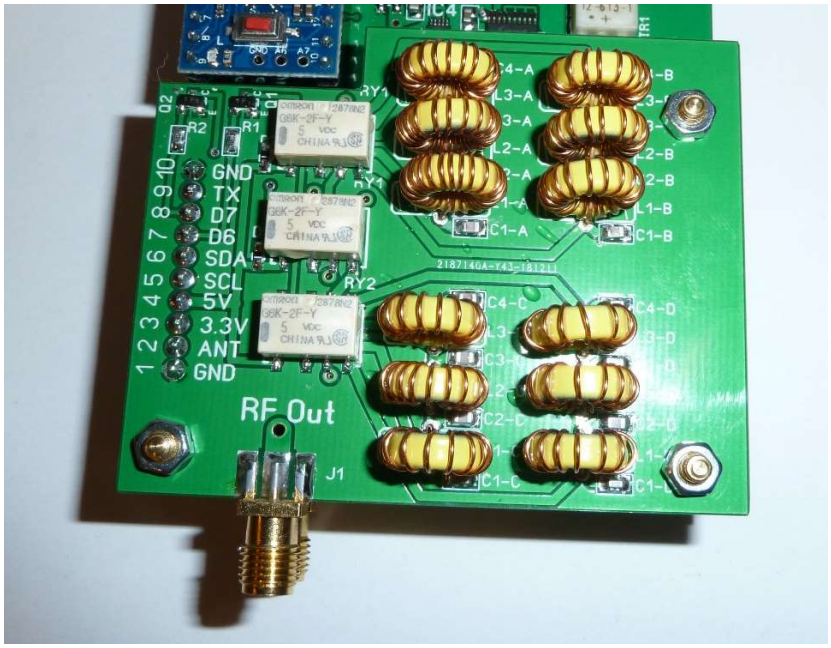
1020 Mezzanine LP4 Build Instructions.



The Mezzanine LP4 card (product number 1020) is an add-on board for the WSPR-TX_LP1 transmitter (product number 1011) and sits on top of it using electrical and mechanical attachments.

The Mezzanine LP4 card expands the capability of the WSPR transmitter giving it four low pass filters.

The WSPR-TX_LP1 + the Mezzanine LP4 card will form an automated WSPR transmitter that can transmit and do band hopping on at least four HF bands (more band for US users; see FAQ at the end of the document).

The Mezzanine LP4 card comes with some of its component soldered but the user need to solder some components that belong to the low pass filters.

This paper describes the steps needed to complete the construction and to configure the transmitter and store the information on the frequency of the low pass filters.

Skills required:

1. Soldering skills.
2. Arduino uploading/programing

Estimated time for build:

2-5 hours depending if you have done something like this before or not.
The soldering should be easy but the Arduino programing and software configuration can be tricky if you are not computer savvy, in that case you might want someone that is used to Arduino programing to help you out.

Preparation.

Preparing and setting up a work area.

Make sure you have the following items at hand:

1. The WSPR-TX_LP1 board
2. The Mezzanine LP4 kit.
3. Low pass filter components (SMD capacitors and T37 Toroidal cores).
4. A PC computer with the Arduino IDE installed.
5. This instruction on paper or on a computer next to you.
6. A pen.
7. A soldering Iron.
8. Solder.
9. Tweezer.
10. Plier or small hand tool to tighten nuts.

Get a clear table space with a soldering iron at hand. If you print this instruction have it next to you or have a computer next to you if you read it as you go along. In that case print the Appendix anyway as it is useful to have on paper.

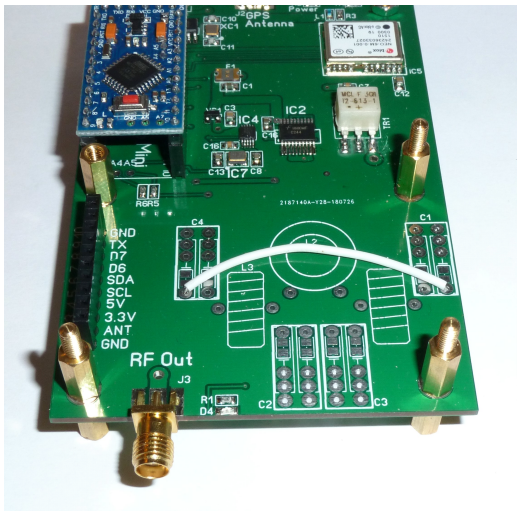
At this stage, make sure the kit has all the parts
Inventory the Kit.

The Kit parts are:

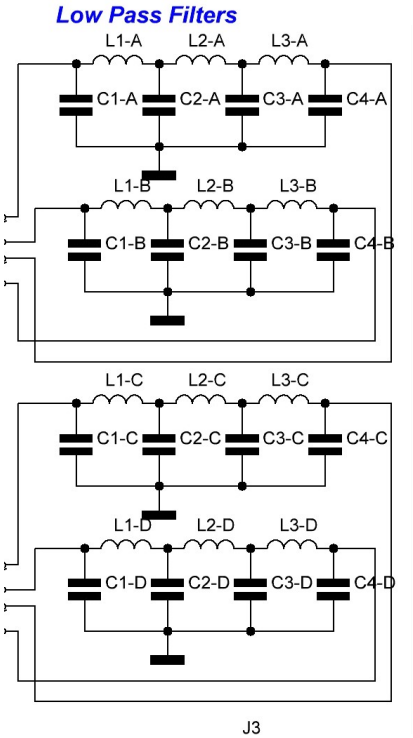
1. A PCB Board.
2. Brass standoffs and nuts.
3. A male and a female pin header

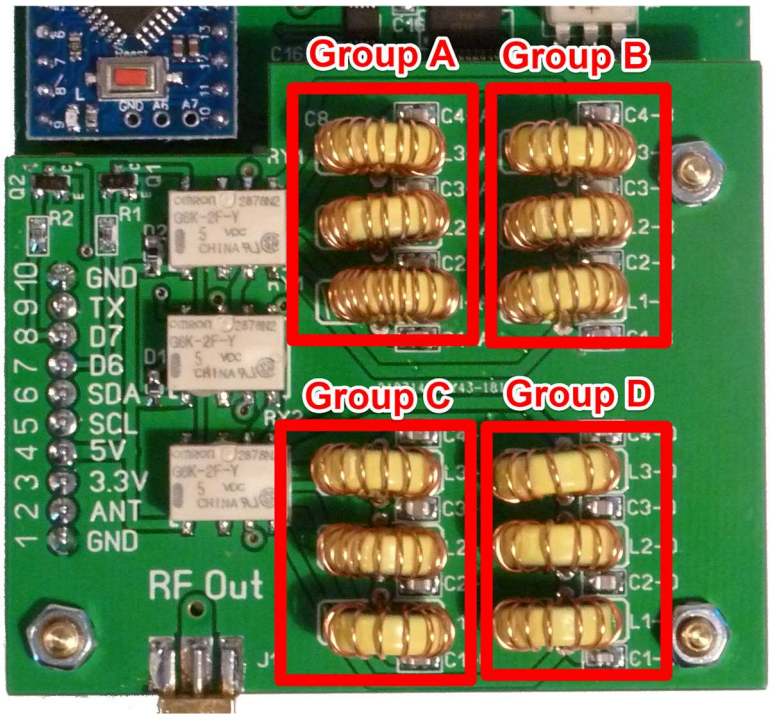
Beside these parts, you need the components for the filters so inventory them as well.
Once you have all this at hand, let's dive in to the build!

Remove the on-board low pass filter on the WSPR-TX_LP1 board.
As a preparation step, you will have to make sure that the WSPR-TX_LP1 board do not have a low pass filter fitted. In case you do have, remove it and replace with a link as shown in the photo.
There is more information in the FAQ on the reason for this.



