**Faraday Battery Rebuild —**

**— This could be you!**

Table of Contents

# Materials

## Consumables

- 18650 batteries (24 required, buy 30)
- Kapton Tape: 2mil with silicone adhesive
- Anti-abrasion tape (preferably something with fiberglass in it)
- Stiff PET tape (typically green)
- Painters “Blue” Tape
- Nickel Strip (8mm, 0.15mm thick). Use youtube techniques to verify that it’s actually nickel, such as soaking in salt water overnight. Steel has higher resistance.
- Weld tabs (optional, can do arts and crafts with nickel strip)
- Solder
- Heatshrink kit
- Fiberglass Tube - Mach 1 Rocketry Airframe BT-60 Tube (41.5mm OD, 40.5mm ID)
- Hot glue or Flexible Superglue (Loctite 4851 or similar)
- Dowsil 738 (small tube)

## Tools

- Cutting mat
- X-acto knifes
- Sharpie
- Metal Ruler
- Tweezers
- Scissors that can cut thin metal
- Isopropanol
- Hot glue gun
- Battery Spot Welder
- Heavy duty scissors or wire cutters
- Flat pliers (for flattening nickel strip)

## For Battery Testing

- RS485 - USB Adapter. Get something with a genuine FT232RL chip in it
- Julet 5p Connector
- Momentary button (any kind will do)
- Multimeter with clips

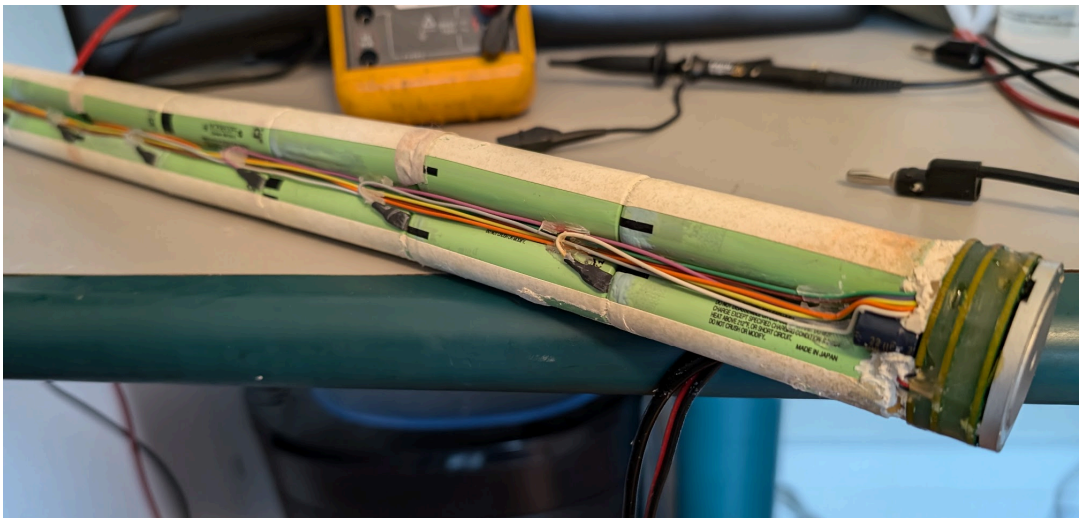
## For BMS Testing

- “Battery Testing” materials
- 51V power supply
- Additional multimeter

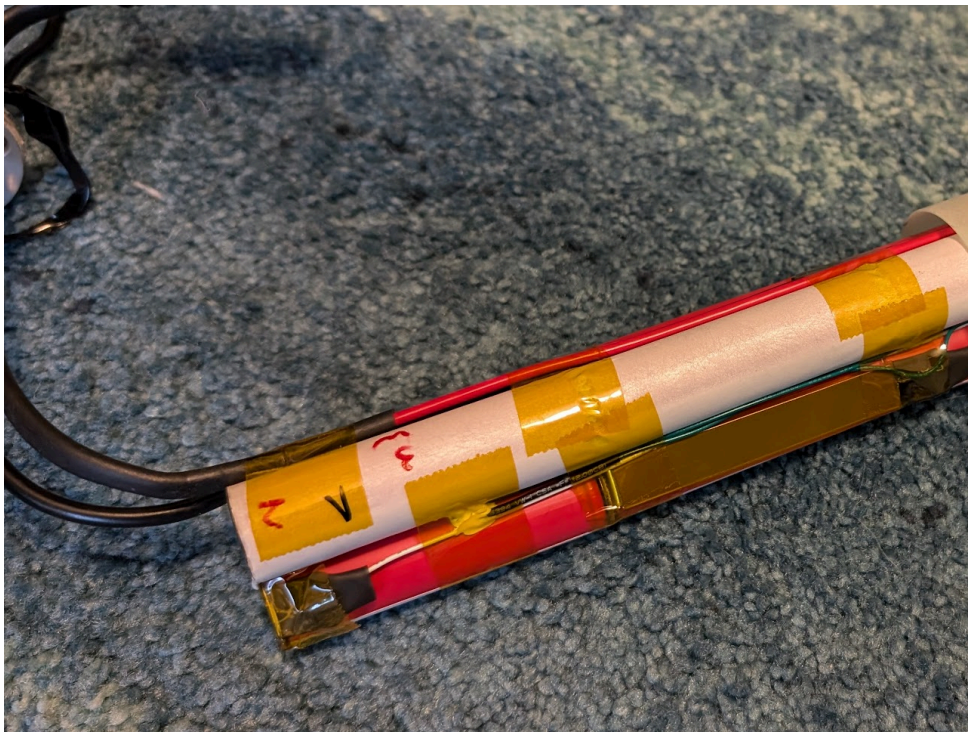
# Battery Teardown

The author knows of two generations of Faraday Batteries:

- Gen 1 (Panasonic/Green cells)



- Gen 2(Sanyo/red cells)



The nickel tabbing layout is slightly different between the two, but otherwise they are similar. The Gen 2 (sanyo) has much nicer construction quality and thicker tabs.

Regardless, the steps for disassembly are the same:

### Remove end caps

1. Use flat-blade screwdrivers to pry on the caps. Drill out the rivets if the cap is extremely stubborn.
2. Depending on the silicone coverage, this could be quite challenging. There is an M6 set screw underneath the sticker that can be used to get additional leverage. Don't drive a large screw into the connector side, you'll puncture a cell.
3. [Not required] I removed the cables from the aluminum end cap with a hacksaw and made new end caps out of aluminum.

### Remove cells from tube

4. Use an appropriately sized dowel to press the battery assembly out from the BMS side (the side without cables). This may take some effort and quite a bit of force. For my Gen 1 battery, I needed to use a cabinet clamp to apply sufficient force. For my Gen 2 battery, it came out easily.
5. Take lots of pictures, especially around the solder tabs! These will be useful later, trust me.

### Remove heat shrink

6. Not sure why this needs to be its own section

### Desolder BMS Wires

7. Making sure that you are grounded (follow basic ESD procedures)
8. One by one, remove the voltage sense wires. LABEL EACH WIRE (I labeled each with the cell number and expected voltage. Do not allow these labels to fall off.
9. Fold a piece of blue tape over the end of each wire to prevent it shorting during handling/testing.
10. Carefully pry off the thermistors (try to not to yank on the wires)
11. Desolder the fuse from the cells
12. Desolder the negative wire
13. Insulate any exposed wires

# Battery Issues

This section contains a list of issues compiled collaboratively by this doc's authors.

