Homebrewing for QRP SSB

First I would like to mention my website www.jessystems.com or in case you forget the site URL, just google my call sign N6QW. Many of my projects are documented there, complete with schematics and links to hints and tips that maybe helpful if you are contemplating building a homebrew QRP SSB transceiver. As an aside I have formally documented much of what we will discuss in this podcast and that document will be up on my website so you can download the circuits and details.

Homebrewing a QRP SSB transceiver is a very interesting subject and one that often "scares" homebrewers who would like to move from the less complex CW transceiver to ones where a rag chew is something other than a blur of sounds at 35 WPM.

But the changes necessary to transition to a homebrew QRP SSB transceiver are not that great and can be readily accomplished if the design is thought of in terms of a process. You will hear me talk a lot about process and processes.

The very 1st step in any homebrew process is to be prepared for the project and that perhaps is the very thing that determines whether your project is successful or "sorta kinda worked –once". There is no rocket science to the preparation phase just some logical thinking and below is my list of things that need to be in place:

- Reference library, much of which can be found on the internet. But that also includes setting up your filing system on your computer so that the data can be readily accessed. I have folders on my computer that include spec sheets for my favorite devices, articles and documentation from others as well as information on my projects

- Basic test equipment including a wide range crystal test oscillator, RF probe, DVM, 0-1 amp DC meter, signal source like a DDS. An Oscilloscope is really handy and almost a necessity. An LC meter such as available from AADE is another handy item that once you have you wonder why you waited so long to get one.

- Basic tools such as a temperature controlled grounded soldering iron with interchangeable fine tips, good quality needle nose pliers, various screwdrivers, exacto knife, tweezers and LED flashlight.
- Junque Box. Purchase parts in bulk and save big time. I purchase 2N3904 and 2N3906 resistors typically for 3 cents a piece buying 100 at a time. Many parts seem to show up over and over again like 100NF and 10NF capacitors, 1N4148 diodes, LM386 audio amps, NE5534's op amps, 2N2219 (good cheap RF transistor), ferrite cores such as the FT 37-43, iron cores such as T-37-6, T50-6, T68-6, T68-2, etc. See http://www.jessystems.com/How%20To%20Stuff%20A%20Junk%20Box where most of these common parts have been identified.

As a prelude to Homebrewing a QRP SSB transceiver, one of the most critical elements is the choice of IF (Intermediate Frequency) since most of the less complex designs are single conversion. This is where some time spent with a calculator can pay off big dividends. Typically (for very good technical reasons) both commercial and homebrew filters are in the range of 3 to 12 MHz. Thus to operate on the ham bands means that the LO (local oscillator) when mixed with the incoming signal results in the IF frequency. 9.0 MHz has been a popular IF frequency and when you mix that with a 5.0 MHz LO results in either 80 Meters (3.8 + 5.2 = 9) or 20 Meters (14.2 – 5.2 = 9). So one can get two bands with one filter and one LO –the band switching of course has to include the proper band pass filters so that only the band selected is received. But that choice of 9.0 MHz is not ideal for 17 Meters as the LO would have to be on about the same frequency as the IF. This presents all sorts of mixing problems. [Mixing problems arise where harmonics of oscillators or frequency generating circuits fall within amateur (or commercial bands) other than the one intended. This will make the FCC very unhappy.]

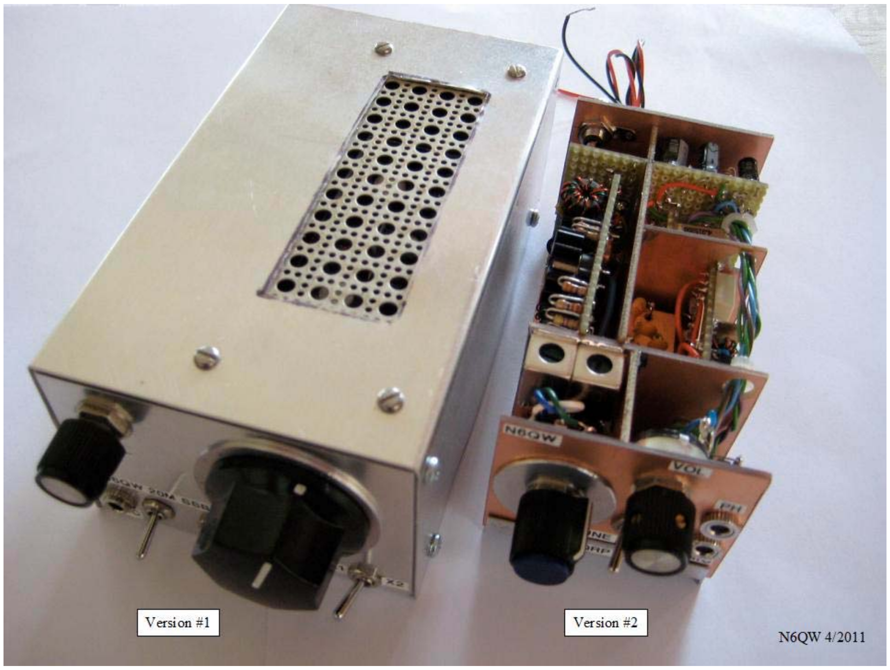
In looking at the design of the Elecraft K2, I noticed the designer's picked 4.9152 MHz for the IF frequency. Well that lit a big bulb for me. With that IF, which happens to be a standard computer crystal frequency that can be had for less than 50 cents each, there are many more possibilities for the ham bands. If you took several 11.52 MHz computer crystals and built a Super VXO which means you can actually vary that crystal frequency over a fairly wide range and then pass that signal through a diode doubler circuit where the resulting signal is 23.04 MHz –rock solid stable. Now 23.04 – 4.9152 = 18.125 which is right in the middle of the 17 Meter SSB band. If you take that same VXO concept using a 12.96 MHz VXO and mix that with a 6.144 crystal you get 19.104 – 4.9152 = 14.188 MHz – you now are on 20 Meters. A 6.176 crystal gives you 14.22. The 12.96 MHz VXO typically has about a 30 KHz spread so you can have a 60 kHz or more slice of the 20 Meter phone band. All of these crystals are stock computer crystals that typically cost less than 50 cents each. [I used this approach in four different QRP SSB radios and can attest it works!]

