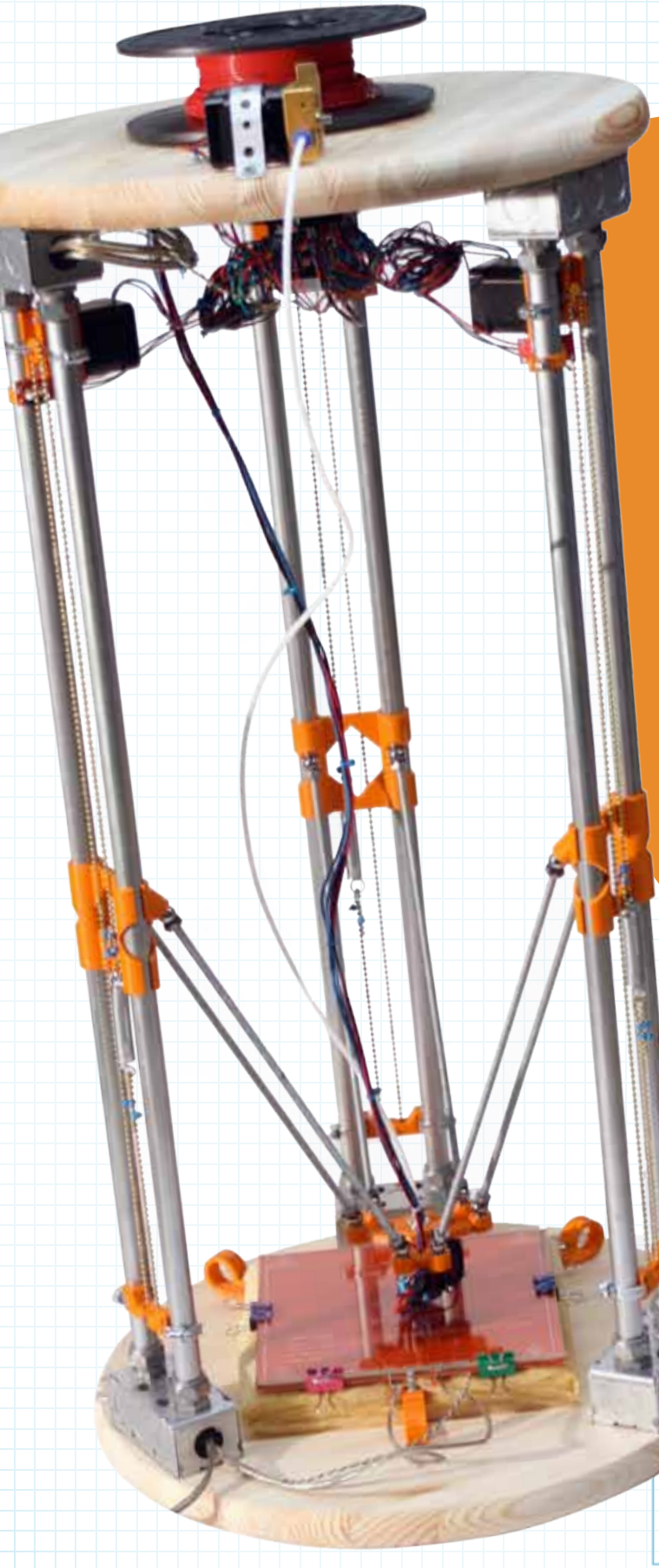
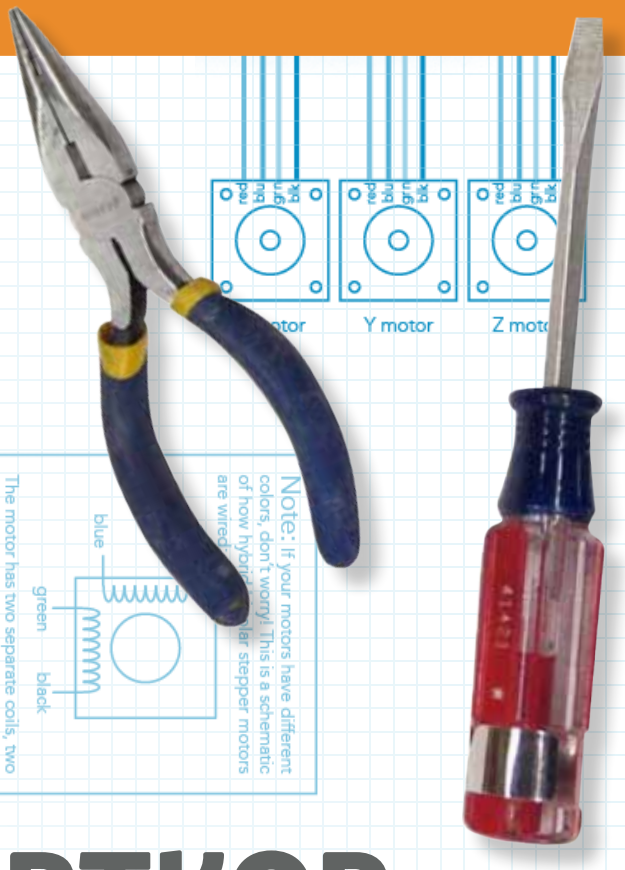
Create Your Own READY RepRap

3D printer made with readily available parts and common household tools





DAVID HARTKOP

Create Your Own Ready RepRap
by David Hartkop

“Tell me and I forget, teach me and I may remember, involve me and I learn.”
-Benjamin Franklin

“Nothing in life is to be feared, it is only to be understood.”
-Marie Curie

“Tomorrow belongs to those who can hear it coming”
-David Bowie

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What is the Ready RepRap?

0.1 Presenting the Ready RepRap

The Ready RepRap is a 3D printer designed to be made at home or in your garage or maker space. It has some parts that are 3D printed, and some parts that should be ordered or otherwise found in a local hardware store.

What's a RepRap?
For some background, the word RepRap is a shortening of the term "Replicating Rapid-Prototyper." The RepRap project started as a British initiative to develop a 3D printer that can print most of its own components. The goal is to spark innovation and to produce this technology at low cost.

The RepRap project is now made up of hundreds of collaborators world wide. Most of the work on various types of RepRaps, including the Ready RepRap, can be found on the website RepRap.org.

This project was conceived as a way to make building a 3D printer more accessible to educators and students with beginning-level technical knowledge. This manual has been organized around a series of pictures showing each and every step of the process. Emphasis has been placed on the use of simple hand tools and the use of easy-to-find materials.

There are a few special parts, like stepper motors and microcontrollers that will need to be ordered online. Building a working RepRap 3D printer can be a challenging project even for seasoned builders and engineers. Fortunately, you are not alone in the process! There are many online resources at RepRap.org and various help threads on the topics of everything related to making 3D printers. The best advice that I can offer is that you should expect this to take longer than you think, that it will not work right the first time, but that you will succeed if you do not give up. If you build this, you will learn how to do lots of other things in the process, and that's the real reason for trying anything new.

When you look at the list of items to collect & print, don't panic. They're organized into categories. Just take your time - it could take a month or more to get all of this stuff together. This project is best accomplished as a team of people with a mixture of different backgrounds and skills. It is part electronics, part programming, part shop, part scheduling, part online shopping, and part problem solving. Have fun!

Specs for the Ready RepRap:
- Estimated cost of parts: $250
- Estimated build time: 8 hours
- Estimated first print tinker-time: 3 hours
- Movement Type: delta
- Overall height: 35 in (88 cm)
- Build volume: Cylindrical r=6 inches (15 cm) h=12 inches (30 cm)
- Print heads: 1
- Print material: PLA or ABS (if used with heated bed)
- Control method: connect to a computer

0.2 Overview of the project

A fun Challenge

Creating a working 3D printer is a fun and challenging project. The Ready RepRap is a suitable learning project for students and makers aged 15 and beyond. The Ready RepRap is designed to make each step of the process easy to understand and to accomplish. It is the goal of this project guide to lead you through each and every step toward building your own working 3D printer. Every aspect of the design has been fully built and tested to make sure that it works when properly assembled and configured. Even a perfectly built machine may need some troubleshooting in order to get it to work - Don't give up! Don't panic! This is an opportunity to put your problem-solving skills to use.

Work in a team

Because of the variety of tasks to be completed, from ordering parts to assembly to tinkering with the software, it is important to work in a team. This is a perfect opportunity to seek out people with the skills needed, and a wonderful chance to collaborate across several disciplines.

Skills required

- Organization of tasks, lists & resources
- Online Shopping
- Hand tool use: drill, screwdriver, tubing cutter
- Basic electronics skills: wire stripping, soldering
- Intermediate Computers: downloading files, printing
- 3D Printing: downloading and printing 3D plastic parts
- Measurement: tape measure, square, ruler etc.
- Computer Hacking: installing software, configuring, trouble shooting

Time to Complete the Ready RepRap

The most time consuming part of the process is the procurement of all of the supplies. It may be a good idea to allow a month or more to collect all of the needed tools and supplies before starting on the assembly portion of the project. Total 3D printing time will be right around 12 hours for all the parts. Assembly can be completed in 6 to 8 hours. Software setup and fine tuning can take 2 to 6 hours. Take your time. There is no need to rush or stress out over any of this.

Preparation

1.1 Set up your workshop & Tools

Workspace & Safety
The Ready RepRap is designed to be created with only hand tools and without need for a full workshop. You will, however, need a clean well lit table area for your project. Most steps can be done with nothing more than a screwdriver. Some other steps require a cordless drill, pliers, and a small utility knife.

Be sure to use judgment with respect to safety when allowing children access to tools. The only part of the process that may require some outdoor work is the necessity to sand the outer surfaces of a set of metal tubes. This produces fine metal powder, and so this step is recommended to be done by adults wearing dust masks and appropriate eye protection, and ideally in an outdoor location. Adhesives such as super glue and two-part epoxy must be also be used in a well ventilated area. Again, use your judgment.

Safety Wear
Dust mask
Eye protection (for sanding tubes, stretching springs)
Plastic gloves (for epoxy glue, applying grease)

Hearing Protection (for electric sander)

Tools

1. Electric or hand sanding block
2. Ruler with inches & cm
3. Tape measure, inches is ok
4. Soldering iron & solder roll
5. Hot melt glue gun & glue stick
6. Cordless electric drill & assorted small bits
7. Pipe cutting tool
8. Needle nose pliers
9. Wire strippers
10. Wire crimp connector crimping tool
11. Small hex wrench set, metric
12. Scalpel
13. Scissors
14. Adjustable spanner wrench, up to 1 inch
15. Screwdriver, regular, large
16. Screwdriver, regular, small
17. Channel Locks, up to 1 inch grip
18. Screwdriver, phillips, large
19. Screwdriver, phillips, small
20. Screwdriver, regular, plastic tip

1.2 Order & Find parts and supplies

This is a complete list of all of the parts and supplies reqired to build the Ready RepRap. Some of these parts can be found in a local hardware store, whereas others will need to be ordered online.

Part No.	Part Name	Description (enter as web search term when online shopping)	Category	Quantity
1	Silicone caulk	high temperature clear silicone caulk	Adhesives	1
2	Super glue	standard fast drying cyanoacrylate super glue	Adhesives	1
3	2-part epoxy glue	tubes of J-B Weld type heavy duty hard-setting 2 part epoxy	Adhesives	1
4	hot melt glue	sticks of hot melt glue for use with a glue gun to glue misc. parts	Adhesives	1
5	heat shrink tube	1/8 to 1/4 inch heat shrink electrical tubing, approx. 12 inches needed	Electronics	1
6	electrical tape	roll of vinyl electrical tape	Electronics	1
7	USB printer wire	8 foot long USB printer-connection type USB cable	Electronics	1
8	heavy speaker wire	20 feet of copper wire pair for power, 12-18 gage copper pair.	Electronics	1
9	Stepper Motor	Nema 17 Stepper Motor Bipolar 2A 84oz.in 48mm length, 4-lead	Electronics	3
10	microcontroller	Arduino Mega 2560 board	Electronics	1
11	driver carrier board	RAMPS shield for Arduino	Electronics	1
12	stepper driver module	A4988 Stepper Driver Module	Electronics	4
13	endstop switch	mechanical endstop lever microswitch	Electronics	3
14	thin hook-up wire	20 foot spool of 26 gage hook up wire, Yellow	Electronics	1
15	DC Power supply	12 Volt DC 12+ Amp power supply. Search for S-360-12 or similar.	Electronics	1
16	crimp connectors	Dupont Jumper Wire Cable Female Pin Crimp Connector 2.54mm	Electronics	50
17	crimp sockets, 4 wire	2.54mm 1x4P Dupont Connector Housing, Female	Electronics	5
18	crimp sockets, 2 wire	2.54mm 1x2P Dupont Connector Housing, Female	Electronics	5
19	Hose clamps	3/4 inch - 1 inch metal hose clamps, 3/8 inch wide bands.	Hardware	12
20	Metal plumbing strap	roll of 3/4 inch wide metal plumbing strap	Hardware	1
21	rubber feet	misc self-adhesive rubber feet for bottom of machine	Hardware	6
22	tempered glass build plate	3D Printer Reprap MK2 Heated Bed Borosilicate Glass Plate 213*200*3mm ter	Hardware	1
23	steel balls	1/2 inch steel ball bearings	Hardware	12
24	electrical box	Raco 11.5-cu in 1-Gang Metal New Work Wall Electrical Box.	Hardware	6
25	electrical conduit	1/2” EMT, 10 ft section	Hardware	2
26	conduit fitting	1/2” EMT connector, compression type	Hardware	12
27	tension spring	1/2” O.D. x 1-1/2”Long x .05” Wire Diameter extension spring or similar	Hardware	3
28	Aluminum extruder feeder	RepRap Aluminum Extruder Feeder kit for 1.75mm Filament	Hardware, specialty	1
29	Hotend	Metal J-head V6 Hotend For 1.75mm 0.4mm Direct Feed Reprap 3d Printer	Hardware, specialty	1
30	push-in fitting	nylon tube male connector push-in fitting for tube O.D. 4mm	Hardware, specialty	2
31	PCB heated bed	RepRap 3D printer PCB heated bed, for 12V power, ideally with wiring and ther	Hardware, specialty	1
32	metal binder clips	metal paper binder clips for holding glass to top of heated print bed	Misc	8
33	Fiberglass material	roll of 1/2 inch thick fiberglass pipe wrap	Misc	1
34	hook & loop tape	roll of self adhesive hook & loop fastener tape	Misc	1
35	machine grease	tube of silicone grease for linear motion guides, chains, and pulleys	Misc	1
36	wooden base/top	18” diameter pine wooden circle, 1-1/4” thick	Misc	2
37	magnet	1/2” diameter x 1/4” thick rare earth magnet, countersink hole	Misc	12
38	tube for extruder	FEP plastic tube, O.D. 4mm, length 95cm	Misc	1
39	ball chain	beaded chain by Westinghouse Item 77043 sold in 12’ lengths for fans	Misc	3
40	sandpaper	sheets of 200 grit sand paper for sanding metal tubing	Misc	4
41	Zip ties	6” zip ties	Misc	20
42	Deck Screws	1 1/2 inch deck screws	Nuts & Bolts	24
43	print bed Stand off screws	1 1/4 inch x #6 machine screws	Nuts & Bolts	3
44	print bed Stand off nuts	#6 nuts	Nuts & Bolts	12
45	print bed Leveling Screws	1 1/2 x 1/4-20 machine screws	Nuts & Bolts	3
46	controller mounting screws	1 1/4 inch x #6 machine screws	Nuts & Bolts	2
47	Endstop switch mounting screws	1/2 inch x #8 machine screw	Nuts & Bolts	3
48	print bed stand off washers	#6 metal washers	Nuts & Bolts	6
49	screw - build plate leveling screw	1/4-20 x 1 1/2” long screw	Nuts & bolts	3
50	threaded rod	12 inch section of 1/4-20 allthread, steel zinc plated	Nuts & bolts	6
51	nuts - connector rod	1/4-20 zinc nuts	Nuts & bolts	12
52	screw - XYZE motor mount	M3x8mm screws	Nuts & Bolts	16
53	nail - idler pulley	3/4” roofing nail, zinc coated, 1/8” diameter	Nuts & bolts	3

The following are some suggested online retailers that I have found to be very useful:

- Adafruit.com
- Sainsmart.com
- robotshop.com
- Amazon.com
- Ebay.com
- aliexpress.com
- allelectroncis.com
- jameco.com
- digikey.com

1.3 3D print the Ready RepRap parts

You will need to use a 3D printer to print this set of parts. The build files for these parts can be downloaded from the following locations:

• GitHub
https://github.com/dhartkop/ReadyRepRap

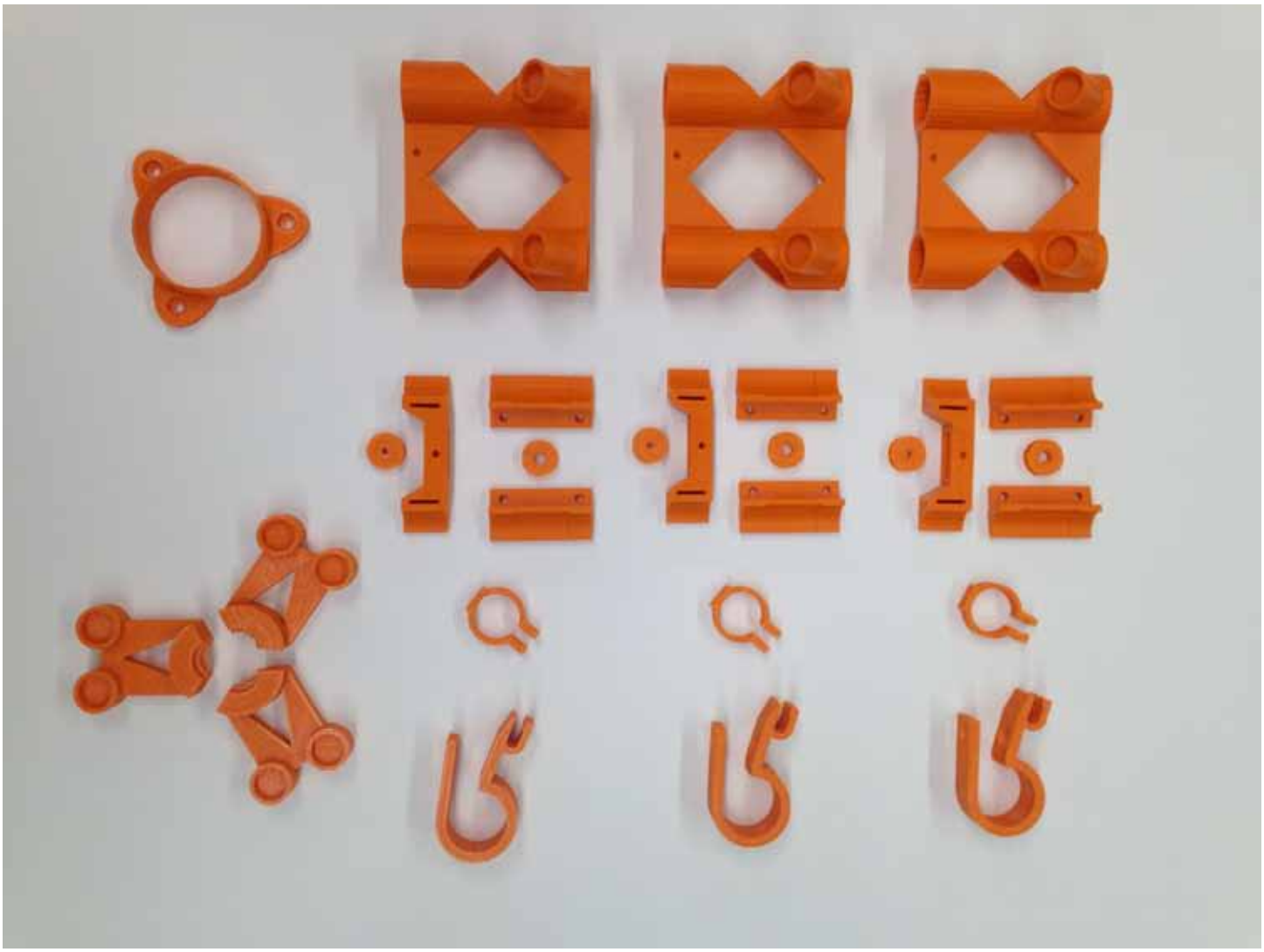
• Tinkercad
https://www.tinkercad.com/things/8LGnUjhzrhr-170116allparts/editv2

• Thingiverse
http://www.thingiverse.com/thing:2042095
The build files are in .stl format, which is a very common file type for 3D files. You may be able to open the files with various 3D modeling programs if you wish to review or to modify them.

Part No.	Part Name	File Name	*Print Profile	Print Time (min)	Weight (g)	Quantity
1	Build Plate Leveling Mount	170116_ReadyRepRap_BuildPlate	A	28	10.4	3
2	Linear Motion Carriage	170116_ReadyRepRap_Carriage	A	120	39	3
3	Endstop Switch Mount	170116_ReadyRepRap_Endstop	A	7	2.3	3
4	Hotend Mount	170116_ReadyRepRap_Hotend	A	31	12.25	3
5	Idler Pulley Mount	170116_ReadyRepRap_Idler	A	25	9	3
6	Motor Mount	170116_ReadyRepRap_Motor	A	34	11.3	6
7	Pulleys	170116_ReadyRepRap_Pulleys	B	4	1.5	3
8	Spool Holder (small hole)	170116_ReadyRepRap_SpoolHolder1	C	33	12.3	1
9	Spool Holder (large hole)	170116_ReadyRepRap_SpoolHolder2	C	30	10.2	1

*Print Profiles:

A	0.2 mm layer thickness, 3 shells, 50% infill, raft + supports
B	0.2 mm layer thickness, 3 shells, 100% infill, no raft or supports
C	0.2 mm layer thickness, 2 shells, 25% infill, no raft or supports



Tips for getting your parts printed:
If you do not have access to a 3D printer, you can order custom 3D printed parts online.

> Try your local library or maker space; I always opt for the local option first!

>MakeXYZ
https://www.makexyz.com/ This is an online printer locating & bidding service. It will help put you in touch with individuals and groups that are willing to print your object for you.

>3D Hubs
https://www.3dhubs.com/
Another online service to connect customers to printers.

>Shapeways
www.Shapeways.com/create
This company has plenty of high-end printers and a good workflow for handling large or small orders. They charge a premium but are reliable.

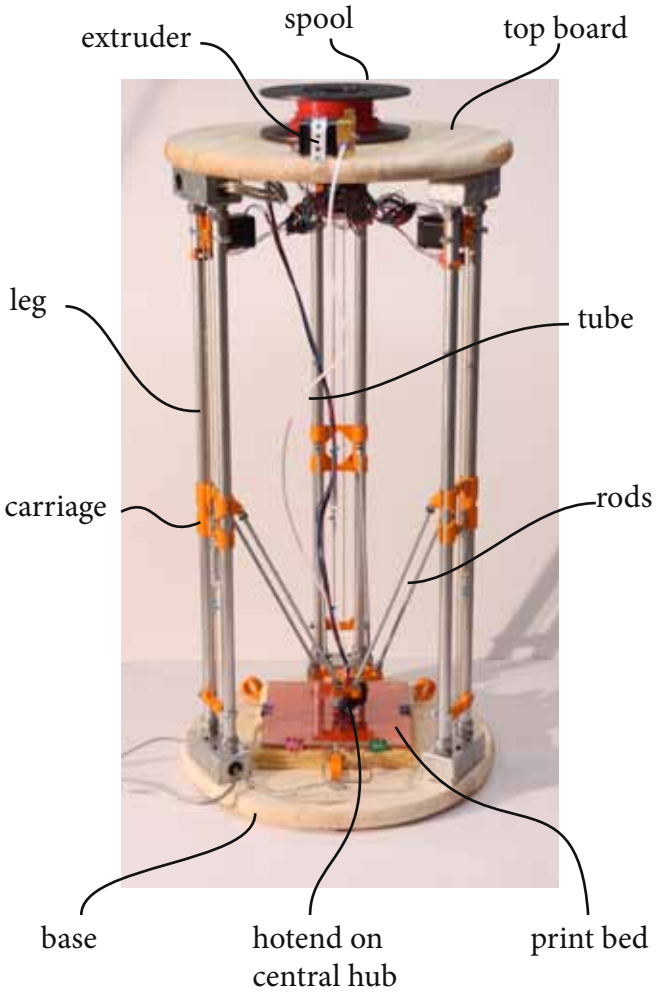
>Quickparts by 3D Systems
http://www.quickparts.3dsystems.com/solutions/
Another high end company with plenty of capability and capacity. They can do several kinds of printing, are reliable but also expensive.

>Sculpteo
https://www.sculpteo.com/en/
Another automated 3D printing business.

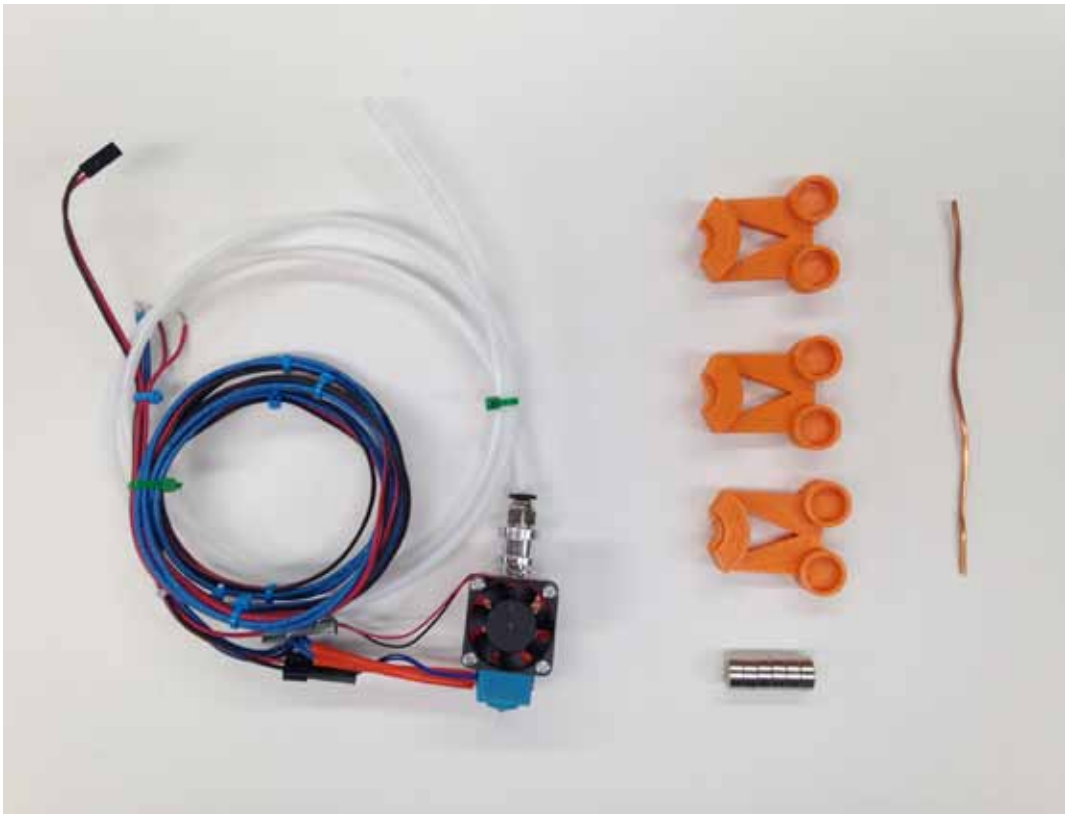
There are tons of other options. Do a web search for “3D Printing Services” and just look through a few of the options. The most appropriate kind of 3D printing to have done is FDM, for fused deposit modeling. You can choose any kind, but FDM tends to provide an excellent combination of detail, strength, and low-cost when compared do other types. Plus, we are building an FDM printer, so it kind of makes sense to use FDM to make it!

