

Alternative Custom Liquid Handler Build Guide

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Total Parts list:

	Item	SKU	Units	Vendor
Extrusions	V-Slot 2020 Aluminum Profile (length 250mm)	VC2020-250	4	Bulkman 3d
	V-Slot 2020 Aluminum Profile (length 500mm)	VC2020-500	10	Bulkman 3d
	V-Slot 2040 Aluminum Profile (length 500mm)	VC2040-500	4	Bulkman 3d
Hardware	M5 Double Tee Nut	HD0007-M5	28	Bulkman 3d
	M3 Tee Nuts	HD0006-M3	4	Bulkman 3d
	M5 Tee Nuts	HD0006-M5	22	Bulkman 3d
	M5 Tee Nuts (Drop-in)	HD0008-S20M5	13	Bulkman 3d
	M5 8mm Screws	HD0028-M508	80	Bulkman 3d
	M5 12mm Screws	HD0028-M512	2	Bulkman 3d
	M5 15mm Screws	HD0028-M515	9	Bulkman 3d
	M5 20mm Screws	HD0028-M520	2	Bulkman 3d
	M5 30 mm Screws	HD0028-M530	8	Bulkman 3d
	M5 40 mm Screws	HD0028-M540	8	Bulkman 3d
	M3 10mm Screws	HD0029B-M310	12	Bulkman 3d
	M3 20mm Screws	HD0029B-M320	5	Bulkman 3d
	M5 6mm Set Screws	HD0034B-M506	6	Bulkman 3d
	Nylon Insert Hex Lock Nut-M3	HD0013S-M3	1	Bulkman 3d
Plates	Nylon Insert Hex Lock Nut-M5	HD0013S-M5	24	Bulkman 3d
	Self-Tapping Screws	HD0033B-M4.8*	19	Bulkman 3d
	M5 3mm Aluminum Spacer (10mm OD)	HD14-5.1*10-3	2	Bulkman 3d
	M5 6mm Aluminum Spacer (10mm OD)	HD14-5.1*10-6	6	Bulkman 3d
	90 Degree Angle Connector	BR0004-black	16	Bulkman 3d
Motion	5 Hole 90 Degree Joining Plate	PL04-20S	12	Bulkman 3d
	Acro Plate Kit	ACRO-11PCS	1	Bulkman 3d
	Y-Axis Bracket Plate (Acro Plate Kit)		2	
	X Carriage Plate (Acro Plate Kit)		1	
	X Carriage Motor Plate (Acro Plate Kit)		1	
	Universal V-Slot Gantry Plate	PL11-3	1	Bulkman 3d
	Delrin Solid V Wheel Kit Unassembled (AL spacer)	VW01-RS-KA	12	Bulkman 3d
	14-Tooth Timing Pulley		3	Bulkman 3d
	Set Screws (in pulley)		6	Bulkman 3d

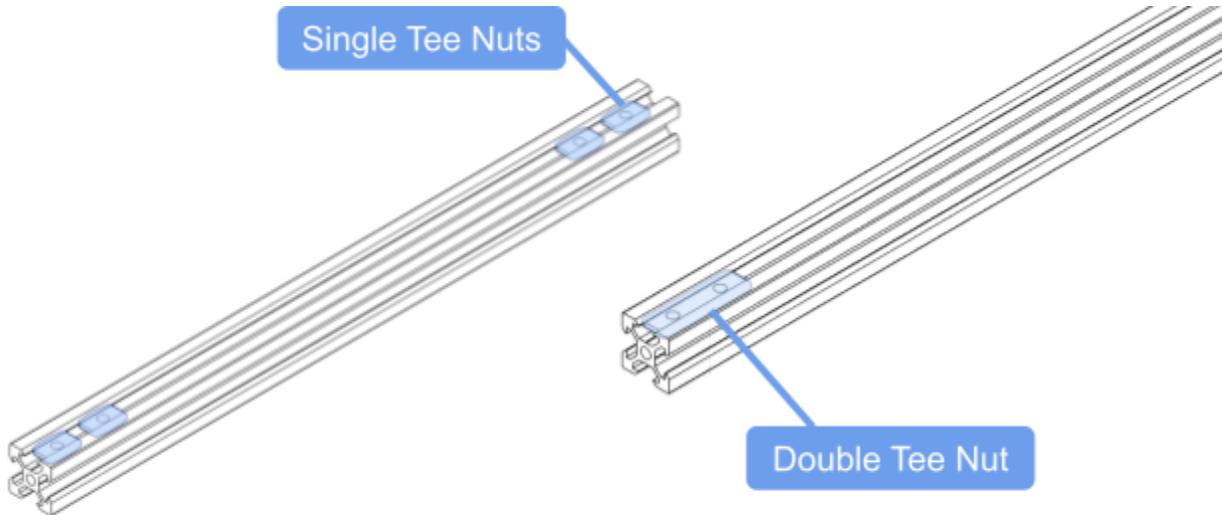
	GT2 5 mm Timing Belt (600mm)	GT2-5W-1000	3	Bulkman 3d
Electronics	NEMA 17 Stepper Motor	N17SM-48-5	3	Bulkman 3d
	CNC Machining Micro Limit Switch Kit	LSK-01	3	Bulkman 3d
	4 Core Shielded Xtension 22 AWG 2.5m cable	SC4P-2500	4	Bulkman 3d
	2 Core Shielded 22 AWG 5m cable	SC2P-5000	2	Bulkman 3d
	MeanWell Power Supply 350W 24V	LRS-350-24	1	Bulkman 3d
	Duet 3D Duet 3 Mini 5+	M-N98-JPQR	1	MatterHacker s
	Welding-free Plug-in Terminal Block 3.81mm 4 pin	TB381A-4P	4	Bulkman 3d
	Ethernet Cable			
	14 AWG 2 core Cable			
Cable Management	Slot Cover	SC6-B1000	10	Bulkman 3d
	Flexible Corrugated Tubing OR Cable chains			
	Tubing Clamp			
Misc	Spacer		3	Bulkman 3d
	Rubber Foot		5	Bulkman 3d
	3D Printed Pipette Holder		1	Bulkman 3d
	Pipette Holder Clamp		1	Bulkman 3d
Bundles	V-Slot NEMA 17 Linear Actuator Bundle 250mm	PL111-2040-250 S	1	Bulkman 3d

Bottom Assembly

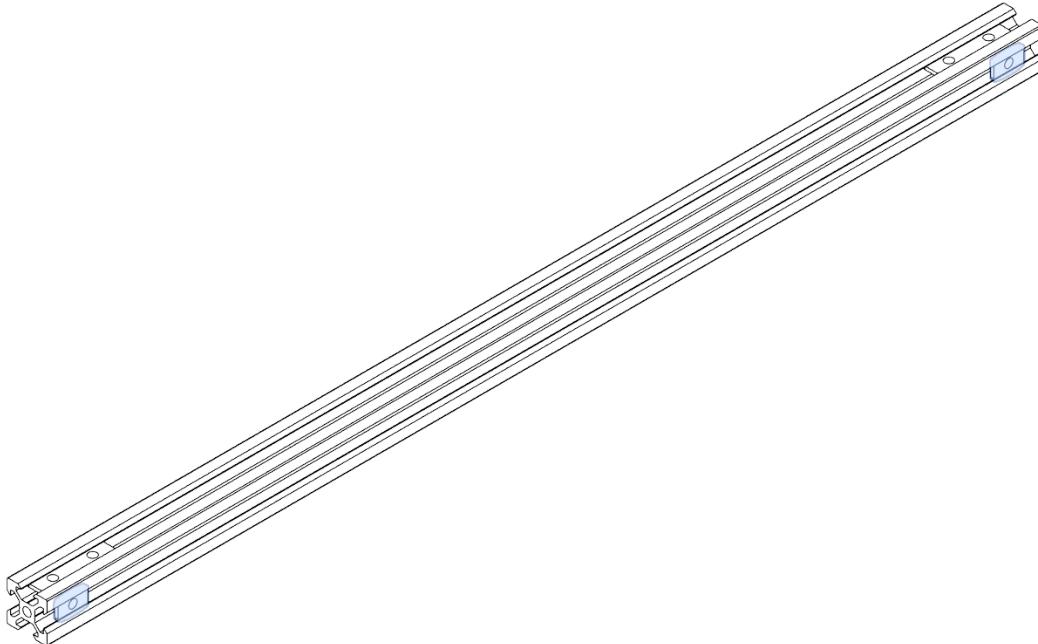
Step 1. Insert Tee Nuts for the Frame Bottom

Part Requirements:(2) 20x20 500mm Al extrusions, (8) M5 Tee Nuts OR (4) Double M5 Tee Nuts, (4) Single M3 Tee Nuts

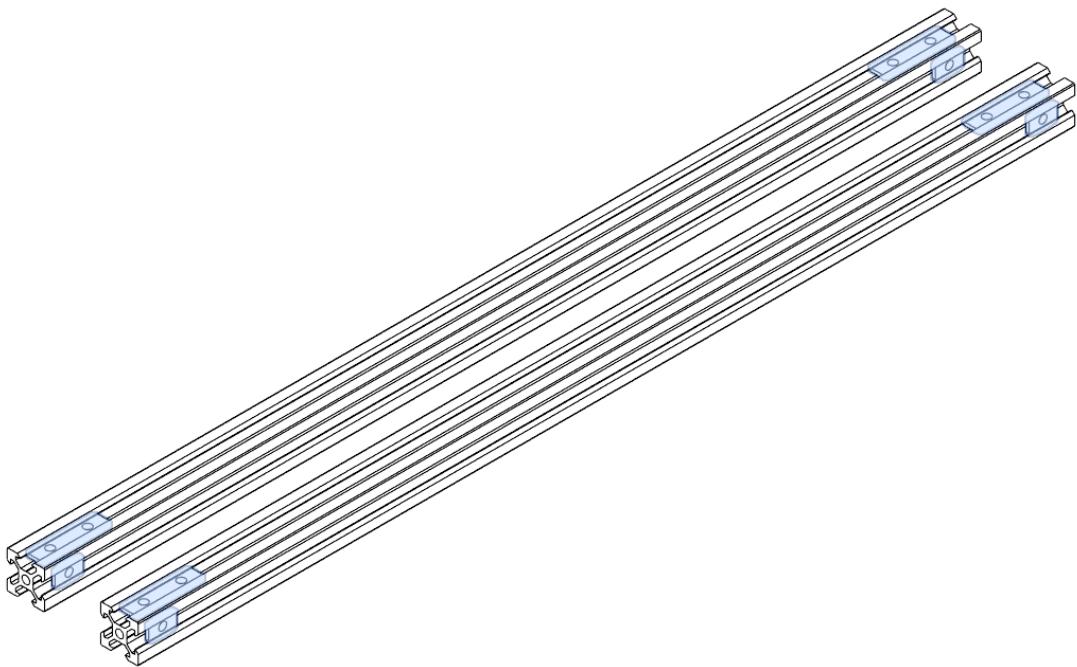
1.1. Slot in four single M5 Tee Nuts into a single 20x20 Al extrusion. A better alternative would be to use two double M5 Tee Nuts, which we will be using for the duration of the build guide.



1.2. Attach a single M3 Tee Nut on the side of the 20x20 Al extrusion, on each corner.



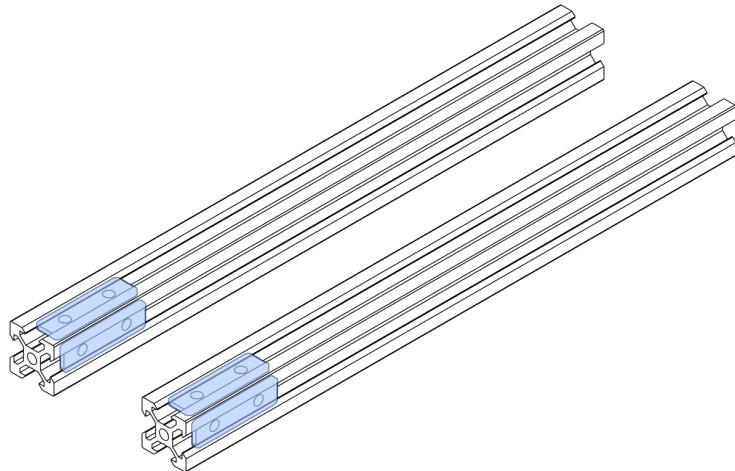
1.3. Repeat this twice so you have 2 of these assemblies.



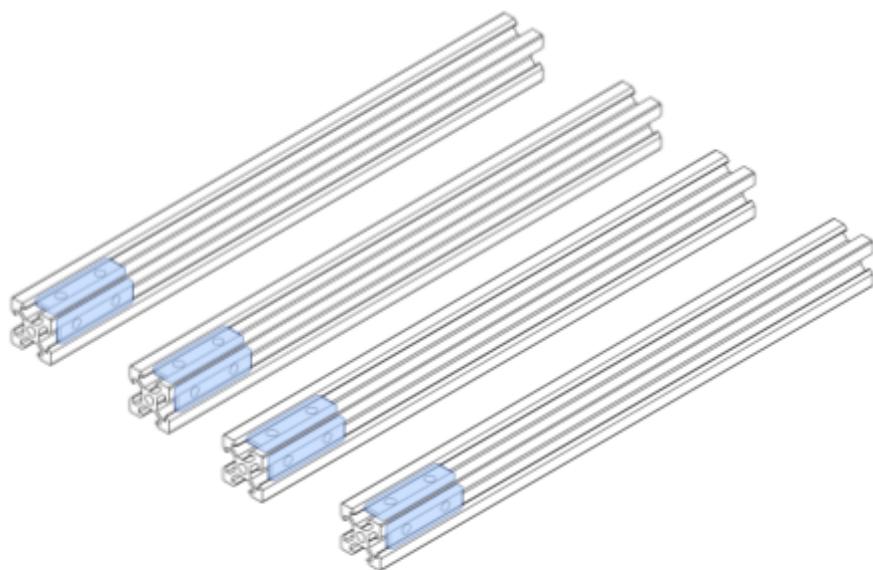
Step 2. Prepare Upright Extrusions

Part Requirements: (4) 20x20 250mm Al extrusions, (8) Double M5 Tee Nuts or (16) Single M5 Tee Nuts

2.1. The upright extrusions will be located at the corners of the frame and will connect the bottom frame extrusions. Slot in two double M5 Tee Nuts on adjacent sides.



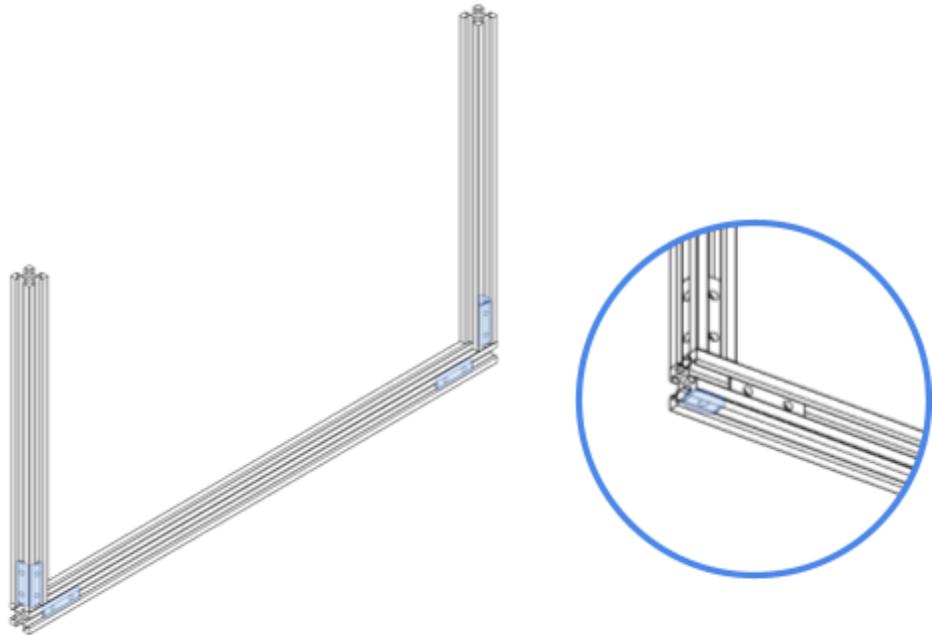
2.2. Repeat step 2.1 to have a total of 4 Upright Extrusion assemblies.



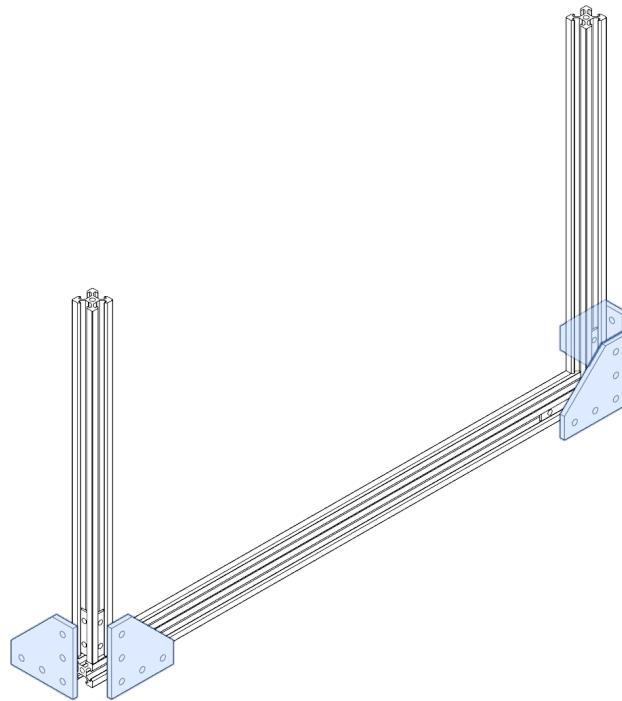
Step 3. Prepare front/back frames

Required Parts: x2 (4) 90 Degree Joining plates, (12) 8mm M5 screws

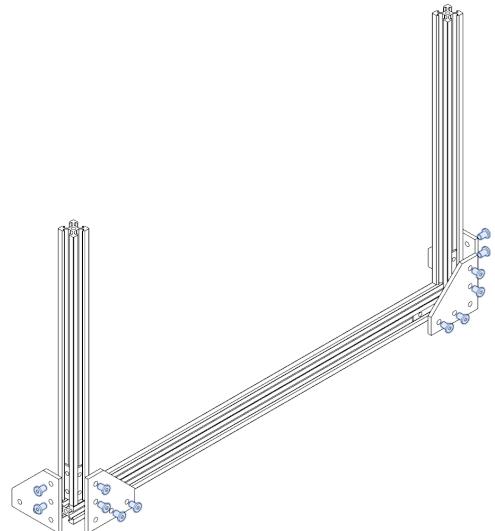
3.1. Place two upright extrusions (made in step 2) on top of the ends of a bottom extrusion (made in step 1). Orient the double M5 Tee nuts facing outwards and the M3 Tee Nuts facing downwards.



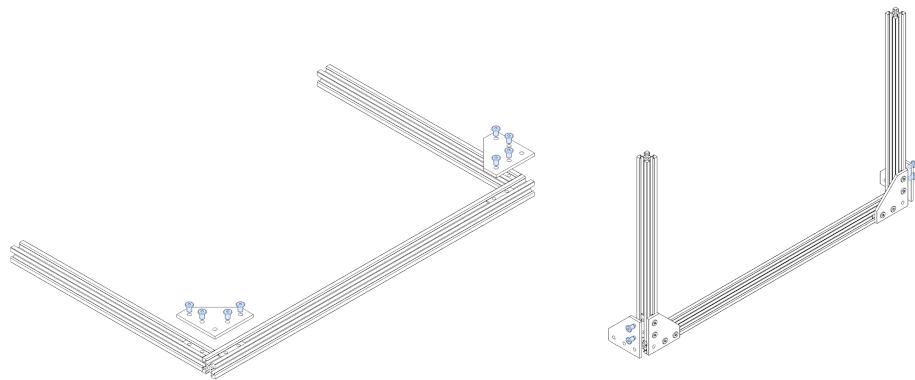
3.2. Orient the 90-degree plates on the outward-facing corners, two on each side.



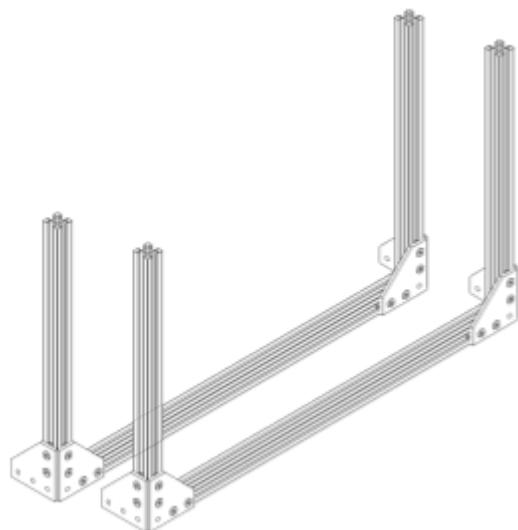
3.3. Attach the 90-degree plates using 8mm M5 screws.



NOTE: It may be easier to connect the 3 extrusions using a 90-degree plate on each side to hold the extrusions together, before attaching the side 90-degree plates.



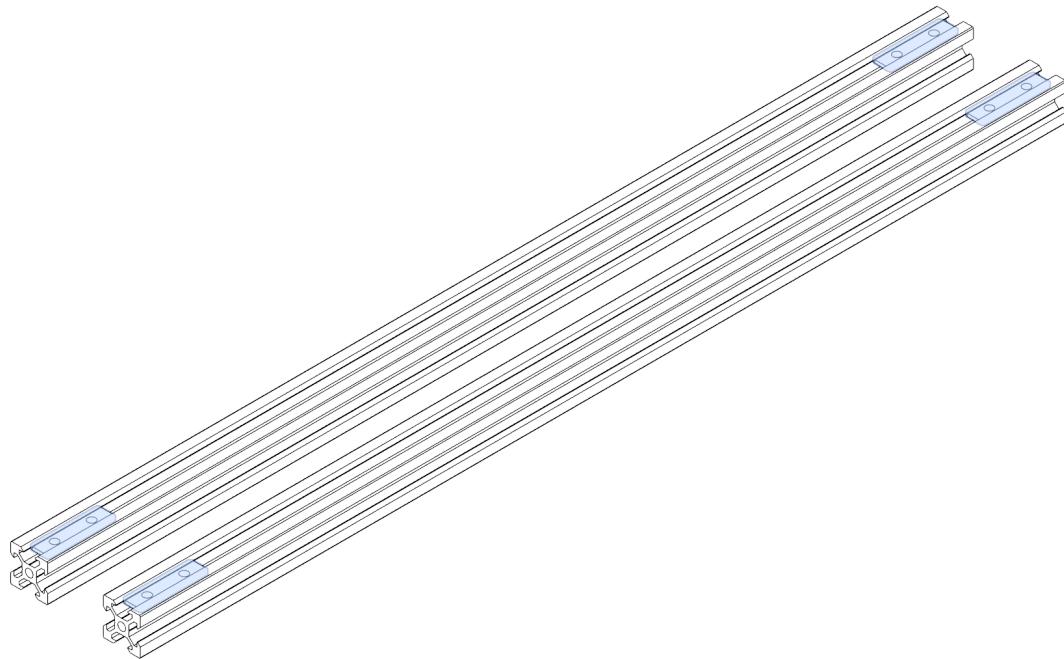
Step 3.4. Repeat steps 3.1- 3.4 to have a front and rear frame.



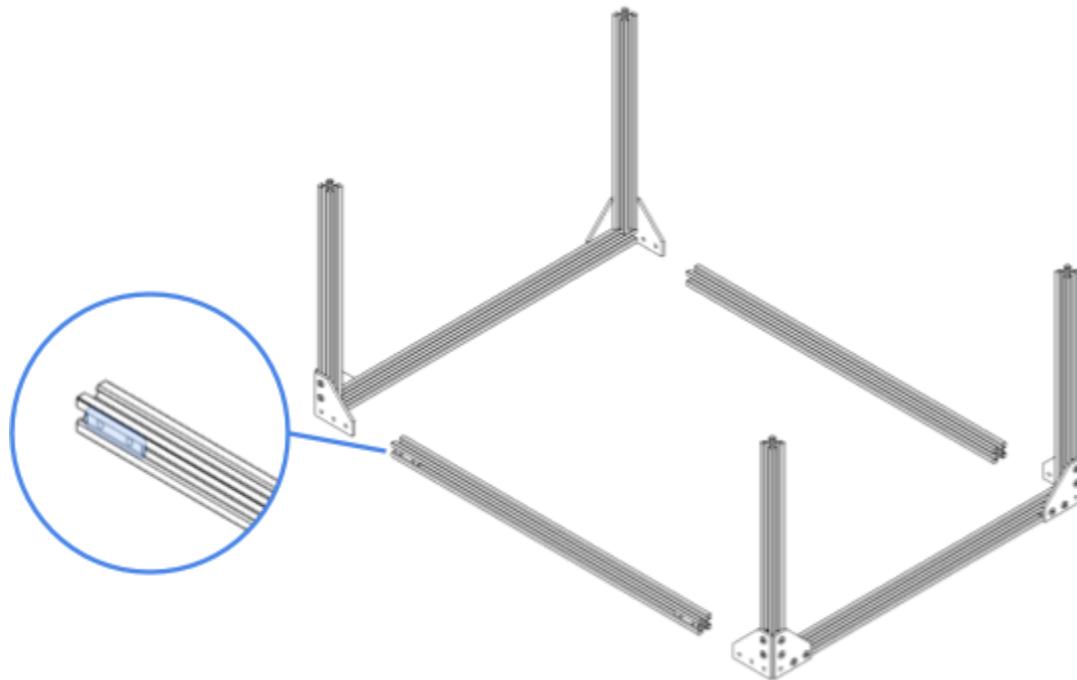
Step 4: Joining the two sides of the frame with Bottom Extrusion

Required Parts: (8) 8mm M5 screws, (4) Double M5 Tee Nuts or (8) Single M5 Tee Nuts, (2) 20x20 500 mm AL Extrusions

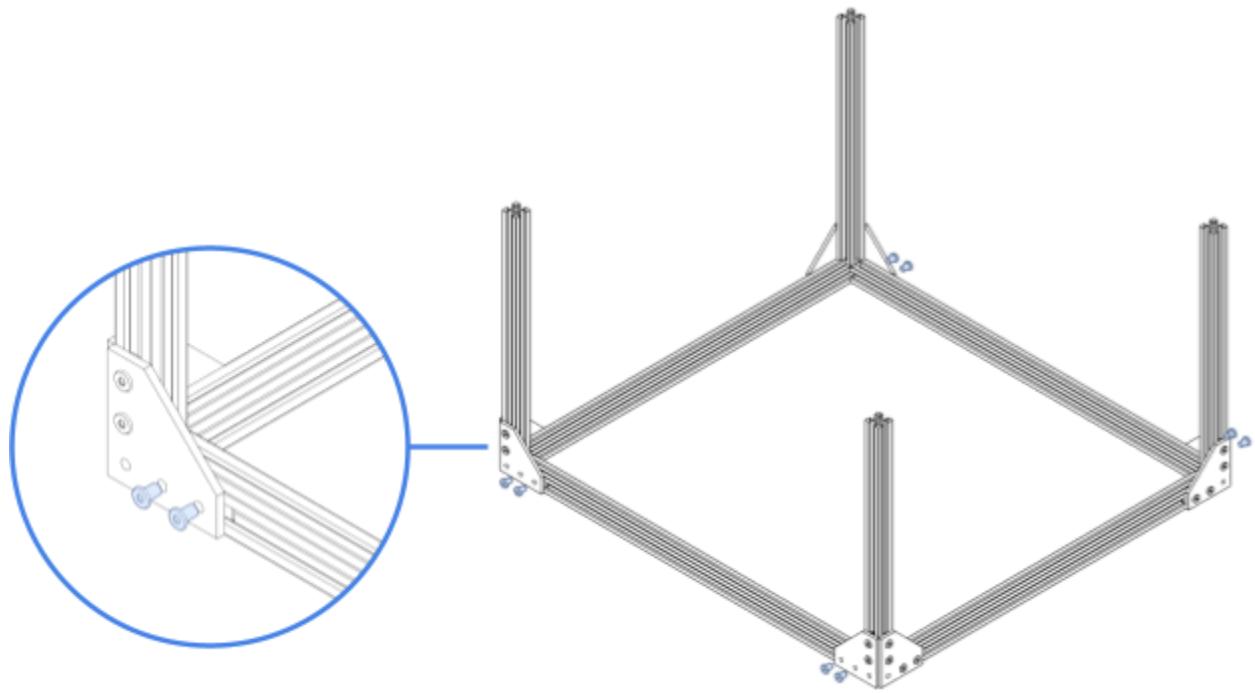
4.1. You will create **two** more of the bottom extrusions with (1) Double M5 Tee nut or (2) Single M5 Tee Nuts on each side.



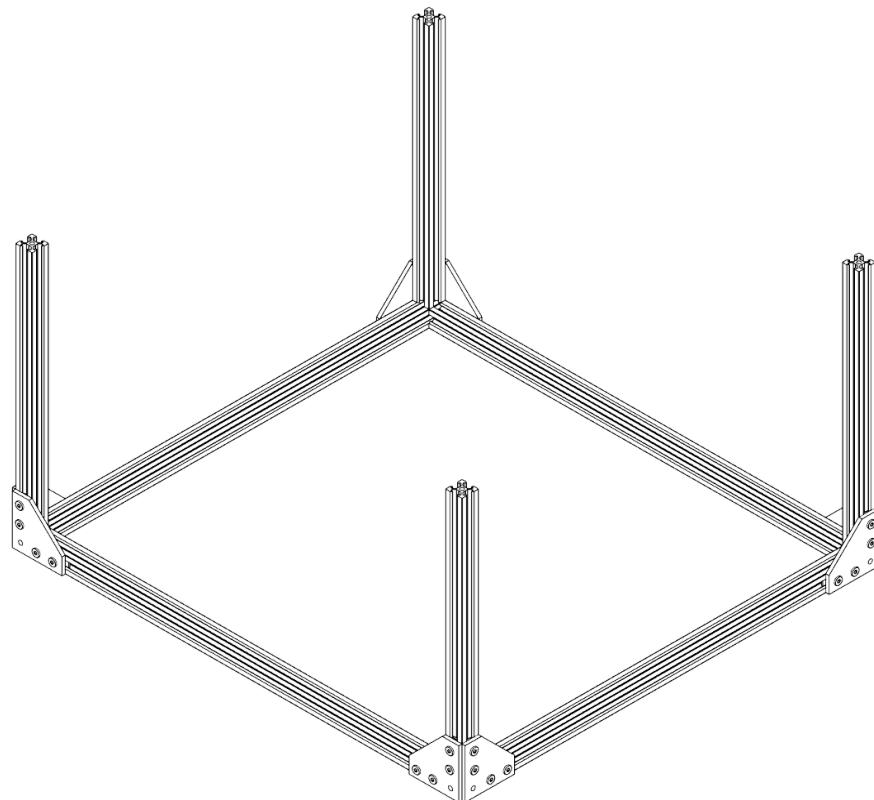
4.2. Orient the two remaining bottom extrusions to have the M5 Tee Nuts facing the open holes of the 90-degree joint plates.



4.2. Fasten the joint plate to the bottom extrusions using 8mm M5 screws.



4.3. On a flat and even surface, make sure the bottom frame is square, flat, and there are no gaps between the extrusions. You may need to loosen the screws and adjust accordingly. Once it is square, tighten the screws.