Homebrew crystal filters entail a small amount of effort and this is where the first use of the test oscillator comes into play. For a four pole filter it is a good idea to purchase 10 crystals on the same frequency as you want to find at least 4 that are very close in frequency. You might get lucky and actually get two filters. Of the remaining crystals at least one will be enough off frequency to be suitable for the BFO/CIO. You can use a general coverage receiver to listen to the test oscillator with each crystal plugged into the oscillator. Pick the ones that sound closest in frequency. With a little practice this can be done quite accurately. If your receiver has a digital display it will tell you exactly the frequencies. I happen to have a frequency counter and thus it is a simple matter of reading the frequencies. For a four pole filter you will need 5 coupling caps of the same value. Typically the smaller the caps the wider the filter bandwidth. At around 68-100 PF the filter will be good for SSB and 300 to 470 PF is best for CW. The input output impedance of the filter is in the range of 200 to 400 ohms. I usually assume 200 ohms as it is an easy 4:1 match to 50 Ohms. There are rigorous calculations and simulations that will give you precise values but my empirical “try it and go” is probably fairly close to the calculated values.

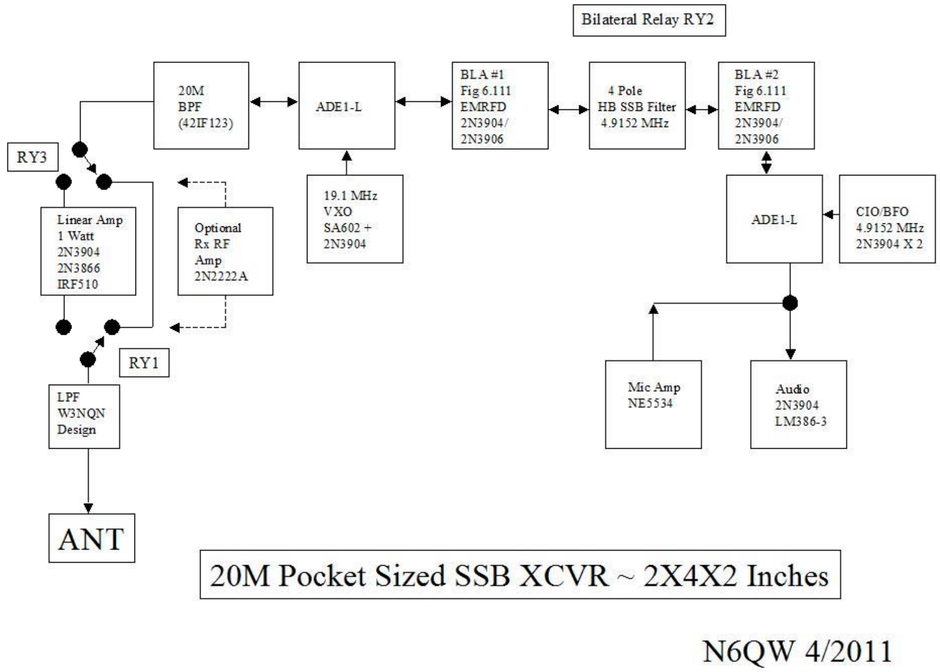
A word here about sideband inversion and frequency mixing schemes. Homebrew ladder type filters (the crystals are all of the same value) tend to favor Lower Sideband (LSB). So when you place the Local Oscillator above the incoming signal such as we have with our 17 and 20 Meter example, the subtractive mix of the LO minus the incoming signal results in what is called a sideband inversion. Thus the subtractive mix is on LSB. This is FB because with a filter favoring lower sideband and using a BFO on the LSB side demodulates the signal as an Upper Sideband (USB) signal. So this is good fortune.

I always like to start a project with a block diagram and then simply fill in the blocks with my favorite circuits. Oh, when I actually build the project I start at the back end and work my way forward. This approach enables me to use the project itself “to test as I build” and should something not work I know exactly where the problem is and do not proceed any further until it is resolved. I should mention that I also have developed standard building blocks that I simply reuse in my projects. I know they work and I know their level of performance.

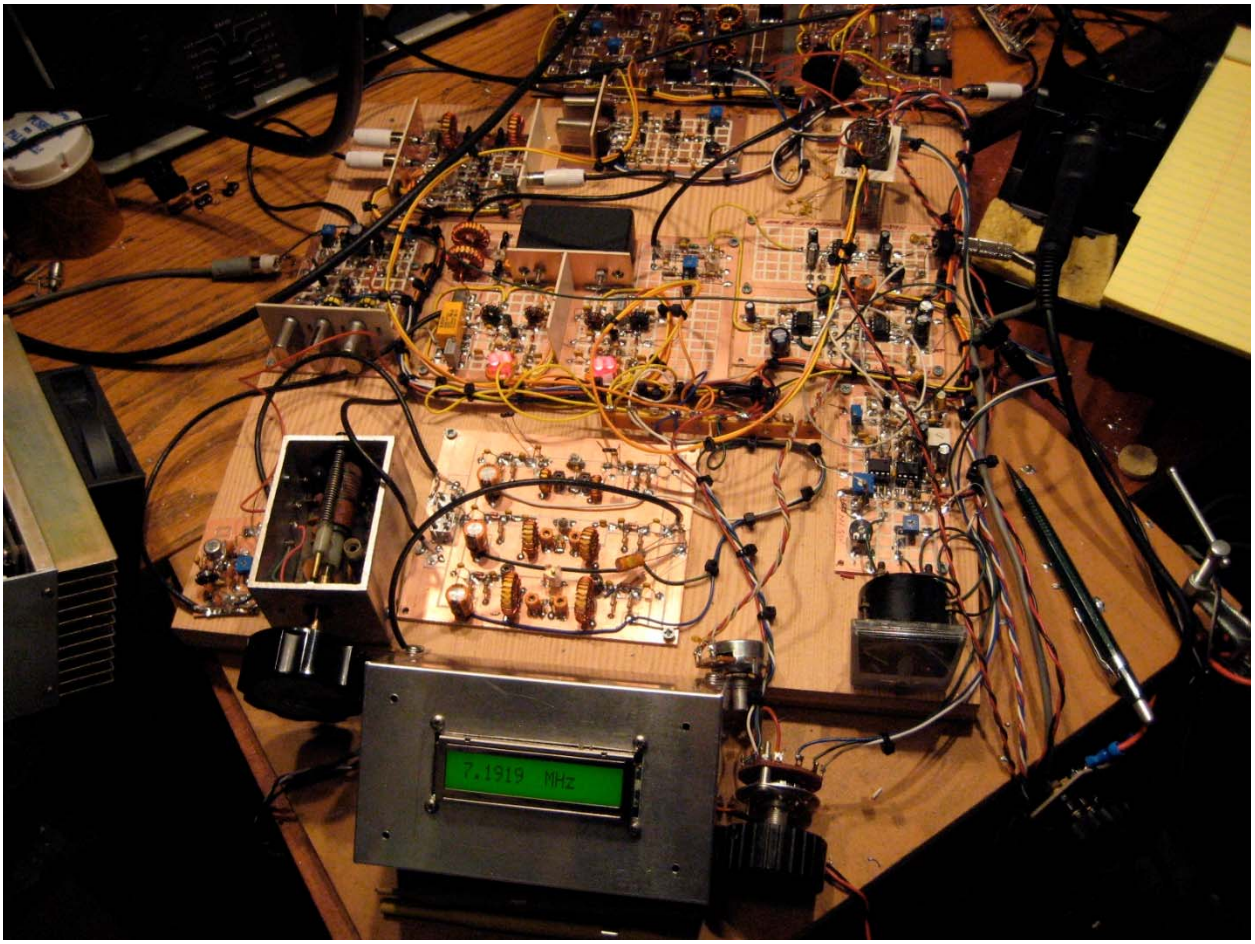
Let us take an example: The next photo is of two transceivers I built which are basically the same circuit with the smaller one being the second build.



