Rotary 3D Printer: Additive Lathe

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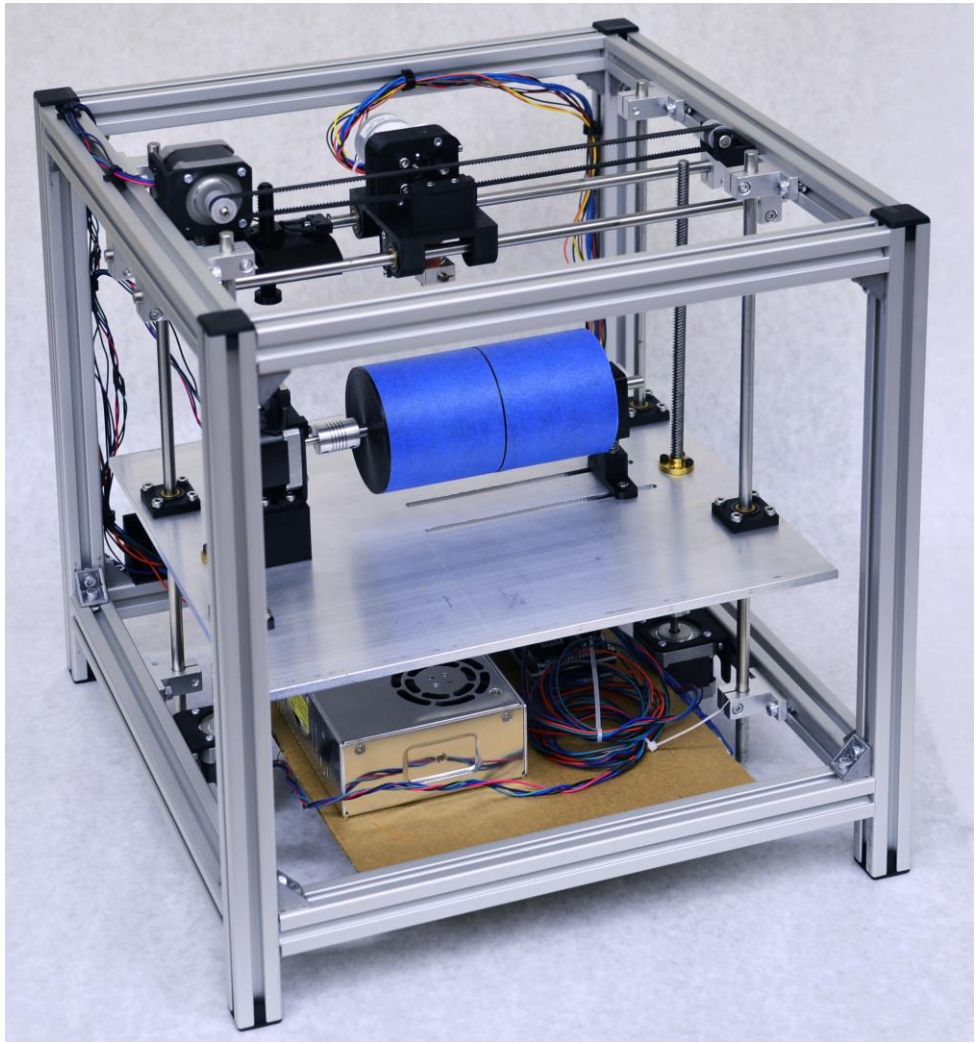
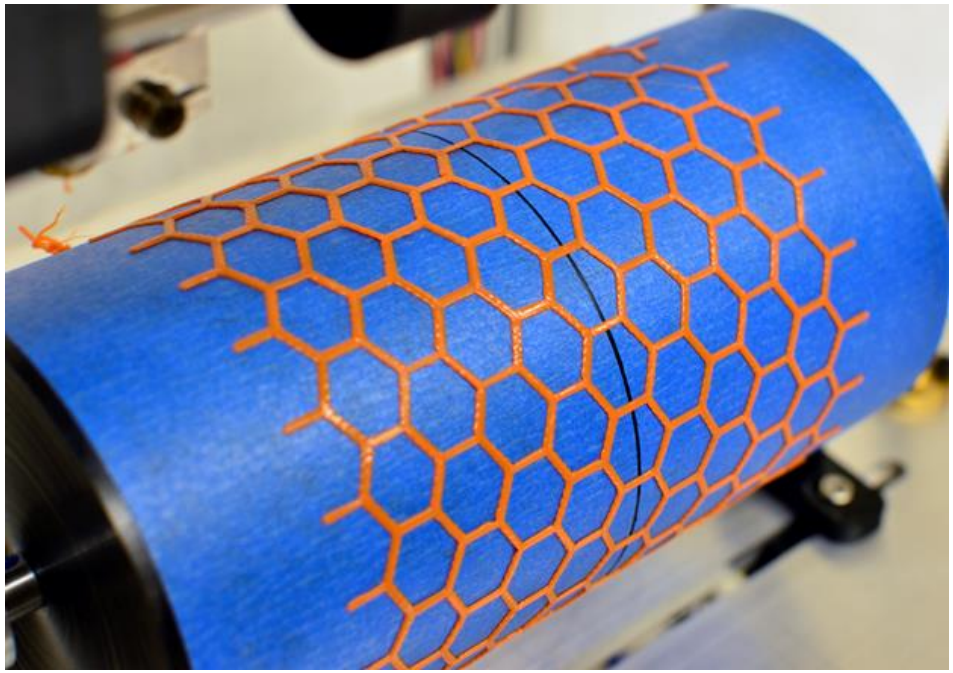


Project Statement

To design and fabricate a rotating cylinder 3D printer that allows manufacturing of complex cylindrical structures.



