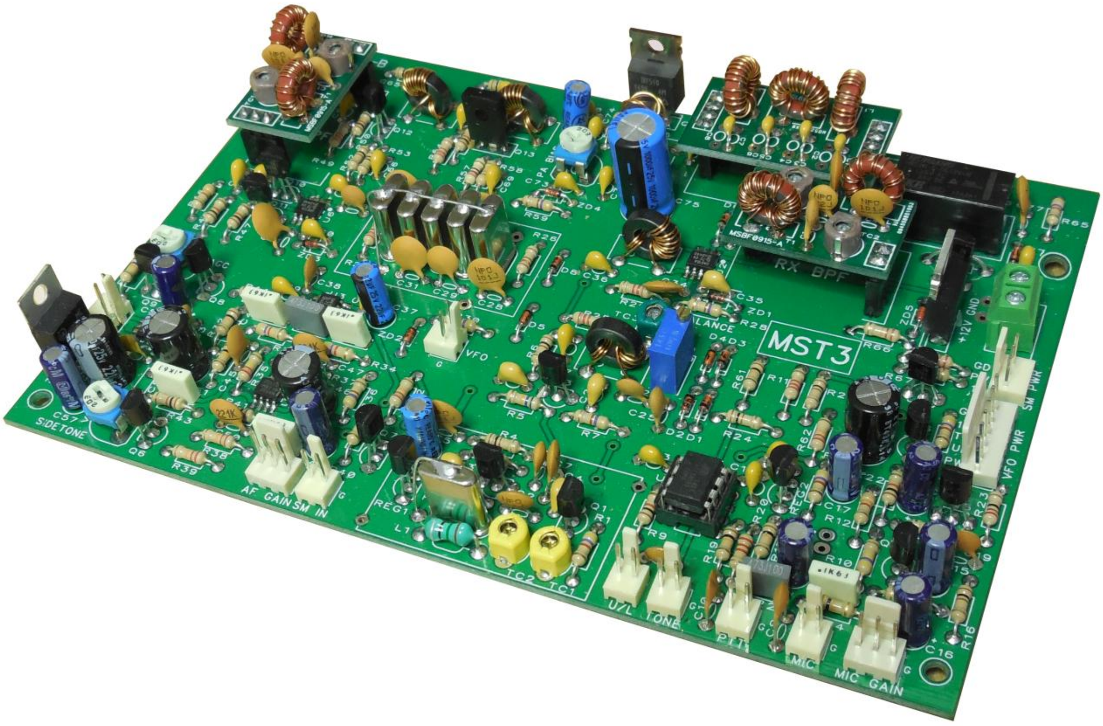
MST3

SSB TRANSCEIVER BOARD KIT



CONSTRUCTION AND OPERATION MANUAL

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1 INTRODUCTION

The MST3 (Minimalist Sideband Transceiver series 3) is the next stage in the evolution of the MST mono-band transceiver board.

While maintaining the minimalist approach of simple design, easy to build yet with good performance, the MST3 takes the concept further by adding new features and performance enhancements. These include:

1. Plug-in band modules, so that a single MST3 can be converted to another band easily and quickly.
2. Switch input to shift the carrier frequency for USB and LSB operation.
3. Power supply reverse voltage protection using an on-board power MOSFET.
4. A new Intelligent Tone Module (ITM) forms a central role in the MST3, generating audible tones and controlling the TX/RX switching:
    a. CW operation. A good quality 800Hz sinewave is injected into the microphone circuit when the Morse key is pressed. Adjustable volume sidetone is also heard in the speaker.
    b. Test and alignment. Three tone sequences can be selected using the Tone button. A Morse test message including a callsign, a stepped frequency sweep and a continuous tone.
    c. Operator feedback. Changing between CW and SSB states is announced with a Morse code message.
    d. MST3 ident. Pressing the Tone button while in SSB transmit state will generate a 'MST3' CW message to identify with other MST3 users.
    e. Power on indication. Two short beeps are generated at each power up to indicate the microcontroller has booted successfully.
    f. Callsign store. This is transmitted in Morse code during the test tone sequence. This is entered using a Morse key.

With the addition of a VFO, an enclosure and a hand full of parts you have a complete and working SSB transceiver.

Full kits of parts for the MST3 transceiver board and plug-in band filter sets are available from www.ozQRP.com.

MST3 transceiver board specifications:

1. Operate on 80M, 40M 20M and 17M via plug-in band modules.
2. Switch selectable USB or LSB.
3. CW operation by keyed tone method. Tone frequency approximately 800Hz.
4. Sensitive Superhet receiver using a 5 pole 10MHz crystal filter. Sensitivity less than 1uV for 10dB S/S+N.
5. Rugged power MOSFET output stage. Typical PEP/CW output power: 80M 7W, 40M 6W, 20M 5W and 17M 4W output.
6. TDA7052A speaker amplifier can deliver 1W into 8 ohms.
7. Audio derived AGC circuit to even out received audio level. Adjusted to cut in above received signal level of S9.
8. Unwanted sideband suppression typically 40dB.
9. All harmonic and spurious transmit outputs below -46dBc.
10. Receive current drain approximately 90mA with no signal (excludes VFO).
11. Transmit current approximately 1A at 5W output.
12. Onboard MOSFET reverse polarity protection.
13. Microphone amplifier accepts standard low impedance dynamic or Electret microphone with selectable on-board bias resistor.
14. Microphone sensitivity 20mV for full output.
15. Easily interfaces to any external VFO which can supply a signal level between 300mV and 600mV pk-pk. Sideband selection and transmit mode control signals for intelligent VFO controllers.
16. AF and microphone gain controls.
17. Connectors for optional LED S meter or a simple front panel LED transmit power and modulation indicator.
18. PCB size 165mm x 110mm. Mounting holes 157mm x 83mm.
19. High quality double sided PCB with groundplane, solder mask and silk screen.

2 Block Diagram

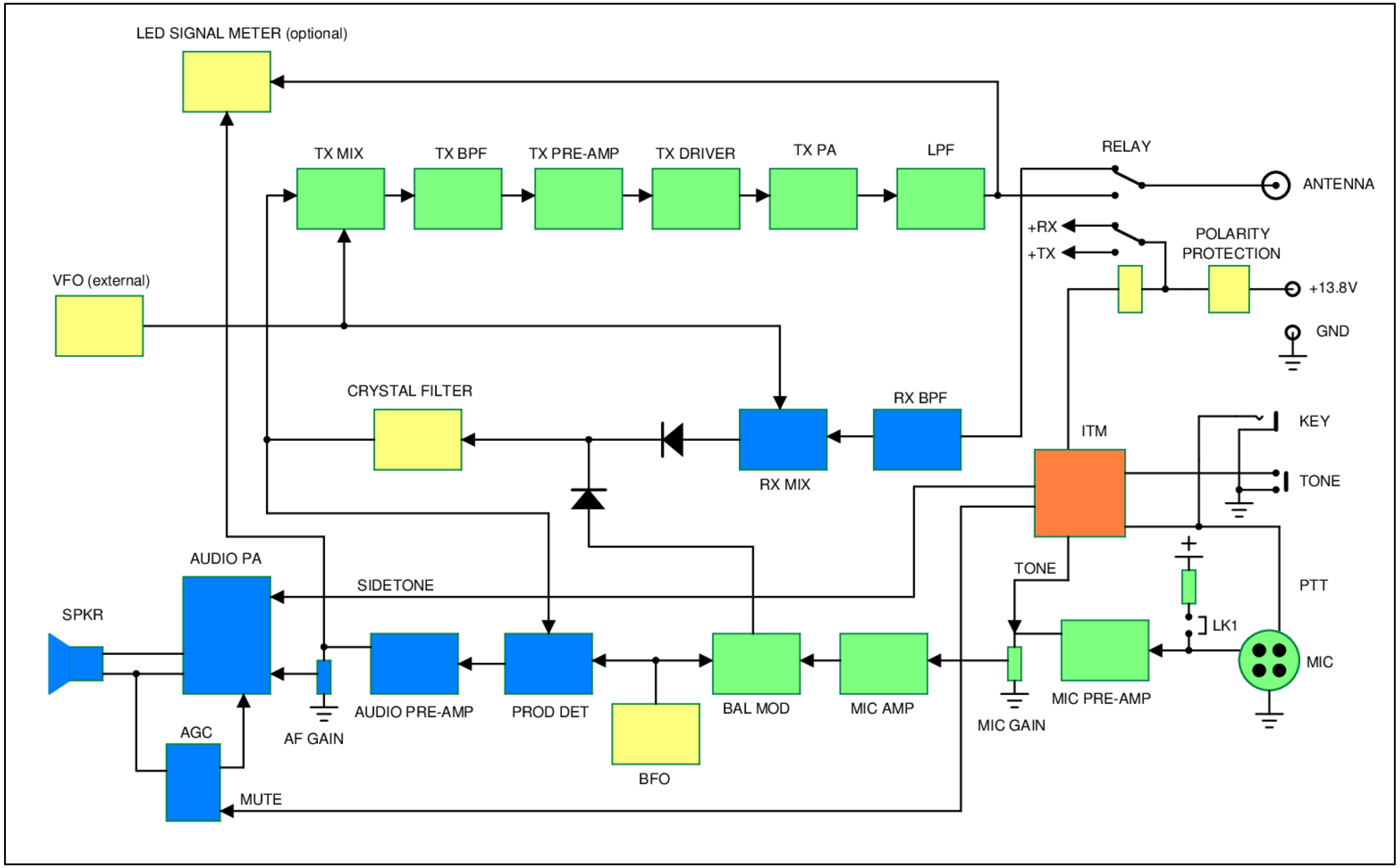


Figure 1 MST3 Block diagram

3 CIRCUIT DESCRIPTION

3.1 CARRIER OSCILLATOR

Transistor Q2 is configured as a Colpitts oscillator and acts as the 10MHz carrier oscillator in transmit and beat frequency oscillator (BFO) in receive. The frequency is determined by crystal X1 and inductor L1 in conjunction with trimmer capacitors TC1 and TC2. When transistor Q1 is turned off only TC2 is in circuit and this is adjusted to set the upper frequency of the oscillator. When transistor Q1 is turned on by applying 12V to the U/L connector, TC1 is connected in parallel with TC2. TC1 is then adjusted to set the lower frequency. Note that the trimmers are not labeled USB and LSB because this depends on whether the VFO is above or below the IF frequency.

The power supply to the oscillator is regulated with an 8V regulator REG1.

The oscillator feeds buffer stage Q3 via a small capacitor to provide minimal loading on the oscillator. The buffer stage gives a low impedance drive for the balanced modulator. A lower level output of around 500mV pk-pk is obtained at the junction of Q2 emitter resistors to feed the receive product detector.

3.2 SSB GENERATOR

Transistor Q4 is the microphone pre-amplifier with a 20K ohm input impedance and gain of around 10. C9 is included to prevent RF feeding into the amplifier. The output of Q4 is fed to the Mic gain control via C15.

If an Electret microphone is used, R8 provides a DC bias current and is enabled by shorting LK1. If a dynamic microphone is used LK1 is left open. Transistor Q5 is the second microphone amplifier and has a gain of about 10. It is biased for higher current and has a low value collector resistor to enable it to drive the balanced modulator. R16 and C19 form a low pass filter to keep RF out of the amplifier.

The balanced modulator is a diode switching type and doubly balanced. The carrier signal, which is much larger in amplitude than the audio signal, is applied simultaneously to both sides of the mixer through trimpot VR1. The carrier signal alternately turns on the diode pairs to give a low resistance and is why it is referred to as a switching mixer. As the carrier is capacitively coupled it swings both positive and negative around ground potential. When the carrier is positive, current flows through diodes D1 and D4 causing them to conduct and become a low resistance. When the carrier signal goes negative diodes D2 and D3 conduct. Note that capacitor C25 holds the junction of D1 and D2 at ground for RF. As the currents are equal through each of the conducting diodes the differential voltage across the primary winding of T1 does not change and as a result no RF is present at the secondary winding. If an audio signal is injected into the bridge at the junction of D1 and D2 the mixer balance is upset because the audio changes state much less frequently than the carrier signal and the resultant instantaneous diode currents are not equal. As a result a signal is now output on the secondary of T1, which is a double sideband suppressed carrier waveform.

Due to variations in component parameters the mixer balance is not exact and if not compensated for the carrier balance would be poor. Trimmer capacitor TC3 and capacitor C26 are used to equalize the capacitance on the mixer sides, while trimpot VR1 is used to balance the diode currents in each side. They are adjusted together to bring the modulator into balance. In practice up to 50dB of carrier suppression can be achieved.

Diode D5 is used as an RF switch. With no DC current flowing through the diode it is high impedance to RF. In TX state around 6mA of DC current flows through D5 and it becomes a low impedance path for RF. This feeds the output of the balanced modulator into the crystal filter. In receive D8 performs a similar function.

3.3 CRYSTAL FILTER

The crystal filter is a 10MHz 5 pole ladder type using closely matched crystals on the same frequency. Capacitors C28 to C33 are selected to provide an approximate 2.7KHz bandwidth. Resistors R26 and R27 terminate the crystal filter in the correct resistance to give low ripple in the pass band.

3.4 TRANSMIT MIXER

The transmit mixer is based around U6 a SA612 balanced mixer. The 10MHz LSB signal from the crystal filter is fed single ended into pin 1 while the other input on pin 2 is grounded to RF by C59. The VFO signal of 300 to 600mV pk-pk is fed into pin 6. Transistors Q10 and Q11 act as emitter follower buffers providing a balanced low impedance feed for the transmit band pass filter. The output of the transmit band pass filter is capacitively coupled to the pre-driver built around transistor Q11 which has both series and shunt feedback. The collector load is a broadband transformer (T3) with a 10 to 3 turn ratio. R52 determines the DC collector current, while R53 and C66 set the AC gain.

3.5 POWER AMPLIFIER

Transmit signal from the pre-driver is applied to the driver stage built around transistor Q13. The circuit is identical to the pre-driver except for the use of a BD139 transistor and a larger quiescent current of around 60mA. This is necessary to give linear operation with the larger output power. The design is well proven using both shunt and series feedback to provide low input and output impedance and good stable gain on the HF bands. The collector load is a broadband transformer (T4) with a 10 to 3 turn ratio.

The power amplifier (Q14) is an IRF510 MOSFET and has been used in many designs. It is a good candidate for the HF bands and can provide in excess of 5 Watts PEP from a 13.8 V drain supply. The output from the driver is applied across resistor R60 and becomes the AC drive component for Q14 gate. Zener diode ZD4 and trimpot VR3 provides a stable and variable DC gate voltage to place Q14 just into conduction for linear service. There is a short ramp up of the gate voltage when switching to TX state as capacitor C71 charges and is included to provide a smooth gate voltage transition.

The drain load for Q14 is a broadband bi-filar wound transformer (T5) and was found to provide maximum output into a 50 ohm load. The waveform from Q14 can be high in harmonics and so a 7 pole low pass filter is included to reduce the level of harmonic and other spurious energy to an acceptable level.

As a visual indication of power output and modulation, the transmit signal is sampled by capacitor C77 and ground referenced by R65. The signal is rectified by D10 and filtered by C78. This drives transistor buffer Q17 to drive an external LED S meter or a front panel LED via current limiting resistor R67.

3.6 Power Supply and RX/TX switching

When the PTT line is active, transistor Q15 is turned on by the ITM and operates the TX/RX relay. When operated the transmit signal is passed to the antenna. When the PTT is not operated the relay switches the antenna through to the receive circuits. The relay also switches power to the TX and RX sections as required.

The power supply is also made available on separate connectors for the external VFO and LED S meter.

A ‘P’ channel power FET (Q18) protects the components in case the power supply is connected in reverse. It works like this. For a P channel MOSFET to be turned on the gate must be at least 4V negative with respect to the source. The internal structure of a MOSFET has a diode connected between the drain and source terminals and is reverse biased in its usual application. However in this circuit if power is applied with the correct polarity, the internal diode will be biased on and the source voltage will be around a volt below the drain voltage. The gate is effectively at ground potential because of the 10K resistor and so the gate voltage is more than 4V negative with respect to the source. This turns on the MOSFET and the drain to source becomes a very low resistance, bypassing the diode, and supplying power to the board.

If the power supply is connected with reverse polarity the internal MOSFET diode will not conduct. As a result the gate to source voltage never exceeds -4V and the MOSFET remains off protecting the board.

Zener diode ZD5 protects the gate from over voltage spikes.

3.7 Receive mixer

Signals from the antenna are applied to the receive bandpass filter. The antenna is unbalanced and capacitively coupled while the output is a balanced winding that feeds the mixer.

The mixer U2 is another SA612. The input is protected with a pair of back to back diodes and fed differentially into pins 1 and 2. Zener diode ZD1 provides a stabilized 6.8 volt supply. VFO signal is injected into pin 6 at about 300 to 600mV pk-pk. The balanced output which contains the sum signal of 10MHz is fed to broadband transformer T2. The output of T2 is passed to the crystal filter when DC current flows through R29 and into D8.

3.8 Product Detector

The 10MHz SSB intermediate frequency (IF) signal from the crystal filter is applied to the product detector U3. The product detector is formed with another SA612 and mixes the IF signal with the 10MHz BFO signal to produce an audio output. The BFO is adjusted slightly above the crystal filter response for LSB and slightly below the crystal filter response for USB detection.

A balanced input audio amplifier is formed with one half of a NE5532dual low noise op-amp (U4a). A reference supply for the non-inverting input is obtained from R31, R32 and C42. The high frequency response of U4a is limited by C41, C45 and C47, while capacitors C43 and C44 reduce the low frequency response.

The output of U4a is fed via a 1uF coupling capacitor to the AF gain potentiometer. The audio signal is also made available via R40 on a separate connector for a LED S meter to display receive signal strength. Transistor Q7 is turned on in TX state and shorts the audio signal input to the LED S meter to ground. This stops switching transients from being displayed.

As the receiver gain is fixed between the antenna and the AF gain control, the audio level across the AF gain control is directly proportional to the receive signal strength. This allows an optional LED S meter to measure this audio level and accurately display the receive signal strength on an LED bar graph.

