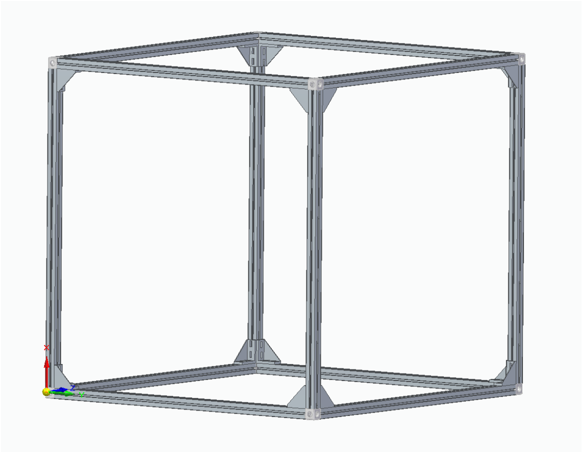
Hugh-M 3D Printer



Preliminary Design Review
Presented to
The Advisory Committee and Project Sponsors
Senior Design Course Fall 2021 & Spring 2022

Florida Institute of Technology

In Partial Fulfillment of the Requirements for the Courses
System Design ECE 4241
And Mechanical Engineering Design MEE 4193

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Dec 10, 2021

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1. Introduction

1.1 Motivation

At the moment, the L3Harris Student Design Center lacks the capacity to create large scale objects through FDM. This limits the scale of projects to about 0.037 m^3. By increasing each dimension by a factor of 3, we can multiply the print area by 27 times.

1.2 Problem Statement

Additive manufacturing is alluring to many different research projects because of the high degree of flexibility and versatility. However, modern FDM manufacturing does not scale well in size due to a variety of factors.

The small size of the nozzle on a modern FDM 3D printer allows for a high degree of accuracy, but becomes a burden at larger sizes due to the time required to create a large part. In addition, when viewing layer count as a variable in failure, with other factors equalized, more layers in a manufacturing job tends to result in a higher failure rate. This is due to more chances for the material to flow in unpredictable ways, resulting in failure.

The enlarging of a 3D printer also comes with structural and mechanical issues, due to material stability as well as vibrations. These must be accounted for if the printhead is to move at a speed proportional to the increase in size.

1.3 Project Objectives

The objective of this project is to design a 3D printer capable of completing large manufacturing jobs with acceptable accuracy while maintaining the high speed normally associated with additive manufacturing. This will allow for the creation of large custom parts quickly and efficiently, increasing the ability of the L3HSDC to produce prototypes more effectively in the future. This machine should, ideally, be able to output 1kg of material in an hour, with the printhead's velocity maxing out at about 300mm/s. Advanced control systems may be implemented to monitor material use as well as operating temperature, which will help determine flow rates and part costs.

1.4 Deliverables

Deliverables will consist of an x-y axis gantry system capable of motion based on G-code files fed into the control board. This gantry system would be set on an external frame constructed from 8020 1515 extruded aluminum with corner connectors.

The control system will consist of BIGTREETECH octopus control board with inserted DRV8825 drivers. Two 23HS22-2804S motors alongside a smaller, yet unspecified NEMA 17 motor will provide movement and extrusion. Microcomputer systems may be added at a later date to monitor variables and add advanced control system functionality.

In addition, the hotend assembly will consist of a Titan Aero based extrusion system connected to a hotend based off of the E3D Supervolcano line. This assembly will feature an 80W heating cartridge inserted into a heat block milled from copper in order to provide adequate temperature stability for high speed flow. The nozzle diameter is expected to be 1.4mm wide, which is over three times the diameter of a standard nozzle.

1.5 Impacts

This project will likely use PLA or PETG plastic in fabrication. Both of these plastics are recyclable, with most forms of PLA being compostable. Neither release any form of harmful fumes when operating at expected temperatures (hotter temperatures may lead to burning).

This project may use less electricity to fabricate large parts, as the high throughput will allow large prints to complete faster while using only about 2-3 times the electricity of a standard size 3d printer, such as the Ender 3.

This project may also reduce waste by reducing failure rate, as explained in 1.2, which would lead to a theoretical higher rate of successful print completion, but this must first be tested.

2. Project Background

3D printing refers to the process of deriving physical objects from their geometrical representation by successfully adding new relevant material. 3D printing stands out as an important illustration of how technology and engineering have revolutionized how people do things. Various innovations such as airplanes, cars, light bulbs, and 3D printers have experienced tremendous improvement due to the efforts of various scientists and engineering to perfect the inventions (Shahrubudin et al., 2019). Like other innovations, 3D printing is expected to continue playing an important role in society as it continues to be adopted in various sectors. In this case, the technology is expected to transform how people approach manufacturing by enhancing efficiency. 3D printing is also expected to have economic, geopolitical, social, security, and environmental implications to the normal lives of the people. One of the main aspects that are likely to determine the impacts of 3D technology on society is the level of efficiency it brings in how people do things.

Currently, the technology is widely used in producing or creating jewelry collections, artificial heart pumps, PGA rocket engines, and 3D printed cornea. One of the most impressive areas that signify the potential 3D printing holds is building a steel bridge in Amsterdam. 3D technology allows human beings to establish new opportunities and meet new possibilities. For example, companies looking to improve their efficiency in the manufacturing sector are increasingly turning to 3D technology. 3D technology can print ceramics, metal, conventional thermoplastics, and graphene-based materials (Shahrubudin et al., 2019). Through this technology, the speed of the manufacturing process will continue to increase as the costs continue to reduce. However, despite the wide application and efficiency of different 3D printers in manufacturing, there is still room for improvement in the area. This project proposes designing a bigger 3D printer that enhances efficiency in the manufacturing process by printing more materials than the existing models.

2.1 Project Relevance

Relatively large-scale 3D printers are relatively uncommon today, and even more uncommon at a decent price point. Being able to present a proof of concept for both of these requirements will allow more larger-scale 3D printers to be introduced to the market.

The popularity of 3D technology in society is rapidly increasing as it is widely preferred by many companies to produce various products. One of the most important aspects of 3D technology is that it allows firms to develop prototypes and end-use parts quickly without relying on third parties. All the company requires is a 3D printer programmed to perform a specific task. Most benefits of the 3D printing technology are accrued from using a large print volume which enables the production of models in one piece (Al Jassmi et al., 2018). In most cases, when a small print volume is applied, the companies are forced to join together various small parts after the printing process is complete. Also, having a small printer means that the organization must remain dependent on a fixed scale. Large scales of models are preferred in the medical and architectural field because they show more details, making it easier to perform analysis (Al Jassmi et al., 2018). Therefore when an organization owns small 3D printers, it becomes impossible to develop models that showcase all important details needed for a study or investigation. Having large 3D printers has multiple advantages for an organization, making it reasonable to invest in designing a larger 3D printing model than those in existence.

