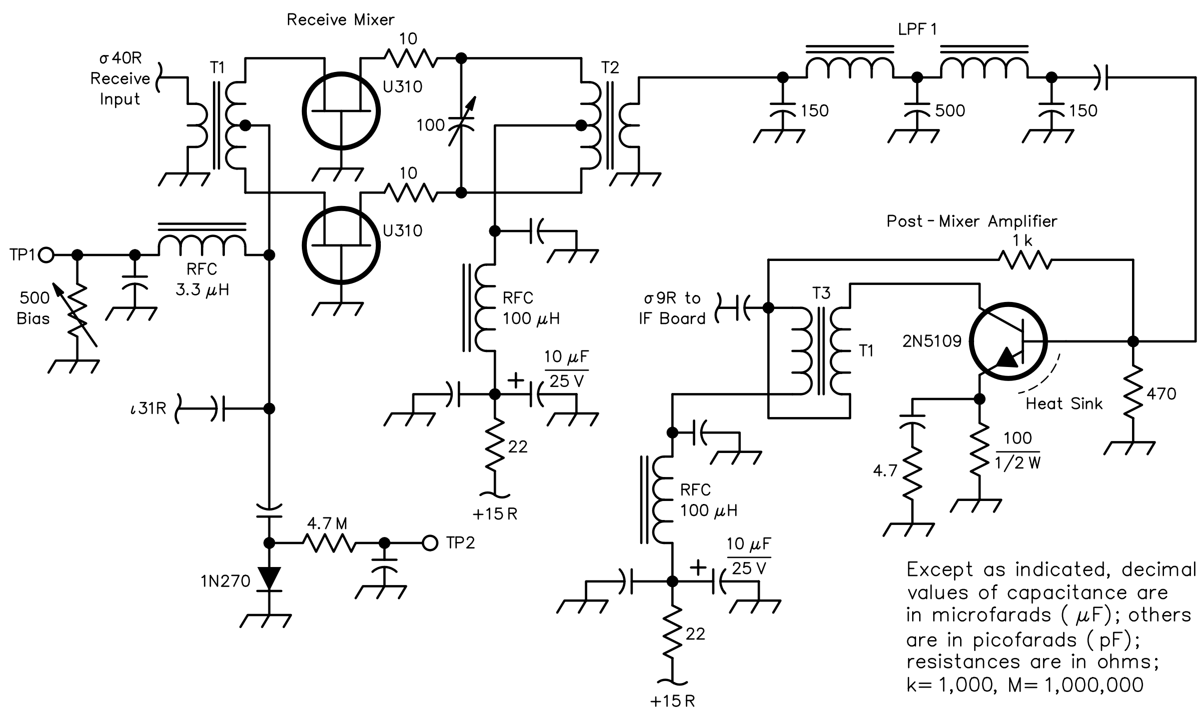


Fig 6—LO-amplifier schematic diagram. For general notes on the schematics, refer to the caption for Fig 3.

BPF3—Same as BPF1 (see Fig 5).
L1—2 µH, T-37-10 powdered-iron toroidal core, 28 turns.
T1—FT-37-61 ferrite toroidal core, 8 bifilar turns.

Fig 7 (below)—Receive-mixer schematic diagram. For general notes on the schematics, refer to the caption for Fig 3. The JFETs comprise a matched pair. Resonance in the mixer drain circuit is with about 80 pF. The tuning capacitor may be made up of convenient components; for example, a 62-pF silver-mica capacitor in parallel with a 9 to 35-pF ceramic trimmer. The 64:1 transformer in the drain circuit presents a load of 1600 Ω to each drain, which is optimum for best IMD performance (see Reference 4).
LPF1—Low-pass filter, cutoff frequency 13 MHz. Inductors, 1 µH, T-37-6 powdered-iron toroidal core, 18 turns.
T1—Mixer input transformer, FT-37-61 ferrite toroidal core, 8 trifilar turns.
T2—Mixer output transformer, T-50-6 powdered-iron toroidal core. Primary, 4 µH, 32 turns, wound over full length of core, center-tapped. Secondary, 4 turns, close-wound at the center of the primary winding.
T3—FT-37-43 ferrite toroidal core, 6 bifilar turns.