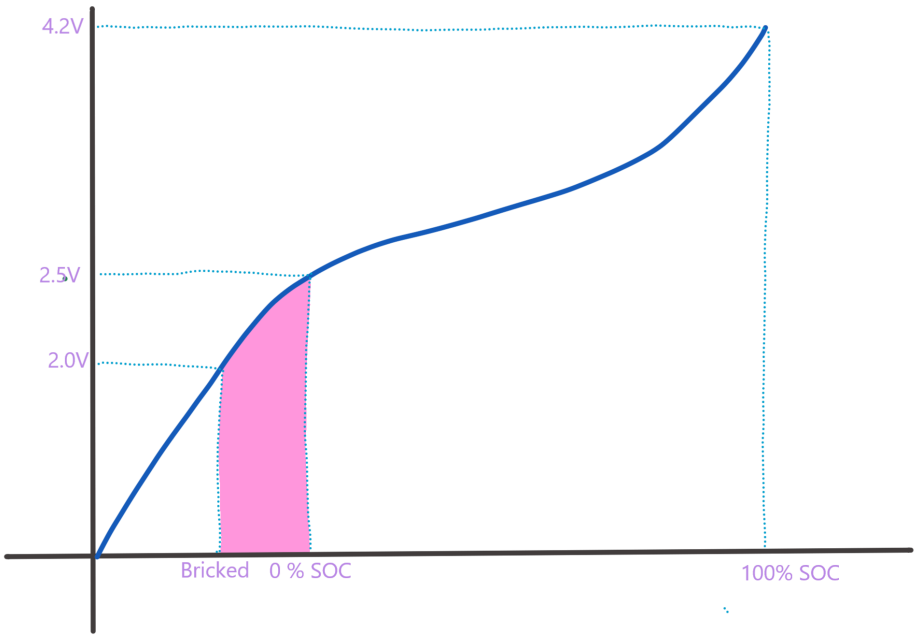
# Issue #1 - The bike Won't Turn On

Symptom: The bike won't turn on with a single press of the button

Root Cause: Cells undervoltaged and likely permanently damaged. Any cell below 2.5V when measured with multimeter. Possibly leaking electrolyte (pungent smell). Cells between 2.0V and 2.5V can be recovered with an extremely low charge current (50mA). However, if lithium dendrites have already grown, then the cells will rapidly self-discharge and the cells need to be replaced.

Actual Root Cause: the BMS has a fairly high quiescent draw when both "On" (back to back FETs on) and when "Off" (back to back fets off). I measured 12.8mW leakage when "On" and 9.6mW when "Off". This means that the bricking time, or the time between 0% SOC (2.5-ish V) and permanent cell damage (~2V) is around 20 days (!) This is several orders of magnitude higher than most consumer devices, which have uW, not mW quiescent powers.

*Author's note - I tried a bunch of tricks to reduce this quiescent, including switching off the 48V feed to the BMS, disconnecting cell voltage taps, etc. Unfortunately, the diode structure inside the LT battery monitoring chip keeps the internal linear regulator powered as long as >2 cells are connected. Without fully disconnecting all cell taps, the quiescent is inevitable without modifying the software.*




*The bricking time of Faraday packs is an order of magnitude shorter than similar batteries in other consumer electronics. Unfavorable reactions occur inside cells in this region which cause permanent damage.*

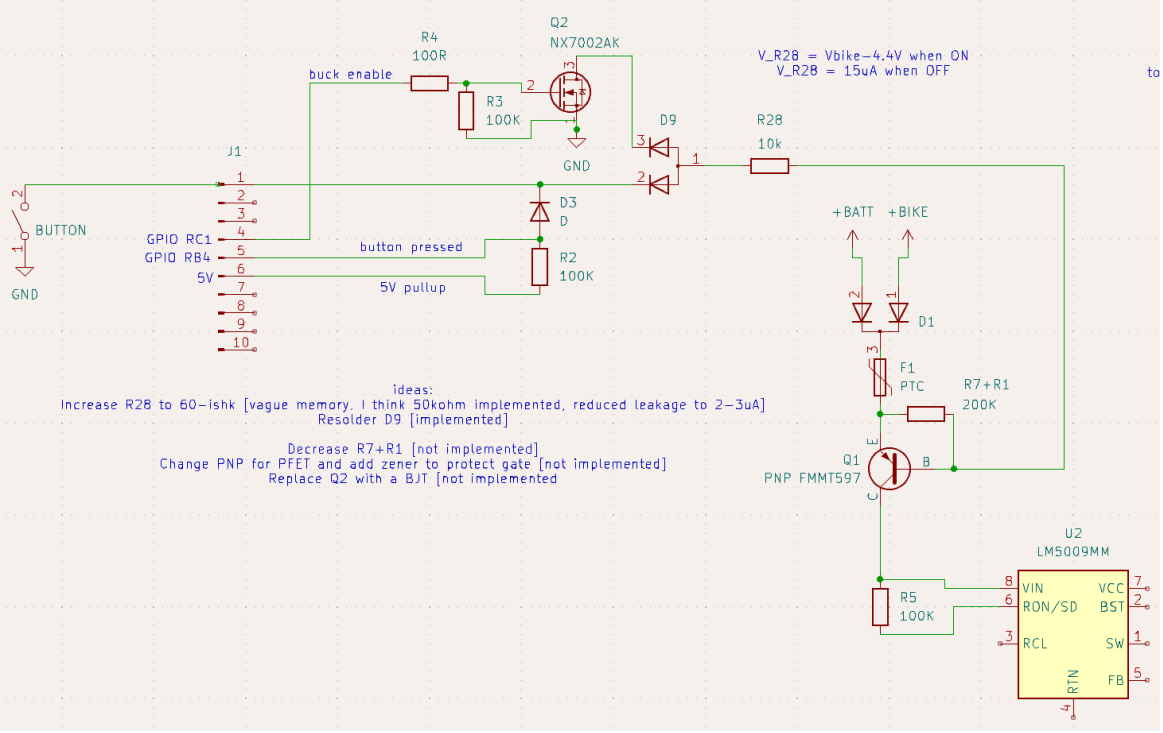
Fix: Replace all cells

# Issue #2 - BMS Won't Turn Off

Symptom: The BMS will turn the bike back on several seconds after a long press of the power button.

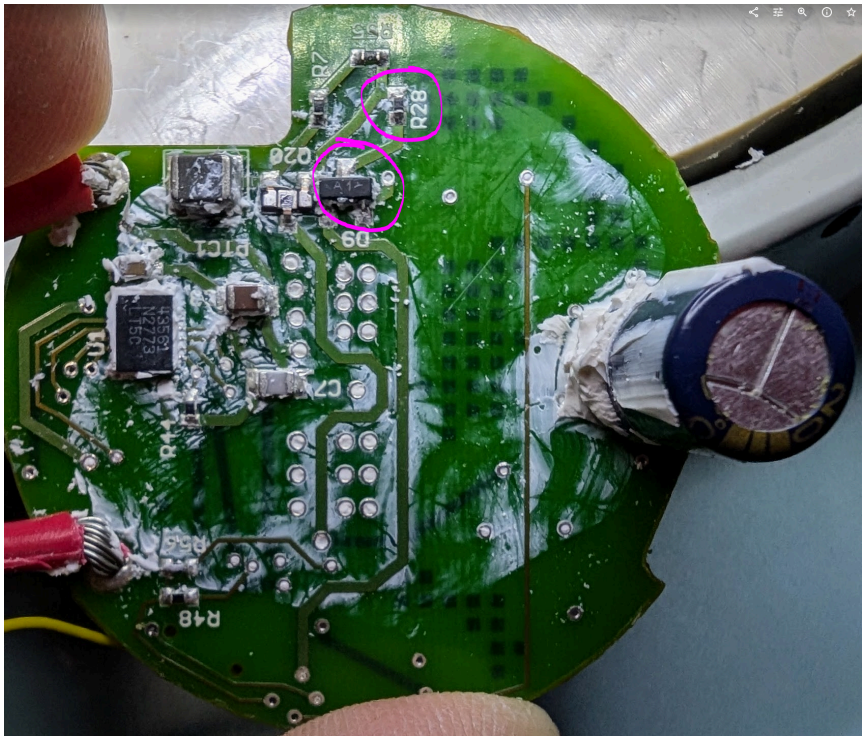
Root Cause: the turn-on circuit on the BMS has excessive leakage to GND, caused by solder flux, humidity, or poor soldering of components. The BMS sees this as the button being constantly pressed. There are several potential fixes listed below.

*Author's note - the turn-on circuit with a BJT is extremely sensitive to component tolerances. Even small leakage currents to ground in the uA regime may turn on battery (even the 10M resistor inside a multimeter can turn on the battery when probing across the "On/off" button!). I think the original designer may have selected a BJT to keep the leakage from 48V to ground to a minimum, or perhaps to keep the voltage at the input of the DCDC below the 9V turn-on voltage. Whatever the reason, the result is a circuit sensitive to uA of leakage to ground.*




Excessive leakage current through R28 turns Q1 on. Turning Q1 on powers the LM5009, which provides 5V to the BMS.

