# 1. Overview

## 1.1. Executive Summary

The purpose of this project is to create an actively heated enclosure for a 3D printer. This is an improvement on current solutions, which are usually heated passively by the printer's bed and are unable to maintain high temperatures within the enclosure. This device will instead use a stand alone electric heater, allowing for it to have a much higher temperature, and allow the temperature to be set to a much more precise value by the user.

Some materials (such as glass nylon fiber) can experience significant warping during printing if they are not kept at a high enough temperature. When complete, this system will allow for 3D printers to use a wider variety of materials more reliably. The project is currently in the planning stage of development.

## 1.2. Team Communication Protocols and Standards

| Name | Email | Role | Expected Contributions |
|---|---|---|---|
| Caspian Hedlund | hedlundc@oregonstate.edu | Heater's Enclosure, Communication Management | Researching and building solutions for the enclosure, making sure that everyone knows what will be discussed in the weekly meetings |
| Mark Ellarma | ellarmam@oregonstate.edu | Heater's Thermometer | Research possible devices that can be used for the enclosures thermometer |
| Arthur Chen | chenji4@oregonstate.edu | Heater's power supply and Video editing | Searching and designing a possible solution for the power supply and editing the weekly video presentation |
| Kaleb Krieger | kriegeka@oregonstate.edu | Heater | Research solutions for heating the enclosure |
| Bradley Heenk | owner@corvallis3d.com | Project Partner | Clarification about the desired function and purpose of the project |

*Communication regarding the development of the project will be done primarily using Discord, as it is the preferred method of communication for all team members and the project partner.

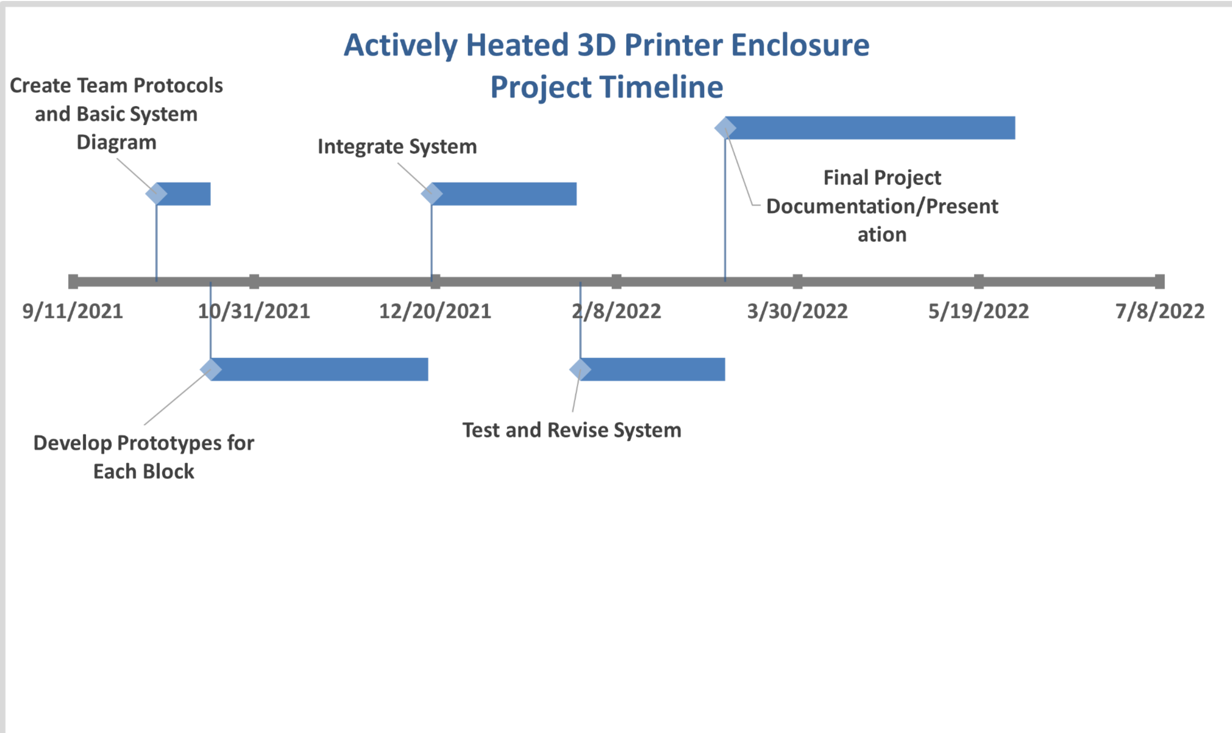
| Standard | Description |
| --- | --- |
| Quality of work | Each section designed will be done so in such a way that it is able to properly interact with the other pieces of the overall design, and will be approved by other team members. Written work will be done in a professional manner, and will be reviewed by the other team members, and revised if necessary. |
| Weekly Meetings | Each member will be present on Wednesday to discuss the current progress of the project with other members and the project partner unless stated that they will be absent. The meeting will have an agenda posted in Discord by Caspian by Monday, and all team members will post any comments or changes by Tuesday. In the case of an absence, the team member will update the others on their progress via Discord before the start of the meeting. |

## 1.3. Gap Analysis

The purpose of this project is to allow 3D printers to use various materials that require a heated environment to properly print. Currently, these are rarely used as they are prone to print failure without the use of an externally heated enclosure, which usually has to be custom made and are unintuitive to use. This device will solve this by allowing the external enclosure to interface directly with the networking device attached to a 3d printer, allowing for a hassle-free enclosure temperature.

This device will most likely be used primarily by business and enthusiast hobby 3D printers. Due to the relatively high cost generally associated with the types of materials that would require a device such as this, it will probably not be used by the majority of 3D printing hobbyists. The main audience for this project is the project partner and owner of Corvallis 3D, Bradley Heenk, though they stated that they wished for the project to be open source. The project partner had several hardware and software requirements that would allow it to work with their current equipment.

## 1.4. Timeline/Proposed Timeline




*Timeline created using Microsoft Excel

## 1.5. References and File Links

### 1.5.1. References (IEEE)

### 1.5.2. File Links

## 1.6. Revision Table

| Date | What was Changed |
|---|---|
| 10/16/2021 | Team: Document created; Initial contents of section 1 |
| 10/19/2021 | Caspian Hedlund: Added a line to reference where timeline was created |
| 10/27/2021 | Arthur Chen: Added roles and expected contribution to each team member |
| 11/10/2021 | Team: Replaced project timeline, revised executive summary, gap analysis and communication protocols according to peer feedback |
| 11/17/2021 | Team: Incorporate all suggestions and comments into the documents. |

# 2. Requirements, Impacts, and Risks

## 2.1. Requirements

### 2.1.1. **Customer Requirement:** The system will keep a steady temperature.

**Engineering Requirement:** The system will be able to maintain a temperature of 40°C-70°C ( ± 3°C) within the print area for 8 hours.

**Testing Method:**

1. Build a separate device capable of logging temperatures over an extended period of time.
2. Send a command to the system to maintain a temperature of 40°C.
3. Repeat step 2 for 55°C and 70°C
4. Check logged data to make sure that it never leaves the acceptable range.

### 2.1.2. **Customer Requirement:** The system will have a controllable temperature.

**Engineering Requirement:** The system will be controlled externally through a web application.

**Testing Method:**

1. Set the temperature via the web application.
2. Check the enclosure temperature to make sure it reaches the expected temperature.

### 2.1.3. **Customer Requirement:** The system will be big enough to hold the 3D printer.

**Engineering Requirement:** The system will be large enough to contain a Prusa i3 MK3S+ without interfering with the printing process (measured at 22”x18”x15.5”).

**Testing Method:**

1. The system will be set up with the Prusa i3 MK3S+ (22”x18”x15.5”) within the enclosure.
2. Move the bed all of the way backwards and make sure that it does not hit the back of the enclosure.
3. Move the bed all of the way forward and make sure that the enclosure can still be latched closed without the door hitting the printer.

4. Make sure that male end of the power cable can reach outside of the enclosure.

**2.1.4.** **Customer Requirement:** The system will be affordable.

**Engineering Requirement:** The system will be cost less than 300$

**Testing Method:**

1. Add up cost of all parts purchased
2. Determine if total cost is less than $300

**2.1.5.** **Customer Requirement:** The system will have have no visible internal wires or components

**Engineering Requirement:** The device will have all components and wires securely attached to the enclosure through the use of wire covers and additional enclosures.

**Testing Method:**

1. This requirement is proven by observation.

**2.1.6.** **Customer Requirement:** The system will have a clean appearance.

**Engineering Requirement:** Any internal components that can reasonably be hidden will be. The enclosure itself will be presentable.

**Testing Method:**

1. Check that all components and wires are placed inside or on the backside of the printer enclosure except for those necessary for monitoring the system (such as the display) and the water cooling.
2. Upon completion of the device, it will be presented to the project partner for approval.

**2.1.7.** **Customer Requirement:** The printer will be visible during operation.

**Engineering Requirement:** The printer will be viewable through a transparent panel while the system is operating.

**Testing Method:**

1. This requirement will be proven by observation.

**2.1.8.** **Customer Requirement:** The system will have safety measures to prevent it from overheating.

**Engineering Requirement:** The system will have a thermal protection circuit that will shut the system off if it is 100°C or above

**Testing Method:**

1. Forcibly heat the enclosure using an external heater to 100°C
2. Check if the thermal fuse has blown.

## 2.2. Design Impact Statement

1. **Public Health and Safety Impacts**

   3D printing is still in its infancy and its impacts on public health and safety are still being researched to this day. The enclosure itself can help prevent injury with the plethora of moving parts out in the open, improving on the safety of many 3D printers. The main purpose of this device is to keep in heat and maintain a temperature of at least 40C and up to 70C with a variance of plus or minus 1C. Studies on the thermal processing of plastics have shown that at high temperatures VOCs (Volatile Organic Compounds) and UFPs (Ultra-fine Particles) which are hazardous to the environment and to the users of the 3D printers [1]. While the enclosure is keeping these plastics at a higher temperature there is the potential to be releasing more of these hazardous compounds that could damage the environment more and even cause medical complications for users. While this enclosure does not get nearly as hot as the nozzle of a 3D printer which can reach upwards of 300C it still will contribute to keeping the plastic at a higher temperature, some intentional design implementations will need to be made in order to minimize the amount of UFPs and VOCs that are unfiltered and escape out into the environment. Some solutions could include filters on the vents to the enclosure but most of this is caused through the filament used. The filament makers will need to research other materials that are able to melt at those temperatures while not producing VOCs and UFPs. Another potential risk of safety is the use of high voltage electricity, the enclosure itself will be using around 12 volts and over 100 watts while on and that power will be supplied continuously until the enclosure no longer needs to be heated. These voltages could easily kill someone if they were to touch a live wire or mess with the components it could result in bodily harm or death, it takes as little as 7mA for 3 seconds is enough to kill someone [2]. It’s inevitable that someone will want to modify the device at some point, even taking it apart or trying to replace parts, in order to minimize the risk to this person we should design the enclosure so that wires are hidden and are easy to avoid unwanted contact. This can be done through the use of a facade that attaches to the enclosure and is bolted down to hide the wires and dangerous components. This still allows for a user to fix the machine or get it fixed while also protecting them from unwanted contact.

2. **Cultural/Social and Welfare Impacts**
   Another major aspect to look at is the cultural and social impacts that this product will have, it is very possible that the product in the future will be redesigned and improved or even adapted 1 for other uses. As a result this could bring in more competition into the 3D printing world and result in fewer failed prints. Prints that warp have their reasons, the most common being uneven cooling and weak adhesion to the printing bed or platform [3]. With our enclosure the filament will be coming into contact with a warmer print surface and as the filament cools down it will better adhere to the print bed resulting in the base not curling. Since this product is also meant to be affordable it is likely to be adopted by others in the 3D print space shifting the culture from open air to use in an enclosure. This enclosure could even be adapted and used in the medical field, imagine an enclosure with the temperature of a human, slowly printing an organ. Scientists are researching how to use the 3D printing process to manufacture living organs such as a heart or liver, but this research is in early stages of development [4]. This could result in cheaper treatment across the US but also switch the way in which medicine is done. 3D printing will continue to push the boundaries of medicine and could completely change the way we look at medicine. In the end it will come down to ethics though, even though we could 3D print an entire human doesn't mean we should. If this product does eventually get used in that way an ethics panel should be tapped for the regulations on its use.

3. **Environmental Impacts**
   One of the most important things to take into account is the environmental impact that this project could have. The use of electronics to control the temperature of this machine is likely to contribute to the huge E-waste (electronic waste) that currently is a major issue, as it stands only 20% of E-waste is collected and even when it is recycled it 30% of the material is lost [5]. This could be sped up by the extreme heat that the electronics causing them to either be thrown away but hopefully recycled, we can avoid this by protecting the electronics from heat or dissipate the heat that is near the electronics through some means. The other issue that arises is the production of VOCs that contribute to smog/haze [6], this contributes to lower insect able to pollinate, as another result plants aren't getting pollinated and could end up dying off. This also has another effect of that there are less plants to take in $CO_2$ (Carbon Dioxide) resulting in harsher haze/smog and could result in even worse environmental conditions. Ways in which this can be avoided is through the implementation of a filter that is able to catch VOCs, it could be a vent area to force the are though it. We could also design a set up to take the filtered air directly outside so that it is also out of the environment of the user. This could be done by exhausting all the air in the enclosure through one outtake and

connecting that outtake to an HVAC (Heating, ventilation, and air conditioning) system that filters it then directly sends the air out above the building. This would result in less dangerous particles in not only the users environment but also in the environment in general. conditioning) system that filters it then directly sends the air out above the building. This would result in less dangerous particles in not only the user's environment but also in the environment in general.

4. **Economic Factors**

One of the big economic factors of this is our budget of $200 that was set by our project partner, this has the effect of having to go towards cheaper parts. Many of these parts tend to come from China or Russia, this results in more money being sent out of the US. This results in the US cutting manufacturing jobs, as seen between 2001 and 2018 there were around 3.7 million jobs lost as a result of this [7]. If there was a higher budget we would be able to get some more expensive material and even source it from the US in order to avoid contributing to this issue facing the US. With a lower budget we are constrained in the type of materials we are allowed to use, that means the use of metals is out of the picture meaning that we are forced to use lumber. By using lumber we run the risk of combustion and contributing to deforestation if not sourced responsibly. This also means that conduction plates are not able to be used in 2 our designs as it would become more of a combustion risk and wood does not conduct heat as effectively as metal does. Due to this we have to use a heating unit that is able to circulate air which uses a fan that can fail, this adds more points of failure to our product. Also since we are sourcing parts from areas other than the US it means that we have to wait a longer period of time for these parts to arrive as well meaning that parts will need to be ordered in advance. Since we are located in Oregon we are able to get the wood from our enclosure without worrying about it being part of deforestation. One of the main things Oregon does when it logged its forests is replant each tree that was harvested [8]. This resulted in both keeping jobs within the US but also making sure that our forests are sustainable. With sustainable practices and purchasing from within the US we are sustaining the economy but also staying within budget, this is one of the few things that will be from within the US. These are just a few of the economic factors that could be predominant with this product.

## 2.3. Risks

| Risk ID | Risk Description | Risk category | Risk probability | Risk impact | Performance indicator | Responsible party | Action Plan |
|---|---|---|---|---|---|---|---|
| R1 | Vendor delay | Timeline | 45% | Low | Supply Shortage | Caspian | Replace |
| R2 | Incompatible interface | Technical | 10% | High | Components cannot communicate | Arthur | Redesign |
| R3 | Damaged prototype | Technical/cost | 20% | Medium | Previously working component breaks | Mark | Rebuild |
| R4 | Over budget | Cost | 5% | Low | Spend more than 300$ | Kaleb | Reduce |

## 2.4. References and File Links

### 2.4.1. References


1. "3D printer safety - concordia university." [Online]. Available: https://www.concordia.ca/content/dam/concordia/services/safety/docs/EHSDOC-148_3DPrinterSafety.pdf [Accessed: 29-Oct-2021].

2. "Fatal electric shock: What voltage causes death?," Metroid Electrical Engineering, 15- Feb-2021. [Online]. Available: https://www.metroid.net.au/engineering/knowledge_center/fatal-electricshock-what-voltage-causes-death [Accessed: 30-Oct-2021].

3. M. Dwamena, "How to fix 3D prints warping, curling, lifting from bed? easy steps," 3D Printerly, 26-Oct-2021. [Online]. Available: https://3dprinterly.com/are-your-prints-warping-or-curling-learn-howto-fix-it/ [Accessed: 30-Oct-2021].

