The Buzzah Neck Speaker
DIY Glove Build

TABLE OF CONTENTS

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.

Feature Summary Table

Feature	2021 Stanford Glove[1]	Buzzah Neck Speaker Build	Typical ERM Build
Approximate Cost	$8,000 est.[2]	$380[3]	$200
Availability	2028 est. [4]	3 Weeks[5]	4 Weeks[5]
Soldering Required	None	Minimal	Extensive
Processor Location	Fanny Pack	Neck Speaker[6]	Fanny Pack
Processor to Glove Cable	Long Hang from Waist	Short Hang from Neck	Long Hang from Waist
Bluetooth Music Player	No	Yes[7]	No
Bluetooth Speakerphone	No	Yes[7]	No
Detachable Gloves	Yes	Yes	No
One Hand Therapy Option	Yes	Yes[8]	No
Tactor	Yes	Yes	Optional
Buzz Pattern	Reg/Noisy[9]	Reg/Noisy/Hybrid/Novel	Reg/Noisy
Buzzer Type	Acoustic Exciter[10]	LRA	ERM
Buzz Direction	Z-axis	Z-axis	XY-axis
Pulse Envelope Shape	Square	Square[11]	Mound[11]
Overlap Between Successive Pulses	Zero	Zero[11]	Some[11]
Buzzer Rise Time	2 ms	2.2 ms	40 to 80 ms
Adjustable Features			
Pulse Amplitude	Yes	Yes	No
Pulse Frequency	Adjustable 250 Hz	Adjustable 250 Hz	Fixed 160 Hz
Pulse Duration	Yes	Yes	Yes
Rest Time Between Pulses	Yes	Yes	Yes w/overlap
Relaxation Period Between Pulse Sequences	Yes	Yes	Yes
Amplitude Randomization	Yes	Yes	No
Therapy Timer	Yes	Yes	No

(1) Specs are for the 2021 Stanford glove prototype described here: https://www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2021.758481/full

(2) When Tass gloves finally become available, they will cost significantly less and probably be covered by Medicare.

(3) Not including tools and workplace prep. See part/tools appendix. Parts list for minimal solder approach is slightly more expensive.

(4) This optimistic 2028 estimate is based on this posting from HealthUnlocked: https://healthunlocked.com/cure-parkinsons/posts/151165382/stanford-glove-trial

(5) Estimates of build time include time for reading, space preparation, parts and tools acquisition. Buzzah build is a bit faster than typical ERM builds because it uses a Kris Wilk processor design utilizing plug-in cables instead of soldered connections.

(6) See appendix for optional box build made to fit in a fanny pack.

(7) The neck speaker used in this build is no longer available. See appendix for suggestions of available alternatives. Alternatives have not been tested in this application.

(8) Dr. Tass suggested in a Q&A session that, like DBS, he would expect one-sided glove therapy to also be effective, but he had not tested this alternative.

(9) Dr. Tass's paper describing the two tested buzz patterns is available here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8055937/

(10) Dr. Tass as switched to a new unspecified type of buzzer in his most current version that is very inexpensive, yet still fulfilling his exacting standards. Given the low cost of a "few bucks", it seems likely that the new type is a piezo. See TrainingWheelsOff video at time 2:08:43.

(11) See Bench Test chapter for a detailed analysis of LRA and ERM buzz characteristics.

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 one of the builds 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, have the corresponding parts list handy to check off the various parts and tools required.

Save the building hassle and hire a 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 we would definitely not be interested in fulfilling, 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 motors eventually start wearing out, so there will be some deferred costs down the line if you are not able to change out motors 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 DIY vibrating glove treatment 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 the authors 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 any 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, especially given that not all patients have uniform experiences even when using the actual Stanford glove under ideal medical supervision.**

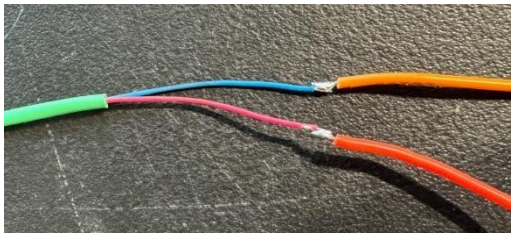
4. There is no guarantee that your glove build will work when you turn it on the first time. In our many years of experience tinkering with electronics, we have seldom experienced a build that worked the first time without having to troubleshoot some kind of error. We have done our best to describe the 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 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, there are many DIY versions on the web you can choose from. We have only carefully studied a few different designs. We stopped looking when we got to Kris Wilk's Buzzah processor design because it satisfied all the criteria we were looking for including, relative ease of construction, high level of mobility, and excellent LRA buzzer performance. That said, you might find another design out there that fits your needs better.

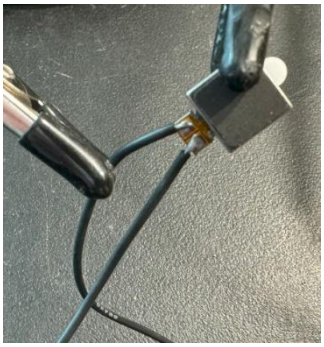
6. While every effort has been made to assure accuracy, the contents of this document may contain errors and/or omissions.

Soldering Required for Buzzah Neck Speaker Build

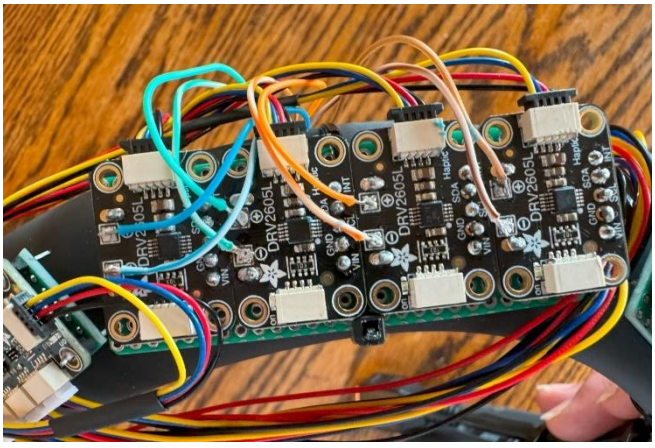
Aside from the 3 types of soldering connections described here, the level of expertise needed for this build is comparable to a very elaborate Hobby Lobby crafts project…



Joining for 8 pairs of wires like this in the gloves… Very easily done with third hand soldering stand.



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

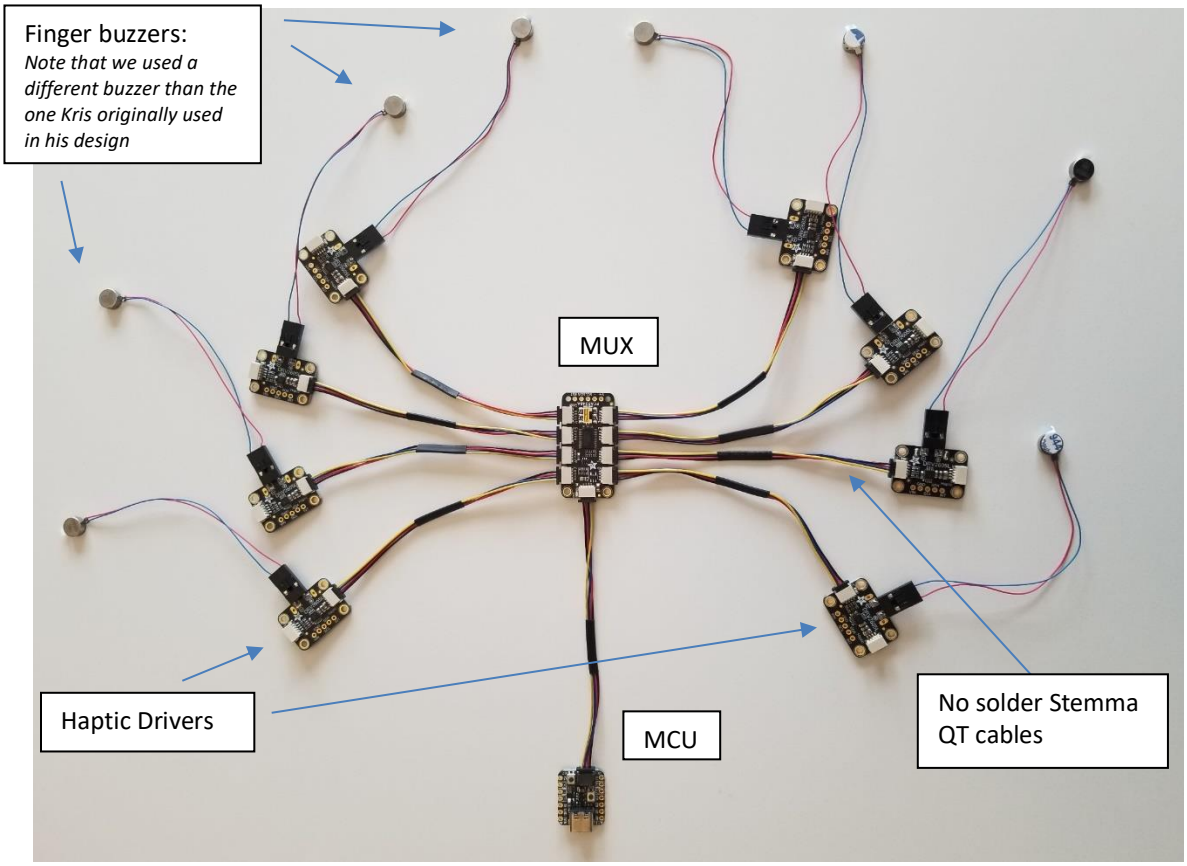


Connecting 8 pairs of wires to driver pads as shown in the 4 pairs above. This is a bit challenging for a novice because it takes a steady hand not to touch all the various wires and board elements with your soldering iron while soldering. One false move and you might damage an $8 board or a $10 wire bundle. **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. It would take a tech person about 10 minutes to do this - my guess at probable cost anywhere between $0 and $40….**

PART 1: Assembling the Buzzah Brain

Step 1.0: Familiarize yourself with the five elements of Kris Wilk's Buzzah

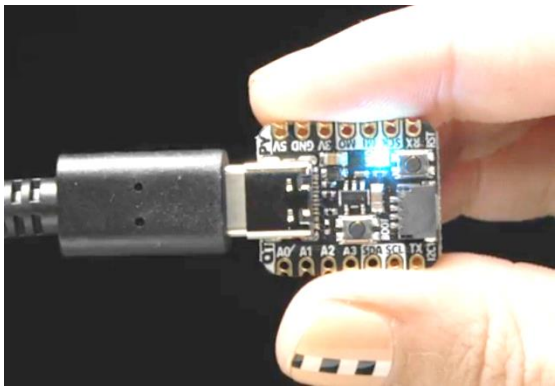
Before we start with assembling the Buzzah Neck Speaker Build, let's first familiarize ourselves with the five elements to Kris Wilk's Buzzah. As you can see in Kris's design shown below, Kris left it to others to incorporate his electronics into a glove design that would house the electronics and hold the buzzers to the fingers in some kind of glove design. My Buzzah Neck Speaker Build is just one possible build that could use Kris's design. Note that, if you prefer to wear a fanny pack instead of a neck speaker, I have an alternate box-based build that uses a fanny pack listed as an appendix to this document.



The MCU

https://www.adafruit.com/product/4900

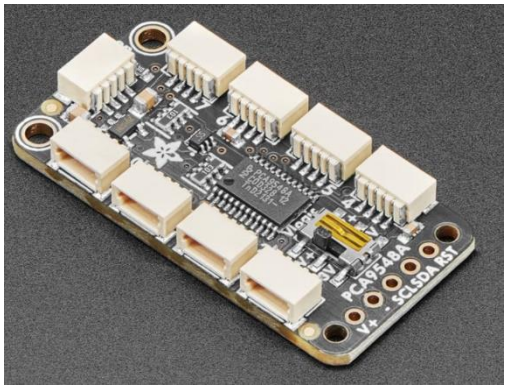
This tiny board is a complete computer processor known as a Raspberry Pi 2040, or RP2040. It is the brain of the Buzzah brain. It has internal memory which enables us to store Kris's code that tells everything what to do. One end connects to a computer or battery pack with USB-C. The other end has a plug in Stemma connector to go to other components of the Buzzah.



The MUX

https://www.adafruit.com/product/5626

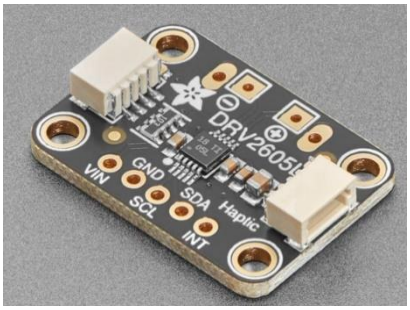
This board takes the output of the MCU and directs signals to one of 8 channels. Each of the 8 output plugs goes to a separate finger on the left and right hands. It is lucky for us that we only need 8 fingers stimulated!



2605L Haptic Driver Boards

https://www.adafruit.com/product/2305

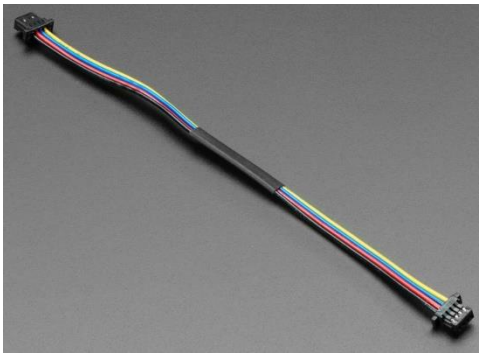
There is one of these drivers for each finger. The driver receives an on/off signal from the MUX, and then it has its own processor which performs optimization for the type of buzzer we are using. It increases voltage over the normal value to get the buzzer started quicker. And it produces reverse voltage to the buzzer to help it stop quicker. This board is why our LRAs are able to perform better than their design specs.



Stemma Cables

https://www.adafruit.com/product/4210

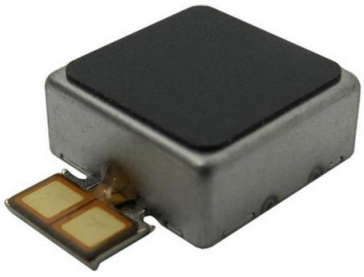
This is a new plug in connection scheme called Stemma cables. Using these 9 Stemma cables saves us from making 9 x 8 = 72 soldering connections!



VLV101040A LRA Buzzers

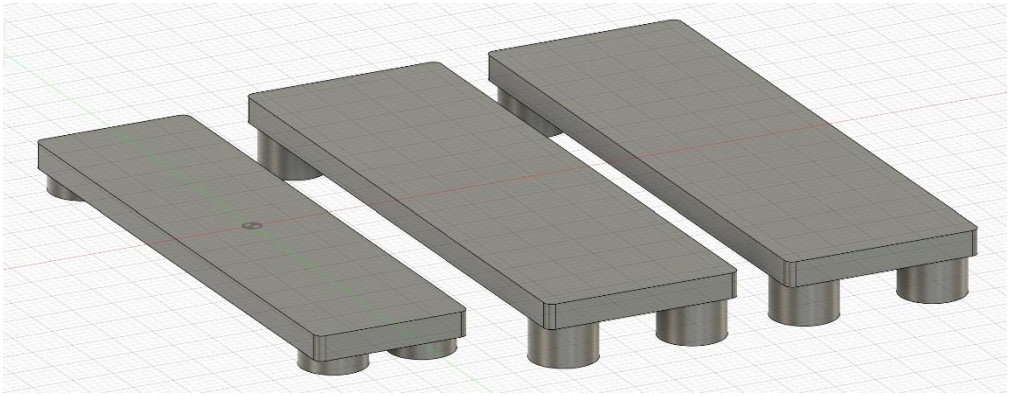
https://www.digikey.com/en/products/detail/vybronics-inc/VLV101040A/12323590

Note that my design calls for a different type of buzzer than in Kris's original design. See the bench test chapter for all the reasons why we prefer this buzzer.



