

K8IQY's "2N2/40" Forty Meter CW Transceiver

by Jim Kortge, K8IQY
P.O. Box 108
Fenton, MI 48430

Introduction.

The beginning of the 2N2/40 came about when Wayne Burdick, N6KR, proposed his "post apocalyptic" design contest for Dayton 1998. The premise of the contest was that "no matter what happens to us or the planet, you'll still be able to find them (2N2222's) in huge quantities." It is as Wayne termed it, "The cockroach of the transistor world." The contest challenge was to design a system, capable of transmitting and receiving, using only 2N2222 transistors as the active device, and using no more than 22 of them. A corollary to the constraints was that only other "cockroach parts" could be used, such as 1N914 diodes, but not three terminal regulators, PNP transistors, ICs, or anything of that ilk!

My interest in accepting this challenge was to design and build a transceiver from the ground up, something that I had always wanted to do, but never set aside the time to accomplish. Here was the "golden opportunity", if one ever existed. Along with this, I had been experimenting with MicroSim's PSPICE off and on for several months, but didn't feel that I had a very good understanding of its capabilities, nor how to use it very well. Combining the two elements, design and computer circuit simulation, would provide a valuable learning experience, provide a robust design assuming I was successful, and maximize the "fun" that could be derived from such a project. With those thoughts in mind, it was time to get serious and design and build a rig.

Design Criteria

At the onset, I struggled with some basic questions: "What will I design and build?" "Should it be on CW, and if so, what band?" "Maybe it ought to be something for SSB, then I could use it for bicycle mobile, if it works well." However, reality set in, and the recognition that I had never done this before, so keeping it relatively simple was most appropriate. Forty meters seemed like a good band for a CW rig, as I didn't have a QRP rig for that band, and kept missing out on the Fox Hunts. Sure, I would listen to the gang on my FT990, but the desire to put it on the air wasn't there; it just didn't fit my notion of what that contest is all about.

Another self imposed constraint was to not just lift circuits or designs from various books, but attempt to design the rig from the knowledge gained over many years of reading, listening, experimenting, observing, and operating. That sounds like re-inventing the wheel a bit, and to some degree it is, but it also frees the mind to consider other approaches. Some of that thinking shows up in the rig, and I'll discuss it later in detail.

So 40 meters got the nod for the band, and CW was the mode selected, mostly because of ease of design and construction. A number of the other issues that one would consider resolving at the beginning of a project were left, because I didn't know how difficult it might be to implement various sections sections of the rig, and how many of the 22 transistors would get used in each section.

However, there were some desired basic features in the rig that did not impact the transistor count. These included an r.f. gain control, and a variable bandwidth filter. Features that did depend on transistor count included having an r.f. amplifier to make up for input filter losses, power output of 1-2 watts, and the ability to drive a speaker. All of these were "desirable", but would be reconsidered if all the transistors got used up elsewhere.

Another criterion was to build the rig as small as practical, so that it could go into a QRP-size cabinet. However, at the onset, I had no idea how large or small that might be. The building approach would be to start out with a fairly large piece of single-sided PC board material and begin building in the middle of it. As the design and construction progressed, the circuitry would be built outward, toward the edges. If all of the room wasn't needed when the rig was finished, then a quick trip to the band saw would remove the unused and unneeded board material.

The anticipated approach to use was to design a particular section, build the computer model for that design, optimize the computer model, build and test the section, and finally, compare the test results with those predicted by the modeling. This approach had been used once before on a two band SSB rig that was started for bicycle mobile use, but never finished. For much of that rig, I didn't know enough about modeling to build the models of the ICs that were being used. However, the approach had been used for the antenna T/R switch and the receiver input filter, and it was amazing how closely the actual circuit matched the frequency response predicted by the modeling. What wasn't known was whether this approach would work for a complete rig, and how

many design iterations would be required before getting it to work satisfactorily.

As it turned out, the approach worked very well. There were a few iterations on one or two circuits, but for the most part, circuits were built with the component values shown by the modeling to be optimal. The total time to do the design and construction was considerable. I started around the middle of November 1997, a short time after the contest was announced and some 2N2222 transistors had been acquired. It wasn't until nearly the end of April 1998 that the job was done. A good portion of that time was spent doing the actual construction. My building speed could best be described "slow and precise", spending far longer on thinking about and visualizing how a section should be done than most builders would. However, the finished product is quite nice; almost "art like" in its appearance. The first part of May 1998 was spent feverishly getting the rig into a case and assembling the documentation package so that I could take it to Dayton.

Construction Background.

Over the past five or so years, many small projects have been built using a method that I was told years ago is called "Manhattan Style Construction". It's also called "Paddyboard" in some circles. The "Manhattan" name I believe comes from the fact that the little pads and parts that are used look a lot like a city in miniature, when they're all on the substrate. The substrate is usually a piece of single sided PC board material, copper side up. The pads are glued to the surface of the substrate, copper side up, and become the junction points for the circuitry that requires support. The copper ground plane is available for soldering all component leads that go to ground.

Editors Note: This special construction feature is intended to encourage anyone to build a QRP rig from scratch. The following construction practices were written by Jim Kortge, K8IQY, and illustrated by Paul Harden, NA5N, as a step-by-step guide on the techniques required to properly build the 2N2 rig, or most any homebrew project from scratch.

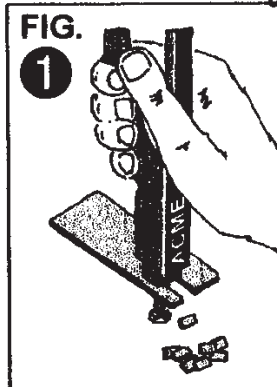
1. Construction Practices & Techniques

The mounting pads - are made of single-sided copper clad PC material, cut into small pieces and glued to the main ground, or substrate board (a 5x7 inch piece of solid copper clad for the 2N2/40).

My favorite method of making the small pads is through the use of an ADEL nibbling tool. This is a tool designed for cutting thin sheet metal, but can handle 1/16 inch thick PC board material quite well. The resulting pads that are produced by this tool are about 3/32 inch wide by 1/4 inch in length. (See Fig. 1) While that might seem a bit small to most, there is ample room on one pad to solder the ends of 3 or 4 components.

Other alternatives for making the pads is cutting the copper clad PC material into small strips in a mitre box or bench vise as illustrated in Fig. 2. The strips can then be cut with wire cutters into the small pads.

Making the "Pads"

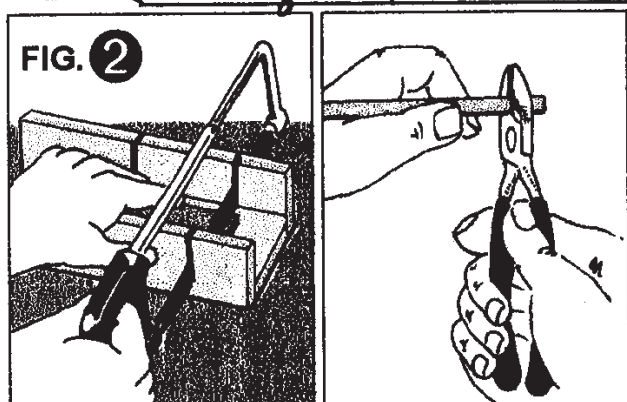


The primary way of making the pads is using a nibbling tool to cut small pieces out of single-sided copper clad board. This also ensures "pads" of uniform size and shape, and fairly fast to perform.

Nibbling tools are available from many tool suppliers and at many Radio Shack stores for about \$15.

The copper clad board with holes on 0.1" spacing can also be used. Cutting along the holes with wire cutters tends to break them off 2-holes at a time for a 0.1x0.2 pad with an "octagon" look, shown in Fig. 3. File or sand the rougher cuts of this method if desired. A round hole punch from Harbor Freight has also been used by many QRPers for making round pads 3/16 to 1/4" dia.

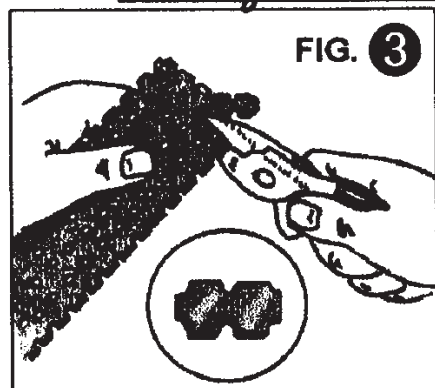
Making the "Pads"



Copper clad strips for the pads can be cut with a sharp saw and mitre box.

Pads are then cut to desired length with wire cutters or tin snips.

Making the "Pads"



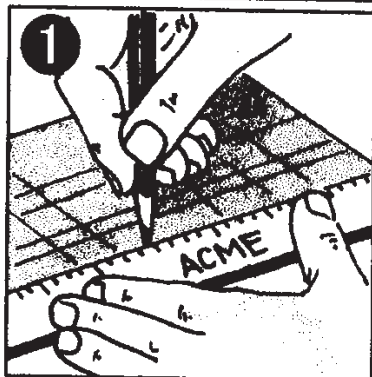
Copper clad with the pre-punched holes on 0.1 inch centers makes good pads also.

Mounting the Pads.

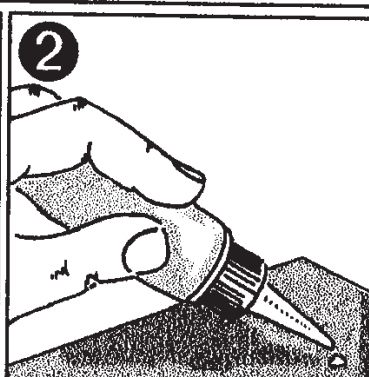
I use common Cyanoacrylate adhesives, (DURO Super Glue) although any of the available, thin adhesives of this type should work. My method for attaching a pad is to hold it in place and put a very small drop against the bottom edge of the pad and the substrate. The thin glue will wick under the pad and attach it in about 5 seconds. Others have tried this method and have had problems and prefer to apply a drop of glue to the board, then mount the pad. The secret is to make sure the surface of the substrate is very clean, and devoid of any sensitizing films, grease, or other contaminants. I scrub my

board material with soap and water and a piece of 3M Scotch Bright pad until the copper is shiny. It is then wiped with lacquer thinner to remove any remaining contaminants. When this method is successful, removing a glued down pad requires twisting it off with a pair of pliers as illustrated in Fig. 4. Each pad is also wiped across a piece of 400 grit wet and dry sandpaper several times on the copper side before gluing to the substrate. This cleans it and makes soldering to it very easy. Cleaning with a mild solvent or alcohol and brush can also be used to "clean up" the pads before soldering as shown in Fig. 5.

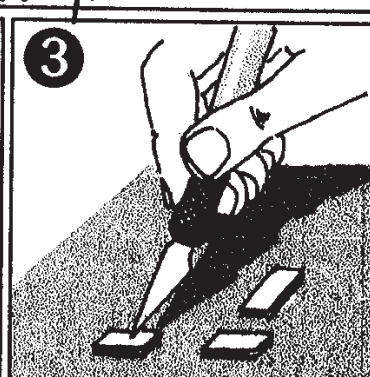
The "Pad" or "Manhattan" Technique



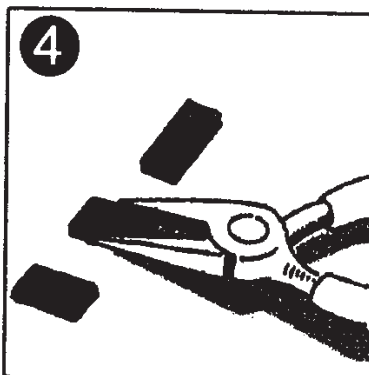
1 Draw footprints of each section and guidelines with pencil on the copper clad board. Planning ahead is important!



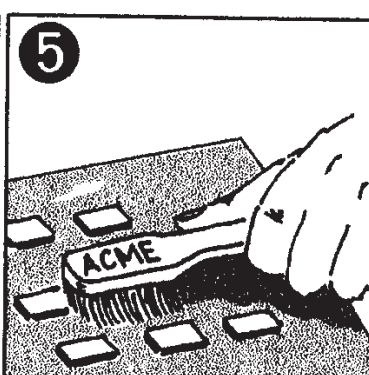
2 Apply drop of Super Glue or other adhesive to the main board where pad is to be placed. (Glue 1 or 2 at a time!)



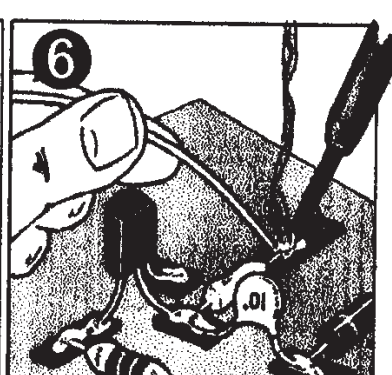
3 Drop pads in place over glue and position with exacto knife or other sharp object.



4 Super glue affixes the pads quite well! To remove or reposition a pad, snap-off by a twist with needle-nose pliers.



5 Board and pads can be cleaned with brush and alcohol, mild solvent or water. Excess glue may have to be scraped off.



6 Solder the components to the proper pads by following the detailed assembly drawings that follow.

Mounting the Components.

Mounting the various parts to the pads is mostly what could be called a "common sense" approach. I let the "geometry of the environment" guide how a part will be mounted, since there is no standard or accepted way of soldering a part into the circuit.

Resistors are generally mounted vertically, for two reasons. First, I think they take up less space that way, allowing one to build more compactly. Second, the higher end also makes a convenient test point; that's why a small loop is put in the higher end lead. It is nice to install resistors with the color codes running from the higher end to the lower end, for easier readability, just in case a mistake is made in building. Occasionally, resistors should be mounted horizontally, either to better span the distances involved, or maybe fit under another component. That's done in several places in the 2N2/40, especially in the audio amplifier section.

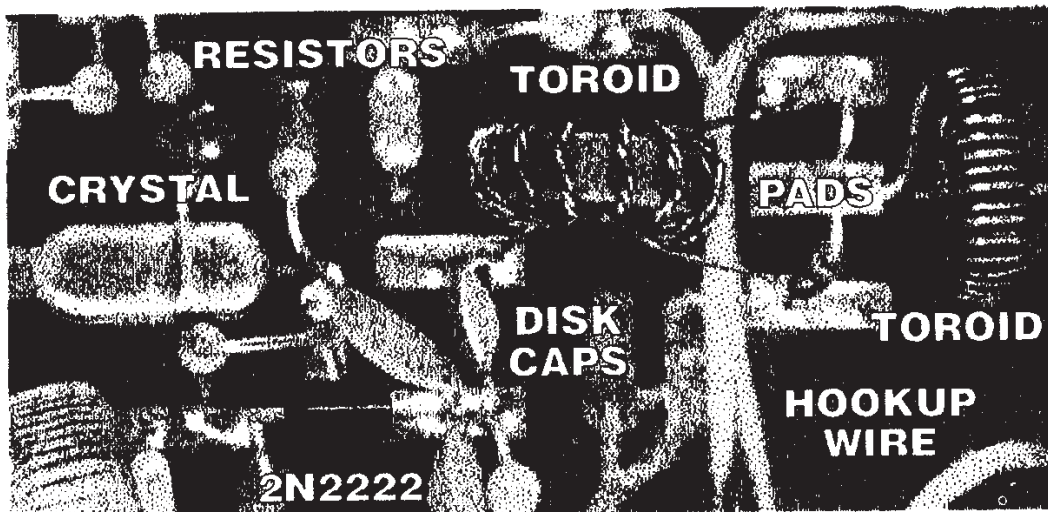
Capacitors. There is not a lot to discuss regarding capacitor mounting, since the predominant type used has radial leads. When capacitors are mounted, I try to orient them so that their value can still be read. With components going to ground, one lead needs to

be approximately 1/16 inch longer than the other to be soldered vertically to the substrate (ground plane). For leads that are soldered to the substrate, I bend the lead at a right angle at the appropriate length, and leave about 3/16 inch of length for soldering. Leads that will attach to a pad are bent at a right angle also, and have about 3/32 inch of length for soldering.

Transistor and diode leads should be bent about 1/4 to 3/8 inch away from the body. One additional comment is that component leads are prepared one at a time to ensure they fit to their respective pads.

Toroidal coils seem to be troublesome for many. There are detailed winding steps on the next page.

A typical mounting scheme is illustrated in Fig. 6 on the previous page, and of course, as illustrated in the step-by-step assembly drawings that follow. On the 2N2 drawings, special components, such as toroidal coils, crystals, varicap diodes, etc. are well illustrated and detailed to show the recommended mounting scheme. There is nothing critical about the parts placements in the following assembly drawings, should you decide to add your own "flair" or arrangement.



A small portion of Jim's 2N2/40 rig showing a few typical components mounted (soldered) onto the pads

2. Handiman's Guide to Toroids

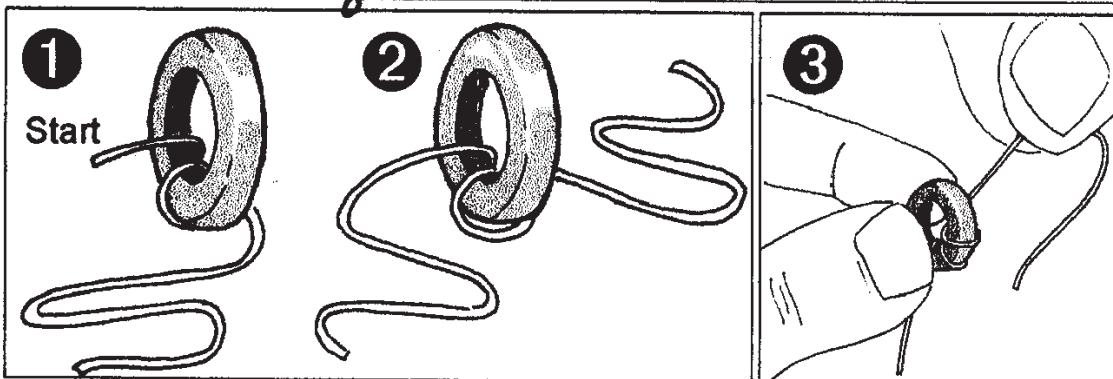
The 2N2 rig, like many QRP rigs today, use toroidal transformers and coils that you must wind yourself. Toroids are cheap, easy to wind, have relatively high-Q's, and "self shielding." Follow these step-by-step instructions, and you will have no problems. Each toroid in the 2N2 is illustrated in detail on the assembly drawing pages to make things easy.

Each time the wire passes through the inside of the toroid, it is one turn. Thus, there are 2-turns in Fig. 1, 3 turns in Fig. 3, and 12 turns shown in Fig. 4.

HINTS for Toroids:

- Estimate wire length needed by:
For T37 - 0.6 inch per turn
For T50 - 0.8 inch per turn
Add 2-3 inches for leads, safety
- It doesn't matter which way you wind the toroid, but in the case of a transformer, ensure primary and secondary are wound in the same direction for proper phasing.
- Use #24-28 enamel covered coil wire, or as specified.
- PVC/mylar covered #24-#30 wire-wrap can also be used, although inductance may vary slightly over coil wire.

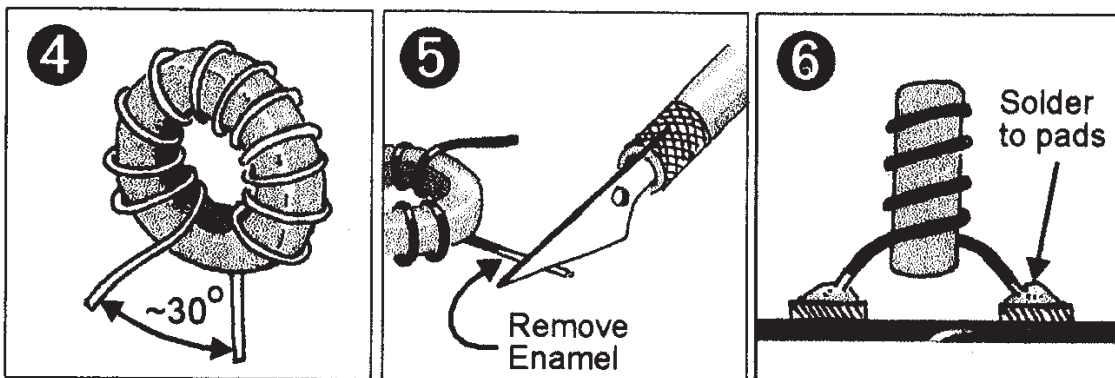
Winding Toroidal Coils



1 Start
For about a dozen turns or less, start coil wire through toroid as shown, leaving 1-2 inches on start end.

2 For 12 turns or more, start at half-way point of the coil wire, winding one-half first, then finish with the second half.

3 Hold toroid and starting turns with one hand, loop wire with the other, keeping the wire snug against the toroidal core.



4 When done, windings should be evenly spaced around toroidal core with a gap at the bottom. Trim leads to 1/2 in. long.

5 Remove Enamel
Scrape off enamel from lead ends with a knife. Tin with solder to ensure all coating is removed for a good connection.

