

GNG1103
Design Project User and Product Manual

THE HEAT EXCHANGE CHAMBER (THEC)

Submitted by:

HOT POCKETS – GROUP 1.3

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List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
THEC	The Heat Exchange Chamber
LCD	Liquid Crystal Display
PC	Polycarbonate
PVC	Polyvinyl Chloride

Table 2. Glossary

Term	Acronym	Definition
Arduino	Arduino Board	Arduino is an open-source platform used for building electronics projects. Consists of both a physical programmable circuit board and a piece of software.
Tinkercad	-	Tinkercad is an online collection of software tools. Users can create circuits and build their own by using premade wire components. There are built-in Code blocks or custom C++ that allows circuit components to run. Users can modify and further define the code until they achieve their desired result.

1 Introduction

This User and Product Manual (UPM) provides the information necessary for homeowners to effectively use the Heat Exchange Chamber and for prototype documentation.

This document is composed of information regarding the proper use of the Heat Exchange chamber. It also consists of the steps to be taken should any of the components of the system not behave as predicted as well as the steps taken to fully create the system. The purpose of this document is to provide homeowners with an overview of the heat exchange chamber and its functionalities. It will explain the process of geothermal heating, how this concept was applied to create the system and how the system can be implemented in different households. It is assumed that the temperature six feet deep underground, will be sufficient to provide heated or cooled air inside households.

The document will also go over the key aspects that make the heat exchange chamber economic, inexpensive, and sustainable. It will provide homeowners with detailed description regarding the purpose of each different subcomponent of the system. It will also go over the different tests that were done on the system to ensure high performance of each component of the system.

This document also safeguards any personal information about the homeowners and protects their user identity. The document also abides by any laws regarding the security and privacy of users. It is also important to empathize that all troubleshooting activities described in this document is completely safe for the user to carry out. Should any extraordinary malfunction occur, it is highly recommended to contact the provider to ensure the safety of the user. Confidentiality is always maintained during any interaction between the user and the provider.

2 Overview

At the beginning of the semester, the client, M.Enendu, expressed the need to design an inexpensive, sustainable, and efficient heat exchange system that could possibly be extended to larger companies and institutional spaces. The client expressed a variety of needs, the most prominent ones were for the heat exchange chamber to:

- Achieve high efficiency performance and must be buried no less than 6 feet below gray level.
- Must be environmentally friendly resulting in low emission of contaminants to the atmosphere.
- The cost of the project must be inexpensive with a cap of approximately 100\$
- Durable, prevent damage from extreme weather conditions and have a life expectancy of at least ~20-30 years.
- Sustainable, seek to reduce negative impacts on the environment, and the health and comfort of building occupants.

It is important to solve this problem with adequate solutions for an economical, eco-friendly THEC to be designed and enhance overall building performance. The current solution to this problem is our prototype. Our prototype is preeminent because it contains an optimal pipe configuration with thermal advantages that differentiate it from other products. Furthermore, the prototype also consists of a temperature activated fan, such that the user can set the house to be at a desired temperature. The fan will only turn on if the house is not at the desired temperature. This strategy proves to be economically conscious because less electricity will be used, thereby, it reduces the monthly expenses on the house utilities bills. The LCD display can also be switched on and off. Finally, the prototype also consists of a filter that prevents entry of contaminants from the atmosphere.

