ADX Construction Manual

Buildathon Project #2 – ADX QRP Digital Radio

By Richard W5ARH / VK2ARH

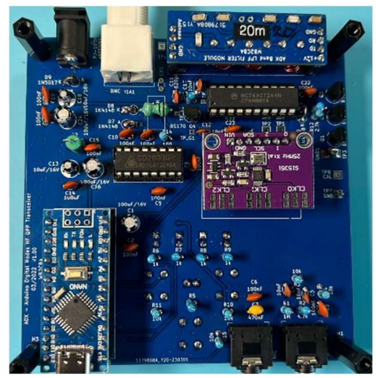
Version 1.2	28 May 2023	Initial Release
Version 1.3	22 June 2023	Minor Spelling and grammatical changes, additional comments on calibration.
Version 1.4	31 July 2023	Updated with learnings from Cowtown Buildathon 2023
Version 1.5	05 Dec 2024	Updated minor corrections
Version 1.6.1	10 Mar 2025	Updated with learnings from Manly Warringah Radio Society Buildathon 2024 and additional details to support the Radio and Electronics Association of Southern Tasmania Build 2025. Reformatted for A4.

Table of Contents

Introduction

The ADX was chosen for the Cowtown Amateur Radio Club (Fort Worth Tx) 2023 Buildathon as the second in a series of projects to create interest and build practical skills amongst our members. The key components of the selection were:

- Low cost using readily available components.
- Use of through hole devices – to enable construction by novice/intermediate builders.
- Provide a practical piece of equipment that can be used on air and promote technician class license holders to expand beyond VHF/UHF and use the HF band on 10m.



This project follows the EFHW project which provides a multiband 40m, 20m, 15m, 10m antenna that can be used in conjunction with the ADX. Later projects augmented the EFHW antenna and the ADX to provide further complimentary equipment for use in the shack or in the field.

Whilst the ADX continues to undergo development and is available in a variety of form factors, this project uses the original ADX designed by 'Barb' WB2CBA. You are free to look to improve the design and experiment if you have the capabilities/desire to do that, but this basic design works and fulfills the aim or the project **We are indebted to Barb for his design and sharing this with the Amateur Radio Community – a HUGE THANKYOU Barb ☺ .**

This is not a kit to be contemplated unaided by a complete novice to kit building, electronics or radio. However, the Buildathon is designed to enable club members irrespective of experience or ability to come together and with guidance and support from each other, enjoy a mutual learning and fun environment in which to build the ADX and enjoy our hobby. The manual was written with a novice constructor in mind and is focused on a step-by-step instructional build process. Seasoned kit builders please ignore/excuse the detail in parts. The manual 'speeds' up as you get to later stages of the project as the construction techniques and details have already been covered earlier in the manual. (Note: The kit has been built successfully by several beginners to electronic kit building, some who learnt to solder during the process. This was accomplished with assistance and guidance from other more experienced club members).

I recommend that you read the entire manual before you commence construction to gain an understanding of the process to be followed, the contents of this manual and familiarize yourself with the journey ahead.

This manual outlines the building process using the Cowtown ADX kit which was put together as a 'Group Buy' by the Cowtown Amateur Radio Club. Information in this manual has been developed by Richard W5ARH/VK2ARH and leverages from the manuals developed by Adam BD6CR (www.crkits.com) and Barb WB2CBA. For an explanation of the theory of operation and background to the ADX, see the documentation by WB2CBA using the links shown below. This document refers at times to Barb's ADX manual which can be found on his github site identified below.

Acknowledgements:
Barb, WB2CBA
https://antrak.org.tr/blog/adx-arduino-digital-transceiver/
https://github.com/WB2CBA/ADX

Step by Step Kit Assembly

Equipment Needed:

The following equipment is recommended to build the kit:

- Soldering Iron / Station (preferably ESD protected with a fine tip, together with a method of venting fumes away from the soldering area)
- Solder: 0.8mm diameter 63% Sn / 37% Pb with ‘no clean’ flux is recommended, if you are comfortable soldering with Pb based solder.
- Wire cutters (fine precision type) and long nose pliers
- Multimeter
- Phillips head screwdriver
- Modeling knife
- Solder sucker or solder wick if needed.
- Access to frequency measurement test equipment (Oscilloscope / HF Radio receiver / Spectrum Analyser etc.). Test equipment will be available at the club house for those participating in the supported building program.
- A magnifying glass or higher power reading glasses can assist with checking the quality of your soldering.

The kit uses all through hole components although surface mounted devices (SMD’s) have been used on the low pass filters and these have been pre-soldered to the LPF boards.

If you do not have access to an LPF configured as per these build instructions, it is recommended that you build at least one LPF before commencing with the main ADX build. The LPF is required for testing the transmitter during the construction process. If you don’t have access to an LPF - jump ahead to Step 11 on p26 and assemble at least one LPF.

Take the time to prepare your work area and layout your tools, keep it free of clutter. An organized work area helps you to focus on the build and not distracted searching for tools and components.

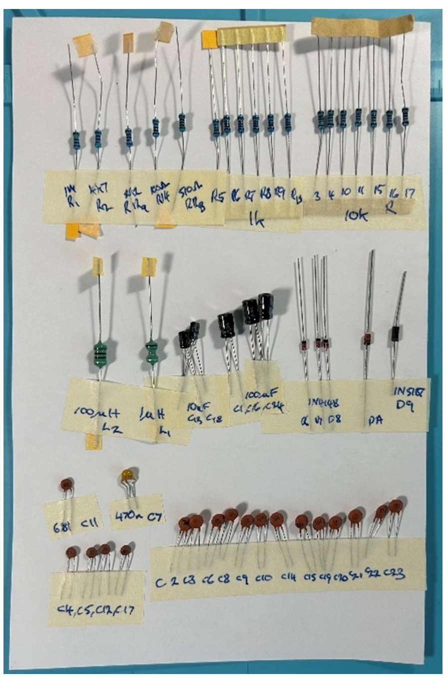
An example of a cleared and ordered work bench ahead of the kit build. Individual equipment will vary.
(My workbench isn’t always that tidy 😊)

Bill of Materials (BOM)

Component Group	Part	Designator	Qty
Capacitors	100uF/16V	C1,C16,C24	3
	10uF/16V	C13,C18	2
	620pF (680pF) 681	C11	1
	100nF 104	C2,C3,C6,C8,C9,C10,C14,C15,C19,C20,C21 ,C22,C23	13
	10nF 103	C4,C5,C4,C5	4
	470nF 474	C7	1
Resistors	1M	R1	1
	2.7k	R12	1
	100	R14	1
	4.7k	R2	1
	10k	R3,R4,R10,R11,R15,R16,R17	7
	1k	R5,R6,R7,R8,R9,R13	6
Diodes & Inductors	LED TX	D1 (Red)	1
	LED FT8, FT4,JS8,WSPR	D2,D3, D4, D5 (Green)	4
	1uH	L1	1
	100uH	L2	1
	1N4148	D6 D7 D8	3
	1N5817	D9	1
	1N4756	PA Protection Diode	1
Static Sensitive Devices	BS170	Q1,Q2,Q3, Q4	4
	CD2003GB_GP	U1	1
	SN74ACT244N	U3	1
	SI5351_Module	U2	1
	Arduino Nano	XA1	1
Connectors and Switches	BNC	J1A1	1
	PJ-102A (PJ-102AH Preferred)	J2	1
	SPK. Mic	CON1 CON2	2
	5.5 x 2.1mm DC Plug	Extra	1
	UP(BAND)	SW1	3
	DOWN(CAL)	SW2	
	TX	SW3	
	16 Pin DIP Socket	U1a	1
	20 Pin DIP Socket	U3a	1
Hardware	40 Pin Header Female	One 40 pin strip supplied - builder to cut into 2 x 15 pin strips (Nano) and 1 x 7 pin socket for Si5351. Female socket for PCB LPF connection included in LPF kit. See construction manual for details.	1
	Pin Header Male 4 pin	PCB LPF Socket - included in LPF Kit	-
	Mounting Spacers	6mm	4
	Mounting Spacers	18mm	4
	Self Adhesive Silicon Pads	For use on bottom of completed ADX	4
	M3 18mm Stainless Machine Screw		4
	M3 8mm Stainless Machine Screw		4
PCB's	Main Board ADX		1
	Upper Cover		1
	Lower Cover		1
LPF Kits	LPF Board	Contains 7 LPF's for 10,15,17,20,30,40,80m	1
	24 or 26 awg magnet wire	To be cut to length for each toroid	5m
	T37-2 (Red)	2 with each LPF <= 20m	8
	T37-6 (Yellow)	2 with each LPF >= 17m	6
	FT37-43 (Grey)	1 for each LPF	7
	Pin Header Male 40 Pin	8 x 4 pin to be snapped off from single 40 pin strip	1
	Pin Header Female 40 Pin	8 x 4 pin strip to be cut from single 40 pin strip	1

Start by unpacking your kit, identifying each component, and checking the components against the BOM.

Whilst every builder will have their own style and approach, identifying, sorting, and labelling smaller components can save time during the build and minimize search effort and errors.

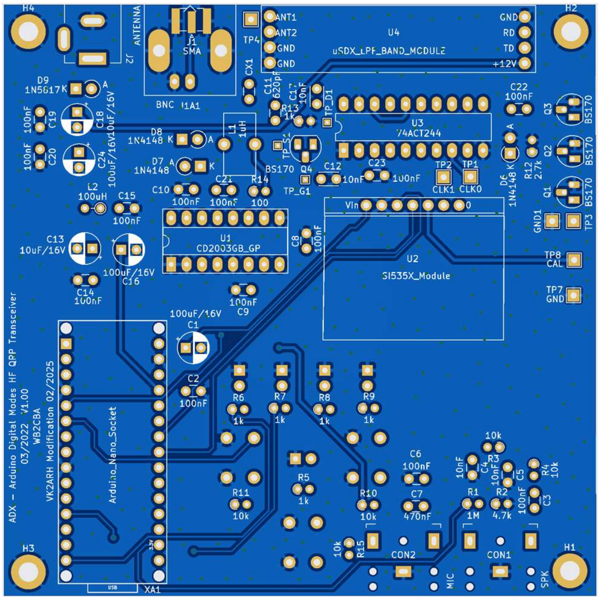


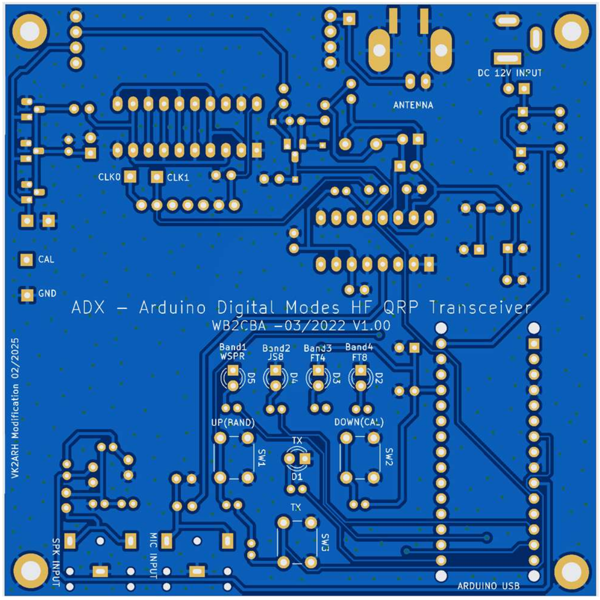
In this example the smaller through hole components have been checked and stuck onto a piece of paper with masking tape before being labelled to speed identification. Testing of each component not only assists in identification but ensures that any faulty or out-of-spec component is not used during the build. Don't worry about any adhesive from the tape contaminating the leads, they are soldered up close to the device and not where the tape is used.

Resistors can easily be tested with a Multimeter; however, capacitors and inductors may need an LCR meter which is not essential but handy if you want to check the tolerances of components. It is not necessary to obtain a high precision meter, but just be aware and allow for the meter tolerance when measuring components. Most components do not need a high level of accuracy, but you may like to check to ensure that they are within their manufactured tolerance.

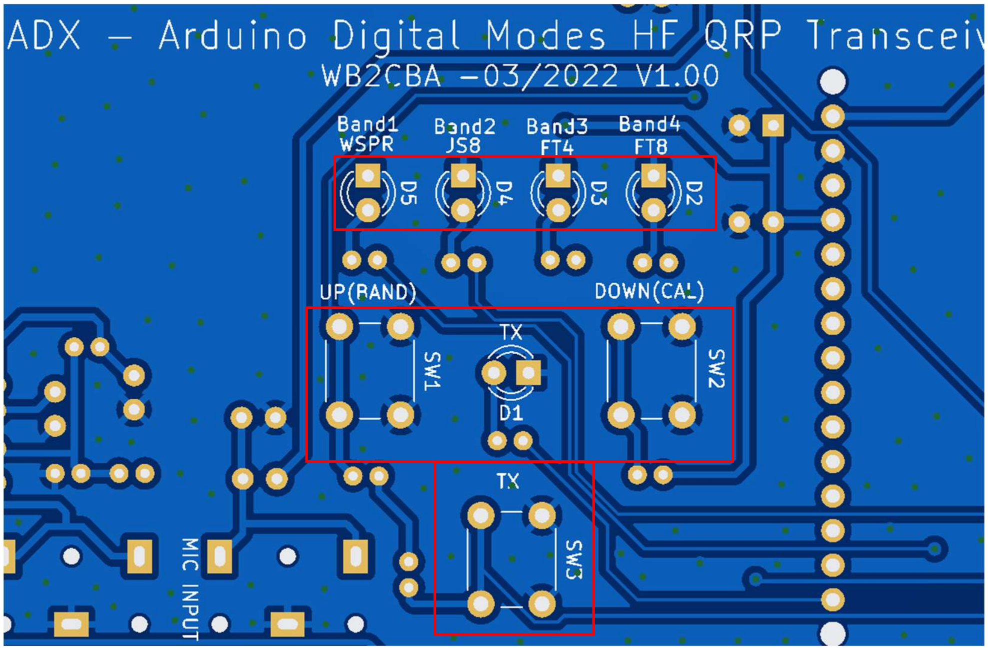
PCB and Schematic Diagram

Here is a layout of the component side (left) and solder side (right) of the main ADX PCB.





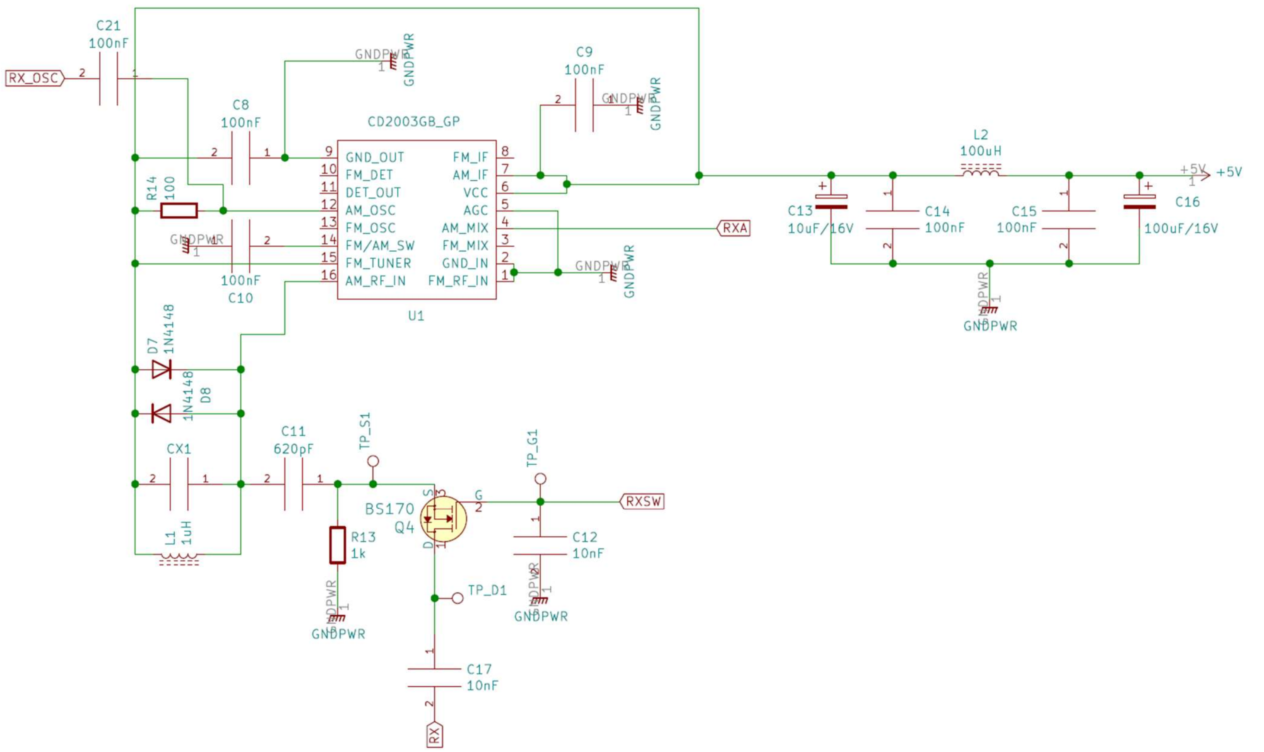
All components are placed on the component side of the board (left) except for the LED's (D1, D2,D3,D4,D5) and small pushbutton switches (SW1, SW2, SW3) which are placed on the solder side of the board in the area shown below.



