MDT

DSB TRANSCEIVER

CONSTRUCTION MANUAL

www.ozQRP.com

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Change History

Date	Issue	Comments
12-6-15	1	First release
20-6-15	2	Corrected values for R43 and C13, and other minor typos.

1 INTRODUCTION

The MDT (Minimalist Double Sideband Transceiver) is an inexpensive and easy to build kit for the 40M band. It is ideal for the first time builder as all parts except the microphone socket are mounted on a single PCB and all the components are through hole. There is a SMD tuning diode but this comes pre-installed. The PCB is a high quality double sided type with ground plane, solder mask and silk screen.

The plastic case is small and lightweight and can easily be held in one hand. The front and rear panels, which are made of PCB material, come pre-cut and feature silkscreened labeling.

The low receive current of the MDT means it is ideal for battery operation. The transmitter outputs between 1.5 and 2 watts DSB which is ample for short distance contacts through the day and long distance contacts under good conditions. DSB transmissions are entirely compatible with SSB transceivers, and in fact most operators won't be aware unless you tell them.

Building the MDT is quick and easy. The receiver doesn't require any alignment and the only setup required for the transmitter is setting the microphone gain and balancing the mixer to null out the carrier.

A kit of parts for the MDT including everything you need, such as enclosure and front and rear panels is available from www.ozQRP.com.

MDT Specifications and features:

1. Size 130mm x 100mm x 50mm.
2. Direct Conversion receiver. Sensitivity 0.4uV for 10dB S+N/N.
3. Double Sideband transmitter. Nominal 1.5W output. Up to 2W depending on power supply voltage.
4. Selectable frequency range. 7.090MHz - 7.130MHz or 7.050MHz - 7.110MHz.
5. Microphone amplifier accepts standard low impedance dynamic or Electret microphone with selectable on-board bias resistor.
6. LED transmit power and modulation indicator.
7. 3.5mm stereo headphone connector. Can power external loudspeaker.
8. Carrier suppression up to 50dB.
9. All spurious transmit outputs better than -46dBC.
10. Receive current approximately 50mA.
11. Transmit current approximately 250mA at maximum power output.
12. Reverse polarity protection using a series-diode.

2 DSB VS SSB

Why DSB? The answer is simple. A DSB transceiver is less expensive, less complicated and easier to build and align than a SSB transceiver. This is due mainly to a DSB transceiver not having a crystal filter, IF amplifier and multiple mixers that are required in a SSB design. Note that in a DSB transceiver the receiver is more often referred to as a Direct Conversion (DC) receiver.

For the first time builder or for a small and cheap rig, DSB is ideal. Over the years countless amateurs have started out this way.

While a DSB rig has many advantages for the home builder, there are some things to consider. Firstly, a DSB transmitter occupies twice the bandwidth of a SSB transmitter. On a quiet band this does not cause any problems but on a crowded band it may not be as easy to find a free spot to operate without interfering with nearby stations. Secondly, the Direct Conversion receiver has equal response to both sidebands. This means you hear signals on both upper and lower sidebands simultaneously. This results in a slightly higher noise level and the possibility of hearing two separate stations at the same time.

There are, however, a couple of nice advantages when a Direct Conversion receiver is used with a DSB transmitter. Firstly, you can operate with SSB stations using Upper Sideband (USB) or Lower Sideband (LSB) without having to change controls or move frequency. Secondly, being able to hear both sidebands means that you can check for other stations on both sides of your frequency before transmitting and avoid interfering with them.

3 DSB TRANSMITTER

Figure 1 shows how a Double Sideband signal is generated. The mixer used here is not to be confused with an audio mixer that combines, for example, microphones. The mixer here is more correctly called a multiplier, where the inputs are multiplied in the same way as in a mathematical equation. When multiplying sine waves there are two main outputs and these are the sum and difference of the frequencies of the input signals.

The first input to our mixer is from the VFO or carrier oscillator. The second input is audio from the microphone amplifier.

The dominant outputs of the mixer are the sum and difference frequencies, that is, the sum and difference of the carrier and audio frequencies. In this case, 7.101MHz (7.100MHz + 1KHz) upper sideband, and 7.099MHz (7.100MHz – 1KHz) lower sideband.

The important thing to note is that only the sidebands are present at the output of the mixer as the carrier and audio signals have been suppressed by the action of the balanced mixer.

The diagram in Figure 1 at top right shows the DSB output signal in the time domain, or how it would be seen on an oscilloscope. Note the overlapping envelope shape that follows the audio waveform. The diagram at bottom right shows the DSB output signal in the frequency domain and how it would be seen on a spectrum analyser. The horizontal axis is frequency and the vertical axis is amplitude. The dotted vertical line in the middle indicates the suppressed carrier frequency.

By contrast, if this was a SSB transmitter, there would be a crystal filter placed after the mixer and one of the sidebands would be filtered out. However, it would then be necessary to add another mixer to move the SSB signal onto the wanted transmit frequency.

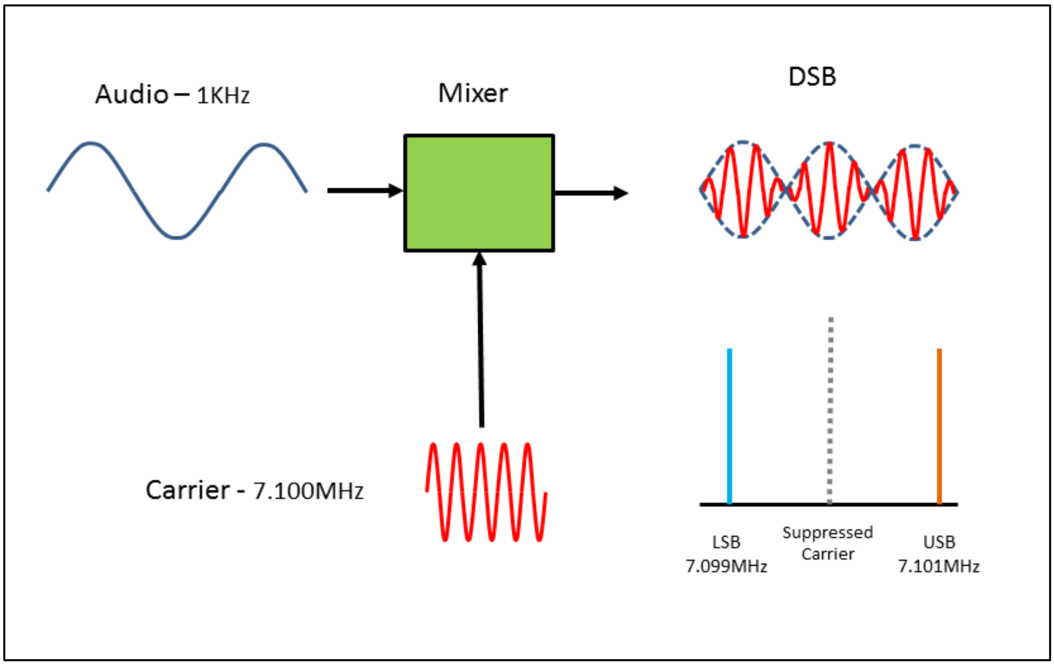


Figure 1 DSB generation

4 DIRECT CONVERSION RECEIVER

Figure 2 shows the simplified diagram of a Direct Conversion receiver. As with a DSB generator the mixer has two inputs and an output, but this time the signal directions are reversed.

Signals from the antenna are presented to the mixer, and mixed with the VFO signal. The output again contains sum and difference signals. The sum frequency of 7.101MHz + 7.100MHz (14.201MHz) is easily filtered out by a low pass audio filter. However the difference frequency of 7.101MHz – 7.100MHz (1KHz) can pass through the filter and be heard in the headphones. This is the upper sideband response as the antenna signal frequency of 7.101MHz is above the 7.100MHz VFO frequency.

Note that there is also another antenna signal that can be heard. This is the lower sideband signal at 7.099MHz. This would also produce a 1KHz tone in the headphones.

This ability to simultaneously detect both upper and lower sidebands is an important characteristic of a Direct Conversion receiver.

Both Figure 1 and Figure 2 show a single 1KHz tone for the audio signal. This is done to make it easier to understand the process involved. In practice there would be a range of voice band frequencies present, but the same mixing conversion principle applies.

