The RK Explorer Construction and user manual

1. Features

- 3 versions available - 20, 40 and 80m
- Full band coverage
- Modes - LSB, USB, Data, CW and CW narrow (with option board)
- Straight key and Iambic keyer (A and B)
- RIT and Dual VFO with split function
- IF AGC (audio derived)
- IF shift
- RF attenuator
- Indication - S Meter, RF power meter, battery state
- CAT control via USB
- Variable output power
- No mechanical pre-sets - all setting-up via user interface

Option board:

- Narrow (300Hz) CW audio filter
- Data input / output, switching via user interface, PTT via RTS
- Tune signal

Specifications

- 10-16V Supply
- 5W + RF output @ 13.8V
- Current consumption - Receive 150 mA (no signal), Transmit 1.2A
- Audio > 0.5w 13.8V 8 Ohm speaker (minimum impedance 4 Ohms)
- Carrier leak & opposite sideband > 40dB relative to PEP
- Spurious emissions
  - Harmonic > 43dB relative to PEP
  - Other spurious > 43dB relative to PEP
- Gain control
  - AGC range ~60dB
  - Attenuator ~-23dB
- Frequency stability – 2.5ppm
- Microphone - Low-cost electret type or low impedance dynamic, link selectable

Note this manual is suitable for version 2.2 kits; kit version is identified on box label.

Introduction

This radio is the successor to the MKARS80 which was originally developed as a club project for the Milton Keynes Amateur Radio Society, this in turn was adopted by many clubs as a project and purchased by amateurs around the world. Approximately 1500 were sold over a 15-year period, sales brought to an end by component obsolescence.

Presented here is a transceiver which can be built for 20, 40 or 80m; modern technology has allowed for a host of features previously impractical in this type of product.

The design philosophy has been to keep the radio simple and low cost, whilst including many features only found on commercial equipment. The most significant issues with the MKARS80 were lack of AGC and poor frequency stability. There were often requests for a 20 & 40m version but due to the topology this wasn't practical. With the availability of the Si5351 synthesiser, a new range of micro-controllers and a little ingenuity it has been possible to provide a design meeting these requirements.

The user interface is menu driven using a single rotary encoder with integral push switch, all frequently used functions are at the top of the menu structure (audio gain, mode change etc.) whilst those only used for setup (calibration items) are at the deepest level. If a single control is thought too cumbersome, use can be mode of the inbuilt USB CAT interface and appropriate software – the radio will appear to software as a Kenwood TS480.

All setup is made via the menu and stored in flash memory – there are no pre-set capacitors or resistors, this is now a necessity due to component availability and cost. To help keep cost low a single PCB has been retained, this does though lead to the generation of a few "birdies" on receive though they are generally below band noise and can be nulled if required by the IF shift function.

Construction

These instructions have been targeted at those with construction experience, it is not recommended as a first kit.

All components except for the display, its socket, TX LED and rotary encoder are mounted on the component side of the board. The PCB silk screen gives component locations, but we recommend also printing off a copy of the PCB overlay to refer to during the build. Be sure to double check component placement and orientation of polarised components like diodes and electrolytic capacitors before soldering. Note that components are numbered from left to right then top to bottom of the board. If you have difficulty in locating a component position place a straight edge across the overlay and look along its length, in this way components will be easy to locate.

The PCB has been designed to accommodate the components supplied, if it doesn't easily fit it probably doesn't belong there!

General construction practice

Static precautions

Most modern components have internal static protection but it's still advisable to take sensible static precautions as static damage may not show mediately but as a reduced performance sometime in the future.

If you get a static shock when touching an earthed object (radiator etc.) then its quite likely you will destroy semiconductors. If you don't have an antistatic work environment, perhaps building on the dining table, working on a biscuit tin lid grounded to the soldering iron is one suggestion – this will also protect the table from burns!

Leaded or lead-free cored solder may be used, the solder must be designed for electronics – do not use plumbers' solder or additional flux as the flux can be very corrosive. I use a modern 22 SWG (0.7mm) lead free (Sn99.3/Cu0.7) multi-core type solder that seems most suitable for this type of work. A hot soldering iron MUST be used, a temperature controlled iron should be set to >350°C; as a preference I use an Antex XS25 iron fitted with 3mm chisel bit.

A double sided plated through hole (PTH) PCB has been used, this has the advantage of greater stability and makes dry joints very unlikely, however incorrectly fitted components can be difficult to remove so it's important to fit them in the right place first time! If a component is inadvertently fitted incorrectly, it is easiest to cut off its leads, apply the soldering iron and pull them out from the topside. A small solder sucker or de-solder braid can be used to clear the holes out ready for a replacement component to be fitted. A stainless steel sewing pin is also very handy for clearing holes; heat the pin and pad simultaneously to allow the pin to pass through – note solder doesn't readily "stick" to stainless steel. When soldering the component leads, it will be noticed that the solder "wicks" up the hole through to the top surface, this is normal.

For a start, place just a few components in place before soldering them, as experience grows you may find it more productive to fit a larger number at a time. As ***each*** component is fitted put a mark in the box provided in the instructions, it's very easy to forget the last component fitted especially if you are distracted. If you make use of the component overlay, you will find it helpful if components are highlighted as they are fitted. Components are taken from one bag at a time keeping the others sealed.

Everyone has their preferred method of retaining components prior to soldering; I pull the leads through with long nose pliers and put a bend in the component lead to stop it falling out of the board. A good policy is not to crop leads until they have been soldered, this should stop you from missing any soldered joints. As this is a PTH board, leads can be cropped quite close to the PCB without damaging the soldered joint. Its not recommended to clean the board after soldering, If you need to, use isopropyl alcohol or a proprietary flux remover but avoid allowing the cleaner to enter the rotary encoder as it is likely to contaminate the contacts.

Where possible fit the components so their values are easily readable. Some components MUST be fitted in the correct orientation as they are polarised; this will be indicated in the text.

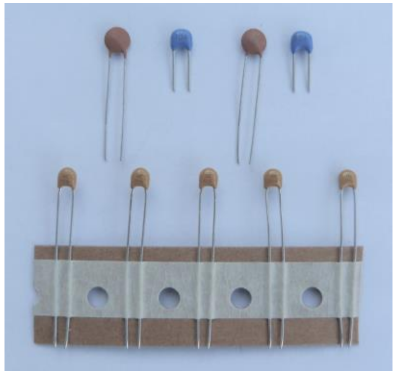
Resistors and capacitors should be fitted right to the board with shortest leads, transistors should be fitted with their bodies approximately 2mm off the PCB – they naturally seat at this position.

Components are packed in multiple bags within the box, each bag contains a list of contents which will show any substitutions that have been made. Bags 1 to 4 are common to all kits (20, 40 and 80m), the fifth bag is band specific and will be identified on the packing list.

Component identification

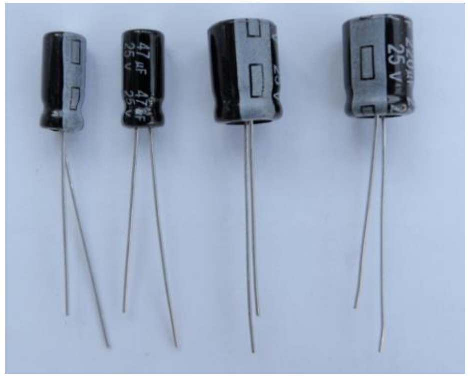
To aid identification, component markings have been given in parenthesis next to the component values. To assist those not familiar with the types of components used in this kit a description follows.

Ceramic Capacitors



Ceramic capacitors used in this kit are marked in one of the following ways.

- Directly with their value, for example 8 for 8pF and 68 for 68pF.
- Numerically based in Pico farads, the first two digits are the value and the third is the multiplier, for example 1nF (1000pF) is marked 102 (1, 0 and two zeroes), 220pF is marked 221 (2, 2 and one zero).



Electrolytic capacitors

These are marked directly with their value, note that the bar along the length of the capacitor indicates the **negative** terminal, **positive** terminal is always the longest lead.

Resistors

Values on all the resistors in this kit use a 4 colour coded bands to indicate value – note that resistors are available with 5 (or more) coloured bands. If in doubt of a colour measure it's value with a multi meter switched to the appropriate range.

Colour	Value	Multiplier	Tolerance
Black	0	x1	
Brown	1	x10	1%
Red	2	x100	2%
Orange	3	x1000	
Yellow	4	x10000	
Green	5	x100000	
Blue	6	x1000000	
Violet	7		
Grey	8		
White	9		
Silver	Divide by 100		10%
Gold	Divide by 10		5%

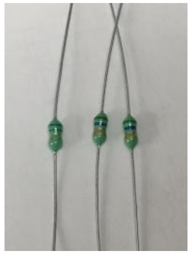
Examples

- 1k 5% (1000Ω) = Brown (1) Black (0) Red (x100) Gold (5% tolerance)

- 4R7 5% (4.7Ω) = Yellow (4) Violet (7) Gold (divide by 10) Gold (5% tolerance)

Note that 1000Ω = 1k, 1000000Ω = 1M, 2K2 = 2200Ω, 2R2 = 2.2Ω etc.

All resistors in this kit have four colour bands, three for value and one for tolerance.

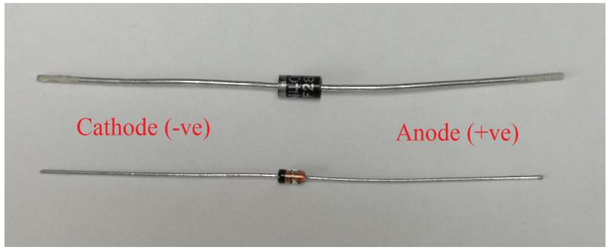


Inductors

Axial inductors use the same colour code as resistors with their value based in micro Henrys; for example 5.6uH is marked Green (5), Blue (6), Gold (divide by 10) and gold (5% tolerance). All inductors used are larger than resistors so are unlikely to be confused – they won't fit a resistor footprint.

Diodes

All diodes used are of the axial type and have their cathode (negative) end marked by a "band" on the encapsulation.

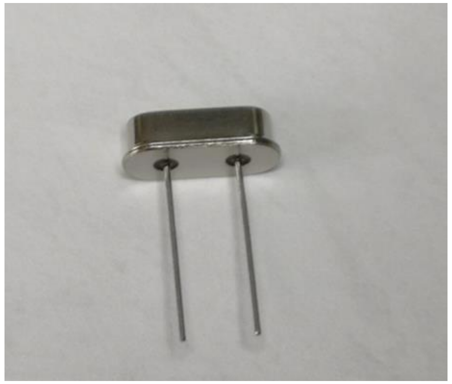


Values are marked on the bodies although for the 1N4148 type they will be hard to read without a magnifying glass.

Transistors and ICs

Two types of package are used in this kit, the LM78L05 which is in the same package as a small transistor (TO92) and the micro and audio output IC (LM386) which are in traditional packages, note that pin 1 end is indicated a notch on the PCB symbol, the IC is marked with a corresponding notch. There are two SMD parts which are already fitted.

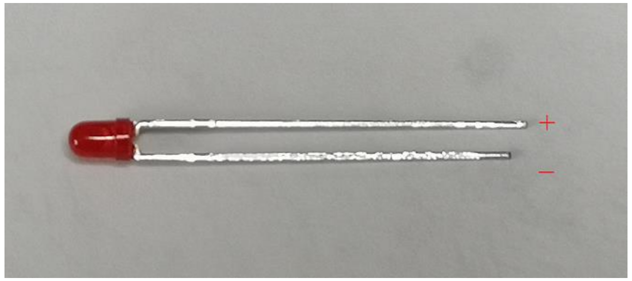
Crystals



The delicate quartz element is cased in a small steel can for protection, they aren't polarized so may be fitted in either orientation.

LED

LED anode is identified by the longer lead.



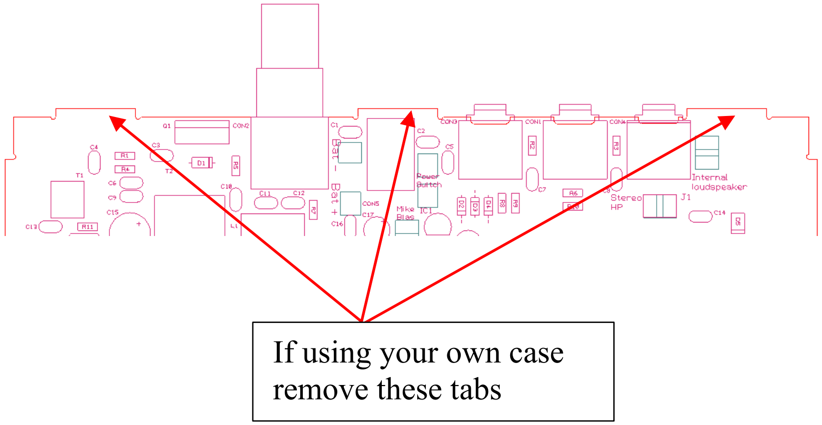
Component Placement

First to be fitted are the components from the band specific bag, there is a separate page in the manual depending on band selected.

It's suggested the two unused pages are either removed or defaced so they won't accidentality get used.

Note:
As an option the kit can be purchased without a case for the constructor to choose their own.

PCB as supplied has three tabs extending beyond the outline intended to interface with the supplied case, these will need to be removed to allow connectors to protrude into rear of the case correctly.



Band specific components 20m

From 20m bag fit the following components:

47R (Yellow, Violet, Black, Gold)	
R90	

Axial inductors have a similar appearance to resistors but larger in size, if measured by a multi-meter they will read a very low resistance.

0.47uH (Yellow, Violet, Silver, Gold)	
L4	

3.9uH (Orange, White, Gold, Gold)					
L6		L8		L9	

Some capacitors may be supplied on a “bandolier”, a strip of cardboard with tape holding components in place. Cut these from the tape before use.

33pF (Marked 330)			
C67		C83	

39pF (Marked 390)	
C76	

120pF (Marked 121)			
C35		C61	

220pF (Marked 221)			
C68		C75	

270pF (Marked 271)			
C12		C53	

470pF (Marked 471)			
C23		C38	

Fit the crystals right to the board with zero lead length.

11.0592 MHz Xtal (Marked 11 – in addition there may be other numbers and letters)									
XTAL1		XTAL2		XTAL3		XTAL4		XTAL6	
XTAL7		XTAL8		XTAL9					

The PCB is common to all bands, some components won’t be fitted.

Components not fitted (for reference only)									
C11		C21		C24		C36		C37	
C54									

Band specific components 40m

From 40m bag fit the following components

47R (Yellow, Violet, Black)	
R90	

Axial inductors have a similar appearance to resistors but larger in size, if measured by a multi-meter they will read a very low resistance.

3.9uH (Orange, White, Gold, Gold)	
L4	

8.2uH (Grey, Red, Gold, Gold)					
L6		L8		L9	

Some capacitors may be supplied on a “bandolier”, a strip of cardboard with tape holding components in place. Cut these from the tape before use.

68pF (Marked 680)							
C35		C61		C67		C83	

82pF (Marked 820)	
C76	

470pF (Marked 471)							
C12		C54		C68		C75	

560pF (Marked 561)							
C21		C23		C36		C38	

Fit the crystals right to the board with zero lead length.

11.0592 MHz Xtal (Marked 11 – in addition there may be other numbers and letters)									
XTAL1		XTAL2		XTAL3		XTAL4		XTAL6	
XTAL7		XTAL8		XTAL9					

The PCB is common to all bands, some components won’t be fitted.

Components not fitted (for reference only)							
C11		C24		C37		C53	

Band specific components 80m

From 80m bag fit the following components

68R (Blue, Grey, Black, Gold)	
R90	

Axial inductors have a similar appearance to resistors but larger in size, if measured by a multi-meter they will read a very low resistance.

8.2uH (Grey, Red, Gold, Gold)	
L4	

18uH (Brown, Grey, Black, Gold)					
L6		L8		L9	

Some capacitors may be supplied on a “bandolier”, a strip of cardboard with tape holding components in place. Cut these from the tape before use.