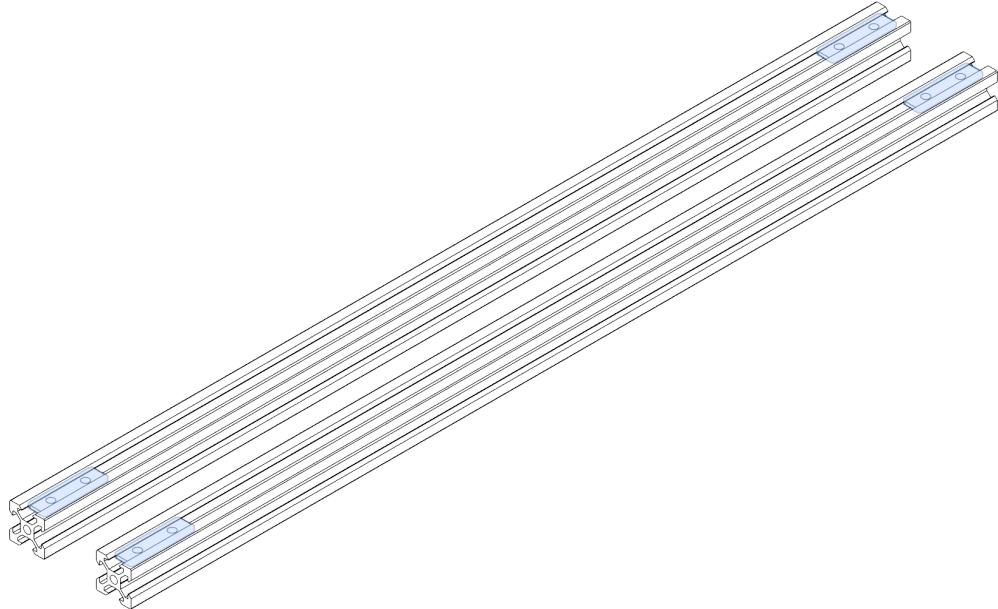


Top Assembly

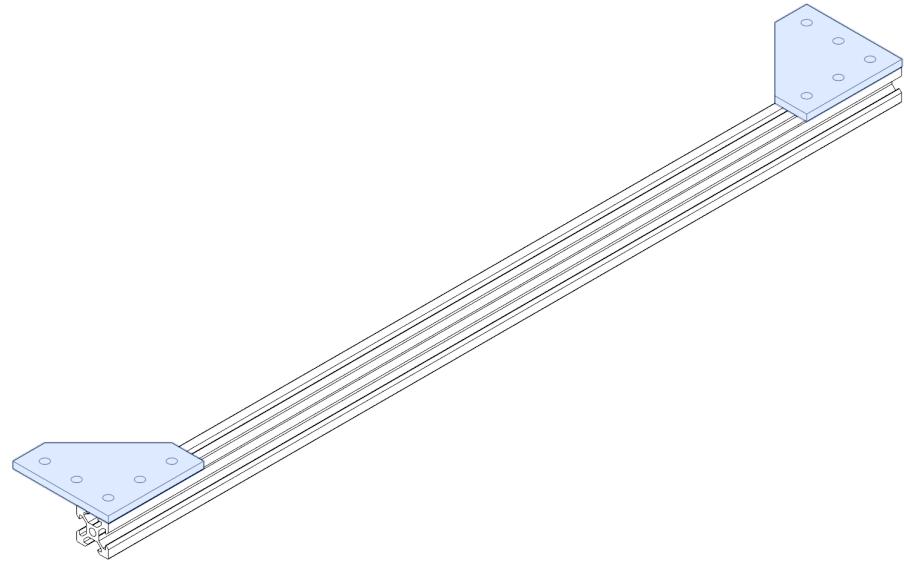
Step 5: Create top front/back extrusion pieces

Required Materials: (2) 20x20 500 mm Al extrusions, (8) Double M5 Tee Nuts (4) 90 Degree joint plates

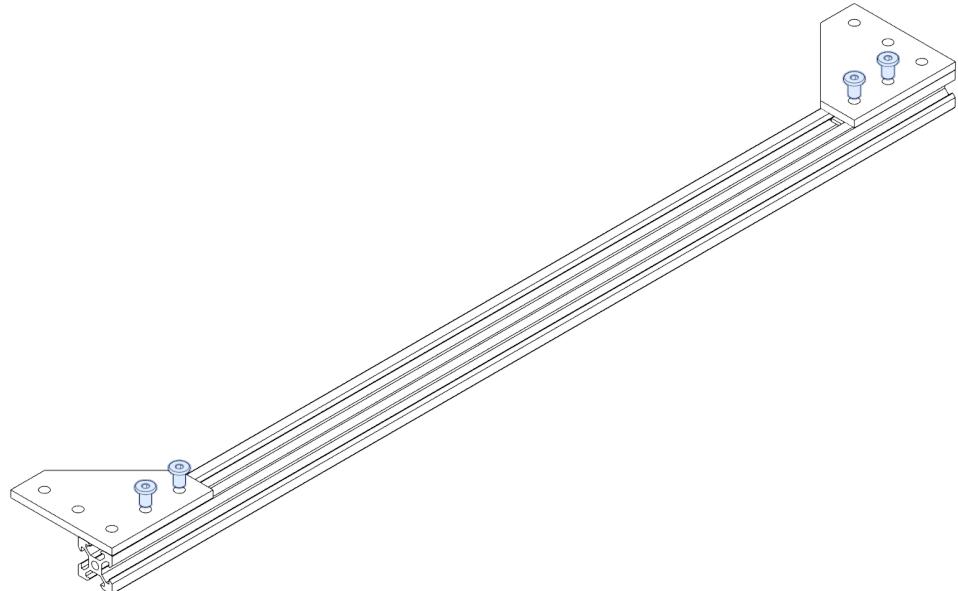
5.1. To start to build the top of the frame, you will create **two** more of the bottom extrusions with (1) double M5 Tee Nut or (2) single M5 Tee Nuts on each side.



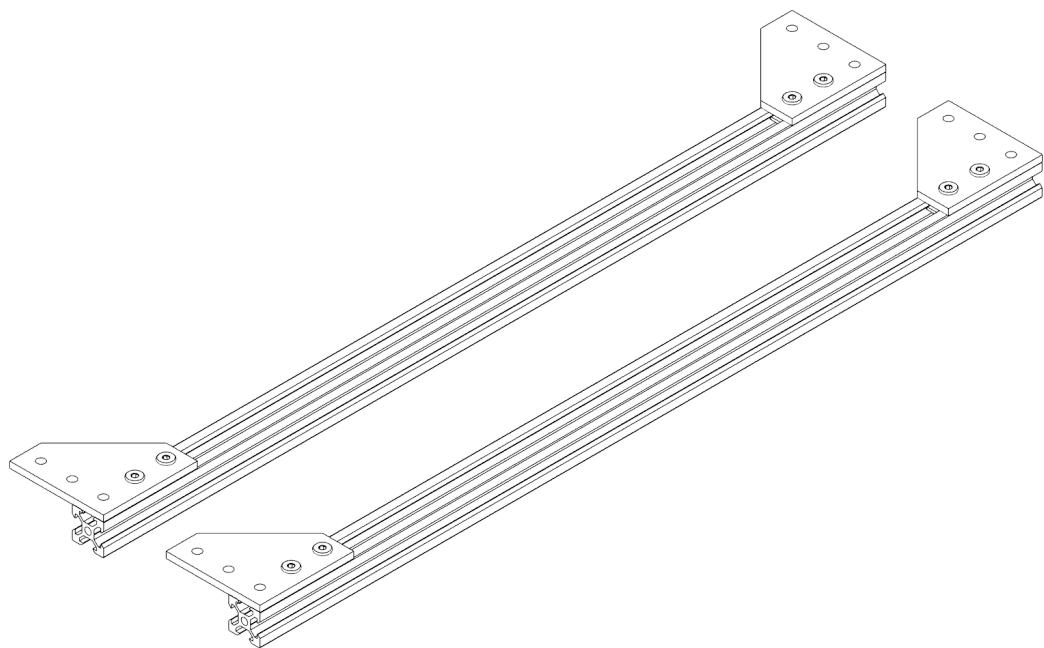
5.2. You will then place a 90-degree joint plate on each end of the extrusion, aligned with the M5 Tee Nuts.



5.3. Using 8mm M5 screws fasten the joint plates to the extrusions.

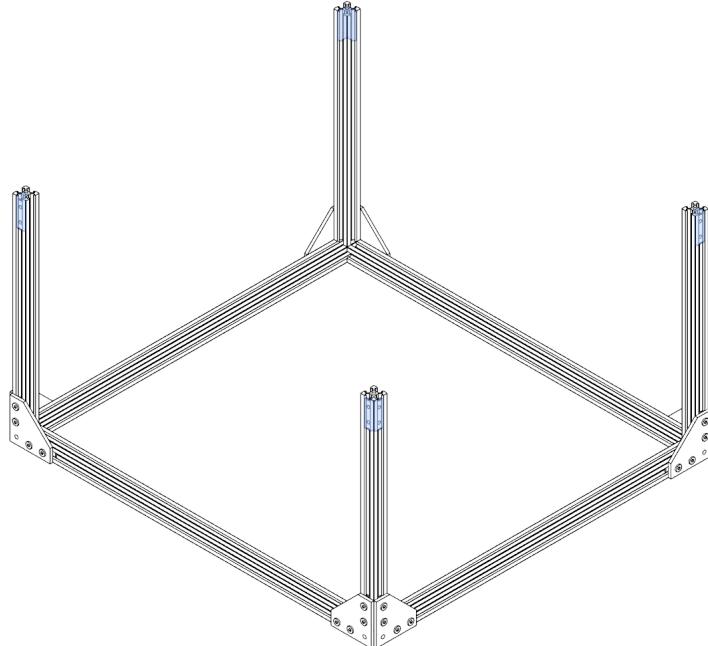


5.4. Repeat steps 5.1-5.3 until you have two top front/rear extrusion assemblies.

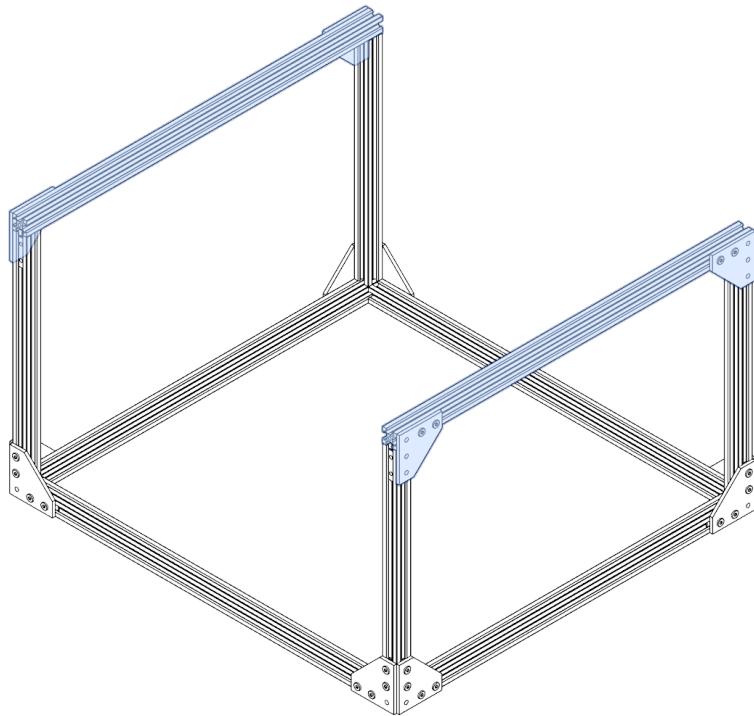


Step 6: Connect the top front/back extrusion pieces to the assembled bottom frame
Required materials: (8) Double M5 Tee Nuts, (8) 8mm M5 screws

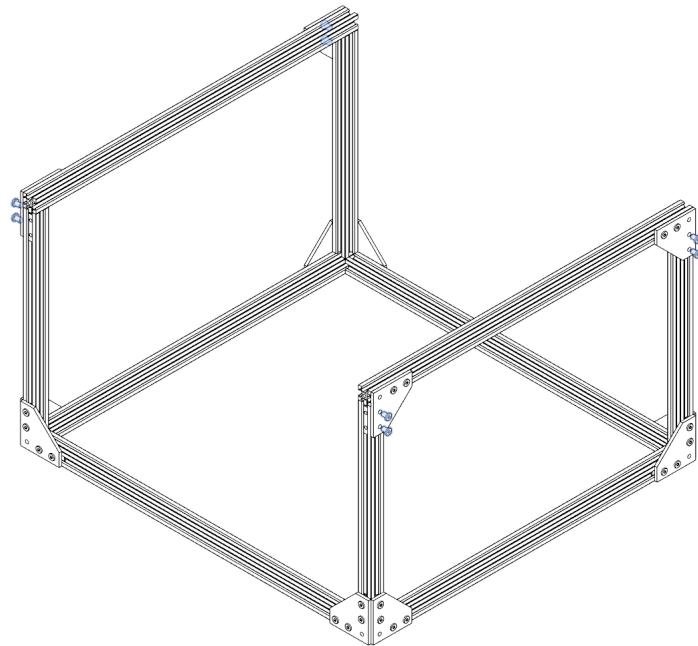
6.1. Slot in a double M5 Tee Nut on the two outside corners of each upright extrusion.



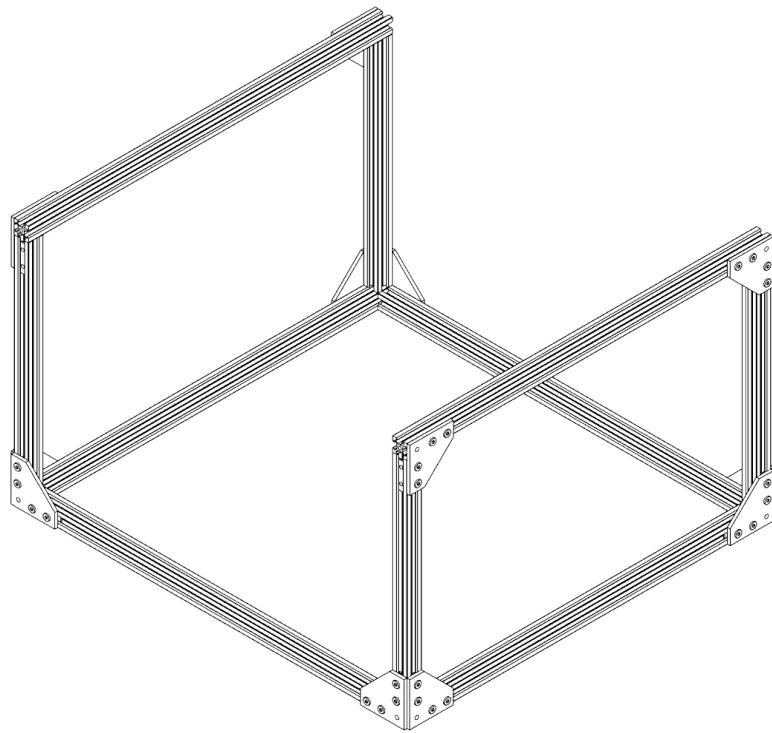
6.2. Place your front/back extrusion pieces on top of the upright extrusions aligned with your inserted M5 Tee Nuts.



6.3. Using 8mm M5 screws fasten the joint plate already on your top front/back extrusion to the upright extrusions.

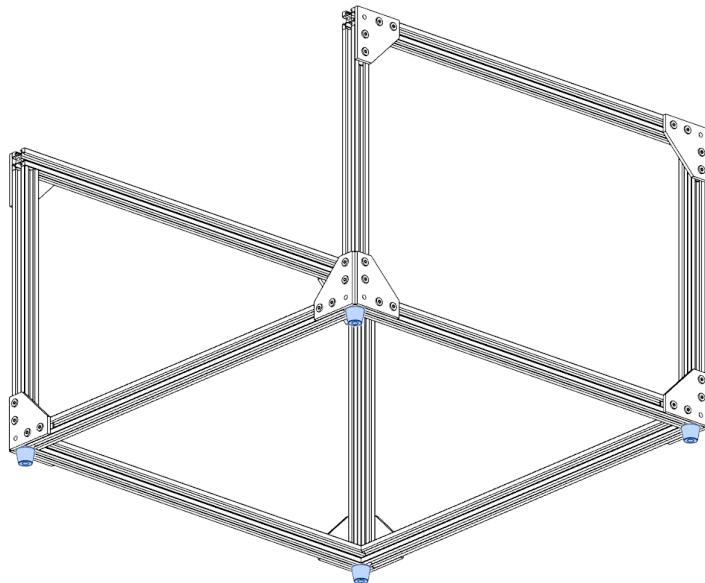


6.4. The unused Double Tee Nut will be kept in place to connect the side extrusions later.

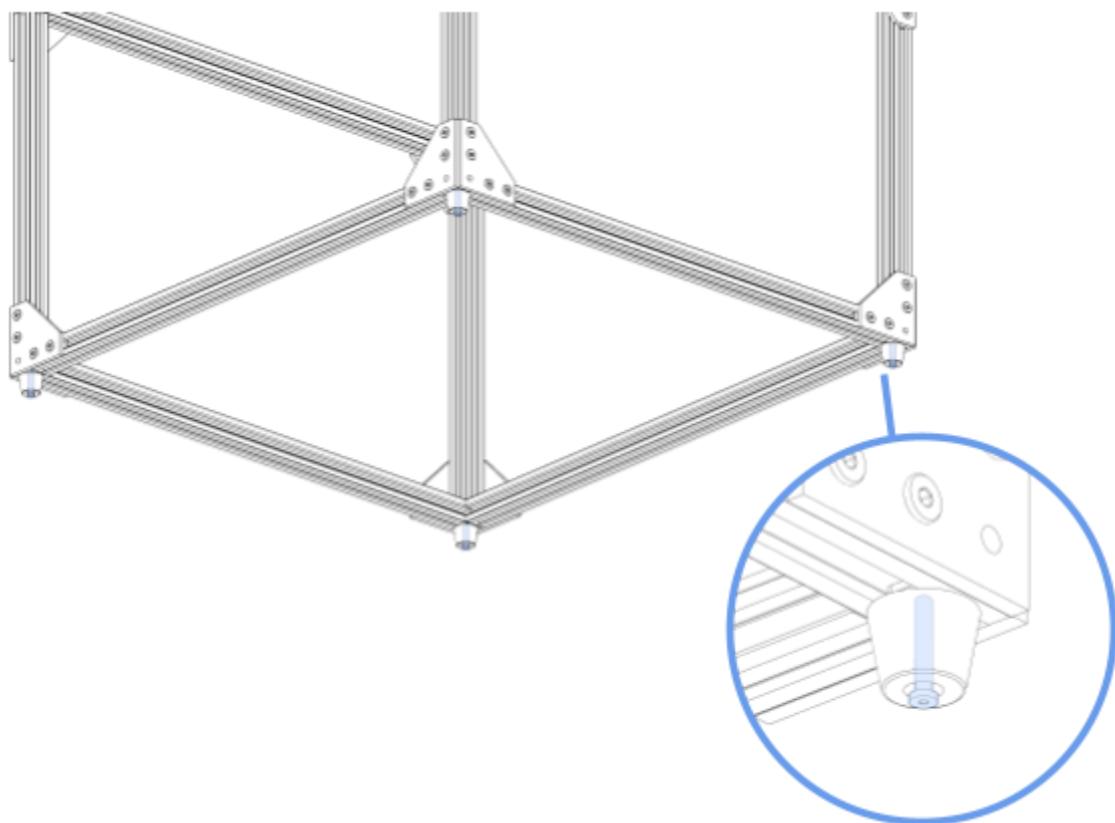


Step 7: Attach the rubber feet on the underside of the bottom frame
Required materials: (4) Rubber Feet, (4) 20mm M3 screws

7.1. Ensure the M3 Tee Nuts placed in step 1 are in the corners of the frame. The rubber feet will be connected to them in each corner.



7.2. Attach the rubber feet using an M3 20mm screw on each corner.



At this point in the build, it is important to create the ACRO System so we can fit it onto the frame we built in steps 1-7. For now, you may put the assembled bottom frame aside.

ACRO System Setup

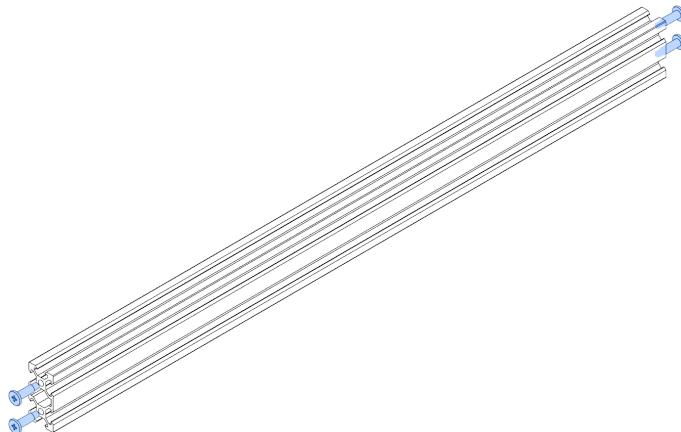
The included link provides additional help in video format for creating the XY axis controller of our system. Our setup is based on the original ACRO system, but modified to fit onto the frame we built in steps 1 through 7.

<https://youtu.be/YDLJrxrMEAo?si=e5ujUbTHnhQ1dSPA>

Step 8: Pre-thread holes in the ends of your 20x40 extrusion

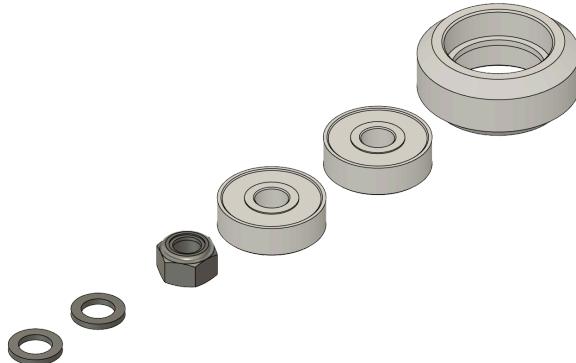
Required Materials: (1) Self-Tapping Screw, (1) 20x40 Al Extrusion

8.1. Using a drill and self tapping screws, individually screw and unscrew into the end holes of the 20x40 to make threads in the extrusion. (This will be used as the X axis extrusion, place aside until mentioned in later steps)

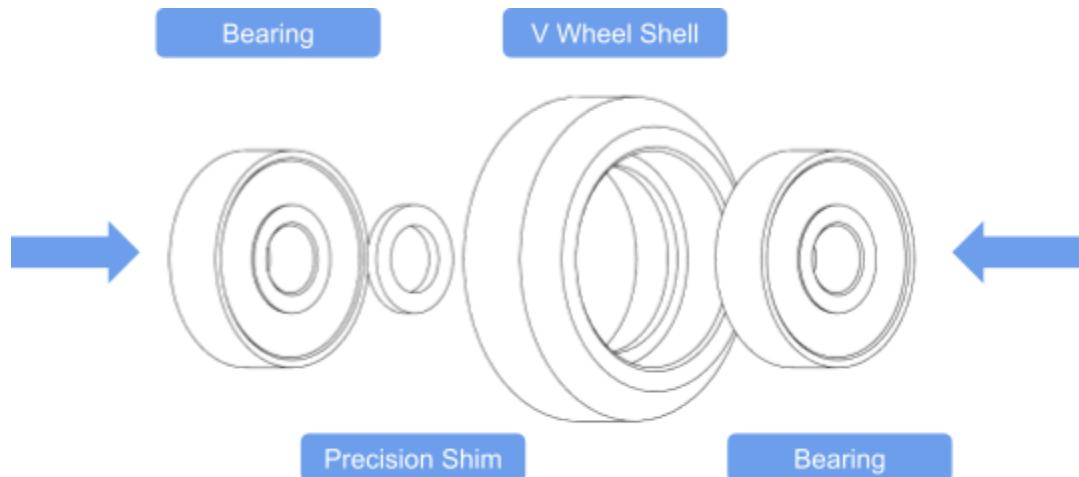


Step 9: V Wheel assembly

Required Materials: (12) Wheel shell, (12) Precision shims, (24) Open Builds Bearings



9.1. Push one bearing into one side of the wheel shell, then on the other side, sandwich a precision shim between an additional bearing.



Note: Ensure the precision shim is sandwiched between the two bearings.



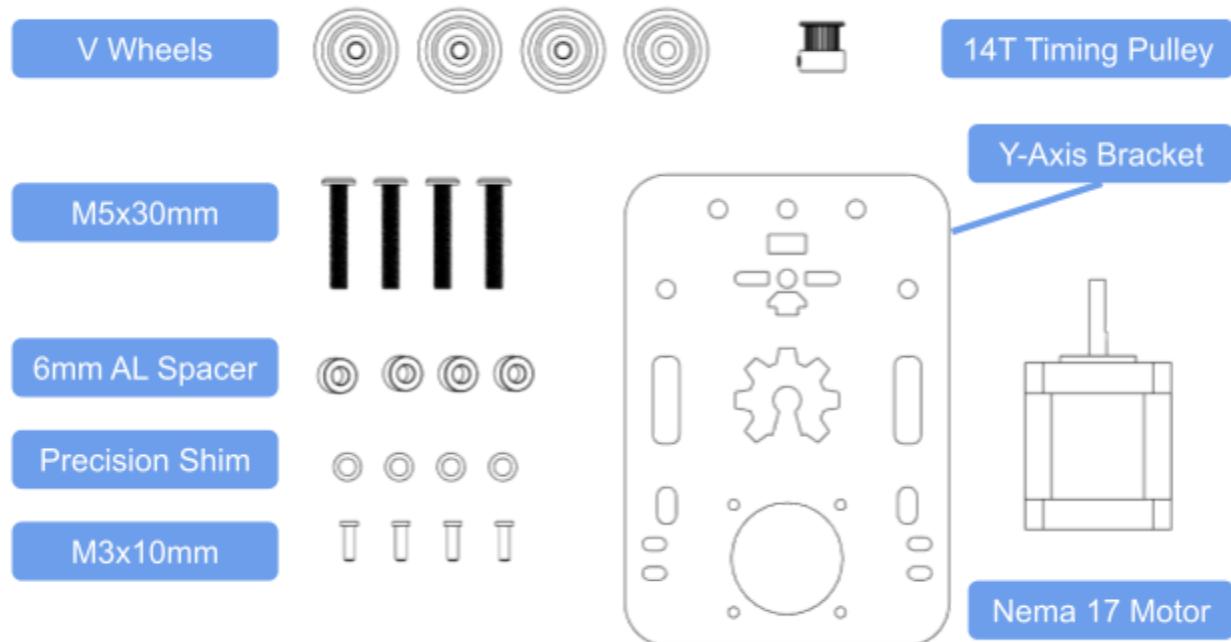
9.2. Repeat this step until you have a total of 12 wheel assemblies. These assembled wheels and leftover Precision Shim and M5 Nylon Hex nuts will be used for the X and Y carriages, so put them aside.



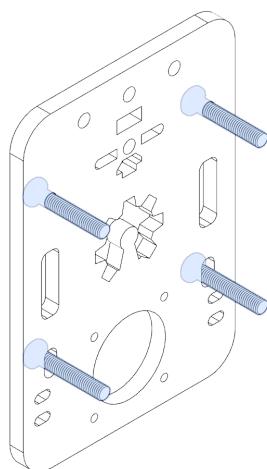
Y-Axis Carriage Assembly

Step 10. Left Y-axis Carriage Assembly

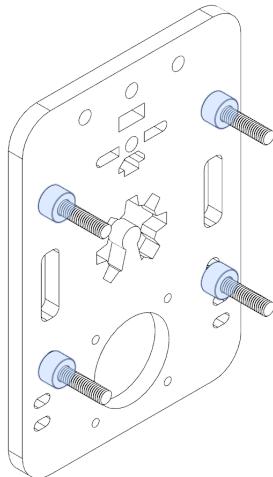
Included Parts: (1) Y-Axis Bracket (plate), (1) Nema 17 Motor, (4) M5 30mm screws, (4) 6mm AL Spacers, (4) Solid V Wheels, (4) M3 10mm screws, (4) Precisions Shims, (4) Nylon Hex Nuts, (1) 14 Tooth timing pulley



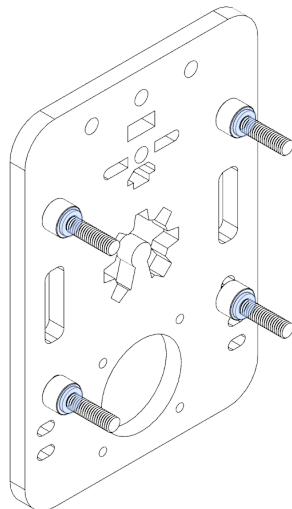
10.1. Orient the Y plate so the large circular hole is at the bottom; this will hold the motor later on. Insert M5 30mm screws into designated holes. The bottom two slotted holes will be used to adjust the wheel position on the rails. The top two holes will act as fixed-position wheels. Then place the y plate on its back where the screws are facing upwards for further assembly.



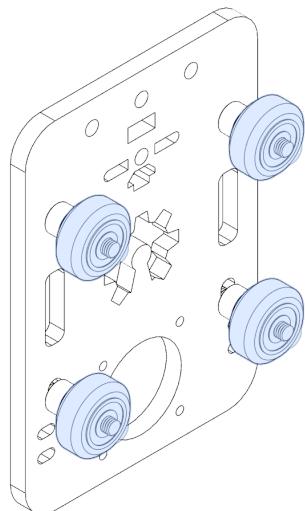
10.2. Place a 6mm Al spacer on each of the 4 screws.



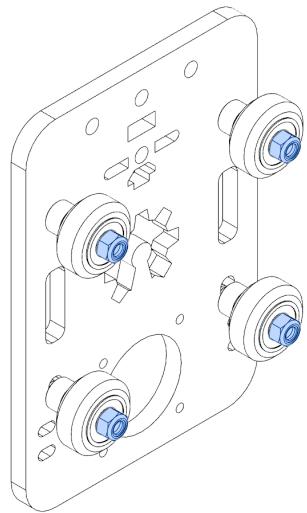
10.3. Place a precision shim on each of the 4 screws.



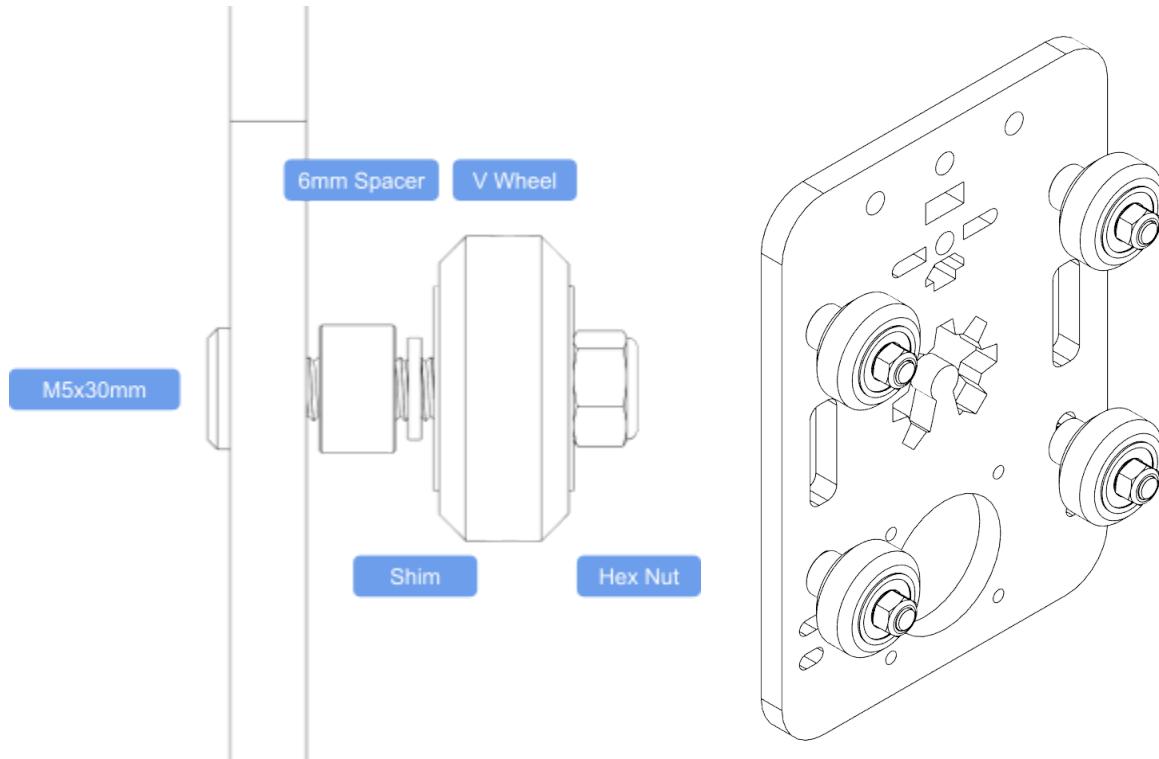
10.4. Place a wheel assembly on each of the 4 screws.



10.5. Place a nylon hex nut on each of the 4 screws to complete the assembly.



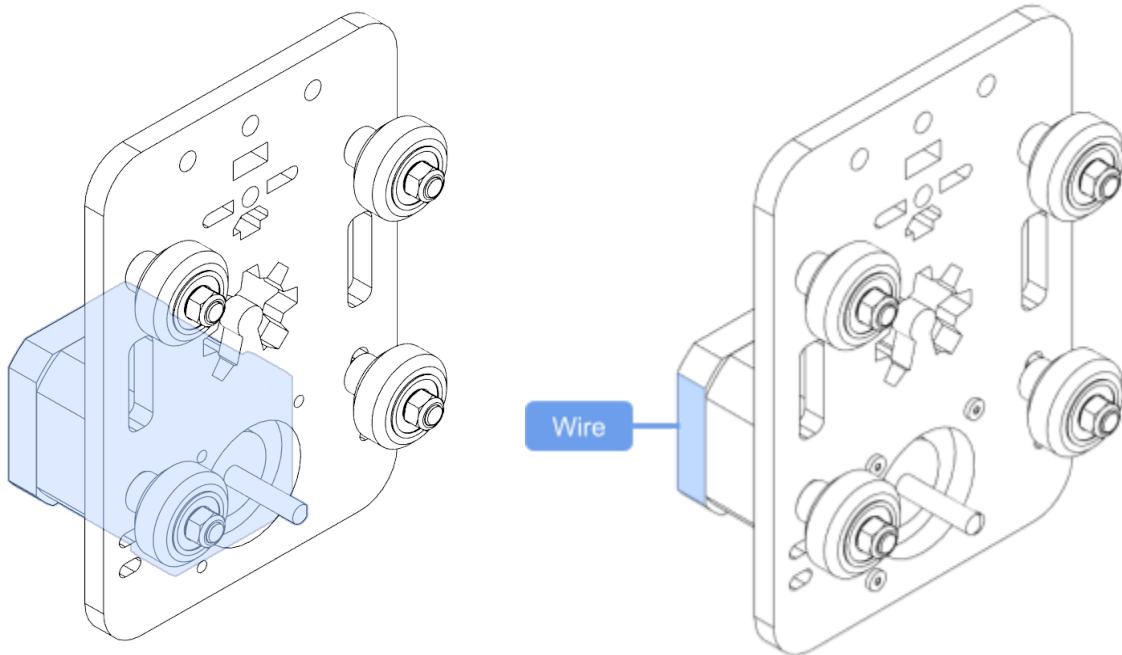
10.6. Ensure each screw has a 6mm spacer, precision shim, V wheel and hex nut in order. Then tighten the assembly at each screw until flush (the bottom two assemblies will be readjusted in later steps to fit to the rails). Do not overtighten, as the acrylic plate can crack.



