OpenESpin Assembly Manual

Electrospin Machine

Douglas Miller

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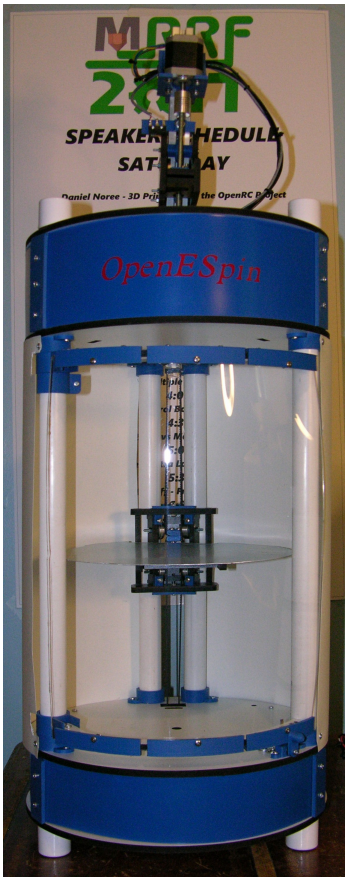


Intention is to use WWW.OpenESpin.Com website as project home.

Table of Contents

Introduction....4
Notes about the build:....4
Part Identification....5
Prepare the posts....7
Fit the bottom deck....7
Add stepper motor and deck spacers....7
Add the Arduino....7
Mount the terminal mount and terminal block....8
Add gShield....8
Start the wiring....8
Powering the gShield....9
Run the Arduino USB cable....9
Add the second deck....10
Leveling collars....10
Door latch....10
Door switch....11
Door hinges....11
Outside Guides....11
Building the carriage....11
Bearings and inserts....12
Preparing bearing supports....12
Carriage adjustment mounts....12
Belt clamp....12
Install bearing supports....12
Table supports....13
Finishing the carriage assembly....13
Installing the carriage on the posts....13
Adding the third plate....14
Starting the syringe swivel. 14
Mounting syringe slide to the top deck....14
Installing the top deck....15
Top leveling collars....16
Add the syringe holder/guide....16
Positioning the third deck....16
Position the swing hinge....16
Pulling the wires to the top....17
Carriage belts and pulleys. 18
Timing belt....18
Door frame....19
Door Track....19
Top outside guides....20
Adding the side covers....20
Building the syringe pump....20
Bearing sleeves....21
Bearing inserts....21

Screw and nut holding block....21
Placing all the carriage pieces....21
Finishing the carriage....22
Mount the T-slot extrusion....22
Put the carriage on the T-slot....22
Prepare the switch and motor mount....22
Make it look like a syringe pump....23
Carriage limit switch.
....23
Syringe stepper wiring....24
USB cable....24
Loading firmware....24
Power supply....25
Making it move....25
Wiring the door switch....26
Side covers....27
Door acrylic cover....27
Making the table....28
Adding the plate supports....29
Adjust the carriage....29
Adding side covers....30
Setting syringe home position....31
About those high voltage leads....32
Wrapping it up....32

Introduction.

OpenESpin is an open source project created by Douglas Miller to allow Citizen Scientists to explore electrospinning. The first version was entered in the 2016 HackaDay prize contest, but lack of funding prevented it from finishing. Much further along, this new version was entered into the 2017 HackaDay prize contest.

This is the assembly manual, and as such will not cover the machines general operation. That can be found in the 'operation' manual (now being developed).

We won't cover what Electrospinning is or why you should try it in this manual. Check out our website, follow the links available there, and do a web search to find out what it's all about and why curious Citizen Scientists need to get involved in it.

We hope you'll get involved, build the machine, and join us in exploring all the new materials and how Electrospinning can expand what those materials are capable of!

Notes about the build:

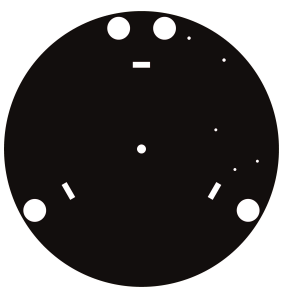
- All files needed to build this project are available at www.OpenESpin.com, and also on the projects 'https://hackaday.io/project/20702-openespin' home page.

- Throughout this manual it is assumed that whenever one of the laser cut parts is called for that you have peeled the protective tape from the surface before using the part. There's no sense mentioning it every time, and no parts are used with the tape on them. If you didn't put tape on to prevent the surface from getting messed up while being laser cut, forget this note.

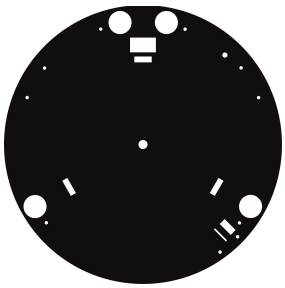
- PVC pipe diameters can be slightly different between manufacturers. It's best to buy the end caps at the same place and time as you do the pipe, to insure a good fit.

- You can use one of several methods to clean the manufacturers lettering from the PVC pipe if you wish. I like to skip that step and just turn the letters to the back of the machine. Since the sides will be covered it'll be hard to see.
- The total cost of the machine, as listed in the BOM, can be reduced considerably. Use what you have, substitute where you may, and shop both local (to save shipping) and online, depending on where the deals are. What's listed here is what it would have cost me had I bought everything new and mostly local. It should be the absolute top of the range you may expect to spend.

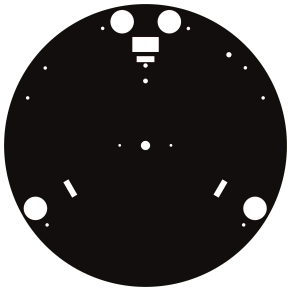
Part Identification



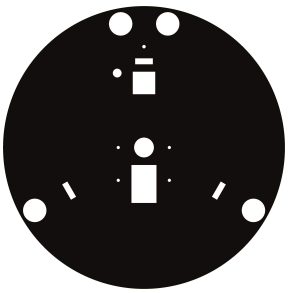
1PCB1



1PCB2



1PCT1



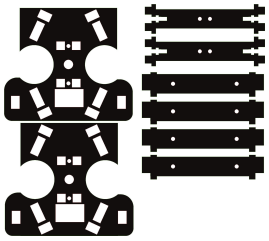
1PCT2

BottomCenterCover

BottomSideCover

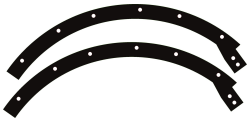
TopCenterCover

TopSideCover



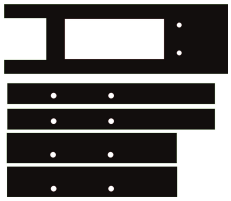
Carriage

DeckSpacers

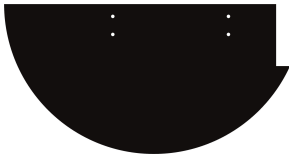


DoorFrame

SyringeHolder

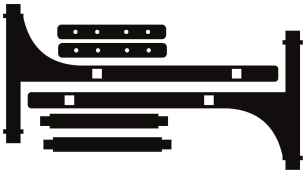


SyringeSlide



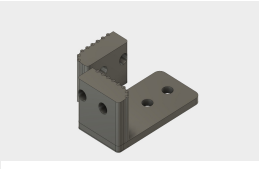
TableA

TableB

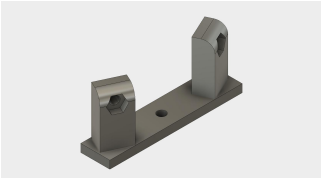


TableSupport

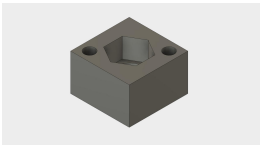
BearingInserts



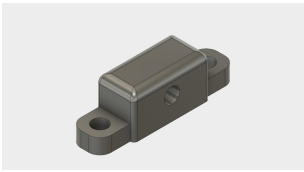
BeltMountClamp

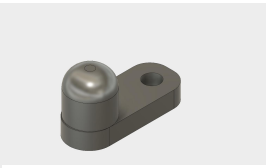


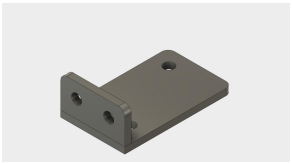
CarriageAdjustmentMount



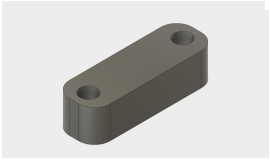
CarriageScrewHolder

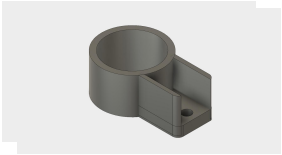

DoorLatchBase
LevelingCollar

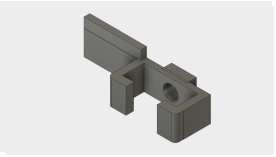

DoorLatchHandle
LevelingCollarB

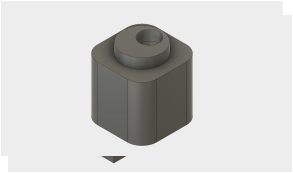

DoorSwitchMount
OutSideGuides

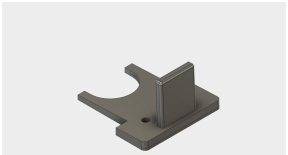

DoorTrack
SideCoverBracket

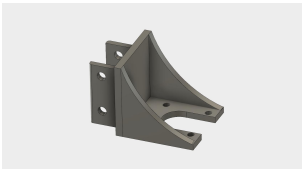

SlideSpaceB

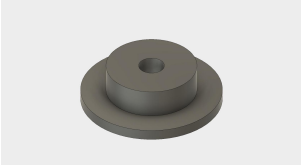

SwingeHinge

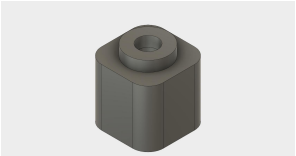

SwitchMount


SyringeBearingInsertsOffset

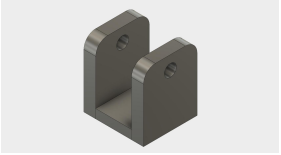

SyringeHoldDown

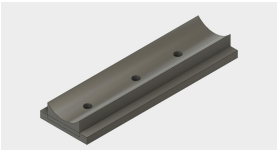

SyringeMotorMount


SyringeSwivel

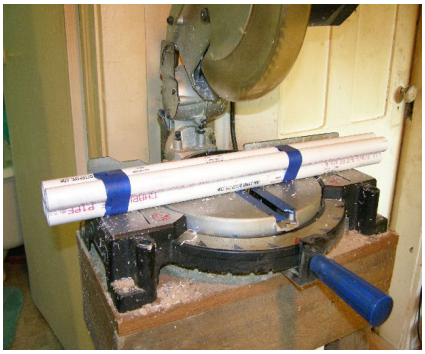

SyringeBearingInsertStraight


TerminalMount


TopIdlerBracketB

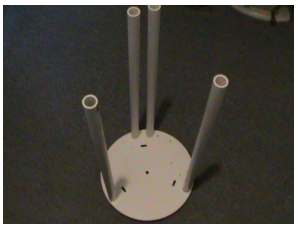

TopSideCoverBracket

Prepare the posts.



