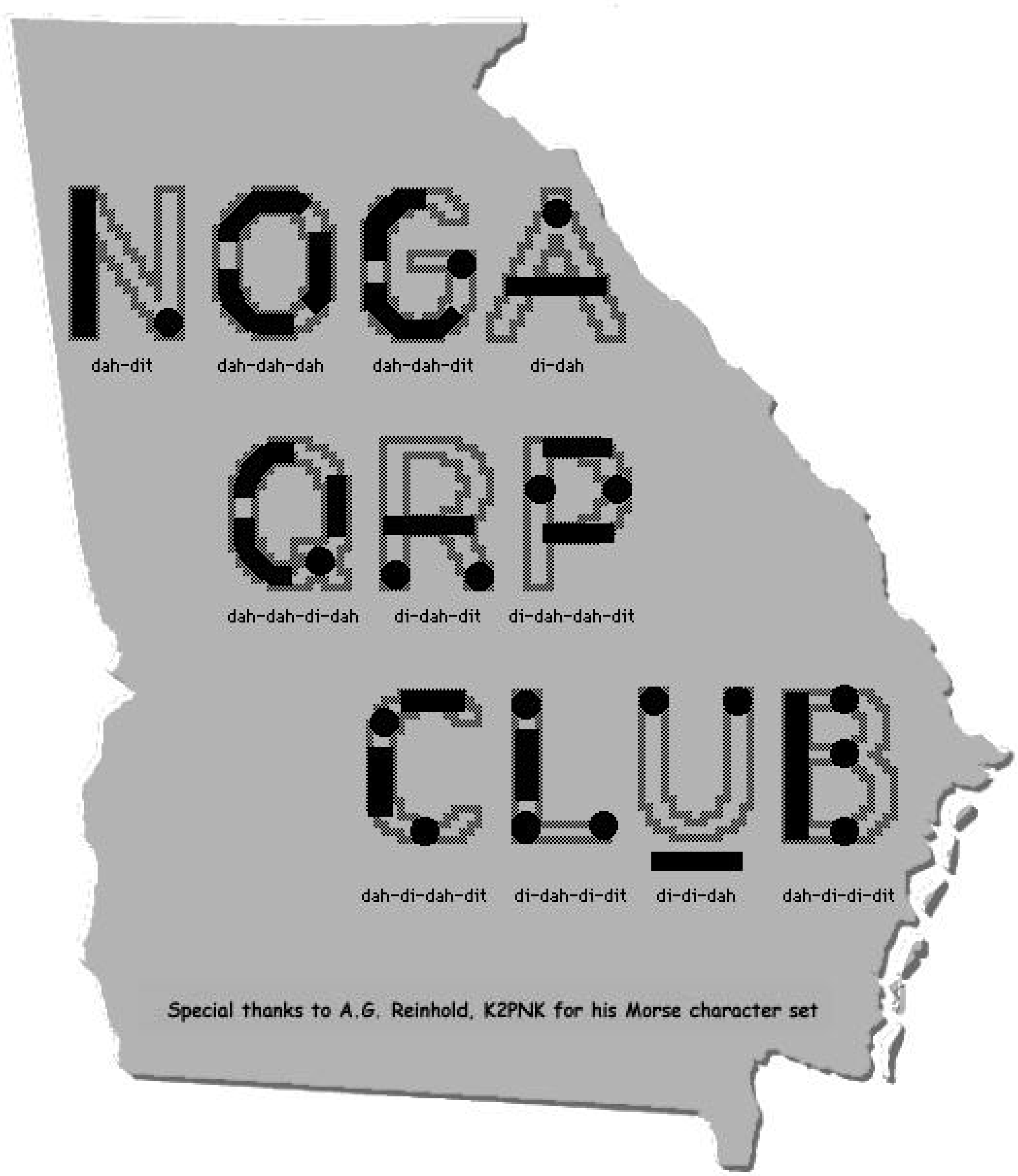
The NOGAnaut – A Y2K Ready Amateur Radio Transmitter



North Georgia QRP Club, June, 1999
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Introduction

Is your big, expensive microprocessor-based transceiver Y2K ready?