3.9 Audio Power Amplifier

Audio fed from the wiper of the AF gain control is amplified by the other half of the dual op-amp (U4b) which is configured for a gain of 5. The amplified signal is then applied to the audio power amplifier (U5) to drive a loudspeaker. This is a TDA7052A device with a Bridge-Tied Load (BTL) output. This configuration has a number of advantages for operation at low supply voltages, and also allows the speaker to be directly connected to the chip without the need for a large coupling capacitor.

⚠ **Both speaker wires are connected directly to the IC. Connecting a speaker wire or external load to ground may damage the IC.**

3.10 Audio AGC

The main reason for choosing the TDA7052A is the ability to alter the gain over a very large range by varying the DC voltage at pin 4. If pin 4 is left floating an internal source provides about 1.1V resulting in a maximum gain of +30dB. As pin 4 is pulled low the gain decreases, and if pulled all the way to ground the device is effectively shut off. By varying the amount of current pulled from pin 4 the gain can be continuously varied. This feature is used here to provide an Automatic Gain Control (AGC) circuit to even out receive audio and limit blasts from the speaker on very strong signals.

The power supply for U5 is set to +8V by a 7808 regulator. This is done for two reasons. Firstly the TDA7502A can become unstable at high supply voltages, but more importantly to fix the voltage at the output pins under no signal conditions. With no signal this voltage is half the supply voltage (+4V), but when audio is fed to the speaker the voltage at pin 5 will swing above and below the 4V quiescent point. The base of transistor Q9 is DC connected to pin 5 by a resistor and a trimpot. The trimpot (VR3) is adjusted so that transistor Q9 is just below conduction when there is no audio. When a signal is received the positive audio peaks at pin 5 will start to turn on Q9 and cause some current to be pulled from pin 4 and lower the gain. When the audio decreases, Q9 will begin to turn off which raises the voltage on pin 4, and increases the gain. This action continually attempts to adjust the audio level and provide AGC action. Capacitor C56 stores the charge in between positive cycles to avoid Q9 turning off during negative peaks and causing distortion. For such a simple circuit the dynamics are very good and make a great addition to the receiver.

Transistor Q8 is controlled by the ITM to mute the audio amplifier as required. When Q8 is turned on it pulls pin 4 immediately to ground and effectively shuts off U4 and prevents any audio being heard in the speaker. When Q8 is turned off audio is passed to the speaker. This is the normal case for receive state, but also to allow tones to be heard during transmission. Whenever Q8 is turned off, capacitor C56 charges slowly and provides a smooth click-less transition.

3.11 Intelligent Tone Module

3.11.1 Overview

The Intelligent Tone Module (ITM) is based around an ATtiny85 microcontroller incorporating a high speed pulse width modulation (PWM) generator. The ITM has a central role in the MST3 and performs the following functions:

- Tone generator for CW operation. The keyed tone bursts are shaped to minimise keying clicks.
- Generate a range of test tones.
- Send a MST3 ident during voice operation.
- Generate user feedback for controls and functions.
- Processing of Push To Talk (PTT), CW key closures and Tone pushbutton contacts.
- Control of PTT and audio mute signals.
- Entry and storage of a call sign.

3.11.2 Circuit operation

The ITM (U1) is clocked by an internal 8MHz oscillator. There is also an internal PLL circuit that is used along with a divider to generate a 16MHz clock for the PWM module. When an audio signal is generated the PWM is continually updated from a 256 value sinewave lookup table. This equates to a sampling frequency of 62.5KHz. The highest required output frequency is 3KHz, and with such a high sample frequency this is easily obtained with a simple RC low pass filter formed by R20 and C22. There is some remnant 62.5KHz ripple but this is inaudible in the receiver and transmitted signal.

The PWM output (pin 6) is driven high and low when generating a tone. When the tone is turned off the firmware forces the pin into a high impedance state, and the 10K resistors hold the pin voltage at 2.5V. This means the tone waveform always starts and finishes at 2.5V and minimizes DC transients that would otherwise cause audible clicks in the tones.

To further minimize the possibility of keying clicks the firmware shapes the start and finish of a burst of tone by increasing the amplitude at the start of the waveform from zero to maximum over about a 5mS period. This is done in reverse at the end of the tone burst.

The tones are coupled to the top of the Mic gain control via R14 and C14. The level of tone and hence the transmitter output can be varied by adjusting the Mic gain control.

Internal tones are supplied to the audio amp via VR2 and C52. During transmit the ITM turns on Q6 taking one leg of VR2 to ground. This now allows VR2 to adjust the level of sidetone during transmit.

The ITM firmware continuously monitors the PTT switch, Morse key and Tone pushbutton. The inputs are held high by internal pull-up resistors and filtered against RF with 1nF capacitors. The Morse key and PTT switch are wired in parallel but are interpreted differently depending on whether it is in SSB or CW mode.

The ITM also controls the audio mute line and the PTT line. In normal default SSB mode, the PTT switch is passed straight to the PTT line.

At power up the ITM emits two short beeps to signal a successful boot up.

The ITM is supplied with +5V by a 78L05 regulator.

