Blue Buzzah 2.0
DIY PD Vibrotactile Glove
Building Instructions

PDF Version 1.0, May 2025
By BlueBuzzah Partners

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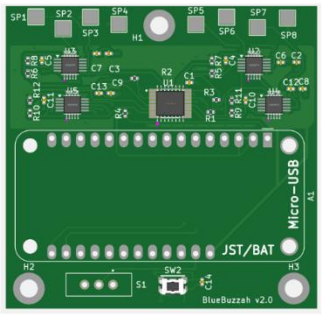
Acknowledgements

Thanks to Dr. Peter Tass for all his tireless work in inventing and improving his vibrating glove treatment for Parkinsons, to Kris Wilk for developing his Buzzah electronics/software design and making it freely available on Github, and to the many PD supporters who have contributed to our communities' efforts to develop DIY versions of vibrating gloves on Health Unlocked, YouTube, Github, and elsewhere.

Overview of Building Process

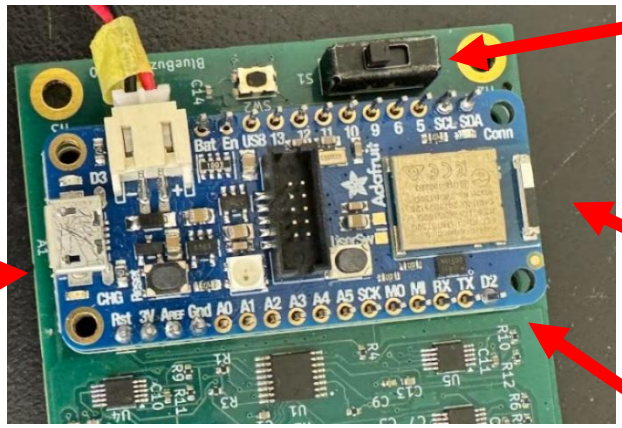
1. **Study building instructions, order preassembled PCB, prepare workspace, order parts and tools needed.**
   (time required = varies, but maybe 4-6 hours)



amazon prime

2. **Prepare PCB for Use**
   (1-2 hours)

Load code files



Solder power supply switch

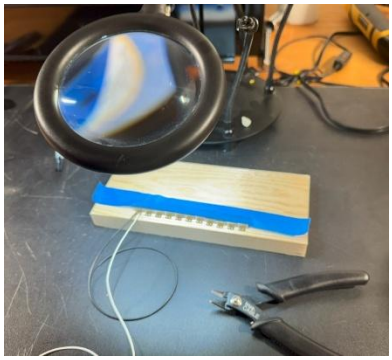
Solder headers to board

Insert Feather module

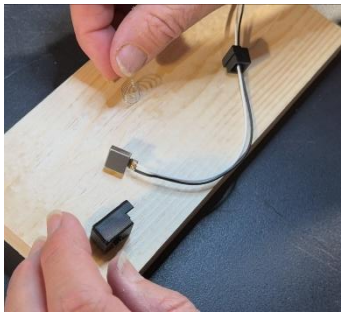
3. **Build Tactors**
   (2-4 hours)

Wind and cut springs

Connect wires to buzzers

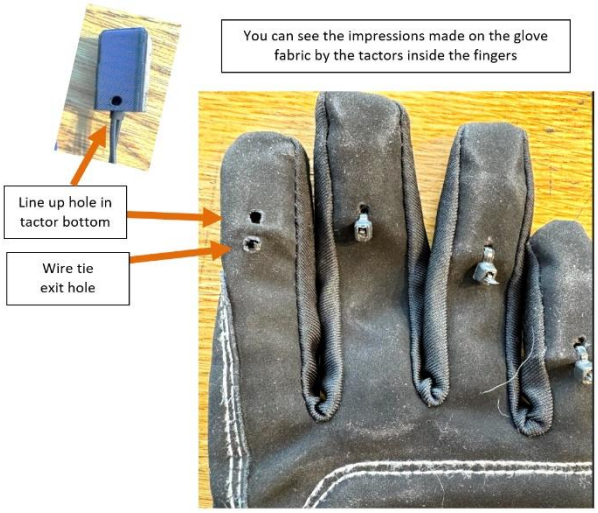


Assemble parts



4. Mount tactors in Gloves (2-3 hours)

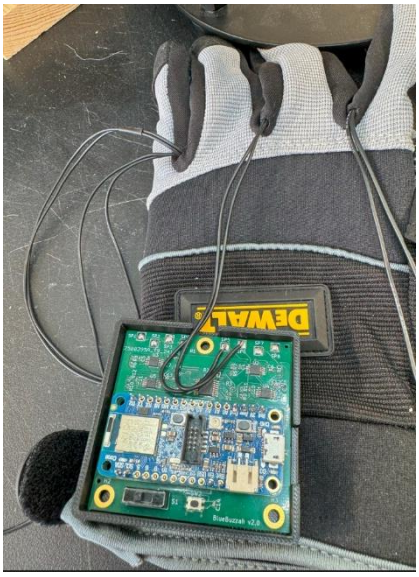
Locate placement of tactor in glove finger



Attach tactors inside fingertips with wire ties

Fish wires out through holes made between fingers

5. Mount Blue Buzzah Boxes (30-60 min)



Solder four pairs of wires for each hand

Put lid on box and you are done!

How to Use This Document

Consult with your doctor before considering DIY therapy.

Content provided here does not replace the relationship between you and doctors or other healthcare professionals nor the advice you receive from them. **People with implanted electrodes from DBS, heart pacemakers, or other internal devices, need to take special precautions around all electronic devices**. https://www.medtronic.com/us-en/healthcare-professionals/therapies-procedures/neurological/deep-brain-stimulation/indications-safety-warnings.html#:~:text=Precautions%3A,their%20physician%20if%20symptoms%20persist.

Read everything before moving forward with building.

If you decide to embark upon your own project to assemble the Blue Buzzah 2.0 described in this document, please start by carefully reading all the disclaimers we have provided. Then, take a couple hours to carefully read through the building steps you plan to follow. As you read each step, check off the various parts and tools required on the parts list to make sure you have everything you need before starting.

Save the building hassle and hire an experienced technician.

If you want to try DIY PD gloves, but don't have the ability to get involved in a DIY project of this magnitude, there are lots of people around with electronics experience who could complete all the wiring and/or building for you. Our biggest concern if you are an absolute electronics beginner attempting to build your own gloves is, you may have difficulties troubleshooting what is wrong if things don't initially work when you fire it up the first time. So, if you are a beginner looking to get into DIY gloves for PD, look through the steps we have outlined, and if it all seems too much to get into, consider finding an electronics repairperson who would be willing to put it together for you for some price. *(Note: This is a service the authors definitely do not provide, so please don't ask).* If you could get a tech person to do it all for the price of the required tools, you would end up breaking even and save yourself a lot of work. But, keep in mind that there will be maintenance to do as the buzzers eventually start wearing out, so there will be some deferred costs down the line if you are not able to change out buzzers yourself.

Disclaimers

1. The devices and therapy described here have not been FDA approved. The research that forms the theoretical basis for the devices described in this document is currently unfinished, and the therapeutic effects (and/or side effects) of such devices are therefore not fully understood. As with any alternative PD treatment that is not FDA approved, if you choose to try some variation of the DIY vibrating glove described here, you will be experimenting with your body. Users of this information assume any and all risks related to the use of the information described.

2. This document is provided freely, solely for personal informational purposes, and does not constitute medical advice. Users should always seek qualified medical advice when considering medical treatments. While we have found the PD vibrating glove approach helpful, we do not claim that this device will improve anyone's symptoms, nor do we take responsibility for any harm that this DIY device may inadvertently cause. In providing this document, we are not encouraging anyone to use DIY therapy to treat their PD without the supervision of a neurologist. If you choose to build a device such as this: (a) BEST WISHES and (b) USE IT AT YOUR OWN RISK. No liability will be assigned to any contributor to this document in the event a user suffers loss as a result of the information

3. DIY versions of vibrating PD gloves such as the one described here may deviate from the official Stanford glove in critical ways that render guidance from Dr. Tass inapplicable to the DIY design. **At the end of the day, no one can know for sure in advance if the DIY gloves will be worth the investment of time, effort and money.**

4. There is no guarantee that your glove build will work when you turn it on the first time. In our many years of experience tinkering with electronics, we have seldom experienced a build that worked the first time without having to troubleshoot some kind of error. We have done our best to describe the steps we have taken to construct our builds, but your decision to move ahead with your own project is yours alone. If you have trouble or questions, the people on Kris's Buzzah Github site, or on this document's GitHub site, can often offer helpful suggestions, but you are fundamentally on your own if you embark on your own build.

5. If you decide to move forward with your own glove build, the Blue Buzzah is one of many DIY versions on the web you can choose from.

6. While every effort has been made to assure accuracy, the contents of this document may contain errors and/or omissions.

7. **No implied or expressed effectiveness, suitability, or warranty for software or device described in this handbook is granted or intended, nor should any level of on-going support be expected.**

8 Commercialization of any products based on the information provided is not warranted, intended or implied. That is, the information in this document is provided for personal use only; it is in no way intended for developing and/or selling similar and/or related products for any commercial purposes whatsoever.

9. Readers interested in learning more about vCR therapy are encouraged to continually visit updates on the work by Dr. Tass and team at Stanford while exploring your own treatment paths in concert with your doctors.

Blue Buzzah Introduction

The Blue Buzzah 2.0 is based on the original wired version of a DIY electronics platform designed by Kris Wilk named ”Buzzah”. Blue Buzzah utilizes ultra-low power (wireless) Bluetooth LE technology to minimize the electronics footprint and power consumption, enable additional features, while eliminating the cumbersome extended wires or cables to a central controller for users. We measured sync timing skew to be 1.2 ms on average with a maximum observed level of 3.0 ms based on a typical continuous 3 minute sample. This is roughly the same level of skew we observed in the wired version of Kris Wilk’s Buzzah. *(Sync timing skew is the difference in arrival times of intended simultaneous right and left buzz pulses).*

Please refer to our GitHub link for more information and future updates:

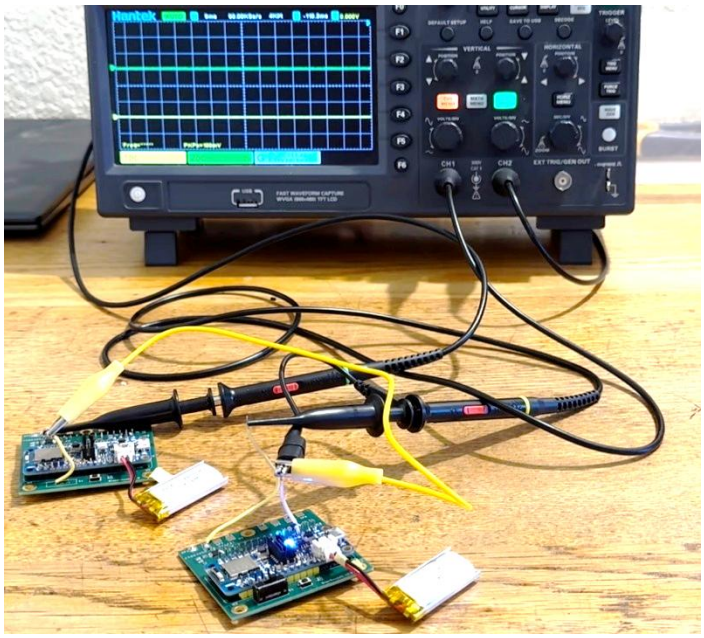
https://github.com/PWPInnovator898/BlueBuzzah-Gloves

We have also posted a highlights video to supplement this document at:

https://youtu.be/fcnbQDe73uA

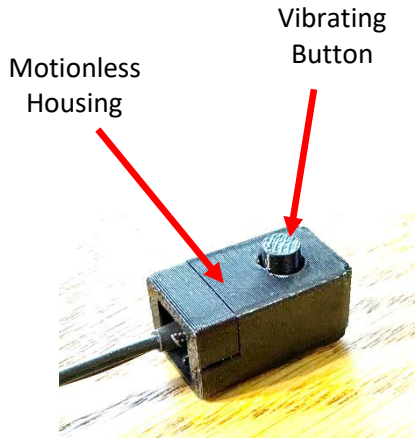
	Specifications *(subject to change)*
Parts Cost	$270 approx. Tools and tariffs may add significant additional cost.
DIY Build Time	1-4 days depending on level of expertise
Github Site	https://github.com/PWPInnovator898/BlueBuzzah-Gloves
Video of Build Summary	https://youtu.be/fcnbQDe73uA
Soldering Level Required	Basic
Processor Connection	Wireless
Buzz Patterns	Regular or Noisy vCR
Buzzer Type	LRA
Buzz Direction	Z-axis
Nominal Buzz Frequency	250 Hz
Buzzer Rise Time	Less than 3 ms
Left/Right Sync Timing Skew	Average = 1.2 ms, maximum = 3.0 ms, based on a typical continuous 3 minute sample. This is very close to the skew we observe in the Kris Wilk's wired Buzzah.
Battery Life	To date, we have only tested performance to 6 hours at which time the battery indicator light was still green indicating 80% remaining.
Prototype Testing Period	12 days to date, 2 x 2 hr sessions per day, no issues reported
Adjustable Pulse Amplitude	Yes
Adjustable Pulse Frequency	Yes, the LRA we use is capable of frequencies from 140 Hz to 300 Hz.
Adjustable Pulse Duration	Yes
Adjustable Rest Time Between Pulses	Yes
Adjustable Relaxation Time Between Pulse Sequences	Yes
Adjustable Therapy Timer	Yes, but switch must be turned off after use to preserve battery life
Amplitude Randomization	Yes, but feature has not been rigorously tested yet
Frequency randomization	Yes, but feature has not been rigorously tested yet

Note: Any changes to default parameters of the Blue Buzzah code must currently be made to processors on each hand. Failure to maintain exactly the same default parameters for each hand may result in erratic buzz performance. We plan to implement a single default parameters file in a future release.



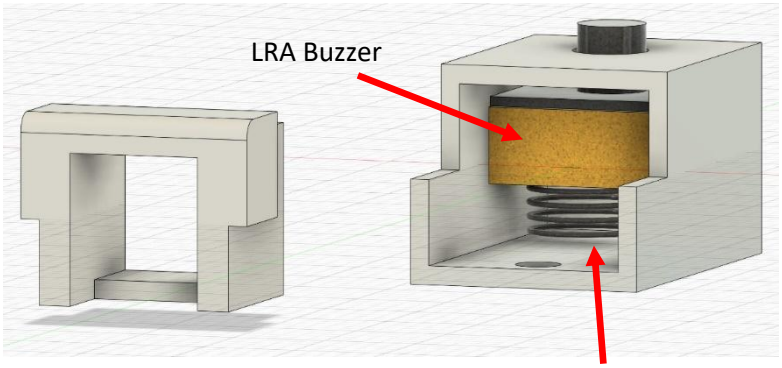
Why We Use Spring Tactors

According to "Coordinated Reset Vibrotactile Stimulation Induces Sustained Cumulative Benefits in Parkinson's Disease", the purpose of a tactor in vCR therapy is to provide a "***strong, point-like sensation that is easily felt and localized***". In order to accomplish this, a button must vibrate perpendicularly against the fingertip while the surrounding skin area is held motionless.

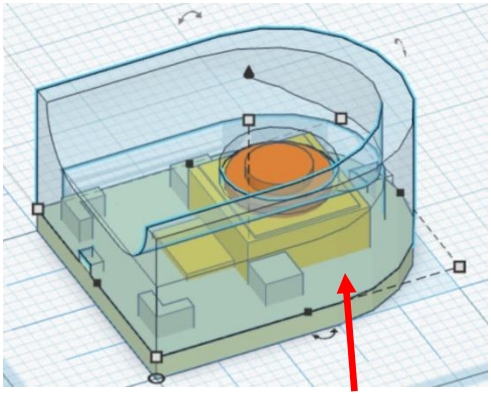


The Blue Buzzah Tactor

In order for the vibration to be sensed by the fingertip, an elastic mount inside the housing needs to push up on the LRA so the button can achieve the proper 0.5 mm preloading displacement against the skin. The mount must be elastic, otherwise the LRA would not be free to vibrate. Other LRA tactor designs we have studied use foam to mount their LRA. As we explain on the following page, we use a spring to mount for our LRA in order to achieve a stronger, more point-like sensation.



We use a weak elastic spring to mount our LRA

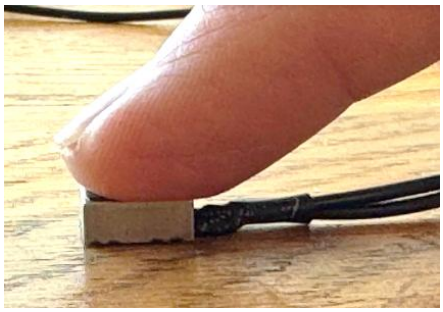


Other designs use foam to mount their LRA

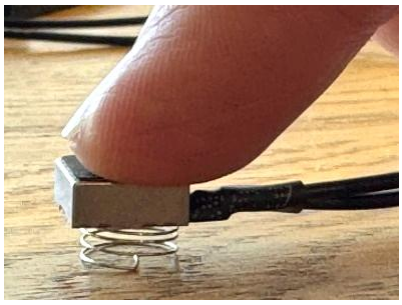
To understand why an LRA must be mounted elastically, consider the following demonstration.

First, we energize an LRA sitting on a tabletop and observe it vibrating vigorously off a table due to an enclosed vibrating mass.

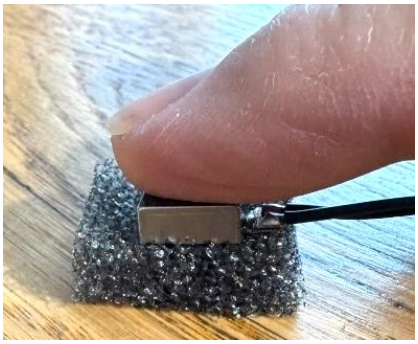
Next, we push gently downward on the vibrating LRA. If you were to perform this experiment yourself, you would find that the LRA's vibration is quickly extinguished by the table, even with only a very slight pressure from your finger.



However, if a weak spring is placed between the vibrating LRA and the tabletop as illustrated here, you would find that the LRA continues to vibrate vigorously up and down against your finger. So, the elastic mount provided by the spring keeps the mass of the table from extinguishing the LRA's vibration.



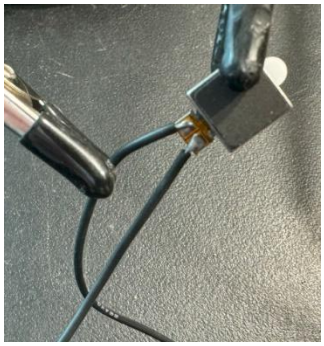
When the same experiment is conducted using foam between the LRA and table, we find that the LRA vibrates with less intensity. This is due primarily to the property of foam whereby it becomes stiffer as it is depressed, allowing the mass of the table to dampen the LRA's vibration.



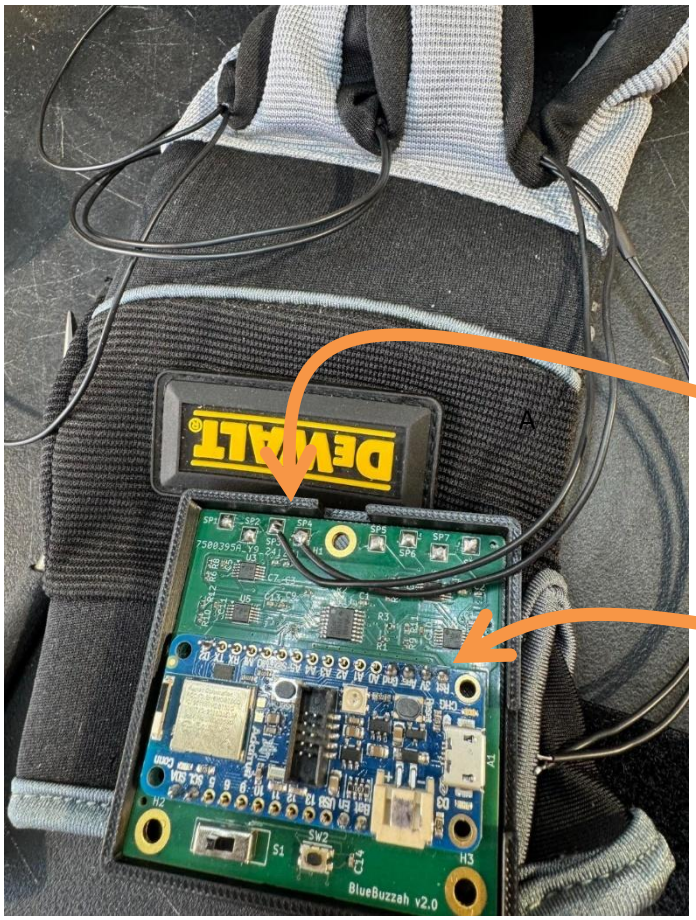
Likewise, if the spring in our LRA tactor is replaced by foam, we find that our button vibrates with less intensity. But, more importantly, with foam the LRA also transmits more vibration to the case, resulting in a less point-like sensation.

Three Steps Where Soldering is Required

Aside from the soldering connections described here, the level of expertise needed for this build is comparable to a very elaborate Hobby Lobby crafts project…



1) Soldering 8 pairs of wires like this to buzzer pads… Very easily done by a novice with third hand soldering stand.



2. Connecting 8 pairs of wires to driver pads as shown.

3. Soldering headers to the “Feather Board” and the PCB.

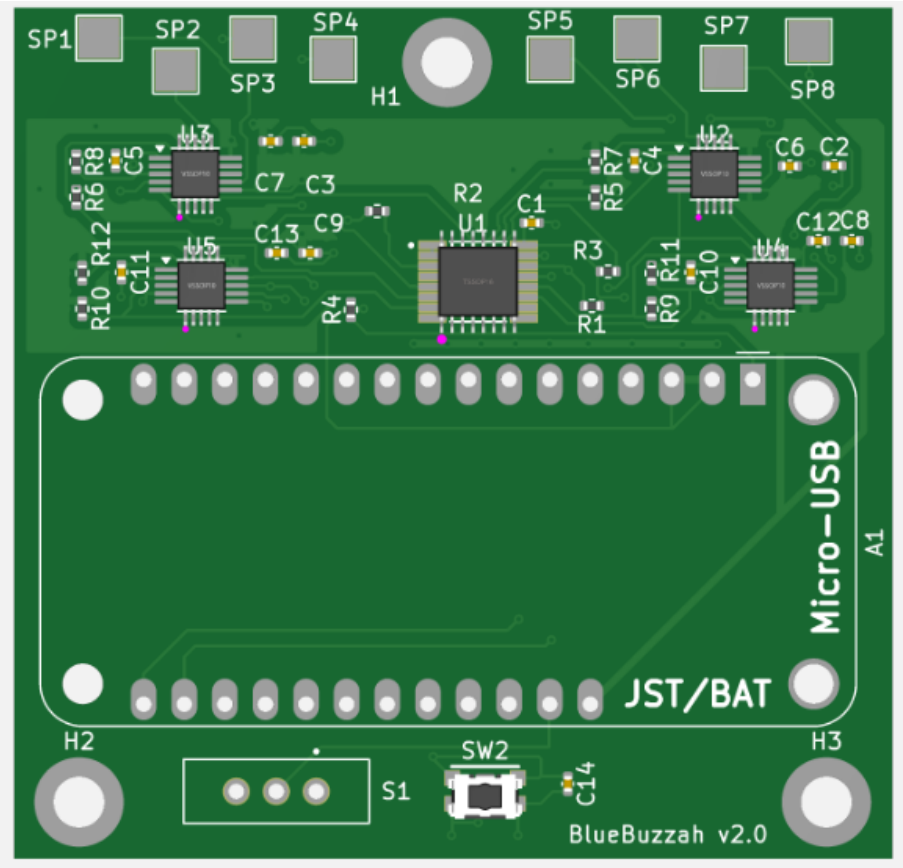
<u>If you wanted to be sure you didn’t accidentally damage anything while soldering, you could take your piece to an electronics repairman and have them do this part of the job.</u>

PART 1: Ordering the Preassembled PCB

The specially designed 2-layer PCB is what makes the the Blue Buzzah small, inexpensive and relatively easy to build for DIYers. It comes 99% preassembled from Hong Kong with everything except the ON/OFF switch and the Adafruit feather that we will add in Part 2. We intend a future revision that will eliminate essentially all soldering requirements for assembly.