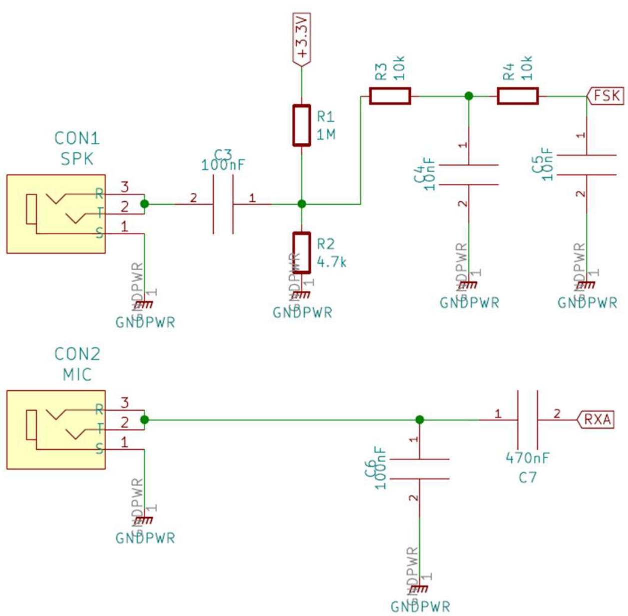
The full circuit schematic diagram can be found here https://github.com/WB2CBA/ADX

The schematic is reproduced here in segments to enable ease of reading and reference during the build should you wish to review the schematic.

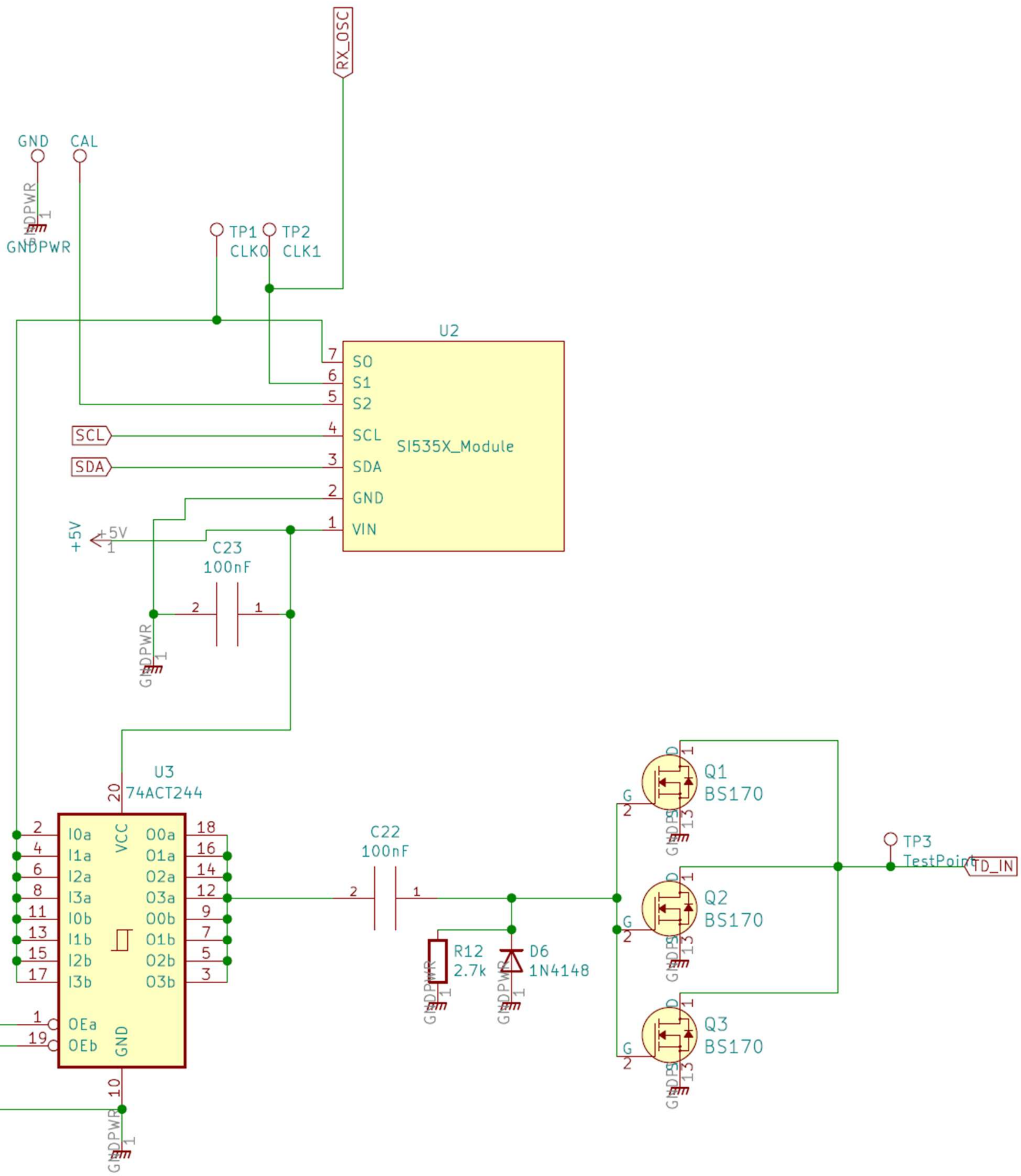
Receiver Section:



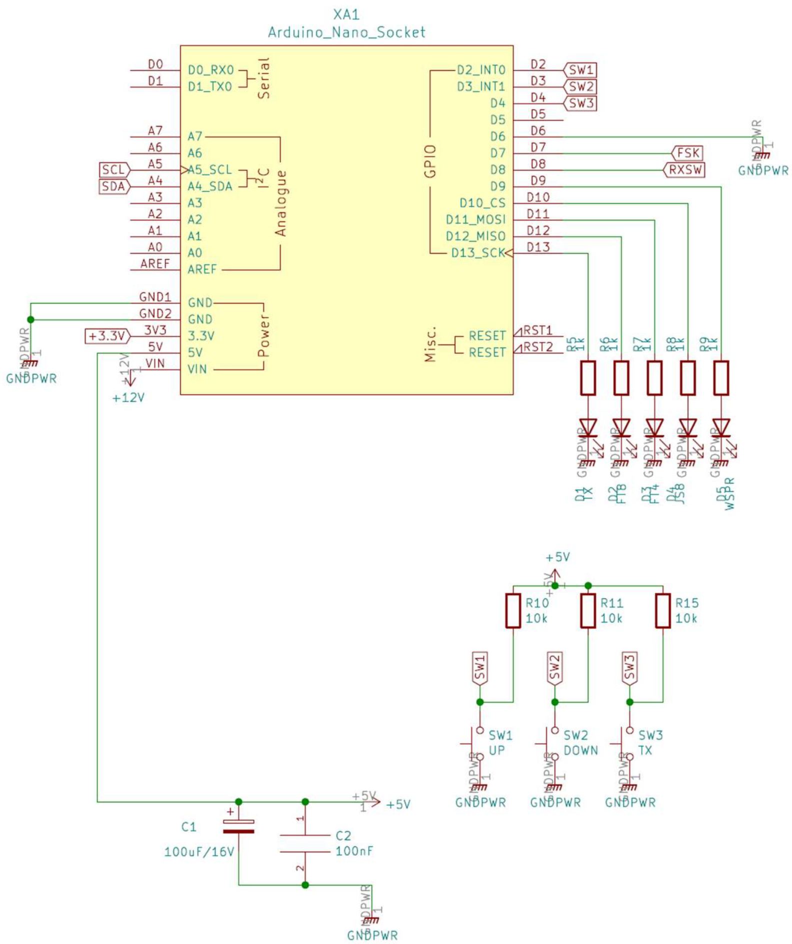
Audio in and Out



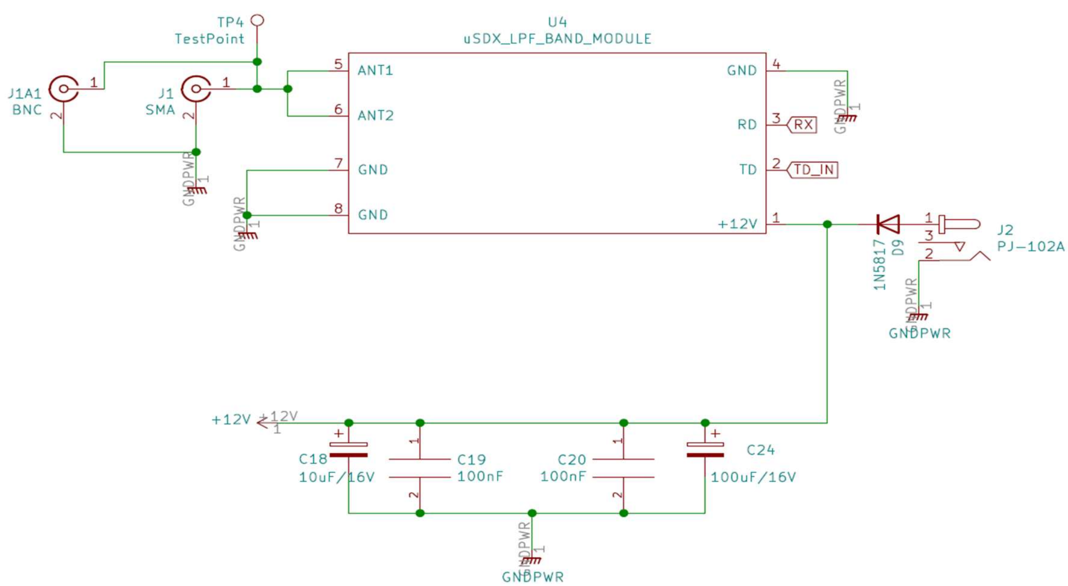
Transmitter and VFO Section



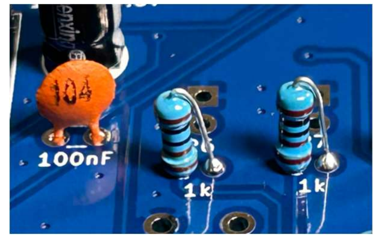
Arduino Nano



Antenna Connection, LPF Band Module and Power



Construction Tips

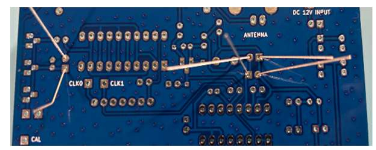


Many of the spaces on the ADX board have 2.5mm hole spacing and this will require several components to be mounted on their end as shown on the right:

Whilst it makes no difference electronically which way the resistors (in this case) are mounted, good practice is to mount each device with the same orientation. By doing so it makes checking the value of components much easier. With resistors, I place the value identifier bands at the top and the tolerance band at the bottom.

For capacitors or devices with identification marks on them, I try to orient them all in the same direction unless their view is being obstructed by another component. When this happens, I orient them where possible, in a direction that enables them to be read easily.

For diodes when mounted standing on an end, I mount them with the cathode band at the top. This aids in checking the correct polarized installation of the diode. The anode is then always down at the bottom aligned with the round solder pad on the ADX board.



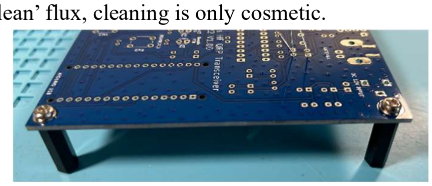
When you place the through hole components on the PCB hold the component down against the PCB and spread the component leads so that when the board is turned over to solder, the components remain in position. Restrict the number of components you place at any one time to avoid a 'rats nest' of leads that will interfere with your soldering iron tip and the solder whilst soldering.

If you have a through hold device whose leads are too wide for the 2.5mm holes on the board, take a pair of long nose pliers and bend the leads as shown on the capacitor. In this case the device is supplied with a 5mm lead spacing which has been reduced to 2.5mm to allow placement on the board.

Don't use excessive heat whilst soldering – this has the potential to damage components and destroy the PCB tracks. I like to tin the solder iron tip, and then use the 3 second rule ensuring that the soldering iron is not in contact with the device for more than 3 seconds at a time when soldering each lead. If you need longer, allow the lead to cool and return to complete or improve the solder joint.

Flux or flux paste is not usually needed if you are using a good quality solder with incorporated flux. Choose a 'no clean' flux if you have the opportunity as this makes for a cleaner result. If necessary, boards can be cleaned with an old toothbrush and isopropyl alcohol.

Hint: Isopropyl alcohol can be purchased from the pharmacy or hardware store. The higher the alcohol content the better. Scrubbing and rinsing with a mild dishwashing detergent and water and then drying with a hair dryer produces good results removing the sticky residue that sometimes is present after cleaning with the isopropyl alcohol, but do this before adding any component that you think will in impacted by the washing or drying process. The rinse is important to ensure that any corrosive detergent residue is removed. If you have access to an ultrasonic cleaner even better, but if that's all too hard – if you used a 'no clean' flux, cleaning is only cosmetic.



You may wish to install the 18mm standoffs onto your main PCB before you start to solder components onto the PCB. This provides a nice stable platform for soldering once you have turned the board over.

If you don't get the results required at each stage of testing as outlined in this manual, **don't proceed to the next step until you have been able to resolve and correct the issue**. In this way you can control and isolate the issue.

In this manual each time a component is to be identified and soldered to the PCB, it is listed separately proceeded with a square check box. You can 'tick' off the components as you progress, and this keeps a record of your progress through the build. You can also check off each page as you complete the activity listed on that page:

- ☑ Component 1
- ☑ Component 2 etc.

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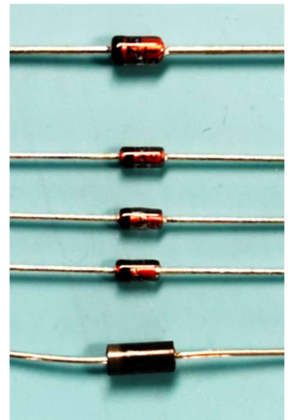
Building the ADX in Stages

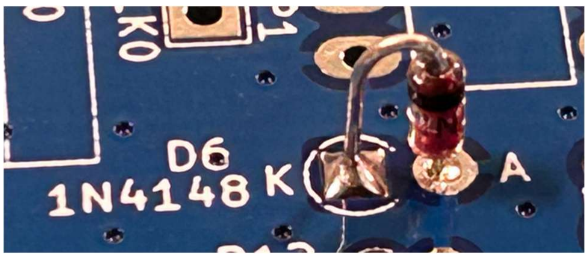
Step 1: Diodes

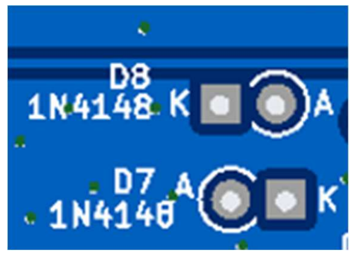
Identify the five diodes:



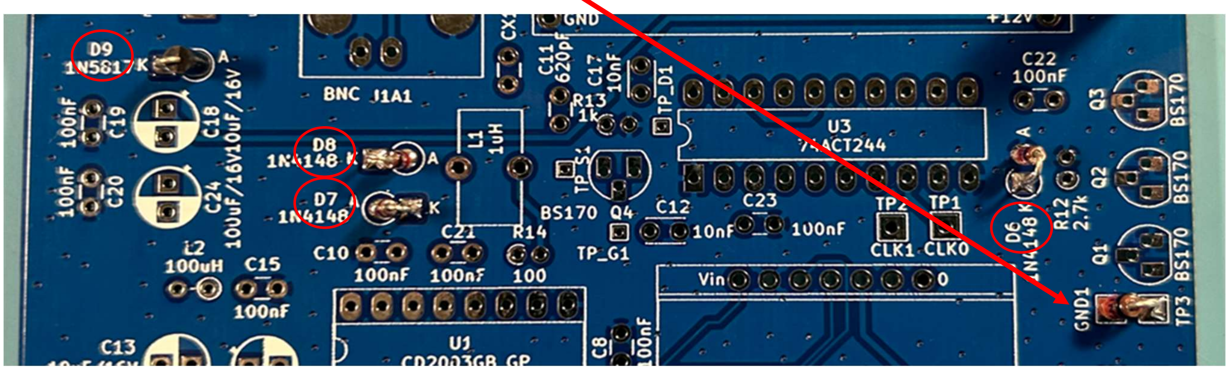
- ☐ PA – 1N4746 this is the larger ‘red’ diode.
- ☐ D6, D7, D8 - 1N4148 these are the smallest of the diodes.
- ☐ D9 – 1N5817 this is the black diode.

All diodes are polarized so it is important that you take the time to identify the correct orientation for installation. The black or silver band on the diode identifies the cathode. **On the ADX board the cathode is denoted by the <u>square</u> solder pad** and the letter K. The **Anode is denoted by the <u>round</u> solder pad** and the letter A. The correct orientation of the diode on the board is shown below:

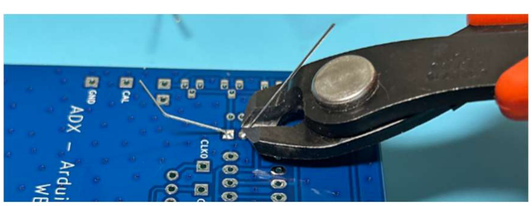




Identify the locations for each component and solder D6, D7, D8, D9 to the board. Double/triple check the orientation before soldering. The PA protection diode is not identified on the board but is soldered on the right side of the board between GND1 and TP3 with the Anode to the GND1 pad.