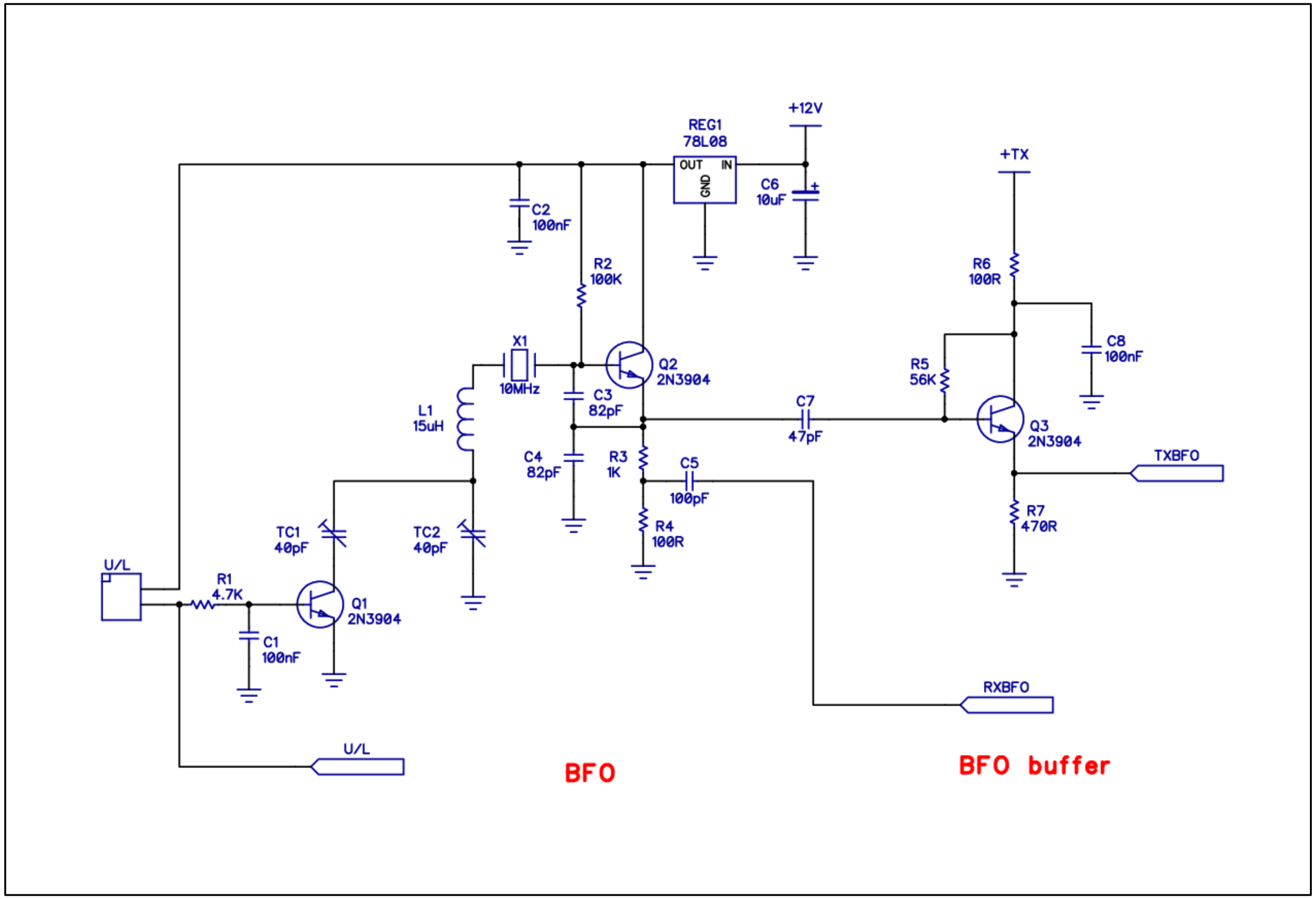


Figure 2 Carrier oscillator

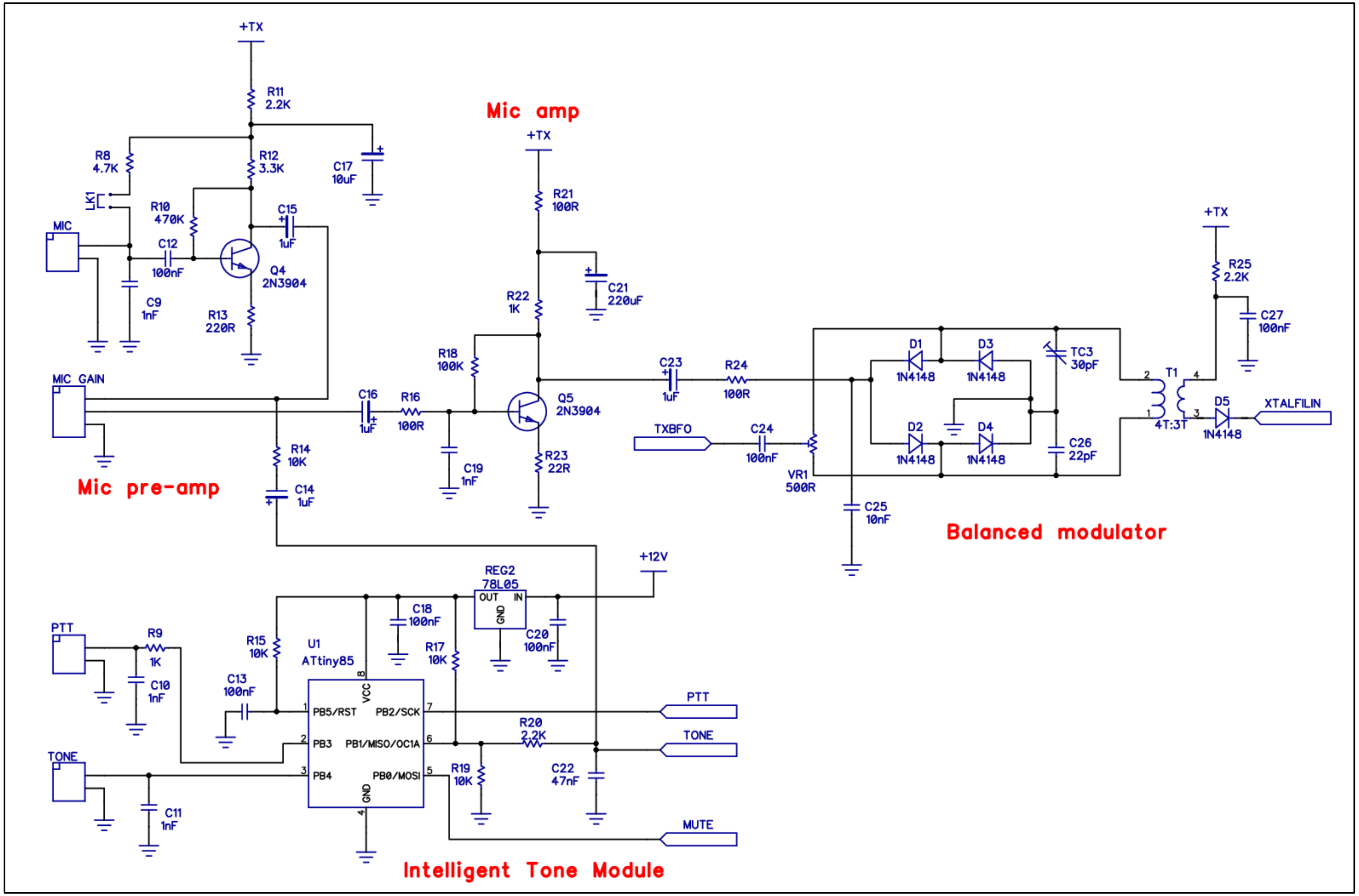


Figure 3 Balanced Modulator

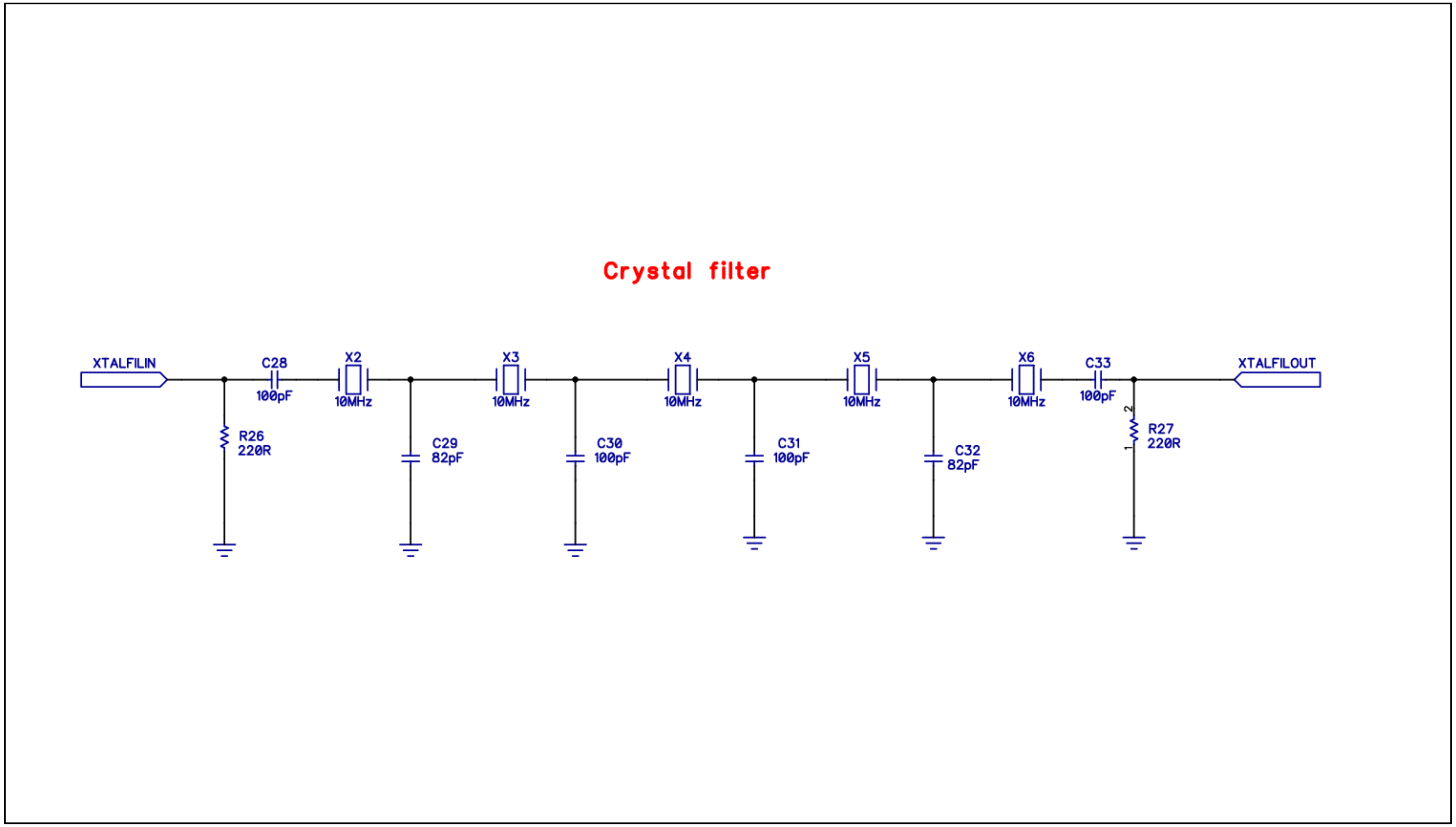


Figure 4 Crystal Filter

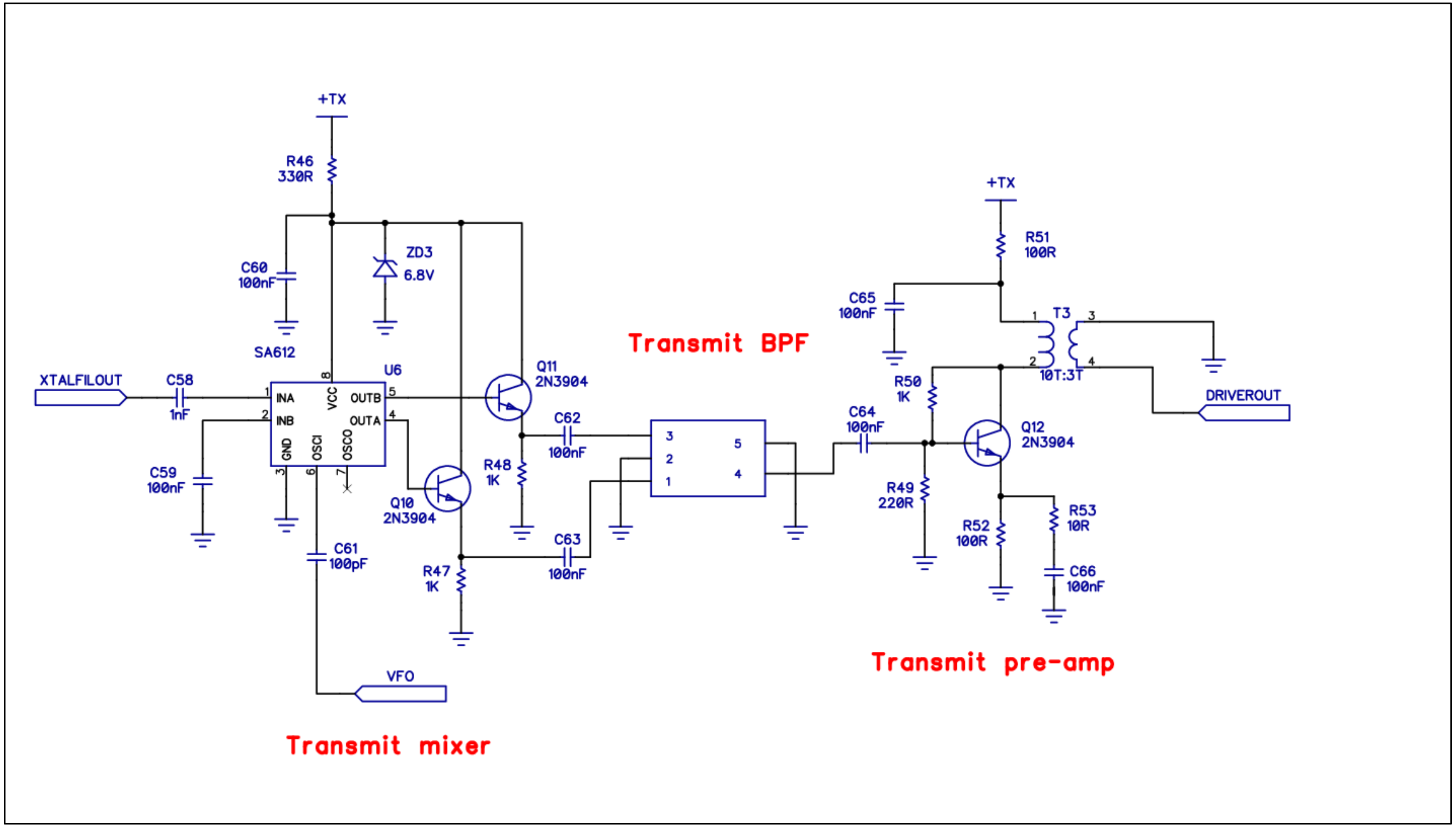


Figure 5 Transmit mixer

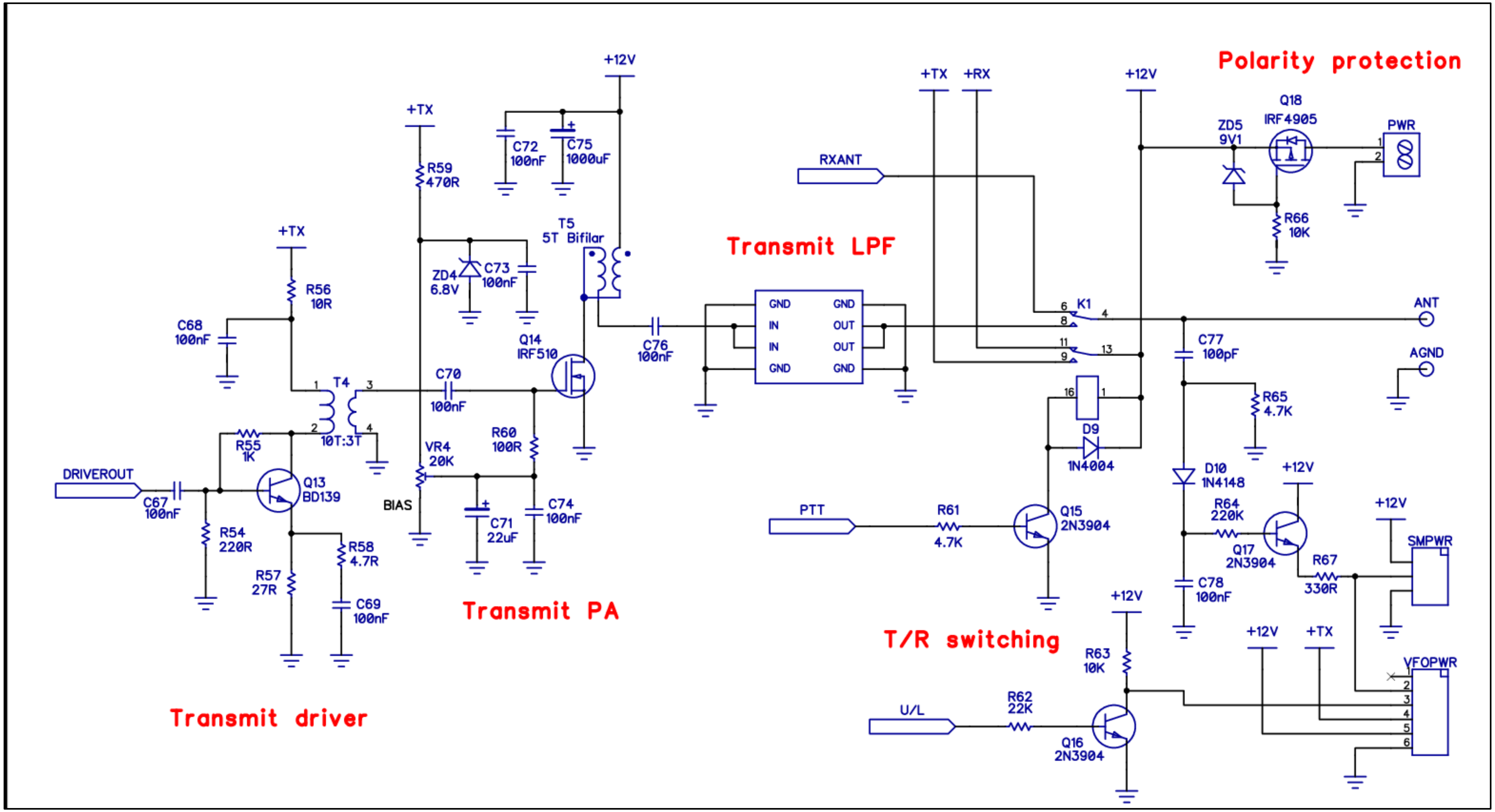


Figure 6 Power amplifier and RX/TX switching

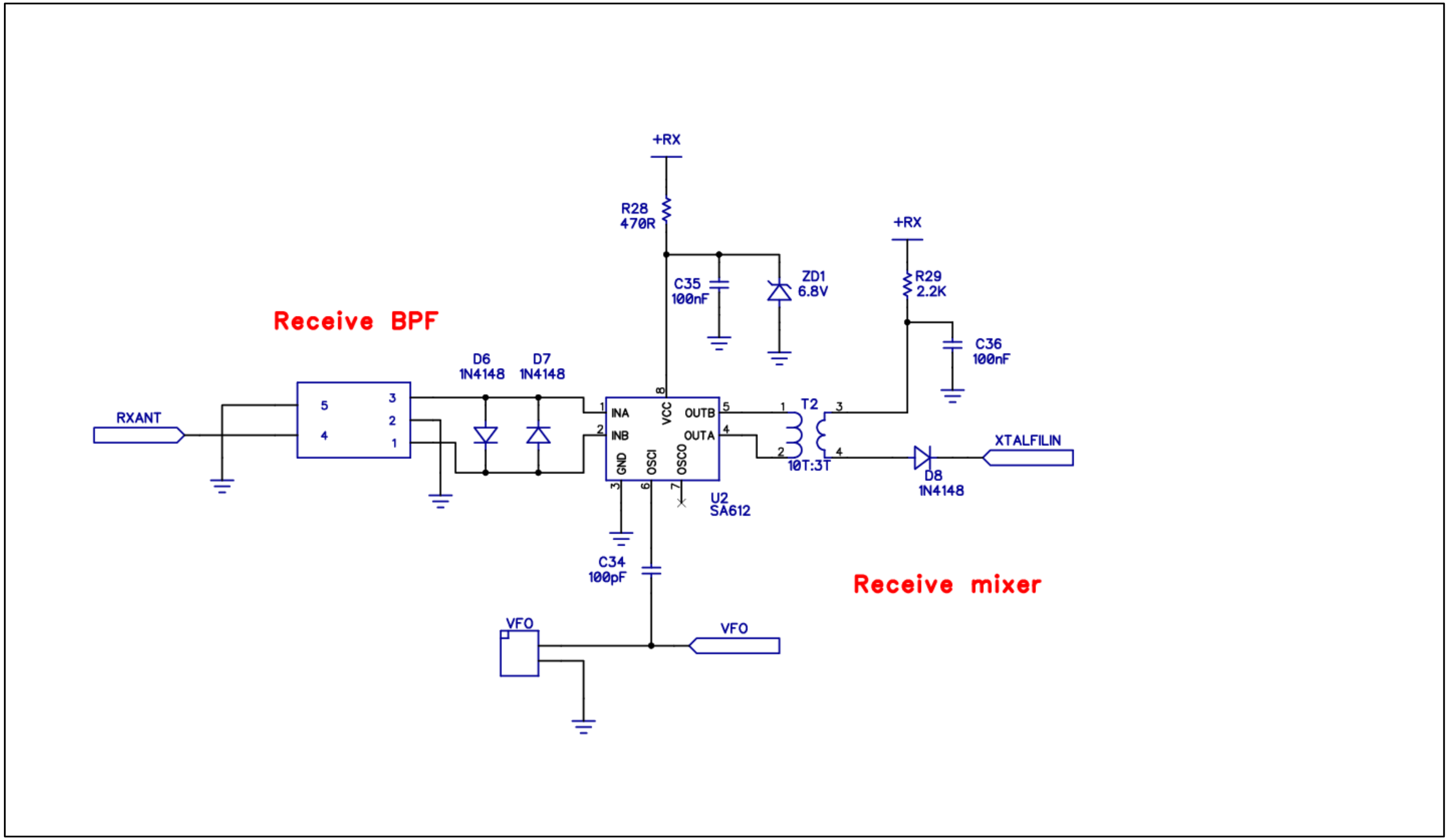


Figure 7 Receive mixer

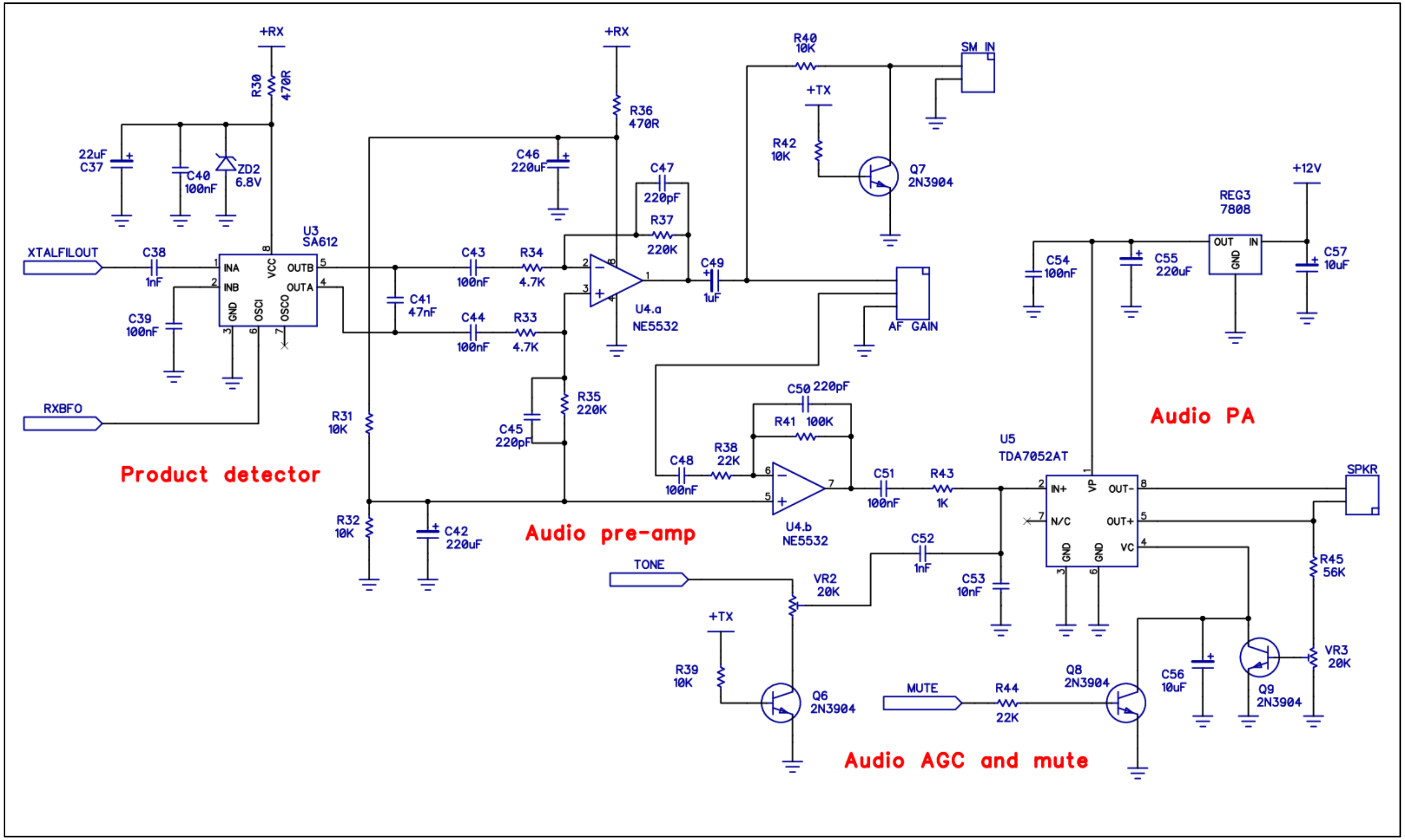


Figure 8 Receive audio

4 KIT SUPPLIED PARTS

QTY	Value	Designator
		Capacitors
1	22pF ceramic disc NPO	C26
1	47pF ceramic disc NPO	C7
4	82pF ceramic disc NPO	C3, C4, C29, C32
8	100pF ceramic disc NPO	C5, C28, C30, C31, C33, C34, C61, C77
3	220pF ceramic disc	C45, C47, C50
6	1nF ceramic disc	C9, C10, C11, C19, C38, C58
2	10nF ceramic disc	C25, C53
1	1nF polyester MKT	C52
2	47nF polyester MKT	C41, C22
5	100nF polyester MKT	C12, C43, C44, C48, C51
29	100nF ceramic MLCC	C1, C2, C8, C13, C18, C20, C24, C27, C35, C36, C39, C40, C54, C59, C60, C62, C63, C64, C65, C66, C67, C68, C69, C70, C72, C73, C74, C76, C78
5	1uF 50V RB electrolytic	C14, C15, C16, C23, C49
4	10uF 25V RB electrolytic	C6, C17, C56, C57
2	22uF 25V RB electrolytic	C37, C71
4	220uF 25V RB electrolytic	C21, C42, C46, C55
1	1000uF 25V RB electrolytic	C75
1	30pF trim capacitor	TC3
2	40pF trim capacitor	TC1, TC2
		Resistors
1	4.7Ω 1/4W 5%	R58
2	10Ω 1/4W 5%	R53, R56
1	22Ω 1/4W 5%	R23
1	27Ω 1/4W 5%	R57
8	100Ω 1/4W 5%	R4, R6, R16, R21, R24, R51, R52, R60
5	220Ω 1/4W 5%	R13, R26, R27, R49, R54
2	330Ω 1/4W 5%	R46, R67
5	470Ω 1/4W 5%	R7, R28, R30, R36, R59
8	1K 1/4W 5%	R3, R9, R22, R43, R47, R48, R50, R55
4	2.2K 1/4W 5%	R11, R20, R25, R29
1	3.3K 1/4W 5%	R12
6	4.7K 1/4W 5%	R1, R8, R33, R34, R61, R65
11	10K 1/4W 5%	R14, R15, R17, R19, R31, R32, R39, R40, R42, R63, R66
3	22K 1/4W 5%	R38, R44, R62
2	56K 1/4W 5%	R5, R45
3	100K 1/4W 5%	R2, R18, R41
3	220K 1/4W 5%	R35, R37, R64
1	470K 1/4W 5%	R10
1	500Ω vertical multi-turn trimpot	VR1
3	20K horizontal trimpot	VR2, VR3, VR4

QTY	Value	Designator
Semiconductors		
9	1N4148 signal diode	D1, D2, D3, D4, D5, D6, D7, D8, D10
1	1N4004 1A power diode	D9
4	6.8V 500mW Zener	ZD1, ZD2, ZD3, ZD4
1	9.1V 500mW Zener	ZD5
15	2N3904 NPN transistor	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q15, Q16, Q17
1	BD139 NPN transistor	Q13
1	IRF510 power MOSFET	Q14
1	IRF4905 power MOSFET	Q18
1	78L05 +5V 100mA regulator	REG2
1	78L08 +8V 100mA regulator	REG1
1	7808 +8V 1A regulator	REG3
1	ATtiny85 microcontroller	U1
3	SA612 RF mixer SMD	U2, U3, U6
1	NE5532 dual op-amp SMD	U4
1	TDA7052A audio power amp SMD	U5
Coils		
1	15uH RF choke	L1
1	FT37-43 4T:3T	T1
3	FT37-43 10T:3T	T2, T3, T4
1	FT50-43 5T bifilar	T5
1	1.5M x 0.4mm enamelled wire	-
Hardware		
1	12V DPDT DIP relay	K1
2	4 pin female header	LPF
2	3 pin female header	BPF
2	2 pin female header	BPF
1	2 way screw terminal block	TB1
7	2 pin polarised header	VFO, MIC, TONE, SM IN, SPKR, U/L, PTT
3	3 pin polarised header	AF GAIN, MIC GAIN, SMPWR
1	6 pin polarised header	VFOPWR
7	2 pin polarised plug + pins	-
3	3 pin polarised plug + pins	-
1	6 pin polarised plug + pins	-
1	8 pin IC socket	-
Crystals		
6	10MHz crystal	X1, X2, X3, X4, X5, X6