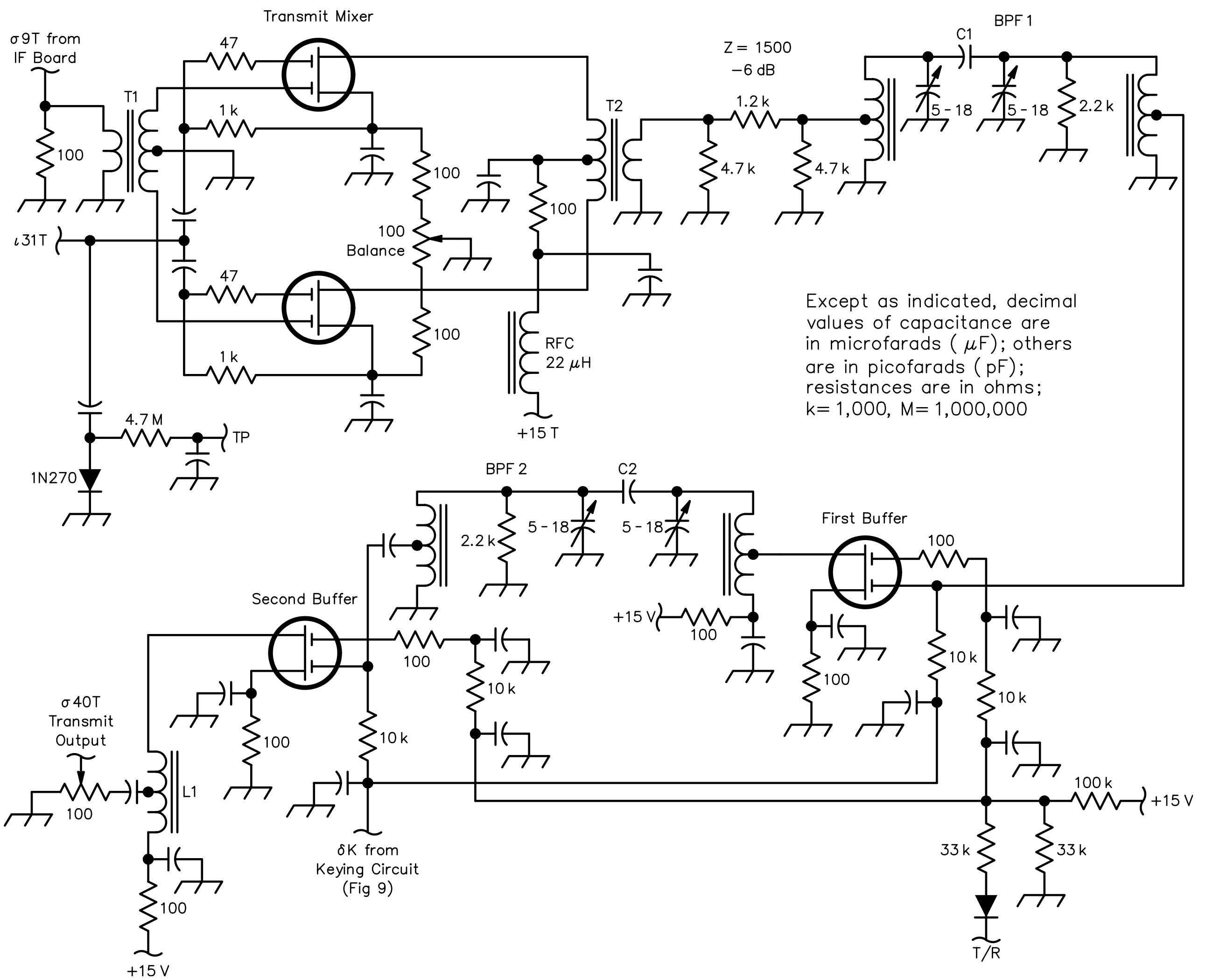


Fig 8—Transmit-mixer schematic diagram. For general notes on the schematics, refer to the caption for Fig 3.