6 Solder to pads
Form leads and solder to the mounting pads, with toroid mounted vertically as shown. That's it!

3. 2N2/40 Specifications

RECEIVER

Narrow front end: 150 KHz bandwidth
Sensitivity: -122 dBm MDS (~0.2 uV)
Diode DBM first mixer
Very low noise
VFO: 100 KHz band coverage
200 Hz maximum drift
Linear varicap diode tuning
3 pole VBW crystal filter: 300-700 Hz
Push-pull audio output
for speaker operation

TRANSMITTER

1.5 watts output using
three 2N2222A's in parallel
Excellent r.f. stability
QSK keying
Meets FCC requirements for
harmonic rejection (-36dBC)

Overall.

- 22 - 2N2222 transistors; four are 2N2222A metal case types
- All circuits modeled with MicroSim DesignLab or Electronics Workbench
- Built from "scratch" - Manhattan style construction
- 5 inch by 7 inch total footprint size
- Easily fits in many ready-made enclosures

Note from NA5N:

I had the pleasure of having Jim's 2N2/40 in my possession for some time for the purposes of performing lab tests, doing the illustrations contained herein, and making a few QSO's with it. I returned the rig and had the privilege of working Jim a week later, with him using the 2N2/40, during the Zombie Shuffle contest on Halloween.

The 2N2/40 is a serious, high-performance QRP transceiver. It has very good sensitivity (MDS <-120dBm), selectivity (300-700Hz variable IF filtering), very stable VFO (<200Hz drift first 5 minutes) and surprisingly good audio fidelity (and plenty of it). The "pads" form 3-8pF to ground, and being built over a solid ground from the copper clad board (and not using I.C.'s) lends itself for a very quiet receiver. You'll be impressed with the signal-to-noise ratio, inspite of the nominal -120dBm sensitivity.

If you've ever wanted to build a QRP rig from scratch, I highly recommend building Jim's 2N2/40. It's a great performer, and why we worked so hard to document it to make it easy to build. I started building mine for the 1999 PacifiCon Building Contest!

4. Physical Layout & Assembly Sequence

Let's talk a bit about the layout used in the 2N2/40 and some of the thoughts and ideas that drove the design. We'll start with the RX/TX driver, only because it is very simple to let you develop your "technique" for making and mounting the pads. Then onto the VFO, since it's shared by both the receiver and transmitter. Then we will do the receiver, starting at the input, and ending at the audio amplifier. And finally, we'll tackle

the transmitter. By the way, that's exactly the order in which the prototype rig was designed and built! As each section is highlighted, I'll also try to impart some insight into the various layouts that I've prepared, as an aid in reproducing the rig. While these layouts aren't exactly as the prototype rig was built, they are quite close. However, the size was opened up to 5 inches by 7 inches for this construction article so that

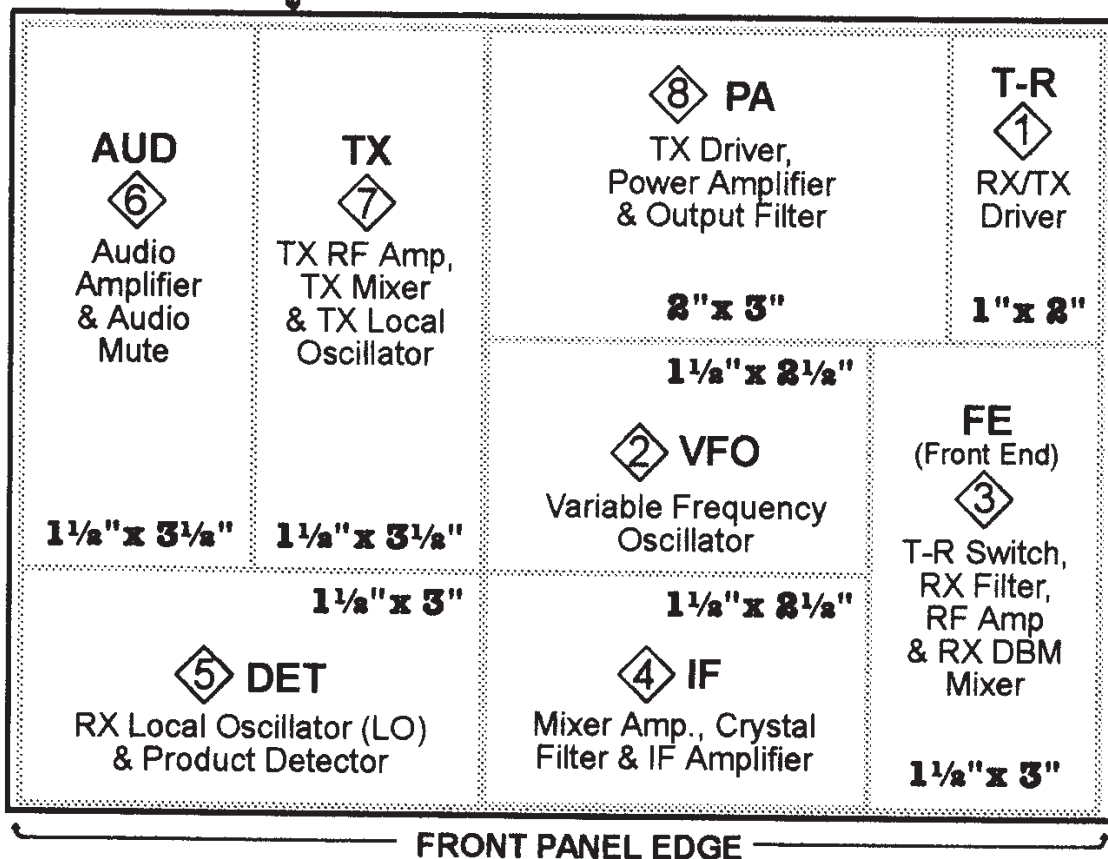
there is significantly more room, hopefully making it easier for the first time builder to construct. However, it can be built in a smaller area if you wish with a little forethought.

Layout. The overall layout for the 2N2/40 is shown below, based on using a 5"x7" copper clad board for the ground substrate. It closely follows how the prototype was built. Each block is numbered with

the **sequence number (SEQ#)**, the suggested order for building each block, and the order for which this article is based. All drawings are based on the SEQ# for easy reference. Each block also shows the circuit functions it contains and the **footprint** ... the size of each block, which should be pencilled out on the board before mounting the pads to ensure proper fit.

5"x7" Copper
Clad Board

2N2/40 BOARD LAYOUT



The original T/R switch, input filter, r.f. amplifier, and double balanced mixer (usually called the receiver "front end", SEQ#3) were built along the right edge of the board, toward the VFO output transformer. When I got the DBM finished and mounted, (more on that later), it seemed like a good place to "turn the corner", so that was done. Before continuing on though, some testing of the existing circuitry seemed appropriate. Using my FT990 tuned to

4.915 MHz, the 2N2/40's intended i.f. frequency, I connected a test lead from the 990's antenna connector to the output of the receiver DBM. I connected a short antenna to the 2N2/40 input filter and powered it up. I could hear 40 meter signals, and they tuned with the VFO pot! Eureka.....it was working.

Building again started with the mixer amplifier (SEQ#4). Next came the crystal filter, the i.f.

amplifier, and the local oscillator for the product detector (SEQ#5) across the front panel edge of the board. This brought construction to a point near the left edge of the board. It was necessary to make another right turn. That allowed construction of the product detector (SEQ#5), mute switch, and audio amplifier (SEQ#6) along the left-hand edge, going from bottom to top.

At this point, the receiver portion was essentially done, and I spent about a week just listening to it, and marveling that it actually worked. In fact, it worked very well, far better than I had expected for just 2N2222 transistors. Spurred on by the success of the receiver, I was anxious to see how the transmitter might fare.

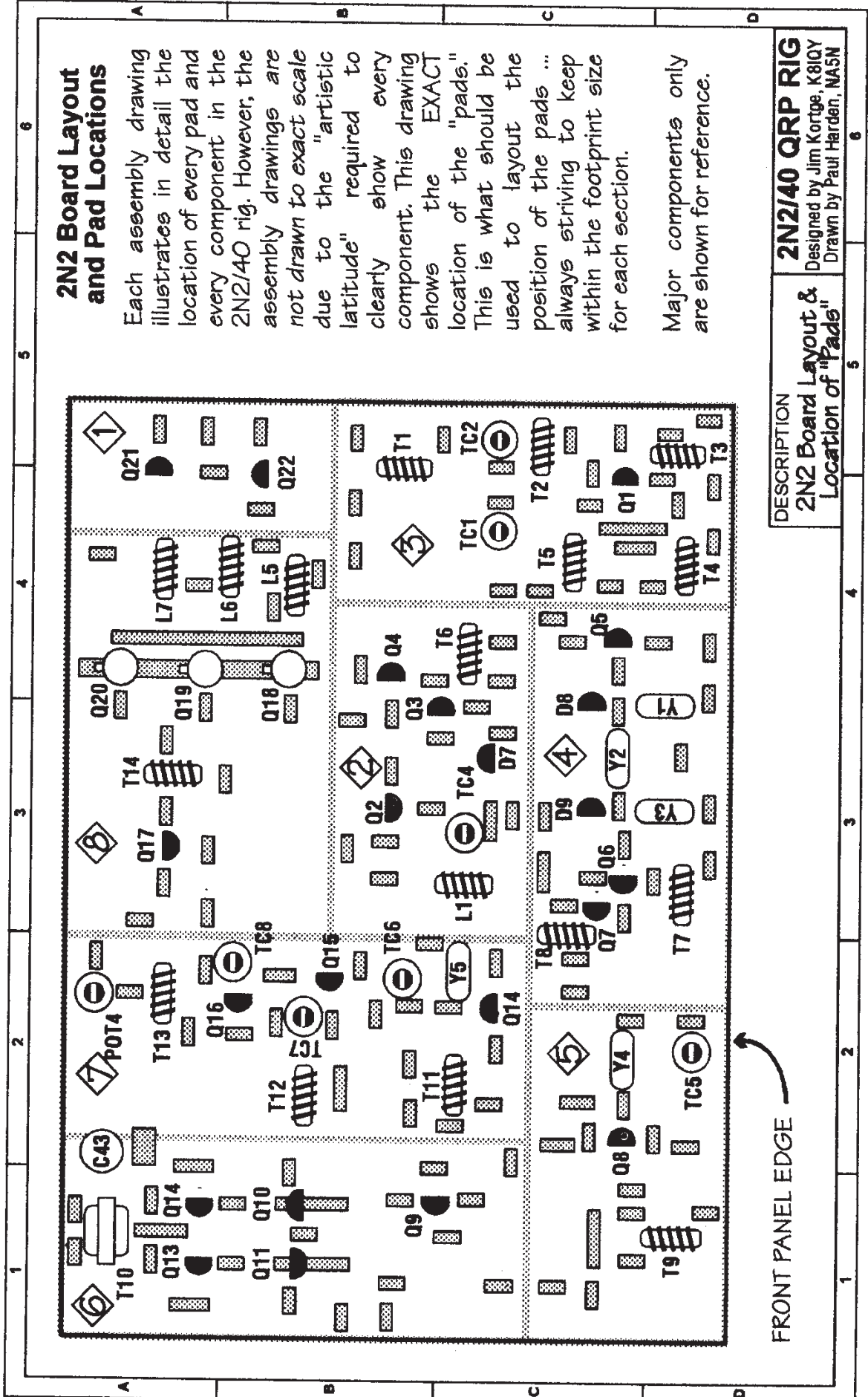
Looking over the remaining unpopulated areas of the substrate, it was pretty clear that the transmitter would need to be placed adjacent to the receiver mute switch and the audio amplifier. That also placed the transmit single balanced mixer reasonably close to the VFO, so that getting drive for it would be easy. I built the transmitter local oscillator, the single balanced mixer, and finally the cascode r.f. amplifier. At this point, there was no more room in the direction of the bottom of the substrate. Time to turn yet another corner, and start building toward the right.

However, I started to get a bit uneasy. The buildup of the transmitter r.f. driver (SEQ#7), the final amplifier output section, and the low pass filter (SEQ#8), was yet to be completed, and not much space was left. It was then that the decision was made to go to a "second story" if the rig was all to fit within the substrate footprint. The details at that point were unclear, but it was certain the final amplifier(s) were not going on the main board, but

it was certain the final amplifier(s) were not going to fit on the main board, but somewhere else. After building the r.f. driver section, as expected, most of the space was used up.

On the prototype rig, the three 2N2222A transistors used in the final amplifier are located on a 1¼ by 2½ inch piece of double sided PC board material. The transistors are on the top side, and the low pass filter components are on the bottom side. The whole affair is mounted on two 1 inch standoffs. Details of that construction are also shown in the Summer 1998 QRPP. As Paul Harden, NA5N pointed out, building the output final amplifier and low pass filter as a separate structure allows it to be replaced easily with another unit, maybe using a different bipolar or a MOSFET PA. The layout I've suggested, based on my second built 2N2/40, leaves ample room to put the three PA transistors and the output filter on the board. However, you could build the driver, PA, and LP filter on a separate 2x3 inch piece of material, just so you have the option of replacing it some time in the future with a different PA.

That completes the rig in terms of overall physical layout. Let's now move on to the various circuits and circuit sections and discuss them in more detail. Before leaving the layout diagram, one additional comment is appropriate. As a building aid on a 5 X 7 inch substrate, use a ruler and black marking pen with permanent ink and layout the lines as shown. When you build, don't put any component closer to a line than 1/8 inch. This will leave 1/4 inch "gutters" between each section which can be used for routing power and various signal lines. That approach worked really well on the second rig I built using the documentation from this article.



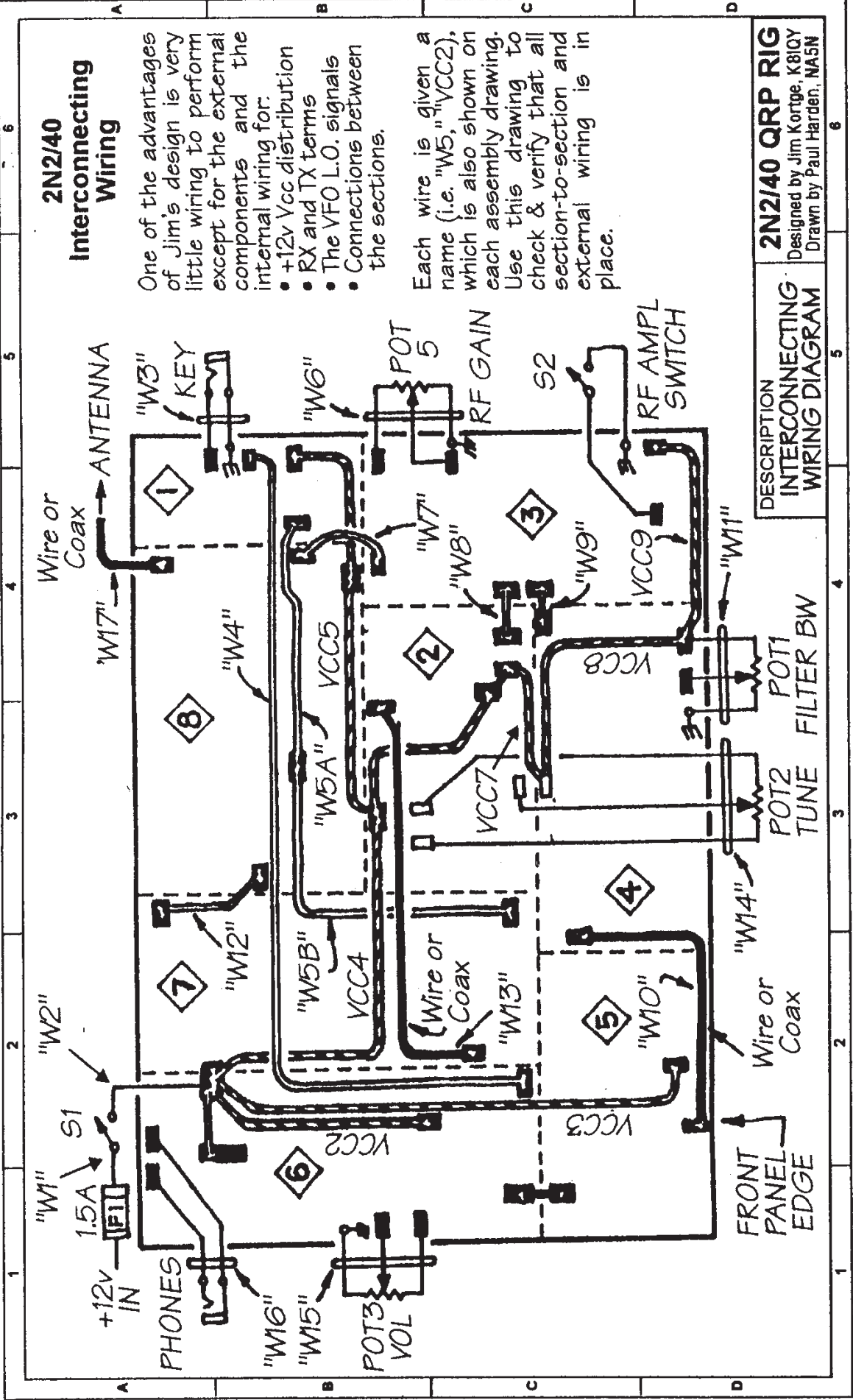
2N2 Board Layout and Pad Locations

Each assembly drawing illustrates in detail the location of every pad and every component in the 2N2/40 rig. However, the assembly drawings are not drawn to exact scale due to the "artistic latitude" required to clearly show every component. This drawing shows the EXACT location of the "pads." This is what should be used to layout the position of the pads ... always striving to keep within the footprint size for each section.

Major components only are shown for reference.

| DESCRIPTION |
|---------------------------------------|
| 2N2 Board Layout & Location of "Pads" |

FRONT PANEL EDGE



2N2/40 Interconnecting Wiring

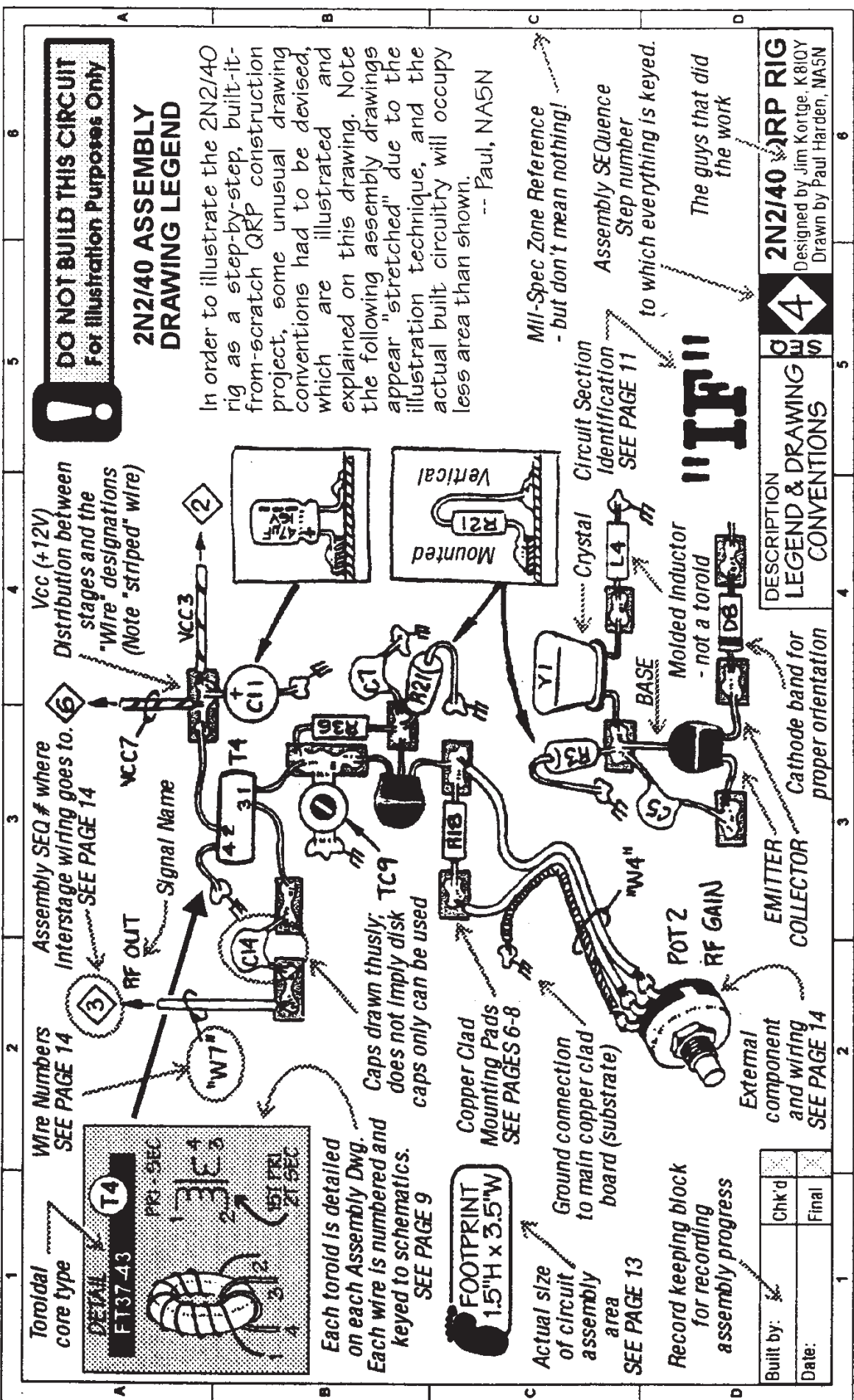
One of the advantages of Jim's design is very little wiring to perform except for the external components and the internal wiring for:

- +12v Vcc distribution
- RX and TX terms
- The VFO L.O. signals
- Connections between the sections.