4. Center for Devices and Radiological Health, "3D printers are used to manufacture a variety of medical devices," U.S. Food and Drug Administration. [Online]. Available: https://www.fda.gov/medical-devices/3d-printing-medical-devices/medical-applications-3dprinting [Accessed: 30-Oct-2021].

5. ”Smog-Who Does It Hurt?” [Online]. Avaliable: https://www.airnow.gov/sites/default/files/2018- 03/smog.pdf [Accessed: 29-Oct-2021].
6. “Health amp; Environmental effects of air pollution - mass.gov.” [Online]. Available: https://www.mass.gov/doc/health-environmental-effects-of-air-pollution/download [Accessed: 30-Oct-2021].

7. Report • By Robert E. Scott and Zane Mokhiber • January 30, “Growing China trade deficit cost 3.7 million American jobs between 2001 and 2018: Jobs Lost in every U.S. state and Congressional District,” Economic Policy Institute. [Online]. Available: https://www.epi.org/publication/growing-china-trade-deficits-costs-us-jobs/ [Accessed: 30-Oct-2021].

8. “Oregonforests.org.” [Online]. Available: https://oregonforests.org/harvest-regulations [Accessed: 30-Oct-2021].

#### 2.4.2. File Links

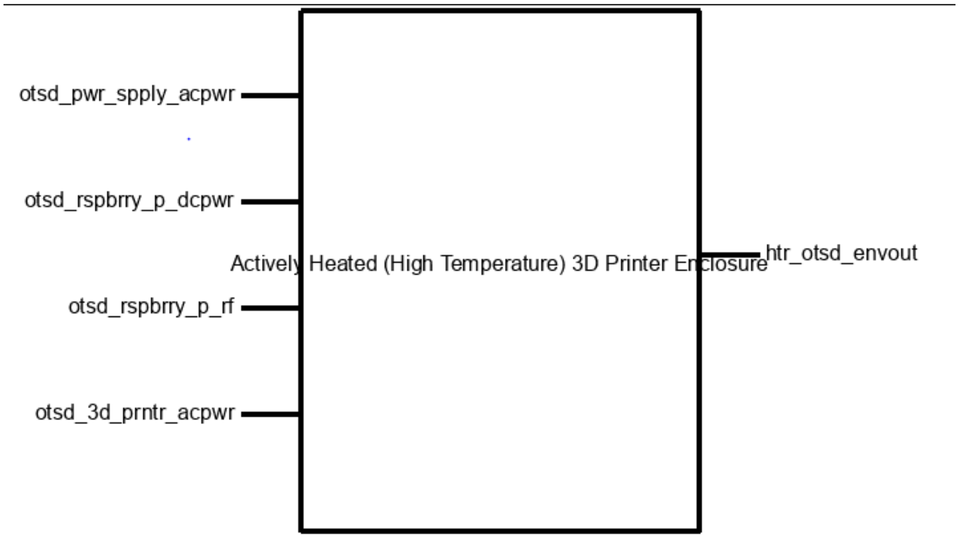
## 2.5. Revision Table

| Date | What was Changed |
|---|---|
| 10/27/2021 | Team: Initial contents of section 2 |
| 11/10/2021 | Team: Added customer requirements for each requirement listed and added two additional requirements |
| 11/17/2021 | Team: Incorporate all suggestions and comments into the documents. |
| 05/06/2022 | Team: Added Design Impact Statement from group member’s writing and reference and sitation |

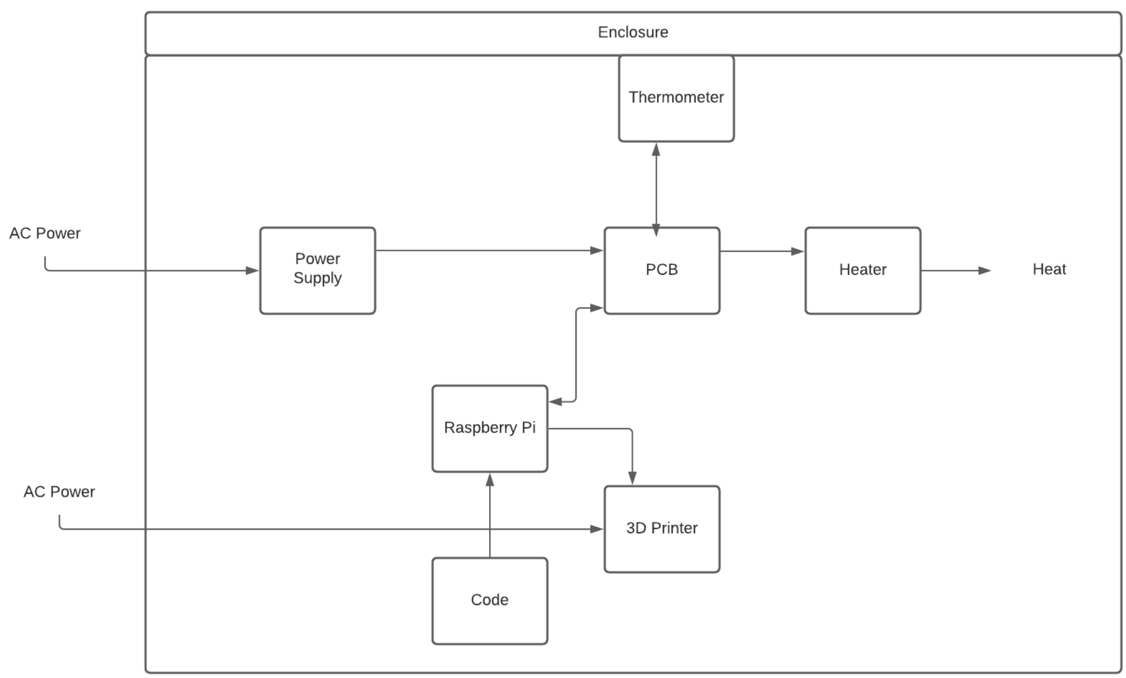
# 3. Top-Level Architecture

## 3.1. Block Diagram

### 3.1.1. Black Box Diagram




### 3.1.2. System Connection Diagram




*Block diagram created using LucidChart

## 3.2. Block Descriptions

### 3.2.1. Raspberry Pi

The Raspberry pi will be the central controller for the entire system. The Raspberry Pi is already installed on the project partner's printers, and is used to control the printers through a web application. The enclosure will receive user commands from the same web application. Caspian Hedlund is championing this block

### 3.2.2. Thermometer

This device will be used to read the current temperature within the enclosure. It will relay the information to the raspberry pi which will determine if the heaters need to be turned on/off. Mark Ellarma will be championing this block.

### 3.2.3. Power Supply

The Power Supply would use a wall charger as the input power and dissipate a 360 Watts Power into Relay on the PCB. Arthur Chen will be championing this block.

### 3.2.4. PCB

The PCB would be used as a relay module buzzer module. The PCB will receive an input signal of the Raspberry Pi from the different GPIO pins. For the relay module, once the signal is received, the relay module determines the on and off of the heater based on this input signal. For the buzzer module, once the signal is received, the buzzer module will alarm the user that the inner temperature of the enclosure is over the previous setting and further action needs to be taken. Arthur Chen will be championing this block.

### 3.2.5. Heater

The heater will be the only source of heat for the enclosure and will be mounted on the bottom of the enclosure and powered by a power supply that goes through a relay. Kaleb Krieger will be championing this block.

### 3.2.6. Enclosure

The enclosure will have two parts. The first is the main portion that will be made of plywood, and is used to hold the heat in to increase efficiency. The second part will be used to mount the PCB and other electronic components. This part will be 3D printed. Caspian Hedlund is championing this block.

### 3.2.7. 3D Printer

The 3D printer will obtain spliced Gcode from the Raspberry Pi and print the spliced object. Kaleb Krieger will be championing this block.

#### 3.2.8. Code

Code that is running on the Raspberry Pi. This will mostly be interpreting the enclosure temperature G-code parameter. provided to the Raspberry Pi from a web interface. The Raspberry Pi is already installed on the 3D printer and is sending other G-code commands to the printer. It will also need to prevent the printer from starting until the enclosure is heated to the desired temperature. Mark Ellarma will be championing this block.

## 3.3. Interface Definitions

| Name | Properties |
| --- | --- |
| otsd_pwr_spply_acpwr | **Ipeak: 4A**<br>**Inominal: 4A**<br>**Vnominal: 120V AC** |
| otsd_rspbrry_p_dcpwr | **Ipeak: 3A**<br>**Inominal: 2A**<br>**Vmax: 5.5V**<br>**Vnominal: 5V**<br>**Vmin: 4.5V*** |
| otsd_3d_prntr_acpwr | **Ipeak: 1.8A**<br>**Inominal: 3.6A**<br>**Vnominal: 120V AC** |
| pwr_spply_thrmmtr__dcpwr | |
| pwr_spply_pcb_dcpwr | **Ipeak: 40A**<br>**Inominal: 20A**<br>**Vmax: 13V***<br>**Vnominal: 12V**<br>**Vmin: 11V*** |
| thrmmtr__rspbrry_p_data | **1 wire interface** |

| | |
|---|---|
| thrmmtr__pcb_dsig | **Logic-Level: 5V**<br>**Vnominal: 5V** |
| htr_otsd_envout | **360W peak** |
| rspbrry_p_3d_prntr_dsig | **USB** |
| rspbrry_p_pcb_dcpwr | **Ipeak: 10mA***<br>**Inominal: 1mA***<br>**Vmax: 5.5V***<br>**Vmin: 4.5V*** |
| rspbrry_p_pcb_dsig | **Logic-Level: 5V** |
| cd_rspbrry_p_data | **Other: Klipper .cfg** |
| pcb_thrmmtr__dcpwr | **Ipeak: 4mA**<br>**Inominal: 1mA**<br>**Vmax: 5V**<br>**Vmin: 3V** |
| pcb_htr_dcpwr | **Ipeak: 40A**<br>**Inominal: 20A**<br>**Vmax: 13V***<br>**Vmin: 11V*** |

*Note that some properties are currently blank as their exact values will require testing as well as that values followed by "*" are subject to change.

## 3.4. References and File Links

### 3.4.1. Revision Table

| Date | What was Changed |
|---|---|
| 11/17/21 | Team: Initial contents of section 3 |
| 11/29/2021 | Team: Added Black Box diagram to section 3.1 and updated block descriptions to include a champion for each block. Updated interface definition |

# 4. Block Descriptions

## 4.1. OLED Display

### 4.1.1. Block Description

This device will be used to display the current temperature and desired temperature within the actively heated enclosure. It will receive the information from the raspberry pi which will have received the current temperature from the thermometer and the desired temperature from the g-code slicer. The OLED Display should update every second. Mark Ellarma will be championing this block.

### 4.1.2. Block Design

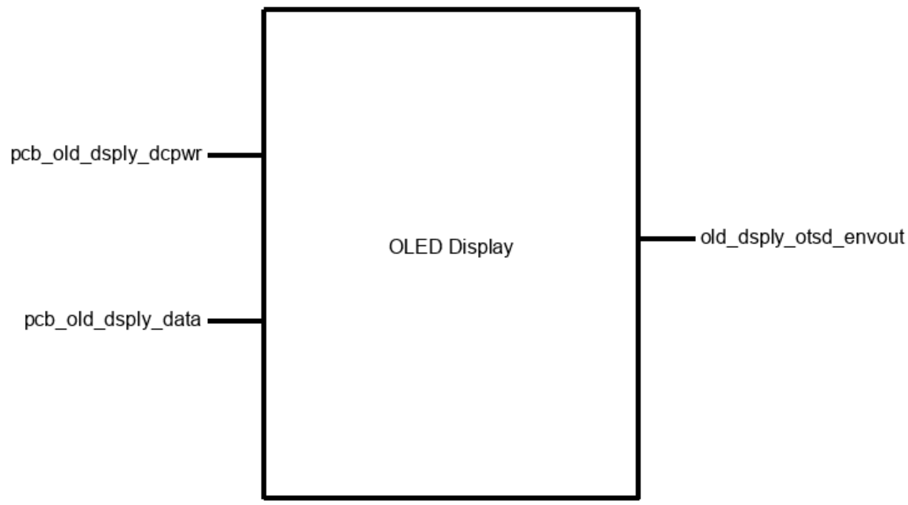



Figure 1: OLED Display black box diagram and interface definitions

#### 4.1.2.1. Block Diagram

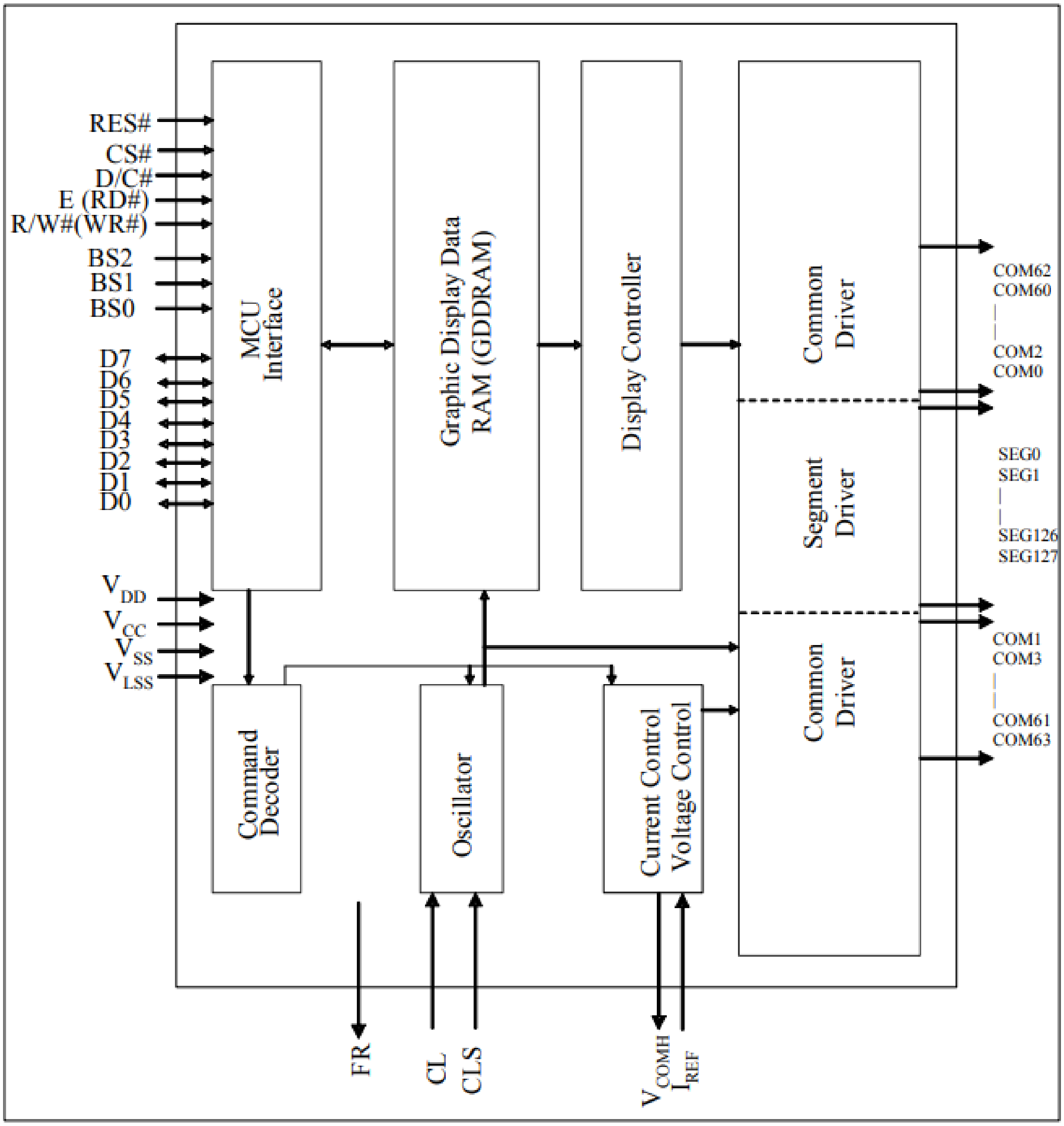



Figure 2: OLED Display block diagram

## 4.1.2.2. Arduino pseudocode

```
while(1){
  //code to read temperature from thermometer
  read (tempPin)
```

```
convert (tempPin)

println ("temperature = ", tempPin)


//code for display

desTemp = gcodeTemp        //provided another block

curTemp = tempPin

display.print("Desired Temperature:",desTemp)

display.print("Current Temperature:", curTemp)

Wait 1 sec

}
```

### 4.1.3. Block General Validation

The SSD1306 OLED display was chosen because of its small form factor, ease of use, and availability. From the time of purchase, the SSD1306 OLED display arrived within the same week. This allowed for more time to test and verify that this device is what we desire from this block.

