VG100 INTRODUCTION TO ENGINEERING
SUMMER 2017

FINAL REPORT FOR PROJECT II

TEMPERATURE CONTROL WATER BOTTLE

GROUP 6 FANTASY

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August 6, 2017

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1 Executive Summary

Our team noticed that drinking water of a certain temperature was a prevalent need for people all around the world, but a portable water bottle that can control the temperature of the water inside is hard to find. We decided to design this temperature control water bottle to enable people to heat or cool the water according to their need and make it easy to use and carry. Our procedures consist of two parts: mechanical part, including heat conduction and dissipation design, component arrangement and decoration; and electrical part, including circuit design and programming. Our bottle successfully changed the temperature of the water according to the need of the user when testing. Users press the button to set the temperature. The Arduino board asks the screen to show this setting temperature and compare it with the current one. The relay modules control the direction of the electric current and thus the water will be heated or cooled. The temperature sensor will continuously sense the temperature. Once the difference between the current and setting temperature is no more than 3°C, the semi-conductor and the fan will stop working. Users of all ages and from all around the world who want to drink water of a needed temperature will benefit from our product.

2 Introduction

Figure 1: Group Members of Team Fantasy

Our team Fantasy is a team with passion and innovation. We have 5 members: Team leader Shi Yiming and team members Wang Zhewei, Su Xingyu, Sun Qin and Lv Lei. The name "Fantasy" means that we aim at realizing the fantasy, which means "dream" and seems impossible, that appears in our daily life.

We five are all freshmen in University of Michigan - Shanghai Jiao Tong University Joint Institute. Our goal is to design a bottle that can change the water into the temperature that people want whenever and wherever they are.

Members in our team have basic knowledge of programming, mathematics, physics and academic writing, so we can realize our goal and convey our ideas effectively. Our success in designing a bridge-crane system proves that we can finish basic tasks of designing and assembling components.

Figure 2: UM-SJTU Joint Institute

UM-SJTU JI is located in the campus of Shanghai Jiao Tong University (SJTU) in Minhang District, Shanghai, China. UM-SJTU JI is an engineering college focusing on mechanical engineering and electrical & computer engineering and has cultivated many excellent engineers.

3 Problem

3.1 Statement of the Problem

Drinking water of wanted temperature has been a very common concern since ancient time. In summer, many people want a cup of iced water to cool them down. In winter, they want hot water to stay warm; when they feel sick, they also want some hot water to make themselves feel better.

We did a survey on people's need of the cold water in summer and the hot water in winter and got some feedback. The results from 50 people shows that although someone can bear cold water in winter and hot water in summer, most people need water of desired temperature.

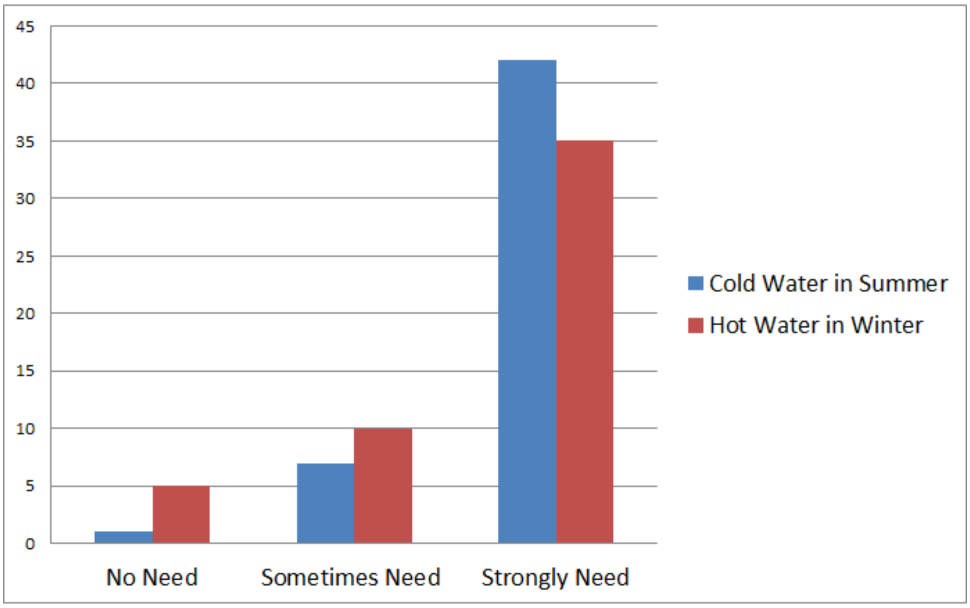

Figure 3: Group Members of Team Fantasy

When people feel like drinking water of the temperature they want, they would make use of refrigerators or electric kettles, which need the power supply and can't be brought with themselves outside the house. People can't choose the temperature of the water when using most devices, and they have to wait for the water to cool down beside the external power if they use the electric kettles.

The problem is very prevalent among people throughout the world, but we find that products which can solve this problem are rare. We cannot even find them in Taobao, which is a widely-used shopping website in China.

Because of the reasons mentioned above, we decided to create a water bottle that is easy to bring and can control the temperature of water inside to serve people's need.

3.2 Summary of the Problem

In summary, the need of drinking water of a certain temperature is very prevalent among people from all around the world, and other devices that can change the temperature of the water have many disadvantages:

1. **Inconvenience to change the temperature according to people's need.**
2. **Needs of extra power supply of high voltage.**
3. **Inconvenience for people to carry.**

4 Needs

4.1 Constraints

Our product has several constraints:

1. **The semi-conductor cold plate will give out heat when cooling the water, so the effect of cooling will be influenced if the setting temperature is relatively high.**
2. **The inner layer can contain only 350mL water, which may not be enough for users.**
3. **The highest setting temperature allowed for the bottle is only 60 °C because of the limits of materials and the ability of the cooling device.**

4.2 Criteria

The temperature control water bottle should satisfy the needs mentioned above:

1. **A system to for users to change the setting temperature easily.**

   The temperature setting procedure should be clear and easy to learn for the users.

