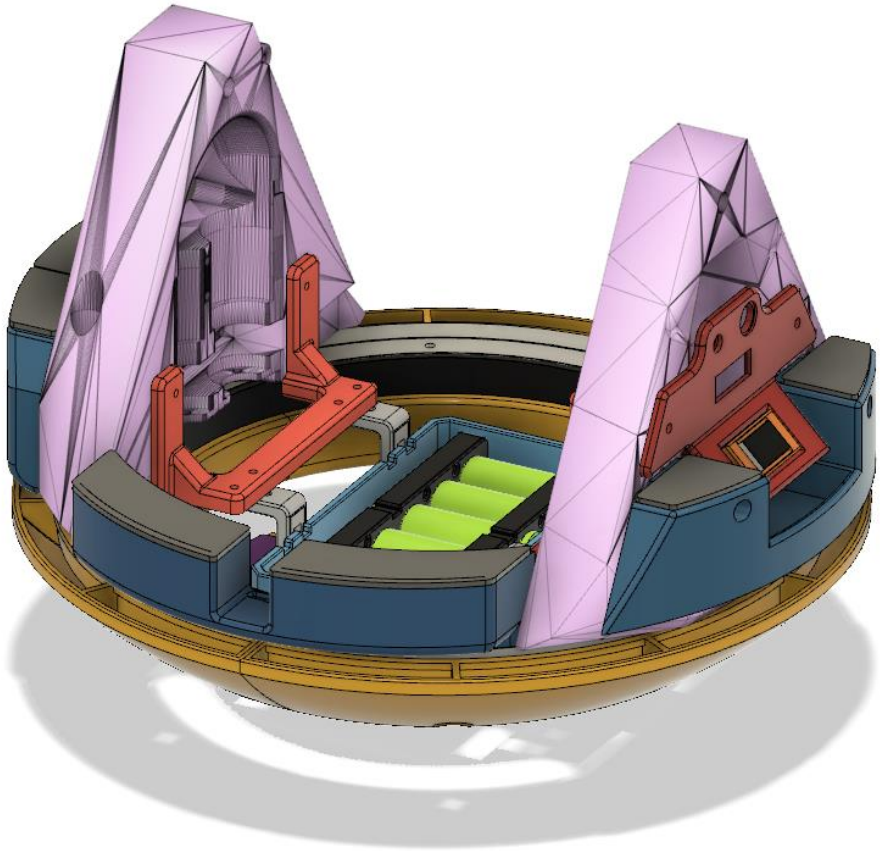
Joe’s Drive MK3 Flywheel

Installation Guide and BOM



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1. Contents

2. About the MK3 Flywheel

The MK3 Flywheel is the next evolution for Joe's Drive. After taking my Joe's Drive with a MK2 Flywheel and MK2 Head Tilt, I felt the stability and operation was not quite as good as I was seeing from Joe's initial videos. It turns out that those videos were based on his MK0 flywheel; aka no flywheel, where the batteries and ballast was completely under the drive. The goal of the MK3 Flywheel is to gain back this amazing drivability while still retaining the flywheel.

To see more about why this project was created and how this design addresses those issues, please watch the YouTube video:

https://youtu.be/Yd66EGwc7J0

3. Bill Of Materials

The bill of materials (BOM) has been separated out into a separate Excel spreadsheet for ease of reading: **MK3 Flywheel BOM.xlsx**. Make sure to choose only ***one*** battery solution: ***either*** the custom 21700 battery pack ***or*** a portable jump starter from Amazon.

4. Parts Printing

The following parts and quantities need to be printed to do the conversion. Note the extra parts required are called out if doing the 21700 custom battery pack as opposed to one of the portable jump starters.

Solid Parts

- (3) Flywheel Third V3 x3
- Back Aframe Support V3
- Front Aframe Support V2
- (2)Battery C-Clamp V4 (x2)
- Under-Battery Ballast Holder V1
- Under-Battery Center Lid
- (2) Under-battery Side Lid (x2)
- Back Ballast Holder V2 [MK2 Head Tilt *only*]
- Front Ballast Holder V1 [MK3 Head Tilt *only*]
- S2S Balancer V2
- One of the following [optional]
  Power Switch Holder V2
  Power Switch Holder V3 [advanced for Suoaki battery]

21700 Custom Battery Pack Solid Parts

- Battery Box V1
- (2) 21700 6x Holder (x2)
- Voltage Display Holder [if using Power Switch Holder V3]

TPU Parts

- (12) Flywheel Plug V7 [optional]
- Side Lid L; Side Lid R

- Back Lid L; Back Lid R [MK2 Head Tilt *only*]
- Front Lid L; Front Lid R [MK3 Head Tilt *only*]

All the parts are recommended to be printed with 3 shells and at least 20% infill. The Flywheel Plug needs to be printed in TPU. Depending on the hardness, the infill should be high; I used 90% for NinjaTek which is a softer material with a shore hardness of 85A. If using something with a harder shore hardness like 95A, then a lower infill might be okay.

5. Existing Flywheel Removal

5.1 MK2 and MK1 Flywheel Removal

To being installing the MK3 flywheel, the MK2 (or MK1) flywheel must be removed. To remove the flywheel, undo the 6 countersunk screws and nuts that hold the flywheel into place. I use a socket wrench with extension for the bottom bolts and prop the drive up slightly while undoing the bolts that are exposed on the left side of the drive (under the left axle).

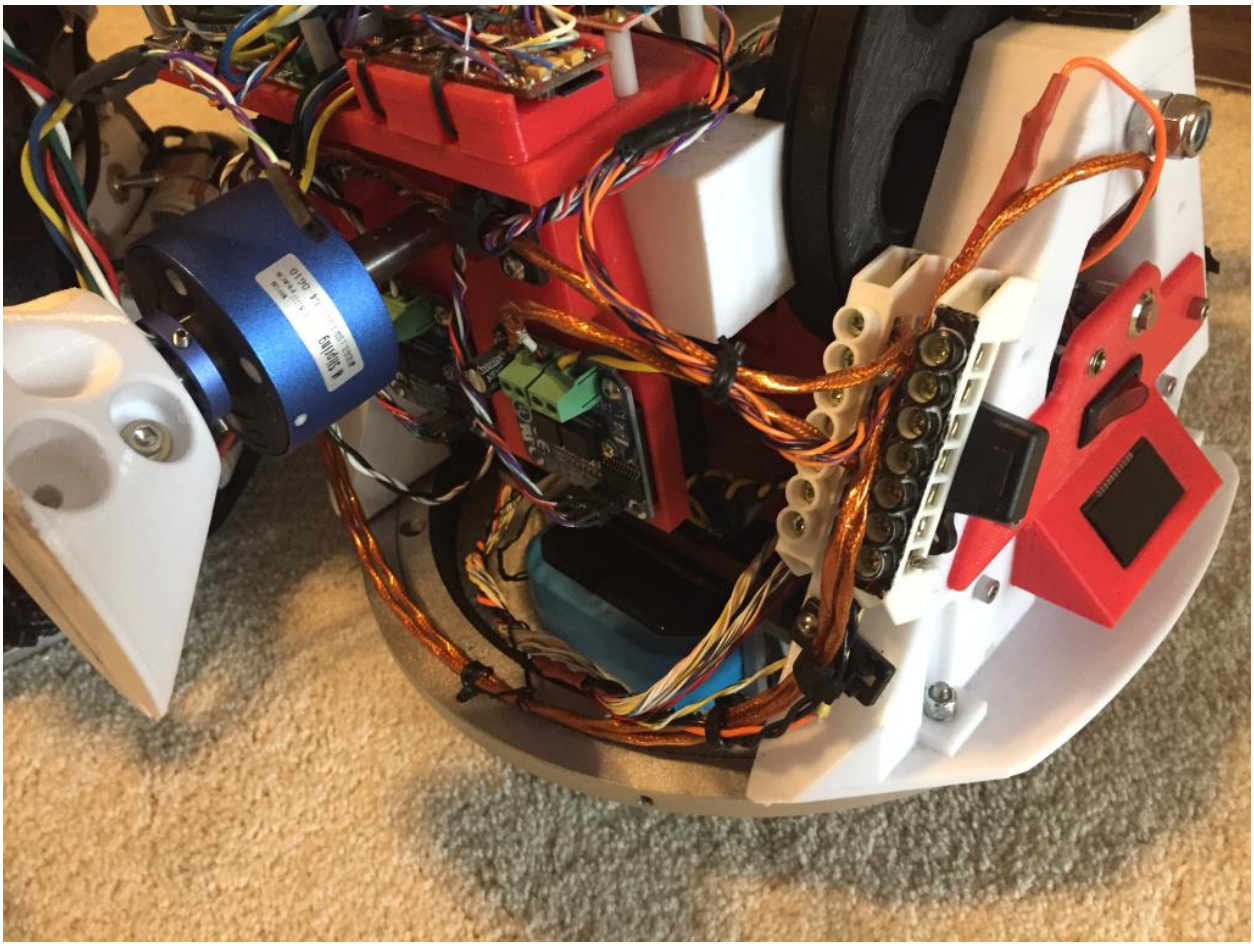

Figure 1 – Access to the existing 6 flywheel screws and bolts can occur from the left side of the drive under the left axle.

With the flywheel removed set aside the flywheel gear as well (this will be used later). The drive should now be sitting directly on the lazy Susan.

5.2 Mk1 A-Arm removal

In the event that the MK1 design for the flywheel is still being utilized (1 motor in the front A-frame) then it is strongly recommended to remove that A-arm, replace with the MK2 A-arm that accepts two motors, and purchase the two 1,621 RPM motors from Servo City per Joe's MK2 flywheel documentation.

6. Non-Flywheel Battery Tray

Joe's original drive used an under-battery tray sans flywheel, and as thus did not have turn on the spot at all. If by chance this is the version that is being modified, the A-frames need to be removed and discarded as well, bringing the drive to the state where it is just the center square, "pants", and head tilt (MK2 or MK3 is acceptable, ie the single-axis with robot city motor, or the dual axis using two servos). I will forgo instructions here as I never fully printed this version, going straight to the MK2 flywheel.

7. Battery Removal

Regardless if you are using the Suaoki already, the existing battery solution must be removed to allow the battery to be mounted underneath the drive.

7.1 Suoaki Box Removal

The existing Suoaki battery if installed in the box must be removed. First, unplug the battery from the 5mm banana plug, which is the main power connection to the battery.

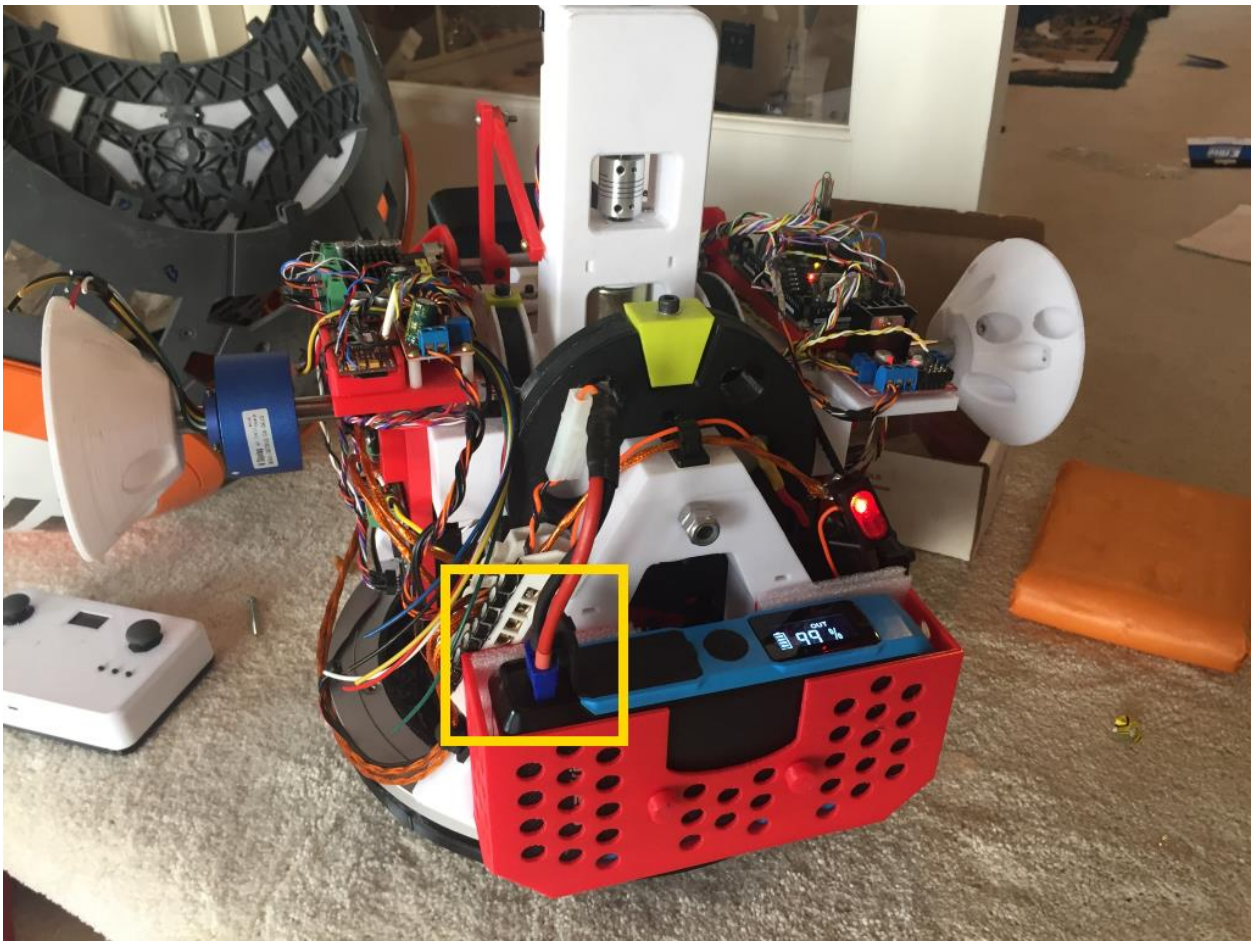

Figure 2 – Unplug the 5mm banana plug to disconnect the battery from the drive.

