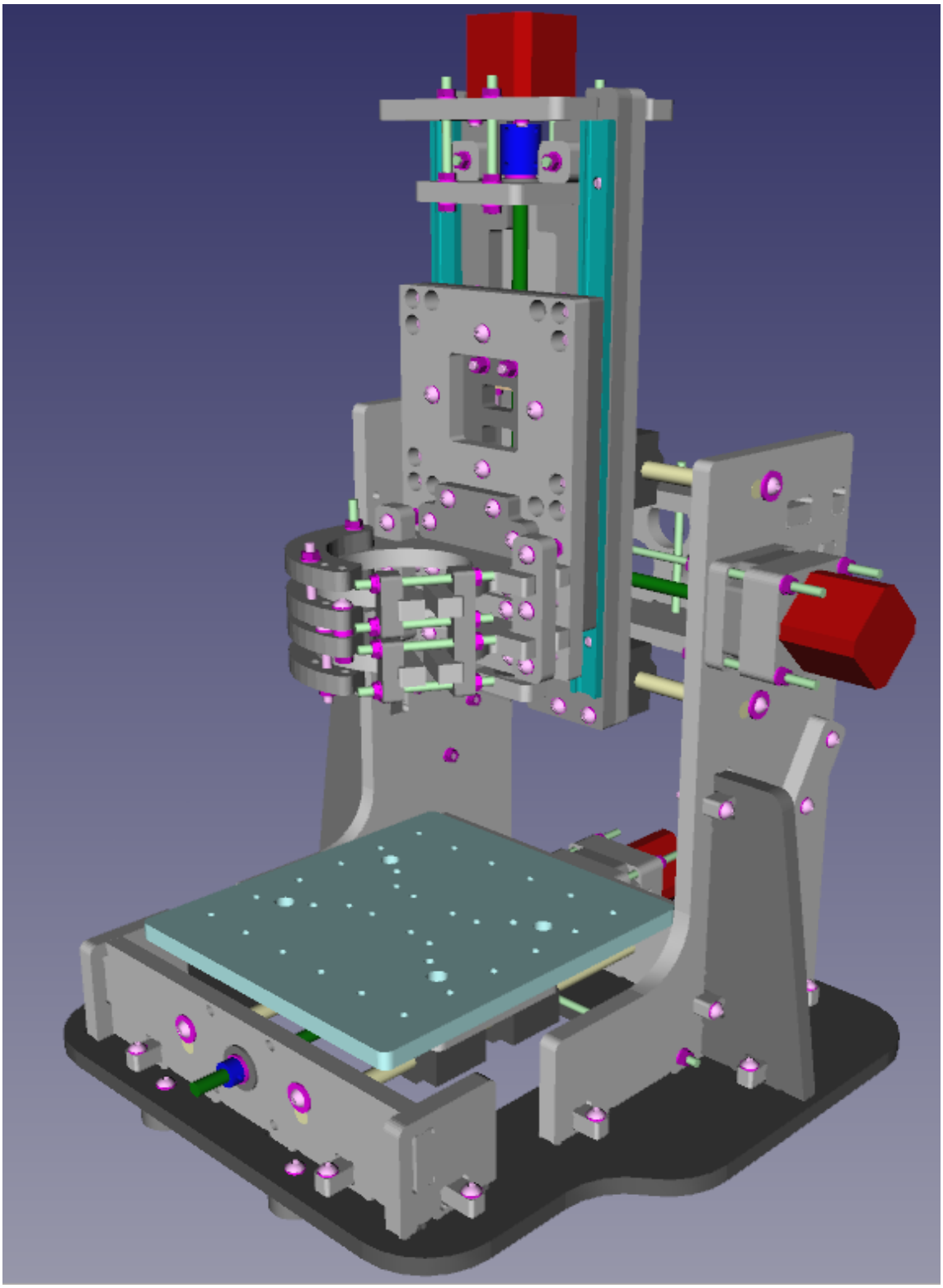
The Bologrew Design
Desktop Milling Machine Kit



Thank-you for purchasing the “Bologrew Design Desktop Milling Machine” kit.

As with all kits, the care that you take in the preparation and building of it will help determine how well it works. Having said that, only a few of the mating surfaces are critical with most surfaces being mostly cosmetic. The length and width of the parts has been precisely routed but the thickness of the Acrylic is a nominal 10mm and can vary by 10%. The kit has been designed to cater for the varying thickness of the material.

DO NOT REMOVE THE PARTS FROM THE SHEETS UNTIL REQUESTED.

Acrylic is strong, rigid but relatively brittle. Machine screws and nuts can exert a huge force on materials so it is important to only tighten nuts to “snug” and no more. For the purposes of this manual, “snug” is defined as just tight enough to prevent two flat pieces of Acrylic, held together by a machine screw and nut, from rotating.

The surface resistance of Acrylic can be increased by cleaning it with a silicone-based furniture spray polish. It is resistant to many chemicals but you must not bring Acetone into contact with it as it will dissolve it.

Should you have an accident and crack a part, it may be possible to repair it by applying a small amount of Acrylic “glue” (actually a solvent) to the crack and letting it wick into the fracture. The “glue” will dissolve the Acrylic along the sides of the crack and when it evaporates, will leave a solid piece of Acrylic again, frequently as strong as the original material. The best prevention for cracks is to not over-tighten the fasteners.

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Specifications

Overall fixed width (excluding stepper motor): 390mm
Overall fixed depth (excluding stepper motor): 340mm
Overall fixed height (excluding stepper motor): ~530mm
Overall depth (excluding stepper motor): 366mm

Machining envelope width: ~105mm
Machining envelope depth: ~135mm
Machining envelope height: ~105mm
Z axis travel: ~150mm

Router mount diameter: 68.75mm (to fit DeWalt D26200 router)
Weight (excluding stepper motors and router): ~8.8kg
Weight (including minimum NEMA 17 stepper motors and router): ~13.86kg

Recommended minimum stepper motor: NEMA 17, 3.2kg-cm holding torque

Parts List

1 x M3/M5/M8 machine screw/washer/hex nut/Nyloc nut kit
1 x 1000mm 8mm diameter stainless steel threaded rod
3 x 1000mm 5mm diameter stainless steel threaded rod
4 x 250mm 10mm diameter hardened steel rods
8 x SC10UU (10mm) linear bearing blocks (including bearings)
1 x 600mm OR 2 x 300mm Igus Drylin NS-01-17 Linear Guide Rail
4 x Igus Drylin NW-02-17 Linear Guide Carriages
6 x F608ZZ flanged bearings
3 x 8mm diameter lock collars
3 x stepper motors
3 x flexible shaft couplers

For NEMA 17 stepper motors use 8mm to 5mm flexible shaft couplers.
For NEMA 23 stepper motors use 8mm to 6.35mm flexible shaft couplers.

Required Tools

M2 Allen (Hex) Key.
M2.5 Allen (Hex) Key.
M3 Allen (Hex) Key.
M8 Open Spanner For M5 Nuts.
M5 Starter Tap.
Tap Handle For M5 Tap.
Small Needle Nose Pliers.
Small Flat Bladed Side Cutters.
Small Flat Blade Screwdriver To Fit M3 Slotted Pan Head Machine Screw.
Junior Hacksaw.
Small (10mm width) File.
Rule or Tape Measure.
Set Square, Woodworking Square or Machinist's Square.
Medium To Fine Grade Abrasive Paper.
Safety Glasses.
Gloves.
Light oil.
Washing-up Liquid.

Desirable Additional Tools

Small Vice.
Small Rounded File.
Vice Grips.
M8 Closed Spanner For M5 Nuts.
Small Box Spanner/Socket For M3 Nuts.
Silicone-Based Furniture Spray Polish.

Preparation Work – Tapping The Bearing Blocks

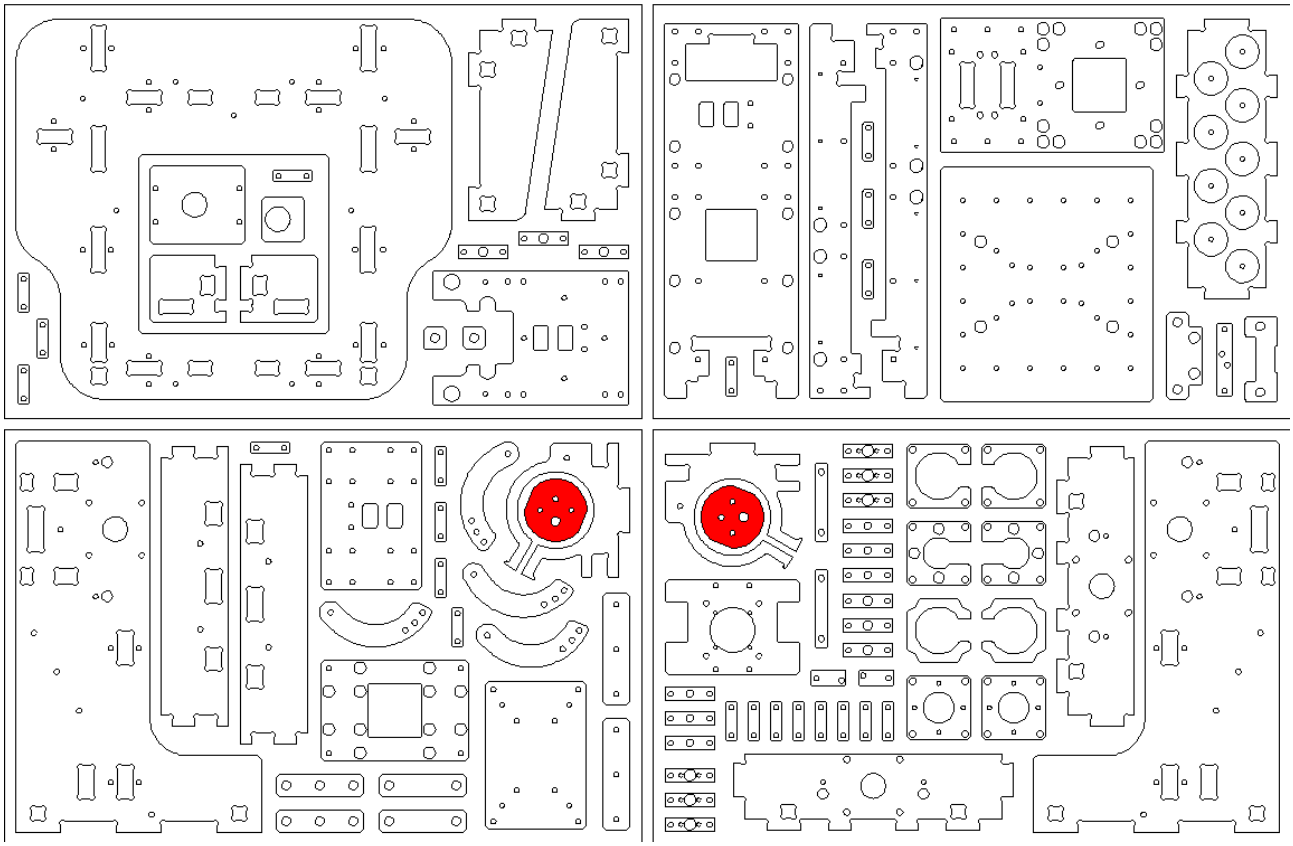
The Linear Bearing Blocks are pre-tapped but the threads do not go all the way through. Depending on the machine screw length and Acrylic thickness, there may not be enough threaded length for the machine screws to fully tighten. Therefore we will tap the bearing blocks to full depth. This also has the advantage that they can then be screwed into from the opposite side which may be useful when fitting travel limit switches.

If available, mount a bearing block in the vice with the threaded holes facing up.
Fit the M5 Tap into the Tap Handle.
Place paper under the vice to catch chips and oil.
Pour light oil into the threaded holes. 3-in-1 is fine if you have it but cooking oil will do.
Liberally coat the tap with oil.
Screw the tap into the existing thread until it tightens.
Holding the tap handle with both hands, smoothly turn the tap handle clockwise maintaining even pressure from both hands. Don't jerk the tap.
Turn the tap 180° clockwise and then turn it 90° anti-clockwise to break the chip.
Repeat this procedure until the tap exits the bottom of the hole.
Wind the tap out and clean any chips and oil out of the hole.
Test the tapped hole by screwing an M5 machine screw all the way in until it comes out the bottom. Then try screwing it in from the reverse side.
Clean the chips off the tap, re-oil it and repeat for the remaining holes in all the bearing blocks.

Even if you've never tapped a hole before, you should now be familiar with the procedure and have acquired a feel for it.

Preparation Work – Making The Tap Guide

We need to tap holes in the Acrylic Sheets. To aid in this task, the kit contains a Tap Guide. Locate the parts shown below in red:

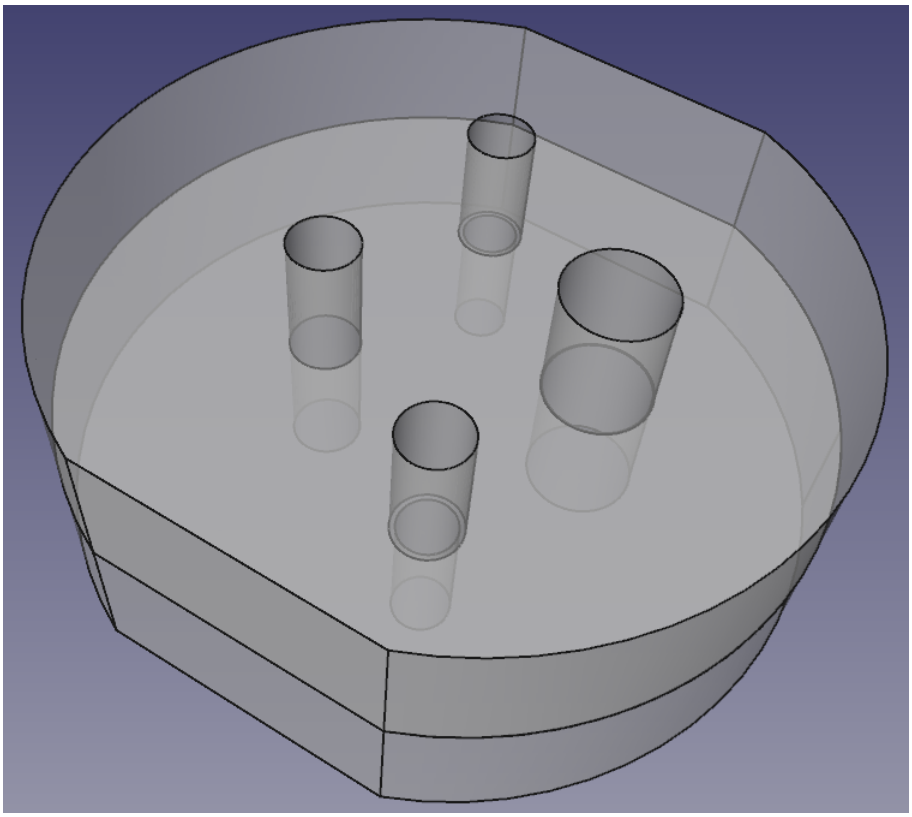


Wearing your safety glasses and gloves, carefully cut the tabs using the side cutters. It is easier to cut the tabs when the sheets are upside down.
Using the file and/or abrasive paper, remove the remains of the tabs from the parts and remove the protective plastic films.

The two parts are similar but different. Both contain a pair of 5mm and 8mm holes but the top one has a pair of 5mm holes and the bottom one has a pair of 4.2mm holes. Put the parts on top of each other aligning the 5mm and 8mm holes. Place a 5mm machine screw through the hole and place an 8mm machine screw if you have one or the end of the 8mm long threaded rod through the other hole. Put a nut on the 5mm machine screw and tighten until snug. All the holes should now be aligned.
Mount the parts in a vice if you have one with the 5mm open holes facing up.
Clean your tap and pour washing-up into the open holes.
Coat your tap with washing-up liquid and drop it into one of the 5mm holes. It should go all the way through to the bottom part. Using the tapping procedure previously described, tap the 4.2mm hole until it comes out the bottom.
Wind the tap out, clean it and re-coat it in washing-up liquid.
Repeat the procedure and tap the other hole.

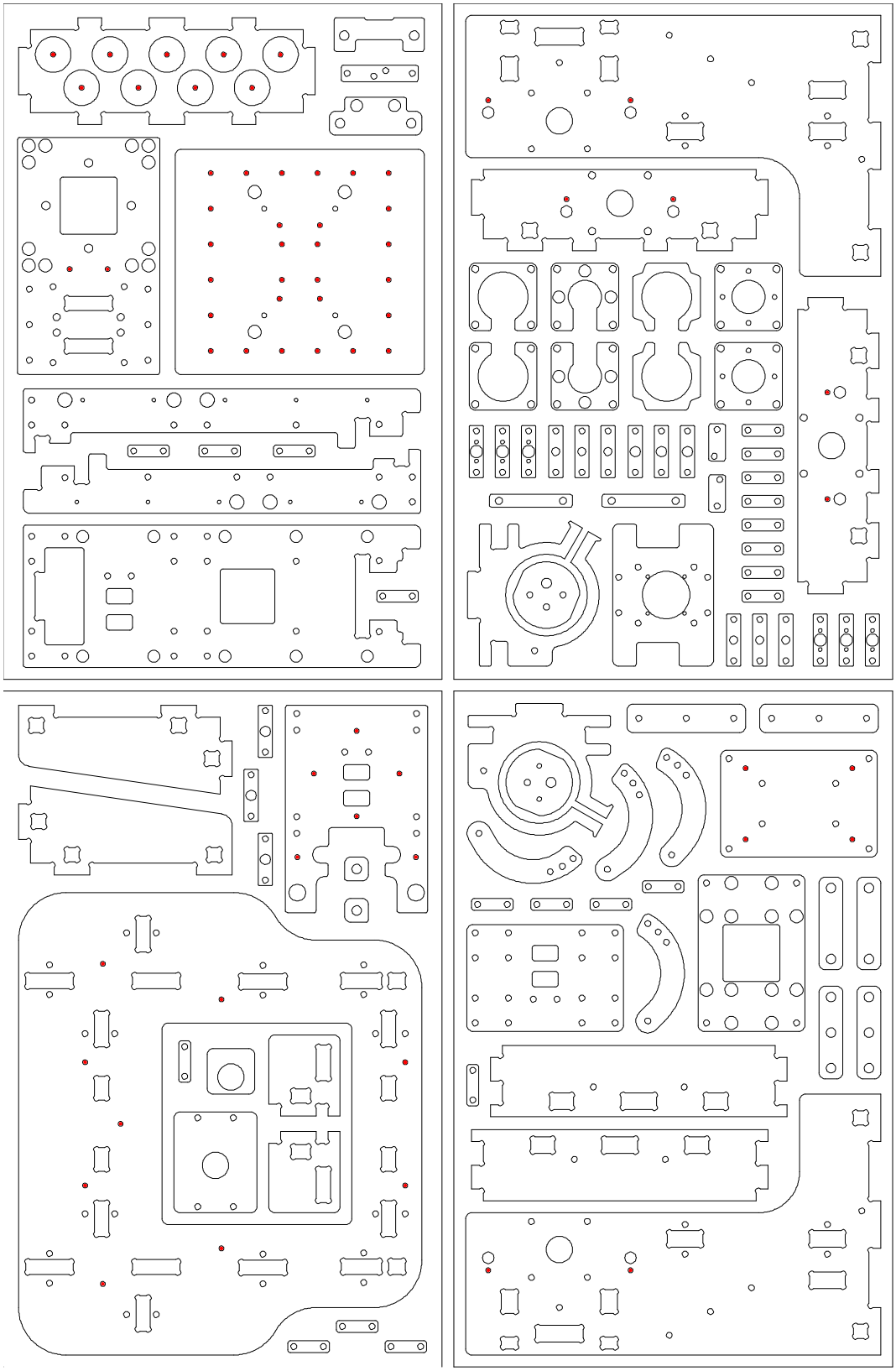
Clean the tapped holes and screw an M5x16mm socket head button into each one. You can now remove the other locating screws.

This completed tap guide will help you tap the other holes. To use it, support the sheet being tapped either side of the hole – the other sheets are ideal for this. This will allow the tap to cleanly exit the bottom of the hole and for the chips to fall out easily. Apply washing-up liquid to the hole being tapped. Position the M5 tap guide hole over the hole and insert the washing-up lubricated M5 tap into the tap guide. With one hand firmly holding the tap guide in place, use the other to gently wind the tap into the hole. The tap guide will help you to keep the tap vertical. Every few turns, rotate the tap anti-clockwise to break the chip. Once you have tapped half-way through the sheet, you should no longer need the guide and can then tap using both hands. Continue until the tap exits the bottom of the sheet leaving a thread all the way through the material. Then wind the tap out of the sheet. Make sure to clean the chips off the tap between holes and to keep the tap well lubricated with washing-up liquid. When you have finished tapping, clean and dry the tap and apply a thin layer of oil to keep it from rusting.



Preparation Work – Tapping The Acrylic Sheets

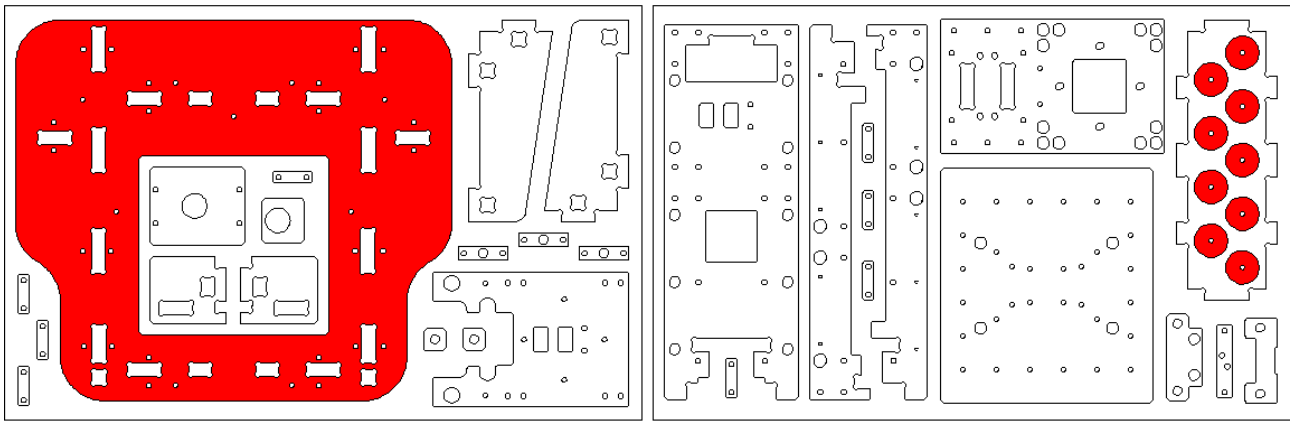
Using the tap guide, we will now tap all the necessary holes using the previously-described procedure. Tap the sixty-six holes shown in red below.
Do not remove the protective films yet.

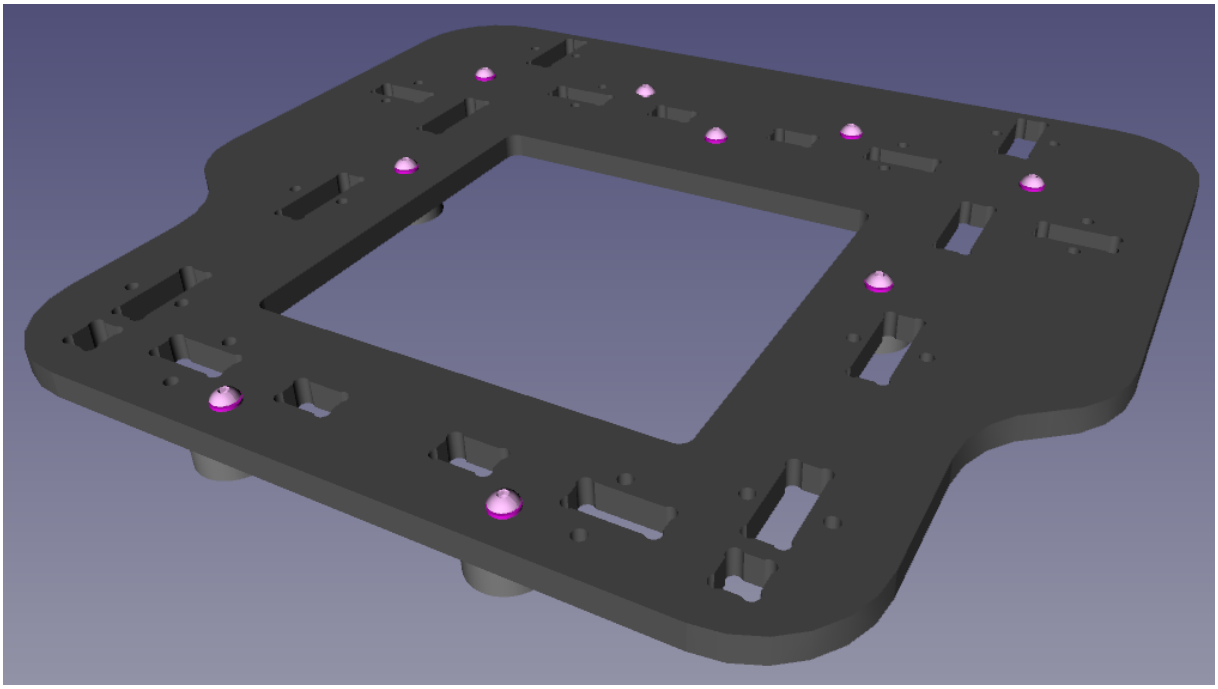


Fitting The Feet To The Base

Parts: 9 M5x16mm socket head buttons, 9 M5 washers.
Locate the parts shown below and use the side cutters to remove them from the sheets. Using the file and/or abrasive paper, remove the remains of the tabs from the parts.
You can now remove the protective films and wash the parts in water to remove any chips and residual washing-up liquid. Dry the parts with a towel.
The base is reversible but there is a logo on the nominal “top” surface.

Screw nine M5 x 16mm socket head button with M5 washers into the tapped holes in the base. Tighten them until they are just snug. Now screw the nine Acrylic feet onto the protruding screws.
This milling machine is intended to be used on a flat surface but if it isn't completely flat you can unscrew the feet slightly to level the machine.



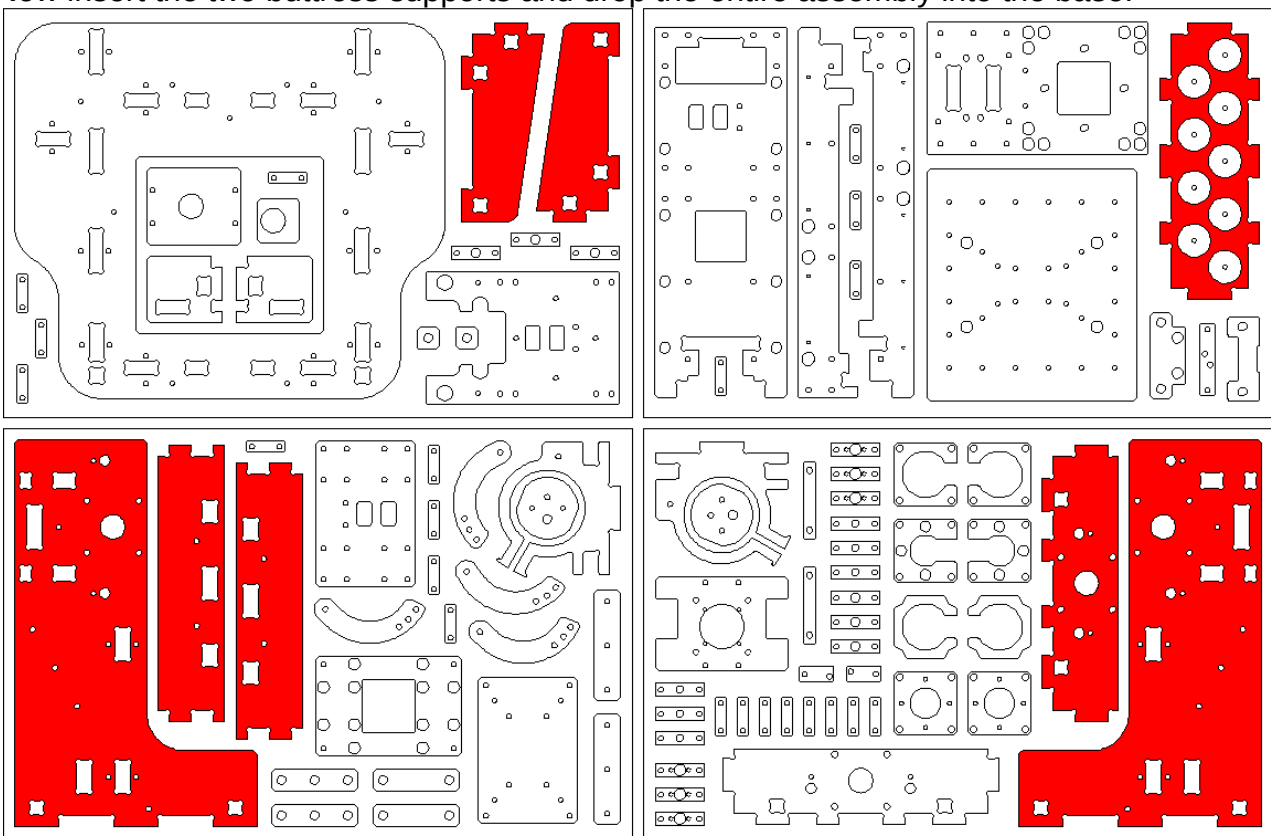


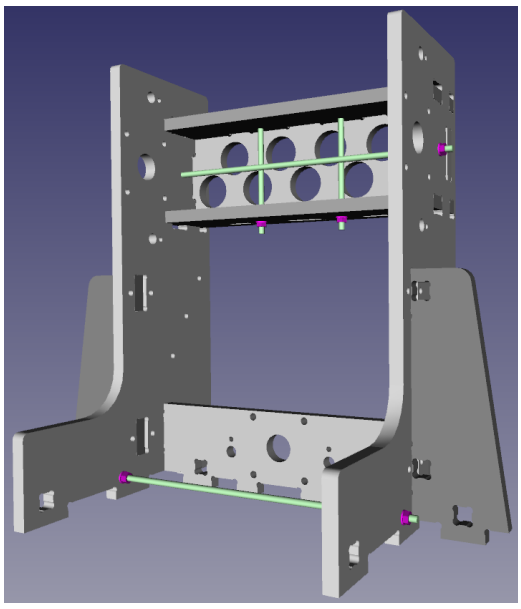
Main Gantry Preparation Work

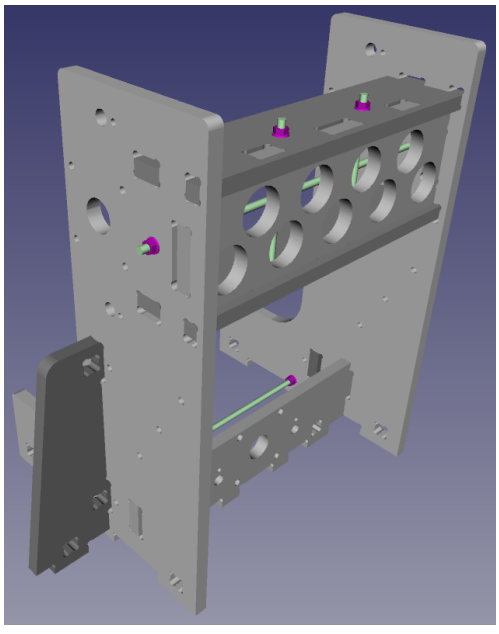
We will now cut the tensioning bars for the main gantry and box section.
Take a 1m 5mm threaded rod and measure off 270mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 270mm section off.
Using the file, remove any sharp edges on the threaded rod and using a full M5 nut, ensure that you can screw the nut onto the bar from either end.
Cut a total of two 270mm sections and two 110mm sections.

Main Gantry And Box Section

Parts: 10 M5 washers, 2 M5 full hex nuts, 8 M5 Nyloc nuts, 3 tensioning bars.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them. Check that a flanged bearing fits smoothly into the uprights and rear Y axis plate.
Assemble them as shown and fit the box section tensioning bars. Wrap cardboard around the threaded rods to prevent damage to the threads and grip with pliers or Vice grips. Screw the Nyloc nuts onto the bar but tighten only enough to keep the parts captive. Fit the gantry base tensioning bar adding the internal washers and full hex nuts as you slide it through. Again, only tighten enough to keep the parts captive.
Now insert the two buttress supports and drop the entire assembly into the base.

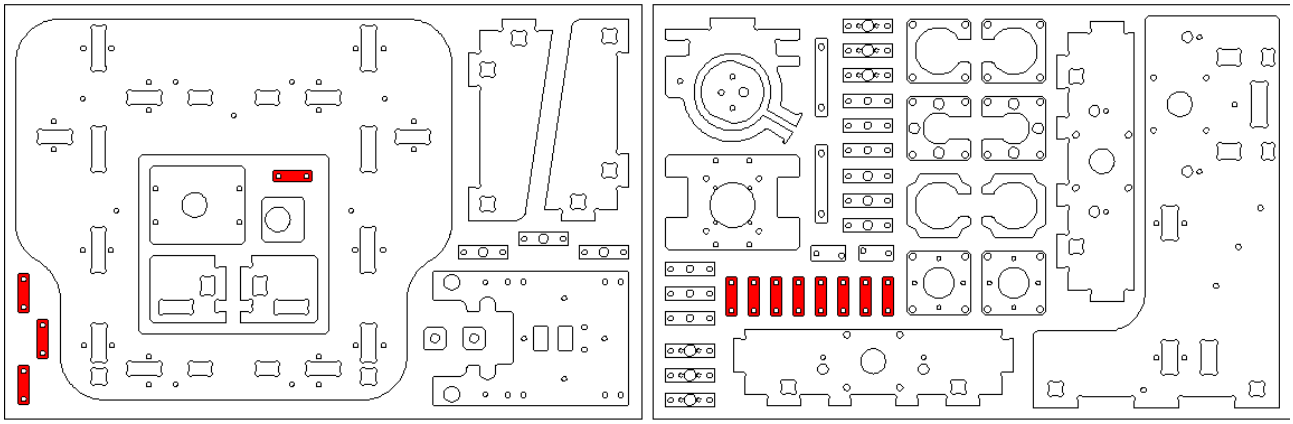


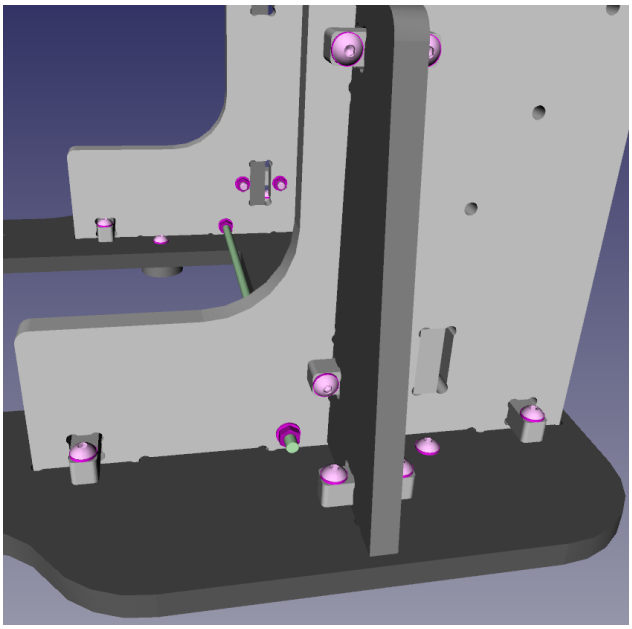


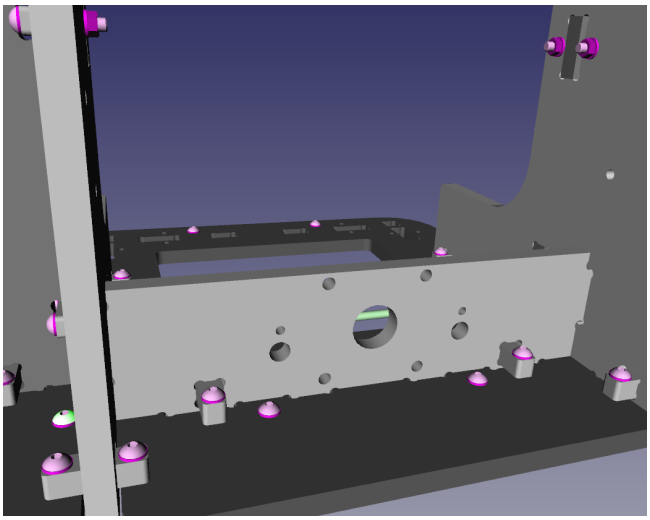


Gantry Clamps

Parts: 24 M5x30mm socket head buttons, 48 M5 washers, 24 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.
These are the clamps that hold the gantry down and tie the buttresses to the gantry uprights. At this stage the clamps only need to be tightened enough to keep the gantry captive.

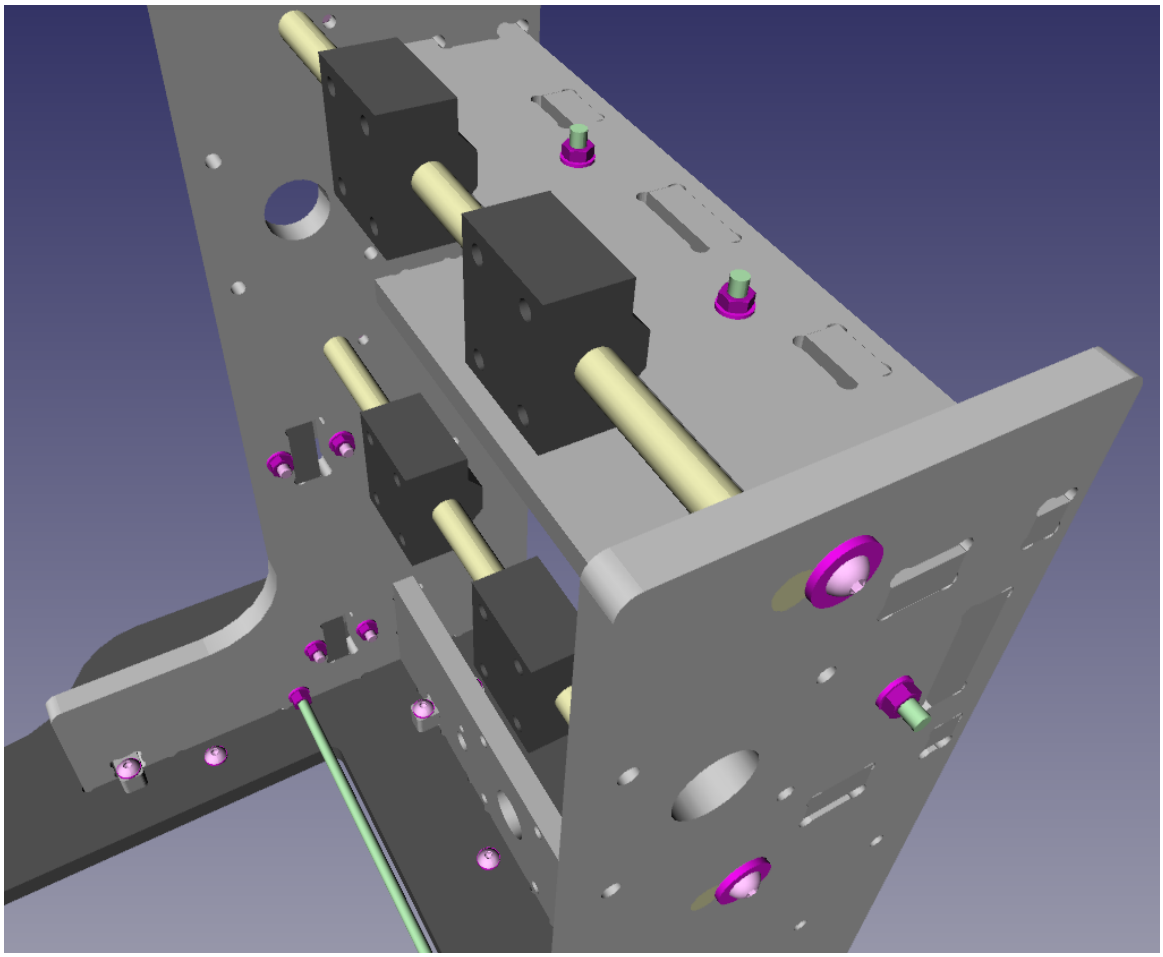






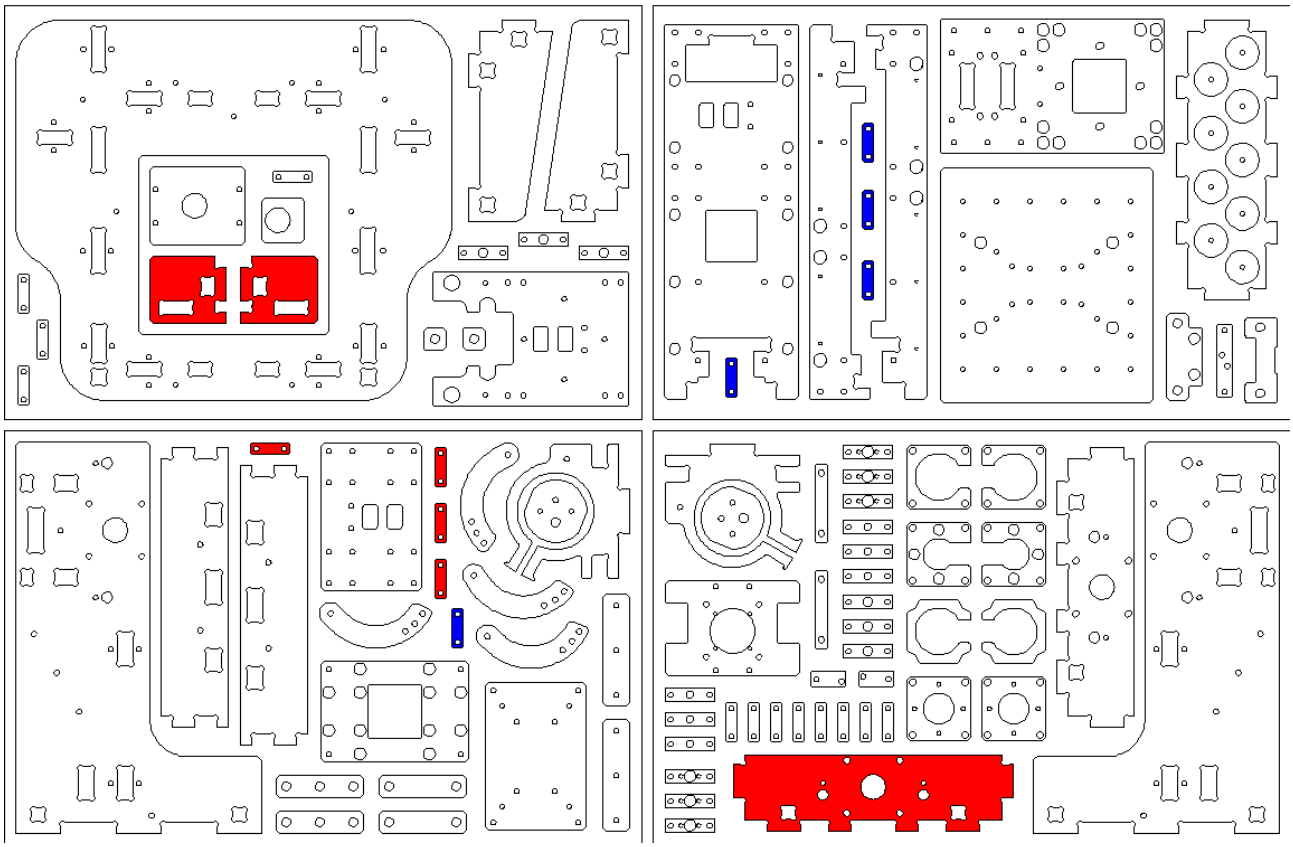
Gantry Rods And Bearing Blocks

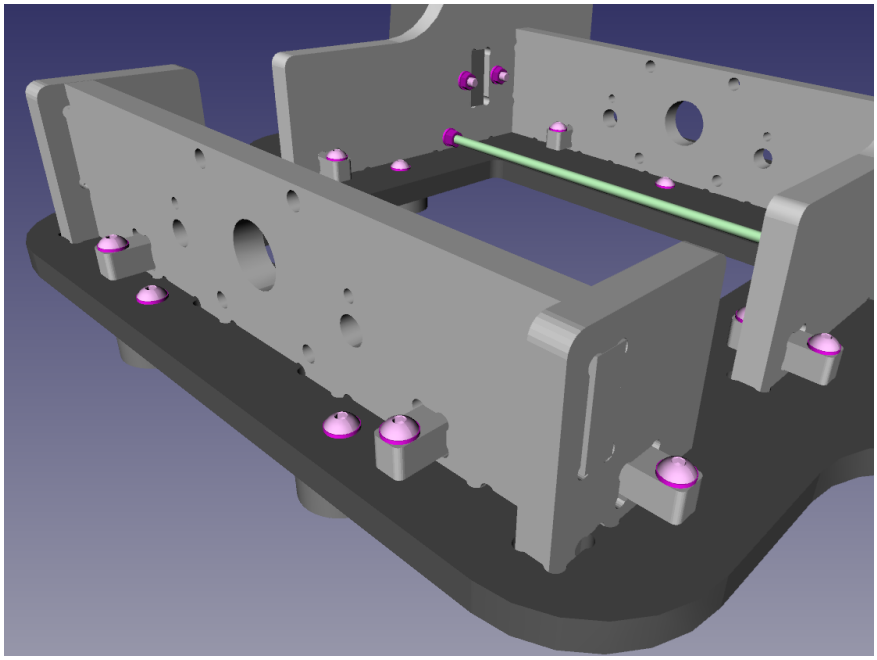
Parts: 4 M5x8mm socket head buttons, 4 M8 washers, 2 10mm steel rods, 4 bearing blocks.
Take one steel rod and slide it through a gantry upright. While it is between the two gantry uprights, slide two of the bearing blocks onto the rod ensuring that they are orientated as in the picture. Repeat for the other steel rod.
The ends of the steel rods may protrude from the gantry uprights depending on the thickness of the Acrylic. Screw one M5x8mm with one M8 washer into the hole next to each rod to prevent the rods from sliding out. Only tighten them very loosely at this stage.



