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

[1]One 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*.

[2]Band 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*.

[3]For information about NorCal, visit **www.norcalqrp.org**.

[4]Most 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.

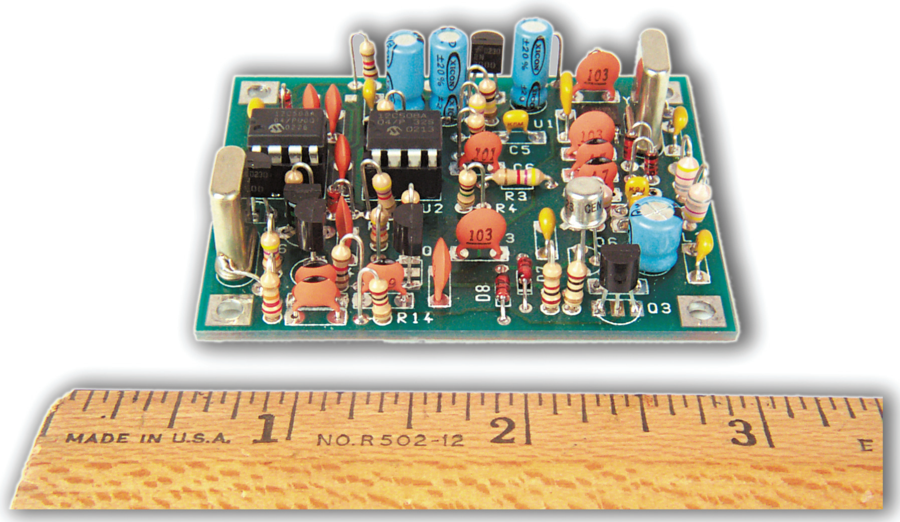
[6]Full and partial kits are available. The full kit comes with all components, controls, connectors, and a detailed assembly manual. Complete band modules kits are available for 80, 40, 30, 20, 17 and 15 m. For information, contact Wilderness Radio, PO Box 3422, Joplin, MO 64803, tel 417-782-1397; **www.fix.net/~jparker/wilderness/sierra.htm**.

[7]The 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.

[8]The 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.

THE ROCKMITE — A SIMPLE SINGLE-BAND CW TRANSCEIVER

Dave Benson, K1SWL, first described the simple 1/2 W RockMite CW transceiver for 40 or 20 meters in April 2003 *QST*. The *RockMite* — named for its crystal control and its small size — has attracted an enthusiastic following, with thousands of the transceivers in circulation. This project builds on the original and adds versions for 80 and 30 meters. Changing the RockMite frequency is a matter of replacing the two (identical) crystals with frequencies of your choosing. If you change bands, however, the output harmonic filter and several capacitor values must be scaled accordingly, and the value of several Zener diodes may change. Details are shown in **Table 15.3**.



