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Thanks for purchasing the Updated Universal QRP Transmitter designed by W7ZOI. Wes refers to it as the "MKII". The article was published in the April issue of QST, 2006. The article, along with this "kitlet", is intended to provide most of the necessary bits and pieces for a builder to construct a simple CW transmitter from scratch. As such, the documentation has been kept to a minimum. You will find only a copy of the article including the schematic along with a parts list which I have included as an inventory so you can be sure all the parts I intended to ship to you have actually arrived. No etched PC board is included. In fact, none has been laid out or is even planned. Two blank pieces of un-etched copper clad board are included for you to "ugly construct" your MKII.

The parts that are included are packed in three separate bags. One bag contains all the non-frequency dependent parts in Figure 1 (RF portion) in the article, the second bag contains all the parts for Figure 4 (T/R control and sidetone) in the article, and the third bag contains all the frequency dependent parts (plus the crystal). Note that there have been a few changes to the frequency dependent components since the article was published. The correct component values are listed in the parts list I include with the kit. Some are different than listed in Table 1 in the original article. An updated Oscillator Stage schematic is also included in the documentation.

If this is your first try at ugly construction you can check my web site (URL above) to look at some photos of several versions of the MKII I have built. The MKII is in the W7ZOI section of the web site.

There are a couple of parts that are supplied that are not exactly what was specified in the article:

The drive control, R17, a 250 ohm pot, is supplied as a 500 ohm pot which is connected in parallel with a 470 ohm fixed resistor (this provides the proper termination for the oscillator stage). The 470 ohm resistor is connected to the two outer terminals of the pot, and the pot is then connected as shown in the schematic.

Several capacitors on Table 1 are supplied as parallel combinations of two, or in the case of C6 and C7 (which are in parallel in the circuit), two parallel capacitors are supplied as one of an equivalent value. See the notes at the end of the parts list for details.

C10 (the VXO tuning capacitor) is supplied as a trimmer capacitor. This will allow you to set the frequency of the oscillator, but is not very convenient to use as a VXO tuning control. You will probably want to replace C10 with a variable capacitor you supply. It can be almost any variable capacitor you have available with a minimum value of about 10 pf and a maximum anywhere form 30 to 100 pf.

Have fun building the MKII. If you have questions, I will do my best to answer them. E-mail is the best way to contact me. Any of the tough technical questions I will pass on to W7ZOI – HI!

73 – Bill – N8ET

Parts List

RF Portion of the Universal QRP TX – MKII

Value	Designators	Quantity
Resistors		
12	R21	1
22	R13	1
47	R26	1
470	R17a (parallel with R17b to form R17)	1
510	R19	1
680	R10	1
1k	R12, R16	2
1.5k	R18	1
2.2k	R23, R24	2
3.3k	R11	1
4.7k	R2, R3, R15	3
10k	R1, R5, R6, R7, R8, R9, R14, R25	8
22k	R4	1
500 pot	R17b (parallel with R17a to form R17)	1
Capacitors		
65 pf trim	C10, C14	2
.1u	C15, C16, C17, C18, C19, C20, C21, C22, C23, C24	10
.68u	C11, C12	2
4.7u	C13	1
Transistors		
2N3904	Q1, Q6, Q7	3
2N3906	Q4, Q5, Q8	3
2SC5739	Q2, Q3	2
Misc		
FT37-43	T2, T3	2
Wire	Bifilar wire for T2 (10” #28) and T3 (7” #22)	2
3.9 uh	RFC1	1
1N967B	D1 (or 1N5260B)	1
1N4148	D2, D3	2
BNC	Antenna In, To Receiver	2
Key Jack	Key	1
Crystal	Y1	1
PB switch	S1	1
	Blank PC board	1

T/R control Circuitry

Value	Designators	Quantity
Resistors		
68	R19	1
390	R16, R17, R18	3
1k	R2, R8	2
3.3k	R7	1
4.7k	R4, R5	2
10k	R1, R10	2
12k	R3, R11, R13	3
22k	R6	1
47k	R14, R15	2
150k	R9, R12	2
Capacitors		
.01u	C2, C3, C7, C8	4
.22u	C4	1
22u	C1	1
100u	C5, C6	2
Transistors		
2N3904	Q2, Q3, Q5, Q7	4
2N3906	Q1, Q4, Q6	3
Misc		
1N4148	D1	1
1N4001	D2	1
K1	12V DPDT Relay	1
Jacks	Audio In, Audio Out	2
	Blank PC Board	1

Band Specific Components (only one band is supplied with each kit)