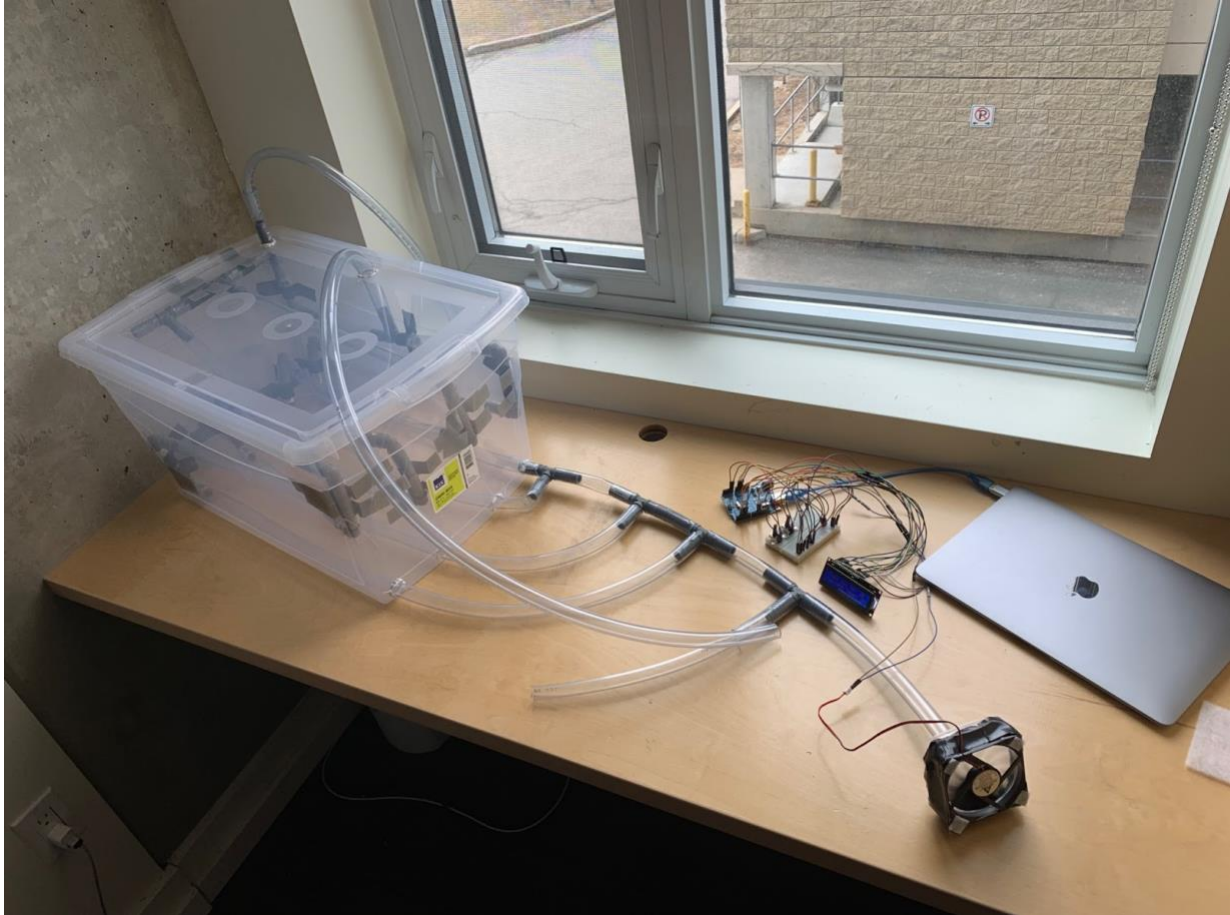


Figure 1: Final Prototype

The final prototype consists of one air inlet pipe, positioned horizontally once entered at the top of the box dividing into 4 other pipes with spacing in between each. Out of the 4 pipes, 1 pipe is the air recycling pipe that comes from the house and leads back to the inlet pipe. The other 3 pipes will come out from the bottom of the box and merge into one pipe that will lead to the fan. Inside the box, the piping configuration is in the form of a zigzag connected with elbow connectors to prevent extreme bending in the pipes. The pipes, the box and the elbow connectors are made from PC material. The pipe that leads to the fan has another pipe connection for our sump pump pipe to prevent condensation. Lastly, the fan consists of a filter, to ensure high quality air entering the house. The fan can be activated by the user from a button that is connected to the LCD display. This can be switched on and off when needed and allows the user to set the house at a desired temperature. The fan continues to be efficient by turning it on and off according to the set house temperature. We have created this program with the help of an Arduino Board and Tinkercad. To better understand, we have provided a flowchart that demonstrates how the software process of our fan system works. We will be demonstrating the two functions.

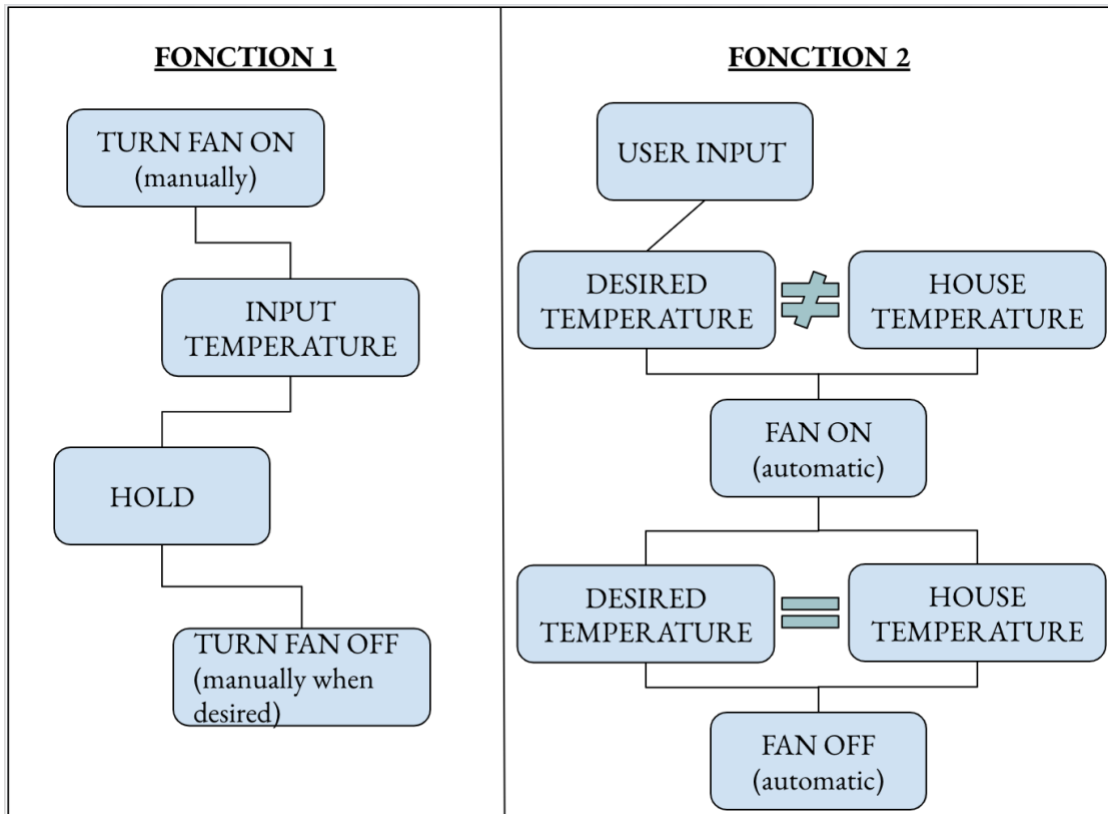


Figure 2: Flowchart

2.1 Conventions

There are no conventions in this report.

2.2 Cautions & Warnings

The button attached to the LCD display that allows the user to set the desired temperature is touch sensitive. Therefore, when turning the button to increase or decrease the temperature, be gentle and turn slowly.