5 Individual Parts List

Designator	Value	Type	Designator	Value	Type
C1	100nF	ceramic MLCC	C44	100nF	polyester MKT
C2	100nF	ceramic MLCC	C45	220pF	ceramic disc NPO
C3	82pF	ceramic disc NPO	C46	220uF	25V RB electrolytic
C4	82pF	ceramic disc NPO	C47	220pF	ceramic disc NPO
C5	100pF	ceramic disc NPO	C48	100nF	polyester MKT
C6	10uF	25V RB electrolytic	C49	1uF	50V RB electrolytic
C7	47pF	ceramic disc NPO	C50	220pF	ceramic disc NPO
C8	100nF	ceramic MLCC	C51	100nF	polyester MKT
C9	1nF	ceramic disc	C52	1nF	polyester MKT
C10	1nF	ceramic disc	C53	10nF	ceramic disc
C11	1nF	ceramic disc	C54	100nF	ceramic MLCC
C12	100nF	polyester MKT	C55	220uF	25V RB electrolytic
C13	100nF	ceramic MLCC	C56	10uF	25V RB electrolytic
C14	1uF	50V RB electrolytic	C57	10uF	25V RB electrolytic
C15	1uF	50V RB electrolytic	C58	1nF	ceramic disc
C16	1uF	50V RB electrolytic	C59	100nF	ceramic MLCC
C17	10uF	25V RB electrolytic	C60	100nF	ceramic MLCC
C18	100nF	ceramic MLCC	C61	100pF	ceramic disc NPO
C19	1nF	ceramic disc	C62	100nF	ceramic MLCC
C20	100nF	ceramic MLCC	C63	100nF	ceramic MLCC
C21	220uF	25V RB electrolytic	C64	100nF	ceramic MLCC
C22	47nF	polyester MKT	C65	100nF	ceramic MLCC
C23	1uF	50V RB electrolytic	C66	100nF	ceramic MLCC
C24	100nF	ceramic MLCC	C67	100nF	ceramic MLCC
C25	10nF	ceramic disc	C68	100nF	ceramic MLCC
C26	22pF	ceramic disc NPO	C69	100nF	ceramic MLCC
C27	100nF	ceramic MLCC	C70	100nF	ceramic MLCC
C28	100pF	ceramic disc NPO	C71	22uF	25V RB electrolytic
C29	82pF	ceramic disc NPO	C72	100nF	ceramic MLCC
C30	100pF	ceramic disc NPO	C73	100nF	ceramic MLCC
C31	100pF	ceramic disc NPO	C74	100nF	ceramic MLCC
C32	82pF	ceramic disc NPO	C75	1000uF	25V RB electrolytic
C33	100pF	ceramic disc NPO	C76	100nF	ceramic MLCC
C34	100pF	ceramic disc NPO	C77	100pF	ceramic disc NPO
C35	100nF	ceramic MLCC	C78	100nF	ceramic MLCC
C36	100nF	ceramic MLCC			
C37	22uF	25V RB electrolytic			
C38	1nF	ceramic disc			
C39	100nF	ceramic MLCC			
C40	100nF	ceramic MLCC			
C41	47nF	polyester MKT			
C42	220uF	25V RB electrolytic			
C43	100nF	polyester MKT			

Designator	Value	Type	Designator	Value	Type
D1	1N4148	Signal diode	R18	100K	1/4W 5%
D2	1N4148	Signal diode	R19	10K	1/4W 5%
D3	1N4148	Signal diode	R20	2.2K	1/4W 5%
D4	1N4148	Signal diode	R21	100Ω	1/4W 5%
D5	1N4148	Signal diode	R22	1K	1/4W 5%
D6	1N4148	Signal diode	R23	22Ω	1/4W 5%
D7	1N4148	Signal diode	R24	100Ω	1/4W 5%
D8	1N4148	Signal diode	R25	2.2K	1/4W 5%
D9	1N4004	1A power diode	R26	220Ω	1/4W 5%
D10	1N4148	Signal diode	R27	220Ω	1/4W 5%
			R28	470Ω	1/4W 5%
K1	DPDT	PCB mount DIP relay	R29	2.2K	1/4W 5%
			R30	470Ω	1/4W 5%
L1	15uH	RF choke	R31	10K	1/4W 5%
			R32	10K	1/4W 5%
Q1	2N3904	NPN transistor	R33	4.7K	1/4W 5%
Q2	2N3904	NPN transistor	R34	4.7K	1/4W 5%
Q3	2N3904	NPN transistor	R35	220K	1/4W 5%
Q4	2N3904	NPN transistor	R36	470Ω	1/4W 5%
Q5	2N3904	NPN transistor	R37	220K	1/4W 5%
Q6	2N3904	NPN transistor	R38	22K	1/4W 5%
Q7	2N3904	NPN transistor	R39	10K	1/4W 5%
Q8	2N3904	NPN transistor	R40	10K	1/4W 5%
Q9	2N3904	NPN transistor	R41	100K	1/4W 5%
Q10	2N3904	NPN transistor	R42	10K	1/4W 5%
Q11	2N3904	NPN transistor	R43	1K	1/4W 5%
Q12	2N3904	NPN transistor	R44	22K	1/4W 5%
Q13	BD139	NPN transistor	R45	56K	1/4W 5%
Q14	IRF510	Power MOSFET N ch	R46	330Ω	1/4W 5%
Q15	2N3904	NPN transistor	R47	1K	1/4W 5%
Q16	2N3904	NPN transistor	R48	1K	1/4W 5%
Q17	2N3904	NPN transistor	R49	220Ω	1/4W 5%
Q18	IRF4905	Power MOSFET P ch	R50	1K	1/4W 5%
			R51	100Ω	1/4W 5%
R1	4.7K	1/4W 5%	R52	100Ω	1/4W 5%
R2	100K	1/4W 5%	R53	10Ω	1/4W 5%
R3	1K	1/4W 5%	R54	220Ω	1/4W 5%
R4	100Ω	1/4W 5%	R55	1K	1/4W 5%
R5	56K	1/4W 5%	R56	10Ω	1/4W 5%
R6	100Ω	1/4W 5%	R57	27Ω	1/4W 5%
R7	470Ω	1/4W 5%	R58	4.7Ω	1/4W 5%
R8	4.7K	1/4W 5%	R59	470Ω	1/4W 5%
R9	1K	1/4W 5%	R60	100Ω	1/4W 5%
R10	470K	1/4W 5%	R61	4.7K	1/4W 5%
R11	2.2K	1/4W 5%	R62	22K	1/4W 5%
R12	3.3K	1/4W 5%	R63	10K	1/4W 5%
R13	220Ω	1/4W 5%	R64	220K	1/4W 5%
R14	10K	1/4W 5%	R65	4.7K	1/4W 5%
R15	10K	1/4W 5%	R66	10K	1/4W 5%
R16	100Ω	1/4W 5%	R67	330Ω	1/4W 5%
R17	10K	1/4W 5%			

Designator	Value	Type	Designator	Value	Type
REG1	78L08	+8V 100mA regulator	X1	10MHz	Crystal
REG2	78L05	+5V 100mA regulator	X2	10MHz	Crystal
REG3	7808	+8V 1A regulator	X3	10MHz	Crystal
			X4	10MHz	Crystal
SK1	U/L	2 pin polarised header	X5	10MHz	Crystal
SK2	MIC	2 pin polarised header	X6	10MHz	Crystal
SK3	MIC GAIN	3 pin polarised header			
SK4	PTT	2 pin polarised header	ZD1	6.8V	500mW Zener diode
SK5	TONE	2 pin polarised header	ZD2	6.8V	500mW Zener diode
SK6	VFO	2 pin polarised header	ZD3	6.8V	500mW Zener diode
SK7	AF GAIN	3 pin polarised header	ZD4	6.8V	500mW Zener diode
SK8	SM IN	2 pin polarised header	ZD5	9.1V	500mW Zener diode
SK9	SPKR	2 pin polarised header			
SK10	SM PWR	3 pin polarised header			
SK11	VFO PWR	6 pin polarised header			
T1	4T:3T	FT37-43 ferrite			
T2	10T:3T	FT37-43 ferrite			
T3	10T:3T	FT37-43 ferrite			
T4	10T:3T	FT37-43 ferrite			
T5	5T Bifilar	FT50-43 ferrite			
TB1	PWR	2 way terminal block			
TC1	40pF	Trimmer cap			
TC2	40pF	Trimmer cap			
TC3	30pF	Trimmer cap			
U1	ATtiny85	Microcontroller			
U2	SA612	RF mixer			
U3	SA612	RF mixer			
U4	NE5532	Dual low noise op-amp			
U5	TDA7052A	BTL power audio amp			
U6	SA612	RF mixer			
VR1	500 Ω	Multi-turn trimpot			
VR2	20K	Horizontal trimpot			
VR3	20K	Horizontal trimpot			
VR4	20K	Horizontal trimpot			

6 OFF BOARD PARTS

The following is a suggested list of parts required to complete the MST3 transceiver board and install in an enclosure. These parts are not included in the kit.

⚠ This list does not include the VFO, LED S meter or associated parts.

The enclosure listed below is an example and the type used in the prototype; however any suitable plastic or metal enclosure with the approximate dimensions can be used. When choosing consider the following:

- Metallic rear panel to act as a heatsink for the transmit PA.
- Placement of mounting screws to match the PCB mounting holes.
- Height of the enclosure to allow clearance for the VFO.
- Sufficient space at the front of the enclosure to mount the controls and sockets, VFO and signal meter clear of the main PCB.

QTY	Item	Comment
1	Plastic instrument enclosure. 200mm x 155mm x 65mm with aluminium panels.	www.altronics.com.au H0480F or equivalent.
1	Red binding post	POS power supply.
1	Black binding post	NEG Power supply.
1	Antenna socket.	SO239 or BNC panel mount.
2	Knobs	Nominally 20mm diameter.
1	Momentary action pushbutton switch	Tone control switch.
1	SPDT toggle switch	U/L switch.
2	10K log pot 16mm	AF gain and Mic gain.
1	5mm amber LED and bezel	If the LED S meter is not installed.
1	Microphone socket	To suit microphone. Must have a separate PTT line.
1	Morse key socket	To suit key plug.
1	Loudspeaker 8 or 16 ohm	67mm square or equivalent minimum recommended size.
4	PCB mounting screws	4g x 6mm self-tapping screws if mounting into plastic posts.
1	3mm x 10mm screw and nut	To mount TX PA.
1	TO-220 insulating washer and bush	To mount TX PA.
1	Front panel label	If required.
	hook-up wire, shielded cable	

7 MAIN BOARD CONSTRUCTION

7.1 GENERAL

The MST3 is built on a high quality fiberglass PCB. The PCB is double sided with the majority of the tracks on the bottom side with the top side forming a ground plane.

To assist construction the component overlay is screen printed on the top side and a solder mask is included to help guard against solder bridges.

The ground plane is substantial and can sink quite a bit of heat from low wattage soldering irons so ensure you use a good quality iron that can sustain the power required. You may find that sometimes solder doesn't appear to flow through to the top side. This is not necessarily a problem because the plated through holes make a connection to the top side automatically.

Another point to consider is that plated through holes consume more solder than non-plated holes and makes it more difficult to remove components. So check the value and orientation of components before soldering!

There isn't a 'best' scheme for loading the components. If desired you can build sections at a time and test them out, but it is not really necessary and in any case some sections rely on others before they will operate. The suggested procedure is to load the smaller components and those that sit closest to the PCB first. This includes resistors and diodes, and then work upwards, leaving the electrolytic capacitors and the TO220 devices till last.

If you did want to build and test stages one at a time, you would need to first install the power supply components and the relay to allow voltage around the board.

7.2 Construction Steps

It's advised to print out the parts list and tick off the components as they are installed. The PCB has a silkscreen component overlay with components designators, but you might like to also print Figure 9 as an additional reference when installing the components.

Step 1: PCB

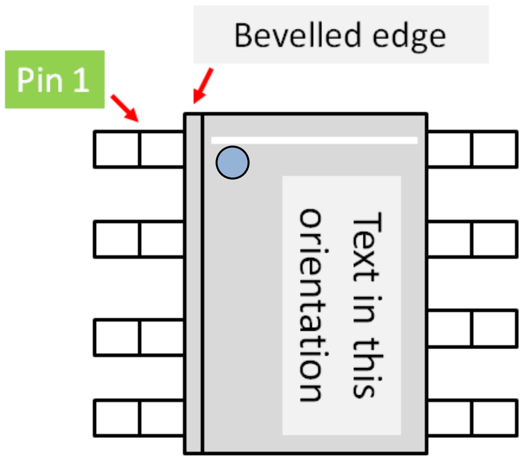
Remove the PCB from its bag.

⚠ **The PCB comes shipped in a static shielded bag to protect against static damage. While the ICs are not particularly sensitive to static damage it is still good practice to take the usual precautions against static discharge during construction.**

The SMD ICs are pre-installed on the board. They are all 8 pin SOIC types with 1.27mm pitch pins. The diagram below shows how to identify the SMD IC pins.

The ICs will have one or more of the following identifiers:

- A dot above pin 1
- A beveled edge down one side starting at pin 1 and ending at pin 4.
- A line across the top from pin 1 to pin 8.



Step 2: Resistors

The resistors are all 5% ¼ watt types with easy to read colour bands.

⚠ **If in any doubt about reading resistor values measure them with a multimeter first.**

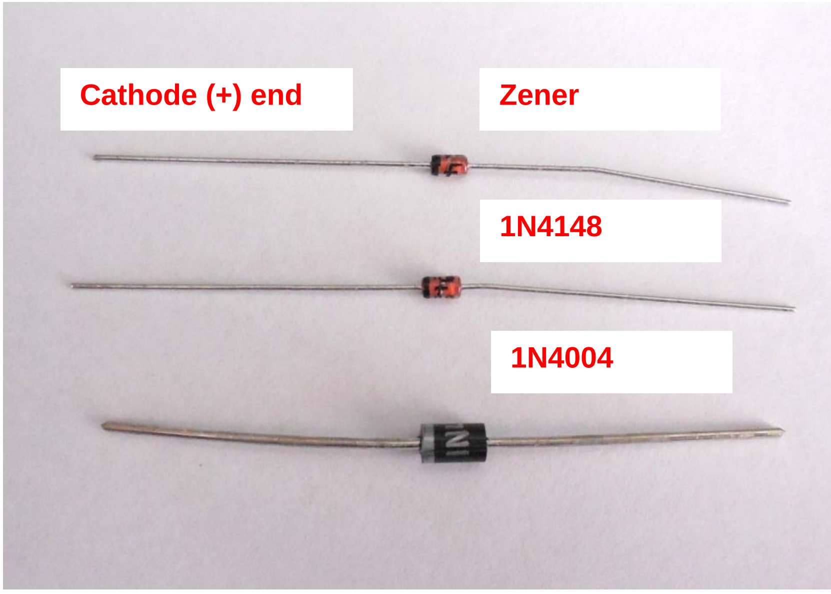
Pass the pigtails through from the top and bend out slightly underneath to hold them in place. Turn the PCB over and press down slightly to press them against the surface and solder. Cut off the excess pigtail with side cutters.

It is easier and less confusing to install a group with the same value rather than to cover a section of the PCB with mixed values. You will also find it more convenient to install 5 or 6 resistors at a time rather than inserting them all before soldering as the pigtails will more than likely get in the way.

Step 3: Diodes

Note the positive or Cathode end before installation. The small Zener diodes look like signal diodes so make sure you don't get them mixed up. You may need a magnifier to identify them correctly. Form the leads before inserting to reduce stress on the body when pulling through the PCB.

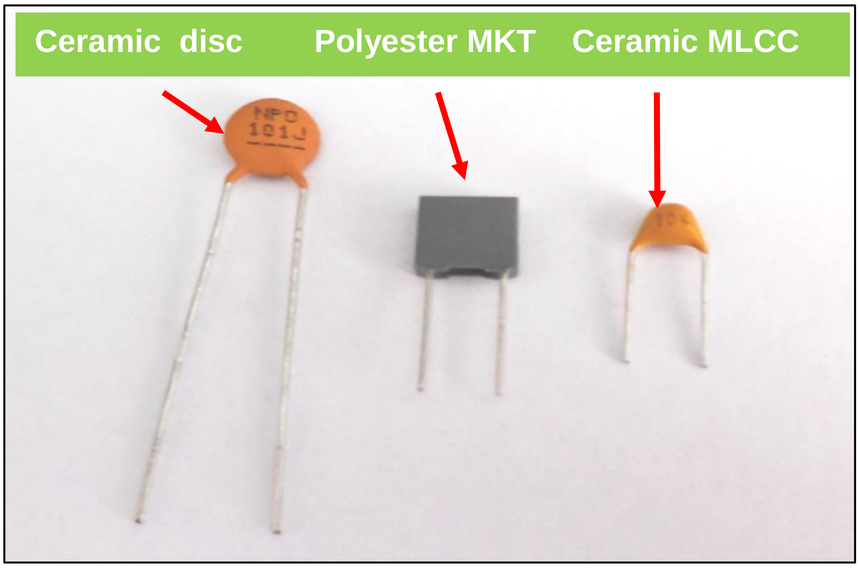
The diodes are identified with a band printed on the case at the Cathode (+) end.



Step 4: Non-polarized capacitors

Note the various types. Ceramic disc (standard and NPO), polyester MKT and ceramic multi-layer chip capacitors (MLCC). These are all non-polarized and can go in either way.

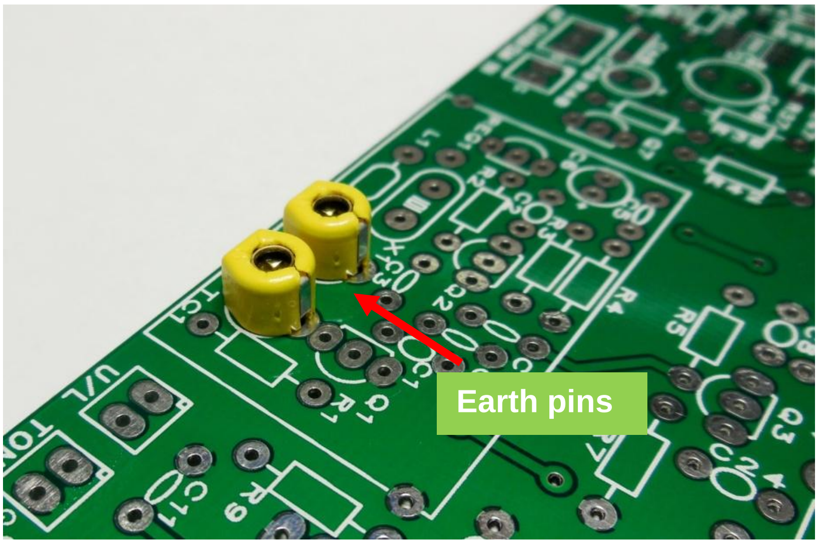
There are 29 x 100nf (0.1uF) MLCC and as they are quite small install these first. Follow this with the disc ceramics and finally the MKT.