120pF (Marked 121)							
C35		C61		C67		C83	

150pF (Marked 151)	
C76	

390pF (Marked 391)			
C11		C53	

470pF (Marked 471)			
C12		C54	

560pF (Marked 561)									
C21		C23		C24		C36		C37	
C38		C68		C75					

Fit the crystals right to the board with zero lead length.

12 MHz Xtal (Marked 12 – in addition there may be other numbers and letters)									
XTAL1		XTAL2		XTAL3		XTAL4		XTAL6	
XTAL7		XTAL8		XTAL9					

Components common to all variants

From bag 1 fit the following components

4R7 (Yellow, Violet, Gold, Gold)	
R43	

10R (Brown, Black, Black, Gold)								
R47		R57		R68		R98		

22R (Red, Red, Black)									
R11		R12		R24		R82		R102	
R103									

33R (Orange, Orange, Black, Gold)								
R71		R72		R74		R79		

47R (Yellow, Violet, Black, Gold)								
R1		R18		R108		R112		

100R (Brown, Black, Brown, Gold)									
R34		R37		R45		R54		R73	
R107		R119							

180R (Brown, Grey, Brown, Gold)			
R75		R78	

220R (Red, Red, Brown, Gold)									
R6		R10		R27		R28		R46	
R56		R60		R61		R77		R81	
R88		R89		R96		R110			

470R (Yellow, Violet, Brown, Gold)									
R2		R3		R16		R58		R80	
R91		R94		R105		R106		R111	

1k (Brown, Black, Red, Gold)									
R9		R13		R15		R49		R52	
R62		R63		R70		R83		R92	
R118									

2k2 (Red, Red, Red, Gold)									
R17		R50		R53		R84		R85	

4k7 (Yellow, Violet, Red, Gold)									
R8		R39		R42		R44		R59	
R86		R87		R93		R95		R99	
R101		R115		R116					

10k (Brown, Black, Orange, Gold)									
R4		R5		R7		R14		R20	
R21		R22		R23		R25		R26	
R30		R31		R33		R35		R36	
R38		R40		R41		R48		R51	
R55		R64		R65		R66		R67	
R69		R76		R109		R113		R114	
R120									

47k (Yellow, Violet, Orange, Gold)									
R19		R104		R117					

100k (Brown, Black, Yellow, Gold)									
R29									

220k (Red, Red, Yellow, Gold)									
R32		R100							

Diodes are polarised devices so can only be fitted one way round, match the band on one end of the encapsulation with the bar printed on the PCB.

Note D17 is not fitted at this point, keep to one side to be fitted during testing.

1N4148 (Marked 1N4148)									
D1		D2		D3		D4		D6	
D7		D8		D9		D10		D11	
D14		D15		D16		D18		D19	
D20		D21		D22		D23			

1N4007 (Marked 1N4007)									
D5		D12		D13		D24		D25	

12uH (Brown, Red, Black, Gold)									
L7		L10							

From bag 2 fit the following components

47pF (Marked 470)									
C106		C107							

68pF (Marked 680)									
C56		C85		C94		C97		C100	

330pF (Marked 331)									
C20									

1nF (Marked 102)									
C40		C45		C115					

10nF (Marked 103)									
C4		C5		C7		C8		C50	
C51		C55		C57		C59		C62	
C63		C66		C69		C73		C77	
C80		C81		C82		C93		C95	
C96		C101		C110		C111		C112	
C113									

100nF (Marked 104)									
C1		C2		C3		C6		C9	
C10		C13		C14		C16		C18	
C22		C26		C27		C32		C34	
C39		C41		C42		C43		C44	
C46		C47		C49		C52		C58	
C60		C64		C70		C71		C72	
C74		C78		C79		C84		C86	
C87		C88		C89		C90		C91	
C92		C98		C99		C104		C105	
C114									

1uF (Marked 105)									
C48									

From bag 3 fit the following components

Note – An IC socket is not used for IC2 as there would be no clearance to option PCB.

LM386N-4 (Marked LM386)									
IC2									

Transistors should be fitted so their outline matches that printed on the PCB, fit close to PCB - about 2mm between PCB and transistor body.

BS170 (Marked BS170)					
Q6		Q18		Q20	

MPSH10 (Marked MPSH10)			
Q7		Q16	

BC327-25 or BC327-40 (Marked BC327-25 OR BC327-40)	
Q13	

BC337-40 (Marked BC337-40)	
Q2	

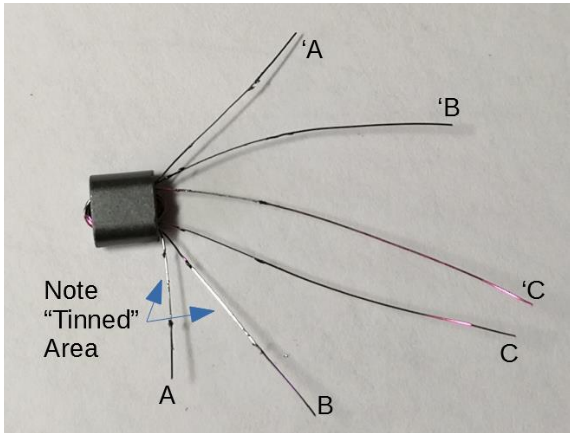
BC547B (Marked BC547B)									
Q3		Q4		Q8		Q9		Q11	
Q12		Q14		Q15		Q17		Q19	
Q21		Q22		Q23		Q24			

BC557B (Marked BC557B)	
Q10	

FQN1N50CTA (Marked FQN1N50CTA or N50C)	
Q5	

LM78L05 (Marked 78L05)	
IC1	

Winding the inductors and transformers



Wire can be found in bag 5.

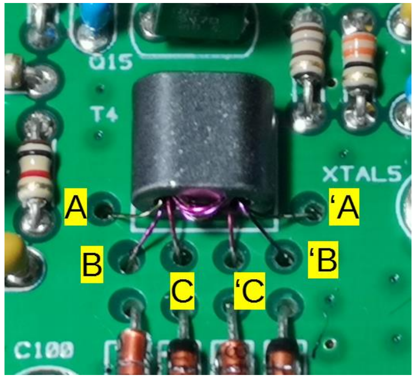
This is probably the trickiest part of the build, although with a little care is not too difficult. The thickest wire has the lowest SWG number; 34 SWG is the thinnest, 24 SWG the thickest.

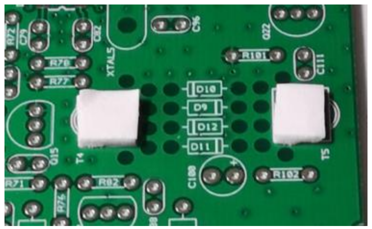
34 SWG wire has been supplied in three colours, any colour may be used for T1 and T3. All three will be used for T4 and 5.

T4 and T5 – These transformers are trifilar wound, that is 3 wires are wound through the ferrite core at the same time.

First cut three pieces of 34 SWG wire about 30cm long (one of each colour supplied). At one end tightly twist all three together for about 12mm, snip the end off and solder together – this will make it easier to thread the wires through the ferrite core. The remaining length may be lightly twisted to stop it getting tangled. Thread the soldered end through one of the holes of a BN43 – 2402 core (the smallest core, see photo) leaving about 10cm remaining then thread the wire back through the other hole – this is one complete turn. Loop the soldered end through a further 3 times to make a total of 4 turns.

Trim the wires back and stagger as shown, this helps to insert into PCB holes, note that wires A - 'A, B - 'B, C - 'C are each a single colour. Its not important and which colour wire is assigned to winding A, B and C. Splay apart and tin wires close to the core with a hot soldering iron and solder.
Make sure that the enamel burns away and the wire tins properly.





From the supplied double-sided sticky pad (found in bag 5) cut two 5mm squares, remove backing paper from one side and stick to PCB – this is to hold transformer in place to avoid leads breaking, preferable to fixing in place with super glue!

Remove top side backing paper from sticky pad, insert wires into PCB as shown and carefully lower on to sticky pad, you only have one chance.

Turn PCB over, solder wires in place and then with a meter set to continuity test (or a low Ohms range), check for continuity from A to A'. B to B' and C to C'.

Balun core BN43 - 2402 core (Small 2 hole ferrite core)				
T4		T5		

Cut two 5mm squares from the unused piece of double-sided sticky pad, remove backing paper from one side and stick to PCB in T1 & T3 positions.

T1 & T3 have two windings, each with 4 turns of 34 SWG wire. Cut two 20cm lengths of 34 SWG wire (any colour). First wind 4 turns through the core from one end of the transformer and crop the leads to about 40mm in length, turn the transformer round and repeat with another 4 turns from the other end. Tin the wires. Remove backing paper from sticky pad, insert wires into holes, lower into position and solder. Check continuity on solder side of PCB.

Balun core BN43 - 2402 core (Small 2 hole ferrite core)				
T1		T3		

L2 – wind 2 turns of 27 SWG wire through the holes of a BN43-2402 core and tin the leads.

Balun core BN43 - 2402 core (Small 2 hole ferrite core) 2 turns 27 SWG		
L2		

Band specific toroids

Wind and fit appropriate to selected frequency band.

20m inductors – Fit for 20M version

Toroid T37-6 (Yellow, Grey) **15 turns 27 SWG through core**	
L1 ☐	L5 ☐

Toroid T37-6 (Yellow, Grey) **16 turns 27 SWG through core**
L3 ☐

40m inductors – Fit for 40M version

Toroid T37-6 (Yellow, Grey) **20 turns 27 SWG through core**	
L1 ☐	L5 ☐

Toroid T37-6 (Yellow, Grey) **19 turns 27 SWG through core**
L3 ☐

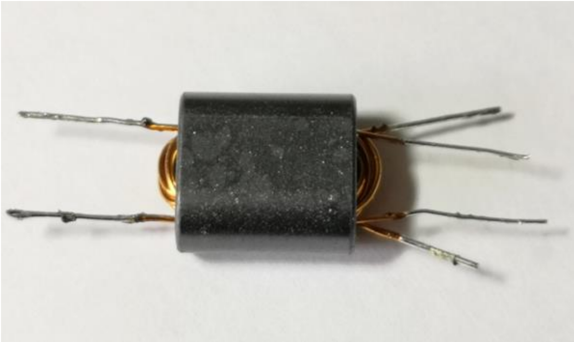
80m inductors – Fit for 80M version

Toroid T37-6 (Yellow, Grey) **30 turns 27 SWG through core**	
L1 ☐	L5 ☐

Toroid T37-6 (Yellow, Grey) **32 turns 27 SWG through core**
L3 ☐

Toroids L1, L3 and L5 – Cut off approximately 45cm of 27 SWG wire and pass half of it through the centre of a T37-6 core, this counts as the first turn. Now wind the remaining turns through the core; as the wire becomes too short turn the core over and continue winding the remaining turns. For 80m inductors the wire needs to be close wound, for L1 and L5 wire will only just fit, L3 may have 2 turns overlapping. For other bands space the wire uniformly around the core. Remember that each pass through the hole counts as a turn. Crop the wires to 10 – 20mm in length and tin the ends with solder.

Wind, then fit cores for the appropriate band. Fit all the toroid inductors vertically against the PCB, refer to the photo of finished radio.



T2 is wound using the same method as T1 and T3, the windings have 4 turns of 24 SWG wire on the larger BN43-0202 core. Each winding will require a cut length of about 30cm of 24 SWG wire. Through one end is wound a single turn of 27 SWG wire, this is a single pass through both holes.

Tin all six wires prior to soldering to PCB; it is easier to first scrape the enamel from the 24 SWG wire using a sharp knife first.

Note that the thin 27 SWG wires are fitted through two smaller holes.

Balun core BN43 - 0202 core (Large 2 hole ferrite core)		
T2		

From bag 4 fit the following components

For all connectors & sockets, solder a single pin first, check alignment and correct if necessary before soldering remaining joints.

A strip of 36 header pins is supplied, from this cut 5 sections:

1. Microphone Bias Select, 2 pins
2. Speaker, 2 pins
3. Stereo headphone select, 2 pins
4. Option pins 1-4, 4 pins
5. Option pins 5-11, 7 pins
6. Display connector, 16 pins

Microphone bias select, option connector and headphone connector pins are fitted on the component side of PCB.

Loudspeaker connector pins are soldered on underside of PCB.

Fit the 16 way pin strip to the underside of the display (from bag 4), solder short pins to front side.

First solder a single pin and inspect strip to ensure its at 90° to display, correct if necessary then solder remaining pins. Place display to one side for later fitment.

Header pins					
Mic bias 2 pins		Loudspeaker 2 pins		J1 Stereo Headphones 2 pins	
Option pins 1-4		Option pins 5-11		Display 16 pins	

Fit stereo jack sockets – ensure these are fitted fully flush with PCB. Push jack sockets close to PCB – they may “snap” into place.

Stereo jack socket 3.5mm						
CON1		CON3		CON4		

The display socket strip is mounted on the underside of PCB and soldered on the component side.

Female Header Strip - 16 way		
Disp 1		

Fit 28 pin socket for IC3 – match notch with that on the PCB. Do not fit IC3 at this stage.

IC socket - 28 pin		
(For IC3)		

Fit DC socket, solder a single terminal and check for correct alignment with marking on PCB, correct if necessary and solder remaining terminals.

DC Socket		
CON5		

Electrolytic capacitors are polarised so may only be fitted one way round. By convention the PCB is marked with a + symbol, the + lead of a capacitor is longest, note the capacitor sleeve is marked -. Fit the capacitors against the PCB with zero lead length but don't put excessive force on the leads as this can make the electrolyte leak out.

1uF 50V (Marked 1uF 50V)						
C17		C65		C109		

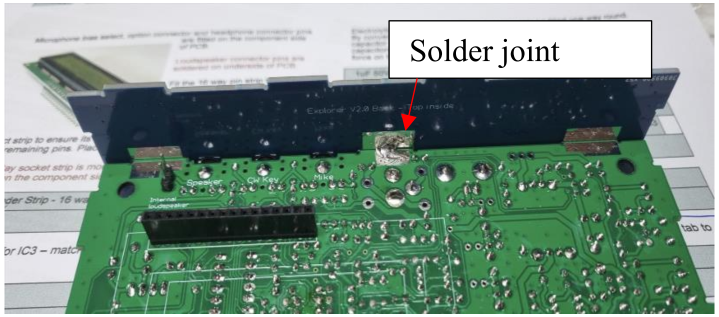
47uF 16V (Marked 47uF – note may be 16V or 25V)									
C19		C25		C28		C29		C33	
C102		C103		C108					

220uF 16V (Marked 220uF – note may be 16V or 25V)						
C15		C30		C31		

USB B Socket		
CONN1		

PCB Mount BNC		
CON2		

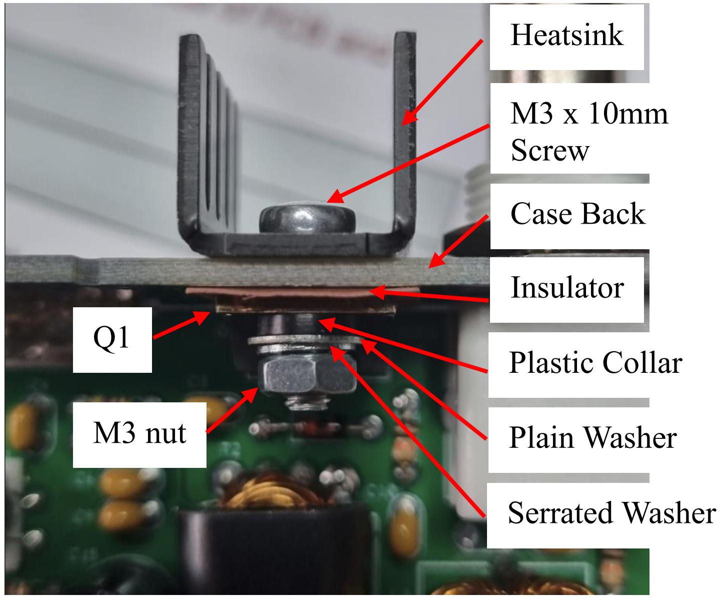
The rear case panel will need fitting prior to fitting Q1 the RF output transistor. Align rear panel and loosely fit BNC connector retaining nut and washer. Solder centre pad on solder side of main PCB. Ensure back panel is pushed fully into position and is 90° to main PCB.



