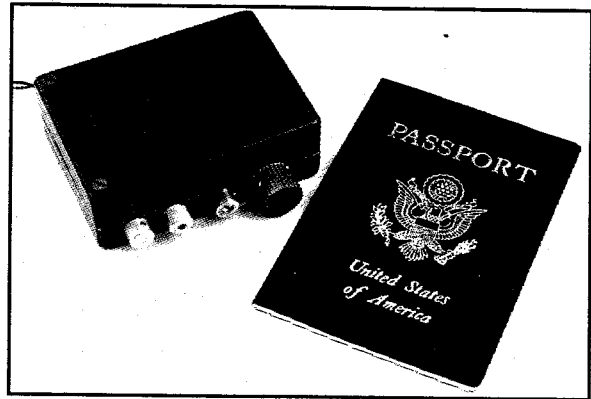


A Small High-Performance CW Transceiver

Can you handle full break-in, 1 W output and single-signal direct-conversion reception in a 20-meter package the size of a 35-mm camera?

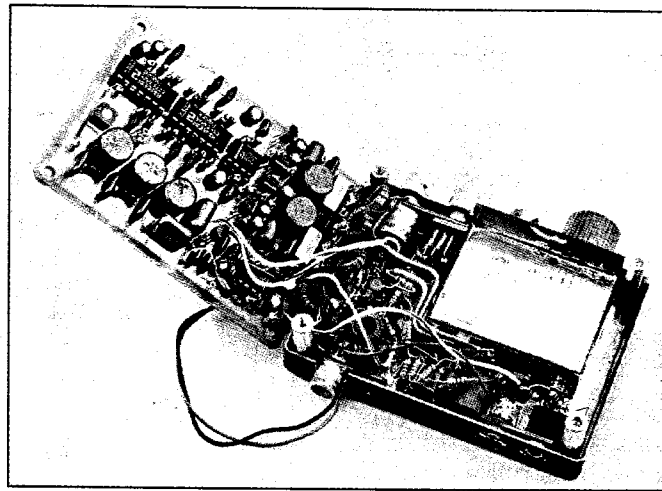
By Rick Campbell, KK7B
 Department of Electrical Engineering
 Michigan Technological University
 Houghton, MI 49931
 e-mail: rlcampbe@mtu.edu



Here is a little radio that I designed as an exercise in cuteness. It is supposed to disappear into my backpack without making a noticeable bulge or increase in weight. Those two constraints dictated a number of engineering decisions. With 1990s RF technology, a radio for any band can be small and light. 1990s battery technology limits the power output of a lightweight rig to about 1 W. A power output of 1 W makes some bands and modes considerably more attractive than others. One watt of VHF FM works well in flat areas, but I don't backpack in flat areas—in fact, my first rule of backpacking is to keep a mountain range between me and civilization. In between mountain ranges, it is nice to bounce signals off the moon or the ionosphere. A backpack EME station requires too many B batteries, so the bouncing mechanism of choice has to be the ionosphere. One watt of SSB on 10 or 12 meters works fine during the sunspot maximum, but that's five years away. SSB on 15 or 17 meters works occasionally these days, but generally during the daylight hours when I would rather be enjoying the scenery. There is nothing technically wrong with 1 W on 20-meter SSB, but it is a bit like riding a bicycle on the rush-hour interstate. Forty meters is a little better, but D-layer absorption is getting high. During the months I like to backpack, 75 and 160 meters are not in very good shape, and efficient antennas for those bands are physically large. Moving over to CW, there are two very good bands: 20 and 30 meters. I flipped a coin and built the radio for 20 meters.

Packaging

I put quite a bit of thought into the packaging. My first inclination was to make the



Opened and unfolded, the miniature CW transceiver displays its VFO/transmitter board (ugly construction, left) and miniR2 board (right, available as a kit per Note 1).

whole station the size and shape of a paperback book. Then I remembered that I always have to think about where I put a book in the backpack so it won't poke me, and that the books I take backpacking always get bent. One thing that slips in easily and never gets hurt is my little Minox 35-mm

camera. After half a dozen sketches I had a packaging scheme that produced a 1-W, 20-m CW transceiver the same size and shape as my camera.

There is always a question of how much to put in the radio enclosure. Should the batteries, antenna tuner, VSWR meter, key

