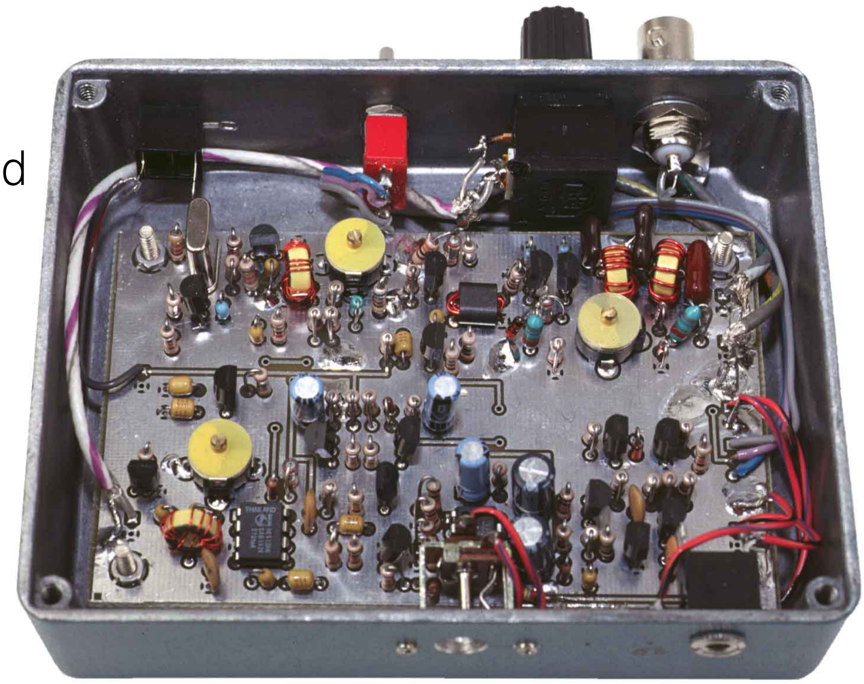
By Wes Hayward, W7ZOI, and Terry White, K7TAU

The Micromountaineer Revisited

Although this easy-to-build transceiver was initially designed for use on 10 meters, you can move it to other bands as well. As a bonus, you get a power meter, too!



An inside view of one of the Micromountaineers enclosed in a die-cast aluminum box.

In the early 1970s, we described a pair of small, crystal-controlled QRP stations.[1, 2] Both use direct conversion (D-C) receivers in the 40-meter band with a transmitter output of half a watt. The first (see Note 1) uses a tunable receiver, while the other, dubbed the Micromountainer (see Note 2), uses the transmitter crystal oscillator as the receiver LO. We reasoned that there is little need to be able to receive on frequencies far removed from those of the transmitter. While a generation has brought much more sophistication to the QRP operator, the premise remains valid.

Although QRP operation has grown to become a major subculture within Amateur Radio, the activity is still largely confined to bands where commercial equipment predominates. Only the high-end commercial QRP boxes or 100-W transceivers with reduced power operate on the 10-meter band. This updated version of the Micromountaineer is aimed primarily at the 10-meter band where excellent propagation allows international communications with low power and simple antennas, but the rig can be built for use on other bands as well. (We're including component values for a 40-meter version of the rig, too.) The original Micromountaineer theme is retained: a $^1/_2$-W transmitter and a D-C receiver share a crystal oscillator. Electronic TR switching and *almost incremental tuning*, AIT, (explained later) have been added to enhance performance while retaining a primitive simplicity.

[1]Notes appear on page 33.

Circuit Details

Transmitter Section

The heart of the transceiver is the crystal-controlled oscillator, Q2 (Figure 1). The circuit uses third-overtone mode 28-MHz crystals and is tuned to frequency with T1 and C4. (See T1 detail in Figure 2.) Q1 is an electronic switch that shifts the oscillator frequency by about 1 kHz. (Large frequency shifts are available in fundamental-mode oscillators, but are more difficult

PHOTOS BY JOE BOTTIGLIERI, AA1GW

to obtain in overtone oscillators.) Without this shift, you might send CQ, get a reply *on-frequency* and never hear a beat note!

The oscillator output, nearly 10 mW, is extracted from T1 and applied to a power splitter consisting of three 51-Ω resistors. One output provides receiver LO injection, while the other is applied to Q3, the transmitter driver. Q3 is keyed through Q4, a PNP switch and shaping integrator that prevents key clicks. Driver output is extracted via ferrite transformer T2 (shown in greater detail in Figure 2). This transformer uses a binocular balun core in which *one wire turn* constitutes a complete pass through *both* holes.[3] This transformer has the primary exiting one end with the secondary at the other end.

