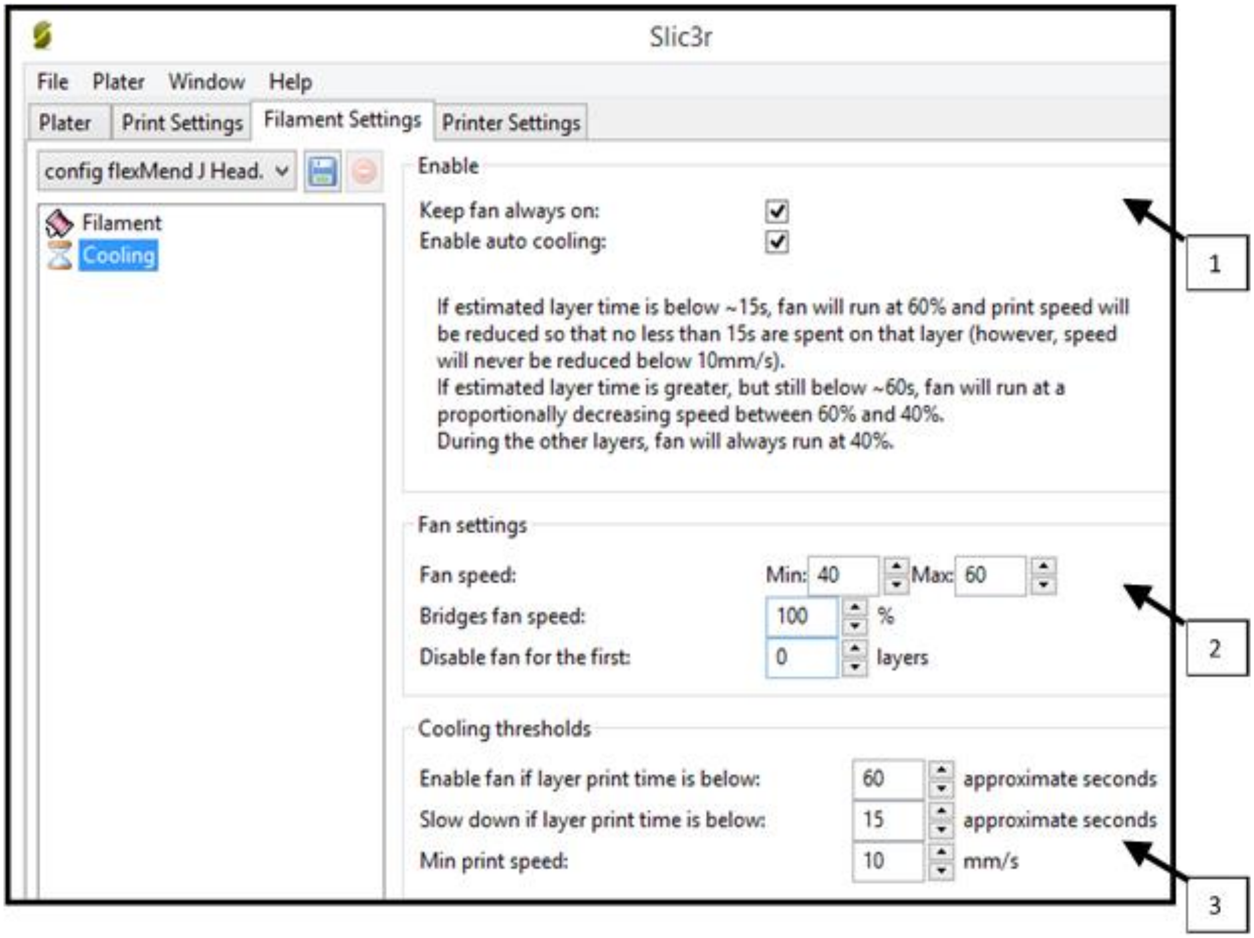
Slic3r Setting Descriptions: c.) Filament Settings Tab – Cooling

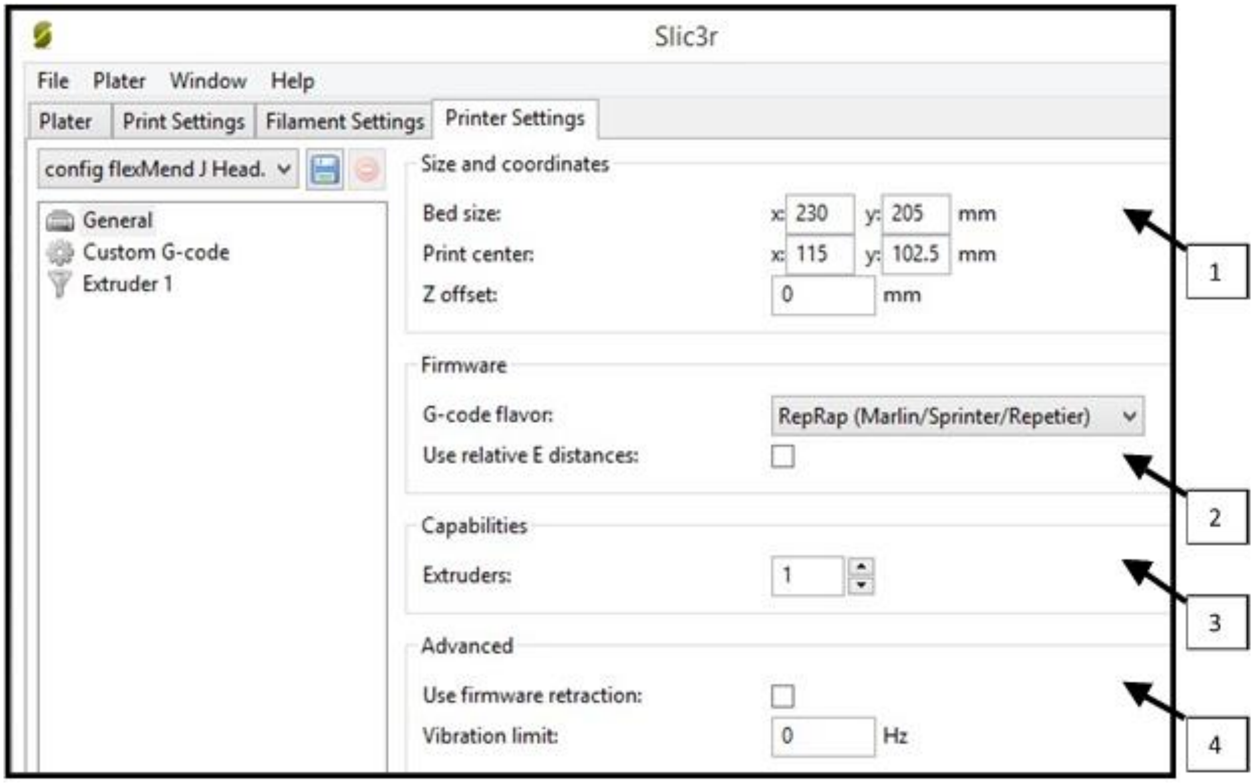


1. *Enable* – This window has two boxes that control when the cooling fans are utilized.

2. *Fan settings* – Fan settings vary from 3D printer to 3D printer. 3D printer manufactures suggest varying fan speeds, others may not use a fan at all. The user has the ability to disable the fan for any number of layers in the beginning of the print.

3. *Cooling thresholds* – Cooling thresholds give the user increased ability to control printing and fan speeds based on the time it takes to print certain layers of the part. Smaller print layers take less time and these settings allow for machine speeds to be slowed down which can increase print quality.

Slic3r Setting Descriptions: d.) Printer Settings Tab – General



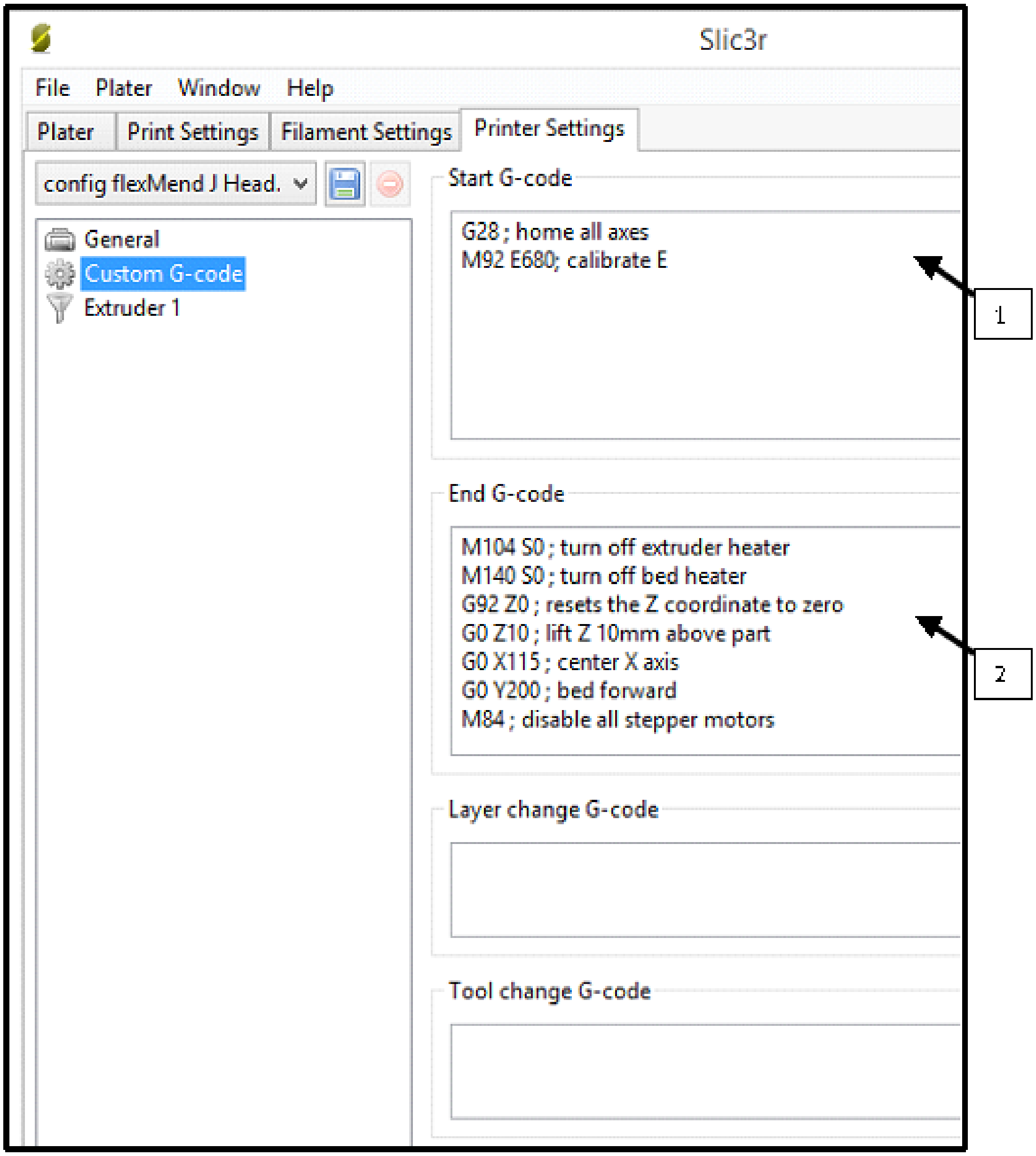
1. *Size and coordinates* – This section is where the user can enter the exact specifications of the mechanical limitations of their 3D printer. Bed sizes are not always square. The ability to change print center allows for rectangular shaped beds to have the center point accurately located.

2. *Firmware* – There are six different firmware options depending on what type of firmware is loaded into the controller of the 3D printer. RepRap (Marlin/Sprinter/Repetier) is the most common for open source 3D printers.

3. *Capabilities* – This allows for the user to set the number of extruders the 3D printer is equipped with.

4. *Advanced* – This feature is experimental and can assign a noise limit that if exceeded, the firmware will slow down the machine speeds. It is an attempt to mitigate excessive vibration during printing.

Slic3r Setting Descriptions: d.) Printer Settings Tab – Custom G-code

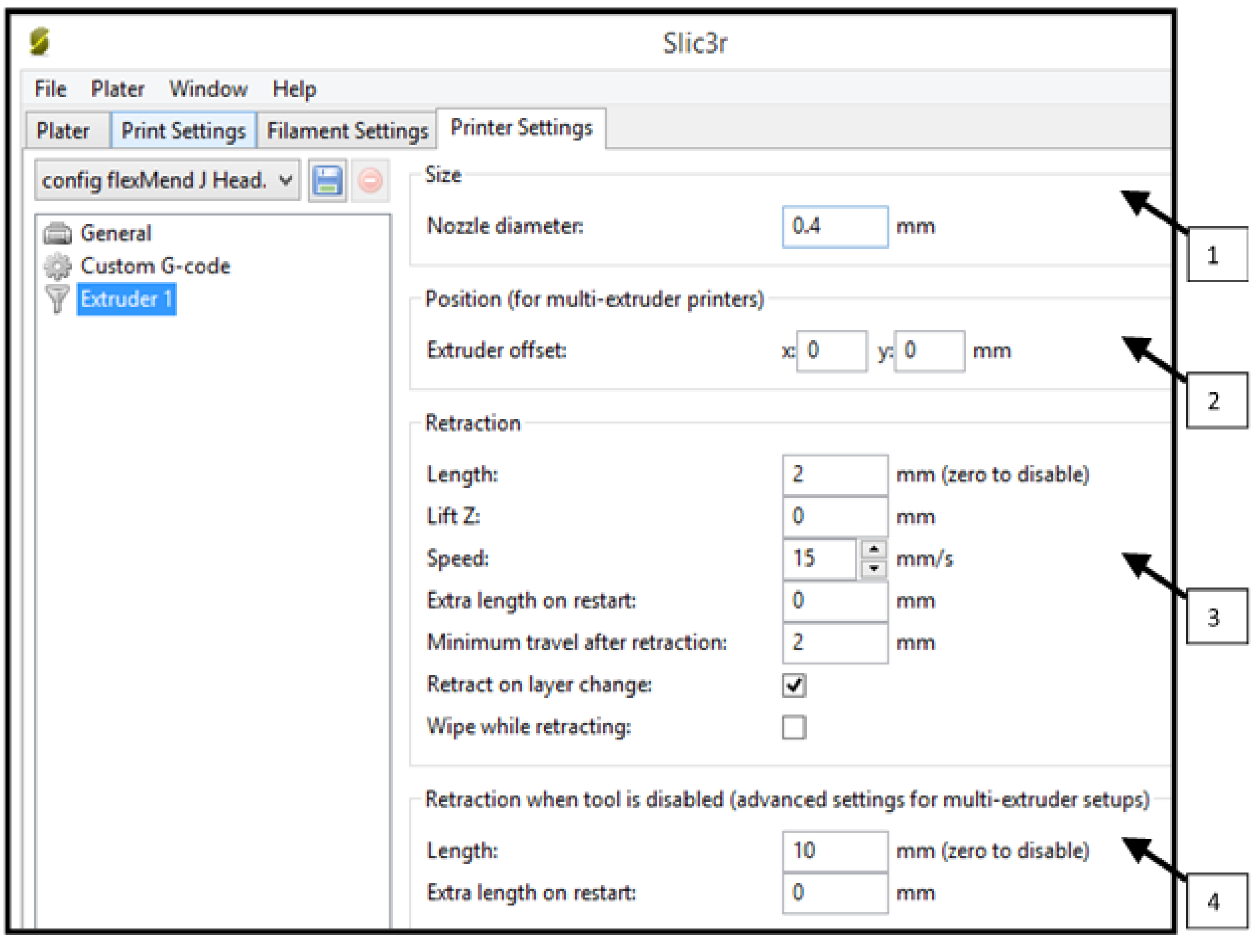


1. *Start G-code* – This box is for the user to enter any custom G-code that will be entered in the beginning of the G-code file. In this case, two commands are used: G28 to home all axis (0,0,0) and an M92 E680 command to calibrate the motor speed for the "Low-mass Extruder" (open source extruder found at: http://www.thingiverse.com/thing:61818).

2. *End G-code* – Similar to the Start G-code box, the end G-code box allows the user to put in custom G-code commands to the end of the G-code file that can add additional functionality. In this example the user has commands to terminate both heating

elements. There are also machine movement commands in place to lift the nozzle away from the part by 10mm, center the extruder, and move the bedplate in the forward position. This creates a “presentation-like” effect when the machine is finished printing so the part is easily accessible. The final G-code command disables all motors on the machine to minimize power consumption when complete.

Slic3r Setting Descriptions: d.) Printer Settings Tab – Extruder 1



1. *Size* – Enter the orifice size (hole on bottom of the nozzle) here.

2. *Position* – This is only used if the 3D printer has multiple extruders. This is the offset distance between the two hotends.

3. *Retraction* – Retraction is a good feature in Slic3r. It will retract the filament after creating a layer on a part to minimize the hot plastic from dripping out the tip of the nozzle when the machine moves to the next part.

4. *Retraction when tool is disabled* – Similar to Retraction, this setting permits the user similar functionality when one of the extruders is not in use.

Turing STL Files into a G-code File –

This process is relatively simple. Load the desired STL files onto the digital platter in Slic3r. Notice that Slic3r automatically will re-center all files into the center of the platter. This is good because the bedplate on a 3D printer is usually most level in the exact center. Change the print settings in Slic3r to dictate how the 3D printed part will be created. When you have all the settings adjusted to how you want them, simply hit the "Export G-code" button. You will see a green progress bar moving to the right as the G-code file is being created on the bottom of Slic3r's window. Slic3r will automatically try to place the new G-code file in the same place or folder that the STL files came from.

There is another way to generate a G-code file. Under the File menu there is an option called "Quick Slice". This will perform the same action of creating the G-code file and placing it back in the location the STL files came from.

Creating Your Own Config Files in Slic3r

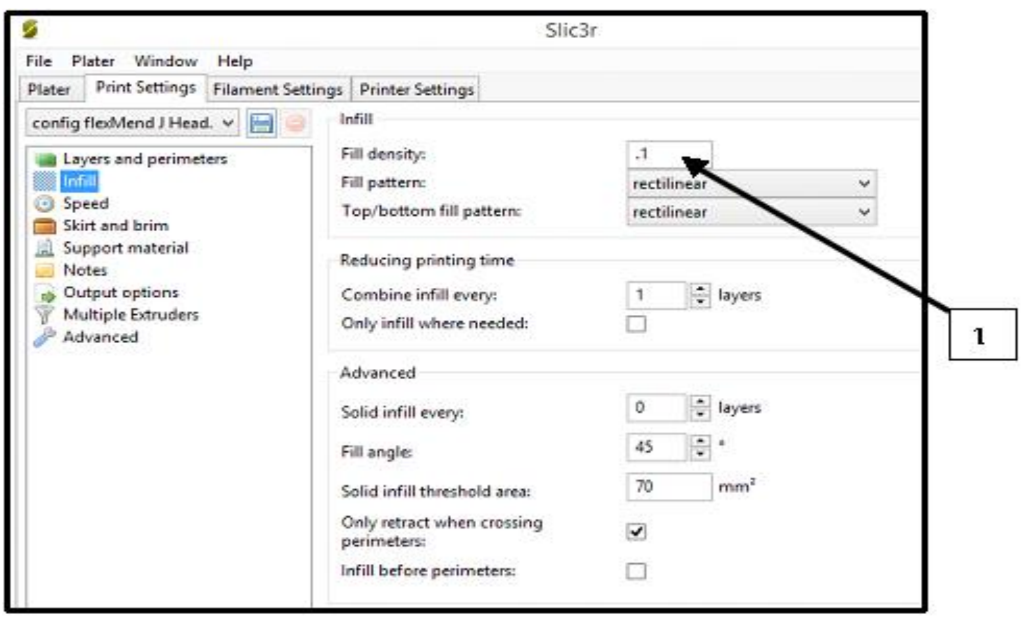
Concept vs. Quality - Example Slic3r Config Files

Creating multiple config files that serve a variety of 3D printing needs in advance can save time when trying to determine what settings should be utilized for specific printed parts. The following are suggestive preconfigured settings that can be saved as separate config files for quick and easy reference. Each new config file started as the ORIGINAL DEFAULT CONFIG FILE for this particular 3D printer. If creating new config files to save for future use, be sure to always load the original config file to refresh original Slic3r settings for your 3D printer.

