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Thank you for deciding to build this transceiver. I hope you are pleased with the final assembly.

This manual details the assembly for the simple qrp 40 meter transceiver. The design includes a high performance receiver and a 5 watt transmitter. This level meets the 5 watt QRP output and can drive an external amplifier if desired. The design includes a color digital display and an adjustable bandwidth crystal filter to provide selectivity for SSB or CW reception. The transceiver will interface with a manual key or an electronic keyer without change and supports keying to ground or keying via a positive voltage being applied. The receiver also has an AGC (automatic gain control) function. Variable selectivity is via a panel mounted potentiometer. Audio output is by way of a speaker or headphones. A side tone function follows key presses to give an audible indication of transmission. If not wanted, it can be turned off by adjusting the level control on the PCB.

The rig is designed to be powered by 12 volts, and capable of CW transmission on 40 meters with a power output of 5 watts. The transceiver is software controlled using an inexpensive Arduino NANO and a Si5351 digital PLL module. These provide exceptional stability and the software can be easily modified to add additional features in the future if desired. Check my web site for software updates if necessary.

The design: (figure 3, schematic), (figure 4, printed circuit board)

As I do with all my designs, I use only through hole parts to make assembly easy. The Arduino NANO and Si5351 do have surface mount parts but these are pre-assembled and the modules just plug into the circuit board.

This circuit board measures (6.24” by 4”).

The power amplifier, IRF510, requires a heat sink but since the transceiver was intended to be enclosed in an aluminum chassis, the chassis functions as the heat sink. It is more than adequate for that purpose. Any aluminum case large enough to hold the board will provide enough heat dissipation as a heat sink at this power level. The IRF 510 Mosfet runs cool even after key down for several minutes. Be sure to isolate this device from the cabinet with a mica or silicone insulation tab as the drain is the mounting tab.

The IRF510 device is driven via a simple low pass filter by a class C amplifier stage. I have used a mini circuits 10 MHz T low pass filter but you can construct a substitute with two 43 mix ferrite beads and a 600 pF capacitor.(figure 8). I have used several different transistors to drive the final including 2N2222A and a 2n3904. The 2n3904 can get hot if keyed too long but the 2N2222 works OK especially with a small heatsink attached. Either will work in the application. Place a 43 mix ferrite bead on the base lead of the driver transistor.

Because of the low cost and wide availability, 2n3904 transistors were used extensively throughout this board. They work well in the receive RF amplifier, the two IF amplifiers, the audio pre-amp, AGC circuitry and side tone oscillator.

For simplicity, I used a simple SPST toggle switch to switch the transceiver from receive to transmit. When activated, it supplies 12 volts to the relay. The relay then switches the band pass filter from receive to transmit configuration and supplies a LOW to the arduino D12 pin to indicate transmit mode. The software is then triggered to shut off the clock 2 (BFO) output and activate the clock 1 (transmit) output that is connected to the RF amplifier. CW output is not active until +12 volts is supplied to the amplifier stages. The key supplies +12 volts to the transmit RF stages, bias regulator and side tone oscillator, or if you prefer to key to ground (most keyers use this method), a key attached can control a P channel Mosfet that then supplies the 12 volts necessary when keyed. Each connection is on the board so either can be connected as desired. This approach is different than usual for keying the final amplifier, that usually grounds the circuit, however by doing it this way, no current is used for bias on the output stage except during the actual key down time thereby saving current and extending battery life when portable. It also reduces heat in the final amplifier device.

A five volt linear regulator supplies bias to the RF final only when keyed but a second 7805 regulator runs all the time and sends 5 volts to the Arduino NANO and Si5351 module and display. This device is also mounted using the cabinet as a heatsink, but does not need to be isolated. It, like the final RF

amplifier, mount under the circuit board and the leads are bent upward through the board. Access for the # 4 mounting screw is available by way of a hole is the circuit board.

The LED display shows an indication when the transceiver is in receive or transmit mode by displaying an "R" or "T" on the screen.

