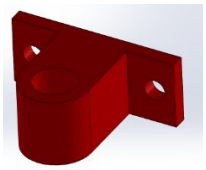
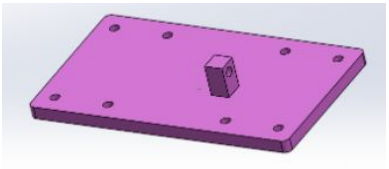
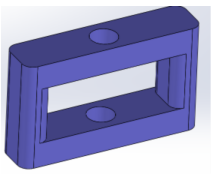
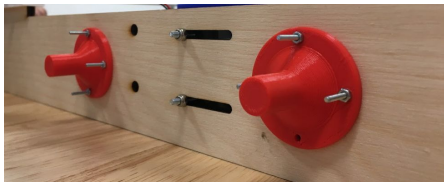
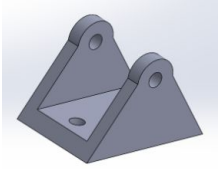
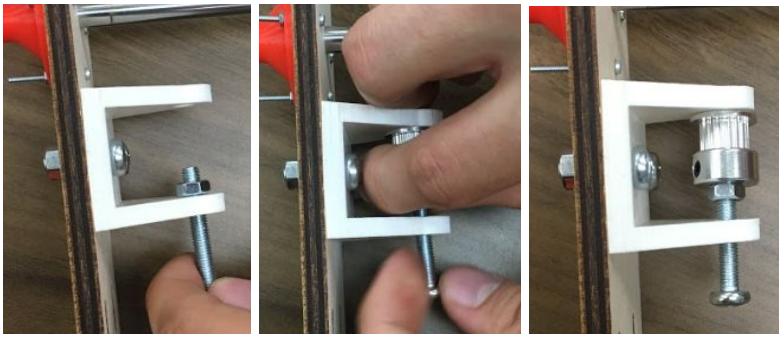
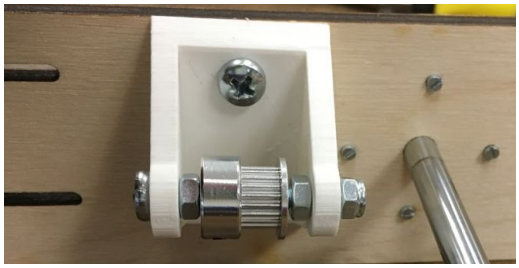
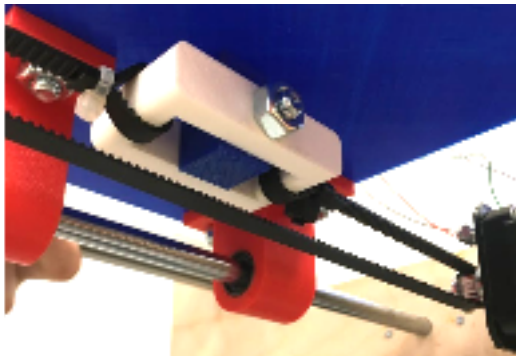
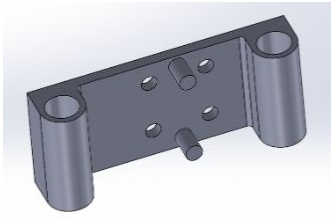
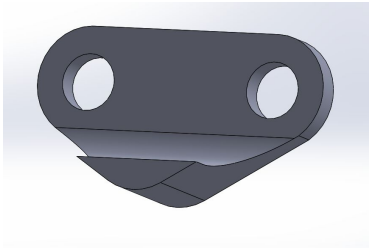
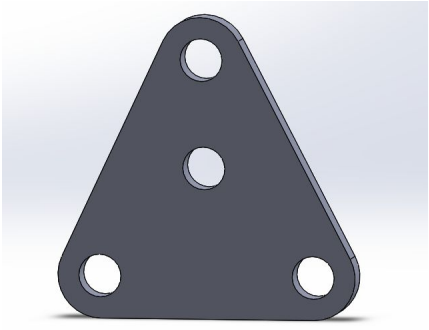
Assembly Instructions

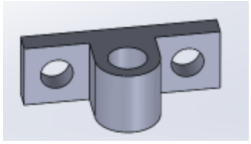
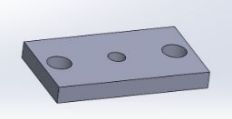
MATERIALS		
Category	**Qty**	**Item**
Body	4	1 ft long T-slot Framing
	18	T-slot Framing Fastener
	2	T-slot Drop-In Fastener
	20	1/4"-20 3/4" Length Bolts
	20	1/4"-20 Nuts
	12	M3 - 15mm length Machine Screws
	2	M5 - 40mm length Hex Bolt
	8	M2 - 25mm length bolt
	8	M2 - nut
	2	Laser cut wood pieces
	4	Metal Rods: 2x 360mm, 2 x 406mm
	8	Linear Bearing
	1	GT2 Timing Belt (about 1 meter long)
	4	Pulleys - 5mm inner diameter, 8mm outer diameter
	6	Magnets
	4	Zip ties (plus extras incase belt is not properly tensioned the first time)
	2	Acrylic Sheet, 1 sq. ft
Electronics	1	Ramps 1.4
	1	Arduino Mega
	2	Stripped Hookup Wires
	1	Three-Pronged Power Cord (pre-stripped)
	1	12 V Power Supply
	1	Stepper Motor Kit + Arduino (includes parts below)
	1	*Longruner UNO R3 Board *not used*
	1	1.5m USB cable for R3 Board
	3	Nema 17 stepper motor 1.7 A (with bracket and screw)
	3	Nema 17 Stepper Motor Mounting Bracket
	3	Mechanical Switch Endstop
	3	3Pin 70cm Cable
	4	DRV8825 Stepper Motor Driver