Trial fit case top, bottom and sides to ensure rear panel is in correct position, then solder 4 remaining pad positions. Note a large iron tip will be required.

Secure BNC connector by tightening nut.

Locate Q1 in PCB (don't solder yet), place the insulator pad between transistor and case back. Take heatsink from case bag and pass M3 x 10mm screw through heatsink, pass through case back aligning with hole in insulator then through hole in transistor. Fit plastic insulator collar over screw thread and locate into hole in transistor. Secure with flat washer, serrated washer and 3mm nut.



Solder transistor in place ☐

IRF510 (Marked IRF510)		
Q1		

Fit rotary encoder to **underside** of PCB soldering on component side.

Solder two small pins first and check rotary encoder shaft is at 90° to PCB, correct if necessary, then solder remaining pins and retention lugs.

Fit washer and nut to rotary encoder shaft ☐

Rotary encoder		
SW1		

Testing

Firstly, clear the work bench of all lead trimmings, tools, solder etc. – its all too easy to lay the PCB on to something conductive. The biggest risk of damage is if the 12V supply becomes shorted to 5V – in this case display, micro and worst of all the surface mount chips will fail.

If using an electret type microphone fit the bias link, this will provide power to the inbuilt buffer amplifier (within microphone). ☐

Fit link to position on option connector marked "Audio Link". ☐

Jumpers				
Mike Bias		Audio Link		

Where necessary, prepare leads with the appropriate connectors for your power, speaker, microphone and antenna. Refer to the accessory section for instructions. The power lead must be fitted with a 2A fuse.

Do not connect any of the leads yet.

For testing you will need a power supply of 12-14V DC, capable of supplying up to 1.3A nominal. A current limiting supply should be used if you have one available but is not essential. DO NOT CONNECT THE SUPPLY YET. If you are using a current limiting power supply, set the maximum current to 400mA. ☐

Before connecting power make a careful inspection of soldered joints especially for any solder splashes etc. At this point the micro-controller and display should **not** be fitted as these components can easily be damaged by incorrectly applied voltages to their pins. ☐

On the PCB, measure between supply positive and ground with a multi-meter on Ohms range to ensure there is not a short circuit. A typical value is 1k Ohms but this will depend on meter used.

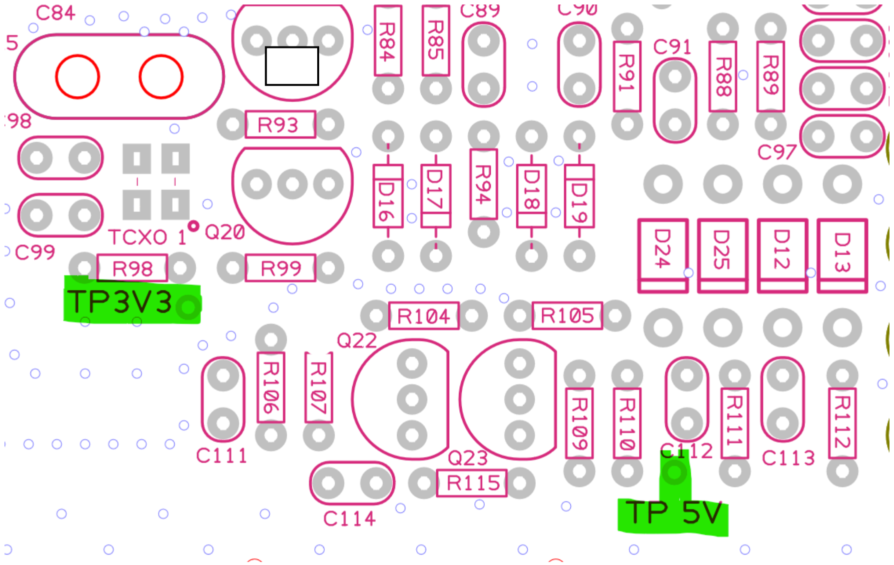
When making **voltage** measurements, clip the -ve (black) meter lead to a ground, this can be found at the PCB mounting holes.

When making **current** measurements place the meter (set to an appropriate range) is series with the power supply – you may have to move one of the meter leads into the current terminal on your multi-meter.

Connect the meter between power supply +ve and +ve supply lead.

Connect the loudspeaker.

Connect 12 – 14V and check for any obvious fault symptoms – loud noises or smoke! Current drawn should be between 50 and 100mA.



Assuming all is OK, measure the 5V regulated supply at TP 5V - see pcb plot. This should read 5 ± 0.25V. If high or low identify and rectify the cause.

Remove power. If all is OK fit D17.

1N4148 (Marked 1N4148)		
D17		

Apply power and measure TP 3V3; voltage should be 3.4 ±0.2V - see PCB plot.

Measure current, this should be between 70 and 120mA.

Disconnect multi-meter and power.

Plug IC3 into its socket, matching aligning with notch on socket and indication on PCB.

PIC18F27Q10 (Marked PIC18F27Q10)		
IC3		

Temporarily fit the LCD display to its socket.

1602 LCD (16 characters x 2 line backlit display)		
DISP1		

For information only.

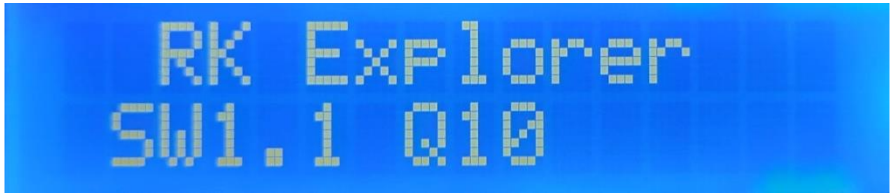
Components already fitted to PCB						
TCXO1		IC4 (Si5351)		IC5 (FT230XS)		DBM1 (ADE-1+)

Components not fitted (Note there are other components not fitted which are band specific)

Components not fitted				
XTAL5				

First Air Test

Connect speaker and Antenna, apply power. Microcontroller should initialise and default to 20m.

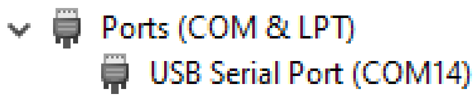


Welcome screen will identify firmware version and controller type.

If you have built the 40 or 80m version, go to *System menu / Band* and select the appropriate band.

Now with any luck you should hear signals, if not refer to the fault finding section.

Plug a USB lead between PC and Explorer, confirm the PC knowledges the connection (no need for any PC software at this stage) and doesn't report any errors. On a Windows machine go to Control Panel / System /Device Manager and check that under "Ports (COM & LPT)" a new USB Serial port has been added, the CAT control software will refer to the COM number.



"COM14" is shown as an example and may be different on your machine.

Now familiarise yourself with the radio controls; refer to the User Instructions, at this point don't attempt to transmit as TX PA bias hasn't been set.

Leave soldering the LED until a case has been assembled, Transmit mode is also indicated by "TX" displayed on the LCD.

The longest lead is the anode (+) terminal.

3mm Red LED		
LED1		

Alignment

Settings will automatically be saved on pressing the rotary encoder.

Display Contrast

Go to System Menu / LCD Con. - Adjust for correctly contrasted display, for "Blue" displays this will often be set to 0.

VFO Calibration

Frequency calibration will already be close due to use of a TCXO but may be improved if required. There are several possible methods to calibrate the VFO depending on equipment available.

Simple method – Tune to a station with known frequency, adjust rotary encoder to show the correct frequency, go to *System Menu / VFO Cal.* - adjust so station is correctly tuned. Make a note of the value in case it must be re-entered after a software update.

Refer to addendum for advanced method of frequency calibration.

PA Bias

Disconnect the antenna and power, fit an ammeter in series with +ve to power supply and -ve lead to +ve power lead, set to read >350mA.

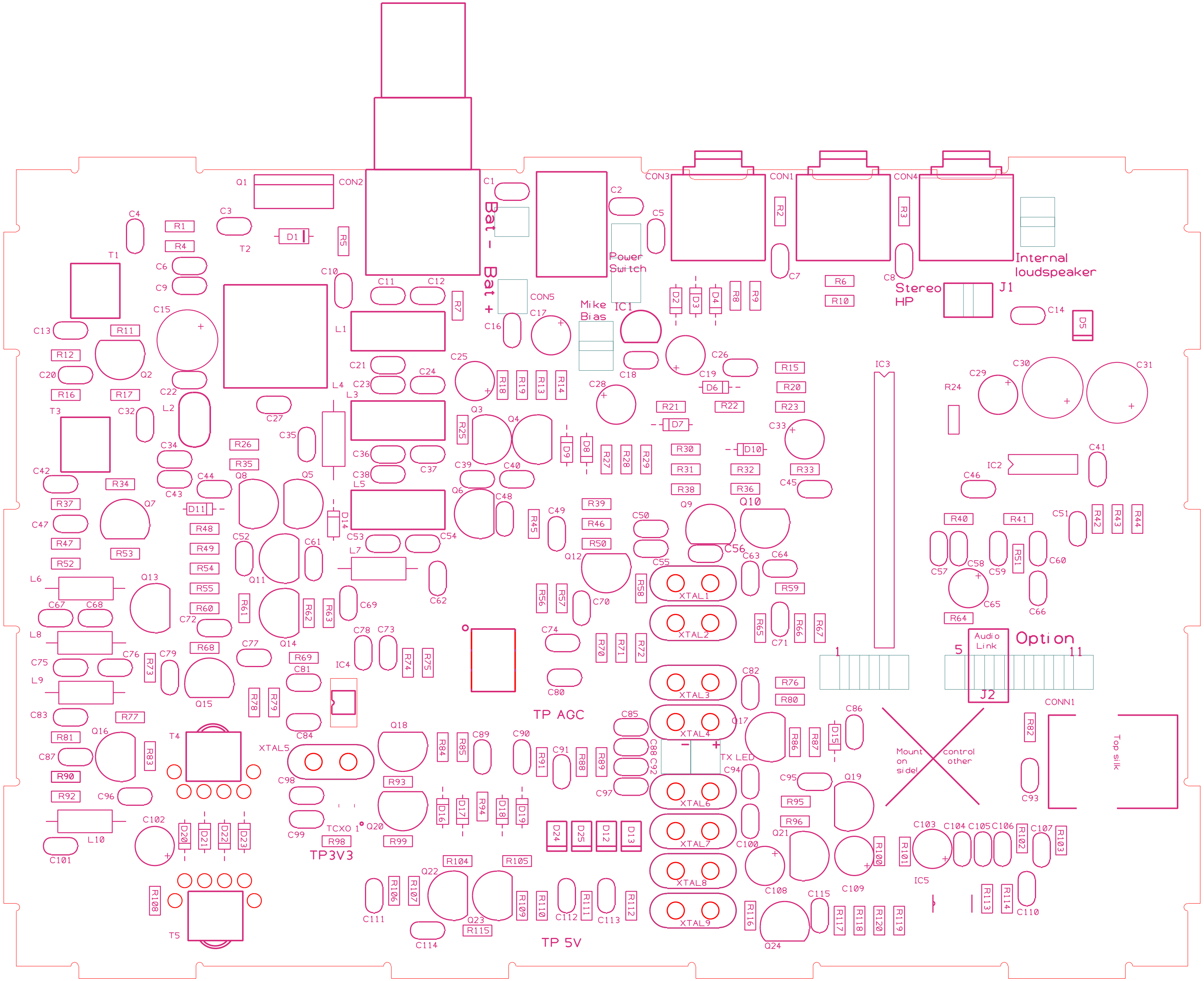
Reconnect power. Go to *System Menu / TX PA Bias Set* – note that the microcontroller presets the bias to a low level (100), this is in case the setting had previously been made for a different transistor.

Make a note of supply current, normally in the range 280 – 320mA. Add 40mA to this value, this is the value the PA Bias needs to be set to.

Rotate control clockwise; current will start increasing slowly and then speed up – adjust to read the previously calculated bias current – value is normally in the range 600 – 1000. Record this value for future reference so it can be reset without need of measuring current should a software reset be made.

Schematic is supplied as a separate document.

Main PCB –
Component overlay



2. Option PCB

Construction

Fit the following components from “Option” bag

22R (Red, Red, Black, Gold)	
R16	

100R (Brown, Black, Brown, Gold)	
R28	

820R (Grey, Red, Brown, Gold)	
R5	

1k (Brown, Black, Red, Gold)					
R4		R12		R17	

1k8 (Brown, Grey, Red, Gold)	
R8	

4k7 (Yellow, Violet, Red, Gold)	
R13	

10k (Brown, Black, Orange, Gold)									
R15		R18		R19		R24		R26	
R29		R30							

22k (Red, Red, Orange, Gold)							
R6		R11		R14		R20	

27k (Red, Violet, Orange, Gold)			
R3		R7	

33k (Orange, Orange, Orange, Gold)	
R9	

47k (Yellow, Violet, Orange, Gold)					
R23		R25		R27	

56k (Green, Blue, Orange, Gold)	
R2	

100k (Brown, Black, Yellow, Gold)	
R1	

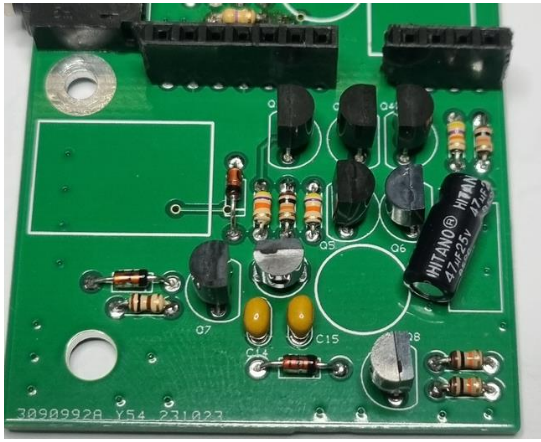
150k (Brown, Green, Yellow, Gold)	
R10	

470k (Yellow, Violet, Yellow, Gold)			
R21		R22	

22nF Polyester (Marked 22n)									
C1		C2		C3		C4		C6	
C8									

100nF Ceramic (Marked 104)			
C7		C9	

1uF Ceramic (Marked 105)									
C5		C10		C11		C12		C14	
C15									



Note C13 is mounted flat to the PCB and at an angle to avoid a clash with components on main PCB.

47uF 16V Electrolytic	
C13	

1N4148 (Marked 1N4148)									
D1		D2		D3		D4		D5	

Transistor must be fitted with approximately 2mm clearance from their body to PCB.

BC547B (Marked BC547B)					
Q1		Q6		Q8	

BC557B (Marked BC557B)	
Q5	

BS170 (Marked BS170)							
Q2		Q3		Q4		Q7	

Please note that a socket can't be used for IC1, this is to avoid a clash with main PCB components.