Y Axis Front Plate and Clamps

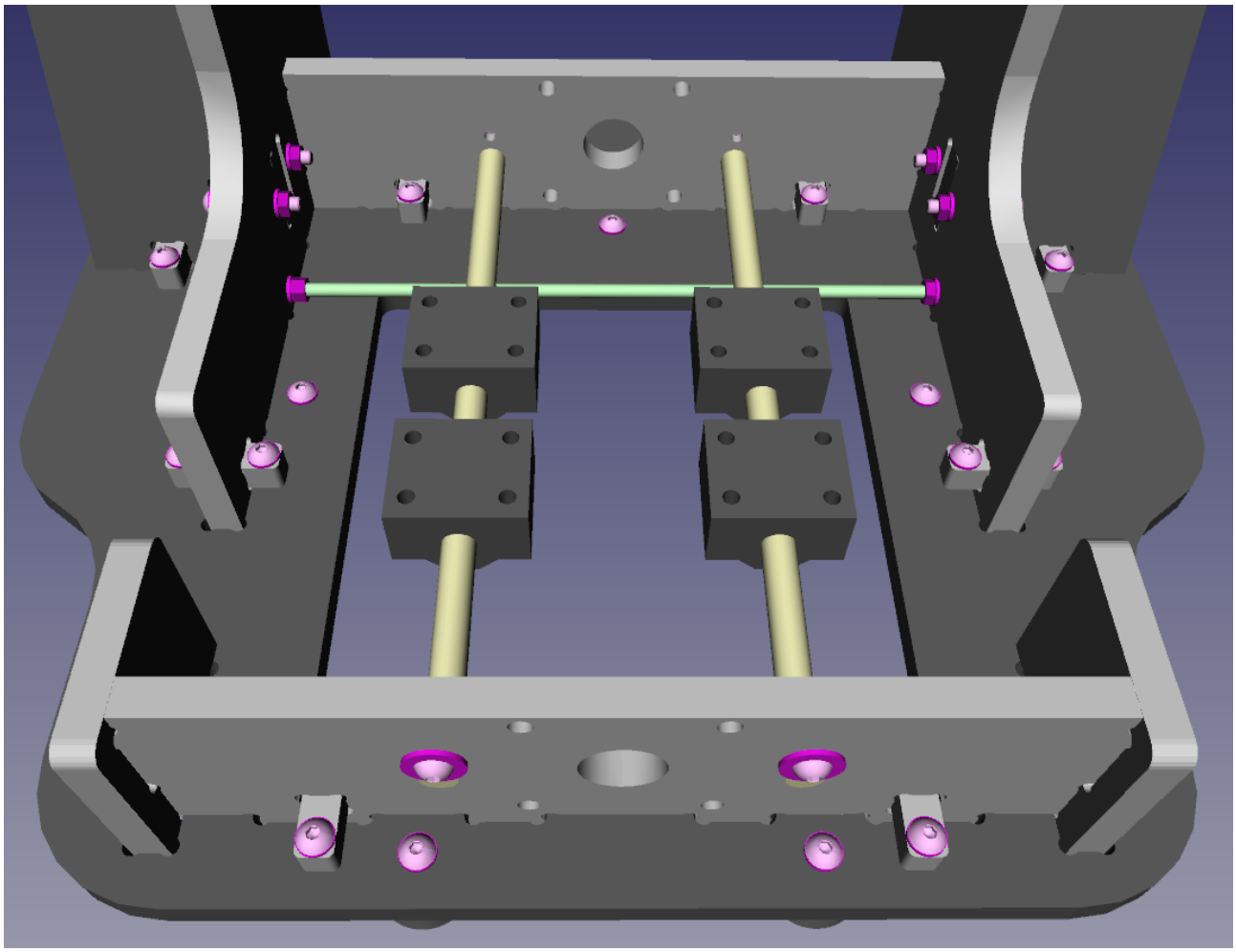
Parts: 8 M5x30mm socket head buttons, 16 M5 washers, 8 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.
Check that a flanged bearing fits smoothly into the front Y axis plate.
The clamps shown in blue are spares in case you over-tighten and break one.
Slot the front Y axis plate into the support plates and drop the assembly into the base. Fit the four clamps and tighten them just sufficiently to keep the parts captive.





Y Axis Rods And Bearing Blocks

Parts: 4 M5x8mm socket head buttons, 4 M8 washers, 2 10mm steel rods, 4 bearing blocks.
Take one steel rod and slide it through the front Y axis plate. While it is between the front and back Y axis plates, slide two of the bearing blocks onto the rod. Repeat for the other steel rod.
The ends of the steel rods may protrude from the Y axis plates depending on the thickness of the Acrylic. Screw one M5x8mm with one M8 washer into the hole next to each rod to prevent the rods from sliding out. Only tighten them very loosely at this stage.



Alignment And Clamping

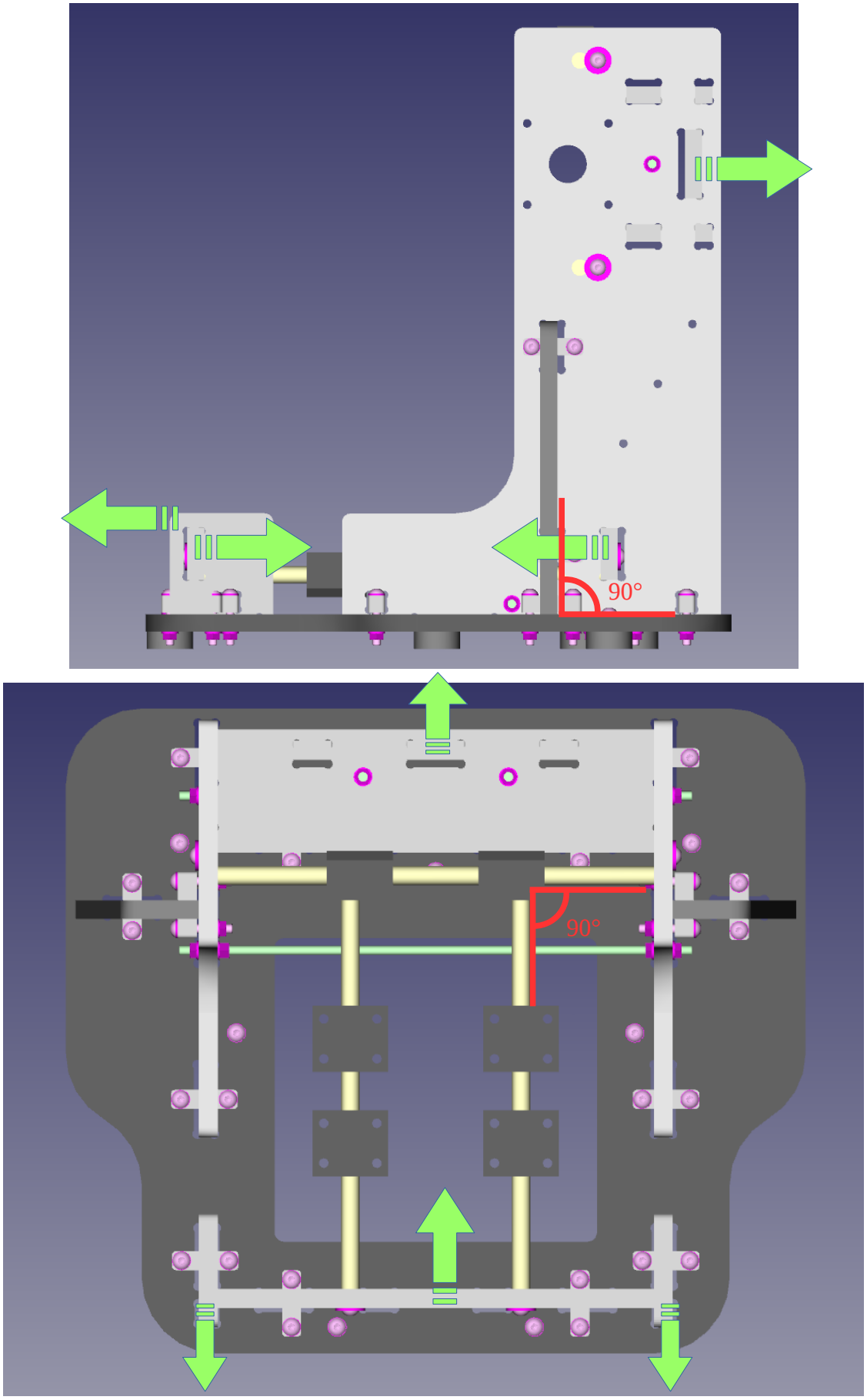
Now it is time to tweak the alignment of the parts and tighten up the clamps.
The back of the box section should be pushed flush to the back of the gantry uprights. Tighten the two vertical box section tensioner bars until they are snug. If you hear creaking noises then you are tightening way beyond snug and if you repeat that with the clamps, they will snap. Tighten the upper horizontal tensioner bar until snug.
The rear Y axis plate should be pushed flush to the front of the gantry uprights.
The whole gantry assembly should sit square in the base.

Measure the distance between the inner surfaces of the gantry uprights at the top. Now measure the distance between the inner surfaces of the gantry uprights at the bottom. We want the bottom distance to be the same as the top one. If the bottom distance is greater, tighten the outer Nyloc nuts of the lower horizontal tensioning bar until the inner distance is the same. If the bottom distance is less, tighten the inner full hex nuts until the inner distance is the same. Once the inner distance is the same, tighten the corresponding Nyloc or full hex nut until snug.
Tighten down the two clamps on each of the gantry uprights to snug. Make sure you tighten them evenly so that the base of the clamp sits flush on the upright. If in doubt, under-tighten rather than over-tighten. No one clamp has to immobilise the entire structure – the job is shared between many clamps.

Tighten down the two clamps on the rear Y axis plate.

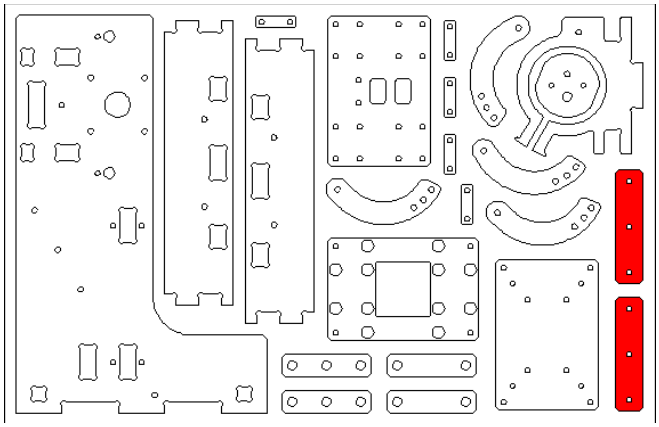
The position of the gantry buttresses is not critical but they should be perpendicular to both the base and the gantry uprights. They should also be in a line with each other. Tighten down the three clamps on each buttress until snug.

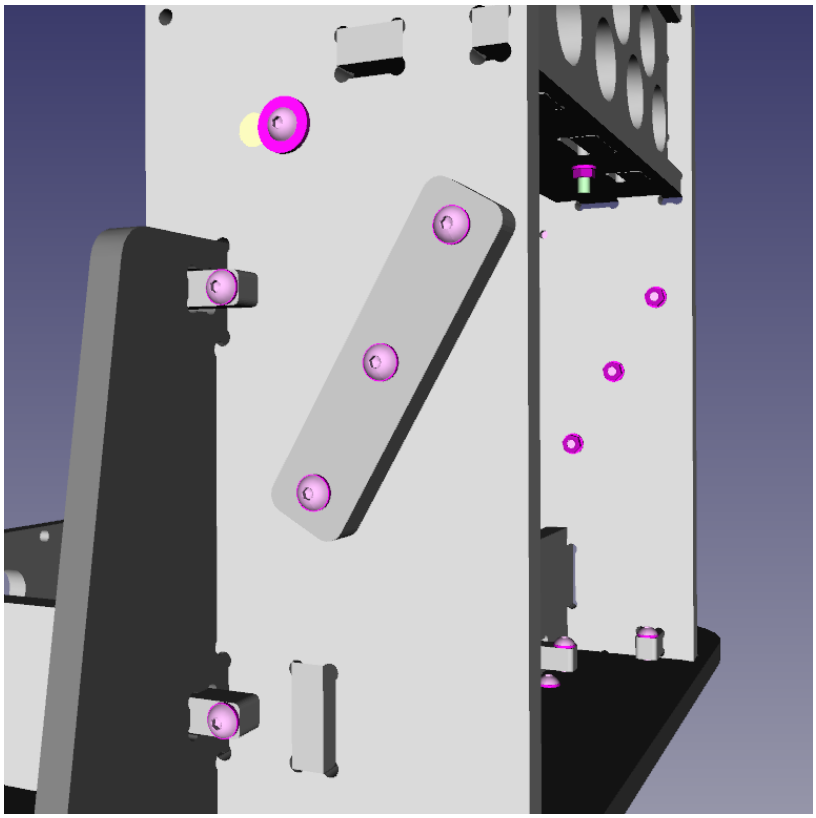
Turning our attention to the front Y axis plate now, it should be pushed as far to the back of the base as possible. We want the Y axis steel rods to be perpendicular to the X axis steel rods. The two Y axis support plates should then be pushed towards the front of the base so that the mating surfaces are flush. This is to ensure the distance between the front and rear Y axis plates is as small as possible while keeping the front Y axis plate vertical. Tighten the two clamps on the front Y axis plate and the clamps on the support plates.


90°
90°

Gantry Upright Stiffeners

Parts: 6 M5x25mm socket head buttons, 12 M5 washers, 6 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.
Snugly attach the stiffeners to the gantry uprights with the machine screws.



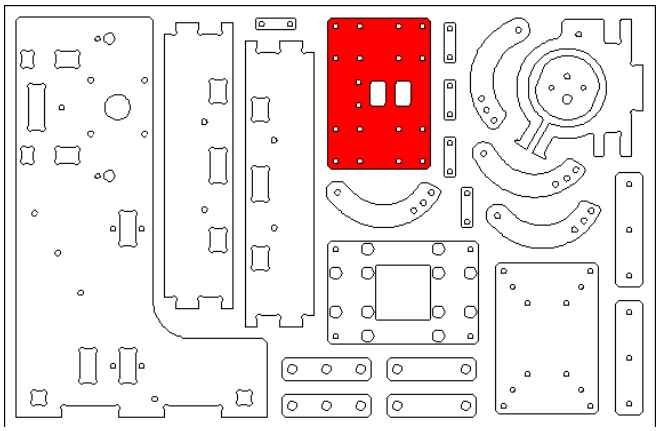


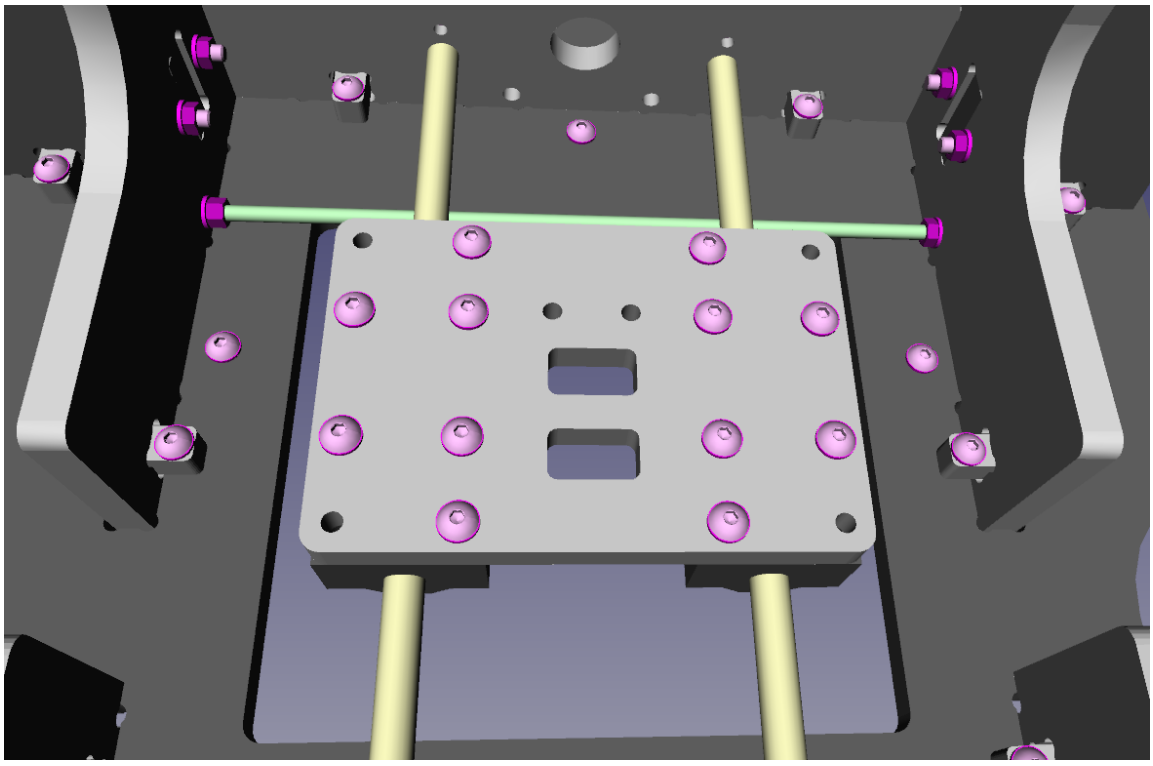
Y Axis Preparation Work

We will now cut the lead screw for the Y axis.
Take a 1m 8mm threaded rod and measure off 290mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 290mm section off.
Using the file, remove any sharp edges on the threaded rod.

Y Axis Bearing Plate

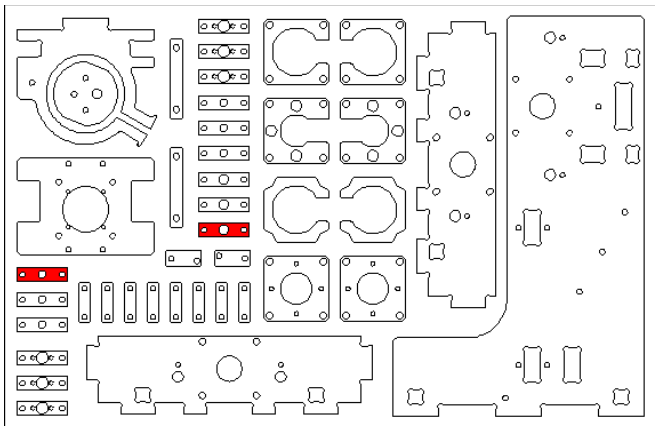
Parts: 12 M5x20mm socket head buttons, 12 M5 washers.
Locate the part shown below, cut it out, file it, remove films, wash and dry it
Screw the machine screws snugly into the bearing blocks below in the pattern shown.
The plate and bearings should slide freely all the way to the back and front without binding.
If it does bind, revisit the earlier alignment procedure until it slides freely.



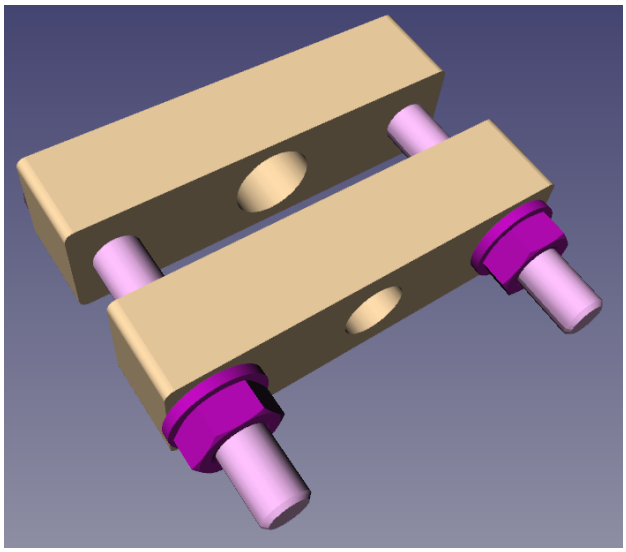


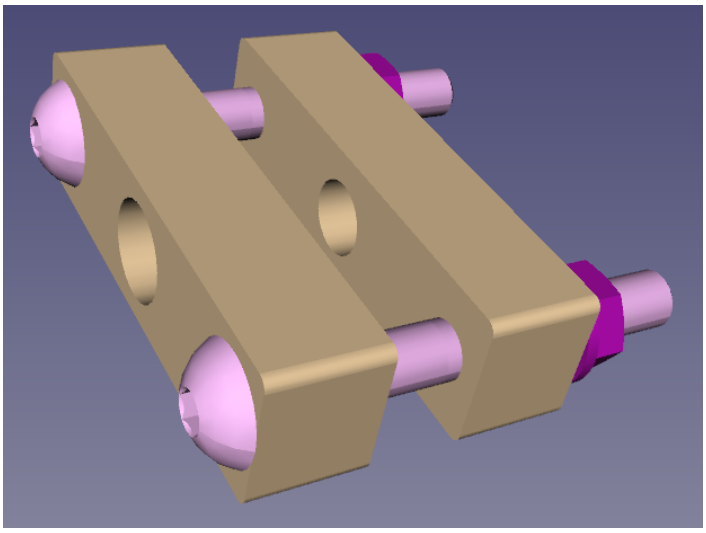
Y Axis Lead Screw And Nut Block Part 1

Parts: 2 M5x40mm socket head buttons, 2 M5 washers, 2 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



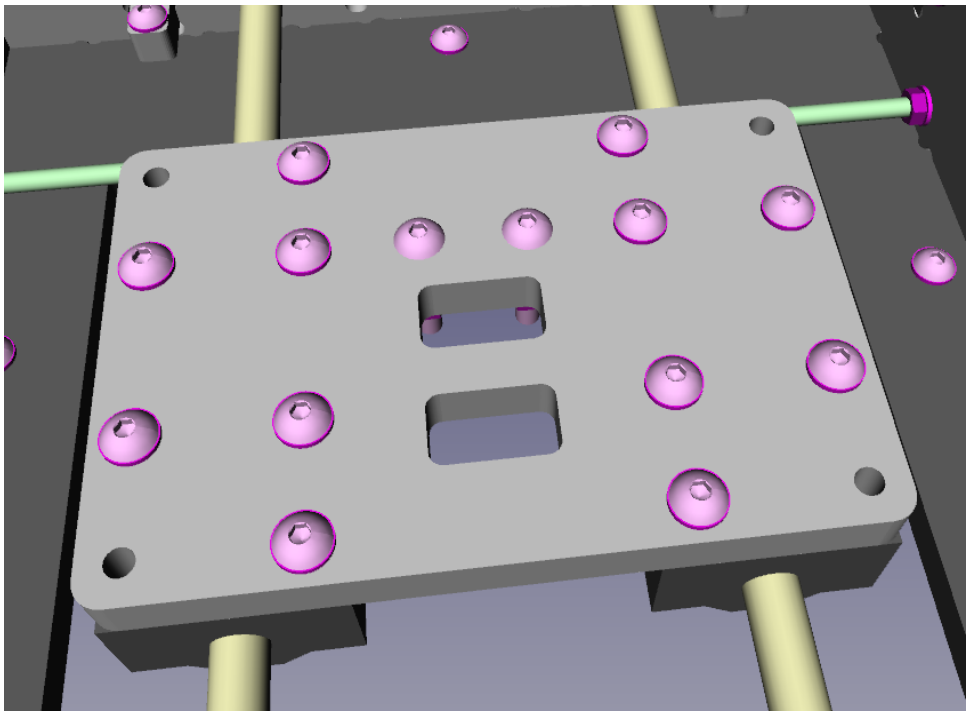
Screw the parts together as shown. The Nyloc nuts are adjacent to the piece with the M8 thread tapped into it. Leave enough distance between the two pieces to just slide an M5 nut in.

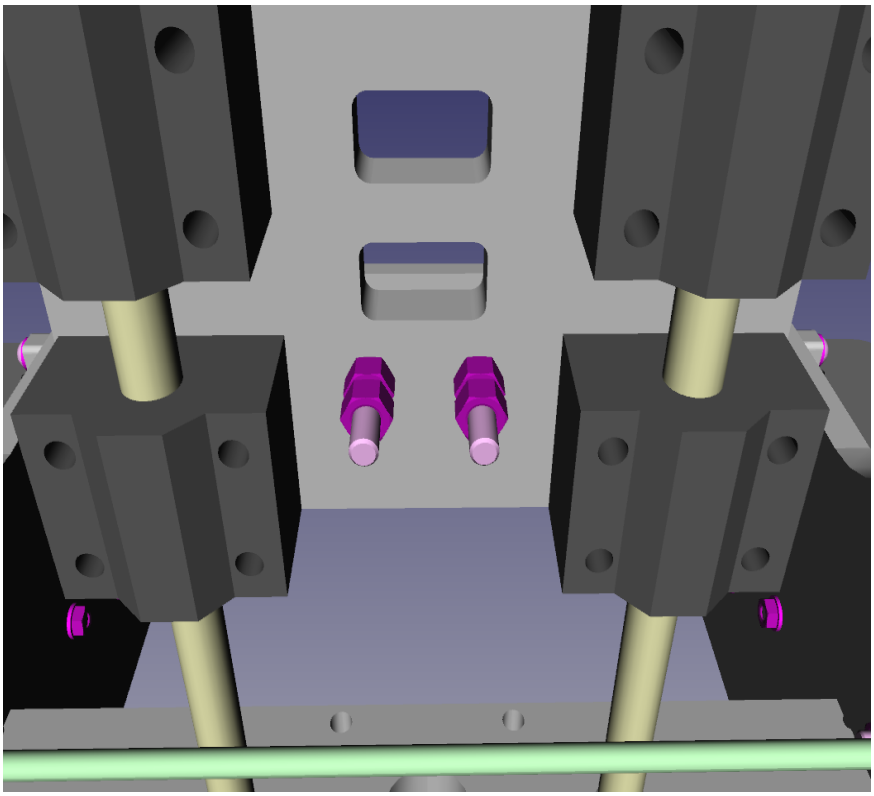




Y Axis Lead Screw And Nut Block Part 2

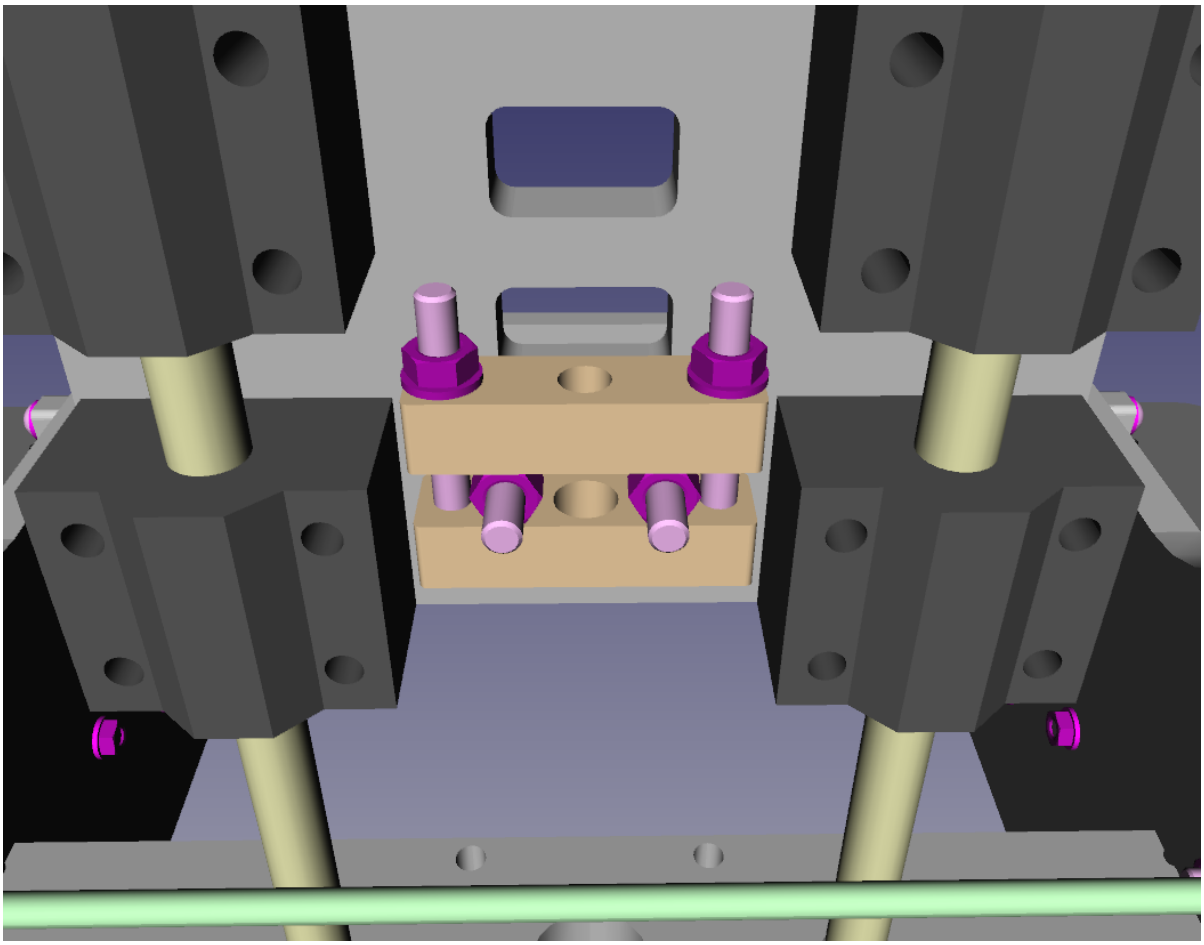
Parts: 2 M5x30mm socket head buttons, 4 M5 full hex nuts.
Snug the full hex nuts so that the sides are parallel to the front and back of the Y bearing plate. Then add a second full hex nut leaving approximately one millimetre between them with the nut faces aligned.





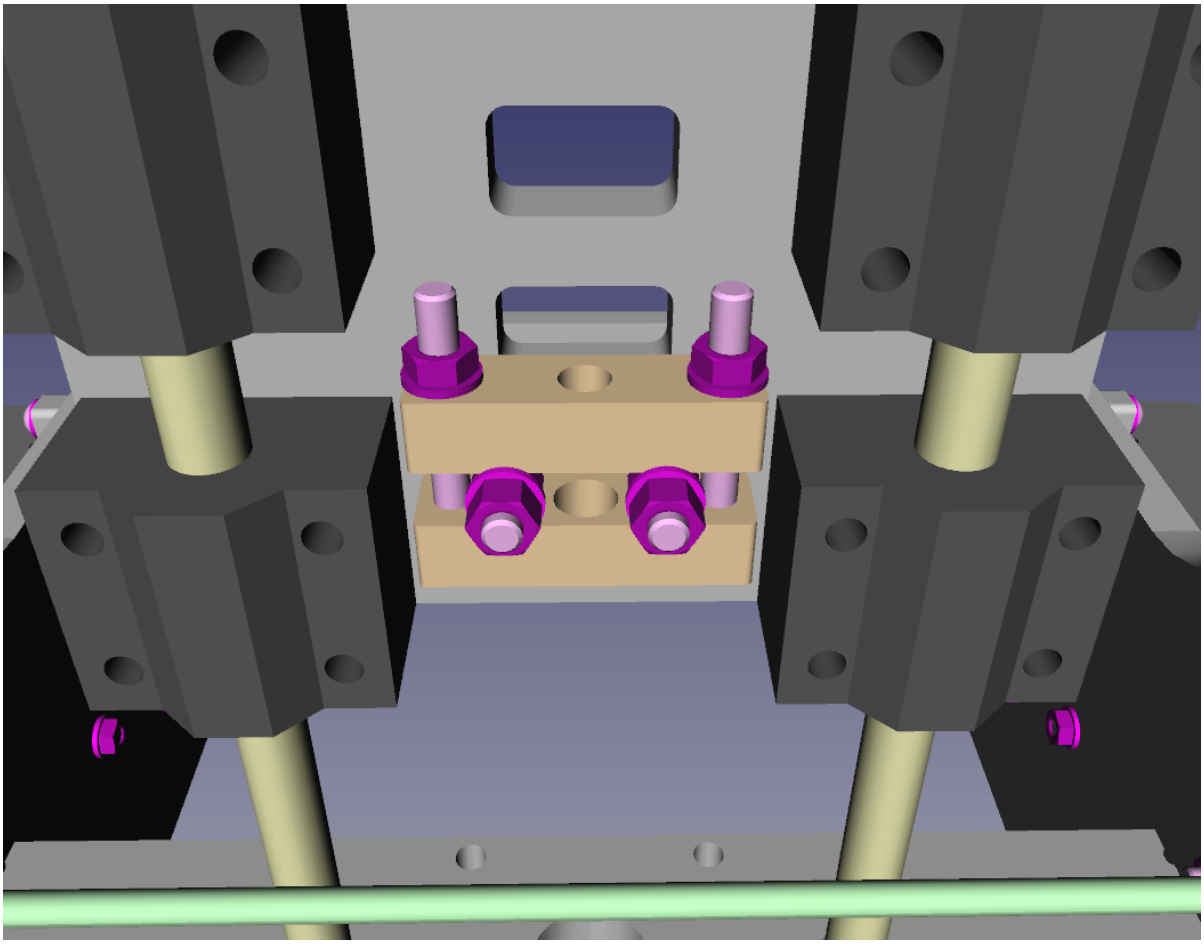
Y Axis Lead Screw And Nut Block Part 3

Slide the nut block assembly over the hex nuts as shown – tapped block towards the centre of the Y bearing plate. Adjust the spacing of the Acrylic nut block so that it can still slide from side to side.



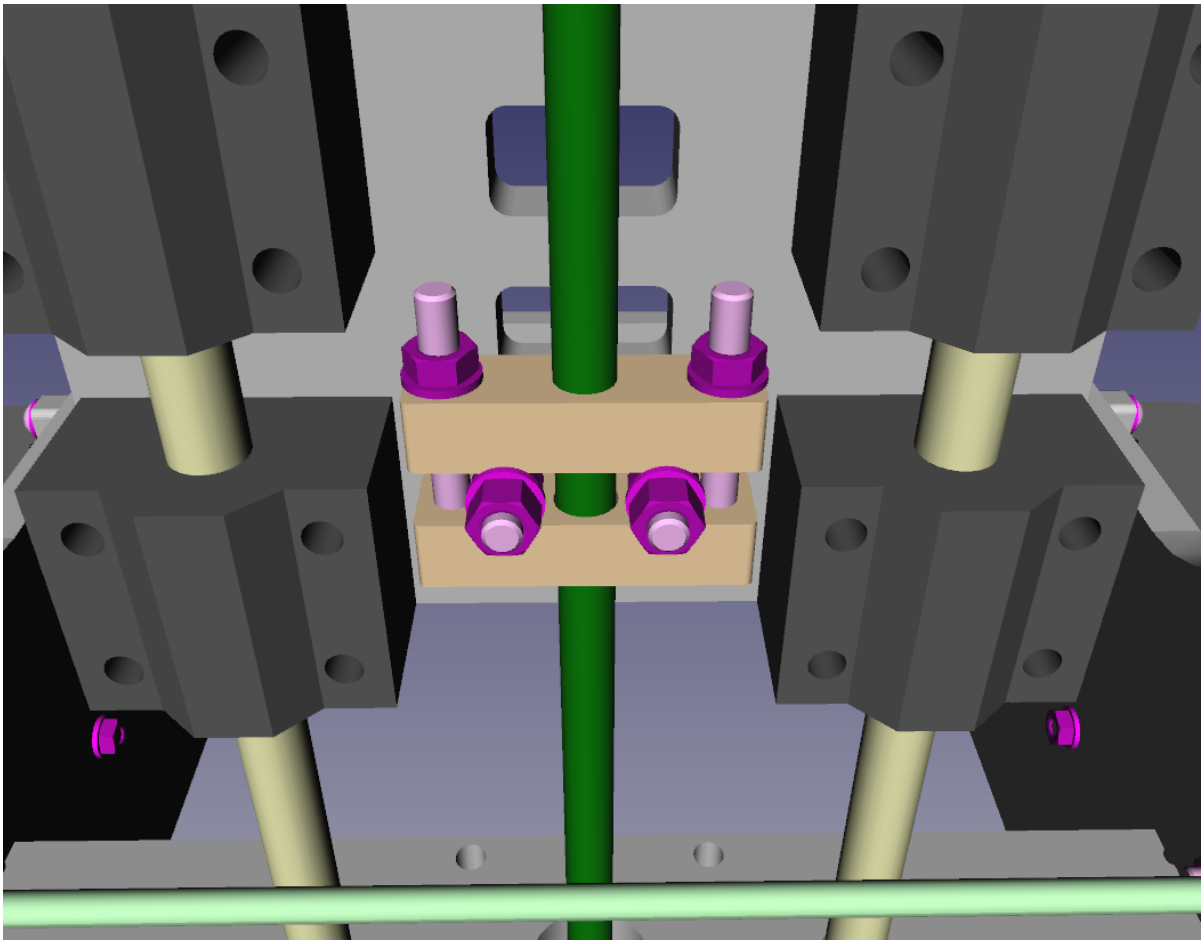
Y Axis Lead Screw And Nut Block Part 4

Parts: 2 M5 washers, 2 M5 Nyloc nuts.
Add the washers to the machine screws so that the edges cover each side of the nut block. Then secure the washers with the Nyloc nuts. Make sure to stop the mounting screws and full hex nuts from rotating by holding them in place with the Allen key while tightening the Nyloc nuts. Do not snug the Nyloc nuts yet. Make sure the nut block can still slide from side to side.



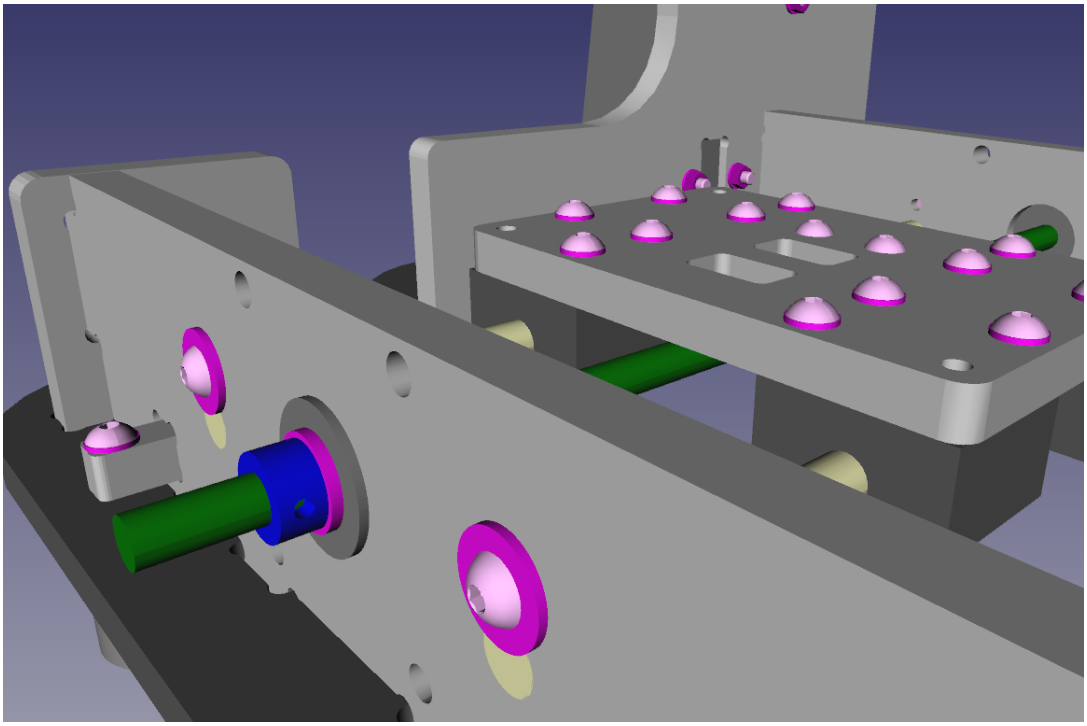
Y Axis Lead Screw And Nut Block Part 5

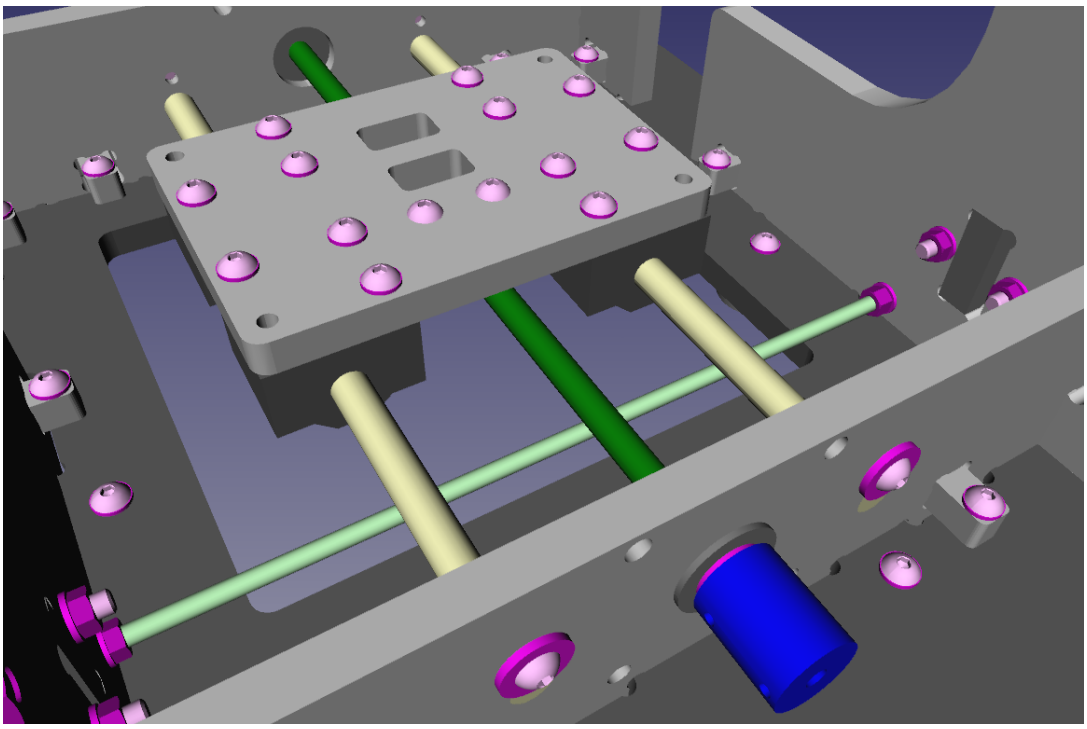
Parts: 1 lead screw.
Feed the lead screw through the bearing hole on the front Y plate and thread it into the nut block. Continue to thread it until the lead screw protrudes through the bearing hole on the back Y plate.



Y Axis Lead Screw And Nut Block Part 6

Parts: 2 M8 washers, 2 flanged bearings, 1 lock collar, 1 flexible shaft coupler.
Slide the flanged bearings over the lead screw and insert into the plates.
Place a washer over the flanged bearing on each end of the lead screw. Slide the lock collar over the lead screw on the front Y axis plate. Leave about 8.5mm of lead screw protruding past the washer on the back Y axis plate, slide a flexible shaft coupler (8mm→5mm for NEMA17 motors, 8mm→6.35mm for NEMA23) over the lead screw and tighten the coupler's grub screws. Now tighten the grub screw on the lock collar so that there is minimal front to back play on the lead screw.