Once you have soldered the components – remove the leads as close as possible to the solder joint using a small pair of wire cutters. This process should be performed after installation of each component group.



I place my finger on the end of the lead when snipping the lead to absorb the ‘snap’ shock of the cut – reducing stress on the recently soldered join (**but not on static sensitive devices**). It also stops the lead ‘flying’ away when you cut it. If the lead is soft and you cut slowly this technique is probably not necessary, but it’s something to consider.

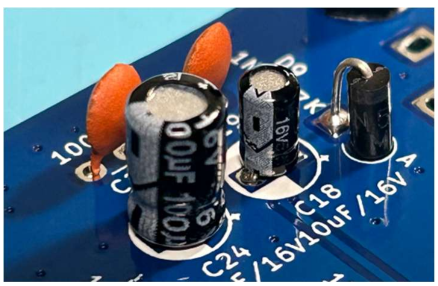
Step 2: +12V Power

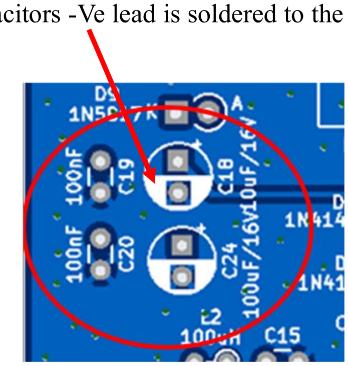
The +12v power supply section uses both electrolytic capacitors and standard ceramic capacitors. The electrolytic capacitors are polarized and need to be installed in the correct orientation. The -Ve lead is the shorter of the two and the body of the capacitor clearly indicates the -Ve lead. The ceramic capacitors are not polarized and are identified with a numeric representation of their value. (See p40 for a capacitor identification chart).

Identify and solder the following components to the board:

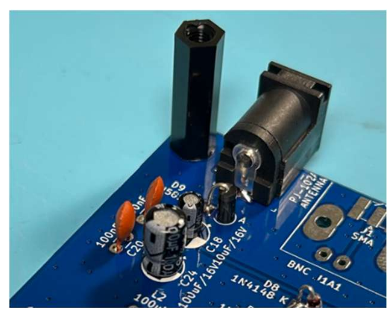
- ☐ C18 – 10uF 16v (your electrolytic capacitors may be rated at 25v which can be used as a direct replacement)
- ☐ C24 – 100uF 16v
- ☐ C19, C20 – 100nF Ceramic Capacitors (Marked 104)

When installed on the board the -Ve (shorter lead) is installed facing the shaded side of the print screen identifying symbol as shown below. The diagram on the right also shows the difference between a polarized (C18 and C24) and non-polarized capacitors (C19, C20) on the PCB screen print. The electrolytic capacitors -Ve lead is soldered to the round solder pad.



- ☐ Install the power jack J2 onto the PCB. Your input power supply sections should now look like this →



We can now proceed to check that the incomming supply will deliver power to the V_{in} pin on the Arduino Nano (XA1)

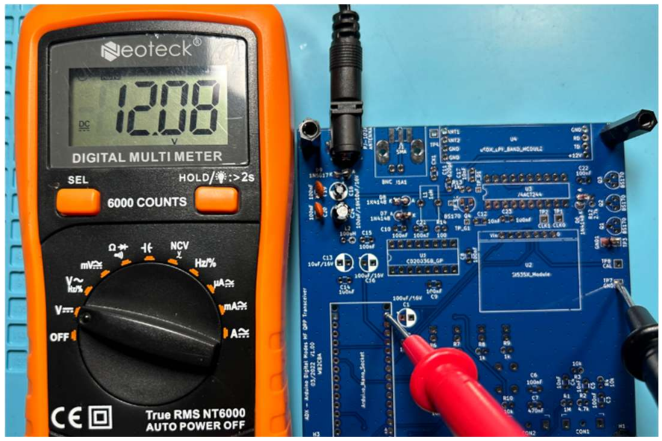
Remember that your incomming power supply should not exceed 12v as this will damage the Nano and the BS170 Mosfets.

In my experience a set of 3x18650 batteries although providing 12.4v at input generally delivers about 12.1v (no load) to the Arduino after it has worked its way through the 1N5817 diode and this has proven safe in operation. These make a great power supply when out in the field, and depending upon the capacity used will provide at least a full day of operation.

If you are providing power using a Lab or 'Bench' Power Supply – set the maximum current to 650mA as this will be sufficient to power the ADX on transmit and undertake any testing required during the build. (The ultra cautious may choose to set I_{max} to a lower value say 100mA until such time as you are testing the power amplifier performance).

Further discussion regarding power options can be found at "Power Supply Options" on p34.

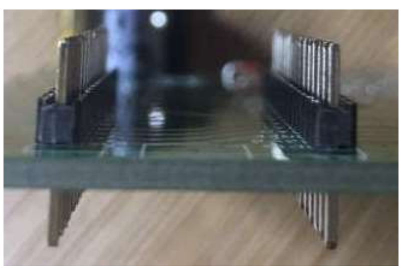
After connecting a 12v supply using the supplied 5.5mm x 2.1mm (**Center Positive)** plug to the ADX board, use a voltmeter to confirm that you are supplying power to pin 1 V_{in} on the Arduino Nano. You can select any of the ground points on the board for the negative probe. The DC Power plug is supplied in the Cowtown ADX Kit.



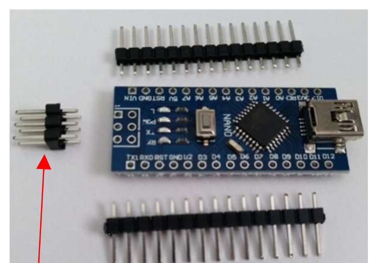
Step 3: Preparing Pin Headers, Arduino Nano and +5V and +3.3V Power

The Arduino Nano (XA1) supplied with the kit will vary from project to project and may have its pins pre-installed or supplied without the headers soldered to the Nano.

In the latter case you will need to solder the pin headers to the Nano before progressing with these instructions.



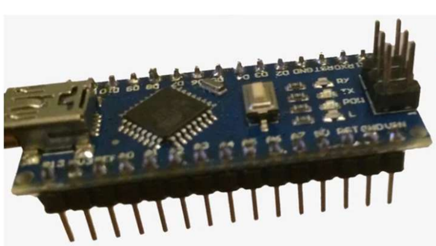
The best way to do this is to place the pin headers that came with the Nano into the main PCB (long lead into the board) to ensure correct alignment. Then place the Nano onto the pin headers and carefully solder the Nano to the pin headers. Solder quickly and spread the heat load soldering every second pin and then returning to pick up the unsoldered pins.



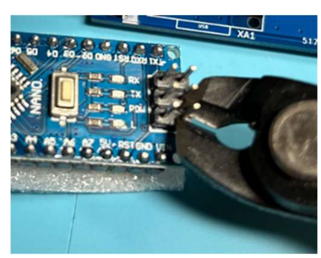
<u>Do not</u> solder the 6 pin I/O pins to the board as these are not needed and will interfere with the fitting of the ADX covers.

I strongly recommend that you DO NOT solder the pin headers directly to the main PCB. Having the flexibility to replace the Nano has its advantages.

The Nano supplied with the REAST kit is shown in the photo to the right. Note the correct installation of the 2 x 15 pin headers leaving the PE1 and PE0 holes blank.



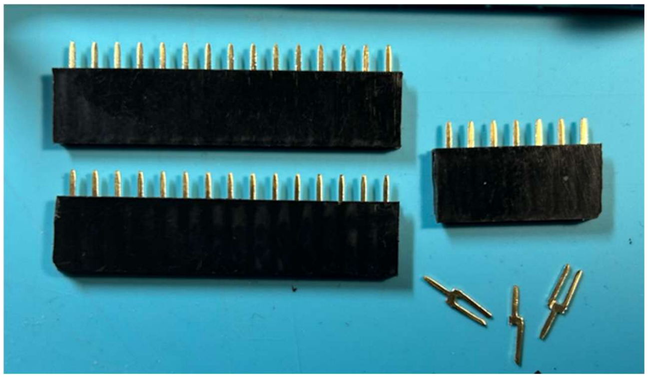
If you are using an Arduino Nano with the pin headers already installed, you will need to remove the 6 I/O pins to avoid interference with the bottom cover. The easiest way to do this is to use your wire cutters and carefully cut off the pins one at a time so that they are flush with the top of the plastic standoffs.

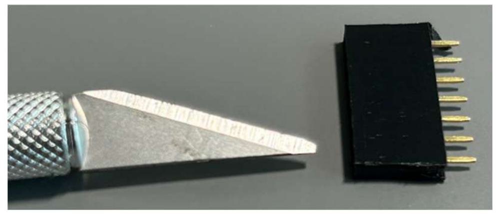


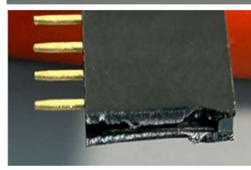
☐ **Preparing your pin header strips**

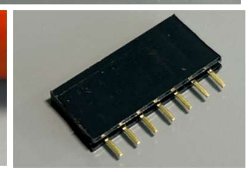
We will be mounting all static sensitive devices (other than the PA transistors) onto the board using sockets to facilitate replacement if required. Each kit is supplied with a 40 pin Female pin header strip. This needs to be carefully cut to length for each of the required headers. The same technique will also be used to make the 4 pin headers for the LPF boards.

The first strip will be cut to provide two 15 pin headers (for the Arduino Nano) and one 7 pin header (for the Si5351). When finished your strip will end up looking like those shown below. The cutting process will destroy one of the headers and leave a ragged edge, but this is cleaned up easily with a modeling knife and/or sandpaper.

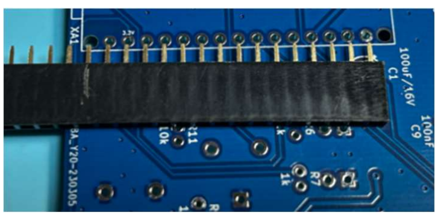


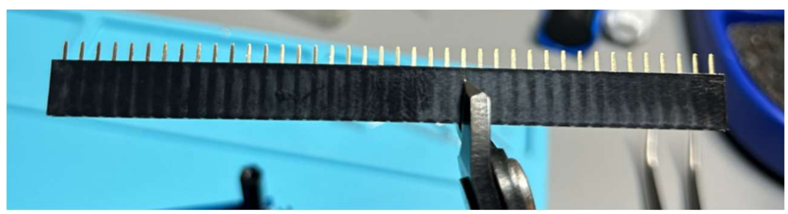




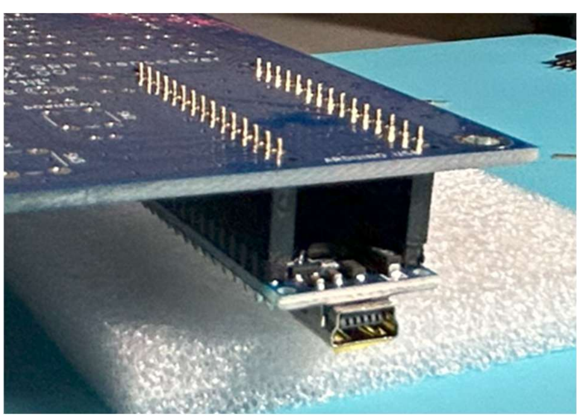


I recommend lining up the strip against the 15 Arduino holes on the PCB and then scoring the pin header where it's to be cut. Double count the number of pins to be left on the header before you make the cut. Take your wire cutters and cut the strip at the score mark. <u>Hint:</u> if you cut the 15 pin strip from each end of the original 40 pin header, you will have one nice clean end on each 15 pin header which you can solder toward the edge of the ADX and will look a lot neater.





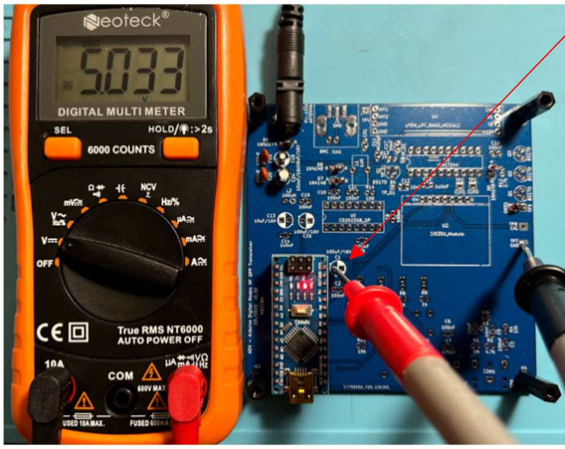
Now to install your pin headers onto the ADX. Fit the pin headers and the Nano onto the board, turn the board upside down and place a piece of foam or similar underneath the nano so that the weight of the board allows the pins to protrude through the solder side of the board. This ensures vertical alignment of the headers. Now solder the pin headers to the PCB. Act quickly as the heat from the soldering iron can easily melt the header. Consider spacing out the soldering by missing every second pin and then returning to solder the remaining pins and in doing so spread the thermal impact on the header pins. The finished results should look similar this:

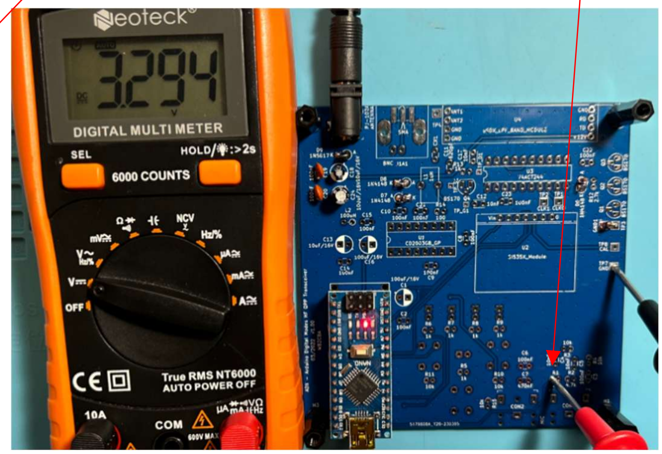


Checking the 5V and 3.3V Supply

The Arduino Nano Module (XA1) supplies +5V and +3.3V power to the main PCB using its onboard voltage regulators.

Install the Nano into the pin headers **ensuring that the USB connector is on the outer edge of the PCB**. Connect the 12V power supply and check that you have +5V at the + pad of C1 and check for +3.3V using the left pin of R1.



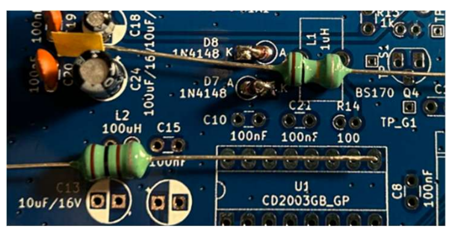


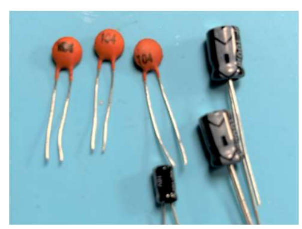
Hint from previous projects: Take care when using the probes that you don't create a short circuit as this may destroy the Nano's onboard voltage regulators with the resulting need to replace the Nano. Should this happen, this can be easily accomplished if you followed the recommendations and used pin headers instead of soldering the Arduino Nano directly to the PCB.

Step 4: CD2003 Power Supply

The CD2003 analogue receiver chip requires a filtered power supply line. There are two fixed inductors supplied with the kit, L1 and L2. Both are shown below however we only need to use L2 the 100uH inductor at this stage. L1 the 1uH inductor is the one with the narrower center. Put L1 (the thinner inductor) to one side for now. You need to identify and solder the following components to the board. (see p42 for the inductor identification chart).

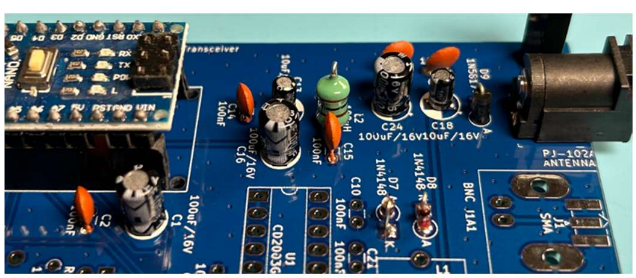
- ☐ L2 100uH Inductor
- ☐ C13-10uF 16v electrolytic
- ☐ C1, C16-100uF 16v electrolytic
- ☐ C2, C14, C15-100nF (104)

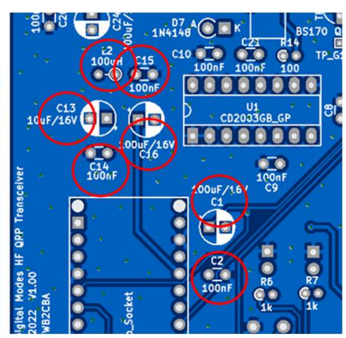




These components are placed as shown on the diagram →

Ensure that you observe the correct polarity of the electrolytic capacitors. Your board should look something like this after this step.