Motivations

- Print strong structures tangential to a cylindrical print surface
- Manufacture cylindrical structures with novel open lattice walls
- Enhance knowledge of motor control and 3D printing technology

Objectives

- Design and fabricate a 3-axis, 3D printing device
- Design mechanical motion system based on translational motion of printer head and rotary motion of cylindrical printing surface
- Design or obtain an appropriate printer head that extrudes material of thickness 0.2 - 0.5 mm onto cylindrical printing surface
- Design cylinder print surface to be adjustable and replaceable with cylindrical printing surfaces up to 4 in diameter and 6 in in length
- Design and fabricate within a self-funded budget of $1,000
- Program motor control and control interface
- Support automated printing with G-code and software slicing*
- Build and design device to be safe to use and operate

Analysis | Motor Torque

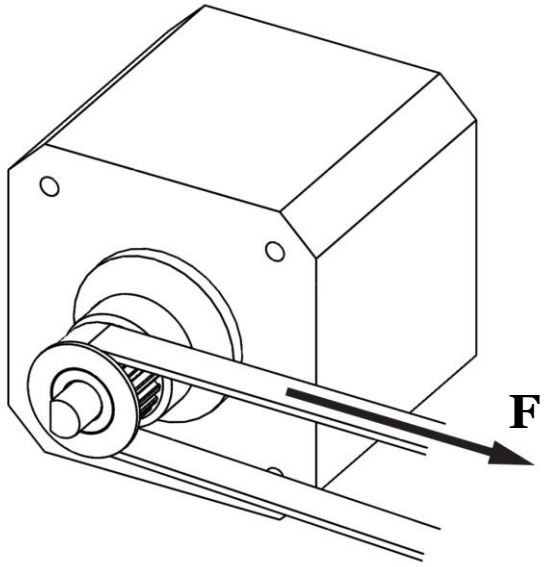
Timing Belt Pulling Force

Find: Maximum resisting force at rest to determine if motor is acceptable.

Assume: Force acts in x - direction.

$$Force = \frac{Torque}{Radius}$$

Results: Force needed to move x carriage and extruder cannot exceed 59 N.



Analysis | Motor Torque

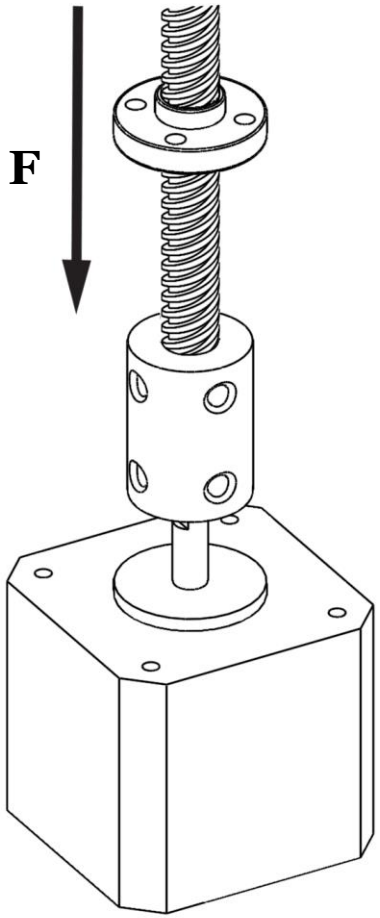
Lead Screw Raising Force

Find: Maximum lifting force of motors.

Assume: Force acts in z direction.

$$F = 2 * T_{raise} * \frac{(\pi d_m - \mu l)}{d_m(l + \pi \mu d_m)}$$

Results: Load of table and print surface cannot exceed 35 kg.



Analysis | Motor Torque

Rotation Acceleration of Print Cylinder

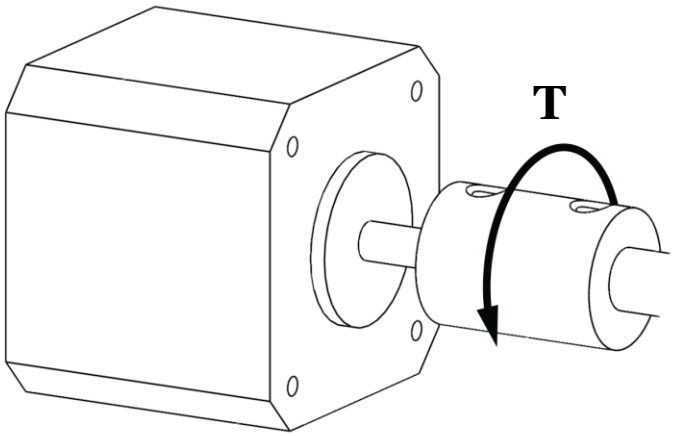
Find: Maximum angular acceleration within motor torque specificaiton.