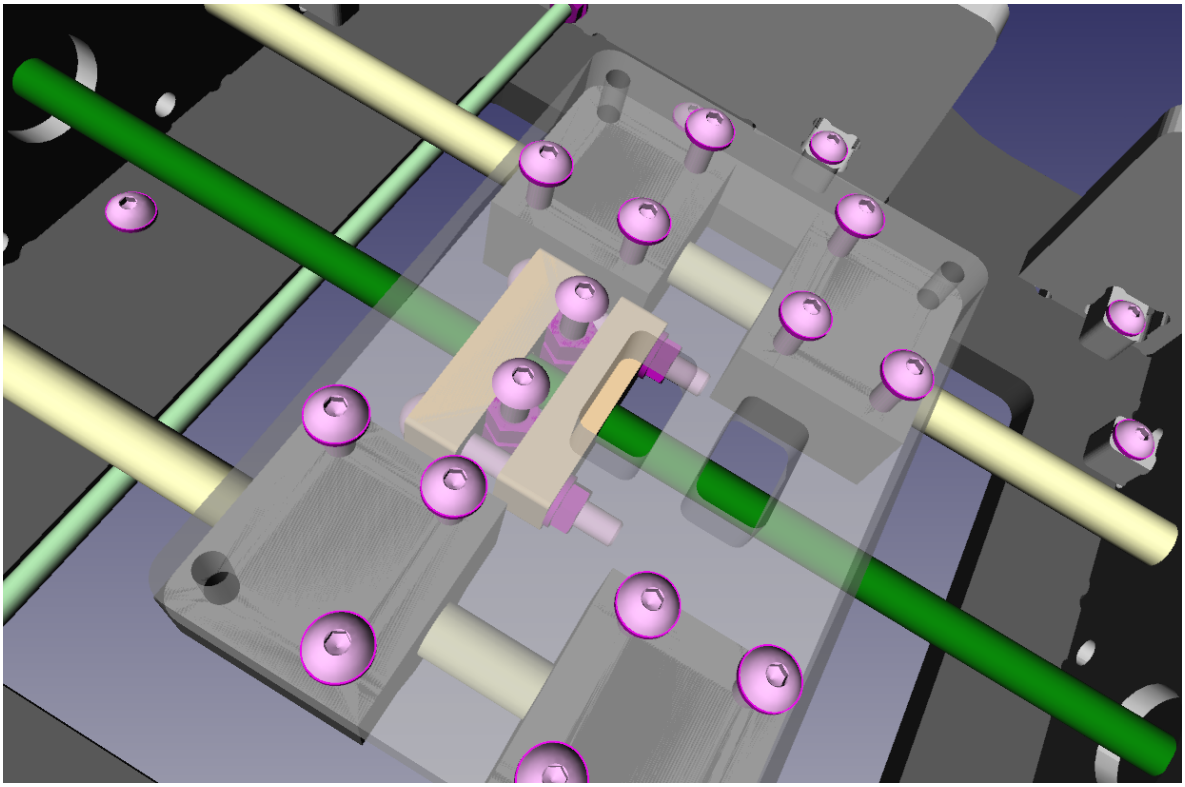




Y Axis Lead Screw And Nut Block Part 7

The nut block should have mostly self-aligned now. You now need to tighten the screws that clamp the two parts of the nut block together and then snug up the Nyloc nuts that help to keep the nut block from twisting. It is best to progressively tighten them so that the nut block has minimal front to back movement, minimal up and down or twisting movement but still allows the Y axis to move from front to back without binding or excessive stiffness when you rotate the lead screw.
Take care when tightening the Nyloc nuts that the full hex nuts keep their faces parallel to the nut blocks. You can do this by holding the screw in position with the Allen key while tightening the Nyloc nut with a spanner.

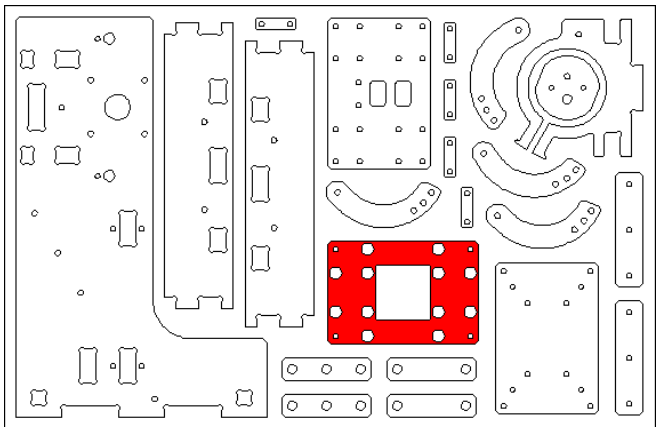
This procedure can be fiddly and it is best to make small adjustments and test how it performs repeatedly. The nut block will loosen over time as it wears and its performance can be enhanced by spraying the lead screw with silicone-based furniture spray polish. That will lubricate the lead screw and nut block without making it sticky.

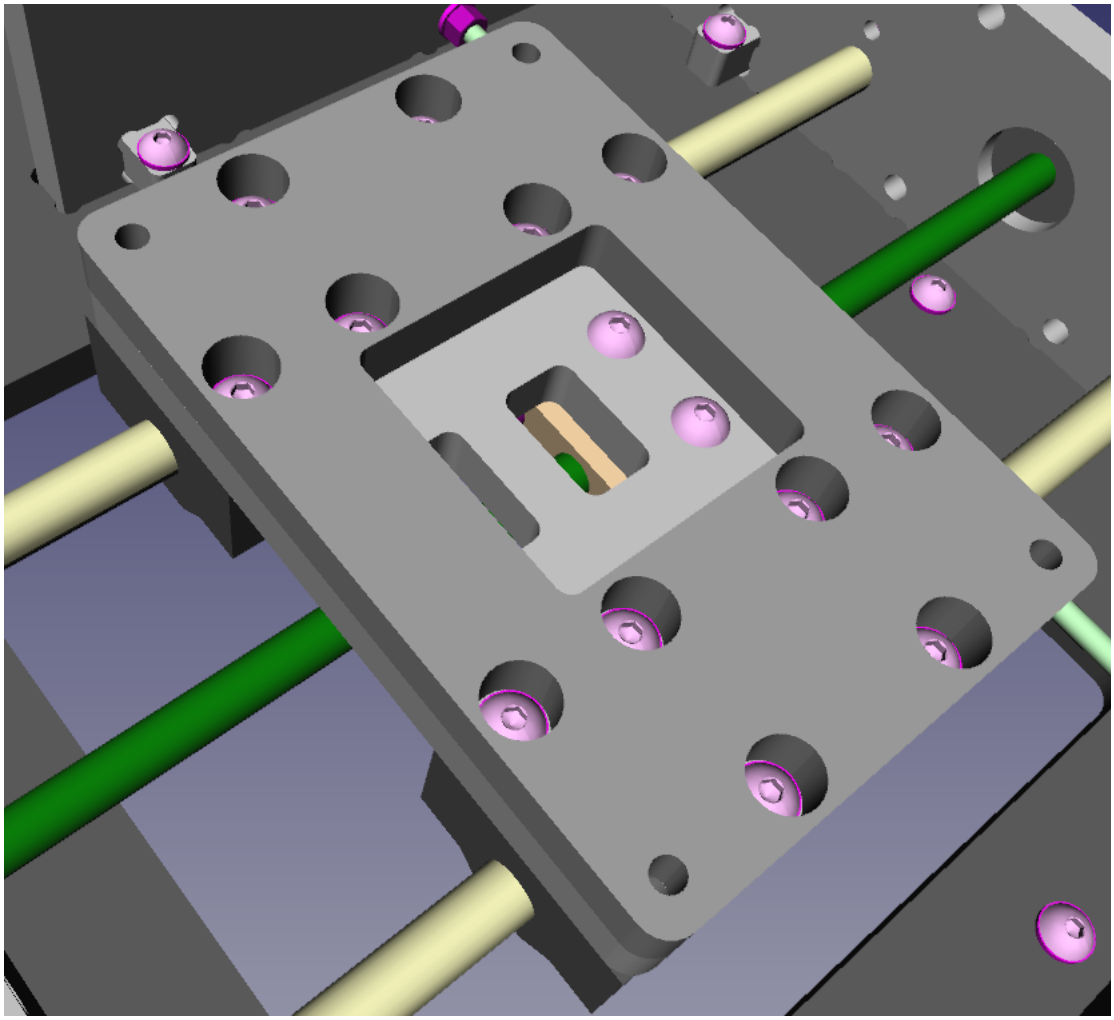


This type of lead screw is very cost-effective but does suffer from relatively high friction. This machine has been designed to accommodate more precise and much lower friction but, unfortunately, also more expensive lead screws and nut blocks and these upgrade options are discussed in the “Lead Screw Upgrades“ section later in this manual.

Y Axis Spacer Plate

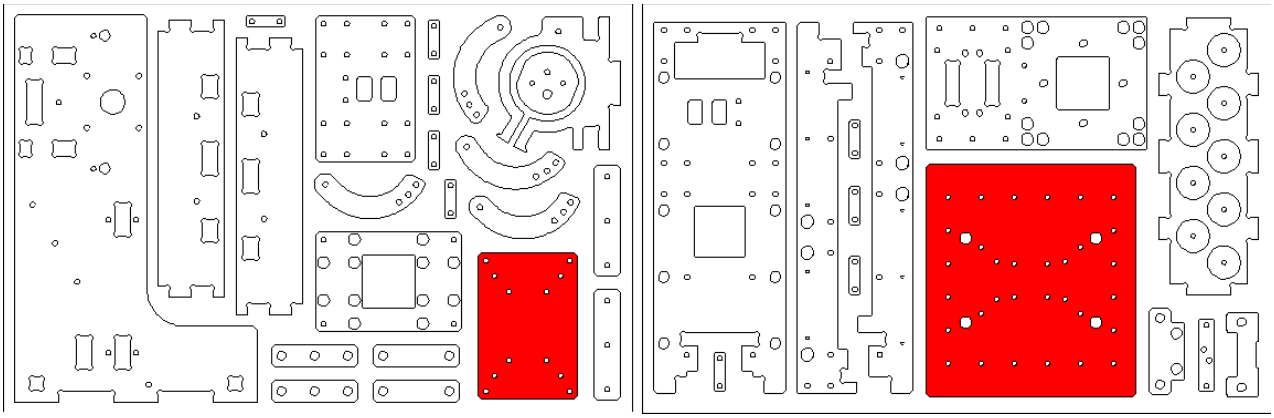
Locate the part shown below, cut it out, file it, remove films, wash and dry it
Place it on top of the Y axis bearing plate ensuring that it sits flush with that part.

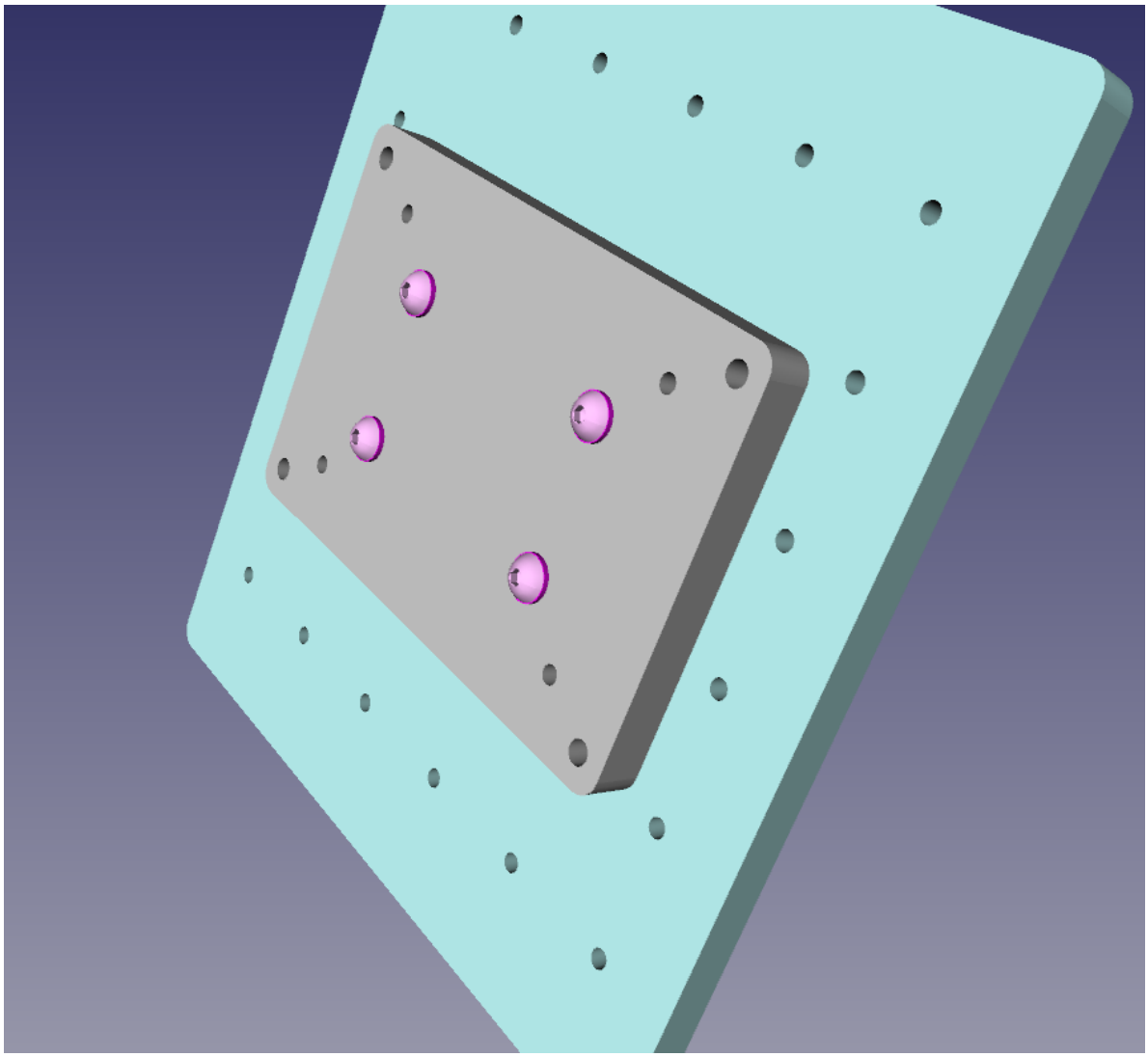




Y Top Plate Part 1

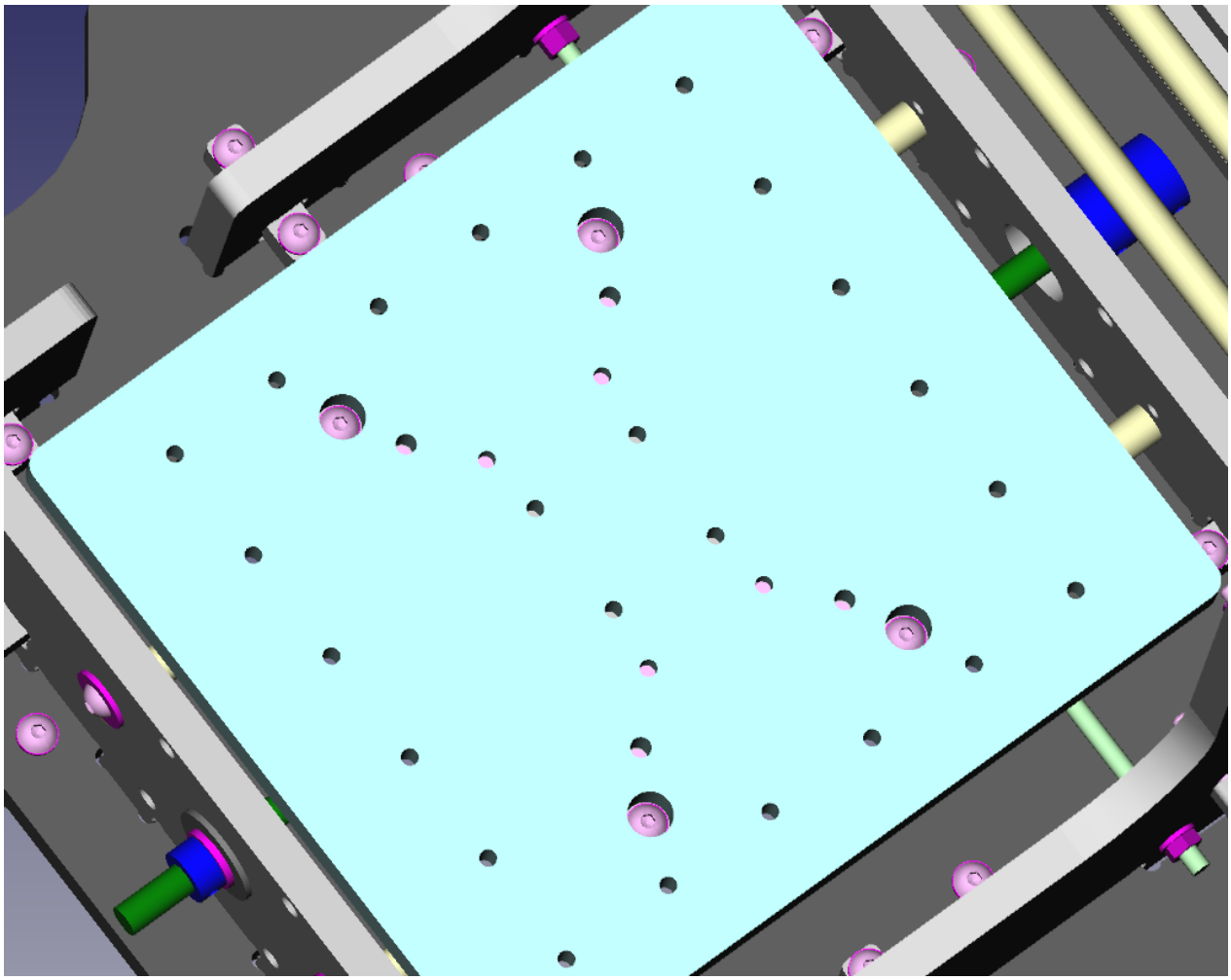
Parts: 4 M5x16mm socket head buttons, 4 M5 washers.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.
Align the parts making sure they sit together flush and screw them together snugly.





Y Top Plate Part 2

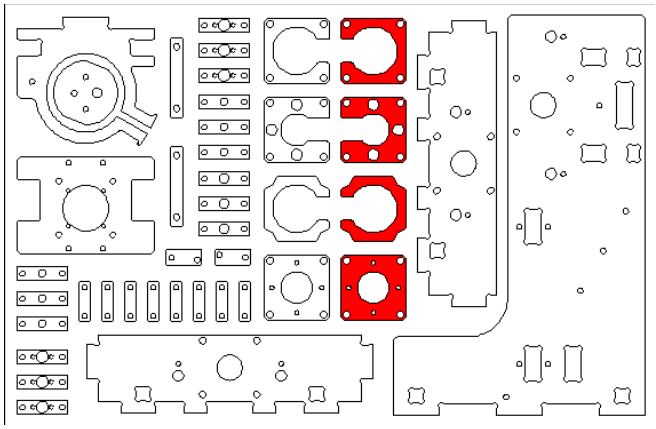
Parts: 4 M5x40mm socket head buttons, 4 M5 washers, 4 M5x10mm grub screws.
Place the Y top plate assembly on top of the Y axis spacer plate and snugly screw the assembly down into the bearing blocks. Drop a grub screw into each of the adjacent holes and screw it down loosely. The grub screws can be used to level the Y top plate later if required.



Y Axis Motor Mounting Preparation Work

We will now cut the mounting screws for the Y axis motor.
Take the 5mm threaded rod and measure off 75mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 75mm section off.
Using the file, remove any sharp edges on the threaded rod.
Repeat the procedure three more times so you end up with four 75mm threaded rods.

Locate the parts shown below, cut them out, file them, remove films, wash and dry them.

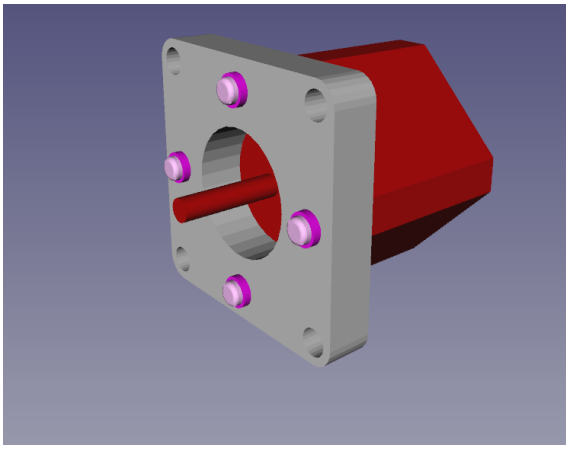


If you are using a NEMA17 motor for the Y axis, proceed to the next section.
If you are using a NEMA23 motor for the Y axis, proceed to the section titled “Y Axis NEMA23 Motor Mounting Part 1“.

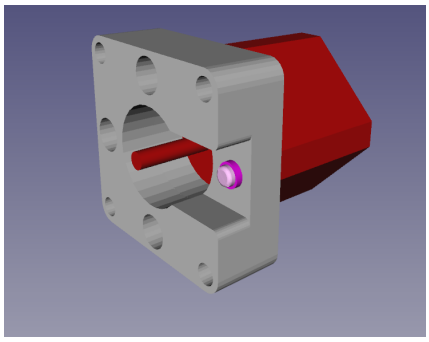
Y Axis NEMA17 Motor Mounting Part 1

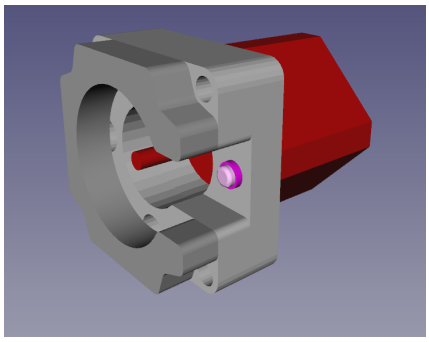
Parts: 4 M3x16mm slotted pan heads, 16 M3 washers.

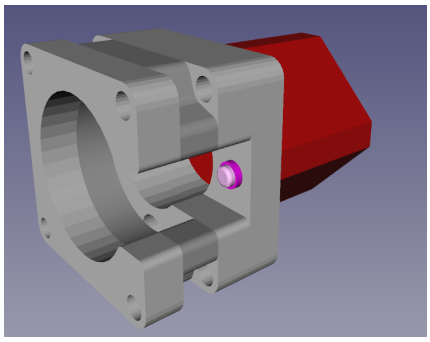
Screw the motor to the mounting plate as shown. Depending on the thickness of the Acrylic and the depth of the threaded holes in the motor you may need three or four washers to achieve a snug fit.



The other three mounting plates should then be arranged as shown.

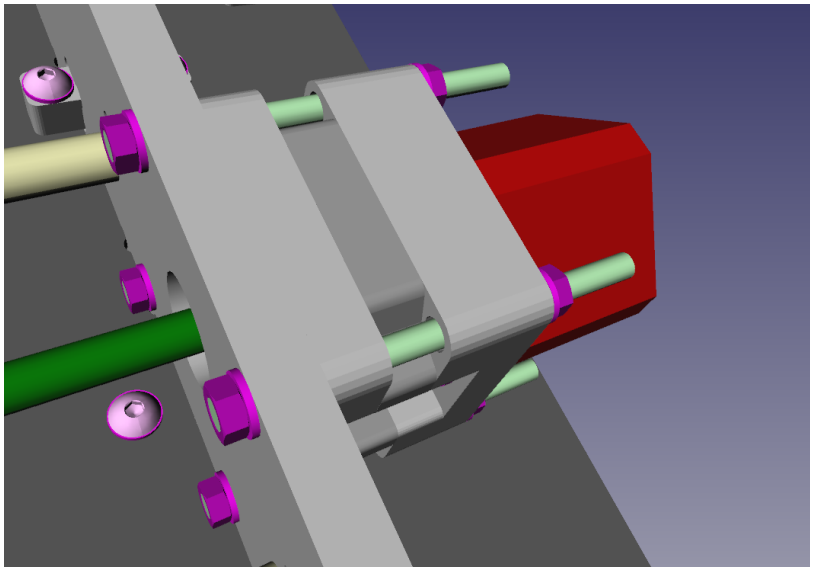




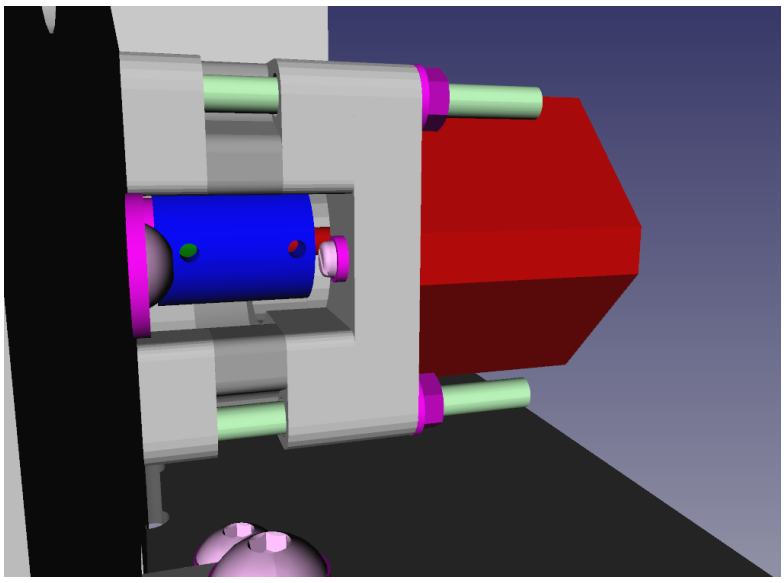


Y Axis NEMA17 Motor Mounting Part 2

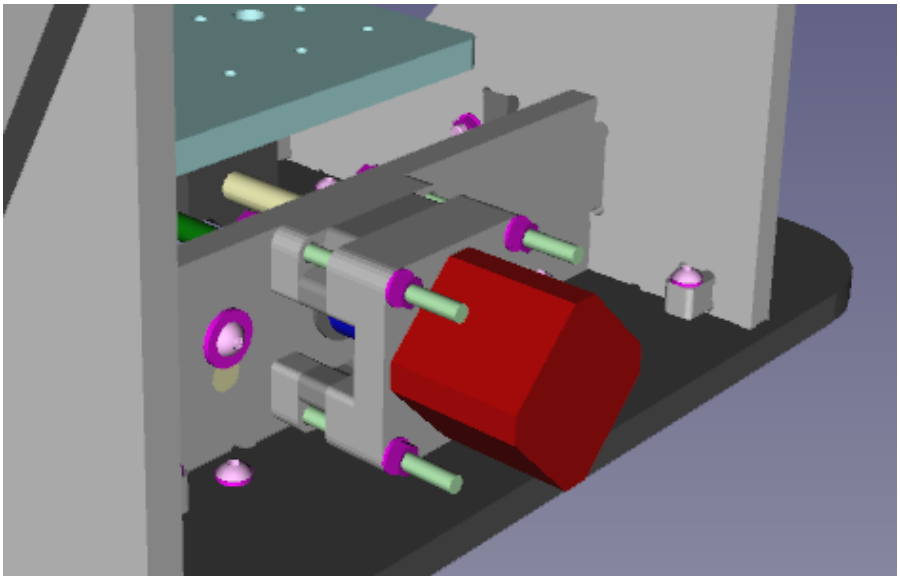
Parts: 8 M5 washers, 4 M5 Nyloc nuts, 4 motor mounting screws.
Thread the four 75mm long Y axis mounting screws through the Y axis motor mounting plates and snugly tighten onto the rear Y axis plate as shown.



Ideally you want the end of the threaded rod to be flush with the end of the Nyloc nut next to the rear Y axis plate. It is easier to measure the rod against the assembly and screw the Nyloc nut for the motor end on first. Then you can grip the exposed threaded end or the exposed inner threaded section and screw the opposing Nyloc nut on.
If you still can't get a good grip on the threaded rod, you could take your file and file a flat on the side of the motor end of the rod.



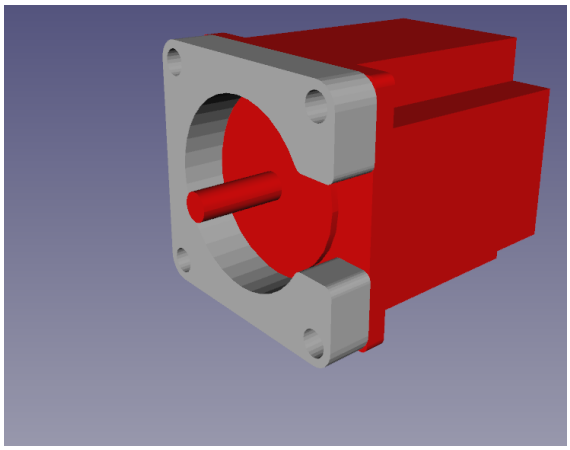
Take care to align the flat on the motor shaft with one of the grub screw positions of the flexible shaft coupler. Make sure the end of the motor shaft does not touch the end of the Y axis lead screw. If it does, move the lead screw towards the front of the machine and take up the slack on the lock collar. Tighten the shaft coupler grub screws.

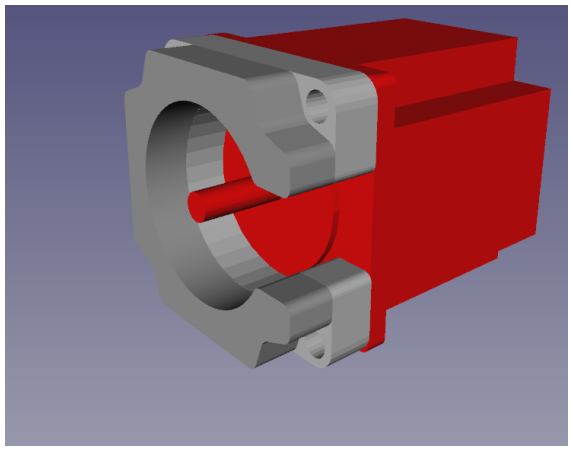


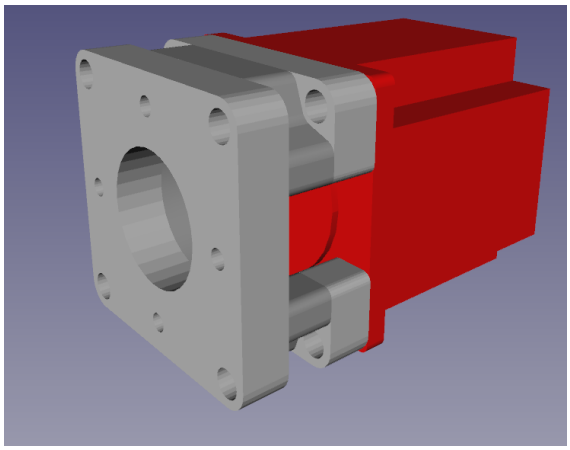
Congratulations - The Y Axis is now complete.

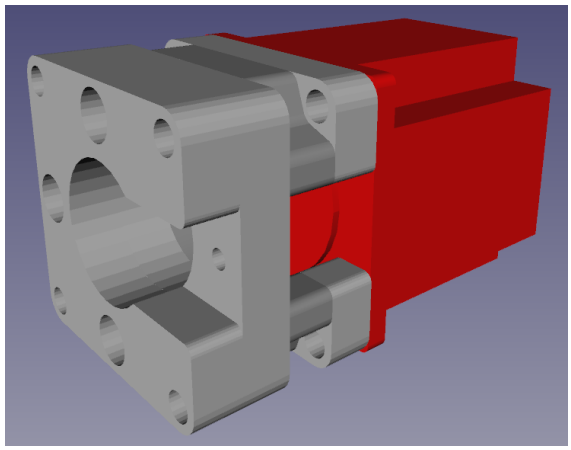
Y Axis NEMA23 Motor Mounting Part 1

The parts should be aligned with the NEMA23 motor as shown.



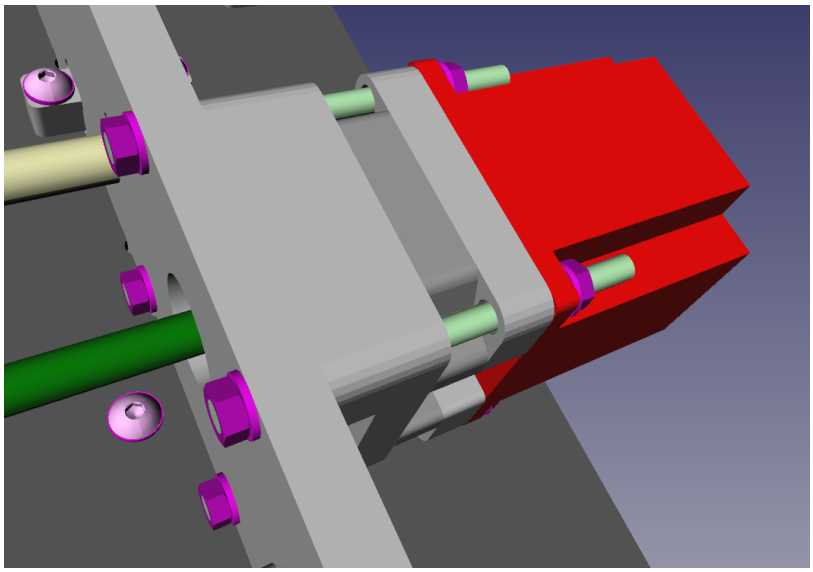




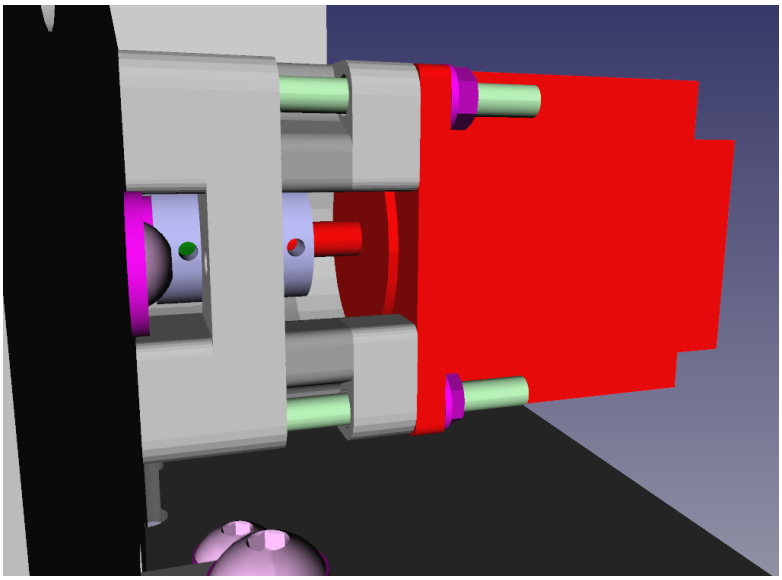


Y Axis NEMA23 Motor Mounting Part 2

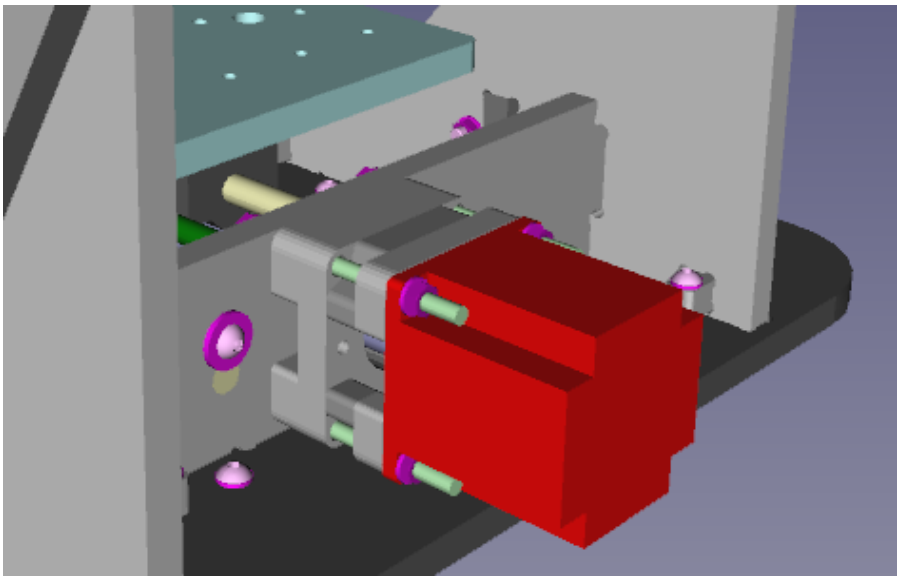
Parts: 8 M5 washers, 4 M5 Nyloc nuts, 4 motor mounting screws.
Thread the four 75mm long Y axis mounting screws through the Y axis motor mounting plates and snugly tighten onto the rear Y axis plate as shown.



Ideally you want the end of the threaded rod to be flush with the end of the Nyloc nut next to the rear Y axis plate. It is easier to measure the rod against the assembly and screw the Nyloc nut for the motor end on first. Then you can grip the exposed threaded end or the exposed inner threaded section and screw the opposing Nyloc nut on.
If you still can't get a good grip on the threaded rod, you could take your file and file a flat on the side of the motor end of the rod.



Take care to align the flat on the motor shaft with one of the grub screw positions of the flexible shaft coupler. Make sure the end of the motor shaft does not touch the end of the Y axis lead screw. If it does, move the lead screw towards the front of the machine and take up the slack on the lock collar. Tighten the shaft coupler grub screws.



Congratulations - The Y Axis is now complete.

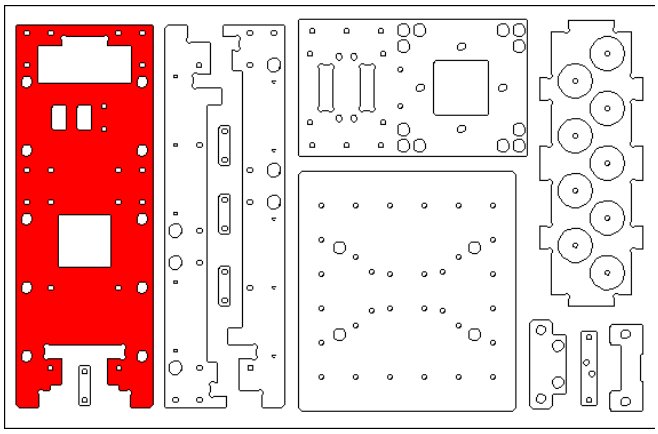
X Axis Preparation Work

We will now cut the lead screw for the X axis.
Take the 8mm threaded rod and measure off 290mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 290mm section off.
Using the file, remove any sharp edges on the threaded rod.

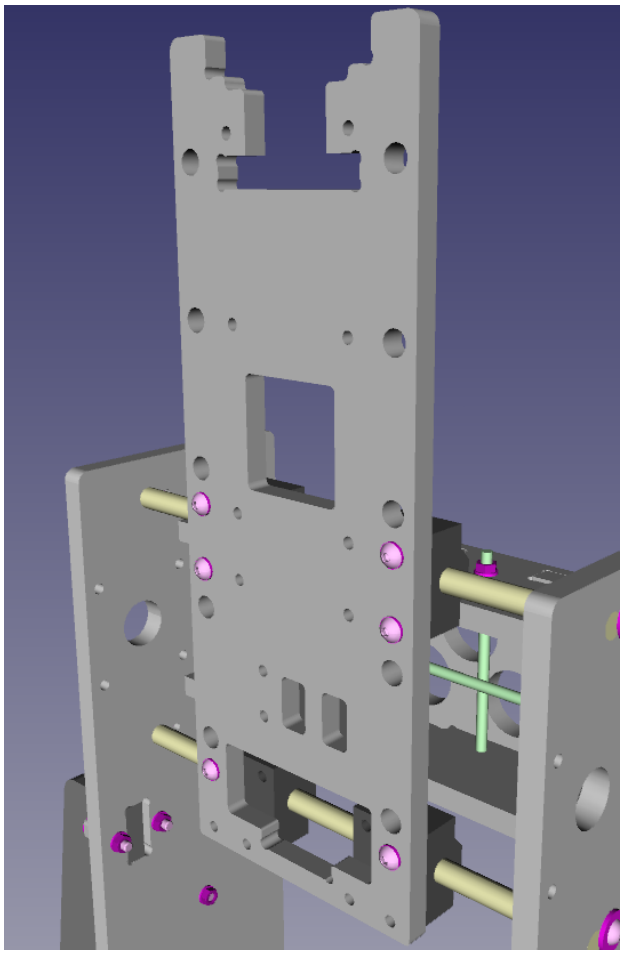
If you purchased your Drylin rails as one 600mm long rail then carefully use the hacksaw to cut it in half to make two 300mm long rails. Use the file and/or abrasive paper to remove any burrs from the cut surfaces.

X Axis Main Plate

Parts: 6 M5x20mm socket head buttons, 6 M5 washers.
Locate the part shown below, cut it out, file it, remove films, wash and dry it



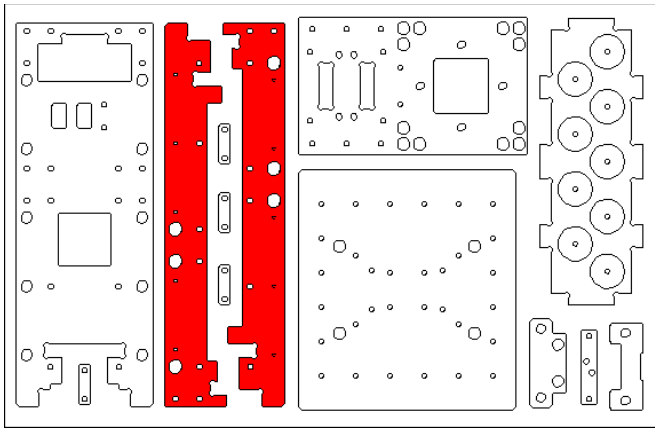
Screw the X axis main plate lightly to the bearing blocks as shown below.



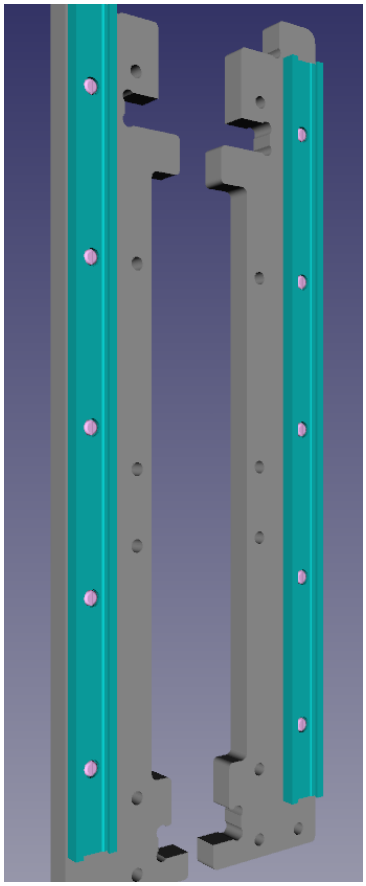
Slide the X axis assembly to be flush with the left or right gantry upright to help vertically align it and then snug the screws.

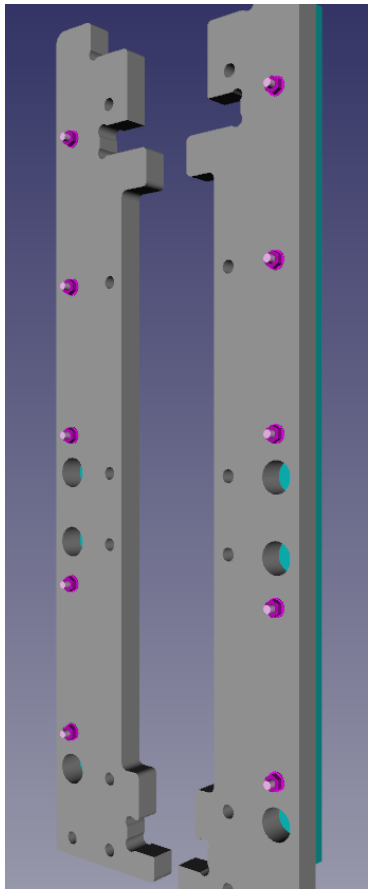
X Axis Left And Right Plates Part 1

Parts: 10 M3x16mm slotted pan heads, 10 M3 washers, 10 M3 Nyloc nuts, 2 300mm Drylin rails.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



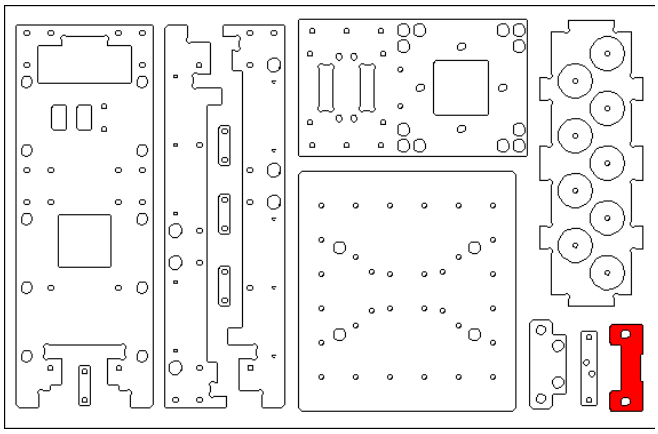
Screw the rails snugly onto the X axis left and right plates as shown ensuring that the sides of the rails are parallel to the sides of the plates.



