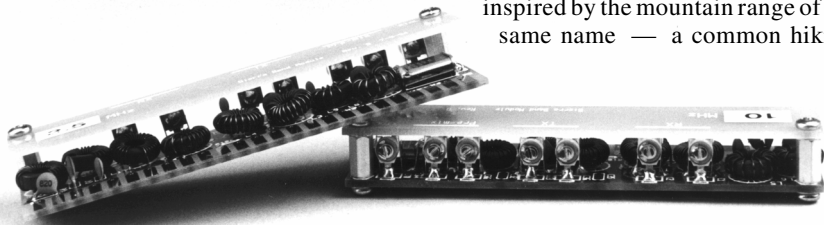


Fig 15.8 — The Sierra transceiver. One band module is plugged into the center of the main PC board; the remaining boards are shown below the rig. Quick-release latches on the top cover of the enclosure make it easy to change bands.



THE NORCAL SIERRA: AN 80-15 M CW TRANSCEIVER

Most home-built QRP transceivers cover a single band, for good reason: complexity of the circuit and physical layout can increase dramatically when two or more bands are covered. This holds for most approaches to multiband design, including the use of multipole switches, transverters and various forms of electronic switching.¹

If the designer is willing to give up instant band switching, then plug-in band modules can be used. Band modules are especially appropriate for a transceiver that will be used for extended portable operation, for example: back-packing. The reduced circuit complexity improves reliability, and the extra time it takes to change bands usually isn't a problem. Also, the operator need take only the modules needed for a particular outing.

The Sierra transceiver shown in **Fig 15.8** uses this technique, providing coverage of all bands from 80 through 15 m with good performance and relative simplicity.² The name Sierra was inspired by the mountain range of the same name — a common hiking

destination for West Coast QRPers. The transceiver was designed and built by Wayne Burdick, N6KR, and field tested by members of NorCal, the Northern California QRP Club.³

FEATURES

One of the most important features of the Sierra for the portable QRP operator is its low current drain. Because it has no relays, switching diodes or other active band-switching circuitry, the Sierra draws only 30 mA on receive.⁴ Another asset for field operation is the Sierra’s low-frequency VFO and premixing scheme, which provides 150 kHz of coverage and good frequency stability on all bands.

The receiver is a single-conversion superhet with audio-derived AGC and RIT. It has excellent sensitivity and selectivity, and will comfortably drive a speaker. Transmit features include full break-in keying, shaped keying and power output averaging 2 W, with direct monitoring of the transmitted signal in lieu of sidetone. Optional circuitry allows monitoring of relative power output and received signal strength.

Table 15.1
Crystal Oscillator and Premix (PMO) Frequencies in MHz

The premer (U7) subtracts the VFO (2.935 to 3.085 MHz) from the crystal oscillator to obtain the PMO range shown. The receive mixer (U2) subtracts the RF input from the PMO signal, yielding 4.915 MHz. The transmit mixer (U8) subtracts 4.915 MHz from the PMO signal to produce an output in the RF range.

RF Range	Crystal Oscillator	PMO Range
3.500-3.650	11.500	8.415-8.565
7.000-7.150	15.000	11.915-12.065
10.000-10.150	18.000	14.915-15.065
14.000-14.150	22.000	18.915-19.065
18.000-18.150	26.000	22.915-23.065
21.000-21.150	29.000	25.915-26.065

Physically, the Sierra is quite compact — the enclosure is 2.7 × 6.2 × 5.3 inches (HWD) — yet there is a large amount of unused space both inside and on the front and rear panels. This results from the use of PC board-mounted controls and connectors. The top cover is secured by quick-release plastic latches, which provide easy access to the inside of the en-

sure. Band changes take only a few seconds.

CIRCUIT DESCRIPTION

Fig 15.9 is a block diagram of the Sierra. The diagram shows specific signal frequencies for operation on 40 m. Table 15.1 provides a summary of crystal oscillator and premix frequencies for all bands.