Fix: Remove potting, re-solder/clean components underneath silicone potting and replace R28 with a much larger value, like 90kOhm. More extreme fixes include swapping out Q1 for a PFET/zener based circuit, but this wasn't needed on the battery I repaired.




“Top” of the battery controller showing the increased R28. I happened to damage Q20 during slightly aggressive potting removal with isopropanol and a plastic scraper.

## Issue #3 - BMS Charges but Doesn’t Discharge

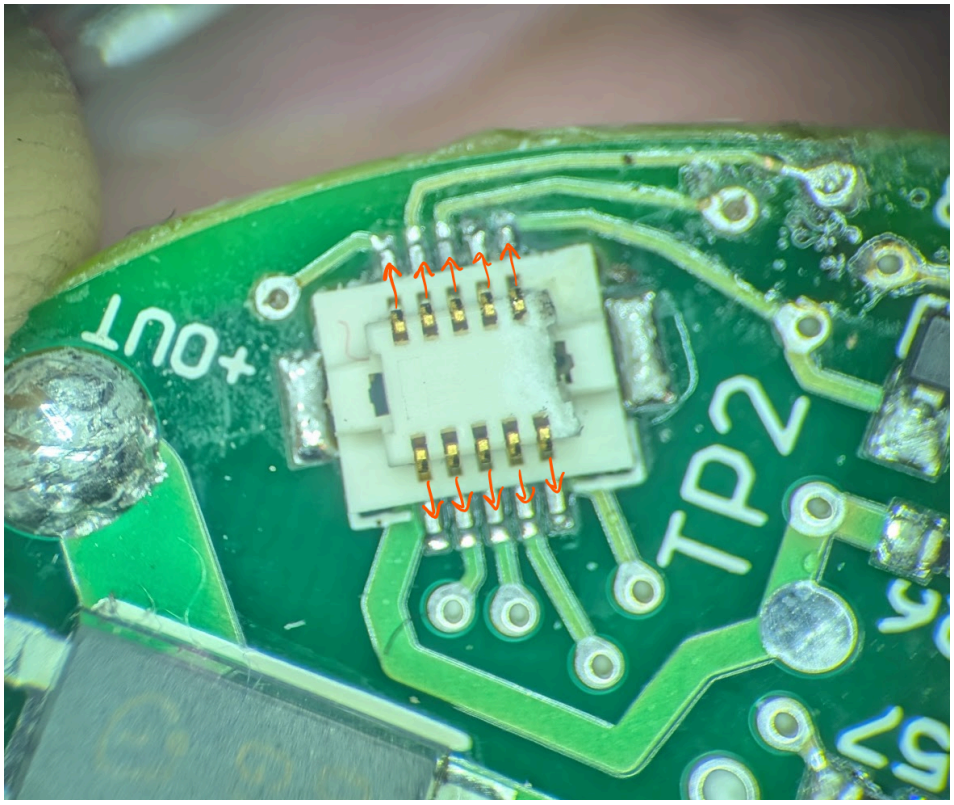
#transistor-man to fill out

Issue #4 - Connector making intermittent contact

Symptom - BMS does not turn on.

Root cause - board to board connector damaged by either creep or force during disassembly. Connector pads may be lifted from force during disassembly, so double check and re-solder any that might have lifted.

Solution - bend the pins of the connector outward to make better contact




Use a needle to bend the pins outward to make better contact.

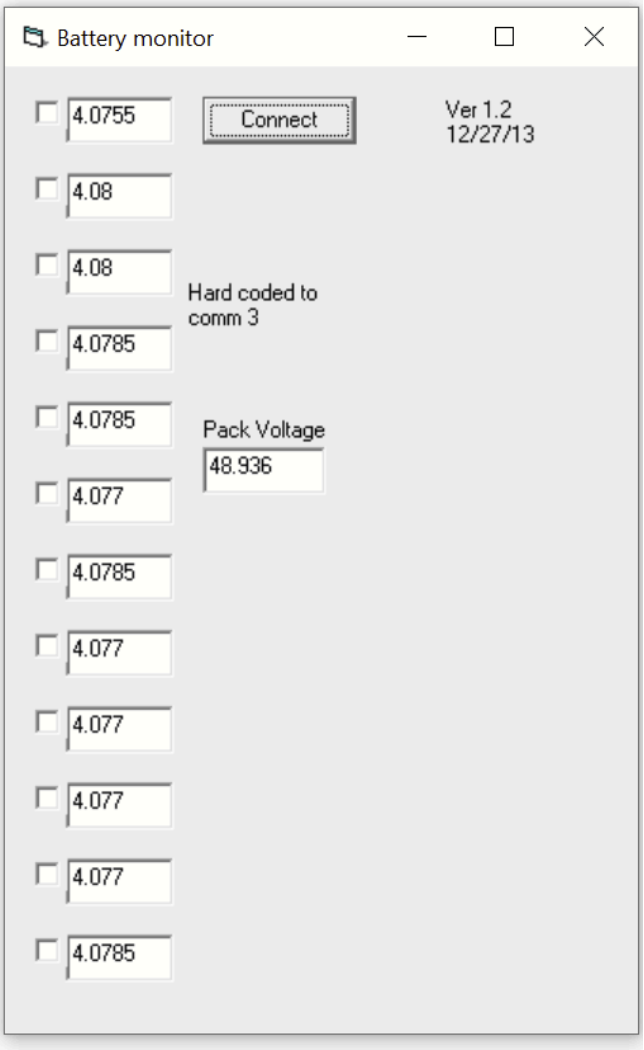
## BMS Disassembly

The BMS is aggressively potted with some sort of hot glue. Isopropanol reduces the adhesion and makes the glue more crumbly, at which point it can be picked out carefully. Applying too much force can damage components. This took me an entire afternoon and cannot be rushed.

When reassembling, you can either use hot glue or printed spacers. Or both! Make sure that the board-to-board connectors are held at the correct distance. Find my designs for printed spacers for Gen2 batteries in the Drive folder.

## BMS Verification

The first step should be connecting to the BMS with a RS-485 dongle and using the Faraday Battery utility to check cell voltages. The RS-485 dongle & Julet adapter should be plugged directly into the battery.



