Some notes on construction of the Willamette 20M transceiver

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This rig is a 5-watt wonder, designed by Jason Millrum, NT7S. I came across his announcement of this rig by accident. I signed up because I was looking for a good Manhattan-style project. I had never done 'Manhattan' before, so it looked like a great place to start. I've built a few kits, and even put together an Elecraft KX-1, but nothing I built was much more complicated than stuffing circuit boards. I graduated from my Radio Shack soldering iron to a nice Weller station about 2 years ago. So now you know where I am coming from.

Putting together this rig is NOT a project for a first time builder! Don't try it if you aren't familiar with all the usual RF parts, or if you don't have a healthy assortment of test gear in your shack. Some may disagree with me on this point. As for me, I was looking for a good excuse to really use that oscilloscope I bought about a year ago – and now I'd found it. Some of the equipment I used for this project include: regulated power supply, a signal generator, a frequency counter, my 60-MHz scope, a dummy load, loads of test clips (leads with miniclips on each end worked really well), a drill press, an LCR meter, a DVM, a small protoboard, a qrp-level wattmeter, etc. No, you don't *need* all of these. But I did *use* them all.

Jason put together a great set of construction notes. I am sure all of you experienced builders out there didn't need to look at these, but if you are a first time manhattan-builder like me, they were very helpful.

The first thing you might do is take a detailed inventory of your parts. I must admit that when I saw how many parts there were, I skipped this step. I use an upside-down box lid to sort all of the parts: the lip of the lid keeps any part from rolling away, and the large, flat area of the lid lets me separate resistors from capacitors, etc. I also have a few egg cartons on hand, which are good for sorting parts that are small but numerous, such as transistors, toroids, pads, and hardware. I write inside each 'cup' of the carton what's inside: 2N2222, 2N7000, T37-43, etc.

Next, I prepared the circuit boards. They didn't need much cleaning. I did put all of the pads down at once, which is possible only because of Jason's nice layout diagrams. Tape the diagram on top of the PC board. Be careful if you use a center punch to mark the locations of your pads: it doesn't take much force to put a large punch-mark on the board. Try a few, and then peek under the paper. If the punch-mark deforms your board too much, the pad will not sit flat on the board. And if the pad is not flat, two things happen: a) it doesn't stick well, and b) the component s on that pad won't be vertical.

Try to get the pads as close to their intended position as possible. Some portions of the circuitry are tightly packed, and a misplaced pad makes component placement challenging. You can always pull out the pad and place a new one, but it is easier to do it right the first time. I found two things that help: use a gel-type glue, rather than the liquid one. And secondly, use the glue sparingly. Too much glue will allow the pad to slide from its intended position. Sliding is more of a problem with the thin liquid glues. I found that I could do about 6 pads at a time (put glue down in 6 places, and then place the pads). If I did more than that, the glue would start to set before I'd get the pad in place. You'll need to experiment to see how many you feel comfortable with. I started out 2 at a time.

A few notes on how to deal with the parts. The most critical difference from traditional kit-building I noticed is attention to the component leads. In your regular PCB kit, you poke them though the hole, solder, and clip. Nothing to it. But with this project, you have to pay much more attention to those leads. They must be bent carefully, and must be just the right size, if you want everything to fit.

Most components are mounted vertically. This saves board space, making the rig much more compact. For components with axial leads, the top lead must be bent back down toward the board. You can try bending with your fingers, but it doesn't look too good. Try bending the lead over a small drill bit. A bit between 1/16" and 1/8" should be just about right. A bit much larger than 1/8" will give you a turn-radius that's just too wide for the pads.

Next, the end of the leads must be bent in 90 degree angles so that they are perpendicular to the component and parallel to the pad. There are some plastic guides that you can buy for such a purpose, and probably will give you nice 90 degree bends. I just bent the leads with my pliers and eyeballed it. There are a lot of leads to bend. You choose.

Finally, cut the leads just beyond the 90 degree bend, giving you a surface to solder to the pad. If you cut the leads too long, they will not fit on the pads. Many pads have 3, 4, or even 5 leads soldered to them. The leads will not solder to the pads well if they are overlapping. It wasn't until half way through the VFO that I realized my leads were too long. If I cut them VERY close to the 90 degree bend, with only a millimeter or so of horizontal lead on the pad, everything fit and looked much better. Bottom line: if your component lead extends more than 50% across the pad, it is too long. For me it was hard to make a lead too short -- but you'll know it when you see it!

I found it helpful to take 5-10 components at a time from my box lid of parts. As I took each part out, I crossed it off the bill of materials. Then I'd prep and place those components before getting any more.

Jason's build sequence does a great job taking you from one end of the circuit to the other, both functionally and geographically. But there isn't much room for adult fingers over those closely spaced pads. Pay attention to the order in which components get added to each pad. It generally works out better to place a semiconductor first (3 leads are harder to deal with than two), and then add in the surrounding resistors and caps. And for me it worked best if I placed a larger component on a pad before the smaller ones. You may develop a different preference. Regardless, avoid getting 'trapped' by the soldered components, taking up the space you need for the unsoldered one in your hand.