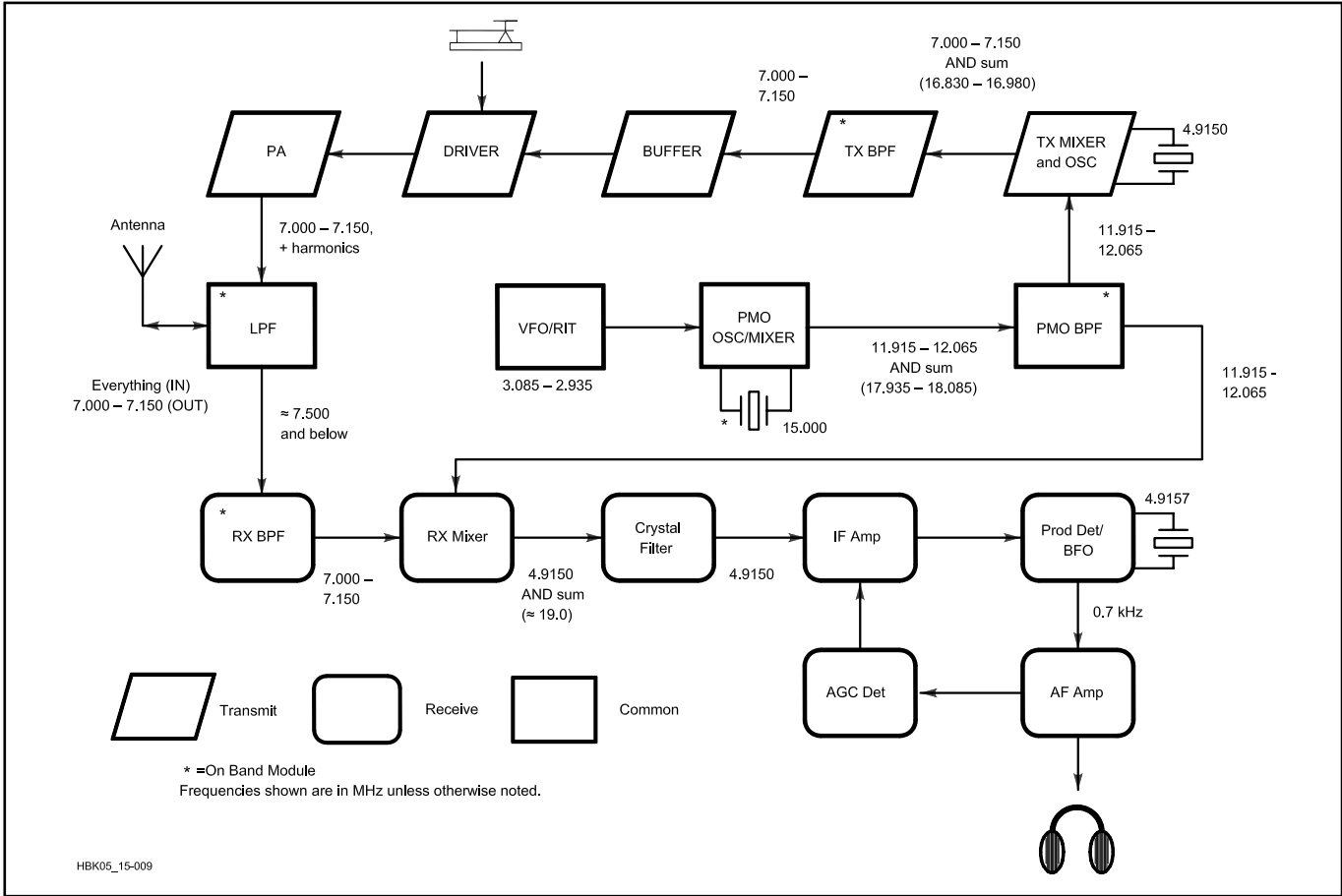


Fig 15.9 — Block diagram of the Sierra transceiver. Three different-shaped symbols are used to show transmit, receive and common blocks. Those blocks with an asterisk (*) are part of the band module. Signal frequencies shown are for 40 m; see Table 15.1 for a list of crystal oscillator and premix frequencies for all bands.

Table 15.2**Band Module Components**

All crystals are fundamental, 15-pF load capacitance, 0.005% frequency tolerance, in HC-49 holders. Fixed capacitors over 5 pF are 5% tolerance. All coils are wound with enameled wire.