3 Getting started

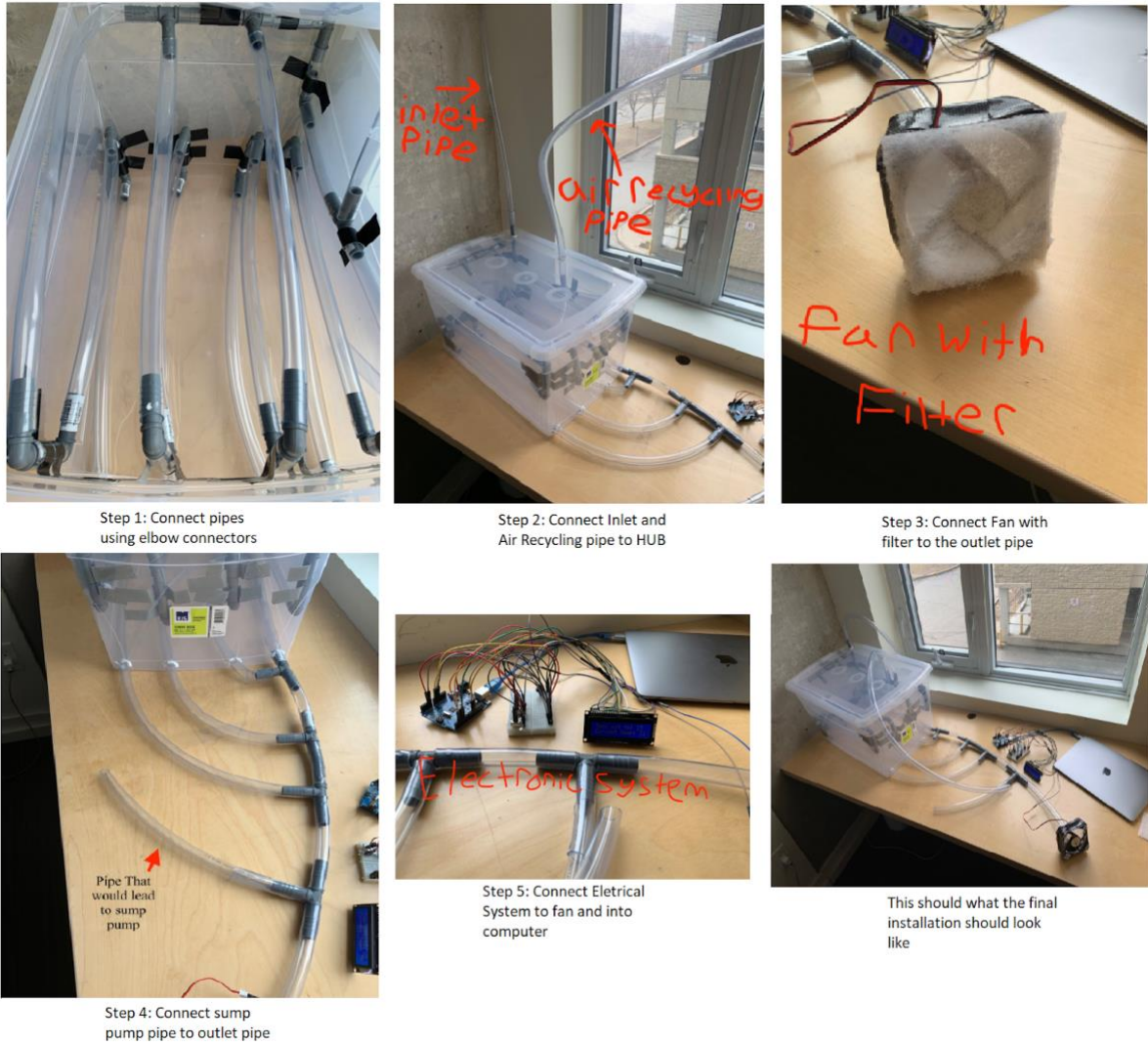


Figure I: Instructions of Installation

3.1 Configuration Considerations

The only equipment needed for this system (*Figure I*) is a laptop to connect the electrical system. The prototype will come with an Arduino file that you will install on your laptop and execute when you would like to start using the system. You input your desired temperature into the Arduino EXE tab, then it will send a signal to the fan that will push either cold or warm air. This is monitored by a sensor that measures the temperature in the room.

3.2 User Access Considerations

Most users will be homeowners because they are free to change the temperature of the space freely. Another group of users will be workers in institutional buildings to accommodate the average worker's desired temperature.

3.3 Accessing/setting-up the System

The only procedure the user must complete is having the Arduino IDE installed correctly on their device and running the program. Once this is accomplished, the sensor will take, approximately, an hour to recognize the temperature in the room. Once it is recognized, type in your desired temperature and the fan will turn on.

3.4 System Organization & Navigation

The key features of this system if the electrical system, the inlet pipe, and the air recycling pipe.

3.4.1 Air Recycling Pipe

This is the pipe that is connected to the main piping system which is crucial to bring in fresh air so the air being pushed out into the room has a lesser chance of being contaminated, if by chance the filter does not catch it.

3.4.2 Inlet Pipe

The inlet pipe is important because it is where the air originally comes from, being made from PVC, it is exceptionally durable and sustainable, causing no leakage for a long time.

3.4.3 Electrical System

The electrical system is the main component in this system because it senses and manages the temperature in the room. Once you open the Arduino IDE, you select/import the dedicated file for this project. You then press run. This runs the program which turns on the sensors to measure the temperature of the room. Once the temperature is measured, you input your desired temperature and the fan will start to blow out air according to what temperature has been input.

3.5 Exiting the System

To turn off this system, you simply click “stop” on the Arduino IDE and this stops the program from executing.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the <System Name and/or Acronym>.

The only user function that our system requires once it is completely assembled is that the desired temperature must be inputted manually into the code. This can be done on the arduino code that must be downloaded onto your computer. Once the desired temperature is inputted into the code, the system will begin to work accordingly and change the temperature in its current room.

