GNG 1103

Design Project User and Product Manual

The Heat Exchange Chamber

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Table 1. Acronyms

Acronym	Definition
BOM	Bill of Materials
LCD	Liquid Crystal Display
PEX	Cross-Linked Polyethylene
PVC	Polyvinyl Chloride
THEC	The Heat Exchange Chamber

Table 2. Glossary

Term	Acronym	Definition
Arduino		Microcontroller board to program system
Liquid Crystal Display	LCD	Display screen used so user can see the status of the system
The Heat Exchange Chamber	THEC	Geothermal heating and cooling system

1. Introduction

This User and Product Manual (UPM) provides the information necessary for homeowners to effectively use The Heat Exchange Chamber (THEC) and for prototype documentation. The manual is structured into 4 parts: **Getting started**- which mainly consist of helping the user have a broad idea of what to consider while using the product and how to navigate it, **Using the system**- this part focuses on giving detailed, step-by-step instructions on how to use the various functions or features of the THEC, **Troubleshooting & Support-** anticipates various issues that might occur while using the product and gives the user ways to solve them, **Product Documentation-** this final sections gives a insight on how the prototype was made so the client can have a better understanding of the prototype. Thus, the User and Product Manual is built to help the client thoroughly understand the prototype, so he can not just properly use it but also make changes and improve parts that benefit him/her the most.

2. Overview

The main issue at hand is that current heating and cooling systems for homes are not environmentally friendly because they consume a lot of energy or use greenhouse gasses which contribute to pollution and issues like global warming.

The fundamental needs of the user are that the system needs to be efficient enough to sufficiently heat/cool the entire house. The system should also be low-tech with minimal electronics components, as well as low maintenance. The price should be reasonable for an average homeowner to be able to afford to install this system. Finally, the system needs to use little energy and be environmentally friendly.

Our product is unique because the box itself is a PVC box rather than concrete which is often used. This allows for easier installation which saves time and money. The pipes that are arranged in a coil shape allow to maximize surface area and increase heat transfer efficiency. Our pipes are made of PEX which is a great option because it's not only affordable and has similar qualities to other options, it's also pliable with the use of a heat gun which allows the coil to take shape relatively easily.

