Kanga US

3521 Spring Lake Drive
Findlay, OH 45840
419-423-4604
kanga@kangaus.com
www.kangaus.com

Jan. 1, 2007

Thanks for purchasing the new microR2 kit! I think you will find it is a good receiver to build and use. The kit has minimal documentation included, so you need to be comfortable building using only a schematic, parts layout, and parts list. If you are not, please return the kit for a full refund.

A copy of the article by KK7B on the MicroR2 that was published in October 2006 QST is included. If you want more background on the microR2, you will find most of the stages of the receiver are in the ARRL Book Experimental Methods in RF Design. The book is a great source of info about DC and phasing type rigs, and a good source of information if you are interested in building your own gear.

Note that there are a few differences between the microR2 as supplied in the kit and the microR2 as published in the article. In particular, the values of the CW filter components are a bit different, and volume control (10k vs 25k) is different. The fixed resistor (R41) associated with the volume control is also a different value. The 25k volume control will provide a higher maximum volume if needed.

The photo in the QST article is of a prototype PC board. There are a few minor differences between the prototype board and the production board.

Be sure to read the construction notes I have included. I have built one microR2, and the first run of 100 has been sold. No significant problems have been reported. If anyone has questions, comments, or suggestions about the microR2, contact me via e-mail at the address above, and I will try to post any helpful information on my web site in the microR2 section. If it looks like it will be helpful, I will start a microR2 Yahoo group.

Enjoy the microR2!

73 – Bill – N8ET
Kanga US

Jan 1, 2007

MicroR2 Construction Notes – Kanga US version

In no particular order –

A volume control has been added. This was done by replacing R41 (1K on the schematic in the article) with a 10k resistor in parallel with a 10k pot. R41 on the parts list and on the separate schematic is shown as 10K. The pot is not shown on the schematic, and does not have a designator on the parts list. The easiest way to connect the pot to the board is to leave out C14 (220 pf) and connect the two wires to the mounting holes for C14. You can mount C14 across the pot off the board.

The mute connection (W6) must be shorted for the LNA to work in the receive mode. It is open in the transmit mode.

+12 volts DC is connected to W10, W7 and W4.

Be sure to put jumpers on jp1 and jp2 – otherwise there will be no audio!

I used twisted pairs to make all off-board and inter-board connections.

W9 connects to W3, and W8 connects to W2. If that gives you the wrong sideband, swap the connections.

Be sure to get the 1% and matched parts in the right part of the circuit. They are packed in a separate plastic bag, and the 1% resistors are blue.

C25 is listed on the parts list as 39pf, and is supplied as 39pf. It is on the schematic in the article it is 36pf.

The schematic shows only SSB values. If you have a CW version of the microR2, use the values for the CW parts as listed on the parts list. That includes 4 resistors in the audio phasing network and the audio filter components.

C40 is the main tuning capacitor. It is mounted off the PC board, and is connected to the board with short stiff pieces of wire.

With the tap on L7 set at 8 turns from ground the receiver I built covered about 225 KHz. If you want to cover less of the band, move the tap closer to the ground end of the coil. For more coverage, move it a turn or two away from the ground end.

Note that C28 (39 pf chip cap) mounts on the bottom of the board. The article schematic shows it as C29.

The microR2 is very quiet. Don't be fooled (like I was the first time) into thinking it is not working when you turn it on and don't hear any background noise.

You will get more volume from the microR2 if you use higher impedance headphones rather than an 8 ohm headset.

R13 and R14 were originally 100k. They have been changed to 27k. C7 was originally 33 uF. It has been changed to 10 uF.

The QST article has some pin numbers (inputs to the op amps) on the NE5532 IC's marked incorrectly. The PC board is correct!

For technical info and theory of operation, read chapters 8 and 9 in Experimental Methods in RF Design.

Parts List – microR2 Receiver

Qty	Designator	Value
1	C36	2.2p
1	C34 (green trimmer)	20p trimmer
1	C28 (taped to piece of paper in parts bag)	39p chip
1	C25	39p
1	C24 (yellow trimmer)	65p trimmer
1	C35	68p
1	C40	100pf variable
2	C13, C14	220p
1	C29	390p
3	C20, C22, C26	470p
4	C8, C9, C10, C11 matched to 1%	10.0nf
6	C19, C21, C23, C27, C37, C38	100nf
2	C5, C6	150nf
4	C30, C31, C32, C33	.82uf
1	C7	10uf
7	C1, C2, C3, C4, C18, C39	33uf
1	C12	100uf
4	R46, R48, R49, R53	51 ohm
3	R8, R47, R52	100 ohm
2	R44, R50	150 ohm
3	R39, R40, R42	470 ohm
1	R4	2.2k
2	R1, R2	2.4k
2	R19, R23	5k trimmer
1	R20	7.5k
2	R6, R7	9.1k
10	R3, R15, R16, R17, R18, R21, R22, R38, R41, R43	10k
10	R28, R29, R30, R31, R32, R33, R34, R35, R36, R37	10.0k 1%
4	R9, R10, R13, R14	27k
4	R5, R11, R12, R45	100k
1	R51	1M
3	Q1, Q2, Q3	2N3904
2	Q4, Q5	J310
5	U1, U2, U3, U4, U5	NE5532
1	U6	LM78L06
2	MX1, MX2	TUF-3
2	RFC1, RFC2	15uh
1	T1 - T37-2 core (red) 17 turns bifilar #28	
1	L3 - T37-2 (red) 18 turns #28	
1	L4 - T37-2 (red) 40 turns #30	
2	L5, L6 (black dot on top)	3.9mh
1	L7 - T50-6 (yellow) 36 turn primary #28, tapped at 8 turns from ground end. 2 turn link #28	
10	W1, W4, W6, W7, W8, W9, W10, J1, JP1, JP2	2 pin header
1	W2, W3 together	4 pin header