2. **A battery system that can be arranged in the bottle and provides enough electric power for the heating and cooling system to work.**

   The batteries should contain electricity of at least 6000mAh to provide enough power for the whole system. The volume of the batteries should be no more than 150cm^3 so it can be arranged in the bottle.

3. **A light and portable circuit that can change the temperature of the water effectively.**

   The volume of the heating and cooling device should be no more than 10 cm^3. The mass of the device should be no more than 100g. So it can be arranged within the bottle. The heating or cooling process is expected to be finished within 30min.

5 Objectives

5.1 Methods to address the needs

1. **Find the way to change the temperature**

   Changing the temperature of the water is the core part in the whole design. So finding a suitable, quick and energy-saving way to change the temperature is the first and most important thing to do.

2. **Ensure the effect of heat conduction**

   To ensure that the energy won't be wasted severely, we need to make the effect of heat conduction better. We chose the best materials to make sure that the heat conduction reaches the best condition.

3. **Ensure the effect of heat dissipation**

   To ensure that the semi-conductor cold plate can work well when cooling, we arrange a heat dissipation system to let the heat transferred quickly outside the bottle.

4. **Design a reliable circuit and Control the system with Arduino Nano board**

   Our bottle is energy-saving and effective, because the whole system is effectively controlled. And the devices won't work if it is unnecessary. This is achieved by designing a reliable and effective circuit. We make sure that the Arduino Nano board can control the working process for the whole system to make the space needed relatively small and the programming relatively easy.

5. **Arrange enough space to place the components**

   Our bottle is easy to hold and easy to carry. We achieved this goal by carefully choosing the size of the inner and outer layer and arranging the devices inside it.

6. **Make the bottle more user-friendly**

   Our bottle is oriented to a wide range of users, so it is important to make it as helpful and beautiful as possible. So we should do some final tasks including testing, doing user surveys and decorating.

5.2 Design to solve the problem

5.2.1 Block diagram

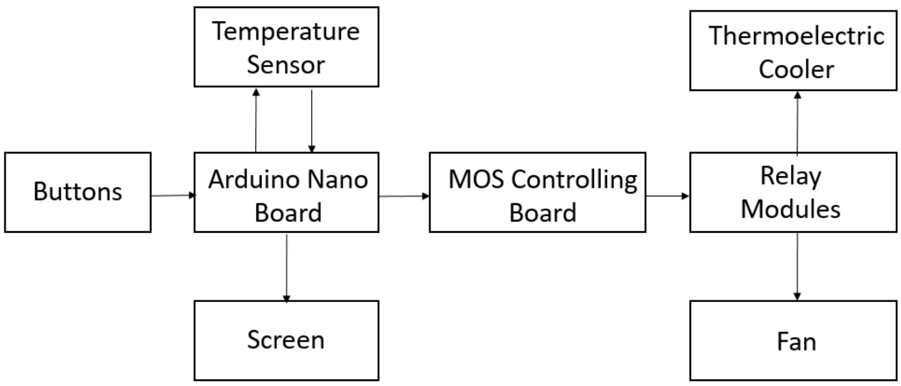

Figure 4: Block Diagram for the System

The block diagram above shows the electrical part of our temperature control water bottle. It clearly shows the relationship between devices.

5.2.2 The Way Each Component Relates to the System

The functional components in our product consist of two buttons, an Arduino Nano board, a temperature sensor, a screen, two MOS controlling boards, two relay modules, a thermoelectric cooler (the semi-conductor cold plate) and a fan.

The Arduino Nano board controls the whole system.

The two buttons and the temperature sensor sends messages to the Arduino Nano board.

The Arduino Nano board sends messages to the screen to show the current and setting temperature.

The Arduino Nano board sends messages to the MOS controlling board to ask it to control the current flow.

The two MOS controlling boards controls the two relay modules.

The two relay modules asks the thermoelectric cooler and the fan to start working or stop working. It also controls the direction of the current to change the direction of heat conduction.

6 Solution: Temperature Control Water Bottle

A temperature control water bottle is proposed along with several features:

1. **An effective temperature changing system.**
2. **A user-friendly interactive mode.**
3. **A portable and easy-holding body.**

6.1 Concept Diagram

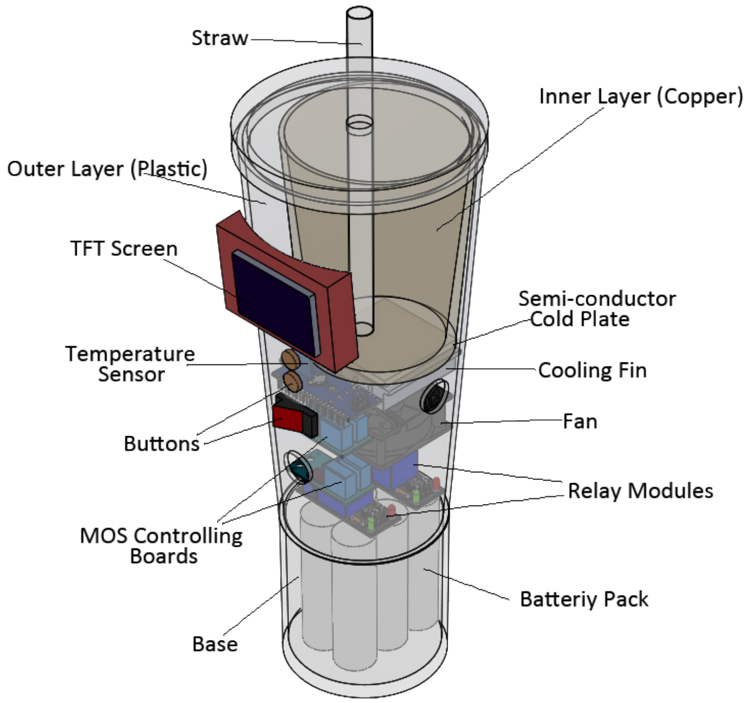

Figure 5: Concept Diagram

The concept diagram of our temperature control water bottle is shown in Figure 3. It includes the mechanical part including the outer layer made of plastic, the inner layer made of copper and the cooling fin. The electrical part consists of an Arduino Nano board, a temperature sensor, two buttons, a screen, a semi-conductor cold plate, a fan, a MOS controlling board and two relay modules.