In New York, the application of 3D technology was brought to a whole new level when a printed house was put on sale. While the project remains relatively new and requires critical assessment to ensure it passes various barriers, it signifies immense potential in using 3D technology. Additive manufacturing technology is rapidly growing and is driven mainly by leading industrial players in Europe, North America, and Asia. It is important to note that as the popularity and application of 3D printing technology continue to grow, so does the need for scalable technology (Silver et al., 2017). Scalable technology is considered the ultimate solution for various problems faced in society. For example, the technology allows companies to print large vehicle components, furniture, and architectural components in one part. Traditionally, furniture and vehicle parts products required companies to assemble various small parts. However, the performance of the products is significantly enhanced when the products are produced as one solid piece creating the need for large 3D printers. Besides, 3D printers reduce the need for fasteners like bolts and nuts, immensely reducing the weight of the products produced.

Some of the main areas where large 3D printers are relevant are the aerospace, automobile, and transportation sectors. Engineers in these sectors design multiple prototypes, tools, and products using different 3D printers. For example, a vehicle designer tasked with creating a standardized seat for the clients will rely on 3D printers rather than doing the work manually. However, without a large 3D printer, the designer will rely heavily on wielding or bonding smaller parts together, which, if not done correctly, will mess up the whole prototype, requiring the entire process to be repeated (Silver et al., 2017). Having big 3D printers solves the problem by simply creating the prototype seat in one print. The technology is also very useful in the aviation sector because the industry produces heavy and large airframes. Large 3D printers make it possible for the industry to successfully build airplanes in a short period by improving efficiency and the employee environment.

The other important factor that makes big 3D printers relevant is that they can utilize pellet extrusion systems. Pellet extrusion utilizes virgin pellets in injection molding rather than relying on the spooled filament, which is expensive. Applying injection modeling makes it easy to mix different types of plastics to produce customized colors and polymer blends (Al Jassmi et al., 2018). Large printers can use shredded plastics as feedstocks making it possible for the industries to recycle milk jugs and water bottles. One of the main aspects that push many users to rely on pellet extrusion is its high speed, enabling them to print more objects. Besides, some large printers are designed to operate both pellet extrusion systems and filament making it possible for users to apply the appropriate tool for the task at hand (Al Jassmi et al., 2018). Numerous applications of large 3D printers and advantages over the smaller printers present them as the future in the manufacturing industry. Therefore designing a new large efficient 3D printer meets the market demand for efficient and reliable manufacturing tools.

Previous Work and Current State of the Art

Current state of the art large format 3D printing companies include BigRep, Structo, and FelixPrinters. All of these companies have large-format printers capable of printing things around the $1m^3$ volume range. BigRep is the main company we are looking at while making our own unique printing solution.

Additive manufacturing or 3D printing technology has experienced tremendous changes or advancements since it was first used in the 1980s. The technology was initially referred to as Rapid Prototyping technology because it was considered the most effective and fast way of developing prototypes for industries. The first attempt, though unsuccessful, to file a patent for the technology was by Hideo Kodama in 1981 after he discovered ways of developing 3D products by printing layers of materials (Shahrubudin et al., 2019). Later, the French General Electric Company adopted the technology before being abandoned after it failed to find a viable use of the innovation. However, in 1986 Charles Hull, an American engineer, patented the first 3D printer before other companies followed suit (Panda et al., 2016). The printer used acrylic-based materials to transform liquids into solid by applying ultraviolet lights. His discovery presented him as the father of 3D printing technology globally.

Once Hull established the foundation of the technology, various companies started improving the discovery in the 1990s. Multiple types of 3D printers were introduced in the market, including new designs that utilize sprayed materials and micro-casting. However, the technology was still considered expensive, limiting its commercialization in the market. In the 2000s, as various patents started expiring, various entrepreneurs and investors took advantage to improve the sector (Shahrubudin et al., 2019). Different companies produced low-cost 3D printers, allowing the technology to make mainstream headlines. The application of 3D printers in various sectors was widely witnessed in the 2010s, emphasizing their importance in the market (Su & Al'Aref, 2018). For example, the technology made it possible to implement quick repairs of machine parts. Companies became free to produce their products without relying on different technological firms heavily. 3D technology opened new doors for different companies, which enhanced efficiency in their business operations, especially in meeting clients' needs.

The reliance on 3D technology has increased exponentially in the last few decades, making it one of the essential technologies in society. In 2020, the rise of the Covid-19 pandemic created the need for critical products and materials in large numbers. Few people expected the demand for critical medical products to be so high. 3D printing technology became the only viable alternative for many countries in meeting the demand for medical tools and products (Choong et al., 2020). Various companies have produced 3D-printed respirators, masks, valves, and other vital products. The role played by 3D printing technology in the fight against the pandemic signifies its importance in society. The scale of application of the technology in different companies and industries globally is impressive. Statistical projections show that the global market for 3D printers is expected to exceed 40 billion dollars by 2024. In this case, 3D printing technology continues to improve and is expected to become better in the future.

The other important aspect is that the cost of 3D printing technology is expected to continue declining as it becomes a preferred technique in the manufacturing industry. Different types of 3D printing technologies exist in the market, currently presenting users with options that meet their individual needs. The first type of 3D printing is binder jetting, which involves using a binding liquid to join powder particles. The technology applies a jet chemical binder onto the powder to form a layer. The other type of 3D printing is directed energy deposition, which involves adding material or repairing existing components (Pîrjan & Petroşanu, 2013). Powder bed fusion is the other important type of 3D printing that is commonly used in the manufacturing sector. The process involves selective laser sintering, electron beam melting, and selective heat sintering techniques. The technique involves the application of a laser or electron beam to fuse the material powder together. Selective laser sintering is particularly useful in developing ceramic objects, metal, and plastic. The existence of various 3D printing techniques is essential because it offers solutions to multiple problems in manufacturing. However, regardless of the method used, the size of the 3D printer also matters.

2.2 Engineer Standards to Consider

https://www.ni.com/pdf/dspdf/en/ds-311

Standards to consider will consist of protecting the motors being used, so things like over current protection, over power protection, over temperature protection, and short circuit protection. Many of these can be found in power supplies as well. Adding temperature probes (or accessing built-in ones) to the stepper motors will allow data to be extracted to make sure the motors will operate in their ideal ranges.

The frame must also be considered. Operating in the weight, torque, and inertial ranges will be paramount to make sure the frame material stays as still as possible, which will be discussed soon in the modal analysis section.