Each wire is given a name (i.e. "W5," "VCC2), which is also shown on each assembly drawing. Use this drawing to check & verify that all section-to-section and external wiring is in place.

2N2/40 QRP RIG
 Designed by Jim Kortge, K8IQY
 Drawn by Paul Harder, N4SN

DESCRIPTION
 INTERCONNECTING
 WIRING DIAGRAM



DO NOT BUILD THIS CIRCUIT
For Illustration Purposes Only

2N2/40 ASSEMBLY DRAWING LEGEND

In order to illustrate the 2N2/40 rig as a step-by-step, built-it-from-scratch QRP construction project, some unusual drawing conventions had to be devised, which are illustrated and explained on this drawing. Note the following assembly drawings appear "stretched" due to the illustration technique, and the actual built circuitry will occupy less area than shown.

-- Paul, NA5N

Mill-Spec Zone Reference - but don't mean nothing!

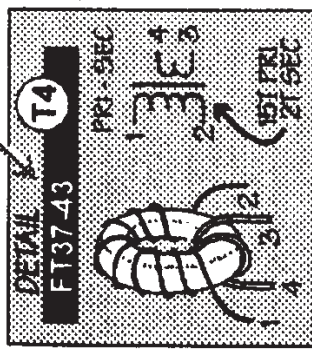
Assembly SEquence Step number to which everything is keyed.

The guys that did the work

Vcc (+12V)
Distribution between stages and the "Wire" designations (Note "striped" wire)

Assembly SEQ # where interstage wiring goes to. SEE PAGE 14

Wire Numbers SEE PAGE 14



Each toroid is detailed on each Assembly Dwg. Each wire is numbered and keyed to schematics. SEE PAGE 9

FOOTPRINT 1.5"H x 3.5"W

Actual size of circuit assembly area SEE PAGE 13

Record keeping block for recording assembly progress

| | |
|-----------|-------|
| Built by: | Chk'd |
| Date: | Final |

DESCRIPTION LEGEND & DRAWING CONVENTIONS

Crystal L4
Molded Inductor - not a toroid
Cathode band for proper orientation

EMITTER COLLECTOR

External component and wiring SEE PAGE 14

External component and wiring SEE PAGE 14

External component and wiring SEE PAGE 14

CONSTRUCTION SECTION

Let's build a rig!

5. Circuit and Construction Details - Receiver

1 RX/TX Driver

| Schematic | Assembly Dwg. |
|-----------|---------------|
| Sht. 4 | SEQ. #1 |

Circuit Description.

The Rx/Tx driver switching circuit provides receiver and transmitter control. Transistor Q21 is normally "on" due to base drive from bias resistor R59 and R60. The port labeled "Rx" supplies current to audio muting transistor, Q9, via resistor R59 also. Since the collector of Q21 is near ground potential, (0.2 volts actually) transistor Q22 is turned "off", and no current is flowing out of its emitter.

When the "key line" is brought to ground via a straight key or keyer, the two transistors revert to their opposite states. Transistor Q21 is turned "off", and the current that was flowing through its collector-emitter junction is now flowing into the base of Q22, turning it "on". The emitter of Q22 now provides current to all of the transmitter sections that require current from the port labeled "Tx". These include the Tx LO, Tx Cascode Amplifier, and the Tx RF Driver stages.

The voltage available at the Q22 emitter is the supply voltage, V_{cc} , minus its base-emitter forward drop, a value of approximately 0.7 volts, minus its collector-emitter saturation voltage, another 0.2 volts, or V_{cc} minus 0.9 volts. Had we been able to use a PNP transistor for Q22, the base-emitter drop would be eliminated, but then we wouldn't be using all 2N2222 transistors, as the contest

rules required. Not having full supply voltage available to the transmit stages reduces their gain and output power by perhaps 10 percent, not enough to keep the design from working.

Assembly.

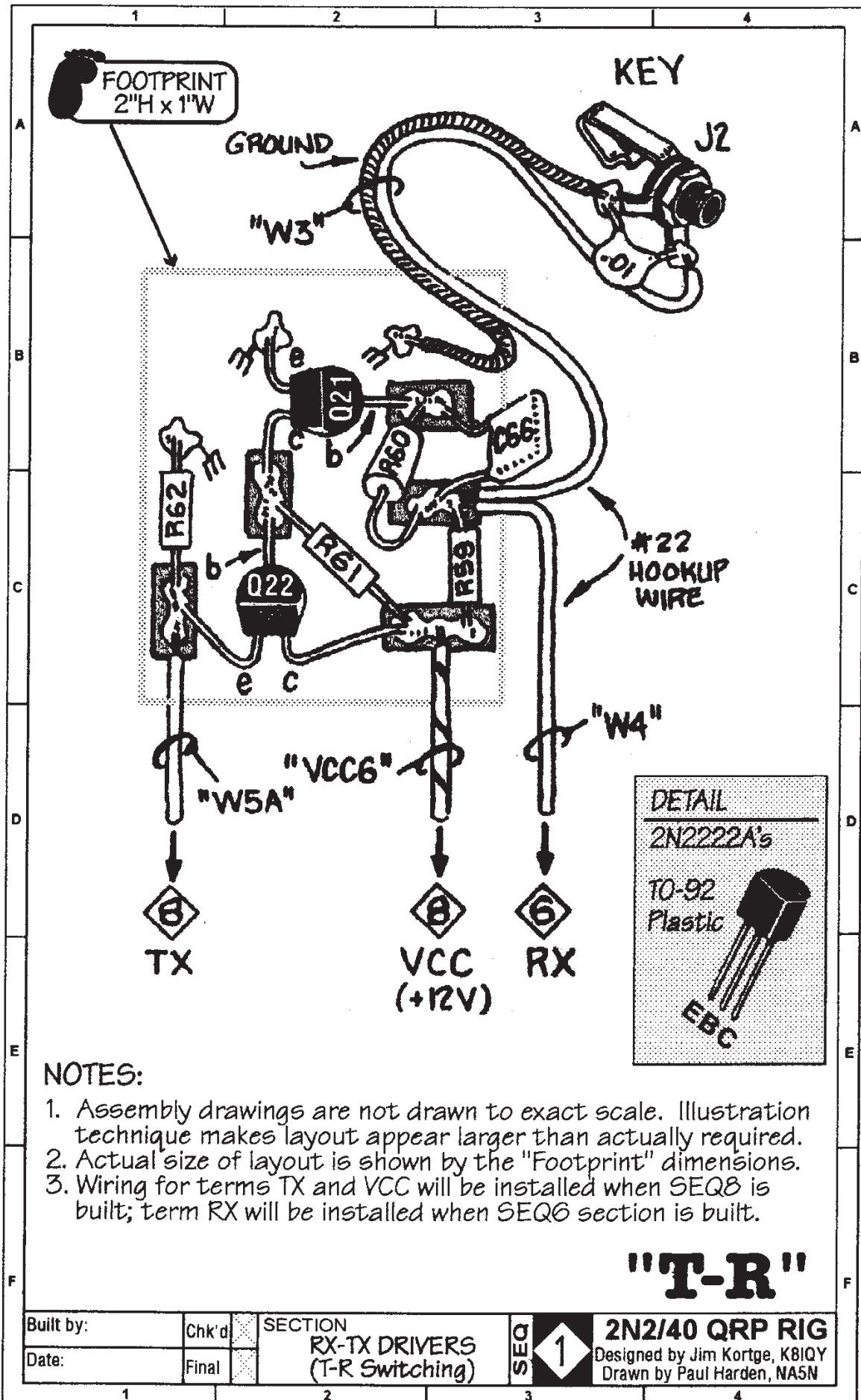
The RX/TX Driver is by far the easiest section in the whole rig to build. For that reason, it is the first to build, just to gain some experience mounting the pads and using the "Manhattan" technique to build the rig on this simple circuit block.

As you can see, this section is really simple - nothing critical in terms of layout, and lots of space to build it. Once completed, its port pads for terms RX and TX will be wired to the corresponding port pads in the receiver and transmitter. These switching terms will be wired to the other sections, as you build them, using hookup wire. Refer to the Interconnecting Wiring Diagram on page 14.

- Term RX is wire run "W4"
- Term TX is wire run "W5"

Testing.

For testing, you can add the external components with leads long enough that they will be appropriate when the rig is assembled in a case. With power applied, it should be in the receive mode, that is, RX=+11v, TX=0V. In the transmit "key-down" mode, RX=0v and TX=+11v. The real testing of this circuit, however, need not be performed until the 2N2/40 construction is completed.



NOTES:

1. Assembly drawings are not drawn to exact scale. Illustration technique makes layout appear larger than actually required.
2. Actual size of layout is shown by the "Footprint" dimensions.
3. Wiring for terms TX and VCC will be installed when SEQ8 is built; term RX will be installed when SEQ6 section is built.

"T-R"

| | | | |
|-----------|-------|----------------------------------|---|
| Built by: | Chk'd | SECTION | 1 2N2/40 QRP RIG Designed by Jim Kortge, K8IQY Drawn by Paul Harden, NA5N |
| Date: | Final | RX-TX DRIVERS (T-R Switching) | |

2 Varicap Tuned VFO

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 1 | SEQ. #2 |

Circuit Description.

The VFO (variable frequency oscillator) is a classic Colpitts design, using a MVAM109 voltage variable capacitance diode for the tuning. It tunes from nominally 2.085 to 2.185 MHz, 100 KHz of band coverage. Trimmer TC4 is used to set the lower frequency limit, and TC3, if included, sets the upper frequency. Some adjustment of the turns on inductor L1 may be required to get the correct frequency range, with the values shown.

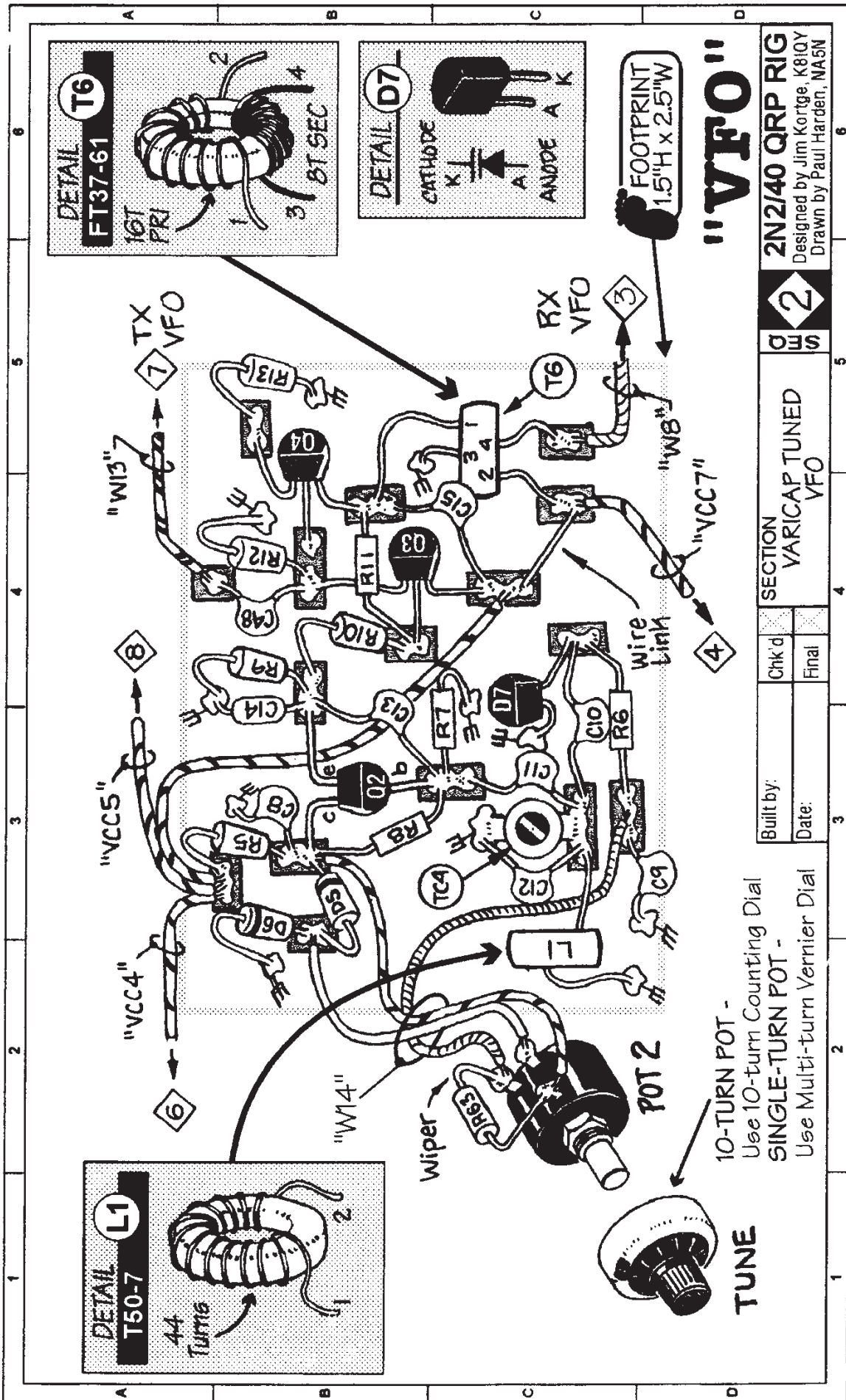
Important features include the main inductor, L1, which is wound on a T50-7 powered iron core. With the 44 turns required on this core, the inductance should come in around 8.5uH. Type 7 cores have the best temperature characteristics of any of the commonly available cores. What frequency drift occurs is downward in frequency as the temperature increases. To compensate for this drift, a negative temperature coefficient capacitor is employed, C12a, which moves the frequency upward with increasing temperature. Polystyrene capacitor C12a, in conjunction with C12b (NPO type) provides the correct amount of compensation to keep the frequency stable with changing temperatures. The combination of Zener diode D5 and power diode D6 provide a total of 6.9 volts from the 13.8 volt supply. Keeping the collector voltage low (~7 volts) on transistor Q2 and its components reduces heat dissipation, also helping VFO stability. All of the capacitors in the VFO are NPO types except for C12a and C13 and C14. C13 and C14 are 5% tolerance polyester capacitors, which are quite stable with temperature. VFO drift from a cold start is under 200 Hz. The VFO tuning

linearity is improved by swinging the varicap diode, D7, between 6.9 and 0.7 volts, avoiding the most non-linear portion of the capacitance curve, which occurs near 0 volts. Resistor R63, also helps linearize the VFO tuning by effectively changing the linear potentiometer, POT2, into a non-linear unit which approximately matches the tuning diode capacitance versus voltage curve.

Transistor Q3 serves as a buffer, keeping load changes from affecting Q2, the oscillator. Output from the emitter of Q3 is used to drive the transmitter single balanced mixer. The VFO signal is further amplified by transistor Q4, to provide the +10 dBm drive level (0.7 volts rms) required by the receiver double balanced mixer. Signal output is transformer-coupled to the receiver mixer from the secondary winding of T6. The primary winding is 16 turns on a FT37-61 core for 14 to 15 uH of inductance, depending how it is wound. It is tuned by capacitor C15 to provide the required driving power, and to reduce harmonic content output. The VFO also has low phase noise, as shown in the spectral display measured by NA5N on page 20.

Assembly.

The VFO layout is shown in Assembly Drawing SEQ#2. As you can see, the construction starts on the left at L1, and flows to the right, where the main output, the secondary of T6, is positioned to be close to the receiver DBM in section SEQ#3. The output going to the transmitter single balanced mixer, Tx VFO on SEQ#7, will be routed through shielded cable (RG-174, etc.) to reduce radiation into surrounding circuitry. There is some latitude for constructing the VFO in terms of alternate part locations. It doesn't have to be built as shown. Just try to keep the overall size within the footprint, so that you have enough room for the other sections.



DETAIL T6
FT37-61
 1GT
 PRI
 3 2 4
 8T SEC

DETAIL D7
 CATHODE
 K
 A
 ANODE
 A K

FOOTPRINT
 1.5"H x 2.5"W

"VFO"

2N2140 QRP RIG
 Designed by Jim Kortge, K8IQY
 Drawn by Paul Harden, NA5N

SECTION 2

VARICAP TUNED VFO

| | | |
|-----------|-------|-------|
| Built by: | Chk'd | Final |
| Date: | | |

POT 2
 10-TURN POT -
 Use 10-turn Counting Dial
SINGLE-TURN POT -
 Use Multi-turn Vernier Dial



DETAIL L1
T50-7
 44
 TURNS

SEQ#2: VFO con't.

Varicap diode D7 looks like a TO-92 transistor, but with only 2 leads. Ensure it is installed properly. See the detail for identifying the anode and cathode on the SEQ#2 drawing.

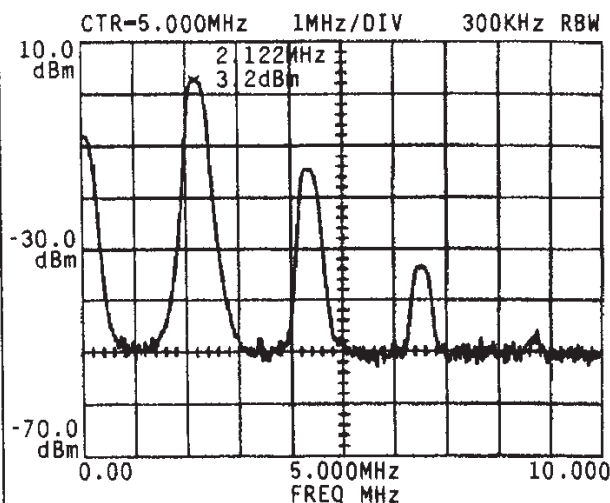
Testing.

Once built, this section can be tested quite easily if you have a general coverage receiver. The VFO needs to tune nominally from 2.085 MHz to 2.185 MHz. Attach

a short length of wire to the pad marked "Rx VFO". Power it up by applying 12 to 13.8 vdc (use a fused supply) to all of the pads marked Vcc, and tune your receiver until you hear the VFO. It should be quite strong. If you have a counter or oscilloscope, they can also be connected to the same output pad for measurement and signal observation. The unloaded output from the secondary of T6 should be around 3 volts peak to peak.

2N2/40 on the Test Bench

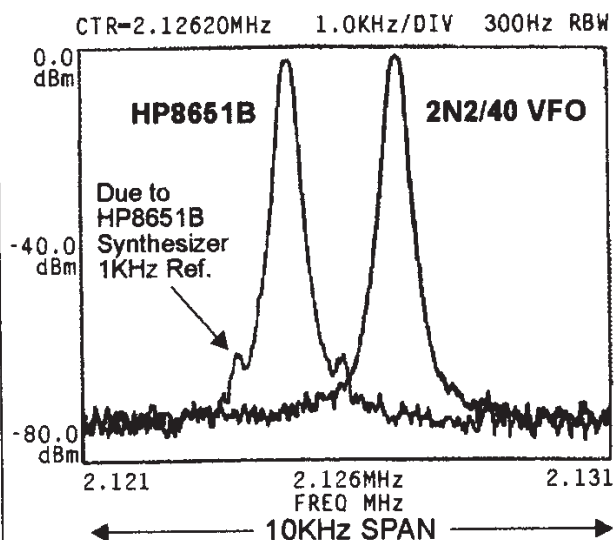
VFO Power & Spectral Output



As Jim discussed in his article, harmonic power from the VFO is reduced by the inductance of T6-primary and C15. Without C15, the 2nd harmonic (4.2MHz) is only down about 6dB. With C15, as shown here, the 2nd harmonic is down 18dB (-18dBc) and the 6.3MHz 3rd Harmonic is -37dBc. The lower the harmonic content of the VFO (LO), the less image power out of the mixer. The spectrum here was measured at the center-tap of T5 (RX LO power).

VFO close-in Purity (Phase Noise)

Oscillator Close-in Sideband Power
2N2/40 VFO vs. HP8651B Sig. Gen.



Oscillator phase noise is the very small "wiggling" of the oscillator that causes power to appear in the very close-in (<20KHz) sidebands. Of interest to QRP rigs is <2KHz, as this will cause noise power in the detected CW audio and other problems. It is also a measure of oscillator quality and stability. The VFO in the 2N2/40 has very low noise power, being -65dBc at 750Hz and -68dBc at 2KHz for a phase noise of slightly less than 2°. The 2N2/40 VFO close-in spectrum is shown here compared to an HP 8651B signal generator.

3 Receiver "Front End"

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 1 | SEQ. #3 |

- RX T/R Switch
- Input Filter
- Switchable RF Amplifier
- Diode Double Balanced Mixer

Circuit Description.

The RX T/R switch configuration used in the 2N2/40 is not the first design that I actually built. My first design was more robust, but required too many transistors to generate the drive signals, and in the end, had to be scrapped. This design, I believe, comes from Roy Lewellan, W7EL and has been used by many others. While it works very well for such a simple design, it does have some limitations. Its main fault is that it doesn't handle strong signals well, which could lead to third order intercept problems. However, if your 2N2/40 isn't used at field day or in similar situations, where really strong signals are present, it does just fine.