Band MHz	T1 Turns core wire	C1	C2	C3	R20	R22	L1 turns core wire	L2 turns core Wire	C4	C5	C6	C7	C8	C9
3.5 note 6	51,3 T68-2 26	270	270	82	33	18	26 T37-2 28	20 T37-2 28	1000	390	1000	1000	300 Note 1	1000
7	32,4 T50-6 28	390	100	82	33	33	19 T37-2 26	14 T37-2 22	470	200	560	470	150	470
10.1	32,4 T50 -6 28	390	100	0	33	33	19 T37-6 28	13 T37-6 28	330	120	390	330	100	330
14	32,4 T50 -6 28	390	100	0	33	33	16 T37-6 28	11 T37-6 28	220	100	270	220	75	220
18.1	20,3 T37-6 28	100	33	0	33	33	14 T37-6 28	9 T37-6 28	180	75	220	180	56	180
21	20,3 T37-6 28	100	33	0	18	33	12 T37-6 28	9 T37-6 28	150	62 Note 2	180	150	50 Note 3	150
24.9	20,3 T37-6 28	33	18	0	18	33	11 T37-6 28	8 T37-6 28	133 Note 4	56	150 Note 5	133 Note 5	43 Note 7	133 Note 4
28	20,3 T37-6 28	33	18	0	18	33	10 T37-6 28	7 T37-6 28	120	47	140 Note 5	120 Note 5	39	120

Note 1 – 300 pf supplied as two 150 pf caps to be used in parallel

Note 2 – 68 pf cap supplied in place of the 62 pf specified

Note 3 – 47 pf cap supplied in place of the 50 pf specified

Note 4 – 133 pf supplied as 100 pf and 33 pf which are connected in parallel

Note 5 – C6 an C7 are in parallel in the output circuit. One 270 pf cap is used in place of the 150 and 133 pf caps in parallel on 12 meters, and one 270 pf cap is used in place of the 140 and 120 pf on 10 meters

Note 6 – 33 Ohm resistor added to xtal oscillator stage. See 80 M Oscillator Schematic.

Note 7 – Supplied as two 22pf caps which ar connected in parallel.

An Updated Universal QRP Transmitter

Looking for a project that will let you try some of your own "scratch built" ideas? Here is a starter low power transmitter circuit for that pursuit.

Wes Hayward, W7ZOI

A frequently duplicated project in the now out-of-print book *Solid State Design for the Radio Amateur*[1] was a universal low power (QRP) transmitter. This was a simple two-stage, crystal-controlled, single-band circuit with an output of about 1.5 W. The no frills design used manual transmit-receive (TR) switching. It operated on a single frequency with no provision for frequency shift. The simplicity prompted many builders to pick this QRP rig as a first solid state project.

The design simplicity compromised performance. A keyed crystal controlled oscillator often produces chirps, clicks or even delayed starting. The single π-section output network allowed more harmonic energy to reach the antenna than we, or the FCC, would really prefer. The relatively low output of 1.5 W, although fun and sporting for the seasoned QRP enthusiast, may seem inadequate to a first time builder.

A Three Stage Transmitter.

An updated design, Figure 1, develops an output of 4 W on any single band within the HF spectrum, if provided with 12 V dc. Q1 is a crystal controlled oscillator that functions with either fundamental or overtone mode crystals. It operates at relatively low power to minimize stress to some of the miniature crystals now available. The stage has a measured output at point X of +12 dBm (16 mW) on all bands. This is applied to drive control R17 to set final transmitter output.

An oscillator subtlety was observed during keying of the 80 meter version of the transmitter. The oscillator was slow to start, leading to an abbreviated or completely missing first dot. The problem was solved with a decrease in loading, realized with fewer turns on the T1 secondary.

A three stage design provides an easy way to obtain very clean keying. Shaped dc is applied to driver Q2 through a keying switch and integrator, Q4.[2] A secondary keying switch, Q5, applies dc to the oscillator Q1. This is a time-sequence scheme in which the oscillator remains on for a short period (about 100 ms) after the key is released. The keyed waveform is shown in Figure 2.

The semiconductor basis for this transmitter is an inexpensive (less than a dollar!) transistor, the Panasonic 2SC5739. This part, with typical F_T of 180 MHz, is specified for switching applications, making it ideal as a class C amplifier. The transistor is conveniently housed in a plastic TO-220 package with no exposed metal. This allows it to be bolted to a heat sink with none of the insulating hardware required with many power transistors. I breadboarded a 2SC5739 power amplifier to confirm my expectations before continuing with the transmitter development. A 2 × 4 inch scrap of circuit board served as both a heat sink and as a ground plane for the circuitry.