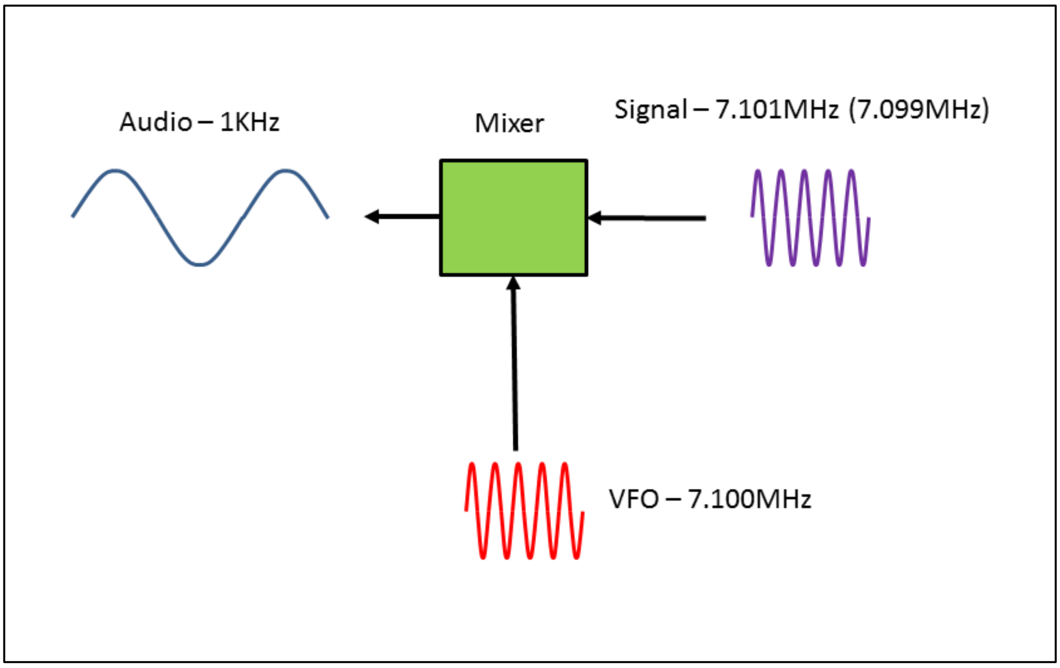


Figure 2 Direct Conversion receiver

5 MDT Block Diagram

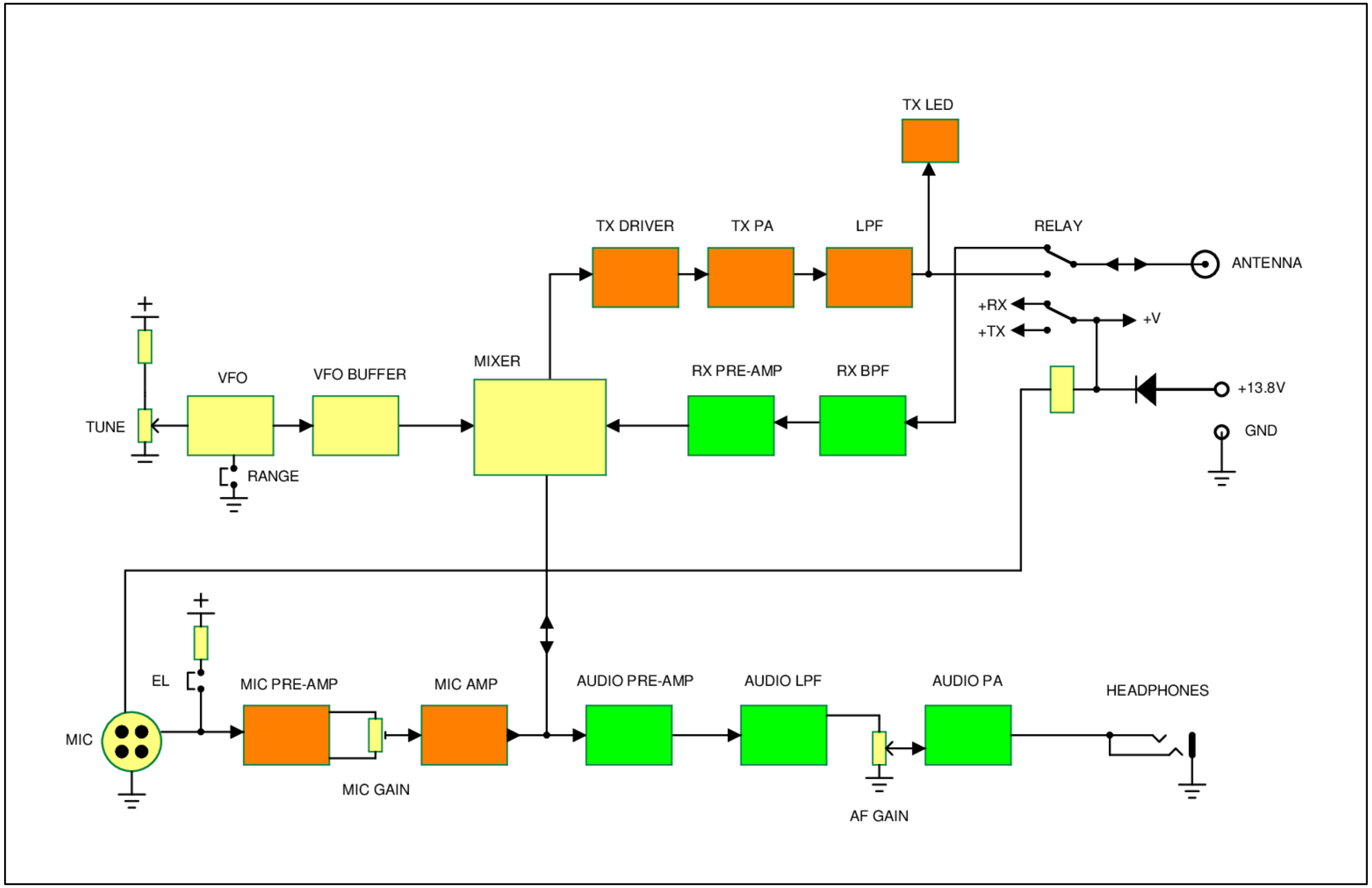


Figure 3 MDT Block diagram

6 CIRCUIT DESCRIPTION

6.1 VARIABLE FREQUENCY OSCILLATOR (VFO)

Transistor Q1 is configured as a Colpitts oscillator and acts as the carrier oscillator in transmit and beat frequency oscillator (BFO) in receive. The frequency is set predominantly by a ceramic resonator (X1) and a dual variable capacitance (varicap) diode D1. The capacitance of D1 is altered by a varying the DC voltage applied to the Cathodes through the Tune control VR1 and R3. To help stabilize the oscillator and minimize frequency drift the power supply to the oscillator and the Tune control is regulated with a 9.1V Zener diode ZD1.

The VFO has effectively two ranges through the Range link. If the link is closed both varicap diodes are in parallel circuit and the tuning range is approximately 60KHz. With the link open, only one varicap diode is in use and the range change is reduced to around 40KHz. Capacitor C3 is not normally used.

The oscillator signal is fed to the emitter follower buffer stage Q2 via a small capacitor (C6). The buffer stage provides light loading of the oscillator and a low impedance drive for the mixer.

6.2 MIXER

The balanced mixer is a diode switching type and doubly balanced. It performs two functions. In TX mode it mixes the VFO carrier signal with the microphone audio signal to produce DSB while in RX mode it mixes the antenna signal with the VFO signal to produce received audio.

The carrier signal, which is much larger in amplitude than the audio signal, is applied simultaneously to both sides of the mixer through trimpot VR2. The carrier signal turns on the diodes to form 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 D2 and D5 causing them to conduct and become a low resistance. When the carrier goes negative diodes D3 and D4 conduct. Note that capacitor C10 holds the junction of D2 and D4 at ground for RF. As the currents are equal through each of the conducting diodes the differential voltage across winding one of T1 does not change and no RF is present at winding three, the output of T1. If an audio signal is injected into the bridge at the junction of D2 and D4 the mixer balance is upset because the audio changes state much less frequently than the carrier signal and the instantaneous diode currents are not equal. As a result a signal is now output on winding three 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 TC1 and C9 are used to equalize the capacitance on the mixer sides, while trimpot VR2 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.

Received signals from the antenna are fed to a broadly tuned band pass filter formed with L1, C14 and C15. The values of C14 and C15 are selected to form a tuned circuit with L1 at 7MHz. The ratio of C14 and C15 provide impedance matching between the tuned circuit and the 50 ohm antenna source. It also sets the loaded 'Q' of the tuned circuit and as a result the overall filter bandwidth. The filter is connected to the receive pre-amplifier via a small 100pF coupling capacitor (C13). The pre-amplifier stage is formed around transistor Q3 in a common emitter configuration and provides around 10 times amplification. The collector load is winding two of the mixer transformer T1, and here the signal is mixed with the carrier. The resultant audio appears at the junction of D2 and D4.

6.3 MICROPHONE AMPLIFIER

Transistor Q7 is the microphone pre-amplifier with an input impedance of around 10K ohm and a gain of around 40 set mainly by C34 and R28. C32 is included across the input to prevent RF feeding into the amplifier. The amplified output appears across the 5K ohm trimpot (VR3) in the collector. This becomes a pre-set microphone gain control, and the signal from the wiper is fed to the microphone amplifier stage Q8. This stage only has a gain of around 3, but it's biased for higher current and a low value collector resistor so it can drive the balanced modulator. C33 and C36 provide heavy low pass filtering to limit the transmitted bandwidth.

If an Electret microphone is used, R25 provides a DC bias current and is enabled by shorting the EL link. If a dynamic microphone is used the link is left open.

6.4 TRANSMIT AMPLIFIER

Transmit signal from the mixer is applied to the driver stage built around transistor Q4. A BD139 works well here when biased with about 50mA of collector current. The design is well proven using both shunt and series feedback to provide low input and output impedance and good stable gain on the low HF bands.

The power amplifier stage is formed from two BD139 transistors (Q5 and Q6) in parallel. They operate in class B and provide up to 2 Watts PEP of power from a 13.8 V supply. The bases of the transistors are held at around 0.6 volts DC by the voltage reference formed by R18 and diode D6. This holds the transistors at or just below the point of conduction and so draw very little current with no RF drive. The 1.5 ohm resistors in the emitters force the transistors to share the load more equally, and provide a small amount of negative feedback which improves stability and prevents thermal runaway.

The collector load for Q5 and Q6 is a toroidal inductor L2. The specified inductance was found to provide maximum output into the low pass filter. The waveform from Q5 and Q6 can be high in harmonics and so a 5 pole low pass filter is included to reduce the level of harmonic and other spurious energy to an acceptable level. L4 and a 150pF capacitor form a parallel tuned circuit to give sharp attenuation of the second harmonic.

As a visual indication of power output and modulation, the transmit signal is sampled by capacitor C28 and ground referenced by R21. The signal is rectified by D9 and filtered by C29. This drives the front panel LED via current limiting resistor R22.

6.5 POWER SUPPLY AND RX/TX SWITCHING

When the PTT is operated the TX/RX relay is energized and 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

Diode D8 provides reverse polarity protection. With the power supply connected with the right polarity, D8 will pass current onto the board. There is a small voltage drop of about 0.3 volts but this has minimal effect on transmitter performance. If the supply is connected in reverse D8 will not conduct and the board will be protected.

6.6 RECEIVE AUDIO

The low level audio signal from the mixer is applied to the audio pre-amplifier stage (U1A). This is formed from one half of an LM833 dual low noise op-amp and has a gain of around 100 or 40dB. A reference supply for the non-inverting input is obtained from R33, R35 and C40. The high frequency response of U1A is limited by C41. The output of U1A is DC coupled to the 2 pole low pass filter (U1B) with a 3dB cutoff frequency of 2400Hz. This stage has only unity gain but its main task is to set the receiver bandwidth.

The output of the low pass filter is coupled to the AF gain control VR4 via a 1uF capacitor (C44). A LM386 (U2) is used to boost the signal from the AF gain control to drive a set of headphones. The gain is set by C47 and R42 to about 50 times or 34dB, while resistor R43 limits the audio to a comfortable level for headphone listening. If an external low impedance speaker is used instead of headphones, then R43 can be replaced with a link.

A MOSFET (Q9) is turned on in TX mode and shorts the audio signal to ground. Even though the audio amplifiers are switched off during transmit, this is still necessary because microphone signals can make their way through to the headphones while the audio amplifiers are turning off.

