Cowtown Amateur Radio Club

Buildathon 2023 Project #2 – ADX QRP Digital Radio

ADX Construction Manual

By Richard W5ARH / VK2ARH

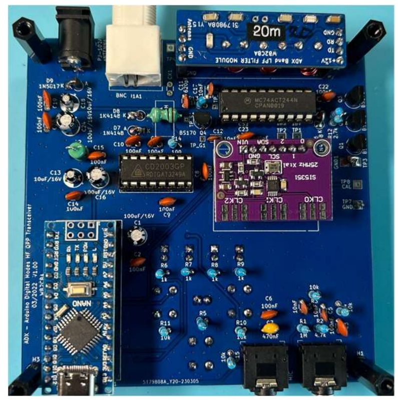
Version 1.1 27 May 2023 Initial Release

Table of Contents

Introduction

The ADX was chosen for the Club Buildathon as the second in a series of projects to create interest and build practical skills amongst the membership. The key components of the selection were:

- Relatively 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 will augment 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. **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 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 others, enjoy a mutual learning and fun environment in which to build the ADX. 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.

I recommend that you read the manual cover to cover 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 and details provided by WB2CBA and BD6CR using the links shown below.

Acknowledgements:

Barb, WB2CBA

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

Adam BD6CR

crkits.com

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 recommended, if you are comfortable with Pb.
- Wire cutters (fine precision type)
- 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 readers can assist with checking the quality of you soldering.

The kit uses all through hole components although 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 a 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 a 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.

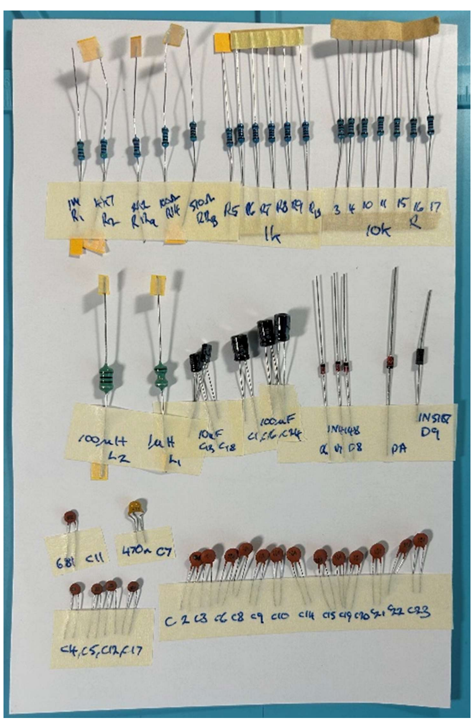
An example of a cleared and ordered work bench ahead of the kit build. Individual equipment will vary.
(My workbench isn’t always that tidy ☺)

Bill of Materials (BOM)

Sub Component Bag	Part	Designator	Qty
Capacitors & Ceramic Filter	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
	5.1Pf	C25	1
	PFB455JR Ceramic Filter	FL1	1
	Self Adhesive Silicon Pads	For use on bottom of completed ADX	4
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
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
Static Sensitive Devices	BS170	Q1,Q2,Q3, Q4	4
	CD2003GB_GP	U1	1
	SN74ACT244N	U3	1
	SI5351_Module	U2	1
	Arduino Nano	XA1	1
Resistors	1M	R1	1
	2.7k (2.2K and 510R to be used in series)	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
Hardware	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.	1
	Pin Header Male 4 pin	PCB LPF Socket	Qty
	Mounting Spacers	6mm	4
	Mounting Spacers	18mm	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 See LPF Kitting List Unique per Order	LPF Board	Include one Spare LPF Board with each kit	Qty
	26awg magnet wire	Qty varies depending upon chosen bands	Qty
	T37-2	2 with each LPF <= 20m	Qty
	T37-6 Use for 10m LPF	2 with each LPF >= 17m	
	FT37-43	1 for each LPF	
	Pin Headers - Male & Female 4 Pin	One set for each LPF (to be cut from 40pin strips)	Qty

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.

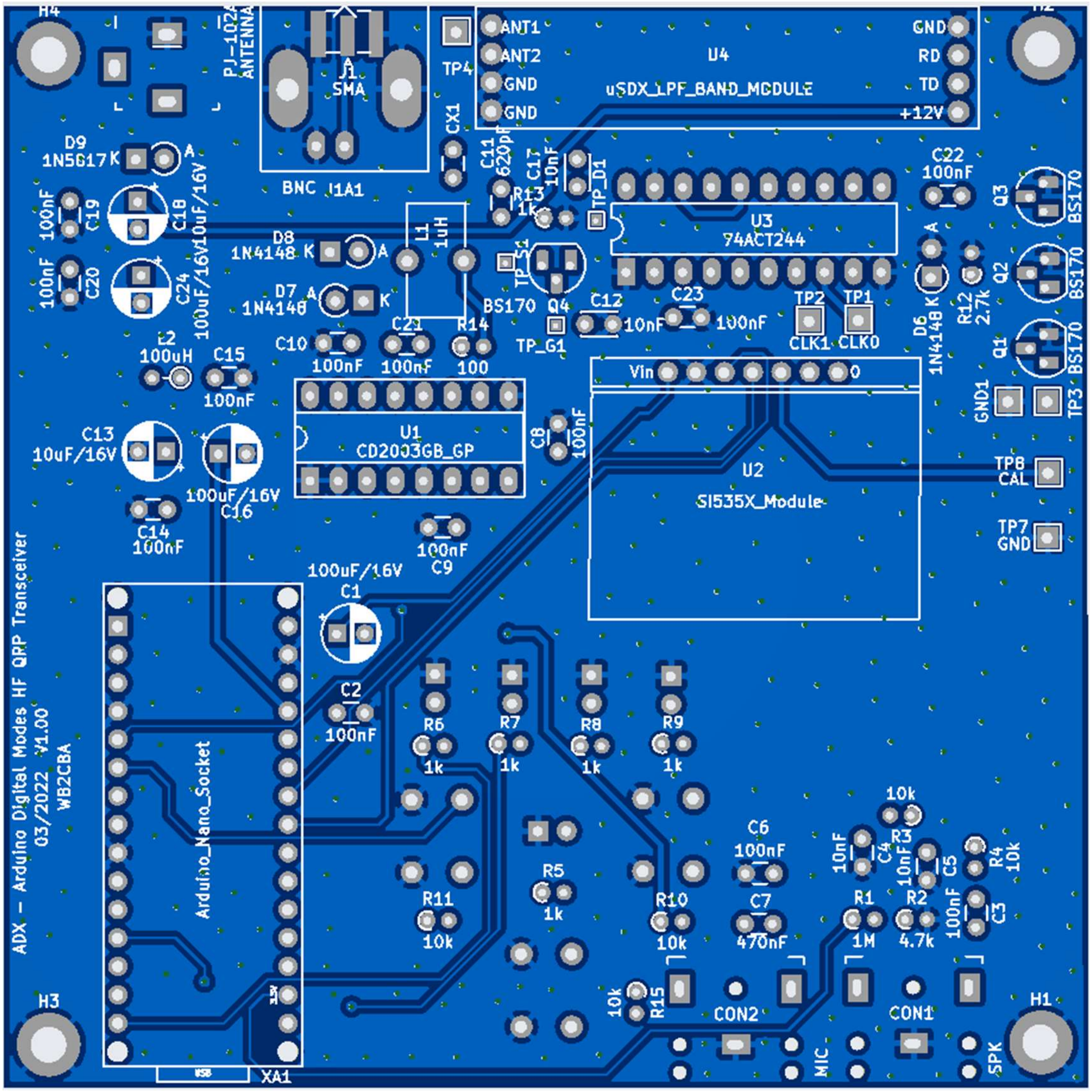


In this example the smaller through hole components have been tested and then stuck onto a piece of paper with masking tape before being labelled to speed identification. Testing of each component not only assists in identification, but also ensures that any faulty or out of spec component is not used 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.

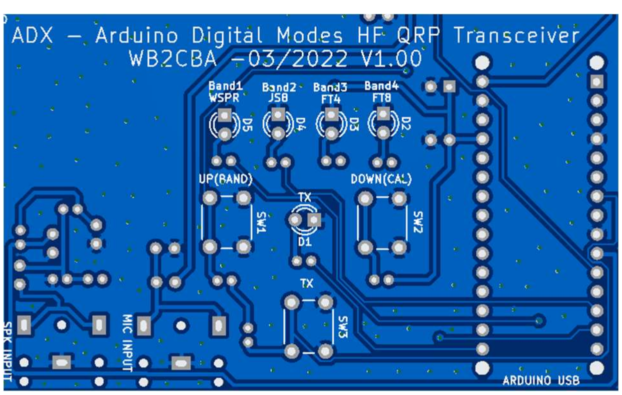
Resistors can easily be tested with a Multimeter; however, capacitors and inductors may need an LCR meter which is not essential but handy if you want to check the tolerances of components. It is not necessary to obtain a high precision meter, but just be aware and allow for the meter tolerance when measuring components.

PCB and Schematic Diagram

Here is a layout of the component side of the main ADX PCB.



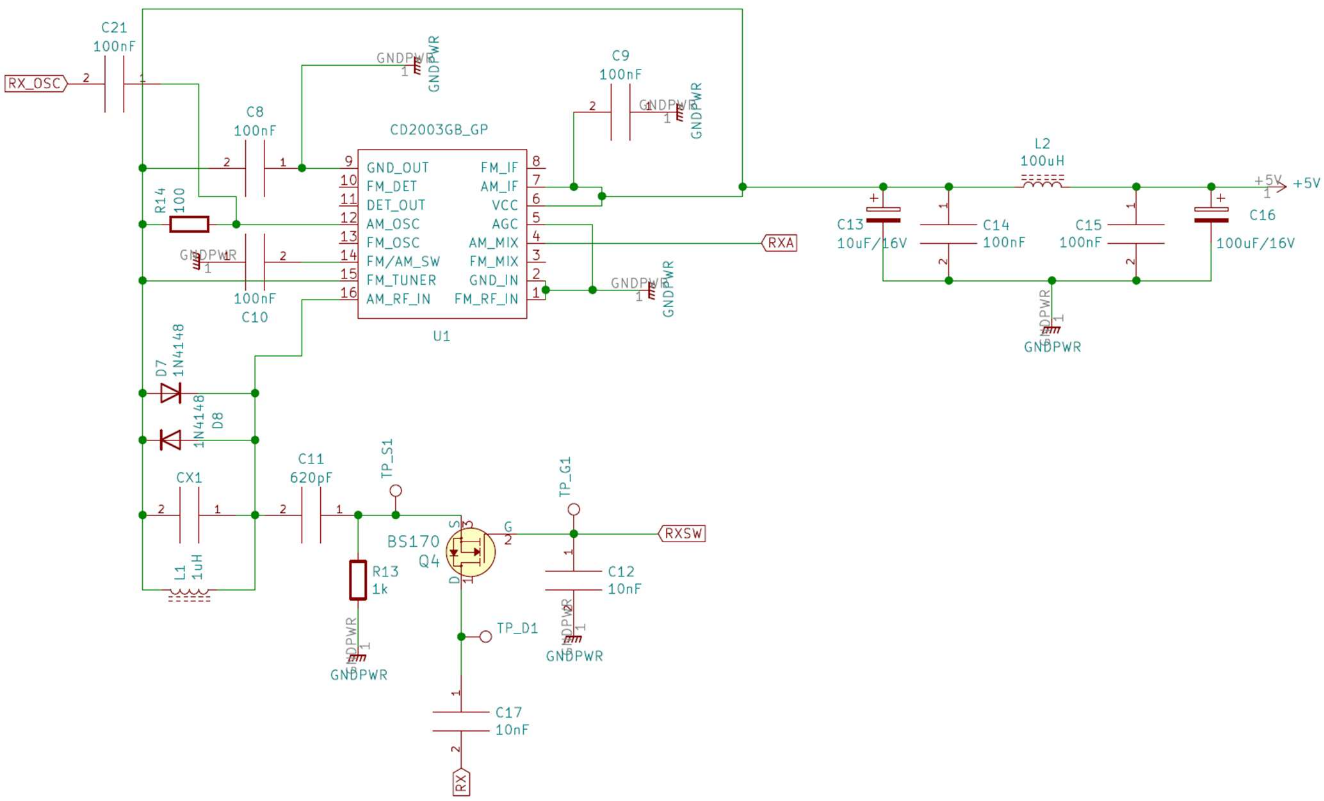
All components are placed on this side of the board except for the LED's and small pushbutton switches which are placed on the solder side of the board shown below.