Step 5: Trimmer capacitors

The trimmer capacitors have one lead electrically connected to the screwdriver adjustment slot. Use a multimeter to determine this pin and solder to the hole in the PCB connected to the ground plane. TC1 ground pin goes towards Q1.

The 40pF sideband trimmers are yellow and the 30pF carrier balance trimmer is green.

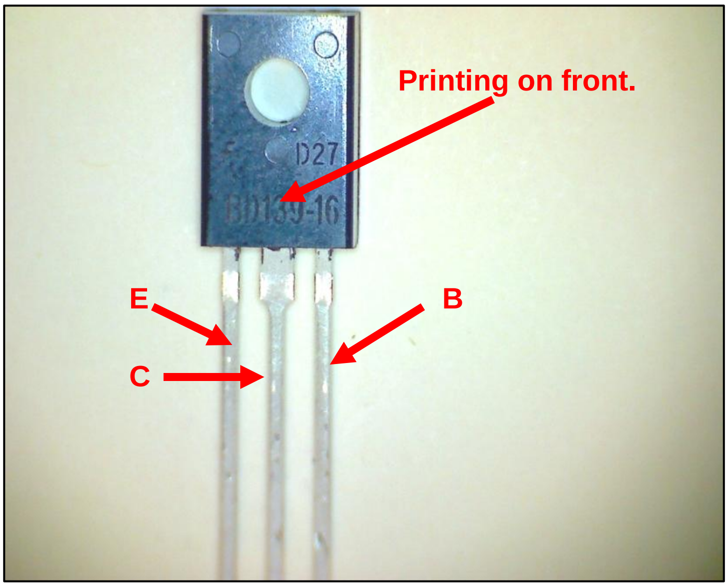


Step 6: Trimpots

Note that the carrier balance trimpot is a multi-turn vertical mount while the PA bias, AGC and sidetone trimpots are horizontal mount types.

Step 7: Transistors

The 2N3904 transistors are orientated to match the screen silk component overlay. The BD139 pins are shown below:



⚠ Leave the IRF510 and IRF4905 power MOSFETs and the voltage regulator installation till later.

Step 8: Connectors

The MST3 board utilizes polarized pin headers for most external connections. If preferred the wires may be soldered directly to the PCB, but the connectors make for a professional looking build, plus allow easy disconnection and testing if required. The connectors have a vertical polarizing piece and the connectors are installed with this piece towards the centre of the PCB.

The power connector is a 2 way screw terminal block and the terminal openings face towards the edge of the PCB.

Install the 8 pin IC socket for the ITM.

Step 9: Filter headers

The plug-in filter boards use 2.54mm (0.1”) pitch male/female connectors. The male connector is soldered to the plug-in board while the female connector is soldered to the main PCB.

The LPF input and output connectors each have 4 pins. This allows the LPF to be inserted in either way as the filter circuit is symmetrical.

The BPF boards have defined inputs and outputs and so use a 3 pin and a 2 pin connector to ensure they are plugged in the correct way.

Step 10: Relay

The relay can only go in one way, so simply insert into the board and solder.

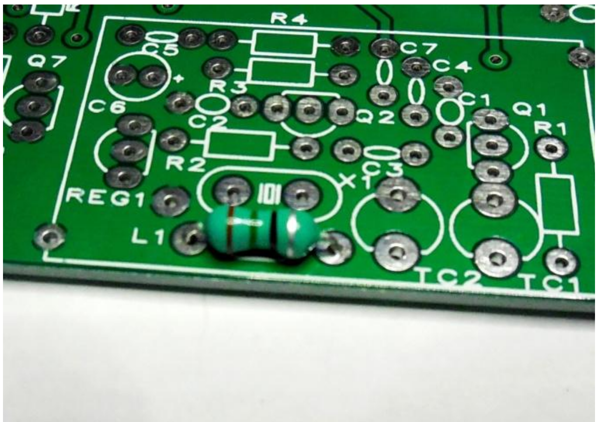
Step 11: Electrolytic capacitors

These are polarized and it is very important that they go in the correct way. Electrolytic capacitors have a line down the side of the case indicating the negative lead and the positive lead is the longer lead. The PCB component overlay has a '+' mark to indicate the hole for the positive lead.

Step 12: Coils

Choke

Install the RF choke in the same manner as for the resistors.

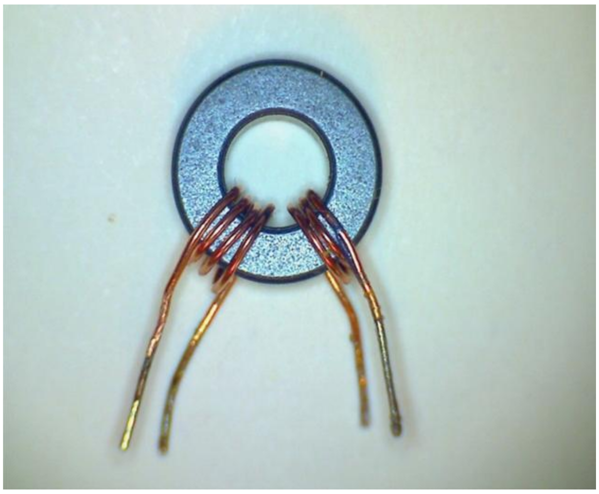


Transformer T1

Take two 80mm lengths of 0.4mm enamelled copper wire.
Wind **4** turns for the primary (bal mod) on a **FT37-43** ferrite toroid.
Then wind **3** turns for the secondary (xtal filter).

Scrape the enamel off the ends of the wires and tin with solder before installing in the PCB.

The winding direction is not important.



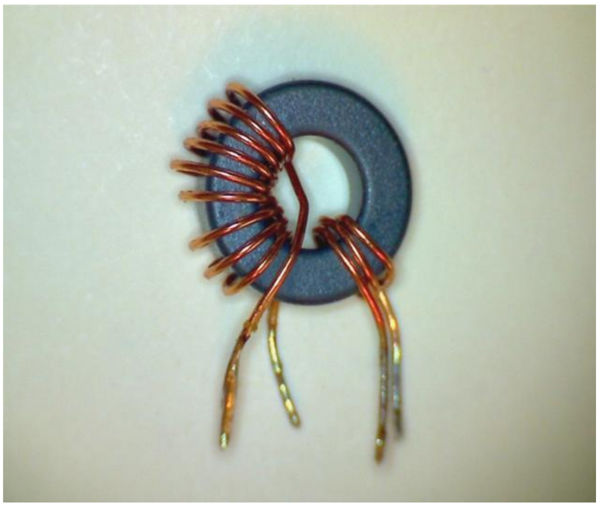
Transformers T2, T3 and T4

Take an 80mm length of 0.4mm enamelled copper wire and wind the **3** turn secondary on a **FT37-43** ferrite toroid.

Take a 150mm length of 0.4mm enamelled copper wire and wind the **10** turn primary.

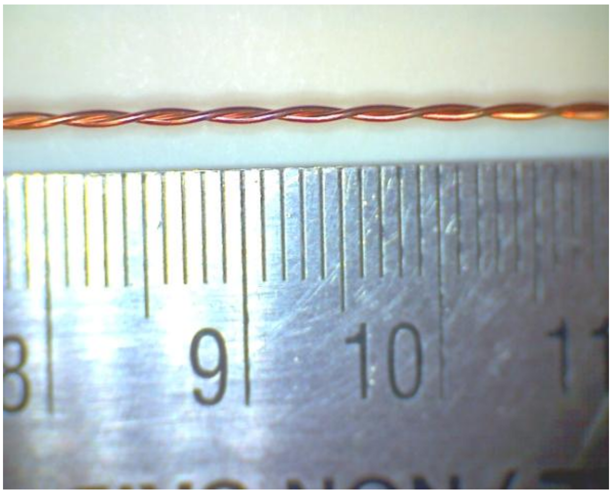
Scrape the enamel off the ends of the wires and tin with solder before installing in the PCB.

The winding direction is not important.



Bifilar transformer T5

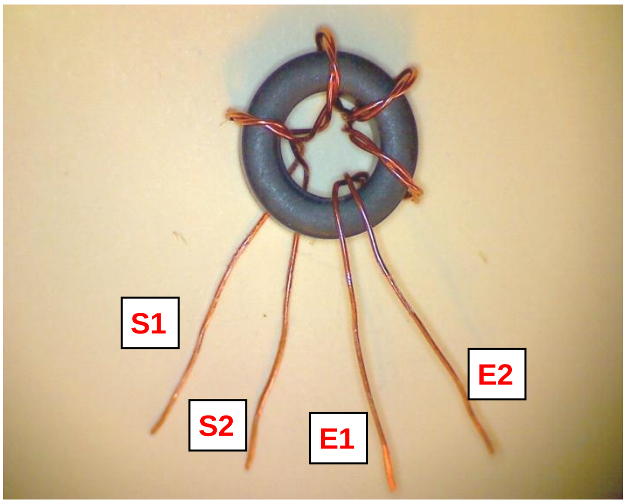
Take a 500mm length of 0.4mm enameled wire and fold in half. The wires need to be twisted together. Following is a suggested method:
Clamp one end of the doubled wires in a vice. Make a loop at the other end and place on a hook shaped bit in a battery drill.
While keeping the wires taut, run the drill on slow speed until there are about 3 twists per cm.



Carefully wind **5** turns on a **FT50-43** ferrite toroid trying to avoid scraping the enamel on the sharp edges of the toroid.

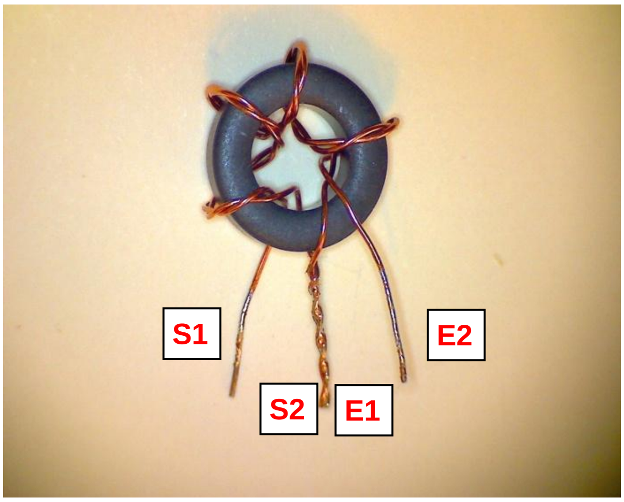
Scrape some enamel off the ends and use a multimeter to find the start (S) and end (E) of each winding.

Also check that there are no shorts between the two windings.



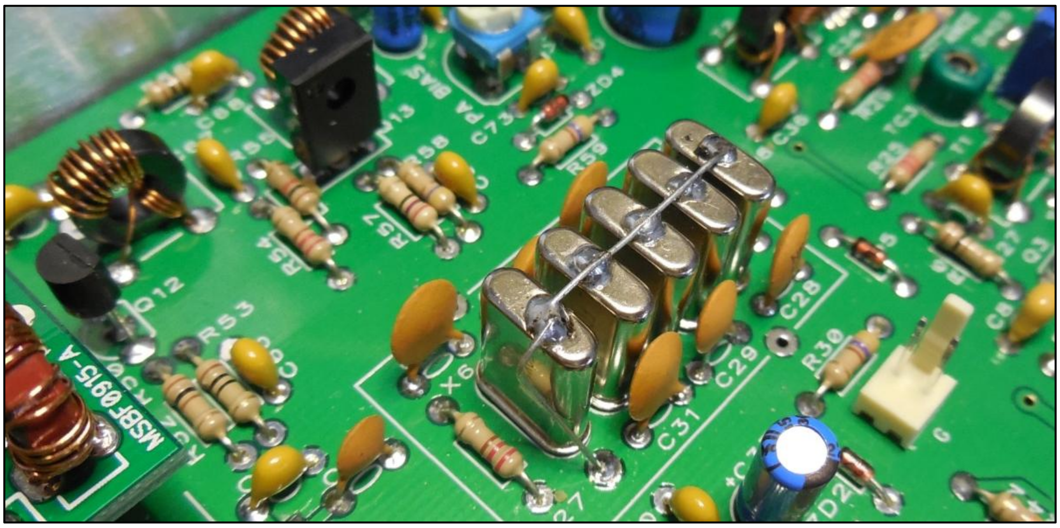
Take the end of the first winding and the start of the second winding and twist together to form the centre tap.
Trim the leads with side-cutters and tin with solder before installing. Push the wires through the holes in the PCB and sit the toroid so that it rests against the surface of the board.

Ensure the two-wire centre tap goes to the middle hole of the T5 component overlay closest to Q14.



Step 13: Crystals

The crystals have been closely matched in frequency, so they can go in any position. The PCB has a solder mask which should insulate the crystal metal cases from the PCB tracks, but to be sure mount them slightly above the PCB. Once the crystals for the filter are installed solder a wire across the top of the metal cases and down to a spare pad in the PCB groundplane set aside for this purpose. The carrier oscillator crystal also has a PCB ground connection hole adjacent to the crystal.



Step 14: Antenna wires

The antenna wires are difficult to solder to the pads once the PCB is installed in the case so solder short lengths to the ANT and GND pads now. As the length is quite small you can use hook-up wire and twist them together or use shielded cable if preferred.

Step 15: Power MOSFETs and regulators

The reason the larger regulators are left to last is simply because they sit high and near the edges and may get damaged as the PCB is turned over and back as other components are being installed.

The 7808 voltage regulator is installed with the metal tab facing to the edge of the board.

Mount the IRF510 MOSFET with the metal tab facing towards the edge of the board and with about 5mm of lead length between the board and body.

The IRF4905 MOSFET is positioned so the metal tab faces towards the middle of the board.

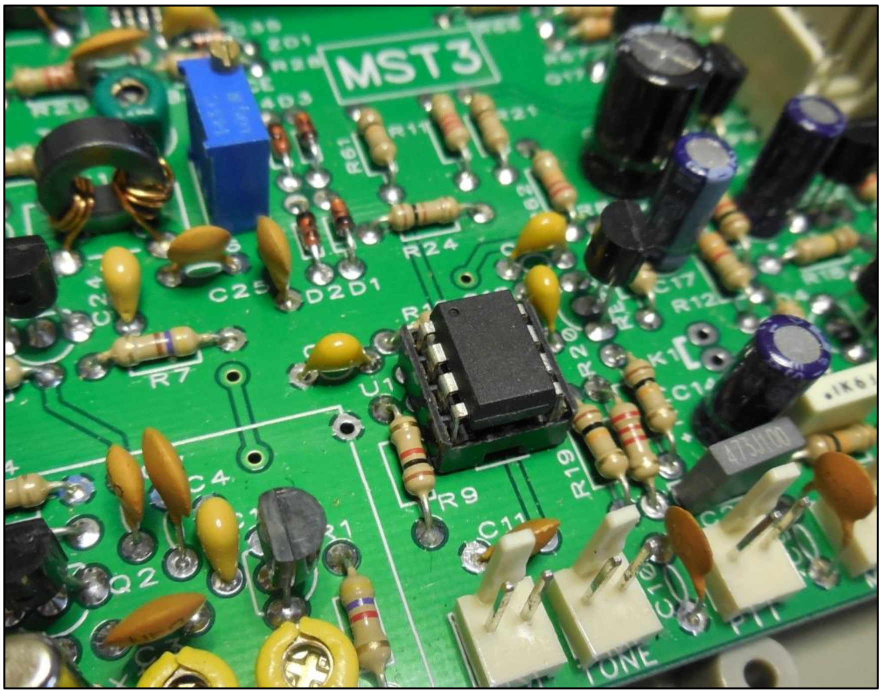
Install the 78L08 8V regulator (REG1) and 78L05 5V regulator (REG2) as shown on the silkscreen component overlay.

⚠ It is very important to check that the 78L05 regulator is inserted next to U1. If the 78L08 is installed here, the ITM will be destroyed.

Step 16: ITM

Remove the ITM from its protective foam and install in the 8 pin IC socket. Pin 1 is closest to C13.

You may need to compress the pins slightly so that they slide easily into the socket.