Like other engineering design projects, developing 3D printers requires the parties to align their operations with various standards. The standards are critical because they enhance safety, health, and quality of life while reducing risk to the end-users. The main engineering standards to consider in the project are the International Stands Organization (ISO). ISO/ASTM 52941 regulations illustrate the main requirements and testing techniques for the re-qualification and qualification of laser beam machines mainly used in aviation additive manufacturing (Pei, 2020). The standards are also critical in verifying the features of a 3D printer in repair and maintenance activities. The standards form a basic part of the design project because they are critical in ensuring that the 3D printer developed performs its tasks efficiently. For example, the standards offer the users the strategies to use when conducting operational tests.

One of the main reasons for adopting the ISO standards in the design project is its efficiency and accountability. The standards are vital in streamlining the design process by ensuring that all the materials and tools used are high-quality to avoid wastage and produce optimal results. The standards are particularly helpful in various areas ranging from manufacturing, product design, and delivery to customer data management. By following the ISO standards, there is a high likelihood of attracting multiple customers for the large 3D printer produced. The other critical aspect is that the ISO standards are vital in building agility and innovation in the design process by increasing adaptation and efficiency. Engineers are required to be accountable for their projects and how their designs impact the community. Through the ISO standards applied, it is possible to attain accountability and compliance with various regulations faster.

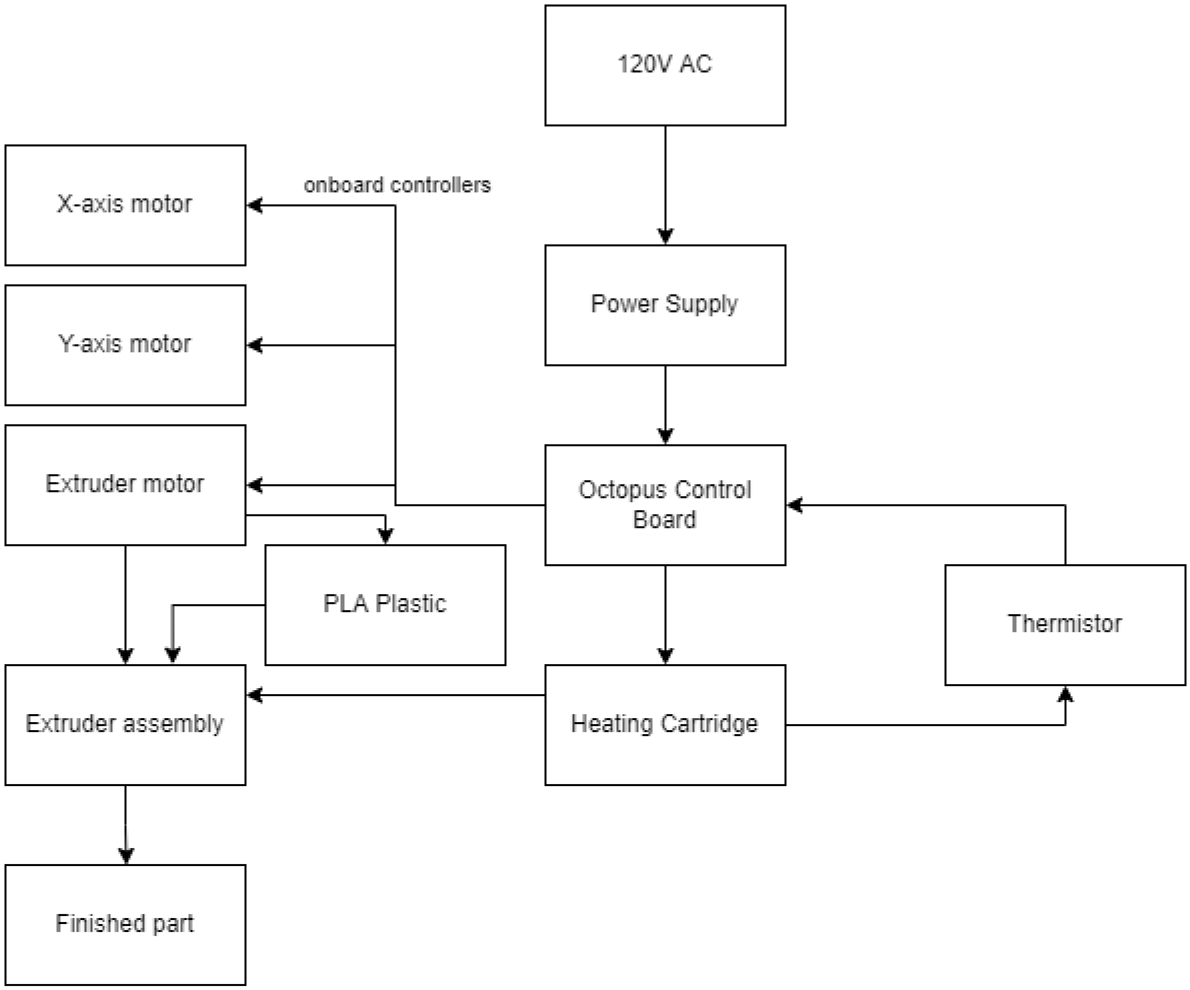
Apart from the engineering standards, the project was influenced by various considerations, including public health, welfare, safety, cultural, global, environmental, societal, and economic factors. Safety and public health stand out as the most important considerations. In this case, the 3D machine should be developed in such a way that it does not harm or adversely affect the health of the public. Secondly, throughout the project, the welfare of the public and that of the employees should not be adversely affected. Instead, the project should have positive impacts on the welfare of all stakeholders. The other important consideration is the environment that should not be damaged by the engineering project. Also, before designing the project, it is critical to establish whether it has positive or negative economic impacts. If the project is likely to affect the economy adversely, it should not be pursued. Lastly, while the social, cultural, and global factors are essential considerations in engineering, they are insignificant in designing a big 3D printer.

3. System Requirements

The mechanical systems must be able to support the two dimensional axis alongside the future z-axis frame. The two dimensional axis should be rigid enough to avoid significant (~3 degrees) rotation during movement while remaining relatively normal to the z axis. This will allow for the bed to be calibrated to be normal to the nozzle and gantry. The frame should be rigid enough for this axis to be mounted on top with little to no movement due to vibration during operation.

The electrical systems must be able to drive the motors and their respective control systems, as well as the thermal systems. It currently consists of a single power supply, which will drive all electrical systems through the control board. This consists of the motors, their controllers, and the heating element.

The control system will have attached calibration limit switches alongside a thermistor as feedback sensors. This will allow the system to maintain temperature stability as well as remain within the intended bounds of motion. The control system must be able to interpret standard g-code commands and move accordingly in order to have the potential for future fabrication. This includes creating mechanical motion in the x-y axis as well as the extrusion motor. The heating element must also maintain a stable temperature in order to melt the material being used.



4. Technical Approach

4.1 Mechanical

The mechanical aspect of this project consists of several components: General Size Requirements given materials, Vibrational modal Analysis, and Thermal Analysis.