6.2 Functional Components

1. **Semi-conductor Cold Plate**

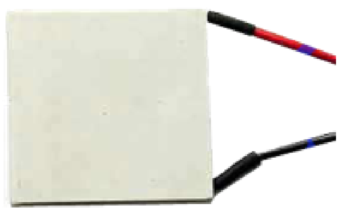

Figure 6: The Semi-conductor Cold Plate

Semi-conductor Cold Plate is the core component in the bottle. It can transfer the heat from one side to another. We can find both N-type and P-type semi-conductor on the cold plate.

N-type semi-conductor has an extra electron close to conducting band, and it can jump off into conducting band by absorbing small amount of energy (heat).

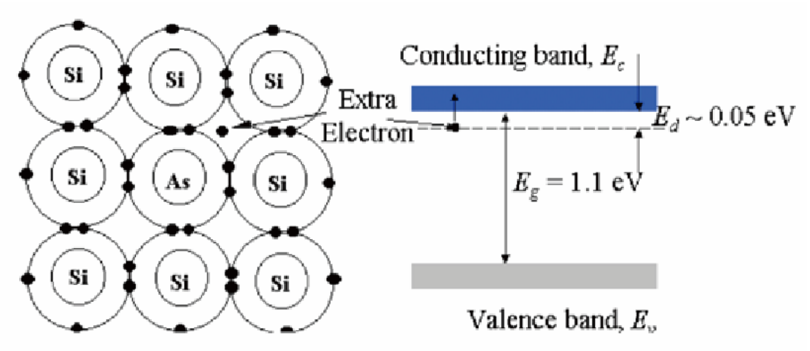

Figure 7: The N-type Semi-conductor

P-type semi-conductor has an electron acceptor close to valence band, and one electron can fill in the electron acceptor by giving away some energy (heat) [1].

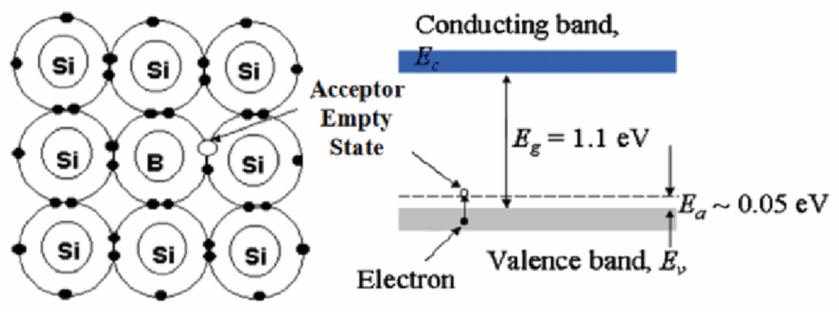

Figure 8: The P-type Semi-conductor

In the cold plate, the N-type and P-type semi-conductors are arranged as follows:

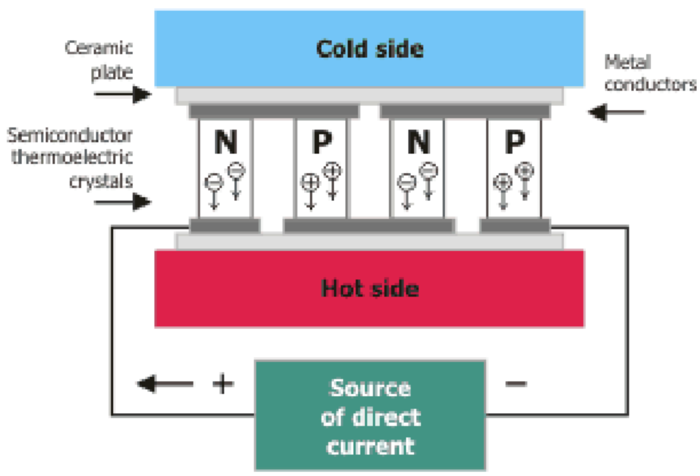

Figure 9: Arrangement of Two Kinds of Semi-conductors in the Cold Plate [2]

On the cold side of the semi-conductor cold plate, the electrons go from N-type to P-type and semi-conductor absorbs heat. In the hot side, the electrons go from P-type to N-type and the semi-conductor gives away heat. So the heating and cooling process can be realized.

The rated voltage of the semi-conductor cold plate is $15.4V$, and the rated current is $6A$, but we let it work under the voltage of $12V$. Here, we roughly assume that the resistant of the semi-conductor doesn't change when the voltage changes. So the working current of the semi-conductor satisfies the equation

$$\frac{12V}{I} = \frac{15.4V}{6A}$$

so the working current should be

$$I = 12V \times 6A/15.4V = 4.68A$$

With these calculation, we know that the rated power of the semi-conductor cold plate should be

$$P = UI = 12V \times 4.68A = 56.16W$$

But for the cooling process, the efficiency of is about 70%. So the power of the cooling process is

$$70\% \times 56.16W = 39.31W$$

which is the rate of absorbing heat of the cooling side. Since the both sides of the semi-conductor cold plate works, and the heat goes from the cooling side to the heating side.
For the heating side, the heat emitted is the sum of the heat absorbed into the cold side and the heat produced by the semiconductor plate itself. That means, the rate of emitting heat of the heating side is:

$$P = P_1 + P_2 = 56.16W + 39.31W = 95.47W$$

In all, The cold plate absorbs $39.31W$ on cooling side. Then emits $95.47W$ on heating side.
These finally emit $56.16W$ in total, which is equal to the power of the whole semi-conductor cold plate.
For our bottle, the maximum capacity is $350mL$. So we do the following calculation under the condition that the bottle is full of water. Assume that the density of the water is $1000kg \cdot m^{-3}$, so the mass of the water is $0.35kg$.

