NorCal 40 QRP Transceiver

Assembly and Operating Manual

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NorCal QRP Club

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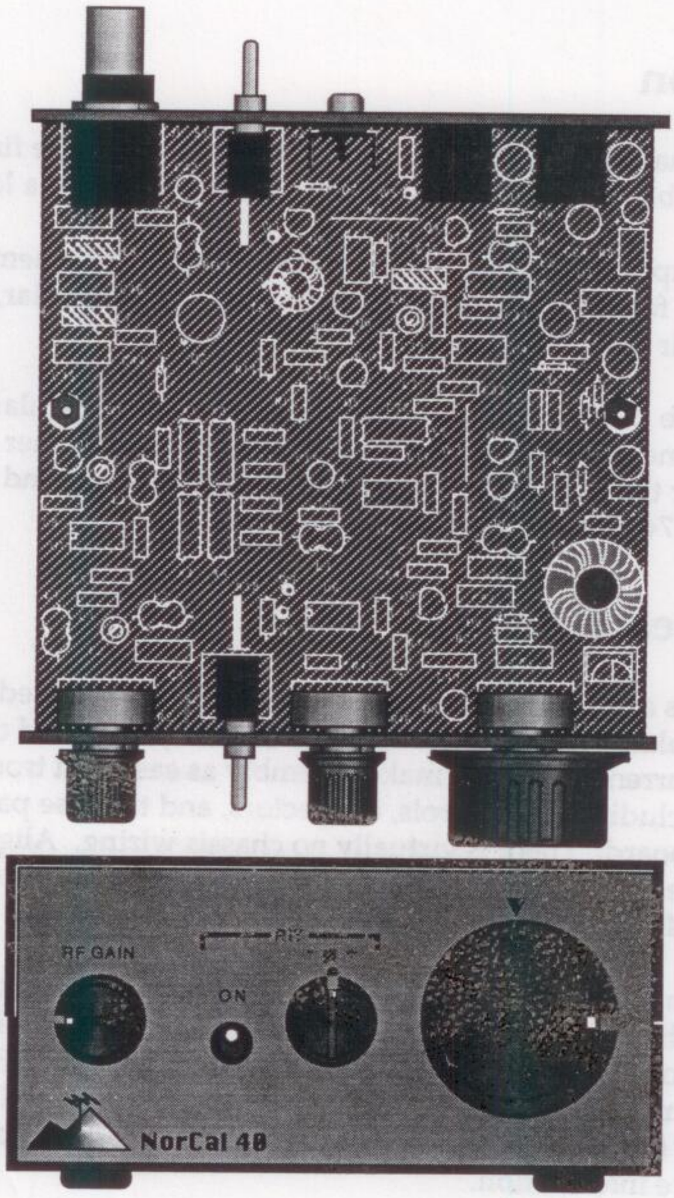


Contents

Introduction

Thanks for purchasing the NorCal 40 QRP Transceiver kit, the first club project of the NorCal QRP Club. We hope you'll find it easy to build, and a lot of fun on-the-air.

In the spirit of experimentation and interaction among club members, we encourage you to share your ideas for using and modifying the rig. In particular, we hope that those new to QRP will try their hand with the NorCal 40.

A number of club members helped with the project, in particular Doug Hendricks and Jim Cates, who did most of the work in getting the kits put together (not to mention cheer leading!). As for the rig design itself or the manual, please send your comments to Wayne Burdick, N6KR, 74 Elm St., San Carlos, CA 94070.

General Description

The NorCal 40 is a compact 40-meter CW transceiver optimized for ease of assembly and use. It is particularly well-suited to portable, battery-powered operation, having very low receive-mode current drain. To make assembly as easy and trouble-free as possible, all components, including the controls, connectors, and the case parts are mounted on a single printed circuit board. There is virtually no chassis wiring. Alignment is reasonably simple, and can in some cases be done with no test equipment, or with only a separate transceiver that covers the 40-meter CW band.

The receiver is a superhet, providing good sensitivity, selectivity, and freedom from 60-Hz hum pickup. The 4-pole crystal filter offers a good CW bandwidth, and a simple AGC circuit is used to keep strong signals relatively constant. An RF gain control is provided to attenuate extremely loud signals. The conversion scheme used results in a stable, low-frequency VFO (variable-frequency oscillator), operating at about 2 MHz. See **Circuit Details** for more information.

Operating features include RIT (receive incremental tuning), solid-state T-R switching, transmit signal monitoring, and variable power output up to about 2 watts.

Specifications

Numeric values given are typical; your results will be slightly different. All measurements were made with a 13.0V supply and 50Ω load at the antenna.

General

Size:	2.2" (H) x 4.6" (W) x 4.5" (D)
Power Requirements:	10 to 15VDC; reverse-polarity protection
Receive:	15mA typ.; increases at high volume levels
Transmit:	200mA typ. at 1.8 watts output
VFO operating frequency:	2.085MHz nominal[1]
Tuning Range:	Any 35 to 40 KHz portion of 40 meters
Drift:	25Hz total from cold start at 65°F

Transmitter

Output:	500mW to 2.0W, adjustable
Final Amp efficiency:	70 - 80%
Load Tolerance:	brief operation into high SWR
Transmit offset:	500-700 Hz
T-R (transmit-receive) delay:	200 milliseconds

Receiver

Sensitivity:	Better than 0.5uV for 10dB S+N/N
Selectivity:	400Hz @ -6dB, 1.5KHz @ -30dB
I.F.:	4.915MHz, 4-pole Cohn crystal filter
R.I.T. Range:	+/- 2KHz at center of VFO tuning range
Audio output impedance:	8 to 32Ω (headphones only)

[1] At an operating frequency of 7.0MHz. (VFO frequency is related to operating frequency using the formula: RF = VFO + 4.915 MHz.)

Assembly

Hold your iron! We know you'd like to jump right in and slap some parts on the PC board, but please follow the instructions in this section. (Some of us remember what happens when you try to build model planes without reading the instructions!)

The check-off boxes ([ ]) should be checked-off, in order, to help you stay on course as you build the NorCal 40.

Preparation

[ ] Before proceeding, you should verify that you've received all of the components in the kit. Check them off on the parts list (Appendix 1) as you go. Most parts have their value or part number clearly marked on them, or they can be identified from the descriptions in the parts list. Resistor and RF choke color codes can be found in any copy of the Amateur Radio Handbook.

➪ **A late addition to the kit is a parts identification drawing, hand-made by Jim Cates. This should be of help to first-time builders.**

➪ **There is no "T1", only a "T2".**

[ ] Inspect the circuit board for any shorts or opens in circuit traces. A minute or so spent here could save hours later! If the board has any opens, bridge them with a small piece of solid copper wire, soldered in place. If there are any shorts, cut them with an exacto knife, taking care not to cut any adjacent traces or pads.

[ ] You may want to file the edges of the PCB slightly if there is excessive PCB material extending beyond the outermost copper surface. Anything over 1/16 of an inch may make assembly of the front and rear panels difficult.

Assembly Tips

We think we've built a few kits in our time, so humor us by following the component installation order given below. Or, if you have a better way, let us know.

1. Install *all* of the components in each group as described below *before* soldering them.

2. As you install each component with long leads, seat it flush against the PC board, then bend the leads at about a 45° angle.

3. After all of the components in the group have been placed–and before soldering–cut the long leads off to a length of about 1/16" on the copper side of the board. The short leads on components such as ICs and connectors need not be trimmed.

4. Finally, solder all of the components in the group. Use a fine-tip iron intended for delicate PCB assembly, not a hefty, two-handed relic from Grampa's garage. Use only good quality 60/40 solder.

Component Installation

Install and solder each group of components as indicated. Part locations can be identified from the outlines and reference designators on the PC board. In the unlikely event that the silk screen becomes damaged, refer to the PC Board Component Side View on the last page of the manual.

There are a few parts numbered 101 or above that are mounted below the PC board. The precise way these parts must be installed is explained in later sections.

Resistors, Diodes, Chokes

[ ] Install all of the resistors, double-checking the color code to make sure you're installing the proper value. The resistors should all be oriented in one direction for ease of reading the color codes later--e.g., first band to the left or top, last band to the right or bottom.

[ ] Diodes must be installed with the cathode end--the end with the widest band--oriented in the same direction as the banded end on the PC board outlines. The exception is D8, which has a flat-sided package like a transistor. Install this part as shown on its PC board outline.