The color display shows the tuned frequency, the tuning step selected, and the "R" or "T" indication. The step is selected by momentarily pressing the tuning knob. It will always be set to 1 kHz steps on power up and each press will decrement the step size down to 100 Hz to 10 Hz then up to 100 kHz, 10 KHz and back to 1 KHz.

The AF control, of course, sets the audio output level to the speaker, or earphones. Power output is adequate to drive a large speaker to a high level. The Bandwidth control adjusts the bandwidth of the IF crystal filter from around 3 kHz to about 300 Hz so it is easy to set optimally for AM, SSB or CW reception.

Since everything except the controls, connectors, and display are contained on the single board, you can package this design in many ways.

Final Circuit Description:

When the transceiver is in the receive mode, the antenna jack is connected to the 40 meter bandpass filter consisting of three toroid inductors, U$1, U$2 and U$6. U$1 and U$2 are T50-6 (yellow) cores with 43 turns of number 28 wire. Inductance is 4.7 uH. U$6 is a T50-6 core but with 6 turns of number 28 wire with an inductance of 0.15 uH. C7 and C8 are mica capacitors and C52 is a high voltage ceramic.

Output from the band pass filter connects to the one contact of the DPDT relay. When not activated, it couples the band pass filter to the input of the receive RF amplifier that then connects to the double balanced diode mixer where this signal is then mixed with the local oscillator from the Si5351 and the output from the mixer feeds the adjustable bandwidth crystal filter at 9 MHz. The bandwidth is controlled by the voltage applied via a potentiometer. Lower voltage narrows the filter response.

Following the filter, two stages of IF amplification provide the gain necessary to feed another double balanced diode mixer/detector. In this mixer, the RF at 9 MHz is mixed with the BFO signal from the Si5351 thereby producing audio. The BFO signal is only applied when in receive mode. The second IF stage gain is controlled by the output of the AGC circuitry. On strong signals, current applied to the emitter connected diode is drawn down by Q4 of the AGC output and thereby cuts the gain in this stage.

The detected audio output is connected to the input of the audio pre-amplifier and then to a volume control. The return from the volume control passes through a low pass filter to attenuate upper audio response above 3 kHz and then into an LM386 audio IC which drives the speaker. Audio is sampled at the output of the audio pre-amp and used by the AGC circuitry to control IF amplifier gain.

When the transceiver is in transmit mode, the antenna is still connected to the band pass filter, but the output now is switched by the relay to the output of the final IRF510 amplifier. Since the band pass filter has been designed for 50 ohms on both ends, it can be used in reverse. The relay also triggers the Arduino NANO to stop BFO output (which then stops the detector from producing audio output), and to turn on the carrier output from the Si5351 on clock 1. This carrier signal is applied to the RF driver stage then through a "T" filter to the final. The NANO also changes the "R" indication to a "T" on the display. When keyed, power is applied to the RF driver, voltage regulator for Bias, the final amplifier and the side tone oscillator circuit. This then produces the CW output to the antenna. The side tone oscillator is coupled to the audio stage so it can be heard in the speaker or headphones when keyed. An initial level adjustment is available on the board, but the level will follow the volume control setting.

The external connections are detailed in (figure 6).

Assembly:

NOTE: BEFORE LOADING ANY PARTS ONTO THE PC BOARD, USE THE BARE BOARD TO MARK THE MOUNTING HOLES AND HOLES FOR THE 7805 REGULATOR AND FINAL IRF510 DEVICES ONTO YOUR MOUNTING SURFACE.

It is recommended assembly for the circuit board is done in the following manner.

1. Mount the two double balanced mixers to the circuit board.

2. Install all resistors.

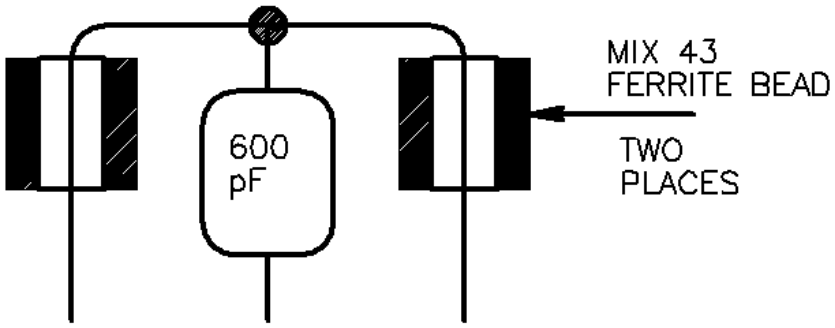
3. install all capacitors.