4.1.1. General Size Requirements

In order to make a 3D printer with a printing space of 1 meter x 1 meter x 1 meter, size requirements had to be put in place in order to maintain space for the additional parts being attached to the system. After analyzing the parts listed by the chosen supplier, 8020, it was determined that the 4ft T-slotted frames would fit the printing space while maintaining the extra space needed for the gantry system and electronic components, which comes out to about 4-5 inches extra on each side of the printing space. Competing printers, such as the BigRep One with the same printing space, are much larger compared to our printer due to them essentially having two frames, with one being a similar size to ours, and an outer frame that supports sides to help maintain temperature regulation within the printer. This size difference can be observed in Figure 4.1 with a six-foot man for reference.

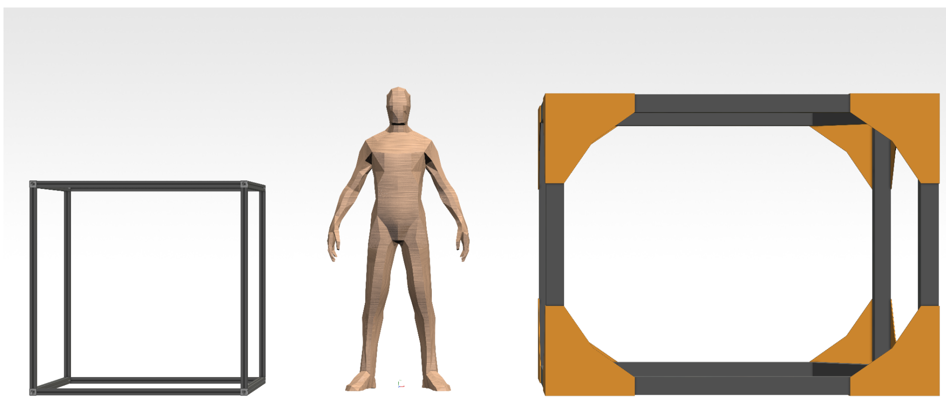


Figure 4.2. Frame Size Comparison of Hugh-M and BigRep One

In addition to this, the corners are supported by cube corner connectors and corner brackets to subdue any vibrational modes the frame may encounter whilst the motors are running. The size and location of bolting is to be determined in the Spring Semester.

4.1.2. Vibrational Modal Analysis

The modal analysis for this project consisted of testing several different design parameters in order to simulate the vibration of the system and how to minimize its effects. The first step taken in order to achieve this was using Solidedge to model the outer frame.

This frame would be essential to this vibrational analysis due to the mechanical properties that can be applied to it within the simulation. When designing this model, it was important to make sure the frame was not perfectly symmetrical. This is due to the complicated nature symmetry inflicts upon a system, therefore making it much more difficult to simulate. In order to avoid this, the frame sides were altered to have different lengths (48in x 47in x 46in). While this does give us less room to work with, the gantry system is on top of the frame and the z-axis will simply be working from underneath the printer, making this okay since the height takes priority due to the overall design. With these considerations, the model was then used in NX for a modal vibrational analysis. This was conducted as a free vibration with no external constraints in order to obtain the natural frequencies of the frame. These frequencies in particular are important due to natural frequencies causing the highest vibrational amplitudes within the system. Vibration is not good for a printer, as this can lead to errors within the printing process. The first mode of the frame, which is also the highest amplitude peak the system will experience, occurred around 145.22 Hz and had a 1.014mm amplitude (2.028 mm full vibration) and while this doesn't seem like much, can still greatly affect the system.

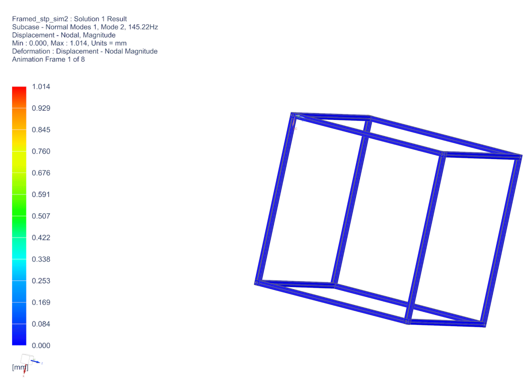


Figure 4.2. 145.22Hz

In order to minimize this, damping was needed to be placed within the system. The damping of the system, not including the feet support to prevent external vibrations that are not accounted for within this analysis, are corner brackets. The size of these brackets, as well as where they are bolted onto the frame can greatly diminish the effects of the vibrational modes. The analysis for these brackets will be conducted during the Spring semester.

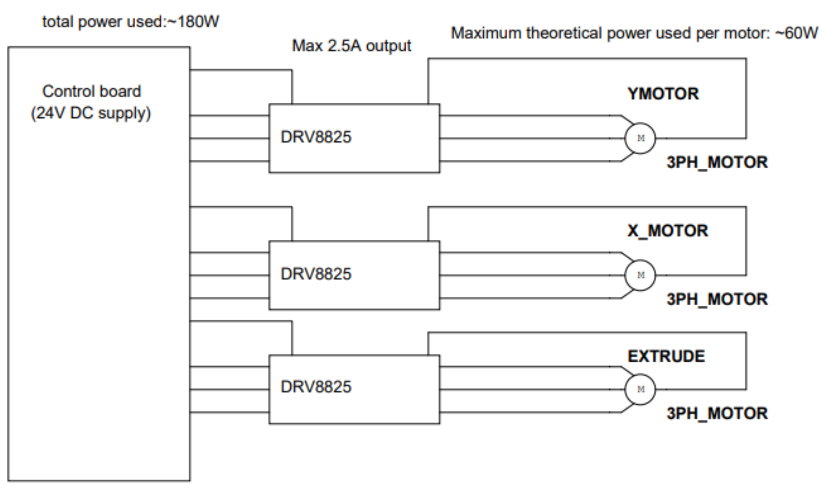
4.1.3. Thermal Analysis

Thermal Analysis has not yet been conducted on this project and will be written about in the Spring Semester.