With the battery set aside, the box can be removed unbolting the 4 screws that go through the A-frame and have nuts on the back.

Figure 3 – Remove the four screws and nuts holding the basket. The first has already been removed in this photo.

At this point the battery and box should be fully removed and there is no additional work.

7.2 D Cell Battery Removal

If using the D Cell solution with split D Cells on each A-Frame, both sides will need to be removed. First, cut the zip ties that are used for secondary protection for the battery. Next, carefully pull out the batteries one by one, being careful not to scratch the battery on the metal as it can damage the seal and allow for shorts. Finally, the screws and bolts should be exposed, and these can be removed, and the box can be pulled off.

Figure 4 – Removal of the D Cell battery solution requires cutting the zip ties, carefully removing each battery taking care not to scratch it on the metal clips, and finally removing the screws.

Once it is removed, the removal of the other side needs to occur. Note that the side with 6 batteries will have four screws compared to the side with two batteries which will only have two. At this point all batteries should be removed from the drive.

8. Lazy Susan Modification

Required Parts

Part	Quantity	Desc
Countersink drill bit for M4	1	From the counter-sink drill bit pack
Countersink drill bit for M3	1	From the counter-sink drill bit pack
M3 nut (or m3 set-sert)	1	
M4 x 45mm	4	Bolt to A-frames from underneath
M4 locknut	4	
M4 washer	4	
M3 x 10?	1	Goes under the side to side motor (I didn't measure this before install so not 100% sure on height)
M3 washer	1	

M3 locknut	1	

Table 1 – Parts required to modify the flywheel

To accommodate the new flywheel, it is required that the lazy Susan must be counter sunk for screws on the bottom as well as the top. The top was a requirement from the MK1 and MK2 design, so now it is being extended. To countersink, use the center drill bit in the hole to create the 60 deg angle.

8.1 Countersink Holes

The five holes that need to be countersunk are shown below. Note that it is better if the hole for the side to side motor is sunk with a smaller bit, as I recommend using a 3mm (or 6-32) bolt there as compared to the 4mm (or 8-32) bolts for the 4 A-Frame ones.

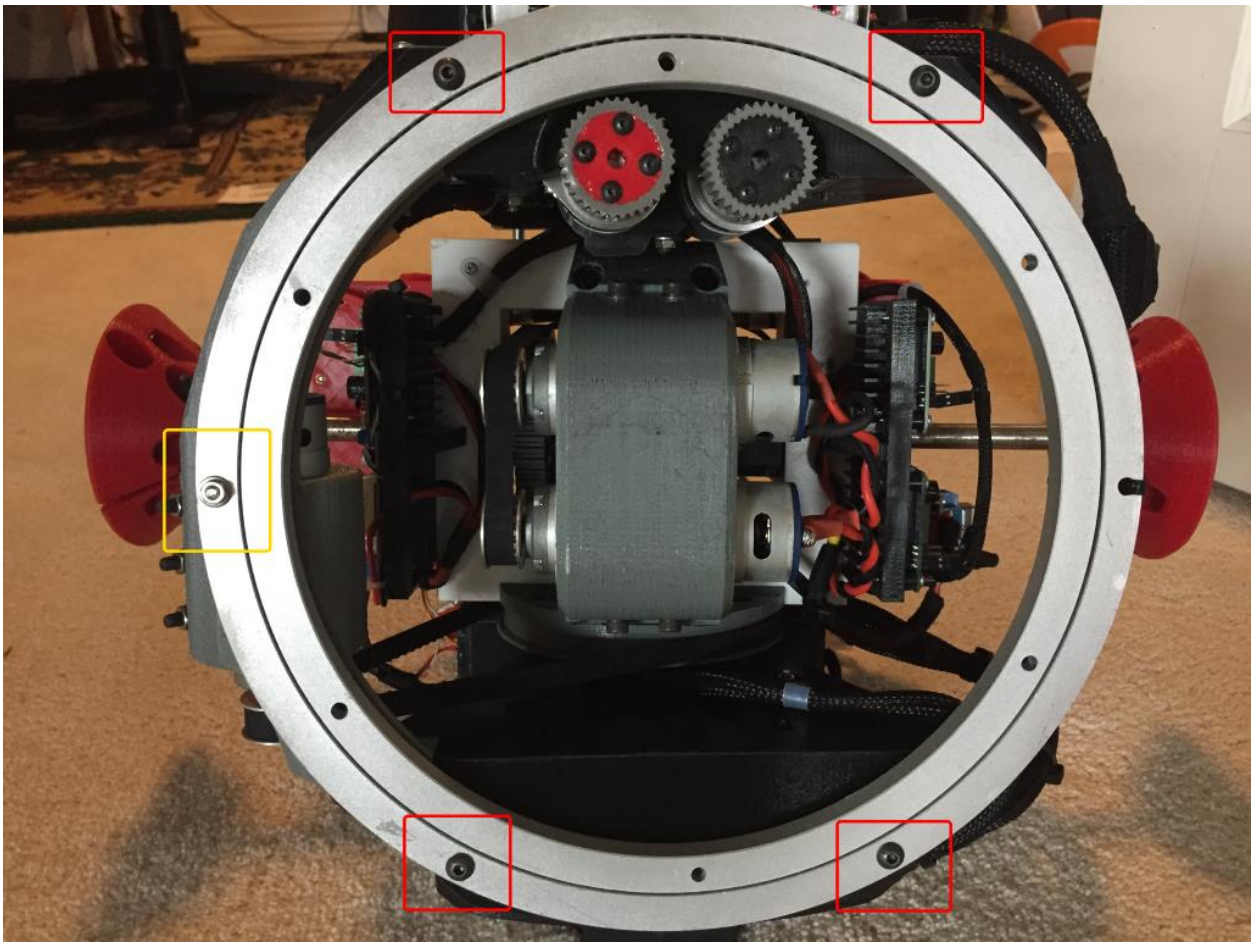

Figure 5 – Five holes that need to be drilled for countersink screws using the center bits. The ones marked in red should use M4 (or 8-32) screws, while the one marked in yellow should use a 3mm (or 6-32) screw, so use the appropriate center bit.

I recommend clamping the lazy Susan down on a drill press to get the most accurate result. Drill in small increments, periodically checking with the screw until it just is flat with the surface. With a drill press you can mark the first one so that the remaining 3 of the same will be much easier to drill. The bigger portion of the bit will be used so allow the smaller portion to go right through the hole.

Figure 6 – Counter sinking the lazy Susan on the drill press. Make sure the part is clamped well, and go slowly checking the screw until it is flush.

If you do not have access to a drill press, I recommend clamping lazy Susan down to a piece of wood, and then using the hand drill with a level to ensure it is being performed at a 90 degree. Go very slowly and check often as to not over-drill the Susan.

8.2 Side to Side Balancer Nut

Because the S2S Balancer needs to be screwed from the top after the flywheel has been installed, the remaining hole needs have either an M3 nut or an M3 insert glued into place. I choose the former as it is what I had on hand.

Pick a drill that is just about the size of the nut. Using a drill press, carefully start opening the hole for the nut to fit. If you do not have a drill press, then a normal drill will work, but be sure to go slowly and keep the bit leveled. Slowly drill the hole, checking until the nut fits down into the hole with a couple mm to spare.

At this point, get your superglue ready. I prefer Gorilla Super Glue Gel, as it does not run much which allows it to set in place well. Screw a long M3 bolt to the nut from the top just a few turns. Then, apply the glue into the hole, and tighten it down tight. This will ensure the nut sets in tightly with the glue.

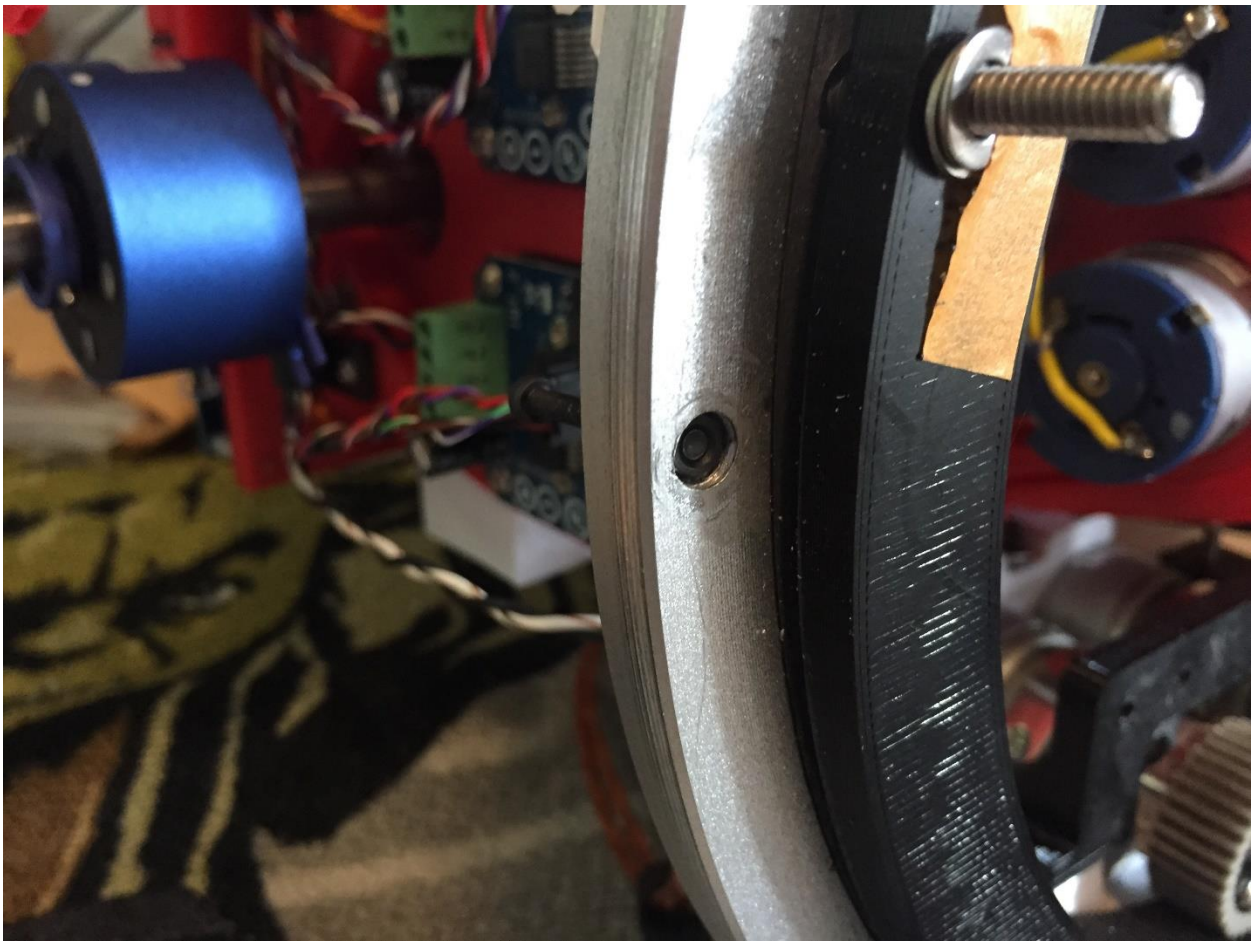

Figure 7 – Drill a hole just large enough in diameter for an M3 nut, and deep enough that there is a couple mm gap as shown in this picture. Then apply the super glue gel and tighten the bolt so the nut sets up. Be careful when applying the glue to not get it all over the threads.

8.3 Reinstall Modified Susan

Once the part is completely countersunk, it needs to be re-installed on the A-frames. This can be a bit tricky now that the nuts need to go deep into the A-frame, and a socket will not fit. To combat this, I used a ¼ socket with a screw bit attached for the screw head underneath the drive, which allowed the drive to remain upright. I then jammed my forceps down into the recess, which prevented the nut from turning, so I could use the socket driver to tighten the bolt.

Figure 8 – Using a socket driver with a ¼" drive with the screw bit inserted in that allows the drive to remain upright. Forceps or a flat-head screwdriver can then be inserted into the recess to hold the nut while the socket tightens the bolt.

Be careful not to overtighten this bolt. Stop right when you feel resistance. It will not come loose as the nut should be a lock nut with the plastic insert.

9. A-Frame Bolt-On Parts

This step adds all the additional parts that attach to Joe's existing MK2 Flywheel front and back A-Frames. This includes both the adapters that will hold the battery brackets; it also includes the balancers.

As a final measure for the project, I added balancers for the X and Y Axis. This will ensure the flywheel is level with the ground when installed inside the sphere to give the best possible flywheel operation, along with better handling.