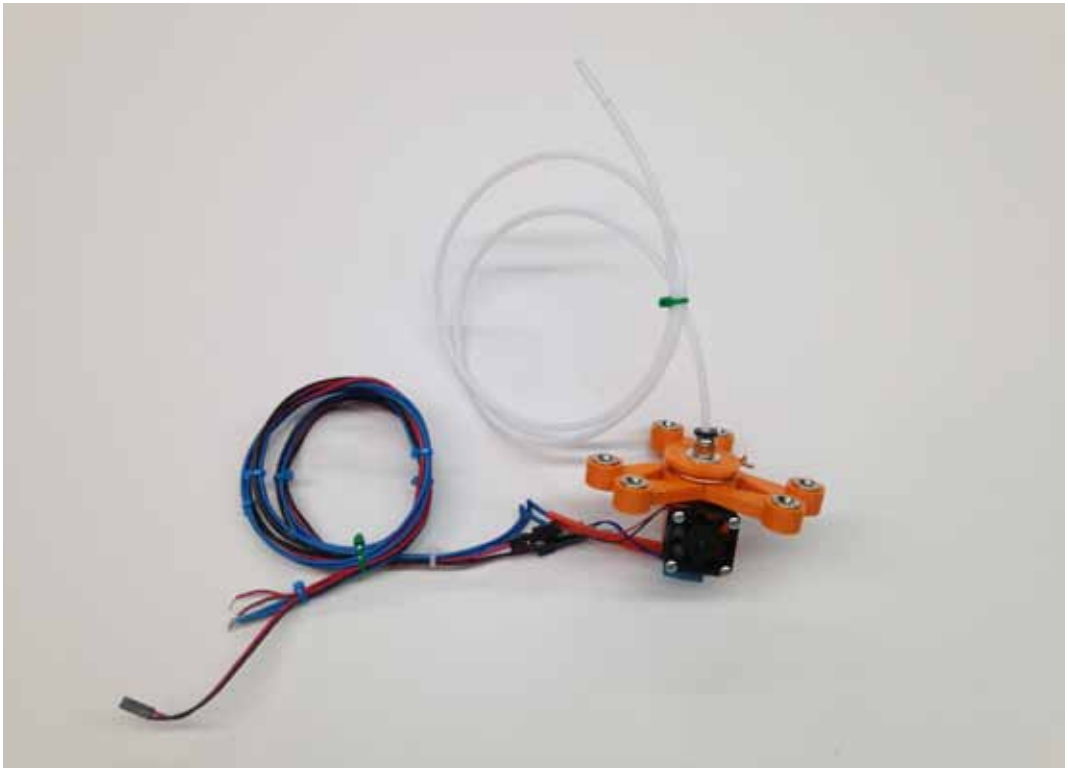
Create it

Here is a diagram of the completed Ready RepRap 3D printer with parts labeled. The following pictorial instructions go through each and every part of assembling and setting up this machine to create your own working 3D printer.



2.1
Make the Central Hub
The central hub is the part that moves around in 3D space in order to ‘draw’ your object in lines of liquid plastic. The hub is essentially the hot end, supported by a set of six 3D printed magnetic ball joints.





Section 2.1 Make the Central Hub: Tools & Supplies

2.1.a Tools

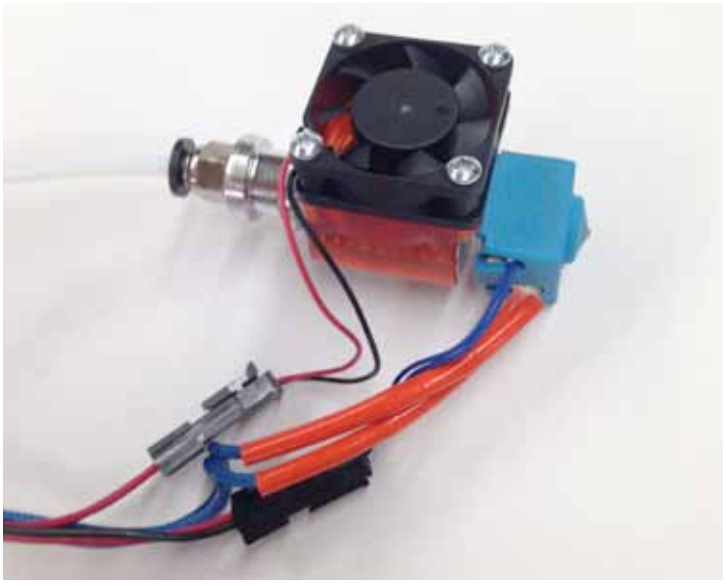
Screwdriver, phillips, small
Needle-nose pliers
Small hex wrench set, small

2.1.b Supplies

1 x Super glue
1 x electrical tape or small heat shrink tube
1 x Steel wire, 16 gage, 4 inches
3 x 3D printed Hotend Mount parts
1 x Metal J-head V6 Hotend For 1.75mm 0.4mm Direct Feed Reprap 3d Printer
6 x Magnets, 1/2” diameter x 1/4” thick, countersink hole

Section 2.1 Make the Central Hub: Instructions Pages

2.1.1 The Metal J-head V6 Hotend kit comes with a small PC fan. Begin by using the supplied screws to attach the fan to the plastic fan-clip. If the kit is already assembled, there will be a heater cartridge and a small thermistor (temperature sensor) already installed into the round holes in the bottom of the J-head. If not, slide these parts into the holes and use a hex wrench to tighten the set screws.



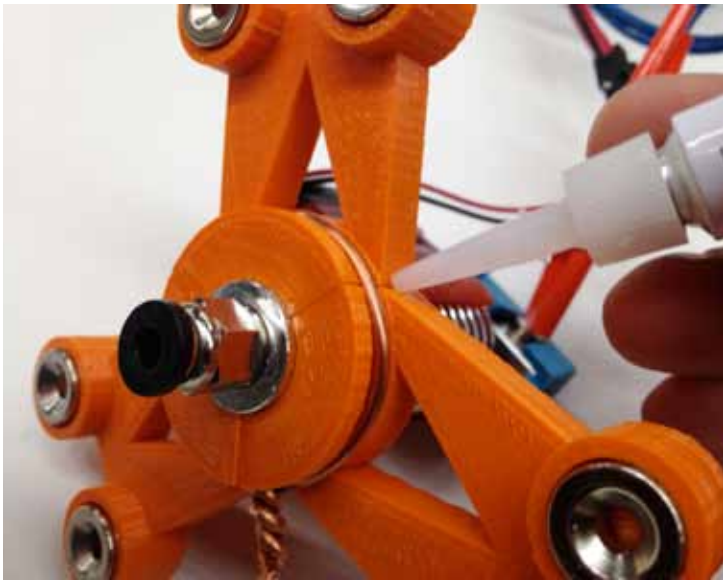
2.1.2 The fan clip can be popped onto the J-head heat sink. The finished J-head will have three pairs of wires, which should extend to be approximately 3 feet (1 M) long. You may need to extend the fan wires to match the length of the other wires. Wires can be spliced by twisting and taping (ok) or by soldering and using small sections of heat shrink tubing (best.)

2.1.3
Glue the magnets into the sockets of the hotend mounts. Start by applying a flat ring of glue to the inside of each socket and then hold each magnet in place for approximately 30 seconds. Once the magnets are fixed in place, strengthen the bond by adding additional glue around the edge of each magnet.

Section 2.1 Make the Central Hub: Instructions Pages

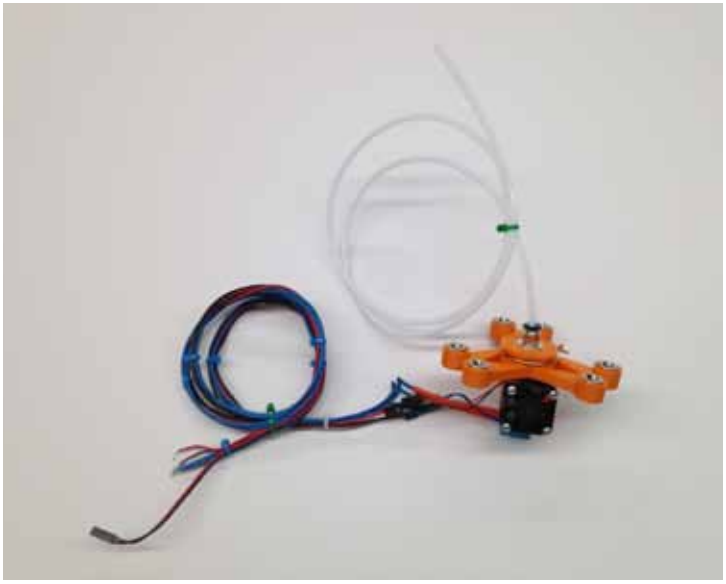
2.1.4
Fit the hotend mounts into place around the hotend. Use the needle nose pliers to pre-form the wire that will fit in the groove around the hotend mounts.

2.1.5
Once the hotend mounts are in place with the wire loosely twisted, tighten the wire firmly by twisting with the pliers.

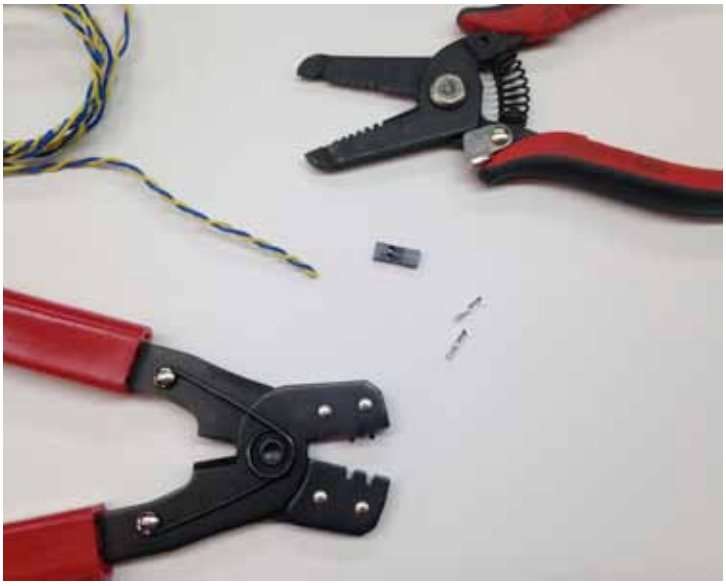


2.1.6
Make final adjustments so that the hotend mounts fit perfectly together, evenly, and with no gaps between the seems. You may need to adjust the wire slightly by bending it with the pliers. Once everything is perfectly even, apply super glue along all of the seams.

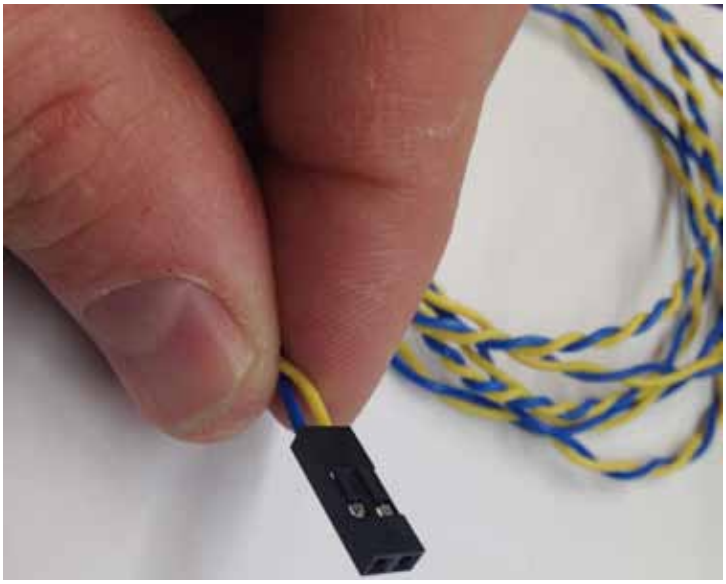
Section 2.1 Make the Central Hub: Instructions Pages



2.1.7
You can use small zip ties to bundle the all the wires together every few inches to keep it nice and neat. :)



2.1.8
Finally, we will put a two pin crimp connector onto the pair of wires connected to the thermistor. This is the small sensor that is inserted into the hot end along with the heater element. Strip the wires and crimp a pair of female crimp connectors onto the leeds.



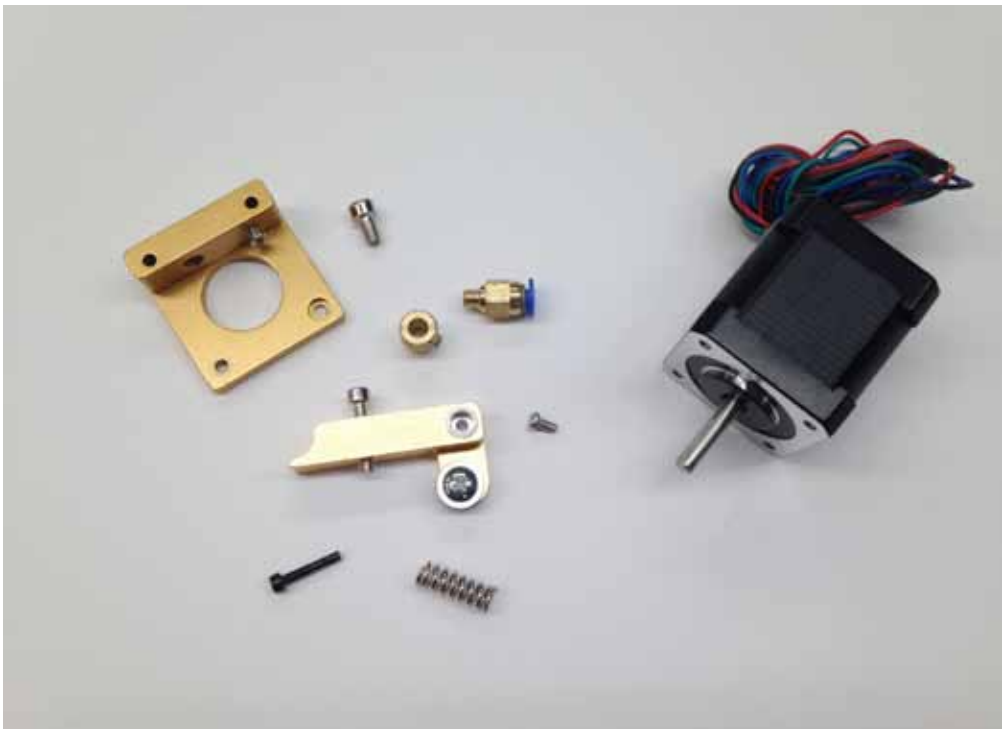
2.1.9
Slide the crimp connectors into a two-pin Dupont crimp connector socket. Now it will be easy to connect to the controller when it is time!

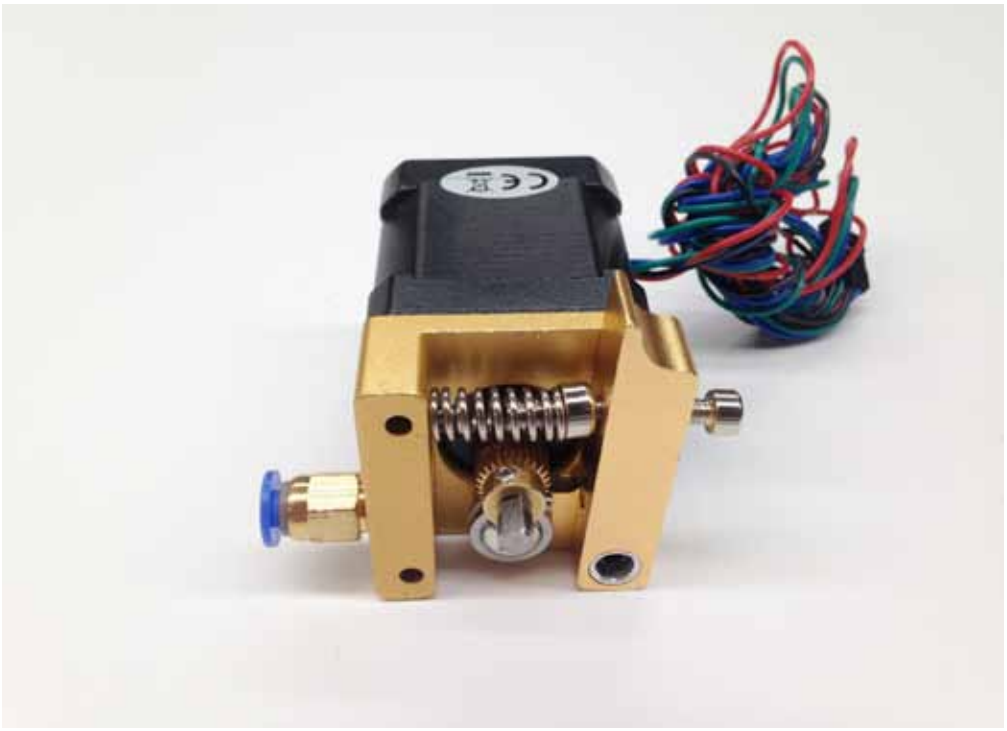
Section 2.2 Make the Extruder Unit

2.2

Make the Extruder Unit

The extruder unit is the machine that draws plastic filament from the spool and pushes it through a tube to the hotend. There are many different extruders available to purchase, as well as several you can make. Here, we incorporated a Bowden style RepRap aluminum extruder feeder kit for 1.75mm filament.





Section 2.2 Make the Extruder Unit: Tools & Supplies

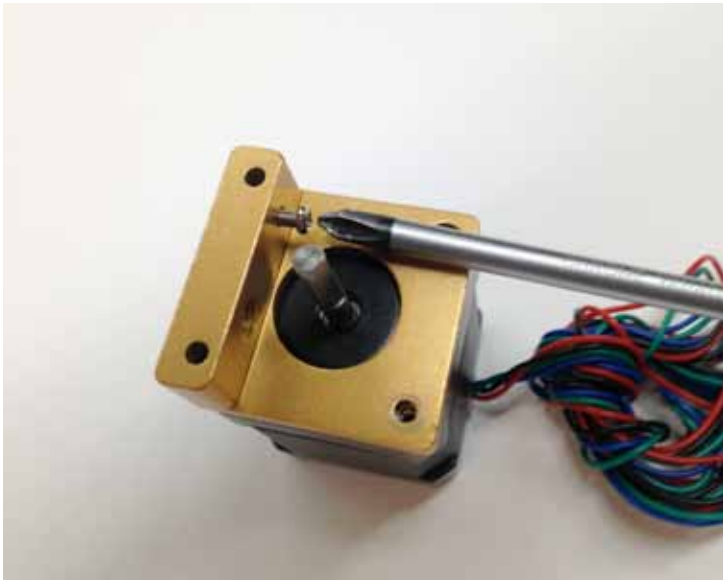
2.2.a
Tools
Screwdriver, phillips, big
Screwdriver, phillips, small
Hex key set, metric
Needle noes pliers

2.2.b
Supplies
Bowden style RepRap aluminum extruder feeder kit
(You can order this online, try searching for ‘all metal bowden extruder wire feeder 1.75mm’)

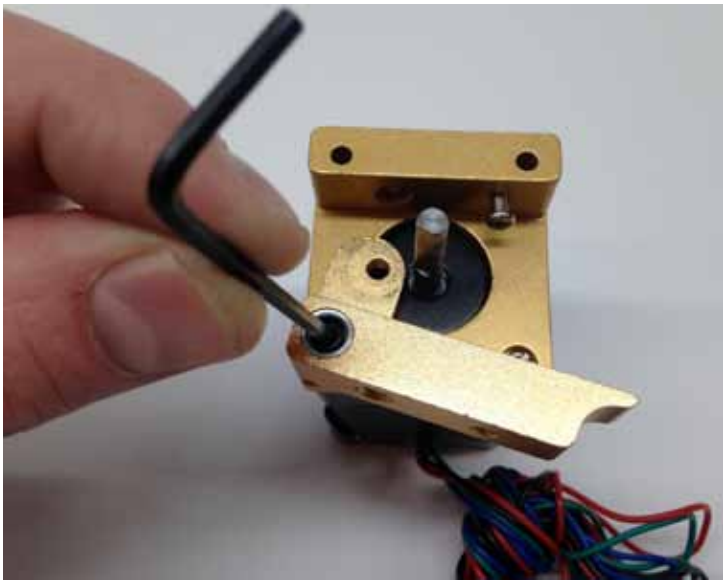
Nema 17 stepper motor, 48mm length.
(also available online, search for ‘Nema 17 Stepper Motor Bipolar 2A 59Ncm(83.6oz.in) 48mm Body 4-lead’)

Section 2.2 Make the Extruder Unit: Instructions Pages

2.2.1
Begin assembling the extruder kit by bolting the main body block to the face of the stepper motor.

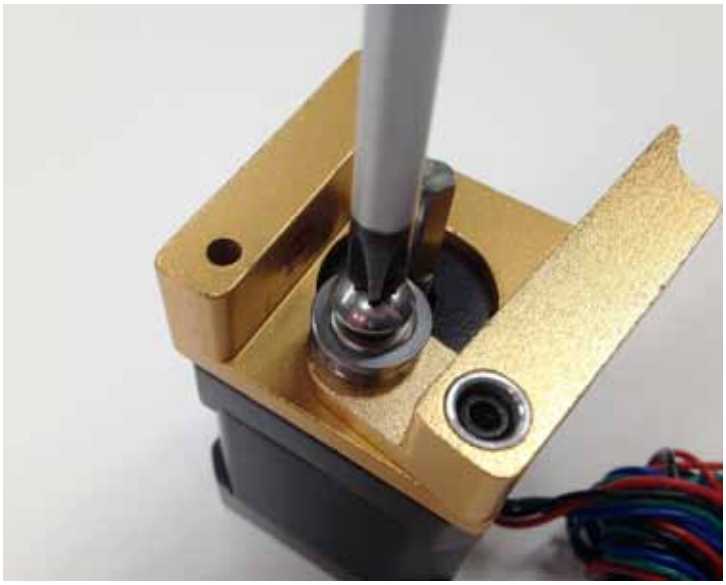


2.2.2
Insert the screw into the hole inset in the raised edge. This will retain the spring.



2.2.3
Now attach the lever arm using the provided bolt. You may need to use a hex key for this. Be sure it is tight, while allowing the lever to still move freely.

Section 2.2 Make the Extruder Unit: Instructions Pages

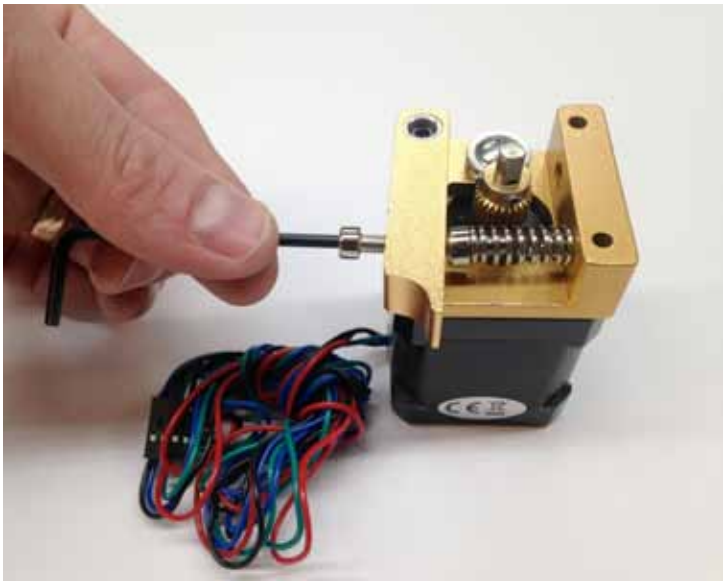


2.2.4
Attach the small bearing roller to the short part of the lever arm. Be sure it is tight.

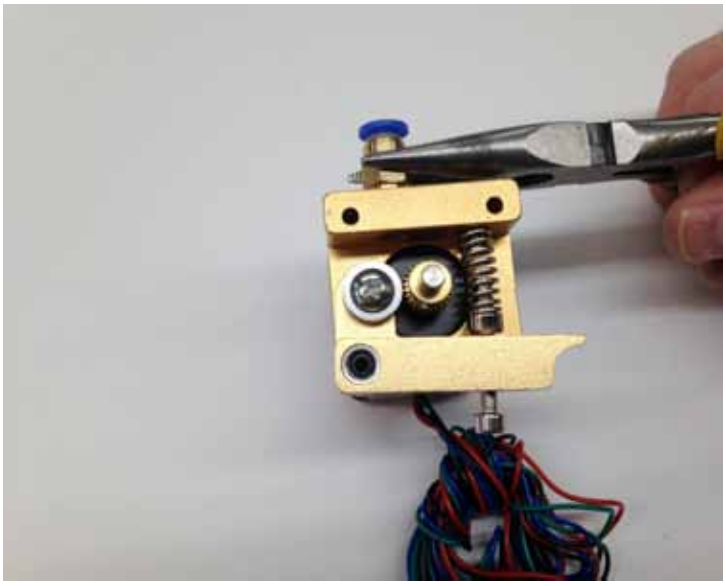
2.2.5
Next, put the hobbed wheel onto the shaft of the motor so that its teeth are at the same level as the small bearing roller. Use a small hex key to tighten the set screws on the hobbed wheel. This wheel will grab the filament with it's sharp teeth as the motor turns.

2.2.6
Find the rest of the parts for assembling the spring. It is probably very similar to the system pictured, where there is one longer spring, one short squat screw, and one longer thinner screw.

Section 2.2 Make the Extruder Unit: Instructions Pages



2.2.7
Place one end of the spring over the small screw that you inserted in step 2.2.2. Insert the threaded end of the short squat screw into the other end of the spring. Finally, screw the longer thinner screw through the lever so that its end presses into the short squat screw's hex-key hole. You can adjust the spring force on the lever arm by tightening the screw further into the lever arm.



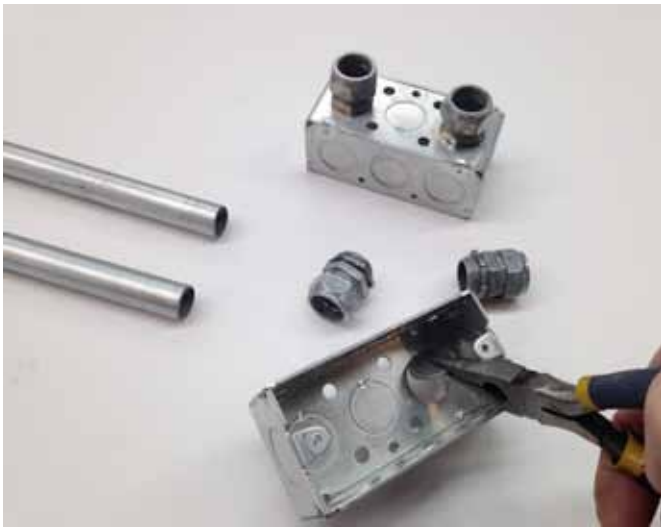
2.2.8
Finally, screw the push-in tube fitting into the threaded hole in the main body block of the extruder unit.

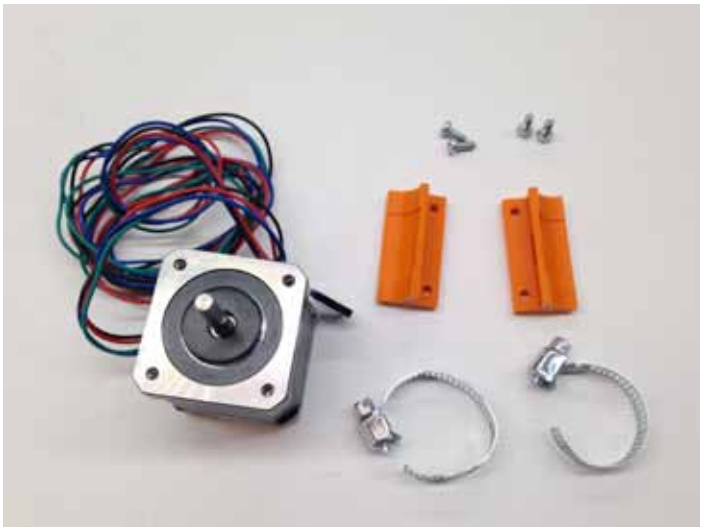
2.2.9 The fully assembled extruder unit.

Section 2.3 Make the Linear Motion Legs

2.3 Make the Linear Motion Legs

The linear motion legs are the main robotic parts of the Ready RepRap. Making the legs is the most mechanically involved part of the entire project, and so it will take the most time. You will be assembling three identical legs. Each leg has a motor, which moves a sliding shuttle along its length by driving a spring tensioned loop of chain.