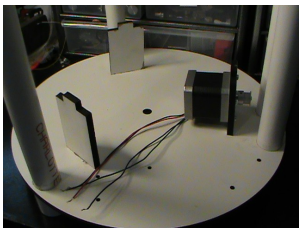
1: Cut each of the two PVC pipes in half.
2: Tape the four pipes you now have together tightly as shown.
3: Cut the pipes off at one end.
4: Now flip the pipes around and measure 25.25” (641mm) from the end you just cut flush. The cut does not have to be that exact size, but try and get it close. The main thing you're looking for is that all four will be the exact same length.
5: Cut the pipes on that mark.
6: Remove the tape.

Fit the bottom deck.



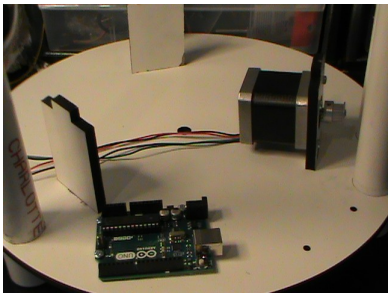
7: Find the laser cut part 1PCB1. Refer to the picture in the parts listing. The most obvious difference it has from the others is the three holes for mounting the arduino.
8: Test fit each of the larger holes around the outside to make sure the PVC pipe will fit. It can be a little loose, as long as it doesn't flop around. If they are too tight use some sandpaper or a Dremel to increase the hole until it fits.
9: When they all fit, put one pipe into each hole far enough to put a cap on. Turn it upside down on the floor and lightly tap each cap in place. You want each cap to be on as far as it will go. When all the caps are in place, turn the assemble right side up, with the caps now on the floor, and tap the PC1B1 plate down until it's snug down on the caps.

Add stepper motor and deck spacers.



10: Fasten the GT2 2mm pitch pulley to the stepper motor.
11: Using M3 x 9mm screws attach the motor to the laser cut deck spacer.
12: Put the desk spacer in the slot at the rear of 1PCB1 bottom plate. The pulley should be facing the rear of the machine, pointing between the rear posts.
13: Put the other two short deck spacers in the other two slots in PC1B1.

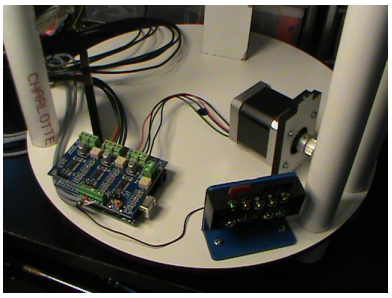
Add the Arduino.



14: Fasten the Arduino Uno to plate 1PCB1 using three M3 x 15mm bolts and M3 nuts. The USB port on the Arduino should point to the back of the machine. (the back of the machine is always towards the

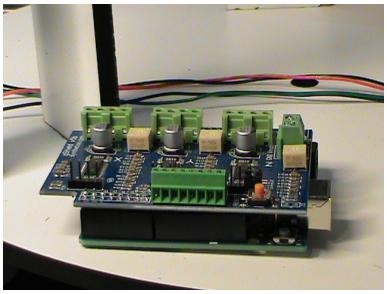
double posts)

Mount the terminal mount and terminal block.



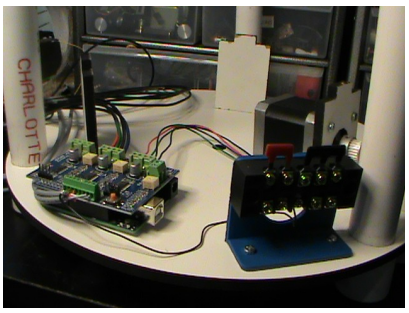
15: Use two M3 x 16mm bolts to fasten the 3D printed terminal mount to the 1PCB1 bottom plate. See the picture for the location.
16: Fasten the terminal block to the 3D printed Terminal Mount. Use two M3 x 12mm bolts and nuts.
17: Cut one red and one black jumper in two pieces. Fasten them to the top of the terminal block. Use the two terminal red and the three terminal black pieces.

Add gShield.



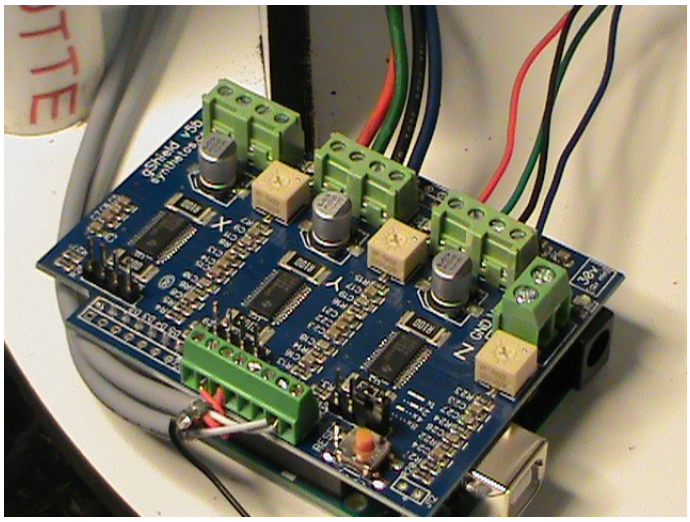
18: Solder an eight pin terminal block to the gShield. It should cover the row of pins that begin with pin D8.
19: Install the gShield on top of the Arduino Uno and pull any jumpers off of it. That will set all the motors to microstepping.

Start the wiring.



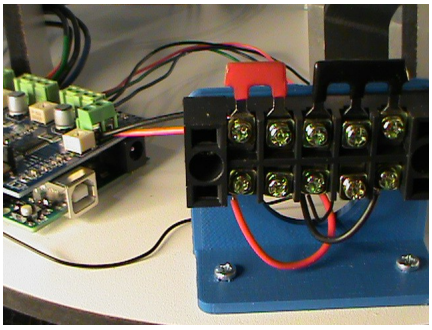
20: Cut one length of 24AWG two conductor shielded wire to a length of 42 inches (1066mm).
21: Cut another length of 24AWG two conductor shielded wire to a length of 58.5 inches (1486mm).
22: Cut one 58.5 length of 22AWG four conductor wire.
23: Strip the insulation from one end of each of the wires.
24: I find it best for me to gather the strands of the shielded cords together, add in one seven inch (178mm) extra 24AWG wire, and solder them all together. The free end of extra wire goes over to the terminal block we mounted earlier. See the photo.

25: Now fasten one of the wires in the shorter, 42 inch wire to terminal ten of the gShield. This will be for the carriage limit switch.
26: Fasten one of the wires on the longer 58.5” cord to terminal nine on the gShield. This is for the syringe limit switch.
27: Fasten the two wires from both cords together that are left over to the Grd connection of the gShield. It should be the second from the right on the terminal block you soldered to the gShield.
28: Leave the cords curled up over to the side for now. We'll pull them up the columns in a later step. We hooked them up now because it's much simpler to get at them now rather than when the next plate is added to the columns.



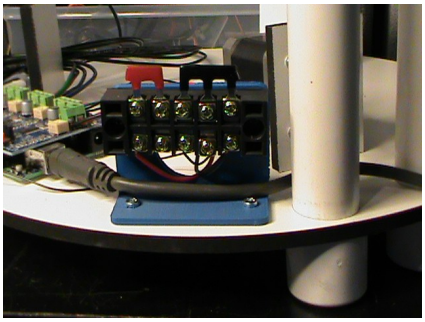
29: Hook up the wires coming from the stepper motor you mounted earlier to the 'Z' axis on the gShield. It will be the terminal block closest to the power in jack. You can switch the axis's around if you like, but you'll have to make some changes in the firmware if you do. The order of the wires is important. The order on the motors I have here is red, green, black, blue. Yours may be the same. Or not. If your not sure on yours you can look your motor up online, or ohm them out. There are many videos on the web to show you how to do that.

30: Hook up the four wires in the 24AWG cable you cut earlier to the 'Y' axis on the gShield. Again, the order they go will differ depending on the colors of the cable you have. In the picture below I just used four individual wires and painted each end to match. That way I could identify them later when we're ready to hook them up to the syringe.



Powering the gShield.

31: To power the gShield we need to run two wires from the main terminal block to the Gshield. Use several short sections of wire pulled from the 24AWG cable and hook them up as shown. Make darn sure you get the ground and power right on the gShield. You can make magic smoke if it's hooked up backwards! Just run a red wire from the Vmot terminal on the gShield to the red jumpered section on the main terminal block. Black goes from grd on the gShield to the black jumpered section on the main terminal block.



Run the Arduino USB cable.

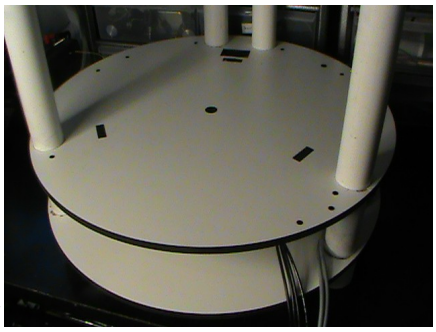
32: Run the USB cable between the two rear posts, then in front of the terminal block and plug it into the Arduino.

That completes the main wiring for the control section of the machine. Now it's time to put the next deck plate on.

Add the second deck.

33: Find the laser cut part 1PCB2. Clean the for large post holes out, and test fit them one at a time on a piece of PVC pipe. They can be snug, but not too snug. A little loose won't hurt anything. Use sandpaper or a Dremel if they are too tight.

34: When the holes feel okay, align the plate on top of the posts on the machine as shown in the photo below. The correct orientation is with the extra two small holes beside the single post are to your left. The other single post does not have these holes.

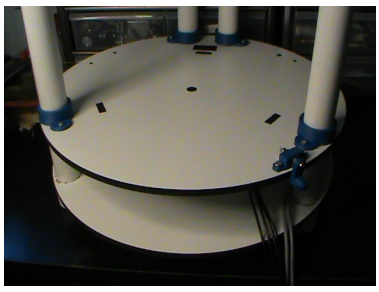


While doing this next step remember to check and see that the wires are not getting caught up between the spacers and the deck.

35: Gently tap the plate down the posts, trying to keep them even on the way down. When they are close to the deck spacers stop. You should be able to align the deck spacers with the slots in the plate and slid them up just a bit into the slots. Then continue tapping the plate down until it's sitting on the deck spacers and the spacers are almost flush with the top of the deck plate.

Leveling collars.

36: Slide one LevelingCollarB down each post, with the tab with the hole in it on the bottom. Fasten each one in place using a M3x16mm bolt inserted from the top and a 3MM nut.

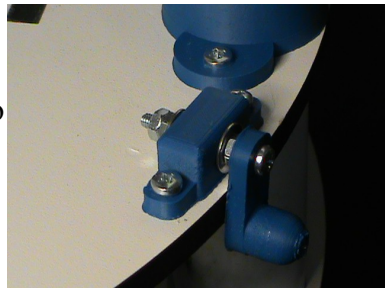


Door latch.

37: Mount the DoorLatchBase using two M3x16mm bolts and nuts. It goes in those two holes close to the right side post.