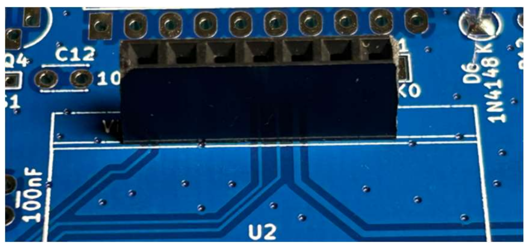




You can now connect the 12v power supply to the main board and check that you have a +5V power supply to pin 15 of the CD2003.

Step 5: Installing the Si5351 Module Header and Pull Up Resistors

Install the 7-pin header you prepared in Step 3 on to the board as shown below:



The best way to do this is to place the header and solder a single pin to the PCB. Check that the board is aligned and if not, apply heat to the solder joint with one hand and with the other move the header into the correct alignment, remove the heat and hold the header in position until the solder solidifies. Once you are happy that it is seated on the PCB and at right angles to the board, proceed to solder the remaining pins. Once again restrict the amount of heat applied to each pin, move quickly, and solder every second pin, then do a second run soldering the remaining pins.

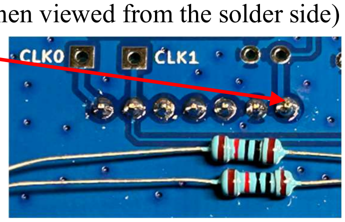
DO NOT install the Si5351 just yet.

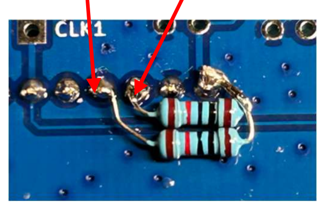
Note: Directly soldering the Si5351 to the PCB provides a more solid connection than the use of pin headers. If this is your preference you can skip installing the 7-pin header and solder the Si5251 directly to the PCB. The Si5351 is installed during construction activity detailed on P19. I have been involved in the construction of over 80 ADX's at this stage and they have all have used Pin Headers as an easy way of removing and testing for a faulty Si5351 and does not appear to have impacted performance. Having said that, I destroyed 3 x Si5351's during the original build developing the first manual back in 2023 and hence the reason why I chose to use pin headers - Your call 😉

Now for the second modification to the original design – we will be installing R16 and R17 as pull up resistors on the SDL and SCA signal lines going from the Si5351 to the Arduino. This was added after the original board was designed, as a precaution to overcome any possibility that your Si5351 does not have pull up resistors on the SDA and SCL lines. Like the PA protection diode (the first modification) there is no provision for these on the PCB, however it's an easy addition. (I'll probably modify the ADX main board to include these resistors and the PA Protection diode on a future PCB production run).

Identify the R16 and R17 - 10K resistors and solder them to the solder side of the PCB under the Si5351 socket. Two resistor leads are joined, and both go to Pin 1. The other leads go to Pin 4 and Pin 3 as shown below.
(Note: Pin 1 is on the right when viewed from the solder side)

☐ R16, R17 – 10K



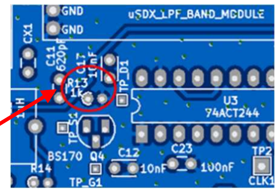


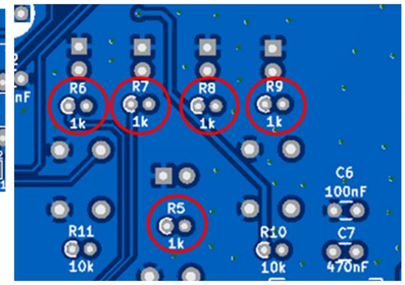
Step 6: LEDs and Buttons

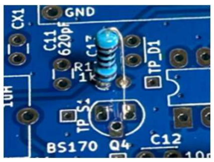
Identify and solder the 1K resistors to the board:

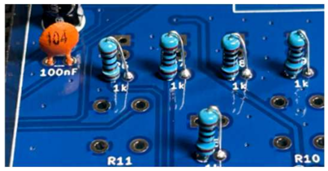
☐ R5, R6, R7, R8, R9, R13 – 1K

R13 is at the top of the board just below the LPF section



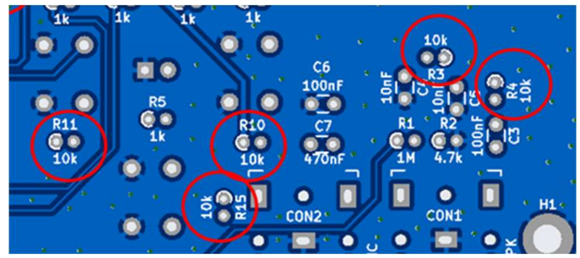




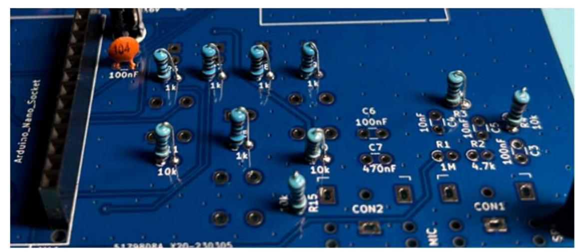


Identify and solder the 10K resistors to the board:

☐ R3, R4, R10, R11, R15 – 10K

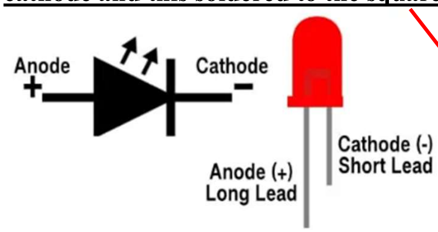


The lower section of the board should look something like this:



NOW TURN THE BOARD OVER – we will be installing the LED's and the button switches from the solder side of the board.

LEDs like any other diode are polarized. The **<u>shorter lead is the cathode and this soldered to the square pads</u>** on the ADX PCB.



☐ Solder D1 (Red LED) as close as possible to the PCB.

☐ Solder D2, D3, D4, D5 (Green LED's) in position also as close as possible to the PCB.

It is important that the LED's and the Switches are mounted flush with the PCB and aligned correctly to ensure there is no interference with the fitting of the top panel board during assembly. You may wish to do a trial fit with the top panel PCB and screw it into place while you solder the LED's just to be 100% sure.

You can also check the correct alignment of the LED's by looking for the flattened edge of the round LED which also denotes the cathode. These should be aligned toward the band labels as shown:

Whilst we supplied a Red LED for TX and Green LED's to indicate status, you may wish to use your own color scheme if you prefer some other arrangement.

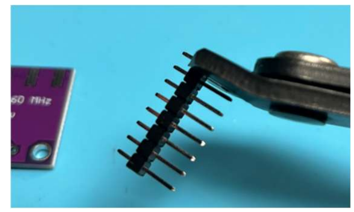
Now it’s time to install the push button switches used to control the ADX.

☐ SW1, SW2, SW3

Mount these switches on the solder side of the board (same as the LED’s) and solder them from the component side of the board. These should be soldered flush to the board. These switches have a rectangular footprint which should be aligned with the through holes. The result is shown to the right:

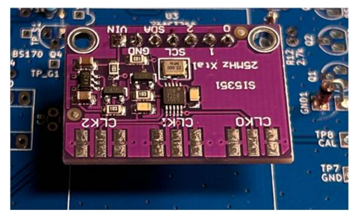
Installing the Si5351

The Si5351 is a static sensitive device, so avoid unnecessary handling and short out any probe (oscilloscope etc.) before you connect it to the Si5351.



The Si5351 comes with an 8-pin header – it only needs 7 pins so cut off the end pin using your wire cutter shown below. Keep the pin you cut off as we’ll be using that later.

Carefully solder the header to the Si5351 and mount it in the female header socket.

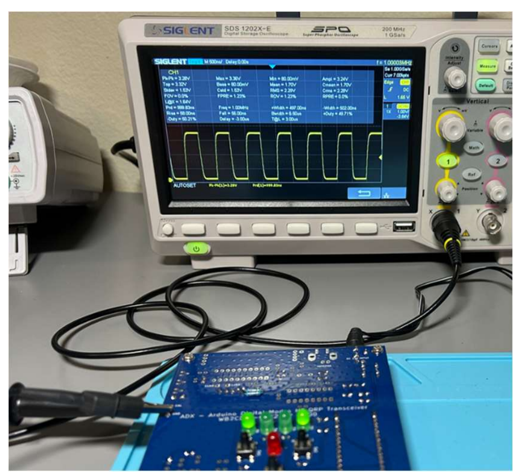


Note: If you chose not to use the 7-pin header outlined in step 5 on p17, you should solder the Si5351 to the PCB here. If you direct solder I suggest soldering the header proud of the PCB in order to enable wire cutters to cut the header pins to remove the Si5351and then cleanly desolder each pin should you need to remove / replace the Si5351. My advice is to use the pin headers as outlined in step 5. You can always return and solder the Si5351 to the PCB if this is your preference at a later stage and everything is working.

Testing the Si5351’s operation.

Press and hold the SW2-DOWN(CAL) button and connect the 12v power supply. Keep holding SW2 down until you see that both B1 and B4 LEDs are flashing. They will flash four times, and release SW2 whilst the lights are flashing. You are now in calibration mode.

With a frequency measurement device (oscilloscope, frequency counter etc.) connect the probe to test point CAL and look for a 1MHz square wave. NOTE: Ground the ADX and the Measuring device before you probe the CAL test point. The Si5351 is a static sensitive device and can be damaged if you don’t ground the device.



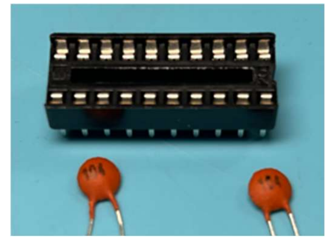
A coarse calibration can be performed here if there is a large variance between your observed oscillator frequency and 1Mhz. Press SW1-UP(BAND) or SW2-DOWN(CAL) several times to get the output frequency as close as possible to 1MHz.

When you are happy with the frequency of the output signal, press SW3-TX which will flash the B1 and B4 LEDs three times to indicate that the setting has been saved. Be aware of the calibration accuracy and tolerance of your frequency measuring device.

Power down the ADX (to exit calibration mode) before you continue with the installation. I also remove the Si5351when I am working on the PCB to ensure that I don’t accidentally damage it with a static discharge. The Si5351 is then placed back on the PCB for testing and operation.

Note: It may be possible to skip this 1MHz test step as I have not yet found a Si5351 yet that didn’t pass this test – finer adjustment of the Tx frequency is carried out when the build is complete.

Step 7: Transmit Driver MC74ACT244



Identify and solder the following to the PCB:

- ☐ C22, C23 - 100nF
- ☐ 20 Pin DIP socket

When installing the DIP socket use the previous technique – solder two diagonally opposite leads, confirm the socket is flush with the PCB, adjust if necessary and then spreading the thermal load by soldering every second lead, returning to pick up the remaining leads.

These components are mounted between the 7 pin Si5351 socket and the LPF module. Mount U3 in the socket as shown here: →

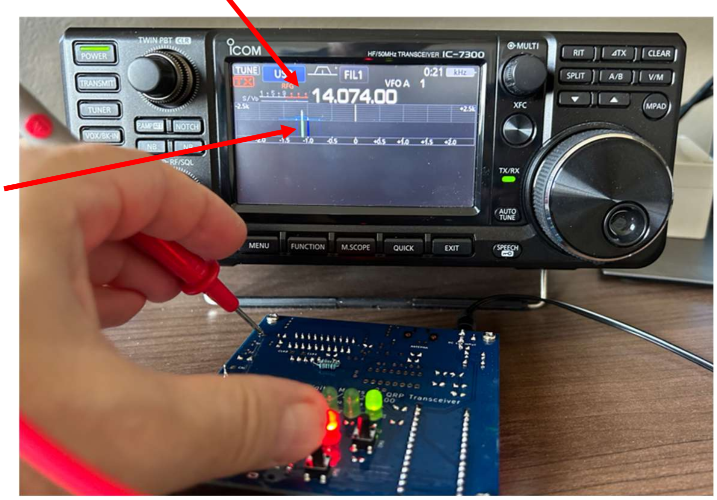
- ☐ U3- MC74ACT244

The new chip comes with its' pins angled out a little from the vertical and they will need some manipulation to push the IC into the socket. Carefully hold the chip with both hands and press on a table to make the pins vertical. Don't bend the pins one by one. It's best to align both rows of pins to be vertical and then insert the IC into the socket. If you have an IC insertion tool that's even better, but most don't have one on hand.

We can now test for the correct radiation frequency.

Reinsert the Si5351 module (if you removed it), turn the board over and reconnect the 12v power supply.

Use a probe lead disconnected from your multimer and touch the center pin for the Q3-BS170 with the lead, which will be used as a radiation antenna. Press the SW3-TX button to transmit (the red LED should illuminate). A nearby receiver should hear a signal when tuned to the correct frequency. I tuned to 14.074MHz because the ADX was identified from the LED that flashed three times on power up as being on Band 2 (20m) and then the LED indicating FT8 was illuminated.



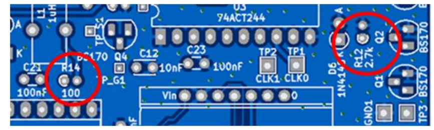
See "Changing the Selected Band" on p29 to change the band, and "Changing the Mode of Transmission" on p30 to change the operating mode.

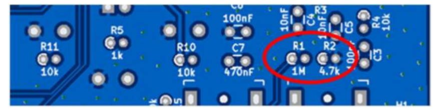
In my example my IC7300 band scope showed a signal, and an audio tone was heard - confirming the ADX was transmitting on or about the correct frequency. The frequency of transmission is set by the combination of the band and mode selected. See the frequency table p30 for the frequency used by each mode per band.

A finer adjustment of the transmitted frequency can be made later.

NOTE: On the IC7300 the '0' position on the band scope indicates the middle of the USB, which is 1500 Hz higher than the 14.074 tone that the ADX is transmitting. The example here shows that the ADX is transmitting at -1100 Hz 400Hz high – this will be resolved during fine tuning of the ADX outlined on p35.

Step 8: Complete the TX





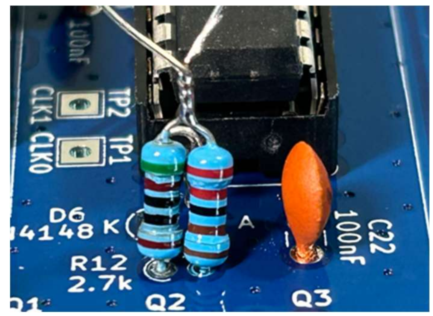
Identify and solder the remaining 4 resistors to the PCB:

- ☐ R1 -1M
- ☐ R2 - 4.7K
- ☐ R12 - 2.7K (or 2.2K and 510R to be installed in series)
- ☐ R14 - 100R.

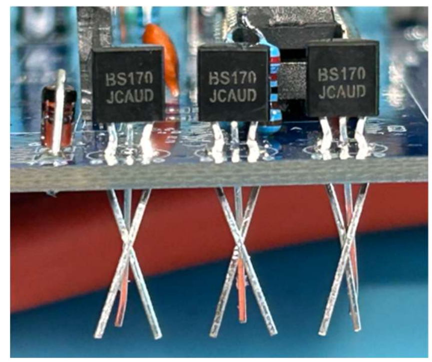
Your kit may have been supplied with a 2.7K resistor for R12 so simply install it as per other single resistors.

If you received a 2.2K and 510R for R12 you will first twist two leads from the resistors together and insert the other ends into the PCB. Effectively installing the two resistors in series for form a 2.71K resistor.

When soldering R12, solder the twisted leads before trimming, ensuring that you have a solder connection holding the leads together as shown:



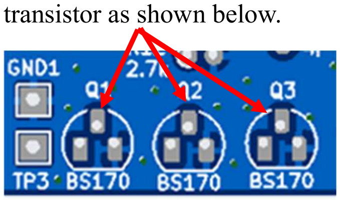
Remove three BS170 transistors from their packaging **being careful not to touch the leads as they are static sensitive**. Take care to insert them correctly aligned into the PCB. It can be a little fiddly alignng the leads into the holes but when you have them in their holes, push the MOSFET down to align it in the board as shown:



- ☐ Q1 -Q3 BS170

Make sure your soldering iron is ESD protected. Act quickly and do not overheat the leads during the soldering process.

If you don't have an ESD protected soldering iron, populate the board with Q1-Q3 as above and solder all leads but **NOT** the center lead for each transistor as shown below.

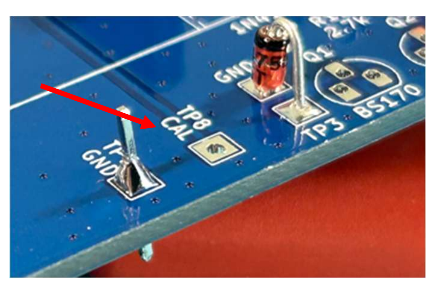


For these three center pins, heat up your soldering iron, disconnect it from mains power, then touch it on an earthed point to 'earth it out' and then acting quickly, solder the center pin with the residual heat in your soldering iron. You may need to reheat the soldering iron and repeat the process for each of the three transistors.