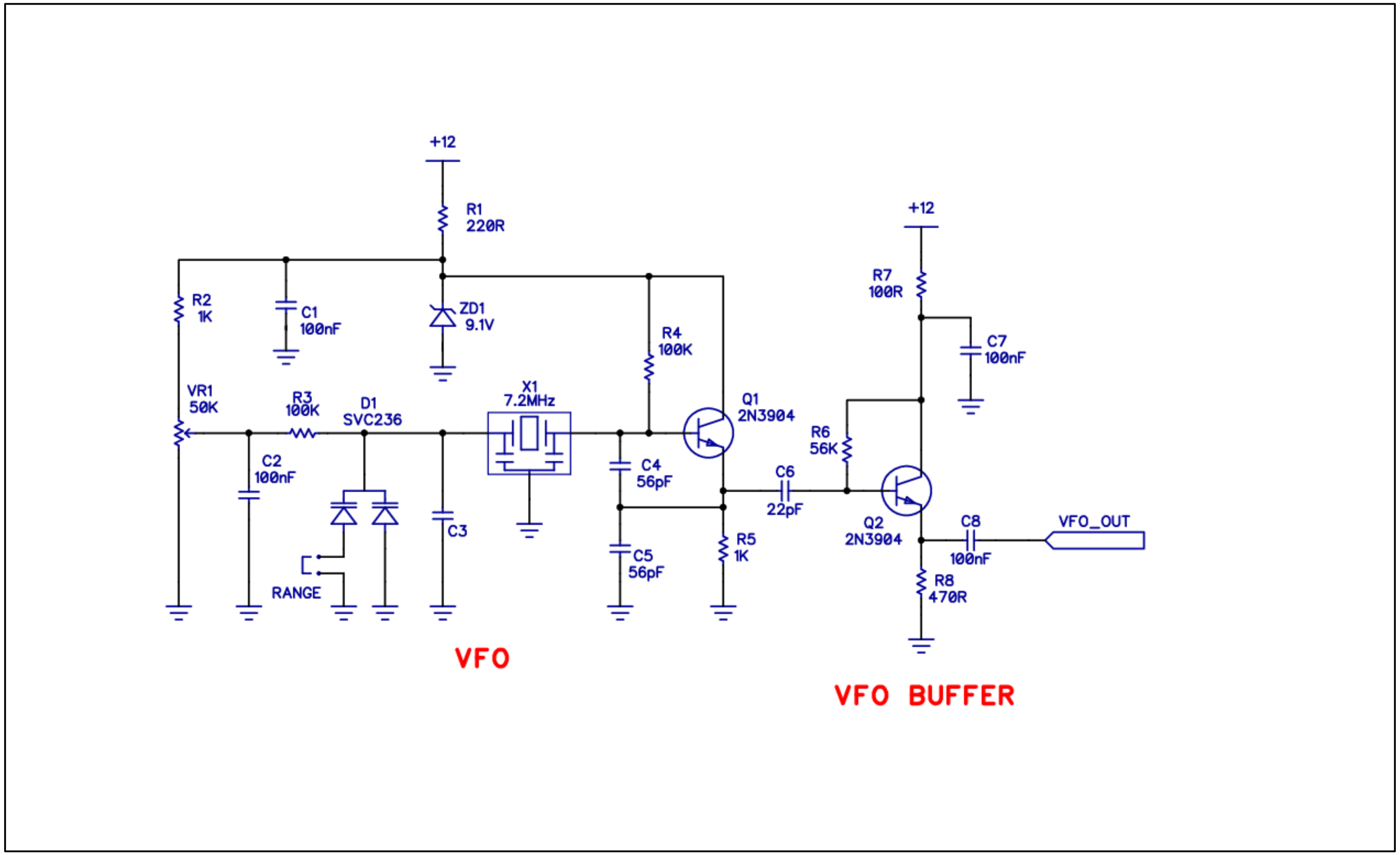


Figure 4 Carrier oscillator

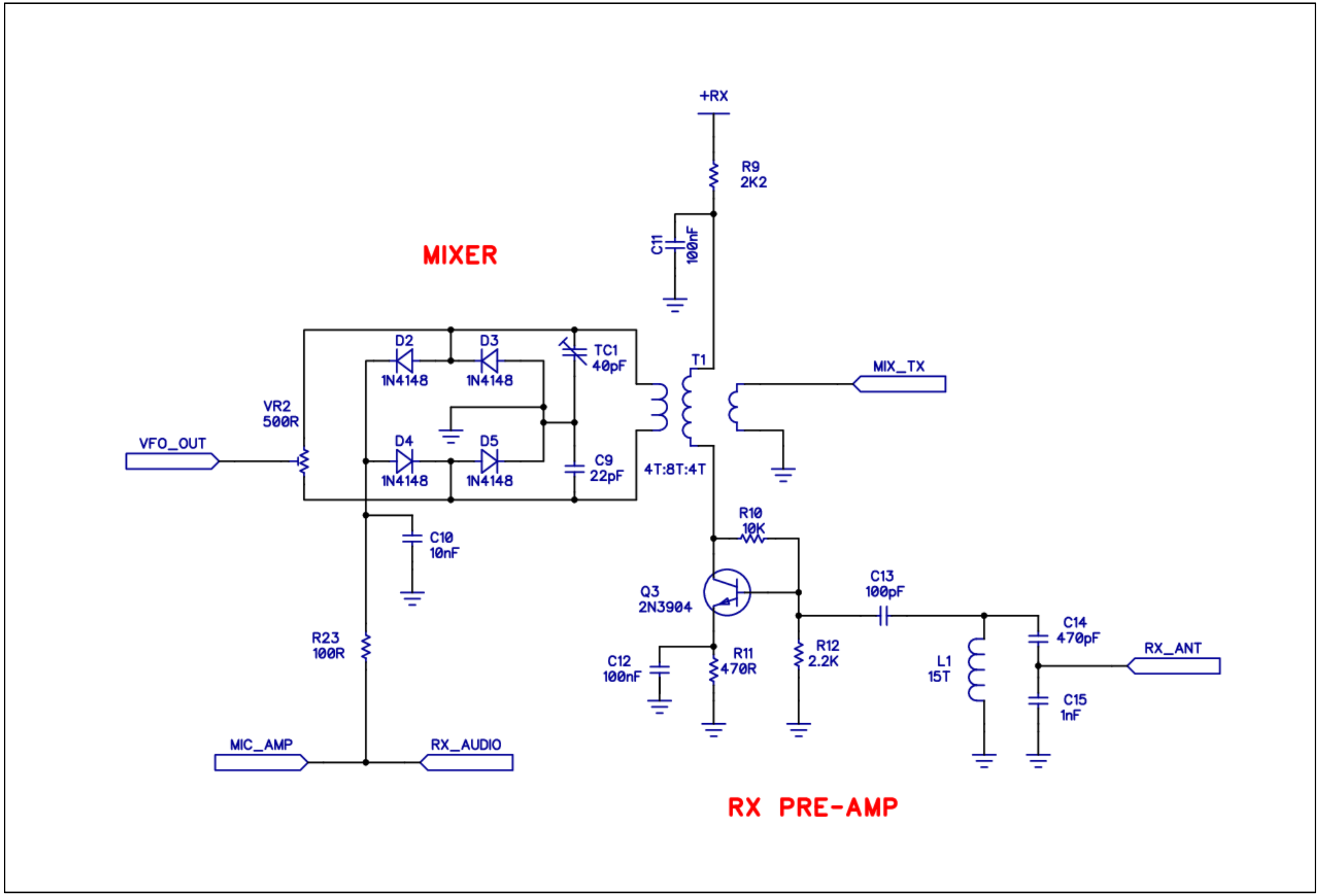


Figure 5 Mixer

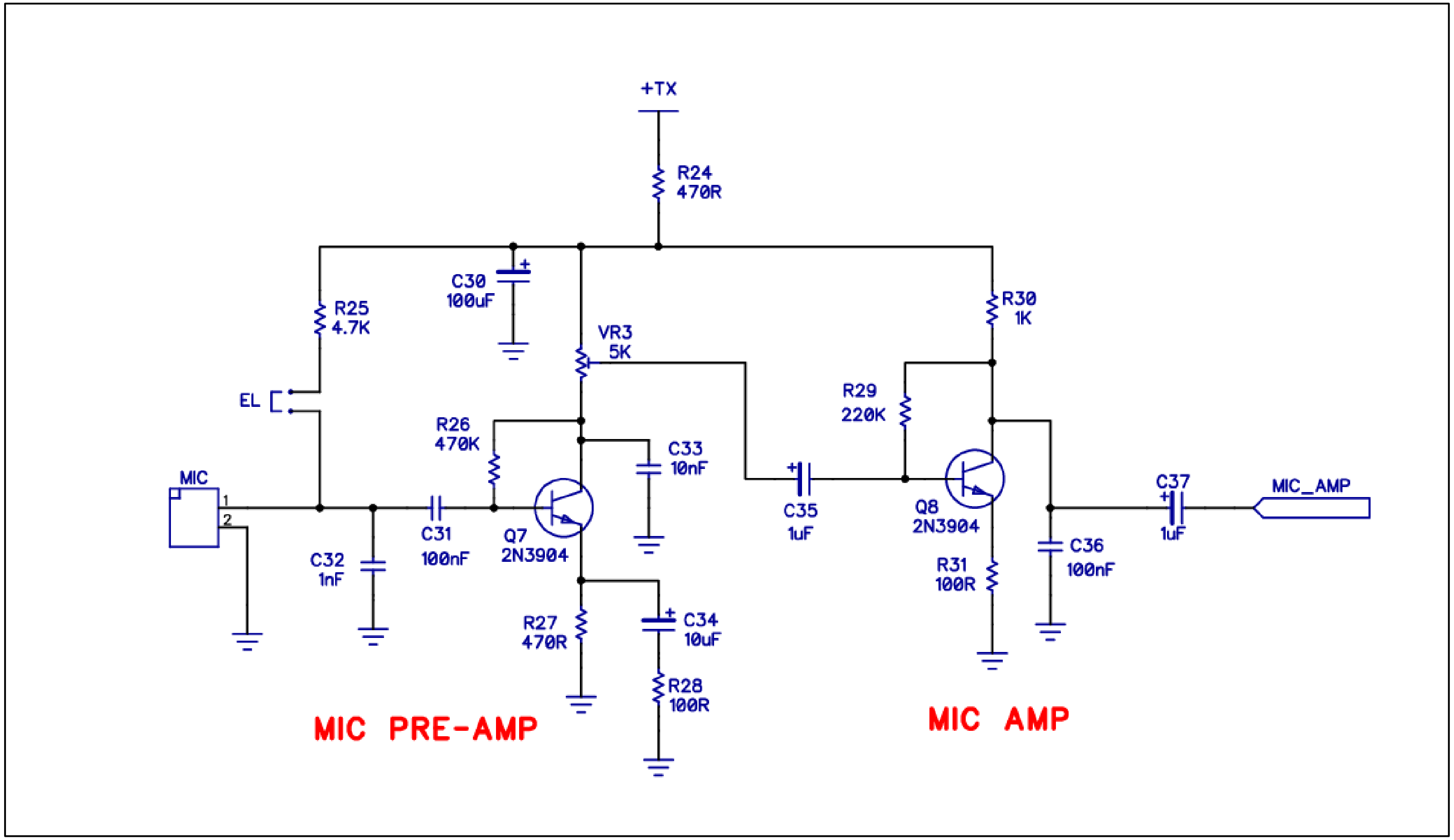


Figure 6 Microphone Amplifier

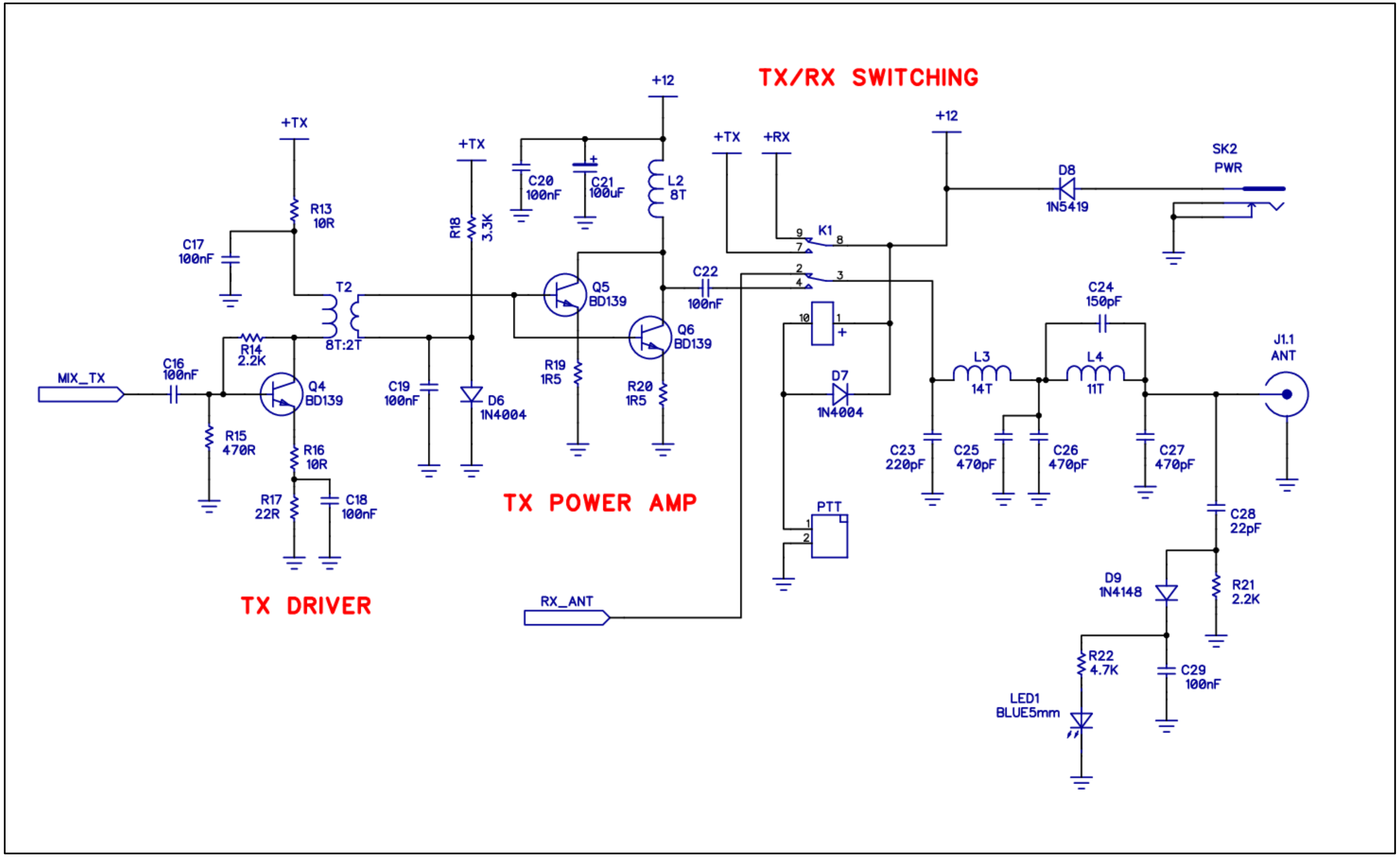


Figure 7 Transmit

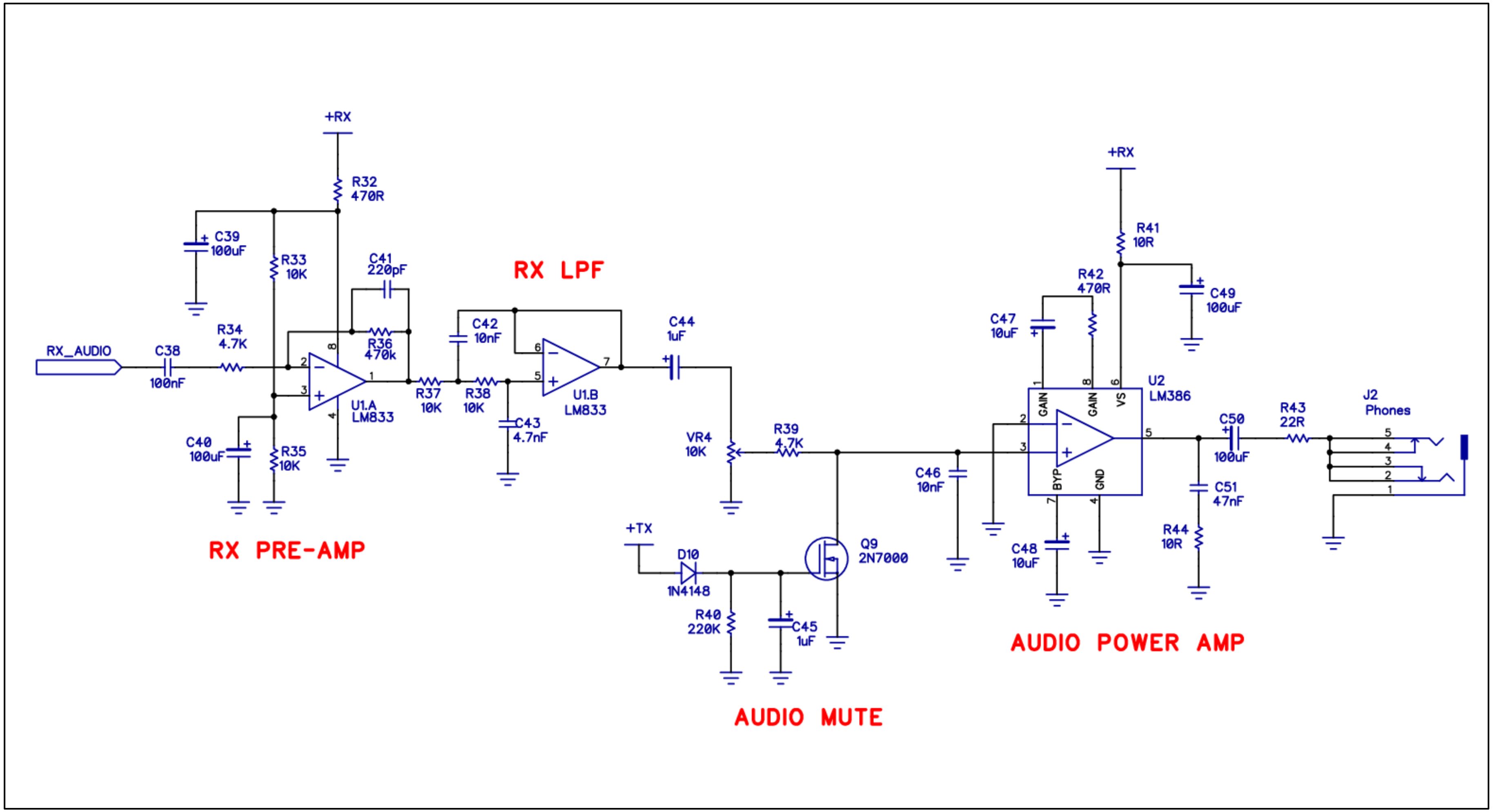


Figure 8 Receive Audio

7 KIT SUPPLIED PARTS

QTY	Value	Designator
		Capacitors
3	22pF ceramic disc NPO	C6, C9, C28
2	56pF ceramic disc NPO	C4, C5
1	100pF ceramic disc	C13
1	150pF 100V C0G ceramic MLCC	C24
1	220pF ceramic disc	C41
1	220pF 100V C0G ceramic MLCC	C23
1	470pF ceramic disc	C14
3	470pF 100V C0G ceramic MLCC	C25, C26, C27
2	1nF ceramic disc	C15, C32
1	4.7nF polyester MKT	C43
4	10nF polyester MKT	C10, C33, C42, C46
1	47nF polyester MKT	C51
2	100nF polyester MKT	C31, C38
14	100nF ceramic MLCC	C1, C2, C7, C8, C11, C12, C16, C17, C18, C19, C20, C22, C29, C36
4	1uF 50V RB electrolytic	C35, C37, C44, C45
3	10uF 25V RB electrolytic	C34, C47, C48
6	100uF 25V RB electrolytic	C21, C30, C39, C40, C49, C50
1	40pF trim capacitor	TC1
		Resistors
2	1.5Ω 1/4W 5%	R19, R20
4	10Ω 1/4W 5%	R13, R16, R41, R44
2	22Ω 1/4W 5%	R17, R43
4	100Ω 1/4W 5%	R7, R23, R28, R31
1	220Ω 1/4W 5%	R1
7	470Ω 1/4W 5%	R8, R11, R15, R24, R27, R32, R42
3	1K 1/4W 5%	R2, R5, R30
4	2.2K 1/4W 5%	R9, R12, R14, R21
1	3.3K 1/4W 5%	R18
4	4.7K 1/4W 5%	R22, R25, R34, R39
5	10K 1/4W 5%	R10, R33, R35, R37, R38
1	56K 1/4W 5%	R6
2	100K 1/4W 5%	R3, R4
2	220K 1/4W 5%	R29, R40
2	470K 1/4W 5%	R26, R36
1	500Ω vertical multi-turn trimpot	VR2
1	5K horizontal trimpot	VR3
1	10K LOG 16mm pot	VR4
1	50K LIN 16mm pot	VR1

QTY	Value	Designator
Semiconductors		
1	SVC236 dual varicap diode	D1
6	1N4148 signal diode	D2, D3, D4, D5, D9, D10
2	1N4004 1A power diode	D6, D7
1	1N5819 1A Schottky diode	D8
1	9.1V 500mW Zener	ZD1
5	2N3904 NPN transistor	Q1, Q2, Q3, Q7, Q8
3	BD139 NPN transistor	Q4, Q5, Q6
1	2N7000 MOSFET	Q9
1	LM833 dual op-amp	U1
1	LM386/4 audio power amp	U2
1	7.2MHz ceramic resonator	X1
1	5mm blue LED	LED1
Coils		
1	FT37-43 4T:8T:4T	T1
1	FT37-43 8T:2T	T2
1	FT50-43 8T	L2
1	T50-2 15T	L1
1	T50-2 14T	L3
1	T50-2 11T	L4
Hardware		
1	BNC RA PCB mount connector	ANT
1	3.5mm stereo PCB mount socket	PHONES
1	12V DPDT DIP relay	K1
1	2.1mm DC PCB mount socket	PWR
2	2 pin 2.54mm pitch header	MIC, PTT
2	2 pin 2.54mm pitch plug with pins	MIC, PTT