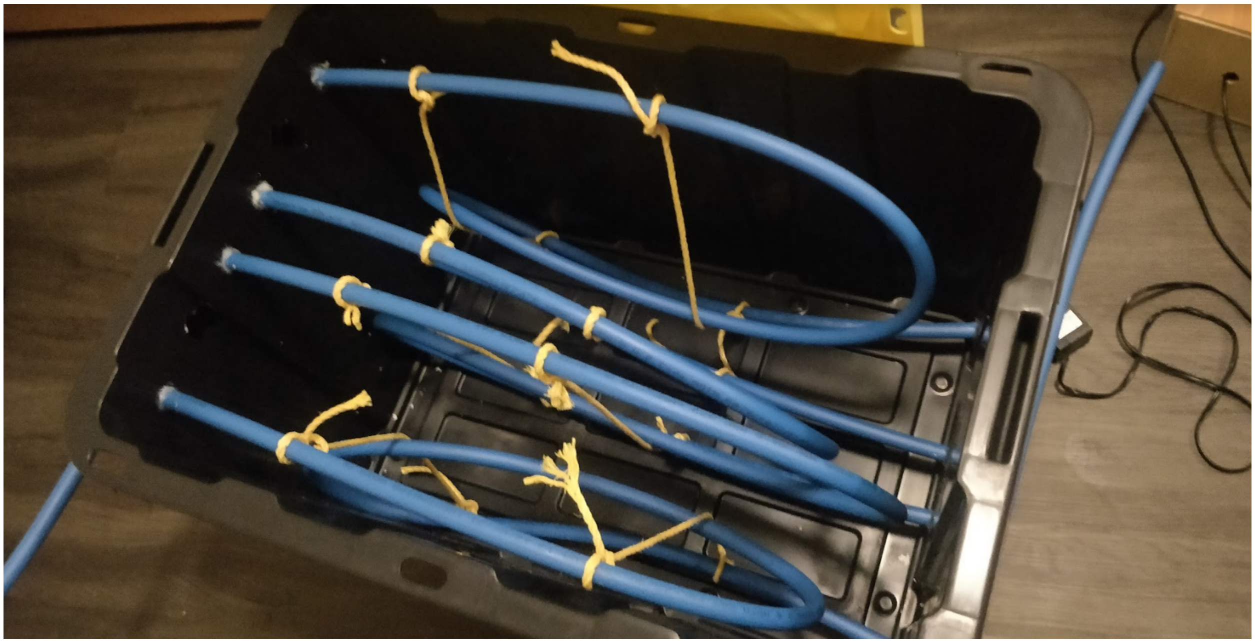


Figure 1: THEC Prototype

One of the key functions of the system is the thermostat. The user can set their desired temperature and sensors will detect the temperature in the house then automatically activate the blower to run the system and heat or cool the house. A sump pump eliminated the water produced by condensation. The chamber itself as well as the piping is where the heat transfer occurs to bring the temperature of the air to a more comfortable temperature before entering the house.

The box is made of PVC material and the piping is PEX. A microcontroller is responsible for activating the system's blower and setting the desired temperature for the house, which the user can do by using the buttons on the electrical components box.

2.1. Cautions & Warnings

The system is very low-tech and safe to use so there shouldn't be any dangers to the user of this system.

3. Getting started

3.1. Configuration Considerations

The only device the user needs to know how to operate is the panel in which the temperature control for the entire system is. The thermostat for our device is very simple to use. We did not integrate anything confusing such as bluetooth and you do not need to download or have any extra tools to be able to control the temperature of your home. The user only needs to simply press the up and down arrow buttons on the control panel to change the temperature.

3.2. User Access Considerations

Since our system may be implemented in nearly any form of building, the range of users is great. Homeowners are the main group but children could also access the system. As our system is not inherently dangerous, there is no need for many precautions. The controls for the thermostat are always installed in a relatively high place along the wall in order to prevent children from accessing and playing with the temperature. This prevents the system from needlessly running when an unreasonable temperature is set. Further, a childproof cover could be easily installed if the system was to be installed in a classroom, for example. Overall, since the large majority of users for our system are home owning adults, there is not a need for many restrictions on system accessibility.

3.3. Accessing/setting-up the System

To set up the system you will need to download and install the arduino software onto a computer, the software can be downloaded from the arduino website. Next, copy and paste the code from this link into the arduino app. Next, you will need to download the libraries from this link. Then, in the arduino app hover over Sketch then Include Library and next Add .ZIP Library, and find and add the libraries found above.

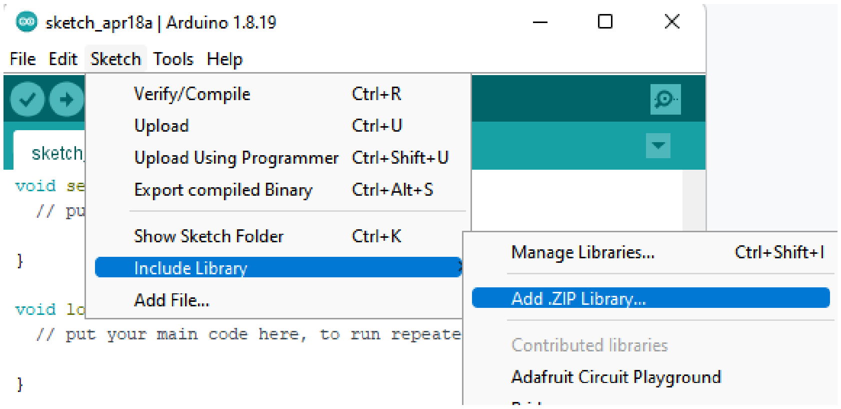

sketch_apr18a | Arduino 1.8.19
File Edit Sketch Tools Help
Verify/Compile Ctrl+R
Upload Ctrl+U
Upload Using Programmer Ctrl+Shift+U
Export compiled Binary Ctrl+Alt+S
Show Sketch Folder Ctrl+K
Include Library
Add File...
Manage Libraries... Ctrl+Shift+I
Add .ZIP Library...
Contributed libraries
Adafruit Circuit Playground
sketch
void se
// pu
}
void lo
// put your main code here, to run repeate
}

Figure 2: Arduino setup (a)

Then, at the top left of the app click verify.

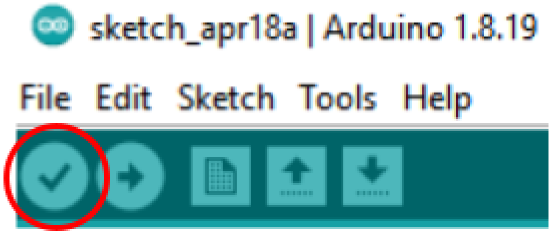


Figure 3: Arduino setup (b)

Finally, plug the arduino into your computer and click the upload button to upload the software onto the THEC.