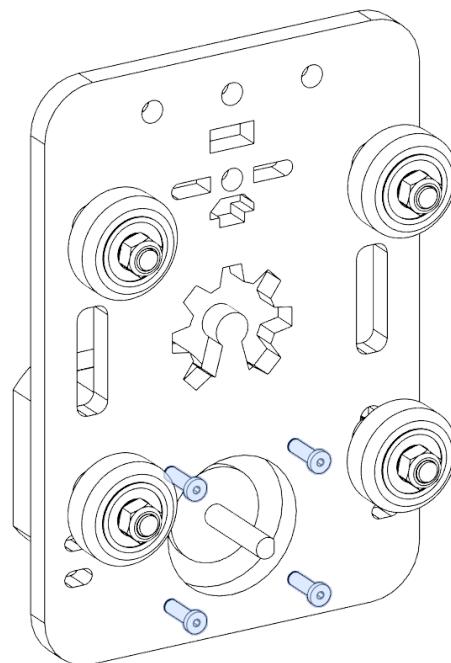
Step 11: Mounting Y Axis Motor

Required Materials:(1) Nema 17 Motor, (4) M3 10mm screws, Y-axis plate with Wheels

11.1. Taking note of orientation, place the motor within its slot on the Y plate. The motor's protruding wires should be facing towards you if you orient the Y plate to allow the four wheel assemblies face right. for ease of wiring in later steps.



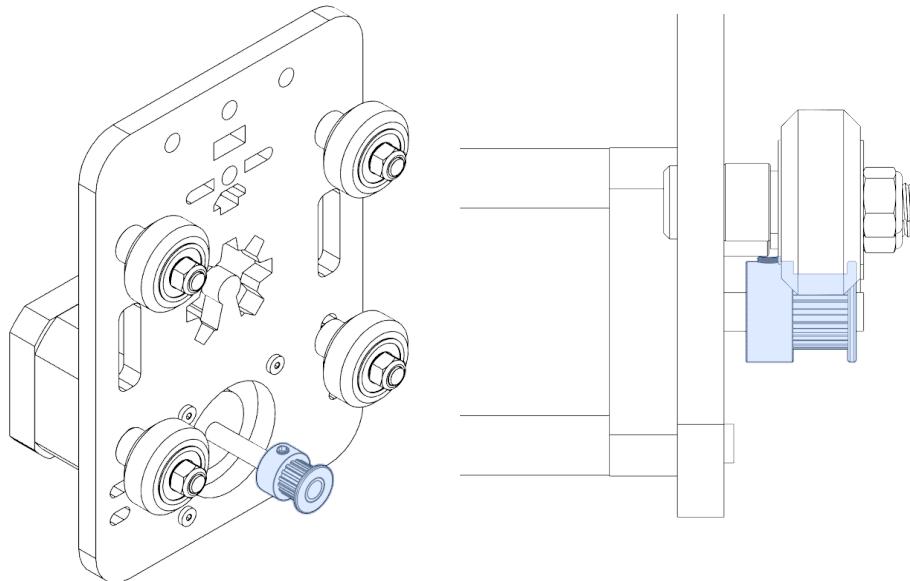
11.2. Using M3 10mm screws fasten the motor to the Y plate using the designated holes. Do not overtighten, as the acrylic plate can crack.



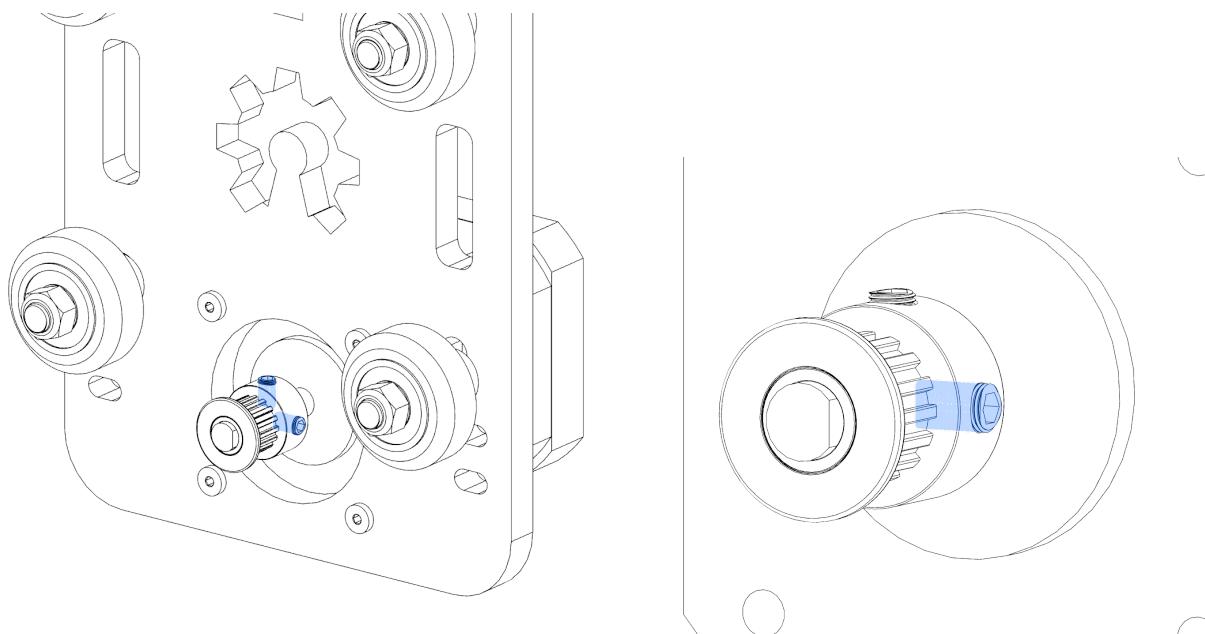
Step 12: Pulley alignment on motor shaft

Required Materials: (1) 14-Tooth Timing Pulley, (2) Set Screws [May be in the timing pulley]

12.1. Slide on the 14-tooth timing pulley, aligning the teeth with the V wheels.

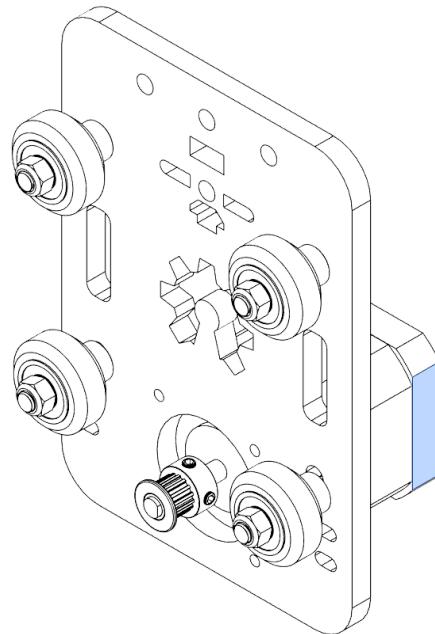


12.2. Tighten set screws until the pulley is fastened onto the motor shaft. Make sure one of the set screws aligns with the flat portion on the motor shaft.

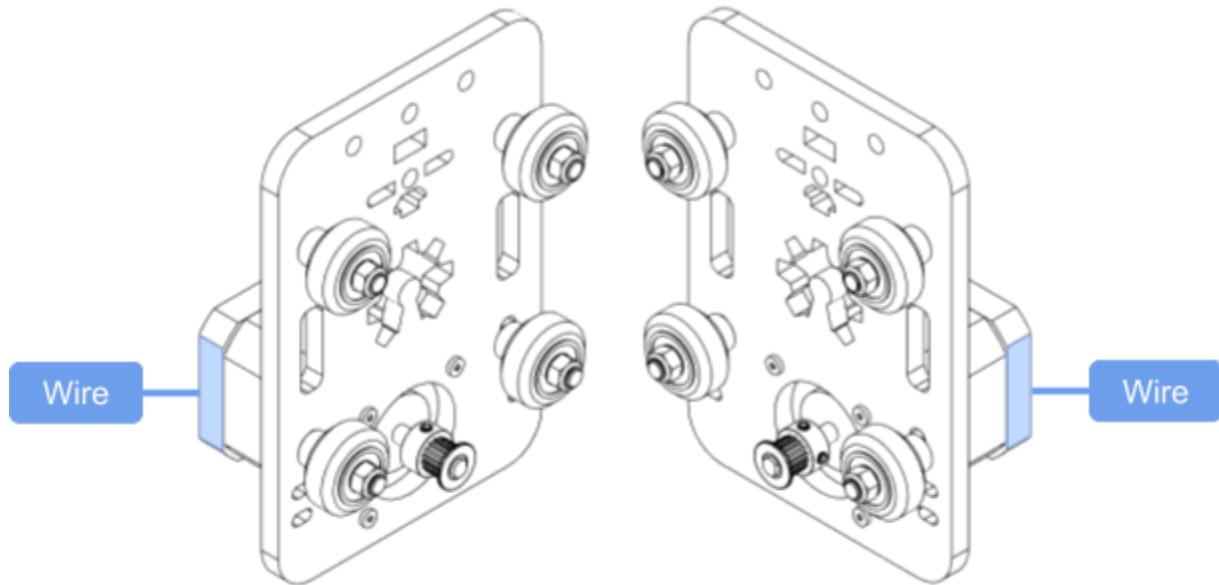


Right Y-axis Carriage Assembly

Repeat steps (10-12) to create an identical copy of the Y-axis Plate assembly, making sure that during step 11.1, the motor's protruding wires are facing towards you if you have the orientation of the Y plate where the four wheel assemblies are facing left.

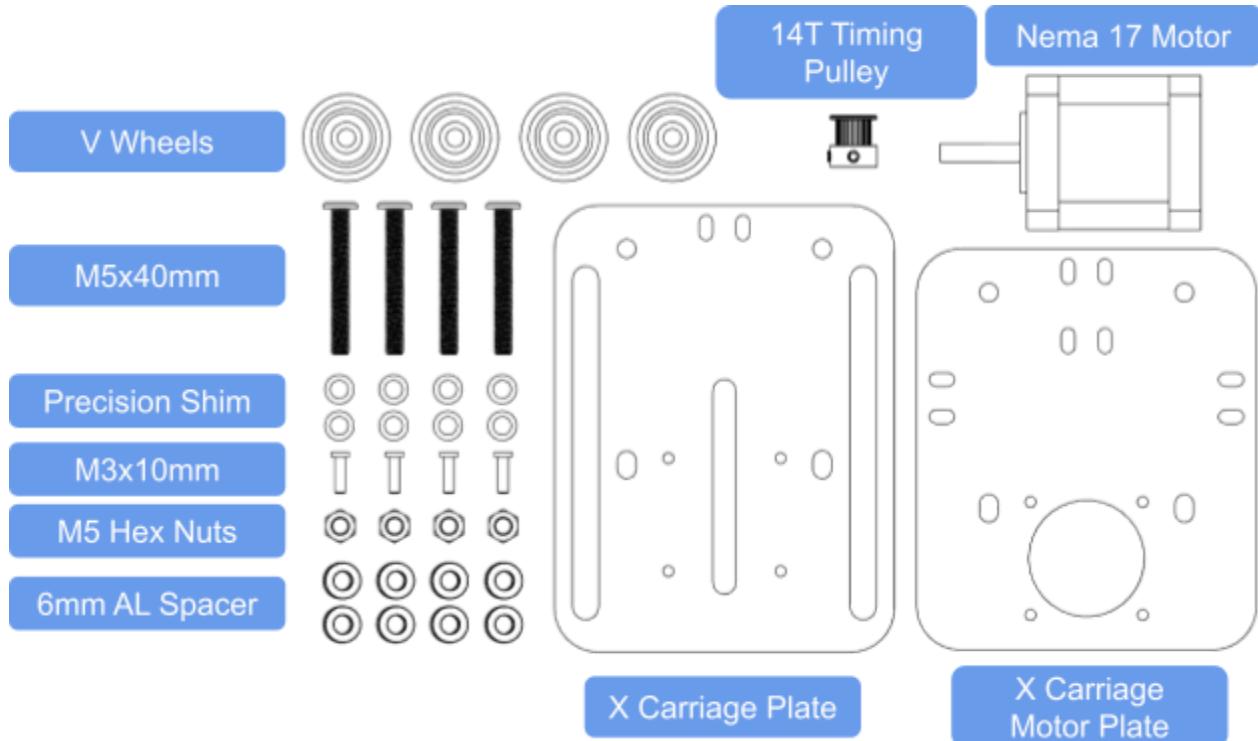


You should then have a left and a right Y-Axis Carriage, with the wires protruding on the highlighted blue region.



X-Axis Carriage Assembly

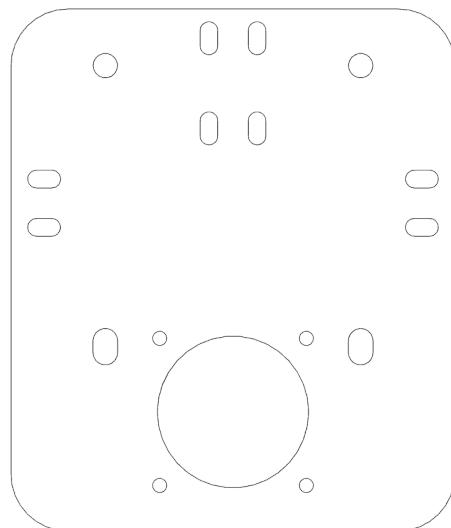
Included Parts: (1) X carriage plate, (1) X Carriage Motor Plate, (1) Nema 17 Motor, (4) M5 40mm screws, (8) 6mm Al Spacers, (4) M3 10mm screws, (4) solid V wheels (Created using Step 9.), (8) Precisions Shims, (4) M5 Nylon Hex Nuts, (1) 14 Tooth timing pulley



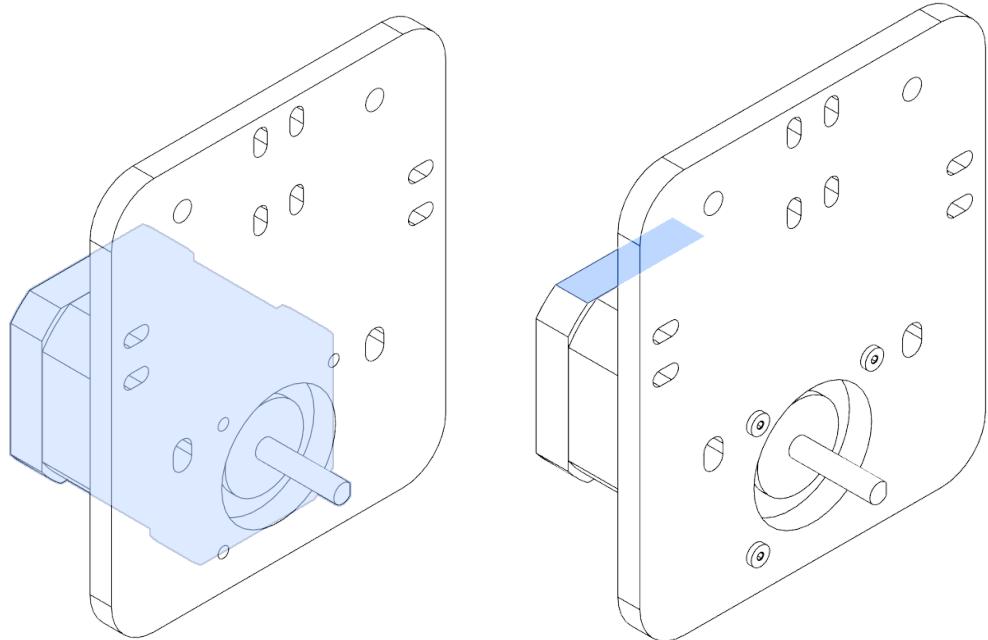
Step 13: X-axis motor placement on X carriage plate

Required materials: (1) X Carriage Motor Plate, (4) M3 10mm screws, (1) Nema 17 Motor

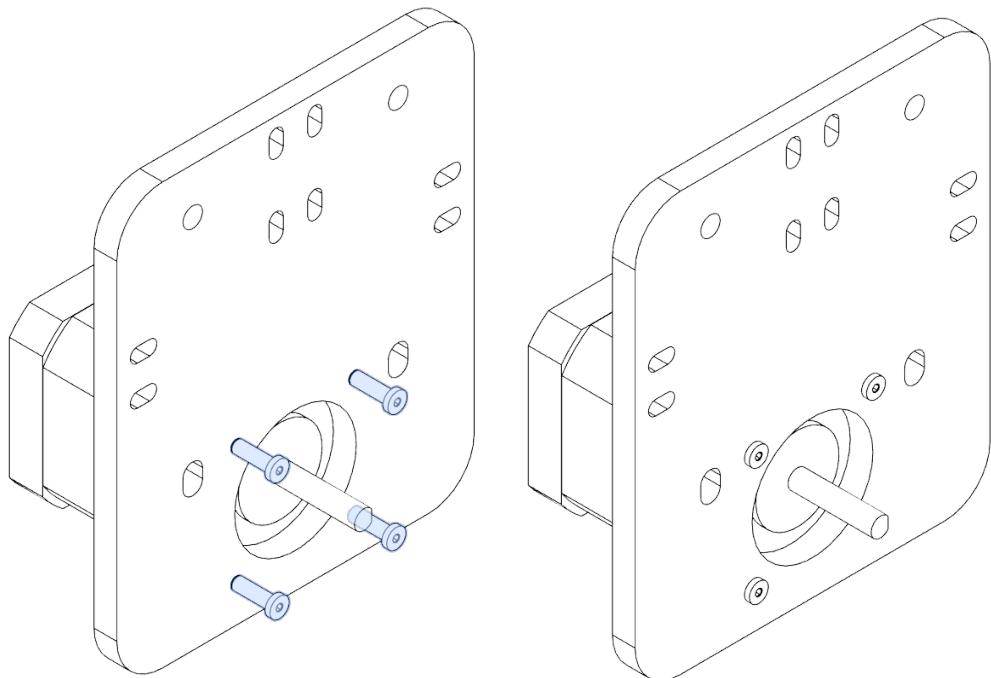
13.1. Orient the X motor plate (designated by a large circular hole) with the large motor hole on the bottom.



13.2. Insert motor onto the X plate, making sure the exposed wires are facing upwards.
(This allows for easier wire management)



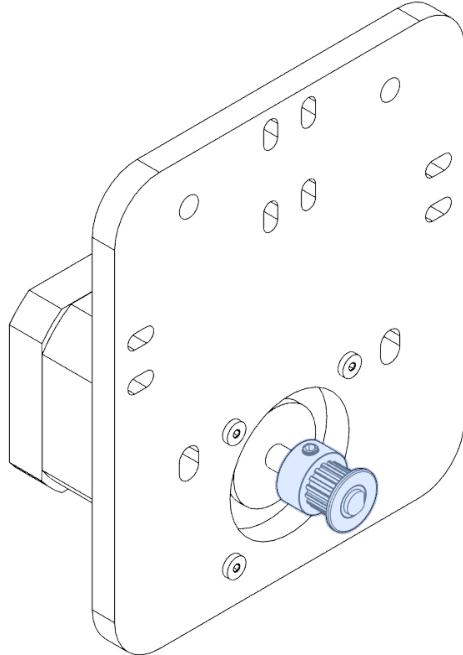
13.3. Align the Y plate motor holes to the motor, fasten four M3 10mm screws until snug.
Do not overtighten, as it can crack the acrylic plate.



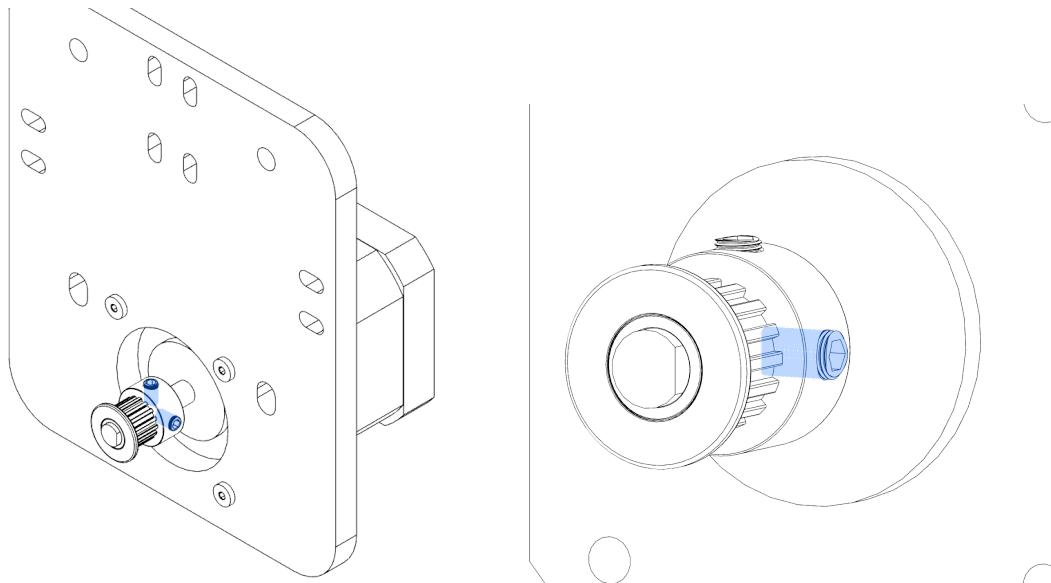
Step 14: Pulley alignment on motor shaft

Required Materials: (1) 14-Tooth Timing Pulley, (2) Set Screws [May be in the timing pulley]

14.1. Slide on the 14-tooth timing pulley, aligning the teeth with the V wheels.



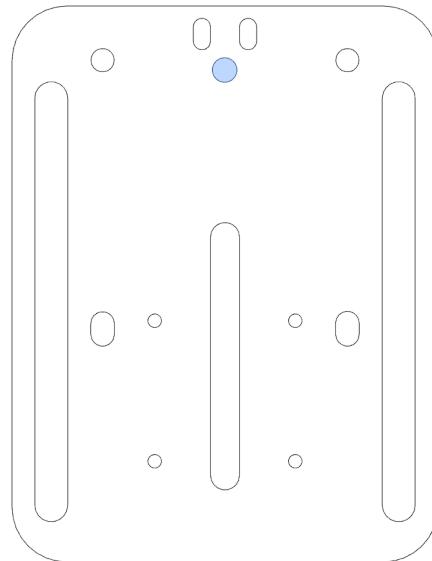
14.2. Tighten set screws until the pulley is fastened onto the motor shaft. Make sure one of the set screws aligns with the flat portion on the motor shaft.



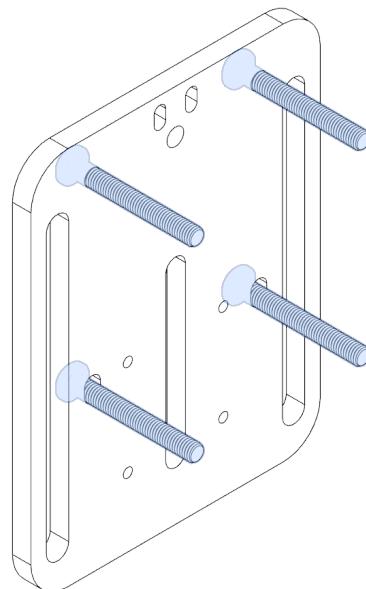
Step 15: Front plate Assembly

Required materials: (1) X carriage plate (Faceplate designated by long slots), (4) M5 40mm screws, (8) 6mm Al Spacers, (4) solid V wheels, (8) Precisions Shims

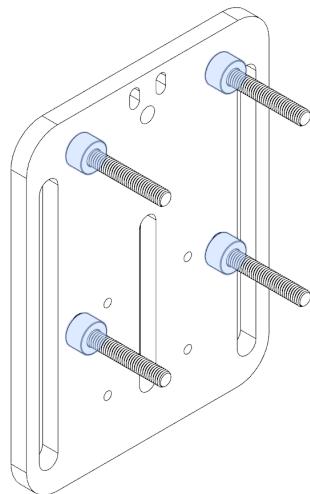
15.1. Orient the plate with the center slot down. Drill a 5.5mm diameter hole in the face plate between the top two slotted holes. This drilling is to allow for a 10-12mm M5 screw to go through it at a later step. (This hole does not have any specific placement just drill it between the two slotted holes shown below, making sure to leave enough material around the holes for structural integrity)



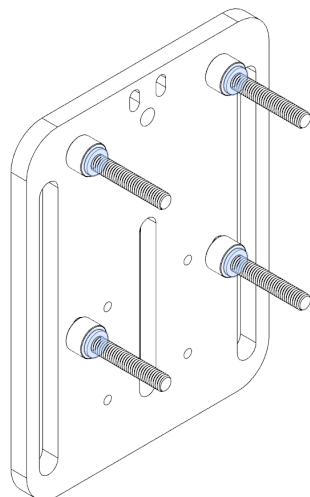
15.2. Insert four M5 40mm screws into the (2) slotted holes and (2) fixed holes on the face plate. Then place the plate on its back with the ends of the screws pointing upwards.



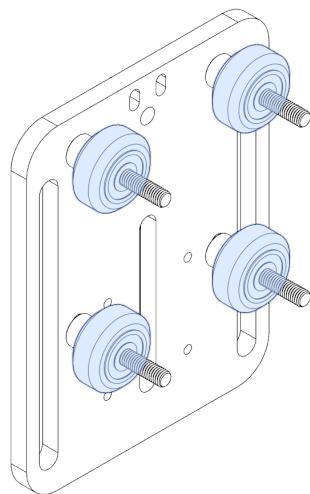
15.4. Place a 6mm Al Spacers on each of the four screws.



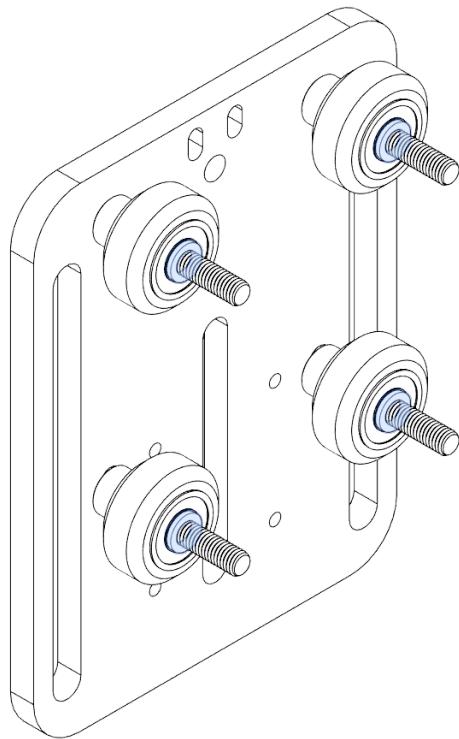
15.5. Place a precision shim on each of the four screws.



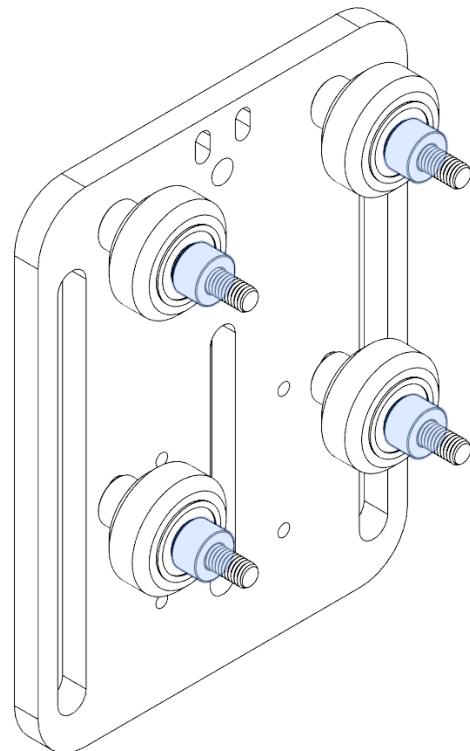
15.6. Place a completed wheel on each screw.



15.7. Place a precision shim on each of the four screws.

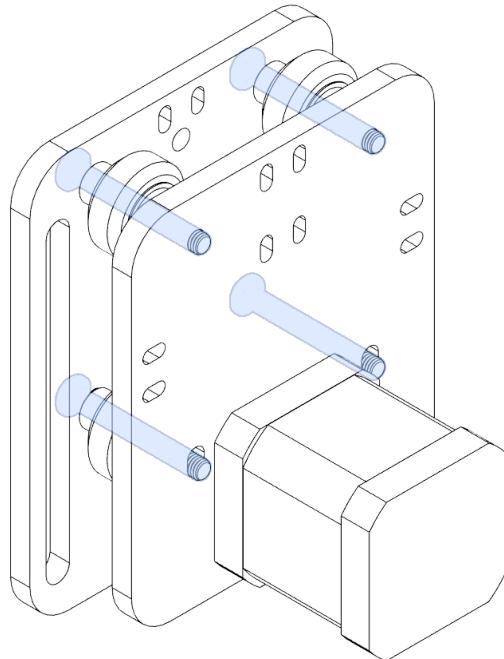


15.8. Place a 6mm Al Spacers on each of the four screws.

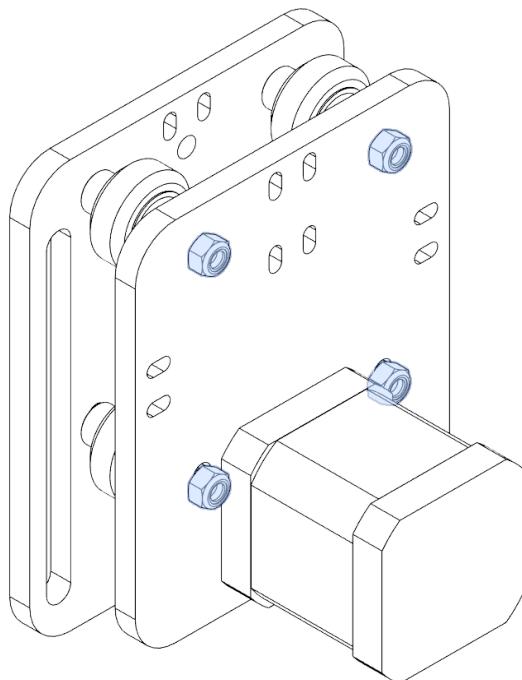


Step 16: Join the Front plate assembly to the X-axis motor plate
Required materials: (4) nylon hex nuts

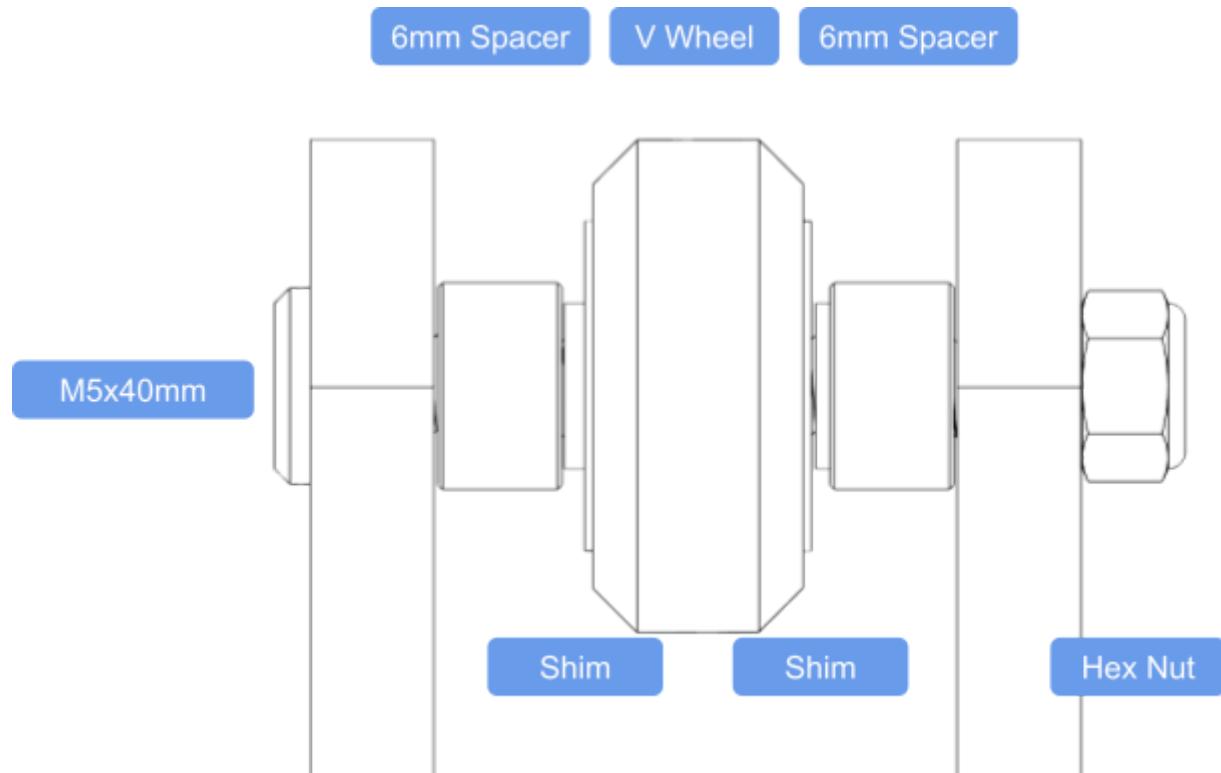
16.1. Align motor plate holes to the outward-facing screws of the front plate.