1	2M 0.4mm enamelled wire	-
1	0.4M hookup wire	-
1	Plastic instrument case including screws	-
1	MDT Front panel	-
1	MDT Rear panel	-
2	Knobs	-
1	4 pin mic socket	-

8 INDIVIDUAL PARTS LIST

Desig.	Value	Type	Desig.	Value	Type
ANT	-	PCB mount RA BNC	C44	1uF	50V RB electrolytic
			C45	1uF	50V RB electrolytic
C1	100nF	ceramic MLCC	C46	10nF	polyester MKT
C2	100nF	ceramic MLCC	C47	10uF	25V RB electrolytic
C3	-	Not used. See text	C48	10uF	25V RB electrolytic
C4	56pF	ceramic disc NPO	C49	100uF	25V RB electrolytic
C5	56pF	ceramic disc NPO	C50	100uF	25V RB electrolytic
C6	22pF	ceramic disc NPO			
C7	100nF	ceramic MLCC	D1	SVC236	Dual Varicap
C8	100nF	ceramic MLCC	D2	1N4148	Signal diode
C9	22pF	ceramic disc NPO	D3	1N4148	Signal diode
C10	10nF	polyester MKT	D4	1N4148	Signal diode
C11	100nF	ceramic MLCC	D5	1N4148	Signal diode
C12	100nF	ceramic MLCC	D6	1N4004	1A power diode
C13	100pF	ceramic disc NPO	D7	1N4004	1A power diode
C14	470pF	ceramic disc	D8	1N5819	1A Schottky diode
C15	1nF	ceramic disc	D9	1N4148	Signal diode
C16	100nF	ceramic MLCC	D10	1N4148	Signal diode
C17	100nF	ceramic MLCC			
C18	100nF	ceramic MLCC	K1	-	PCB mount DIP signal relay
C19	100nF	ceramic MLCC			
C20	100nF	ceramic MLCC	L1	15T	T50-2 toroid
C21	100uF	25V RB electrolytic	L2	8T	FT50-43 toroid
C22	100nF	ceramic MLCC	L3	14T	T50-2 toroid
C23	220pF	100V C0G ceramic MLCC	L4	11T	T50-2 toroid
C24	150pF	100V C0G ceramic MLCC	LED1	-	5mm Blue LED
C25	470pF	100V C0G ceramic MLCC			
C26	470pF	100V C0G ceramic MLCC	MIC	-	2 pin vertical header
C27	470pF	100V C0G ceramic MLCC			
C28	22pF	ceramic disc NPO	PHONES	-	PCB mount 3.5mm stereo socket
C29	100nF	ceramic MLCC	PWR	-	PCB mount 2.1mm DC socket
C30	100uF	25V RB electrolytic	PTT	-	2 pin vertical header
C31	100nF	polyester MKT			
C32	1nF	ceramic disc	Q1	2N3904	NPN transistor
C33	10nF	polyester MKT	Q2	2N3904	NPN transistor
C34	10uF	25V RB electrolytic	Q3	BD139	NPN transistor
C35	1uF	50V RB electrolytic	Q4	BD139	NPN transistor
C36	100nF	ceramic MLCC	Q5	BD139	NPN transistor
C37	1uF	50V RB electrolytic	Q6	BD139	NPN transistor
C38	100nF	polyester MKT	Q7	2N3904	NPN transistor
C39	100uF	25V RB electrolytic	Q8	2N3904	NPN transistor
C40	100uF	25V RB electrolytic	Q9	2N7000	N ch MOSFET
C41	220pF	ceramic disc			
C42	10nF	polyester MKT			
C43	4.7nF	polyester MKT			