BPF1-BPF2—Band-pass filter, bandwidth 2 MHz, center 39.5 MHz. Inductors, 1 µH, T-37-6 powdered-iron toroidal core, 18 turns, center-tapped.
C1, C2—Nominally 0.5 pF; adjust for desired passband with sweep generator. Homebrew fractional-pF piston trimmer capacitor; cover a 1-inch piece of #16 bare wire with teflon-sleeving, then wrap #24 bare wire completely over a 1/2-inch range of the teflon. Adjust by sliding the teflon, with wrapping, partially off the larger wire.
L1—FT-37-61 ferrite toroidal core, 11 turns, tap 2 turns from ground end.
T1—FT-37-43 ferrite toroidal core, 6 trifilar turns.
T2—FT-37-61 ferrite toroidal core, 6 trifilar turns.

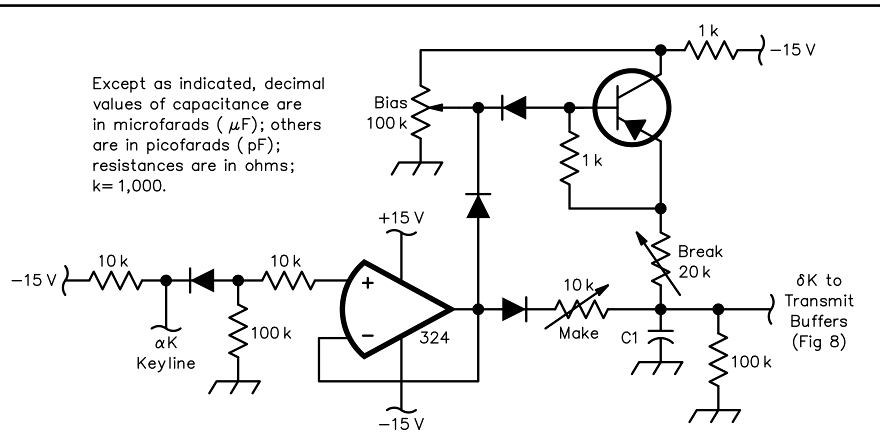


Fig 9—Keying-circuit schematic diagram. For general notes on the schematics, refer to the caption for Fig 3. The bias trimpot sets the cutoff bias. When the key is closed, the transistor is turned off and the Break trimpot has no effect; the Make trimpot determines the rise time. When the keyline is open, the Make trimpot has no effect and the transistor is turned on; the Break trimpot determines the decay time. The voltage-follower op amp isolates the timing circuit from external influences.
C1—Low-loss timing capacitor, 0.47 µF. Panasonic P-series polypropylene, #ECQ-P1H474GZ. Digi-Key #P3474 (see Reference 8).

noise off the main 40-MHz line with no significant loading of the main receiver circuits. With no input matching, the preamplifier has only moderate gain; it serves mainly as a buffer. The noise mixer is a simple MOSFET, which is adequate for this task. The LO injection power is provided by a free-running oscillator tuned by a varactor diode with a front-panel control. The total range is about 2 MHz, providing considerable over-range. The 1 MHz

