POV staff

Alexander Kirillov

May 03, 2024

TABLE OF CONTENTS
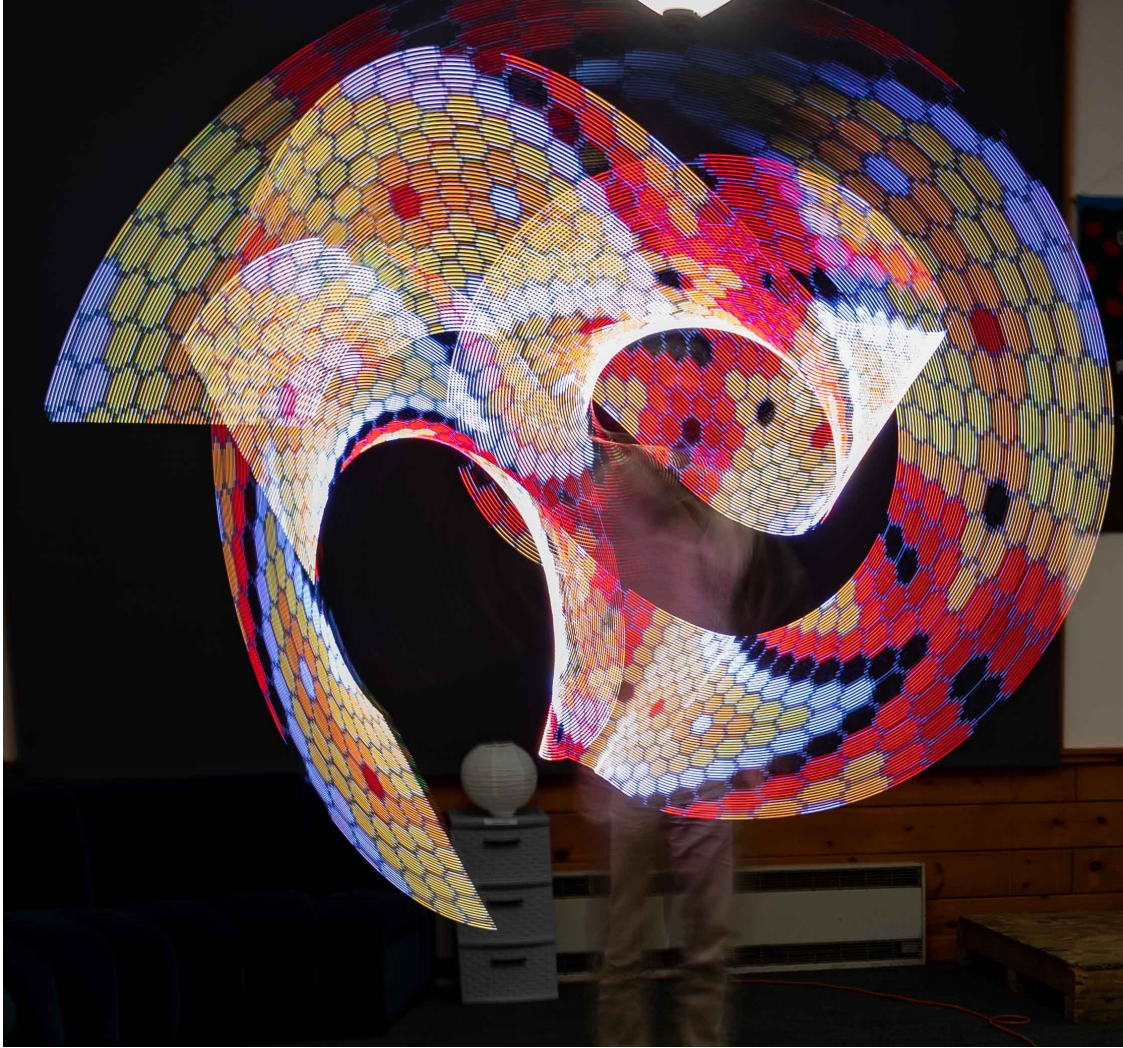
This guide contains documentation for Persistence of Vision (POV) LED staff project, created by Alexander Kirillov <irobotics.store@gmail.com>.

This document describes version 4.1, which was released on May 10, 2023. An earlier version of this project was documented on Instructables web site. The version described here contains several improvements compared to the earlier one, see below.

For those wishing to reproduce this project, we are offering a kit of parts for sale through our Tindie store. However, all design files, software, BOM and more are published under open source license, so anyone can build their own version from scratch. You can find these files in the project GitHub repository: https://github.com/shurik179/povstaff

OVERVIEW

It is well known that even after a light has been turned off, human eye keeps "seeing" it for a fraction of second. This is known as Persistence of Vision, or POV, and it allows one to "paint" pictures by quickly moving a strip of LEDs, drawing one line of an image at a time in quick succession. If you search online (e.g. on Etsy), you can find quite a few toys based on this idea: pois, staffs, and more.

However, these are expensive: typical prices for a POV staff of decent resolution start at $500, and they use proprietary software, so there is no easy way to modify their behavior or add extra functionality. Thus, when looking for a birthday gift for a friend who enjoys painting with light, I decided to create my own open source version using readily available components.

My project builds upon the outstanding work of Phillip Burgess and Erin St Blaine from Adafruit; however, I made a few changes, upgrading the electronics.

KEY FEATURES

- It is a two-sided staff, of total length 141 cm (55in); it is not collapsible. Each side of the staff has two 50cm/72 pixels LED strips, for the total of 288 LEDs. Thus, you can use it to show images with 72-px resolution.

- Staff is powered by two 18650 Li-Ion batteries, which should be enough for at least 1 hr show, possibly as much as 2 hours, depending on intensity of your images. The batteries can be recharged via 5.5mm/2.1 barrel connector (or USB C cable, using included adapter); full charge time is about 5 hrs.

- Images (in bitmap format) can be easily uploaded to the staff over WiFi. It has enough memory for about 50 images. The order in which images are shown is described in a separate plain text file, where you can put a list of images and durations. An image can be listed there several times, or none at all.

- The staff contains an Inertial Motion Unit (IMU) which can be used to detect when the staff is in motion. The software uses it to adjust update frequency for images, so the images will not appear stretched or compressed regardless of how fast you are rotating it. You can also use it for controlling your show: e.g. stopping the staff vertically is used as a signal to move to the next image in the slideshow.

- The software is based on Arduino IDE. It is available under an open source license and is easy to modify to suit your needs.

DIFFERENCES FROM VERSION 3

- New MCU (ESP32-S3 QT Py)

- Wireless uploading of images

- Many changes to wiring

- New 3d printed spacers and other components, printed in black resin.

- Foam protectors at the ends of the staff, to protect the staff when dropped

3.1 Build Guide

Please follow the steps below to build your staff.

3.1.1 Tools and materials

You will need the following materials:

- Kit of parts from my Tindie store, version 4.

- Two **18650 Li-Ion batteries**. Look for high-capacity (at least 3000mAh), **unprotected** batteries from a reputable manufacturer such as Panasonic, Samsung, or Sanyo. Do not try to save money by buying no-name battery on eBay or Amazon; instead, use a specialized store such as 18650batterystore.com. Batteries must be **identical**, ideally from the same batch. Current rating (5A/10A/20A) doesn't matter much for this project. I used these batteries.

- Polycarbonate tube, 11F (55in/141cm), 1 inch outer diameter, from flowtoys.com. Note: while the tube is listed as 55", the actual length is 54.5".

- 1/2 inch (or 12 mm) square **wood dowel**, from HomeDepot or any other hardware store. You need two pieces, each at least 52 cm (slightly over 20").

Tools

You will need the usual tools and supplies:

- wire strippers

- pliers

- flush cutters

- scissors

- decent soldering iron, solder, and flux

- heat gun

- hack saw

- electric tape, black, 3/4"

- fast-setting epoxy (I use JB Weld Clearweld 5 minute epoxy)
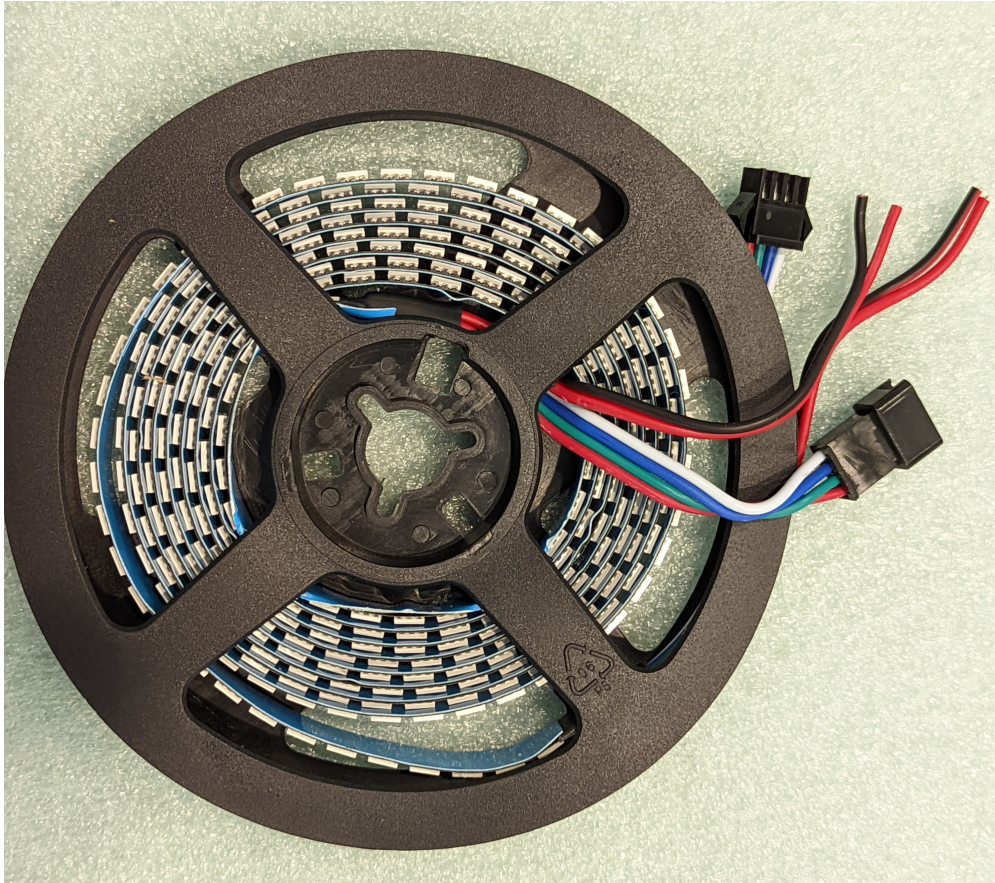
- black spray paint

You will also need a computer with WiFi to upload the images and a charger (either 5v charger with 5.5mm/2.1mm barrel jack connector, or a USB charger and USB C cable) to charge the batteries.

3.1.2 Kit of parts

Below is listing of parts included in the kit sold on Tindie.

- LED strips (2m, 144 LED/m APA102 or compatible, black PCB)


- **Bag A**: materials for LED assemblies

    1. two power distribution boards (PDB),

    2. two 2x3 pin headers (to be soldered to the PDBs)

    3. 22AWG solid core wire (to be soldered to LED strips)

    4. 3d printed press tool, to be used for pressing the PDBs into the dowels. Discard after use

    Note: color of the wire and press tool may vary.