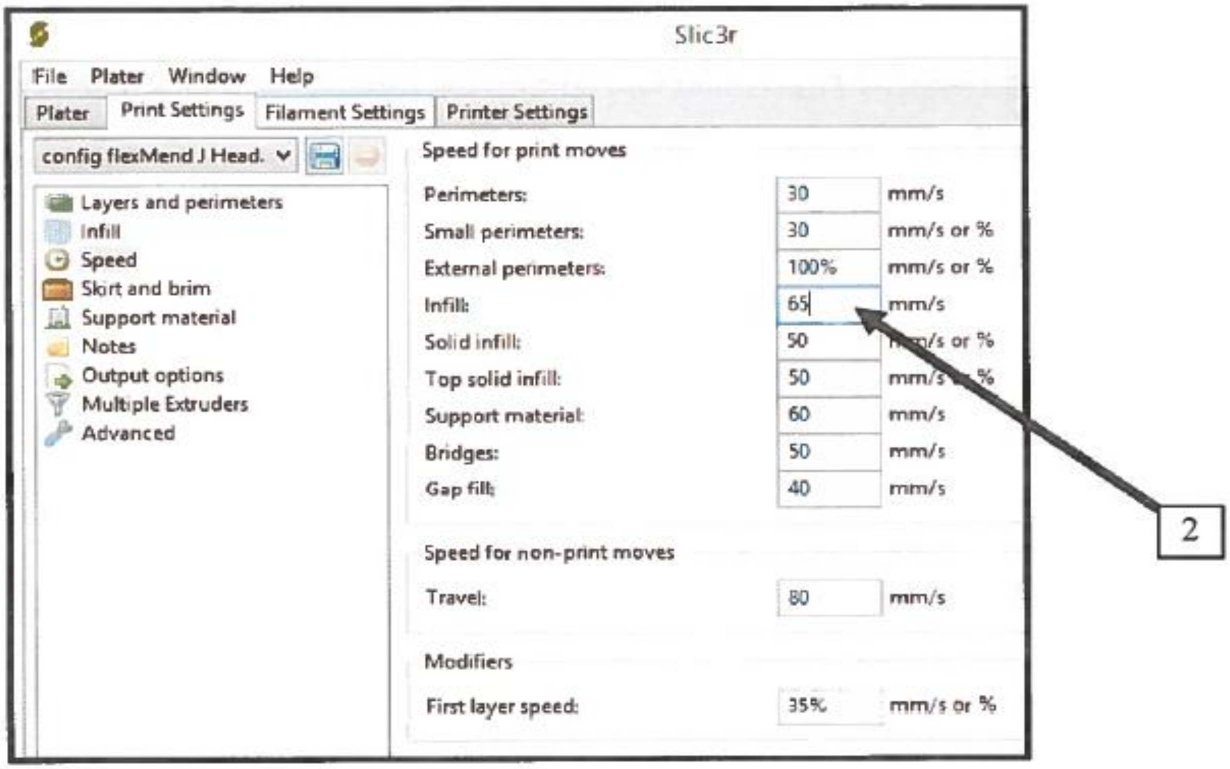
How to save a config file after changing the specific print setting changes:

1) Go to: FILE > Export Config.
2) Make sure the new config file will be placed in the folder named "Config Files."
3) Name the config file with a descriptive name for easy reference.
4) Click "Save."

Prototype-Proof of Concept (minimum material usage)



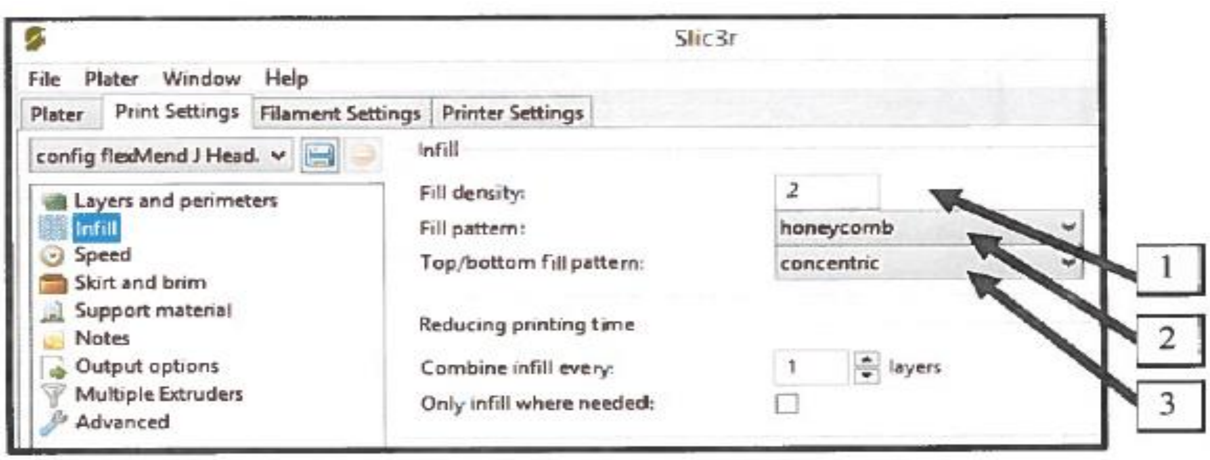
1. Change the "Fill density" to 0.1 or 10%. This will minimize the plastic usage inside the part but will still provide material to support the printed structure.



2. Change the Speed of the Infill to 65 mm/ s. For "prototype" and "proof of concept" prints, speed is of greater importance than overall quality because the design is still in the developmental stage. Speeding up the speed of the infill will not affect the outer perimeter of the part but will help to get the idea created faster.

3. Go to File > Export Config and save the file as: "Prototype."

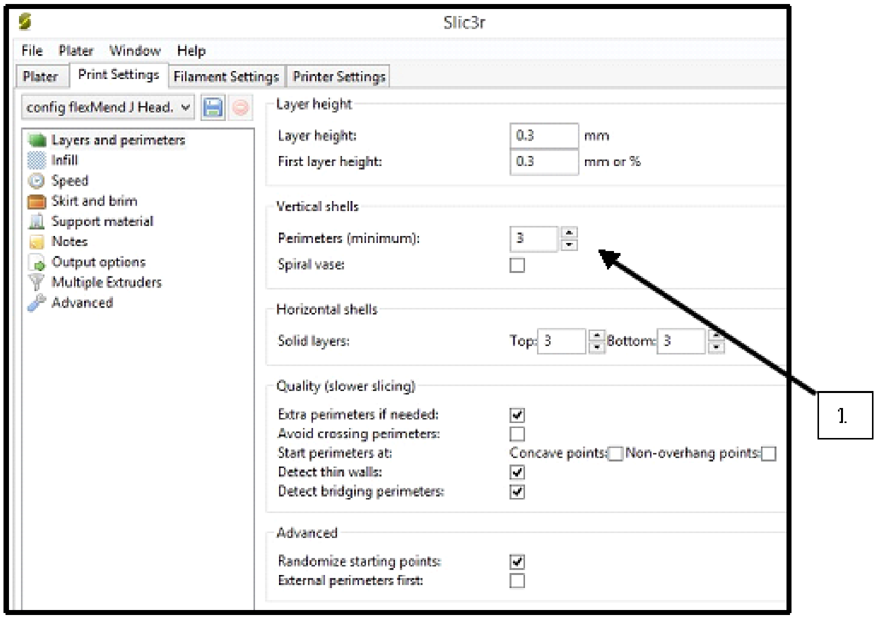
Light Strength-Functional w/out forces (dissectible frog, biology models, etc.)



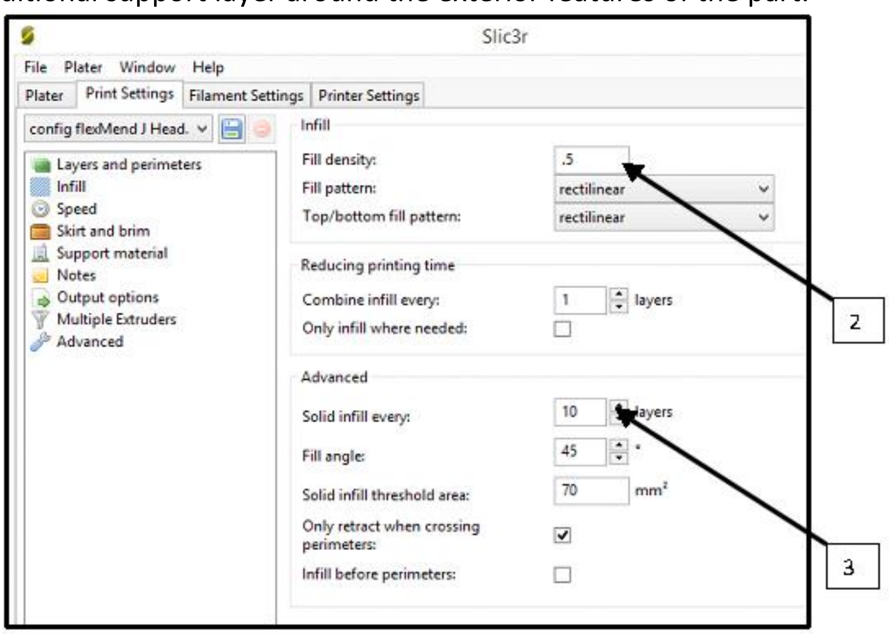
1. Change the Fill Density to "0.2" or 20% to reduce overall material usage.

2. Change the fill pattern to "Honeycomb" to provide better support for round and odd-shaped models.
3. Change the Top/bottom to "Concentric." This will give the model a somewhat more pleasing aesthetic appearance.
4. Go to File > Export Config and save the file as: "Light Strength."

Moderate Strength-Functional w/light forces (mating parts, brackets, etc.)

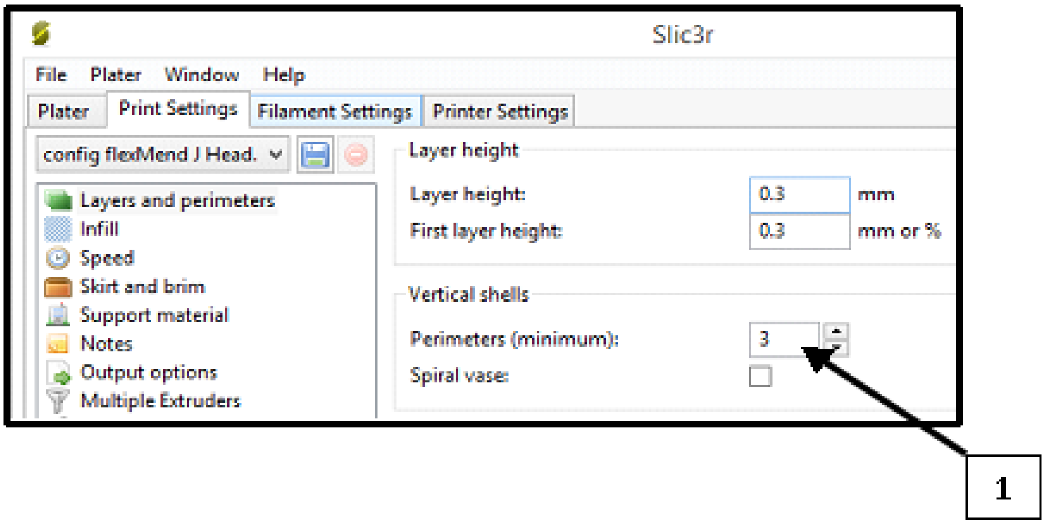


1. Change the "Vertical Shells-Perimeters" to contain 3 perimeters instead of 2. This will add an additional support layer around the exterior features of the part.

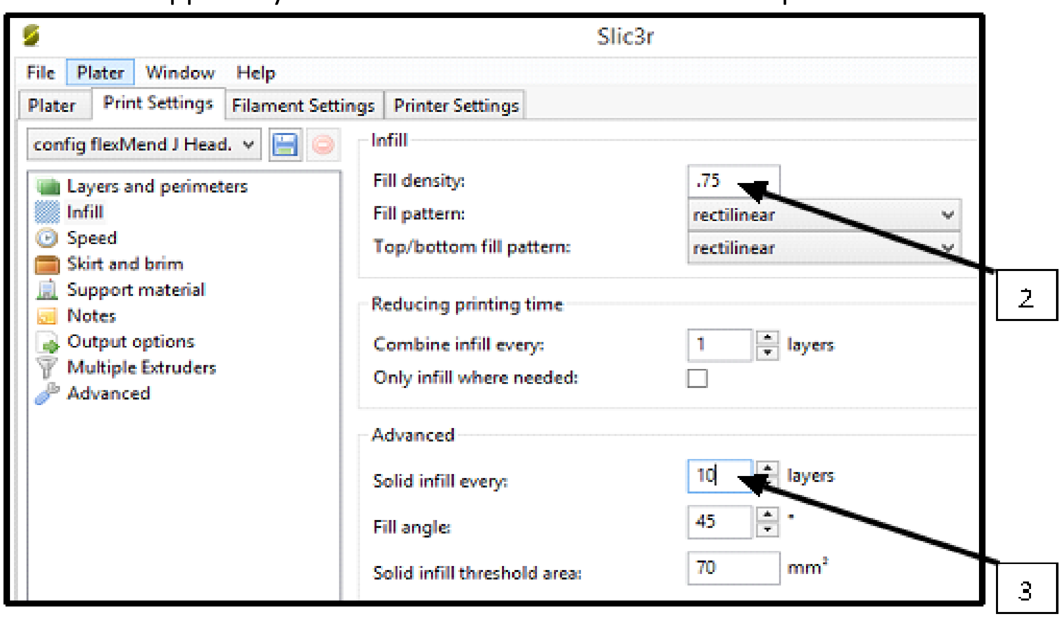


2. Change the Infill Fill density to 0.5 or 50%. This will provide much more integrity to the inside structure of the part.
3. Add a "solid" layer of infill every 10 layers. This may not seem like it would help that much, but considering that each layer is 0.3 mm, every 3 mm will be a solid layer of infill. It will add structural integrity without adding too much plastic to the finished part.
4. Go to File > Export Config and save the file as: "Moderate Strength."

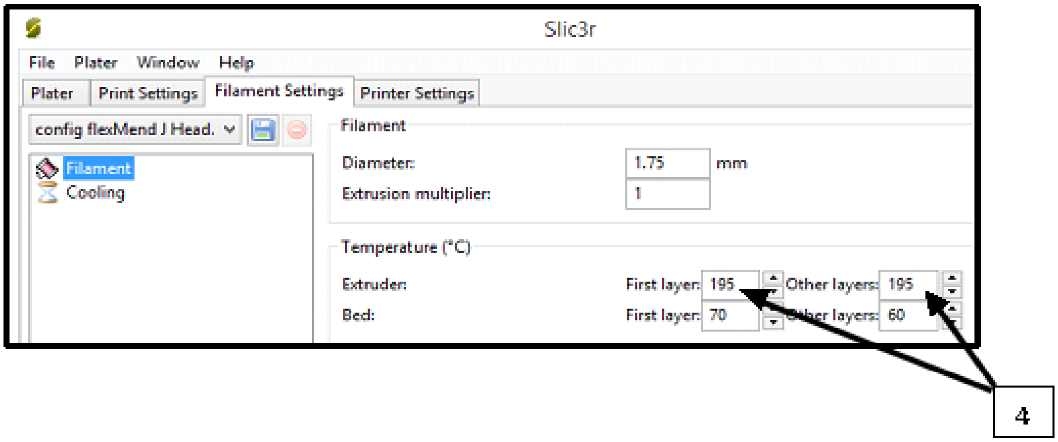
Heavy Strength-Structural w/ strong forces (printed gears, mechanisms, etc.)



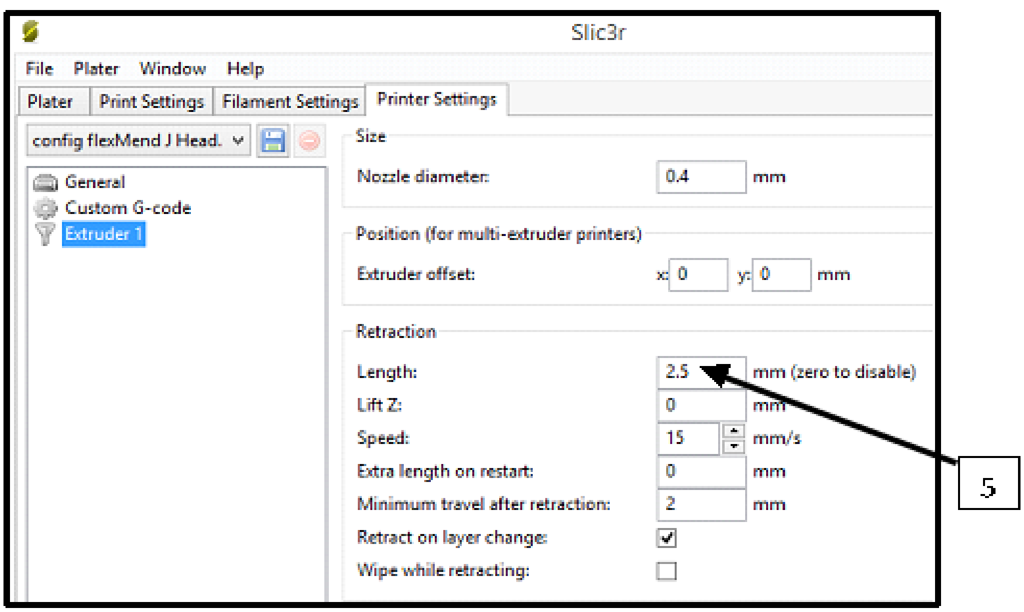
1. Change the "Vertical Shells" to contain 3 perimeters instead of 2. This will add an additional support layer around the exterior features of the part.



2. Change the Fill Density to "0.75" or 75% to increase the structural integrity of the interior.
3. Add a "solid" layer of infill every 10 layers. Again, this increases strength and reduces the chance of failure when the finished part is being used for its intended purpose.

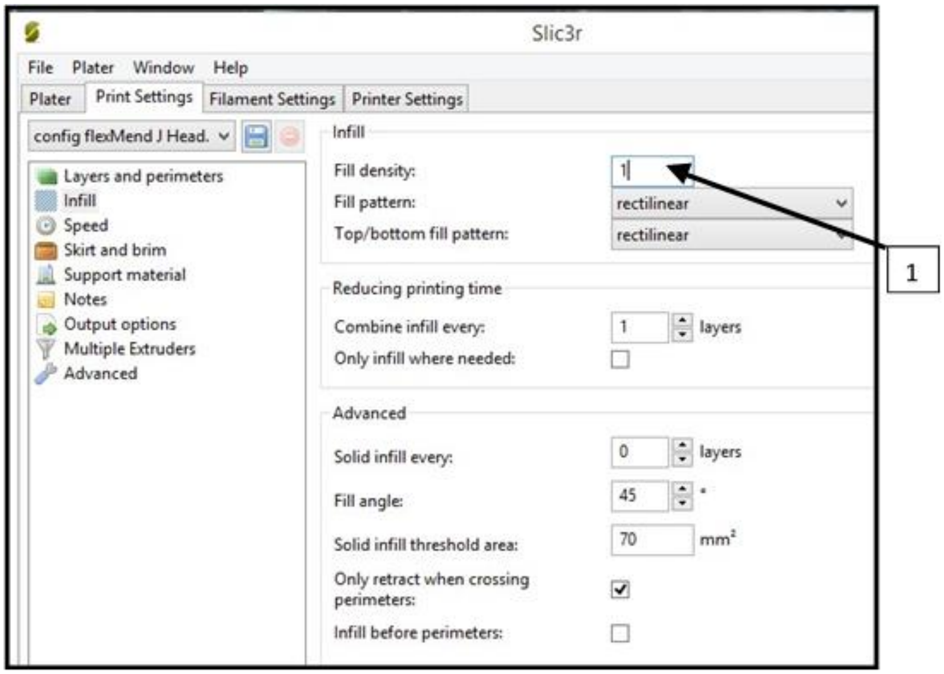


4. Increase the Extruder temperature by 5° C. This will help the plastic bond to itself better during the manufacturing process, which creates a stronger finished product. When changing this setting, be weary of adding multiple STL files on a single plate to be printed because the increased temperature will cause the plastic to be more susceptible to dripping out of the nozzle during machine travel. If there is only one part being printed at a time, it will only drip on the interior of the part, which doesn't cause any problems



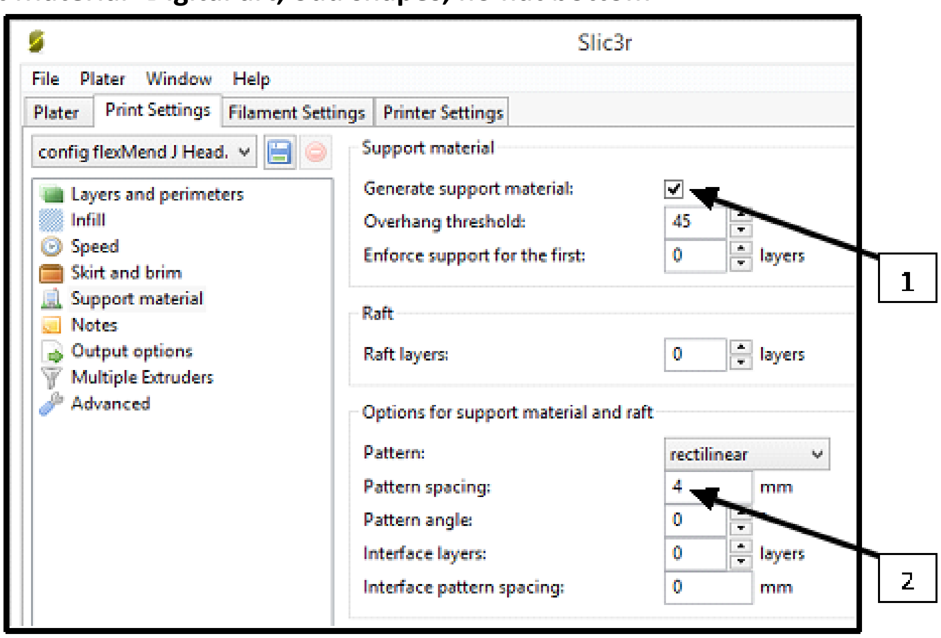
5. OPTIONAL - Increase the "Retraction Length" by 25% (from 2 mm to 2.5 mm in this case) to help compensate for the potential extra dripping of plastic due to the increased extruder temperature.
6. Go to File > Export Config and save the file as: "High Strength."