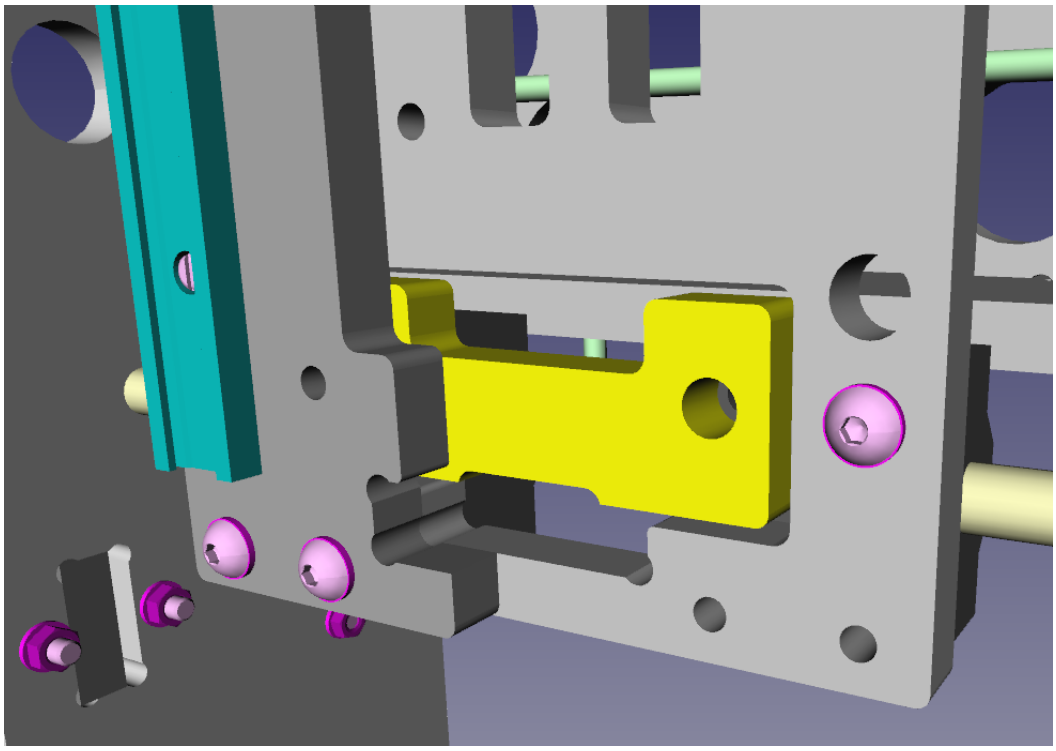


X Axis Left And Right Plates Part 2

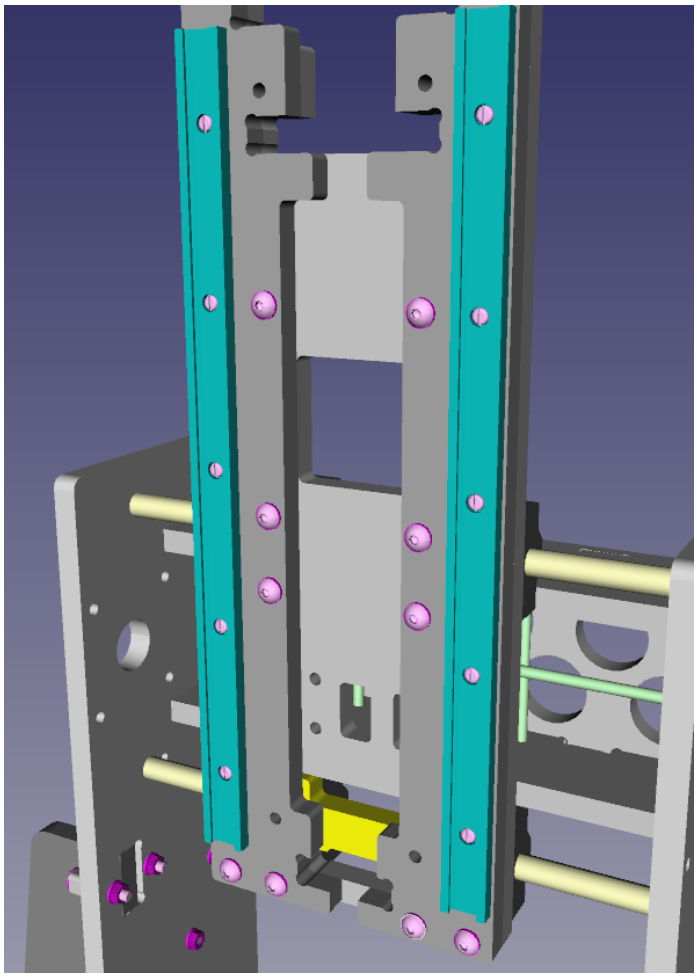
Parts: 10 M5x30mm socket head buttons, 12 M5 washers, 2 M5 Nyloc nuts.
Locate the part shown below, cut it out, file it, remove films, wash and dry it



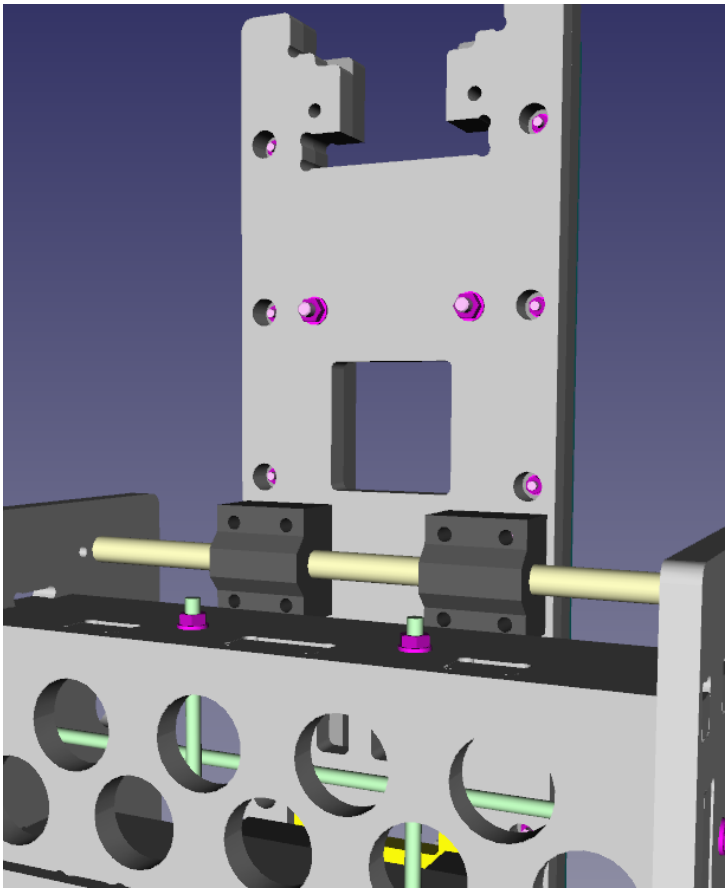
Insert the Z axis lower bearing plate clamp into the recess in the X axis main plate as shown.



Align the X axis left and right plate assemblies over the X axis main plate and screw them together. You can snug up all the screws except for the four at the bottom of the left and right plates. Leave these ones loose enough that the Z axis lower bearing plate clamp is still mobile.

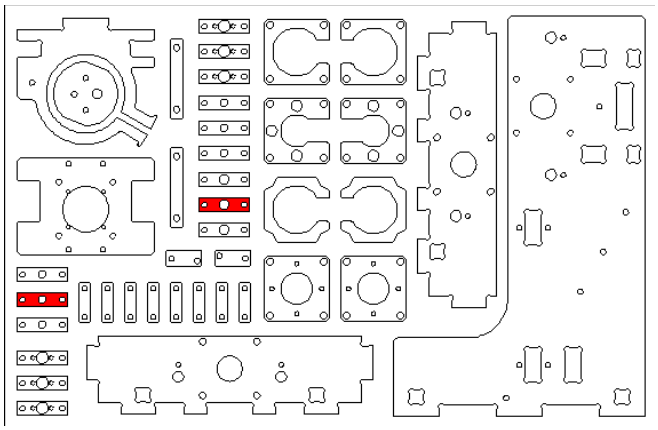


Snug up the two Nyloc nuts.

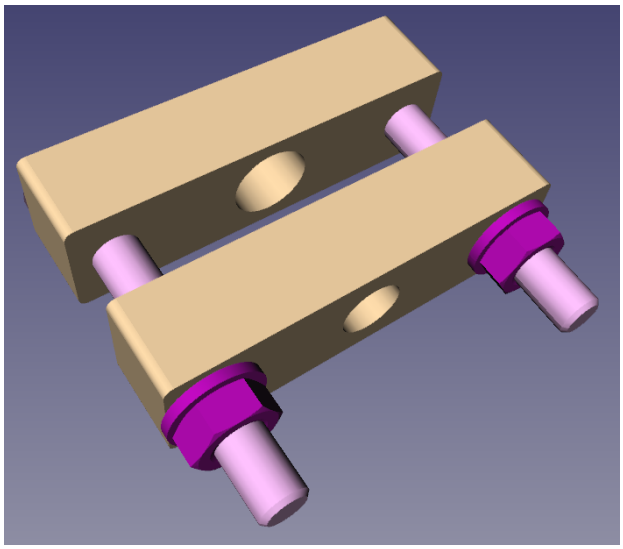


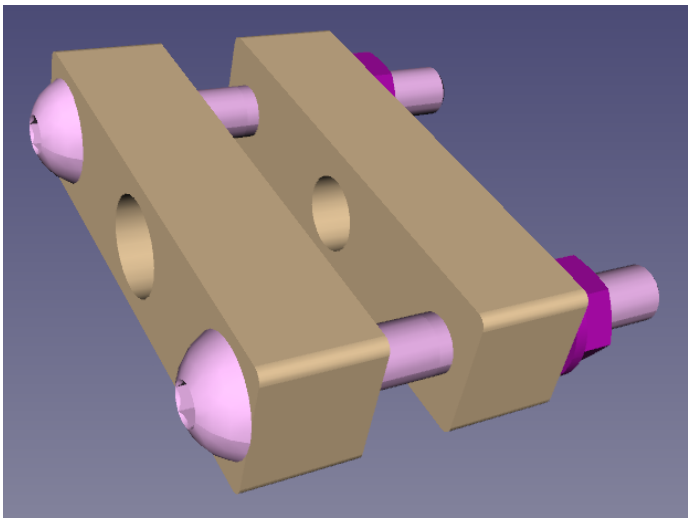
X Axis Lead Screw And Nut Block Part 1

Parts: 2 M5x40mm socket head buttons, 2 M5 washers, 2 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



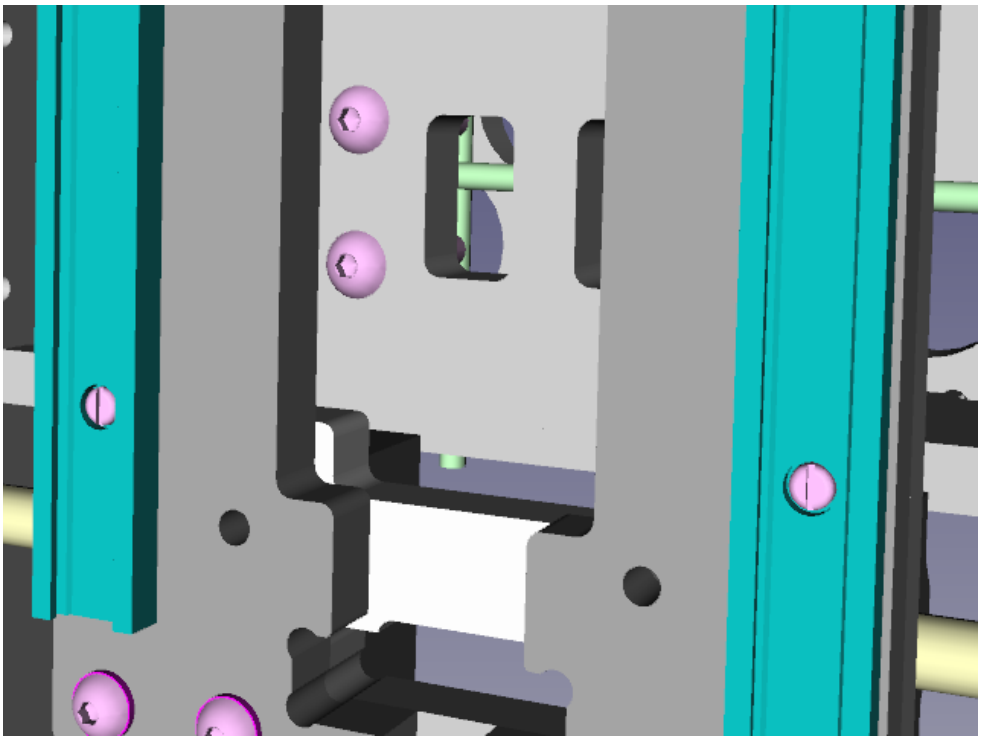
Screw the parts together as shown. The Nyloc nuts are adjacent to the piece with the M8 thread tapped into it. Leave enough distance between the two pieces to just slide an M5 nut in.

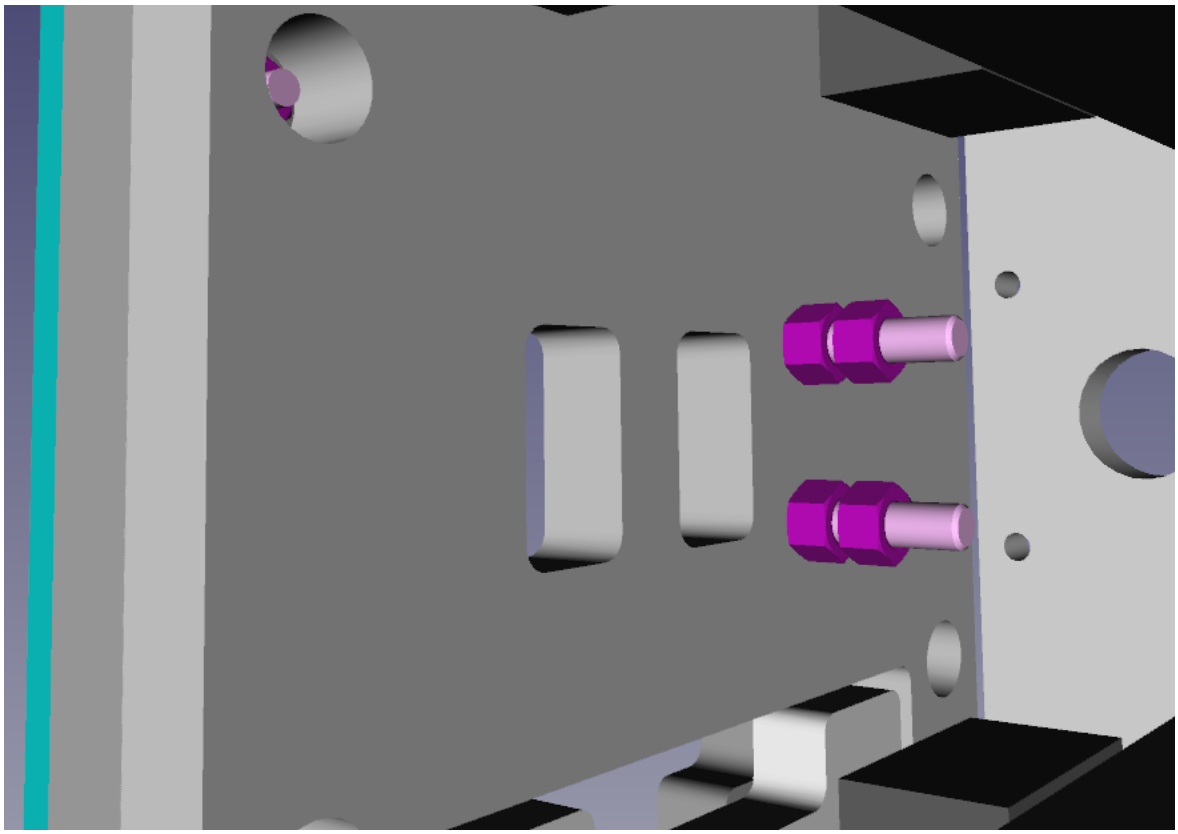




X Axis Lead Screw And Nut Block Part 2

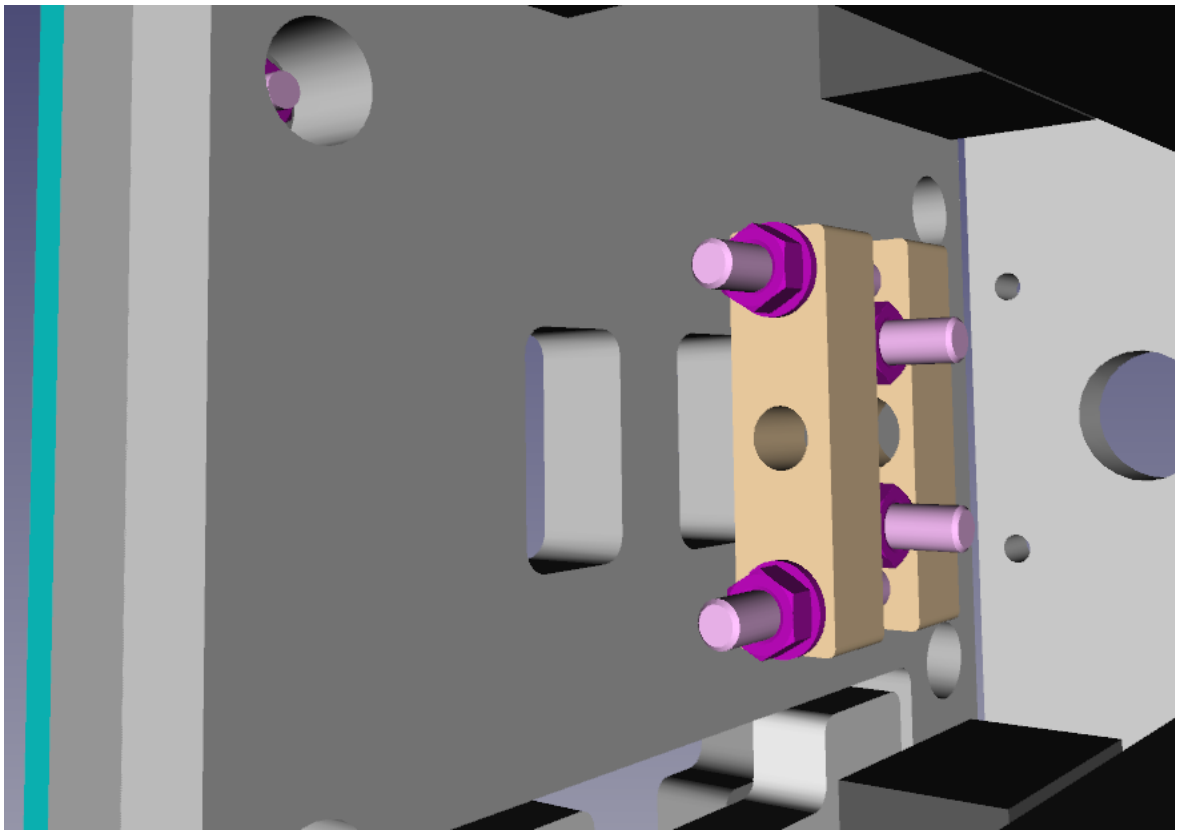
Parts: 2 M5x30mm socket head buttons, 4 M5 full hex nuts.
Snug the full hex nuts so that the sides are parallel to the sides of the main X plate. Then add a second full hex nut leaving approximately one millimetre between them with the nut faces aligned.





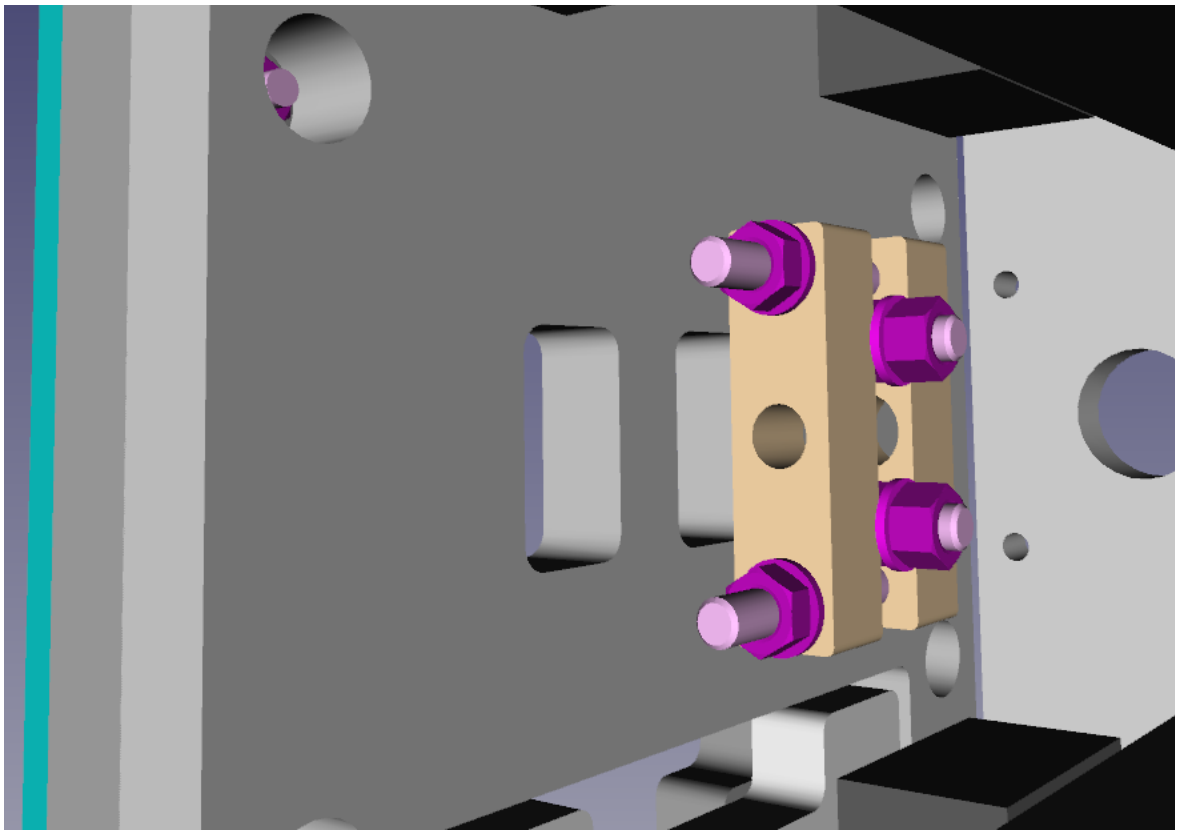
X Axis Lead Screw And Nut Block Part 3

Slide the nut block assembly over the hex nuts as shown – tapped block towards the centre of the main X plate. Adjust the spacing of the Acrylic nut block so that it can still slide up and down.



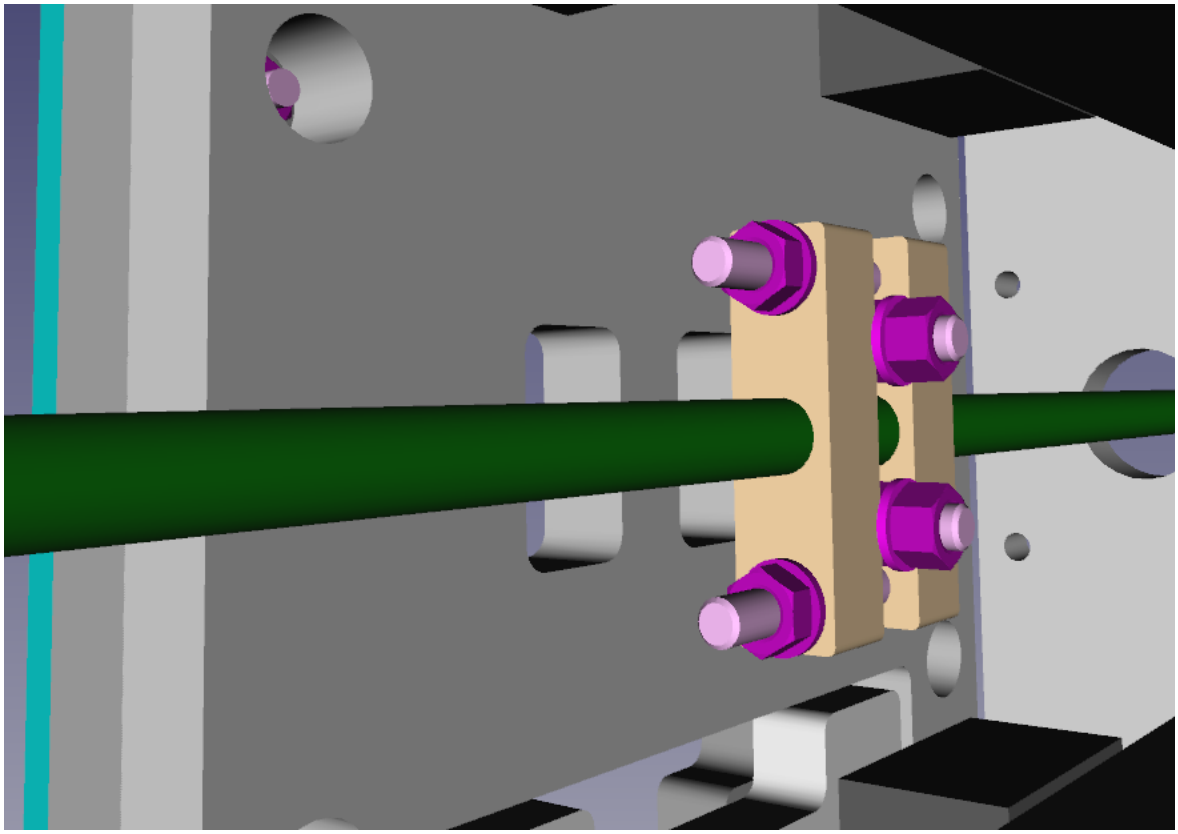
X Axis Lead Screw And Nut Block Part 4

Parts: 2 M5 washers, 2 M5 Nyloc nuts.
Add the washers to the machine screws so that the edges cover each side of the nut block. Then secure the washers with the Nyloc nuts. Make sure to stop the mounting screws and full hex nuts from rotating by holding them in place with the Allen key while tightening the Nyloc nuts. Do not snug the Nyloc nuts yet. Make sure the nut block can still slide up and down.



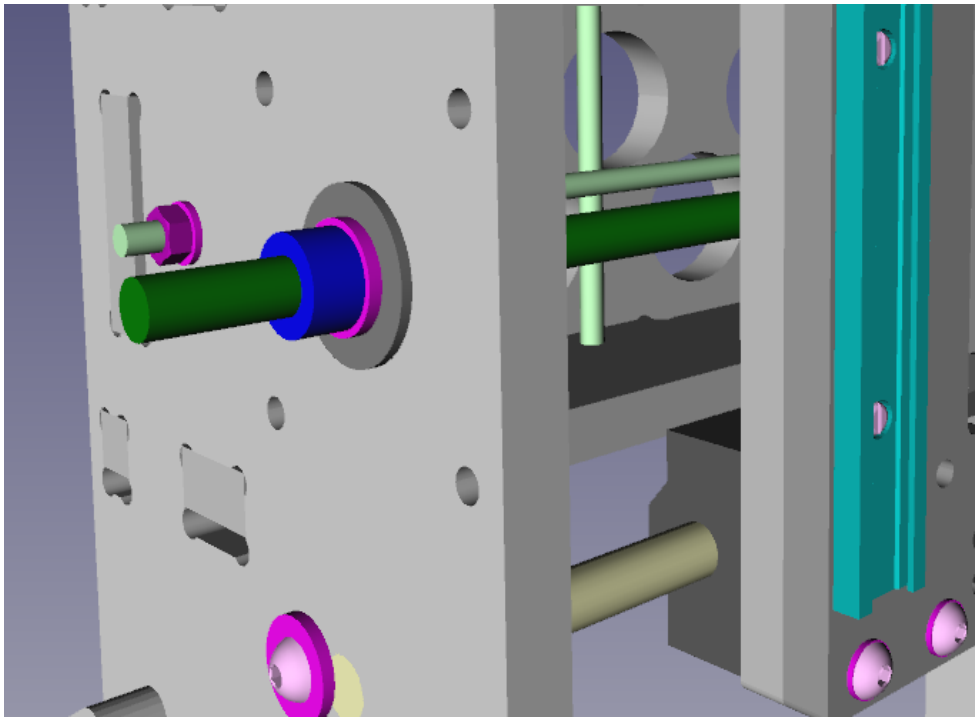
X Axis Lead Screw And Nut Block Part 5

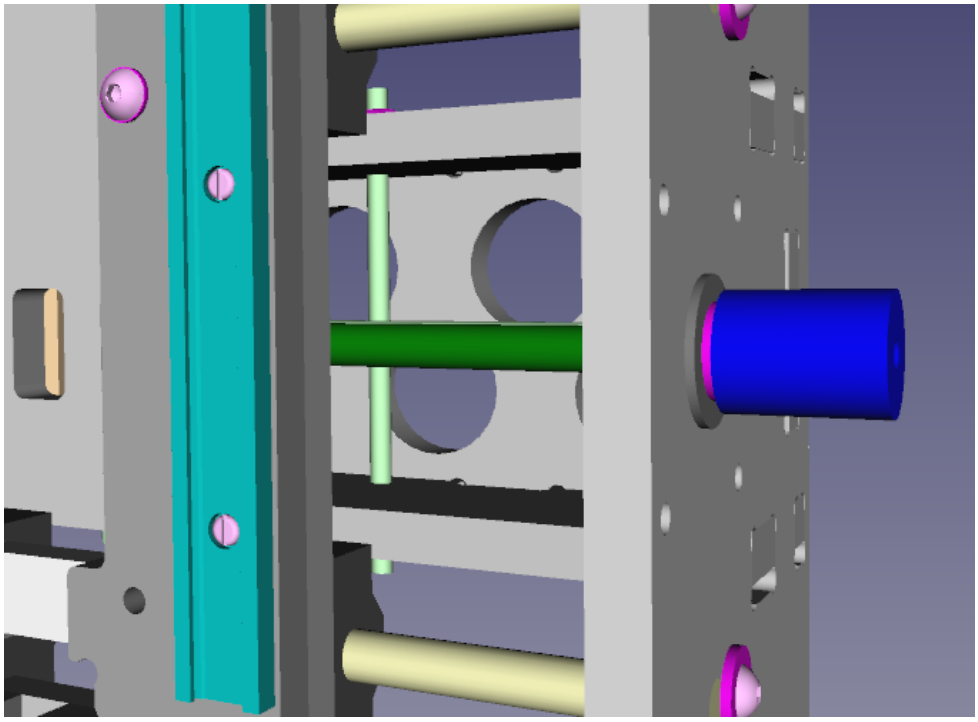
Parts: 1 lead screw.
Feed the lead screw through the bearing hole on the right gantry upright and thread it into the nut block. Continue to thread it until the lead screw protrudes through the bearing hole on the left gantry upright.



X Axis Lead Screw And Nut Block Part 6

Parts: 2 M8 washers, 2 flanged bearings, 1 lock collar, 1 flexible shaft coupler.
Slide the flanged bearings over the lead screw and insert into the gantry uprights.
Place a washer over the flanged bearing on each end of the lead screw. Slide the lock collar over the lead screw on the left gantry upright. Leave about 8.5mm of lead screw protruding past the washer on the right gantry upright, slide a flexible shaft coupler (8mm→5mm for NEMA17 motors, 8mm→6.35mm for NEMA23) over the lead screw and tighten the coupler's grub screws. Now tighten the grub screw on the lock collar so that there is minimal side to side play on the lead screw.

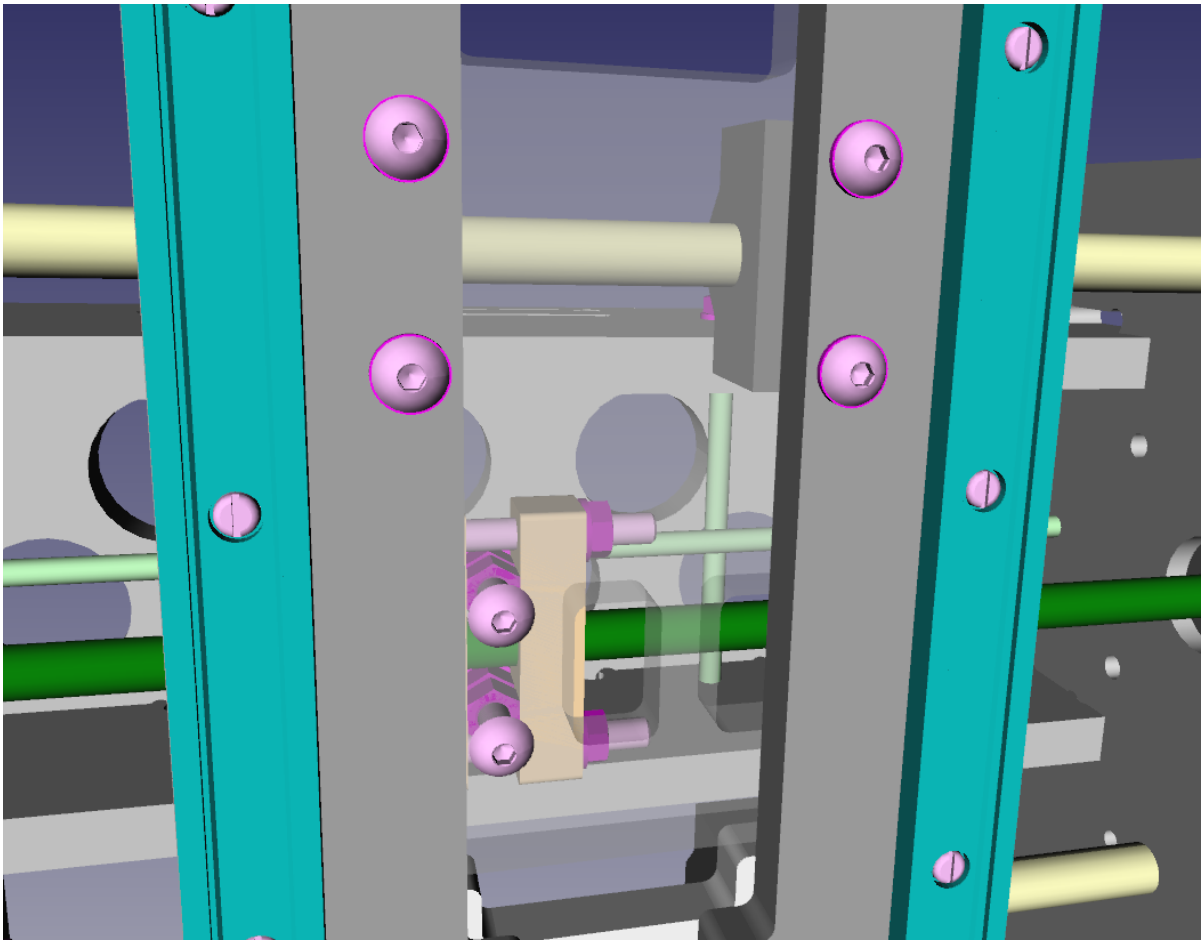




X Axis Lead Screw And Nut Block Part 7

The nut block should have mostly self-aligned now. You now need to tighten the screws that clamp the two parts of the nut block together and then snug up the Nyloc nuts that help to keep the nut block from twisting. It is best to progressively tighten them so that the nut block has minimal side to side movement, minimal up and down or twisting movement but still allows the X axis to move from side to side without binding or excessive stiffness when you rotate the lead screw.
Take care when tightening the Nyloc nuts that the full hex nuts keep their faces parallel to the nut blocks. You can do this by holding the screw in position with the Allen key while tightening the Nyloc nut with a spanner.

This procedure can be fiddly and it is best to make small adjustments and test how it performs repeatedly. The nut block will loosen over time as it wears and its performance can be enhanced by spraying the lead screw with silicone-based furniture spray polish. That will lubricate the lead screw and nut block without making it sticky.

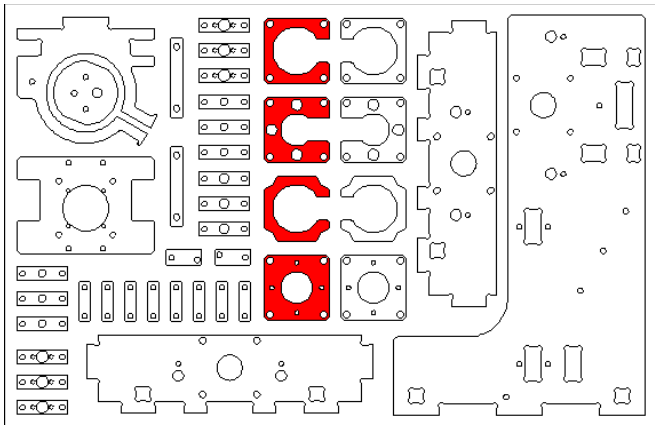


You have probably noticed that the gantry uprights are identical. Therefore, if it is convenient for you, you can mount the X axis motor on the left side. Just swap the positions of the lock collar and shaft coupler. Follow the motor mounting instructions but swap them to the other side.

X Axis Motor Mounting Preparation Work

We will now cut the mounting screws for the X axis motor.
Take the 5mm threaded rod and measure off 75mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 75mm section off.
Using the file, remove any sharp edges on the threaded rod.
Repeat the procedure three more times so you end up with four 75mm threaded rods.

Locate the parts shown below, cut them out, file them, remove films, wash and dry them.

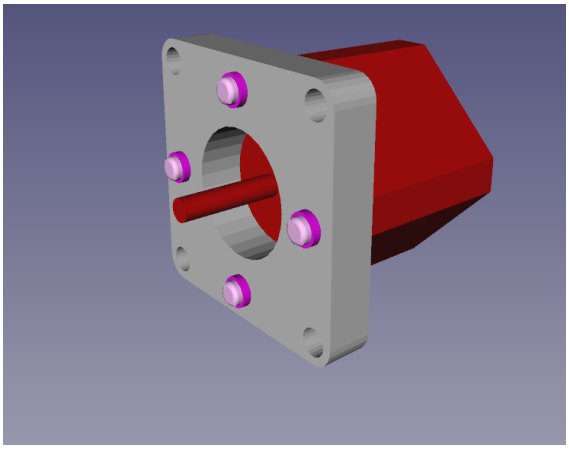


If you are using a NEMA17 motor for the X axis, proceed to the next section.
If you are using a NEMA23 motor for the X axis, proceed to the section titled “X Axis NEMA23 Motor Mounting Part 1”.

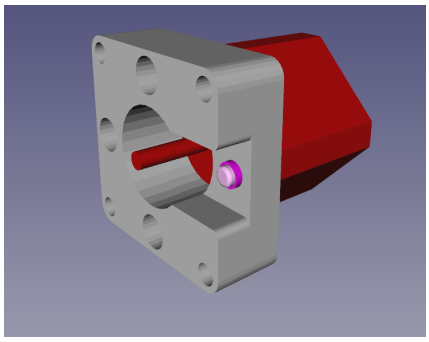
X Axis NEMA17 Motor Mounting Part 1

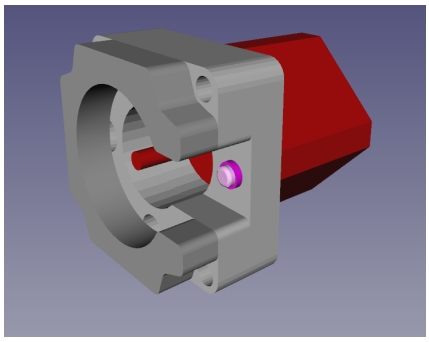
Parts: 4 M3x16mm slotted pan heads, 16 M3 washers.

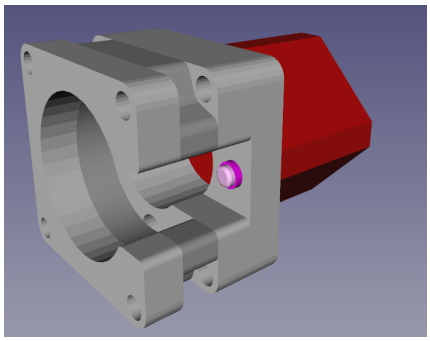
Screw the motor to the mounting plate as shown. Depending on the thickness of the Acrylic and the depth of the threaded holes in the motor you may need three or four washers to achieve a snug fit.



The other three mounting plates should then be arranged as shown.

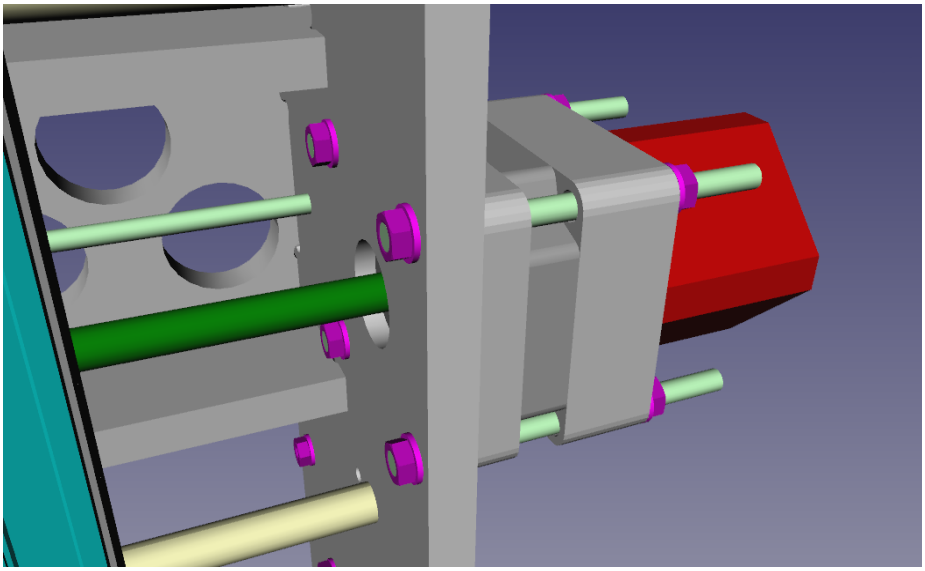




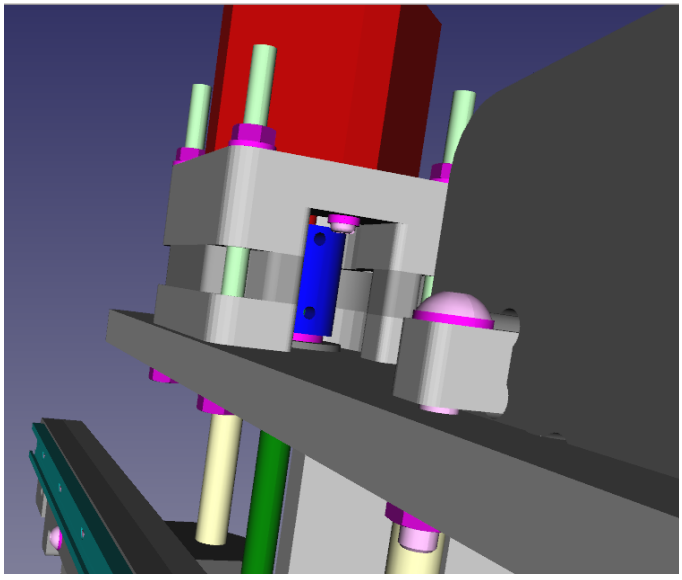


X Axis NEMA17 Motor Mounting Part 2

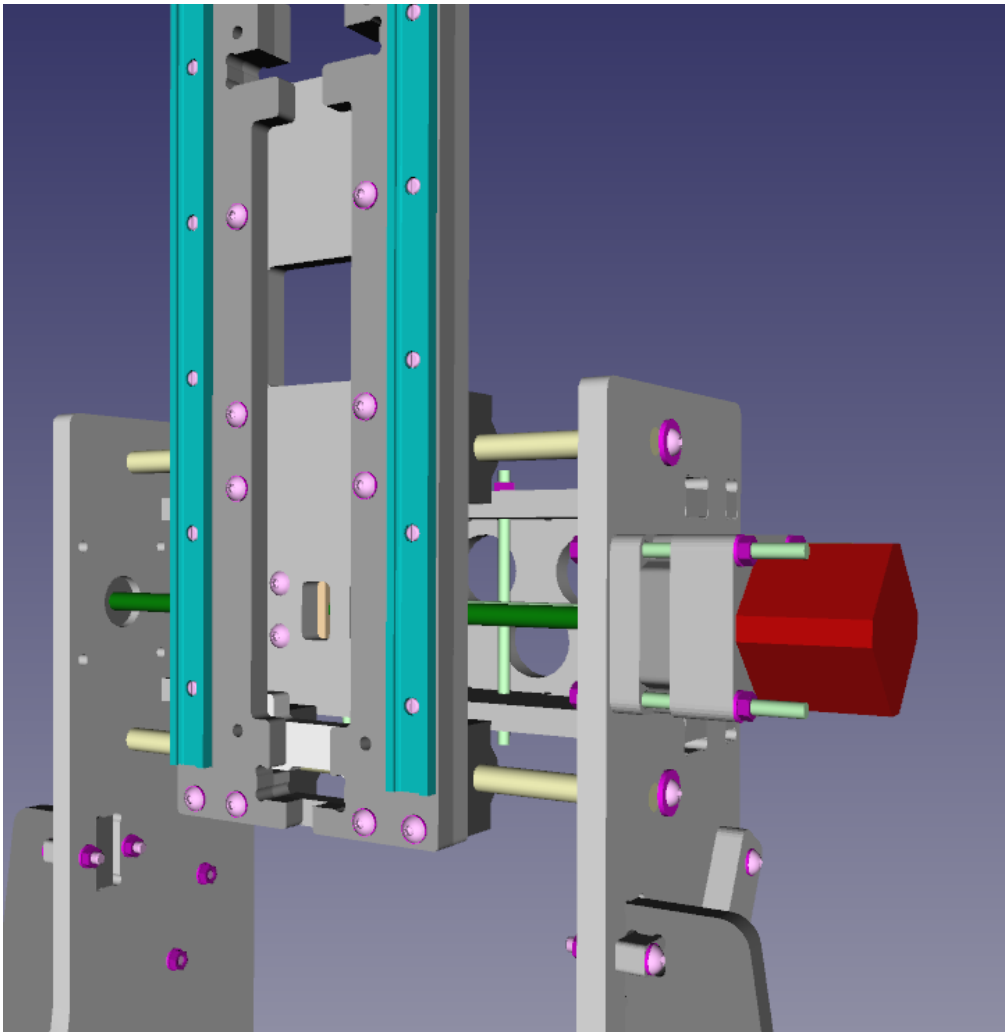
Parts: 8 M5 washers, 4 M5 Nyloc nuts, 4 motor mounting screws.
Thread the four 75mm long X axis mounting screws through the X axis motor mounting plates and snugly tighten onto the right gantry upright as shown.



Ideally you want the end of the threaded rod to be flush with the end of the Nyloc nut next to the right gantry upright. It is easier to measure the rod against the assembly and screw the Nyloc nut for the motor end on first. Then you can grip the exposed threaded end or the exposed inner threaded section and screw the opposing Nyloc nut on.
If you still can't get a good grip on the threaded rod, you could take your file and file a flat on the side of the motor end of the rod.