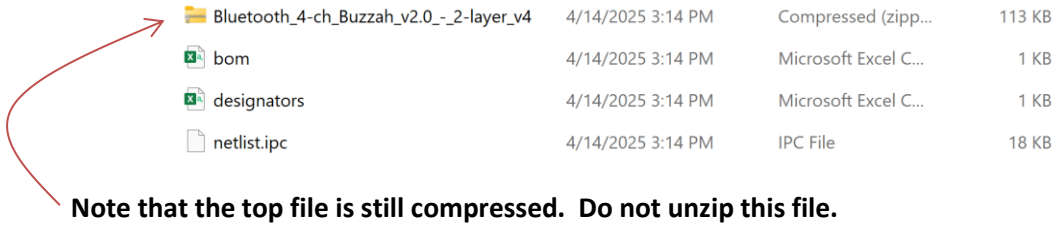
In order to enable the factory named JLCPCB in Hong Kong to make the boards, you will need to provide all the necessary information through their website. In this section, we detail the elaborate steps that are necessary to complete your order for the two boards you will need. Unfortunately, JLCPCB does not offer a way for us to share the order details directly, so you must enter all the steps yourself.

Ordering Disclaimer: We have used the Gerbers we posted on Github to make three successful orders. BlueBuzah Partner #1, who designed the schematics, made the first two orders totaling 7 boards, all of which have worked perfectly. The most recent order for 15 boards, that was used to obtain the screen shots you will see in this section, was made in April 2025 from scratch by BlueBuzah Partner #2 as a Guinea pig to make sure the process worked for a novice to JLCPCB ordering. So far at the time of this writing, we have only assembled one board from our recent order, but it also worked perfectly and fit perfectly in our 3-D printed enclosure. While we have provided these the detailed instructions and Gerbers files we used for informational purposes in good faith, we do not guarantee that there are no errors here, or that JLCPCB will ultimately provide working boards. If you decide to make your own order as we did, we wish you all the best.



Step 1-1. Before ordering you must complete the following tasks:

a) Download the zipped Production PCB folder from the Blue Buzzah Github site mentioned in the introduction.
b) Save the zipped folder somewhere on your computer you can locate later (like your desktop).
c) Unzip the folder until you have a folder with these four files.

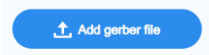


Note that the top file is still compressed. Do not unzip this file.

Step 1-2. Navigate to https://jlcpcb.com/ and set up a free account.

Step 1-3. Make sure you are logged into your account then go back to the home screen of JLCPCB

Step 1-4. Click on ORDER NOW near the top right part of the screen.

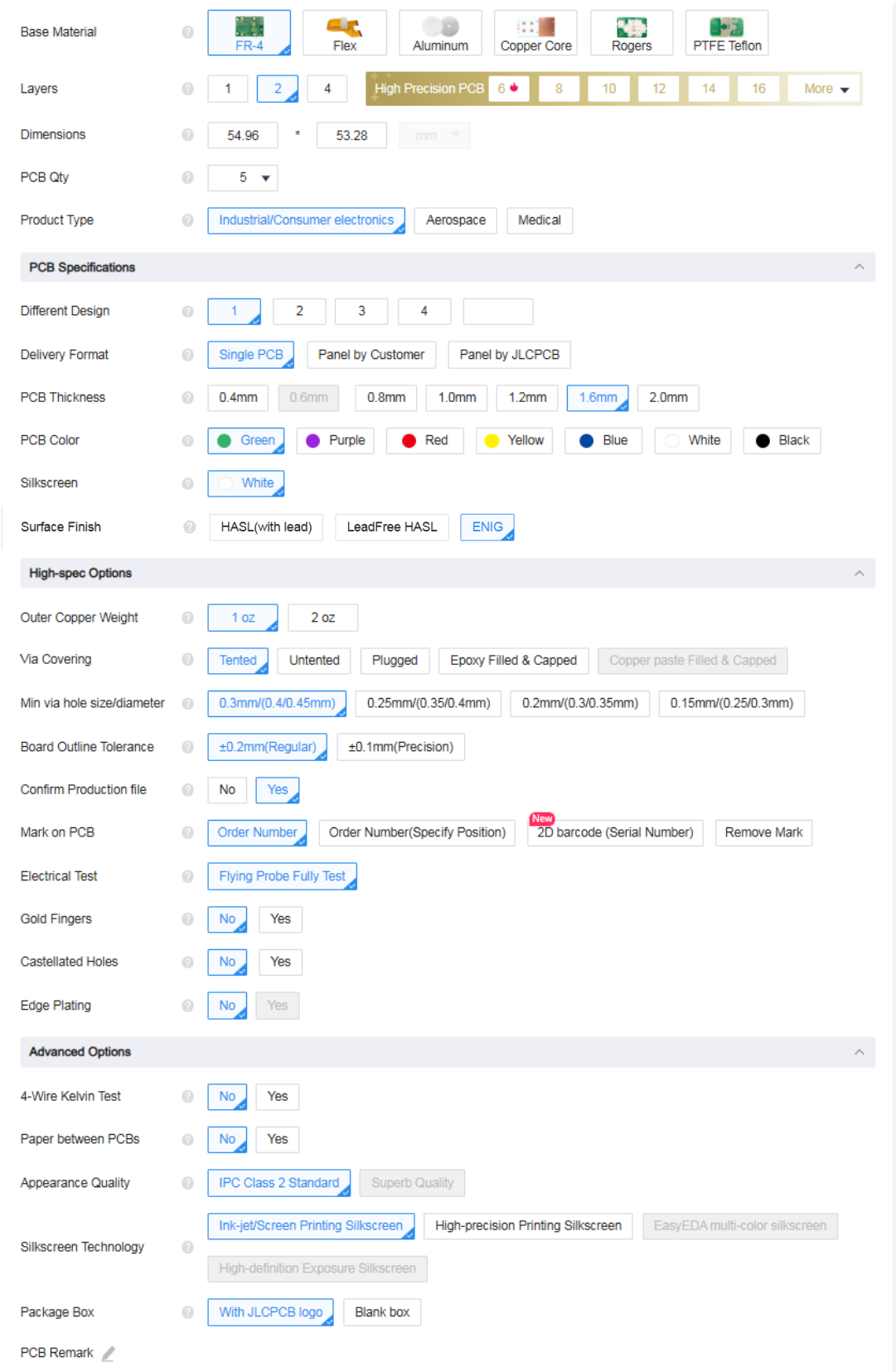
Step 1-5. Click on 

it the top of the screen.

Step 1-6. Use the window that opens to Bluetooth_4-ch_Buzzah_v2.0_-_2-layer_v4 from the place you saved it on your computer. (Note this zipped file contains all the Gerber files for our board.)

Step 1-7. Confirm that the board pic shown below shows up at the top of your ordering page and the Standard PCB/PBCA is selected as shown:

Step 1-8. Most of the choices shown here are automatically be selected for you, but there are a few changes you will notice, so double check everything so that your screen matches the choices below. Note that the PCB QTY of boards has to be entered in multiples of 5. If you want more, the next step up is 10 boards.

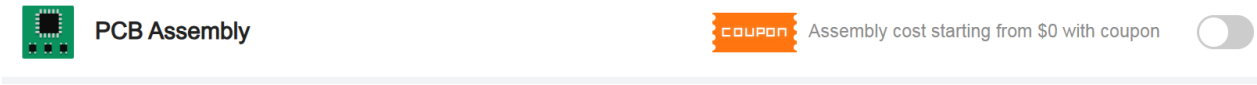


Click these little arrows if a menu needs to be expanded to see the criteria

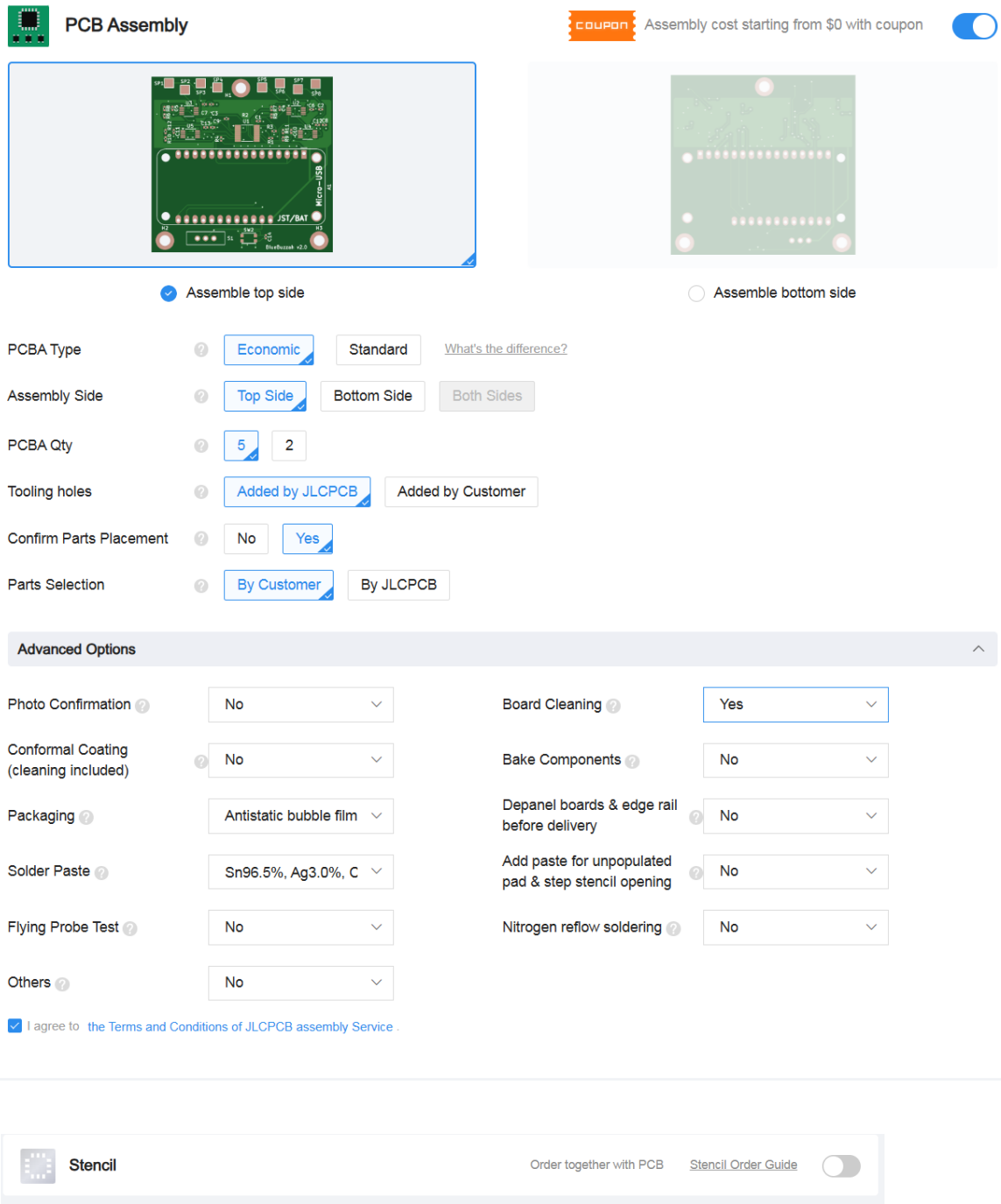
Click these little arrows if a menu needs to be expanded to see the criteria

Click these little arrows if a menu needs to be expanded to see the criteria

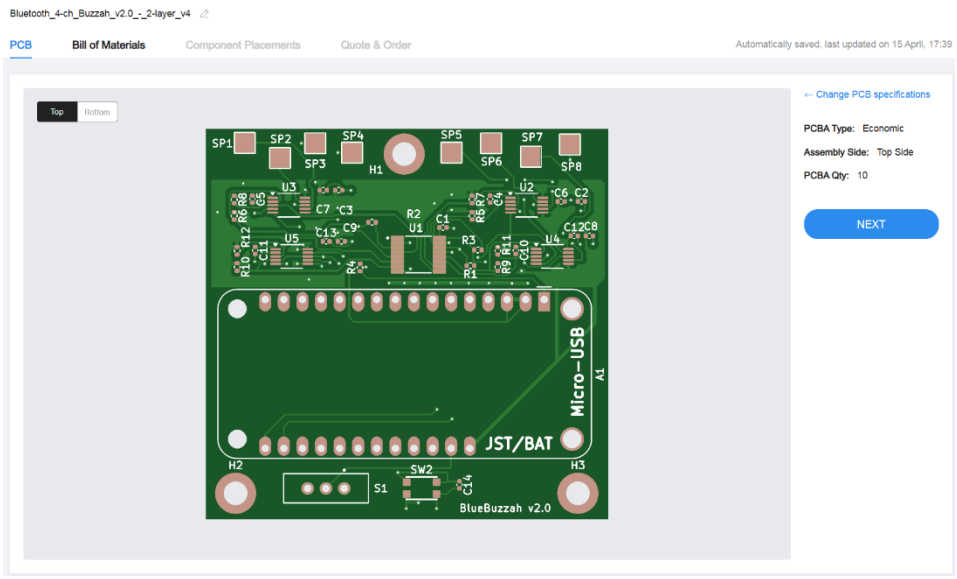
Step 1-9. Click on the button to include PCB assembly



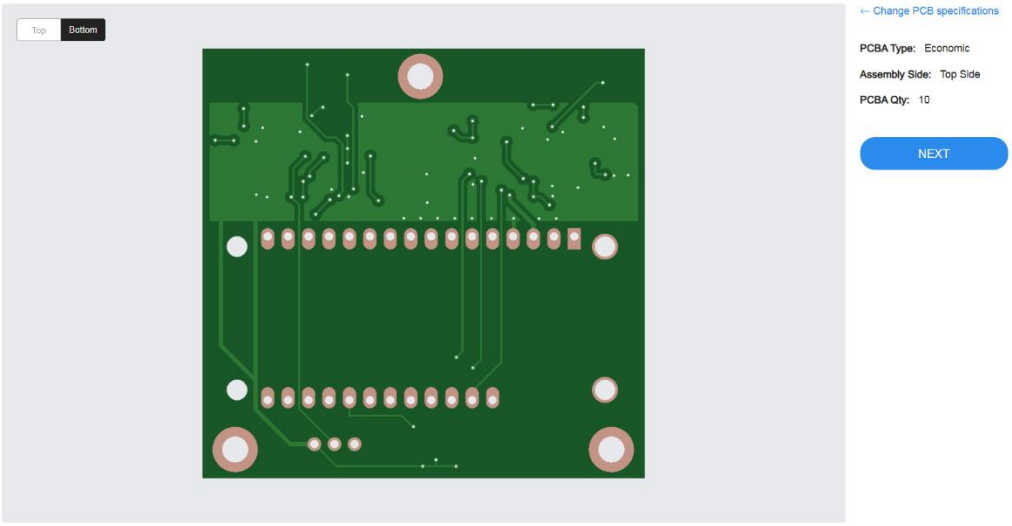
Step 1-10. The window below opens up. Verify the following criteria are chosen. Most will populate automatically, but there are a few differences.



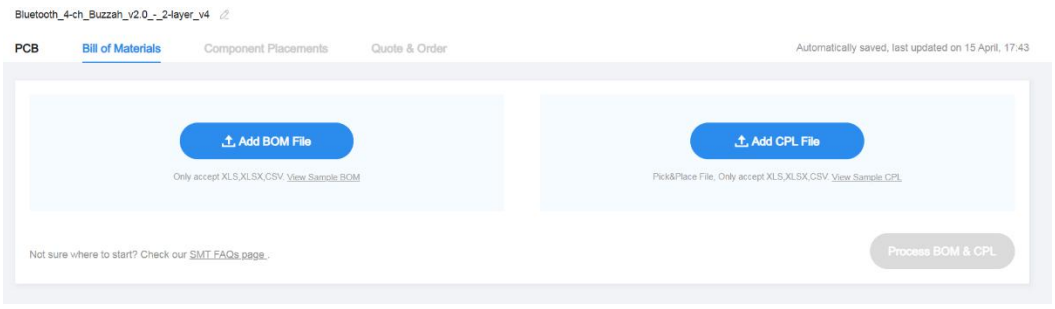
Step 1-11. Click NEXT and you should see the picture below. Verify that it looks the same.

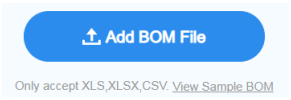


Step 1-12. Click BOTTOM and it should look like this:



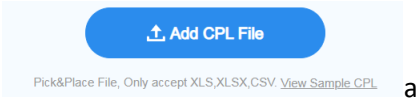
Step 1-13. Click NEXT to get to the Bill of Materials menu shown here



Step 1-14. Click 

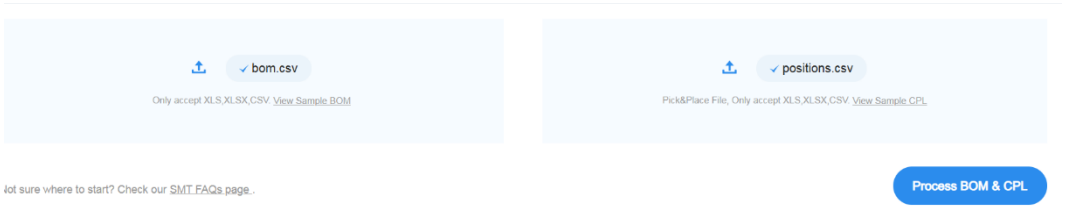
and upload the BOM file you saved on your computer.

bom 4/14/2025 3:14 PM Microsoft Excel C... 1 KB

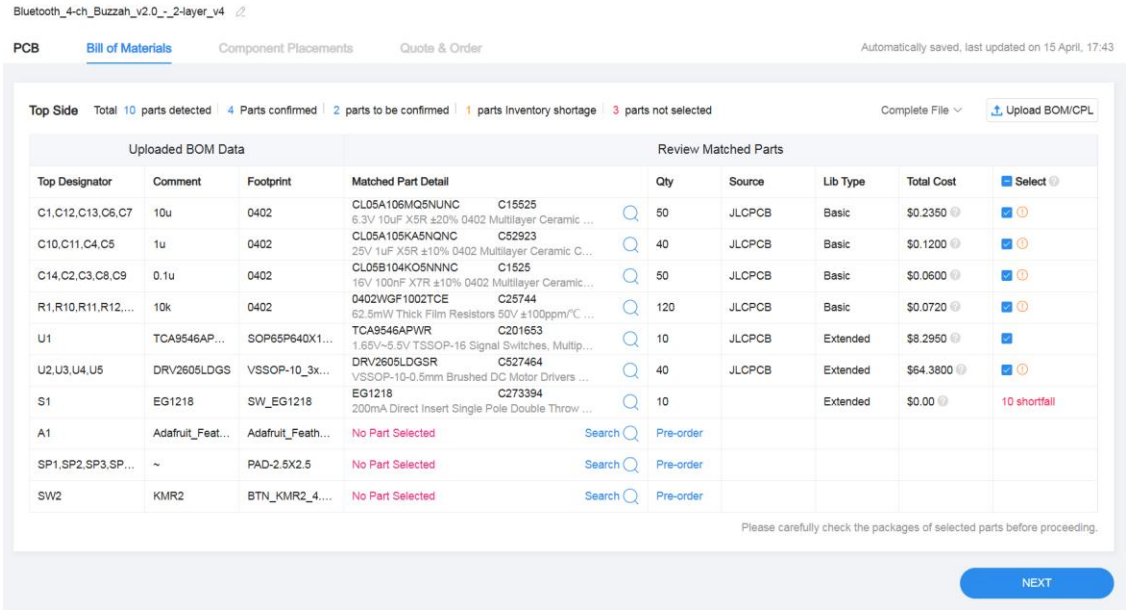
Step 1-15. Click 

and upload the POSITIONS file you saved on your computer

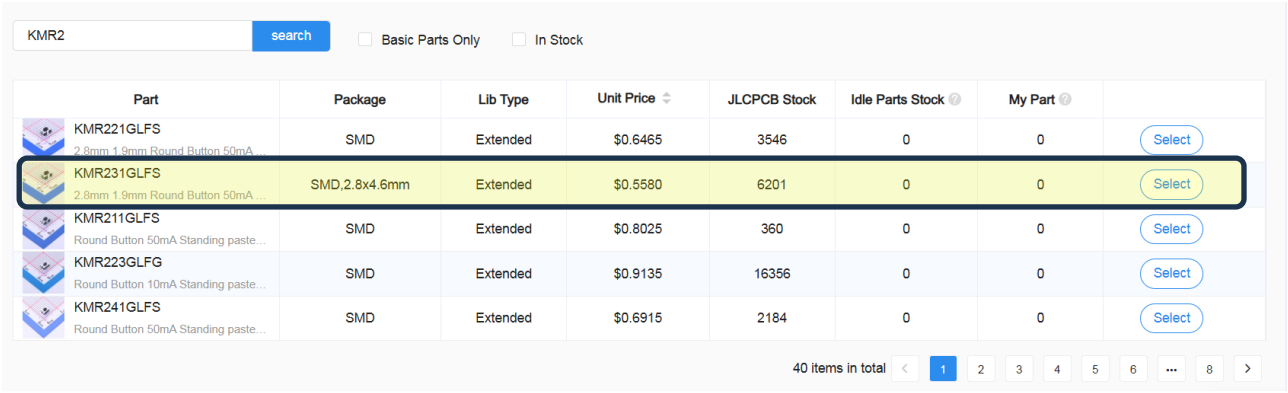
Step 1-16. Verify your screen now looks like this:



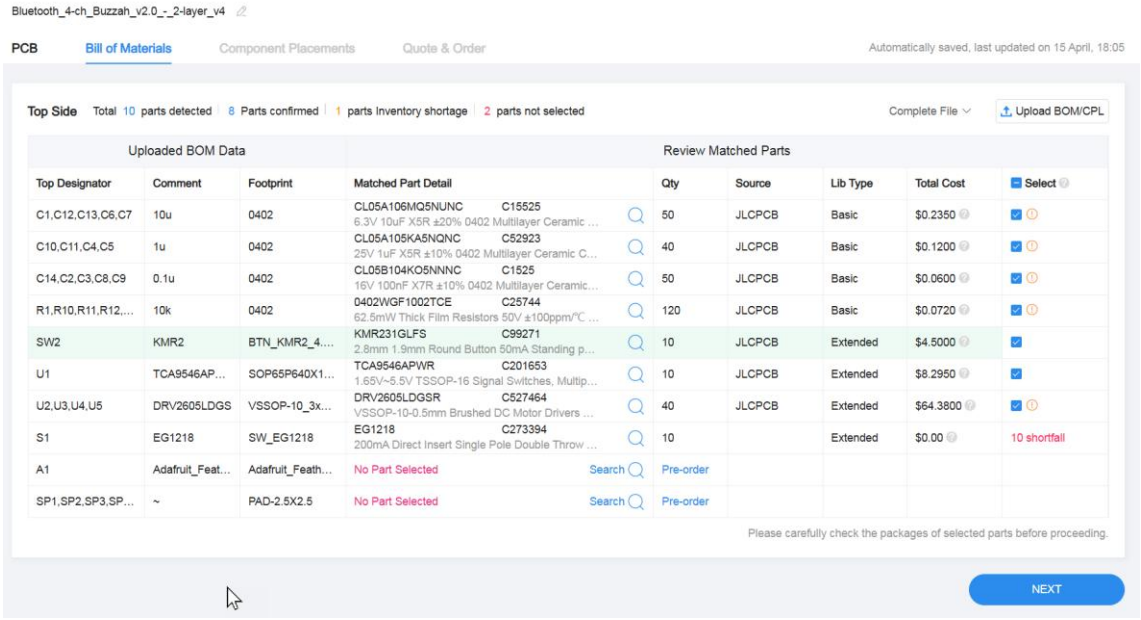
Step 1-17. Click PROCESS BOM & CPL and verify you get a screen that looks like this:



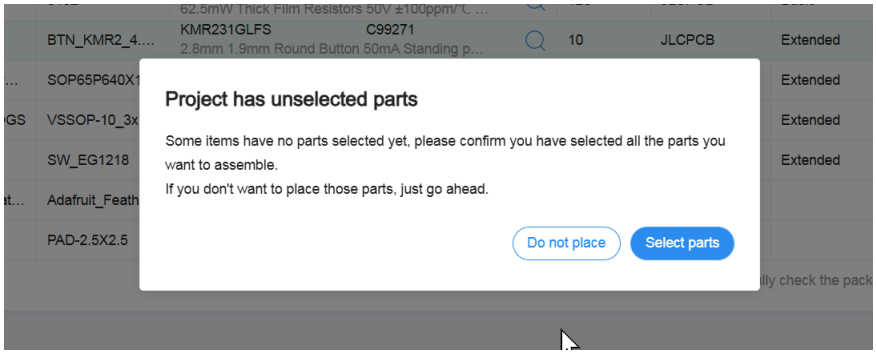
Step 1-18. Note the three parts that indicate NO PART SELECTED. The first two are OK not selected, but we need to select the third one (SW2) by hand. Click on SEARCH for the SW2 part and you should get what is shown below. Select the part we highlighted.