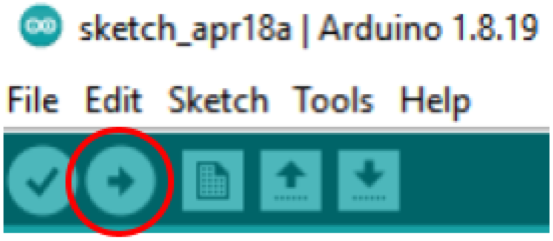


Figure 4: Arduino setup (c)

Your arduino is now programed and the system is set-up.

3.4. System Organization & Navigation

3.4.1. The Display

On the left side of the display TEMP1 and TEMP2 can be seen, TEMP1 is the temperature measured inside the house and TEMP2 is the temperature measured inside the THEC.

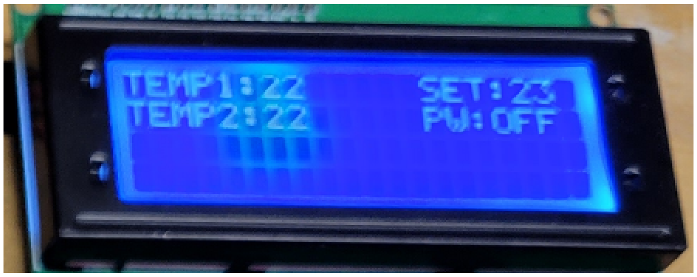


Figure 5: Display screen

On the right side of the display SET and PW can be seen, SET is the desired house temperature which can be changed by using the two buttons below the display and PW tells you whether the system is running or not.

3.4.2. The User Inputs

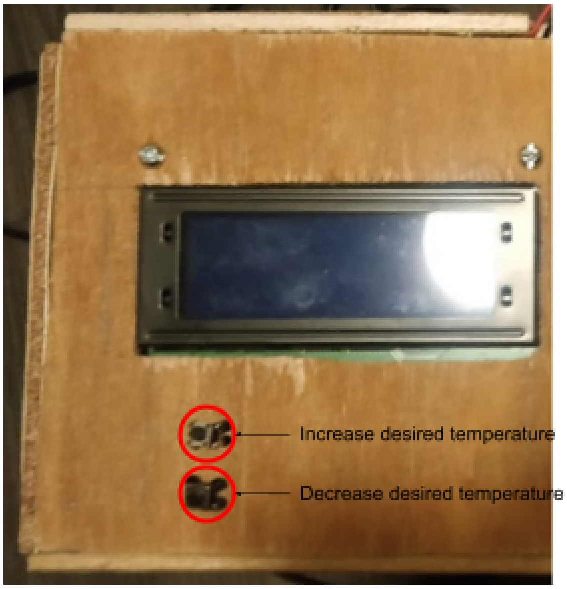


Figure 6: Temperature button controls

There are two push buttons below the display which are the main user input for the system. The top button increases the desired temperature and the bottom button decreases the temperature, this can be seen next to SET on the display.

3.5. Exiting the System

To properly turn off the system, unplug both the arduino and the blower from the outlet. The display and the blower will turn off and your system will be shut down.

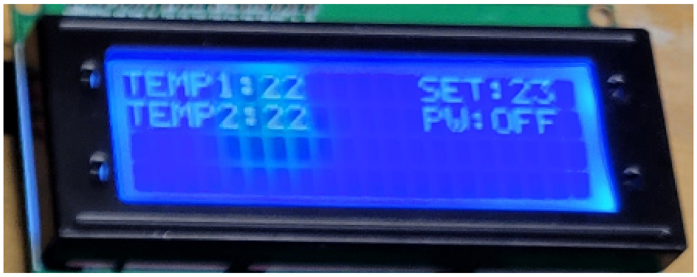
4. Using the System

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the THEC.

4.1. Temperature Control

The THEC works on a target-based system. You can set a target temperature that you would like the environment to be at, and the system will automatically run, as needed, to attain or maintain that temperature. Because the system leverages ambient ground temperatures, there is no heating or cooling-specific element - air is simply drawn from the inlet, through the system, and into the environment.

The display can be considered as divided into a left and right half, each displaying information regarding the system's operation.



```
TEMP1:22      SET:23
TEMP2:22      PW:OFF
```

Figure 7: Display screen

The left side contains the readings of the two temperature sensors, TEMP1 and TEMP2.