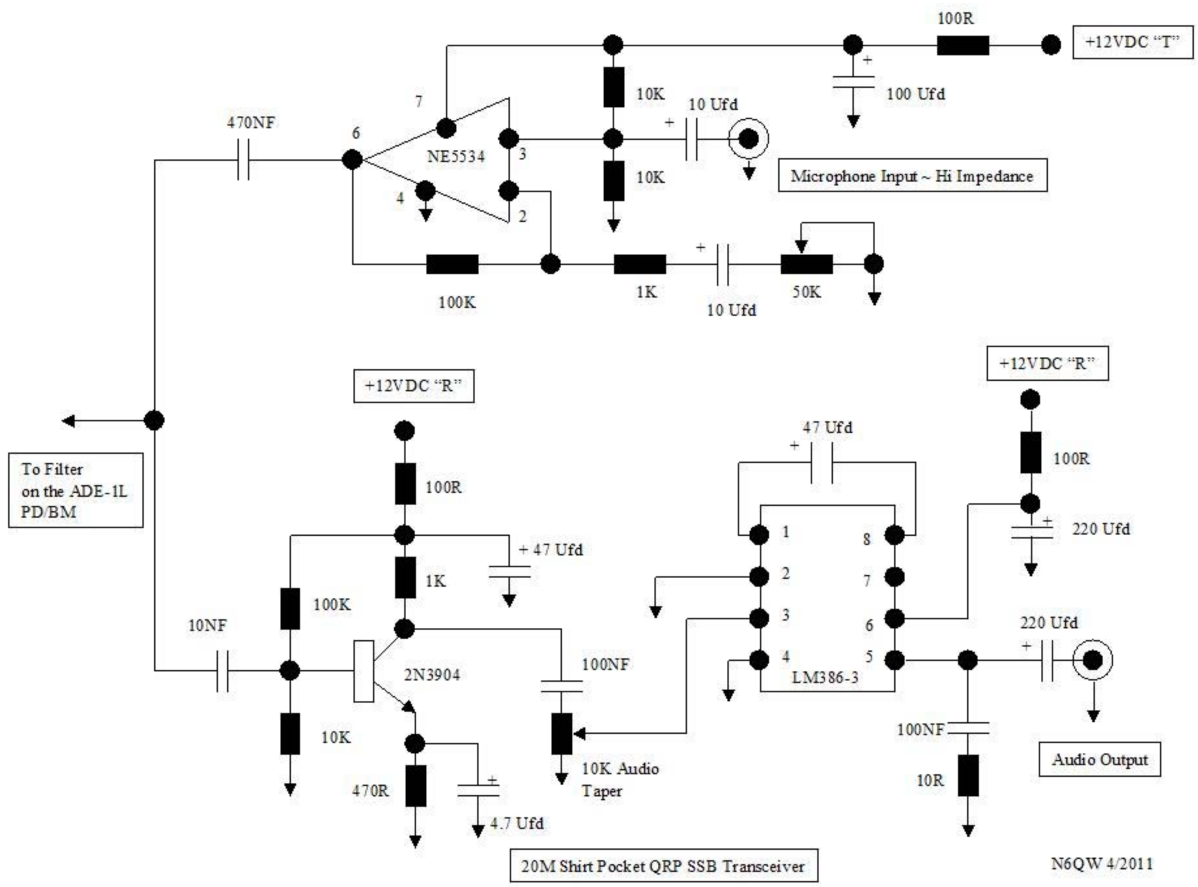
The block diagram for these radio is shown below. The variation between the 1st and 2nd build is the second does not have an Rx RF amp stage and a different RF output stage. These changes were to conserve space and enable making the second one about 1/3 the cubic size of the 1st.



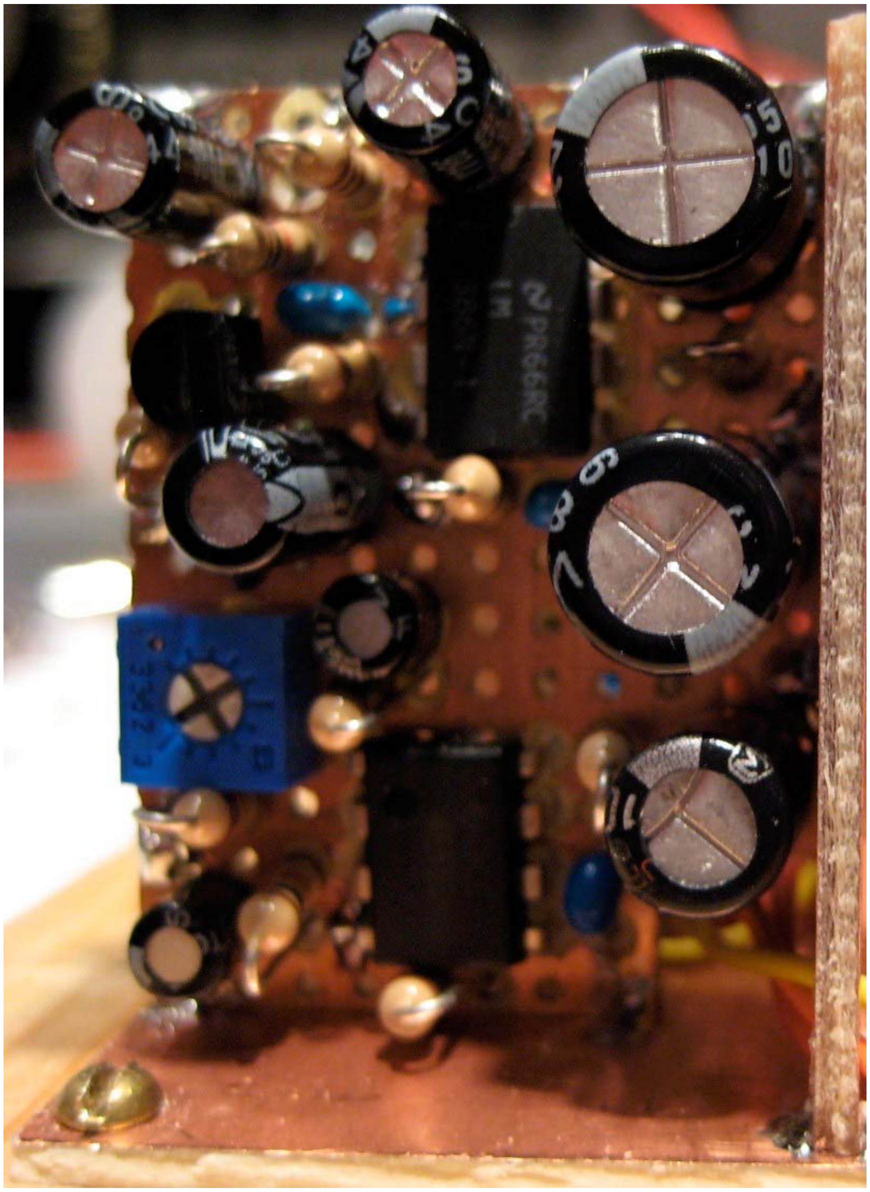
This is a block diagram of a 20 Meter QRP SSB transceiver that could fit in your shirt pocket. Much time was spent on this block diagram in a process I call "noodling", that is thinking about the topology and how to make this an efficient design while at the same time making it physically small. So the first thing to be done is to not heat up the soldering iron but spend some time doing research and collecting information. Once that is done then it is a matter of finding circuits that will work in the blocks. This also is a really good time to think about how the final package will look. I learned that the hard way when I built a tri-band QRP SSB transceiver using the filter and frequency scheme from the Heathkit HW-100. I usually "bread board" all of the radios using a piece of 2' X 2' plywood and that forms the base for temporarily installing circuit boards and thus the radio is tested "out in the open" and then packaged. Here is what the bread board looked like for that project. Once I was at this stage I knew I was in trouble as I hadn't really thought about the final box. Spend some time on this –first. BTW I actually made QSO's with this breadboard radio!