4.2 Electrical

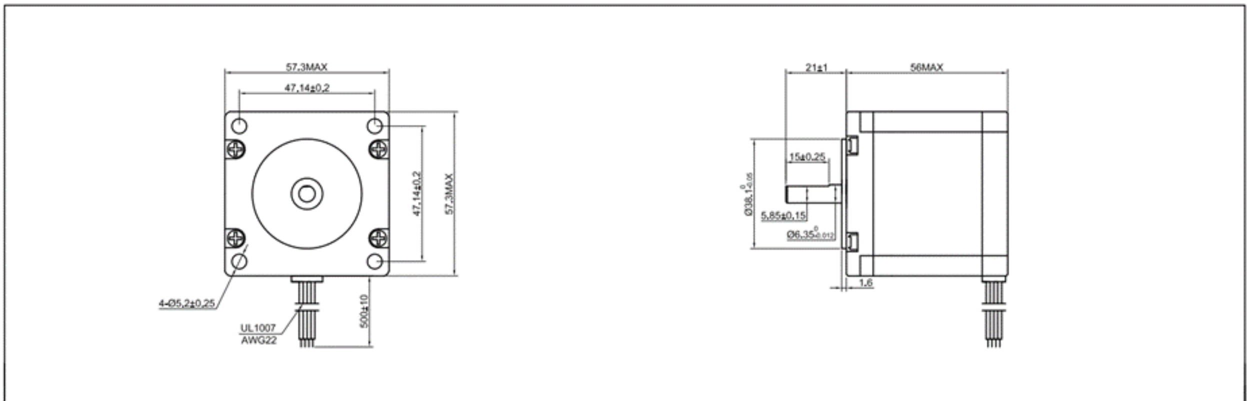
4.2.1 Motors

The motors running in the project are all stepper motors due to the need for accurate control and high holding torque. There are two models used in this project, the Nema-23 and Nema-17.



Axes Motor - Nema-23HS22-2804S

The Nema-23 Motor is the selected axis motor for this project, it provides the necessary power to drive the axis across the printing surface whilst maintaining the precision of the movement. These motors would be connected to the DRV8825 motor drivers for precision control.

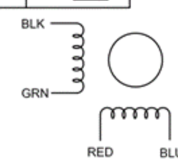


SPECIFICATION \ CONNECTION	BIPOLAR
AMPS/PHASE	2.80
RESISTANCE/PHASE(Ohms)@25°C	0.90±10%
INDUCTANCE/PHASE(mH)@1KHz	2.60±20%
HOLDING TORQUE(Nm)[lb-in]	1.20[10.63]
STEP ANGLE(°)	1.80
STEP ACCURACY(NON-ACCUM)	±5.00%
ROTOR INERTIA(g-cm²)	300.00
WEIGHT(Kg)[lb]	—
TEMPERATURE RISE:MAX.80°C（MOTOR STANDSTILL;FOR 2PHASE ENERGIZED）	
AMBIENT TEMPERATURE -10°C~50°C[14°F~122°F]	
INSULATION RESISTANCE 100 Mohm（UNDER NORMAL TEMPERATURE AND HUMIDITY）	
INSULATION CLASS B 130°C[266°F]	
DIELECTRIC STRENGTH 500VAC FOR 1MIN.(BETWEEN THE MOTOR COILS AND THE MOTOR CASE)	
AMBIENT HUMIDITY MAX.85%(NO CONDENSATION)	

TYPE OF CONNECTION (EXTERN)		MOTOR	
PIN NO	BIPOLAR	LEADS	WINDING
1	A+ —	BLK	A+
2	A- —	GRN	A-
3	B+ —	RED	B+
4	B- —	BLU	B-

FULL STEP 2 PHASE-Ex. ,
WHEN FACING MOUNTING END (X)

STEP	A+	B+	A-	B-		
					↓ CW	CCW ↑
1	+	+	-	-		
2	-	+	+	-		
3	-	-	+	+		
4	+	-	-	+		



Extruder Motors - Nema-17 Hybrid Motor

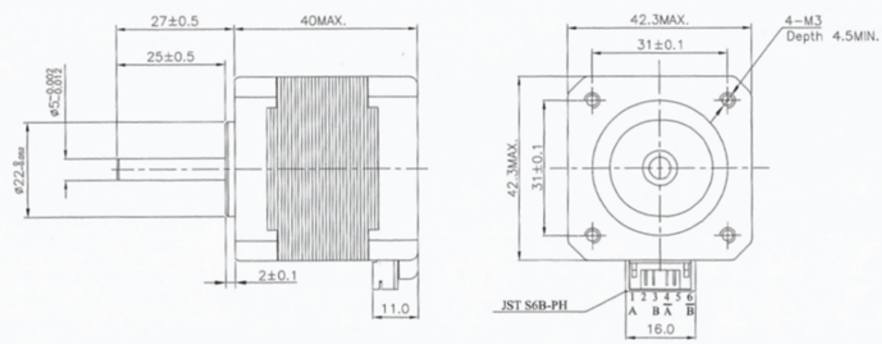
For the extruder gears there is a more compact motor being used to control the rate that the filament is going to be pushed through the hot end. The motor selected for this is the Nema-17 motor. This is a much smaller motor that offers a high amount of holding torque, this is further increased with the gear ratio that is applied to this motor, which allows the extruder to both remain light and not slip during high-speed print.

MOTECH MOTOR CO., LTD

Product Name	**Hybrid Stepper Motor MT-1703HSM168RE**	Rev A

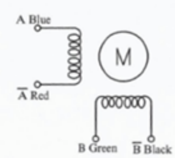
Made by	P.T	Approve	Martin	Date	2/27/2017

E3D SKU: E-MOTOR-NEMA17-40MM



Items	Specs	Items	Specs
Phase Number	2 phases	Step Angle	0.9°±5%
Rated Voltage	2.8 VDC	Rated Current	DC 1.68 A / Phase
Resistance(20℃)	1.65±10% Ω / phase	Inductance	3.6±20% mH / Phase
Holding Torque	≥ 3.5 Kg-cm(48.6 Oz.in)	Detent Torque	220 g-cm REF.
Rotate Direction	AB$\overline{AB}$A CW	MAX Starting PPS	2500 PPS
MAX slewing PPS	2500 PPS	Insulation Resistance	≥100 MΩ(DC 500V)
HI POT	AC600V/1mA/1S	Insulation Class	Class B
Rotor Inertia	54 g.cm²	Weight	0.28 Kg REF.

Wiring Diagram

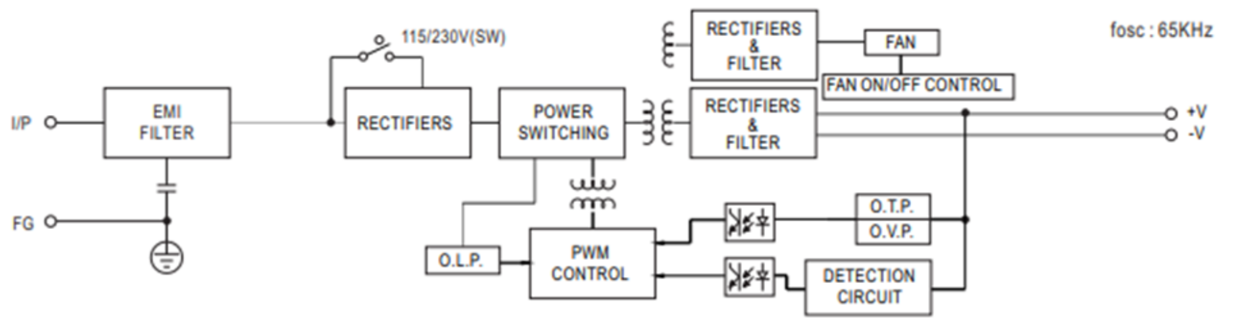


4.2.2 Power Supply

Mean Well LRS-350-24

This power supply is a 350W power supply with 24V output, this limits that all the components would be running on 24V. There will be two power supplies included with this project so that there is enough power for future updates that would be done to the printer.