Although the SSD1306 OLED display is only around 1 inch by 0.5 inch in size, it is still easy to read what is being displayed. Along with the fact that we have purchased a pack of two displays, it is possible to display current and desired temperatures on separate displays if need be.

Since the SSD1306 OLED display is widely used alongside microcontrollers, there are many different resources to reference when implementing this device alongside the thermometer. With an existing library, we are able to easily customize the text being displayed and alter how it is displayed.

### 4.1.4. Block Interface Validation

**old_dsply_otsd_envout : Output**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Other: Display Desired Temperature | Will be used to verify that the desired temperature is accurate | The desired temperature being displayed is correct |
| Other: Display Current Temperature | Will be used to verify that the current temperature is | The current temperature being displayed is the same as what is being read from the thermometer |
| Other: Update Every Second | Current temperature will update every second | Due to the delay used when reading data from the thermometer, the current temperature is updated every second |

**pcb_old_dsply_data : Input**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Datarate: 9600 bps | This will be the rate at which data is sent between the microcontroller and OLED display | Rate programmed onto the microcontroller |
| Other: Data received every second | Data will be sent to the display every second updating the current temperature reading | Due to the delay used when reading data from the thermometer, the current temperature is updated every second |
| Other: I2C communication | The protocol used to receive data that will be displayed on the device | Page 19 within the SSD1306 datasheet[1]:<br>● MCU I2C Interface |

**pcb_old_dsply_dcpwr : Input**

| Interface Property | Why is this interface of this value? | Why do you know that your design details <u>for this block</u> above meet or exceed each property? |
|---|---|---|
| Inominal: 8.5mA | This nominal current was taken from the active range given within the datasheet | Tested through the use of a DMM |
| Ipeak: 10mA | The thermometer is not expected to draw more than this amount of current | Tested through the use of a DMM |
| Vmax: 5V | This is the recommended voltage range to operate the device | When supplied Vmax the OLED display should still function normally |
| Vmin: 3.3V | This is the recommended voltage range to operate the device | When supplied Vmin the OLED display should still function normally |

### 4.1.5. Block Testing Process

1. Flash an Arduino nano with the correct program to be able to communicate with both the thermometer and OLED display
2. Connect the thermometer and OLED display to the Arduino nano
3. Verify that the current temperature updates every second
4. Use a DMM to test that the current being supplied is below 780uA
5. Use a variable voltage supply and test that the OLED display functions within 3.3V - 5V

### 4.1.6. References and Links


[1] "SSD1306 - Adafruit Industries," Apr-2008. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/SSD1306.pdf. [Accessed: 04-Feb-2022].


### 4.1.7. Revision Table

| Revision | Date |
|---|---|
| Mark: Block Section Created | 3/6/2022 |

## 4.2. Thermometer

### 4.2.1. Block Description

This device will be used to read the current temperature within the enclosure. It will relay the information to the raspberry pi which will determine if the heaters need to be turned on or off. The thermometer is expected to have an accuracy of ±3°C. Mark Ellarma will be championing this block.

### 4.2.2. Block Design

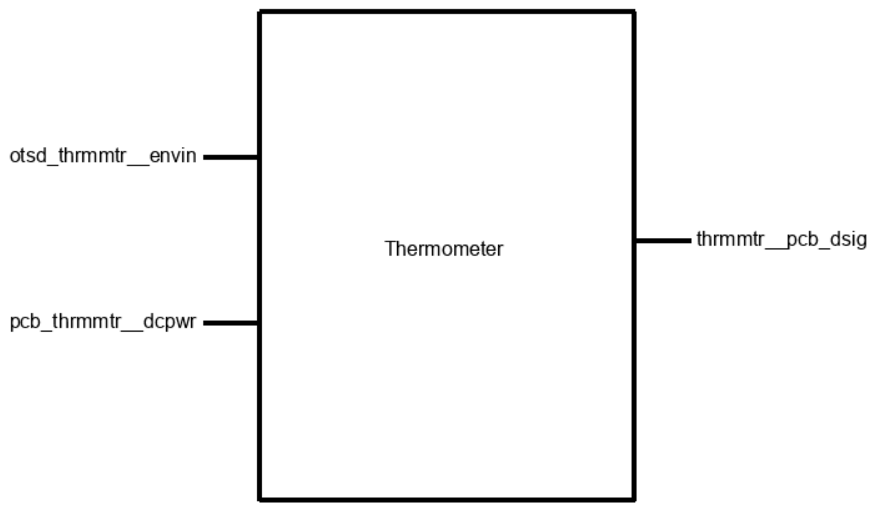



Figure 1: Thermometer black box diagram and interface definitions

#### 4.2.2.1. Block Diagram

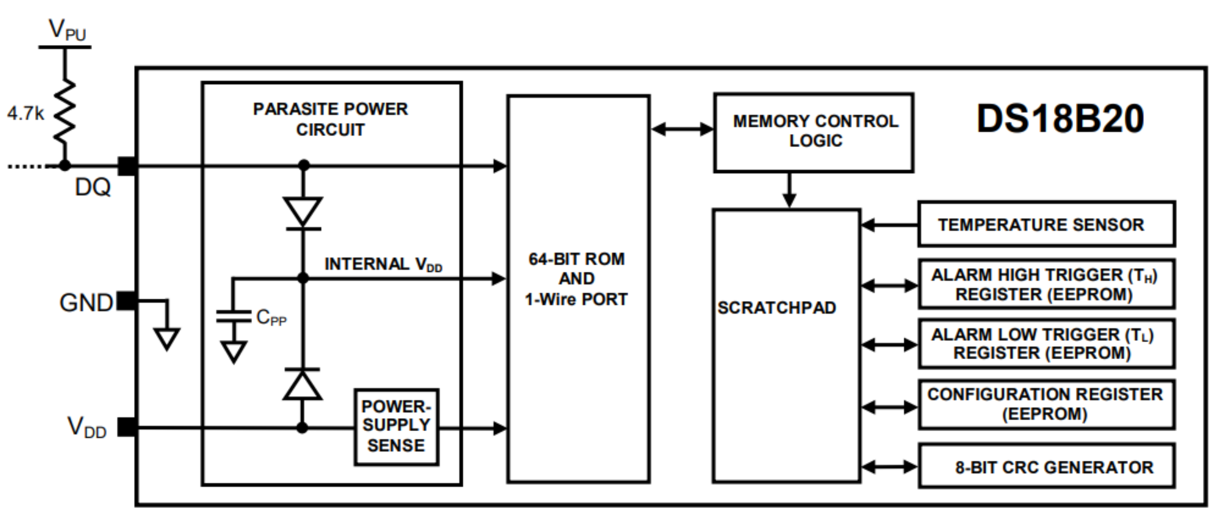



Figure 2: Thermometer block diagram

#### 4.2.2.2. Arduino pseudocode

```
while(1){
  read (tempPin)
  convert (tempPin)
  println (“temperature = “, tempPin)
  Wait 1 sec
}
```

### 4.2.3. Block General Validation

The DS18B20 digital thermometer was chosen due to its low cost, availability, and ease of use. From the time of purchase, it took less than a week to be delivered allowing us to quickly test the accuracy of the device to ensure it will work within our specifications.

Since this temperature sensor is widely used alongside microcontrollers, there are many resources on how to correctly wire and interpret the data being sent from the thermometer. This means that there were very few issues creating a program to test the accuracy of the device. When compared to an off-the-shelf non-contact temperature sensor, it was well within the ±3℃ requirement.

The way this thermometer is designed allows for the temperature sensor to be secured in a different location from all the other circuitry. This is important because it will allow us to not need to worry about the electronics getting too hot since it can be secured outside of the enclosure that we are heating. Along with this, the temperature sensor itself is able to function from -55℃ to 125℃, meaning there will be no issues with the sensor overheating. In addition, its small size means that there will be no issues installing such a device onto the enclosure.

In the end, the temperature sensor will be able to fulfill all requirements needed along with being easily installed and integrated into the final product.

### 4.2.4. Block Interface Validation

**otsd_thrmmtr__envin : Input**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Other: 40°C-70°C | This is the requirement that was specified when talking to our project partner | Page 1 within the DS18B20 datasheet[1]:<br>● Measures Temperatures from -55°C to +125°C |

**thrmmtr__pcb_dsig : Output**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Other: One wire communication | The protocol used by this device in order to read the digital output signal will be done through a one-wire bus system. | Page 9 within the DS18B20 datasheet[1] |
| Other: ± 3°C Accuracy | This is the requirement that was specified when talking to our project partner | Page 1 within the DS18B20 datasheet[1]:<br>● ±0.5°C Accuracy from -10°C to +85°C |

**pcb_thrmmtr__dcpwr : Input**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u>** |
|---|---|---|

| | | |
|---|---|---|
| | | **above meet or exceed each property?** |
| Inominal: 1mA | This nominal current was taken from the active range given within the datasheet | Page 19 within the DS18B20 datasheet[1]:<br>● Active current $I_{DD}$ range is 1mA - 1.5mA |
| Ipeak: 4mA | The thermometer is not expected to draw more than this amount of current | Page 19 within the DS18B20 datasheet[1]:<br>● The current sink value is 4mA |
| Vmax: 5.5V | This max voltage is taken from the operating voltage given within the datasheet | Page 19 within the DS18B20 datasheet[1]:<br>● Can Be Powered from Data Line; Power Supply Range is 3.0V to 5.5V |
| Vmin: 3.0V | This min voltage is taken from the operating voltage given within the datasheet | Page 19 within the DS18B20 datasheet[1]:<br>● Can Be Powered from Data Line; Power Supply Range is 3.0V to 5.5V |

### 4.2.5. Block Testing Process

1. Flash the Arduino nano with the correct program to be able to communicate with the thermometer
2. Connect the Arduino nano to the thermometer in accordance with the wiring diagram above.
3. Verify that the thermometer is reading temperatures and updating every second
4. Compare the temperature being read from the thermometer to an off-the-shelf thermometer. The difference between both thermometers should be less than 3℃
5. Use a DMM to read the thrmmtr__pcb_dsig output signal and verify that it is operating at 5V
6. Use a DMM to read the pcb_thrmmtr__dcpwr input signal and verify that it is operating at 1mA
    a. In addition, the current should be less than 5mA with a Vmax of 5.5V and Vmin of 3.0V

### 4.2.6. References and Links

[1] "Programmable resolution 1-wire digital thermometer." [Online]. Available: https://cdn-shop.adafruit.com/datasheets/DS18B20.pdf. [Accessed: 07-Jan-2022].

### 4.2.7. Revision Table

| Revision | Date |
|---|---|
| Mark: Block Section Created | 3/6/2022 |

## 4.3. Power Supply

### 4.3.1. Block Description

Block Champion: Jingwei Chen

The Power Supply, *ALITOVE AC 110V/220V to DC 12V 30A 360W Universal Regulated Switching Power Supply*, will take a wall socket as the input power and support the operation of the PCB Board. The requirement for this block is providing a stable 300W DC power, and the extra 60W is redundancy for back-up purpose. The reason for selecting the Power Supply for our design is due to the safety issue. The ALITOVE AV 110V/220V to BC 12C 30A Power Supply was in-built with the function of automatic overload cut-off protection, over-voltage cut-off protection, thermal cut-off protection and short circuit cut-off protection. Meanwhile, the Power Supply is in-built with a cooling fan which enhances the heat dissipation efficiency.

### 4.3.2. Block Design

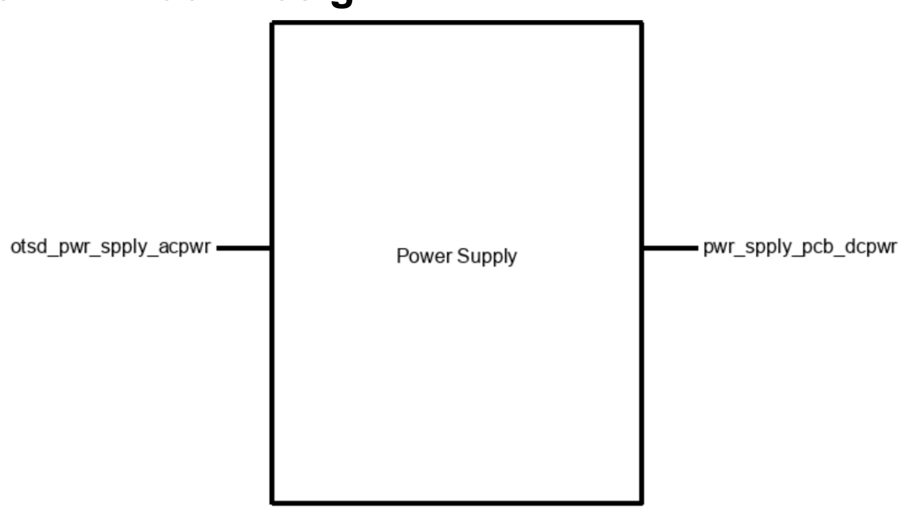


**Figure 1:** The Power Supply Block

The Power Supply is used for supporting the operation of Heater Fan and preparing as a back-up power supply for other possible designs.

**Figure 2:** The left-side view of the power supply**[4]**

**Figure 3:** The right-view of the power supply**[4]**

**Figure 4:** The back and side view of the power supply**[4]**

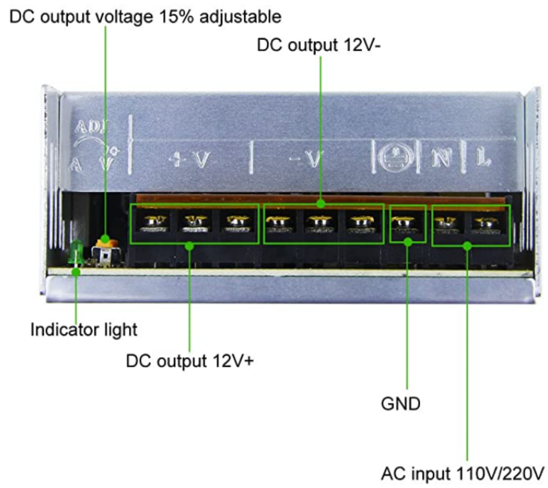



**Figure 5:** The front view of the power supply**[4]**

| | |
|---|---|
| **Length** | 21.5cm/8.46in |
| **Width** | 11.2cm/4.41in |
| **Height** | 5cm/1.96in |
| **Weight** | 820g/1.81lb |

**Table 1:** Dimensions**[4]**

### 4.3.3. Block General Validation

The purpose and requirement for this block is to provide a stable 360W power to both the Heater Fan and the PCB Board. Since the Power Supply does not request an additional component for the input interface, the Power Supply will consume the wall socket directly as an input power. The input mode of the Power Supply will be set to 110V in order to match with the United States standard voltage setting as well as preventing the Power Supply from overheating. Once the Power Supply was connected to the wall socket, the Indicator light (LED Green) would be turned on, indicating that the Power Supply is powered-on and it is stable.
After the Power Supply was powered-on, a multimeter would be applied to the output interface to verify that the output voltage was 12V and the output current was 10A.

### 4.3.4. Block Interface Validation

**otsd_pwr_spply_acpwr:** Input

| | | |
|---|---|---|
| Vnominal: 120v | The standard setting of US outlet is Vnominal: 120V | In the USA, the standard voltage output is set to 120V **[1].** |
| Ipeak: 20A | The standard setting of US outlet is Ipeak: 20A | In the USA, the standard peak current output is 20A **[2]**. |
| Inominal:15A | The standard setting of US outlet is Inomial: 15A | In the USA, the standard nominal current output is 15A **[2]**. |

**pwr_spply_pcb_dcpwr:**output

| | | |
|---|---|---|
| Ipeak: 40A | This is the default of the ALITOVE Power Supply | This value is provided by the official webpage of ALITOVE **[3]** |
| Inominal: 20A | PCB required 20A supply | 480W = 12V*I; I = 40A. 40A is more than enough to validate that nominal to maintain 20A **[3] [4]**. |
| Vmax: 12V | This is the default of the ALITOVE Power Supply | This value is provided by the official webpage of ALITOVE and the website where we purchased the Power Supply (Amazon) **[3] [4]**. |
| Vmin: 10.2V | Output voltage is adjustable 15% | This value is provided by the official webpage of ALITOVE and the website where we purchased the Power Supply (Amazon) **[3] [4]**. |

### 4.3.5. Block Testing Process

1. Testing the power inputs
    a. Connecting the GND to one of the V- interfaces.
    b. Connecting the charging cable to N/L interface
    c. Checking whether the indicator light is light-on or not
2. Testing the power output
    a. Applying the multimeter to one of the V+ and V- interfaces.

b. Checking whether the reads from the multimeter are matching with the requirement (12V and 10A).