- To the right of TEMP1 is the current temperature inside the house.
- To the right of TEMP2 is the temperature inside the chamber.

The right side of the display contains two pieces of information: the target temperature, and the fan's status.

- The target temperature is denoted by SET.
- PW indicates the operational status of the fan.

4.1.1. Setting the Target Temperature

Part of the circuit consists of two push buttons, arranged vertically (pictured below). The top button corresponds to an increase in the target temperature, while the bottom button decreases the target temperature.

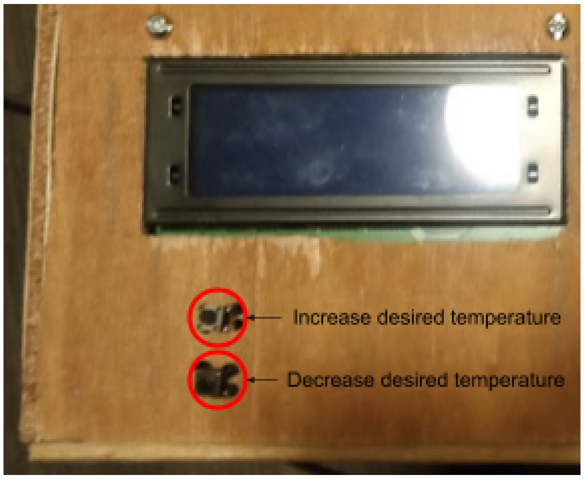


Figure 8: Temperature button controls

The target temperature can be dynamically updated in real-time. Any changes made will be reflected on the number next to SET on the LCD display.

Of note: the temperature increments in degrees Celsius (°C). One button press corresponds to an increase or decrease of one degree Celsius, and temperature readings are rounded to the nearest integer value. This means that, if a temperature is 22.4°C, the system will display it as 22°C.

4.1.2. Fan Behaviour

The fan's operational status can be determined by the PW reading, in the bottom right corner of the LCD display. This is binary: either the fan is running (indicated by ON), or it is off (indicated by OFF).

The criteria for the fan to be running depends on the current room temperature and the target temperature:

- In the winter, the fan will run if the target temperature is above the current room temperature.
- In the summer, the inverse will be true: the fan will run when the target temperature is below the current room temperature.

4.2. Sump Pump

The sump pump is an autonomous system that operates without user input, as required. Located on the inclined stretch of piping, underground, the sump pump is contained inside a box. Within this box, any condensation that occurs due to temperature differences inside and outside the system will naturally drain, due to its lowered position. When a sufficient water level is reached within the pump's chamber, the pump will run, drawing water out and into the surrounding ground. This water then naturally drains over time.

The pump is connected to the rest of the electronics, supplying it with power. Aside from that, however, it is entirely independent of the fan, and requires no user input to properly operate.

5. Troubleshooting & Support

5.1. Error Messages or Behaviors

Since this system is very low-tech as it contains minimal electronic components or moving parts, the chance of technical malfunctions occurring is much lower. Issues that could occur are the following:

1. Faulty temperature reading:

   If the temperature readings that appear on the screen are abnormally high there could be an issue with the temperature sensors. This could then lead to the blower not activating as it should. This faulty reading could potentially be caused by the area in which the sensors are located. If the sensor is in contact or in close proximity to something hot or cold it could influence the temperature reading so that it doesn't truly represent the entire area where it's located. The user should check the area near the sensors if accessible to see if there is anything influencing the temperature and adjust the positioning of the sensors if that's the case. If this doesn't resolve the issue, the problem might be with the wiring in which case the user should talk to customer support for professional assistance.

2. Blower malfunction:

   If the blower doesn't seem to activate when it should or if it is running when it most likely shouldn't, there could be an issue with the blower. This could be caused by faulty temperature readings like mentioned previously. However, there could also be a physical issue with the blower and its components such as a broken or damaged piece or wire. In this case it would be best to contact customer assistance to deal with the issue.

3. Faulty temperature input:

   If when pressing the up/down buttons to change the set temperature, the set temperature doesn't adjust properly there could be an issue with input buttons. First, the user should check to make sure that the buttons aren't jammed in place. If they are stuck, the user should be able to dislodge the button relatively easily on their own. If the issue persists the issue is most likely due to the wiring that could be damaged. To resolve this issue, customer assistance should be contacted.