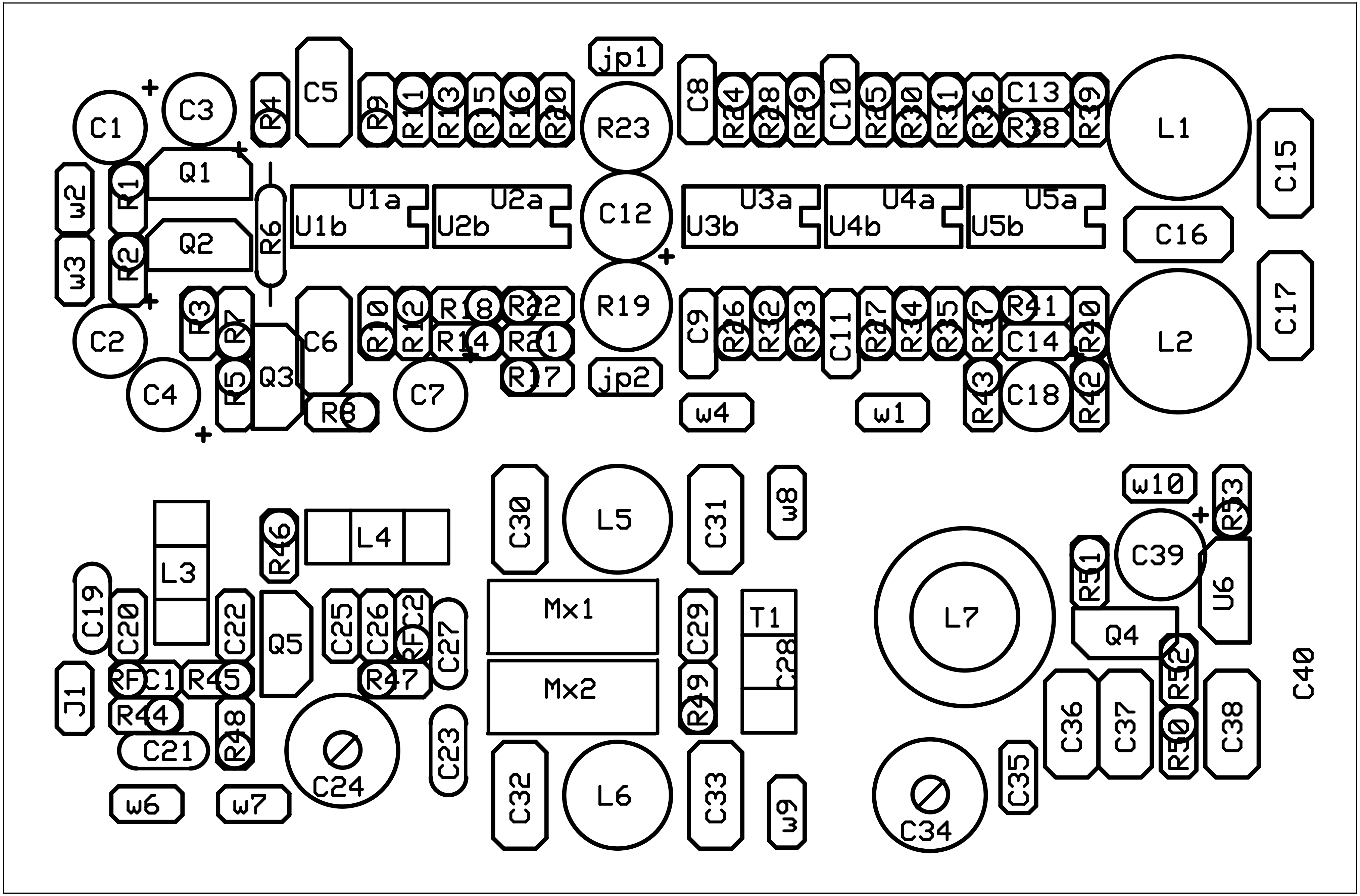
	SSB Specific Parts	
1	R24	2.32k 1%
1	R25	28.0k 1%
1	R26	9.53k 1%
1	R27	115k 1%
1	L1, L2	33mh
1	C15	150nf
1	C17	180nf
1	C16	220nf

	CW Specific Parts	
1	R24	4.75k 1%
1	R25	41.2k 1%
1	R26	16.9k 1%
1	R27	147k 1%
2	L1, L2	100mh
2	C15, C17	390nf
1	C16	560nf