Part	Band					
	80 m	40 m	30 m	20 m	17 m	15 m
C32, C35	33 pF, 5%	47 pF, 5%	not used	not used	not used	not used
C34	5 pF, 5%	5 pF, 5%	2 pF, 5%	2 pF, 5%	2 pF, 5%	2 pF, 5%
C47, C49	820 pF, 5%	330 pF, 5%	330 pF, 5%	220 pF, 5%	150 pF, 5%	150 pF, 5%
C48	1800 pF, 5%	820 pF, 5%	560 pF, 5%	470 pF, 5%	330 pF, 5%	330 pF, 5%
C65	5 pF, 5%	5 pF, 5%	2 pF, 5%	1 pF, 5%	1 pF, 5%	1 pF, 5%
L1	50 μ H, 30 t #28 on FT-37-61	14 μ H, 16 t #26 on FT-37-61	5.2 μ H, 36 t #28 on T-37-2	2.9 μ H, 27 t #28 on T-37-2	1.7 μ H, 24 t #28 on T-37-6	1.9 μ H, 25 t #28 on T-37-6
L3, L4	32 μ H, 24 t #26 on FT-37-61	5.2 μ H, 36 t #28 on T-37-2	4.4 μ H, 33 t #28 on T-37-2	2.9 μ H, 27 t #28 on T-37-2	1.7 μ H, 24 t #28 on T-37-6	1.9 μ H, 25 t #28 on T-37-6
L5, L6	2.1 μ H, 23 t #26 on T-37-2	1.3 μ H, 18 t #26 on T-37-2	1.0 μ H, 16 t #26 on T-37-2	0.58 μ H, 12 t #26 on T-37-2	0.43 μ H, 12 t #26 on T-37-6	0.36 μ H, 11 t #26 on T-37-6
L8, L9	8.0 μ H, 12 t #26 on FT-37-61	2.5 μ H, 25 t #28 on T-37-2	1.6 μ H, 20 t #28 on T-37-2	1.3 μ H, 18 t #26 on T-37-2	0.97 μ H, 18 t #26 on T-37-6	0.87 μ H, 17 t #28 on T-37-6
T1 (Sec same as L1)	Pri: 2 t #26 on FT-37-61	Pri: 1 t #26 on FT-37-61	Pri: 3 t #26 on T-37-2	Pri: 2 t #26 on T-37-2	Pri: 2 t #26 on T-37-6	Pri: 2 t #26 on T-37-6
X8	11.500 MHz (ICM 434162)	15.000 MHz (ICM 434162)	18.000 MHz (ICM 434162)	22.000 MHz (ICM 435162)	26.000 MHz (ICM 436162)	29.000 MHz (ICM 436162)

The schematic is shown in **Fig 15.10**. See **Table 15.2** for band-module component values.

On all bands, the VFO range is 2.935 MHz to 3.085 MHz. The VFO tunes “backwards”: At the low end of each band, the VFO frequency is 3.085 MHz. U7 is the pre-mixer and crystal oscillator, while Q8 buffers the pre-mix signal prior to injection into the receive mixer (U2) and transmit mixer (U8).

A low-pass filter, three band-pass filters and a pre-mix crystal make up each band module. To make the schematic easier to follow, this circuitry is integrated into Fig 15.10, rather than drawn separately. J5 is the band module connector (see the note on the schematic).

The receive mixer is an NE602, which draws only 2.5 mA and requires only about 0.6 V (P-P) of oscillator injection at pin 6. An L network is used to match the receive mixer to the first crystal filter (X1-X4). This filter has a bandwidth of less than 400 Hz. The single-crystal second filter (X5) removes some of the noise generated by the IF amplifier (U7), a technique W7ZOI described.⁵ This second filter also introduces enough loss to prevent the IF amplifier from overdriving the product detector (U4).

The output of the AF amplifier (U3) is dc-coupled to the AGC detector. U3's output floats at $V_{cc}/2$, about 4 V, which happens to be the appropriate no-signal

AGC voltage for the IF amplifier when it is operated at 8 V. C26, R5, R6, C76 and R7 provide AGC loop filtering. Like all audio-derived AGC schemes, this circuit suffers from pops or clicks at times.

Transmit signal monitoring is achieved by means of a separate 4.915 MHz oscillator for the transmitter; the difference between this oscillator and the BFO determines the AF pitch. Keying is exponentially shaped, with the rise time set by the turn-on delay of transmit mixer U8 and the fall time determined by C51, in the emitter of driver Q6.