As originally implemented, the circuit used a trimmer at TC9, a 12uH inductor at L8, and the series resonance of this pair could be tuned. However, the loaded Q of the circuit is quite low, about 4, which makes the tuning so broad that this capability is wasted. I'd recommend building this circuit with TC9 being a fixed 47pF capacitor, and L8 being a 10uH molded inductor. That saves a trimmer, and the performance is virtually unchanged.

The input filter receives the signal from the T/R switch. This filter is a classic double tuned band pass filter, using light coupling between the two resonators. Its half power bandwidth is about 150 KHz with the component values used. The secondary of input transformer T1 has an inductance of 3.6uH, and is

QRPp - Winter 1998

resonated at 7.05 MHz with capacitor C1 and trimmer TC1. The three-turn primary provides a 50 ohm match to the antenna.

Output transformer T2 uses a 7-turn link, to match the 350 ohm input impedance of the r.f. amplifier. T2 is tuned to resonance with capacitor C3 and trimmer TC2. The coupling between the two resonators is 3pF. In the prototype rig, this capacitor is 3.9pF, but additional circuit tests suggests a 3pF value provides flatter frequency response over the desired 7.0 to 7.1 MHz region, without appreciable change in overall 3dB bandwidth. It should also make input tuning a bit less critical.

The r.f. amplifier is based on a common emitter design. With the component values used, it has 10 dB of power gain. Computer modeling shows that it can handle an input signal in excess of +13 dBm without distortion or going into gain compression. Another 10 dB of gain can be accomplished by paralleling emitter resistor R4 (82 ohms) with a 12 ohm resistor (R65). My 2N2/40 has a front panel switch for doing this, although I don't use the 20 dB gain position very often. Running the higher gain also reduces the input impedance to about 100 ohms, causing a mismatch with the input filter. However, it does let you to hear really weak signals, under the right conditions. A 4:1 impedance ratio bifilar transformer, T3, is used to couple the output to the receiver's diode DBM.

The receiver diode double balanced mixer (DBM) in the prototype rig was constructed on a very small (1/2 inch X 3/4 inch) piece of single sided PC board material, instead of on the main substrate. The reason for doing this was so that it could be easily replaced (after Dayton, of course) with a commercial DBM if my

home-brew unit didn't work well. That DBM implementation was detailed in Paul Harden, NA5N's "QRP Hints and Kinks" section of the Summer 1998 issue of QRPp. (see below). I'm not sure that I would recommend building yours quite that small, unless you have lots of patience! The provided layout essentially uses the same geometry, but with more room between the various components. However, keeping the all the leads as short as possible helps maintain the balance necessary for the DBM to work well. Also, the 1N4148 diodes should be matched for forward resistance. Just measure a bunch, and pick 4 that are within a 1 ohm of each other. Since the diode leads are cut short, don't keep the soldering iron on these connections very long, or you will overheat the diode and change it's forward resistance characteristics.

Assembly.

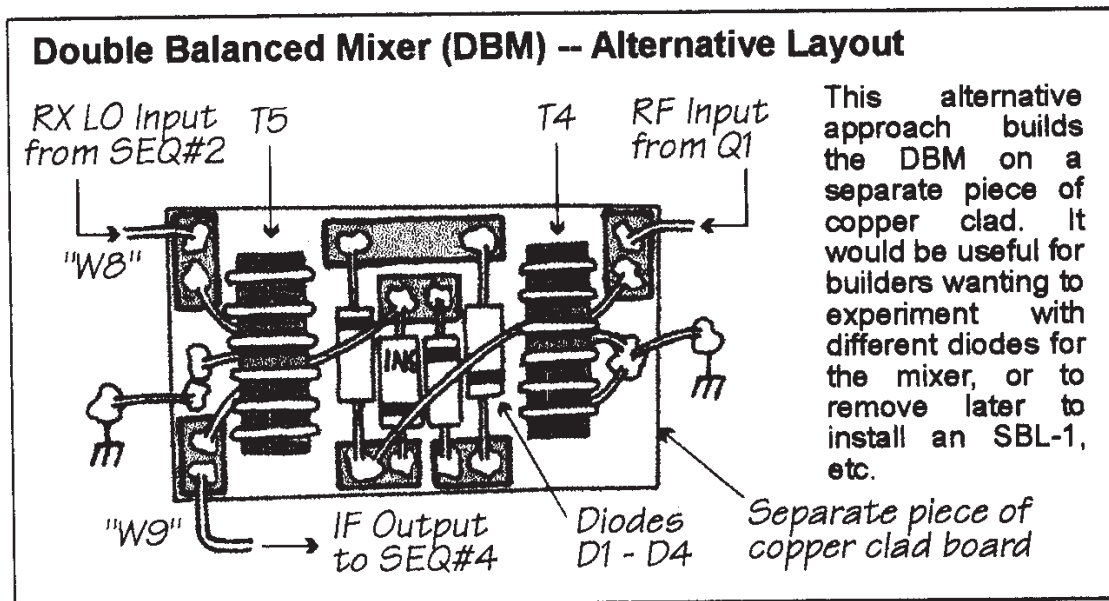
This section should be built from the (rear panel end) to the bottom (towards front panel edge), and from right to left. Start with the input pad for the T/R switch (Port A on the schematic, or wire "W7" on the assembly drawing) and end with the DBM on the bottom left. Once this portion is built, it too can be tested, using a general coverage receiver. I'm assuming

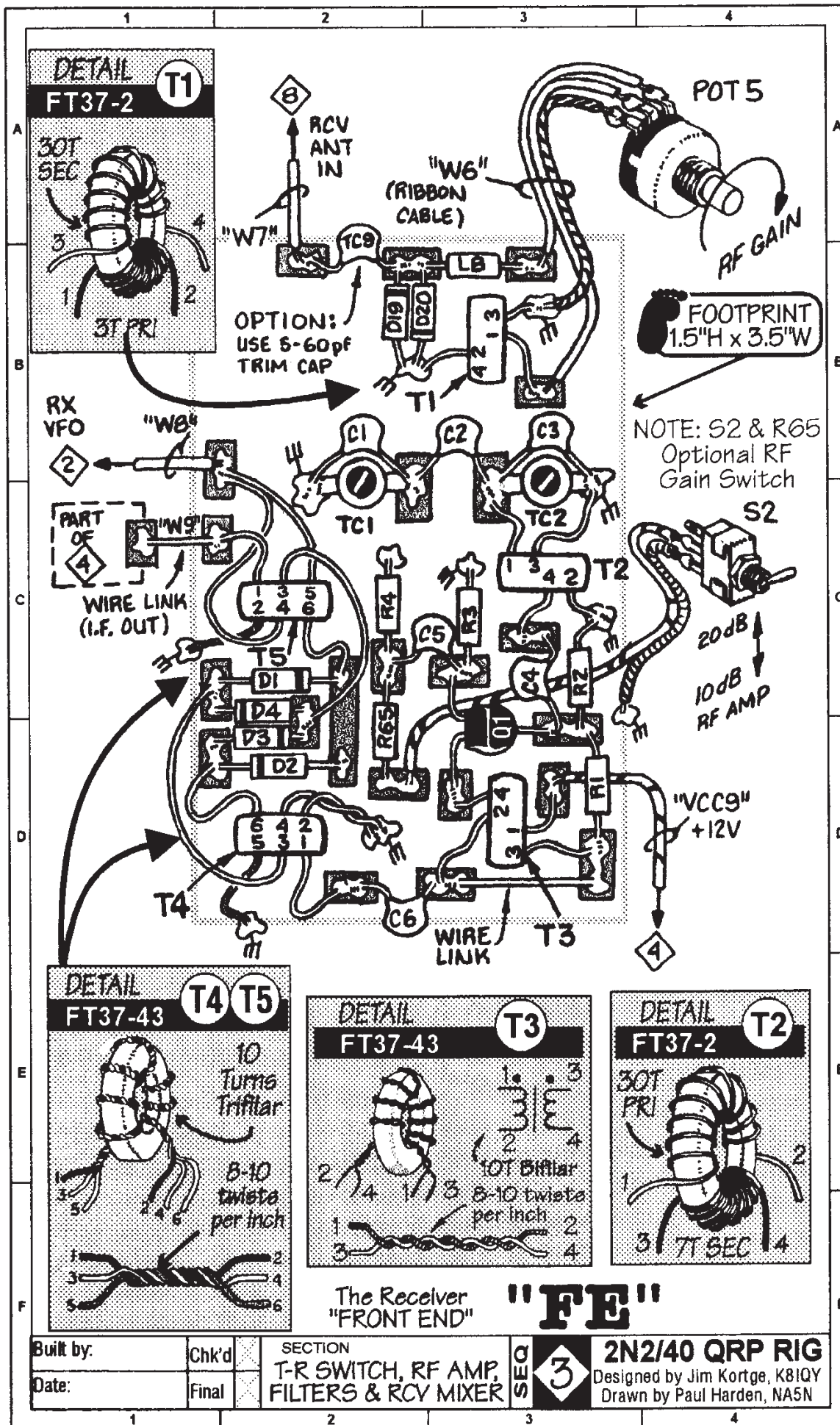
that you have the VFO built and working correctly and its output is routed to the pad labeled VFO (Term RX VFO, wire "W8" from dwg. SEQ#2). Solder a temporary jumper across the two pads labeled Pot 5 Wiper and Pot 5 High (RF Gain control).

Testing.

Set the VFO to its mid-frequency, 2.135 MHz. Attach an antenna or 4-5 foot piece of wire to the pad labeled A. (Wire "W7"input). Connect the output pad labeled "C" (Wire link "W9") to the antenna input on your receiver with a piece of coax cable. Tune the receiver to 4.915 MHz. Using a signal generator, or a QRP rig fed into a dummy load, generate a signal on 7.050 MHz. You should find a signal very near 4.915 MHz, the 2N2/40 i.f. frequency.

Once you find the signal, peak the input trimmers TC1 and TC3. Go back and forth between these two a couple of times until it is as strong as you can get it. If you built this section using a trimmer for TC9, peak that trimmer also. At this point, you should be able to leave the receiver tuned to 4.915 MHz, and tune the 40 meter CW band using the VFO. The general coverage receiver is acting as our crystal filter, i.f. amplifier, and detector. We'll build those next.





Built by: _____
 Date: _____

Chk'd _____
 Final _____

SECTION
 T-R SWITCH, RF AMP,
 FILTERS & RCV MIXER

DESIGN #
3

2N2/40 QRP RIG
 Designed by Jim Kortge, K8IQY
 Drawn by Paul Harden, N4SN

4 Crystal Filter/IF Amp

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 2 | SEQ. #4 |

- Mixer Amplifier
- Variable Crystal Filter
- I.F. Amplifier

Circuit Description.

These elements make up the next major section of the receiver. With the addition of the Local Oscillator (RX LO) and the Product Detector in the section SEQ#5, we have essentially a complete receiver, down to detected audio. We'll get to that point shortly.

Mixer Amplifier. The diode DBM IF output signal (from SEQ#3) is fed to common base amplifier Q5. I've not seen this done before, and am not sure why. Since one of the goals in terminating a DBM is to have it working into a constant impedance load, this amplifier fits the bill nicely.

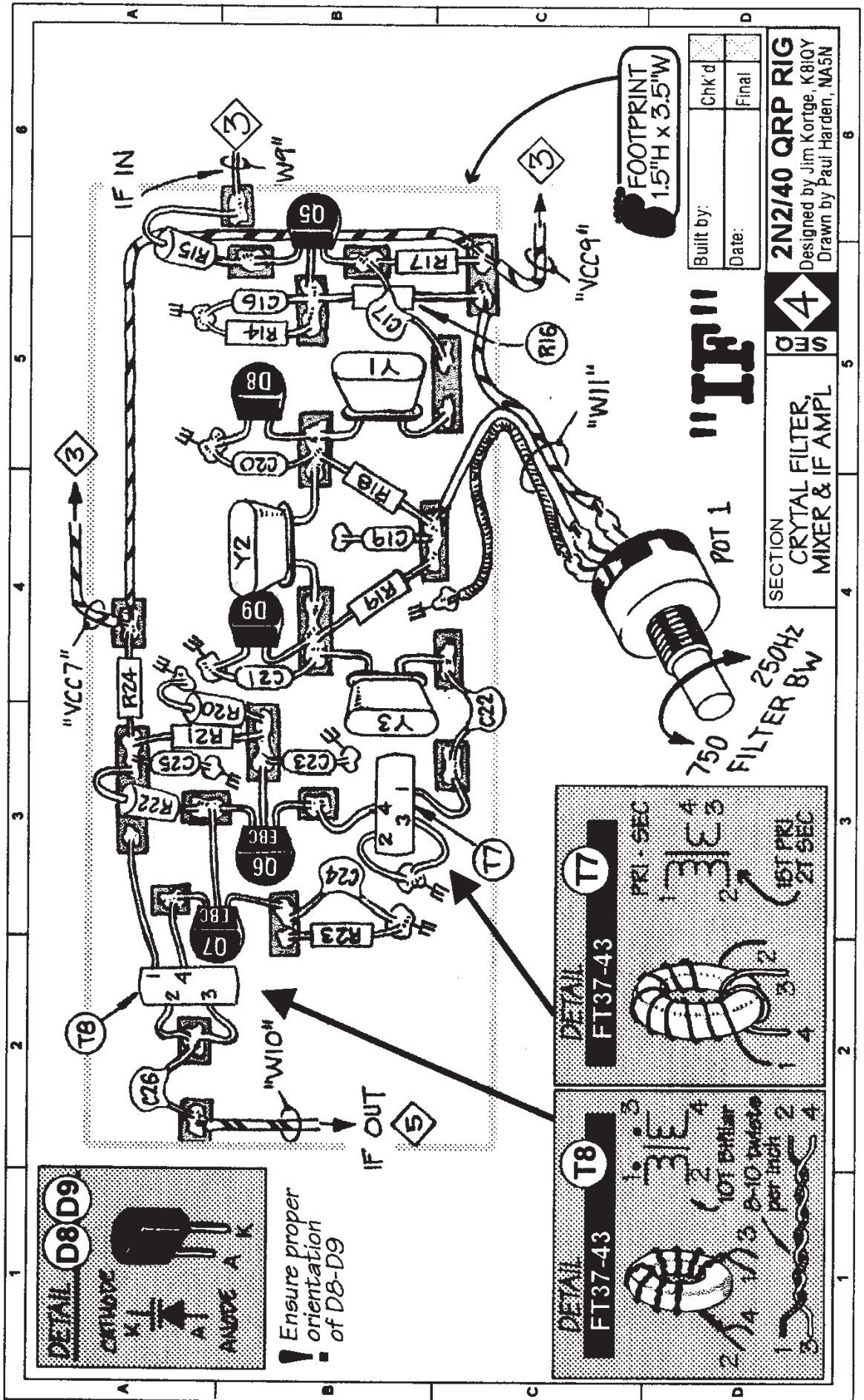
As configured, the input impedance is constant at 50 ohms resistive, from DC to beyond 30 MHz. Using this circuit, we don't need a diplexer, nor do we need an attenuator, to keep the load on the mixer i.f. port constant. In addition, with the 270 ohm collector resistor, this amplifier produces about 6 dB of power gain. It also has reasonable output to input isolation, so that impedance changes from the downstream crystal filter don't reflect back to the mixer.

Variable IF Crystal Filter. Following the mixer amplifier is a 3 pole, variable bandwidth (VBW), Cohn style crystal filter, consisting of Y1 to Y3. It uses matched 4.915 MHz series mode crystals. The bandwidth can be changed from about 700 Hz, down to 300 Hz. (See the NA5N measurements on page 26). Bandwidth control is accomplished using a pair of MV2115, voltage variable capaci-

tance diodes. These diodes provide a capacitance change of about 100pF, as the voltage on them is varied from 0 to 13.8 vdc. Bandwidth control voltage is provided by a variable potentiometer, POT1. The 270 ohm source and terminating impedances for the filter are provided by collector resistor R17, on the input side, and the transformed input impedance of Q6, the first i.f. amplifier transistor, on the output side. The output impedance transformation is done with transformer T7, which has a 15-turn to 2-turn turns ratio, and approximately 56 to 1 impedance ratio. The 2-turn secondary should be wound on the "cold" (grounded) end of the primary.

The IF Amplifier. Following the VBW crystal filter is the intermediate frequency amplifier, Q6 and Q7, using another somewhat unconventional design. My first thought for the i.f. amplifier was to use a common cascode arrangement, i.e. a common emitter amplifier driving a common base amplifier. That configuration was modeled, and although it provided plenty of gain, it showed a wide variance in the input impedance with frequency. I felt the crystal filter ought to be working also into a constant load, just like the receiver DBM, for optimum performance. This led to building a new computer model which had the common base amplifier first (Q6), driving a common emitter amplifier (Q7).

As with the common cascode configuration, the two transistors, Q6 and Q7, are direct coupled. Modeling once again showed this configuration could supply more than enough gain, but more importantly to me, the input impedance was constant over a very wide frequency range. However, the input impedance is only a few ohms, which resulted in the wide turns ratio transformer, T7, being required to couple the



crystal filter into the amplifier. With the component values shown, the power gain of this stage is nearly 50dB, with a response peak at 4.9 MHz. Output is taken from a bifilar wound, 4:1 impedance ratio transformer, T8. The output impedance from this stage is 50 ohms, suitable for driving the product detector. This amplifier also shows no stability problems when properly terminated.

Assembly.

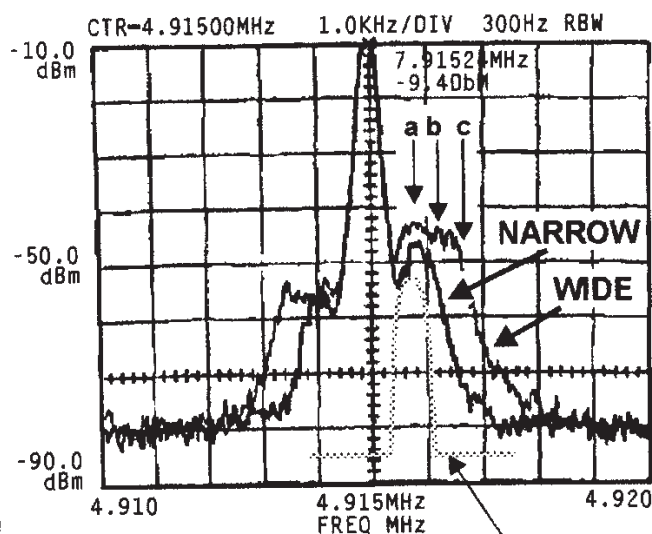
I'd recommend building this portion of the rig by starting at the right, near the DBM output in SEQ#3, and building toward the left until you're done with the i.f. amplifier. Probably the only critical thing here is keeping as much room between the i.f. input and output transformers, T7 and T8, as you can. This will help to insure stability. Placing the transformers at right angles to each other also minimizes coupling, but is not required.

Testing.

If you would like to test the rig at this point, connect the output of the i.f. (port pad marked "IF Out," or wire "W10") to the antenna input of your general coverage receiver, again using coax or a shielded scope probe. Tune the general coverage receiver to 4.915 MHz and power up the 2N2. This time, signals should be very strong, since we now have another 50 dB of gain from the i.f. amplifier. In fact, on very strong signals, you may have to reduce the r.f. gain of the communications receiver to keep from overloading it. You can also play around with the VBW crystal filter by grounding the pad marked "Pot 1 Wiper" or by taking this point to the Vcc supply. When this pad is grounded, the filter will be in its most "narrow" position, and when at Vcc, the filter will be running in its "wide" position. Of course, if you hook up POT1, you can set the filter to any passband width within its capability.

2N2/40 on the Test Bench

The Variable Bandwidth IF Crystal Filter



RF Signal (Station being worked)

This spectrum analyzer display was made by injecting a -70dBm wideband noise source into the antenna (an S3-S4 signal) to "paint" the overall shape of the IF response.

This spectrum analyzer display shows the IF bandwidth at the crystal filter output for both the **wide** and **narrow** settings on the VBW control (POT1). Point "a" is the IF peak. The -3dB points are shown at "b" (narrow) and "c" (wide). This shows a bandwidth of 800Hz in the wide setting, and 300Hz at narrow, for a very nice variable IF filter for CW reception. If there was a signal 1KHz higher, note it would be attenuated by 6dB in *wide*, and in *narrow* by 28db! This gives the 2N2/40 good selectivity and rejection of nearby interfering signals.

-NA5N

5 RX LO Oscillator and Product Detector

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 2 | SEQ. #5 |

Circuit Description.

The receiver local oscillator is a Colpitts configuration, just like the VFO. Perhaps the only unique feature of the circuit is tapping the output off the split emitter resistor pair, R29 and R28 and using a parallel tuned circuit to shape the waveform and reduce harmonics. I'm not sure going these extra steps has any payoff, but the output waveform is a clean sine-wave. Something that may not be obvious about this oscillator setup is that its frequency is below the i.f. passband because this rig uses the Cohn filter as an upper sideband filter, instead of the more traditional, lower sideband arrangement. Lowering the crystal frequency is accomplished by adding inductive reactance from L2, in series with the crystal. Trimmer TC5 lets us adjust the amount of inductive reactance. For proper receiving, the frequency of this local oscillator is adjusted to be 750 Hz *below* the 4.915 MHz passband. When this signal is mixed with the i.f. signal in the product detector, our de-

sired 750 Hz CW note is recovered.