### 4.3.6. References and Links


[1]J. Bytheway, "What's the difference between a 110 outlet and a 120 outlet?", *Quora*, 2022. [Online]. Available: https://www.quora.com/Whats-the-difference-between-a-110-outlet-and-a-120-outlet#:~:text=Today%20the%20US%20standard%20(per,be%20between%20116V%20and%20122V. [Accessed: 21- Jan- 2022].

[2]J. James, "What Is the Standard Voltage and Amps for an Outlet?", *Survival Freedom*, 2022. [Online]. Available: https://survivalfreedom.com/what-is-the-standard-voltage-and-amps-for-an-outlet/. [Accessed: 21- Jan- 2022].

[3]"AC 110V 220V to DC 12V 30A 360W Transformer Switch Power Supply Converter of Led lighting accessories from China Suppliers - 166116865", *Detail.en.china.cn*, 2022. [Online]. Available: https://detail.en.china.cn/provide/p166116865.html. [Accessed: 21- Jan- 2022].

[4]"ALITOVE AC 110V/220V to DC 12V 30A 360W Universal Regulated Switching Power Supply Transformer Adapter LED Driver for LED Strip, CCTV Camera System, Radio", *Amazon.com*, 2022. [Online]. Available: https://www.amazon.com/ALITOVE-Universal-Regulated-Switching-Transformer/dp/B06XJVYDDW/ref=sr_1_4?crid=267QD4UPV9ZFQ&keywords=12v%2Bpower%2Bsupply&qid=1637206781&sprefix=12v%2B%2Caps%2C240&sr=8-4&th=1. [Accessed: 21- Jan- 2022].


### 4.3.7. Revision Table

| Revision | Date |
| --- | --- |
| Jingwei Chen: Block Section Created | 3/6/2022 |

## 4.4. PCB Board

### 4.4.1. Block Description

Block Champion: Jingwei Chen
The functionality of the PCB is to work as a controller for both the heater and the fan. The PCB board will take the “5v” output from the Raspberry Pi as an input voltage as well as a controlling voltage signal. While the

thermometer detects enough heat within the enclosure (70±3°C), the Raspberry Pi generates a voltage signal to the relay in order to determine the on and off status of the heater and the fan.

The purpose of using a relay is to convert a small electrical input into a high-current output is no easy feat, but this task is necessary to efficiently operate a wide range of standard appliances and vehicles. Many circuits achieve these conversions through the use of relays, which are indispensable in all kinds of electronic equipment **[1].** The benefit of using a relay is that relays are capable of reducing the requirement of high-amperage and high-voltage wiring and switches. It allows low-amperage and low-voltage signals to control the status (on or off) of high-amperage and high-voltage devices.

### 4.4.2. Block Design

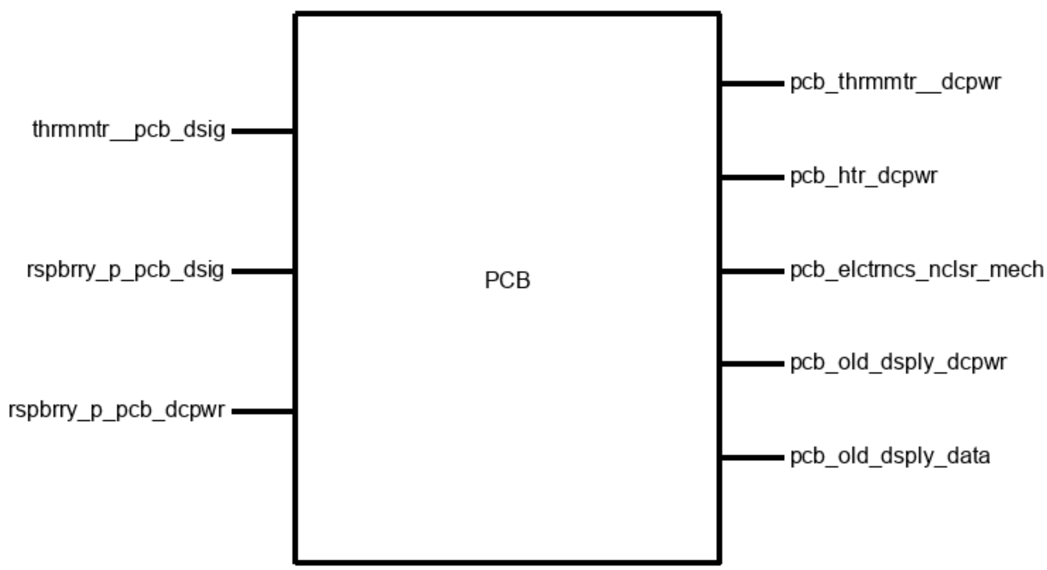



**Figure 1:** The PCB Board Block

The PCB Board would be used to regulate the status of both heater and fan as well as a central transfer station for the whole system.

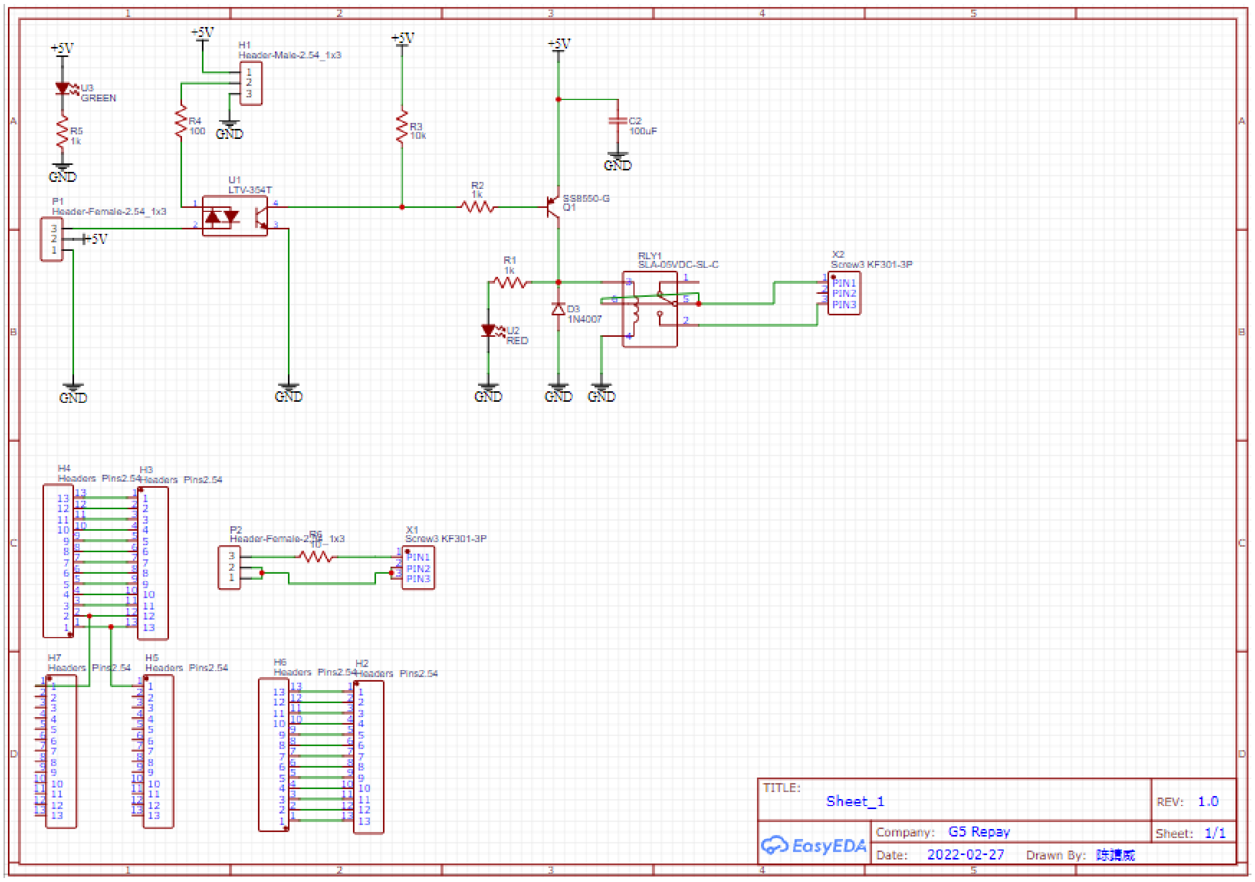



**Figure 2:** The schematic of the PCB Board

The relay used for this project is SLA-05VDC-SL-C which is a production of SONGLE. It indicates that the channel voltage of this relay is 5v. Meanwhile, the loading voltage of this relay is 30 VDC and the loading current is 30 A. **[1]**

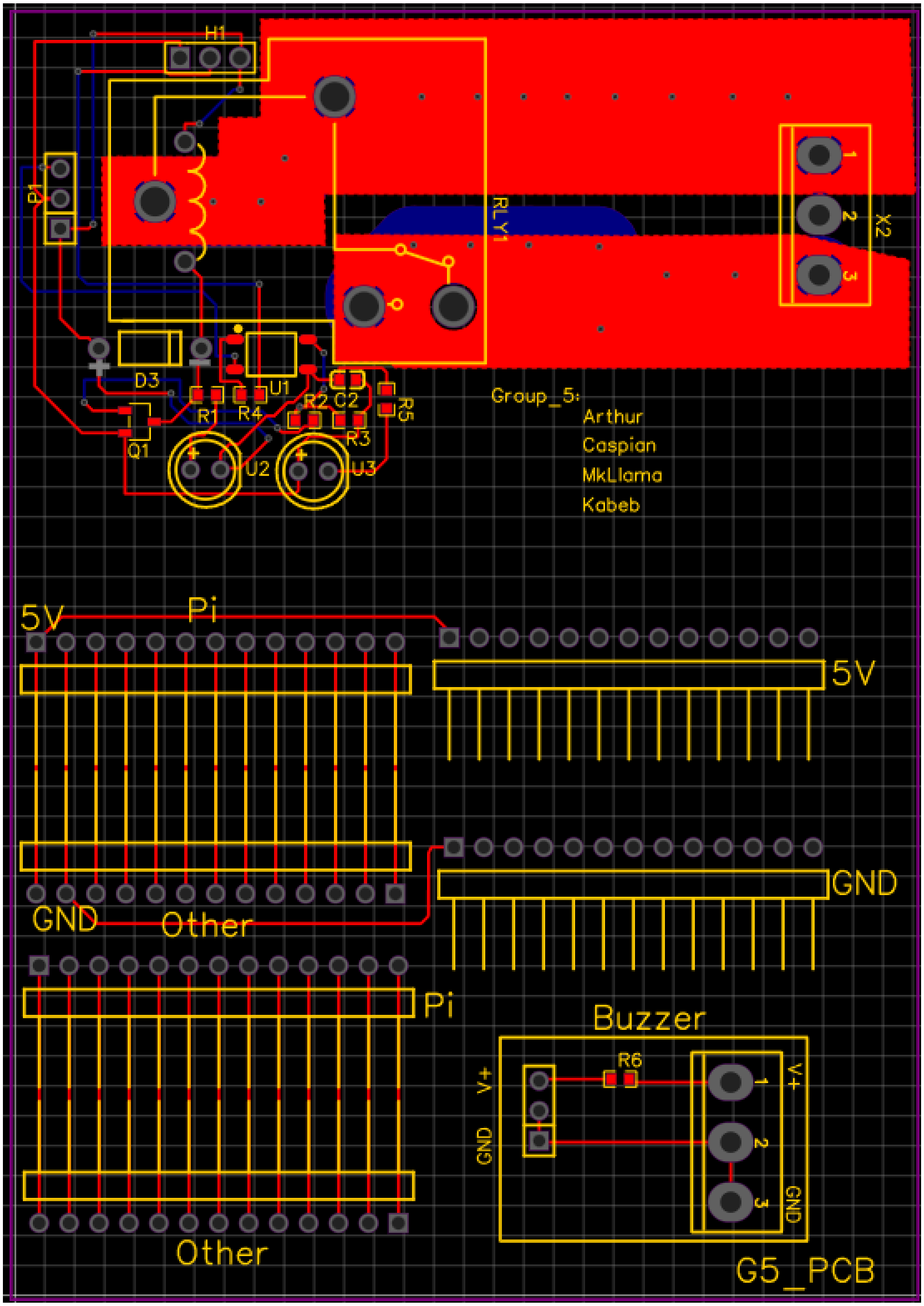



**Figure 3:** The layout of the PCB Board

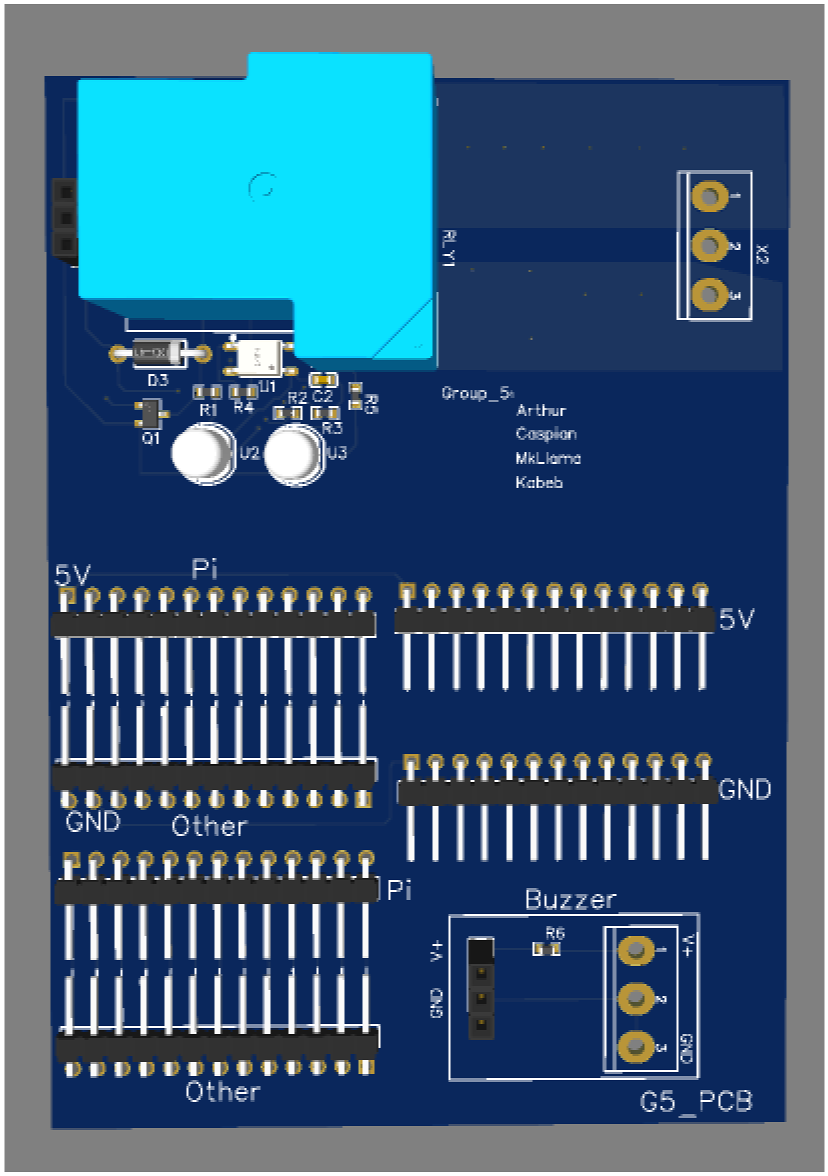



**Figure 4:** The 3D view of the PCB Board

### 4.4.3. Block General Validation

The purpose and requirement for this block is to take the input (5v) from the Raspberry pi as a voltage input and boost this voltage input (5v) to voltage output (12v), to determine the status of the heater and fan, on or off. When the voltage input (5v) is cut-off, the voltage booster part of this PCB Board would be shut down as well, then the heater and fan would be in the off status. Meanwhile,the PCB would be used as a central transfer station for the whole system. The central transfer station is to use a PCB to replace the wiring connection between the Raspberry pi and the other parts of the project such as the thermometer, the OLED display, and the relay (Note: more parts might be added to the PCB). The parts are not controlled by the voltage booster part of the PCB Board; they are controlled by the Raspberry pi directly.

### 4.4.4. Block Interface Validation

PCB Block does not require an interface Validation.

### 4.4.5. Block Testing Process

1. Testing the Input
    a. Assemble the Raspberry Pi with the PCB Boardand check whether the LED is lit up.
2. Testing the Output
    a. Assemble the PCB with the other devices and check whether the device is operating properly.