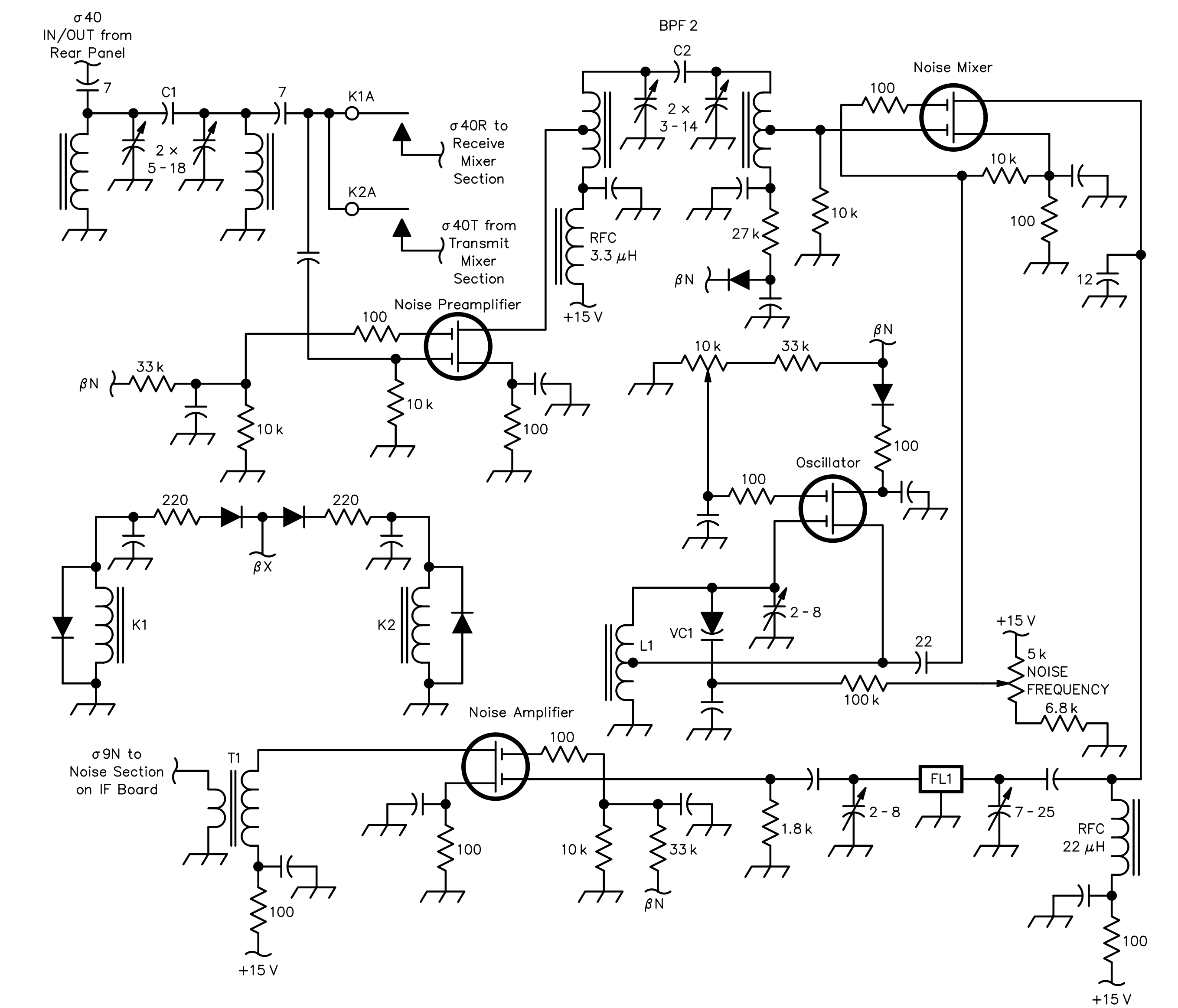


Fig 10—Tunable noise-channel schematic diagram. For general notes on the schematics, refer to the caption for Fig 3. This diagram includes the main 40-MHz band-pass filter and the TR relays. Reed relays are used to allow high-speed, break-in CW (QSK) operation.

The βN control line is provided by the Logic board. It switches from –15 to +15 V when the blanker is turned on. The control line is used here in three different ways. Most conveniently, for the noise-channel preamp and the noise-channel post-mixer amp, it controls the MOSFETs by means of gate 2. For the noise mixer, a diode is added; this simulates a µ-type control line and controls the MOSFET using gate 1. The βN line is also used to directly power the noise channel's local oscillator. Later designs avoid µ-type control lines and use only β-type control lines. This simplifies the logic board circuit; only a diode is needed for a β-type control line to simulate an µ-type line. The βX line switches from –15 V in receive mode to +15 V in transmit. Thus it powers one or the other of the TR reed relays.

BPF1—Main band-pass filter, center 39.5 MHz, bandwidth 1.4 MHz. Inductors, 800 nH, T-37-6 powdered-iron toroidal core, 15 turns.
BPF2—Noise band-pass filter, center 39.5 MHz, bandwidth 2 MHz. Inductors, 1.2 µH, T-37-6 powdered-iron toroidal core, 19 turns, center-tapped.
C1, C2—Same as C1 and C2 in Fig 8.
FL1—Crystal filter, 25-kHz bandwidth, four-pole. This filter was salvaged from an irreparable CX7; it has an impedance of 3200 Ω.
K1, K2—Miniature reed relay, SPST, NO, 12 V dc coil, 1450 Ω, 8 mA; Gordos #0490-1478DZ; Hosfelt #45-191 (see Reference 11); Jones #3806-RL (see Reference 15).
L1—Noise local-oscillator coil, 1.8 µH, T-50-6 powdered-iron toroidal core, 21 turns, tapped 5 turns from the ground end.
T1—FT-37-43 ferrite toroidal core. Primary, 11 turns; secondary, 2 turns wound on low end of primary.
VC1—Varactor diode, nominal 6.8 pF. Motorola type MV2101; NTE type 610 (see Reference 11).

