The NorCal 20 Construction Manual

A QRP CW Transceiver Kit For 20m

By Dave Fifield, AD6A
Revision 1.0
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Embedded Research's NorCal 20 TiCK Upgrade

We are pleased to offer an upgrade path for the TiCK keyer chip used in the NorCal 20 Transceiver Kit. The SuperTiCK (a.k.a. TiCK-3) is the suggested upgrade for your radio. This chip is pin-for-pin compatible with the TiCK chip supplied with the kit. In addition to all the features of the kit-supplied chip, the SuperTiCK offers beacon mode and two 50 character message memories! The user interface is the same, except for the ability of the user to put the keyer in beacon mode, and play back the two 50 character memories. We think you will really like the SuperTiCK, and that it will enhance your enjoyment of the NorCal 20!

This upgrade chip has been tested by the NorCal 20 design team, and is known to work FB! To order your SuperTiCK upgrade chip, fill out the form below:

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San Luis Machine Company's Deluxe NorCal 20 Case

Doug Hauff, KE6IRE, who owns and runs the San Luis Machine Company has previously supplied superb cases for the NorCal 38 Special and the New Jersey QRP Club's Rainbow Tuner. He was the obvious choice to supply the case for the NorCal 20.

We are pleased to be able to offer a really good looking, hard wearing black anodized and machine engraved case to complete the professional look and feel of your NorCal 20 rig. These cases are the same size and basic construction as the case supplied with your kit but are hard black anodized and engraved to make them look a million dollars!

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The NorCal 20 Construction Manual

Introduction

The NorCal 20 is a high performance QRP CW transceiver kit for the 20m band. It has been designed to operate well in the presence of large out-of-band (short-wave broadcast) and in-band (contest station just down the road) unwanted signals. It should easily meet the requirements most QRP'ers, from the most competitive contester to the casual operator.

The kit contains all the parts needed to build a complete working radio. The only things the user will have to supply are the power source and supply cable, a loudspeaker or headphones, a set of paddles or straight key (suitably wired) and a matched 20m antenna system.

The kit is designed with no wiring required - all the components are mounted on a single double-sided with plated through holes, solder masked and silk screened printed circuit board that measures 4.5" by 5". Pre-drilled front and rear panels with U shaped top and bottom panels are provided that form a clamshell type case that is smart, strong and functional. The case is bare aluminum. Painting and labeling (not necessary, but nice) is left to the constructor.

General Description

The NorCal 20 is a single band QRP CW transceiver optimized for good RF performance rather than for low current drain. As such, it is suited mainly for operation from home-based stations or portable operations with fairly large battery capability (e.g. field day). On receive the current drain can be as much as 150mA. It can produce any output power from 0 to about 7 Watts. The output power is set with a small trimpot inside the rig.

The NorCal 20 uses fully electronic RX/TX switching (no relays) that gives very smooth, thump-free, semi-break-in operation. The transmit output waveform is edge controlled to minimize bandwidth usage. As a bonus, this makes for very nice sounding Morse code on the air.

The NorCal 20 offers many advanced features that make it easy to use.

The NorCal 20 has a single conversion superheterodyne receiver and an equivalent single stage up-conversion transmitter. The I.F. is 9MHz with the VFO at 5MHz.

The NorCal 20 has been designed to utilize either a 1 turn (supplied) or a 10 turn (you supply) TUNE pot. It also has an RIT pot with center detent.

No frequency calibration or scale is needed because the rig has a built in frequency counter, known as the Audible Frequency Annunciator (AFA). This plays the KHz digits of the frequency to you in Morse code over the speaker/headphones. The AFA has two modes of operation. Manual mode, where the frequency is announced only when you press the front panel push-button, and automatic mode, where the AFA "pips" at every KHz as you tune up or down the band, then, recognizes when you stop tuning, and announces the frequency automatically.

The NorCal 20 has a built in Morse code keyer chip from the Embedded Research TiCK line. This keyer allows you to swap the paddles over, set the speed, tune-up, run straight key mode and run in either iambic A or B modes.

The NorCal 20 is VFO tuned. Much attention has been paid to making the VFO as stable as possible. Some warm-up drift is to be expected, as, from cold, the rig will warm-up significantly due to the large amount of current sacrificed in making the receiver front-end performance satisfactory. Typical warm-up drift is in the region of a few hundred Hz.

The receiver has AGC – two AGC loops in fact – that is audio derived (IF derived was too expensive to add, but could be done as a modification). In addition to the AGC, the user still has ultimate front-end signal level control - the rig includes an RF Attenuator pot (rear panel mounted).

The receiver consists of a double tuned Cohn bandpass filter feeding a moderate gain tuned FET pre-amplifier (about 6 to 8dB gain, just enough to overcome mixer loss). This feeds a +7dBm level Minicircuits TFM-2 diode-ring double balanced mixer. This device is almost identical to the more commonly used TUF-1, but was significantly cheaper. The mixer output is fed into a broadband 50? terminated amplifier that runs enough current to ensure the 2nd and 3rd order intercept points (IP2/3) of the radio are not compromised. The output of this amplifier is terminated with a 50? -6dB pad then fed to the four crystal main receive filter. The crystals used for the NorCal 20 were specially selected and matched to within 50Hz (or better), ensuring a flat topped narrow-band response that is a joy to listen to.

The main filter is followed by a low noise IF amplifier with a matched roofing crystal filter feeding the product detector.

The roofing filter removes a lot of opposite sideband noise that would otherwise be present as audio noise in the product detector's output. Careful attention has been paid to the IF layout resulting in an overall stopband attenuation that is remarkably good.

The product detector (NE602) feeds balanced audio to a simple low-pass op-amp filter/amplifier with a cutoff frequency around 1.2KHz and a passband gain of about 11dB. The output of this is fed via the TX/RX mute FET to another bandpass filter/amplifier stage that has a center frequency of 700Hz, a Q of 5 and a gain of about 30dB. The output of this is fed to the 2W LM380N audio amplifier via the front panel mounted volume control.

The transmitter mixes the VFO and a carrier oscillator up to 14MHz, filters it and amplifies it to a user adjustable level up to about 7W. The class A driver stage uses a parallel pair of 2N2222 transistors that drive the 2SC1969 output power transistor in class C. This transistor uses the rear panel of the rig as its heatsink.

The transmitter output filtering uses a novel harmonic attenuation arrangement that was recently described in the ARRL QEX journal. This significantly reduces transmitted harmonics. A spectrum analyzer plot shows them all (including 2nd and 3rd harmonics) to be below –70dB from the main carrier.

TX/RX changeover is all electronic. When a paddle key is pressed, the TiCK output drives a switching circuit that provides a linearly ramped transmit power supply rail to the low power transmit stages. This ensures a clean, almost ideally shaped transmit output RF envelope. Likewise, at the end of a Morse code element, the TiCK output drives the switching circuitry to ensure a linearly ramped trailing edge to the transmit power. This ensures a clean tail end for the output RF envelope.

The RX mute signal is also derived from the transmit timing/switching circuitry. The mute signal ensures the AGC is disabled and the receiver is muted prior to the transmit output envelope rise, and that the transmit output envelope is complete, and the receiver stable, prior to enabling the AGC and opening the receiver mute once more. This all happens in the space of a few milliseconds, which gives the rig semi-break-in capabilities

Acknowledgements

Many people have contributed their time, energies and kindness to make the NorCal 20 kit a reality. I would ask you to join me in thanking them for all they did to help:

Doug Hendricks, KI6DS – Master project management, coaching, component procurement and kitting, and without whom the project would never have seen the light of day.

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Caroline Fifield, KF6MOV, my wonderful wife – without her infinite patience and understanding, this rig would never have been possible.

NorCal 20 Specifications

Size	5” x 5” x 2” nominal
Weight	1 lb. 2 oz. (515 g) +/- your soldering style!
Mode	CW
Keying	Semi-break-in, all electronic, TiCK (Rev. 1.02) keyer built in. 1/8” stereo jack connection – DIT = tip of the jack plug (can be modified)
Frequency control	VFO, varicap diode tuned, main tuning control and RIT control
Stability	Approx. +300Hz drift first 30mins, +50Hz drift per hour thereafter
Frequency counter	AFA, accurate to within 1KHz, manual and automatic modes – user selectable
Frequency range[1]	A (nominal) 30KHz segment of the CW end of 20m (14MHz) – user selectable
Antenna	50? BNC
Output power	0 to 5 Watts nominal (7 Watts typical) – user adjustable
Output protection	2SC1969 output device is SWR protected - will run into open or short circuit loads
Output match	Better than 1.5:1 into 50? nominal
Output spectrum	Relative to main carrier at 5W output, all harmonics –70dB or better, all spurii –50dB or better
Receiver	Single conversion superheterodyne, JFET pre-amp, high level double balanced mixer
Receive sensitivity	MDS –135dBm nominal
Intermediate frequency	9MHz
Receive filter	4 crystal main filter, 1 crystal roofing filter
Receive bandwidth	300Hz nominal
Stopband attenuation	-70dB min
AGC	2 AGC loops, audio derived, 3 PIN diodes plus N6KR’s NE602 method
AGC range	80dB nominal
Audio output[2]	2W into 8? (loudspeaker or headphones) from an LM380N. The output will directly drive high impedance earphones. Speaker/headphone connection is by 1/8” stereo jack.

⚠ Please be careful using headphones with the NorCal 20 - the output is LOUD so some external attenuation will be required when using sensitive earphone types (Walkman and ear bud style phones in particular). ⚠

Power supply[3]	10V to 14V D.C. Negative ground. 2.1mm standard power jack (center = +)
Receive current	150mA nominal
Transmit current	Depends on output power setting – user adjustable – and power supply voltage. The transmitter is about 60% efficient (class C output stage).

1 This is with the standard 1 turn, 270? pot as supplied. Ergonomics dictate the maximum frequency range with this type of pot. Modification pads are provided on the PCB for a 10 turn pot. With this user modification in place, the frequency range can be increased to 70KHz or more. See the Modifications/Experimentation appendix on page 20.

2 Since the LM380N produces noise at all audio frequencies, it is recommended that the user place a suitable low pass filter in circuit when using headphones – this will help to reduce annoying hiss. A suitable filter is described in the Modifications/Experimentation appendix on page 21. This can be fitted inside the radio with a separate headphone jack if required.

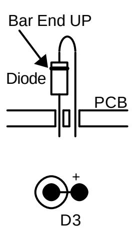
3 Some reduction in RF power output will be noticed as supply voltage is reduced. There is no AGC on the transmit output power.

Before You Do Anything Else - Read This!

Construction of the NorCal 20 is best done in sections, one at a time. The manual therefore uses the “build-a-section, test-a-section” method. Building it this way saves lots of trouble in the long run. The NorCal 20 is a fairly complex radio: all the parts are closely spaced and there is great potential for error both in picking the correct part and placing it in the board. You **must** positively identify the parts correctly prior to soldering them into the PCB. Special care should be exercised over identifying the capacitors for the transmit amplifier, these are 100V components and should not be mixed up with the lower voltage parts used elsewhere. There are part identification tips and insertion/mounting details throughout the manual.

Also, please pay careful attention to the winding of the toroids. They can only be wound one way properly. Pictures are provided to help you to do this correctly.

Like the resistors (apart from R80), all the axial leaded diodes in the NorCal 20 are mounted vertically. They are all mounted the same way to avoid confusion. They should **all** be mounted with the BAR end of the diode (the cathode) UP:



The PCB silkscreen shows a circle with a wire going to the adjacent hole. Next to the wire end, there is a small + sign. This appears to be a European notation. It works, so I decided to keep it. The + end is where the bar end of the diode should go – just as in the drawing above. Be careful when bending any of the glass encapsulated diodes – try to bend them a little away from where the wire enters the body – they are not easily broken, but I have known them to get damaged like this on occasion.

Note also that all 37 of the 0.1?F and all 13 of the 0.01?F decoupling capacitors (items 65 and 64) are fitted vertically like the resistors and diodes. Follow the layout silk screen for orientation.