9.1 Side To Side Balancer

Required Parts

Part	Quantity	Desc
Steel shot	NA	This is from Joe's BOM; I'm assuming you already have it
S2S Balancer	1	3D printed part from the files
Side Lid L	1	3D printed part from the files; printed in TPU/TPC
Side Lid R	1	3D printed part from the files; printed in TPU/TPC
M3 x 10 socket cap	1	Used to secure the S2S Balancer into the nut or set-sert from the previous step.

Table 2 – Parts required to install the ballast holders. Note that only one of the front or rear ballast holders are needed depending on the lean of your drive, so that's why there are some choices in the table.

After printing this part, the first thing to do is to use a metal file on the edge of the lip. This is because the lids will be a friction fit, so the tolerance is very tight. File at a slight angle to generally hit the top corner, and then lightly on the edges to remove any print anomalies.

The *S2S Balancer* needs to be filled with steel shot. I filled both cups evenly to make the total unit weight just under 11 oz, but I had some offset weight in the *Back Ballast Holder*; I filled about 2 oz in the side closest to the S2S Balancer only, so this meant that I needed less in the *S2S Balancer*.

With the ballast filled, you can now insert the two lids. The lids need to be printed in TPU or TPC; basically, they should be a flexible material. If you really cannot print flexible, then try printing them at 98% with a solid material. Snap on the lids to prevent any spillage of the ballast inside.

The filled balancer then gets installed on the flywheel utilizing the nut that was glued in from **8.2 Side to Side Balancer Nut**. Simply use an M3 Screw that is the correct length and screw it down. It is very important that the screw is not too long, or it will run into the flywheel underneath.

Figure 9 – The filled S2S Balancer for me came in at about 11 lbs. However, I put some extra ballast towards one side of the back ballast; only doing the side to side would require closer to 12 oz.

9.2 Front and Back Ballast Holders

Required Parts

Part	Quantity	Desc
Steel shot	NA	This is from Joe's BOM; I'm assuming you already have it
Front Ballast Holder **Or** **Rear Ballast Holder**	1	3D printed part from the files
Back Lid L **Or** **Front Lid L**	1	3D printed part from the files; printed in TPU/TPC
Back Lid R **Or** **Frond Lid R**	1	3D printed part from the files; printed in TPU/TPC
Front Lid M **Or** **NA**	1	3D printed part from the files; printed in TPU/TPC

Table 3 – Parts required to install the ballast holders. Note that only one of the front or rear ballast holders are needed depending on the lean of your drive, so that is why there are some choices in the table. Also note that the bolts required for this step are listed in 9.4 Inner A-Frame Adapters.

If you are using the MK2 Head tilt as I was, you can fill the *Back Ballast Holder* with a couple oz of steel shot. I put mine towards the side of the S2S balancer to minimize the amount of shot that was added to the side to side.

If you are using the MK3 Head Tilt (2-axis) then you would probably need the *Front Ballast Holder*, as the two servos to run the MK3 Head Tilt are large and towards the outside. However, this might not be the case if you are running speakers as opposed to the piezo transducers. Thus you should test to ensure this is the part you need by picking up the drive by the axel and seeing which way it leans.

Once you have filled the desired amount to make the drive level using a small leveler, then you can use two M4 bolts (or 8-32) that go through the A frames and through the inner A-Frame adapters as well. I recommend putting the bolts through and then immediately proceed to the section below to install the Inner A-Frame adapters as well.

9.3 Power Switch Holder

Optionally, it is possible to install the *Power Switch Holder Simple* or the *Power Switch Holder Voltage*. In both versions, the rocker switch needs to be snapped on from the front before wiring. Also, the charge port should be threaded on from behind as well; you can use a small file or sand paper to get the diameter just right so that the threads work directly on the printed part.

9.3.1 Power Switch Holder Simple

Required Parts

Part	Quantity	Desc
Power Switch Holder Simple	1	3D printed part
Rocker Power Switch	1	Turns the drive on/off
2.1mm Charge Port	1	Used for charging the battery solution

2.1mm Barrell Jack	1	Used for the portable jump starter to extend the 2.1mm charge port.
24 AWG PTFE Wire	2	Used to wire the charge port
16 AWG Power Wire	3	NOTE: Assuming that you already have this from Joe's BOM

Table 4 – Parts required to install the Power Switch Holder Simple Bolts required for this step are listed in 9.4 Inner A-Frame Adapters.

The *Power Switch Holder Simple* is the basic version that has a provision for the recharge port and the main power switch. This version is great for the portable jump starter solution as it allows for an easy way to extend the separate charge port on that battery.

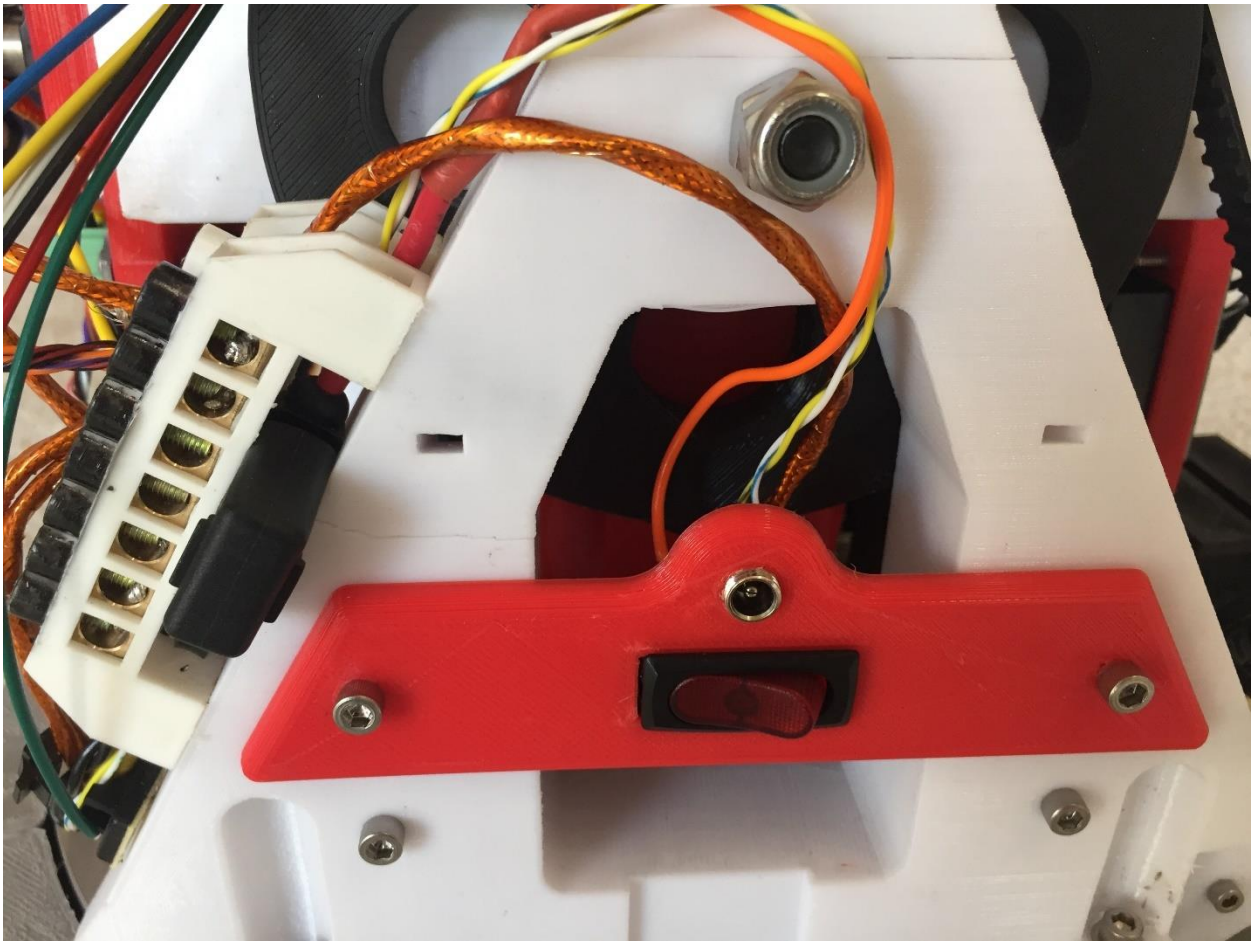

Figure 10 – The *Power Switch Holder Simple* is a good choice for those wanting to do a basic install but have ease of access to the recharge port. Note I used an illuminated switch I got from Ace hardware; you can go illuminated as well but to keep the manual and wiring simple I'm recommending a non-illuminated in the BOM.

If using this version, the following wiring diagram should be utilized for the recharge port and the main power switch.

Figure 11 – Wiring for the Power Switch Holder Simple using a portable jump starter.

If you are using a completed 21700 3S2P pack, then the wiring will slightly be modified to accommodate the way that drive charges; charging and discharging is right from the main drive. This means that the battery pack needs to be able to be disconnected and put directly into the charger[1]. Thus, I recommend the EC5 connectors, and then adding that to the battery, drive, and the corresponding one to the charger.

[1] Note: if you wire the switch to kill negative instead of positive you might still be able to wire the charge port to charge, but I have not tested this functionality and thus am sticking with the safe option until someone tries the other way.

Important: *When charging it is critical that you turn off the power switch for the 21700 pack as charging and discharging are from the same power rail.*

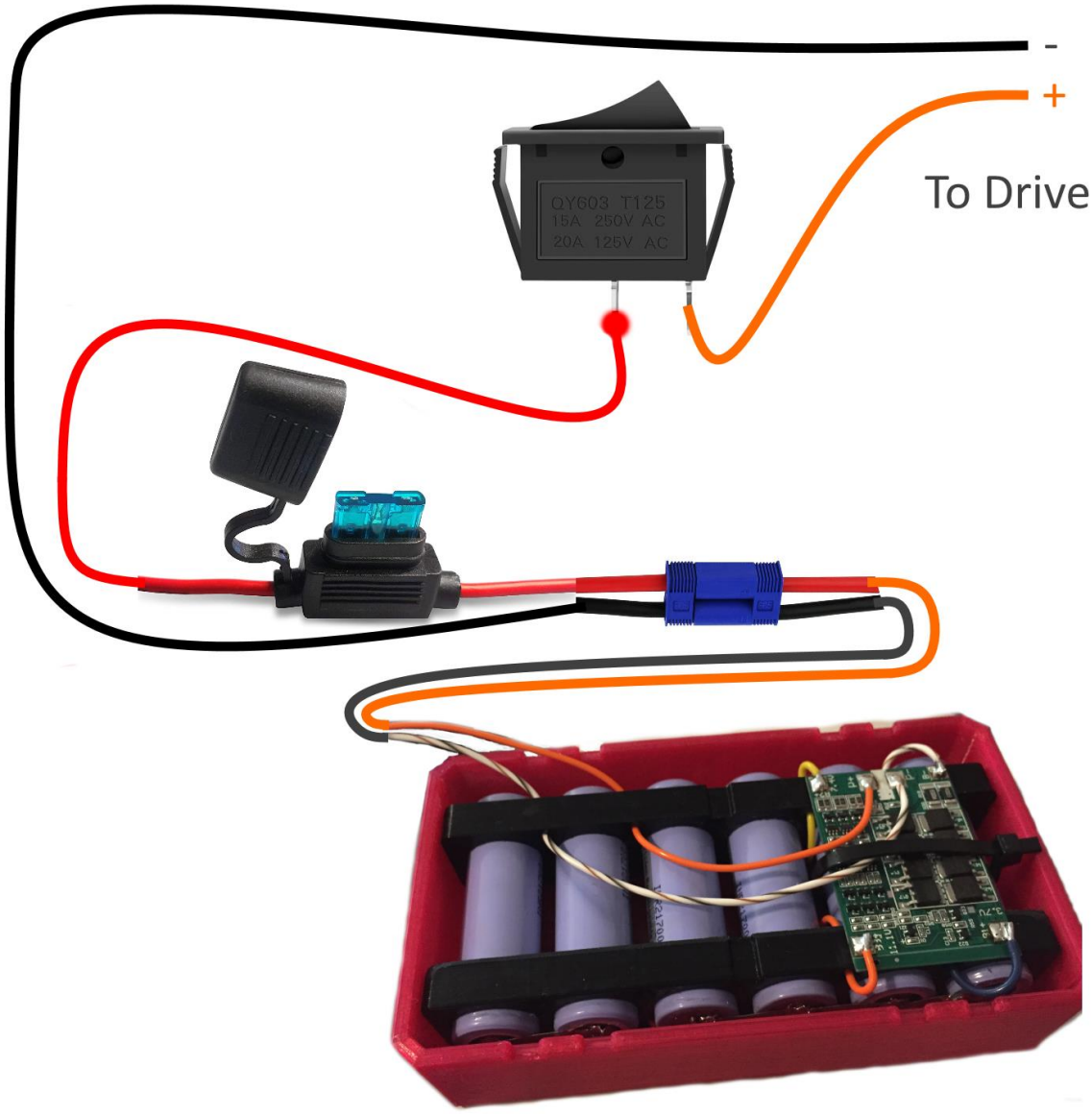

Figure 12 – *Power Switch Holder Simple* wiring diagram when using the 21700 LI-ION pack. To see the details of how to construct the pack, see the section 13. 21700 3S2P Custom Battery Construction below. Make sure the EC5 connect is accessible as you need to unplug your drive to charge.