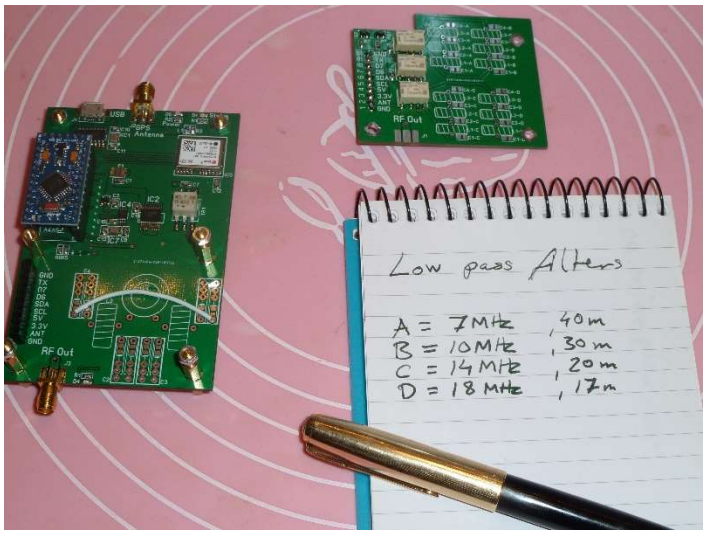
You have one more preparation step you need to do before you can start the build.
You need to decide what HAM bands the filters are to be built for. Maybe you already have figured this out. If not, think this over and decide on what band to build and make sure you have the correct components at hand. If you live in the US it might be a good idea to read the FAQ to get guidance in deciding the bands as a single filter can be used to filter more than one HAM band.





Writing down what low pass filter goes were.

Once you have decided what band you want to use you also have to decide what low pass group A to D will have what band. You do not have to have them in a particular order. In the example below I have a 40, 30, 20 and 17m filters placed in order from filter group A to D. I did this as it seems logical but as I wrote before - you can have it in any order. Regardless, I suggest you write it down.



If you printed out the “placement guide” from the appendix, you can use this paper to write down your decisions. In addition, pull the capacitor values from the low pass filter table (also in the Appendix) and write it in to the squares of the placement guide.

Put the placement guide next to you as you will need it in the next step.

Assembly.

Winding the Toroids.

For each filter there are three toroids, two have the same inductance - same number of turns and the third one that sits in the middle of the three has a larger inductance and thus has more number of turns.
I suggest that you start winding the middle toroid that has most turns first, then put it aside and wind the other two.

Start by putting the cores and wires for Low pass filter A in front of you.

Get the wire and cut it in to three pieces. You will find the length for the wires by looking in the low pass table, the wire for the middle toroid will be slightly longer as it has more turns.

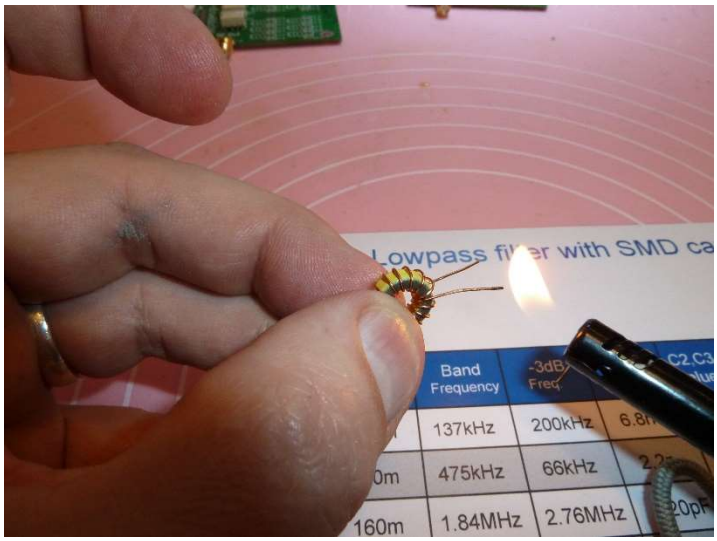
Once you have three wires, pick the longest one.
This wire will be used for inductor L2.
Check the low pass table in the appendix and see how many turns to use for L2.
Wind the L2 inductor, if you are unfamiliar how to wind toroidal inductors - see the winding guide in the appendix.

After you have wound inductor L2 - put it down on the placement guide paper in the correct circle.
Now continue winding the other two - L1 and L3, they have the same number of turns, again look in the low pass filter table to find out how many turns to wind.
When they are completed put them down on the placement guide paper in the correct circles.

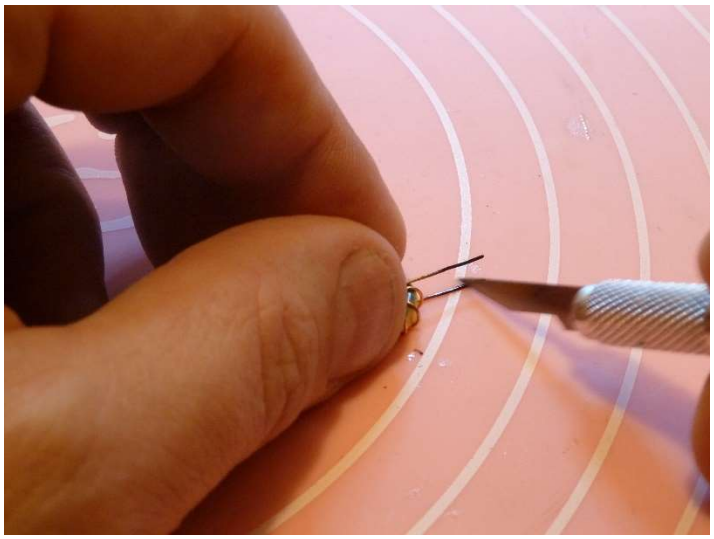
When you have done these first three inductors, they have quite long leads so it is now time to trim the leads and prepare the ends for soldering.

Prepare the leads for soldering.

Cut the leads of about 12mm/half an inch from the core and burn the ends with a flame.



Use a knife to scrape of the burnt isolation until the ends are shiny all around.



Now you have prepared all three toroid inductors that will go in to the A filter group, put them back on the placement guide paper.
In case you happen to mix them up, you have to count the turns to sort them out.

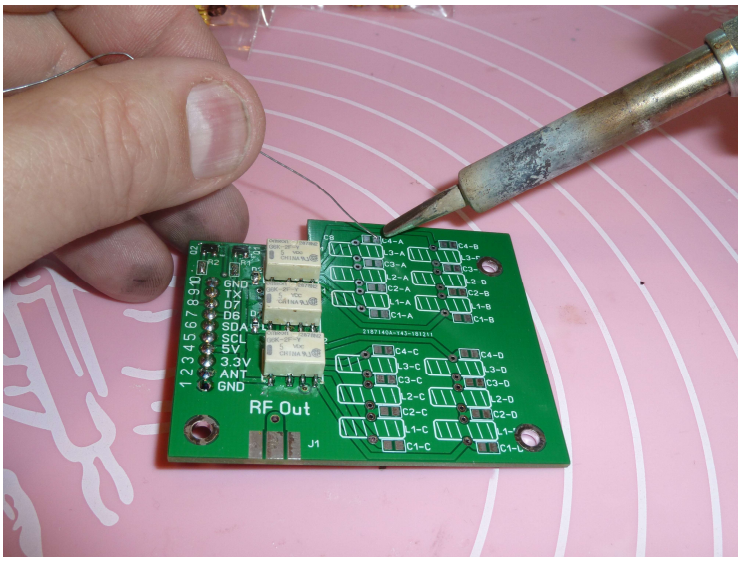
Repeat the winding procedure for the B group and then the C and D groups in the same manner until all toroids are prepared.