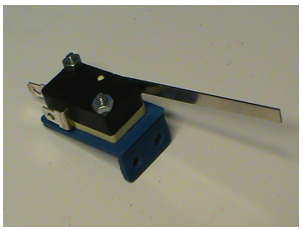
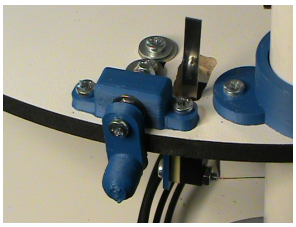
38: Put one M3x24mm bolt through the front of the DoorLatchHandle. Fasten in it place with 3mm nut. Tighten it down fairly well.

39: Put one 3mm washer onto the bolt, then stick it into the DoorLatchBase.



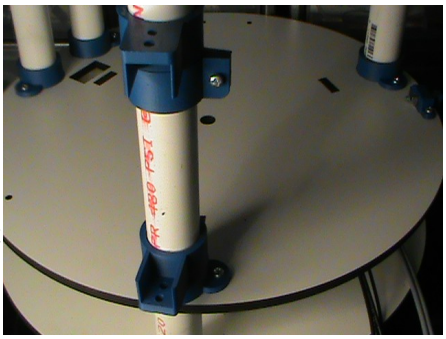
40: Put another 3mm washer onto the bolt, and fasten in place with two 3mm nuts, using one as a locking nut for the other. You want it to turn, so make sure it can do that. If you later find out it needs more space between the DoorLatchHandle and the DoorLatchBase, just add one or two more washers between them.

Door switch.

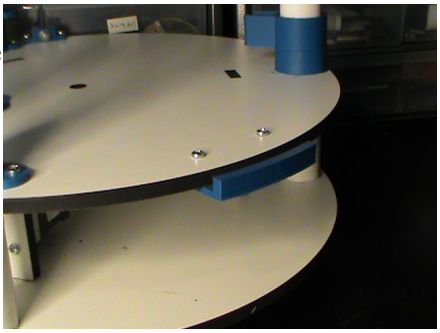
41: Mount the limit switch with the long arm to the DoorSwitchMount using two M3x16mm bolts and nuts. Refer to the picture for orientation.
42: Mount the switch assembly onto the plate 1PCB2 in the slots provided right behind the door latch base. Use two M3x16mm bolts, two 3mm washers and two 3mm nuts.

Door hinges.



42: Drop one SwingHinge down onto the front left post, with the opening pointing up.
43: Drop the LevelingCollar down onto the same post.
44: Drop another SwingHinge onto the same post, this time with the opening pointing down.
45: Put a M3x12 bolt and nut in the LevelingCollar. You can leave it a bit loose at this time, we'll be fastening it in place in a bit.

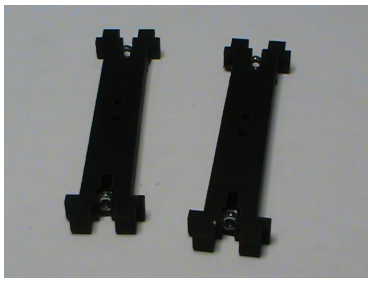
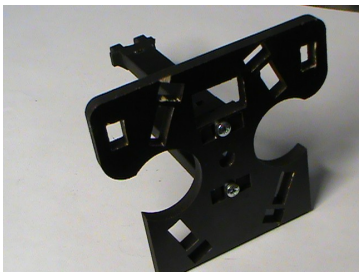
Outside Guides.



46: Fasten two OutSideGuides onto the 1PCB2 plate. They go on the bottom of the plate with the tab pointing up. Use M3x16mm bolts and nuts.

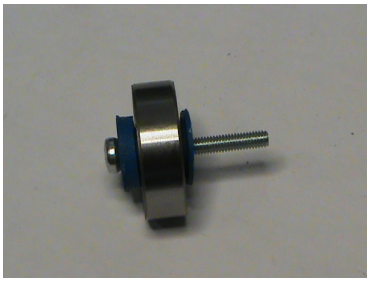
At this point we need to switch gears for a bit. Before we can put the top plates on we need to get the carriage built and in place.

Building the carriage.

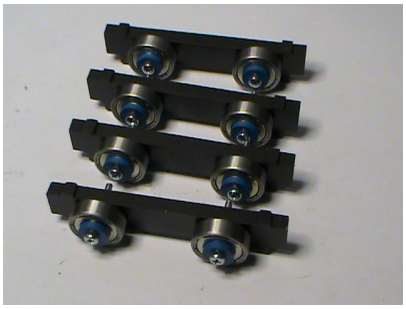
47: Take the two carriage center supports and place a small piece of tape across the slot where the nut will go. Do this for only one side of the supports.
48: Turn the pieces over and place one 3mm nut in each slot, then cover that with another small piece of tape. This will hold those nuts in place while we put the rest of it together.
49: Take one of the Carriage top/bottom plates and place one of the carriage supports you just placed the nuts in down into the slots near the center of the plate. Fasten in place with an M3x16mm bolt from the other side.

Bearings and inserts.



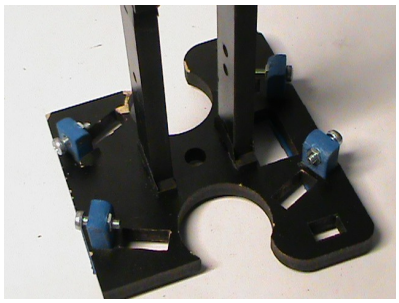
50: Find all sixteen Bearing Inserts. There should be eight with a thin base and eight with a thick base.
51: Take one each of the bearing inserts and place them in a 608ZZ bearing.
52: Push a M3x25mm bolt through the thick base insert, then all the way through the thin one on the other side.

Preparing bearing supports.



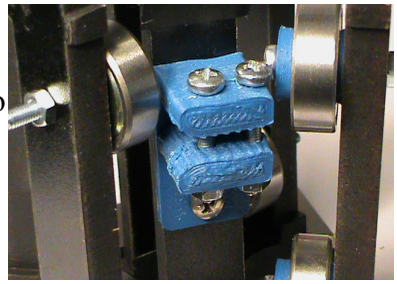
53: Now push the bolt through one of the holes in one of the Carriage Bearing Supports, and fasten in place with a 3mm nut.
54: Repeat step 53 until all eight bearings are mounted on the bearing supports.

Carriage adjustment mounts.

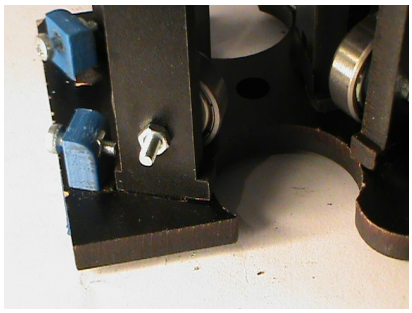


55: Press all four CarriageAdjustmentMountB's into the slots on the carriage top/bottom plates. If they fit good and snug, fine. If not you can drill a hole through the carriage adjustment mount and bolt them into place.
56 Put one M3x12mm bolt and one M3 nut in each of the eight holes in the carriage adjustment mounts. Run the bolt through and use it to pull the nut into the space provided for it, then loosen the bolt back up.

Belt clamp.



57: Use two M3x12mm bolts and nuts to fasten the BeltMountClamp to the front of the carriage center support. The front one is the one on the side of the top/bottom plate that is widest and has two slots on either side. Look at the picture below and you'll see what I mean.
The BeltMountClamp should have the small tab towards the top.
58: Fasten the BeltMountclamp movable piece to the BeltMountClamp. Use two M3x20mm bolts.



Install bearing supports.

59: Place the carriage bearing supports with the bearings attached into the slots on the carriage bottom plate. The bearings go on the side

towards the center of the plate. Look closely and you can see towards the end of each bearing support are two notches sticking out. The *shorter* one goes towards the carriage adjustment mount, the *longer* one points towards the center of the plate.

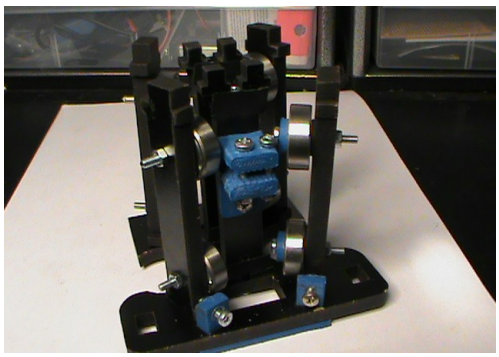
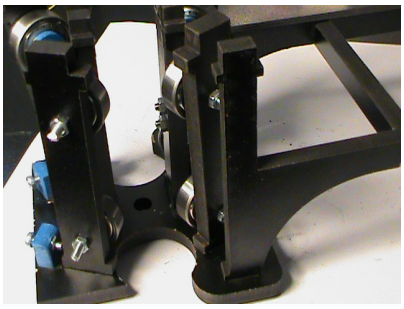


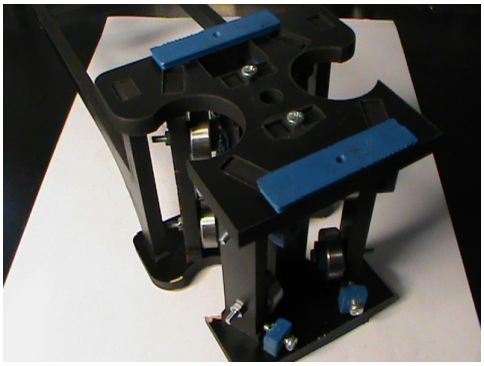
Table supports.



60: Place the Table Support Cross Braces into the two plate supports. You can glue them in if you wish.

61: Place the Table Plate Supports into the two slots on the bottom carriage plate. Make sure they are seated all the way down.

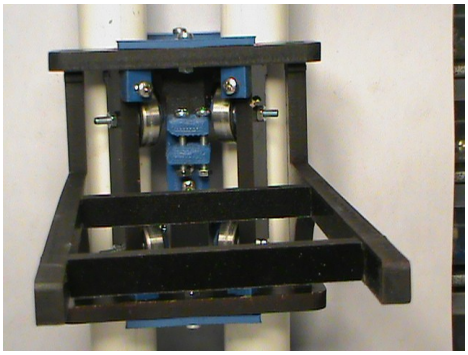
Finishing the carriage assembly.



62: Now comes the fun part. Place the top carriage plate on top of the assembly you have so far. Start at one side (I recommend the front, where the plate supports are), and get each piece to fit into it's matching slot on the top plate.

It can get tricky to get them all to line up, but take your time and don't try to force it. With a little bit of work, and luck, you'll have them all in place. When you do make sure they are all seated, then use two M3x16mm bolts through the top plate and into the center supports to hold it all together.

Congrats! The carriage is ready to be put into the machine.

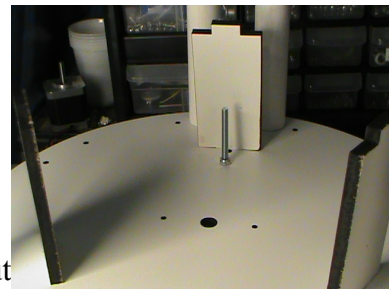


Installing the carriage on the posts.

63: Slide the completed carriage down onto the two rear posts of the machine. We'll adjust for level in a later step.

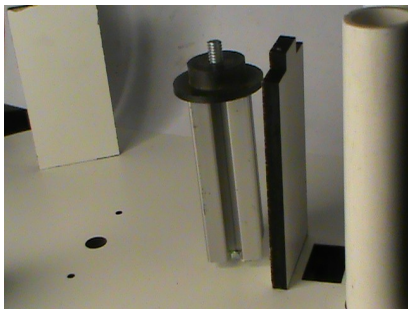
Now we can get back to assembling the machine itself. Yeah!