LM324 (14 pin device marked LM324)	
IC1	

78L08 (Marked 78L08)	
IC2	

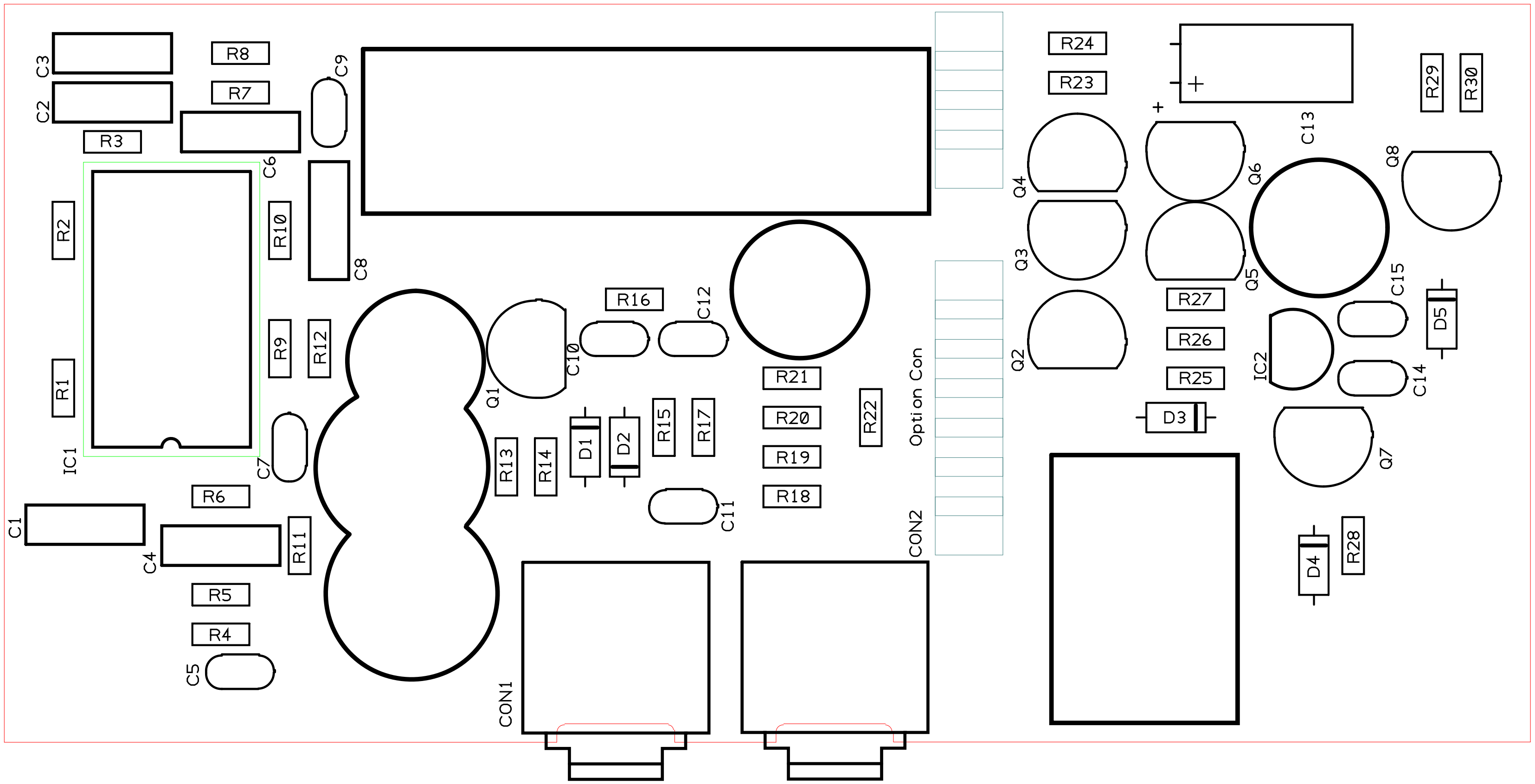
Ensure CON1 and CON2 are fitted right down to the PCB.

Stereo jack socket 3.5mm				
CON1		CON2		

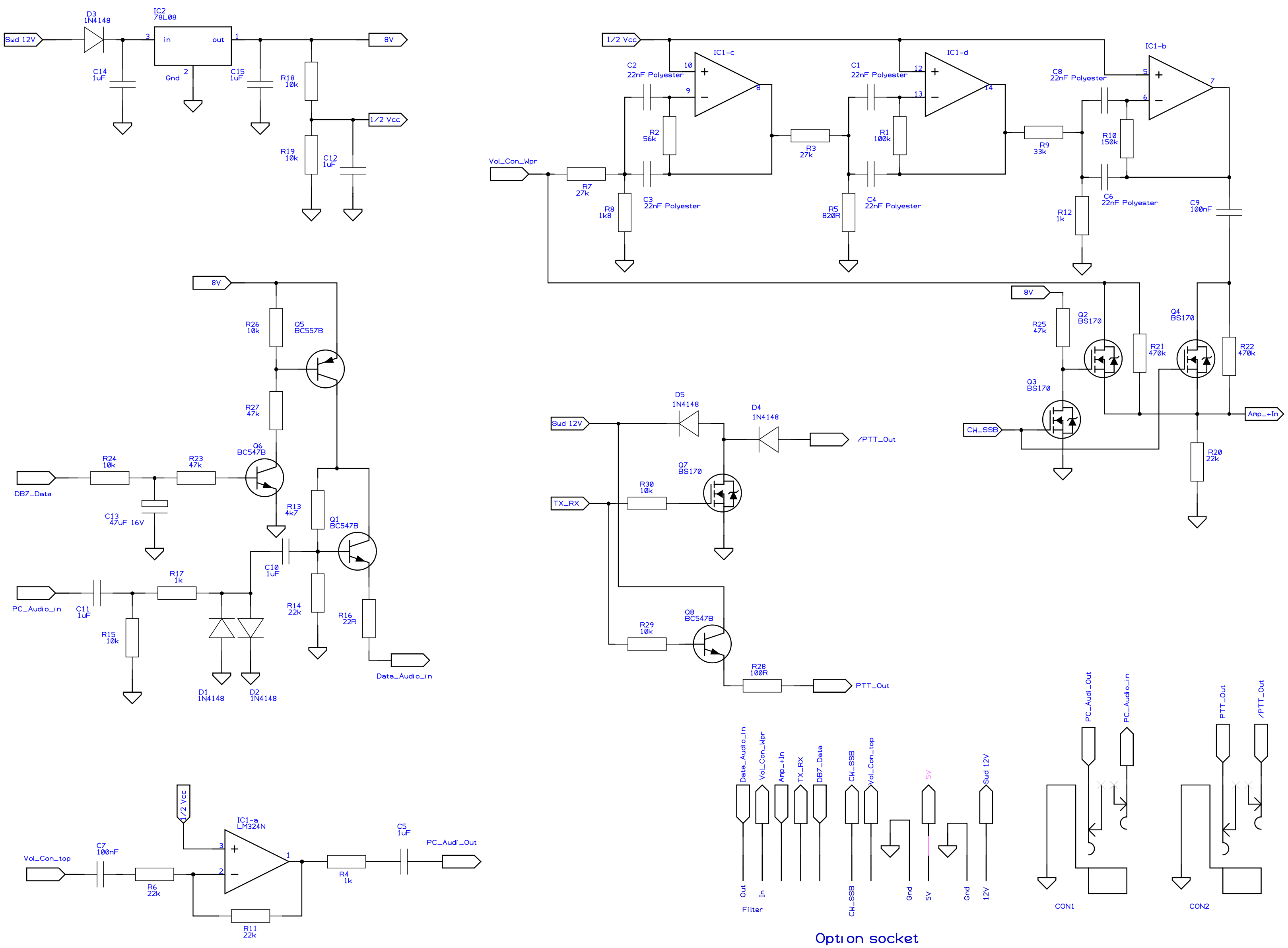
The option socket has been cut from a long strip, trim the two parts to remove waste plastic. Solder one pin first and ensure the socket is straight and at 90° to the PCB before soldering all connections.

The sockets are mounted on component side.

Socket strip				
4 way		7 way		



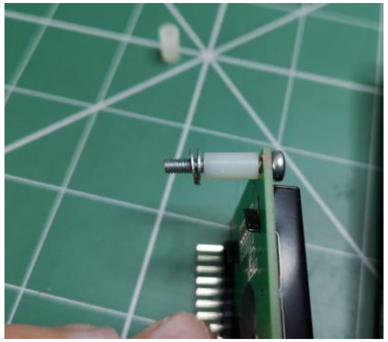
Option PCB – Component overlay

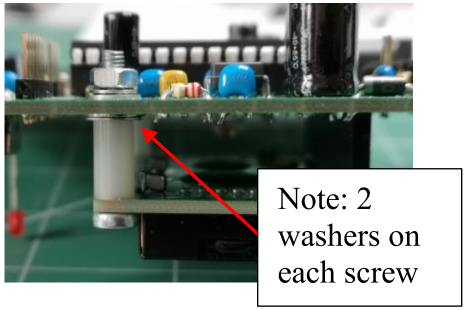


Option socket

3. Assembly into Case

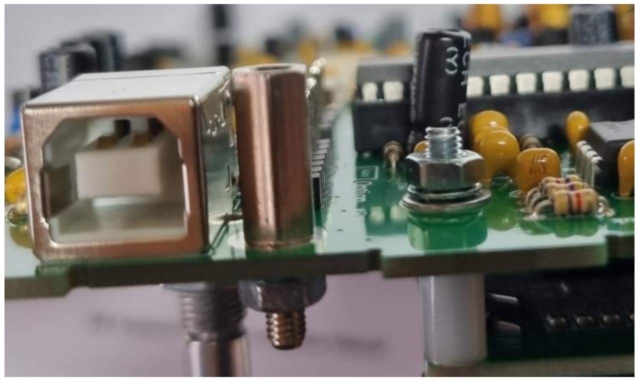
Fit display





Pass two M3 * 20mm screws through display PCB from topside. Hold screws in place and with display upside down place 2 x 10mm plastic spacers on to screws followed by two 3mm flat washers on to each screw thread.

With display still inverted plug display into PCB guiding screws into holes in PCB, secure with M3 nut, flat and serrated washer.



PCB stand-off

Pass male thread of 12mm male / female stand-off through PCB (adjacent to USB connector) from component side, place 3mm plain and serrated washer on male thread and secure with M3 nut.

Loudspeaker

The speaker is fixed in place by trapping under three 3 x 10mm plain washers; pass three M3 x 10mm screws through front panel, fit 3 x10mm plain and serrated washers securing with M3 nuts. Align speaker as shown before tightening.

Cut a female socket with about 250mm of wire from each of the pre-terminated jumper leads, solder to each of the two speaker terminals – note polarity and wire colour isn’t important.

Option PCB

Plug PCB assembly into place and secure using M3 x 6mm screw with flat and serrated washer.

PCB assembly to case assembly

Assemble case sides around main PCB – its possible to temporarily hold in place with an elastic band. Note the sides are marked with “Top side”, place these towards the front cover as they aren’t symmetrical.

Pass TX LED through holes from solder side of PCB – long lead is anode (+), temporarily retain in place by bending leads on component side. Locate front panel onto sides and push TX LED into place, solder on component side of PCB.

☐

Remove front panel and fit speaker plugs to their sockets, dress leads around display – avoid trailing leads over the TX section and low pass filter.

☐

Assemble case bottom and secure from topside with 4 x 50mm M4 screws, flat and serrated washers – don't overtighten or case will become distorted.

☐

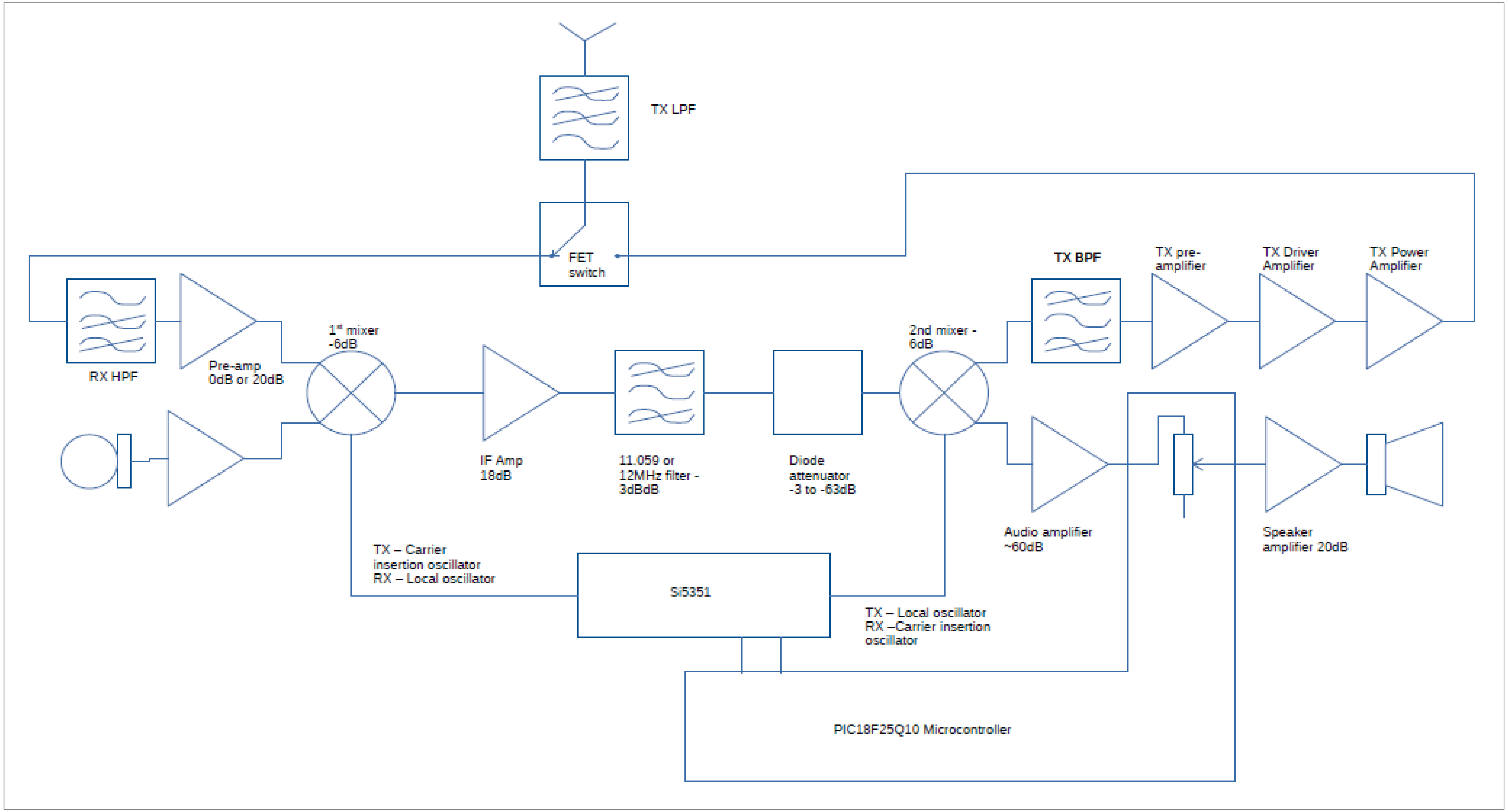
Fit 4 adhesive feet.

☐

Fit rotary encoder knob leaving approximately 1mm gap between knob and case front to allow switch to actuate.

☐

4. Circuit Description



Simplified Block Diagram

Transceiver Topology
Explorer is a single conversion superheterodyne transceiver with an IF frequency of either 11.0592MHz or 12.0MHz (band dependent) shared between TX and RX. This topology was first used in military transceivers and made popular in amateur radio by the ATLAS 180, the first solid state mobile transceiver.

Signal Flow
1st mixer, IF amplifier, crystal filter, AGC stage and 2nd mixer are common to both TX and RX. This is accomplished by switching local oscillator and carrier insertion oscillator (CIO) between the two mixers.

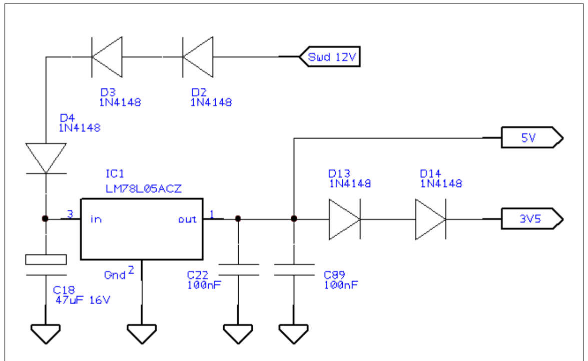
Receive
Signals pass through the transmit low pass filter, RX / TX switch then through a high pass filter – this combination forms a bandpass filter. Amplified signals are applied to the 1st mixer where they are translated to the IF frequency, amplified again and presented to the AGC stage. The second mixer is used to reinsert the carrier, detecting the original audio from the transmitting station. The detected audio passes through a high gain audio amplifier, volume control and finally amplified by the speaker amplifier.