9.3.2 Power Switch Holder Voltage

Required Parts

Part	Quantity	Desc
Power Switch Holder Voltage	1	3D printed part
Voltage Display Adapter	1	3D printed part
Rocker Power Switch	1	Turns the drive on/off
2.1mm Charge Port	1	Used for charging the battery solution

2.1mm Barrell Jack	1	Used for the portable jump starter to extend the 2.1mm charge port.
24 AWG PTFE Wire	2	Used to wire the charge port
16 AWG Power Wire	3	NOTE: If you already have this from Joe's BOM
Illuminated Power Switch	1	Turns the drive on/off
12mm AV Momentary Switch	1	Holding this shows the voltage
Small 3-Wire Voltage Display	1	Actual voltage display

Table 5 – The Power Switch Holder Voltage requires a few more parts and more wiring. Bolts required for this step are listed in 9.4 Inner A-Frame Adapters.

While the simple version is the easiest and convenient, there is one issue when using the portable jump starter as the power solution: there is no way to know when the battery is charged. That is because the screen is attached to the jump starter under the drive, and it really is not visible.

To combat this issue, the *Power Switch Holder Voltage* can be used instead. This version adds both a voltage display and a 12mm momentary switch to active the voltage display. This allows checking the voltage through out the charge or at any time to see what the battery charge state is looking like. This feature is nice for the custom 21700 battery pack as well.

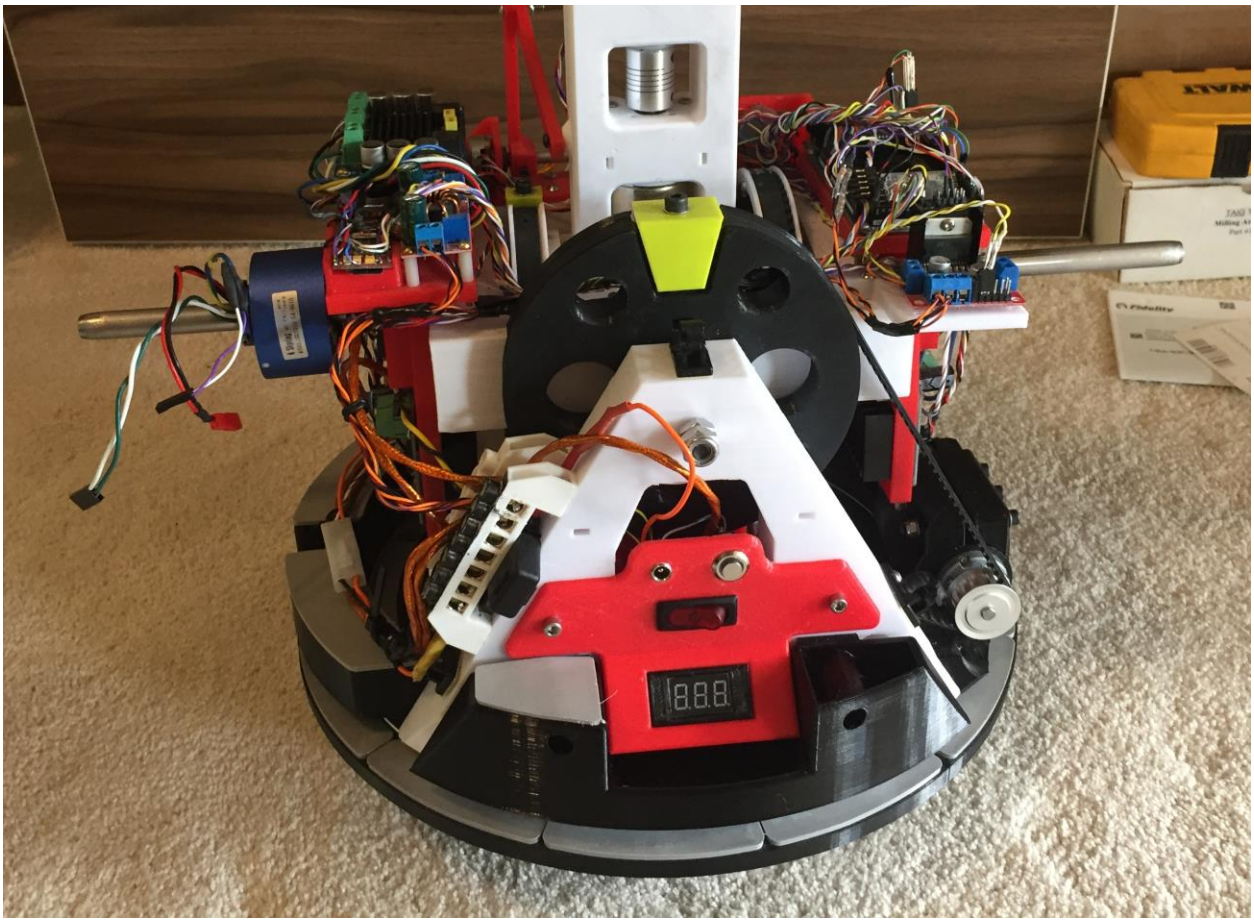

Figure 13 – The Power Switch Holder Voltage allows using the digital voltage display. Holding the button displays the voltage. This can be performed if the main switch is on or off.

Before wiring the drive, not only does the rocker switch and charge port need to be installed, the momentary switch and voltmeter need to be installed as well. The 12mm momentary switch has a nut that can be screwed from behind; just widen the hole and then use the nut to tighten it down.

The voltmeter needs to first be screwed into the back of the *Voltage Display Adapter*. Since this is a very light part, I found it best to just thread the adapter using an M3 tap; if you don't have a tap, you can opt to just use a small sheet screw in these holes. After the voltmeter is installed in the adapter, you can just friction fit the unit into the *Power Switch Holder Voltage*. It should be a tight fit with no glue necessary, but you can feel free to use a dab of super glue if you desire.

The wiring diagram using the portable jump starter is shown below.

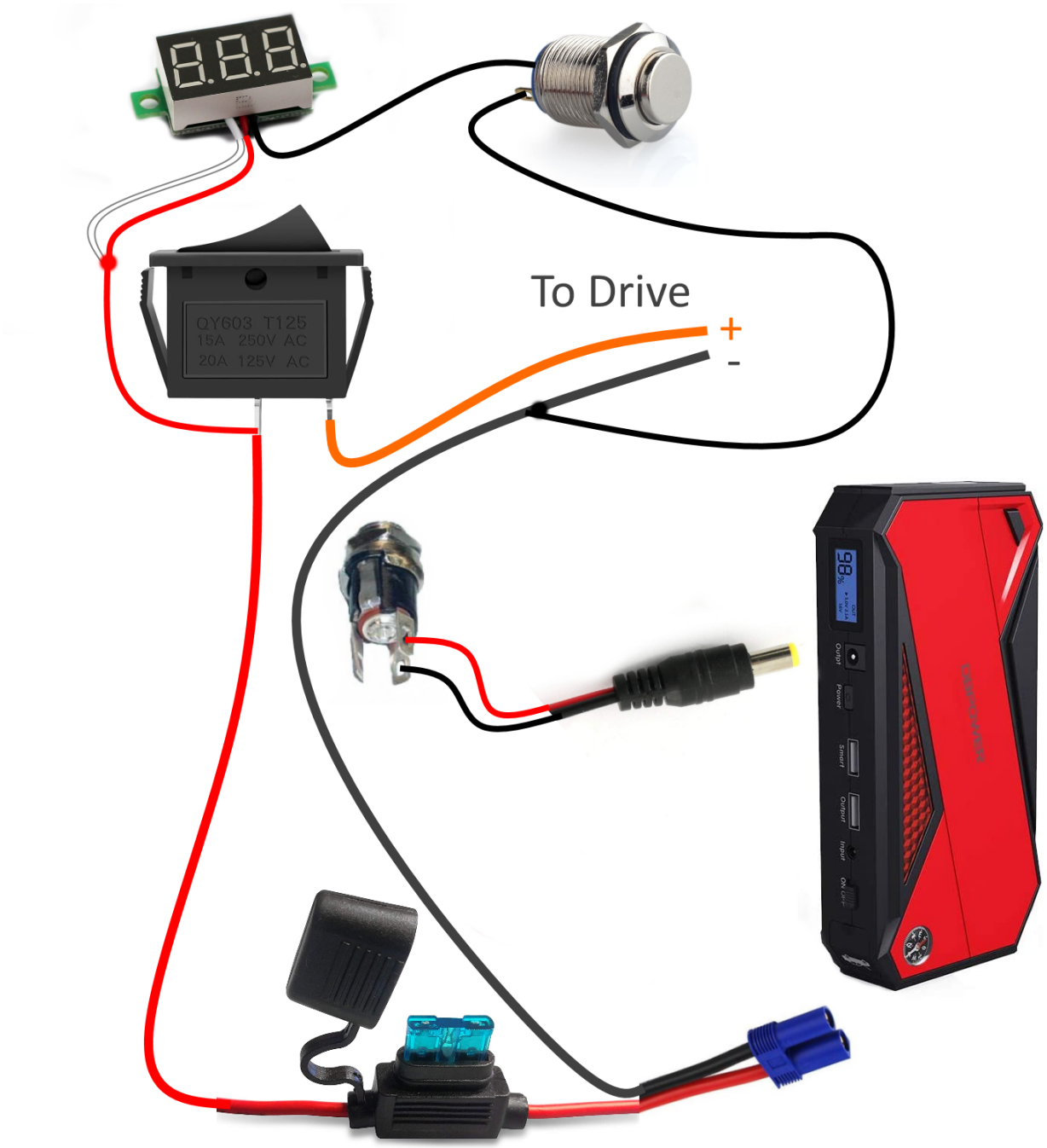

Figure 14 – Wiring the Power Switch Holder with the Voltmeter. The momentary 12mm AV switch is used to show the voltage; it displays as the button is being depressed. This can be shown regardless of the position of the main power switch and works when the battery is charging.

If you are using the 21700 battery pack, the following diagram is the correct one to use.

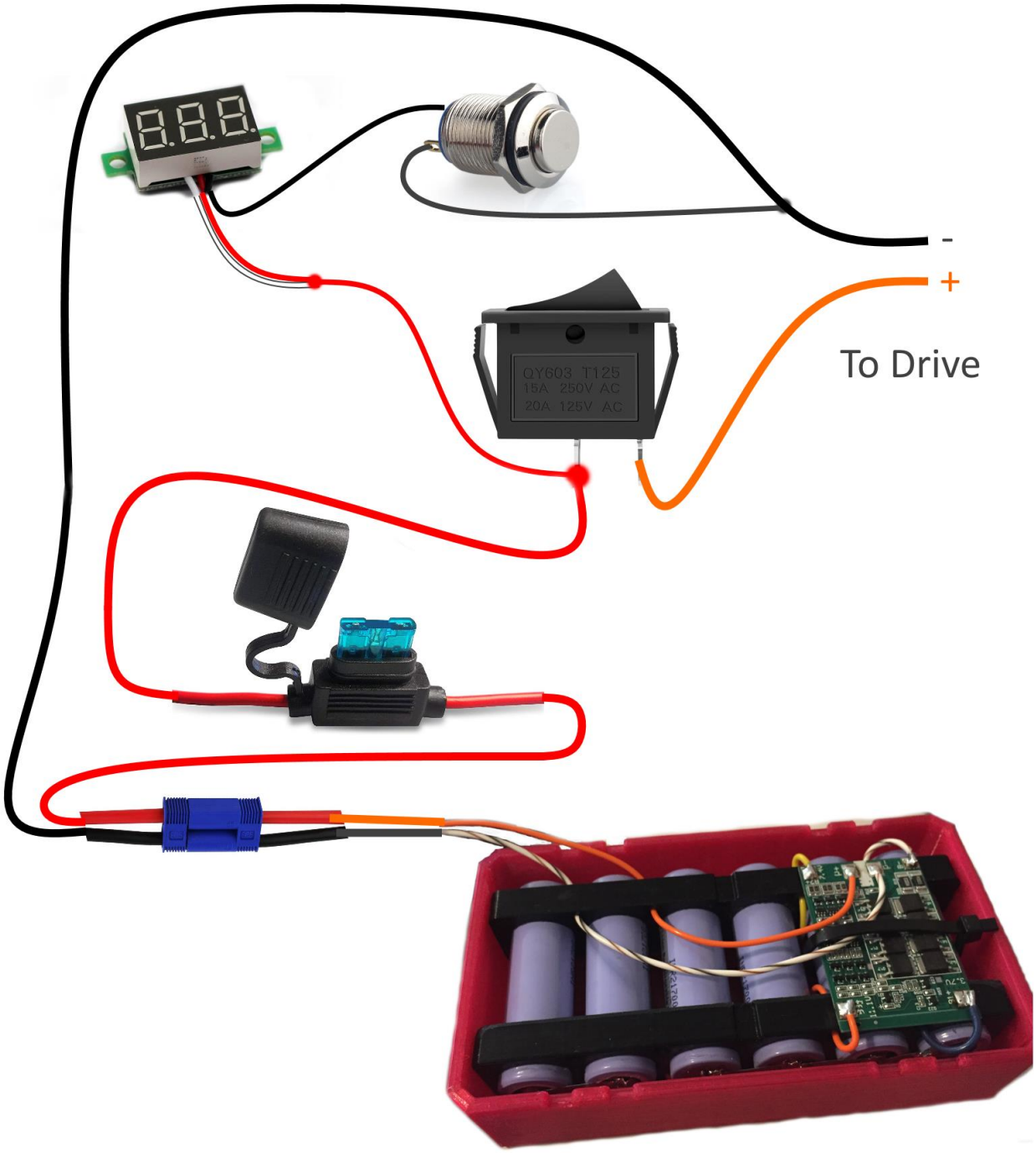

Figure 15 – Wiring diagram for the voltage meter display using the 21700 pack. Holding down the momentary button will display the voltage as it is being held; this works regardless of the position of the main power switch. Make sure the EC5 connector is accessible from the drive as you need to unplug the battery to charge it.