CONSTRUCTION

The Sierra's physical layout and packaging make it relatively easy to build and align, although this isn't a project for the first-time builder. The boards and custom enclosure described here are included as part of an available kit.⁶ Alternative construction methods are discussed below.

With the exception of the components on the band module, all of the circuitry for the Sierra is mounted on a single 5 × 6 inch PC board. This board contains not only the components, but all of the controls and connectors as well. The board is double-sided with plated-through holes, which permits flexible arrangement of the circuitry while eliminating nearly all hand-wiring. The only two jumpers on the board, W1 and W2, are short coaxial cables between the RF GAIN control and

the receiver input filters.

A dual-row edge connector (J5) provides the interface between the main board and the band module. The 50 pins of J5 are used in pairs, so there are actually only 25 circuits (over half of which are ground connections).

The band module boards are 1.25 × 4 inches (HW). They, too, are double-sided, maximizing the amount of ground plane. Because the band modules might be inserted and removed hundreds of times over the life of the rig, the etched fingers that mate with J5 are gold-plated. Each etched finger on the front is connected to the corresponding finger on the back by a plated through hole, which greatly improves reliability over that of a single finger contact.

Each band module requires eight toroids: two for the low-pass filter, and two each for the receive, transmit and pre-mix band-pass filters. The builder can secure the toroids to the band module with silicone adhesive or Q-dope. Right-angle-mount trimmer capacitors allow alignment from above the module. Each band module has a top cover made of PC board material. The cover protects the components during insertion, removal and storage.

The VFO capacitor is a 5-40 pF unit with a built-in 8:1 vernier drive. The operating frequency is read from a custom dial fabricated from 0.060-inch Lexan. The dial mounts on a hub that comes with the capacitor.