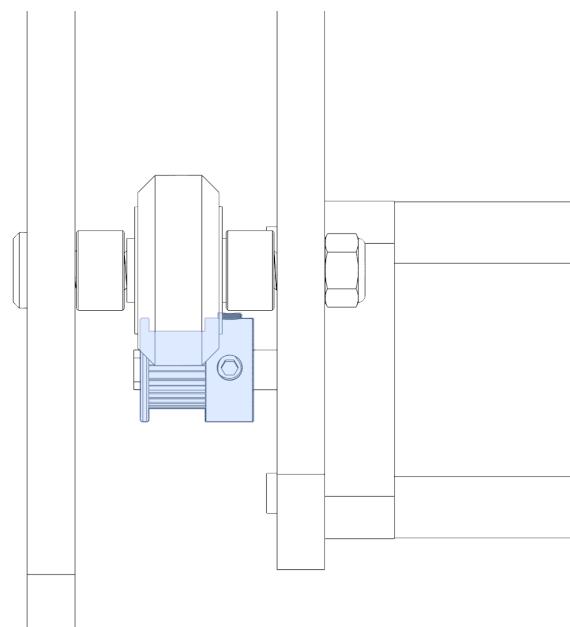
16.2. Place a nylon hex nut at each end of the four screws and snuggly tighten to keep them in place.



16.3. Ensure each screw has a 6mm spacer, precision shim, V wheel, precision shim, 6 mm spacer, and hex nut in order.



16.4. Once the wheels are secure, unscrew and tighten the Timing Pulley to be aligned with the center of the wheel assemblies.

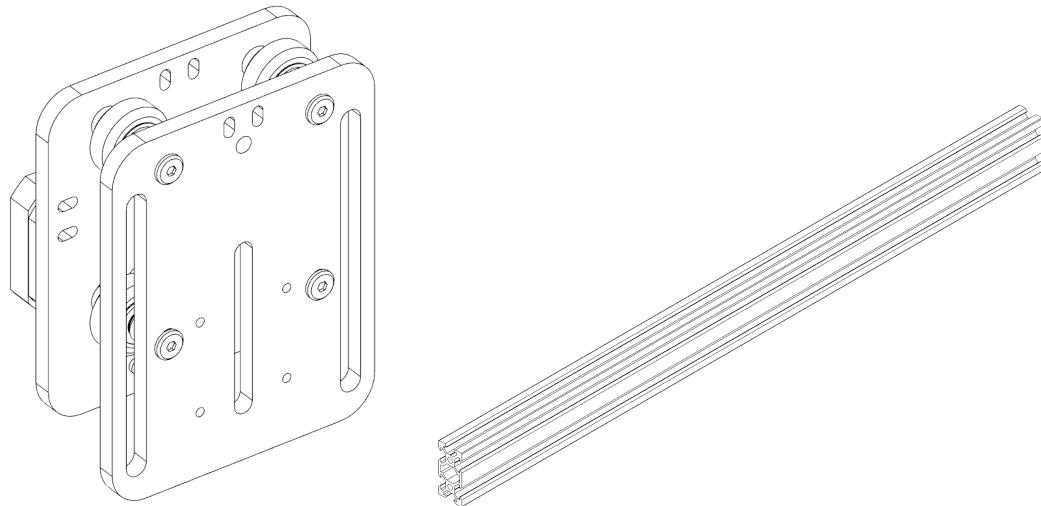


Assembling X-Axis Carriage to 20x40 Al Extrusion

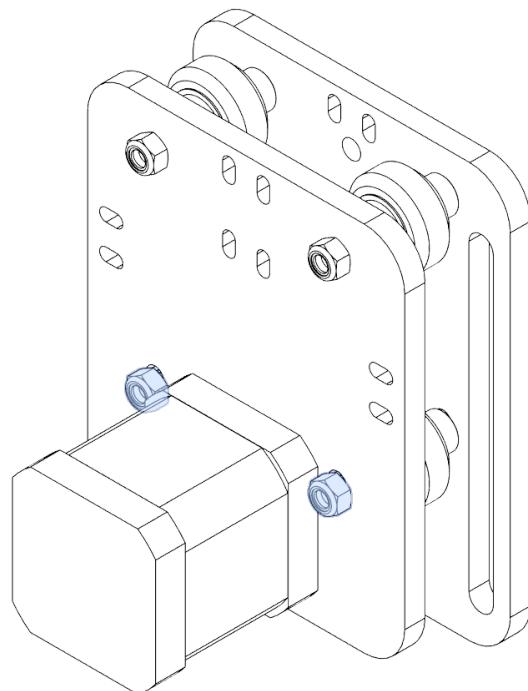
Required materials: (1) X carriage (Finished in Step 16), (4) Black angle Corner Connectors, (6) M5 Tee Nuts, (4) M5 8mm Screws, (2) M5 Set Screws, (1) GT2 Timing Belt, (1) 20x40 Al Extrusion

Step 17: Preload X carriage onto 20x40 rail

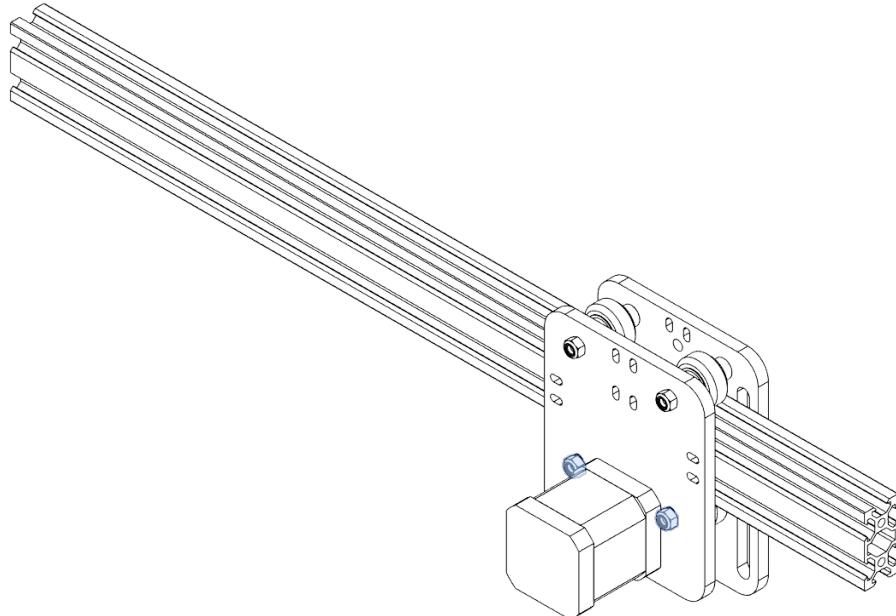
Required materials: (1) X carriage (Finished in Step 16), (1) Drilled 20x40 Al Extrusion (Created in step 8)



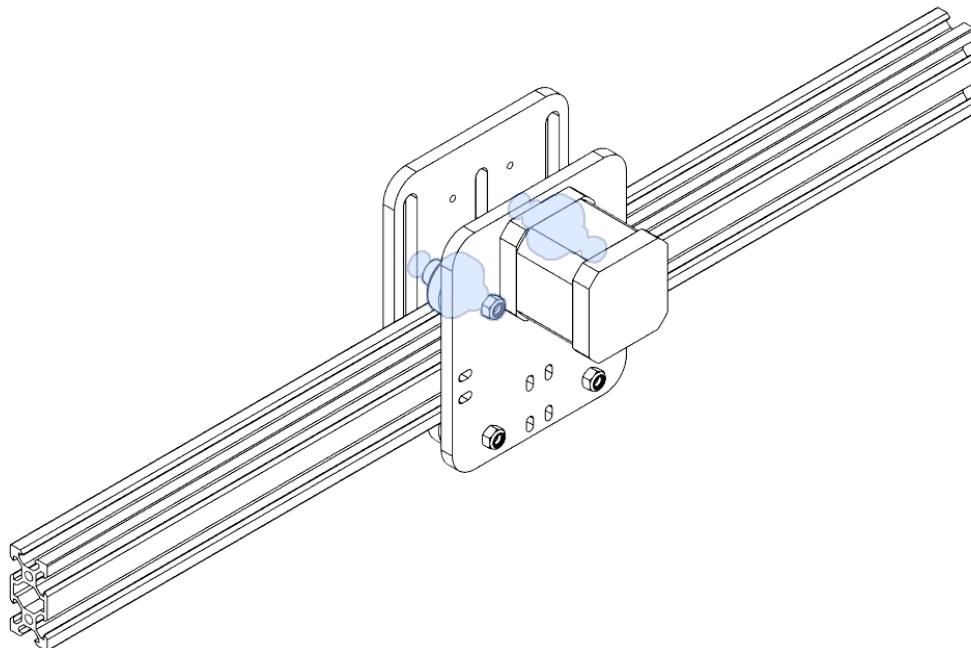
17.1. If your X carriage does not slot into the extrusion you will need to loosen the bottom two screws to make room.



17.2. The loosened screws will allow movement of the bottom screws to allow one to slot the carriage onto the rail.



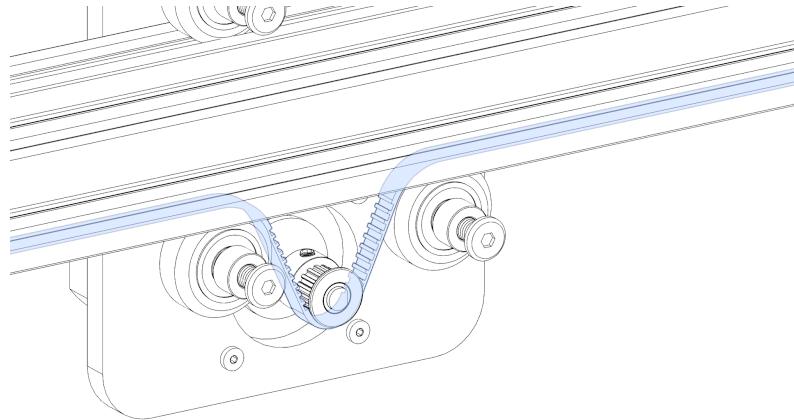
17.3. To sufficiently re-tighten the screws to allow the wheels to glide easily along the rail you must orient the bottom two wheels to be on the top. Applying downward pressure to the individual wheels start to re-tighten the screws to complete the pre loading process.



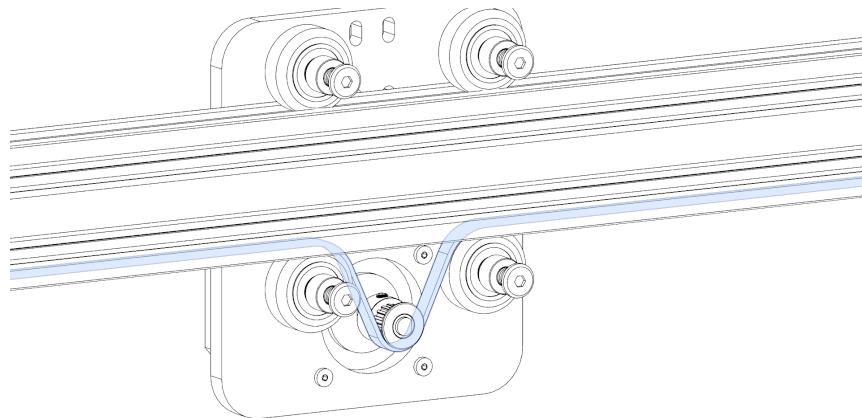
If the step is done correctly, then the X carriage should glide easily in a linear motion along the rail. There should be no rocking motion present. If present, assess the tension along each of the slotted holes.

Step 18: Fixate the GT2 Timing Belt to the timing pulley
Required materials: (1) GT2 Timing Belt

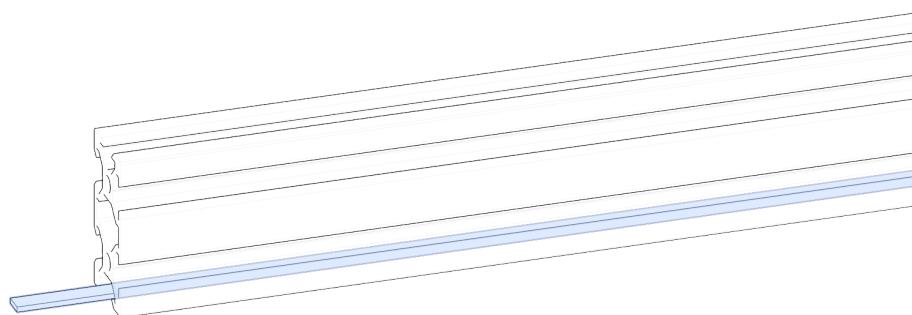
18.1. Run the belt through the Tee Nut channel down the length of the extrusion with the teeth facing down towards the track. Orient the X carriage to the center of the rail. Pinch the belt to create a tent between the wheels to wrap it around the timing pulley.



18.2. Align the teeth of the belt and the timing pulley and pull the belt to create tension flush against the pulley.



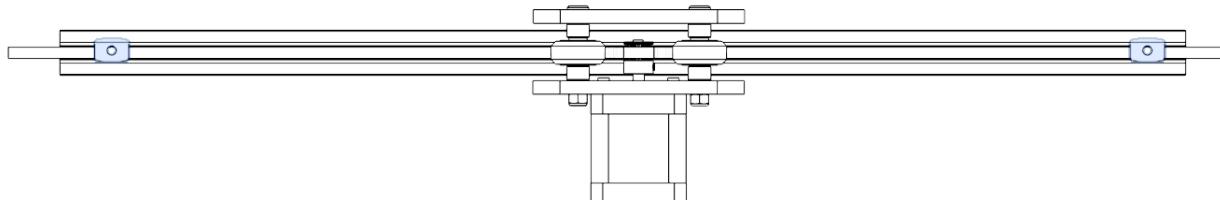
(Feed the entire belt through the system keeping a relatively equal amount of extra length on each side of the rail)



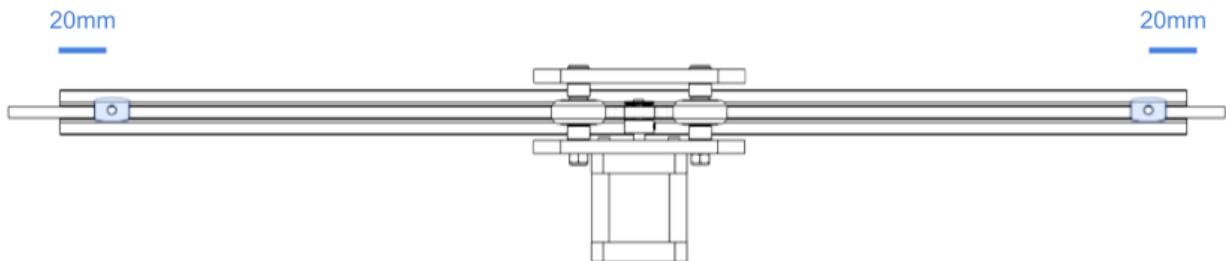
Step 19: Create tension on the GT2 Timing Belt

Required Materials:(2) M5 Tee Nuts, (2) M5 set screws

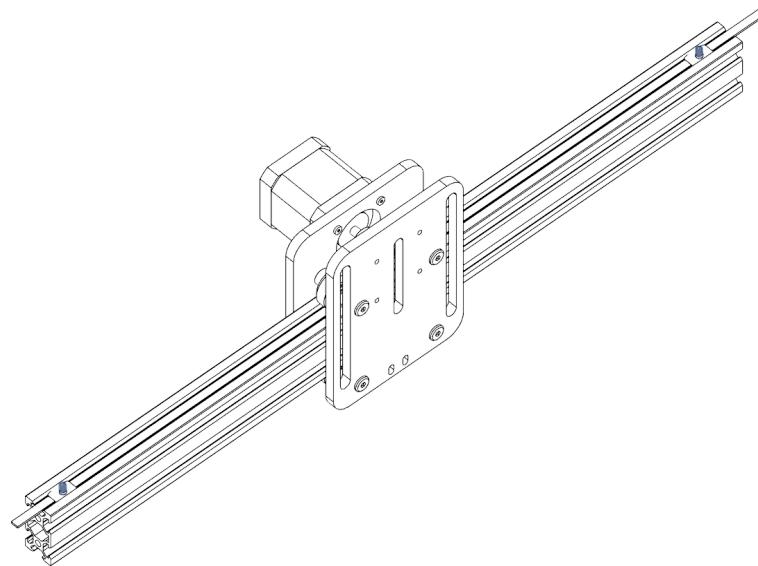
- 19.1. On one side of the 20x40 place an M5 Tee Nut over the GT2 Timing Belt.



- 19.2. Bring the Tee Nut about 20mm from the edge of the rail. (This allows for space for the black angle corner connector joining the X and Y axis rails in a later step)



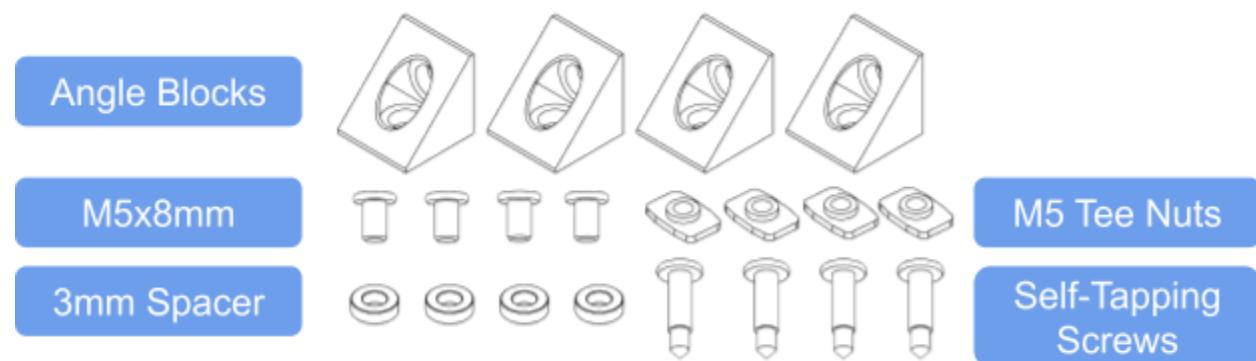
- 19.3. Tighten one set screw. Then pull a little tension into the belt, and use a set screw on the placed Tee Nut to lock the belt in place. Do not fasten too hard; it could damage the belt.



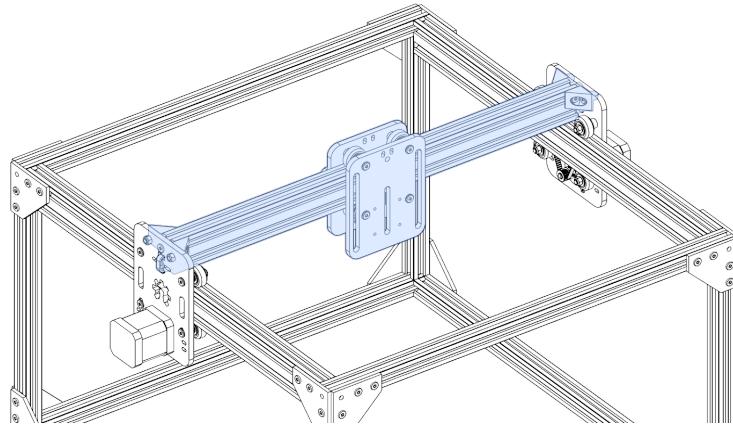
To identify if there is enough tension in the belt, once both set screws are placed and fastened, there should be a slight bounce when pressure is applied and released.

Step 20: Mount Black angle corner connectors to the X-axis 20x40 extrusion

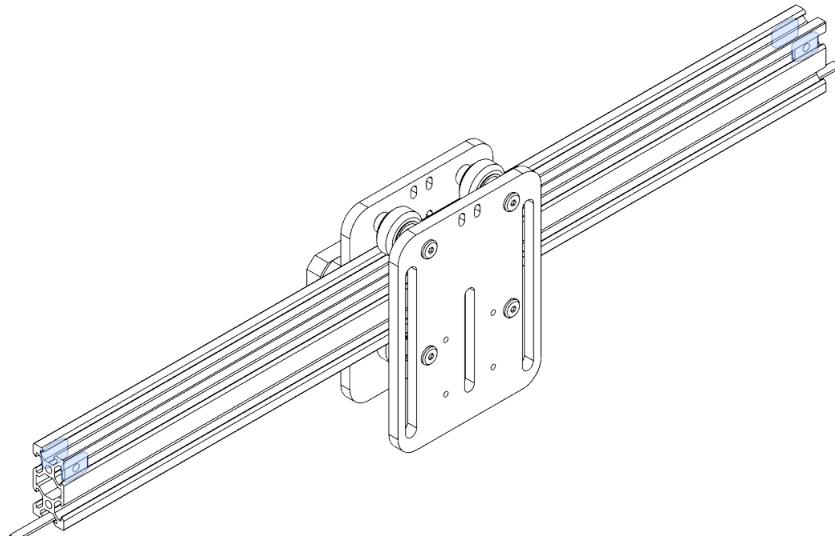
Required materials: (4) Black angle Corner Connectors, (4) M5 Tee Nuts, (4) M5 8mm Screws



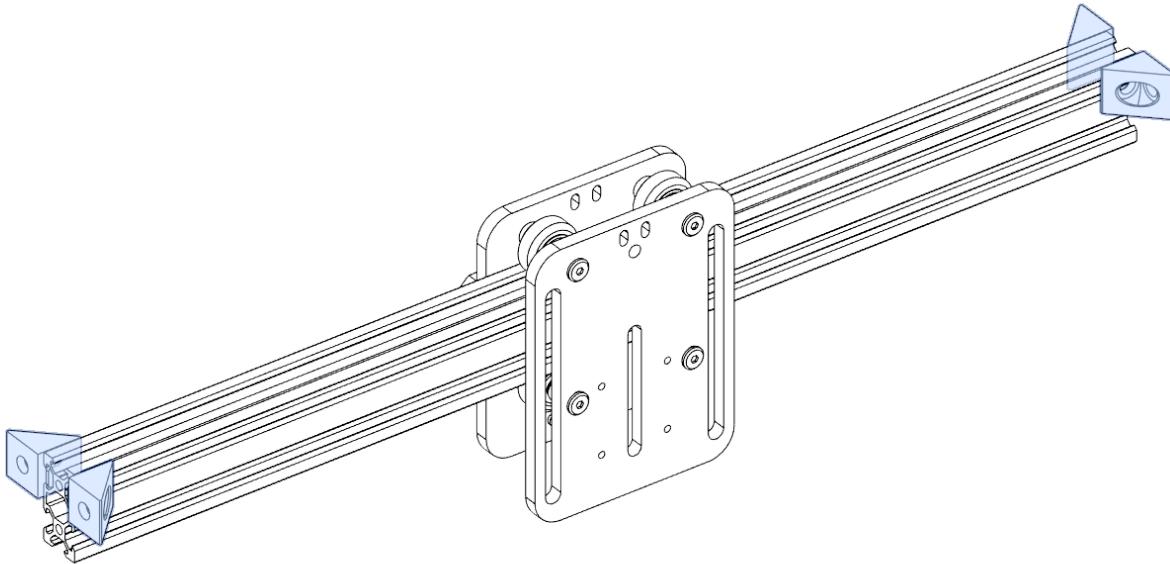
20.1. First, identify how the system will loop once mounted on the Y-axis frames. The motor and the Tee Nut channel holding the belt should be oriented on the bottom.



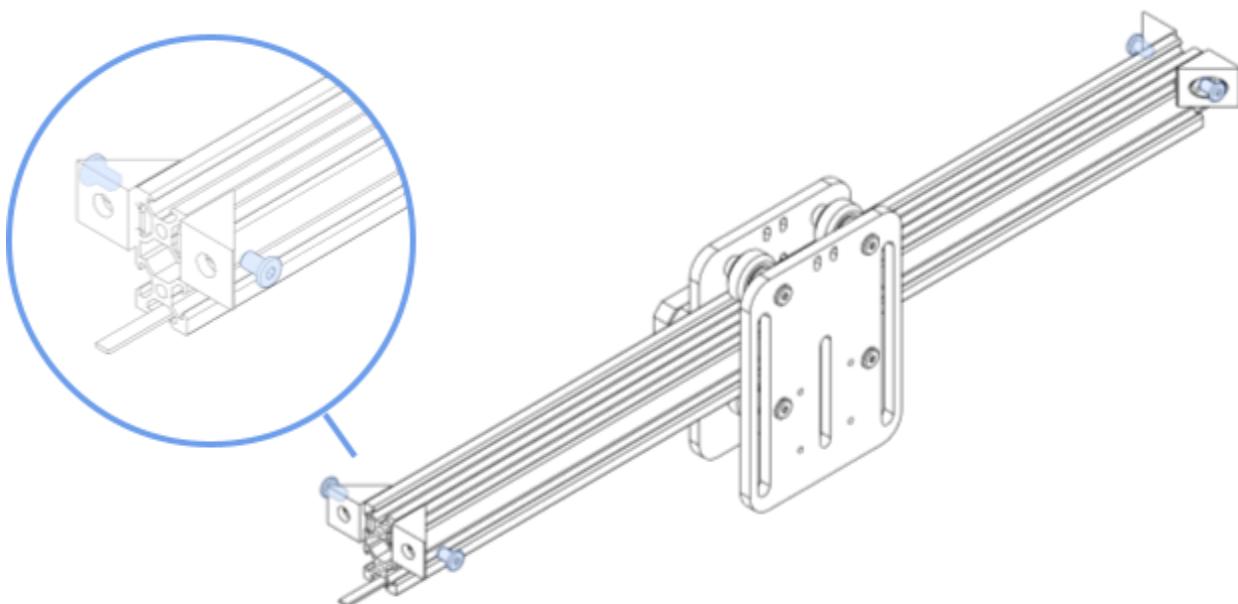
20.2. On the top side rails of the 20x40 (when the belt is on the bottom), slide in a single M5 Tee Nut on both sides of the extrusion.



20.3. Align a black angle corner connector over the placed M5 Tee Nut, making sure that the flat side is aligned with the edge of the 20x40 extrusion.

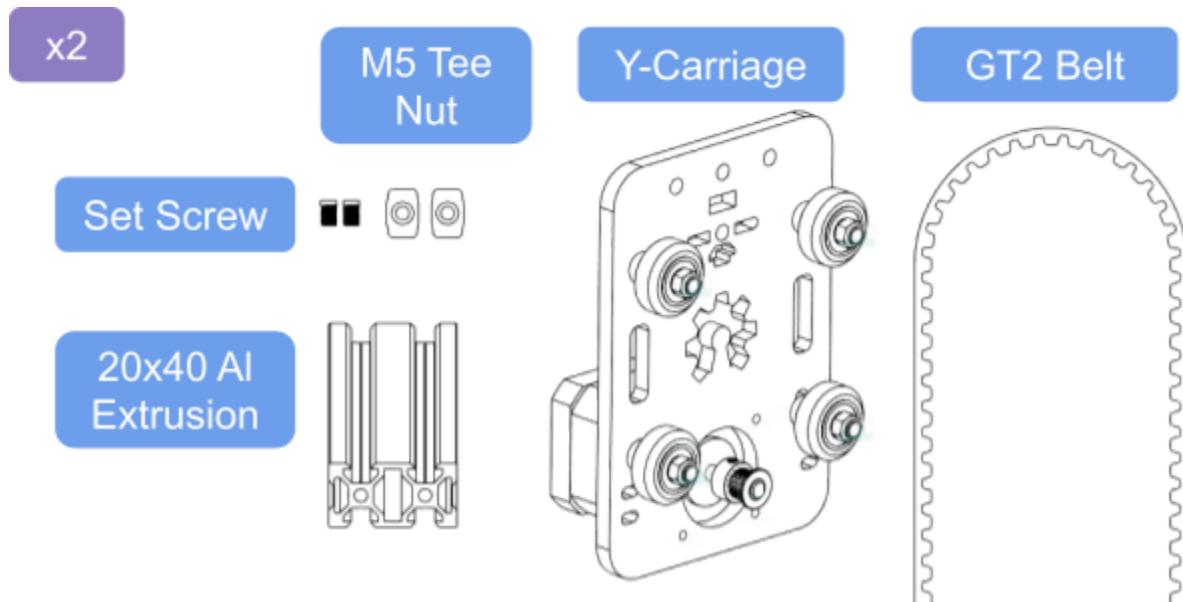


20.4 Using an M5 8mm Screw, fasten the black angle corner connector in place. (making sure that the flat side is still aligned. If not, loosen the screw and move into place)



Assemble Y-Axis Carriages to 20x40 AI Extrusions

Required Materials: (2) Assembled Y Carriages (Steps 10-12), (4) M5 Tee Nuts, (4) M5 Set screws, (2) GT2 Timing Belt, (2) 20x40 AI Extrusion

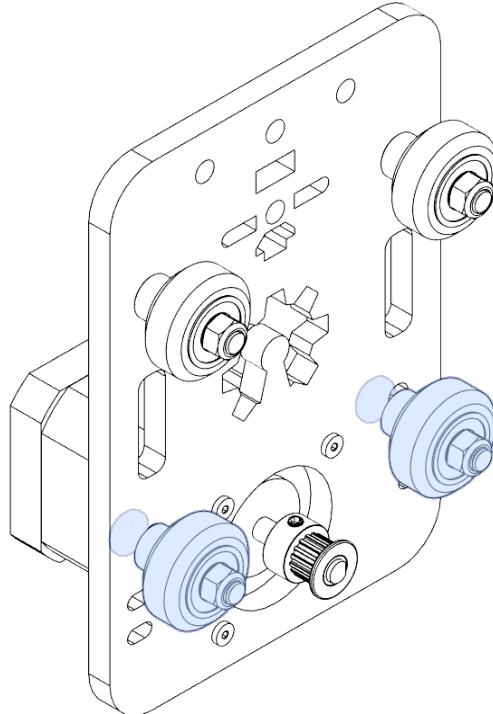


Remember to understand the orientation of your Y-axis carriages. Both carriages should have their exposed cables towards the back of the device.

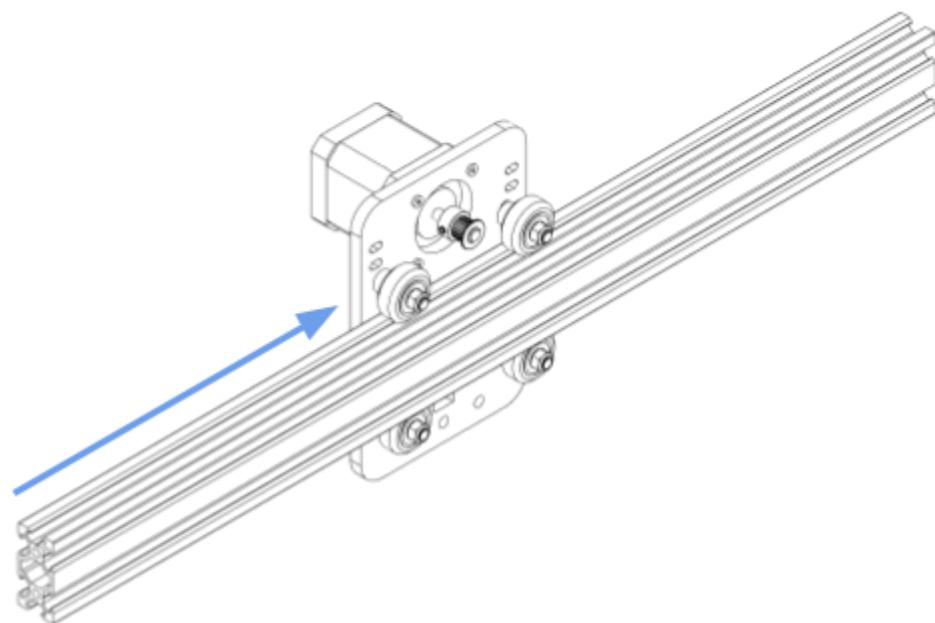
Step 21. Preload Y-axis carriages on 20x40 rail

Required Materials: (2) Assembled Y Carriage (Steps 10-12), (2) 20x40 Al Extrusion

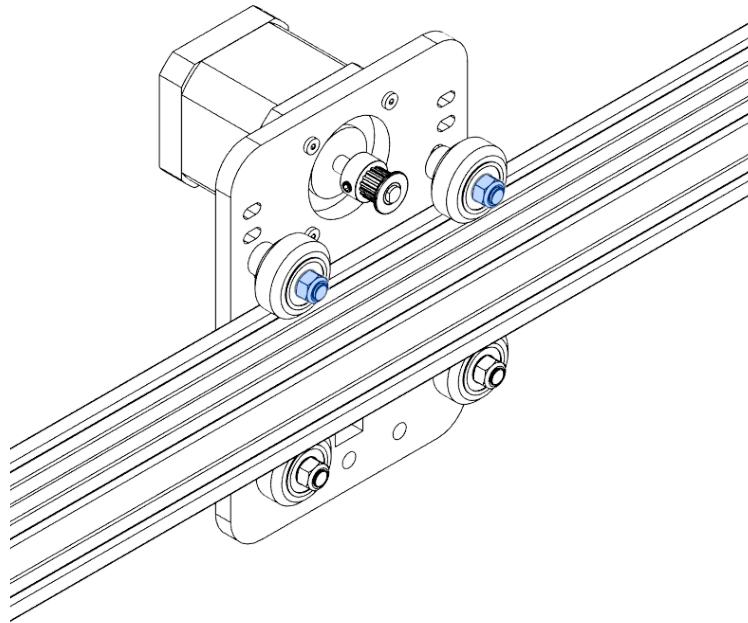
21.1. If your Y-axis carriage does not slot into the extrusion you will need to loosen the bottom two screws to make room.