desired range is conveniently obtained over the upper 180° swing of the panel knob. Drift problems were anticipated with this free-running circuit, but in seven years of operating, this has not been a problem. The diode typically covers a range of 4 to 14 pF when reverse biased from 15 to 0.1 V. Less range is actually required here, and the panel control is wired accordingly. This prevents conduction in the varactor diode, which might otherwise result from the RF voltage in the tank circuit. The mixer output at 9 MHz is filtered by a two-pole crystal filter and amplified by a MOSFET, with the output going to the noise amplifier on the IF board.

Construction

The RF board is shown in Fig 1. The general method of construction was described in Part 1, where the need for careful shielding and lead filtering was discussed. Part 2 gave further construction details, most of which also apply to the RF board. The power and control leads are filtered as described in Part 2, except for the π-section filters in the power and control lines feeding the circuits operating above 30 MHz. Those instead consist of two 1-nF bypass capacitors and a 100-μH RFC. The board's underside is shown in Fig 11.

Some of the circuits are built on perfboards: some with no solder pads, some with pads and some with a ground plane on the underside. These were all poor choices for RF circuits. Plain copper board and true dead-bug construction—as used in the noise channel and later in the IF board (Part 2)—is much better. In addition, the LO amplifier should be in a separate compartment. All these circuits are scheduled for rebuilding.

Test and Alignment

The BFO trimpots in the IFS circuit are adjusted in the transmit mode for 8816.5 kHz in USB and 8813.5 kHz in LSB. This assumes selection of first-rate, prime-condition SSB crystal filters with the correct passband of 8814-8816 kHz. The USB and LSB BFO-buffer-level trimpots are adjusted to obtain –16 dBm at the IF port of the BFO mixer. The trimpot at the BFO section output (terminal φ9A leading to the AF board) is adjusted for 100 mV P-P output. The BFO voltage on this line is kept low to minimize leakage into the IF strip and elsewhere. A BFO amplifier on the AF board provides the proper LO injection levels for the product detector and balanced modulator.

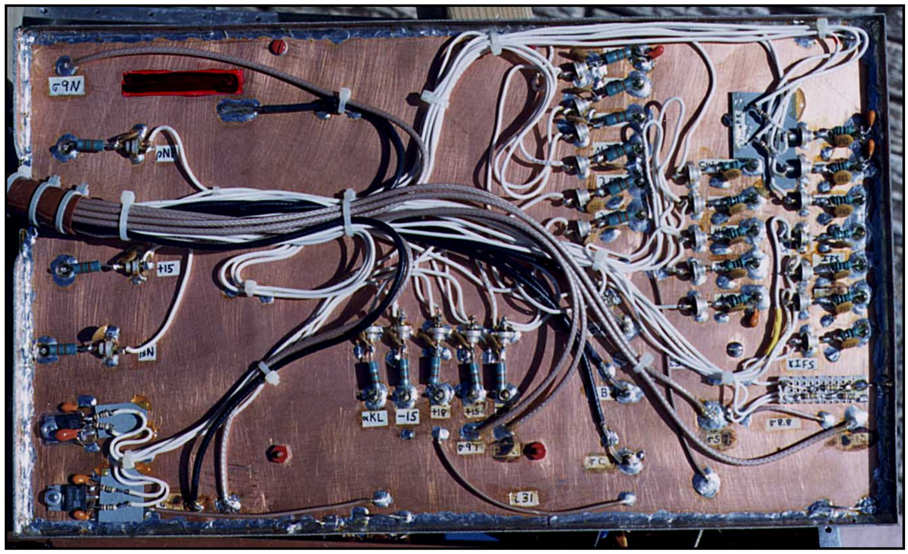


Fig 11—Bottom view of the RF board. Effective filters are installed at each terminal and coax cables are soldered directly to the double-sided circuit board; see the discussion in Part 2. To minimize connector troubles, the board is hard-wired to the radio; a 12-inch-long bundle of wires and cables allows the board to be easily lifted and serviced.