Below are two pictures of our system at work:

The first picture is taken before the code is manually inputted into the arduino code and the second image demonstrates the output capabilities that our system has.

Image 1:



Image 2:



4.1 <Given Function/Feature>

In regards to the only user function that our system has, all the functions are done within the Arduino code.

The following is the code that allows our system to run and is the code that the user must master in order for the proper function of our system. The desired temperature must be inputted where it says (temperature, input). Once this occurs, the code will activate the system and cool or heat the room to the desired temperature.

```
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
int temperature = A0;
int fan = A2;
int sensorInput;

void setup()
{
  Serial.begin(9600);
  pinMode(fan, OUTPUT);
}
```

```

pinMode(temperature, INPUT);
// set up the LCD's number of columns and rows:
lcd.begin(16, 2);
// Print a message to the LCD.
lcd.print("Temperature set:");
}

void loop()
{
//getting input temperature value
double sensorValue = analogRead(A1);
byte setTemp = map(sensorValue,0,1023,15,30);
delay(1000);

//converting the voltage double tmp;
sensorInput = analogRead(A0);
double tmp;
tmp = (double)sensorInput / 1024;
tmp = tmp * 5;
tmp = tmp - 0.5;
tmp = tmp * 100;

//turning fan on if the temperature is not what is required by the user
if(tmp <= setTemp + 2)
{
  analogWrite(fan,250);
  delay(1000);
}

else if(tmp >= setTemp - 2)
{
  analogWrite(fan,250);
  delay(1000);
}

//setting up LCD display
lcd.setCursor(0, 1);
lcd.print(setTemp);
delay(1000);
}

```

4.1.1 <Given Sub-Function/Sub-Feature>

There are no additional sub sections necessary for system sub-function or sub-feautres.

5 Troubleshooting & Support

The following subsections include any information on the prototypes troubleshooting and/or support

5.1 Error Messages or Behaviors

Part of the prototype that is prone to cause problems is the wiring. Make sure the wires are properly connected at all times. To identify this problem is if the system is not working properly, the temperature reading/changing screen is not lit up or the fan isn't activating a usual fix is to make sure wires are properly connected.

5.2 Special Considerations

A special circumstance of the prototype is that the fan only activates if the set temperature is outside of a one-degree radius of the current temperature. This feature is part of the prototype as this save's energy. For example, if the set temperature is 28 degrees Celsius, the system will only activate if the current temperature reading of the room is higher than 29 degrees Celsius or lower than 27 degrees Celsius.

5.3 Maintenance

General maintenance on the system consists of changing the air filter when needed. You should check on the filter once a week and when it is full of dust and/or very dirty we recommend replacing it with a new filter.

Also, you should change the battery once the electronic system isn't working due to power reasons (screen or fan will not be on or working once the battery is dead). Therefore, should change the battery when the electronic system is not turning on.

5.4 Support

- Help electronic system:

If help is needed on the electronic system which consists of the Arduino, the fan or any of the wiring, Oliver Burpee (oliverburpee@gmail.com) is the most experienced in this field and could help at his earliest convenience.

- Assembly related support:

As Maria drew most of the designs, if any questions or concerns about the design itself and how to assemble it you can contact mariabril9703@gmail.com

- Emergency related incident:

If anyone is in serious danger and/or injured the first number to call is 911. If the situation is controlled however and are in need of assistance as soon as possible about the prototype contact anyone of our team members at meadsquin@gmail.com, ayushsookun1@gmail.com, oliverburpee@gmail.com, mariabril9703@gmail.com, lordriaden@gmail.com, ldeforge27@gmail.com

- General questions/maintenance support:

Any member of our team would be more than happy to assist you in answering any questions, concerns or how to do maintenance at meadsquin@gmail.com, ayushsookun1@gmail.com, oliverburpee@gmail.com, mariabril9703@gmail.com, lordriaden@gmail.com, ldeforge27@gmail.com

6 Product Documentation

6.1 Box

The original plan for the box was to make it out of concrete, but after some analysis of cost, we deemed it to be too expensive for the system that we wanted to build. We next looked onto using plywood, but that brought many issues including waterproofing and cost. We finally decided on a plastic box as it was much more affordable for our project.

6.1.1 BOM (Bill of Materials)

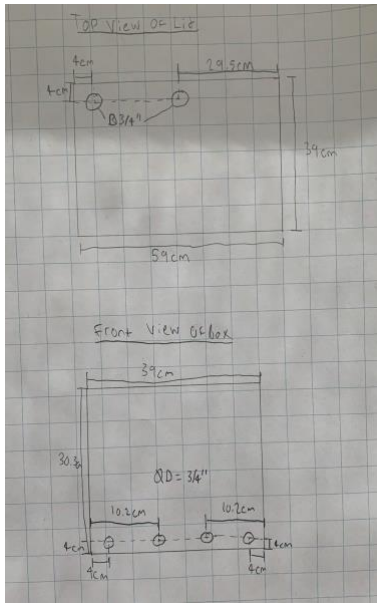
Item Name with embedded link	Cost Per Unit (\$)	Quantity (pcs)	Total Cost (\$)
Box	9.98	1	9.98
8cm by 8cm Tupperware Container	0	1	0
Total Cost:			\$9.98
Cost with Tax			\$11.28

6.1.2 Equipment list

- Hand Drill
- 3/4" Drill bit
- Measuring Tape

6.1.3 Instructions

Here is an image of the holes the must be drilled into the box.



Using the image provided above, you will want to drill the holes into the box. When drilling the holes, it is highly recommended that you have someone to hold the box in place when drilling. Also, take your time when drilling the holes as the plastic may crack if you try to put too much pressure on it. You will then want to make a hole right in the center of your Tupperware container which will be used to mount the pipe to the fan.