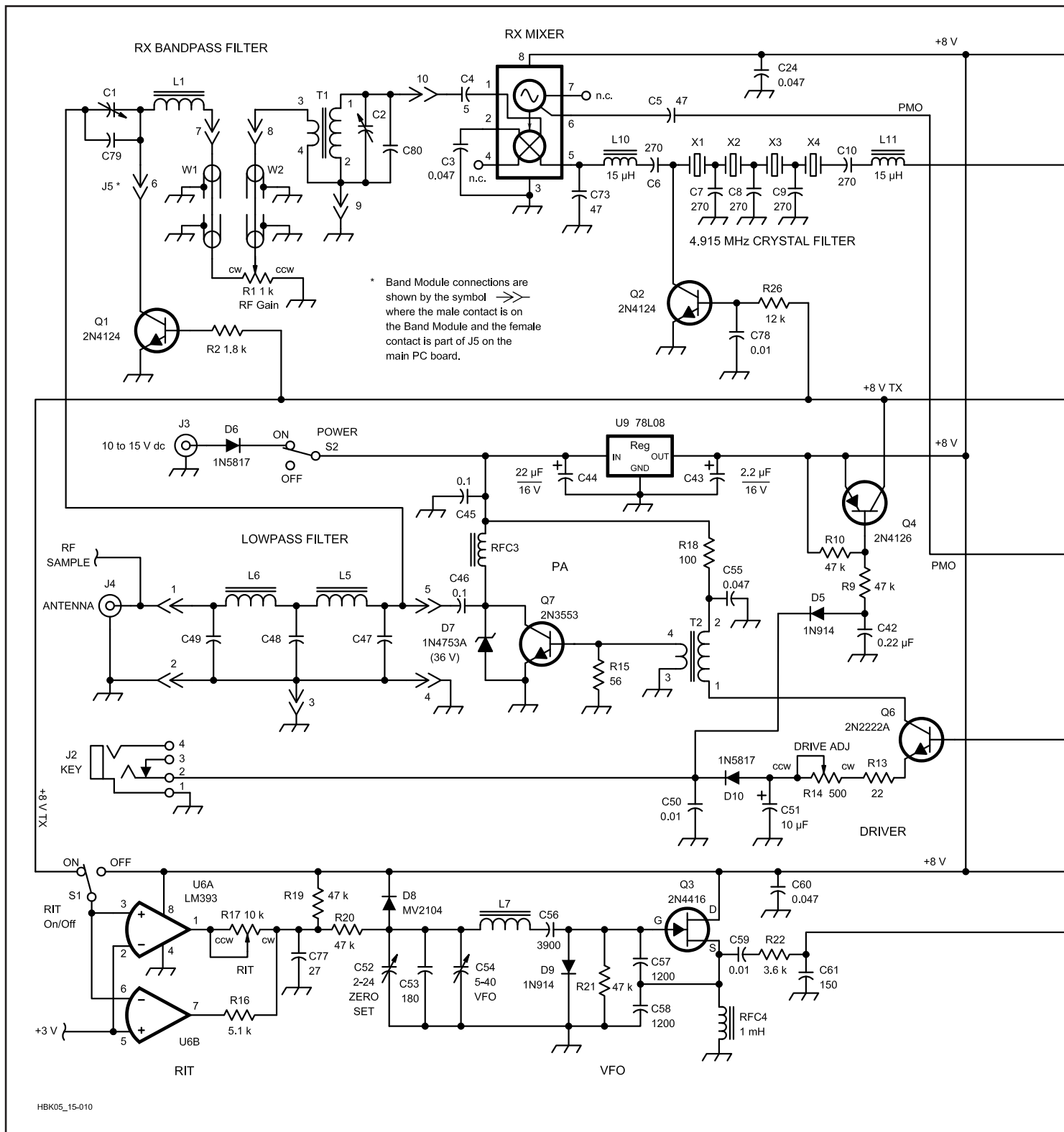
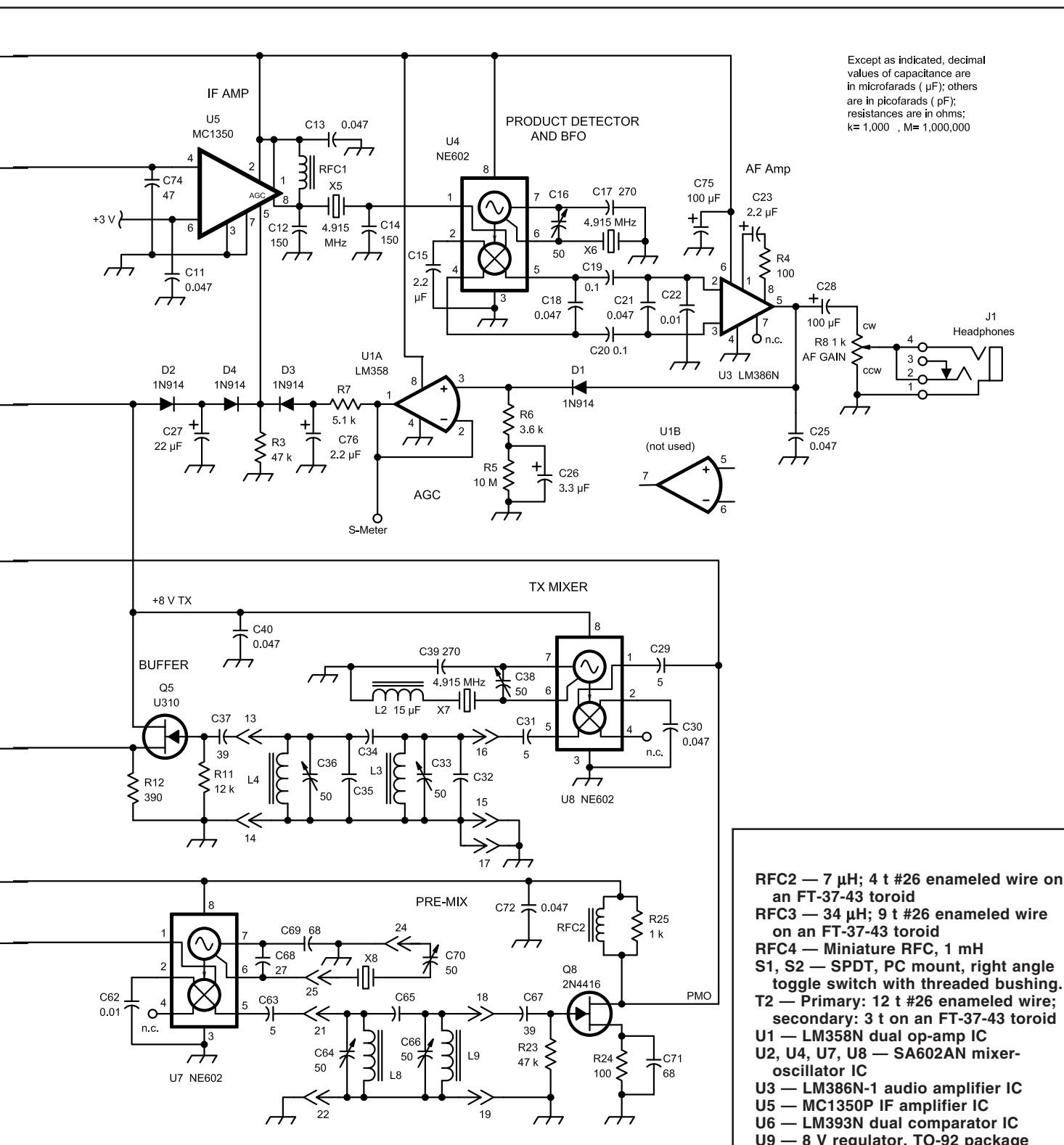