### 4.4.6. References and Links

**Unknown. (n.d.). *Songle Relay Relay ISO9002 SLA - files.seeedstudio.com*. SONGLE RELAY. Retrieved March 7, 2022, from https://files.seeedstudio.com/wiki/Grove-SPDT_Relay_30A/res/SLA-05VDC-SL-C_Datasheet.pdf**

### 4.4.7. Revision Table

| Revision | Date |
| --- | --- |
| Jingwei Chen: Block Section Created | 03/06/2022 |

# 4.5. Block Description

## 4.5.1. Printer Enclosure

### 4.5.1.1. Block Overview

The printer enclosure is the portion of the device that will surround the printer. It’s purpose is to both keep the heat from escaping the print area, and to mount the other components. This component will be made primarily out of plywood, with a front panel made of a clear acrylic sheet that will open to allow access to the printer. Caspian Hedlund is the Champion of this block.

### 4.5.1.2. Block Design

#### 4.5.1.2.1. NW Isometric Diagram

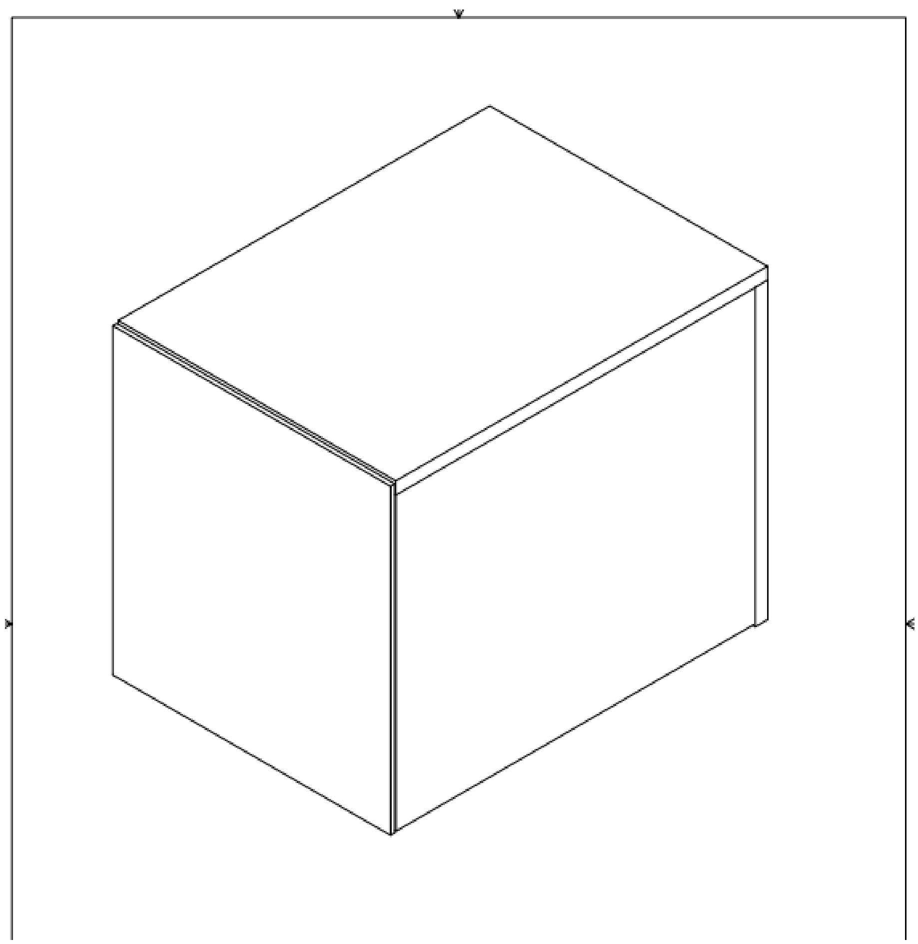


Figure 1: NW Isometric view of the enclosure.

### 4.5.1.2.2. Front View Diagram

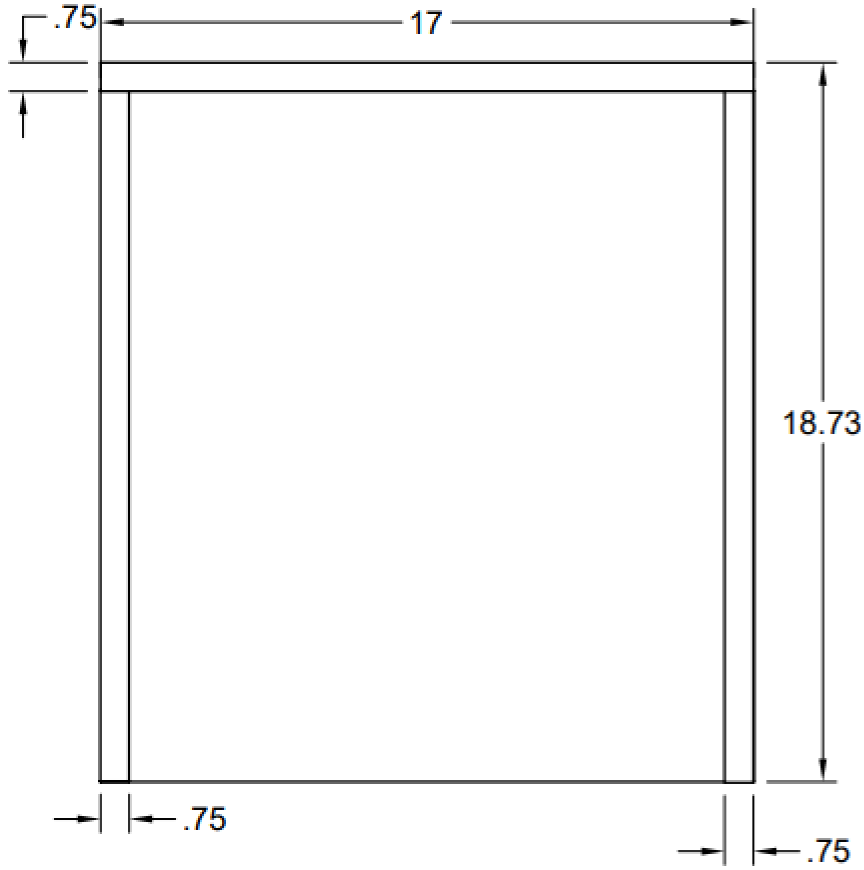



Figure 2: Front view diagram

#### 4.5.1.2.3. Left View Diagram

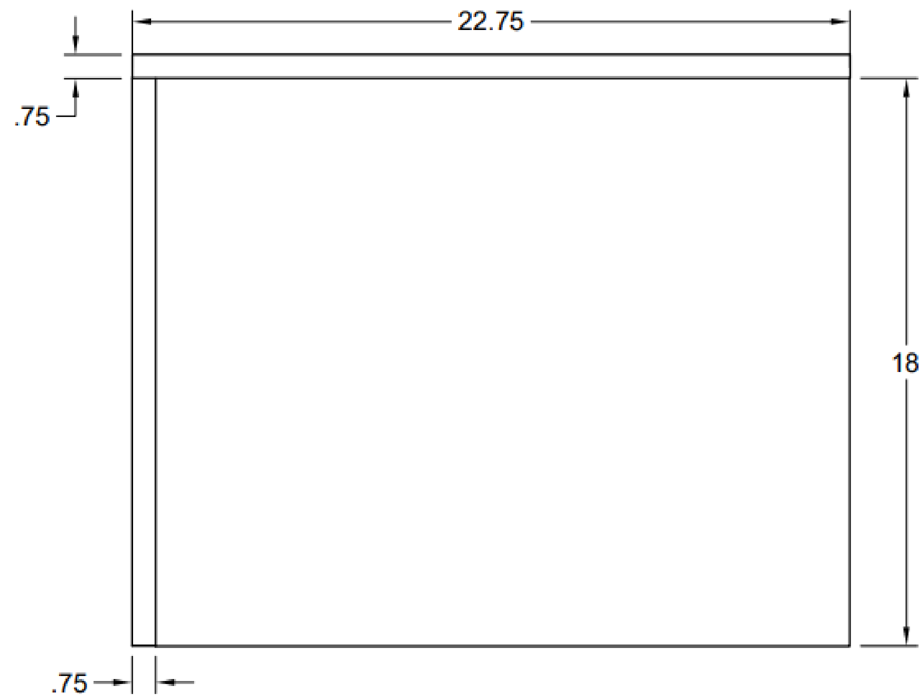



Figure 3: Left View Diagram

#### 4.5.1.2.4. Top View Diagram

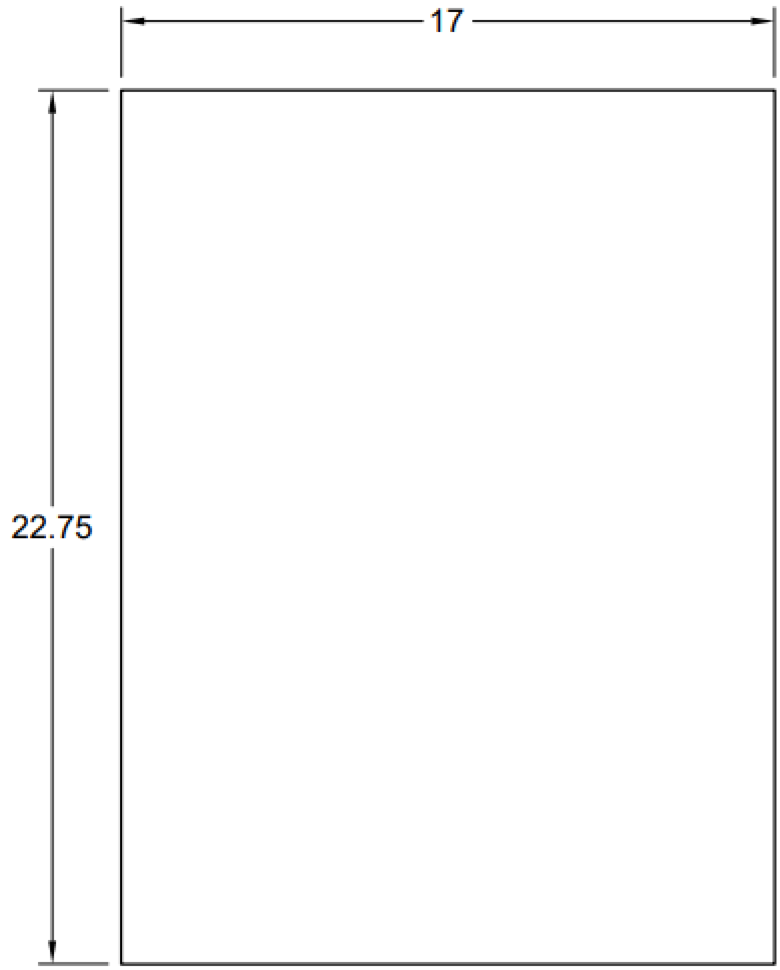



Figure 4: Top View Diagram

## 4.5.1.2.5. Back View Diagram

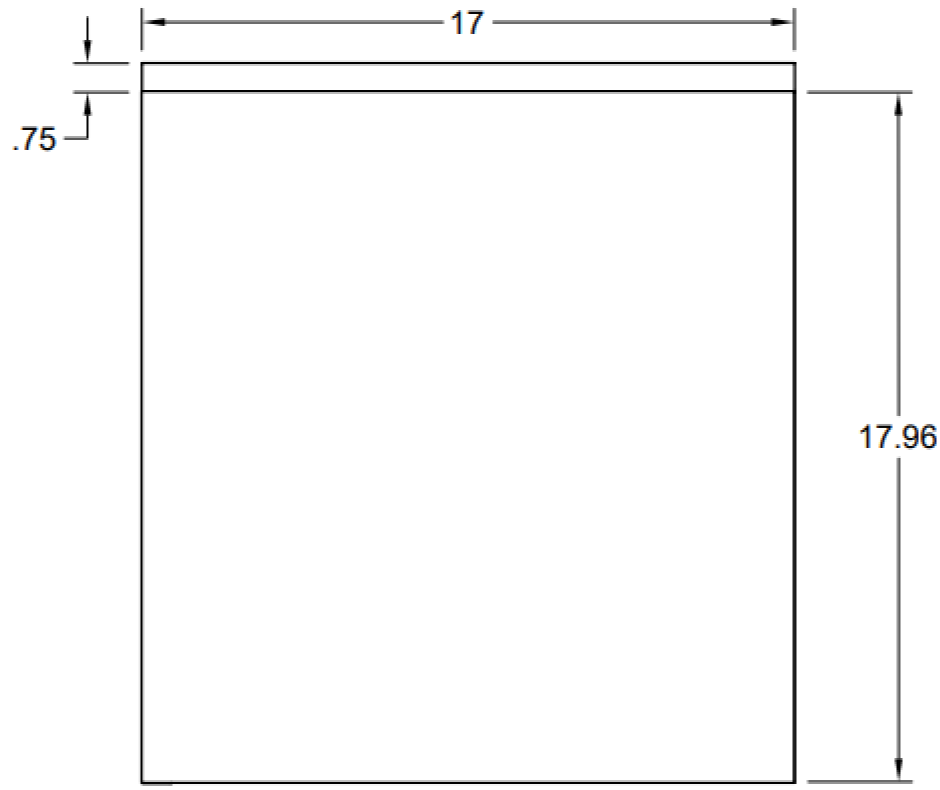



Figure 5: Back View Diagram

## 4.5.1.2.6. Assembly Details

The wooden panels will all be held together using wood glue. The acrylic front panel will be attached using two 2” hinges placed 3 inches from the top and bottom of the left side panel. These hinges will be attached to both the side panel and the acrylic panel using 2 20mm m4 bolts. The electronic enclosure will be mounted on the back side of the main enclosure near the bottom, the exact fasteners and position will be determined once the electronics enclosure has been designed.

#### 4.5.1.3. Block General Validation

The materials for the enclosure were chosen because of their easy availability, low cost, ease of assembly and physical appearance. Plywood is easy to get at most hardware stores, meaning that it doesn't need to be shipped. It can also be easily cut and assembled using tools that we already have on hand. Similarly, acrylic is relatively cheap compared to glass, is more durable, and will provide an adequate view of the printer.

The plywood will be cut into the proper pieces using a circular saw, and assembled using wood screws and glue. The plexiglass sheet will then be attached using metal hinges that open from the left side, and will be held closed using magnets glued to both the plywood and the enclosure.

The enclosure will need to be able to hold the printer without interfering with its function. It is important to note that this means that it needs to be bigger than the printer itself, since the bed will move forward and backwards during operation on the Prusa i3 MK3S+. The measured dimensions for this are 22”x18”x15.5”, which is the internal dimensions of the enclosure.

#### 4.5.1.4. Block Interface Validations

1. Draw an outline of all components that will be attached to the enclosure and make sure that they will fit.

#### 4.5.1.5. Block Testing Process

1. Measure the enclosure to make sure that it is large enough to hold a Prusa I3 MK3S+ without interfering with printing operation (18”W x 22”L x 15.5H).
2. Place a high temperature heater in the enclosure.
3. Turn on the heater.
4. Monitor the thermometer to make sure that it reaches an internal temperature of 70°C.
5. Check to make sure that there is no visible heat damage to the enclosure.

#### 4.5.1.6. References

#### 4.5.1.7. Revision Table

| **Revision** | **Date** |
|---|---|
| Caspian: Block Section Created | 1/5/2022 |
| Caspian: Updated Testing process. | 1/30/2022 |

### 4.5.2. Buzzer

This block will consist of an electric buzzer that will be used to alert the user if the device is overheating. It will be set to beep for one second, then stay silent for 1 second, and repeat this pattern as long as the enclosure is over 85°C and will be controlled by the Raspberry Pi connected to the printer. This will allow the user to intervene in case of any errors and prevent the device from overheating. The device will be mounted on the top of the enclosure alongside the display using a 3D printed mounting bracket.