The NOGAnaut transmitter is guaranteed to operate in the year 2000 (assuming of course, that you build it correctly!). It only draws milliamperes of power, so fancy generators and other large sources of power are unnecessary—just about any solar cell, lemon or Tabasco ™ battery or even gerbil-generator will get this rig on the air!

This transmitter was adapted from the Micronaut, first made popular by Dave Ingram, K4TWJ, and sold in kit form by SESCOM™, Dave, and built by many, many others. The NOGA QRP club modified Dave's original design to develop a transmitter that would operate on the NOGA net frequency (3686.4KHz), to increase power output (over 100 milliwatts!) and to improve stability.

The NOGAnaut was designed to be an easily constructed 80M CW-transmitter, as an entry into the exciting world of QRP/QRPp. It is a one-transmitter oscillator matched to a 50-ohm load on a fixed frequency of 3686.4 KHz. The North Georgia QRP Club meets on this frequency on Tuesday nights at 9:30PM Eastern Time. The North Carolina KnightLites group also meets on this frequency on Sunday nights at 9:30PM Eastern Time. 3686.4KHz is a popular QRP frequency because,

1. Surplus computer crystals are readily available for this frequency and are relatively inexpensive.
2. 3686.4KHz is in the Novice CW portion of the 80M band (meaning you can almost always find somebody to QSO with and you don't have to worry about them sending CW at blinding speeds!).

The circuit is a basic bipolar-transistor crystal oscillator, with a keyed power supply. It can generate over 100 milliwatts (at 15V-supply voltage) of power into a 50-ohm load (as you will see below, 100 milliwatts is a lot of power!).

This kit is meant as a starting place for learning about QRP operations, home brewing, and experimentation. One of the key differences between the amateur radio license and all other FCC-granted licenses is the permission, even encouragement, to experiment. Experiments include (and are certainly not limited to):

- How far can I go using only milliwatts of power?
- What happens when I change different compenent values in this circuit?
- How can I make this circuit generate more power?
- What other uses can I make for this circuit?

About QRP/QRPp

Technically, QRP is the universally accepted "Q" signal meaning "Decrease Power." QRP has become generally accepted to represent amateur radio operations at low power: output power of 5W or less on CW and 10W input/5W output (assuming PA efficiency of 50%) on SSB.

OK, so what's the big deal about QRP? Well, in the true nature of amateur radio, QRP'ers are always trying to "push the limit." Whereas for many the thrill is to log as many countries as possible (and many QRPers share that thrill), "pushing the limit" in QRP means, "doing more with less." The challenge is to improve your operating skills and technical capabilities to go "further with fewer."

Assume two amateur radio stations have identical antennas and identical transmitting and receiving equipment. One of the stations transmits a 1000-watt CW signal and that signal is measured at "10 dB over S9" on a receiving station. If the CW transmitter output is reduced to 5 watts, it will be measured at the receiving station as a little under S7!

Power Output	Signal Strength Received
1000 watts	S9 + 10 dB
100 watts	S9
25 watts	S8
6.25 watts	S7
1.563 watts	S6
391 milliwatts	S5
98 milliwatts	S4
24 milliwatts	S3
6 milliwatts	S2
1.5 milliwatts	S1

One of the earliest references to “miles per watt” was in 1923, when Robert Kruse, 1XAM, noted in QST “…doesn’t more credit belong to the man who hauls signals fifty miles per watt than to the one who has to use greater power to haul them only 25 miles per watt?” (quoted by Richard Arlan, K7YHA, in the September 1995 QST, page 66).