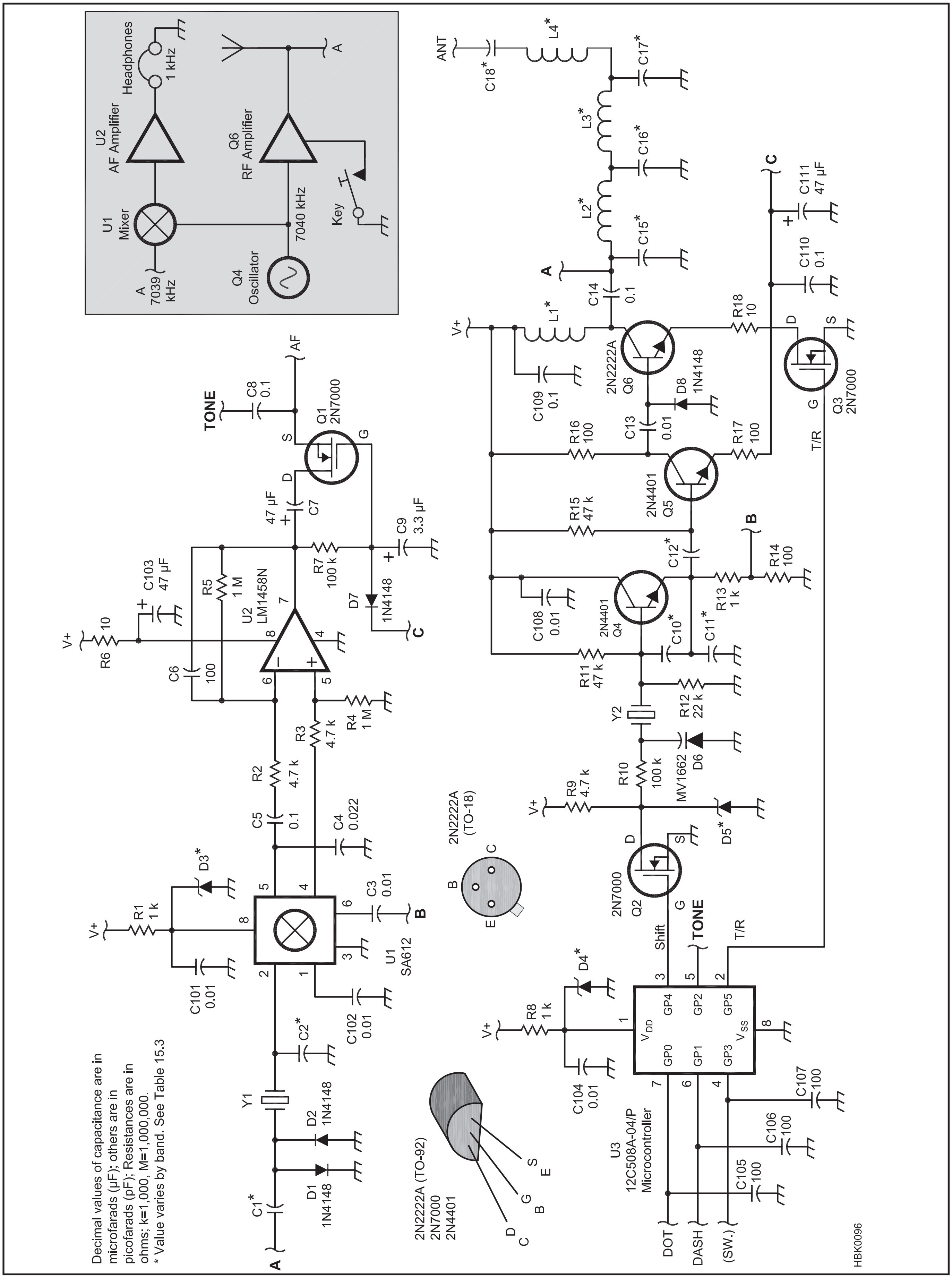
Overview

The RockMite printed-circuit board measures 2.0 × 2.5 inches and fits in the Altoids tin that is beloved by the QRP community as an enclosure. Kits are available.[1] A custom made aluminum enclosure is available from **www.americanmorse.com**.

The RockMite uses the familiar direct conversion (D-C) receiver scheme shown in **Fig 15.12**. There isn't much to it — an oscillator and a mixer convert received signals directly to audio and an amplifier boosts that audio to usable levels. On transmit, the same oscillator serves as the transmitter frequency source, and only gain and keying stages are needed to bring the oscillator signal up to levels usable for making CW contacts.

Several crucial details are missing from this oversimplified picture, however. The operator who calls "CQ" with a crystal-controlled D-C rig will most likely get replies on zero-beat with his signal and without some means of shifting frequency (offset) between transmit and receive, will copy only low-frequency thumps. Additionally, the joy of sending CW will be somewhat tempered by the lack of a sidetone circuit to monitor your own sending.

By using an 8-pin PIC microcontroller, it becomes possible to add an iambic keyer along with other functions. This can be done with minimum cost and with little printed circuit board acreage. Having made the decision to use a controller chip, a spare pin on that IC was dedicated to providing a 700 Hz sidetone during key-down conditions. The controller also supplies a TR control signal and a shift signal. This shift signal merely provides a dc voltage level to a varicap (tuning) diode to pull the crystal oscillator frequency between transmit and receive. The TR offset is reversible, as described later, so that the RockMite offers two possible oper-



Decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); Resistances are in ohms; k=1,000, M=1,000,000.
* Value varies by band. See Table 15.3
U1
Mixer
U2
AF Amplifier
Headphones
1 kHz
A
7039
kHz
Q4
Oscillator
7040 kHz
Q6
RF Amplifier
Key
U1
SA612
U2
LM1458N
Q1
2N7000
Q2
2N7000
Q3
2N7000
Q4
2N4401
Q5
2N4401
Q6
2N2222A
U3
12C508A-04/P
Microcontroller
2N2222A (TO-92)
2N7000
2N4401
2N2222A
(TO-18)
TONE
Shift
T/R
DOT
DASH
(SW.)
ANT
V+
AF
HBK0096

Fig 15.12 — The RockMite transceiver simplified block diagram (inset) and schematic. Most components are stocked by major distributors such as Digi-Key, Mouser and Ocean State Electronics (see the *TISFind* database at www.arrl.org/tis). Resistors are 5% ¼ W.