	4	Aluminum heatsink w/ 3M tape backing
	12	M3 Screws for bracket of stepper motor
Extrusion Mechanism	1	Fully Threaded Rod: 200mm
	1	Metal Rod: 200mm
	2	Linear Bearing
	1	Coupler - 5mm to 8mm
	1	Hex Nut - 8mm
	1	Syringe, plastic, 60 mL
Software	1	Arduino IDE Software
	1	Marlin 1.1 Firmware
	1	Pronterface Software
3D Printed Parts	1	Extruder Box
	1	Syringe Presser
	1	Wedge Lock
	1	Print bed
	4	Bearing Holder
	1	Belt Anchor
	1	Extruder Mount
	1	Extruder Pulley Mount
	4	Guide Rail Cap (two red, two white)
	4	Rod Endcaps
	1	Motor Bracket
	1	Belt Guide
	2	Triangular T-slot Base Bracket
	2	Rectangular T-slot Base Bracket

	ASSEMBLY INSTRUCTIONS
1	**Assemble the base**
a.	Attach the four Bearing Holders to the base of the Print Bed using 8 bolts.   *Bearing holder* *Print bed*
b.	Attach the Belt Anchor to the protruding piece on the print bed part using a bolt.  *Belt anchor*
c.	Insert a bearing into each of the Bearing Holders (4 total), then slide the two 360 mm rods through the bearings.
d.	Stand the two Wooden Endplates upright and insert the rods (with the print bed attached) into the 8mm diameter holes in the wood. Attach the Guide Rail Caps to the outside of the wood and fasten to the wood using four screws each.  *Guide Rail Caps*
e.	Align two T-slots (horizontally and parallel with the rods) with the outer holes on the endplate and use bolts on each end to fasten them to the wood.
2.	**Setup the print-bed belt and motor system**
a.	Fasten the Bearing Mount to the inside of either one of the wood pieces using bolts.  *Bearing Mount*

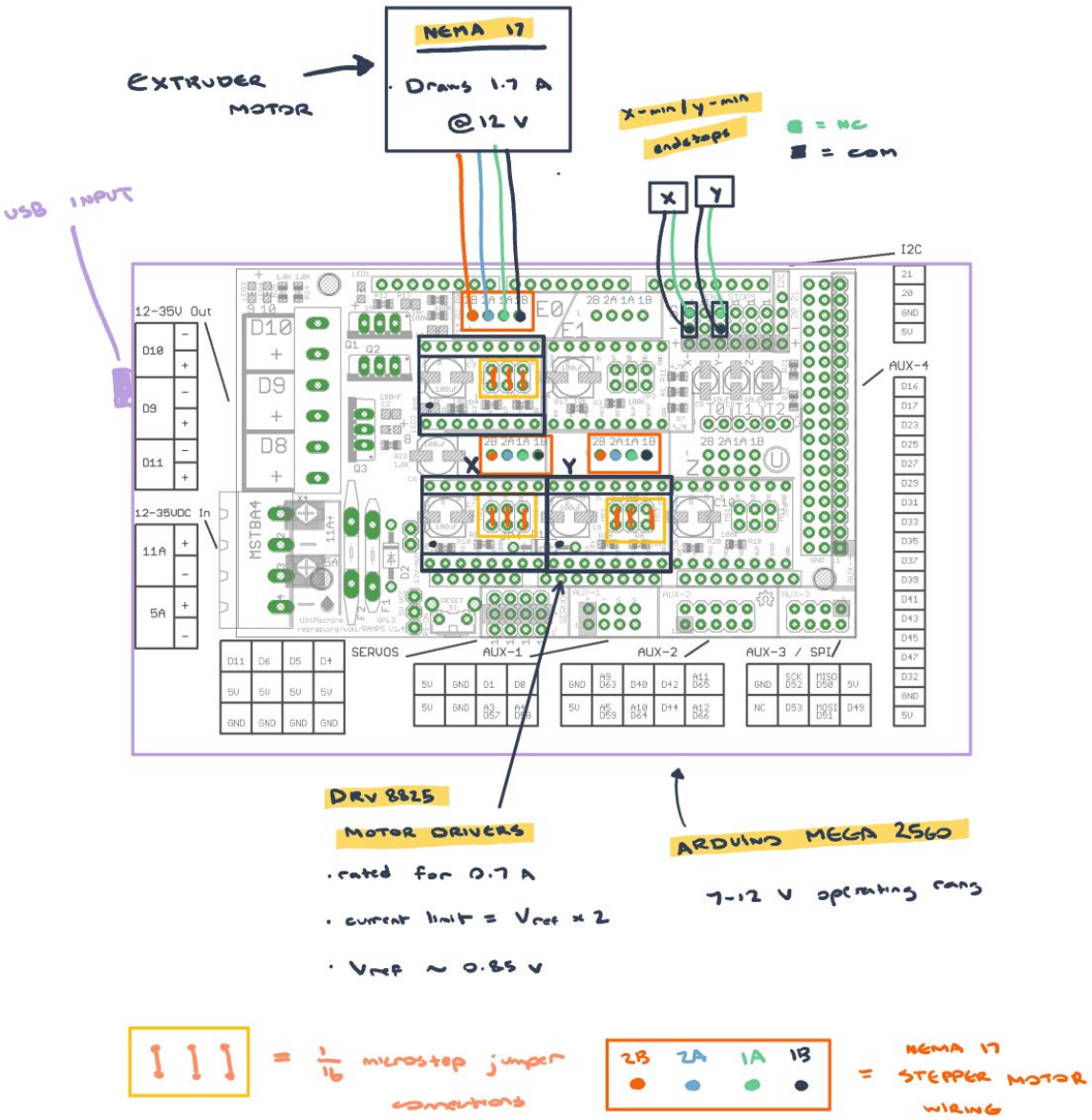
b.	Insert a bolt partially into one of the ends of the Bearing Mount. Twist on the hex nut, then sandwich the pulley between the bolt end and the opposite hole so that they align. Continue to twist the bolt until it protrudes past the pulley, then twist on another hex nut in between the pulley and the inside of the bearing mount. Finally, twist the bolt until it protrudes on the other side of the bearing mount, then fasten with another hex nut.   *Final Bearing Mount Setup*
c.	Fasten the metal motor bracket and motor to the inside of the wood piece opposite from the bearing mount. Fasten a pulley to the shaft using the appropriate allen wrench.
d.	Cut the belt to about 2 ¼ feet. Use a zip tie to attach one end to the belt anchor. Hook the belt around the pulley attached to the bearing mount, then pull it through and hook it around the pulley on the motor. Attach the remaining end to the other end of the belt anchor. 
3.	**Assemble the extrusion mechanism**
a.	Insert two bearings into the side holes in the Syringe Presser, then insert a hex nut into the center hole.
b.	Insert the threaded rod through the top center hole of the extrusion box, and thread it all the way down.
c.	Insert the two 200mm metal rods halfway into the extruder box housing.