Adding the third plate.



64: Slide another LevelingCollarB down onto each post. This time with the tab at the top.
65: Clean up the four post holes on plate 1PCT1just like you did the bottom plates. Make sure the holes aren't too tight. This plate only has one clue about how it should be oriented. That is it has one extra hole towards the back, close to the two holes the OutSideGuides will go in. That hole should be on the right side. If it's not, flip the plate over.
66: Align the post holes on the posts and tap it down. Don't go past about five inches (127mm) from the top. You're going to have to tap it back up a bit in a few minutes, so why make it harder than it has to be?
67: Insert a M5x50mm bolt up from the bottom into the hole in plate 1PCT1 that is about 22mm in front of the slot for the rear deck spacer. There are two holes there. Use the one closest to the center of the plate. Put a 5MM nut on it and fasten it tight.
67: Slide the three large DeckSpacers into place. The one with the extra long tab goes in the back by the duel posts, with the long tab down. We'll mount the carriage limit switch there in a bit.

Starting the syringe swivel.

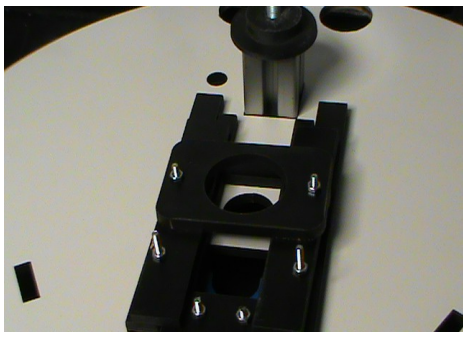


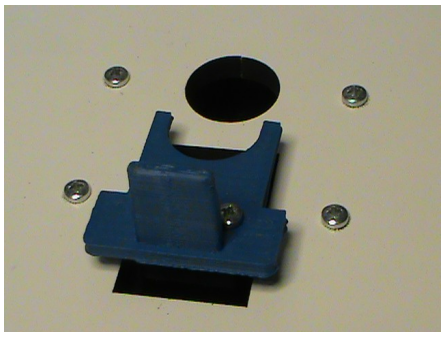
68: Cut 78mm off of the aluminum T-slot profile.
69: On one end of each of the pieces tap 1/4-20 threads. Try to go down at least 10mm to 15mm or so if you can.
70: On the end of the shorter piece that you did *not* tap, make sure the hole is clear and will slide down onto the M5x50mm bolt you put fastened onto plate 1PCT2. It doesn't need to be snug, as a matter of fact we don't want it to be too sloppy but we *do* need it to slide up and down.
71: Cut a 31mm length off of the 1/4-20 all-thread. Set the rest back for the syringe.
72: Thread the 31mm piece into the end of the shorter piece of T-slot profile.
73: Push the SyringeSwivel onto the all-thread you just installed, large diameter down.
74: Put the completed part down onto the M5x50mm bolt you fastened to the plate 1PCT1.

Mounting syringe slide to the top deck.

75: We need to do some work on the top deck before it's put on. First, prepare the plate by making sure all the large holes will fit down on the posts with no trouble. Lightly sand them if they are too tight.
76: Now orient the 1PCT2 plate so that the hole beside the square cut-out towards the back of the plate is to your right. That's the plate right side up.
77: Insert four M3x35mm bolts into the holes towards the center of the plate.
78: Flip the plate over while holding those bolts from coming out. You are now looking at the bottom of it.
79: Find the laser cut parts SyringeSlide. There should be five parts. Two are short and wide, two are longer but thinner, and the fifth is the slide itself.
80: Set the slide itself down on plate between those four bolts. The open notch at the end goes towards

the square hole in the rear of the plate. To help with the alignment put the short section of T-Slot you slid onto the bolt on plate 1PCT1 into the square hole. Just don't forget to return it before you put the top plate on the machine.
81: Slide the longer and narrow laser cut pieces down onto two of those bolts. Follow the pictures to see how they set. The stubby end of them goes towards the front of the machine.
82: Put one M3 flat washer down on each bolt. They'll act as spacers to give the slide some room to move.
83: Slide the two remaining pieces down on top of those pieces. This time the wider side overhangs the two bottom pieces you just placed. The idea is they will hold the slide from dropping out and still let it slide back and forth.

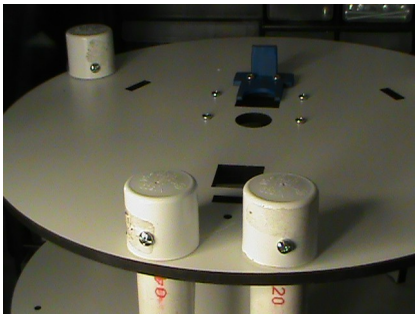




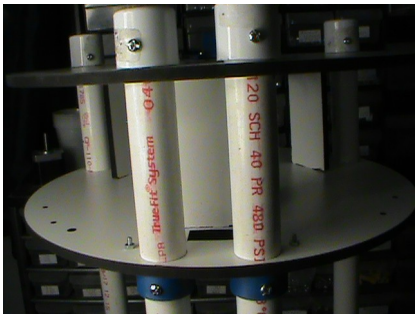
84: Put the SyringeHolder down on the two bolts closest to the center hole.
85: Put M3 nuts on each of the four bolts, then pick the plate up so you can get to both sides and fasten all four down. Check a few times to make sure the pieces are all aligned right to guide the slide forward and back okay and that it slides up beside the T-Slot extrusion.
86: Insert two M3x25mm bolts down through the SyringeHoldDown, then through the SlideSpacer, and into the SyringeSlide you just mounted on the top plate. Once again, consult the pictures to see how it all goes together.
87: Fasten both bolts down using M3 nuts.

Don't forget to return the T-Slot to it's place on the bolt on 1PCT1!

Installing the top deck.



88: Time to put the top plate on the machine. Align it on top of the posts, and slowly tap it down. You'll want to go down far enough that the PVC end caps can sit all the way down onto the posts. What we are going to do is take everything down far enough that we can put the end caps on, fasten those in place, and then bring everything back up to the bottom of the caps.
89: To make it simpler I recommend you drill a small hole into each end cap. What it does is let air escape while you're tapping them down into place. Now's the time to do that. It doesn't take much of a hole, but it does make a difference.



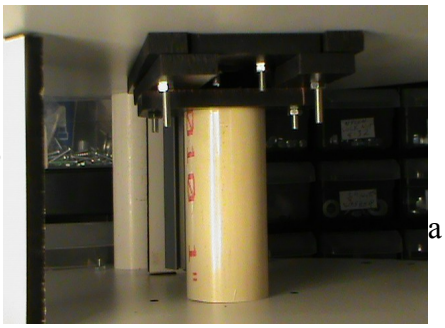
90: Set the machine on the floor and tap all four end caps into place. Make sure they are all seated down as far as they can go.

91: Turn the machine around so the back is towards you, and drill a small hole in each of the end caps and through the PVC posts. Put a #6x1/2” (3.5mm x 13mm) pan head screw into each hole.

Top leveling collars.

92: Use M3x16mm bolts and nuts to fasten each of the LevelingCollarB's you previously slid down each of the posts. Put the bolts up from the bottom and the nuts on top of the plate 1PCT1.
93: With these next steps you might notice your machine leaning to one side or another. That's because not all the plates are in their final position. Just tap them around a bit and get it as straight as you can. No biggy, they'll come into place one by one as we go along. Just getting them close and then giving the posts a bit of a twist now and then will help bring them into alignment.

94:Tap the top plate up until it's tight against the top PVC caps.



Add the syringe holder/guide.

95: Cut a piece of one inch PVC pipe and place it in between the two plates right in the center. The top side goes up inside the SyringeHolder you fastened to the bottom of the syringe slide. Take look at the picture to see what I mean.

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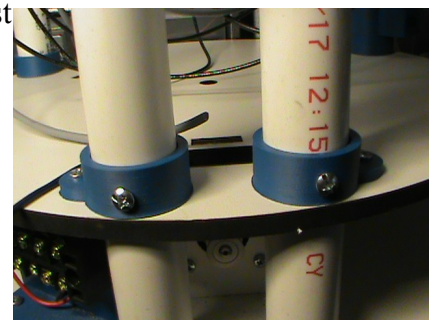
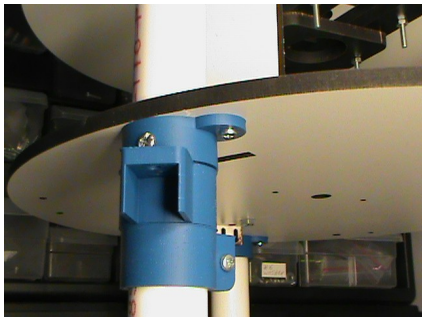
Positioning the third deck.

96: Now tap the second from the top plate up and into position. Make sure the deck spacers are lined up with the slots on both plates. A bit of fiddling around with them and you should get it into place okay.
97: When the top two plates are in position drill a small hole that you can thread #6x1/2” screws or their metric equivalent into through each LevelingCollarB and into the posts. Make sure you hold the plate up tight as you do so. You should have the top plate snug against the PVC end caps.



98: Drill a slightly larger hole through just the LevelingCollarB's. Make it just large enough so that the screws have enough room that they don't crack the plastic when you tighten them down.
99: When you have the top ones done, go ahead and do the bottom ones right on top of the plate 1PCB2. Make sure the lower plates are pushed down as far as they will go onto the PVC end caps and all the deck spacers are in place.



Position the swing hinge.

100: Push the top SwingHinge that you placed on the left post back in step 44 up the post and fasten the LevelingCollar to hold it in place. Leave enough slack that the SwingeHinge can move freely.

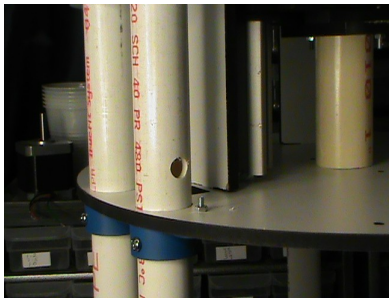
That completes the basic skeleton of the machine. We still have a bunch of work to do, but at least it's looking more like a machine not a pile of parts, right?

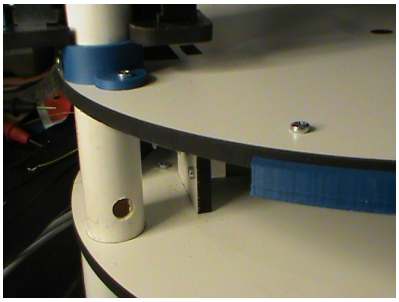
Pulling the wires to the top.

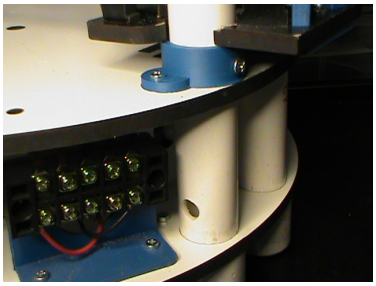
101: We need to get those wires we ran in the bottom of the machine up to the top. We'll do that through the rear two PVC posts. Now that we can see exactly where the decks are going to be we'll do that now. Drill a 3/8” (9.5mm) hole in the locations shown on this picture. If you want more room to pull the wire through you can even make the holes a bit bigger, like maybe 7/16” (11mm).