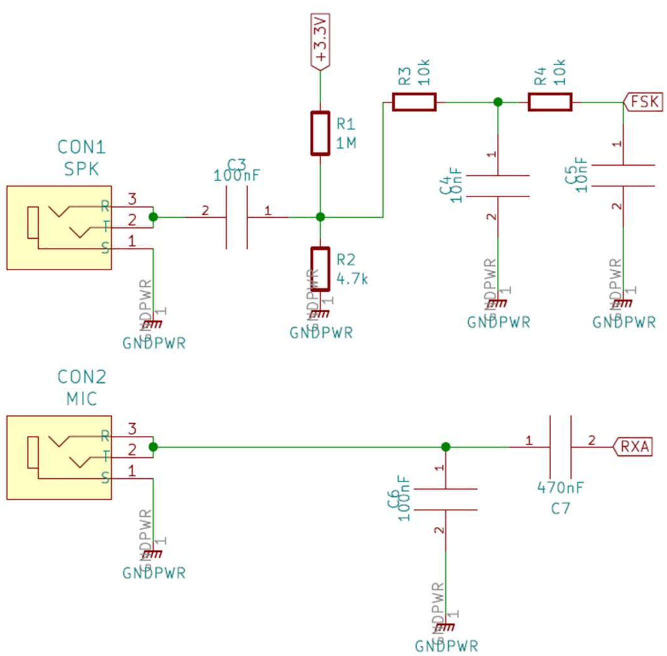
The full circuit schematic diagram can be found here https://github.com/WB2CBA/ADX

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

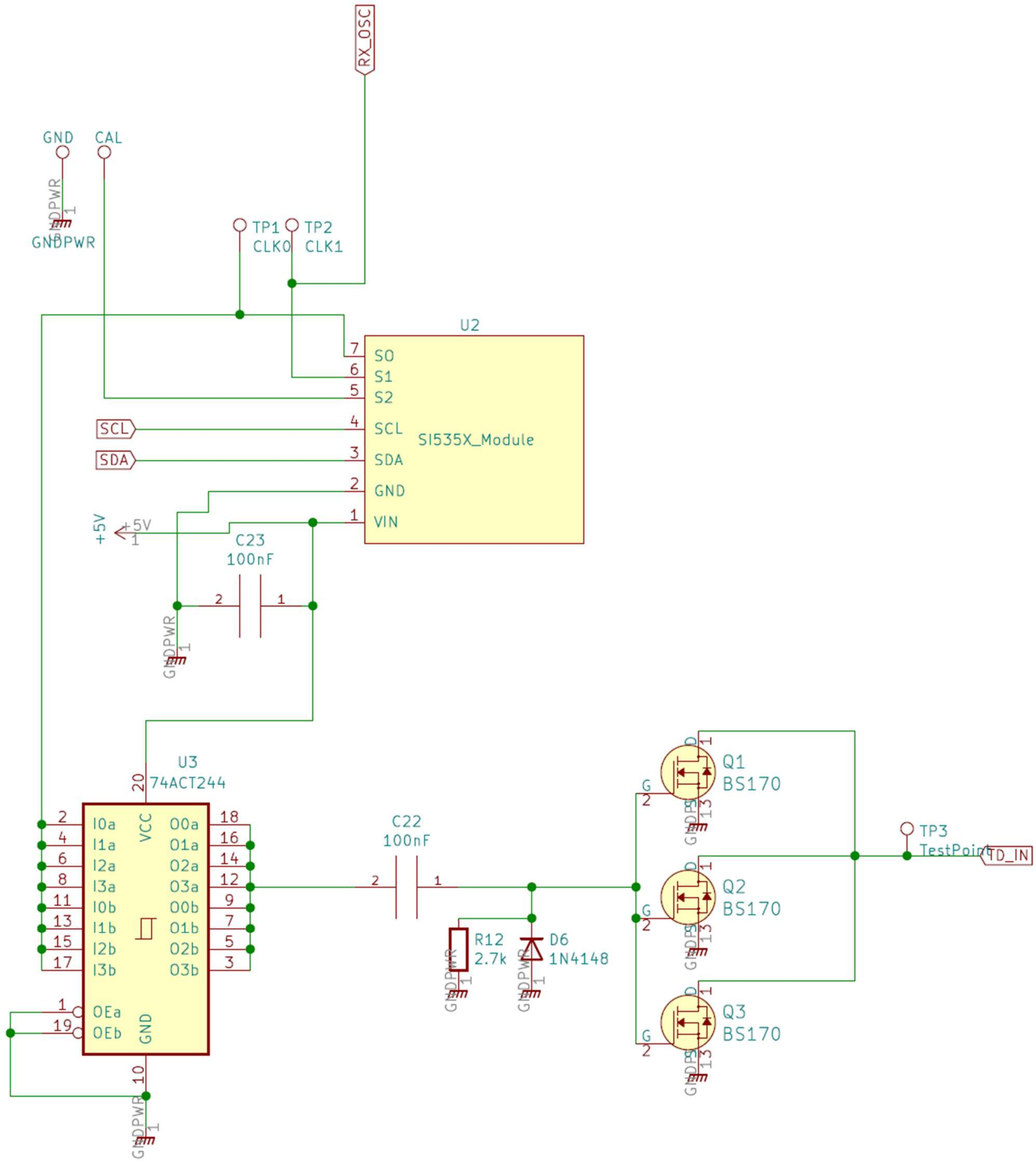
Receiver Section:



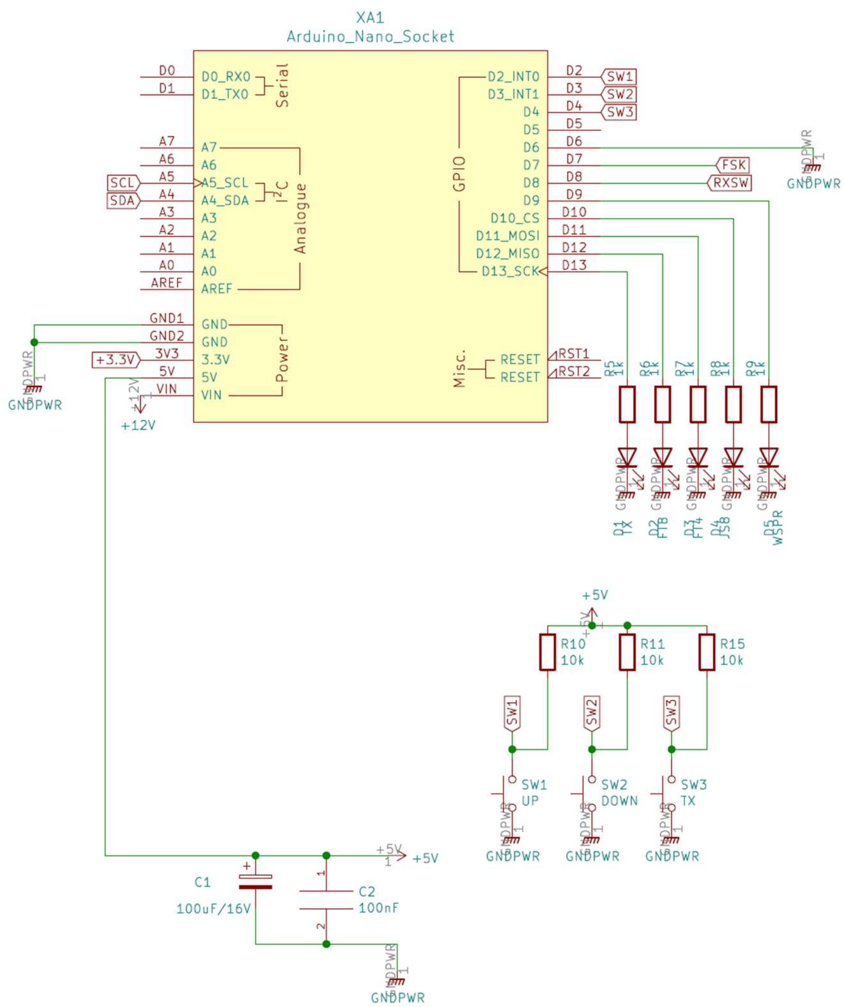
Audio in and Out



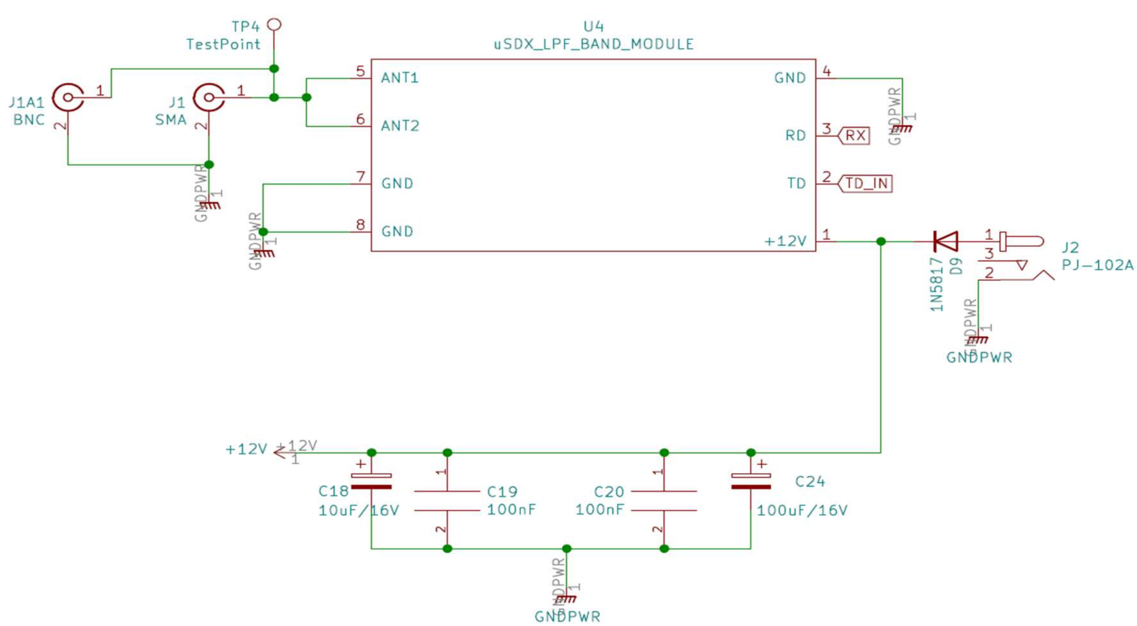
Transmitter and VFO Section



Arduino Nano

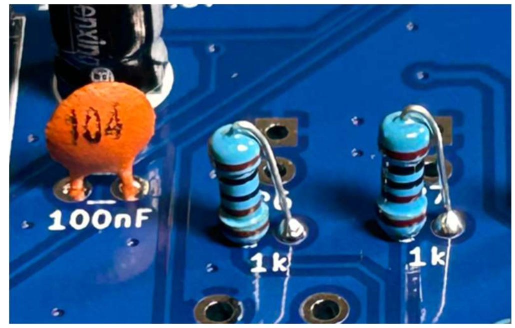


Antenna Connection, LPF Band Module and Power



Construction Tips

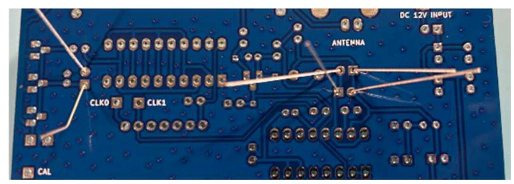
Many of the spaces on the ADX board have 2.5mm hole spacing and this will require several the components to be mounted on their end as shown below:



Whilst it makes no difference electronically 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.

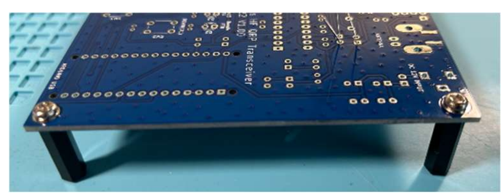
For diodes when mounted standing on an end, I mount them with the cathode band at the top. This aids in checking the correct polarized installation of the diode. The anode is then always down at the bottom aligned with the round solder pad on the ADX board.



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 before soldering, in order to avoid a 'rats nest' of leads that will interfere with your soldering iron tip and the solder.

If you have a through hold device whose leads are too wide for the 2.5mm holes on the board, take a pair of needle 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.

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. Don't go buying the expensive stuff, 99% isopropyl alcohol can be purchased from the pharmacy section at Walmart for less than $5 for a 16oz bottle.



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

If you do not get the results required at each stage of testing as outlined in this manual, <u>do not proceed to the next step until such time as you have been able to resolve and correct the issue</u>. 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 et.

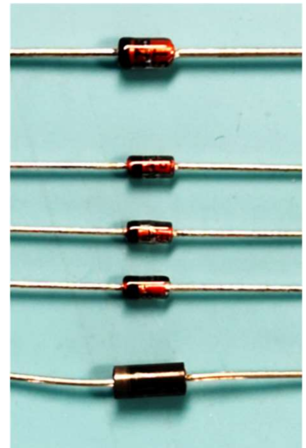
Page | 15 ☑

Building the ADX in Stages

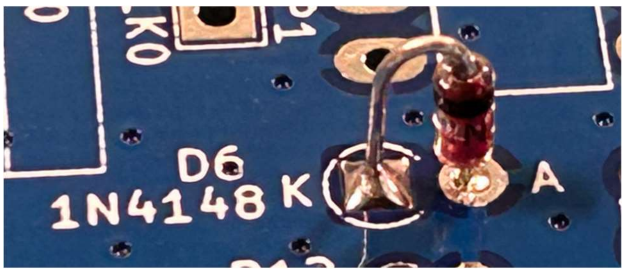
Step 1: Diodes

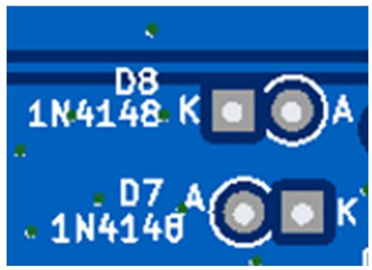
Identify the five diodes:

- ☐ 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.