6.2 Piping

6.2.1 BOM (Bill of Materials)

Pipe (10 ft)	9.84	1	9.84
Pipe (20 ft)	13.41	1	13.41
Fittings (T-Shaped)	1.02	8	8.16
Elbow Fittings	1.18	17	20.06
Caulking	3.65	1	3.65
Filter for fan	9.98	1	9.98

Cost:	\$65.10
Cost with tax	\$73.56

6.2.2 Equipment list

- Tube Cutters
- Measuring Tape
- Duct tape

6.2.3 Instructions

Step 1:

To start off, I will provide a cut list for pipe lengths, so to begin cut out:

- 12pcs at 3” length
- 2 pcs at 8” length
- 2pcs at 12” length
- 6pcs at 15” length
- 3pcs at 16” length
- 1pcs at 17” length
- 2pcs at 25” length
- 1pcs at 32” length

Step 2:

Once all those pieces have been cut, you will want to take 3 of your T-fittings and connect them together with the one on the left rotated 90 degrees with respect to the others. Then mount them on lid as shown in the image below.

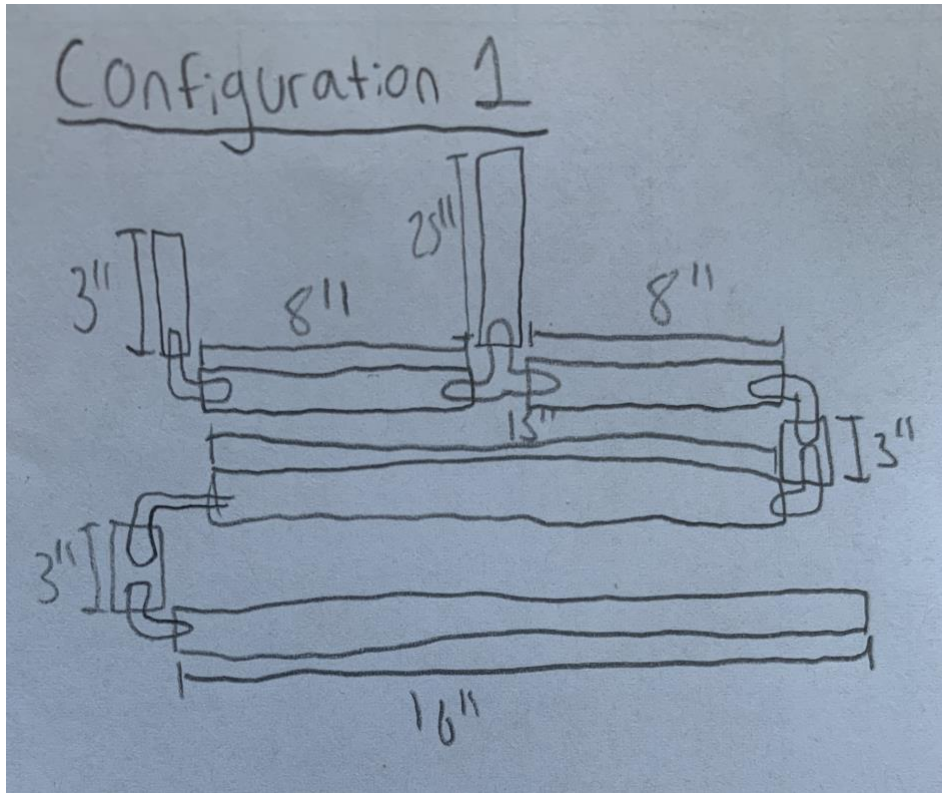


Step 3: Configuration 1

In this step we will assemble the first pipe configuration. We will start with what I will call configuration 1 which will be the one that has the recycling pipe attached to it. For it you will need:

- 3pcs 3" long
- 2pcs 8" long
- 1pcs 15" long
- 1pcs 16" long
- 1pcs 25" long
- 1 T-fitting
- 5 elbow joints

Follow the drawing below to make configuration 1:

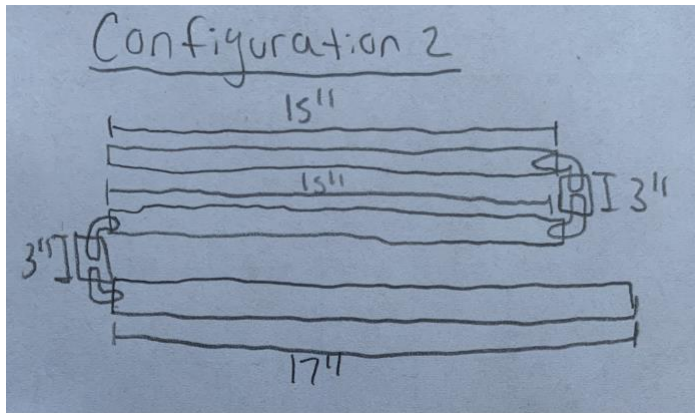


Step 4: Configuration 2

In this step we will assemble the second pipe configuration. For it you will need:

- 2pcs 3" long
- 2pcs 15" long
- 1pcs 17" long
- 4 elbow joints

Follow the drawing below to make configuration 2:

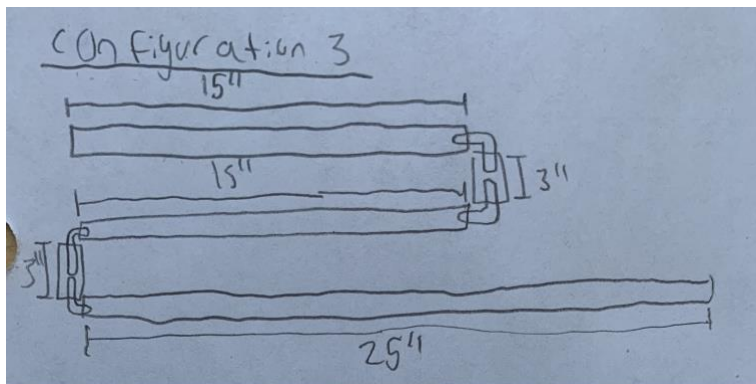


Step 5: Configuration 3

In this step we will assemble the Third pipe configuration. For it you will need:

- 2pcs 3" long
- 2pcs 15" long
- 1pcs 25" long
- 4 elbow joints

Follow the drawing below to make configuration 3:

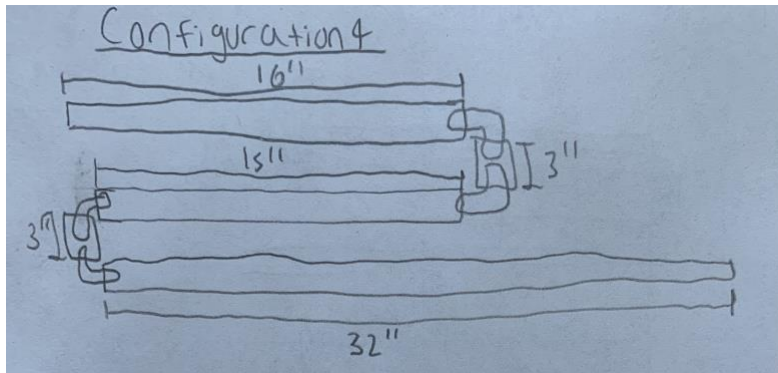


Step 6: Configuration 4

In this step we will assemble the fourth pipe configuration. For it you will need:

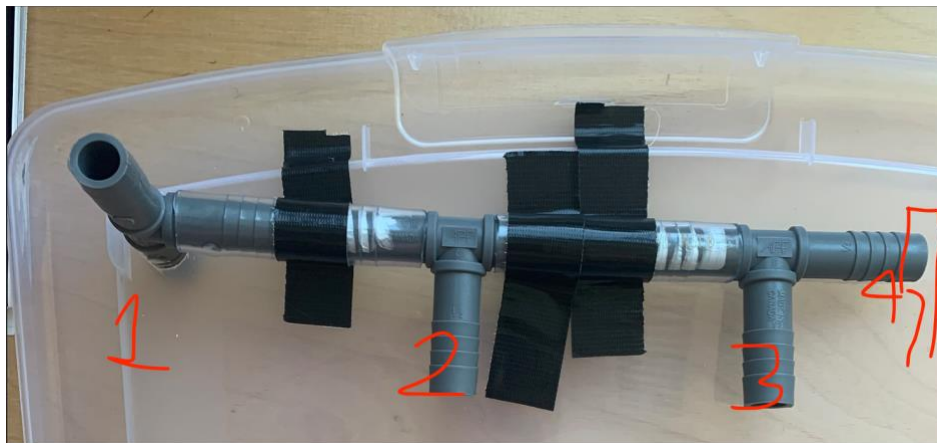
- 2pcs 3" long
- 1pcs 15" long
- 1pcs 16" long
- 1pcs 32" long
- 4 elbow joints

Follow the drawing below to make configuration 4:



Step 6: Assembling the configurations into the box

To start this step, you must know where each configuration gets put in the box, in the image below it shows where each configuration needs to be connected to the lid.



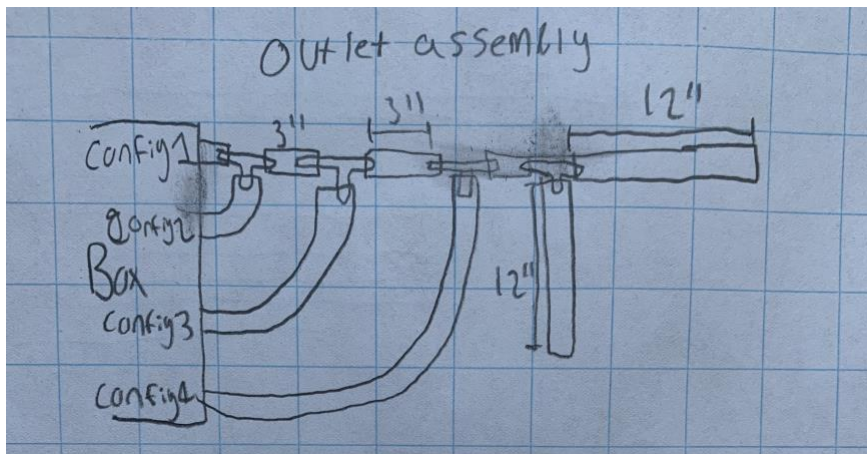
You will want to make your connections to the lid, then insert the configurations in the box and run the bottom row of piping out of the holes at the bottom of the box.

Step 7: Connecting the pipes into an output pipe

For this step you will need:

- 4 T-fittings
- 3pcs 3" long
- 2pcs 12" long

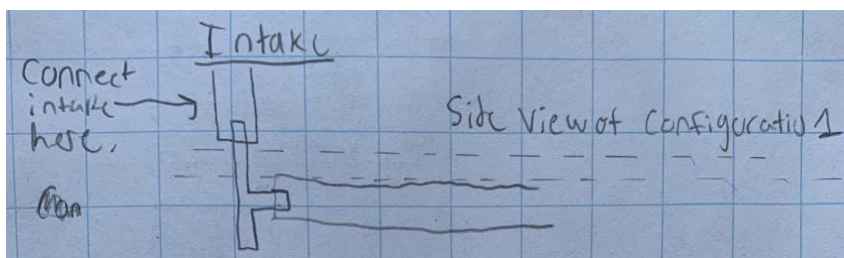
Now follow the diagram below to assemble the outlet pipe assembly



Step 8: Intake Pipe

Here we will connect the internal piping system to the intake pipe, you will need:

- 1pc 16" long



Step 9: Caulking and finalizing fan.