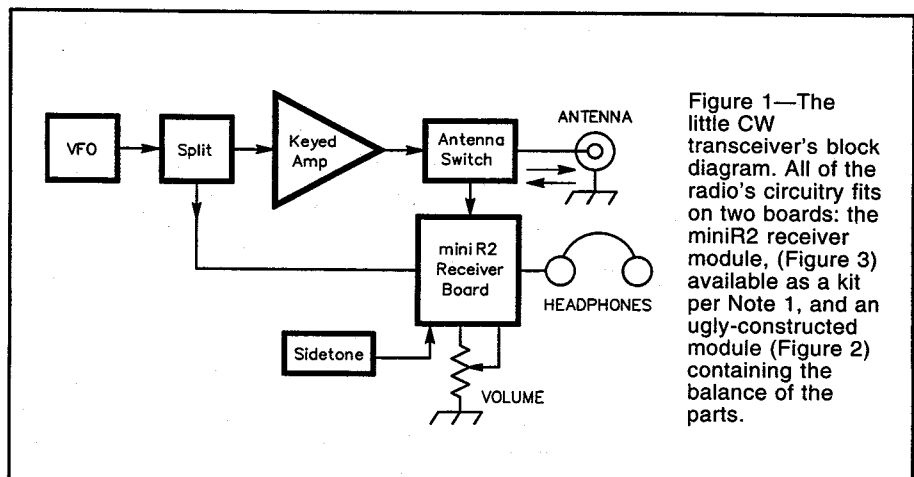
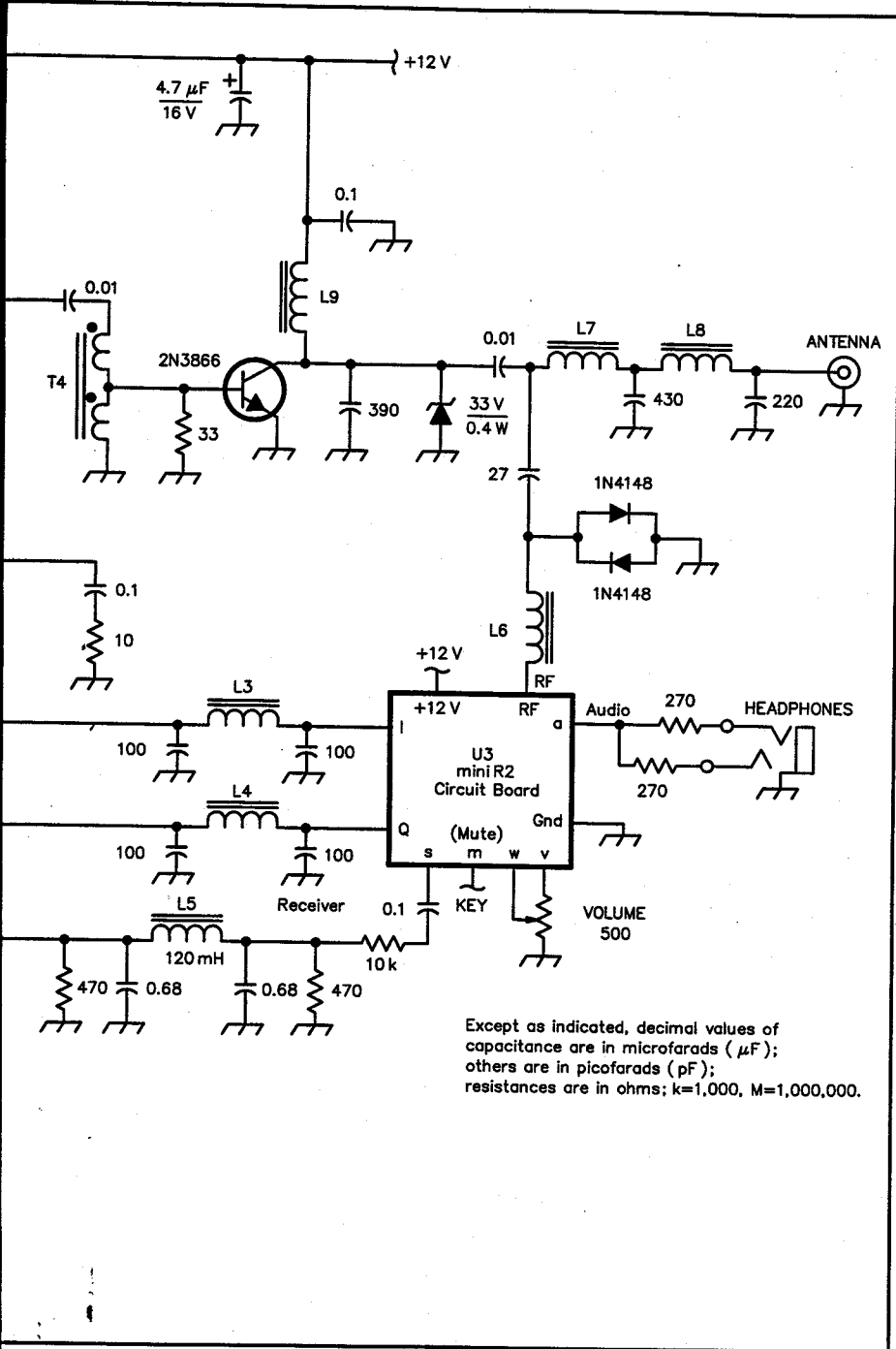


Figure 1—The little CW transceiver's block diagram. All of the radio's circuitry fits on two boards: the miniR2 receiver module, (Figure 3) available as a kit per Note 1, and an ugly-constructed module (Figure 2) containing the balance of the parts.