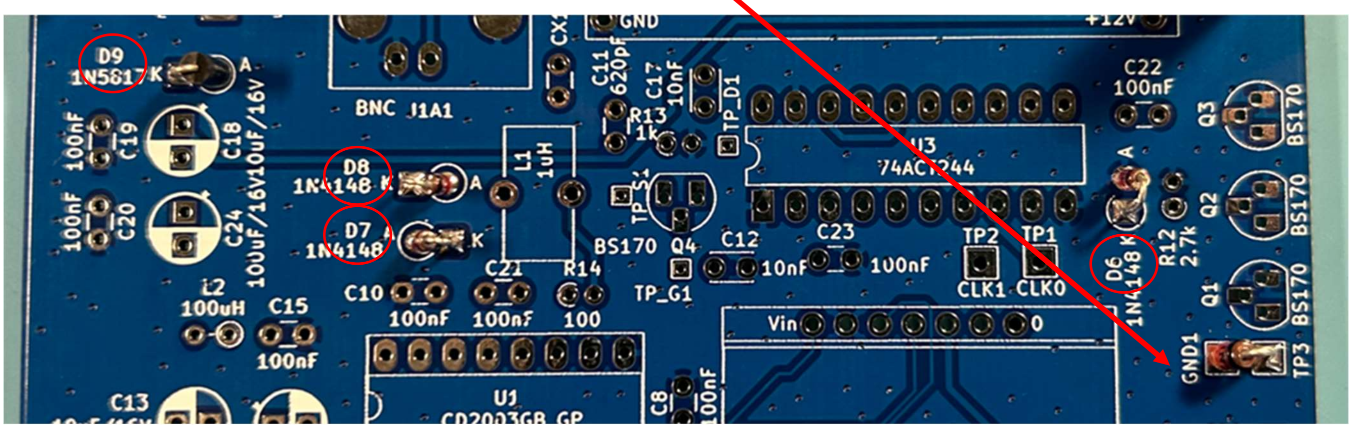


All diodes are polarized so it is important that you take the time to identify the correct orientation for installation. The black or silver band on the diode identifies the cathode. **On the ADX board the cathode is denoted by the square solder pad** and the letter K. The **Anode is denoted by the round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

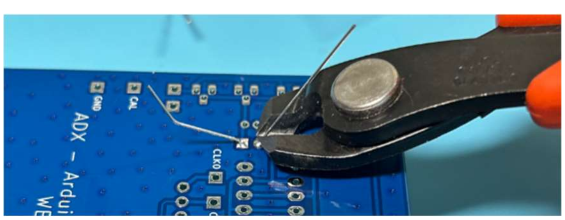




Identify the locations for each component and solder D6,D7,D8,D9 to the board. Double/triple check the orientation before soldering. The PA protection diode is not identified on the board but is soldered on the right side of the board between GND1 and TP3 with the Anode to the GND1 pad.



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**). If the lead is soft and you cut slowly it is probably not necessary, but it’s something to consider.

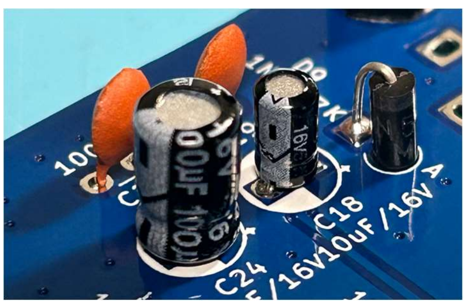
Step 2: +12V Power

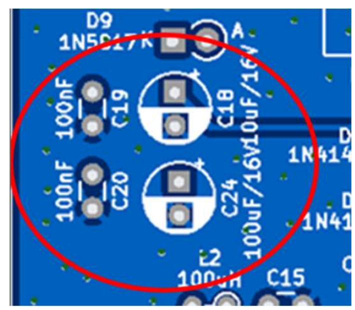
The +12v power supply section uses both electrolytic capacitors and standard ceramic capacitors. The electrolytic capacitors are polarized and need to be installed accordingly. The -Ve lead is the shorter of the two and the body of the capacitor clearly indicates the -Ve lead. The ceramic capacitors are not polarized and are identified with a numeric representation of their value. (See P35 for a capacitor identification chart).

Identify and solder the following components to the board:

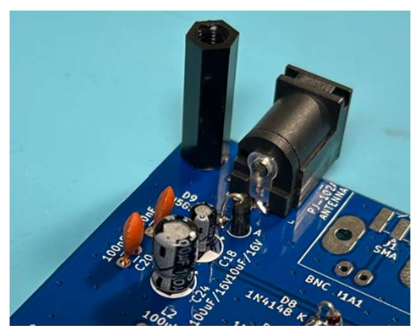
- ☐ C18 – 10uF 16v (your electrolytic capacitors may be rated at 25v which can be used as a direct replacement)
- ☐ C24 – 100uF 16v
- ☐ C19, C20 – 100nF Ceramic Capacitors (Marked 104)

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.





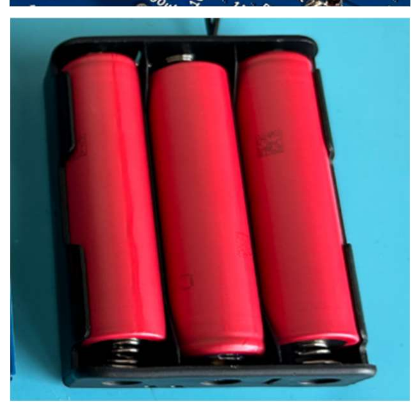
- ☐ Install the PJ-102AH power jack onto the PCB. Your input power supply sections should now look like this →



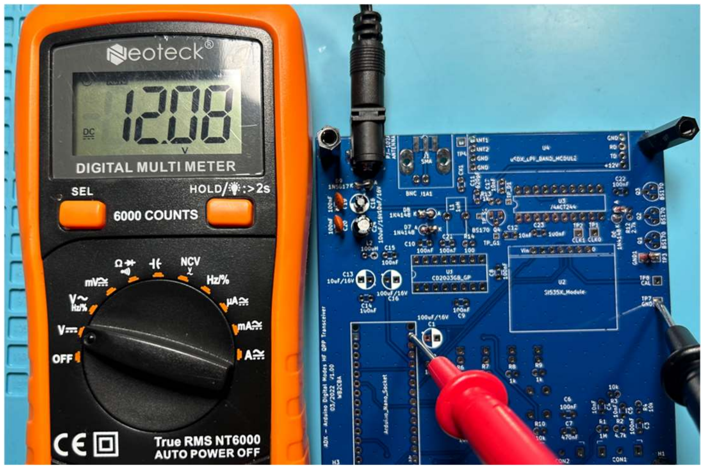
We can now proceed to check that the incomming supply will deliver power to the V_{in} pin on the Arduino Nano (XA1)

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.



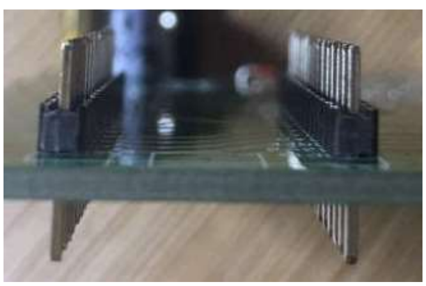
After connecting a 12v supply using a 5.5mm x 2.1mm (**Center Positive)** plug to the ADX board, use a voltmeter to confirm that you are supplying power to pin 1 V_{in} on the Arduino Nano. You can select any of the earth points on the board for the negative probe. The DC Power plug is supplied in the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



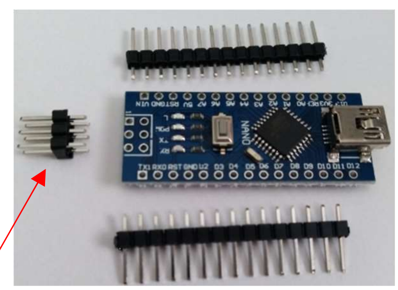
Step 3: Preparing Pin Headers, Arduino Nano and +5V and +3.3V Power

The Arduino Nano (XA1) supplied with the kit will either have its pins pre-installed (in most cases) although a small number were supplied without the headers soldered to the Nano.

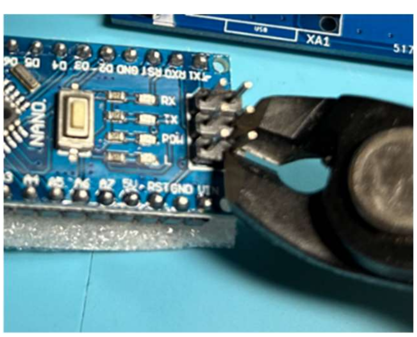
In the latter case you will need to solder the pin headers to the Nano before progressing with these instructions.



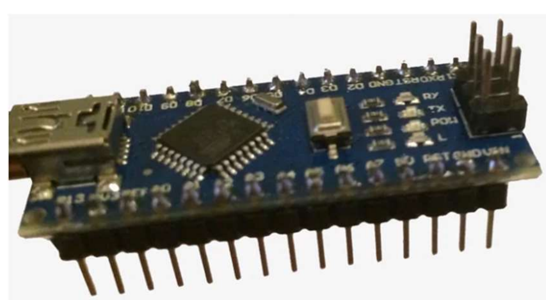
The best way to do this is to place the pin headers that came with the Nano into the main PCB (long lead into the board) to ensure correct alignment. Then place the Nano onto the pin headers and carefully solder the Nano to the pin headers. Solder quickly and spread the heat load soldering every second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



Do not 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. It is strongly recommended that you DO NOT solder the pin headers directly to the main PCB unless you plan to permanently install the Nano. Having the flexibility to replace the Nano has its advantages.



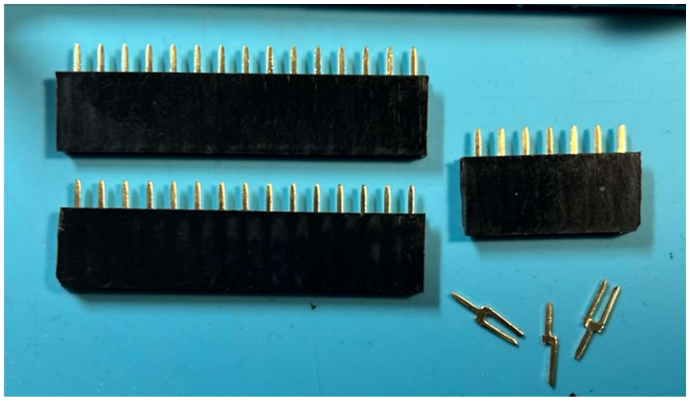
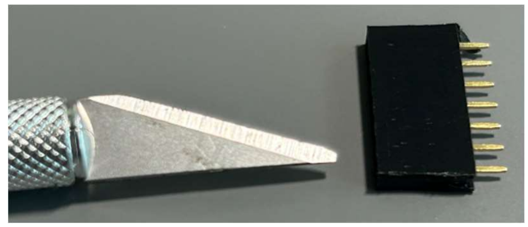
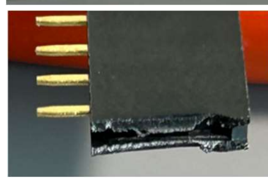
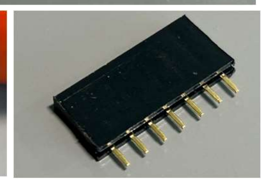
Most kits were supplied with the Arduino Nano with the pin headers already installed as shown here. However, before installation we will need to remove the 6 I/O pins. The easiest way to do this is to use your wire cutters and carefully cut off the pins one at a time so that they are flush with the top of the plastic standoffs.



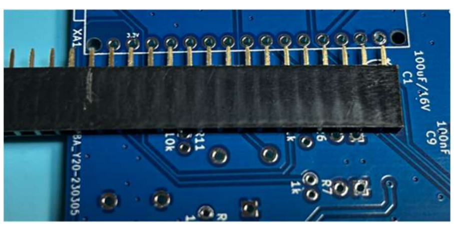
☐ Preparing your pin header strips

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.