OK, time to warm up the soldering iron and create some solder smoke!

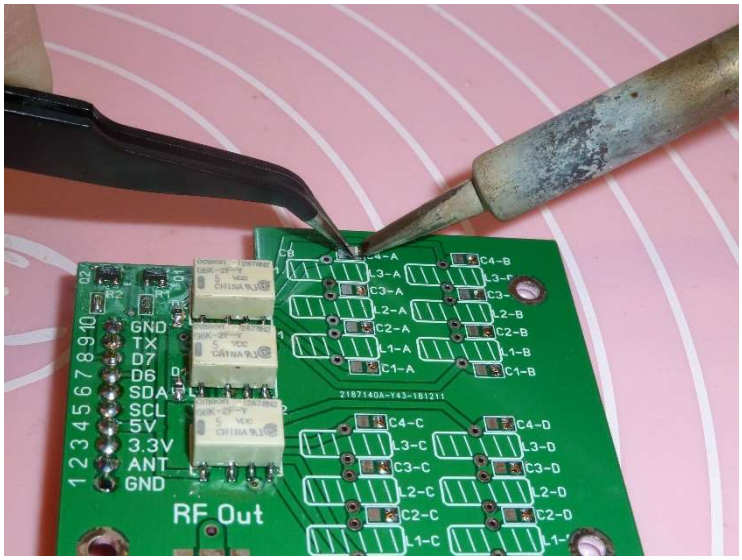
Soldering the capacitors:

First, solder the capacitors. There are several ways to solder the surface mount capacitor depending what tools you have. I will describe how to do it with a normal soldering iron and solder wire.

Apply some solder to one side of the pads that will hold the surface mount capacitor. Start with the “A” group of the four groups of low pass filters. The A group is the top left group.
Do not place the SMD capacitor at this stage, only apply some small amount of solder tin to one side of the pads.



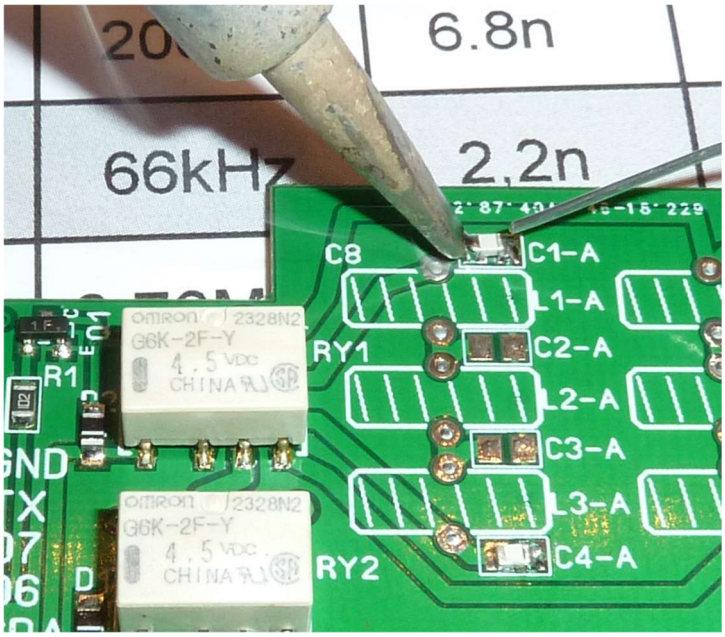
Once you have applied some solder to one side off all the pads, then pick the correct capacitor and hold it to the pad with a tweezer while re-heating the solder. This will solder the capacitor on one side.



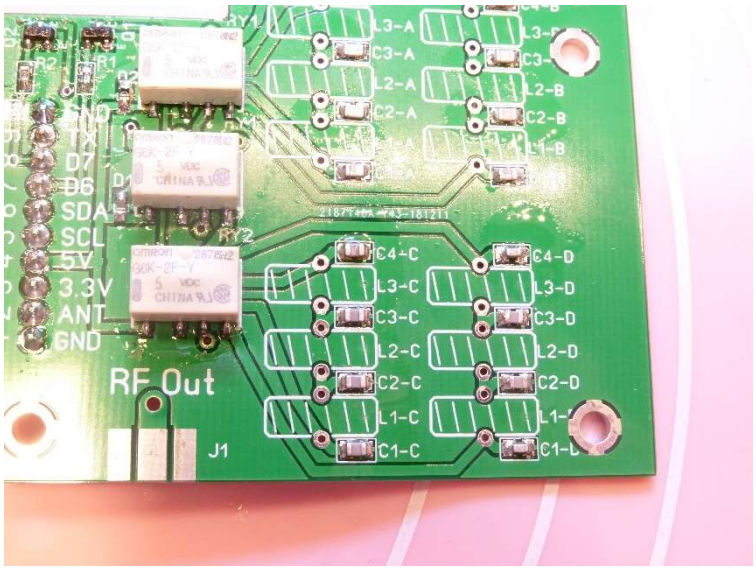
Continue with the next capacitor and do the same until all four of the capacitors for that filter group are soldered to one side.
Capacitor C1 and C4 that sits at the ends of the group have the same value and capacitor C2 and C3 on the inner side have other values. In view of this, it might be easier to solder C1 and C4 first and then C2 and C3 to avoid mixing up the values as the SMD capacitors look the same regardless of their values.
If you do happen to mix up the capacitor and are uncertain of what value a certain SMD cap has you have to

use a LCR meter to determine it again so keeping the caps in their bags right until they are soldered are generally a good idea.

Now that the capacitors are fixed and soldered to one side let's go ahead and solder the other sides as well. Be quick when heating and applying solder so you avoid melting the opposite side or else the cap might come lose and move about on the board.

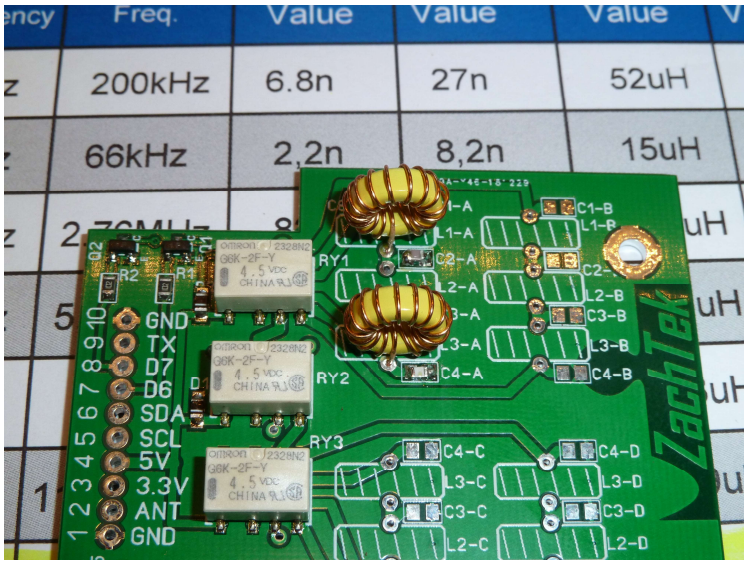


When you have soldered all four caps in group A then continue and do the same for group B, C and D

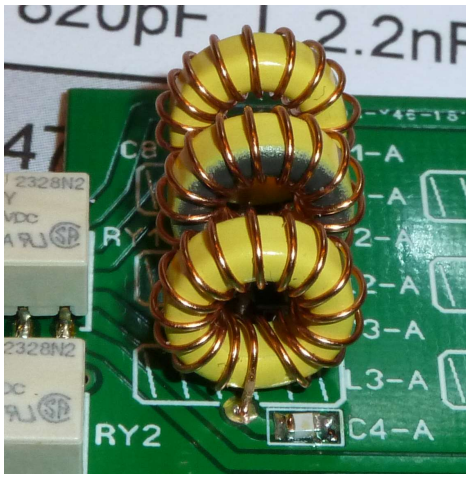


Soldering the Toroids.