- **Bag B**:

    1. Charge connector

    2. 3d printed housing for charge connector

    3. 2-pin wire (55 cm, 24 AWG)

    4. Charging adapter (USB C to 5.5mm barrel jack)

- **Bag C**:

    1. Switch

    2. 3d printed housing for the switch
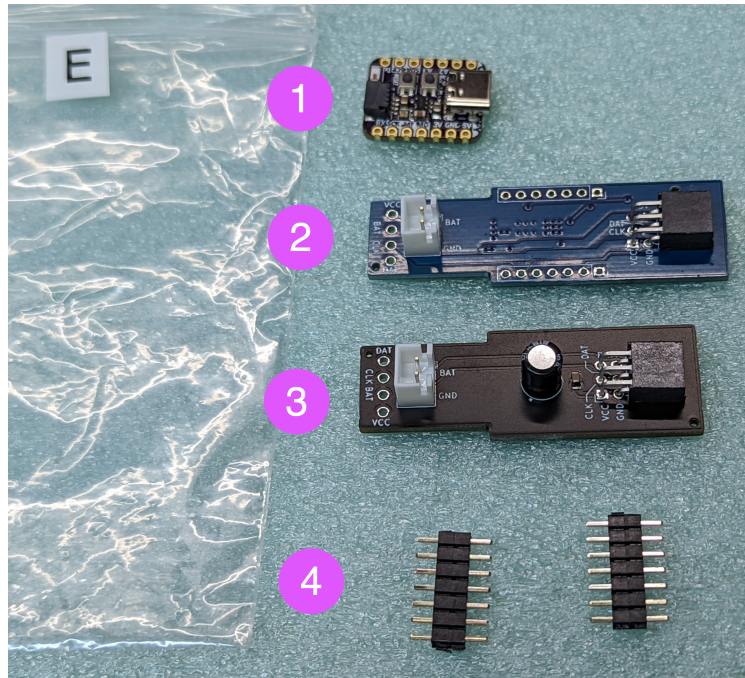
    3. 2-pin wire (55cm, 20 AWG)

- **Bag D**: battery assembly components
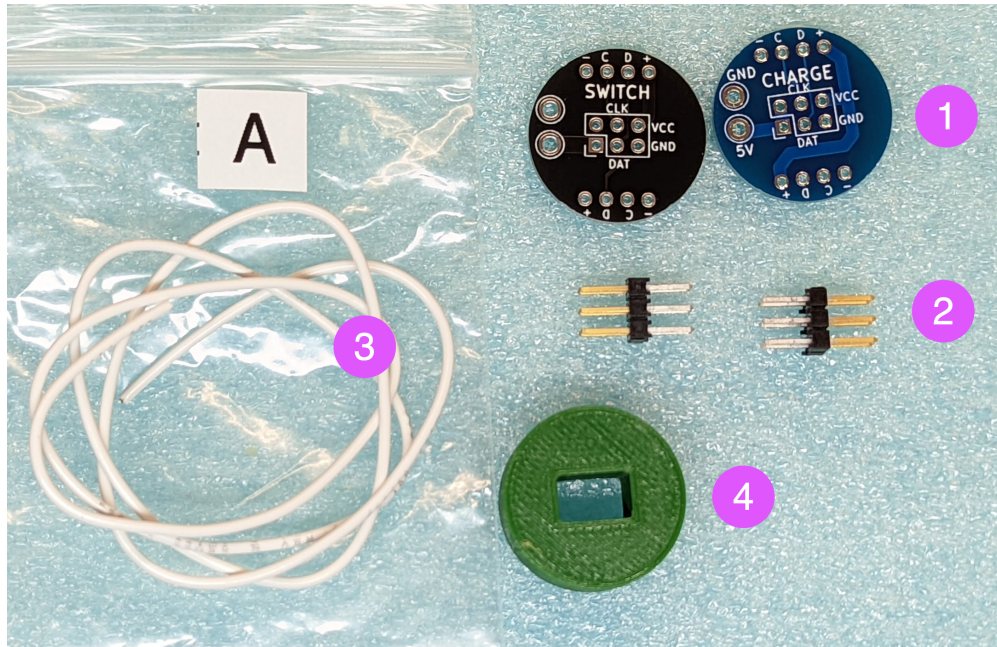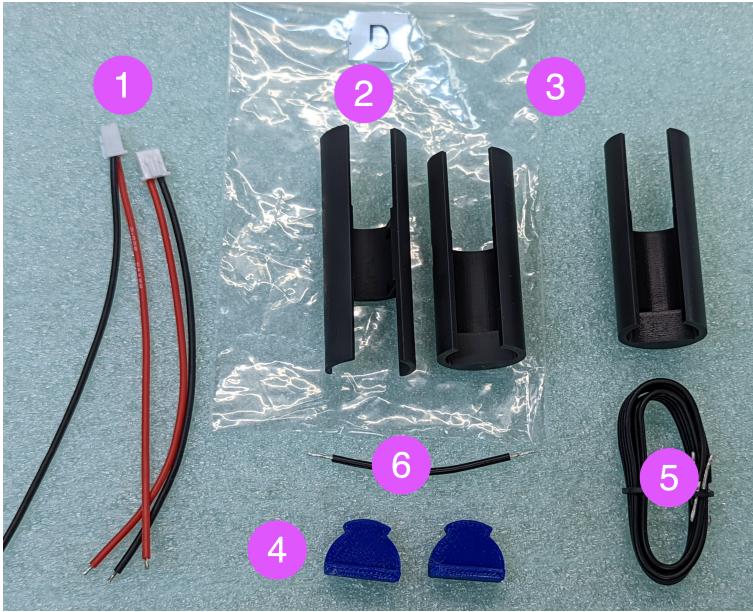
1. two 2-pin wires, with JST XH connector

2. 3d printed spacer, to go between batteries

3. Two 3d printed spacers to go at the ends of batteries

4. 3d printed "plugs"

5. 4-pin wire (22cm, 22AWG)

6. Wire, 5.5 cm, 22 AWG

- **Bag E**: electronics

1. QT Py ESP32-S3 MCU, preprogrammed

2. Custom-made POV controller board (blue), containing Inertial Motion Unit, battery charge circuit, and more.

3. Switch connector board (black)

4. Two 7-pin headers

- **Bag F**:

  1. two shrink wrap sleeves

  2. two foam sleeves

3-4. two 3d printed end protectors

  5. tennis grip tape

  6. Foam washers

3.1.3 Build overview

The staff consists of the following subassemblies:

- **battery assembly**, containing two batteries, controller board, wiring, and spacers. This assembly is placed in the center of the staff

- two **LED assemblies**, one on each side of the battery assembly. Each LED assembly consists of the wood dowel with two 50cm LED strips on opposite sides of the dowel. On inner end of the dowel, there is a power distribution board (PDB) to which both LED strips are connected; on the outer, one assembly has a charging connector, and the other, a switch.

All of the above are inserted into the **polycarbonate tube** and protected at both ends by 3d printed endcaps wrapped in soft foam. The middle of the tube is wrapped in tennis racket **grip tape** to provide secure grip.

Warning:

1. At some steps you will be using epoxy. Please be careful that it doesn't get on your skin - to be on the safe side, you can put on thin latex gloves.

2. You will be soldering leads to 18650 Li-Ion battery. It can be dangerous if not done right. Make sure to **carefully read the instructions** before doing this. If you are not sure you can do it, then this project is not for you.

If you messed up, destroying one of the parts, or misplaced it, do not worry! Email me at irobotics.store@gmail.com and I can send you a replacement.

3.1.4 Step 1: Dowels

Materials:

- two 1/2" square wood dowels

- Bag A from the kit
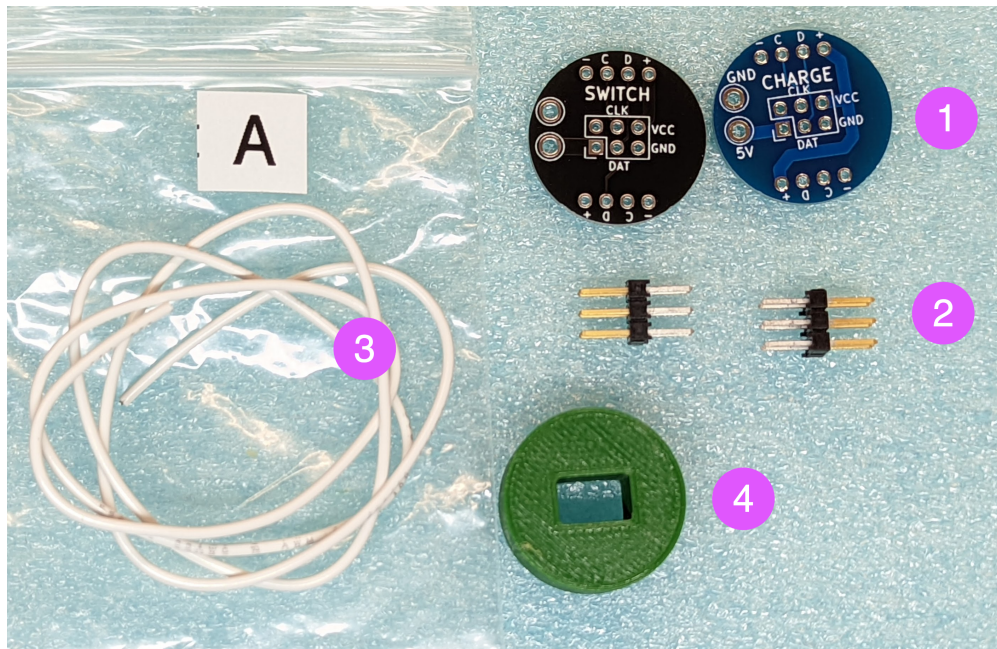
1. two power distribution boards (PDB),

2. two 2x3 pin headers (to be soldered to the PDBs)

3. 22AWG solid core wire (to be soldered to LED strips)

4. 3d printed press tool, to be used for pressing hte PDBs into the dowels. Discard after use

Note: color of the wire and press tool may vary.

- Spray paint, epoxy resin.

Steps:

1. Take the two 1/2" square wood dowels. Use hacksaw to cut each of them to **51.9 cm** length; try to keep the cuts square.