I also used a 2SC5739 for the driver, Q2. This circuit is a feedback amplifier with RF feedback resistors that double to bias the transistor, a favorite topology of mine.[3] Driver output up to 300 mW is available at point Y. Ferrite transformer T2 moves the 200 Ω output impedance seen looking into the Q2 collector to 50 Ω. The maximum output power of this stage can be changed with different R2 values. Higher stage current, obtained with lower R2 values, is needed on the higher bands. The 2SC5739 needs only to be bolted to the circuit board for heat sinking.

The Q3 power amplifier input is matched with transformer T3. The nominal 50 Ω of the driver is transformed to 12 Ω by T3.

My original design started with a simple L network output circuit at the Q3 collector followed by a third-order elliptic low-pass section to enhance harmonic suppression.[4] C5 is a moderately high reactance capacitor at the collector to bypass VHF components. This L network presented a load resistance of 18 Ω to the Q3 collector, the value needed for the desired 4 W output. But this circuit displayed instabilities when either the drive power or the supply voltage was varied. The output amplifier sometimes even showed a divide-by-two characteristic. The original L network was modified with the original inductor replaced with an LC combination, C4 and L1. The new series element has the same reactance at the operating frequency as the original L network inductor. This narrow band modification provided stability on all bands. The components for the various bands are listed in Table 1.

The inductance values shown in Table 1 are those calculated for the networks, but the number of turns is slightly lower than the calculated value. After the inductors were wound, they were measured with a digital LC meter.[5] Turns were compressed to obtain the desired L value. Eliminate this step if an instrument is not available.

The divide-by-two oscillations mentioned above could be observed with either an oscilloscope or a spectrum analyzer and

[1]Notes appear on page 32.