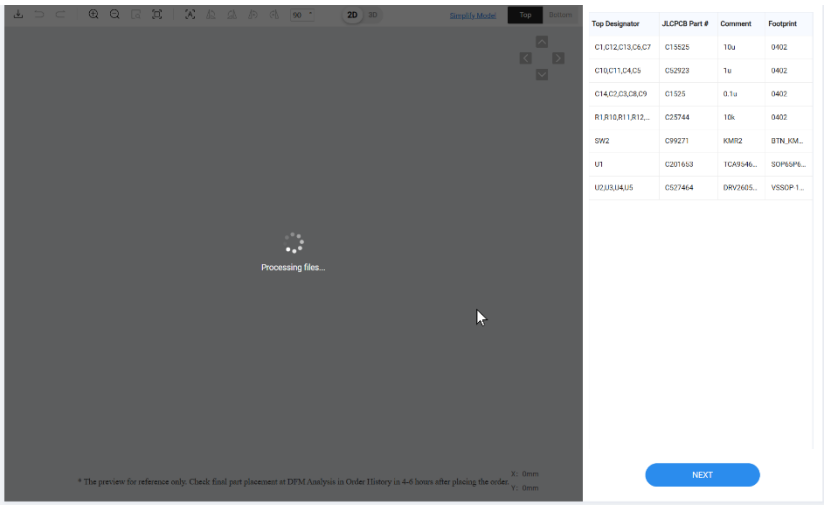
Step 1-19. Now your BOM page should look like this with SW2 selected with a blue box check:



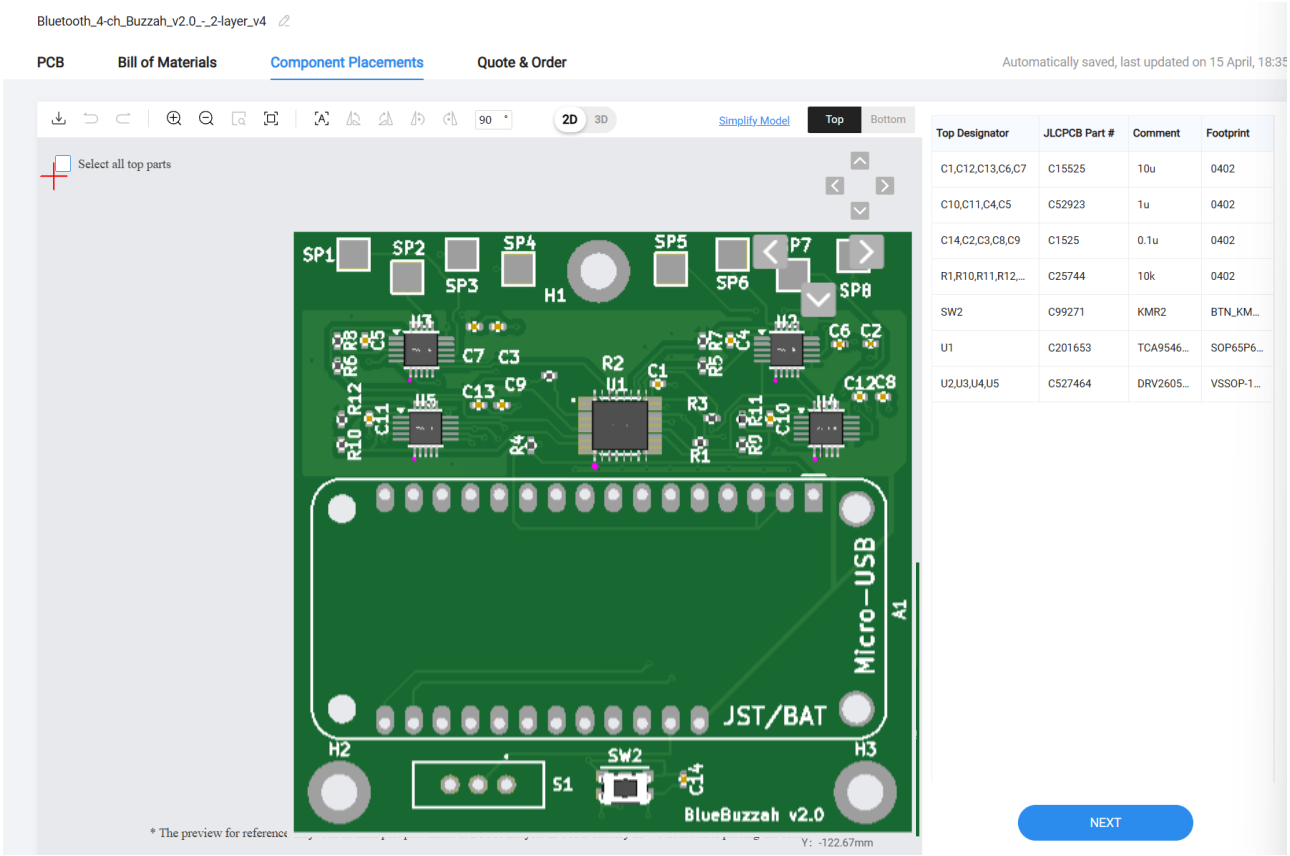
Step 1-20. Click NEXT. You will receive this message, but you can ignore it since A1 and SP1, etc are not supposed to be selected. Click DO NOT PLACE



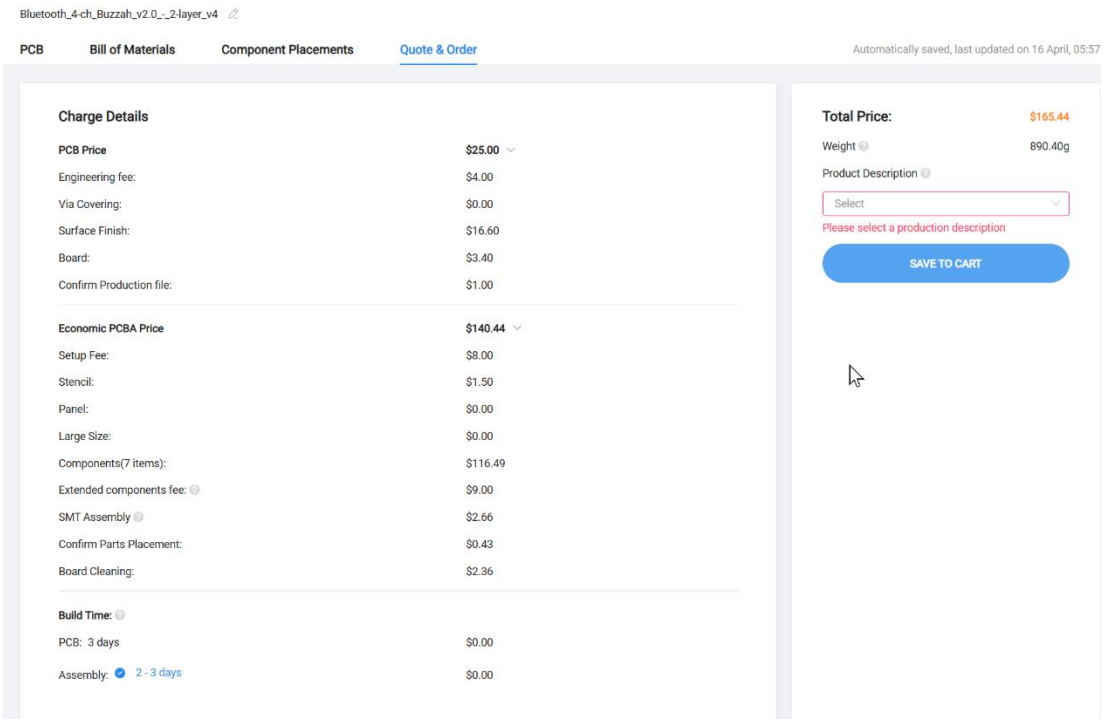
Step 1-21. Wait for the JLCPCB site to process the files



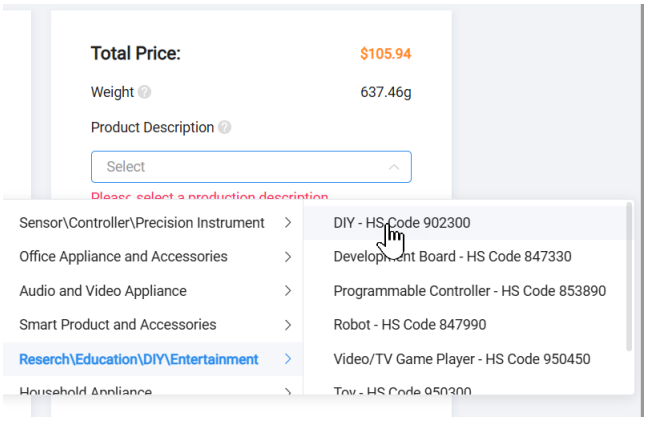
Step 1-22. When the processing is finished you will see the image below with the parts placed on the board.



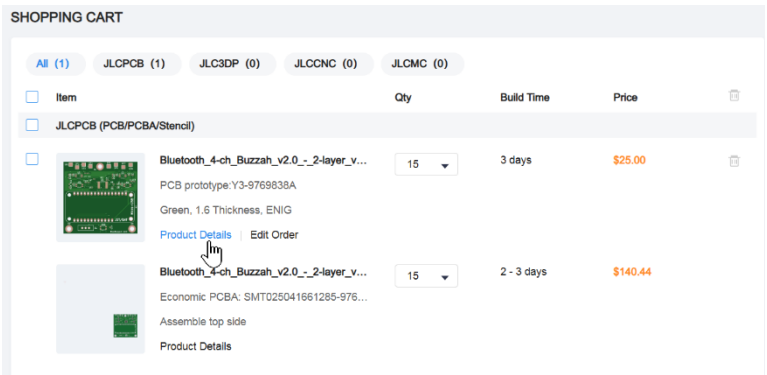
Step 1-23. Click NEXT and you get something like this. The charges will be different because I checked 15 boards and you will probably be ordering fewer.



Step 1-24. Select RESEARCH/EDUCATION and DIY in the drop down menus on the right.



Step 1-25. Click SAVE TO CART and you get this.



Step 1-26. Click PROJECT DETAILS for the PCB in the above screen. Verify all the product details shown here (except your quantity will be different)

Product Detail

Gerber file:	Bluetooth_4-ch_Buzzah_v2.0_-_...	Build Time:	3 days
Base Material:	FR-4	Layers:	2
Dimension:	54.96 mm* 53.28 mm	PCB Qty:	15
Product Type:	Industrial/Consumer electronics	Different Design:	1
Delivery Format:	Single PCB	PCB Thickness:	1.6mm
Specify Stackup:	no	PCB Color:	Green
Silkscreen:	White	Material Type:	FR4-Standard TG 135-140
Via Covering:	Tented	Surface Finish:	ENIG Gold Thickness: 1 U"
Deburring/Edge rounding:	No	Outer Copper Weight:	1 oz
Gold Fingers:	No	30°finger chamfered:	No
Electrical Test:	Flying Probe Fully Test	Castellated Holes:	no
Edge Plating:	No	Mark on PCB:	Order Number
Blind Slot:	No	Min via hole size/diameter:	0.3mm/(0.4/0.45mm)
4-Wire Kelvin Test:	No	Paper between PCBs:	No
Appearance Quality:	IPC Class 2 Standard	Confirm Production file:	Yes
Silkscreen Technology:	Ink-jet/Screen Printing Silkscreen	Package Box:	With JLCPCB logo
Inspection Report:	No	Board Outline Tolerance:	±0.2mm(Regular)

Step 1-27. Close the PCB product details and then click on the PCBA product details. Verify all these details (except quantity)

Product Detail

PCBA Parameters | Bill of Material | Part Placement

PCBA Type	Economic
Assembly Side	Top Side
PCBA Qty	15
Tooling holes	Added by JLCPCB
Confirm Parts Placement	Yes
Photo Confirmation	No
Board Cleaning	Yes
Conformal Coating (cleaning included)	No
Bake Components	No
Packaging	Antistatic bubble film
Depanel boards & edge rail before delivery	No
Solder Paste	Sn96.5%, Ag3.0%, Cu0.5%(260℃)
Add paste for unpopulated pad & step stencil opening	No
Flying Probe Test	No
Nitrogen reflow soldering	No
Others	No
File provided as	Single Piece, pls help me repeat the data
Panel Format	1 * 1
Build Time	2 - 3 days

Step 1-28. Click on the Bill of Materials in the same window and verify

PCBA Parameters | **Bill of Material** | Part Placement

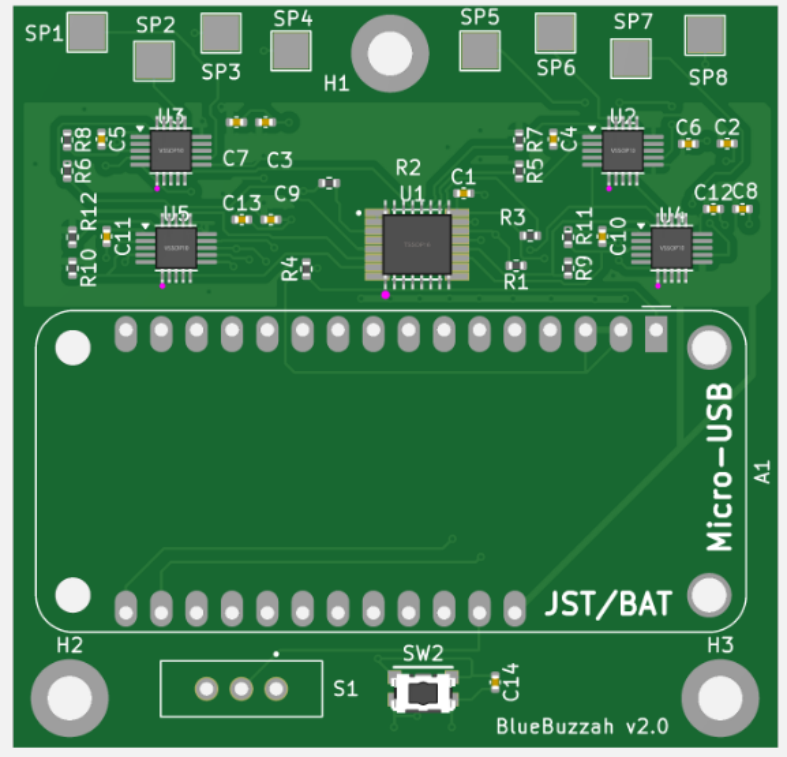
Selected Parts(7 items) Download Selected Parts List

Part Detail	Selected by	Top Designator	Qty	Source	Ext. Price
CL05A106MQ5NUNC Basic C15525	System	C1,C12,C13,C6,C...	75	JLCPCB	$0.3525
CL05A105KA5NQNC Basic C52923	System	C10,C11,C4,C5	60	JLCPCB	$0.1800
TCA9546APWR Extended C201653	System	U1	15	JLCPCB	$12.4425
KMR231GLFS Extended C99271	Customer	SW2	15	JLCPCB	$6.7500
CL05B104KO5NNNC Basic C1525	System	C14,C2,C3,C8,C9	75	JLCPCB	$0.0900
0402WGF1002TCE Basic C25744	System	R1,R10,R11,R12,...	180	JLCPCB	$0.1080
DRV2605LDGSR Extended C527464	System	U2,U3,U4,U5	60	JLCPCB	$96.5700

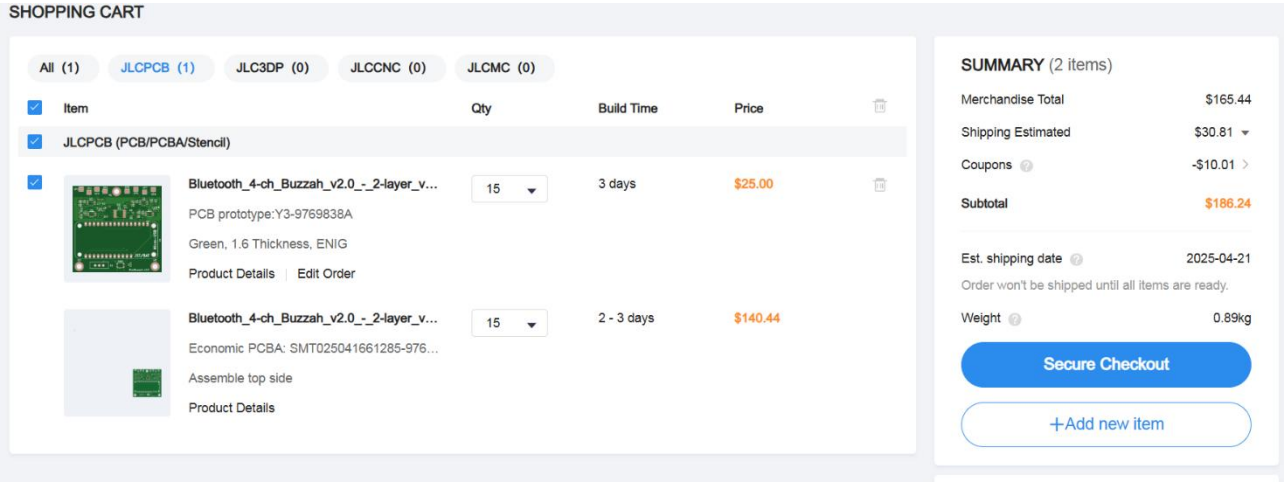
Unselected Parts Download Table

Designator	Comment	Footprint	Reason	Qty
S1	EG1218	SW_EG1218		1
A1	Adafruit_Feather_Generic_mountingholes	Adafruit_Feather_WithMountingHoles		1
SP1,SP2,SP3,SP4,SP5,SP6,SP7,SP8	~	PAD-2.5X2.5		8

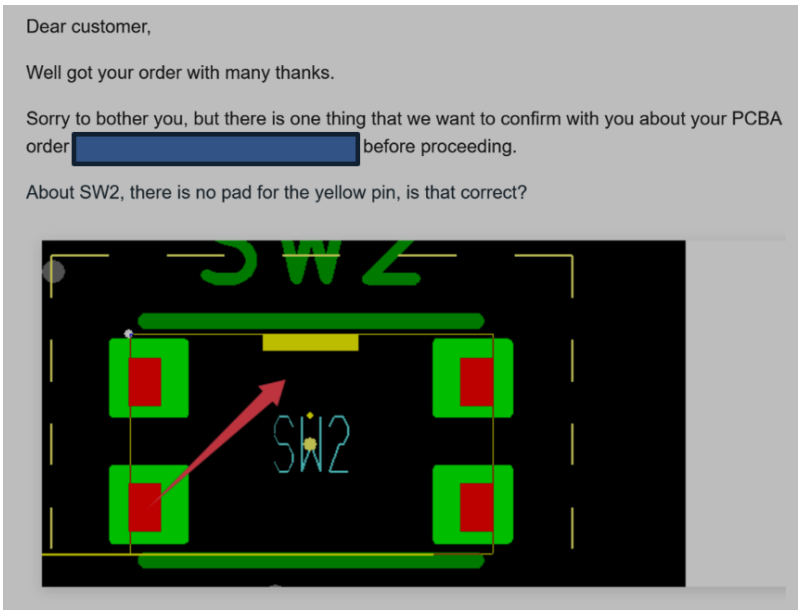
Step 1-29. Click on Part Placement and verify it looks like this



Step 1-30. Select the blue check boxes for items and click SECURE CHECKOUT

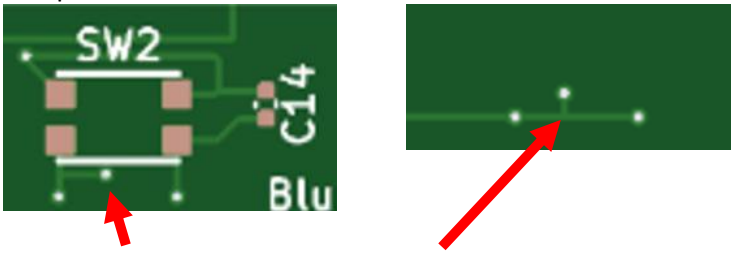


Step 1-31. You may get an email from JLCPCB like I did questioning whether a yellow pad on near SW2 on the PCB was supposed to be a real pad. This yellow pad is some kind of artifact introduced in the preparation process that can be disregarded. If you get this email, reply to JLCPCB and confirm that there are only four pads for SW2.



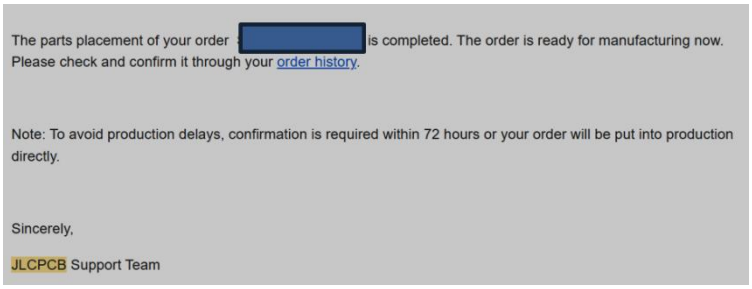
Top of PCB

Bottom of PCB



This little trace has no purpose but it does not hurt anything by being there

Step 1-32. After a day or two, you will get an email from JLCPCB asking you to confirm your parts placement.



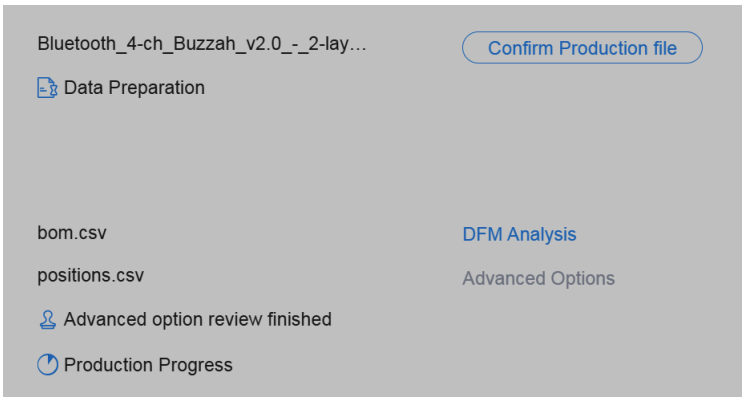
The parts placement of your order [redacted] is completed. The order is ready for manufacturing now. Please check and confirm it through your order history.

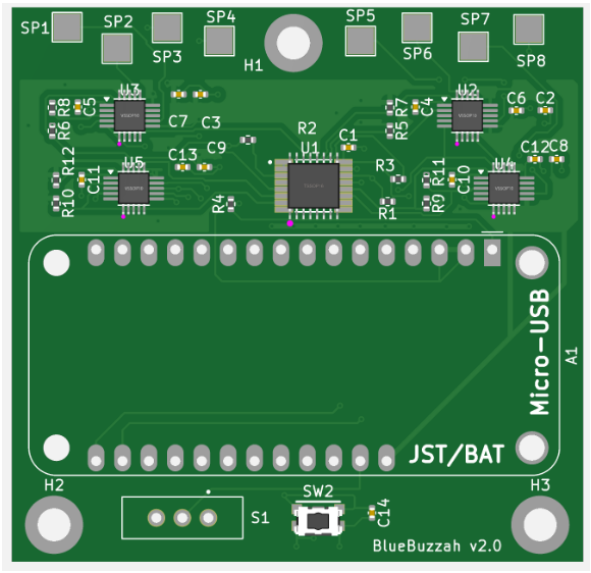
Note: To avoid production delays, confirmation is required within 72 hours or your order will be put into production directly.