heating power is P = $95.47W$. We know that the specific heat of the water is

$$c_{water} = 4200J \cdot kg^{-1} \cdot^{o} C^{-1}$$

So with the equation

$$E = Pt = cm\Delta t$$

we can calculate that for the temperature to increase or decrease by $1^{o}C$, theoretically we need energy of

$$4.2J \cdot g^{-1} \cdot^{o} C^{-1} \times 350mL \times 1g/mL = 1^{o}C^{-1} = 1470J$$

For the cooling process, we need the time of

$$t = \frac{E}{P} = 37.40s$$

to cool down $350mL$ of water by 1^oC.
For the heating process, we need the time of

$$t = \frac{E}{P} = 15.40s$$

to heat up $350mL$ of water by 1^oC.
So we can finish the general need of heating and cooling at a relatively quick speed. We tested the abilities of the semi-conductor cold plate under the ambient temperature of 24 °C and here are the results:

t_0	t_1	time(s)
20	25	61
20	25	68
20	25	69
20	25	50

Table 1: The Testing Data of the Semi-conductor (Heating)

The efficiency of the semi-conductor cold plate is enough for the basic needs.

t_0	t_1	time(s)
40	35	158
40	35	156
40	35	150
40	35	148

Table 2: The Testing Data of the Semi-conductor (Cooling)

2. **Temperature Sensor**
   The temperature sensor detects the temperature of the water and sends the data to the Arduino Nano board.

3. **Cooling Fin**
   Cooling fin is stuck to the semi-conductor cold plate. Its specially designed shape maximizes the density of heat transfer. With the help of the fin, the system can effectively dissipate heat to ensure that the cooling process won't be seriously influenced [3].

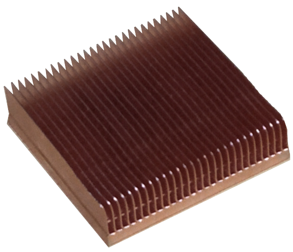

Figure 10: The Cooling Fin

4. **Arduino Nano Board**
   Arduino Nano board receives signals from the temperature sensor and the button. It processes signals according to the program and sends signals to the TFT Screen, MOS controlling board and the relay modules.

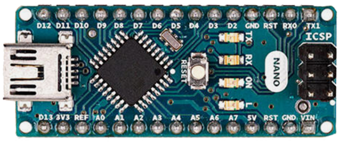

Figure 11: The Arduino Nano Board

5. **Buttons**
   There are three buttons on our product. The first one controls the current of the whole system. The second one is used to set the temperature. The third one is to lock the system and make sure the setting temperature won't change until the user unlocks it.

6. **TFT Screen**
   TFT screen shows the temperature of the water and visualizes the process of setting temperature.

7. **Batteries**
   A chargeable battery pack of $6000mAh$ serves as the energy resource.

$$Q = 6000mAh = 6Ah = 21600C$$

   The semi-conductor cold plate uses most of the energy. Since here we only need a rough estimate to decide whether the electric energy is enough, we only consider the semi-conductor.
   According to calculation above, we know the electric currency of the cold plate is I $= 4.68A$. Assume that the battery pack can provide 70% of its own electricity for the system to work, and we can know that

$$t = \frac{70\% \times Q}{I} = \frac{70\% \times 21600C}{4.68A} = 3230.8s = 53.8min$$

   So the fully charged battery pack can support the semi-conductor for 53.8 minutes. That is already enough for the system to heat or cool the water for general needs.

8. **Relay Modules**
   Relay Modules receive signals from the Arduino Nano board. It decides whether the current will pass through the NC or the NO port. There are two relay modules in our product and they controls two circuits. One circuit is for the cooling mode and the other is for the heating mode.

Figure 12: The Relay Module

When relay modules receive HIGH signal, the NO port will be on and the NO port will be off. When they receive LOW signal, the NC port will be on and the NO port will be off. So the bottle switches to the cooling mode or the heating mode when receiving corresponding signals.

9. **MOS Controlling Board**
   MOS controlling board receives signals from the Arduino Nano board and decides the ON or OFF of the circuit. When it receive HIGH signal, it will make the circuit ON. When it receive LOW signal, it will make the circuit OFF. So no current will pass through the system when we don't use it.

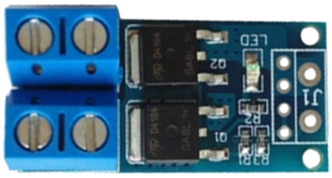

Figure 13: The MOS Controlling Board

10. **Fan**
    The fan accelerates the dissipation of heat when the bottle is switched to the cooling mode.