Be careful not to get solder in the wrong hole - the parts are very close together on the PCB so it is easily done. Use a very fine tip soldering iron (1/16” bit), 22awg solder (with flux core) and lots of care. If you do get solder in the wrong hole, or if you need to remove a component for some reason, use a de-soldering pump (solder sucker), or a piece of de-soldering braid and carefully remove the solder. Do not heat the pad/hole for long, as overheating **will** damage the PCB. It is better waste a component by snipping it out then removing the short stubs of wire left in the holes rather than ruining the PCB and saving the component.

All the pots used in the NorCal 20 will require their panel mounting lugs (…) to be removed prior to fitting to the PCB/panels. To do this, simply bend the lug with a pair of pliers. You may need to bend the lug back and forth a couple of times, but it should easily break off.

Some of the parts in the NorCal 20 kit are sensitive to damage by static electricity. Make sure your soldering iron has a grounded bit and that you are working in a reasonably static-free environment. Prior to handling any of the semiconductor devices in the kit, it is a good idea to ground yourself by touching your station’s ground bar (you do have a station ground, don’t you?!). Better still would be a proper anti-static mat and wrist ground strap arrangement, but we can’t all go that far!

The NorCal 20 is easiest to build with the PCB assembled with the front and rear panels. This allows you to fit a component then turn the rig over to solder it in place. It also allows you to connect the rig up to a power supply, speaker/phones, a key and an antenna or dummy load for easy testing of the rig in stages.

Every pin of every electronic component must be soldered. Even though it may appear that an IC pin or component lead is not connected to anything (on the underside of the board), it may still be connected on the top layer where you cannot see it, so must be soldered in place to complete the circuit. All the holes on the PCB are plated through, so they make connection from the top to the bottom of the board.

Aim to complete each section of the rig build in one sitting. This will ensure you don’t miss a part or step out. The kit should take about a week of evenings to complete.

Good luck and have fun building it!

Section 1 - Opening the Parts Bags

The parts have been pre-sorted into several bags and sealed. The bags are doubly protected: they are inside an outer bag that is also sealed. This should ensure no parts go astray in shipping. Check that you have the following items in your kit before going any further:

1. Manual – if you're doing this check, you've got it!
2. Four pieces of pre-drilled case - taped together to prevent damage in transit (you may need to remove some of the tape glue using a solvent cleaner prior to painting)
3. Large sealed plastic bag containing:
    a) Double sided, plated through hole, solder masked, silk screened printed circuit board
    b) Plastic bag containing resistors
    c) Plastic bag containing capacitors, including the trimmer capacitors
    d) Plastic bag containing transistors, diodes and a heatsink
    e) Plastic bag containing a paper envelope of 9MHz crystals, a plastic bag with a tiny crystal, a large diode and a piece of anti-static foam with IC's on it.
    f) Plastic bag containing three small reels of wire, toroids and inductors
    g) Plastic bag containing hardware including miniature push-button switches and rubber feet
    h) Plastic bag containing pots, knobs, connectors and miniature trim pots

The first thing you should do is open the bag of transistors and diodes. In this bag you will find 21 small 1N914 diodes strung together ("tape and reel" fashion). You will also find two similar looking diodes loose in the bag. These are the 1N754A 6.8V zener diodes (item 74). In order for these not to get mixed up with the 1N914 diodes, you should immediately identify, separate and mark the zener diodes. For example, wrap a piece of masking tape around the two diodes and write "1N754A" on it.

Sort the other transistors carefully. All the TO-92 cased devices look the same. The lettering/numbering on them is very small – if necessary, use a magnifying glass to identify the parts. Notice that 4 of the TO-92 devices have only 2 leads. These are diodes. Three of them are PIN diodes for the AGC and the fourth is the varicap for the VFO.

Using the parts list at the back of this manual, select and identify the other parts. In particular, pay careful attention to the capacitors. There are several instances where there are capacitors of the same value, but where the type of capacitor and the job it is intended to do are quite different. An identification guide is provided alongside the parts list. The capacitors used in the transmitter output stage are most critical. These must be 100V low dielectric loss types as there are very high RF voltages at this point in the circuit. Make sure you get this right - you don't want to let any smoke out of them! Also, the 82pF C0G capacitor for the VFO is critical. This capacitor has the marking "C0G" on it just below the value "820".

The tiny 100KHz crystal (X8) should be handled with great care – it is very small and fragile, so it will easily get lost or broken.

Check that you have all the parts listed in the parts list. If you have any missing or obviously broken parts, contact NorCal for a replacement straight away. Please be warned - many of the parts used in the NorCal 20 kit will not be available later as spares. If you are going to leave your kit untouched and later find a part is missing, you may not be able to get the part from NorCal. We are going to set a reasonable time limit of 1 month from the date of shipping for this. After this time we'll do whatever we can to help but you may be out of luck.

If you are having trouble identifying any part or have any technical questions on the NorCal 20, please let me know by email and I'll do what I can to help (AD6A@qsl.net)

When you have built the kit, you will have two resistors (R9 and R52), a diode (1N914) that was removed from the design, and quite a bit of 26/28awg wire left over. Don't panic, this is normal.

Section 2 - Rear Panel

The rear panel should be assembled prior to the front panel to allow easier alignment of the panels with the PCB.

? Fit and solder the two stereo jack sockets J1 and J3 to the PCB. Make sure their fixing nuts are removed and they are pushed down flat against the board before soldering them.

? Loose fit the BNC, J2, the power connector J4 and the RF attenuation pot, VR3 to the PCB. Place the flat washer on the pot VR3 but leave the toothed washer off the BNC for now.

? Align the PCB with the rear panel. Place the toothed washer and ring nut on the BNC and finger tighten it in place.

? Place the two nuts on the stereo jack sockets J1 and J3, finger tight. Place the nut on the shaft of the pot (VR3) finger tight.

? Making sure the PCB is perpendicular to, and level across the width of, the rear panel, turn it over and solder the BNC (J2) and the pot, VR3, in place.

? Next, look at the alignment of the power connector, J4, through the hole in the rear panel. Make sure it is centered in the hole before soldering it in place. Fill the power connector's PCB through holes with solder – quite a bit of current is going to be flowing here.

The output power transistor will be fitted later.

? Find the solder lug (item 107) and cut the end off it so that when positioned on the rear panel it does not protrude into R80's PCB space. Fit it to the rear panel grounding hole at the opposite end of the rear panel to the jack sockets. Use 4-40 1/4" screw (item 108) and nut (item 109) to hold the solder lug in place. Orient it so that it aligns with the GND pad on the PCB. Once aligned and tightened in place, bend and solder the lug directly to the GND pad on the PCB with a healthy dab of solder. This connection needs to be as electrically short as it can possibly be.

Section 3 - Front Panel

If you are going to fit a 10 turn pot to your NorCal 20, now is a good time to buy it/find it and fit it. If you purchased one of the 10 turn pots from the QRP-L group buy, then with just a little bit of modification the lugs it should fit nicely into the board holes.

You may have to twist and/or bend the lugs a little to make it fit. Alternatively, you can file a tiny bit off the lugs to make them appear vertical to the PCB and fit it without any bending. If you did not buy your 10 turn pot from the QRP-L group buy, then you can either purchase the correct item from Mouser (phone 1-800-346-6873, or email sales@mouser.com) part number 569-7286-10K, or find a similar item from elsewhere. The PCB will accept the BI Technologies 7286 series, the Spectrol 534 series or the Bourns 3540 series pots without much problem. You will have to cut/file/bend the lugs a little to make your pot fit. The group buy pots need a little trimming off the lugs with a pair of cutters to get them to fit snugly. Whichever pot you choose to use, do not solder it in place just yet.

You may require a large flat washer on the 10 turn pot behind the front panel to fill out the gap from the front panel to the shoulder on the 10 turn pot. I found some standard 0.825" O.D., 15/32" I.D. by 1/16" thick washers that worked very well indeed. No extra build-up washer should be necessary using the 1 turn pot. Also, you will probably have to cut off a small piece of the 10 turn pot's shaft (about 3/16") to get the large tuning knob to fit nicely back against the front panel. Do this in a vise, prior to soldering the pot - it's much easier than trying to cut it when it's mounted!

? Note that SW1 and SW2 are fitted underneath the PCB, on the track side. Fit and solder them into the PCB at this time. Make sure they are flat against the PCB or they will not line up with the front panel holes.

? Loose fit all the other front panel controls to the PCB, but do not solder them yet - VR1, VR2 and VR4. VR2 will need its lugs bending dead straight in-line with the metal connectors as they come off the pot's body. You will need to use a small pair of needlenose pliers to do this. If the lugs are not straight, the front panel will not fit properly - it will be the wrong distance from the PCB that could result in a gap. There should be essentially no gap between the PCB and either the front or back panels. This would have the knock-on effect of the case top and bottom not fitting correctly.

? If you are using a 10 turn pot, you'll notice about now that it doesn't fit in the front panel hole. You will need to first drill out the hole to fit your particular pot. Users of the QRP-L group buy pot - simply drill it out to 3/8". Then you will need to use a circular file to elongate the hole towards the top of the front panel. The 10 turn pot's center is higher than the other pots, and this will allow everything to align properly.

? Place the flat washers (or toothed washer if you are fitting a 10 turn pot) onto the shaft of each pot.

? Place the large solder lug (item 106) onto the shaft of the RIT pot, VR2, with the lug to the right hand side of the rig as you look at the front panel. The lug should be on the same side as the TUNE pot, so that you can easily solder a wire from it to the GND pad on that side of the PCB (the pad is positioned "inside" the pins of SW2).

? Align the PCB with the front panel. The next part is probably the trickiest part of the whole rig assembly. You need to ensure that SW1 and SW2 poke through the front panel roughly in the center of their small holes. At the same time, you need to align the RIT pot, VR2, so that it sits flat against the PCB. It helps to loosely fit the nuts to the pot shafts during this operation. Also, you need to ensure the front and rear panels sit flat (using a known flat surface to check), otherwise the top and bottom of the case will not fit correctly later. Care to the alignment at this stage is crucial to the final fit of the panels.

? Once you are happy with the alignment of the switches and VR2, solder the center lug of VR2 to the PCB, then take another long hard look at the front panel alignment. Is the PCB more or less at right angles to the front panel? Is there a large gap between the PCB and the front panel? There should be no gap. Are the switches off center? Does the rig sit flat on a flat surface? This is your last chance to adjust the alignment of the panel, since you only have one lug soldered in and you can re-flow that joint to adjust everything.

? Once you are entirely happy with the alignment of the controls then go ahead and solder them all into the PCB. If you are using the 1 turn pot supplied with the kit for the TUNE pot, VR1, one of its lugs will need bending over slightly to make contact (in the large hole) before it can be soldered in place.

? When everything is in place and soldered up, tighten the nuts on the pots a little more. You can disassemble the panel at any time for painting/lettering. You will need to use a piece of discarded resistor or capacitor lead to connect the front panel ground lug to the pad on the PCB. Do this later when you have the piece of wire available. You will be reminded.

Section 4 - Regulators/Power Supply Components

? Insert and solder U2, U8, D1, C9-12, C91-93 and C95. These components are on sheets 1 and 5 of the circuit diagram.

? Connect a suitable (13.8V nominal) power supply to the power input jack J4 whilst measuring the input current on a meter (set to 50mA FSD or thereabouts). Turn on the power. The input current should be no more than 10mA. If it is just a little more than this, up to, say double, then you may have a problem with the actual voltage regulators U2 or U8 and further detailed investigation will be necessary. If all is well (typically see about 8mA), then turn off, connect the power up directly without the meter and turn on again. With the meter set to read DC Volts (20V range or thereabouts), measure the voltages at the following points (red lead or +) with respect to GND (black lead or -):

? J4 center pin (at the rear of J4) - should be the same as the supply voltage (+13.8V)

? D1 cathode (bar end - the wire facing the front of the rig) - should be about 0.3V less than the power supply rail (+13.5V)

? U9 pin 1 (square pad) - should be between +4.75 and +5.25V (+5V +/- 0.25V)

? Q2 drain (Q2 pin nearest U2) - should be between +7.6 and +8.4V (+8V +/- 0.4V)

If you don't see these voltages there is a problem. Look for short circuits between tracks, particularly between the pins of U2 and U8. Sometimes tiny silvers of metal can be made when this type of component is inserted into a PCB, this can short pins together on the topside of the PCB, so make sure to look there too. If there is no solder bridging and everything is soldered correctly, then suspect a defect in the voltage regulators.