C1, C2, C10, C11, C12, C18 — NP0 disk capacitor, 5%. See Table 15.3 for values.
C3, C13, C101, C102, C108 — 0.01 µF disk capacitor.
C4 — 0.022 µF monolithic capacitor.
C5, C8, C14, C104, C109, C110 — 0.1 µF monolithic capacitor.
C6, C105-107 — 100 pF disk capacitor.
C7, C103, C111 — 47 µF, 25 V electrolytic capacitor.
C9 — 3.3 µF, 50 V electrolytic capacitor.
C15, C17 — Disk capacitor, 5%. See Table 15.3 for values.
C16 — C0G monolithic capacitor 5%. See Table 15.3 for values.
D1, D2, D7, D8 — 1N4148 diode.
D3, D4, D5 — Zener diode, 0.5 W. See Table 15.3 for values.
D6 — MV1662 varicap diode.
L1, L2, L3, L4 — Molded RF choke, 10% tolerance. See Table 15.3 for values.
Q1, Q2, Q3 — 2N7000 FET.
Q4, Q5 — 2N4401 transistor.
Q6 — 2N2222A transistor.
U1 — SA612AD mixer/oscillator IC. (Surface mount part is used on the kit PC board. If building from scratch, consider the SA612AN in a DIP package.)
U2 — LM1458N dual op-amp IC.
U3 — 12C508A-04/P microcontroller. (Must be programmed before use. See Note 1.)
Y1, Y2 — HC49/U crystal (20 pF load) for operating frequency of interest. Crystals for popular QRP frequencies, including those shown in Table 15.3, are available from expandedspectrumsystems.com or AF4K.com.

Table 15.3
RockMite Component Values by Band

Band	*80 m*	*40 m*	*30 m*	*20 m*
Freq (MHz)	*3.560*	*7.030*	*10.106*	*14.060*
C1	47 pF	47 pF	47 pF	47 pF
C2	33 pF	47 pF	47 pF	47 pF
C10, C11	68 pF	68 pF	33 pF	39 pF
C12	47 pF	47 pF	33 pF	39 pF
C15, C17	560 pF	470 pF	330 pF	220 pF
C16	1200 pF	1000 pF	680 pF	470 pF
C18	330 pF	150 pF	82 pF	82 pF
D3	1N5231B (5.1 V Zener)	1N5231B (5.1 V Zener)	1N5231B (5.1 V Zener)	1N5233B (6.0 V Zener)
D4	1N5231B (5.1 V Zener)	1N5231B (5.1 V Zener)	1N5231B (5.1 V Zener)	1N5230B (4.7 V Zener)
D5	Omitted	1N5236B (7.5 V Zener)	1N5231B (5.1 V Zener)	1N5230B (4.7 V Zener)
L1	15 µH	10 µH	6.8 µH	4.7 µH
L2, L3	2.2 µH	1 µH	0.68 µH	0.47 µH
L4	5.6 µH	3.3 µH	3.3 µH	1.5 µH

ating frequencies. This function has traditionally been done with a double-pole switch, but it's easier and cheaper to perform that function in firmware.

There is one other noteworthy trick employed in the RockMite. Builders of simple receivers for 40 meters have all experienced the joys of listening to shortwave broadcasts mixed in with their CW. For most simple gear, the high levels of broadcast RF cause intermodulation distortion (IMD). This can be mitigated by the use of more robust (higher-current consumption and complexity) receiver front ends. Another approach is to ensure that the broadcast signal levels reaching the receiver mixer are attenuated enough to avoid their IMD effects. If you're interested in only a small segment of an amateur band, a sharply tuned (narrow) band-pass filter may be used to good effect to accomplish that. The RockMite uses this approach by utilizing a second crystal at the operating frequency at the receiver front end. The performance improvement with the added crystal is significant.