Solid- Machine components, rugged applications, etc.



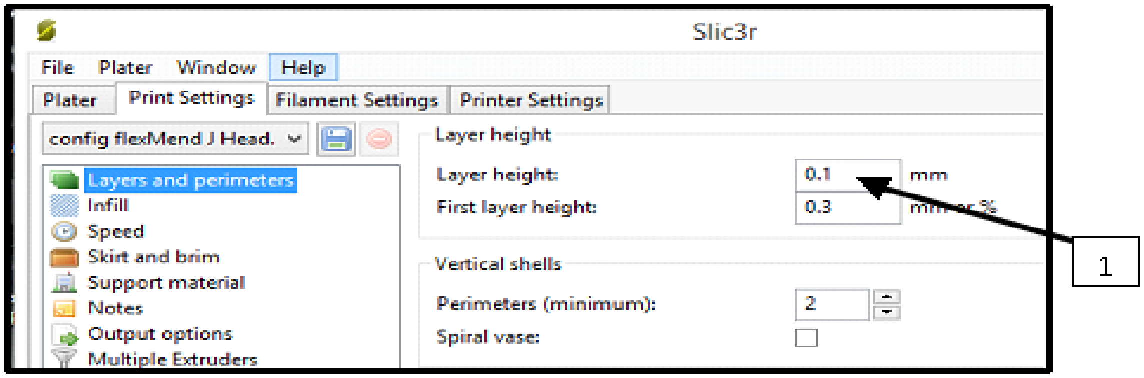
1. Change the "Fill Density" to 1 or 100%.
2. Go to File Export Config and save the file as: "Solid."

Support Material- Digital art, odd shapes, no flat bottom



1. In the Support Material control box, check the box labeled "Generate Support Material."
2. Change the pattern spacing from 2.5 mm to 4 mm. This will help to speed up printing time and not use as much material for support.
3. Feel free to adjust any other settings that you might want with this particular config file.
4. Go to File > Export Config and save the file as: "Support - General."

High Resolution- Very small parts with intricate details.



1. Change the "Layer height" to 0.1 mm. Keep the First layer height at its current setting (changing this would make that layer more difficult to print). Keep in mind that when printing in High Resolution with reduce layer heights, total printing time almost triples from default settings.
2. Go to File > Export Config and save the file as: "High Resolution- General."

Additional References:

Slic3r Online Manual
http://manual.slic3r.org/

Detailed Information about open source 3D printing:
http://illinoiscte.org/index.php/resources/3d-open-source-printing

List of open-source/free G-code generators for 3D printing and CNC milling:
http://replicat.org/generators

Ongoing Cost Estimations

Material Usage Estimations

After the G-code file has been generated, the user has the ability to perform calculations from the estimated amount of material used to figure out how much the printed part will cost after it is done printing. This information can be found at the very bottom of the G-code file. To perform these cost calculations, you will need to open the G-code file using "Notepad", "Text Edit," or another simple text-based software. When you open the G-code file, you will see all of the preliminary settings that were entered into Slic3r before generating the G-code file.

```
; infill_speed = 50
; travel_speed = 80
; nozzle_diameter = 0.35
; filament_diameter = 1.75
; extrusion_multiplier = 1
; perimeters extrusion width = 0.35mm
; infill extrusion width = 0.37mm
; solid infill extrusion width = 0.37mm
; top infill extrusion width = 0.37mm
; first layer extrusion width = 0.60mm

G21 ; set units to millimeters
M190 S70 ; wait for bed temperature to be reached
M104 S185 ; set temperature
G28 ; home all axes
M92 E720; calibrate E
```

To find the material usage estimation, you will need to scroll to the bottom of the G-code file. G- code files can sometimes contain 10,000 lines of G-Code. It is a long file. One might appreciate the fact that every single line of code is a command for each movement of the 3D printer as it creates the object being printed. At the very bottom of the G-code file, you will see the custom G-code commands that were entered into Slic3r. On the very last line of code, it displays how many millimeters of filament was used to create this part, and it gives the cubic centimeters of material in parenthesis"()." See below.

```
G1 X113.576 Y121.966 E4.23469
G1 X113.613 Y121.858 E4.23991
G1 F900.000 E2.73991
G92 E0
G1 Z19.200 F4800.000
M107
M104 S0 ; turn off extruder heater
M140 S0 ; turn off bed heater
G92 Z0 ; resets the Z coordinate to zero
G0 Z10 ; lift Z 10mm above part
G0 X115 ; center X axis
G0 Y200 ; bed forward
M84 ; disable all stepper motors
; filament used = 2747.9mm (6.6cm3)
```

To estimate the cost of the 3D printed part before sending it to the 3D printer, you can use the volume generated in the G-code and apply this simple equation to estimate the total material cost.

Given factors:

PLA weighs about 1.3g per 1cm^3
PLA costs about $0.05 per gram

ABS weighs about 1 gram per 1cm3
ABS costs about $0.06 per gram

1) **Figure out how many grams of PLA was used**

    (Total volume)* (g/ 1 cm^3) = total grams
    Ex: (6.6cm^3) * (1.3g/ cm^3) =8.58 grams

2) **Multiply number of grams of plastic used by the cost per gram**

    (Total grams)*($/ g) = Total material cost
    Ex: (8.58g) * ($0.05) = $0.43

Plastic Parts Cost Calculator

Included on the USB drive is a "Plastic Part Cost Calculator" that was designed to help calculate the cost of materials for 3D printed parts. The formulas are already programmed into the calculator. Input the appropriate raw material and shipping costs into the top section. The Breakdown Specifics section shows smaller increments of the actual cost of the plastic. To find the cost of a plastic part after printing, weigh the part in grams, input the number in the green box and press enter. The number that appears in the yellow box is the calculated cost of the amount of plastic used for the part.

	A	B
1	**Plastic Part Cost Calculator**	
2	**Raw Material Cost**	
3	Cost Per 5lb reel of PLA	$106.00
4	Number of reels	3
5	Number of lbs per reel	5
6	Shipping Cost	$14.62
7	Total	$332.62
8	**Breakdown Specifics**	
9	Cost per lb	$22.17
10	Grams per lb	453.592
11	Cost per gram	$0.05
12	**Part Cost Analyzer Tool**	
13	Number of grams per part	0
14	**Total cost per part**	**$0.00**
15		
16		
17	Enter number grams of PLA plastic part into the green	
18	box and hit ENTER. The amount shown in the yellow	
19	box is the extimated cost of your plastic part.	

Troubleshooting

STL File Corruption

Sometimes when printing a part the 3D printer may seem like it is malfunctioning and moving in unpredictable ways. It could have been printing the part perfectly fine for an hour or more and then start acting wildly. This is usually not a malfunction in the 3D printer, but is often the result of a corrupt STL file. If you have ever tried to slice a file and received an error code, then chances are high that you have a corrupt STL file.

STL files of a 3D model are based on ambiguous numbers that contain placements of points and lines in a digital, three dimensional environment. They operate on the vertex-to-vertex rule which creates the surface dimensions of a 3D object. If the STL file is corrupted, there could be missing information in the surface dimensions of the model. If this is true, there is a chance that when converting the STL file into a G-code file the algorithm could not accurately create the machine path for this particular object. If this happens, you will need to repair the STL file using a program like Autodesk NetFABB and re-export the new STL file before slicing it again. The repaired STL file should provide you with no error codes when slicing the file and it should print the new part with no problems.

Incorrect Design Features

Another area where people often have problems with their 3D printer is if they are trying to print an object which contains features that are extremely difficult or impossible to create using a 3D printer. This could be due to any number of factors including incorrect orientation of a part, odd shapes, gross overhangs, and tiny details that are too small for the printer to accurately create them. If having difficulties when printing an object, be sure to inspect the object and locate any features that could pose potential problems when printing. This can also be done by inspecting the part while the 3D printer is creating it. If you notice where the plastic did not create the features that were intended, you may need to make changes in the Slic3r settings or in the features of the 3D model. (See the Design Intent section of this guide for assistance ways to optimize features of the 3D model for 3D printing)

Where to go for help

One of the easiest ways to find a solution to a problem with 3D printers is to simply type in the question into a simple Google search. This should return thousands of possible websites that could offer a solution. Below are several online resources that provide a place for questions and answers to be posted.

3D Printer Blogs/Forums

http://reprap.org/wiki/Print_Troubleshooting_Pictorial_Guide

The wiki on the RepRap site provides almost all types of troubleshooting information that is related to problems with 3D printers. Here there is an extensive guide of common problems associated with 3D printers and lots of documentation about how to fix those problems.

www.3dprintingindustry.com

This website contains many news stories about 3D printing activities in the news in a variety of industries. They have tabs for education and related resources for teachers using 3D printers in their classrooms.

www.3ders.org

This website provides an extensive forum where many questions and answers about 3D printing have been posted over the past several years. There is a review section that contains product and service reviews from companies involved in 3D printing and largely encourage the online community to engage through their website with questions and comments. A good resource to for hard-to-find answers about 3D printers.

RepRap Discussion Boards

http://forums.reprap.org/index.php?173

The RepRap discussion boards contain many conversations from owners of 3D printers. To use this site, simply type the topic on which you would like to discover more information about in the search bar and review the related articles that are recovered from the search. There are lots of people who ask many different types of questions on this discussion board and can be a great resource for those who are searching for hard-to-find answers.

Project Source

If you are working on an open source project and are having difficulties with certain aspects of the project, it never hurts to reach out to the project source with your questions. Chances are that they probably encountered similar difficulties and can provide you with shortcuts to the solution or great resources to help you solve the problem. Do not be afraid to reach out to the publisher of a project.

Safety Hazards of the flexMendel

3D Printer Safety

There are several hazards that the 3D printer has that you need to be aware of. While there are several safety features built into the flexMendel's design, users should become aware of the safety hazards and use caution when operating the 3D printer.

1. *Burn Hazards -*

AB with all 3D printers, the flexMendel has components that operate at very high temperatures. The small heater block on the hotend is the most dangerous because it operates at 190° C (~400°). Touching the heater block will burn the skin INSTANTLY! DO NOT TOUCH THE HOTEND WITH ANY PART OF YOUR BODY WHILE IT IS HOT! The bed also contains a heating element but usually only heats up to 70°. It will be warm to the touch, but shouldn't be able to burn you.

2. *Pinch Points -*

The flexMendel has moving parts including the extruder and the bedplate. These components are in motion while the flexMendel is printing. Do not place your fingers and/or hands in the travel path of these components because the flexMendel has no way of detecting whether or not something is obstructing its motion path.

3. *Glass -*

The bedplate of the flexMendel is covered with a custom-cut mirror that measures 9.75" x 9.75". This is not shatterproof glass. If the machine is not properly calibrated or if someone hits the glass with a tool, it has the potential to shatter and cause increased safety hazards. DO NOT OPERATE THE flexMendel IF THE MIRRORED GLASS HAS BEEN CRACKED OR SHATTERED. You can go to Lowe's or Ace Hardware and have them cut a new piece of mirror for replacement.

4. *Electrical Shock Hazards -*

The flexMendel comes equipped with a GCFI attached to the AC wire that plugs into the wall. Theoretically, this should disconnect the flexMendel 3D printer if any circuits short out or loose connectivity. This does not mean that it will not shock someone if they are touching exposed electrical components.

Please use caution when working with electricity. If you are performing any maintenance on the electronics of the flexMendel, make sure to unplug it from the AC outlet to prevent any shocking hazards.

The heated bed runs on 120V AC electricity and is potentially the most dangerous part of the electrical system because the wires are located below the bedplate and they are constantly in motion. DO NOT REMOVE the protective wire sheath from the wires underneath the heated bedplate as they serve to protect the wires from wear and tear from rubbing on the workbench.

Beware of liquids around the flexMendel 3D printer. The machine is NOT waterproof. If liquids are spilled on the RAMPs controller, power supply, or any other electrical connections there is a high risk of shock hazard and the potential of ruining that particular component. Please do not have liquids of any kind around the flexMendel 3D printer in order to reduce the potential of accidentally spilling liquids onto the electronics.

5. *Razor Scraper -*

The razor scraper used to clean off the bedplate is sharp and can cause lacerations to flesh if not used correctly. USE CAUTION WHEN HANDLING THE RAZOR SCRAPER.

6. *Hazardous Materials and Off-Gassing Fumes -*

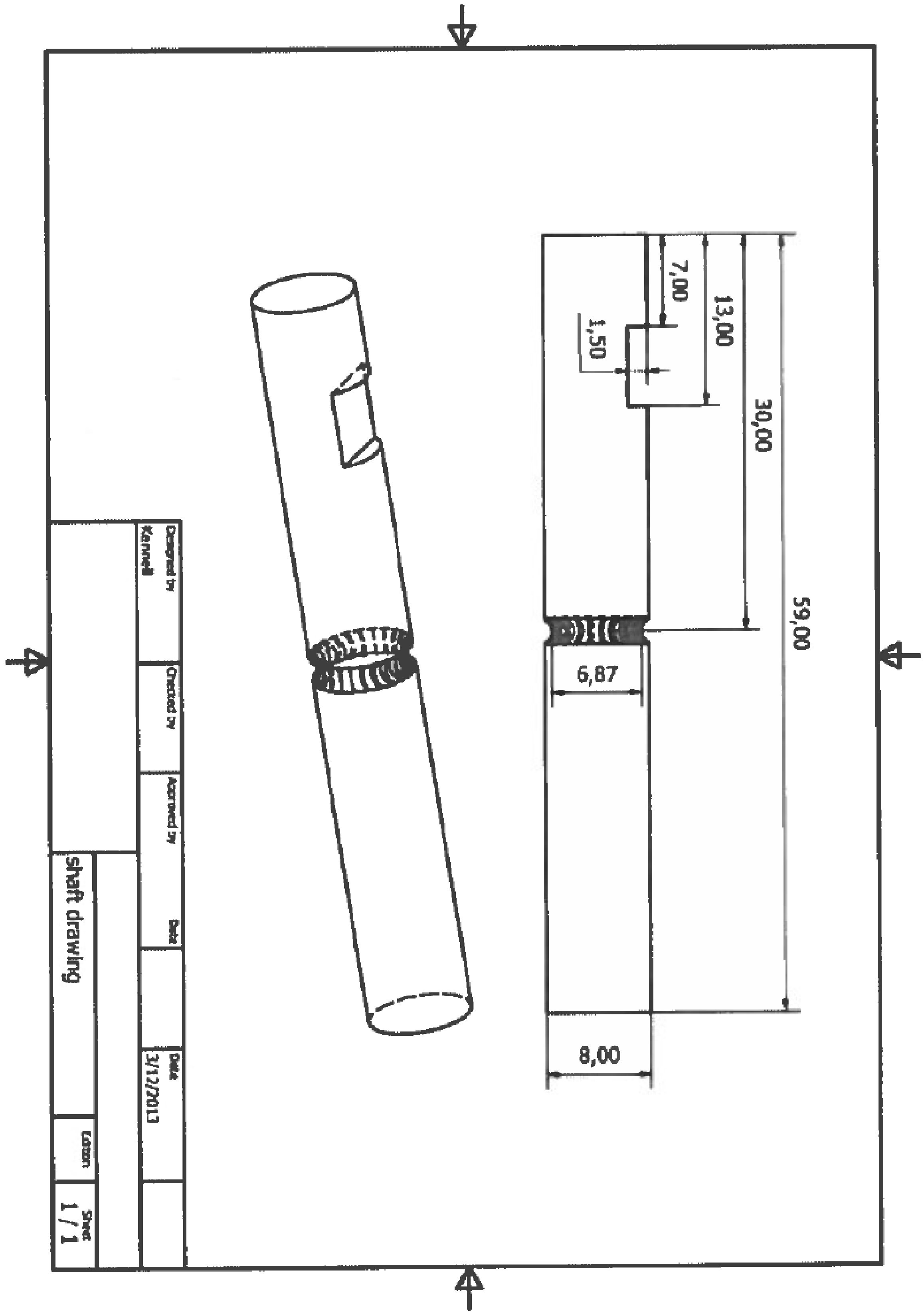
If using materials other than PLA, be cognitive of the potential fumes that off-gas while printing. If not ventilated properly, these fumes can cause headaches and nausea to those people with extended exposure.

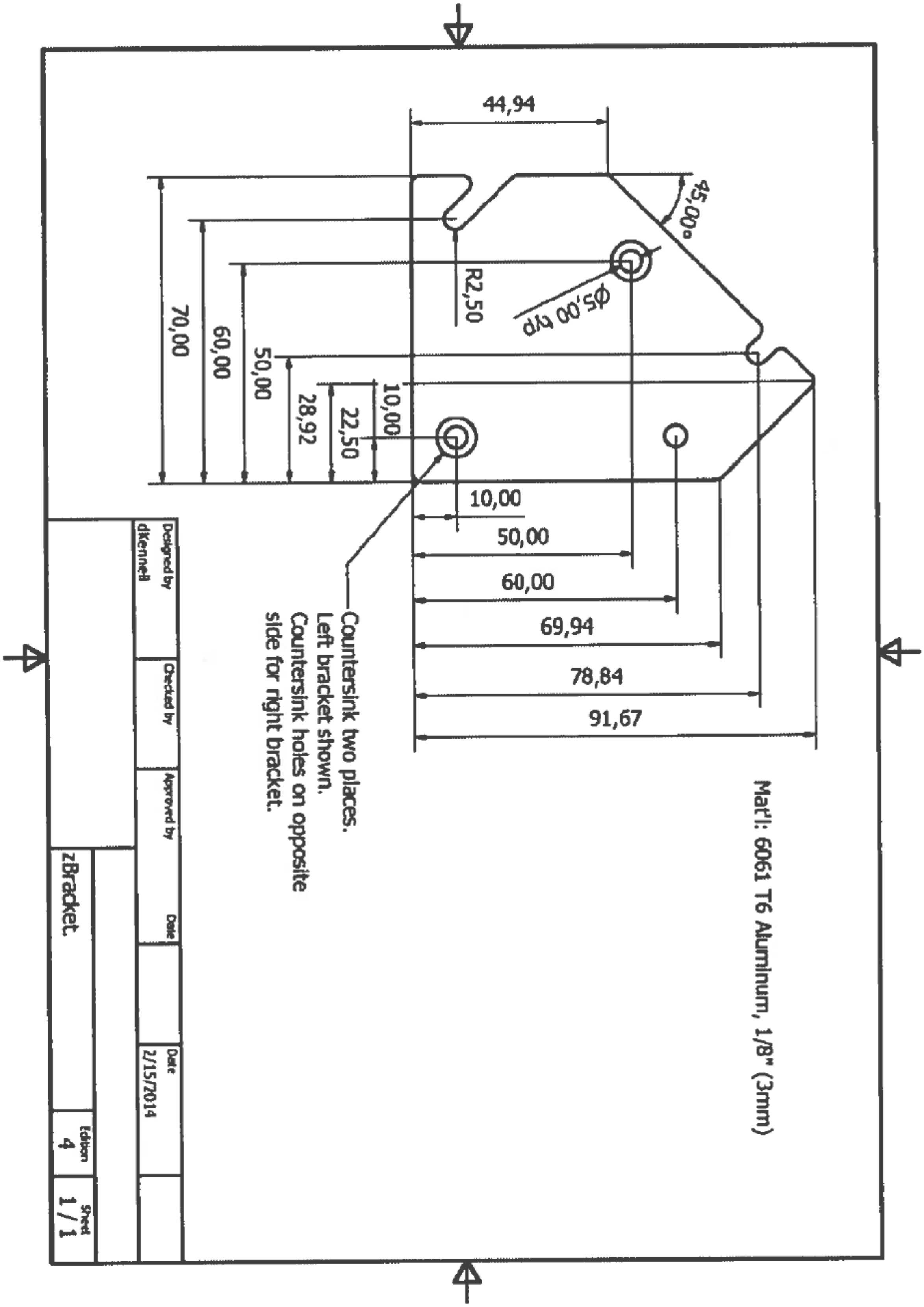
7. *WEAR SAFETY GLASSES!!!*

Your eyes are one of the most precious organs in the human body. It only takes a split second for a flying particle to damage your eyes permanently if the user neglected to wear safety glasses.