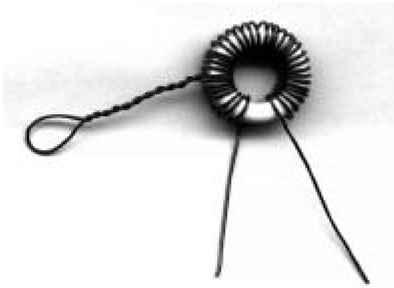
Section 5 - VFO

? The first component to fit is the VFO main tuned circuit inductor, L1. Locate the T50-7 toroid core (item 96, white, bigger than the others), the 26awg wire (the thickest enameled wire, red, item 127), the two black fiber shoulder washers (Item 110), the 6-32 x 1/2" nylon screw (item 111) and the 6-32 nut for it (item 112). Cut 28" of the wire.

? Holding the T50-7 core in your left hand, with the white face up, with your right hand, thread about 2" of one end of the wire through the core from the top to the bottom away from you. Wrap the long end of the wire around the toroid and thread it up through the toroid from the bottom to complete the second turn (the first turn was when you pushed the wire through at the start). Holding the short end of the wire tight against the toroid body with your left hand, pull the long end of the wire tight with your right hand so the winding is kept tight and each turn is placed beside the previous. Each pass through the center of the toroid is 1 turn.

? Continue adding turns like this up to turn number 8. At the "end" of turn number 8, you need to bend the long end of the wire back double on itself to make a 2" tap. With the wire bent back on itself, grab the small loop that is formed and twist the tap many times around so that it forms what looks like a single wire. Make sure you twist it real tight so that the twists go all the way back to the body of the toroid. Then, take the long end of the wire again, passing it up through the bottom of the toroid to form turn number 9.

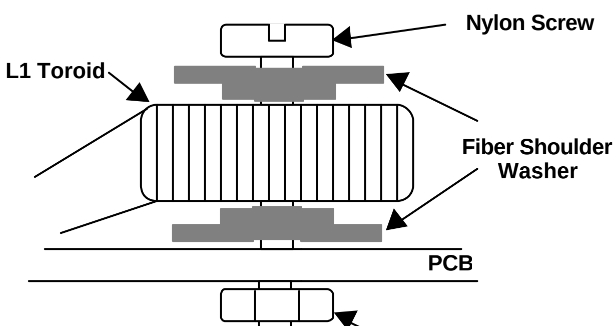
? Continue adding turns till you have 35 of them on the toroid all nice and tightly wound. Loose windings will allow changes in the inductance to occur which will affect the frequency stability of your VFO. 35 turns fit just snug on this toroid. Make sure they are evenly spaced. Here is how your L1 should look at this point:



Completed L1 Toroid
(Prior to cutting off the TAP loop)

At this point, some constructors may choose to bake their L1 in a very low oven or boil it in water for a time. Do whatever you think you need to do in order to anneal the copper. This may or may not affect the overall frequency stability of the final VFO - I have seen no proof one way or the other. If you do “cook” your L1, please allow it to completely cool and make sure it is dry before soldering it into place.

? L1 is fitted as per the drawing below. The HOT, TAP and GND connections are all marked on the PCB. The holes for the wires are almost directly below where they come off the toroid. You will have to cut the small loop end off the tap to fit it through the hole in the board.



L1 Assembly

? You can either cut and tin the wire ends before you insert them into the PCB or after they are inserted. Let us assume you are going to tin the wire before you insert it into the PCB. The magnet wire supplied with the kit has an insulation that will burn off easily at soldering iron temperatures. To tin the wire, take a hot soldering iron with a clean, wetted (with solder) tip, and, starting at the very end of each wire, apply the iron and feed in solder (be generous, the excess will stay on the iron). As the wire’s insulation burns off, run the iron down the wire to the length you need tinned. When you have finished tinning the end, clean off the excess solder from the iron and run it along the wire again, from the junction of the tinned part and the insulated part to the end. This will wipe any excess solder off the wire and ensure it is easily inserted in the PCB hole. Sometimes a small blob of melted insulation material forms at the junction with the tinned part. To remove this, simply run your fingernail over it and it will crack right off neatly.

? With the 6-32 nylon screw fitted from the underside of the PCB, place a fiber shoulder washer on it, followed by the inductor L1, being careful to make sure L1’s wires are inserted in the correct holes, then add the second fiber shoulder washer and the nylon nut to finish. The nylon screw and nut should only be tightened a little: just enough to hold L1 in place without moving. Any excess pressure exerted by this screw will result in possible loss of VFO stability as temperature changes.

? Finish off the L1 assembly by trimming and soldering the HOT, TAP and GND connections on the PCB underside.

? Insert and solder C5 before fitting TC1. It’s much easier this way!

? Next, insert TC1. Make sure this trimmer capacitor is the right way around. Follow the PCB silk screen legend. The moving vanes (connected to the screw slot) should be grounded. Ensure TC1 is fully pushed flat to the PCB before soldering it in place.

? Insert and solder C108, C6 and C107 being careful not to overheat these last two - they are polystyrene capacitors and will melt easily.

? Insert and solder C7, R11, D4, Q2, C8 and R12. Use one of the discarded resistor leads to connect the front panel ground lug to the PCB GND pad.

? Referring to sheet 4 of the circuit diagram, insert and solder C86, R81, D23 and C87. This is the built-in RF probe that we are going to use to test some of the circuits.

? Find a 5” piece of scrap hook-up wire to use as a jumper. Connect it from the junction of C8 and R12 to the anode of D23 (that’s the junction of D23, R81 and C86). If you don’t have any hook-up wire, use a 5” piece of the 26-awg magnet wire provided with the kit, but don’t throw it away afterwards, you’ll need it again. Connect power to the rig and turn it on.

? Using your meter set to a low voltage range (DC, 2V range is good), measure the voltage between GND (black probe or -) and the RF test point on the PCB (red probe or +). You should get between +0.5V and +1.5V. This means the VFO is producing RF nicely. Don't worry about the frequency of the VFO for the moment.

? If you don't get any voltage here you have something wrong in the VFO circuitry. Go back over and check your work, look for solder bridges (90% of all problems!) or components in the wrong way.

If you have access to an oscilloscope, you can probe the same point as the hook-up wire is connected to. You should see a nice clean 1 to 1.5V peak-to-peak sinewave of around about 5MHz.

Section 6 - VFO Buffer-Amp

? Insert and solder Q3, Q4, R13-18, C13-15, C66 and C67.

? Connect the 5" piece of scrap hook-up wire from the junction of C15 and U3 pin 4 to the anode of D23 (that's the junction of D23, R81 and C86). Connect power to the rig and turn it on.

? Using your meter set to a low voltage range (DC, 2V range is good), measure the voltage between GND (black or -) and the RF test point on the PCB (red or +). You should get somewhere between +1V and +2V. This means the buffer/amp is doing its job properly.

Section 7 - TUNE and RIT controls

? Insert and solder Q1, D2, U1, R1-8, R10, R100, C1-4 and D3 to the PCB. Note that resistors R1, R3, R4, R6 and R7 are 1% tolerance parts.

? R9 should be selected depending on which TUNE pot type you are going to use. For a 1 turn pot, R9 needs to be 100K? and for a 10 turn pot, R9 needs to be 220K? . Both values are supplied with the kit. Choose the correct R9 for your TUNE pot and insert and solder it in now. You also need to insert and solder two small link wires (use some discarded resistor leads) to select the type of TUNE pot you are using. To the left of the TUNE pot, as you are looking at the front of the radio, are two sets of links labeled 1t and 10t. You need to make the appropriate two links for your TUNE pot type. These links swap the two ends of the pot around electrically. This has to be done like this because the 1 turn pot and 10 turn pot tune in opposite directions from each other! These links ensure the TUNE control has the correct ergonomic sense (that is, turning the control clockwise means the frequency goes up).

? Once you have fitted all the above parts, connect power to the rig and turn it on.

? Using your meter set to the 20V DC range (or thereabouts), with the black lead (-) to GND, probe the voltage at U1 pin 6 (the junction of U1 pin 6 and R10). Vary the TUNE control from fully counter-clockwise to fully clockwise and note the measured voltage at each extreme.

? For a 1 turn TUNE pot, the voltage should vary from about +3V to about +6.5V. A little either way will not be a problem; you just need to find out if the voltage is varying as you tune.

? For a 10 turn TUNE pot, the voltage should vary from about +2V to about +10V. Again, a little either way is not a problem here.

? Depending on the accuracy of your meter, try varying the RIT pot and see if the voltage at U1 pin 6 varies at all. We will be testing the RIT pot more fully later, so don't worry if you can't do this test now. The voltage should vary by about +/- 0.1V using the 1 turn TUNE pot and by about +/- 0.2V using the 10 turn TUNE pot (actually, it's the different R9 values that make these voltage swings different, not the TUNE pot type!).

Section 8 - Audio Amplifier

? Insert and solder U6, C56-62, R57 and R58.

? Connect a suitable loudspeaker or set of headphones to J1 then connect power and turn the rig on. You may hear a small click from the speaker/phones upon turn-on. Rotate the volume control VR4 fully clockwise. Using a small piece of wire or a small screwdriver blade, touch the ungrounded end connection of VR4 (the right most terminal as you look at the radio front).

? You should hear crackling and buzzing from the speaker/phones.

Section 9 - Audio Pre-Amplifier

? Insert and solder U5, Q9, C43-55, R44-51, R53-56 and D13-15. Note that R52 is included for test, setup and modification purposes and is not soldered in at this time. Experimenters may like to use an 8-pin DIL socket (not supplied) for U5 to allow experimentation with super-low noise (expensive) op-amps later.

? Connect up the loudspeaker/phones and power-up the radio again. With the volume control fully clockwise, dab your test wire/screwdriver tip onto the pads for U4 pins 4 and 5 respectively.

? You should hear crackling/buzzing from the speaker/phones again, but this time it should sound "bandwidth limited" since it's going through a sharp 700Hz bandpass filter. Compare it to the sound you get by dabbing on the volume control pot directly and you should easily be able to hear the difference.

? The maximum volume the radio can generate is set with R56 (47K?). The standard level (as shipped) is set so that for most small speakers and stereo headphones there is no chance of eardrum busting audio from the rig! Thus it is set lower than some constructors may like. If, when you have completed the construction, you find the maximum audio output a little limited, you can change R56 for lower value (e.g. I use R56 = 33K? in my prototype rigs, since I like to use it with a 5W surplus mobile radio loudspeaker that needs just a bit of extra output to drive it).

Section 10 - Audible Frequency Annunciator (AFA)

? Insert and solder U10, Q22, Q23, D27, C97-104, C106, R86-96, VR8 and X8. Be especially careful when soldering X8 into the board as it is extremely tiny and fragile. It is a good idea to hold it in place with a dab of hot glue or wax after you have soldered it to the board. Note that R92 is near the front of the PCB, next to the AFA mode setting links LK1-4.

? You now have to make another decision. That is, do you want the AFA to operate in Auto mode, Manual mode, have a switch to change modes on the fly or a set of 0.1" headers with jumpers to allow occasional changes to be effected?

? Four links are provided on the PCB to facilitate any of the above choices, LK1-4. They are positioned so that a small DPDT slide switch will fit the holes. A suitable part is E-Switch (http://www.e-switch.com) part number 500SDP1M2QEA or 500SDP1M2REA (Mouser part numbers 612-500-D121 and 612-500-D122 respectively). These can be fitted on either side of the PCB. If you fit it to the topside, you will only have access to it when you remove the lid of the radio (4 screws). If you fit it to the underside of the PCB you will be able to change modes quite easily from the underside of the rig. You will have to cut a small rectangular hole in the bottom of the case to allow access to the slide switch if you choose this method.