The finished installation will look similar to this →

Hint: Solder the BS170's with the legs a little longer than shown in the picture, makes the replacement process a lot easier and offers greater PCB track preservation during the desoldering process. You are then able to remove the transistor by cutting the legs off with wire cutters and then desolder the legs one at a time from the PCB.

Whilst you are working in this area, you may wish to solder a spare pin to the GND test point (using the spare pin that you cut off the Si5351 8 Pin Header on p19) to provide an easy GND test point to attach an alligator clip. This makes later testing a little easier. I soldered the pin with protrusions on each side of the PCB so that I had a GND access point to clip to from either side.



Before we can test the ADX power amplifier we need to install the pin headers for the low pass filters AND either make or have a Low Pass Filter (LPF) available. **If you don't have access to an LPF, you should stop here and jump ahead to section 11 p26 and make at least one LPF before continuing from this point.**

When installing the LPF connections to the PCB, I recommend using a combination of male and female pin headers as shown below as this will ensure that you insert the LPF in the correct orientation. If everyone follows this protocol, LPF boards can be exchanged between club members for testing and comparison purposes etc. The pin headers should be installed with the 4-pin female on the GND, RD, TD, +12v connections and the male pin header connected to ANT1 AN2, GND, GND connections as shown below:

When soldering the LPF Pin headers ensure they are perpendicular to the PCB surface. If you have already manufactured an LPF, you can insert it into the headers to assist in alignment whilst soldering the headers to the PCB.

- ☐ LPF 4 Pin Headers (Male and Female)

Use the same alignment technique you used soldering the Nano and Si5351 pin headers to the board.

Now solder the BNC Connector to the PCB making sure it's flush with the PCB and aligned perpendicular to the edge of the PCB. The screen print on the PCB assists in this alignment.

- ☐ J1-BNC Connector

<u>The assembly of the TX portion of the ADX is now complete.</u>

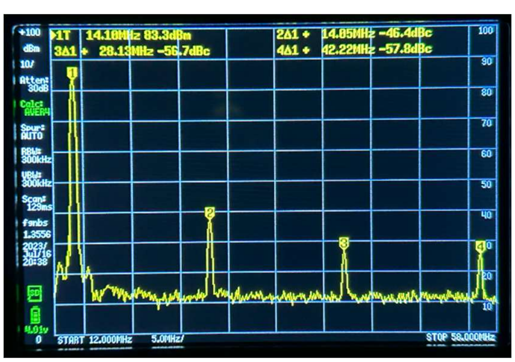
YOU MUST INSTALL A LOW PASS FILTER MODULE AND SELECT THE CORRECT BAND FOR THE FILTER BEFORE PROCEEDING

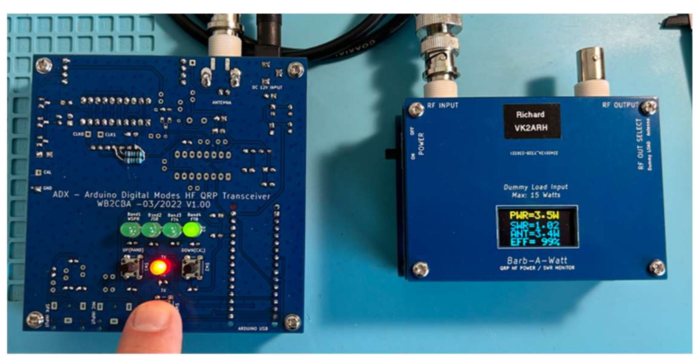
Make sure the LPF module and the band setting of Nano are matched. If not, you will need to activate the band configuration mode and change the operating band. See 'Changing the Band' on p29 and select the band which matches the band and LPF you want to test. The default band settings are B1–40m, B2–20m, B3–15m, B4–10m, B5–80m, B6–30m and B7–17m. The selected band is indicated by the LED which flashes three times during the power on sequence, before an LED illuminates permanently to indicate the chosen mode.

Connect the ADX to an RF power meter and/or a spectrum analyzer and a 50-ohm dummy load. If connecting to a spectrum analyzer insert at least a -30dB power attenuator between the antenna out and the spectrum analyzer.

Press the SW3-TX button to activate the transmitter and examine the power output and if using a spectrum analyzer, the level of spurious emissions. If all is working correctly the power out will be between 1.5w and 4.0w depending on the band chosen and efficiency of your PA section. Lower frequency bands are likely to emit more power than higher frequency bands.

The overall current draw on transmit should be in the range of 450 - 600mA, depending on your low pass filter and amplifier efficiency. The current can be measured with your multimeter or a bench power supply.

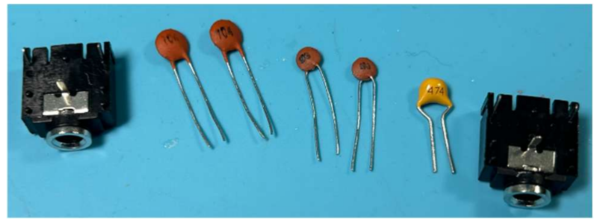




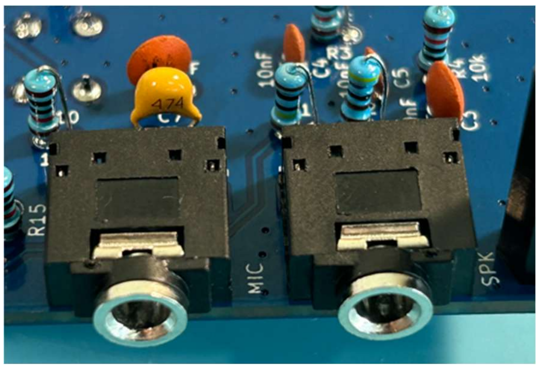
Step 9: Audio Jacks

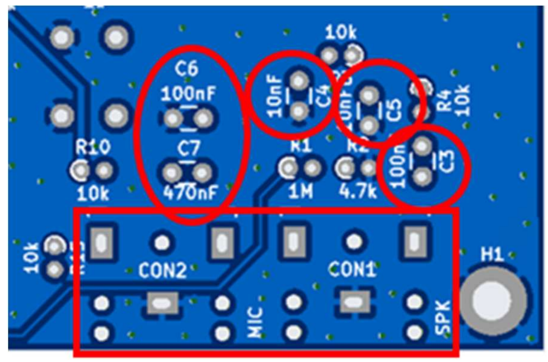
Identify and solder the following components to the PCB:

- ☐ C3, C6 -100nF (104)
- ☐ C4, C5 -10nF (103)
- ☐ C7 - 474pF (474)
- ☐ CON1 (TO SPK) and CON2 (TO MIC)



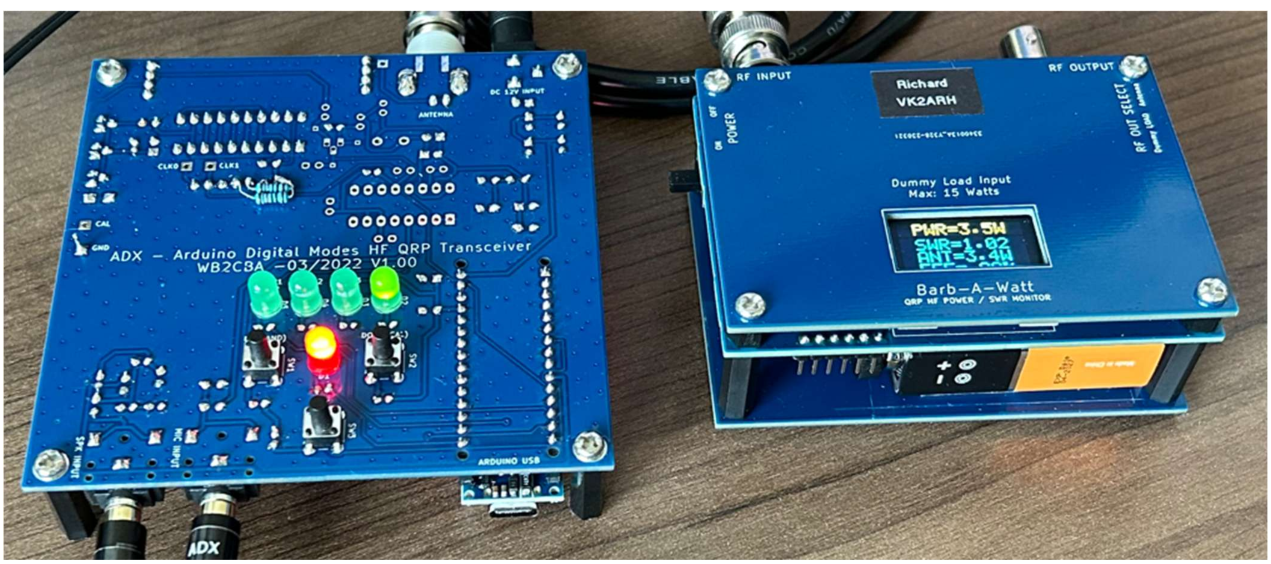
These components are all located in a cluster near the bottom edge of the board:





Now we can test the ability to switch to transmit when an audio input signal is detected. The easiest way to do this is to plug your ADX into your computer which has been set up with WSTJ-X (see section dealing with WSJT-x setup on pp32-33) and activate the tune button in WSJT-X which should switch the transmitter into TX.

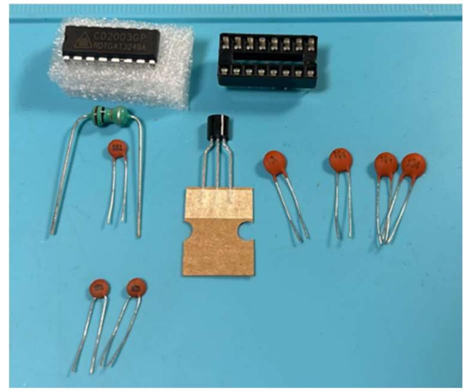
MAKE SURE YOU HAVE THE CORRECT BAND SELECTED, LPF INSTALLED AND A 50 OHM DUMMY LOAD CONNECTED TO THE BNC SOCKET FOR THIS TEST BEFORE CONNECTING POWER.



The red LED Illuminates indicating activation of the transmitter when an audio signal is supplied to the SPK socket. If connected to a power meter you should also see an indication of output power.

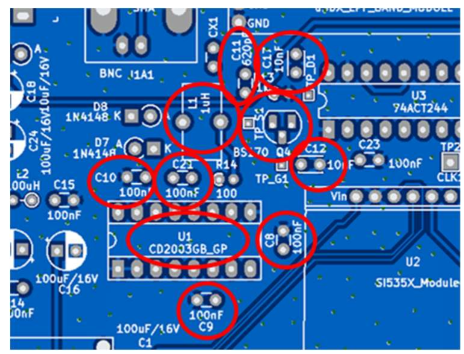
Step 10: Installing the CD2003 Receiver

Identify and install the following components:



- ☐ L1 - 1uH
- ☐ C8, C9, C10, C21 - 100nF (104)
- ☐ C12, C17 - 10nF (103)
- ☐ C11 - 680pF (681)
- ☐ 16 Pin DIP Socket
- ☐ U1 - CD2003
- ☐ Q4 - BS170

Before you solder L1, the 1uF fixed inductor, you will need to modify the leads so that they will fit into the allocated space. Use the same technique as you used with the 470nF capacitor (see construction tips), so that you end up with the inductor leads shaped to the correct spacing as shown in the photo: You can also install it vertically using the same technique as the resistors.

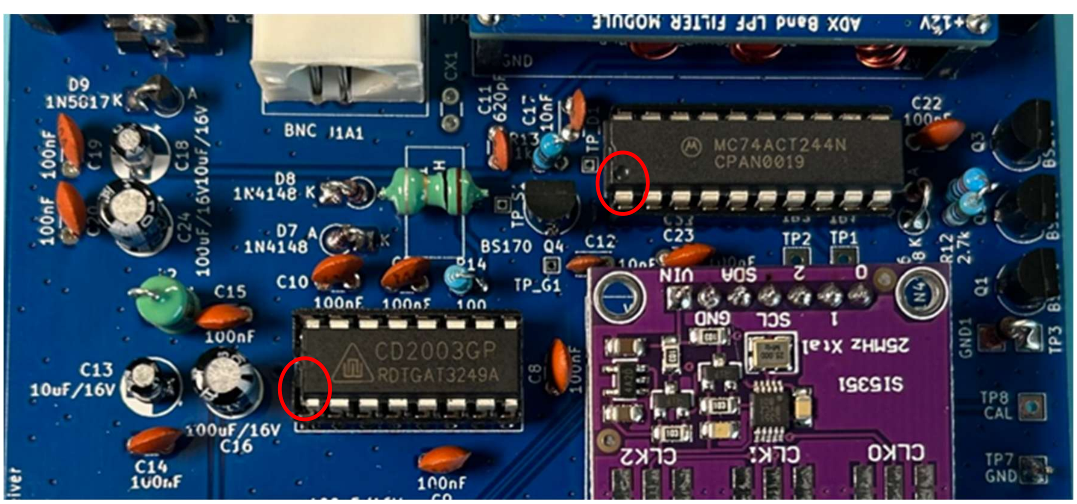


Install all the remaining capacitors. The location of these components is shown on the diagram.

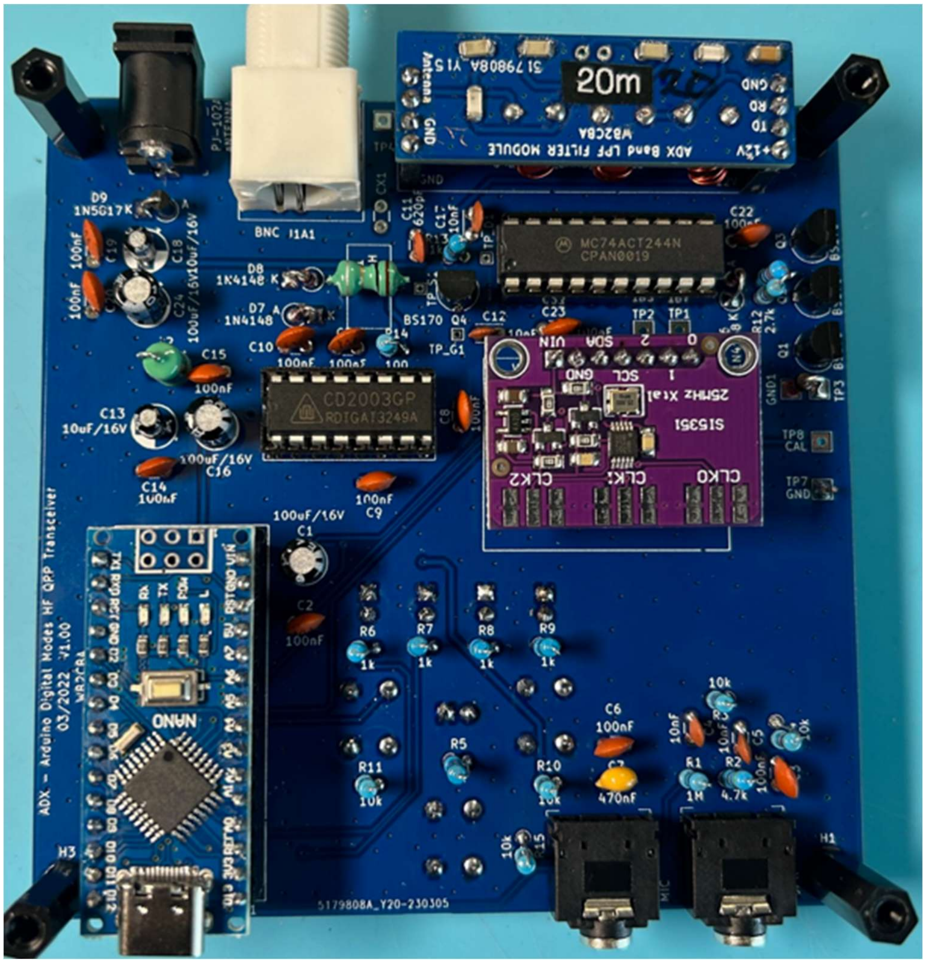
Solder the 16 Pin DIP socket to the PCB using the same technique as the 20 Pin DIP Socket and insert the CD2003 after straightening the pins to fit into the 16 Pin DIP Socket. As with the MC74ACT244N chip ensure that the chip is inserted in the correct orientation as seen in the photo at the bottom of this page. Pin 1 on the IC's is identified with the red circles.

Remember that the CD2003 and Q4 – BS170 are static sensitive devices. Take care to ensure they are safe from static discharge during handling and soldering. Solder the BS-170 using the same technique as used for the other BS-170's on p21.