5.2. Maintenance

Maintenance for this system is very simple, but very important to ensure it works at its highest potential. The filter at the air inlet should be replaced or cleaned every three months in order to maintain good air quality. It's also important to verify that the blower is working properly by simply checking in on it from time to time. These first two recommendations can be done by the homeowner. Finally, the piping system should be cleaned every two years. This should be done professionally, either by a specialized cleaning company or the installers of the system.

5.3. Support

For customer assistance in the case of an issue with the THEC or questions regarding the system, users can contact the builder of the product, Chinedu J. Enendu at Rockville Eng Inc at info@rockvilleenginc.com. Any problems detected with the system should be reported immediately by sending an email to the address listed above. The user should include a detailed description of the problem as well as their name and contact information in their email. In case of serious malfunction, the user should attempt to completely deactivate the system while waiting for a response team to arrive and assess the situation.

6. Product Documentation

6.1. Box

6.1.1. BOM (Bill of Materials)

Item Name	Description	Quantity	Unit Cost	Link
Box	PVC box	1	$16.97	Box

6.1.2. Equipment list

The equipment required to build this subsystem is as follows:

- Drill Press
- Tape Measure
- Sandpaper

6.1.3. Instructions

Setting up the Box subsystem is one of the most simple elements of the design:

1. Start by taking measurements of your box
2. According to the number of pipes, in our case 6, divide the WIDTH of the box into 6 even sections, with a small buffer area to the very edges. Do this as close to the top of the box as possible, without interfering with the lid.
3. Once the gaps between pipes is determines, use a tape measure to measure these specific intervals, and mark them on the box
4. Ensure that each interval is aligned properly, and clearly marked
5. Once the intervals are marked, set up a drill or drill press with a ½ inch drill bit (the diameter of your PEX pipe if making variations)
6. Slowly drill the appropriate sized holes at each marking, ensuring a very clean hole is made
7. OPTIONAL: Using sandpaper, clean the edges around the hole for a better look and ensuring that no sharp edges may damage any future piping and making it easier and safer to assemble later.
8. Repeat these steps but on the opposite side of the box, at the bottom of the face. Make sure to give a small buffer from the very bottom of the box.

6.2. Piping

6.2.1. BOM (Bill of Materials)

Item Name	Description	Quantity	Unit Cost	Link
Pipes	½ inch PEX	1	$31.98	Pipe
Silicone		1	$8.79	Silicone
Rope		1	$8.91	Rope

6.2.2. Equipment list

The equipment required to build this subsystem is as follows:

- Heat Gun
- Caulking Gun
- Knife/Scissors
- Any sturdy item of 5 inch diameter
- Tape measure
- Pipe Cutter

6.2.3. Instructions

To set up the Piping subsystem, follow these steps:

1. Upon acquiring piping, unravel it until you have a workable amount
2. From the design of the prototype, we understand the length for a single pipe is
3. Using a tape measure, mark the following intervals on the piping:
    a. 24 cm + 4 cm buffer at the start
    b. 9.4 cm
    c. 16.5 cm
    d. 9.4 cm
    e. 24 cm + 4 cm buffer at the end
4. Once these intervals are measured, cut off the entire 87.7 cm long section from the 100 ft coil.
5. The intervals of 9.4 cm are where the piping must be bent in order to fit in the box.
6. Turning on the heat gun, start heating the general area around where this interval has been marked
    a. Make sure to not overheat the piping, as it is plastic and can easily melt if not heated with caution

7. Once the plastic starts to be easily pliable, wrap the first 9.4 cm around your sturdy item of 5 inch diameter, putting the middle of the 9.4 cm section on the middle of the curve.
8. Slowly, with pressure, wrap the 9.4 cm section around the 5 inch diameter object, shaping the curve of the pipe to this diameter.
   a. If necessary, go as far as possible, then reheat the pipe and continue
9. Once the section has the desired curve, repeat with the other 9.4 cm section, but curving the pipe in the opposite direction.
10. Once both sections are curved, use an amount of rope to pull a few inches before each curve together, helping keep the pipe in shape.
    a. This can be done by wrapping the rope around two layers of the now curved pipe, and forming a simple knot. Length of rope is unimportant, simply make sure that it is not too tight, but tight enough to hold the shape of the pipe
11. Once the pipe has been formed and the shape has been reinforced with rope, insert the pipe into the box, inserting the first layer of the pipe into the top hole, and the bottom layer into the bottom hole.
12. Once the pipe has been inserted, use the caulking gun to silicon around the hole of the box, forming a seal with the box and the pipe.
    a. Make sure to do this on both the outside and inside of the box to ensure the best seal
13. Once the holes have been sealed, you can optionally silicon the bottom layer of the pipe to the box.
    a. This makes sure that the pipe will not move out of place, and helps it hold its shape better, however is not 100% necessary.
14. Repeat these steps for the next 5 holes of the box, until you have a full box with a system of pipes.
15. Now, take a length of pipe of ~70 cm
16. Use the heat gun to straighten this piece of pipe if necessary
17. Using the same intervals we used to drill the horizontal holes in the box, drill the same width holes into the side of the pipe, making sure to only go through one layer of PEX. You do not want to drill completely through the pipe.
18. There is piping sticking out of either side of the box that we installed earlier, insert each one into its respective hole on this newly drilled piping piece.
    a. Once the box pipes are inserted, silicon the hole just as you did earlier, creating a seal.
19. Repeat steps 15-18 for the other entrance/exit of the pipes.
20. The piping system is now assembled.