? If you choose to panel mount a DPDT switch, either on the front or rear panels, you can use just about any DPDT switch you have to hand and wire it pin-for-pin back to the 6 holes on the PCB. It was not feasible to place another switch directly on the front or rear of the PCB, so this switch will have to be panel mounted and wired up manually if you need access to it directly on either the front or rear panels.

? If you only want to change the AFA mode very occasionally, or if you just want to try each mode for a while to see what your preference is, then you may consider putting two small 3-pin 0.1" spacing "headers" into the LK1-4 holes. You can then use two 0.1" jumper blocks (just like they use on computer boards to configure the IRQ/Address etc.) to set the mode.

? Alternatively, if you know which mode you want already, just go ahead and solder small wire links into the PCB. Use two links. For Auto mode, solder the links into LK1 and LK3, for manual mode, solder the links into LK2 and LK4. You can use two discarded resistor leads for the links.

? Set the volume control to about half way, the tune control to minimum and the trimpot VR8 to about 1/3 clockwise from fully counter-clockwise. Connect the loudspeaker/phones and power-up the radio. Press the AFA announce push-button SW2. You should hear an announcement in the speaker/phones in Morse code at about 1800Hz. The announcement may be one of three things:

a) '0' in which case there is something wrong with the VFO signal getting to the AFA
b) 'xxx', a three digit number (e.g. 965) in which case the VFO needs adjustment
c) 'xx', a two digit number (e.g. 14) in which case the VFO still needs adjustment!

The next section deals with the tuning of the VFO.

Section 11 - Setting the VFO Frequency

? If the AFA announcement is a three-digit number like '965' this means the VFO is too low in frequency and is actually at 4.965MHz. It is just possible that the VFO could be too high, say at 5.116MHz for example, in which case the AFA will announce '116'. You need to adjust the VFO's trimmer capacitor TC1 so that the lowest frequency (with the TUNE pot fully counter-clockwise) is what you want it to be. In most cases you will want the lowest VFO frequency to be 5.000MHz. It's a good idea to set the lowest frequency to '999' so you can guarantee full coverage of the low end of the band.

? Some constructors who use the 1 turn TUNE pot may like to have the rig operate around the US QRP calling frequency of 14.060MHz. Since with the 1 turn pot you have about a 30KHz tuning range, set the pot to mid-point and then tune the VFO to '60' exactly.

? If you are in AFA Auto mode the AFA will announce frequencies as you tune TC1, each time you stop. Notice that you will also hear 'pips' as you tune through each KHz. In manual mode, you will need to press the AFA's announce push-button SW2 every time you want to know the frequency.

? Set VR8 to the level you find comfortable to listen too. This will depend on your personal preference and what mode you have the AFA set to. It is adjustable from nothing up to very loud, catering to all tastes.

Section 12 - Keyer and Transmit Control

? Insert and solder U9, Q19-21, C88-90, C94, C96, R82-85, R97-99, VR7 and D24-26. You may like to put U9 in an 8-pin DIL socket (not supplied) to make upgrading to the Embedded Research Super TiCK III keyer (with memory) a lot easier later. Make sure you insert U9 the correct way round. The label makes it difficult to see the "indent" in the package that identifies the end with pin 1.

? Set the volume control at half way and the keyer sidetone level control VR7 to about 1/3 clockwise from fully counter-clockwise. Connect up the loudspeaker/phones and power-up the radio again. This time when you turn-on the power you should hear a 'dit-dit' in the speaker/phones at the sidetone frequency of about 700Hz. This tells you that the TiCK keyer powered up correctly. The 'dit-dit' that you hear is the version of TiCK. If you were to plug in a Super TiCK III instead, you'd hear 'dit-dit-dit dah' for "s t".

? Power off the rig, connect a set of paddles to J3 and then turn the power back on. Operate your paddles to check both the dit and dah works. Don't worry if they are the wrong way round at the moment, we'll get to that later. Press the TiCK programming push-button SW1 and hold it.

? You should hear the programming menu sequence of the TiCK keyer 's t p a sk m k' in the speaker/phones. This will repeat if you hold SW1 continuously. The TiCK keyer programming instructions are included in an appendix at the end of the manual.

? Connect your meter (set to 20V DC range or thereabouts) from GND (black or - lead) to the +12VTX signal at the junction of R98 and C94 (red or + lead). You can get at this signal easiest on the looped end of the wire on R98 on the topside of the PCB. At the moment, the meter should read 0V.

? Press the TiCK programming button and hold it until you hear 's t' then let go. This puts the rig into tune-up mode (continuous transmit). You should hear a continuous sidetone at this time. The meter should now read about +13.3V. This tests the transmit switching. Hit either the dit or dah paddle or SW1 again to stop the tune-up mode. If you have access to a 'scope, you can try looking at the +12VTX signal as you send with the paddles. Notice the linear rise and fall waveform that contributes to clean, minimum bandwidth use on the band.

? Next you have another decision to make. Are the paddles the right way around for you? You probably already have paddles that are wired up to your liking. The "standard" wiring method is with DIT to the tip of the stereo plug, but there is no "standard" that says which paddle that has to be!!! For this reason, there is a way for you to electrically swap the paddles over so that when you first turn the rig on, they will be right for you.

? Of course, you can re-program the TiCK to swap the paddles over any time you like, but this information is lost at power off time. This feature is nice for guest operators who have different dit/dah preferences to you, but is a pain if it's your radio and you have to program the TiCK every time you turn it on!

? On the PCB, right behind the paddle jack J3 you will see two sets of 4 holes in a row. There are two links labeled 'DIT' and 'DAH', plus two pairs of holes labeled 'Cap'. The capacitor holes are there just in case you need to keep RF out of your rig - they decouple the dit and dah lines to GND - they will not normally be required at QRP power levels. 1000pF or 0.01?F capacitors (not supplied) can be used here but only fit them if they are really needed. The DIT and DAH links have thin PCB traces on the underside of the board. If the paddles are the wrong way round (for you) at power-up, cut the thin traces carefully and, using two insulated jumper wires soldered into the PCB holes, swap the paddles over by crossing the links.

Section 13 - Receiver

? First you are going to fit the crystals X1-6. Before you insert each crystal, tin its metal case near the bottom of one end with your soldering iron. Do this as quickly as possible - you should be able to tin it fast enough that you can hold the crystal's metal case with one hand while you do the tinning, and not get burned. Insert each crystal with the tinned end at the same end as its GND pad. Solder each crystal into the board using the minimum amount of soldering time/heat possible, then take a discarded resistor lead and make a connection from the GND pad for each crystal to the tinned area on the end of the crystal. The GND pads are not marked on the PCB legend – they are at one end of each crystal and are obvious.

The trick to getting a neat looking job with no excess solder on the top of the PCB is to push the wire through the board then bend it over at 90 degrees underneath and solder it underneath the PCB first. Then move to the topside, cut the wire to length, bend it toward the crystal case and solder it quickly to the point you previously tinned. Grounding each of the crystal cases greatly improves the IF stop band attenuation.

? At this time, it also makes sense to fit the transmit crystal X7 to the board using the same technique as you did to fit X1-6. You do not have to do this now - you will be reminded later during the transmitter construction phase.

? Next, insert and solder TC2-6. Please take care to insert them the correct way around as per the silk screen legend on the PCB. This ensures the part where you insert your screwdriver/trimmer tool is connected to GND (except TC2 and TC6 of course), that will make tuning up the receiver much easier.

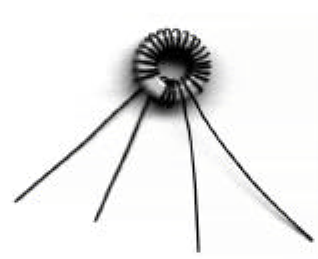
? Next, insert and solder U3, U4, Q5-8, Q13, L2, L4, C16-42, C64, R19-43, R67-69, D5-12 and D17-18. Take care not to mix up D12, the 1N754A zener diode, with the 1N914 diodes - they look basically the same! When fitting Q6, the 2N4427, place the TO-5 standoff insulator over the legs of the transistor before inserting it into the board. Raising this transistor off the ground plane helps reduce conduction of heat to the VFO. When Q6 is soldered in place, take the TO-5 finned heatsink and push it over the transistor case as far as it will go. This requires some pressure but can be done just with the hands (no tools - they will scratch the transistor case) using a good firm push.

The TFM-2 mixer (U3) has a blue insulation material around pin 1.

Lastly, you need to wind and fit the receiver toroids. Each receiver toroid is different so make sure you don't mix them up. The best way to ensure this is to fit each one to the PCB as soon as it is wound. Remember to keep count of the turns and not get distracted. Each time the wire passes through the center of the toroid it counts as one turn. For each turn, pull the long end of the wire tight to ensure a tightly wound toroid overall.

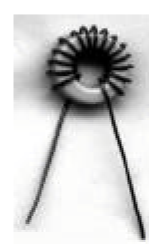
? T1 and T2 are almost the same - T1 has a 2 turn link (its primary) while T2 has a 4 turn link (its secondary). Both T1 and T2 use T37-6 toroid cores. Cut two 13" pieces of red 28awg (item 129) wire for the main 21 turn windings of both T1 and T2. Cut a 3" piece of red 28awg (item 129) for the 2 turn link winding on T1 and a 4" piece of red 28awg (item 129) for the 4 turn link winding on T2.

T2 is shown below, T1 looks essentially the same and is wound in exactly the same way. Notice that the link winding starts and finishes on the same side of the toroid as the main 21 turn winding. This will require you to start the link winding by pushing the wire up through the center of the toroid from below - the opposite to how you started the main winding off. This can be a little awkward to do physically, but with a little perseverance you will find that it's not too hard to do neatly. The windings are done this way to a) ensure correct insertion into the PCB (this way around, there's no doubt which wire goes in which hole) and b) to make the PCB easier to lay out.



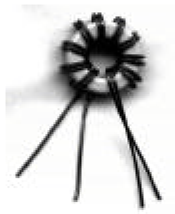
Completed T2
(T1 is the same except it has a 2 turn link winding, not 4 turns)

? L3 uses a T37-2 toroid core. Cut 11" of red 26awg (item 127) wire and wind 16 turns onto the toroid:



Completed L3

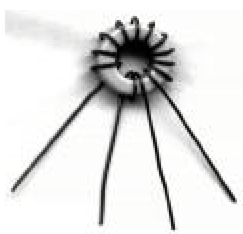
? T3 uses an FT37-43 toroid core. Cut two 9” pieces of 26awg wire, one red (item 127) and the other green (item 128) and, keeping them neatly side by side, wind 10 bifilar turns onto the toroid:



Completed T3

To ensure correct phasing of the windings, the wire ends should be Red-Green-Red-Green as you look at the transformer (from left to right in the picture).

? T4 uses an FT37-43 toroid core. Cut 8” of red 26awg wire (item 127) for the main winding of 11 turns and 3” of red 26awg wire (item 127) for the link winding of 2 turns:



Completed T4

? Temporarily connect a short (about 1.5”) piece of hookup wire, or piece of 26awg wire from the kit, from the antenna input (junction of J2 and C86) to the receiver input (junction of TC2 and C79). Connect a 20m antenna (a simple dipole will do) to J2. Connect a speaker/phones to the rig. Set the RF Attenuator on the rear panel fully clockwise (as you look at the rear panel) for minimum attenuation. Set the receiver trimcaps TC2-5 to half way. Connect power to the rig and turn it on. You should hear noise from the receiver.

? Starting with the product detector, adjust TC6 so that the noise is just a little above zero beat frequency wise and suits your taste. When you are able to receive a carrier, check that when tuning up the band (clockwise), the audio frequency goes from high to low – this is the correct (lower) sideband.