CONGRATUATIONS – this now completes the soldering of all the components to the ADX Board 😊

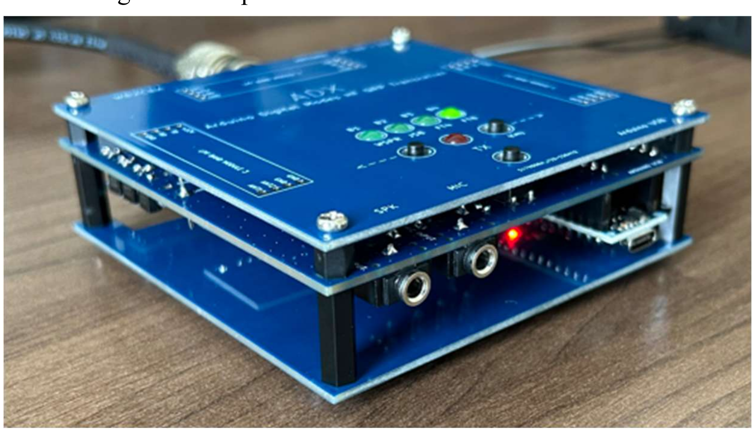


The completed component side of the board should now look similar to this:



You should now progress by testing your ADX in receive mode. For connection to WSJT-X see the 'Using Your ADX' section on pp 31-33 of this manual.

Once you are happy that the ADX is working correctly, install the top and bottom cover on the ADX and tighten the screws to secure the boards. DO NOT OVERTIGHTEN the screws otherwise you will strip the thread in the nylon spacers. The longer 18mm screws go through the top panel, the smaller 6mm spacer, the main PCB and then screw into the larger 18mm spacer. The shorter screws are inserted from the bottom of the board into the larger spacer.

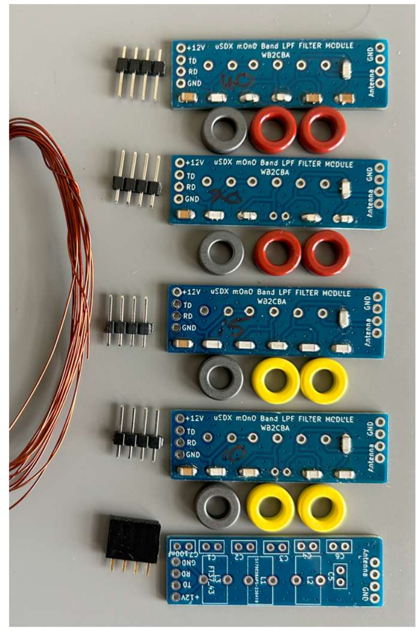


It's easier to install the bottom screws and the longer spacer first before attaching the top cover, smaller spacer and the main PCB.

The kit is supplied with silicon feet which can be stuck on to the bottom of the enclosure to prevent the possibility of case screws scratching your desk surface and prevents the ADX sliding around.

Sit back, admire and enjoy your achievements.

Step 11: Building the Low Pass Filters (LPF's)



You will need to build a low pass filter (LPF) for each of the bands you wish to operate. You will also need an LPF to undertake testing of the transmitter during the build, so it is a good idea to build at least one LPF before you commence constructing of the transmitter section of your ADX.

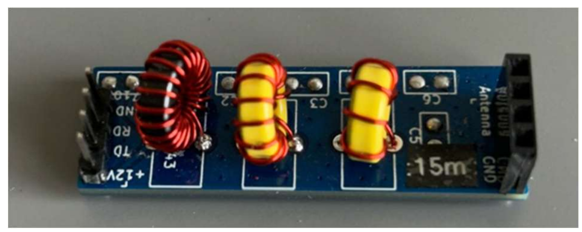
The ADX kit comes with a full set of LPF components to cover each of the 80m, 40m, 30m, 20m, 17m, 15m, and 10m bands.

The photograph on the right shows a set of 40m, 20m, 15m and 10m LPF components which was a popular selection with the Cowtown members. This provides the ability to operate on each of the bands we built into the EFHW Antenna in Buildathon Project #1. The EFHW project introduced members to winding toroid's – a skill which is now used here.

We chose to use SMD capacitors for the LPF to secure the value specified by Barb WB2CBA in his design.

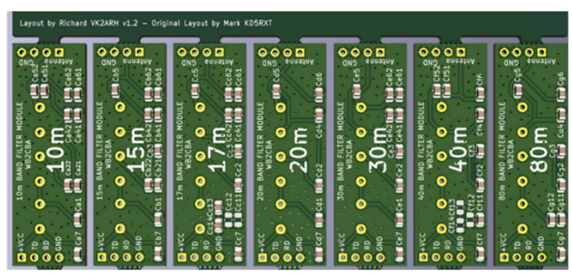
The photo shows the 4 pin male headers supplied with the kit and a single 4 pin female (you'll need one for each LPF) which you manufacture from the 40pin strips supplied. See p15 of this manual for details.

To build a LPF you need to undertake the following:



- ☐ Solder the header pins to the boards as shown on the completed LPF. The female headers are soldered to the end marked Antenna and GND.
- ☐ Wind each toroid according to the table on the following page. The amont of magnet wire required for each toroid is listed on this table. Solder the toroids to the LPF board **after scraping off the enamel coating** on the magnet wire. This is an example LPF for the 15m band.

Each band uses a different combination of L1 and L2, as outlined in the table on the following page. L3 which uses the FT37-43 is common for all band LPF's. The capacitors used in the LPF are identified in the table on p37 but have been pre installed onto the LPF PCB's.



The LPF's shown above were hand soldered – the kits provided to REAST have the LPF's SMD capacitors pre-installed and band information printed on the LPF. This will make production and use of the LPF's a lot easier. You just snap off the band you want, file down the 'mouse bites' and install the inductors and pin headers. The production boards are the same colour blue as the ADX.

Don't worry there aren't any missing capacitors on this layout – there are several areas where options were provided for parallel or series installation of capacitors. This was by design to deliver the required capacitance and voltage rating using more commonly available capacitors.

Storing your LPF's

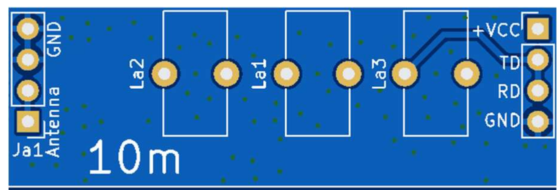
If you don't want to be chasing around looking for your LPF's, the top cover supplied has three positions available for storing LPF's not currently in use. You can take advantage of this by soldering pin headers onto the top cover. This is an old photo of one of the first ADX's builds, but you get the idea. The additional header pins are not supplied in the Kit, but additional 40 pin headers are easily obtainable on line.

If you have access to a 3D printer Simon VK2YU has designed a nice LPF storage case which can be downloaded from here: https://www.thingiverse.com/thing:6675282 . Simon also has a nice 3D ADX case available using the same link. Be sure that your LPF's are operating at optimal efficiency before mounting in a case to avoid possibility of your BS170's overheating.

Toroid Winding Chart

Band	L1		Mag Wire (mm)	L2		Mag Wire (mm)	L3		Mag Wire (mm)	Total Mag Wire
	Turns	Toroid		Turns	Toroid		Turns	Toroid		
80	19	T37-2	270	8	T37-2	205			280	755
40	15	T37-2	220	6	T37-2	155			280	655
30	12	T37-2	175	5	T37-2	130			280	585
20	10	T37-2	155	4.5	T37-2	120	20	T37-43	280	555
17	11	T37-6	170	4.5	T37-6	120			280	570
15	11	T37-6	170	4.5	T37-6	120			280	570
10	9	T37-6	230	4	T37-6	105			280	615
								Total Mag Wire		4305

The toroid naming convention corresponds to that shown on the LPF board on the right. (eg: La2 is L2, the second letter in the identifier representing the band a=10m, b=15m, c=17m etc.). The toroid with the least number of turns (L2) is the one closest to the Antenna end, L3 (T37-43 grey) is closest to the +Vcc end with L1 in the middle.



The capacitors used on each LPF are shown in the table to the right. C7 is a 100nF capacitor and is common on each band LPF. All these capacitors are pre- installed on the LPF in your kit.

Band	C1	C2	C3	C4	C5	C6
80	660pf	1000pf	1000pf	2000 pf	620pf	2000pf
40	130pf	470pf	470pf	1000pf	300pf	1000pf
30	100pf	330pf	330pf	660pf	220pf	660pf
20	68pf	470pf		470pf	150pf	470pf
17	91pF	180pF	180pF	360pF	120pF	360pF
15	68pF	300pF	15pF	300pF	100pF	300pF
10	39pF	240pF		240pF	75pF	240pF

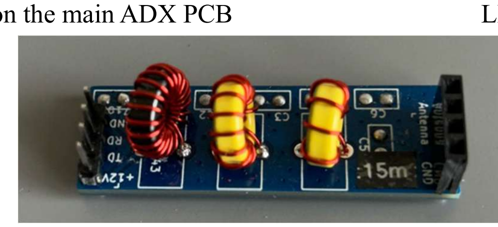
When winding the toroid, a turn is counted each time the magnet wire is passed through the center of the toroid. Whilst there is a little extra magnet wire supplied with each kit, measure and use the correct amount of wire required for each toroid as shown in the table to ensure that you have enough wire to complete all your LPF's. You can allow an extra 20mm or so per winding and still have enough wire.

When installing the LPF connections on the board, I recommend using a combination of male and female pin headers as shown below. This will ensure that you insert the LPF in the correct orientation. If everyone follows this protocol, LPF boards can be exchanged between club members for testing and comparison purposes etc.

The LPF connections on the main ADX PCB

LPF fitted to the ADX

Finished 15m LPF →



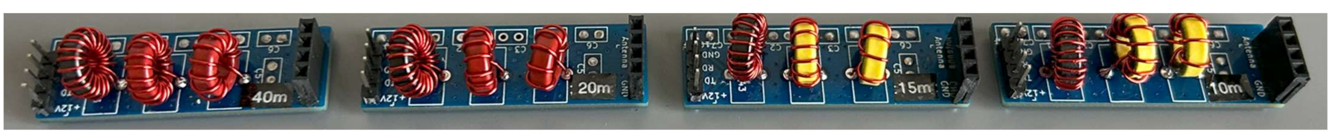
Some Tips on building the LPF's from Barb WB2CBA:

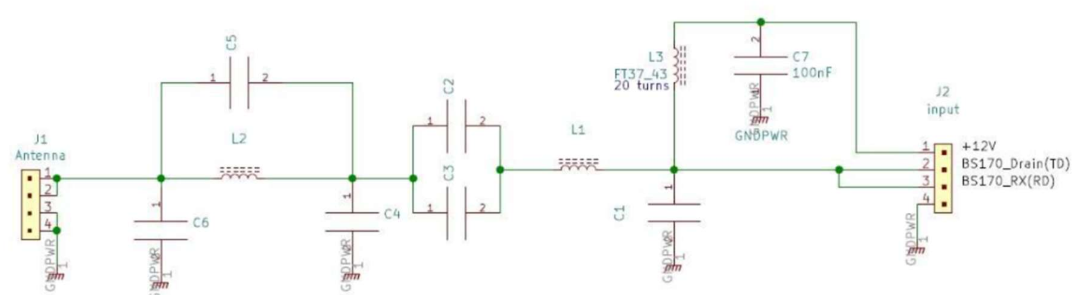
One important point to consider is that the edges of FT37-43 Toroid's can be quite sharp which can scrape the enamel coating on the inductor wire. To fix this issue the easiest method is to taper the edge a little with an oversized drill bit. Use the oversized drill bit and turn with your fingers inside the toroid ring to smoothen out any sharp edges. Do not use a drill to turn the drill bit, you will snap the toroid and most likely harm your fingers in the process. (VK2ARH Comment – with the FT37-43's I sourced for the kits I have not experienced this problem.)

- Lowering one turn from L1 in each band will slightly increase RF output power, although it might increase the TX current, so exercise caution.
- For L3, 12 turns also works well so this can be a nice option to play with and is easier to wind. Although there is some caution here, DO NOT EXCEED 5 WATTS RF POWER otherwise the BS170 voltage limit will be exceeded which will destroy your BS170's. Note: BS170's are inexpensive so don't stress too much about destroying them but don't be reckless, it's just a little tedious having to replace them. If you take care you shouldn't have to do this. In my own testing (using a 40m and 20m LPF) I found that using 12T on L3 whilst increasing power out slightly by about 200mW but it didn't assist PA efficiency, so have stuck to winding 20T on L3) this may be different for other bands.
- One turn is counted each time the wire passes inside the toroid ring. For example, in the 7 turn T37-2 toroid used as L2 on a 20m LPF in this photo, the wire passes 7 times inside the ring. →

- After passing the turn through the toroid, stretch the wire so it is tightly wound around the toroid.
- When you have finished winding your turns, carefully count every turn that passes through the inner ring of toroid. The best method to do is to take a close-up photo of the toroid, enlarge and count the turns. This way it is easier to see turns and you won't miss a turn.
- **<u>Never</u>** let one turn overlap another one. Every turn should be side by side. This is important in toroid's that have 20 or more turns and it is easy to overlap turns.
- Always scrape the ends of magnet wire to clean the enamel coating before soldering. To clean the enamel coating there are two methods which can be used separately or together. Scrape the enamel coating with a cutter knife thoroughly or the second method is to heat up wire with your soldering iron so that enamel coating just burns off during the soldering process. This generally requires that you hold your soldering iron on the joint until you observe the enamel 'smoke' away which will be at least 10 seconds. Scraping first and then burning the residue enamel coating during soldering is the best approach.
- Before soldering try to spread the toroid windings as evenly as possible as in the photos above.
- After soldering the toroid in its place check your solder joints and their connection with the magnet wire with your multimeter to ensure good solder joints and connections.

Here is an example of a set of completed band pass filters for reference. This shows from L to R: 40m, 20m, 15m, and 10m LPF's and is followed by the LPF Schematic:





Settings and Calibration

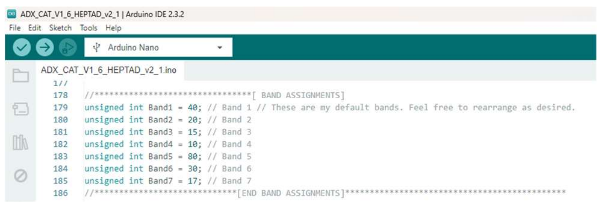
Before using the ADX you need to configure your chosen BAND and MODE of operation. Once set the ADX will remain on this band and mode each time you power up the ADX, until you reset/change the BAND and MODE.

Setting the BAND

The ADX has seven bands available (Band 1 … Band 7) these are hard coded in the Arduino firmware. The firmware for the ADX was loaded into the Arduino Nano included in your Kit, but the firmware is available for download from the following site if you wish to modify and reload your own. https://github.com/VK2ARH/Cowtown-ADX-Project

The default band setting are: **Band 1:** 40m, **Band 2:** 20m, **Band 3:** 15m, **Band 4:** 10m, **Band 5:** 80m, **Band 6:** 30m, **Band 7:** 17m.

To change these band assignments, you need to go into the Arduino code and change the band assignment declaration in lines 179 to 185. It is beyond the scope of this construction manual to cover Arduino programming, but it is a relatively easy process to undertake such a change. Once changed in the code, you compile and upload your changes to the Nano. The ADX's top cover screen print represents these band assignements so if you change them you will need to put a new lable on the top cover.


ADX_CAT_V1_6_HEPTAD_v2_1 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Arduino Nano
ADX_CAT_V1_6_HEPTAD_v2_1.ino

```
177
178 //********************************[ BAND ASSIGNMENTS]
179 unsigned int Band1 = 40; // Band 1 // These are my default bands. Feel free to rearrange as desired.
180 unsigned int Band2 = 20; // Band 2
181 unsigned int Band3 = 15; // Band 3
182 unsigned int Band4 = 10; // Band 4
183 unsigned int Band5 = 80; // Band 5
184 unsigned int Band6 = 30; // Band 6
185 unsigned int Band7 = 17; // Band 7
186 //****************************[END BAND ASSIGNMENTS]******************************************
```

The firmware loaded into the Nano provided with the Kit is version: **ADX_CAT_V1.6_HEPTAD_v2.1**

This version of the firmware supports CAT control for frequency changes, but the original ASX does not automatically check that you have the correct LPF installed to operate on the new band. For this reason, I recommend that you manually change the band using the ADX control panel and don't use the CAT function to change bands.

Controlling the ADX

A video showing how to configure and operate your ADX can be found here:

https://youtu.be/r9B3RibANnY?si=r34qIer-_NsLd4T4

When you power on your ADX the Tx light will flash briefly followed by either one or two of the band LED's (green) flashing three times to indicate the band currently selected. The table to the right shows the band identification schema and this corresponds to the screen print of the panel.

Band LED Indications - Flashes 3 times on power on

Band (m)	LED	LED	LED	LED
40				
20				
15				
10				
80				
30				
17				

The display will then illuminate a single solid LED to indicate the chosen mode.

Changing the Selected Band:

Press both the < --- and the --- > buttons simultaneously <u>after</u> the ADX is powered on and in normal operating mode. This will switch the ADX into band selection mode. The currently selected band LED will flash three times and then remain on indicating that this is the band currently selected. The red TX LED will also illuminate indicating that you are in band select mode.

Press the < --- or the --- > switch to select the desired band (the illuminated LED will move to indicate the selected band as per the previous table). Press the TX button briefly to save the new band, the TX LED will extinguish, and the chosen band LED/s will flash 3 times to confirm the chosen band. The display will then default to a single LED illumination to highlight the chosen mode (WSPR, JS8, FT4 or FT8).