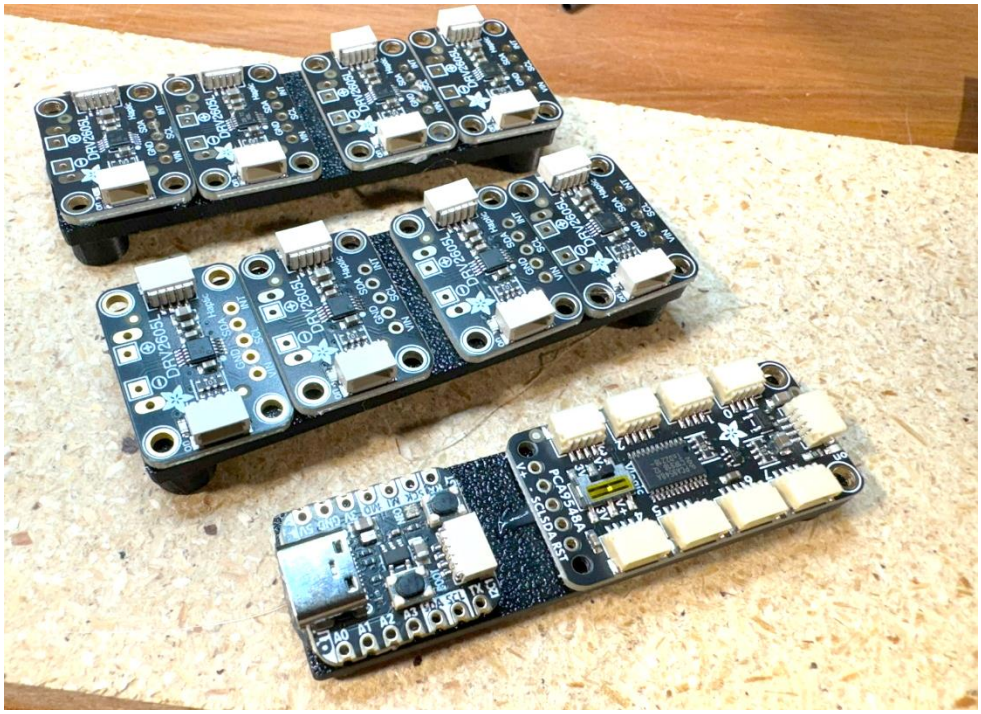
Step 1.1: 3D Print or Fabricate Electronics Platform Boards

Three NON-CONDUCTIVE platforms are needed for mounting the Buzzah components to the neck speaker. The MCU and MUX will be mounted on one 70mm X 19mm board. And, four 2605L drivers will be mounted on each of the two 75mm X 24mm boards. I have included 3D print files of proper dimensions, but similar boards could easily be fabricated using non-conductive plastic board.



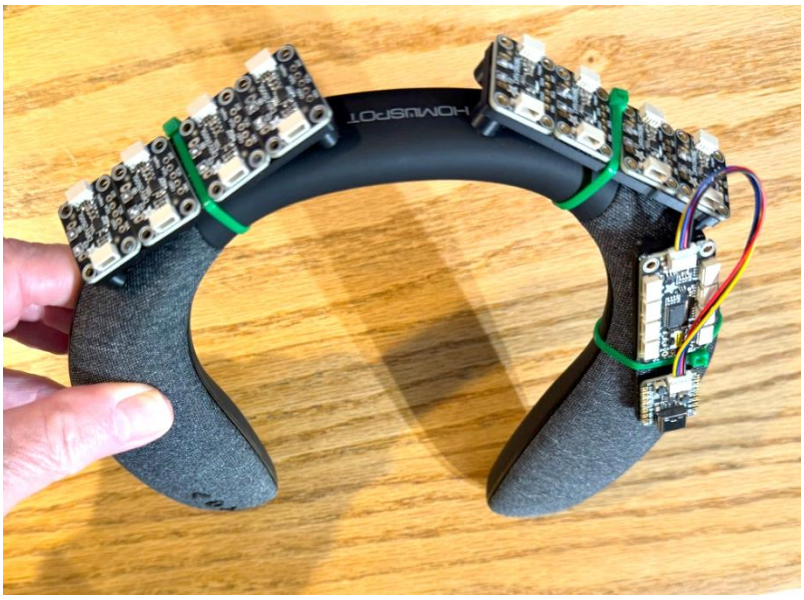
Step 1.2: Hot glue Buzzah components to perf boards as shown

Note the gaps in centers allow wire ties to hold boards to neck speaker.



Step 1.3: Mount boards to neck speaker as shown.

Leave the space with the HOMESPOT logo open to allow for flexing of the neck speaker.



Step 1.4: Use two thick wire ties to mount a CAT-6 extension cable to the left side of the neck speaker. Cut to length allowing plenty of extra for wires to reach the left driver board.

Step 1.5: Use stripper to carefully strip the CAT-6 extension.

Note that this procedure must be done in small strip segments to avoid damaging the wires. Take care not to accidentally scrape any of the twisted pairs.

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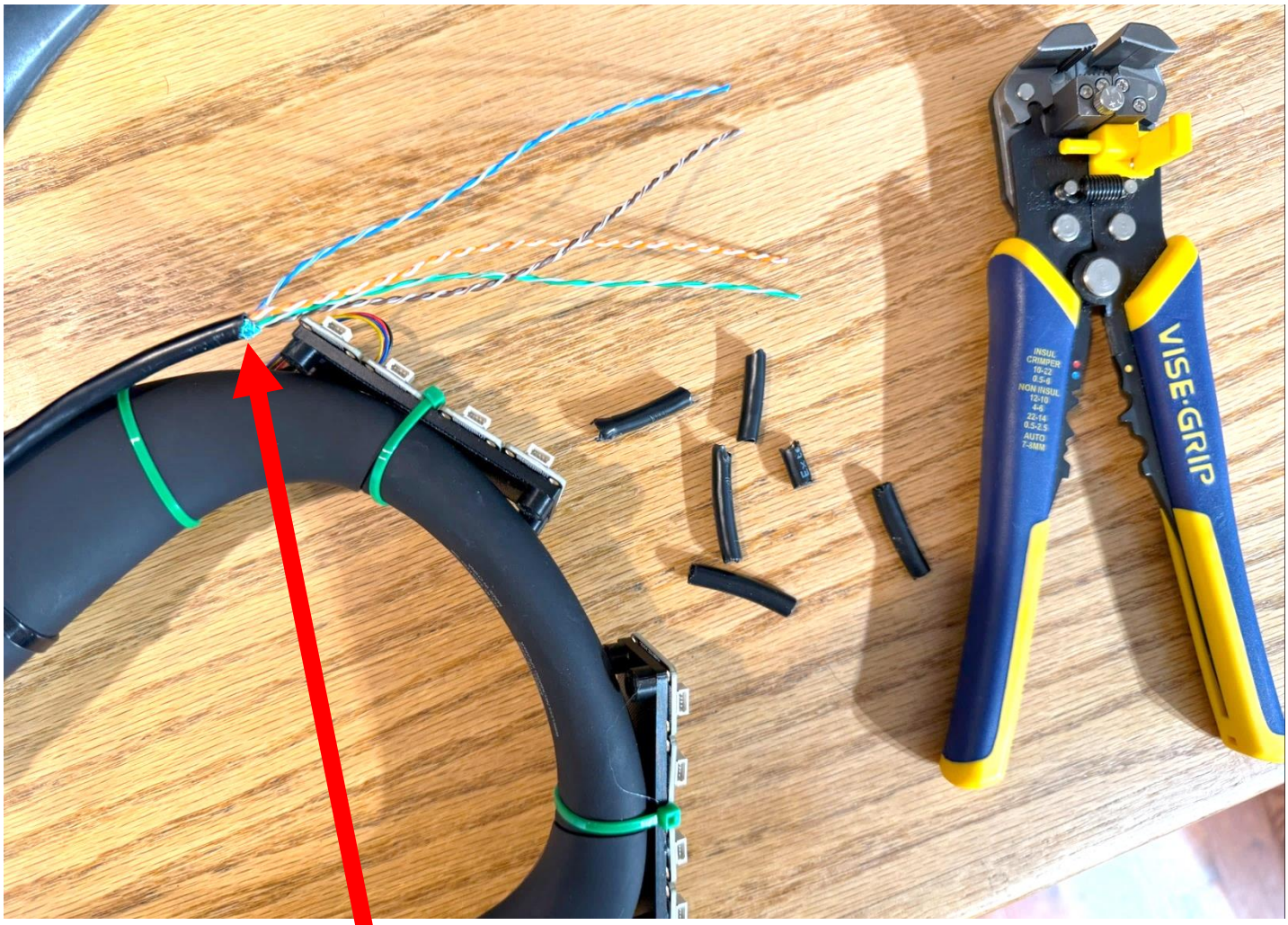
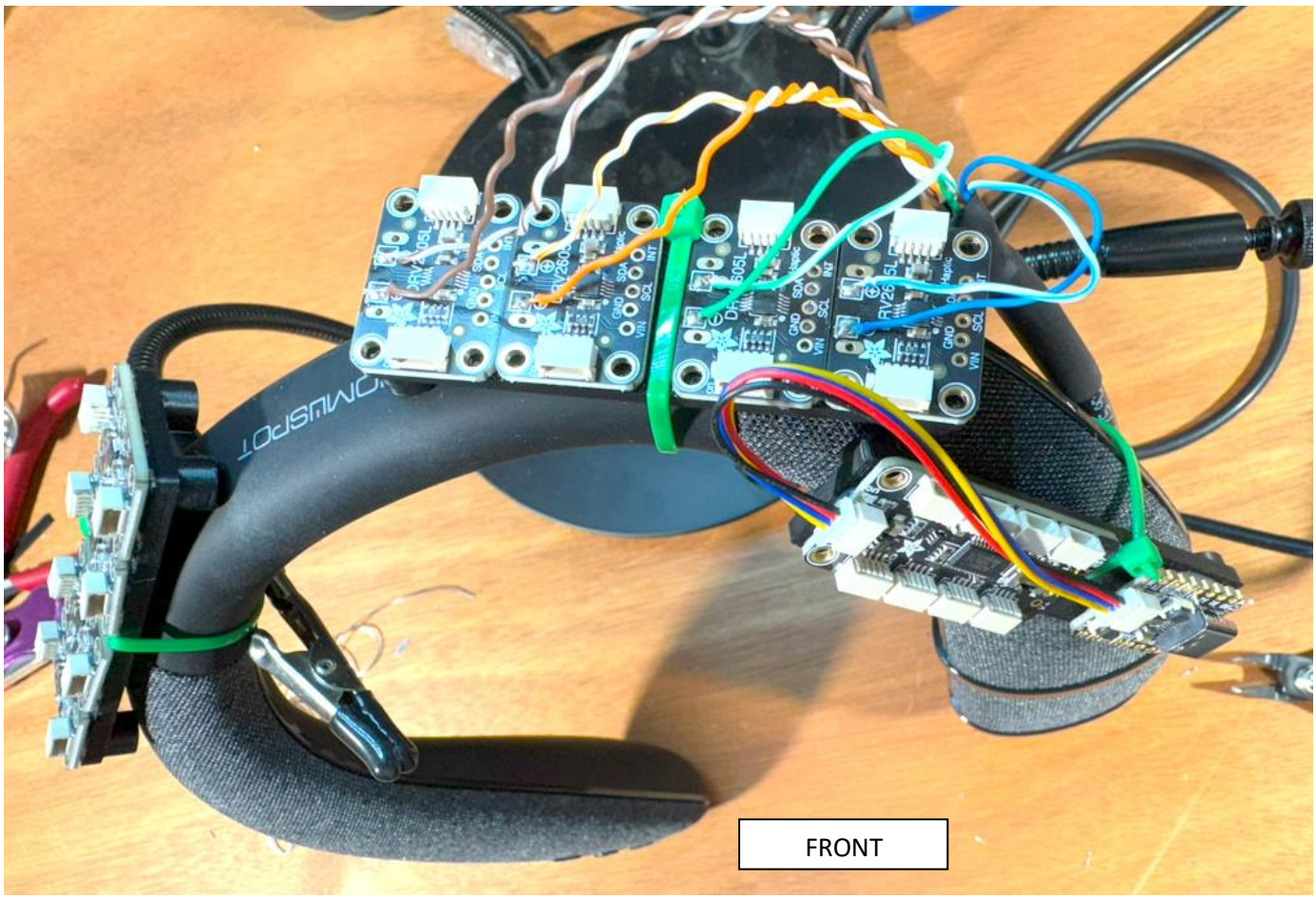


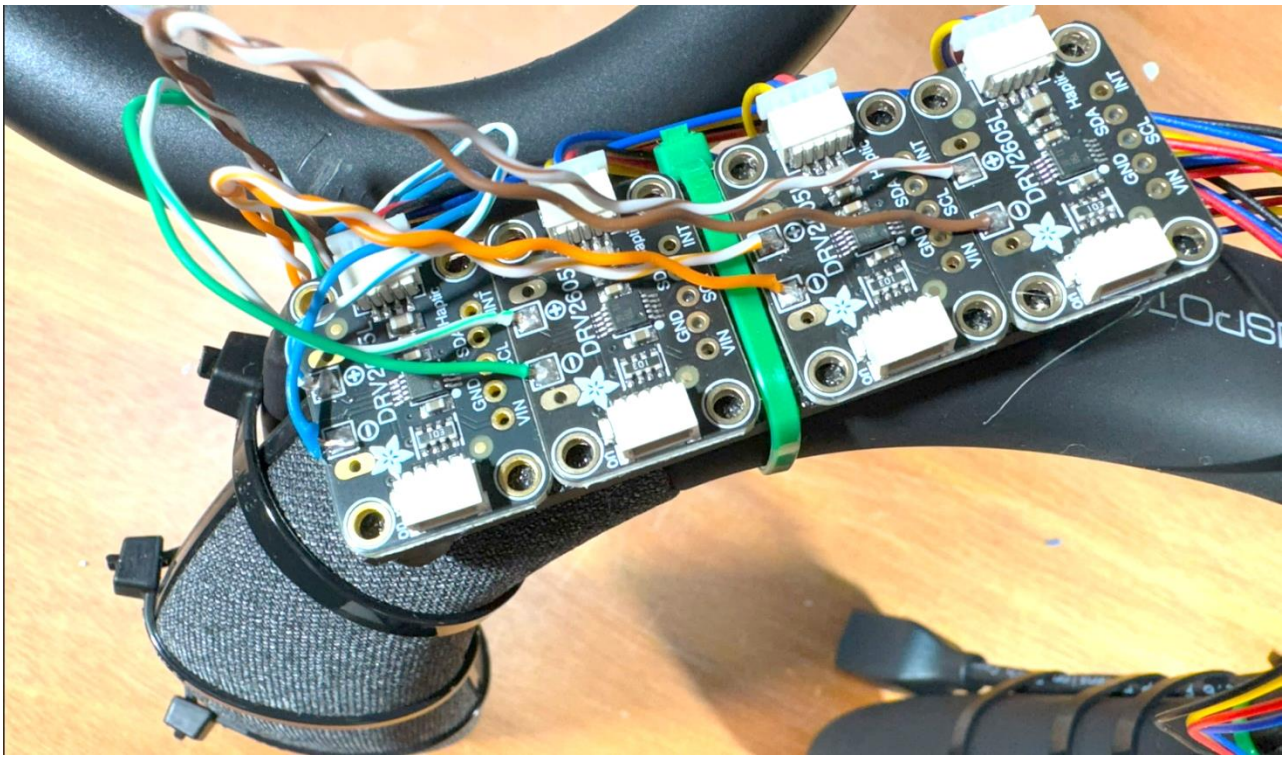
OPTIONAL: It would be a good idea to cover any exposed foil with a shrink tubing sheath to avoid shorting any exposed connections on the driver board. You will see small shrink sleave here on subsequent photos.