Assume: No slip between rotating motor and print surface.

$$I = \frac{1}{2}mr^2$$

$$\alpha < T_{max,motor}$$

Results: Angular acceleration of stepper motor must be less than 40 mm per s^2.



Analysis | Z Axis Table

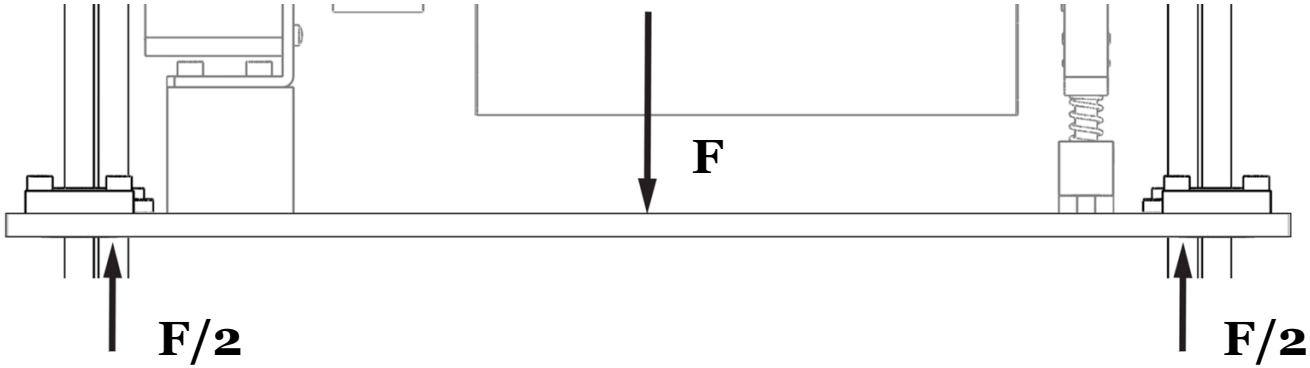


Table Thickness

Find: Maximum load table can hold.

Assume: Table is loaded at center.

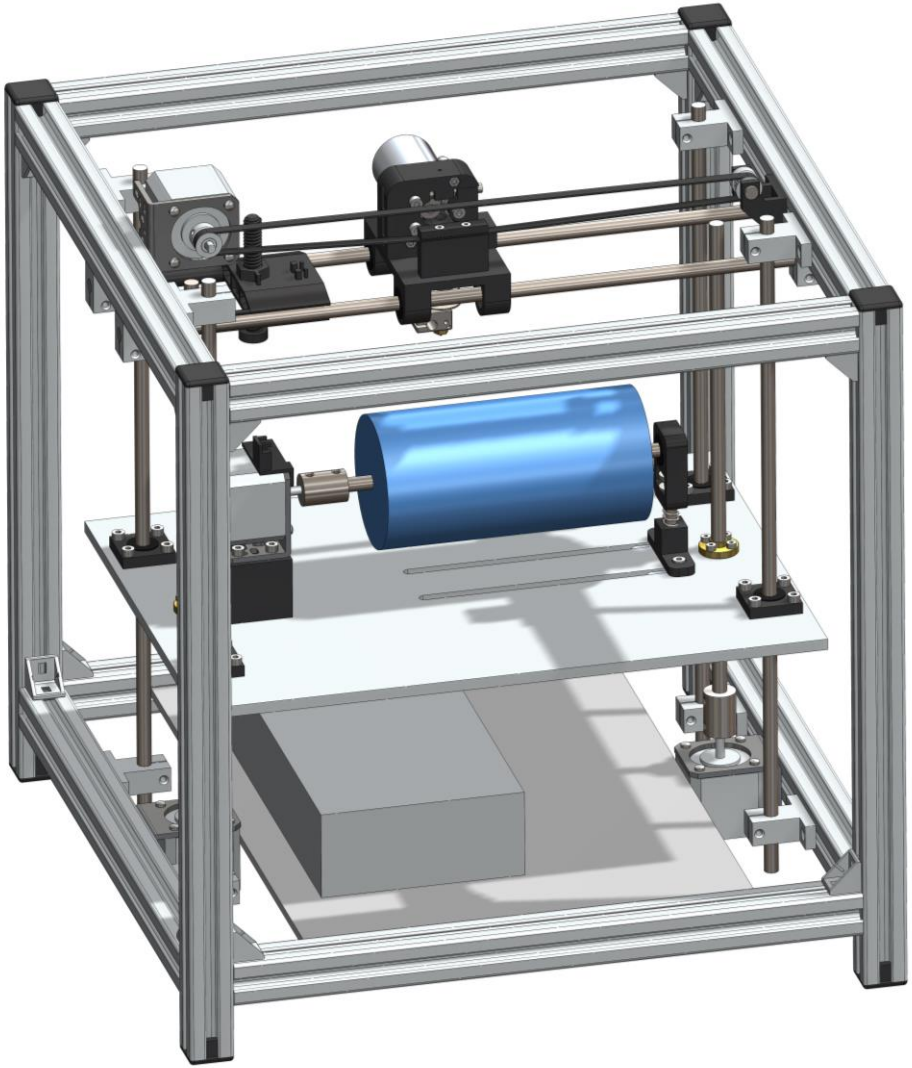
$$\sigma = \frac{\left(\frac{FL}{4}\right)\left(\frac{h}{2}\right)}{\left(\frac{bh^3}{12}\right)}$$