[ ] Install all of the chokes (L1 through L5, and RFC1 and 2).

[ ] Solder all of these components as described above.

Capacitors

[ ] Install all of the capacitors, starting with the disc, mica, and polystyrene types. These capacitors are easily damaged, so don't pull on or stress the leads.

[ ] Next, install the electrolytic capacitors. Many of these are polarized; be sure that the (+) lead is installed in the (+) hole in the board. This lead is usually longer than the (-) lead. The (-) lead is frequently marked on the body of the capacitor with a black band. Non-polarized electrolytic capacitors have no marking on the leads and may be installed either way.

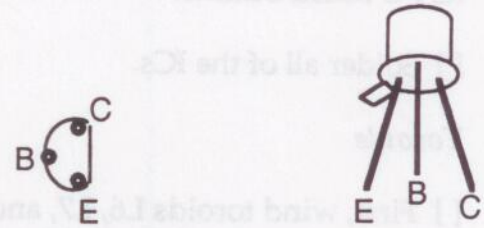
[ ] Next, install the variable capacitors. It is important that C50, the VFO setting capacitor, be installed in the proper orientation so that the rotor (the part that moves) is grounded; this allows adjustment of C50 with a metal screwdriver. Align C50 as it appears on its PC board outline. The short leads on the variable capacitors can be bent slightly if necessary to hold them in.

[ ] Solder all of the capacitors.

ICs and Transistors

[ ] Install all of the transistors *except* Q7, the final amplifier transistor. Align the flat side of each transistor with its PC board outline.

Some kits come with metal-case 2N2222A transistors for Q1 and Q6 rather than plastic. The drawing below shows how the leads on the metal can relate to the PCB silk-screen, which is laid out for the plastic case. As you can see from the drawing, the "B" (base) lead of the metal case will be bent backwards between the "C" (collector) and "E" (emitter) leads when the transistor is properly installed.



PCB Outline — Metal Case

[ ] Q7 uses a heat sink, which should be pressed carefully onto Q7 *before* installing it on the board. If you've never used a press-on heat sink before, be forewarned that it's tricky. Don't bend the leads as you're doing it--they may break.

[ ] Solder all of the transistors installed so far.

[ ] Install Q7 with its body about 1/16" above the PC board, making sure that the

heatsink doesn't touch any other components.

⇨ <u>If you substitute an MRF237 transistor for Q7</u>, remember that the emitter lead is NOT the one by the tab; this transistor uses a grounded-emitter case where the tab marks the <u>collector</u>. Bend the base lead backwards and down between the emitter and collector leads, then rotate the device so it is still aligned over the PC board outline, except with the tab on the "wrong" side.)

[ ] Solder Q7.

[ ] Install all of the ICs. All ICs except U5 are 8-pin DIPs (dual-inline packages) and are oriented in the same direction. The notched or dimpled end of each IC must be aligned with the notched end of its PC board outline. **(Since there are no sockets used, please be careful to install the ICs correctly!)** U5 is a flat-sided unit like a plastic transistor; install it as indicated on its PC board outline.

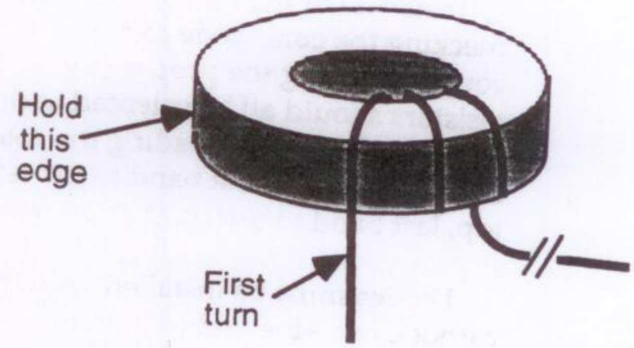
[ ] Solder all of the ICs.

Toroids

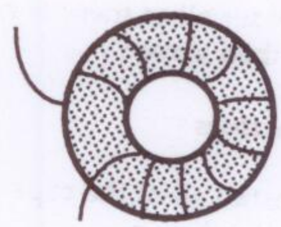
[ ] First, wind toroids L6, L7, and L8 as indicated in the drawings below, using the cores and number of turns specified in the parts list. The enamel wire used to wind the toroids is provided in the kit, and the wire lengths for each toroid are given in the parts list.

Always begin winding toroids as shown: grip the core on its left side, pass the first turn over the top, then pull all the wire through, winding from left to right. Be very careful not to kink the wire.

Since each pass *through* the core counts as one turn, the toroid shown has 3 turns on it so far. The remaining wire to be wound on the core continues off to the right.



After winding, the turns should be spaced evenly around most of the core, leaving a small gap between the first and last turns as shown below. (Note that the number of turns shown in the drawing is different from the actual number of turns used.)

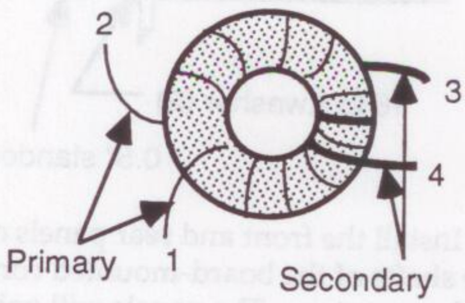


[ ] Cut the toroid leads to about 1/2 inch long, then use medium-grit sandpaper to remove the insulation to within about 1/8" of the toroid body. It is important to remove all of the insulation, but don't nick the wire or sand it down too thin. It is also possible to use a cigarette lighter or matches to burn off most of the insulation. Don't burn the rest of the turns, though!

[ ] Install these three toroids as indicated by the PC board outlines. Keep the toroids firmly pressed up against the board and pull the leads taut on the other side. Trim the leads and bend them down onto the pads for soldering.

[ ] Solder toroids L6, L7 and L8.

[ ] Next, wind transformer T2. The secondary winding (4 turns) should be wound on top of the primary winding (14 turns), resulting in something like the drawing below.

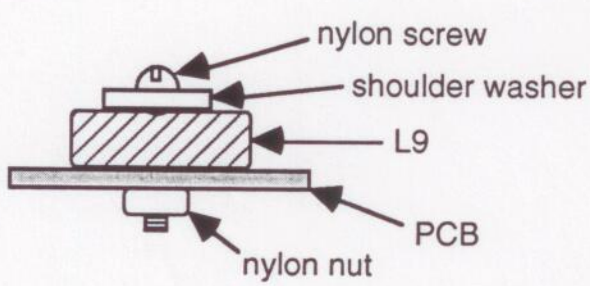


[ ] Remove the insulation from T2's leads and install it on the circuit board. Make sure that the primary and secondary leads line up with the numbers on the PCB outline. Solder.

[ ] Wind L9, the VFO toroid. This toroid has a lot of turns, so be sure to wind the turns as close together as possible without overlapping. Prepare the leads as described previously.

⇨ **<u>Important</u>: If you're planning to use the NorCal 40 in the Novice band, use 59 turns on L9 rather than 62.**

[ ] Secure L9 to the PC board as shown below using non-metallic hardware, then solder.



Miscellaneous Components

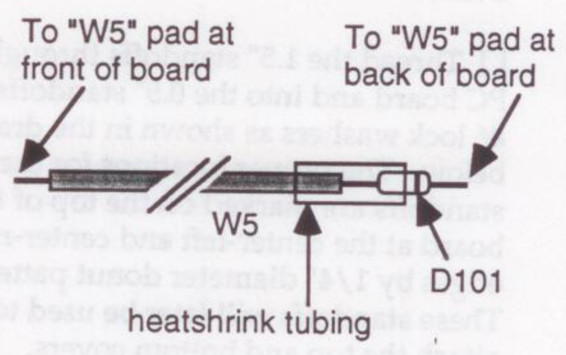
[ ] Install trimmer potentiometers R8 and R13 and solder.

[ ] Install all crystals and solder. After soldering, straighten the crystals so that they're vertical and not touching each other. All six crystals are matched, so any four can be used for the crystal filter (X1-X4).

[ ] Using #22 or #24 bare copper wire, make short jumpers and install them at W1, W2 and W3. Solder.