Sincerely,

JLCPCB Support Team

After you log into your account, navigate to your orders page and you will see the button to confirm your Production file. Click on DFM ANALYSIS and you will see a picture of the parts placement come up. This is your last opportunity to check that the parts placement is correct. I also took this opportunity to check the PRODUCT DETAILS for the PCB and PCBA. **<u>THIS IS YOUR LAST CHANCE TO STOP PRODUCTION!</u>** Once you click CONFIRM PRODUCTION FILE, your order will go into final processing and get shipped out to your address.





Product Detail

Gerber file:	Bluetooth_4-ch_Buzzah_v2.0_-_2-layer_v4_Y3	Build Time:	3 days
Base Material:	FR-4	Layers:	2
Dimension:	54.96 mm* 53.28 mm	PCB Qty:	15
Product Type:	Industrial/Consumer electronics	Different Design:	1
Delivery Format:	Single PCB	PCB Thickness:	1.6mm
Specify Stackup:	no	Layer Sequence:	
PCB Color:	Green	Silkscreen:	White
Material Type:	FR4-Standard TG 135-140	Via Covering:	Tented
Surface Finish:	ENIG Gold Fingers: 1U"	Deburring/Edge rounding:	No
Outer Copper Weight:	1 oz	Gold Fingers:	No
30°finger chamfered:	No	Electrical Test:	Flying Probe Fully Test
Castellated Holes:	no	Edge Plating:	No
Mark on PCB	Order Number	Blind Slot:	No
Min via hole size/diameter:	0.3mm/(0.4/0.45mm)	4-Wire Kelvin Test:	No
Paper between PCBs:	No	Appearance Quality:	IPC Class 2 Standard
Confirm Production file:	Yes	Silkscreen Technology:	Ink-jet/Screen Printing Silkscreen
Package Box:	With JLCPCB logo	Inspection Report:	No
Board Outline Tolerance:	±0.2mm(Regular)		

PCBA Parameters | Bill of Material | Part Placement

PCBA Type	Economic
Assembly Side	i18n_shared_403
PCBA Qty	15
Tooling holes	Added by JLCPCB
Confirm Parts Placement	Yes
Photo Confirmation	No
Board Cleaning	Yes
Conformal Coating (cleaning included)	No
Bake Components	No
Packaging	Antistatic bubble film
Depanel boards & edge rail before delivery	No
Solder Paste	Sn96.5%, Ag3.0%, Cu0.5%(260℃)
Add paste for unpopulated pad & step stencil opening	No
Flying Probe Test	No
Nitrogen reflow soldering	No
Others	No
File provided as	Single Piece, pls help me repeat the data
Panel Format	1 * 1
Build Time	2 - 3 days

PCBA Parameters | Bill of Material | Part Placement

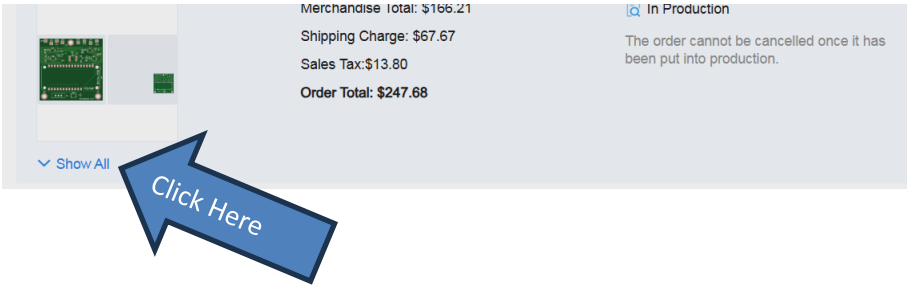
Selected Parts(7items) Download Selected Parts List

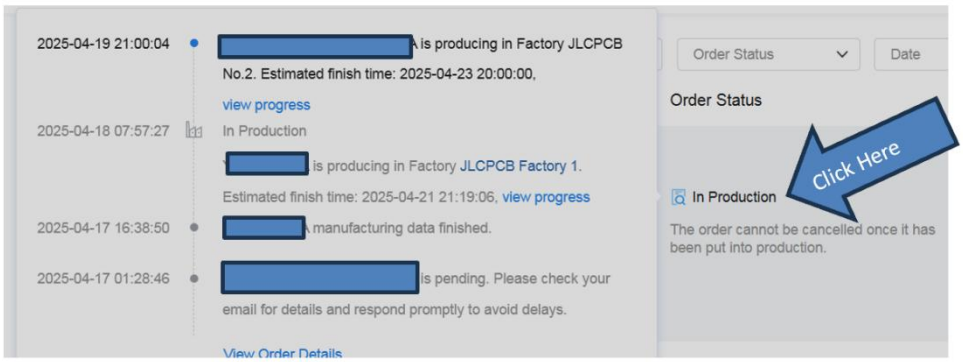
Part Detail	Selected by	Top Designator	Qty	Source	Ext. Price
CL05A106MQ5NUNC Basic C15525	System	C1,C12,C13,C6,C7	75	JLCPCB	$0.35
CL05A105KA5NQNC Basic C52923	System	C10,C11,C4,C5	60	JLCPCB	$0.18
TCA9546APWR Extended C201653	System	U1	15	JLCPCB	$12.44
KMR231GLFS Extended C99271	Customer	SW2	15	JLCPCB	$6.75
CL05B104KO5NNNC Basic C1525	System	C14,C2,C3,C8,C9	75	JLCPCB	$0.09
0402WGF1002TCE Basic C25744	System	R1,R10,R11,R12,R2,R3,R4,R5,R6,R7,R8,R9	180	JLCPCB	$0.11
DRV2605LDGSR Extended C527464	System	U2,U3,U4,U5	60	JLCPCB	$96.57

Unselected Parts Download Table

Designator	Comment	Footprint	Reason	Qty
S1	EG1218	SW_EG1218		1
A1	Adafruit_Feather_Generic_m...	Adafruit_Feather_WithMount...		1
SP1,SP2,SP3,SP4,SP5,SP6,SP7,SP8	~	PAD-2.5X2.5		8

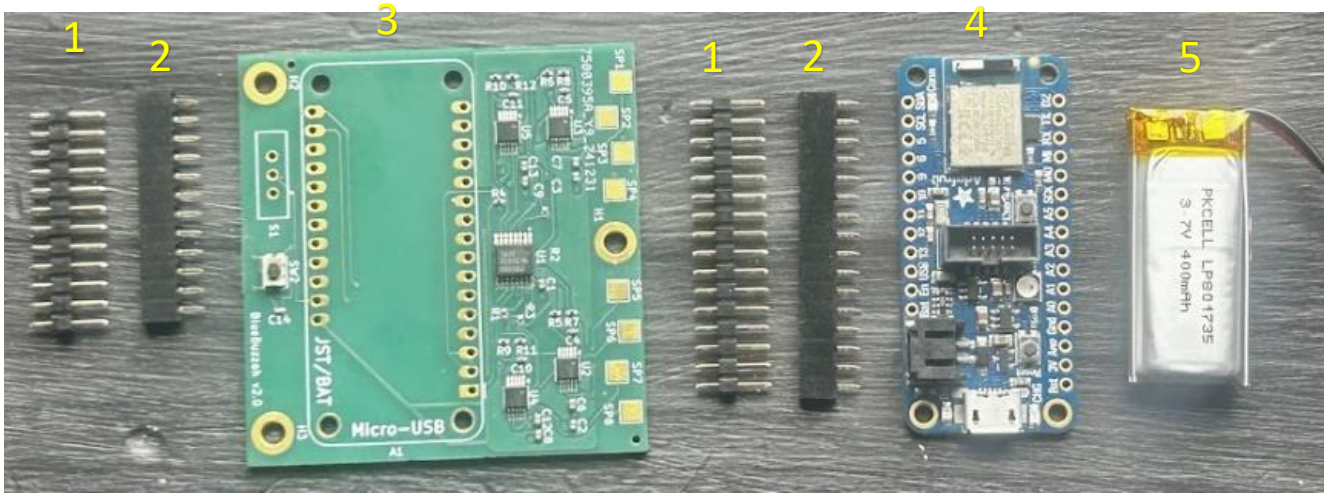
Step 1-33. You can check the ORDER status of your production any time on the JLCPCB web site.



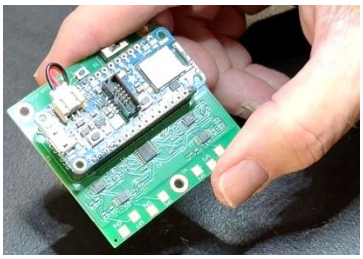


Once you have your boards ordered, make sure you order all the other parts and tools you will need. You can make use of the time you have to wait for your boards to arrive (about 1 week) to get everything else ready and prepare a clean workspace.

PART 2: Preparing the PCB Boards



1 = Short Feather male header
2 = Short Feather header
3 = Main PCB
4 = Adafruit Feather module
5 = LiPo battery



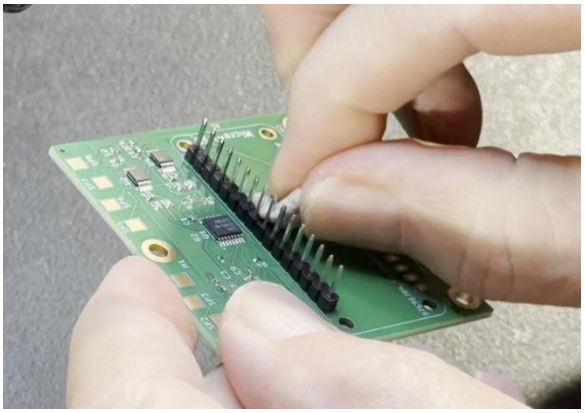
This section details how to prepare each of the PCBs for use in the Blue Buzzah.

Important Notes:

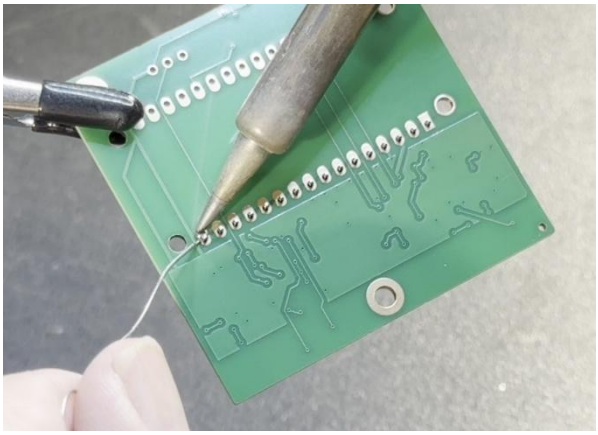
* This is the most solder intensive part of Blue Buzzah assembly. Keep in mind you can always hire an electronics technician to do this for you.
* The level of soldering skill needed is very basic, but if this is your first time soldering
  - Watch a "how to solder headers to PCB" video on YouTube
  - Get some cheap perf boards from Amazon and practice before you actually start this build
* Each of the two boards is prepared in the same way, except the software you load for the MASTER (left hand) board is different than the software for the SLAVE (right hand) board.
* Watch our video illustrating this process. It is really easier than it looks in the video! (see introduction for video link)
* Use with high quality tools for best results. Using a Weller soldering iron makes the process easier.
* You absolutely need a third hand soldering station to hold parts while soldering.
* Using the magnifying glass of the soldering station makes it easier to do the fine work.
* Clean your soldering tip after each solder joint. If you don't do this, your tip will get dirty and not heat your parts quickly.
* There are different philosophies about what temperature to use. We have best luck at 600 C, which heats the parts quickly and allows for shorter contact times.

Step 2.1a: Place short header using mounting putty

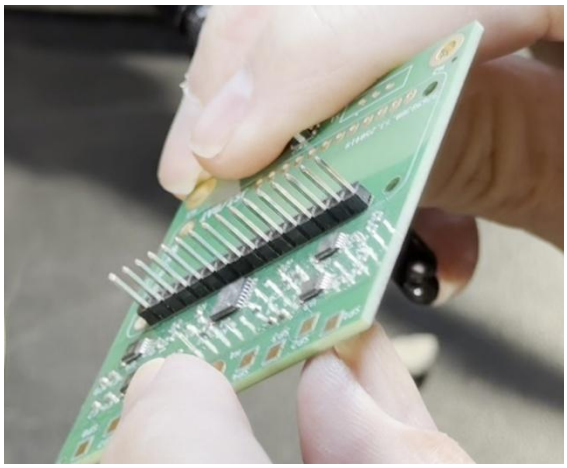
Long pins facing up!

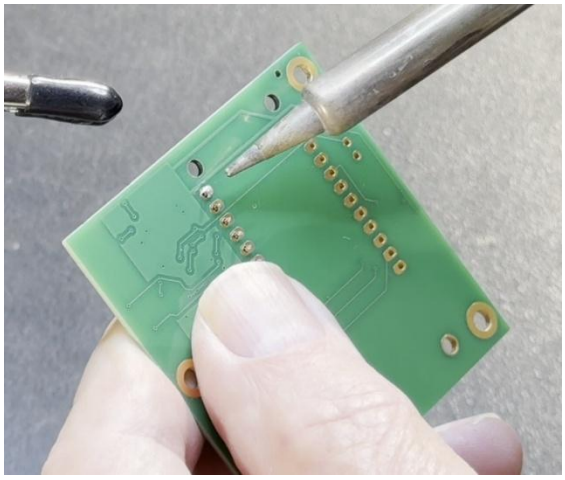


Step 2.1b: Solder one pin of header on back of PCB



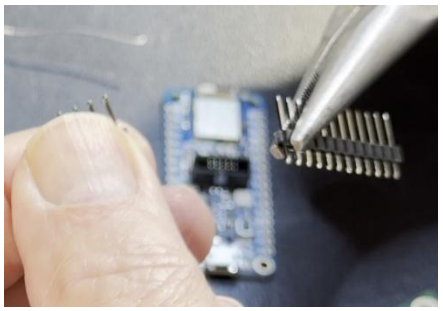
Step 2.1c: Inspect header placement and adjust orientation if needed



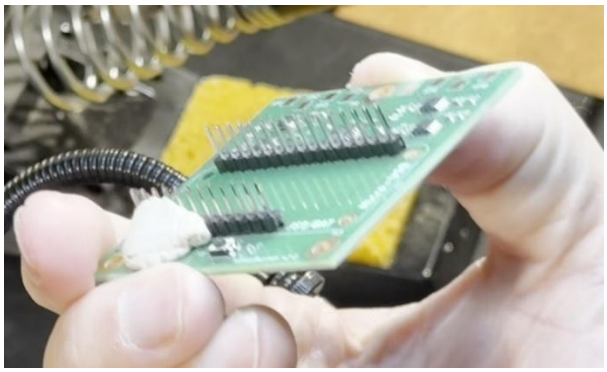


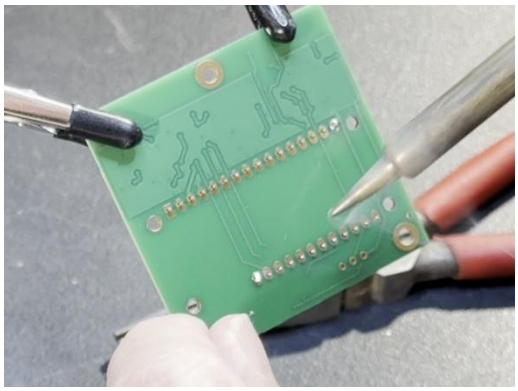
Since only one pin has been soldered, the connection may be heated again and loosened if your initial placement is crooked. Once two pins are soldered, the only way to adjust placement would be to use a desoldering tool.

Step 2.1d: Break a short header to make a 12-pin short header



Step 2.1e: Place the 12-pin short header and solder one pin as before

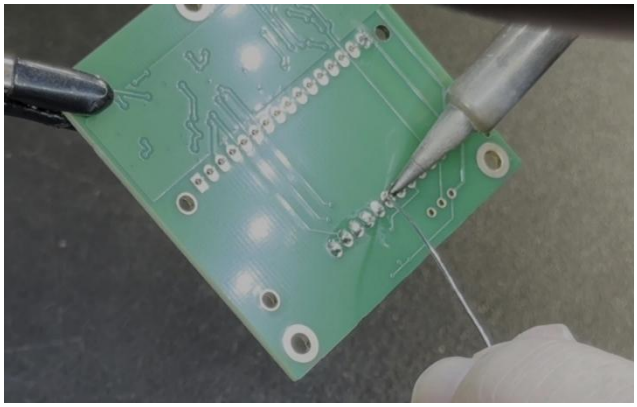


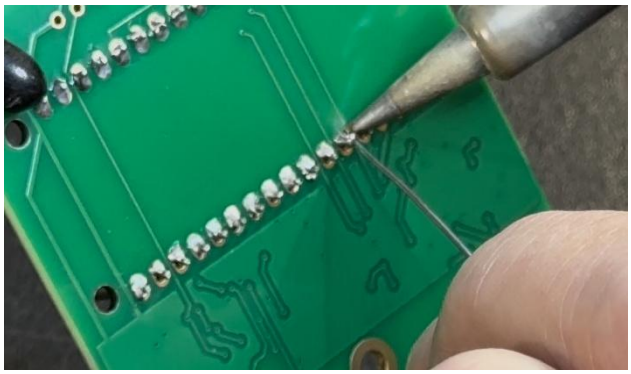


Step 2.1f: Check alignment of pins using a Feather module

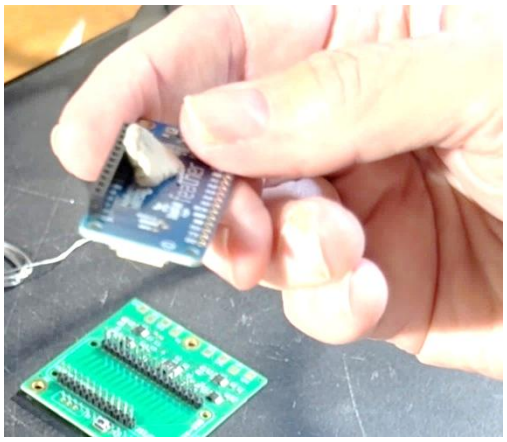
Adjust placement of headers if needed

Step 2.1g: Finish soldering the rest of the header pins under the PCB

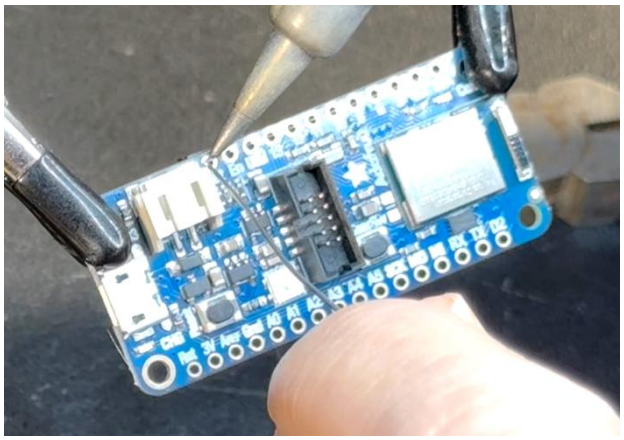




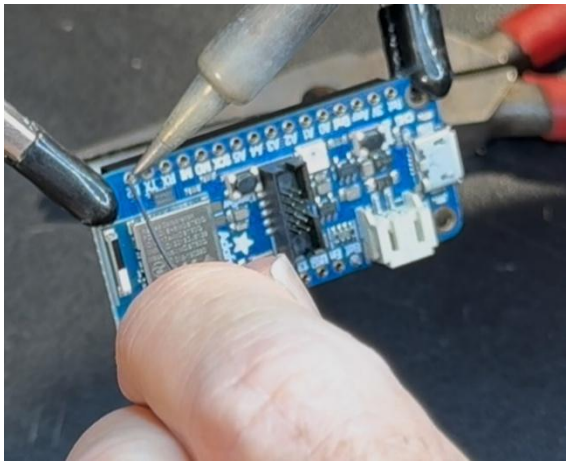
Step 2.2a: Use mounting putty to place your short 12-pin socket header to the bottom of the Feather module



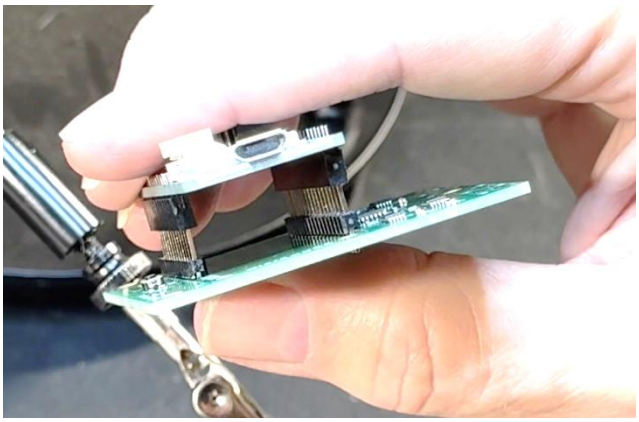
Step 2.2b: Solder one pin of the 12-pin socket header to the top of the Feather

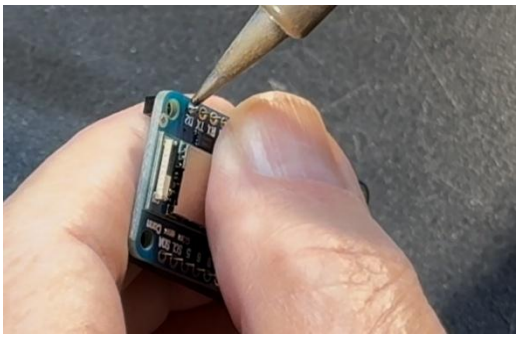


Step 2.2c: Solder one pin of the 16-pin socket header to the top of the Feather as before



Step 2.2d: Check the alignment of the sockets with the short headers on the PCB

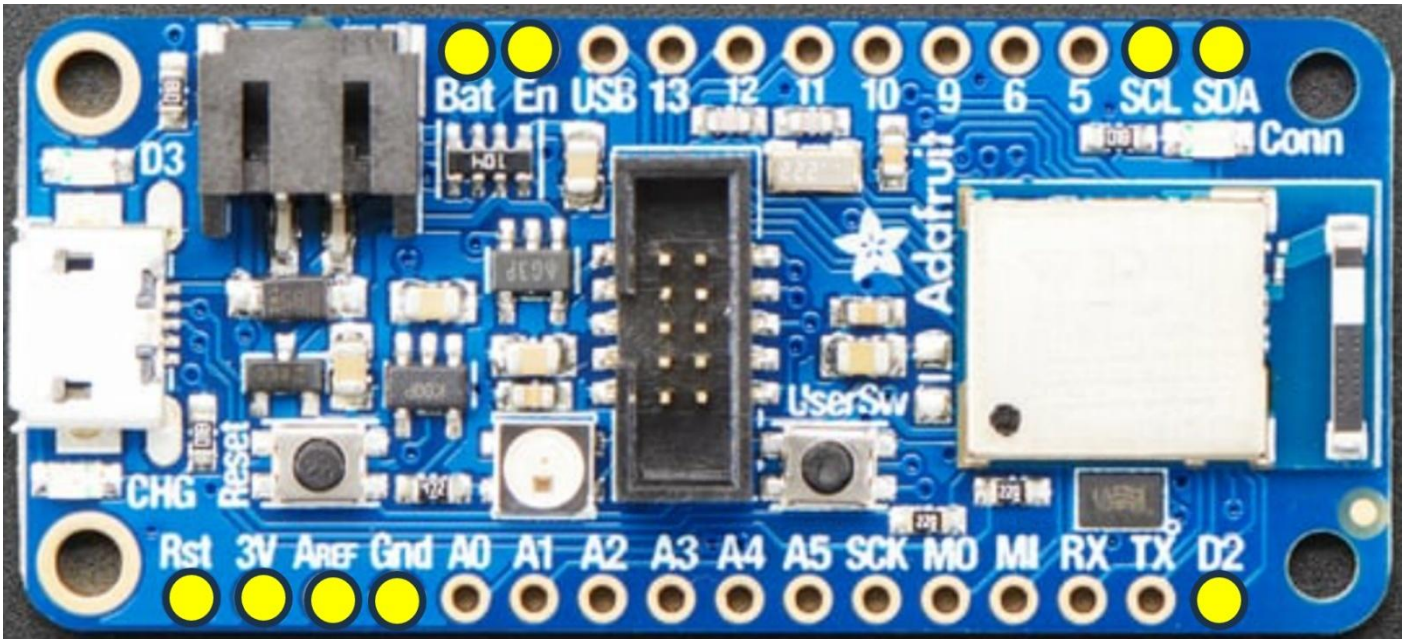




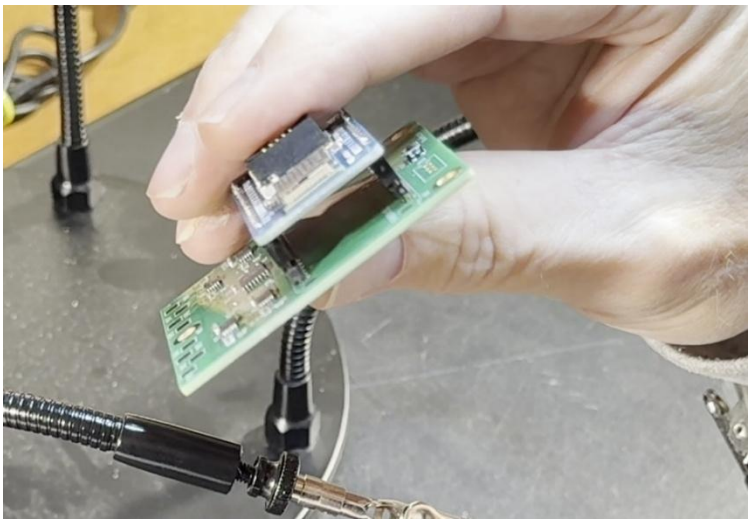
Adjust placement of socket headers if needed