First solder the L1 and L3 for group A. L1 and L3 have the same number of turns so you can't internally mix them up. You solder them on the underside of the board so you have to be able to turn the board up-side-down without the toroids falling out. You can hold the toroids in place in some way or you can bend the leads on the underside, use whatever works for you.



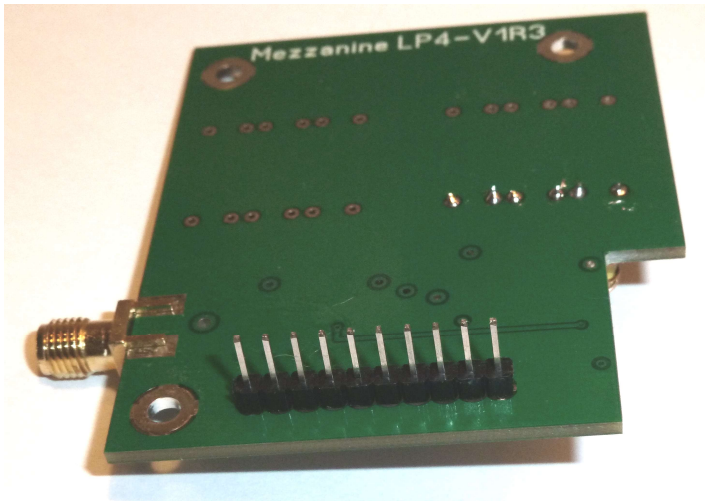
Now solder L2 between L1 and L3.



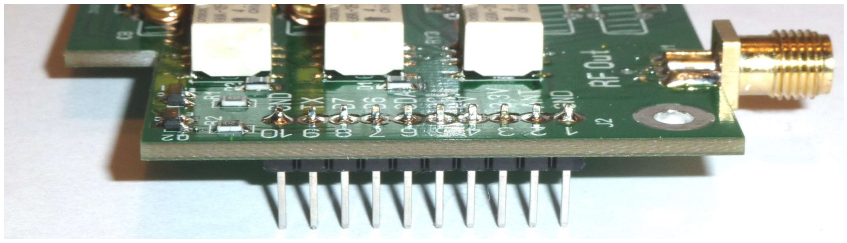
When you have soldered all three inductors in group A, then continue and do the same for group B, C and D

Solder the pin headers and the SMA connector

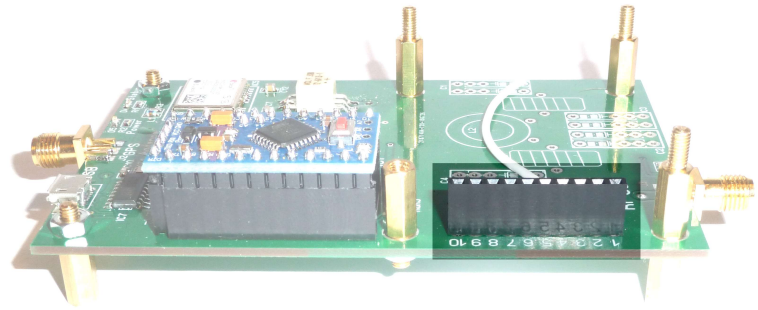
Mount the male pin-header on the underside of the Mezzanine LP4 card and flip the board to solder it on the top side.



Solder the pins on the top side.



Mount the female pin-header on the WSPR-TX_LP1 board and solder it on the underside.



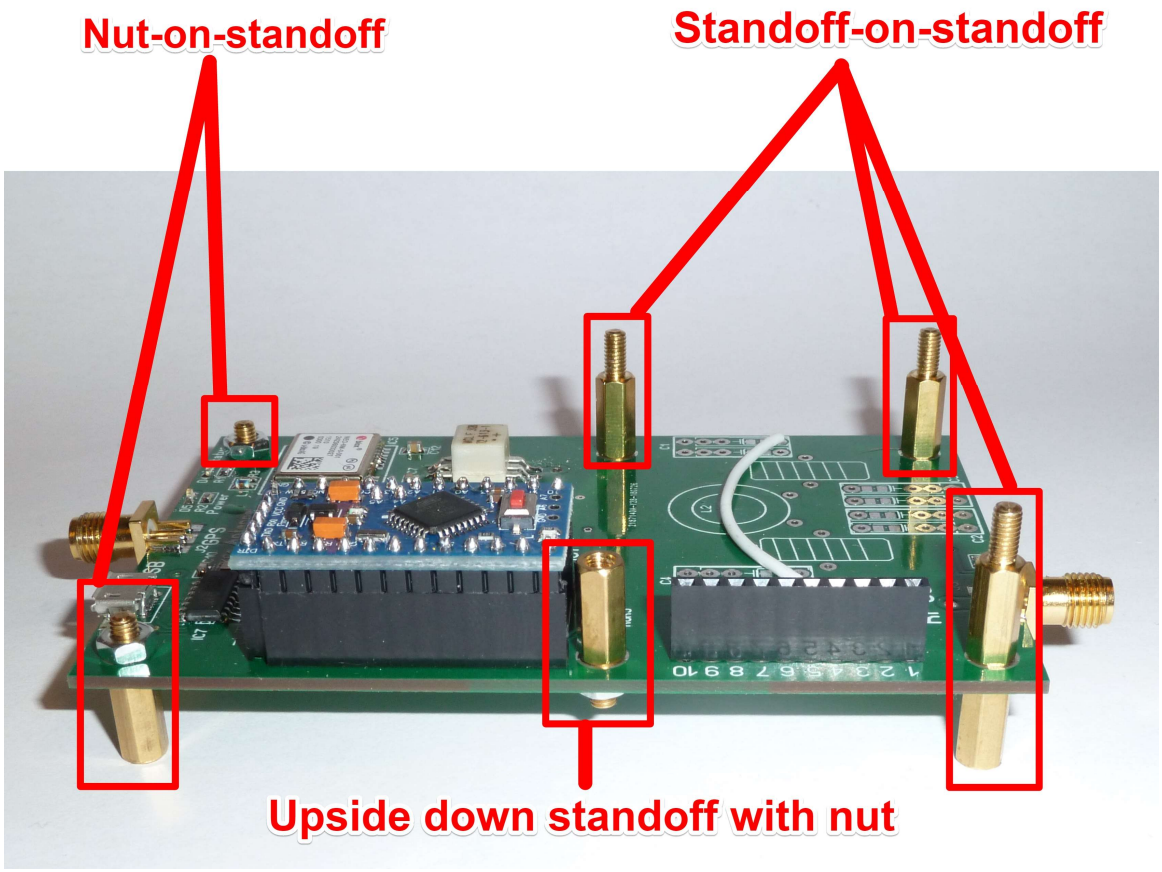
Solder the SMA on the Mezzanine card. If it is already soldered to the board when you get the kit, make sure it soldered on both sides on the PCB. If you solder the underside of the SMA please note that it takes a lot of heat to melt the solder for the tabs on the side of the SMA connector, just be patient while warming the tabs.

OK, you have completed the soldering part, well done!