6.3. Circuit

6.3.1. BOM (Bill of Materials)

Item Name	Description	Quantity	Unit Cost	Link
Arduino	Uno	1	$9.00	Arduino
Breadboard	8.5 cm x 5.5 cm	1	$2.50	Breadboard
Temp Sensor		2/5	$7.59	Temp Sensor
Push Button		2	$0.20	Push Button
Cables		36	$0.10	Cables
LCD	4 pin, 20x4	1	$14.48	LCD
Relay SPDT	4 channel	1	$22.69	Relay
Resistors		4	$0.01	Resistors

6.3.2. Equipment list

The equipment required to build the circuit is as follows:

- Soldering iron
- Tweezers
- Needle nose pliers
- Wire strippers

6.3.3. Instructions

Instruction on how the circuit was built. A more detailed tinkercad circuit drawing follows the instructions.

1. Connect the four pins at the back of the LCD display in the order as seen in the image below, black, red, brown, orange, from top to bottom with female to male cables

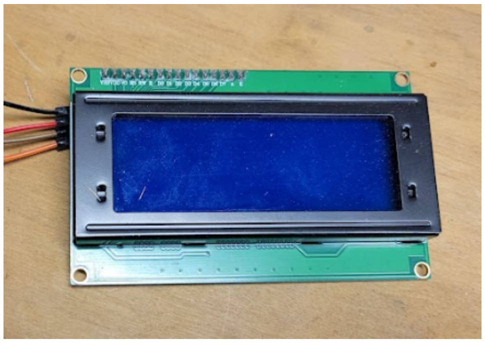


Figure 9: Screen wiring

2. Connect the male end of the black and red cables to the same colour positive and negative on the breadboard
3. Connect the male end of the orange cable to SCL on the arduino and the brown cable to SDA on the arduino, as seen in the image below

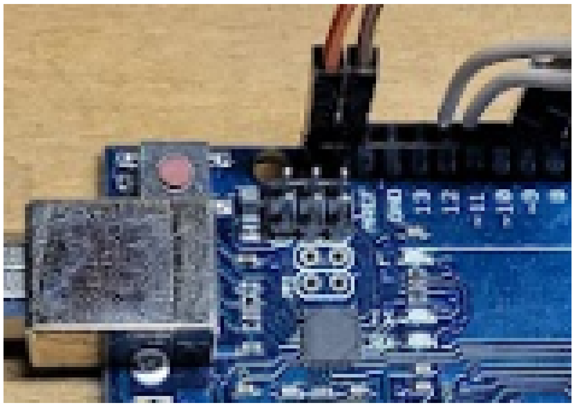


Figure 10: Arduino wiring (a)

4. Using male to male cables connect the bottom 5V and GNG on the arduino to the corresponding sides of the breadboard
5. On the relay attach three female to male connectors red to the 5V, black to the GNG and green to the left of the black cable as seen in the image

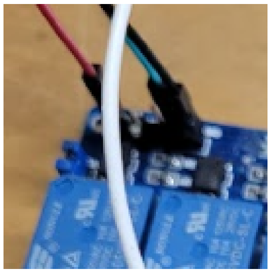


Figure 11: Arduino wiring (b)