#### 4.5.2.1. Design

##### 4.5.2.1.1. Block Diagram

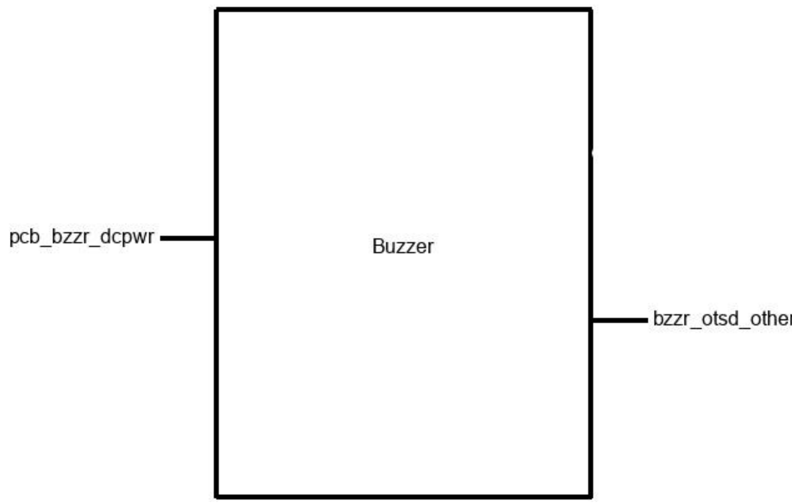



Figure 1: Buzzer black box diagram

### 4.5.2.1.2. **Electrical Schematic**

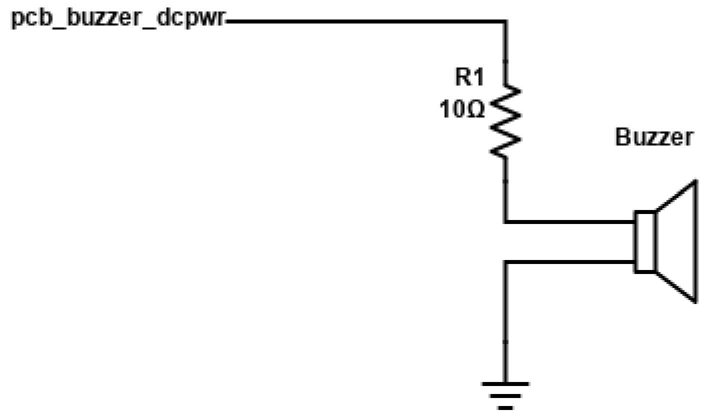



Figure 2: Electrical schematic

## 4.5.2.2. Pseudocode

```
While(1){
        if(temp > 85){
                turnOn(buzzPin)
                delay(1s)
                turnOff(buzzPin)
                delay(1s)
}
```

## 4.5.3. General Validation

The TDK PS1420P02CT Piezoelectric buzzer was chosen because it was available locally for a low price, and it met all of the requirements we had set. It is rated to output 70Db, which should be more than enough to alert the user of any issues from 20ft away. It is also rated for a 5V input voltage, which will make it easy to integrate with our PCB and other components that are also powered by 5V. This component could easily be replaced with most other piezoelectric buzzers, as there are few rigid requirements for the component in particular.

## 4.5.4. Interface Validation

**pcb_bzzr_dcpwr : Input**

| Interface Property | Why is this interface this value? | Why do you know that your design details for this block above meet or exceed each property? |
|---|---|---|
| Inominal: 500mA | Several values were tested and this | This value is set using resistor |

| | | |
|---|---|---|
| | produced the most desirable result. | R1shown in Figure 2 and can be calculated using Ohm's Law. |
| Vmin: 3.3V | This was the lowest the block was tested at. | This is well below the voltage that the PCB will run on (5V). |
| Vmax: 30V | This is the maximum voltage according to the datasheet | Nothing in our system should ever reach this voltage |

**bzzr_otsd_other : Output**

| Interface Property | Why is this interface this value? | Why do you know that your design details for this block above meet or exceed each property? |
|---|---|---|
| Sound: Audible at 20ft | It is the size of a fairly large room. | The datasheet rated the buzzer for 70Db, which should be enough to hear it from 20ft. |
| On period: 1 second | This on and off period seemed like a good "warning" tone. | The code is set to a 1 second delay between toggles. |
| Off period: 1 second | This on and off period seemed like a good "warning" tone. | The code is set to a 1 second delay between toggles. |

### 4.5.5. Verification Plan

1. Upload the test code onto an Arduino Nano.
2. Check to make sure that it turns on when the temperature variable is greater than 85°C.
3. Use a stopwatch to check if the delay between turning on and off is approximately 1 second.
4. Move 20 feet away and make sure that it is still clearly audible.
5. Use a multimeter to make sure that the voltage is about 5V consistently, always less than 30V, and the current draw is 500mA.

### 4.5.6. References and File Links

[1] 2022. *Piezoelectronic buzzers*. [online] Available at: https://product.tdk.com/system/files/dam/doc/product/sw_piezo/sw_piezo/piezo-buzzer/catalog/piezoelectronic_buzzer_ps_en.pdf [Accessed 4 February 2022].

### 4.5.7. Revision Table

| Date | What was changed |
|---|---|
| 02/04/2022 | Document Created (Caspian Hedlund) |
| 02/18/2022 | Updated based on peer feedback and testing results (Caspian Hedlund) |

# 4.6. Heater Block

## 4.6.1. Block Description

The heater block itself is just the ceramic heater which is rated for 12V 200W and is 4.7 x 2 x 1 inches. The heater will be contained within the enclosure, the positive and ground wires will go out of the enclosure and connect with a relay that regulates the voltage and ground. The relay will change the output voltage depending on the temperature needed for the enclosure. These parts will be located outside the enclosure in order to avoid damaging them from the temperatures. The heater is expected to heat the enclosure up to 70°C and be able to maintain that temperature requested for a set amount of time.

## 4.6.2. Block Design

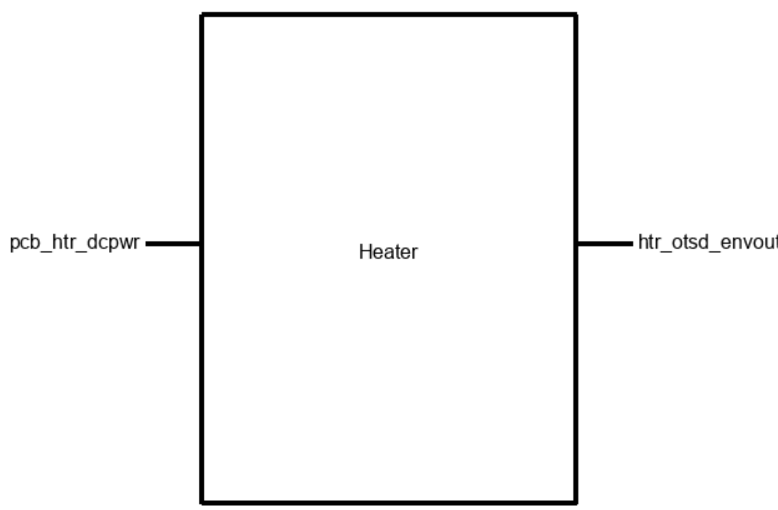



**Figure 1**: Heater black blox diagram with interface definitions

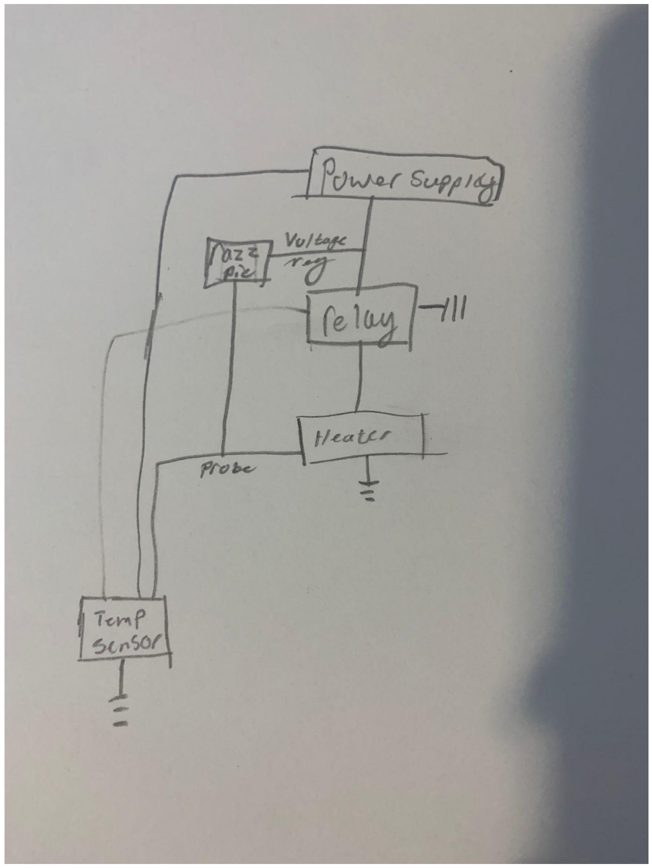



**Figure 2**: Block Diagram

**Figure 3**: Heater top view

**Figure 4**: Heater Bottom view

| | |
|---|---|
| Length | 4.7 in |
| Hight | 2 in |
| Width | 1 in |

**Table 1**: Dimensions of the heater

### 4.6.3. Block General Validation

This heater was picked because it was one that fit within the power usage of the power supply we chose and would be able to produce enough heat for the enclosure which was 12V 200W. Most of the heaters that would be used for this project come from either Russia or China so they take around 2 - 3 weeks to get here so it was crucial to try and get one that fits our criteria on the first purchase.

This heater directly connects to a power supply so in order to regulate it the power will come from a relay controlled by a microcontroller. This means when testing a multivariable power supply will be used alongside a temperature sensor to monitor the heat generated from the heater. The ceramic heater is mounted onto two hard plastic stands which will allow for it to be mounted to different areas within our heater so that it can be placed in the most optimal position to heat the enclosure.

The heater itself can reach temperatures between -17.77℃ - 93.33℃, this demonstrates that the heater is able to generate enough heat to reach the desired temperature within the enclosure which is 70°C. Alongside the heat output the heater is also small in size being only 4.7 x 2 x 1 inches which allows for more freedom of placement and is less intrusive than other heaters. The heater was also cheap being only $19.99 meaning we are not using a huge portion of our budget on it. This checked all the boxes that we needed a heater to do and would integrate well within our final project.

## 4.6.4. Block Interface Validation

**htr_otsd_envout: Output**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Other: Ambient - 70°C | These are the temperatures that the enclosure will be experiencing. | This is due to the heater being able to output up to 93.33℃. |

**Pcb_htr_dcpwr: Input**

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Inominal: 6 A | This is the nominal current to maintain a consistent heat | This is the normal amperage that this device sits at during use |
| Ipeak: 20A | This is the peak amount of current that will pass through the heater in order to heat it up | This is the maximum amount of current able to pass through standard 14 gauge wire |
| Vmax: 13V | The heater is not expected to draw more than 13V at a time | The maximum rating is 12V but there is usually a spike at the beginning in order to overcome the initial resistance |
| Vmin: 11V | The minimum voltage the heater will use is 11V | Running the heater at a constant 11V will allow for continuous heat at the required temperature |

## 4.6.5. Block Testing Process

1. Place the heater within the middle of the enclosure
2. Connect the heater wires to the multivariable power supply

3. Place a temperature sensor within the corner of the enclosure to record thehtr_otsd_envout
4. Connect a DMM to the wires of the heater to monitor Pcb_htr_dcpwr and change it to current mode
5. Turn the multivariable power supply on at 0.5V and allow for the temperature to stabilize
6. Measure the Pcb_htr_dcpwr current on the DMM
7. Record the temperature and increase it by 0.5V
8. Repeat step 5 until you hit 12V

The data collected from this will be used when programming the enclosure to regulate the voltage that goes through the heater when a specific temperature is requested.

### 4.6.6. References and Links


1. Jeff, "How many AMPS can a 14 gauge wire handle? (best tips)," *RV and Playa*, 22-Sep-2021. [Online]. Available: https://www.rvandplaya.com/how-many-amps-can-a-14-gauge-wire-handle/. [Accessed: 06-Dec-2021].
2. "12V heater fan - AKOZON PTC heating 200W DC 12V electric insulated ..." [Online]. Available: https://www.amazon.com/Akozon-Heating-Electric-Insulated-Thermostatic/dp/B07YV4C773 [Accessed: 10-Dec-2021].


### 4.6.7. Revision Table

| Date | What was changed |
|---|---|
| **1/6/2022** | **Kaleb: Document created and content added** |
| **1/21/2022** | **Kaleb: Added multiple figures and tables. Changed the procedure for testing and added to multiple sections** |

## 4.7. Main Code

### 4.7.1. Block Description

This code will be running on the raspberry pi itself, it will receive a parsed G-code file from the web interface. This code will look through that file to set the temperature the enclosure needs to be heated up to. Once the heater is turned on the code will also be watching the temperature sensor connected to the raspberry pi, if the temperature exceeds what is required it will turn off the relay that is connected thus turning off the heater. Once the temperature falls below the required amount it will then turn the heater back on.

### 4.7.2. Block Design

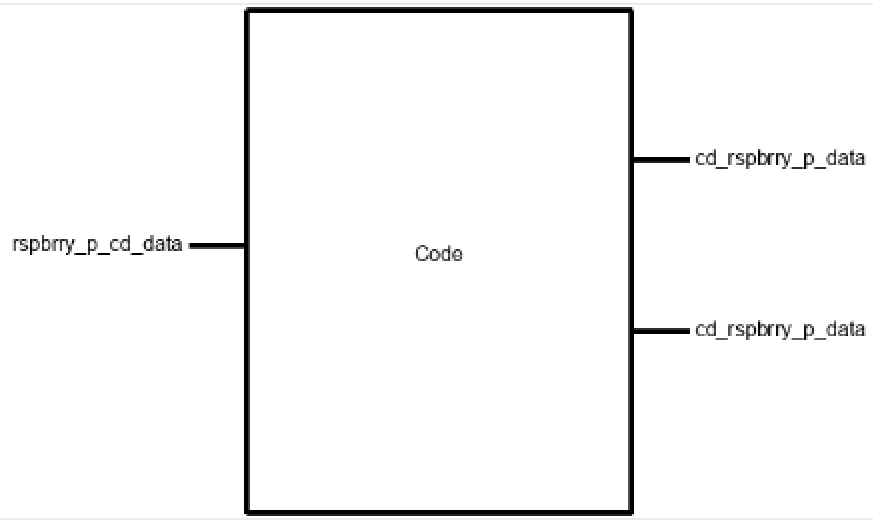



**Figure 1**: Heater black blox diagram with interface definitions

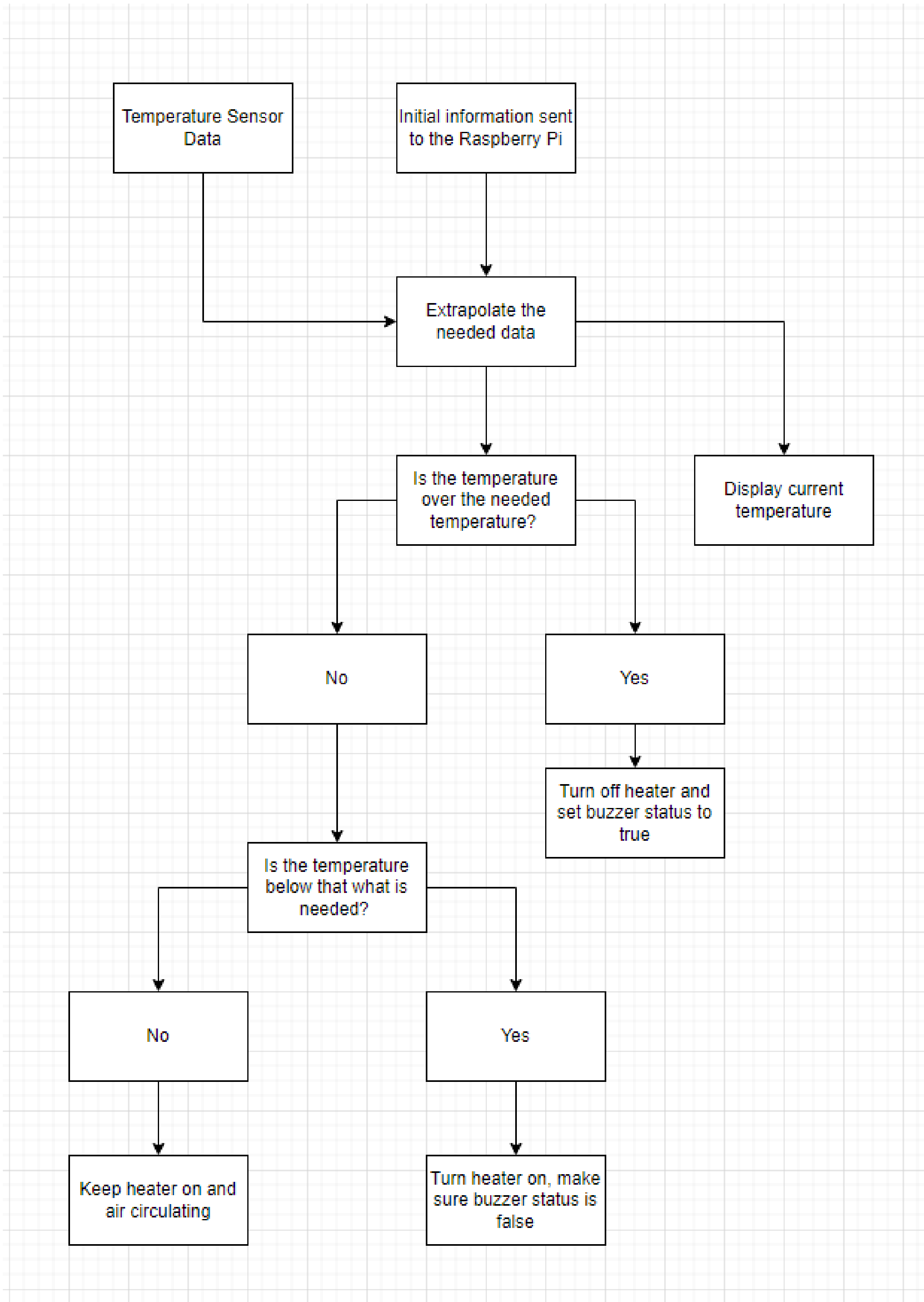



**Figure 2**: Flowchart for Pseudocode

### 4.7.3. Block General Validation

G-code is used for this task as it is what 3D printers use to determine the location that the nozzle needs to go to, this information also happens to carry the temperature information that is needed for the enclosure. This code will come already pre sliced from the clipper software that is running on the mainboard of the 3D printer. This code will then be sent to the raspberry pi where the information will be run through the code and the needed information extracted.