The build process then as previously stated starts at the back end by building the audio amplifier and microphone amplifier stages using designs that I have found really work and involve commonly available parts –no exotic unobtanium parts here! Shown below is the design for these two stages and the beauty is that once built they can be tested and debugged. Thus you know that these are viable circuits and are working!

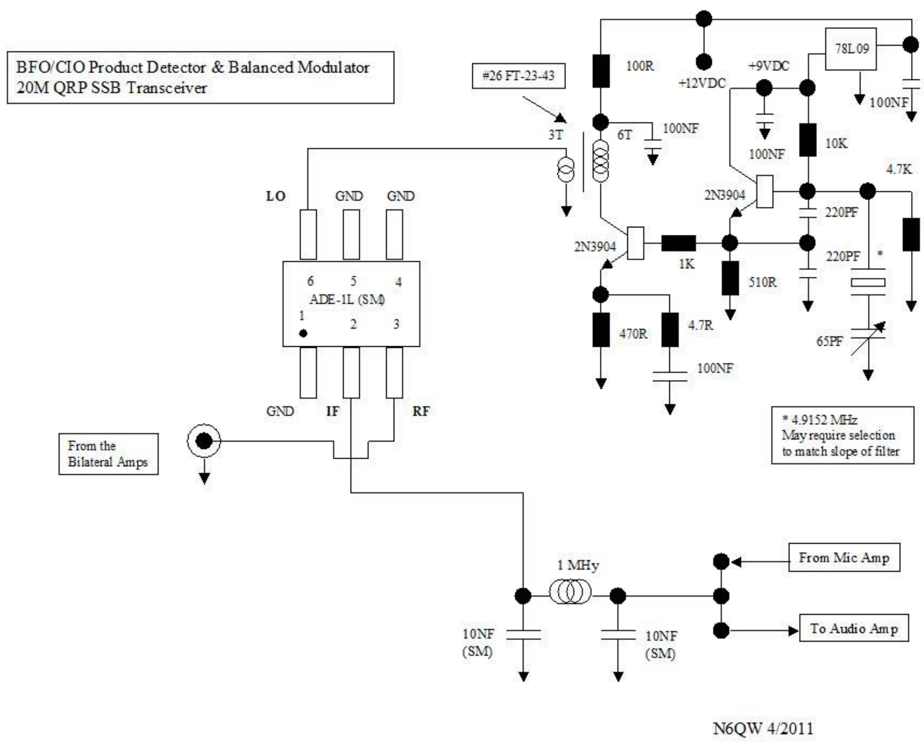


The finished circuit board is shown below and involved the use of single sided copper vector board (read expensive) and was a challenge to build. This board was mounted physically near the back panel of the radio and a 5/16 inch hole was drilled in the back panel so a small screwdriver could be inserted in the hole and aligned with the small trim pot –yes that is the microphone gain control. The only reason I mention this is that front panel space actually dictated the final size and there was no room for a microphone gain control on the front panel. But I had to think about this before I turned on the soldering iron!

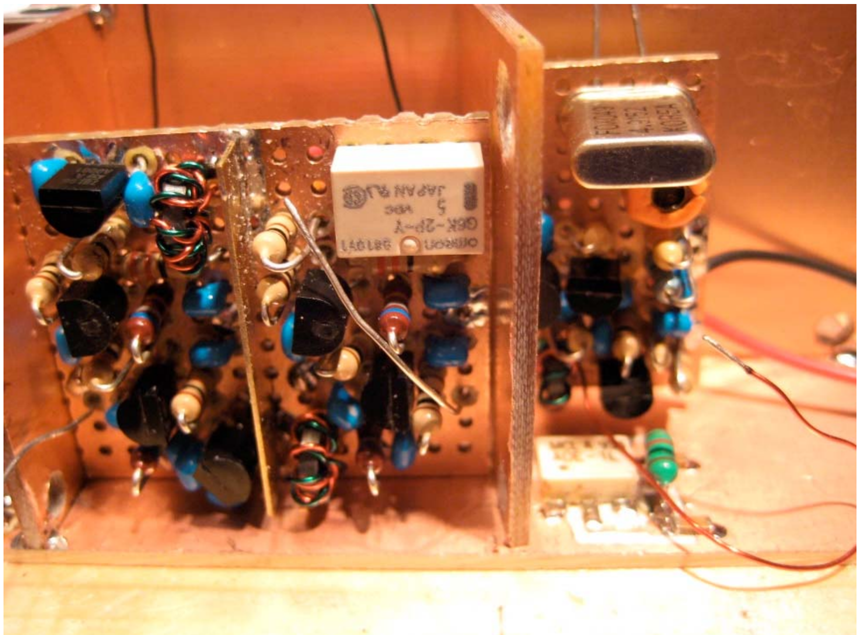


Oh, I have very sophisticated test process for these two circuits. Once built I start with the audio amp and after hooking up power, gain control and a 8 ohm speaker taking a metal screwdriver I simply touch the input pin on the 2N3904 –big hum I know it works. Adjusting the audio gain control should have control of the hum and that the control wires give max gain in the CW direction. Now I power up the microphone amp in addition to the audio amp – using the same procedure –touching the input pin of the NE5534 should result in a loud squeal –adjusting the 50K should show that the microphone gain works.