Results: Table weight cannot exceed 416.7 lb for ¼ in aluminum.

Analysis | Material Selection

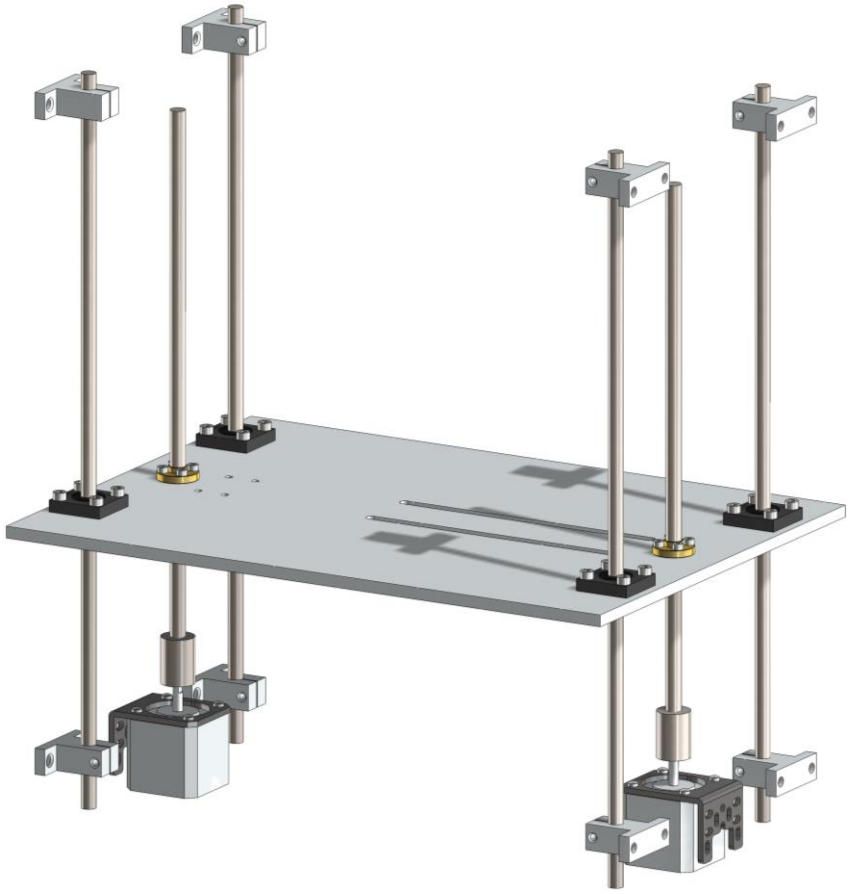
		Silicone		PLA		ABS		Flexible TPE	
Design Considerations	**Weight**	**Score**	**Weighted**	**Score**	**Weighted**	**Score**	**Weighted**	**Score**	**Weighted**
Cost	0.3	3	0.9	4	1.2	4	1.2	2	0.6
Existing Extruder Designs	0.3	2	0.6	5	1.5	5	1.5	4	1.2
Ease of Printing	0.2	2	0.4	4	0.8	4	0.8	2	0.4
Print Adhesion	0.2	5	1	4	0.8	2	0.4	3	0.6
Resources	0.1	1	0.1	5	0.5	5	0.5	4	0.4
Total			**3**		**4.8**		**4.4**		**3.2**