2. Spray paint each of them black. Let dry (you can work on the other steps while the dowels are drying).

3. Solder the 2x3 header to each PDB. Make sure to solder it on the correct side: the plastic spacer should be on the side labeled CHARGE (or SWITCH)

4. Use flush cutters to trim the 4 corner metal pins on the back side of each PDB, leaving the two middle ones intact:
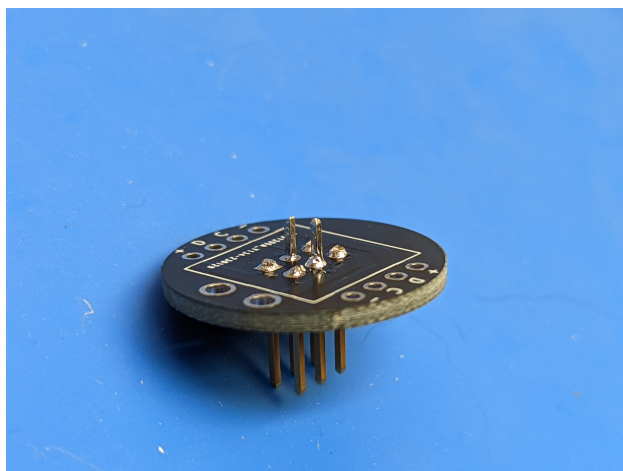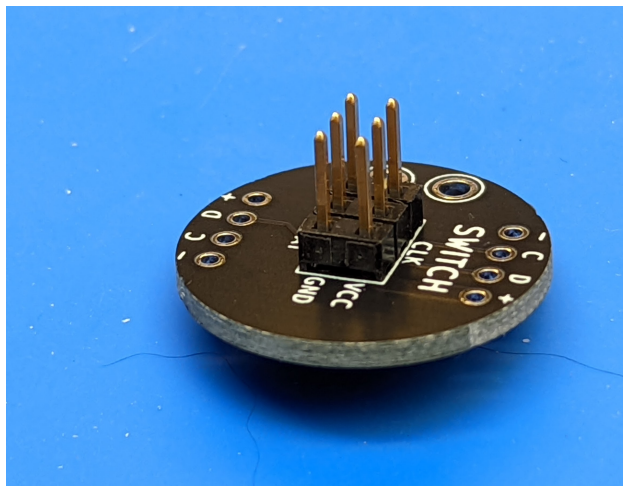
5. Use the flush cutters to cut about 1 mm off the tip of the two remaining pins on the back at 45 degree angle, creating sharp points.
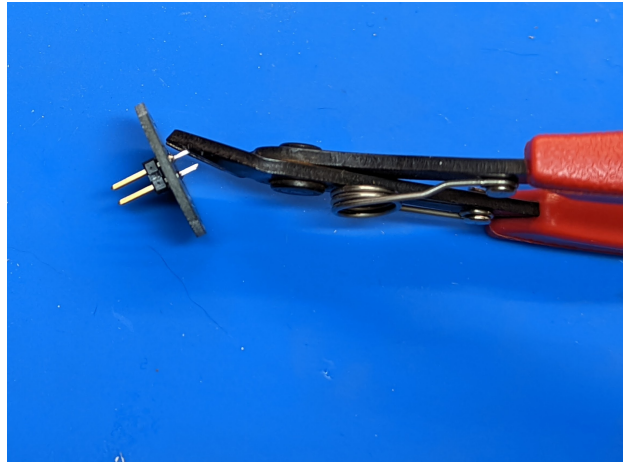
6. Press the PDB with soldered headers into the end of the dowel. Use the square drawing on the back for alignment with the dowel. To avoid damaging the header pins, use the included 3d-printed press tool: place it on the table, then the PDB on it (face down), then press the dowel into it. Make sure to press it all the way in: there should be no gap between the dowel and the PDB. Repeat with the other dowel and power distribution board.

7. Remove the PDB from the dowel. Mix some epoxy glue, apply it to the end of the dowel and replace the PDB seating it fully. Repeat with the second PDB and dowel. Be careful that no epoxy gets on the holes for wires. Leave for an hour to let the epoxy set.

After completing this step, you can discard the 3d printed press tool - you won't need it any longer.

3.1.5 Step 2: LED assemblies

Materials and tools:

- Wood dowels with attached PDBs (from step 1)
- LED strips
- 22AWG solid core wire (from bag A in kit of parts)

Steps:

1. Get the LED strip(s). If they have any wires soldered, de-solder them; remove excess solder using a braid wick. If you ordered 1m or 2m strips, cut them into 50 cm pieces, making sure to leave as large as possible soldering pads in the beginning of each strip (this should be easy, as usually longer strips are created by soldering together 50cm ones, so you will be just undoing someone else's work).

2. Tin the pads in the beginning of each LED strip. **Warning: LED strips are directed!! in each strip, the signal goes in one direction only, as indicated by the arrows. You should tin the pads in the beginning of the strip, so that arrows go from tinned pads to the opposite end - see photos below.**

3. Solder 2cm long pieces of 22AWG wire to each of the pads. The easiest way to do it is as follows:

   - Strip 2cm of insulation from the end of wire; do not cut it yet.

   - Holding the wire by insulated part, solder the stripped end to the pad. You will be soldering very close to the first LED, so please watch your iron carefully - do not touch the LED!

   - Cut the wire. To make the next steps easier, trim the wires so that they are of different lengths (length of each should be at least 1 cm)
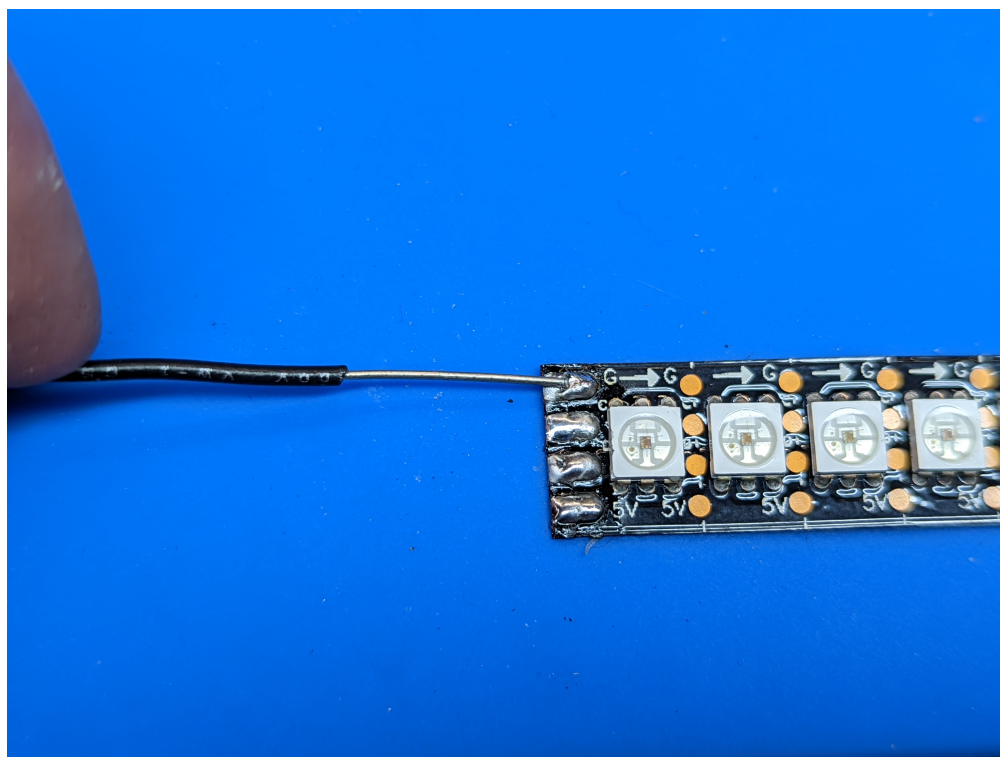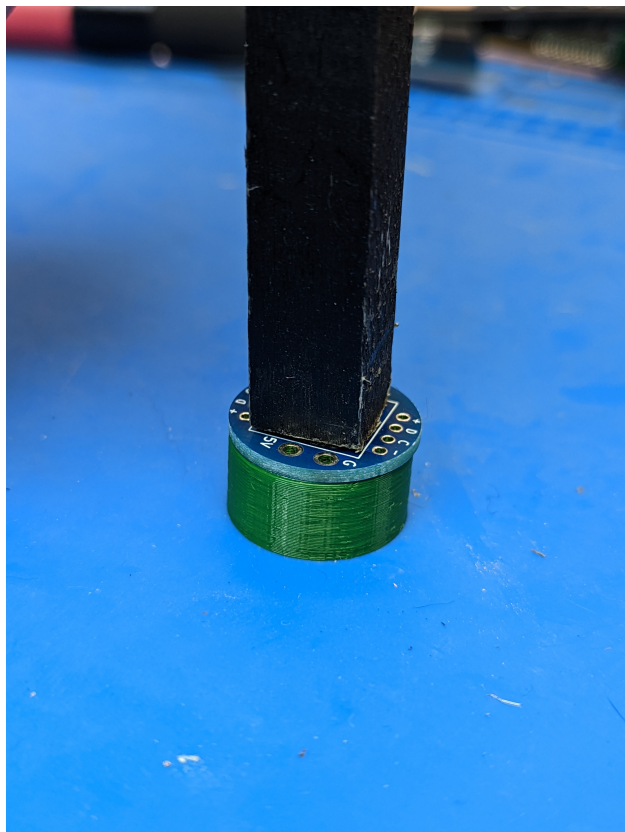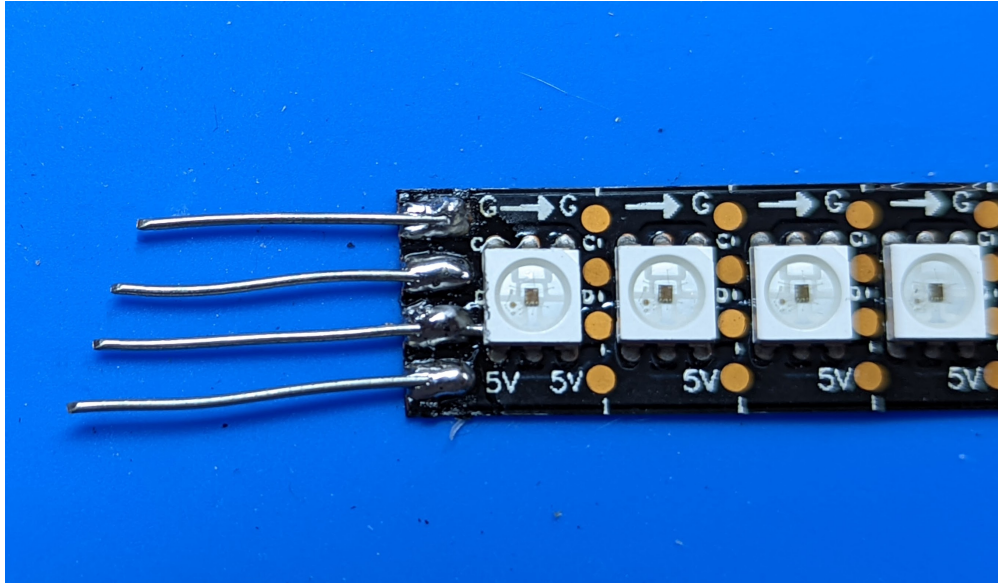
4. Remove the backing paper from the first 5-10 cm of adhesive strip on the back of the LED. Insert the soldered wires into the holes of the power distribution board you had previously attached to the wood dowels and attach the strip to the wood dowel, aligning it so that the beginning of the strip is about 5mm away from the power distribution board. Remove the remaining backing paper and attach the strip to the dowel.

5. Solder the wires to the power distribution board. Trim them using flush cutters. Repeat the previous steps for all 4 LED strips, placing two LED strips on each dowel, on opposite sides of the dowel.

Note: the adhesive on LED strips is not very strong, so your strips might start peeling off. It is OK; we will make a more permanent attachment later.

3.1.6 Step 3: Charge connector

Materials and tools:

- Bag B from the kit

    1. Charge connector

    2. 3d printed housing for charge connector

    3. 2-pin wire (55 cm, 24 AWG)

    4. Charging adapter (USB C to 5.5mm barrel jack)

- flush cutters, soldering iron

Steps:

1. Take the two-pin wire from bag B. Insert the ends of the wire into holes in the charge connector contacts as shown below. **Important**: the wire with white stripe should be soldered to the shorter contact (this goes to the center pin, which is the positive contact).