Desig.	Value	Type	Desig.	Value	Type
R1	220Ω	1/4W 5% resistor	T1	4T:8T:4T	FT37-43 toroid
R2	1K	1/4W 5% resistor	T2	8T:2T	FT37-43 toroid
R3	100K	1/4W 5% resistor			
R4	100K	1/4W 5% resistor	U1	LM833	Dual low noise op-amp
R5	1K	1/4W 5% resistor	U2	LM386-4	Audio power amp
R6	56K	1/4W 5% resistor			
R7	100Ω	1/4W 5% resistor	VR1	50K	LIN 16mm potentiometer
R8	470Ω	1/4W 5% resistor	VR2	500Ω	Multi-turn trimpot
R9	2.2K	1/4W 5% resistor	VR3	5K	Horizontal trimpot
R10	10K	1/4W 5% resistor	VR4	10K	LOG 16mm potentiometer
R11	470Ω	1/4W 5% resistor			
R12	2.2K	1/4W 5% resistor	X1	7.2MHz	ceramic resonator
R13	10Ω	1/4W 5% resistor			
R14	2.2K	1/4W 5% resistor			
R15	470Ω	1/4W 5% resistor			
R16	10Ω	1/4W 5% resistor			
R17	22Ω	1/4W 5% resistor			
R18	3.3K	1/4W 5% resistor			
R19	1.5Ω	1/4W 5% resistor			
R20	1.5Ω	1/4W 5% resistor			
R21	2.2K	1/4W 5% resistor			
R22	4.7K	1/4W 5% resistor			
R23	100Ω	1/4W 5% resistor			
R24	470Ω	1/4W 5% resistor			
R25	4.7K	1/4W 5% resistor			
R26	470K	1/4W 5% resistor			
R27	470Ω	1/4W 5% resistor			
R28	100Ω	1/4W 5% resistor			
R29	220K	1/4W 5% resistor			
R30	1K	1/4W 5% resistor			
R31	100Ω	1/4W 5% resistor			
R32	470Ω	1/4W 5% resistor			
R33	10K	1/4W 5% resistor			
R34	4.7K	1/4W 5% resistor			
R35	10K	1/4W 5% resistor			
R36	470K	1/4W 5% resistor			
R37	10K	1/4W 5% resistor			
R38	10K	1/4W 5% resistor			
R39	4.7K	1/4W 5% resistor			
R40	220K	1/4W 5% resistor			
R41	10Ω	1/4W 5% resistor			
R42	470Ω	1/4W 5% resistor			
R43	22Ω	1/4W 5% resistor			
R44	10Ω	1/4W 5% resistor			

9 CONSTRUCTION

9.1 GENERAL

The MDT is built on a high quality fiberglass PCB. The PCB is doubled 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 closest to the PCB first and then work upwards.

9.2 BUILDING THE PCB

It's advisable 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 print Figure 20 as an additional reference when installing the components.

Step 1: PCB

Remove the PCB from its protective bag. The PCB comes shipped with the SMD dual tuning diode pre-installed. This is the only SMD device in the kit.

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

See Figure 9 to identify the positive or Cathode end of the diodes before installation. The small Zener diode looks like a signal diode so make sure you don't get it 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.

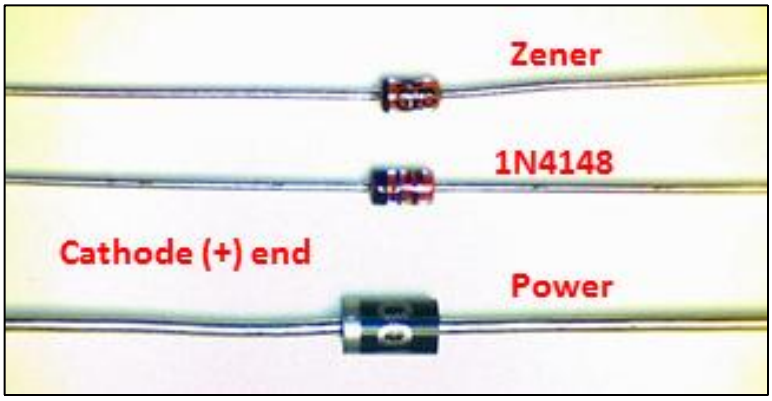


Figure 9 Diode identification

Step 4: ICs

There are two 8 pin ICs to be installed. Figure 10 shows how to identify pin 1 of the ICs and where they are installed on the PCB.

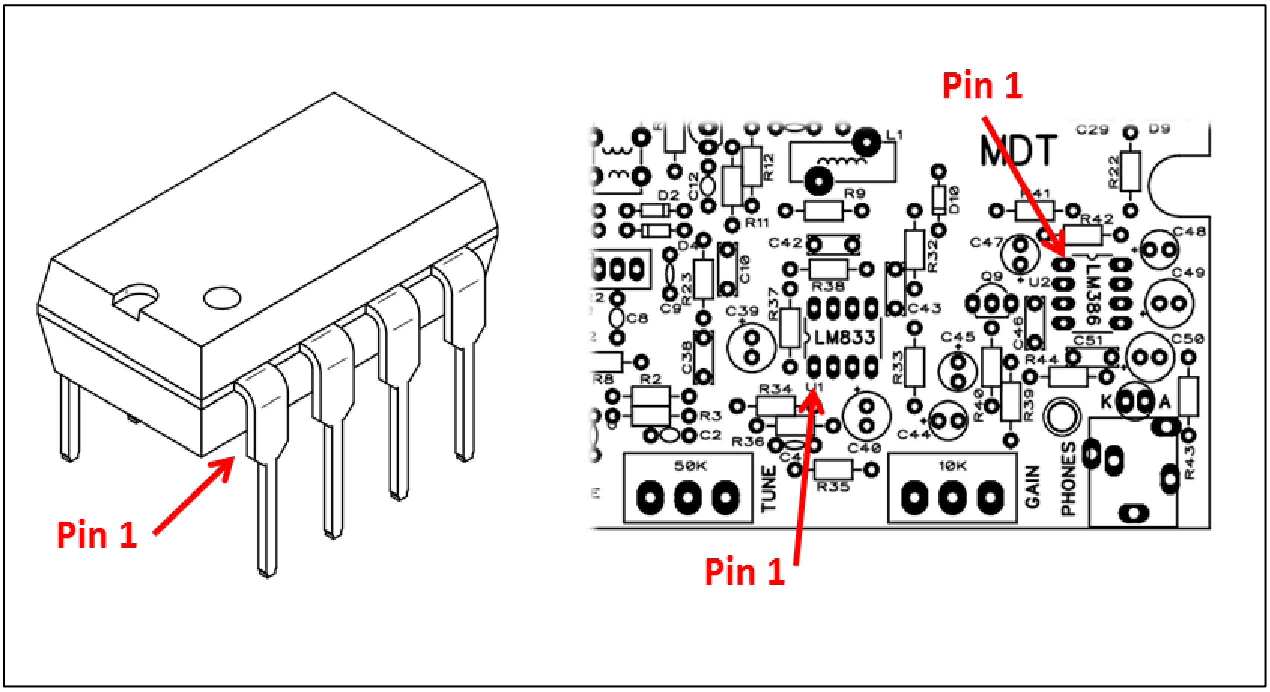


Figure 10 DIP ICs

Step 5: Relay

The relay is inserted with pin 1 towards D7 as shown in Figure 11. This end of the relay has a line printed on top of the case for identification. Once inserted hold against the PCB and solder the pins.

Figure 11 Relay install

Step 6: Non-polarised capacitors

Note the various types as per the examples shown in Figure 12. Ceramic disc NPO, standard ceramic disc, polyester MKT and ceramic multi-layer chip capacitors (MLCC). These are all non-polarized and can go in either way. There are 14 x 100nf (0.1uF) MLCC and as they are quite small install these first.

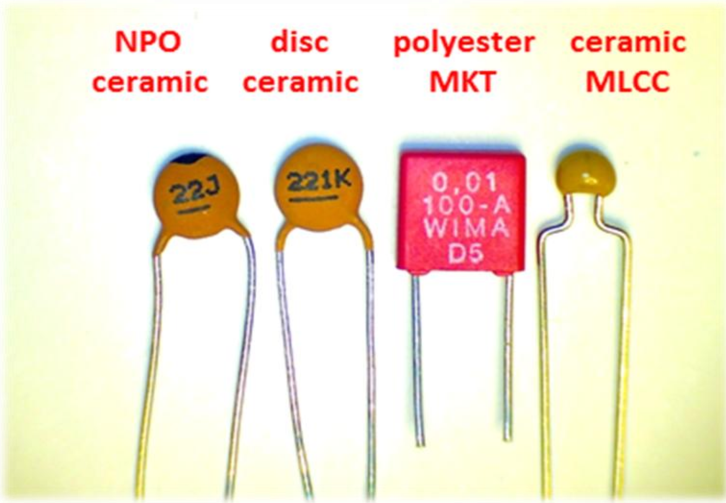


Figure 12 Non-polarised capacitors

Step 7: Low pass filter capacitors

These look like 0.1uF MLCC types, so don't get them mixed up.

Figure 13 shows how to identify the LPF capacitor markings.

Capacitor	Marking	Value
C24	151	150pF
C23	221	220pF
C25, C26, C27	471	470pF

Figure 13 LPF capacitor marking

Step 8: trimmer capacitor

The trimmer capacitor supplied is quite small and has 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. If you find the leads too wide for the PCB holes, simply trim them down with sidecutters before inserting. The earth pin of the trimmer capacitor is highlighted in Figure 14.

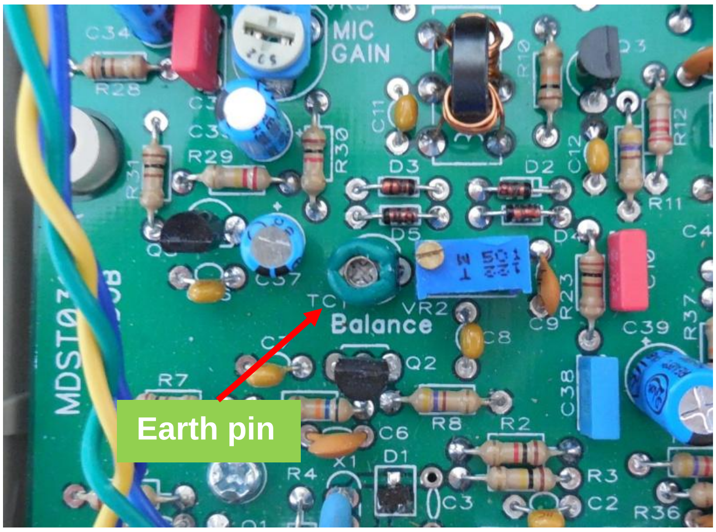


Figure 14 Trimcap install

Step 9: trimpots

Note that the carrier balance trimpot is a 500 ohm multi-turn vertical mount while the Microphone gain trimpot is a 5K horizontal mount type.