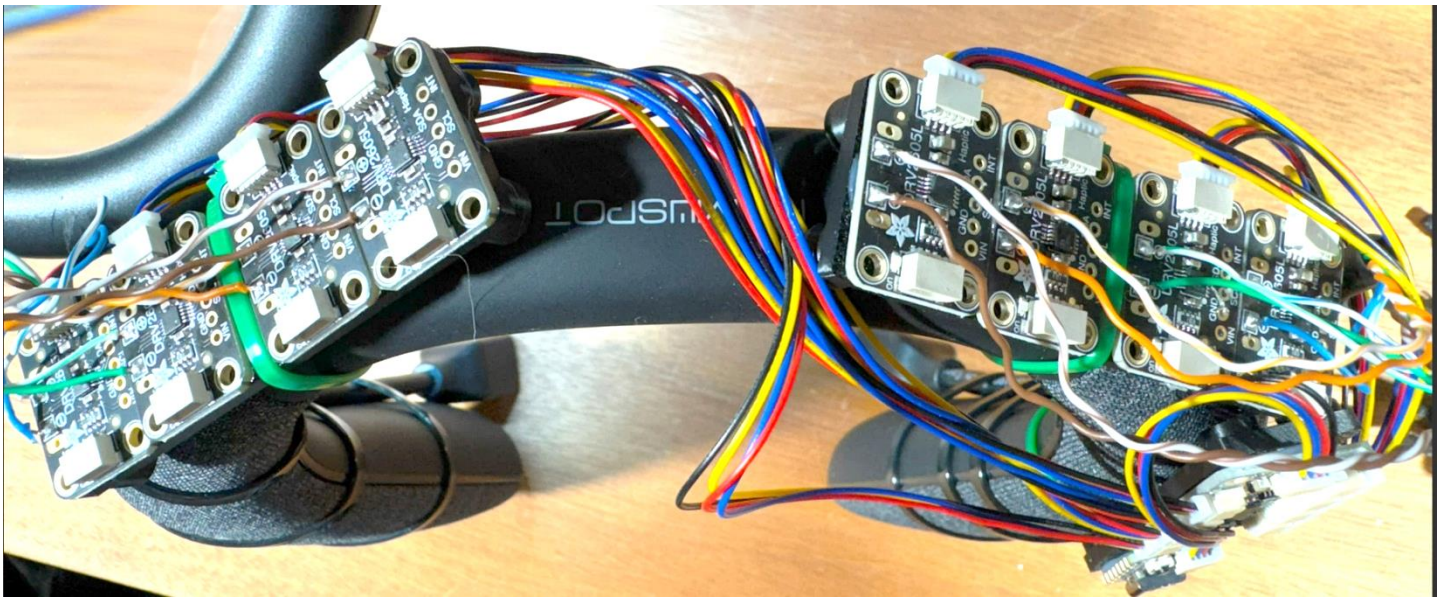
Step 1.6: Trim wires and solder to pads using the color order shown.



Note: If you end up getting the color order off, it is probably not an issue. The color/finger order of the wires is only important if you opt to use “MIRRORED” finger buzzing treatment. I never use the mirroring option. But, if you want to preserve the mirroring option for maybe some new pattern in the future, you need to make sure the color order is mirrored on the two driver boards.

Step 1.7: Repeat procedures 1.4-1.6 for right side.



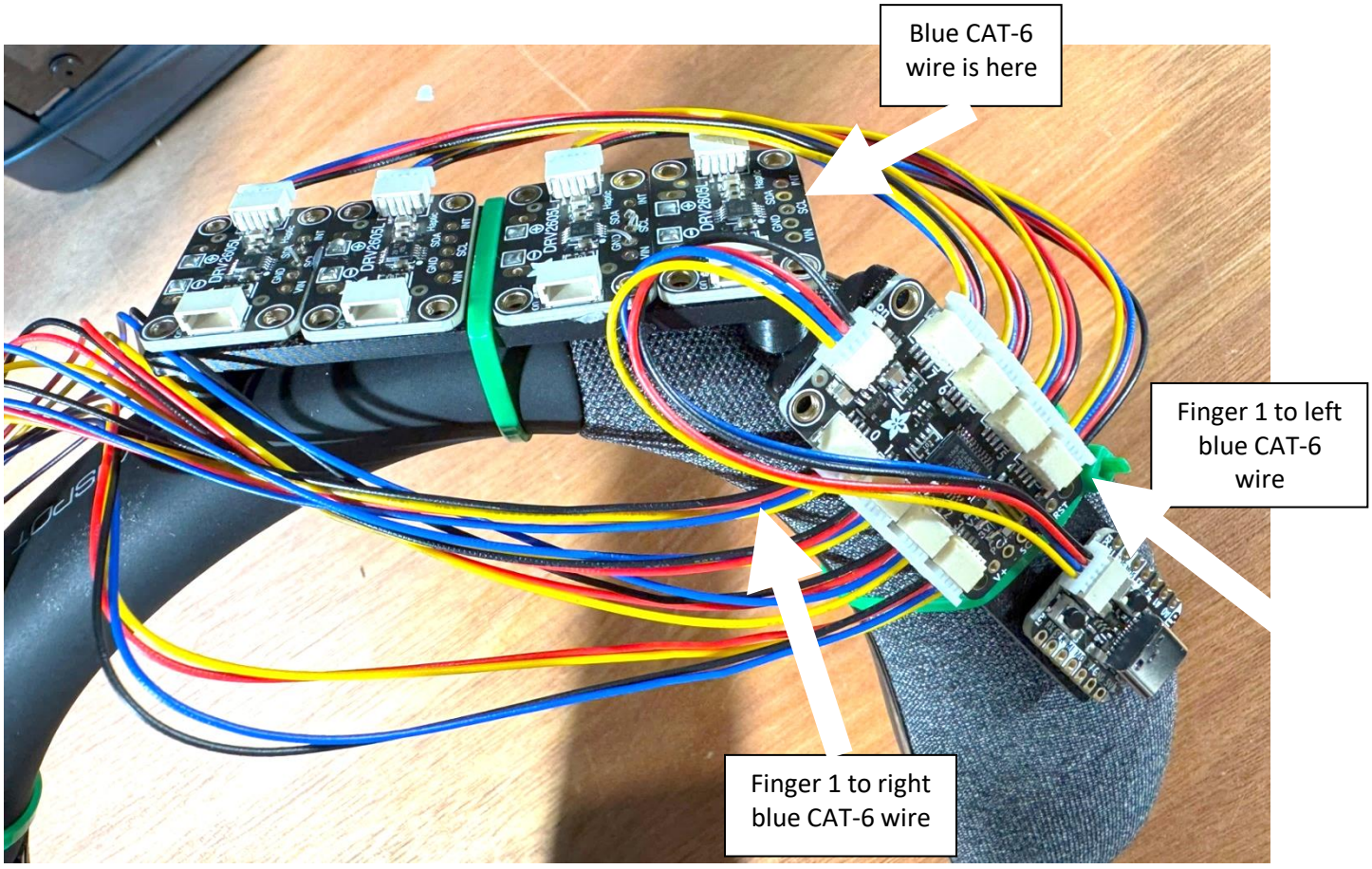


Note 1: The left side in this picture is the right side of the neck speaker when on a person

Note 2: Unfortunately, I didn't take a picture before I added the Stemma connectors. So, use your imagination.

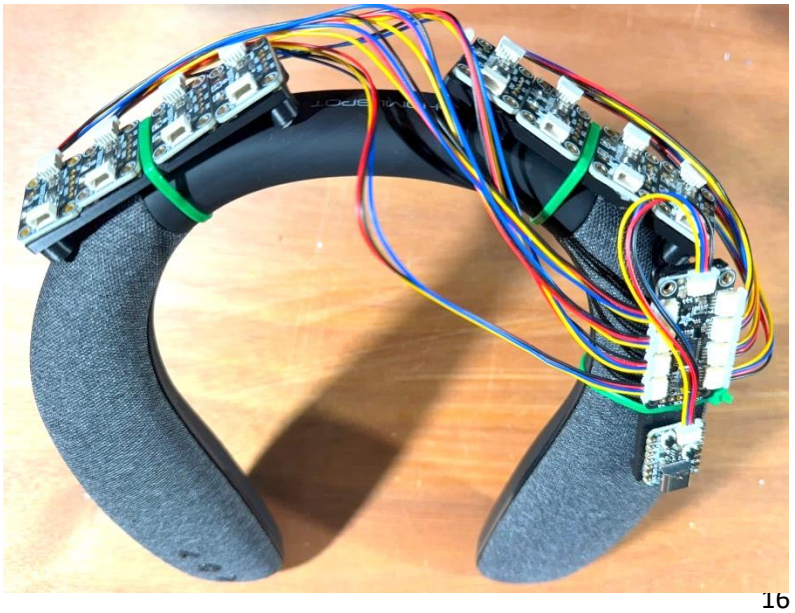
Note 3: The color order is mirrored

Step 1.8: Install Stemma connectors to join the MUX ports to the corresponding driver ports.

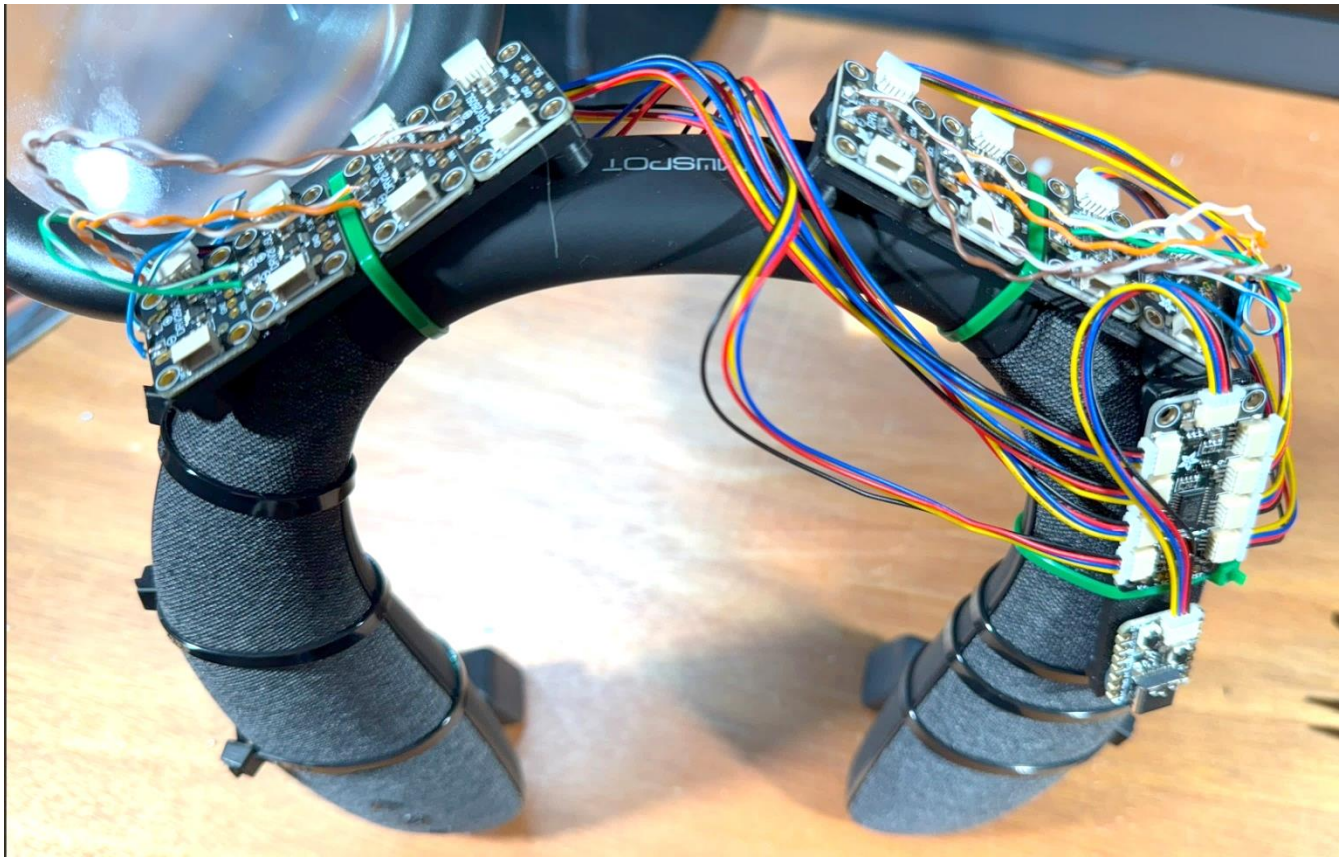


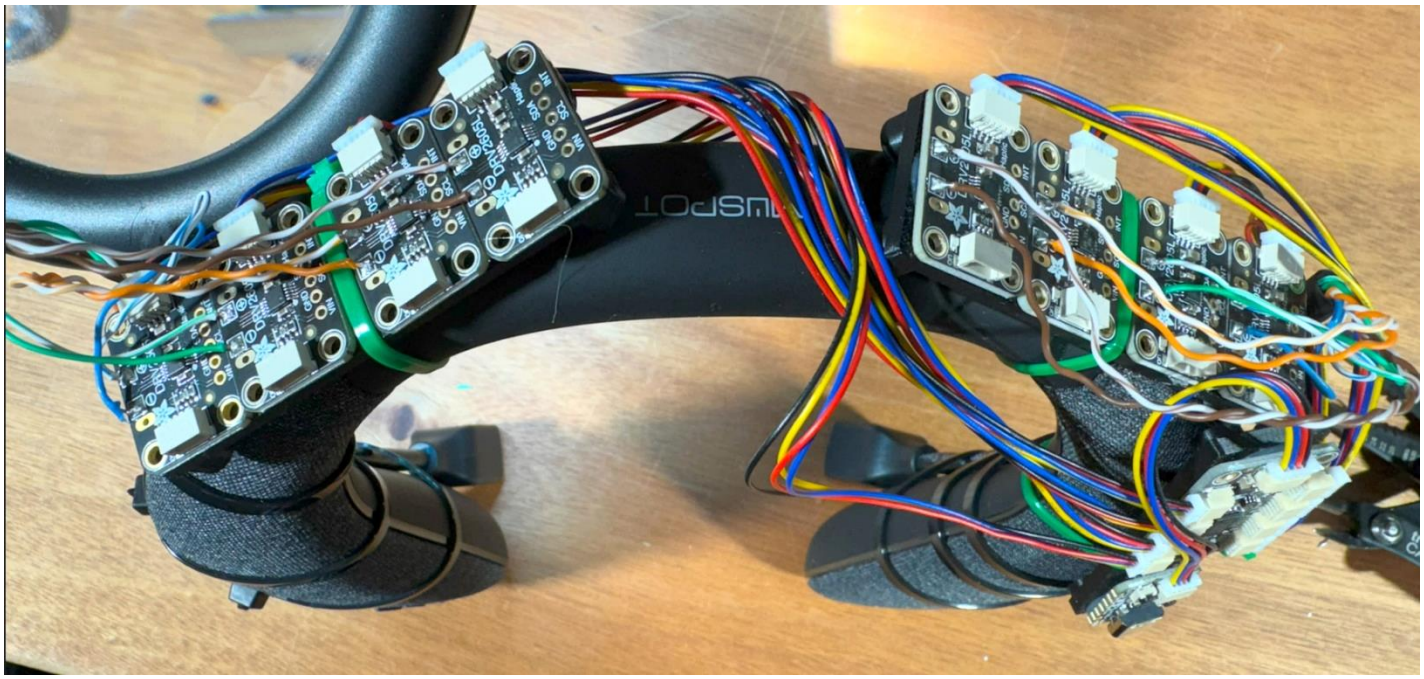
Note 1: This picture was staged for clarity before soldering the CAT-6 cables to the driver pads. I show what it all looks like together on the following page.

Note 2: Make sure you use needle nose pliers to firmly seat the Stemma plugs into each socket. If the plugs are not firmly seated, you may end up with fingers that don't work.