QRPp is QRP operating at power levels less than one watt (milliwatts or microwatts). For example, on December 26, 1994, Fran Slavinski, KA3WTF, copied Paul Stroud, AA4XX’s, 221 **microwatt** (211 millionths of a watt) signal on 7050KHz at a pre-arranged time. He immediately sent back a 229-signal report to complete a 2xQRP QSO, establishing a new 40-meter world record of over 1,900,000 miles per watt! They were using standard QRP equipment (an Oak Hills Research “Classic” QRP 40/20-meter transceiver at AA4XX and a Ten-Tec Argonaut II at KA3WTF).

Another advantage of QRP is that by running less power out, less power supply is needed, allowing for more easily transportable gear. Many QRP enthusiasts are also backpacking, hiking and camping enthusiasts and many QRP contests involve field operations.

Finally, many QRP operators enjoy designing and building their own equipment. Building your own gear is not a requirement of QRP operations, but can be a whole lot of fun—especially the first time you realize that **Ohm’s Law really does work!** Not only does home-brew improve the state-of-the-art, but it also improves the individual’s technical skill. Truth is, though, that very few home-brew rigs are ever “finished,” as there is always “one more mod” to do!

Circuit Description

The crystal oscillator is the simplest form of transmitter. Normally, oscillators are used to drive buffer amplifiers and power amplifiers, which provide increased output, as well as prevent the output circuit from adversely loading the oscillator.

Most transistors exhibit a characteristic impedance different from the 50-ohm impedance of a well-tuned antenna system. An improper match between the impedance of the transistor and the load (e.g. antenna system) can cause severe power degradation, and worse, can seriously affect the signal, including shifting the oscillator frequency in unpredictable ways.

In the NOGAnaut transmitter, the 2N2222A transistor, which exhibits a characteristic impedance of approximately 200 ohms, is matched to a 50-ohm load via the pi-network filter composed of C1, C2 and L2. The values of these components were chosen to provide a close match between the 200-ohm transistor and a 50-ohm antenna (it is therefore critical that a good 50-ohm antenna system be used with this transmitter). It so happens that these values also form the familiar half-wave harmonic filter, thus satisfying FCC spurious emissions requirements.