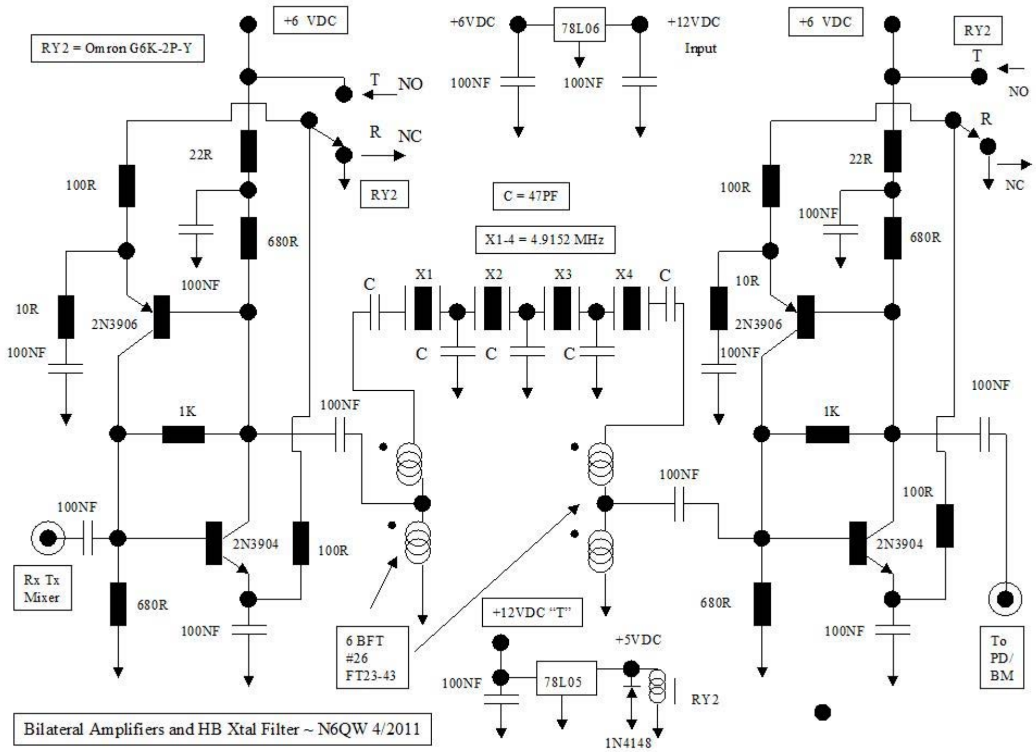
The next block is the BFO/CIO and combination product detector / balanced modulator. That schematic is shown below. A comment here about the choice of DBM (Double Balanced Mixer) the ADE1-L. It was chosen because it is small, an SMD part, and is a 4 dBm device meaning it only needs 1.0 Volt Pk to Pk to drive it. Here is where some time spent researching can pay big dividends. The ADE1-L is built by mini-circuits labs. At the time I bought these the price for a single unit was close to $16. If you bought three that would be $48. But if you bought 10 the price was under $4 each. So if you bought 12 ($48) that is the same price if you only bought 3. I still have a couple of units in my junk box that are being reserved for the next project!



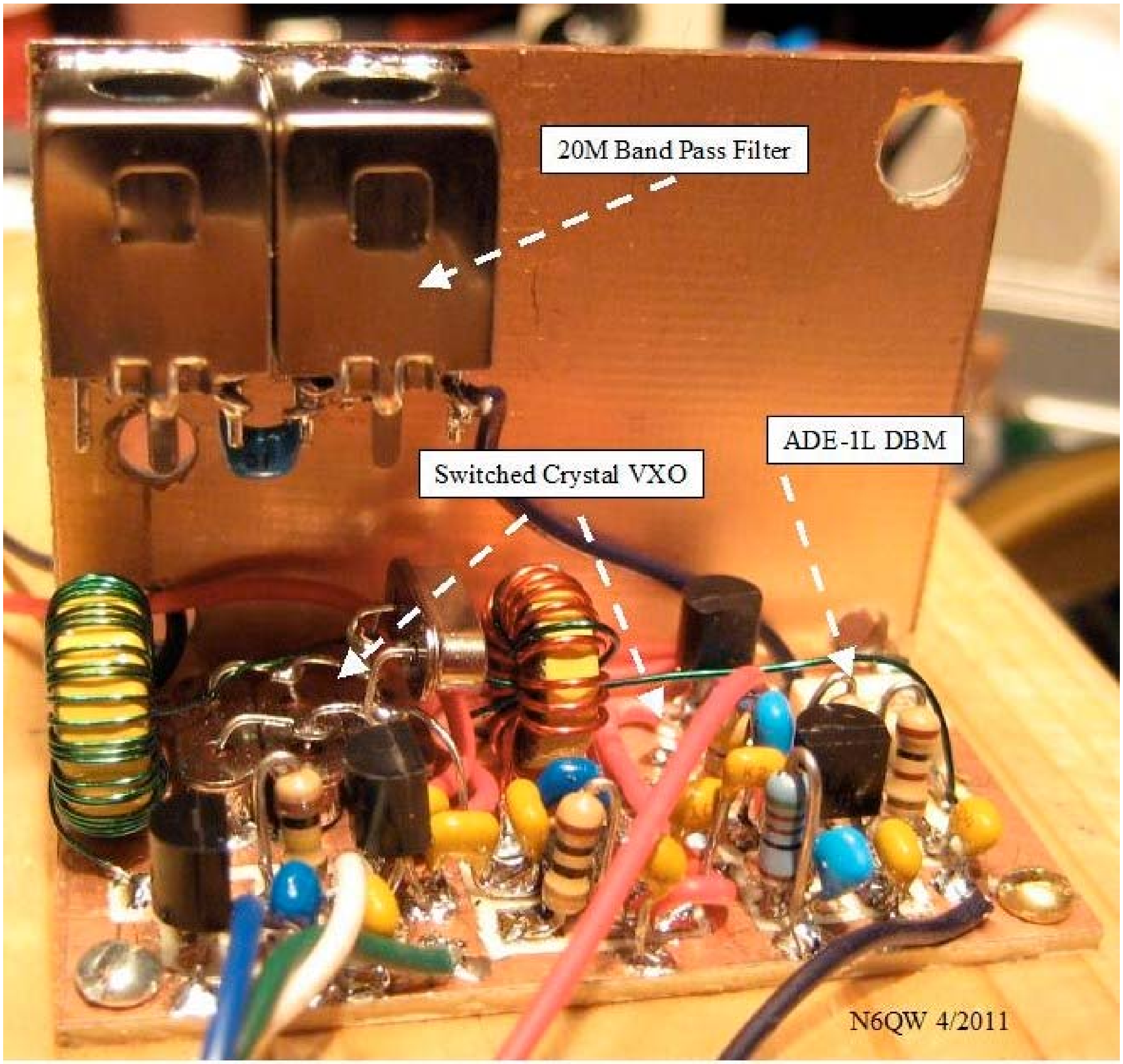
The photo below shows the next two blocks during the construction process with the circuits on the right side being the CIO/BFO and the PD/BM. Once this part of the circuit was built its output was connected to the audio amp module and then using a signal near 4.9152 MHz (nothing more than a one transistor test oscillator tuned slightly off of the BFO/CIO frequency) and then a beat note can be heard coming from the speaker. Now it was clear that these four elements were working. The circuit board on the left side is the bilateral amp stages and behind that the home brew crystal filter. Again the same process of building and then a temporary hookup and test. Using that same test oscillator these two stage and the filter can be checked – as you move the test oscillator through the stages the sound from the speaker should get louder –any stage where it doesn't then you know where the problem is.