9.4 Inner A-Frame Adapters

Required Parts

Part	Quantity	Desc
Back A-Frame Support	1	Attaches to the back A-frame
Front A-Frame Support	1	Attaches to the front A-frame
M4 x 50 Socket Cap	4	Top bolts for back; bolts for front
M4 x 45 Socket Cap	2	Bottom bolts for back
M4 washer	6	
M4 locknut	6	

Table 6 – Parts required to install the ballast holders. Note that only one of the front or rear ballast holders are needed depending on the lean of your drive, so that's why there are some choices in the table.

With the bolts in place holding the *Front Ballast Holder* or *Back Ballast Holder* depending on which was required, ensure the remain bolts are pushed through the A-Frames. Now, line up the *Front A-Frame Adapter* to the side with two holes. Use an M4 washer and M4 locknut to secure each side so that the *Front Ballast Holder* (if being used) is attached to the outside and the Front A-Frame Adapter is attached to the inside.

Repeat the steps for the *Back Ballast Holder*, making sure that the Power Switch Holder V2 or Power Switch Holder V3 is secure on the outside, and the Back A-Frame Adapter is secure inside. For the side where the S2S belt is, it is crucial that the bolt does not interfere; you may need to cut/grind down that bolt to ensure it doesn't rub as overtime it could ruin the belt.

Important: *Ensure the bottom nut towards the S2S belt does not stick out on the inside past the belt, as it can rub and ruin the S2S belt. If it rubs you may need to cut down the bolt for a perfect fit.*

10. Under Battery Installation

Required Parts

Part	Quantity	Desc
Battery C-Clamp	2	3D printed part
14" Zip-Ties	2	Used to attach the battery into the clamps
M4 x 50 Socket Cap	4	Top bolts for back; bolts for front
M4 x 45 Socket Cap	2	Bottom bolts for back
M4 washer	6	
M4 locknut	6	
Portable Jump Starter **OR** **21700 Battery Pack**	1	

Table 7 – Parts required to install a completed 21700 battery pack or a portable jump starter.

At this point it is time to install the battery under the drive.

If you are building a custom 21700 pack using six 21700 batteries, then please follow the instructions in the section **MK3 Flywheel**

Required Parts

Part	Quantity	Desc
Flywheel Third	3	3D printed part
Flywheel Plug	12	3D printed part in TPU/TPC
M3 x 15mm	3	Holds Under-Battery Ballast Holder to the Battery C-Clamp
M3 washer	3	
M3 nut	3	

Table 9 -

The new MK3 Flywheel needs to be assembled and installed at this point. First the flywheel needs to be constructed; then then it can be installed on the drive.

10.1 Flywheel Construction

The flywheel needs some minor assembly before it can be installed into the drive. First, using 3 M3 Allen head bolts, 3 M3 washers, and 3 M3 nuts, assemble the *3 Flywheel Third* sections into one ring. The holes are on the inside so be careful to not drop the bolt or washer into the flywheel part (though if you do you can easily just dump it back out). Because the opening is tight, I found it best to use a long flat-head screwdriver to hold the nut from spinning, and then I used the Allen key in the long orientation to twist it tight.

Figure 25 – Due to the tight openings, it is easier to tighten the M3 bolt using the end of a flat-head screwdriver than a socket or wrench.

With all three pieces together, it is now time to file down the inner edges of the openings. This will ensure the edge that was on the print bed is smooth so the lid will snap on with a good fit. Use a metal file along all the inner edges to clean them up.

Now that the flywheel has been sanded, it can be filled with ballast. Use the same steel shot recommend by Joe; it is also used in the *Under-Battery Ballast Holder* and all the balancers. Fill each section until the ballast is 3mm from the top to leave room for the plugs. After that the lids can be snapped on.

Note: *The lids are made to be printed in TPU or TPC; do not print in a rigid material as they will not fit appropriately. It is possible that if you do want to print in a rigid material, you can scale them down to 98% to 99%. This is untested so try at your own risk.*

At this point the flywheel should weigh in at about 6.5 lbs.

Figure 26 – Inserting the TPU caps on the flywheel after it is filled. These are designed for a tight fit, so make sure to squeeze them into place.

10.2 Flywheel Installation

After the flywheel has been assembled, it is time to install it into the drive. I like to do this on the carpet or a rug. First, take the 10-32 countersunk bolts (same ones used for the MK2 Flywheel) and push them through the Susan on the drive. You can access then under the axel that does not have the side to side motor under it. Insert one countersunk screw, and then turn the Susan to reveal the next hole.

Note: *If you find that the flywheel is not spinning freely you can add a single washer between the flywheel and the Susan. If you need this, I found the best time to do that is at this point. You can slide the washer on the countersunk screw under the flywheel, and then use a small piece of masking tape to hold it in place. That way it will not fall off when setting the drive down onto the flywheel.*

Now, set the drive carefully trying to line up the holes of the flywheel with the countersunk screws sticking out of the Susan. Push the flywheel up until all six screws have passed into the flywheel. This is where I use my feet to hold the flywheel in place and tilt the drive back while doing so, and quickly get one bolt and washer in place. Then, spin the flywheel 360 degrees to get the opposing bolt as well. After this it should be easy to add the remaining bolts. Take care not to over-tighten these as you want the flywheel to be able to spin freely; the nuts here should be the self-locking kind.

Figure 27 – Tightening the flywheel countersunk screws. I do this on the floor as I like to use my feet to hold the flywheel in place until I get the first to nuts hand tight underneath. Access to these nuts and bolts can be done under the axle on the side of the drive that does not have the side to side motor.

21700 3S2P Custom Battery Construction to complete construction of the pack and assembly into the battery box. Once that is complete, the installation will be the exact same as with the portable jump starters.

Get the two printed *Battery C-Clamp* frames, and the 4 screws, washers and bolts needed to secure the battery holders. Place the washers so that there is one washer outside the screw, one washer between the Battery Holders and A-Frame adapters, and one at top before the nut. Finger-tighten the nut for three of the

four holders, allowing one to swing freely. This will allow insertion of the battery box or portable jump starter into one end, and the other frame can swing into place. Be mindful of the locations for the clamps; for the Suoaki specifically, at least the clamp towards the front needs to be in the inner most position to allow clearance for the charge plug and power connector.

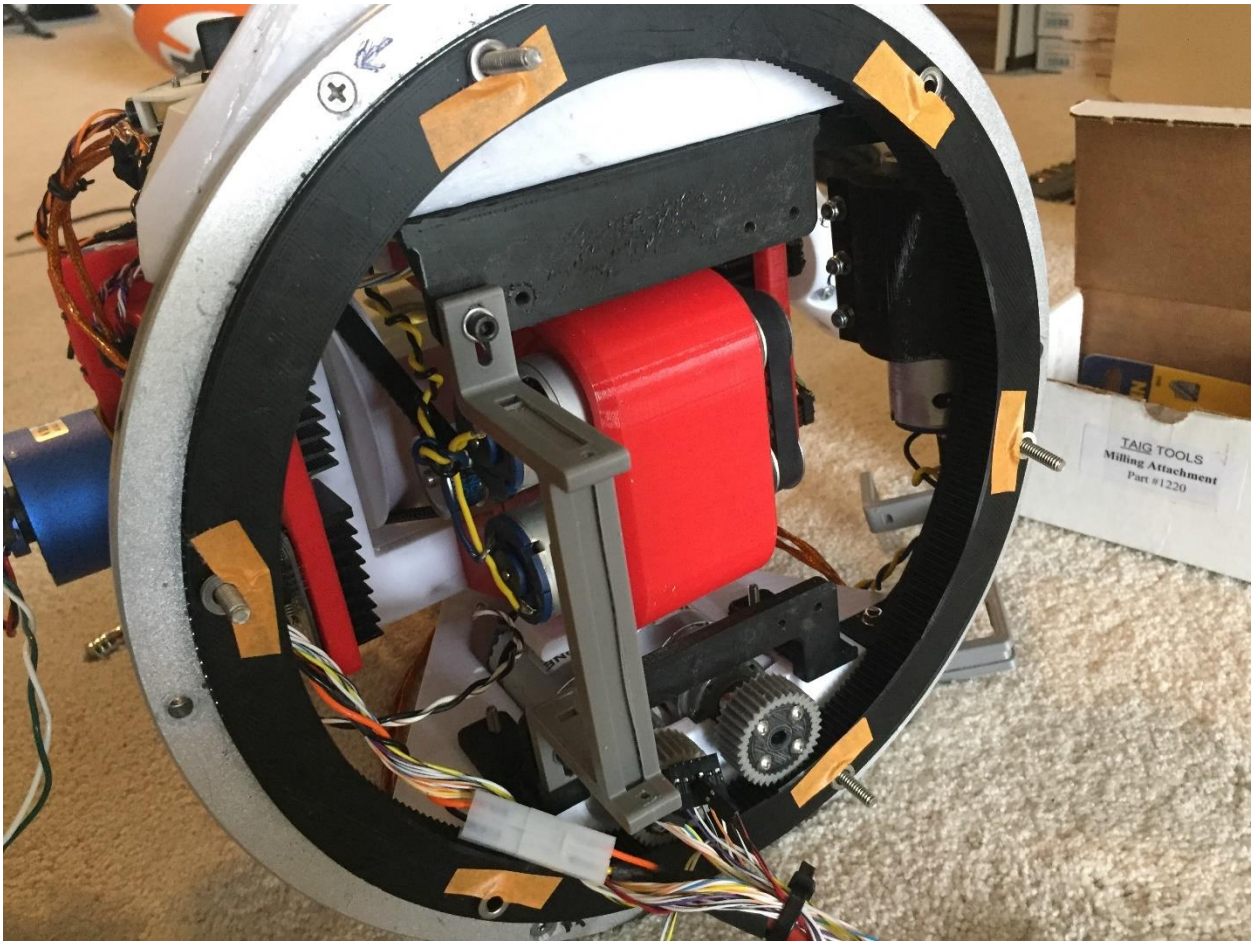

Figure 16 – Insert both screws with washers for one, and only the bottom for the second. This will allow swinging the holder into place after the battery box or portable jump starter is inserted.

If you are using the portable jump starter, this is the time to cut the small 1/16” or 1/8” strips where the battery rests upon the battery holders. This will ensure enough friction between the battery and the holder so that it acts like a vise to prevent the battery from coming out. This step is not needed when using the custom 21700 battery pack in the battery box, as the box has notches for the zip ties to directly side into, which prevents the need for the tight clamping force.

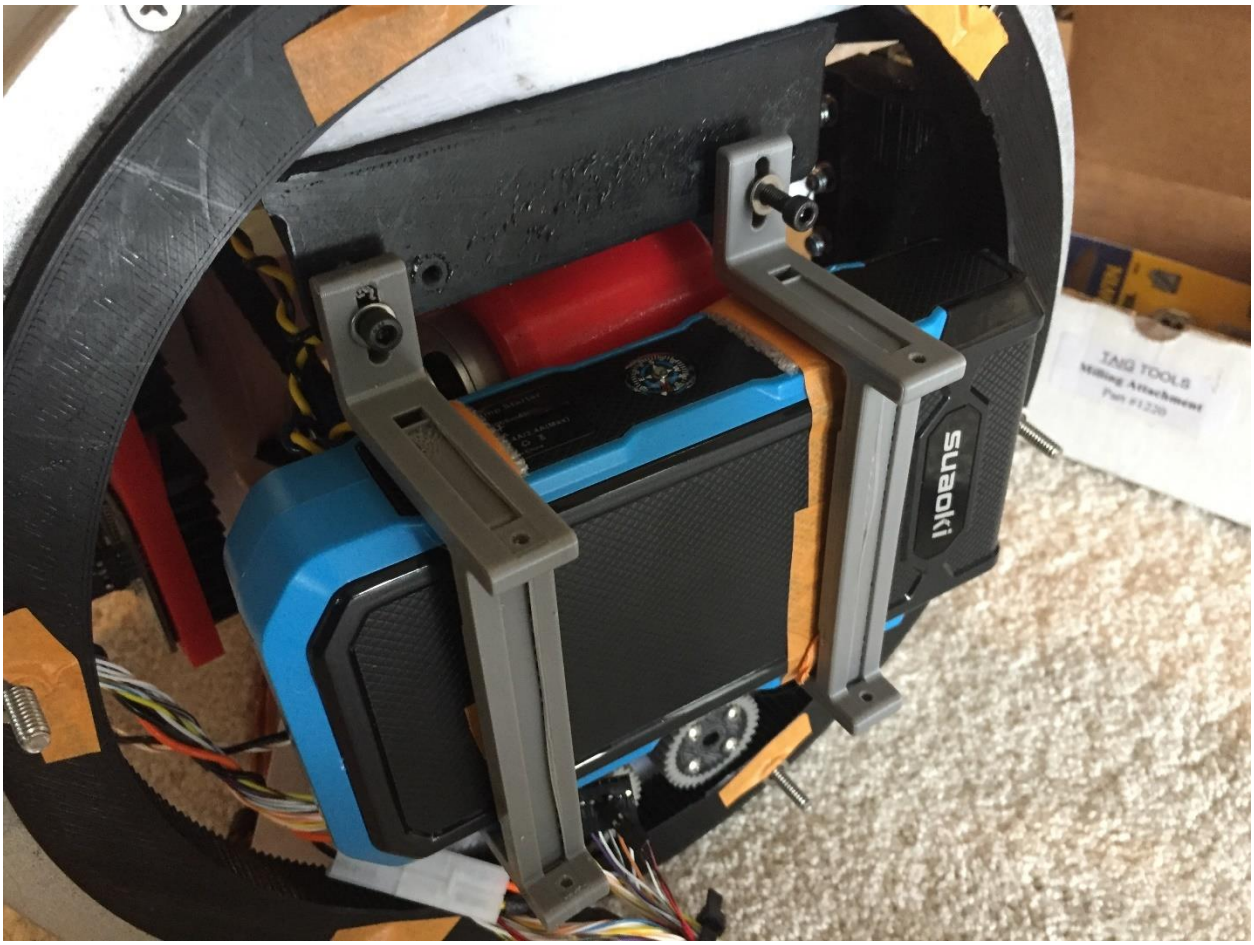

Figure 17 – Portable jump starter is situated with the foam strips taped into place. It is very important to use the foam as this ensures enough friction to prevent the battery from sliding in the clamps. Also notice here that specifically for the Suoaki, the camp towards the battery's front is in the lower position to allow clearance for the charge port and banana connector for the main power.