The power supply does contain openings where the connection is made to the wires, for safety concern the power supply would be stored in a custom designed housing so those points would not be in reach of anything. The housing would also contain the necessary cooling for the electronics.



MODEL		**LRS-350-24**
OUTPUT	**DC VOLTAGE**	**24V**
	RATED CURRENT	**14.6A**
	CURRENT RANGE	**0~14.6A**
	RATED POWER	**350.4W**
	RIPPLE A NOISE (max.) Note.2	**150mVp-p**

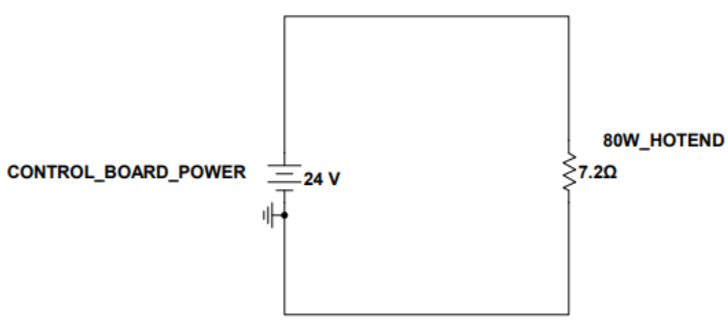
	VOLTAGE ADJ. RANGE	21.6~28.8V
	VOLTAGE TOLERANCE Note.3	+1.0%
	LINE REGULATION Note.	+0.5%
	LOAD REGULATION Note.	+0.5%
	SETUP, RISE TIME	1300ms, 50ms/230VAC 1300ms,50ms/115VAC at full load
	HOLD UP TIME (Typ.)	16ms/230VAC 12ms/115VAC at full load
INPUT	VOLTAGE RANGE	90 ~ 132VAC 180 264VAC by switch 240 370VDC (switch on 230VAC)
	FREQUENCY RANGE	47 63Hz
	EFFICIENCY (Typ.)	88%
	AC CURRENT (Typ.)	6.8A/115VAC 3.4A/230VAC
	INRUSH CURRENT (Typ.)	60A/115VAC 60A/230VAC
	LEAKAGE CURRENT	<2mA/240VAC
PROTECTION	OVER LOAD	110 ~ 140% rated output power
		3. I-36V Hiccup mode, recovers automatically after fault condition is removed. 48V Shut down and latch off o/p vltage, re-power on to recover
	OVER VOLTAGE	28. 33.6V

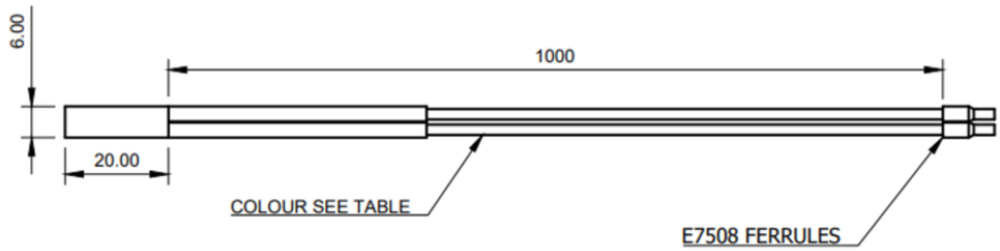
		3. I-36V Hiccup mode, recovers automatically after fault condition is removed. 48V Shut down and latch off o/p vltage, re-power on to recover
	OVER TEMPERATURE	3. I-36V Hiccup mode, recovers automatically after fault condition is removed. 48V Shut down and latch off o/p vltage, re-power on to recover
FUNCTION	FAN ON/OFF CONTROL (Typ.)	RTH3>= 50°C FAN ON, <40°C FAN OFF
ENVIRONMENT	WORKING TEMP.	-25°C~+70°C (Refer to "Derating Curve")
	WORKING HUMIDITY	20 90% RH non-condensing
	STORAGE TEMP., HUMIDITY	-40 +85°C, 10~ 95% RH
	TEMP. COEFFICIENT	+0.03%/C (0 -50°C)
	VIBRATION	10~ 500Hz, 5G 10min ./cycle, 60min each along X Y, Z axes
SAFETY	SAFETY STANDARDS	IEC/UL 62368-1 , BSMI CNS14336-1 , BS TPTC 004.KC K60950-1 (for LRS.35C-12,'24 only), BIS IS13252(Part1): 2010/1EC 60950-1 : 2005, ASINZS62368.1 approved; Design refer to BS EWEN62368-1
	WITHSTAND VOLTAGE	I/P-O/P:3KAVC I/P-FG:2KVAC O/P-FG:0.5KVAC
	ISOLATION RESISTANCE	I/P-O/P, I/P-FG, O/P-FG:100M Ohms/500VDC /25°C/70°C RH
	EMC EMISSION	Compliance to BSMI CNS13438, EAC TPTC 020.KC LRS-350-12/24 only)
	EMC IMMUNITY	Compliance to EAC TP TC 020,KC LRS.350-12/24 only)

4.2.3 Heater Cartridge

E3d 24V-80W heater cartridge

The heater cartridge is a critical part of the design, this is responsible for maintaining the temperature of the hot end as the printer is operated at high speed, our project would be running a 24V 80W heater that should heat up and maintain the temperature with ease. The increased surface area of the cartridge would offer a better heating across allowing the printer to have a better melt zone. The current on this specific cartridge would be 3.9A so a mosfet would not be needed for it to be stable. The heater cartridge would be mounted directly into the heater block and secured with a set screw mechanism to ensure it would not fall out during operation.





Item Name	24v 12mm stainless steel electric cartridge heater
Resistance heating wire	Ni-Cr or FeCr
Sheath	Stainless steel 304,321,316, Incoloy 800, Incoloy 840,
Insulation	High-purity Mgo
Maximum temperature	550 degree Celsius
Voltages available	24V
Power available	80W
Wattage Tolerance	+5%, -10%
Thermocouple	K type or J type
Lead wire	300mm length; Different type of wire is available

4.2.4 Thermistor

Semitec 104NT thermistor

This thermistor is a high precision thermistor used for high temperature around the hot end, the temperature allowance on this thermistor is sufficient for the highest temperature that this printer would be running at. It produces precise reading so the temperature in the heater block would be stably controlled.