The product detector is simply a two-diode, single balanced mixer. The i.f. signal is mixed with the receiver local oscillator producing principally two frequencies. The sum frequency is at 9.83 MHz and is shunted to ground by the reactances of C27 and C28. The difference frequency is 750 Hz, and adjustable by changing the frequency of the receiver local oscillator (also called the BFO -- the Beat Frequency Oscillator) via trimmer TC5. This is the recovered audio that will drive the speaker after it is amplified.

Assembly.

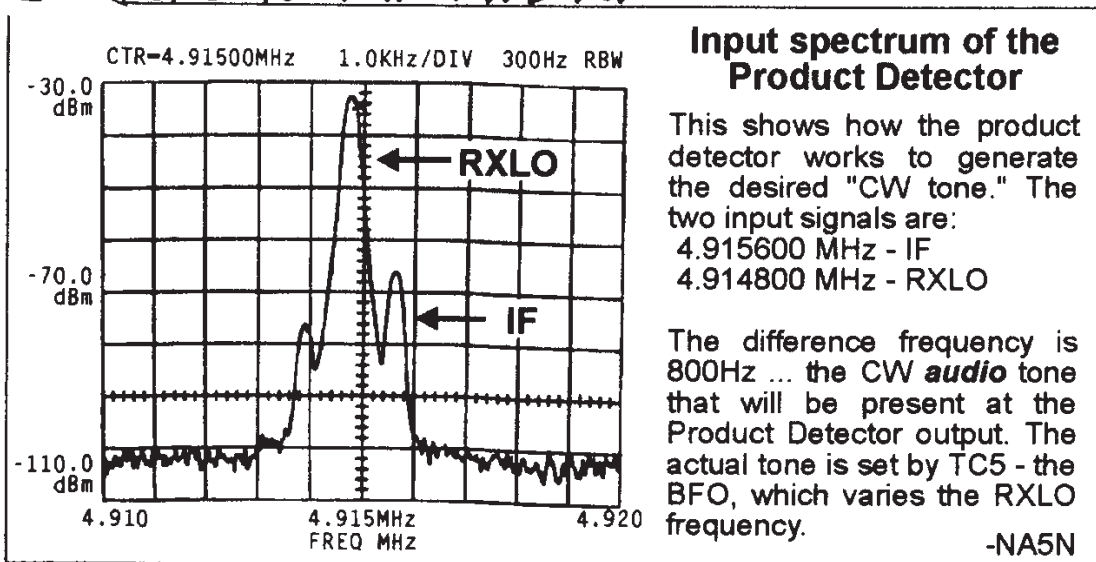
The RX LO oscillator and the Product detector are built to the left of the IF/crystal filter section to the left edge of the board. Layout is not tight, but plan things out to ensure you're not running out of "board" space.

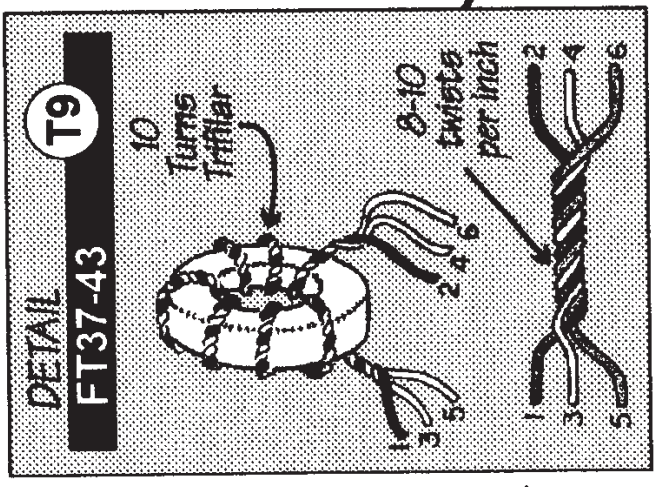
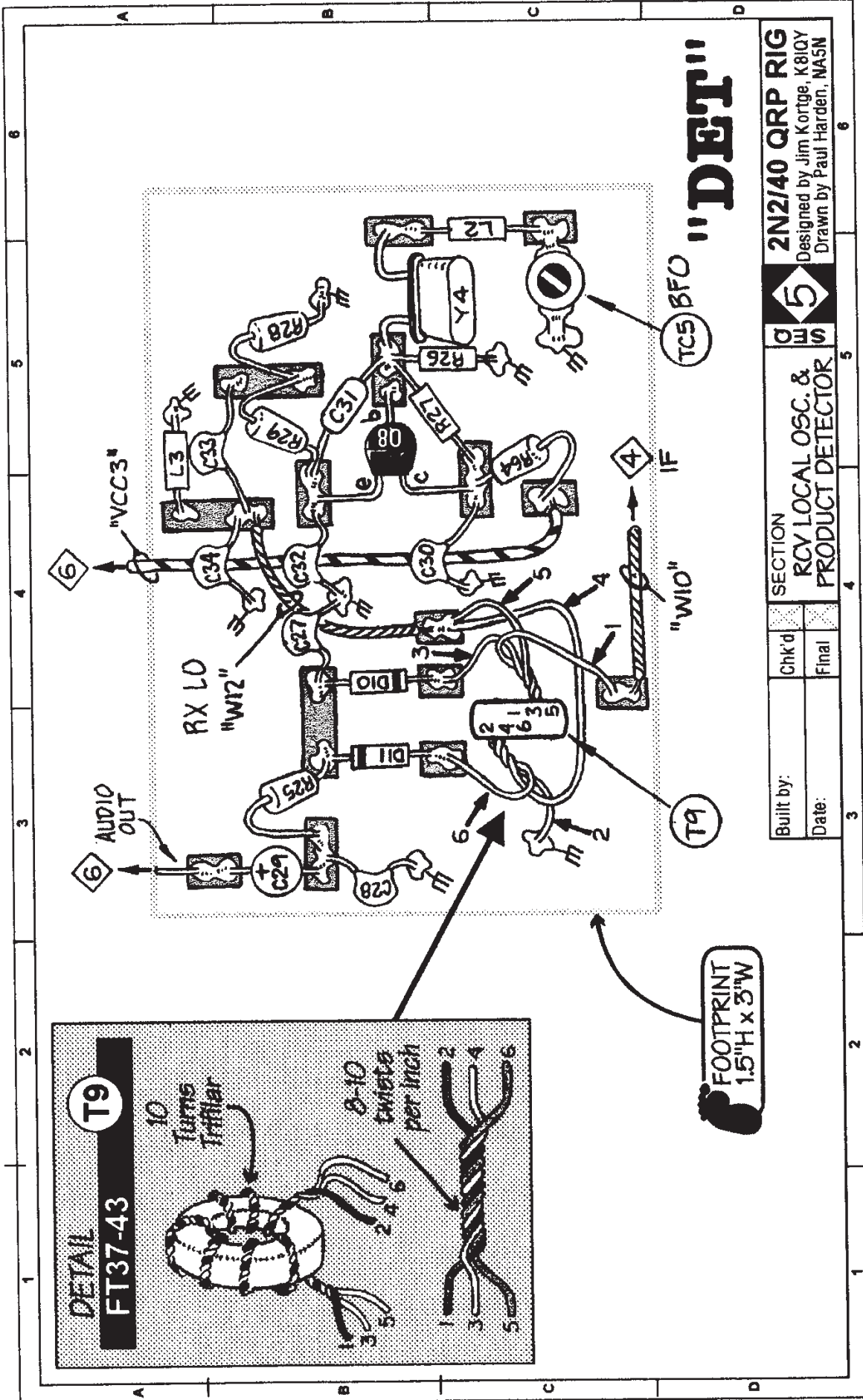
Note T8, the trifilar wound transformer. Details for winding T8 are on the assembly drawing.

Testing.

There's not much to test at this point. Let's build the next section, the audio amplifier, and then we'll have a complete receiver to test and align.

 2N2/40 on the Test Bench





FOOTPRINT
1.5"H x 3"W

2N2140 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

5

SECTION
RCV LOCAL OSC. &
PRODUCT DETECTOR

| | | |
|-----------|-------|-------|
| Built by: | Chk'd | Final |
| Date: | | |

6 Receiver Mute and Audio Amplifier

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 2 | SEQ. #6 |

Circuit Description.

The receiver mute circuit passes recovered audio to the audio amplifier when the rig is in receive mode. In this condition, diodes D12 and D14 are forward biased, and have very low forward resistance. The bias is provided by transistor Q9, which is turned "on" by the "Rx" signal applied to the base. When the rig transmits, drive is removed from Q9, causing the bias on D12 and D13 to be removed. These diodes now appear as open circuits, and audio is blocked. A small amount of sidetone audio is passed on to the audio amplifier during transmit by resistor R31. Sidetone audio is provided by having the receiver listen to the transmitter. Caps C35 and C36 provide delays to keep audio "thump" to a minimum during receive-to-transmit and transmit-to-receive transitions.

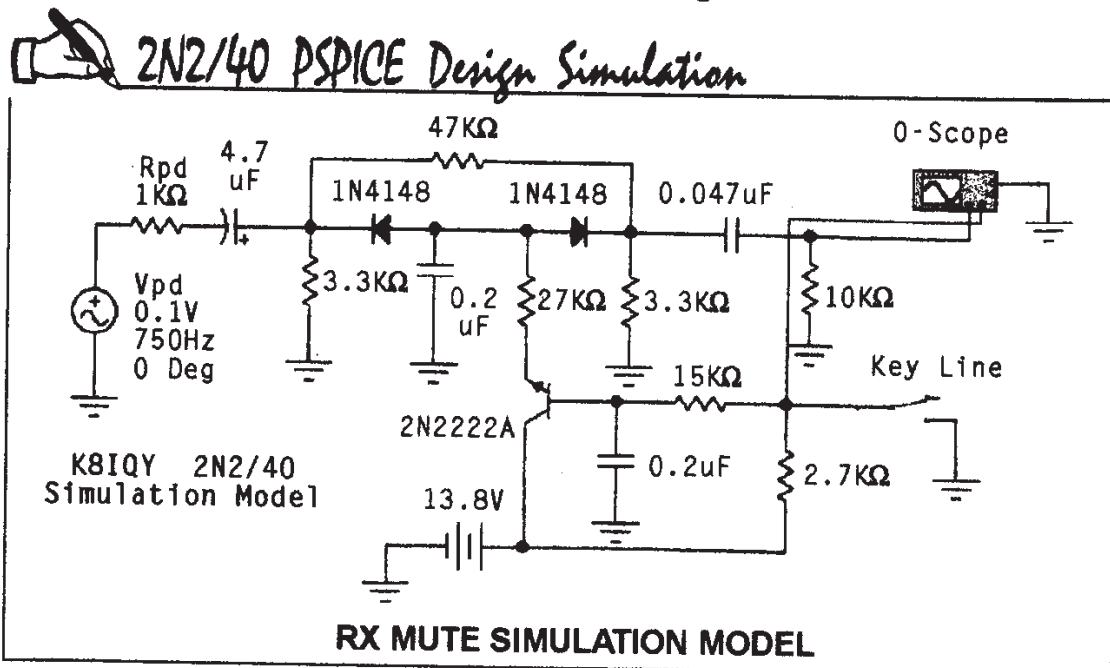
PSPICE Analysis.

Before leaving this section, it seems appropriate to show an example of the analysis that can

be done with today's computer modeling tools. In this case, the software product is the Personal Edition of Electronic Workbench. The company that produces this system offered it at reduced pricing this summer, so EWB was purchased. It works much like the MicroSim DesignLab (PSPICE) demo that I had been using, but is even more full-featured. When the educational Manhattan/Elmer 300 Project is done this winter over the internet, many more of these analyses will be discussed and shown. This one is just to whet your appetite!

The computer model of the receiver mute circuit is shown below.

As you can see, this simulation circuit is a duplicate of the real thing shown in the 2N2/40 schematic. Product detector output, which is the signal source for this simulation, is the ac source labelled Vpd, set for 100 millivolts rms at 750 Hz. The product detector source impedance is the 1K resistor labelled Rpd. The small oscilloscope in the upper right hand of the model is a simulated scope within EWB, and can be expanded to show waveforms while the simulation is running. That will be shown next.

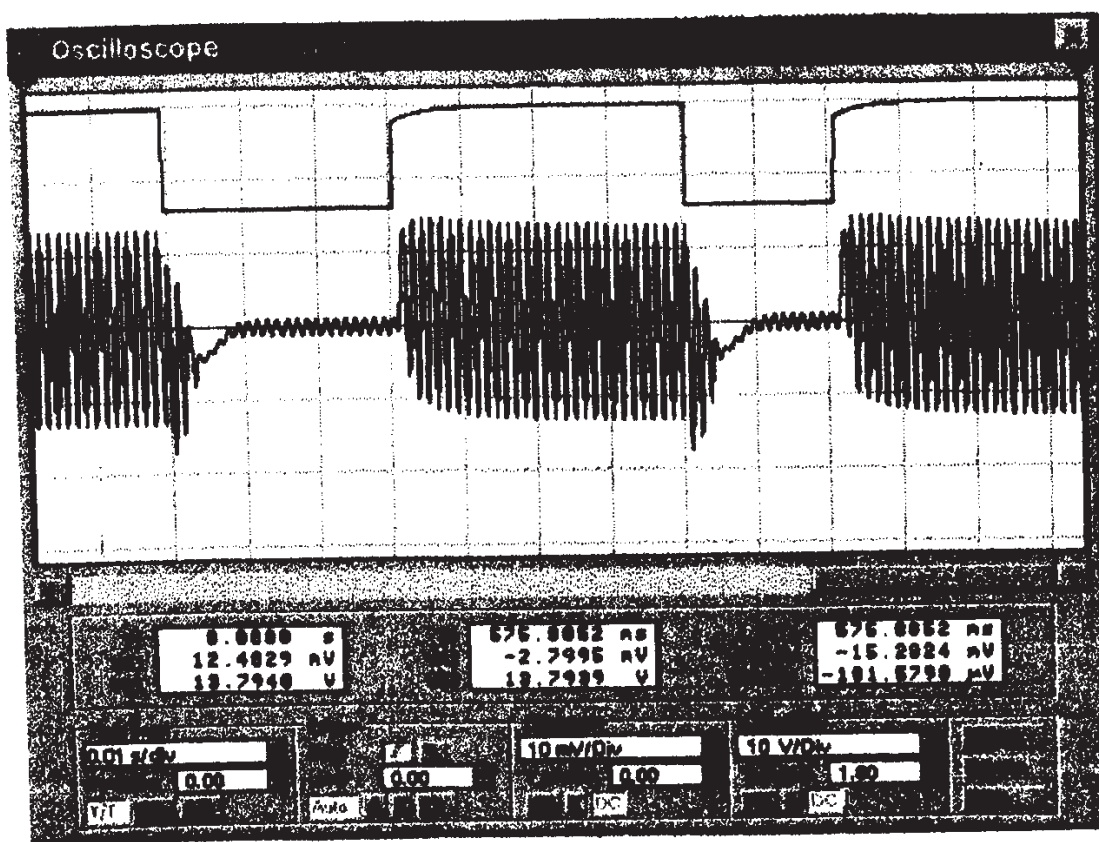


The "key line" can be toggled while the simulation is running by tapping the space bar on the computer keyboard, so that the transitions from "receive mode" to "transmit mode" and back again can be studied. Actual CW could be simulated by hooking up the EWB digital word generator in place of the key line switch, but that's overkill for this simple circuit.

The resulting waveforms as the circuit is keyed is shown below.

The upper trace is the "key line"

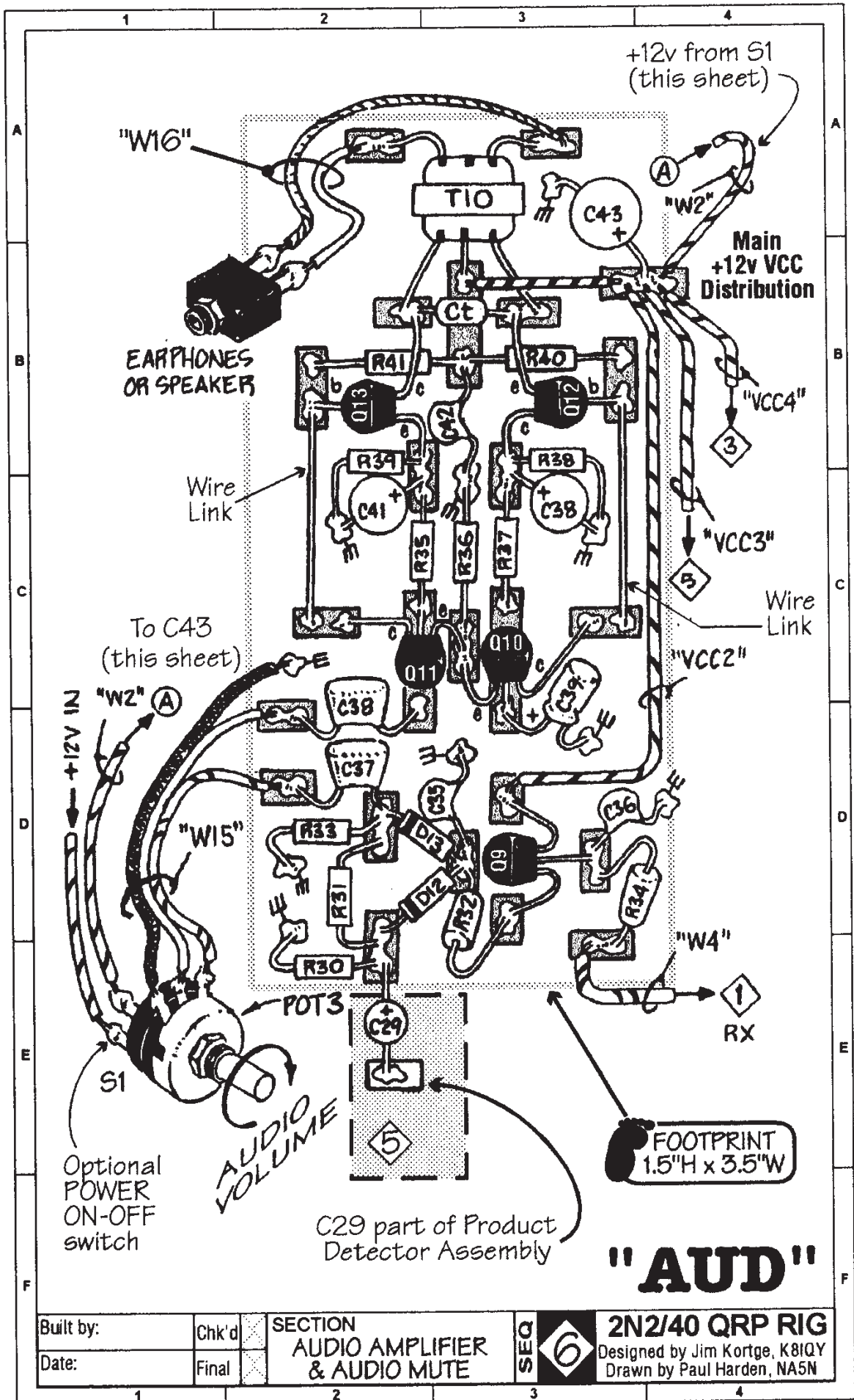
signal shown at 10 volts/division. The bottom trace is the output that is present on the wiper of the volume control potentiometer, POT3, at the full volume setting, shown at 10 millivolts/division. You can clearly see the effects of R31, the 47K resistor which "leaks" a bit of audio through during transmit so that we have keying sidetone. It should be apparent from this example what a marvelous tool modeling is, and the help it can be for checking out ideas, studying circuits, etc. without having to build anything physical.



Finally, getting back to the actual 2N2/40 ... the audio amplifier rounds out the receive chain.

The Push-Pull Audio Amplifier is another circuit of my design. Incoming audio is applied to the base of transistor Q11. As can be seen, Q11 shares a common emitter resistor, R36, with Q10. Q10's base is grounded for audio purposes, so it becomes yet another common base amplifier, being driven in its emitter from

the signal provided by Q11. The collector signals on Q11 and Q10 are of equal amplitude and 180 degrees out of phase with each other. These signals are then directly coupled to the bases of Q13 and Q12, where they are further amplified. Transformer T10 couples the push-pull signals from the collectors to the speaker. Note that the biasing of the input pair of transistors is derived from the emitters of the output pair. The large capacitors on the output



"AUD"

| | | | | |
|-----------|-------|--|-------------|---|
| Built by: | Chk'd | SECTION AUDIO AMPLIFIER & AUDIO MUTE | DESIGN 6 | 2N2/40 QRP RIG Designed by Jim Kortge, K8IQY Drawn by Paul Harden, NASN |
| Date: | Final | | | |

The large capacitors on the output pair emitters bypass all audio. Capacitor Ct is chosen to resonate the primary inductance of T10 at 750 Hz, thereby providing additional CW signal selectivity. In the prototype rig, this capacitor is 0.082uF. While I haven't measured the power output of this amplifier, it is more than enough to drive a speaker to uncomfortable levels at full volume. It also has very low internal noise.

Assembly.

This layout is a bit more open than the others, since the size of T10 could vary depending on the part source. Circuitry should be built from T10 down. Nothing is very critical here, since we're now dealing with audio, and it's a bit easier to control. When you get to the audio amplifier, note that the leads of base bias resistors R35 and R37 need to pass under their respective transistor bodies, Q10

and Q11 (that is, Q10-Q11 sit on top of R35 and R37, or closer together than they appear on the SEQ#6 assembly dwg.) This is also true for resistors R40 and R41. I'd recommend that all of these resistors be soldered in first, before adding the other components. Before testing, you should wire in POT3, so you have a volume control. **At this point, you now have a complete receiver.**

Testing.