Circuit Description

The RockMite schematic is shown in Fig 15.12. Local oscillator Q4 is a crystal- controlled Colpitts oscillator and runs continuously. Its operating frequency is determined by crystal Y2 and the surrounding components. Diode D6 is a varicap (tuning) diode and it furnishes a voltage-dependent capacitance. This effect is used to pull the crystal oscillator frequency about 700 Hz between transmit and receive to provide a beat-frequency offset. The voltage applied to D6 through resistor R10 is 0 V with Q2 turned on (conducting) or it is the rated Zener voltage of D5 with Q2 off.

A sample of the local oscillator signal is coupled to the base of Q5. Q5 provides no voltage gain but instead serves to improve key-up isolation between the local oscillator and the antenna. This ensures that the key-up energy to the antenna (back-wave) is negligible. Equally important, the lowered signal level at the antenna terminal prevents blocking effects from desensitizing the receiver.

The output of the buffer stage is coupled via C13 to the power amplifier stage, Q6. Diode D8 provides a clamp function, making it easier to drive the base of Q6. Transistor Q6 runs Class C, is driven hard and, in theory, has only conducting and nonconducting states for high efficiency. The waveform at Q6's collector would ideally be a square wave. In practice, there's considerable waveform distortion at that signal point and, in any case, it's nothing you'd want to apply directly to an antenna.

Capacitor C14 couples this waveform to the output harmonic filter, which comprises L2 and L3 and C15, C16 and C17. Since the original RockMite article was published, FCC requirements for spectral purity changed from –30 dBc to –43 dBc. A series L-C circuit (L4 and C18) between the output of the low pass filter and the antenna provides the needed additional harmonic attenuation. In an effort to save space and reduce construction complexity, subminiature epoxy-molded RF chokes were used instead of the traditional toroids. For the frequencies and power levels encountered in the RockMite, performance appears adequate – – loss and self-heating were not significant. Power output is about 500 mW with a 13 V dc supply and it will work at lower supply voltages.

The receiver is continuously connected to the antenna through coupling capacitor C1. Diodes D1 and D2 limit the key-down voltage swing appearing at the receiver front-end to safe values. The presence of Y1 at the receiver front-end may seem somewhat startling, but it serves as a narrow band-pass filter to keep RF energy from frequencies far removed from the operating frequency to a minimum. The SA612 mixer, which does the conversion from RF to audio, needs all the help it can get.

Readers may recognize the circuit as an adaptation of a Roy Lewallen, W7EL, circuit — a widely used series-LC TR switch. The inductance in this circuit is being furnished by crystal Y1 at a frequency slightly off its series-resonant point. Perhaps less obviously, capacitor C2 forms an L network in combination with a portion of the crystal motional inductance. It's impedance step-up; there's about 10 dB of voltage gain prior to the mixer input (U1, pin 2). The values of

C1 and C2 were twiddled empirically to yield a 6 dB bandwidth of about 2 kHz and to straddle the two operating frequencies fairly evenly. For the 40 meter version, receiver filter response is –35 dB at 7100 kHz and up. Although this value of ultimate rejection is unacceptably poor for typical crystal filters, here it needs to be only good enough to yield significant improvement in IMD performance.

The mixer IC, U1, converts the received signal from the operating frequency to audio; that signal appears at pins 4 and 5 of U1. C4 provides some low-pass filtering to cut unwanted audio hiss. U2 is a garden-variety dual op-amp (one-half is unused) configured for a gain of about 200 (46 dB). This boosts the mixer's output audio to headphone-usable levels. Capacitor C6 provides an additional pole of audio low-pass filtering.

Transistor Q1 provides a simple mute function to reduce the amount of keydown thump. It disconnects the audio amplifier from the headphones whenever the rig is keyed. The large (transmitted) signal appearing at the receiver during key-down yields a dc offset at the mixer output, which is amplified to a large transient by the audio amplifier. The muting isn't perfect but it's a lot less fatiguing than none at all. Key-up recovery time is set by C9 — this value may be reduced if you prefer quicker QSK (break-in). U3 is a 12C508A microcontroller device and has been custom programmed to provide iambic keyer (Mode B) and frequency shift functions. U3 pins 6 and 7 are typically connected to a pair of paddle inputs to provide the keyer functions. Ground one of those two inputs during rig power up and the RockMite will use the other input for the straight key or more capable external keyer.