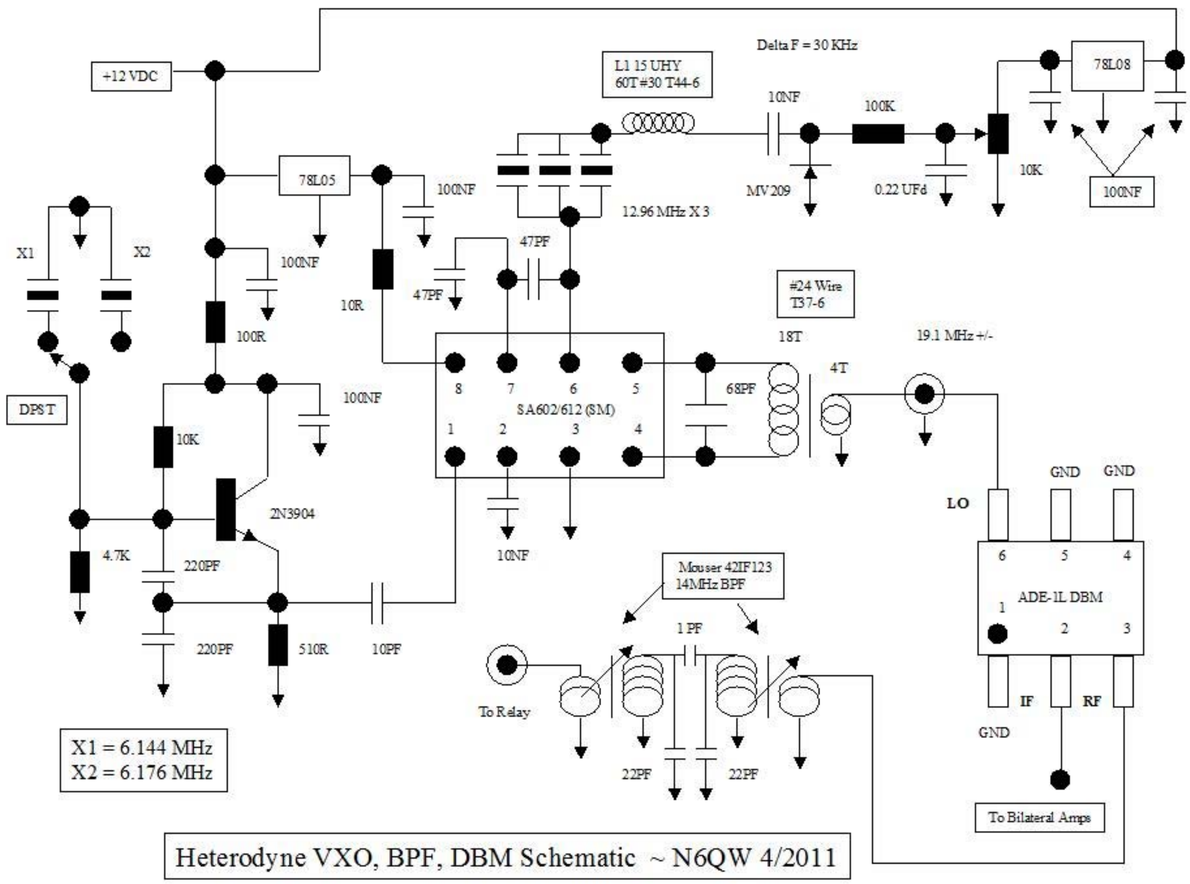
The schematic for the left side is shown below:



The next several blocks, consisting of the Rx Tx mixer, another ADE1-L, the switched crystal VXO and the 20 Meter Band Pass Filter. The width and height is 2 inches so a lot of parts in a small area. Thus the noodling process has to take place first before heating up the iron.