The only test to perform at this juncture is to see if it works in its entirety. Connect an antenna to the Port A pad, and a speaker on the T10 secondary pads, and apply fused power. If you've done the building correctly, and have passed the previous tests, you should have a 2N2/40 receiver that is working, maybe even hearing signals, but as yet, not aligned. Here is how to do the alignment.

2N2/40 on the Test Bench -- Receiver Alignment

Receiver Alignment -

✓ Set trimmer potentiometer TC5 to its maximum capacity position by either listening to the receiver local oscillator on another receiver tuned to approximately 4.914 MHz, or by measuring the output frequency of the local oscillator by attaching a probe to the ungrounded end of L3 and adjusting TC5 for the lowest frequency obtainable.

✓ Tune the receiver to a signal, or if possible, generate a signal about mid-band, around 7.050 MHz. Tune across this signal by rotating tuning potentiometer POT2. Notice that as the tuning potentiometer is rotated clockwise, the audio pitch of the signal goes lower.

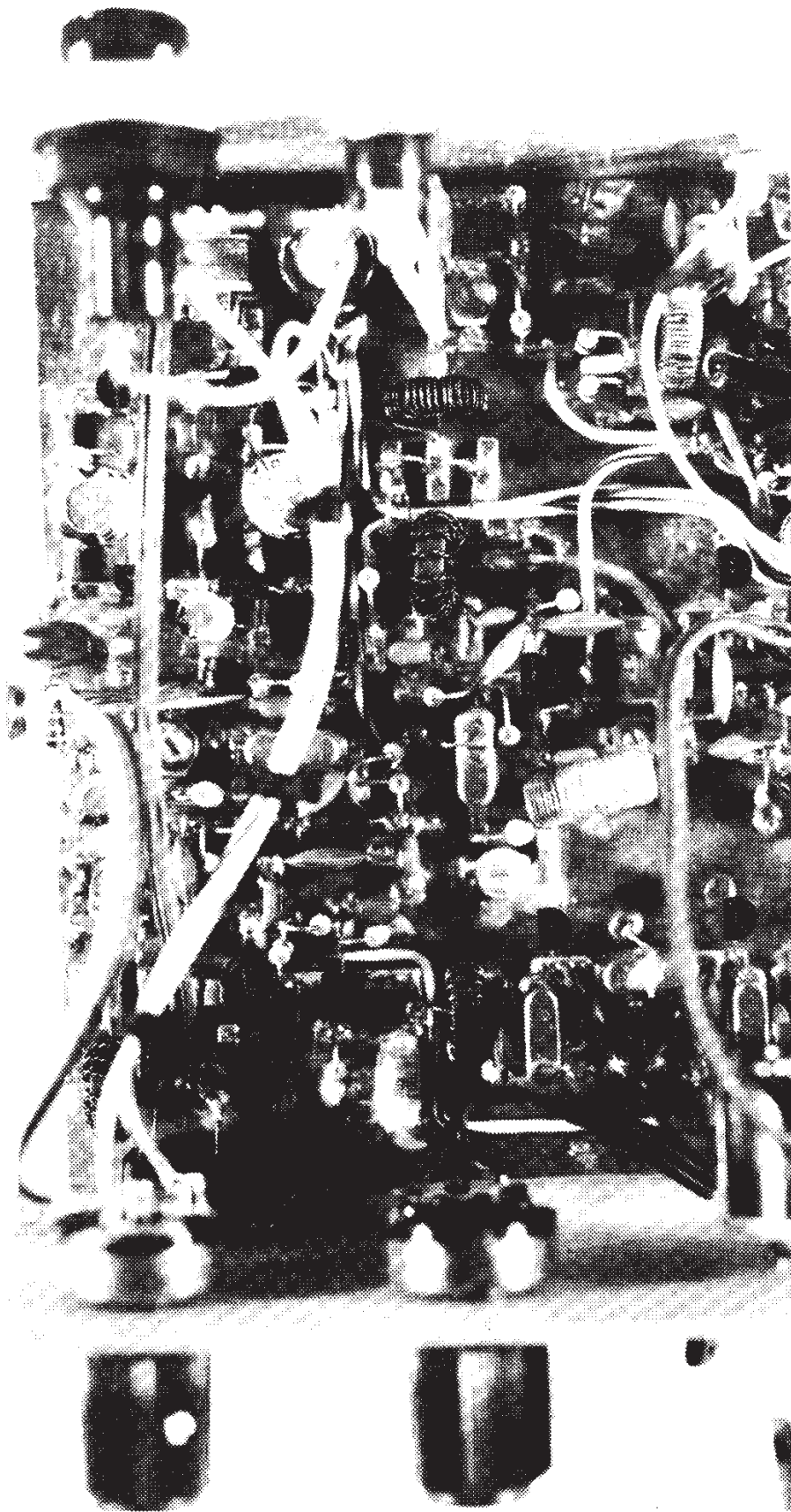
✓ Listen for a peak in audio response as the signal is tuned. We want this peak to occur at about 750 Hz. With TC5 set for maximum capacity, the peak is probably upwards of 1500 Hz. Slowly rotate TC5 to a lower capacity setting. Go

a little at a time, and retune the receiver, listening for the audio peak. You will hear it progressively moving to a lower pitch.

✓ Repeat the adjustment of TC5 and retuning the receiver until the pitch is where you like to listen to CW, and is the loudest you can make it. That's it.....the receiver is aligned.

What this does is place the receiver local oscillator frequency about 750 Hz below the center of the crystal filter passband. Remember, the crystal filter is being used as an upper sideband filter. To confirm that everything is working as it should, find a SSB station and see if you can tune in the audio so that it is intelligible. If you've done the alignment correctly, you should not be able to properly tune in the signal, since the station is operating on lower sideband, and the receiver is listening to the upper sideband.

- K8IQY



You're now completed with the 2N2/40 receiver portion. Next, we'll build the transmitter stages. Your receiver should look something like this. This is a photo of the the RXLO, Product Detector and Audio stages of Jim's first 2N2/40 rig, which differs only slightly from his 2nd version that this construction article is based.

6. Circuit & Construction Details - Transmitter

7 TX Local Oscillator, Mixer & Amplifier

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 3 | SEQ. #7 |

Circuit Description.

The Tx Local Oscillator, Single Balanced Mixer, and Cascode RF Amplifier - These elements make up the first section of the transmit strip.

TX Local Oscillator. The transmitter begins with another crystal oscillator, Q14 and associated circuitry, used to generate a CW signal at 4.915 MHz. This circuit is virtually a duplicate of the receiver local oscillator. Output signal is taken from the emitter through a 47pF capacitor, C46.

TX Mixer. The TX LO signal is fed to a diode, single balanced mixer (SBM) along with a signal from the VFO, which is applied to the SBM through capacitor C48. The SBM consists of a trifilar wound transformer T11, along with four 1N4148 diodes, D14 through D17. Details for winding the trifilar transformer, T11, is shown on the SEQ#7 assembly drawing. As with the receiver DBM, the diodes should be matched for forward resistance. The sum of the Tx LO signal and VFO signal produce an output at 7 MHz that is used in the transmit strip. The difference frequency, along with the original mixer signals and higher order mixer products, are filtered out by the tuned input and output circuits of the next stage, a cascode RF amplifier.

The TX Cascode RF Amplifier uses a conventional grounded emitter stage, Q15, direct coupled to a grounded base stage, Q16. Total power gain for this transistor

pair is on the order of 40 dB. The input is a link-coupled, tuned circuit comprised of T12 and capacitors C49, C50, and trimmer TC7. A tuned output is employed using another link-coupled transformer, T13 and capacitor C52 and trimmer TC8. Output from this stage is taken from the 5-turn secondary link, and feeds the power control potentiometer, POT4. As a point of reference, the 26-turn windings on T12 and T13 should measure at 3.0uH. Maximum power output from this stage is about 10 milliwatts, or 0 dBm. However, with the 2N2/40 running at 1.5 watts output, this stage only needs to feed the driver with 0.2 milliwatts, or -6 dBm.

Assembly.

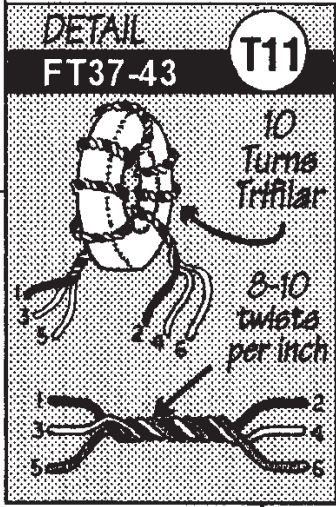
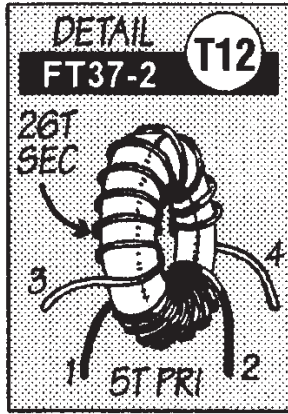
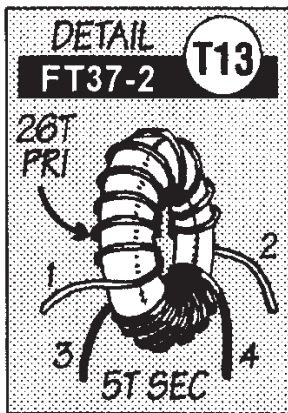
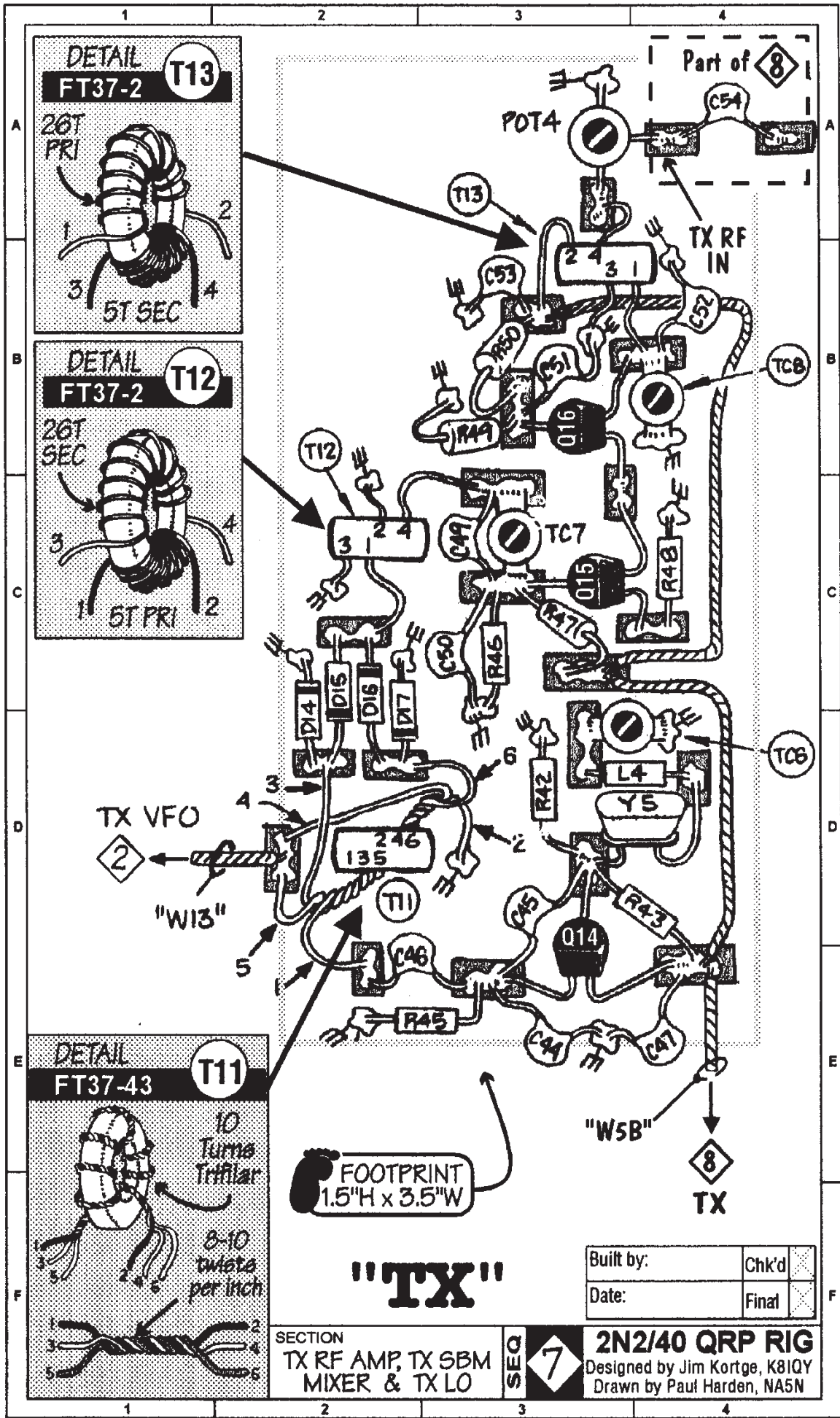
I'd recommend starting with the single balanced mixer and then follow that with the local oscillator. These two sections could almost be done together, since they are adjacent to each other, and tightly integrated.

When the local oscillator and single balanced mixer have been completed, build the cascode RF amplifier. Items that are critical here are the placement of the input and output transformers. They should be as far apart as you can get them, and ideally, at right angles to each other. They're not shown in that orientation on the layout for clarity, and will also work fine as shown.

Testing.

Once all of the elements are completed, they can be tested following this procedure.

The Tx local oscillator can be tested by itself by applying power to the Tx lead, and listening for a signal at 4.915 MHz on a general coverage communications receiver. You can also attach a frequency counter probe to the mixer side of



FOOTPRINT
1.5" H x 3.5" W

"TX"

| | |
|-----------|-------|
| Built by: | Chk'd |
| Date: | Final |

SECTION
TX RF AMP, TX SBM
MIXER & TX LO

7

2N2/40 QRP RIG
Designed by Jim Kortge, K8IQY
Drawn by Paul Harden, NA5N

capacitor C46 to verify that the circuit is oscillating at the correct frequency.

Once all of the elements are complete, they can be tested following this procedure. Connect a short test lead or your counter probe to the wiper pad of POT4 and adjust POT4 to maximum by turning the screwdriver adjustment to the full CW position. Apply power to the receiver in the normal manner. Apply power to the pads labeled Tx through a 1N4004 or equivalent diode, to

simulate the approximate voltage level that will be present when the Rx/Tx switch is active. Listen for a signal at 7 MHz on a receiver. Verify that the signal changes frequency when the VFO is tuned. With the VFO set to a frequency of 2.135 MHz, its mid-frequency, adjust trimmers TC7 and TC8 for maximum signal. Go back and forth between these two a few times as there is some interaction. When you are done with this test, we are ready to build the other half of the transmit strip.

8 Transmit RF Driver, Power Amplifier & Output Filter

| | |
|-----------|---------------|
| Schematic | Assembly Dwg. |
| Sht. 3 | SEQ. #8 |

Circuit Description.

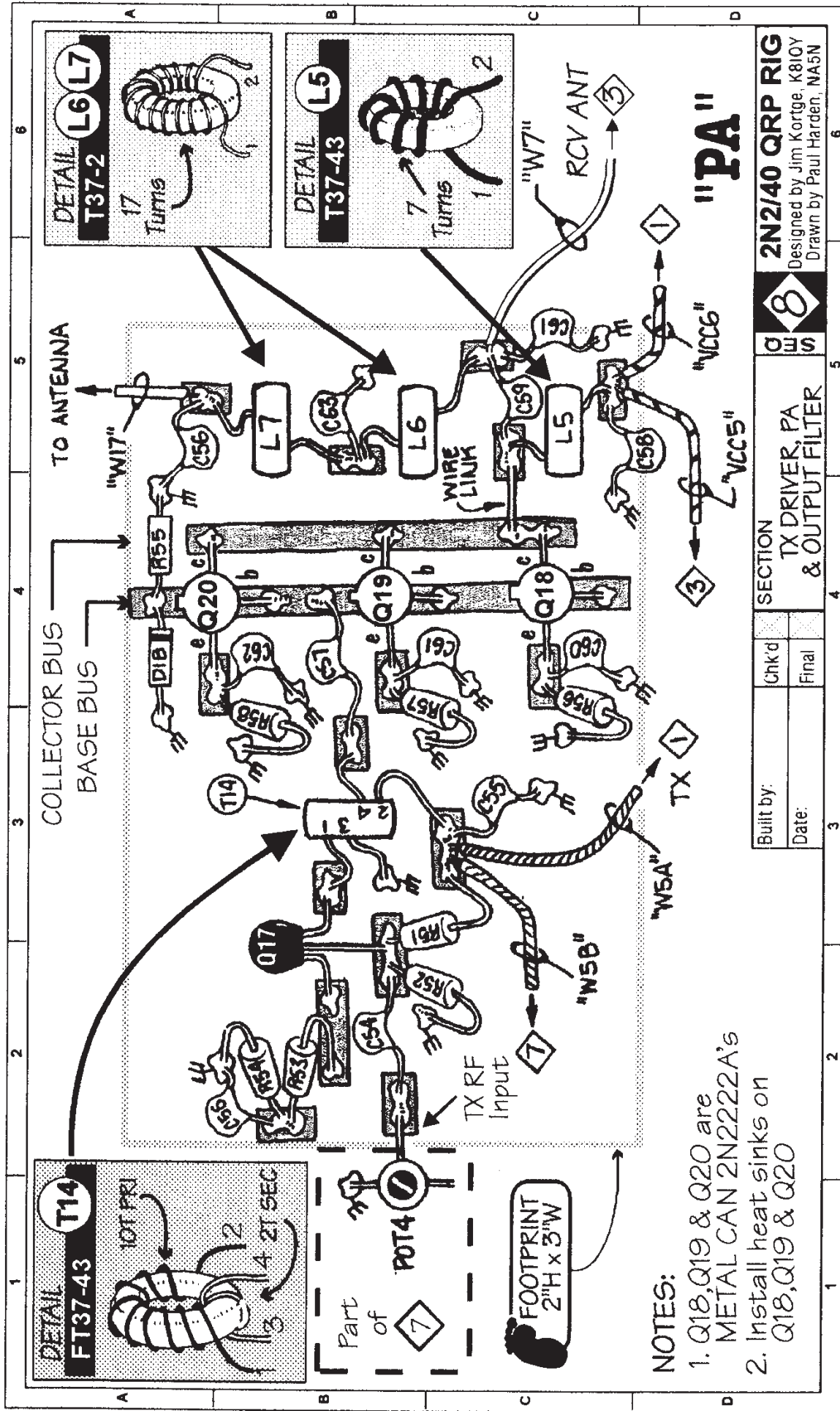
The Tx RF driver consists of Q17 and associated circuitry. Q17 is the first of the 2N2222A metal transistors used in the rig. A heat sink can be used on this transistor to manage the power being dissipated, but is not necessary. This stage is an untuned, class A amplifier, which produces the drive necessary for the final. Its output is via a 2-turn link on transformer T14. This transformer translates the higher collector load impedance down to the lower input impedance of the three parallel 2N2222A metal output transistors. Power output from this stage is about 10 milliwatts, or +10 dBm, with -6 dBm of drive from the previous stage.

The Power Amplifier (PA). The output from the TX driver is fed through capacitor C57 and on to the input circuitry of the final. This circuitry is a 1N4148 diode, D18, in parallel with R55, a 100 ohm resistor. Capacitor C57 charges minus to plus on the negative excursion of the drive

signal. On positive going excursions, the voltage on C57 is added to the positive signal, thereby doubling the effective positive level, and providing more drive to the final transistors. This circuit is often referred to as a "dc restorer".

The final transistors, Q18, Q19, and Q20, are also 2N2222A metal case types and *should be run with heat sinks*. This amplifier stage runs in class C, and measured efficiency is around 70 percent. Each transistor uses a bypassed 2.2 ohm resistor in its emitter to help keep the collector currents balanced, without having to gain match the 3 devices. Three transistors were used in the final because that's how many were left after building all of the rest of the rig (in keeping with the original rules of 22 maximum transistors).

I had expected to get about 1 watt output from the three 2N2222A's, and was pleasantly surprised to find that one can easily get 2 to 2.5 watts of output without excessive heating. I originally ran about 1.5 watts of output power without the heat sinks, but added them later, just to be on the safe side. The output impedance is about 50 ohms if the calculations are done with a Vcc of 12.5 volts and a power output of 1.5 watts, i.e. $V_{cc}^{2/2} \cdot P_o$.



The Output Filter. The output power from the PA leads us to the output filter. This is a very standard, 5 pole, Chebyshev low pass filter taken out of table 11, page 2-44, of the 1988 ARRL handbook. It is filter number 86, using standard E24 capacitor values. The capacitors for this filter should be C61 and C65 at 430pF and C63 at 820pF. However, capacitor C61 is reduced to 360pF to compensate for the output capacitance of the 2N2222 finals, and the Rx T/R switch capacitance, that of TC9 (located on SEQ#1). These two sources add a total capacitance of 70pF in parallel with C61. All output capacitors should be silver mica units. Inductors, L6 and L7, should measure 1.6uH. Mine have fewer turns than the formula predicts, but measure at that value, using an AADE L/C Meter IIB. By the way, if you don't have one of these meters, get one! It is one of the best investments you will ever make in an inexpensive, very accurate, component test instrument.