? Adjust TC5 for maximum perceived noise then adjust TC2/3/4 likewise. You may need to go over and re-adjust all these trimcaps several times to hear anything in the way of atmospheric noise from the antenna. Persevere - when you have adjusted all the receiver tuned circuits for maximum received noise, you should be able to hear a distinct difference in the noise level when the antenna is unplugged and plugged back in again. If possible, find a weak signal in the center of your rig’s tuning range and tune the receiver for best reception. Of course, you can use a signal generator if you have access to one.

? Test the receiver muting by pressing and holding the TiCK programming push-button SW1. Wait until you hear ‘s t’ in the speaker/phones then let go. The rig will then go into tune-up mode. You should hear sidetone but no receiver noise. Press SW1 or one of the paddles to go back to receive mode.

Section 14 - AGC

? Insert and solder Q10-12, D16, D19-21, VR5, C63, C65, R59-66 and R101.

? Disconnect the antenna from J2. With a speaker/phones connected, power up the rig. Measure the AGC2 voltage on the test pad labeled ‘S’ next to X6 - connect your meter (set to the 20V DC range or thereabouts) with black (-) to GND and red (+) to the ‘S’ test pad. Adjust VR5 to get +5.5V at this point. Because of FET variations, different radios will exhibit different VR5 behavior. Set AGC2 to the first +5.5V you encounter as the trimpot is turned clockwise from fully anticlockwise.

? The attenuators in the AGC2 circuit start to attenuate at about +5V, so the idle voltage (no signal) needs to be set slightly above to allow for temperature variation and to ensure maximum receiver gain for weak signal reception.

? Test the “AGC disable during transmit” feature by pressing SW1 (TiCK programming). Hold SW1 until you hear ‘s t’ in the speaker/phones then let go and the rig should go into tune-up mode. Measure the AGC2 voltage again. It should be 0V. Press SW1 or one of the paddles to go back to receive mode.

? Be sure to remove the link wire from the antenna connection to the receiver input before proceeding.

Section 15 - Transmitter

? First fit the output RF power transistor to the rear panel. You will need the TO-220 insulating washer (item 102), a nylon 6-32 screw (item 104), a metal 6-32 nut (item 105) and, of course, the 2SC1969 power transistor (item 86) to accomplish this. Note there is no need for silicone grease or any other heat transfer cream or agent here. The TO-220 insulation washer supplied is specially designed to be “dry” fitted. This makes things a lot easier and cleaner to do, especially since, once you have the radio working correctly, you will probably want to remove the front and rear panels for painting.

? Insert, but do not solder, Q18 into the PCB. Place the TO-220 insulating washer between the rear panel and Q18’s heatsink tab, then insert the nylon 6-42 screw through from the outward facing side of the rear panel, the insulating washer and the transistor (in that order). Fit the 6-32 nut to the nylon screw and tighten the whole assembly with a screwdriver. Notice that the 6-32 nut will “self-lock” on the body of the transistor - it’s just the right size to do this. The nylon screw thread will strip easily, so do not overtighten it. When Q18 is in position and secured, solder it into the PCB.

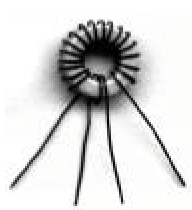
? Next insert and solder C76-78 and R80. These parts are close to the rear panel, so fitting them now will ease construction.

? If you didn’t fit crystal X7 along with crystals X1-6 earlier, you need to do so now. Insert and solder crystal X7 the same way you used when fitting X1-6 in section 13 (receiver) above.

? Then insert and solder U7, Q14-17, D22, TC7-9, L5, C68-75, C79-85, C105, R70-79 and VR6. Identify the transmit output filter capacitors carefully - the writing on them is very small - you may need a magnifying glass to make them easier to read. Note also that C79 is a 100V component with radial leads, not like the rest of the axial leaded 0.1?F decoupling capacitors.

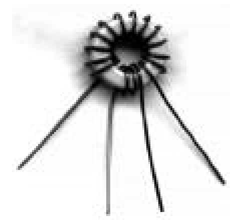
Lastly, the fun part, winding the transmitter toroids. Here are the details:

? T5 and T6 use a T37-2 toroid core. Cut 12” of red 28awg wire (item 129) for the main 18 turn windings and 3” of red 28awg wire (item 129) for the 2 turn link windings:



<u>Completed T5</u>
<u>(T6 is the same)</u>

? T7 uses a T37-2 toroid core. Cut 8” of red 26awg wire (item 127) for the main 13 turn winding and 4” of red 26awg wire (item 127) for the 3 turn link winding:



<u>Completed T7</u>

? T8 uses an FT37-43 toroid core. Cut two 9” pieces of 26awg wire, one red (item 127) and one green (item 128) and, keeping them neatly side by side, wind 10 bifilar turns onto the toroid:

<u>Completed T8</u>

To ensure correct phasing of the windings, the wire ends should be Red-Green-Red-Green as you look at the transformer (from left to right in the picture).

? L6 and L7 use T37-2 toroid cores. Cut 9” of red 26awg wire (item 127) for 10 turns on L6 and 8” of red 26awg wire (item 127) for 9 turns on L7:

<u>Completed L6</u>
<u>(L7 is the same, but with 1 turn less)</u>

? Connect a speaker/phones, an antenna and a set of paddles. Set VR6 and TC7-9 at their half way points. Connect your meter to the RF probe circuit at the transmitter output as before (meter on 20V DC range or thereabouts). Connect up the power and turn on. Tune the rig to mid-band.

? Re-peak the receiver tuning using TC2-4. You may have to go round the trimmers several times to get the best peak possible (incremental improvement). When you are happy with it, turn the rig off and connect a suitable 50? resistive dummy load to the antenna jack instead of the antenna. If you do not have a suitable dummy load, first make sure your antenna represents a good 50? resistive load to the radio (using a tuner), then find a clear frequency somewhere mid-band, listen for several minutes to make sure the frequency is dead. If it is clear, use this frequency to set the rig up. This is a last resort method. Even if you can find a 50? 1W carbon resistor, you would be better off tuning the transmitter up into that rather than an antenna.

? Using the TiCK programming push-button, SW1, set the rig into tune-up mode (continuous TX – 's t'). You should hear the continuous sidetone in the speaker/phones. If you are lucky, you will also see a small voltage reading on the meter. If you do, then you merely have to peak the reading using TC8 and TC9.

? Use the power control, VR6, to keep the maximum reading to around +4 to 5V on the meter. This will ensure the transmitter is easy to tune. Like many QRP transmit amplifier strip designs, it is much easier to find the tuning peaks while the power is kept to around the 1 to 2W level. If you don't see any reading on your meter, keep twiddling TC8 and TC9. Try both ends of the capacitance range and/or try setting the output power higher using VR6 temporarily to see if you can obtain a reading.

? The trimmer capacitors supplied with the kit either have a pointer or a tiny indentation (dot) that shows you where they are in their capacitance range. When the pointer, or dot, points to the flat end of the trimcap's body, that's minimum capacitance. When it points to the opposite end, that's maximum capacitance. There are two ways to get from minimum to maximum capacitance, so that's why you should always see two peaks in the tuning. If you don't see two peaks, something is wrong with the tuning. This is true for the filter receiver front-end filter (TC2-4) as well as the transmitter.

? Once you have peaked the transmitter tuned circuits at the 1 to 2W level, you can simply adjust VR6 to set the output power from nothing (0W) to around 6 or 7W. The maximum power available will depend heavily on the gain of the devices in your radio. Unfortunately, the output power monitor probe circuit is not calibrated in any way, so a direct relationship to the reading you obtain and the power level actually transmitted is not possible. The meter type used will also have a large effect on the readings obtained. Older analog meters with as low as 10K? /V input resistance will show much smaller readings than modern DMM's. As a reference point, using my Fluke 75 series DMM, at 5W output my meter reads +9.3V on the probe output. There are two sure ways to set the power output to 5W (exact enough for QRP purposes). The first is to use a calibrated power meter (such as the Stockton Wattmeter from Kanga or the Oak Hills Research WM-1 or WM-2 QRP Wattmeters). The second is to run the transmitter into a good dummy load then use a calibrated oscilloscope to measure the RF voltage at the load and convert it to Watts. To save you the trouble with the math, 4.95W output is 44.5V peak-to-peak into 50? .

If you cannot get at least 5W out of the transmitter, then you might start looking at the various critical devices in the transmit chain to see if a swap out may improve things. Start with the VFO FET (Q2, J310) - we have found that some FETs exhibit lower gain and produce less VFO output. If you have access to an oscilloscope, try checking the VFO output level. You should see about 4V peak to peak at Q3's collector. Please contact NorCal if you need a replacement FET.

? When you are happy with the power output setting, you need to set up the transmit frequency offset. This is set using TC7. Turn off the power to the rig and temporarily insert R52 (1M?) or the other spare resistor (100K? or 220K?). You can simply push it into the PCB holes without soldering it for this test. Power the rig on again. Press and hold the TiCK programming push-button SW1 until you hear 's t p a' then let go. Hit the dit paddle to turn the TiCK sidetone OFF. When you transmit now, you should not hear any TiCK sidetone: you will hear real sidetone from the receiver.

? Press and hold SW1 again until you hear 's t' then let go. This will put the rig into tune-up mode again. Set the volume control to maximum. Using an insulated adjustment tool (a sharpened/shaped stick end will do), adjust TC7 until you hear your "real" sidetone at the frequency *you* want the offset to be. This will be your real transmit offset regardless of the sidetone frequency from the TiCK (which is about 700Hz). To make zero beating with received stations simple, it is best to set the transmit offset to the same frequency as the TiCK sidetone, or very close. Remove the temporary R52 when you are done.

? If you really don't like the fixed frequency sidetone from the TiCK and prefer to hear "real" sidetone, you can insert a resistor into the R52 position permanently. 1M? is too high for this purpose. Start with 100K and adjust from there. A miniature 470K? pot for R52 would allow you to adjust the level to your liking easily. Of course, since the TiCK always powers up with sidetone enabled, you will have to disable it every time you power on your rig. This only takes a couple of seconds to do, so may be worth it: you decide.

Section 16 - Conclusion

At this point you should have a working NorCal 20 transceiver on your workbench. If it doesn't work, you will need to spend some time troubleshooting using the included guide (Appendix A). This shows typical voltages around the radio as well as signal levels expected. Simply running through the table till you find a mismatch between typical and your rig should allow you to pinpoint the problem fast.

If you followed the manual to build your radio, there should be no way that you let the smoke out of any of the devices in it. If you didn't follow the manual and have let the smoke out of one or more devices, you should be able to find the culprit/s quite quickly using the troubleshooting guide.

The number one problem with newly built kits is solder bridging between pins and the number two problem is pins not soldered (either badly or not at all). Take some time to check the rig thoroughly for these two things before you pronounce it dead! When you are convinced that the soldering is good, have someone else check it again - often the builder of a rig cannot see a problem as they are too close to it and "can't see the forest for the trees".

You will probably want to fine tune everything again and set the TiCK and AFA levels to suit your operating practices as well as make several simple modifications. Some modifications were planned for (pads put onto the PCB). These are described in Appendix B. The simplest modification by far is the TiCK upgrade to the Super TiCK with memories and beacon mode (see advertisement at the front of the manual).

You can simply fit the top and bottom case panels and use the rig as it is or spend some time and effort to paint and decorate the radio to your liking. If you want a really good looking case don't forget the black anodized and machine engraved cases available from the San Luis Machine Company (see advertisement at the front of the manual).

Lastly, please send me details of any other modifications, improvements or problems you find with the rig, I'd love to hear about them. Email me at AD6A@qsl.net with the subject line "NorCal 20 Feedback".

Have fun operating your newly built NorCal 20 rig.