4. install diodes. Be sure to orient them with the band end as indicated on the board.

5. install headers for the Arduino NANO and Si5351 modules. (trim to size)

6. install low pass filter (LCL1) in transmitter stage. Alternate assembly shown below.

ALTERNATE PART FOR LCL1



7. Construct all inductors and install.

8. Install all trimmers on the circuit board.

9. Install inductor L1

10. Install the relay.

11. Install all transistors and the audio amplifier IC. There is room provided for a socketif desired. Be sure to follow orientation shown on the circuit board.

12. Install the 7805 voltage regulator IC3

13. Install the keying Mosfet (Q6) on the circuit board. Follow orientation indicated.

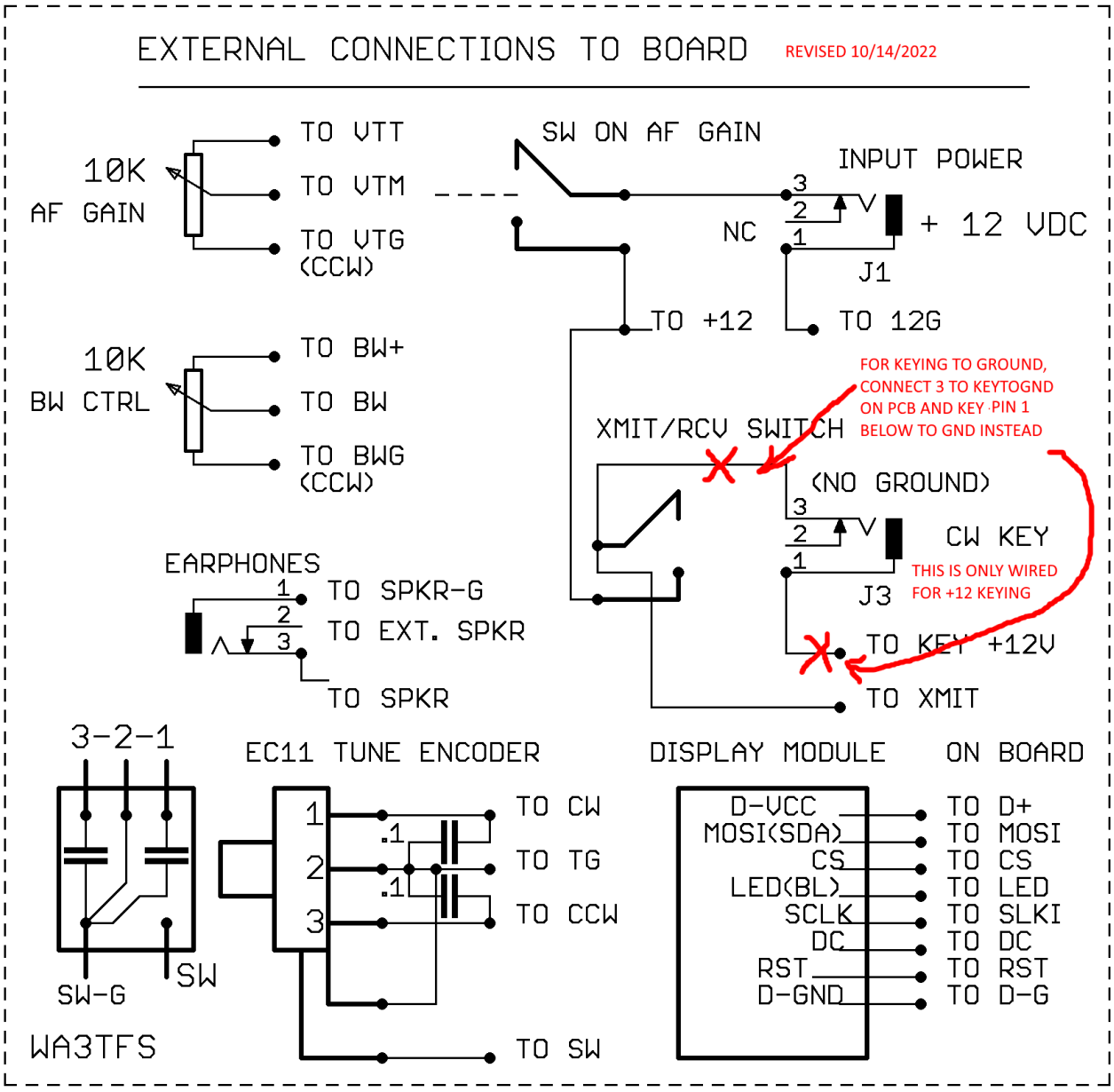
14. Bend the leads of the 7805 voltage regulator upward 90 degrees at the point where the leads narrow. Place the leads through the circuit board from the bottom side but do not solder yet.