2. Solder the wires. Use flush cutters to trim the soldered wires.
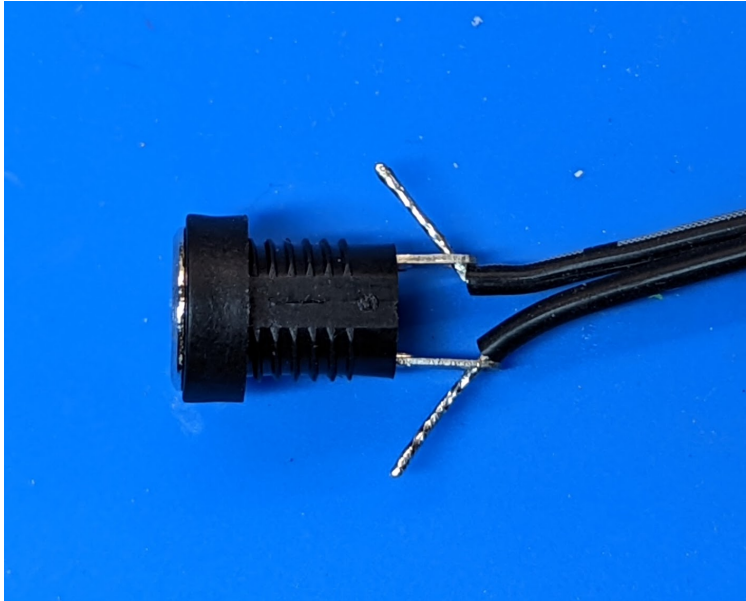
3. Insert the charge connector in the 3d printed spacer as shown below. Push against a flat surface (e.g. the table) to make sure it is all the way in.
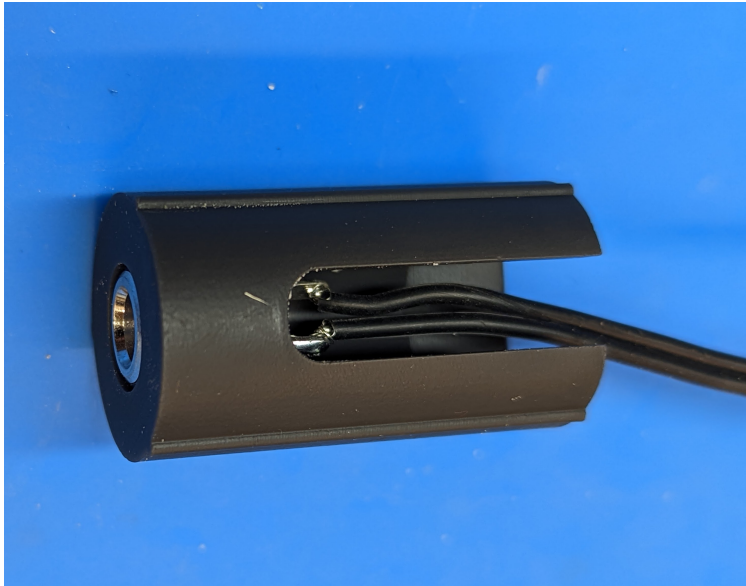

4. Take the LED assemblies created previously. Select the one with PDB labeled "CHARGE" (blue PDB). **Important: make sure you got the correct assembly!** Put the 3d printed spacer with charge connector onto the other end of the dowel, making sure that the opening in the spacer is on the same side of the dowel as the two holes in the PDB.
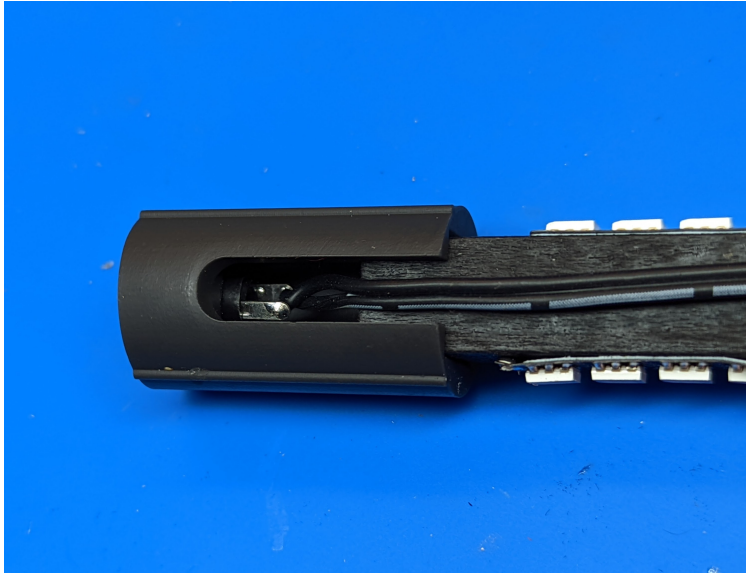
5. Run the wire along the wood dowel; straighten it to remove twists. Insert the tinned ends of the wire into the holes in the PDB. **The wire with white stripe should go into the hole labeled "5V".** Solder the wire and then trim the wire ends protruding on the other side.

Bag B also contains the charge adapter - keep it to use when charging the staff.
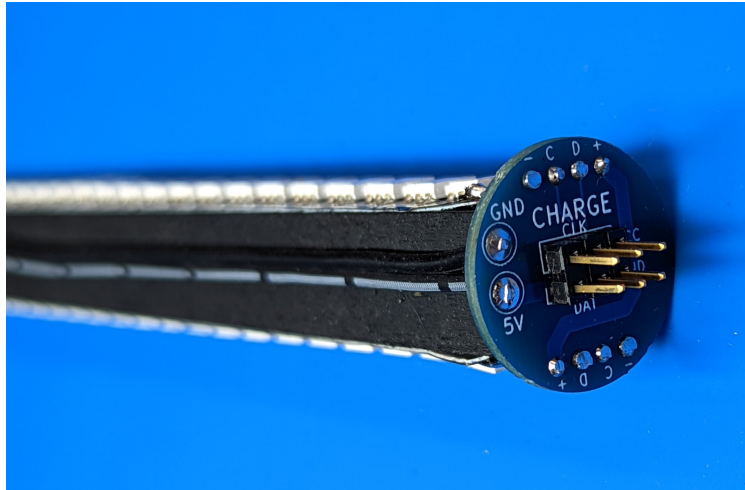
3.1.7 Step 4: Switch connector

Materials and tools:

- Bag C from the kit

1. Switch
2. 3d printed housing for the switch
3. 2-pin wire (55cm, 20 AWG)

- flush cutters, soldering iron

Steps:

1. Take the two-pin wire from bag C. Insert the ends of the wire into holes in the switch terminals as shown below. Note: one of the wires must be soldered to the **middle** terminal, and the other, to one of the other terminals (doesn't matter which one). It doesn't matter which of the two wires is soldered to the middle terminal.

2. Solder the wires. Use flush cutters to trim the protruding end of the wires.

3. Using flush cutters, cut open the plastic retention tabs on both sides of the switch as shown below. Note: it is recommended to cut it below the "joint".

4. Insert the switch in the 3d printed spacer as shown below.

5. Take the remaining ("SWITCH") LED assembly, with black PDB. Put the 3d printed spacer with the switch onto the other end of the dowel, making sure that the opening in the spacer is on the same side of the dowel as the two holes in the PDB.

6. Run the wire along the wood dowel; straighten it to remove twists. Insert the tinned ends of the wire into the holes in the PDB. It doesn't matter which wire goes into which hole. Solder the wires and use flush cutters to trim the wire ends protruding from on the opposite side of the PDB.

3.1.8 Step 5: Finishing LED assemblies

1. Mix some epoxy resin.

2. Take the two LED assemblies created in the previous steps. Peel off about 1 cm of the LED strip (from the end farthest from the PDB), add epoxy underneath and put back. Repeat with all 4 LED strips. Use zipties to hold LED strips in place while the epoxy sets.

3. Straighten the wires that go from switch and charge connector to PDBs; push any slack inside the 3d printed spacer so that the part of the wire running along the dowel is taut. Add epoxy in 2-3 places along the dowel to attach the wire to the dowel. Again, use zipties to hold wire in place.

4. Leave the LED assemblies aside for an hour until epoxy sets. After that, remove and discard the zipties.

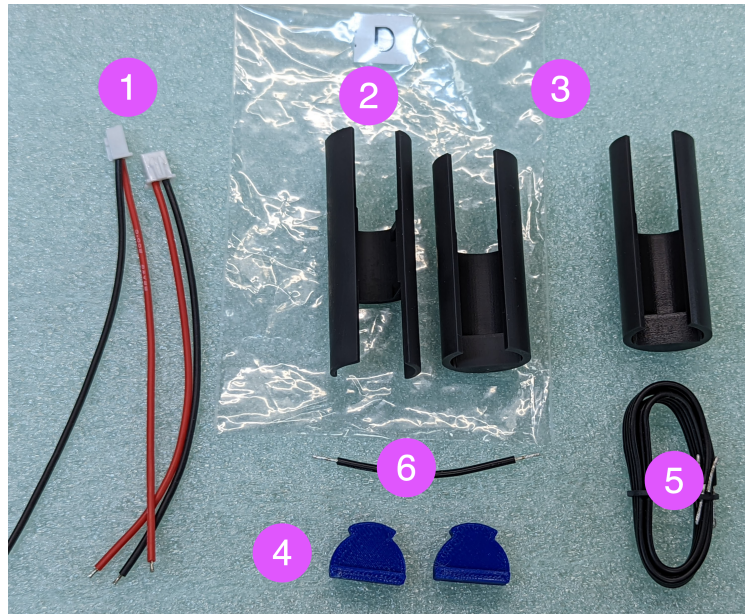This completes the construction of two LED assemblies.
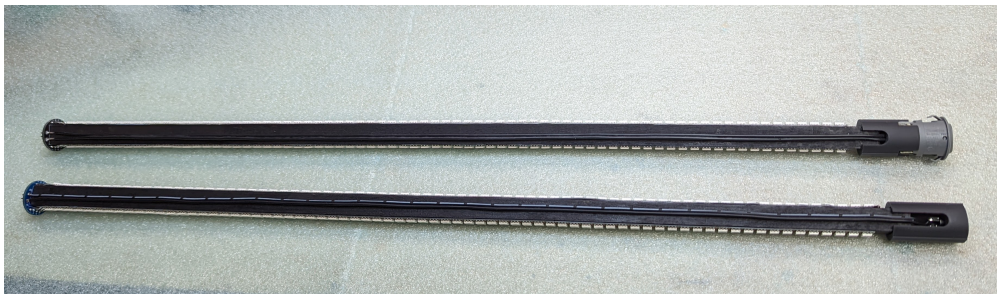
3.1.9 Step 6: Batteries

Warning: In this step, you will be soldering leads to Li-Ion batteries. This could be dangerous if not done right! Please read all instructions carefully and wear eye protection. You are working at your own risk!