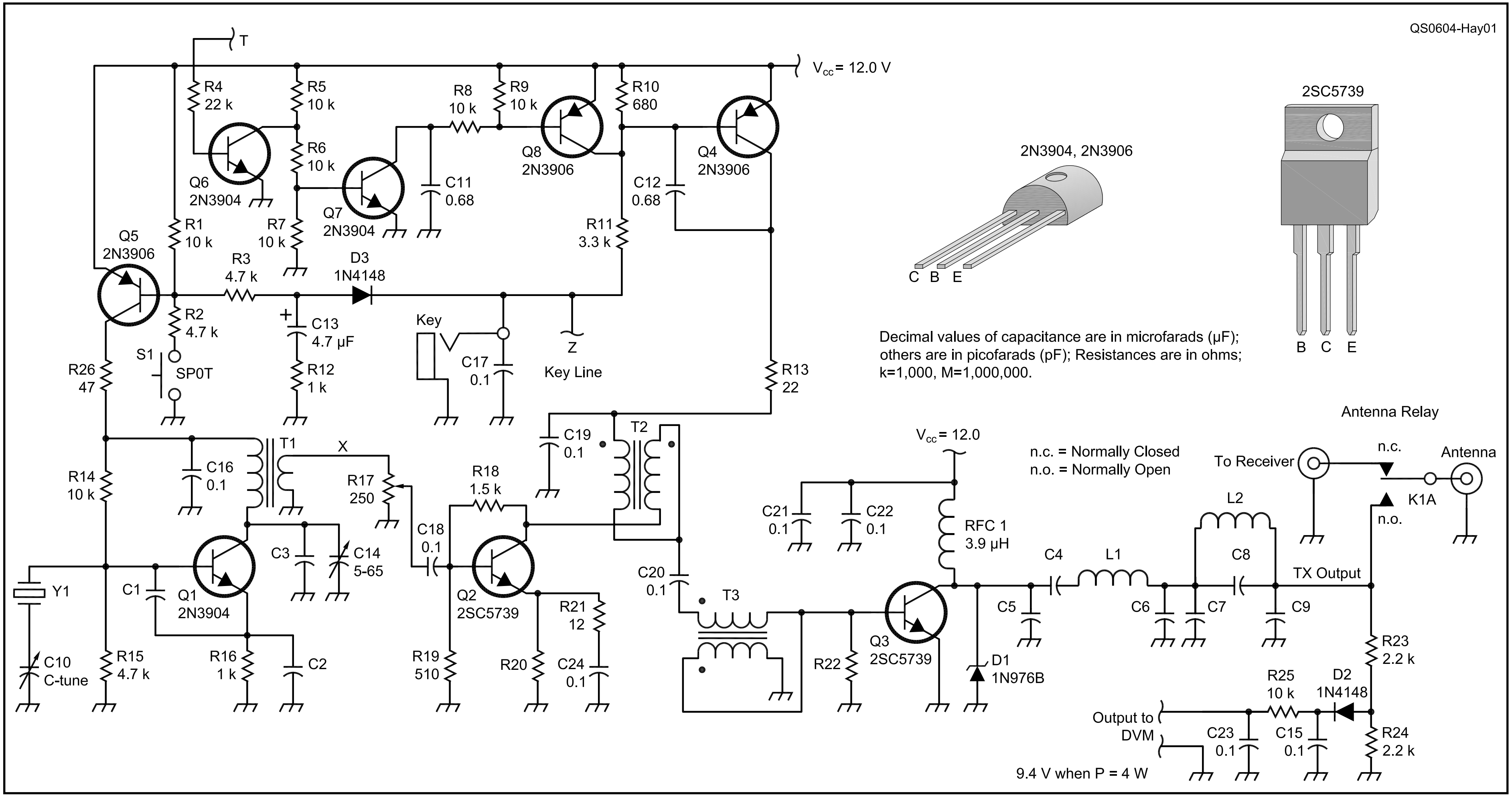


Figure 1 — Detailed schematic diagram and parts list for the RF portion of the Universal QRP transmitter. Resistors are ¼ W, 5%. A kit of component parts is available from Kanga US.[7] C10 is a VXO capacitor placed in series with the crystal to provide some frequency adjustment around the crystal frequency. Use what you have in your junk box, although smaller capacitance values provide a wider tuning range. We used a small 2 to 19 pF trimmer. TR switching is performed with a relay and additional circuitry shown in Figure 4.

C1-C9 — See Table 1, all 50 V ceramic or mica.
C10 — VXO control, see text.
C11, 12 — 0.68 µF, 50 V metal film or Mylar.
C13 — 4.7 µF, 25 V electrolytic.
C14 — 5-65 pF, compression or plastic dielectric trimmer.
C15-24 — 0.1 µF, 50 V ceramic.
D1 — 1N976B, 43 V Zener diode.
D2 — 1N4148, silicon general purpose diode.
K1A — See Figure 4.
L1, L2 — See Table 1.
Q1, Q6, Q7 — 2N3904, NPN silicon small signal transistor.
Q2, Q3 — 2SC5739 NPN silicon switching power transistor.
Q4, Q5, Q8 — 2N3906, PNP silicon small signal transistor.
R1, R5-R9, R14, R25 — 10 kΩ, carbon film resistor.
R2, R3 — 4.7 kΩ, carbon film resistor.
R4 — 22 kΩ, carbon film resistor.
R10 — 680 Ω, carbon film resistor.
R11 — 3.3 kΩ, carbon film resistor.
R12 — 1 kΩ, carbon film resistor.
R13 — 22 Ω, carbon film resistor.
R15 — 4.7 kΩ, carbon film resistor.
R16 — 1 kΩ, carbon film resistor.
R17 — 250 Ω, potentiometer (a 500 Ω potentiometer in parallel with 270 Ω fixed resistor can be substituted).
R18 — 1.5 kΩ, carbon film resistor.
R19 — 510 Ω, carbon film resistor.
R20, R22 — See Table 1, carbon film resistor.
R21 — 12 Ω, carbon film resistor.
R23, R24 — 2.2 kΩ, metal film resistor.
RFC1 — 3.9 µH, 0.5 A molded RF choke. In place of a manufactured product, a T68-2 toroid wound with 26 turns of #22 enameled wire can be used.
T1 — See Table 1
T2 — 10 bifilar turns #28 enameled wire on FT-37-43 or FB-43-2401 ferrite toroid core.
T3 — 7 bifilar turns #22 enameled wire on FT-37-43 or FB-43-2401 ferrite toroid core.

Table 1
Band Specific Components of the Transmitter

Band MHz	*T1 turns-turns wire, core*	*C1 pF*	*C2 pF*	*C3 pF*	*R20 Ω*	*R22 Ω*	*L1 nH, turns wire, core*	*L2 nH, turns wire, core*	*C4 pF*	*C5 pF*	*C6 pF*	*C7 pF*	*C8 pF*	*C9 pF*
3.5	51t-3t #26, T68-2	200	270	100	33	18	3000, 26t #28,T37-2	1750, 20t #28, T37-2	1000	390	1000	1000	300	1000
7	32t-4t #28, T50-6	0	100	100	33	33	1750, 19t #26, T37-2	890, 14t #22, T37-2	470	200	560	470	150	470
10.1	32t-4t #28, T50-6	0	100	0	33	33	1213, 19t #28, T37-6	617, 13t #28, T37-6	330	120	390	330	100	330
14	32t-4t #28, T50-6	0	100	0	33	33	875, 16t #28, T37-6	445, 11t #28, T37-6	220	100	270	220	75	220
18.1	20t-3t #28, T37-6	0	33	0	33	33	680, 14t #28, T37-6	346, 9t #28, T37-6	180	75	220	180	56	180
21	20t-3t #28, T37-6	0	33	0	18	33	583, 12t #28, T37-6	297, 9t #28, T37-6	150	62	180	150	50	150
24.9	20t-3t #28, T37-6	0	33	0	18	33	490, 11t #28, T37-6	249, 8t #28, T37-6	133	56	150	133	43	133
28	20t-3t #28, T37-6	0	33	0	18	33	438, 10t #28, T37-6	223, 7t #28, T37-6	120	47	140	120	39	120