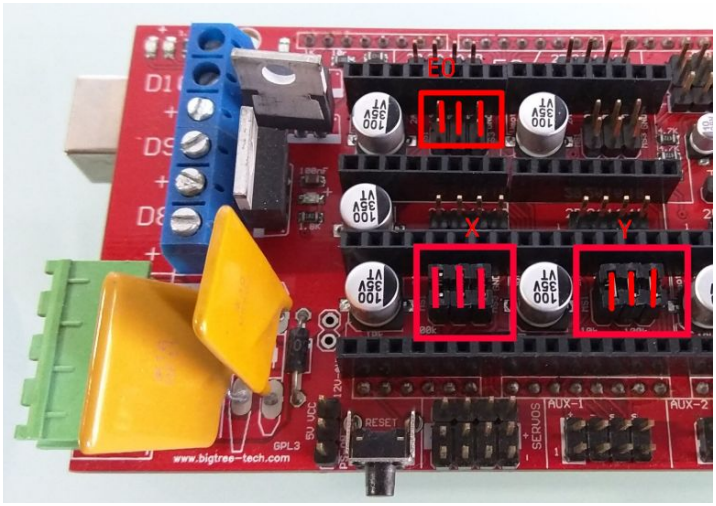
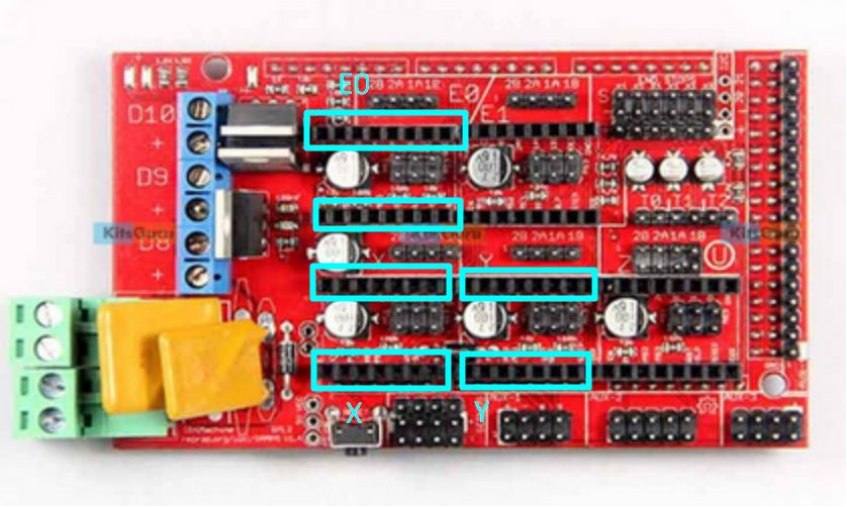
d.	Place the motor on the top of the box so that the shaft fits through the center hole. Attach the coupler to the shaft end that protrudes through the box.
e.	Use M3 - 15mm long machine screws to secure the stepper motor to the extruder box
f.	Attach the Extruder Mount to the back of the extruder box using four bolts.  *Extruder Mount*
g.	Add the Belt Guide to the bottom two bolts on the back of the extruder mount.  *Belt Guide*
h.	Insert a linear bearing into each one of the holes of the Extruder Mount.
i.	Insert the Wedge Lock into the rectangular slot at the base of the Extruder Box.
j..	Insert the syringe into the Wedge Lock. Superglue one magnet to the bottom of the Syringe Presser and one on top of the syringe plunger so that they are aligned.
3.	**Setup vertical rails**
a.	Use a tape measure or ruler to mark a line 3.5" from the end of the endplate along one of the horizontal T-slots. Place a vertical T-slot at this point, and attach it to the horizontal T-slot using the Triangular T-slot Base Bracket on the outside of the rail, and the Rectangular T-slot Base Bracket on the inside. Use the T-slot fasteners to secure it in place. Repeat for the other rail.  *Triangular T-Slot Base Bracket*