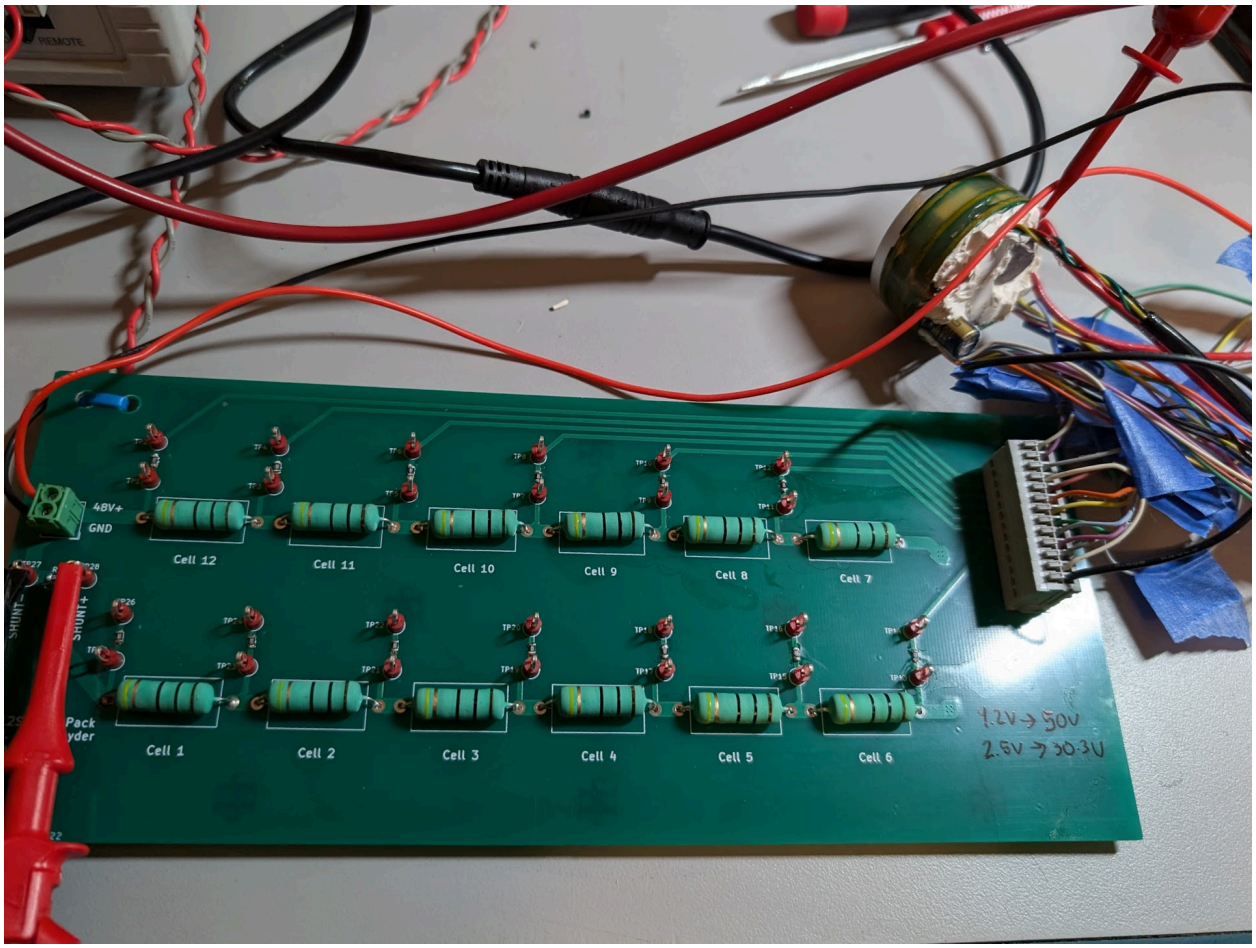

Faraday BMS tester showing a working battery. Check the box to force balancing current.

Note that the RS-485 dongle *must* be set to COM3 (windows required). Google how to do set the COM number of a port manually if it shows up as something else.

If the values are irrational, verify that your RS-485 adapter has a 120 ohm terminating resistor installed and that nothing else is connected to the RS485 bus.

To further verify proper functioning of the BMS, I fabbed a battery pack simulator using power resistors (10 ohm). By varying the input voltage and current, all cell conditions (over/under voltage/balancing) can be verified.

*Note: the 1 ohm resistors in series with the sense leads are there for measuring the bleed current. However, the voltage drop across those resistors causes higher than expected values to be measured by the BMS, causing premature turn-off during simulated charge. The 1 ohm resistors should be changed out for 0 ohm resistors to allow for correct behavior.*

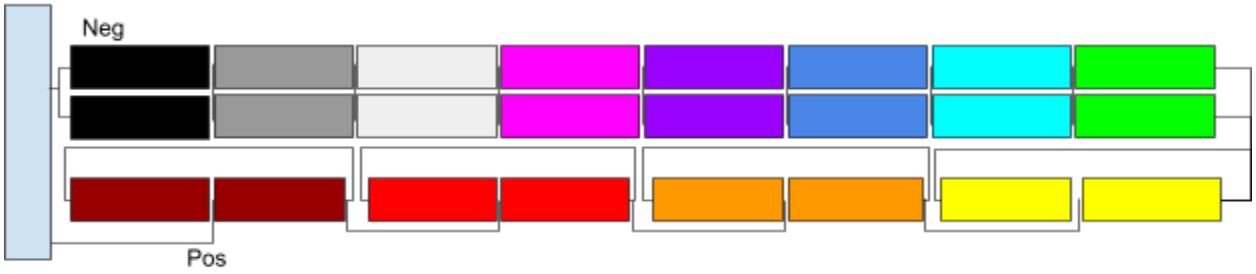



*12S battery pack simulator*

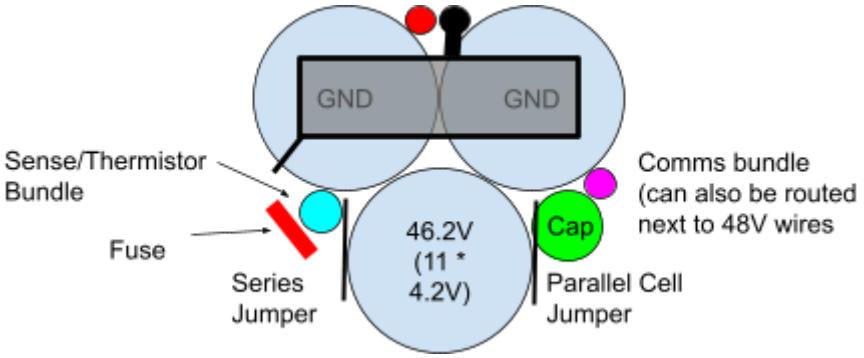
Gerber and BOM Files for this are available in my Faraday Drive folder.

# Battery Rebuild

Carefully examine the batteries you have and examine how they're arranged. I suggest making a drawing of the layout to reinforce it in your mind. We're going to build the battery starting from the negative most cell.




Series and Parallel Configuration



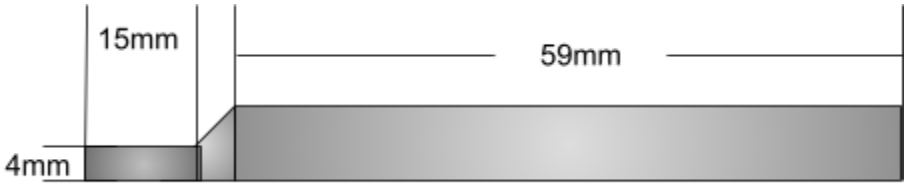

View from the BMS side of the battery. Orientation is super important.

*Author's note - there are many guides online for how to weld batteries - do your research! Buy extra batteries and test your welding destructively by peeling the nickel off. If the weld is good, small bits of nickel should rip off and remain on the cell. If the weld is bad, the nickel strip will peel cleanly off. Technique makes a surprising difference…I found that an initial hard push followed by a light touch produced the best result.*

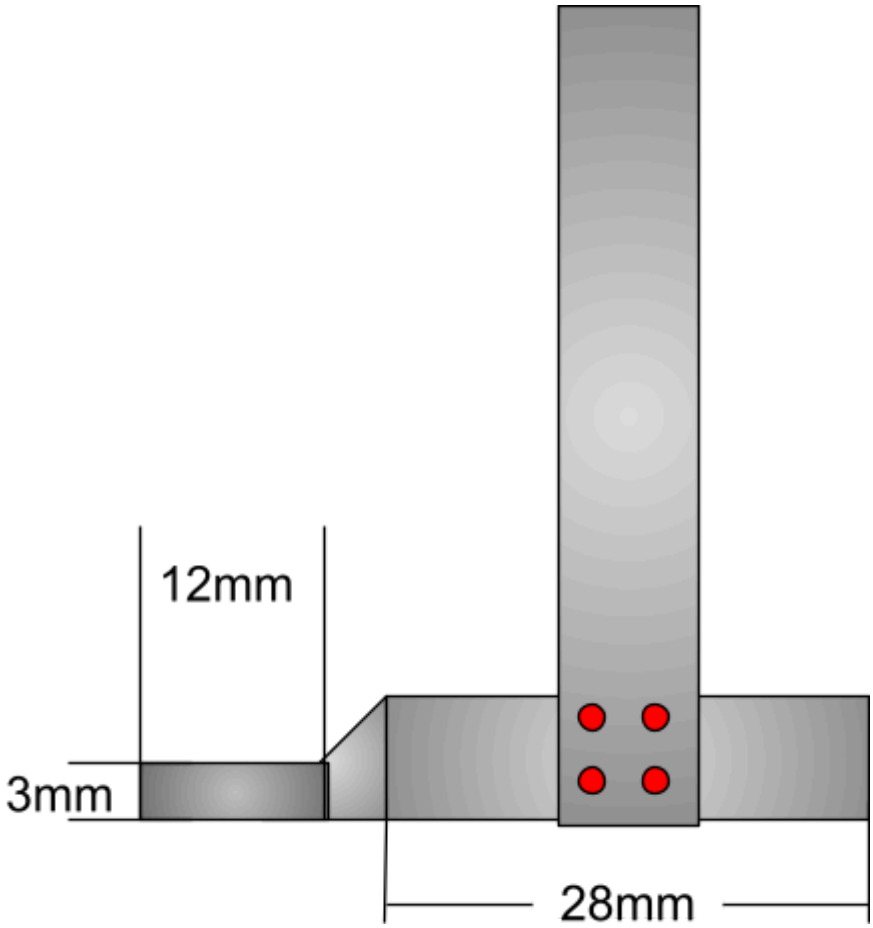
## Part 1: The way out

Begin by building the 8S 2P (8 in series, 2 in parallel) stack. I suggest doing this one at a time using the fixtures in the Google Drive folder.