Here is what all the wires look like together…





Step 1.9: Format the MCU

At this point, you have completely assembled Kris Wilk's Buzzah brain. This is the point where I connected my Buzzah to to my computer and followed Kris's Github directions to format my MCU (also shown below). This process was very easy, similar to formatting a thumb drive and copying a few files over in MS-Windows. Kris provides directions for programming here under the heading SETUP: https://github.com/kriswilk/buzzah

Note that, since buzzers are not attached to the driver boards yet, you will not get any buzzing when the process is complete as Kris describes. I did the programming at this point in the process (instead of waiting till everything was together) because,

a) I wanted to see if the Buzzah was working before I covered my neck speaker, and

b) You will need one time access to the two tiny buttons on the MCU when you first program it. It turned out that I got a blinking red error light on my MCU which told me something was wrong. After emailing Kris, I found out that I had not seated the sockets firmly enough. Once I used needle nose pliers to seat the sockets as Kris recommended, the red light on the Buzzah stopped blinking when plugged into power.

From Kris Wilk's Github Site

Setup

To make the assembled parts do something useful, a tiny program ("firmware") must be loaded onto the microcontroller. As promised, this doesn't require any special tools. However, it does require following a few instructions carefully.

Update/Upgrade the Microcontroller

- Visit this page and DOWNLOAD the latest "stable" release.
- Plug the microcontroller into your computer.
- On the microcontroller, there are TWO very tiny buttons. HOLD the button CLOSEST to the USB port.
- WHILE HOLDING the first button, press and release the other button.
- CONTINUE TO HOLD the first button until your computer recognizes a new USB drive called "RPI-RP2".
- RELEASE the first button.
- Copy the "UF2" file to the "RPI-RP2" drive.

The "RPI-RP2" drive should disappear and a new drive called "CIRCUITPY" should appear.

Load the Firmware

- Download and unzip the latest release of the Buzzah! archive.
- Copy the `lib` folder to the CIRCUITPY drive, overwriting any existing files.
- Copy the `code.py` to the CIRCUITPY drive, overwriting the existing file.

As soon as you copy `code.py` to the USB drive (and assuming all your connections are correct), your Buzzah! device should come to life and start buzzing its motors.

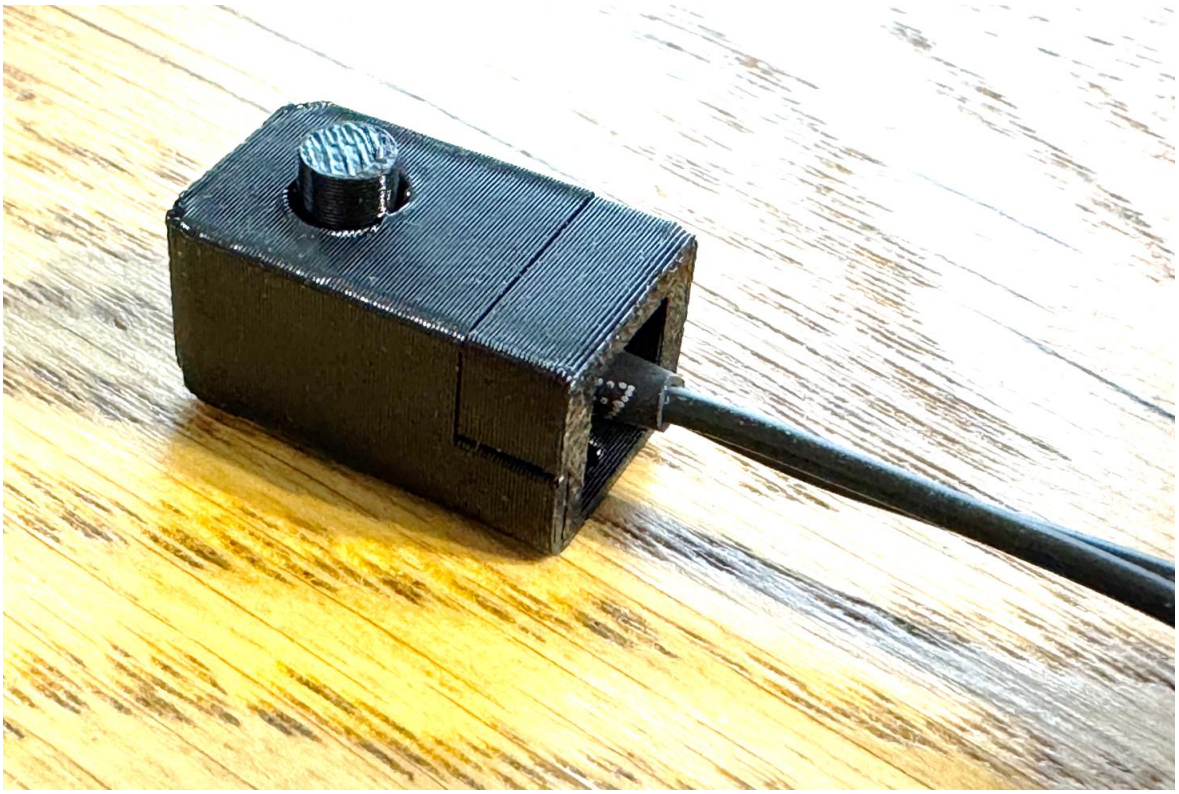
Step 1.10: Wrap Up the Wires

Use rubberized stretchy ankle wrap to hide and protect the wires of the Buzzah electronics.

Note that you need to leave access to the power jack on the left-hand side of the neck speaker (*right side in pic*).

The Buzzah brain is now complete! Next, how to construct the tactors…

PART 2: Building the Tactors

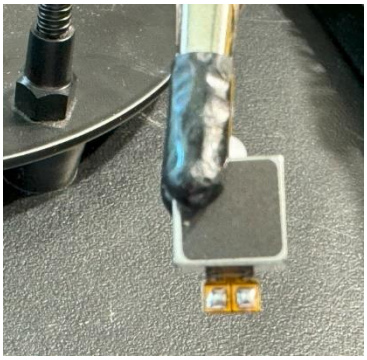


Buzzer Note: I used the VLV101040A LRA from Digikey instead of the model Kris Wilk originally used in his Buzzah design. I went with it mainly because its vibrational amplitude is over 2X greater. The following steps will be identical if you go with a different LRA.

Step 2.1: Solder wires to the buzzers

(A) Cut sixteen 15-inch segments of 28 gauge stranded black 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 probably a bit longer than you need, but it much better to be longer than you need that shorter! You have plenty of wire in your spool.

(B) Clamp a buzzer in your third-hand clip. Solder little pillows of solder on the two pads of your buzzer as shown.



(C) Since you already have solder on the pads and solder on the wires, you can use your third hand to solder your black wires to the pads without any additional solder. 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. Take you time and relax during this monotonous process until you have all 8 buzzers wired up. If you have the patience, it might be good at this point to wire up a couple extra buzzers in anticipation of needing to replace them as time goes on.

(D) After all buzzers are wired up, use shrink tubing 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 2.2: Make springs

(A) Put on safety glasses to protect your eyes against accidental whipping of the coiled wire. This is definitely a place where an ounce of prevention is worth a pound of cure!

Amazon Basics Safety Glasses (Clear/Black), Anti-Fog, 12-pack (Previously AmazonCommercial brand)

Visit the Amazon Basics Store

4.6 ★★★★½ (571) | Search this page

Amazon's Choice

(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.

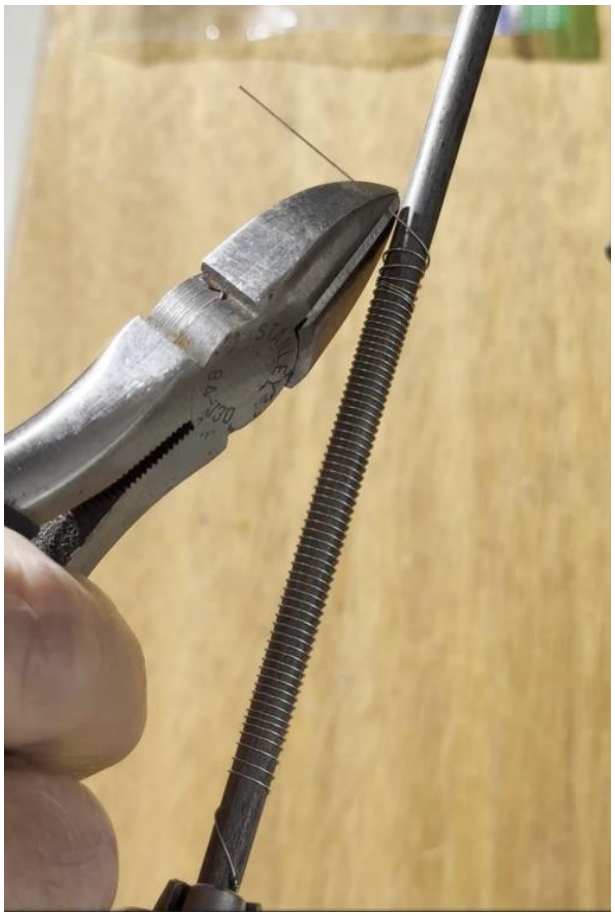
(D) Slowly rotate the drill and wind the wire around the top of your rod. The pictures shown here were taken early in my testing. **I have since learned to make the coils a bit closer together to end up with more compact springs**. If you end up with coils that are too tight, you can always stretch them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

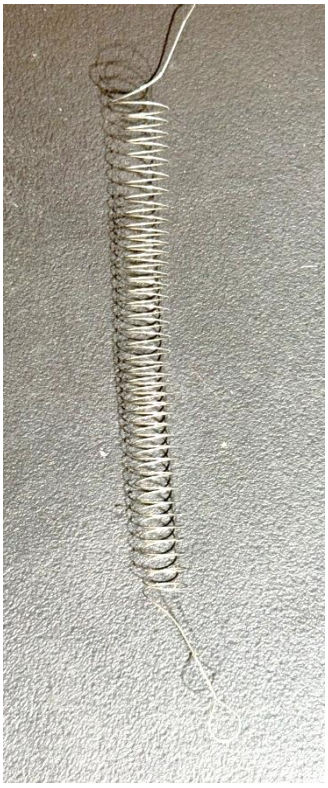
<u>Safety glasses will protect your eyes from any accidents.</u>

If you are lucky, you can get up to 7 springs from one string. If unlucky, you might get 0.



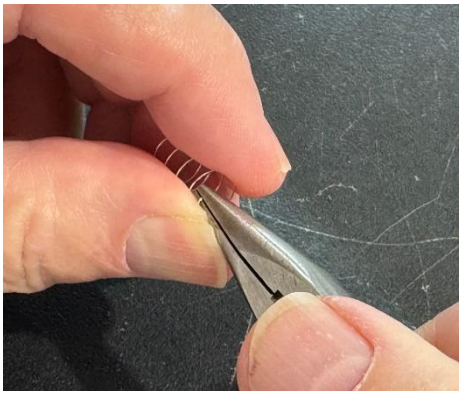
(F) Cut your long coil down to make individual springs, each with about 4.5 coils.

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. So, use a heavy-duty wire cutter like the one shown above to cut your springs to size.

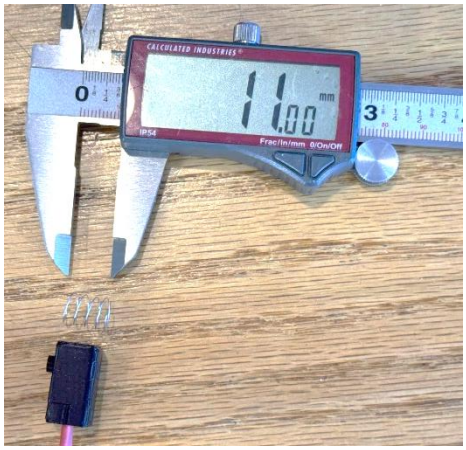


If you get a nice uniform coil pitch, you can get up to 7 springs from one string. If unlucky, you might get zero springs from a string.

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

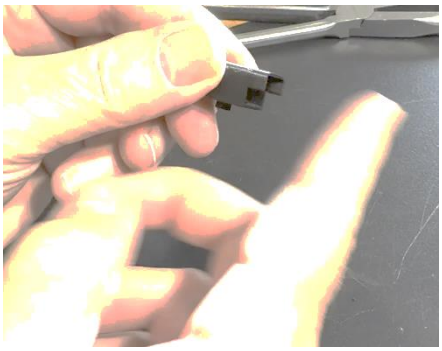


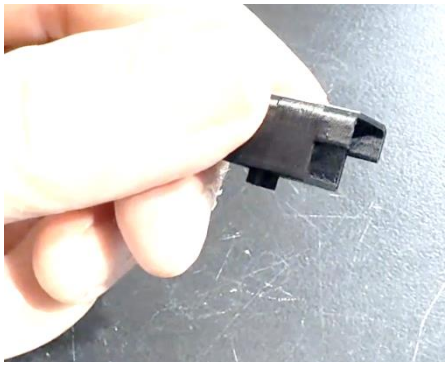
(H) Stretch your spring **if needed** so that you end up with a spring length of around 10-11 mm. This is coincidentally the same as the height of a tactor housing as shown here. If your spring came out with length over 12-13 mm, you will probably need to make a new spring with closer coils.



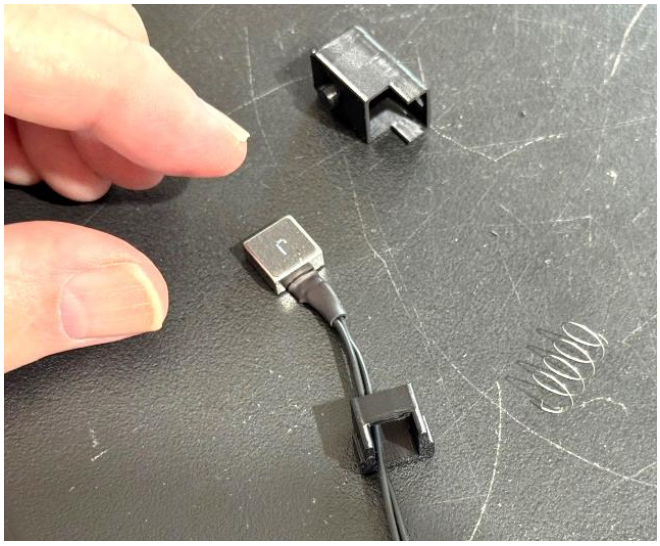
Step 2.3: Assemble Tactors

(A) Insert a button in a tactor housing and tap on the end until the button eventually falls loosely in place inside the housing. It take a bit of practice.

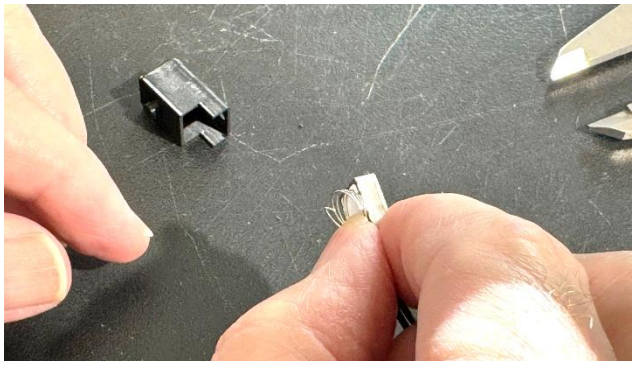


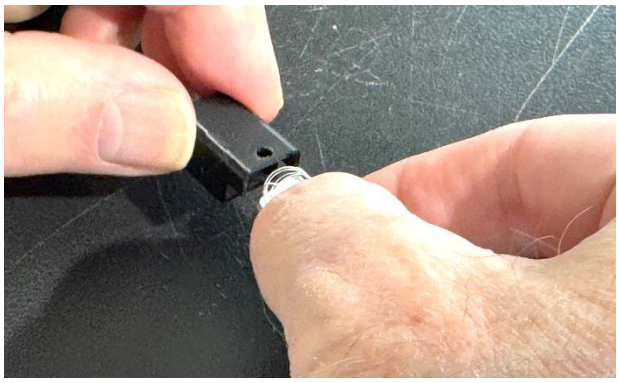


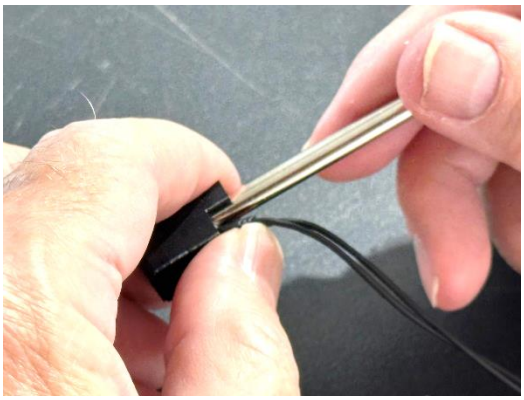
(B) Set the case and button aside, and slide an endcap over your LRA wires. Note the direction of the U-shaped gap that allows a wire tie to be treaded through the bottom hole is pointed away from the LRA.