Design

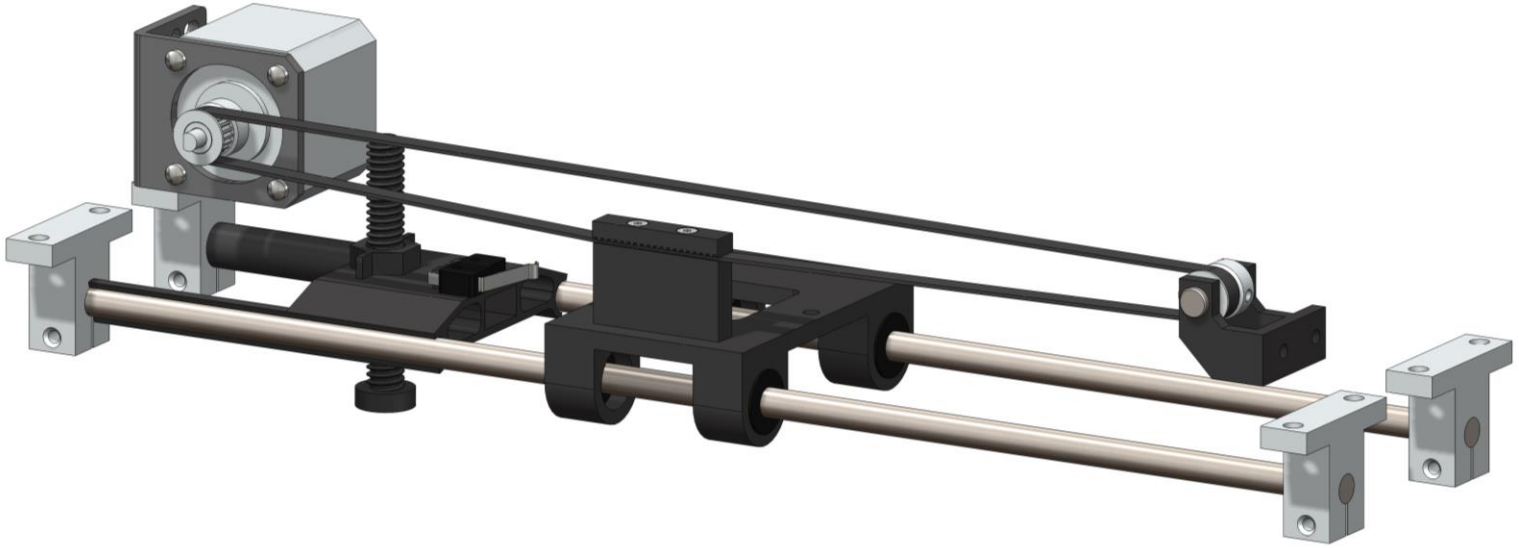


Design | Z - Axis

- Twin lead screws driven by stepper motors
- Travelling nut translates lead screw rotation to linear table motion
- Four guide rods align the table
- Motor and rod arrangement chosen to avoid cantilever loading

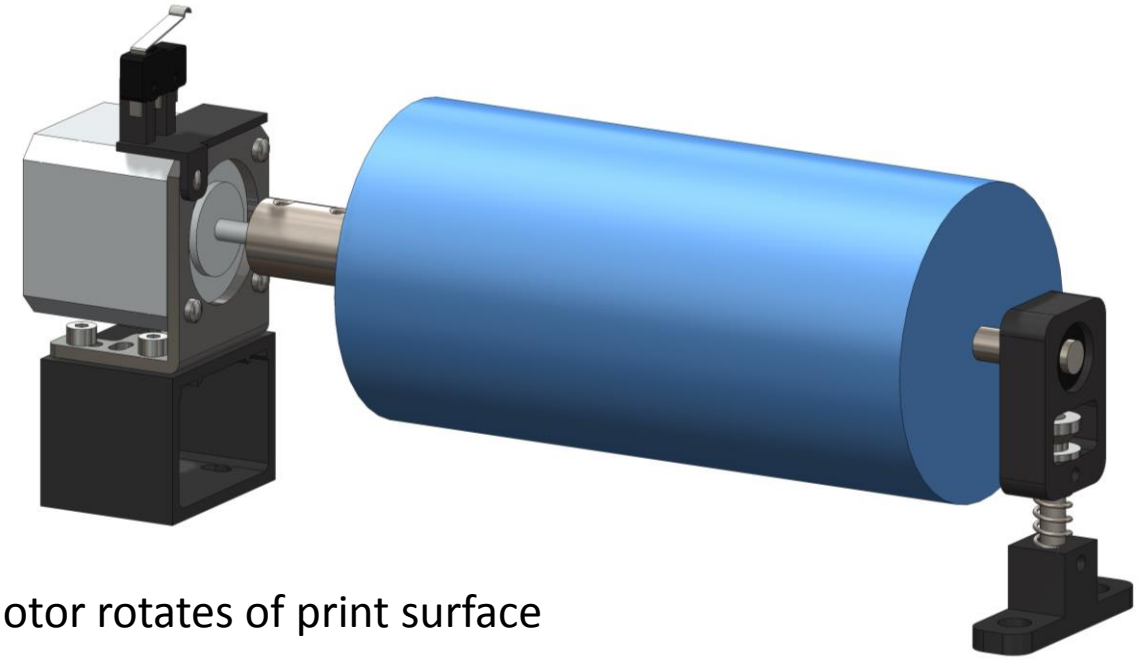


Design | X - Axis



- Extruder carriage driven by stepper motor and pulley with timing belt
- Twin rods guide linear carriage motion
- Calibration screw for zeroing z-axis endstop