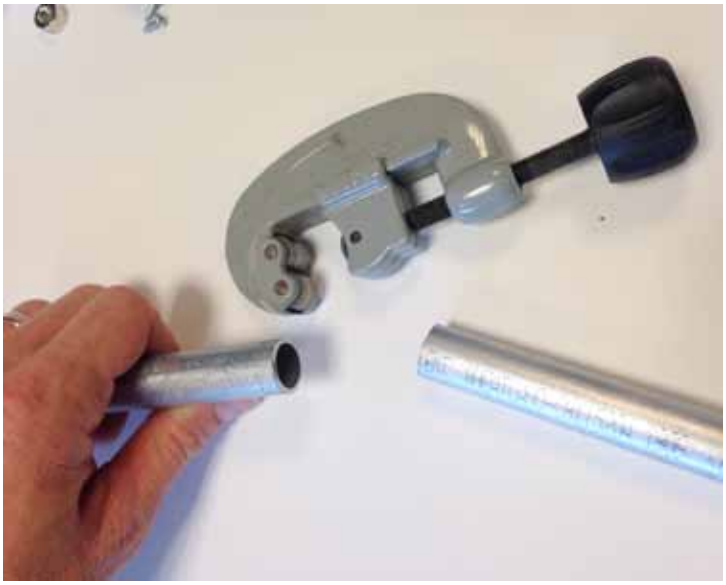
Section 2.3 Make the Linear Motion Legs: Tools & Supplies

2.3.a
Tools
Pipe cutter
Needle nose pliers
Screwdriver, regular, large
Screwdriver, phillips, small
Wire cutters
Tape measure
Electric or block sander
Hot melt glue gun

2.3.b
Supplies
Dust mask (make sure you use this when sanding!!)
3D Printed parts:
- 3 x Linear Motion Carriage
- 3 x Endstop Switch Mount
- 3 x Idler Pulley Mount
- 6 x Motor Mount
- 3 x Pulley Pairs (idler + drive pulley)

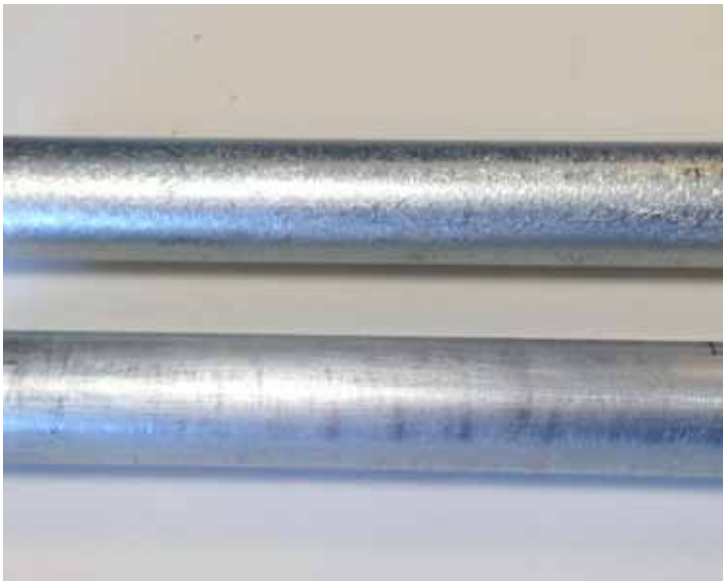
6 x electrical box
12 x conduit fittings
1 x length of electrical conduit
3 x tension spring
12 x hose clamps
1 x length of beaded chain
6 x nylon zip ties
1 x pack of 220 grit sandpaper
hot melt glue sticks
silicone machine grease
Screws & Fastners
- 12 x M3x8mm screws for stepper motors
- 3 x roofing nails, 3/4” long x 1/8” diameter for idler pulleys
- 24 x deck screws, 1 1/2 inch for mounting electrical boxes
- 6 x 1/2 inch x #8 machine screws for shuttles & endstop switch mounts

Section 2.3 Make the Linear Motion Legs: Instructions Pages



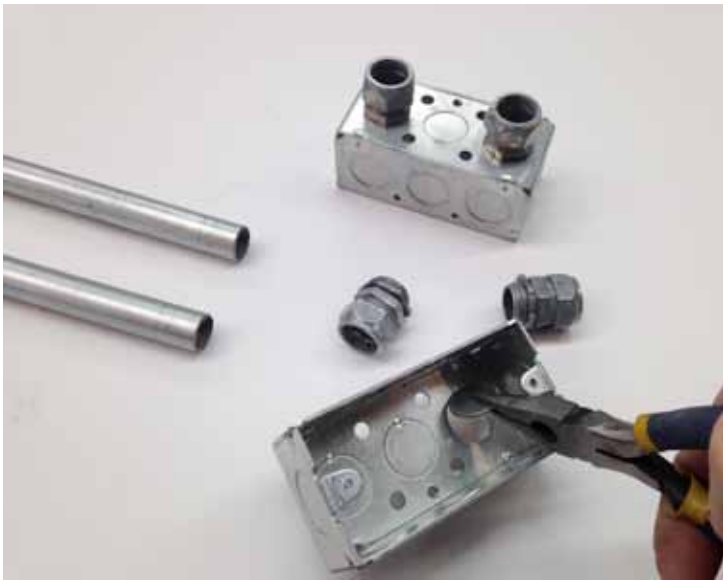
2.3.1

Use a conduit cutter to cut six lengths of 1/2 inch EMT conduit to XX inches long. Take your time making these lengths as EXACT as possible. It is easier to make it perfect now, than to try to deal with inaccuracies later! This is actually the most critical measurement you will have to make.



2.3.2

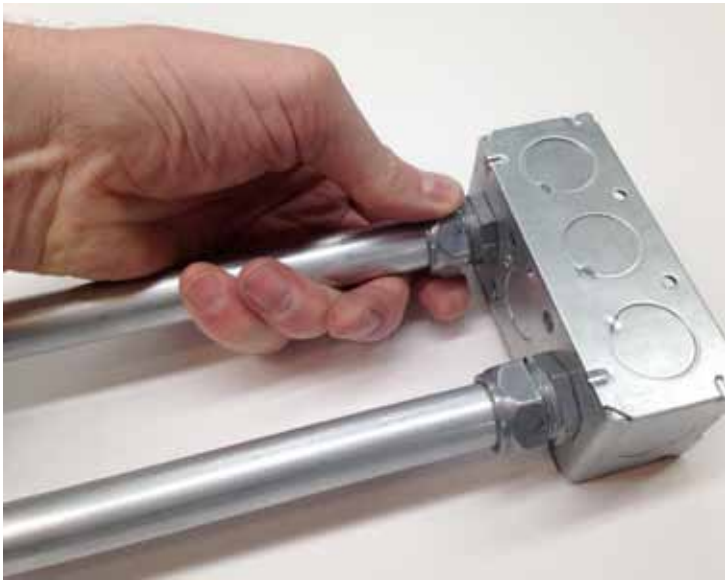
Use the electric sander or the hand sanding block to thoroughly sand the pipes. I recommend performing the sanding outdoors and using a dust mask. The metal dust is not good to breath or to spread around indoors! Sanding all six tubes with 220 grit sand paper twice will suffice.



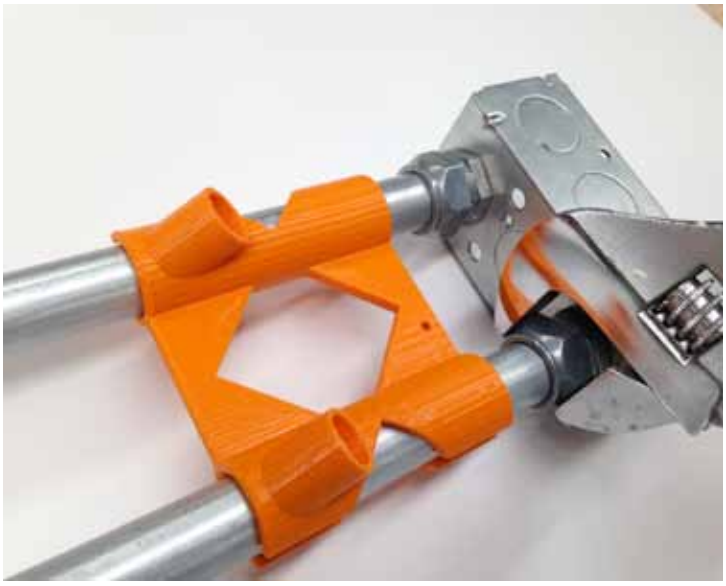
2.3.3

Use a screwdriver and the needle nose pliers to remove the back two ports in each box as shown. You may have to knock the screwdriver with a hammer to knock the circles out. Place the compression type conduit fittings into the holes as shown, and finger tighten. Be sure to push the rods all-the-way into each of the fittings before tightening.

Section 2.3 Make the Linear Motion Legs: Instructions Pages



2.3.4
Put two of the cut conduit rods into the two fittings of one of the boxes, and finger tighten.



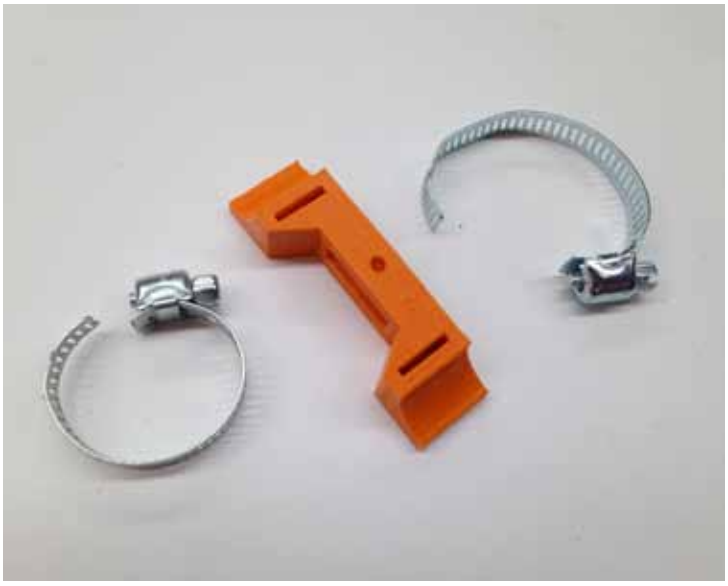
2.3.5
Slide a 3D printed Linear Motion Carriage onto each pair of rods. Slide it almost all the way to the conduit fittings; this establishes perfect spacing between the rods in the box. Now, use the adjustable spanners and channel lock pliers to tighten the compression fittings as well as the rings that hold the fittings into the box.

2.3.6
Place another box with fittings onto the other two ends of the rods, being sure the rods are seated all-the-way into the fittings. Slide the Linear Motion Carriage almost all the way to the other end; this sets the spacing between this end of the rods. Just as before, use the adjustable spanners and channel lock pliers to tighten the compression fittings as well as the rings that hold the fittings into the box.

Section 2.3 Make the Linear Motion Legs: Instructions Pages

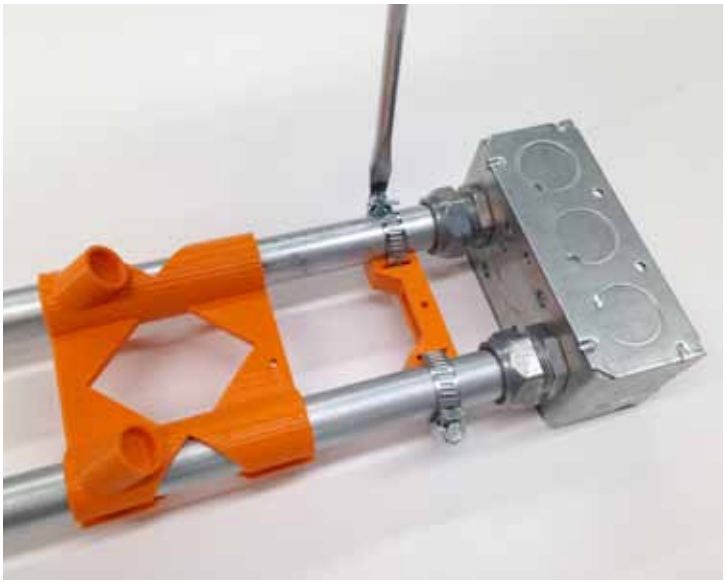
2.3.7

You may have noticed the Linear Motion Carriage felt somewhat tight when sliding on the rails. This is as it should be. For this step, we will need to slide each of the carriages back and forth on the rails by hand in a back-and-forth sawing motion to wear them in. This process may seem unnecessarily painstaking, but it insures that the carriages are warn in perfectly for the otherwise imprecise metal pipes. You will need to slide the carriages back and forth nearly 100 times each, the faster the better. This process uses the friction to actually melt and reform the minute ridges within the shuttle's linear guides. *Do not use lubrication, as this will slow down the friction-forming process. Lubrication will be added later!



2.3.8

Locate the 3D printed Idler Pulley Mount, and two hose clamps for each.

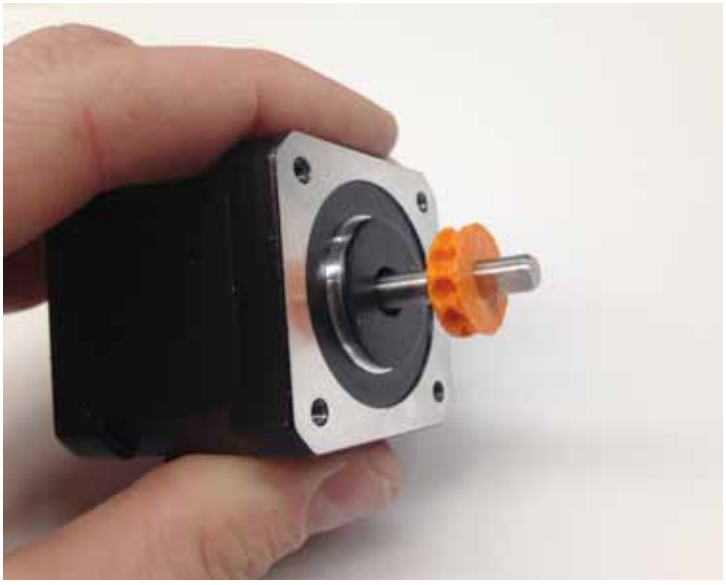


2.3.9

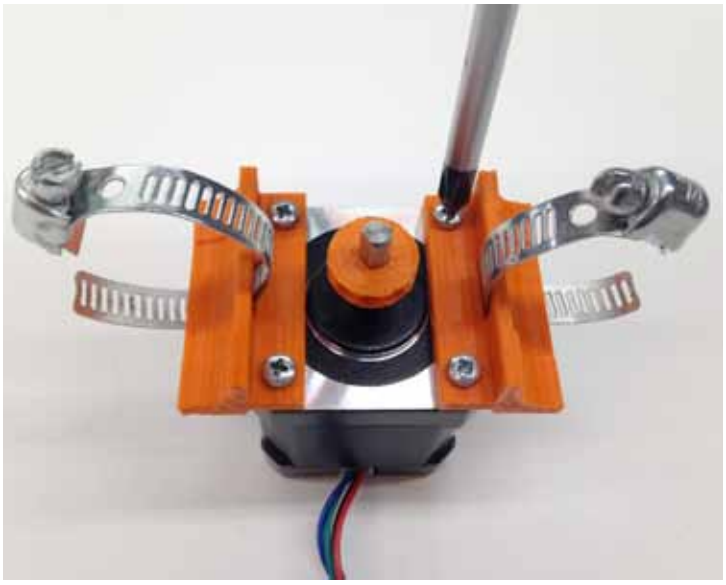
Fit each Idler Pulley Mount onto the pipes as shown, being aware of the direction the Linear Motion Carriage is facing. Place the Idler Pulley Mounts on the rail nearly an inch from the pipe fittings, and temporarily clamp into place with two hose clamps each. (The Idler Pulley Mounts will be slid to tension the chains in a later step.)

Section 2.3 Make the Linear Motion Legs: Instructions Pages

2.3.10
Locate all of the parts for mounting the stepper motors. Each leg will have one stepper motor, two 3D printed Motor Mounts, two hose clamps, one 3D printed Pulley for the motor, and four M3x8mm machine screws.

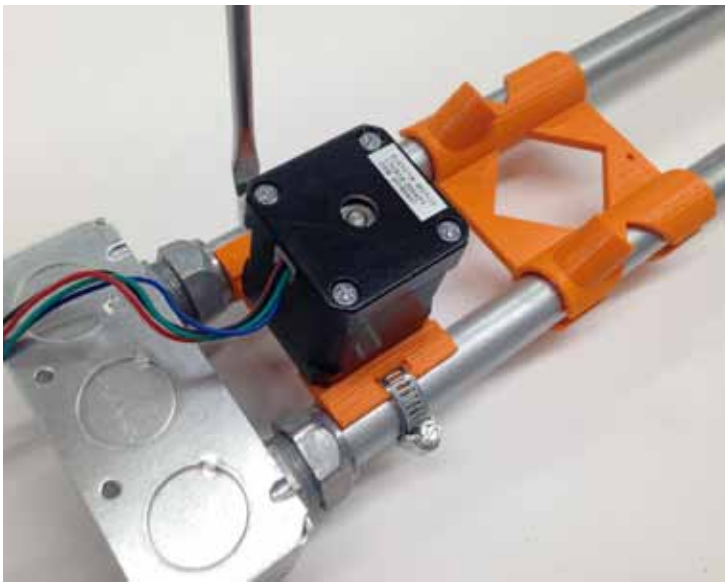


2.3.11
Push the 3D printed Pulley onto the shaft of the stepper motor. You may need to slightly trim the edges of each pulley's hole using the scalpel. It will be somewhat difficult to push the pulley on, and you may need to use a nut and a small block of wood to lightly tap the pulley down onto the shaft to get it started. It should be pushed down about 1/4 inch, as shown.



2.3.12
Bolt the Motor Mounts onto the motor's body using the four screws. Finally, slip the pipe clamps into place through the slots in the Motor Mounts.

Section 2.3 Make the Linear Motion Legs: Instructions Pages



2.3.13
Place the completed motor section onto the rails, at the end opposite the Idler Pulley Mount. Slide all the way to the pipe clamps. Use a screwdriver to tighten the hose clamps, holding the motor firmly into place. As with the Idler Pulley Mounts, be aware of how you have the motor oriented, looking at the Linear Motion Carriage (as pictured.)

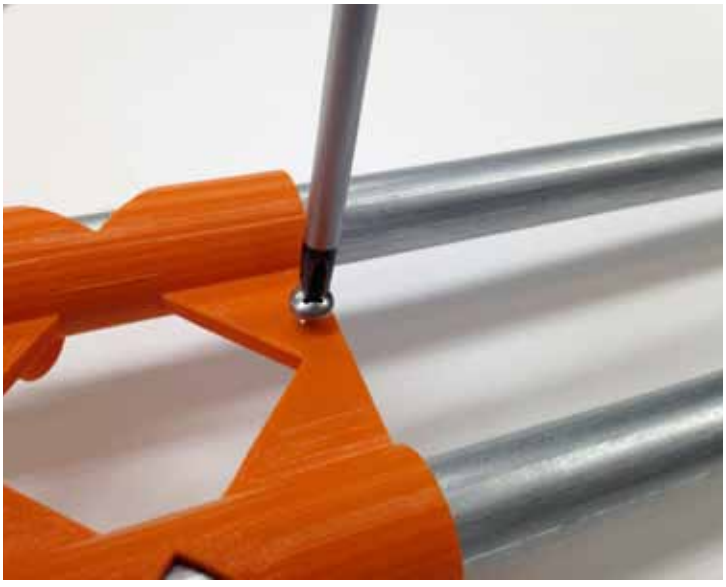
2.3.14
Use a tape measure and wire cutters to measure out and cut three lengths of beaded chain, 55 inches each. Be sure to stretch the chain out while measuring!

2.3.15
Locate four 6” zip ties for each chain. These will be used to form loops at each end.

Section 2.3 Make the Linear Motion Legs: Instructions Pages

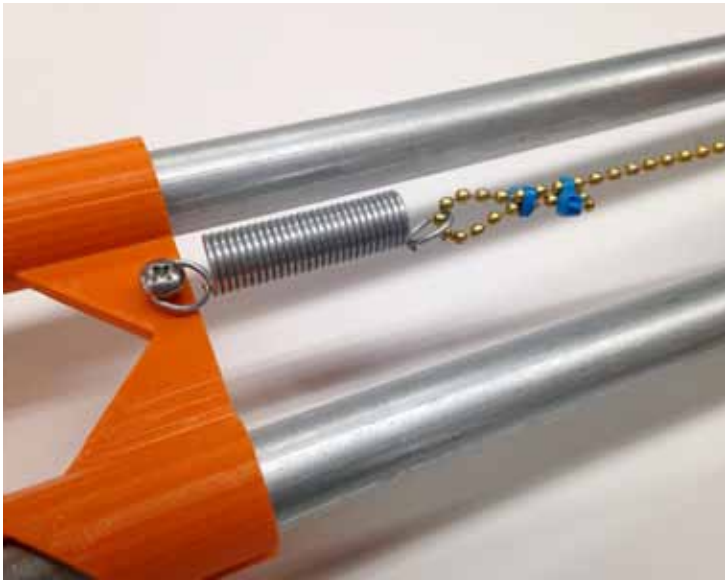
2.3.16
Use two zip ties at each end of the chains to form loops as pictured. The loops need to fit over the heads of the screws that will go into the Linear Motion Carriages. These will be the 1/2 inch x #8 machine screws.Try it out with a screw so you don't make the loops too small.

2.3.17
For each of the three linear motion legs you are creating, locate one 1/2 inch x #8 machine screw, one tension spring, one cut beaded chain with loops, one 3D printed Idler Pulley, and one roofing nail (3/4" long x 1/8" diameter).

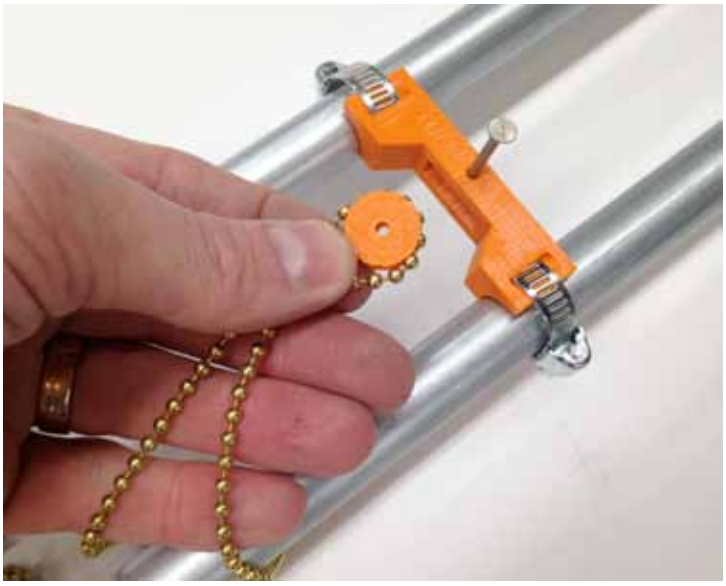


2.3.18
Screw the 1/2 inch x #8 machine screw half way into the mounting hole in the linear motion carriage as shown. Note: the angled magnet cups are facing down, away from the head of the screw.

Section 2.3 Make the Linear Motion Legs: Instructions Pages



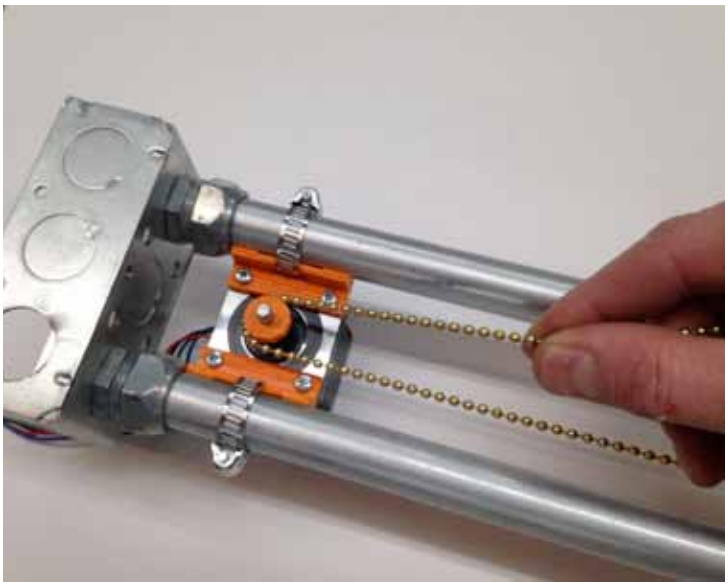
2.3.19
Slip one end of the tension spring over the screw in the Linear Motion Carriage. Now, slip one loop of the chain onto the loop of the other end of the spring.



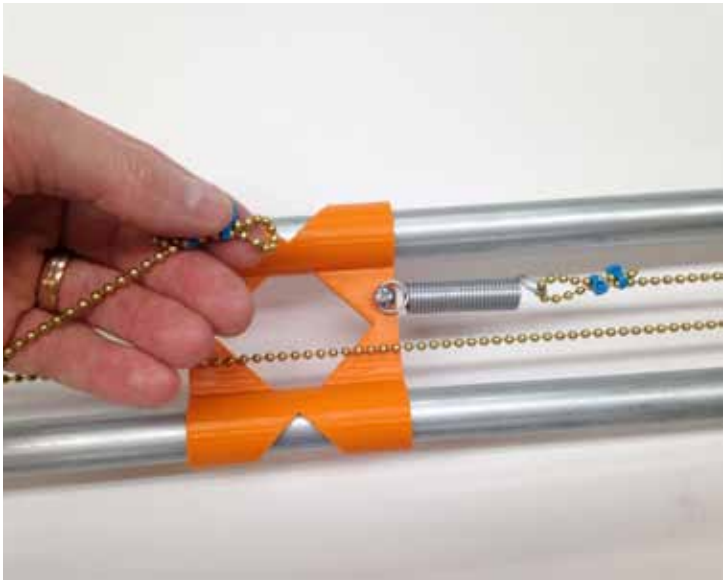
2.3.20
Use a screwdriver to loosen the hose clamps of the Idler Pulley Mount, then slide it toward the Linear Motion Carriage by two or three inches. Now, loop the beaded chain over the idler pulley as shown. Place the roofing nail into the hole in the Idler Pulley Mount.

2.3.21
Apply a dab of silicone machine grease to either side of the idler pulley, and to the shaft of the roofing nail. It should now be possible to insert the Idler Pulley into the slot in the Idler Pulley Mount, and then push the nail through the hole in the center of the pulley. Pull the chain tight take up slack with the spring, as shown in the picture.

Section 2.3 Make the Linear Motion Legs: Instructions Pages



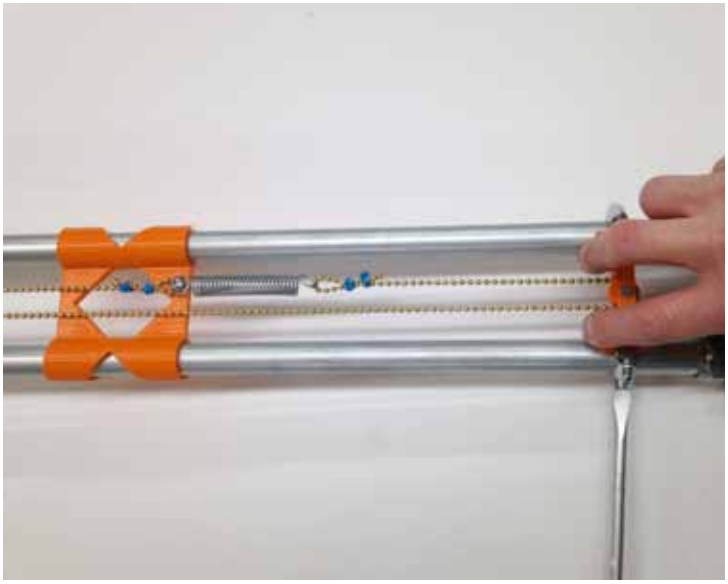
2.3.22
Keeping the chain finger tight, loop it up past the Linear Motion Carriage, and over the Pulley on the motor, as shown.



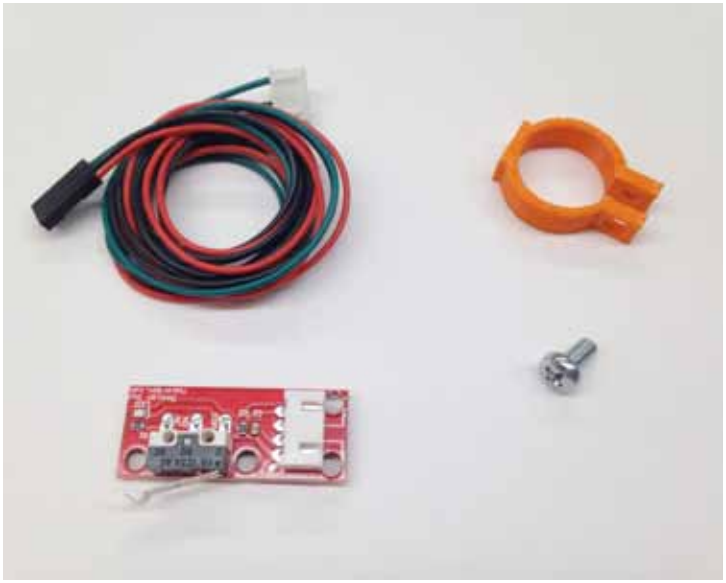
2.3.23
The loop at the free end of the chain should reach all the way back to the same screw that we put the spring onto. Slide the Idler Pulley Mount a little if you need more or less slack.

2.3.24
The chain is fully installed around both pulleys and looped from the spring at one end to the screw at the other. (You might want to pull off the spring and put its loop on over the other end of the chain if it seems less likely to pop off.)