Once the battery box or portable jump starter is in place, the zip ties need to be added to the clamps. Carefully wrap the zip ties around, and slowly tighten to ensure they remain centered in the groove in the holder. If you are using the *21700 Battery Box*, ensure the zip tie falls into the groove on the top of the box as that ensure it will not slide out of the clamp.

Figure 18 – Tighten the zip ties around the clamp to ensure a secure fit of the battery into the holders.

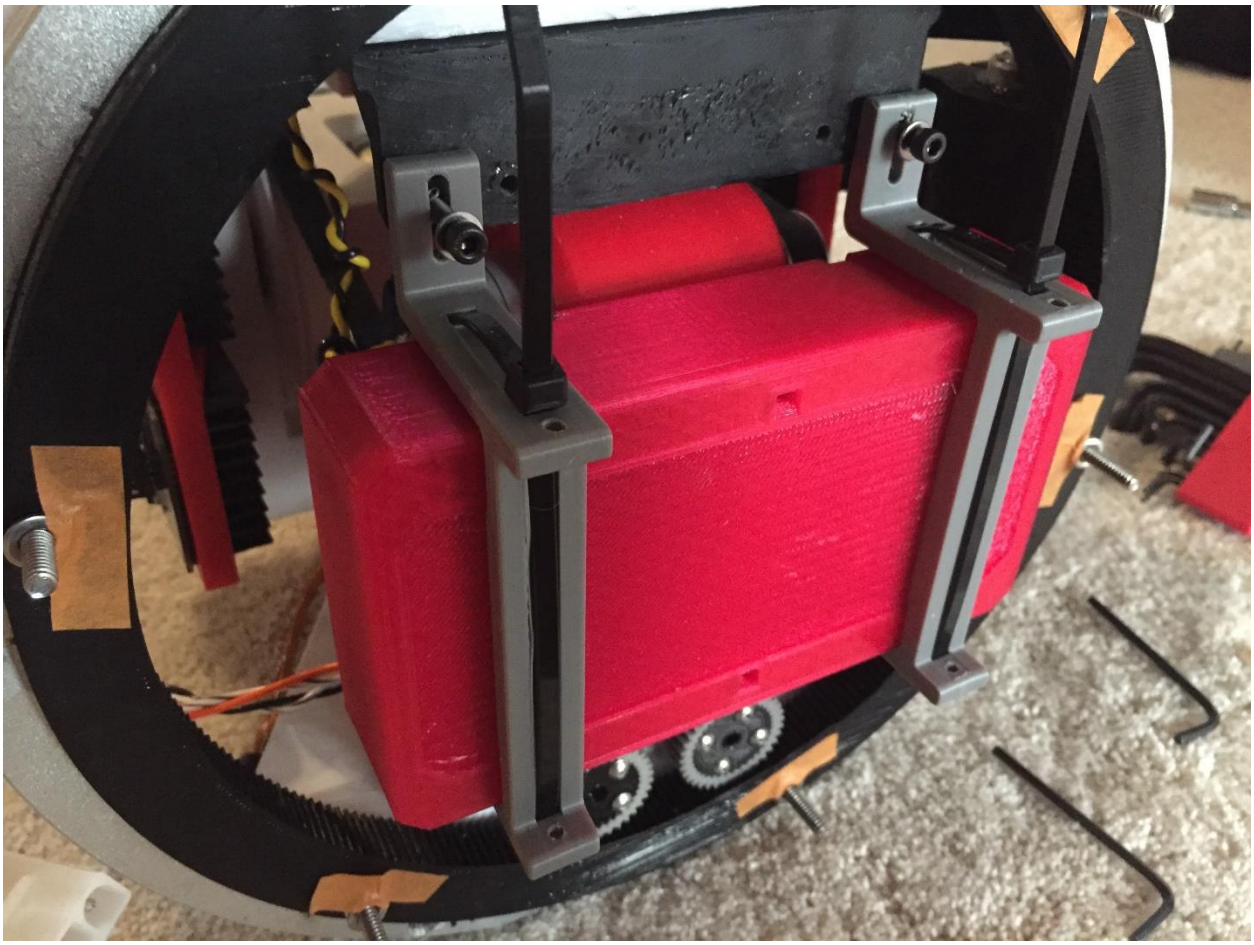

Figure 19 – When inserting the zip ties for the custom 21700 battery pack, the zip ties need to fit into the cut outs on top of the box to ensure the box does not slide out of the clamps.

With this the battery solution is now installed properly.

11. Under-Battery Ballast Holder Installation

Required Parts

Part	Quantity	Desc
Under-Battery Ballast Holder	1	3D printed part
Under-Battery Center Lid	1	3D printed part
Under-Battery Sid Lid	2	3D printed part
M3 x 15mm	4	Holds Under-Battery Ballast Holder to the Battery C-Clamp
M3 x 10mm	6	Holds the lids to the main body
M3 washer	4	I did not use washers for the lids
M3 nut	10	

Table 8 – Parts required to assemble and install the *Under-Battery Ballast Holder*.

In my initial testing with just the batteries under the drive, I ran into an issue that the drive had trouble getting started if there was uneven flooring or any other minor obstruction. This was due to the drive being too light compared to the frame and panels, and the drive would roll up a lot before the ball caught up. To avoid this issue, I designed a ballast holder that attaches to the battery clamps that holds an extra 2.2 lbs. This weight being very low causes the entire center of gravity to be moved quite closer to the ground, which really aids in driving and head stability.

11.1 Under-Battery Ballast Holder Construction

After printing the *Under-Battery Ballast Holder*, the Under-Battery Center Lid, and two of the Under-Battery Side Lid (x2) STL files, it is important to sand all the edges to ensure the lid fits. This is required as it is important for the lid to be a tight fit that snaps on, so the tolerances require some filing to get the printed surface even.

Figure 20 – It is very important to file the edges of the weight holder to ensure the lid is a tight fit, as out of the printer this edge that was on the print bed is normally too big and needs to be filed.

With the sanding complete and the lids test fit correctly, the next step is to fill the holder with the steel shot. This is the same steel shot that Joe recommends for his MK2 Flywheel, and this will be used in this Flywheel and side to side balancers as well. For my drive, I filled the entire holder which gave about 2.2 lbs total; I'm using Cary's Injection V1 skeleton and the club panels. However, less may be needed if using the Vonjet, since that is a much lighter frame and panel combination.

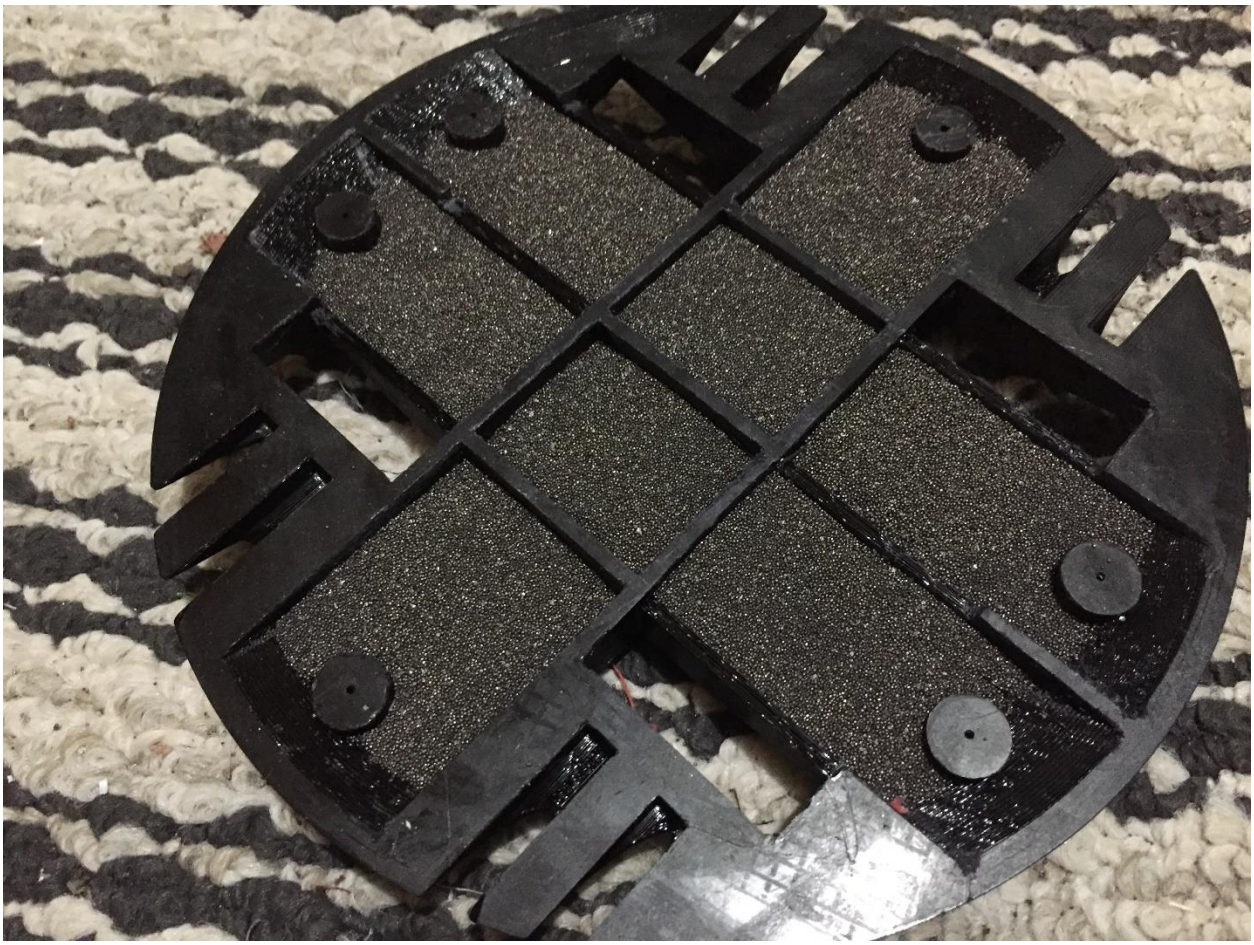

Figure 21 – Filling the *Under-Battery Ballast Holder* with steel shot. For Cary's Injection sphere and the club panels I filled the entire holder which gives about 2.2 lbs. If using the Vonjet less may be required since that is a lighter frame and panel combination.

With the Under-Battery Weight Holder filled, it is time to install the lid. I snapped on the center lid first, screwing it down, and then angled on the two side lids and secured them as well. Doing the side lids first is probably okay as well, but since there are only outside screws on them putting the main first made sense to me per the way I designed it.

To secure the lids, use M3 screws and bolts. It is important that the bolts do not extend more than 3.25mm above the lid as they will hit the battery box or portable jump starter if they are longer. I cheated and just tapped the holder directly and used only M3 screws to hold the lid down, since the lid stays mostly upright, but I do recommend using an actual nut to ensure it is secure.

Finally, since the lids are printed in the same rigid material as the holder, a secondary seal needs to be created to ensure that the steel shot does not seep out the edges. A gasket forming material like silicone could be used here, but for dry seals (i.e. the material is not liquid that is being sealed) I've found the cheapest easiest method is to apply masking tape to the area to be sealed, and then use a very thin layer of hot glue over the tape. The masking tape is porous on the back side and will suck up a bit of the glue, making for a nice leak-proof seal that is easy to remove if desired.

Figure 22 – With the lid secured on the *Under-Battery Ballast Holder*, a seal needs to be applied to the edges. I choose to use masking tape along the entire edge, and then I applied a very thin layer of hot glue to that seam. The masking tape sucks up the glue, making for a nice seal that is easy to remove.

11.2 Installation

With the lid installed and sealed it is time to install the filled Under-Battery Ballast Holder into the drive. First, make sure to drill out the holes in both the *Battery C-Clamp* and the holes in the *Under-Battery Ballast Holder*. I recommend M3 Allen key bolts, washers, and nuts for this, but 6-32 could probably work as well.