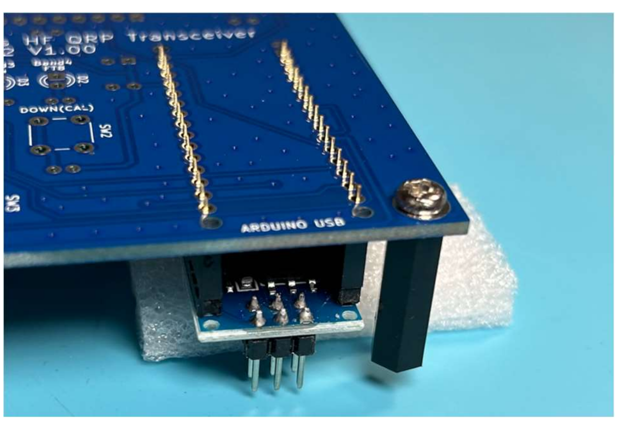
The strip will be cut to provide two 15 pin headers (for the Arduino Nano) and one 7 pin header (for the SI5351). When finished your strip will end up looking like those shown below. The cutting process will destroy one of the headers and leave a ragged edge, but this is cleaned up easily with a modeling 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 a nice clean end on each 15 pin header which you can solder toward the edge of the ADX and will look a lot neater.



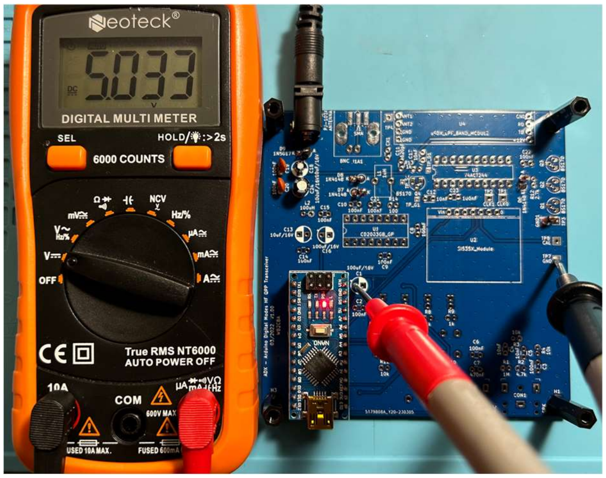
Now to install your pin headers onto the ADX. Fit the pin headers and the Nano onto the board, turn the board upside down and place a piece of foam or similar underneath the nano so that the weight of the board allows the pins to protrude through the solder side of the board. This ensures vertical alignment of the headers. (I realize that the 6 I/O pins had not yet been removed when this photograph was taken): 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 it to spread the thermal impact on the header pins. The finished result should look similar this:

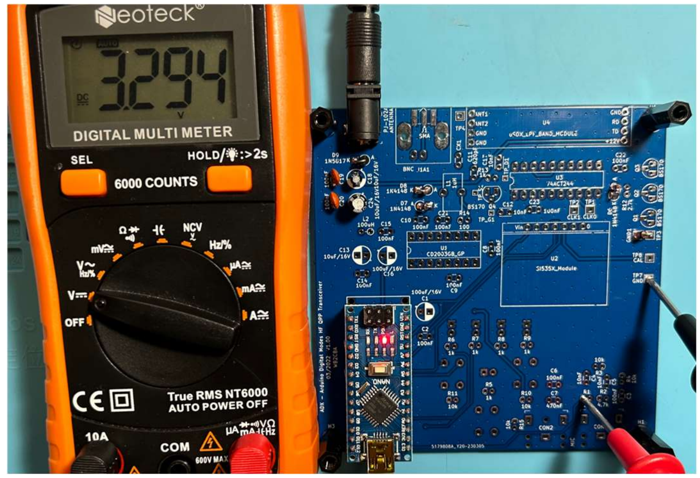


Checking the 5V and 3.3V Supply

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 then check for +3.3V using the left pin of R1.



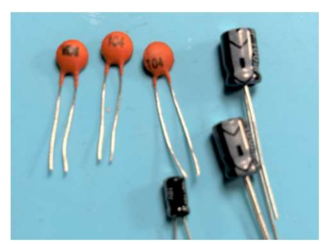


Take care when using the probes that you don’t create a short circuit as this may damage the regulators. If you do, you will have to replace the Nano which can be accomplished as you used pin headers instead of soldering the Nano directly to the PCB.

Step 4: CD2003 Power Supply

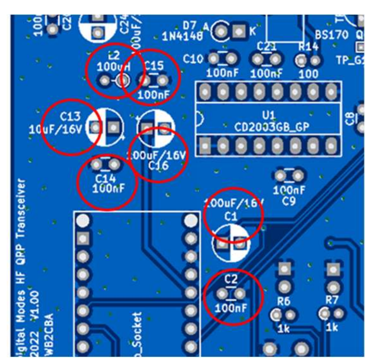
The CD2003 analogue receiver chip requires filtering of its’ power supply line. There are two fixed inductors supplied with the kit, L1 and L2. Both are shown below however we only need to use L2 the 100uH inductor at this stage. L1 the 1uH inductor is the one with the narrower center. Put L1 (the thinner inductor) to one side for now. You need to identify and solder the following components to the board. (see P35 for an inductor identification chart).

- ☐ L2 100uH Inductor
- ☐ C13-10uF (103)
- ☐ C1, C16-100uF
- ☐ C2, C14, C15-100nF (104)



These components are placed as shown on the diagram →

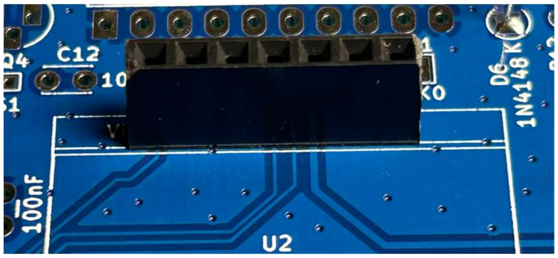
Be careful to ensure that you observe the correct polarity of the electrolytic capacitors. Your board should look something like this after this step.



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 5351 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.

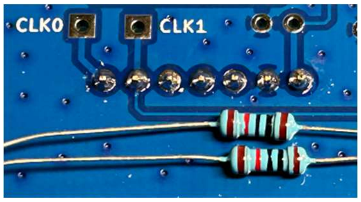
DO NOT install the Si5351 just yet.

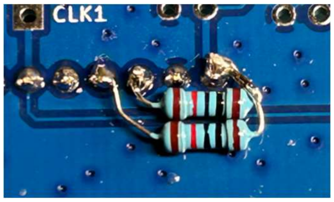
Now for the second modification to the original design – we will be installing R16 and R17 as pull up resistors on the SDL and SCA signal lines going from the Si5351 to the Arduino. This was added after the original board was designed, as a precaution to overcome any possibility that the Si5351 you are using 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.

Identify the R16 and R17 - 10K resistors and solder them to the <u>solder side</u> of the PCB under the Si5351 socket. Two leads are joined, and both go to Pin1. The other leads go to Pin3 and Pin4 as shown below.

(Note: Pin 1 in on the right when viewed from below)

- ☐ R16, R17 – 10K



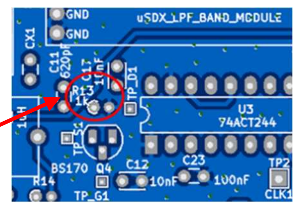


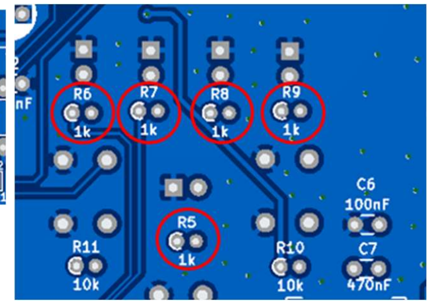
Step 6: LEDs and Buttons

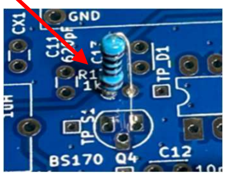
Identify and solder the 1K resistors to the board:

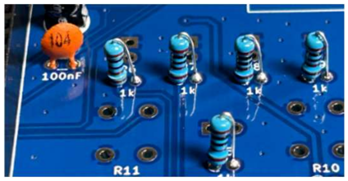
- ☐ R5, R6, R7, R8, R9, R13 – 1K

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



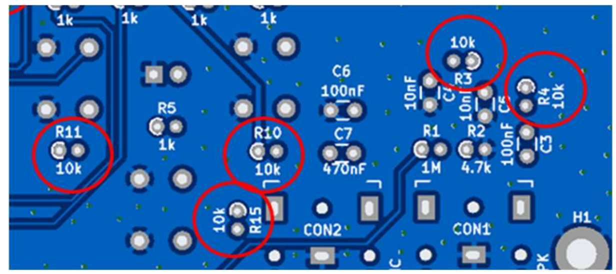




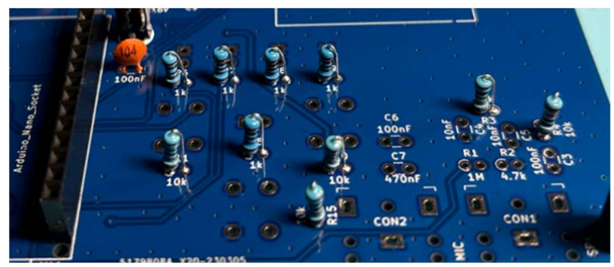


Identify and solder the 10K resistors to the board:

- ☐ R3, R4, R10, R11, R15 – 10K

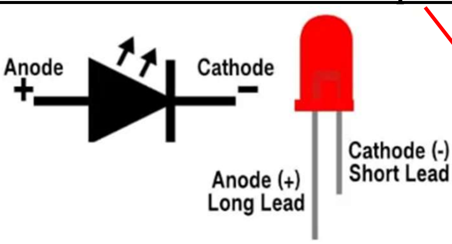


The lower section of the board should look something like this:



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 __**shorter lead is the cathode and this soldered to the square pads**__ 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. The result is shown to the right:

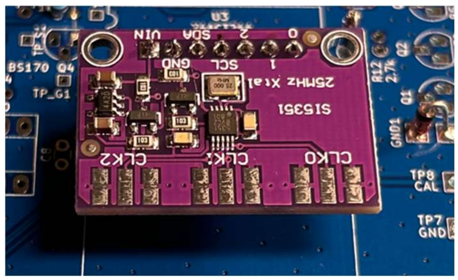
Installing the Si5351

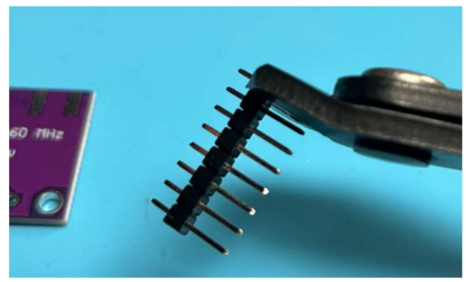
The Si5351 is a static sensitive device, so avoid unnecessary handling and short out any probe (oscilloscope etc.) before you connect it to the Si5351.

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 we'll be using that later.

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

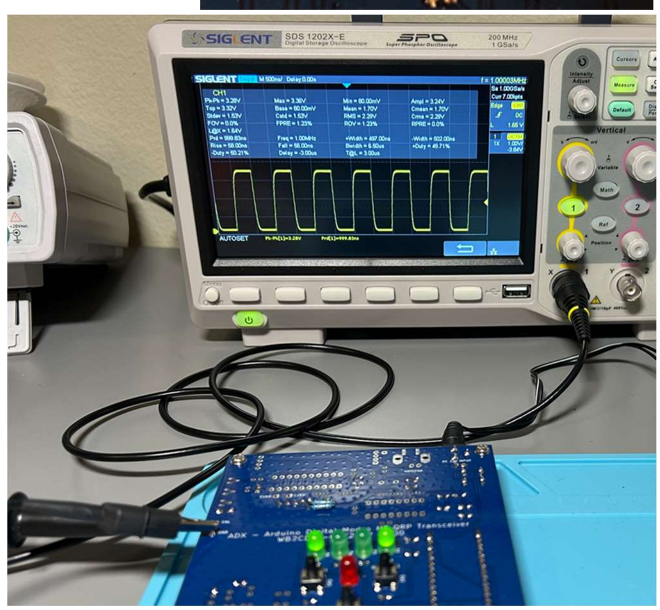




We can now progress to check the Si5351's operation.

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 permanently on. Release SW2. 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 devices.



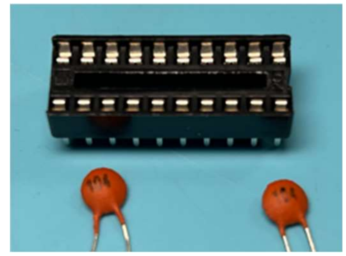
A coarse calibration can be performed here if there is a large variance between your observed oscillator frequency and 1Mhz. Press SW1-UP(BAND) or SW2-DOWN(CAL) several times to get the output frequency as close as possible to 1MHz.

When you are happy with the output signal frequency, 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.