¹Notes appear on page 46.



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000.

There are four controls: **VOLUME**; bandset (**SET**); tuning (**TUNE**); and **RIT**. The band-set control is a very stiff capacitor that sets the tuning range somewhere in the 20-meter ham band. Normally, it is set to the CW portion. The tuning control then tunes from 14.000 to 14.070 MHz with a mark every 10 kHz. The tuning rate is quick, but acceptable. The combination of RIT and excellent skirt selectivity makes a very effective interference-fighting tool during contacts. Since full-break-in CW is used, no manual TR switch is needed.

There is a flaw in the ergonomics. Conventional radios have a "front panel" with

controls and a "rear panel" with connectors for power, antenna, headphones and key. Hand-held radios are designed to be conveniently operated while being held. This radio is neither, but it is much closer to a hand-held. Because of its conventional "rear panel" connections, there is no easy way to hold the radio while operating, and it needs to be propped up somewhere in the tent, with as much weight holding it in place as possible. The next time I build a backpack radio, I will make the box first and then find out how I want to operate it before blindly following conventional wisdom.

I made the clamshell case out of sheet

brass with soldered corners. Don't try this at home, kids. I have built almost as many sheet brass boxes as radios, and the first few hundred were pretty ugly. Even if you build one that looks nice, it still has a problem: It weighs more than the radio it contains. Next time I will make the case out of foam-sandwich-wood-epoxy composite. Trips to the local hobby shop for a sheet of $1/16$ inch aircraft plywood and the local boat store for a West System Maxi Repair kit and a little fiberglass cloth will provide the materials. I have built a bunch of those, too, and they started looking pretty good after about number 10. Rounded corners are a good idea for anything that is going to bounce around in a cloth bag.

Circuitry

Figure 1 shows the transceiver's block diagram and Figures 2 and 3 show the schematic. I call this circuit the "generic low-power transceiver," or "G-QRP rig" for short. It is full of ideas contributed by several generations of homebrew transceiver artists over the past few decades. I have used the same basic circuit for a number of different radios because it works well. The only significant departure from such classic QRP rigs as Roy Lewallen's "Optimized"¹ and Wes and Roger Hayward's "Ugly Weekender"^{2,3} is the use of an image-reject receiver. Sometimes I call this circuit "The Imposter" because it is impossible to tell that it is not a superhet just by operating it.

The circuitry in Figure 2 is all built "ugly style" on a piece of unetched copper clad board cut to the same dimensions as the miniR2 circuit board, with small vertical pieces soldered on and a shield enclosure soldered completely around the VFO. Ugly construction takes optimum advantage of the available space, builders talent and available parts, and generally outperforms printed circuitry in RF applications. "Ugly" radios can also be real original works of art, and their builders are justifiably proud of their creations.

Receiver module U3 (Figure 3), is a miniR2 kit, available from Kanga Products.⁴ The circuitry is described in detail in references cited at Notes 5 and 6. The miniR2 is half the size of the R2, has headphone-only audio output, and doesn't need any hand-picked parts. It sacrifices a little skirt selectivity and close-in dynamic range, but its improved noise figure makes its dynamic range, measured using ARRL's standard spacing of 20 kHz, a little better than the R2. I recommend the miniR2 for portable applications and the R2 for base-station operation in crowded bands.

The dashed line around the VFO is shielding. It is part of the circuit and is *not* optional. When a transmitter operates on the same frequency as its VFO, the VFO tank circuit acts as an antenna and picks up a little of the transmitted signal. The transmitted signal adds to the VFO signal, and