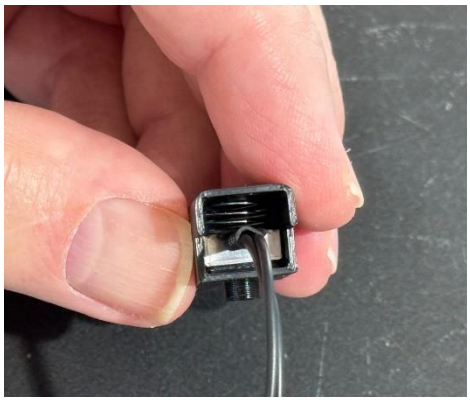


(C) Compress the spring against the LRA bottom, and then slide the spring and LRA together into the tactor case under the button flange while holding the case upside down so that the button remains in place. This is harder to do that it looks in the pictures. It takes a bit of practice to get the spring 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. I sometimes use a small blunt rod or piece of shrink tubing 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.)*

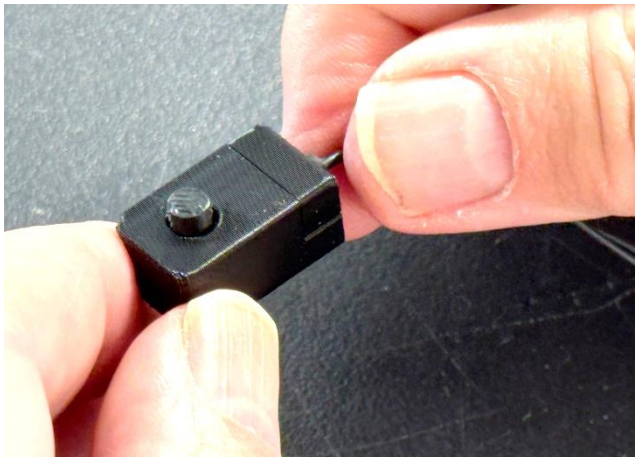






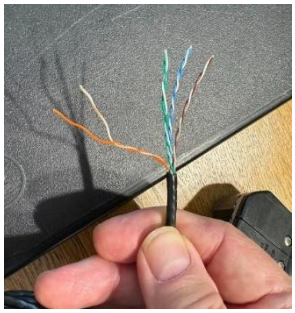


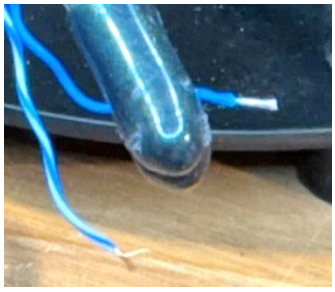
(D) When the spring is seated inside the case, the combination is unstable without the endcap. The spring can easily pop out if you accidentally pull on the wires. So, carefully, without disturbing the spring and LRA inside the case, slide the endcap into place in the case. It is a tight fit, so you might want to practice doing this a few times with an empty case before you have the spring and LRA inside the case.



Step 2.4: Make a CAT-6 test cable so you can test your tactors

A) Cut and strip one end of a CAT-6 cable
B) Strip and tin just one of the colored pairs





C) Tape off the wire pairs you are not using to prevent accidental shorting of your Buzzah brain.

CAUTION: If any of the exposed wires touch each other while plugged into your Buzzah brain, you could damage a driver board and have to replace it!

D) Use a pair of alligator cables to connect your exposed wire ends to the stripped ends of your tactor wires.

(Note the neck speaker in the picture is my Bose which has the power jack on the right side)

E) Connect your test cable to your Buzzah brain and test the tactor function outside the glove. (Connecting the battery turns it on)

DON'T ALLOW THE EXPOSED ENDS OF THE ALLIGATOR CLIPS TO TOUCH!!!!

When testing the feel of the buzz when depressing the tactor button on a tabletop, the buzz should feel light, zesty, and zingy. Tass specifications call for a point-like light vibrational sensation that is strong enough to easily perceive, but not so strong as to cause vibration in your finger bones. You may need to experiment with different initial spring heights until you are satisfied with the sensation you are getting. If you simply go with my preferred 4.5 coils with initial height 11 mm, you will get the buzz characteristics that I settled on for myself. But your physiology might be different than mine. Your fingertips might be more or less sensitive, your skin might be more or less springy, etc… If the vibrational sensation is not strong enough, you need to disassemble your tactor and stretch the spring out a bit. If the buzz is too strong, you will need to wind a new spring with tighter coils for use in your tactor.

F) After you are satisfied with the tactor buzz on a tabletop, slide your tactor inside a glove finger and repeat your buzz trial without actually mounting the tactor. Recall that the buzz intensity of a tactor inside your glove (lashed to your fingertip with velcro if needed) will probably be about 20% less that you feel when the case is grounded to a table. So you want to be sure you also test in the same conditions you will actually be using your tactor.

Take your time with this step. Your entire treatment depends on administering point-like vibrational sensations to your fingertips. If you prematurely settle on spring parameters that are not ideal and install your tactors inside a glove, you will end up spending a lot of time later to disassemple your gloves to reinstall springs with different initial length. This is a lesson I learned the hard way. I initially felt like I wanted to really feel a strong buzz from my tactors and started with 15 cm springs in my first glove prototype. Then, after using my first glove for a while, I decided my buzz was too strong and I ended up having to change out all four springs. The good news, while it is quite awkward, it is possible to disassemble the tactor without cutting the wires and completely removing the LRA and endcap from your glove.

Note that, while this testing is a hassle for your first tactor, once you have settled on your ideal personal initial spring length, you will not have to repeat this tedious testing for each of your 8 tactors. But, even if you don't end up testing each tactor in the intended glove finger before installing, it is a good idea to at least do a table test just to make sure the spring is not binding and the mechanics of the tactor are all functioning OK.

PART 3: Building Buzzah Gloves

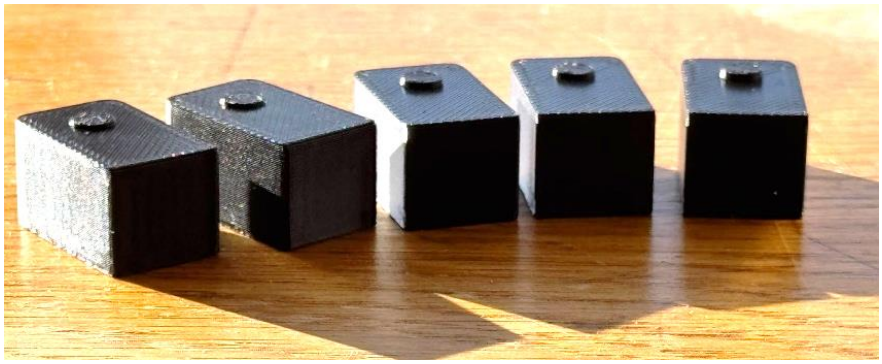
Step 3.0: Find an ideal Goldilocks glove that is not too tight and not too loose

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 tight enough to securely hold the tactors against my fingers, but not so tight as to be uncomfortable. 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 push your finger against the button and leave just 0.5 mm of the button above the tactor surface.

I actually purchased a large number of gloves so I could test the tactors while hooked up to my Buzzah brain. I returned the ones I didn't use with no problems.

How do you know what it feels like to have 0.5 mm above the surface? You bring along your 3D printed dummy test tactors to compare the button feels as described in the previous chapter.



If you don't want to go through the hassle of finding the perfect glove, Lowe's Project Source gloves come in two sizes and work very well in holding the tactors. They are also easy to work with. I would say that my Project Source gloves have a 90% of perfect fit.

The 100% perfect fit glove for my hand turned out to be this Wells Lamont Work & Home (Large).

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 the heavy metal chemicals used in leather tanning can actually cause PD! So, I decided not to use any leather gloves.

The gloves I finally settled on are made by Dewalt (Large). I would rate the Dewalts as a 97% perfect fit. They are easy to get on an off, but just a bit too stretchy in the fingers and I have to do about 2-3 seconds of adjusting when putting on each finger.

Since the Dewalts are not “100% perfectly perfect”, and I am currently in the process of making one of these gloves that are faux leather to see if they might be even better than the Dewalts. *“Oh, my life would be so sublime if I could just get that Wells Lamont leather glove 100% fit in a faux leather glove…”*

Step 3.1: 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.

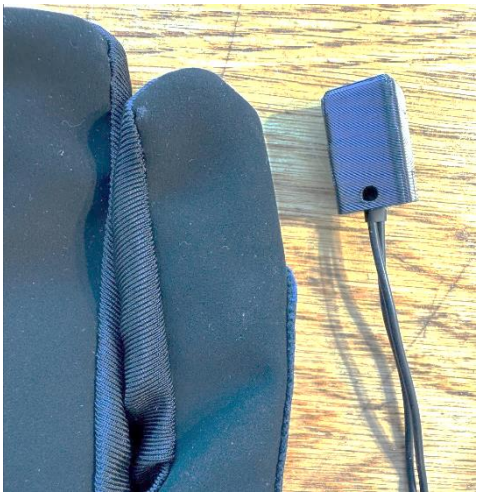
(B) Use alligator clips to attach your tactor leads to your special Buzzah test cable as described in Chapter 1.

(C) 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.

(D) When you think you have the perfect spot, plug your test cable into your Buzzah brain and verify that you have the placement right with the buzzer on. **Take your time to get this right because you will have to live with the placement once your tactor is mounted!** *(Note: If you were using the traditional Velcro external mount for your tactor, you don't have to worry about placement since it is automatically done for you by the external design.)*

(E) 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.

(F) 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.



(G) Remove the tactor from the glove.

Step 3.2: 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 3.3: 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.

Line up hole in tactor bottom

Wire tie exit hole

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

(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 3.4: Mount tactor inside glove fingertip

(A) Put the tactor back in the fingertip.

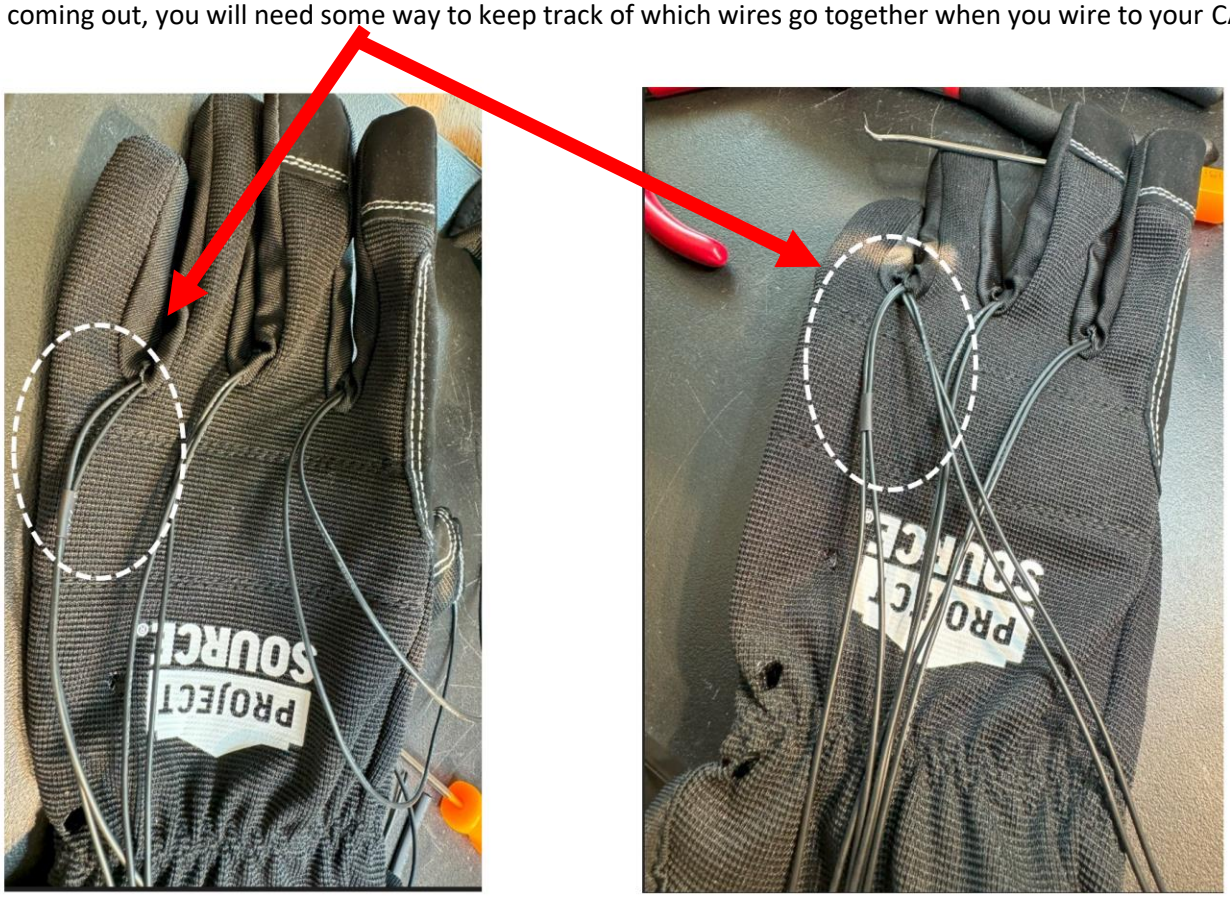
(B) Thread a small wire tie through the tactor mounting hole and glove holes as shown. Note that this picture was taken on a different glove I was testing, but the procedure is the same.

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 CAT 6 cable.



Repeat steps 3.1 – 3.4 for all fingers until all tactors are mounted with their wires coming out the web holes….

Step 3.5: Melt holes for CAT 6 cable mounting

(A) Use the backing plate **outside of the glove** (under the glove) to make two 1/8-inch holes that pass totally through the outer edge of the cuff (opposite the thumb) as shown for the left-hand glove. These two holes are located near the seam to provide strength because they will ultimately hold the large wire ties that hold the CAT 6 cables to the gloves. This is a stress point which takes a lot of tugging, so two large wire ties are used for strain relief to the fragile wires connecting to the buzzers.

Take care not to damage your wires when performing this step. Do not insert a CAT 6 cable yet.

Of course, when you repeat the procedure for the right-hand glove, make sure they on on the side **opposite the thumb** as show here.

(B) Using the backing plate inside the glove again, burn another hole that will allow the CAT 6 cable to pass out to the top of the glove. Again, **<u>these holes are both on the opposite sides of the thumb</u>**. *(The pictures shown here were taken at a later stage of construction where the CAT 6 had already been installed through the holes.)*

Step 3.6: Attach a half CAT 6 cable to each glove

(A) Cut your 14 ft Monoprice CAT 6 cable in half. Thread the cut end through the glove and out the hole you prepared for this purpose. There will be several feet of extra wire you will need to trim off before soldering the wires as shown here.

(B) Lightly secure the CAT 6 with large wire ties through the holes cut previously for this purpose. Wait to fully tighten and cut the large wire ties until you have adjusted the cable length to your body dimensions in the following steps.