Fig 15.10 — Schematic of the Sierra transceiver. Parts that change for each band are shown in Table 15.2. See the Templates Section on the ARRL Handbook CD-ROM for more information on parts for this project.

C1, C2, C33, C36, C64, C66, C70 — 9-50 pF right-angle-mount ceramic trimmer (same for all band modules)
 C16, C38 — Ceramic trimmer, 8-50 pF
 C52 — Air variable, 2-24 pF
 C53 — Disc, 180 pF, 5%, NP0

C54 — 5-40 pF air variable with 8:1 vernier drive
 C56 — Polystyrene, 3900 pF, 5%
 C57, C58 — Polystyrene, 1200 pF, 5%
 D6, D10 — 1N5817, 1N5819 or similar
 D7 — 36 V, 1 W Zener diode (1N4753A)

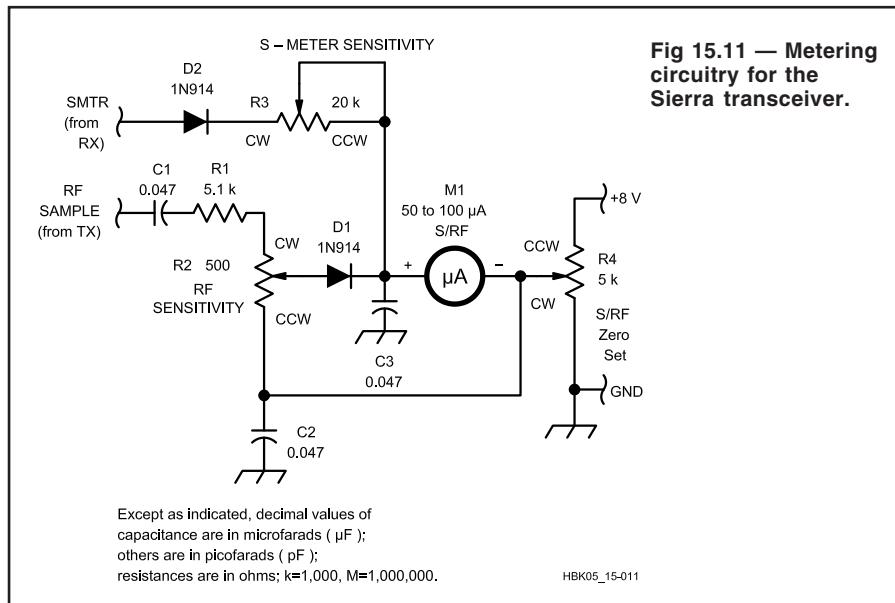
D8 — MV2104 varactor diode, or equivalent
 J1, J2 — PC-mount 3.5-mm stereo jack with switch
 J3 — 2.1-mm dc power jack
 J4 — PC-mount BNC jack



J5 — 50 pin, dual-row edgeboard connector with 0.156-inch spacing
L10, L11 — 18 μ H; 18 t #28 enameled wire on an FT-37-61 toroid
L2 — Miniature RFC, 15 μ H
L7 — 19 μ H; 58 t #28 enameled wire on a T-68-7 toroid