Users of the flexMendel 3D printer are encouraged to wear safety glasses at all times when using the machine or any types of projects that involve 3D printed parts, electronics, and hazardous tools.

Blueprints of Machined Parts




44,94
45,00°
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50,00
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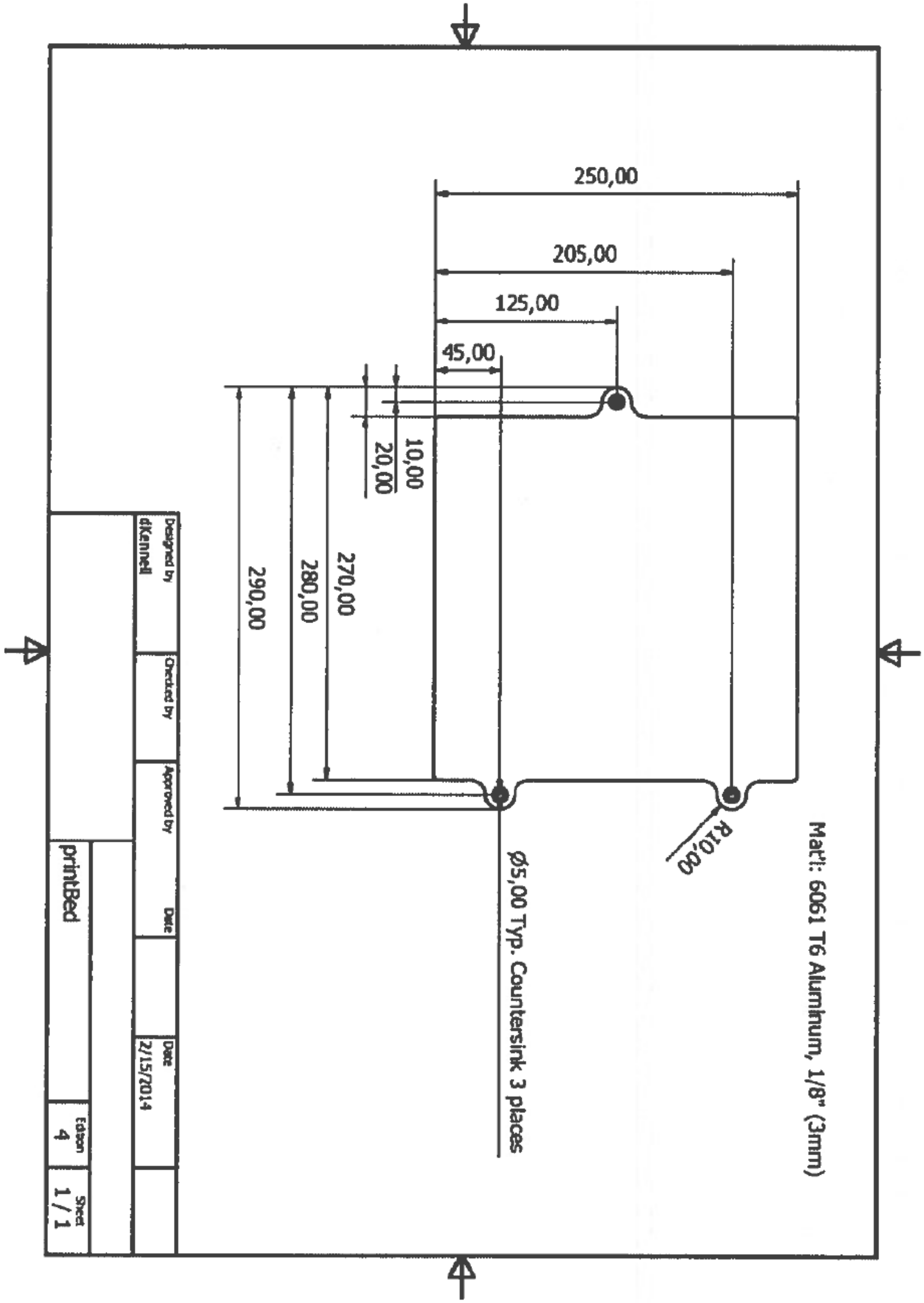
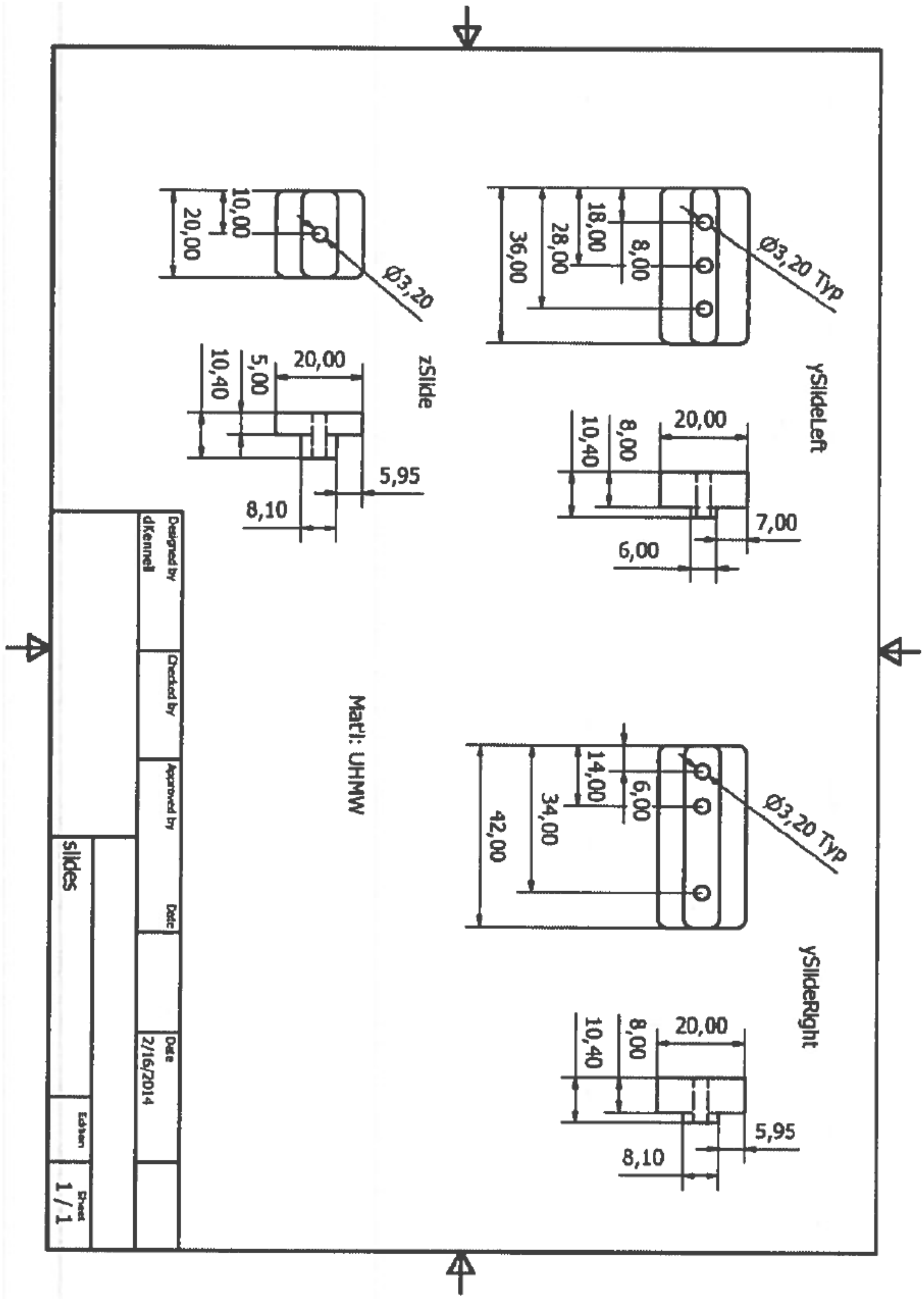
69,94
78,84
91,67
Countersink two places.
Left bracket shown.
Countersink holes on opposite
side for right bracket.
Mat'l: 6061 T6 Aluminum, 1/8" (3mm)
Designed by
dkennell
Checked by
Approved by
Date
Date
2/15/2014
zBracket.
Edition
4
Sheet
1 / 1

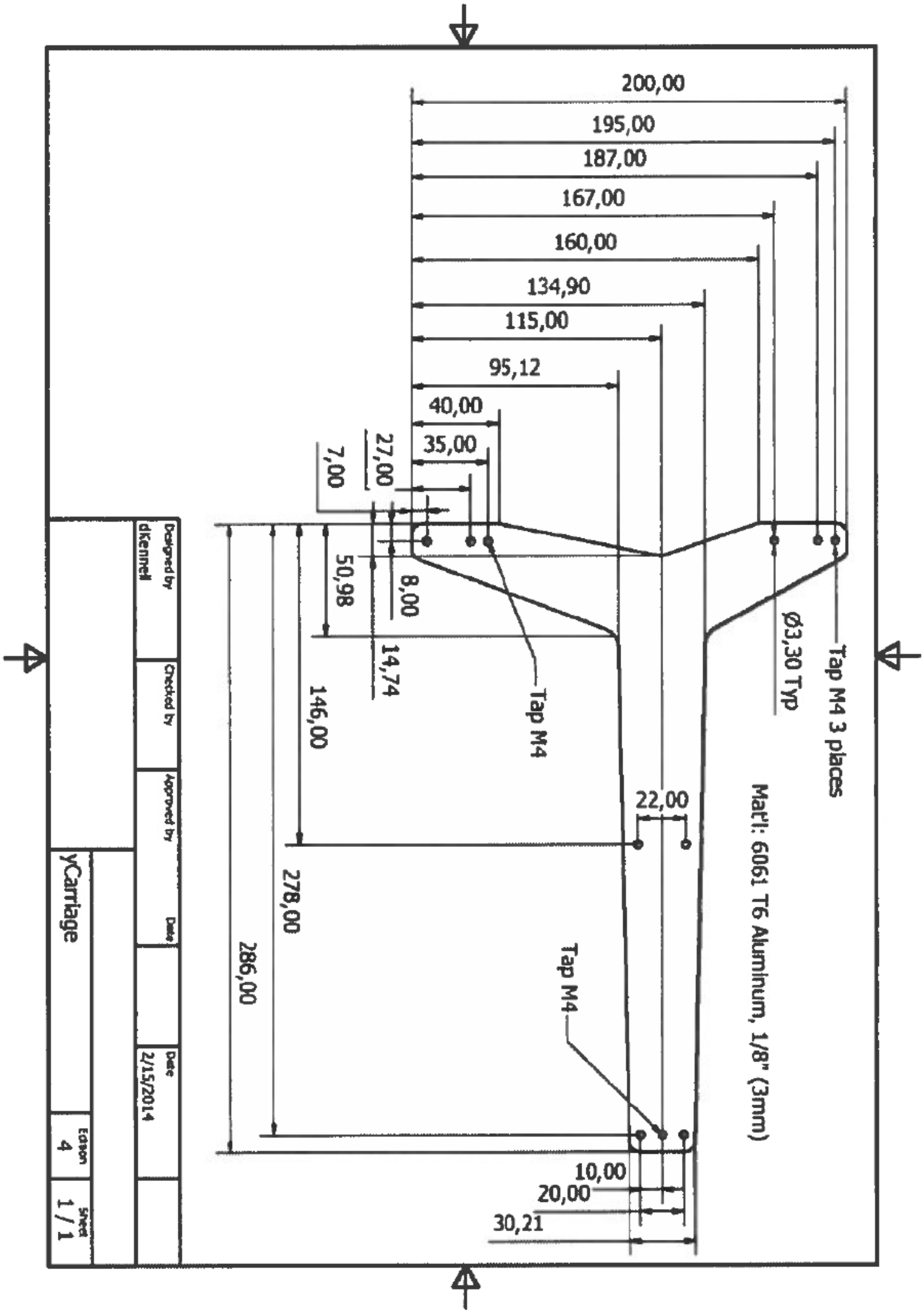
Blueprints of Machined Parts



Blueprints of Machined Parts



Blueprints of Machined Parts



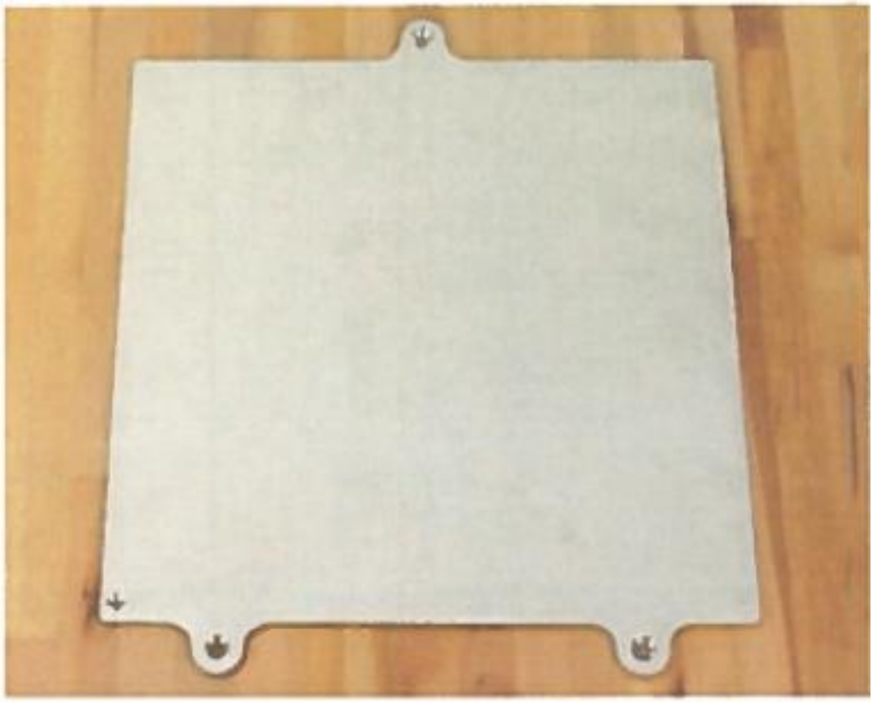
Files on the USB Drive

1. 3D Literacy Essentials
2. Master flexMendel 3D Printed Parts
3. flexMendel firmware file
4. PDF drawings
5. S1ic3r files
6. 3DP Inventory Check List
7. Concept to Reality Process – Short
8. flexMendel BOM Calculator
9. Plastic Part Cost Calculator
10. Printed Part Cost Information

flexMendel Part Identification Key

Custom Aluminum Parts:

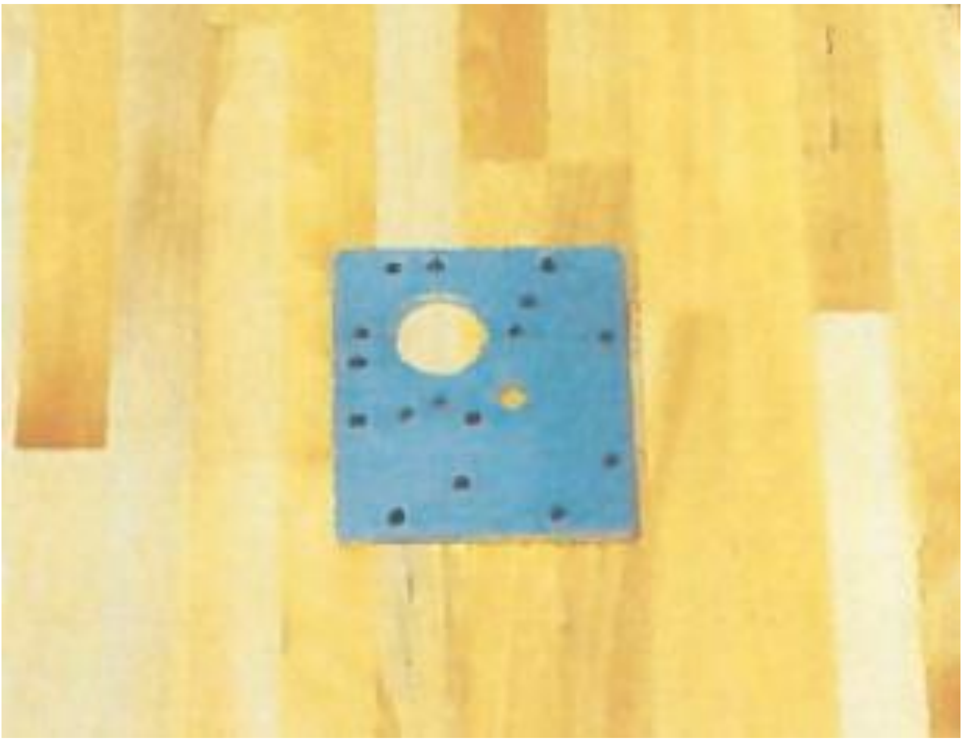
Bed Plate



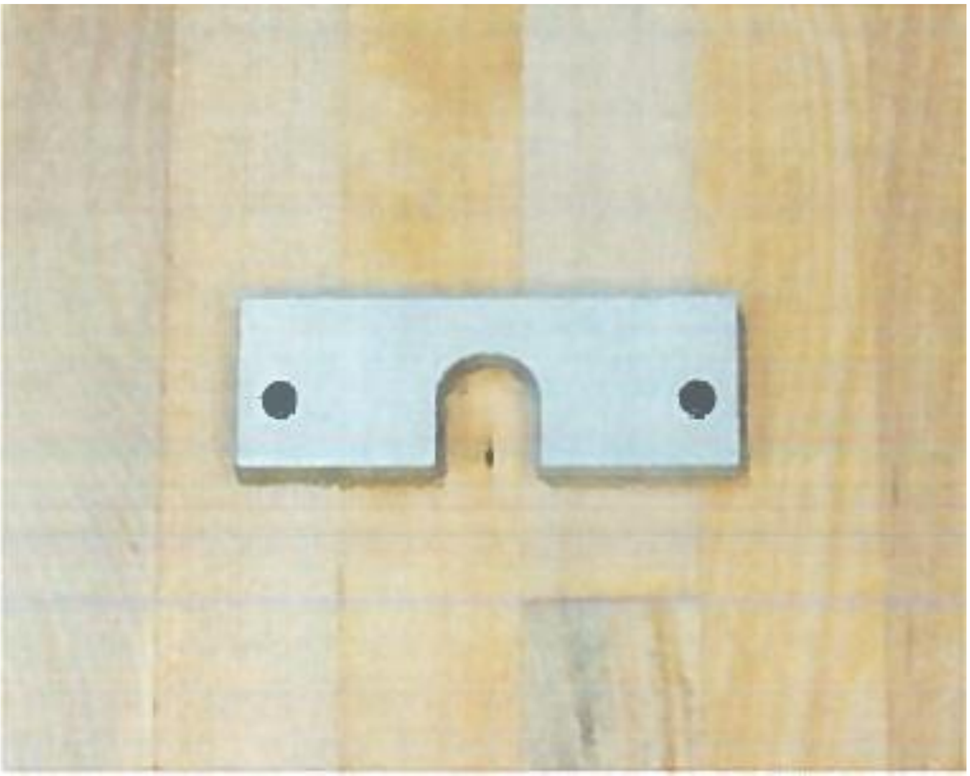
Electronics Tray

Custom Aluminum Parts:

Extruder Plate

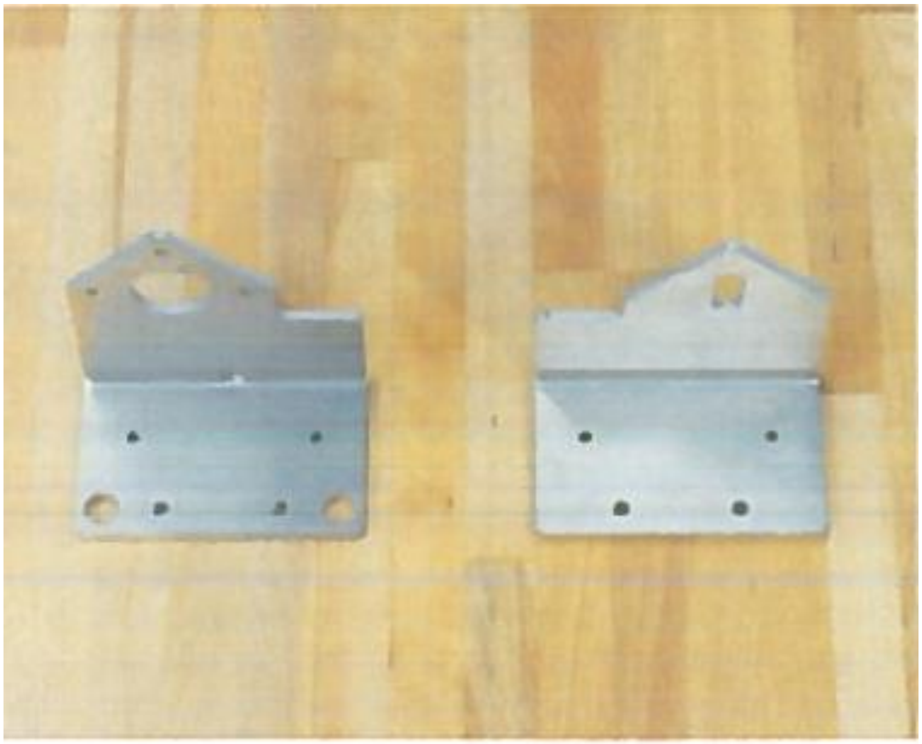


Hotend Plate

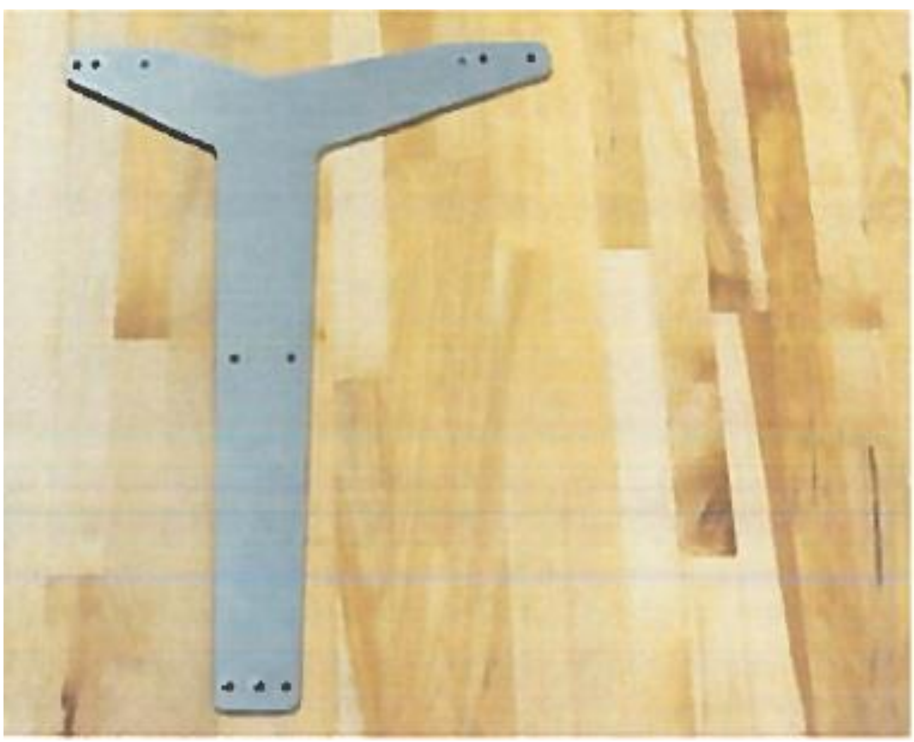


Custom Aluminum Parts:

X Carriage Plates (Motor and Idler)

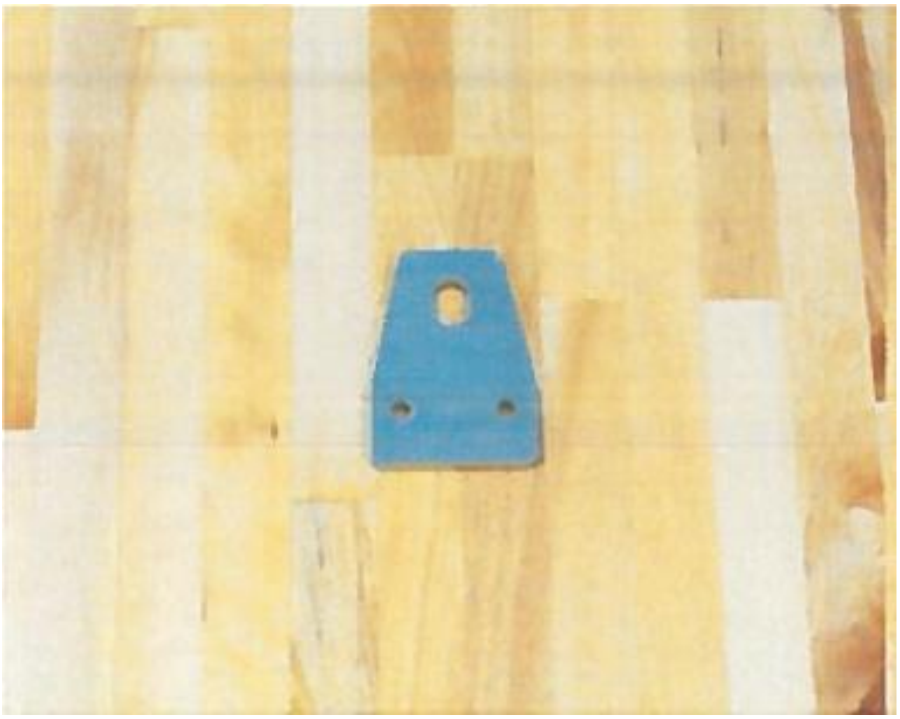


Y Carriage

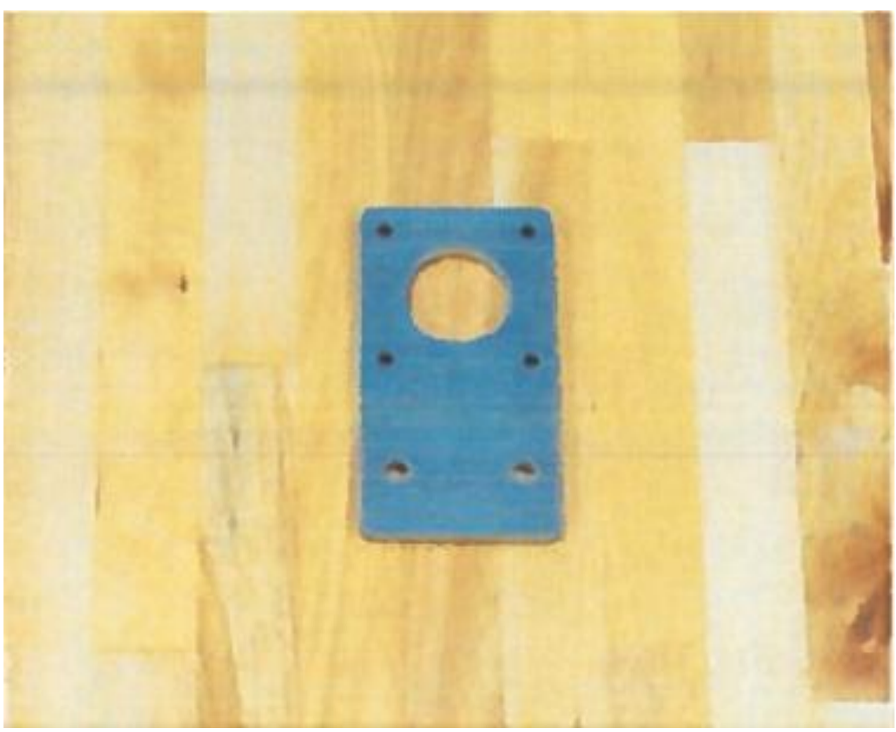


Custom Aluminum Parts:

Y Idler Bracket

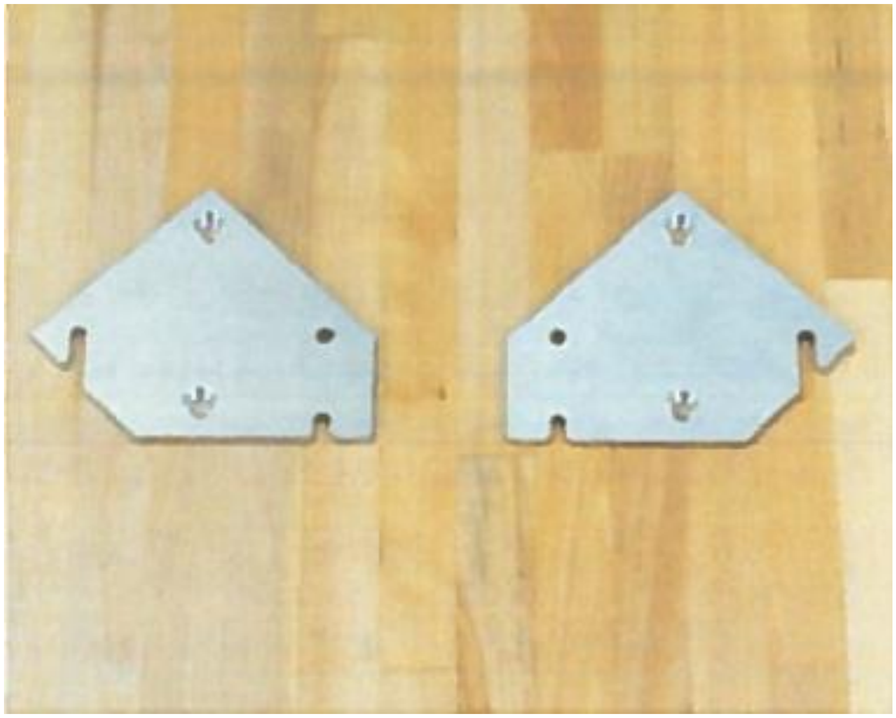


Y Motor Bracket

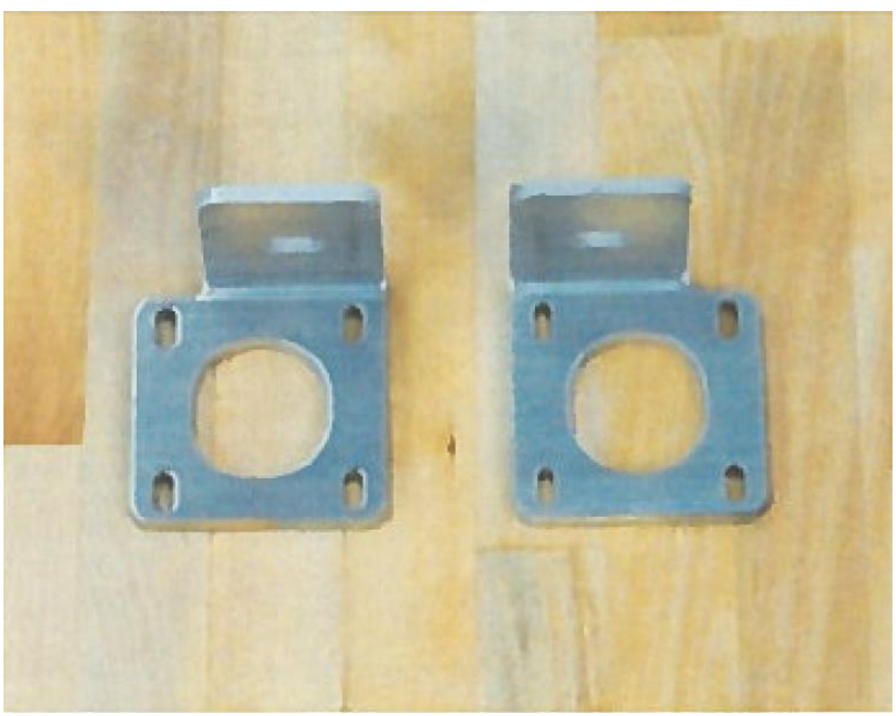


Custom Aluminum Parts:

Z Brackets

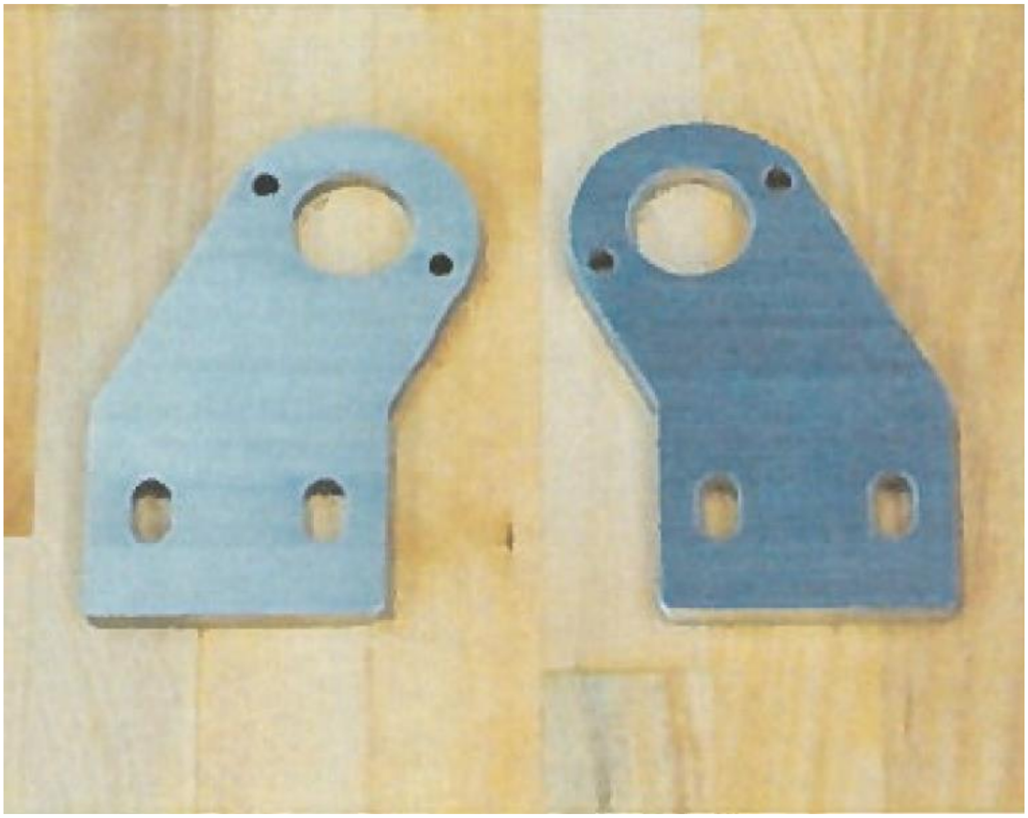


Z Motor Brackets (Left and Right)



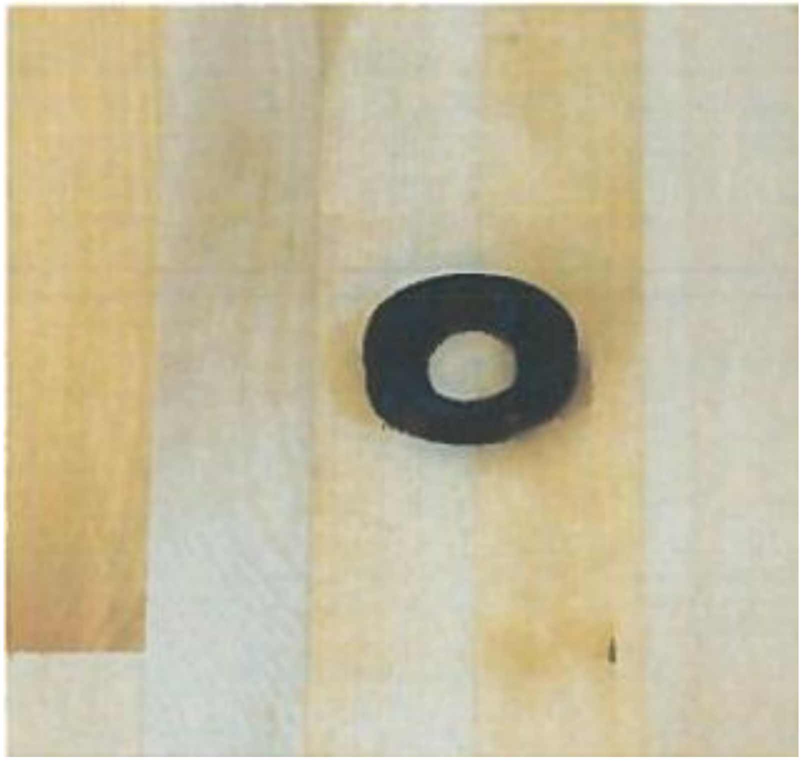
Custom Aluminum Parts:

Z Motor Brackets (Left and Right)