The power amplifier (Q5 and Q6 in parallel) uses a pair of modest and inexpensive 2N3904s. Emitter degeneration forces the transistors to equally share current and provides thermal stability. A Zener diode, D5, prevents severe stress on the transistors during momentary operation without a load. Experimenters might want to try using other transistors in the PA stage. A single 2N4427 we tried worked well, as did four 2N2222As in parallel, both PAs producing over 1 W output. The 2N3904 pair is normally operated at about $^1/_2$ W output, a level at which the transistors are not thermally abused, even without a heat sink. L3 and L4, with C13, 14, and 15, form a low-pass filter doubling as an impedance-matching network.[4] The result is a cool, robust amplifier with an efficiency of over 50%. Measured second-harmonic output is 58 dB below the desired output, easily meeting FCC 2002 spectral-purity requirements.[5] To obtain maximum output, the turns on L3 are spread or compressed as required. If you decide to try an alternative PA, you might need to alter the output-network component values to obtain maximum output with reasonable efficiency.

Receiver Section

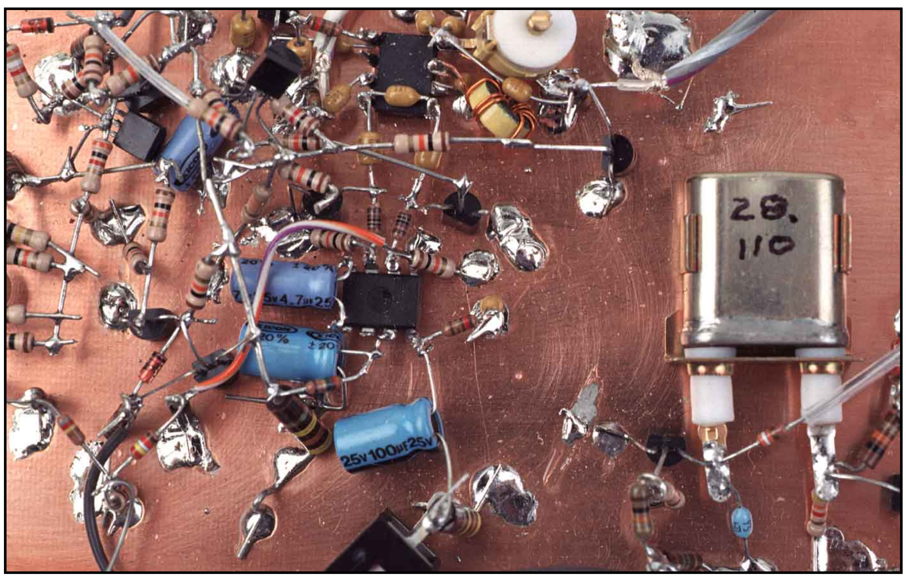
The receiver is a variation on the familiar Neophyte popularized by John Dillon, WA3RNC.[6] Mixer U2, an NE602 (an obsolete part, but still available—*Ed*.) or NE612 mixer, serves as a product detector followed by U3, an LM386D audio amplifier. The detector is biased at 5 V from U1, a 78L05 regulator. To provide receiver muting and a simple way of injecting a sidetone oscillator, the receiver is modified slightly from the original circuit. MOSFETs Q8 and Q9 are turned on during transmit intervals, shorting the audio from the detector. (The MOSFETs have a very low *on* resistance that is unavailable from a bipolar transistor with modest base current.) The input to U2 is tuned, but with an unbalanced input. This produced a large dc offset during transmit intervals until Q7 was added to enhance receiver muting. Replacing L5 with a balanced transformer will also reduce dc offset.

This Micromountaineer is housed in an LMB enclosure. Take care to remove paint on the inside of these enclosures to ensure contact with grounded components.

U2 uses very little current. Although this is a great advantage for portable applications, the low current results in severely degraded dynamic range. Enterprising experimenters can expect a large-signal performance improvement of up to 20-dB using diode-ring-based designs.[7]

A sidetone oscillator (Q10 and Q11) is keyed with a PNP switch, Q12, to produce a signal that is fed to U3 via R32. Sidetone level may be adjusted by changing the value of R33. Oscillator pitch can be decreased by increasing the values of R39 and R41.

Two PNP switches generate additional timing voltages when the key is pressed. Q16 mutes the receiver for a mute time determined by the values of C35 and R25. Q15 causes the +12R line to go low while the +12T line goes high. These signals are both present at toggle switch S1. Operating S1 allows you to apply the frequency offset to the crystal oscillator during either transmit or receive, affording some ability



A close-up of a portion of the prototype Mountaineer. Yes, it works just fine!