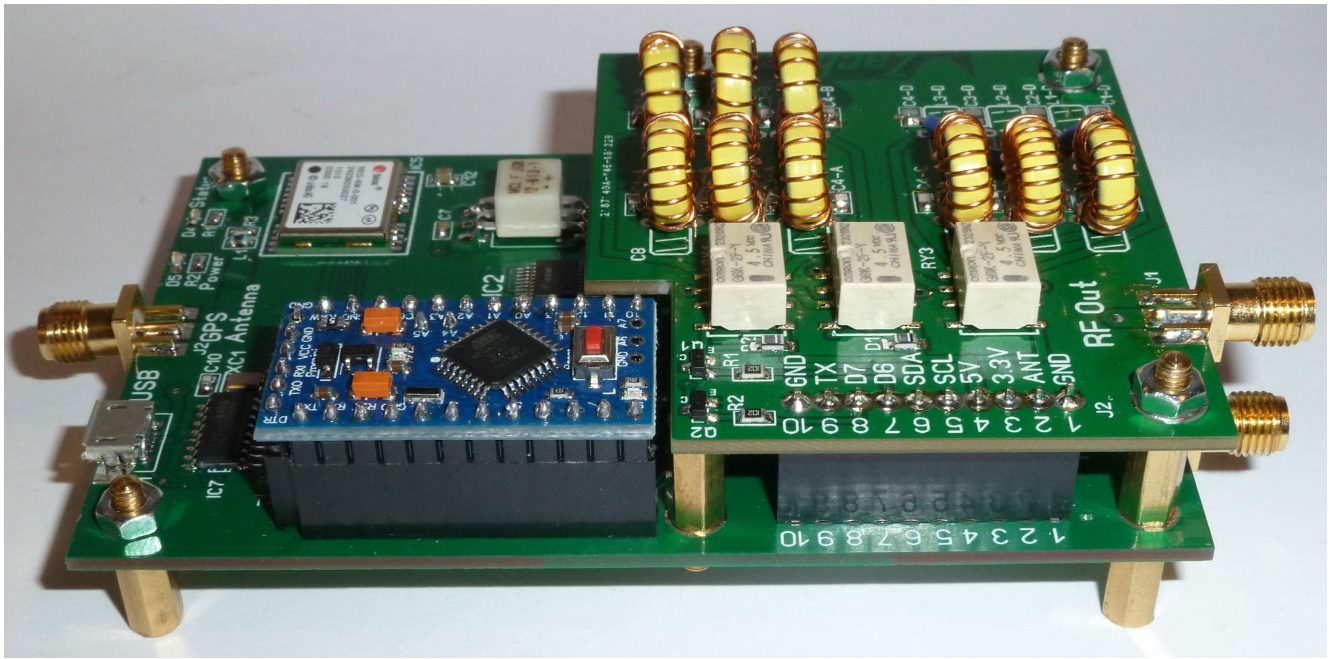
Now, let us mount the Mezzanine board to the WSPR transmitter.

Mounting the Mezzanine card.

Mount brass standoffs and nuts according to the picture below:



Put the mezzanine card on top and fasten with the three remaining nuts.

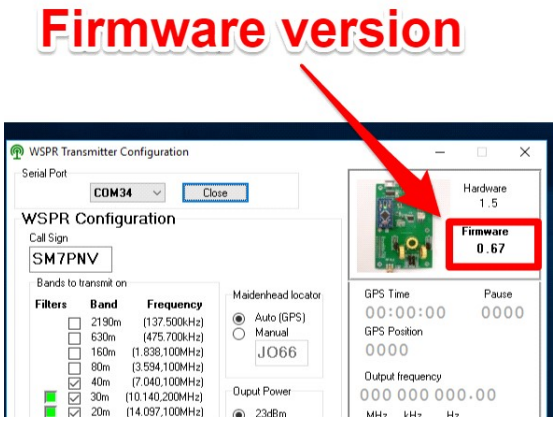


You have completed the hardware build!
Congratulate yourself for a job well done and now let us move on to the software portion of this build.
You will need to plug in the WSPR-TX to a PC and upload Arduino code to it.

Optionally compiling and uploading new Arduino code to the WSPR transmitter.

For the Mezzanine LP4 card to work correctly you have to have firmware version 0.67 or higher in the Arduino on the WSPR-TX_LP1.

You can see what firmware you have by starting the PC configuration software and look in the status info at the top right.



If you need to recompile and upload the latest Arduino software there is a separate document that describes how to do that. You will find that document in my Github here: https://github.com/HarrydeBug/1011-WSPR-TX_LP1/tree/master/Standard%20Firmware

Once you have downloaded the latest firmware and before you compile you need to set a constant in the code to indicate what hardware you have. Set the "Product_Model" to 1020 as shown in the picture.

```
26    0.62 Added functionality to automatically use one of the Low Pass filter in WSPR and SignalGen routines
27    0.63 Changed Software Version and Revision to constants that can be read by the Serial API [FSV] and [F
28    0.64 Added function BandNumOfHigestLP to find the bandnumber of higest fitted LP filter, expanded on th
29    0.65 Fixed bug that forced Hardware Revision to 4
30    0.66 Fixed relay driving bug that affected Desktop transmitter with hardware revision higher than 4
31    0.67 Added support for relay driving the WSPR-TX_LP1 with the Mezzanine LP4 card that contains relays
32  */
33
34  const uint8_t  SoftwareVersion = 0; //0 to 255. 0=Beta
35  const uint8_t  SoftwareRevision = 67; //0 to 255
36
37  // Product model. WSPR-TX_LP1                          =1011
38  // Product model. WSPR-TX Desktop                      =1012
39  // Product model. WSPR-TX_LP1 with Mezzanine LP4 card  =1020
40  const uint16_t Product_Model                           =1020;
41
42
43
44  #include <EEPROM.h>
45  #include <TinyGPS++.h>  //TinyGPS++ library by Mikal Hart https://github.com/mikalhart/TinyGPSPlus
46  #include <JTEncode.h>   //JTEncode  by NT7S https://github.com/etherkit/JTEncode
47  #include <SoftwareSerial.h>
```

The reason for this is because the firmware is shared between all my WSPR transmitters but they have slightly different features and ways of switching relays etc.

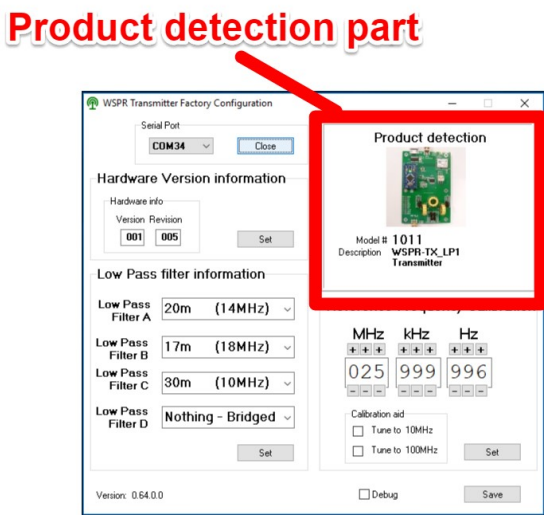
When you have the correct firmware running it's time for the final step in the build that is to run the Factory configuration software so the Arduino knows what filters you have installed.

Configuring the WSPR-TX_LP1 with the Factory configuration software.

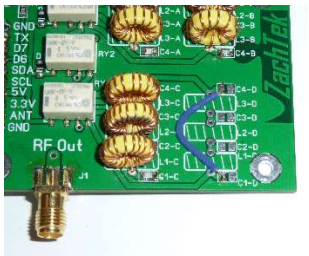
As mentioned, this is the final step in the build.
Connect the WSPR to your PC and download and start the Factory Configuration.
You will find it in my Github here: https://github.com/HarrydeBug/1011-WSPR-TX_LP1/tree/master/Factory%20Config

Pick the correct Serial port and click the Open button.
As a sanity check, make sure that "Product detection" show model # 1011 or 1020.
In case it does not show this and there is no image displayed, try just simply closing the serial port and open it again. (There is a bug in the software that misses the information first time after power on)

Once it shows either 1011 or 1020 as product number, you are good to start the configuration.



In the "Low Pass filter information" section set the low pass filters you have installed.
In the example picture above filter A is set to 20m, filter B=17m, filter C=30m and filter D has a no filter and only a wire bridging it, see picture below.