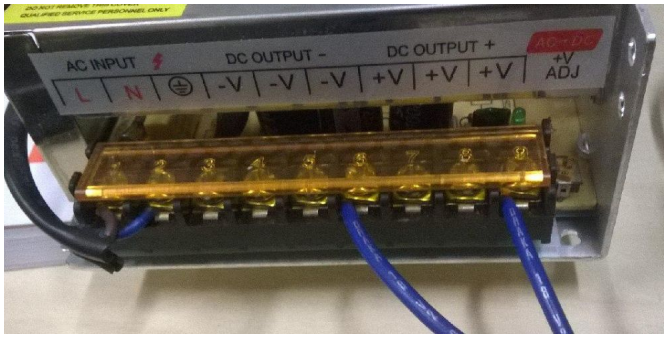
4.	**Setup print head translational motion system (*at least two people required*)**
a..	Slide a 400mm rail through each linear bearing on the Extruder Mount.
b.	Put a white rail cap on both ends of the bottom rod, then insert a T-slot fastener through each of the outside holes of the Rail Cap.  *Rail Cap*
c.	Prepare the Extruder Pulley Mount by placing a T-slot fastener through each of the outside holes, and a bolt through the center hole so that the head of the center bolt is on the opposite side of the heads of the outside bolts.  *Extruder Pulley Mount*
d.	Using two people, with one person handling each end of the bottom rod, slide the rail caps (with the bottom rod and entire extrusion mechanism attached) 2 inches down the T-slot at the same time so that the rail is horizontal the entire time. **Ensure that the Rail Caps are inserted on the face of the T-slot that faces the closest endplate. This ensures that the syringe hovers over the center of the print bed.*
e.	Once the bottom rail caps are partially down the T-slot frame, have one person slide in the Extruder Pulley Mount on their side, with the bolt facing out, on the same face of the frame as the Rail Cap.
f.	Once the Extruder Pulley Mount has been inserted, slide in the 3D printed Motor Bracket on the vertical rail opposite of the rail with the Extruder Pulley Mount. Attach this bracket to the face of the frame facing away from the center of the printer using the T-slot fasteners.
g.	Attach the red rail caps to the ends of the top rods, insert the T-slot fasteners, then slide them into the T-slot frame. Once the tops of the red rail caps are flush with the top of the frame, tighten all fasteners so that the system is secure in its place.  

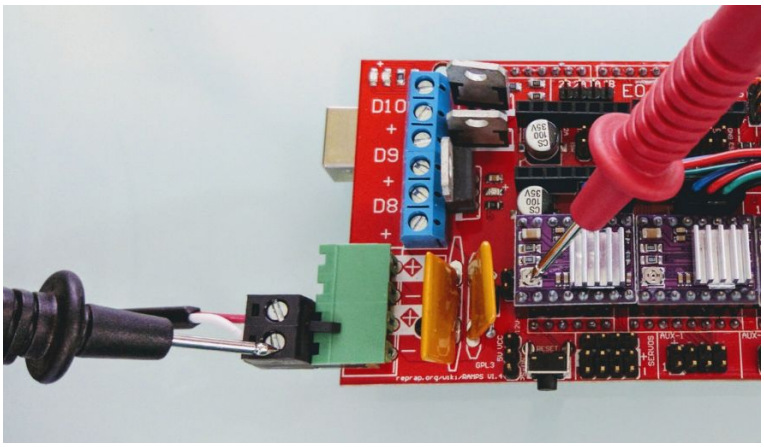
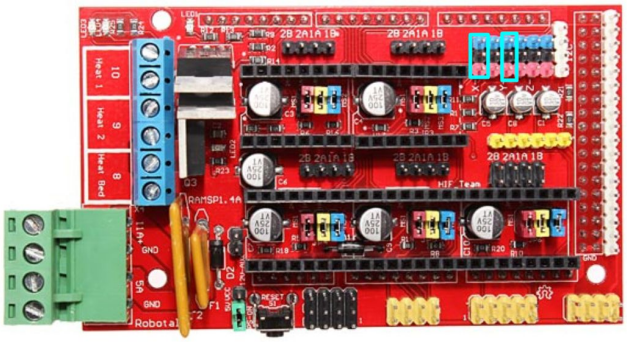
	Final assembly of top rail system
5.	**Setup print head belt and motor system**
a.	Use four small bolts to attach a motor to the motor bracket so that the shaft is facing the same direction as the back of the extrusion box. Fasten a pulley to the shaft using the appropriate allen wrench.
b.	Fasten a pulley to the bolt protruding from the Extrusion Pulley Mount.
c.	Cut the belt to about 3 feet. Use a zip tie to attach one end of the belt to one of the pegs on the Extruder Mount . Hook the belt around the pulley attached to the Extruder Pulley Mount, then pull it through and hook it around the pulley on the motor. Pinch the belt around the peg and fasten it in place with a zip tie.  *Extruder Mount Belt Attachments*
6.	**Attach the endstops**
a.	Position the endstop just above the end-plate, with the switch facing the print bed base. Use quick dry super glue to attach it to this place on the T-slot
b.	Position the other endstop halfway up the T-slot rail and glue it into place.
7.	**Attach acrylic sheet**
a.	Position acrylic sheet centered over print bed, and mark the location of the bolts on the print bed. Using the gel superglue permanently attach the magnets to the marked location. Once dry, magnetically attach the acrylic sheet to print bed.