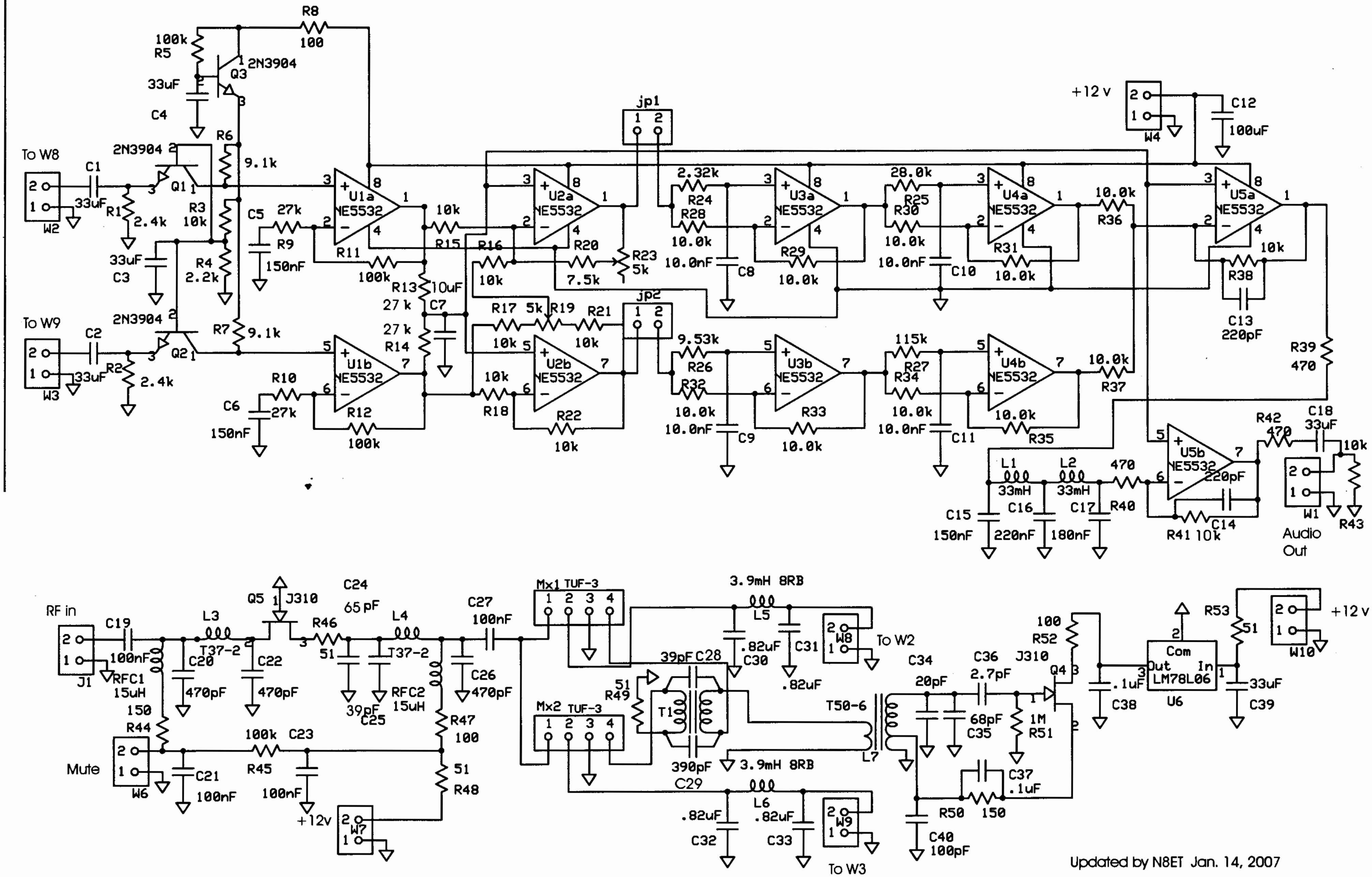
10k pot – volume control – see notes

PC Board

Also included are 2 shorting blocks for JP1 and JP2, along with 10 x 2 pin sockets to mate with the headers.



C:\Documents and Settings\rcampbe\Layouts\R2micro.pcb (Silkscreen)



Updated by N8ET Jan. 14, 2007

KK7B		
microR2		
Rick Campbell	Rev 4 3/8/06	Page # or name

The MicroR2 — An Easy to Build "Single Signal" SSB or CW Receiver

A noted radio designer shows us how to make a simple receiver with very fine performance.

Rick Campbell, KK7B

Throughout the 100 year history of Amateur Radio, the receiver has been the basic element of the amateur station. This little single PC board receiver captures some of the elegance of the classic all-analog projects of the past while achieving the performance needed for operation in 21st century band conditions across a selected segment of a single band.

Elements of an Amateur Radio Station

The block diagram of a basic Amateur Radio station shown in Figure 1 has not changed for more than a century. It could be a spark station or Elecraft KX-1. In earlier times, the Amateur Radio operator built and maintained the various pieces — or at least obtained a working receiver and transmitter and then assembled them into a working station. These days that enjoyable task has often been delegated to the radio designer, so that even a kit transceiver like the KX-1 leaves few decisions to the owner-operator.

Why should kit designers and a few lucky radio engineers at radio manufacturers have all the fun? Well, there are good reasons. A complete spark station might have a total of 20 or 30 components (half of which can kill you quicker than a bottle of Scotch and a Corvette). Modern radios have several thousand parts — over a hundred on back-order at any given time. Even for those who have the time to build an airplane, sailboat or transceiver, the practical difficulties of parts procurement and modern construction techniques, to name a couple, conspire against the successful completion of an all homebrew station.

So most of us don't build complete stations, even though we often think about it. We repair and restore old boatanchor receivers, wire up the stereo speakers, and maybe build a simple QRP kit or a transmitter like Wes Hayward's MKII from April 2006 *QST*. Occasionally we dig through the junk box in the garage and stare off into space while holding that old National Velvet Vernier dial from the flea market, daydreaming about the receiver we imagined building with it. Oh, for the good old days.

Bringing Back the Homebrew Station

We can recapture the joy of assembling a unique station by dividing the effort up into smaller tasks and working on them one at a time. We can approach a homebrew station the same way. Start with a simple transmitter like the MKII, make a few contacts using the receiver section of a transceiver, and then spend some time thinking about an appropriate companion receiver. I like the simplicity of a three-transistor receiver, as described in Chapter 8 of *Experimental Methods in RF Design* (*EMRFD*) but I prefer the performance of the classic Drake 2B receiver.[1] Thus, I designed a relatively simple single PC board receiver that performs like a '2B over a 100 kHz segment of a single band.