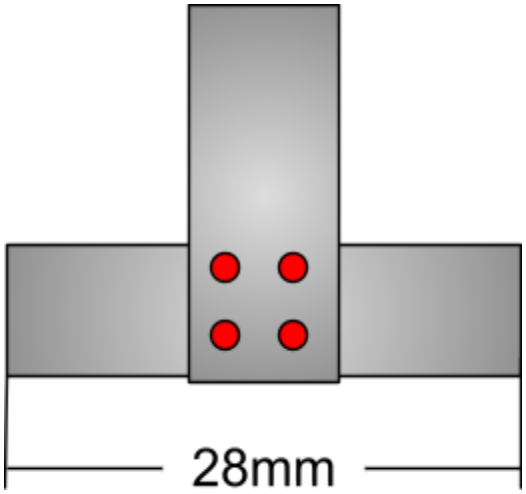
First, make 7x **Parallel Strip Asy Strips** like so:



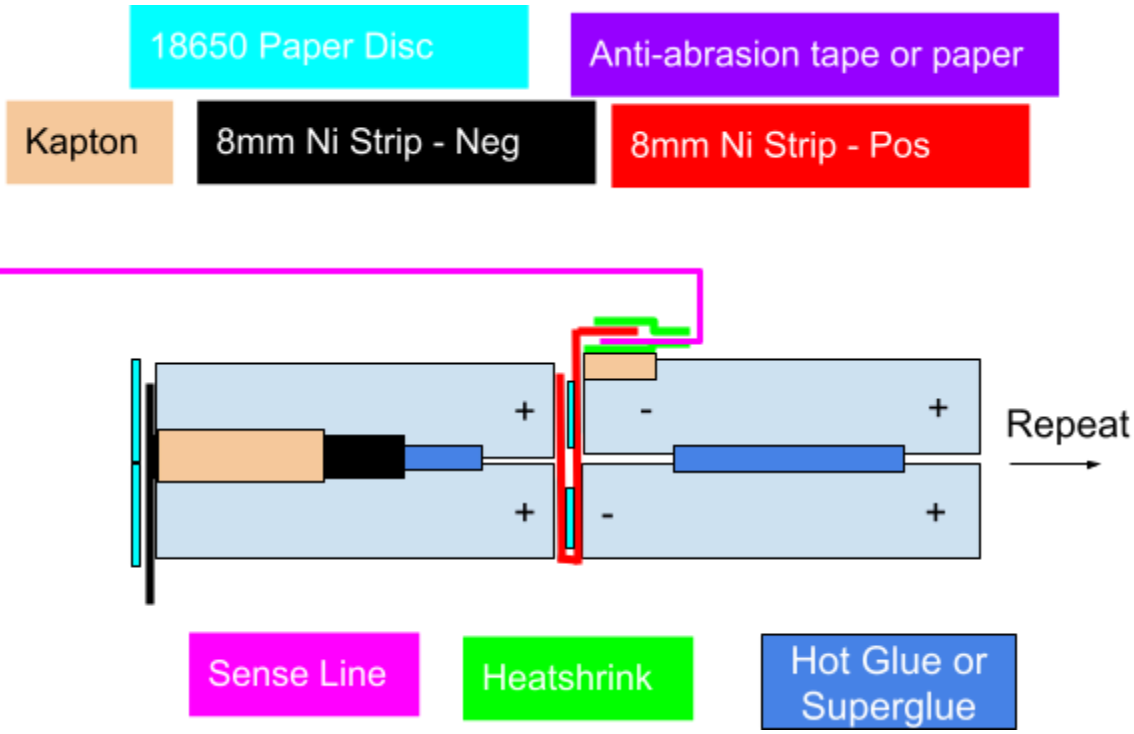

Next, make 1x **Negative-most Terminal Asy** these by pinching the nickel tab with the welder tips:




And finally make one **Stack-end Asy**:



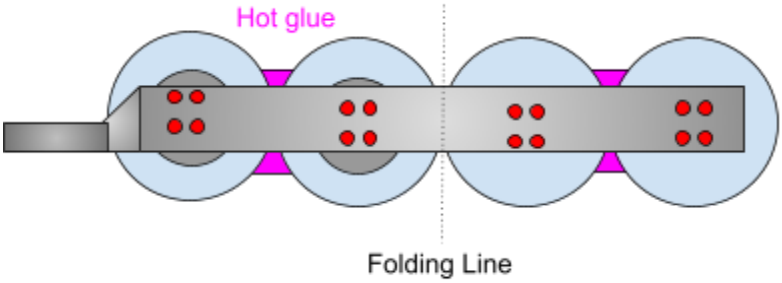

Now, with these tab and a bunch of tape in hand, start from the negative-most side and start building. The objective is to achieve a layout like this:



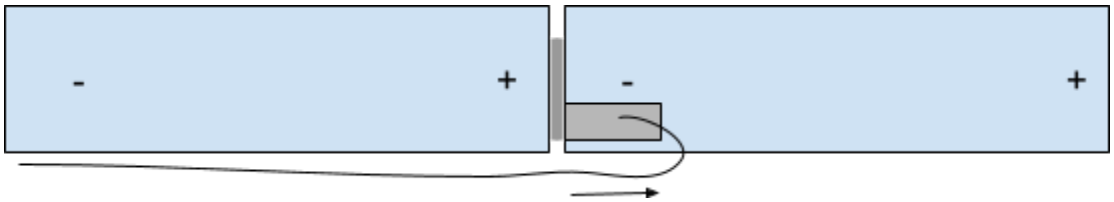

Now let's start the build.

1. Hot glue two groups of two cells together, making sure there is absolutely no gap between them. Use the smallest amount of hot glue you think you can get away with.
2. Line up the two groups of cells, 2 of positive polarity and 2 of negative polarity. Temporarily tape tab in place on the cells to verify that you have the correct

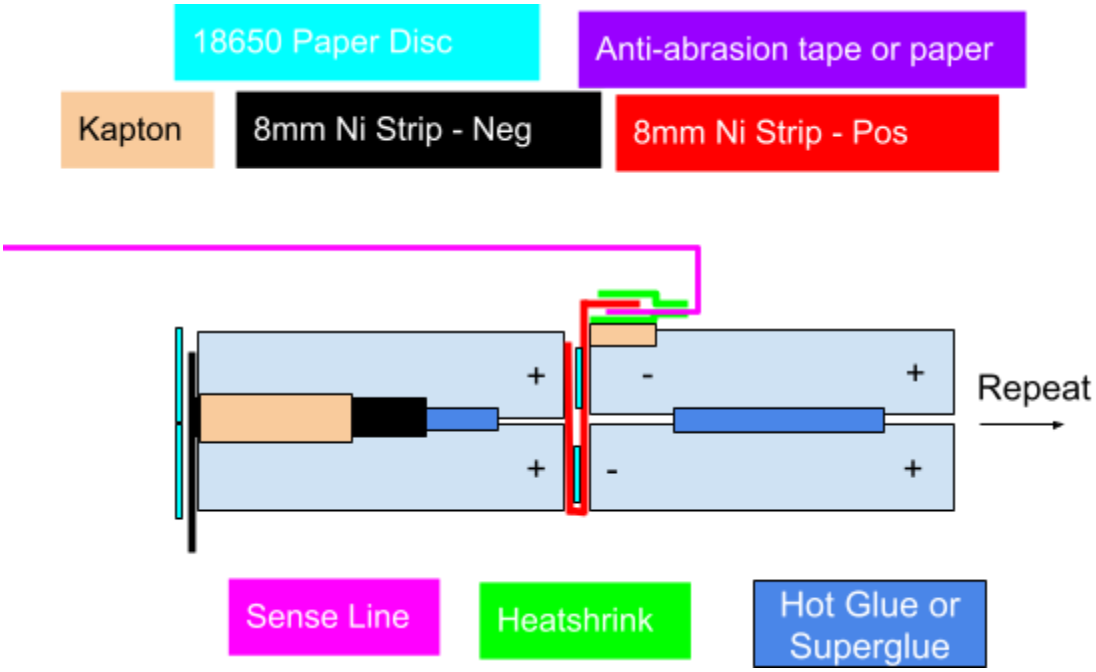
orientation. DO NOT WELD UNTIL ABSOLUTELY SURE THAT THE SENSE TAB IS IN THE CORRECT LOCATION