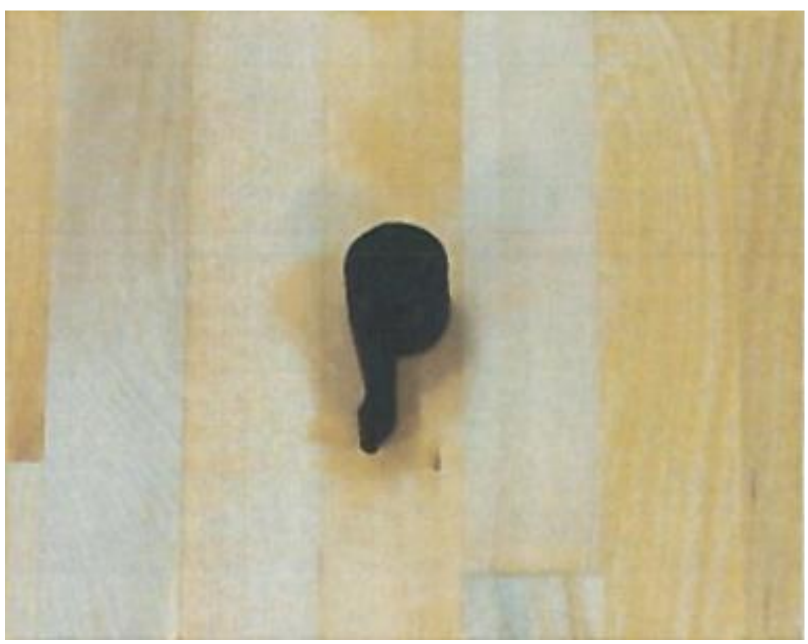


3D Printed Parts: Extruder

Bearing Circle

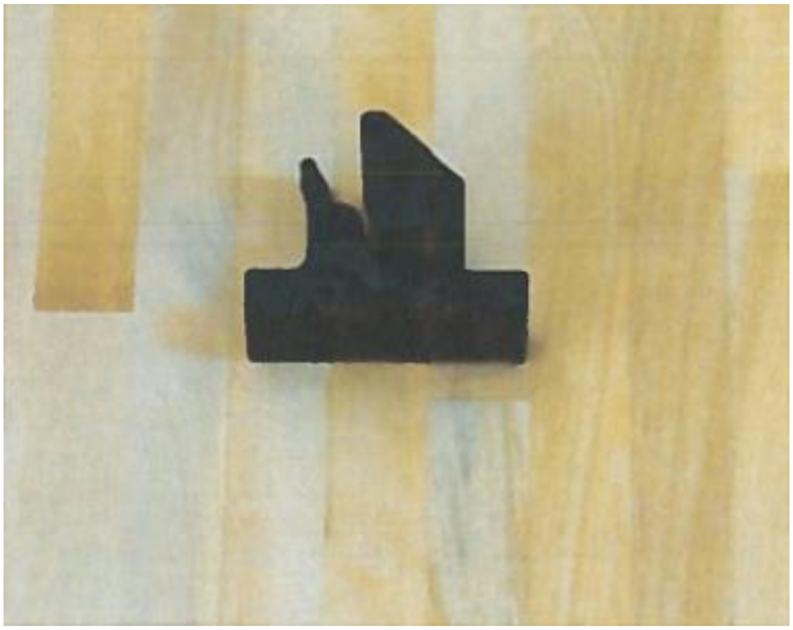


Cam



3D Printed Parts: Extruder

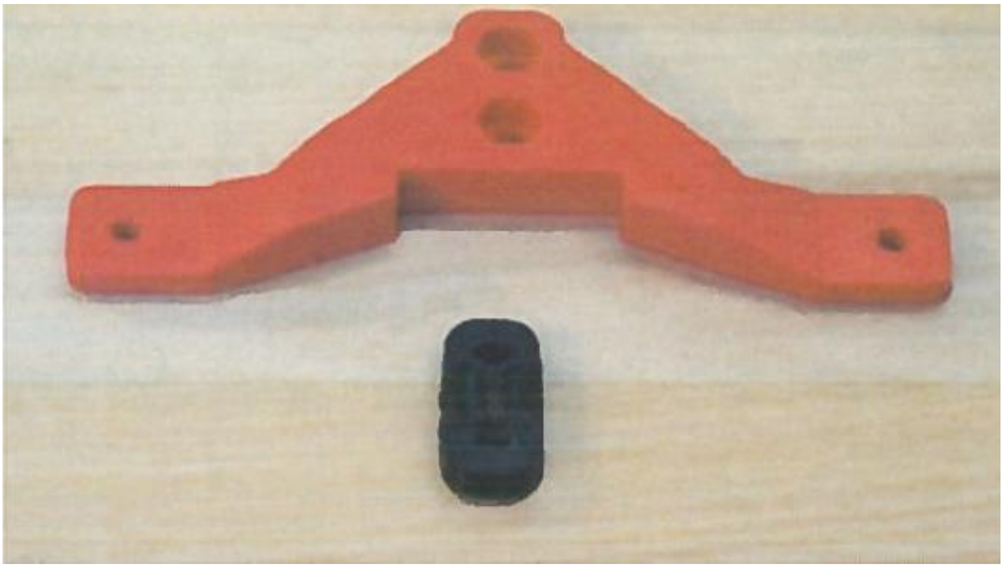
Pinch Lever and Extruder Front



Gearbox6

3D Printed Parts: Extruder

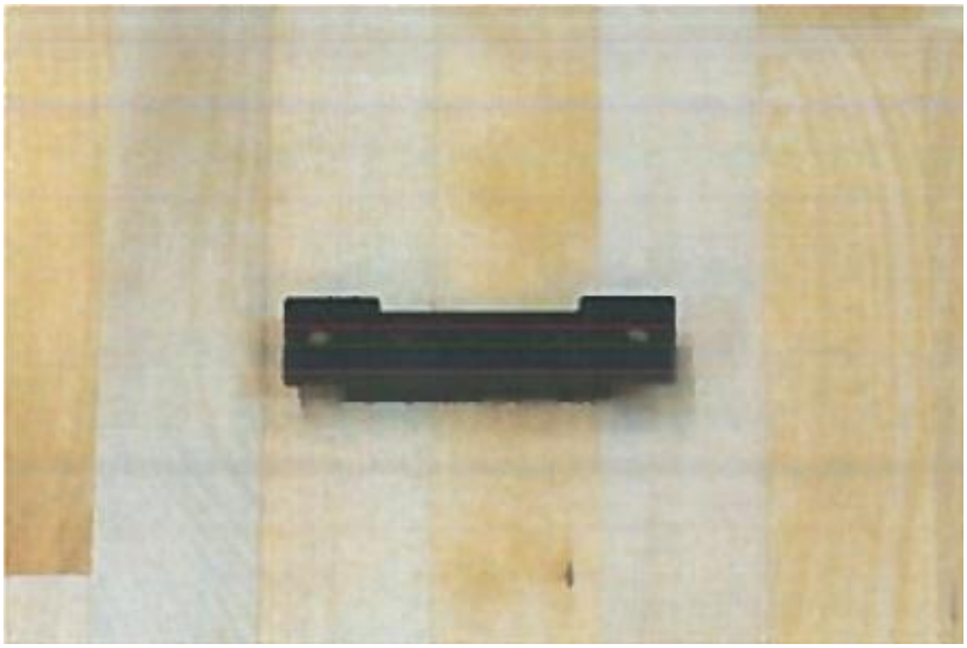
X Belt Bracket and Clamp



X Carriage V2

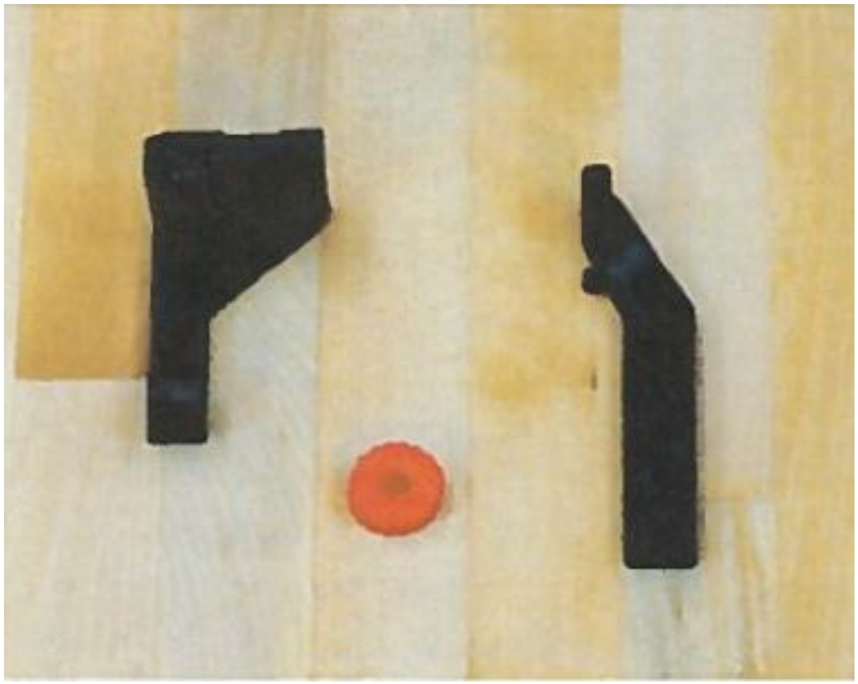
3D Printed Parts: Extruder

Connector Bracket

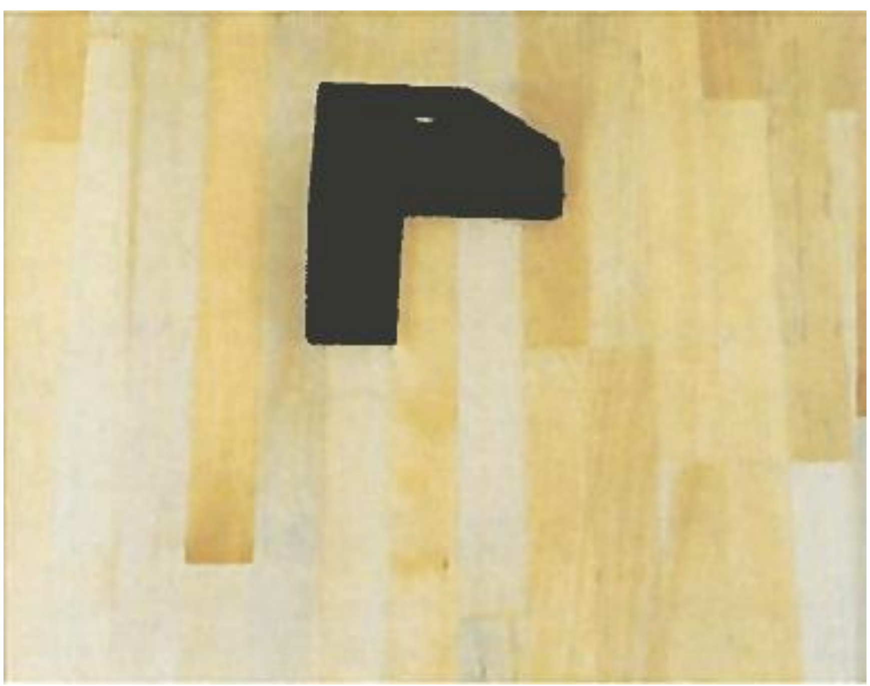


3D Printed Parts: flexMendel

Adj. Z Limit Switch and knobTiny

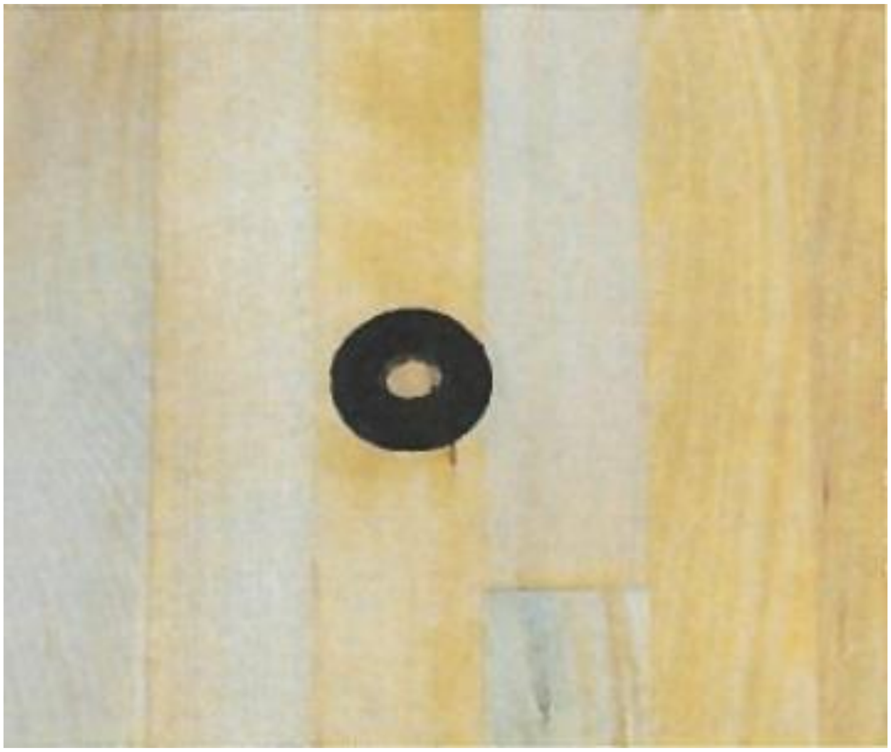


Foot

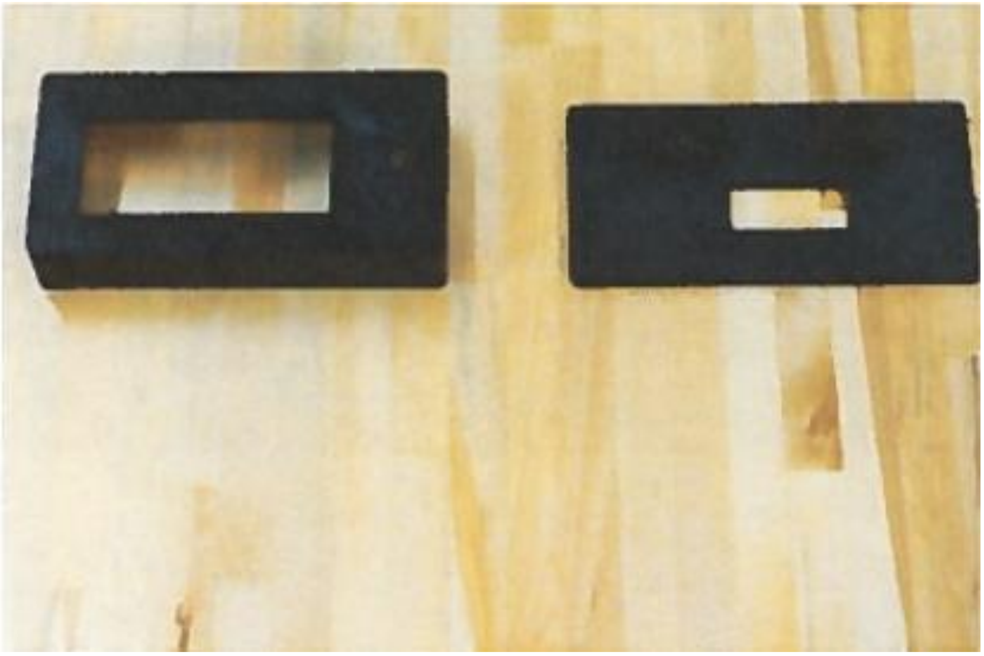


3D Printed Parts: flexMendel

Idler Washer

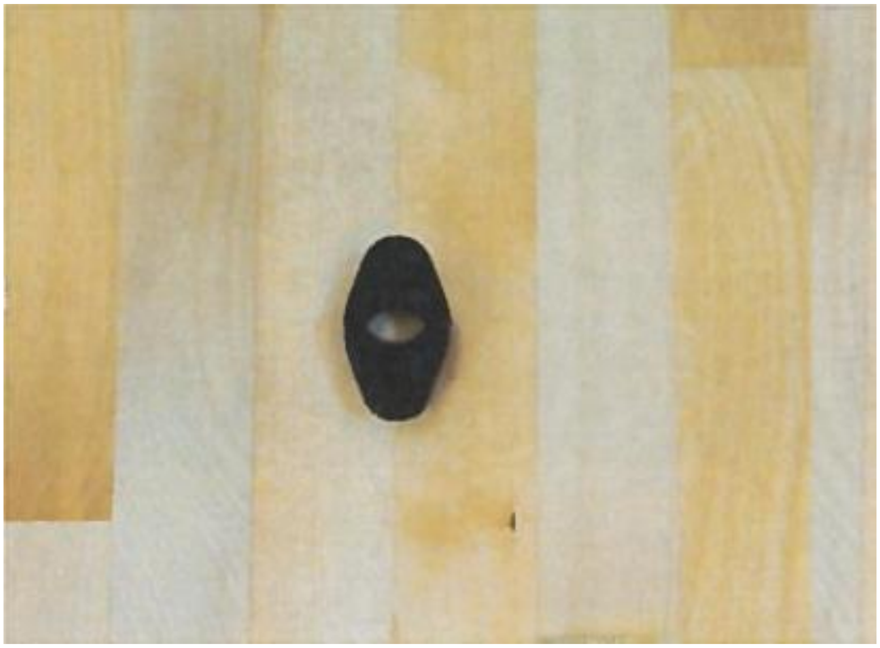


LCD Panel Front and Back



3D Printed Parts: flexMendel

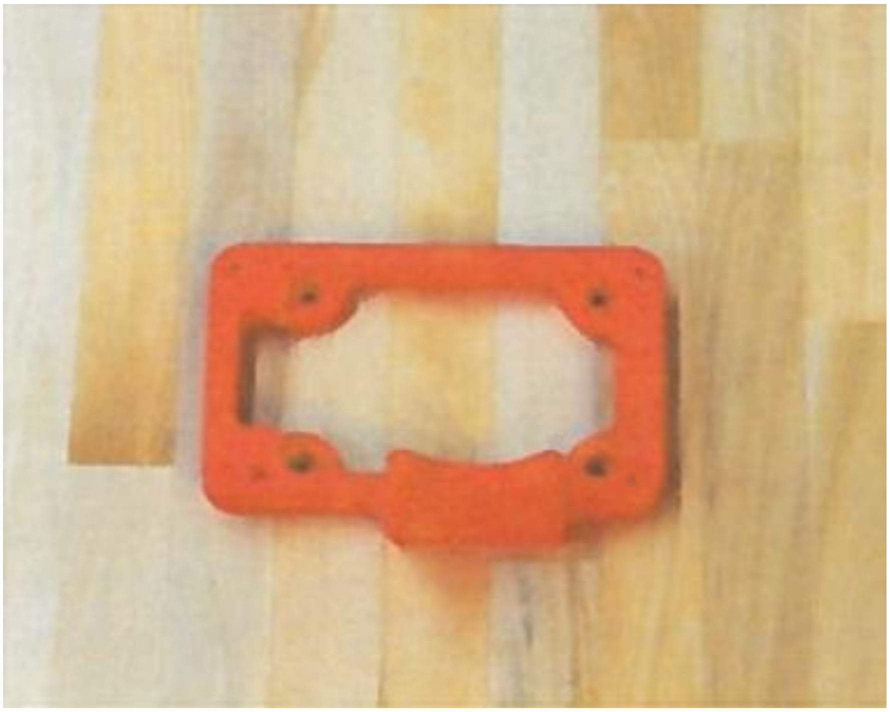
Nut Cap



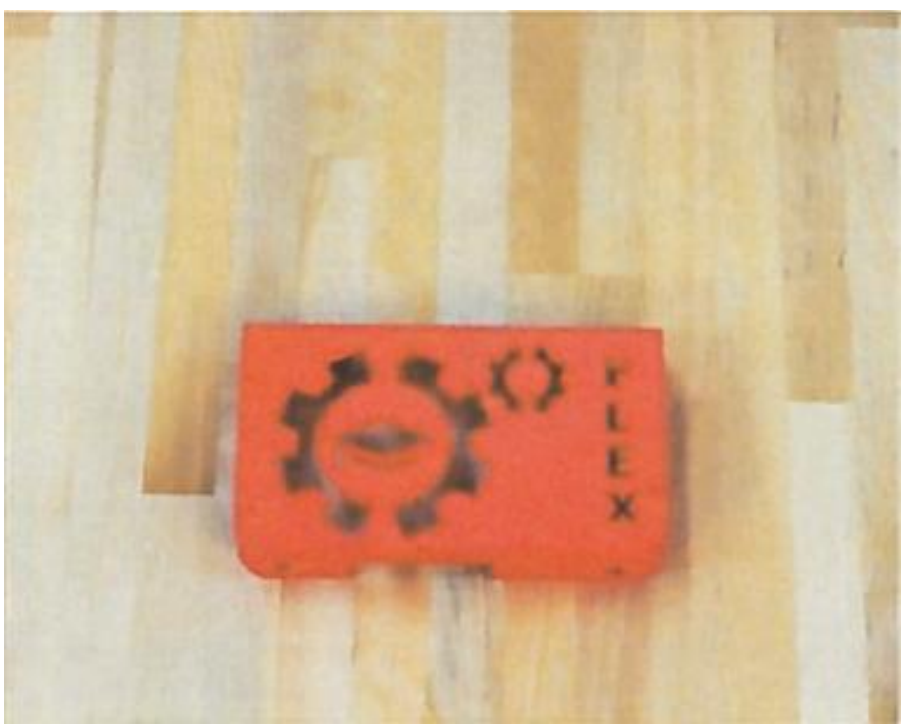
OSC Knob

3D Printed Parts: flexMendel

RAMPs Bracket

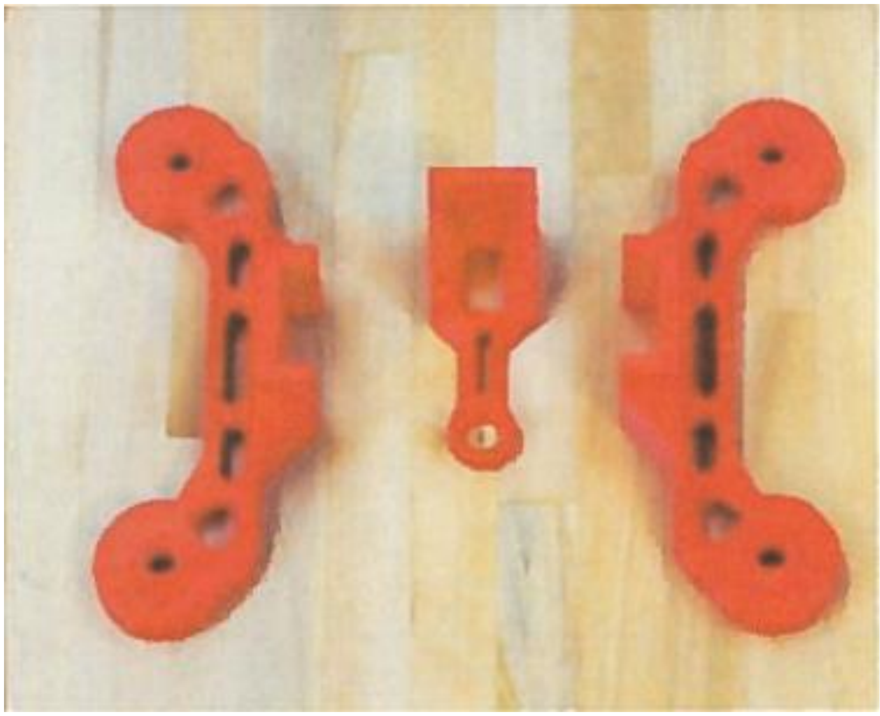