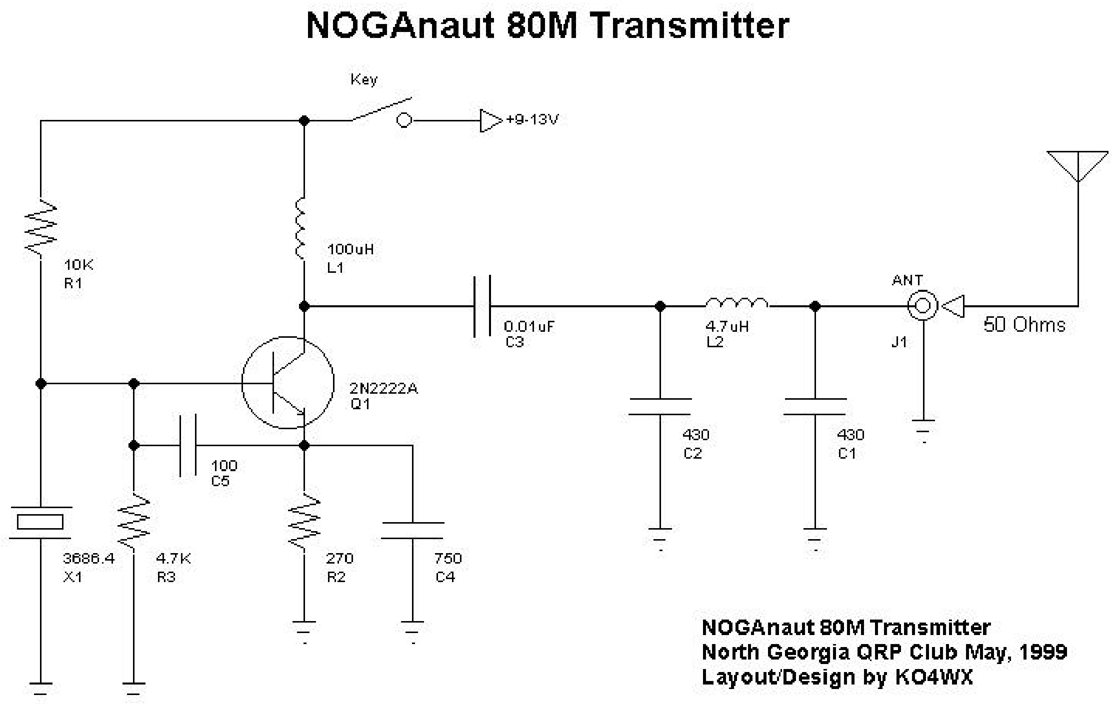

Figure 1. NOGAnaut 80M Transmitter Schematic.

Capacitor C5 provides the necessary feedback to begin oscillation. You may find that you can operate your NOGAnaut without this capacitor--stray capacitance in the circuit provides a certain amout of feedback without C5. However, it was found during development of this circuit that the oscillator can have troubles starting at times, therefore it is recommended that you leave C5 in the circuit.

The 0.01 uF capacitor, C3, serves as a DC-blocking capactor. At 3.6864 MHz, this capacitor is essentially a dead-short to RF, but blocks the DC current from flowing into the load.

This is a familiar Colpitts oscillator, operated in “common-base mode.” The usual base-bypass capacitor is replaced by the capacitance of the crystal. With a 15V supply, this transmitter has been measured to deliver as much as 134 milliwatts into a perfectly matched 50-ohm load (“your mileage may vary”). With a 9V supply, about 20-50 milliwatts should be expected.

The transmitter is keyed by interrupting the positive supply voltage. You can modify this to be grounded keying, if necessary (just interrupt the negative supply voltage instead of the positive voltage). This may be necessary if you use a keyer that expects grounded or negative keying.

For a very good description of crystal oscillators, check out *Solid State Design for the Radio Amateur* by Wes Hayward, W7ZOI, and Doug DeMaw, W1FB. This is one of the most popular amateur radio books ever written and is packed full of practical information about how solid state circuits behave. It is published by the ARRL, and can be purchased directly from them, as well as from many electronics retailers.

Further information about pi-network filters can be found in *The ARRL Electronics Data Book*, by Doug DeMaw, W1FB, also published by the ARRL. This book contains most of the nuts and bolts of basic circuit design, and is a must for any ham shack.

Parts List

Part	QTY	Value	Tech America Part Number	Label
C1,C2	2	430 pF or 330+100 or 220+220	430 pF not carried 900-2208+900-2201 900-2205+900-2205	431 331 + 101 221 + 221
C3	1	0.01 uF	900-2253	103 or .01
C4	1	750 pF or 680+68 or 470+330 or 560+180	750pF not carried 900-2214+900-2199 900-2213 + 900-2211 560pF not carried	751 or 750 681+68 471+331 561+181
C5	1	100 pF	900-2201	101
J1	1	RCA jack	910-0869, -0870, -4091	
L1	1	100 uH	900-4967	brown-black-brown
L2	1	4.7 uH or 4.3 uH	900-4958 33 t #26 on T37-2 core (900-7008)	yellow-violet-gold red core
Q1	1	2N2222A	900-5428	2N2222A
R1	1	10K ¼watt	900-0242	brown-black-orange
R2	1	4.7K ¼watt	900-0234	yellow-violet-red
R3	1	270 ¼watt	900-0204	red-violet-brown
X1	1	3686.4 KHz	900-5096	3.6864
J2	1	9V holder	900-0344 or equivalent	

Construction

The NOGAnaut is constructed “dead-bug” or “ugly-style.” Unlike most kits with which you may be familiar, there are no holes to poke the component leads through the PC board. In this project, all components are soldered onto the same side of the board as the circuit traces. This is similar to “surface-mount construction” with which you may be familiar (there was a series of articles in QST, winter-spring 1999, on surface-mount construction if you are interested).