72, Dave Fifield, AD6A

Appendix A – Troubleshooting Guide

Typical Voltages and signal levels with power supply = +13.8V, dummy load connected to antenna jack:

Circuit Ref.	Pin	Measured D.C.	Measured A.C.	Measurement Conditions/Comments
U1	2	3.93V	-	
U1	3	3.93V	-	
U1	6	3 - 8V 2 - 10V	-	1 turn pot, varies with TUNE setting 10 turn pot, varies with TUNE setting
Q1	gate	3.1 - 4V 0.4V	- -	RX, as RIT varied
Q1	source	3.5 - 4.4V 3.5 - 4.4V	- -	RX, as RIT varied TX, as RIT varied
Q1	drain	3.5 - 4.4V 3.8V	- -	RX, as RIT varied TX, shouldn't change as RIT varied
D3	cathode	3 - 8V 2 - 10V	-	1 turn pot, varies with TUNE setting 10 turn pot, varies with TUNE setting
L1	HOT	0V	20V p-p sine @ 5MHz	Probing will lower the VFO frequency Use 10x probe with approx. 10pF cap.
Q2	gate	0V	2.5V p-p sine @ 5MHz	Probing may stop VFO totally
Q2	source	0V	5V p-p sine @ 5MHz	
Q2	drain	7.9V	-	
U2	IN	13.45V	-	
U2	OUT	7.9V	-	
Q3	base	0.74V	0.1V p-p sine @ 5MHz	May appear slightly distorted
Q3	collector	9.3V	2.5V p-p sine @ 5MHz	
Q4	emitter	8.7V	2.3V p-p sine @ 5MHz	Bottom of waveform may be slightly flattened, this is okay
Q4	collector	13.2V	-	
Q5	source	1.6V	-	
Q5	drain	12.6V	-	
U3	4	-	0.5V p-p @ 5MHz	Waveform will be flattened/clipped sine, almost a square wave
Q6	base	4V	-	
Q6	collector	13V	-	
Q6	emitter	3.3V	-	
Q7	base	0.73V	-	
Q7	collector	7.2V	-	
Q8	collector	13.25V	-	
Q8	emitter	6.2V	-	
U4	1	1.4V	-	
U4	2	1.4V	-	
U4	4	5.4V	-	
U4	5	5.4V	-	
U4	6	6.5V	0.45V p-p @ 9MHz	Roughly sine - will probably be distorted
U4	7	5.9V	0.15V p-p @ 9MHz	Roughly sine - will probably be distorted
U4	8	6.6V	-	
D9	anode	0.81V	-	
D10	anode	0.81V	-	
D11	anode	3.1V	-	
D11	cathode	2.3V	-	
U5	1	6.7V	-	

Circuit Ref.	Pin	Measured D.C.	Measured A.C.	Measurement Conditions/Comments
U5	2	6.7V	-	
U5	3	6.7V	-	
U5	5	6.7V	-	
U5	6	6.7V	-	
U5	7	6.7V	-	
U5	8	13.4V	-	
Q9	gate	6.1V 0.4V	- -	RX TX
Q9	drain	6.7V	-	
U6	1	6.8V	-	
U6	6	0V	-	
U6	8	5.9V	0.1V p-p Noise	With VOLUME control full up
U6	14	13.4V	-	
Q10	gate	0.16V	-	
Q10	source	3.2V	-	
Q10	drain	12.7V	-	
Q12	base	1.1V	-	
Q12	collector	6V	-	
Q12	emitter	0.5V	-	
Q13	base	6.2V 0.9V	- -	RX TX
Q13	collector	13.4V	-	
Q13	emitter	5.5V 0.3V	- -	RX TX
U7	1	1.4V	0.15V p-p sine @ 5MHz	RX and TX
U7	2	1.4V	-	TX
U7	4	5.35V	0.15V p-p rough sine @ 14MHz	TX
U7	5	5.35V	0.15V p-p rough sine @ 14MHz	TX
U7	6	6.4V	0.3V p-p rough sine @ 9MHz	TX
U7	7	5.8V	0.15V p-p rough sine @ 9MHz	TX
U7	8	6.5V	-	TX
Q14	base	0.76V	Too small /noisy to measure successfully	TX
Q14	collector	6.6V	3V p-p sine @ 14MHz	TX
Q15	collector	11.5V	-	TX
Q15	emitter	6.0V	3V p-p sine @ 14MHz	TX
Q16	base	2.1V	1.5V p-p very rough sine @ 14MHz	TX
Q16	collector	13.4V	20V p-p sine @ 14MHz	TX - Output power set to maximum
Q16	emitter	1.5V	-	TX
Q17	emitter	1.5V	-	TX
Q18	base	0V	5V p-p distorted sine @ 14MHz	TX - Waveform will have positive going tops chopped off
Q18	collector	13.3V	20Vp-p distorted sine @ 14MHz	TX
J2	center	-	45V p-p clean sine @ 14MHz	TX

Circuit Ref.	Pin	Measured D.C.	Measured A.C.	Measurement Conditions/Comments
U9	1	4.9V	-	
U9	3	2.5V 2.5V	- 4.8V p-p square wave @ 600Hz	RX TX
U9	4	4.9V 0V	- -	SW1 open SW1 pressed
U9	5	0V 4.9V	- -	RX TX
U9	6	4.9V 0V	- -	RX TX, when the DAH paddle is pressed
U9	7	4.9V 0V	- -	RX TX, when the DIT paddle is pressed
Q19	base	0V 0.77V	- -	RX TX
Q19	collector	13.2V 0.06V	- -	RX TX
Q20	base	13.48V 12.46V	- -	RX TX
Q20	collector	0V 13.18V	- 1.5ms/2.5ms rise/fall	RX TX - rise/fall edges are linearly ramped
Q20	emitter	13.5V	-	
Q21	base	0V 0.76V	- -	RX TX
Q21	collector	6V 0.07V	- -	RX TX
Q22	base	0.63V 0.1V	0.7V p-p sine @ 5MHz 1.0V p-p sine @ 5MHz	RX - tops of sinewaves flattened a little TX - noisy
Q22	collector	2.47V 0.86V	4.2V p-p square @ 5MHz 1V pulses @ 2.85KHz	RX - almost squarewave, tops rounded TX - mostly noise, plus small pulses from AFA
Q23	collector	4.9V	-	
Q23	emitter	2.3V 0.3V	4V square @ 5MHz 1.2V pulses @ 2.85KHz	RX - superimposed with 39?s “blanking” every 0.35ms TX - 39?s positive going pulse every 0.35ms
U10	1	4.9V	-	
U10	2	2.35V	3.5V p-p sine @ 100KHz	
U10	3	2.8V	5V p-p square @ 100KHz	Top and bottom slightly rounded off
U10	4	0V 4.9V	- -	AFA in Manual mode - SW2 open AFA in Manual mode - SW2 pressed
U10	4	4.9v 0v	- -	AFA in Auto mode - SW2 open AFA in Auto mode - SW2 pressed
U10	5,6	~0.3V	Complex (4V) pulsed pulses waveform with bursts of 5MHz signal Complex (4V) pulsed pulses waveform	RX TX
U10	7	2.5V 2.5V	- 4.8V p-p pulsed square @ 1570Hz	AFA inactive AFA announcing frequency in Morse code

Appendix B – Modifications/Experimentation

TiCK upgrade

The NorCal 20 uses the basic TiCK keyer device. Users may upgrade this to the latest SuperTiCK or TiCK III from Embedded Research easily – the upgrade part is a drop-in replacement for the TiCK. The SuperTiCK provides extra features such as memories and beacon mode. An order form is provided for your convenience at the front of this manual.

Straight Key Input

There are two ways to run the NorCal 20 using a straight key. The first is simply to make up a special cable or adapter for your straight key, so that it can be plugged straight into the existing paddle jack socket. The second is to mount another jack socket, that matches your straight key's jack, on the rear panel (say, just below the existing paddle socket) and wire it to the DIT or DAH input of the TiCK.

There is a test pad labeled 'K' on the board where you could connect an external keyer or straight key directly. Grounding this point will cause the NorCal 20 TX to operate, but will not generate any TiCK sidetone. "Real" sidetone from the RX can be had by inserting an audio "leak" resistor at R52 (approximately 100K?).

Frequency Range

The LF351 op-amp used for U1 is a compromise device (price/performance) and as such has some limitations. For best results, this op-amp should be operated with the output voltage in the region (approximately):

(Vss + 2V) < Vout < (Vdd –2V)

The NorCal 20 circuit is designed to stay within this range. Fortunately, the characteristics of varicap diodes are such that below about 2V, although their capacitance change is largest, they are inherently non-linear - not very useful for a tuning dial. Experimenters may like to substitute other op-amps with full rail-to-rail performance (expensive) for U1, in which case may wish to use an 8-pin Dual In-Line (DIL) socket for this part (not supplied).

The tuning range of the rig as supplied with the 1 turn pot is limited to about 30KHz. With a 10 turn pot and the required changes ('10t' links and R9 = 220K?) this is extended to about 70KHz. Increasing the value of C5 can further extend the tuning range. This capacitor must be an NPO part.

VFO output

A clean sine wave VFO output is available from the 'V' test point on the board. This output is ideal for feeding LCD frequency displays such as the K1MG DCC Kit, from Blue Sky Engineering. A coupling capacitor is required to feed this output (not supplied). Use the lowest possible value you can (start with 5pF and work up), to avoid loading the NorCal 20 VFO circuitry.

XIT/RIT

Although the NorCal 20 only has RIT as standard, it is a relatively simple matter to add a switch to allow selection of RIT/OFF/XIT. The switch required is a simple SPST with center OFF position. To do this modification, cut the XIT mod-track on the underside of the board. Then, take two wires from the XIT holes and a third from the test point marked 'T' on the board (sheet 5 of the schematic). These three wires go to the switch. Voila, it's done.

If you did the 10 turn pot modification, you will notice that the RIT range will have changed from about ? 1.2KHz with the 1 turn pot to about ? 3KHz with the 10 turn pot. This is as a result of the gain of U1 changing from –1 to –2.2 roughly. You can change the RIT range to just about any value you desire by changing the value of R5. Making R5 smaller will increase the RIT range and making it larger will decrease the RIT range.

Data Modes

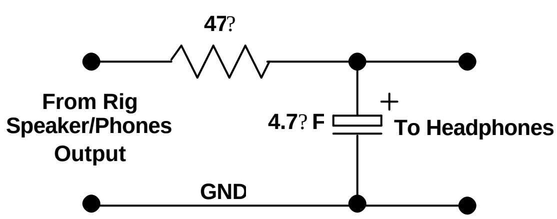
The NorCal 20 can be modified quite simply to add RTTY or other data modes. Since the rig is varicap diode tuned and the varicap is fed by a summing op-amp, any FSK offset you desire (positive or negative) can be had by feeding the appropriate voltage to the 'D' test point on the board - via a resistor to set the gain of course. Received audio for data recovery is available from the 'A' test point on the board – PCB traces are provided to add a miniature trimpot to vary the fixed audio output level (next to VR4) labeled "Trimpot" and either a resistor or a capacitor in the position labeled "R/C". The constructor will have to supply these parts.

Internal Loudspeaker

It is possible to use an internal loudspeaker with the NorCal 20. However, care and attention should be paid to the effect that the magnetic field of the chosen loudspeaker will have on the tuned circuits (toroids) in the rig. It is recommended that the user pay due diligence by experimenting with the chosen loudspeaker before drilling holes in the rig's top! I found a 3" low profile 8? 0.8W speaker that fitted perfectly. The only effect it had on the circuitry was to lower the VFO frequency a couple of KHz. Your mileage may vary – experiment before drilling holes.

Headphones

Some users will notice high frequency hiss when using sensitive hi-fi type earphones plugged directly into the loudspeaker jack socket. This is due to the LM380 audio amplifier. Some samples of this amplifier are worse than others. Should this be a concern, you can add a simple RC low pass filter to the output. A 47? resistor in series with the earphones with a 4.7?F capacitor in parallel across them (as per the circuit below) will be a good starting point – you can play with the values here to find what suits you and your headphones.



The RC filter can be added externally, in the form of an adapter cable assembly, or internally (permanently), either by cutting the tracks under the loudspeaker jack socket and adding the components to the underside of the board, or by adding another rear panel mounted jack socket especially for phones, with the RC filter components feeding it from the main PCB.