Materials and tools:
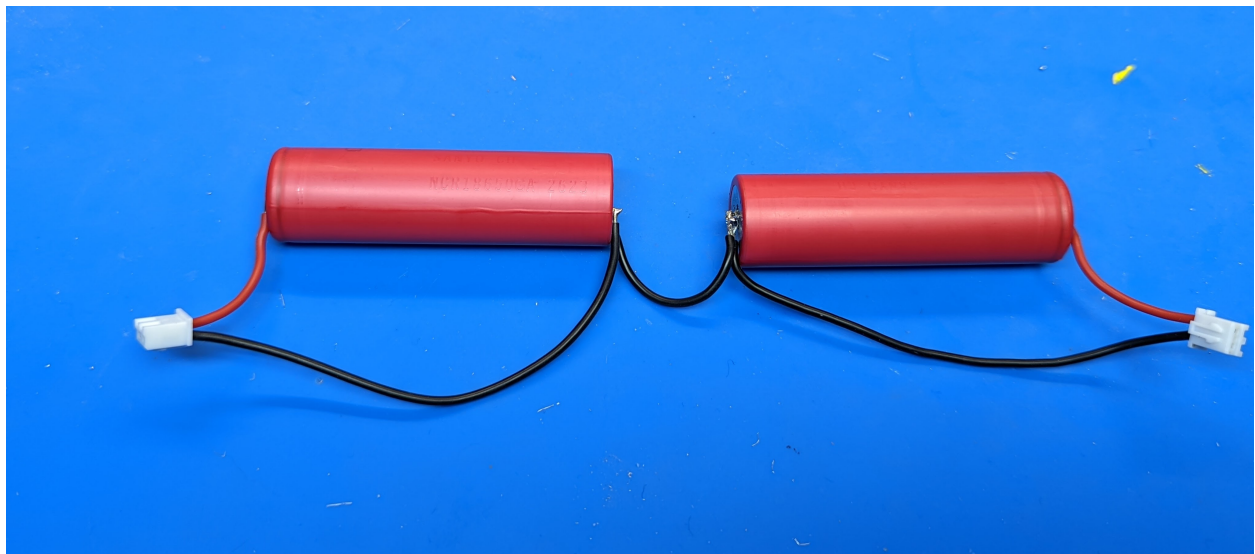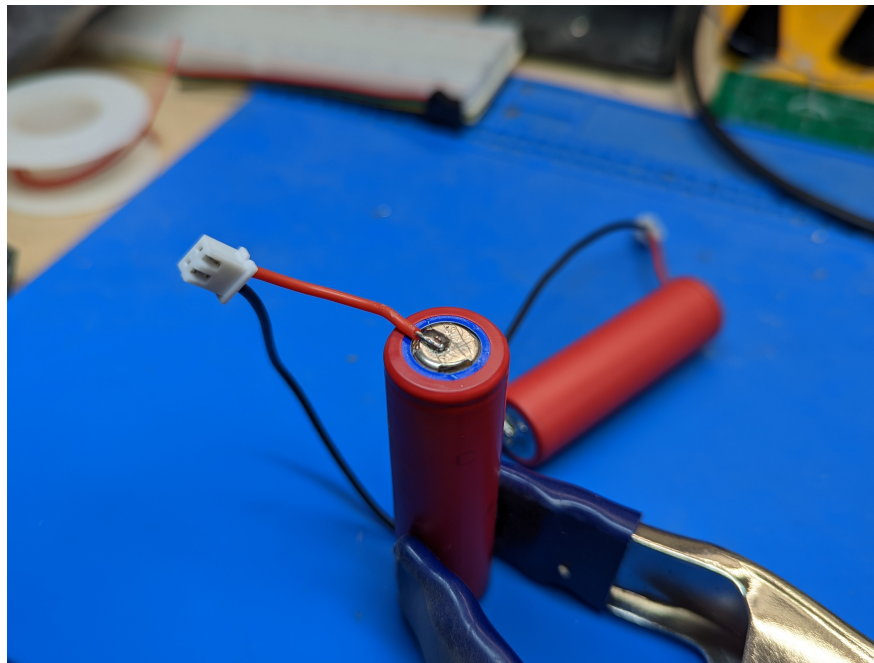
- Bag D from the kit

1. two 2-pin wires, with JST XH connector

2. 3d printed spacer, to go between batteries

3. Two 3d printed spacers to go at the ends of batteries

4. 3d printed "plugs"

5. 4-pin wire (22cm, 22AWG)

6. Wire, 5.5 cm, 22 AWG

- Two 18650 Li-Ion batteries

Steps:

1. Find the two 2-pin wires with XH connectors. In each of them, cut the **red** wire to the length of 3.5 cm (not including the connector). Strip about 5mm of the red wire and tin.

2. Solder the red lead of the 2-pin wire connector to positive (+) terminal of each battery. Follow instructions on this page for soldering. Tip: an easy way to keep the battery vertical while soldering is by using the clamp as shown in the photo below.

3. Turn each of the batteries over, with the negative terminal up. Solder the black lead to negative terminal.

4. Take the short black wire and solder it to negative terminals of both batteries as shown below. Take care not to desolder the previously soldered wires.

5. Use voltmeter to check the voltage difference between the positive terminals of the two batteries. If it is more than 0.1V, find a low ommage resistor (1 Ohm or about); insert it into positive terminals of the two battery connectors and leave for an hour to equalize the voltage.
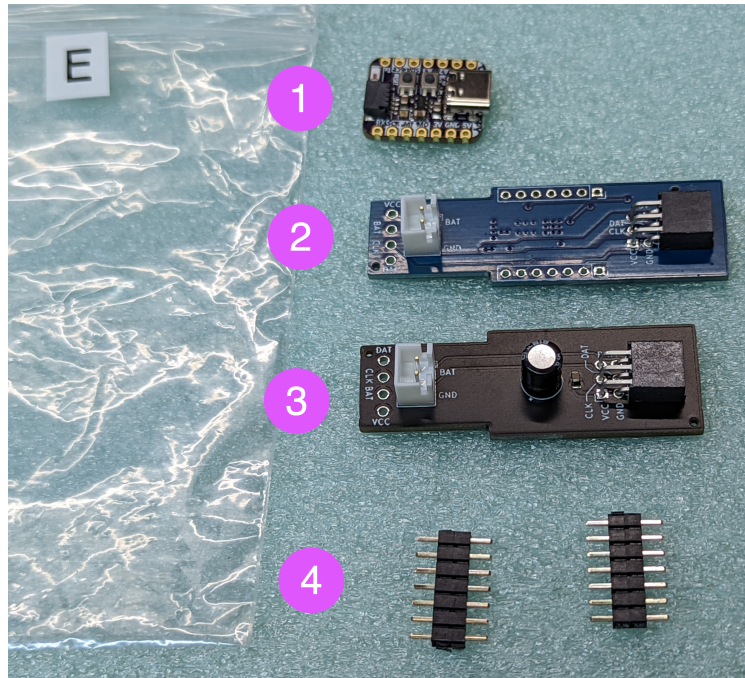
Bag D also contains 3d printed spacers and 4-pin wire; they will be used in the following steps.

3.1.10 Step 7: Controller assembly

Materials

- Bag E from the kit

1. QT Py ESP32-S3 MCU, preprogrammed
2. Custom-made POV controller board (blue), containing Inertial Motion Unit, battery charge circuit, and more.
3. Switch connector board (black)
4. Two 7-pin headers

- 4-pin wire, left over from the previous step

Steps:

1. Before doing any work, get the ESP32-S2 Qt Py microcontroller from the bag and test it. To do that, connect it by USB cable to a computer or charger to power it up. The on-board NeoPixel LED should blink red, then yellow, then turn green. **Wait for 20-30 seconds** and open the WiFi connection dialog of your computer. You should see there a new WiFi network with the name *POVSTAFFXXXX*, where XXXX will be replaced by a 4-digit number, unique for each staff. Connect to this network; the password is in the information sheet which was included with your kit - if you misplaced it, email *irobotics.store@gmail.com* for help. Type the following address in the URL field of the browser: *http://povstaff.local:8080* (note: the staff doesn't support https protocol. If your browser gives you a warning about unsecure connection, click on "continue to site".) You should see the webpage of the staff, which looks as follows:

   If you see the files *imagelist.txt*, *rg-lines.bmp* and *bg-triangles.bmp*, everything is good - you can disconnect the USB cable and proceed. Otherwise, check the troubleshooting section.

2. Solder the headers to the custom POV controller shield as shown below. **Make sure to solder it on the correct side of the board.** The easiest way to keep the headers straight while soldering is to plug them into a breadboard.

			Size: 1.50 MB (1.572.864 B), used: 48.00 kB (49.152 B)				
	by-triangles.bmp	15.606	D	R			
File Drop Zone	imagelist.txt	40	D	R	E		
	rg-lines.bmp	20.790	D	R			
	Download all files						
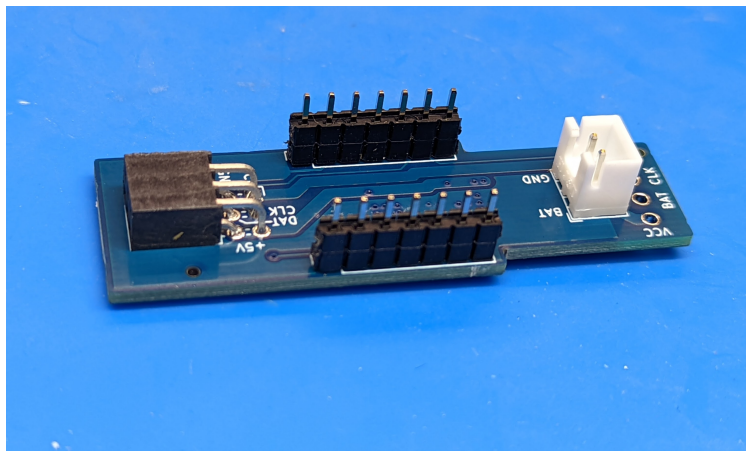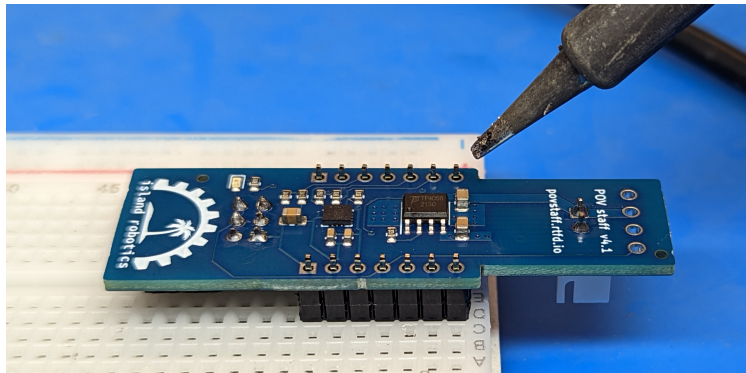
3. Solder the ESP32-S2 QT Py board to the headers, forming a "sandwich" of two boards as shown in the photos below. Make sure to solder it in the correct orientation: the USB connector should be on top and facing the same way as the black 6-pin header on the controller shield.
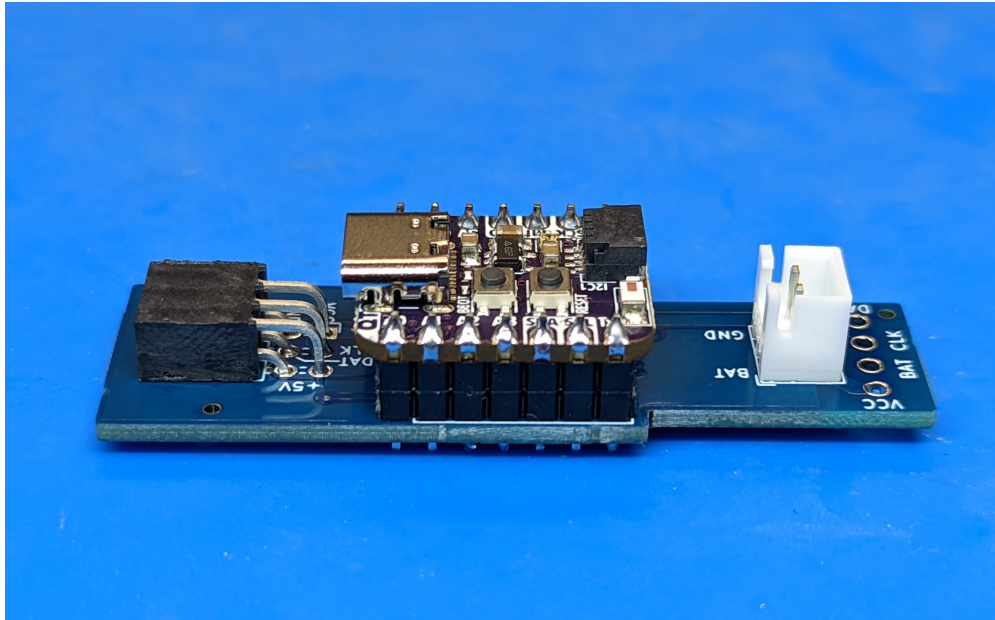
4. Take the 4-pin wire left over from the previous step and solder it to the controller board on one side and to the switch connector board on the other as shown below. On each board, the **wire with white stripe should go into the hole labeled "VCC"**.