were one of the more interesting subtleties of this project. The oscilloscope waveform looked like amplitude modulation. In the more extreme cases, every other RF cycle had a different amplitude that showed up as a half frequency component in the spectrum analyzer. The amplitude modulation appeared as unwanted sidebands in the spectrum display for the "moderately robust" instabilities. (Never assume that designing even *a casual QRP rig* will offer no development excitement!)

I examined the output spectrum of this transmitter when V_{CC} was set to 12.0 V and the drive control was set for an output of 4 W. The relative harmonic outputs are presented in the second column (N=3) of Table 2 below with relative frequencies in the first. A 14 MHz version of the original two stage design (N=2) was also measured at 12 V with output of 1.2 W with data in the third column of the table.

I breadboarded the oscillator and buffer section for all HF amateur bands from 3.5 to 28 MHz.[6] The power amplifier circuit has been built at 3.5, 7, 14 and 21 MHz. The crystals, obtained from Kanga US, were fundamental mode units through 21 MHz, and third overtone above.[7] The breadboard was built on two scraps of circuit board. Q1 and Q2 were on one with Q2 bolted to the board to serve as a heat sink. The second board had Q3 bolted to it, also serving as a heat sink.

After the breadboarding work was done, I moved the circuits to an available 2 × 3 × 6 inch box, an LMB #138. A new circuit board scrap was used, but most of the circuitry was moved intact from the breadboard. I elected to build my version for 40 meters. A diode detector was added to aid tune-up. The final RF board is shown in Figure 3.

Transmit-Receive (TR) Switching

Numerous schemes, generally part of a transceiver, are popular for switching an antenna between transmitter and receiver functions. When carefully refined, full-break-in keying becomes possible, an

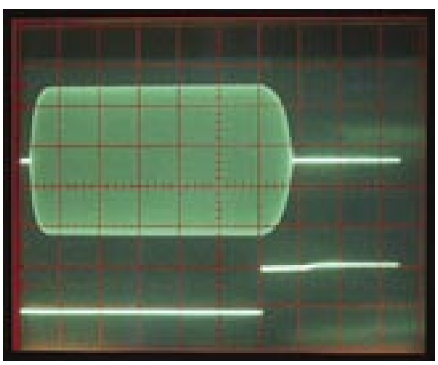


Figure 2 — Keyed waveform. The lower trace is the keyer input, which triggered the oscilloscope in this measurement. The horizontal time scale is 5 ms/div.

Figure 3 — A photo of the transmitter packaged in a 2 × 3 × 6 inch LMB #138 box. The basic RF circuitry is on the larger board. TR control is on the smaller board along the top.