Step 7: Transmit Driver MC74ACT244

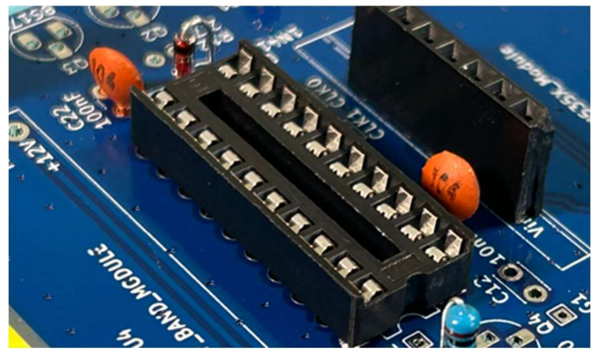
Identify and solder the following to the PCB:



- ☐ 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: →



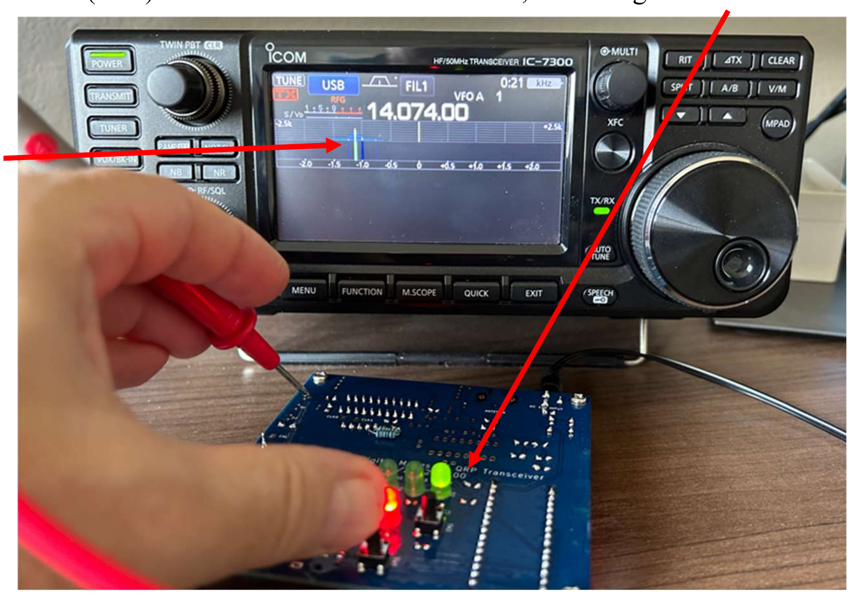
- ☐ U3- MC74ACT244

The new chip comes with its' leads 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 leads vertical. Don't bend the pins one by one. It's best to align <u>both</u> strips of leads 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 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. 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 a LED was illuminated, indicating the mode was set to FT8.

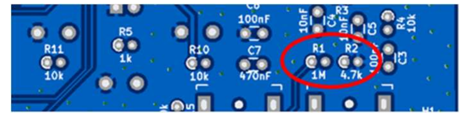


In my example my IC7300 band scope showed a signal, and an audio tone was heard - confirming the ADX was transmitting on the correct frequency.

The frequency of transmission is set by the combination of the band and mode selected.

See p30 for details of frequencies for each band and mode setting.

Step 8: Complete the TX

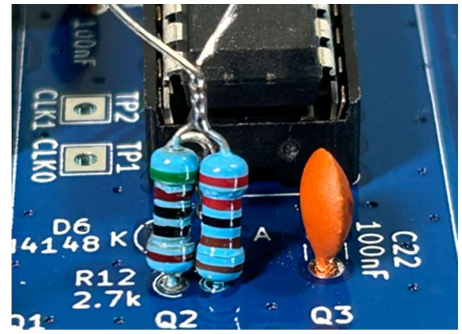


Identify and solder the remaining 4 resistors to the PCB:

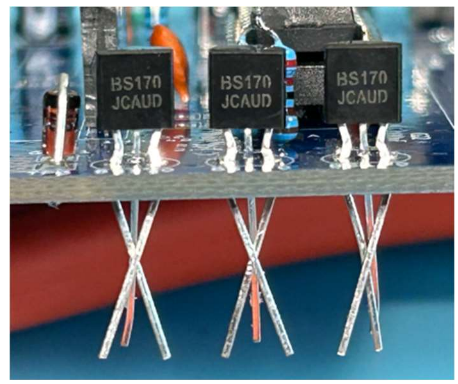
- ☐ R1 -1M
- ☐ R2 - 4.7K
- ☐ R12 - 2.7K (2.2K and 510R to be installed in series)
- ☐ R14 - 100R.

When installing R12 you will first twist two leads from the 2.2K and 510R 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:



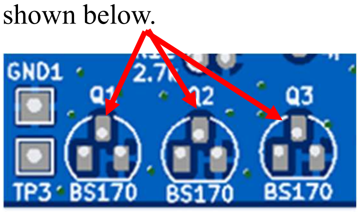
Remove three BS170 transistors from their packaging **<u>being careful not to touch the leads as they are static sensitive</u>**. Take care to insert them correctly aligned into the PCB. It can be a little fiddly alignng the leads into the holes but when you have them in their holes, push the MOSFET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

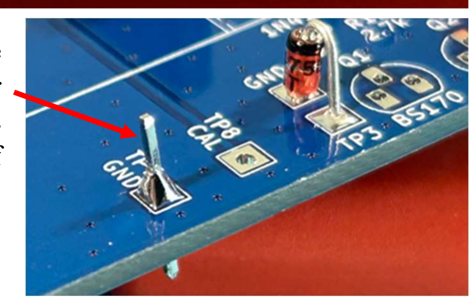
If you don't have an ESD protected soldering iron, populate the board with Q1-Q3 as above and solder all leads but **NOT** the center lead for each transistor as shown below.



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 →

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 a LPF, you should stop here and jump ahead to section 11 p29 and make at least one LPF before continuing from this point.** LPF's will be available for use during the supported 'Buildathon' program.

When installing the LPF connections to the PCB, 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 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.

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 is flush with the PCB and aligned perpendicular to the edge of the PCB.

- ☐ J1-BNC Connector

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

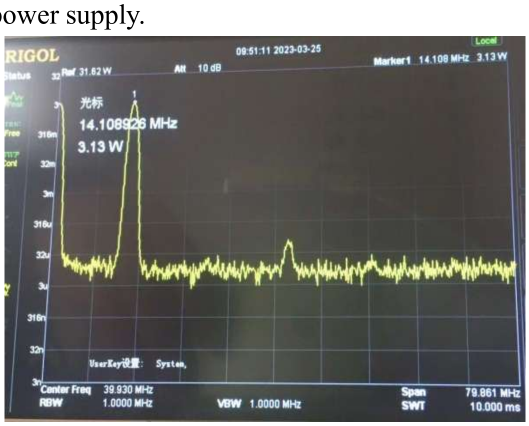
YOU MUST INSTALL A LOW PASS FILTER MODULE AND SELECT THE CORRECT BAND FOR THE SELECTED FILTER BEFORE PROCEEDING

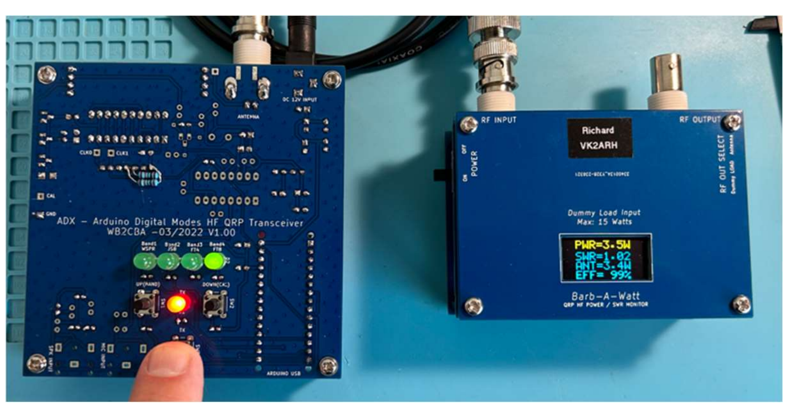
Make sure the LPF module and the band setting of Nano are matched. If not, press and hold the SW1-UP(BAND) button during power on, to enter the band configuration mode. To adjust the band, press SW1-UP(BAND) or SW2-DOWN(CAL) until you select the band that matches the LPF. The default band settings are B1 – 40, B2 – 20, B3 – 15, B4 – 10. Press SW3-TX to confirm the band setting. The TX light will illuminate briefly and the selected band will flash three times before a Green LED will illuminate 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 -45dB 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 well the power out will be between 1.5w and 4.5w depending on the band chosen. Lower frequency bands will emit more power.

The overall current draw on transmit should be around 600mA, this can be measured with your multimeter or a bench power supply.

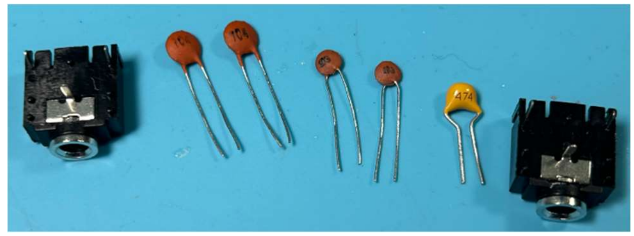




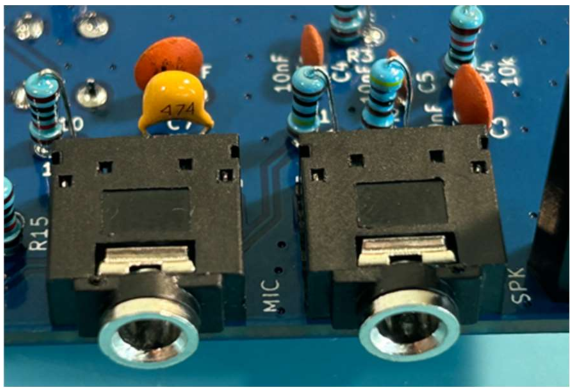
Step 9: Audio Jacks

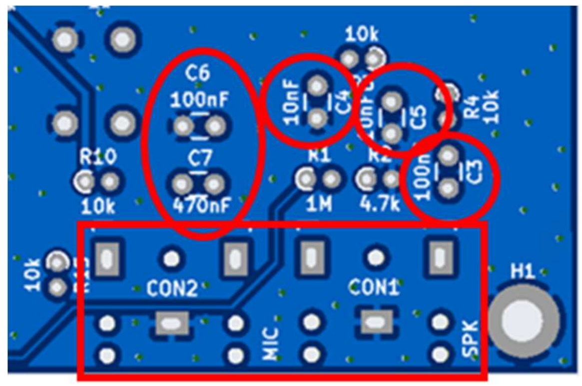
Identify and solder the following components to the PCB:

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



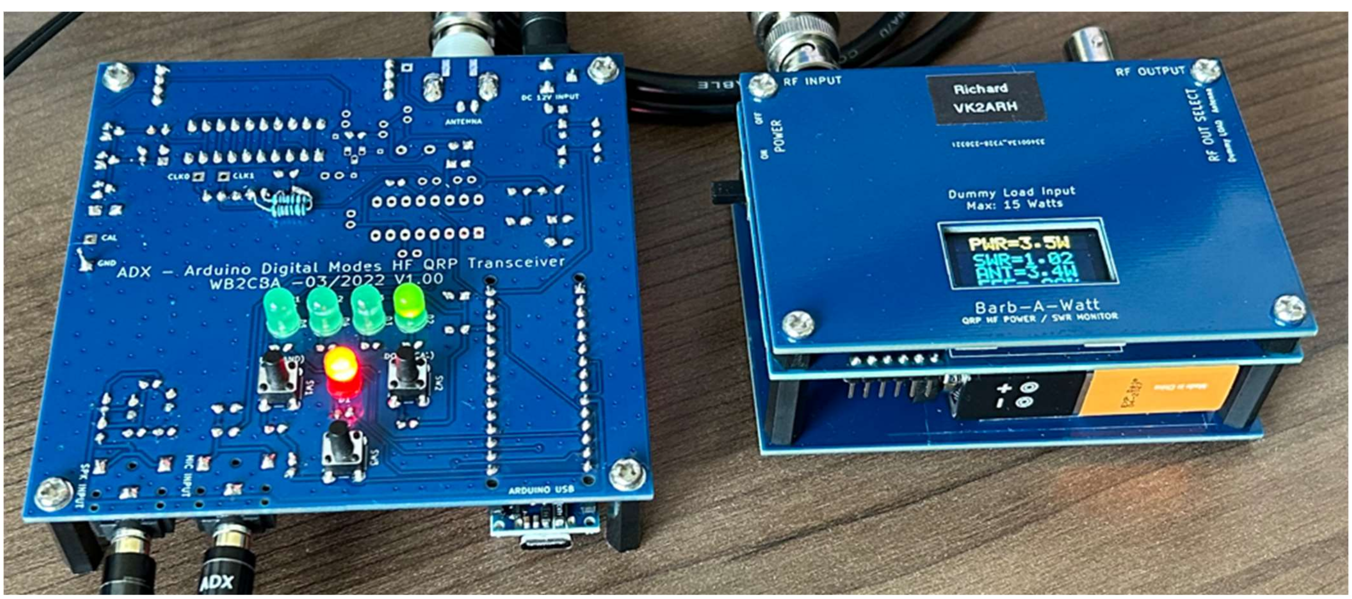
These components are all located in a cluster near the bottom edge of the board:





Now we can test the ability to switch to transmit when receiving an audio signal. You can use an audio signal generator like the Sonic Tools App on iPhone to inject audio to SPK jack. Turn the volume to MAX and it should trigger TX and the TX LED will illuminate. You can also plug your ADX into your computer which has been set up with WSTJ-X (see later section dealing with WSJT-x setup) and activate the tune button which should switch the transmitter into TX.