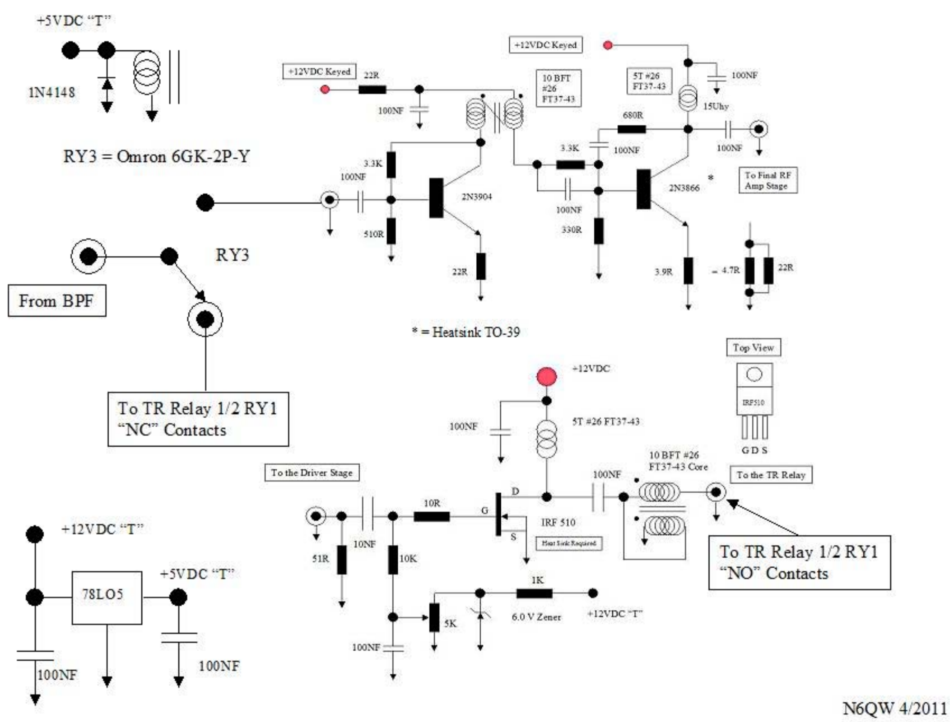


The schematic for this part of the build is shown below. Again these circuits once built can be connected to the already working circuits and the test process here is to inject a 14. 2 MHz signal into the BPF and it should be clearly heard in the audio output.



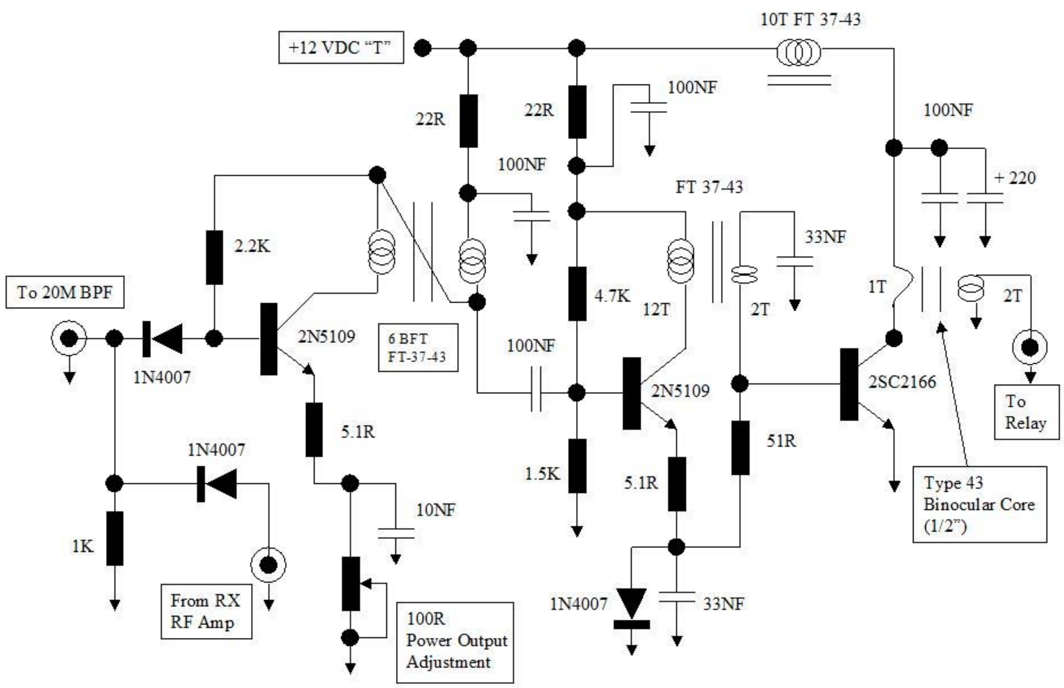
Spend some time now getting acquainted with the receiver by optimizing the Band Pass Filter for the portion of the band being worked and there may need to be some adjustment of the BFO/CIO frequency so that it is placed on the proper portion of the filter slope. This is also an opportunity to see how well it hears in terms of sensitivity. As the old adage says if you can hear them you can work them. There are several you tube videos which can be found by searching under N6QW and you can hear the two versions of this radio –it hears quite well! The 1st version is more sensitive as it has an RF amp stage but one feature is missing since this project was entirely designed with the idea of miniaturization. No AGC and on occasion really strong signals with the RF amp version WILL overload. Backing off on the audio gain does help. The second version without the Rx RF amp will not overload as much. So adding an AGC would help but that requires more space. PD7SSB on seeing this design added an audio AGC circuit which helps. So that is yet more opportunity for experimentation.

On both versions the circuit black which gave me the most headaches or as some know –heartburn, was the transmitter RF amp stages. This is where one really has to pay attention to circuit layout, unwanted coupling, shielding and heat sinks. In the second version which uses a slightly different "final brick" the problem was heat. The final is an IRF510 and the final bias made it more than warm to the touch –if you wanted max smoke! I tried several of the TO-220 style heatsinks and none were really adequate. Finally I tried using a slab of copper on the back side of the circuit board in addition to the TO-220. In the local hardware store there were heavy duty copper fittings such as are used on grounding cables for house wiring. I found a fitting and smashed it flat in a vise and drilled a hole in the middle to attach to the IRF510. Copper is a much better heatsink than aluminum. Many of the high power RF amplifiers use a copper spreader between the device and the aluminum heatsink –so I just borrowed the idea. The circuits for the smaller version came form EMRFD!



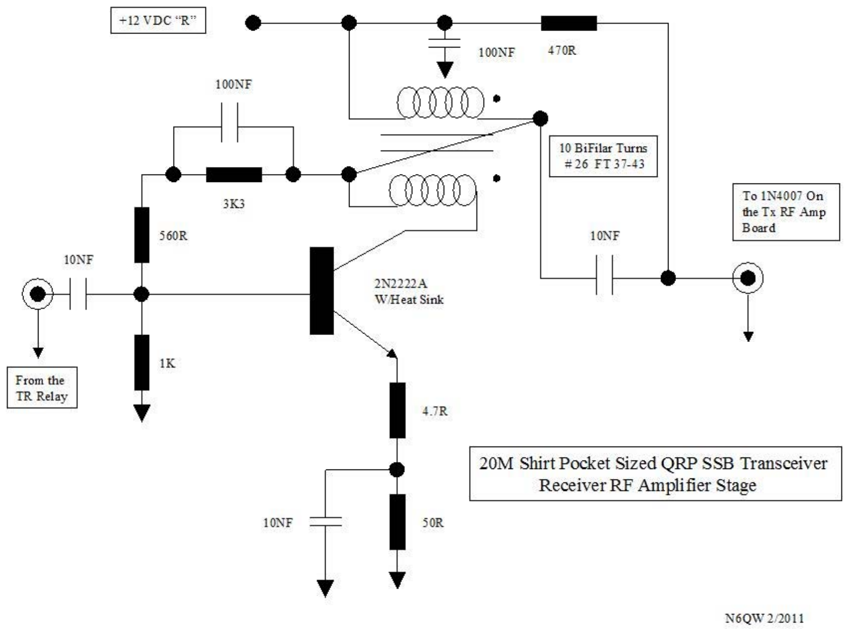
Final RF Amplifier Stage: Source EMRFD Figs 2-93 & 2-98