3.1.11 Step 8: Testing

Before continuing, let us do the final test. Make sure to clear large area on your desk or floor for this step.

Take the controller assembly you had created in the previous step and plug it into the LED assemblies as follows:

- The POV controller shield with the QT Py should be plugged into the LED assembly labeled CHARGE.

- The switch connector board should be plugged into the LED assembly labeled SWITCH

The LED assemblies are not interchangeable!

In each case, the board must be plugged into PDB so that the label CHARGE (or SWITCH) should be above the plugged board:

Double-check that everything is plugged correctly. Make sure that the switch at the end of SWITCH LED assembly is in the middle (Off) position.

Now, take the batteries. Plug the battery connectors into the 2-pin JST XH connectors on the POV shield board and the switch board (doesn't matter which battery goes into which board).

Turn the switch on (you will have to try both positions to figure out which of them is ON).

The staff should come to life; it will show the battery voltage, by lighting part of the LED strips. The longer the strip, the higher the battery charge.

Note: the software uses the motion sensor (IMU). If you turn the staff on while the staff (to be precise, the electronics board containing the motion sensor) is horizonal, the staff goes into charging mode, so it will show the battery voltage but will not show any images. If you want to test images, make switch the staff on holding the sensor board vertical. See User guide for details.
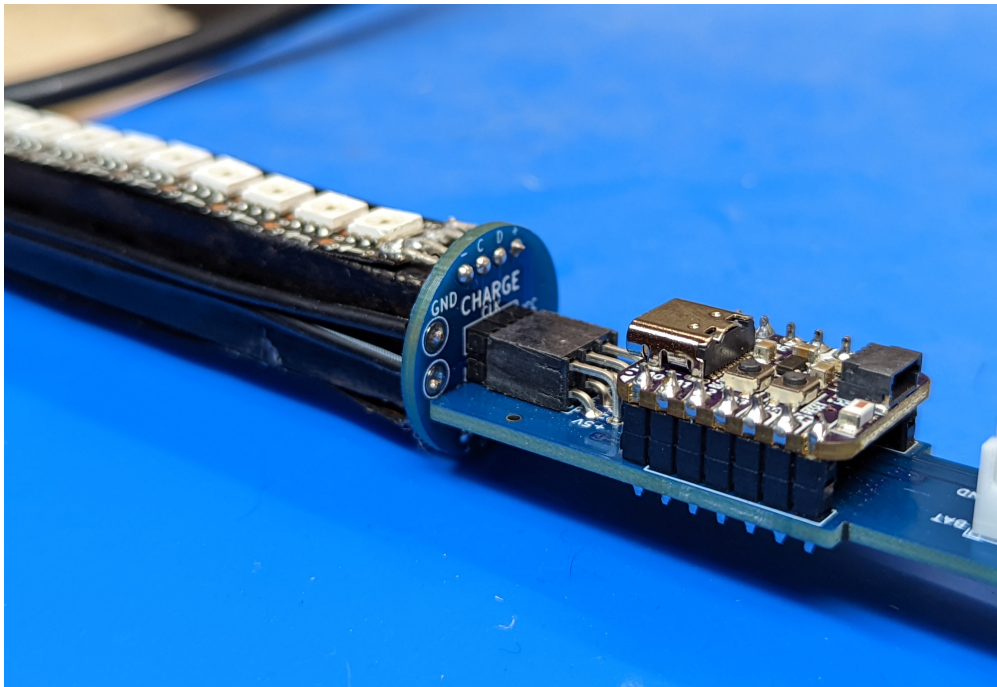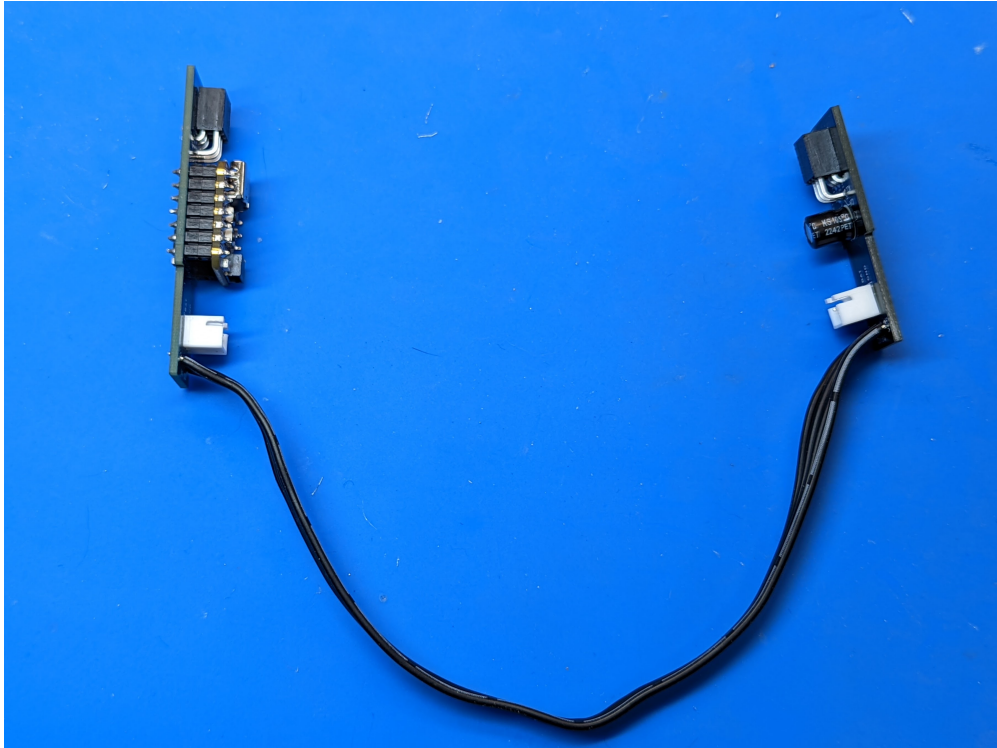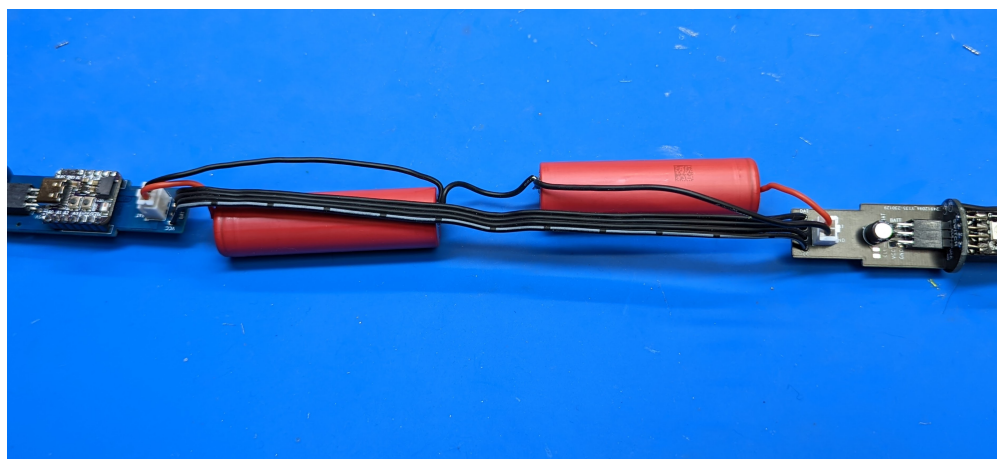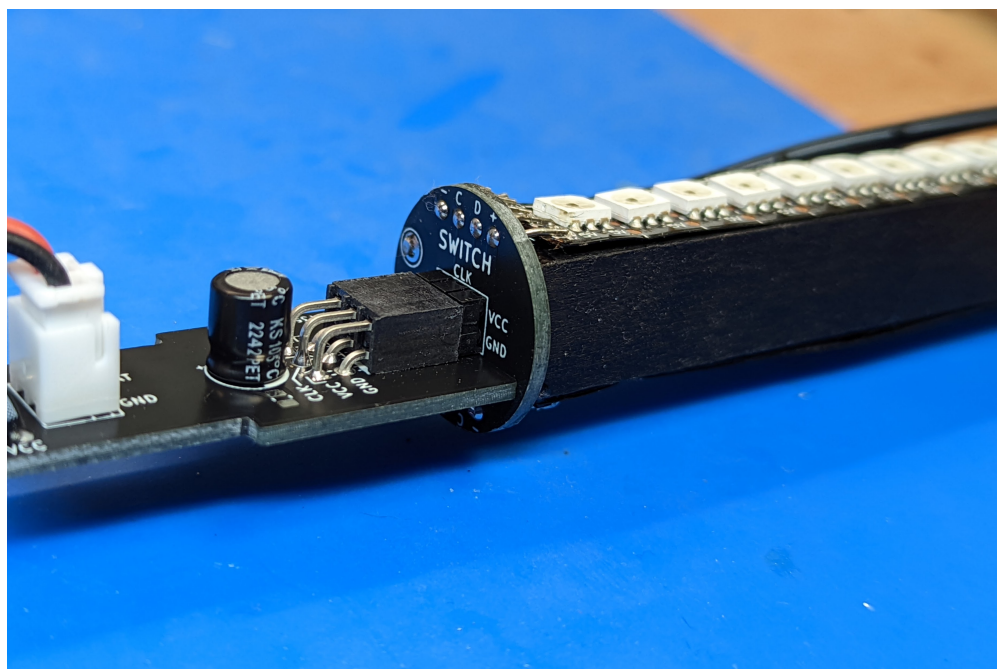

If this works, you can turn the staff off and proceed to the next step.

3.1.12 Step 9: Battery and controller assembly

1. Disconnect the batteries from the boards. Do not pull on the wires; instead, grab the plastic connector and pull it out (it takes some effort). Set the batteries aside for now.

2. Take the 3d printed spacers left in bag D. You should have one spacer that goes between the batteries, two spacers that go onto the ends of batteries, and 2 small "plugs". Make sure you have them all.