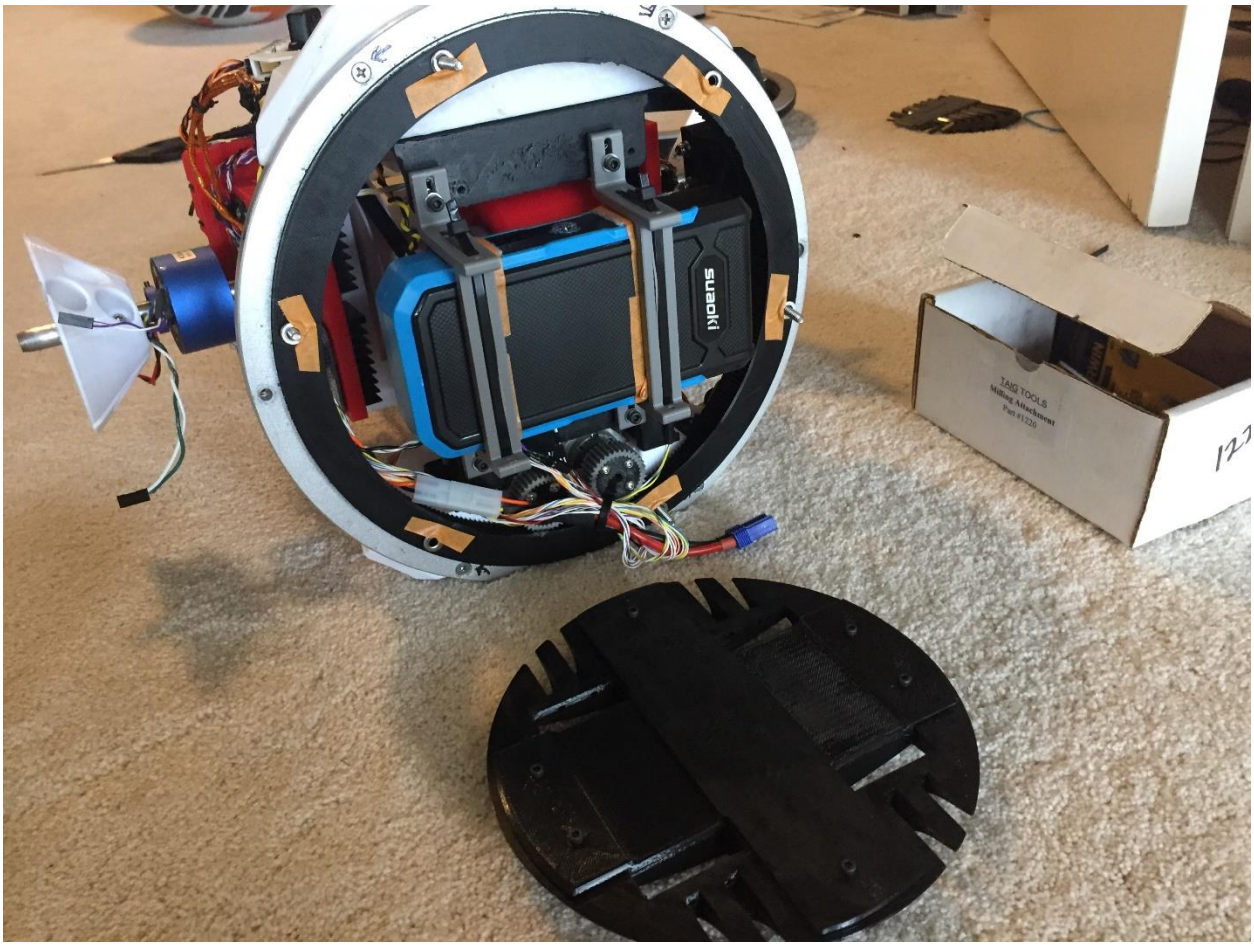

Figure 23 – With the drive on it's "front" lay the Under-Battery Ballast Holder near the edge of a stair to prepare setting the drive down on top of it.

I found the easiest way to install was to go near a stair (edge of a table could work, but it is a bit more dangerous), and set *the Under-Battery Ballast Holder* near the edge. Then set the drive with under-battery installed on top of the weight holder so that all the screws line up. Then put the bolts through the front and reach up with your hand to put the washer and nut in the back. Tighten down with the Allen key and wrench.

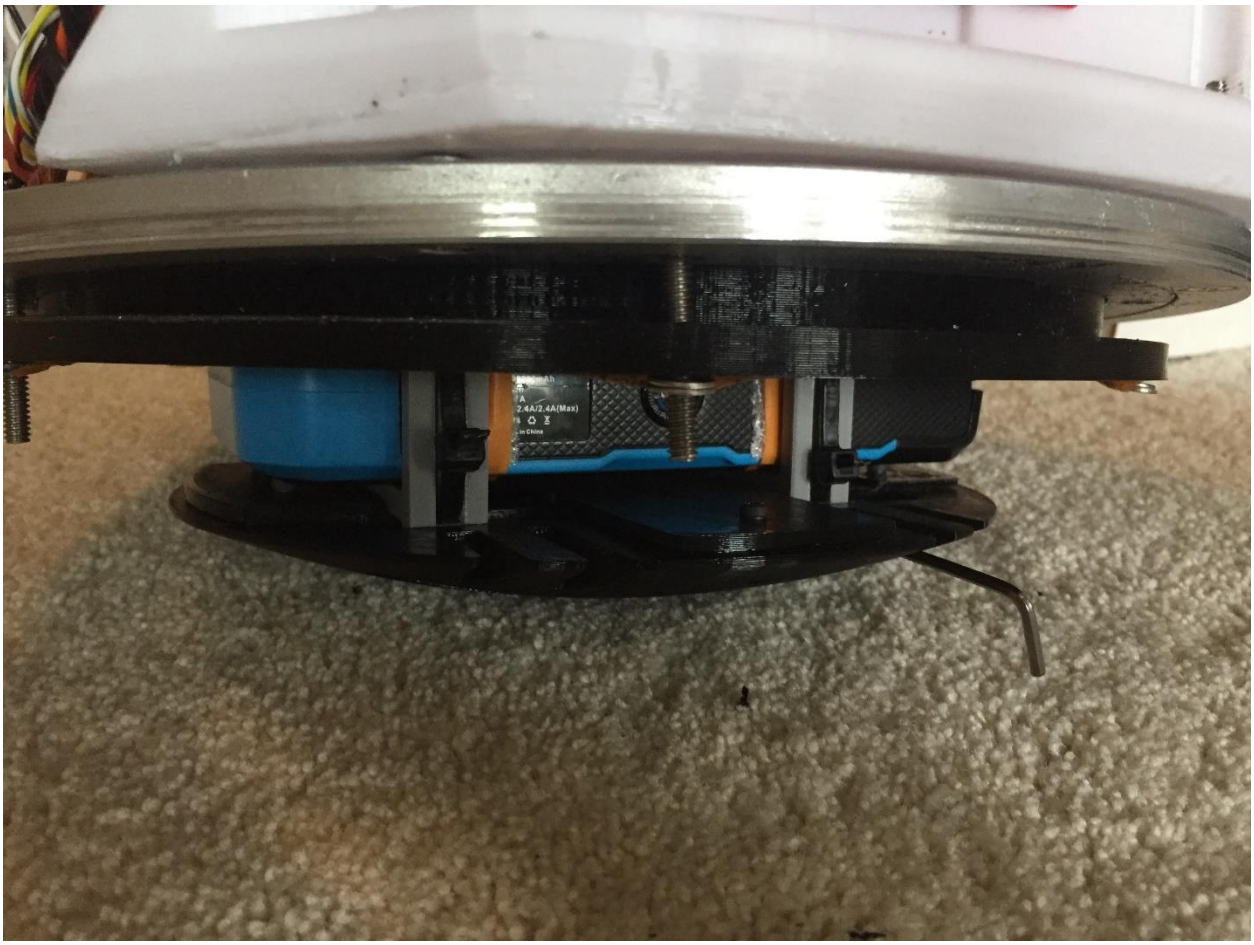

Figure 24 – After the drive is resting on the *Under-Battery Ballast Holder*, use the Allen key and wrench to tighten the bolts. Being at the edge of a stair will help to get your hand underneath the weight.

Repeat this process for all four screws and bolts to complete this step.

Note: *If you are having trouble securing the nut that goes on the back it is probably okay to directly tap the Under-Battery Ballast Holder with an M3 tap, since the force of the screw is applied laterally even if the screw isn't 100% tight it won't really matter. But, this should be decided before drilling out the Battery C-Clamp brackets.*

12. MK3 Flywheel

Required Parts

Part	Quantity	Desc
Flywheel Third	3	3D printed part
Flywheel Plug	12	3D printed part in TPU/TPC
M3 x 15mm	3	Holds Under-Battery Ballast Holder to the Battery C-Clamp
M3 washer	3	
M3 nut	3	

Table 9 -

The new MK3 Flywheel needs to be assembled and installed at this point. First the flywheel needs to be constructed; then then it can be installed on the drive.

12.1 Flywheel Construction

The flywheel needs some minor assembly before it can be installed into the drive. First, using 3 M3 Allen head bolts, 3 M3 washers, and 3 M3 nuts, assemble the *3 Flywheel Third* sections into one ring. The holes are on the inside so be careful to not drop the bolt or washer into the flywheel part (though if you do you can easily just dump it back out). Because the opening is tight, I found it best to use a long flat-head screwdriver to hold the nut from spinning, and then I used the Allen key in the long orientation to twist it tight.

Figure 25 – Due to the tight openings, it is easier to tighten the M3 bolt using the end of a flat-head screwdriver than a socket or wrench.

With all three pieces together, it is now time to file down the inner edges of the openings. This will ensure the edge that was on the print bed is smooth so the lid will snap on with a good fit. Use a metal file along all the inner edges to clean them up.

Now that the flywheel has been sanded, it can be filled with ballast. Use the same steel shot recommend by Joe; it is also used in the *Under-Battery Ballast Holder* and all the balancers. Fill each section until the ballast is 3mm from the top to leave room for the plugs. After that the lids can be snapped on.

Note: *The lids are made to be printed in TPU or TPC; do not print in a rigid material as they will not fit appropriately. It is possible that if you do want to print in a rigid material, you can scale them down to 98% to 99%. This is untested so try at your own risk.*

At this point the flywheel should weigh in at about 6.5 lbs.

Figure 26 – Inserting the TPU caps on the flywheel after it is filled. These are designed for a tight fit, so make sure to squeeze them into place.

12.2 Flywheel Installation

After the flywheel has been assembled, it is time to install it into the drive. I like to do this on the carpet or a rug. First, take the 10-32 countersunk bolts (same ones used for the MK2 Flywheel) and push them through the Susan on the drive. You can access then under the axel that does not have the side to side motor under it. Insert one countersunk screw, and then turn the Susan to reveal the next hole.

Note: *If you find that the flywheel is not spinning freely you can add a single washer between the flywheel and the Susan. If you need this, I found the best time to do that is at this point. You can slide the washer on the countersunk screw under the flywheel, and then use a small piece of masking tape to hold it in place. That way it will not fall off when setting the drive down onto the flywheel.*

Now, set the drive carefully trying to line up the holes of the flywheel with the countersunk screws sticking out of the Susan. Push the flywheel up until all six screws have passed into the flywheel. This is where I use my feet to hold the flywheel in place and tilt the drive back while doing so, and quickly get one bolt and washer in place. Then, spin the flywheel 360 degrees to get the opposing bolt as well. After this it should be easy to add the remaining bolts. Take care not to over-tighten these as you want the flywheel to be able to spin freely; the nuts here should be the self-locking kind.

Figure 27 – Tightening the flywheel countersunk screws. I do this on the floor as I like to use my feet to hold the flywheel in place until I get the first to nuts hand tight underneath. Access to these nuts and bolts can be done under the axle on the side of the drive that does not have the side to side motor.

13. 21700 3S2P Custom Battery Construction

The 21700 custom battery needs to be constructed out of the six 21700 batteries, the 11.4V BMS, and some pure nickel strip. This requires some soldering and assembly to make the battery into a completed pack that can be installed into the box.

Note: *This step should be completed before the section **Under Battery Installation** if using the custom 21700 battery pack.*

13.1 Install Batteries into the two holders

First, take the two printed 21700 6x Holders, and ensure the six large holes and two sides are cleaned up with a file or rough sandpaper. This step is required as these holders are a tight fit into the box and the batteries are a tight fit into the holes, so sanding is required near the print edge and inside to ensure a proper fit.

With a test fit of the part into the box and a battery into all six holes, it is time to construct the battery. First, insert the batteries into one of the two 21700 6x Holders. They should snuggly slide in and should be about 5mm to 10mm below the tops of the batteries. It is critical that the batteries be installed in pairs, i.e. first two batteries with negative end (flat side) pointing out, then the middle two with the positives pointing out, then finally the last two with the negatives pointing out.

Figure 28 – Install the batteries into one of the 21700 6x Holders in the correct orientation with the first two having negative facing up, the second two having negatives facing down, and the final two up again.

After the batteries are inserted correctly into one holder, get the second holder, and align it with all six batteries. Carefully slide the batteries down into the second holder. I found using the edge of a counter worked well to push it all the way on.

13.2 Wire Batteries Using Nickel Strip

Now it is time to wire the batteries together using the nickel strip. First, you need to cut strips accordingly. You need two strips that are the width of two batteries, and two strips that are the width of four. If your

strips are not long enough to reach four batteries, then you can cut two that are length of two and solder them together on the batteries.

Figure 29 – Wiring of the nickel strips to correctly construct the 11.4v pack. This is 3S2P configuration, which is a pair of batteries in series of three.