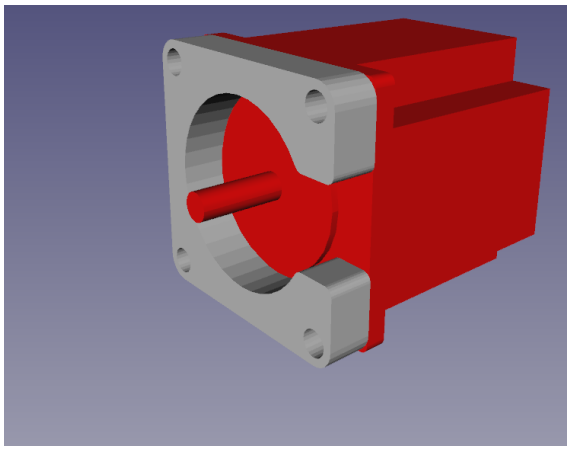
Take care to align the flat on the motor shaft with one of the grub screw positions of the flexible shaft coupler. Make sure the end of the motor shaft does not touch the end of the X axis lead screw. If it does, move the lead screw towards the left of the machine and take up the slack on the lock collar. Tighten the shaft coupler grub screws.

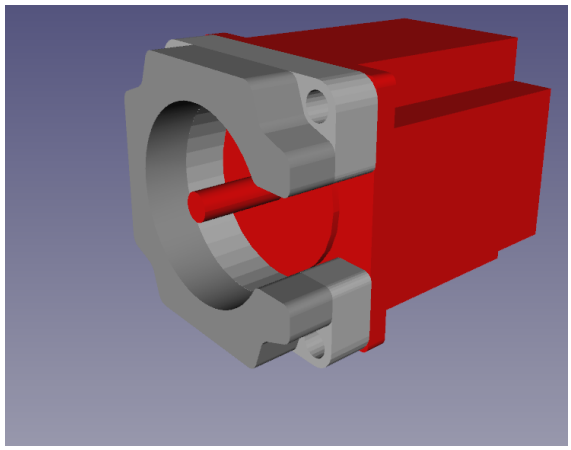


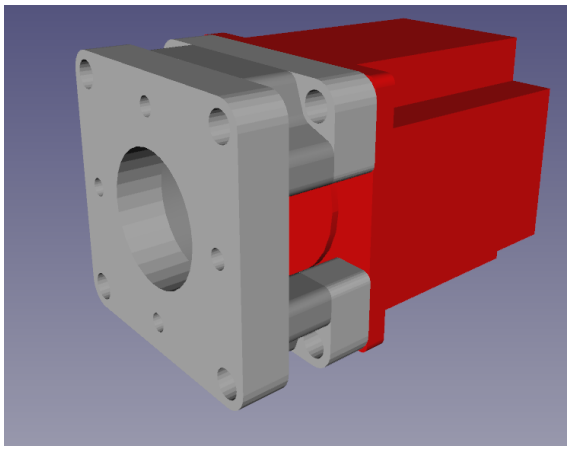
Congratulations - The X Axis is now complete.

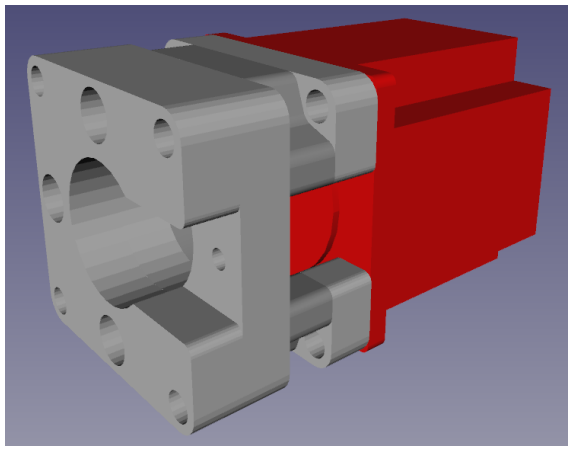
X Axis NEMA23 Motor Mounting Part 1

The parts should be aligned with the NEMA23 motor as shown.



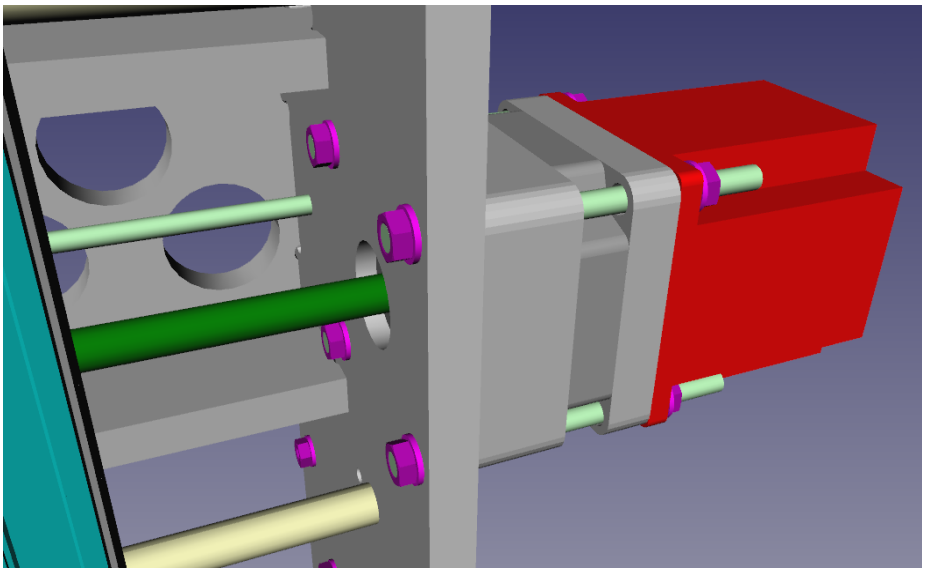




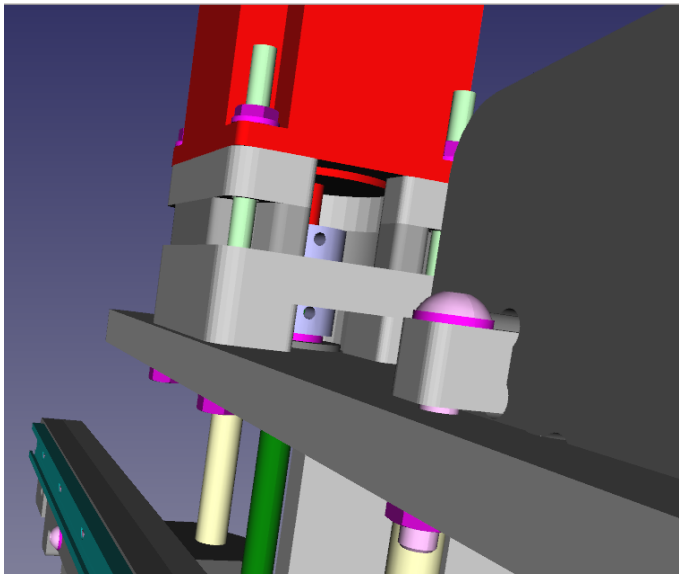


X Axis NEMA23 Motor Mounting Part 2

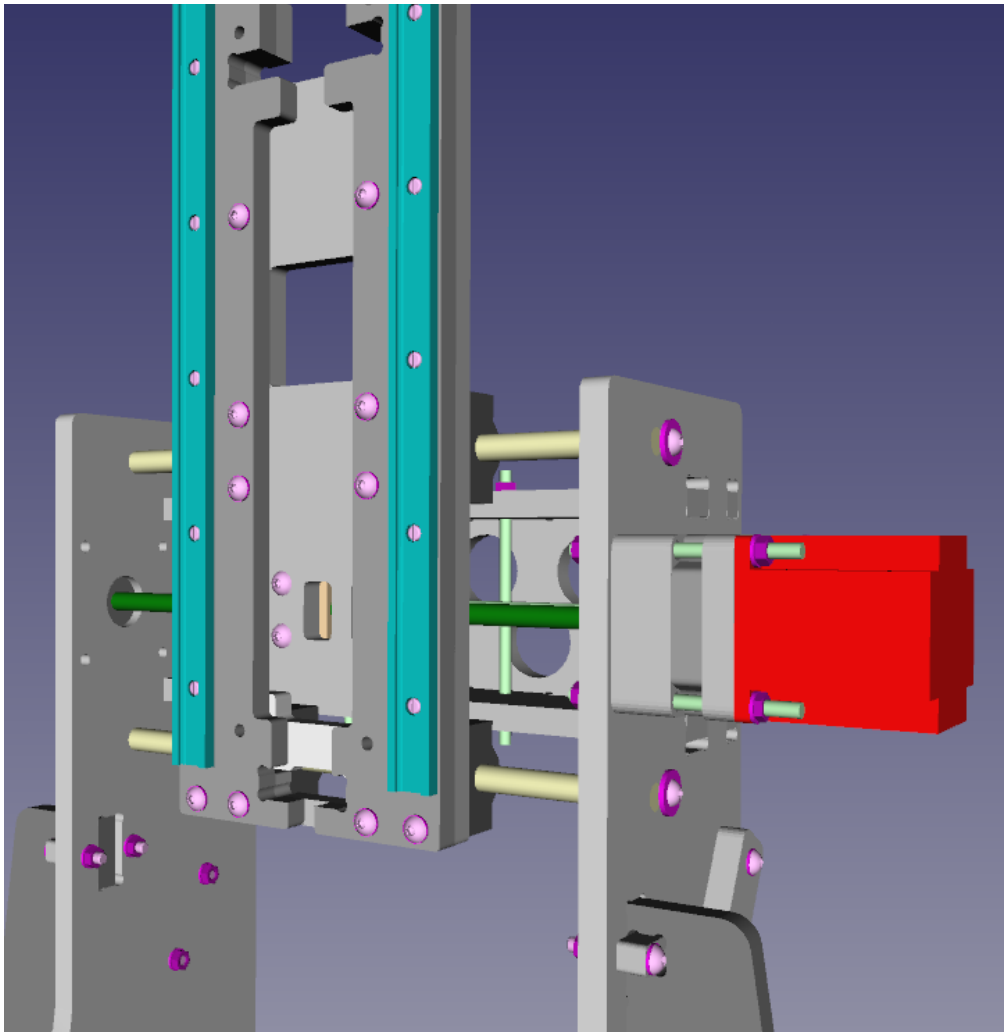
Parts: 8 M5 washers, 4 M5 Nyloc nuts, 4 motor mounting screws.
Thread the four 75mm long X axis mounting screws through the X axis motor mounting plates and snugly tighten onto the right gantry upright as shown.



Ideally you want the end of the threaded rod to be flush with the end of the Nyloc nut next to the right gantry upright. It is easier to measure the rod against the assembly and screw the Nyloc nut for the motor end on first. Then you can grip the exposed threaded end or the exposed inner threaded section and screw the opposing Nyloc nut on.
If you still can't get a good grip on the threaded rod, you could take your file and file a flat on the side of the motor end of the rod.



Take care to align the flat on the motor shaft with one of the grub screw positions of the flexible shaft coupler. Make sure the end of the motor shaft does not touch the end of the X axis lead screw. If it does, move the lead screw towards the left of the machine and take up the slack on the lock collar. Tighten the shaft coupler grub screws.



Congratulations - The X Axis is now complete.

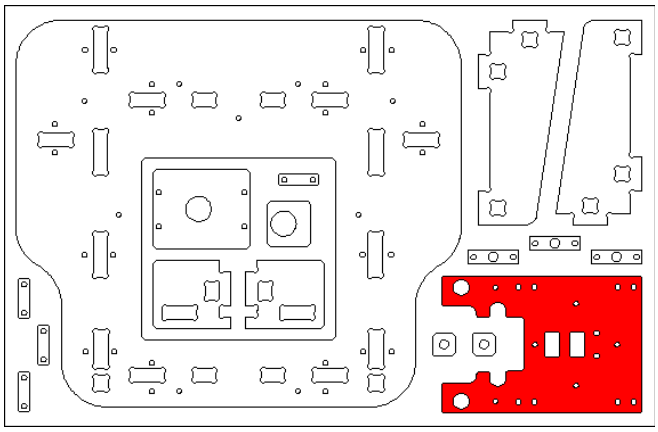
Z Axis Preparation Work

We will now cut the lead screw for the Z axis.
Take the 8mm threaded rod and measure off 290mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 290mm section off.
Using the file, remove any sharp edges on the threaded rod.

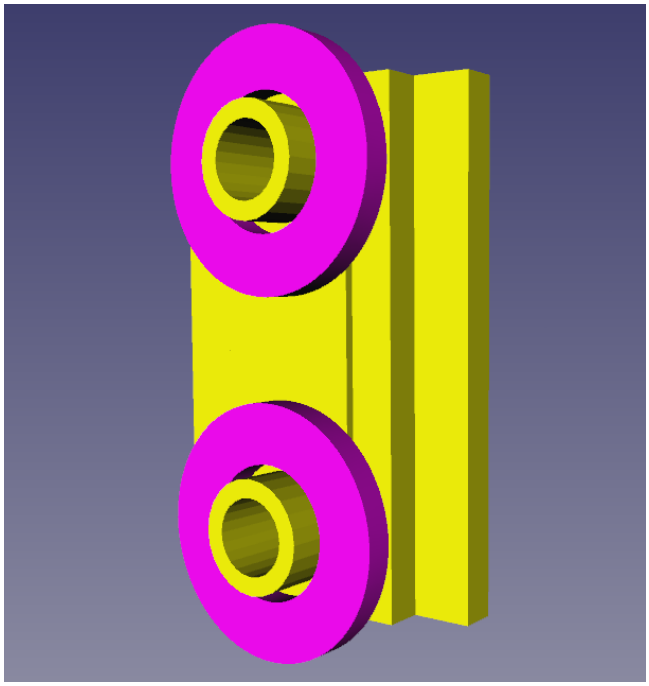
We will now cut the clamping screws for the Z axis upper bearing plate.
Take the 5mm threaded rod and measure off 65mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 65mm section off.
Using the file, remove any sharp edges on the threaded rod.
Repeat the procedure so you end up with two 65mm threaded rods.

Z Axis Main Plate

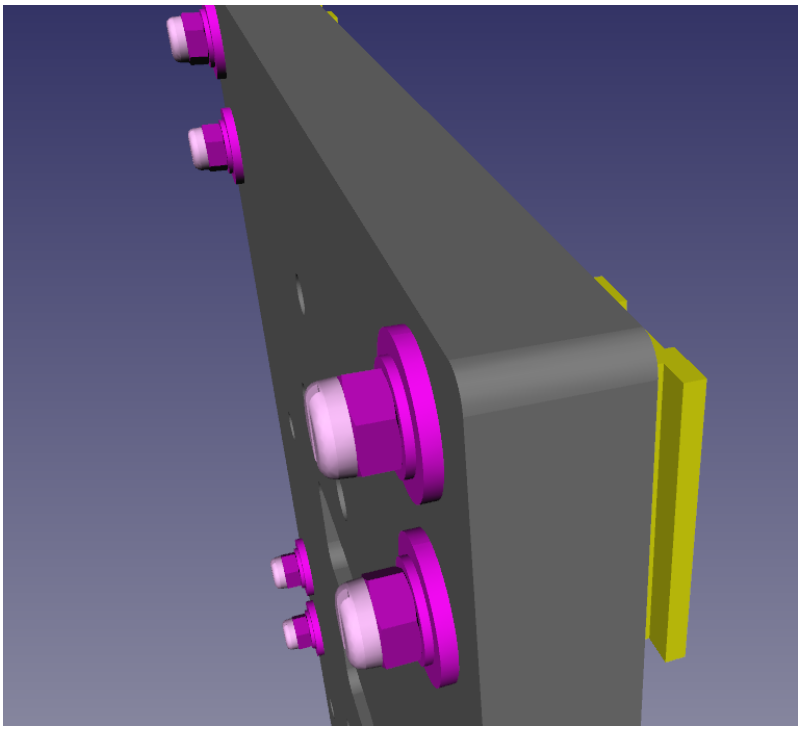
Parts: 8 M3x16mm slotted pan heads, 8 M3 washers, 16 M5 washers, 8 M3 full hex nuts, 4 Drylin carriages.
Locate the part shown below, cut it out, file it, remove films, wash and dry it.

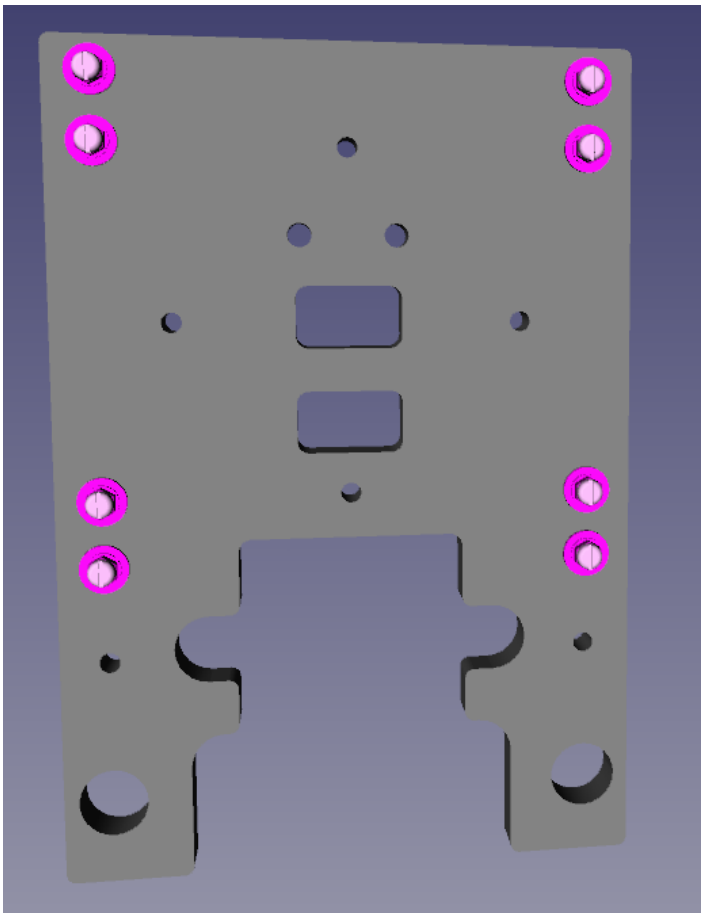


Screw an M3 nut onto an M3 slotted pan head snugly. Add an M3 washer followed by an M5 washer. Repeat eight times.
Place an M5 washer over each of the mounting threads of a Drylin carriage.

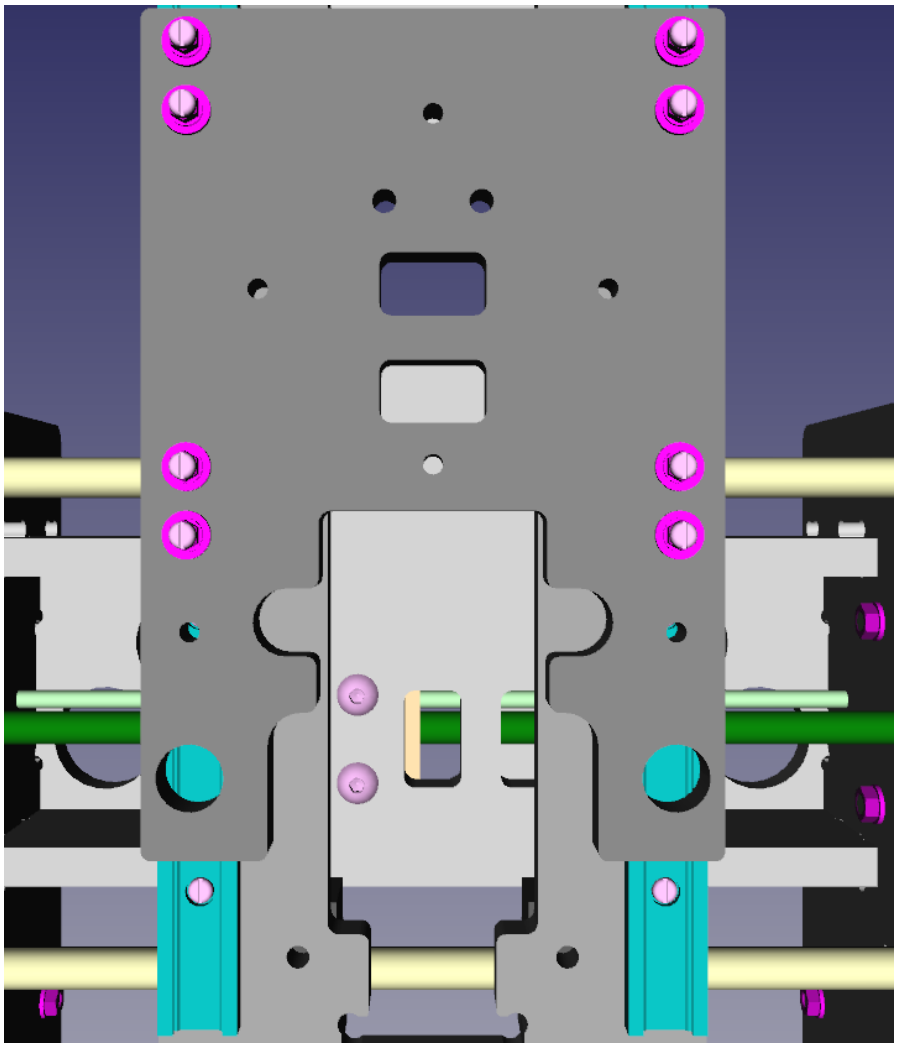


Insert the Drylin carriage and washers into the rear of the Z axis main plate and screw the M3 slotted pan head assembly into the carriage loosely.
Repeat for all four carriages.





Slide the Z axis main plate assembly down into the Drylin rails.



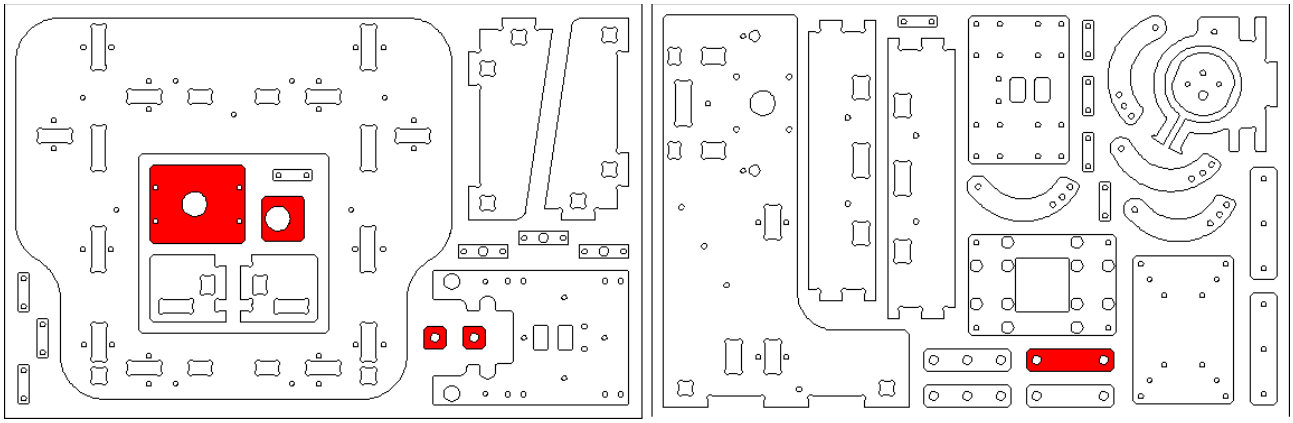
Slide a currently unused M5 machine screw or an offcut of the M5 threaded rod through a Z axis nut block mounting hole to stop the plate falling out the bottom of the rails.

Tighten the M3 screws keeping the M5 washers centred on the screws while aligning the Z axis plate vertically (using two M5 screws in the nut block mounting holes may help here).
The aim is for the Z axis to slide vertically from top to bottom with a minimum of side to side movement without binding.
You can reduce side to side movement by pushing the carriages sideways while tightening the screws.
If you have too much sideways movement even after adjusting the carriages, you can loosen the X axis left or right plates on which the Drylin rails are mounted and nudge them horizontally to take up any further slack. It is possible to adjust the position of the rails themselves if you have a small M3 box spanner but it really shouldn't be necessary and it is tricky with the Z axis main plate in position.

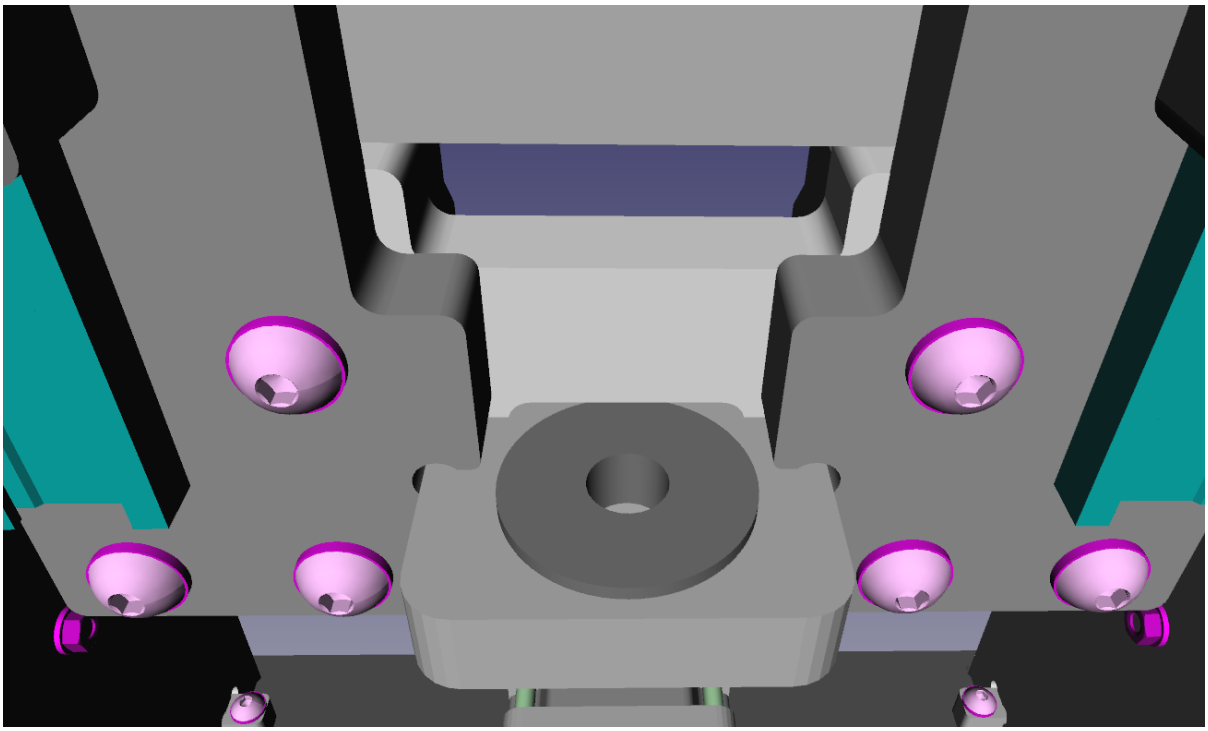
When the Z axis lead screw and nut block is added, more of the lateral movement should be taken up so you should revisit the alignment again after fitting them.

Z Axis Lead Screw Bearing Plates

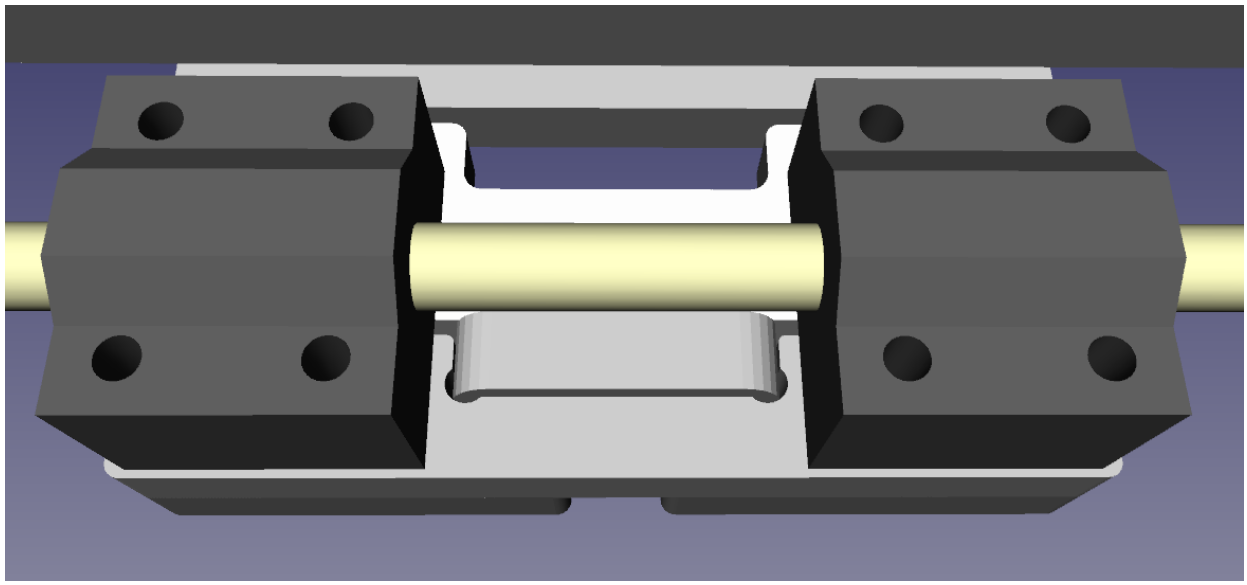
Parts: 2 M5x30mm socket head buttons, 6 M5 washers, 4 M5 Nyloc nuts, 2 flanged bearings, 2 clamping screws.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



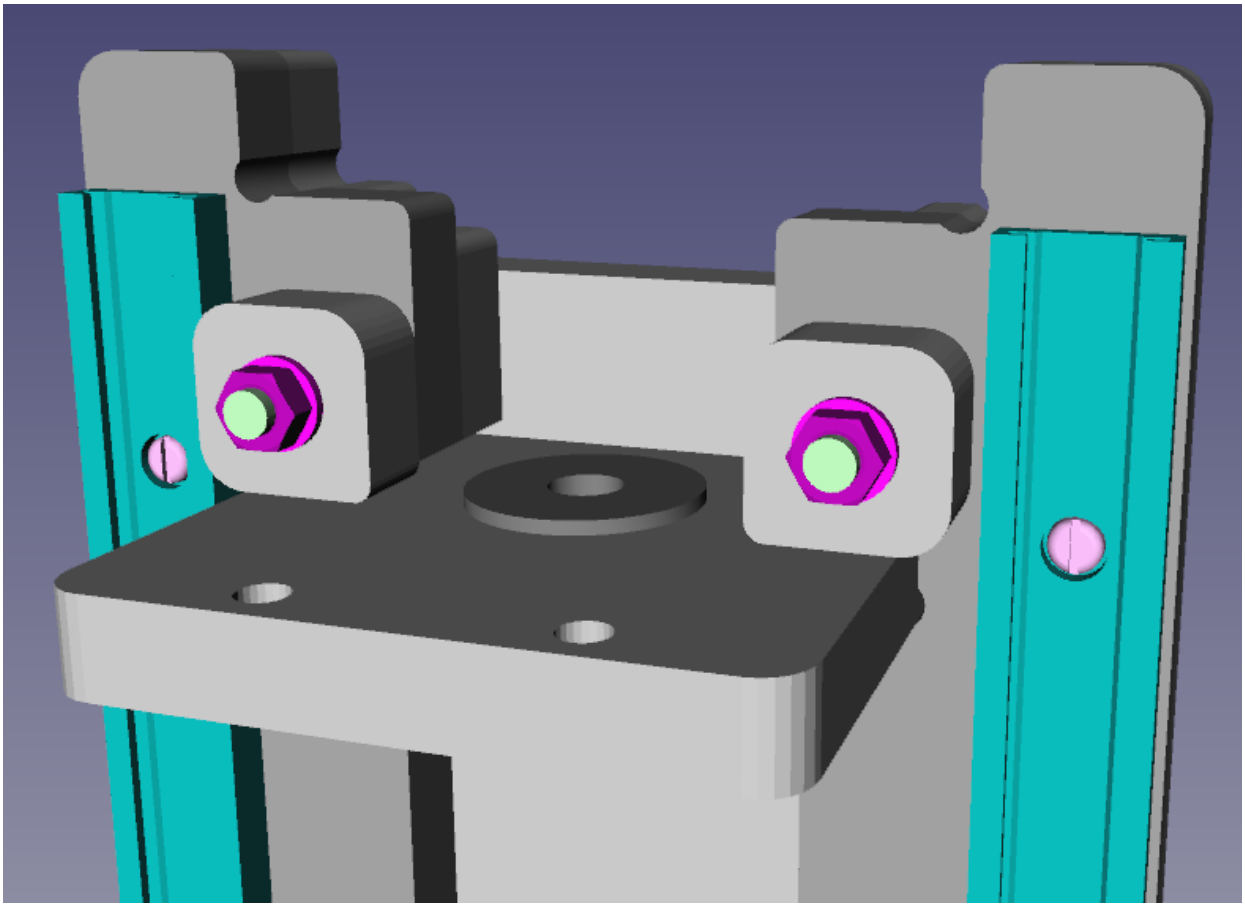
Fit a flanged bearing into the Z axis lower bearing plate and slide the assembly into the slot at the base of the Drylin rails. Tighten the M5 screws and washers loosely into the bearing blocks.



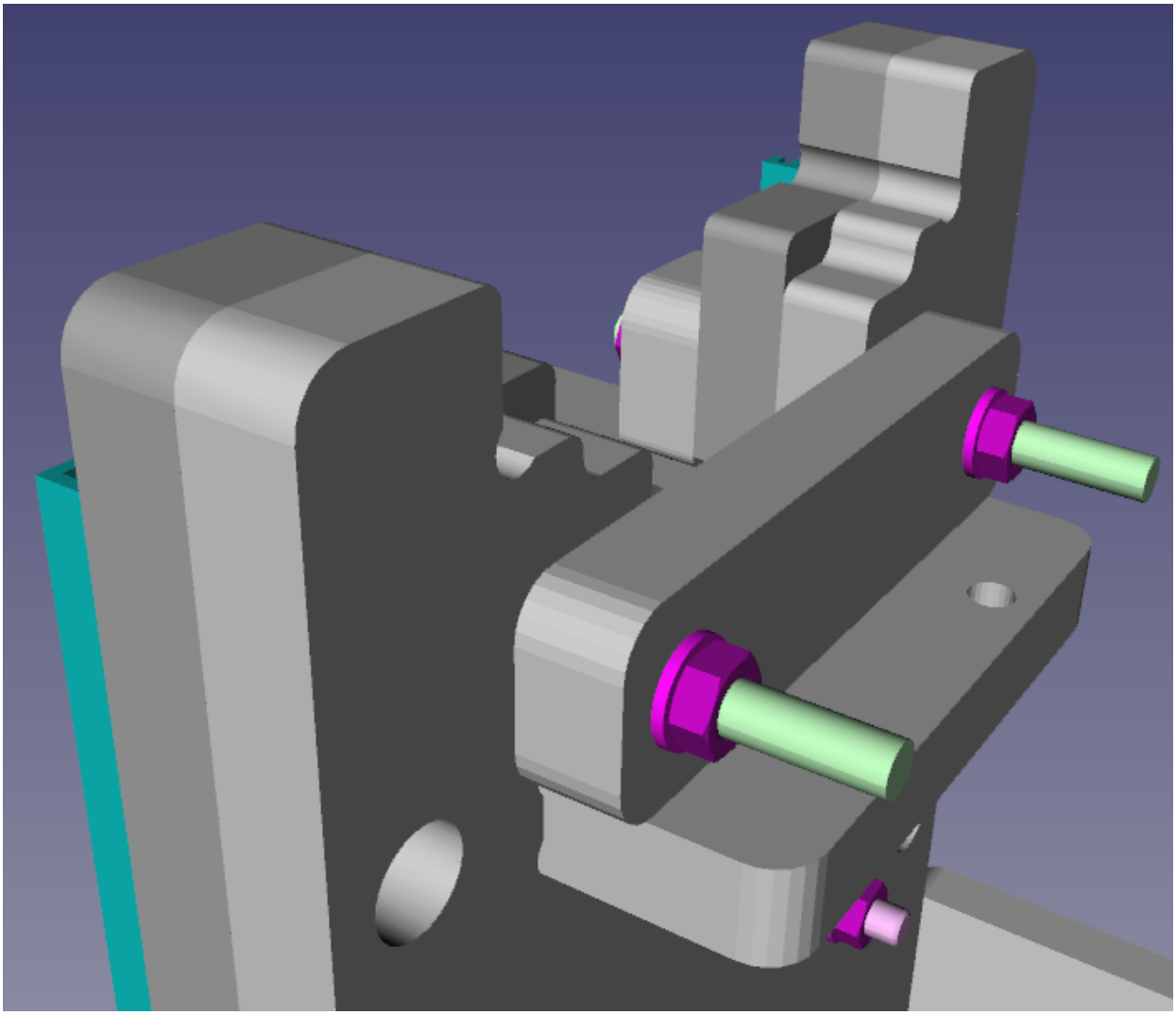
Slide your fingers up behind the lower steel rod and bearing blocks and into the slot above the captive Z axis lower bearing plate clamp. As you squeeze the clamp down, tighten the screws so that the bearing plate is still just able to slide in and out.



Fit a flanged bearing into the Z axis upper bearing plate and slide the assembly into the slot at the top of the Drylin rails -short bearing to edge length at the front, long bearing to edge length at the back.

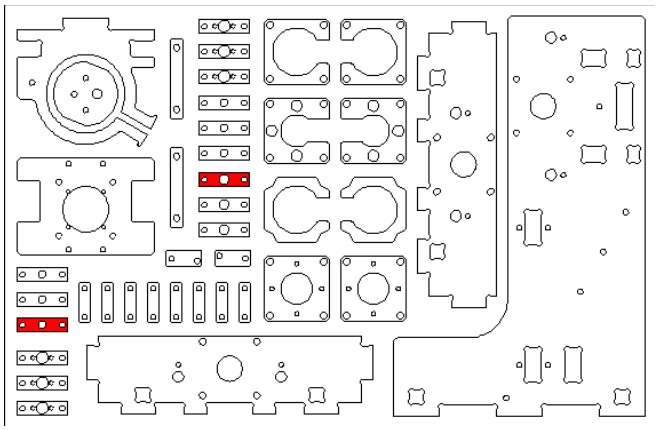


Thread the two 65mm clamping screws through the single rear clamp and into the two front clamps taking account of their shape and orientation. Tighten the Nyloc nuts while pressing down on the clamps so that the upper bearing plate sits horizontal but is still just able to slide in and out.

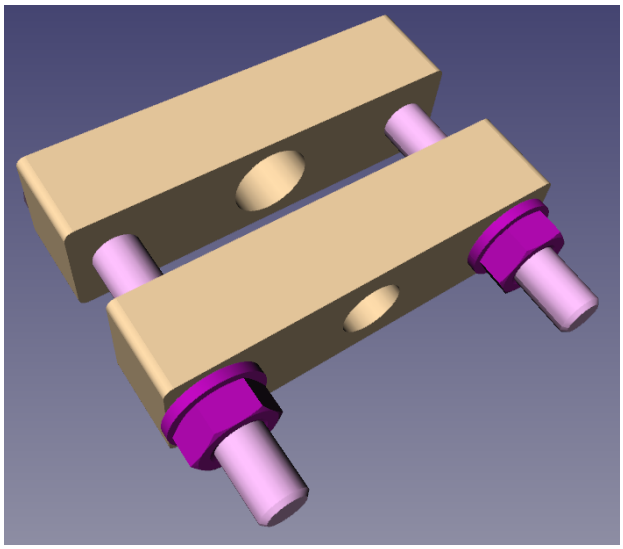


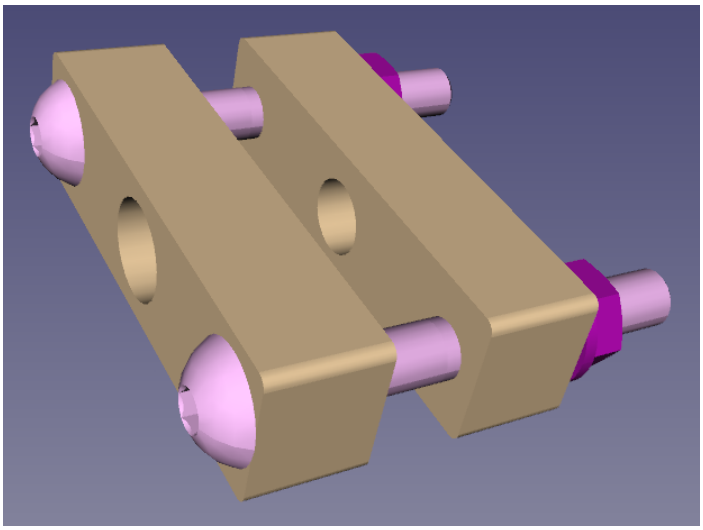
Z Axis Lead Screw And Nut Block Part 1

Parts: 2 M5x40mm socket head buttons, 2 M5 washers, 2 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



Screw the parts together as shown. The Nyloc nuts are adjacent to the piece with the M8 thread tapped into it. Leave enough distance between the two pieces to just slide an M5 nut in.

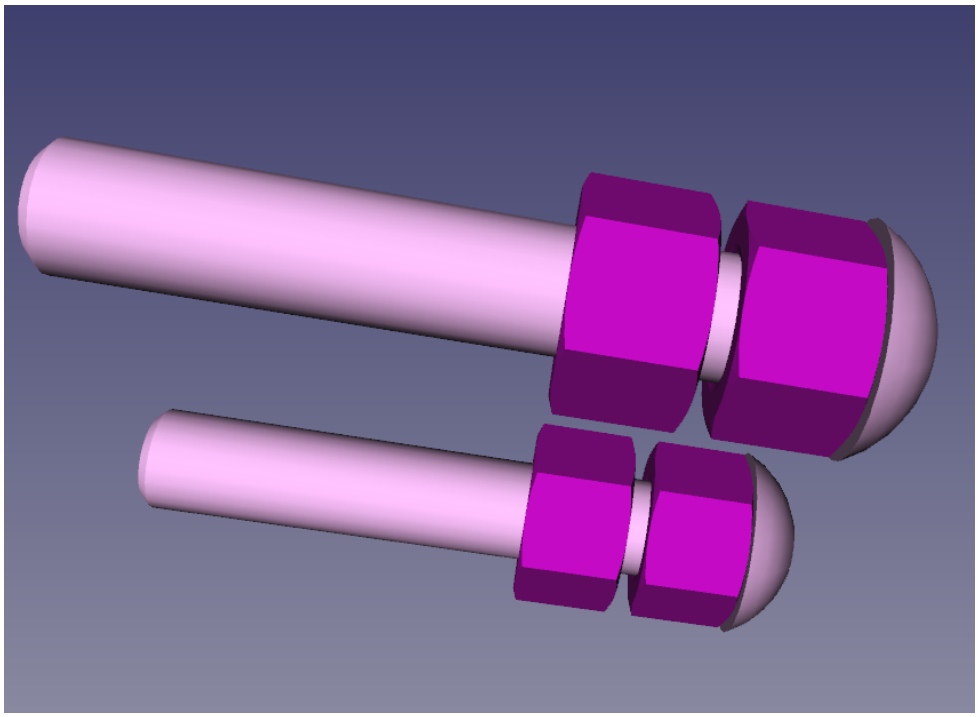




Z Axis Lead Screw And Nut Block Part 2

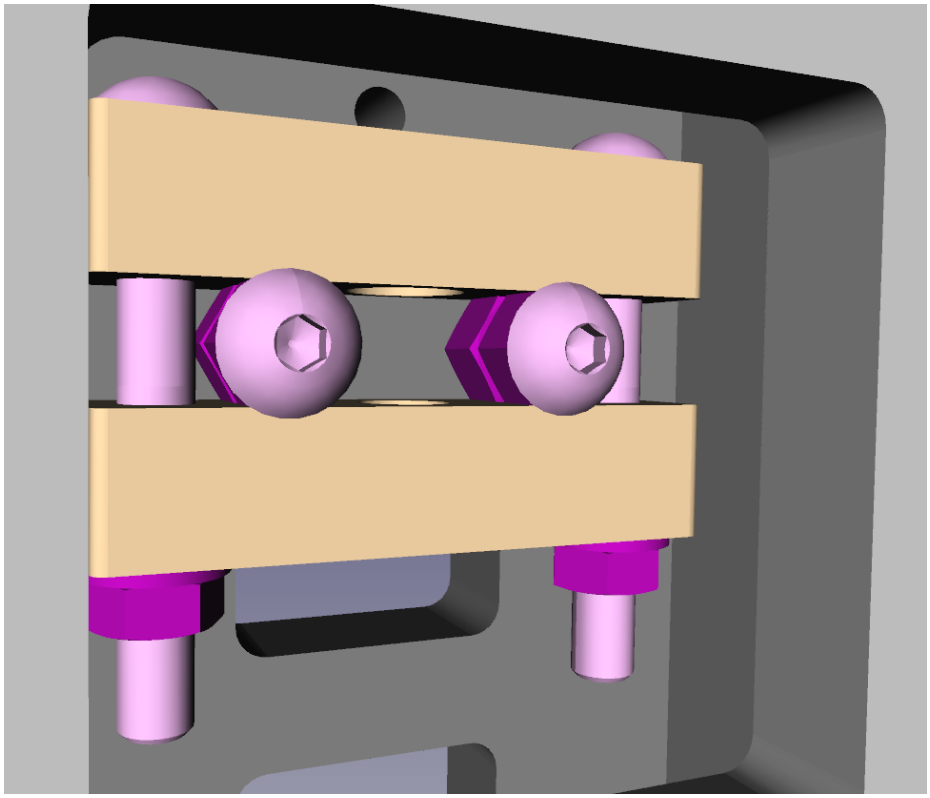
Parts: 2 M5x30mm socket head buttons, 4 M5 full hex nuts.