RAMPs Cover



3D Printed Parts: flexMendel

Reel Holder and Filament Guide

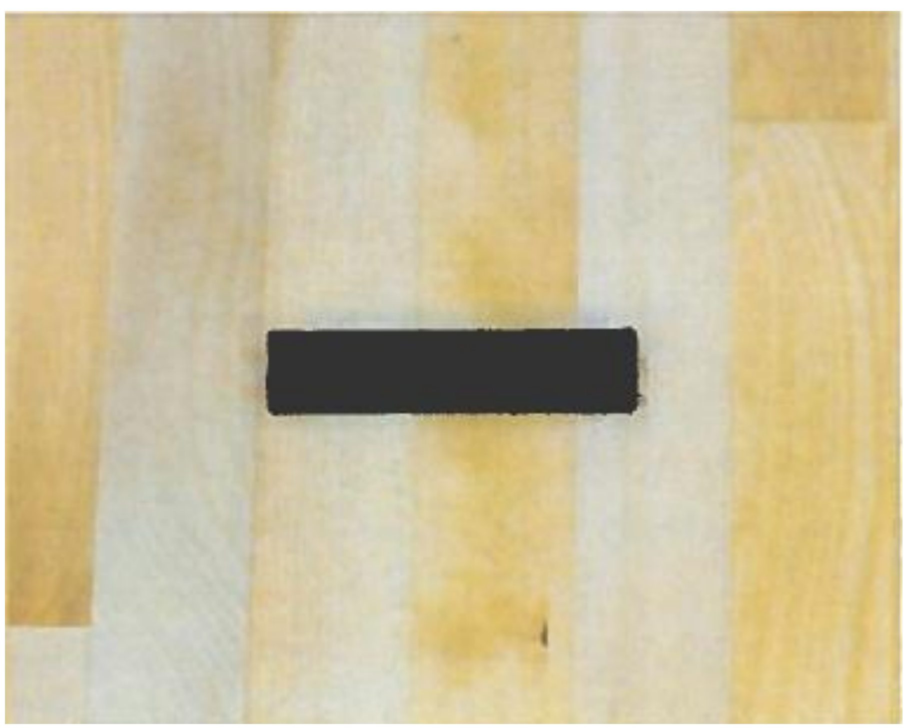


Smooth Rod Lock

3D Printed Parts: flexMendel

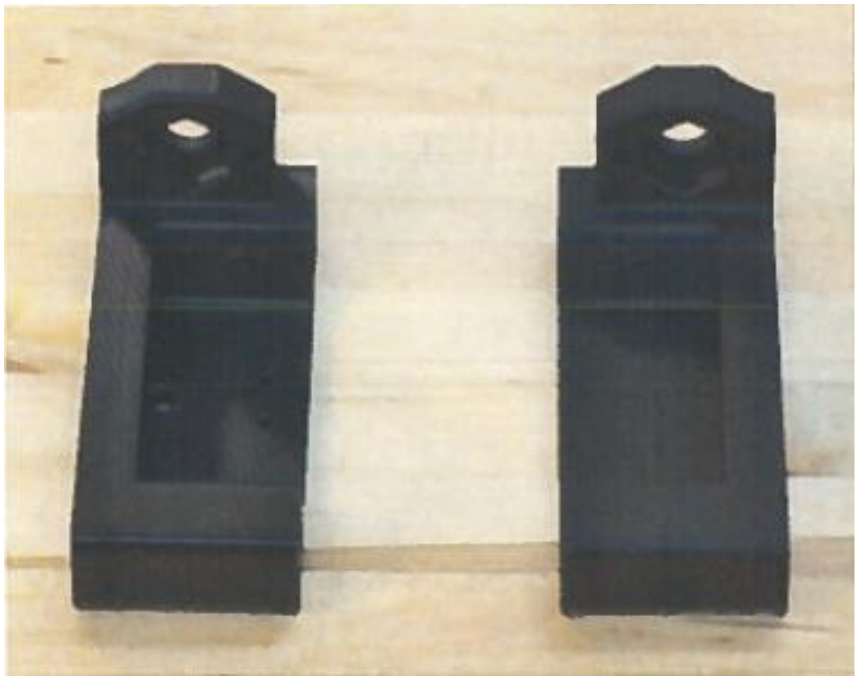
Solid State Relay Bracket

T-Slot Cover

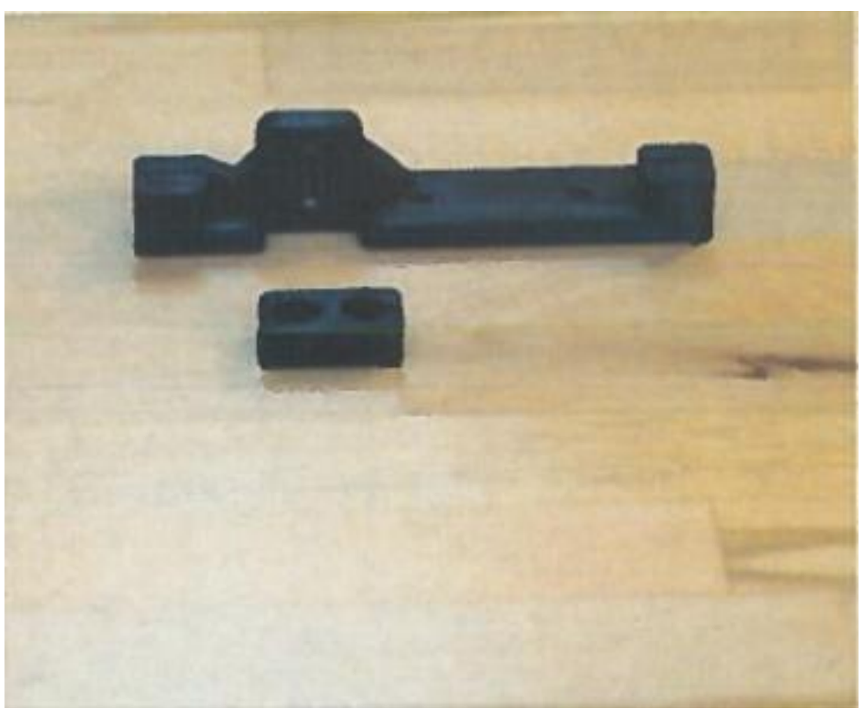


3D Printed Parts: flexMendel

xRodSupport Motor and Idler

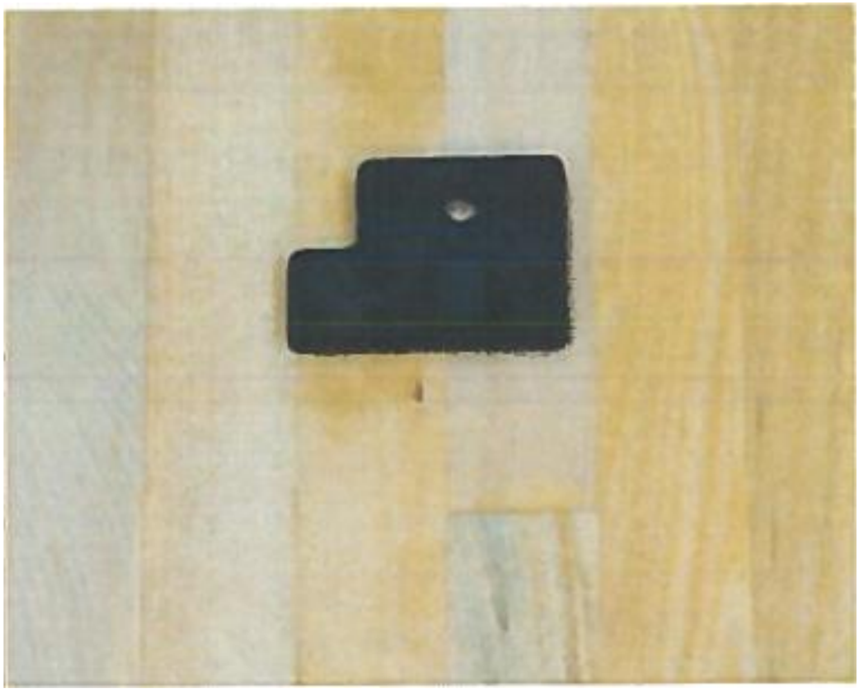


Y belt Bracket and Y Belt Clamp

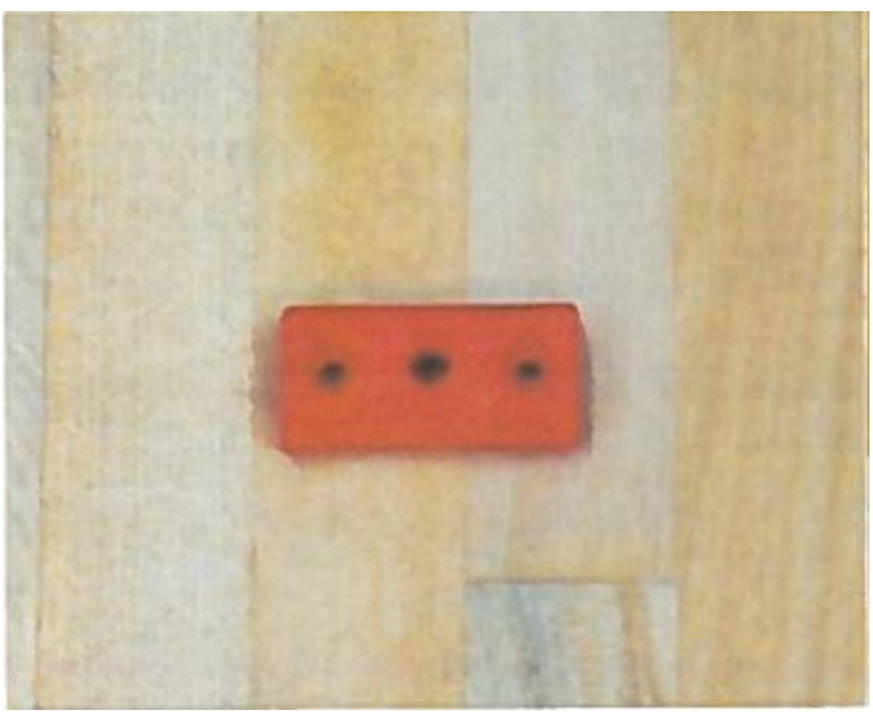


3D Printed Parts: flexMendel

Y Limit Switch Bracket



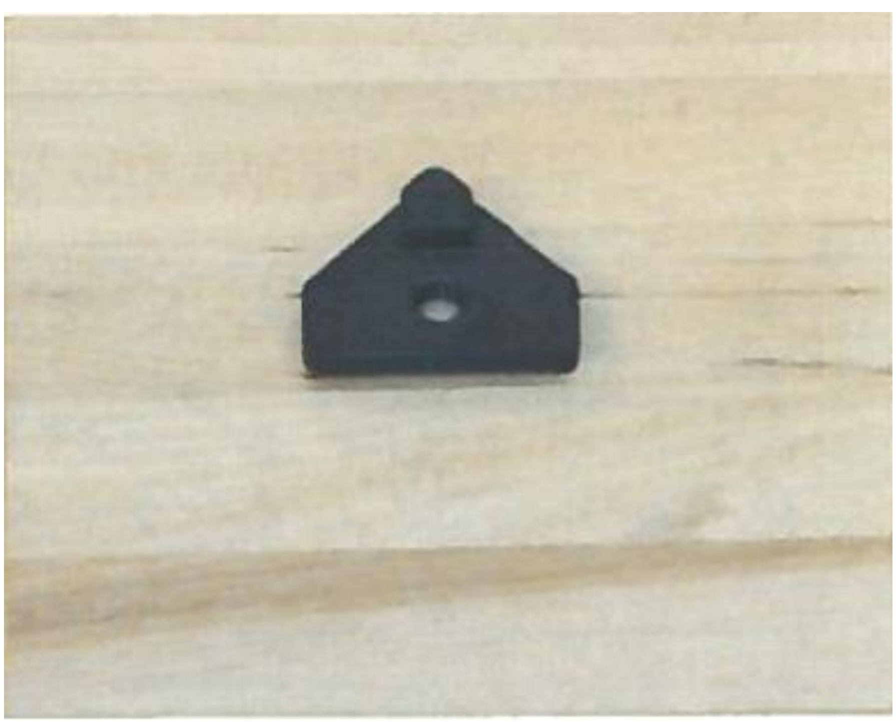
Y Slide Retainer



3D Printed Parts: flexMendel

Z Bearing Housing

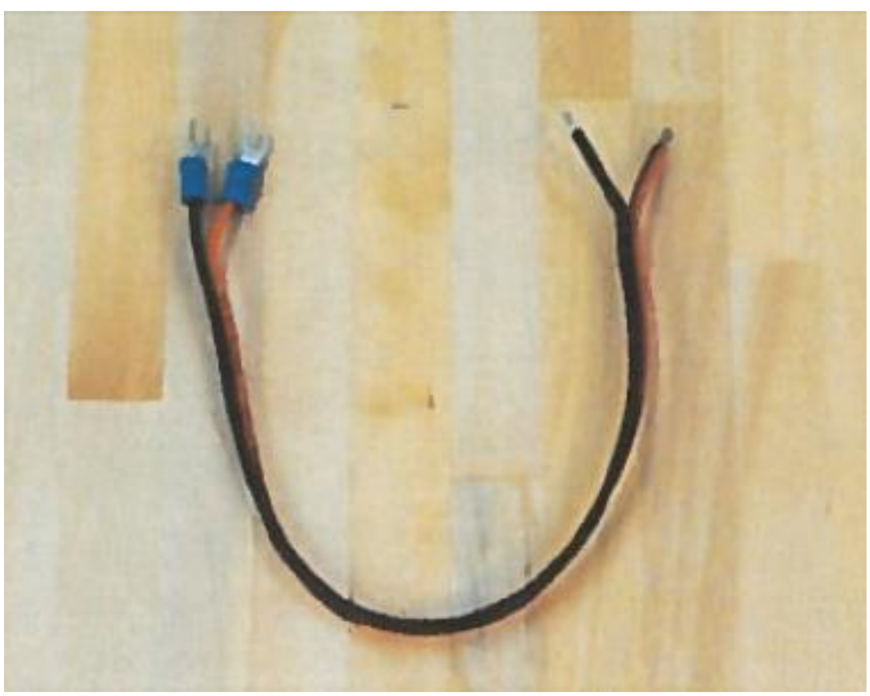
Z Locator Bracket



Wire Kit:

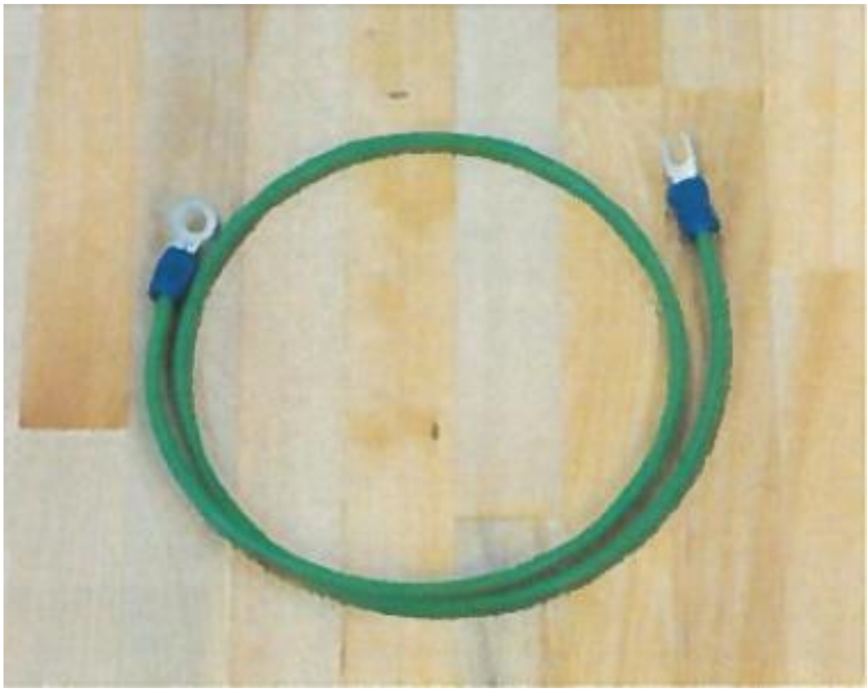
AC Power Switch Wire

AC SS Relay Wire

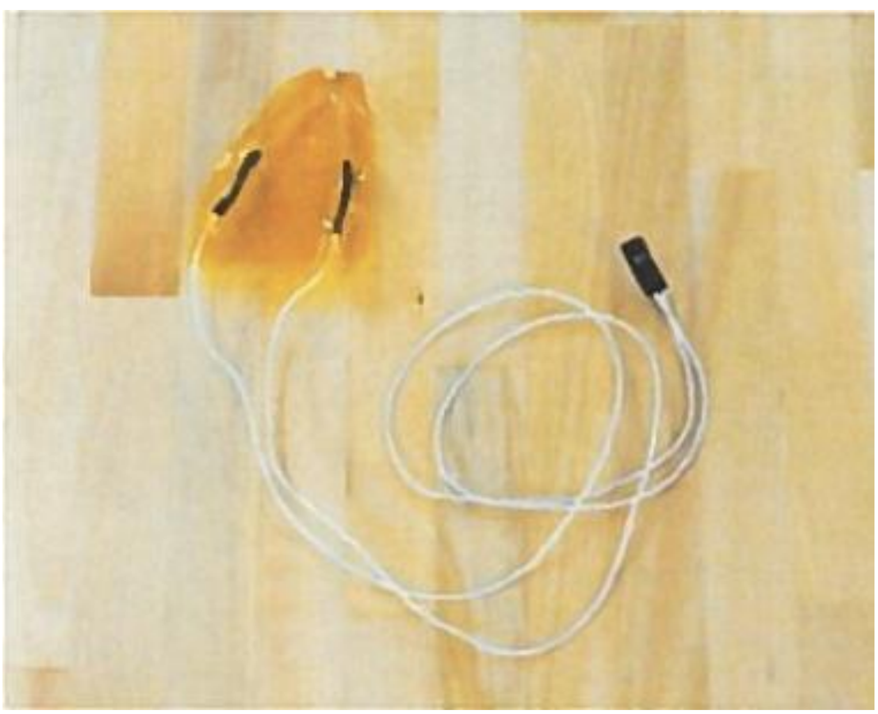


Wire Kit:

Bed Grounding Wire

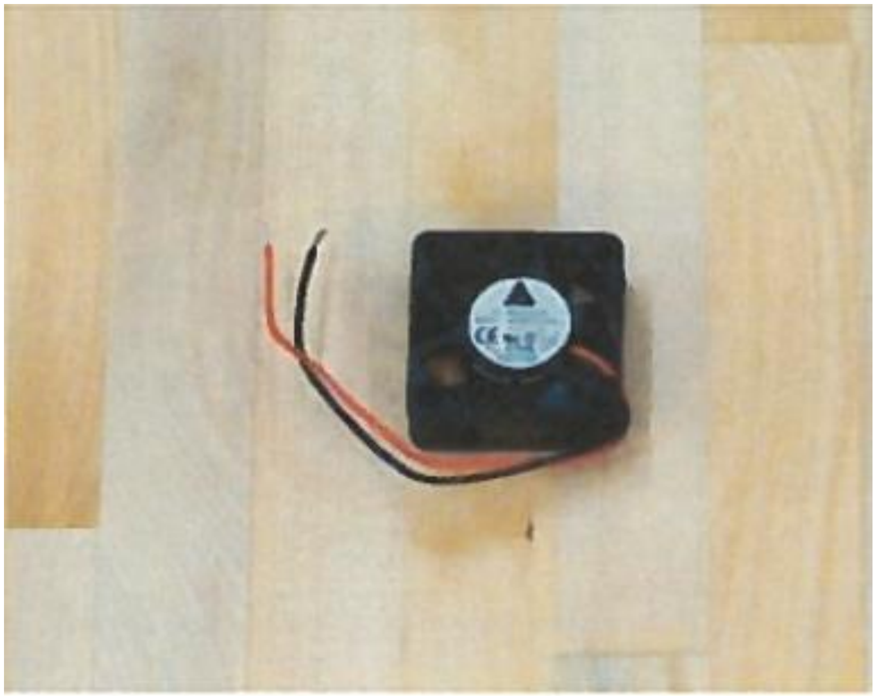


Bed Thermistor Wire

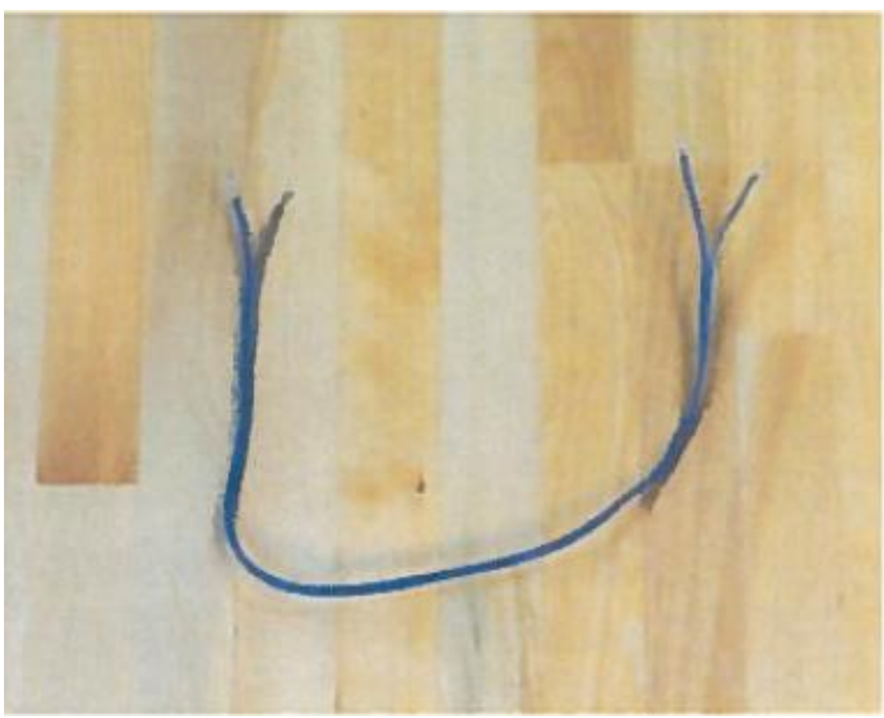


Wire Kit:

30mm Box Fan

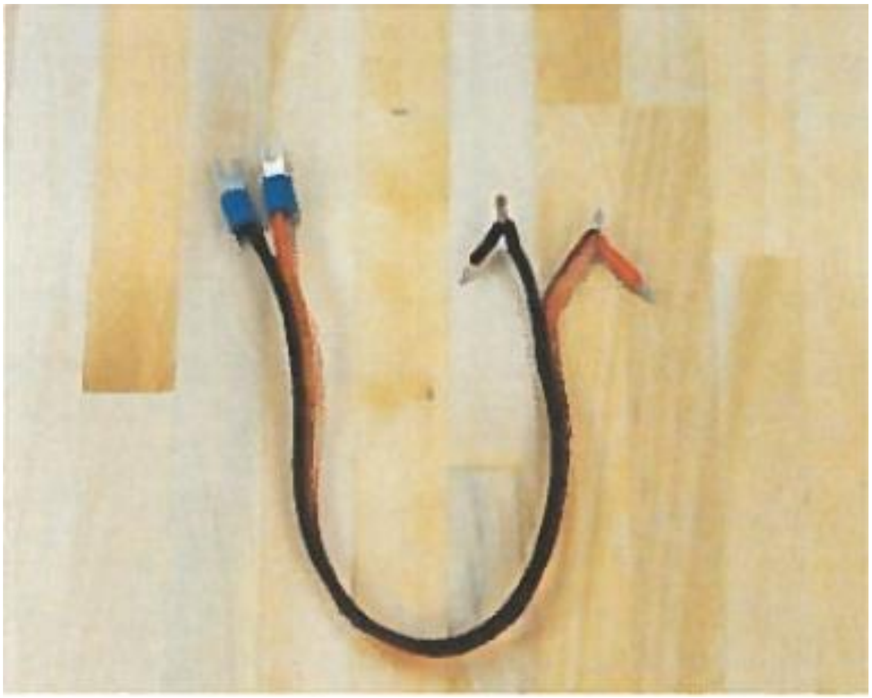


DC Bed Heater Control Wire



Wire Kit:

DC to RAMPs Power Wire

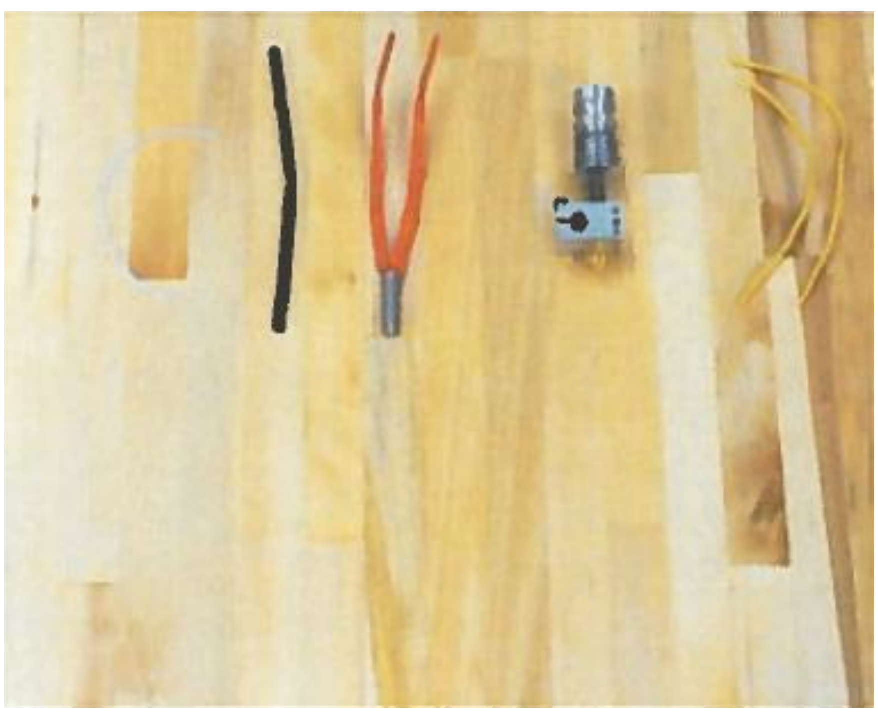


CGFI AC Wall Plug

Wire Kit:

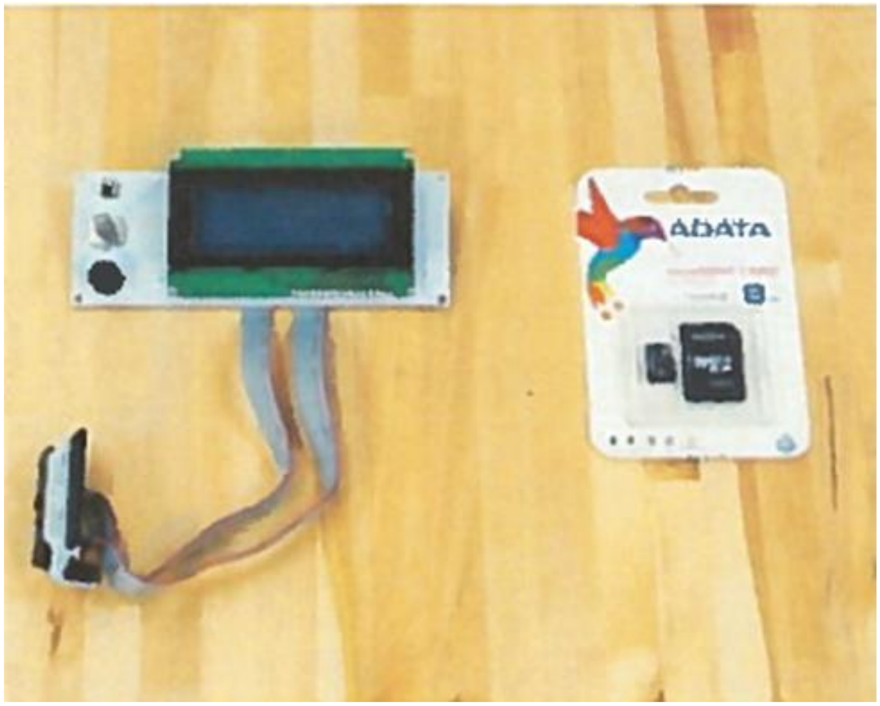
Heat Pad

Hot End Kit

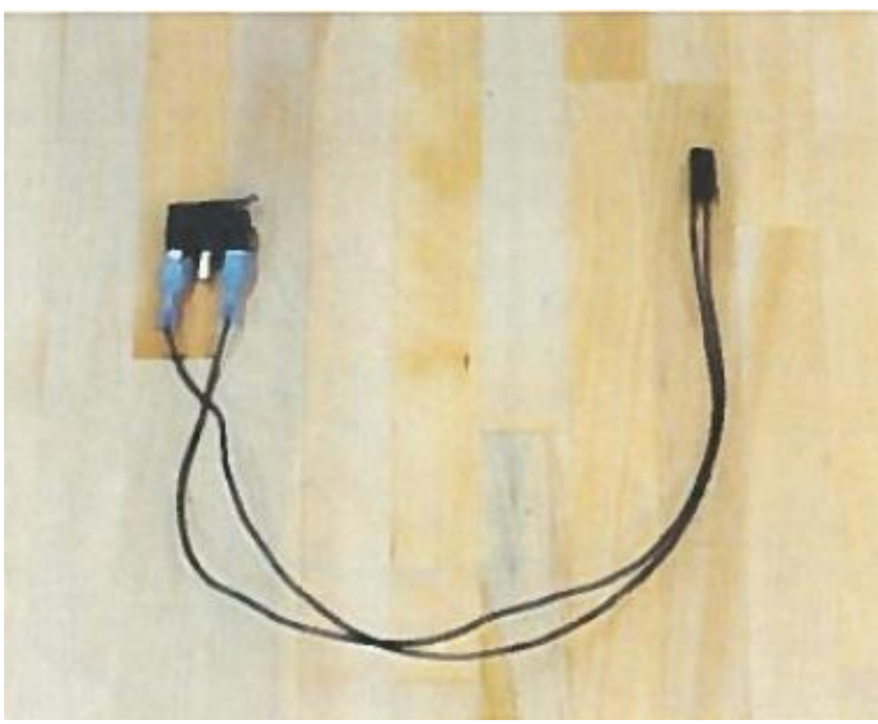


Wire Kit:

LCD Smart Controler

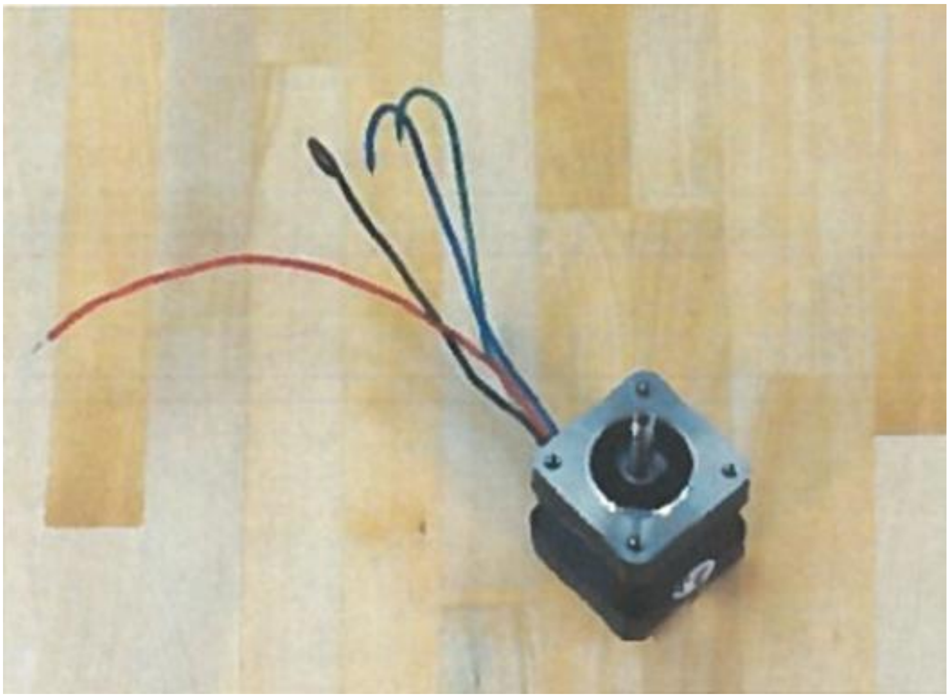


Limit Switch

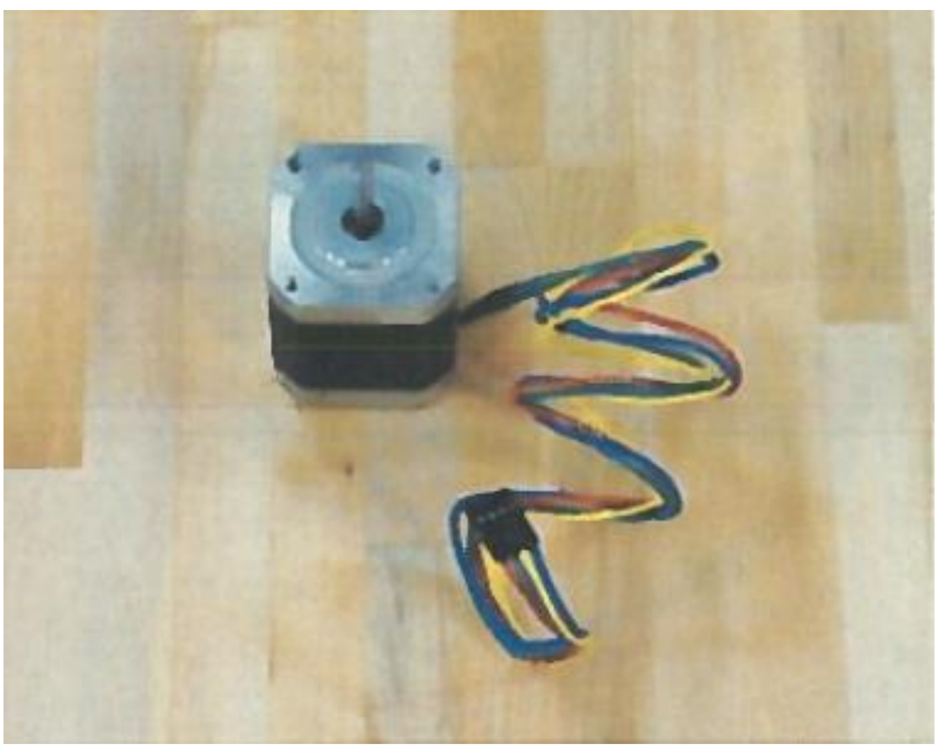


Wire Kit:

NEMA 14 Stepper Motor (Ext)

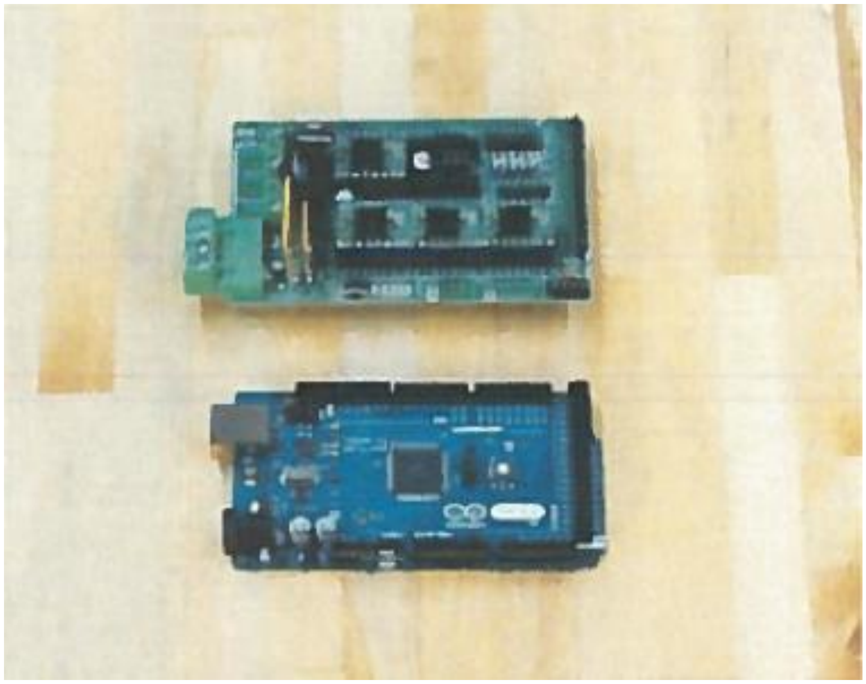


NEMA 17 Stepper Motor (X,Y,LZ,RZ)

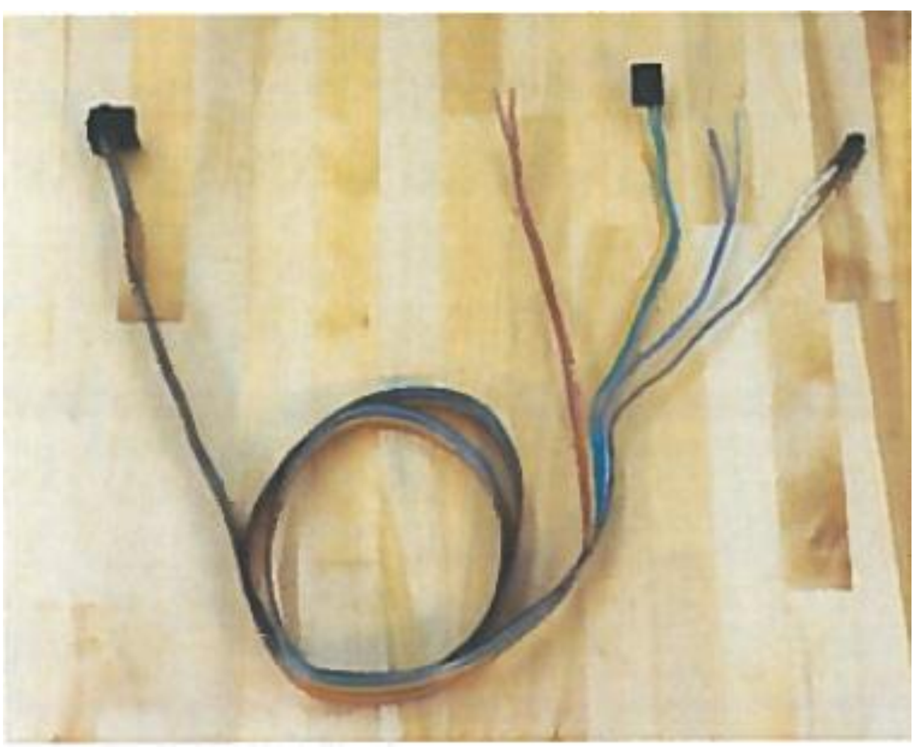


Wire Kit:

RAMPs Shield/Arduino



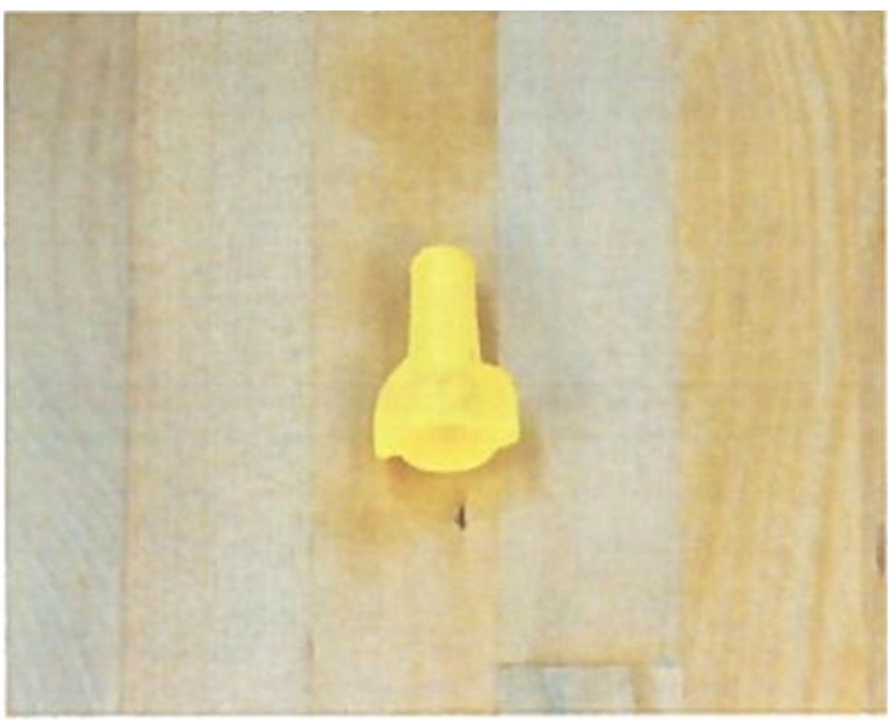
Ribbon Cable



Wire Kit:

Wire Sheaths

Yellow Wire Nut



Wire Kit:

Zip Ties (small and large)