One hole will go on the PVC post right by the terminal mount, with a matching one between the top two decks. Matching holes will go on the other rear post.

Don't drill them in the back of the post because we're going to be covering up that area later. You want them at an angle, where you can see to get the wires through but they won't be in the way of anything later. Follow the pictures and you'll do fine.

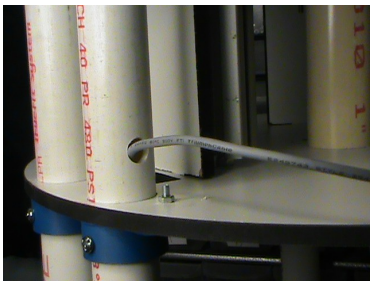




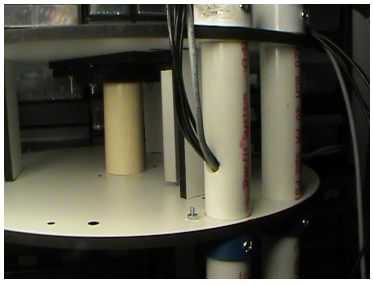


With the duel rear post closest to you, push the shorter two conductor shielded wire up the post to your right.

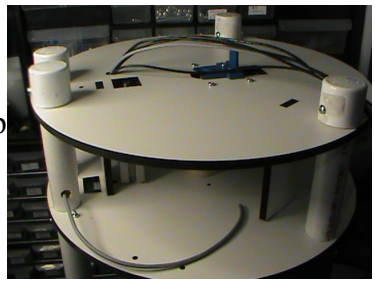
To get them out at the top, bend a paper clip into a small hook and fish them out.

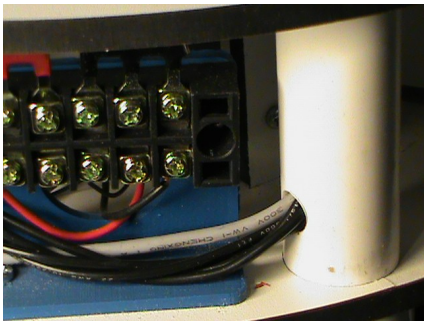


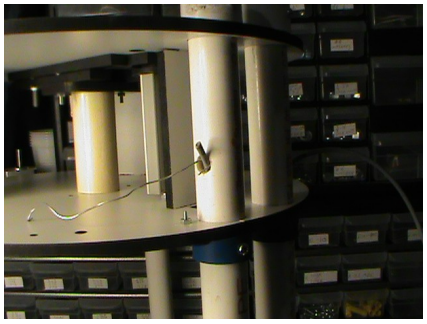
The other two conductor shielded cable and the four conductor 22awg wires go up the post to your left. Depending on how thick the insulation is on your cables it might be easier for you to run both two conductor cables up the post on the right. It's up to you, it won't hurt anything either way.



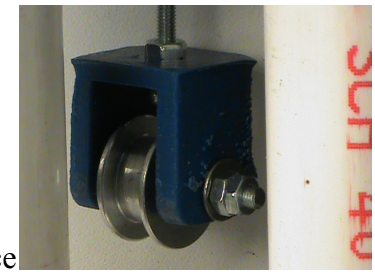
102: Push the four conductor 22awg cable and the longer of the 24awg shielded cables up through the small hole beside the square hole towards the rear of plate 1PCT2. Leave the shorter 24awg cable in between the top two decks.





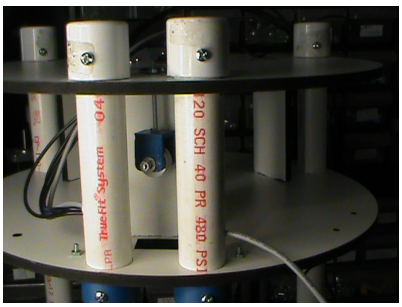


Carriage belts and pulleys.



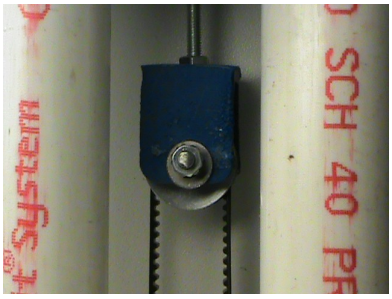
103: Prepare the TopIdlerBracketB by inserting one M3x55mm bolt into the bracket from the inside, where the pulley will go. Fasten it in place with a M3 nut.
104: Now take one M3x25mm bolt use it to mount the idler pulley in place in the center of the bracket. Hold it in place with a M3 nut. Go ahead and double nut it to be sure it doesn't come apart on you.

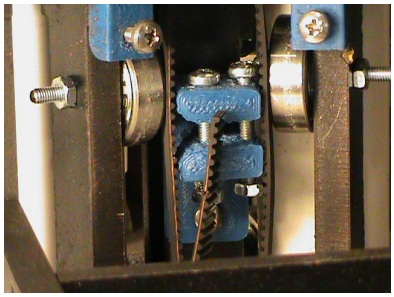
105: Now stick the center bolt up through the hole in the rear of the top plate 1PCT2, right in front of the duel posts. Fasten it with a 3mm washer and nut. Leave it loose, we'll use that slack to tighten up the belt.



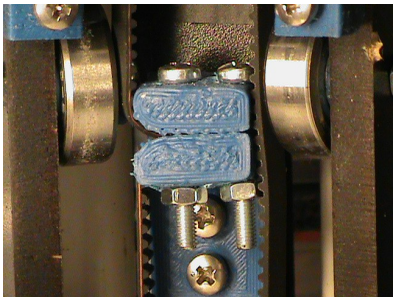
Timing belt.

106: Run the GT2 timing belt around the upper pulley and down through the slot in plate 1PCT1. With the front of the machine facing you the belt should go straight through the slot in the top of the carriage, past the bearings and out the slot in the bottom of the carriage.





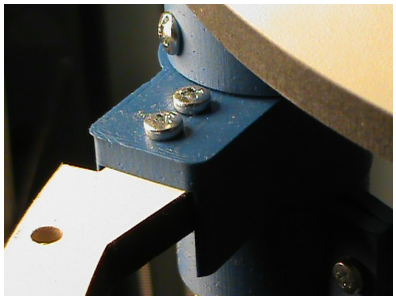
From there run it down and around the pulley on the stepper motor and back up and through on the left side of the slot in the carriage. The two ends of the belt should meet in the middle of the left side of the carriage.

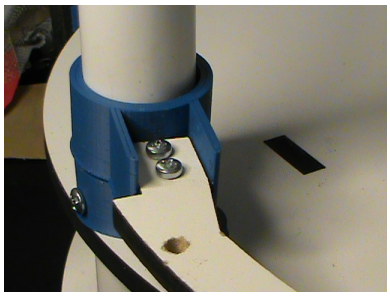


107: Slip one end of the belt into the clamp *behind* the bolts. Using needle nose pliers helps get it in there.
108: Making sure you don't pull that end out of the clamp tug the belt to take some of the slack out, mark the spot where it needs to be cut, and then cut it off. *Make darn sure the belt didn't slip off of the pulley on the stepper motor before you cut!*
109: Using the needle nose pliers again, work it into the clamp by the first one. Again, *behind* the two bolts.
110: Stick a screw driver down through the top slot in the carriage and tighten both bolts on the clamps down.
111: Tighten the bolt on the top of the machine to tension the belt. You don't need it too tight, just take out all of the slack and then a bit more.

That's it for the carriage. It's ready for movement as soon as the wiring is in place and the Ardunio is programmed. But that will have to wait a little longer. We still have some work to do.

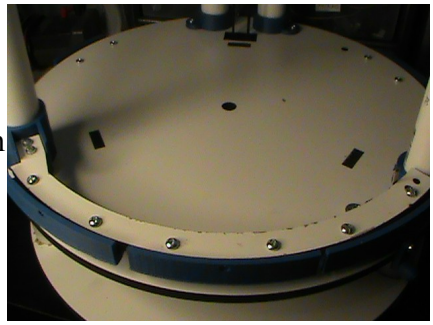
Door frame.





112: Fasten the two Door Frame's to the two SwingHinge's that are waiting on the left hand post. Use M3x16mm bolts and nuts.

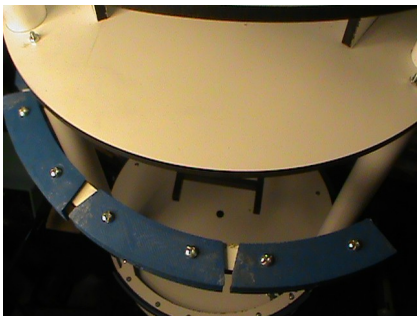
Door Track.



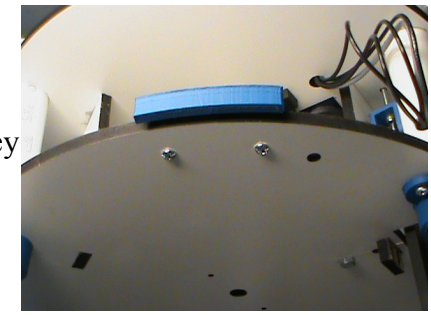
113: Attach the six 3D printed DoorTrack pieces to the DoorFrame. Use M3x15mm bolts and nuts. On the top DoorFrame, which goes on on top of the DoorFrame and aims down, put the bolts down through the DoorTrack first then the DoorFrame. On the bottom the bolts go through the Doorframe first, then through the DoorTrack, and the DoorTrack points up.

Line up the *back* edges of the DoorTrack with the back edges of

the door frame. We want that space it creates on the front side to put the door itself later.



Top outside guides.



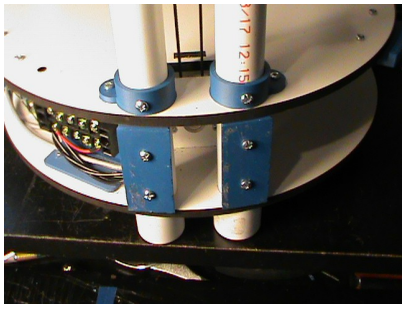
114: Attach the top two OutsideGuides to plate 1PCT2. This time they go on top of the plate pointing down, and the bolts come up from underneath. Fasten with M3x16mm bolts and nuts.

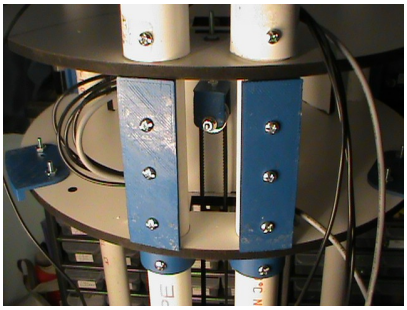
Adding the side covers.

115: Using #6x1/2” screws or the metric equivalent, attach the four SideCoverBracket's onto the posts between the bottom two decks, and the four TopSideCoverBracket's between the top two decks.