A major advantage of a station with a separate receiver and transmitter is that each can be used to test the other. There is a particularly elegant simplicity to the combination of a crystal controlled transmitter and simple receiver. The receiver doesn't need a well-calibrated dial because the transmitter is used to spot the frequency. The transmitter doesn't need sidetone, VFO offset or other circuitry because the crystal determines the transmitted frequency and the receiver is used to monitor the transmit note off the air. Even the receiver frequency stability may be relaxed, because there is no on-the-air penalty for touching up receiver tuning during a contact. This was the well thought out logic behind the original Novice license rules. Novices in the '50s and '60s developed skills that few Amateur Extra class hams possess these days. Later articles in

[1]Notes appear on page 32.

this series will explore a number of options for setting up simple stations and moving to different bands — but let's dive into the design and construction of a simple receiver that may be used as a companion for an SSB or CW transmitter on 40 meters, or as a tunable IF for higher bands.

Introducing the MicroR2 SSB/CW Receiver

Figure 2 is the block diagram of this little receiver, which can be built in a few evenings. The block diagram is similar to the simple direct conversion receivers of the early 1970s, but there the similarity ends. This radio takes advantage of 40 years of evolution of direct conversion HF receivers by some very talented designers. If you don't think that makes a difference, compare the performance of a superhet built in 1930 with one built in 1970.

"Single Signal" Reception Makes All the Difference

One major difference from early direct conversion receivers is the use of phasing to eliminate the opposite sideband. The receiver in Figure 2 is a "single-signal" receiver that only responds to signals on one side of zero beat. Basic receivers in the '50s and '60s would hear every CW signal at two places on the dial, on either side of zero beat. As you tuned through a CW signal, first you heard a high-pitched tone, and then progressively lower audio frequencies until the individual beats became audible, and then finally all the way down to zero cycles per second: zero beat. As you tuned further you heard the pitch rise back up until the high frequency CW signal became inaudible again at some high pitch.

You can hear this on a modern transceiver if you switch in an AM bandwidth IF filter in SSB mode. It's not too terrible to hear the desired signal at two places on the dial — but having twice as much interference and noise is inconvenient at best. Add-on accessories to improve selectivity, external Q-multipliers or Sideband Slicers, or internal mechanical or crystal filters were once popular. Most modern radios, even simple ones, include a simple crystal or mechanical filter for single-signal IF selectivity. Since a direct conversion receiver has no IF, selectivity is obtained by a combination of audio filtering and an image-rejecting mixer. These are old techniques — the Central Electronics Sideband Slicer used them in the 1950s. Chapter 9 of *EMRFD* has a complete discussion of image-reject or "phasing" receivers, and the 2006 edition of *The ARRL Handbook for Radio Communications* has a good overview of both conventional superheterodyne and phasing receivers.

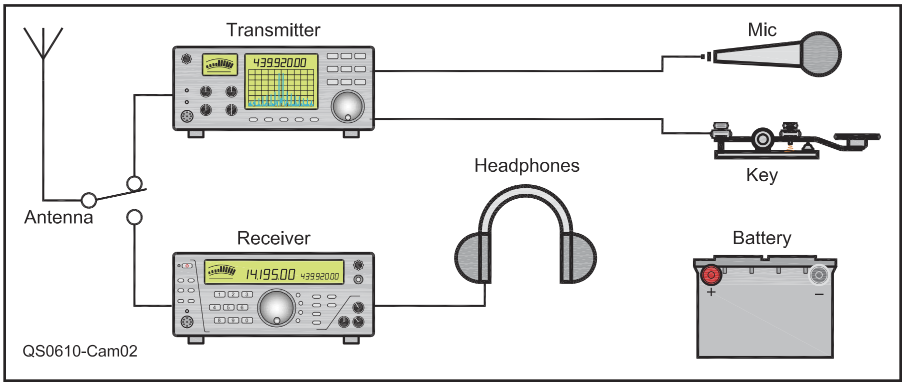


Figure 1 — Block diagram of a basic Amateur Radio station.

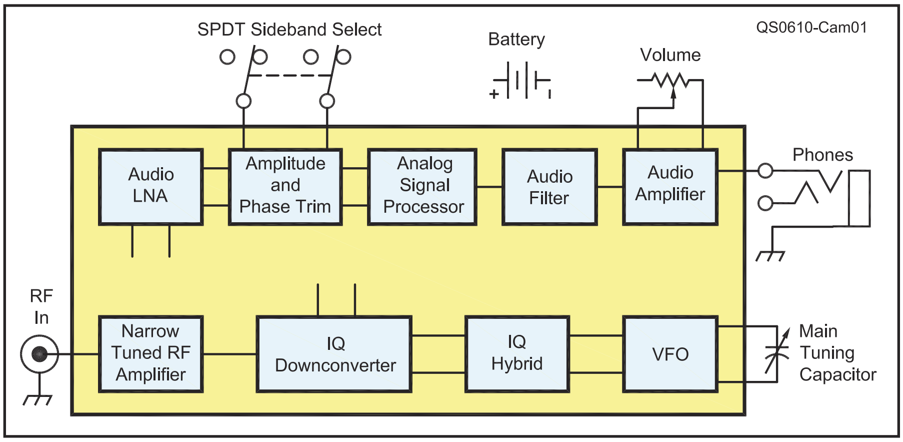


Figure 2 — Block diagram of the MicroR2 SSB/CW receiver.