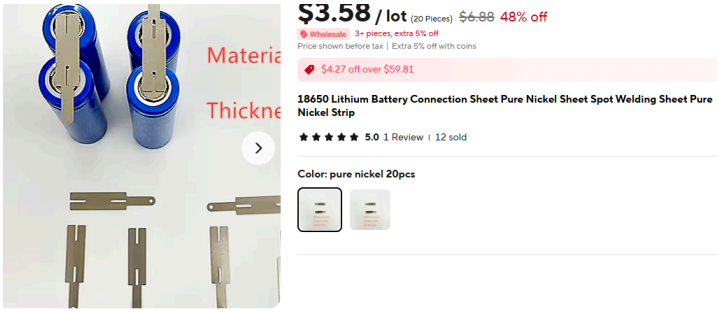

1. Clean and then weld the four cells.
2. After welding, place two paper insulators (to maintain proper spacing) on top of the welds
3. Fold the assembly.
4. Bend the tab towards the battery at the same voltage as the tab to reduce the chance of shorting during later soldering and heatshrinking operations.
5. Add a bit of kapton underneath the tab if you prefer.



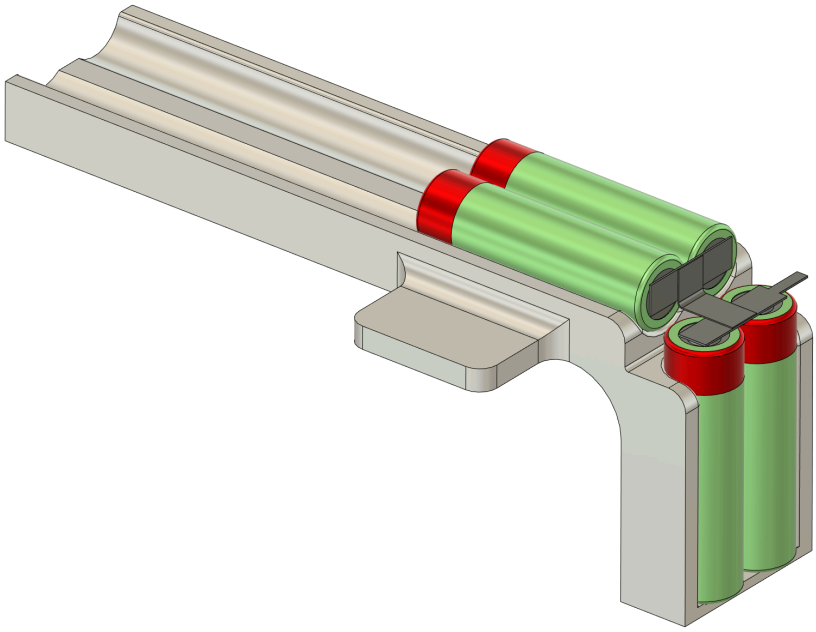

6. Continue this process until you have a stack of cells 8 long and 2 wide. The sense tabs must all be in the exact same position. Diagram for reference again:



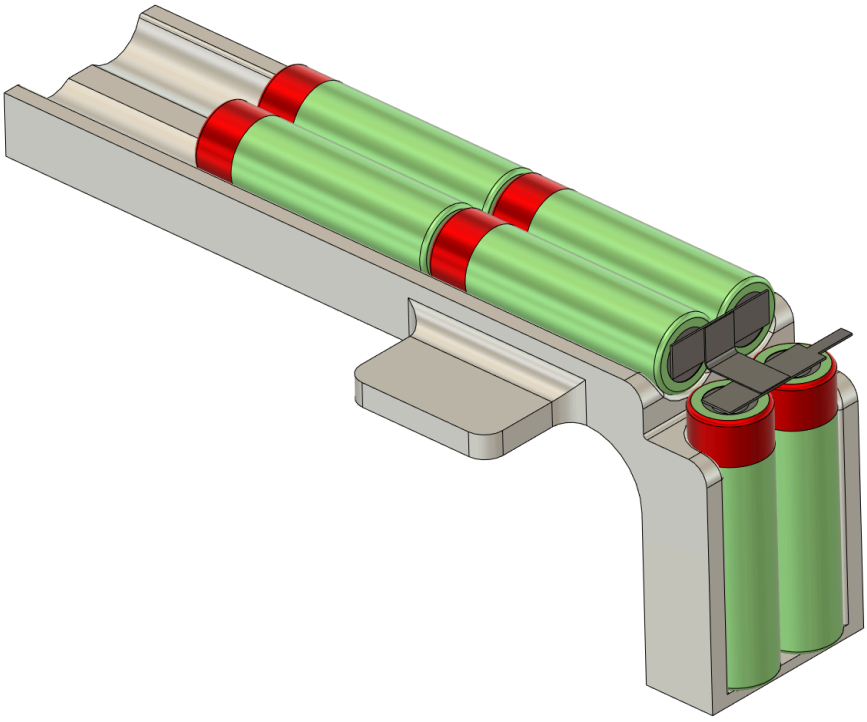

If using “Style 2 tabs” - refer to these photos



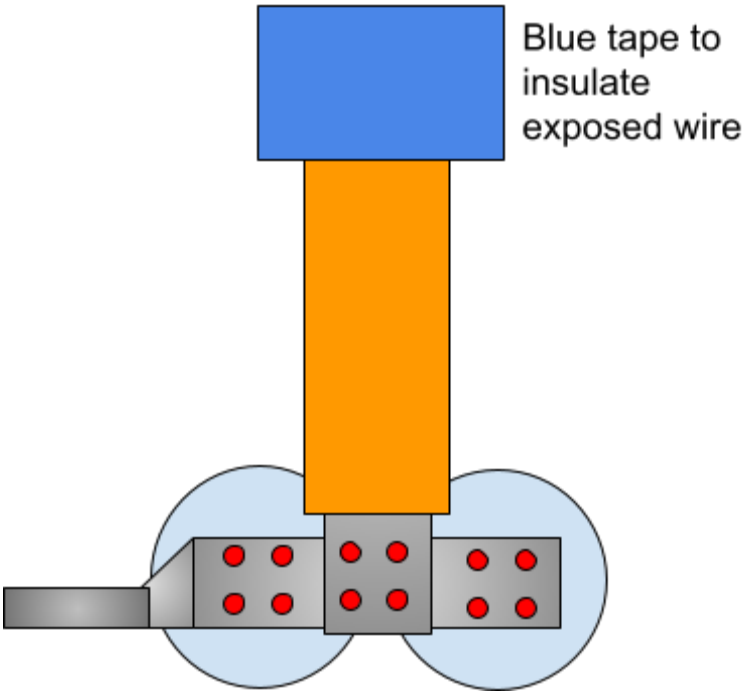

If using straight nickel strip, I would recommend ‘style 1’



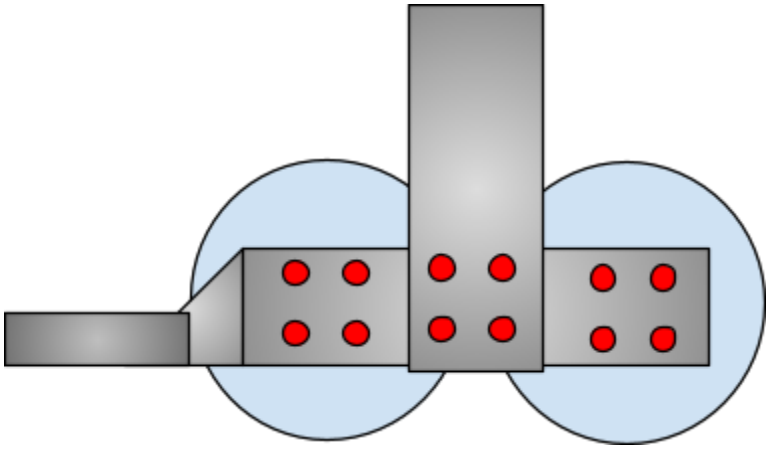
“Style 2” recommended if you bought pre-made tabs from Aliexpress



7. Now, you will need to terminate the negative end. Weld the remaining long strip to the negative-most end of the stack (it’s possible to do this first if you want).