[ ] Using *insulated* #22 or #24 copper wire, install long jumper W4. The ends of this jumpers are marked on the PC board outline, with one end near the front center of the board, and the other end near the back center. You can install this jumper on the back of the board if you like to keep the component side looking clean.

[ ] Install long jumper W5 in the same manner as W4, but install diode D101 in series with W5 as shown below. A small piece of heatshrink tubing or black tape can be used to prevent shorting. Be sure to connect the D101 end of this assembly to the pad labeled "W5" near the back edge of the PC board, and the wire end to the other "W5" pad near the front edge.



Installing Controls and Connectors

When installing controls and connectors, keep them flush with the PC board. This will insure good alignment with the front and rear panels.

[ ] Install J3 and J4. Bend the leads slightly to hold the jacks in place, and solder. Note: these jacks may have one less pin than the PC board has holes--just ignore the extra hole.

[ ] Install J1, J2, S1, and S2, and solder.

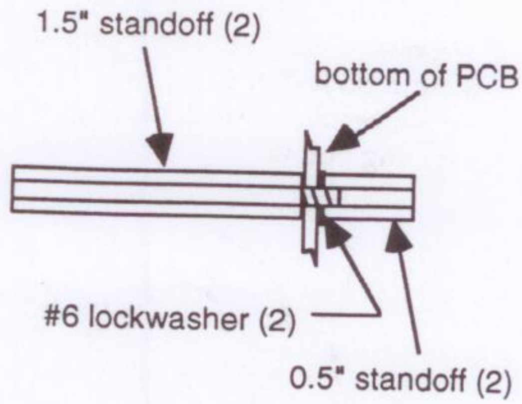
[ ] Remove the small metal tabs (near the shafts) of potentiometers R2, R16, and R17. Install the pots on the PC board. When seated correctly, each pot will sit a bit above the PC board. Double-check the values before soldering--all three are different (1K, 10K, and 100K, respectively).

Final Assembly

[ ] Do a final inspection for cold solder joints, solder splashes, shorts, and broken component leads. This could save you from a protracted troubleshooting session!

⇨ **You should have exactly three parts left over: C101, C102, and L101. These are for the 7.023MHz trap and can be installed later; see "Modifications" for details.**

[ ] Thread the 1.5" standoffs through the PC board and into the 0.5" standoffs using #6 lock washers as shown in the drawing below. The proper locations for the standoffs are marked on the top of the board at the center-left and center-right edges by 1/4" diameter donut patterns. These standoffs will later be used to attach the top and bottom covers.



[ ] Install the front and rear panels onto the shafts of the board-mounted controls and connectors. The panels will only fit one way. Tighten the control nuts provided. The front panel may be slightly wobbly at this time, but will be held rigidly in place once the top and bottom covers are installed following alignment and test.

Alignment and Test

Refer to the panel labeling drawings (page 12) for control and connector locations. If you have any difficulty with the procedure below, refer to the **Troubleshooting** section.

Initial Test

Before turning on power, follow these steps:

1. Make sure S1 (power) is in the down (off) position.

2. Connect a 50-ohm, 2-watt (minimum) dummy load to the antenna jack. You can make a dummy load from a parallel combination of larger resistors, if necessary; for example, eight 390-ohm, 1/4-watt resistors will be close. Keep the leads short.

3. Using a small (1/8") flat-blade screwdriver, turn R13 (drive) and R8 (AF output) both fully counter-clockwise *as viewed from the right edge of the board.*

4. Connect a well-regulated and filtered 11 to 15V DC power supply (or battery) capable of supplying 300mA to J2; the preferred voltage is 12 to 13V. Then turn on the power supply and S1. If any component is hot to the touch or you see or smell smoke, chances are you have a short or open or bad component.

5. If you have a milliameter, connect it in series with the supply and note the current reading, which should be approximately 15mA. If the reading differs by more than a few mA from this value, chances are you have a short or open or bad component.

Receiver Pre-test

1. Connect an antenna--at minimum a long (40') piece of wire--to J1, and turn on power.

2. Set VFO setting capacitor C50 to its midpoint (plates half meshed).

3. Set VFO tuning pot R17 to its midpoint. Make sure the RIT switch (S2) is off (down). Set the RF gain control (R2) fully clockwise.

4. Connect a pair of headphones to J4. Adjust the volume setting trimmer, R8, until you can hear some noise (hiss).

5. Using a small (preferably non-metallic) tuning tool, alternately adjust C1 and C2 for maximum atmospheric noise. The peaks will be fairly sharp. If the band is quiet and you can't hear any increase in noise, try loosely coupling a 7-MHz signal generator to the antenna wire (in other words, put the generator next to the wire). Tune the signal generator between 6.9 and 7.1 MHz until you hear a signal, then peak C1 and C2 a couple of times.

You may also be able to hear the 7.023-MHz "birdie" if you tune the VFO around. The birdie is generated *after* the crystal filter, so it will sound very broad and will have a response on both sides of zero-beat. This signal can be tamed later at your option.

After the VFO is aligned in the following step, C1, C2 and R8 will be re-adjusted for best performance.

VFO Alignment

➡ If you plan to use the NorCal 40 in the Extra band, please refer to Modifications after completing alignment for information on eliminating the birdie at 7.023MHz. General and Advanced class licensees can use 7.025 MHz as the low end of the tuning range. In this case, the 7.023MHz signal can be used as an Extra band-edge marker.

1. Rotate the VFO knob fully counter-clockwise. Also make sure the RIT on/off switch, S2, is in the off (down) position.

2. There are three possible ways to set the VFO frequency, depending on what equipment you have available:

2A. If you have a frequency counter: The VFO operates at a frequency exactly 4.915MHz below the rig's operating frequency. Knowing this, you can calculate the desired low end of the VFO's range. For example, if the low end of the range to be covered is 7.025MHz, the VFO will be at 7.025-4.915 = 2.110MHz. Connect a frequency counter to C7 (on the U1, pin 6 side), and adjust C50 for the desired reading.

2B. If you have a calibrated CW signal generator or 40-meter transmitter: Set up the signal source for the low end of the desired RF range (e.g., 7.025MHz). Loosely couple the output of the signal source to the antenna input of the NorCal 40. Adjust C50 until the signal is heard at a pleasant, intermediate pitch (about 800 Hz).

2C. If you have no equipment at all: The VFO circuit produces an audible spurious tone at 7.023MHz. While this would normally be an inconvenience, it can serve as a band-edge marker for setting the low end of the VFO to 7.025 MHz. Rotate C50 until you hear the "birdie," then adjust C50 to a bit lower capacitance (plates less meshed) until the pitch becomes so high you can't hear it. Bingo! You're at about 7.025MHz.

3. If you can't get the VFO set to the proper frequency, you may need to add or remove turns from L9, depending on whether you can't go low enough or high enough, respectively. Be sure you've wound L9 tightly and evenly spaced the turns. (Each turn changes the VFO center frequency by about 35KHz. C50 varies this center frequency by 75KHz.) After adjusting the turns, re-do steps 1 and 2.

4. Once the low end of the VFO has been set, you may want to check the high end of the range. Rotate R17 fully clockwise and confirm--using the counter or signal generator--that the VFO is now 35 to 40 KHz higher. You might also check the RIT range by turning S2 on and adjusting R16.

Final Receiver Alignment

1. Turn the RF gain control all the way up (clockwise). Connect a 40-meter antenna to J1.

2. Locate a weak signal near the middle of the VFO tuning range, and re-peak C1 and C2 for maximum signal.

3. Finally, find a clear frequency and adjust the volume setting trimmer (R8) so that you can just hear the atmospheric noise. See Operation for more information about the setting of R8.

Transmitter

1. Set R13 to about mid-range. Rotate the VFO knob fully CCW, then turn it CW about 1/3 of its total rotation. Turn the RIT off.

2. Connect a 50-ohm dummy load to J1. If an inline watt meter or SWR bridge is available, connect it in series with the dummy load. If not, you'll need an RF voltmeter or oscilloscope to check the

output at J1 (don't disconnect the load during the measurements!). If you don't have any way at all of measuring the output, you can peak the transmitted signal by listening to the volume level of the monitor tone during key-down periods.

3. Connect a key or keyer to J3.

4. Key the transmitter for brief periods and adjust C39 for maximum signal on the meter, scope, or by ear , listening with headphones.