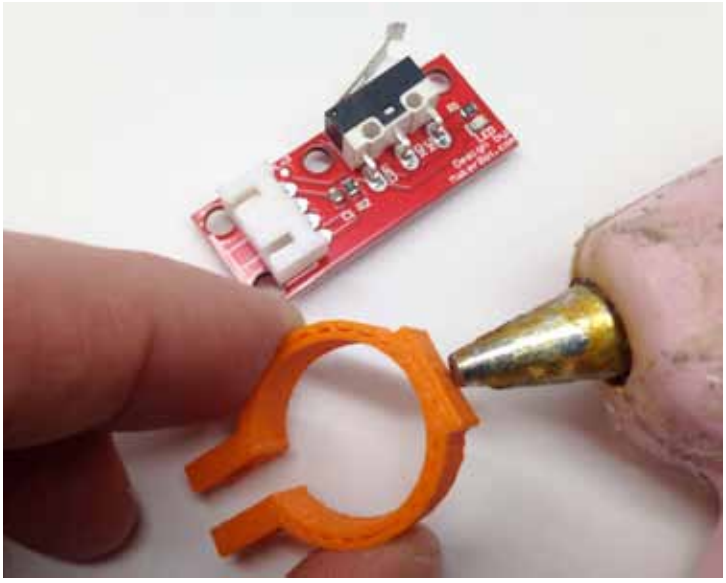
Section 2.3 Make the Linear Motion Legs: Instructions Pages



2.3.25
Tension the spring by pulling the Idler Pulley Mount away from the Linear Motion Carriage, firmly with two fingers. The spring should be stretched to be 1/3 to 1/2 longer than when it is un-stretched. Use a screwdriver to tighten the hose clamps that hold the Idler Pulley Mount into place.



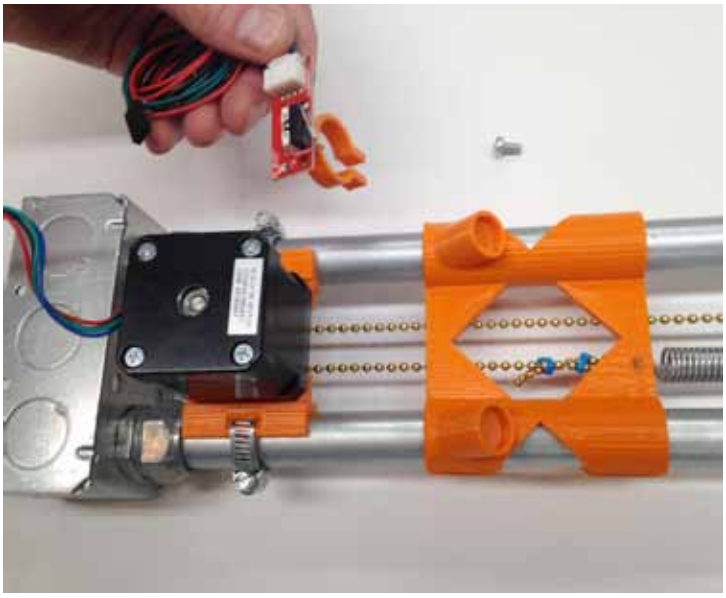
2.3.26
Locate the the 3D printed Endstop Switch Mounts, the mechanical endstop switches, and the 1/2 inch x #8 machine screws.



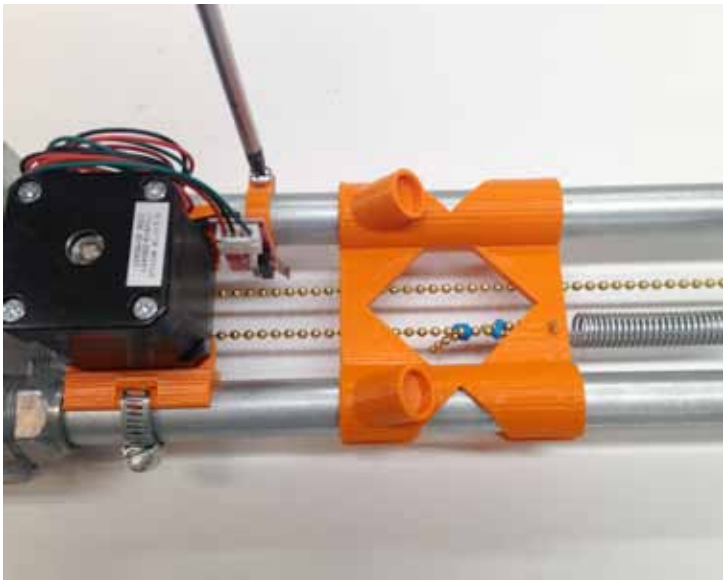
2.3.27
Use a hot melt glue gun to affix each endstop switch to each Endstop Switch Mount, see the next step for placement.

Section 2.3 Make the Linear Motion Legs: Instructions Pages

2.3.28
Each endstop switch should be glued onto an Endstop Switch Mount such that the lever switch is lined up with the middle and top edge of the flat part of the mount. (See picture.)

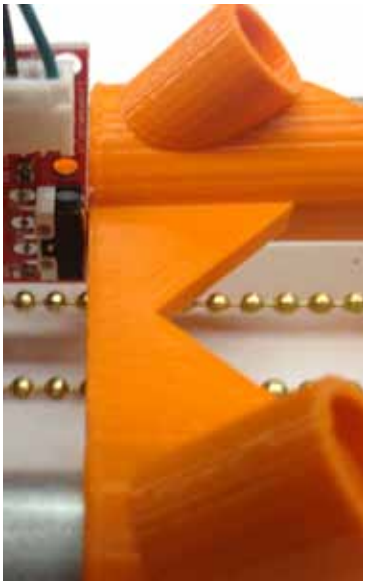


2.3.29
Slide one Endstop Switch Mount onto one of the metal tubes, located between the stepper motor and the Linear Motion Carriage.

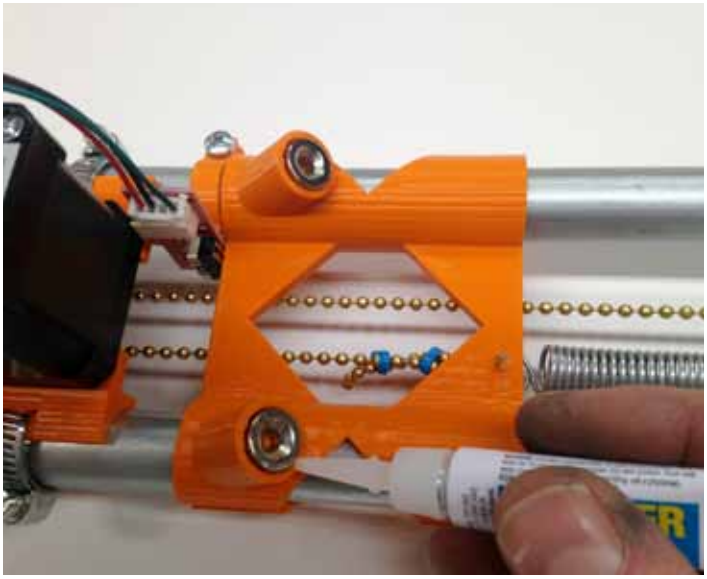


2.3.30
Orient the endstop switch so that its PCB is up against the motor or the motor mount, and so that the lever of the switch faces inward where the Linear Motion Carriage can press it. Tighten the switch into place with the #8 machine screw.

Section 2.3 Make the Linear Motion Legs: Instructions Pages



2.3.31
Slide the Linear Motion Carriage up to meet the switch in order to check that the switch gets pressed at the very top of its range.



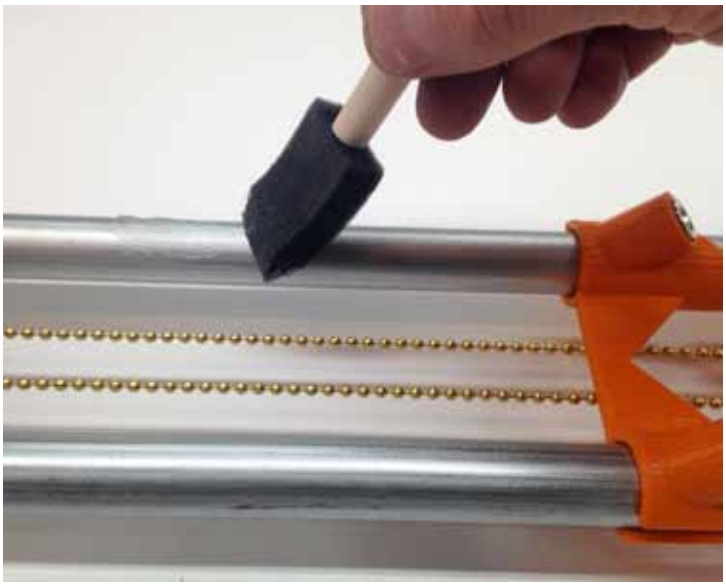
2.3.32
Use super glue to glue the magnets into the magnet cups of the Linear Motion Carriage. Follow the same gluing instructions presented in step 2.1.3.

Slide the Linear Motion Carriage on the rails by hand to test that it moves easily over its whole range. It should be easy to make the carriage move back and forth by turning the stepper motor's shaft with your fingers like a knob. If the carriage sticks in some parts of the length of rails, or it hurts your fingers to turn the motor, it is too tight. You may need to do more friction-sliding of the Linear Motion Carriage. (Remove the chain before you do this or you'll be overloading your motor!)

2.3.33
In the worst case scenario, you may need to hand-sand the metal tubes some more. You can do this without removing the metal boxes - just do it in place!

Once everything slides smoothly, it is time for some silicone machine grease!

Section 2.3 Make the Linear Motion Legs: Instructions Pages



2.3.34
Brush silicone grease over the full length of each metal tube, coating the entire surface.

2.3.35
Brush grease into the beaded chain and into the dents in the motor and idler pulleys.

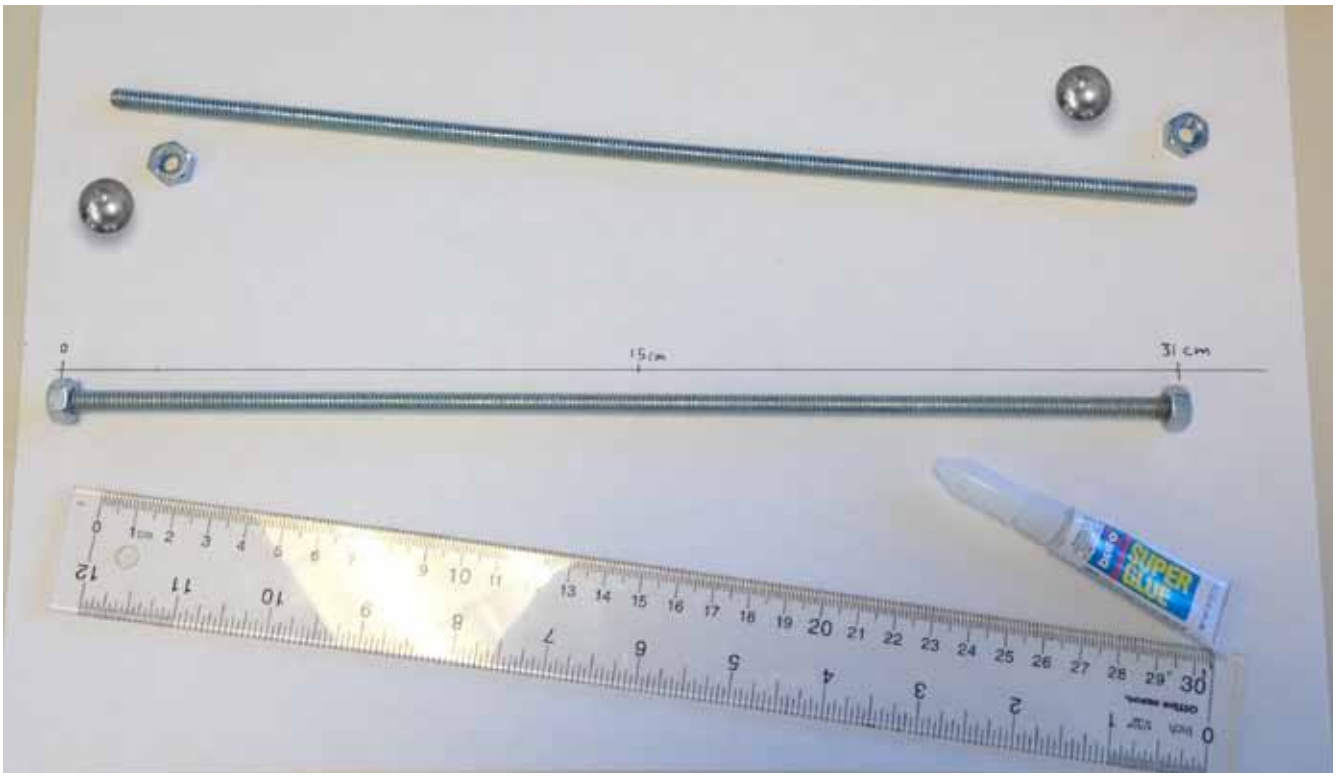
2.3.36
Place the finished linear motion legs onto a flat surface and press the boxes flat. This removes any twist in the pairs of rails. You may wish to give all of the fittings a final tightening. Good job!

Section 2.4 Make the Universal Joint Rods

2.4

Make the Universal Joint Rods

In the finished Ready RepRap, the hotend is connected to each of the Linear Motion Carriages by a pair of rods. The rods have steel balls at the ends, which are attracted firmly into each of the small cup-shaped magnets. This lets them act like little universal joints.

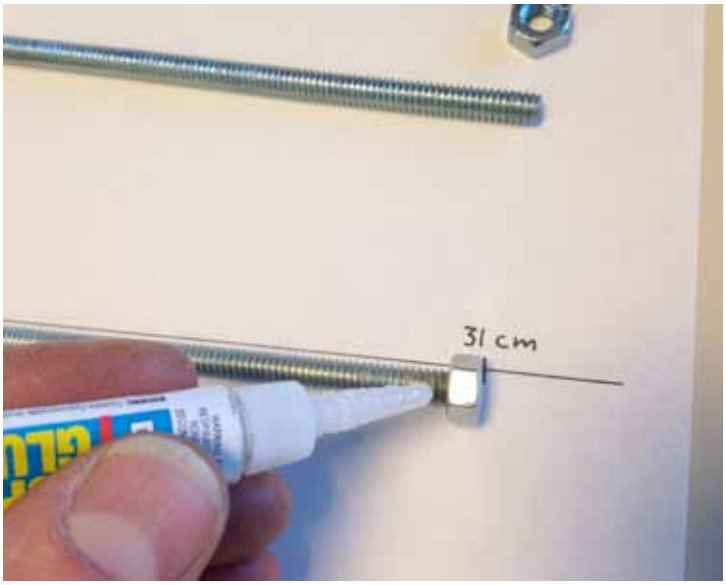


Section 2.4.1 Make the Universal Joint Rods: Tools & Supplies

2.4.a
Tools
Ruler to draw a template line

2.4.b
Supplies
Super glue
Tape or magnets to hold rods upright while drying
Two-part epoxy (JB Weld)
Sharpened pencil to mix and apply epoxy
12 x precut 1/4-20 allthread rods measuring 12 inches each
24 x 1/4-20 steel nuts
24 x 1/2 inch steel ball bearings

Section 2.4 Make the Universal Joint Rods: Instruction Pages



2.4.1

Draw a template line on a sheet of paper, and make two marks exactly 31cm apart. Finger tighten a nut onto either end of an allthread rod. Adjust the nuts carefully so that the total length of the rod (including the nuts) is exactly 31cm. Use a drop of super glue on each nut to lock it into place as shown.

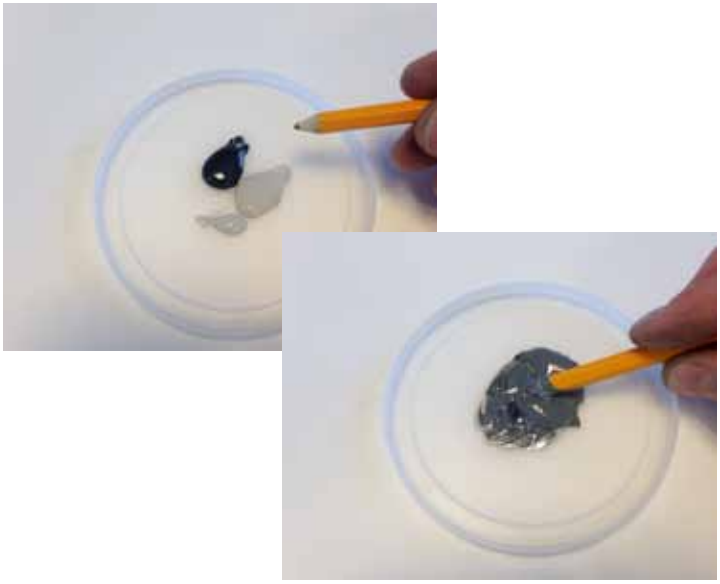
2.4.2

Repeat this process until you have created all 12 rods, being careful to space the nuts so that the total length of each rod you have made is exactly 31cm.

2.4.3

Use magnets or tap to hold the rods upright against a shelf or a box in your workshop. They will need to remain overnight to dry, so put them somewhere out of the way.

Section 2.4 Make the Universal Joint Rods: Instruction Pages



2.4.4
Use the sharpened end of a pencil to mix the two parts of the epoxy glue.

2.4.5
Place a round blob of mixed epoxy glue around the interior of the nut as shown.

2.4.6
Carefully set and press a steel ball bearing into the top of each nut. The ball should sit nicely into the small cup formed by the nut. Do not mess up the ball's otherwise smooth surface by getting extra epoxy on it!

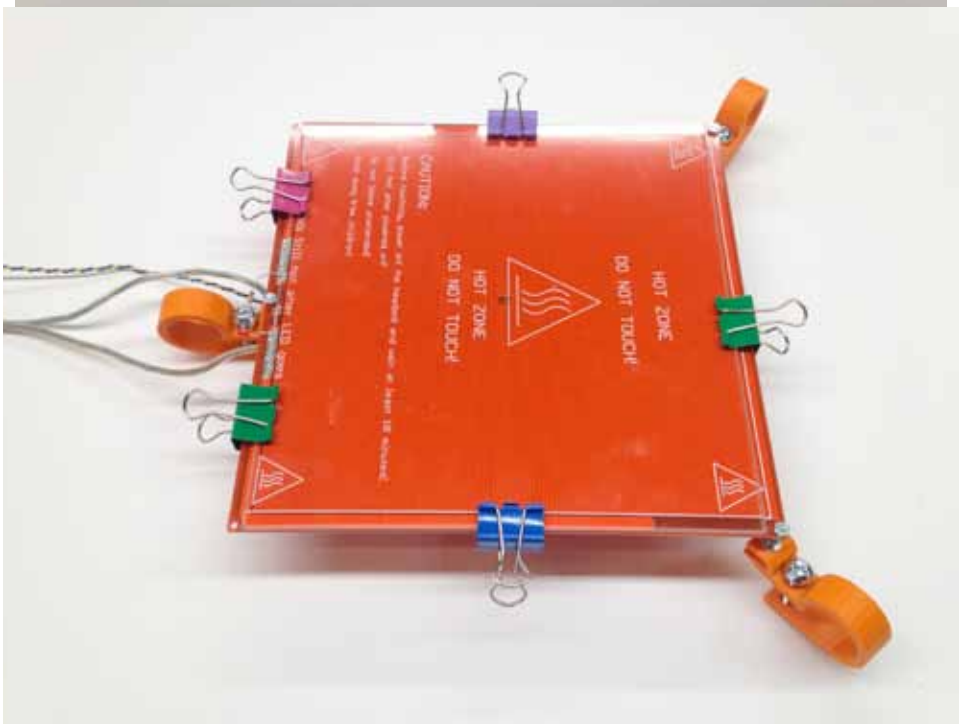
It will need to dry overnight. Repeat the same gluing process to place steel balls on the other ends and allow to dry for a second night.

Section 2.5 Make the Print Bed

2.5
Make the Print Bed
The print bed is the flat surface onto which plastic will be deposited to make your prints.

If you are using ABS plastic, the print bed needs to be heated in order for the plastic to stick down during the process. Steps 2.5.1 - 2.5.10 explain how to build the heated bed.

If you are using other materials such as PLA, a simple flat pane of glass will suffice. In both cases, it the print bed must be adjusted so that it is perfectly level with respect to the moving print head. Steps 2.5.11 - 2.5.12 explain how to build the unheated bed.

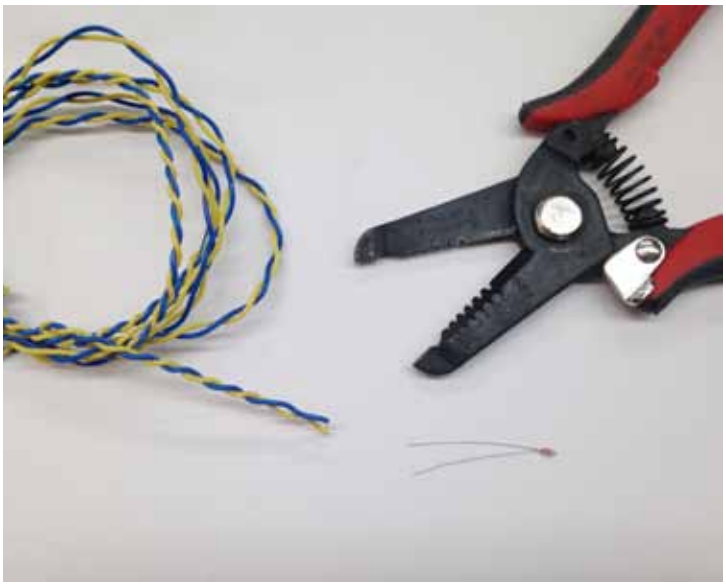


Section 2.5 Make the Print Bed: Tools & Supplies

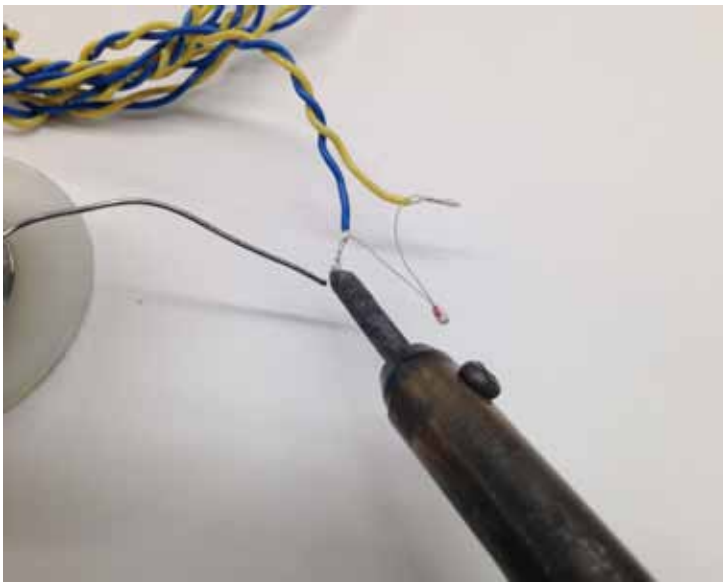
2.5.a
Tools
Wire strippers
Soldering Iron & Solder
Crimpers for crimp connectors
Needle nose pliers
Hot melt glue gun

2.5.b
Supplies
1 x tempered glass build plate
1 x PCB heated bed kit with thermistor and LED
1 x Silicone caulk
8 x Metal binder clips
3 x 3D printed Build Plate Leveling Mounts
3 x 1 1/2 inch long 1/4-20 machine screws
3 x 1 1/4 inch long #6 machine screws
12 x #6 nuts
6 x #6 metal washers
1 x length of copper speaker wire pair, 6 feet length
1 x length of 26 gage wire pair, 5 feet length

Section 2.5 Make the Print Bed: Instructions Pages



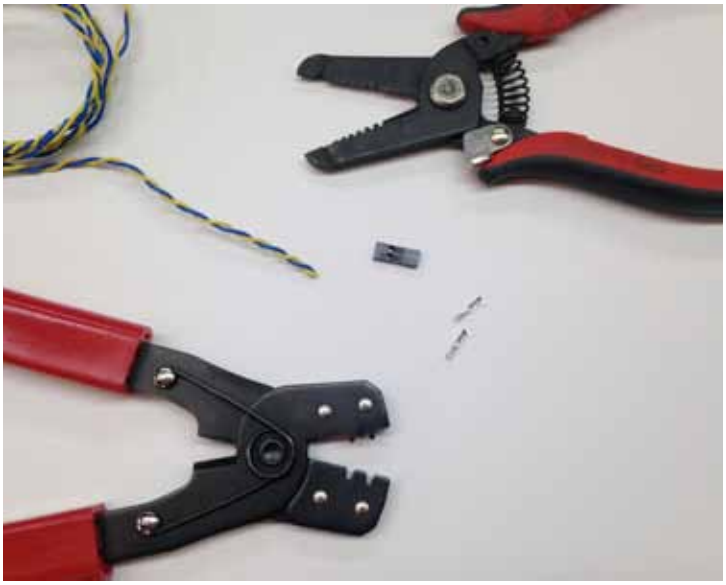
2.5.1
(Heated Bed)
Create a 6 foot length of 26 gage wire pair. You may do this by twisting two lengths of wire together, or by using already paired wire. Strip the wire leads at both ends.



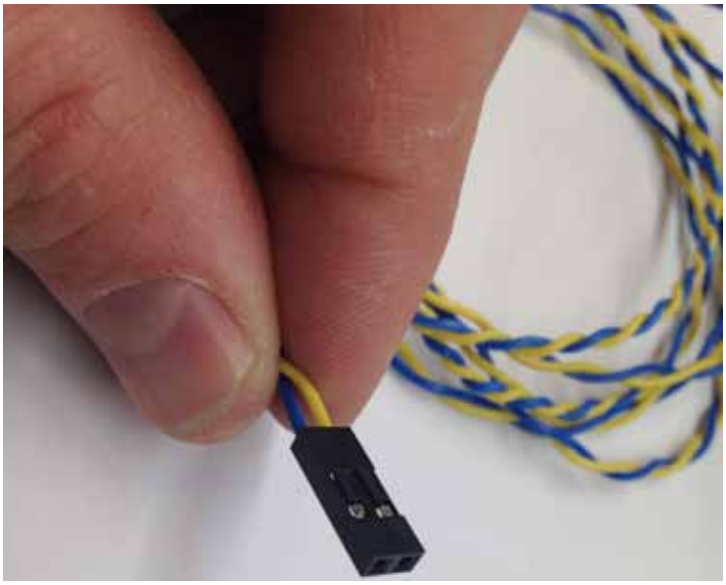
2.5.2
Use a soldering iron to attach the two leads of a thermistor to one end of the twisted wire pair. You do not need to keep track of which wire is which.

2.5.3
Glue the thermistor into the center hole of the PCB heated bed using the high temperature silicone caulk. Glue the thin wires down, keeping them from touching each other. The top side (with the copper traces) needs to stay perfectly flat, so you should put a pieced of tape over the hole on this side. This keeps the caulk from oozing out. The tape can be removed once the caulk is dry.

Section 2.5 Make the Print Bed: Instructions Pages



2.5.4
Attach a two-conductor female crimp connector to the other end of the thermistor wires. First, strip the wires then use the crimper to crimp the small metal connectors onto the leads.



2.5.5
Finally, slip the metal crimp connector leads into the two pin female crimp connector socket. They should click into place nicely.

2.5.6
There should be a small LED and resistor that come with the PCB heated bed kit when you ordered it. If not, a standard red LED and a 10Kohm (brown-black-orange)resistor are what you need. Put the resistor and LED in series and solder them across the large solder pads on the PCB's edge as shown. This will indicate that the heater bed is receiving power and is handy for troubleshooting.

Section 2.5 Make the Print Bed: Instructions Pages

2.5.7

Cut a 6 foot length of copper speaker wire pair. These will be the power wires for the heater. Strip the ends of the wires, and solder the two leads to the large solder pads on the PCB as shown. *Note: It may be handy to assign the copper colored wire to the positive (+) side of the LED indicator light. If you don't know which side this is, don't worry - you can figure that out when hooking it up later.