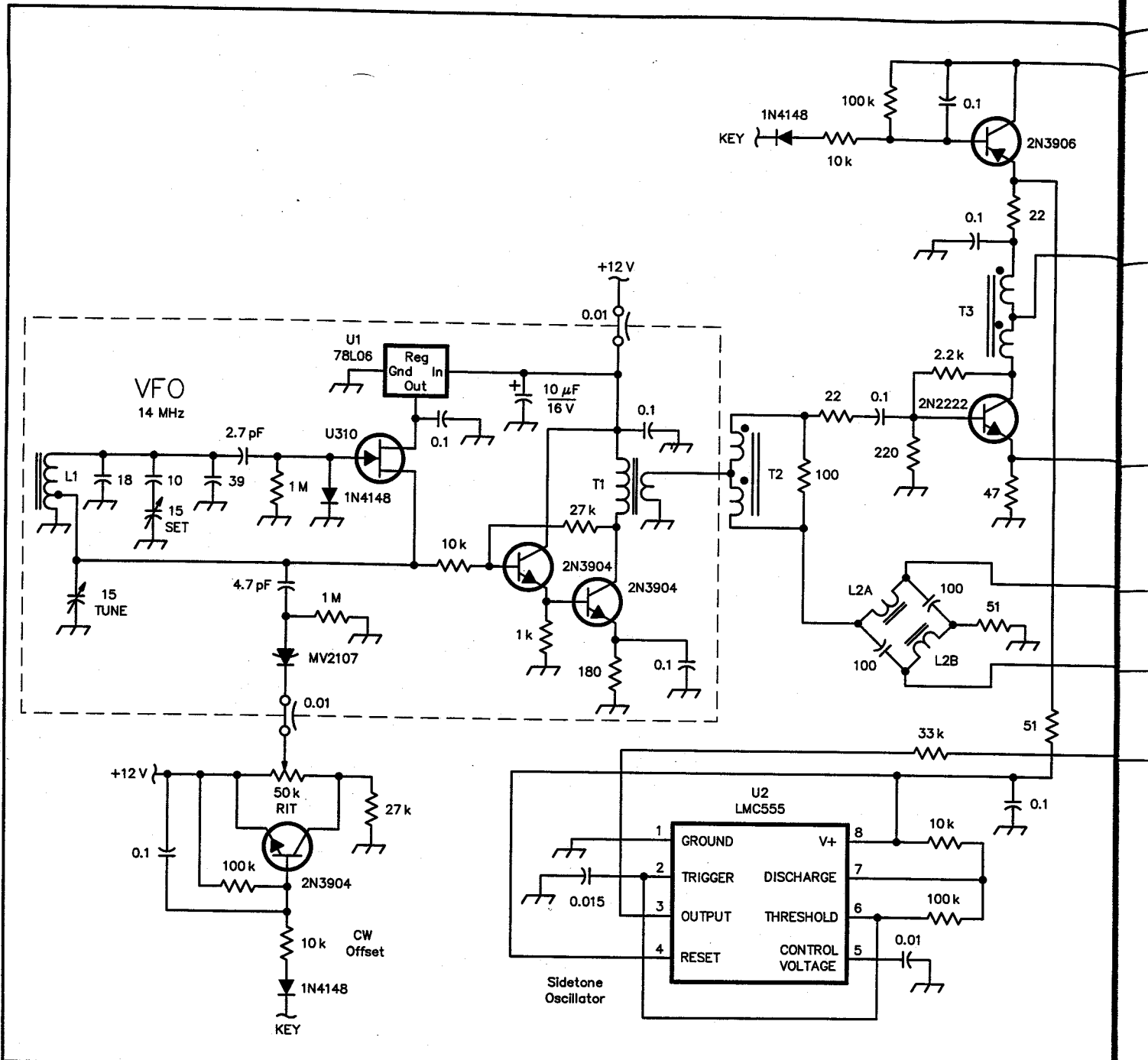


Figure 2—The miniature CW transceiver's VFO, transmitter and sidetone circuitry. All of the circuit's resistors are 1/4-W, 5%-tolerance units unless specified otherwise. The protective 33-V Zener diode at the 2N3866's collector is a 1N973 or equivalent; the MV2107 tuning diode used in the RIT circuit has a nominal capacitance of 22 pF at a tuning voltage of 4 V.

- L1—24 turns of #28 enameled wire on a T-37-6 toroidal powdered-iron core.
- L2—14 bifilar-wound turns of #28 enameled wire on a T-37-6 toroidal powdered-iron core.
- L3, L4—10 turns of #28 enameled wire on a T-37-6 toroidal powdered-iron core.