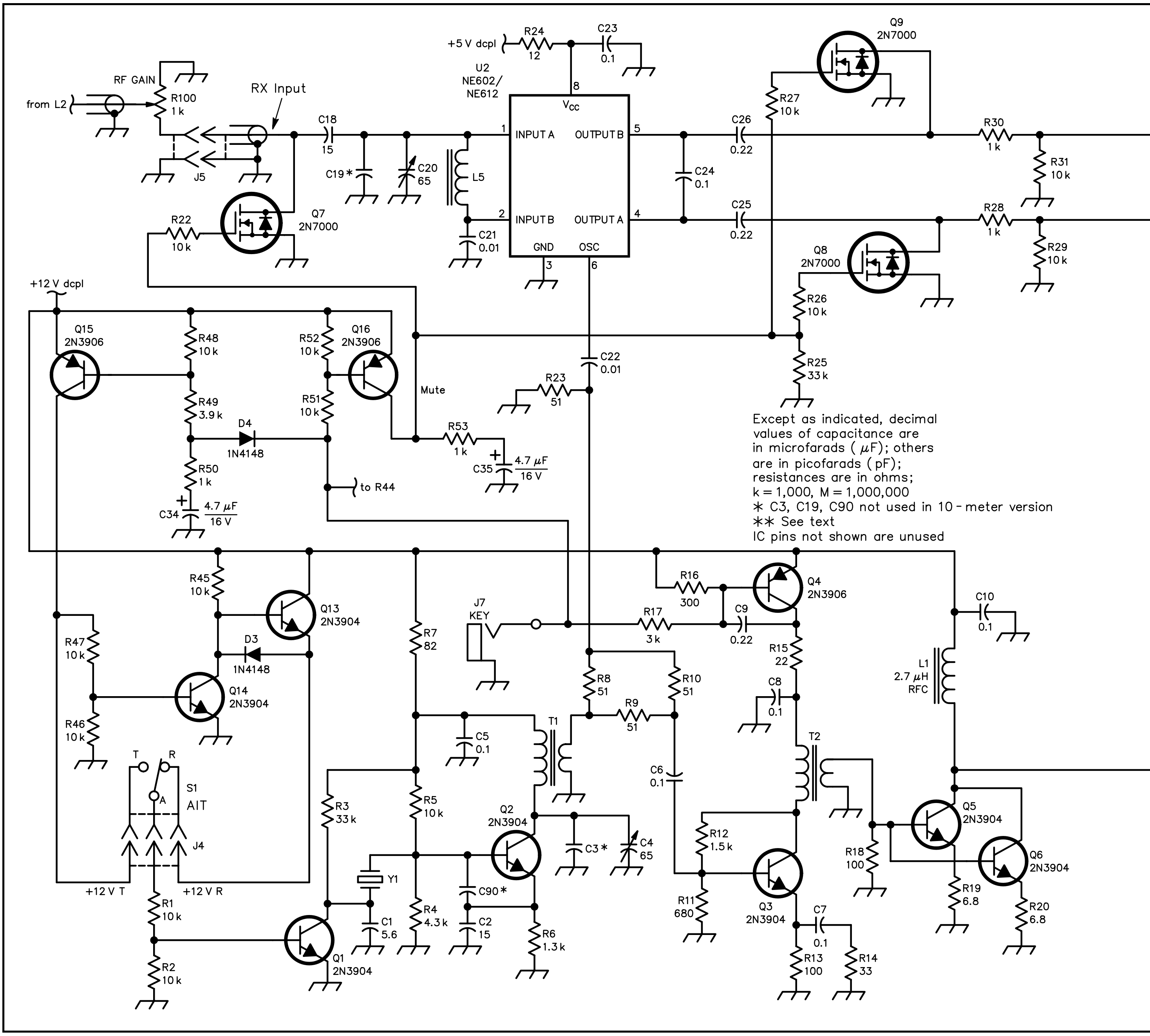


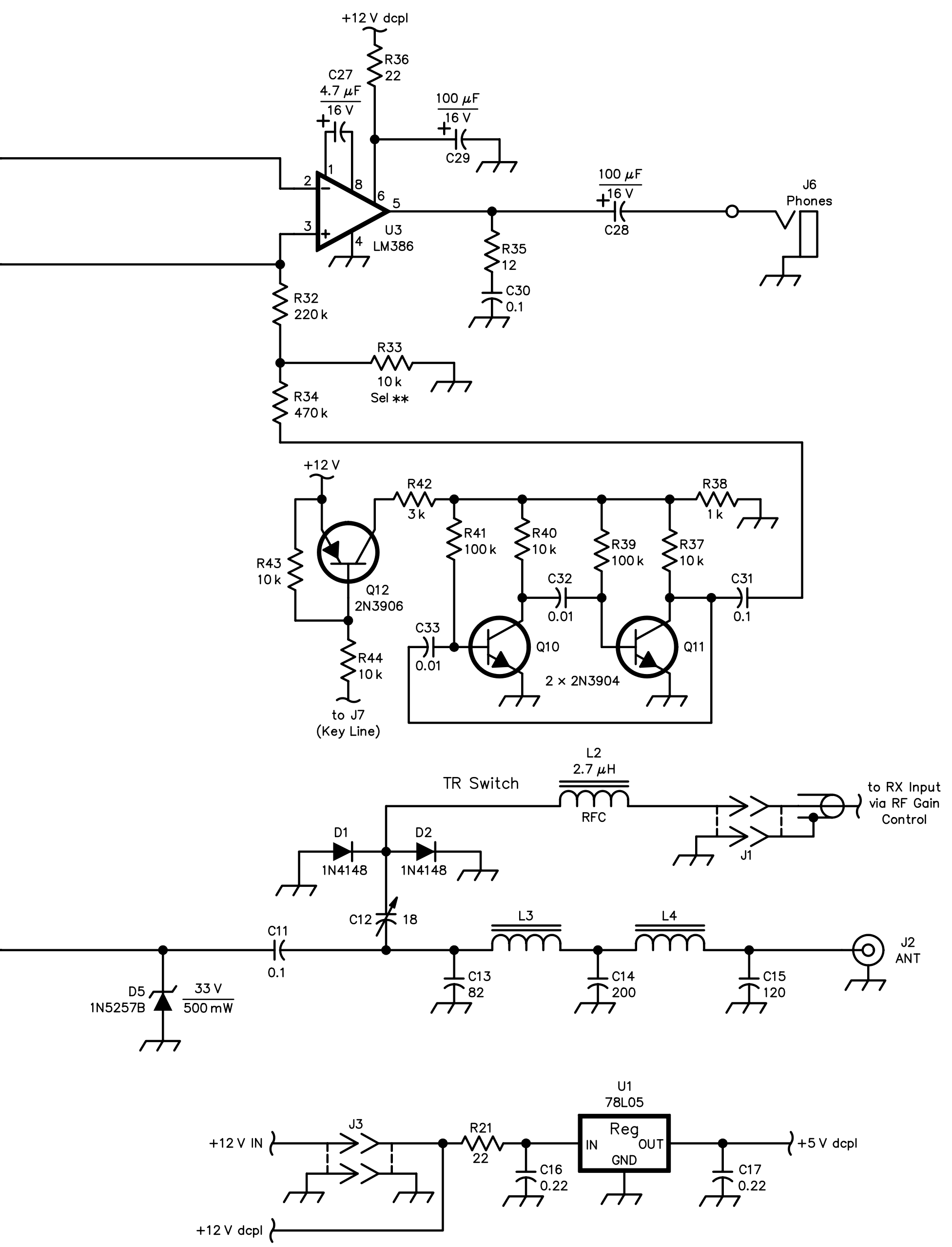
Figure 1—Schematic of the 10- and 40-meter Micromountaineer. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. Fixed-value capacitors should be 5% tolerance; either ceramic (NP0/C0G) or mica are suitable. Equivalent parts can be substituted; n.c. indicates no connection. The parts list identifies band-specific components. In addition to the PC-board/component collection in Note 11, parts are available from several sources: Mouser Electronics, 958 N Main St, Mansfield, TX 76063-4827; tel 800-346-6873, 817-483-4422, fax 817-483-0931; sales@mouser.com; http://www.mouser.com; Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, 218-681-6674, fax 218-681-3380; http://www.digikey.com; RadioShack and others.

to dodge QRM. It's almost like having receiver incremental tuning (RIT) in a more-refined radio, hence the term AIT: *almost incremental tuning*. We have used the scheme in several simple VFO-controlled transceivers proved in severe portable situations.[8] Timing of the frequency toggle is controlled by the values of R49 and C34. You can reduce the frequency shift (about 1 kHz in our transceivers), by increasing the value of C1.

TR switching is handled by D1 and D2.

The front panel of the dual-range QRP power meter.