Step 10: transistors

The 2N3904 transistors are orientated to match the screen silk component overlay. The BD139 transistors are mounted so that their Bases face the left hand side of the PCB when viewed from the front as shown in Figure 15.

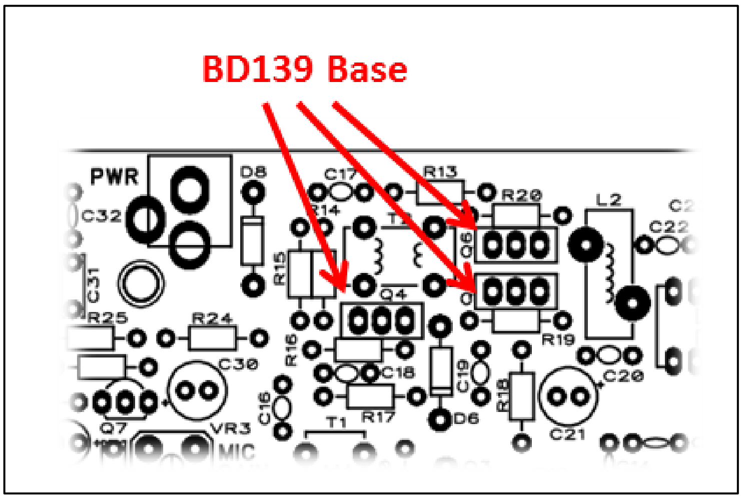


Figure 15 BD139 location

Figure 16 shows how to identify the BD139 pins.

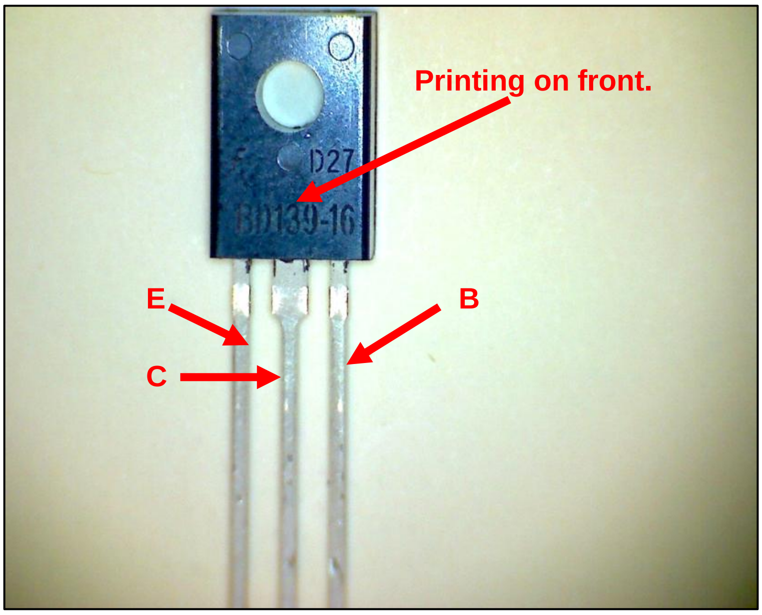


Figure 16 BD139 lead identification

Step 11: ceramic resonator

The ceramic resonator has 3 pins. The resonator can go in either way as long as the centre pin is connected to ground, which is the middle hole in the PCB pattern.

Step 12: electrolytic caps

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 13: Connectors

The MDT board utilizes polarized pin headers for the microphone and PTT. 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.

Install the DC power connector, the BNC antenna connector and the 3.5mm headphone connector. These can only go in one way and should be held flat against the board while soldering.

Step 14: LED

The LED leads need to be bent so that it can pass through the hole in the front panel. Figure 17 shows how this done. Once bent insert the LED leads into the PCB just far enough to allow them to be soldered. Ensure the anode(A) and cathode(K) leads go in the correct holes as shown in Figure 18.

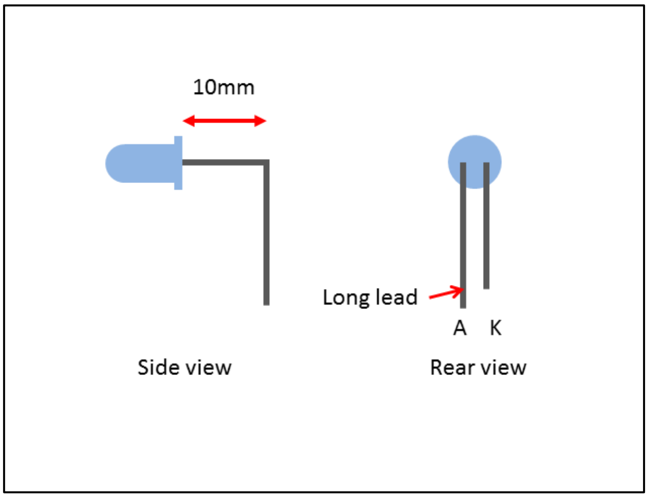


Figure 17 LED lead bending

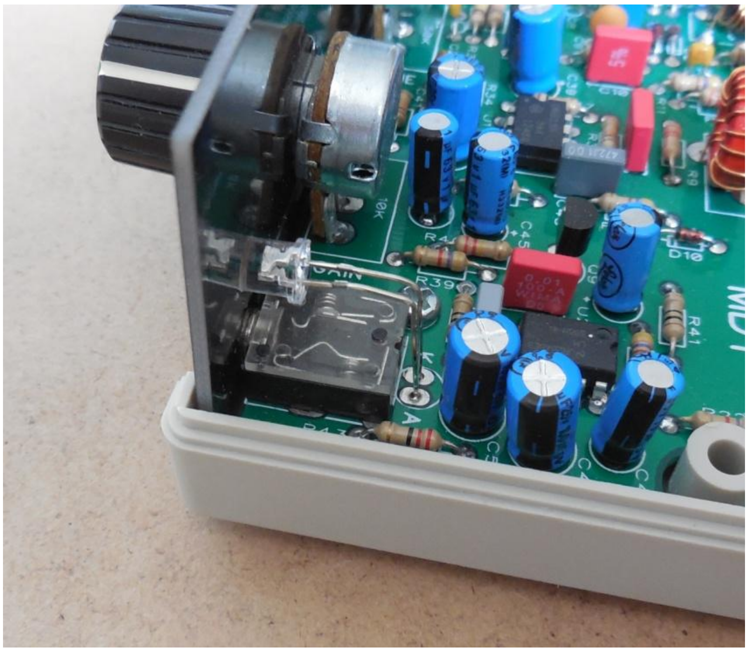


Figure 18 LED install

Step 15: Coils

Count turns on the inside of the toroid. A turn is considered to be counted when a wire passes through the center hole.

Transformer T1

Take a 120 mm length of 0.4mm enamelled copper wire. Wind **4** turns on a **FT37-43** ferrite toroid. This is winding 1. Take a 180 mm length of 0.4mm enamelled copper wire. Wind **8** turns on the ferrite toroid. This is winding 2. Take a 120 mm length of 0.4mm enamelled copper wire. Wind **4** turns on the ferrite toroid. This is winding 3.

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

Take a 180mm length of 0.4mm enamelled copper wire and wind the **8** turn primary on a **FT37-43** ferrite toroid.

Take a 90mm length of 0.4mm enamelled copper wire and wind the **2** turn secondary.

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

The winding direction is not important.

Receiver Coil L1

Take a 320mm length of 0.4mm enamelled copper wire and wind on **15** turns on a T50-2 toroid. Spread the turns to cover about 80% of the circumference.

Note the direction of winding as this makes for a neater alignment on the PCB.

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

Collector Coil L2

Take a 220mm length of 0.4mm enamelled copper wire and wind on **8** turns on a FT50-43 ferrite toroid. Spread the turns to cover about 80% of the circumference.

Note the direction of winding as this makes for a neater alignment on the PCB.

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

Low Pass Filter Coil L3

Take a 300mm length of 0.4mm enamelled copper wire and wind on **14** turns on a T50-2 toroid. Spread the turns to cover about 80% of the circumference.

Note the direction of winding as this makes for a neater alignment on the PCB.

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

Low Pass Filter Coil L4

Take a 280mm length of 0.4mm enamelled copper wire and wind on **11** turns on a T50-2 toroid. Spread the turns to cover about 80% of the circumference.

Note the direction of winding as this makes for a neater alignment on the PCB.

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

Step 16: Pots

The two pots are soldered into the locations marked at the front of the board. The Tune control is a 50K linear pot and the AF gain control is a 10K logarithmic pot. Before placing into the board, break off the metal tabs as shown in Figure 19. This allows the front face of the pots to sit flat against the front panel.

Push the pot pins through the board as far as they will go and solder in place. Double check when mounted that the pot shafts are parallel to the PCB.