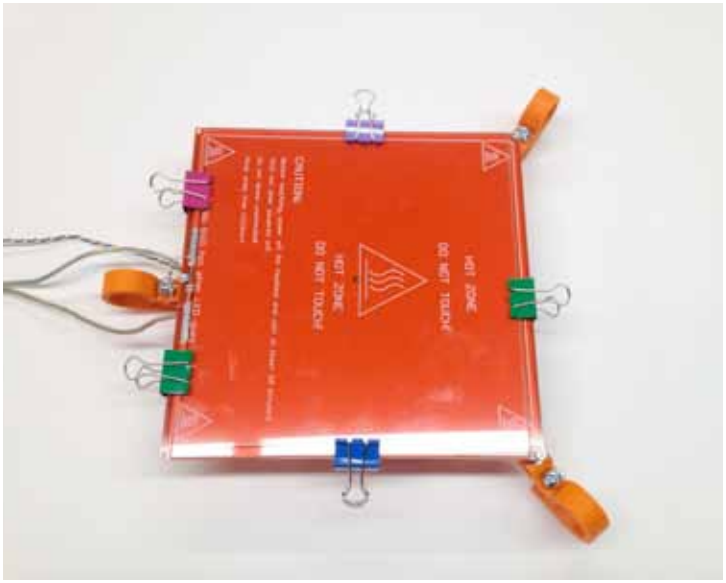
2.5.8

Set up the standoff bolts for the PCB heater bed. Insert the 1 1/4 inch long x #6 machine screws through the holes of the Build Plate Leveling Mounts as shown. Place a washer on either side of the leveling mount, then secure with a nut.

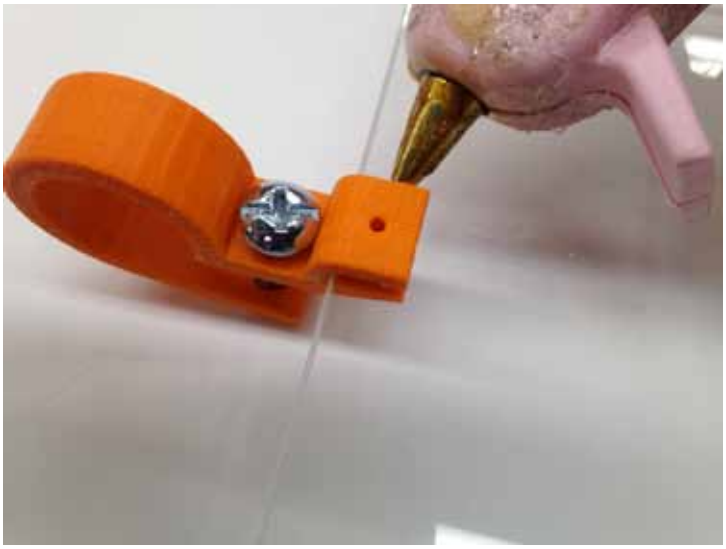
2.5.9

Bolt the Build Plate Leveling Mounts into three holes at the outer edges of the PCB heater plate. Use needle nose pliers to tighten the small nuts through the PCB. Be careful not to twist the mounts, as the PCB corners can be fragile!

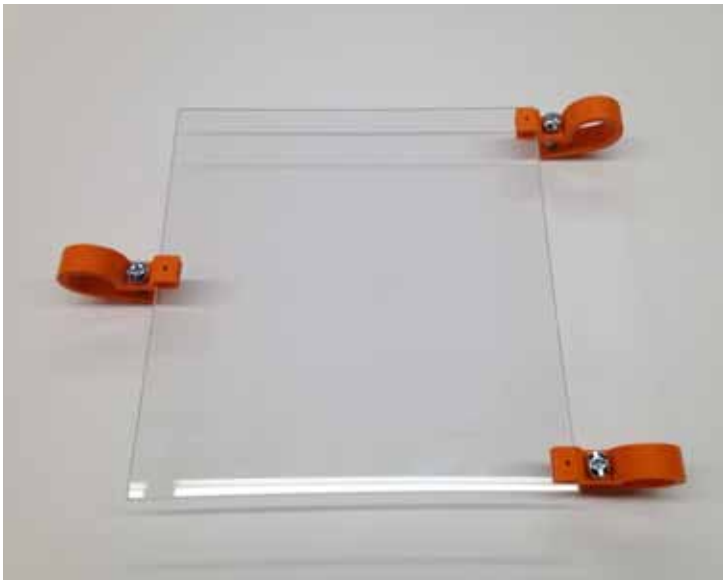
Section 2.5 Make the Print Bed: Instructions Pages



2.5.10
Use metal binder clips to hold a square of tempered glass securely to the top of the PCB heater bed as shown. With the wires attached, the heated print bed is ready to be installed.



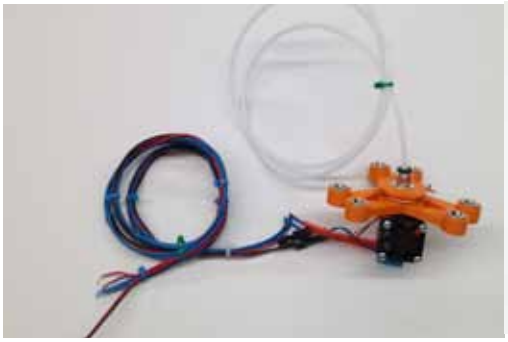
2.5.11
(Unheated Bed)
Place the three Build Plate Leveling Mounts around the outer edge of the square of tempered glass. Alternatively, a square of mirror or window glass may be used.

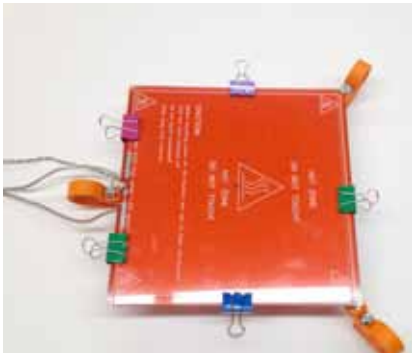


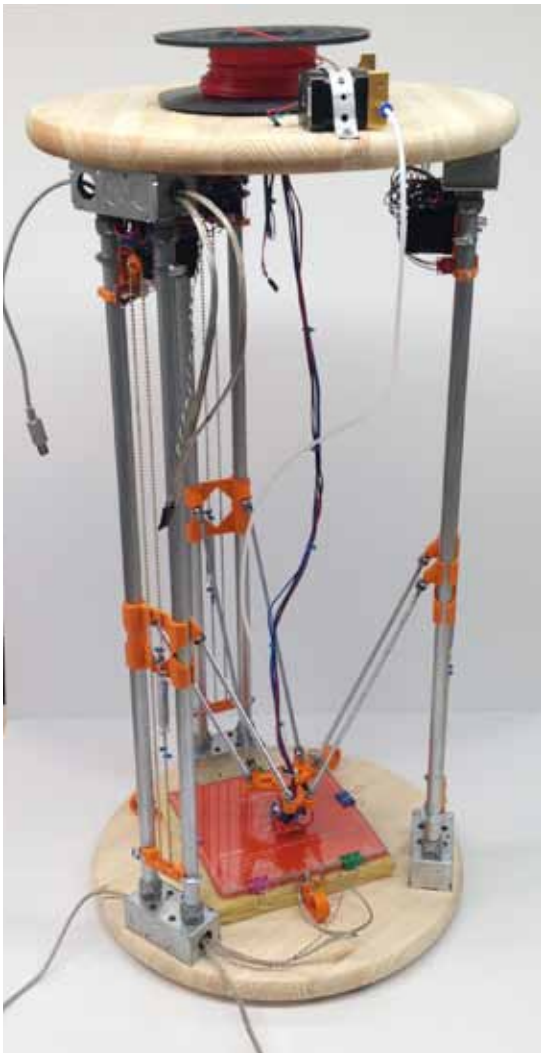
2.5.12
Use hot melt glue to secure the clips to the surface of the glass.

Section 2.6 Assembly

2.6
Assembly of the Machine
Now that you have put together the main subunits of the Ready RepRap, you can assemble the full machine!





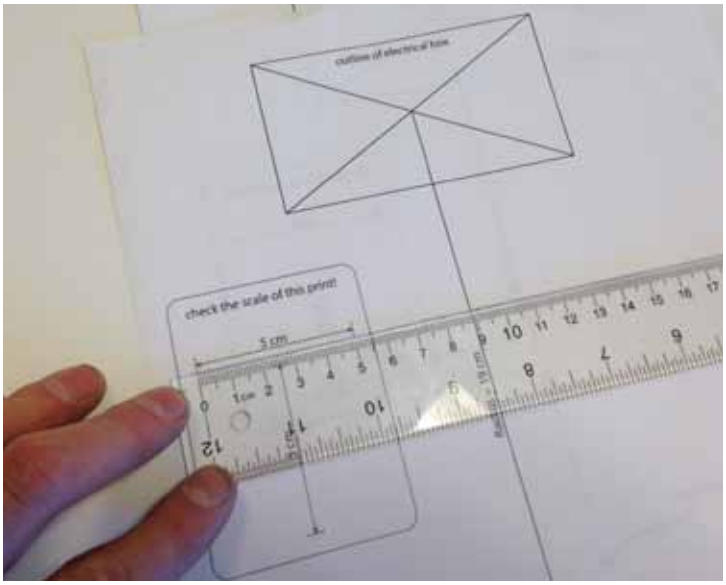


Section 2.6 Assembly: Tools & Supplies

2.6.a
Tools
Ruler
Screwdrivers (phillips & regular, large & small)
Needle noes pliers
Scissors

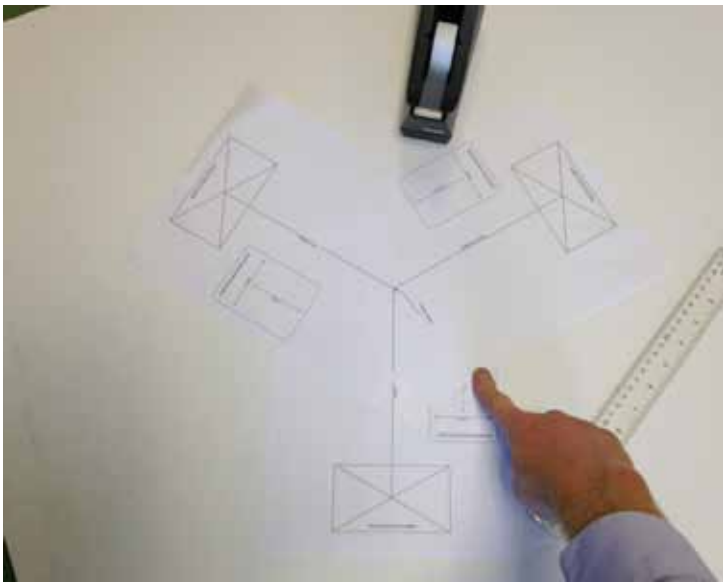
2.6.b
Supplies
Completed Center Hub assembly
Completed Extruder unit assembly
3 x Completed Linear Motion Legs assemblies
6 x Universal Joint Rods
Completed print bed assembly
1 x 3D printed Spool Holder (large or small hole type)
2 x round wooden boards
Scotch Tape
electrical tape
Pen
6 x Stick-on rubber feet
8 foot USB printer cable
10 foot length of copper speaker wire pair
24 x 1 1/2 inch deck screws
Roll of 1/2 inch thick fiberglass pipe wrap material
10 x 1/2 inch long #8 machine screws
5 inches of metal plumbing strap
10 x 6 inch zip ties
2 x Wooden base/top pieces
1 meter length of push-in plastic tube, 4mm O.D.

Section 2.6 Assembly: Instructions Pages

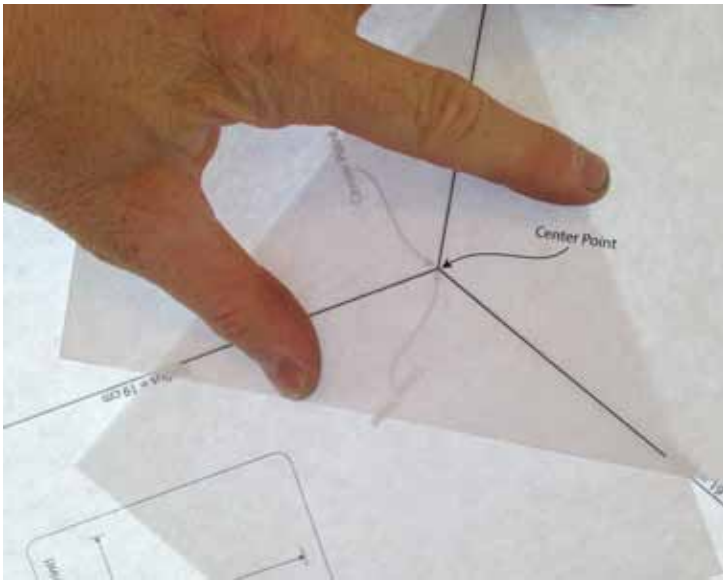


2.6.1
Print three copies of the Radial Layout Template on the following page. You can also download it here: https://github.com/dhartkop/ReadyRepRap/

Once printed, make sure the scale is exactly correct using a ruler. The scale marks should measure exactly 5cm. You may need to adjust the print scale slightly and print again!

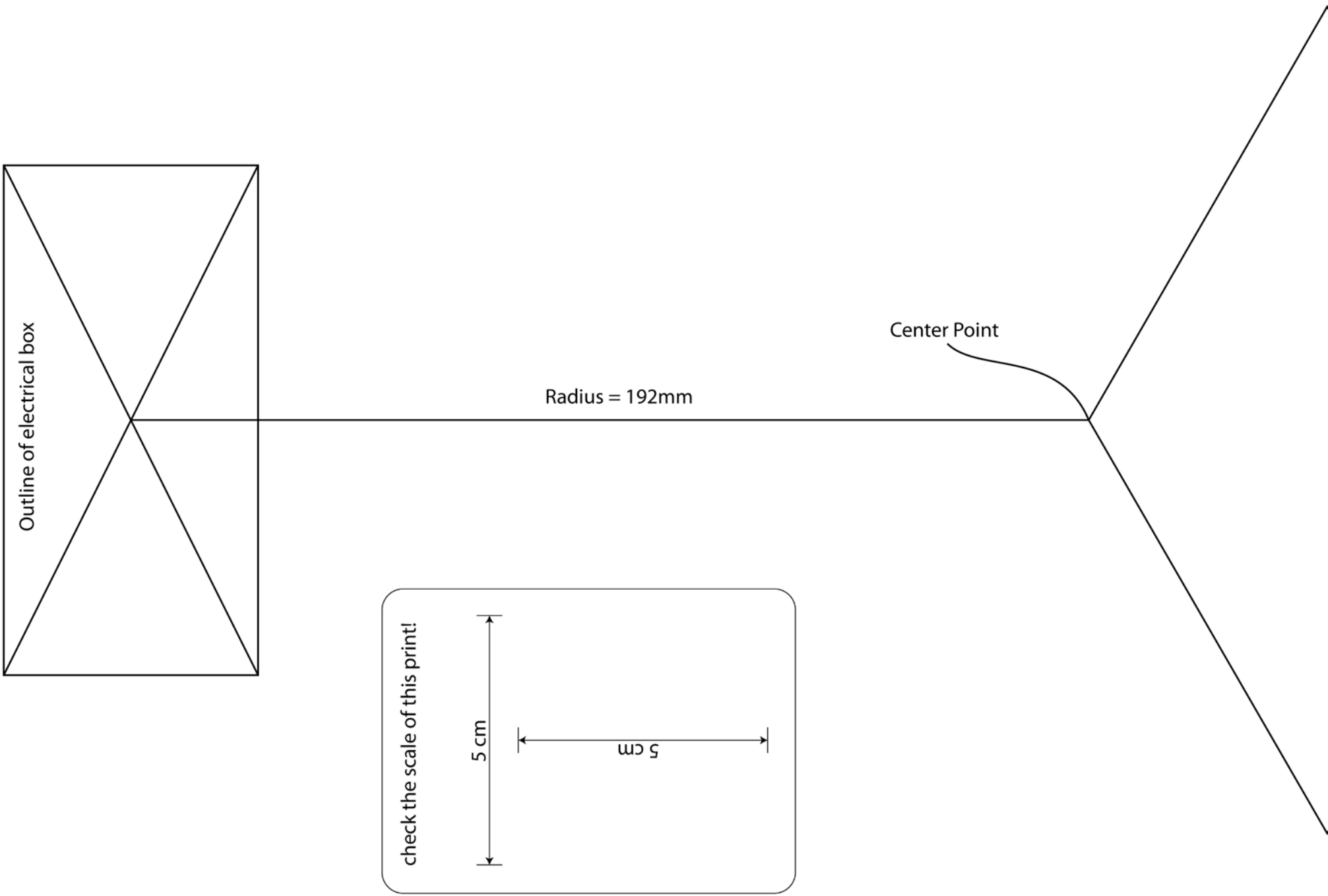


2.6.2
Tape the three Radial Layout Template sheets together so that their centers overlap.

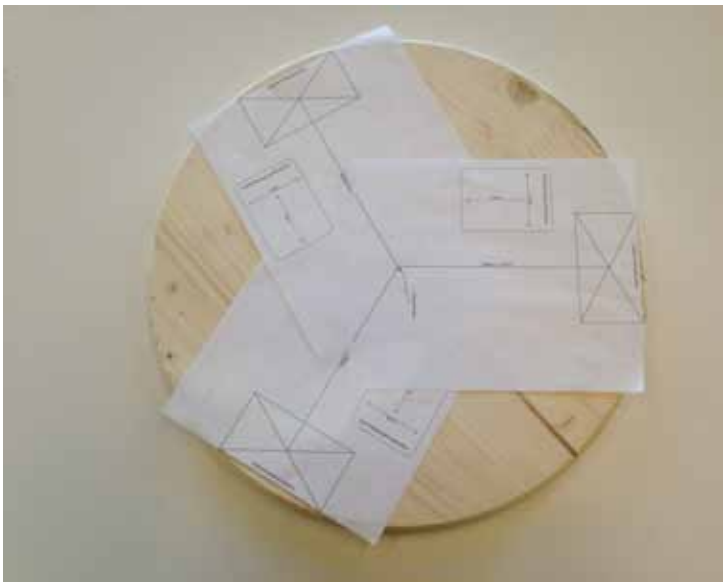


2.6.3
You can check to see that the template sheets line up perfectly by holding it up to a light or a window.

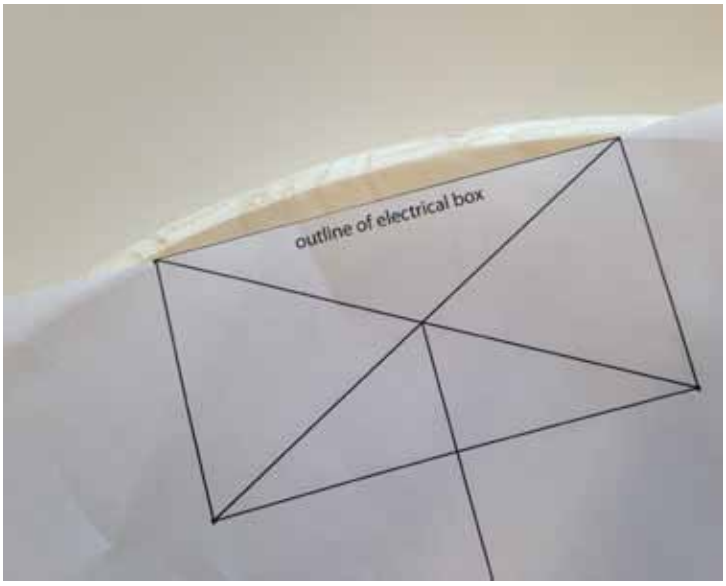
Ready RepRap box layout template



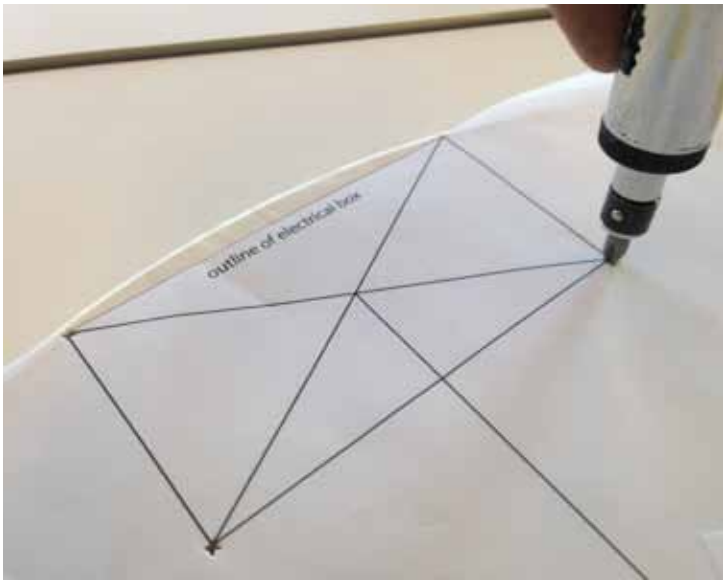
Section 2.6 Assembly: Instructions Pages



2.6.4
Place the Radial Layout Template onto the face of one of the wooden base/top pieces.

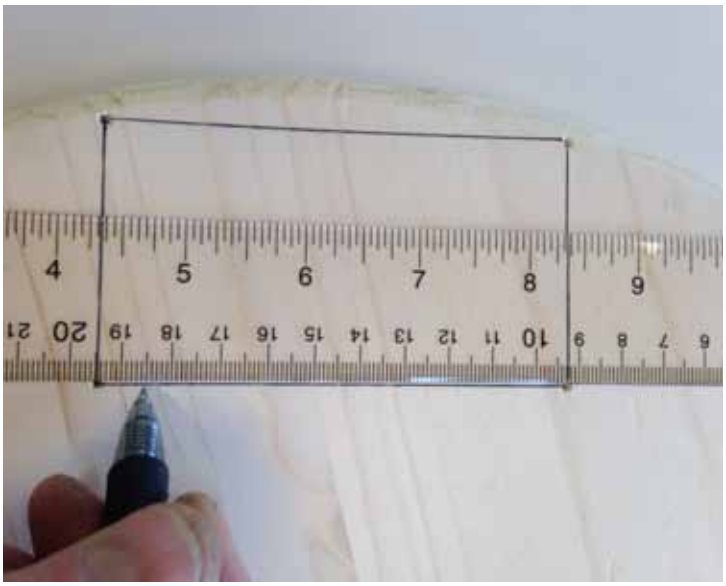


2.6.5
Position the template so that the corners of the electrical box outlines are all on the surface of the wood. You may need to carefully slide the template around to get this just right.

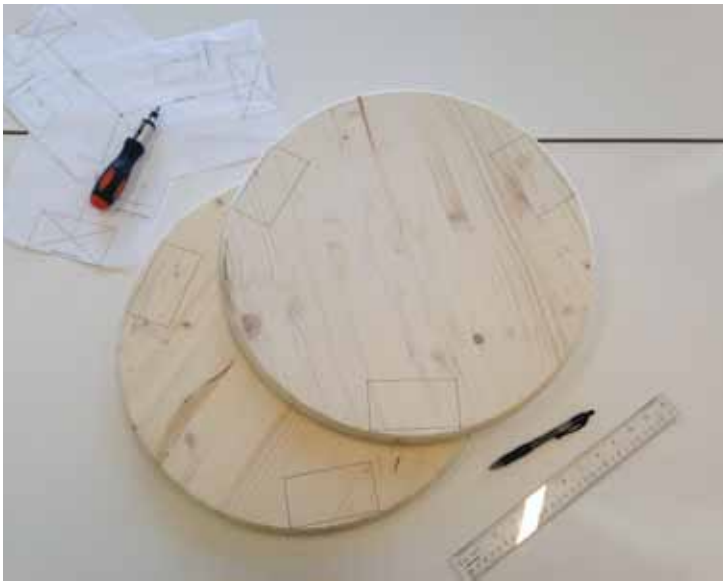


2.6.6
Use a punch or the end of a small phillips screwdriver to punch through the corners of all three box outlines. This will mark the box positions on the wood.

Section 2.6 Assembly: Instructions Pages



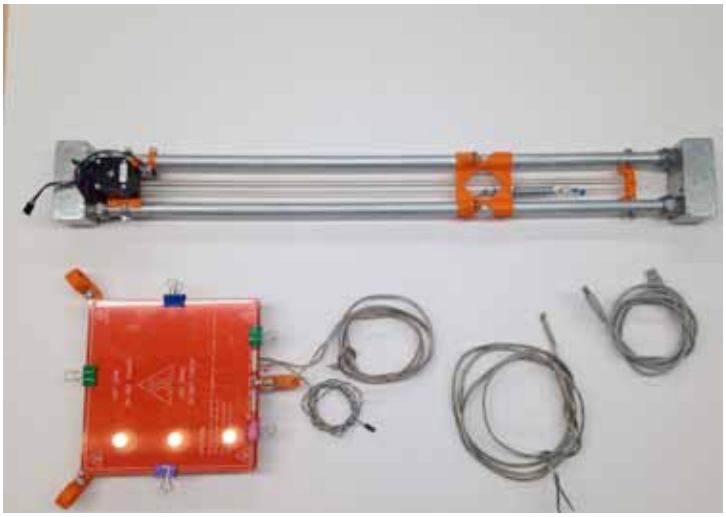
2.6.7
Use a ruler and a pen to carefully connect the punched marks in the wood, outlining the positions of the boxes.



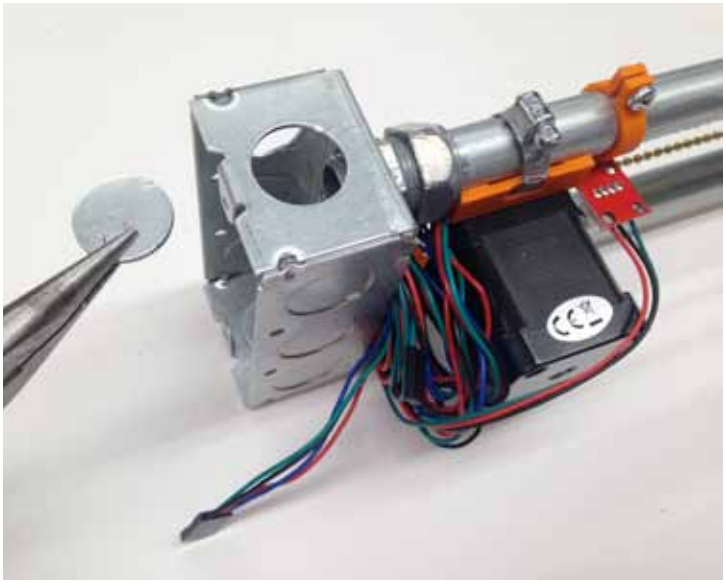
2.6.8
Repeat steps 2.6.4 to 2.6.7 for the other wooden base/top piece.

2.6.9
Choose one of the wooden base/top pieces to be the base. Stick six rubber feet on the bottom of the wooden piece as shown. (The bottom is the side without the box outlines!)

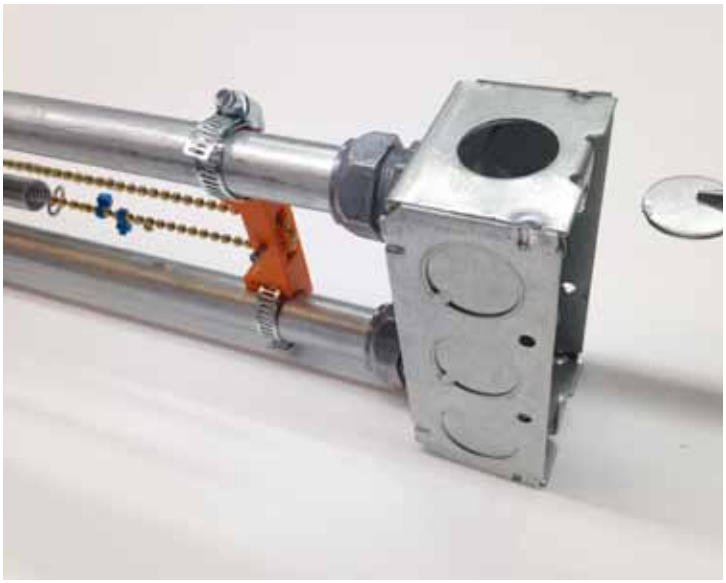
Section 2.6 Assembly: Instructions Pages



2.6.10
Next choose one of the three Linear Motion Legs. This will be the one we'll run all of the top-to-bottom wires through. We'll run a USB wire, a power wire, and the four wires from the heated print bed through the conduits of this linear motion leg.