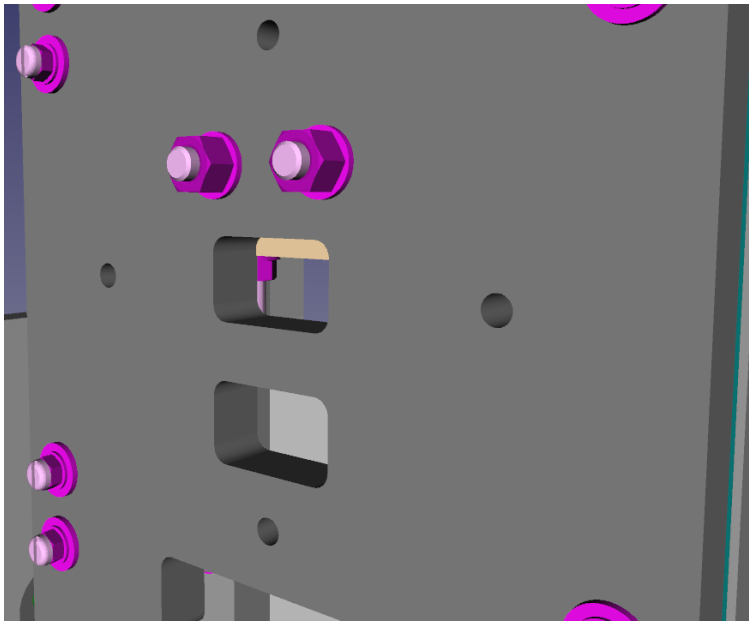
Snug a full hex nut onto each machine screw. Then add a second nut to the machine screw leaving approximately one millimetre between them with the nut faces aligned.



Z Axis Lead Screw And Nut Block Part 3

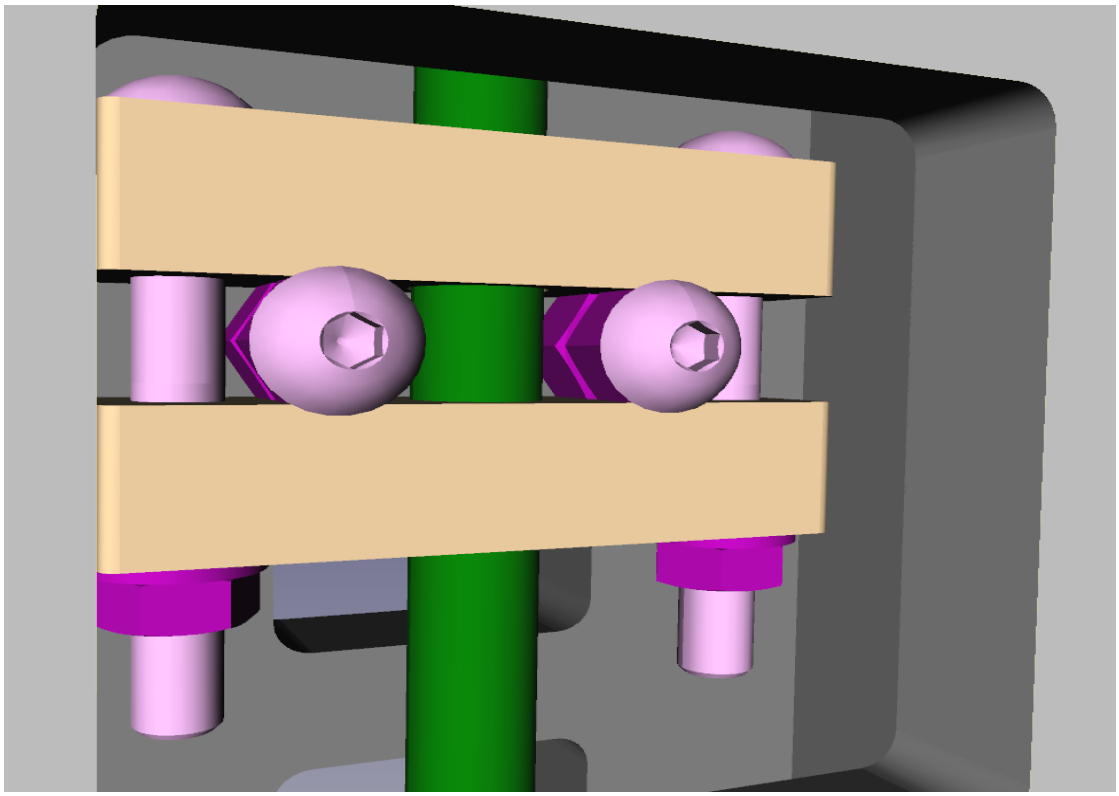
Parts: 2 M5 washers, 2 M5 Nyloc nuts.
Insert the mounting screws into the nut block assembly and insert the complete assembly through the hole in the back of the main X axis plate so that the mounting screws exit through the front of the Z axis main plate. The heads of the screws should just cover both sides of the nut blocks. Fit the washers and Nyloc nuts to the ends of the mounting screws. Make sure to stop the mounting screws and full hex nuts from rotating by holding them in place with the Allen key while tightening the Nyloc nuts. Do not snug the Nyloc nuts yet. Make sure the nut block can still slide from side to side.





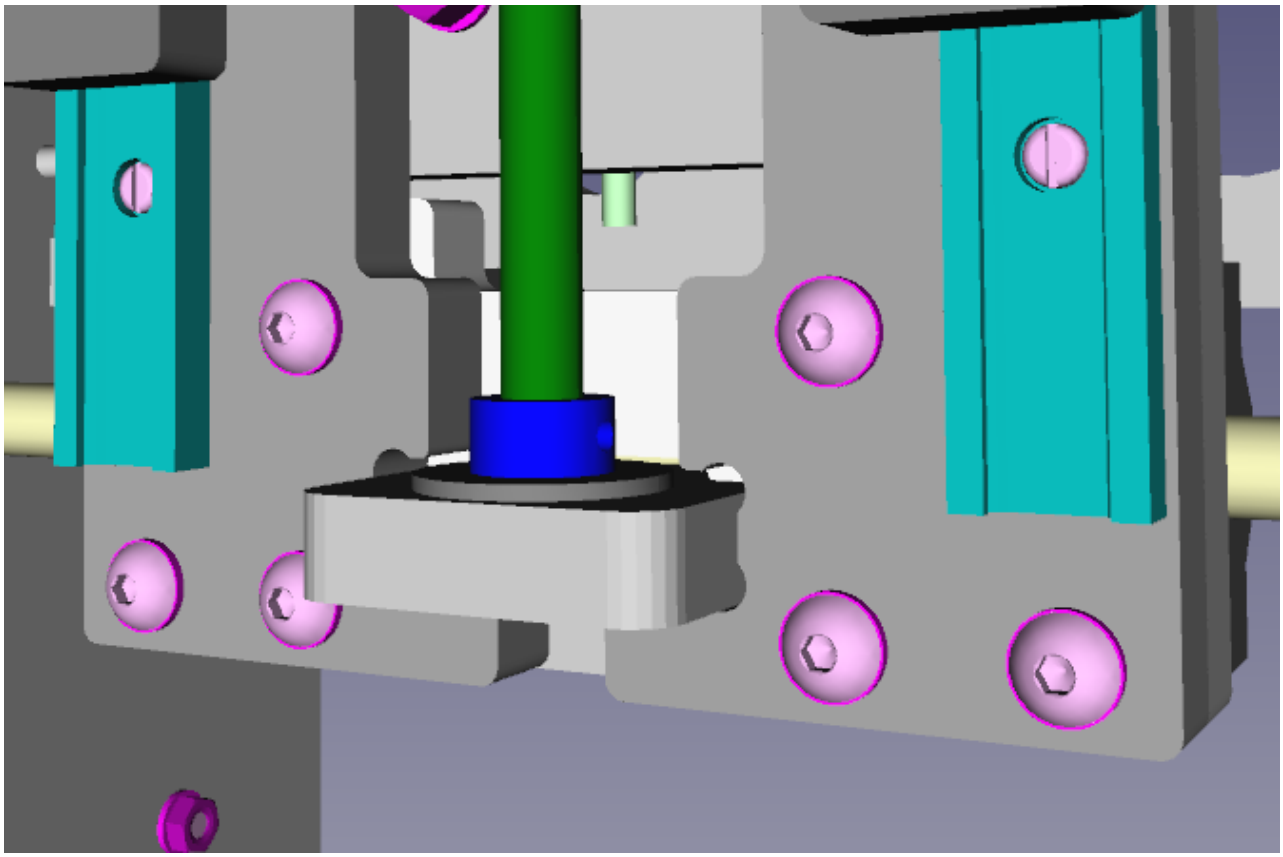
Z Axis Lead Screw And Nut Block Part 4

Parts: 1 lead screw.
Thread the lead screw through the nut block from above. It may be easier to temporarily remove the upper flanged bearing.
Slide the Z axis upper bearing plate in or out until it is aligned over the Z axis lead screw and nut block. Replace the bearing.



Z Axis Lead Screw And Nut Block Part 5

Parts: 1 lock collar.
Continue threading the lead screw down until it is almost at the lower bearing. Slide the lock collar over the lead screw without tightening its grub screw and continue to thread the lead screw down through the lower bearing, sliding the Z axis lower bearing plate in or out as appropriate. Once the lead screw is into the lower bearing you can temporarily tighten the grub screw so the lead screw cannot drop any lower.



Z Axis Lead Screw And Nut Block Part 6

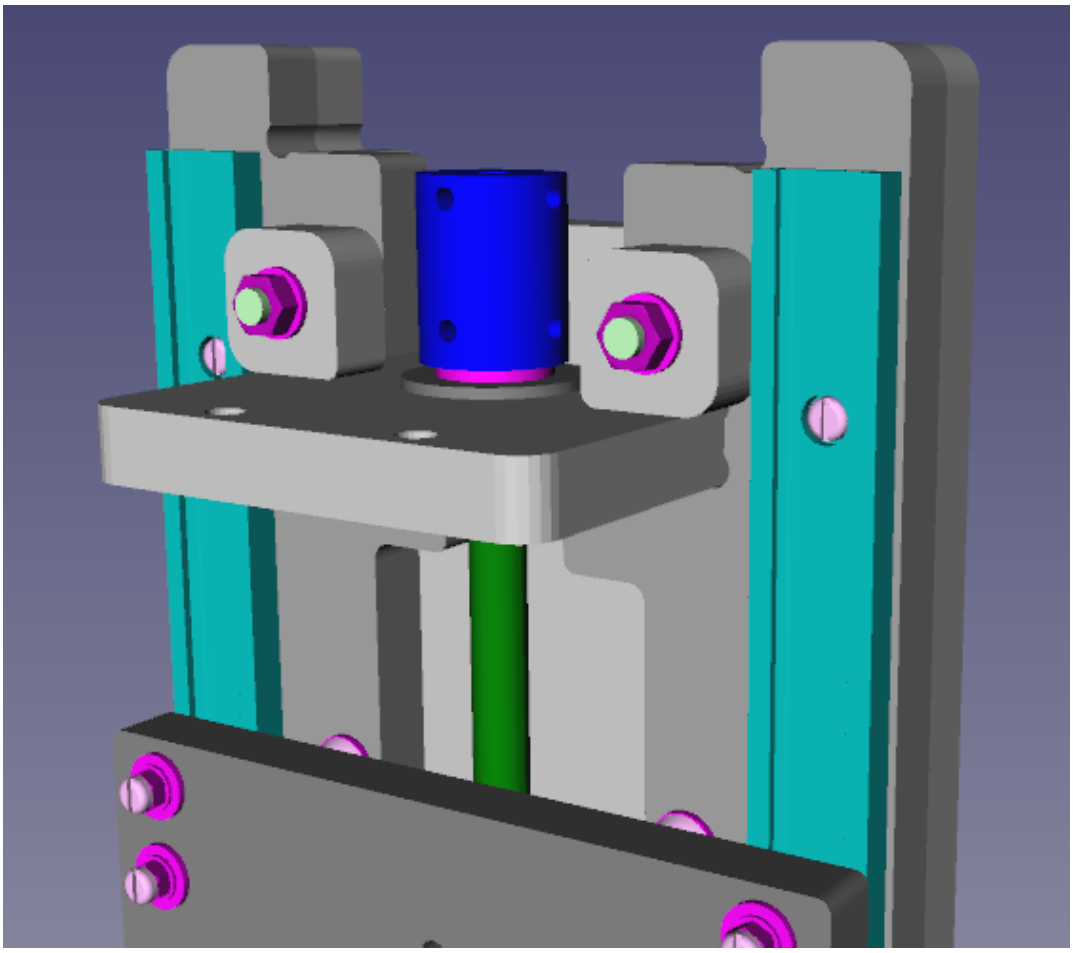
The four screws that are holding the nut block should still be loose at this stage. You now need to progressively tighten them so that the nut block has minimal up and down movement, minimal side to side or twisting movement but still allows the Z axis to move up and down without binding or excessive stiffness when you rotate the lead screw.
You may also need to slide the upper and lower bearing plates in or out to maintain alignment.
Take care when tightening the nut block mounting screws that the full hex nuts keep their faces parallel to the nut blocks. You can do this by holding the screw in position with the Allen key and only tightening the Nyloc nut on the front of the Z axis main plate.

This procedure is fiddly particularly since you have to use the cut out in the X axis main plate to reach the Nyloc nuts of the nut block. It is best to make small adjustments and test how it performs repeatedly. The nut block will loosen over time as it wears and its performance can be enhanced by spraying the lead screw with silicone-based furniture spray polish. That will lubricate the lead screw and nut block without making it sticky.

Once the nut block is aligned and sufficiently tightened you should also make sure the Z axis lower bearing plate is tightly clamped in position and tighten snugly the six machine screws which go into the lower X axis bearing blocks (see picture on previous page).
Similarly, you should tighten snugly the Z axis upper bearing plate clamping screws so that the upper bearing plate is held horizontal without any wobble and cannot slide in or out any more.

Z Axis Lead Screw And Nut Block Part 7

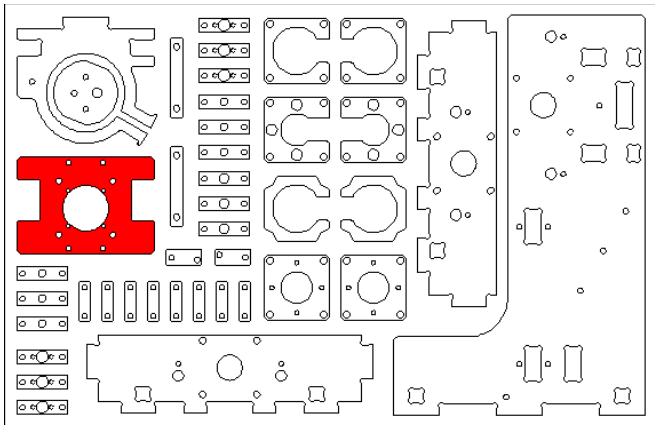
Parts: 1 M8 washer, 1 flexible shaft coupler.
Place the washer over the lead screw on the upper flanged bearing. Loosen the locking collar on the lower flanged bearing and allow the lead screw to slide down until about 8.5mm of lead screw protrudes above the washer. Snugly tighten the grub screw of the lock collar.
Slide a flexible shaft coupler (8mm→5mm for NEMA17 motors, 8mm→6.35mm for NEMA23) over the lead screw until it sits on the washer and snugly tighten the coupler's grub screws. The purpose is to distribute the weight of the Z axis between the upper and lower bearing plates.



Z Axis Motor Mounting Preparation Work

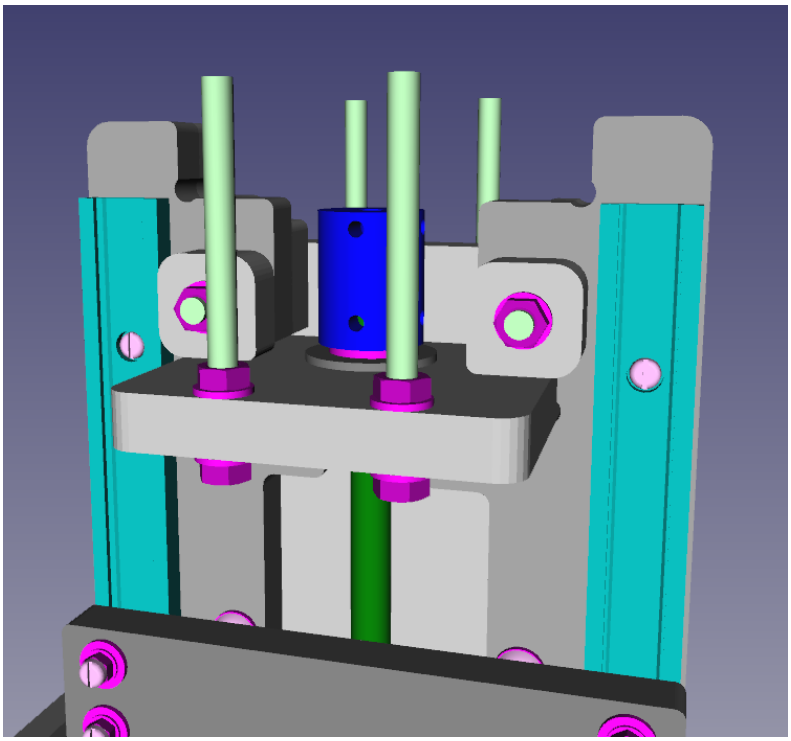
We will now cut the mounting screws for the Z axis motor plate.
Take the 5mm threaded rod and measure off 65mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 65mm section off.
Using the file, remove any sharp edges on the threaded rod.
Repeat the procedure three more times so you end up with four 65mm threaded rods.

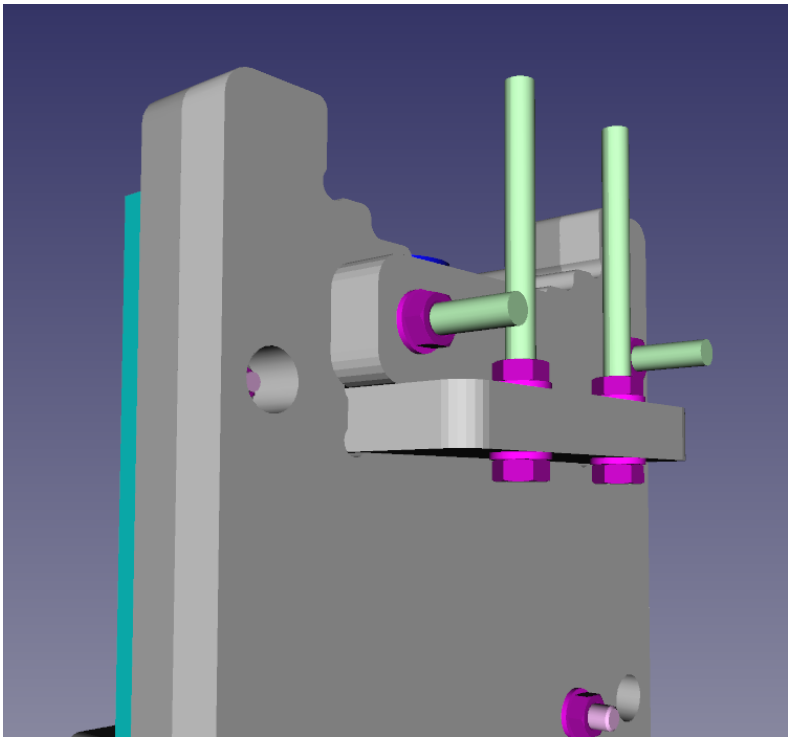
Locate the part shown below, cut it out, file it, remove films, wash and dry it.



Z Axis Motor Mounting

Parts: 4 motor plate mounting screws, 8 M5 washers, 8 M5 Nyloc nuts.
Fit the 4 motor plate mounting screws as shown. Do not tighten them at this stage.

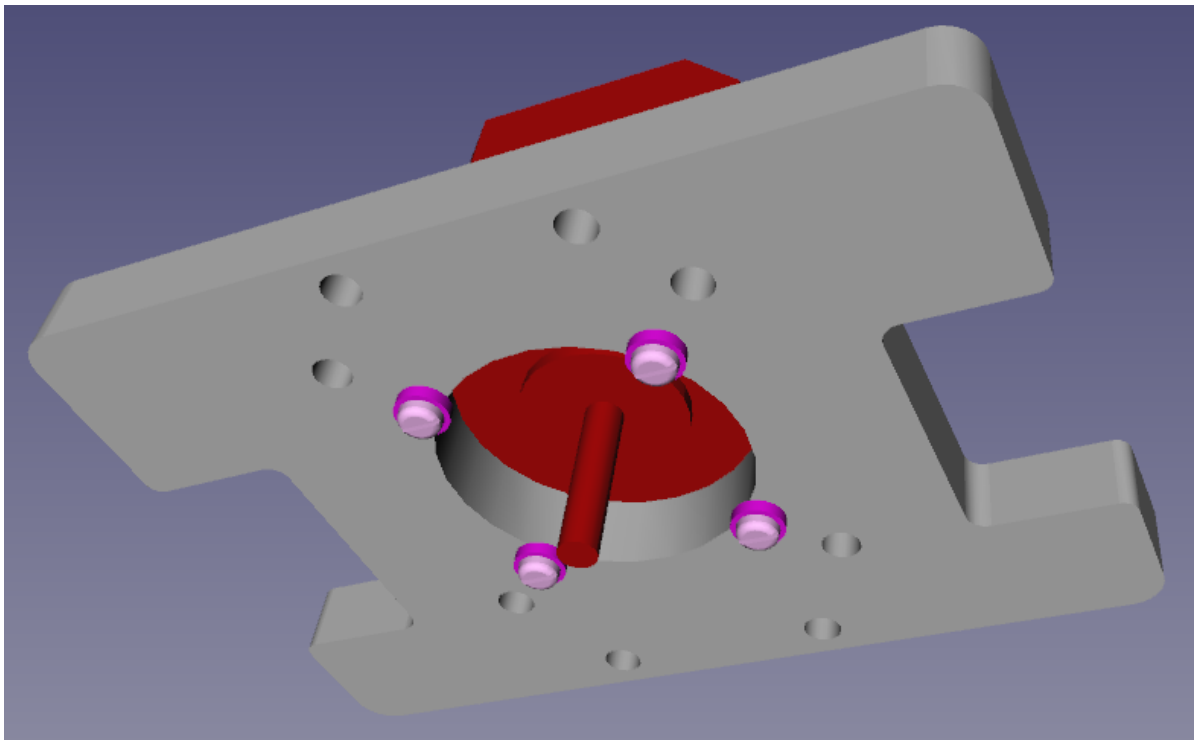




If you are using a NEMA17 motor for the Z axis, proceed to the next section.
If you are using a NEMA23 motor for the Z axis, proceed to the section titled “Z Axis NEMA23 Motor Mounting”.

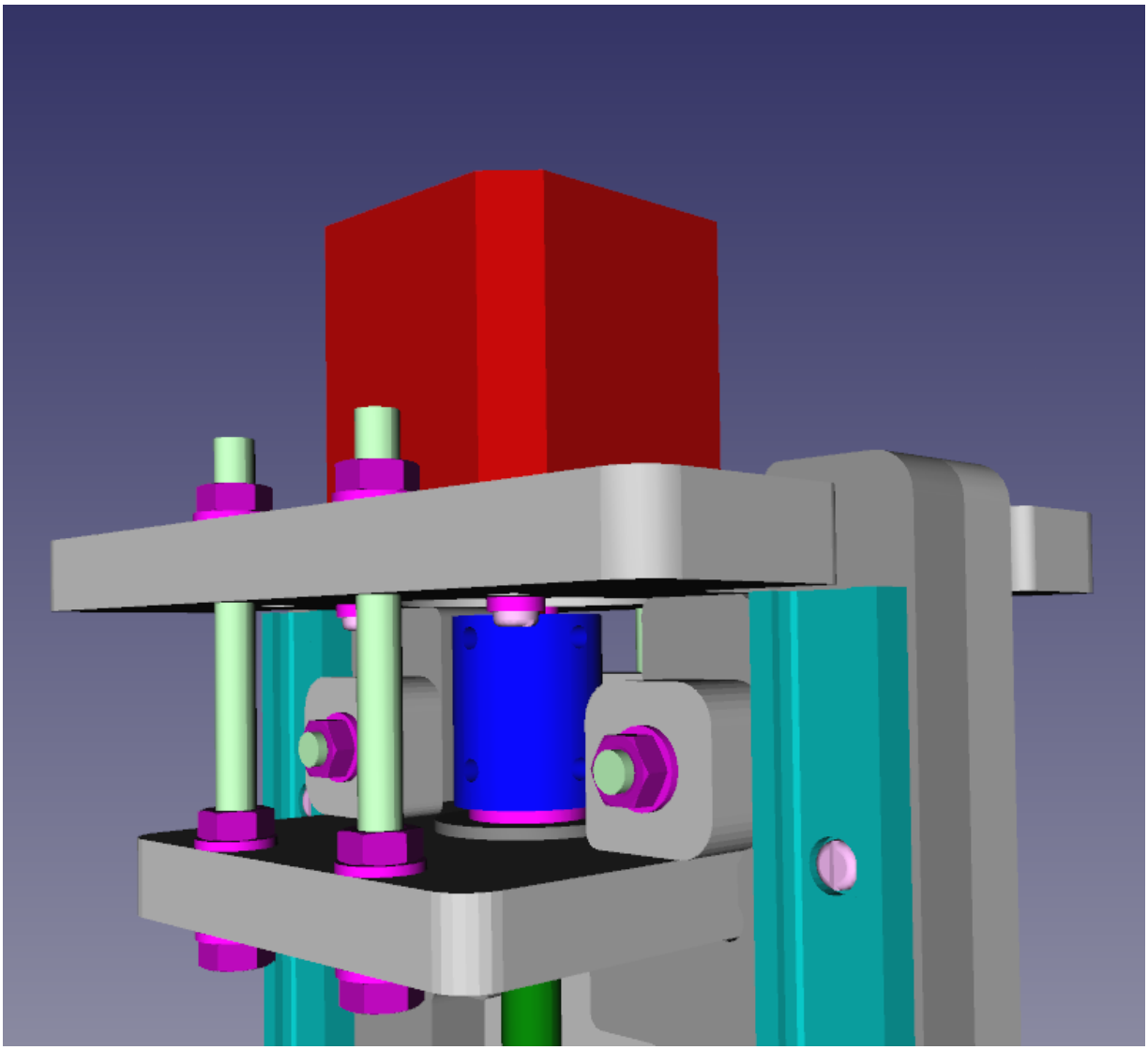
Z Axis NEMA17 Motor Mounting Part 1

Parts: 4 M3x16mm slotted pan heads, 16 M3 washers.
Screw the motor to the mounting plate as shown. Depending on the thickness of the Acrylic and the depth of the threaded holes in the motor you may need three or four washers to achieve a snug fit.



Z Axis NEMA17 Motor Mounting Part 2

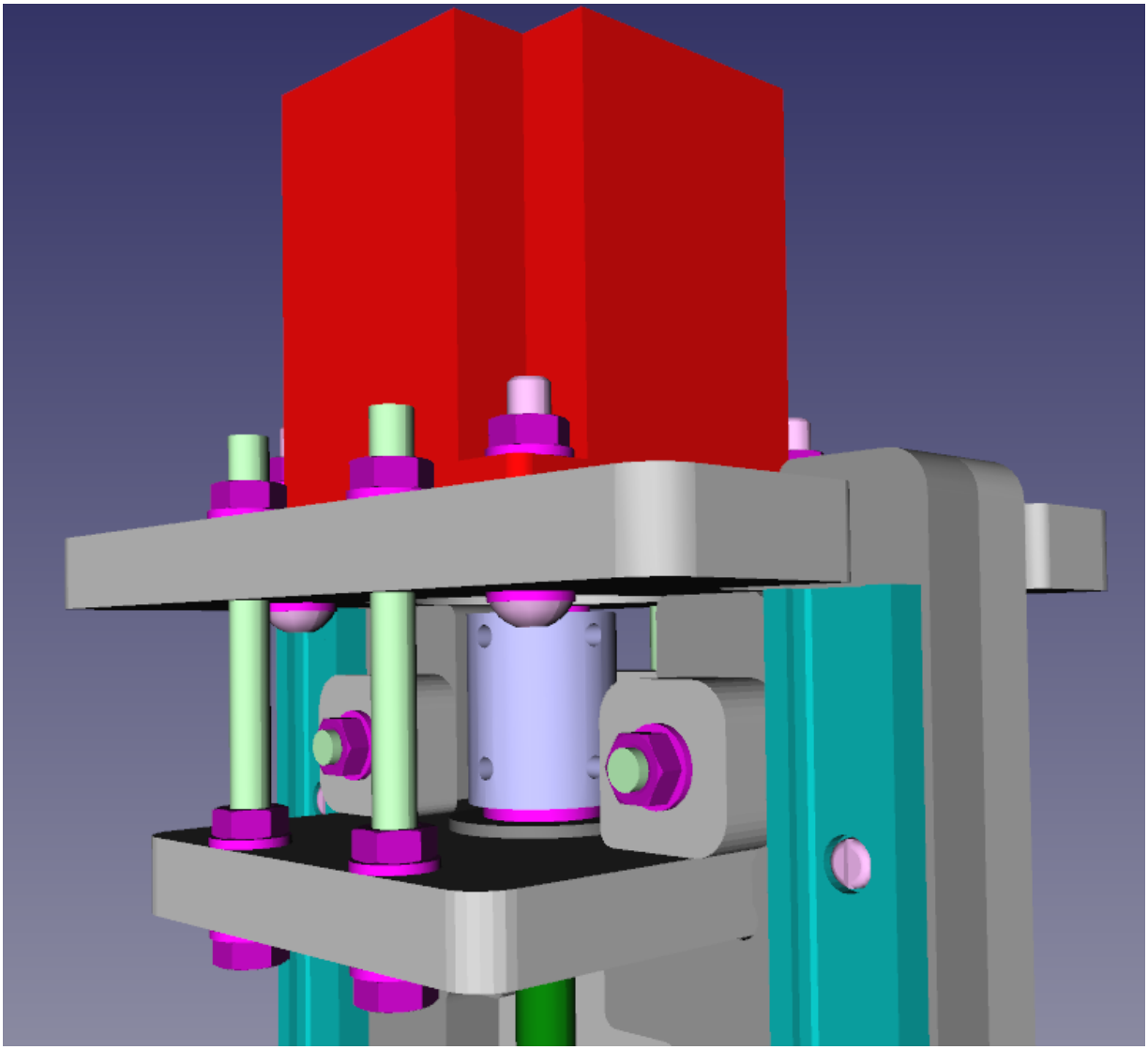
Parts: 4 M5 washers, 4 M5 Nyloc nuts.
Place the Z motor assembly over the motor plate mounting screws while ensuring the flat on the motor shaft aligns with one of the grub screws of the flexible shaft coupler. Add the washers and Nyloc nuts to the mounting screws and snugly tighten while ensuring that the motor plate remains horizontal. Then tighten the Nyloc nuts above the upper bearing plate that were left loose in the previous operation. Finally, tighten the grub screws of the flexible shaft coupler.



Congratulations - The Z Axis is now complete.

Z Axis NEMA23 Motor Mounting

Parts: 4 M5x25mm socket head buttons 12 M5 washers, 8 M5 Nyloc nuts.
Place the Z motor plate over the motor plate mounting screws. Add the washers and Nyloc nuts to the mounting screws and loosely tighten while ensuring that the motor plate remains horizontal and vertically aligned above the upper bearing plate.
Place the motor on the motor plate while ensuring the flat on the motor shaft aligns with one of the grub screws of the flexible shaft coupler. Fasten the motor snugly with the screws, washers and Nyloc nuts.
Snug the Nyloc nuts at the top of the motor plate mounting screws and then tighten the Nyloc nuts above the upper bearing plate that were left loose in the previous operation. Finally, tighten the grub screws of the flexible shaft coupler.



Congratulations - The Z Axis is now complete.

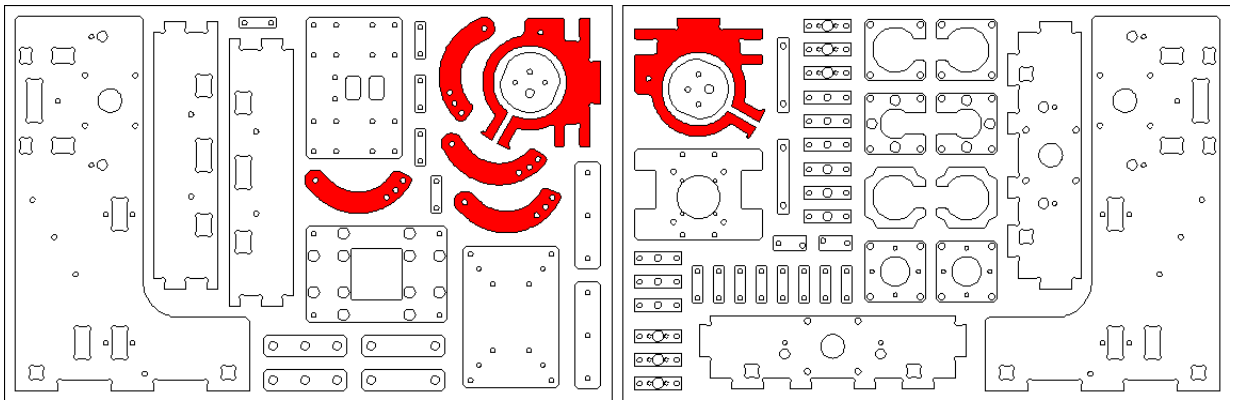
Router Mount Preparation Work

We will now cut the arm hinge for the router mount.
Take the 5mm threaded rod and measure off 90mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 90mm section off.
Using the file, remove any sharp edges on the threaded rod.

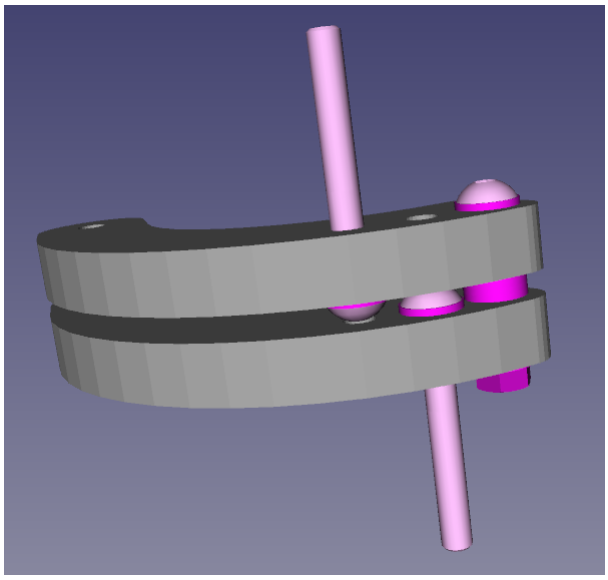
We will now cut the fastener rods for the router clamp closure.
Take the 5mm threaded rod and measure off 65mm.
If you have a vice, wrap some cardboard around the threads so they are not damaged and clamp it in the vice.
Measure the length again and use the junior hacksaw to cut the 65mm section off.
Using the file, remove any sharp edges on the threaded rod.
Repeat the procedure three more times so you end up with four 65mm threaded rods.

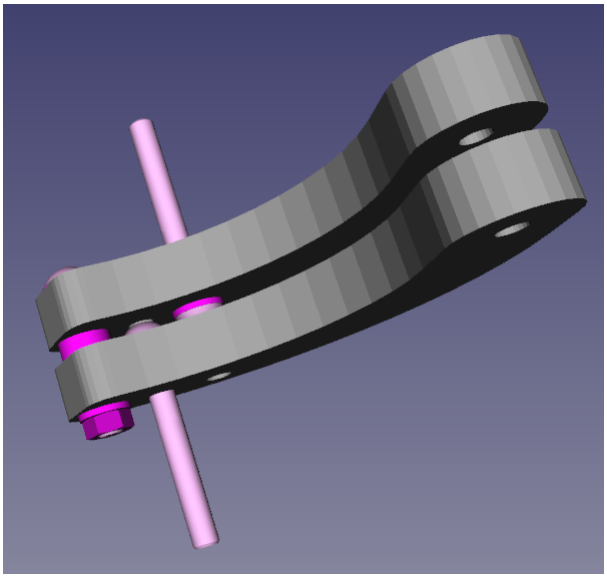
Router Mount Arms Part 1

Parts: 2 M5x40mm socket head buttons, 1 M5x30mm socket head button, 8 M5 washers, 1 M5 Nyloc nut.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



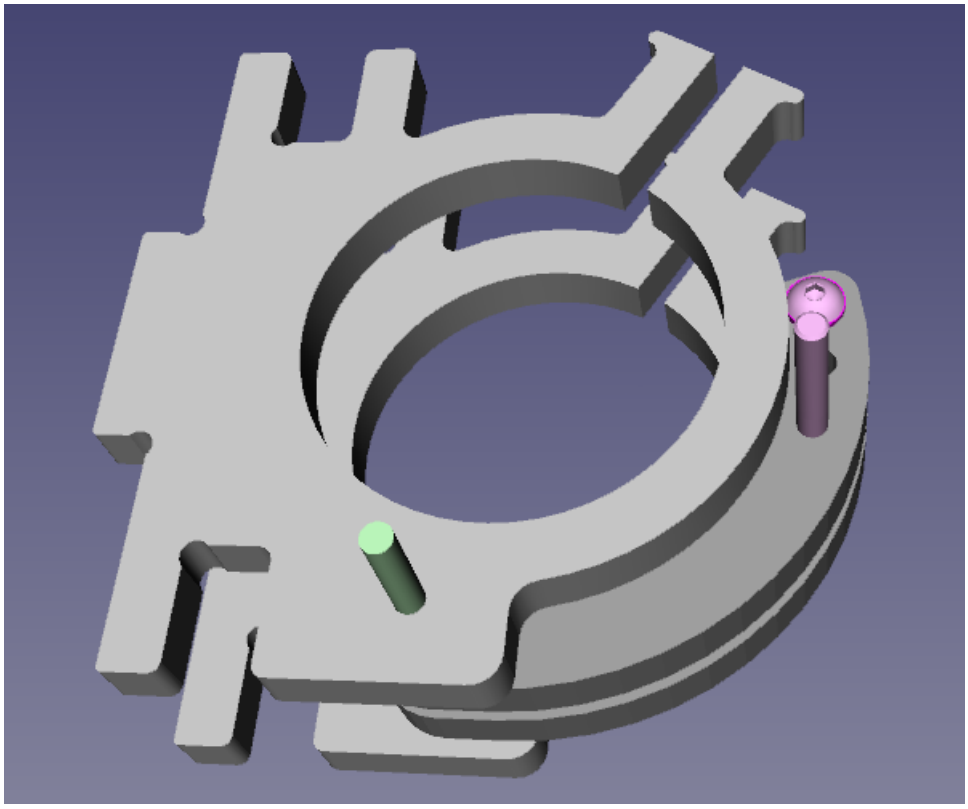
Start by threading the M5X30mm through the last of the three holes on the clamp arms placing four washers between the two arms. Insert the two M5X40mm screws and washers into the adjacent holes as shown. Then add the final M5 washer and Nyloc nut to the M5X30mm screw. Tighten it but keep it loose for now.

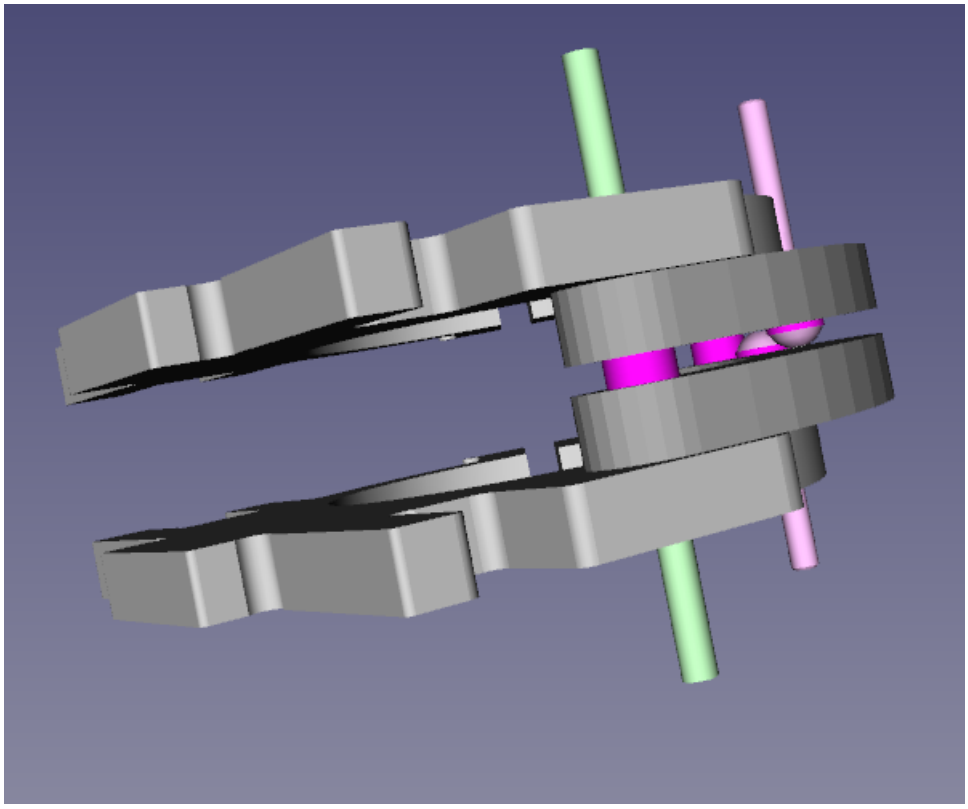




Router Mount Arms Part 2

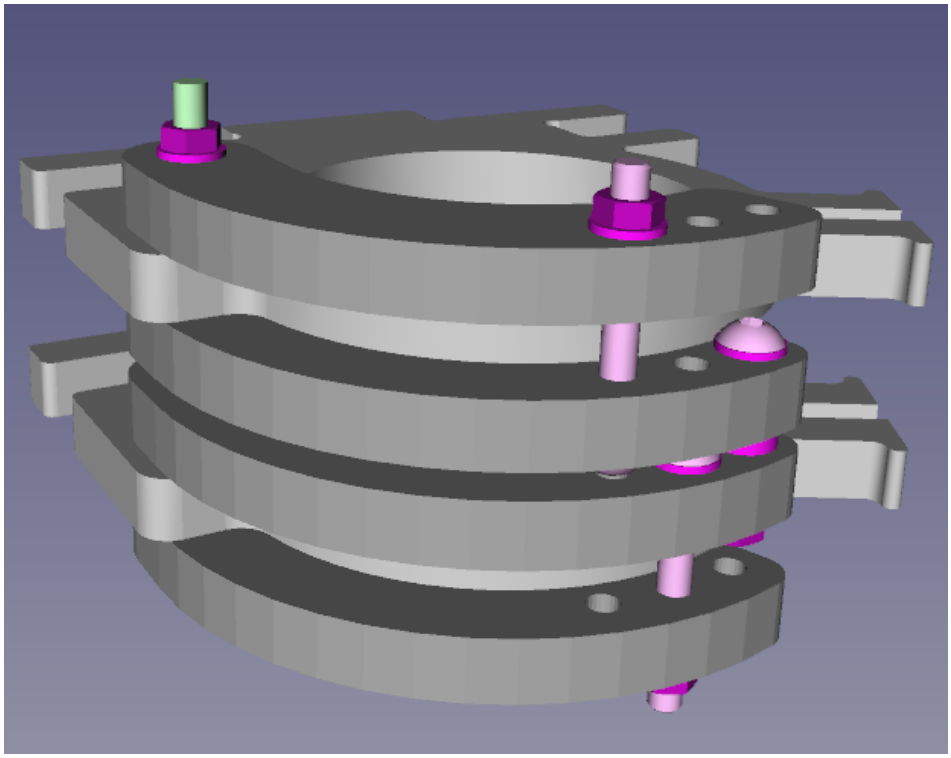
Parts: 1 arm hinge rod, 4 M5 washers.
Align the parts as shown and slide the arm hinge through. When it is half way through, insert the four M5 washers.