Q5 — U310, J310, 2N4416 or other
high-transconductance device
R1, R8 — PC-mount 1-k Ω pot
R14, R101 — 500 Ω trimmer
R17 — PC-mount 10-k Ω pot
RFC1 — 3.5 μ H; 8 t #26 enameled wire
on an FT-37-61 toroid

RFC2 — 7 μ H; 4 t #26 enameled wire on an FT-37-43 toroid
RFC3 — 34 μ H; 9 t #26 enameled wire on an FT-37-43 toroid
RFC4 — Miniature RFC, 1 mH
S1, S2 — SPDT, PC mount, right angle toggle switch with threaded bushing.
T2 — Primary: 12 t #26 enameled wire; secondary: 3 t on an FT-37-43 toroid
U1 — LM358N dual op-amp IC
U2, U4, U7, U8 — SA602AN mixer-oscillator IC
U3 — LM386N-1 audio amplifier IC
U5 — MC1350P IF amplifier IC
U6 — LM393N dual comparator IC
U9 — 8 V regulator, TO-92 package
W1, W2 — RG-174 coaxial jumper, about 3 inches long (see text)
X1-X7 — 4.915 MHz, HC-49. X1 through X5 should be matched (their series-resonant frequencies within 50 Hz)



The Sierra's custom 0.060-inch aluminum enclosure offers several benefits in both construction and operation. Its top and bottom covers are identical U-shaped pieces. The bottom is secured to the main board by two 0.375-inch standoffs, while the top is secured to the bottom by two long-life, quick-release plastic latches. As a result, the builder can easily remove both covers to make "live" adjustments or signal measurements without removing any controls, connectors or wires. The front and rear panels attach directly to the controls and connectors on the main board. This keeps the panels rigid and properly oriented.

As can be seen in the photograph, the interior of the rig is uncluttered. NorCal QRP Club members have taken advantage of this, building in keyers, frequency counters and other accessories — and even storing up to four band modules in the top cover. One popular addition is an S/R/F meter, the circuit shown in **Fig 15.11**.

The construction techniques described above represent only one way to build the Sierra; other physical layouts may better suit your needs. For example: If no built-ins are needed, the rig could be built in a smaller enclosure. You could replace the VFO capacitor with a small 10-turn pot and a varactor diode. If necessary, eliminate RIT and metering.

If a different physical layout is required, determine the orientation and mounts for the band module connector first, and then arrange the various circuit blocks around it. Use short leads and good ground-plane techniques to avoid instability, especially on the band modules. Point-to-point or

"dead-bug" construction are possible, but in some cases shields and additional decoupling may be required. Use a reliable connector if band modules will be repeatedly inserted and removed.

ALIGNMENT

The minimum recommended equipment for aligning the rig is a DMM with home-made RF probe and a ham-band transceiver. Better still is a general-coverage receiver or frequency counter.⁷ Start with a 40- or 20-m module; these are usually the easiest to align.

First, set the VFO to the desired band edge by adjusting C52. If exactly 150 kHz of range is desired, squeeze or spread the windings of L7 and readjust C52 iteratively until this range is obtained. RIT operation can also be checked at this time. Reduce the value of R19 if more RIT range is desired.

Prepare each band module for alignment by setting all of its trim caps to midrange. (The final settings will be close to mid-point in most cases.)

Receiver alignment is straightforward. Set BFO trimmer C16 to midrange, RF GAIN (R1) to maximum and AF GAIN (R8) so that noise can be heard on the phones or speaker. On the band module, peak the premix trimmers (C64 and C66) for maximum signal level measured at Q8's drain. Set the fine frequency adjustment (C70) by lightly coupling a frequency counter to U7, pin 7. Next, connect an antenna to J4 and adjust the receiver filter trimmers (C1 and C2) for maximum signal. The AGC circuitry normally requires no adjustment, but the no-signal

gain of the IF amplifier can be increased by decreasing the value of R3.

Before beginning transmitter alignment, set the drive-level control, R14, to minimum. Key the rig while monitoring the transmitted signal on a separate receiver and peak the transmit band-pass filter using C33 and C36. Then, with a dummy load or well-matched antenna connected to J4, set R14 to about 90% of maximum and check the output power level. It may be necessary to stagger-tune C33 and C36 on the lower bands in order to obtain constant output power across the desired tuning range. On 80 m the -3 dB transmit bandwidth will probably be less than 150 kHz.