The reason this type of construction was chosen for this project is simple: it makes it much, much easier to make modifications to the circuit in the future. This kit is meant as a starting place for you to make your own modifications, and experimentation. Unsoldering components mounted through a PC board is much more difficult—in fact, the better made the PC board, the harder it can be to remove components (some “plated-through” boards make it down right impossible to remove components).

Looking at the PC board (see Figure 2), you will see that most of the board’s surface is a ground plane. However, “islands” have been cut out of the board to provide places to solder circuit connection points together.

Notice also in Figure 2 that C1, C2 and C4 are shown with two capacitors, one slightly grayed out. In order to achieve the necessary capacitance for these circuit components, you may have to parallel two capacitors. For example, if you don’t have a 750-pF capactor for C4, you can parallel a 680-pF and a 68-pF capacitor. There are other combinations as well, using standard value capacitors, such as 470-pF and 330-pF, 560-pF and 180-pF, etc. If you have a second capacitor, place it where the grayed-out component is shown in Figure 2.

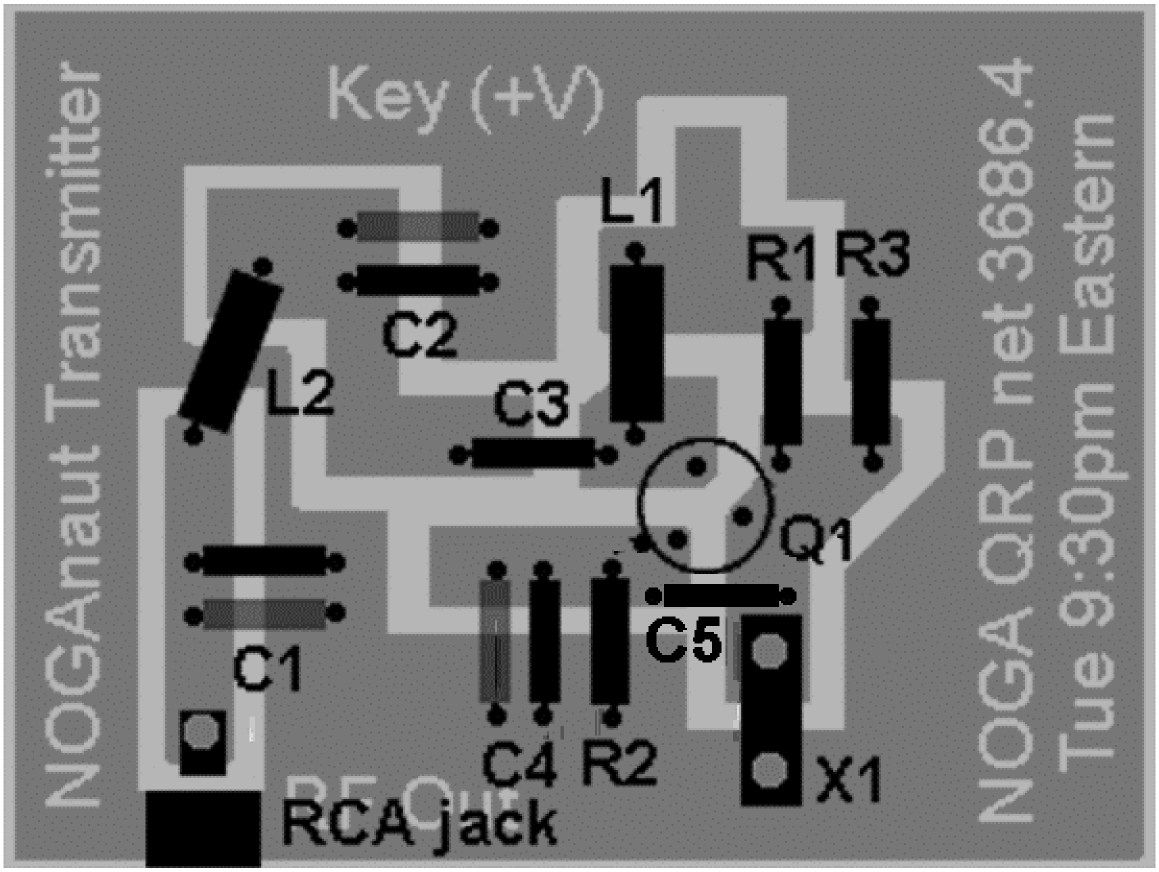

Figure 2. NOGAnaut PC board traces and parts layout.

There are several ways to mount a part onto to the circuit board. The easiest is to cut the component leads to approximately ½ inch, and then bend a very small part (about 1/16th to 1/8th of an inch) of the end of each lead perpendicular to the lead. For some components (such as resistors), you may have to bend one of the leads parallel to the part to fit neatly on the board. This is where you get to make decisions about how you want your board to look when you're done. Some suggestions are shown in Figure 3.