Step 2.2e: Use the diagram below to identify and solder only the 9 pins that are needed on the Feather module

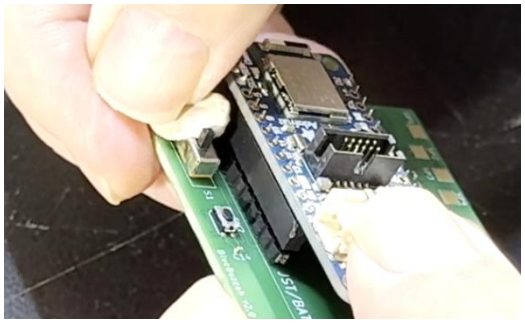
Try to limit the time you heat the circular pads of the Feather as quickly as possible to avoid damaging the chips



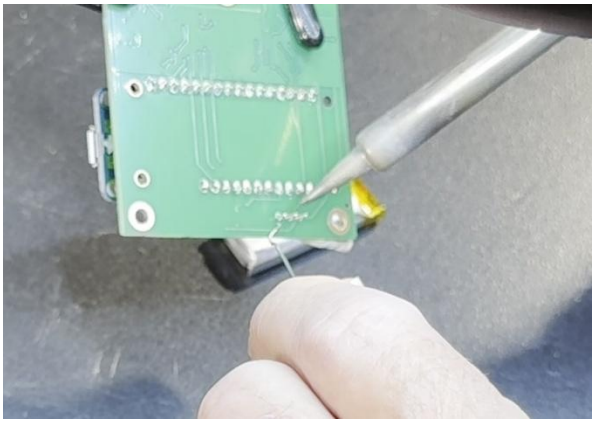
Step 2.2f: Push the Feather module in place atop the PCB

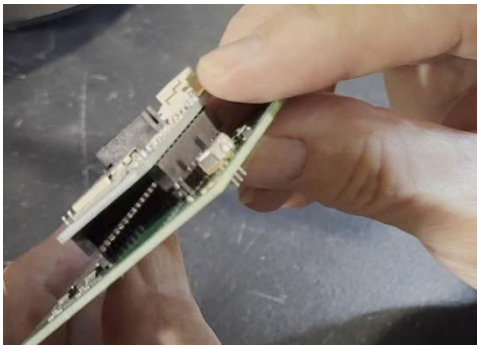


Step 2.3a: Place the switch on the PCB using mounting putty



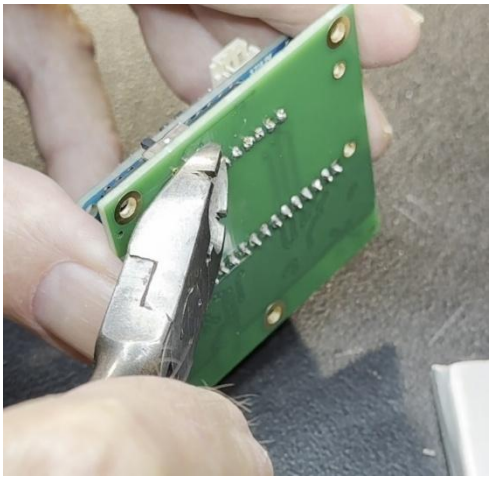
Step 2.3b: Solder one pin of the switch and check placement



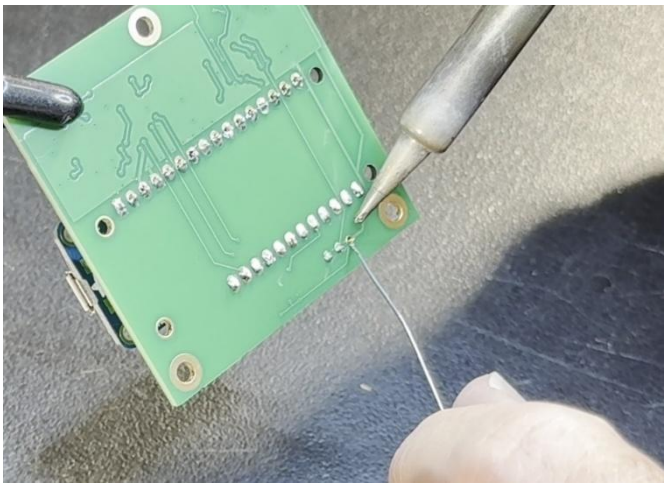


Adjust placement of switch in needed

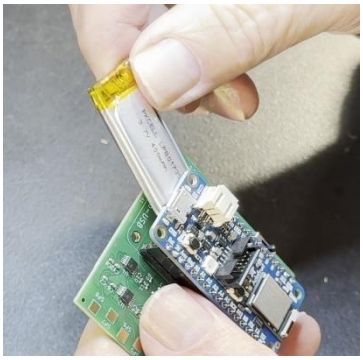
Step 2.3c: Trim pins and finish soldering the other two pins



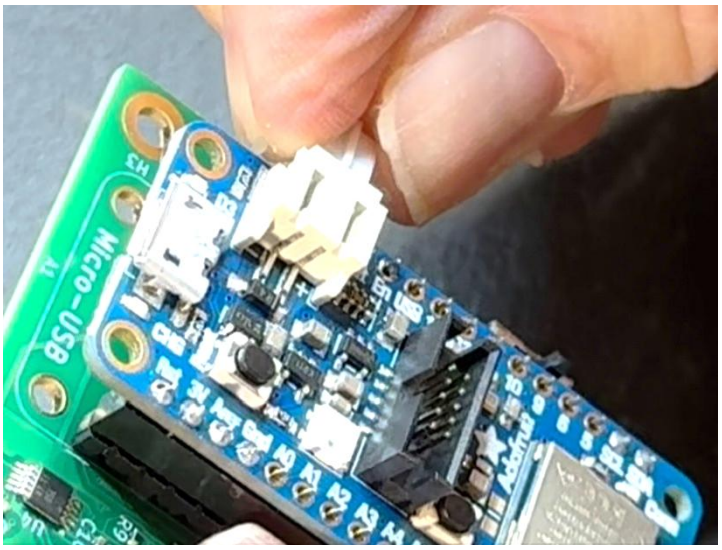
Trim height to 1mm or less



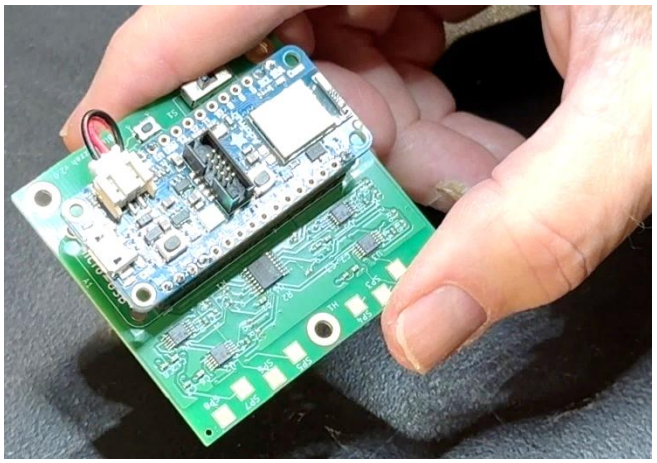
Step 2.4a: Insert battery in compartment under Feather



Step 2.4b: Plug socket in

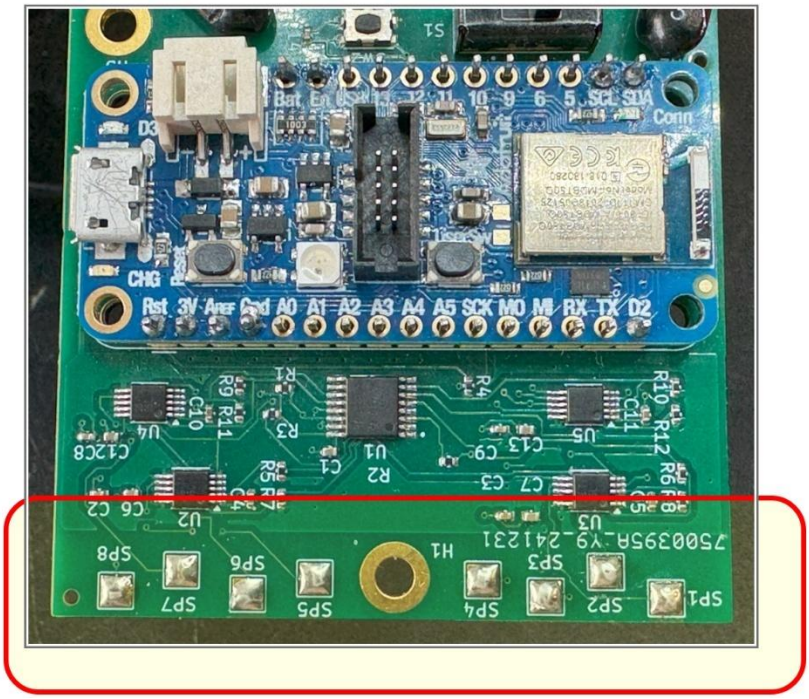


Ridge on socket goes up



Battery nicely tucked under feather!

Step 2.5: Solder “solder pillows” on all eight driver pads

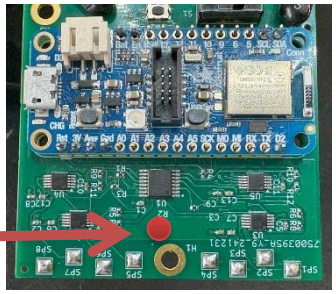


Solder pillows on pads SP1-SP8 in preparation for adding the tactor wires later in the process.

Make sure you don’t simply drip liquid solder on the pads. You need to heat the pads to get the solder to stick.

Step 2.6: Repeat steps 2.1-2.5 to prep another PCB for your other hand

Use a Sharpie to place a mark on one board so you will be able to easily identify the Master (left) and SLAVE (right)



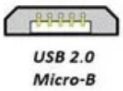
Step 2.7: Download CircuitPython 9.2.4

Download this version of CircuitPython to your desktop. *(note: Do not install the latest version since the software is designed to function on the software version in the link below) :*

https://adafruit-circuit-python.s3.amazonaws.com/bin/feather_nrf52840_express/en_US/adafruit-circuitpython-feather_nrf52840_express-en_US-9.2.4.uf2

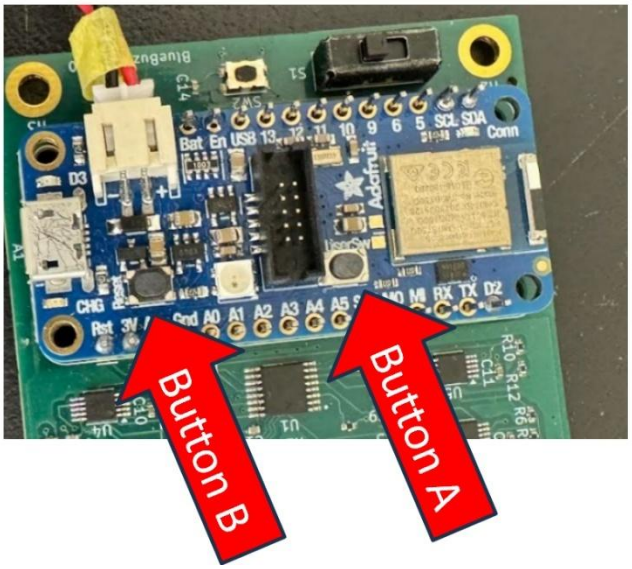
Step 2.8: Initialize each Feather

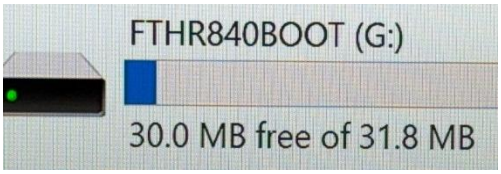
Slide the switch to the ON position which points inwardly to the power cable as shown below. Plug a Feather into your computer using a USB cable. *(The type on our Feather is a USB Micro-B, however, Adafruit has announced they are changing to a USB-C connector soon…)*



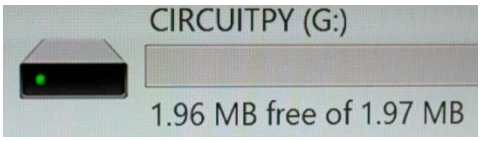
Press and hold BUTTON A. While continuing to hold BUTTON A, press and release BUTTON B.

Your computer should now recognize your Feather as a new USB drive called “FTHR840BOOT”. Then release BUTTON A.





Step 2.9: Copy the U2 file to the FTHR840BOOT drive.



Once you have copied the Circuit Python UF2 file to your Feather, it should appear as a new drive icon called “CIRCUITPY” on your desktop.

Open the drive and delete all the files you can see on the drive.

Step 2.10: Load the Blue Buzzah code files to each Feather

(a) There are two sets of zipped code files on our Github site, one set up for the “Regular vCR” pattern from Dr. Tass’s research papers, and the other set up for “Noisy vCR”. Download the code files corresponding to the pattern you would like to load.

(b) When you unzip your code files, you will have one folder for the left hand (Master) and one folder for the right hand (Slave). Copy all the files in the left hand folder and paste them into one of your Feathers. Use a sharpie to mark this board so you will know later that it is to be installed on your left glove.

(c) Remove your first Feather from your computer. Repeat steps 2.8 - 2.10 to set up the software for your second Feather.

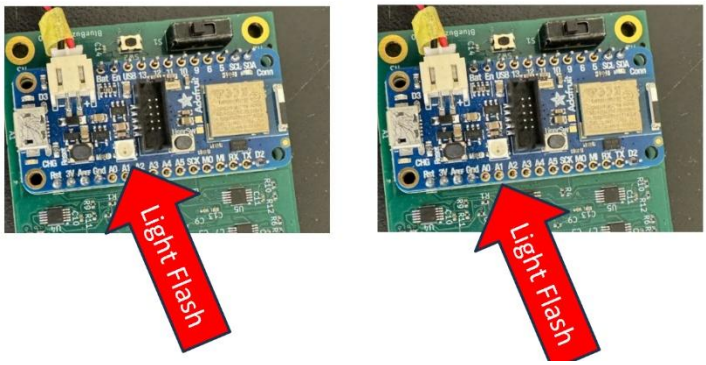
Step 2.11: Charge the batteries

Plug each of your boards into a USB power source for at least 1 hour to charge up the batteries. Make sure your switch is in the OFF position away from the battery socket. A tiny yellow light to the right of the USB connector will glow to indicate the battery is charging. This light goes out when charge is 100%. Charge time is regulated by the Feather and may vary depending on the strength of your USB power source. The feather also prevents overcharging.

Step 2.12: Test your boards

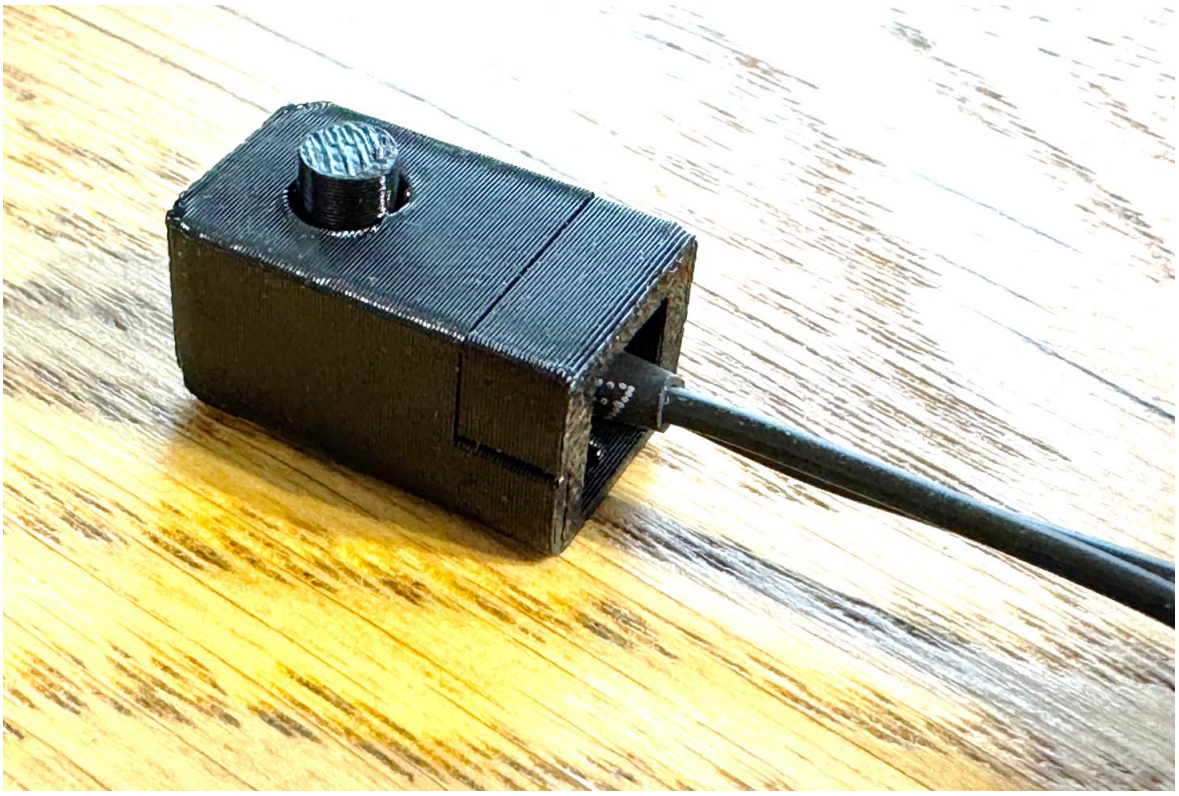
Remove each board from USB cable charging. To test your boards, first turn the MASTER board ON, then within 3 seconds turn SLAVE board ON.

Verify that sync is obtained within 15 seconds by observing the flashing lights. When you see the blue light flash simultaneously on each board, you will know your board pulses are synchronized. Your Buzzah brain is now complete! Next, turn off your boards and construct the tactors…



(Note: Don’t panic if the boards don’t seem to work. If they don’t sync, there are a number of diagnostic troubleshooting steps you can implement to find out what the problem is. We plan to provide a troubleshooting chapter in a future update to this PDF.)

PART 3: Building the Tactors



Step 3.1: Make eight springs

(A) **Put on safety glasses to protect your eyes against accidental whipping of the coiled wire**. You might also get little pieces of wire shooting at your eyes when cutting wire.

This is definitely a place where an ounce of prevention is worth a pound of cure!

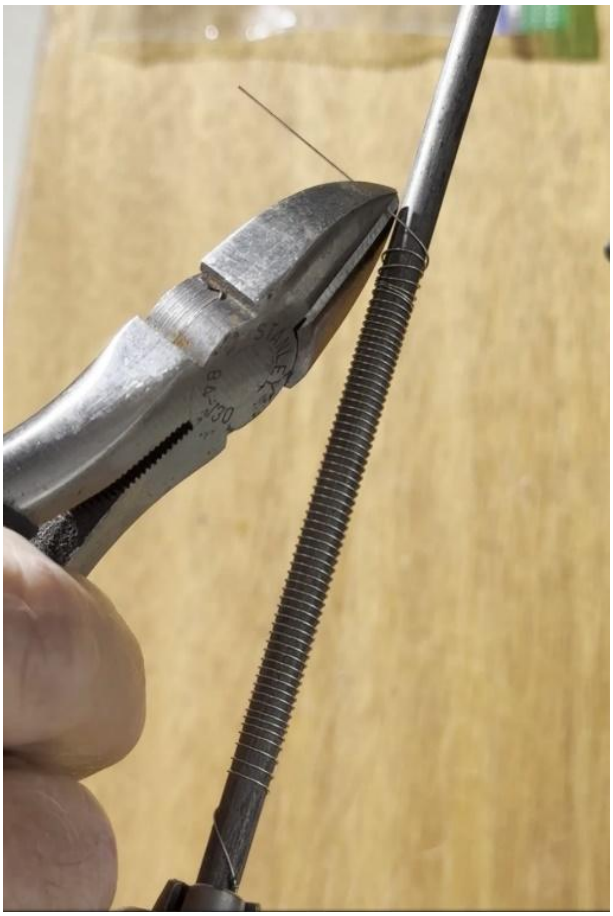
(B) Put your 3/16 rod in your drill chuck.

(C) Insert the looped end of your wire in the chuck and tighten it against your rod.

(D) Slowly rotate the drill and wind the wire around the top of your rod. The pictures shown here were taken early in my testing. **I have since learned to make the coils a bit closer together to end up with more compact springs**. If you end up with coils that are too tight, you can always stretch them out. If the coils turn out too widely spaced, you have to throw your attempt out and make a new spring.

Note: It helps create a uniform pitch if you "ride your thumb" on the windings that are already done as shown here.

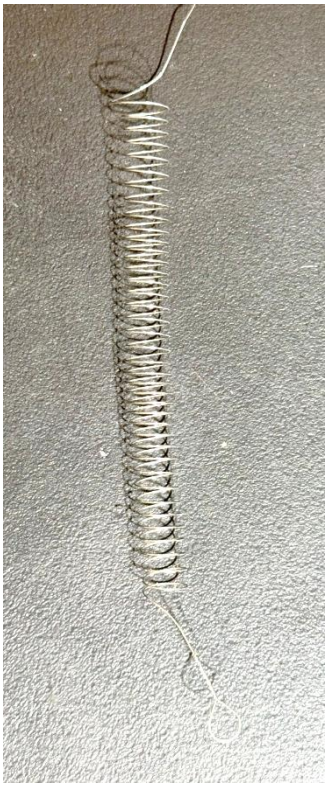
(E) When you get near the end of your wind, grasp the wire end with a pair of pliers to prepare for releasing (instead of holding it with your fingers). When you release the wire, it whips around violently and can draw blood if you release using your fingers. There is no way a human can pull fingers away quick enough to avoid a lashing. If you are lucky, you can get up to 7 springs from one string. If unlucky, you might get 0.



Safety glasses will protect your eyes from any accidents.

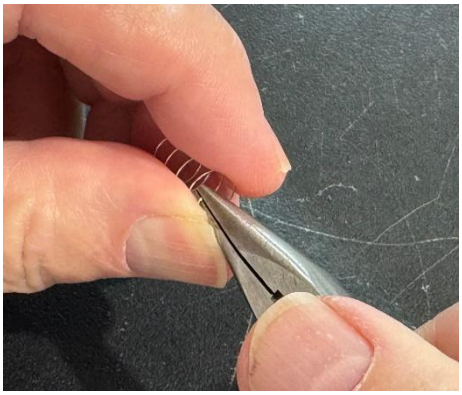
(F) Cut your long coil down to make individual springs, each with about 4.5 coils. (I will post a video of this process)

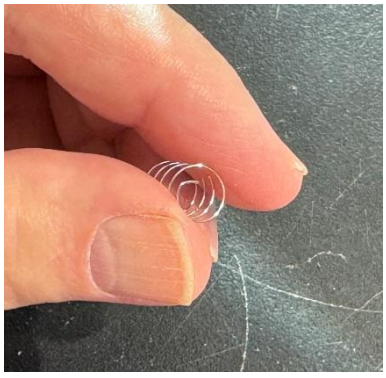
CAUTION: Don't use your sharp wire cutter to cut the spring! Each cut will leave a dent in your cutting edge and quickly ruin your cutter. Instead, use a heavy-duty wire cutter like the one shown above to cut your springs to size.