ALWAYS MAKE SURE YOUR BAND SETTING AND INSTALLED LPF ARE ALIGNED

Changing the Mode of Transmission:

The mode can be changed during normal operation without entering a configuration process. Press either the < --- or the --- > button to change the mode when the ADX is powered on. The illuminated LED will change position indicating the mode (WSPR, JS8, FT4, FT8) currently assigned. When you power off the ADX your last used mode is stored and the ADX will return to that mode when you next power on.

Whilst the ADX now supports CAT control, you should read carefully the details pertaining to the use of CAT control and operating in Barb's ADX manual pp28-30. My initial recommendation is to NOT use CAT control until you are totally familiar with operating the ADX and understand all the issues.

The frequency and mode of operation is hard coded into the firmware, and changes to the Band and Mode of operation result in the ASX operating on the frequencies shown on the following table:

$f_{(MHz)}$	80m	40m	30m	20m	17m	15m	10m
WSPR	3.573	7.0386	10.1387	14.0956	18.1046	21.0946	28.1246
JS8	3.578	7.078	10.130	14.078	18.104	21.078	28.078
FT4	3.575	7.0475	10.140	14.080	18.104	21.140	28.180
FT8	3.573	7.074	10.136	14.074	18.100	21.074	28.074

Entering Calibration (CAL) Mode:

Hold down SW2 (CAL) when powering on and keep holding it down while the chosen band light flashes three times and the FT8 and WSPR LED's illuminate and remain ON – release SW2 and you are now in calibration mode. Make whatever calibration changes you need (see instructions) and then press the TX button briefly to save your changes – the TX light will flash 3 times to indicate that the calibration value has been saved.

The main calibration required is frequency calibration which is accomplished by ensuring that the output from the Si5351 is set to 1MHz when in calibration mode. This is undertaken on P19 of this manual. Wait at least 2 minutes for the unit to warm up and stabilize before undertaking the calibration.

The standard calibration method is that you probe the test point CAL with a frequency counter of 1Hz resolution, press SW1-UP(BAND) or SW2-DOWN(CAL) to adjust to as close to 1MHz as possible, then press SW3-TX to save the setting.

If you don't have a frequency counter, you can consider using a commercial ham radio transceiver with an accurate frequency display as an alternative, an SDR radio or digital oscilloscope with a measurement capability.

A detailed explanation of using the calibration mode to fine tune the ADX VFO can be found on p34 of this manual.

Connecting the ADX to your Computer

The following extract is taken from WB2CBA's original manual on the ADX.

Connecting the ADX transceiver to any computer is straight forward. We need a MIC (Microphone input) and SPK (Speaker input or headphone input). We can either use the PC's built-in soundcard or a cheap USB Soundcard adapter.

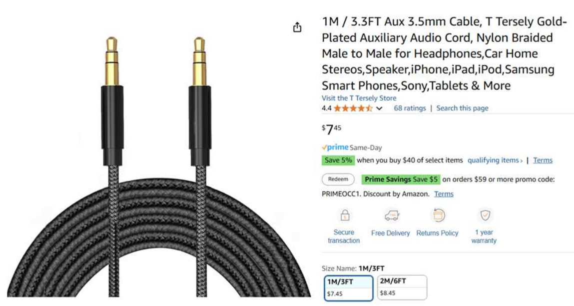
I suggest using a USB soundcard adapter for a couple of reasons. If anything goes wrong the built-in soundcard won't be damaged and it also helps with ground-loop situations.

For USB isolation and peace of mind from ground loop dangers you can use one of these isolators between the USB soundcard and the computer's USB port: (VK5ARH Comment – this is a nice to have and relatively expensive but not essential) .

These are Australian Amazon Prices.

For the USB soundcard I use this sound card from amazon: (Note from VK5ARH – several builders have used this soundcard, and it works well).

We need two x 3.5mm audio jack male to male extension adapter cables. These are readily available but if you don't have two of them there are many options available including manufacturing your own. Select a shorter, preferably shielded cable rather than longer cable to avoid the possibility of interference.



These are just examples. You can use anything similar to these.

- Connect the Soundcard MIC input to ADX MIC input and the soundcard SPK output to the ADX SPK input with the 3.5mm audio cables.
- Run WSJT/X or JSCALL software on your computer.
- Power on ADX.
- When you power on the ADX, one of the LED's will briefly flash 3 times and then another LED will be on solid. The first LED that flashed 3 times indicated the active selected BAND, ensure that this is the band you want to operate and the installed LPF matches the band. If not select your desired band (see band selection process P29) and ensure that the matching LPF is installed.
- Now that the band and LPF are set, check/adjust your desired mode (WSPR, JS8, FT4, FT8) and check the configuration of your software.

Using the ADX with Digital modes is like operating WSJT-X with any other HF Transceiver.

WSJT-X Settings

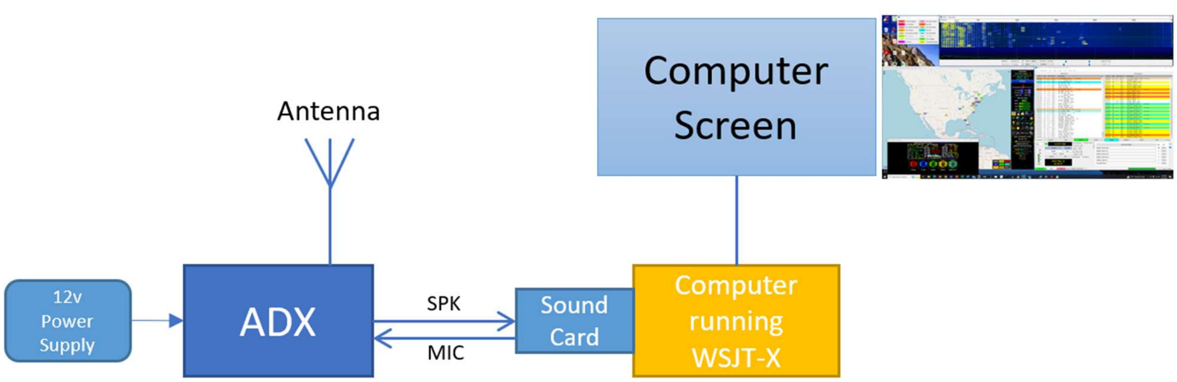
For setting WSJT-X to work with the ADX in Manual Mode:

- Go to Settings/Radio and activate PTT as VOX.
- Choose your soundcard under Settings/Audio menu
- Set Speaker Volume to 100%.

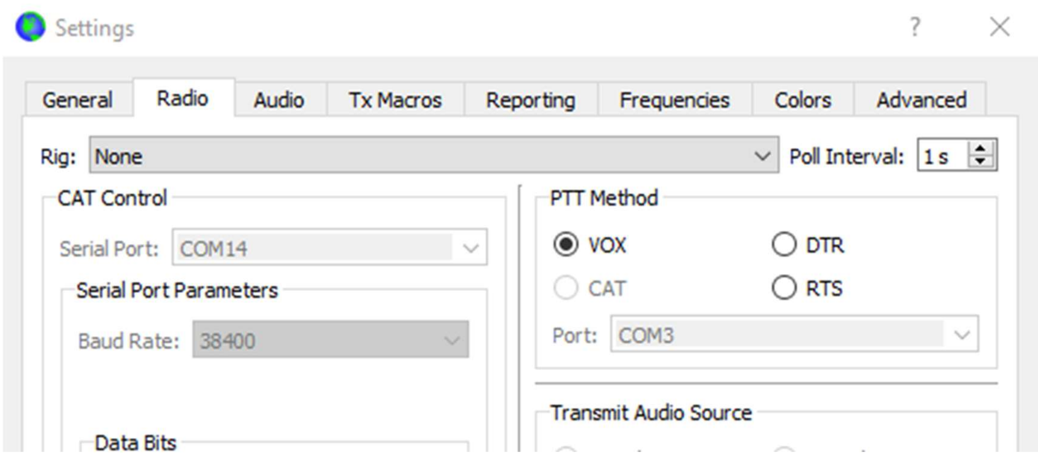
That's all you need to start working with WSJT-X. This applies pretty much to other software such as JS8Call or WSJT/Z etc.

CAT Control is not covered in this manual.

An example setup is summarized diagrammatically below:

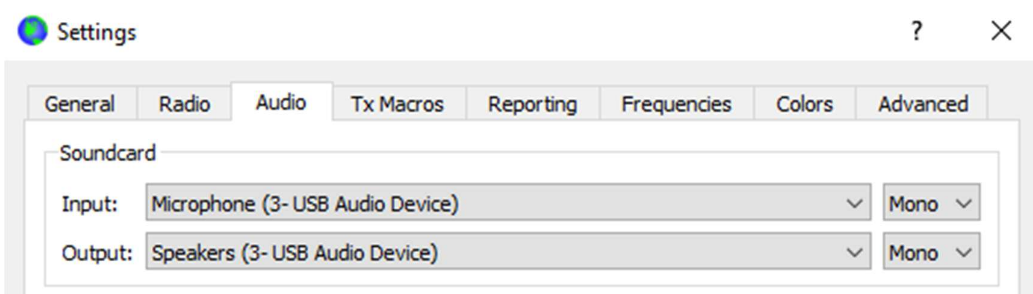


By way of example these are the settings in WSJT-X when using the ADX:



The only relevant setting here is to set the PTT Method to VOX.

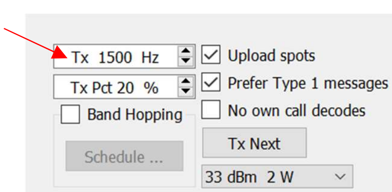
The input and output port will need to match the port allocated on your computer and the soundcard you are using. In this case I am using the Sabrent USB Sound Card recommended earlier which simply shows up as a USB audio device.



For full details on downloading, installing and using WSJT-X software including the latest documentation go to:

https://wsjt.sourceforge.io/wsjtx.html

Further calibration can be made with the ADX to align the transmitted audio tone to the correct frequency specified in your digital software (eg:WSJT-X), by using a spectrum scope (eg: as found on an IC7300 or similar). One method is to set the desired transmit tone in your software and then adjust the Arduino Nano in calibration mode to establish the correct frequency. The calibration process is covered in detail on the following pages but the WSJT-x tone settings and a summary of the process is shown below:



- Set the required transmission tone frequency in your software (eg:WSJT-X).
- Monitor the actual transmitted tone on the spectrum scope and note the difference between the observed and desired frequency.
- Enter calibration mode (see bottom of p30) and adjust up or down as required (you may need a lot of key presses of the up or down key to adjust the frequency), store the new values and then power cycle the ADX.
- Monitor the new transmitted tone on the spectrum scope to ensure correct frequency – repeat the process until the observed audio tone frequency is as close as possible to the desired. This will be an iterative process, and movement of a few hundred Hz may require quite a few key presses or holding down the button to make a meaningful adjustment. As you get closer to the desired tone frequency, a few key presses will be all that is needed to make minor frequency adjustments during calibration.

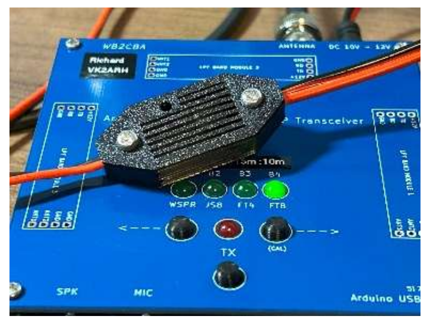
Additional Technical and Optimization Information

Power Supply Options

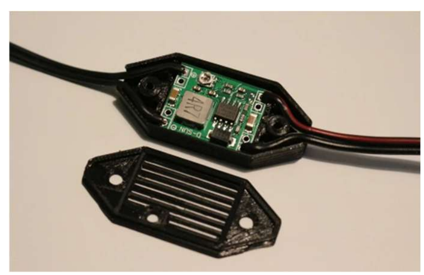
How will you be powering your ADX? The input voltage requirement is a regulated DC supply between 10-12v. **NOT 13.8v.** If you exceed the input voltage limit, you run the risk of destroying the Arduino Nano and overheating the PA FET's. Fortunately, the BS170's are an inexpensive replacement should they get damaged. The ADX will draw less than 500mA on transmit when optimized and the typical receive current is approx. 70mA. Some power supply options to consider include:

- A variable of fixed voltage power supply set to 12v if you are running the ADX in the shack.

- LiFePO4 battery voltage fully charged is typically 13.4v which is too high for the ADX. A battery pack of 3 x LiPo 18650 batteries provides a good portable solution. Although a little higher than the 12v requirement, the ADX protection diode will drop the voltage to a safe level to protect the Arduino Nano, and a lot of builders have had success with this type of battery supply.
- An in line buck converter to drop a regulated DC supply down from 13.8v works well. This will deliver slightly less than 12v with little impact on the RF power out. Be careful which one you choose as they can be quite noisy. We have seen good success using an MP1584 buck converter. You can buy them for less than $1 each (set of 10) from Ali Express. These little devices will support up to 3A and have a variable resistor to adjust the output voltage. When operating from a 13.4v LiFePO4 battery or 13.8v supply you can get a reasonably stable output around 11v with a noise level that does not appear to impact the ADX performance. The full data sheet for the MP1584 can be found here:
https://www.digikey.com/en/htmldatasheets/production/1785679/0/0/1/mp1584.html



- If you have access to a 3D printer there is a neat and practical housing for the MP1584 as shown in the photos - the .stl file can be found here: https://www.thingiverse.com/thing:1512385



- You can run the ADX as a low power WSPR beacon simply by powering it from the USB cable. In such a situation output is of the order of 300mW, but most will want to get 3-5 watts output for digital mode use.
- The 5.5mm x 2.1mm plug used for the power input to the ADX is included in the ADX kit.

Fine Tuning the ADX

The tuning of the ADX during construction (see page 19) established the operation of the Si5351 by monitoring the output of CAL test point and adjusting to establish a 1MHz square wave.

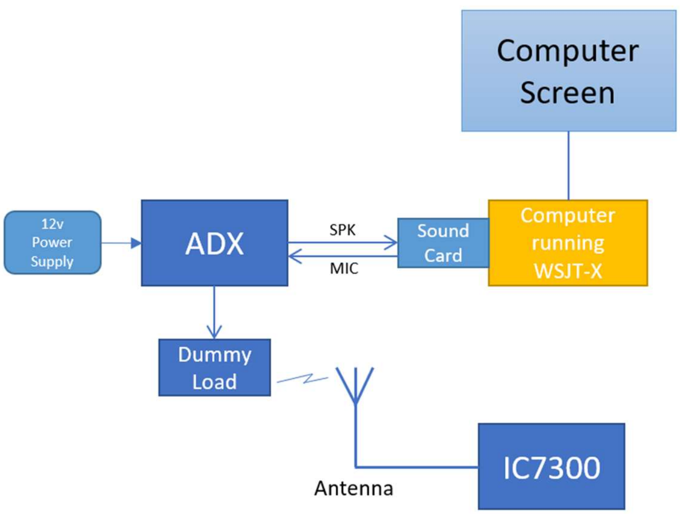
When you have built your ADX, it is a good practice to fine tune and calibrate your VFO. **There are several ways to do this**, but I have found the following technique the easiest to perform if you have access to a spectrum scope on a radio or SDR receiver. In this example I am using the spectrum scope on the Icom 7300 to perform the calibration, but any spectrum scope that you trust the frequency reading can be used. A video of this technique can be found here:

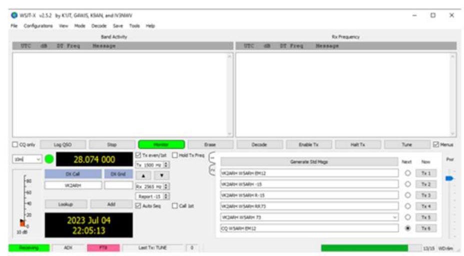
Fine tuning the ADX by calibrating the VFO

https://youtu.be/U0XXhpoytVk?si=i4EY2oaxJujAzzlQ

Setup

Set up the ADX with the correct band/LPF combination and connect it to WSJT-X. 'Warm up' the ADX for about 2-3 minutes to allow the VFO to stabilize. You will observe some drift in the VFO during the first couple of minutes as the Si5351 oscillator warms up and stabilizes. Attached a dummy load to the ADX and positioned an 'antenna' next to the dummy load. I used a short VHF whip antenna connected to the IC7300 in order not to overdrive the receiver, but a piece of wire connected to the receiver antenna input would work just as well. Schematically the setup is shown below:



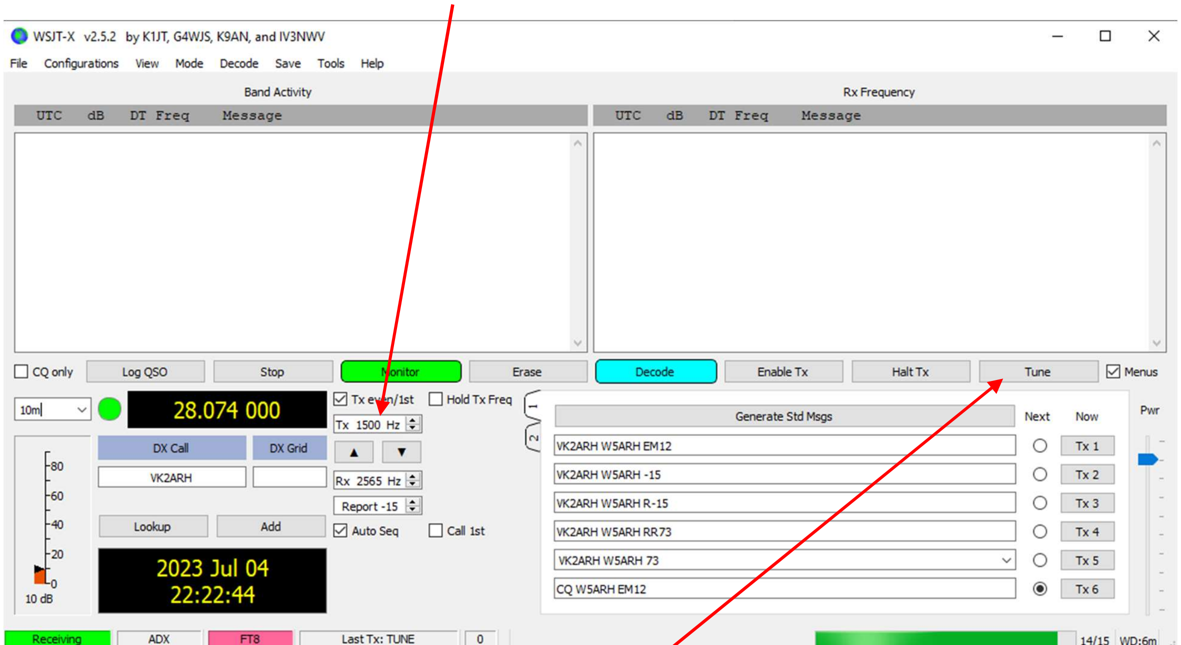


The actual setup I used is shown below:

Set the receiver to 28.074 MHz with the spectrum scope span set to 2.5KHz. Set the ADX to FT8 Mode (when powered up hit to left or right button to change mode).