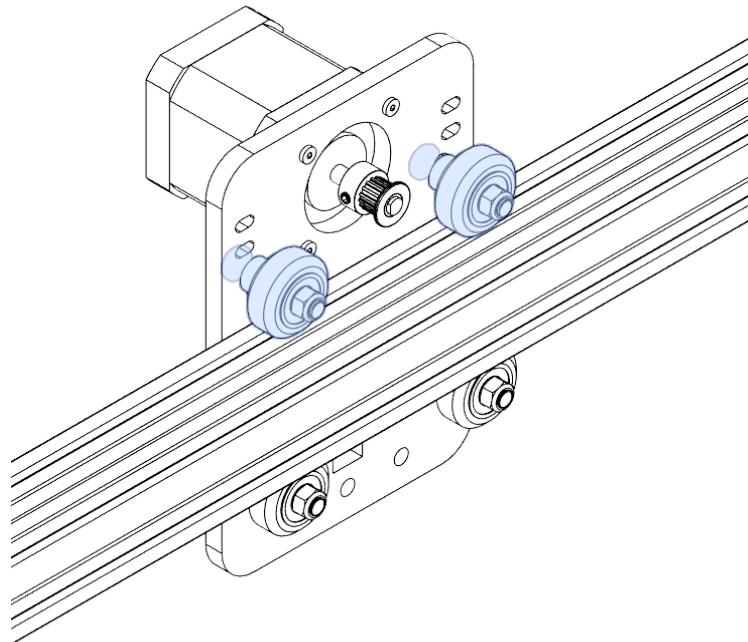
21.2. The loosened screws will allow movement of the bottom screws to allow one to slide the carriage onto the rail.



21.3. To sufficiently re-tighten the screws to allow the wheels to glide easily along the rail you must orient the bottom two wheels to be on the top.



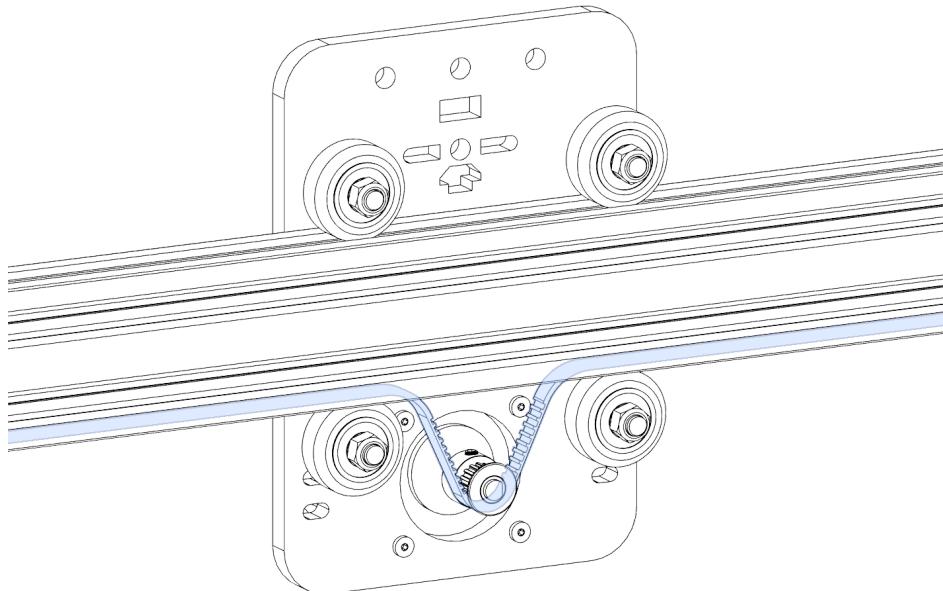
21.4. Applying downward pressure to the individual wheels start to re-tighten the screws to complete the pre loading process.



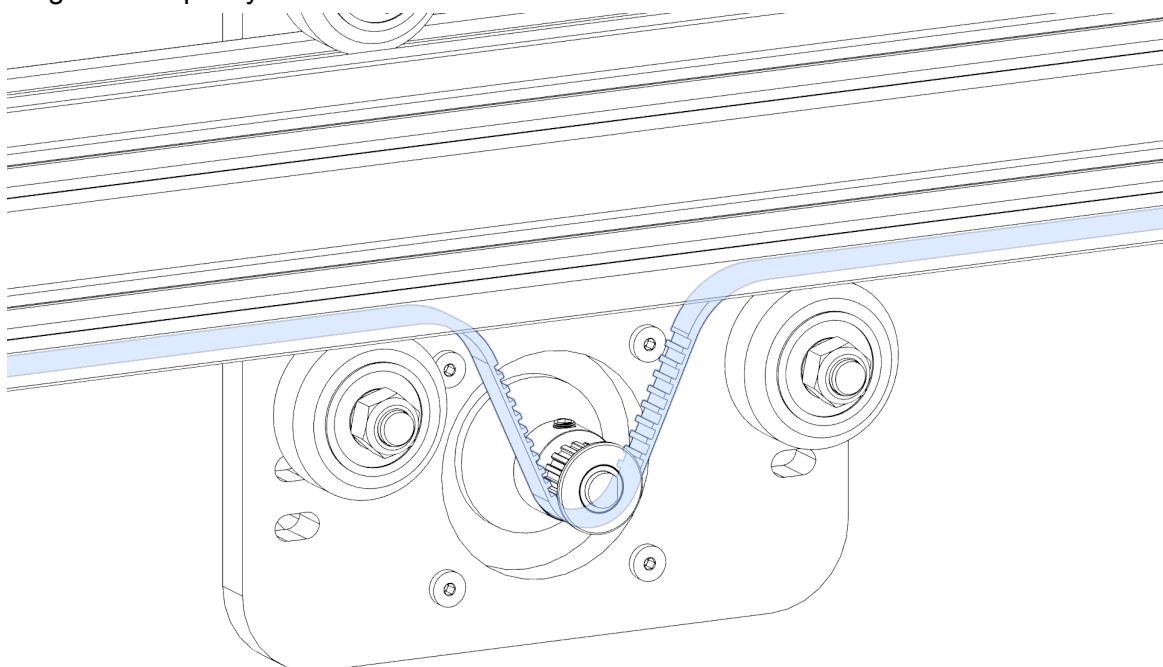
If the step is done correctly, then the Y-axis carriages should glide easily in a linear motion along the rail. There should be no rocking motion present. If present, assess the tension along each of the slotted holes.

Step 22: Route the GT2 Timing Belt to the Y-axis timing pulley
Required materials: (1) GT2 Timing Belt

22.1. Run the belt through the Tee Nut channel down the length of the extrusion with the teeth facing down towards the track. Orient the X carriage to the center of the rail. Pinch the belt to create a tent between the wheels to wrap it around the timing pulley.



22.2. Align the teeth of the belt and the timing pulley, and pull the belt to create tension flush against the pulley.

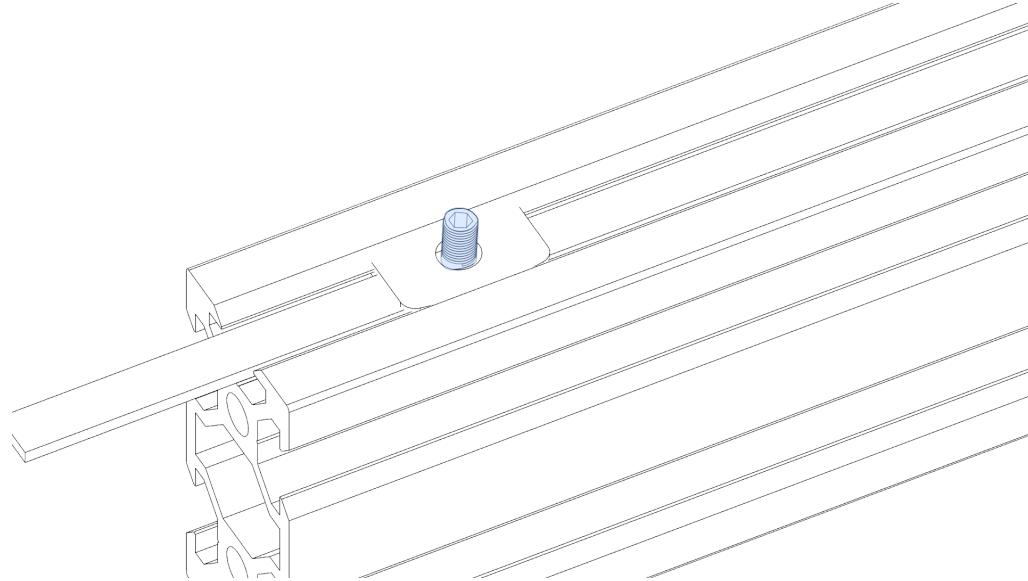


(Feed the entire belt through the system, keeping a relatively equal amount of extra length on each side of the rail)

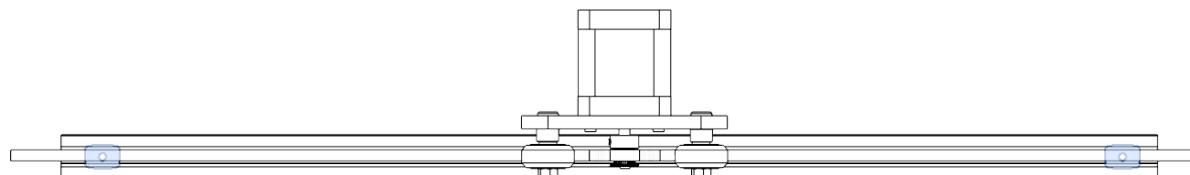
Step 23: Create tension on GT2 Timing Belt

Required Materials:(2) M5 Tee Nuts, (2) M5 set screws

23.1. On one side of the 20x40 place an M5 Tee Nut over the GT2 Timing Belt.



23.2. Bring the Tee Nut about 10mm from the edge of the rail.



23.3. Use a set screw on one side of the belt and screw into the Tee Nut to lock the belt in place. Do not fasten too hard; it could damage the belt.

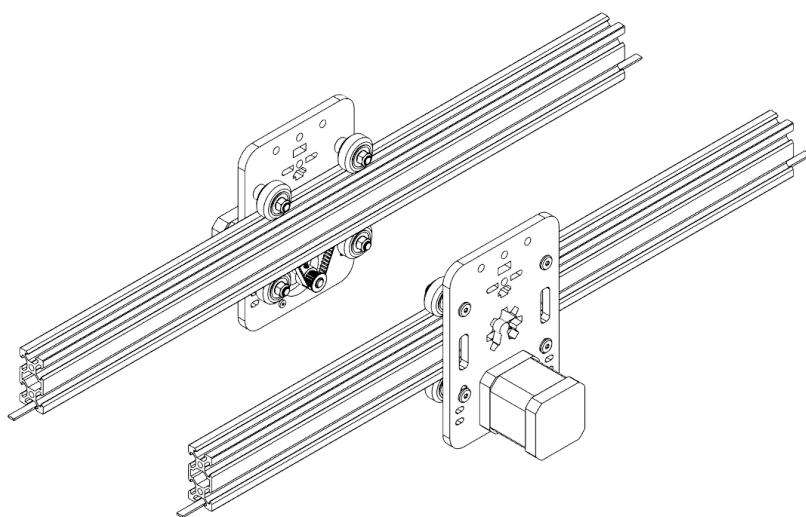


23.4 Now on the other side, pull a little bit of tension on the belt, and use a set screw in the Tee Nut to lock the belt in place.



To identify if there is enough tension in the belt, once both set screws are placed and fastened there should be a slight bounce when pressure is applied and released.

Repeat steps (21-23) for both the left and right Y-axis plates, and you should have two fully built Y-axis assemblies.



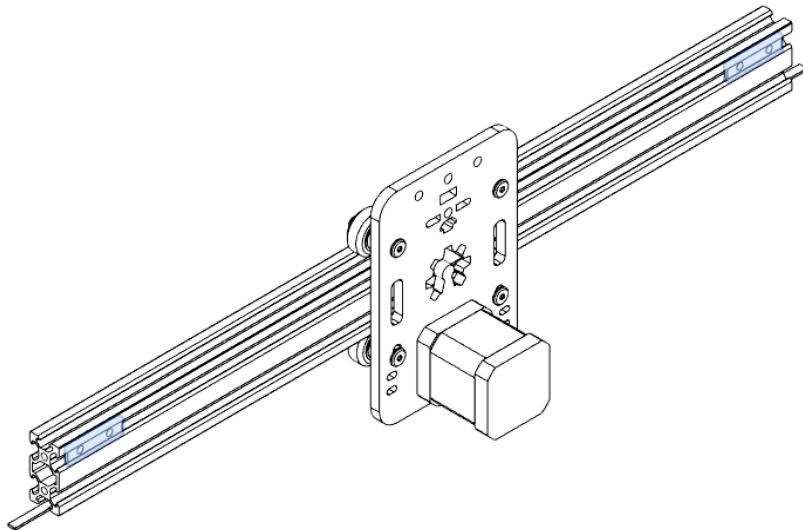
Join Y-Axis Assemblies to the Bottom Frame

Required Materials: (2) Assembled Top Y-axis extrusion, (4) Double M5 Tee Nuts, (4) 90 Degree joint plates, (16) M5 8mm Screws, Bottom Frame (Assembled in steps 1-7)

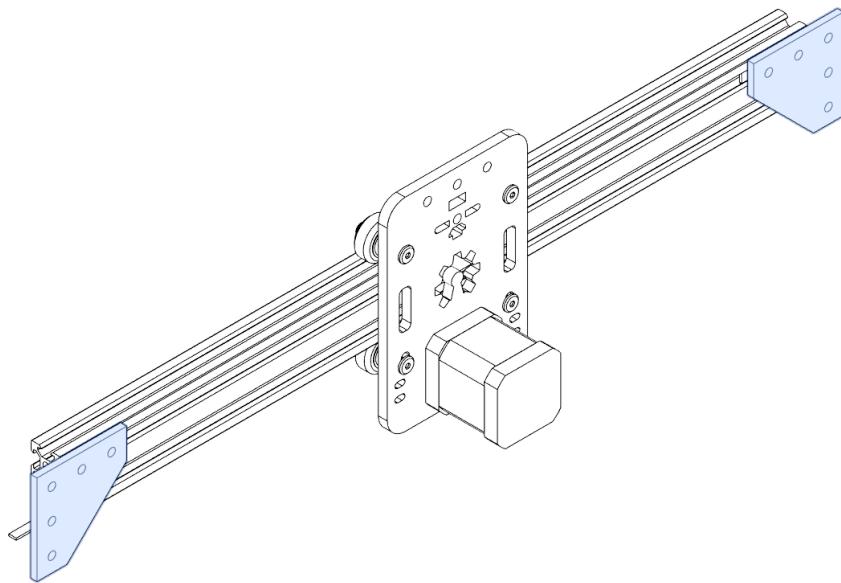
Step 24. Prepare Y-axis extrusions for Bottom Frame attachment

Required Materials: (2) Assembled Y-axis assemblies, (4) Double M5 Tee Nuts, (4) 90 Degree joint plates, (8) M5 8mm Screws

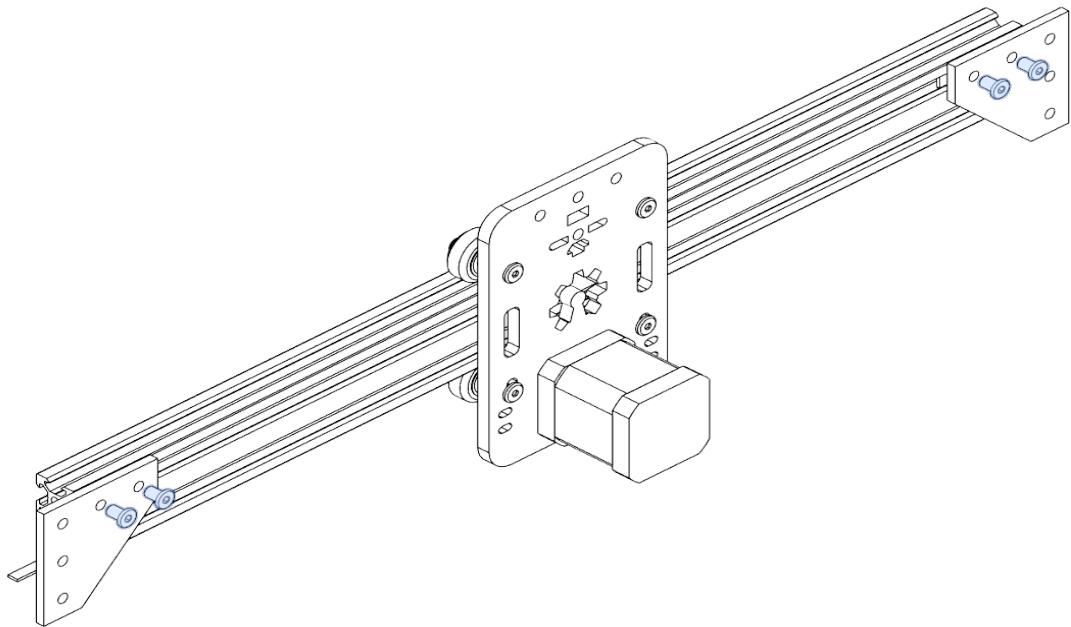
24.1. Place a Double M5 Tee Nut on each end of the outer side of the Y-axis extrusion. They should be on the upper-level Tee Nut slot on the same side as the motor.



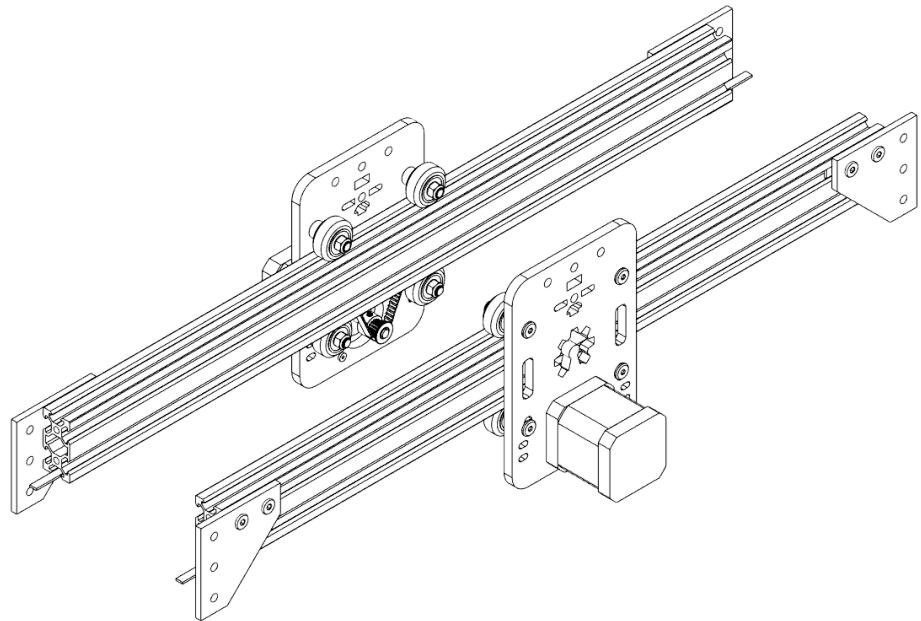
24.2. Place a 90-degree joint plate over each double M5 Tee Nut with the angled portion in the direction of the motor.



24.3. Attach the 90 degree joint plates using M5 8mm Screws. To allow for mounting to the assembled Bottom Frame, create sufficient space to free up the other side of the 90-degree joint plate.

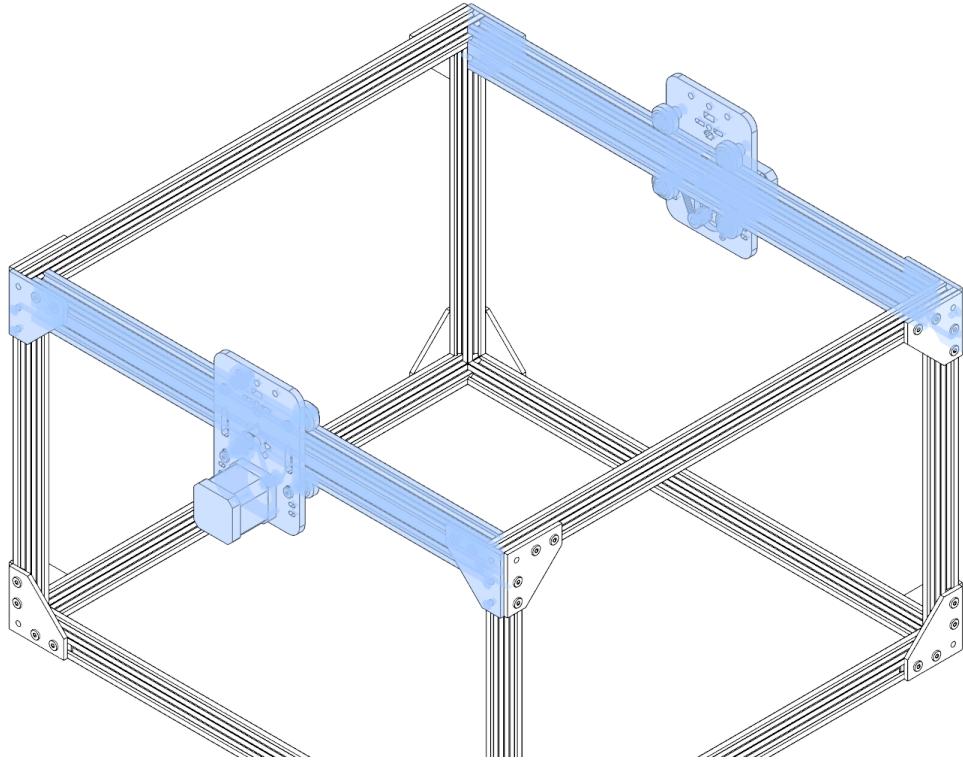


24.4 Repeat for each Y-axis extrusion, making sure to properly orient the 90 degree joint plates.

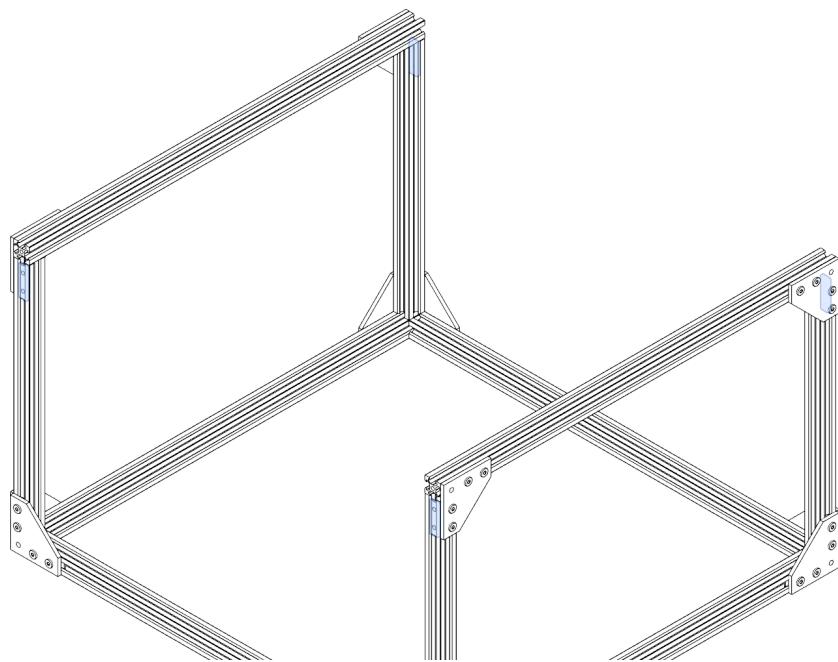


Step 25. Mount Y-axis extrusions to the Bottom Frame

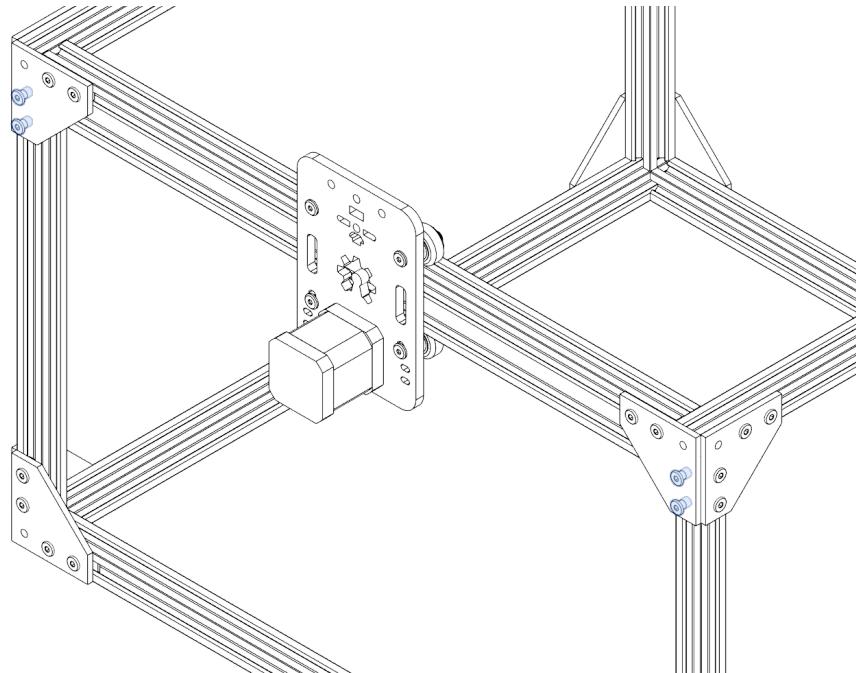
Required Materials: (8) M5 8mm Screws



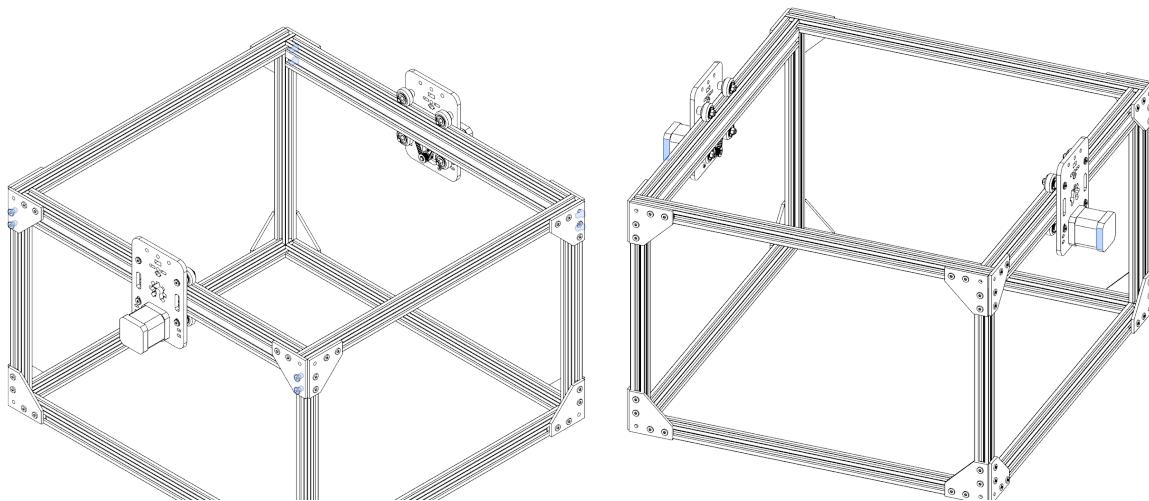
25.1. During step 6.1. We slotted in a double Tee Nut on the two outside corners of each upright extrusion. The unused M5 Tee Nuts placed in this section will be used; if this step was skipped, either replace with Drop-In M5 Tee Nuts, or go back to step 6.



25.2. Place a Y-axis assembly inside the bounds of the upright extrusions lined up with the Double M5 Tee Nuts. (It may assist during this step to rotate the frame on its side) Using 8mm M5 screws attach the 90 degree joint plates to the upright extrusions.



25.3. Repeat this step for each Y-axis assembly, taking into account that the cables for the Y-axis motors are aligned to each other and facing towards the back of the machine.



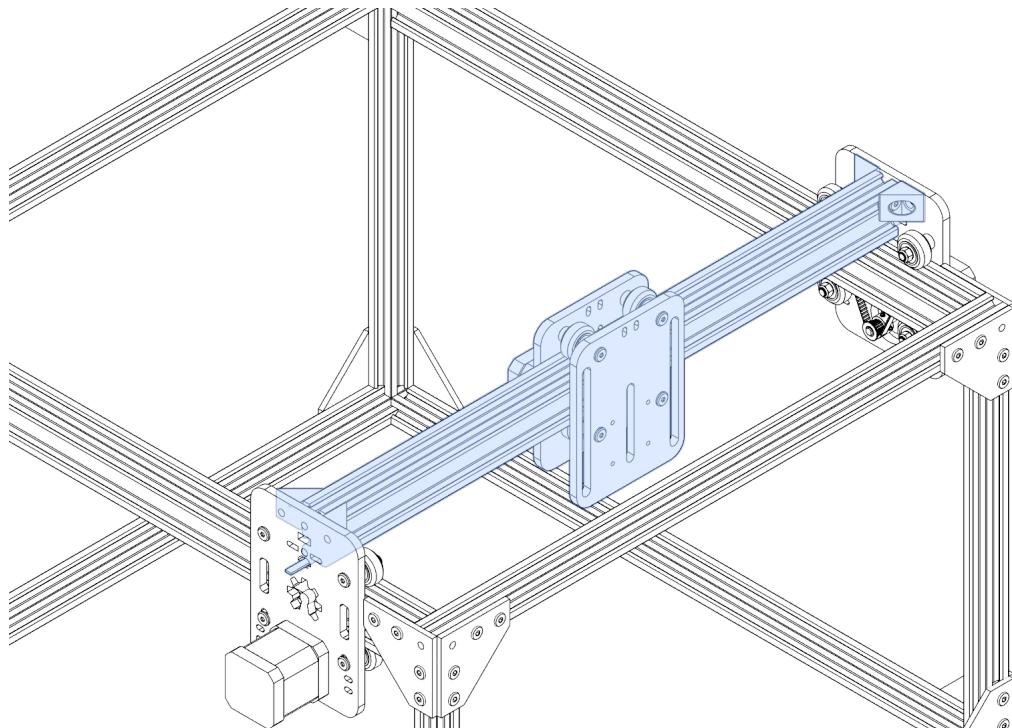
25.4. To make sure that the frame is in its proper shape and extrusions are perfectly aligned, it may be necessary to untighten and retighten the screws.

Attach X-axis assembly to join with Y-axis Carriages

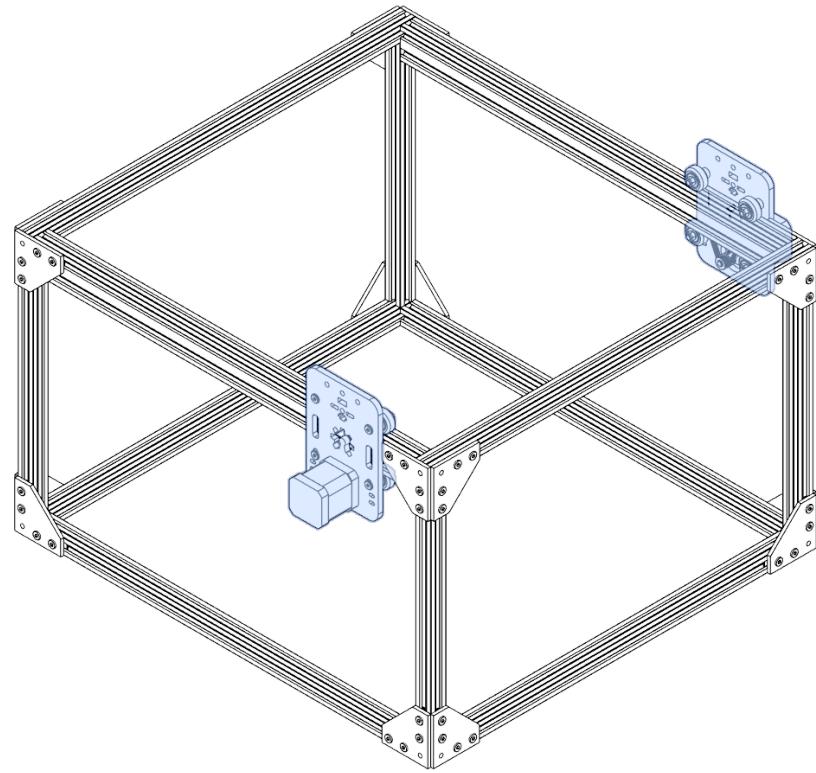
Step 26. Connect the mounted Black angle corner connectors of X-axis extrusion to Y-axis extrusions

Required Materials: (4) Self tapping screws, (4) M5 15mm screws, (4) Nylon Hex Nuts

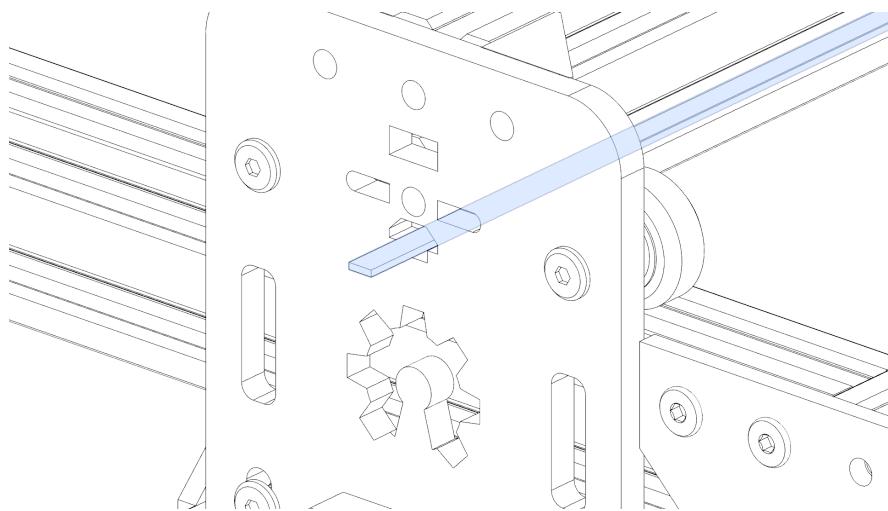
*REMINDER - Keep in mind the orientation of your device all motor extension cables should be facing towards the back of the device.