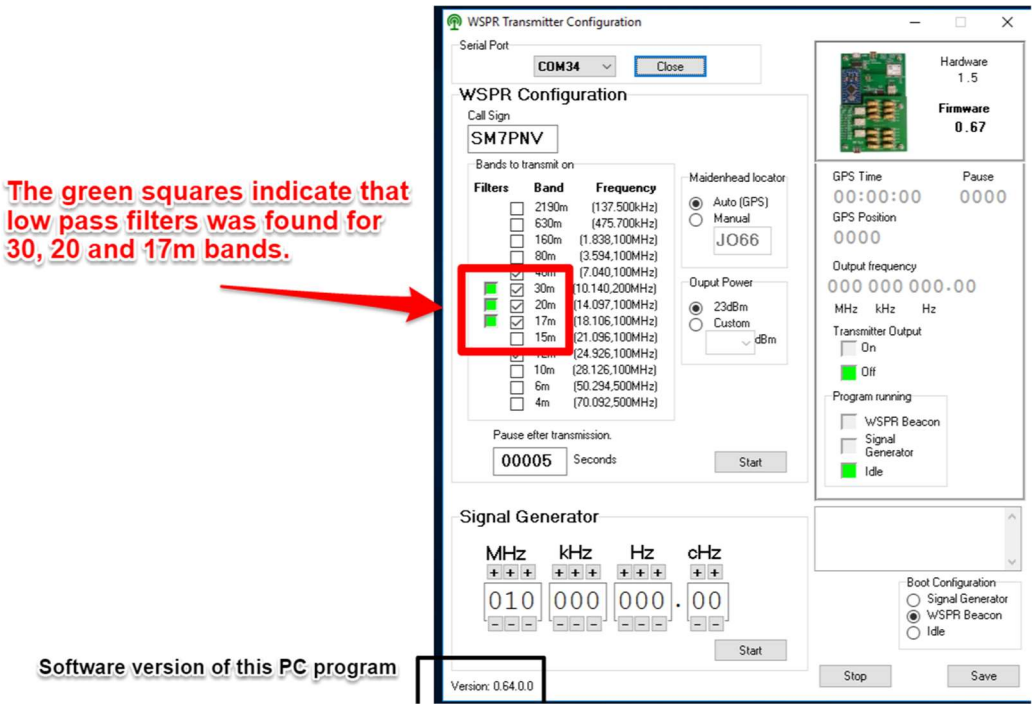
Click the "Set" button in the Low pass filter section.

Click the "Save" button in the lover left.

Close the program and restart it again, connect to the serial port and make sure everything was save correctly.

Verify that the filters show up in the "User configuration software"

Start the User configuration software and check if you can see a number of green squares in the WSPR configuration box.



If you do not see any green squares, it is probably because you are running an older version of the configuration software. Everything will still work fine and the correct low pass filter will be used at transmission but if you want to see the green squares as a visual reminder on what low pass filters you have - you need to download the latest version of the configuration software.
In the picture above I was running version 0.64 and the WSPR transmitter it was configuring was running firmware version 0.67 .

OK you made it!

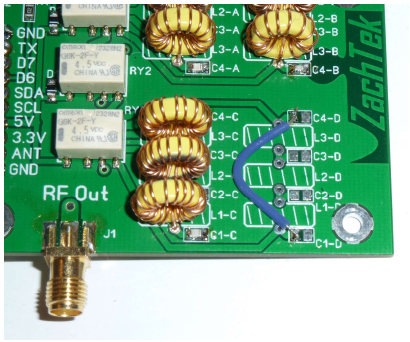
You now can do band hoping on several bands and get the correct filter automatically.
As before, you can operate the WSPR transmitter standalone without a computer, it now knows what low pass filter you have attached to it and will use the correct one automatically!

Frequently Asked Questions:

Q: Can I use my own components for the low pass filters?
A: Yes, no problem, The PCB is made for capacitors with either 0805 or 0604 sizes and T37 cores, you might be able to squeeze in T50 cores as well.

Q: If I have two Mezzanine cards and one WSPR Transmitter can I switch between the Mezzanine cards?
A: yes but you have to run the Factory configuration each time you change the Mezzanine cards if they have different low pass filters fitted. OR alternative have two Arduinos that you also switch between when you switch Mezzanine cards as the configuration is stored in the Arduino EEPROM.

Q: Do I have to put four low pass filters on the Mezzanine card, what if I only want two or three filters?
A: No problem, the factory configuration software supports this, in the unpopulated places set the LP filter to "Nothing – Open Circuit" or if you have placed a link instead of a filter set it to "Nothing – Bridged"
Bridged filters will be used if no other filter is a god match for the band you are transmitting on.
Open Circuit filters will never be used. Se picture below for a bridged filter.



Q: Can I transmit on other bands than the band I have low pass filters on?
A: Yes that is fine, the transmitter allows you to do it and will pick the closest higher filter, however the overtones might be to high in amplitude depending on what frequency/filter combination, what antenna you use and what the rules are in your country.
If you are using a broadband antenna and you are outside the US then you should not do it if you have no other filtering externally.

Q: Does the low pass filter attenuate my output on the transmitter?
A: Yes with less than 1dB (typically 0.5dB) on the intended transmit frequency.

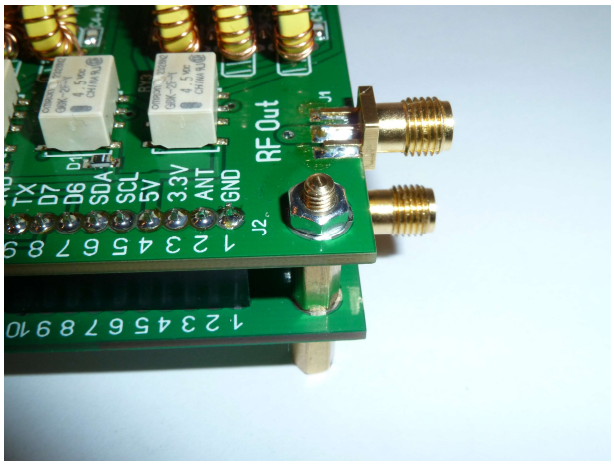
Q: How much overtone suppression will the LP filters get me?
A: 50 dBC or more (typically 55-65dBC) for the band it is designed for.

Q: As an example can I transmit on 7MHz and still have enough overtone suppression with a 10MHz filter?
Yes, if you live in the US where the regulation is 40dBC instead of the 50dBC that the rest of the world have.

However if you live outside the US and transmit in to a 7MHz loop antenna then you might be OK as there will be additional filtering in the antenna.

Q: As another example If I as a US users have filters for 80m, 30m, 17m and 12m fitted to the Mezzanine board will I be able to transmit on 80m, 40m, 30m, 20m, 17m, 15m and 12m and still be compliant with US regulations?
A: Yes.

Q: There are now two SMA connectors, one on the WSPR-TX_LP4 board and one on the Mezzanine card. Which one do I use?
A: The top one. The bottom one is unused when the Mezzanine LP 4 card is fitted. It can still be used if unfiltered square wave output is wanted, for example when using the Transmitter as a signal generator.



Q: Can I have a low pass filter on the WSPR-TX_LP1 Board itself and still use the Mezzanine LP4 board?
A: No. The one exception when you can leave a low pass filter on the WSPR-TX_LP1 board is if the filter is high enough in frequency to not interfere. Eg, if it is a 50 or 70MHz filter.

Appendix.