From there raspberry pi sends a signal to the relay to either turn on or off and will adjust the voltage sent to the relay from our PCB. The relay will then control the current for the heater thus controlling the temperature. This is critical to the function of our enclosure. One concern here is that the code will not be able to communicate effectively with the system and will not update fast enough. Other than that there aren't many concerns for the codes.

### 4.7.4. Block Interface Validation

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Data Rate: 1 per second (Temp value) | This is how often the temperature should be pulled to update the heater | This information is needed to turn the heater on or off |
| Messages: Temperature value (Double) | A double is used for accuracy on the temperature | This information is used to show the current temperature of the enclosure |
| Messages: G-code file | This is the file that will be sent over the network to communicate with the enclosure and printer | The only file that will be taken in by the code is a gcode file |

| **Interface Property** | **Why is this interface of this value?** | **Why do you know that your design details <u>for this block</u> above meet or exceed each property?** |
|---|---|---|
| Messages: Heater Status (Bool) | This is used to communicate if the heater is on or off, a bool is used for true/false | The heater is either on or off so true or false works |
| Messages: Buzzer State (Bool) | This is used to communicate if the buzzer is on or off, a bool is used for true/false | The buzzer is either on or off so true or false works |
| Messages: Display Message (String) | This is used to display something on the screen a string is used to communicate a word | A string is the common command used to store words or values |
| Other: C++ | C++ is the language that this will be coded in | C++ is used in a huge variation of applications and is able to do a variety of things |

## 4.7.5. Block Testing Process

1. Create a parsed G-code file with multiple inputs and instructions
2. Run the spliced script through the code
3. Send a live output of the temperature as it goes through the G-code file
4. Compare the values with those that were coded into the G-code file

## 4.7.6. References and Links


1. Twooscoops, "What is G code in 3D printing," *Beginner3DPrinting*, 26-Sep-2021. [Online]. Available: https://beginner3dprinting.com/what-is-g-code-in-3d-printing/. [Accessed: 06-Dec-2021].

2. "G-Codes - Klipper documentation," *Klipper3d.org*, 2022. [Online]. Available: https://www.klipper3d.org/G-Codes.html [Accessed 07-Dec-2021].


## 4.7.7. Revision Table

| Date | What was changed |
|---|---|
| 02/01/2022 | Kaleb: Document created and content added |
| 02/02/2022 | Kaleb: Flushed out document adding verification plans and references |
| 02/18/2022 | Kaleb: Added flowchart for pseudocode and revised the description and general block validation |

# 5. System Verification Evidence

## 5.1. Universal Constraints

### 5.1.1. The system may not include a breadboard

This will be verifiable through observation.

### 5.1.2. The final system must contain both of the following: a student designed PCB and a custom Android/PC/Cloud application

All modules used in this will be connected by using a student designed PCB and the relay which is used for this project is mounted on the PCB as well. This will be verifiable through observation.

### 5.1.3. If an enclosure is present, the contents must be ruggedly enclosed/mounted as evaluated by the course instructor

This will be verifiable through observation.

### 5.1.4. If present, all wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors

This will be verifiable through observation.

### 5.1.5. All power supplies in the system must be at least 65% efficient

The Power Supply which is used for this project was verified, and turns out that the Power Supply will provide 12v voltage supply under 40 A current flows.

#### 5.1.6. The system may be no more than 50% built from purchased modules

Pre-built modules:

1. Thermometer
2. OLED Display
3. Power Supply
4. Heater

Not pre-built modules:

1. Main Enclosure
2. Electronics Enclosure
3. Buzzer
4. PCB
5. Code
6. Relay Module

## 5.2. Engineering Requirements

### 5.2.1. System will Enclose a Prusa i3 MK3s+

#### 5.2.1.1. Requirement

The system will be large enough to contain a Prusa i3 MK3S+ without interfering with the printing process (measured at 22”x18”x15.5”).

#### 5.2.1.2. Testing Processes

1. The system will be set up with the Prusa i3 MK3S+ (22”x18”x15.5”) within the enclosure.
2. Move the bed all of the way backwards and make sure that it does not hit the back of the enclosure.
3. Move the bed all of the way forward and make sure that the enclosure can still be latched closed without the door hitting the printer.
4. Make sure that male end of the power cable can reach outside of the enclosure.

#### 5.2.1.3. Testing Evidence

The dimensions of the printer “Prusa i3 MK3S+ (22”x18”x15.5”)”, is smaller than the dimensions of the enclosure (22.75”x18.75”x17”).

### 5.2.2. Printer Viewable During Operation

#### 5.2.2.1. Requirement

The printer will be viewable through a transparent panel while the system is operating.

#### 5.2.2.2. Testing Processes

This requirement will be proven by observation.

#### 5.2.2.3. Testing Evidence

A transparent plastic glass will be used as an observation window.

### 5.2.3. System will Hold a Steady Temperature

#### 5.2.3.1. Requirement

The system will be able to maintain a temperature of 40°C-70°C ( ± 3°C) within the print area for 8 hours.

#### 5.2.3.2. Testing Processes

1. Build a separate device capable of logging temperatures over an extended period of time.
2. Send a command to the system to maintain a temperature of 40°C.
3. Repeat step 2 for 55°C and 70°C
4. Check logged data to make sure that it never leaves the acceptable range.

#### 5.2.3.3. Testing Evidence

The log from the temperature measuring system

### 5.2.4. System will have a Controllable Temperature

#### 5.2.4.1. Requirement

The system will be controlled externally through a web application.

#### 5.2.4.2. Testing Processes

1. Set the temperature via the web application.
2. Check the enclosure temperature to make sure it reaches the expected temperature.

#### 5.2.4.3. Testing Evidence

This is proved by observation.

## 5.2.5. System will be Affordable

### 5.2.5.1. Requirement

The system will be cost less than $300

### 5.2.5.2. Testing Processes

1. Add up cost of all parts purchased
2. Determine if total cost is less than $300

### 5.2.5.3. Testing Evidence

The BOM with the various components and their price.

## 5.2.6. System will have a Clean Appearance

### 5.2.6.1. Requirement

Any internal components that can reasonably be hidden will be. The enclosure itself will be presentable.

### 5.2.6.2. Testing Processes

1. Check that all components and wires are placed inside or on the backside of the printer enclosure except for those necessary for monitoring the system (such as the display and buzzer) and the water cooling.
2. Upon completion of the device, it will be presented to the project partner for approval.

### 5.2.6.3. Testing Evidence

The approval of the project partner.

## 5.2.7. The system will have have no visible internal wires or components

### 5.2.7.1. Requirement

The device will have all components and wires securely attached to the enclosure through the use of wire covers and additional enclosures.

### 5.2.7.2. Testing Processes

This requirement is proven by observation.

#### 5.2.7.3. Testing Evidence

This is proved by observation.

### 5.2.8. System will have Safety Measures to Prevent Overheating

#### 5.2.8.1. Requirement

The system will have a thermal protection circuit that will shut the system off if it is >= 90°C.

#### 5.2.8.2. Testing Processes

1. Forcibly heat the enclosure using an external heater to 100°C
2. Check if the thermal fuse has blown.

#### 5.2.8.3. Testing Evidence

The heaters will no longer be on, and the thermal fuse will no longer have continuity.

## 5.3. References and File Links

## 5.4. Revision Table

| **Revision** | **Date** |
| --- | --- |
| Mark: Initial creation included two requirements and their testing methods | 3/6/2022 |
| Team: Requirements, testing processes and testing evidence updated. | 4/22/2022 |

# 6. Project Closing

## 6.1 Future Recommendations

### 6.1.1 Technical Recommendations

1. **Higher Voltage Heaters**

   Switching to high voltage heaters would allow for the system to use much lower current, meaning that many of the parts could be less robust and cheaper. It would also allow for the system to reach higher peak temperatures. The 12V heaters that we used have a maximum temperature of about 120℃, while 120V heaters can reach temperatures above 1200℃. While this is much hotter than is necessary for a project such as this, it would easily allow for temperatures above 100℃, which may be necessary for some materials.

## 2. Different PCB/Relay

While our relay/PCB works, we believe that it could be improved. We are currently using a mechanical relay that while cheap, is also very slow. Additionally, the relay is mounted directly onto the PCB, meaning that all of the current for the heaters is running through the PCB. To make this work, we had to modify our PCB by hand to make the traces large enough to accommodate the high currents needed for the heaters. One useful website for determining the width of trace is PCB Trace Width Calculator [1].This could be improved by switching to a solid state relay that is a separate module from the PCB. This would reduce the current flowing through the PCB, and the improved speed would allow for more advanced methods of heating, such as proportional–integral–derivative (PID) control. We chose not to do this because solid state relays that are rated for the current of our heaters are expensive, but as mentioned before, this could be solved by using higher voltage heaters.

## 3. Different Materials for the Enclosure

We used plywood to construct the enclosure due to the relatively low cost and ease of construction. The problem with plywood is that it has poor thermal insulation, and it was not as easy to work with as we had originally thought. One potential option for improving this is by making the enclosure out of polycarbonate [2]. This is the material used to build greenhouses, so thermal insulation is one of the defining properties of it.

## 4. Combination of the enclosure with the 3D printer

Currently the design of the enclosure is based on the fact that the 3D printer and the enclosure are separated. However, this is inefficient. Firstly, for every new 3D printer, a new enclosure needed to be designed. Secondly, once the 3D printer and the enclosure is combined (such as a laptop) mobility of the 3D printer would be enhanced.

### 6.1.2 Global Impact Recommendations

1. **The Functionality of the Enclosure**

   The only functionality of this enclosure is increasing the inner temperature. However, with the increasing numbers of different materials which might be used in the future 3D printing, the functionality of the enclosure should be more diverse. For example, since 3D printing technology is getting more involved in the field of medicine, human-tissue 3D printing [3] would be realistic. In this case, cooling down the inner temperature and cleaning the chamber on a biological level might be necessary.

2. **Heat Recycling**

   In the system's current form, it uses about 800W of power between the enclosure and the printer itself. This is a lot of power to be dumped into the system's atmosphere as waste heat. This system could be made more sustainable by adding some way to reuse this heat. One option would be to convert the heat back into electricity using a thermal generator, though this is probably unrealistic with current technology. Another option would be to divert the heat into a building’s existing central heating system, allowing for the heat to be re-routed to other rooms.

### 6.1.3 Teamwork Recommendations

1. **Improved Meeting Agendas**

   While most of our team meetings had an agenda, it was usually not very detailed and didn’t entirely encompass what needed to be discussed in the meeting. This could be improved by having a living document that all team members could add to at any point in the week, detailing anything they thought was important to discuss with the team. This would help to make sure that everyone is always on the same page.

2. **Meeting Notes Taken**

   Throughout the course of this project, we did not have any consistent note taking. What was discussed would sometimes be recorded in our project documentation, but it was often just taken as mental notes. This sometimes led to confusion about what each of the team members were doing and how our various blocks would interact with each other. Having someone assigned to take and publish notes on the meeting could have allowed for all team members to have somewhere to quickly reference rather than having to ask the other team members and wait for a reply.