Transmit
Audio from the microphone is first amplified to an appropriate level before being translated to the IF frequency by 1st mixer and CIO, here the IF follows the same route as in receive before being mixed to the output frequency by the 2nd mixer and local oscillator. The image frequency and unwanted mixing products are removed by the band pass filter, wanted signal then has three stages of amplification to generate the required transmit power, passed to the TX LPF where harmonics are removed providing a “clean” signal to apply to the antenna.

Controller
A microcontroller, amongst other tasks sets the oscillator frequencies, provides volume control and AGC control voltage.

Detailed Circuit Description
NOTE Component references in this section are local to the circuit description – for fault finding purposes refer to schematic relevant to the kit version being built.

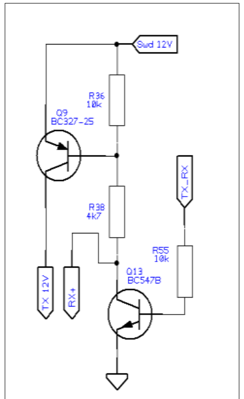
Power Supplies



Regulated 5V and 3.5V supplies

There are two regulated supplies sourced from the 12V rail – references will be made to 12V as a supply voltage but the transceiver will function with a stable supply of between 10-16V DC.

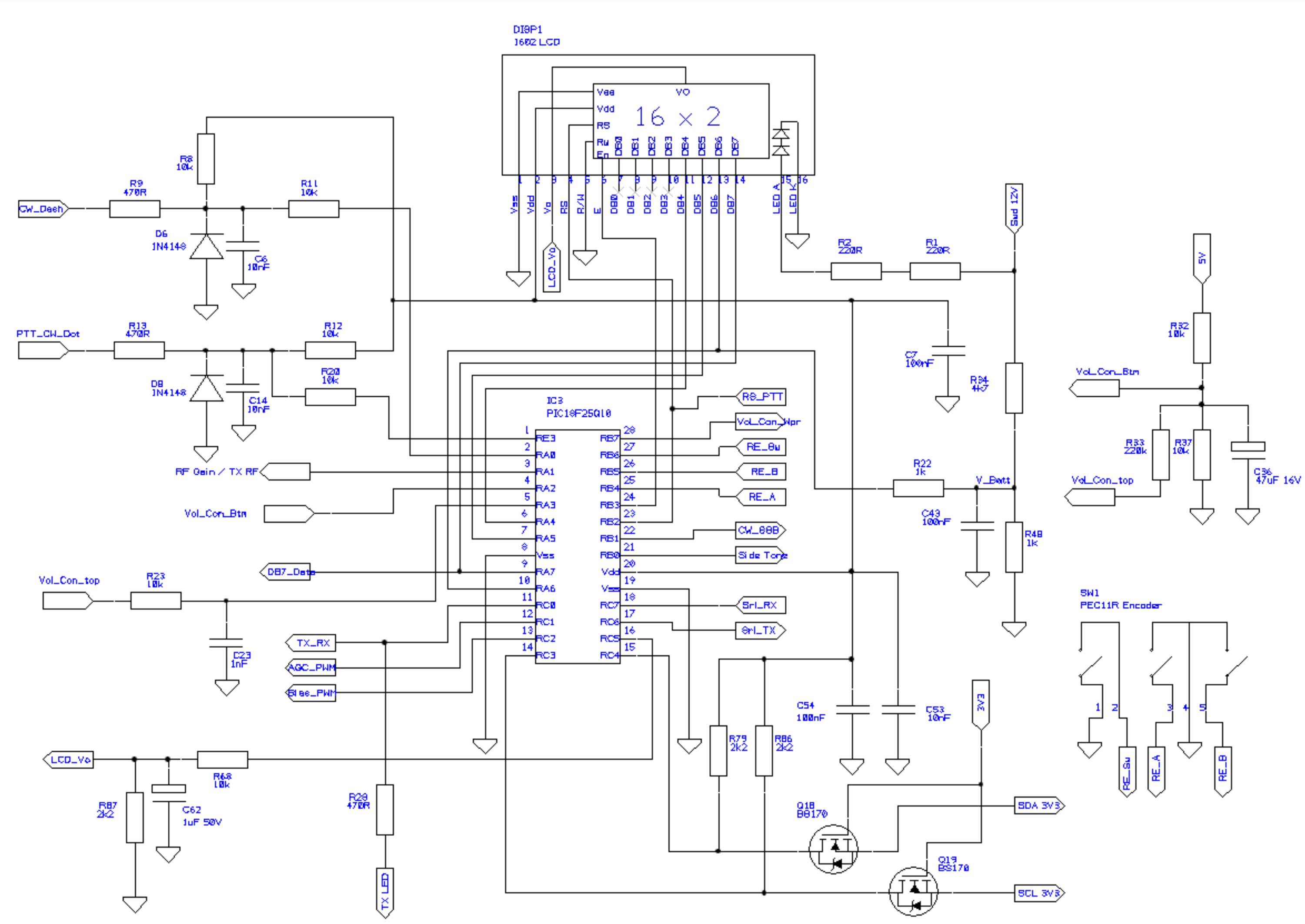
12V is applied to input of 5V regulator IC1, diodes D2, 3 and 4 provide reverse polarity protection and help to reduce the dissipation of IC1 by dropping the supply by approximately 2V, leaving sufficient headroom for the regulator to function from a minimum of 10V battery supply. Note that the regulator will get quite warm in use.



12V TX supply

3.5V (Approximately) for the Si5351 synthesiser chip is generated by placing D13 and 16 in series with the 5V output.

Transmit 12V is switched by Q9 via Q13 from the microcontroller, this powers the low power transmit amplifiers, all other power is taken from the 12V supply.



Microcontroller and user interface

Microcontroller

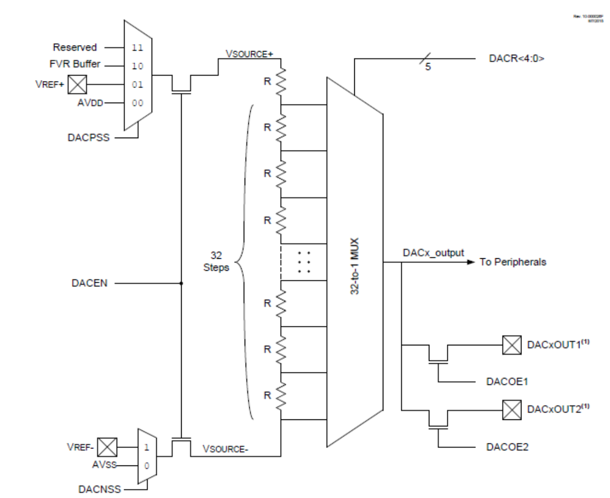
The microcontroller is the heart of the whole transceiver, the type selected is a PIC18F27Q10 from Arizona Microchip. This device was chosen in preference to others due to its wide selection of built in peripherals, all help to keep cost low and make the transceiver feature rich.

The device is powered directly from the 5V supply with capacitors C53 and C54 providing decoupling – these provide short term supply to the micro "smoothing out" current pulses and maintaining stability, also stopping noise from the micro power source being received by the radio.

User interface is provided by a 2 line LCD display and rotary encoder with integral push switch.

LCD is driven in the 4 bit mode from ports RA4-7, En (data **En**able) from RB3, and RS (**R**egister **S**elect) from RB2. RB2 is also shared with the RTS signal output from the USB to serial converter for remote PTT switching – display function takes precedence over the PTT input. R/W (**R**ead / **W**rite) line is permanently held low, LCD busy state isn't polled, with all display instructions being timed by the micro. Refer to display driver data sheet for description of pin names and device function. A bias voltage (Vo) is required to set the display contrast, this is supplied from a PWM peripheral on RC5 filtered and level shifted by

R68, R87 and C62. By varying the PWM duty cycle Vo is changed setting the display contrast. Backlight is supplied via R1 and R2 from 12V, these resistors can be increased in value if current consumption is a concern.
Rotary encoder contacts A and B are applied to ports RB4 and RB5, internal “pull ups” are used saving additional components. The microcontroller detects the direction of rotation by the phase relationship of the two signals. Push switch is applied to port RB6 again using an internal “pull up” resistor.
Communication to the synthesiser chip is via an I^2C bus. The I^2C peripheral uses schmitt trigger input logic levels which are not compatible with the synthesiser 3.5V supply, level conversion is therfore required, provided by Q18 and Q19 – they also provide isolation between the two voltage systems, the Si5351 will be damaged if 5V is applied to any pins – being a SMT device they are not easy to replace! R86 and R87 are pull-up resistors required by the I^2C interface.



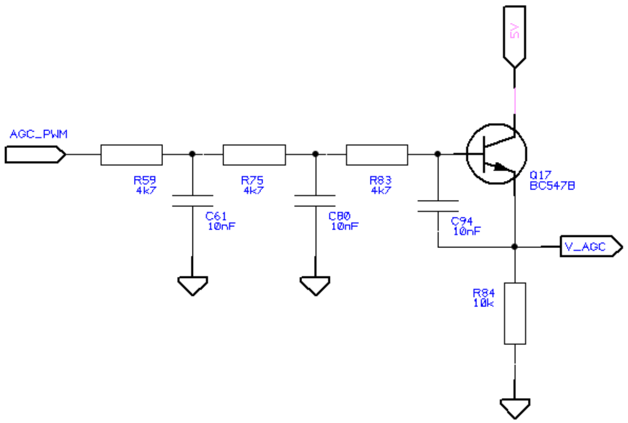
DAC peripheral - Extract from PIC18F25Q10 data sheet

The D to A converter peripheral is used as a volume control. *In the explorer, this circuit is not used to provide a DAC function but is instead used as an amplitude control. Rather than supplying a fixed reference voltage over the series network, the input audio signal voltage is fed across the resistor network. The signal at each resistor junction is accordingly the attenuated audio signal (with attenuation given by the effective voltage division of the resistor network for that junction) and by using the five bit input word to the mux to select which one of the resistor junctions is coupled to the output, the effective attenuation of the audio signal can be digitally controlled by the microcontroller. Thus, the DAC circuit is used to provide a digitally controlled analogue attenuation of the input audio signal, i.e. it provides a digitally controlled analogue volume control.*

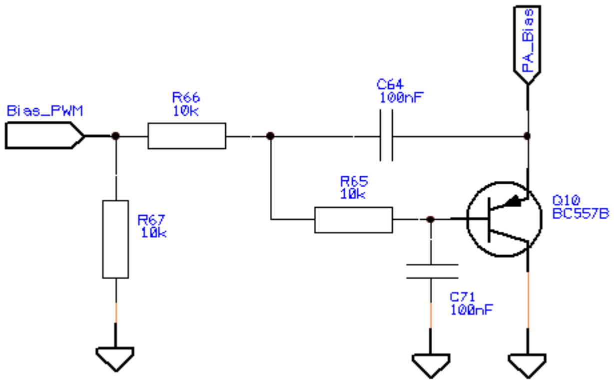
Its usually expected that the positive reference will be higher than negative, also for use as a volume control noise coupled from the micro core could also be an issue – from tests I found neither were issues, as long as the references were biased between 0 and 5V all worked “*nearly”* as expected. The DAC input is from an amplifier with a 12V supply, if there was a noise impulse the controller would reset – not very convenient! There was a simple solution in fitting a current limiting resistor (R23) in series with the DAC input port RA3, any voltage excursions above supply are clamped by the internal ESD protection diodes. The DAC port pin is also enabled as an ADC for an AGC detector – more on this in the AGC description. C23 removes any high frequency component on the audio signal which would affect AGC operation, it also acts as a reservoir capacitor for the ADC sampling circuit. DC bias for the DAC references is provided by R32, R33, R37 and C36. Output from the DAC is on port RB7 which is applied to the audio amplifier.

There are several other inputs to the ADC peripheral; port RA6 is shared with display DB6 for the battery voltage detection, when set as an input the display pin has an internal pull-up, this is overcome by the potential divider R34, R48 and R22 which are designed for relatively low impedance, C43 stops any noise from the converter getting back to receiver circuits. A DC input of the TX RF level is applied to ADC on RA1, this port pin is shared as an output to switch the RX attenuator – possible as neither are used at the same time.
There are numerous inputs; PTT is aplied to port RE3, R8 is a pull-up resistor, it isn’t possible to use the internal pull-up due to the port protection resistor R20, which protect against a high voltage (12V or static discharge for example) on the microphone socket. D8 protects from any back EMFs should the PTT be switched by an inductive source, R13 is included as a current limiter in a fault situation. A similar circuit is used for the CW “dash” input on port RA0.

The DAC of the PIC comprises a resistor series network of 32 resistors. A reference voltage over the resistor network is thus divided into 32 equidistant voltage levels. The DAC further comprises a 32 to 1 *multiplexer which is digitally controlled by a five bit input word to connect one of the resistor junctions to the output of the DAC. For a fixed reference voltage over the resistor network, the output of the DAC is thus a voltage proportional to the five bit digital input word (and to the reference voltage).*

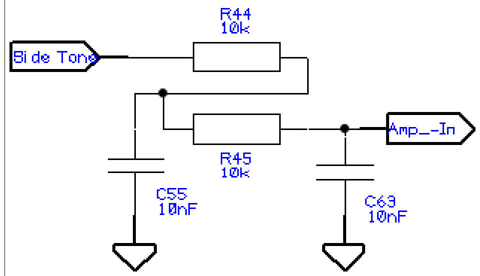


AGC Low Pass Filter



PA Bias filter

The PWM peripheral provides several outputs; all PWM peripherals are derived from the same internal clock which is set to run as fast as possible (62.5kHz). This allows the wanted DC or low frequency signal to be easily filtered. PWM is output from port RC1 which is actively filtered and applied to the AGC circuit. This filter has a 3dB cut-off of about 1.2kHz with an attenuation > 50dB at 62kHz. The AGC needs to function fast to be able to attenuate noise pulses, the same circuit is also used to shape the CW TX waveform and SSB TX level.



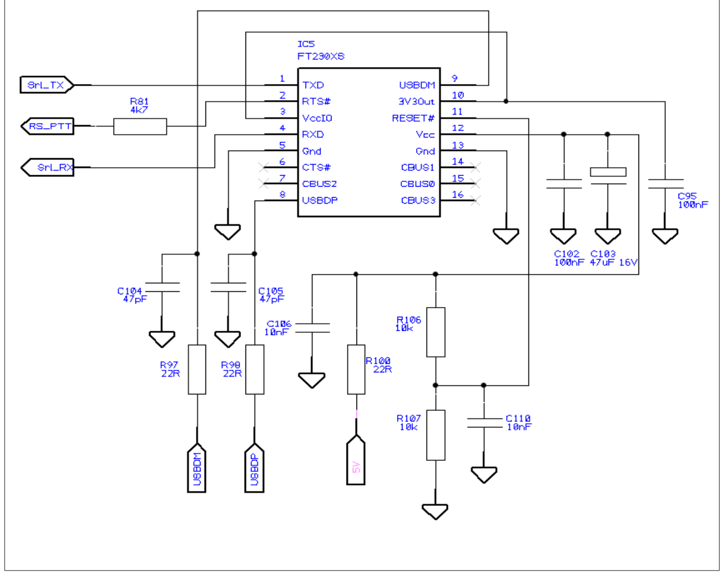
Side-tone Filter

PWM from port RC2 is filtered to provide bias for the PA transistor, this filter has a lower cut off frequency and higher Q factor needed to avoid the residual PWM noise from amplitude modulating the transmitted RF signal.

A 4 bit sine wave is generated by code and applied to the PWM generator peripheral with output appearing on port RB0, a simple RC filter is used to filter the waveform before applying to an input of the audio amplifier. Side-tone volume is set by scaling the 4 bit waveform in software.

Outputs not mentioned so far are; TX_RX from port RC0 which controls the 12V TX supply and CW_SSB from port RB1 for switching the narrow CW audio filter on Option PCB (when fitted).