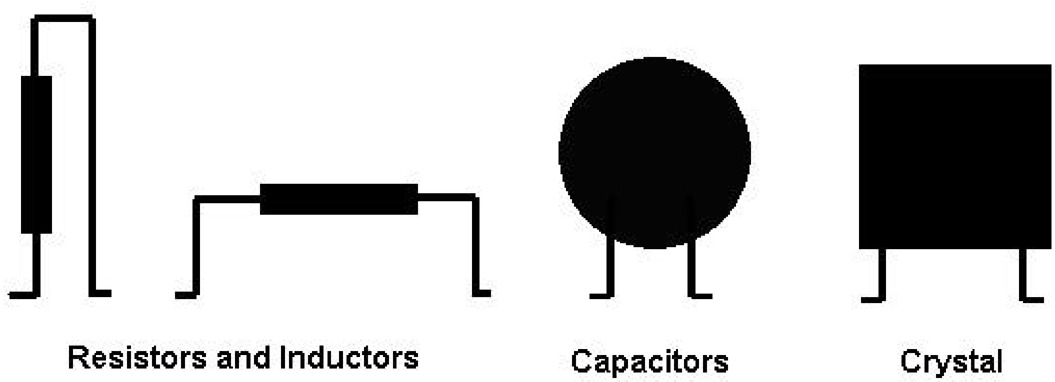

Figure 3. Some suggestions on how to mount parts onto the PC board.

Use a pencil soldering iron (say between 25 and 45 watts or so) to build the circuit. To solder a component lead to the board, first touch the tip of the iron to the place on the board where you wish to place the lead. After briefly heating the board, apply a small amount of solder, to make a small blob on the board. Put the solder down, pick the part up by the other lead with needle-nosed pliers and place the lead that you wish to solder to the board on top of the blob you just made. Then reapply heat touching the blob with the iron long enough to remelt the solder around the bent component lead. Finally, grab the lead with your needle nose pliers for about 20-30 seconds, to dissipate some of the heat away from the part.

This may take some practice--you can practice by soldering small pieces of component lead anywhere you'd like on the ground plane (the big open area covering most of the outer part of the board). Clip them off when you're done practicing—it is, after all "ugly" construction! It's not hard, once you get used to it.

Once you install the first lead of a component, installing the other lead(s) is easy—just apply a small amount of heat and solder to the appropriate place where the lead contacts the board, melt enough solder to hold it in place and remove the heat. Again, grab the lead with needle-nosed pliers for 20 or 30 seconds to help draw off excess heat and avoid damaging the component.

You can install the components in any order that you wish, however, we've found the following order of installation to be simple and straightforward.