Table 1

MicroR2 Receiver Performance

Parameter	*Measured in the ARRL Lab*
Frequency coverage: Receive, 7.0-7.1 or 7.2-7.3.	Receive, as specified.
Power requirement.	50 mA, tested at 13.8 V.
Modes of operation: SSB, CW.	As specified.
Receiver	*Receiver Dynamic Testing*
SSB/CW sensitivity,	7.0 MHz, –131 dBm
Opposite sideband rejection;	1000 Hz, 42 dB
Two-tone, third-order IMD dynamic range: Not specified.	20 kHz, 7.0 MHz, 81 dB
Third-order intercept: Not specified.	20 kHz, –5 dBm, 7.0 MHz.

Third-order intercept points were determined using equivalent S5 reference.

Block by Block Description

A brief description of each block in Figure 2 and the schematic in Figure 3 follows. The circuits are all described in detail in *EMRFD*.

The 50 Ω RF input connects to a narrow tuned RF amplifier. The first circuit elements are a low-pass filter to prevent strong signals above the receiver tuning range — primarily local TV and FM broadcast stations — from arriving at the mixers where they would be downconverted to audio by harmonics of the local oscillator. The common-gate junction field effect transistor (JFET) low-noise amplifier (LNA) sets the noise figure of the receiver and provides some gain, but even more importantly, it isolates the mixers from the antenna. Isolation prevents the impedance at the RF input from affecting the opposite sideband suppression, and reverse isolation prevents local oscillator leakage from radiating out the antenna

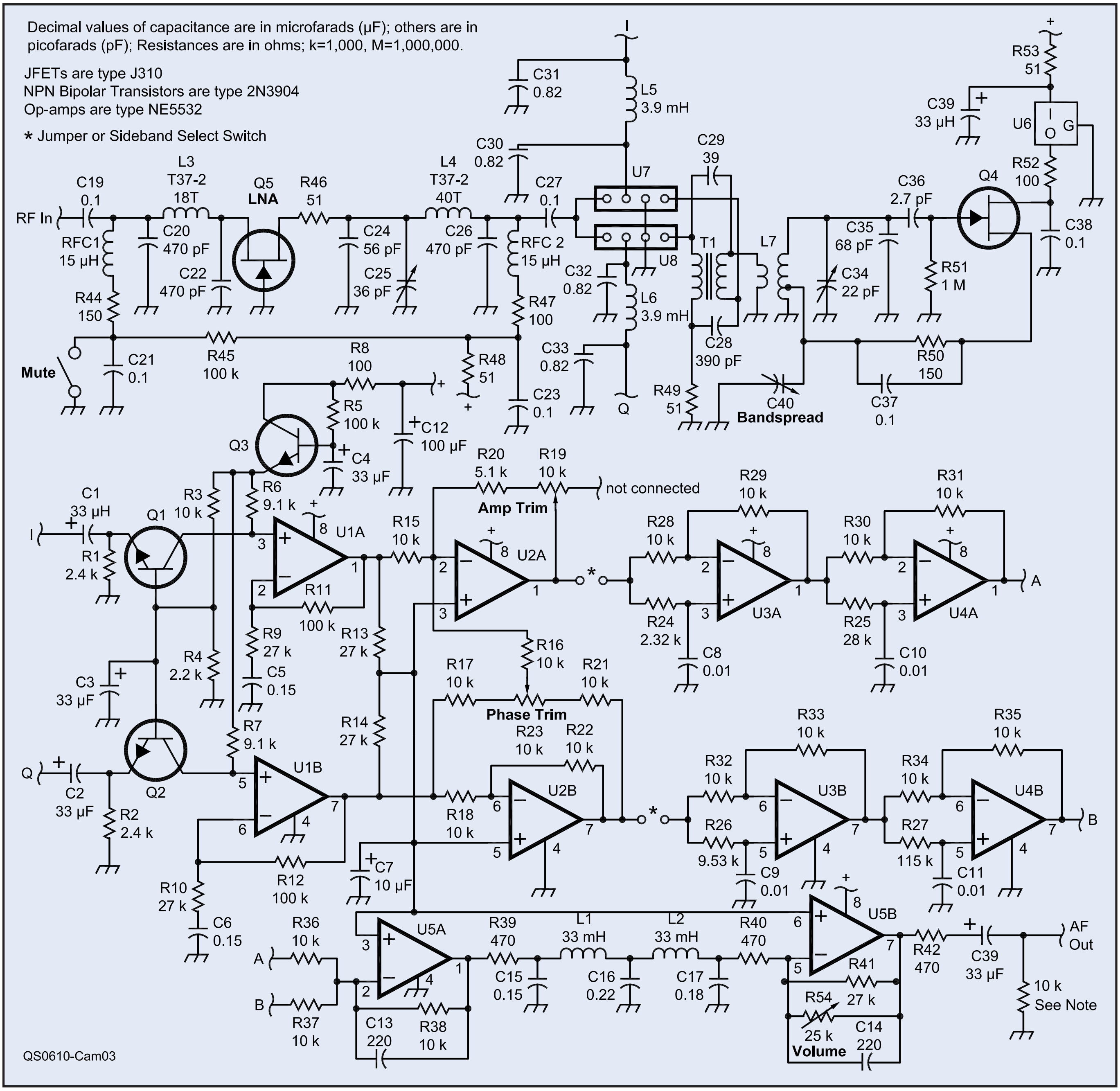


Figure 3 — Schematic diagram of the MicroR2 SSB/CW receiver. The parts are listed in Table 2.

and causing interference to others as well as tunable hum.