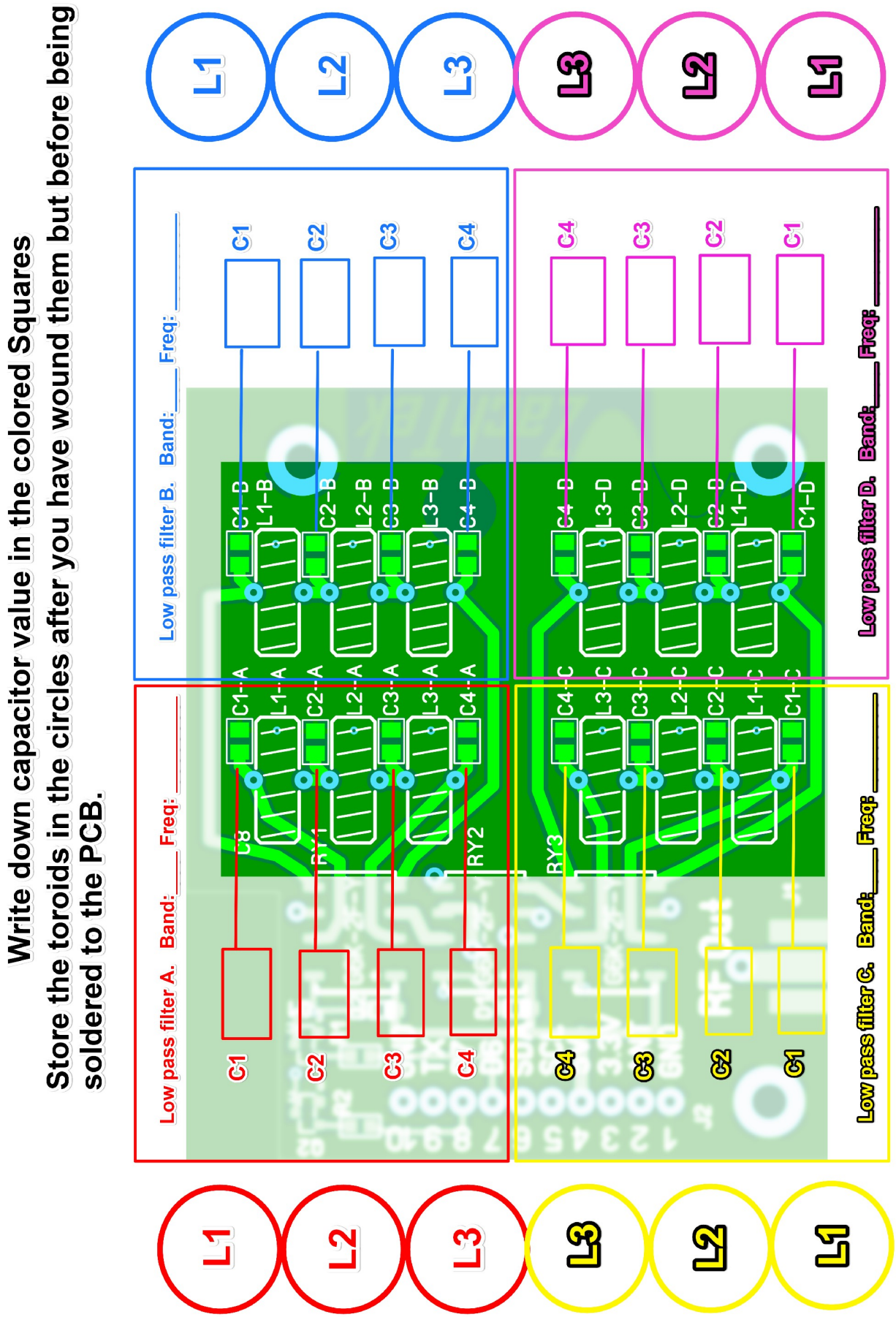
SMD low pass filter table:

Lowpass filter with SMD capacitors and T37 Toroids Ver.2

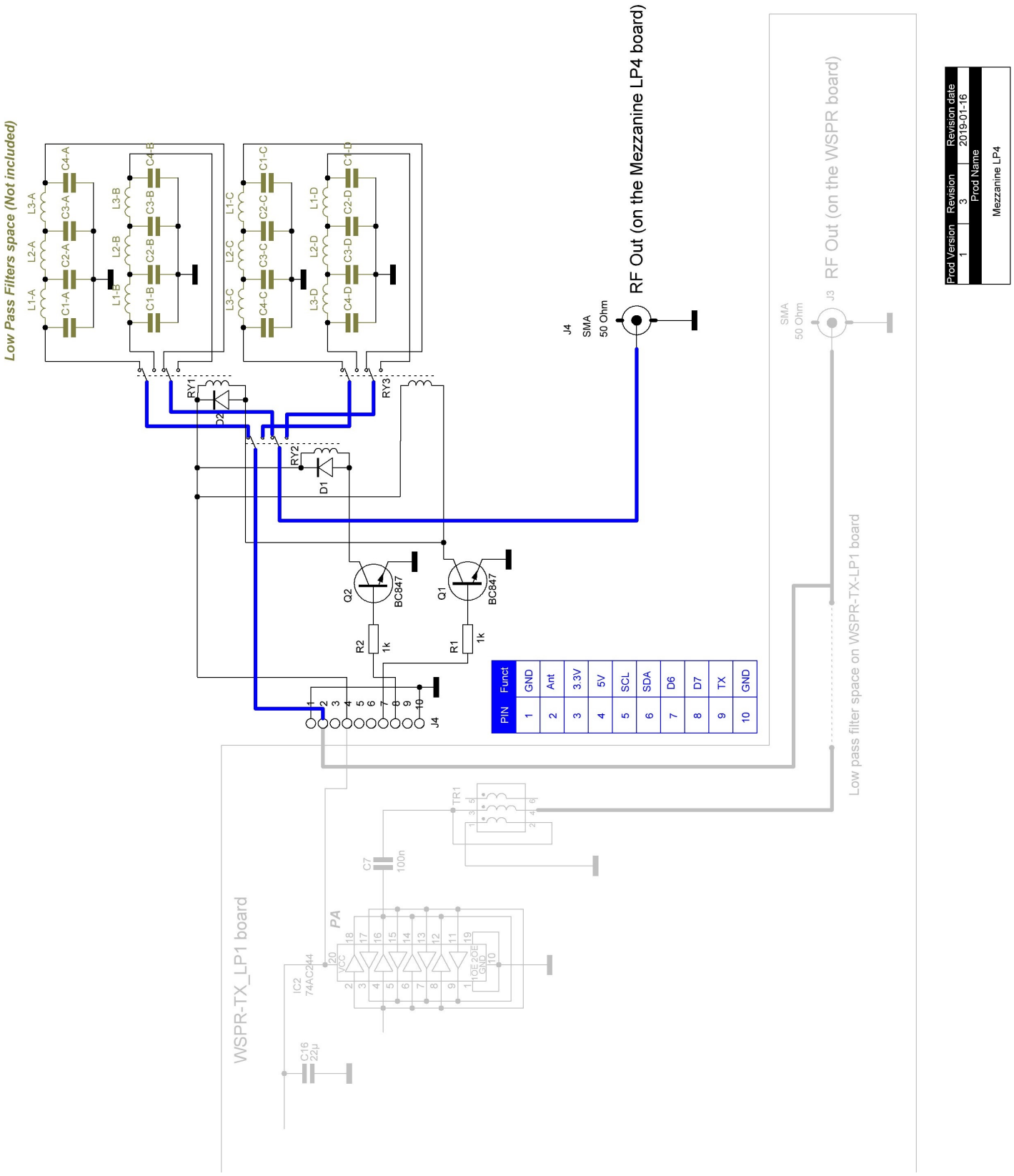
							Number of turns on toroids		Lenght of wire before being wound	Lenght of wire before being wound	Core Material
Band Wavelength	Band Frequency	-3dB Freq.	C1,C4 Value	C2,C3 Value	L1, L3 Value	L2 Value	L1,L3 Turns	L2 Turns	L1,L3 L1,L3 Wire cm - inch	L2 L2 Wire cm Wire inch	L1,L2,L3
2190m	137kHz	178kHz	33n	47n	56uH	60uH	32	33	46cm / 18inch	47cm / 18.5inch	Amidon Material 61 (Ferrite)
630m	475kHz	620kHz	9.1n	15n	16uH	17uH	28	29	41cm / 16.1inch	42cm / 16.6inch	Amidon Material 67 (Ferrite)
160m	1.84MHz	2.76MHz	820pF	2.2nF	4.44uH	5.61uH	33	37	47cm / 18.5inch	52cm / 20,5inch	Amidon Material 2
80m	3.39MHz	5.11MHz	470pF	1200pF	2.43uH	3.01uH	28	32	40cm / 16inch	45cm / 18inch	Amidon Material 6
40m	7.04MHz	9MHz	270pF	680pF	1.38uH	1.7uH	21	24	32cm / 12,5inch	35cm / 14inch	Amidon Material 6
30m	10.4MHz	11.6MHz	270pF	560pF	1.09uH	1.26uH	19	20	29cm / 11.5inch	30cm / 12inch	Amidon Material 6
20m	14.1MHz	16.4MHz	180pf	390pF	773nH	904nH	16	17	25cm / 10inch	26cm / 10.5inch	Amidon Material 6
17m	18.1MHz	23MHz	120pF	270pF	548nH	668nH	13	15	21cm / 8.5inch	24cm / 9.5inch	Amidon Material 6
15m	21.1MHz	27.6MHz	100pF	270pF	444nH	561nH	12	13	20cm / 8inch	21cm / 8.5inch	Amidon Material 6
12m	24.9MHz	29MHz	100pF	220pF	438nH	515nH	12	13	20cm / 8inch	21cm / 8.5inch	Amidon Material 6
10m	28.1MHz	40.5MHz	75pF	180pF	303nH	382nH	10	11	18cm / 7inch	19cm / 7.5inch	Amidon Material 6
6m	50.3MHz	62MHz	36pF	100pF	197nH	248nH	9	10	16cm / 6.5inch	18cm / 7inch	Amidon Material 10
4m	70MHz	82MHz	27pF	75pF	149nH	187nH	10	11	18cm / 7inch	19cm / 7.5inch	Amidon Material 17