15. Likewise, bend the final RF amp (IRF510) leads upward, place leads through the circuit board but do not solder yet. After the circuit board is mounted to the enclosure, this device and the voltage regulator can be soldered after they are mounted. The IRF510 must be isolated from the enclosure as the mounting tab is the drain of the device. Check after mounting that the tab does not ground to the chassis by using a multi-meter. After checking that the tab (drain) is not grounded, solder this device and the voltage regulator. (the voltage regulator tab is connected to ground and requires no isolation).

16. Upload the control software to the Arduino NANO. When complete, plug into the headers on the circuit board.

17. Plug in the Si5351 module. Check orientation with the markings on the circuit board. It will extend over the crystal filter.

Make all external connections to the display, bandwidth control, audio control, on/off switch, transmit/receive switch, antenna jack, key jack, and power input.



Initial setup:

Initial setup requires no test equipment other than some indicator of RF output such as SWR bridge, wattmeter, or an external nearby receiver not connected to an antenna.

1. Connect the antenna jack to an antenna.
2. Be sure the transmit/receive switch is placed in receive mode.

3. Apply 12 volts to the rig. The display will become active in about 2 seconds after turn on and indicate 7150.000 and "R" in upper corner. 'Step' will be set at 1 kHz.
4. Increase the volume control and note the audio output from the speaker/earphones. Bandwidth should be set to 'wide' for this adjustment. Adjusting the control will change the tone of the received signal and when tuning in a signal, it will become obvious when set to narrow.
5. With only atmospheric noise (no signal when attached to an external antenna) adjust the AGC control to the point where the noise just starts to lower in amplitude. This initial setting can be changed later as desired.
6. Connect the antenna jack to a dummy load. (if none is available, a matched antenna will work)
7. Put the transmit/receive switch into transmit mode.
8. Note the indicator on the display indicates "T" but there will be no RF out and receiver will mute.
9. Key the transmitter by activating the key at the key jack.
10. Adjust the BIAS control for maximum output. Level should be around 5 watts. Adjust the Bias control to set desired output.
11. Adjust the SIDETONE LEVEL for desired output. Do this with the volume control set to a good comfortable listening level.
12. Un-key and switch back to receive mode. Note "R" is displayed.
13. SETUP is now complete and the transceiver is ready to use. Tune in a CW signal and adjust the BW control and audio gain for best reception. Re-adjust the AGC setting if necessary so that a weak signal is received without attenuation and a strong signal is attenuated so as to not make excessive audio output. The response is set for very fast action but when the strong signal ends, a very short period of silence will be noted before atmospheric noise increases to normal level. Once set, no more adjustment is needed.