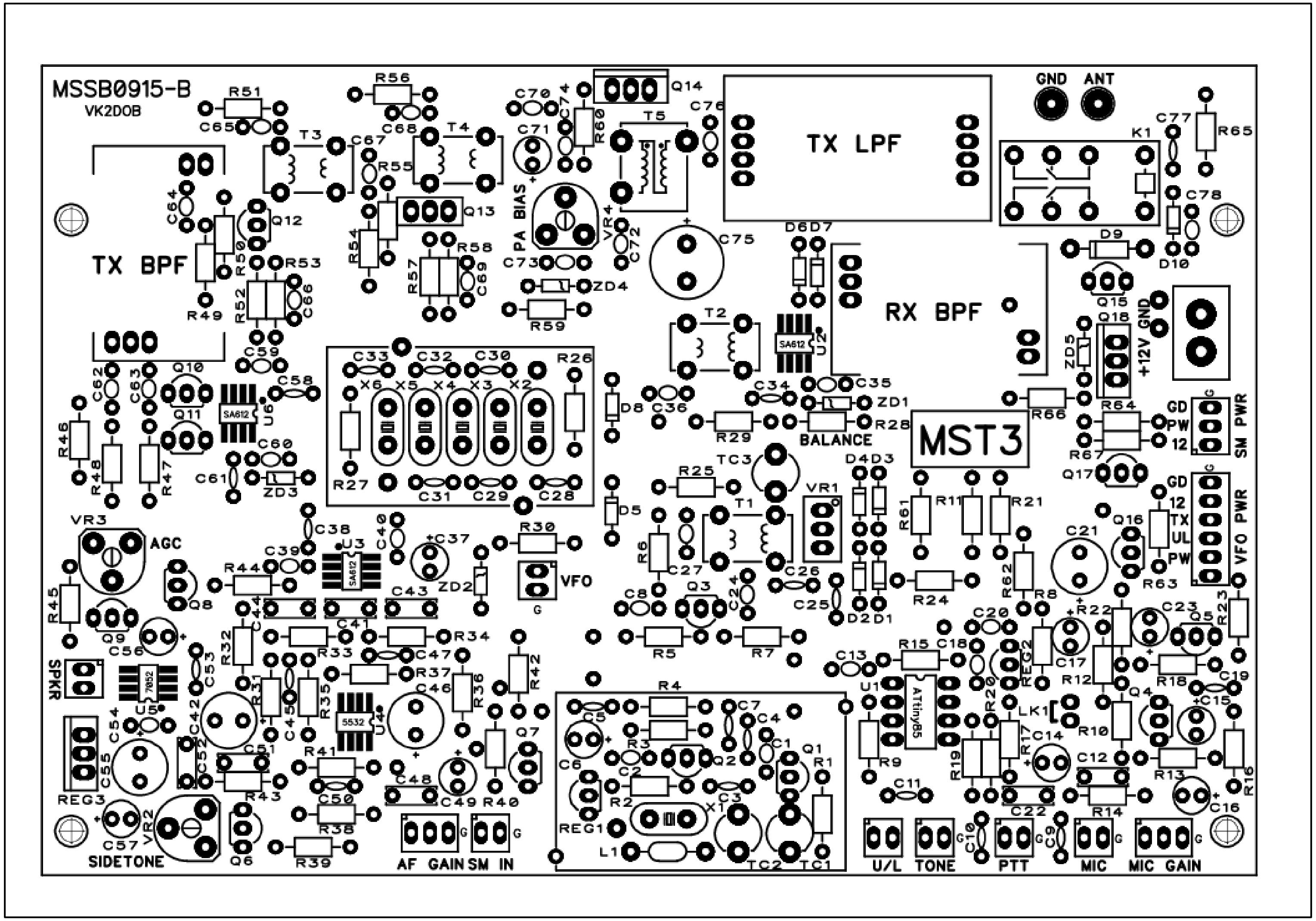


Figure 9 Component overlay

8 BAND PASS FILTERS

8.1 CIRCUIT DESCRIPTION

The bandpass filters are a two pole type with a Butterworth response and top coupled with a small capacitor (C3). One end (T1) is link coupled to provide a balanced termination, while the other end is capacitively coupled to 50 ohms by C4. Fixed capacitors C1 and C2 resonate with T1 and L2, while trimmer capacitors TC1 and TC2 allow fine adjustment of the centre frequency. The schematic is shown in Figure 10, and a completed BPF is shown in Figure 11.

All coils are wound on T37 iron powder toroids. Type 2 (Red) is used for the lower bands while Type 6 (Yellow) is used for the higher bands. All fixed capacitors are ceramic disc.

The TX and RX bandpass filters for each band are identical apart from the number of turns on the coupling winding of T1. This is done to match the different impedance of the TX and RX mixers.

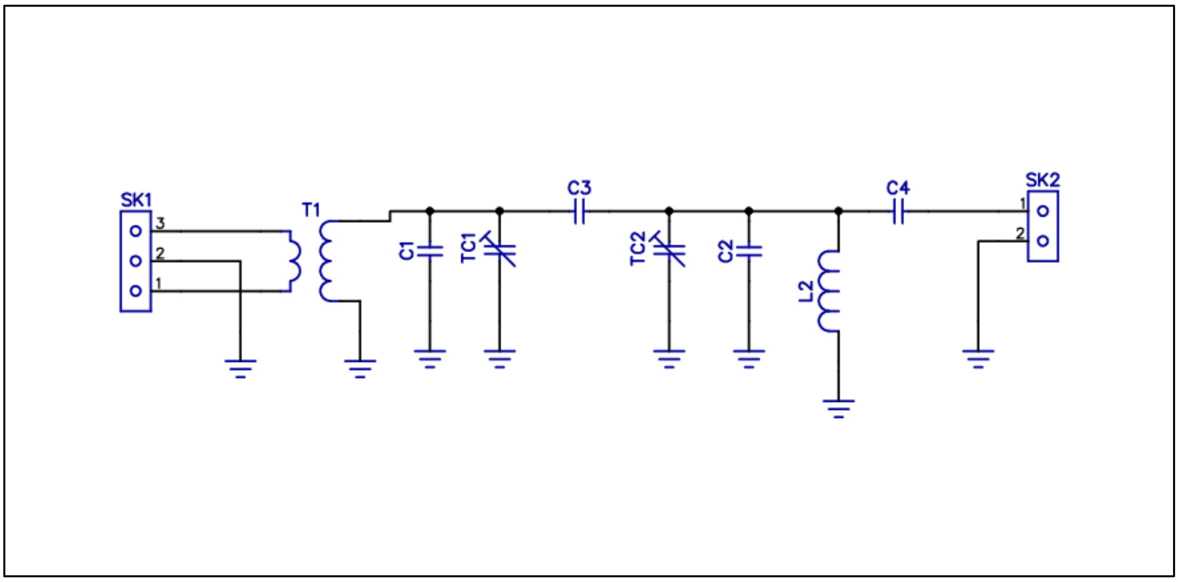


Figure 10 BPF schematic

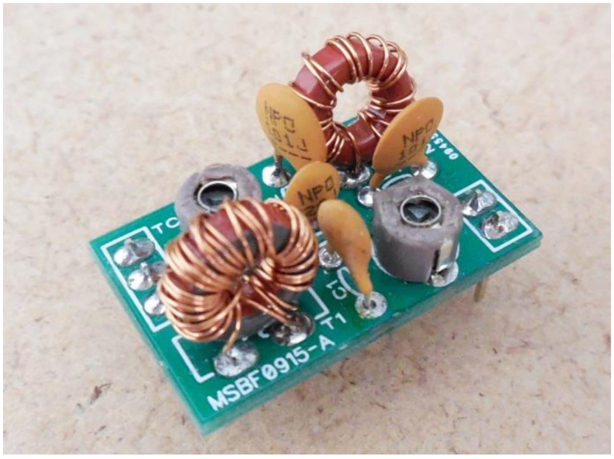


Figure 11 Completed BPF

8.2 CONSTRUCTION

There are two filters required for each band - a RX filter and a TX filter. Refer to Table 1 to select the components for the filter being built. The BPF PCB overlay is shown in Figure 12.

The suggested construction sequence is:

1. **Trimmer capacitors**. The trimmer capacitors supplied have one lead electrically connected to the screwdriver adjustment slot. Use a multimeter to determine this pin and solder to the hole in the PCB connected to the ground plane.
2. **Capacitors**. Double check the values before inserting. Then simply insert into the PCB and solder.
3. **Coil T1**. Cut a length of enamelled copper wire as listed in the table and wind on the required number of turns for the tuned coil. Spread the turns to cover about 80% of the circumference.
   Cut another length of enamelled copper wire as listed in the table and wind on the required number of turns for the coupling coil.
   Note the different turns for the RX and TX windings. Place the turns towards the bottom of the toroid.
   Scrape the enamel off the ends of the wires and tin with solder before installing.
4. **Coil L2**. Cut a length of enamelled copper wire as shown in the table and wind on the required number of turns for the tuned coil. Spread the turns to cover about 80% of the circumference. Scrape the enamel off the ends of the wires and tin with solder before installing.
5. **Pins**. Break off or cut with side-cutters 2 pin section and 3 pin sections from the supplied strip. Insert from the opposite side of the PCB, ensuring they are at right angles to the board, and solder in place. The pin strips have a long section and a short section either side of the plastic separator. Solder the shorter section in the filter PCB.

⚠ **Winding tips**.

1. When winding a toroid with many turns it is easier to first pass the wire through the toroid to the midpoint of the wire. Then wind on half the turns with one wire end. Once done wind the remaining turns using the other wire end proceeding around the toroid in the opposite direction. This saves having to pass the full length of wire through the toroid for each turn at the start of winding.
2. It is easy to get the ends of multiple windings mixed up once both windings are complete. To make it easier it is best to mark the ends of the first winding before commencing the second winding. One method is to complete the winding with the most turns first and keep the ends long. When the second winding is finished cut these ends shorter. That way after scraping off the enamel the windings are easy to identify before inserting in the PCB.

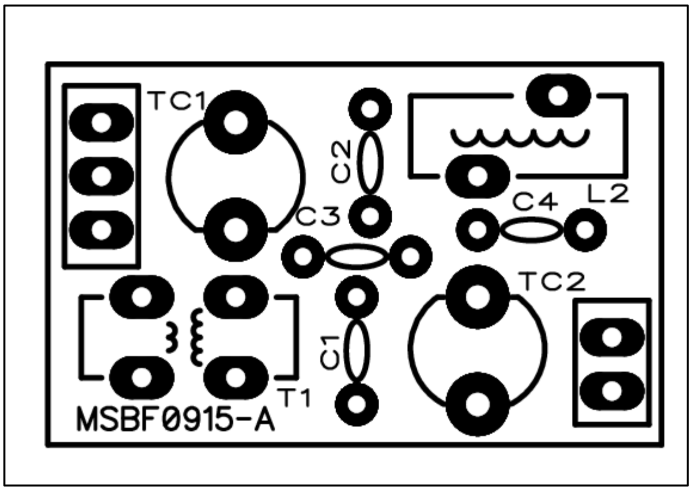
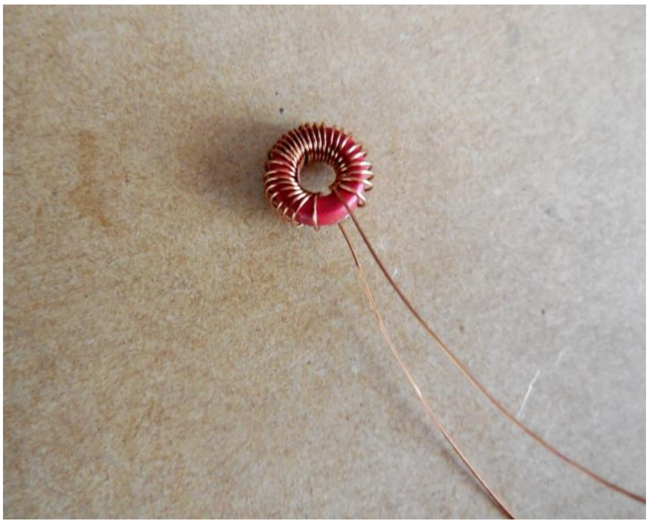
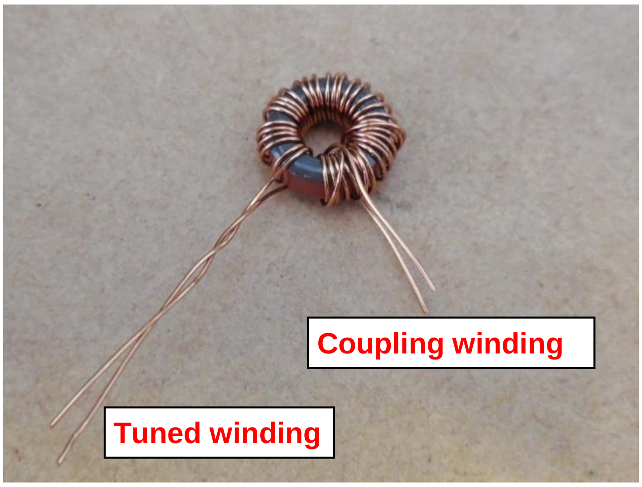


Figure 12 BPF overlay



BPF coil
Tuned winding only. Note long wire leads.



BPF coil
Coupling winding wound over bottom section of tuned winding.
Coupling winding wires shorter to allow easy identification.

80M TX and RX BPF			
T1 (L1) tuned	**29** turns. T37-2 (red) core. 0.3mm enameled wire. 410mm long.	**C3**	56pF
T1 TX coupling	**8** turns of 0.3mm enameled wire wound over T1. 150mm long.	**TC2**	100pF trimcap
T1 RX coupling	**22** turns of 0.3mm enameled wire wound over T1. 330mm long.	**C2**	150pF
C1	330pF	**L2**	**29** turns. T37-2 (red) core. 0.3mm enameled wire. 410mm long.
TC1	100pF trimcap	**C4**	220pF

40M TX and RX BPF			
T1 (L1) tuned	**19** turns. T37-2 (red) core. 0.3mm enameled wire. 290mm long.	**C3**	22pF
T1 TX coupling	**5** turns of 0.3mm enameled wire wound over T1. 110mm long.	**TC2**	100pF trimcap
T1 RX coupling	**14** turns of 0.3mm enameled wire wound over T1. 220mm long.	**C2**	100pF
C1	180pF	**L2**	**19** turns. T37-2 (red) core. 0.3mm enameled wire. 290mm long.
TC1	100pF trimcap	**C4**	100pF

20M TX and RX BPF			
T1 (L1) tuned	**16** turns T37-6 (yellow) core. 0.4mm enameled wire. 250mm long.	**C3**	5.6 or 6pF
T1 TX coupling	**4** turns of 0.4mm enameled wire wound over T1. 100mm long.	**TC2**	60pF trimcap
T1 RX coupling	**12** turns of 0.4mm enameled wire wound over T1. 200mm long.	**C2**	56pF
C1	82pF	**L2**	**16** turns T37-6 (yellow) core. 0.4mm enameled wire. 250mm long.
TC1	60pF trimcap	**C4**	33pF

17M TX and RX BPF			
T1 (L1) tuned	**14** turns T37-6 (yellow) core. 0.4mm enameled wire. 220mm long.	**C3**	3.3 or 4pF
T1 TX coupling	**4** turns of 0.4mm enameled wire wound over T1. 100mm long.	**TC2**	40pF trimcap
T1 RX coupling	**10** turns of 0.4mm enameled wire wound over T1. 170mm long.	**C2**	56pF
C1	82pF	**L2**	**14** turns T37-6 (yellow) core. 0.4mm enameled wire. 220mm long.
TC1	40pF trimcap	**C4**	22pF

Table 1 BPF components

9 Low Pass Filter

9.1 Circuit description

The TX low pass filter is a seven pole type with a 0.1dB Chebyshev response for a sharper frequency roll off. The input and output impedances are 50 ohms. As the filter is symmetrical the PCB has been designed so that it can be inserted into the main board either way. The schematic is shown in Figure 13.

All coils are wound on T37 iron powder toroids. Type 2 (Red) are used for the lower bands while Type 6 (Yellow) is use for the higher bands. All capacitors are 100V or higher CG0 (NPO) ceramic MLCC.

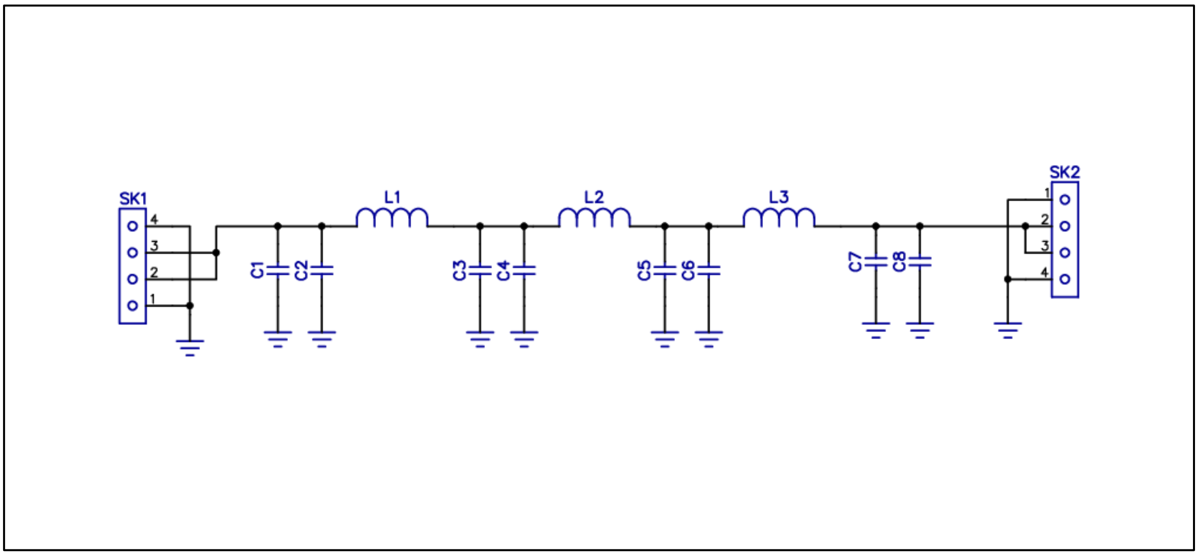


Figure 13 LPF schematic

9.2 Construction

Refer to Table 2 to select the components for the filter being built. The PCB overlay is shown in Figure 14, and a completed LPF is shown in Figure 15. The suggested construction sequence is:

1. **Capacitors**. Use the chart below to check the values before inserting. Then simply insert into the PCB and solder. Note that not all filters use all capacitor positions.

Marking	Value
151	150pF
221	220pF
331	330pF
471	470pF
821	820pF
152	1500pF

2. **Coils**. Cut a length of enamelled copper wire as shown in the table and wind on the required number of turns. Spread the turns to cover about 80% of the circumference. Scrape the enamel off the ends of the wires and tin with solder before installing.
3. **Pins**. Break off the required number of pins from the supplied strip and solder in place on the opposite side of the PCB, ensuring they are at right angles to the board.