1. First, mount the transistor standing up, as is shown in Figure 4. Leave plenty of lead on the transistor. This will help to dissipate the heat as you solder (however, you can still damage the transistor by applying too much heat). It will also make it easier to remove, should you need to replace it in the future. Note the orientation of the tab on the 2N2222A transistor. The lead closest to the tab (the emitter) should be soldereed to the same trace as R2, C4 and C5.

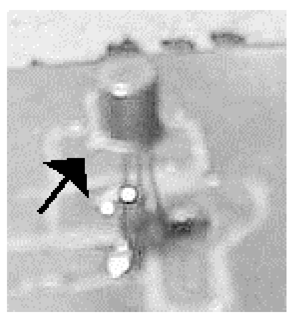

Figure 4. The 2N2222A transistor mounted on the PC board using "ugly construction."

2. Next, mount the resistors, R1, R2 and R3. Pay careful attention to installing the proper value in the proper location, as shown in Figure 2. When you mount R3, be sure to leave just a little room for C5 that mounts between the emitter and base of the transistor. Refer to Figures 1 and 2 as you mount each component to be sure that each is placed in its proper location.
3. Mount the capacitors. C3 should be mounted first, then C5, then C4, C1 and C2. Note that there is not much room to mount C5. Mount it carefully to ensure that you don't bridge the gap between circuit board traces with solder (known as a "solder bridge").
4. Mount the inductors. You may need to install them "standing up" (one lead parallel to the inductor) depending on how much room you left yourself for these components. If you need to, you can always move a component lead slightly, by reheating the solder around the lead. Just be careful that you don't overheat the component.
5. Install the crystal. Be extra careful mounting this component, as too much heat can damage it.
6. Remove the grounding lug from the RCA plug and bend about 1/8th of an inch (up to the small hole) of the narrow end of the lug perpendicular, so that once soldered on the board, the lug stands straight up with the large opening on top. Solder it to the board as close as possiible to the edge, parallel with the edge, where indicated in Figure 2. Insert the RCA jack, and then install and tighten the nut so that the jack is held firmly in place. Note that the hole in the center connector of the jack should be directly over the "RF Out" trace on the PC board. It's best to tighten it such that the hole of the center connector of the jack is down; that is, it looks sort of like a "U" when looking at it on end.

Now take an excess piece of component lead and solder it between the “RF Out” trace (the one where C1 and L2 meet) and the center conductor of the RCA Jack.

7. Cut a 3” piece of the red wire on the 9V-battery connector and solder to the trace labeled “Key (+V)”. Connect the other end of this wire to your telegraph key (or other switch) and connect the remaining red wire to the other pole of your telegraph key (or switch).
8. Connnect the black wire to any convenient point on the ground plane (the large area around the perimeter of the PC board
9. Check over the entire board to ensure that all components were installed correctly, that there are no solder bridges, and that there are no loose connections.
10. Install a 9V battery or connect to a 9-15V source.
11. Connect a 50 ohm antenna to the RCA jack (unbalanced coaxial connection).
12. Key the transmitter, and you should be able to hear your signal in a nearby receiver tuned to 3686.4 KHz (note that this could vary by a couple of hundred Hz or so—that’s OK).

Tune Up, Testing and Experimentation

If you have built this circuit correctly, no tune up should be necessary. You should be able to use a nearby 80M receiver on 3686.4 KHz to hear the signal. If it doesn’t start oscillating when you key the transmitter into a dummy load or matched (50-ohm) antenna system, check again to make sure that all components were installed correctly, that there are no solder bridges, and that there are no loose connections.

If it still doesn’t work, ensure that there is a positive voltage difference between the collector and the emitter (about 6.3V with a 13V supply). If not, then either one or more components is not installed correctly (most likely Q1, R1 or L1) or there is a problem with your transistor. Replacement 2N2222A transistors are available at both Radio Shack and Tech America. At last resort, you can use a 2N3904 or 2N4401 transistor (however, expect less power output).