Conclusion:

This design has been proven to be a very usable QRP transceiver. The display provides the ability to accurately select a frequency and the controls allow selection of various tuning steps to select to fine tune the frequency. The rig is very frequency stable and will stay on frequency for hours on end. The bandwidth control helps eliminate interfering signals and the audio is high quality with enough output level to fill the room or can be adjusted so as not to overdrive headphones if used. The RF output is typically 5 watts and, by adjusting the bias control, can be set to the QRP level desired. Receiver performance is excellent. The Bandwidth control allows adjustment for good reception of LSB, CW or AM modulation modes.

I think you will find this a great rig for portable or emergency use or even as the main transceiver for CW operation. As with many of my other designs, I have circuit boards available. The Parts listing shows order numbers for components available from Digi-Key.com. Just send them the list for fulfillment.

Parts not available from them are listed in RED and can be obtained from other sources such as eBay or Amazon or similar. (figure 7, Parts List)

Software can be downloaded from my web page http://www.wa3tfs.com and additional information will be available as needed there. Since the transceiver is optimized for CW, receive frequency displayed when receiving LSB will be low by 1 kHz. I have provided the offset for LSB in the software by wiring a spst switch connected to D8 (available under the Nano), to ground, to set proper offset for LSB if that function is desired in software. Activate the switch and rotate the tune encoder to select the LSB frequency.

With the final design consisting of a single circuit board and some external controls, this can be packaged in many ways. The original Bud chassis (CU-3008-A) provides a sturdy, compact design that is a pleasure to use but this could be made much thinner, if desired, for backpacking. I think that if you decide to duplicate this design, you will be pleased with the performance and find it reliable and easy to use and enjoyable to operate.

If you have any questions or suggestions, contact me at e-mail listed on my web site. wa3tfs@arrl.net

ITEMIZED PARTS LIST Items listed in RED not available from DigiKey You can substitute parts but keep parts values as designed

QTY:	PART NUMBER	LOCATION	DESCRIPTION
CAPACITORS	(DIGIKEY.com)		
1	338-2844-ND	C7, C8	110 Pf silver mica CAP, 500V
1	BC2681CT-ND	C45	470 Pf CERAMIC CAP, 50V
5	BC2662CT-ND	C6, C11, C12, C34,C51	.01 CERAMIC CAP, 50V
25	478-3192-ND	C1-5, C9, C10, C13-17	.1 CERAMIC CAP, 50V
		C19, C20, C25, C27-29	
		C32, C40-44, C46	Two additional for tune encoder
3	BC2678CT-ND	C31, C36, C38	.22 CERAMIC CAP, 50V
1	399-4371-ND	C30	.047 CERAMIC CAP, 50V
2	399-9886-1-ND	C23, C26	1 uF CERAMIC CAP, 50V

1	105RSS050M-ND	C24	1 uF ELECTROLYTIC CAP, 50V
1	399-4294-ND	C52	3300 pF CERAMIC CAP, 200V
4	493-15163-ND	C35, C37, C39, C47	10 uF ELECTROLYTIC CAP, 50V
1	493-14555-1-ND	C49	47 uF ELECTROLYTIC CAP, 50V
5	35YXJ100M6.3X11	C18, C21, C22, C33, C50	100 uF ELECTROLYTIC CAP, 50V
DIODES			
5	1N4148FS-ND	D3, D4, D5, D6, D7	SWITCHING DIODE
2	BB204	D1, D2	DUAL VARACTOR DIODES
CRYSTALS			
3	XC2383-ND	Q1, Q2, Q3	9 MHz 49/s CRYSTALS
TRANSISTORS			
8	2368-2N3904-ND	T1, T2, T3, T4, T5, T6, T7	SMALL SIGNAL NPN
1	2368-2N3906-ND	Q4	SMALL SIGNAL PNP
1	IRF9530NPBF	Q6	MOSFET, P CHANEL
1	2N2222	Q5	SMALL SIGNAL NPN
1	IRF510	IRF510	MOSFET, MOUNT UNDER BOARD
IC'S			
1	296-43960-5-ND	IC1	AUDIO AMPLIFIER
2	LM7805	IC2, IC3	5 VOLT LINEAR REGULATOR
RESISTORS			
1	CF14JT10R0CT-ND	R30	10 OHM 1/4 W FILM, 5%
1	CF14JT39R0CT-ND	R48	39 OHM 1/4 W FILM, 5%
1	CF14JT47R0CT-ND	R46	47 OHM 1/4 W FILM, 5%
3	CF14JT82R0CT-ND	R2, R3, R4	82 OHM 1/4 W FILM, 5%