Figure 14: Fan

6.3 Exploded View

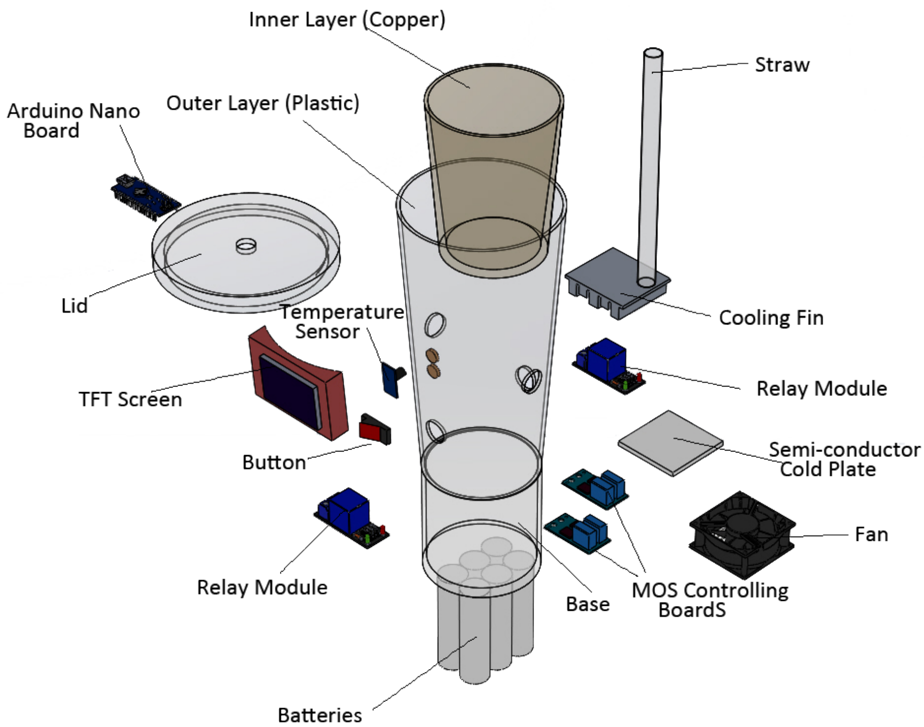

Figure 15: Exploded View

The exploded view of the temperature control water bottle is in Figure 4. It clearly shows the components in the bottle.

6.4 Functional Algorithms and Working Process

1. **Setting the Temperature**

   The temperature setting process in our bottle is done by pressing the button. Once the user presses the temperature setting button, he or she increases the setting temperature by 5°C. The highest setting temperature allowed in our bottle is 60°C, so we designed a algorithm to change the setting temperature into 0°C once the setting temperature is higher than 60°C. The message of the changing setting temperature will be sent to the Arduino Nano board.

2. **Sensing and Showing the Temperature**

   We use the TFT screen to show the current temperature and the setting temperature. The temperature sensor senses the current temperature and the button receives the message of setting temperature. These will all be sent to the Arduino Nano board and then to the screen.

3. **Locking and Unlocking the Screen**

   In order to improve the stability of the temperature setting process and prevent the setting temperature from accidentally changing by unexpected collision, we designed the function of “lock” and “unlock”.

Users presses the "LOCK" button to lock or unlock the setting function. The algorithm allows the lock button to lock the temperature setting button by one press and unlock the temperature setting button by another. The locking condition will be shown on the screen.

4. **Deciding Whether to Heat or Cool**

   We use the function

   void CooldownHeatup(int currentT,int settingT);

   to compare the current temperature and the setting temperature. If the current temperature is higher than the setting temperature, the bottle will heat the water and vice versa.

5. **Heating and Cooling the Water**

   We use the function

   void heatup();

   and the function

   void cooldown();

   to control the semi-conductor cold plate to heat or cool the water. These two functions change the working condition of the relay module and thus change the direction of the current. The direction of heat transformation will then be changed so the function of heating or cooling will be realized.

6. **Controlling the Fan**

   We use the function

   void fanon();

   and the function

   void fanoff();

   to control the fan and realize the heat dissipation effectively. The decision on whether the fan should work will be made after the heating or cooling process starts.

   If the semi-conductor is in the cooling condition, the fan will start working and blow the heat out of the bottle. To save the energy, the fan won't work when the bottle is heating the water.

7. **Standing by**

   Once the difference between the setting temperature and the current temperature is smaller than 3°C, we use the function

   void standby();

   to stop the semi-conductor cold plate and the fan from working. During this process, the temperature sensor will continuously sense the current temperature and the system will start working once the difference reaches 3°C.

7 Tasks

7.1 Task Flow Diagram

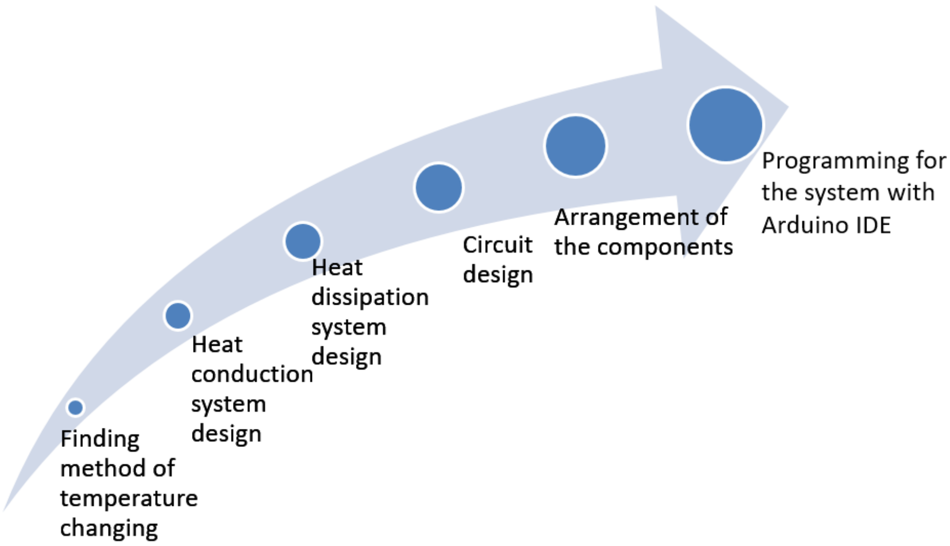

Figure 16: Task Flow Diagram

This task flow diagram shows the rough process of our Project II including 6 steps. These steps will be covered in this part.

7.2 Procedures

7.2.1 Finding Method of Temperature Changing

Time: June 24th, 2017 - June 30th, 2017

After investigating different heat changing method, we decided to choose the semi-conductor cold plate as the heat transfer part because it was light and effective. When the current flow changes the direction, the direction of heat transformation will also change. The process is easy to control.