Serial data for the USB interface is received on RC7 and transmitted on RC6, RS232 speed is set to 9600 baud.

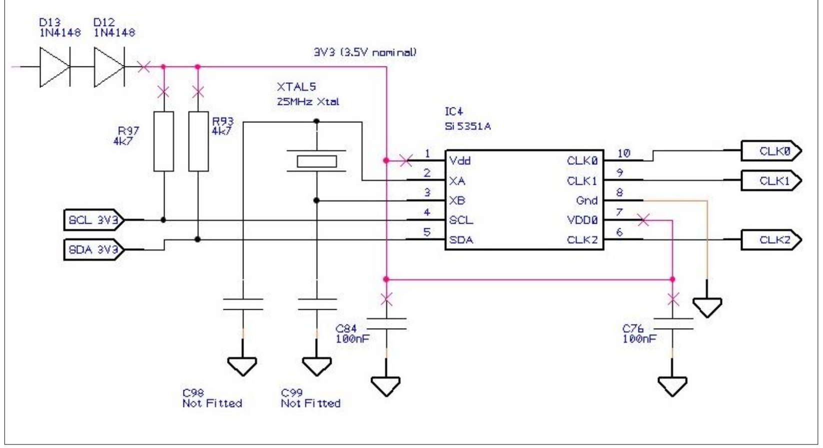


USB Interface

Device FT230XS from FTDI has been chosen for the USB to serial conversion, this is compatible with all host systems without special drivers being required. The chip has its own regulator; low pass filter R100 and C106 and decoupled by C102 and C103 provide the regulator with a 5V supply. The internal regulator output on pin 10 is decoupled by C95 and applied to VCC pin 3. A reset reference is set by R106 and R107 decoupled by C110. The balanced USB signals pass through noise filters R97, C104 and R98 C105. The RTS output from pin 2 is used for remote PTT with current limiting resistor R81 – this connects to a dual purpose I/O port on the microcontroller.

Synthesiser

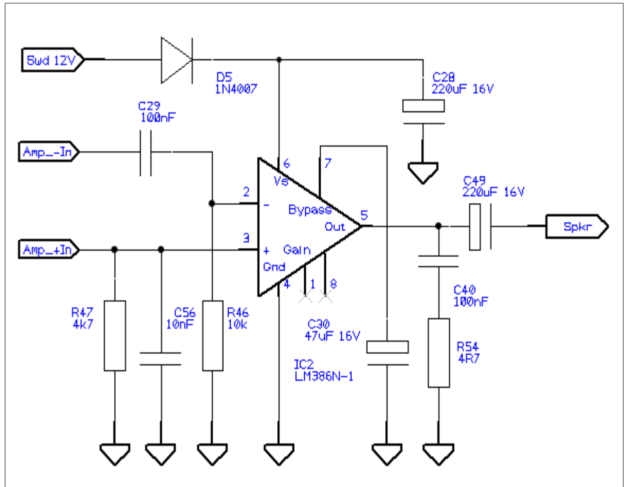
This uses the now ubiquitous Si5351 clock generator device from Silicon Labs, there has been much discussion over the suitability as a local



Synthesiser

oscillator / CIO however the device is now accepted by the QRP community. An internal ~900MHz oscillator locked to the 25MHz crystal is counted down using multisynths™ to the required output frequency. Specified crystal load capacitance is achieved with C72, C82 and capacitors within the device. The crystal is not fitted with a trimmer, calibration is applied mathematically in software. The 10 pin device used here has three outputs, all are used; CLK0 and CLK1 are used as local and CIO oscillators, CLK2 provides an IF for the CW function. Numerous internal registers control frequency and function, set by the microcontroller over the I²C bus. R92 and R94 are pull-up resistors for the I²C interface. The device is specified for 3.3V operation but is safe to use up to a maximum of 3.6V.

Speaker Amplifier



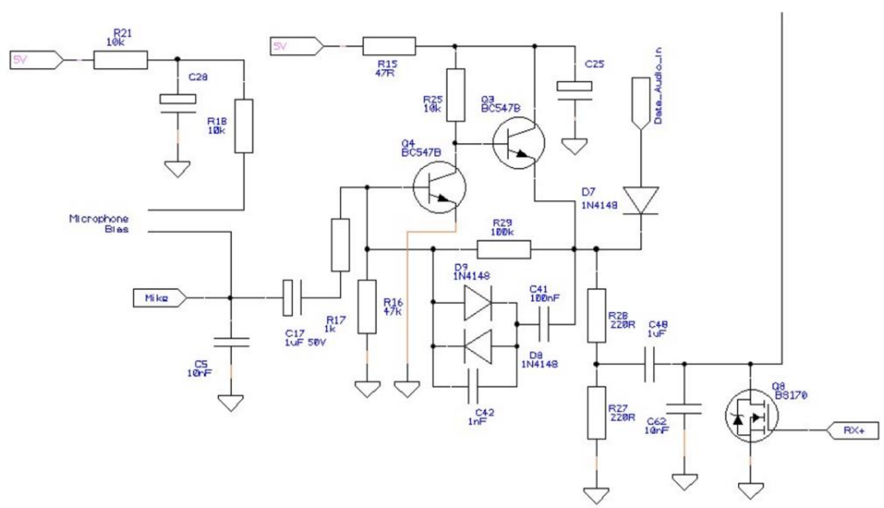
Speaker Amplifier

An inexpensive LM386 amplifier is used, this is the -4 version which is safe up to a supply voltage of 16V. These chips are known to be noisy (audio hiss) however this is only if used in their high gain mode, with a capacitor between pins 1 and 8. As we have a high level of audio from the microcontroller DAC this mode isn't required. Power is taken from the 12V supply via D5 for reverse protection, C28 is a reservoir capacitor supplying the large current pulses on speech peaks. Output DC isolation provided by C49, C40 and R54 form a Zobel network to compensate the speaker inductance, without the circuit the output may oscillate causing distortion and excessive dissipation. C30 decouples the internal bias circuit improving the power supply rejection ratio (noise from power supply getting to the speaker output). Conventionally volume controls have a logarithmic law, R47 provides a load for the microcontroller DAC, this helps to give a rising rate as you turn up the volume control as the microcontroller DAC has a linear relationship to input. C56 gives some "top-cut" to roll off high frequencies. Much like an op-amp the amplifier has two inputs, inverting and non-inverting – both are referenced to ground so DC isolation is required, this is provided by C29 for side-tone and C44 for audio input (not shown).

Microphone Amplifier

The microphone amplifier drives the low input impedance of the 1st mixer; a low noise circuit with stable gain and low output impedance is required.
Q3, Q4 with bias components R17, R24 and R25 form a stable amplifier with a voltage gain of about 16 (24dB). R16 and C5 provide decoupling from the 5V supply. Input impedance of approximately 1k Ohms is set by R21, this is suitable for typical electret microphone, bias provided by R18 and R19 from the 5V supply. C17 decouples the bias supply to avoid noise being heard on transmitted audio. Output to the mixer is via R31

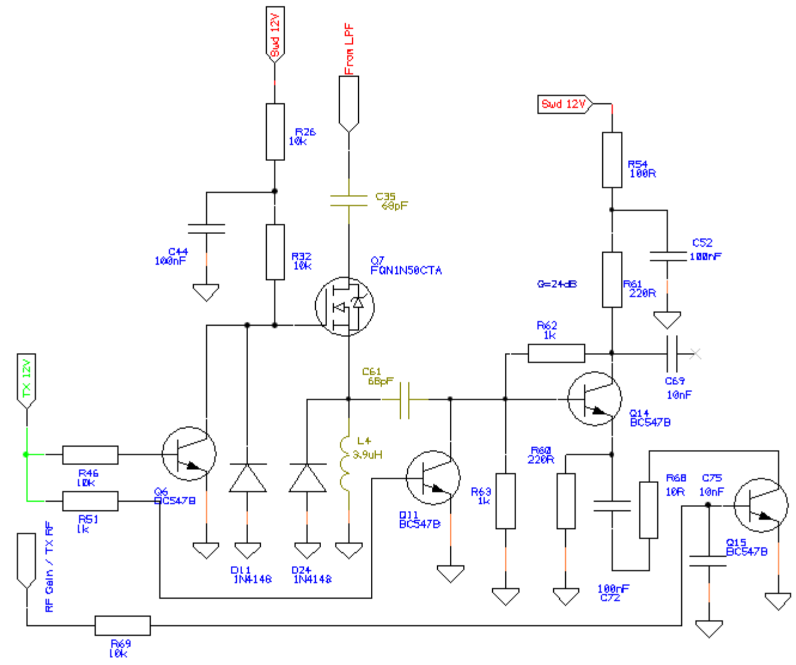
Microphone Amplifier



and C46 – C46 is a non-polarised ceramic capacitor – leakage current from an electrolytic capacitor could impair mixer balance. Q8 mutes TX audio on receive; the microphone amplifier is powered during receive to avoid a "burst" of RF when going to transmit due to a large transient on the output. C60 decouples any RF coming back from the mixer.

TX / RX Switch and RX Pre-amp

C35, L4 and C61 form a high pass filter, Q7 is the RX antenna switch, when TX 12V is at 0V (during receive), Q6 is turned off allowing R26 and R30 to apply bias to the gate of Q7 so turning it on and providing a signal path from antenna to RX pre-amp. Note that Q7 has a high gate to source capacitance so RX signal will appear at the collector of Q6. Q14 is the pre-amp transistor; when attenuator switched off, Q15 is switched on by the microcontroller switching in R68 and C72 across R60, this sets

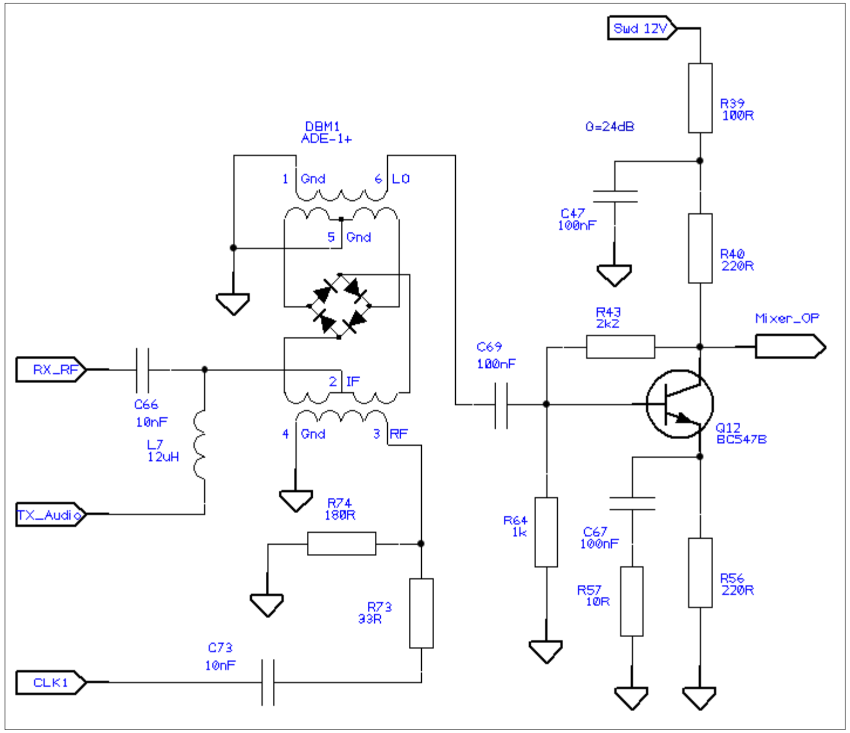


TX /RX Switch and RX Pre-amp

the stage to high gain. With Q15 switched off, emitter degeneration occurs reducing the stage gain to unity. During transmit, TX 12V biases Q6 on, removing gate bias and isolating the pre-amp stage from transmitter, Q11 turns on clamping any residual RF to ground.

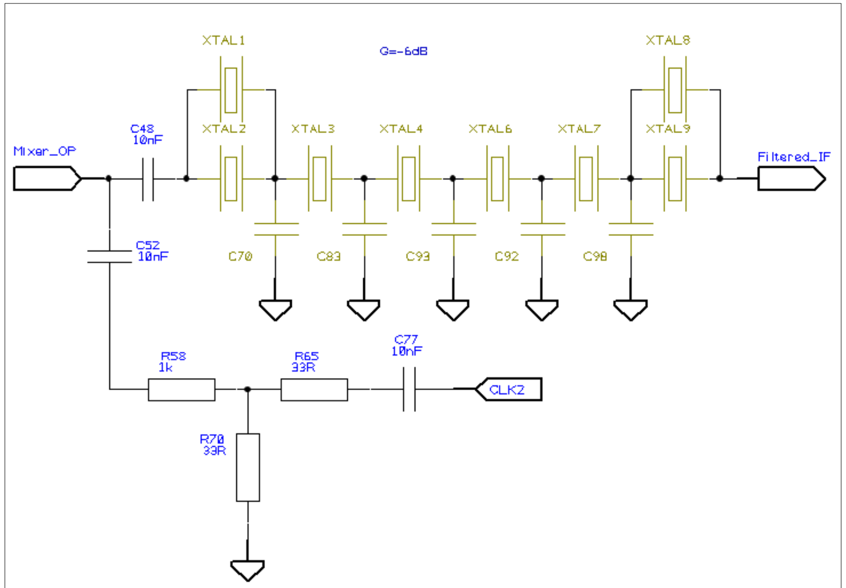
1st Mixer and IF pre-amp

1st mixer is a module from Minicircuits, this was chosen to ensure mixer balance without needing adjustment, early versions of the transceiver used a traditional home brew mixer using 1N4148 diodes, this was found



to be very temperature sensitive with local oscillator to IF isolation varying with temperature, note for best isolation the local oscillator is applied to the mixer RF port. C66 and L7 form a simple diplexer separating transmit audio and RX RF from the front end circuit. In receive mode incoming signals are mixed with local oscillator producing an IF signal which is passed to Q12 for further amplification. CLK1 from the synthesiser is used for local oscillator (and CIO in TX), this is attenuated and impedance matched into the mixer by R73 and R74 – note that the synthesiser output is not a 50 Ohm source. Q12 is a common emitter amplifier similar to the RX pre-amp, its primary purpose is to overcome the losses in the following crystal filter but it also provides a partial match to the mixer at non IF frequencies, without it there would be a serious impedance mismatch to the crystal filter.

Crystal Filter and CW IF Injection

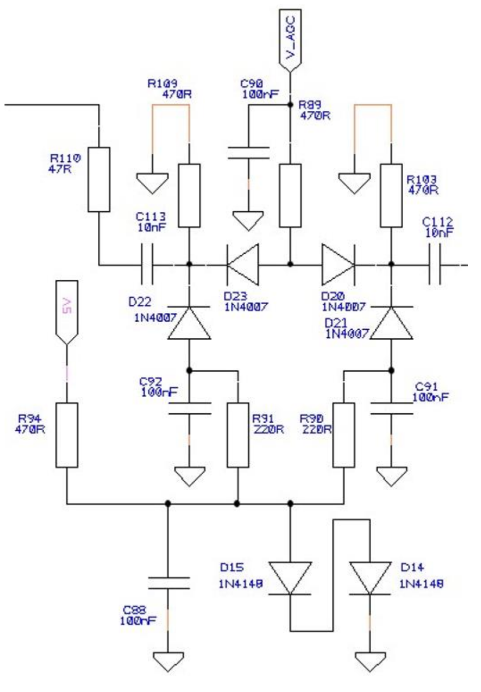


Crystal Filter and CW IF Injection

The crystal filter is a 6 pole G3UUR Cohn type where the first and last poles have parallel crystals, this significantly reduces ripple and makes the filter less sensitive to impedance mismatch. All crystals are of the same frequency. For CW transmit operation no signal comes from the first mixer as the CIO is turned off, during the CW on period an IF frequency signal is injected via the attenuator consisting of R58, R65 and R70. The filter has a nominal bandwidth of 2.7kHz.