(C) Put your Buzzah Neck Speaker on. Plug the CAT 6 into the female CAT 6 plug on tied to the neck speaker. Now, put your glove on and move your arm up and back to the greatest stretch length you think you will ever make. While you are in this pose, have a friend tighten your two wire ties down tightly to lock the cable to the glove. The idea is to have plenty of slack in the cable that will allow you to have full freedom of motion while wearing your Buzzah. But, on the other hand, you don't want too much slack so that you are carrying around a lot of extra wire to flop around. Don't worry if you think you are off and inch or two after tightening down. Even with the wire ties tightened as tight as I can get them, I am always still able (with effort) to adjust the wire length a bit with the ties tightened.

NOTE ABOUT MONOPRICE CAT 6: I have been SO IMPRESSED with the Monoprice CAT 6! I used unshielded to have greater flexibility. And there is no plastic core like most have. So, it is ultra flexible, which is important because I wear this for 4 hours a day! Having a stiff cable would really be a nuisance for motion. One might think that since the wires are SO thin inside, they would not hold up to all the abuse of walking and moving 4 hours a day. After all, these cables were designed to connect two pieces of stationary gear. But I go walking for hours every day - and I take exaggerated arm swings - and I have not had any problems with cable breakage! Really amazing!!!

(D) Once you are satisfied you have plenty of slack for motion, cut off the excess CAT 6 cable so that there remains about 12 inches of CAT 6 coming out the top of your glove. **Keep in mind you can always cut shorter, but you would have to get a new cable if you cut too short**. I have started leaving more extra on the glove in recent builds. **It is good to have a bit extra here on the top in case you end up making a mistake when you are stripping in the next step!**

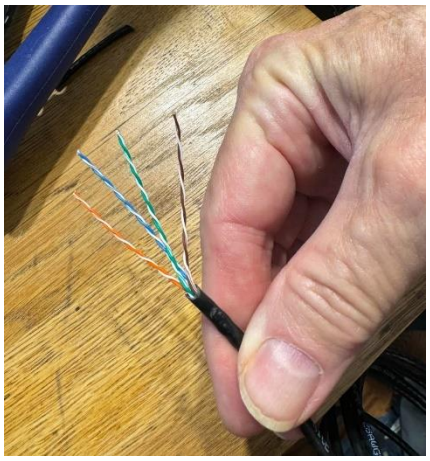
As a general rule, if you put the Buzzah neck speaker around your neck while standing, and you let the gloves hang down without your hands in them, they will probably hang down around the level of your kneecaps.

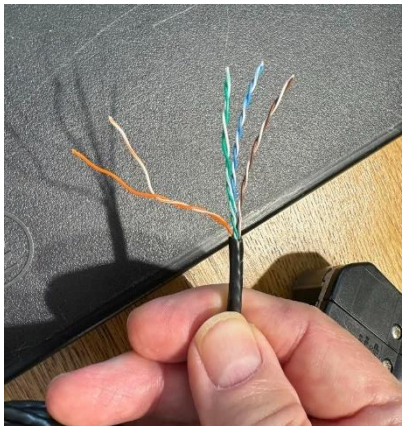
I would say the grey glove shown here has the ideal amount of excess cable on top…

Note the shrink tubing sleave on the pinky wires.

Step 3.7: Strip and tin the 8 wires coming from the CAT 6

(A) Use your wire stripper to strip about 2 inches from the CAT 6 cable. You will now see the 4 colored pairs inside. Partially unwind one of the pairs.

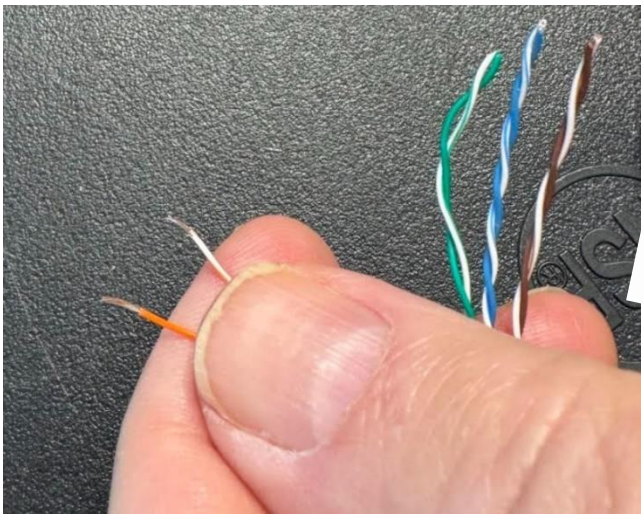




(B) Use the Klein Tool stripper to gently strip 1/8-inch insulation from the ends on your CAT 6 wires. Then tin the ends with solder.

Unfortunately, the wires in the CAT 6 are SO thin that the Irwin Vise-Grip grip stripper will not work to expose the ends for joining to the buzzer wires. If you try using the vice-grip stripping tool, it will leave unacceptable breaks in the insulation where its metal jaws grab hold of the wire. If there is exposed wire from the tool gripping it could cause failure of one or more of your driver boards! It would also be bad if you cut a wire short because you only have so much CAT 6 to work with before you have to start with a new CAT 6 half. It would be even worse if the metal in the wire was pinched and dented, so that it still worked for a while, but then failed later after you have been using your gloves for a while. **I have never had a problem when using the Klein – use a cheap stripper at your own risk!**

Before attempting this delicate feat, I suggest you practice stripping ends on some of the extra CAT 6 that you had cut off previously. Practice on the extra cable until you can reliably strip the ends without a problem. If you make one error and cut a wire too short, you have to cut the entire bundle short and start over…



Step 3.8: Trim, Strip and tin the 8 wires <u>coming from the tactors</u>

(A) Cut the tactor wires to the appropriate length, roughly as shown at the here. It's not critical to get it exactly like I have, just as long as you leave enough slack for hand motion in the glove and to allow for repairs if you end up having to cut any wires shorter later.

(B) Strip 1/8 inch from each wire.

(C) Tin each of the wire ends

Step 3.9: Solder tactor wires to corresponding CAT 6 wires

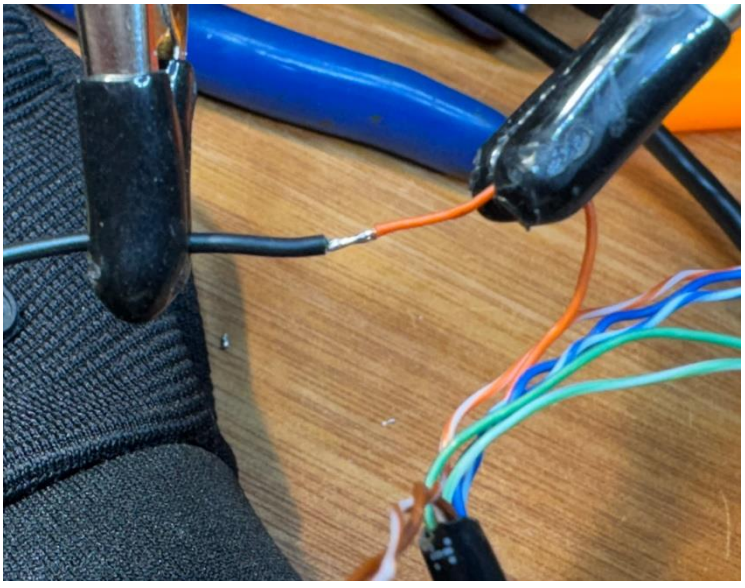
(A) Identify a black buzzer wire pair from the pinky finger.

(B) Put a small diameter piece of shrink tubing on each of the wires BEFORE soldering.

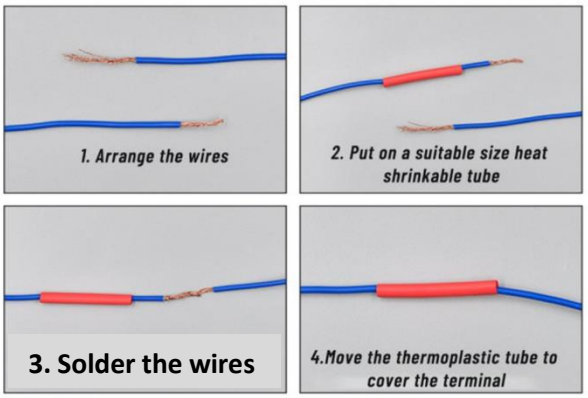
(C) Solder the pinky wire ends to the two brown wires in the CAT 6 using the soldering clips as shown below. *(Note that these pics were taken when making a repair on two black wires, but the process of soldering is the same.)*

Here is a video of someone joining wires like I do:
https://www.youtube.com/shorts/iVcX3O_KHMM

Note: he is using much thicker wire than we have, and he stripped more than 1/8 inch. I also use a Helping Hands Soldering Station with a magnifier to hold the two wires together while I solder. I never use flux like he does because it is already in the solder.



Don’t forget to put the shrink tubing sleeve on <u>BEFORE</u> you get the wires joined. (Otherwise, you will have to undo the solder joint you just made to add the shrink tubing …)



D) Slide the shrink tubing over your joint and use your heat gun to shrink.

(E) Work through joining each of the tactor wires with all the eight CAT 6 wires. Use this color scheme:

PINKY → Brown CAT wires
Ring Finger → Orange CAT wires
Middle Finger → Green CAT wires
Index Finger → Blue CAT wires

Step 3.10: Test your masterpiece

Hook up the USB battery pack to the power jack on the Buzzah and test that all 8 buzzers in the glove fingertips are working. If you completed all the steps correctly, the buzzers will all start buzzing in the vCR pattern. If one or more of them is not working, you can read past questions and post your own questions on Kris's Buzzah site. Allow 24-48 hours for someone to respond.

Step 3.11: Secure wires on top/back of glove

(A) Bunch excess wires together using small wire ties.

(B) **While your assistant pulls the loop away from the area**, use your cheap soldering iron and backing plate to burn two tiny holes in the back of the glove to wire tie to hold the loop of wires down on the glove. I waited till the end to locate these two holes because their position depends on how the loop lies once you get it tied in a bunch. You may add additional holes and ties depending on your preference. **Just be careful not to touch any of your wires with the cheap soldering iron! It is very hot and could easily melt through the wire insulation and spoil your entire build.**

This pic is from my most recent build where I left a LOT of extra wire on the top to accommodate LRA replacements in the future. This is probably too much, but I don’t mind carrying around a bit of extra wire.

Step 3.12: Add Velcro tighteners to fingertips as needed

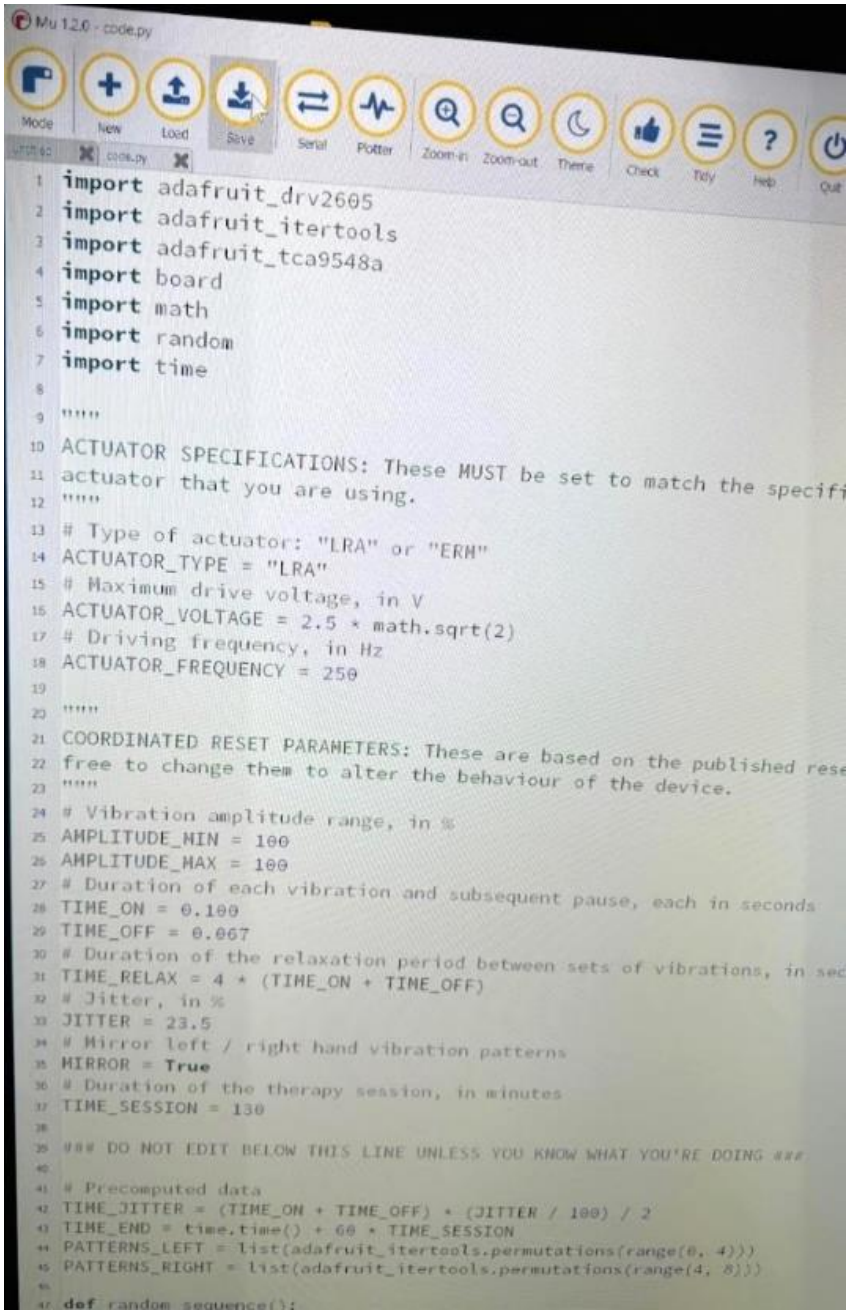
Double sided Velcro strips may be added to fingertips to ensure that you are getting reliable contact between your fingertips and the tactors attached inside the gloves. When these gloves were new, I initially didn't need any tighteners. But, as I used them for a while, I found that the glove material in the fingertips stretched out a bit and some tactors were not making good contact all the time. I then started adding Velcro to the loose fingers, until presently, I have bands on all fingers except my two index fingers.

To add a strip, cut a length of double-sided Velcro long enough to wrap completely around the intended fingertip with enough extra length to double over in the area above your fingernail. I always cut them a bit longer than I think I will need, then I trim to length once I have them wrapped into position.

Put the hook side inward so that it will also cling somewhat to the glove material. This keeps the tightener from slipping off your fingertip while using. Depending on the glove material you end up using, the strips hold on to some material better than others. The Project Source gloves cling to the Velcro enough to hold the strips on most the time. But, I have to be careful when grasping other fabrics that have great affinity for Velcro. There are enough hooks exposed around the edges that they will happily bind to another material and get pulled off if given the chance. The worst situation is when I am putting on my rain jacket that has its own Velcro hook side exposed around the zipper. When wearing that jacket, I sometimes get my fingertips stuck to the zipper Velcro hooks since the fuzzy side of my tighteners is facing outward. I am always on the outlook for another suitable pair of gloves that have tight fingertips that won't stretch out since it would be nice not to have to use the Velcro tighteners.

Note: This Velcro is too thin – If you use the thicker kind for secure tightening, they also make it more difficult to put the gloves on quickly.

PART 4: Adjusting Buzzah Settings



You could begin using your gloves at this point and simply use the stock settings that come standard with Kris's 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. I detail the steps below.

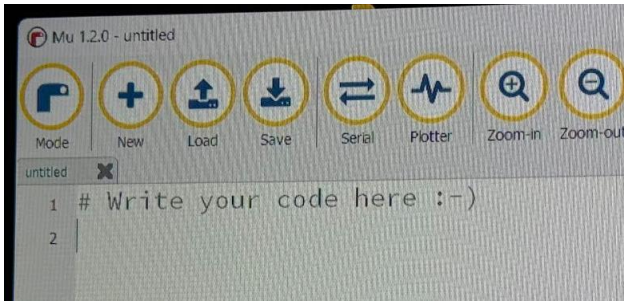
Step 4.1: Download and install the free Mu editor on your computer

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 Kris's code.