Resistance/Temperature Characteristics

Temperature (°C)	104NT-4-R025H43G
-50	10090
-30	2353
10	657.0
0	368.1
10	213.5
25	100.0
40	49.90
50	32.42

60	**21.54**
80	**10.13**
85	**8.486**
100	**5.122**
120	**2.763**
140	**1.574**
160	**0.9414**
180	**0.5873**
200	**0.3804**
220	**0.2549**
240	**0.1760**
260	**0.1250**
280	**0.0910**
300	**0.06772**

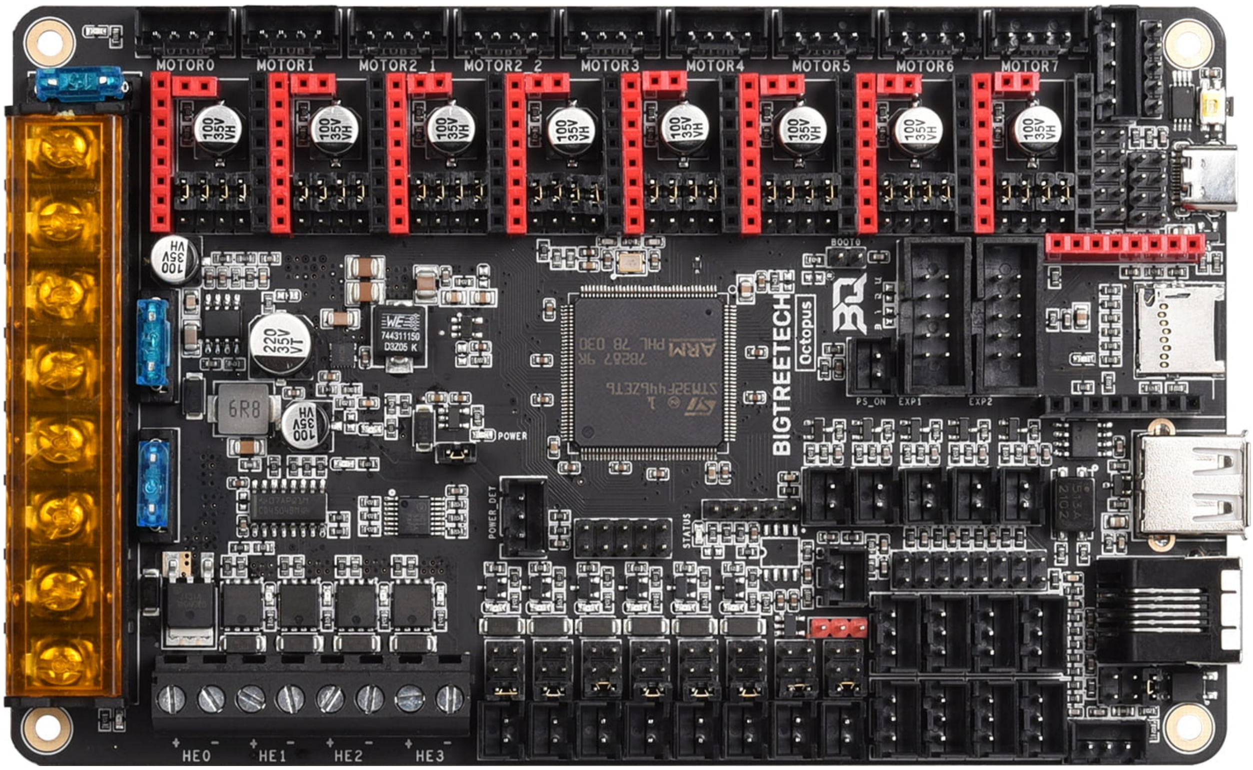
4.2.5 Fans

40x40mm fan

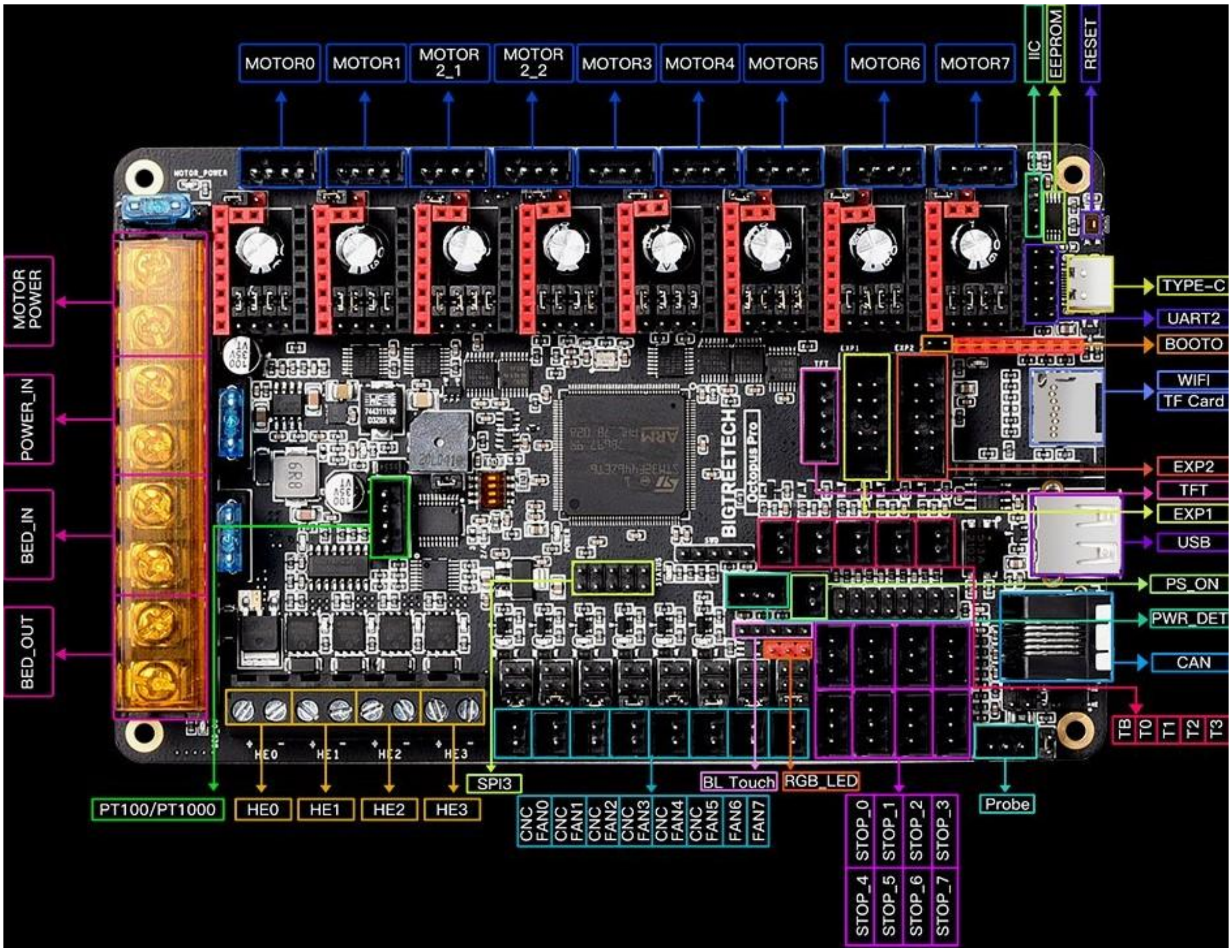
These are commonly found in small project to produce cooling over a small area.