In this step you will use your caulking to seal the whole where the pipes come of the box to make it airtight. Then, you will attach your filter to the fan using the adhesive Velcro that is included in the filter purchased. You will then want to connect the fan to the Tupperware container from before using duct tape od adhesive. You will then insert the outlet pipe to the fan and put caulking around it to seal it.

You have now completed the piping and box assembly.

6.3 Electrical and Software

Here are the steps for constructing our electrical and software component. For our electrical and software system we decided on having a system that could read what the temperature is and display it to then allow a user to modify what they want the temperature to be at using potentiometers. If the temperature was not with 2 degrees Celsius of the desired temperature than the fan would activate and in turn heat or cool the building.

6.3.1 BOM (Bill of Materials)

Item Name with embedded link	Cost Per Unit (\$)	Quantity (pcs)	Total Cost (\$)
Arduino UNO	9.00	1	9.00
Jumper Cable	0.10	20	2.00
LCD display	10.56	1	10.56
TMP 36	3.40	1	3.40
Resistor (220 ohm)	0.01	1	0.01
Potentiometer	0.95	2	1.90
ProtoBoard	0.50	1	0.50
Arduino IDE	Free	1	FREE
Fan	8.99	1	8.99

Cost:	\$38.79
Cost With Tax:	\$43.83

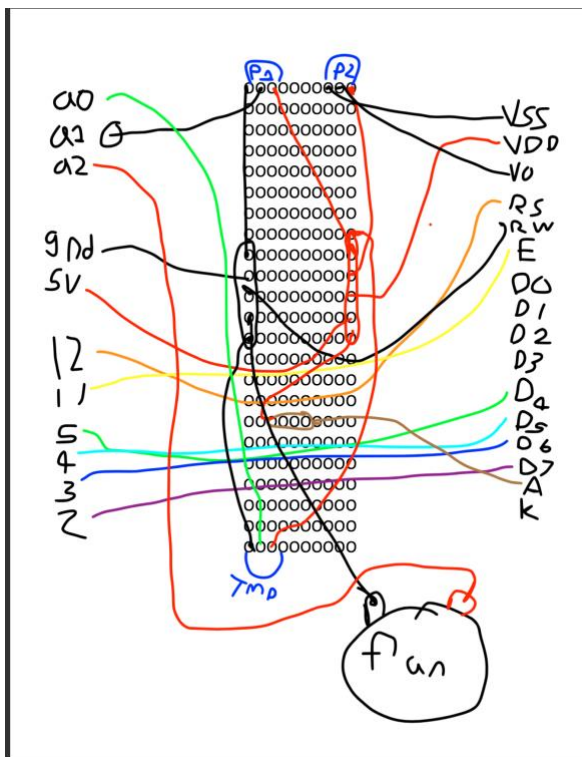
6.3.2 Equipment list

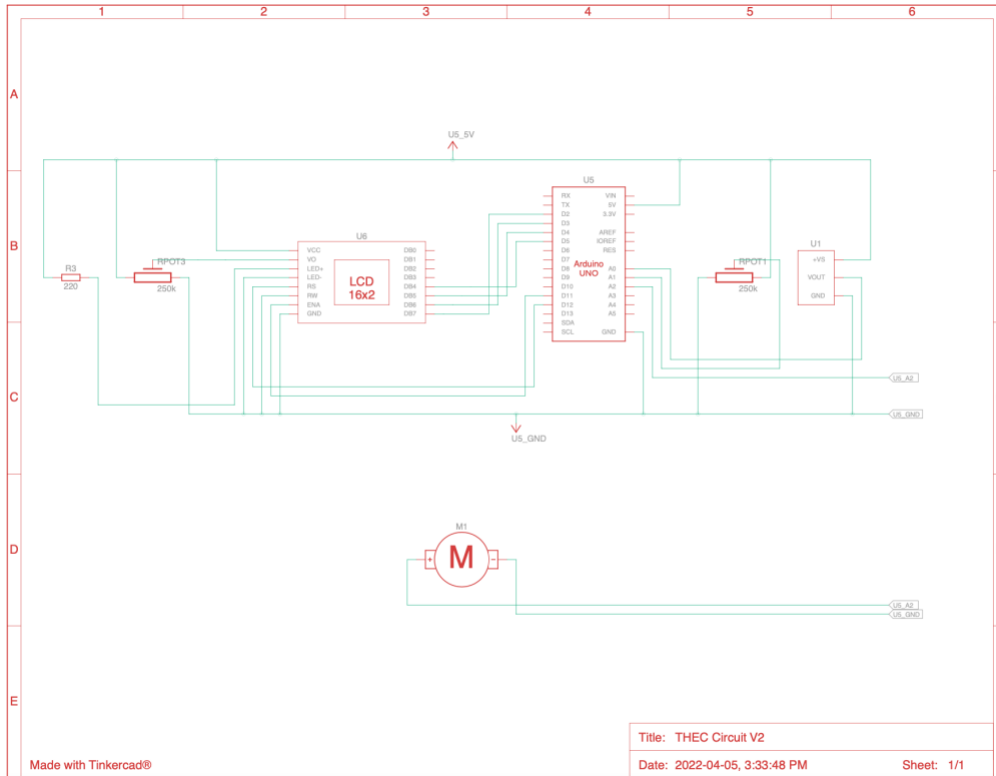
- Soldering Iron
- Solder
- Wire Cutters / Strippers

6.3.3 Instructions

To start it is highly recommended that the two following pictures are studies to know exactly where to put each wire.