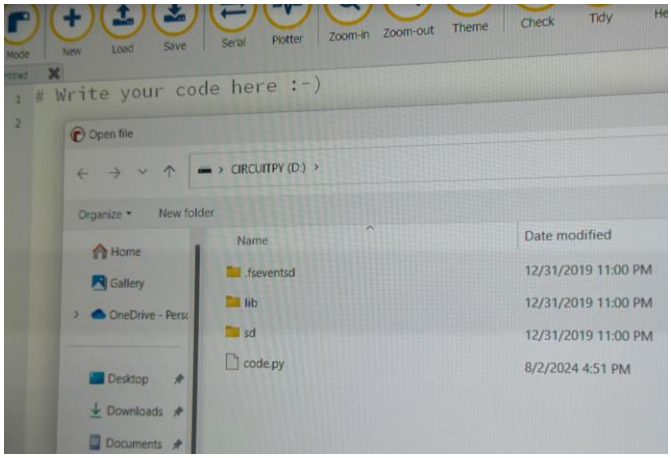
Step 4.2: Connect Buzzah processor to your computer

IMPORTANT! Disconnect your power pack from your Buzzah before trying to connect to your computer. Your computer would not like it if you accidentally tried to connect your battery to its USB port!

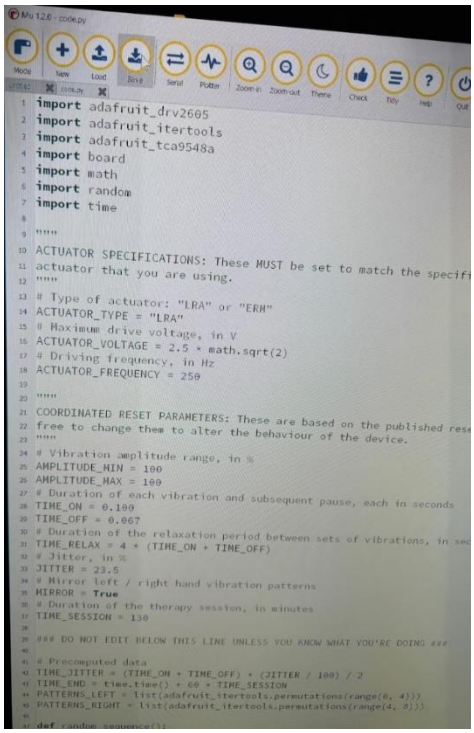
Open the Mu program on your computer with your Buzzah already connected. You should see this window:



Click on LOAD and Mu will open a folder on your Buzzah as if it was a thumb drive:



Click on code.py and Mu will open Kris's code for driving your Buzzah. It will look like this ---------->



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, it is not a huge issue. You will simply have to save a copy of Kris's code *(from his Github site)* over the code you accidentally altered.

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/

 # Type of actuator: "LRA" or "ERM"
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".

 # Maximum drive voltage, in V
ACTUATOR_VOLTAGE = 1.8 * math.sqrt(2)
The nominal voltage on the VLV101040A buzzer we are using is 2.5 volts rms. So, change the "1.8" stock setting to "2.5". It does not hurt to have this number set lower than the LRA rating for the actual buzzer you are using, but if you set it higher, you can cause your buzzers to prematurely fail.

 # Driving frequency, in Hz
ACTUATOR_FREQUENCY = 235
Kris had this set at 235 Hz because that is the resonant frequency of the buzzer he originally used. Dr. Tass used 250 Hz in his paper. Dr. Tass 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. You might need to nudge down to 235 if you want to get more amplitude of vibration since we are above the natural frequency of our buzzers. I 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.

 # Vibration amplitude range, in %
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. Kris allowed for increasing amplitude up to 127%, but we are already near the peak output from our driver boards. Also, if you push your buzzers at higher voltage than the are designed for, you will shorten life and end up having to do replacements more frequently. I have gone 3 months with only one buzzer going out, which is way better life than I had been getting with my ERMs.

If you want to experiment with randomly varying amplitudes of your buzzes, this is where you could adjust the max and min for your range. I figured that since I am not using tactors, I already am getting too much variation in amplitude, so I left this setting alone. Leaving max and min amplitudes at 100/100 signifies no variation in vibrational amplitude will be implemented and you are following the same approach as Dr. Tass did in his paper.

 # Duration of each vibration and subsequent pause, each in seconds
TIME_ON = 0.100
TIME_OFF = 0.067
Kris has the pulse time 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. I left these settings alone. That said, it seems quite a coincidence that the optimal pulse width just happens to be exactly 100 ms! I think this value must be a rough estimate by Dr. Tass of the pulse time that most people would respond best to. Someday I may try experimenting with a shorter time, for example 90 ms, or a longer time like 110 ms, to see if the different times give better or worse results. For now, I am sticking with the stock settings in Dr. Tass's paper.

 # Duration of the relaxation period between sets of vibrations, in seconds
TIME_RELAX = 4 * (TIME_ON + TIME_OFF)
This is the same setting as from Dr. Tass's paper for the relaxation time between the 3 sequences of random pulses. I left this as stock. If you wanted more recovery time between pulse sequences, you could change the 4 to 5.

 # Jitter, in %
JITTER = 23.5
 # Mirror left / right hand vibration patterns
MIRROR = False
These two settings together determine what type buzz pattern you want to use. Most systems I have looked at in depth use Dr. Tass's "Regular vCR" pattern where each the respective fingers on each hand are not mirrored and there is no randomized jitter. Some use Dr. Tass's "Noisy vCR" pattern where buzzes are mirrored on left and right fingers and there is a small amount of jitter introduced in the buzz timing. Dr. Tass tried both patterns on his subjects and found the same positive response with both. Alternatively, the stock settings on Kris's Buzzah come with a hybrid pattern where left/right fingers are not mirrored and there is jitter in the timing. Since Dr. Tass has spent about 15 years developing his technique, I think it is probably a good idea to stick with one of the patterns he tested in his subjects, but the choice is yours! You can go with Regular vCR, Noisy vCR, Hybrid vCR, or you can invent your own new pattern! I initially went with the hybrid setting because it seemed like it might be better. But, after writing this explanation up, I have decided to go with back to Regular vCR or Noisy for a while to see if either of these seem to work better for me.

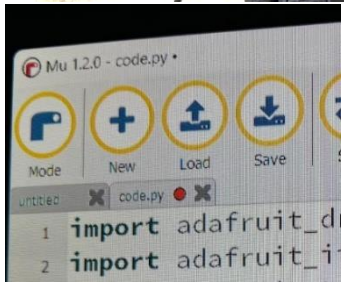
vCR Pattern	JITTER setting	MIRROR setting
Regular Tass vCR	0	False
Noisy Tass vCR	23.5	True
Hybrid vCR	23.5	False
Your own new vCR	Anything from 0 to 50	True or False

 # Duration of the therapy session, in minutes
TIME_SESSION = 120
Dr. Tass prescribed 120 minutes of therapy twice a day. I set my session time at 130 minutes to account for times I take my hands out of gloves to go to the bathroom, etc… If I have time, I often restart the system in the evenings right after it ends in order to get an extra 20-30 minutes of treatment.

IMPORTANT BATTERY NOTE: Keep in mind that when your buzzer times out and stops buzzing, the Buzzah remains ON, and it is still using juice from your battery. So don't forget to remove the USB connection from your battery after each use! Failure to do so will lead to a dead battery when you come to use it again and your battery life will be shortened.

You can get as many as 3 therapy sessions per charge, but I always go for two sessions per charge so I don't drain my battery level down which shortens life. I have two of these batteries so I always have one that is charged up when I need to swap.

Once you are done making changes in your settings, click on save. The red dot next to cope.py will now go away in the Mu program to signify that your changes have been saved to your Buzzah. **You can now unplug your Buzzah from your computer and start your therapy!**



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.

Usage	Parts List: Neck Build	source	Part #	#	price	Net	notes
OEM	QT Py RP2040	digikey	1528-4900-ND	1	$9.95	$9.95	The MCU
OEM	STEMMA QT 8-CHAN I2C MUX PCA9548	digikey	1528-5626-ND	1	$6.95	$6.95	The MUX
OEM	Adafruit DRV2605L Haptic Controller	digikey	1528-1346-ND	8	$7.95	$63.60	Driver boards
OEM	VLV101040A LRA Buzzer	digikey	LV101040	10	$5.65	$56.50	Included 2 extra in case of failures. You might consider even getting a few more
OEM	I2C Qwiic Cable Kit Stemma QT Wire for SparkFun Development Boards Sensor Board Breakout Breadboard 4 Pin Sh1.0 Connector	amazon	B08HQ1VSVL	2	$8.99	$17.98	You need 4 x 10cm and 4 x 20cm Stemma cables. Each kit only comes with 3. But that is good because some might be bad
OEM	Tactor 3D Prints, Electronics platform 3D-prints (The 3D print files are posted in the same place you found this document)	Make yourself or hire someone on Itsy		1	$20	$20	You can print them yourself if you have a 3D printer, or send the files to someone on Itsy who will make the prints for you. I have never had prints made, so I am just estimating $20 for the total cost.
OEM	D'Addario LE012 Plain Steel Loop End Single String, .012	Amazon	B000OR8NB2	10	$1.19	$11.90	Ideally, you could get by with only two strings. I included 10 to allow for practice spring making and errors
OEM	HomeSpot JY508 Wireless Neckband Speaker - 3D Stereo Sound, 12 Hrs Play Time, Low Latency for Gaming/TV, Type-C Quick Charging, Wearable Speaker for Home, Office, and Outdoors	amazon	B0CDG81TH2	1	$39.99	$39.99	I used a vintage Bose neck speaker for my build, but these are no longer available new. A local PWP used this Homespot model and it works great.
OEM	Amazon Basics USB-C to USB-C 2.0 Fast Charger Cable, 480Mbps Speed, USB-IF Certified, for Apple iPhone 16/15, iPad, Samsung Galaxy, Tablets, Laptops, 3 Foot, Black	amazon	B0CL4KKKGR	1	$8.54	$8.54	For powering Buzzah brain. Neck speaker should come with its own cable for charging
OEM	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
OEM	TR Industrial Multi-Purpose UV Resistant Black Cable Ties, 12 inches, 100 Pack	amazon	B01018CW92	1	$8.99	$8.99	You absolutely have to have these thick ties to protect and hold your CAT 6 cables
OEM	Monoprice Cat6 14ft Black Component Level Patch Cable UTP 28AWG 550MHz Pure Bare Copper Snagless RJ45 SlimRun Series Ethernet Cable	amazon	B014ULBHII	2	$9.78	$19.56	This cable is amazingly strong and flexible - do not substitute! A single cable is cut in half to make two neck-to-glove cables. Two cables are included here so you can also make a test cable
Substitute	Self Adhesive Bandage Wrap,4 Inches 5 Yards Elastic Vet Wrap Cohesive Bandages, Tattoo Grip Tape, Breathable Athletic Sports Tape(Black)	amazon	B0BBRSD1Y4	1	$7.43	$7.43	
OEM	BNTECHGO 28 Gauge Silicone Wire Spool 250 ft Black Flexible 28 AWG Stranded Tinned Copper Wire	amazon	B07149HTS2	1	$17.98	$17.98	I love this wire! Strong, flexible and easy to strip.
OEM	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	Using all black to give inconspicuous appearance
OEM	Adafruit Small Alligator Clip Test Lead (set of 12) [ADA1008]	Amazon	B00XW2MFU6	1	$8.22	$8.22	To make test cable for tactors
OEM	Project Source Large Polyester Mechanical Repair Gloves, (3-Pairs)	Lowes	Item #792206	1	$12.98	$12.98	comes with 3 pairs – You may want to find your own glove as describing earlier
OEM	Cable Matters 10Gbps 2-Pack Shielded Cat 6 Ethernet Extension Cable 6 ft (Shielded Ethernet Extension Cable, Cat6 Extension, Ethernet Extender, Ethernet Cable Extender)	amazon	B06Y46T8H9	1	$13.99	$13.99	
OEM	Dual USB Output Super Slim Power Bank Ultra Thin, 3000mAh Portable Charger Mini External Phone Battery Pack Small Dual Outlet, Emergency Phone Power Backup (Black)	amazon	B07JZCZSH9	1	$16.95	$16.95	Has enough charge for 3 to 4 sessions before recharge. You may want to get a bigger USB power bank that will last longer. I currently use Amazon ASIN# B09176JCKZ
Substitute	VELCRO Brand - 1801-OW-PB/B-75 VELCRO BRAND ONE-WRAP TAPE 1/2" X 25 YARD ROLL	amazon	B071Y3TVNT	1	$15.98	$15.98	Depending on how the buzzers fit in your glove, **you may get by without needing these** You can buy smaller quantity at Home Depot
					TOTAL PARTS	**$378.47**	

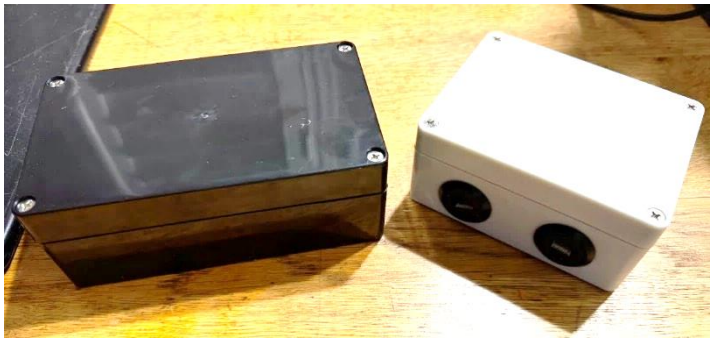
	***Tools List* Neck Speaker Build**	***source***	***Part #***	***#***	***price***	***Net***	***notes***
OEM	*Weller 70 Watt Digital Soldering Station | WE1010NA*	*amazon*	*B077JDGY1J*	*1*	*$115.00*	*$115.00*	*You could get by with a much cheaper soldering station, but it is nice to have the best especially if you are a novice*
OEM	*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!*
OEM	*Gorilla Dual Temp Mini Hot Glue Gun Kit with 75 Hot Glue Sticks, Precision Nozzle, and Easy Squeeze Trigger, for DIY, Craft, Repairs, and More, Orange (Combo Pack:1 Mini Gun, 75 Glue Sticks)*	*amazon*	*B07K798MK9*	*1*	*$19.25*	*$19.25*	*I have never tried glueing the boards with hot glove but I think it will be strong enough for this light duty application*
OEM	*XYK Helping Hands Soldering Station with 3X Magnifying Glass with light, 4 Flexible Helping Hand Arms Magnifier and Third Hand Soldering Tool for Electronic Repair Soldering Jewelry Crafts*	*amazon*	*B09DRZLM5N*	*1*	*$26.99*	*$26.99*	*This make soldering these tiny wires SO MUC easier*
OEM	*3/16 in. x 36 in. Plain Steel Round Rod*	*Home Depot*	*Store SKU # 550813*	*1*	*$3.92*	*$3.92*	*You will also need a hacksaw to cut this down to size.* ***Note that the rod comes coated with very dirty oil and you will need to wash it and cut it down to about 18 inches before you start making springs****.*
OEM	*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*
Substitute	*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 tightening Stemma cables*
OEM	*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*	*Works great except for the ultra fine Monoprice CAT 6s which need to be stripped using the Klein below*
OEM	*Klein Tools 11057 Wire Cutter / Wire Stripper, Made in USA, Heavy Duty Wire Cutter Stripper for 20-30 AWG Solid Wire and 22-32 AWG Stranded Wire*	*Amazon*	*B000XEUPMQ*	*1*	*$20.97*	*$20.97*	*If you use a cheaper stripper, you will probably regret it…*
Substitute	*Soldering Iron Kit, 80W 110V LCD Digital Soldering Welding Iron Kit with Ceramic Heater, Portable Soldering Kit with 5pcs Tips, Stand, Solder Tube, Sponge, Solder Paste,for Metal,Electric, DIY*	*amazon*	*B08R3515SF*	*1*	*$9.96*	*$9.96*	*This is better than the cheap iron I used for melting holes in the gloves. Don't use your Weller for this purpose!*
Substitute	*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*
OEM	*EBOOT 20 Pack Clear Plastic Ruler 12 Inch Straight Ruler Flexible Ruler with Inches and Metric for School Classroom, Home, or Office (Clear)*	*amazon*	*B07PHP17NZ*	*1*	*$7.99*	*$7.99*	*I use these all time for various measurements*
OEM	*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.*
Substitute	*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*	*I couldn't find the hook tool I used, but you should have more than you need with this set*
Substitute	*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*	
OEM	*Amazon Basics Folding Utility Knife, Lightweight Aluminum Body, Red*	*Amazon*	*B07TBNH4ZT*	*1*	*$9.90*	*$9.90*	
Substitute	*SEEKONE Mini Heat Gun, 350W 2-Temp Settings 500℉& 842℉ (260℃& 450℃) Fast Heat Hot Air 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*	*This is the one tool I missed having! I always use a lighter to heat shrink tubing, but I think these are better for obvious reasons.*
OEM	***Bambu Lab A1 mini 3D Printer***	*Bambu Labs*		*1*	*$299*		*I am assuming you will just hire someone on Itsy to make your prints. But if you want to make your own parts, this model is great*
					Total Tools	***$329.41***	