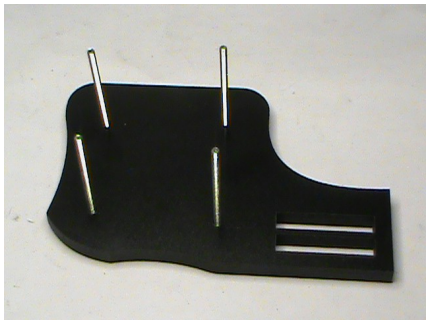
Be careful when drilling into the back duel posts! Remember, there are wires in there!

You can just align them by eye. I find it helpful to eyeball the top of the bracket and the plate. You can get a pretty good idea of when they are straight by the amount of bracket showing on each side that way.





Well, you're really closing in on it now. Time to shift our attention and get that syringe pump put together and mounted on top.



Building the syringe pump.

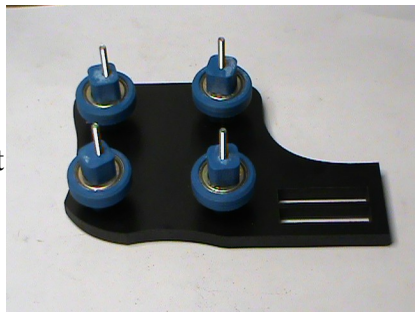
116: Insert four M3x50mm bolts into the four holes on the SyringeCarriage side with the closed slots, and lay it down on the

table, bolt heads down.

Bearing sleeves.

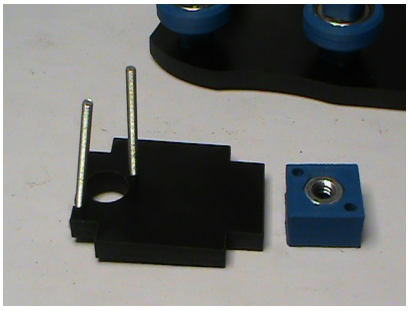
117: Snap the sixteen BearingSleeves onto four 608zz bearings, two on each bearing.

Bearing inserts.



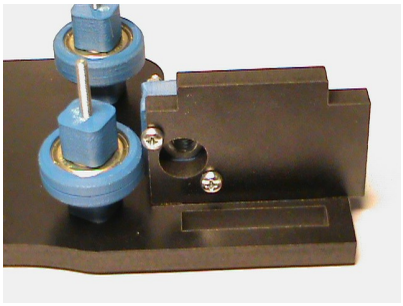
118: On the two bolts on the left, slide a SyringeBearingInsertOffset, one each. The wide end should be down. On the two bolts on the right side drop a SyringeBearingSleeveStraight, also wide end down.
119: On top of each of those drop one bearing with sleeves.
120: Finish the stack off with another SyringeBearingInsert, offset ones on the left, straight on the right.

Screw and nut holding block.



121: Press a 1/4”-20 nut into the CarriageScrewHolder, then fasten that to the small carriage piece with the hole in it, using two M3x16mm bolts and nuts. Put the screw up through the laser cut part first, then through the CarriageScrewHolder. The nut should be trapped between the two.

Placing all the carriage pieces.

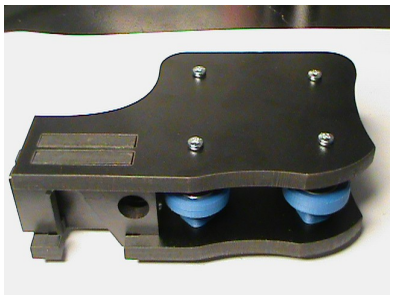


122: Take that assembly and place it into the top slot on the SyringeCarriage side piece. The end with the CarriageScrewHolder goes towards the bearings, with the CarriageScrewHolder on the side away from the remaining slot.

123: Take the remaining piece of the SyringeCarriage, the one with the angled slot in it, and place it in the other slot. The steeper angled side of the piece goes towards the bearings, making the hole it it line up with the hole coming from the first piece.

Check this picture to see if you have it all in place correctly.

Finishing the carriage.



124: Place the top side piece into place on top of the entire assembly you have so far. Check and make darn sure the bearings and their spacers are sitting like they should, and the two smaller laser cut pieces are in their respective slots.
125: Fasten the entire assembly together with four M3 nuts. You can leave the ones on the back (the ones with the offset inserts) just a little loose. Those are our adjustment ones, for when we get it put on the t-slot.

Mount the T-slot extrusion.

126: Do you remember that longer piece of T-Slot extrusion you cut off back in step number 68? Good, because it's time to make use of it.

If you recall, you threaded one end of it to take a 1/4-20 threaded rod. With one hand reach in between the top two plates and, making sure the slide on top is all the way out, push the shorter piece of t-slot up. The 3D printed SwingSwivel on top of the short piece should push up through the square hole.

Now thread the two t-slot pieces together. Get it pretty tight up against the SwingSwivel.

Now you'll notice that you can rotate it and lower it into the square hole. When it's down push the slide to the back of the machine and the t-slot can't go back up, it gets locked into place. If you had a syringe in place it also would get help in place at the same time. How convenient is that!

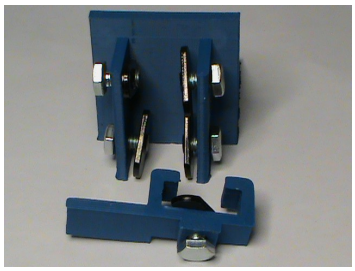
Put the carriage on the T-slot.

127: Slide the syringe carriage down onto the t-slot.

128: Using pliers turn the two bearing inserts on each rear bearing until you have smooth movement with no free play. If you recall, you left those bolts a little bit loose, and this is why.
When you are satisfied everything is right where you want it, tighten down the two through bolts.

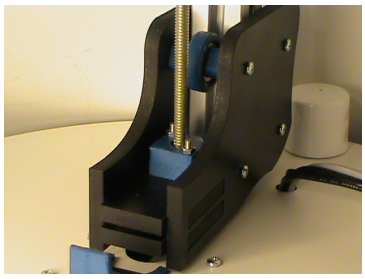
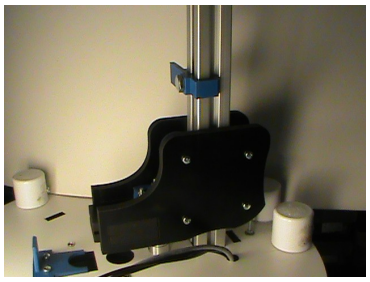
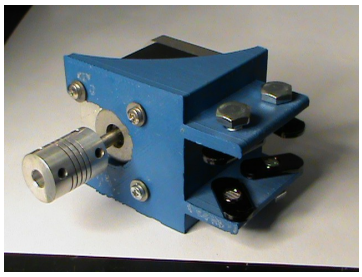
Prepare the switch and motor mount.

Note: For the five 1/4-20 bolts below you can certainly use the standard bolts sold for use with the T-slot nuts. However, at least for the one used to hold the switch mount in place I recommend a standard bolt. That adjustment will be right behind the threaded rod and is hard to get tight with an Allen wrench. It's much simpler to get at with an open end wrench. Your choice, though.

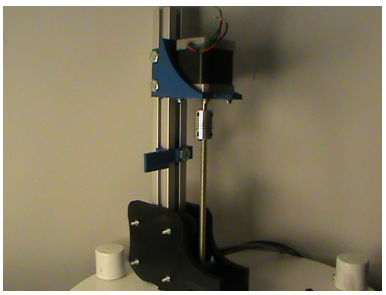


129: Install two 1/4-20x1/2” bolts and t-nuts on the SwitchMount, then drop it down onto the T-Slot extrusion above the SyringeCarriage.
130: Take the remaining piece of 1/4-20 all-thread that you cut back in

step #71 and screw it down into the nut that's trapped between the two plates on the syringe carriage.
131: Install four 1/4-20x1/2” bolts and t-nuts on the SyringeMotorMount.

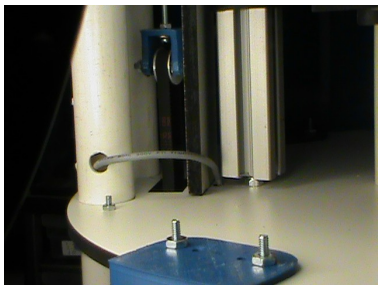




Make it look like a syringe pump.

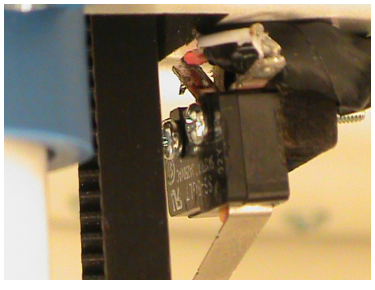


132: Install the stepper motor onto the SyringeMotorMount using four M3x10mm bolts and washers.
133: Install the 5mm x 6.35mm Flexible Shaft Coupling to the stepper motor.
134: Slide the SyringeMotorMount assembly down onto the T-slot extrusion.
135: Slide the stepper motor assemble down until you can get the all-thread into the flex coupling. Fasten it there by tightening the set screws.
136: Fasten the four bolts on the stepper motor mount down tight. You should have a little bit of free play you can use to get the motor shaft and the all-thread in alignment.

Carriage limit switch.



137: Tuck the shielded wire you left between the top two plates down into the hole right in front of the rear deck spacer. Measure down from the bottom of deck 1PCT1about two inches (51mm) or so, and cut it off there. Strip the wires back enough to solder the ends onto a micro switch in the normally open tabs. solder them up.



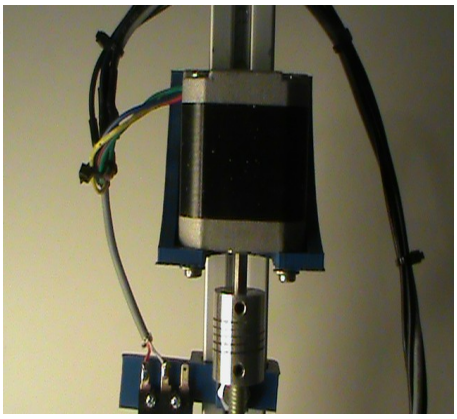
Now mount the switch on the *back* side of the deck spacer, bolting them in place in the two slots with two M2x16 pan head machine screws. The bolts should go through the switch first, then the mounting plate. In other words, the bolt heads go on the side beside the belts, and the nuts are up against the deck spacer.

The wire raps around from the front to the back of the deck spacer, and you should try to get it above the bolts.

137: Hold the micro switch for the syringe limit switch up to the SwitchMount and position it so the switch will get tripped when the carriage comes up. Drill two holes to match the mounting holes in the

switch. Fasten in place with two M2x16mm pan head machine screws and nuts.

138: Use some small wire ties to organize the wires on top of the machine. You will want them in a loop going up to the top of the T-slot extrusion and then back down to the switch. That is so they don't get strained when you rotate the syringe assembly loading and unloading syringes. Make sure you leave enough so that you can slide the limit switch bracket up and down to where you need it.



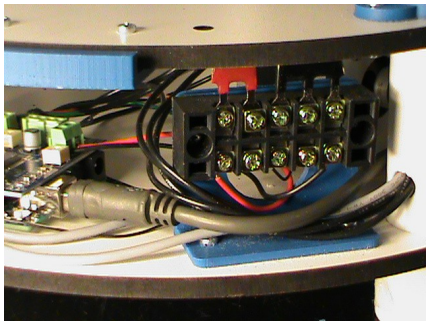
139: Cut off and strip the shielded cable for the limit switch and solder the two wires onto the normally open terminals on the switch.