7.2.2 Heat Conduction System Design

Time: July 1st, 2017 - July 13th, 2017

We arranged an inner layer to contain the water and put the semi-conductor cold plate under it to transfer heat. Here, we chose copper as the materials of the inner cup.

We glued the semi-conductor cold plate and the inner layer made of copper together with the heat conductive adhesive to achieve a better effect of heat conducting.

The temperature sensor was glued on the external wall of the copper cup to sense the current temperature.

7.2.3 Heat Dissipation System Design

Time: July 3rd, 2017 - July 13th, 2017

We needed to design an effective heat dissipation system. According to our experiment without heat dissipation system, the cooling side grew hot quickly and the temperature was higher than 50 $°C$, which might damage the inner structure. So we arranged a cooling fin to dissipate the heat. The fin was stuck to the semi-conductor cold plate with heat conductive adhesive.

We did the experiment again and proved that the heat was transferred to the cooling fin. But this was still not enough, because the cooling side of the semi-conductor was still 40 $°C$.

We then decided to use a fan to release the heat and arranged some holes on the wall of the bottle to let out the heat. The fan was placed under the cooling fin and would work in the cooling process to blow the heat out of the bottle through the holes.

We tested the result of this design. The temperature of the cooling side can be less than 5°C even after ten minutes. This proves that the heat dissipation system works well.

In all, our heat dissipation system is made of the heat sink, the fan and the holes on outer layer.

7.2.4 Circuit Design and Programming

Time: July 5th, 2017 - July 13th, 2017

Since we needed to change the direction of current passing through the semi-conductor cold plate by programming, we should design a corresponding circuit.

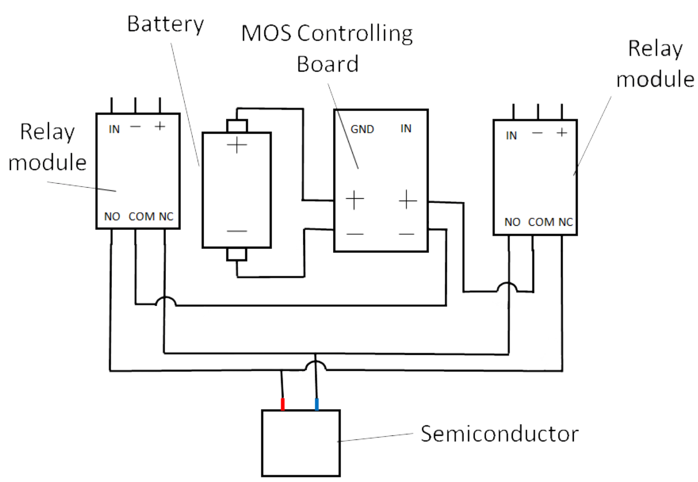

Figure 17: Electrical Circuit

When the relay module receives HIGH signal, the NO side will be connected while the NC side will break. Then the structure of this circuit becomes

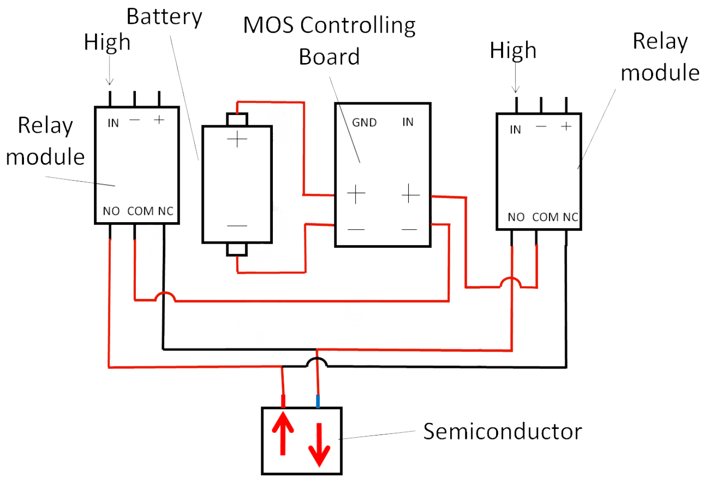

Figure 18: Circuit Structure Receiving HIGH Signal

The arrows show the direction of the current. When the relay module receives LOW signal, the NC side will be connected while the NO side will break. Then the structure becomes

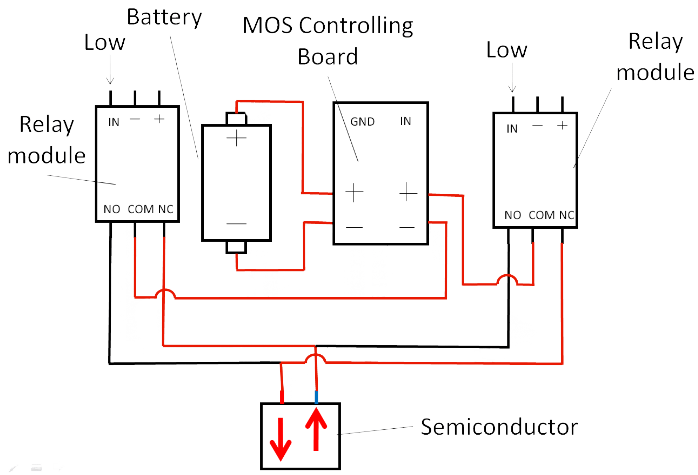

Figure 19: Circuit Structure Receiving LOW Signal

The direction of the current passing through the semi-conductor changes. So the working condition of the semi-conductor cold plate changes.

The following circuit realizes the goal of using the Arduino Nano board to connect the message from the sensor and the buttons and then send it to the screen.