5. Adjust R13 for the desired output level. The maximum output should be between 1.5 and 2 watts using a 2SC799 as the final transistor. (If you have substituted an MRF237, you'll get up to 3.3 watts; you may want to consider a larger heat sink at this level!)

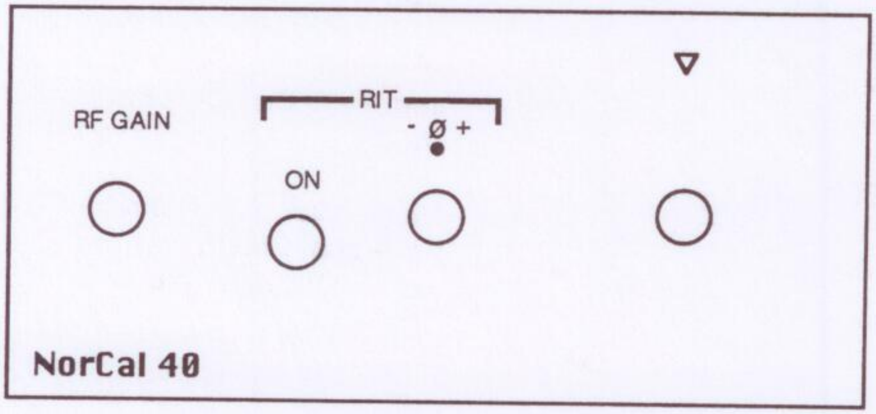
If you'd like to calculate the final amplifier efficiency, you'll need an accurate watt meter (or oscilloscope, or an RF probe), a 50-ohm dummy load, and milliameter in series with the power supply. Example: Suppose you measure 1.5 watts output, and a key-down current drain of 200mA at a supply voltage of 12V. Not all of this current is going into the final amplifier; about 40 mA is used by other receiver and transmitter circuits. This leaves 160mA of final amp current. Efficiency = power out/power in = 1.5 / (12 * .16) = 0.78, or 78%.

6. The monitor tone should be plainly audible in the headphones, and its pitch should be between 500 and 700 Hz. If you prefer a different pitch, see **Modifications**. The received background noise should return shortly after keyup--around 200 milliseconds or so (1/5 of a second).

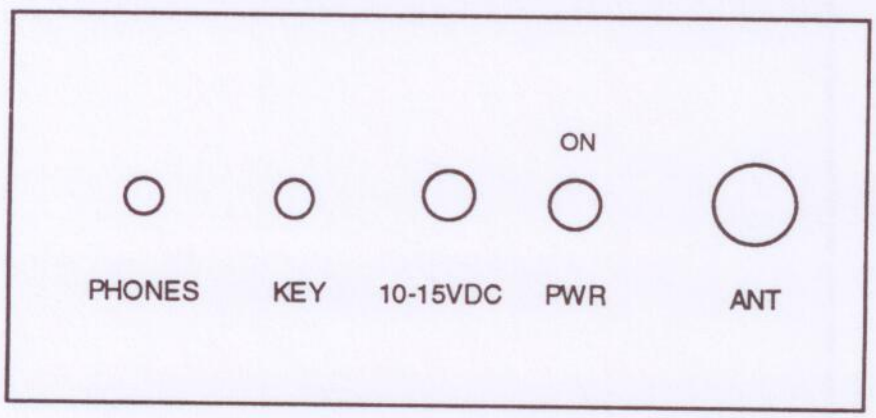
Cover Assembly

[ ] You may want to remove and label the front and back panels. One possible labeling is shown below.

➪ There are at least two different ways to label the VFO knob: using a pointer on the panel, as shown here, combined with tic marks on the knob itself; or a pointer on the knob, combined with tic marks on the panel. Either way, your labeling will depend on what your VFO tuning range is. Make one tic mark every 5KHz or so using a calibrated signal source, and be sure to err on the conservative side when labeling band edges.



Front Panel



Rear Panel

[ ] Assemble the top and bottom covers, which are identical, using four #6 flathead screws. The screw holes in the top and bottom covers are slightly offset from center. When properly assembled, the covers should overlap the front and back panels by about the same amount--about 1/10 of an inch.

Operation

Refer to the front- and rear-panel labeling drawings from the previous section to identify the controls and connectors.

Front Panel Controls

RF gain: Most of the time, the RF gain control will be set to maximum (fully clockwise), and the NorCal 40's AGC circuit will maintain a comfortable listening level. However, you will need to turn the RF gain down if signal levels are extremely high, such as when listening to local, QRO (high-power) stations. You may also want to turn down the RF gain if you're using a large antenna array, or if you're on a mountaintop (or preferably, both!). This will help prevent the receive mixer from getting overloaded, which can cause unwanted spurious signals to be heard.

R.I.T. On/Off and Adjust: With the RIT switch ON, the VFO will be offset during receive by the amount set with the RIT adjust control. The transmit frequency is unaffected. The RIT control range is about +/- 1KHz at the high end of the VFO range, and increases to about +/- 2.5Khz at the low end.

⇨ RIT (receive incremental tuning) is used to slightly offset the frequency you're listening to without affecting your transmit frequency. This is especially important if the received signal is drifting: RIT lets you track the other signal without forcing them to track *you* in the same direction. Without RIT, both stations might work their way down or up the band and smack into another QSO. Other uses for RIT include: allowing you to listen to signals at a different pitch while still answering them on their frequency; working small splits, such as when a DX station says to call him "up 2" (KHz); shifting the VFO position slightly to move an interfering signal out of the pass band or into zero beat.

VFO: The VFO (variable-frequency oscillator) control covers about 35 to 40 KHz of the 40-meter band. The coverage is slightly non-linear due to the varactor tuning (see Circuit Details).

Rear-Panel Controls and Connectors

Key jack: You can use a hand key or any type of "key-to-ground" keyer here. If you're not sure what kind of keying your keyer produces, look at its output circuit: if the keyed output is connected to an NPN transistor's collector, chances are your keyer will work. Most keyers have an output of this kind.

Headphone jack: The NorCal 40 requires stereo headphones; mono headphones will short the AF output to ground. Almost all commonly-available "Walkman"-style headphones are stereo and will work. Good-quality stereo headphones with larger ear covers work best-they'll be more comfortable and more sensitive. If you have only mono headphones, you'll have to make an adapter to convert them to stereo.

⇨ The NorCal 40 won't drive a speaker very well directly. Small, amplified speaker units are available from Radio Shack (and other sources) that have enough "oomph" to drive a speaker even in high-noise environments, like the inside of a car.

Power jack and on/off switch: The NorCal 40 requires 10 to 15 VDC. Transmit current requirements vary, but will rarely be over 300mA (see Alignment). There is a low-voltage-drop diode in series with the supply to protect the NorCal 40 should you accidentally reverse the DC polarity. This shottky diode only "drops" 0.2 volts or so, compared to 0.7V for a 1N4001, so it will not significantly affect your transmit power output. The on/off switch completely disconnects the NorCal 40 from the power supply.

Antenna jack: Always use a well-matched, 50-ohm antenna. If you have any doubts, use an SWR bridge and, if necessary, an antenna tuner. It is possible to damage the output transistor of the NorCal 40 if you operate it into a poorly matched load for an extended period. Some protection is provided in the form of a zener diode, but this will not handle all mismatches, especially if you keep the transmitter keyed down for a long time.

➪ The preferred type of SWR bridge to use with antenna tuners is the "absorptive" kind (see W1FB's QRP Notebook or the Handbook for example circuits). This type of bridge works well with simple QRP rigs because a relatively good load is provided to the final amplifier during tune-up.

Operating Tips

In general, your QRP signal will be harder to hear than higher-power signals. For this reason, experienced QRPers usually spend much more time listening than transmitting. If you've never operated QRP, there are many good books on the subject to help you get started.

The NorCal 40 doesn't have a side tone oscillator. Instead, the signal you hear when you key the transmitter is the output signal itself, being picked up by the receiver (and limited to a very low volume). Because of this, you can tell what pitch to listen to as you tune in other stations by just occasionally checking the pitch of your own transmitted signal. On the other hand, if a station calls *you* off frequency, just turn on the RIT and tune them in. This is preferable in many cases to changing the frequency of your own VFO.

When listening to your transmitted signal, note that a sudden change in its volume can indicate a problem with the transmitter. If the volume goes way down, chances are the final is blown or R13 isn't aligned properly.