5	CF14JT100RCT-ND	R21, R25, R36, R37, R44	100 OHM 1/4 W FILM, 5%
2	CF14JT220RCT-ND	R20, R22	220 OHM 1/4 W FILM, 5%
1	CF14JT270RCT-ND	R45	270 OHM 1/4 W FILM, 5%
3	CF14JT330RCT-ND	R26, R28, R32	330 OHM 1/4 W FILM, 5%
8	CF14JT1K00CT-ND	R15-18,R19,R23, R40, R47	1K OHM 1/4 W FILM, 5%
4	CF14JT2K20CT-ND	R13, R29, R42,R43	2.2K OHM 1/4W FILM, 5%
5	CF14JT3K30CT-ND	R8, R9, R10, R27, R34	3.3K OHM 1/4 W FILM, 5%
1	CF14JT4K70CT-ND	R11	4.7K OHM 1/4 W FILM, 5%
1	CF14JT5K60CT-ND	R50	5.6K OHM 1/4 W FILM, 5%
4	CF14JT10K0CT-ND	R1, R35, R39, R41	10K OHM 1/4 W FILM, 5%
1	CF14JT22K0CT-ND	R33	22K OHM 1/4 W FILM, 5%
2	MFR-25FBF52-34K8	R5, R6	34.8K OHM 1/4 W FILM, 1%
1	CF14JT47K0CT-ND	R51	47K OHM 1/4 W FILM, 5%
1	CFM14JT220K	R31	220K OHM 1/4 W FILM, 5%
4	CF14JT1M00CT-ND	R7, R12, R17, R24	1 MEGOHM 1/4 W FILM 5%
2	CT6EP102-ND	R14, R38	1K TRIM POTENTIOMETER
1	CT6EP103-ND	R49	10K TRIM POTENTIOMETER

INDUCTORS

1	AIAP-02-330K	L1	MINIATURE 33uH INDUCTOR
3	FT37-43 TOROID	U$3, U$4, U$5	9 BIFILAR TURNS ON FT37-43 CORE
1	FT50-43 TOROID	U$8	7 TURNS ON FT50-43 CORE
1	FT50-43 TOROID	U$9	5T PRI,14T SEC ON FT50-43 CORE
2	T50-6 TOROID	U$1, U$2	35 TURNS ON T50-6 CORE
1	T50-6 TOROID	U$6	6 T ON T50-6 CORE, CLOSE WOUND