Size	**40 x 40 x 10 mm**
Connector	**4-Pin**
Bearing	**SS02**
Blade geometry	**A-Series with Flow Acceleration Channels**
Frame technology	**AAO (Advanced Acoustic Optimisation)**
Max. input power / operating voltage	**0.48W / 12V**
Max. rotational speed (+/-10%)	**3700RPM**
Max. airflow	**6.6 m^3/h**
Max. acoustical noise	**12.9 dB(A)**
Max. static pressure	**1.21 mm H2O**

4.2.6 Main Board



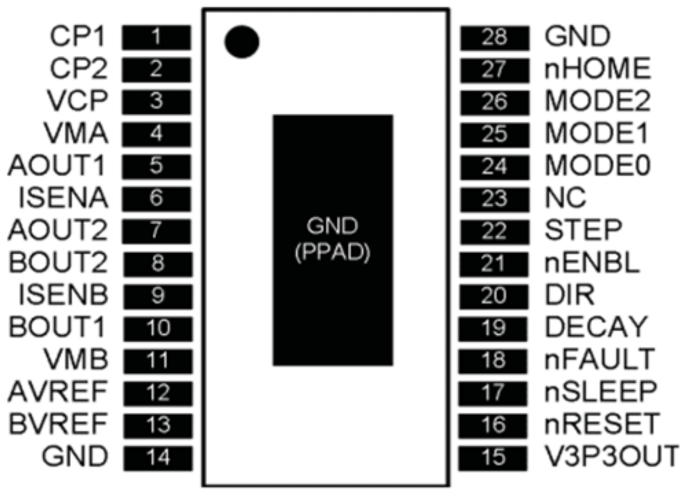
The BIGTREETECH Octopus is the most flexible control board for our budget and project direction. It uses a 32-bit ARM Cortex-M4 main control chip, compatible out of the box with Marlin, the firmware package we will be developing off of. It has 8 motor driver sockets each with their own separate power inputs for finer control of power use, as well as additional separate power inputs for up to 4 hotend heaters, bed heating, and up to 8 (6 PWM and 2 always-on) fans. Planning to run both power and data to the stepper motors directly through the main board, the Octopus can handle up to 24V input with built-in regulators for 12V, 5V, and 3.3V peripheral use. Additionally, high performance MOSFETs are used throughout the board to increase heating efficiency and to reduce heat generation on the motherboard, this is particularly important as all of our electrical components are being both powered and managed by this board. Multiple thermal sensor inputs and automatic power down wiring are present to safely cut power to the mainboard in case of a failure somewhere else in the system. SAM



4.2.7 Motor Drivers

Texas Instruments DRV8825 drivers

This is one of the few drivers that could operate the Nema23 motors we have whilst maintaining compatibility with the BIGTREETECH Octopus board. The driver can handle up to 2.5A of current which is within the limit of the motors even at peak current, it provides accurate steps up to 1/32steps per movement. There will be heatsinks that would be over these drivers, so they remain at a low temperature.



Pin Functions

4.3 Software

4.3.1. Overview

The software component of this project will be utilizing the open-source firmware, Marlin, which many commercial printers, laser cutters and engravers, and CNC mills use. The firmware's license is under the GNU General Purpose License v3. Marlin is adaptable across various boards with 8-bit and 32-bit microcontroller support and numerous printer types through its extensive configuration list for tuning any individual printer. Marlin runs G-code (computer numerical control programming language) that handles the machine's actions.

4.3.2. Configurations

To use Marlin effectively, the *Configuration.h* settings file must be properly set with respect to the components used in the printer. These settings include details on the printer style, driver board, extruders, motors, and thermistors. Each change in the settings requires the firmware to be recompiled. The following will be some of the basic settings that need to be set and tested for our printer system.

4.3.3. Thermal

The thermal settings consist of configuring the sensors that will be used on our system and the allowed ranges that they can safely reach. The tuning aspect will be done using a PID loop that will be optimized through the thermal testing that is taking place in the Spring Semester. A well implemented PID loop will maintain a stable target temperature in both the extruder and the bed in order to produce a consistent final print without warping. This section of settings also includes many safety precautions that can help to prevent damage to the printer. One of the key settings in this section is the thermal protection that checks to see if the temperature is increasing when a heater has been activated. A failure to show an increase in temperature detects that a thermistor has been disconnected or damaged and will throw an error to shut down the system before the heater can continue to work beyond a safe level. The *Configuration_adv.h* file includes more thermal protection settings that will need to be tuned in order to reduce the number of false positives and further increase the thermal safety in our printer system.

4.3.4. Movement

The movement settings are a key component for optimizing print speed as well as increasing safety measures. This section will require tuning based on the steppers as well as other factors such as the belt pitch, number of teeth on the pulley, and extrusion style. These tuning calculations will determine the number of steps per millimeter and therefore how accurately the steppers can position the extruder head. A key set of settings in this portion is the acceleration settings, which is where some of the print speed optimizations will take place. The maximum print and travel accelerations will be tuned here based on extrusion speeds and vibration testing that will take place in the Spring Semester.

5. Technical Budgets

BIGTREETECH Octopus	1	$47.99	control board + stepper driver slot
E3D Titan Aero No Cables	1	$43.58	extruder
copper block 1/2X1X6 in	1	$30.76	heatblock material
1515 Aluminum extrusions 1300 mm	12	$420.19	framing
block parts	1	$24.61	misc heatblock parts
total		$567.13	
budget alloted		$1,500	
budget remaining		$932.87	

6. Conclusion and Plans for Future Work

Our work next semester will focus on construction and system analysis as well as the implementation of most of our designs. This will involve the construction of the outer frame as well as the gantry. Alongside the mechanical systems, the enclosure of the power supplies as well as wiring will be conducted before testing of the control systems begins. This will precede any testing of control systems, which will be tested alongside software. Due to the nature of the firmware, we will be unable to perform testing until the x-y axis is established. In addition, flow and heat tests will be conducted on the hotend and the heat block, which will be milled from copper.

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[Employ ASME Citation Criteria]

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