Optional Box-Based Buzzah Build

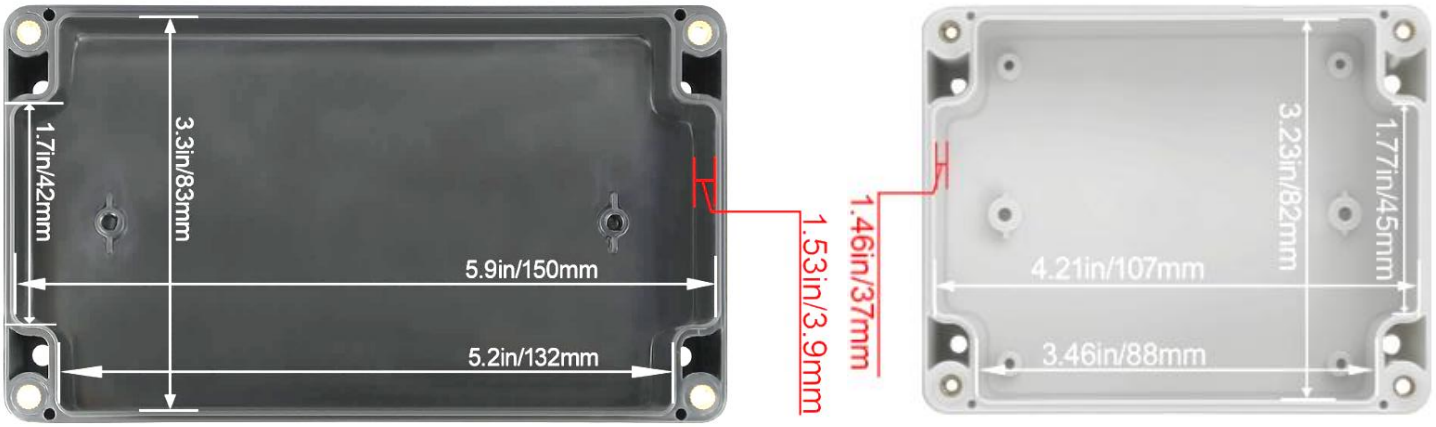
I have included a brief description of a way to house the Buzzah brain in a box for those who might prefer not to wear a neck speaker. My first Buzzah prototype was box-based and is described here. While I squeezed the electronics into the smallest box possible *(it turned out to be too small)*, I still found it to be too heavy and I didn't like wearing a bulky fanny pack getting in my way four hours a day.

Box Step 1: Use a Bigger Plastic Box Than I Did

The box I used was too small! I measured everything ahead of time and everything seemed like everything would fit perfectly when I got started, but I had not accounted for the substantial mass of wadded up Stemma QT cables, USB cable and the CAT 6 pigtails which are called for inside. The 3 panel-pass-throughs I used also had big nuts I had not considered, making it impossible to fit all three on the same side as I had planned. This led to even more crowding inside since the connectors were sticking towards one another inside. Once everything was attached inside, there was an unwieldy mess of wires that I was barely able to stuff in! The box design with the pass-throughs is solid, you just need to go bigger. With that in mind, for anyone wanting to go with a box design, I suggest using a bigger box like the one I have listed in the parts list. Space will still be tight inside, but it will definitely be an easier fit.



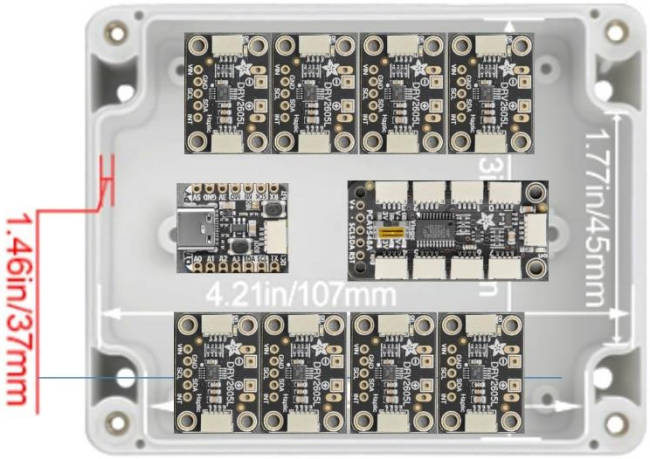
For the rest of this brief description, I will use pictures from my too-small build for reference. It will be up to you to decide exactly how to fit your things in since I have not constructed a box with the preferred box size. The problem is that, you want to go as small as possible since you will be lugging this box around in a fanny pack for 4 hours a day. But you don't want to be too small to where it is difficult to cram everything in. I show the dimensions of the box I suggest using compared to the one I used below. The black box is essentially the same width and depth as the one I used, but you get an extra 1.7 inches in length. I THINK this should be enough room for you, especially since your pass-throughs will all be on the same side, but it will still be tight.



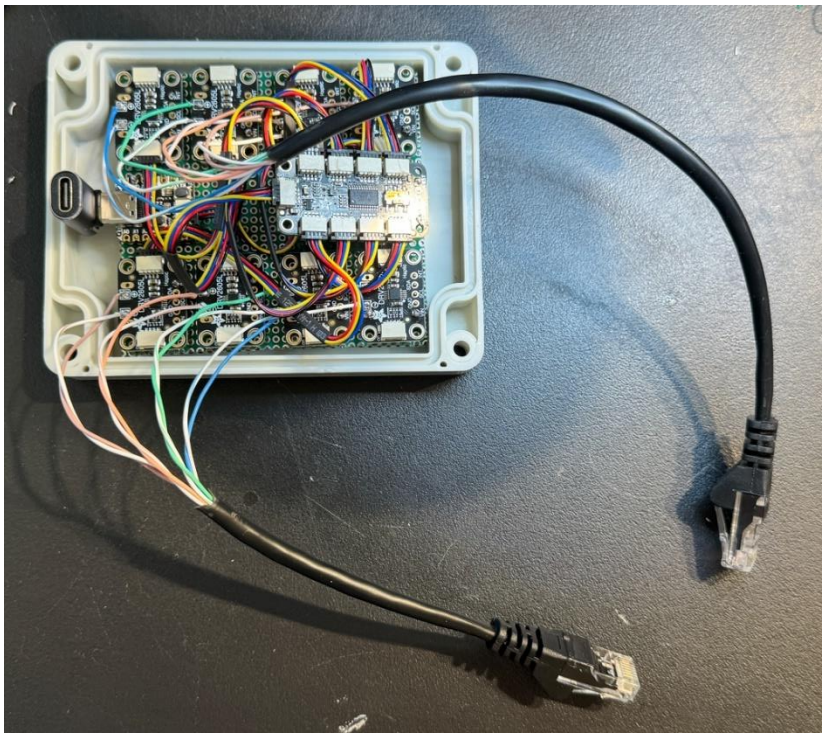
Box Step 2: Glue the Buzzah Brain Components Inside the Lid of the Box

The lid is a nonconductive plastic, so you can glue your Buzzah brain components directly to the inside of your lid. As with my neck speaker build, I soldered my components into perf board before mounting inside my lid. But that is an unneeded extra step that takes up time and space. Gluing directly inside you box with a hot glue gun should work fine for you. *(that said, I have never done the gluing technique myself, so I can't guarantee that there might be difficulties that come up with gluing I do not anticipate.)*

This is the layout I made to scale for my component placement before purchasing the small grey box. It seemed like there would be plenty of space!



Here is what the lid ended up looking like with the Stemma cables and CAT 6 pigtails installed. Note how I had to awkwardly lift the MUX away from my perf board in order to make room for the Stemma cables. The black box has the same width, but I think you could get around that problem by using the extra length of the black box to mount your MUX to the right of the driver boards *(with the same orientation as the driver boards)*.



REMEMBER: As with my neck speaker build, if you decide to glue, you cannot use the regular perf board with conductive circles. This could lead to short circuits that could fry your components! If you glue, you can just glue straight into your lid without any worry about shorts.

Box Step 3: Drill Holes <u>On One Side</u> of the Box and Install the Panel Pass-Throughs

Since the length of my box was too small, I had to mount the USB pass-through on its own side. I ALMOST didn't have enough room to fit the usb cable going at a 90-degree angle to the CAT 6's. It is very tight and under strain. With the longer black box, there is room to fit all on the same side so they don't fight each other for inside space. It would have been nice if all three panel mounts took 7/8 inch holes. But, unfortunately, the CAT 6 pass-throughs needed a 15/16 inch hole. Since I didn't have a 15/16 inch hole bit, I drilled 7/8 holes and reamed them out with a rounded file.

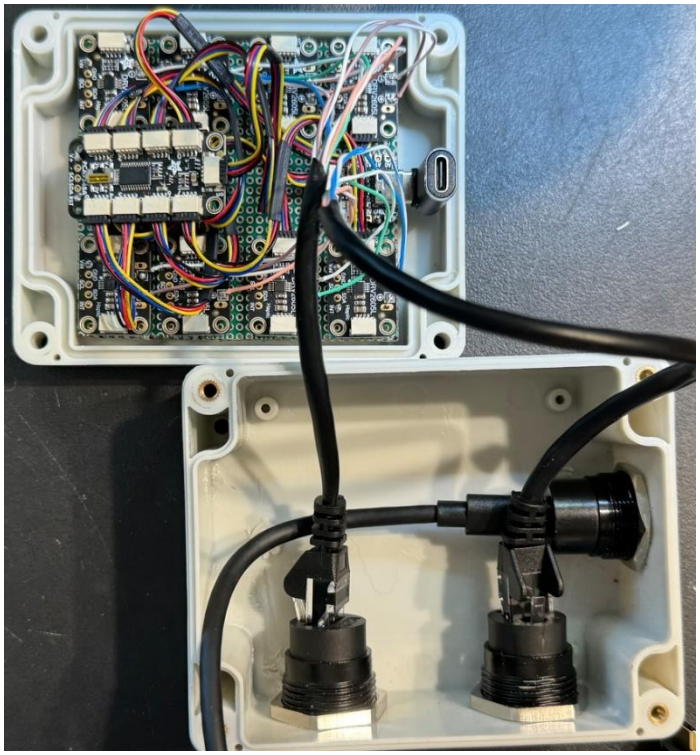
Box Step 4: Connect CAT 6 Pigtail Wires to Driver Board +/- Pads

The two male CAT 6 pigtails you see in this picture serve the same function as the female CAT 6 pigtails in the neck speaker build. Zooming in on this mess of wires is useless. Refer to how I connected the female CAT 6 pigtails in step 1.8 from the neck speaker build. Just as then, the order of colors matters and make sure you keep the same color wire on each driver board.

Note 1: You can connect to either side of a driver board.

Note 2: This build happened before I discovered Monoprice CAT 6 cables so you might notice the color of the wires in this picture are slightly different than the Monoprice cable in the neck speaker build.

Note 3: Depending on where you mount your MCU, you may need a USB 90 female-to-female connector like I did to connect your usb cable to the MCU.



Box Step 5: Make Gloves

Make Gloves Using Same Procedure as in Part 2 of Neck Speaker Build. The only difference is that the cables need to be much longer in order to wrap around your neck and come down to your hands. This is the only orientation I could get to work that didn't have the cords flopping down around my knees when walking straight armed.
The battery pack rides along with the box in the fanny pack.

Additional Parts/Tools for Optional Box Build

OEM	*Project Box IP65 Waterproof Dustproof Junction Box ABS Plastic Enclosure Box for Electronics Black Outdoor Project 6.2 x 3.5 x 2.4 inch (158 x 90 x 60 mm)*	*amazon*	*B0BY8YNJ49*	*1*	*$8.98*	*$8.98*	*This is the smallest possible. The box I used was TOO small!*
OEM	*PENGLIN 2Pack RJ45 Panel Mount Coupler, Ethernet LAN Pass Through Connector, CAT6 Female to Female Bulkhead Extension Interface Adapter*	*amazon*	*B09WM63PGR*	*1*	*$15.99*	*$15.99*	*Pass through for CAT 6 cables*
OEM	*USB-C 3.1 Panel Mount Adapter - Threaded Fixed Mount, Type-C Female-to-Female Connector, 10Gbps, with Anti-Loosening Gasket & Dust-Proof Cover for Dashboards & Device Panels*	*amazon*	*B0CVXLXSMZ*	*1*	*$9.99*	*$9.99*	*Pass through for power cable*
OEM	*Quick Charge USB Type C Right Angle 90 Degree Male to USB Type C Male 3 AMP Sync and Charging Cable Cord Wire Adapter Convertor Extension Cable 11 inch (Right Angle M to M)*	*amazon*	*B07VMKRKBR*	*1*	*$5.45*	*$5.45*	
OEM	*AreMe 90 Degree USB-C Male to Female Adapter, 2 Pack Right Angle 100W Type-C Adapter Extender for Steam Deck, ROG Ally, Switch, Notebook Computers, Tablet and Mobile Phones (Metallic Purple)*	*amazon*	*B0B2NJ3P3L*	*1*	*$5.60*	*$5.60*	
	fanny pack					*$20.00*	*Pick one you like that will fit the box*
Substitute	*AVID POWER 20V MAX Lithium Ion Cordless Drill Set, Power Drill Kit with Battery and Charger, 3/8-Inch Keyless Chuck, Variable Speed, 16 Position and 22pcs Drill Bits (Red)*	*Amazon*	*B07CR1GPBQ*	*1*	*$37.39*	*$37.39*	*This is a cheapy, but you only need to drill 3 holes in plastic.*
Substitute	*Cobalt Drill Bit Set, 13Pcs M35 High Speed Steel Jobber Length Drill Bit Kit for Hardened Metal, Stainless Steel, Cast Iron, Wood and Plastic, with Index Storage Case, 1/16"-1/4"*	*Amazon*	*B0BDKR2KFZ*	*1*	*$9.98*	*$9.98*	*This is a cheapy, but you only need to pre-drill 3 holes in plastic.*
Substitute	*NEIKO 10185A Titanium Step Drill Bit, High-Speed Alloy-Steel Bit, Hole Expander for Wood and Metal, 12 Step Sizes from 3/16 Inch to 7/8 Inch.*	*Amazon*	*B000RP4B76*	*1*	*$8.97*	*$8.97*	*Need for 3 holes*
Substitute	*KALIM Half Round Medium Cut File, Double Cut Teeth, 6'' Length, Made of High Carbon Steel, Hand File without Handle Suitable for Wood, Metal, Sharpening, etc.*	*Amazon*	*B08C9LDB36*	*1*	*$5.99*	*$5.99*	*You need this to ream out two 7/8 holes to 15/16 for the CAT 6 pass throughs*