ELECTRONICS SETUP	
1.	**Connect hardware to Arduino and RAMPS 1.4 board (use the following schematic to guide your wiring).**

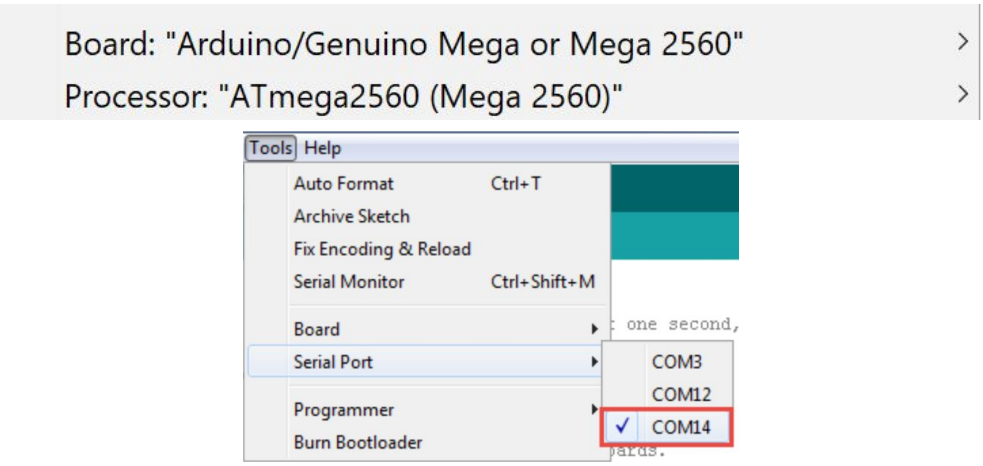
	
a.	Connect the RAMPS 1.4 board by aligning the pins above the pinouts on the Arduino Mega and pushing down firmly.
b.	Attach 3 jumpers for each motor to be used (X, Y, and E0). These jumpers will be used to enable our motors to achieve 1/32 microstepping. Slide each jumper onto the two pins underneath where each motor driver would go (see schematic below for exact pin connections).

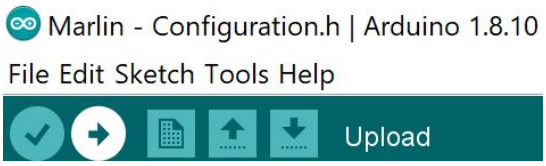
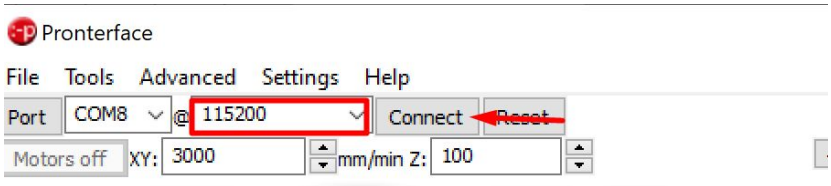
	
c.	Connect the motor drivers for X, Y, and E0 to the appropriate pinouts. Read the labels on the underside of the drivers to make sure the EN (enable) pins and GND pins line up with the labels on the RAMPS board. 
d.	Remove the sticky backing on the aluminum heat sinks to attach a heat sink to the square on top of each driver.
2.	**Wire RAMPS board to DC Power Supply**
a.	Note: Do NOT connect the power cord to the wall outlet during this stage to avoid electric shock.

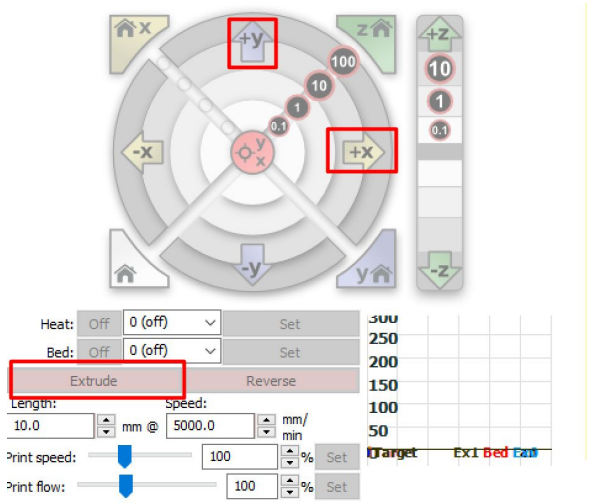
	 Use the stripped power cord to wire to the L (Live), N (Neutral), and Ground connections on the DC power supply as shown. Stick each wire beneath the appropriate screw terminal and use a screwdriver to tighten the screw until each wire is locked in place. Tug lightly on each wire to make sure that the connection is secure. Make sure NO loose wires are exposed or crossed. Be very careful and double check that the connections are wired properly.
b.	Wire the two stripped hookup wires to the V+ and V- screw terminals on the power supply as shown. 
c.	To finish, connect the other end of the hookup wires from the power supply to the green screw terminal pinouts designated by the **5A** (this is the circuit that controls the motors, the 11A pinouts are for a separate circuit that controls heating, which is not used for our printer). Use a screwdriver to tighten the screw until both wires are locked in place. Note: Be VERY CAREFUL that the polarity is correct (V+ to V+ and V- to V-), otherwise you will fry the RAMPS board and possibly damage other electronics.
3.	**Set voltage limits on motor drivers**
a.	Double check that your polarity is correct on the RAMPS board and that your G, N, L connections are correct on the DC power supply. You may now connect the DC power supply to the wall outlet. Note: It is best practice to first connect to a power strip and before the wall outlet to easily switch the power on and off when calibrating the printer later.
b.	Set a digital multimeter (DMM) on the 2 V or 20 V setting. Use an alligator clip to connect from the black end of the DMM to a small screwdriver.