C12 and L2 form a series-tuned 28-MHz circuit that routes antenna signals from the transmitter to the **GAIN** control and the receiver. When the transmitting key is pressed (creating a strong signal), the diodes conduct, keeping the received-signal level low enough to prevent damage to mixer U2. Gain is controlled by R100, a panel-mounted potentiometer at the receiver input. Although a trimmer capacitor is used at C12 in the 10-meter transceiver, a fixed-value capacitor is employed in the 40-meter version.



C1—10 m: 5.6 pF; 40 m: 82 pF
C2—10 m: 15 pF; 40 m: 390 pF
C3—10 m: not used; 40 m: 100 pF
C4, C20—10 and 40 m: 4.5-65 pF trimmer (Digi-Key SG3009)
C12—10 m: 4.5-65 pF trimmer (Digi-Key SG3009); 40 m: 33 pF, 5%-tolerance NP0
C13—10 m: 82 pF; 40 m: 360 pF
C14—10 m: 200 pF; 40 m: 820 pF
C15—10 m: 120 pF; 40 m: 470 pF
C18—10 m: 15 pF; 40 m: 56 pF
C19—10 m: not used; 40 m: 180 pF
C27, C34, C35—4.7 µF, 16 V electrolytic
C28, C29—100 µF, 16 V electrolytic
C36-C89—not used.
C90—10 m: not used; 40 m: 390 pF
D1-D4—1N4148 or 1N4152
D5—33 V, 500 mW Zener diode
J1, J3, J5—Two-pin 0.1-inch male headers
J2—SO-239 or BNC
J4—Three-pin 0.1-inch male header
J6, J7—Two-circuit phone jack
L1, L2—10 m: 2.7 µH RFC; 40 m: 15 µH RFC
L3—10 m: 10 turns #24 enameled wire on a T30-6 core; 40 m: 22 turns #26 enameled wire on a T37-2 core; vary turns spacing to adjust power output; see text.
L4—10 m: 9 turns #24 enameled wire on a T30-6 core; 40 m: 19 turns #26 enameled wire on a T37-2 core
L5—10 m: 12 turns #26 enameled wire on a T30-6 core; 40 m: 22 turns #28 enameled wire on a T37-2 core
Q1, Q2, Q3, Q5, Q6, Q10, Q11, Q13, Q14—2N3904 NPN
Q4, Q12, Q15, Q16—2N3906 PNP
Q7-Q9—2N7000 MOSFET
R100—1 kΩ, linear-taper, panel-mount pot
S1—SPDT toggle
T1—10 m: 15 turns #26 enameled wire on T30-6 core, with 3-turn link of #22 enameled wire; 40 m: 30 turns #28 enameled wire on T37-2 core, with a 4-turn link of #22 enameled wire
T2—Pri: 4 turns #28 enameled wire; sec: 1 turn #22 enameled wire on BN-43-2402 ferrite balun core; keep lead lengths short.
U1—78L05 positive 5 V, 100 mA regulator
U2—NE602/NE612 (SA602/SA612) mixer/oscillator; see text
U3—LM386-4 audio amp
Y1—10 m: third-overtone; 40 m: fundamental mode; Hy-Q type JG07C, HC-49/U holder; see Note 10. Experimenters wishing to try a VXO at 28 MHz should consider using a fundamental-mode crystal.

A Simple Power Meter

Figure 3 is a schematic of a simple dual-range power meter that you can use to test this rig (or other similar power sources). Consider first the 1-W range. D200 rectifies the peak RF voltage appearing across the 50-Ω, 1-W load formed by the parallel combination of R200 and R201. The resulting dc voltage is applied to a voltmeter (formed by R202 and the meter) having a 10-V full-scale reading.

After we built the single-range power meter, we noted that the dc voltage across the meter movement was small. Investigation showed that the meter had an internal resistance of only 100 Ω, a typical value for