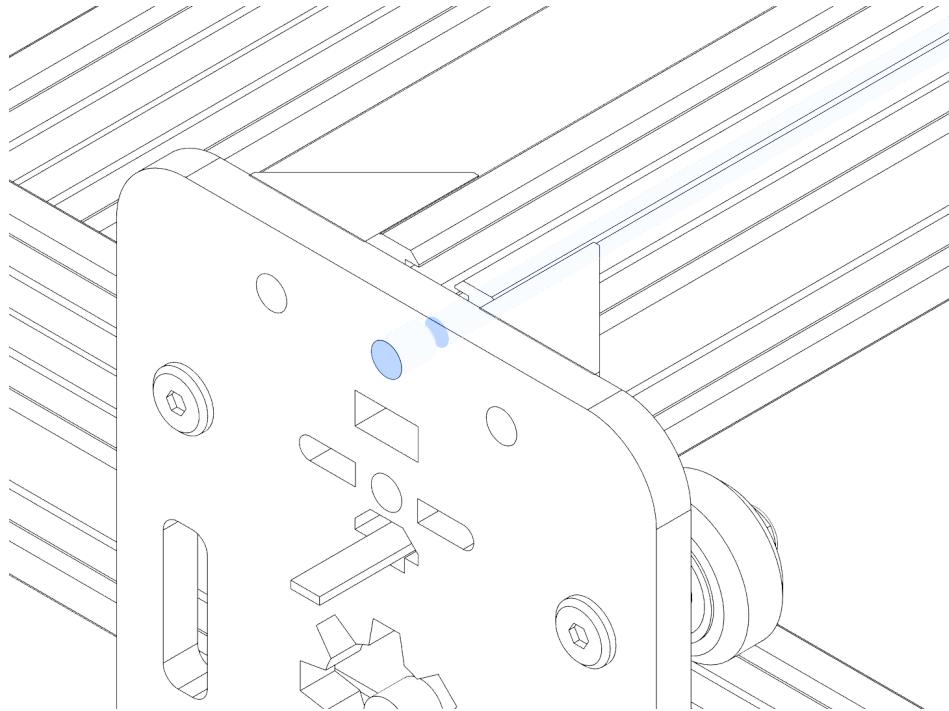
26.1. Align your Y-axis carriages opposite from each other. This can be easily done by pushing the carriages to one side until they are stopped by the 90-degree joint plates.



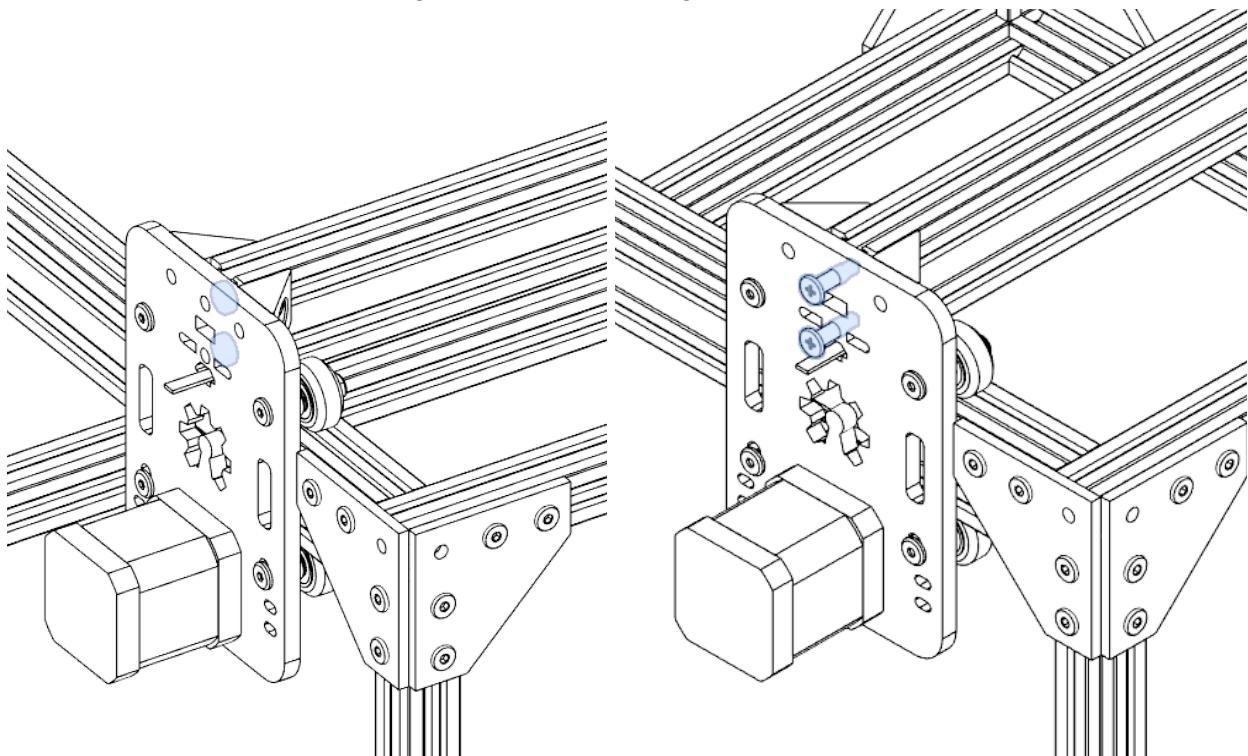
26.2. Place your X-axis assembly against your Y-axis carriage threading the excess belt line through the flat bottom hole.



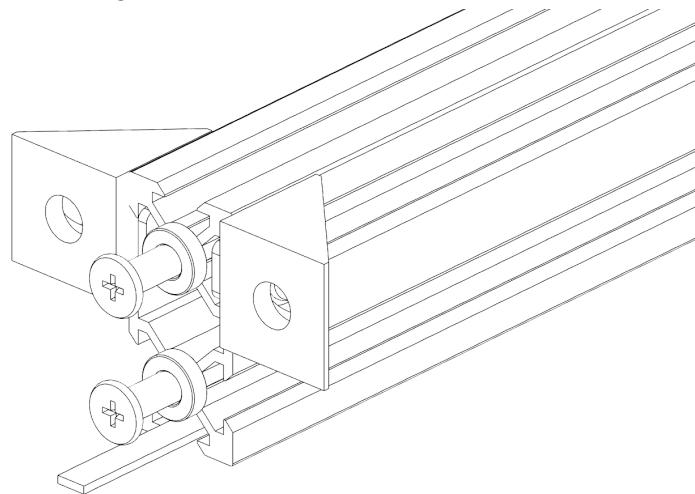
26.3. Align the top hole of the Y-axis plate with the top and bottom threaded hole of the X-axis 20x40 extrusion. Use an object, like a thin screwdriver or bolt, to hold the extrusion in place for easier assembly.



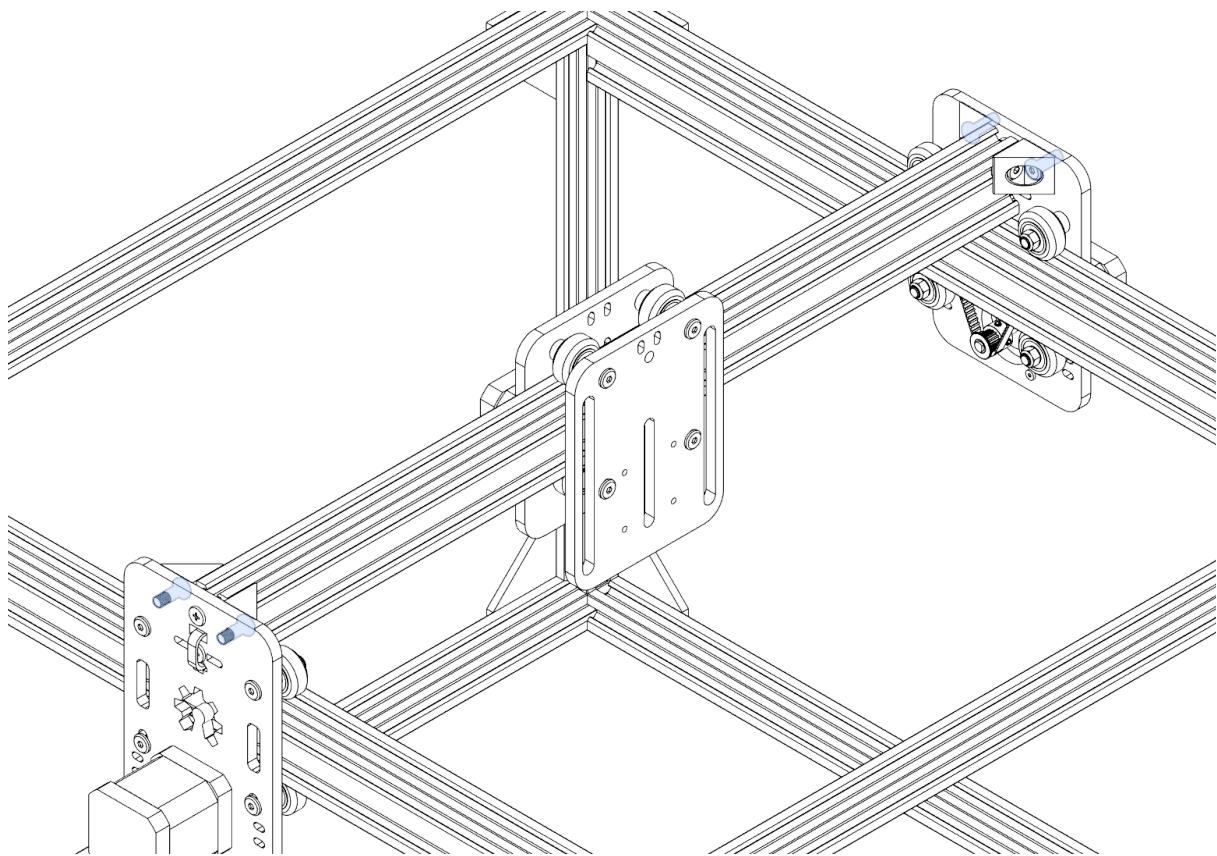
26.4. Secure the X-axis by placing 3mm spacers between the carriage and the end of the extrusion, and then fastening it with a self-tapping screw.



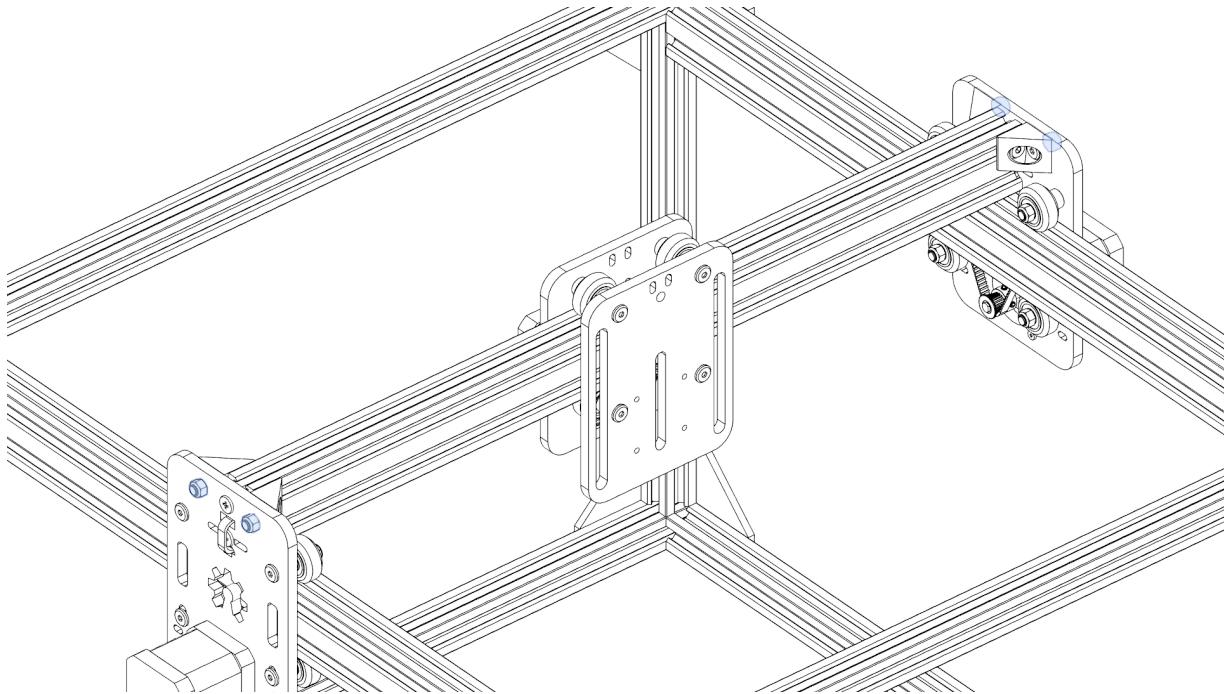
(Close View of self tapping screws without Y-axis carriage blocking. Screws are fastened in the holes drilled in the 20x40 during Step. 8)



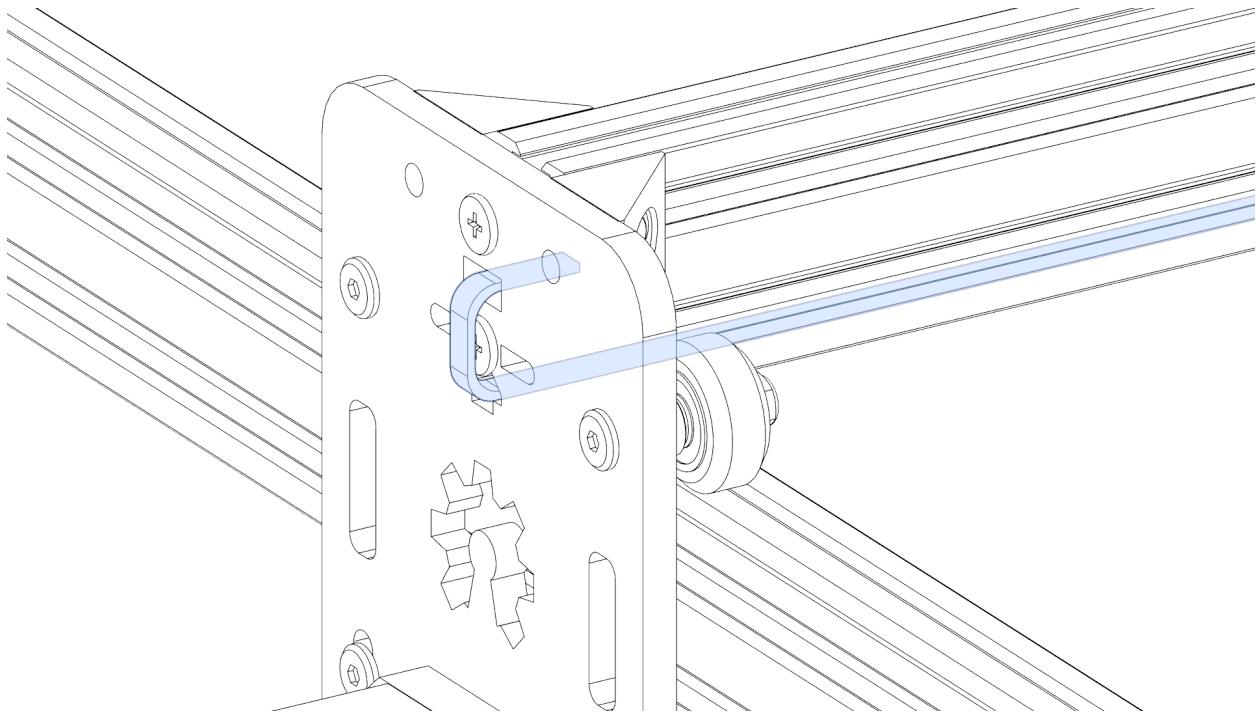
26.4. Connect the black angle corner connectors to the top left and right holes using M5 15mm screws. Place the M5 15mm screws with their ends faced outwards.



26.4. Use M5 Nylon Hex Nuts to fasten the angle corner blocks to the Y-Carriages. These Hex Nuts may be taken off during cable management to attach cable conduit clamps.



26.5. Bend the excess belt through the top flat hole on the Y-Carriage. If the belt is excessively long and has not been shortened yet, you may shorten it. But ensure there is enough excess to be stored for potential future use.



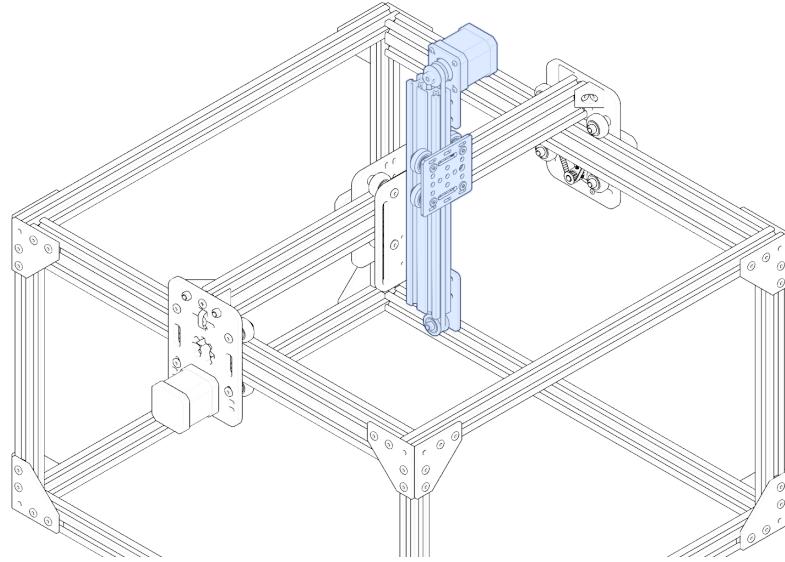
Linear Actuator Assembly and attachment

Step 27. Linear Actuator Assembly

The included Links will explain in depth the creation of the Z axis controller of our system there is no deviation from this instructional video

<https://us.openbuilds.com/v-slot-nema-17-linear-actuator-bundle-belt-driven/>

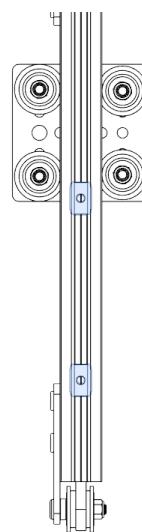
https://youtu.be/eCr1ogUuNPA?si=HvmjLC_kqwif3cx



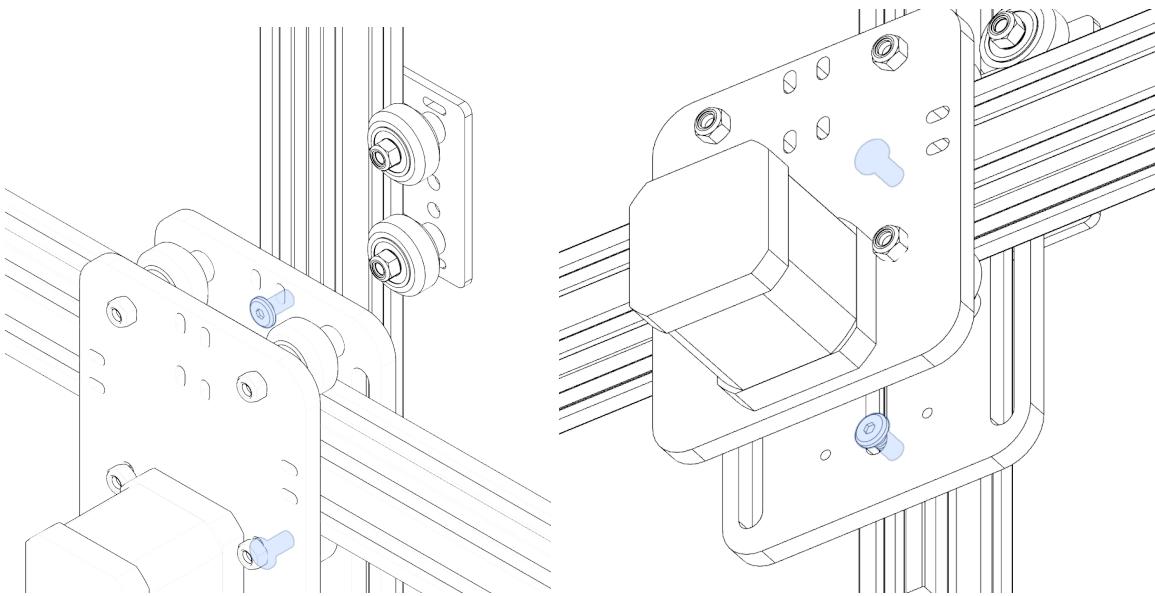
Step 28. Attach Linear Actuator (Z-axis) to X-axis Faceplate

Required Materials: (2) 12mm M5 screws, (2) M5 Tee Nuts

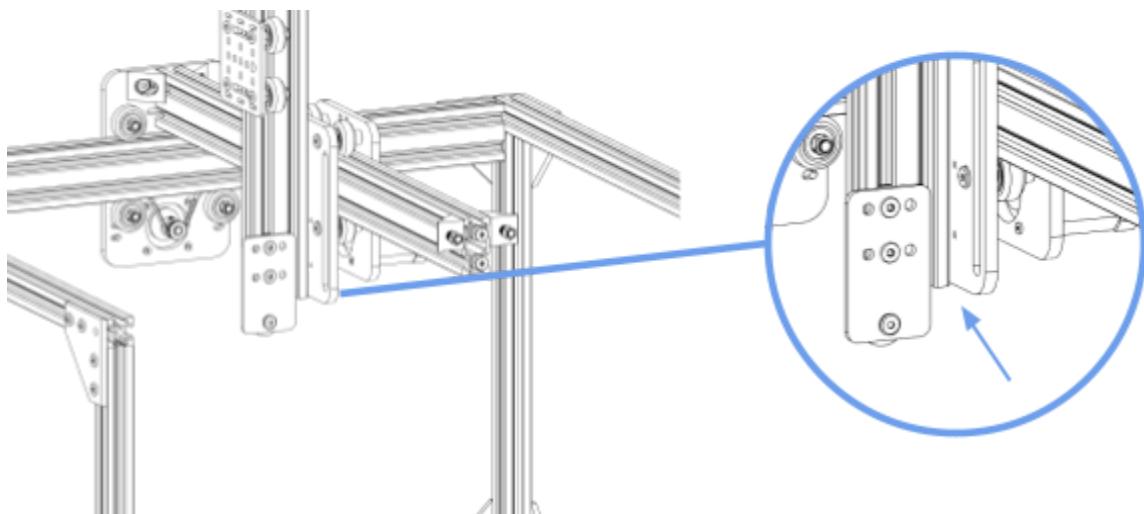
28.1. Slot in two Tee nuts into the opposing side of the Linear actuator face plate. To keep them in place it may be useful to use tape as they will fall down while you try to mount them.



28.2. Using the drilled hole and the large slot, fasten in your 12mm M5 screws to join the two pieces together.



*REMINDER: The exact height of your linear actuator should depend on the required clearance of your use case, but for our system, line up the bottom extrusion with the bottom of the X Carriage plate



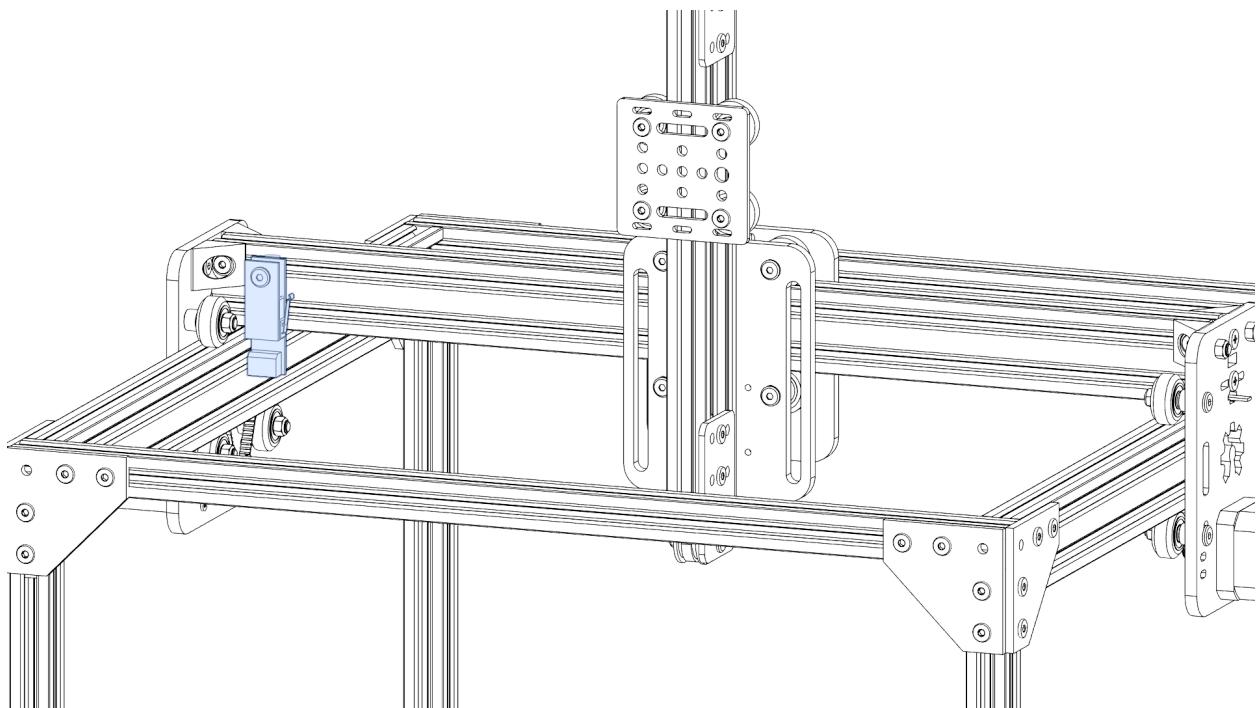
End Stop Placement

This section will describe the placement of the end stops (Xtension Limit Switch) on the lattice to help create 0,0,0 homing positions and define operational boundaries. Each end stop was placed to allow for a maximum usable area and to reduce wire clutter. If your setup requires different locations it would only require minor adjustments.

Required materials: (3) Xtension Limit Switch, Provided Mounting materials: (3) 15mm M5 screws, (3) M5 Drop in M5 Tee Nuts, (3) Rubber Spacers, (2) Black angle Corner Connectors, (2) 8mm M5 screws

X-Axis End Stop

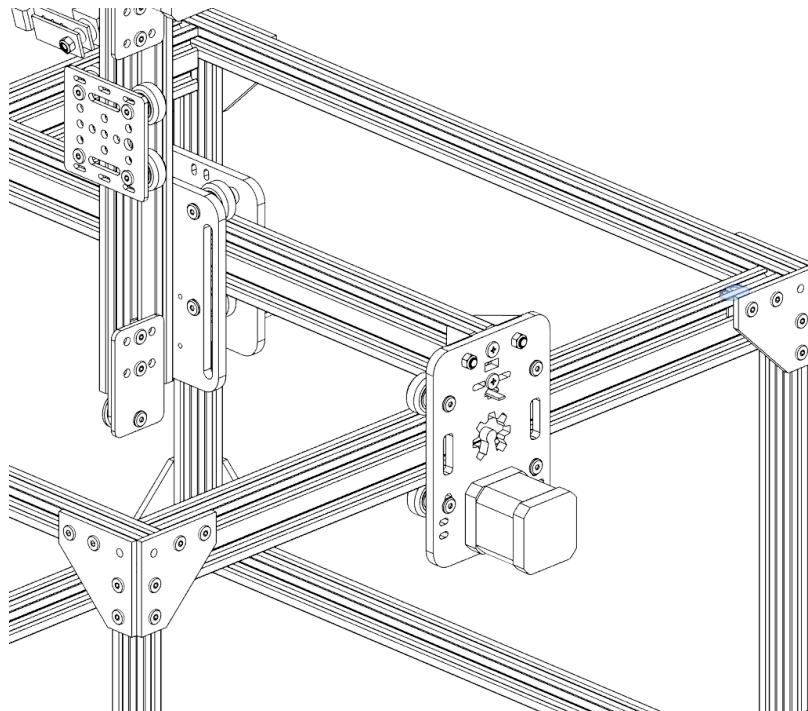
Step 29: To fix this end stop, use a drop in Tee Nut on the top-side X-axis extrusion. Face the end stop towards the track. Using a 15mm M5 screw fix the end stop in place with a rubber spacer to have correct orientation



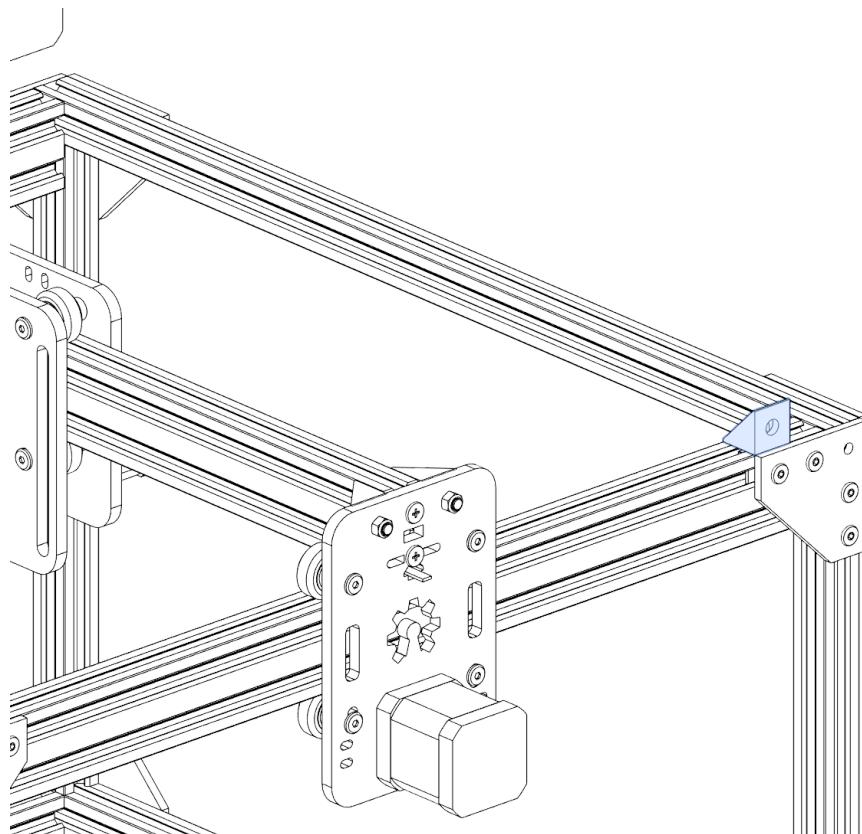
Y-Axis End Stop

Step 30: Attach Y-Axis End Stop

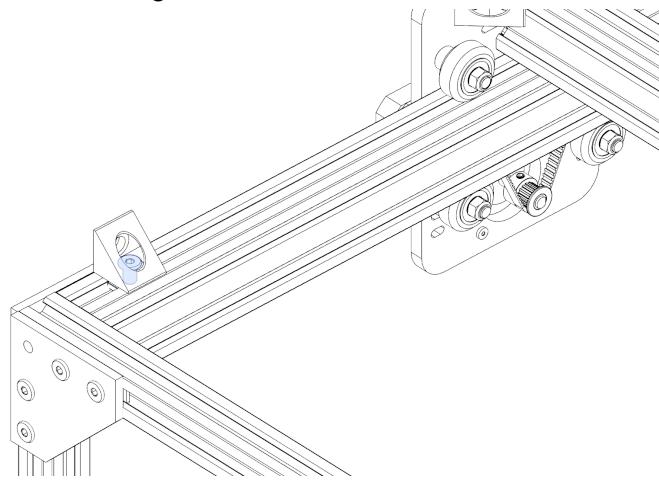
- 30.1. Attach an M5 Single Tee Nut on the back right corner of the machine.



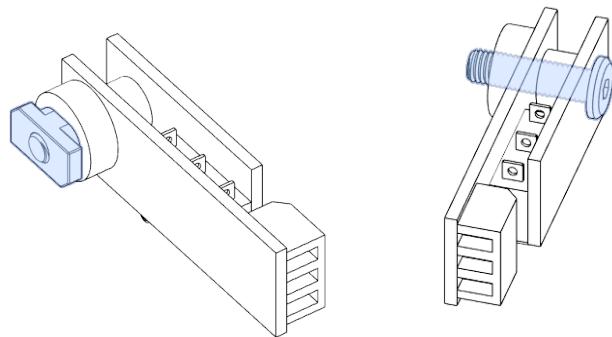
- 30.2. Place black angle corner block on top of the Tee Nut, facing outwards.