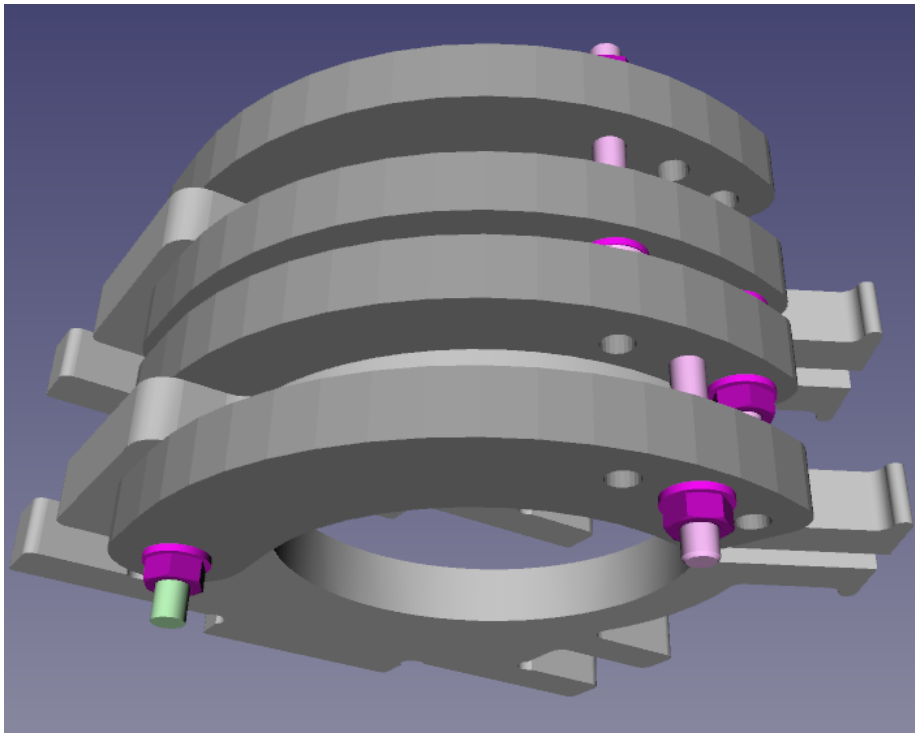




Router Mount Arms Part 3

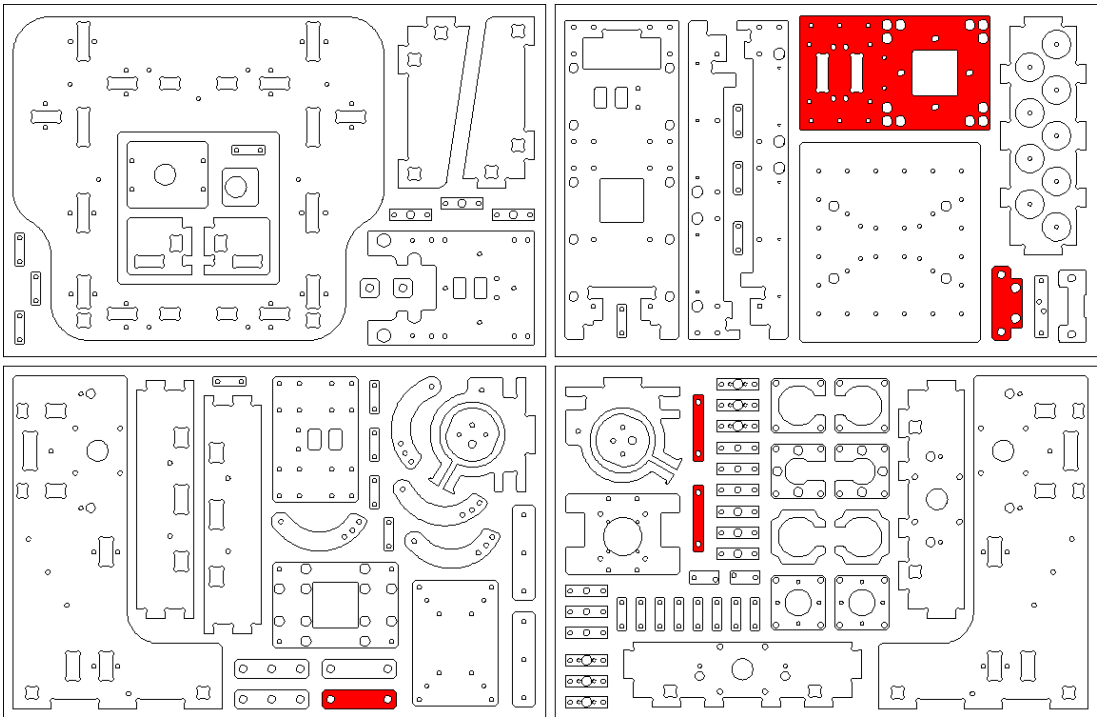
Parts: 4 M5 washers, 4 M5 Nyloc nuts.
Add the final two arms as shown and secure with the washers and Nyloc nuts. Leave the Nyloc nuts on the M5X40mm screws loose for now (feed your Allen key through the holes in the arms) but tighten the nuts on the arm hinge enough to make the hinge firm but not so tight as to lock it.



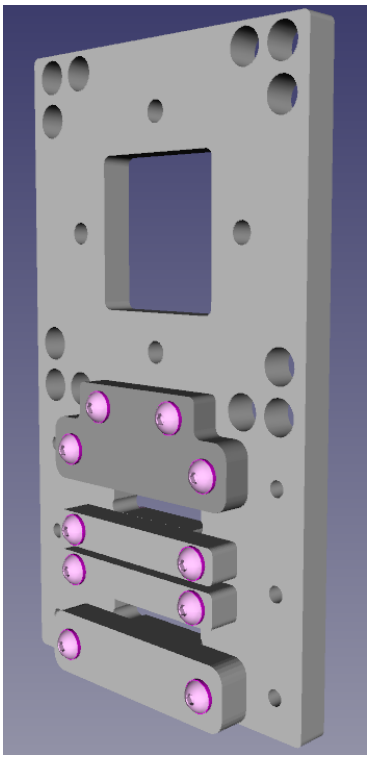


Router Mount Backing Plate

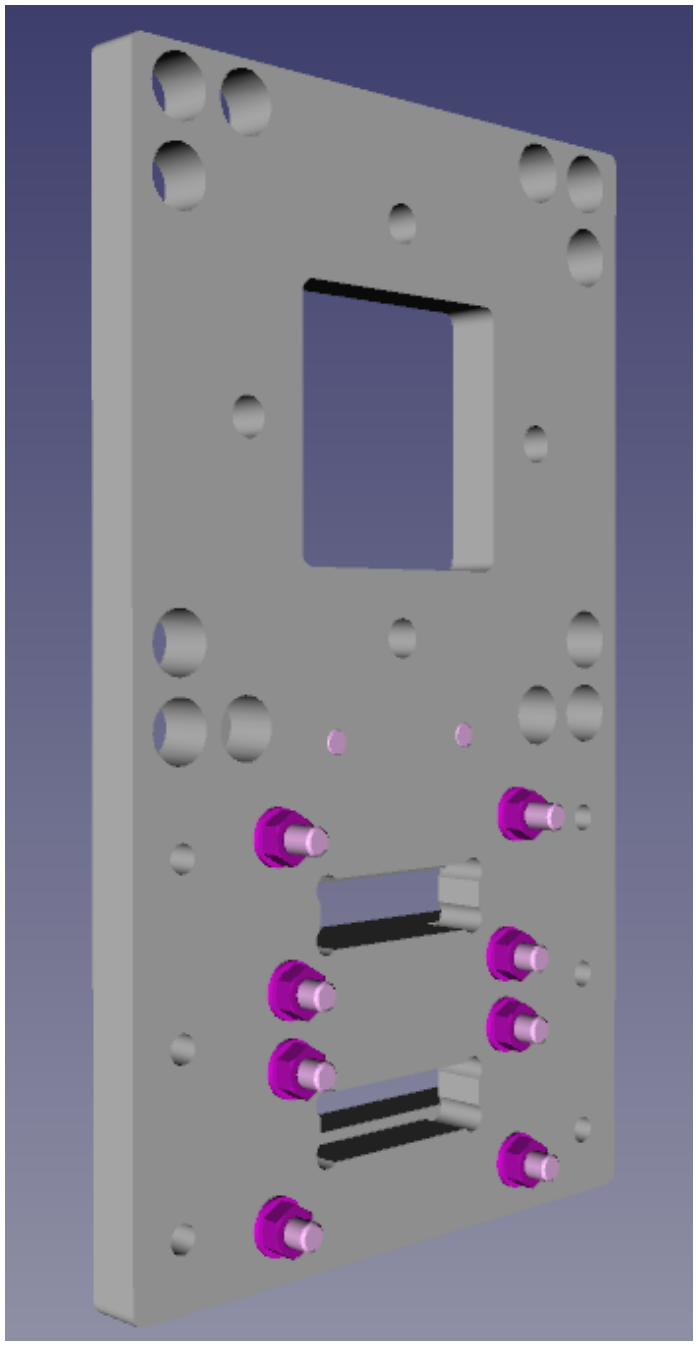
Parts: 2 M5x20mm socket head buttons, 8 M5x30mm socket head buttons, 18 M5 washers, 8 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



Start by screwing the top two holes of the four hole part with the M5x20mm screws and washers. These screw directly into two tapped holes in the router mount backing plate. Tighten the screws but leave the part still mobile.

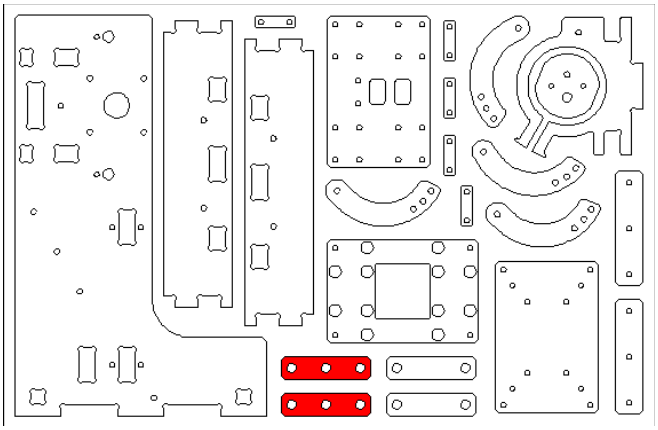


Attach the other parts using the M5x30mm screws, washers and Nyloc nuts. You will have noticed that one side of the parts did not have tabs so that they were as smooth as possible. The smooth side should face the slots in the router mount backing plate for best results. Tighten the screws but leave the parts still mobile.



Router Mount Final Assembly Part 1

Parts: 4 M5x40mm socket head buttons, 8 M5 washers, 4 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



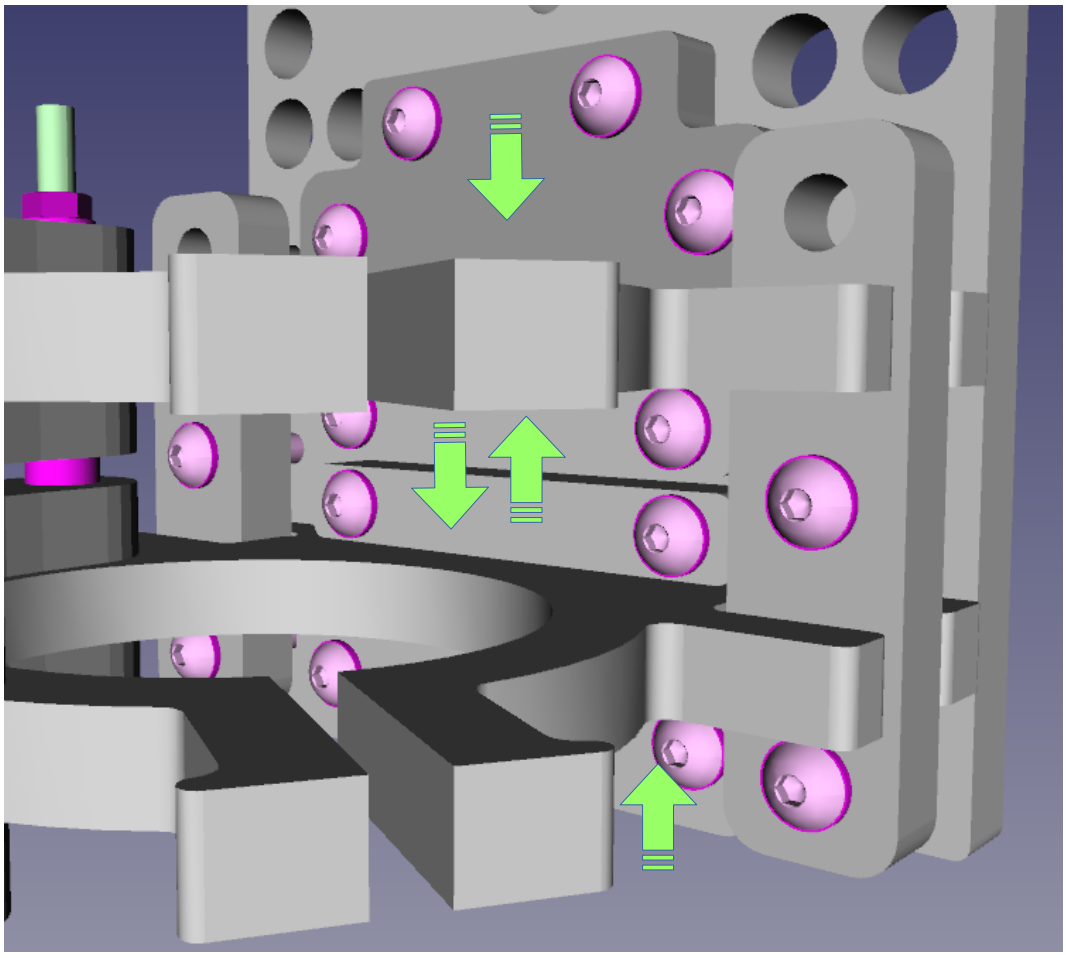
Fit the screws and washers into the lower two holes of the clamps and slide the side clamps into the slots on the side of the router mount assembly. Then slide the router mount assembly into the router mount backing plate.

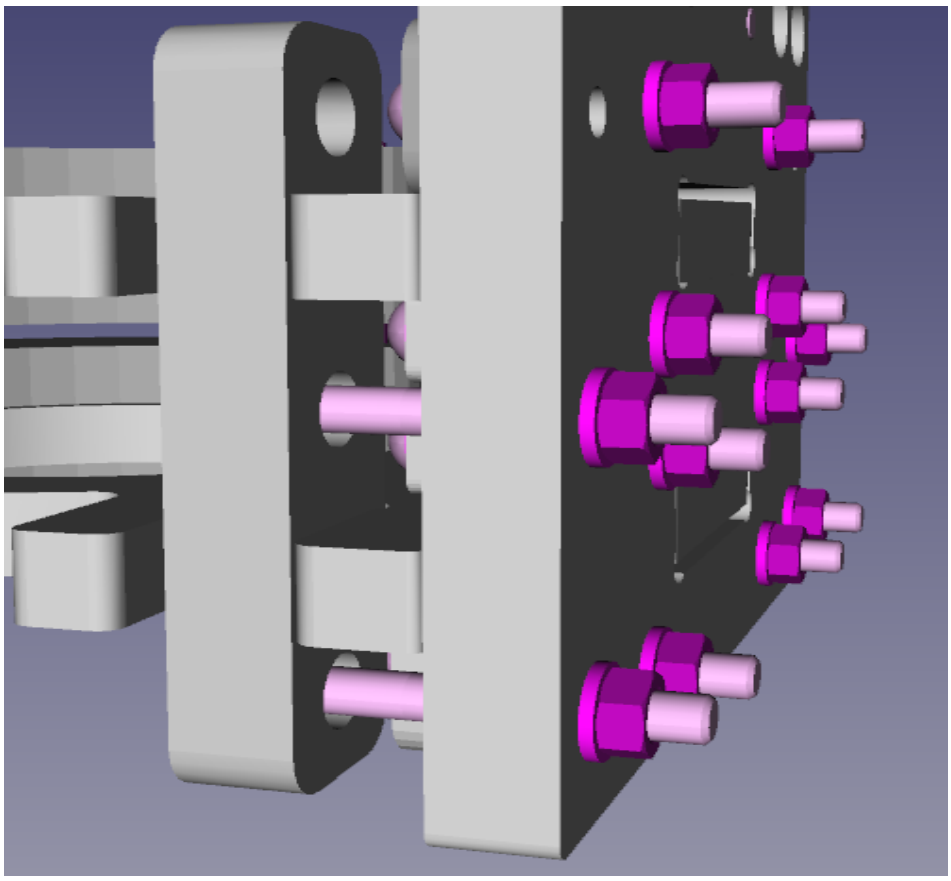
The exact fit of the two assemblies will depend on the thickness of the Acrylic sheets. If the thickness approaches either limit of the manufacturer's tolerance, it may necessary to add or remove a washer to both of the two groups of four washers in the router mount assembly. Ideally the tab of the top router mount should sit flush on the bottom of the upper slot.

Add the remaining washers and Nyloc nuts and tighten them until the router mount assembly is kept flush and perpendicular to the router mount backing plate but so that the router mount assembly can still be slid up and down.
You may find it difficult to tighten the middle screw on the left hand side clamp depending on the size and shape of your Allen key. If so, wrap a piece of cardboard around the exposed thread and use small pliers to grip the screw while tightening with a spanner.

Push the upper clamp of the upper slot down (the one with four screws) and snugly tighten its upper two screws.
Push the lower clamp of the upper slot upwards firmly and snugly tighten the two screws.
You may find it easier to temporarily remove the upper clamp of the lower slot to achieve this.
Now push the upper clamp of the lower slot down and snugly tighten the two screws.
Push the lower clamp of the lower slot upwards firmly and snugly tighten the two screws.
Lastly, tighten the remaining two screws of the topmost clamp.

Ensure the two sides of the router mount assembly are flush with the edges of the router mount backing plate and that the two router mounts are parallel to each other and to the sides of the router mount backing plate
Tighten the side clamp screws just a little bit more to clamp the whole assembly together.

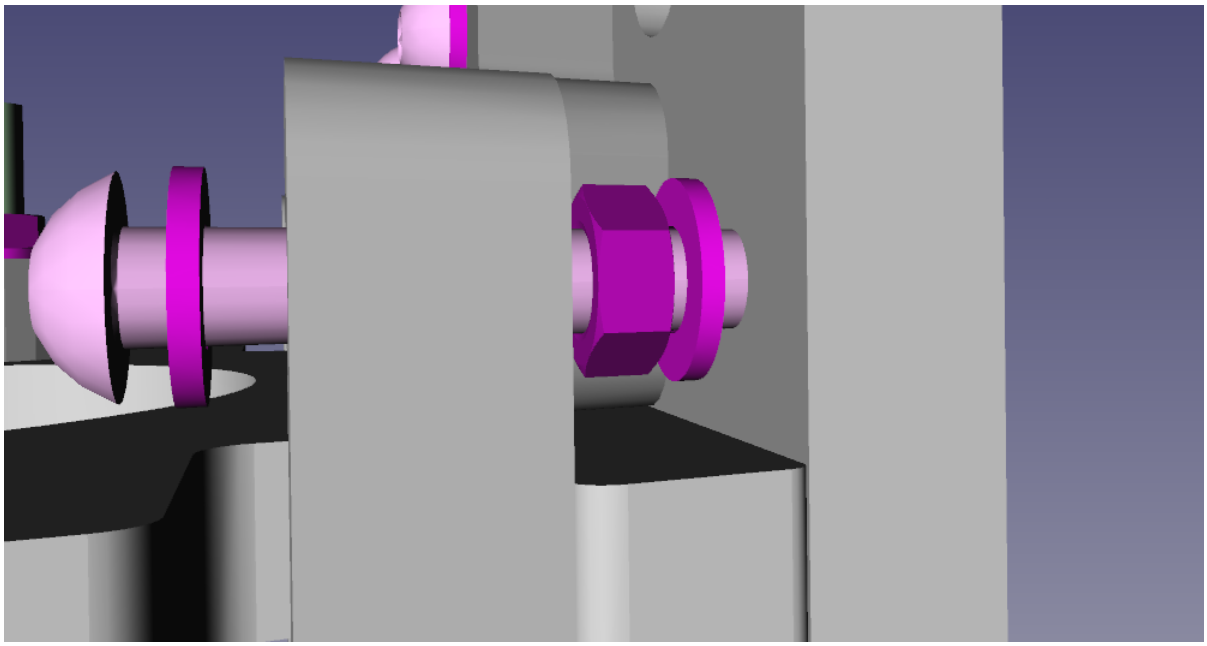




Router Mount Final Assembly Part 2

Parts: 2 M5x40mm socket head buttons, 4 M5x20mm socket head buttons, 8 M5 washers, 2 M5 full hex nuts.

Thread the two M5x40mm screws with the washers and full hex nuts through the top hole in the side clamps as shown.

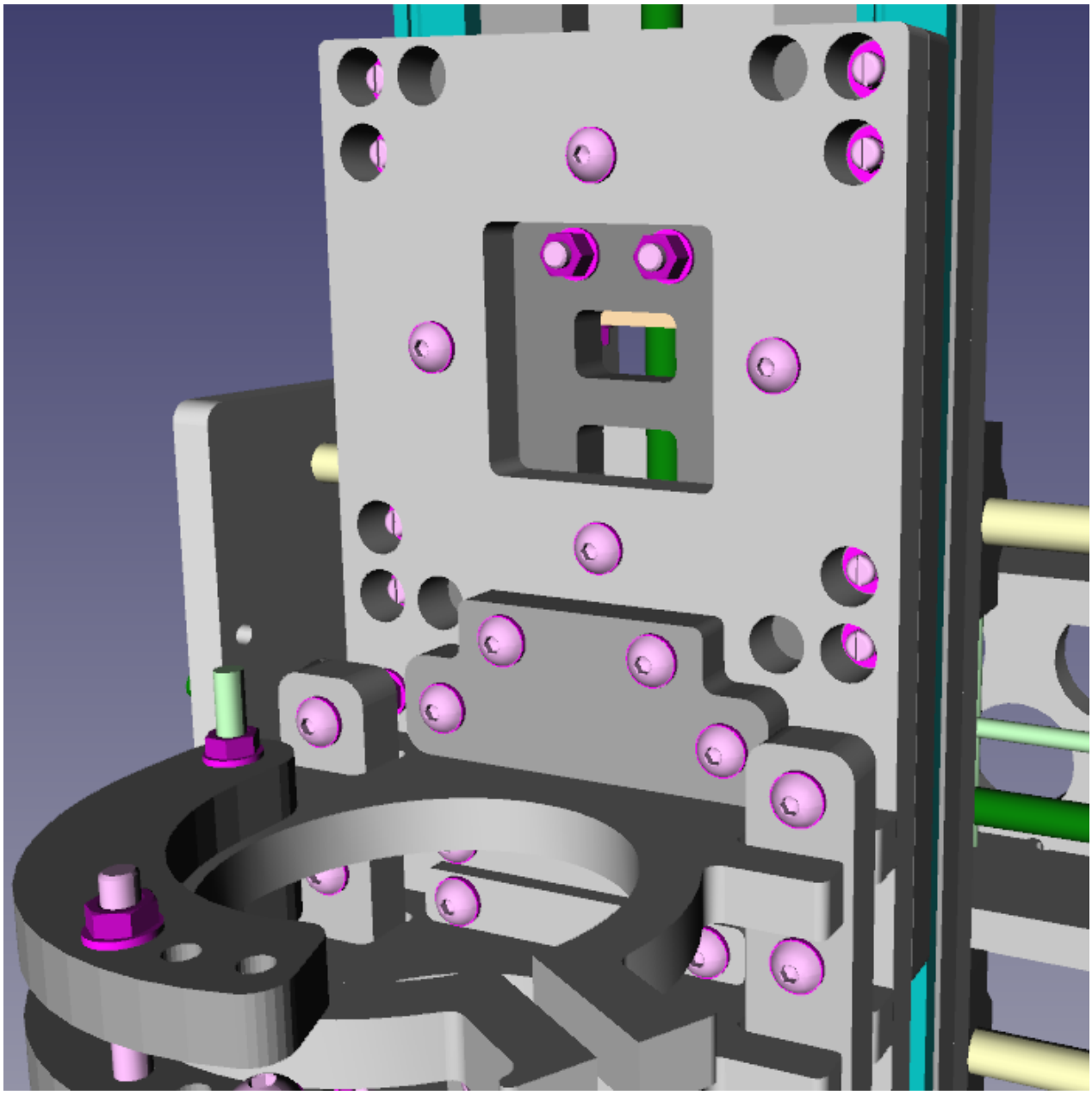


Offer the whole router mount assembly up to the Z axis main plate. It should fit flush over the plate such that the top side clamp screws align with the threaded holes in the Z axis main plate.
Chances are though that it fouls on at least one of the washers on the carriage mounting screws. If this happens then it is easiest if you lay the whole milling machine on its back so you don't have to fight gravity. Then identify which of the washers is fouling and loosen that screw to permit the washer to be repositioned.

When the two plates are sitting flush, start to screw both of the side clamp screws into the Z axis main plate. Don't allow the hex nuts to touch the Z axis main plate at this stage.

Unfortunately, access to the top left-hand side clamp screw is very limited. The best way to gain access to it is to unscrew and remove the Nyloc nut on the top of the router mount arm hinge and slide the hinge rod down until you can swing the top arm out of the way.

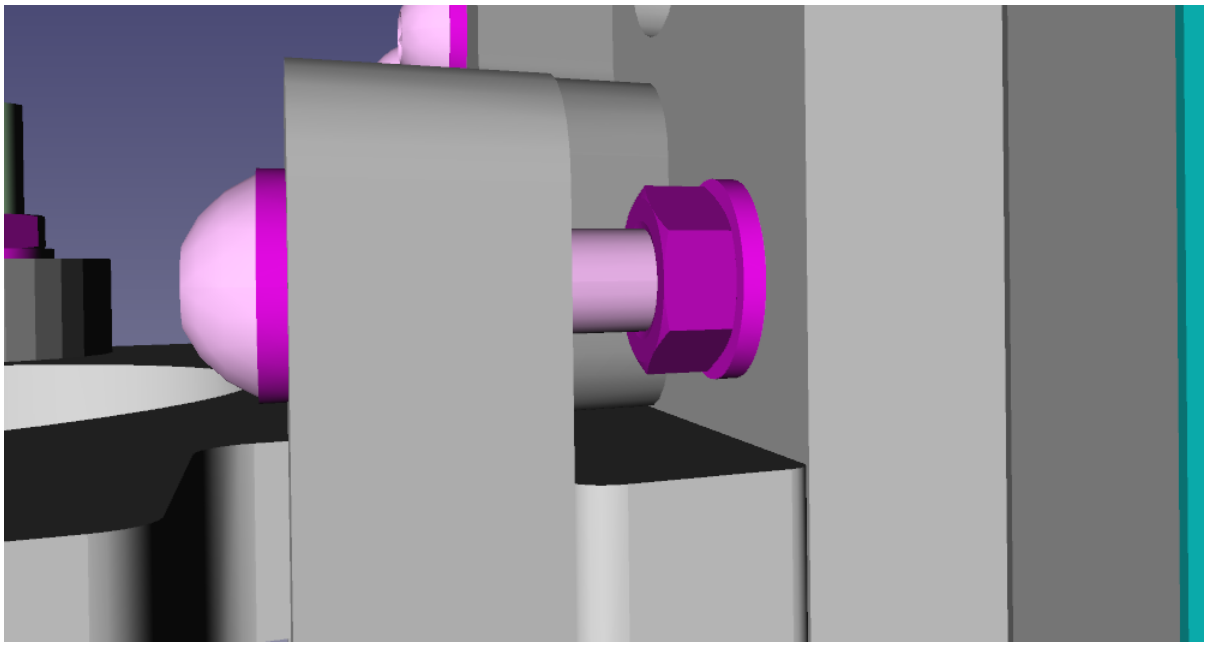
With both side clamp screws partially screwed into the Z axis main plate, partially screw the four M5x20mm screws and washers into the diamond shape threaded holes.



Ensure the router mount assembly is square to the Z axis main plate and tighten the four M5x20mm screws until just snug.

Now tighten the two side clamps screws until just snug.

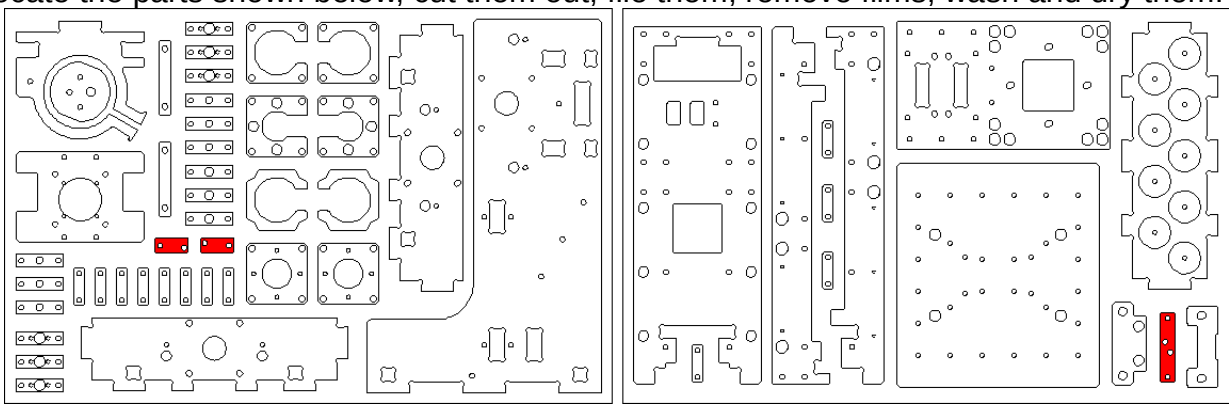
While holding the side clamp screws in position with an Allen key, use a spanner to tighten the hex nuts so they clamp the router mount backing plate to the Z axis main plate.



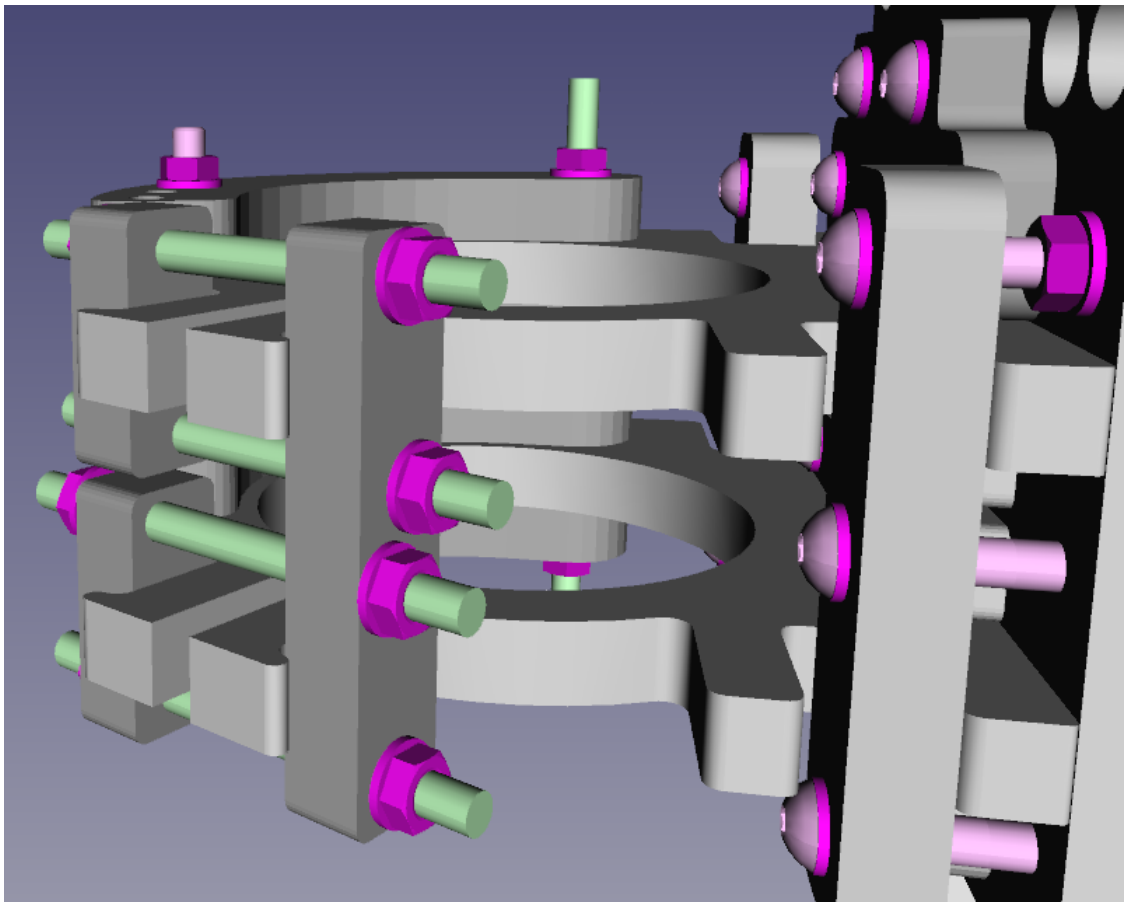
Swing the router arm back into position over the hinge, slide the hinge rod back up and replace the washer and Nyloc nut.
Stand the machine back upright again if required.

Router Mount Closure Clamps

Parts: 4 65mm fastener rods, 8 M5 washers, 8 M5 Nyloc nuts.
Locate the parts shown below, cut them out, file them, remove films, wash and dry them.



Align the three parts and thread the fastener rods through them. Add the washers and Nyloc nuts to both ends but do not tighten them at this stage.

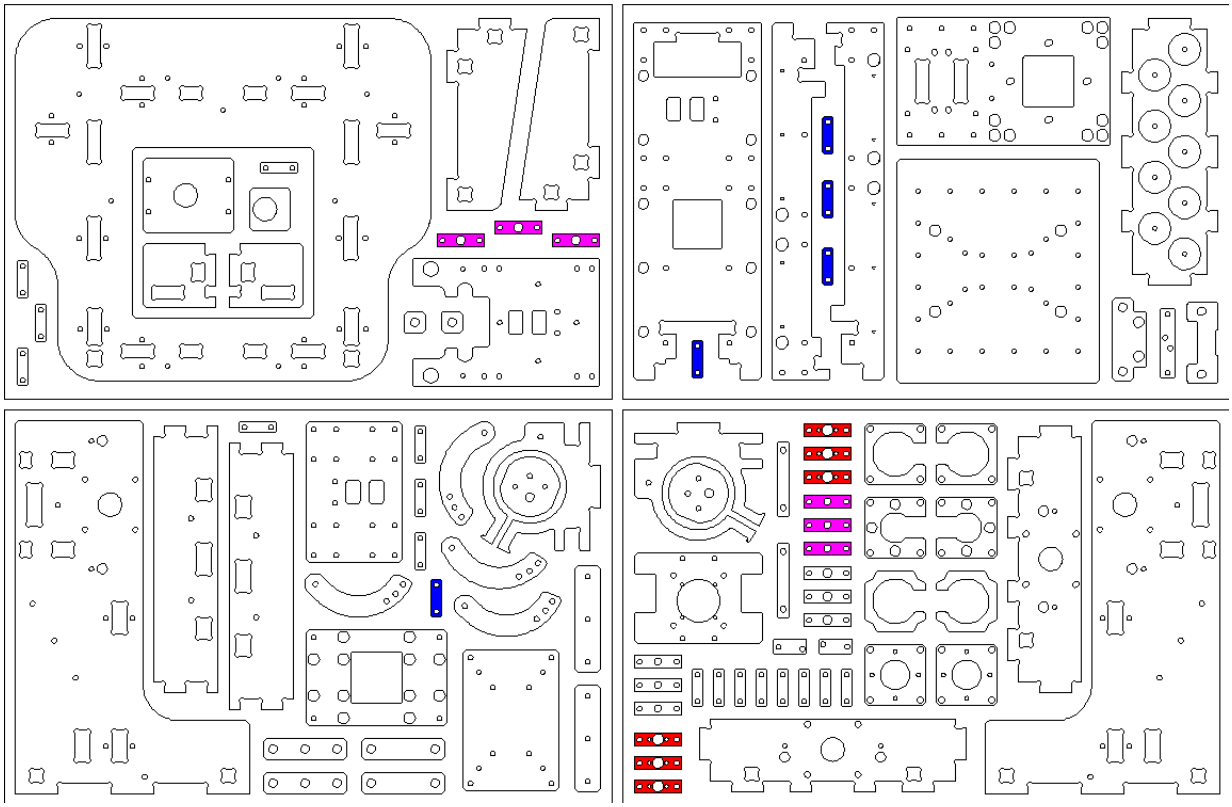


Congratulations - You have successfully constructed your desktop milling machine.

It is now a good time to check all your screws and nuts are snug and further adjust each axis so they have minimal play and polish all the Acrylic with silicone-based furniture spray polish.

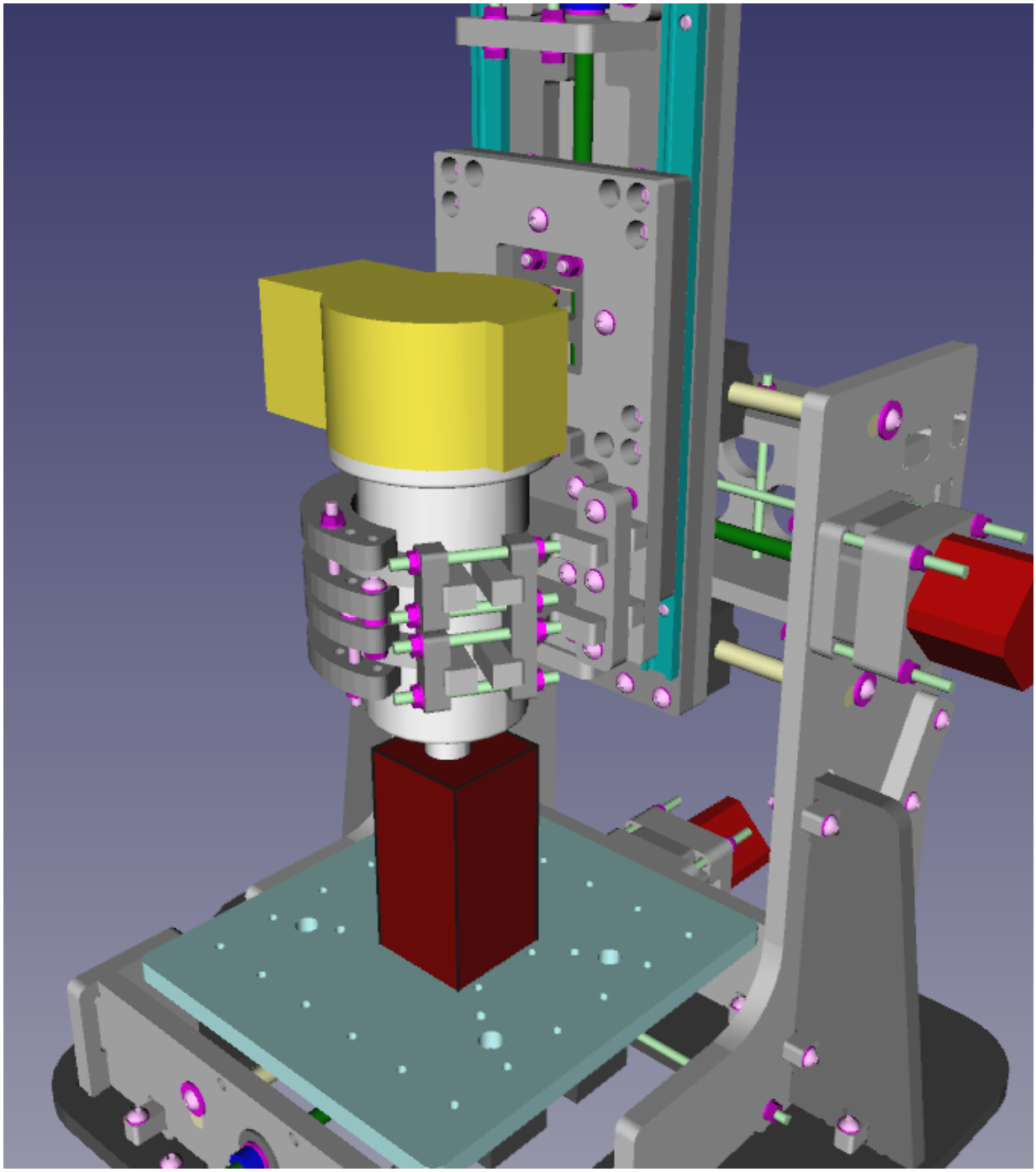
The Leftover Parts

You will have noticed that there are some leftover parts. The parts shown in blue are, as previously described, spare clamps.
The parts in purple are spare threaded nut blocks and universal nut blocks.
The parts in red are a set and a spare set of mounting nut blocks for round ACME nuts as described later in the “Lead Screw Upgrades” section.



Mounting the Router

To mount the DeWalt D26200 router, place a block on the milling machine table to support the router. Partially open the router mount arms and ensure the router mount closure clamps are loose.
Now slide the router into the mount until the spindle is sitting on the support block. Close the router mount arms and tighten the Nyloc nuts on the closure clamps only until the body of the router cannot be rotated by hand in the mount. Tighten the router arm hinge Nyloc nuts until the arms are locked and snug the three screws in the other end of the arms.
The router should now be securely clamped in place.

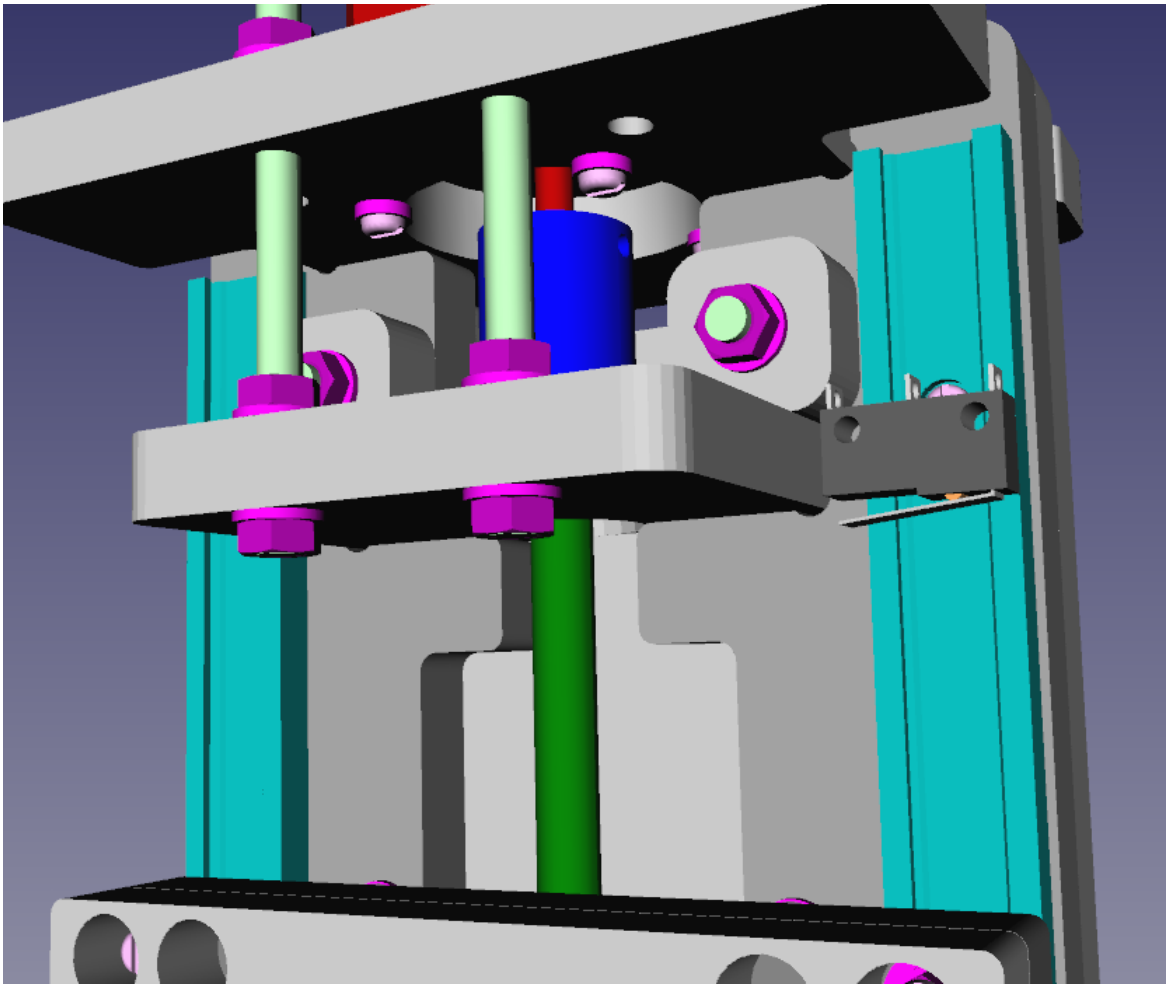


Home and Limit Switches

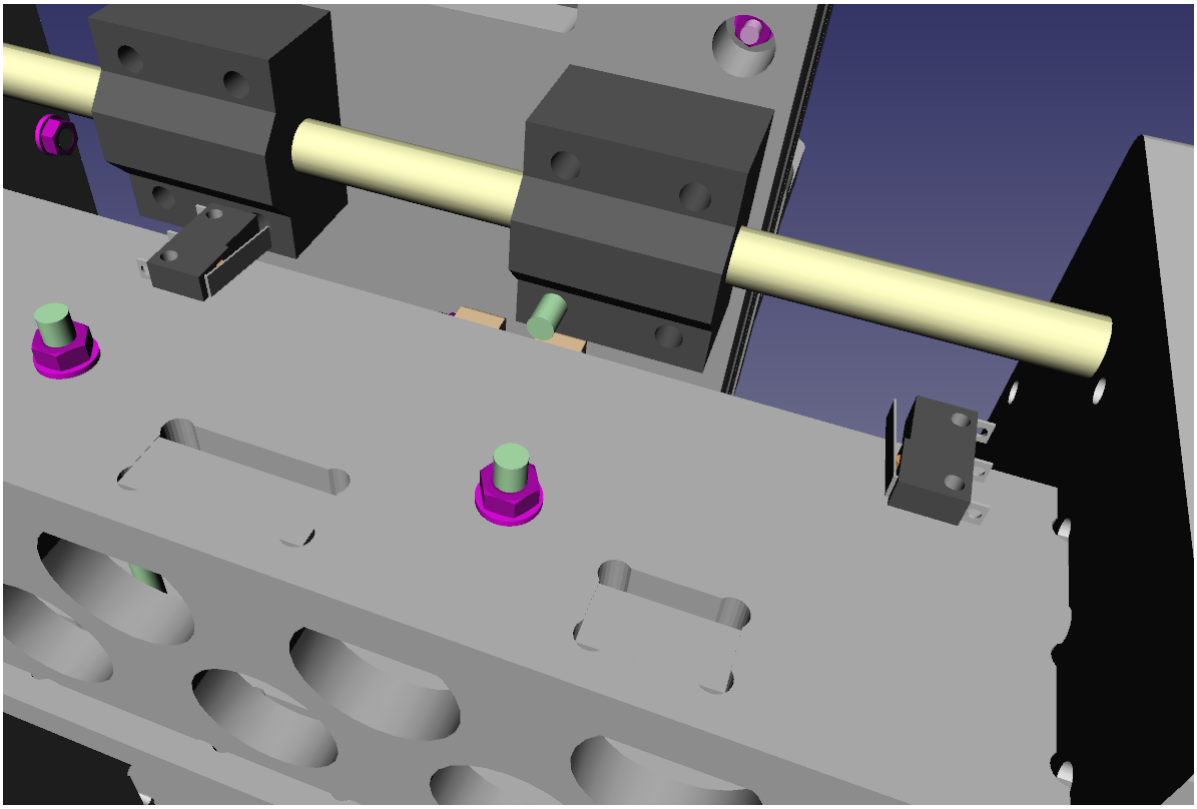
There is no requirement to fit home or limit switches but safety and usability will be greatly improved if you do. With three home switches fitted, the controller will know exactly where the machine is positioned and will therefore be able to return to a previous location even if the controller has been power cycled.