You have two options to get the strip onto the batteries. The first is the most professional and is faster but requires expensive equipment. This is using a battery spot welder to weld the nickel strips to the batteries. While this is probably the best choice, it is quite expensive to purchase a spot welder, so I am going to focus on the alternative option.

The other option is to just use solder on the strips to the batteries. To do this, it is important to sand both the terminals of the batteries and the nickel strips to ensure a solid connection between the batteries and the strips.

Important: *It is critical to use 120 grit sandpaper to sand **both** the nickel strips and battery terminals to ensure a good solder connection between the batteries and strips.*

With the strips cut and everything sanded, prop the battery up and lay the first strip over the two batteries that need to be connected on that side. Use a wide soldering iron tip and heat the iron to 375 C to 400 C. Use flux on the batteries, and then lay the strips so the stick to the flux. I found it best to then pre-tin the strips with solder, flowing the solder completely across the strip where it touches the battery terminal. After that, I used the iron on the battery and applied solder to the perimeter of the strip, then using the solder to bridge up to the solder already on the strip.

Figure 30 – Soldering the first side of the battery, starting with the right two batteries first. After applying flux and laying the trimmed strip on the battery, I first soldered the strip so it was covered, then soldered the perimeter of the battery terminal where it met the strip, pushing the solder up to bridge onto the solder on the strip.

Repeat this process for the other side of the battery. To keep the battery secure, I used my helping hands arm between the center two batteries to prevent it from tipping over. This allowed me to have the batteries facing up for the second side.

13.3 Wiring the BMS

After the strips are wired, the battery needs to be wired into the battery management system (BMS). This board will aid in charging to ensure all batteries get an even charge and will help to prevent a giant spike upon discharge as well. The diagram below shows the appropriate wiring for the BMS.

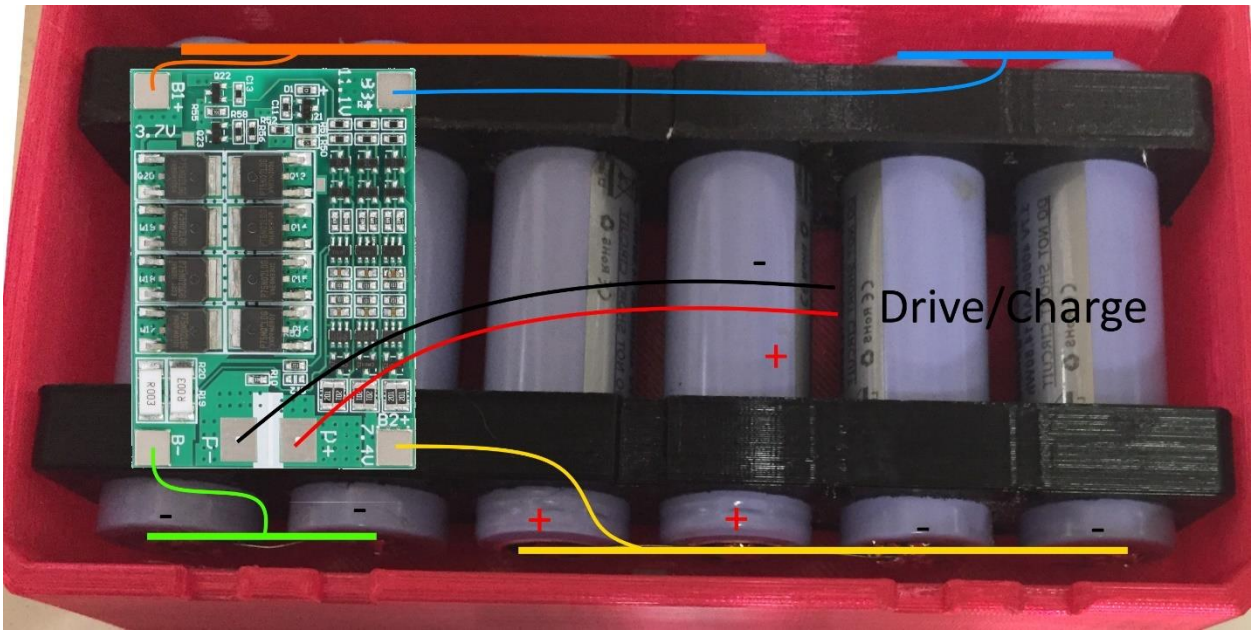

Figure 31 – BMS wiring diagram to properly ensure charging protection and discharge protection.

To solder the wires to the strip. I chose to solder between two batteries. Again, with the strip sanded in that area, just pre-tin the strip with solder, pre-tin the wire, and solder them together. After this, I used the small holes I created in the 21700 6x Holders to neatly route the wires; some pictures of that routing is below. You can choose to route anyway that is comfortable though.

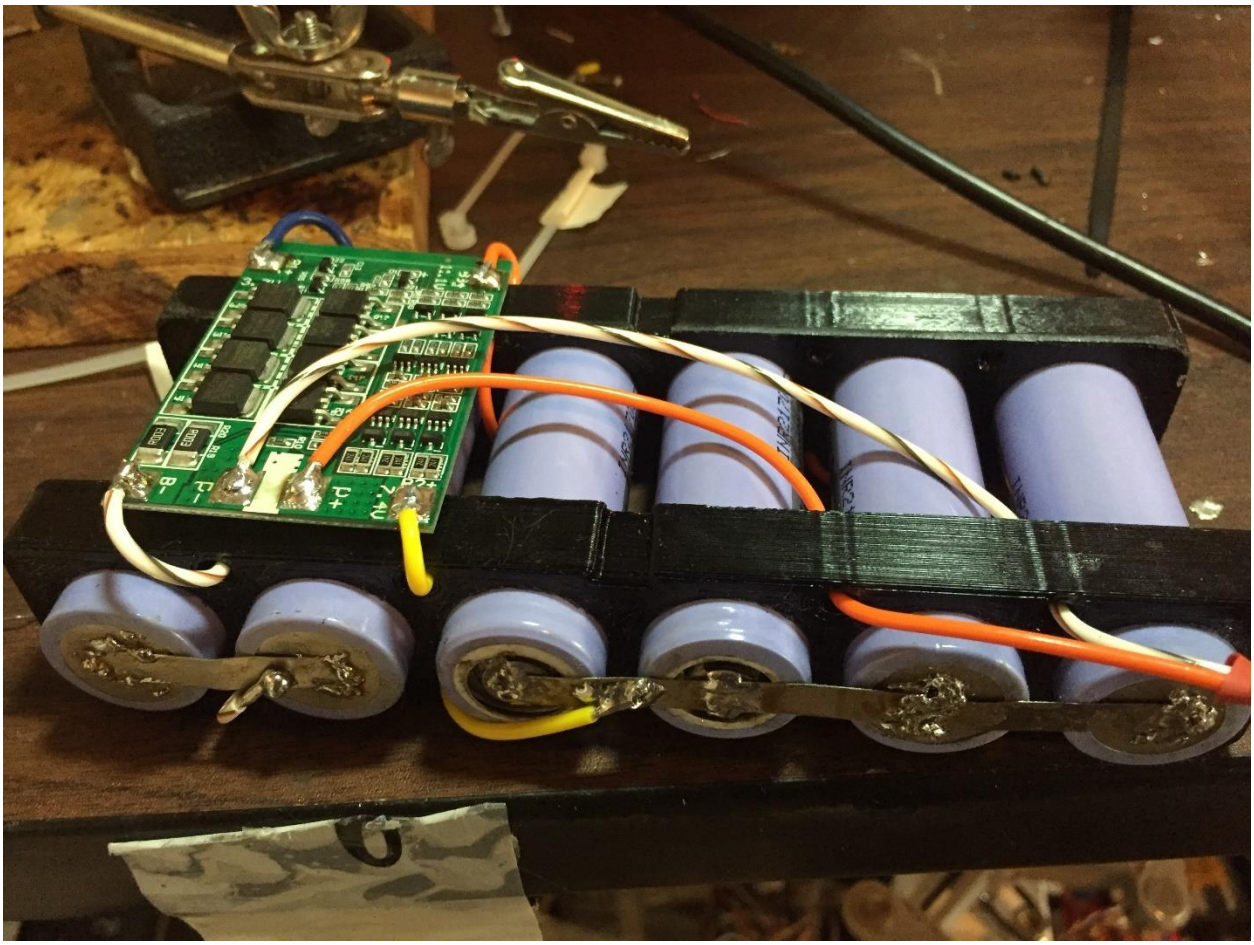

Figure 32 – Fully routed wiring for the BMS. You can follow the wire colors to see how I utilized the small holes for a tug proof wiring to make sure the wires will not come loose if they are tugged on for any reason.

Finally, carefully push the battery pack into the box, ensuring it is centered. Then use a zip tie to hold down the BMS around the back two batteries and use another zip tie around the entire pack through the two bottom square holes of the box. You can also insert any required connector to the battery. And with that, the battery unit is complete and will act exactly like a portable jump starter for the droid.

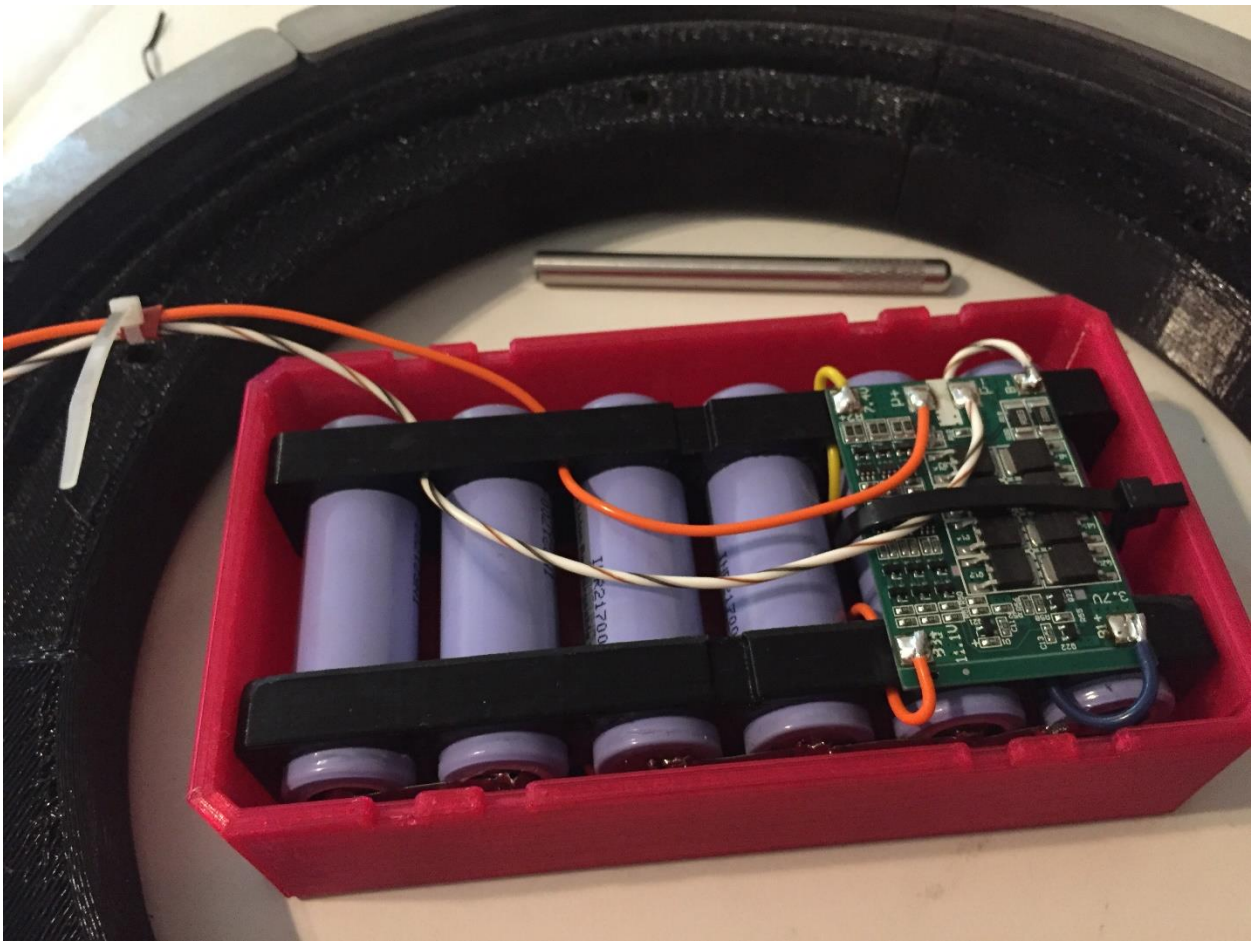

Figure 33 – Completed battery box that is ready to be assembled into the droid. From here on this unit will act exactly like a portable jump starter from the droid's perspective, save for charging as the portable jump starter does not charge through the main connection, but rather through its own charge port.

14. Special Thanks

The following people really helped to make this project of mine become a reality.

Greg Carpenter

Greg was instrumental in this project coming to fruition. He created an initial mockup of what it could be like to have the battery under the drive with a wider flywheel. His ides helped to form my vision and make this project a reality.

Dave "Daver" Ferreira

Dave gave me solid advice about flywheel and drive weight and how it relates to the body movement. It helped form some of the final changes, like the inclusion of the *Under-Battery Ballast Holder*.

Joe Latiola

The maker! Where would any of us be without the original "Space Wizard Droid Master".