Once tuned to 28.074 MHz all other bands will be tuned, and there should be no need for any further tuning.

Configure WSJT-X to Tx with a 1500 Hz tone:



Activate the Tune function of WSJT-X by pressing the 'Tune' button. The button should turn red and your ADX will transmit a 1500 Hz tone on the selected frequency. Press the 'Tune' button again when you wish to stop transmitting.

The 1500 Hz tone is in the middle of the transmitted 'sideband' so the output should appear in the middle of the band scope display ('0' offset). You should see a signal detected on the spectrum scope 'waterfall' as shown below. Adjust the tuning dial so that the observed signal is in the center of the scope and read the Tx frequency offset:

In this case the observed signal is a little below the '0' point and adjusting the tuning dial to center the signal shows that the transmitted signal is 28.073.86 MHz, 140Hz lower than the desired frequency of 28.074.00 MHz. Your Tx frequency will most likely be a little different from this example, I de-tuned my ADX to illustrate the point.

Stop the transmission by pressing the Tune button again in WSJT-X (the button should turn grey) and record the Tx frequency. If an adjustment is required adjust the frequency as follows:

Place the ADX into Calibration Mode:

- Power down the ADX
- Hold down the right hand ‘CAL’ button and keep it held down whilst you power up the ADX. The TX LED will flash briefly, and the FT8 and WSPR LED’s flash four times simultaneously and then remain illuminated indicating that you are in Calibration Mode. Release the CAL button when the FT8 and WSPR lights are flashing before they permanently illuminate. (otherwise you will start incrementing the counter value used to set the frequency of the Si5351).

Adjust the output frequency:

- You will need to press the left and right buttons many times to adjust the frequency. Start by pressing the button at least 20 times in quick succession. For larger frequency adjustments hold down the button for several seconds as the button will auto repeat the presses and increase the count. For larger frequency adjustments you may need to press the button for up to a minute. (Hint: start by pressing for about 10 seconds and observe the change in frequency and then adjust the amount of time the button is pressed for future frequency adjustments).
    - To increase the frequency repeatedly press or hold down the LEFT button.
    - To decrease the frequency repeatedly press or hold down the RIGHT button.
- To store the adjustment, briefly press (a short press) the TX button. The TX LED flashes three times indicating that the calibration adjustment has been saved and the ADX restarts, loading the new VFO settings from memory and displaying the previously established band and mode settings.

Test the output frequency:

- Activate the tune function again and observe the new Tx frequency on the spectrum scope.
- Determine the movement that has occurred as a result of the calibration, and **if necessary, repeat the calibration procedure** adjusting the number of button presses or time you hold the button down proportionally with the amount of frequency adjustment required. Do not be surprised if you need to hold the button down for up to a minute or more to move the Tx frequency in larger increments. You will likely have to repeat the process several times adjusting the amount of frequency adjustment as you hone in on the required frequency.

Ultimately you are looking for the FT8 transmitted signal with a 1500 Hz tone to appear in the middle of the spectrum scope, confirming that the ADX is accurately tuned.

Good Luck 😌

Optimizing and Determining ADX LPF Efficiency and Power Out

The efficiency of the ADX class E power amplifier is impacted by the bias applied to the BS170's by the LPF. The value of this bias can most easily be adjusted by varying the inductance of L2. Adjusting the winding spacing of L2 using the original number of turns or after reducing the number of turns by one turn will result in better performance. For most there will be no need to reduce the L2 turns, with good results possible from adjusting L2 winding spacing with the original number of turns.

A few simple adjustments to the L2 winding spacing can have a significant impact on the efficiency and power output from the ADX.

It is recommended that you adjust the winding spacing of L2 on the LPF for each band to achieve the best possible efficiency and optimize the power output from the ADX. You will typically see 3-4 Watts on the lower bands and 2.5 to 3W on the higher bands when operating at best efficiency. This will ensure that the BS170's do not overheat and potentially get damaged as a result. It is also important that the **ADX transmits into a resonant 50 Ohm antenna system** to prevent overheating and damage to the BS170's.

The following is one way of adjusting the LPF to achieve maximum efficiency and power output. The aim is to achieve the maximum power out with and efficiency greater than 70%. If you must choose between maximum power and maximum efficiency, choose the maximum efficiency to be on the safe side.

A video demonstrating the use of this technique can be found here:

Tuning the ADX LPF's to Optimize Power Out and...

https://youtu.be/XUK73C4GAUE?si=32XI5tZuAB7YwcqJ

The video also includes an explanation of the Barb-a-Watt so if you are not interested in that you can jump straight to 3:35 in the video for LPF tuning.

Equipment Needed:

You will need the following equipment to perform this process:

- An ADX and associated LPF's
- A stable regulated power supply
- An accurate ammeter
- A 50 Ohm dummy load
- A power meter capable of accurate measurement of the ADX output power (or a method of calculating the output power by measuring the output voltage from the BS170's).

In my own testing I used the Barb-A-Watt and its associated 50 Ohm dummy load, together with a Bench Power Supply as shown in the following photograph:

Efficiency Calculation

The efficiency of the PA section is calculated as follows:

PA Efficiency = Power Out / Power In to the PA section

Power Out is recorded by the RF power meter in Watts

Power In is calculated by observing the power consumed during transmit (Voltage * Current) – the power consumed by the circuitry within the ADX during the transmit cycle (excluding the PA section)

The power consumed by the ADX during the transmit cycle can be established by removing the LPF and observing the supply voltage and current consumption when pressing the Tx button. This will show all power consumed by the ADX during Tx without the PA section, as 12v is only supplied to the BS170's when the LPF is inserted.

It is recommended that you set up a spreadsheet as an aid to this process along the following lines for each LPF that you set out to optimize:

Test	Band	V_{in}	Tx Current No LPF mA	Non PA Pwr (W)	TX Current (mA)	P_{out} W	Tx $P_{in\,W}$	Eff %	Heat Loss (W)	Changes Made
1	40	12	72	0.864	340	2.6	3.216	80.85	0.616	Base state with even L2 windings
2	40	12	72	0.864	320	2.2	2.976	73.92	0.776	record changes made here eg: expanded L2 windings to Max Spacing
3	40	12	72	0.864		3.5	-0.864	-405.09	-4.364	
4	40	12	72	0.864		3.5	-0.864	-405.09	-4.364	
5	40	12	72	0.864		3.2	-0.864	-370.37	-4.064	
6	40	12	72	0.864		3.2	-0.864	-370.37	-4.064	
7	40	12	72	0.864		3.2	-0.864	-370.37	-4.064	
8	40	12	72	0.864		3.2	-0.864	-370.37	-4.064	
9	40	12	72	0.864		3.2	-0.864	-370.37	-4.064	
10	40	12	72	0.864		3.2	-0.864	-370.37	-4.064	

A blank copy of this sheet is available at my github page here:

https://github.com/VK2ARH/Cowtown-ADX-Project/blob/main/Blank%20LPF%20Testing%20Spread%20Sheet.xlsx

Method for Optimizing (For each band):

1. Your test setup should have the ADX connected to a 50 Ohm dummy load and enable you to record the power out whilst observing the input voltage and current.

2. Establish the non-PA power consumption by removing the LPF from the ADX and observing the voltage and current consumed when the TX button is pressed.

   There will be no power output from the ADX, but you will see an increase in power consumption from the receive state as additional components are now consuming power.

   Record the power consumption as this will be deducted from the power consumption during transmission with the LPF inserted to determine how much power is being supplied to the PA section.

3. Reinstall the LPF and ensure that the ADX is set to the desired band.

4. Press the Tx button again (Tx into a 50 Ohm Dummy Load) and observe the RF power out, and the input voltage and current.

5. Subtract the power consumption observed in step 2 from the input power in step 4 to determine how much power is being consumed by the PA section of the ADX.

6. Determine efficiency by dividing the RF power out by the PA power consumption. This is done automatically in the supplied spreadsheet if you are using that. Eg:

Test	Band	V_{in}	Tx Current No LPF mA	Non PA Pwr (W)	TX Current (mA)	P_{out} W	Tx $P_{in\,W}$	Eff %	Heat Loss (W)	Changes Made
1	40	12	72	0.864	420	2.6	4.176	62.26	1.576	Base state with even L2 windings

7. Now adjust the L2 inductance by varying the spacing on the windings. Record what change you made (eg: spread the windings a little further apart) and then repeat steps 4 to 6 and record the new result.

8. Continue to adjust the L2 windings until you reach your optimized state. You should be targeting efficiency greater than 70% with the maximum power out you can achieve at your best efficiency.

9. I adjust the colour of the cells in the efficiency and heat loss column of the spreadsheet to provide a visual indication of the LPF performance. The colour coding is shown in the sample spreadsheet on the GitHub page.

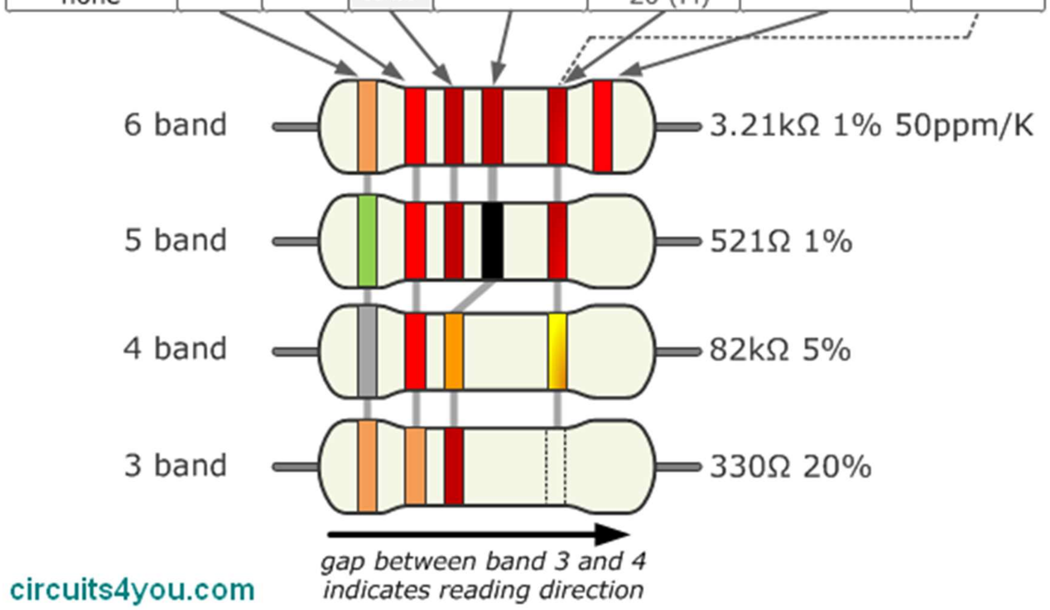
	Tx Efficiency above 70%	
		Heat loss suitable for WSPR without additional cooling (less than 1.5W)
		Heat buildup in BS170's suitable for FT8 but exercise caution with WSPR (2 min Tx Cycle) may need additional cooling (1.5 - 2W)
		Heat loss not suitable for operation without additional PA cooling (> 2W)

10. Undertake this test for each of the LPF's you wish to use.

Useful Information

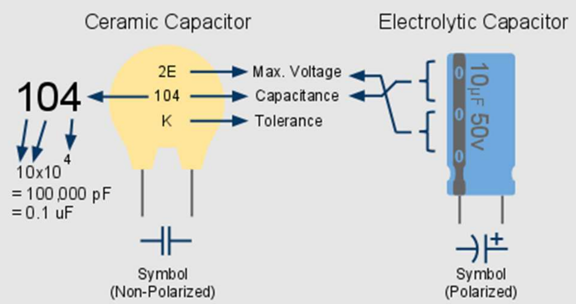
Resistor Color Code Chart

Color	Signficant figures			Multiply	Tolerance (%)	Temp. Coeff. (ppm/K)	Fail Rate (%)
black	0	0	0	x 1		250 (U)	
brown	1	1	1	x 10	1 (F)	100 (S)	1
red	2	2	2	x 100	2 (G)	50 (R)	0.1
orange	3	3	3	x 1K		15 (P)	0.01
yellow	4	4	4	x 10K		25 (Q)	0.001
green	5	5	5	x 100K	0.5 (D)	20 (Z)	
blue	6	6	6	x 1M	0.25 (C)	10 (Z)	
violet	7	7	7	x 10M	0.1 (B)	5 (M)	
grey	8	8	8	x 100M	0.05 (A)	1(K)	
white	9	9	9	x 1G			
gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)		
silver				x 0.01	10 (K)		
none					20 (M)		



Capacitor Identification Chart

Capacitors



Max. Operating Voltage

Code	Max. Voltage
1H	50V
2A	100V
2T	150V
2D	200V
2E	250V
2G	400V
2J	630V

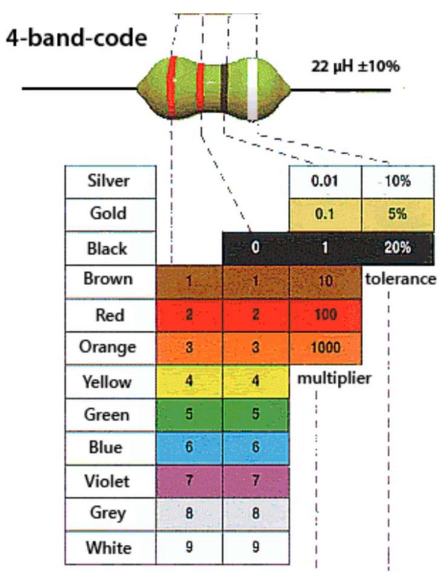
Capacitance Conversion Values

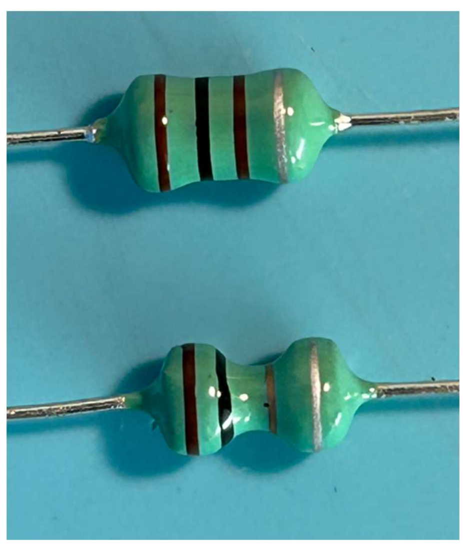
Microfarads (µF)	Nanofarads (nF)	Picofarads (pF)
0.000001 µF	0.001 nF	1 pF
0.00001 µF	0.01 nF	10 pF
0.0001 µF	0.1 nF	100 pF
0.001 µF	1 nF	1,000 pF
0.01 µF	10 nf	10,000 pF
0.1 µF	100 nF	100,000 pF
1 µF	1,000 nF	1,000,000 pF
10 µF	10,000 nF	10,000,000 pF
100 µF	100,000 nF	100,000,000 pF

Tolerance

Code	Percentage
B	± 0.1 pF
C	±0.25 pF
D	±0.5 pF
F	±1%
G	±2%
H	±3%
J	±5%
K	±10%
M	±20%
Z	+80%, -20%

Inductor Identification – Used in the ADX Kit





Brown: Black: Brown: Silver
1: 0: x 10 (multiplier)
= **100uH** 10% tolerance

Brown: Black: Gold: Silver

1: 0: x 0.1 (multiplier)
= **1 uH** 10% tolerance