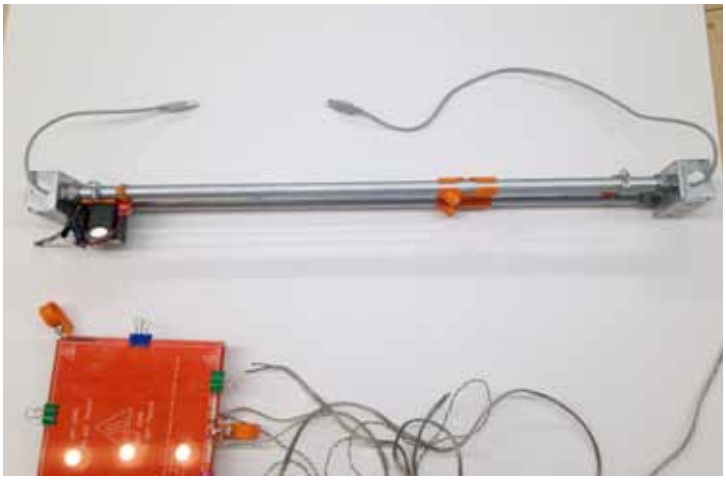


2.6.11
Punch out the two end circles of the motor end of the linear motion leg's box.

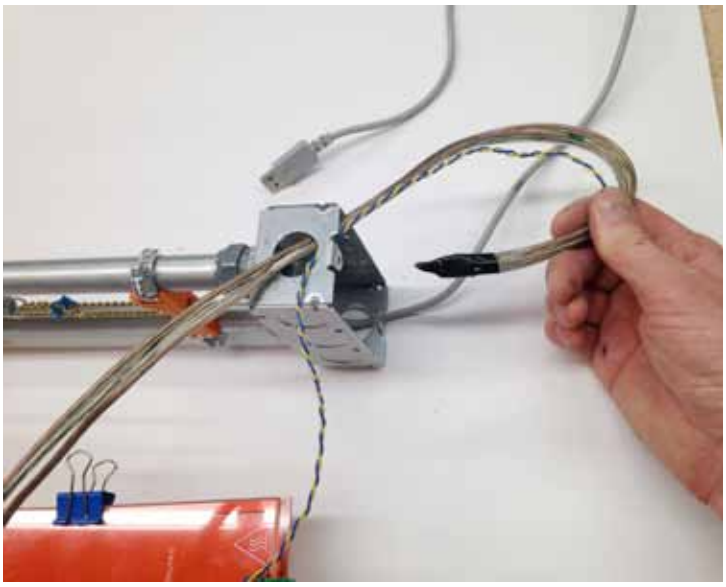


2.6.12
Punch out the two end circles of the idler end of the linear motion leg's box.

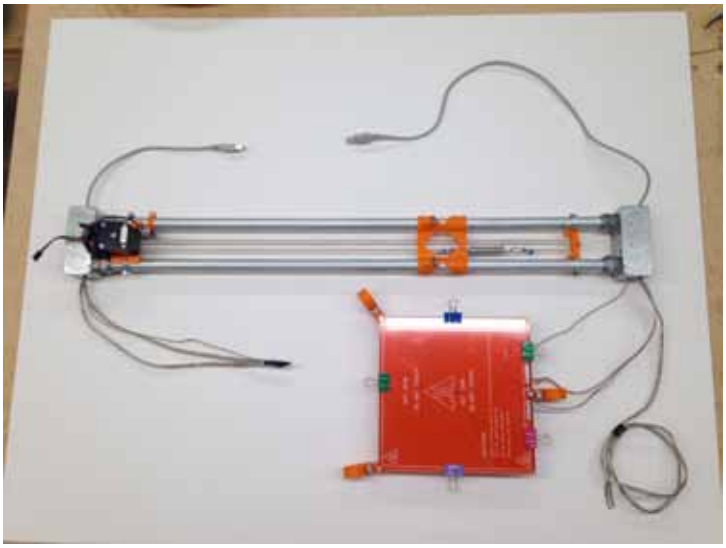
Section 2.6 Assembly: Instructions Pages



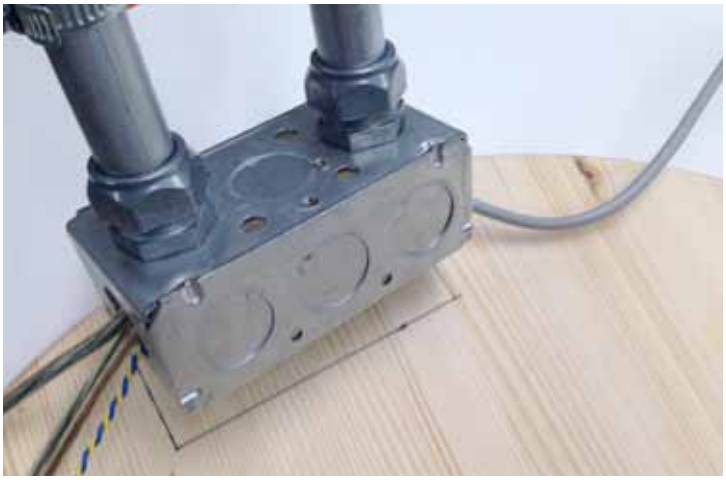
2.6.13
Feed the 8 foot USB printer cable up through one of the conduits and then out the sides of the boxes on either end. You will need only 12 inches of USB cable coming out of the motor end of the box. This should be the PRINTER end (the squarer of the two ends.) The remaining length of the USB cable should come out the idler end of the Linear Motion Leg.



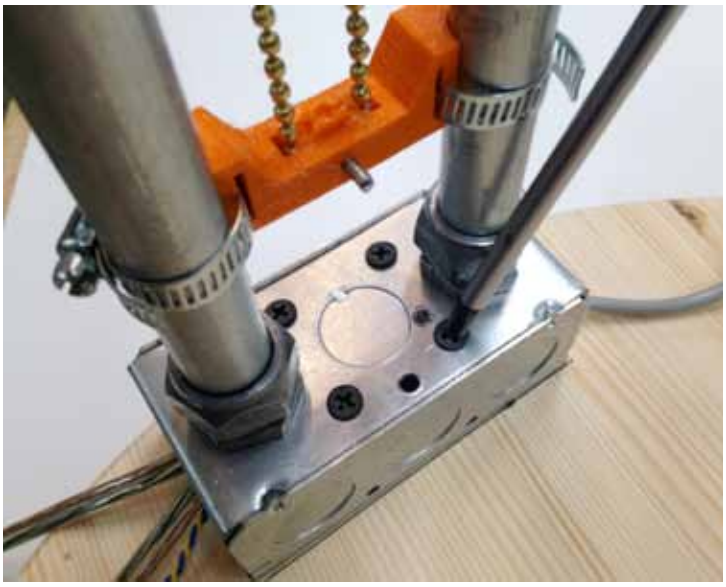
2.6.14
Prepare the next set of wires to be passed through the second conduit in the Linear Motion leg. Use electrical tape to wrap the ends of the following wires together:
1. Wire pair for the printer bed
2. Twisted pair of thin wires from the printer bed
3. One end of the 10 ft speaker wire pair for power



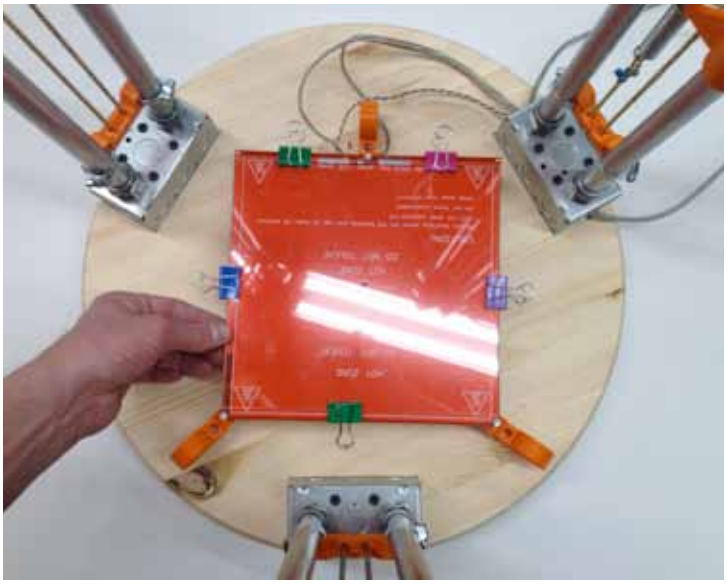
2.6.15
Pass the taped wire bundle into one side of the idler-end box, up the empty conduit, and out through the side of the motor-end box. You will need approximately 18 inches of wire at the motor end. See diagram of finished wired Linear Motion Leg.



2.6.16
Mount the linear motion legs to the wooden base, one at a time. Align the idler end of each leg with the drawn outline as shown.

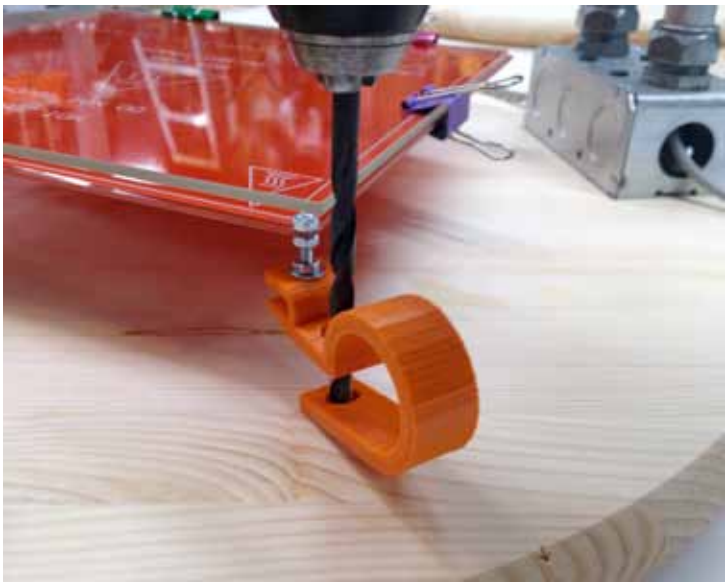


2.6.17
Mount the idler end box of each Linear Motion Leg to the wooden base using four deck screws, as shown. Flip the entire set of linear motion legs up-side-down onto the wooden top piece. Now mount the motor end boxes onto the top piece using four deck screws each. Be sure to line the boxes up exactly with the outlines!



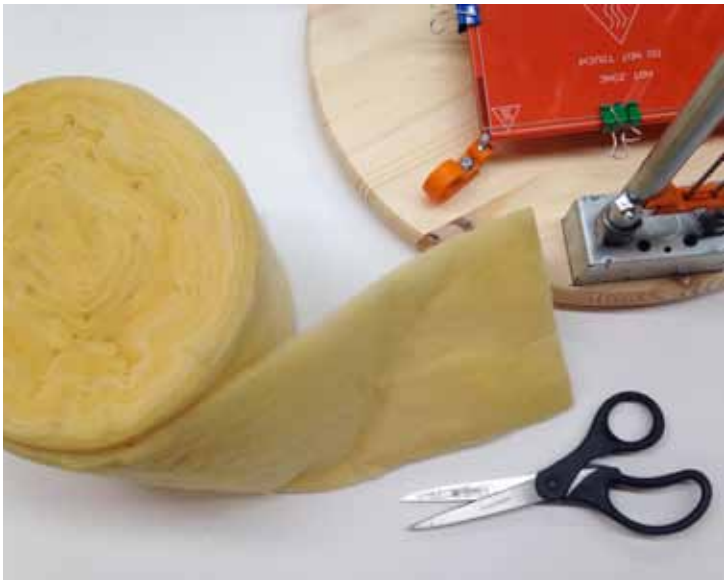
2.6.18
Once all of the linear motion legs are mounted between the wooden top & base pieces, flip the whole thing right-side-up (rubber feet down.) Position the build plate assembly by hand between the electrical boxes at the machine's base. You don't have to be perfectly exact with this step; just center it as best as you can by eye.

Section 2.6 Assembly: Instructions Pages



2.6.19
Once you are satisfied with the position of the build plate assembly, use a drill with a 3/16-inch bit to drill pilot holes through the Build Plate Leveling Mount holes.

2.6.20
Use a large phillips screwdriver to screw 3 x 1/4-20 machine screws into each of the Build Plate Leveling Mounts. Screw them in until each leveling mount is about half-way between its fully open and fully clamped-down position.



2.6.21
If you are using a heated build plate assembly, you will need to insulate under it. Use scissors to cut sections of fiberglass pipe wrap.

Section 2.6 Assembly: Instructions Pages

2.6.22
You slide small pillowed layers of the fiberglass under the build plate. They should be easy to fit in, but not so loose that they slide right out.

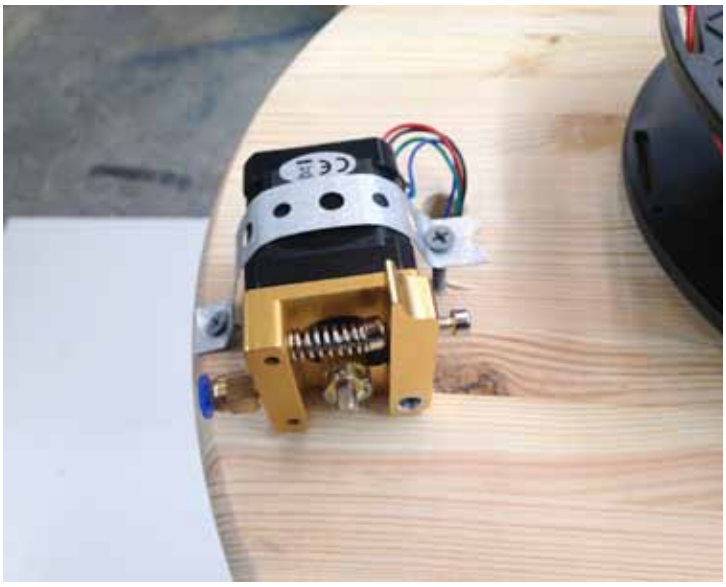
2.6.23
Mount the 3D printed Spool Holder to the top of the wooden top piece. (Use whichever size matches the spools you intend to use!)

2.6.24
Shown is a spool resting on an installed spool holder on the top of the Ready RepRap.

Section 2.6 Assembly: Instructions Pages

2.6.25
Mount the filament extruder device to the top of the wooden top using a length of approx. 4 inches of plumber strap. The push-in tube fitting should face away from the spool.

Use a pair of metal washers or the disks punched out of the electrical boxes as spacers under the motor body. Tis lets the lever arm of the extruder swing freely when it is surface mounted.

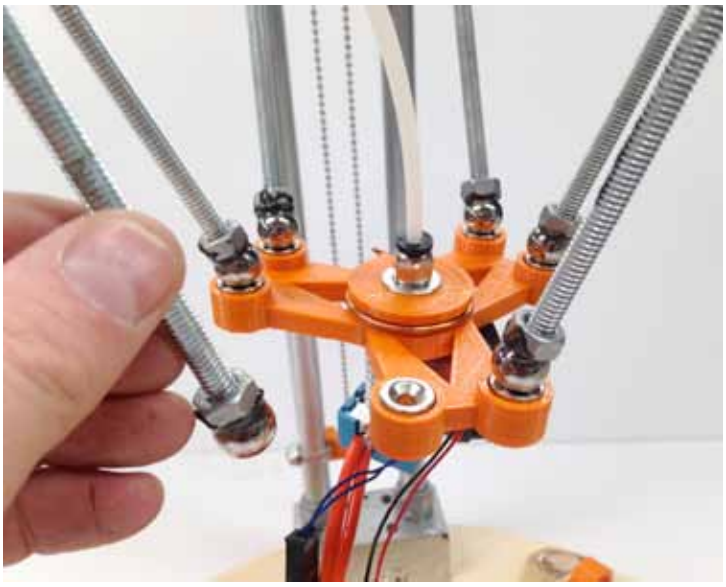


2.6.26
Pass the wires of the extruder device down through a drilled hole in the wooden top. The extruder should be firmly mounted into place with a pair of wood screws.

2.6.27
Place the six universal joint rods into the magnets of the Linear Motion Carriages in the Linear motion legs.

Section 2.6 Assembly: Instructions Pages

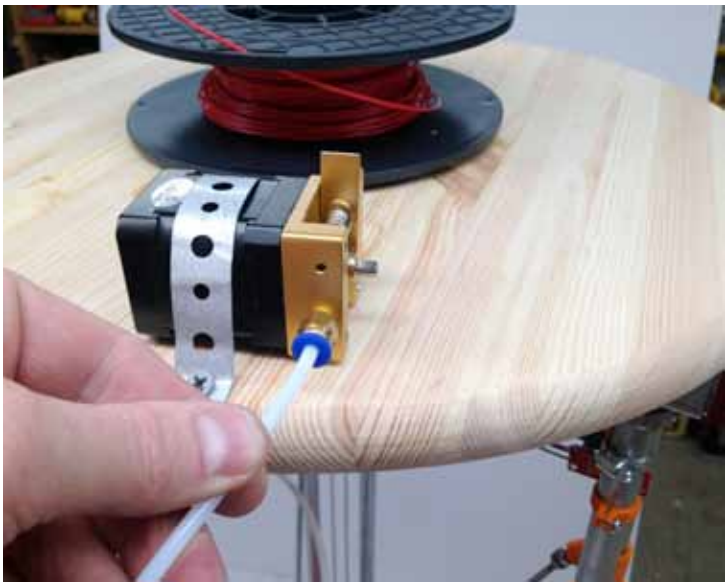
2.6.28
The ball bearings should seat firmly into the cupped magnets, and rotate freely.



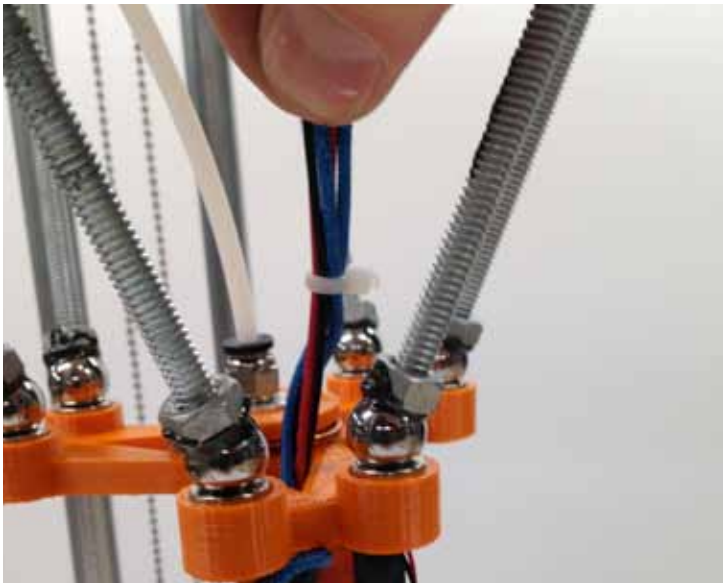
2.6.29
Snap the six free ends of the universal joint rods into the cupped magnets in the Center Hub Assembly.

2.6.30
Notice that, once all six rods are in place, the position and rotation of the Center Hub Assembly is firmly locked into place. You can slide the Linear Motion Carriages up and down the linear motion legs and observe the change in position of the Center Hub Assembly.

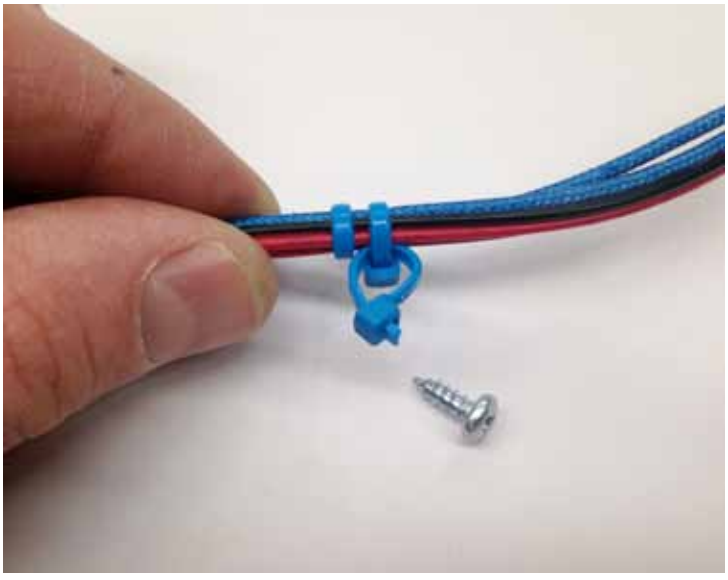
Section 2.6 Assembly: Instructions Pages



2.6.31
Find a 1 meter length of Push one end of the plastic filament guide tube. Push one end of the tube into the push-in fitting of the extruder unit on the top of the Ready RepRap.

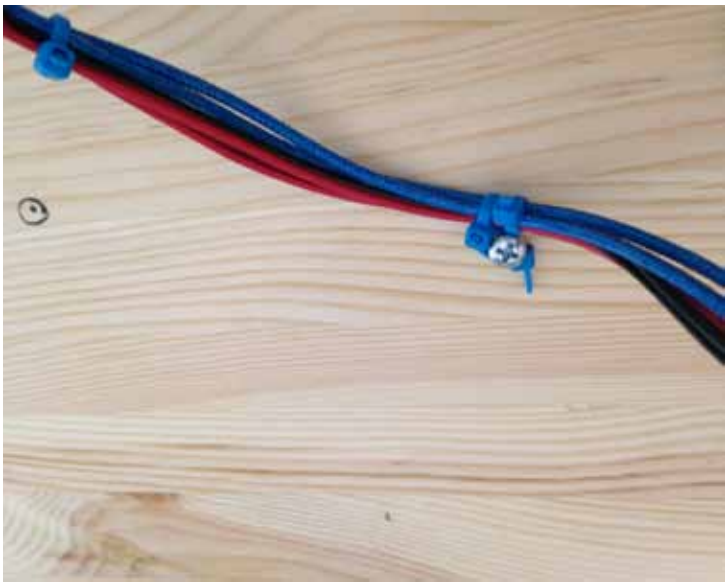


2.6.32
Push the other end of the plastic filament guide tube into the fitting on the hot end, in the center of the Center Hub Assembly.

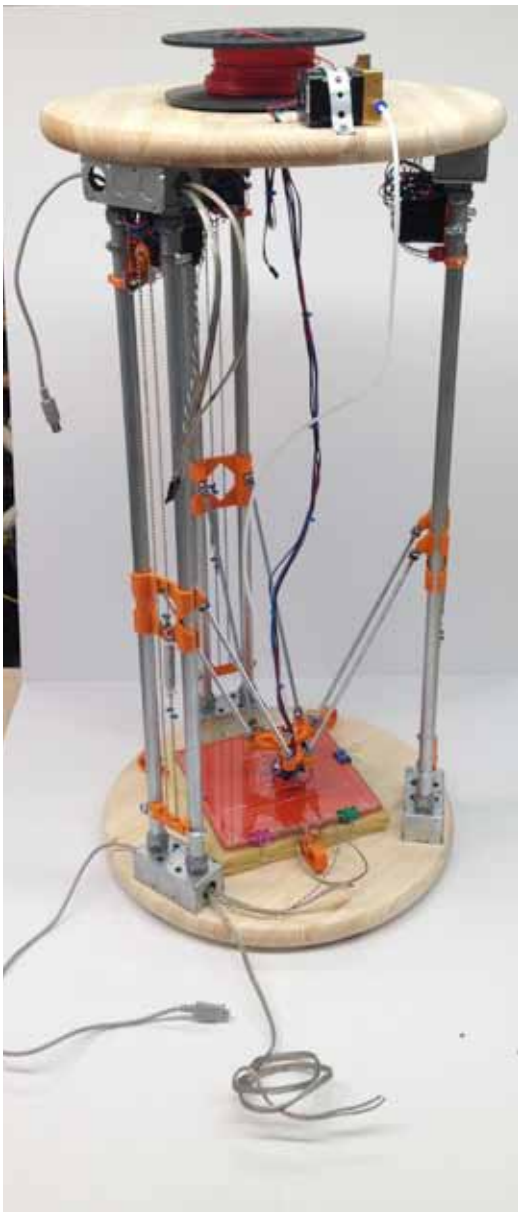


2.6.33
Group the set of wires from the Center Hub Assembly using zip-ties placed every 6 to 8 inches. The wire should extend upward approximately 1 meter. You will need to anchor this wire bundle to the underside of the wooden top, but will need about 10 inches of loose wire to hook everything up at the top. Place a double zip-tie arrangement as shown approximately 10 inches from the free ends of the wires.

Section 2.6 Assembly: Instructions Pages



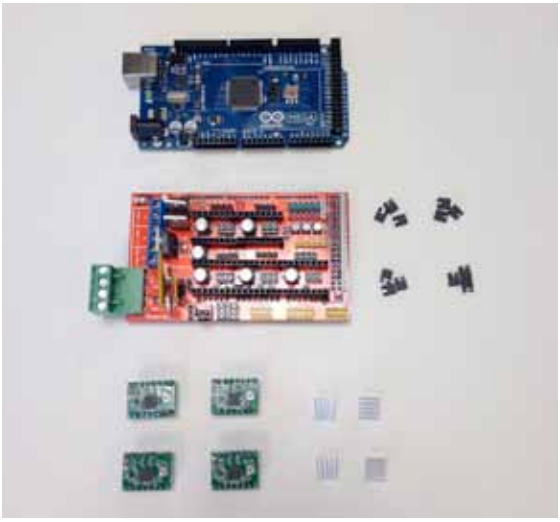
2.6.34
Anchor the end of the Center Hub Assembly's wire group to the underside of the wooden top, somewhere near the center.

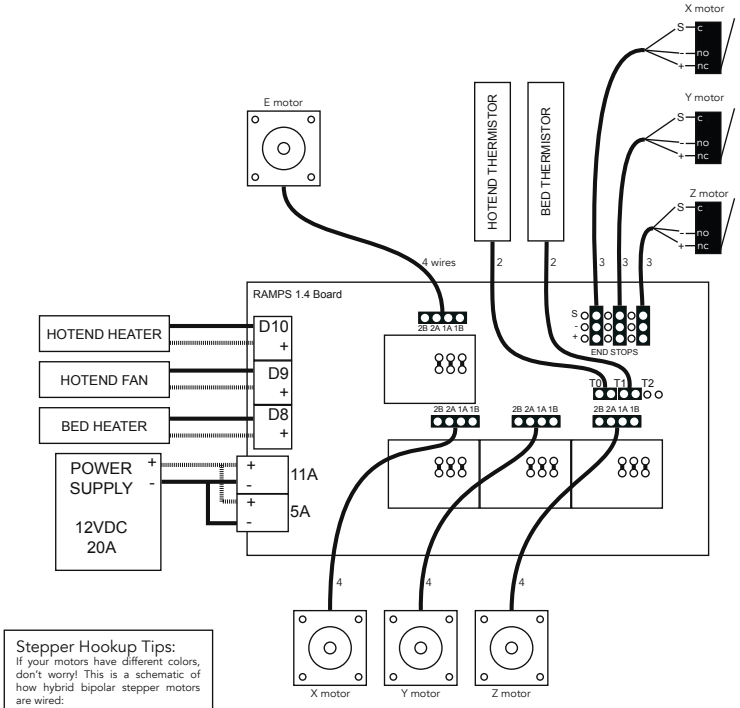


2.6.35
Good job! All of the mechanical components of the Ready RepRap are assembled. The next steps involve installing the microcontroller and wiring it all together.

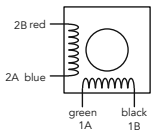
Section 2.7 Wiring

2.7
Wiring
With the mechanics of the machine complete, it is time to install the microcontroller and hook up all of the wires to make things work.





Stepper Hookup Tips:
If your motors have different colors, don't worry! This is a schematic of how hybrid bipolar stepper motors are wired:



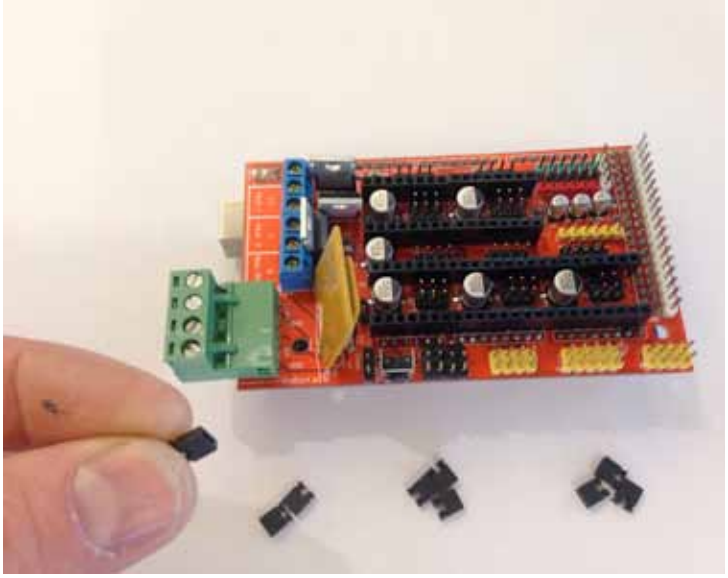
The motor has two separate coils, two wires for each. If you cross a pair of wires and feel the shaft get harder to turn, then you have found one of the coils. If you hook up the coils backwards, the motor simply goes in the opposite direction.