If the band is very noisy or you hear very loud stations, turn the RF gain control down. The NorCal 40 uses NE602 ICs in the receiver, which provide excellent sensitivity at low cost but can't handle huge signals without a little help.

If you switch to a different pair of headphones, you may need to readjust R8 (inside the cabinet, back left). This trimmer sets the AF (audio frequency) volume level, and the AGC circuit keeps signals in the proper range.

Troubleshooting

The first thing to do when you have any problem is to turn off power and disconnect the power supply or battery from the rig. Next, ***no matter how careful you think you've been,*** inspect the board for:

- solder bridges
- cold or non-existent solder joints
- incorrectly-installed parts (backwards or wrong part)
- broken parts
- open circuit traces

in that order. To paraphrase a famous but nearly extinct kit company, 90% of all problems are the result of one or more of these problems. They weren't kidding! The first NorCal kit built would have worked the first time if it weren't for two leads that had been left unsoldered. It took us a half an hour of debugging (over the phone!) to find this out, so save everyone some trouble and really give that board a good look.

Next, double-check your setup and try the alignment procedure again if it seems safe to do so.

If you still have difficulties, the chart below may be of help. As a last resort, write to Wayne Burdick. NorCal members: call me *only* if you've tried everything first!

Symptom(s)	Resolution
Smoke, flame, or smell of burnt parts	Turn off power, disconnect all cables, and use an ohmmeter to locate the shorted component or trace. Most likely components are the PA RF choke (RFC1), the PA transistor (Q7), or the voltage regulator (U5). Nose and eyes may suffice as test equipment here!
No sound in headphones	Try increasing the volume setting (R8).
	Verify supply voltage. Look for a shorted cap (C26 , C27) or bad headphones or headphone jack.
	Touch a wire or long screwdriver blade to U3 pin 2. If you don't hear any hum or noise pickup, U3 or one of its associated parts may be bad. Make sure you find about 8 volts on U3 pin 6. If you do hear noise, keep using the screwdriver trick, tracing backwards through the circuit to U2 pin 1 until the noise stops; you may have found an open.

Low receiver output	Make sure you have followed the alignment procedure carefully; the settings of C1, C2, and R8 are critical. Make sure you have about 8 volts on U1 and U2 pin 8. If you know the transmitter is working but you can't hear the monitor tone on key-down, chances are the receiver's problem is in the product detector (U2) or AF amp (U3) stages. If you can hear the transmitter signal on key down, your receiver problem may be somewhere in the receive mixer (U1) or crystal filter (X1-X4). Using a long wire or scredriver blade, touch U1 pin 1 to see if you suddenly get gobs of signal. Work backwards through the circuit all the way to the antenna jack to see where the signal is getting lost.
TX monitor level is WAY too loud	Look for a problem around the mute circuit (Q2, Q3, D1, D2).
TX monitor level is WAY too soft (can't hear it)	R4 is probably open, or the product detector isn't working.
TX monitor level is a little too loud or too soft	Increase or decrease, respectively, the size of R4 (measure it to make sure it isn't shorted or the wrong value).

Low or NO transmitter output

Make sure you've done the alignment procedure carefully; the settings of C38 and R13 are critical. Verify proper installation of the P.A., driver, and low-pass filter components.

Turn R13 all the way down. Then, starting with the VFO, use an RF probe or oscilloscope to find where the signal is disappearing. Note that the TX mixer needs two inputs (VFO and crystal oscillator) to have an output. You'll have to key the transmitter to check for output at U4 pin 5 (about .3V RMS), Q5 source (about .5V RMS) and Q6 collector (4 or more volts RMS). You should see 8 volts DC at U4 pin 8 and Q5 drain on key down, and 12 volts or so at Q6 and Q7 collectors at all times.

If you get up to the driver and have good RF readings, but have no PA output, chances are the PA transistor (Q7) or RF choke (RFC1) is open or shorted.

Replacement Parts

While there is nothing exotic about the parts used in the NorCal 40, you might have trouble locating the exact replacements listed in the parts list. If you really get stuck, write to NorCal c/o Jim Cates (3241 Eastwood Rd., Sacramento, CA 95821) to see if we have the part you need in stock. At the very least, we'll recommend a source.

Circuit Details

Basic Theory of Operation

The NorCal 40's receiver is a single-conversion superhet. U1 (see schematic, sheet 1) mixes incoming RF at 7.000MHz with a nominal 2.085MHz VFO signal to produce an I.F. (intermediate frequency) of 4.915MHz. This I.F. frequency is constant; i.e., for an RF signal of 7.100MHz, the VFO is set to 2.185MHz, and the difference frequency is still 4.915MHz. Note that the internal oscillator of U1 is not used as the VFO, because large signals at the input might pull such a VFO's operating frequency.

The 4.915MHz I.F. frequency was chosen for a couple of reasons. First, inexpensive crystals are available at this frequency. Second, it is a low enough frequency that a narrow crystal filter (X1-X4) can be constructed without special test equipment.

After passing through the crystal filter, the 4.915MHz signal is fed to the product detector, U2. The on-chip oscillator of U2 forms the BFO, using a crystal frequency about 700Hz higher than the center frequency of the crystal filter. The resulting output of U2 is a signal in the audio range. This type of receiver provides "single-signal" reception, in that a signal will only be heard on one side of a station's zero-beat (0 audio frequency). This means half as much QRM compared to a direct-conversion receiver.

The output of the product detector is kept relatively constant by Q2 and Q3, the AGC/mute transistors. Q2 and Q3 are JFETs, and their resistance increases as their gate voltages go more negative. D3 and D4 rectify the output of the audio amplifier, U3, to provide a voltage that is about 0.5 volts with no received signal, but goes as low as -3 volts when a loud signal is present.

When the transmitter is keyed, Q4 (see sheet 2 of the schematic) conducts, providing +8V from the voltage regulator, U5, to the transmit circuits. Transmit mixer U4 mixes the VFO signal with the signal from its on-chip oscillator to provide an output at the operating frequency.

Note that crystal X6 (transmit mixer) is the same type as X5 (product detector), but operates at a lower frequency due to L5. Ideally, you want X6 to operate at the center frequency of the receiver's crystal filter, so that when you transmit, your signal will be very close to that of the station you're listening to. X5 operates higher than this to provide an offset and hence an AF note of 700Hz that you can hear when transmitting.

Q5, Q6, and Q7 amplify the transmitted signal to about 0.5 to 2 watts, depending on the setting of R13. C45-C47 and L7-8 form a 5-element low-pass filter that clean up Q7's class-C output waveform.

The receiver's RF input is obtained at the pickoff point between C44 and the lowpass filter. This signal is routed to U1 via C1 and L1 (sheet 1), which form a low-loss series-resonant circuit. When transmitting, Q1 is saturated, shunting nearly all of the transmitted signal to ground before it gets to U1, and effectively making C1 a small part of the lowpass filter.

The VFO is a fairly standard Colpitts type. D8 is a hyper-abrupt junction varactor diode, which just means that it has a wide capacitance range. R17 controls the voltage applied to D8 and hence the VFO frequency. U6 switches in RIT control R16 during receive if the RIT switch is on.

Advanced Circuit Details

In this section, we describe a few tricks and compromises that make the NorCal 40 different from similar rigs. We'd like to hear your ideas for modifications. After all, this is a club project!

Receive Mixer: The usual input transformer with a 2-turn primary has been eliminated in favor of capacitive coupling (C2/C3). This allows the use of a cheap inductor (L2). Note that the rig has been optimized for fewest *unique* components; an example of this is that L1 and L2 have the same value. Light coupling to U1 provides good isolation from the input tank, minimum input signal into the NE602, and adequate signal strength on 40 meters.

I.F..: In case you hadn't noticed, there is no I.F. amp. It really isn't needed since the '602 has plenty of gain at 7 MHz, and because gain control has been moved to the AF channel (see below). As anyone who has used an MC1350 I.F. amp with NE602s can attest, that's more gain than you really need for a 40-meter receiver, and it adds about 15mA of current drain, not to mention 10 or so components.

Crystal Filter: The coupling to the input and output of the crystal filter is simple and effective: L-networks provide a small amount of selectivity while transforming the high impedance of the '602s down to around 400 ohms. This matching technique provides as flat a pass band as transformer coupling does, but without toroids or I.F. cans (note, again, those cheap 15uH inductors). The small loss in using the '602s single-ended isn't missed much at this I.F. frequency.