The master oscillator is adjusted for 43.1 MHz. The offset oscillator is adjusted for a range of 34.2835 MHz (for 0 Hz offset) to 34.2825 MHz (for 1000-Hz offset). The PTO trimpots are adjusted to provide –16 dBm at the IF port of the PTO mixer. Injection to both the BFO and PTO mixers at the LO ports is about +4 dBm. Although the doubly balanced mixers (DBMs) are +7 dBm devices, the lower LO power results in only about 1 dB more conversion loss. This lower LO power is in accordance with the manufacturer's suggestions for situations where dynamic range is not a factor.[7] Lessened LO power reduces harmonic mixing and decreases stray LO power in the system.

For convenience, RF probes that measure LO injection level at the main mixers are permanently built into the circuits. This enhances the repeatability of measurements, difficult to achieve with external RF probes and their questionable grounding leads. The proper dc voltages at the receive- and transmit-mixer LO test points are 1.1 and 1.4 V, respectively (on a 10 MΩ meter). The two trimpots at the LO-amplifier output compensate for the different impedances of the two mixers and for circuit reactance; one trimpot is kept at maximum. The **GAIN ADJUST** trimpot in the LO amplifier is set as required to obtain the specified injection levels.

The RF-board receiving circuits operate at a gain of 15 dB, overall, between terminal σ40 (the rear-panel 40-MHz jack) and terminal σ9R, which leads to the IF board. The mixer drain-circuit tuning capacitor is peaked on a weak signal. The input to the transmit mixer at terminal σ9T is adjusted for 200 mV P-P using trimpots on the IF board. The transmit mixer's balance trimpot is adjusted to minimize LO energy at the output. The trimpot at the output of the transmit-mixer section is set to obtain –7 dBm at the 40-MHz jack on the rear panel of the radio. Other alignment specifications are included above in the discussions of the individual circuits.

Summary

This article gives a complete description of the RF board in a high-performance homebrew transceiver. The board establishes the 40 MHz to 9 MHz transitions.

References

[1] M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 1," *QEX*, Mar/Apr 1999, pp 16-24.

[2] M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 2," *QEX*, Sep/Oct 1999, pp 3-8.

[3] A long-term temperature-compensation program was carried out over a six-month period while work continued on the next board in the radio. A garage workshop, quite cold on winter mornings, provided daily temperature cycling.

[4] E. Oxner, KB6QJ, "Designing FET Balanced Mixers for High Dynamic Range," Application Note LPD-14, pages 9-114 to 9-145 in the Low Power Discretes Data Book, 1989, Siliconix Incorporated, 2201 Laurelwood Rd, Santa Clara, CA 95054-1516; tel 408-988-8000, fax 408-727-5414; **www.siliconix.com**.

A High-Performance Homebrew Transceiver: Part 3 (Nov/Dec 1999) and A High-Performance AGC System for Homebrew Transceivers (Oct 1995)

Doug,

Here are a few corrections to Part 3 of my 1999 article series: At the upper right of Fig 3, the trimpot label "IF SHIFT" should be deleted. At the lower left, the USB IFS transistor should be inverted (emitter should connect to the diode and collector to the trimpot). At the right in Fig 8, there should be a blocking capacitor between the output of BPF1 and the first buffer. At the upper left of Fig 10, the network surrounding C1 (near the σ40 terminal) should be labeled BPF1.

In my 1995 article, at lower right of Fig 5, the lower meter should be labeled "M2—SQUELCH/CLIPPING" and M1 should be labeled "SIGNAL/ ALC." Unfortunately, the M1-M2 meter labels in the 1999 article series are reversed from those in this earlier article. There are several corrections to Fig 7: To the right of U202's output, the unlabeled terminal should be labeled "Va—to S-Meter Section," and the unlabeled resistor should be 100 k. At the lower left, U204 should have a dot at the output—this specifies an LM339 (see the caption of Fig 6). At the upper left, the IN and OUT terminal labels of the 7815 are reversed. I hope these have caused no inconvenience for readers. Thanks to Paul Bardell, N2OTD, for pointing out the errors in the AGC article.—*Mark Mandelkern, K5AM,* **k5am@zianet.com**; **k5am@arrl.net**. □□