Assembly.

The TX driver, PA and output filter is built on the last section remaining on the substrate board, as shown on assembly drawing SEQ#8. Note that the collectors and bases of PA transistors Q18, Q19 and Q20, are connected

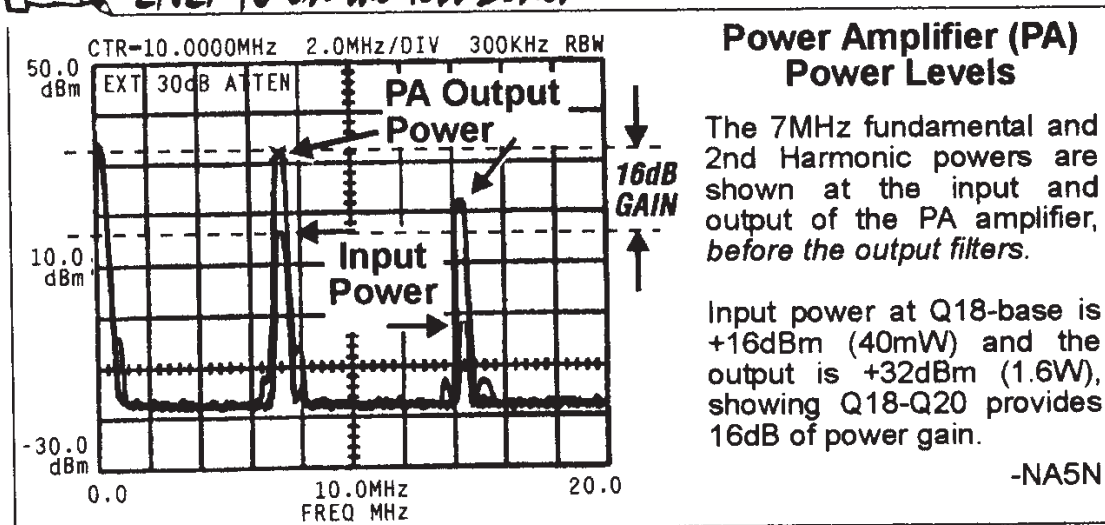
together in parallel by making two strips of copper clad to make two long pads. If you have difficulty making these long strips, an alternative would be to solder a buss wire (#20 solid or so) between two pads, ensuring they do not make contact with the ground board. Also ensure you allow sufficient clearance around the PA metal 2N2222A's for the heatsinks to be added.

Your 2N2/40 rig is now virtually complete. Ensure all wiring interconnecting the sections, such as the RX and TX terms, and all Vcc wiring is installed.

Testing.

You should add all external components (if you haven't already) with leads long enough for mounting in an enclosure. You can run it on the bench "as is." I did this with mine and had a blast making contacts with it sitting "nude" on the benchtop. To me, there is a certain fascination and beauty with having an operating rig on the bench, uncased, so that you can see all of the components, while watching the output power meter swing up as you key it in QSO. One can almost imagine all of the electrons moving here and there, doing their part to allow reception, or generating RF to be radiated.

Hand icon **2N2/40 on the Test Bench**



2N2/40 on the Test Bench -- Transmitter Alignment

Transmitter Alignment.

Before aligning the transmitter, be sure the rig is connected to a dummy load, since we will be keying it and generating r.f.

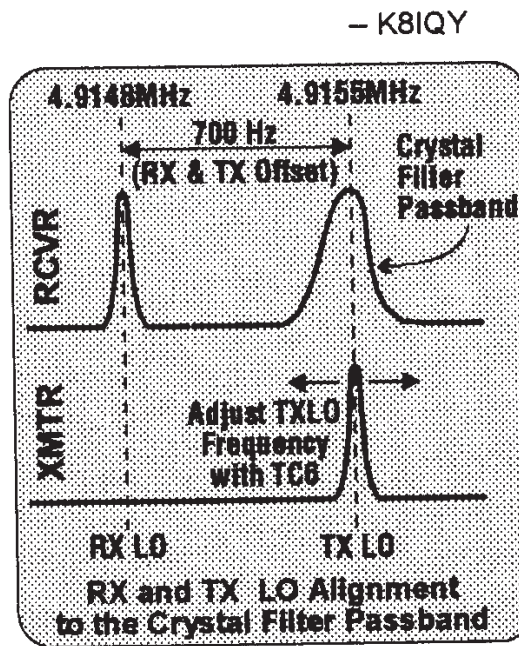
✓ Setting the transmitter local oscillator trimmer, TC6, to the minimum capacity position. Use the same method we used with the receiver to determine where this is. With TC6 at minimum capacity, the transmitted signal will be far above the center of the crystal filter. Our goal is to slowly move the transmit frequency down until it is in the center of the receive passband. When that happens, we will hear it at the same pitch as we hear a properly tuned CW station.

! Do not keep the transmitter on the air continuously for longer than 20 seconds while making these adjustments. If you have a keyer, let it send a series of dits.

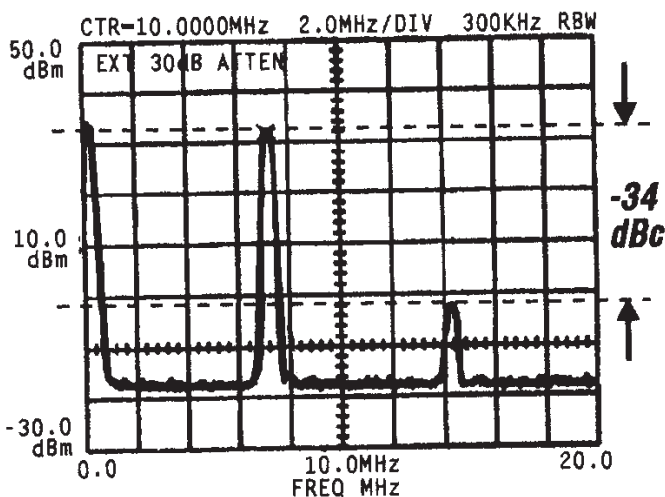
✓ With the transmitter keyed, slowly turn trimmer TC6. As you do, you will eventually hear the transmit signal at a very high pitch as it enters the crystal filter passband from the higher frequency end. Keep turning until the pitch of the note heard is the same as a properly tuned CW station. When

they are nominally the same, stop adjusting TC6.

✓ Once you're on the air with the rig, you can trim up the setting of TC6 so that the receiver and transmitter are "dead on". The station you are listening to and your transmitted signal will be heard at the exact same pitch. Shown below is a diagram of a properly aligned rig, showing example Rx and Tx local oscillator frequencies and their relationship to each other and the crystal filter passband.



2N2/40 on the Test Bench



The 2N2/40 Output Spectrum

The 7MHz fundamental and 2nd Harmonic power after the output filters (at the antenna terminal) are shown here. Compare with the spectrum on page 38 and notice how the second harmonic (14MHz) has been attenuated to 34dBc (34dB below the carrier) for FCC compliance. This is due to low-pass filters L6-L7 and C61-C65.

-NA5N

7. Bill of Materials (BOM)

K8IQY 2N2/40 Parts List (Ver. 2.1) - Sheet 1 of 2

| ITEM | QTY | REF. DESIG./DESCRIPTION | VALUE | MFR/PART NO. | ✓ |
|------|-----|----------------------------------|----------------------|--------------|---|
| 1 | 3 | R56, R57, R58 | 2.2Ω | | |
| 2 | 1 | R53 | 10Ω | | |
| 3 | 1 | R65 | 12Ω | | |
| 4 | 1 | R15 | 27Ω | | |
| 5 | 1 | R24 | 33Ω | | |
| 6 | 1 | R65 | 47Ω | | |
| 7 | 2 | R4, R54 | 82Ω | | |
| 8 | 2 | R48, R55 | 100Ω | | |
| 9 | 1 | R28 | 150Ω | | |
| 10 | 1 | R17 | 270Ω | | |
| 11 | 2 | R44, R64 | 330Ω | | |
| 12 | 1 | R13 | 390Ω | | |
| 13 | 4 | R3, R36, R38, R39 | 470Ω | | |
| 14 | 2 | R5, R29 | 560Ω | | |
| 15 | 1 | R23 | 680Ω | | |
| 16 | 6 | R1, R9, R12, R22, R25, R45 | 1.0K | | |
| 17 | 1 | R52 | 1.5K | | |
| 18 | 2 | R2, R46 | 2.2K | | |
| 19 | 2 | R40, R41 | 2.4K | | |
| 20 | 2 | R59, R61 | 2.7K | | |
| 21 | 4 | R14, R20, R30, R33 | 3.3K | | |
| 22 | 1 | R62 | 4.7K | | |
| 23 | 1 | R8 | 5.6K | | |
| 24 | 1 | R51 | 6.8K | | |
| 25 | 7 | R7, R10, R26, R42, R47, R49, R50 | 10K | | |
| 26 | 4 | R27, R34, R43, R6 | 15K | | |
| 27 | 1 | R32 | 27K | | |
| 28 | 2 | R35, R37 | 39K | | |
| 29 | 4 | R6, R16, R21, R31 | 47K | | |
| 30 | 3 | R18, R19, R60 | 100K | | |
| 31 | 1 | R11 | 220K | | |
| 32 | 1 | POT4 (Trim Pot) | 100Ω | | |
| 33 | 1 | POT5 | 1.0K | | |
| 34 | 1 | POT1 | 10K | | |
| 35 | 1 | POT3 (Includes switch SW1) | 10K | | |
| 36 | 1 | POT2 (10 Turn) | 20K | | |
| 37 | 1 | C2 | NPO 3pF | | |
| 38 | 3 | C11, C46, or TC9 Alternate | NPO 47pF | | |
| 39 | 6 | C1, C3, C20, C21, C31, C45 | NPO 100pF | | |
| 40 | 2 | C10, C52 | NPO 120pF | | |
| 41 | 2 | C17, C22 | NPO 150pF | | |
| 42 | 2 | C32, C44 | NPO 180pF | | |
| 43 | 2 | C12B, C34 | NPO 220pF | | |
| 44 | 1 | C50 | NPO 270pF | | |
| 45 | 1 | C12a | Polystyrene 330pF | | |
| 46 | 1 | C15 | NPO 330pF | | |
| 47 | 1 | C61 | Silver Mica 360pF | | |
| 48 | 1 | C49 | NPO 390pF | | |

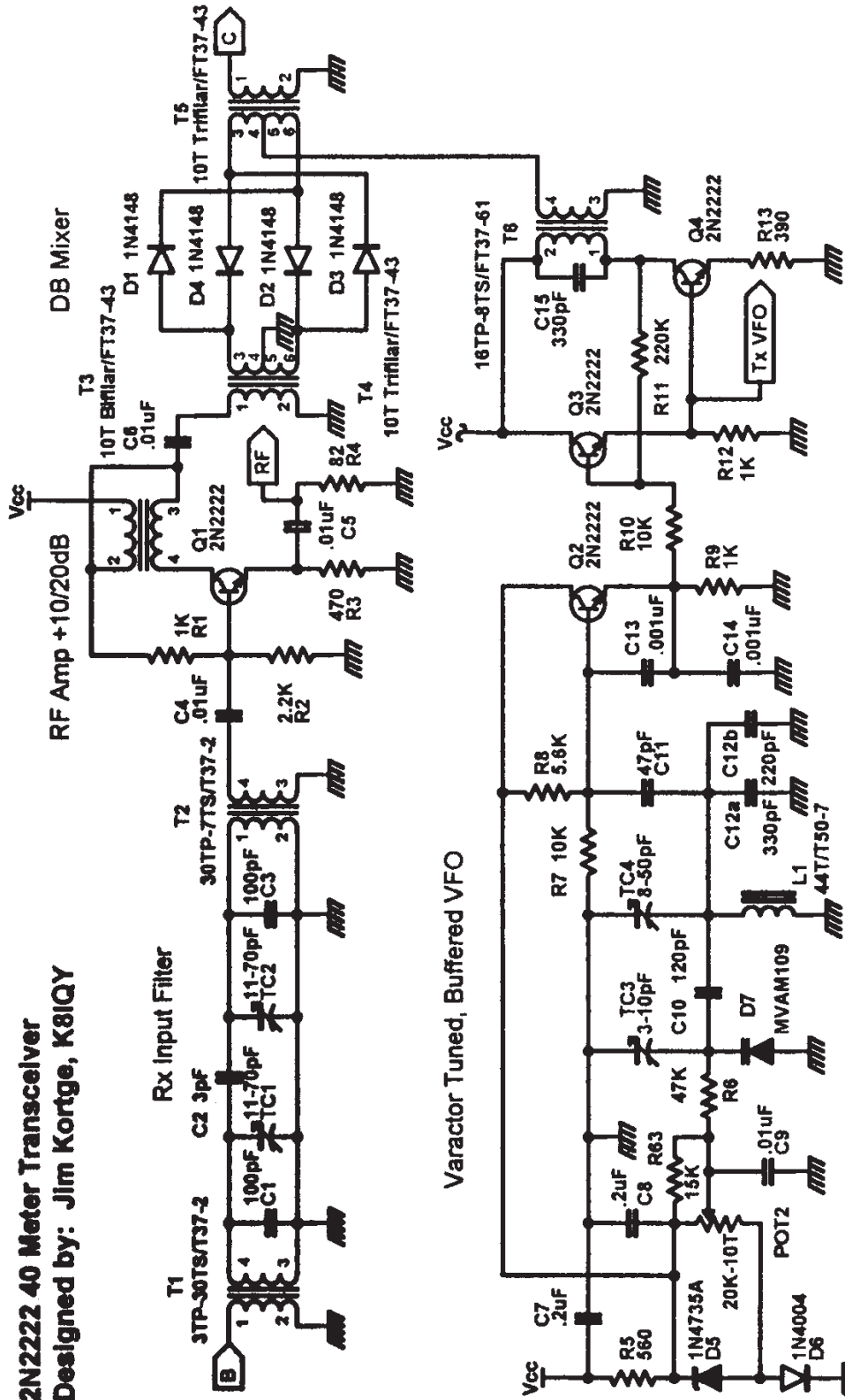
K8IQY 2N2/40 Parts List (Ver. 2.1) - Sheet 2 of 2

| ITEM | QTY | REF. DESIG./DESCRIPTION | VALUE | MFR/PART NO. | ✓ |
|------|-----|--|-------------------------|--------------|---|
| 49 | 1 | C65 Silver Mica | 430pF | | |
| 50 | 1 | C24 NPO | 820pF | | |
| 51 | 1 | C63 Silver Mica | 820pF | | |
| 52 | 2 | C13,C14 5% Polyester | | | |
| 53 | 1 | C48 | .001uF | | |
| 54 | 11 | C4,C5,C6,C9,C26,C33, C47,C51,C53-C55,C68 | .01uF | | |
| 55 | 2 | C37,C38 | .047uF | | |
| 56 | 1 | Ct (Select to tune primary @ 750 Hz) | .082uF | | |
| 57 | 2 | C27,C28 | .1uF | | |
| 58 | 18 | C7,C8,C16,C18,C19,C23 C25,C30,C35,C36,C42, C56-C60,C62,C64,C66 | .2uF | | |
| 59 | 2 | C29,C39,C67 | 4.7uF | | |
| 60 | 3 | C40,C41,C43 | 470uF | | |
| 61 | 1 | TC3 Trim Cap-optional | 3-10pF | | |
| 62 | 1 | TC4 Trim Cap | 8-50pF | | |
| 63 | 6 | TC1,TC2,TC5-TC8 | 11-70pF | | |
| 64 | 2 | L2,L4 (Molded) | 39uH | | |
| 65 | 1 | L3 (Molded) | 4.7uH | | |
| 66 | 1 | L8 (Molded) | 12uH | | |
| 67 | 6 | L6,L7,T1,T2,T12,T13, T37-2 | | | |
| 68 | 1 | T6 | FT37-61 | | |
| 69 | 1 | L1 | T50-7 | | |
| 70 | 9 | L5,T3,T4,T5,T7,T8,T9 T11,T14 | FT37-43 | | |
| 71 | 1 | T10 Audio Transformer 1200Ω CT:8Ω CT | | | |
| 72 | 15 | D1,D2,D3,D4,D10,D11, D12,D13,D14,D15,D16, D17,D18,D19,D20 | 1N914B or 1N4148B | | |
| 73 | 1 | D5 6.2 volt Zener | 1N4735A | | |
| 74 | 1 | D6 Rectifier diode | 1N4001 | | |
| 75 | 1 | D21 15 volt Zener | 1N4744A | | |
| 76 | 1 | D7 Varicap | MVAM109 | | |
| 77 | 2 | D8,D9 Varicap | MV2115 | | |
| 78 | 5 | Y1 thru Y5 (Match Y1-Y3 within 25 Hz) | 4.915 MHz | | |
| 79 | 18 | Q1-Q16,Q21,Q22 TO-39 | 2N2222A | Plastic | |
| 80 | 4 | Q17 thru Q20 TO-18 | 2N2222A | Metal | |
| 81 | 1 | LS1 8-ohm Speaker | | | |
| 82 | 1 | F1 Fuse | 3AG 3A | | |
| 83 | 4 | HS1 TO-18 Heatsink | | | |
| 84 | 1 | PC1 Power Connector | | | |
| 85 | 1 | J1 Stereo Jack | 3.5mm | | |
| 86 | 1 | J2 Mono Jack | 3.5mm | | |
| 87 | 1 | J3 Antenna Connector | BNC | | |
| 88 | 1 | FH1 Fuse Holder | | | |
| 89 | 1 | SW2 Toggle Switch | SPST | | |

MFR/Part No. - Use to record exact manufacturer part number, or ordering part number/stock number from Mouser, DigiKey, Radio Shack, etc.

✓ - Use to indicate part on-hand, on-order, received, installed, etc.

2N2222 40 Meter Transceiver
 Designed by: Jim Kortge, K8IQY



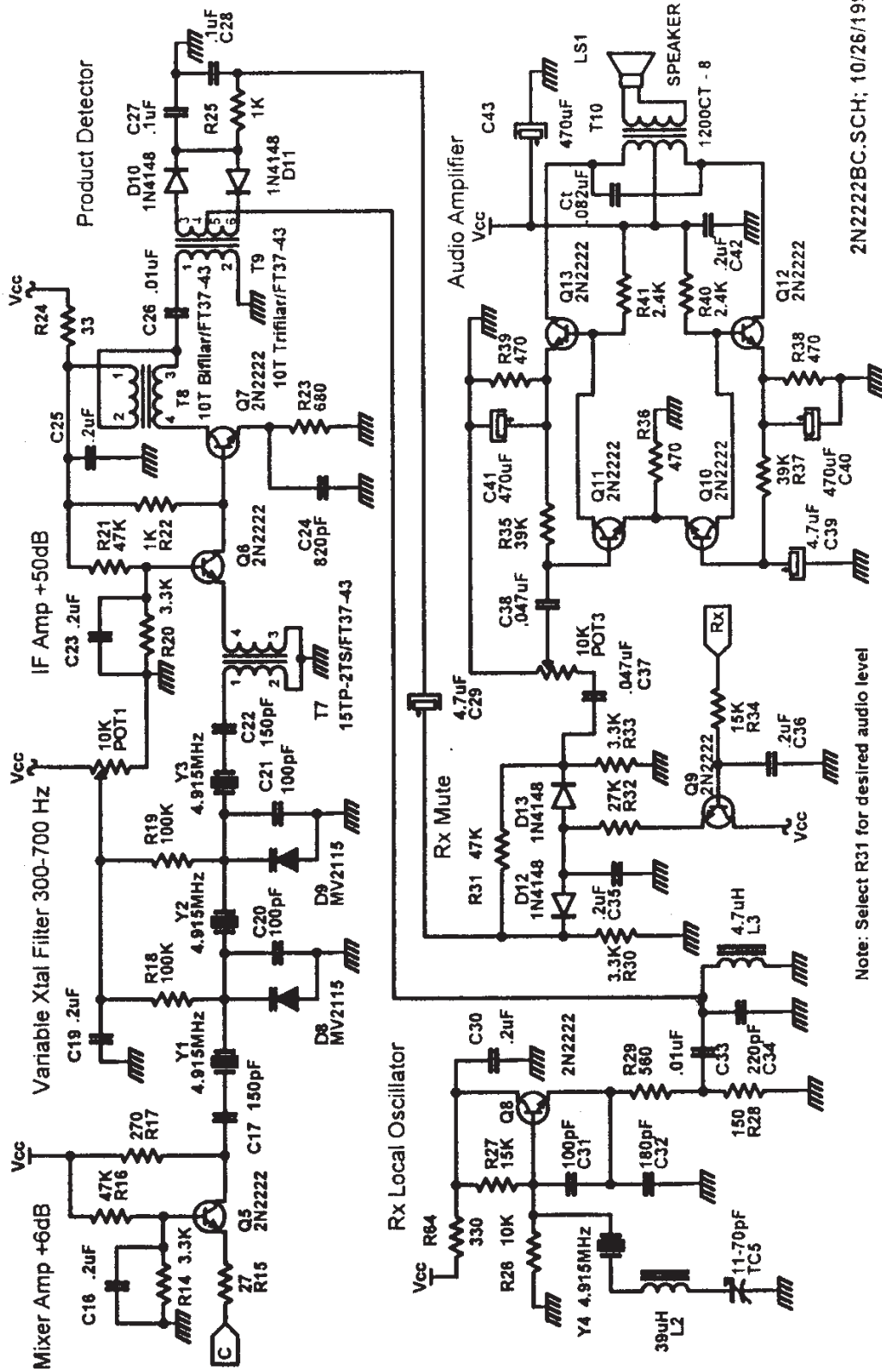
Note: Select C15 from 270-390pF for max output