AGC/Mute: Q2 and Q3 form a balanced version of the usual AF-thump mute circuit, and double as moderate-range AGC elements. The balanced configuration is used to take advantage of the balanced input to the LM386. The gate bias network (R5/R6/D3/D4) sets the gate voltage such that, with no signal, the FETs are at about their minimum R_{ds} of around 150 ohms. As the AF level increases, C29 acquires a negative DC voltage, pulling the gates lower and increasing R_{ds} up to 1M ohms or more. Only a few microamps of current are required for this AGC circuit. (On the negative side, you have the usual thumps associated with AF-derived AGC; however, since the detector is working into such a high impedance, C29 can remain fairly small, and the response time is better than many such circuits. Also, there is a limit to the size of signals that Q2 and Q3 can pass without distortion–hence the RF gain control.) D1 was added to keep the AGC time constant from affecting the mute time constant, and vice-versa. C29 is nonpolarized because the DC voltage at that point can be positive or negative. That same capacitor is then used elsewhere in the rig where a small-value electrolytic is called for--even though a polarized electrolytic would work--again in the name of minimizing unique components.

AF Amp: This LM386 circuit is similar to others, except for the arrangement of R8 and C26. Usually, you use a 20 ohm resistor and .05uF cap to ground from pin 5 to kill any high-frequency instability. There is also often a need to remove both internal LM386 noise and input noise using low-pass filter components. Here, we kill two birds with one stone by arranging R8 and C26 as a low-pass filter. C27 is quite a bit larger than C26, so not much is lost at the headphones. R8 sets both the volume level and the frequency response in this configuration, which works pretty well. For example, high-quality headphones typically have both good efficiency and good high-frequency response, so R8 will be set for around 50 ohms, which lowers the gain and removes a good deal of hiss.

TX Mixer: This is a conventional circuit, except for C32, which has the effect of reducing the harmonic content from U4 and reducing the VFO shift induced by U4 when it turns on. By the way, did you notice yet another 15uH inductor (L5)? There's also one more that we'll let you find, for a total of six!

TX Buffer/Driver: Q5's gate circuit saves one component by providing DC bias through L6 and R10 rather than using capacitive coupling and a separate 100K resistor. The value of R10 is a compromise, chosen to look like a small coupling cap at AC, and yet still isolate the gate from L6 to improve DC bias stability. Q5 and Q6 form a minimum-component source-follower/driver, and the usual emitter-bypass cap isn't needed because Q6 has plenty of gain at 7MHz.

RIT and VFO: D8 is a very high-capacitance device (50 to 150 pF). That, combined with the nonlinear resistance/rotation curve of R17/R20, and the relatively small value of C49, results in a fairly linear frequency tuning range. R16 is 10% of the size of R17, so if the VFO range is 40 KHz, the RIT range is about +/- 2KHz. Comparator U6 drops in a fixed resistor, R15, during transmit or when S2 is in the "OFF" position. The RIT range increases as you turn the VFO knob CCW with this arrangement. That has the beneficial effect of giving you over +/- 2.5 KHz near the bottom end of the band, useful when you want to call DX stations up or down.

Modifications

This section describes some modifications to the original design that individual builders may want to include. Please submit your own ideas for modifications to NorCal.

7.023 MHz Trap

Because of the mixing scheme used in the NorCal 40, a spurious signal ("birdie") can be heard at about 7.023MHz. If you want to tune the Extra band, you will probably want to suppress this signal using a trap. If you don't need the Extra band, you can leave the trap out and use the 7.023MHz signal as a band-edge marker during alignment.

(For the technically inclined: the birdie is caused by the 7th harmonic of the VFO when it is at 2.108 beating against the 3rd harmonic of the BFO. Both of these come out to around 14.745MHz, so you end up with an audible signal from the product detector.)

To install the trap:

[ ] Turn the NorCal 40 upside-down and remove the bottom cover.

[ ] Solder C101 (0.01uF) between pins 2 and 3 of U2.

[ ] Wind toroid L101 and prepare its leads as described for L6-L8 in the Assembly section.

[ ] Solder L101 and C102 (50pF trimmer) together, in series, keeping the leads short.

[ ] Solder one end of this pair of components to pin 1 of U2 on the bottom of the PC board.

[ ] Solder the other end to pin 3 of U2.

[ ] After you have performed the normal receiver alignment, tune the VFO until you hear the birdie, then adjust C102 until the volume of the birdie is minimized.

Other Suggested Modifications

Here are just a few of the many tweaks you can make to the NorCal 40:

TX Monitor pitch and volume change

If the transmit monitor tone is too loud or too soft, try a different value of R4. A smaller value will make the monitor tone louder. You can change the pitch of the tone, too: if it is too low, try a 10-pF cap in parallel with C34; if it is too high, replace C34 with a 39-pF cap.

TR delay change

The TR (transmit-receive) delay time can be increased by changing C28. A smaller value of C28 is not recommended, as you may hear loud clicks.

Other Bands

Although no one has tried putting the NorCal on a different band yet, it shouldn't be too hard. Depending on how you affect the mixing scheme, though, you may find new birdies in the tuning range. Here are some possibilities:

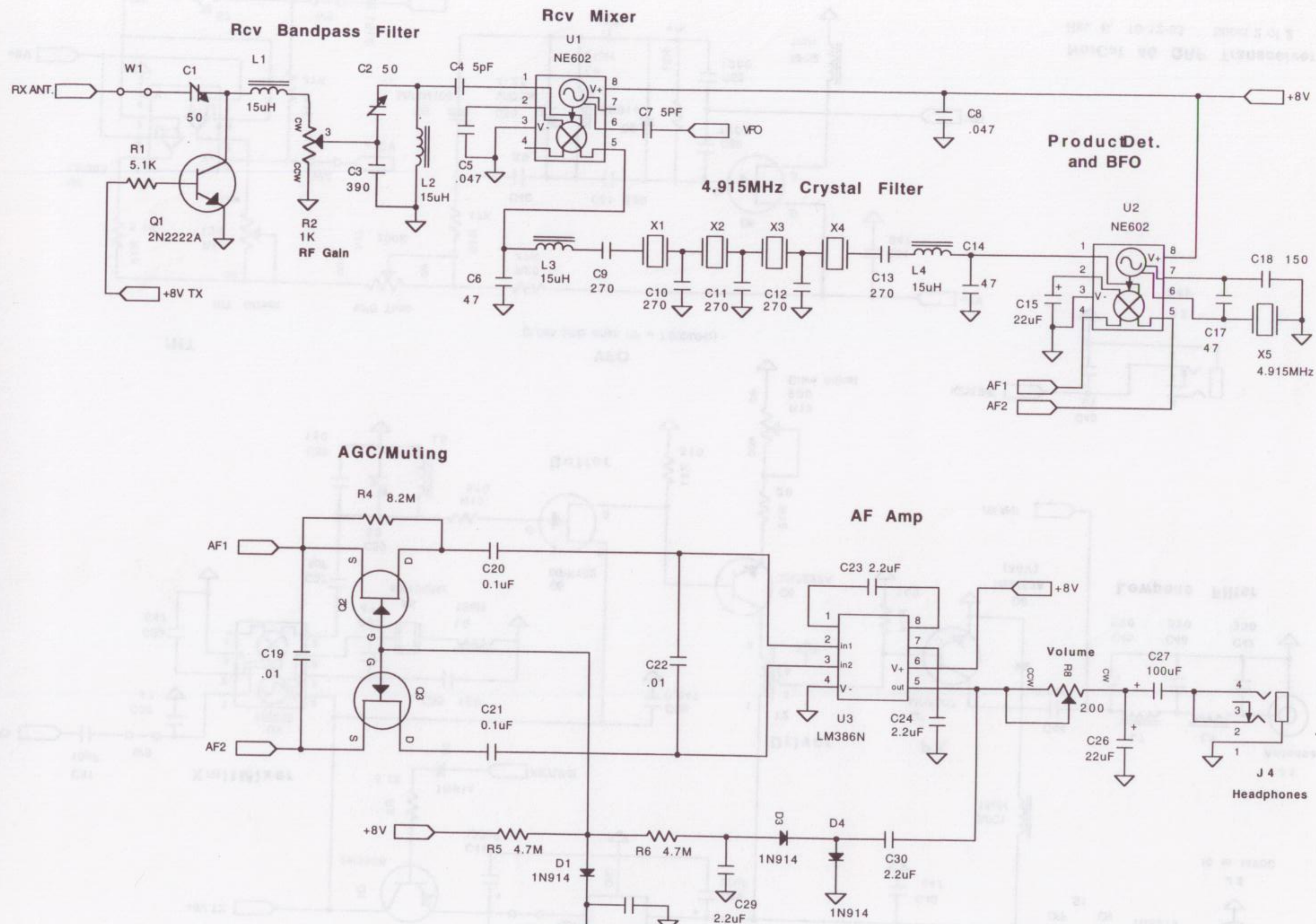
80 meters: Change the VFO to cover 1.315 to 1.415 MHz to cover 3.5 to 3.6 MHz. It will tune backwards from the 40-meter tuning.