If you get a nice uniform coil pitch, you can get up to 7 springs from one string. If unlucky, you might get zero springs from a string.

(G) Use needle nose pliers to kink both ends of your spring to prevent it from snagging on the LRA inside the enclosure.





(H) Stretch your spring **if needed** so that you end up with a spring length of around 10-11 mm. This is coincidentally the same as the height of a tactor housing as shown here. If your spring came out with length over 12 or 13 mm, you will probably need to make a new spring with closer coils.

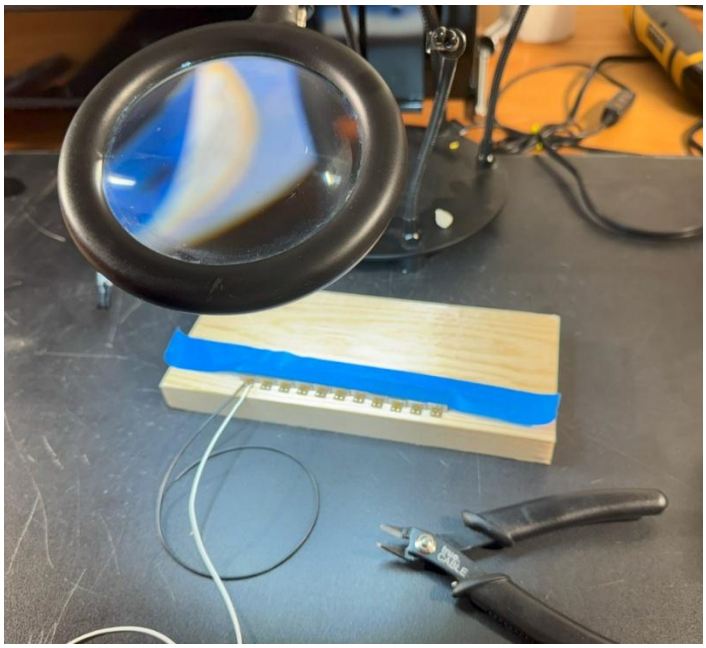
Step 3.2: Solder wires to the buzzers

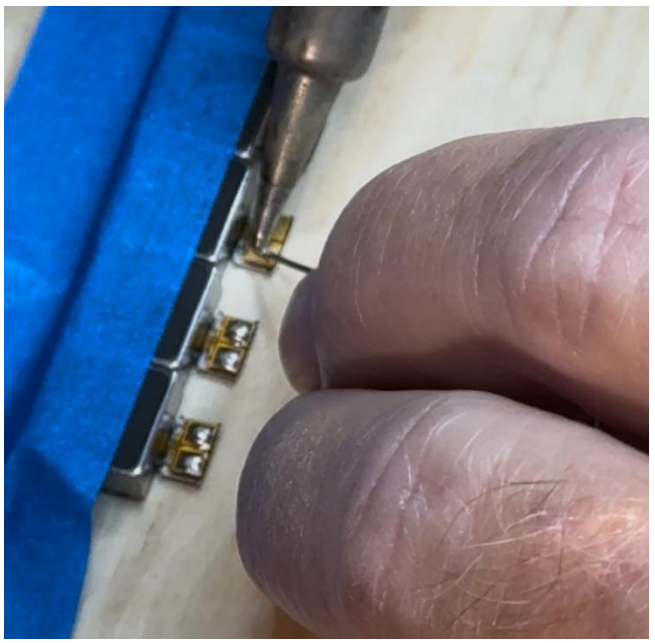
(A) Cut cut eight 15-inch segments of 28 gauge stranded black wire. Cut cut eight 15-inch segments of 28 gauge stranded grey (or any other color) wire. Strip and tin 1/8-inch ends. Note that you only need to strip and tin one end. You will be cutting off the other ends to fit your glove when you are connecting the wires later. Also note that 15 inches is longer than you need, but it much better to be longer than you need that shorter! You have plenty of wire in your spool. You will trim to the ideal length once you have mounted your tactors in your gloves.

(B) Clamp a buzzer in your third-hand clip. Solder little pillows of solder on the two pads of your buzzer as shown. Alternatively, you can save time by taping all your LRAs on a thin piece of wood as shown.

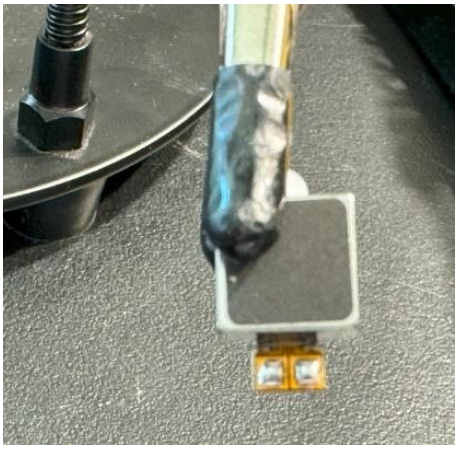
I set my soldering station to a temperature of 600 C.

Try to minimize the time you are heating the pads because they can get stressed and pull away from the tab. (Although this has never happened to me.)

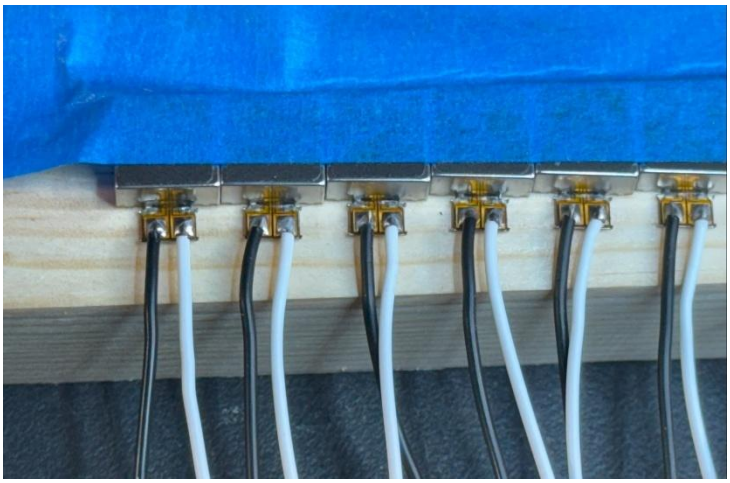


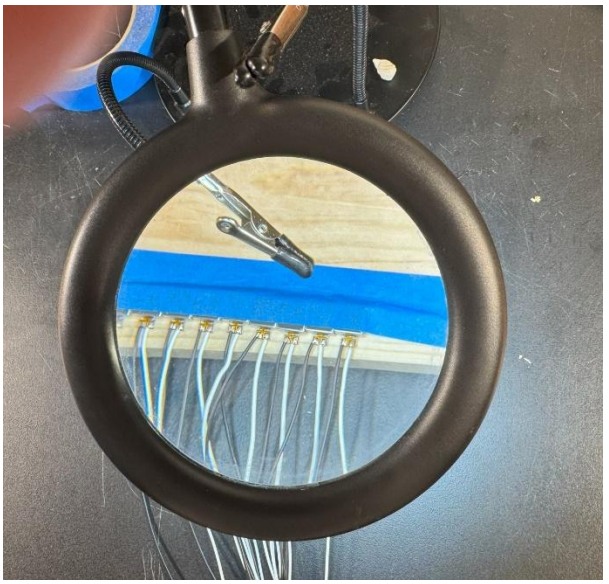


Using the magnifying glass on your third hand helps a lot to make this job less tedious.



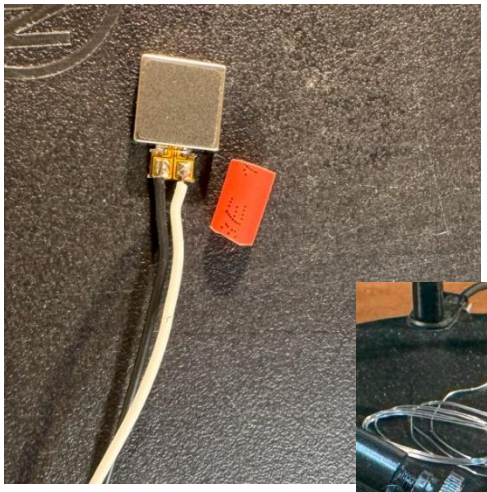
(C) Now, since you already have solder on the pads and solder on the wires, you can easily use your soldering iron to join the wire to the solder pillows on the pads.

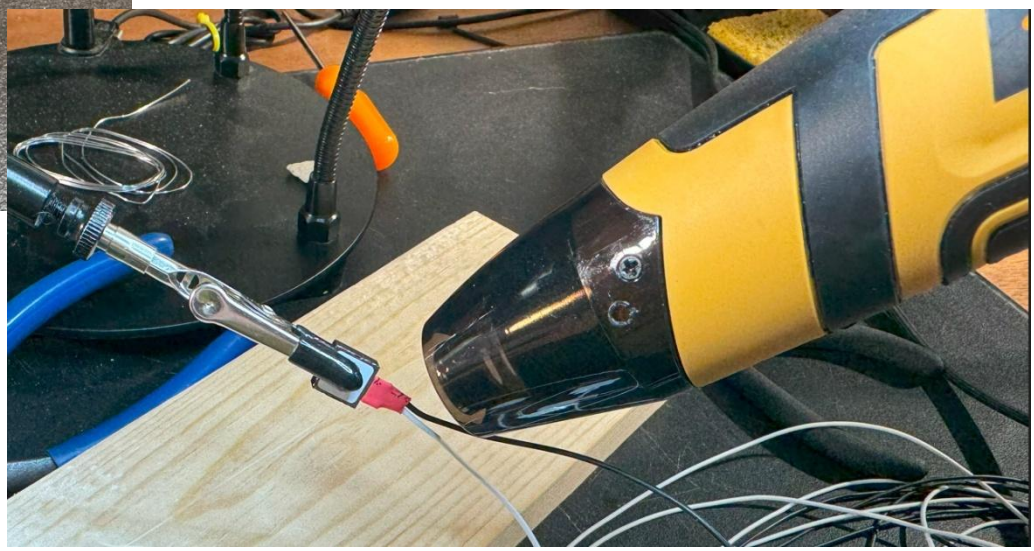




SOLDER THE BLACK WIRE TO THE LEFT PAD AND WHITE TO THE RIGHT

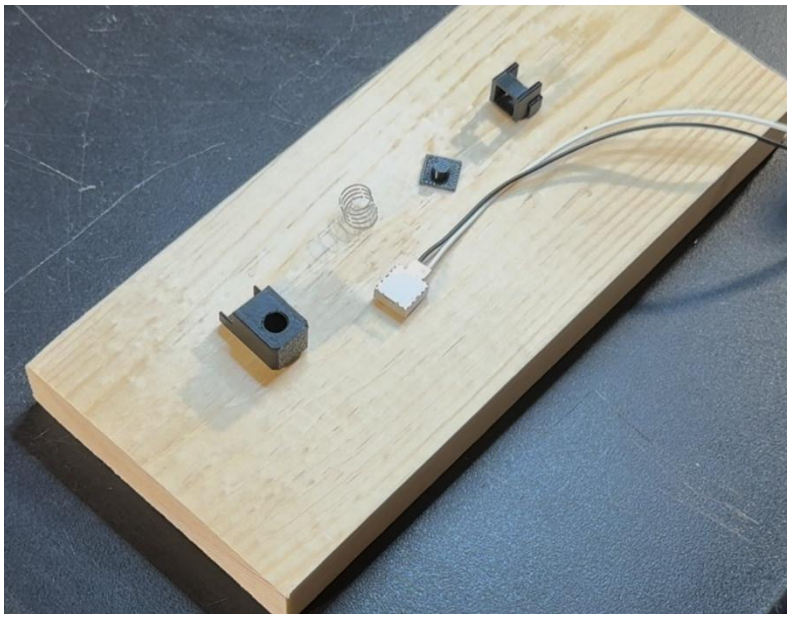
(D) After all buzzers are wired up, use shrink tubing AND YOUR HEAT GUN to secure your contacts. I used to use 2 or 3 layers of shrink tubing, but lately I realize that one layer is plenty good. I have also moved to using shorter lengths of shrink tubing because it makes the wire stiff which interferes with finger movement. I now use only 1/4 - 3/16 inch and have not had any problems.





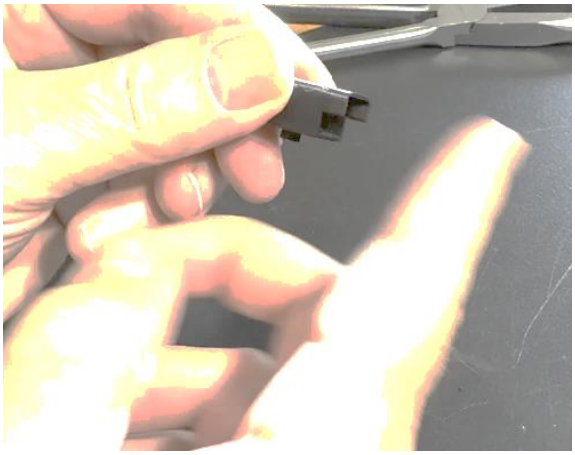
Step 3.3: Assemble Tactors

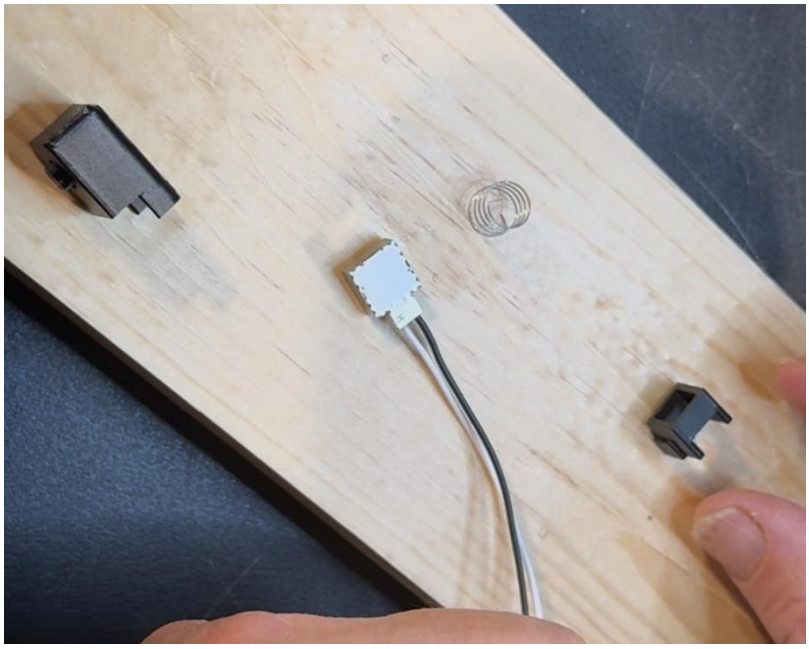
(A) Lay out the 5 components of the a tactor to be assembled



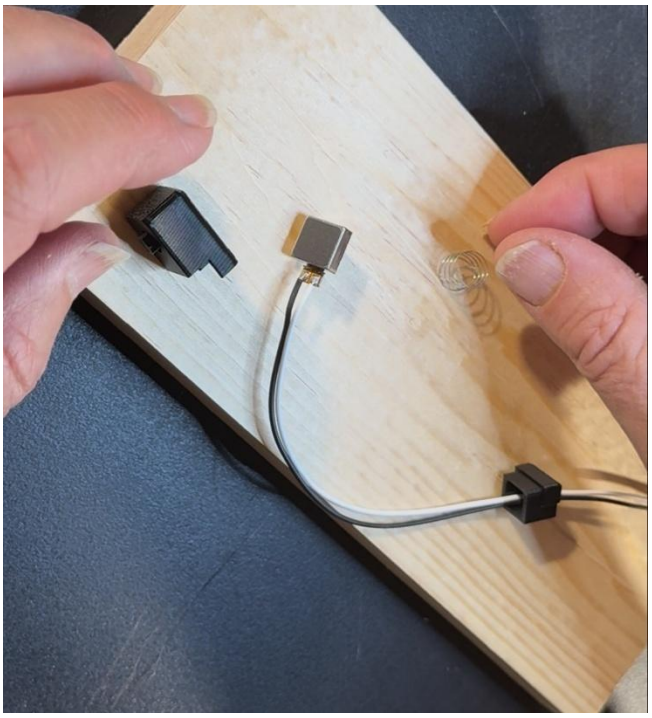
Note that there should be shrink tubing over the LRA connections. In the excitement of filming, we forgot this step and had to dismantle several tactors to go back and get do the shrink tubing!

(B) Insert a button in a tactor housing and tap on the end until the button eventually falls loosely in place inside the housing. It takes a bit of practice. Lay the case on its side when the button is through the hole. Be careful when handling you don't let the button fall out of the hole!

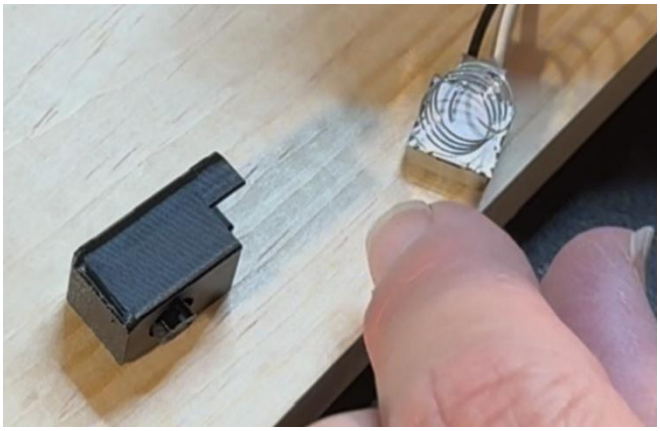




(C) Slide an endcap over your LRA wires. Note the direction of the U-shaped gap that allows a wire tie to be treaded through the bottom hole is pointed away from the LRA.

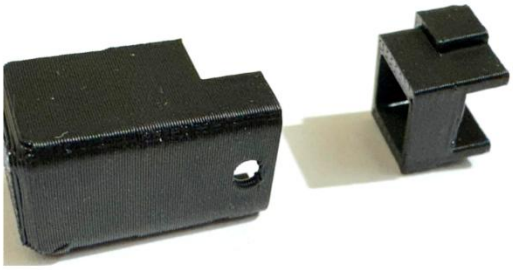


(D) Compress the spring against the LRA bottom, and then slide the spring and LRA together into the tactor case under the button flange while holding the case upside down so that the button remains in place. This is harder to do that it looks in the pictures. It takes a bit of practice to get the spring in without it catching on the edge of the case. My number one problem in this step is that it is easy to slide the LRA in without getting the spring to go along for the ride. Use your needle nose pliers with jaws closed to push the spring into place if it does not end up sliding all the way in place along with the LRA. *(Note: A bright flashlight is helpful if your spring pops to the floor.)*



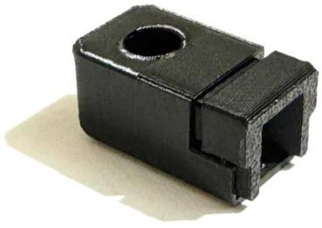
(E) When the spring is seated inside the case, the combination is unstable without the endcap. The spring can easily pop out if you accidentally pull on the wires. So, carefully, without disturbing the spring and LRA inside the case, slide the endcap into place in the case. It is a tight fit, so you might want to practice doing this a few times with an empty case before you have the spring and LRA inside the case. If you ever need to pull the cap off you will need to use your needle nose pliers as shown below.

1. Initial orientation



2. Cap partially inserted

3. Cap inserted farther



4. Cap completely inserted

5. Removing cap with pliers

(F) Repeat the above process until you have all eight tactors assembled. Store them in a Baggie until you are ready to assemble your gloves.

PART 4: Mounting Tactors in Glove Fingertips

IMPORTANT NOTE: You may choose from a wide variety of of gloves available at your local hardware store to use for your Blue Buzzah build. You need to find a glove that is comfortable. The brand we settled on after testing a number of types (Dewalt Large) is only one possible choice. In fact, when my next shipment of PCB boards arrives from Hong Kong, I plan to make a set using winter gloves to use on cold weather morning hikes.

Also, you could choose to forgo gloves completely by mounting the Blue Buzzah electronics box on a wrist band, and simply lash the tactors to your fingertips with Velcro strips or rubber bands. While such an arrangement would allow you to skip the glove preparation steps that follow, using such a contraption would be cumbersome in daily practice.

Step 4.1: Find an ideal Goldilocks glove that is <u>not too tight and not too loose</u>

I am very active all day and I want a glove that I can slip on and off quickly if I need to tie my boot laces, go to the bathroom, take a sweatshirt off while working out, etc…. To accomplish this feat, I needed to find a glove where the fingers were **<u>tight enough to securely hold the tactors against my fingers, but not so tight as to be uncomfortable</u>**. I don't want my gloves so loose that I need Velcro tighteners on the fingertips since the Velcro slows me down while putting the gloves on. In other words, I want a glove that can be put on almost as quick as a normal glove without tactors.

To find the perfect glove, I took a tactor to Lowes with me on my shopping trip. *(Home Depot is OK, but Lowes has about twice the number of glove types).* Insert the tactor in a glove and test the fit. If the fit is perfect, the glove tightness will tight enough to push your finger securely against the button, but not so tight as to limit your blood circulation to your fingertips.

Bring a tactor along with your long needle nose pliers to Lowe's to try out your glove fit. I actually purchased a large number of gloves so I could test the tactors while hooked up to my Buzzah brain at home. I returned the ones I didn't use with no problems.

If you pick a glove that already has Velcro on the wrist, it will save you the trouble of sewing Velcro on later in order to mount your Blue Buzzah electronics box.

Note: The best glove fit for my hand turned out to be this Wells Lamont Work & Home (Large). I made a set with this glove, but I ended up noticing a leather smell on my hands after using the leather gloves for 4 hours a day. I looked it up on PubMed, and <u>the heavy metal chemicals used in leather tanning can actually cause PD</u>! So, I went with the Dewalt gloves instead.

Step 4.2: Determine the exact location for your tactor in a glove fingertip

(A) Use your extra long pliers to insert a tactor into a fingertip with the **button facing up when the glove is facing down** as in the pictures.

(B) Slide your hand into your glove and adjust the location of your tactor until the tactor button is **ideally located** on your fingertip. The general rule I use is I find the place on my fingertip where I would use if I were pushing a button with a particular finger. Keep in mind you will be pushing a button with each finger 4 hours per day.

(

(C) Without moving the tactor from its perfect location inside your glove finger, use a small awl or nail to gently probe the fingertip fabric to locate the small mounting hole in the bottom of the the tactor.

(D) Use some method to mark the location of the mounting hole. I use a sharp awl to poke a tiny hole, but a white fabric marker would also work.

(E) Remove the tactor from the glove once you have the mounting hole location marked on the glove.

Step 4.3: Get out your cheap soldering iron and prepare your space to safely melt holes in your gloves

DISCLAIMER: I am showing you how I made holes in my gloves. While working with a quality soldering iron, I always feel safe. But I used a cheap soldering iron in this application because I didn't want to ruin my good soldering iron tip. The cheap soldering irons like I used here are inherently dangerous - they are hotter than good soldering irons and since they are so light, their stiff cords tend to pull them off the wobbly stands when you set them down. If you are uncomfortable using a cheap soldering iron like I did, there are other safer ways to punch holes in your gloves! If you use my technique, you do so at your own risk…

(NOTE: Some builders may prefer to use whip stitching to hold the tactors in place)

As shown here, I use a soldering iron to melt holes for the wire tie tactor mounting because the melting process automatically cauterizes the plastic fabric around the holes to prevent fraying and it is easy to precisely control the size of hole you are making. As you will see if you use this technique, the soldering iron gets so hot, all you need to do is lightly touch it to the material and it will quickly melt a hole. **Note that this technique does not work on leather. Use a sharp awl to make holes in leather.**

DON'T FORGET TO USE A DULLED CHISEL (OR A FILE) TO PROTECT YOUR GLOVE: A wood chisel is used to create a backing plate inside the glove to keep from burning holes where no holes are wanted. If you use an unprepared chisel, the sharp edges will get caught on the fabric and threads inside the glove resulting in tears. To avoid this, I took a metal file and filed down all the sharp edges of the chisel. Of course, this will ruin your chisel for its normal function in the future.