The tuned drain circuit provides additional selectivity and greatly improves dynamic range for signals more than a few hundred kHz from the desired signal. Lifting the source of the JFET allows a convenient mute control — changing the LNA from a 10 dB amplifier to a 40 dB attenuator.

Following the LNA are the IQ (short for "in-phase" and "quadrature," the labels we use for the two signal paths in a phasing system) downconverter and local oscillator (LO) IQ hybrid. Many of the more subtle difficulties of phasing direct conversion receivers are avoided by a compact, symmetrical layout and direct connection of all the mixer ports to the appropriate circuit elements without the use of transmission lines. The audio low-pass filters ensure that only audio exits the downconverter block, and set the close-in dynamic range of the receiver. The inductors in the low-pass filters will pick up magnetic hum from nearby power transformers — more on this topic later.

To the right of the IQ hybrid is a basic JFET Hartley VFO. In this application, it is stripped of all the usual accoutrements like buffer amplifiers and receive incremental tuning (RIT). The drain resistor and diodes in the mixers set the operating level. This simplified configuration, with a link on the VFO inductor directly driving the twisted-wire hybrid, works very well over a 5% bandwidth (350 kHz at 7 MHz) when the quadrature hybrid is optimized at the center frequency and all voltages except the LO are less than a few millivolts.[2]

The top half of the block diagram operates entirely at audio. The left block is a matched pair of audio LNAs with a noise figure of about 5 dB and near 50 Ω input impedance, to properly terminate the low-pass filters at the IQ mixer IF ports. These are directly coupled into a circuit that performs the mathematical operations needed to remove amplitude and phase errors from the I and Q signal paths. This is a classic use of operational

Table 2
MicroR2 Parts List

Parts for CW and SSB Version

C1-C4, C18 — 33 µF, 16 V electrolytic.
C5, C6 — 0.15 µF, 5% polyester.
C7 — 10 µF, 16 V electrolytic.
C8-C11 — 0.01 µF, polyester matched to 1%.
C12 — 100 µF, 16 V electrolytic.
C13, C14 — 390 pF, NPO ceramic.
C15 — 0.15 µF, 5% polyester, see Note A.
C16 — 0.22 µF, 5% polyester, see Note A.
C17 — 0.18 µF, 5% polyester, see Note A.
C19, C21, C23, C27, C37, C38 — 0.10 µF, 5% polyester.
C20, C22 — 470 pF, NPO ceramic.
C24 — 3-36 pF, poly trimmer capacitor.
C25 — 56 pF, NPO ceramic.
C26 — 470 pF, NPO ceramic.
C28 — 39 pF, NPO ceramic on back of board.
C29 — 390 pF, NPO ceramic, see Note B.
C30-C33 — 0.82 µF, 5% polyester, see note C.
C34 — 2.2-22 pF, poly trimmer capacitor.
C35 — 68 pF, NPO ceramic.
C36 — 2.7 pF 5% NPO 1000V ceramic.
C39 — 33 µF, 16 V electrolytic.
C40 — Variable capacitor, see Note D.
L1, L2 — 33 mH inductor, see Note A.
L3 — 18t #28 T37-2, see Note E.
L4 — 40t #30 T37-2, see Note E.
L5, L6 — 3.9 mH inductor, see Note C.
L7 — 36t #28 T50-6, tap at 8 turns with a 2 turn link, see Note E.
Q1-Q3 — 2N3904.
Q4, Q5 — J310.
R1, R2 — 2.4 kΩ.
R3, R15-R18, R21, R22, R38, R43 — 10 kΩ.
R4 — 2.2 kΩ.
R5, R11, R12, R45 — 100 kΩ.
R6, R7 — 9.1 kΩ.
R8, R47, R52 — 100 Ω.
R9, R10, R13, R14, R41 — 27 kΩ.
R19, R23 — 10 kΩ trimpot.
R20 — 5.1 kΩ.
R24 — 2.32 kΩ, 1% see Note A.
R25 — 28.0 kΩ, 1% see Note A.
R26 — 9.53 kΩ, 1% see Note A.
R27 — 115 kΩ 1% see Note A.
R28-R37 — 10.0 kΩ 1%.
R39, R40, R42 — 470 Ω.
R44, R50 — 150 Ω.
R46, R48, R49, R53 — 51 Ω.
R51 — 1 MΩ.
R54 — 25 kΩ volume control.
RFC1 — 15 µH molded RF choke.
RFC2 — 15 µH molded RF choke.
T1 — 17 t two colors #28 bifilar T37-2, see Note E.
U1-U5 — NE5532 or equivalent dual low-noise high-output op-amp.
U6 — LM7806 or equivalent 6 V three terminal regulator.
U7, U8 — Mini-Circuits TUF-3 diode ring mixer.

Note A: Make the following parts substitutions for a CW only version:
R24 — 4.75 kΩ, 1%.
R25 — 41.2 kΩ, 1%.
R26 — 16.9 kΩ, 1%.
R27 — 147 kΩ, 1%.
C15 — 0.47 µF, 5% polyester.
C16 — 0.68 µF, 5% polyester.
C17 — 0.56 µF, 5% polyester.
L1, L2 — 100 mH inductor.

Note B: The total reactance of the parallel combination of C28 and C29 plus the capacitance between the windings of T1 is $-j50$ Ω at the center of the tuning range. Placing most of the capacitance at one end is a different but equivalent arrangement to the quadrature hybrid we often use with equal capacitors. C29 is only needed if there is no standard value for C28 within a few % of the required value. C29 is tack soldered to the pads provided on the back of the PC board, and may be a surface mount component if desired.