AGC

There is great scope for experimentation and modification of the AGC system in the NorCal 20. The time constants chosen (standard values supplied) may be too long or short for your liking. You can modify them to your heart's content. The value of C63 or R60 can be changed to adjust the time constant of AGC2. Changing C63 to 0.47?F or 0.33?F is a popular modification. The gain of the AGC2 circuits can be altered by changing R59 (this can be made a 470K? trimpot if you like). AGC1's time constant is not so variable. Capacitor C65 is the only variable here. This capacitor needs to be quite large to keep audio out of the AGC – horrible sounding motorboating can result if it is made too small.

The setting of the idle level of AGC2 can be experimented with. This level is slightly temperature sensitive – it will drift downwards as the rig's temperature rises. It should be set so the AGC starts to act (i.e. the attenuators start to attenuate) at the chosen incoming signal level. The setting in the manual is a median, you may find it works better with the level set higher or lower than 5.5V.

Other Bands

The NorCal 20's architecture lends itself to conversion for operation on several other bands, but with some caveats. In particular, the AFA is designed to work ONLY at 5MHz. It will NOT work at other VFO frequencies. K1MG/Blue Sky Engineering may produce replacement AFA chips specially designed for other common bands, but nothing is guaranteed/promised at this time.

With some simple tuned circuit changes and a change in the VFO frequency from 5 to 5.5MHz, the rig can work on 3.5MHz (80m). The VFO can be brought up to 5.5MHz simply by removing a few turns from L1. The RX and TX tuned circuit changes are left for the user to experiment with. Since the VFO will tune "backwards" for 80m, it is a simple matter of changing the '1t/10t' links for the TUNE pot to get the tuning control the right way round.

The rig could also be made to operate on 40m and 30m with some more extensive VFO changes as well as the requisite RX/TX tuned circuit changes. Remember that it took 4 beta testers hundreds of test hours to get the VFO temperature coefficient right for 5MHz operation – an equivalent amount of work will be imperative if operation on other bands is to be successful.

Operation on higher bands will require extensive changes (highly undesirable) to the design, such as a higher IF, which would require the crystal filter to be re-designed, and a premixed local oscillator scheme.

Test Points

There are many test points (pads) provided on the board and most signal points are easy to probe directly on the relevant pin. There are also several ground points (marked 'G') provided. The user can fit these with test points/headers (not supplied) to make testing/measuring signals in the rig easier.

Appendix C – Operating Guide

TiCK operating instructions

ACTION	TiCK RESPONSE	FUNCTION – When SW1 Released
Press pushbutton SW1	"**S**" (dit-dit-dit)	**SPEED:** To adjust speed: press DIT paddle to decrease, DAH paddle to increase
Hold Pushbutton Down	"**T**" (dah)	**TUNE:** To end tune-up, press either paddle or SW1 again
Hold Pushbutton Down	"**P**" (dit-dah-dah-dit)	**PADDLE:** Press the paddle you want to designate as the DIT paddle. Default : DIT = tip of stereo jack
Hold Pushbutton Down	"**A**" (dit-dah)	**AUDIO:** Press the DIT paddle to enable sidetone, DAH paddle to disable. Default: enabled.
Hold Pushbutton Down	"**SK**" (dit-dit-dit, dah-dit-dah)	**STRAIGHT KEY:** Pressing either paddle toggles the TiCK between Straight Key and Keyer Mode. Default: Keyer Mode.
Hold Pushbutton Down	"**M**" (dah-dah)	**MODE:** Pressing the DIT paddle puts the TiCK into Iambic Mode A, DAH paddle puts it into Iambic Mode B. Default: Iambic Mode B
Hold Pushbutton Down	"**K**" (dah-dit-dah)	**KEYER:** If the user releases the pushbutton, keyer returns to normal operation
Hold Pushbutton Down	"**S**" (dit-dit-dit)	Cycle repeats with **SPEED** adjust.

Warm-up period – VFO drift

There is a trade-off for having good receiver performance. The receiver uses about 150mA, at 13.8V. That's just a little over 2 Watts! This heat has to go somewhere. It goes into the whole rig, slowly, from power-up. This means the VFO also sees a fairly substantial temperature rise from power-up. The effect has been mitigated with careful VFO design and component choice. The overall temperature coefficient of the VFO is quite low, but still non-zero. As a result, there will be some small amount of VFO drift from power-up.

The worst drift will be in the first few (~5) minutes when the VFO may drift a few hundred Hz (+200 to +400Hz is typical). The drift slows rapidly and, once the internal temperature has stabilized, at around 30 minutes, becomes almost negligible at around +30 to 50Hz per hour. Of course, local environmental conditions will have a lot to do with the actual drift experienced so your mileage may vary. In reality, this drift is a whole lot better than some other radios currently on the market.

Experimenters may like to optimize their particular rig for minimum possible temperature coefficient. Two capacitors, the combination of C6 in series with C107, and C108 are the components to adjust. Try more polystyrene capacitance and less C0G or vice-versa, but be careful to keep the combined capacitance the same as the original design.

A temperature-controlled oven would be the fastest and most accurate way to determine the temperature coefficient, although simply measuring the frequency every few minutes from a cold start is quite a reasonable method.

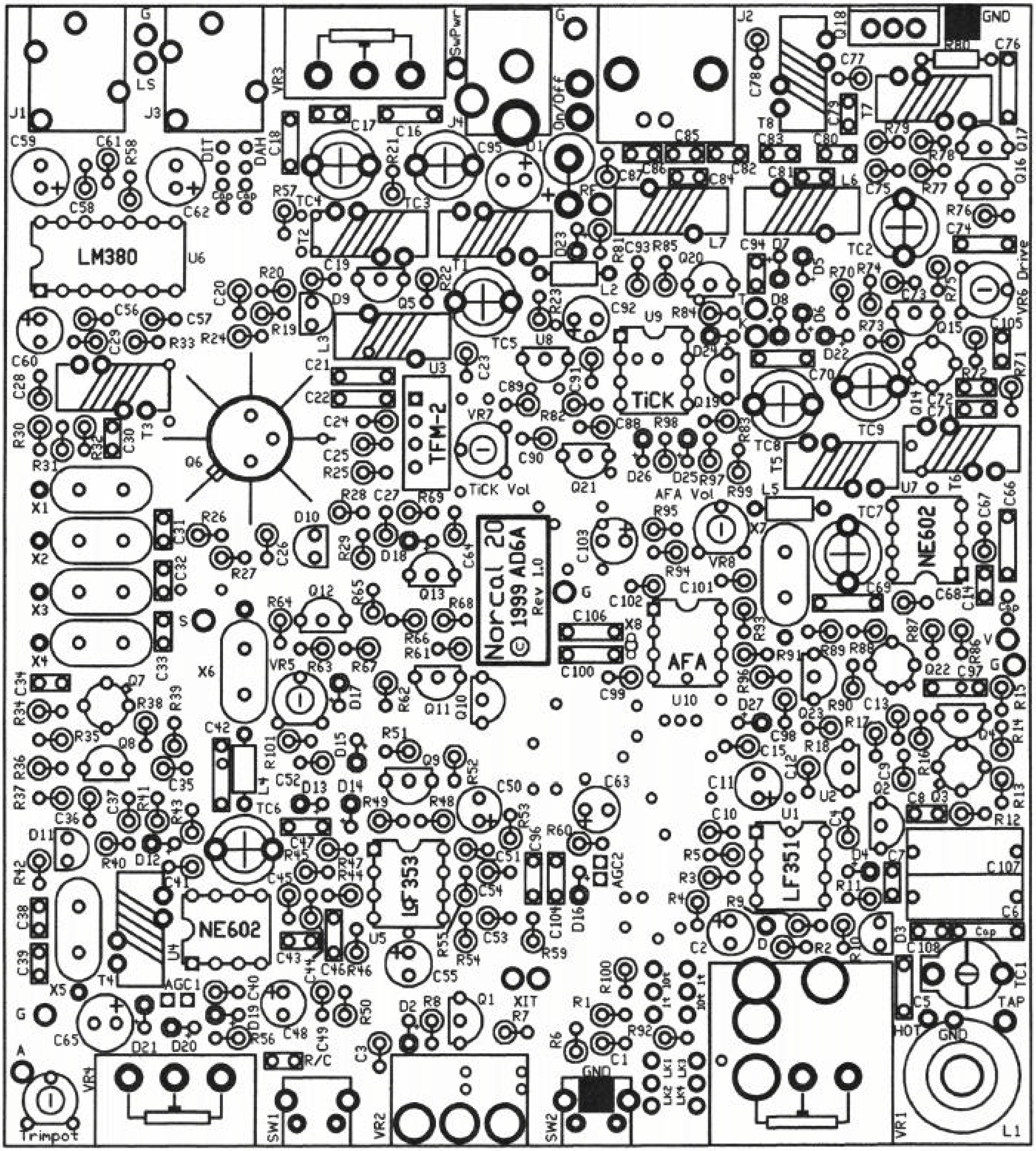
Whatever the actual start-up drift of your particular rig, make sure it has stabilized prior to going on the air.

Using the RF Attenuator

Certain loud stations may induce what is known as AGC "popping". Really loud stations may cause the AGC to almost completely shut down the receiver for a second or so until the AGC loop/s have a chance to recover. The cure for this is simply to turn up the RF attenuation using the pot on the rear panel.

Appendix D - PCB Component Placement

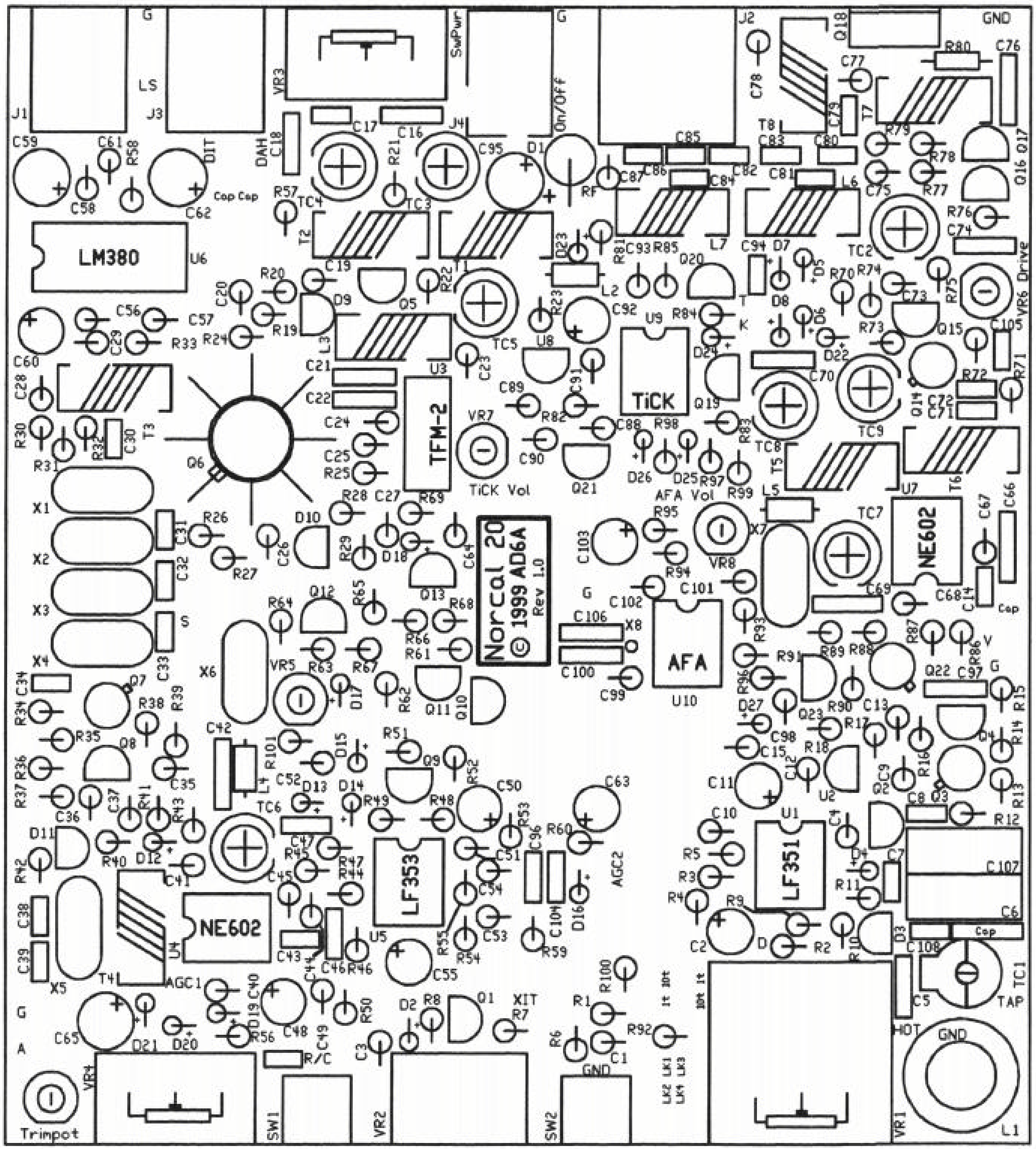
Rear Panel



Front Panel

Appendix E – Silk Screen

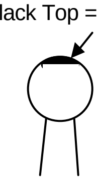
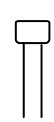
Rear Panel