3. Take QT Py microcontroller with the POV shield, a plug and one of end battery spacers. Assemble them together, putting the "plug" onto the board and then pushing the whole assembly into the spacer as shown below. Note: the "shelf" on the plug should be facing the white battery connector. Make sure to push it all the way in.
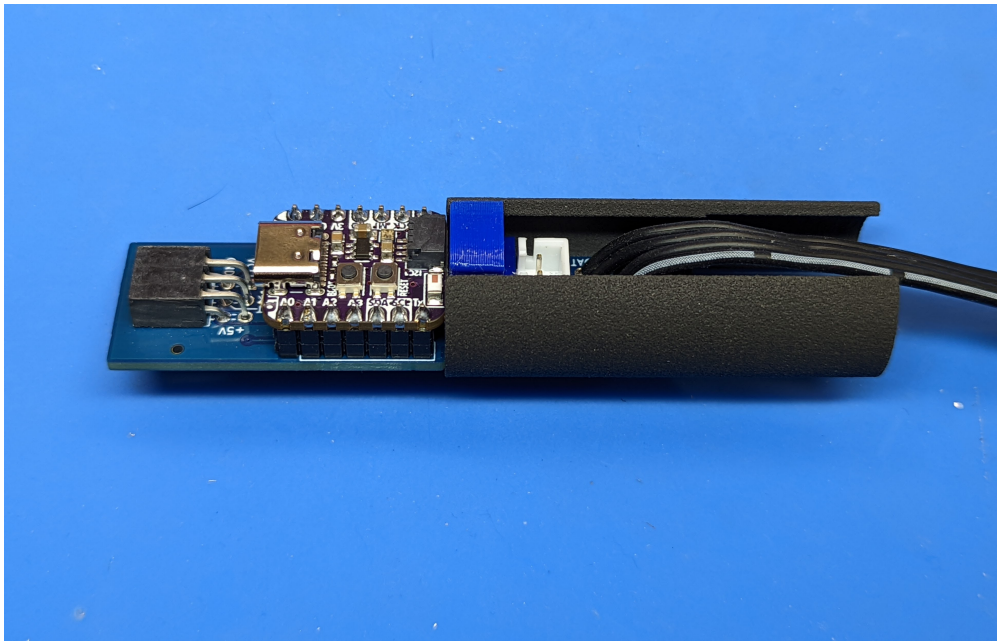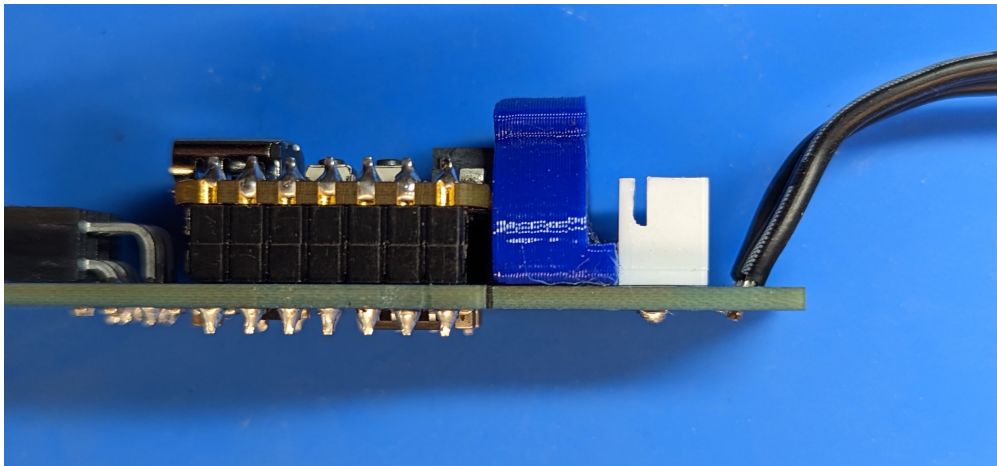
4. Repeat the same with the other spacer and plug and switch controller board.

5. Once you verified that everything fits, take it apart. Mix some epoxy glue and apply it to the outside of the plug (where it would be touching the inside of the spacer) and also on the bottom of the boards (again, where they

would come in contact with the spacer). Assemble again; make sure the boards are fully inserted into the spacers and sit straight. If necessary, use electric tape or similar methods to keep the boards and plug in position. Put aside for one hour so that epoxy sets.

6. Once the epoxy sets, insert the batteries (positive terminal first) into the spacers. Plug the battery leads into the connectors on boards. Carefully arrange the wires so that they run along the battery through the openings in the spacers, with no wires crossing. Use 3/4" electric tape to attach the spacer to the battery, as shown below. Make sure to apply the tape without any twists or kinks - otherwise, it will not fit into the tube. Do it with both batteries.

7. Finally, take mid-battery spacer. Insert the negative terminal of each battery into this spacer. **Warning**: only insert batteries from the end; do not try to force the batteries from top/bottom - you can break the spacer. Hide the slack of the wires into the spacer between the batteries, so the wires on the surface of the batteries is taut. Use electric tape to hold everything together as shown below.

8. Try inserting the whole assembly into the tube. It should go in, possibley with some friction, but it shouldn't require force. If it doesn't go in easily, try to locate the offending place (usually some slack in the wires or kink in the electric tape) and fix it.

3.1.13 Step 10: Final assembly

Materials:

- LED assemblies, from previous steps

- battery and controller assembly, from step 9

- bag F:

1. two shrink wrap sleeves

2. two foam sleeves

3. Switch end protector

4. Charge end protector

5. tennis grip tape

6. Foam washers

- Clear polycarbonate tube (11F/141 cm), from flowtoys.com

Steps:

1. Make sure you have a large area to work. Lay out the LED assemblies, battery and electronics assembly. Make sure that the switch at the end of SWITCH LED assembly is in middle (OFF) position.

2. Plug the battery assembly into the LED assemblies. As before, the side which contains QT Py MCU should be plugged into the CHARGE LED assembly, and the other side, into the SWITCH LED assembly. In each case, the board must be plugged into PDB so that the label CHARGE (or SWITCH) should be above the plugged board:

3. Double-check that everything is plugged correctly. Do the final test: turn the switch on. The LEDs should briefly light up, showing the battery charge. If they don't, check the troubleshooting section. If everything is OK, turn the switch off and proceed.

4. Start inserting the whole assembly into the tube, CHARGE end first. Do it slowly. If you meet with resistance, push gently; if it is not enough, do not use excessive force - try to locate the problem. If necessary, remove from the tube and fix the wiring or electric tape. Watch that the LED assembly does not get disconnected from the battery and electronics assembly. Continue until everything is fully in. Push to fully insert the switch; make sure the switch retaining tabs are inside the tube. If everything worked as expected, the charge connector should now be level with the opposite end of the tube or several millimeters inside the tube. In the latter case, use the included foam washers to fill the rest of the tube.

5. Take the 3d printed switch end protector (item 3 in bag F, the one with larger opening). For shipping, it might have been placed inside the foam wrap; if so, remove it from the foam wrap. Put it over the switch end of tube.
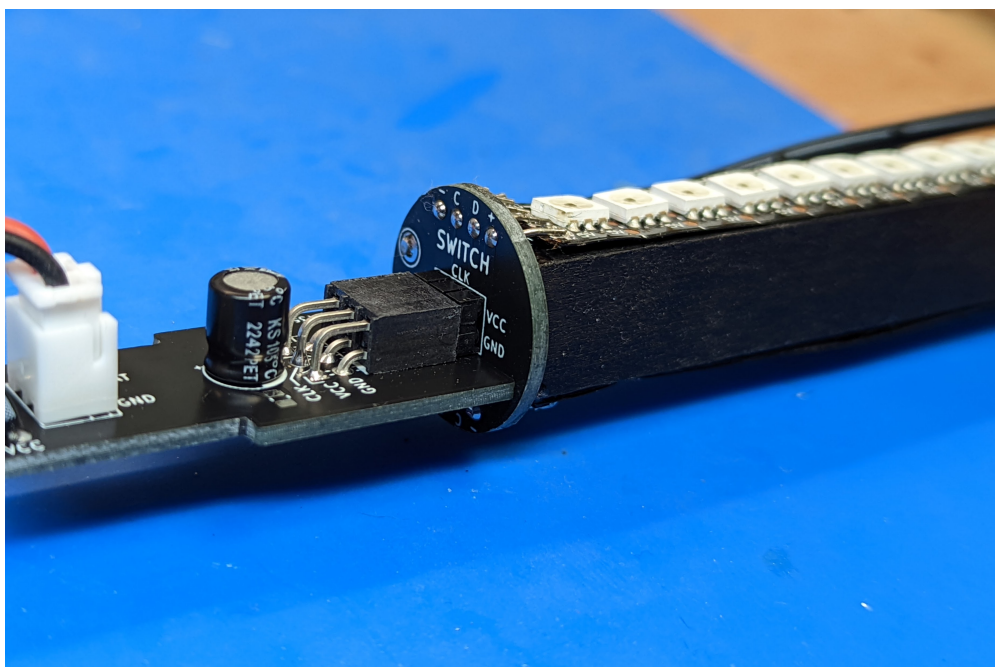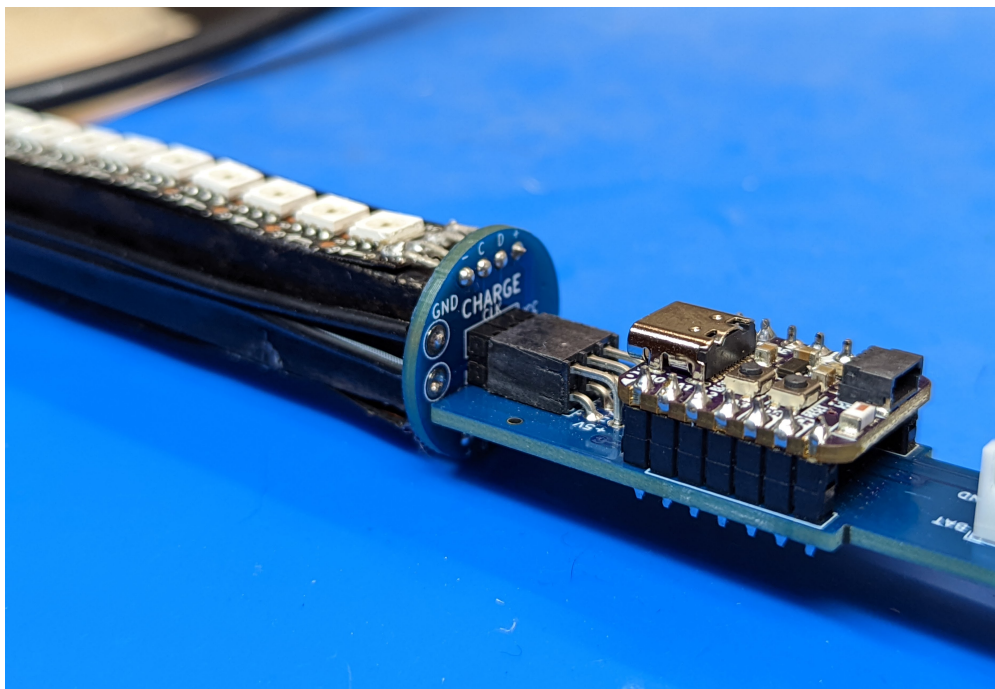
There are two small bumps inside the protector which should go into the holes in the tube; if necessary, turn the end protector until you hear the click.

6. Repeat the same with the charge switch protector (item 4 in the bag), putting it on the opposite end of the tube. Test the whole staff once again, turning it on and off.

7. Put the two pieces of the foam tube over the end protectors so that the foam tube extends beyond the protector by 2-3 mm. In 2-3 places, put some epoxy (or crazy glue) between the foam and the 3d-printed end protector.

8. Put the shrink wrap over the foam as shown in the photo below. It should extend beyond the end of the foam wrap by another 5 mm
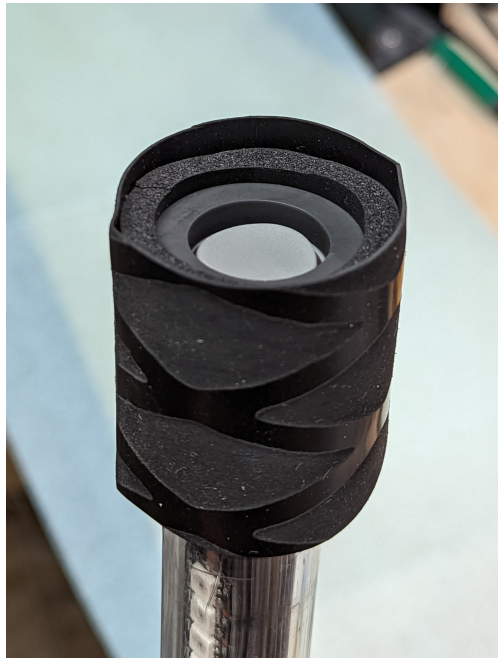
9. Use heat gun (on low setting) to shrink the shrink wrap.