http://www.gqrp.com/harmonic_filters.pdf

Placement guide and toroid storage page.



Schema.

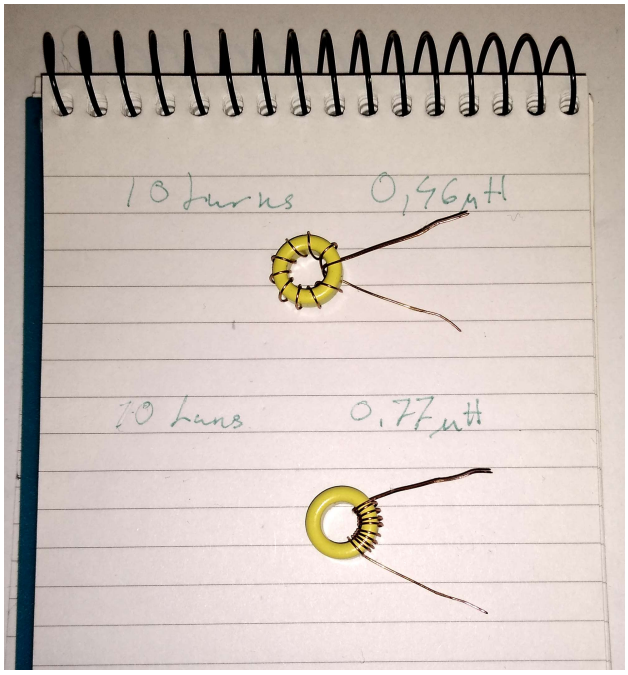

Low Pass Filters space (Not included)
L1-A
L2-A
L3-A
C1-A
C2-A
C3-A
C4-A
L1-B
L2-B
L3-B
C1-B
C2-B
C3-B
C4-B
L1-C
L2-C
L3-C
C1-C
C2-C
C3-C
C4-C
L1-D
L2-D
L3-D
C1-D
C2-D
C3-D
C4-D
RY1
RY2
RY3
D1
D2
Q1
Q2
BC847
R1
R2
1k
J4
SMA
50 Ohm
RF Out (on the Mezzanine LP4 board)
RF Out (on the WSPR board)
J3
PIN
Funct
1 GND
2 Ant
3 3.3V
4 5V
5 SCL
6 SDA
7 D6
8 D7
9 TX
10 GND
Low pass filter space on WSPR-TX-LP1 board
WSPR-TX_LP1 board
TR1
C7
100n
PA
IC2
74AC244
C16
22µ
Prod Version
Revision
Revision date
1
3
2019-01-16
Prod Name
Mezzanine LP4

Winding guide:
There is no special trick to winding a toroidal core, simply wind the wire in any direction and any way you like. However there are some recommendation how to do, it and you need to know what counts as a turn and what does not.
In addition, the way you apply the turns will affect the inductance slightly. In my calculations for this design, I assume that you spread out the turns as much as you can.

How to spread the windings on the core.

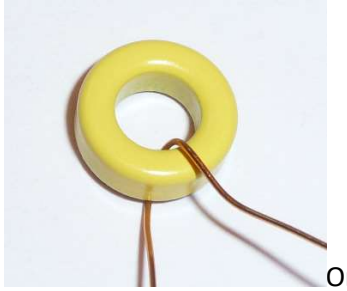
Look at the picture below. It shows two inductors, both with 10 turns of wire but the lower one has all the turns compressed. The top Inductor is the normal way of winding and the inductance as measured is 0.46uH. The lower one has a much higher measured inductance of 0.77uH. Note that there is nothing wrong with the lower inductor if you wanted 0.77uH in your circuit. However, most designers - me included - has standardized on winding with turns spread out on the core and calculate the number of turns based on this assumption.

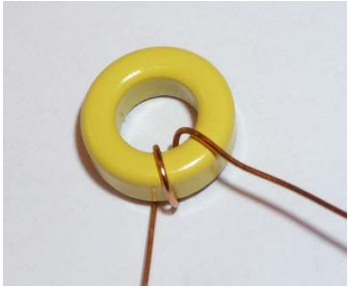
If you happen to not follow this and compress the turns or wind it in a messy way it will not be the end of the world in this low pass filter, it will give more attenuation of unwanted signals with is good, but will also give slightly more insertion loss which is bad.



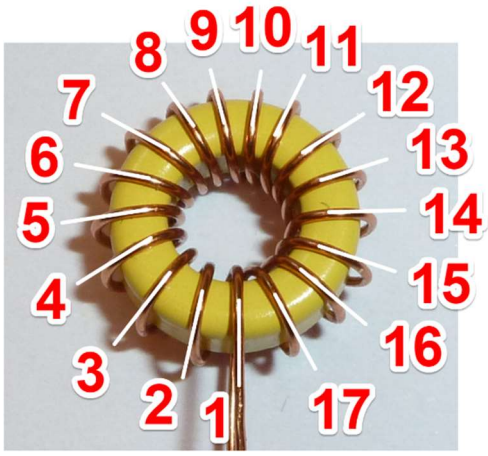
What to count as one turn.

The general rule how to count the cumbers of turns can be summarized as follows: every time the wire passes in to the middle hole it counts as one turn, se picture below.


One Turn


Two turns

If you get lost in the count then you can recount the number of turns by using the following rule: *look at the core from above and count the number of wires that cross the top side of the core*, se picture for an example of a 17-turn toroid



END OF DOCUMENT