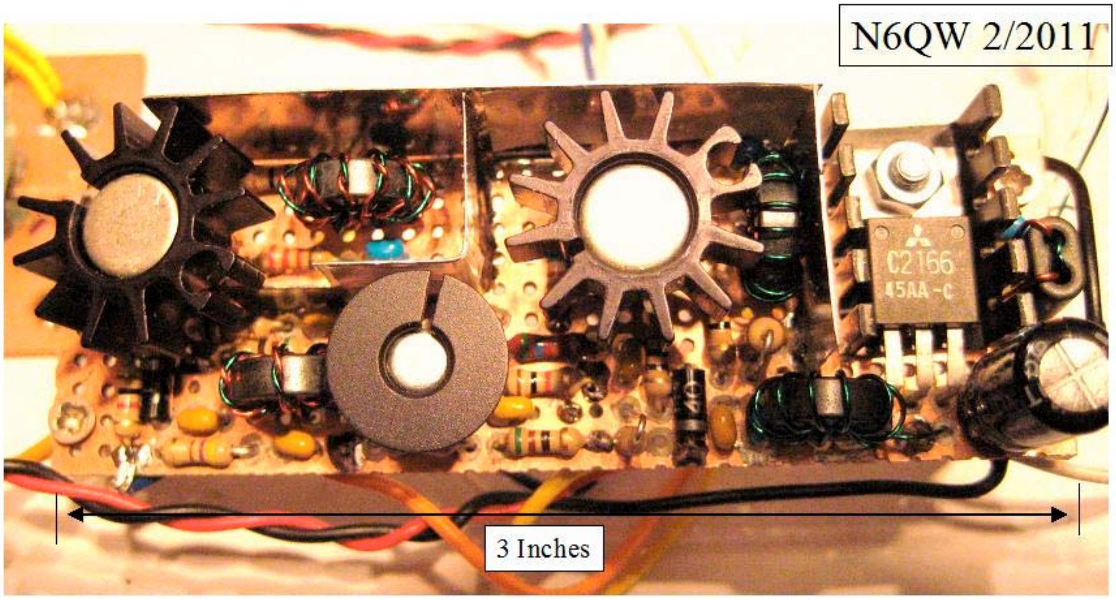
The larger version of the radio used a different RF chain which was physically too big to fit in the space available so it was not used. That said it does produce more power by again the same attention to detail on unwanted coupling, shielding, and heat sinks was very much the same considerations.



20M Shirt Pocket XCVR Tx RF AMP STAGE
(Rx RF Amp not included on this schematic.)

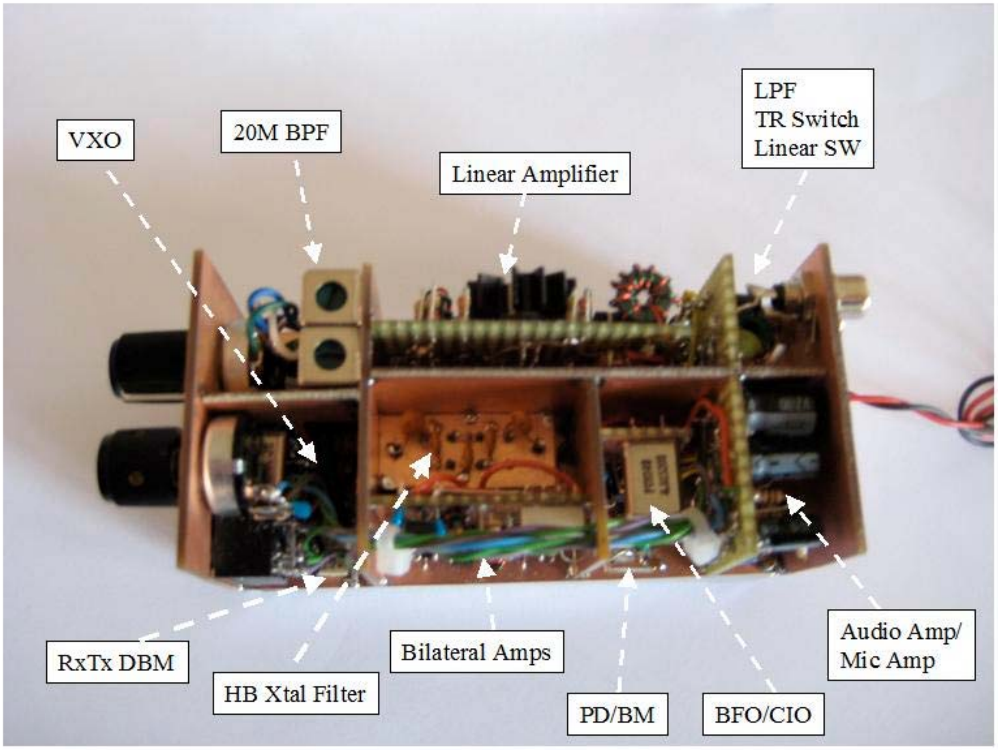
This version has the Receiver RF amplifier stage and note that diode steering was used to route signals between transmit and receive to/from the common band pass filter network. The 2N2222 is biased "hot" and needs a heatsink. In the photo you can see that the circuit elements are very tight and the use of single sided copper vector board enables a common ground plane so ground loops are not so much of a concern. This approach enables solder shielding directly to the copper surface and it made the task so much easier.


+12 VDC "R"
100NF
470R
100NF
10 BiFilar Turns
26 FT 37-43
3K3
560R
To 1N4007 On the Tx RF Amp Board
10NF
10NF
2N2222A
W/Heat Sink
From the TR Relay
1K
4.7R
20M Shirt Pocket Sized QRP SSB Transceiver
Receiver RF Amplifier Stage
10NF
50R
N6QW 2/2011



Final Receiver and Transmitter RF Amplifier Board
20M Shirt Pocket Sized QRP SSB Transceiver

A special not here about version two and the concept of a copper “spine’ down the center with many shielded compartments. This is not original work but thanks in large measure to Allison KB1GMX who shared this approach with me. It really works and affords a compact final product with more than adequate circuit isolation and a good deal of surface area to remove heat. Yes some of the circuits do get hot to the touch. In fact in version one after building the enclosure I had to go back and cut a vent hole in the top of the case!



20M Pocket Size QRP SSB Transceiver 2X4X2 Inches ~ N6QW 4/2011