Section 2.7.1 Wiring: Tools & Supplies

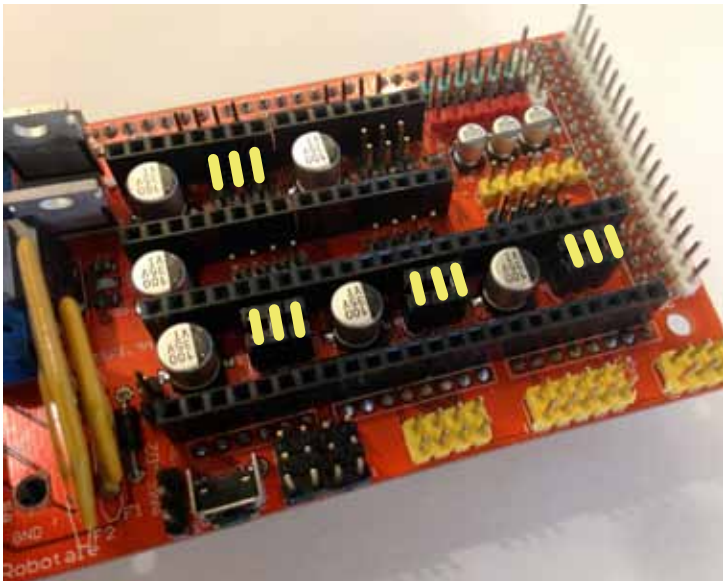
2.7.a
Tools
Needle nose pliers
Scissors
Screwdrivers
Wire cutters
Wire crimpers

2.7.b
Supplies
1 x Arduino Mega 2560 microcontroller board
1 x RAMPS shield for Arduino Mega
4 x A4988 Stepper Driver Module
12 Volt DC 12+ Amp power supply. Search for S-360-12 or similar.
Dupont Jumper Wire Cable Female Pin Crimp Connector 2.54mm
2.54mm 1x4P Dupont Connector Housing, Female
2.54mm 1x2P Dupont Connector Housing, Female
6” zip ties
1 x roll of self adhesive hook & loop fastener tape
2 x 1-1/4 inch x #6 machine screws

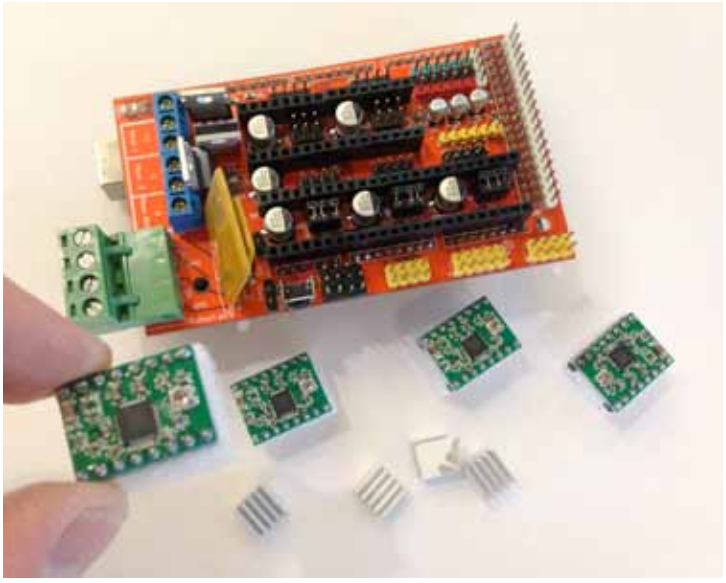
Section 2.7 Wiring: Instructions Pages



2.7.1
Locate the RAMPS shield and find a set of small jumper connectors. These jumpers probably came with the small stepper motor driver cards.

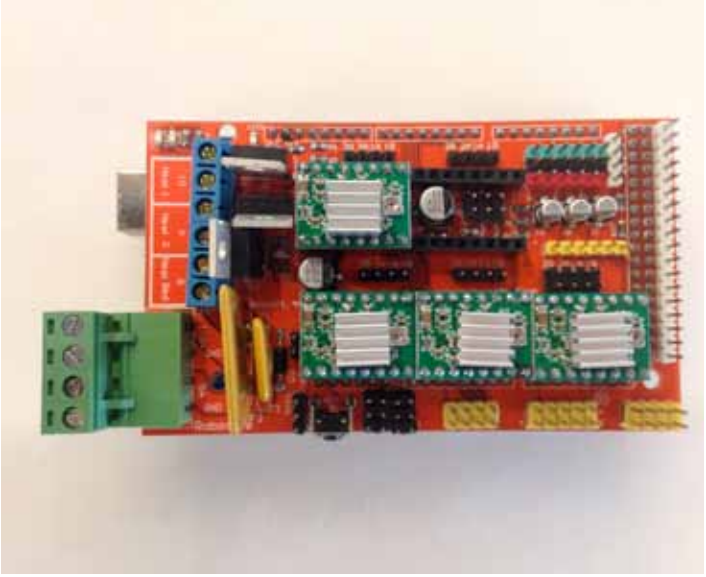


2.7.2
Use needle nose pliers to carefully place the jumpers onto into the slots shown in the picture. Three jumpers each for the extrude driver, the x-driver, the y-driver, and the z-driver cards.



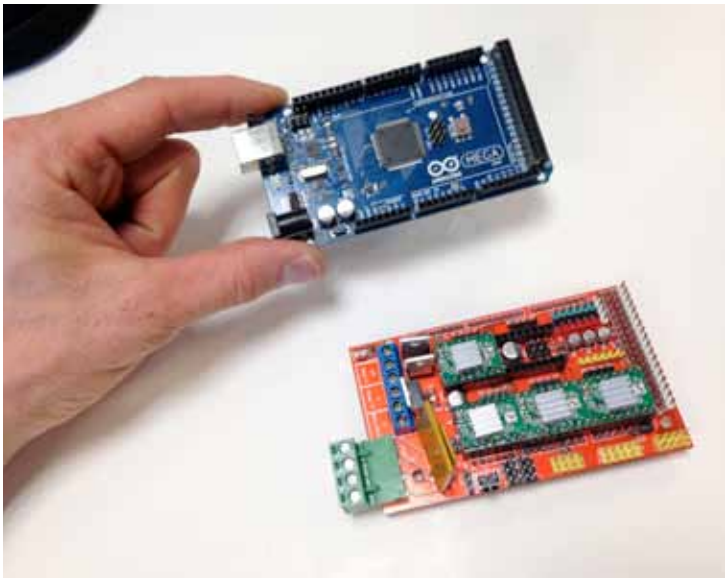
2.7.3
Next locate four of the A4988 Stepper Driver Modules. These small boards will deliver the power to the motors. Begin by attaching the miniature heat sinks to the tops of each of the black chips. Take care not to handle the pins as they can be static sensitive. If possible, use a conductive mat or do this step in a slightly humid location.

Section 2.7 Wiring: Instructions Pages



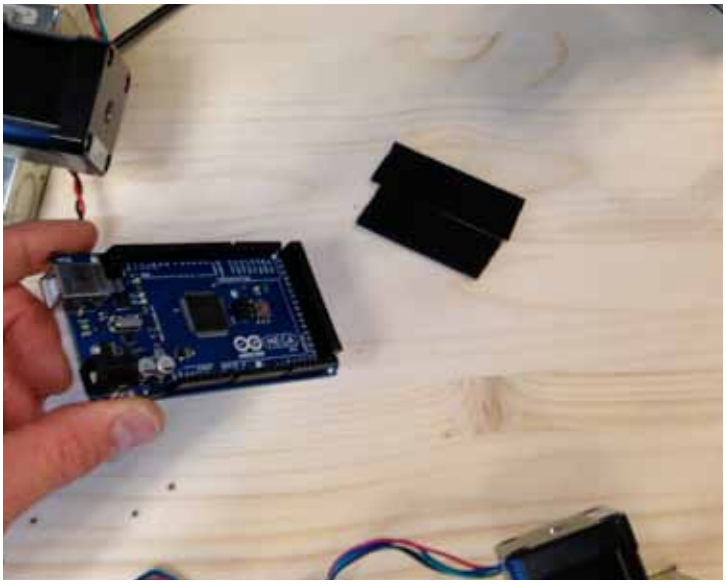
2.7.4

Next, install the A4988 Stepper Driver Modules into the RAMPS card. Take care to plug them in in the correct orientation, as they will fry if you put them in backwards! With the RAMPS board laying before you with its row of power terminals to the left, each stepper driver's miniature trim-pot should be to the RIGHT of the heat sink.



2.7.5

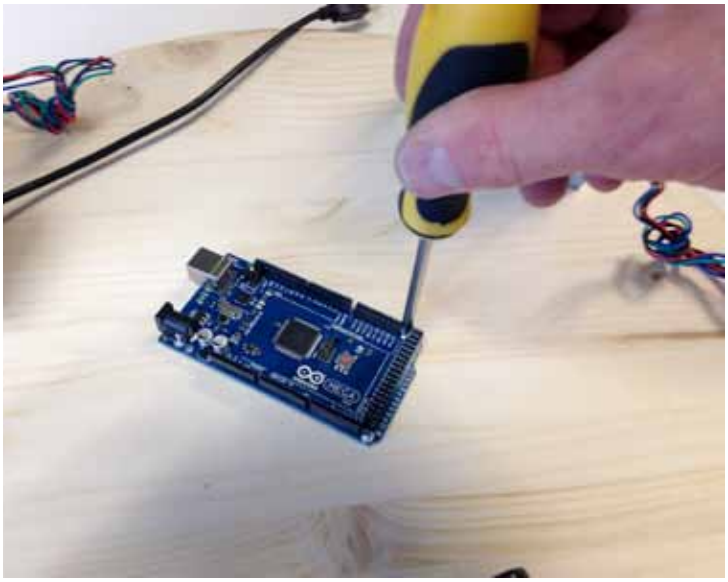
Now locate the Arduino Mega 2560 board.



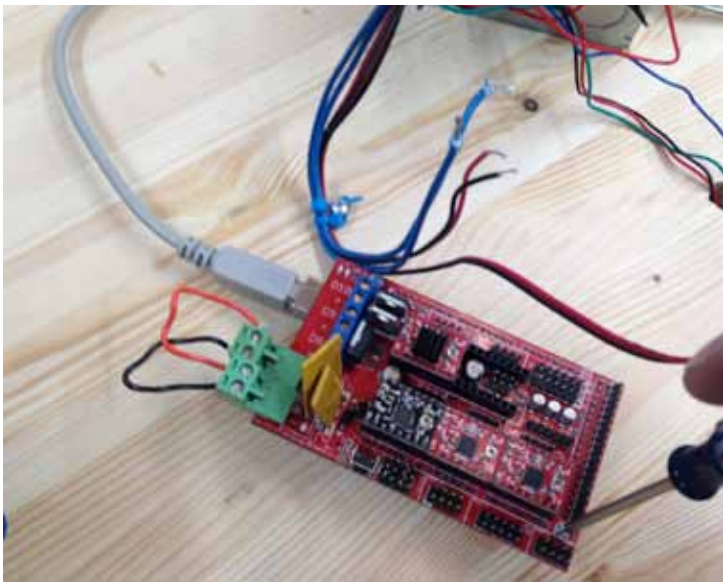
2.7.6

Use self adhesive hook & loop fastener tape to create a small pad for the circuit board on the underside of the wooden top piece as shown. You do not actually need to stick the tape to the circuit board, as it will actually be held onto the board with screws. The pad just helps keep the pins under the board from bending or sticking.

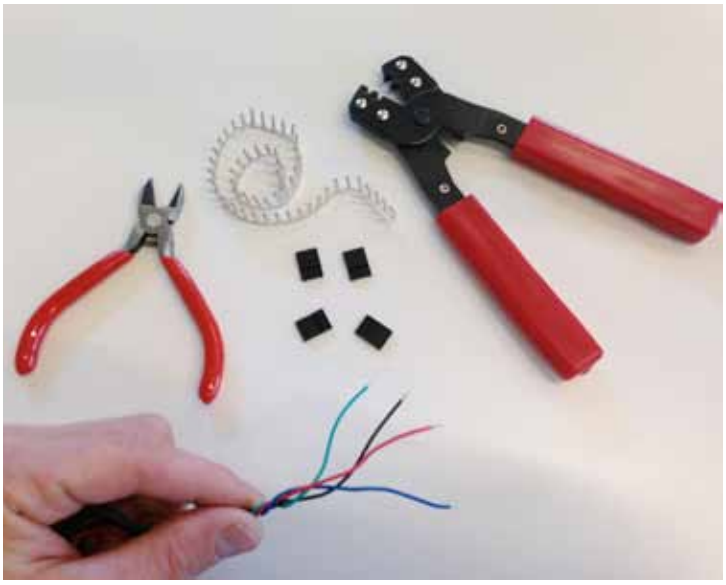
Section 2.7 Wiring: Instructions Pages



2.7.7
Fit the RAMPS shield onto the Arduino Mega micro controller board. You may need to carefully bend some of the pins of the RAMPS so they perfectly line up with the many socket holes of the Arduino. Once the pins are all lined up to the sockets, squeeze the boards together a little at a time with your fingers. Move around the edges, squeezing more each time until the RAMPS is fully seated onto the ARDUINO.

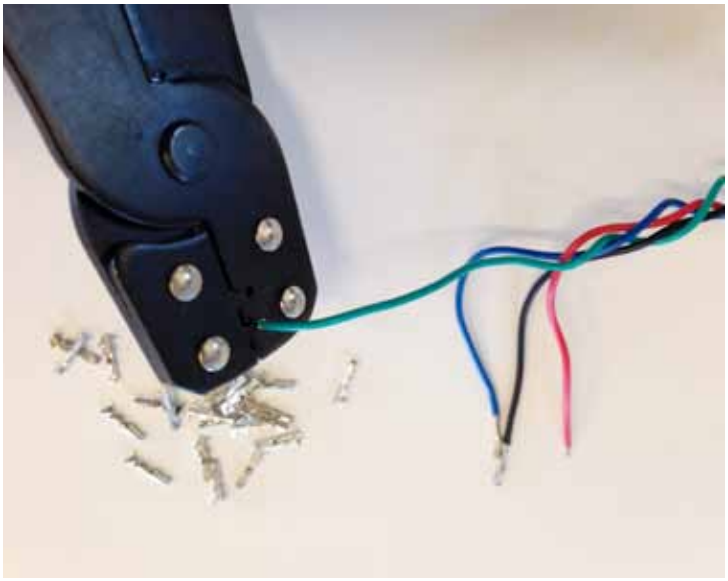


2.7.8
Mount the micro controller system on the underside of the wooden base piece by placing it on the pad and screwing it down fish a pair of 1-1/4 inch x #6 machine screws.

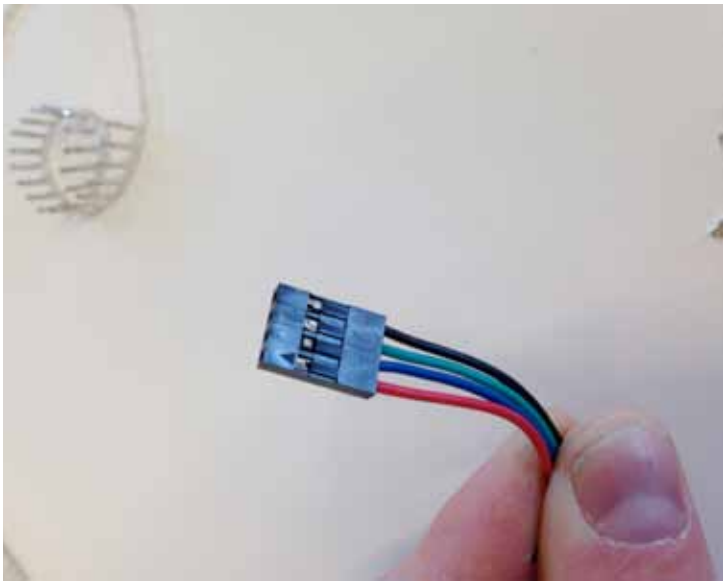


2.7.9
Next, find the supplies for putting crimp connectors onto the stepper motor wires. Each motor has four wires and will have a 4 pin female Dupont connector.

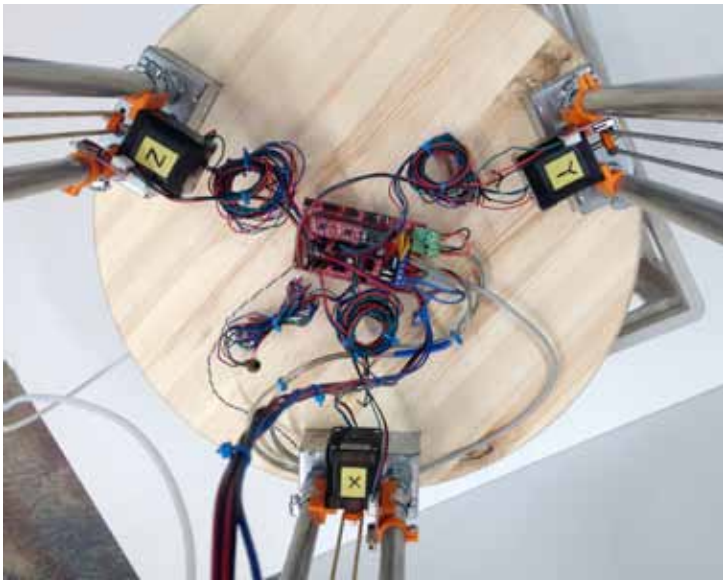
Section 2.7 Wiring: Instructions Pages



2.7.10
Use wire strippers to strip the ends of the motor wires. Then, crimp the small female crimp connectors onto each end.



2.7.11
Click the crimp connectors into the 4 pin female Dupont connector housing. The order of the wires should be coded RED-BLUE-GREEN-BLACK, or alternatively BLUE-RED-GREEN-BLACK. If your colors differ or you are unsure, please refer to the box for Stepper Hookup Tips at the bottom of the Master Wiring Schematic for the Ready RepRap.



2.7.12
Connecting everything to the board
The following is a check list of the different things to connect to the micro controller board. You should refer to the Master Wiring Schematic on the following page (2.7.13) for details about where each set of wires goes. Take your time and be meticulous with this step! Also, it is a good idea to label each of your motors with tape and a marker as shown in the picture. This will make life easier.

Section 2.7 Wiring: Instructions Pages

1. Connect the power wires to both the 11A and the 5A power terminals. This will require using a couple small additional lengths of wire to bridge between them. Be aware of the + / - polarity for the terminals.

2. Connect the wires for the heated print bed.

3. Connect the wires for the hotend fan

4. Connect the wires for the hotend's heater element.

5. Connect the hotend thermistor to the TO port.

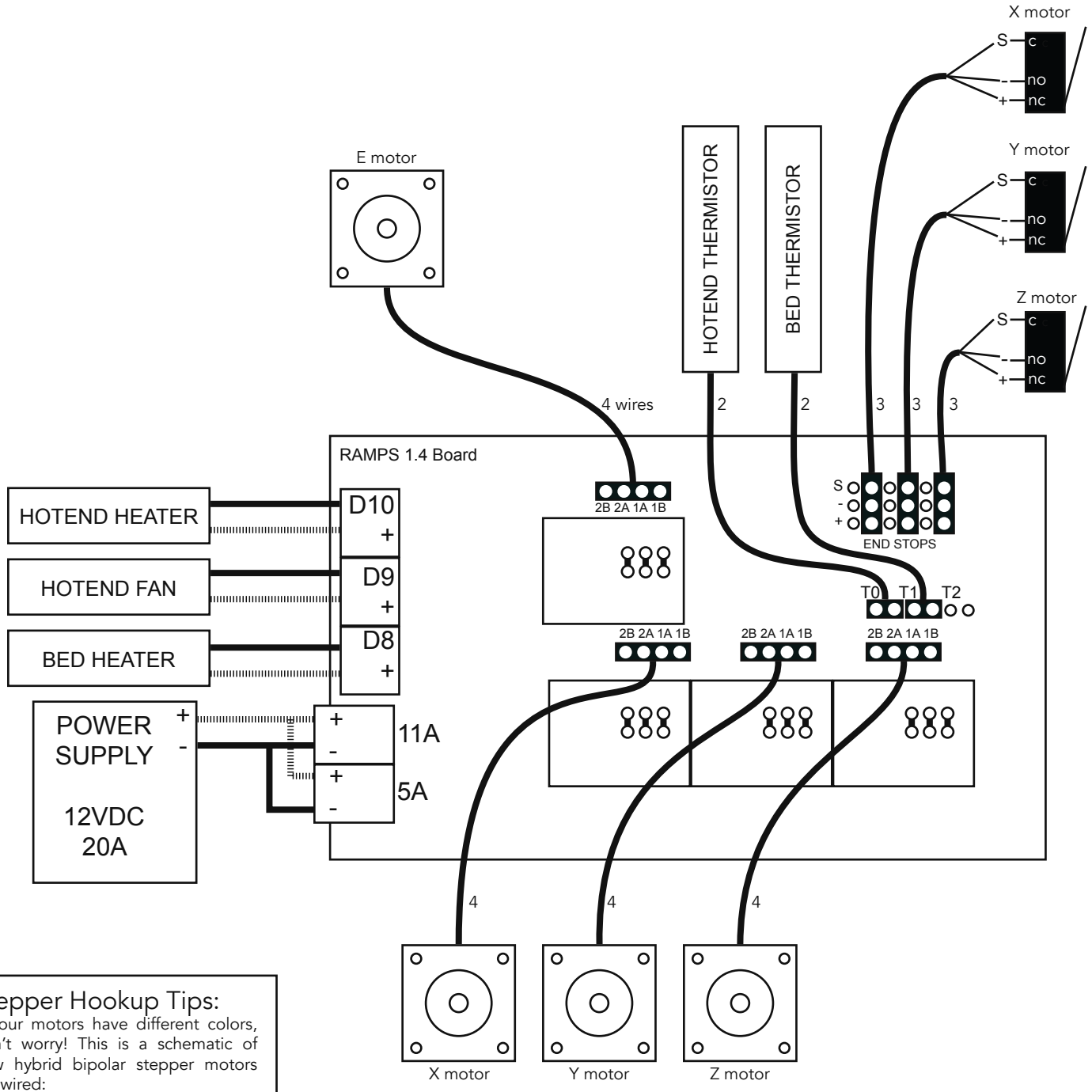
6. Connect the print bed's thermistor to the T1 port.

7. Connect the wires from the endstop switches to the xMAX, yMAX, and zMAX END STOPS ports as shown. Be sure to connect the end stops to the correct ports for their motors or it can cause very confusing problems later!

8. Connect the X motor, Y motor, Z motor, and Extrude motor to their proper driver ports as shown.

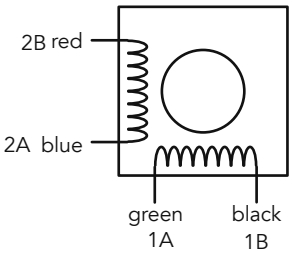
9. Plug the USB printer cable into the port at the terminal end of the Arduino microcontroller.

10. Finally, connect the wire pair left trailing from the Ready RepRap to the terminals of the 12v Power Supply. Be sure to connect it so that the +/- wires are correct. Please see the Master Wiring Schematic 2.7.13 and double check that you have not connected power backwards before connecting power!



Stepper Hookup Tips:

If your motors have different colors, don't worry! This is a schematic of how hybrid bipolar stepper motors are wired:



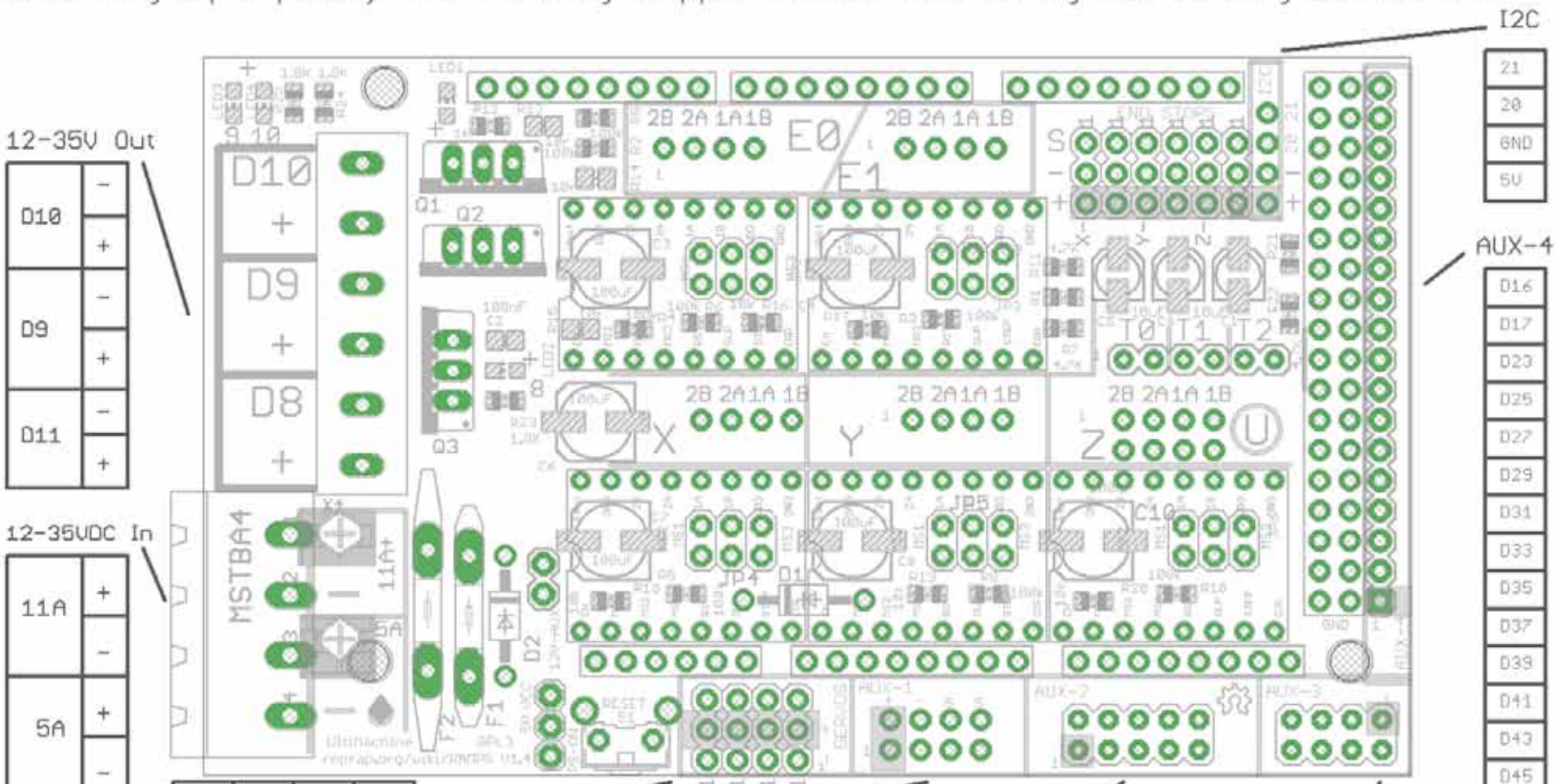
The motor has two separate coils, two wires for each. If you cross a pair of wires and feel the shaft get harder to turn, then you have found one of the coils. If you hook up the coils backwards, the motor simply goes in the opposite direction.

RAMPS 1.4 (RepRap Arduino MEGA Pololu Shield)

GPL v3

reprap.org/wiki/RAMPS1.4

Reversing input power, and inserting stepper drivers incorrectly will destroy electronics.



Document revision 2

Section 2.8 Getting The Software Running

2.8 Get the software running
RepRap 3D printers are built around open-source software. This is software that is written by experts and published online for free. There are many different options in terms of software to use.

It is typical to use a few different pieces of software for different stages in the process of creating, laying out, and printing a 3D object. The software programs that you choose to accomplish the various steps are often times referred to as your 'tool chain.' You can picture the programs as being connected to each other like links in a chain. The output of one becomes the input for the next, and so on.

We recommend three different software programs for use with the Ready RepRap:

1. Tinkercad as an introductory 3D modeling program
2. Slic3r as the program to prepare files to print
3. Printrun as the 'host' program to control the printer
4. Marlin as the 'firmware' that runs in the microcontroller

These four programs make up a working RepRap toolchain. If you have experience with other software used for RepRap printers, by all means use the programs that you like. The steps here, however, will focus on these four programs.

Note: The software and setup is a different world from the hardware portion. If you have team members who are more comfortable with computers and programming than with tools and wires, now is their chance to shine!

2.8.a
Tools
Laptop or desktop computer (Windows Macintosh or Linux)

2.8.b
Supplies
Ready RepRap 3D printer with power supply & USB cable

2.8.1
Download Arduino development environment
The microcontroller in the RepRap is an Arduino Mega 2560. This small computer can be easily programmed using the Arduino software, which you can download for free from the following website:
https://www.arduino.cc/en/Main/Software
The Arduino website is a wonderful resource to those just getting started with microcontrollers or for those looking for ways to improve their electronics and programming skills. There are many different tutorials and example projects that can be done with an Arduino board and some basic electronics components.
We will use the Arduino software to install the control program, or 'firmware' onto the Arduino Mega 2560 at the heart of your Ready RepRap. Once you have downloaded the Arduino Software, install it on your computer and launch it. The program opens with a blank 'sketch' as shown below:

2.8.2
Download the latest firmware
In order for your Ready RepRap to work as a 3D printer, its small computer needs to be programmed with the Ready RepRap firmware. Firmware is the general term given to software that is installed into a computer to give it some basic functions. In a 3D printer, the firmware contains all the information needed to let your printer connect to a laptop or desktop computer and translate the build instructions from that computer into mechanical action.
The Ready RepRap's firmware is based on Marlin, which is a flavor of firmware commonly used for open source 3D printing projects. In this case, the firmware has been pre-configured for you in a way that takes into account the print size and exact mechanical configurations of your Ready RepRap. You can download this pre-configured version of Marlin here: https://github.com/dhartkop/ReadyRepRap/ and it is located within the folder

for Firmware & Software.