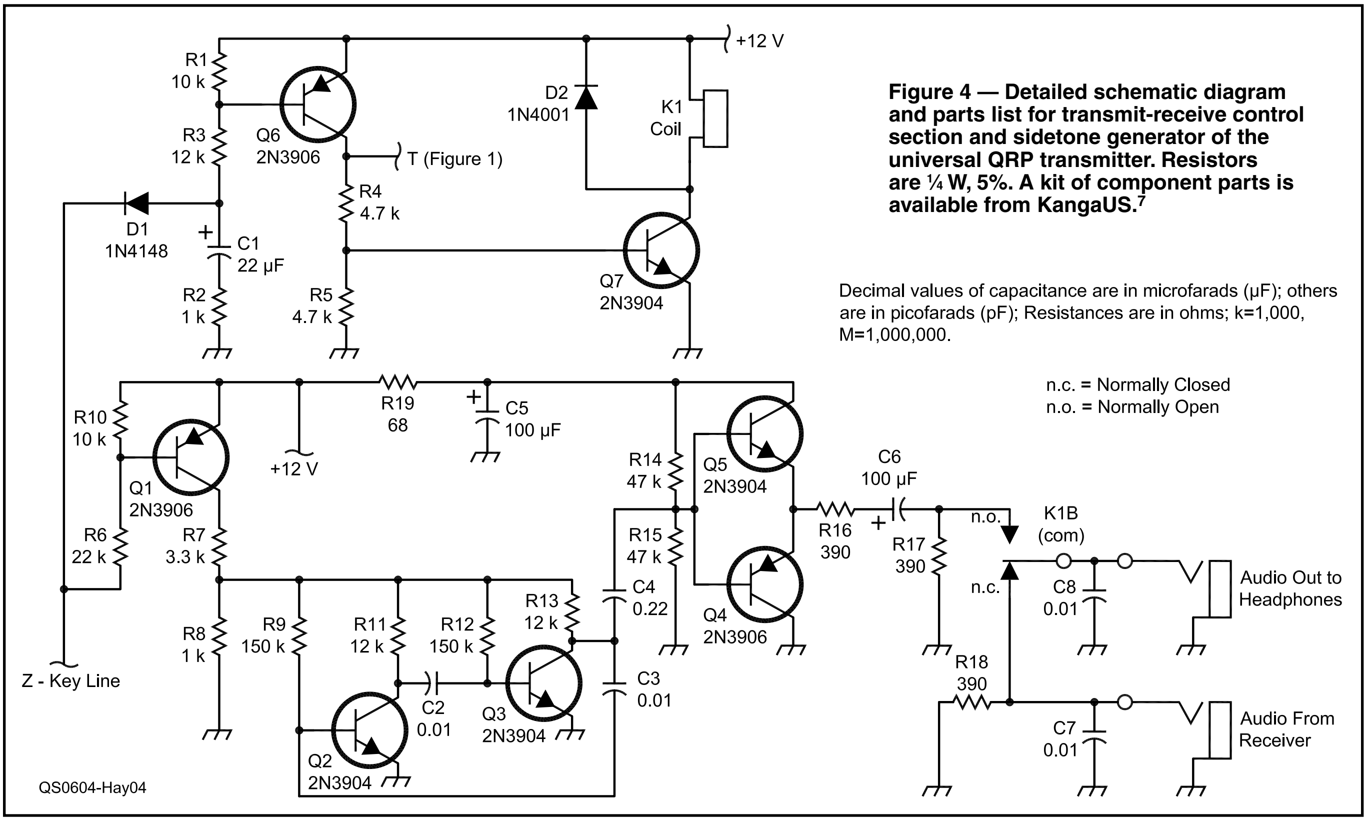


Figure 4 — Detailed schematic diagram and parts list for transmit-receive control section and sidetone generator of the universal QRP transmitter. Resistors are ¼ W, 5%. A kit of component parts is available from KangaUS.[7]

C1 — 22 µF, 25 V electrolytic.
C2, C3, C7, C8 — 0.01 µF, 50 V ceramic.
C4 — 0.22 µF, 50 V ceramic.
C5, C6 — 100 µF, 25 V electrolytic.
D1 — 1N4148, silicon general purpose diode.
D2 — 1N4001, silicon general purpose diode.
K1 — DPDT 12 V coil relay. An NAIS DS2Y-S-DC12, 700 Ω, 4 ms relay was used in this example.
Q1, Q4, Q6 — 2N3906, PNP silicon small signal transistor.
Q2, Q3, Q5, Q7 — 2N3904, NPN silicon small signal transistor.
R1, R10 — 10 kΩ, carbon film resistor.
R2, R8 — 1 kΩ, carbon film resistor.
R3 — 12 kΩ, carbon film resistor.
R4, R5 — 4.7 kΩ, carbon film resistor.
R6 — 22 kΩ, carbon film resistor.
R7 — 3.3 kΩ, carbon film resistor.
R9, R12 — 150 kΩ, carbon film resistor.
R11, R13 — 12 kΩ, carbon film resistor.
R14, R15 — 47 kΩ, carbon film resistor.
R16-R18 — 390 Ω, carbon film resistor.

interesting option for transceivers. But these schemes tend to get in the way when one is developing both simple receivers and transmitters, perhaps as separate projects. A simple relay based TR scheme is then preferred and is presented here. In this system, the TR relay not only switches the antenna from the receiver to the transmitter, but disconnects the headphones from the receiver and attaches them to a sidetone oscillator that is keyed with the transmitter.

The circuitry that does most of the switching is shown in Figure 4. Line Z connects to the key. A key closure discharges capacitor C1. R2, the 1 kΩ resistor in series with C1, prevents a spark at the key. Of greater import, it also does not allow us to "ask" that the capacitor be discharged instantaneously, a common request in similar published circuits. Key closure causes Q6 to saturate, causing Q7 to also saturate, turning the relay on. The relay I picked for my example has a 700 Ω, 12 V coil with a measured 4 ms pull-in time.