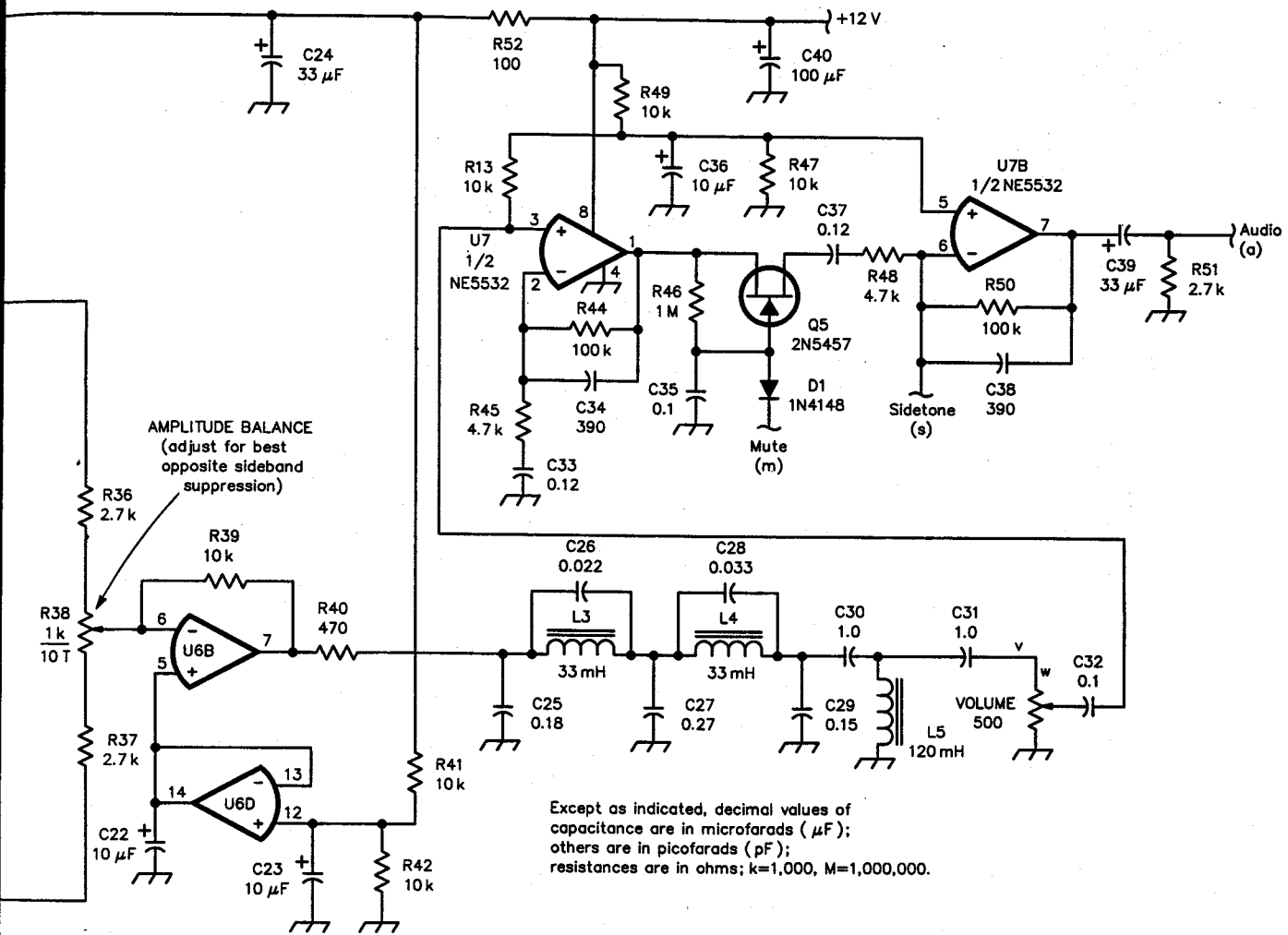
- L5—120-mH miniature choke.
- L6—35 turns of #28 enameled wire on a T-37-2 toroidal powdered-iron core.
- L7, L8—13 turns of #28 enameled wire on a T-37-6 toroidal powdered-iron core.
- T1—Primary (winding on 2N3904 side): 15 turns of #28 enameled wire on an FT-37-43 toroidal ferrite core; secondary: 3 turns of the same wire over the primary.

- T2, T3, T4—10 bifilar-wound turns of #28 enameled wire on an FT-37-43 toroidal ferrite core.
- U1—78L06 6-V, 100-mA voltage regulator.
- U2—LMC555 (or equivalent) CMOS 555 timer.

and speaker be external or built-in? For that matter, there are lots of very good reasons to dis-integrate the radio even more, with separate VFO, transmitter and receiver modules. I decided on external batteries

because disconnecting them positively turns off the radio, and they can be used in my flashlight if needed. An antenna tuner and VSWR meter are not always needed, so they are left out. Sometimes it is nice to use

a "real" key (bigger and heavier than the whole radio!) so I left that out too. I use headphones to keep battery drain low, so there is no speaker. Everything else is in the little package.



the phase of the vector sum of both signals differs from that of the VFO signal by itself. To satisfy the Barkhausen criteria for oscillation,⁷ the VFO quickly changes its frequency to maintain 0° of phase shift around the loop. This is called *chirp* (in polite company). There are several good ways to eliminate chirp. One is to operate the VFO on a different frequency than the transmitted signal, either by using a frequency multiplier or a heterodyne scheme. Another is to properly shield the VFO, so that the transmitted signal can't get in. Since shielding is inexpensive in a homebrew radio and also improves thermal and mechanical stability, it is a good approach.

The LO phase-shift network shown in Figure 1 is different than those shown in the original R2 article. It provides 90° of

phase shift over a very broad bandwidth, and acceptable amplitude balance when used to drive saturating LO ports. With the component values shown, it works nicely from 13 to 15 MHz, after tweaking at any frequency in the 20-meter band. The lumped-element eighth-wave transmission lines in each leg provide a means of tweaking the relative phase of the output ports. This network was described in *SPRAT*.⁸

The Complete Station

The complete station consists of the radio, a dipole antenna with tuned feed line, a microswitch key, Walkman headphones, and an 8-AA-cell battery pack. It all fits in a little camera bag. I stuff all the pieces in zipper-lock bags—a habit I picked up in the rainy Pacific Northwest. The entire

package weighs about as much as one good meal, and is small enough that I don't have to leave anything home to make room in the backpack.