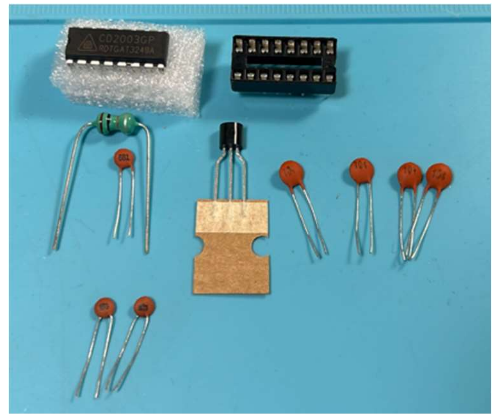
MAKE SURE YOU HAVE THE CORRECT BAND SELECTED, LPF INSTALLED AND A 50 OHM DUMMY LOAD CONNECTED TO THE BNC SOCKET FOR THIS TEST BEFORE CONNECTING POWER.



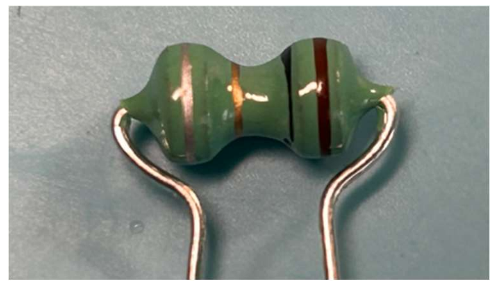
The red LED Illuminates indicating activation of the transmitter when an audio signal is injected into the SPK socket. If connected to a power meter you should also see an indication of output power.

Step 10: Installing the CD2003 Receiver

Identify and install the following components:

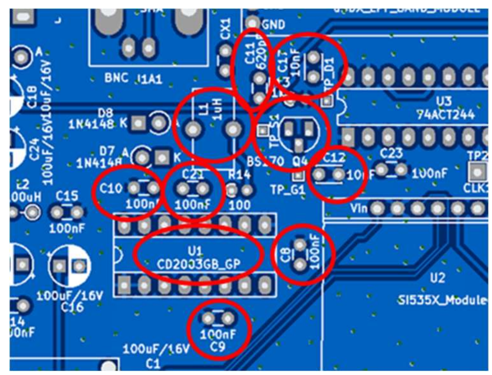


- ☐ L1-1uH
- ☐ C8, C9, C10, C21 - 100nF (104)
- ☐ C12, C17 - 10nF (103)
- ☐ C11 - 680pF (681)
- ☐ 16 Pin DIP Socket
- ☐ U1 - CD2003
- ☐ Q4 - BS170



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 lead spacing as shown in the photo:

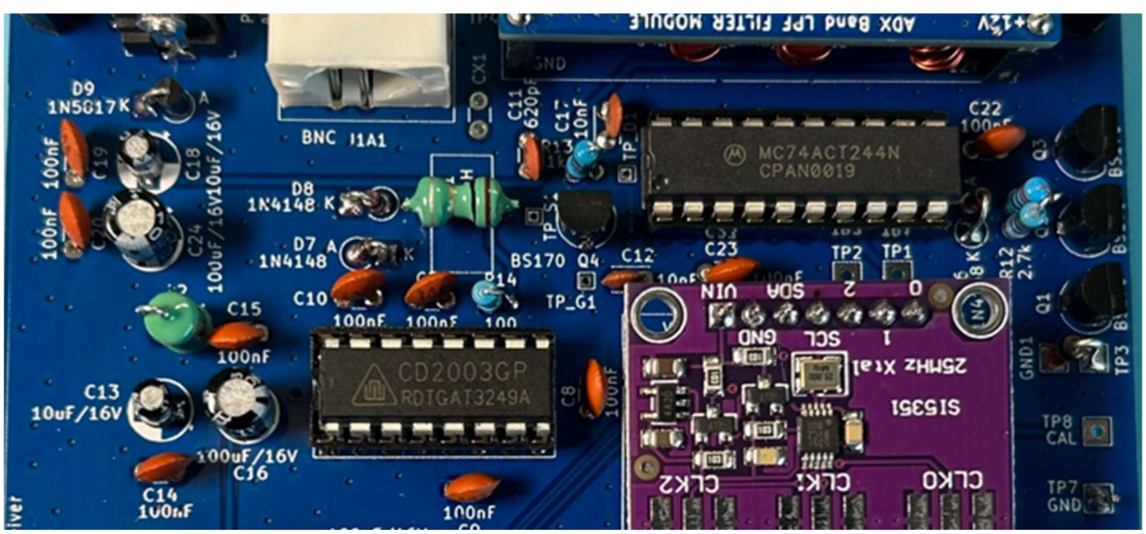
Install all the remaining capacitors. The location of the components is shown on the diagram.



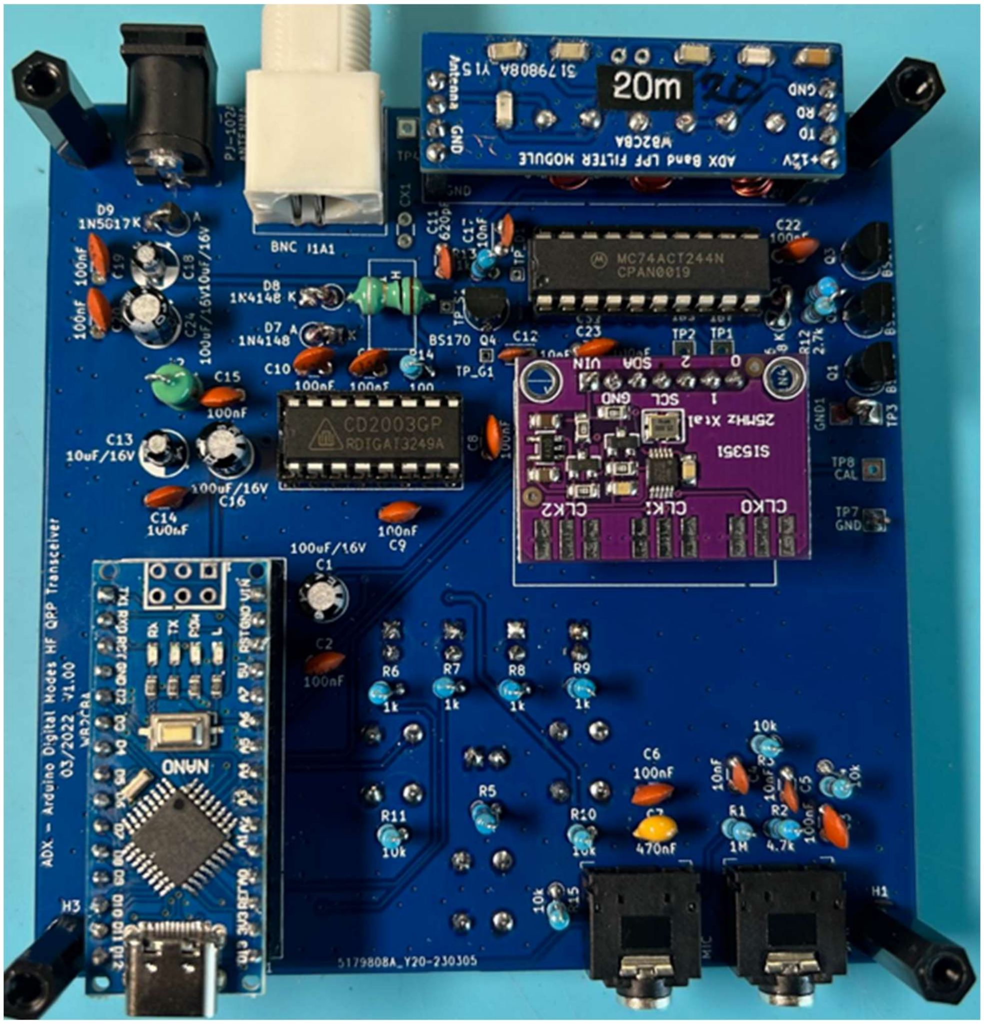
Solder the 16 Pin DIP socket to the PCB using the same technique as the 20 Pin DIP Socket and insert the CD2003 after straightening the leads to fit into the 16 Pin DIP Socket.

Remember that the CD2003 and Q4 – BS170 are static sensitive devices. Take care to ensure they are safe from static 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 😊

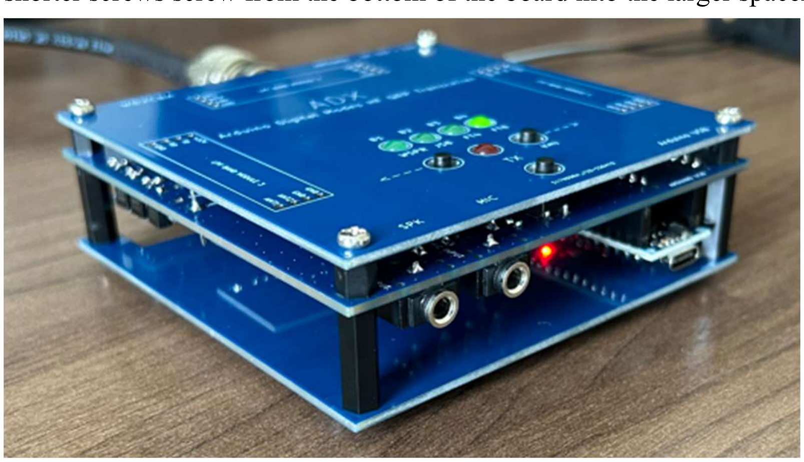


The completed board should now look like this:



You should now progress to testing out your ADX on 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 screws go through the top of the board and the smaller spacer and screw into the larger spacer. The shorter screws screw from the bottom of the board into the larger spacer.

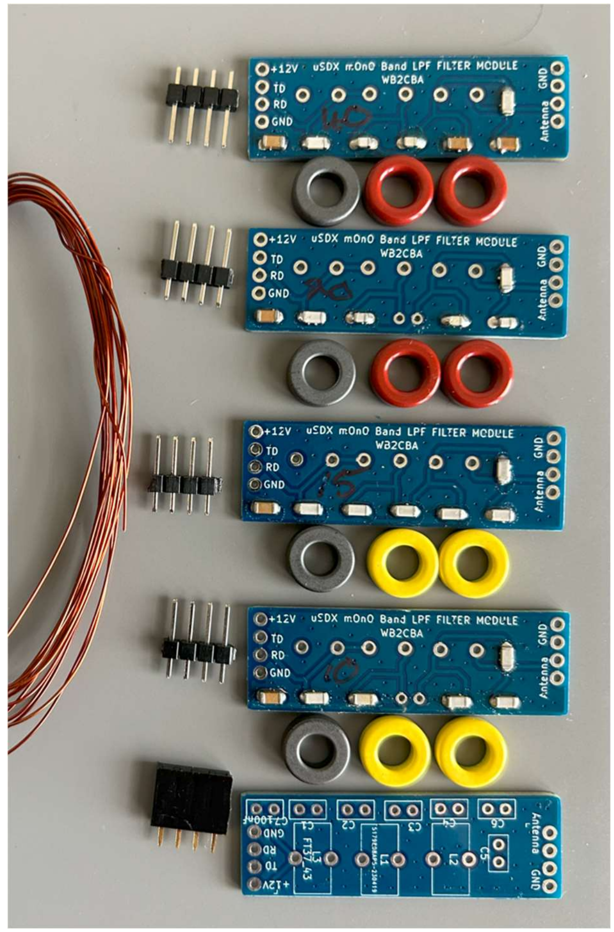


It's easier to install the bottom screws and the longer spacer first before attaching the top cover and smaller spacer.

The kit is supplied with silicon feet which can be stuck on to the bottom of the enclosure to prevent the case screws scratching a surface and prevent 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 band you wish to operate. You will also need a 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 Cowtown ADX kit came with the 10m LPF components as standard and additional band LPF's could be ordered. We chose to supply the 10m LPF to provide our technician license holders and ability to use the ADX on the 10m HF segment.

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). This project also introduced members to winding toroid's – a skill which is now used here.

We chose to use SDM capacitors for the LPF to secure the value specified by Barb WB2CBA in his design which is optimized for the digital segment of each band. These capacitors are 100v rated. Through hole capacitors with 2.5mm spacing can be used, but we supplied the LPF's with the SMD's already mounted. Variations in capacitor appearance reflect different manufacturers and size of the capacitors.

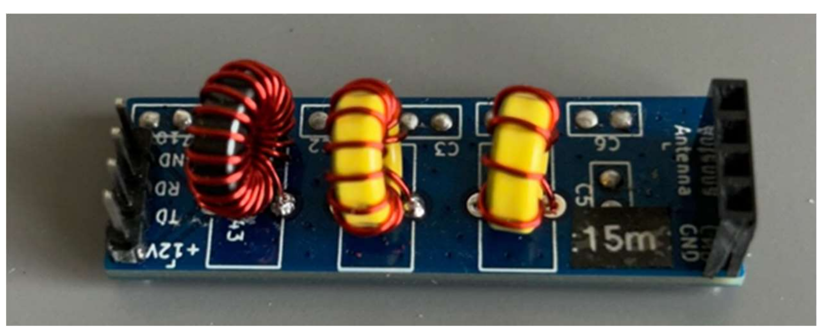
The photo shows the 4 pin male headers supplied with the kit and a single 4 pin female which you will need to manufacture from the 40pin strip supplied. See P15 of this manual for details.