A few words about toroids: in the first version of the build instructions there is often no mention of how much wire to use. Go to Diz' website (www.kitsandparts.com) for all of your toroid needs. A T37 core takes almost exactly one-half inch of wire per turn. Add 2", or one inch allowance for each end.

Therefore 16 turns on a T37-6 will require 16/2 = 8 inches on the core plus 2 for the leads = 10” total. Yes, 9” will be enough, but do you really want to run out of wire after winding all those turns?

It seems like everyone has their favorite method for stripping those pesky toroid leads, so I will share mine, too. I’ve tried the ‘solder blob’ method, where you put a big blob of solder on the end of your iron, and then put the end of the enameled wire into that blob. It doesn’t work for me. If you have nice, heat-strippable wire, try this: put a aluminum heat-sink or small clip/hemostat on the wire, just as it leaves the toroid. Now put the end of the wire into the flame of a butane lighter. The insulation will quickly burn back to the clip, but will go no further. Then use a small square of 440-grit sandpaper, folded between your thumb and forefinger, to sand off the residual, burnt enamel. Tin the bared leads with solder. For me, this method is very reliable and fast. As you get facile with this technique, you will anticipate how fast the enamel burns, and you will be tempted to not use the clip. Don’t do this! You can very quickly burn the enamel back into the last turn, and ruin your winding.

For toroids that lay flat on the board, such as the ferrite transformers, you can use 28 gauge wire or smaller without any difficulty. But 28 gauge wire is too flimsy to support a toroid that is standing up; use 26 gauge wire for these.

For me, the biggest toroid challenge was laying out the trifilar’s used in the mixers. If you don’t have a good system for this, consider mine. You probably already know that the phase of the windings is marked on the schematic with dots. Choose a toroid side for the dot: the toroids are laying flat against the PCB, so I chose the dotted side to be side 1 = ‘down’, in other words, against the board. The undotted side of the winding is therefore side 2 = ‘up’, or facing you. Next, assign each winding to a wire color. I chose brown as primary, and green and red as the secondaries. Pencil on your schematic what each lead should be, like this: B1, B2, G1, G2, R1, R2.

Now place the toroid on the board and solder to its pads, remembering that 1 = down and 2=up. From left to right we first connect the output of C2, which I’ve labeled as B1. So I need the brown winding that is against the board. The next lead I need is the output from the 18 MHz oscillator, so that is G2 and R1. So I take the green lead that’s facing up and the red lead that’s against the board, twist them, and attach to pad. And so on.

The installation notes and schematics use a few power measurements, and I found out that I needed to review AC measurement. It’s not quite the same as reading DC volts off a digital voltmeter. The first thing you must know is that the scope tells you voltage in terms of peak-to-peak, but power is determined by Vrms. How do you convert between the two? Vpp is twice the peak voltage, Vpk, which is 1.414*Vrms. Doing the math,

$$V_{rms} = 0.354 * V_{pp}$$

So now how do you get power, in dBm, from your scope readings? Convert Vpp to Vrms, then use the power formula $P = V_{rms}^2/R$, where R is often 50 ohms. With a little algebra, you can skip all that: for a 50-ohm load,

$P(mW) = 2.5 * Vpp^2$

$P(dBm) = 20*\log(Vpp) + 4$

Here is a little table with QRP power values:

Vpp	P(mW)	P(dBm)
2	10	+10
4	40	+16
5	63	+18
8	160	+22
45	5000	+37

Hardware: I am not too good at mechanical stuff, so take my advice about enclosures with a grain of salt. I did some trial and error with a piece of scrap metal, just to get the hole sizes right. The pots take up room themselves, so keep the holes away from the top or bottom of your VFO enclosure.

Here is what I got: for the main tuning pot, drill a 5/16" hole. You need to drill a second smaller hole for the metal tab. This small hole should be 1/8", at a distance of 7/16" center-to-center from the larger hole. To install the RIT pot, try a 5/16" (looser) or 9/32" (tighter) hole. Use a 1/8" hole for the tab, at a distance of 5/16" inch, center-to-center. For the BNC jack, you'll need a 3/8" hole. For 4-40 hardware, use a 1/8" hole.

Drilling the larger holes can be very difficult to do in one pass. Try drilling all of your holes at 1/8" size first. Then try a step bit or 'unibit' for the larger holes. They work really well.

Prepping coax cable: RG-174 is very easy to strip. The outer jacket can be removed with a wire stripper in the 14 gauge hole. Peel back the braid, then strip the inner dialectric with a wire stripper in the 22 gauge hole. Attaching coax to the male connectors is a bit harder than the usual back-of-the-rig female connectors, so I cheated and cut a RG-174 coax jumper in half. Some of you are probably cringing at this, but it sure made it easy, and gave me some extra coax to play with.

Everything so far I've told you relates to construction of the VFO. There isn't much different to the rest of the rig, except I thought some of the circuitry on the main board was a more closely spaced, and required a little bit more care in placement. In the double-balanced mixer it is easy to get a toroid lead in the wrong spot, or to reverse a diode, so take your time in that section.

73,

Bruce.