Operation

I try to get the antenna up as high as I can in the trees. Then I listen and see if the band is open. If there are lots of loud signals, especially up near 14.060 MHz, I tune around for a loud CQ to answer. Full break-in and a good clean CW signal just like the appliance at home make for easy contacts. When the band is open, 1 W of CW to a dipole works out just fine—there is no need to go begging "alms for the weak" by sending "QRP" every other word. (Opinions run strong on the HF bands, and some stations hear much better if they think you are run-

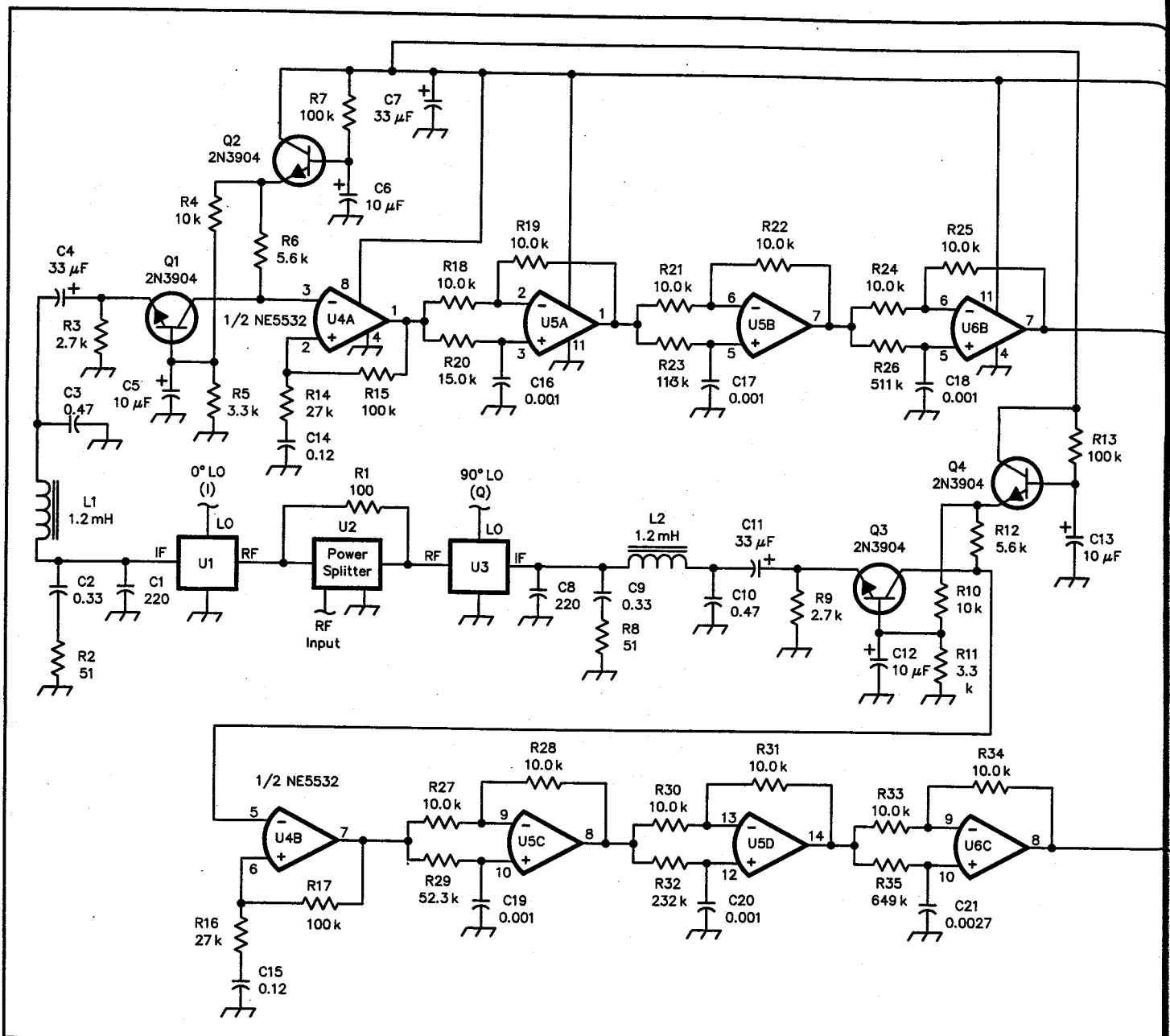
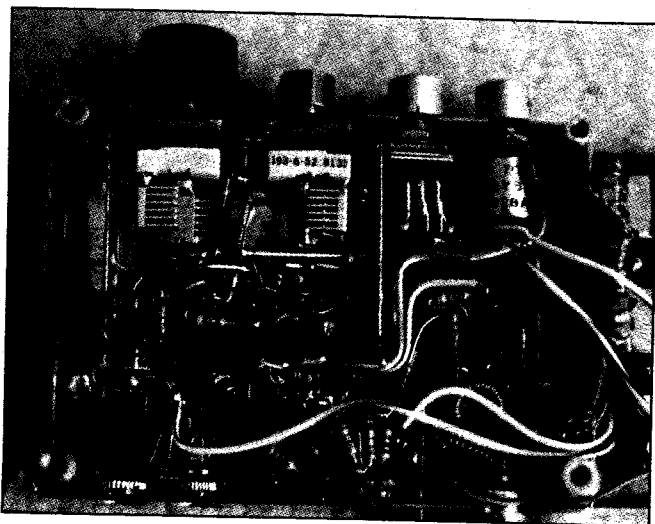