1	MURATA NFV510	LCL1	LOW PASS FILTER 10 MHZ or per assembly detailed in this manual.

RELAY

1	PB384-ND	K1	DPDT RELAY

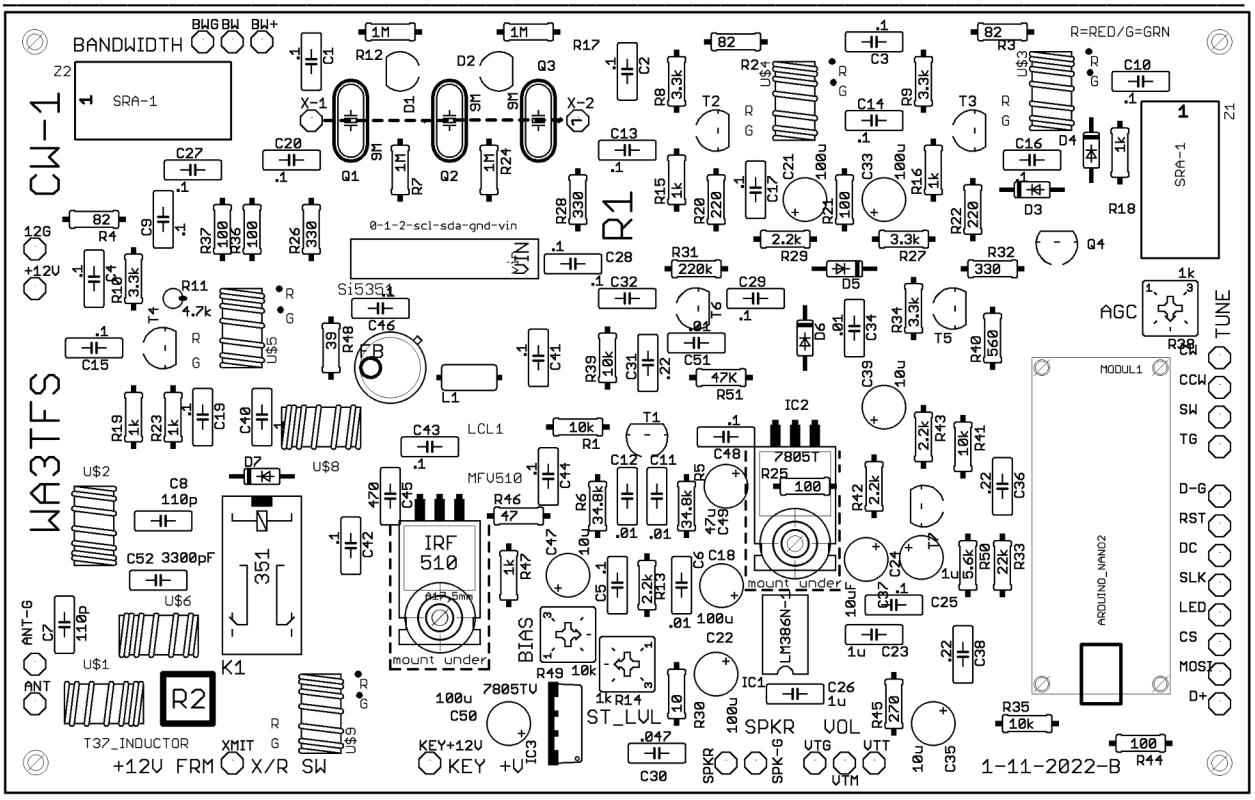
MISC

1	NANO WITH USB	MODULE 1	ARDUINO NANO MICROPROCESSOR
1	Si5351 MODULE	U$7	Si5351 ADAFRUIT PLL MODULE
1	DISPLAY		COLOR LCD 1.8" ST7735 DRIVER
3	952-1905-ND	PIN HEADER	20 POSITION, CUT TO LENGTH REQ.
1	WA3TFS 1-11-2022	pcboard	Order at http://wa3tfs.com