Each kit was supplied with a spare LPF board for you to experiment with if you choose to do so.

Whilst 'no clean' flux was used when affixing the SMD capacitor to the LPF board, you may want to clean both sides with isopropyl alcohol and an old toothbrush to remove any sticky residue from the flux. The LPF's use a combination of 1206 and 0805 SMD's. You can also check the installation of the SMD's with a multimeter and the traces on the LPF Board. Don't clean all the LPF boards at once as the isopropyl alcohol will also clean off the band identification on the board and you will need to reapply it once cleaned.

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 the to table on the following page. Solder the toroids to the LPF board after scraping off the enamel coating on the magnet wire.

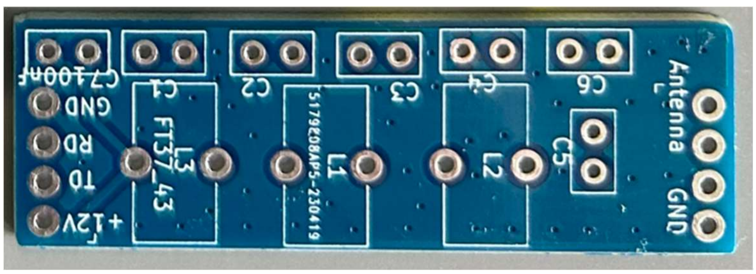


This is an example LPF for the 15m band. Each band uses a different combination of L1 and L3, and capacitors as outlined in the table on the following page.

The T37-2 is the Red Toroid, T37-6 is the Yellow Toroid and the FT37-43 is the Silver Toroid

	L1	Mag Wire"	L2	Mag Wire"	L3	Mag Wire"	Total Mag Wire
80	19Turn/T37-2	10.5	14 Turn/T37-2	8	20Turn/FT37-43	11	29.5
40	15Turn/T37-2	8.5	10Turn/T37-2	6	20Turn/FT37-43	11	25.5
30	12Turn/T37-2	7	8Turn/T37-2	5	20Turn/FT37-43	11	23
20	10Turn/T37-2	6	7Turn/T37-2	4.5	20Turn/FT37-43	11	21.5
17	11Turn/T37-6	6.5	7Turn/T37-6	4.5	20Turn/FT37-43	11	22
15	11Turn/T37-6	6.5	7Turn/T37-6	4.5	20Turn/FT37-43	11	22
10	9Turn/T37-6	5.5	6Turn/T37-6	4	20Turn/FT37-43	11	20.5

The toroid naming convention corresponds to that shown on the LPF board below. Remember the toroid with the least number of turns (L2) is the one closest to the Antenna.



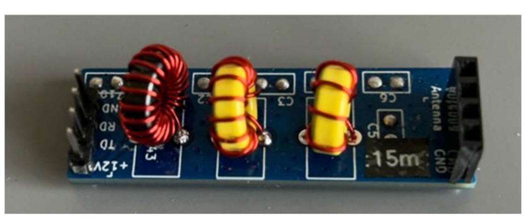
When winding the toroid, a turn is counted each time the magnet wire is passed through the center of the toroid. Whilst there is a little extra magnet wire supplied with each kit, measure and use the correct amount of wire required for each toroid as shown in the table to ensure that you have enough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

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 board

LPF fitted to the ADX

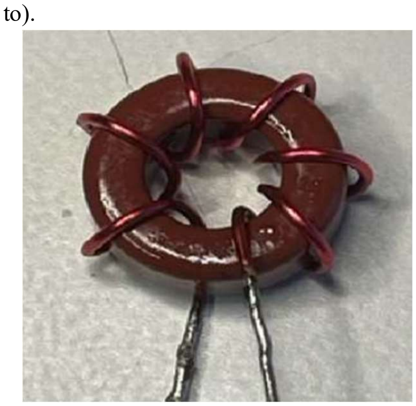
Finished LPF board →



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

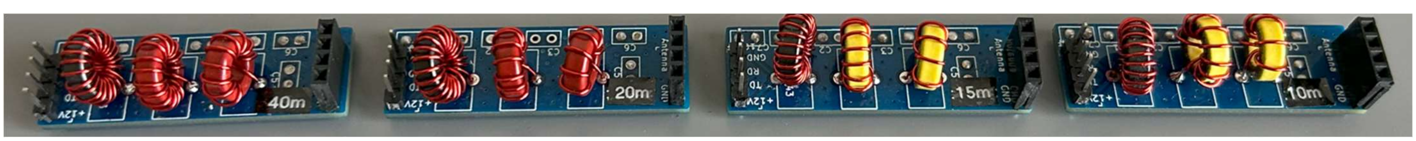
One important point to consider is that the edges of FT37-43 Toroid’s can be quite sharp which can scrape the enamel coating on the inductor wire. To fix this issue the easiest method is tapering the edge a little with an oversized drill bit. Use the oversized drill bit and turn with your fingers inside the toroid ring to smoothen out 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.

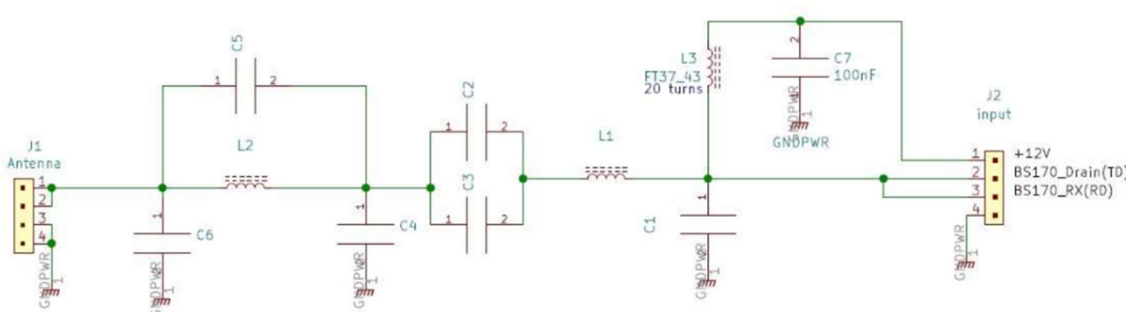
- Lowering one turn from L1 in each band will slightly increase RF output power, although it might increase the TX current, so exercise caution.
- For L3, 12 turns also works well so this can be a nice option to play with and is easier to wind. Although there is some caution here, DO NOT EXCEED 5 WATTS 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 difficult removing them. If you take care and won’t have to).
- One turn means enameled copper wire passes once inside the toroid ring. For example, in the 7 turn T37-2 toroid in this photo, the wire passes 7 times inside the ring. (This is L2 on the 20m band). →



- 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.
- Never ever let one turn go over 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 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 L to R: 40m, 20m, 15m, and 10m LPF’s: and is followed by the LPF Schematic:





Settings and Calibration

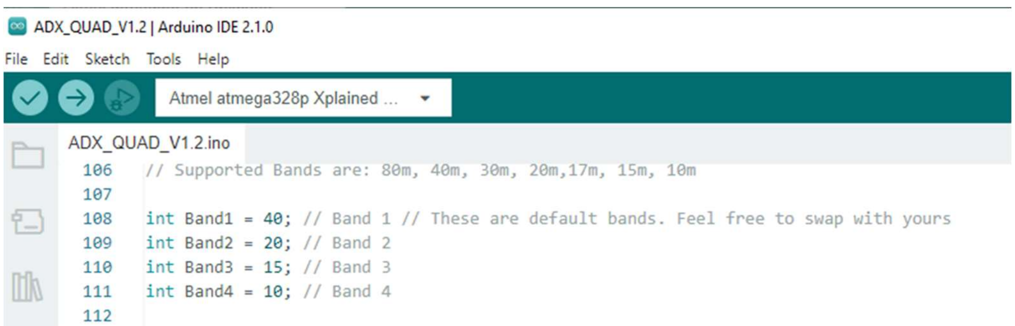
There are two settings required to operate the ADX. The BAND and the MODE of operation.

Setting the BAND

The ADX has four bands available (Band 1, Band 2, Band 3, Band 4) these are hard coded in the Arduino firmware. The firmware for the ADX was loaded into the Arduino Nano included in the Cowtown Kit.

The default band setting are: **Band 1:** 40m, **Band 2:** 20m, **Band 3:** 15m, **Band 4:** 10m

To change these band assignments, you need to go into the Arduino code and change the band assignment declaration in lines 108, 109, 110 and 111. In addition to the four bands above, the ADX also supports the 80m, 30m, and 17m bands. 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. This process will be covered during the buildathon sessions.



The firmware loaded into the Nano provided with the Cowtown Kit is version:

ADX_Quad_1.2 Released 12/20/2022.

This is the pre-CAT control version as CAT control has only just been released and is undergoing several changes as its stability and functionality stabilize.

Controlling the ADX

When you power on your ADX the Tx light will flash briefly followed by one of the band LED's (green) flashing three times indicating the band currently selected.

Changing the Selected Band:

Press both the < --- and the --- > buttons simultaneously when the ADX is powered on. 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 remain illuminated indicating that you are in band select mode.

Press the < --- or the --- > switch to select the desired band (the illuminated LED will move indicate the selected band). Press the TX button briefly to save the new band, the TX LED will extinguish, and the chosen band LED will flash 3 times to confirm the chosen band. The display will then default to a single LED illuminated to highlight the chosen mode LED. It is recommended that you place a 'sticker' on your ADX to indicate the band assignment programmed into your firmware:

ALWAYS MAKE SURE YOUR BAND SETTING AND INSTALLED LPF ARE ALIGNED

Changing the Mode of Transmission:

The mode can be changed during normal operation. Press either the < --- or the --- > button to change the mode when the ADX is powered on. The illuminated LED will move 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 firmware loaded onto the Nano in the Cowtown kit does not support CAT Control, so you will need to load new firmware to use CAT Control.

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 as 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 only 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. You can exit the calibration mode only by recycling the power.

If you don't have a frequency counter, you can consider a commercial ham radio transceiver with an accurate frequency display as an alternative. See Adam's ADX-s manual pp36-37 for details of the tuning procedure using a commercial ham radio transceiver.

Using the ADX

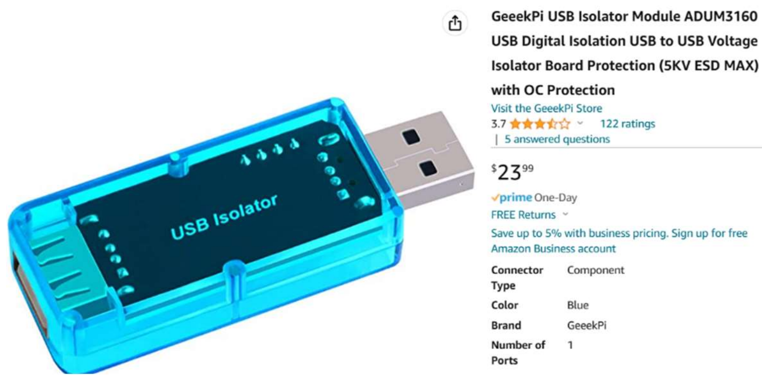
The following extract is taken from WB2CBA's manual on the ADX.

Connecting 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 couple of reasons! This way if anything goes wrong the built-in soundcard won't be damaged. This also helps with ground loop instances.

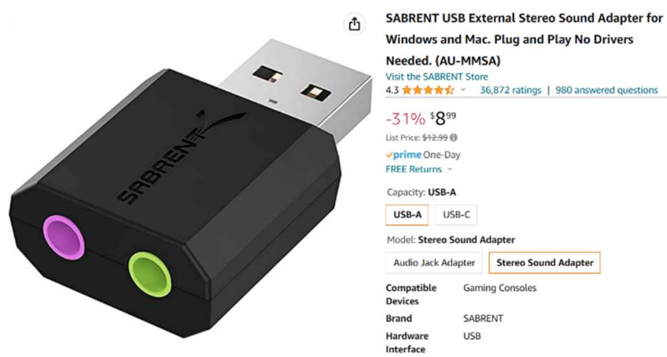
For USB isolation and peace of mind from ground loop dangers you can use one of these isolators between the USB soundcard and the computer's USB port:

[Click here:]



For the USB soundcard I use this sound card from amazon: (Note from W5ARH – I also use this soundcard, and it works well).

[Click Here:]



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 this is a good quality option although a little expensive compared to others.

[Click Here:]

These are just examples. You can use anything like 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 on 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 operation with any other HF Transceiver.