Figure 3—The transceiver's receiver portion consists of a miniR2 (miniature single-signal direction-conversion receiver) module (see Note 1). All of the circuit's resistors are 5%-tolerance, 1/4-W types unless otherwise indicated.

- | | | |
|---|--|--|
| C1, C8—220 pF, chip | C30, C31—1.0 μ F, 100 V, 10%
(Panasonic ECQ-E Series) | R5, R11—3.3 k Ω |
| C2, C9—0.33 μ F, 50 V, 5% (Panasonic V Series) | C32, C35—0.1 μ F, 50 V, 5%
(Panasonic V Series) | R6, R12—5.6 k Ω |
| C3, C10—0.47 μ F, 50 V, 5% (Panasonic V Series) | C33, C37—0.12 μ F, 50 V, 5% (Panasonic V Series) | R7, R13, R15, R17, R44, R50—100 k Ω |
| C4, C7, C11, C24, C39—33 μ F, 16 V, 20%
(Panasonic KA Series) | C34, C38—390 pF, 63 V, COG (Panasonic monolithic ceramic) | R14, R16—27 k Ω |
| C5, C6, C12, C13, C22, C23, C36—10 μ F, 16 V, 20% (Panasonic KA Series) | C40—100 μ F, 16 V, 20% (Panasonic KA Series) | R18, R19, R21, R22, R24, R25, R27, R28, R30, R31, R33, R34—10.0 k Ω , 1/4 W, 1% |
| C14, C15—0.12 μ F, 50 V, 5% (Panasonic V Series) | D1—1N4148 diode | R20—15.0 k Ω , 1/4 W, 1% |
| C16—20—0.001 μ F (Xicon 102 FT) | L1, L2—1.2 μ H (Toko 10RB, Digi-Key TK4401) | R23—113 k Ω , 1/4 W, 1% |
| C21—0.0027 μ F (Xicon 272 FT) | L3, L4—33 μ H (Toko 10RB, Digi-Key TK4418) | R26—511 k Ω , 1/4 W, 1% |
| C25—0.18 μ F, 50 V, 5%
(Panasonic V Series) | L5—120 μ H (Toko 10RB, Digi-Key TK4426) | R29—52.3 k Ω , 1/4 W, 1% |
| C26—0.022 μ F, 50 V, 5%
(Panasonic V Series) | Q1-4—2N3904 NPN BJT | R32—232 k Ω , 1/4 W, 1% |
| C27—0.27 μ F, 50 V, 5%
(Panasonic V Series) | Q5—2N5457 N-channel JFET | R35—649 k Ω , 1/4 W, 1% |
| C28—0.033 μ F, 50 V, 5%
(Panasonic V Series) | R1, R52—100 Ω , 1/8 W chip | R38—1 k Ω , 10-turn trimmer pot (Spectrol 74W or equivalent) |
| C29—0.15 μ F, 50 V, 5%
(Panasonic V Series) | R2, R8—51 Ω | R40—470 Ω |
| | R3, R9, R36, R37, R51—2.7 k Ω | R45, R48—4.7 k Ω |
| | R4, R10, R39, R41, R42, R43, R47, R49—10 k Ω | R46—1 M Ω |
| | | U1, U3—TUF-1 mixer (Mini-Circuits) |
| | | U2—TK2818 splitter (Toko) |
| | | U4, U7—NE5532 dual low-noise op amp |
| | | U5, U6—NE5514 quad op amp |



RICK CAMPBELL, KK7B

A look into the transceiver's VFO before the VFO shield enclosure was soldered closed. Air-dielectric trimmer capacitors serve as the VFO's SET and TUNE controls; the VFO tuned-circuit inductor (L1) is between them.

ning 100 W.) When 20 meters is in bad shape, I put the batteries in the flashlight and dig out the bent-up paperback that has been poking me in the ribs all day.

Conclusions

This little radio works well. Its audio distortion is low; its two-tone, third-order dynamic range is better than most commercial transceivers; and its full-break-in CW makes it easy to operate. The combination of ugly construction for the RF stages and a commercially available PC board kit for the receiver signal processing is an attractive approach to high-performance custom radio engineering. In the past, I only put radio equipment in the backpack for special events like Field Day. This rig is small and light enough that I can throw it in just in case I feel like operating.