8. Insulate the end with two paper stickers.
9. Now, weld the **Stack end tab** to the positive-most side of the battery.

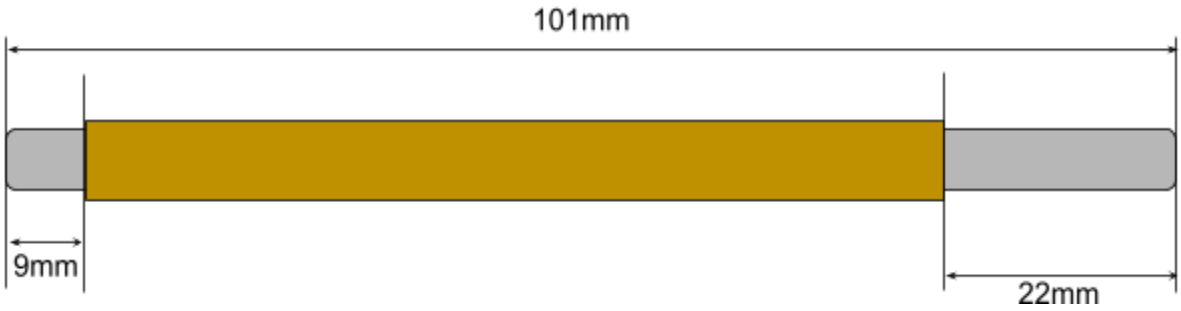


10. You are done with this side for now (dun dun dun).

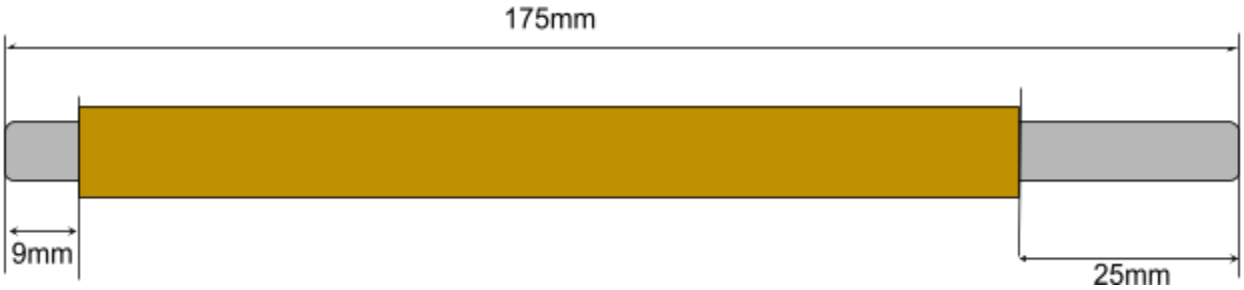
## Part 2: The Long way Home (Series count 8 to 12)

Side view of the four return groups

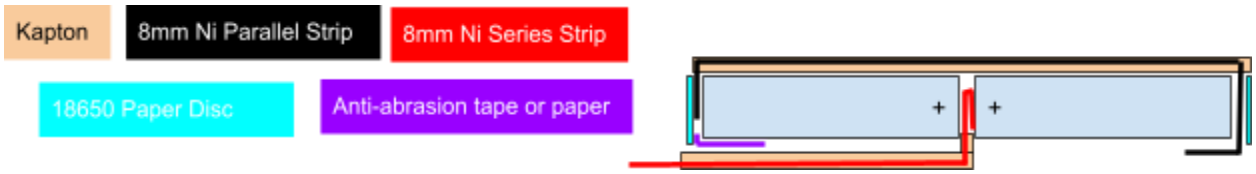
1. First, make 4x kapton-insulated 101mm tabs:



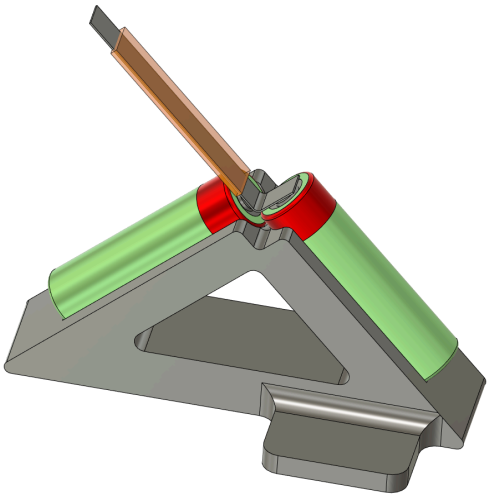

2. Then make 4x kapton-insulated 175mm tabs




3. Next, your goal is to make 4x of the below assembly. Pay attention to the layers of tape and their positions.

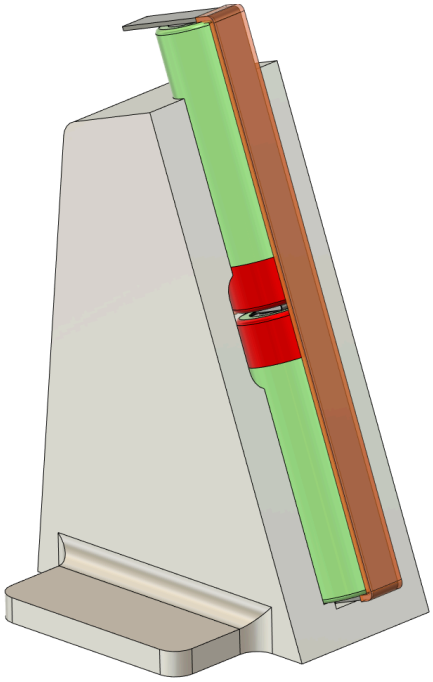


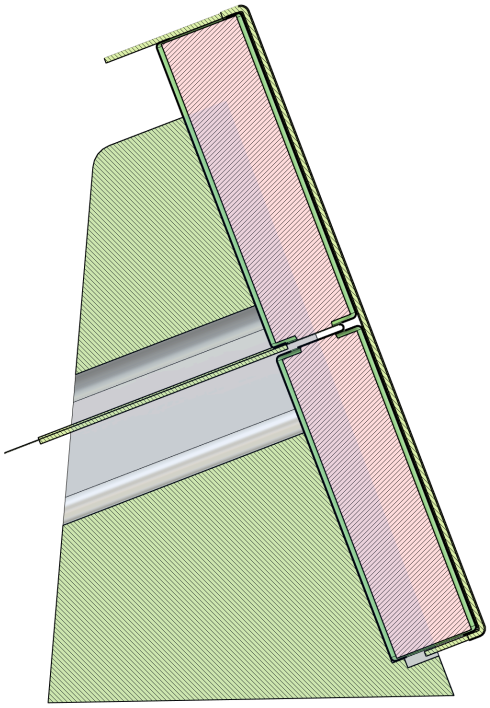

4. Start by arrange two batteries as shown in the fixture, positive side in. Pre-fold the tab so that it sits flush on both batteries. Weld the tab to both batteries. Cover the exposed end with blue tape to avoid accidental shorting.