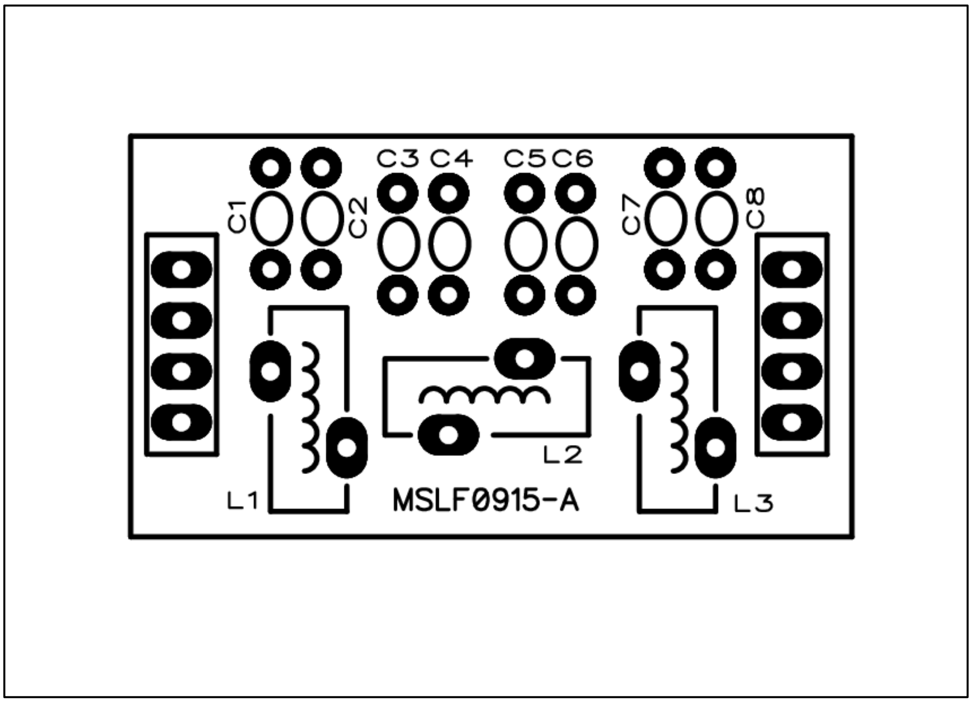


Figure 14 LPF overlay

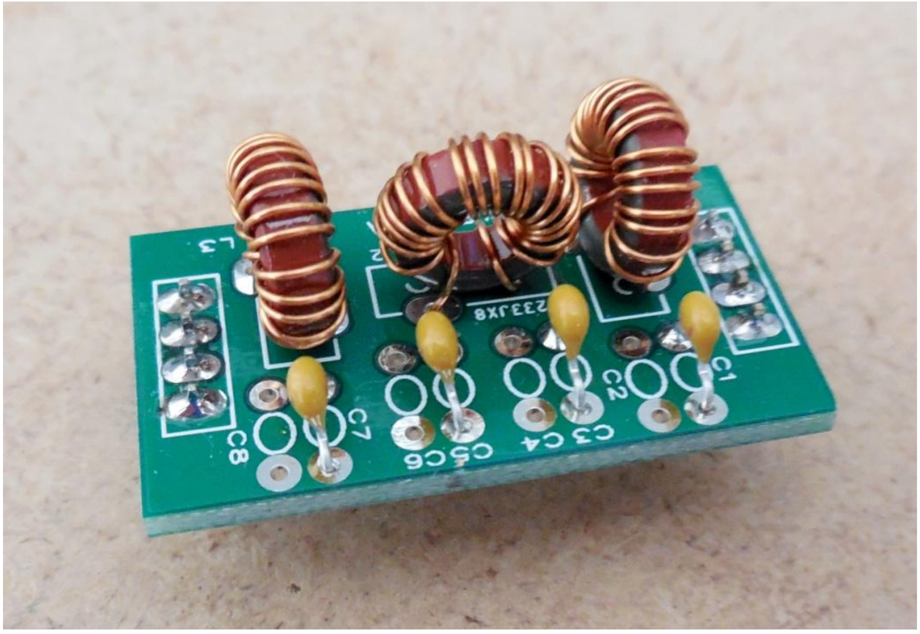


Figure 15 Completed LPF

80M LPF			
C1	820pF (821)	**C5**	1500pF (152)
C2	N/A	**C6**	N/A
L1	T37-2 (red) core. **25** turns of 0.4mm enameled wire. 380mm long.	**L3**	T37-2 (red) core. **25** turns of 0.4mm enameled wire. 380mm long.
C3	1500pF (152)	**C7**	820pF (821)
C4	N/A	**C8**	N/A
L2	T37-2 (red) core. **26** turns of 0.4mm enameled wire. 380mm long.		

40M LPF			
C1	470pF (471)	**C5**	820pF (821)
C2	N/A	**C6**	N/A
L1	T37-2 (red) core. **18** turns of 0.4mm enameled wire. 290mm long.	**L3**	T37-2 (red) core. **18** turns of 0.4mm enameled wire. 290mm long.
C3	820pF (821)	**C7**	470pF (471)
C4	N/A	**C8**	N/A
L2	T37-2 (red) core. **19** turns of 0.4mm enameled wire. 290mm long.		

20M LPF			
C1	220pF (221)	**C5**	180pF (181)
C2	N/A	**C6**	220pF (221)
L1	T37-6 (yellow) core. **14** turns of 0.4mm enameled wire. 240mm long.	**L3**	T37-6 (yellow) core. **14** turns of 0.4mm enameled wire. 240mm long.
C3	180pF (181)	**C7**	220pF (221)
C4	220pF (221)	**C8**	N/A
L2	T37-6 (yellow) core. **15** turns of 0.4mm enameled wire. 240mm long.		

17M LPF			
C1	180pF (181)	**C5**	330pF (331)
C2	N/A	**C6**	N/A
L1	T37-6 (yellow) core. **13** turns of 0.4mm enameled wire. 220mm long.	**L3**	T37-6 (yellow) core. **13** turns of 0.4mm enameled wire. 220mm long.
C3	330pF (331)	**C7**	180pF (181)
C4	N/A	**C8**	N/A
L2	T37-6 (yellow) core. **14** turns of 0.4mm enameled wire. 220mm long.		

Table 2 LPF components

10 ADDING A VFO

The MST3 can be used with any VFO that has the correct frequency range and can supply between 300 and 600 mV p-p. If upgrading from an MST or MST2, the existing DDS VFO will be suitable.

The VFO is connected to the MST3 PCB using a 2 pin connector near the middle of the board for the RF signal, and a 6 pin connector on the edge of the board which provides power and control signals. The 6 pin connector pinout is:

1. Not Connected.
2. PW. Current source relative to transmit power to drive a LED or LED S meter.
3. UL. This pin switches between ground and +12V indicating the sideband selection.
4. TX. This pin goes to +12V when the MST3 is in transmit mode.
5. 12. +12V power supply for the VFO.
6. GD. Common ground.

When choosing a VFO, an important consideration is that the VFO frequency can be above or below the 10MHz IF frequency and still produce the correct output frequency.

Shown in Table 3 is a guide to select the correct VFO frequency and U/L switch setting for each band.

Note that if the VFO frequency is below 10MHz, USB will be generated with the U/L switch closed, while LSB will be generated with the switch open. If the chosen VFO frequency is above 10MHz, the sideband selection will be reversed.

Band	VFO frequency	Mixing Formula	U/L Switch	LSB or USB
80M	6.5MHz	10-6.5 = 3.5	Open	LSB
	13.5MHz	13.5-10 = 3.5	Open	USB
	6.5MHz	10-6.5 = 3.5	Closed	USB
	13.5MHz	13.5-10 = 3.5	Closed	LSB
40M	3MHz	10-3 = 7	Open	LSB
	17MHz	17-10 = 7	Open	USB
	3MHz	10-3 = 7	Closed	USB
	17MHz	17-10 = 7	Closed	LSB
20M	4MHz	10+4 = 14	Open	LSB
	24MHz	24-10 = 14	Open	USB
	4MHz	10+4 = 14	Closed	USB
	24MHz	24-10 = 14	Closed	LSB
17M	8MHz	10+8 = 18	Open	LSB
	28MHz	28-10 = 18	Open	USB
	8MHz	10+8 = 18	Closed	USB
	28MHz	28-10 = 18	Closed	LSB

Table 3 VFO selection

11 ENCLOSURE

The MST3 PCB has the same dimensions and mounting hole locations as the previous MST versions. This allows for easy upgrading of existing MST transceivers without changing enclosures.

The PCB was designed to fit inside a plastic instrument case 200mm wide by 155mm deep by 65mm high. A suitable type is catalogue number H0480F available from www.altronics.com.au. It can be purchased with aluminium panels or you can easily make them yourself from 1.5 or 2mm thick aluminium sheet. The PCB mounting holes match plastic pillars on the bottom of the enclosure and it will be necessary to remove unwanted pillars using either a large pair of side-cutters or carefully with a large drill.

Of course any other enclosure that accommodates the PCB will be suitable, although you will need to take into consideration the size and mounting arrangements for the controls and connectors, the VFO and optional LED S meter.

Before installing the board in the enclosure, carefully look for errors, such as components in the wrong way and solder bridges between tracks. The risk of solder bridges is greatly reduced due to the solder mask, but check anyway. A few moments spent here is cheap insurance against big problems later on. One of the more common problems is poor solder joints with enamel covered wire. Some types when soldered will melt the enamel but most will not, so it is advised to scrape the enamel off the ends of the wires with sandpaper or a sharp knife before soldering.

11.1 FRONT PANEL

The front panel accommodates the controls and connectors, the VFO and optional signal meter. An example of a completed transceiver using an MST3 board is shown in Figure 16.

Figure 16 MST3 in an enclosure

11.2 REAR PANEL

The rear panel only contains the antenna socket and two binding post to connect the power supply. Remember to locate the antenna socket near the PCB ANT and GND pins so the wires are kept short, but clear of the LPF so that it can be removed.

11.3 MOUNTING THE PCB

This section assumes the PCB is mounted in a plastic enclosure, but the same general procedure applies for other enclosures.

Temporarily put the rear panel in place and sit the PCB on the mounting pillars. If needed bend the leads of Q14 slightly so that the metal tab is resting parallel against the rear panel. Use a sharp pencil or scriber and run around the inside of the hole in the tab to mark the position for the mounting hole on the rear panel. Remove the rear panel and drill a 3mm hole ensuring that you remove all burrs.

Screw the PCB to the mounting pillars using small self-tapping screws. Slide an insulating washer between the rear panel and Q14 tab. Insert a plastic bush into Q14 tab then pass a 3mm screw from the rear through the bush and screw on a nut and tighten.

Figure 17 shows how the MST3 board is mounted inside an enclosure and the wiring to the rear connectors. It also shows the output PA MOSFET screwed to the rear panel to act as a heatsink.

⚠ **Check with a multimeter that there is no electrical connection between the rear panel and Q14 tab.**

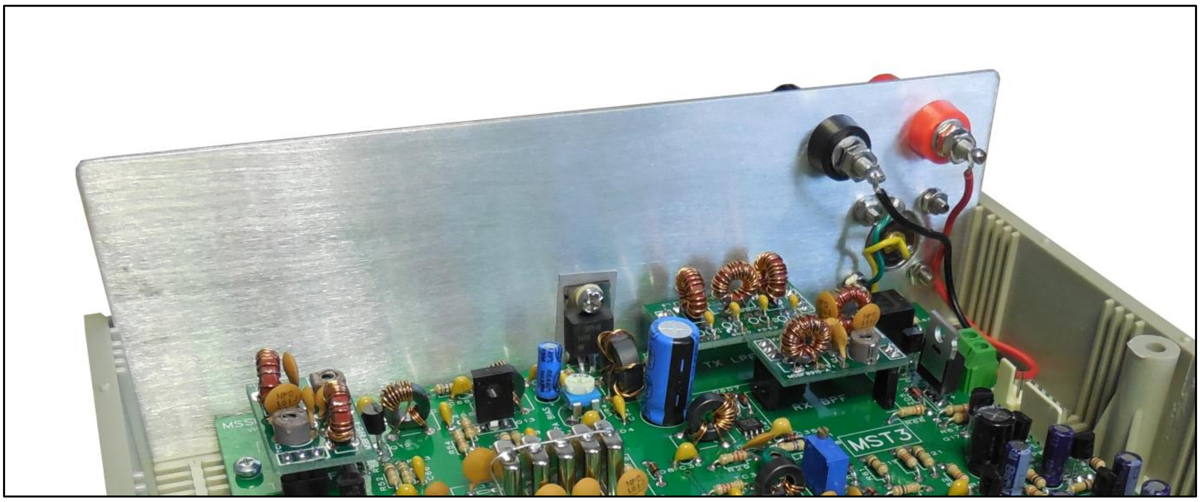


Figure 17 MST3 board and rear panel

12 WIRING UP

12.1 GENERAL

The wiring diagram is shown in Figure 18. Use light duty hookup wire of different colours for easy identification and twist parallel wires together. The connections that carry audio signals should be in light duty shielded audio cable.

12.2 HEADERS

Most PCB connections utilize 2.54mm (0.1") pitch polarized headers and mating plugs. These are inexpensive, give a professional looking appearance and allow easy disconnection and removal of the PCB if required. The plugs are comprised of a plastic housing and crimp contacts which slide into the housing and click in place. If you don't have a suitable crimper it is best to squeeze the contact wings around the wire with long nose pliers to hold in place and then solder. Be careful not to use too much heat and solder as it will make it difficult to insert the contact into the housing.

12.3 POWER SUPPLY

The power supply connection uses a screw terminal block because of the higher currents involved.

12.4 ANTENNA

The antenna connection uses short wires soldered between the antenna socket and PCB pins to give a low resistance connection. You will also need to install a solder tag for the earth wire under the closest antenna socket screw. Twist the two wires together and keep as short as possible.

12.5 KEY SOCKET

The key socket is wired in parallel with the PTT wires on the mic socket. Ensure that the ground wires of each connector are common.

12.6 SWITCHES

The Tone switch is not polarized and can be wired in either way. The U/L toggle switch will need wiring to suit the sideband selection front panel labelling.

12.7 VFO

If preferred the VFO RF cable can be made from shielded audio cable rather than coax cable as the length is quite short.

The control cable can be a multi-wire cable or a set of twisted individual wires. The number of wires used will depend on the capabilities of the selected VFO.

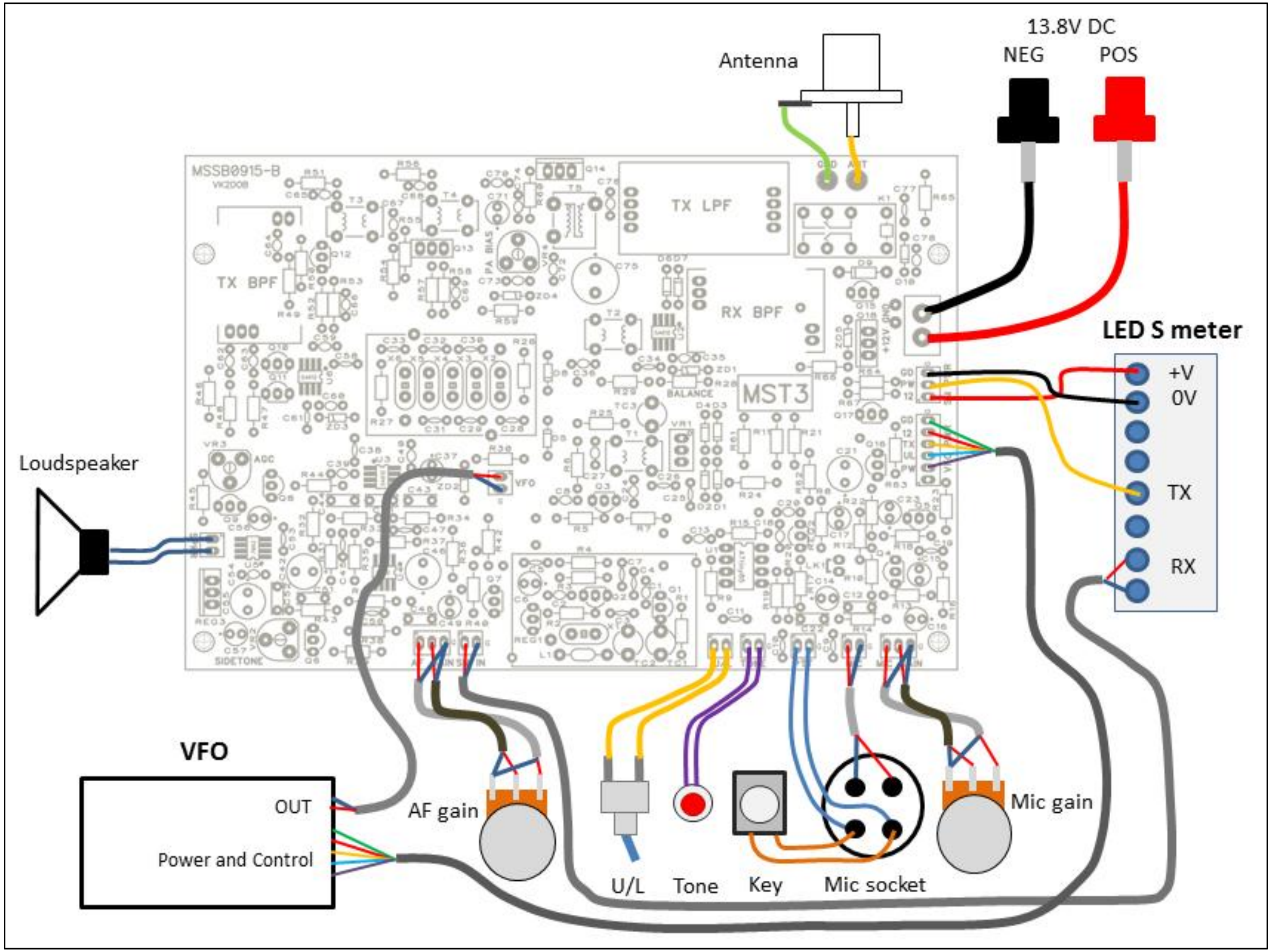


Figure 18 Wiring diagram

13 TESTING AND ALIGNMENT

13.1 GENERAL

A suggested list of basic tools and accessories to undertake testing is shown below.

- Digital multimeter.
- 50 ohm dummy load capable of dissipating at least 5 Watts.
- QRP wattmeter or oscilloscope.
- Power supply capable of 13.8V DC regulated at more than 1 Amp.
- Small adjustment screwdriver.
- An audio signal generator.
- An RF signal generator.
- A frequency counter.