Note C: To sacrifice close-in dynamic range and selectivity for reduced 60 Hz hum pickup, make the following substitutions, as illustrated in Figure 5. This modification is recommended if the MicroR2 must be used near 60 Hz power transformers.
C30, C31 — 0.10 µF 5% polyester.
C32, C33 — Not used.
L5, L6 — Not used. Place wire jumper between pads.

Note D: Capacitor C40 is the tuning capacitor for the receiver. The MicroR2 was specifically designed to use an off-board tuning capacitor to provide mounting flexibility, and to encourage the substitution of whatever high-quality dual bearing capacitor and reduction drive may be in the individual builder's junk box. Any variable capacitor may be used, but values around 100 pF provide a little more than 100 kHz of tuning range on the 40 meter band, which is a practical maximum. The MicroR2 needs to be realigned (RF amplifier peaked and the amplitude and phase trimpots readjusted) when making frequency excursions of more than about ±50 kHz on the 40 meter band. To prevent tunable hum and other common ills of direct conversion receivers, the MicroR2 PC board and tuning capacitor should be in a shielded enclosure. See Chapter 8 of *EMRFD* for a complete discussion.

Note E: L3, L4, L7 and T1 are listed as number of turns on the specified core rather than a specific inductance. This is how I build duplicate versions of the same design. For those who wish to study the design with a calculator, simulator, and inductance meter, L3 should be about $+j100$ Ω at about 8 MHz (not particularly critical). L4 and L7 should be about $+j250$ Ω at mid band. Each winding of T1 should be $+j50$ Ω at mid band.

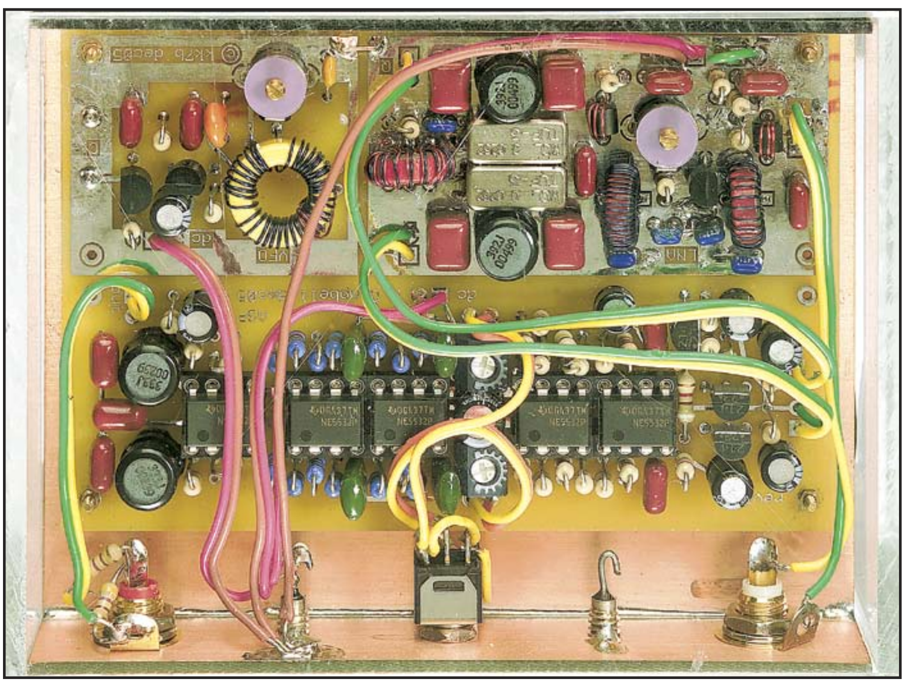


Figure 4 — Photo of the inside of the receiver.

amplifiers to do basic math, and is described in detail in Chapter 9 of *EMRFD*.

The next block is a pair of second-order all-pass networks, as shown Figure 9.54 of *EMRFD*. Use of second order networks limits the opposite sideband suppression to 37 dB, which sounds very good. For a CW only receiver, the four different resistors in *EMRFD* Figure 9.52 may be used to improve the opposite sideband suppression to well over 50 dB across a CW passband. This selectivity is about the same as some of the truly great classic single-signal receivers of the 1960s, and the impulse response is as good as the best of them. This results in a receiver that sounds exceptionally clean with multiple CW signals and static crashes in the passband.

It is straightforward to improve the opposite sideband suppression by 10 dB or so, but

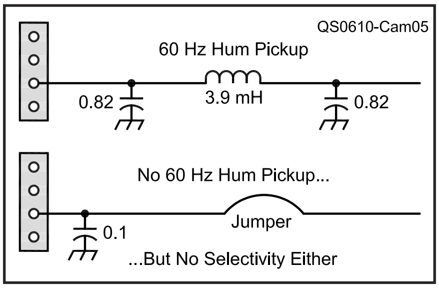


Figure 5 — Modified circuit to minimize hum.

doing so requires much more circuitry, not just a third-order all-pass network. See the R2pro discussion in *EMRFD* for a thorough description. Relaxing the opposite sideband suppression to a level comparable with the Drake 2B permitted cutting the parts count in half, and the construction and alignment time by a factor of 10.

The final blocks are the summer, audio low-pass filter and headphone amplifier. These are conventional, near duplicates of those used 10 years ago in the MiniR2. But unlike the MiniR2, everything is on one PC board. When the board is finished it is an operating receiver. The completed circuitry is shown in Figure 4.