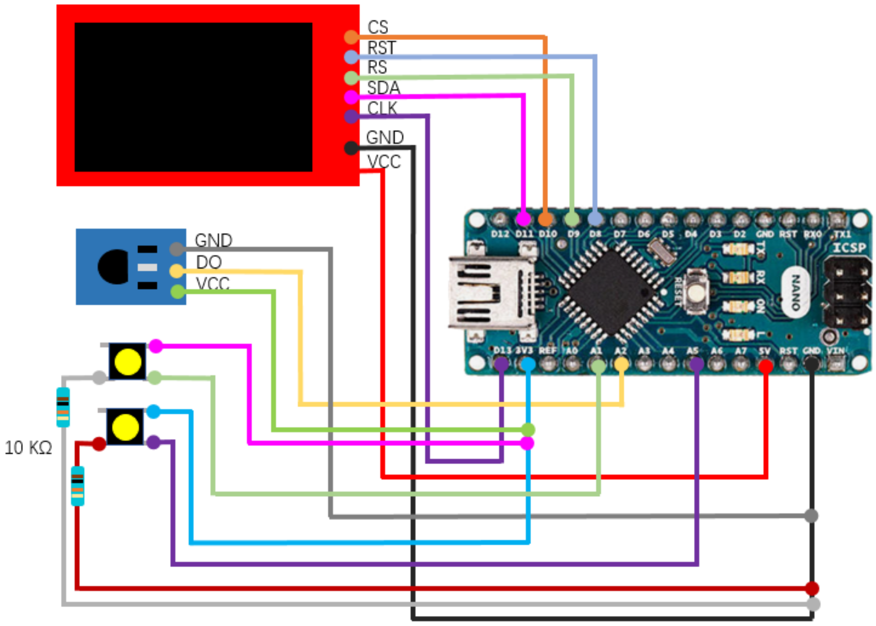

Figure 20: Circuit of the Screen, Temperature Sensor and Buttons

7.2.5 Arrangement of the Components

Time: July 8th, 2017 - July 21st, 2017

We had two layers of cups. All the devices should be put under the inner layer. The first one should be the semi-conductor cold plate. Then the cooling fin and the fan should be placed under it. Next, the electrical devices including two MOS controlling boards, an Arduino Nano board and a relay module should be under or next to the fan. The battery pack was placed at the bottom because it was relatively big.

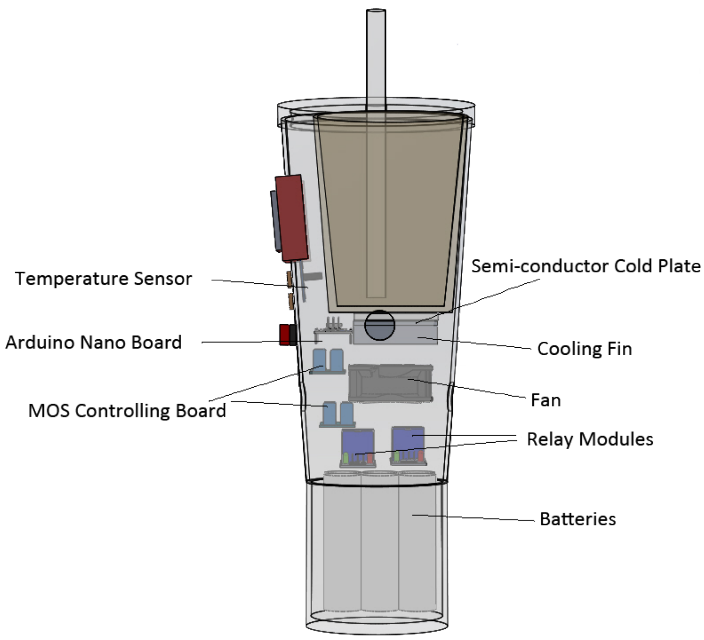

Figure 21: Arrangement of Devices

7.2.6 Final Tasks

Time: July 18th, 2017 - July 24th, 2017

1. **Testing the Stability**

   We tested the ability of the bottle to change the temperature of the water in cooling mode and heating mode respectively. For each mode, we choose four testing times and for each testing time, we prepare two kinds of water with different initial temperature. At last, we find that, the ability of our bottle to cool or heat the water is by 1.3 °C per minute. The rate of cooling the water will decrease as the water becomes colder and the rate of heating the water will decrease as the water becomes hotter.

   Our testing results are shown below. The ambient temperature is 24°C. These data shows that our bottle succeeded in serving people's needs.

t_0	t_1	time(s)
20	40	248
20	40	247
20	40	251
20	40	230

Table 3: Testing Data for Heating

t_0	t_1	time(s)
40	15	730
40	15	748
40	15	780
40	15	772

Table 4: Testing Data for Cooling

2. **Taking Surveys among Users**

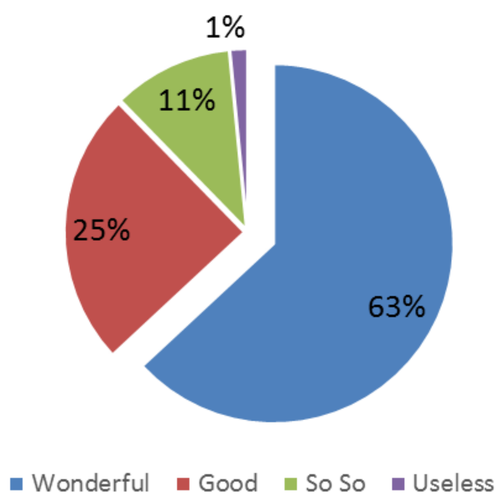

Figure 22: User Comments

We invited some volunteers to use our bottle and got feedbacks from them. Most of them were interested in our product and viewed it as a cool design. Very few people were not interested in our product. They thought that we still had many things to improve.