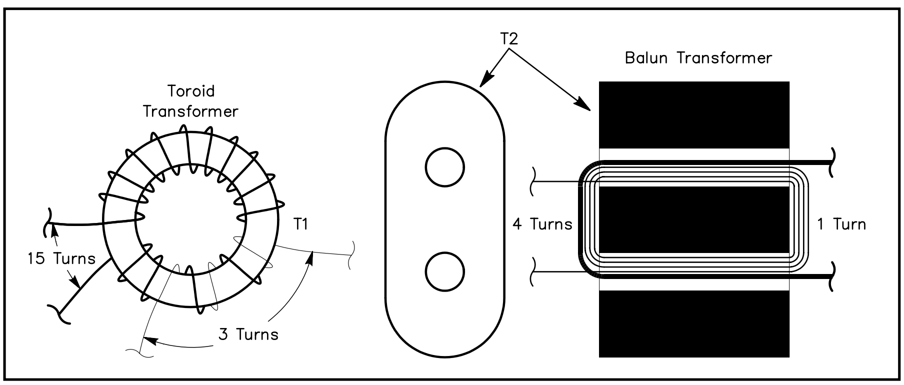
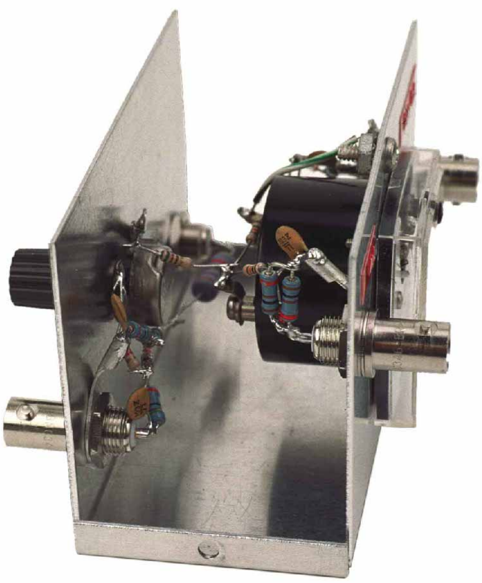


Figure 2—Winding details for the two transformers used in the 10-meter Micromountaineer. Each pass through the core center counts as a turn in a traditional toroid, T1 above. But each turn must pass through *both holes* of a balun core (see Note 3).



As this inside view of the power meter shows, it's simplicity itself. The components mounted on the rear panel of the box serve functions unrelated to that of the power meter.

inexpensive 1-mA movements. This allowed us to add a second detector and RF load to form a second, more-sensitive (50-mW) range. We calibrated this against the 1-W meter using the transmitter and a step attenuator, resulting in the calibration chart of Figure 4. This curve may be used directly for approximate measurements.[9]

This power meter includes 50-Ω terminations, acting as loads for whatever source is applied. This design differs from popular in-line power meters used by QRP operators that require an external load.

Building the Transceiver

There are probably as many ways to build this rig as there are experimenters. For our first version, we used "ugly construction."[10] But there are sure to be many prospective builders who want a PC-board version of the transceiver.[11] In any case, we strongly recommend that you build and test the rig as you build it *one stage at a time.*

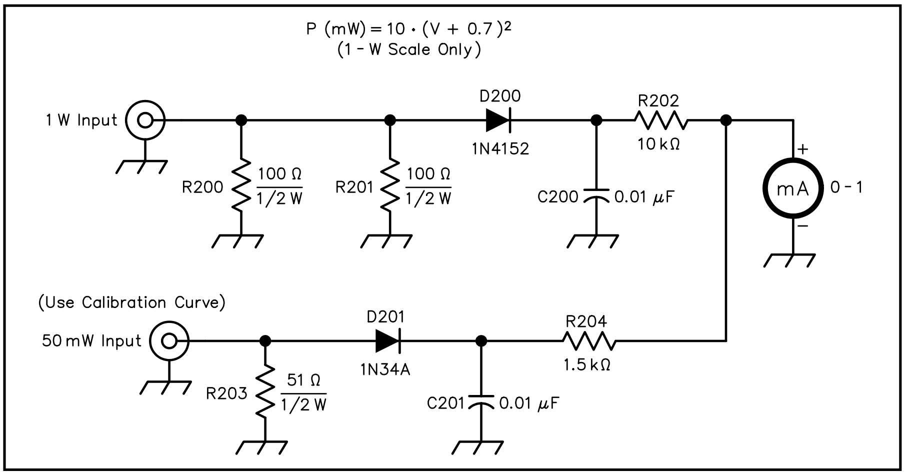


Figure 3—The transmitter can be tested with this simple power meter. When the meter reads 0.5 mA with RF applied to the 1-W input port, the indicated peak RF voltage is 5 V and the power is 325 mW, calculated with the formula shown. D200 is a 1N4152, 1N4148, or 1N914, while D201 is a more-sensitive 1N34A germanium diode.