Relay contacts B switch the audio line. R17 and 18 suppress clicks related to switching. I used low impedance headphones in this system. A depressed key turns on PNP switch Q1, which then turns on the sidetone multivibrator, Q2 and Q3. The resulting audio is routed to switching amplifier Q4 and Q5. Although the common bases are biased to half of the supply voltage, emitter bias does not allow any static dc current to flow. The only current that flows is that related to the sidetone signal during key down intervals. Changing the value of R16 allows the audio volume to be adjusted, to compensate for the particular earphones used.

Table 2
Harmonic Spectral Output of the Original and Updated Universal QRP Transmitter

Fundamental	*0 dBc (N=3)*	*0 dBc (N=2)*
2 F	–80	–24
3 F	–58	–39
4 F	–71	–38
5 F	–71	–45
6 F	–81	–48
7 F	–80	–48

There is an additional interface between Figures 4 and 1. Recall that Q4 of Figure 1 keys buffer Q2 while Q5 provides a time sequence control to oscillator Q1. Additional circuitry uses Q6, Q7 and Q8, and related parts. Under static key up conditions, Q7 is saturated, which keeps C11 discharged. Saturated Q7 also keeps PNP transistor Q8 saturated. This closed switch is across the emitter-base junction of Q4. Hence, pressing the key will start relay timing and will allow the oscillator to come on, but will not allow immediate keying of Q2 through Q4. Key closure causes Q6 in Figure 4 to saturate causing point T to become positive. This saturates Q6 of Figure 1 which turns Q7 off, allowing C11 to charge. When C11 has charged high enough, Q8 is no longer saturated and Q4 can begin its integrator action to key Q2.

This *hold-off* addition has solved a problem of a loud click, yielding a transmitter that is a pleasure to use. There is still a flaw resulting in the initial CW character being shortened. The result is that an I sent at 40 WPM and faster comes out as an E. Further refinement of timing component values should resolve this.

The TR system circuitry for my transmitter was built on a narrow scrap of circuit board that is then bolted to the transmitter rear panel.

What's Next?

This has been an interesting project from many viewpoints. The resulting transmitter, which is usually used with the S7C receiver from *Experimental Methods in RF Design*,[8] is a lot of fun to use and surprisingly effective in spite of its crystal control. Primitive simplicity continues to have its place in Amateur Radio. Also, the development was more exciting than I would have guessed from the onset. The observed instabilities were interesting, as were the subtleties of the control system. Perhaps we should not approach simple CW systems with a completely casual attitude, for they continue to offer education and enlightenment.

There are clearly numerous refinements available for this transmitter. The addition of an adjustable reactance in series with the crystal will allow its frequency to move more. I used just a small variable capacitor. Two or more similar crystals in parallel form a "super VXO" topology for even greater tuning range. Higher power supply voltage will produce greater output power. I saw over 10 W on the test bench. The transmitter could certainly be moved down to 160 meters for the top band DXer looking for QRP sport. It is not certain that the 2SC5739 will allow operation as high the 6 meter band. The transmitter could easily be converted to a modest power direct conversion transceiver using, for example, the Micromountaineer scheme offered in *QST*.[9]

There is no circuit board offered for this circuit. There are already numerous kits on the market. On the other hand, there are many seasoned experimenters interested in building a "from scratch" project and this is aimed at them. A "kit" consisting of a sack of parts for the transmitter is available from Kanga US.[10]

Many thanks to Bill Kelsey, N8ET, who verified the design and documentation by successfully building a 20 meter version of this transmitter.

Notes

[1]W. Hayward, W7ZOI, and D. DeMaw, W1FB (SK), *Solid State Design for the Radio Amateur*, ARRL, 1977, pp 26-27.

[2]W. Hayward, W7ZOI, R. Campbell, KK7B, and B. Larkin, W7PUA, *Experimental Methods in RF Design*, ARRL, 2003, p 6.63. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 8799. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[3]See Note 2, pp 2.24-2.28, for information on feedback amplifiers.

[4]See Note 3, p 3.6, for low pass filter designs, 3.29 for matching network designs.

[5]See **www.aade.com** for details. A homebrew alternative is offered in Note 2, Chapter 7. Also see Carver, "The LC Tester," *Communications Quarterly*, Winter 1993, pp 19-27.

[6]See Note 2, p 1.2, and Hayward and Hayward, "The Ugly Weekender," *QST*, Aug 1981, p 18.