c.	 For each motor driver, touch the screwdriver to the potentiometer at the corner of the motor driver. Read the voltage on the DMM. The motor drivers for this printer (DRV8825) are rated for 1.7 A. The ideal voltage limit is half this value at 0.85 V. Gently turn the potentiometer screw until it is at this value or a little below.
3.	**Connect motors and endstops.**
a.	Connect the motors to the pinouts in the schematic, and make sure the lead wires are in the correct order as shown (red, blue, green, black).
b.	Connect the endstops to the Xmin and Ymin pins as shown in the schematic. Be very careful that they are correctly oriented or you may short the circuit. 
4.	**Connect USB cable from Arduino USB port to computer.**
5.	**Connect the power supply to the wall outlet or to the power strip (recommended). If any adjustments need to be made to the wiring, be sure to turn off power or unplug before making changes.**

SOFTWARE SETUP	
1.	**Configure Marlin firmware.**
a.	Open the Marlin.ino file in the Arduino IDE. To make sure your Arduino is connected, click the

	tools tab. Make sure the Board is set to Arduino Mega and Processor is "ATmega2560". Your serial port should show up as COMXX where the value of XX may vary as shown. 
b.	Switch to the Configuration.h tab to begin configuring the printer's firmware.
c.	Start by setting the baudrate (the rate of data transmission) to 115200. `124 * :[2400, 9600, 19200, 38400, 57600, 115200, 250000, 500000, 1000000]` `125 */` `126 #define BAUDRATE 115200`
d.	Set TEMP_SENSOR_0 to 999. This will set the temperature sensor to a value that you specify, in this case, 250 C. *(Failure to enable this will cause the print to fail because the printer will wait for the heat bed to reach this temperature, which will never happen because there is no thermal system for our setup).* `317 #define TEMP_SENSOR_0 999 // extruder` `318 #define TEMP_SENSOR_1 0` `319 #define TEMP_SENSOR_2 0` `320 #define TEMP_SENSOR_3 0` `321 #define TEMP_SENSOR_4 0` `322 #define TEMP_SENSOR_BED 0` `323 #define TEMP_SENSOR_CHAMBER 0` `324` `325 // Dummy thermistor constant temperature readings, for use with 998 and 999` `326 #define DUMMY_THERMISTOR_998_VALUE 25` `327 #define DUMMY_THERMISTOR_999_VALUE 250 // OG 100`
2.	**Calibrate stepper motor movement.**
a.	Set the DEFAULT_AXIS_STEPS_PER_UNIT to the following pre-calculated values (using https://blog.prusaprinters.org/calculator/) for optimal smoothness and accuracy given our chosen belt and pulley systems. Make sure your DEFAULT_MAX_FEEDRATE and DEFAULT_MAX_ACCELERATION are set to the values below as well. Note: The E0 controls the extruder stepper motor and we experimentally determined that a value of

	150 was found to be best for our food consistency, but you may want to change this to match with your desired extrusion rate. `618 * Default Axis Steps Per Unit (steps/mm)` `619 * Override with M92` `620 * X, Y, Z, E0 [, E1[, E2[, E3[, E4]]]]` `621 */` `622 #define DEFAULT_AXIS_STEPS_PER_UNIT { 160, 160 4000, 150 }` `623` `624 /**` `625 * Default Max Feed Rate (mm/s)` `626 * Override with M203` `627 * X, Y, Z, E0 [, E1[, E2[, E3[, E4]]]]` `628 */` `629 #define DEFAULT_MAX_FEEDRATE { 300, 300, 500, 25 }` `630` `631 /**` `632 * Default Max Acceleration (change/s) change = mm/s` `633 * (Maximum start speed for accelerated moves)` `634 * Override with M201` `635 * X, Y, Z, E0 [, E1[, E2[, E3[, E4]]]]` `636 */` `637 #define DEFAULT_MAX_ACCELERATION { 3000, 3000, 150, 8000 }` `638`
b.	Click the Upload button in the top left corner to upload your firmware to the Arduino. This may take about 30 seconds. 
3.	**Launch Pronterface and configure motor directions.**
a.	Make sure your baud rate is also set to 115200 in Pronterface and click Connect to connect to your printer. 
b.	Once connected, click the X, Y, and Extrude buttons to test motor movement. You may only be able to move the motors in the positive direction, but this is because we have not yet set up endstops. If the motors are not moving at all, you may want to recheck your wiring.

<table>
<tr><td></td><td> 
</td></tr>
<tr><td>c.</td><td>If any of your motors are moving in the wrong direction, you can invert their direction in the Marlin firmware.