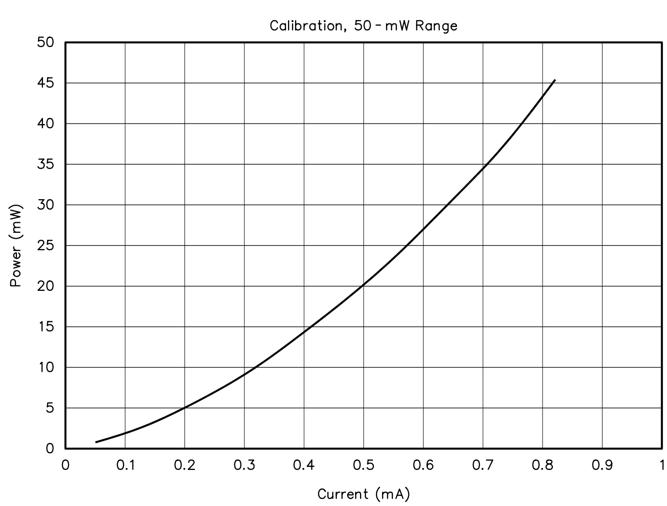


Figure 4—Calibration curve for the 50-mW range of the power meter.

Transmitter Section

Begin by building the crystal oscillator, including the frequency-controlling switch, Q1. Apply power and confirm oscillator operation by listening for its signal in a receiver tuned to the crystal frequency. To test the oscillator, attach the T1 link to a short piece of 50-Ω coaxial cable connected to the power meter. Adjust C4 for maximum output. Using the sensitive (50-mW) range of the power meter, the output from T1 should measure about 10 mW into the 50-Ω load. Only after this measurement is made and confirmed is the transformer secondary (link) attached to the next stage.[12]

Next, build the driver stage (Q3), including the keying switch (Q4) and confirm operation. Start with a 15-Ω resistor for R14, knowing that its value will be adjusted later. Confirm this stage's operation by attaching the output of T2 to a 50-Ω coaxial cable connected to the power meter. The indicated power should be about 35 mW. After testing, the T2 output is routed to the PA transistor bases.

Assemble the PA and output network. Then attach the output to the power meter's 1-W range, apply dc power and press the key. Adjust the circuit for maximum power output by squeezing or compressing the turns on L3. We found it useful to measure the inductor values prior to installing them. For this, we used a small LC meter available from Almost All Digital Electronics.[13]

Receiver Section

Wire the audio amplifier (U3) and test it by listening for a slight hiss in headphones plugged into J6. Touching one of the input leads with your finger or a screwdriver should produce some hum or perhaps even an AM broadcast signal. After building and testing the regulator circuit, U1, assemble the detector (U2) and attach an antenna. Even if it's late at night and the band is dead, you should still be able to hear background noise. Adjust C20 for maximum noise output. If you've got a signal generator, by all means, use it. Signal levels of 0.1 µV are easily copied with this receiver.

If you build this receiver on a PC board that's sitting on a table or workbench, you might observe considerable hum in the receiver. Don't be concerned—this tunable hum will go away once the board is installed in a metal box. With the ugly breadboard unit, the hum was barely detectable, but the hum was considerably louder when testing the PC-board version.

Other Circuits

Once the basic transceiver parts are working, you can start to add the "frills." Install the muting transistors (Q8 and Q9) and related switch, Q16. Make sure you have a 50-Ω load attached to the transmitter output. (Don't operate the transmitter without a proper load attached.) Then apply power and press the key. You should hear the receiver noise drop to nearly nothing. Add and test the AIT-related parts, followed by the sidetone components. Finally, install the TR diodes and L2/C12 at the PA. Route a coaxial cable between the receiver input and the TR output and adjust C12 for maximum receiver output.

You're now ready to put the transceiver in a box. Avoid using a small enclosure that makes component access difficult. Once the rig is in the box, you might want to adjust R14 (discussed earlier) to maintain the power output at around 500 to 650 mW. For the 10-meter transceiver, we ended up with a value of 33 Ω for R14; on 40 meters, R14 is 47 Ω. It's also wise to anticipate changing R33's value for sidetone-level adjustment.

Putting the Rig on the Air

Now it's time to see what the rig can do! As always, a lot depends on the antenna used. We used a modest dipole at 30 feet. When we first put the rig on the air, 10 meters was open, but relatively quiet. After calling CQ a few times, a station 2000 miles away answered. Following a 20-minute chat, we ended the QSO by getting his e-mail address so we could QSL with a digital photo of the rig. The following day was even more productive, netting contacts from Vermont to Alaska.

Good operating practice calls for *listening first* to be sure that the frequency is not in use before calling CQ. If an answering station returns your call right on the same frequency, you'll hear the signal shortly after releasing the key, and at a pitch equal to the offset. By switching in the AIT, you can pick the best place to answer any other station that might have responded.

Concluding Thoughts

Although *any* QRP activity can be great fun, 10-meter CW QRP is about as good as it gets! You can work the world with a watt or less, even with a modest antenna. But the good band conditions won't be with us forever, so seize the moment!