DANGER!!! **If you are at all uncomfortable with the obvious risks of this technique *(fire, burning, inhaling fumes),* you can just use an ice pick instead of a soldering iron to punch holes, or get someone who is used to working with a soldering iron to do this for you.**

IMPORTANT CAUTION 1! **Be careful when handling so you don't get burnt! Also, don't leave it plugged in when you are not using it. It is easy to walk away and forget you have it plugged in, resulting in burning your house down or bumping it and getting an accidental burn later. These cheap soldering irons get much hotter than the good kind of irons. Don't plug in until you are ready to make holes and unplug as soon as you are done.**

IMPORTANT CAUTION 2! **When melting holes make sure you are in a well-ventilated area. I always have a fan going when doing this to blow the fumes away. Every time you melt a hole you will encounter rising fumes from the melted plastic that you will not want to breathe. Another hazard is potentially setting the glove on fire! I never had any fire start from doing this in the many holes I made, but just be aware that fire is possible since plastic is flammable. It would be a good idea to perform this task somewhere like outside on your driveway where there would be no way to catch anything else on fire if the gloves caught fire. In contrast, the worst place to make your holes would be somewhere where you have carpeting and you are surrounded with flammable materials that could catch fire if you accidentally dropped your soldering iron or caught your glove on fire.**

Step 4.4: Melt holes in the glove fingertip you marked for a small wire tie to secure the tactor inside the glove

(A) Melt a small hole at the point you marked on the fingertip. The hole should be just big enough for a small wire tie to pass through. Keep your holes small because the tactor will be putting stress on the fabric. The heat will cauterize the edges. **Use a dulled wood chisel to create a backing plate inside the glove to keep from burning holes through to the other side of the glove.**

(B) Burn a second hole 5/16 inch below the first hole you made as shown at right below.

The dulled wood chisel provides a backing plate for your soldering iron

You can see the impressions made on the glove fabric by the tactors inside the fingers

Line up hole in tactor bottom

Wire tie exit hole

(C) While you have your soldering iron out, burn 3 more holes in top of your glove webbing between fingers as shown here. The tactor wires will later exit through these holes.

(Note that this pic was taken later in the process after wires had been threaded through the holes)

Step 4.5: Mount tactor inside glove fingertip

(A) Put the tactor back in the fingertip.

(B) Thread a small wire tie through the tactor mounting hole and glove holes as shown. Note that this picture was taken on a different glove I was testing, but the procedure is the same.

I have to mention that I find this task difficult. It takes me a lot of time and patience to thread the wire ties. It is easy to insert the wire through the tactor hole. But getting the end of the tie to exit the other hole is challenging. My technique is to: (i) place the finger under the magnifying glass, (ii) Use my left hand to insert the tie through the main hole barely just enough so that the reflection of light from the tie tip can be seen through the exit hole, (iii) Depress the fabric with my right thumbnail just under the exit hole in order to align the exit hole with the tie tip. (iv) Push the tie tip through the hole

(v) Finally, make sure you check that you have not inadvertently caught one of the tactor wires with your wire tie under the fabric. If a wire is bound by the wire tie, the bound wire will prevent the LRA from vibrating freely. If you inspect and can feel a wire between the tie and fabric, you will need to remove the tie and start over. This rarely occurs for me, but it has happened. In fact, it happened in one finger of the first PWP to replicate my design. Their error was only discovered later - when end testing the glove, they found that one tactor was hardly vibrating.

(D) Use your locking forceps to thread the tactor wires through the corresponding hole between fingers.

(E) **<u>Put a shrink tubing band around the pinky finger pair when they come out</u>**. Since this hole will have two pairs of wires coming out, you will need some way to keep track of which wires go together when you wire to your PCB board.

Repeat above steps for all fingers until all tactors are mounted with their wires coming out the web holes….

(F) Cut the thumbs off both gloves.

(G) It may also probably be helpful to whip stitch the pinky wires near the main pinky knuckle as shown below. Since the pinky glove finger is tighter than the other fingers, the wires sometimes get bunched up on top of the tactor when putting the gloves on. **BE CAREFUL NOT TO STITCH THROUGH THE WIRE INSULATION!**

Stitch pinky wires to inside of glove to prevent them from bunching up over the button when putting your glove on.

The other fingers generally do not require stitching.

PART 5: Mounting Electronics Boxes on Gloves

Step 5.1: Mount an enclosure tray to the glove wrist

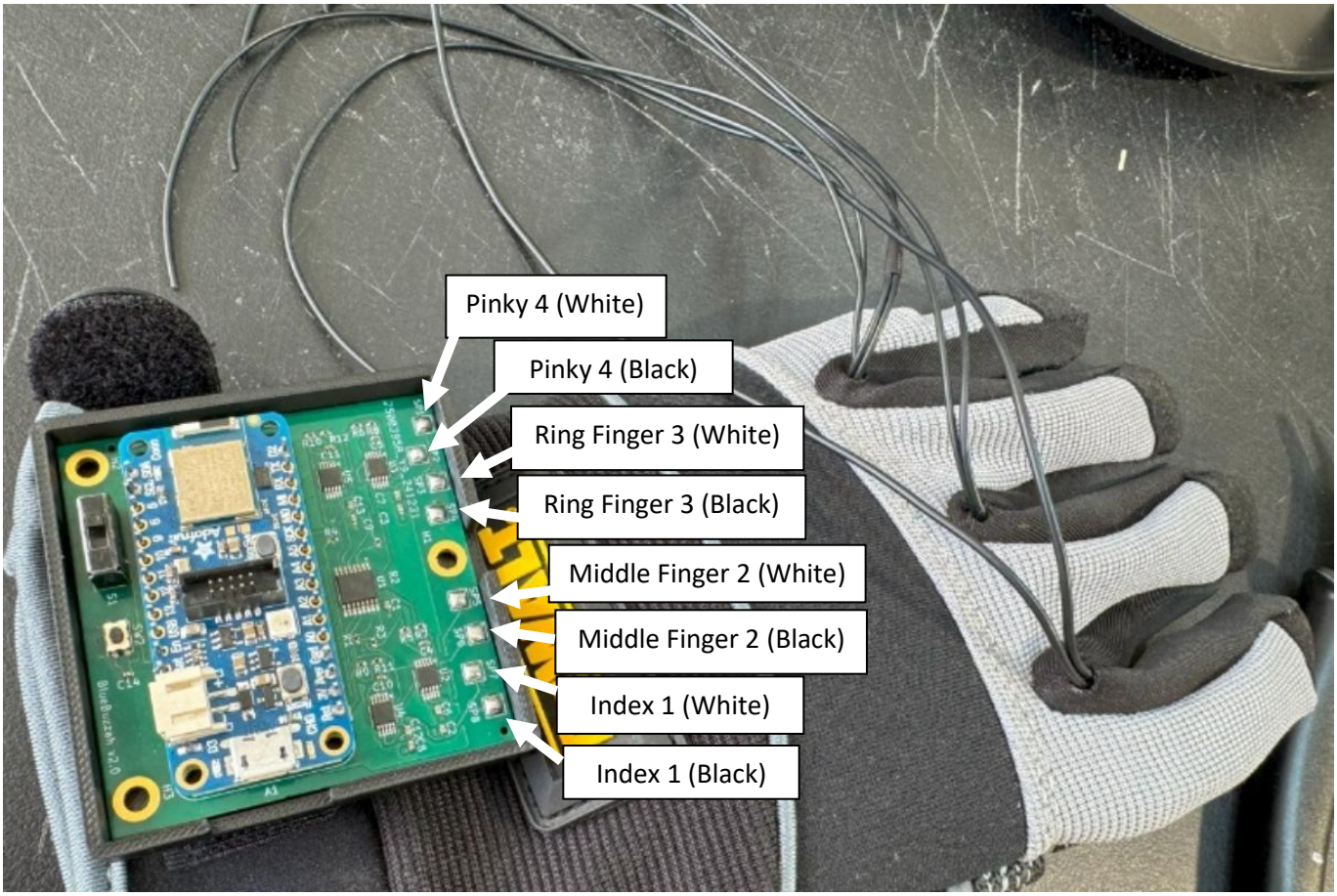
Use a piece of sticky Velcro on the back of a tray to mount it to the Velcro on the glove wrist.

(If you chose a glove that does not have Velcro already stitched to its wrist, get your needle and thread out!)

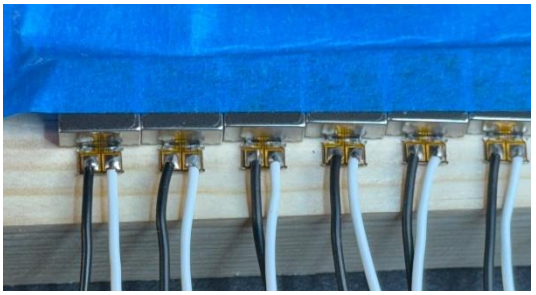
Make sure the square wire slot is positioned forward as shown below

`Step 5.2: Place a PCB board in your tray

Put the MASTER board in your left glove and SLAVE board in the right.



Note that this picture was taken before we started color coding the two terminals to the LRAs as shown below. The buzzing will still work if you don't color code the terminals, but some of your buzzers will be vibrating up while others vibrate downward during buzzes. You would never be able to sense a difference consciously, but it is possible this subtle effect could make a difference in therapy as discussed below:

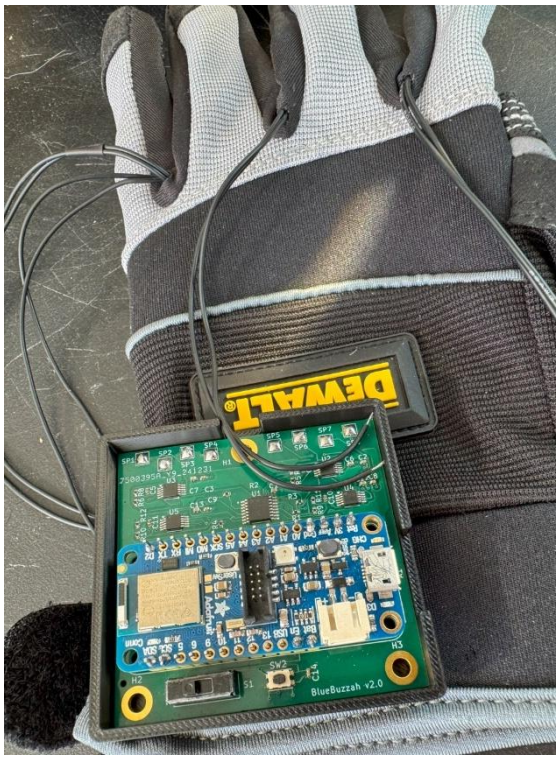


According to https://pmc.ncbi.nlm.nih.gov/articles/PMC8570683/, research in tactile psychophysics indicates that humans have the temporal resolution necessary to perceive these kinds of timing differences between spatially separated vibrotactile stimuli. The ability to judge the temporal order or relative timing of tactile events is quite refined, with thresholds potentially low enough (in the range of ~1-2 ms under optimal conditions) to detect phase differences at 250 Hz. Therefore, after reading this research paper, we decided to start color coding our terminals so that all LRAs are vibrating "in phase" with one another. So, the prototype we took pictures of above needs to be rewired with color coded connections to achieve the highest specifications.

Step 5.3: Trim, Strip and tin the 2 wires <u>coming from finger 2</u>

Leave some slack in the wires to allow for flexing your fingers into a fist. Best to have a little more than you need since you will have plenty of space in the box later to stuff your extra wire.

After you tin the ends of your wire, cut the exposed wires so that you have no more than the width of a pad exposed. The main problem I see in novice solderers is that they tend to leave way more wire exposed than is necessary. When you leave extra stripped wire hanging off a pad, you risk having short circuits to you drive chips which could possibly result in a trashed PCB board. The drivers are supposed to have short circuit protection, but it is best not to tempt fate with sloppy soldering!



Step 5.4: Trim, Strip and tin the 2 wires <u>coming from finger 2</u>

Use your soldering iron to solder the white and black wires for finger 2 to their corresponding pads as noted below.

Be careful not to touch anywhere on your PCB board (aside from the solder pads) with your soldering iron! Doing so may cause your board to fail

TIME TO TEST YOUR BUZZER!

Now that you have an LRA wired up, you can take this opportunity to test your newly installed tactor buzzer. To test the buzzer, simply turn the SLAVE board ON (right hand board) , then turn your MASTER board ON (left hand board). Once the boards achieve sync, your newly installed buzzer should start buzzing!

Every time I have gotten to this point and tested, my LRAs have always buzzed. But, if you got the blue sync flash and the LRA does not buzz, it could be any of the following

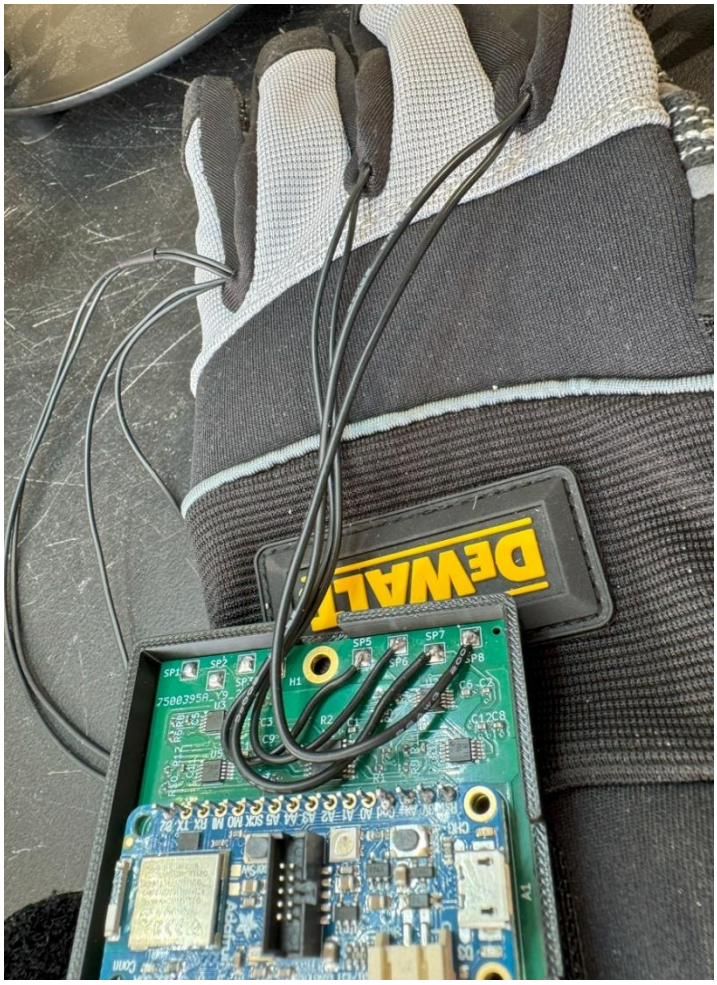
a) bad solder joints on the board pads
b) bad solder joints on the LRA
c) break in the wiring
d) broken PCB

Once your LRA has passed the buzz test, you may move on to the next step…

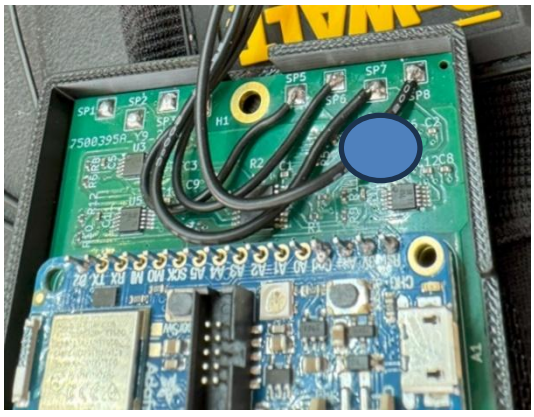
Step 5.5: Repeat the previous procedure for finger 1 wires

Use your soldering iron to solder the white and black wires for finger 1 to their corresponding pads as noted below.

Be careful not to touch any of your insulated wire with your soldering iron! Doing so will melt through the insulation are require you to patch your beautiful job with ugly electrical tape



PRO SOLDERING TIP: As you get more wires soldered in place, the space inside the tray gets pretty cramped for your fingers to hold the wires in place while soldering them to the pads. To make the soldering go easier (and faster) I will often use a small wad of mounting putty to hold the wires in place while soldering.



Step 5.6: Repeat the previous procedure for finger 3 wires

Use your soldering iron to solder the white and black wires for finger 3 to their corresponding pads as noted below.

Be careful not to touch any of your insulated wire with your soldering iron! Doing so will melt through the insulation are require you to patch your beautiful job with ugly electrical tape

Step 5.7: Repeat the previous procedure for finger 4 wires

Step 5.8: Put the lid on the tray

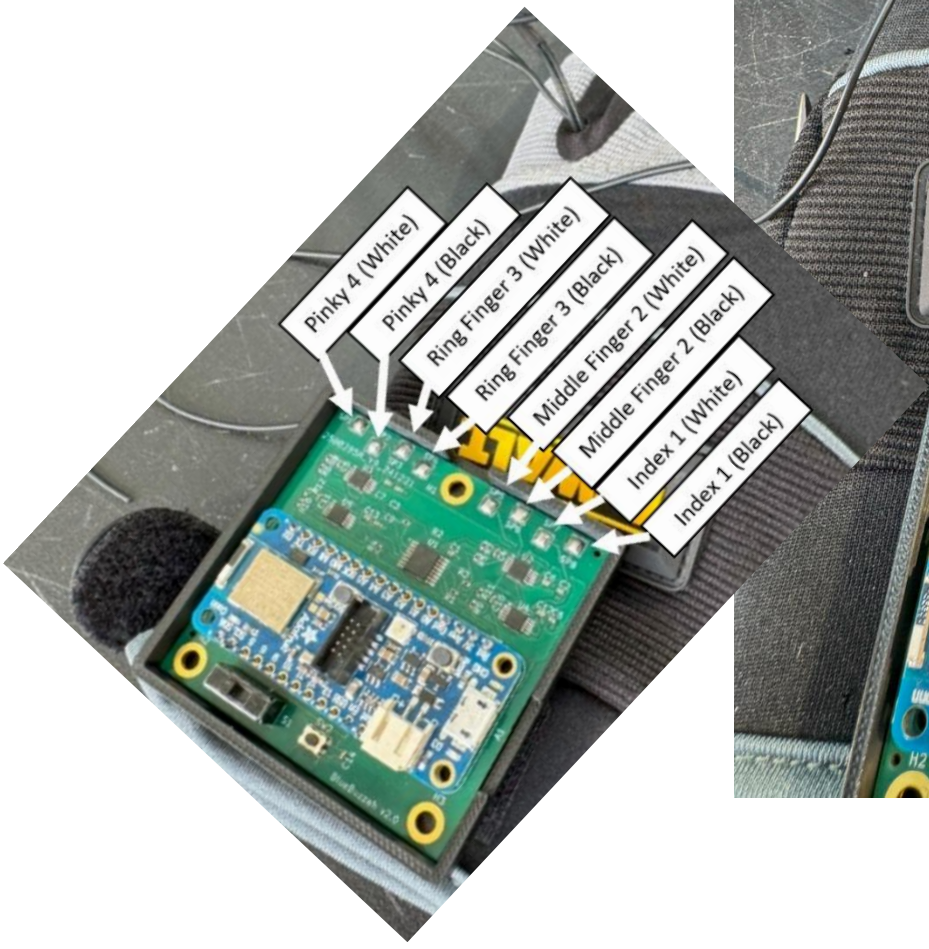
Close up your left-hand box and use a wire tie to gather your wires in a neat bundle.

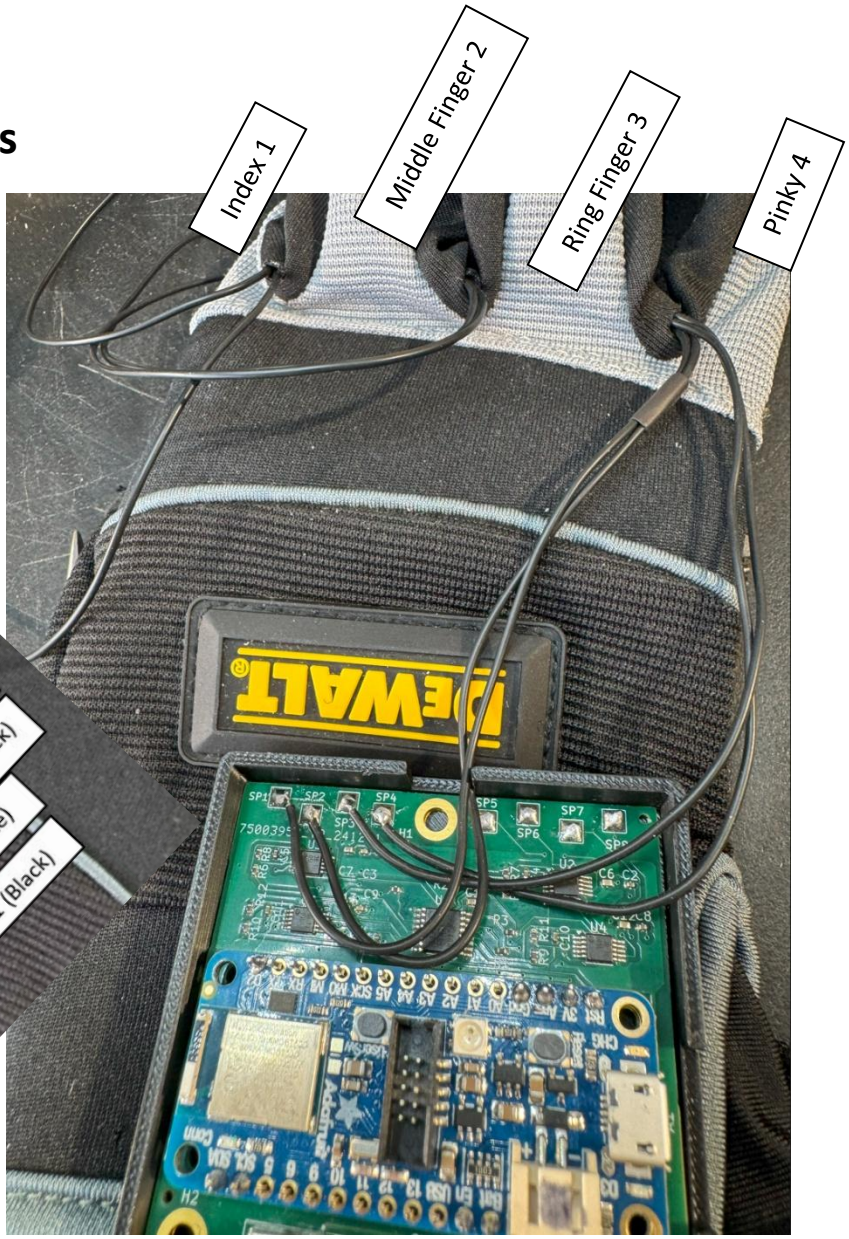
You are done with your left-hand glove!