Note: TC3 is optional
 C10 & C11 are NPO
 C12a is polystyrene; C12b is NPO
 C13 & C14 are 5% polyester

SHEET 1

2N2/40 QRP RIG
 SCHEMATIC DIAGRAM
 SHEET 1 of 4

Designed by
 Jim Kortge, K8IQY



2N2222BC.SCH; 10/26/1998

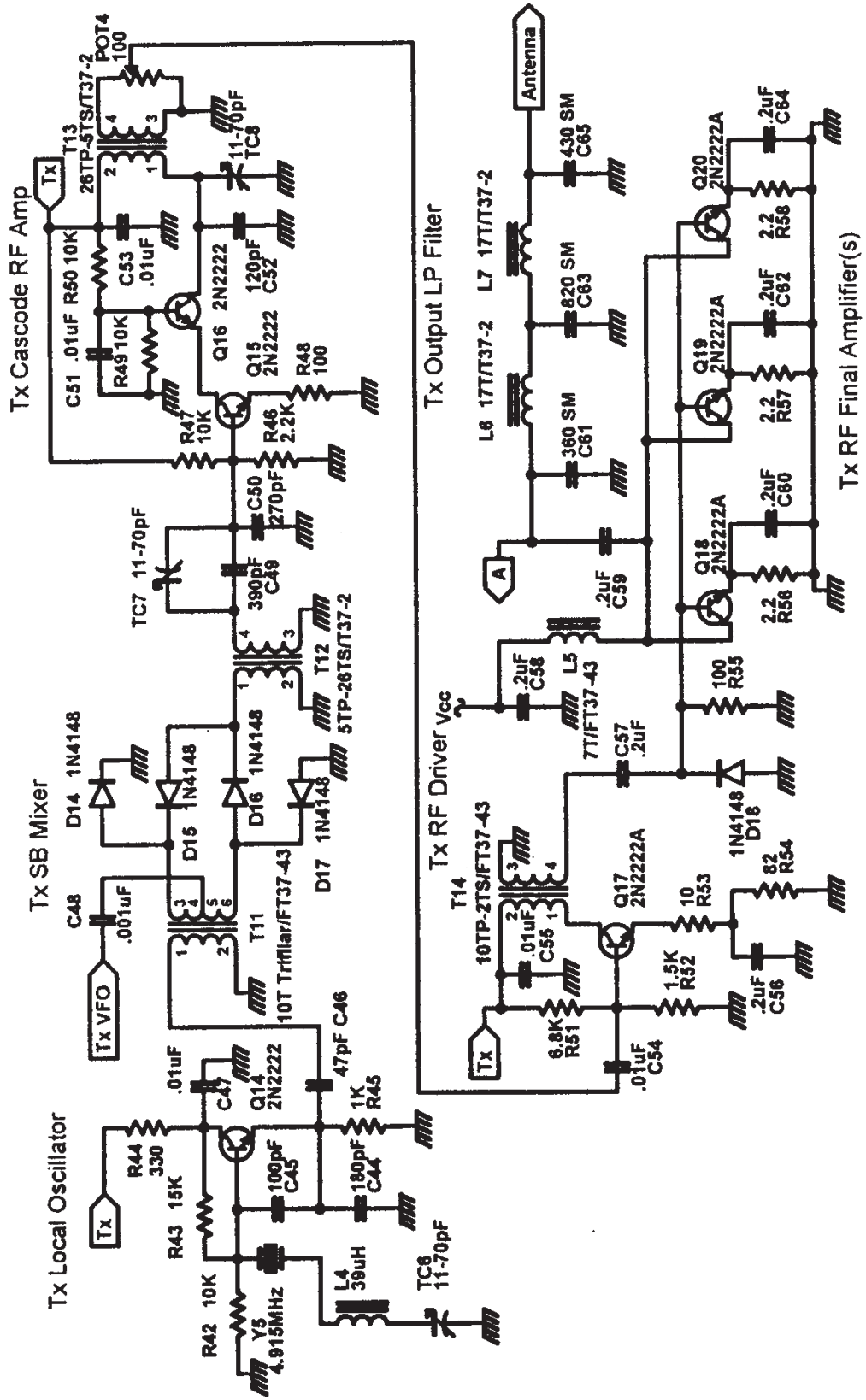
Note: Select R31 for desired audio level

Designed by
Jim Kortge, K8IQY

SCHEMATIC DIAGRAM
SHEET 2 of 4

2N2/40 QRP RIG

SHEET 2



Designed by
Jim Kortge, K8IQY

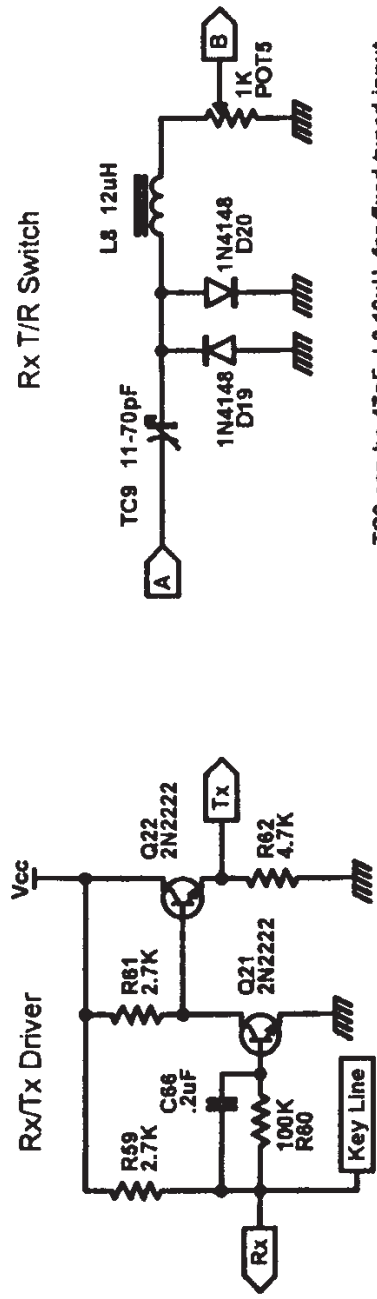
SCHEMATIC DIAGRAM
SHEET 3 of 4

2N2/40 QRP RIG

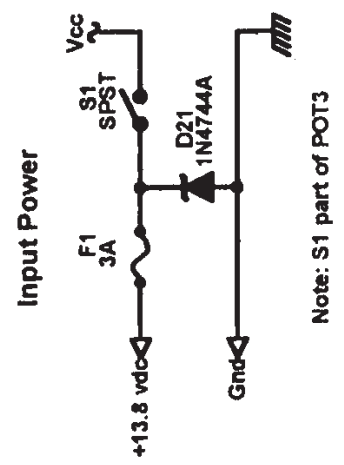
SHEET 3

Note: 2N2222A is TO18 case version

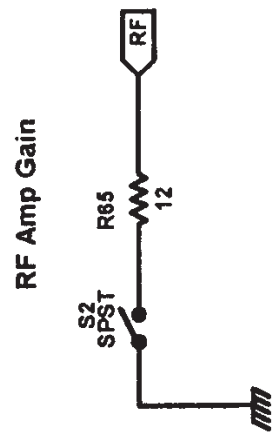
2N2222 40 Meter Transceiver
 Designed by: Jim Kortge, K8IQY



TC9 can be 47pF, L8 10uH, for fixed tuned input



Note: S1 part of POT3



9. Miscellaneous Assembly Notes

This section will cover everything else that didn't fit under one of the previous categories. There are some general information items that are worth mentioning, which might make building a 2N2/40 a bit more successful.

Interconnecting Wiring. If you look at the overall layout of the sections (see Interconnecting Wiring Diagram on page 14), it is apparent that there really are not very many wiring runs required. Standard hookup wire (and two short coax runs) are used throughout the 2N2/40.

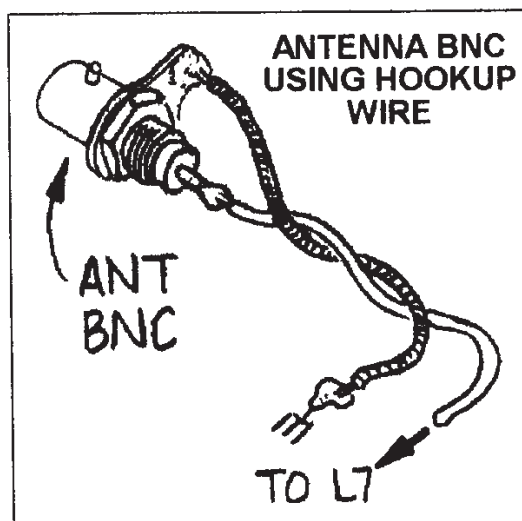
Wiring. I used 22 gauge (AWG 22) stranded, Teflon coated hookup wire for this task. The Teflon wire is really nice because you can't melt the coating with normal soldering iron temperatures. This makes for better looking wiring, I think. Routing the wires between pads is more of following logic than anything else. I tried to add the "Vcc" wiring as the sections were built, so that it could be routed against the surface of the substrate. In some cases, it passes underneath the leg of a resistor or capacitor as an aid in keeping it tight to the surface (for example, see SEQ#5). The "Tx" and "signal" wiring was done in a similar manner. All external wiring to controls and connectors also use the AWG 22 hookup wire for the flexibility. Solid wire is not recommended for external wiring.

Coaxial Cable. The only two places that shielded signal wire was used were from the VFO to the Tx SBM ("W13" between SEQ#2 and #7) and from the i.f. amplifier to product detector transformer T9 ("W10" between SEQ#3 and #4). In these cases, a short length of RG-174 was prepared, with the shield grounded only at the VFO or i.f. amplifier end. The shield at the mixer and product detector ends were cut off,

and the outside jacket pulled over the shield so that it could not make contact with the substrate surface. Doing the installation this way prevents having the shield grounded in two locations, which could cause a ground loop to exist.

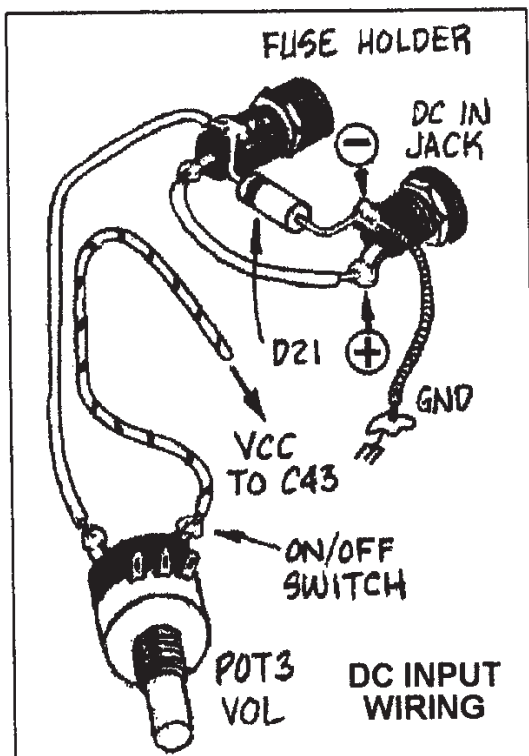
External Wiring. External wiring should also use *stranded* hookup wire for flexibility. Wiring to the potentiometers was done with flat, multiconductor cable, my favorite way to connect controls. If you haven't used this method, I encourage you to try it. You'll never go back to your old ways. You can buy 2 feet of 64 conductor, multi-colored cable from many of the electronics suppliers for a couple of bucks, and that's enough wire for many, many rigs.

Antenna Jack. The lead from the "Antenna" pad to the coaxial connector (See SEQ#8) was so short in the prototype rig that I didn't bother with coax. A pair of 22 gauge wires was twisted together and used to make the connection.



However, the lead serving as the "shield" was terminated on the sub-board holding the PA transistors and output LP filter, and the BNC connector ground terminal. The total length of this run is about 1.5 inches.

DC (+12V Vcc) Wiring to the power connector was also done with leads twisted together. The Zener diode, D21, is just wired between the fuse holder "hot" lead and its ground terminal. Switch S1 is part of the audio control pot, POT3. By all means, make sure that you put in the fuse and the Zener diode. They will prevent smoking the rig if the power is hooked up backward, or if a power supply with an output higher than the Zener voltage (15 volts) is connected.



Lacing. After all of the wiring was done, it was secured at a number of locations with old fashioned, waxed nylon lacing cord to keep the wires together. (HINT: use dental floss if you don't have lacing cord). Tie wraps can also be used. This is one of those cosmetic items, and has no effect at all on the performance of the rig.

Soldering. A good soldering iron is a must. Mine is a 25-watt, temperature controlled unit, with a 1/8 inch chisel point. For normal soldering, I keep the tip temperature at 320 degrees C. When I am soldering a lead to the substrate, I

raise the temperature to 350 degrees C, which gives a bit more heat capacity to melt and flow the solder. Two of the musts in doing this type of construction are to have some desoldering braid on hand and some pure rosin liquid flux. The soldering braid is used to wick up extra solder on a connection, or remove all of it, if a component gets installed incorrectly.

While all electronic grade solders contain flux, most have the minimum amount needed to properly "wet" a joint. A tiny amount of liquid flux can be brushed on a connection that appears to look overheated or "dry", and reheated to produce a superior solder joint.

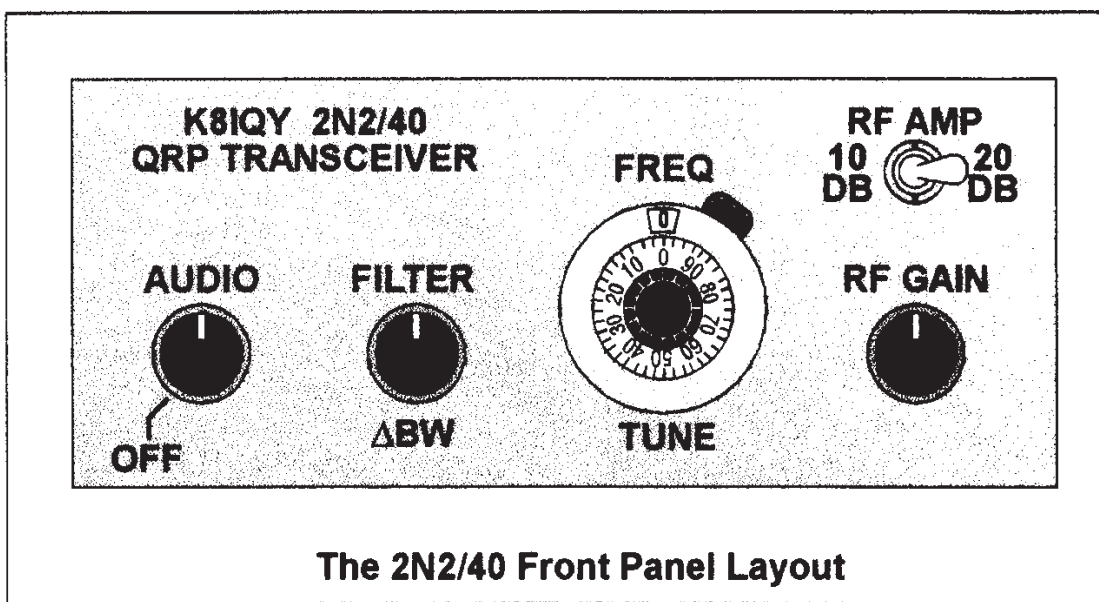
Toroids. Winding toroidal inductors and transformers is explained on pages 8 and 9, and of course the details on the assembly drawings. Most people wind toroids without the use of any tools. The job is much easier if you use a small crochet hook. Each turn is wound by reaching through the center of the core with the crochet hook, and pulling the wire through the hole as the hook is retracted. Winding the core this way keeps the windings tight to the surface, and is much faster.

Use 26 or 28 gauge wire for all of the conventional transformers, but make sure there is a 20 to 30 degree gap remaining after all the windings are on a core. Transformer T14, and inductors L5 through L7 can be wound with a heavier gauge; number 24 is a good choice. All of the bifilar and trifilar transformers were wound using about 300 degrees of the core circumference. I use three strands of number 28 gauge, and twist them together at 6 to 8 turns per linear inch with an electric drill motor. Make a long piece (3 feet) of 3 strand, and another shorter piece (2 feet) of 2 strand, and then cut suitable lengths for winding each transformer.

The Enclosure. No rig is complete until it is installed in a case. For the 2N2/40 prototype, "home" became the inside of a TenTec TP-42 aluminum case. The case was painted flat black on all surfaces except the front and rear panels. These were painted light gray. A front panel overlay was drawn using COREL Draw. This overlay image was then reversed, and printed using a laser printer on a piece of transparency film. After trimming to size, the overlay was attached to the front panel with the printing on the inside, to keep it from being rubbed off. The

control nuts from the various front panel controls hold it in place. If you build a 2N2/40 from this article, you will need to find a slightly larger case, as the TP-42 won't accommodate a 5X7 inch board. However, it appears a TenTec TP-46 or TP-47 case is the correct size case for the larger footprint. A custom case could also be built.

Front Panel. Here's what the front panel of the prototype rig looks like, which you can use for general control placement.



10. ACKNOWLEDGEMENTS

Here is my chance to publicly thank all of the people that have helped along the way. There have been many, and they have helped immensely. First off is one of my heroes, Wayne Burdick, N6KR. It was Wayne who had the insight to propose the contest, and was the driving force behind keeping it pure. Many thanks to Bob Berlyn, N1PWU at HB Electronics, and their generosity in supplying ready-made 2N2222 semiconductor packages, at absolutely bargain basement prices. Their components are the heart of my original 2N2/40, and the second unit built for this article. Then

comes Steve "Melt Solder" Weber, KD1JV. It was Steve who led the 2N2222 design charge, building the first working rig, and demonstrating to all of us that a viable design could be accomplished. Next comes Doug Hendricks, KI6DS, and his silent twin, Jim Cates, WA6GER. Without this "dynamic duo" there would be no NorCal, nor 2N2222 building contests, nor a long, admirable, legacy of great club kits. We are all indebted to these two fine gentlemen. Next on my heroes list is Paul Harden, NA5N. Paul was most helpful in putting the prototype through his "top 10 tests", to

verify that what I had observed qualitatively, was indeed based on quantitative performance measures. He alone is also responsible for all of the wonderful illustrations and pictures that are now a part of the 2N2/40 story. Without his help, this article would not have happened in the format you see it. And the last three that I'd like to thank are tall, skinny, Chuck Adams, K5FO, from big D, Preston Douglas, WJ2V, from the "big Apple", and another of my heroes, "Professor" Glen Leinweber, VE3DNL. It was Chuck (along with Doug H.) who provided much of the "push" to get the 2N2/40 project "out to the public", almost to the point of making me "go ballistic" with his timeline. He is a "let's do it" person. Preston Douglas' building a working 2N2/40 from an inaccurate set of schematics is almost an unbelievable feat. I had sent K5FO (and NA5N) an early set of schematics after Dayton, so he could see the general layout of the rig. While Preston was visiting Chuck, he also got a set. On his flight back to New York from Dallas, Preston decided that he was going to build the rig. To his credit, he did ask my permission and concurrence to proceed. Having him do that served two purposes: it gave me more confidence that the rig was reproducible, by hams who do not "bend wires or chase electrons" for a living; and we found one major and several minor, but none-the-less important, errors in the documentation. Kudos to Preston for his work. All but two of our communications took place via the internet, for those interested. And finally, Glen, VE3DNL for taking the time out of his busy fall schedule at the university to look over an early schematic and layout package. His observations always inspire me to "look out of the box" for unique solutions and better designs.

The very last person who needs to be thanked is here, all alone,

because of her importance to me. That is my dear wife, soul mate, and lifelong friend, Kathy, KB8IMP. She has put up with untold hundreds of hours of my being squirreled away in the ham shack, working on the rig's design, building them, operating them, and putting the documentation together. Through it all she has been most patient, understanding, and supportive. Among her many areas of expertise is written English, and she contributed to this project by being my primary proof reader, and resident advocate for "getting the project done".

Summary - I indeed hope that this article has inspired you to get the parts and dive into scratch building a 2N2/40, or another design that you have fancied, but never built, using "Manhattan Style" construction methods. It is really a whole lot easier than it might appear at first blush. From personal experience, I can tell you that nothing you will ever build as a kit will compare to the satisfaction realized with doing a complete rig from scratch. If the dimensions of the layouts I provided look still look too small, build it on an even larger platform, maybe 6 X 8 inches, or even 7 X 9 inches. Or you could split it up into sections and build it that way, with the receiver on one board, the transmitter on another, and the VFO and Tx/Rx driver on a third, all appropriately wired together. I think the design is forgiving to the extent that it will work in almost any reasonable configuration. What I'm encouraging you to do is learn to build from scratch. It's fun, and a wonderful way to satisfy those creative desires. **Happy building!**