MIXERS

2	SRA-1/SBL-1	Z1, Z2	DOUBLE BALANCED DIODE MIX
1	4880SG	TO220 MOUNTING KIT	USE ON IRF510

ITEMS LISTED IN RED ARE NOT AVAILABLE THROUGH DIGIKEY, CHECK EBAY, AMAZON, ETC


CW-1
WA3TFS
BANDWIDTH
BWG BW BW+
SRA-1
R=RED/G=GRN
0-1-2-scl-sda-gnd-vin
Si5351
IRF 510
mount under
LM386N-1
7805T
7805TV
MODUL1
ARDUINO_NANO2
AGC
TUNE
CW
CCW
SW
TG
D-G
RST
DC
SLK
LED
CS
MOSI
D+
ANT-G
ANT
+12V
12G
BIAS
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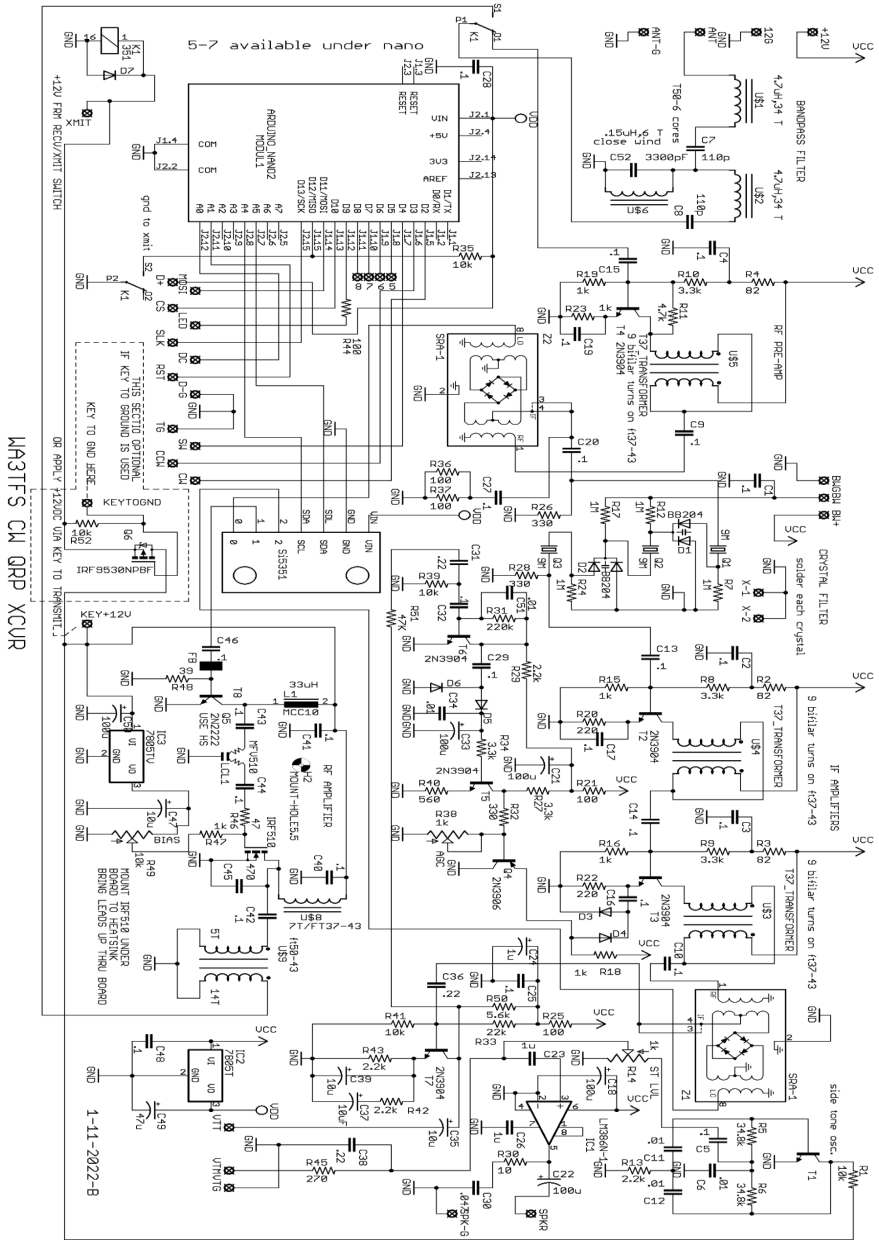
SPKR
VOL
KEY+12V
KEY
+V
+12V FRM
X/R SW
XMIT
T37_INDUCTOR
1-11-2022-B


WA3TFS CW QRP XCVR
5-7 available under nano
ARDUINO NANO2 MODUL1
+12V FOR RECV/XMIT SWITCH
OR APPLY +12VDC VIA KEY TO TRANSMIT
IF KEY TO GROUND IS USED THIS SECTIO OPTIONAL
KEY TO GND HERE
KEYTOGND
IRF9530NPBF
KEY+12V
XMIT
grd to xmit
BANDPASS FILTER
RF PRE-AMP
T37 TRANSFORMER 9 bifilar turns on ft37-43
IF AMPLIFIERS
T37_TRANSFORMER
CRYSTAL FILTER
solder each crystal
RF AMPLIFIER
MOUNT-HOLES5
MOUNT IRF510 UNDER BOARD W/ HEATSINK BRING LEADS UP THRU BOARD
BIAS
side tone osc.
SPKR
1-11-2022-B