Typically, output on 80, 40 and 20 m is 2.0-2.5 W, and on the higher bands 1.0-2.0 W. Some builders have obtained higher outputs on all bands by modifying the band-pass filters. However, filter modification may compromise spectral purity of the output, so the results should be checked with a spectrum analyzer. Also, note that the Sierra was designed to be a 2-W rig; additional RF shielding and decoupling may be required if the rig is operated at higher power levels.

PERFORMANCE

The Sierra design uses a carefully selected set of compromises to keep complexity low and battery life long. An example is the use of NE602 mixers, which affects both receive and transmit performance. On receive, the RF gain will occasionally need reduction when strong signals overload the receive mixer. On transmit, ARRL Lab tests show that the rig complies with FCC regulations for its power and frequency ranges.

Aside from the weak receive mixer, receiver performance is very good. There are no spurious signals (birdies) audible on any band. ARRL Lab tests show that the Sierra's receiver has a typical MDS of about -139 dBm, blocking dynamic range of up to 112 dB and two-tone dynamic range of up to 90 dB. AGC range is about 70 dB.

The Sierra's transmitter offers smooth break-in keying, along with direct transmit signal monitoring. There are two benefits to direct monitoring:

- the clean sinusoidal tone is easier on the ears than most sidetone oscillators and
- the pitch of the monitor tone is the correct receive-signal pitch to listen for when calling other stations.

The TR mute delay capacitor, C27, can be reduced to as low as 4.7 µF to provide faster break-in keying if needed.

The prototype Sierra survived its chris-

tening at Field Day, 1994, where members of the Zuni Loop Expeditionary Force used it on 80, 40, 20 and 15 m. There, Sierra compared favorably to the Heath HW-9 and several older Ten-Tec rigs, having as good or better sensitivity and selectivity — and in most cases better-sounding sidetone and break-in keying. While the other rigs had higher output power, they couldn't touch the Sierra's small size, light weight and low power consumption. The Sierra has consistently received high marks from stations worked too, with reports of excellent keying and stability.

CONCLUSION

At the time this article was written, over 100 Sierras had been built. Many have been used extensively in the field, where the rig's unique features are an asset. For some builders, the Sierra has become the primary home station rig.

The success of the Sierra is due, in large

part, to the energy and enthusiasm of the members of NorCal, who helped test and refine early prototypes, procured parts for the field-test units and suggested future modifications.⁸ This project should serve as a model for other clubs who see a need for an entirely new kind of equipment, perhaps something that is not available commercially.

Notes

¹One of N6KR's previous designs, the Safari-4, is a good example of how complex a band-switched rig can get. See "The Safari-4...." Oct through Dec 1990 *QEX*.

²Band modules for 160, 12 and 10 m have also been built and are available for the kit (see note 6). PC board patterns, construction hints, alignment and troubleshooting tips, and other information about the Sierra is included in the Template Packages section of the CD-ROM bundled with this *Handbook*.

³For information about NorCal, visit www.norcalgrp.org.

⁴Most multiband rigs draw from 150 to 500 mA

on receive, necessitating the use of a larger battery. A discussion of battery life considerations can be found in "A Solar-Powered Field Day," May 1995 *QST*.

⁵*Solid-State Design*, p 87. This book is out of print but may be available used.

⁶Full and partial kits are available. The full kit comes with all components, controls, connectors, and a detailed assembly manual. Complete band modules kits are available for 80, 40, 30, 20, 17 and 15 m. For information, contact Wilderness Radio, PO Box 3422, Joplin, MO 64803, tel 417-782-1397; www.fix.net/~jparker/wilderness/sierra.htm.

⁷The alignment procedure given here is necessarily brief. More complete instructions are provided with the ARRL Template Package on the accompanying *Handbook CD* and the kit instructions.

⁸The author would like to acknowledge the contributions of several NorCal members: Doug Hendricks, KI6DS; Jim Cates, WA6GER; Bob Dyer, KD6VIO; Dave Meacham, W6EMD; Eric Swartz, WA6HHQ; Bob Warmke, W6CYX; Stan Cooper, K4DRD; Vic Black, AB6SO; and Bob Korte, KD6KYT.