30 meters: Change the I.F. (meaning all six crystals: the filter, BFO, and transmit mixer oscillator) to 8.000 MHz, and retune the VFO to cover 2.1 to 2.15MHz. Change the crystal filter L-networks (C6, L3, L4

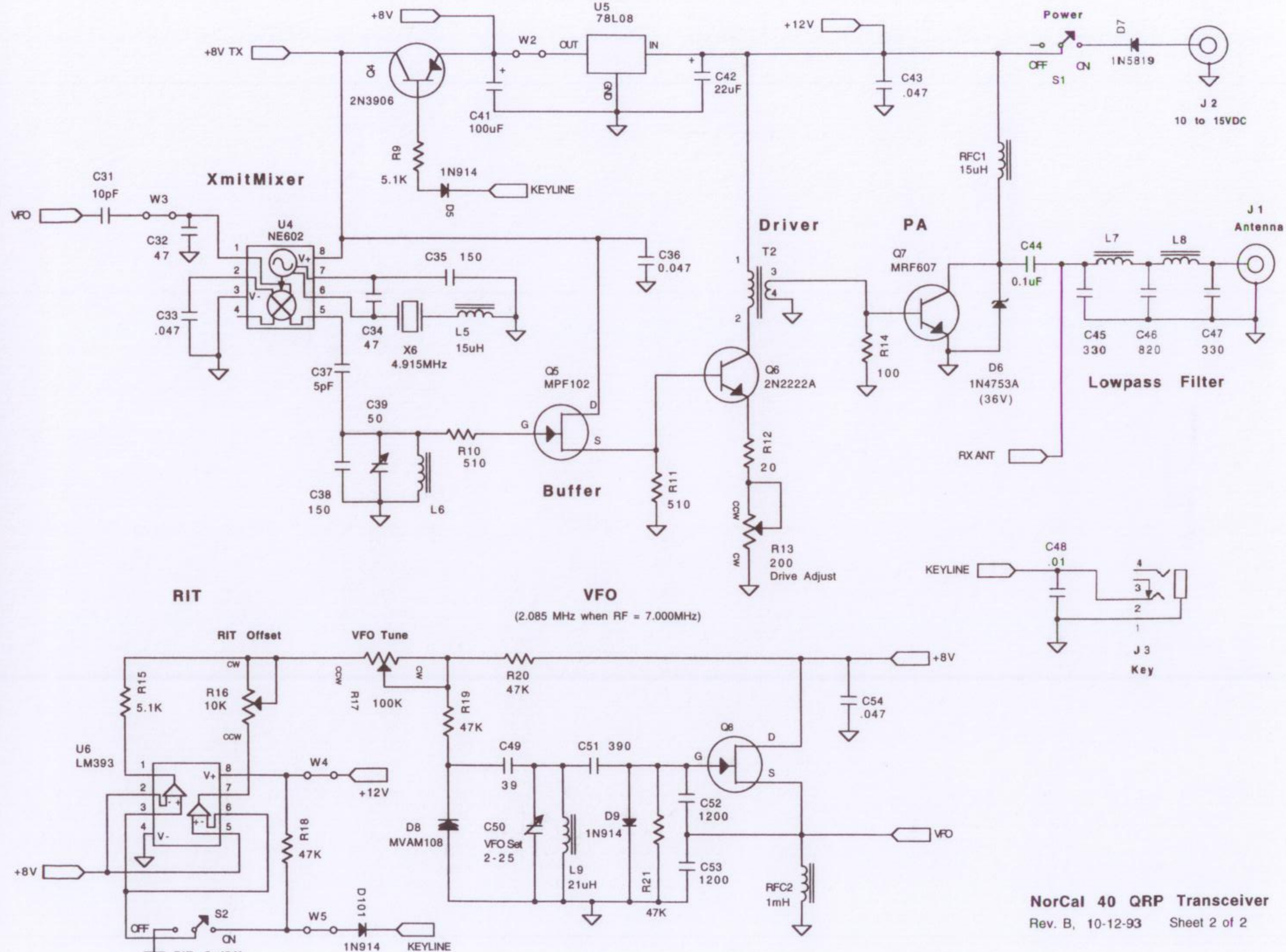
and C14) to provide the necessary impedance match to/from the NE602s.

20 meters: Change the I.F. to 12 MHz and retune the VFO to cover 2.0 to 2.1. You will probably have a birdie at 14.000 that acts as a band-edge marker. To get more gain on 20 meters, you will probably have to remove C6, L3, L4 and C14 and use two toroidal transformers instead. With an I.F. of 12 MHz, the filter bandpass will be wider than 500 Hz. Another possibility is to use 8MHz as the I.F. and change the VFO range to 6.0 to 6.1, but the VFO will not be as stable under temperature extremes as it is at 2.0MHz.

In any case, if you change the band of operation, you'll have to scale the RF input and output components and retune. The parts you'll have to change are: L1, L2, L6, C38, L7, L8, C45, C46, and C47. You may have to chage others as well depending on the band. This is not an effort to be undertaken lightly: a good, high-frequency scope will be needed to make sure you're not outputting some kind of radical spurious energy due to your new mixing scheme. On the other hand, if it works, let us know!



NorCal 40 QRP Transceiver
Wayne Burdick, N6KR
Rev. B, 10-12-93 Sheet 1 of 2



NorCal 40 QRP Transceiver

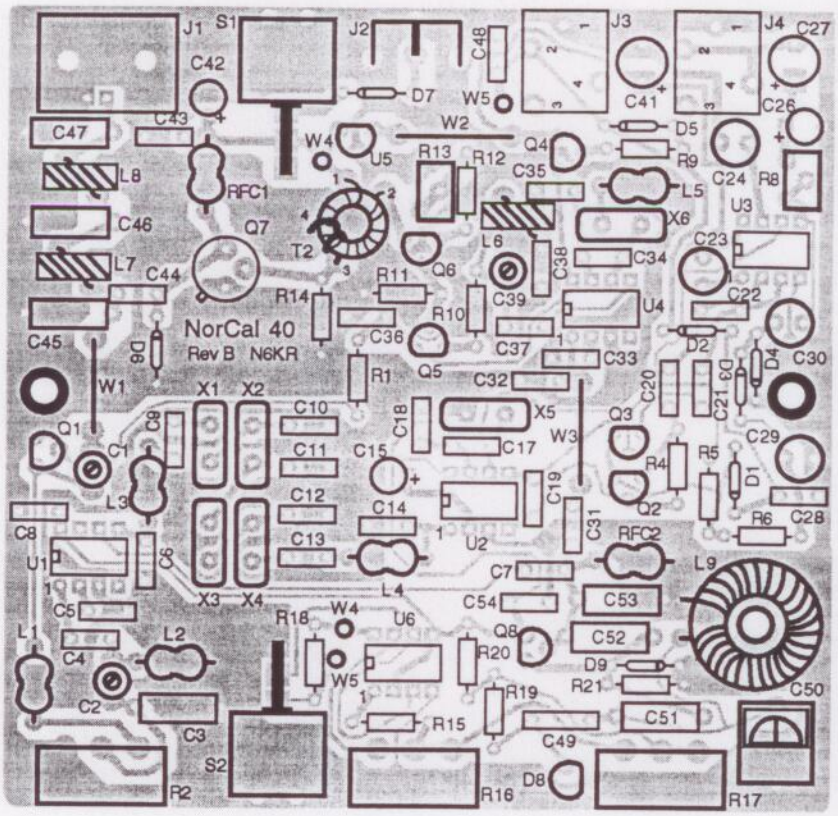
Rev. B, 10-12-93 Sheet 2 of 2

NORCAL 40 PARTS LIST, REV. C, 10-12-93

Note: Prices given are for reference only, and reflect purchases for 100 units. Most individual component prices are much higher in small quantities.