## 6.2 Project Artifact Summary with Links

### 6.2.1 PCB Schematic

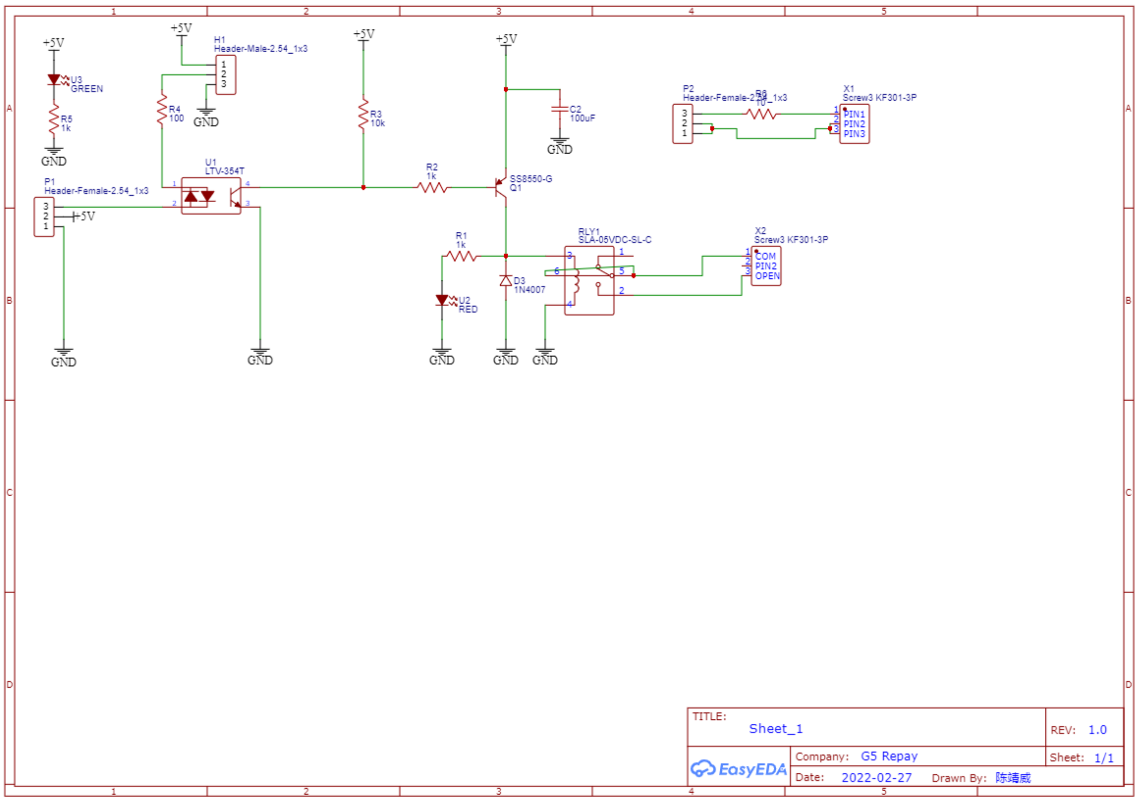



Figure 1: The schematic of the PCB Design

## 6.2.2 PCB 3D Modeling

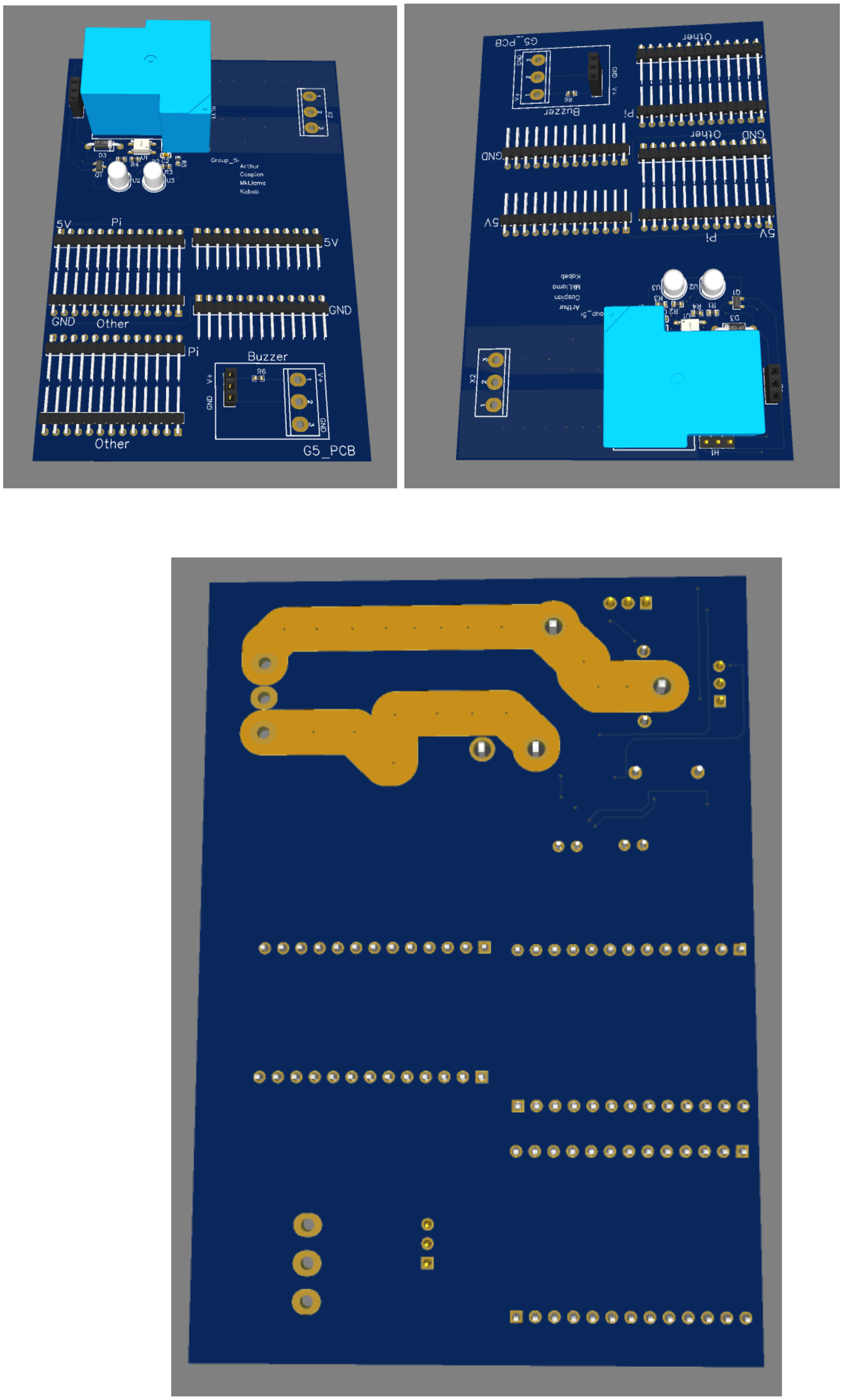



Figure 2: The 3D layout of the PCB

### 6.2.3 Enclosure Mechanical Drawings

#### 6.2.3.1 NW Isometric view of the enclosure.

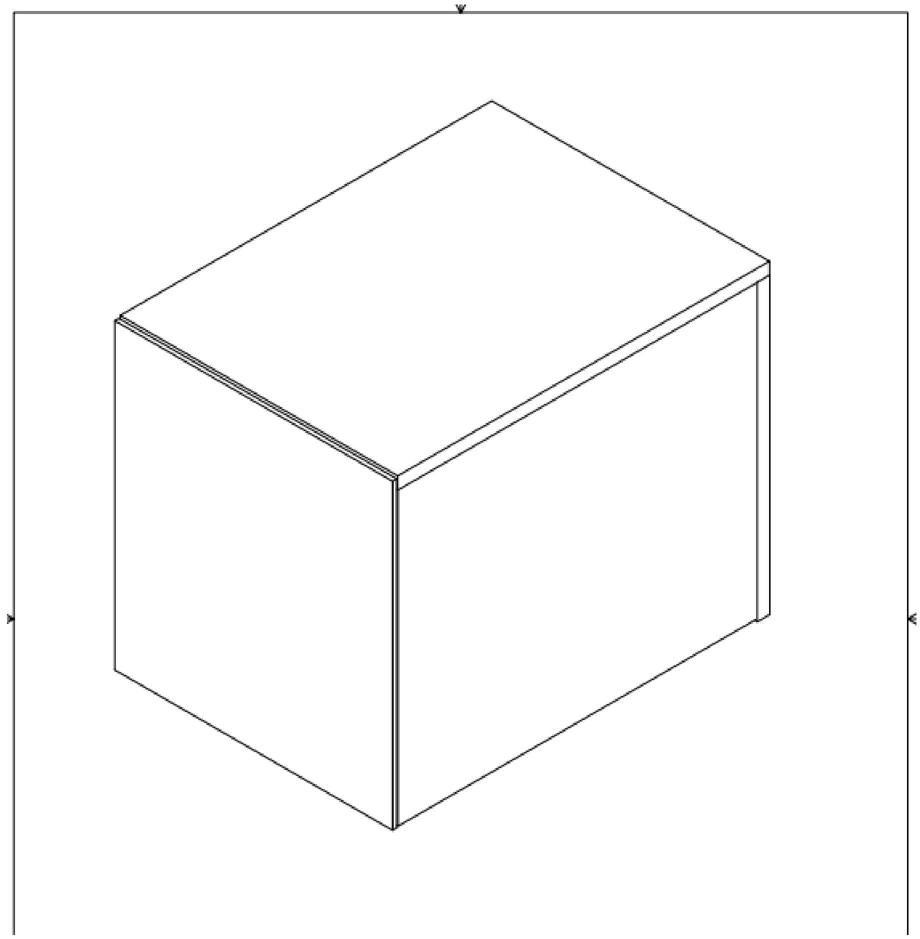


Figure 1: NW Isometric View

## 6.2.3.2 Front view diagram

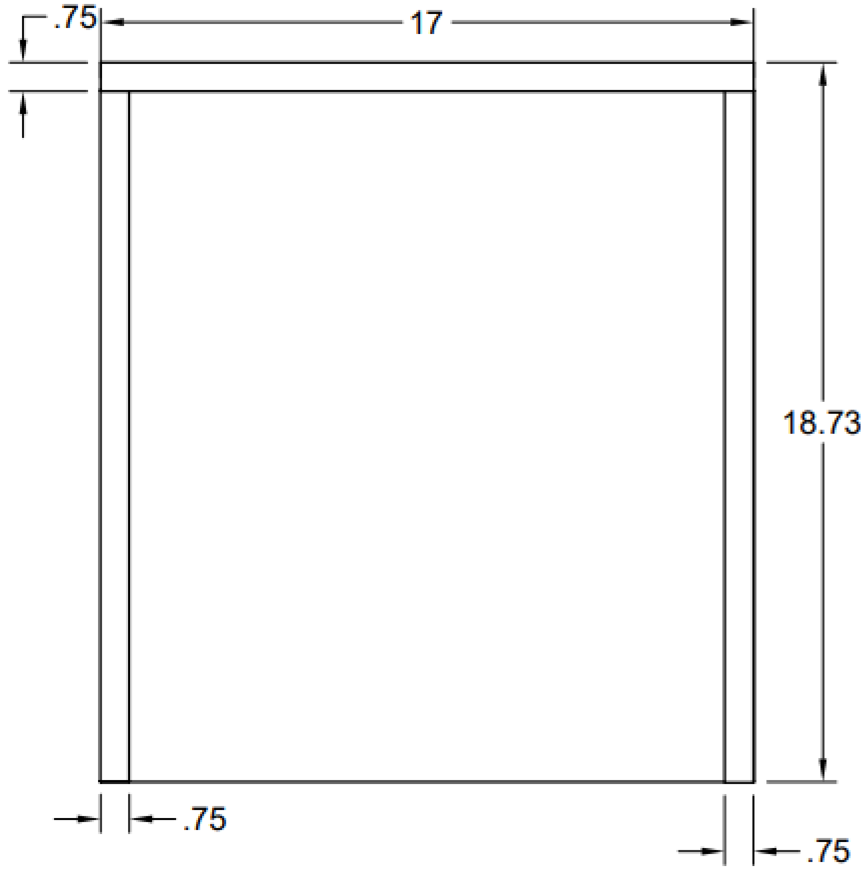



Figure 2: Front view diagram

## 6.2.3.3 Left View Diagram

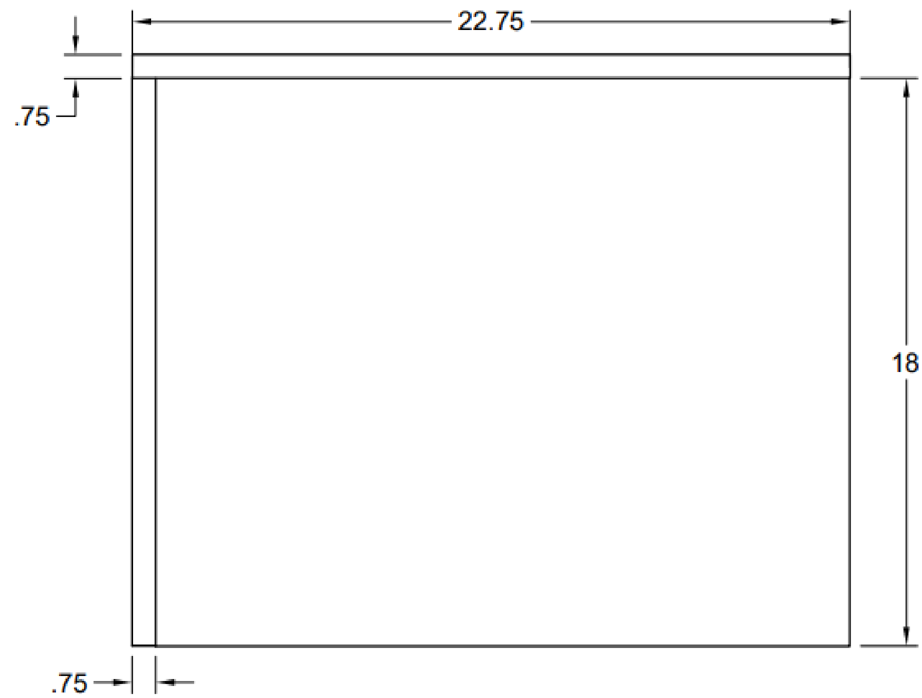



Figure 3: Left View Diagram

### 6.2.3.4 Top View Diagram

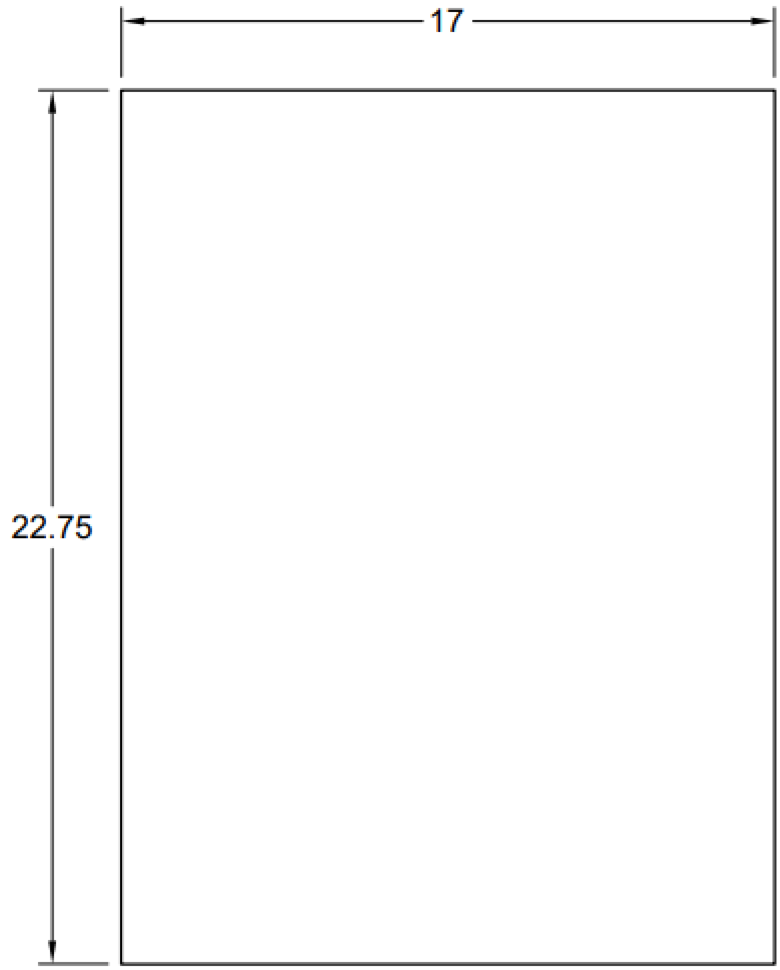



Figure 4: Top View Diagram

### 6.2.3.5 Back View Diagram

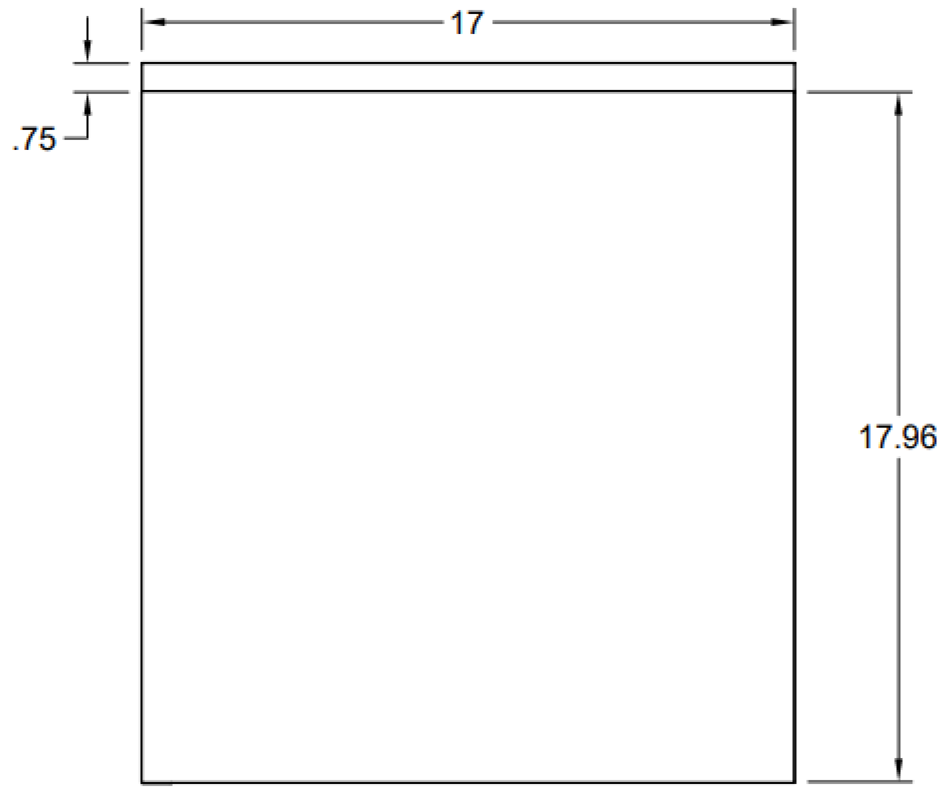



Figure 5: Back View Diagram

## 6.2.3 Codes

The following link is a github for all codes:
https://github.com/hedlundc/Heated-3D-Printer-Enclosure/blob/main/printer.cfg

## 6.2.4 Klipper User Guide

The following link is used for Klipper User Guide [4].

https://www.klipper3d.org/Overview.html

## 6.3 Presentation Materials


## 6.4 References and Links


[1]B. Suppanz, "Advanced circuits," *Printed Circuit Board Trace Width Tool*, 2018. [Online]. Available: https://www.4pcb.com/trace-width-calculator.html. [Accessed: 06-May-2022].

[2] T. Rogers, "Everything you need to know about polycarbonate (PC)," *Everything You Need To Know About Polycarbonate (PC)*, 21-Aug-2015. [Online]. Available: https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-polycarbonate-pc. [Accessed: 06-May-2022].

[3] S. Naghieh, "3D-printed organs could save lives by addressing the transplant shortage," *The Conversation*, 11-Jan-2022. [Online]. Available: https://theconversation.com/3d-printed-organs-could-save-lives-by-addressing-the-transplant-shortage-132491#:~:text=3D%20bioprinting%20prints%203D%20structures,body%20does%20not%20reject%20it. [Accessed: 06-May-2022].

[4] Unknown, “Klipper documentation,” *Overview - Klipper documentation*. [Online]. Available:https://www.klipper3d.org/Overview.html. [Accessed: 06-May-2022].

## 6.5 Revision Table

| **Date** | **What was changed** |
|---|---|
| 05/06/2022 | Team: Initial documentation created, revised, and added onto. |