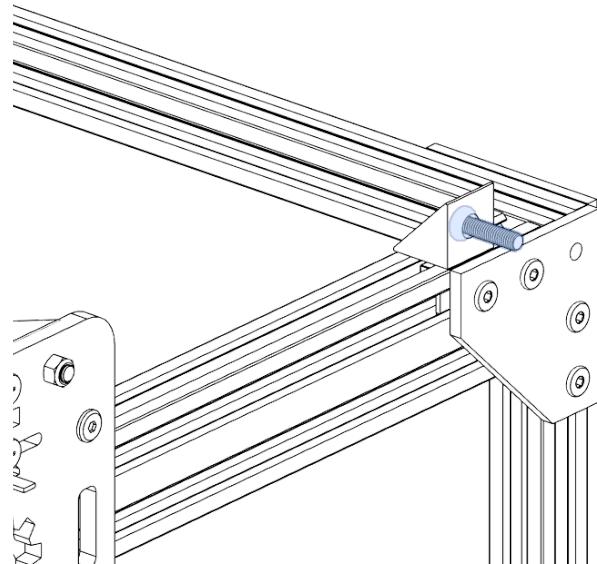
30.3. Attach angle block using an 8mm M5 Screw



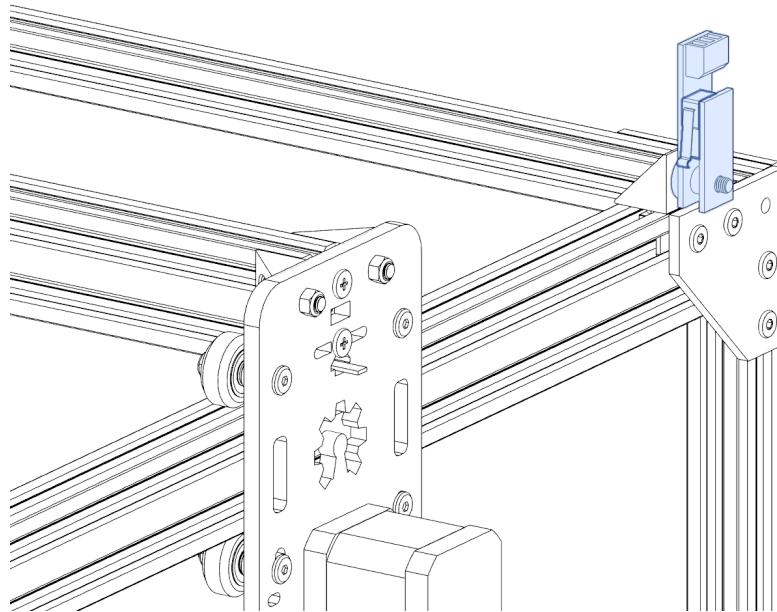
30.4. Remove the Tee Nut and bolt from the Xtension Limit Switch. The bolt will be used in the next step.



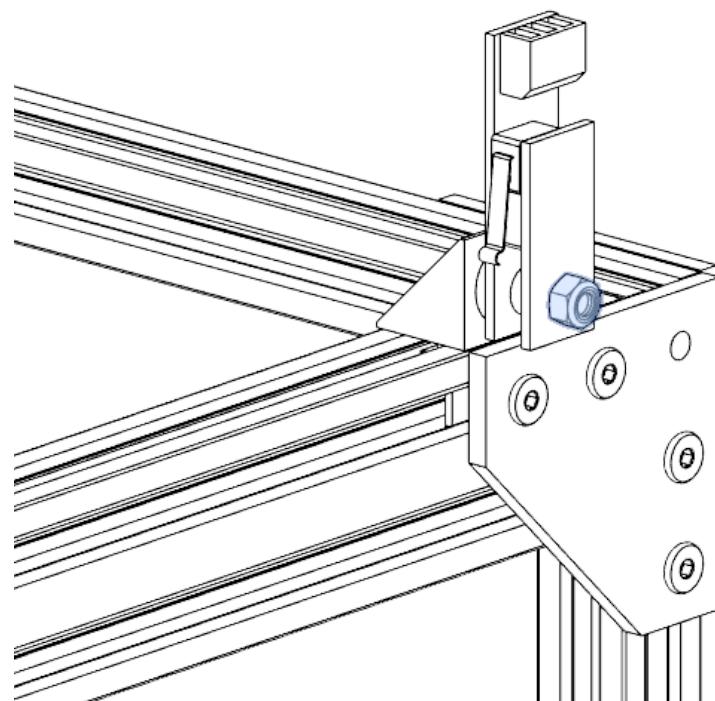
30.5. Attach the M5 bolt you just removed into the black angle corner block facing outwards



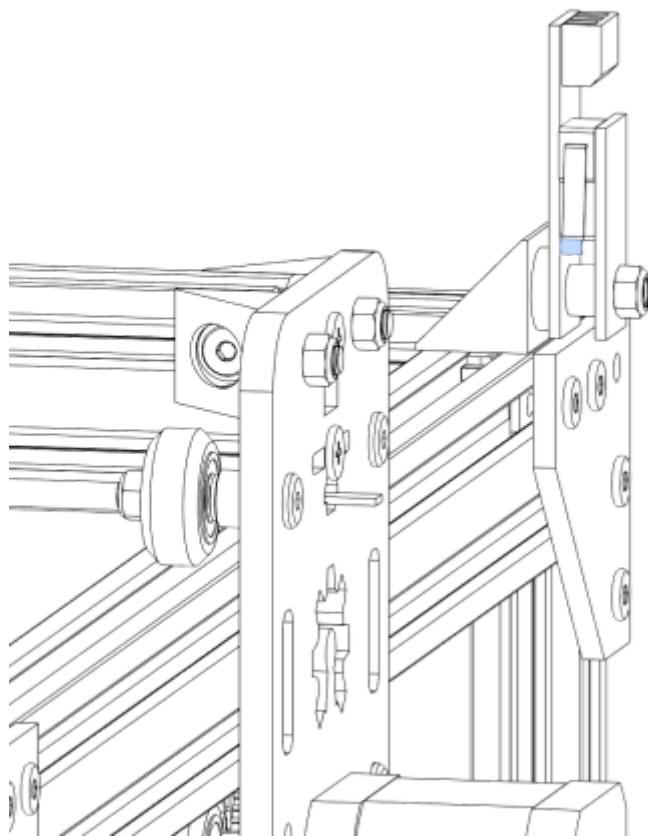
30.6. Attach the plastic spacer, then the Xtension limit switch on the black angle corner block.



30.7. Fasten an M5 Nylon Hex Nut, making sure not to overtighten and damage the circuit board.



30.8. Ensure the limit switch is inline with the Y-carriage, and that the limit switch is activated before hitting any obstacle in the frame (like the 90-degree angle plates)

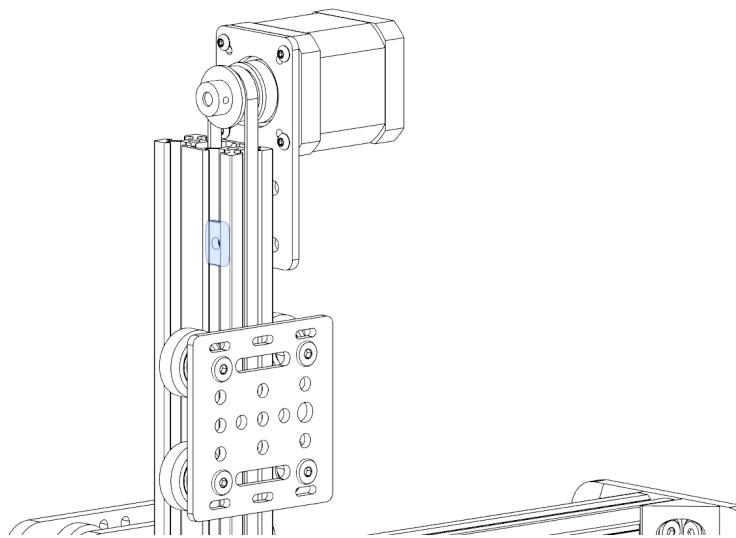


Z-axis End Stop

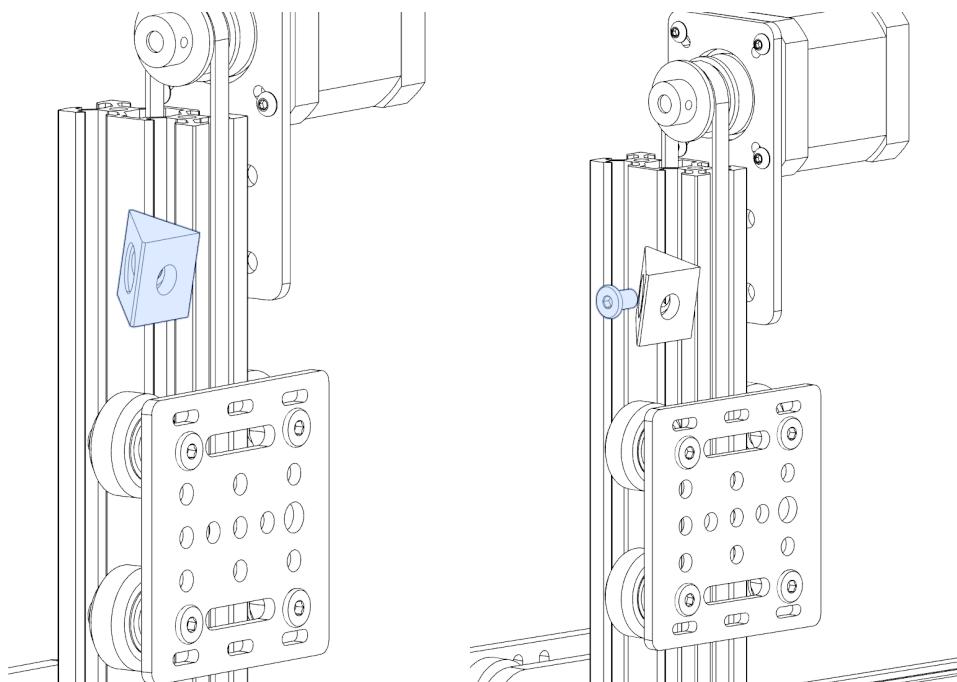
Step 31: Attach Y-Axis End Stop

To fix this end stop, we used a black angle corner connector on the side of Z-axis extrusion to create optimal orientation

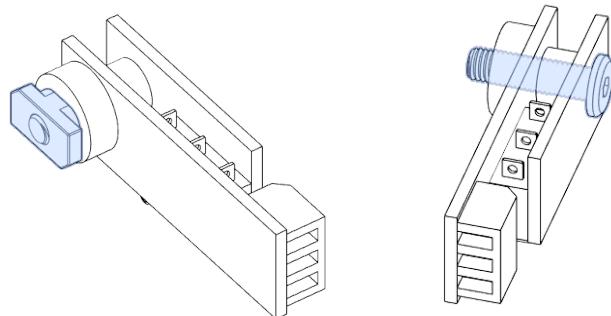
31.1. Place a drop in Tee Nut on the Z-axis extrusion. (To keep this in place it may be beneficial to use tape as a stopper underneath the Tee Nut)



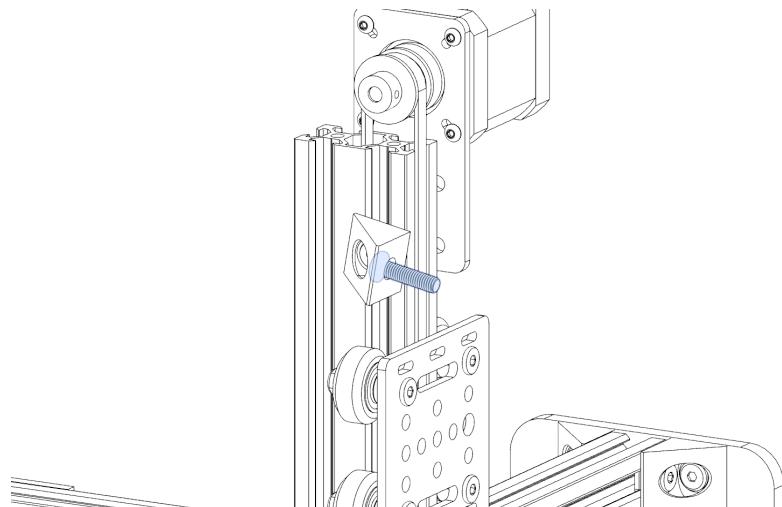
31.2. Apply a M5 8mm screw to fixate the corner connector in place. The corner connector will be rotated at a slight angle to create a consistent contact point for the end stop. (Do this through trial and error once the end stop is placed at a later step)



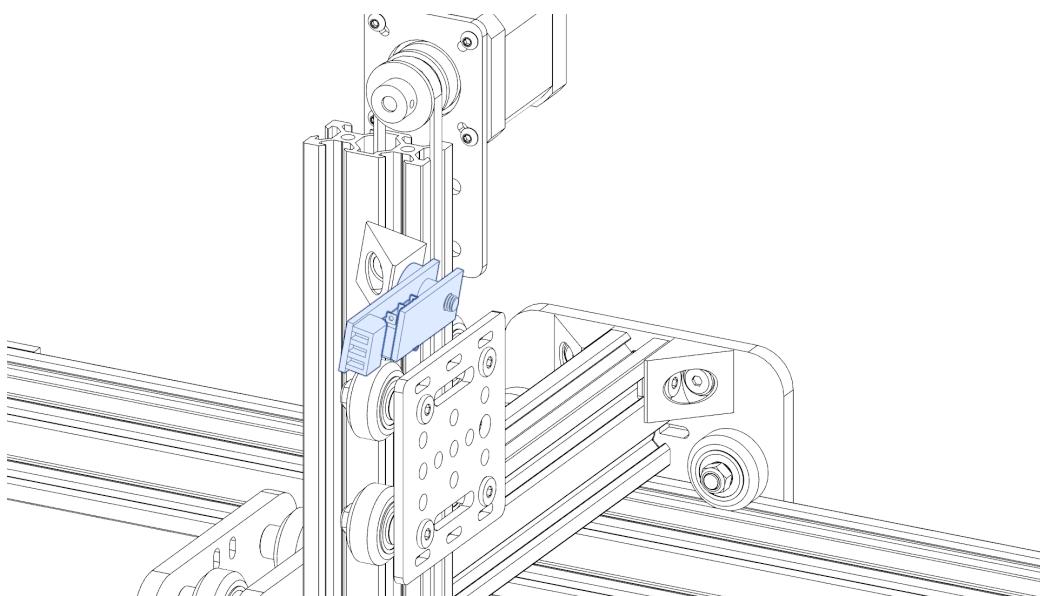
31.3. Remove the Tee Nut and bolt from the Xtension Limit Switch. The bolt will be used in the next step.



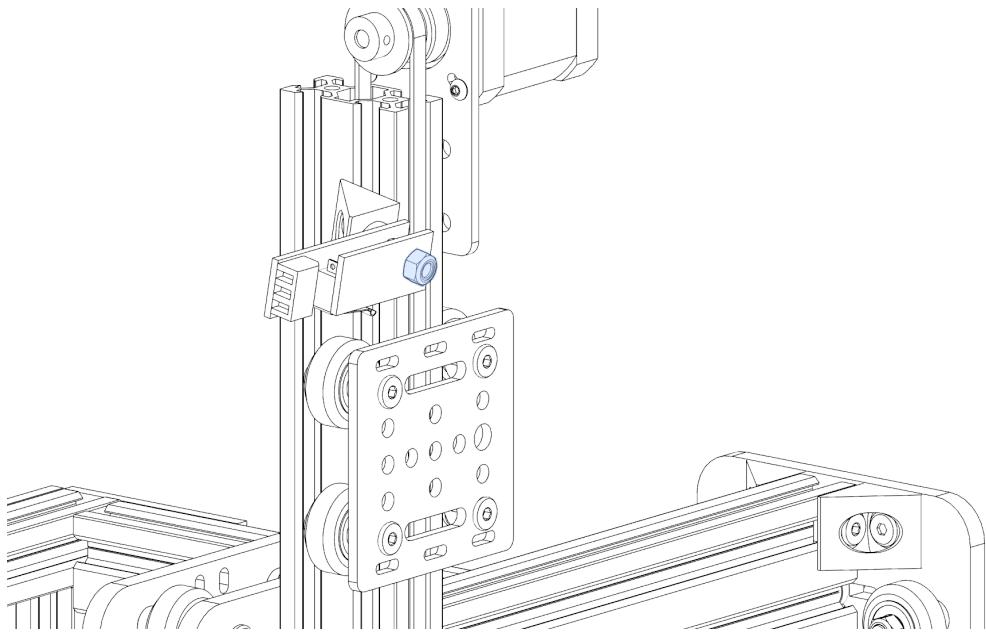
31.5. Attach the bolt you just removed into the black angle corner block facing outwards.



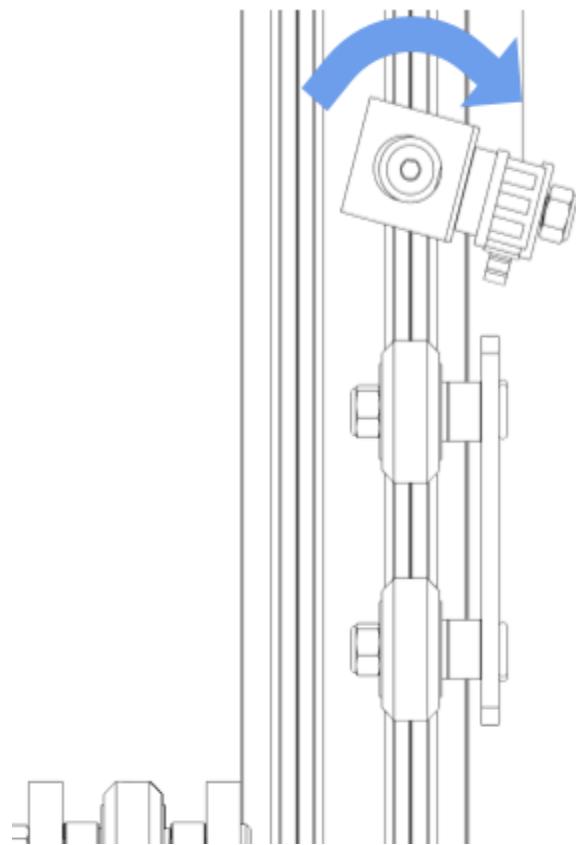
31.6. Apply your plastic spacer. then the Xtension limit switch on the black angle corner block.



31.7. Fasten an M5 Nylon Hex Nut, making sure to not overtighten and damage the circuit board.



31.8. Adjust the rotation of the angle block, making sure the switch can be fully pressed and unpressed by the z carriage.



Liquid Handler Specific Steps

The previous sections discuss the creation of the general structure of the machine. To retrofit the machine for an automated liquid handler using an Integra autoPipette, you will require specific extra steps.

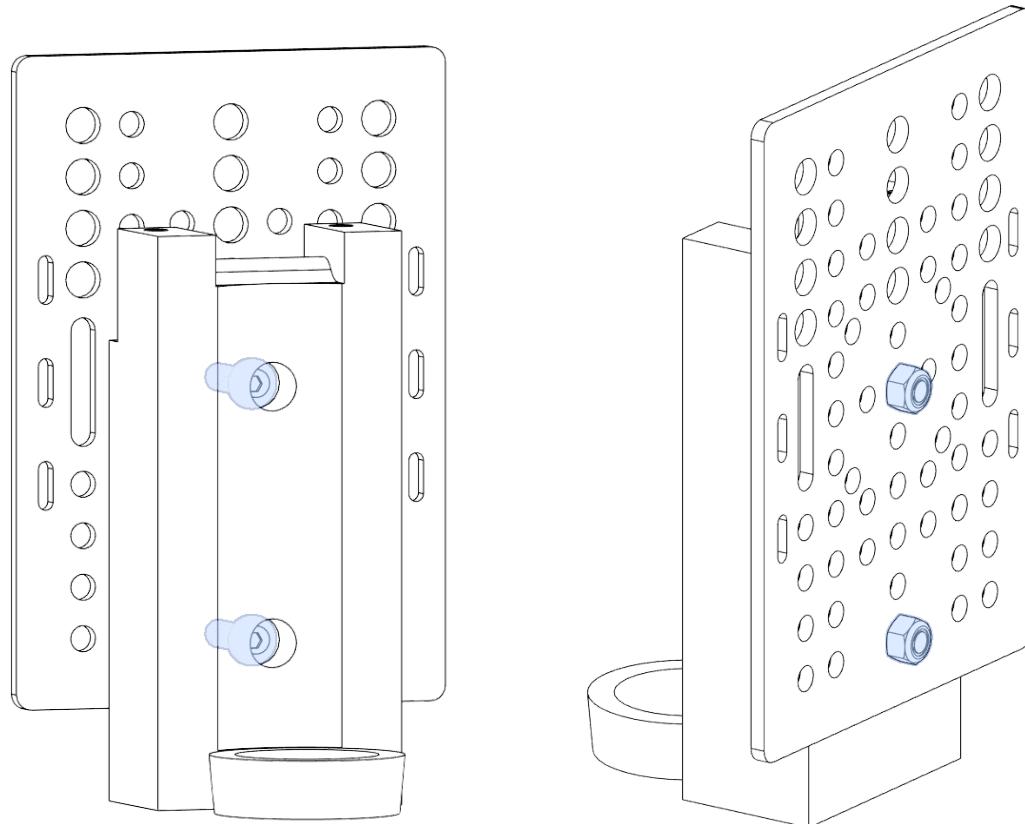
Auto Pipette Attachment to Z-axis linear actuator

Required materials: AttachedSTL/CAD file for the 3D printed parts, (1) V-slot Universal Gantry Plate, (2) 20mm M5 Screws, (4) M5 Hex Nuts, (2) 15mm M5 Screws, (2) 6mm Spacer

Step 32. Attach V-slot Universal Gantry Plate to 3D printed pipette holder

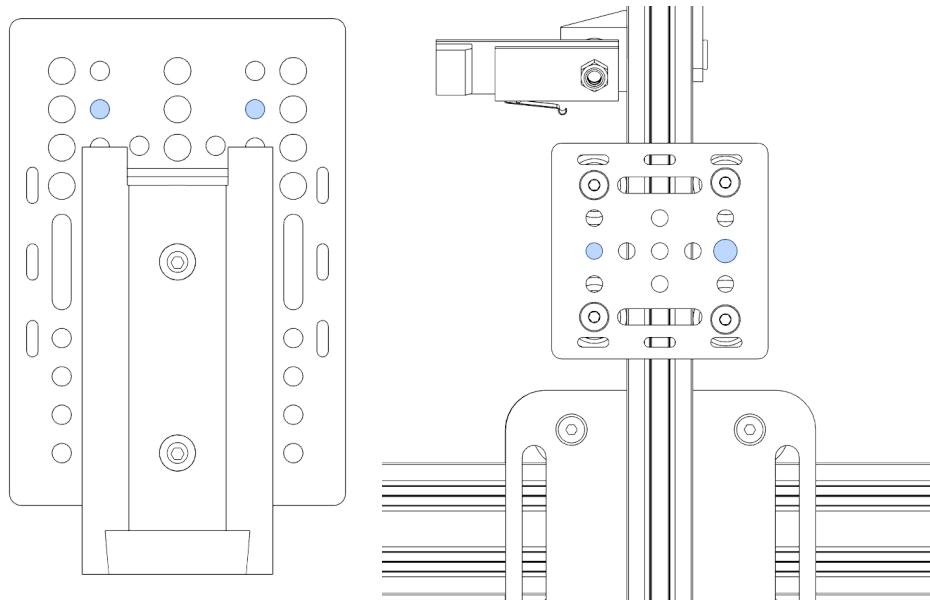
Required Materials: (1) V-slot Universal Gantry Plate, (2) 20mm M5 Screws, (2) M5 Hex Nuts

32.1. Place two 20mm M5 screws within the designated holes of the 3D-printed pipette holder, and attach them to the first and sixth holes from the bottom. Secure the screws with M5 Hex Nuts. Do not over-tighten as this could crack the print.

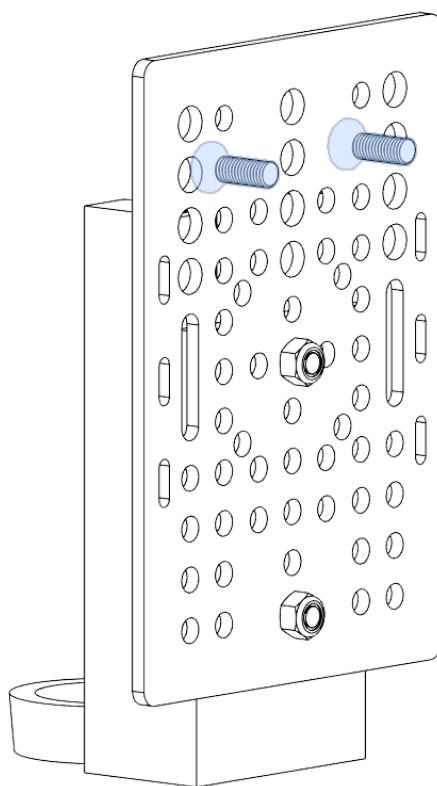


Step 33. Attach V-slot Universal Gantry Plate to Z-axis Linear actuator plate
Required Materials: (2) 15mm M5 Screws, (2) Hex Nuts, (2) 6mm Spacer

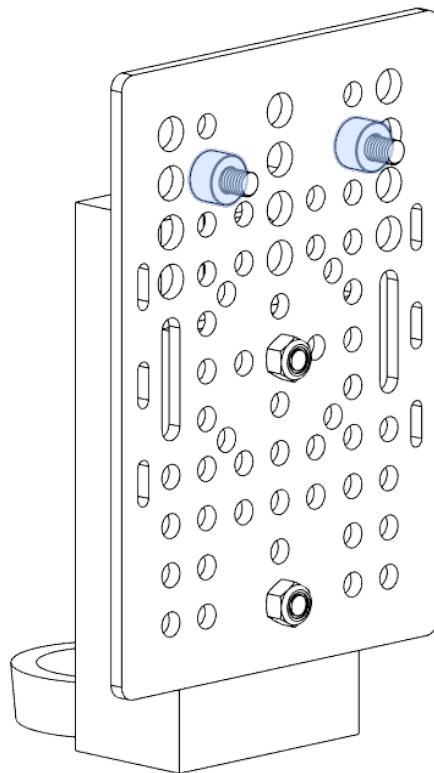
These corresponding holes will be attached.



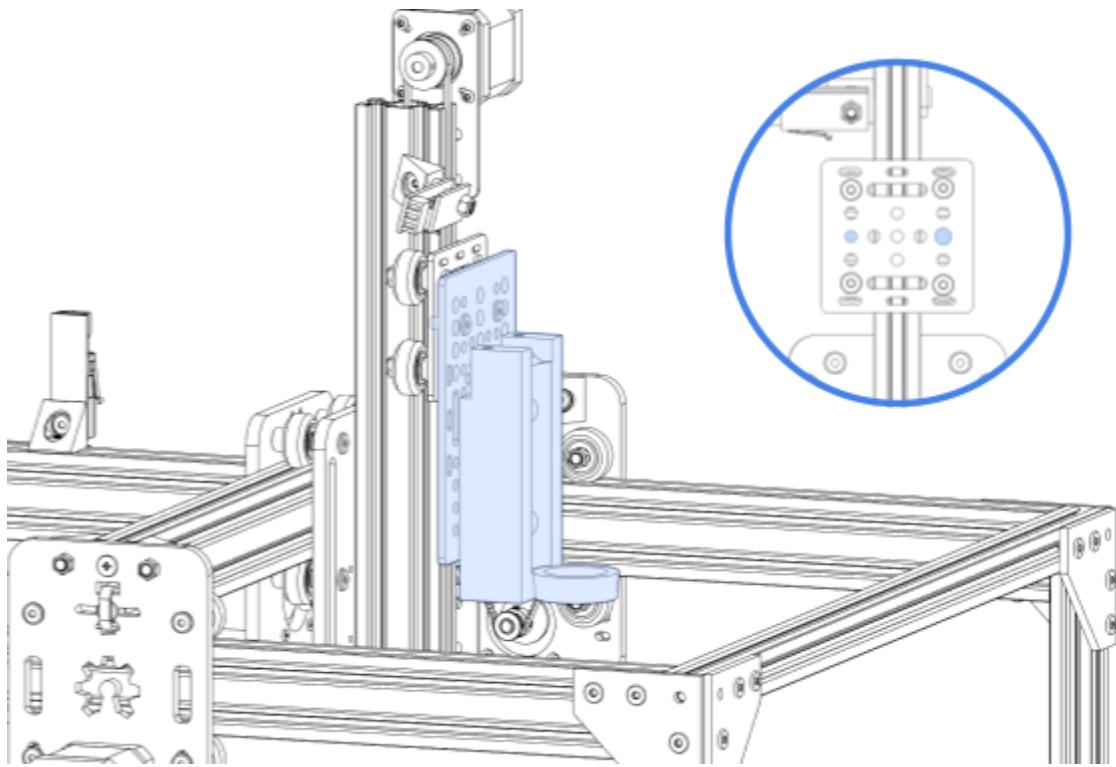
33.1. Place two 15mm M5 Screws into circular holes on the V-slot universal gantry plate facing away from the attached 3D-printed piece



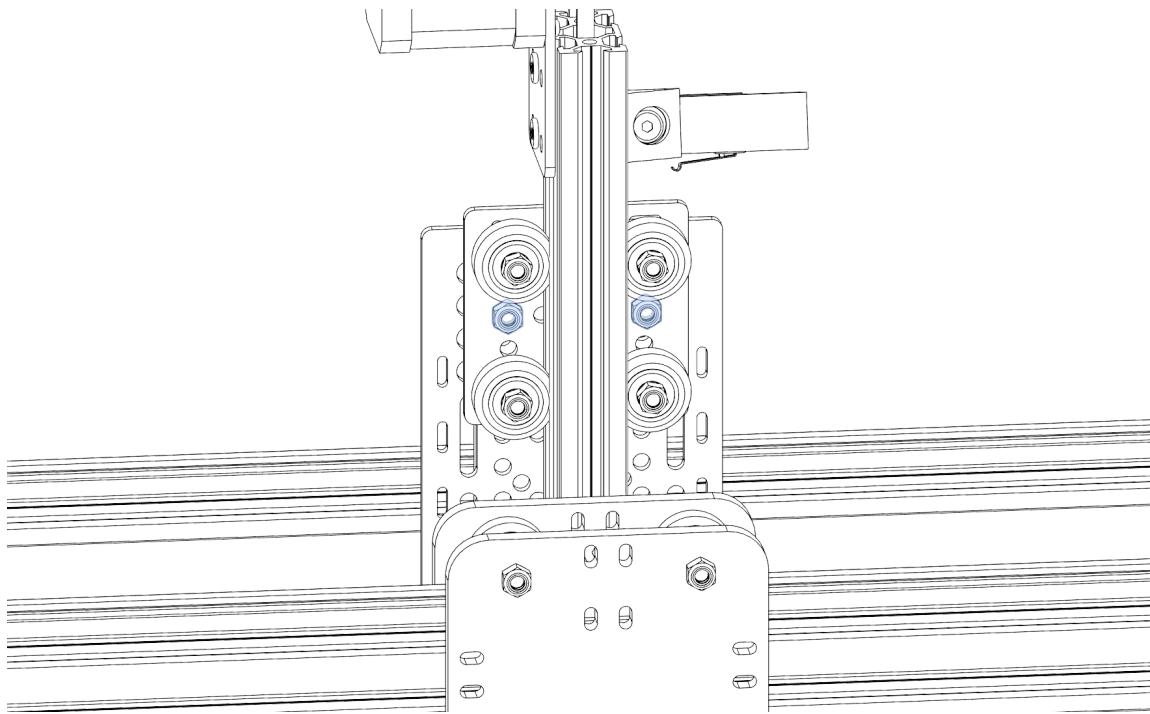
33.2. Place a 6mm Spacer on top of the screw to create a buffer from the pipette holder interacting with the Z-axis Linear actuator



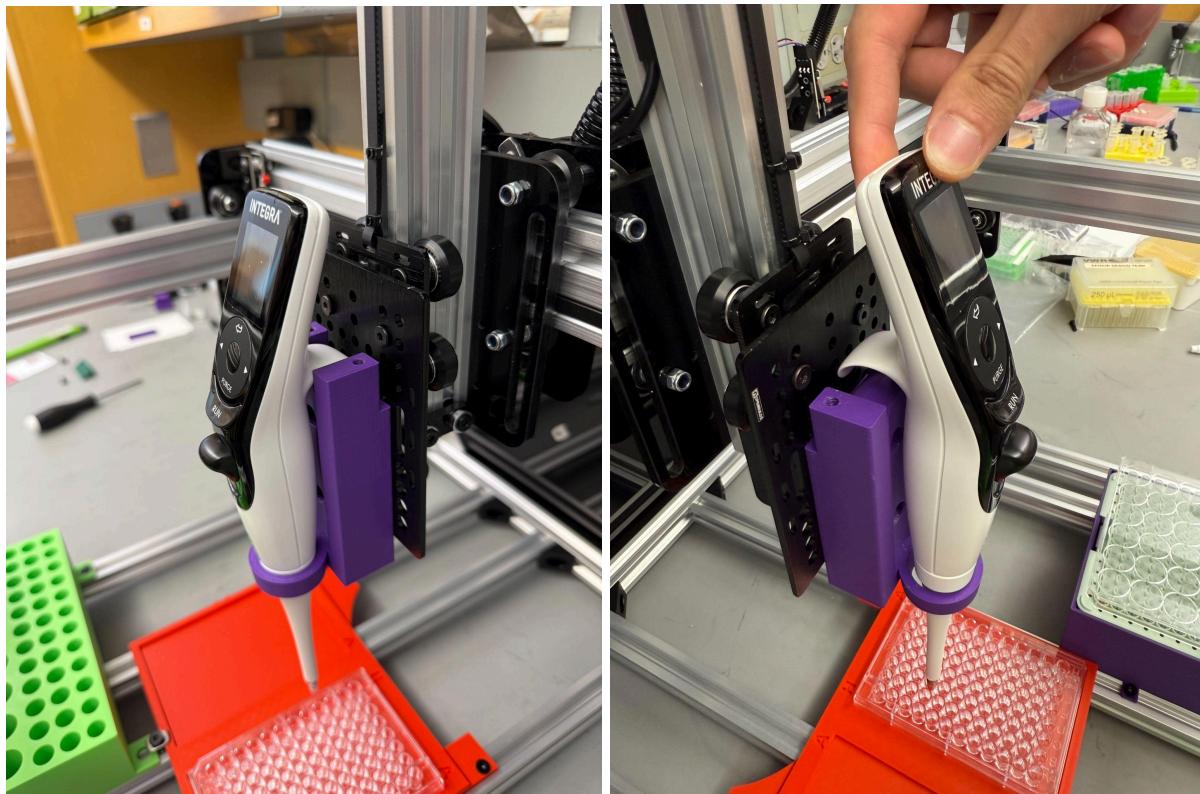
33.3. Attach the open ends of the screws to the faceplate of the Z-axis linear actuator



33.4. Attach M5 Nylon Hex Nut and tighten.



33.5. To mount your Autopipette, place the tip side downwards and rest the handle into the designated spot on the top of the 3D print, as shown in the pictures.