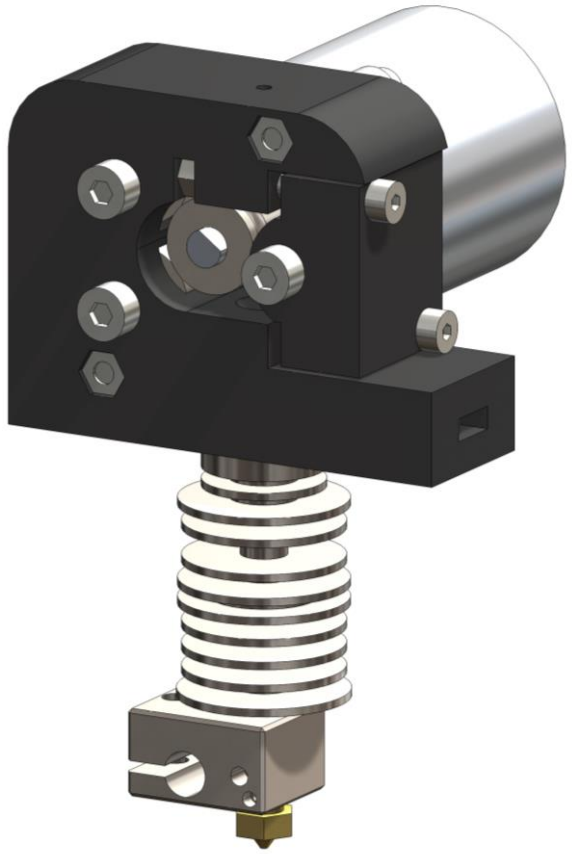
Design | Print Spindle



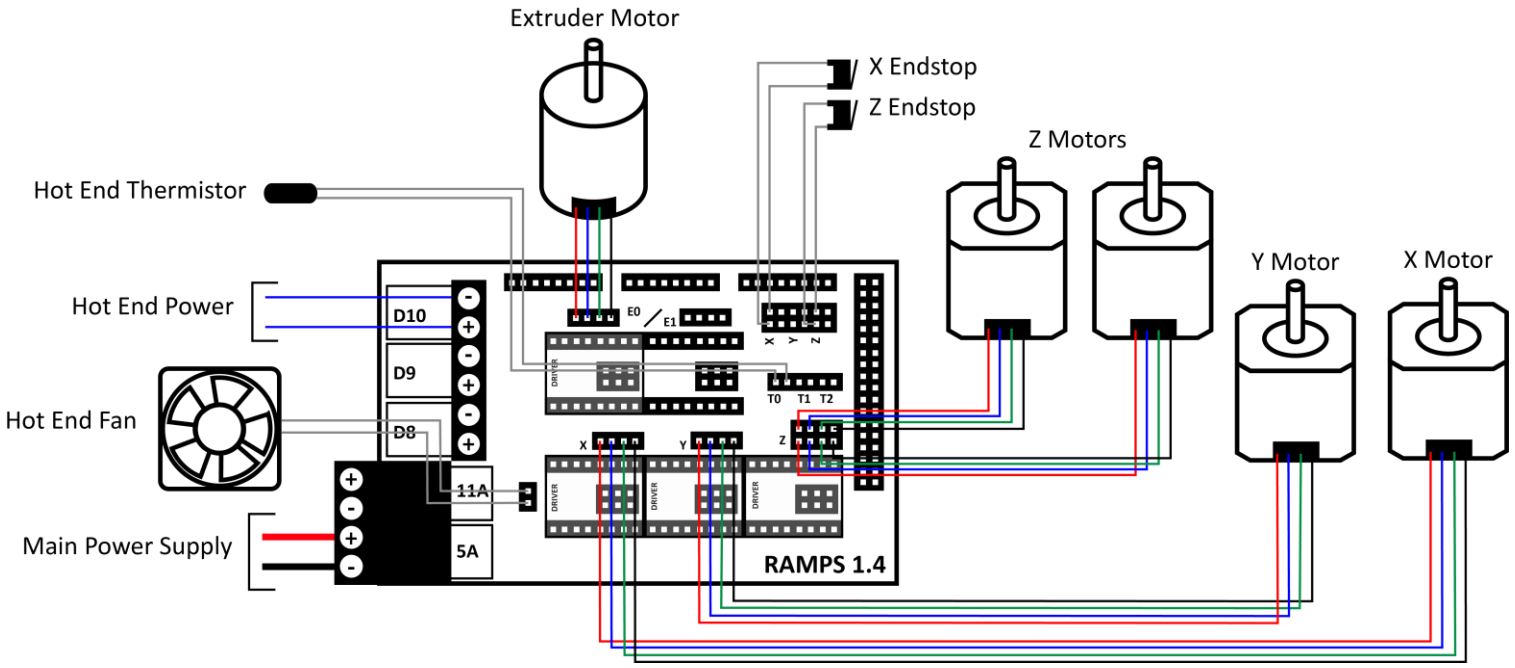
- Stepper motor rotates of print surface
- Delrin cylinder pressed on spindle rod coupled to motor
- Adjustable support for print surface leveling
- Bump switch attached to motor for z-axis zeroing

Design | Extruder

- RepRap filament extrusion design
- Stepper driven gear feeds plastic into hot end
- E3D Lite v6 heater and nozzle
- Mounts on x-axis carriage
- Temperatures of 245°C



Design | Control Electronics



- Arduino Mega and RepRap motor control board
- Marlin 3D print firmware and G-Code Interpreter