Step 5.9: Solder right hand wires

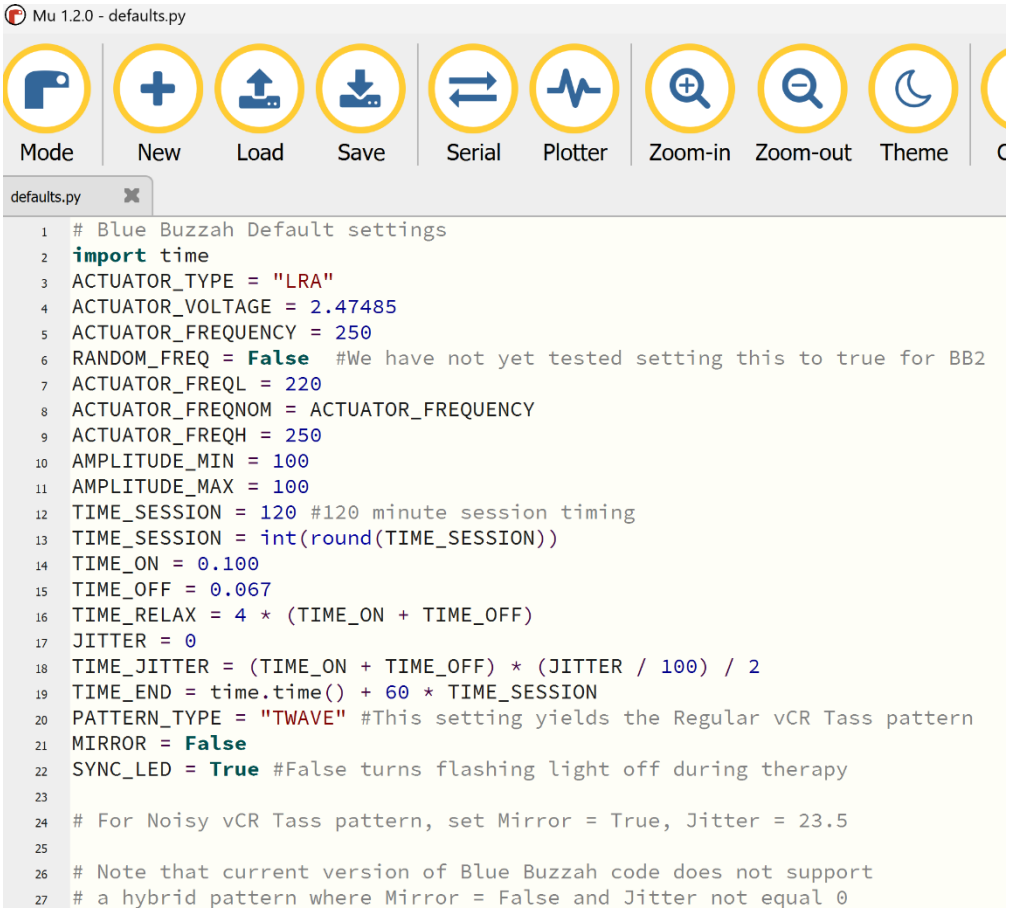
Repeat the wiring procedure for the right hand glove.

Note that, since the left-to-right order of your fingers on your right hand are mirrorred to your left hand, the order of the wires must be reversed.





PART 6: Adjusting Buzzah Settings




```
# Blue Buzzah Default settings
import time
ACTUATOR_TYPE = "LRA"
ACTUATOR_VOLTAGE = 2.47485
ACTUATOR_FREQUENCY = 250
RANDOM_FREQ = False  #We have not yet tested setting this to true for BB2
ACTUATOR_FREQL = 220
ACTUATOR_FREQNOM = ACTUATOR_FREQUENCY
ACTUATOR_FREQH = 250
AMPLITUDE_MIN = 100
AMPLITUDE_MAX = 100
TIME_SESSION = 120 #120 minute session timing
TIME_SESSION = int(round(TIME_SESSION))
TIME_ON = 0.100
TIME_OFF = 0.067
TIME_RELAX = 4 * (TIME_ON + TIME_OFF)
JITTER = 0
TIME_JITTER = (TIME_ON + TIME_OFF) * (JITTER / 100) / 2
TIME_END = time.time() + 60 * TIME_SESSION
PATTERN_TYPE = "TWAVE" #This setting yields the Regular vCR Tass pattern
MIRROR = False
SYNC_LED = True #False turns flashing light off during therapy

# For Noisy vCR Tass pattern, set Mirror = True, Jitter = 23.5

# Note that current version of Blue Buzzah code does not support
# a hybrid pattern where Mirror = False and Jitter not equal 0
```

When starting therapy the first time, the easiest option is to simply use one of the two stock settings we discussed earlier in the section on loading code. But, sooner or later, you will probably want to start experimenting with various settings to suit your own preferences. The procedure for changing the settings is straightforward, but requires that you install a free code editor on your computer.

IMPORTANT NOTE: If you change ANY settings in the defaults file of either hand, YOU MUST ALSO CHANGE THE DEFAULTS FILE IN THE OTHER HAND TO THE SAME EXACT SETTINGS! Failure to update changes to both hands will lead to erratic buzz performance that is out of specifications.

For our initial release of Blue Buzzah code, we recommend staying with either of these pattern settings:

Regular vCR: Mirror = False, Jitter = 0, PATTERN_TYPE = “TWAVE”

Noisy vCR: Mirror = True, Jitter = 23.5, PATTERN_TYPE = “RVS”

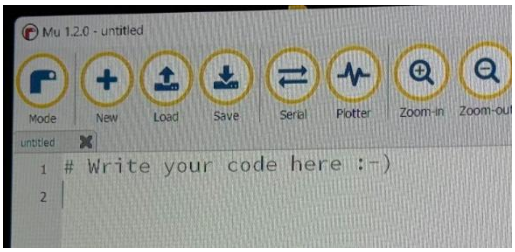
The current version of Blue Buzzah code does not support a hybrid pattern where Mirror = False and Jitter is not equal 0

Step 6.1: Download and install the free Mu editor on your computer

Here is a link to the download: https://codewith.mu/ It is a very sophisticated editor, but all we need it for is the ability to change parameters in the code.

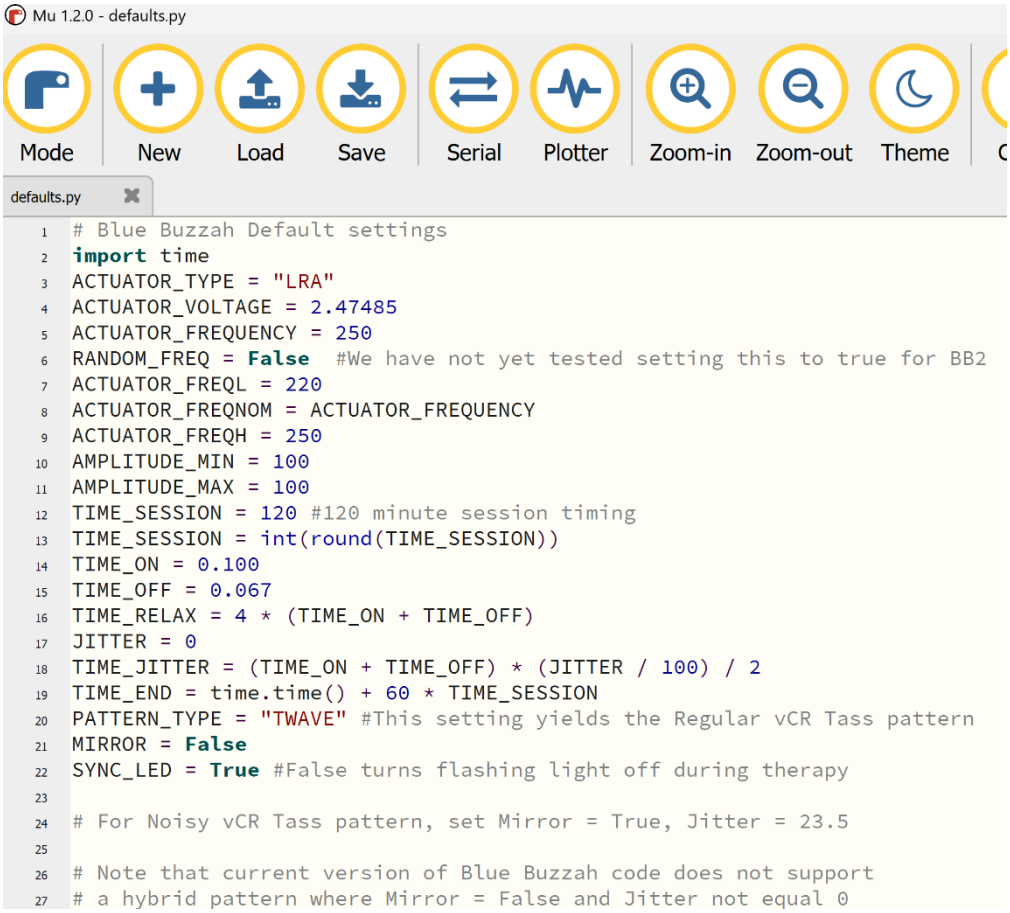
Step 6.2: Connect Buzzah processor to your computer

Open the Mu program on your computer with your Buzzah already connected. You should see this window:



Click on LOAD and Mu will open a folder on your Buzzah as if it was a thumb drive. Open the DEFAULTS file

Click on defaults.py and Mu will open the settings code for driving your Blue Buzzah. It will look like this:




```
# Blue Buzzah Default settings
import time
ACTUATOR_TYPE = "LRA"
ACTUATOR_VOLTAGE = 2.47485
ACTUATOR_FREQUENCY = 250
RANDOM_FREQ = False  #We have not yet tested setting this to true for BB2
ACTUATOR_FREQL = 220
ACTUATOR_FREQNOM = ACTUATOR_FREQUENCY
ACTUATOR_FREQH = 250
AMPLITUDE_MIN = 100
AMPLITUDE_MAX = 100
TIME_SESSION = 120 #120 minute session timing
TIME_SESSION = int(round(TIME_SESSION))
TIME_ON = 0.100
TIME_OFF = 0.067
TIME_RELAX = 4 * (TIME_ON + TIME_OFF)
JITTER = 0
TIME_JITTER = (TIME_ON + TIME_OFF) * (JITTER / 100) / 2
TIME_END = time.time() + 60 * TIME_SESSION
PATTERN_TYPE = "TWAVE" #This setting yields the Regular vCR Tass pattern
MIRROR = False
SYNC_LED = True #False turns flashing light off during therapy

# For Noisy vCR Tass pattern, set Mirror = True, Jitter = 23.5

# Note that current version of Blue Buzzah code does not support
# a hybrid pattern where Mirror = False and Jitter not equal 0
```

Step 4.3: Adjust settings according to your preferences

IMPORTANT: ONLY CHANGE THE SETTINGS, NOT THE CODE! If you accidentally change some executable line in the code, your Buzzah will probably stop working. If that happens accidentally, you may end up getting buzzes that are way out of specifications.

DISCLAIMER AGAIN: Keep in mind that you are experimenting with this treatment. Since none of us has a neurologist like Dr. Tass to direct our treatment, if we decide to move forward, we do so without the benefit of medical advice. With that in mind, if you decide to proceed, it would probably be best to choose settings in the beginning that are very close to what Dr. Tass used. Dr. Tass's team does adjust various parameters to suit different patients, but as far as we know, there is no protocol for adjusting parameters that has been published. Please read Dr. Tass's paper yourself: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8055937/

ACTUATOR_TYPE = "LRA"
The Buzzah has the ability to drive ERMs as well as LRAs. We are using LRAs, so leave this setting as "LRA".

ACTUATOR_VOLTAGE = 2.50
This is the peak voltage applied to the LRA. The maximum peak voltage on the VLV101040A buzzer we are using is 3.536 V (equivalent to 2.5 Vrms). Therefore, the ACTUATOR_VOLTAGE may be set anywhere from zero to 3.536. We find a setting of 2.5 gives sufficient buzz to sense without being excessive. Note that buzzer lifespan will be increased with lower voltages.

ACTUATOR_FREQUENCY = 250
Dr. Tass used 250 Hz in his paper. He stipulated 250 Hz because these high frequencies stay on the surface and only activate the one kind of nerve ending that is being targeted. But he did write that using the exact frequency of 250 Hz was not critical. Note that since the LRA responds with differing amplitude to different frequencies, achieving maximum amplitude at its resonant frequency of 170 Hz. You can nudge your frequency down to 235 Hz or so if you want to get more amplitude of vibration without having to increase your amplitude. We will also note here that being able to adjust frequency like this is quite a luxury! ERM systems are stuck at the frequency that the buzzers do naturally - usually down in the range of 160 Hz where the wrong kind of nerves are being excited. While the LRA we use can be used to reproduced frequencies from 140 Hz to 300 Hz, we have only tested frequencies in the range of 220 Hz to 250 Hz.

RANDOM_FREQ = False
ACTUATOR_FREQL = 220
ACTUATOR_FREQH = 250
These settings allow the Buzzah to vary the frequency randomly between 220 Hz and 250 Hz. Since this option has not been thoroughly tested, The Blue Buzzah does not currently yet support setting this to TRUE, so please leave it as FALSE.

AMPLITUDE_MIN = 100
AMPLITUDE_MAX = 100
If you think you are getting too much vibration from your buzzers, try backing both settings to 90 and 90, or 80 and 80, and the buzz amplitude will be less. The system allows for increasing amplitude up to 127%, but we are already near the peak output from our driver boards. However, if you push your buzzers at higher voltage than they are designed for, you will shorten life and end up having to do replacements more frequently. Longevity will be greatest if you keep amplitude 100 or less.

If you want to experiment with randomly varying amplitudes of your buzzes, you can adjust the max and min to different values. Leaving min and max amplitudes both at 100, you will get no variation in vibrational amplitude as Dr. Tass did in his 2021 paper. If you set MIN = 50 and MAX = 90 for example, your buzz amplitude will vary randomly between 50% and 90%.

SYNC_LED = False
If this is set to True, the internal LED will flash blue at the start of each 12-pulse buzz sequence. Setting this to False will turn off the blue flashes during treatment.

TIME_SESSION = 120
Dr. Tass prescribed 120 minutes of therapy twice a day. You may set this timer to be more or less depending on your preference. **Keep in mind that when your buzzer times out and stops buzzing, the Blue Buzzah is still draining juice from your battery even though the buzzers stop. So don't forget to turn the Blue Buzzah off after each use! Failure to do so may lead to a dead battery when you come to use it again and your battery life will be shortened.**

TIME_ON = 0.100
TIME_OFF = 0.067
The pulse time is nominally set here at 100 ms (0.100) and rest time between pulses 67 ms (0.67), which is the same as Dr. Tass uses in his study. That said, it is possible to adjust the relative stimulation by increasing or decreasing. Whenever we have experimented with this setting, we have sought to keep the sum of ON and OFF to be equal to 0.167 so as not to change the overall rate of firing from what was used in Dr. Tass's published studies. So, for example, if we reduced the TIME_ON to 0.090 to achieve less stimulation, we correspondingly increased TIME_OFF to 0.077 to keep the overall sum constant.

TIME_RELAX = 4 * (TIME_ON + TIME_OFF)
This is the setting used by Dr. Tass. You could increase or decrease the relaxation time here.

MIRROR = False
If MIRROR = True, then each hand will be stimulated with the same random pattern, with index fingers stimulated together, ring fingers stimulated together, and so on. If MIRROR = False, then each hand receives its own randomized pattern of finger order. We have this set nominally at False to get the Regular vCR pattern.

JITTER = 0.0
Jitter is randomized variation in the rest time between pulses. Setting at 0% (as in the "Regular vCR") means that all rest times between pulses will be whatever is set in the TIME_ON parameter. In Dr. Tass's "Noisy vCR pattern", the jitter is set at 23.5%, meaning that the rest time between pulses is varied randomly by a factor of 23.5%. Even when jitter is non-zero, pulses on right and left hands will be coincident within the limits of sync skew.

PATTERN_TYPE = "TWAVE"
This is a setting that is unique to the Blue Buzzah that relates to how we generate patterns in the software. It needs to be set as shown in the table below.

In order to reproduce Dr. Tass's patterns from his paper, you must reproduce the following settings:

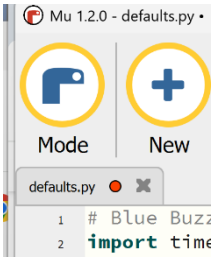
Tass Buzz Pattern	Mirror	Jitter	Blue Buzzah PATTERN_TYPE
Regular vCR	False	0	TWAVE
Noisy vCR	True	23.5	RVS
Hyrbrid	False	23.5	NOT SUPPORTED AT THIS TIME

At this time, no other patterns have been tested on the Blue Buzzah. Other settings may result in erratic buzz behaviou.

A single iPhone app to adjust and significantly simplify the stimulation settings is under development.

IMPORTANT NOTE AGAIN: If you change ANY settings in the defaults file of either hand, YOU MUST ALSO CHANGE THE DEFAULTS FILE IN THE OTHER HAND TO MATCH THE SAME EXACT SETTINGS! Failure to update changes to both hands will lead to erratic buzz performance that is out of specifications.

Once you are done making changes in your settings, click on save. The red dot next to defaults.py will then go away in the Mu program to signify that your changes have been saved to your Buzzah. If you don't click save, none of your changes will be applied.



You can now unplug your Buzzah from your computer and start your therapy!

Blue Buzzah Parts and Tools Lists

IMPORTANT NOTES:

Read this entire document carefully before moving forward with building.

If you decide to embark upon your own project to assemble one of the Buzzah builds described in this document, please start by carefully reading the disclaimers. Then, take a couple hours to carefully read through the building steps you plan to follow. As you read each step, have the corresponding parts list handy to check off the various parts and tools required. **I could easily have made mistakes or left something out, so double check everything!**

OEM vs SUBSTITUTE parts and tools in parts lists.

Most of the parts and tools listed were actually used in my own prototypes. You can feel pretty confident these parts and tools will work as intended since I have already used them. These parts I have already used are listed as "OEM" in the parts lists. There are also parts and tools that I already had on hand. In these cases, I searched for parts and tools that are currently available and listed these parts as "substitutes". The substitutes should work fine, and in some cases better, but just be aware that they might not work exactly as mine did.

Our Part #	Parts List:	source	Part #	#	price	Net	notes
1	Special Order Blue Buzzah PCB	JLCPCB	See Part 1 of instructions	2	$17.00	$34.00	Price is at discounted volume of 15 - I think minimum purchase might be 5 - Probably a good idea to purchase an extra board in case of a bad board - tariffs may raise price
2	3D Prints of tactor parts and case	3DGiftsandTreasures on Etsy	Buzzah Print	1	$19.99	$19.99	We found two vendors who have the same type of printer and have verified they can reliably print our design
3	VLV101040A LRA Buzzer	digikey	LV101040	10	$5.65	$56.50	Included 2 extra in case of failures.
4	Adafruit Feather nRF52840 Express	Adafruit	4062	2	$24.95	$49.90	The module that does processing and Bluetooth
5	Lithium Ion Polymer Battery Ideal For Feathers - 3.7V 400mAh	Adafruit	3898	2	$6.95	$13.90	Fits under the Feather module
6	Short Headers Kit for Feather - 12-pin + 16-pin Female Headers	Adafruit	2940	2	$1.50	$3.00	
7	DEWALT Large Black PVC PVC 1 -Pairs	Lowes	4964203	1	$20.98	$20.98	You may want to find your own glove as described earlier
8	NTECHGO 28 Gauge Silicone Wire Kit Red Black White Blue and Green Each 50ft 28 AWG Stranded Tinned Copper Wire	amazon	B077GRNMMC	1	$17.98	$17.98	I love this wire! Strong, flexible and easy to strip.
9	uxcell Nylon Strip Zip Wire Cable Tie Fastener Off 2mmx150mm 500pcs	amazon	B019GIEWWS	1	$12.19	$12.19	These small wire ties are good - tough and not brittle
10	12-pack 12ga. (.012 inch) Steel Guitar Strings - Made in the USA!	amazon	B008UX4O1A	1	$8.99	$8.99	12 pack so you have plenty to practice with
11	Anker USB to USB C Cable [2 Pack, 3FT], USB A to USB C Charger Cord for Samsung Galaxy S10 S10+, LG V30, Beats Fit Pro and More (USB 2.0, Black)	amazon	B07DD5YHMH	1	$8.99	$8.99	2 pack
12	Industrial Strength Sticky Back Hook and Loop Strips | 2 x 6 Inch 8 Sets | Aniced Heavy Duty Self Adhesive Strips for Sofa Couch Cushions, Rug, Mattress - Black	amazon	B0B8RRR4YH	1	$8.98	$8.98	
13	MILAPEAK 650 PCS Heat Shrink Tubing Kit, UL Approved Heat Shrink Tube Wire Wrap, 2:1 Ratio Electrical Cable Sleeve Assortment with Storage Case for Long Lasting Insulation Protection (8 Sizes, Black)	amazon	B07QM8249H	1	$8.79	$8.79	
14	SPDT Mini Micro Slide Switch - SS12D00G(1P2T) 2 Position - 40pcs 3mm Toggle Vertical Panel - Mount Small High Knob Vertical for Breadboard PCB Arduino Electronic Board Dip Miniature Slide Switch	amazon	B0DN69PJ43	1	$7.99	$7.99	You only need two of these even though the package comes with 40
					TOTAL PARTS	$272.18	

Tools List:	***source***	***Part #***	***#***	***price***	***Net***	***notes***
Weller 70 Watt Digital Soldering Station | WE1010NA	*amazon*	*B077JDGY1J*	*1*	*$115.00*	*$115.00*	*You could get by with a much cheaper soldering station, but it is nice to have the best especially if you are a novice*
63-37 Tin Lead Rosin core solder wire for electrical soldering (0.6mm 100g)	*amazon*	*B076QD1W9X*	*1*	*$11.99*	*$11.99*	*Make sure you use in well ventilated area!*
XYK Helping Hands Soldering Station with 3X Magnifying Glass with light, 4 Flexible Helping Hand Arms	*amazon*	*B09DRZLM5N*	*1*	*$26.99*	*$26.99*	*This make soldering these tiny wires SO MUCH easier. It is also helpful when assembling tactors*
Soldering Iron Kit, 80W 110V LCD Digital Soldering Welding Iron Kit with Ceramic Heater,	*amazon*	*B08R3515SF*	*1*	*$9.96*	*$9.96*	*Cheap iron for melting holes in the gloves. Don't use your Weller for this purpose!*
IRWIN VISE-GRIP Wire Stripper, 2 inch Jaw, Cuts 10-24 AWG, ProTouch Grip for Maximum Comfort (2078300)	*amazon*	*B000OQ21CA*	*1*	*$23.39*	*$23.39*	*You could get by with a cheaper stripper - but since you use it so often, it is nice to have a good one*
Cordless Drill with variable speed trigger	*Amazon*	*B07CTDBRNP*	*1*	*$29.99*	*$29.99*	
SEEKONE Mini Heat Gun, Tool with Reflector Nozzle and 4.9Ft Long Cable Overload Protection for Crafting, Vinyl Wrap and Shrink Tubing	*Amazon*	*B08VFY8THD*	*1*	*$17.99*	*$17.99*	*For shrink tubing*
Amazon Basics 3-Piece Long Reach Pliers Set, Black	*amazon*	*B07TWFCV44*	*1*	*$15.26*	*$15.26*	*These come from Amazon very dirty and oily. You will need to wash them off well before inserting into your gloves.*
HURRICANE 4 Piece Wood Chisel Set for Woodworking, CR-V Steel Beveled Edge Blade, Durable PVC High Impact Handle Wood Chisel	*amazon*	*B07GGYNHSQ*	*1*	*$13.99*	*$13.99*	*You need a wide surface. If you have a metal file it would probably work better*
11-Piece Hook and Pick Set with Clip Removal Tool, Precision O-Ring Removal Kit for Automotive Mechanic and Electronic Maintenance Car Auto Oil Seal Mini Hooks	*amazon*	*B0CQVKLBW1*	*1*	*$12.99*	*$12.99*	*For heling get the tactors placed. I couldn't find the hook tool I used, but you should have more than you need with this set*
Amazon Basics Folding Utility Knife, Lightweight Aluminum Body, Red	*Amazon*	*B07TBNH4ZT*	*1*	*$9.90*	*$9.90*	*to cut the little white tabs off LRAs*
WORKPRO Premium 8" Needle Nose Pliers, Paper Clamp Precision, Heavy-Duty CRV Steel, Large Soft Grip with Wire Cutter, Long Nose Cutting Pliers, W031269	*amazon*	*B08F7F5C8N*	*1*	*$8.99*	*$8.99*	*For working with tactors*
iexcell 4.0" Flush Cutter Side Cutter Wire Cutter Pliers Nippers Repair Tool, Red, Chrome-Vanadium Steel	*amazon*	*B0CH4ZWMV6*	*1*	*$7.86*	*$7.86*	*Nice clippers - don't use dull clippers because you end up with wire failures*
3/16 in. x 36 in. Plain Steel Round Rod	*Home Depot*	*550813*	*1*	*$3.92*	*$3.92*	*For winding springs*
Safety Glasses with Adjustable Temples and Anti-Scratch Lenses, Black Frame/Clear	*Amazon*	*B06XBVNZJF*	*1*	*$3.06*	*$3.06*	*Eye protection for making springs and soldering. Do not skip this safety measure!*
MABIS Precision Kelly Forceps Locking Tweezers Clamp, Silver, Curved, 5-1/2 Inch, 1 Count (Pack of 1)	*amazon*	*B00GGAAPD0*	*1*	*$2.97*	*$2.97*	*To fish wires through holes in gloves*
				Total Tools	***$314.25***	