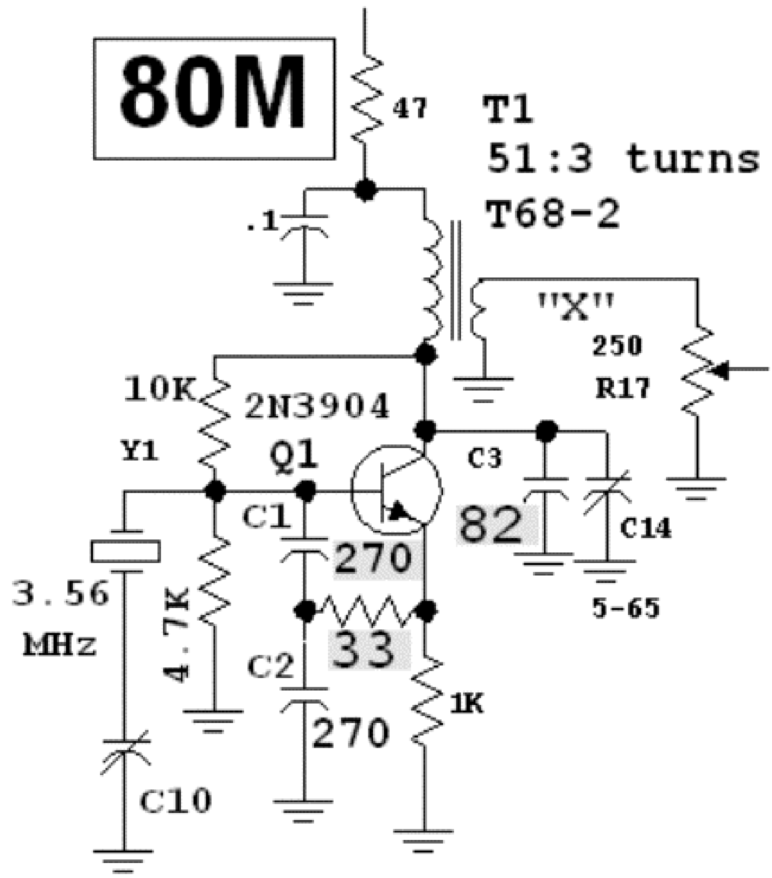
[7]See **www.kangaus.com**.

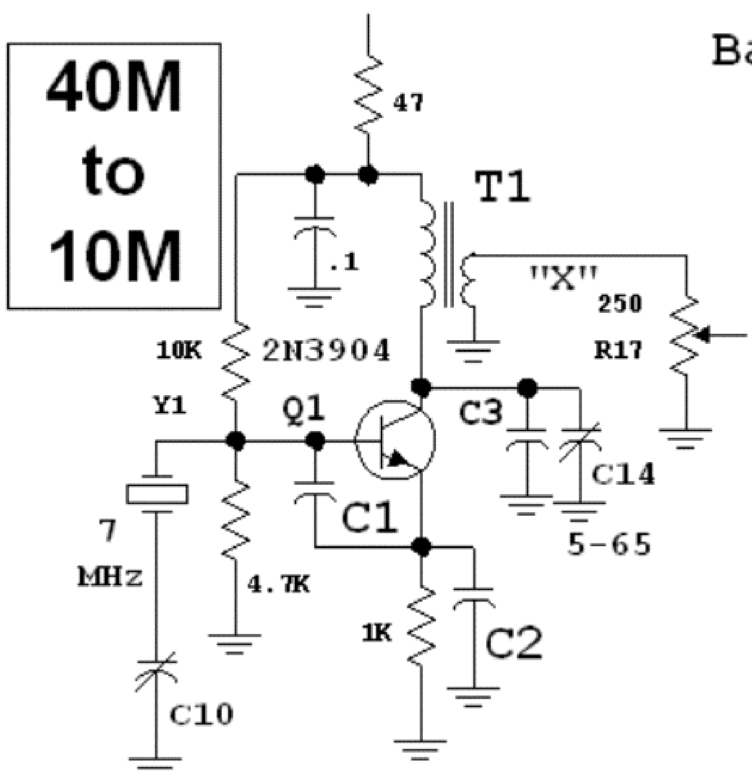
[8]See Note 2, p 12.16.

[9]Hayward and White, "The Micromountaineer Revisited," *QST*, Jul 2000, pp 28-33.

[10]See Note 7.

Wes Hayward has been licensed as W7ZOI since high school in 1955. His career in electron-device physics and circuit design took him to Varian Associates, Boeing, Tektronix, and TriQuint Semiconductor. He is now semi-retired and devotes his time to writing, consulting and some circuit research with a smattering of backpacking. His latest writing effort is the ARRL book (with KK7B and W7PUA), Experimental Methods in RF Design. *You can reach Wes at 7700 SW Danielle, Beaverton, OR 97008, or at* **w7zoi@arrl.net**.





Band	C1	C2	C3
40	390	100	82
30	390	100	0
20	390	100	0
17	100	33	0
15	100	33	0
12	33	18	0
10	33	18	0

Updated Oscillator Schematics