To invert the direction of the extruder motor, switch INVERT_E0_DIR to true or false depending on which way you want the positive direction of extrusion to be.

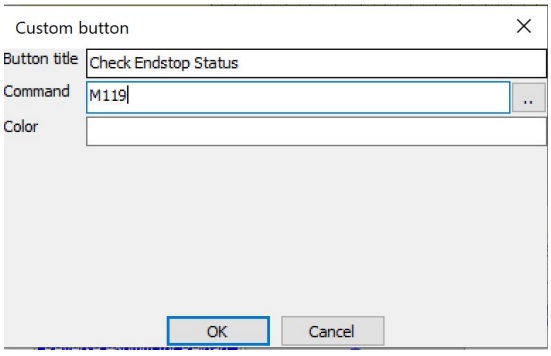
```
// For direct drive extruder v9 set to true, for geeared extruder set to false.
#define INVERT_E0_DIR true
#define INVERT_E1_DIR false
#define INVERT_E2_DIR false
#define INVERT_E3_DIR false
#define INVERT_E4_DIR false
```


To invert the direction of the X or Y motors, switch INVERT_X_DIR or INVERT_Y_DIR to true or false depending on which way you want the positive direction of axis movement to be.

```
// Invert the stepper direction. Change (or reverse the motor connector) if an axis goes the wrong way.
#define INVERT_X_DIR false
#define INVERT_Y_DIR false
#define INVERT_Z_DIR false
```


Save the firmware, but do not upload unless you have disconnected from Pronterface, otherwise the upload will fail.</td></tr>
<tr><td>4.</td><td>Verify that endstops are working.</td></tr>
<tr><td>a.</td><td>Hold down the switch on the endstop with your finger. While keeping the switch pressed down, send the following command through the command window in Pronterface: M119. Click ‘Send’.
 

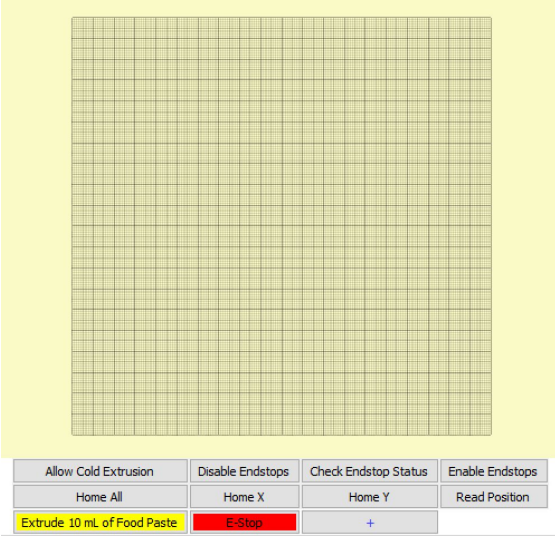
If the endstop is working properly, it should display “Triggered” if your finger is on the switch, and “Open” otherwise. If the logic is reversed on either the X or Y endstop, you will have to invert the logic in the Marlin firmware.</td></tr>
</table>

	To correct your endstop settings, open the Configuration.h tab in the Marlin firmware again. Check that your minimum endstop pinouts are defined (they should be defined by default). `512 //===========================================================================` `513 //============================= Endstop Settings ============================` `514 //===========================================================================` `515` `516 // @section homing` `517` `518 // Specify here all the endstop connectors that are connected to any endstop or probe.` `519 // Almost all printers will be using one per axis. Probes will use one or more of the` `520 // extra connectors. Leave undefined any used for non-endstop and non-probe purposes.` `521 #define USE_XMIN_PLUG` `522 #define USE_YMIN_PLUG` `523 #define USE_ZMIN_PLUG`
b.	Correct X_MIN_ENDSTOP_INVERTING or Y_MIN_ENDSTOP_INVERTING to true or false depending on your endstops. `541 // Mechanical endstop with COM to ground and NC to Signal uses "false" here (most common setup).` `542 #define X_MIN_ENDSTOP_INVERTING true // set to true to invert the logic of the endstop.` `543 #define Y_MIN_ENDSTOP_INVERTING true // set to true to invert the logic of the endstop.` `544 #define Z_MIN_ENDSTOP_INVERTING false // set to true to invert the logic of the endstop.` `545 #define X_MAX_ENDSTOP_INVERTING false // set to true to invert the logic of the endstop.` `546 #define Y_MAX_ENDSTOP_INVERTING false // set to true to invert the logic of the endstop.` `547 #define Z_MAX_ENDSTOP_INVERTING false // set to true to invert the logic of the endstop.` `548 #define Z_MIN_PROBE_ENDSTOP_INVERTING false // set to true to invert the logic of the probe.` `549` For example, for our printer, both are endstops incorrectly displayed as "OPEN" even when they were triggered, so we inverted the logic by switching false to true.
c.	Save and upload your firmware (but make sure Pronterface is disconnected).
d.	Connect to your printer through Pronterface and send the M119 code again while manually triggering the endstops with your finger. If all is well, they should display as "TRIGGERED" when your finger is on it, and "OPEN" otherwise.
5.	**Set up customized buttons in Pronterface.**
a.	Custom buttons are extraordinarily useful and highly recommended for sending g-code commands that you will need to repeat (such as M119: Check Endstops). To begin, click the "add new custom button" at the bottom of the window.
b.	Type in the desired name of your button and the g-code command as shown. Click OK to add the button to the interface. 