Syringe stepper wiring.

140: Strip and solder together the four wires on the syringe stepper motor to the four wires you ran up the inside of the post. Don't forget to either electrical tape the connections or slide heat shrink tubing on the wires before soldering them.

USB cable.

141: Run the USB cable for the arduino into the back of the machine between the two rear posts. This is, of course, between the bottom two decks. Have it run around the left side post (you should have the rear of the machine facing you) and then in front of the terminal block, and from there over to the arduino where you plug it in.



Since the arduino is going to be controlled by a computer anyway, we'll let the USB port supply the power to it. The gShield will be powered from a different power source.

Loading firmware.

Once you have that cable ran it's time to load the firmware to the arduino. We'll do this before we even hook up the gShields power.

If you are new to programming the Arduino you will need the Arduino IDE. You can find that here: https://www.arduino.cc/en/Main/Software

There are some guides at https://www.arduino.cc/en/Guide/HomePage to get you started.

You will also need the Accelstepper library, available at http://www.airspayce.com/mikem/arduino/AccelStepper/

The firmware is available on the projects website at https://hackaday.io/project/20702-openespin

When you have the software ready to go, make sure you have the USB cable plugged into both the arduino and the computer and upload the firmware.

When that's done successfully, it's back to the machine for a bit.

Power supply.

142: We've already run the power for the gShield from it to the terminal block. So now we need to get that terminal block itself powered up.

The power supply can be any 12 volt supply, such as a desktop computer supply, or one like this one, which is preferable:

What ever you use all you need is the 12 volt and the ground lines. Run them in the back of the machine right alongside the USB cable, and fasten them to the terminal block, positive to the red section of the terminal block, negative to the black.

Making it move.

143: Double check all your wiring to make sure you have the polarity right. If everything looks good in the arduino IDE click 'tools' then 'serial monitor'. If everything is working you should see two lines, the first 'Start Up' and the second 'Setup Needed'. If you see garbage, you most likely need to set the baud rate to 57,600. You can do that in the lower right corner of the serial terminal window. Also make sure it's set to 'Both NL & CR'. Then close down the serial terminal and reopen it.

When you see the line 'Setup Needed' then all is well and they are communicating correctly.

At any time you can type the letter 'R' and you will get a list of the current settings. The other commands are listed in the read me file for the firmware, and I'll let you look that over yourself. I'll just give you the commands needed to give it a little test run here.

Now, if you are using the 1/4-20 threaded rod on the syringe, the default settings should be all you need. If you're *not* running 1/4-20 rod you'll have to change the settings. See the read me file that came with the firmware download on how to do that.

I'm going to assume you *are* using 1/4-20 for the rest of this. If not, go look at the read me file, make the changes needed, then come back here.

To get it to recognize that it's ready to go you just need to change one setting, even if it's right back to what's in there as the default. Basically, it just sets a flag saying you've been in here checking the settings out and all is now well.

Type 'ms1000' and hit enter. That sets the rotary, which you don't have, to a speed of 1000. Doesn't matter that you don't have it, changing just that setting lets it know you've looked the settings over and are ready for some movement.

Shut down the serial terminal window, then run it again. Now you see three lines, 'Start Up', 'Loading Setup', and 'Needs Homed'.

See, progress already!

Before we go getting carried away lets test those limit switches to make sure they are working okay. Do that by typing 'ts' and hitting enter. You'll get a response showing the current state of the switches. Now hold one of them closed and try again, then the other one.

If you don't get the response your looking for, check your wiring. If the the wrong one changes then you have they backwards on the gShield, so swap them.

When all is well, you can move on to homing the machine.

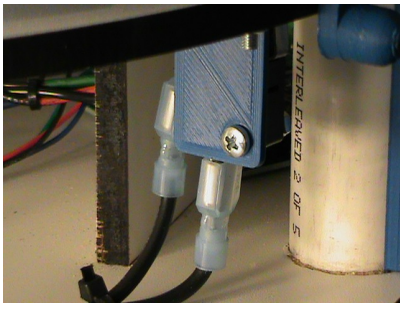
144: Well, if you got through that last step, congratulations! I know it was a long one, but it was necessary before we moved on.

Set the syringe limit switch so that it will get made before the carriage hits the motor coupling or the motor mount. Don't worry about exact positioning yet, we just want to see if it moves in the right direct and get the carriage up towards the top for now.

Type 'h' and hit enter.

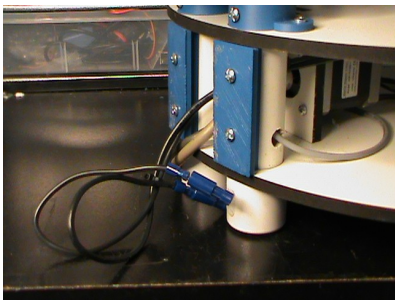
The syringe will slowly move up until it hits the switch. If it goes in the wrong direction reverse the wires on the gShield. If it doesn't move, just makes funny noises or moves erratically, the wires are not in the correct order on the gShield. There are plenty of resources on the web that describe how to determine the correct order, so I won't go into it here. Rest assured, the help you need is only a few clicks away. You may also have to (and should!) set the current for each motor. Directions for that in the gShield manual.

Wiring the door switch.



145: We have one more little wiring task we need to take care of, the matter of that door switch. It's meant to be used to cut off the high voltage when the door is open. At this point all we need to do is cut a piece if the 24awg two conductor cable about 18 inches (457mm) long. Crimp two female spade terminals to each of the wires on one end, and slip them onto the door switch's terminals.

Run the other end out the back of the machine between the two read posts.

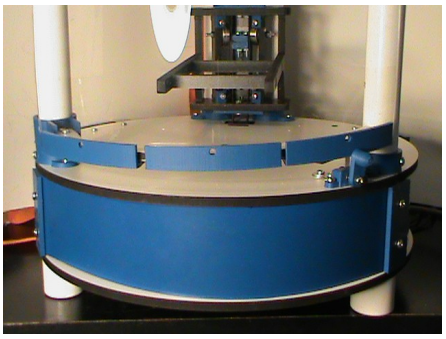


Those wires will later hook up to the high voltage power supply's 12 volt supply. The door switch is rated for both 12 volt DC and AC line current, so all you need to do is splice the positive line feeding the high voltage power supply into these two wires, and the high voltage will be cut off if the door is opened.

The actual high voltage output should never be hooked to these lines! You want to cut the low voltage going into the high voltage supply, ***not it's output!***

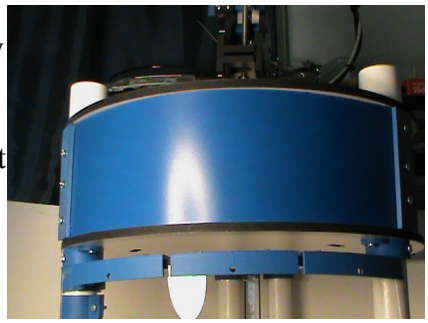
Read that last short paragraph again a couple of times. It's important!

Side covers.



146: Take the six acrylic side covers and snap them into place. They are the two topsidecovers, one topcentercover, two bottomsidecovers and one bottomcentercover. Be careful or they'll snap on you!

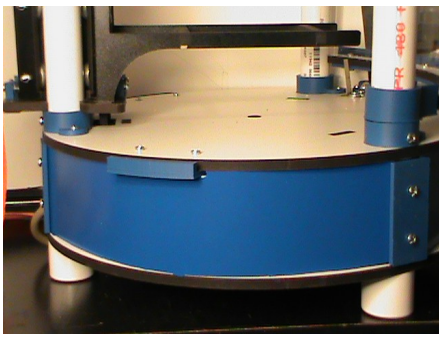
On the side covers notice that the little notch is not centered on the piece. The end where the notch is closest to the end goes towards the back on the machine. It usually works out best if you put that side in first.



Bend them slow and easy so they don't break. If you would like you can take the sidecoverbracket off and do it that way, slowly bending the piece into place.

I recommend taking a heat gun and heating them up a bit as you bend them into shape. That takes the brittleness out of them just enough to get them where they go. After they are all in place it doesn't hurt to give each one of them a bit of the heat treatment, either. When they cool back down they'll hold the curve a lot better.

Once it's cooled back down and is in the shape you want you can



decorate it if you wish. Painting it works great. You can even apply vinyl to them, but I'd the caution that you do so *after* it's curved into the shape you want. If not, it'll crack on you every single time.

If you ever remove them it's best to take the sidecoverbracket off while holding the acrylic in place, and then slowly let the pressure off. It's not that big of deal, but I've broken one now and again not doing that, so take it for what's it's worth.

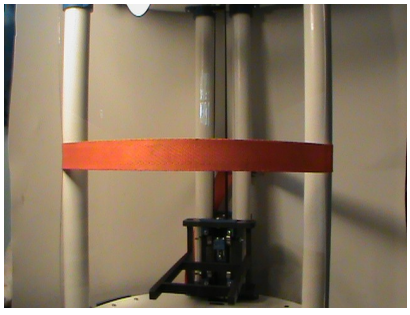
Door acrylic cover.

147: Lets get that door cover in place next.

First, measure the opening between the hinges, inside of the grove to inside of the other groove, and subtract about 1mm to 1.5mm. For sideways measurement go from even with the door track on the right side of the door, and about 8 to 10 mm past the door track on the left.

Cut that piece out.

A heat gun *really helps* this next step!



If you have something around about the same diameter as the door frame just lay the acrylic on top of it and apply heat to the acrylic until it bends down.

If you *don't* have such a thing around, you can still get this. Trust me, it works.

What you do is place the acrylic about a half inch into the door track, top and bottom, on the left side of the machine. Heat the acrylic up on that side until you can budge it a bit farther into the track. Then just repeat until it's all the way in. The father you get the larger area

you'll need to keep warm. It's a bit time consuming, and you need to make sure top and bottom are staying even, the same distance into the track, but eventually you'll get it. Just don't try to force it or you chance snapping it in pieces.

Once in place you may notice the middle top to bottom on both sides buckles out. If so, I use a strap clamp and rap it around the entire middle of the machine, heat the acrylic up, and slowly pull it into place. Take it just a bit beyond where you want it, as it'll spring back a tad when you take the clamp off.

Let it sit and cool off for a while.

148: To fasten the door acrylic in place, start on the top right side. Push the acrylic all the way up into the top door track, and make sure the right edge is even with the end of the door track. As we go along here, always push it up into the upper track, they push the lower track up to meet the acrylic.

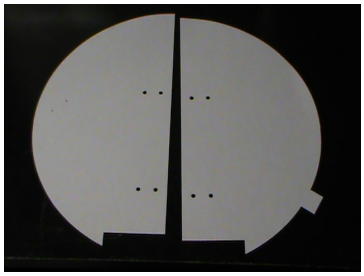
Drill a small hole through the hole in the center of the door track and through the acrylic. Go slow and don't put very much pressure on it or it'll crack on you. Hold in place with an M3x10mm bolt and nut. Tighten only enough to pull the acrylic out and in touch with the door track. Don't over tighten it.

When that ones done, go to the one below it, drilling and installing the bolt and nut. Continue until all six bolts are in.