There are two operator controls on the RockMite and they're both implemented via a push-button switch closure, in order to ground controller pin 4. The two functions are discriminated by the duration of the switch closure.

A brief (< 250 ms) closure on the switch reverses the offset to provide a second operating frequency. When you wish to work another station, use this function to select the higher of the two pitches on a received signal. Note that the pitch at the converse setting is a measure of how close to zero-beat you are; ideally it would be just a low-frequency thump. If the two selections yield a high pitch and a still higher pitch, you probably won't be able to work the other station.

A longer closure on the switch input puts the keyer in a speed-adjustment mode. The RockMite outputs a Morse code S to acknowledge entry into this mode. Tapping (or holding) the dot paddle speeds up the keyer; the same operation on the dash paddle slows it down. The default (power-up) speed is approximately 16 WPM and the speed range is about 5 to 40 WPM. If no dot/dash inputs are received after about 1 second, the RockMite outputs a lower frequency tone and reverts to normal operation. The Morse S and subsequent tones are not transmitted on the air.

Modifications

The idea of a transceiver whose only control is a pushbutton switch probably flies in the face of recent trends in transceiver design. If you feel the need to "manage" your radio, resistor R5 may be replaced with a 1 MΩ audio taper potentiometer (wiper and one end-terminal used) to serve as a volume control. Keep the leads short.

Sidetone level can be altered by changing the value of C8. Note: the "raspy" nature of the RockMite sidetone is caused by the square-wave nature of the signal. One or more R-C networks (series-R, shunt-C to ground) in the path from U3 pin 5 to C8 will soften the tone. A good starting point for this filter is 10 Ω/10 µF.

Adding a 1N4001 diode in series with the power supply (V+) feed will preclude reverse-polarity mishaps. (The banded end goes toward the RockMite board.) Or better yet, use a 1N5818 Schottky diode for lower voltage drop. Any of the diodes 1N4001-1N4007 or 1N5818-1N5820 series is fine. They're noncritical and all overkill for this application.

The RockMite will run on a 9 V battery if R1 and R8 are changed from 1 kΩ to 470 Ω. This change increases receiver current consumption from 25 mA to 40 mA when using a 12-14 V supply.

Troubleshooting

Detailed troubleshooting information can be found in the file RMhelps.pdf, available for download from the Small Wonder Labs Web site (see note 1). Here are some of the more common problems.

AC hum: Make sure Y2's case is grounded. The RockMite has a lot of audio gain. You may experience difficulty when using an unregulated power supply or wall transformer to power the rig. A regulated supply will help considerably in this regard. If in doubt, try a battery supply. You may use a 9 V battery temporarily to check out the difference.

Howl in headphones: (Make sure you're not in straight-key mode with the key down. That's the sidetone.) The combination of high audio gain and wire lead treatments can yield an audio oscillation or "howl," although this has not been reported often. Here are some things to try.

- If using a battery supply, make sure it's reasonably well charged. A nearly-exhausted battery may cause howl or motorboating.
- Provide separation between wires run to and from the RockMite board and the board components. Close lead proximity affords more chances for unwanted signal crosstalk. Where wires do need to cross, keep them at right angles to one another to minimize the coupling.
- Don't count on the enclosure itself to provide ground return continuity. It may be helpful to run a ground return wire from the board to the headphone jack ground lug and from there to the dc power return. If you do this, continue to use a wire from board ground to the main dc power return. You want to avoid conditions where one circuit path is carrying both audio and dc ground currents, and for that matter, RF as well.
- Ensure that the ground braid is used on the coax connecting the PC board to the antenna jack. Connect the rig end to a convenient ground point near the antenna pad and be sure the other end makes connection to the antenna jack ground lug.

Broadcast pickup: There are two potential issues with the RockMite. Shortwave broadcast (SWBC) will be more likely during the evening hours. Despite the presence of the front-end crystal filter, some SWBC may occasionally be heard. A fix involves reducing the signal levels getting to U1, which can be accomplished by changing R5 to a 1 MΩ variable volume control as described in the previous section. The use of an antenna tuner will also assist in reducing the out-of-band RF energy getting to U1.

Local AM broadcast interference is more likely during daylight hours when local AM stations are on the air. Install a 1 kΩ resistor at the two unused pads immediately below D1/D2. Note that this fix does not help with shortwave broadcast. The fix was tested successfully at the ARRL lab, located within two miles of several 5 kW AM broadcast stations.