If you ave a good voltage difference between the collector and the emitter, then if you have an oscilloscope, check to see if you have a sine wave at either lead on C3. If you do, and you don’t have one coming out from the RCA jack, then one or more of the components in the output filter (C1, C2, L2, RCA jack) is not connected correclty.

You will most likely see little, if any, deflection on a normal ham shack power meter, unless you have one designed for QRP. A good circuit for testing the power output of QRP rigs can be found in *Solid State Design for the Radio Amateur* by Wes Hayward, W7ZOI, and Doug DeMaw, W1FB. This is a workhorse, utility circuit that has multiple uses in the QRP station.

The possibilities for experimentation with this circuit are endless. Initially, try making contact with a nearby ham (within a couple of miles, if possible). You’ll be surprised how well he can hear your QRPp signal. As you get more familiar with operating this rig, try making contacts further and further out—even try checking in the NOGA and/or Knightlights nets (Tuesday and Sunday nights, respectively, at 9:30 Eastern time on 3686.4 KHz).

This circuit can be the basis for many more complicated circuits—nearly every piece of radio transmission and reception equipment has at least one oscillator in it. Experiment with placing a variable capacitor (available at any ham fest) in series with the crystal (remove the grounded end of the crystal and attach to one end of the capacitor, and connect the other side of the capacitor to ground). The oscillator in this configuration is known as a VXO or variable crystal oscillator. VXO’s are very stable, but at 80M you will probably only get about 1KHz or so of swing, using a 200 pF to 300 pF variable capacitor. You can also adjust the frequency (downward) by adding inductance (say 33 uH to 56 uH) in series between the crystal and the variable capacitor.

The number one object of QRP operations, home-brew, and home-construction is HAVE FUN! Talk to others. Ask questions. MELT SOLDER!

About the North Georgia QRP Club

NOGA QRP is a loose knit band of crazies who love QRP, construction, wilderness radio operations, etc. We have no dues or fees, no formal organization, and make no pretenses of formality in any way. Essentially, to become a member of NOGA, all you have to do is say the words, "I am a member of the North Georgia QRP Club."

The NOGA QRP Club's Internet website is located at http://www.qsl.net/nogaqrp (on the QTH.NET server). In addition to lots of good information about NOGA and pictures of our activities, it has several home-brew projects that you can try.

We also have a NOGAQRP list on the Internet on the QTH.NET server. If you have Internet Web access, you can link to:

http://www.qth.net

Select NoGAQRP then press Archives.

All messages for the latest period will be displayed for your review. You can go back in time by selecting specific months. You can also subscribe to the list at this site.

For those of you with ONLY EMAIL service you can subscribe to this list service and begin receiving NOGAQRP messages automatically on near real-time or DIGEST (daily or multiple days) mode by doing the following:

- Send a message to: majordomo@qth.net, NO subject
- In body of message: subscribe nogaqrp <your email address>
- Or, in body of message: subscribe nogaqrp-digest <your email address>
- Use the first subcribe option for regular (instantaneous) delivery, and the second subscribe option for digest mode or delayed delivery. Replace <your email address> with your actual e-mail address, and don't put the <> around your email address.
- In a few minutes you should receive confirmation that you are a member of the list.
- Once you receive confirmation, send a test message to the list. This way you can see that it works and also that others will see you are subscribed. Please be patient if the confirmation doesn't come back as fast as you think it should.

The http://www.qth.net site also has instructions on how to change from Real-time or Digest mode, suspend for vacations, etc.).

Club members meet on-the-air for chatting, testing rigs, and HAVING FUN on Tuesday nights

1. At 9 PM on the Atlanta 145.41 Telephone Pioneer repeater. AE4NY is the NCS
2. At 9:30 PM Eastern on 3686 KC. Join us and try out your NOGAnaut rig. If you don't have a QRP rig, call us with your KW or what-have-you. But try to turn off all the power you can and HV FN!