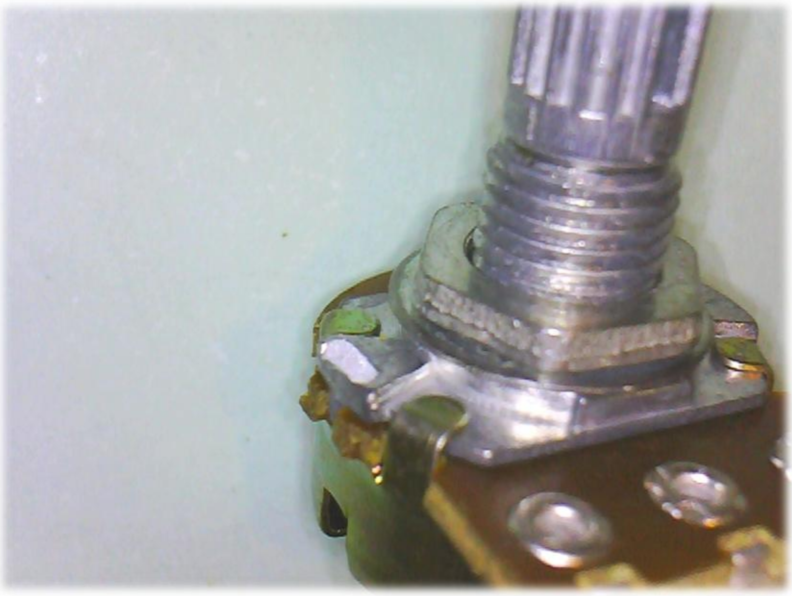


Figure 19 Pot with tab removed

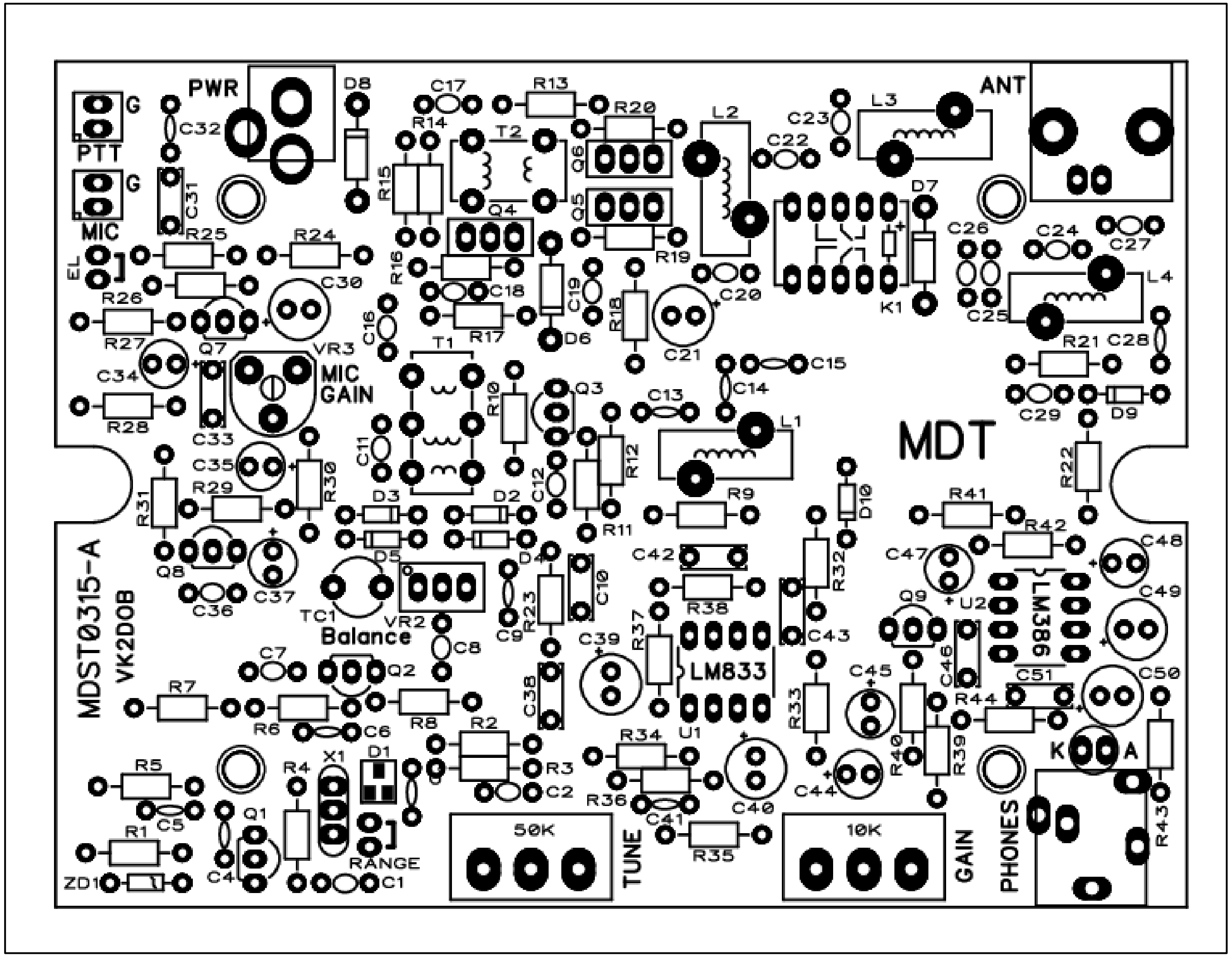


Figure 20 Component overlay

10 FINAL ASSEMBLY

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 easily melt the enamel but most will not, so it is important to scrape the enamel off the ends of the wires with sandpaper or a sharp knife before soldering.

The enclosure comes with two plastic panels. These are not required and can be set aside for some other use. In this kit they are replaced with pre-cut and printed front and rear panels. These are actually made from PCB material with a black solder mask and white silkscreen lettering. The front panel has a white circle placed around the Tune control to allow marking frequency steps with a pen - more on this later.

10.1 MICROPHONE SOCKET

The kit comes with 4 lengths of hook up wire. Cut each to about 95mm long. Terminate the Mic connector and the two plugs as shown in Figure 21. Once terminated twist the wires of each connector together to help keep out interference. Insert the microphone socket into the front panel and secure with the supplied washer and nut.

Colour	Function
Yellow	Microphone signal
Green	Microphone ground
Blue	PTT signal
Blue	PTT ground

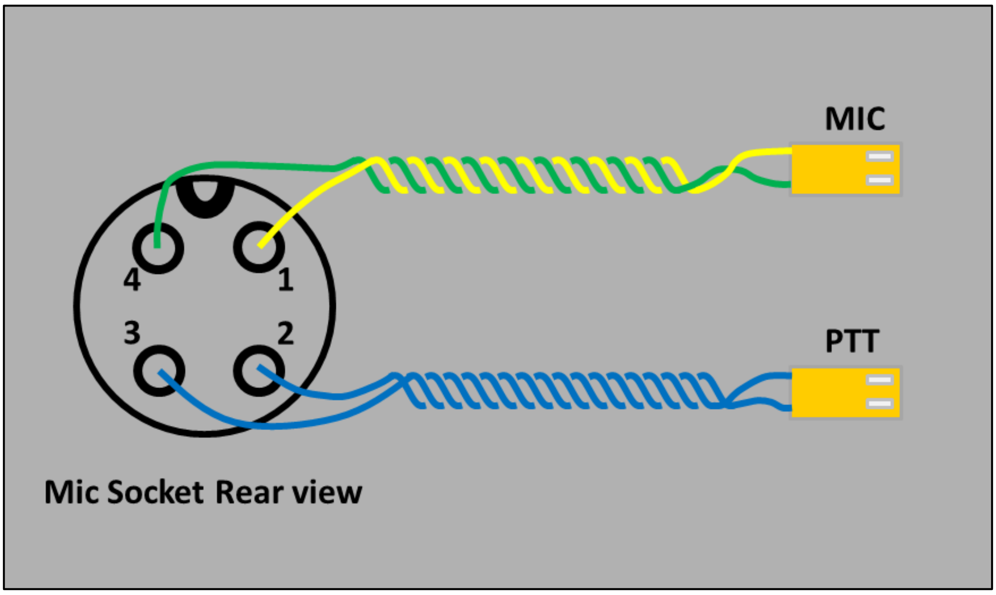
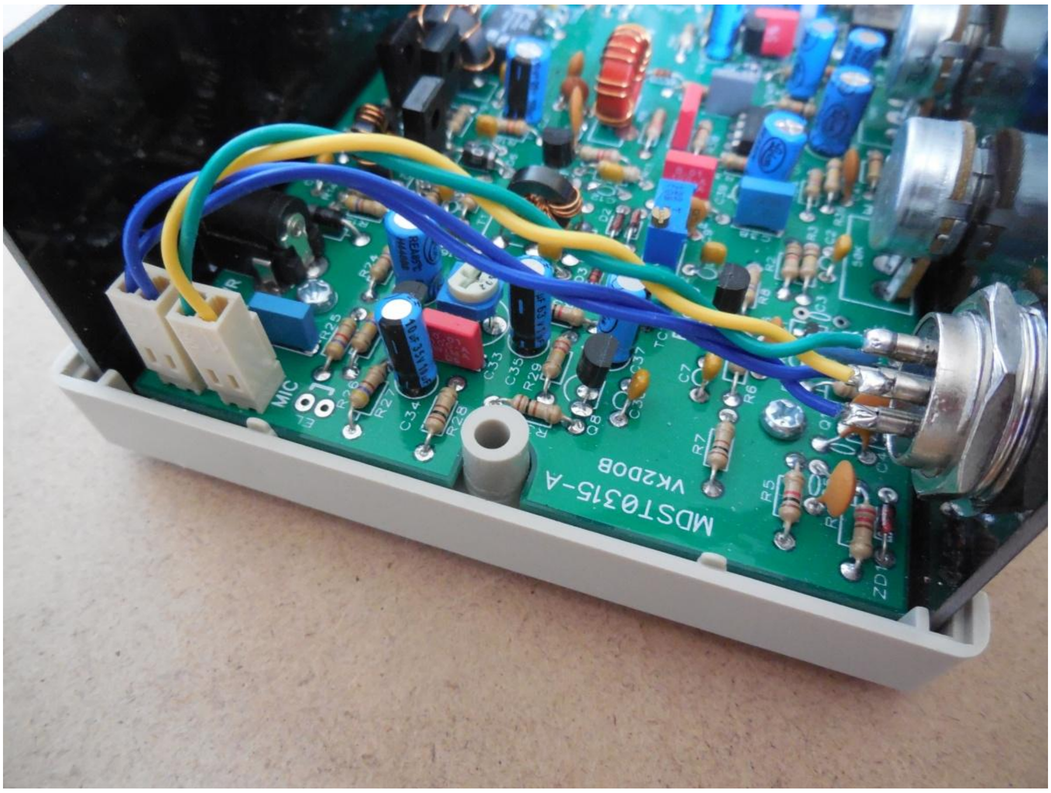


Figure 21 Mic connector wiring

10.2 TERMINATING PLUGS

- Strip 3mm of insulation from the wire and place into the pin. There are two sets of tabs on each side of the pin. The bare wire locates between the front tabs while the insulation locates in the rear tabs.
- Using a pair of small long nosed pliers bend the tabs around the wire to hold it in place.
- Using as little heat as possible solder the wire to the pin. The soldering iron tip is placed on the pin tabs at the end of the bare wire. Be careful as too much heat and solder will melt the insulation and interfere with the contact.
- Slide the pin into the housing ensuring the small locking piece on top of the pin locates within the rectangular cutout on the housing.



10.3 Front Panel

Remove the nuts and washers from the pots and slide the panel onto the pot shafts. Ensure the headphone connector sits inside its cutout. Place the washers back on the shafts and tighten the nuts. You may need to tilt the pots slightly so that the panel is at 90 degrees to the PCB.

Press the knobs onto the pot shafts. You may need to do this a couple of times to get the knob marker to sit equally at each end of the travel.

Push the LED through its cutout so that it pokes out about 2mm proud of the panel.

10.4 Mounting the PCB

Place the rear panel onto the rear of the PCB so that the antenna connector and DC socket pass through the cutouts. Place the PCB onto the enclosure base, ensuring the front and rear panels slide into the slots on each side of the base. The PCB should then fit flat on the base plastic pillars.

Screw the PCB to the mounting pillars using the supplied self-tapping screws.

11 TESTING AND ALIGNMENT

11.1 GENERAL

The minimum tools and accessories needed to get the MDT tested and aligned are listed below:

- Digital multimeter.
- 50 ohm dummy load capable of dissipating at least 2 Watts.
- Power supply capable of 13.8V DC regulated at 1 Amp.
- A second receiver.
- Small adjustment screwdriver.

These additional instruments are recommended to fully test and align the MDT.

- QRP wattmeter or oscilloscope
- An audio signal generator.
- An RF signal generator.
- A frequency counter.

⚠ **Figure 22 lists typical voltages at various points around the board and can be used to verify operation.**

11.2 POWER ON

- Connect a 50 Ohm dummy load to the antenna socket.
- Connect the power supply to the DC connector.
- 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 and note the supply current. It should be around 50mA. If it's far from this turn off immediately and look for problems.
- The relay should be de-energized and the board in RX mode. 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 Figure 22.

11.3 RECEIVE

- Set the Tune control to around the middle of the range.
- Turn the AF gain control to halfway. You should hear some low level hiss come from the headphones indicating that the audio stages are working.
- Remove the dummy load and apply a RF signal of about 100uV to the antenna connector and rotate the Tune control until a clear tone is heard in the headphones.
- If no signal is heard check the receive circuit.
- If you don't have a signal generator simply plug in an antenna and listen. You will get a good idea if the receiver is working correctly by comparing to another receiver.