Alignment

The receiver PC board may be aligned on the bench without connecting the bandspread capacitor. There are only four adjustments. I do the complete alignment in a few minutes with just an antenna, the crystal oscillator in the companion transmitter (or a test oscillator) and headphones. First, center the trimming potentiometers using the dots. Then slowly tune the VFO variable capacitor until the crystal oscillator is heard. The signal should be louder on one side of zero beat. Peak the LNA tuning carefully for the loudest signal. Then tune to the weaker side of zero beat and null the signal with the amplitude and phase trim pots. That's all there is.

If the adjustments don't work as expected or there is no opposite sideband suppression, look for a construction error. Don't forget to jumper the MUTE connection on the LNA — it is a ground to receive terminal just like simple receivers from the '60s. Once the receiver PC board is working on the bench, mount it in a box, attach the bandspread capacitor (with two wires — the ground connection needs to be soldered to the PC board too). Reset the VFO tuning capacitor for the desired tuning range, and do a final alignment in the center of the desired frequency range.

Performance

Is it working? I don't hear anything! Most of us are familiar with receivers with a lot of extra gain and noise, and AGC systems that turn the gain all the way up when there are no signals in the passband. I'm sorry, but I got tired of that sound when I outgrew my super-regenerative, FCC Part 15 walkie-talkie 40 years ago. Imagine instead a perfect receiver with no internal noise. With no antenna connected, you would hear absolutely nothing, like a CD player with no disk. The MicroR2 is far from perfect — but it may be much quieter than your usual 40 meter receiver, and it probably has less gain. It is designed to drive good headphones. Weak signals will be weak and clear and strong signals strong and clear over the entire 70 dB in-channel dynamic range — just like a CD player. This receiver rewards listening skill and a good antenna — don't expect to hear much on a couple feet of wire in a noisy room.

The measured performance is shown in Table 1. For some applications I add a speaker amplifier with an optical compressor circuit to the output — I'll discuss that in a later article. For now let's keep it simple.

Now, about that hum. One reason this receiver sounds so good is that the selectivity is established right at the mixer IF ports, before any audio gain. Then, after much of the system gain, a second low-pass filter provides additional selectivity. Distributed selectivity is a classic technique. My earlier designs included aggressive high-pass filtering to suppress frequencies below 300 Hz. That works well and has other advantages — but the audio sounds a bit thin, particularly to my son's trombone player ears. He, K7XNK, suggested that I try a receiver with the low frequency response wide open. It sounds great, but 60 Hz hum is audible if the receiver is within about a meter of a power transformer. Any closer and the hum gets loud. This makes it difficult to measure receiver performance in the lab, as there is a power transformer in every piece of test equipment.

To make measurements, I put the receiver on a separate table and run cables over to it. Hum pickup may be eliminated by modifying the circuit as shown in Figure 5. This hurts performance in the presence of strong off-channel signals, but in some applications — an instrumentation receiver on the bench — it is a good trade-off. The receiver sounds the same either way. Most of my applications involve battery operation in the hills, or on a picnic table in the backyard, and there is no hum pickup there. For home station use, hum pickup is about the same level as old magnetic phonograph cartridges, and that problem was solved in a hundred thousand living rooms by moving the furniture until the hum went away. The physics hasn't changed.

Okay—enough writing for today. I need to get back to the bench and finish up the measurements on the matching MicroT2 exciter.

PC Boards and Parts Kits

A kit of parts for the microR2 including a professional quality PC board and bandspread capacitor with built-in reduction drive is available for $80 plus $5 shipping and handling from Bill Kelsey, N8ET, at Kanga US. A parts placement diagram with reference designators matching the parts list is also included.

For more information, see the Kanga US Web site at **www.bright.net/~kanga/kanga/** or contact Bill at Kanga US, 3521 Spring Lake Dr, Findlay, OH 45840; 419-423-4604 or toll-free in the US 877-767-0675; **n8et@kangaus.com**.

Acknowledgment

Wes Hayward, W7ZOI, has been subjected to a barrage of correspondence on this project from conception through review of the manuscript. Some of the more elegant simplifications in this receiver resulted from revisiting his seminal work with Dick Bingham, W7WKR, on the modern direct conversion receiver in the 1960s. Bill Kelsey, N8ET, assisted with component questions and built an early PC board version. Roger Hayward, KA7EXM, Richard Campbell K7XNK, Mark Hansen, KI7N, and Merle Cox, W7YOZ, all contributed valuable insights, and their interest moved this project along.

Notes

[1]W. Hayward, W7ZOI; R. Campbell, KK7B; R. Larkin, W7PUA; *Experimental Methods in RF Design*, available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 8799. Price, $49.95 plus shipping. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[2]R. Fisher, W2CQH, "Twisted-Wire Quadrature Hybrid Directional Couplers," *QST*, Jan 1978, pp 21-24.

Rick has a BS in Physics from Seattle Pacific University and MS and PhD degrees in EE from the University of Washington. He started building receivers as a young child, and his career has followed a twisted path from church camp counselor through the US Navy as a Radioman, four years of basic physics research at Bell Labs, 13 years on the faculty at Michigan Technological University and seven years designing receiver integrated circuits at TriQuint Semiconductor. He is now with the advanced development group at Cascade Microtech, Inc and an adjunct professor at Portland State University, where he teaches RF Design. Rick was recently elected chair of IEEE MTT Committee 17, which studies and promotes HF-VHF and UHF Technology. He is one of the authors of EMRFD. *He divides his spare time between music, playing with old radios and windsurfing, and is a full time husband and dad.*

You can contact Rick at 4105 NW Carlton Ct, Portland, OR 97229, or at **kk7b@ieee.org**. QST