6. Attach the male end of the of the red and black wire from the relay to the corresponding rows on the breadboard and attach the green cable to D7 on the arduino
7. On the relay you need to attach the red wire from the 24V power supply and the black wire from the blower
8. Connect the remaining wires from the blower and power supply to each other
9. Solder three cables (red, black and green) to both of the push button and to each of the wires (red, black and yellow) on both temperature probes and cover with shrink wrap
10. Connect the red and black cables from the temperature probes to their corresponding GNG and power row on the breadboard
11. Take two resistors and put them from the positive row on the breadboard to row 29 and 30 on the top half of the breadboard
12. In the same rows attach the yellow wire from the temperature probes
13. Take two male to male wires and connect them from rows 29 and 30 to D11 and D12 on the arduino
14. Take the last two resistors and connect them from the negative row on the breadboard to J12 and J24
15. Connect the black wire from the buttons to rows J12 and J24 on the breadboard
16. Connect the red wire from the buttons to the positive row on the breadboard
17. Connect the green wire from the buttons to D9 and D10 on the arduino

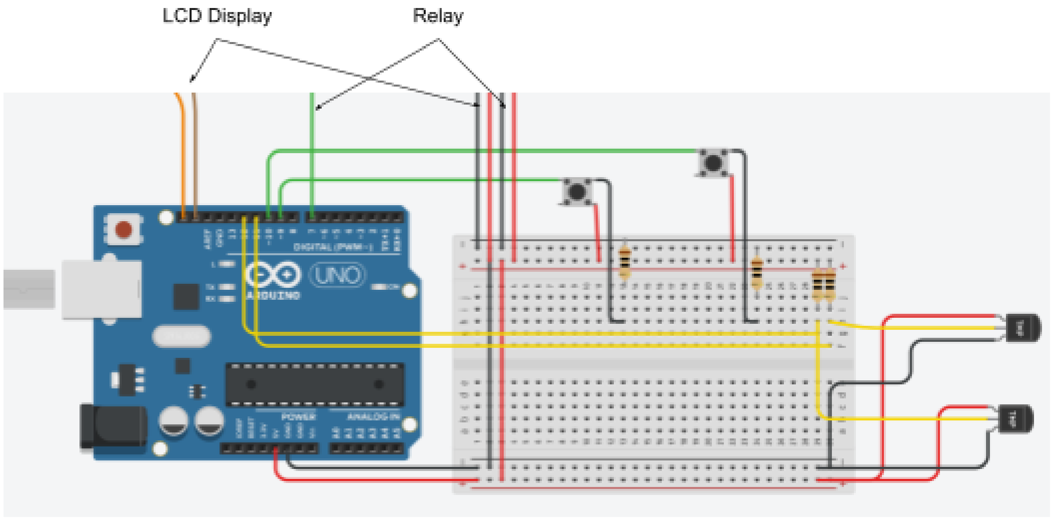
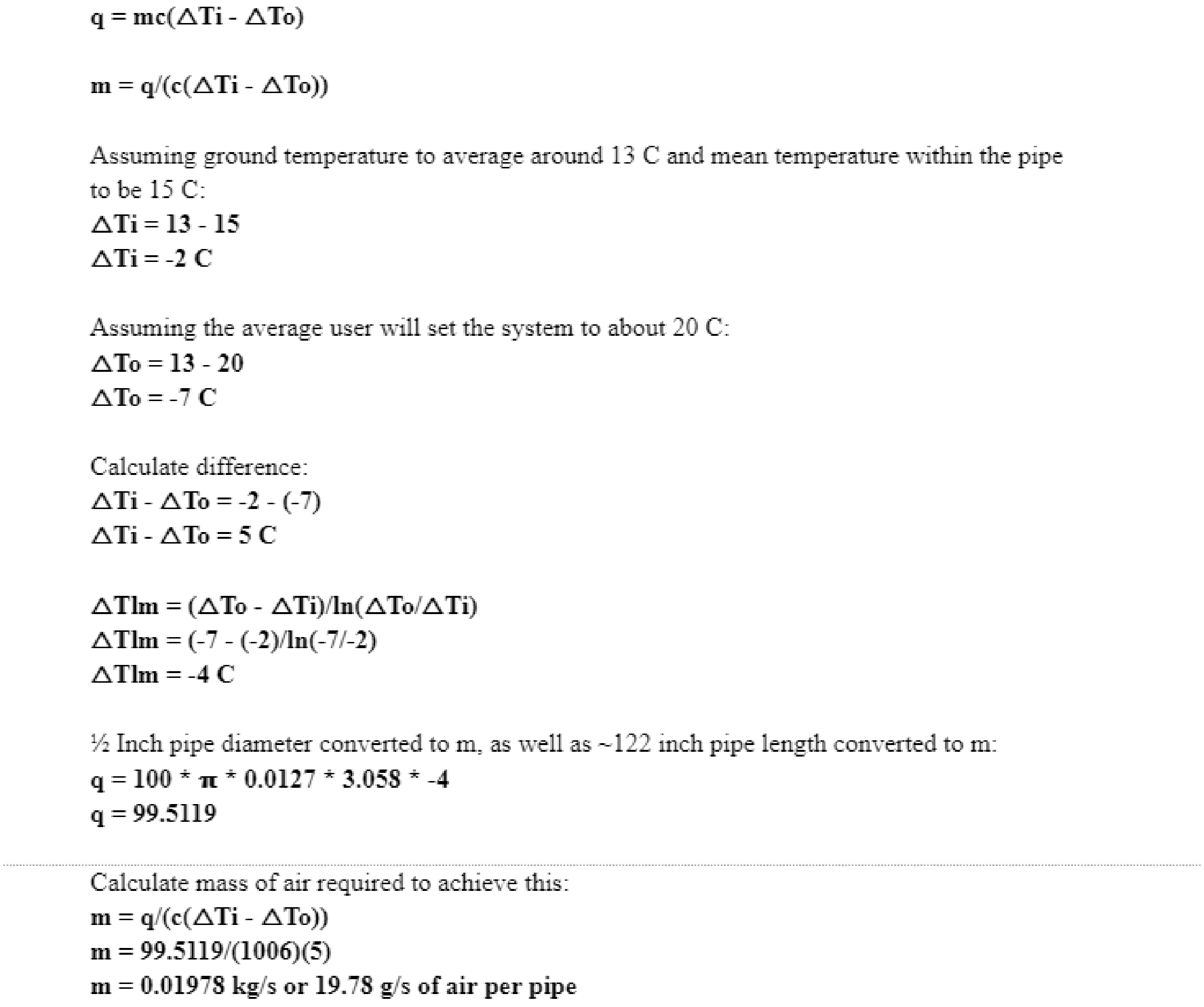