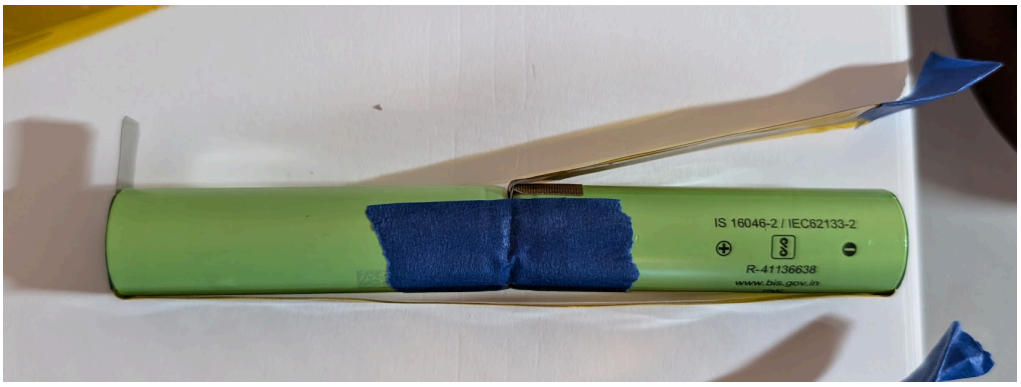
5. Transfer the assembly to the second fixture, inserting the center tab through the hole in the middle.

6. Fold the ends of the 175mm tab, making sure that there is a layer of kapton between the nickel and rim of the cell.
7. Line up the 175mm tab to be normal to the positive tab as shown.
8. Weld the short end first. Flip the assembly upside down and weld the long side.





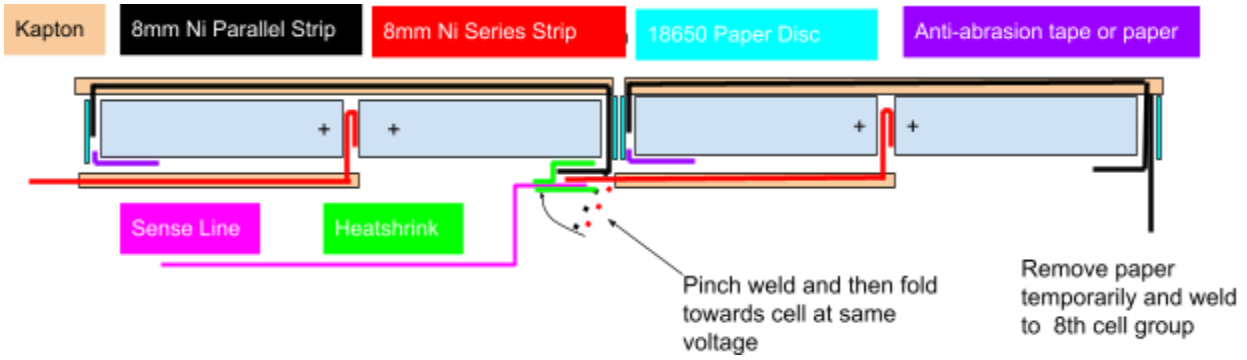
9. Add paper stickers on both ends of this stack
10. Add some blue tape or kapton to increase the rigidity of the stack
11. Repeat this 4 times.




The finished subassembly

12. Now, weld the first group to the 8S stack you made earlier. Remove the paper disc, clean any residue, and carefully spot weld. The positive tab points towards the most negative cell, the stubby tab will be bent in and used as a voltage sense tab.

13. Next, weld the remaining three groups by using a pinch weld technique (see the diagram). I recommend adding a stiff PET tape as you go make the sausage easier to handle.

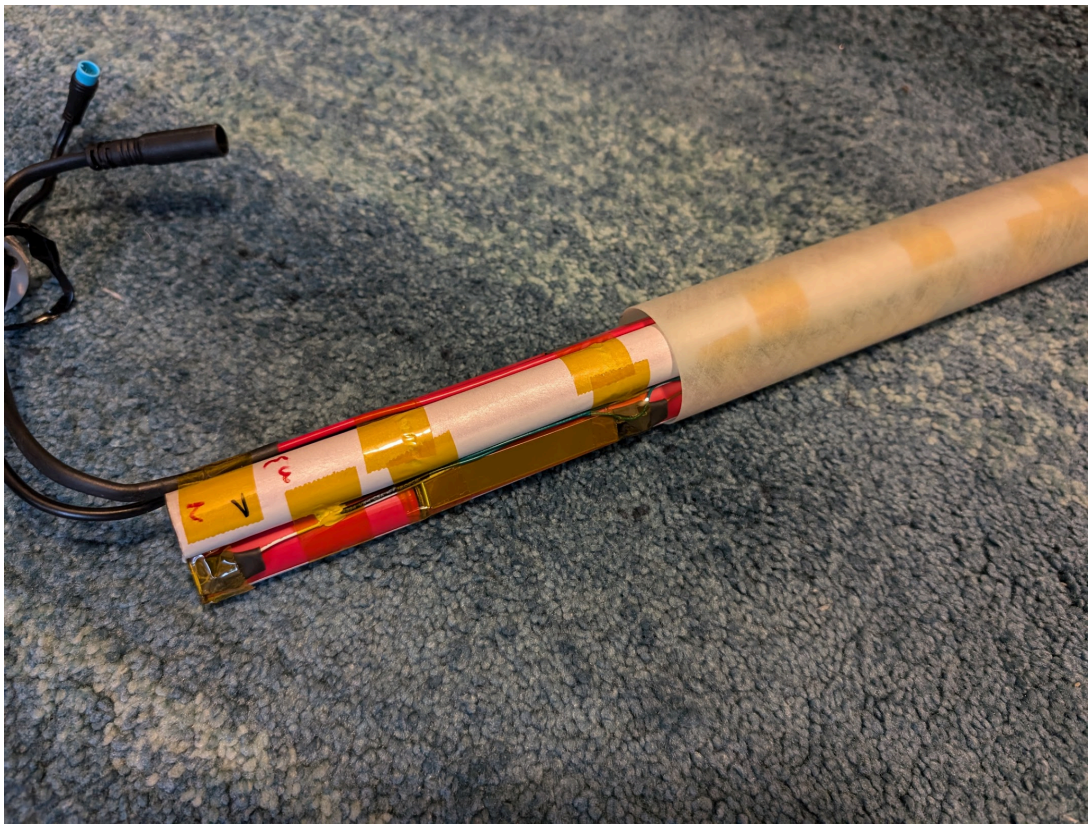



## Part 3: Contact!

1. Hot glue the BMS onto the end of the pack, making extra sure that it's concentric with the cells. Use the capacitor as a guide for orientation. Use IPA wicked onto the hot glue if the position is wrong.
2. Untangle, lay, and re-solder the sense wires one at a time (I started from the negative-most cell). Use heatshrink or kapton to insulate each exposed end! Use tape or a spare piece of heatshrink to prevent loose sense wires from shorting on the battery! Don't forget the 0V (GND) sense wire and the thermistor grounds.
3. Use kapton to tape the sense wires down as you go
4. Re-glue the thermistors (bonus points if you use thermal epoxy)
5. Use kapton to tape the sense wires down as you go
6. Solder the fuse to the positive-most strip. Insulate thoroughly with heatshrink and anti-abrasion tape

## Part 4: Making the sausage

1. Add stiff PET tape strips everywhere you can to stiffen the sausage o.O. Take care not to add too much thickness or wrinkles to the outermost diameter of the sausage, since it will make insertion into the tube more difficult. Wrinkles and double layers of tape are the enemy.
2. Use the sizer ring you printed to verify that the maximum diameter of the sausage is no greater than 39.9mm
3. Test-fit the battery in the tube.



4. Plug in the battery to the bike. Verify that the bike operates as expected. This includes turn-on, turn-off. I recommend using the RS-485 tool to verify that all cell voltages are reporting.
5. Gently tug the heatshrink over the entire battery, making care not to cause any wrinkles in tape.
6. Gently heat-gun the entire battery to shrink the heatshrink. Trim any excess at the ends, taking care not to nick a cell.
7. Stuff the battery in the tube.
8. Install endcaps
    a. I made an aluminum endcap with an o-ring for the BMS side for heat dissipation and a press-fit end-cap for the wire side. I used Dowsil 738 to seal the wire-side because of the three-point seals.

9. If using a fiberglass tube, add a few layers of tape where the set screws touch. Also, add periodic wraps of tape to make sure the fiberglass tube is the same diameter as the aluminum tube.
10. You're done! Install and enjoy.