I named this radio the "Passport" because it has been all the way around the world. I carried it with me to the Asia-Pacific QRP conference in Kuching, Sarawak, East Malaysia, in November 1994, and loaned it to the Reverend George Dobbs, G3RJV. He carried it back to England, and then returned it to me at Dayton. It has also made two trips to the West Coast and back. Judging by the amount of travel this little radio has done, my original goals for its design must have been met!

Acknowledgments

Once again, I thank the Reverend George Dobbs, G3RJV, for twenty years of publishing delightful little radio circuits. Much of the circuitry presented here is a natural evolution of material from the past two decades of *SPRAT*.⁹

This radio has "Wes Hayward" written all over it. From the first inklings of ultraportable backpacking radios to his review of this manuscript, he has been a part of the entire process. Wes made significant contributions to the development of the miniR2 board from the R2, and did an extensive performance evaluation of the radio.

Notes

- ¹Roy Lewallen, W7EL, "An Optimized QRP Transceiver," *QST*, Aug 1980, pp 14-19; also see Feedback, *QST*, Nov 1980, p 53.
- ²Roger Hayward, KA7EXM, and Wes Hayward, W7ZOL, "The 'Ugly Weekender,'" *QST*, Aug 1981, pp 18-21.
- ³Roger Hayward, KA7EXM, "The 'Ugly Weekender' II: Adding a Junk-Box Receiver," *QST*, Aug 1992, pp 27-30.

Strays

AN UNUSUAL RFI PROBLEM

◇ Ben Cook, W7MHR, is on the staff at KSRV radio, in Ontario, Oregon. Here is the gist of a story from nearby Fruitland, Idaho, that he and KSRV recently covered.

The employees of Dame Moulding Co started hearing the sound of a baby crying on the company's intercom system. A quick check convinced them that there was no baby on the premises, so they called the local police. Fruitland Police Officer Stephanie Steele, KC7DBA, responded. Reviewing the evidence, Stephanie had a hunch. Maybe the baby's cries were getting into the intercom from a radio transmitter.

Officer Steele enlisted the help of Bob Haggerty, AB7HL, for a fox hunt. They quickly zeroed in on an apartment building. Officer Steele, accompanied by Police Chief Bud Reifsnnyder and a representative of the Idaho Department of Health and Welfare, soon found the crying baby, whose bedroom was monitored by one of the radio-transmitter "baby monitors."

Chief Reifsnnyder reported that the baby was not a victim of child abuse, as had first been feared, and expressed his thanks to the hams for quickly solving this mystery.—Thanks to Bob Haggerty, AB7HL, for this crimebusters tip.

⁴Kanga US, 3521 Spring Lake Dr, Findlay, OH 45840, tel 419-423-5643. A miniR2 kit that includes the circuit board and the parts that mount on it is available for \$95; a board by itself is \$20. Add \$4.50 for shipping and handling. More information on Kanga kits is available by e-mail (kanga@bright.net) and from Kanga's World Wide Web home page (<http://qrp.cc.nd.edu/kanga/>), which includes the full Kanga catalog.

⁵Rick Campbell, KK7B, "High-Performance, Single-Signal Direct-Conversion Receivers," *QST*, Jan 1993, pp 32-40.

⁶Rick Campbell, KK7B, "A Single-Board No Tune Transceiver for 1296?" *Proc of Microwave Update '93*, pp 17-38 (Newington: ARRL, 1993).

⁷See, for example, the How Oscillators Work section of Chapter 14, AC/RF Sources (Oscillators and Synthesizers), in *The ARRL Handbook for Radio Amateurs*, 1995 edition.—Ed.

⁸Rick Campbell, KK7B, "KK7B SPRAT Technical Cartoon #1, A Passive Phase-Shift Network to Cover the Whole Band," *SPRAT*, Winter 1994/5, pp 20-22.

⁹*SPRAT* is the membership journal of the G QRP Club, annual dues for which are US\$10 (MasterCard and VISA payment is acceptable). For details, a sample of the journal *SPRAT* and an application form, write to George Dobbs, G3RJV, St Aidan's Vicarage, 498 Manchester Rd, Rochdale, OL11 3HE, United Kingdom, or use e-mail (g3rjv@gqrp.demon.co.uk). Membership renewal facilities are available in the US. *SPRAT* is airmailed 4 times a year to each member.

QST-



COURTESY OF MAC MCNEELEY, WN3C

I was fascinated by the homebrew towers shown in Up Front in *QST* in August. This photo shows a 40-foot, tilt-over homebrew steel tower designed by my father, Orland McNeeley, K8SGW (SK). He and I built it together in 1959, and each piece of tower leg and lattice was hand cut, drilled and bolted together. This is also a reminder of the "old days"; unlike modern ham stations that are predominantly set up in the operator's home, ham shacks were often kept in buildings separate from the house—garages, storage sheds, farm buildings or, as in this case, a "shack" built just for the station.—Richard "Mac" McNeeley, WN3C, 498 Brampton Ct, Millersville, MD 21108.