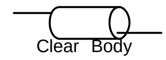
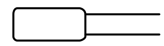
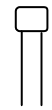
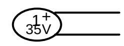
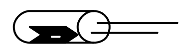
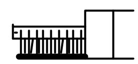
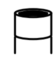
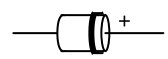
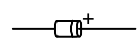
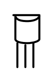
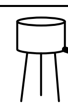
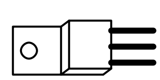


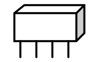
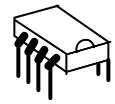
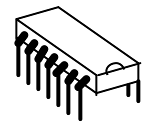
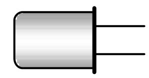
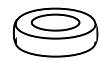
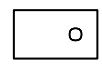
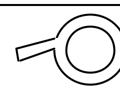
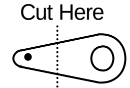
Front Panel

Appendix F - Circuit Diagram

Appendix G - Parts List

Item #	Description	Value/Type (Marking)	Quantity	Circuit References	Identification
1	Resistor 1/4W 5%	2.7? (Red-Vlt-Gld)	1	R58	
2		5.6? (Grn-Blu-Gld)	1	R26	
3		10? (Brn-Blk-Blk-Gld)	5	R17,33,39,48,57	
4		15? (Brn-Grn-Blk-Gld)	3	R22,77,78	
5		22? (Red-Red-Blk-Gld)	1	R80	
6		39? (Org-Wht-Blk-Gld)	2	R31,79	
7		47? (Yel-Vlt-Blk-Gld)	2	R18,34	
8		100? (Brn-Blk-Brn-Gld)	7	R19,23,27,28,41,74,96	
9		150? (Brn-Grn-Brn-Gld)	3	R30,32,35	
10		220? (Red-Red-Brn-Gld)	3	R21,66,67	
11		330? (Org-Org-Brn-Gld)	1	R64	
12		470? (Yel-Vlt-Brn-Gld)	4	R15,25,37,89	
13		680? (Blu-Gry-Brn-Gld)	2	R43,70	
14		1K? (Brn-Blk-Red-Gld)	8	R24,40,42,62,63,69,85,91	
15		1.2K? (Brn-Red-Red-Gld)	2	R36,76	
16		1.5K? (Brn-Grn-Red-Gld)	1	R16	
17		2.2K? (Red-Red-Red-Gld)	6	R20,29,71,73,90,99	
18		3.3K? (Org-Org-Red-Gld)	4	R53,86,100,101	
19		4.7K? (Yel-Vlt-Red-Gld)	3	R38,75,84	
20		5.6K? (Grn-Blu-Red-Gld)	1	R13	
21		6.2K? (Blu-Red-Red-Gld)	1	R54	
22		10K? (Brn-Blk-Org-Gld)	13	R10,49,50,61,65,68,81,83, 92,94,95,97,98	
23		12K? (Brn-Red-Org-Gld)	1	R87	
24		15K? (Brn-Grn-Org-Gld)	1	R72	
25		22K? (Red-Red-Org-Gld)	3	R44,45,93	
26		27K? (Red-Vlt-Org-Gld)	1	R12	
27		33K? (Org-Org-Org-Gld)	1	R88	
28		47K? (Yel-Vlt-Org-Gld)	2	R14,56	
29		56K? (Grn-Blu-Org-Gld)	1	R82	
30		82K? (Gry-Red-Org-Gld)	2	R46,47	
31		100K? (Brn-Blk-Yel-Gld)	2	R2,9	
32		220K? (Red-Red-Yel-Gld)	3	R9,55,59	
33		330K? (Org-Org-Yel-Gld)	1	R5	
34		1M? (Brn-Blk-Grn-Gld)	4	R8,11,51,52	
35		4.7M? (Yel-Vlt-Grn-Gld)	1	R60	
36	Resistor 1/4W 1%	8.2K? (Gry-Red-Blk-Brn-Brn)	1	R1	
37		10K? (Brn-Blk-Blk-Red-Brn)	2	R3,4	Blue Body
38		33K? (Org-Org-Blk-Red-Brn)	2	R6,7	
39	Capacitor radial disc ceramic NPO	2pF (2)	2	C86,105	
40		5pF (5)	2	C7,17	
41		10pF (10)	3	C8,14,72	Black Top = NPO
42		22pF (22)	1	C5	
43		33pF (33)	2	C100,106	
44		39pF (39)	2	C16,18	
45		68pF (68)	1	C70	
46		100pF (101)	3	C21,74,97	
47		150pF (151)	4	C42,66,69,76	
48	Capacitor radial disc ceramic	270pF (271 no black top)	1	C22	
49	Capacitor radial ceramic C0G 5%	82pF (820, G0G)	1	C108	
50		820pF (821)	5	C30,31,32,33,34	
51	Capacitor radial ceramic C0G 100V 5%	47pF (470)	3	C71,81,82	
52		100pF (101)	1	C84	
53		270pF (271)	1	C85	
54		330pF (331)	1	C80	
55		560pF (561)	1	C83	
56		680pF (681)	2	C38,39	

57	Capacitor axial polystyrene 5%	120pF (120J)	1	C107	 Clear Body
58		180pF (180J)	1	C6	
59	Capacitor radial polyester film 100V 10%	1000pF (102)	2	C96,104	Green Body 
60		1500pF (152)	2	C46,47	
61	Capacitor radial ceramic X7R	0.047?F (473)	1	C43	
62	Capacitor radial X7R 100V 10%	0.1?F (104)	1	C79	
63	Capacitor Z5U 50V 20%	0.47?F (474)	1	C94	
64	Capacitor axial X7R 50V 10%	0.01?F (103)	13	C3,20,24,27,36,37,53,54, 57,88,89,99,101	
65	Capacitor axial X7R 50V 10%	0.1?F (A1, MO, 74 in tiny characters)	37	C1,4,9,10,12,13,15,19,23, 25,26,28,29,35,40,41,44, 45,49,51,52,56,58,61,64, 67,68,73,75,77,78,87,90, 91,93,98,102	
66	Capacitor radial tantalum bead 35V	1?F (1, 35V)	1	C63	
67	Capacitor radial elec alum 16V	4.7?F 16V	2	C55,60	
68	Capacitor radial elec alum 16V	10?F 16V	6	C2,11,48,50,92,103	
69	Capacitor radial elec alum 16V	100?F 16V	4	C59,62,65,95	
70	Precision air trimmer capacitor	2 - 20pF	1	TC1	
71	Ceramic trimmer capacitor	8 - 50pF	8	TC2,3,4,5,6,7,8,9	
72	3A Schottky Diode	1N5822	1	D1	
73	General purpose small signal diode	1N914	20	D2,4,5,6,7,8,13,14,15,16, 17,18,19,20,21,23,24,25, 26,27	
74	Zener diode 6.8V 400mW	1N754A	2	D12,22	
75	Varicap diode, TO92	MV209	1	D3	
76	PIN Diode, TO92	MPN3404	3	D9,10,11	
77	JFET, TO92	MPF102	2	Q1,9	
78	JFET, TO92	J310	3	Q2,5,10	
79	NPN GP transistor, TO92	PN2222A	4	Q4,15,16,17	
80	NPN GP transistor, TO92	2N3904	6	Q8,12,13,19,21,23	
81	PNP GP transistor, TO92	2N3906	2	Q11,20	
82	Voltage reg.+8V 100mA, TO92	LM78L08	1	U2	
83	Voltage reg.+5V 100mA, TO92	LM78L05	1	U8	
84	NPN RF transistor, TO72	2N5179	4	Q3,7,14,22	
85	NPN medium power RF transistor, TO39	2N4427	1	Q6	
86	NPN RF power transistor, TO220	2SC1969	1	Q18	

87	Minicircuits +7dBm mixer, B02 case	TFM-2	1	U3	
88	GP single op-amp, 8-pin DIL	LF351N	1	U1	
89	GP dual op-amp, 8-pin DIL	LF353N	1	U5	
90	Double-balanced mixer/oscillator, 8-pin DIL	NE602A	2	U4,7	
91	Programmable keyer, 8-pin DIL	TICK Rev.1.02	1	U9	
92	Audible Frequency Annunciator (AFA), 8-pin DIL	12C508A	1	U10	
93	Audio amplifier 2W, 14-pin DIL	LM380N	1	U6	
94	Crystal AT cut fundamental, HC-49/u	9.000MHz	7	X1,2,3,4,5,6,7	
95	Crystal, C-2 type	100KHz	1	X8	
96	Toroid core	T50-7 (White)	1	L1	
97		T37-6 (Yellow)	2	T1,2	
98		T37-2 (Red)	6	L3,6,7 & T5,6,7	
99		FT37-43 (Plain)	3	T3,4,8	
100	Miniature RFC	15uH (Brn-Grn-Blk-Gld)	2	L4,5	
101		4.7uH (Yel-Vlt-Gld-Gld)	1	L2	
102	TO-220 insulating washer		1		
103	TO-5 transistor standoff insulator for Q6		1		
104	Nylon screw (for Q18)	6-32 x 1/2"	1		
105	Metal nut for nylon screw (Q18)	6-32 Nut	1		
106	Large solder lug for front panel ground	0.4" ID	1	Fits on RIT pot VR2	
107	Solder lug (rear panel ground)		1		
108	Screw (solder lug ground)	4-40 x 0.25"	1		
109	Nut for screw (solder lug ground)	4-40 Nut	1		
110	Fiber shoulder washer for L1		2		
111	Nylon screw for L1	6-32 x 1/2"	1		
112	Nylon nut for L1	6-32 Nut	1		
113	Screws for assembling box - countersunk	4-40 x 0.25"	8		
114	PCB - double sided, plated through, solder masked		1		
115	Box (4 pieces)		1		
116	Push-button switch	TL1105S	2	SW1,2	
117	Potentiometer, min., 17mm, PCB	10K	3	VR1,3,4	
118	Potentiometer, min.,16mm, center detent	10K	1	VR2	
119	Potentiometer, 6mm, carbon trimmer (trimpot)	10K	3	VR5,7,8	
120	Potentiometer, 6mm, carbon trimmer (trimpot)	500R	1	VR6	

121	Knob, black for TUNE control	1.39" dia.	1		
122	Knob, black for RIT, AF & RF controls	0.77" dia.	3		
123	Power jack (socket) PCB mount, NC switch	2.1mm	1	J4	
124	BNC socket with lock ring and nut	50 Ohm BNC	1	J2	
125	Stereo jack socket, switched, with nut	3.5mm	2	J1,3	
126	Finned Heatsink for Q18	TO-5	1		
127	Magnet wire - NYSOL, red	26awg	10 feet	Toroid inductors	
128	Magnet wire - NYSOL, green	26awg	10 feet	Toroid inductors	
129	Magnet wire with poly coating - heavy NYSOL	28awg	10 feet	Toroid inductors	
130	Stick-on rubber feet	0.5"dia	4		