33.6. Place the pipette holder clamp, and fasten it with 2 8mm M5 screws.



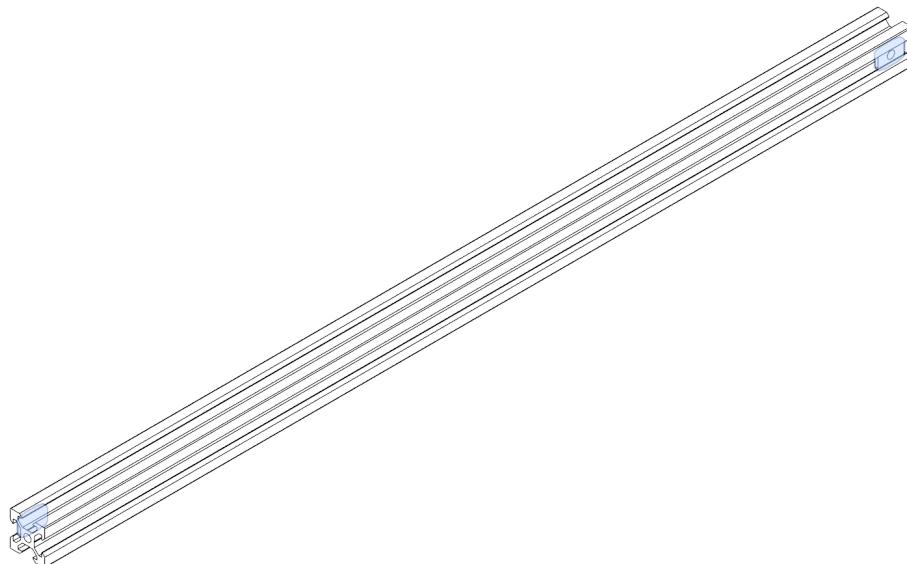
Reagent Trough Holders

This add-on adds spaces on your lattice that can allow one to fix reagent holders in place.
Required materials: (8) Drop in M5 Tee Nuts, (8) Black Angle Corner Connector, (4) 20x20 Al Extrusions, (8) Single M5 Tee Nuts, (16) 8mm M5 Screws

Step 1. Extrusion setup

Required Materials: (1) 20x20 Al Extrusions, (2) M5 Tee Nuts

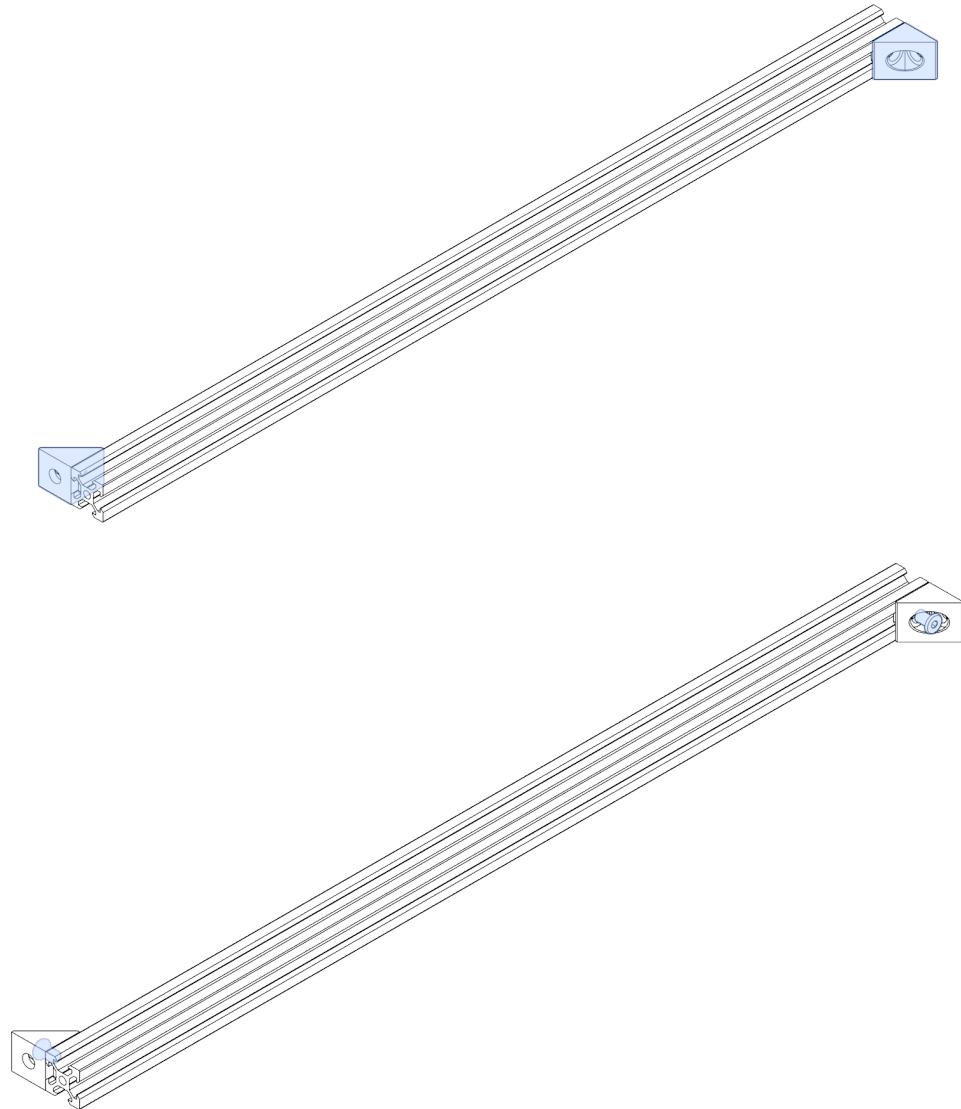
Place one single M5 Tee Nut on the end of an Al Extrusion. On the opposite side and opposite end of the extrusion place another M5 Tee Nut.



Step 2. Corner connector to extrusion

Required materials: (2) Black Angle Corner Connector, (2) 8mm M5 Screws

Using a M5 screw fastens black angle corner connectors to the inserted M5 Tee Nuts. Make sure that the corner connectors are facing opposite sides to have proper fixation.



Step 3. Apply drop in Tee Nuts to the bottom lattice

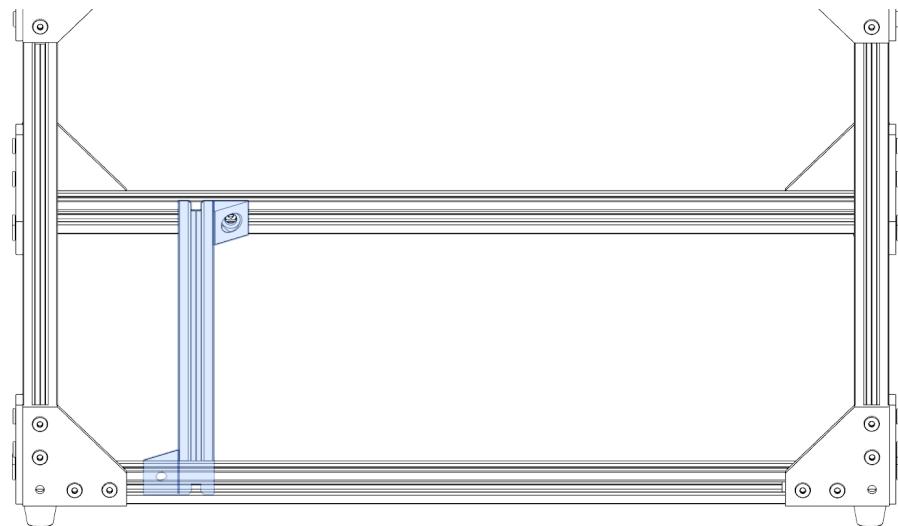
Required materials: (2) Drop in M5 Tee Nuts



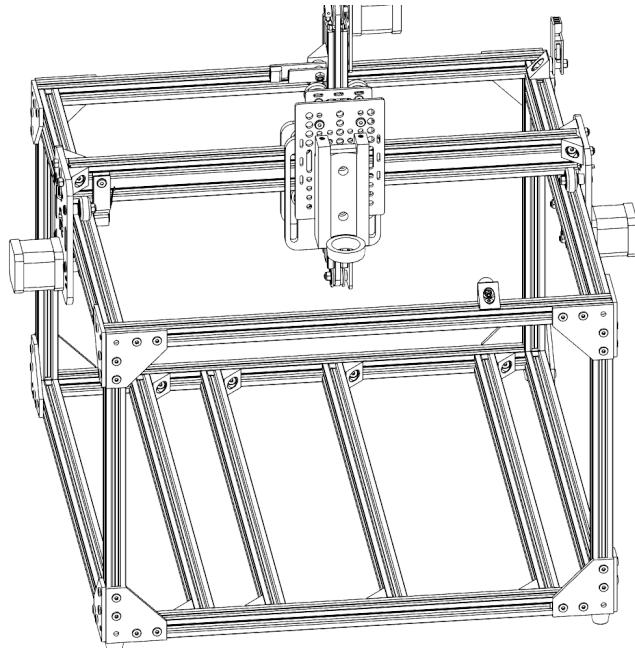
Step 4. Connect corner connectors to desired locations on lattice

Required materials: (2) 8mm M5 Screws

Using Drop in Tee nuts inside of the Tee Nut Track of your bottom extrusions attach the reagent holder extrusions at desired locations



Repeat the steps to have enough support for the components attached to the lattice.



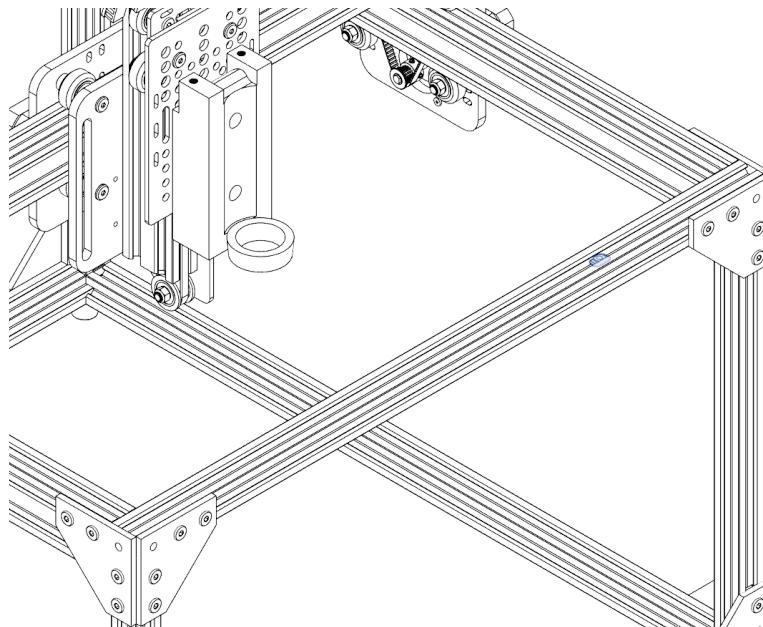
Our setup looks like this,

Pipette Tip Remover

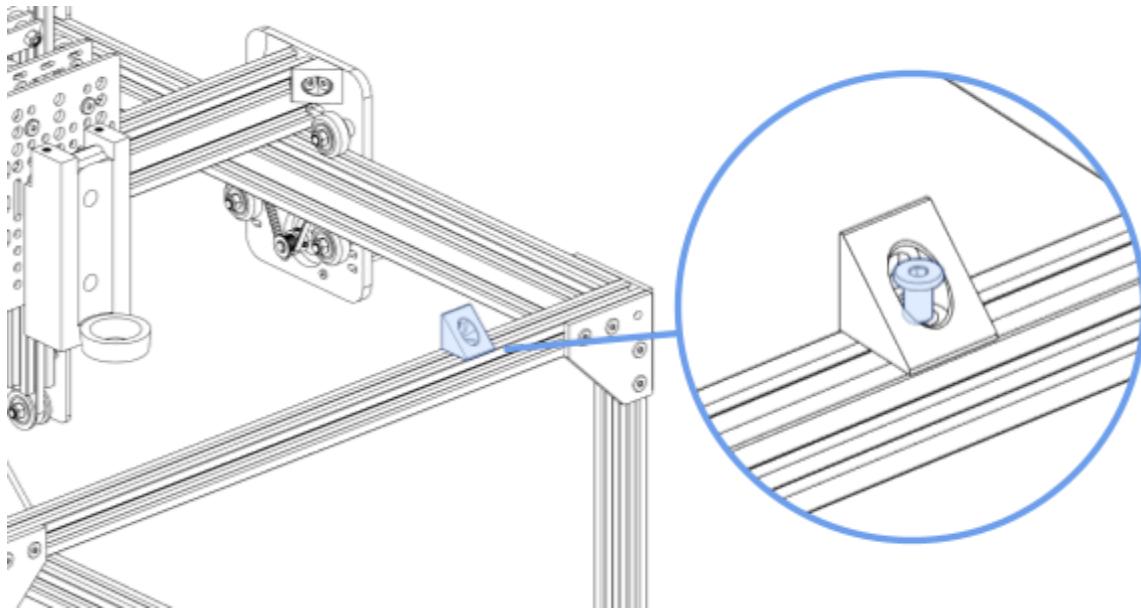
This simple addition allows you to set a location that can activate the button that removes the used tips off the pipettes

Required Materials: (2) Drop-in M5 Tee Nut, (1) Black angle Corner Connector, (2) 8mm M5 screw, (1) rigid material ((1) rubber foot)

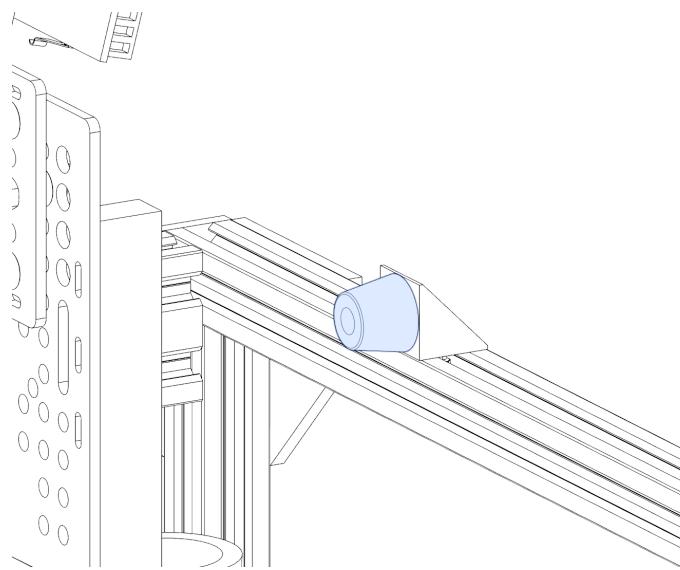
Step 1. Designate a space for your pipette tip remover by slotting in a Drop-in M5 Tee Nut.



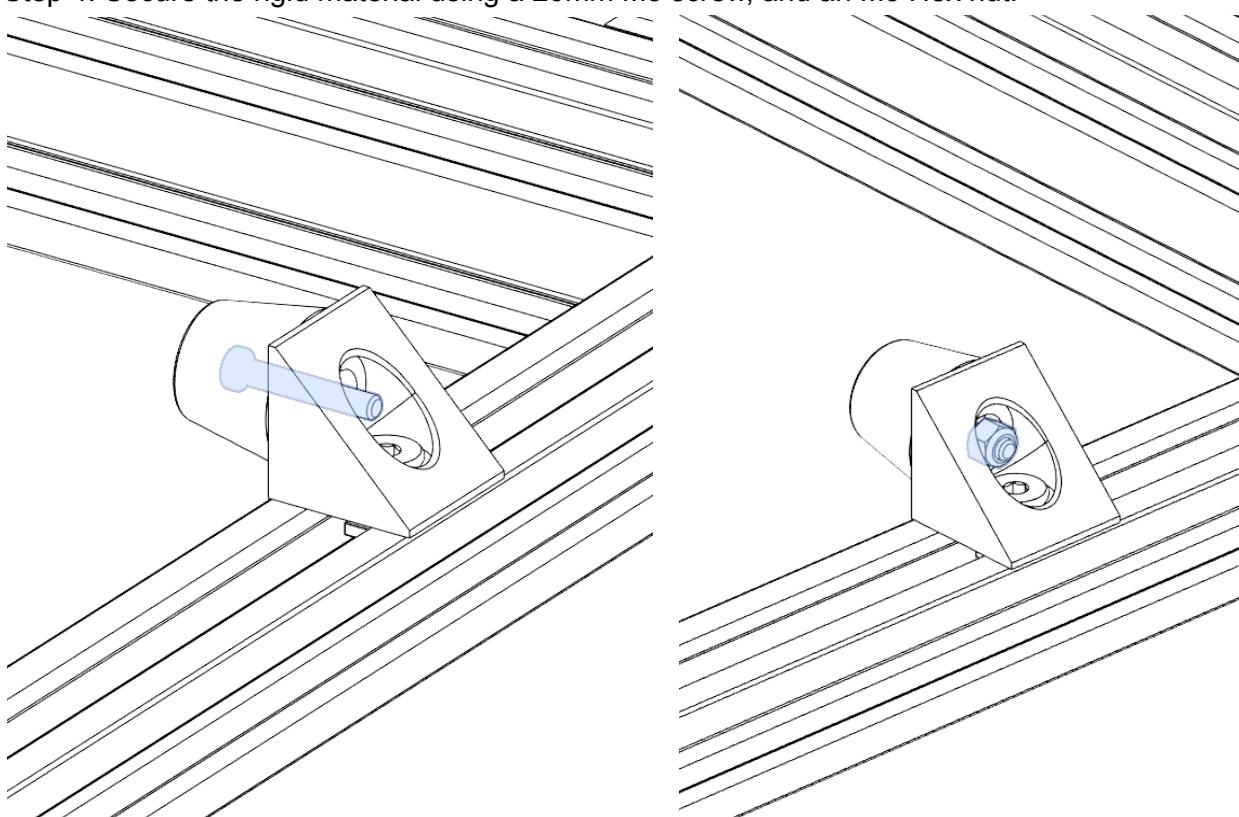
Step 2. Attach a Black angle Corner Connector using a 8mm M5 screw



Step 3. Attach your rigid material facing towards the inside of the machine.



Step 4. Secure the rigid material using a 20mm M3 screw, and an M3 Hex nut.



Electronic Guide

This section of the guide will loosely explain the necessary steps for the integration of the lattice structure you've created and the wiring/electronics. All pieces were fixed on a hard plastic sheet that is mounted onto the back of the device using drop in Tee Nuts.

Note. Cable management, Fixation placement, and orientation will not be discussed as that is up to user discretion. Standard care and safety practices should be upheld.

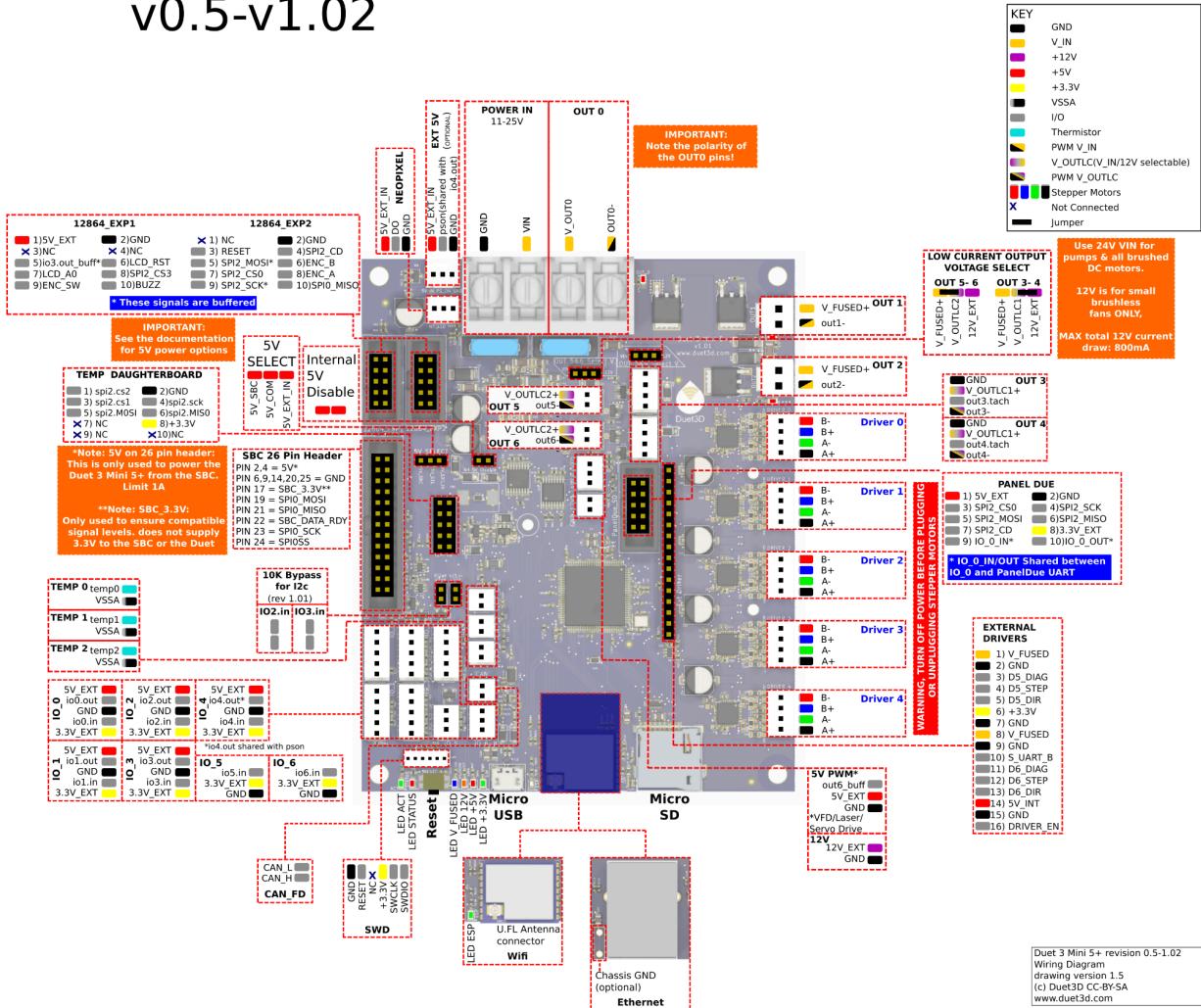


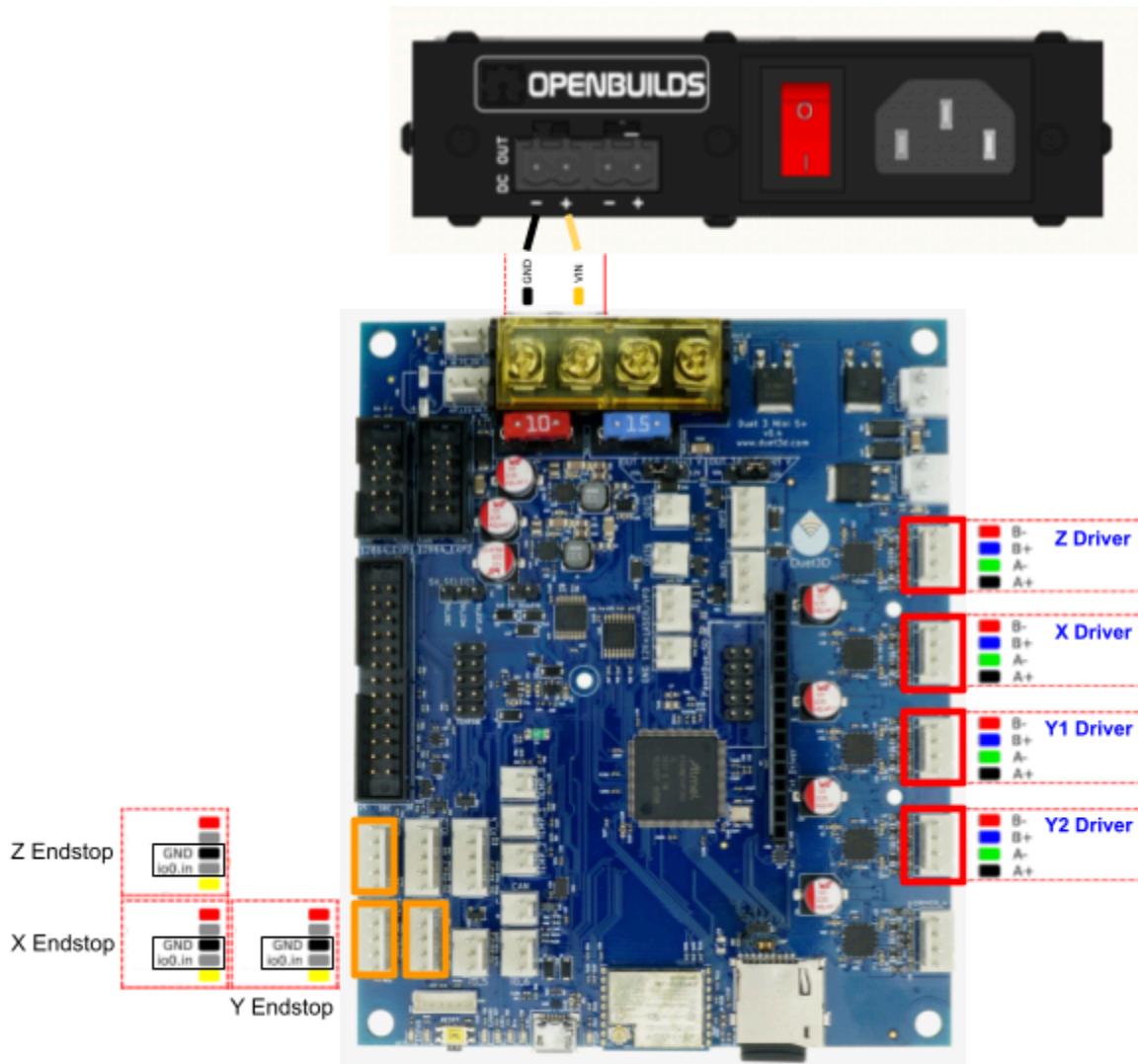
Wiring Diagram

Follow Duet 3D documentation:

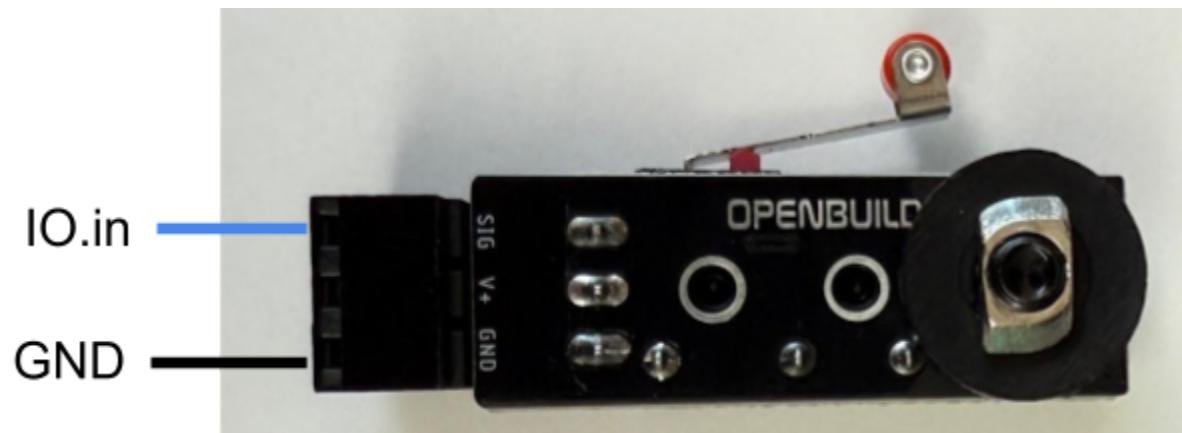
https://docs.duet3d.com/en/How_to_guides/Getting_connected/Getting_connected_to_your_Duet

Duet 3 Mini 5+ Wiring Diagram v0.5-v1.02

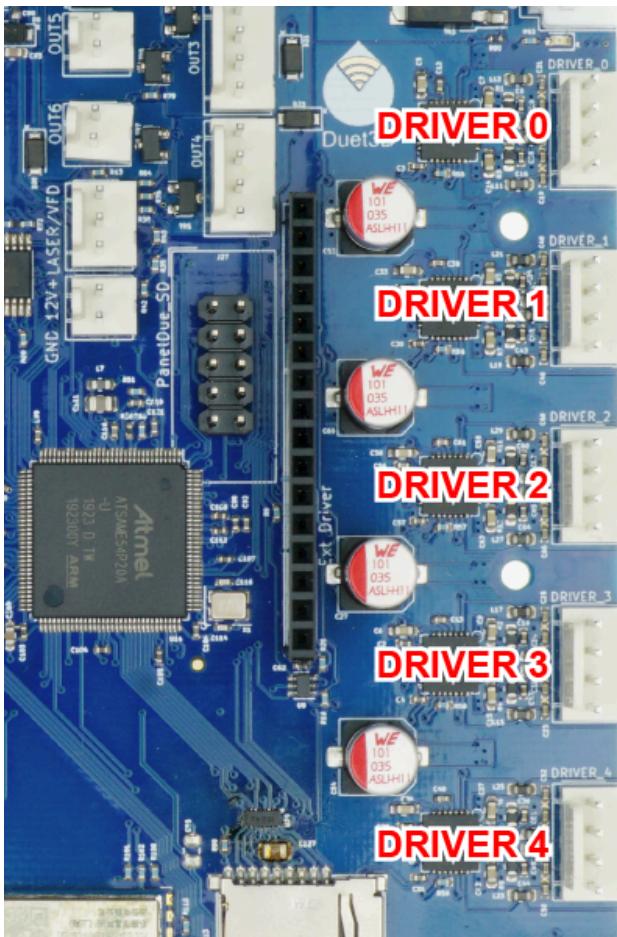




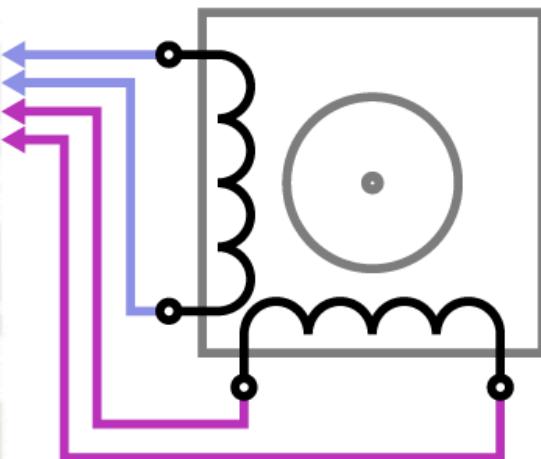
Endstop Wiring



Stepper Motor Wiring



Duet 3 Mini 5+



To determine which wires correspond with each coil, touch two wires together and attempt to spin the motor shaft. If there is resistance, then those two wires are one coil. If two wires are touching but do not add resistance, they are separate coils.

Power Supply

Locate the yellow sticker, and underneath it, make sure the switch is set to the correct voltage for your location. For the United States, we used 115 V.



Firmware/Software

The firmware and software can be found on the GormleyLab Github [LINK].

To get the machine connected and configured correctly, follow the documentation of your controller board. If you followed the exact build guide and have Duet 3 Mini 5+, follow this link to the documentation and start-up guide.

https://docs.duet3d.com/en/How_to_guides/e3p_Mini5+_guide_part2_configuration

Using the provided config files and with the help of the documentation, you should be able to safely start up and configure the machine to get it running. The end stops should be (0,0,0). Moving away from the end stops means going in the positive direction. This is true for the Z-axis as well, meaning +Z is down.

The only changes needed in the software are ensuring the right COM ports are linked for the Duet board and Integra autopipette, as well as positions for the well plates, tips, reagent reservoirs, and tip waste. The software is unfinished, so getting it to be fully self-driven will require some more work; however, this should give you a good groundwork.