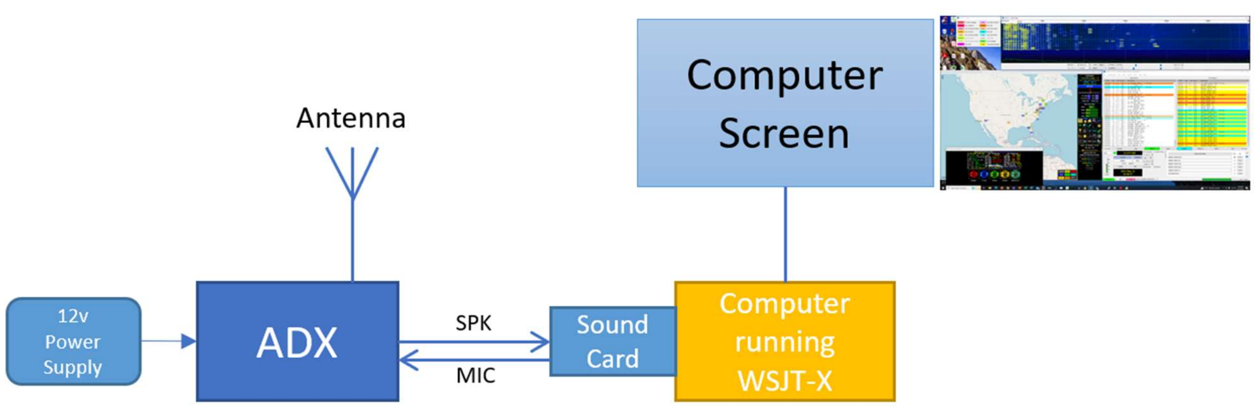
For setting WSJT/X to work with ADX in Manual Mode:

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

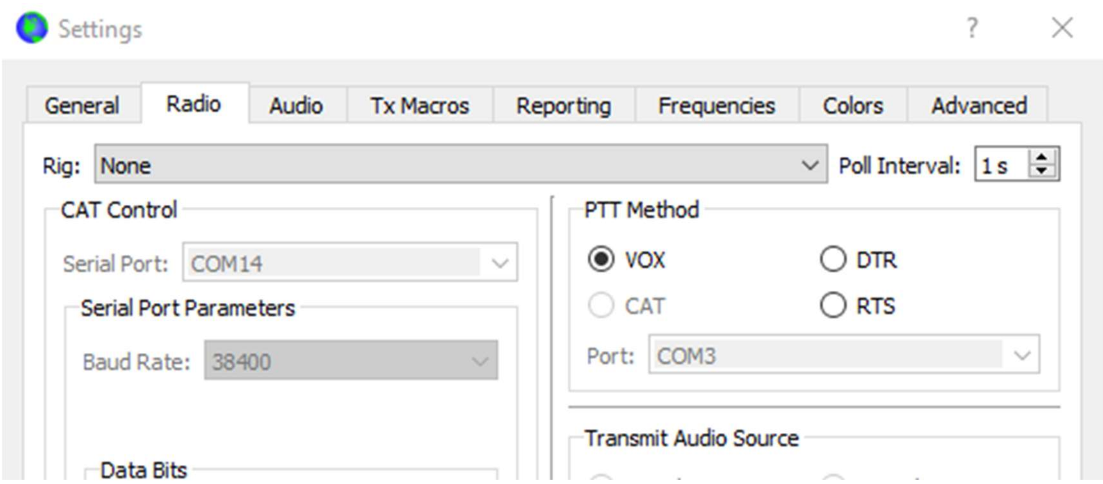
That's all you need to start working with WSJT/X. This applies pretty much to other software such as JS8Call or WSJT/Z etc.

CAT Control is not covered in this manual or the firmware installed in the Cowtown ADX.

An example setup is summarized diagrammatically below:

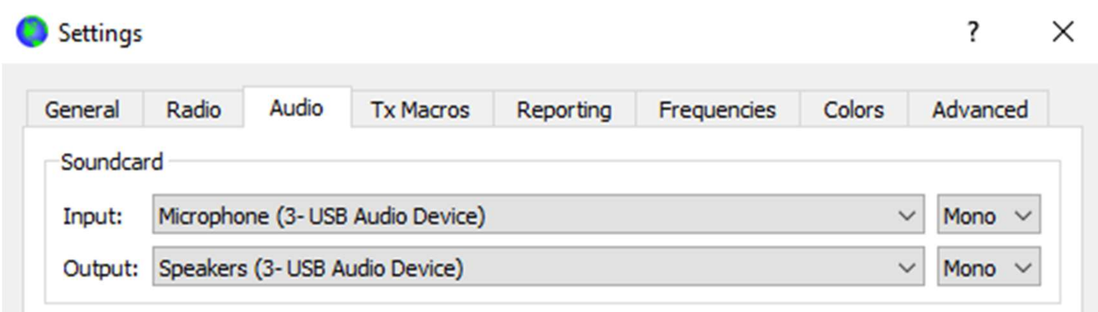


By way of example these are the settings in WSJT-X when using the ADX:



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.



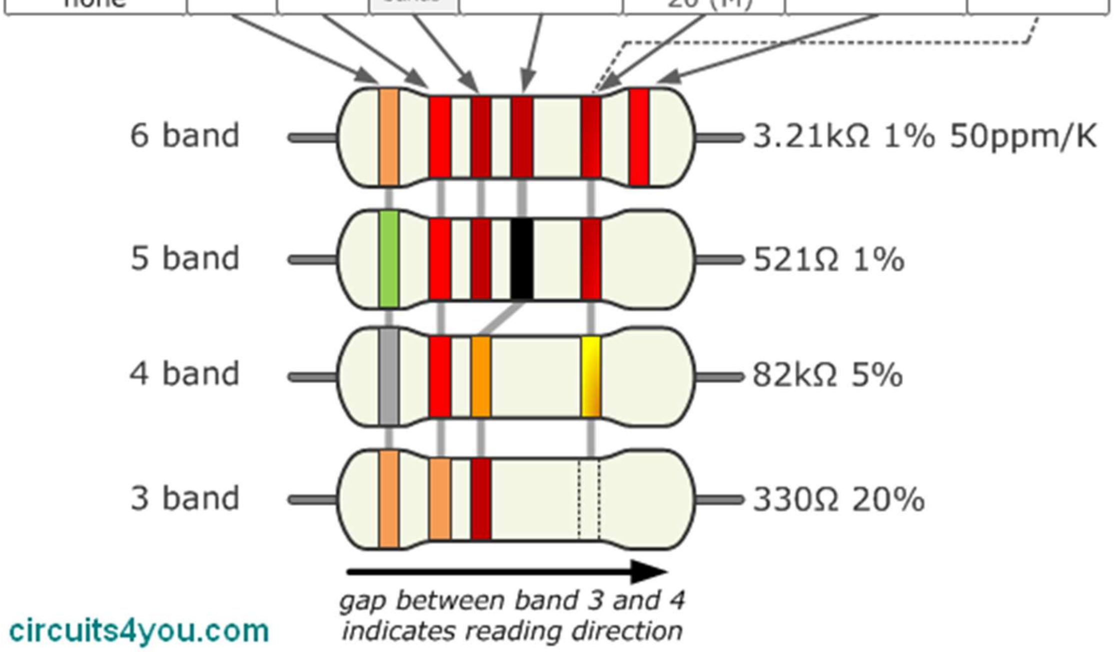
For full details on downloading, installing and using WSJT-X software go to: [WSJT Home Page (sourceforge.io)]

For the latest pdf version of the WSJT-X manual click here: [wsjtx-main-2.6.1.pdf (sourceforge.io)]

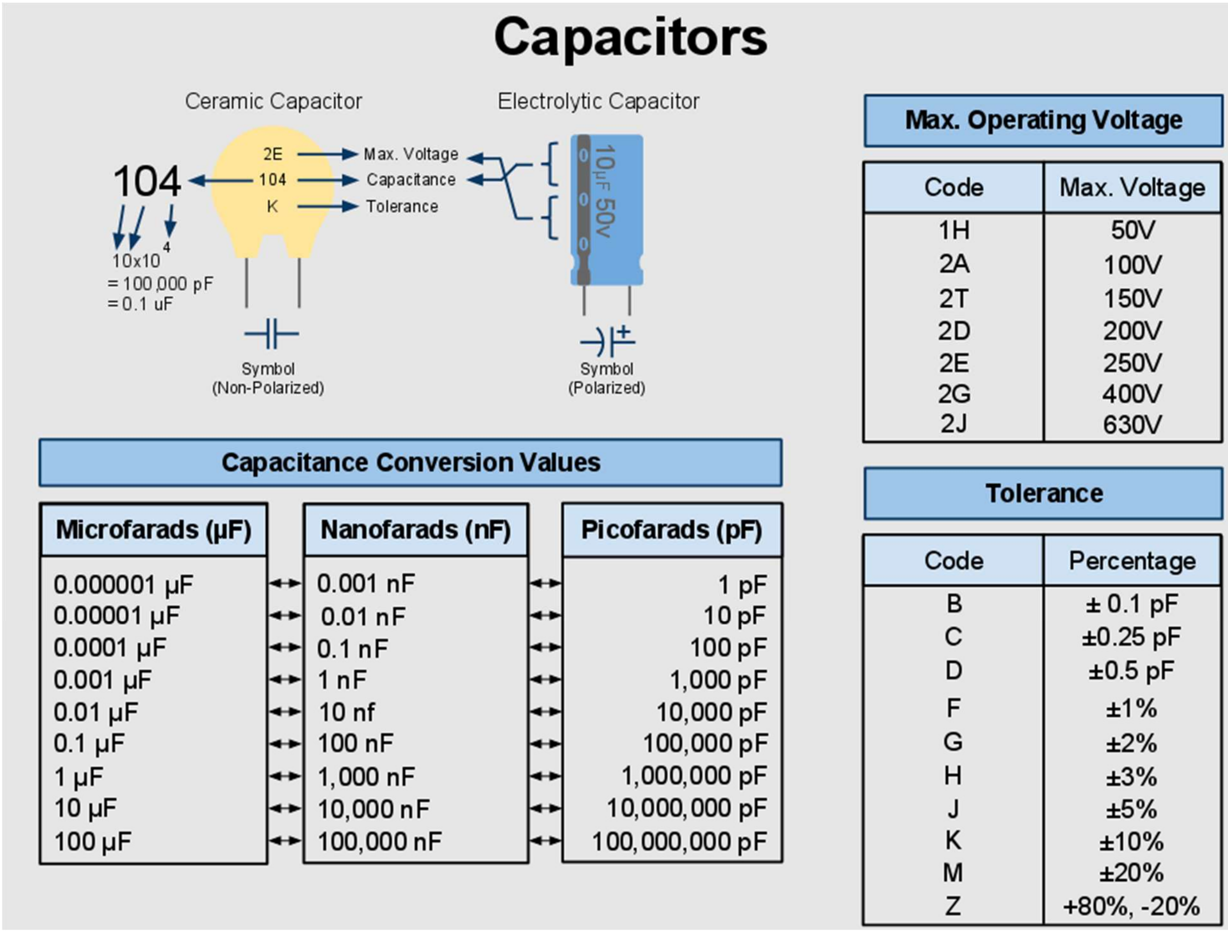
Useful Information

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



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

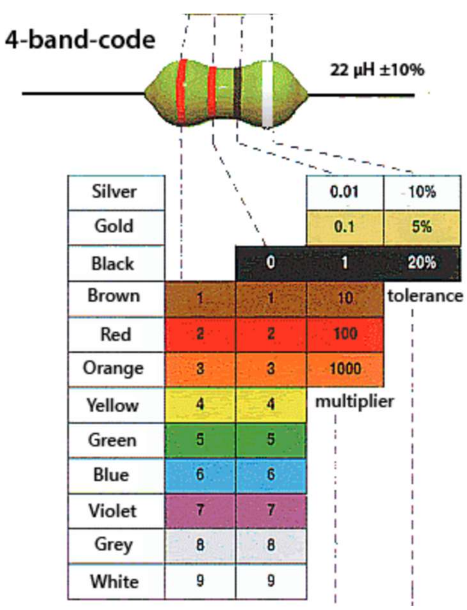
Max. Operating Voltage

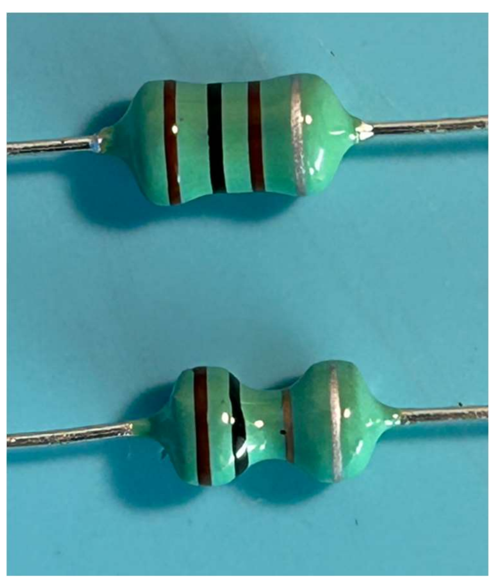
Code	Max. Voltage
1H	50V
2A	100V
2T	150V
2D	200V
2E	250V
2G	400V
2J	630V

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)
= **100uF** 10% tolerance

Brown: Black: Gold: Silver

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