Aggressive experimenters will want to consider expanding the performance of this transceiver. The rig can, of course, be put on bands other than 10 and 40 meters. The next refinement of interest is more flexible frequency control. Probably the simplest way to accomplish this is with a VFO. VFO stability is not as easy to obtain at 28 MHz as it is on lower bands, so a heterodyne approach may be required. In any case, use care to maintain spectral purity.

Builders of the original Micromountaineer often converted the oscillator to a VXO. This is considerably more difficult to do with overtone crystal-oscillator circuits than it is with fundamental crystal-oscillator circuits. It's also challenging to implement an offset circuit with uniform frequency shift in a VXO. But let's see what *you* can do!

Notes

[1]Wes Hayward, W7ZOI, and Terry White, K7TAU "The Mountaineer—An Ultraportable CW Station," *QST*, Aug, 1972, pp 23-26.

[2]Wes Hayward, W7ZOI, "The Micromountaineer," *QST*, Aug, 1973, pp 11-13 and 45. Also see Wes Hayward, W7ZOI, and Doug DeMaw, W1FB, *Solid-State Design for the Radio Amateur* (Newington: ARRL, 1977), p 219.

[3]Experiments easily demonstrate that there is minimum coupling from one hole to the next. A single winding through one hole produced a signal 16 dB lower in a single winding in the other hole. When both windings were in the same hole, the loss was only 4 dB. Measurements were at 28 MHz with 50-Ω terminations.

[4]The network was originally designed as a 31-MHz, 0.1-dB ripple Chebyshev low-pass filter with 50 Ω terminations at each end. L3 and C13 were then modified using Smith Chart analysis to provide a 28-MHz impedance of 100+*j*0 Ω at the PA collectors.

[5]Rick Campbell, KK7B, "Unwanted Emissions Comments," Technical Correspondence, *QST*, Jun 1998, pp 61-62.

[6]John Dillon, WA3RNC, "The Neophyte Receiver," *QST*, Feb 1988, pp 14-18.

[7]Rick Campbell, KK7B, "High-Performance Direct-Conversion Receivers," *QST*, Aug, 1992, pp 19-28.

[8]Read more about portable operation beyond the traditional mobile situations at the Web site for the Adventure Radio Society, **www.natworld.com/ars** and look at the online magazine, *The ARS Sojourner*.

[9]RadioShack sells a 0-15 V dc meter (RS 22-410), which is a 1-mA meter movement equipped with an external 15 kΩ resistor. The resistor is not needed in this application.

[10]This method is a point-to-point wiring scheme using circuit board scraps serving as a ground foil. Most components are supported by other components if they are not themselves soldered to the ground foil. Additional mechanical supports can be added in the form of dummy resistors of high value. See Roger Hayward, KA7EXM and Wes Hayward, W7ZOI, "The 'Ugly Weekender'," *QST*, Aug, 1981, pp 18-21. Also, visit our Web page at **www.teleport.com/~w7zoi/bboard.html**.

[11]A double-sided, plated-through-hole PC board and a component collection (but *not a kit*) are available from Kanga USA. See their Web site for price and availability information: **www.bright.net/~kanga/kanga**. The crystal used in this circuit is a third-overtone type in an HC-49 package. We recommend Hy-Q type JG07C from Hy-Q International, 1438 Cox Ave, Erlanger, KY 41018-3166; tel 606-283-5000, fax 606-283-0883; e-mail **sales@hyqusa.com**, **http://www.hyqusa.com**. The 10-meter QRP calling frequency is 28.060 MHz. A crystal lower in the band might be more productive for DX enthusiasts.

[12]This is a substitutional measurement, which is typical of RF studies. In contrast, most measurements in analog electronics are in situ (in place) measurements where probes are attached to functional systems.

[13]Almost All Digital Electronics 1412 Elm St SE, Auburn, WA 98092; tel 253-351-9316, fax 253-931-1940; e-mail **neil@aade.com**; **www.aade.com**.

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Terry White, K7TAU, taught himself Morse code and theory and received his Novice license, KN7TAU, in 1962. Employment has taken him worldwide, operating from New Delhi, India (VU2TAU) and Fairbanks, Alaska (KL7IAK). In 1992, he joined TriQuint Semiconductor in Hillsboro, Oregon, and is part of the advanced-receiver development group. Terry enjoys homebrewing his radios and test equipment with a twist on craftsmanship to each project. You can contact Terry at 9480 S Gribble Rd, Canby, OR 97013; **twhite@TQS.com**. QST

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