AGC Attenuator

The AGC circuit has an attenuation range of approximately 60dB, this and the 23dB of the pre-amp attenuator give the transceiver sufficient gain control. The variable attenuator is used for AGC action and TX level control during transmit, it is also used to shape the CW waveform avoiding "key clicks" across adjacent frequencies.

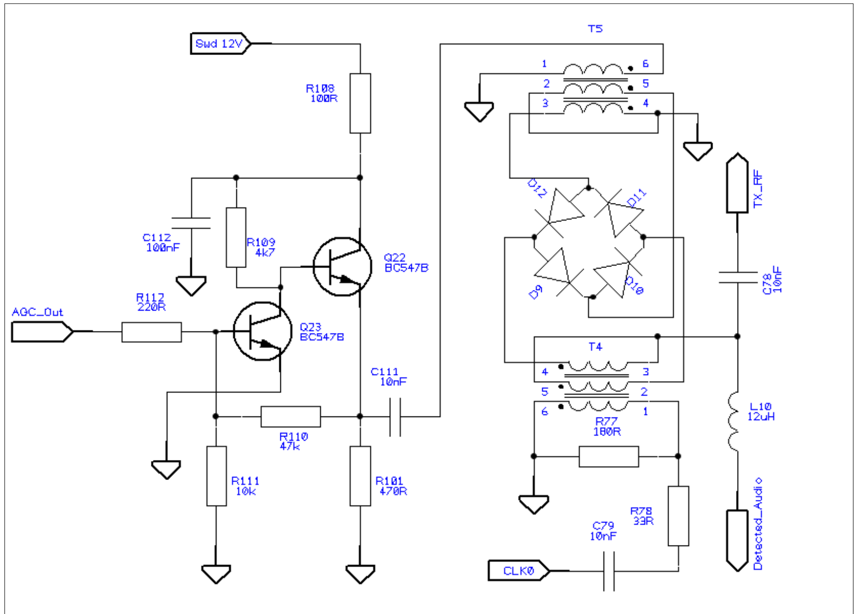


AGC Attenuator

The circuit is based on a standard "PI" attenuator normally constructed from RF PIN diodes. PIN diodes are expensive and now obsolete in through hole versions; its long been known that the doping of the silicon in 1N4007 diodes, required to achieve their 1000V rating has a PIN diode effect. With appropriate biasing an effective variable attenuator can be built. A standing 1.3V bias from the 5V supply is set by R95, D15, and D16 – C85 providing an RF path to ground. V_AGC is provided by the microcontroller via low pass filter and applied via R88. Two instances will be considered, maximum and minimum attenuation. For minimum attenuation D17 and D20 are heavily biased, V_AGC is approximately 4V turning on D17 and D20 raising the voltage across R103 and R104 so reverse biasing D18 and D19 as their anodes are held at 1.3V, they have little effect. For maximum attenuation V_AGC is set at 0V, D17 and D20 are then reversed biased as a current will flow from the 1.3V bias supply through D18 and D19 becoming forward biased and raising the voltage at cathodes of D18 and D19. All 100nF capacitors provide RF paths to ground. Note that this isn't a constant impedance circuit, at maximum attenuation D18 and D19 are very low impedance effectively short circuiting RF to ground, R105 is included to give a better impedance match to the crystal filter so avoiding excessive pass band ripple.

IF Amplifier and 2nd mixer

Q22 and Q23 form a feedback amplifier, input impedance is set by R112 to provide a match to the crystal filter. The 2nd mixer is a discrete design consisting of T4, T5 and diodes D9 – D12, CLK0 output of the synthesiser is applied to attenuator consisting of R77 and R78, as with

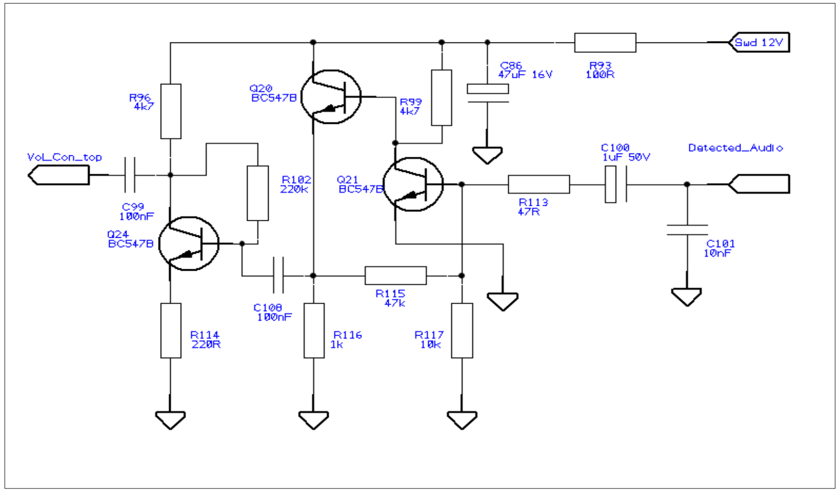


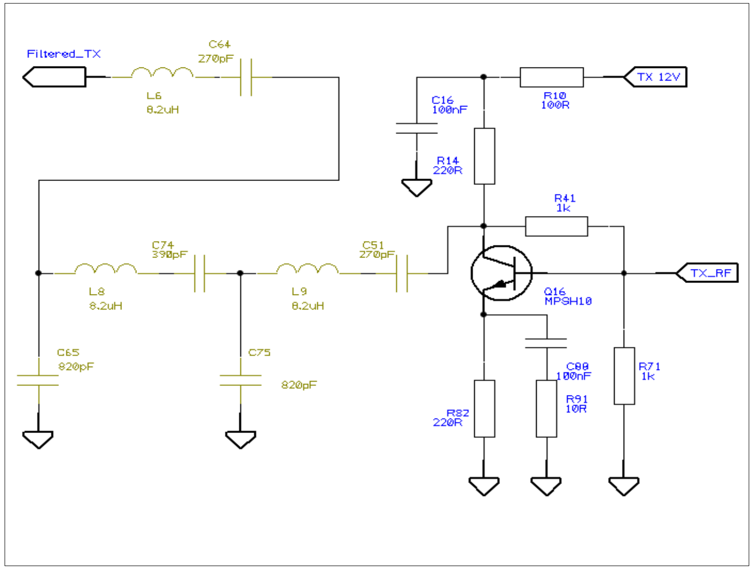
IF Amplifier and 2nd Mixer

the 1st mixer a good impedance match is important. L10 and C78 form a simple diplexer, high frequency transmit RF coupled to the transmit low pass filter amplifier by C78 and low frequency receive audio coupled to the audio preamplifier via L10.

Audio Preamplifier

Detected audio from the 2nd mixer will be at a low level and needs to be amplified before being passed to the volume control. Q20, Q21 and associated components form a feedback amplifier as used elsewhere, R113 sets the input impedance at approximately 50 Ohms to match the mixer output impedance (at audio frequencies). Q24 is a further common emitter amplifier, a later addition after gain redistribution was made following test with the prototype. In hindsight, the gain provided by this 3 transistor preamplifier could have been accomplished with a two stage common emitter amplifier. It's very important that post AGC attenuator amplification is known and constant for the AGC circuit to function correctly, too high gain will amplify noise which will be detected as a signal and shut down the AGC – a deaf radio!

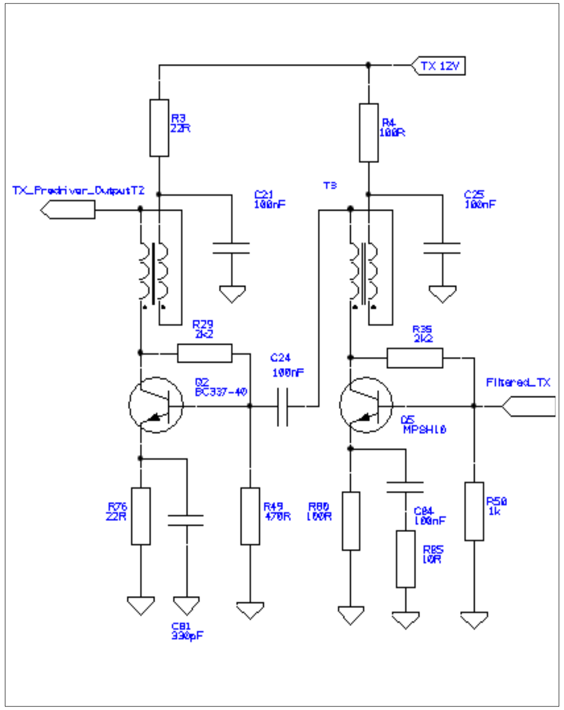




TX Pre-amp and Band Bass Filter

Q16, a common emitter amplifier increases the TX signal from mixer prior to being passed through the band pass filter. The filter removes the image frequency and reduces unwanted mixing products prior to the signal being amplified further.

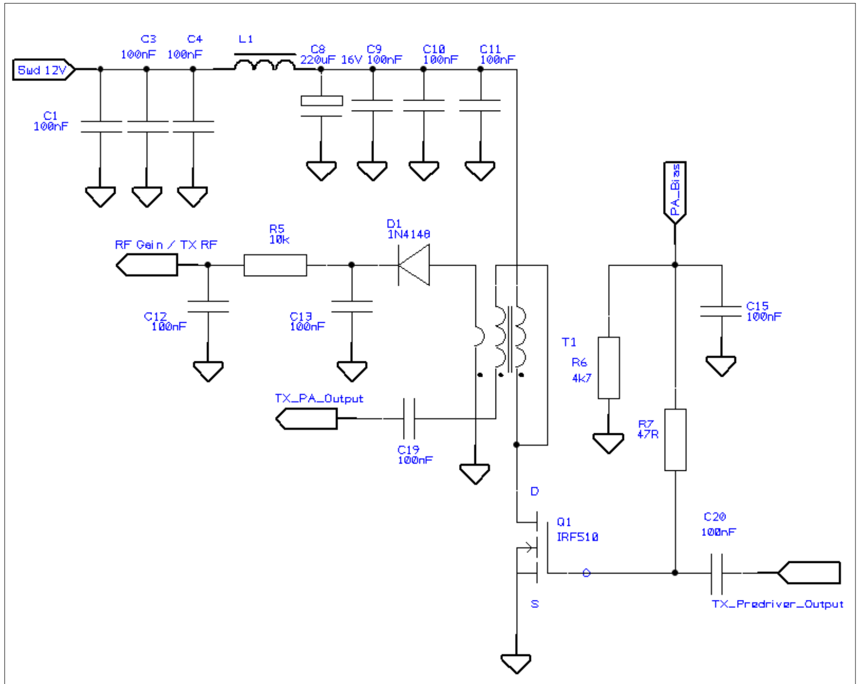
TX Pre Driver



The TX Pre driver consists of two similar broadband common emitter amplifiers, for Q5 gain is set by C84 and R85, for Q2 frequency compensation is required to provide flat gain from 80m to 20m, this is provided by C81 which bypasses the emitter resistor R76. Both stages have transformer impedance matching on the output.

TX Power amplifier

The transmit final stage uses an IRF510 FET, widely used for QRP transmit output stages. Although not intended for this use, its low gate to source capacitance allows it to perform well at the lower HF frequencies. Note that the tab must be screwed to a heat sink (the case) or the transistor will quickly overheat and fail - the tab is drain so has to be electrically insulated from the case. The transistor needs to be biased slightly on so it will amplify with reasonable linearity – the filtered PWM waveform from the microcontroller is applied to the gate via R7 and decoupled to ground by C15, R7 is also a load for the drive signal, this swamps the reactance of the input capacitance providing a flatter frequency response at the expense of gain. T1 matches the transistor output impedance to a 50 Ohm load. A DC signal related to the peak of the peak of the drain waveform is provided by diode D1 from a single turn overwind on the output transformer, C12, C13 and the resistor R5 filter the signal before applying to the microcontroller ADC port. Significant power supply filtering is provided by C1, C3, C4, C9, C10, C11 ans L1 – this is required to stop RF from entering previous stages

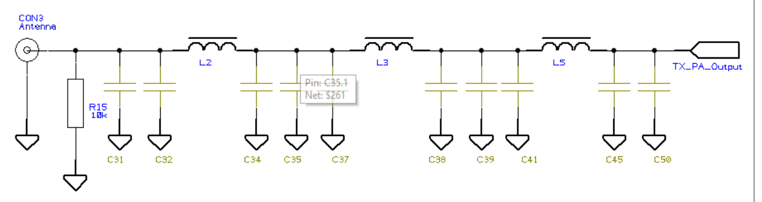


TX Power Amplifier

and causing oscillation. C8 is a reservoir capacitor supplying current on speech peaks.

Output Low Pass Filter

A low pass filter must always be used on the output of an RF power amplifier to remove harmonics of the fundamental signal, as this is a “single ended” amplifier, without a LPF the second harmonic would only



Output Low Pass filter

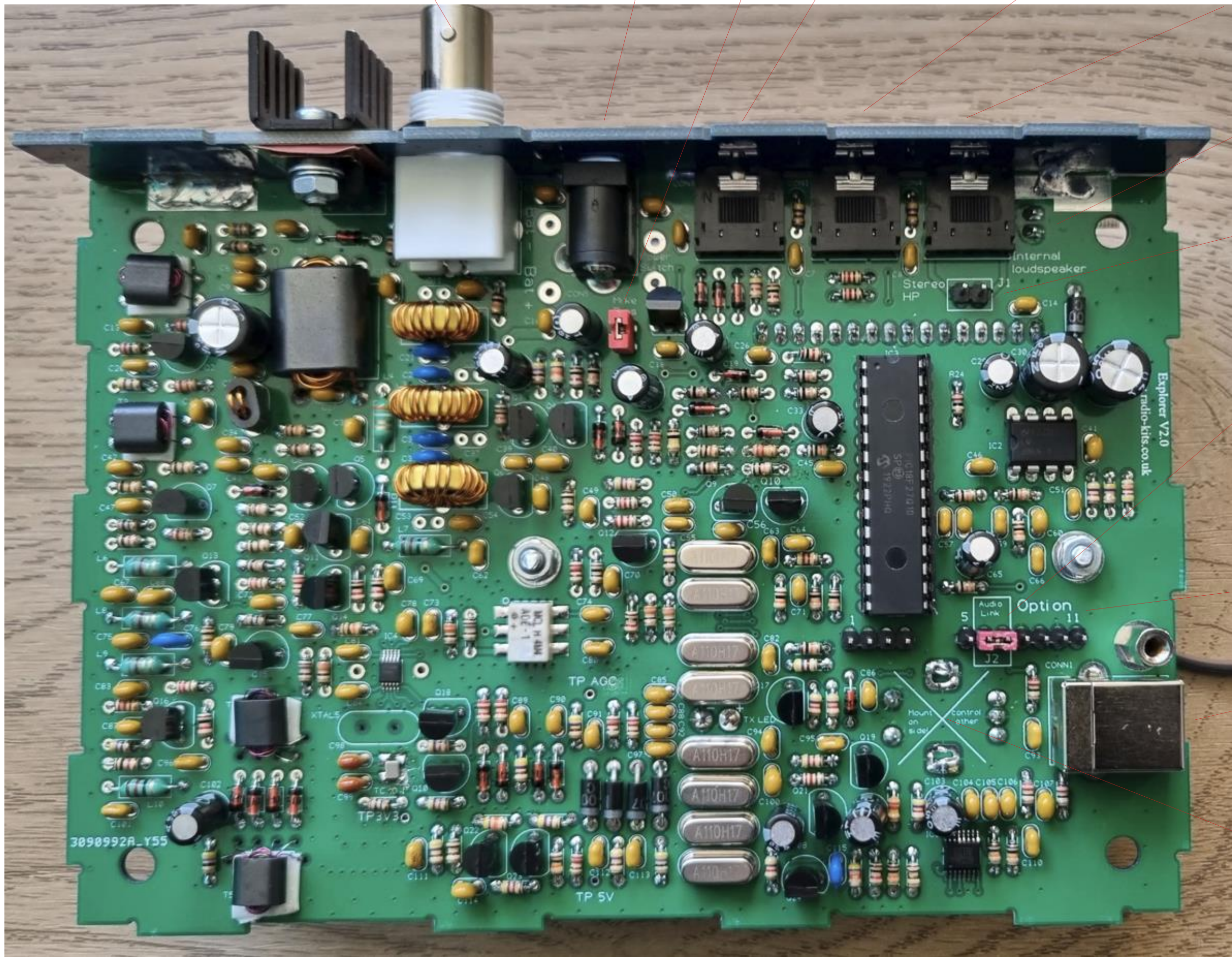
be 10 - 15dB lower than the wanted signal. This filter is a modified 7 pole chebyshev - “modified” as ideal component values aren’t available so suitable values were determined by simulation. R15 is included to discharge any static to prevent breakdown of the capacitors.