Once set up, you can simply click the button to send the g-code command instead of typing the whole command into the command window. At a minimum, you will want to do this with the common functions tabulated below:

Check Endstop Status	**Home X**	**Home Y**	**Home All**	**Read Position**	**E-stop**
M119	G28 X	G28Y	G28	M114	M112

For example, this is our complete custom button interface.



6. **Set up homing.**

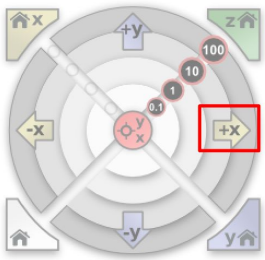
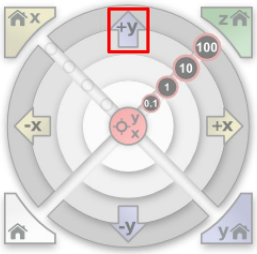
a. From the previous step, assure that the motors are moving in the desired direction and that the X and Y endstops are both working correctly.

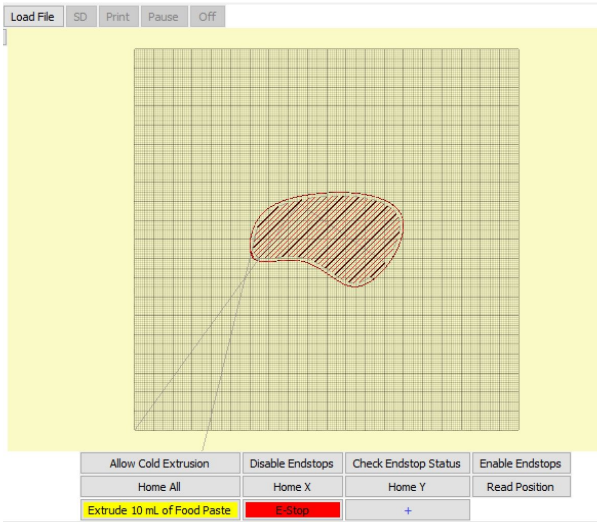
b. Since we are using minimum endstops, make sure the following homing directions are all set to MIN in the Marlin firmware (should be default).

```
881 // Direction of endstops when homing; 1=MAX, -1=MIN
882 // :[-1,1]
883 #define X_HOME_DIR -1
884 #define Y_HOME_DIR -1
885 #define Z_HOME_DIR -1
```

c. During the homing testing stage, you may damage your printer if your endstops are not working correctly when you attempt to home. Use the software emergency stop (E-stop) on your interface to kill the printer's motion instantly.

d. Test X-axis homing with the Home X button. If all goes well, the extruder head should move in the negative direction toward the endstop and stop once it triggers the limit switch. If the extruder tries to keep moving past the switch, click the E-stop or remove power immediately to avoid damage.

	If homing fails, here are a few diagnostic methods: 1. *Check that the extruder is actually physically triggering the endstop when it reaches it.* 2. *Check that your endstop logic is not inverted.* 3. *Check that your minimum endstops are defined for X and Y.*
e.	Test Y-axis homing with the Home Y button. Similarly, follow the diagnostic suggestions if homing fails.
f.	Test homing of both axes with the Home All button.
6.	**Set up travel limits.**
a.	This step is important so that your printer knows not to overstep its bounds. To begin, make sure that your X and Y are homed at the min endstops. Click the Read Position button to get coordinates of your position *(should read X:0 and Y:0, otherwise review steps 4 and 5).*
b.	Incrementally click the +X to carefully move the extruder toward the other end of the axis. When it has reached the opposite (max) end, click the Read Position again to get a reading of the coordinates. The X coordinate will be your MAX travel limit on the x axis. Take note of this number. 
c.	Now, incrementally click the +Y button to move the print bed toward the other end of the Y-axis. Click the Read Position again to get a reading of the coordinates. The Y coordinate will be your MAX travel limit on the y axis. Take note of this number. 
d.	Open up the Marlin firmware and configure this piece of code to match the travel limits you just found:

	`` // @section machine // The size of the print bed #define X_BED_SIZE 42000 #define Y_BED_SIZE 20320 // Travel limits (mm) after homing, corresponding to endstop positions. #define X_MIN_POS 0 #define Y_MIN_POS 0 #define Z_MIN_POS 0 #define X_MAX_POS X_BED_SIZE #define Y_MAX_POS Y_BED_SIZE #define Z_MAX_POS 200 ``` Your printer's travel limits are now defined and you can safely test run a g-code file. Save and upload to Arduino.
7.	**Test run a g-code file.**
a.	Connect to Pronterface again.
b.	Click the 'Load File' button and select your desired test g-code file. The outline of the print should appear in the middle of the interface. 
c.	Click the 'Print' button to start the print.
d.	Observe your motors' movements to make sure that they are moving how you want. During this stage, you will likely be doing a lot of calibrating, especially with the extruder, to make sure that it is extruding the food paste at a good flow rate. *(You will almost certainly need to tweak your extrusion in addition to the basic calibration steps outlined in this guide depending on the unique consistency of your food paste.)* Review the steps previously outlined to adjust your firmware. Calculate and readjust your motor steps per mm and extruder flow as necessary. There are many other options for fine tuning your system in the Marlin firmware not used in this guide. Feel free to experiment with these settings (described in detail in http://marlinfw.org/docs/configuration/configuration.html) to make sure that your system is perfectly calibrated.