Ref.	Description	P/N	Source	QTY	COST EA	EXT COST
C4,C37,C7	CAP,DISC,5pF,10%,50V	21CB005	MOUSER	3	0.06	0.17
C31	CAP,DISC,10pF,10%,50V	140-CD50S2-010J	MOUSER	1	0.06	0.06
C6,C14,C17,C32,C34	CAP,DISC,47pF,10%,50V	21CB047	MOUSER	5	0.06	0.29
C18,C35,C38	CAP,DISC,150pF,10%,50V	21CB150	MOUSER	3	0.06	0.17
C9-13	CAP,DISC,270pF,10%,50V	140-CD50S2-271J	MOUSER	5	0.07	0.35
C49	CAP,MICA,39pF,5%	232-1000-039	MOUSER	1	0.59	0.59
C45,C47	CAP,POLY,330pF,5%	23PS133	MOUSER	2	0.10	0.20
C3,C51	CAP,POLY,390pF,5%	23PS139	MOUSER	2	0.10	0.20
C46	CAP,POLY,820pF,5%	23PS182	MOUSER	1	0.10	0.10
C52,C53	CAP,POLY,1200pF,5%	23PS212	MOUSER	2	0.11	0.22
C19,C22,C48,C101	CAP,MYLAR,.01µF,10%,100V	140-PM2A103K	MOUSER	4	0.07	0.26
C5,C8,C28,C33,C36,C43,C54	CAP,MYLAR,.047µF,10%,100V	140-PM2A473K	MOUSER	7	0.08	0.59
C20,C21,C44	CAP,MYLAR,0.1µF	140-PM2A104K	MOUSER	3	0.13	0.39
C23,C24,C29,C30	CAP,ELEC,2.2µF,NON-POL	140-NPRL50V2.2	MOUSER	4	0.20	0.80
C15,C26,C42	CAP,ELEC,22µF, 25V	140-XRL25V22	MOUSER	3	0.09	0.27
C27,C41	CAP,ELEC,100µF,25V	140-XRL25V100	MOUSER	2	0.13	0.26
C50	CAP,VAR,2-24pF, AIR	530-189-0509-5	MOUSER	1	2.25	2.25
C1,C2,C39,C102	CAP,VAR,8-50pF,MICA	24AA024	MOUSER	4	0.67	2.68
D1-5,D9,D101	DIODE,SWITCHING	1N914BPH	DIGIKEY	7	0.05	0.35
D6	DIODE,ZENER,36V,1W	333-1N4753A	MOUSER	1	0.19	0.19
D7	DIODE,SHOTTKY	IN5817GI	DIGIKEY	1	0.29	0.29
D8	DIODE,VARACTOR	MVAM108	HALLMARK	1	0.53	0.53
U3	IC,AF AMP	LM386N	DIGIKEY	1	0.40	0.40
U6	IC,COMPARATOR	LM393N	DIGIKEY	1	0.36	0.36
U1,U2,U4	IC,MIXER/OSC	NE602AN	ANTHEM	3	0.99	2.97
U5	IC,VOLTAGE REG.,8V,TO-92	AN78L08	DIGIKEY	1	0.30	0.30
L1-5,RFC1	IND,CHOKE,15UH	43LS155	MOUSER	6	0.25	1.50
RFC2	IND,CHOKE,1MH	43LS103	MOUSER	1	0.29	0.29
L6,L101	IND,TOROID,25 turns #28 (16"),T-37-2	T-37-2 (red, 0.37" O.D.)	AMIDON	2	0.40	0.80
L7-8	IND,TOROID,18 turns #26 (12"),T-37-2	T-37-2 (red, 0.37" O.D.)	AMIDON	2	0.40	0.80
L9	IND,TOROID,62 turns #28 (56"),T-68-7	T-68-7 (white, 0.68" O.D.)	AMIDON	1	0.40	0.40
T1	IND,TOROID,14 turns PRI (10"),4 turns SEC (4"),#26,FT-37-43	FT-37-43 (black, 0.37" O.D.)	AMIDON	1	0.40	0.40
J3,J4	JACK,3.5MM,STEREO,PC-MT	161-3501	MOUSER	2	0.76	1.52
J1	JACK,BNC,PC-MOUNT	177-3138	MOUSER	1	1.46	1.46
J2	JACK,RCA,PC-MT	161-4215	MOUSER	1	0.31	0.31
R12	RES,20Ω,1/4W,5%	20Q	DIGIKEY	1	0.02	0.02
R14	RES,100Ω,1/4W,5%	100Q	DIGIKEY	1	0.02	0.02
R10,R11	RES,510Ω,1/4W,5%	510Q	DIGIKEY	2	0.02	0.04

R1,R9,R15	RES,5.1K,1/4W,5%	5.1KQ	DIGIKEY	3	0.02	0.05
R18-21	RES,47K, 1/4W, 5%	47KQ	DIGIKEY	4	0.02	0.07
R5,R6	RES,4.7M,1/4W,5%	4.7MQ	DIGIKEY	2	0.02	0.04
R4	RES,8.2M,1/4W,5%	8.2MQ	DIGIKEY	1	0.02	0.02
R8,R13	RES,TRIMMER,200Ω	531-PT10H-200	MOUSER	2	0.34	0.68
R2	RES,POT, 500Ω	31CW205	MOUSER	1	0.62	0.62
R16	RES,POT, 10K	31CW401	MOUSER	1	0.62	0.62
R17	RES,POT,100K	31CW501	MOUSER	1	0.62	0.62
S1,S2	SWITCH, SPDT, PC-MT, RIGHT ANGLE	10TF130	MOUSER	2	2.80	5.60
Q1,Q6	TRANS,2N2222A,PLASTIC	511-2N2222A	MOUSER	2	0.23	0.46
Q7	TRANS,2SC799 (or MRF607, MRF237)	2SC799	RF PARTS CO.	1	1.70	1.70
Q2,Q3,Q5,Q8	TRANS,MPF102	MPF102	DIGIKEY	4	0.18	0.72
Q4	TRANS,2N3906	333-KN3906	MOUSER	1	0.13	0.13
X1-6	XTAL,4.915 MHZ, HC-18,MATCHED +/- 20HZ	10008	NORCAL	6	0.91	5.46
	MISCELLANEOUS					
MISC	CABINET, NORCAL 40	10002	NORCAL	1	6.35	6.35
MISC	FOOT, RUBBER	517-SJ-5018GY	DIGIKEY	4	0.09	0.36
MISC	HEATSINK	33HS502	MOUSER	1	0.55	0.55
MISC	KNOB, 0.60"	450-2034	MOUSER	2	0.51	1.02
MISC	KNOB, 1.38"	450-2039	MOUSER	1	0.84	0.84
MISC	LOCKWASHER,#6, INTERNAL TOOTH	10009	NORCAL	2	0.01	0.02
MISC	MANUAL, NORCAL 40	10007	NORCAL	1	1.00	1.00
MISC	NUT,NYLON,6-32	561-G632	MOUSER	1	0.05	0.05
MISC	PC BOARD, NORCAL 40	10001	NORCAL	1	6.00	6.00
MISC	SCREW, FH 6-32X3/8"	10003	NORCAL	4	0.01	0.04
MISC	SCREW,NYLON,0.5",6-32	561-J632.5	MOUSER	1	0.06	0.06
MISC	STANDOFF, HEX,0.5" LONG,6-32 THD	J178-ND	DIGIKEY	2	0.13	0.27
MISC	STANDOFF, HEX,M-F,1.5" LONG, 6-32 THD	J218-ND	DIGIKEY	2	0.37	0.73
MISC	WASHER,FIBER,#6	534-3233	MOUSER	1	0.05	0.05
MISC	WIRE,#26 ENAMEL, 5 FEET	10005	NORCAL	1	0.10	0.10
MISC	WIRE,#28 ENAMEL, 9 FEET	10006	NORCAL	1	0.05	0.05
TOTAL:						57.08



NorCal 40   Rev. B, 9-8-93

W. Burdick, N6KR

Component Side View   1:1