Letters to the Editor

A High-Performance Homebrew Transceiver, Corrections and Improvements

In Part 3 (Nov/Dec 1999), on page 50, I suggested running the +7 dBm mixers with only +4 dBm of LO injection. This idea came from the manufacturer's manual in regard to operation "where dynamic range is not important." I had thought, since these were merely LO premixers handling no receive or transmit signals, that dynamic range was not a factor. However, even in this case there are spurious mixer products, which can be reduced using the higher LO level. IMD in the PTO mixer is of particular concern when the dual-receive function is enabled, when two input frequencies are applied. I have raised the levels in both the BFO and PTO mixers to +7 dBm, with a noticeable improvement. The modification required an additional MAV-1 amplifier ahead of the MAV-11 in Fig 5 for the PTO mixer. The LO level for this mixer is now adjusted by a gimmick capacitor used in place of the 1 pF coupling capacitor in the 34.285 MHz filter shown in Fig 4. (This is a very sharp, single-frequency filter using under-coupled resonators; the capacitor consists merely of a short, heavy wire connected to one coil, and positioned near the other coil.) For the BFO mixer in Fig 4, it was sufficient to adjust the resistor between the MO and the MAV-11. Further improvement in mixer performance is clearly possible; see Chapter 6 in Wes Hayward, W7ZOI's, *Introduction to Radio Frequency Design*.[1]

The bias resistor for each MAV-11 was reduced to 270 Ω. I also found that the RFCs in the supply leads to the MMICs could be eliminated with little change in gain and a probable reduction in any tendency to parasitics or stray radiation. In Part 4 (Jan/Feb 2000), on page 48, I explained that the 47 Ω resistors in the LO lines to the product detector (Fig 4) and balanced modulator (Fig 9) were included to enable measurement of LO power. This was a bad idea; it increases the required LO power, worsens the spurs caused by stray LO energy, and still does not provide an accurate measurement. The usual practice is to disconnect the LO from the doubly balanced mixer (DBM), connect a 51 Ω resistor from the LO amplifier output to ground and measure the level with a scope. The trimpots previously used to adjust LO levels have been eliminated; the levels are now adjusted by selecting components in the BFO amplifier (Fig 3). Thanks to George Cutsogeorge, W2VJN, for all these corrections and suggestions concerning DBM operation.

Some builders may have difficulty locating surplus Signal/One crystal filters for the IF board at 8815 kHz. Those found at flea markets are up to 30 years old and of questionable quality. (I was lucky to find a few good filters in a large junk-box supply.) An easy substitute would be new filters from International Radio, 13620 Tyee Rd, Umpqua, OR 97486; tel 541-459-5623, fax 541 459 5632; e-mail **INRAD@rosenet.net**; **www.qth.com/inrad/**. The IR filters designed for Kenwood radios at 8830 kHz would work splendidly. The filter matching circuits will need a slight change, the two BFO crystals will need replacing, and the 25-kHz-bandwidth noise-blanker filter will need to be homebrewed. No other circuits in the radio will require modification. The reason for this flexibility is the premixing scheme (described in Part 1, Mar/Apr 1999) in which the tunable BFO is used to obtain IF-shift operation, but is not a factor in determining the transceiver frequency.

Another correction applies to the frequency counter in Part 5 (Mar/Apr 2000). In the caption to Fig 13, I twice referred to an IC as type 7473; it should say 7493. Thanks to Ulf Edlund, SM3CUX, for pointing out this error.—*Mark Mandelkern, K5AM, 5259 Singer Rd, Las Cruces, NM 88005;* **k5am@zianet.com**.

[1]Order No 4920, $30. ARRL publications are available from your local ARRL dealer or directly from the ARRL. Check out the full ARRL publications line at **http://www.arrl.org/shop/**.

A Simple, Rapid and Precise Method of Finding True North Using GPS

GPS receivers have become ubiquitous in the ham-radio community because of their well-known abilities to provide exact location and altitude information. When used in conjunction with a simple plumb line, though, they also possess the ability to precisely and quickly provide the exact direction of true north at any location during day-