Adding additional switches to at least the X and Y axes will provide protection from accidentally crashing the machine into the end stops. At best the stepper motors will stall but at worst the nut blocks will have their threads stripped out or even snapped in half. You can add an additional switch to the bottom of the Z axis but in practice it provides very little protection due to the varying lengths of the tools in the spindle collet and the varying heights of the workpieces.

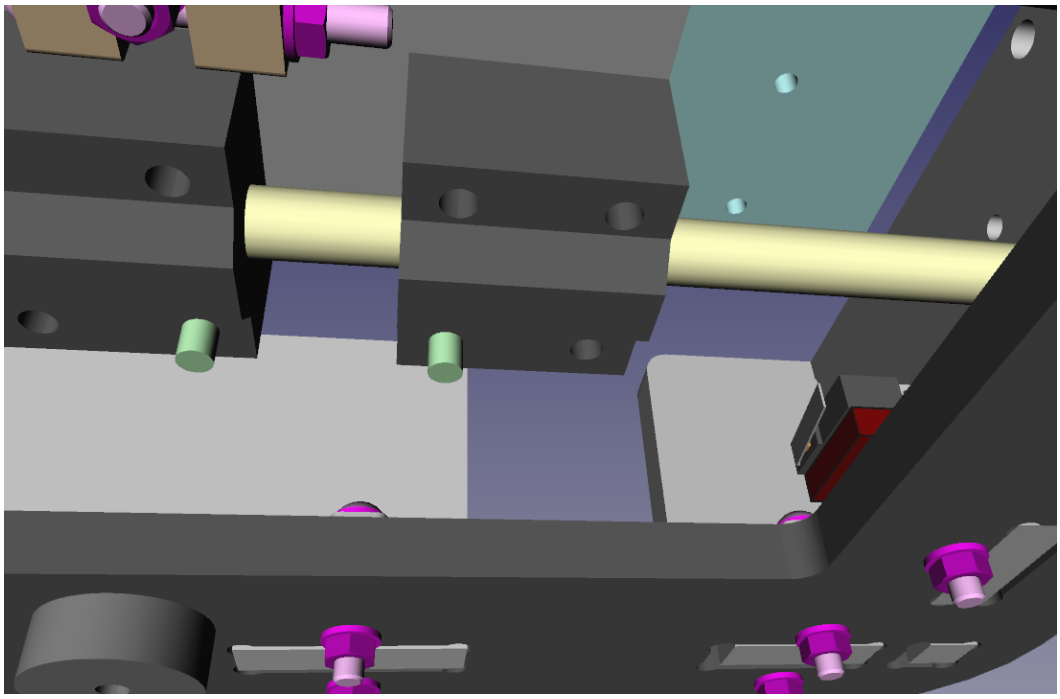
There are several different types of limit switches available including Hall-effect ones, optical ones and, of course, simple microswitches. When two are used for an axis they can be wired in parallel. Shielded two core cable should be used for best results. Particularly if you haven't decided where to mount the switches permanently, just fixing them with hot glue can be very effective. Wherever you do mount them, ensure there is at least 1mm of additional travel past the switch activation point and the cable is routed so as not to interfere with moving parts.

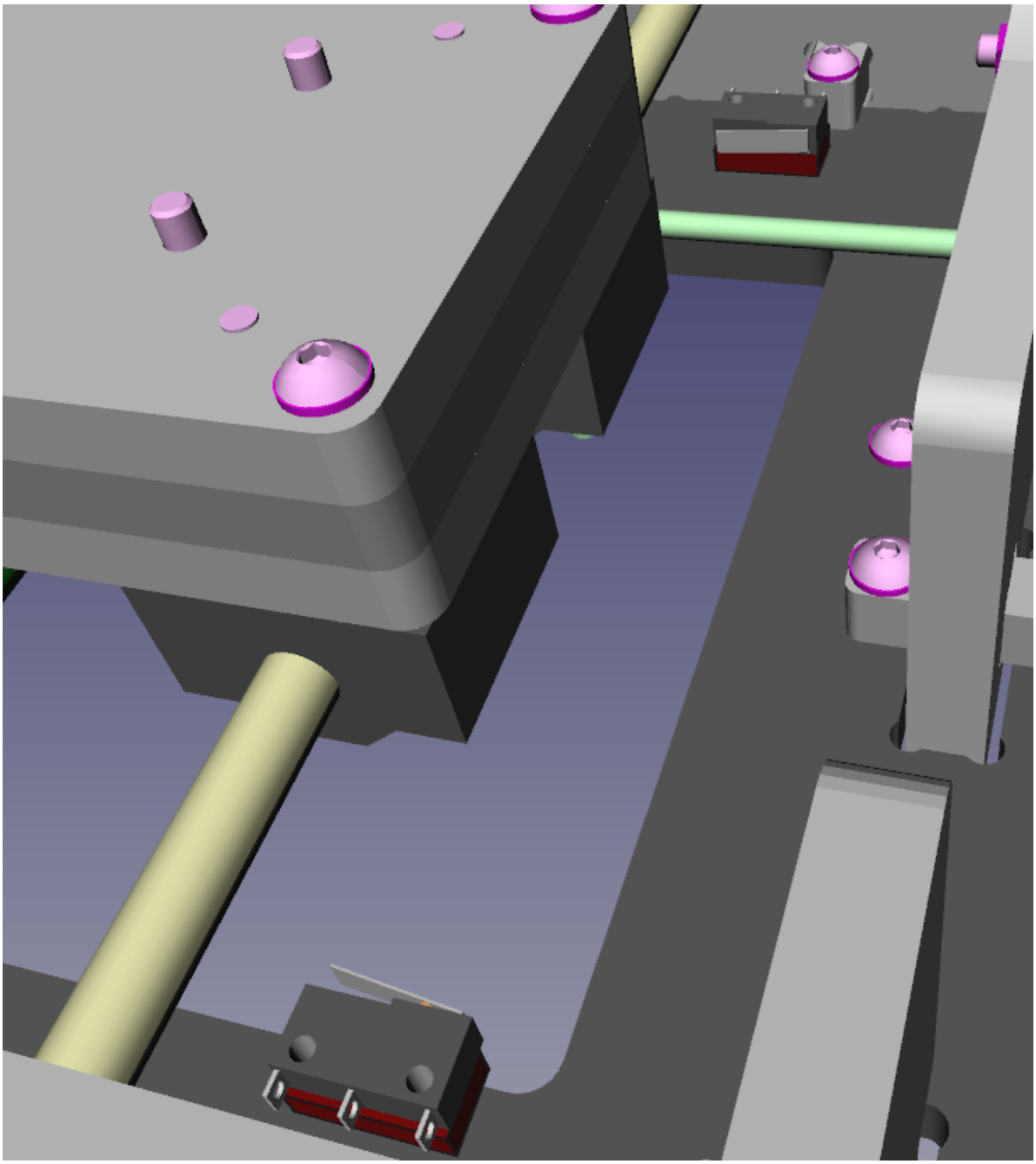


This suggestion for the X axis uses a short piece of 5mm threaded rod screwed into the rear of a bearing block. This one bar can then trigger both limit switches.



This suggestion for the Y axis uses two short pieces of 5mm threaded rod screwed into the bottom of bearing blocks. In this case the switches are raised up on spacers which provides some protection from chips jamming the lever assembly. If you use something like this suggestion, make sure the bars have clearance with respect to the horizontal tensioning rod. Consider gluing the bars in place so that vibrations cannot make them loosen and unscrew causing the very thing they were supposed to prevent.





(Y Axis top plate removed for clarity.)

Lead Screw Upgrades

The default 8mm threaded rod used for the lead screws is cheap and cheerful. It was never designed to be used as a transport mechanism but instead for bonding items together. As such it has quite a lot of friction and so performance is much improved by lubricating it with silicone (silicone-based furniture spray polish works quite well) as it is not sticky and hence chips tend not to adhere to it.

Provision was made in the design though to upgrade to ACME lead screws. These were specifically designed as transport mechanisms and have much less friction which means less of the motor torque is wasted.

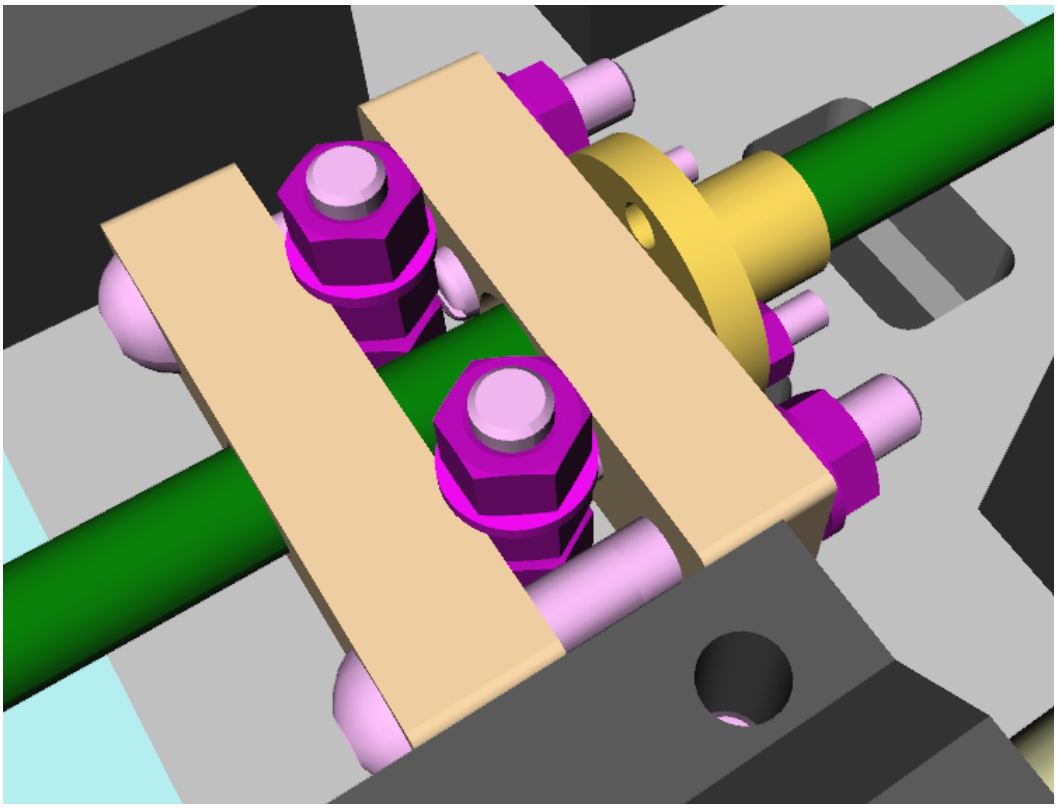
ACME lead screws are available with different numbers of thread starts. They might have one like the default 8mm threaded rod or two or even four. They will also have a particular thread pitch. The default 8mm threaded rod has a pitch of 1.25mm which means a nut will move 1.25mm down the rod for each complete revolution of the rod. The “lead” is the term given to the linear travel the nut makes per one screw revolution. For a single start threaded rod, the lead and the pitch are the same but for a threaded rod with two starts, the lead is twice the pitch and similarly, for a threaded rod with four starts, the lead is four times the pitch. So for an ACME rod with four starts and a pitch of 2mm, the lead is 8mm.
This means that for the same number of motor steps, a four start, 2mm pitch screw will move an axis four times faster than a single start, 2mm pitch one but at the cost of a corresponding reduction in motion resolution. Obviously, the nut block you purchase must have the same number of starts and pitch as the lead screw or else they won't fit.

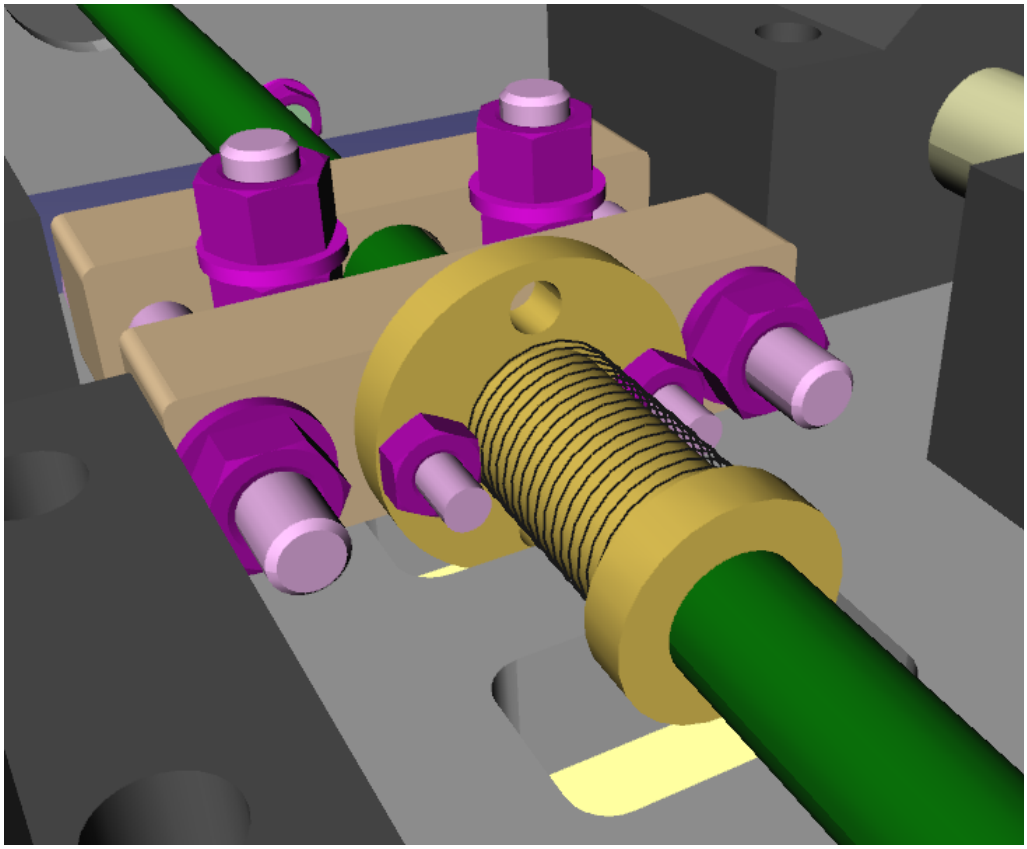
Just a quick word on the motion resolution. A typical stepper motor may have a step angle of 1.8°. The number of full steps to make a complete revolution is therefore 360° ÷ 1.8° which is 200. If the threaded rod has a lead of 1.25mm then 200 steps are required to move that distance. The distance travelled by just one step is 1.25mm ÷ 200 which is 0.00625mm. However, to improve stepping smoothness, the motor drivers are usually run on at least half-stepping which produces 400 steps per revolution. The distance travelled by just one step is then 1.25mm ÷ 400 which is 0.003125mm.
If you switch to an ACME lead screw with a lead of 8mm then using half-stepping, the distance travelled by one step will be 8.0mm ÷ 400 which is 0.02mm. That is still just one fiftieth of a millimetre and if you wanted to make that smaller while keeping the same lead screw, you could alter the stepping ratio of the stepper motor driver from ½ to ¼, ⅛, 1/16 or possibly even 1/32.

So first choose an 8mm diameter ACME screw with the desired pitch (usually 2mm) and number of thread starts.
You then have a choice of nut blocks.

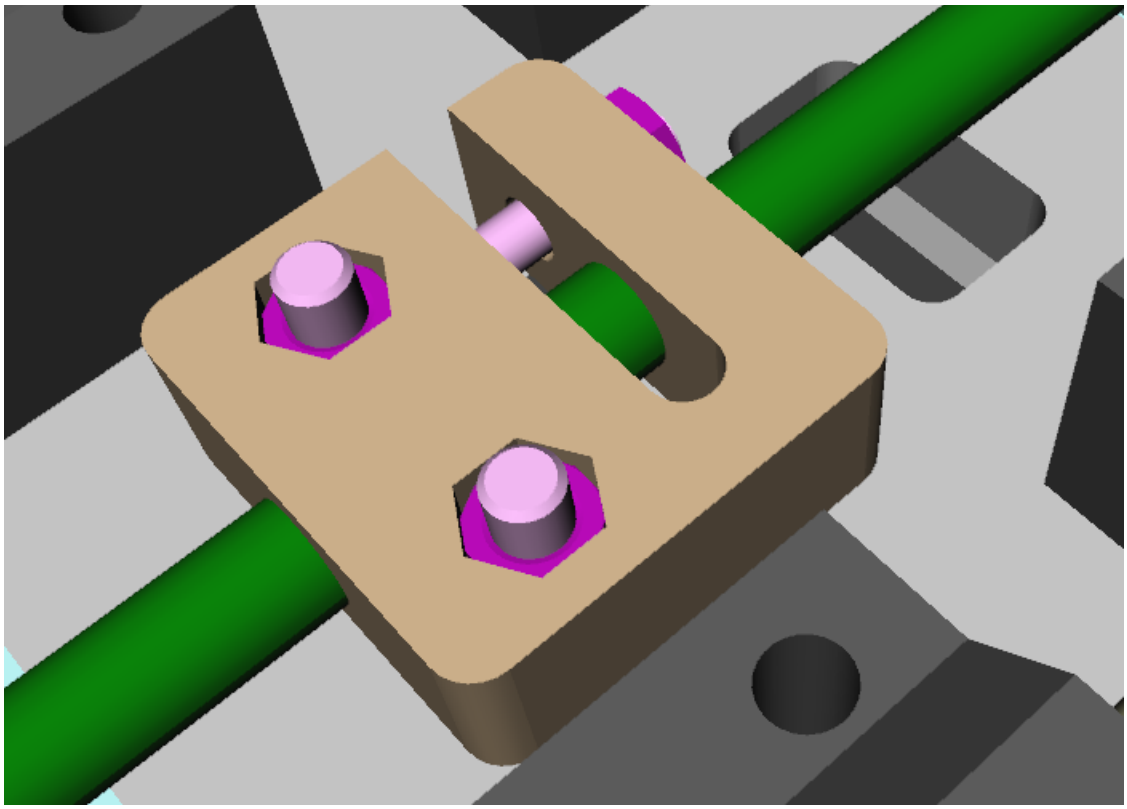
The first sort are the round brass ones 22mm in diameter with four equally-spaced 3.5mm diameter holes drilled at a diameter of 16mm. They are available in regular and anti-backlash versions. Anti-backlash ones are useful for the X and Y axes but not necessary for the Z axis as gravity pre-loads the nut block for you.
Round nut blocks can be used directly on the X and Y axes but one side will need to be trimmed if you want to use them on the Z axis. To mount such a nut block you need to use the alternative nut block pictured in red as shown in “The Leftover Parts”.

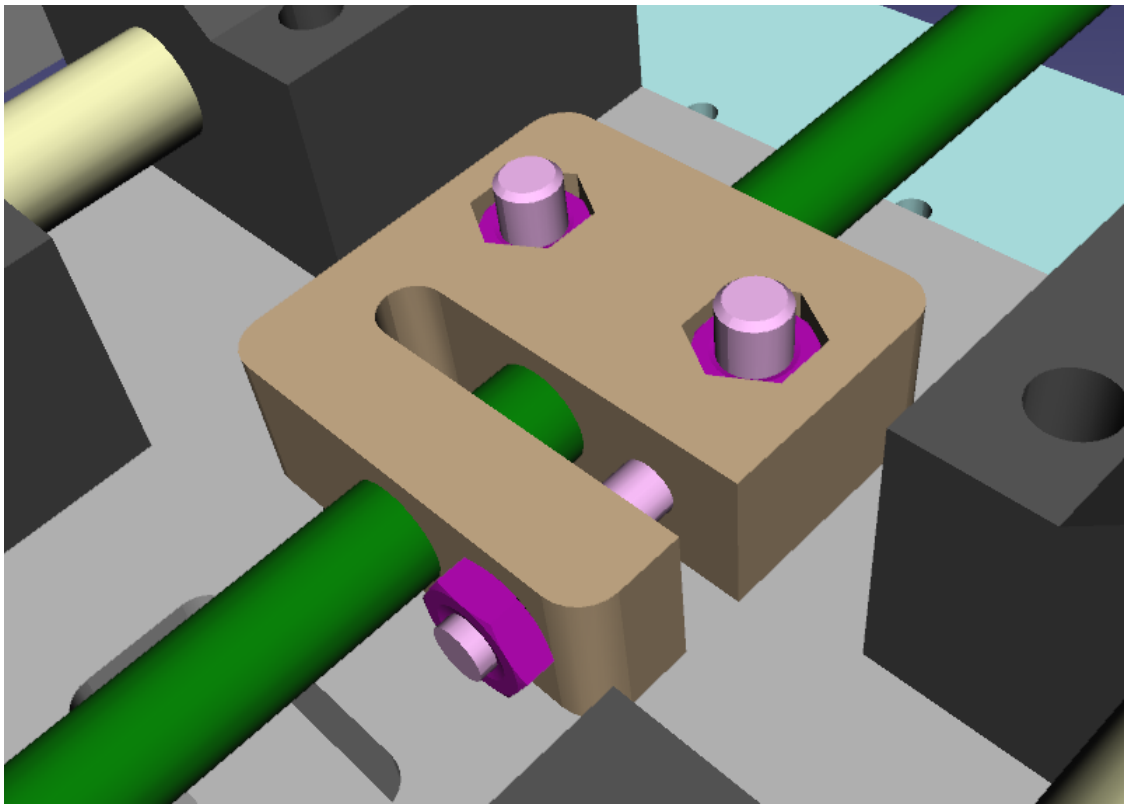
You will also need 2 M3x20mm slotted pan heads and 2 M3 nuts (not supplied) to clamp the brass nut to the Acrylic nut block.





The second sort are the “OPENBUILDS” style of nut block which are also available in regular and anti-backlash versions. These are easy to use on any axis without modification and bolt flush to the plates. As before, the anti-backlash version is not necessary for the Z axis as gravity pre-loads the nut block for you.





Mounting Workpieces

It's worth taking a little time to discuss workpiece mounting. If your workpiece is not securely mounted then at best your surface finish will be bad and at worst, it may break free, partially or fully, possibly breaking your end mill which will also fly off possibly causing damage or personal injury. Always wear protective glasses when using any power tools.

Hot glue can be an effective way to hold a workpiece down. Make sure you press the workpiece flush to the bed and apply the glue all the way round the periphery in sufficient quantity to get a good bond. Allow the glue to cool and become hard and rigid before attempting to do any machining. When you're done you can peel the glue off cleanly. Be careful not to machine down into the bed of the machine.

Superglue and masking tape is another effective method. Cover an appropriate area of the bed with masking tape ensuring the edges butt up so the superglue can't reach the bed and burnish the surface so that the masking tape bonds well to the bed. Apply masking tape to the bottom surface of your workpiece and burnish it too. Then apply a thin wavy stream of superglue to the masking tape on the workpiece and press the workpiece down firmly onto the masking tape on the bed. It will bond rapidly so make sure you align the part carefully. If you leave an excess of masking tape on the bed it will make it easier to peel it off after machining. As before, this method is no good if you want to machine through the full thickness of the material.

Using a waste board or spoil board is another common workholding technique. Typically a waste board is just a piece of MDF attached to the bed. The workpiece is then mounted on the waste board and the waste board itself is sacrificial so you can drill or machine into it without damaging the underlying bed. To attach your part to the waste board you can use the previously described hot glue method or superglue and masking tape or even simply screw the part down depending on what it's made of. When the waste board surface is too damaged you simply replace it. The waste board itself can be attached to the bed by bolting it down or the superglue and masking tape method.

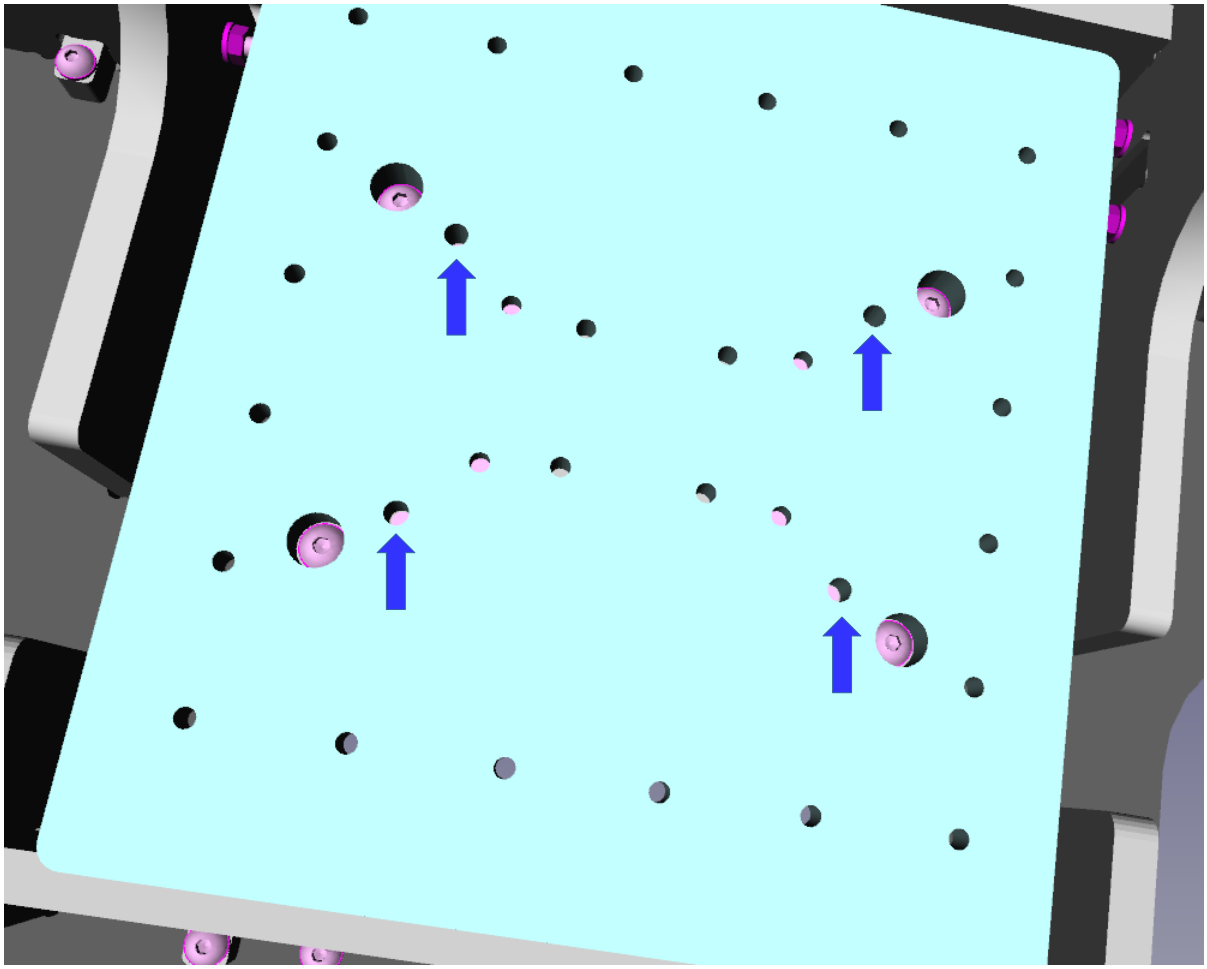
The bed itself has a number of M5 threaded holes in it. You can use any M5 machine screw or bolt to hold parts down either directly or by using clamps. You can even screw bolts up from below the bed but make sure the heads have clearance over the Y axis end plates. This can be useful if you want to machine a piece larger than the working area of the machine. Bolt a straight guide onto the bed in the Y axis direction to align your piece to. Now you can progressively slide the piece through the machine, clamping it down in each successive position.

Last but not least, you can mount a small vice onto the bed using the threaded holes either directly or with clamps. This can be an excellent way to securely hold parts. It will be important to align (“tram”) the vice with the X axis and this can be done quite effectively by using the “touch probe” functionality available in some controllers to find the location of the inside surface of the fixed jaw of the vice at its left and right extents.

Whatever method or combination of methods you use, always make sure you have sufficient clearance in all directions. Don't forget the router itself can be moved up and down in its clamp if required.

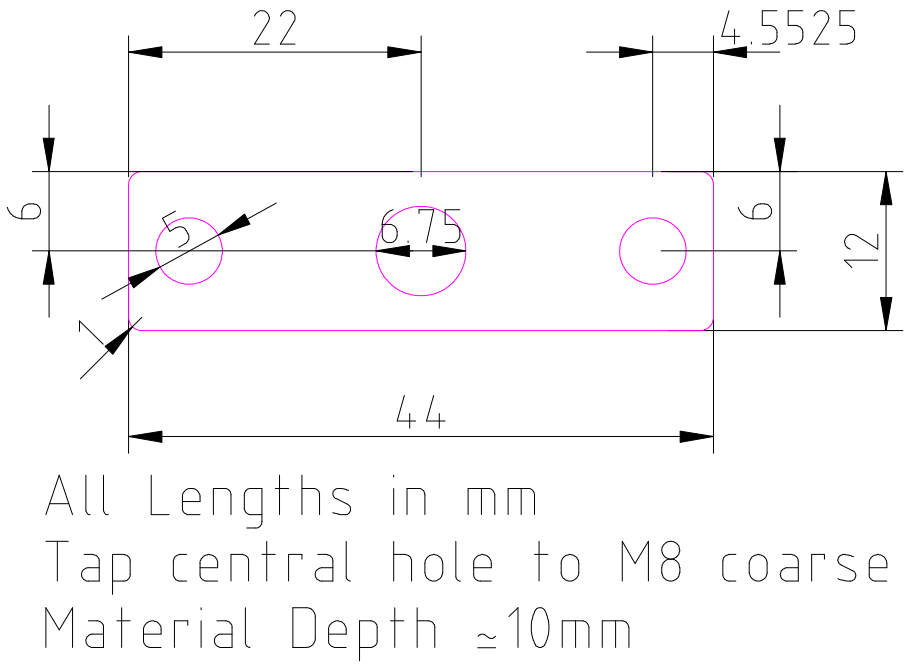
Bed Levelling

This feature was designed in as I thought it might be desirable to replace the router with a 3D printer extrusion head to make a 3D printer.
The four screws holding down the Y axis bed should first be loosened so that the bed becomes mobile. Then the four grub screws shown by arrows below can be adjusted to tilt the bed in any direction. The idea is that you can tweak the bed to be perpendicular to the Z axis and parallel to the X axis. Once done you then tighten up the four bed screws.



Nut Block Design

Spare nut blocks are provided but now that you have a milling machine you can make additional replacement ones. The tap guide supplied in the kit has a hole for M8 to help you get good alignment for the central lead screw hole.



CNC Controller

You've made a three axis, desktop milling machine complete with bipolar stepper motors and homing/limit switches but there is a crucial bit missing – the CNC controller.
There are lots of CNC controllers on the market and I'm not going to tell you which one to buy as that depends on what sort of set-up you wish to create.
What I will do is show you the controller I put together for my desktop milling machine as an example of what you could do and hope it inspires you to make something cool.

I wanted a completely standalone system but didn't want to pay a fortune. Having said that, I wanted to be able to plug it into my network easily if required. I decided on a Raspberry Pi with a Protoneer GRBL-based CNC controller piggy-backed onto it. The Protoneer board has sockets for stepper motor drivers which makes it easy to replace one if it burns out.

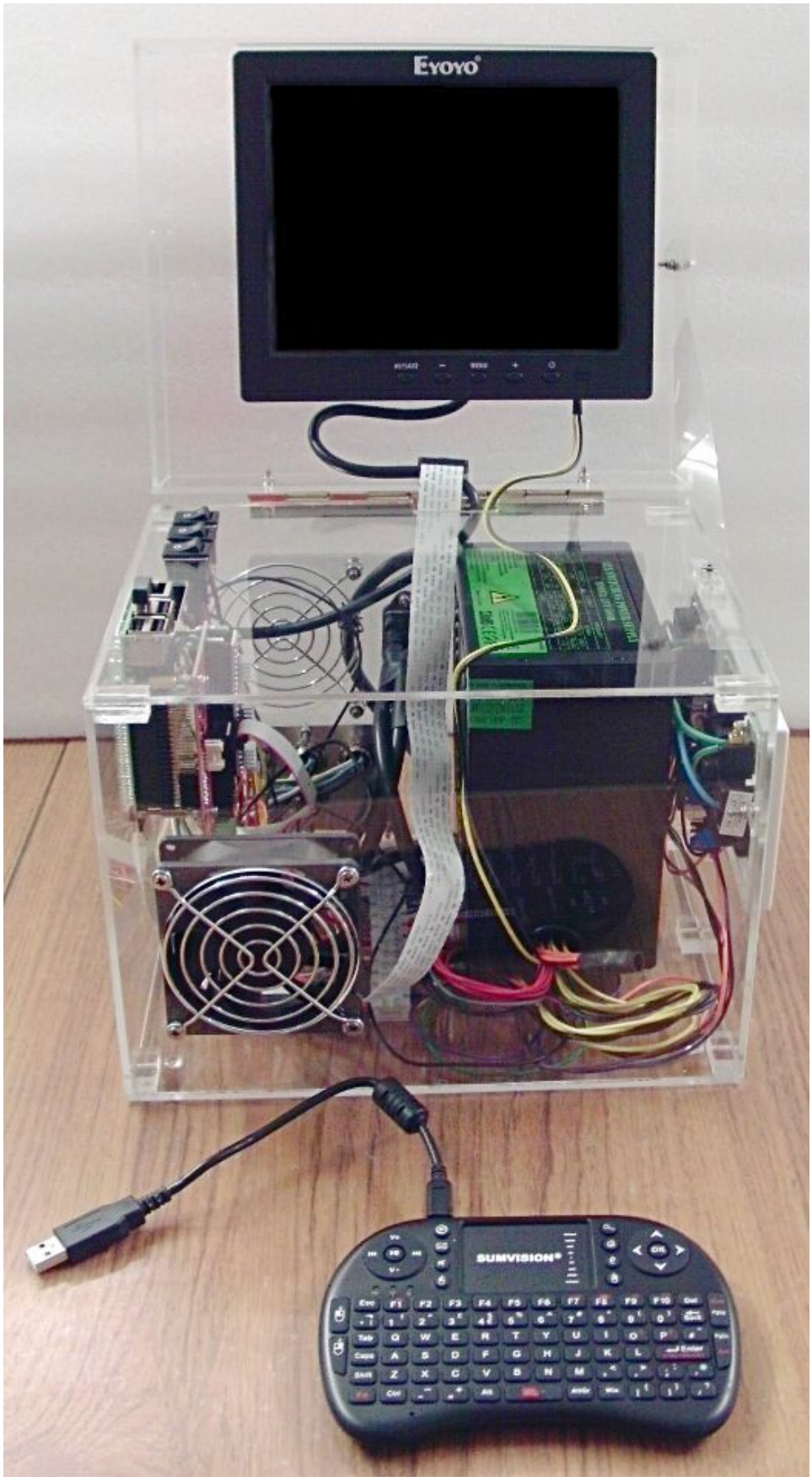
The system would need its own display unit with a DVI or HDMI input and a miniature wireless keyboard with built-in touchpad and extra multimedia keys that could be repurposed as a jog controller.

The Protoneer board has outputs for spindle drive and coolant so I wanted to be able to plug the DeWalt router directly into the controller box and also use the coolant control to run a vacuum cleaner to automatically suck up chips as they are produced.

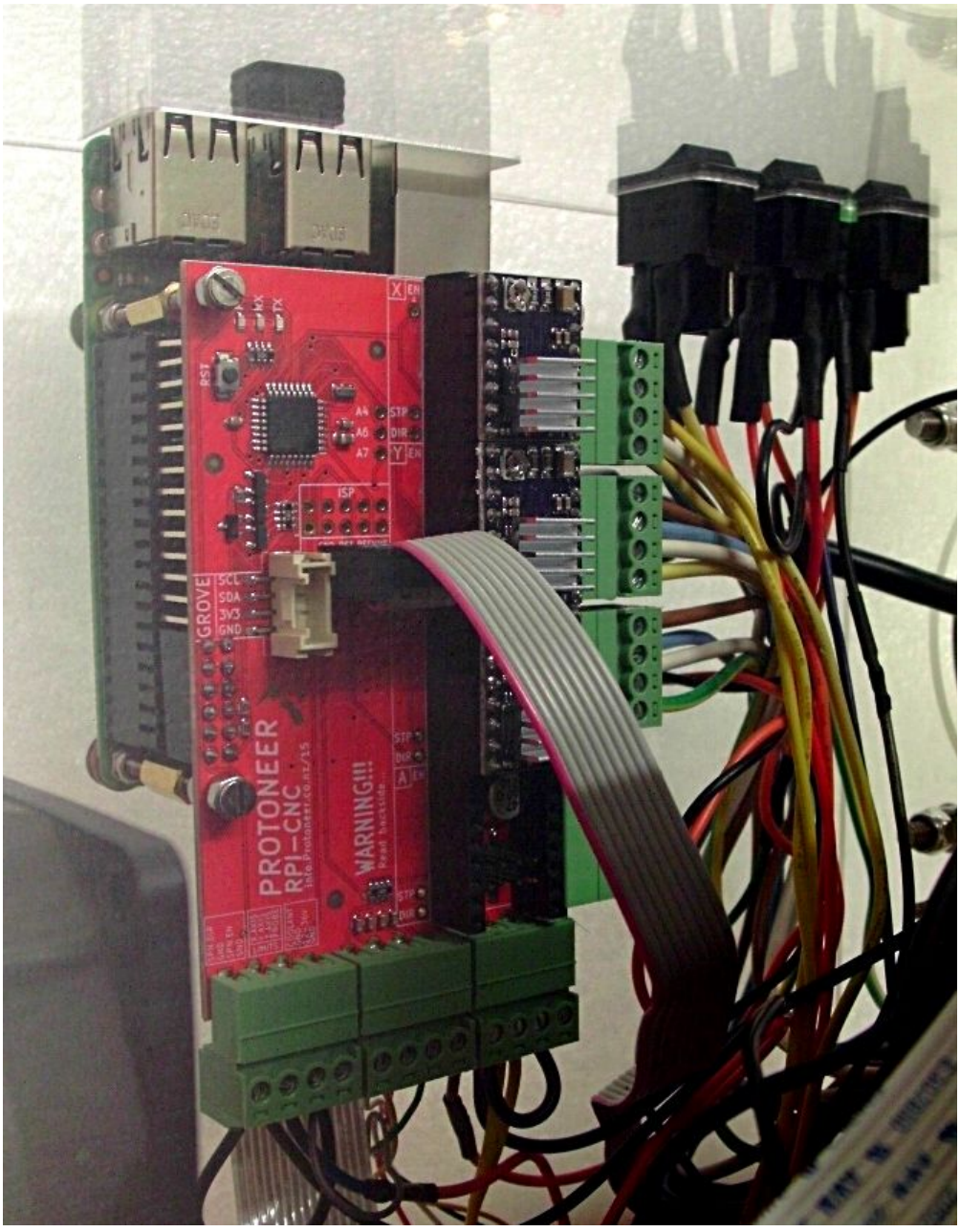
Finally I needed a power supply unit that could power the display unit, Raspberry Pi with Protoneer board, case fan, relay driver boards and, of course, the bipolar stepper motors which might take up to 2A for each of the two windings for each of the three motors at, say, 12V D.C. That's a lot of power but a budget PC PSU can supply it all very cheaply.

Then I designed a box in which to fit all these components which was subsequently cut out of Acrylic using a GRBL-based CNC controller and the same DeWalt router.

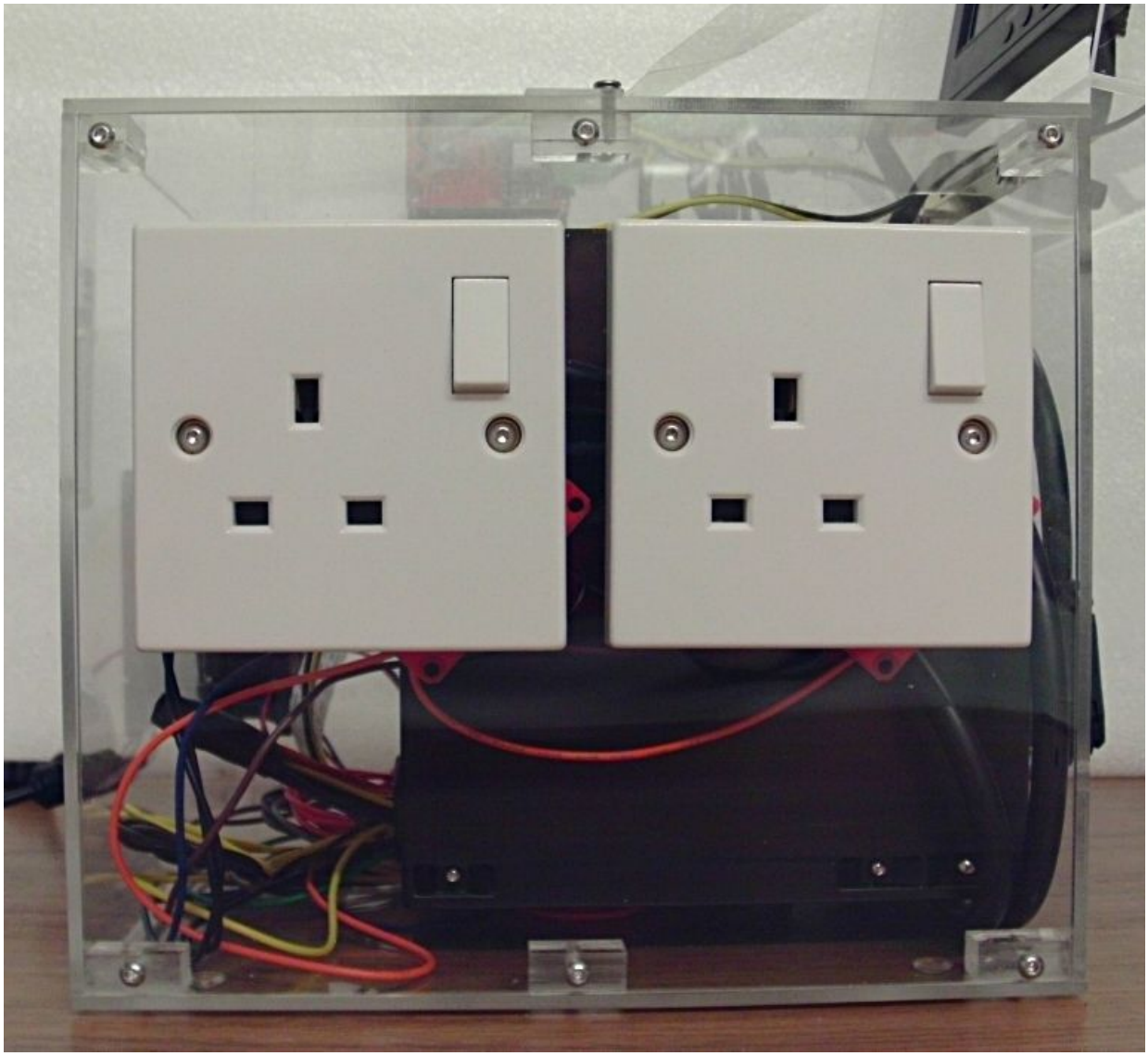
This is the result.



This picture shows the Protoneer GRBL-based controller mounted on the Raspberry Pi. The central ribbon cable carries the reset, hold, resume and emergency abort lines from the controller to the back panel and then on to an external box. The three plug-in stepper motor drivers can be seen with their finned heat sinks. The rear green connectors take the motor drive signals to the back panel – one for each axis (yes, there is a fourth unused driver slot).
The bottom green connectors take the home/limit switch and touch probe signals to the back panel and also house the spindle drive and coolant signals which are fed to relay driver boards as well as a 12V input from the PSU that is fed to the stepper motor drivers.
The three switches in the top right corner turn on the power supply, display unit and case fan (12V), turn on power to the Raspberry Pi, Protoneer board and relay driver boards (5V) and turn on power to the stepper motor drivers (12V).
The fan cools the Raspberry Pi and blows air directly over the stepper motor driver heat sinks to the exhaust vent on the rear of the case.



This picture shows the two mains sockets on the right-hand side of the case. The left one is linked to the spindle drive signal and the right one to the coolant signal. You can just see the red corners of the relay driver boards sticking out behind the sockets that supply mains power to the sockets when activated.



This picture shows the rear of the controller case. You can see the three identical upper sockets which contain the drive signals for the X, Y and Z axis stepper motors. The lower sockets contain the reset, hold, resume and emergency stop signals for the external control box on the left and the homing/limit switch and touch probe signals on the right.
The ribbon cable from the Raspberry Pi is a micro SD extension cable so that the micro SD card can be backed up easily without unscrewing the case.

The program that does all the hard work on the Raspberry Pi is called “bCNC”. It can create G code from scratch or from DXF files. It can visualise the G code in 2D or 3D and, most importantly, it feeds the G code to the Protoneer GRBL controller and produces real-time feedback on screen. It can also handle tool changes, probing in multiple directions and auto-leveling which is very useful when routing printed circuit boards.