11.4 Transmit

- Remove the RF signal source and reconnect the dummy load. It is suggested you have some way of measuring the power output. A QRP power meter or oscilloscope would be ideal.
- Turn the Mic gain trimpot VR3 fully counter-clockwise.
- Briefly switch to TX mode by shorting the PTT contacts. Check the power supply current. If the mixer is already balanced there will be no output and the current and should rise to about 130mA. If the mixer is not balanced there may be RF output and the current may be higher. If it is way in excess of 250mA this indicates a problem and should be investigated.
- Place a short across the PTT line. Adjust carrier balance controls TC1 and VR2 for minimum power output. Initially you can use the LED indicator to monitor this, but as the mixer reaches balance the output power will decrease significantly and the LED will not turn on. At this point it's necessary to use some other way to monitor the power output to do the final balancing. The following are some suggested methods:
    - Using a second receiver placed nearby listen to the transmitted signal. Ensure you are not listening to the VFO signal as this is on the same frequency.
    - Connect an oscilloscope across the dummy load.
    - Connect a sensitive RF probe across the dummy load.
    - Connect a spectrum analyser across the dummy load. An attenuator may be necessary.

  In all cases it's simply a matter of monitoring the transmitted signal for minimum output while adjusting TC1 and VR2. The carrier null is quite sharp, and there is some interaction between the controls, so you will need to go back and forwards to obtain maximum balance.
- Check the TX mode DC voltages as shown in Figure 22. If there are any off scale readings turn off immediately and look for construction errors.
- Remove the short across the PTT line. Apply an audio signal generator to the Mic socket set to 1KHz at around 50mV. Operate the PTT again and slowly rotate the Mic gain trimpot clockwise while monitoring the power output. The power output should increase smoothly without any sudden dips or surges and you should be able to easily achieve 1.5 to 2 Watts output. At this level the front panel LED should be brightly lit. Remove the signal generator and check that the RF output goes to zero, and the LED turns off.
- If you intend to use an Electret microphone place a short across the EL link. This can be a soldered link or you can install a 2 pin header and a removable shunt. Leave the link open for dynamic microphones.
- Plug in a microphone and check the relay operates when the PTT is pressed. When you speak there should be RF output, and the LED should flash. You will now be able to monitor yourself with a receiver placed nearby and determine an appropriate Mic gain setting.

11.5 MARKING THE VFO SCALE

The VFO dial on the front panel comes without any markings. The reason for this is that the frequency range will be slightly different for each kit due to variations in component values and the selected frequency range etc. There are many ways to mark the scale, but following is an easy and simple method:

- Ensure the MDT has been powered on for at least 10 minutes to allow the VFO section to warm up and stabilize. This is especially important if any of the VFO components have been recently soldered.
- Connect a frequency counter across R8.
- Rotate the Tune control fully anti-clockwise. Read and note the frequency on the counter.
- Rotate the Tune control fully clockwise. Read and note the frequency on the counter.
- From the two readings determine what markings you wish to make on the scale. Marks at every 10KHz would be a convenient option.
- Start at the low frequency end of the tuning range and while monitoring the counter rotate the Tune control until you reach a 10KHz point. For example 7.060MHz.
- Make a mark on the scale at the knob pointer line. A fine point felt marker is ideal.
- Rotate the Tune control until you reach the next 10KHz point. For example 7.070MHz and make a mark.
- Repeat the process across the tuning range.

Location	V DC Receive	V DC Transmit	RF pk-pk @ 1.5W output
Q1 collector Note 1	9.1	9.1	-
Q1 emitter Note 2	4.8	4.8	9
Q2 collector	12	12	-
Q2 emitter Note 2	6.7	6.7	5.2
Q3 collector	8.4	0	-
Q3 emitter	0.8	0	-
Q4 collector	0	12.9	3.1
Q4 emitter	0	1.6	-
Q5/Q6 collector	13.8	13.6	40
Q5/Q6 base Note 3	0	0.6	-
Q5/Q6 emitter Note 3	0	0.02	-
Q7 collector	0	4.8	-
Q7 emitter	0	0.6	-
Q8 collector	0	6.3	-
Q8 emitter	0	0.45	-
U1.A pin 8	11.1	0	-
U1.A pin 3	5.5	0	-
U1.A pin 1	5.4	0	-
U1.B pin 7	5.4	0	-
U2 pin 6	13.5	0	-
U2 pin 5	6.6	0	-

Notes:
1. Zener tolerance +- 5%.
2. DC measurement approximate. Oscillator running.
3. No RF drive.

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

Figure 22 Typical circuit voltages.

12 MODIFICATIONS

12.1 SETTING THE VFO RANGE

The VFO tuning range is reasonably fixed due to the characteristics of the ceramic resonator and the available capacitance swing of the varicap but it can be adjusted slightly if required.

- The Range link. With the link shorted the two varicap diodes are in parallel and the tuning range is approximately 7.050MHz to 7.110MHz. With the link open only one varicap diode is in circuit and the tuning range becomes approximately 7.090MHz to 7.130MHz.
- Resistor R2. Increasing the value of R2 will lower the maximum voltage across the Tune control and will in turn decrease the tuning range and maximum frequency of the VFO.
- Capacitor C3. This isn't included in the parts list, but adding a small value NPO ceramic here will lower the overall frequency range.

12.2 RECEIVER ALIGNMENT

The tuned circuit at the front end of the receiver containing coil L4 is designed for a bandpass wide enough to cover the 40M band without adjustment. If it is necessary for some reason to alter the tuned circuit frequency then this will require a change in the turns on L4.

If, however, only a small adjustment is required this can be done by compressing or spreading the turns on L4. Nominally the turns should be evenly spaced over about 80% of the circumference. However if the turns are compressed the inductance will increase slightly and lower the tuned circuit frequency. Conversely, if the turns are separated the inductance will decrease slightly and the frequency will increase. To check the frequency of the modified tuned circuit do the following:

- Inject a stable signal into the antenna socket in the middle of the tuning range.
- Rotate the Tune control until a clean tone is heard in the headphones, and adjust the AF gain control for a comfortable level.
- Place an audio level meter or oscilloscope across the AF gain control and monitor the amplitude of the audio tone for maximum while spreading and compressing the turns on L4.
- When a maximum is reached the alignment is complete.

12.3 CRYSTAL OPERATION

The MDT kit comes supplied with a 7.2MHz ceramic resonator which gives about 60KHz of tuning range. This gives much better frequency stability than a conventional LC oscillator but is not rock steady. If very stable frequency operation is required the resonator can be replaced with a crystal. This is soldered into the outer resonator holes in the PCB. The centre earth hole is ignored. The Tune control can then be used as a fine tune control with around 1KHz of adjustment.

12.4 USING A LOUDSPEAKER

If you wish to use an external loudspeaker with the MDT, it is necessary to replace the 22 ohm resistor R43 with a wire link. Otherwise the speaker level will be greatly reduced.

13 OPERATION

The following sections describe how to set up and use the MDT.

13.1 SETTING UP

1. Connect the antenna. You will require a BNC male plug on the antenna cable. If your antenna cable has another type of plug, you will need an adaptor.
2. Plug in headphones. The MDT is intended to be used with 32 ohm stereo headphones. It can drive any type of headphones but they must use a 3.5mm stereo phono plug.
3. Plug in the microphone. The MDT kit comes with a 4 pin socket which is a type commonly used on radio transceivers. If your microphone does not use this type of connector, then you will have to either replace the plug or change the socket on the MDT. If making changes remember that the audio line must be independent of the PTT line, however a common earth is allowed.
4. Connect the power supply. The MDT is designed to operate from a 13.8V DC power source. This can be a battery or a regulated DC power supply. Don't be tempted to use an unregulated plug pack as the AC hum will make its way into the audio sections. The supply connection is via a 2.1mm DC socket on the rear of the MDT. The positive wire goes to the centre pin and the negative wire goes to the outer barrel of the connector. The MDT can operate down to around 10V, but the transmit power output will be significantly reduced. A supply of 15V DC is the recommended maximum voltage to use.

13.2 RECEIVING

⚠ **The VFO is a free running oscillator and there will be some drift after powering on as the components warm up. It is best to avoid transmitting until it stabilizes. This only takes a couple of minutes and any drift after this period is quite small.**

13.2.1 SSB

The Tune control is used to tune in stations. The MDT doesn't have a fine tune control so you need to adjust the control slowly and carefully to tune in correctly. As you move across a SSB station you will find a spot where the voice becomes clear and sounds natural. This should coincide with the VFO and the transmit station being on or very near the same frequency.

The AF gain is the only other MDT control. Always start with the control set low when tuning around so that sudden or strong signals do not overload your ears. The MDT does not have automatic gain control (AGC) to level out the audio from different stations, so you need to set the AF gain to match the level of the signal you are tuned.

13.2.2 CW

When tuning CW signals you can tune either side of the transmit frequency to listen in. Tuning across the signal the tone frequency will decrease as you approach zero beat. Zero beat is where the VFO frequency is the same as the station transmit frequency. At zero beat you will hear nothing or at least a very low frequency thumping sound. As you tune away on the other side of zero beat the tone frequency will increase. Simply adjust the Tune control for a pleasant sounding tone. Sometimes if there is an interfering signal on one side, you can tune to the other side and reduce the interference while still receiving the wanted station.

13.3 Transmitting

Do not transmit without a matched 40M antenna or 50 dummy load connected.

To transmit press the PTT button on your microphone and talk. The LED on the front panel will flash as you speak. This provides an indication of the 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.

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

To check your signal you can either, connect the MDT 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 receiving station sweeps across your transmission looking for distortion and unwanted spurious byproducts. Set the Mic gain control just below the point where these are noticeable. A screenshot from an oscilloscope placed across a dummy load to monitor the output waveform is shown in Figure 23. The audio input to the MDT mic socket was a 1KHz sine wave.

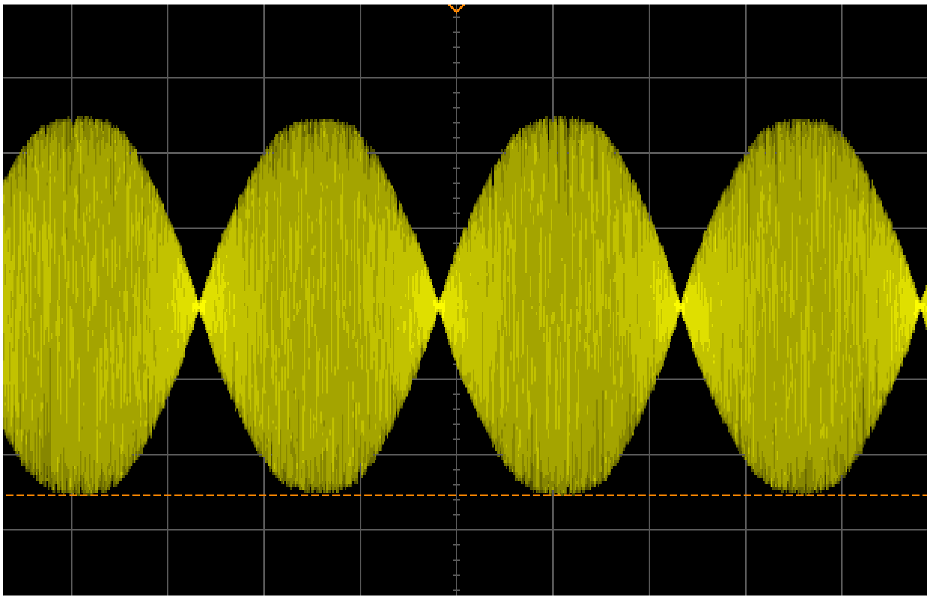


Figure 23 DSB transmit waveform

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

Place the lid on the case, do up the two screws and have fun!