⚠ **A VFO set to the correct frequency range is required for testing and alignment.**

⚠ **Table 4 lists typical voltages at various points around the board and can be used to verify operation.**

13.2 POWER ON

- Temporarily remove the power connector for the VFO so that the MST3 board current can be measured alone.
- Using a small screwdriver:
  - Rotate the bias trimpot VR4 fully counter-clockwise so that the gate bias voltage is zero volts.
  - Set carrier balance trimpot VR1 to halfway by counting turns. You should hear a slight click as you reach either end.
  - Rotate the AGC trimpot VR3 fully counter-clockwise.
- Connect a 50 Ohm dummy load to the antenna socket.
- Connect the power supply to the board terminals.
- If your power supply does not include a current meter, connect a multimeter in series with the power supply positive lead and set to measure current.
- Turn on the power supply. Check you hear two short beeps from the speaker indicating that the ITM has booted successfully.
- Note the supply current. It should be around 90mA. If it's far from this turn off immediately and look for problems.
- The relay should be de-energized and the board in RX state. To verify that there are no obvious problems do a quick probe around the board with a multimeter and check the DC receive voltages as shown in**Error! Reference source not found.**.
- Plug in the VFO power connector. Set the VFO to a frequency in the middle of the band.
- Turn the AF gain control to halfway. You should hear some low level hiss come from the speaker indicating that the audio stages are working.

13.3 Receive

13.3.1 Carrier Balance

- Connect a frequency counter at the emitter of transistor Q3. Open the U/L switch.
- Adjust trimmer capacitor TC2 until the frequency is 9.999MHz. This is the upper carrier (BFO) frequency and is placed on the upper skirt of the crystal filter.
- Close the U/L switch. Adjust trimmer capacitor TC1 until the frequency is 9.997MHz. This is the lower carrier (BFO) frequency and is placed on the lower skirt of the crystal filter.
- Switch the U/L switch back and forwards noting the frequency. There is some interaction between the settings, so you may need to adjust them a little each time until they are correct.

⚠ **These are the suggested carrier frequencies and may need adjusting slightly depending on the precise crystal filter characteristics. See section 13.6 for more details.**

13.3.2 Receive BPF

- Remove the dummy load and apply a moderate RF signal (100uV) to the antenna connector and tune the VFO until a clear tone is heard in the speaker. Carefully adjust the trimmer capacitors in the receive BPF for maximum volume. As you approach maximum you may need to reduce the AF gain control to avoid overload. You can experiment with the position of the two trimmer capacitors to obtain a specific bandwidth, but in general, peaking at the middle of the band will be satisfactory.
- If fitted, set up the LED S meter display as per the instructions in the LED S meter construction manual.

13.4 Transmit

- Remove the RF signal source and reconnect the dummy load. It will be an advantage to have either a QRP power meter or oscilloscope to obtain an indication of power output.
- Turn the Mic gain control fully counter-clockwise.
- Un-plug the VFO power connector.
- Briefly switch to TX state by shorting the PTT contacts. Check the power supply current. This is the idle transmit current of the MST3 board only and should be about 210mA. Anything far from this indicates a problem and should be investigated.
- Plug in the VFO power connector. Check that the current draw now is the sum of the MST3 idle transmit current plus the specified VFO current. If not check your VFO and connections.
- Write the new idle transmit current value down so that it can be used to measure and set the PA bias current.

13.4.1 PA bias setup

- Operate the PTT and using a screwdriver slowly rotate the bias trimpot clockwise. At about half rotation the power supply current should start to rise gradually and smoothly. Any excessive spikes in current indicate instability and need to be investigated.

- Keep increasing until the power supply current is around 150mA more than the idle transmit current written down in the step above. The increase in current is mainly due to the output MOSFET starting to conduct and move into linear operation, but some will be because we have not balanced the carrier yet and there is some power output.

⚠ **The final bias current is set in a later step. Ensure now that the current is not too high or the output MOSFET will get very hot.**

- Adjust carrier balance controls TC3 and VR1 for minimum power output. The null is quite sharp, and there is some interaction between the controls, so you will need to go back and forth to obtain maximum balance.
- With the carrier balanced rotate the bias trimpot fully counter-clockwise to turn off the MOSFET.
- Slowly rotate the bias trimpot clockwise again until the power supply current is 150mA higher than the idle transmit current recorded earlier. The output stage bias current is now set.
- If you still notice some power output readjust the carrier balance controls again for minimum.

13.4.2 Transmit BPF

- Apply an audio signal generator to the Mic socket set to 1KHz at around 50mV. Operate the PTT and slowly increase the Mic gain while monitoring the power output. When some power (about 1 Watt) is indicated carefully adjust the trimmer capacitor in the transmit BPF for maximum output. You may need to readjust the Mic gain to get a suitable power output to see the peak. Once the BPF is peaked operate the Mic gain up and down while monitoring the power output. The power output should change smoothly up and down and you should be able to easily achieve 4-5 Watts output. Once satisfied release the PTT.
- Refer to the LED S meter Construction manual and verify operation. If you are not using the LED S meter, check that the RF power LED illuminates and changes intensity with varying power output.
- If you intend to use an Electret microphone place a short across LK1. This can be a soldered link or you can install a 2 pin header and a removable shunt. Leave LK1 open for dynamic microphones.
- Plug in a microphone and check there is RF output when you speak and the relay operates when the PTT is pressed. You will now be able to monitor yourself with a receiver placed nearby and determine an appropriate Mic gain setting.

Location	V DC Receive	V DC Transmit
Q2 collector	8V	8V
Q2 emitter	5V note 2	5V note 2
Q3 emitter	0V	6.9V note 2
U1 pin 1	5V	5V
U1 pin 8	5V	5V
U1 pin 3	2.5V	2.5V
Q4 collector	0V	4.9V
Q5 collector	0V	5.1V
U2 pin 8	6.8V note 1	0V
U3pin 8	6.8V note 1	0V
U6 pin 8	0V	6.8V note 1
U4 pin 8	10.4V	0V
U4 pin 1	5.2V	0V
U4 pin 7	5.2V	0V
U5 pin 1	8V	8V
U5 pin 4	1.1V	0V note3
U5 pin 5	3.8V	3.8V
Q12 emitter	0V	1.3V
Q13 emitter	0V	1.6V
Q14 gate	0V	4.2V note 4

Notes:

1. Zener tolerance +- 5%.
2. RF present.
3. No tone in speaker.
4. No RF drive.

Readings taken with a digital multimeter.
Power supply voltage set at 13.8V DC.

Table 4 Typical circuit voltages.

13.5 Audio AGC adjustment

The audio AGC is easy to set up and the procedure outlined below has been refined after many hours of on-air listening.

- Set the AF gain control to about half way
- Inject an S9 RF signal into the antenna connector.
- Slowly rotate the AGC trimpot (VR3) clockwise until you can just notice a lowering of the audio level. This sets the point where AGC starts to operate.
- Increase the RF signal level and check that the rate of increase of the audio level is much less than the RF input level change.

⚠ **The AF gain control is located before the audio AGC circuit and so adjusting the AF control for signals above S9 may not have the expected outcome. This is because the AGC circuit is attempting to adjust the audio and keep it constant. For signals below S9 the AF gain control works in the expected manner.**

If the audio AGC is not required simply rotate VR3 fully counter-clockwise.

13.6 Carrier Frequency Adjustment

For proper SSB operation it is important to align the carrier frequency with the frequency response of the crystal filter.

To help illustrate this, shown in Figure 19 are three possible conditions that can occur.

⚠ **The example shows a LSB signal, but the same is true for USB except the sidebands are reversed.**

The DSB signal produced by the balanced modulator contains both LSB and USB sidebands. LSB extends below the carrier, while USB extends above the carrier. The carrier oscillator is shown as a dotted line as it is suppressed in the modulator and not present in the transmitted signal. Also shown is the crystal filter frequency response.

The suggested carrier frequency for LSB operation is 9.999MHz which places it on the upper skirt of the crystal filter frequency response. This is shown in the top diagram in Figure 19.

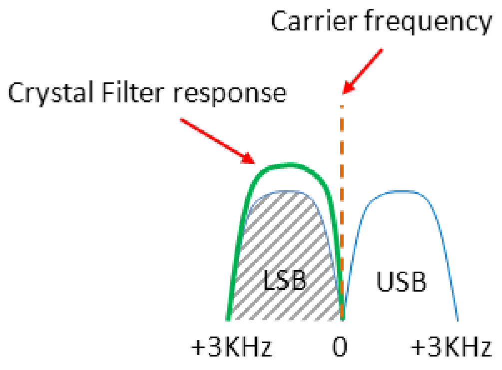
Due to small variations in individual crystal filters the carrier frequency may need shifting slightly to match the filter. The middle and bottom diagrams in Figure 19 show the two scenarios where the carrier frequency and the crystal filter response are misaligned.

There are a number of ways to correct this but without instruments the easiest is to listen to a good strength station of known quality in LSB while gently adjusting the relevant trimmer capacitor. Adjust until the received audio sounds natural and the balance of high and low audio frequencies appears correct.

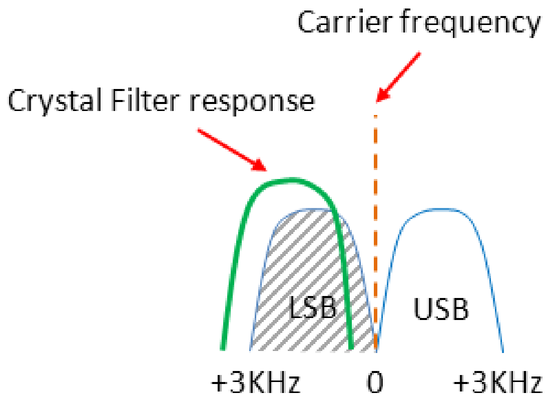
Switch to USB and repeat the process using the other trimmer capacitor. As the two trimmer capacitors are not fully independent it may be necessary to repeat this procedure a couple of times to get equal sideband response.

Alternatively you can adjust the carrier frequencies while transmitting into a dummy load and monitoring yourself on a nearby receiver. While speaking adjust the relevant trimmer capacitor until you sound ‘normal’ and the opposite sideband suppression is acceptable.

This diagram shows the carrier frequency correctly aligned with the crystal filter passband. The whole of the LSB is passed but the USB is filtered out.



In this diagram the carrier frequency is shifted high in comparison to the crystal filter. This results in the low audio frequency components of the LSB being filtered out. This would make the signal sound thin and lack body.



In this diagram the carrier frequency is shifted low in comparison to the crystal filter. This results in the high audio frequency components of the LSB being filtered out. This would make the signal sound muffled and have too much bass.
Note also that some of the USB signal is passed by the filter.

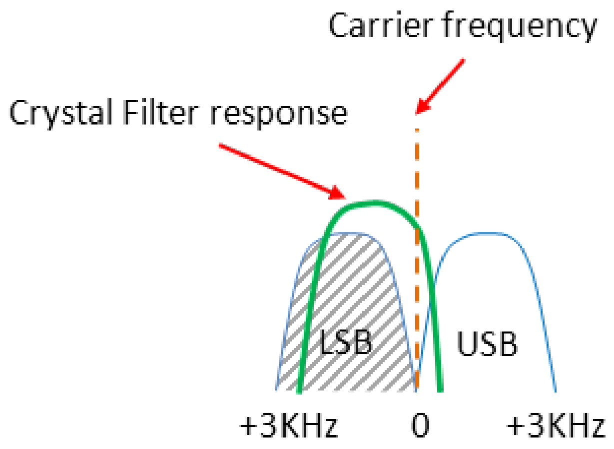


Figure 19 Carrier frequency and crystal filter relationship

14 OPERATION

14.1 POWER ON

To power the MST3 you will need a DC power supply or battery. The voltage should ideally be 13.8V for the rated power output, however the supply can range from 12 to 15V. The power supply is connected to the screw terminal block on the PCB. The MST3 incorporates polarity protection, so if nothing powers up, check you have the wires the right way. Reverse connections will not harm the MST3.

When power is applied and the ITM boots up two short beeps will be heard in the speaker.

14.2 RECEIVE STATE

At power on the MST3 is automatically placed in receive state. The relay will be de-energized and the antenna will be connected to the receiver.

Use the controls on the VFO to tune across the band and adjust the audio volume with the AF gain control. The MST3 incorporates a form of automatic gain control (AGC) where the audio level to the speaker is limited for input signals above about S9 level. This is performed in the audio power amplifier which is after the AF gain control. Advancing the AF gain control will not seem to act in the normal way for large signals, as the AGC circuit will attempt to keep the speaker level constant. For signals less than S9 the AF gain control will act in the normal way as the AGC circuit has not been activated.

If for some reason you don't want AGC rotate the AGC trimpot fully counter-clockwise.

14.3 SSB Mode

14.3.1 Introduction

In SSB mode the desired upper or lower sideband can be selected via the U/L switch. This shifts the carrier frequency by around 3KHz. A consequence of this is that the transmitted frequency will also shift by this amount. For example, if you are transmitting on the 40M band at 7.100MHz using LSB, and you toggle the U/L switch to operate USB, the transmitted frequency will move to 7.097MHz.

A pin on the VFO connector has been provided that switches between 0V and +12V to indicate to the VFO which sideband has been selected. If the VFO used is capable of shifting frequency under external control the carrier frequency shift can be overcome using this signal.

14.3.2 Operation

1	Insert the microphone.
2	If the MST3 is in CW mode, press the Tone button until a single long beep is heard. Release the Tone button and a 'SSB' Morse message will be heard in the speaker.
3	Set the U/L switch to the desired sideband.
4	To transmit press the PTT button on your microphone and talk.
5	The LEDs on the LED S meter will illuminate giving an indication of the power output. If the LED S meter is not installed the front panel RF LED indicator will illuminate on voice peaks. It can also be used as a rough guide to power output as the current through the LED, and therefore its brightness, is dependent on the peak RF output. If the LED is illuminated at a constant level when talking, it indicates that you are driving the transmitter too hard and causing clipping of the RF signal.
6	Pressing the Tone button briefly while the PTT is operated, will send a 'MST3' Morse message. This is a fun feature intended to identify with other MST3 users.

⚠ **Overdriving will create distortion and excessive harmonic generation and must be avoided.**

To check your signal either connect the MST3 to a dummy load and monitor yourself with headphones on a nearby receiver, or have a friend that lives close by listen to your signal. The idea is to increase the Mic gain progressively while the receiver sweeps across your transmission looking for distortion and unwanted spurious byproducts. Set the Mic gain control just below the point where these are noticeable.

14.4 CW Mode

14.4.1 Introduction

The MST3 has been designed to be primarily a SSB transceiver however CW operation has been added for occasional use and testing. The method used to generate the CW signal is to key a tone on and off and inject this into the microphone channel. The tone is a shaped 800Hz sinewave of good quality, however this is not the usual approach to a CW transmitter and so there are a few things to consider:

1. As the tone is sent via a SSB generator and crystal sideband filter there will be some CW information present on the opposite sideband. The level depends on the opposite sideband suppression and will typically be 40 to 50dB below the wanted sideband. This should place it down in the noise in most circumstances; however if the band is very quiet and your signal is very strong at the remote receiver, it may be also audible in the opposite sideband.
2. The balanced modulator carrier balance must be accurately adjusted. If the carrier is not suppressed, and the receiving station is not zero beat with the carrier, there may be two tones audible at the remote receiver. One low level constant tone as a result of the carrier and one much stronger which is keyed on and off.
3. The MST3 receiver does not employ a narrow crystal filter so other adjacent CW transmissions may be heard simultaneously on a busy band.
4. The frequency of the transmitted CW signal is the suppressed carrier frequency plus or minus 800Hz depending on the U/L switch setting. This is equivalent to shifting the carrier frequency by 800Hz as might be done in a CW only transmitter.

14.4.2 Operation

1	Remove the microphone and insert the Morse key.
2	Press the Tone button until a single long beep is heard. Release the Tone button and a ‘CW’ Morse message will be heard in the speaker. The MST3 is now in CW mode, but still in receive state. When the Morse key is operated sidetone will be heard in the speaker along with received audio and can be used to ‘net’ the other station.
3	To switch to transmit state press the Tone button briefly. The relay will energize and the Morse key can now be used to send. Sidetone will be heard in the speaker and the volume can be adjusted with the sidetone trimpot. To adjust transmit power rotate the Mic gain control. Clockwise increases power, while counter-clockwise decreases power.
4	To return to receive state press the Tone button briefly. Each brief press of the Tone button toggles between receive and transmit state.
5	To exit CW mode and return to SSB mode press the Tone button until a single long beep is heard and then release.

14.5 Test Tones

The MST3 has three inbuilt test tones that can be used to check power output levels, SWR and antenna tuners etc.

1	Press the Tone button until two long beeps are heard and then release. Ignore the first single long beep.
2	A sample of continuous tone, which is the first test sequence, will be heard. Pressing the Tone button briefly will cycle through each test tone where a small sample of each is heard.
3	Once the required test tone is selected, press the Tone button again until a single long beep is heard. This turns on the PTT and starts the test tone transmission. The level of the test tone and hence the transmitted power can be adjusted with the Mic gain control. The tone will repeat until stopped.
4	To stop the test tone, press the Tone button until the tone ends and the MST3 returns to receive state.

14.6 Entering a Callsign

The MST3 can transmit a callsign during the CW message test sequence.

The CW test sequence will become: 'TEST DE <***callsign***>'.

The callsign is stored by the ITM in its internal non-volatile memory. The callsign is entered by a Morse key, and the procedure is as follows:

1	Remove the microphone and insert the Morse key.
2	Press the Tone button until three long beeps are heard and then release. Ignore the first single long beep, and the second two long beeps.
3	Tap in the callsign using the Morse key. The ITM can recognize speeds between about 5wpm to 20wpm. While the decoder is tolerant to non-perfect Morse, try and form the characters as close to ideal as possible to avoid misreads. If the ITM is having trouble decoding the Morse characters, try slowing down the keying rate. Adding a larger than normal space between characters is also helpful. The memory can store up to 10 characters.
4	At the end of the callsign entry press the Tone button until a single long beep is heard.
5	The entered callsign will then be announced, and the MST3 will return to normal receive state.
6	If the entered callsign is incorrect, simply repeat steps 2 to 5.

Congratulations your new SSB QRP transceiver is ready to put on the air.

Have fun!