Circuit Diagrams:



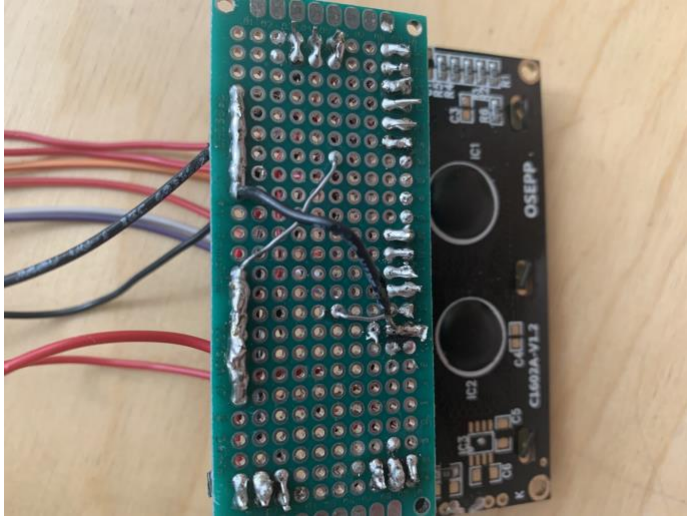


Step 1:

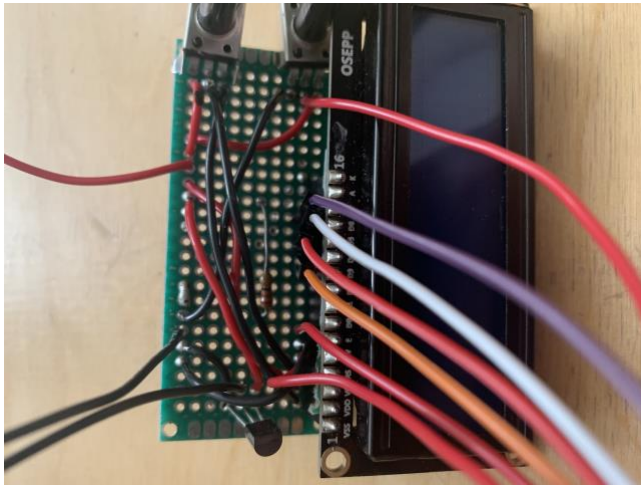
To start, heat up your soldering iron. When it has reached desired temperature, solder your components such as the potentiometers, temperature sensor and LCD display onto the protoboard in the shown locations.

Step 2:

Next you will want to start making your connections, to do this you will follow the wire configuration in the above diagram, it is recommended that the connections between potentiometers, temperature sensor and Lcd display, and the ground and power are made first, as it will be harder to access these spots once the wires to the Arduino have been connected. You will need to make a solder bank for each the ground and 5v signals.



Solder bank Example



This image shows why it's best to do the on-board connections first.

Step 3:

Now you will want to solder your wires onto the protoboard that are going to be connected to the Arduino.

Step 4:

Now we will set up the fan, to do this you will want to make the connections to it shown on the diagram by soldering a wire to the fans wires rather than soldering the fan to the actual board, to give the fan extra length.

Step 5:

Now you will want to connect all your wires to the Arduino using the diagrams above. Once you have finished that, you will want plug in your Arduino to your laptop. Next, download the Arduino IDE provided in the BOM and paste the following code into it:

```
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
int temperature = A0;
int fan = A2;
int sensorInput;

void setup()
{
  Serial.begin(9600);
  pinMode(fan, OUTPUT);
  pinMode(temperature, INPUT);
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  // Print a message to the LCD.
  lcd.print("Temperature set:");
}

void loop()
{
  //getting input temperature value
  double sensorValue = analogRead(A1);
  byte setTemp = map(sensorValue,0,1023,15,30);
  delay(1000);

  //converting the voltage double tmp;
  sensorInput = analogRead(A0);
  double tmp;
  tmp = (double)sensorInput / 1024;
  tmp = tmp * 5;
  tmp = tmp - 0.5;
  tmp = tmp * 100;
```

```
//turning fan on if the temperature is not what is required by the user
if(tmp <= setTemp + 2)
{
  analogWrite(fan,250);
  delay(1000);
}

else if(tmp >= setTemp - 2)
{
  analogWrite(fan,250);
  delay(1000);
}

//setting up LCD display
lcd.setCursor(0, 1);
lcd.print(setTemp);
delay(1000);
}
```

You should now go into Tools file and initialize the board and the port it is connected to. You are now ready to initialize then run the program.

You have now completed the Electrical component of this prototype.

6.4 Testing & Validation

The first test we ran was to make sure that the electronic system works as expected, to do this I changed the temperature that the system was set to so that the fan would have to activate in order to cool my room, when the current temperature lies outside of a one-degree radius of the set temperature, then the fan activates. In this test I was able to see that the electronic system works, both when the house is too hot and too cold.

For the next test, I cracked my window open ever so slightly and stuck the inlet pipe out the window. At the time it was roughly 7 degrees outside, and 24 degrees in my room. This is what it looked like:



7 Conclusions and Recommendations for Future Work

Several lessons were learned throughout the course of creating this project, out of which, time management proved to be the most important one. For the most part of creating this project, time was very limited and hence, some ideas and concepts had to be excluded for the prototype to be completed on time. The recommended avenue for future work on this project is MakerLab at the University of Ottawa.

If there were a few months to continue working on the project, a sump pump would have been added to the system to extract any accumulated water within an hour. Aluminum would also have been used as the box containing the pipes since it is very durable, can be buried more than six feet underground, does not rust and is a good conductor of heat.

8 Bibliography

APPENDICES

9 APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Maker Repo	LINK	04/05/2022
Code	LINK	04/05/2022
Finalized Design and Final Prototype	LINK	04/05/2022
TinkerCAD Electronics	LINK	04/05/2022