10. Apply the tennis overgrip tape over the middle part of the tube, containing the battery and electronics assembly - everything between the ends of LED assemblies. You can watch this video to see the proper way of applying the overgrip tape: https://www.youtube.com/watch?v=HNc34XlUBww. Make sure to keep the overlaps between tape turns small - if you make them too large, your tape will run out before you reach the end of battery assembly.

This completes your staff assembly - congratulations!!

Please check the User Guide for instructions on using your staff.

3.2 User Guide

3.2.1 Basic usage

To **turn the staff on and off**, use the switch at one end of the staff. It is a 3-position switch; middle position is always OFF; one of the two other positions is ON.

As soon as you have turned the staff on, it will show the battery voltage, by lighting part of the LED strips. The longer the strip, the higher the battery charge.

If you only see one or two LEDs light up, the battery charge is too low for use. You need to recharge the batteries as described in the next section.

After using the staff, **make sure to turn it off**! If left on, LEDs will drain the battery rather fast - even if you are not using the staff. To remind you to turn it off, the staff will be blinking red LEDs once every 30 seconds while it is on and not being used.

To **start the show**, turn the staff ON and start spinning it. The staff will begin showing your first image, one line at a time, and will continue doing that as long as you are twirling the staff. It will adjust the interval between successive lines depending on the rotation speed, to keep the image ratio close to original regardless of how fast you are rotating the staff.

You can find a number of staff spinning tutorials on YouTube - just search for "staff spinning tutorials for beginners". I learned a lot from these two: https://www.youtube.com/watch?v=L0madJzk3Wc and https://www.youtube.com/watch?v=gm5D8TS3mNY.

The staff will continue showing the image for the duration given in *imagelist.txt* file or until you pause the staff as described below, whatever comes first. If duration for a given image was not provided, the staff will continue showing this image until you pause.

To **pause** the show or move to the next image in the list, stop the staff **in vertical position**. It will go blank; as soon as you start spinning it again, it will resume the show, moving to the next image. After reaching the last image in the list, it will loop over, starting again with the first image.

After you are done, do not forget to **turn the staff OFF**, to avoid draining the batteries.

3.2.2 Charging

To charge the staff, turn it off by setting the switch in the OFF position. You can charge using one of the following methods.

- Use a 5V power supply with 5.5mm OD/2.1mm ID barrel jack (center pin positive). Plug it into the connector at the charging end of the staff (opposite the switch).

- Alternatively, use the included USB C to 5.5mm barrel jack adapter and a USB C cable, plugged into a USB charger. Note: if using a USB C to USB C cable, many "smart" chargers (e.g. Apple macbook charger) will refuse to charge the staff as they require the connected device to identify its capabilities. To avoid this problem, use a USB C to USB A cable.

Full charge should take about 5 hrs.

3.2.3 Uploading new images

Finding images

You can use any image satisfying the following requirements:

- Images must be in bitmap (BMP) format, with 24 bit color depth. Use any software you like to convert images in other formats to bmp - e.g. you can use Microsoft Paint 3D.

- The images are shown one **horizontal** line at a time; thus, it is recommended to use images with **width** of 72 pixels - to match the number of LEDs on the staff. Maximal image size is 72x288 pixels.

- Image filenames must be at most 30 symbols long and can only contain letters, numbers, dashes and underscores. No spaces or special symbols!

You can create your own images or search for existing ones. A good source for POV image patterns is Visual POI Zone. When downloading images from there, make sure to choose *Visual poi V4 mini (72px)* option. You will also need to rotate images 90 degrees.

Please note that the same color (i.e. the same RGB values) can look quite different on the screen of your computer and on LED strip. Experiment with colors to get some feel for it.

To help you figure out correct rotation and orientation of images, the pictures below show the same image in BMP file and how it will look when using the POV staff.

Directory *images* in the GitHub repository https://github.com/shurik179/povstaff contains some sample images and *imagelist.txt* file. These images have already been uploaded to the staff.

Creating imagelist file

Once you have found or created your own images, move them all to the same folder on your computer.

Now, you need to create a list showing in which order these images should be played during the show. Create the file *imagelist.txt* in the same folder as the images (or open the file if it already exists) and put there the list of image files in the order you want to use them in your show, one filename per line. Include the *.bmp* extension in each filename, and put leading slash (/) before each filename, as shown below. Optionally, you can also add how long the image should be shown, in seconds (whole numbers only!), separated from filename by one or more spaces:

```
/image1.bmp 20
/image2.bmp 41
/image5.bmp 10
/image1.bmp
```
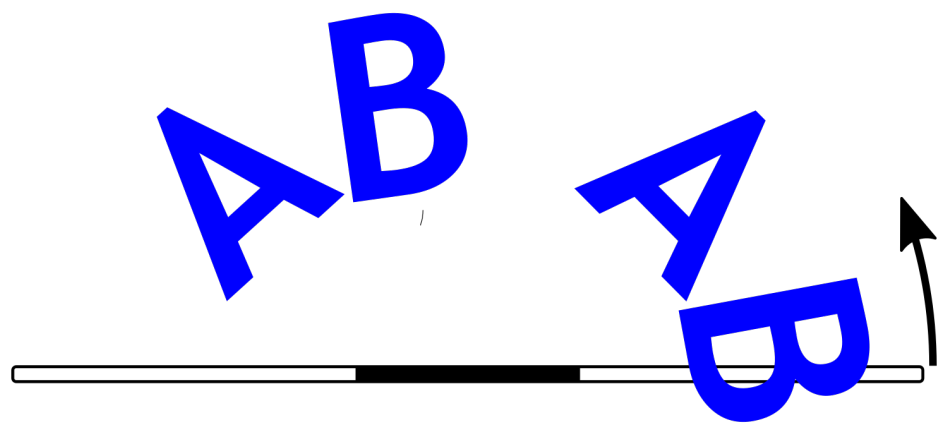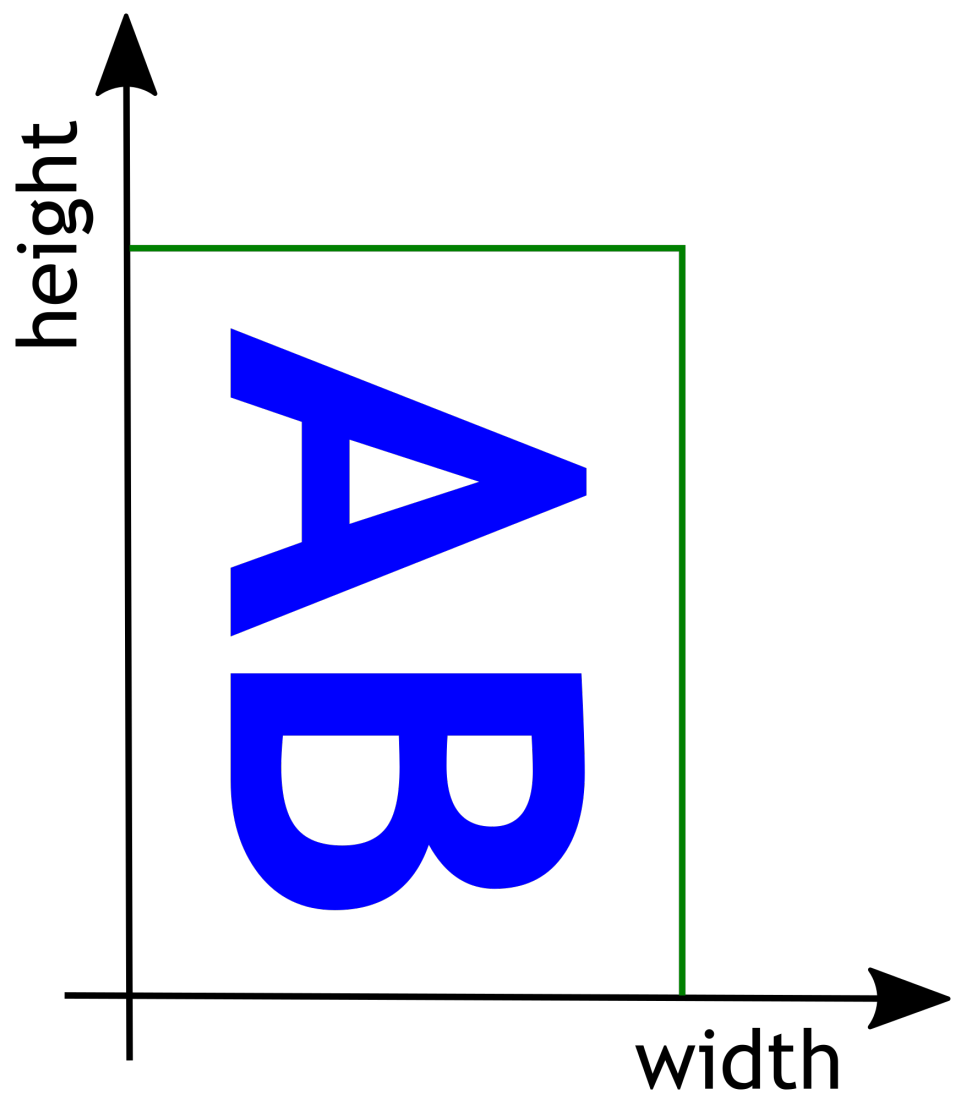
You can include some image file more than once, or not at all - it is your choice. The name of your image list must be *imagelist.txt*, all lower case.

Uploading images

To upload images, place the staff on a horizontal surface (e.g. on the floor) and turn it on. It will briefly light up to show the battery voltage and then go into upload mode; to indicate that, every 4th LED should be lighted in light green color.

Wait for 20-30 seconds and open the WiFi search dialog of your computer. You should see there a new WiFi network with the name *POVSTAFFXXXX*, where XXXX will be replaced by a 4-digit number, unique for each staff. Connect to this network, using the password which you can find in the information sheet included with your kit; if you misplaced it, email *irobotics.store@gmail.com* for help.

Type the following address in the URL field of the browser: *http://povstaff.local:8080* (note: the staff doesn't support https protocol. If your browser gives you a warning about unsecure connection, click on "continue to site".) You should see the webpage of the staff, which looks as follows:
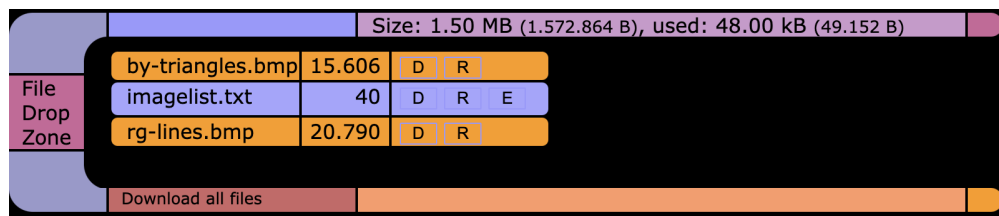
Drag and drop the image files and the imagelist.txt file to the *file drop area* area of the webpage.

You can delete files you no longer need by pressing on letter 'D' next to the filename. You can also edit imagelist.txt file online by clicking on 'E'.

Once the files have been uploaded, just turn the staff off.

3.3 License and Acknowledgments

This project was created by Alexander Kirillov <irobotics.store@gmail.com>.

All source files for the project (both software and hardware) are available under MIT license from the project GitHub repository: https://github.com/shurik179/povstaff. Please check *LICENSE* file in that repository for details.

Many thanks to users of the previous versions of this staff for their feedback and suggestions: Christopher Biernacki, Kevin Williams, and many others.

Any comments/suggestions are appreciated; please email irobotics.store@gmail.com.