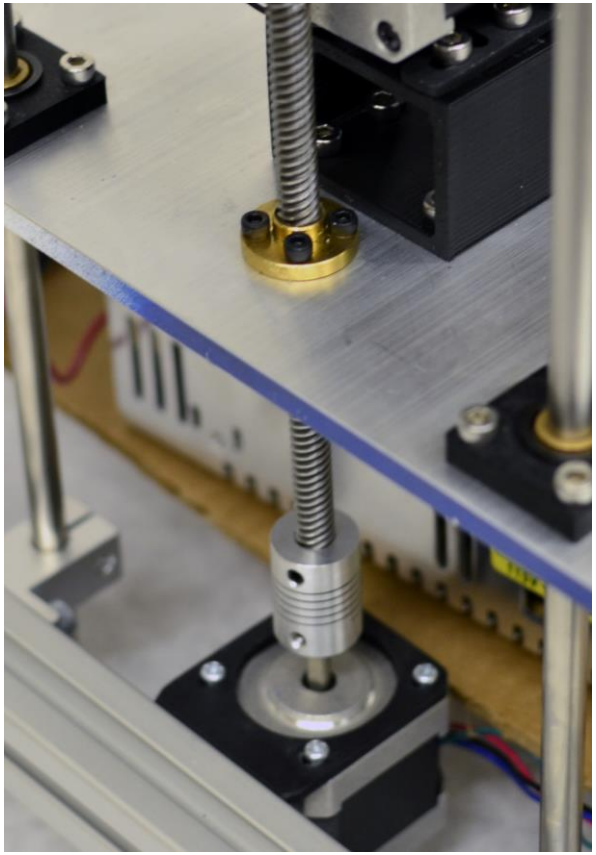
Test | Motor Calibration

Ensure actual travel distance is within tolerance to input travel distances.

System Parameters: Use motor step angle and geometries of motion components.

Calculate: Theoretical motor steps per millimeter for firmware.

Verify: Motion accuracy by measuring travel and adjust until accurate.



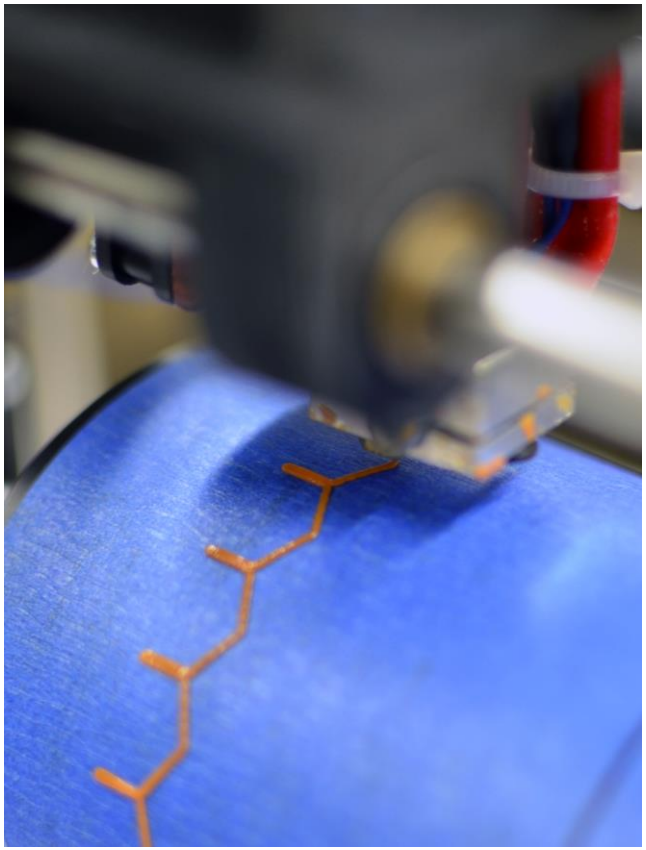
Test | Extrusion Calibration

Determine ideal temperature and material extrusion rate for filament extruder.

System Parameters: PLA thermal properties and size of extrusion nozzle.

Calculate: Volume of extruded material on a layer based on nozzle geometry.

Verify: Temperature selection and volume extrusion by observing print quality and quantity.