References

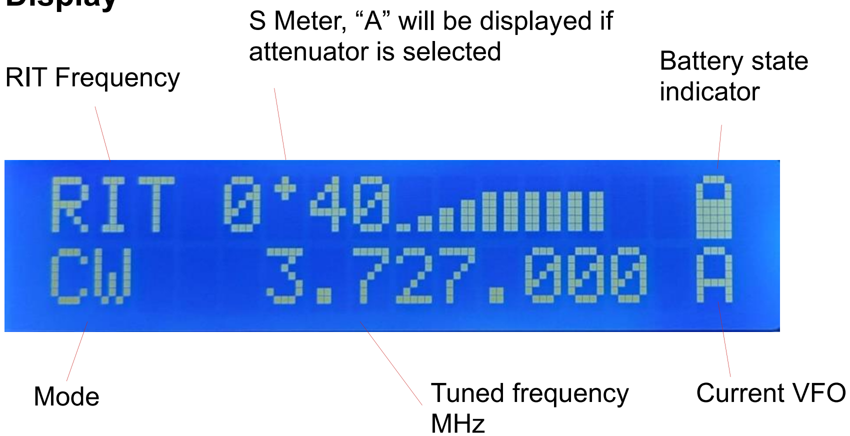
1 LCD Driver data sheet
2 Rotary Encoder data sheet
3 I2C Bus
4 S15351 Data sheet
5 Zobel Network
6 Elsie simulation software

Transceiver Operating Instructions

PCB Connections



Display



Connections

Antenna socket – BNC connector for 50 Ohm unbalanced antenna and feeder.

Power socket – 2.1mm DC socket, 10 – 16V centre pin +ve.

Microphone – 3.5mm jack, circuit designed for electret type, centre pin microphone (with 5V bias if enabled), ring contact PTT, outer contact ground.

Microphone bias link – Fit if electret type used

Loudspeaker – 4 Ohms or greater. Without stereo link fitted, centre contact speaker, outer contact ground. With stereo link fitted, centre contact and ring contact both loudspeaker (mono), outer contact ground.

Stereo / Mono link – When fitted connects centre pin of loudspeaker jack with ring contact for use with stereo headphones. Should not be fitted if mono jack fitted (will short out audio).

Option socket – For optional I/O and CW filter PC and user additions.

Audio link – Must be fitted if no option PCB is installed (connects audio in to audio out).

USB socket – For CAT control, USB for RS232 converter, refer to CAT control section for parameters.

Menu Structure

Receive Menu

Press rotary encoder to advance through menus. Most menu item are obvious by their name, the menu structure has been designed to be intuitive, often used items at the top menu and seldom used functions in the deepest menu.

Menu	Value	Function
Base Menu		
		Rotate encoder to tune current VFO, frequency increment is rotation speed sensitive. Whilst in VFO A or B, pressing and rotating encoder changes RIT frequency. If SPLIT mode is selected, pressing and rotating whilst pressed changes the transmit frequency of VFO B.
Stored after 3 seconds of no changes being made.		
Audio Gain (Tune)		
	0 to 15	0 is muted, 15 maximum volume. Pressing and rotating rotary encoder whilst pressed adjusts the IF Offset, useful for nulling any "birdies". Pressing PTT (or CW key) whilst in this menu will generate a CW test tone in centre of modulation bandwidth selected.
Stored after 3 seconds of no changes being made.		
Mode		
VFO A		Selects VFO A
VFO B		Selects VFO B

Menu	Value	Function
Split		Sets split mode, RX on VFO A, TX on VFO B
B = A		Sets VFO B to frequency in VFO A
Reset VFO		Resets to VFO A, no split, zeros RIT and zeros IF Offset
Stored after 3 seconds of no changes being made.		
Modulation		
LSB		Lower side band
USB		Upper side band
CW		CW with SSB filter (CW uses USB)
CW Narrow		CW with narrow audio filter enabled (only with option PCB)
DAT		Sets upper sideband, TX RTS enabled and takes audio from line-in jack
Stored after 3 seconds of no changes being made.		
CW		
Next		Punch through to next menu
Practice	Off	Normal transceiver mode
	On	Turns on practice mode, side-tone only, no RX or TX
Strt/Iambic	Straight	Selects straight key mode (if CW selected)
	Iambic A	Selects Iambic A mode
	Iambic B	Selects Iambic B mode
CW Offset	400 – 900	CW offset frequency Hz, narrow CW filter is set to centre frequency of 700Hz
S. Tone Vol	0 – 31	Sets side tone volume
Keyer Speed	5 – 40 WPM	Sets Iambic keyer speed in WPM
Hang Time	0 – 1000	Semi break-in delay in mS

Menu	Value	Function
Stored after selection		
AGC		
Next		Punch through to next menu
Atten.	Off	Deselects attenuator
	On	Selects 20dB RX attenuation by reducing gain of preamplifier to zero
Floor	0 – 1023	Value 0 = no effect, advancing reduces RX sensitivity, useful to reduce consistent band noise
Hang Time	0 – 250	AGC Hang, increments of 10mS
Attack	1 - 20	Speed of AGC reaction 1 = fast 20 slow
Decay	1 – 10	Speed of AGC recovery 1 = slow 10 = fast
L Thresh	50 - 250	Threshold for spike detector – nominal 150
ON/Off	Off	Turns AGC off (no gain control)
	On	Normal mode (AGC active)
Gain	1 - 7	AGC Loop gain – higher number less change in volume from low to high signal – nominal 2
Stored after selection		
Sys (System)		
Next		Return to base menu
Data Mode	Off	Normal phono / CW operation
	On	External transmit audio routed via Option PCB (when installed), Microphone is muted.
	(Setting is not stored, POR will reset to off)	
RTS PTT	Off	Normal PTT operation
	On	RS232 RTS signal (Via USB) is “ored” with PTT, to switch to TX

Menu	Value	Function
SSB TX Gain	0 – 100	Gain of SSB TX chain
CW TX Gain	0 – 100	Gain of CW TX chain
LSB Offset	Value dependent of band	Adjust CIO offset to suit crystal filter response Note 1
USB Offset		Adjust CIO offset to suit crystal filter response Note 1
LCD Con.	0 – 100	LCD contrast Note 1
VFO Cal	0 ± 5000	Reference frequency correction Note 1
Bat V Cal	0 – 1023	Calibrates battery state indicator Note 1
Band Set	20m, 40m or 80m	Selects band appropriate to build state Note 1
TX PA Bias	0 – 1023	Sets TX PA transistor bias Note 1
Full Reset	Exit	Exits menu with no effect
	Continue	Resets radio to factory default Note 1
Stored after selection		

Transmit Menu

A restricted menu for adjusting transmit relevant items only – menu items are dependent on function.

Base Menu CW	Value	Function
Keyer Speed	5 – 40 WPM	Sets Iambic keyer speed in WPM
S. Tone Vol	0 – 31	Sets side tone volume
CW TX Gain	0 – 100	Gain of CW TX chain
Hang Time	0 – 1000	Semi break-in delay in mS

Base Menu CW	Value	Function
CW Offset	400 – 900	CW offset frequency Hz, narrow CW filter is set to centre frequency of 700Hz
Stored after selection – Note: Menu only available with key down		

Base Menu SSB	Value	Function
SSB TX Gain	0 – 100	Gain of SSB TX chain
Stored after selection – Note: Menu only available with key down		

If no changes are made in the current menu, pressing and releasing encoder button advances to next menu. For Audio, Mode and Modulation menus; if a change is made, menu returns to base menu on next button press. Except where indicated all changes are immediately stored in non-volatile memory.

Note 1 – Refer to construction manual “Set Up instructions” for information on these settings.

Setup for typical operation

- Connect suitable antenna.
- Connect microphone; for electret type ensure bias link is installed.
- Connect loudspeaker or headphones, if using headphones, those with integral volume control are recommended.
- Apply power via DC connector, 10 – 16V centre +ve.
- Set attenuator to “On” for strong signals, this is indicated by “A” on LCD in place of “S” of S meter. Attenuator can be found under AGC menu.
- Typical “S” meter calibration is 100uV pd for an S9 indication with 1 “S” point = 6dB.

- Set appropriate modulation, LSB, USB, CW or if option board is fitted CW narrow which will enable the narrow audio filter.

- Select transceiver mode, VFO A, VFO B or split operation – note that if VFO A or B is set, RIT is available by pressing and turning rotary encoder while still pressed, RIT setting is displayed on LCD. If Split is selected reception frequency will be from VFO A and transmit from VFO B, VFO B can be tuned by either selecting in the menu or by pressing encoder and tuning whilst pressed.

- Set frequency with rotary encoder – tuning rate is speed sensitive

- AGC menu has a "Floor" function, this sets the minimum sensitivity by raising the AGC threshold and is handy for reducing a consistent level of band noise.

Transmit setup

- Transmitter gain will need setting and is dependent on microphone, user style and supply voltage.

- SSB - With transceiver connected to dummy load press and hold PTT, from menu select "SSB TX Gn". Adjust so speech peaks (displayed on bar graph) just reach full scale – gain can be reduced to reduce output power. Note that power bar graph is derived from PA peak voltage so will only indicate correctly with a 50 Ohm load.

- CW – With "Straight key" set, hold key down to transmit, from menu select "CW TX Gn", adjust so bar just reaches desired power output. Gain can be reduced to reduce output power. Note that power measurement may not react quick enough to display power during Iambic operation.

Data modes

- USB interface can be used to provide the PTT function via the emulated RS232 RTS line, most PC software have this facility. Enable Data mode by selecting "DAT" from the Modulation menu. Note that during boot and as USB devices are plugged or removed from the PC, the PTT may momentarily operate.

- With Option PCB installed – connect to PC audio input / output using stereo 3.5mm jack, note that jack centre pin is audio in and middle ring audio out, interface has been designed for typical line levels.

- With transceiver connected to dummy load, set PC to transmit and adjust audio output to required level – its suggested for data modes to set power at two thirds maximum for best linearity. If the transmitter is over driven RF output WILL be distorted as there is no ALC.

CAT control

CAT functionality is provided by a built in FTDI USB to serial converter, settings for PC are: 9600 Baud, 8 bits, no parity and 2 stop bits. As far as possible Explorer emulates the Kenwood TS840, 54 commands are implemented.

Fault Finding

Before we get technical, whatever the problem check for the obvious. Do not assume that a symptom is caused by a faulty component – modern components are extremely reliable and are unlikely to be initially faulty, that's not to say that an error in assembly has over stressed one and caused it to fail.

Fault finding methods given here are assuming the builder doesn't have sophisticated test equipment – oscilloscope, signal generator etc.

Visual Inspection

First carry out a very careful visual inspection, in order of likely causes; enamel not burned or stripped off transformer wire before soldering, dry joints, solder splashes and incorrectly located components (all transistors in correct places and orientation?). A plot of the bottom copper layer is available on the website, this will help locate solder splashes or confirm damage to PCB tracks.

Having failed to identify a problem by a visual inspection, make a note of all the symptoms you see and can measure – is the display working, are the voltages correct, is the supply current normal, any strange noises from the loudspeaker and was there any smoke and if so where did it come from?!

To be reviewed based on user experience!

Addendum

Advanced VFO Calibration

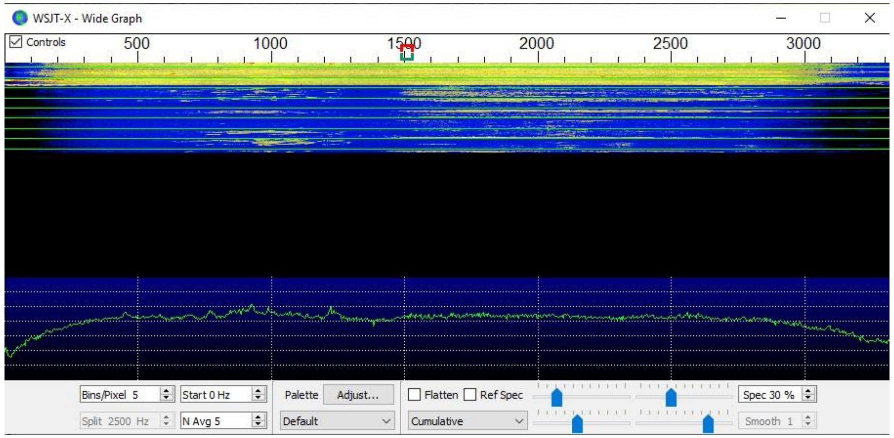
Having CAT control and line level audio output, the inbuilt frequency calibration utility of WSJT-X can be used to calibrate the VFO and set LSB / USB IF offsets accurately.

Setup WSJT-X for Explorer

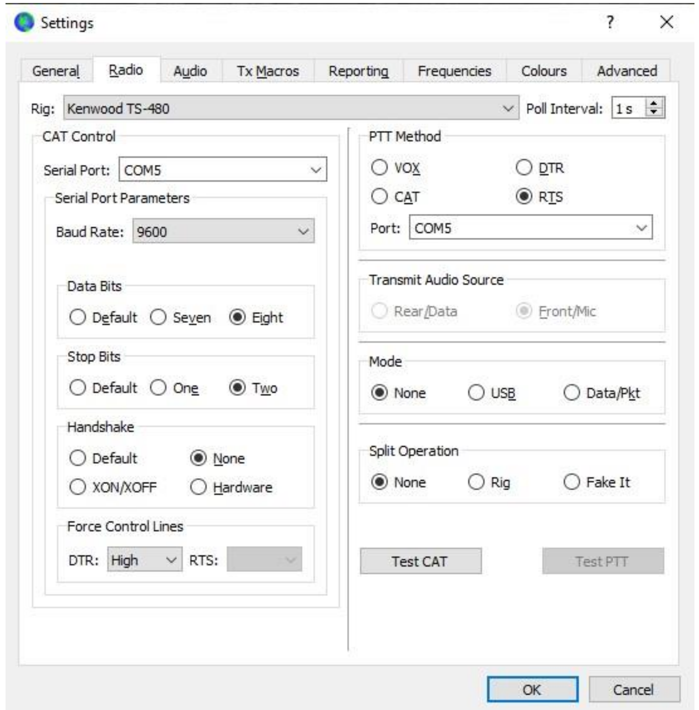
- Install WSJT-X
- Set WSJT-X CAT serial port settings
- Set Explorer to Data mode
- From WSJT-X Mode menu select frequency Cal
- Select a frequency where a transmitted test tone can be heard
- Select in Explorer menu “Sys… VFO Cal”
- Adjust VFO Cal so received tone is exactly 1500Hz and exit menu to save

LSB / USB IF offsets

IF offsets have been preprogramed for typical crystals; for best received and transmitted audio quality, it is beneficial to adjust the IF offset for LSB and USB.



Set WSJT-X running and tuned to a wideband signal or noise. Monitor the FFT window and adjust both LSB and USB so that the filter bandwidth is centred on 300 – 3000Hz, note the exact filter bandwidth is determined by actual crystals used and component tolerances. Note that “Flatten” box is not ticked in the FFT window.



Example radio settings for Explorer in WSJT-X

Document End

Document History

Version	Date	Change
Released 1.7.1	12/02/22	Revised for pre-series production units
Draft 2	19/11/23	Revised for review
V2.1	12/12/23	First release
V2.2	11/02/24	Typo corrections – colour code of 4R7 changed, now 1% tolerance due to availability