Figure 12: Electrical circuit

6.4. Testing & Validation

We tested our parts and the ability to fit them together using 3D modeling software such as Onshape. We also made heavy calculations on each part of our prototype to ensure not only everything would fit together, but that we would get maximum heat transfer while also using as little energy as possible.



$q = mc(\Delta Ti - \Delta To)$

$m = q/(c(\Delta Ti - \Delta To))$

Assuming ground temperature to average around 13 C and mean temperature within the pipe to be 15 C:
$\Delta Ti = 13 - 15$
$\Delta Ti = -2$ C

Assuming the average user will set the system to about 20 C:
$\Delta To = 13 - 20$
$\Delta To = -7$ C

Calculate difference:
$\Delta Ti - \Delta To = -2 - (-7)$
$\Delta Ti - \Delta To = 5$ C

$\Delta Tlm = (\Delta To - \Delta Ti)/\ln(\Delta To/\Delta Ti)$
$\Delta Tlm = (-7 - (-2))/\ln(-7/-2)$
$\Delta Tlm = -4$ C

½ Inch pipe diameter converted to m, as well as ~122 inch pipe length converted to m:
$q = 100 * \pi * 0.0127 * 3.058 * -4$
$q = 99.5119$

Calculate mass of air required to achieve this:
$m = q/(c(\Delta Ti - \Delta To))$
$m = 99.5119/(1006)(5)$
m = 0.01978 kg/s or 19.78 g/s of air per pipe

These calculations helped us verify that our product would be efficient in all areas.

7. Conclusions and Recommendations for Future Work

Our prototype was overall a success; considering the time and resources that was given to us, but we still believe we could have done better. The main lesson that we learned during this project is time management and organization, we were not fully able to utilize the amount of time giving to us, because we did not have the capability to notice that the time given was not coinciding with what the group was trying to achieve, due to our lack of organization and time management. The most productive avenues for future work on our prototype will be for the other group to revise our user and product manual and judge for themselves if the prototype fully fulfills the client demand, if not they can help the prototype get closer to its end goal by organizing ideas and managing their time better than we did.

The major aspect of our prototype that we were not able to entirely complete was its physical build up. We spent more time on the concept of the prototype but did not have time to fully illustrate what we had in mind as the perfect prototype for our client.

8. APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
MakerRepo	https://makerepo.com/danielletaylor/1098.gng1103-sweddy-thec-d12	04/20/22