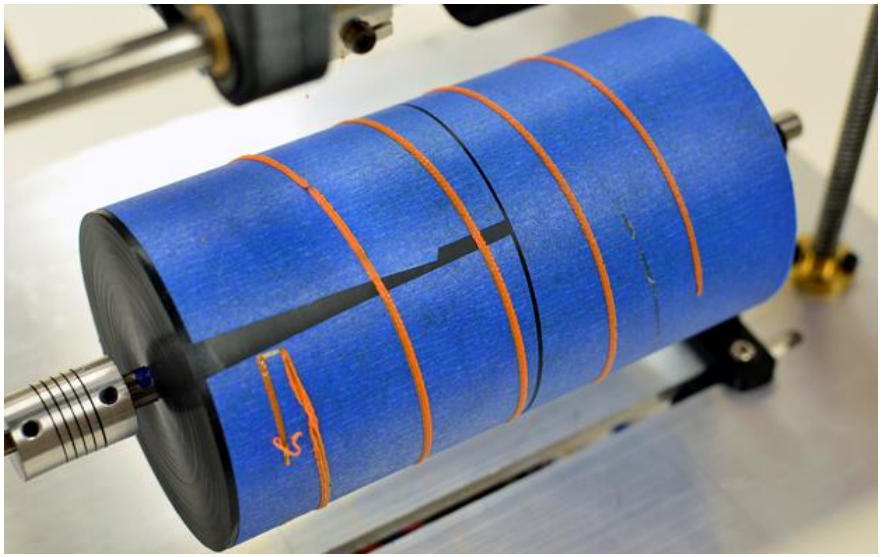
Test | Printing

Test simple print instructions to verify component operation.

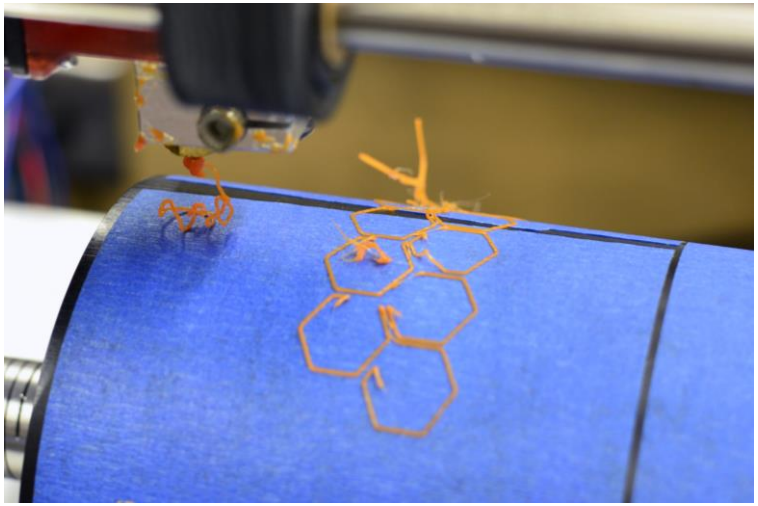
Test Program: G-code instructions to print spiral around cylinder.

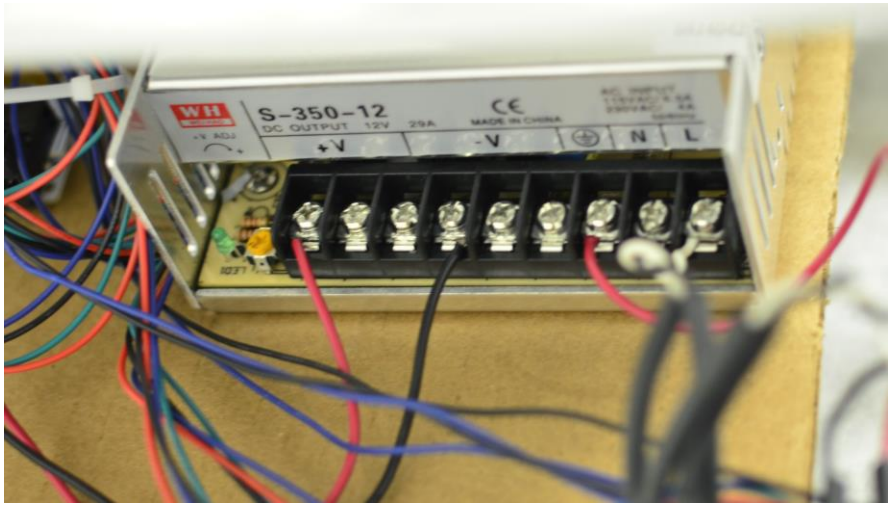
Preparation: Ensure print bed is level and nozzle is correct distance from surface.

Print: Home axes, heat extruder, and verify program prints as expected.



Safety Issues





Safety Issue	Likelihood	Magnitude	Solutions
200°C Printhead	Low	Medium	Protective shield around the printhead to avoid contact
Sharp corners	Low	Low	Fillet table corners
Table and x-axis motion	Low	Low	Protective shield around exposed motion components
Exposed electronics	Low	Medium	Electronics housing and improved wire management

Future Improvements

- Add a Y-axis for 4D printing
- Improve automation of slicing CAD models for cylindrical printing
- Create an adjustable cylindrical print surface for removing prints
- Increase rigidity and precision of machine for better prints

Conclusions

- Fabricated a 3-axis 3D printer system with translational motion of printer head and table with rotary motion of the print surface
- Obtained a print head with an extrusion thickness of 0.2 mm
- Programmed motor control and interface
- Build a safe device to use and operate
- Self funded budget under $1,000

Acknowledgements

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- Adrian Avila - Helping cut and machine metal parts
- Dr. Watson - Insight and guidance during project development
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- Alex Vargas - Assistance with the CNC machining
- Jeremy Hanlon - Initial 3D print prototypes
- RepRap Community - Creating software and hardware for DIY printers

Questions?