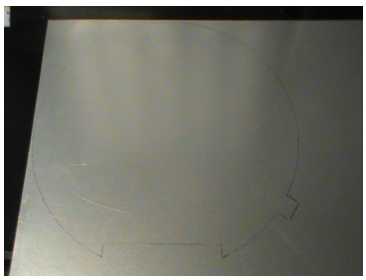
Pushing it up into the upper track and then pulling up the lower track makes the door hang better and swing correctly.

That's all there it to it! Your door is done. We only have three more small items to take care of before we wrap this up and the machine's ready for use. The first of them is the table, so lets get that done now.

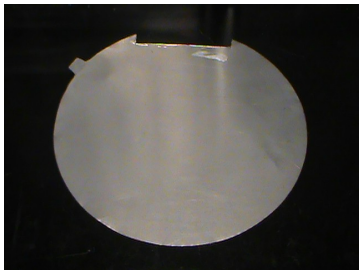
Making the table.



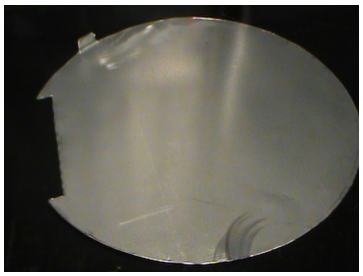
149: Print out both TableA and tableB paper copies of the door pattern, *or*, laser cut them out of paper.
150: Tape them together.



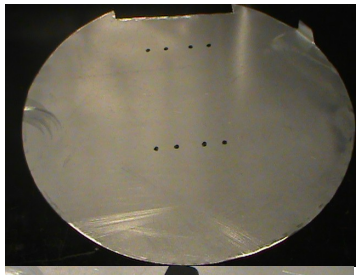
151: Place them on the metal you have for the bed. This can be whatever conductive metal you want, and you can save some money and not get the Stainless Steel, but whatever you choose should be as flat as you can get it. Heavier, to a degree, is better, in that you don't want it going anywhere during a run. The one I'm using here is 26ga plated steel. Any lighter and I'd make a table out of wood and glue the metal to it.
152: Mark all around the outside of the pattern. Don't bother with marking the holes just yet.



153: Cut out all around the lines, staying just a bit off of them. You can cut it with shears or a jig saw, or whatever you have that will do the job.
154: The final shaping I do on the belt sander, but a Dremel will work too. Sand it down right to the line all the way around, keeping the tool moving so you don't go to far in here and there. You're looking for a nice smooth curve when you're done.



155: Bend the tab down. The down side is the one with the most scratches, of course. Keep the top as pretty as you can. :) Personally, I prefer the tab on the left side, but that's just me, for which side I run the power supply on.



156: Now that you know which is the bottom side you can lay your pattern back on the metal and mark where those holes should be. *Don't drill those holes out! They are for placement purposes only.*

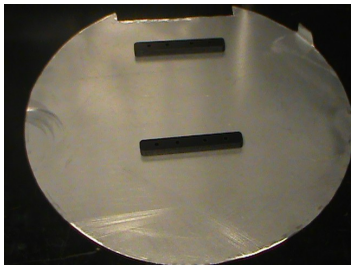
Adding the plate supports.

157: Find the two small laser cut pieces of melamine you had left over from the 'tablesupport' pattern. They should have four small holes in each of them.

What we're going to do is glue those onto the *bottom* of our table. Here's why you marked the holes in the table pattern onto the metal. I recommend Gorilla Glue for this. It holds the two different materials together really well. Use what you wish, of course.

Apply the glue to the pieces and glue them in place. Gorilla Glue expands, so take that into account when you decide how much to put on each piece.

Align each piece so the holes in the wood pieces matches the marks on the metal. Clamp them down, or put something heavy enough to hold them in place while the glue sets up.

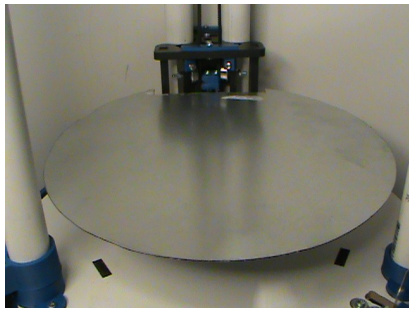


Now go take a break while the glue sets up and dries.

All set? Good! Take the clamps off/remove the weights and the table is ready.

The table slides onto the table supports in the machine. Those pieces you glued onto the bottom should slide in between the table supports and keep it centered. The tab, of course, is where you will attach the alligator clamp from your high voltage power supply.

The table is easily removed for cleaning/gathering fibers after a run. You can also build a rotary or other accessory and it'll have tabs to hold it into place the same way.



Adjust the carriage.

158: Put the table in place on the table supports in the machine. It's

time to adjust that carriage so it's sitting even with the bottom in the machine. This is not as critical as it is in a 3D printer, but we should still at least make the effort.

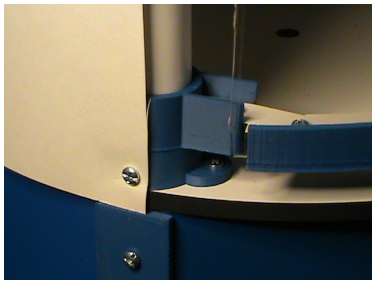
The carriage is adjusted using the screws on the carriage adjustment mounts. Taking the tops ones in and the bottom ones out on the screws inside of the machine will tip the table up, and the opposite will happen if you reverse those.

It's a bit time consuming if you really want to get it perfect, but we really don't need it perfect. When you start making runs on the machine if you notice it's all going to one side or another, or all to the front or back, yeah, then it needs to be adjusted. But otherwise it's just not that critical.

Push the carriage to the middle of it's travel, and with the table in place measure side to side and front to back, and adjust as needed. If you turn the machine to where you can get to the front and the back of it at the same time you might find it's easier.

For now, get within 1-2mm and you'll be just fine.

Adding side covers.



159: Okay, all the main work is done. All that remains is to cover those sides so wondering hands don't get shocked when it's in operation. We'll use construction paper, craft board, whatever it's called where you live. As long as it can be bent around the machine and will fit in the slots on the outside guides, you're good.

You'll need two pieces cut out, one for each side of the machine. Measure from the inside of slot formed by the outside guides, top to bottom. Mine measured 16 3/8” (416mm) tall and 12 1/2” (317.5mm) wide.

What we're going to do is let the screws that hold the levelingcollarB's to the post also hold the paper in place. Take the four screws out on one side of the machine. Leave the ones on the other side until you're ready for that side.

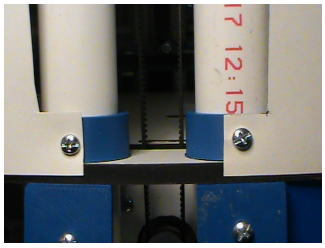
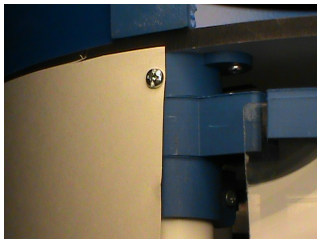
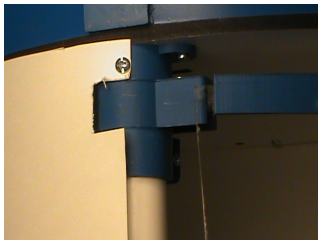
Start on the front of the machine and, while holding the paper in place in the outside guides groove, position the paper so it overlaps the screw holes by a 1/4” (6.35mm) or so. Mark where the hole under it is, and push the screw through the paper and fasten it back in place.

Then go to the top screw on the same post, and do the same there.

Now move to the back. You'll see right away we have a problem here. The paper will interfere with the carriage. We'll solve that by trimming the paper out until it misses the carriage. Hold the paper in place and mark where the top of the leveling collar is. Do the same at the top, only mark where the bottom of the leveling collar is.

Take the paper off of the machine and lay it down flat. Now mark about 1/2” (12.7mm) in from those marks you already made. Run a straight edge between the two marks, then cut that section out. When that's done hold it back up into place to check for the fit. If all is well fasten it into place with the four screws into the leveling collars.

Repeat for the other side.

I    

I'm sure you've seen one other little problem on the door hinge side. You can't open the door very far without the hinges hitting the paper. Mark out the paper at the top and bottom of each hinge, then cut in about a 1/2” (12.7mm) and remove that section of paper. Again, look at the photos. It's a lot easier to see and do than it is to describe it.

Setting syringe home position.

We still need to set the syringe limit switch so it knows where home is. The machine is designed to use 20ml syringes, and you'll need one to get this set.

With the limit switch fairly high up on the T-slot run the syringe up to it. Then pull the plunger on a syringe back until its right at the 20ml mark.

Pull the syringe hold down towards you on the machine so you can raise the entire syringe assembly up and rotate it counterclockwise a bit.

Drop the syringe into the hole in the center of the top plate, then lift it up until the top of the plunger on the syringe fits into the slot for it on the syringe carriage.

Rotate the syringe carriage clockwise until it slips down in the square hole all the way. Make sure it's down all the way. You'll notice the top of the syringe body is not setting flat on the top plate. That's just fine, it's what we're here to set.

Rotate the motor coupling by hand, lowering the syringe down into the hole. Check checking that the center of the syringe body is going down into the hole in plate 1PCT1 and is not getting stuck on the edge of the hole.

As soon as the flange on the syringe body touches the top deck, stop. That's your home position right there.

Move the syringe limit switch down until it gets made right at that point, and tighten it down.

Now whenever you go to home the syringe it will go to the 20ml mark. From there you can just tell it to go to a certain point and know where it'll wind up.

About those high voltage leads...

We have one tiny little thing left to do, and I'm going to let you decide how to do it, after I tell you what the problem is.

In the original version of the machine I always had the high voltage positive on the top, clamped to the needle. The bottom was always negative. The high voltage leads where run in through holes, one on top of the machine for the positive lead and the negative lead going up through the holes in the center of the bottom two plates. Since then, I've discovered some materials like the polarity to be reversed, with the positive on the bottom plate.

Now, knowing we're going to be switching polarity back and forth depending upon the material being run, that's not a very good way to do it. It's a hassle to pull the wires in and out all the time.

What I'm doing now is cutting two slots in the outer paper covers, one at the top and one at the bottom, and making them just big enough to get the alligator clips through. I haven't run it enough to see if it's the way to go or not, but it's an option to start with.

Another option is drilling larger holes through the plates to let us pull the clips through.

Yet another one is designing the power supply itself to let us switch polarity there. That way we could go back to permanently routing the leads through the machine as it was originally designed. The draw back to that is we're talking some pretty high voltages, and sparks jumping at the switch is going to be a problem if we don't design for it.

Of course, we could just leave the terminal attachment at the high voltage supply out where we could manually move the leads back and forth, but that rather leaves those leads out and available to shock the crap out of someone.

For now, I'm going to go with the slots cut into the paper and see how it goes. If you come up with something that works better and is safe and relatively cheap, please, let me know and we'll give it a go.

Wrapping it up.

That pretty much raps up the machine's build. You do, of course, still need a high voltage supply, and the plans for mine will be available shortly. But you don't have to use mine at all. There are a lot of designs on the web, and almost any of them can be used. As long as it has an adjustable output, you're good to go.

Unless you plan on studying low voltage electrospinning, and by low I mean <2000 volts, I would recommend getting or building one that goes to at least 30kV. For the materials I'm running right now 18kV-20kV seems to be the sweet spot.