Very low volume: This is a minimalist transceiver, so it won't provide ear-splitting volume. Even so, with a good antenna and headphones you should have little trouble hearing signals. If everything else checks out, consider the following. Use a resonant antenna, 50 Ω nominal, such as a dipole. If the antenna is nonresonant (random wire, etc), use a tuner to make the antenna look like 50 Ω at the rig. SWR is not especially critical here. The worst that could happen is the loss of an inexpensive transistor (Q6).

Headphones should be a low-impedance stereo type, such as those used for personal MP3 or CD players. If there are specifications on the package, look for a sensitivity spec of 104 dB/mW or better. And a final caution related to audio output: You'd be surprised how often reports of very low audio are traced to use of incorrect audio jack or plug types. You won't hear much with the audio output shorted to ground!

Does It Really Work?

The receiver is direct-conversion, so the audio you hear is busier than what's typically found in a big rig. There's some audio low-pass filtering, but it still doesn't have the sharp roll-off characteristics prevalent with crystal IF filtering. Because the D-C receiver receives both sidebands equally well, there are twice as many signals as you'd expect of a more capable receiver. Once you get the hang of selecting which of the two operating frequencies to call someone on, the operation is pretty straightforward.

A Thriving Community

This project started out as a party favor and indeed, it was initially dubbed "a wireless code practice oscillator" — somewhat tongue-in-cheek. Once the first samples were available, it became clear that the RockMite was a usable radio. Much of this success can be attributed to the QRP community's use of watering holes. Many QRPers monitor those frequencies when they're in the shack and your chances of success with a "CQ" are surprisingly good.

A gallery of construction pictures, modification information, links and related topics may be found at **www.qsl.net/n0rc/rm/**. There's also a very active user's group on-line at **groups.yahoo.com/group/Rock-Mite_Group/**.

A special thanks to Doug Hendricks, KI6DS, for his material support with this project and to Rod Cerkoney, NØRC, for his enthusiastic Web site support. Thanks also to Steve Weber, KD1JV, for design suggestions during the development phase.

[1]Complete parts kits for the RockMite, including PC board, all on-board parts, a programmed microcontroller and instructions, are available from Small Wonder Labs (**www.smallwonderlabs.com**). Programmed microcontroller ICs alone are also available. RockMite object code (.hex file) may be found in the Templates section of the *Handbook* CD-ROM.

Transverters

At VHF, UHF and microwave frequencies, transverters that interact with factory-made transceivers in the HF or VHF range are common and are often home-built. These units convert the transceiver transmit signal up to a higher frequency and convert the receive frequency down to the transceiver receive frequency. The resulting performance and signal quality at the higher frequencies are enhanced by the frequency stability and the signal processing capabilities of the transceiver. For example, SSB and narrowband CW from 1.2 to 10 GHz are feasible, and becoming more popular. Some HF and VHF transceivers have special provisions such as connectors, signal-path switching and T/R switching that facilitate use with a transverter.

VHF TRANSVERTERS

The methods of individual circuit design for a transverter are not much different than methods that have already been described. The most informative approach would be to study carefully an actual project description.

The interface between the transceiver and transverter requires some careful planning. For example, the transceiver power output must be compatible with the transverter's input requirements. This may require an attenuator or some modifications to a particular transverter or transceiver.

When receiving, the gain of the transverter must not be so large that the transceiver front-end is overdriven (system IMD is seriously degraded). On the other hand, the transverter gain must be high enough and its noise figure low enough so that the overall system noise figure is within a dB or so of the transverter's own noise figure. The formulas in the **Receivers and Transmitters** chapter for cascaded noise figure and cascaded third-order intercept points should be used during the design process to assure good system performance. The transceiver's performance should be either known or measured to assist in this effort.

MICROWAVE TRANSVERTERS

The microwave receiver section of the **Receivers and Transmitters** chapter in this *Handbook* discusses a 10-GHz transverter project and provides references to the *QST* articles that give a detailed description. The reader is encouraged to refer to these articles and to review the previous material in that chapter.

Other Information

The ARRL Microwave Projects CD, several RSGB publications and VHF/UHF microwave conference proceedings contain additional information about transverter design and construction. More information about these publications is available from the ARRL Bookstore at **www.arrl.org/shop**.