2.8.3

Upload firmware onto Ready RepRap

Once you have downloaded the RepRapLibro firmware to your computer, it is a good idea to sort the files into a folder on your computer. The easiest may be to simply put the entire downloaded folder into your 'Documents' directory so that you know where it is.

Start the Arduino software. Choose File/Open and browse into the RepRapLibro folder until you find the file Marlin.ino in the directory. Choose this and click Open. This will open the entire Ready RepRap Marlin firmware within the Arduino program:

Now, from the menu at the top, choose Tools/ Board and choose "Arduino Mega2560 or Mega ADK" from the list. This lets the Arduino software know which kind of Arduino microcontroller board you will be programming.

Connect the Ready RepRap's controller to your computer via the USB port. You should make sure that the cable is connected to both your computer and to the USB port on the Arduino board. You should see a 'powering on' light blink a couple times. Your computer may also audibly signal that a USB device has been connected.

Upload the firmware to the Ready RepRap's controller by clicking the Upload button at the top of the Arduino software window, circled here:

This process may take a minute or so, as all of the Marlin firmware is being compiled and written onto the controller.

2.8.4

Download a 'host' program

In it's present form, the Ready RepRap requires a laptop or desktop computer to control it. The program that runs on this computer that is used to start prints is called the Host program. Printrun, AKA Pronterface is very easy to use free host program that runs across many different platforms. It was created to operate various different open source 3D printing projects, and provides a lot of useful features. You can download Printrun here:

https://github.com/kliment/Printrun

Important: Instead of clicking on Download Zip, scroll down the page to find the links to download the pre-compiled versions. For instance, you can download a version for Windows or a version for Macintosh or for Linux.

2.8.5

Setup the host program's settings & custom buttons

Once Printrun is downloaded, start it up. The main window of Printrun looks like this when it starts:

Now we are going to setup Printrun so that it works to control the Ready RepRap. There are some settings that you will need to go into and change.

First, click on the menu at the top labeled "Settings" and choose "Options." Now carefully change the settings in the fields so that they match the settings in the following diagram:

Now that the main settings are customized, it's time to add some custom control buttons to the interface. These buttons will make it easy to do things like leveling the build plate, which we will do in the next main step.

The five custom buttons that we will create are as follows:

FanOn
CenterOnPlatform
LevelingA
LevelingB
LevelingC

Each of these custom buttons has a small snippet of custom code that you will paste into a window and then save. The snippets of code for each button are included in the downloaded RepRapLibro-master folder from earlier. For your reference, the following table also shows the code for each custom button:

Code for Custom Buttons in Printrun

CUSTOM BUTTONS G-CODE:

FanOn
M106;

FanOff
M107;

Center on Platform
g28;
g90;
g0 Z-272;

LevelingA
G0 x70 y30;

LevelingB
G0 x-60 y30;

LevelingC
G0 x0 y-80;

Middle
G0 x0 y0;

To add a custom button to the Printrun interface, click on the small button circled in the following diagram:
This opens up the custom button dialog box. Click on the "..." button. This will open up the new macro window. Enter the name of each button you create in this window. The following is an example of naming the CenterOnPlatform button:
Once the Macro name has been entered, press "Ok" and a macro window should open up. Paste in the snippet of code for that button. For instance, the CenterOnPlatform code would be pasted in as follows:
Once the code is pasted into the window, click on "Save" and the button should appear at the bottom of the Printrun interface.

The figure below shows the active Printrun interface, with some key features pointed out. This program is way easier to use than it looks. That strange bulls eye with arrows is just a fancy set of control buttons for moving the printer head up, down, forward, backward, left and right. You can also manually turn the extruder head's heater on and off, and run the extruder forward or backward. The yellow window at the right will show you the profile of whichever part you are currently printing. Your custom buttons appear across the bottom of this yellow preview window.

2.8.6
Level the Build Platform
In order for plastic to stick to the build plate during the build process, the build plate must be level and set to the right height with respect to the print head. The following steps will guide you through the leveling process:

a. Connect to The Printer
Connect the Ready RepRap's microcontroller to your computer with a USB cable. The most common type of cable used for ordinary printers will work just fine. This is commonly referred to as a USB A to B cable.
Also, make sure the Libro is connected to a 12 volt DC power supply. Be sure to connect the power supply to the Arduino according to the correct polarity, as shown in the Master Wiring Schematic on page 51.
Open Printrun on your computer and press Connect at the top. If all goes well, the controls will become active and the button will change to say Disconnect. If there is a problem connecting, you may wish to click on Port at the top and try choosing a different port. Also, the baud rate (the next box over at the top) should be set to 250000. Please refer to the figure on pg. 64 for details of the Printrun interface.

b. Fan On
Press the custom button FanOn. Check to see that the small fan on the extruder head has started running. It is a good habit to just always switch on the fan when you are operating the manual controls. This keeps you from accidentally melting your center hub if you turn on the heater manually.

c. Home All Axes
Press the Home All Axes button on the manual control panel. This is the small button in the lower left of the circular pad shaped like a small

log cabin home. The three shuttles of the Ready RepRap should each zip upward to the top of each leg in turn, and stop. If the motors do not stop but keep running and clicking, check to see that the endstop switches are being pressed and are wired correctly.

d. Screw Down Leveling Clips
Use a screwdriver to screw down each of the three leveling clips. Tightening each screw will close the spring loop in each clip and will move the glass plate to its lowest setting.

e. Center On Platform
Press the CenterOnPlatform custom button. This should send the print head all the way down to a place very near the surface of the build platform. It should stop several millimeters above the surface of the platform.

f. Leveling A
Press the LevelingA button. The print head will travel toward one of the three screws. Mark this screw as A with a sharpie. Use the screwdriver to loosen the screw. This will cause the bed to rise on this side. Adjust the screw so the platform just barely lets a sheet of paper slide between the platform and the tip of the extruder.

g. Leveling B
Press the LevelingB button. Mark this screw as in the previous step, and adjust the same way.

h. Leveling C
Carry out the same steps described for Leveling A and Leveling B.

i. Re-Center on The Platform
Press Center On Platform again. Once the machine has stopped moving, check to see if you can pass a sheet of paper under the print head. If so, then your printer is properly leveled. If not, then repeat the steps f, g, & h previous to this step.

3.1
Making your first print
You've come a long way!
You've gathered and ordered tons of parts.
You've 3D printed a bunch of stuff.
You've assembled everything into a working robot.
You've downloaded and configured open source software.
You're ready to make your first test print!
At this stage you may be feeling impatient and ready to jump ahead into full-time printing for your makerspace. The printer you have constructed will work well, but it will take a little time to get everything fine-tuned and running. As with all of the previous steps, patience is key to making it happen.
If you are having some outright problems just getting the machine to connect to a computer or to move, please look ahead to section 3.2 Troubleshooting. It will work, it just takes a little problem solving. Don't give up!
The best way to shake-out the problems is to just go ahead and try to make a print.

3.1.a
Tools
Laptop or desktop computer (Windows Macintosh or Linux)
Phillips screwdriver (large)
Plastic regular screwdriver (small)

3.1.b
Supplies
Ready RepRap 3D printer with power supply & USB cable
Spool of 3D printing filament (ABS for heated bed, PLA for unheated bed)

3.1.1
Download a test object to print
There are lots of places to get 3D object files for printing. One website that hosts thousands of free objects is thingiverse.com. All of the object files for creating the Ready RepRap are actually published for free on Thingiverse.
For your first print, I recommend choosing a relatively simple part to print. The following is a download link for one of the build plate leveling clips for the Ready RepRap:
http://www.thingiverse.com/download:1974745
You can browse for other objects on Thingiverse if you wish, but at this stage, simple is best. The link will let you download the object file in the .stl format. This is the best format to use for the next

step.

3.1.2

Slice the object into G-code

A 3D printer constructs objects by drawing them layer-by-layer with hot plastic. In order to know how to physically draw an object in this way, the 3D object file must be converted into layer-by-layer computer instructions. The process of converting a file into layer based instructions is called 'slicing' and is done with a special computer program. For the Ready RepRap, we recommend using the open source slicing software Slic3r.

Begin by downloading and installing Slic3r. Go to the following address and download the latest version:

http://slic3r.org/download

When you start the program, it should launch on your computer with its default settings. The program should look like this:

From the drop down menus at the top of Slic3r, go to Slic3r / Preferences... and set it to Expert Mode.

This will reveal the configuration presets, which are probably set to Default just as shown:

Next we will load up the Ready RepRap presets for Slic3r. These presets inform Slicer about the specific hardware setup of the Ready RepRap, including things like the print bed size, the print resolution, speed of the motors, etc.

There is a .config file in the RepRapLibro-master folder that you downloaded earlier. If you didn't download it earlier, or if you lost it, you can download it again from this address:

https://github.com/dhartkop/ReadyRepRap/

In Slic3r, from the drop-down menus at the top, choose File / LoadConfig... and browse to the config file you loaded.

Now that your Slic3r program is configured with the latest ReadyRepRap_config.ini files, it's time to load an object to print! Do this by clicking the Add button at the top of the Slic3r window.

Browse to the .stl file that you downloaded earlier in step 1. The object will be loaded into Slic3r's preview window as shown:

Double check to make sure your Print settings, Filament, and Printer settings are all set to the configuration file that you loaded. With the configurations loaded, all you need to do is press the Export G-code... button. This will let you save the G-code file to your computer. Save it somewhere that you can find later. Perhaps save it into the RepRapLibro-master folder.

3.1.3

Load the object into Printrun

Open your install of Printrun aka Pronterface. Open the .gcode file that you created with Slic3r. You will see an overhead view of the object appear on the print layout grid. Printrun is ready to send this object to your 3d printer. Now it's time to get the printer ready to go.

3.1.4

Load PLA filament into the printer

Connect power to your Ready RepRap. The 'Libro requires 12 volts direct current. Be sure to hook it up according to the correct polarity. You should use a 50W or bigger laptop power supply or filtered DC power supply. See the electrical diagram on page 54 for details about the polarity if you are not sure.

Make sure the Ready RepRap is connected to the computer's USB port and click 'Connect.' You may need to click on the "Port" button at the top to select a different serial port if Printrun has difficulty connecting the first time. The printer is connected when the 'connect' button changes to say 'disconnect.' Also, the manual controls will become active.

Press the FanOn button in the row of your custom buttons. Check to make sure the small fan on the hot-end is running. IMPORTANT: This keeps the heater from overheating and melting the center hub of your printer!

In the manual controls next to the word Heat set the extruder temperature to 225 and press Set. This is technically very hot for PLA but our experiments have shown that the loading process works best at a higher temp. (The G-code you loaded for the object will automatically set the temperature during the actual print.)

It is time to load some filament through the extruder. Begin by setting number for Length to 100 mm and setting Speed to 500 mm/min. Now, click the Extrude button. The central gear

in the LibroStruder should begin turning, rotating the peripheral gears around it. Feed the end of the filament spool into the input hole in the LibroStruder's I/O module. The picture on the next page shows a closeup of where the filament should be inserted.
You may need to press the Extrude button another time in order to advance the filament all the way through so that it is beginning to feed down the clear plastic tube.
Wait until the filament comes to a stop before pressing the Extrude button again. Keep doing it until the filament enters the extrude head and begins to flow from the heated nozzle.
Once the extruder stops, the filament is loaded and ready to go!
Reset the printer to its start position by pressing the home axis button.

3.1.5
Press print & pay attention
A quick checklist:
The printer is powered up
Printrun is running and connected
You have an object loaded into Printrun.
Filament is loaded into the printer
Each leg jumps in turn when you press the home button.
Go ahead and press Print and see what happens! The printer should leap into action by first re-zeroing each axis. It will then seem to do nothing while it heats up the extruder. Nearing full temperature, the fan should automatically switch on. Finally, once temperature is reached, the printer will move the print head down and begin the print.
Getting the first layer of any print to stick properly seems to be the biggest challenge in the entire process. The most common cause for trouble is that the build plate is not quite at the right height. Use a screwdriver to make slight adjustments to the 3 screws while it is starting the print. You may make 1/4 of a turn and find that fixed it!
If your printer works on the first try, you are extremely lucky! If you are like me, it will take some trouble shooting and problem solving to have it totally up and running. The next section is for you problem-solvers.

3.2
Troubleshooting
It is not easy to get a self-built 3D printer running on your first try! Don't worry, the problem solving is part of the process. To help, I've compiled a list of over twenty 'symptoms' you may encounter on your way to getting everything to run properly.

List of troubleshooting issues:
1. HELP! I am panicking! This is impossible! I'll never get this thing to work! (It'll work... I've seen it done.)
2. Slic3R: Why can't I see which configurations are currently loaded?
3. Printrun custom buttons: is the code supposed to go all on one line or what??!
4. I cant' get Printrun to connect to the printer
5. um... I smell burning...!?! (Turn on the fan! Type m106 into the Printrun G-Code command terminal and press Send!)
6. Printer is connected but motors don't move when I press home
7. When I load an object in Printrun, it isn't centered in the circle
8. Printer is connected but manual controls don't work, shuttles just go up slowly
9. The extruder manual control stopped working
10. The extruder is being weird, running backwards when it shouldn't
11. Plastic doesn't flow fast enough through the extruder to do much
12. The filament snaps or doubles up around the gear of the LibroStruder
13. The extruder doesn't stay level when I move it the X & Y directions.
14. When I press the LevelingA, B, or C, the extruder does not go down to the build plate.
15. The first layer of filament doesn't stick to the build plate
16. The extruder tip keeps dragging through the filament that it just put down
17. The print keeps coming out reversed like a mirror image
18. The movement of the shuttles on the rail seems rough
19. The ball chain keeps making popping sounds and rolling unevenly on its pulleys
20. A motor makes sound but is not moving the shuttle up or down
21. Prints run for awhile but keep pausing or

stopping mid-print
22. It prints but doesn't look that great... how do I do fine-tuning?

1. HELP! I am panicking! This is impossible! I'll never get this thing to work!
Take a break! Don't throw it out the window just yet... Building a working RepRap 3D printer is not easy. Not even for seasoned builders and engineers. You are not alone! There are many online resources, including those at RepRap.org and various help threads on the topics of everything related to making 3D printers. The main thing is to not give up. This kind of project generally takes longer than you might think, but you will learn lots of things through the process. Don't panic! Seek help! Enlist others with different skill sets when your knowledge and skills come up short.

2. Slic3R: Why can't I see which configurations are currently loaded?
You need to set Slic3r to 'Expert Mode' in order to see which configurations are loaded.

3. Printrun custom buttons: is the code supposed to go all on one line or what??
The custom G-code can be entered into a blank window that has room for several lines of code. This window only pops up after you click on the ... button to create a button and then click on the ... button to name the macro. Once you press Save, the blank window will open, but it may actually open behind some of the other windows. It's kind of strange.

4. I cant' get Printrun to connect to the printer.
First check to see if the USB cable is connected to your computer and to the printer. Then check to make sure that Printrun's baud rate is set to 250,000.

The third thing to check is the setting for Port, which can be chosen from the drop down in the upper left. You may need to choose a different port and try again. Sometimes you simply need to unplug the USB cable from the computer, plug it back in, and try again.

5. um... I smell burning...!?!
Turn on the fan! Type m106 into the Printrun G-Code command terminal and press enter! The manual controls let you activate the heater without necessarily activating the cooling fan. This can lead to overheating the hot-end and melting the plastic center piece. When in doubt, DON'T TOUCH the hot-end because it could be extremely hot!

6. Printer is connected but none of the motors move when I press home.
Check to make sure the power is connected to the printer. And switched on. Make sure the USB cable is still connecting the printer to the computer. Try pressing Disconnect and then Connect again and try pressing home again. You may need to disconnect the USB cable and reconnect it, and then press Disconnect / Connect.
If none of these things works, check to see that the LEDs on the printer's motherboard are lighted and blink when you send commands. If there are no LEDs blinking, then there is a problem with the motherboard. The motherboard is usually powered by the USB connection to the computer. If the LEDs are lighted and blink when you send commands, the problem is with the 12 volt power system. Maybe your power supply is improperly connected. You may also want to check the actual connections of the motors to the motherboard. If just one motor will not run, it may be that motor's connection or the small stepper driver chip that are bad. Refer to the master wiring diagram in section 2.7.

7. When I load an object in Printrun, it isn't centered in the circle.
This sounds like you may have tried to load a .stl file directly into Printrun instead of using Slic3r first. Slic3r contains configuration presets that will line the objects up correctly. You should only open .gcode type files into Printrun. Be sure, however, that you do have the Ready RepRap presets loaded into Slic3r before you slice a .stl file into a .gcode file.

8. Printer is connected but manual controls don't work, shuttles just go up slowly.
The printer lost its reference point and is 'looking' for it. If you press Disconnect / Connect and then

press home, it will zero the X, Y, and Z axis and manual control will be returned to you.

9. The extruder manual control stopped working.
The software will only let you control the extruder motor when the print head is up to temperature. If the heater is switched off, it will cool off and once it drops below a certain temperature, the controls for the extrude motor will be locked out. Turn on the heater again, and be sure to also turn on the fan.

10. The extruder is being weird, running backwards when it shouldn't.
This weird extruder-reversing can happen if there is trouble with the heater staying up to temperature, or with the wires to the temperature sensor. First check your connections. A thermistor sensor with intermittent connection will cause all sorts of weird control problems!

11. Plastic doesn't flow fast enough through the extruder to print.
Try turning up the temperature of the hot-end. You may have a miscalibrated thermistor and might need to simply turn the temp up hotter than is realistic, just to get the clay to flow. If you are using PLA, just don't turn it up much past 230 or so because that can end up being way too hot.

12. The filament has snapped or has doubled up around the gear of the LibroStruder.
The LibroStruder will not slip, but if it is asked to push against a total jam under full power, the filament may actually snap up near the top. If it keeps running after that happens, it may drag the filament around for a second lap of the gear. Here's what to do:
First, stop the whole process by pressing Disconnect / Connect in Printrun.
Turn the fan back on from the custom buttons.
Turn the extruder heater back on.
Run the extruder in reverse until the filament leading to the spool is free of the LibroStruder.
Use needle nose pliers to reach into the LibroStruder to grab the snapped end that leads all the way down to the hot-end. Just pull this out (it is about 2 feet of filament down to the hot-end). If you can't get a hold of the broken end, untwist the steel wire holding the tube fitting into the LibroStruder's I/Omodule. You can then unscrew it by hand and pull it free, letting you access the broken end of filament.
Go through the ordinary process of re-loading filament through the LibroStruder into the hot-end. Refer to section 3.1.4 on pages 69-70 for instructions on how to do this.

13. When the extruder is down on the build surface, the tip seems to lift up or dive downward when it moves away from the center position.
The extruder tip should move in a flat X, Y plane and not on an imaginary bowl or dome shaped surface. This is a calibration problem. We worked out most of the important offsets when we set up the presets for the Ready RepRap, but there are a few things that can throw it off.
Check the following, using a tape measure and square:

Make sure all of the linear motion legs are the same exact length.

Make sure the linear motion legs are perfectly vertical.

Make sure the machine does not have an over-all twist or lean to it.

You should also check to see that the offset-screws at the tops of each linear motion carriage are in the fully-in position, and that they are all properly contacting the endstop switches when the carriage retracts to the top. See section 2.6 on page 57 for details about where to find the offset screws and the endstop switches.
See also page 79 for the set of calibration settings we used when setting up the Marlin firmware. Your build may be a little different, and so you'd need to adjust these for the specific measurements of your machine.

14. When I press the LevelingA, LevelingB, or LevelingC, the extruder does not go down to the build plate.
You have to first press the CenterOnPlatform button. That takes the extruder tip all the way down to the center of the platform. Then you can use the LevelingA, LevelingB and LevelingC buttons.

15. The first layer of filament doesn't stick to the build plate.
Is the nozzle extruding a solid stream of plastic or is it a thin little hair? If it is extremely thin or not present, you may have a clogged extruder or (more likely) the temperature is set too low for it to flow properly. The temperature for printing needs to be adjusted in Slic3r and not in the Printrun menu. When a print is happening, the G-code entirely takes over all of the settings of the machine, including the temperature. See section 3.4 starting on page 78 for clues about how to tweak the Slic3r print settings.
If it still doesn't stick, the distance between the nozzle and the build plate may be too great or too small. You may be able to begin the print and then adjust the build plate's leveling on the fly with a screwdriver. Turning the screws in the leveling clips as little as 1/4 turn may make all the difference at the very start of a print! This leveling needs to be just right for it to work.

16. The extruder tip keeps dragging through the filament that it just put down.
This sounds like classic over-extrusion. You may need to adjust the 'extrusion multiplier' down slightly in the Slic3r settings. Adjusting the settings in Printrun will have no effect on the print extrusion rate, as those are directed by the G-code. See section 3.4 starting on page 78 for clues about how to tweak the Slic3r print settings.

17. The print keeps coming out reversed like a mirror image.
Two of your leg motors are swapped where they plug into the motherboard. Refer to section 2.6 on page 53 to see the position of the motors with respect to the schematic, in section 2.6 on page 51. Remember, if you swap the motor positions on the motherboard, you need to also swap the wires for the endstop switches for those legs too!

18. The movement of the shuttles on the rail seems rough.
You may need to add more machine grease to the pipes. If the pipes were not well sanded, or if you did not sufficiently 'wear in' the linear bearings by moving them up and down 100 times by hand, they will not feel very smooth.

19. The ball chain keeps making popping sounds and rolling unevenly on its pulleys.
Check to see that all of the pulleys are intact. Occasionally, a 3D printed pulley will shear into two pancakes along its middle layer. You might not spot this unless you are looking for it. It will cause the chain to run rough or to skip.
If all of the pulleys are intact, you might need to increase the spring tension on the chain. Additionally, the pulleys and the chain should be covered in machine grease. Use a glove and just put it on by hand.
If the chain continues to pop or skip and just doesn't fit into the groove of the pulleys, you may have a chain of an incompatible size. See the specs for the ball chain in section 2.3 on page 23 for details. You can either find a chain that fits, or re-design the pulleys to fit your chain.

20. A motor makes sound but is not moving the shuttle up or down.
Check to see that all of the pulleys are intact. Occasionally, a 3D printed pulley will shear into two pancakes along the middle layer. You might not spot this unless you are looking for it. It may let the motor turn without actually moving the chain.
Check the wiring for each of the motors. If one of the four wires is disconnected, the motor will make sound but will not rotate its shaft.
The torque setting pot on the stepper motor's driver may be set too low. This would prevent the motor from turning. Use a flashlight to check the position of the tiny torque setting pot on the stepper driver for each motor. All of the pots should be set as shown in section 2.6 on page 54. DO NOT adjust while power is connected! This can burn it out. $12...poof! Gone!
If all of the motors make sound without moving, you probably have a power supply problem. Be sure you have a 12 volt DC power supply that can provide up to 6 amps of current.

21. Prints run for awhile but the printer keeps pausing or stopping mid-print.
This often has more to do with the computer than with the printer. It can be caused by your computer going to sleep or switching into screen-saver mode. Running Printrun in the background while doing something else with your computer can also cause pauses in printing. Go into your

computer's screensaver or power saver settings and disable them before you make a print.

22. It prints but doesn't look that great... How do I do fine-tuning?
A very good question! There are several parameters that can be adjusted that will affect the quality of the print. There are also some excellent online resources for helping you to determine how best to adjust an FDM (plastic filament based) 3D printer.
Section 3.3 lists several useful online resources.
Section 3.4 contains some more technical tips and a guide to the most useful variables in the Ready RepRap toolchain to adjust.

3.3
Online Resources

DOWNLOADS FOR MAKING READY REPRAP:

GitHub
https:// .com/dhartkop/ReadyRepRap

Tinkercad
https://www.tinkercad.com/things/8LGnUjhzrhr-170116allparts/editv2

Thingiverse
http://www.thingiverse.com/thing:2042095

OTHER GENERAL ONLINE RESOURCES:

RepRap Community Portal:
http://reprap.org/wiki/Community_portal

The RepRap 3D printing community wiki:
Reprap.org

RepRap Forums:
http://forums.reprap.org/

Free ready-to-print objects online:
Makerbot Thingiverse: http://www.thingiverse.com
Grabcad:http:// www.grabcad.com
Cubify: http://www.cubify.com/

Free 3D modeling programs to create your own objects:
Tinkercad: http://www.tinkercad.com
3DTin: http://www.3dtin.com/
Autodesk 123D Design: http://www.123dapp.com/design
Blender: http://www.blender.org/download/
FreeCAD: http://www.freecadweb.org/
OpenSCAD: http://www.openscad.org/

Some different 3D printing services:
Shapeways: http://www.shapeways.com
Quickparts: http://www.3dsystems.com/quickparts
More visit:
http://www.3ders.org/3d-printing/3d-print-services.html

Visual guides to solving common print problems:
https://www.simplify3d.com/support/print-quality-troubleshooting/
http://reprap.org/wiki/Print_Troubleshooting_Pictorial_Guide
https://all3dp.com/common-3d-printing-problems-and-their-solutions/
https://www.youtube.com/watch?v=XbX5Ilmc8m0

Awesome delta printer simulation tool
http://www.thinkyhead.com/_delta/

3.4
Notes for hacking your Ready RepRap

Hack It
Part of the fun of using an open-source software platform is the ability to hack the settings. They are all available for you to edit. The two programs that provide the most ability to adjust are Slic3r and the Marlin firmware. We have compiled a list of the most relevant settings in each of these. The settings that we spent the most time messing with are highlighted in yellow. Enjoy!

3.4.1
Slic3r Settings
Print Settings tab:
Layers and perimeters options:
Layer height: 0.2mm
First layer height: 0.25mm
Speed options:
Perimeters: 30 mm/sSmall perimeters: 15
External perimeters: 15
Infill: 20
Solid infill: 10
Top solid infill: 15
Support material: 30
Bridges: 30
Gap fill: 20
Travel: 100
First layer speed: 10
Max print speed: 50
Advanced option:
Infill/Perimeters overlap: 15%
bridge flow ratio: 1
Filament Settings tab:
Filament options:
Diameter: 1.75
Extrusion Multiplier: 1.20
Cooling options:
Keep fan always on: YES (checked)
Enable auto cooling: YES (checked)
Printer Settings tab:
Custom G-code options:
Start G-Code:
G28 ; home all axes
End G-code:
M104 S0 ; turn off temperature
G28 X0 ; home X axis
M84 ; disable motors
Extruder 1 options:
Nozzle diameter: 0.25mm
Retraction length: 2mm
Lift Z: 0mm
Speed: 40 mm/s
Extra length on restart: 0mm
Minimum travel after retraction: 2mm

3.4.2
Marlin firmware settings

(Found in Arduino library Configuration.h)

Delta Settings for Ready RepRap
L325 #define DELTA_SEGMENTS_PER_SECOND 200
L331 #define DELTA_DIAGONAL_ROD 322.0
L335 #define DELTA_SMOOTH_ROD_OFFSET 181.5
L339 #define DELTA_EFFECTOR_OFFSET 29.5
L343 #define DELTA_CARRIAGE_OFFSET 33.0
L346 #define DELTA_RADIUS (DELTA_SMOOTH_ROD_OFFSET-DELTA_EFFECTOR_OFFSET-DELTA_CARRIAGE_OFFSET)
L349 #define DELTA_PRINTABLE_RADIUS 140
L701 #define MANUAL_Z_HOME_POS 272 // For delta: Distance between nozzle and print surface after homing.
Movement Settings
L719 #define DEFAULT_AXIS_STEPS_PER_UNIT {73.157, 73.157, 73.157, 503.45}
L720 #define DEFAULT_MAX_FEEDRATE {250, 250, 250, 25} // (mm/sec)

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A vast amount of technical knowledge was gleaned from the pages of the RepRap.org wiki, including pages detailing the open-source delta 3D Printer, the Mendel Rostock: http://reprap.org/wiki/Mendel_Rostock.

About the Author
David Hartkop holds a BA in communication arts from Loyola Marymount University, and has a background in digital special effects. When not teaching classes in 3D printing and computer basics, he is developing side projects such the Mini Metal Maker 3D metal clay printer. You may also find him running somewhere along the Rogue River trail. He lives in Medford Oregon with his wife and son.