3. **Decorating**
In order to place plenty electronic component into a small cup, the space utilization rate of our cup is really high. The electric wire nearly occupies the whole space between the inner layer and the outer layer. Thus we made some decoration to make both the electric circuit save and the appearance of the cup attracting.
To protect our circuit, we wrapped a layer of insulated plastic around wall of the inner layer of our bottle to prevent the water from flowing into our circuit and to avoid the leakage of electricity.
To make the appearance attracting, we used a waterproof opaque material to cover the outer layer.

8 Schedule

Here are six Gantt Charts showing the schedule of our tasks. Each chart represents a main task, including finding methods of temperature changing, heat conduction system design, heat dissipation system design, circuit design and programming, arrangement of the components and final task. The main tasks are listed at the beginning of each chart along with its beginning time and lasting time. Below them are some small steps to finish the tasks and the detailed time arrangement for them.

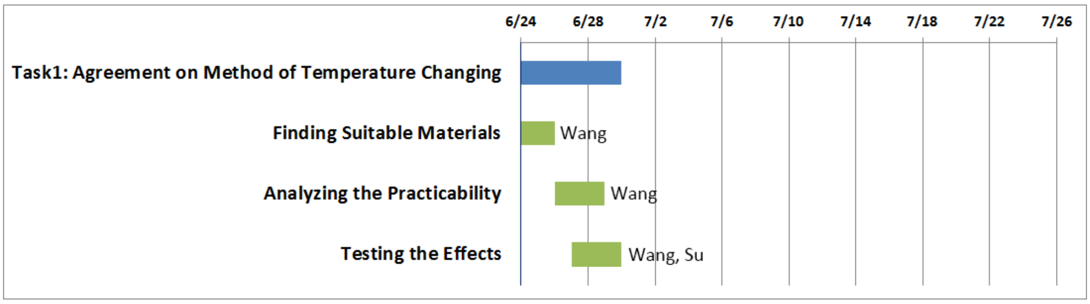

Figure 23: (Gantt Chart for Task 1) Agreement on Method of Temperature Changing

Task 1 was to agree on the temperature changing method, which was the foundation of the whole project. The whole process was finished on June 30^{th}.

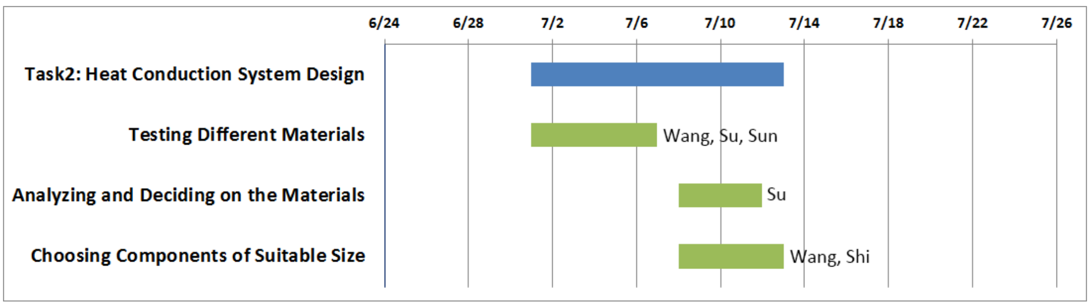

Figure 24: (Gantt Chart for Task 2) Heat Conduction System Design

Task 2 was to design the heat conduction system to ensure the satisfying efficiency of the bottle. The whole process was finished on July 13^{th}.

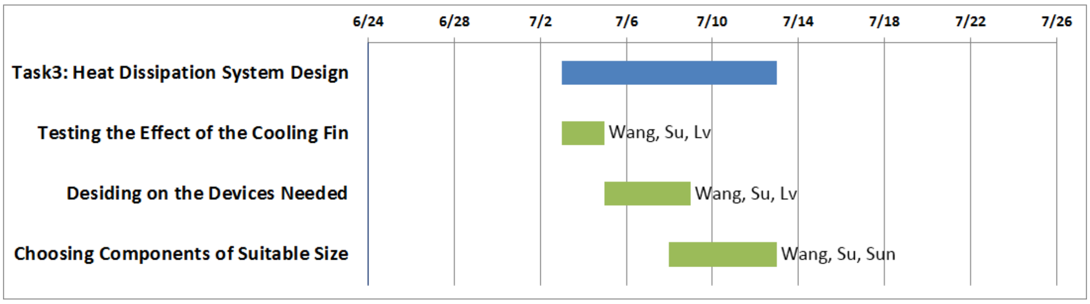

Figure 25: (Gantt Chart for Task 3) Heat Dissipation System Design

Task 3 was to design the heat dissipation system to make the cooling process go on smoothly. The whole process was finished on July 13^{th}.

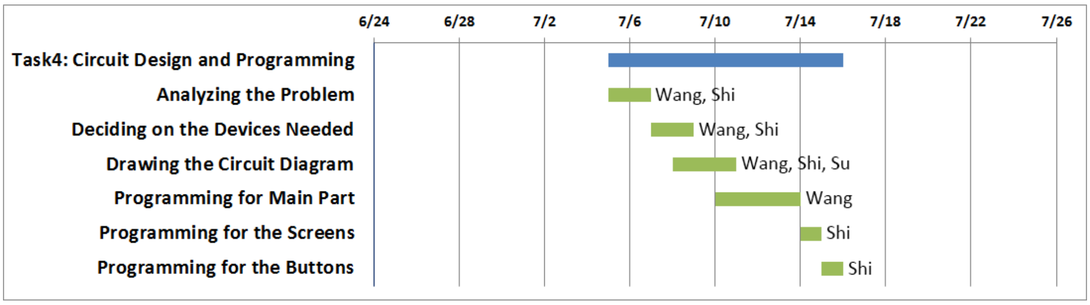

Figure 26: (Gantt Chart for Task 4) Circuit Design and Programming

Task 4 was to design the circuit and do the programming part to make the system work. The whole process was finished on July 16^{th}.

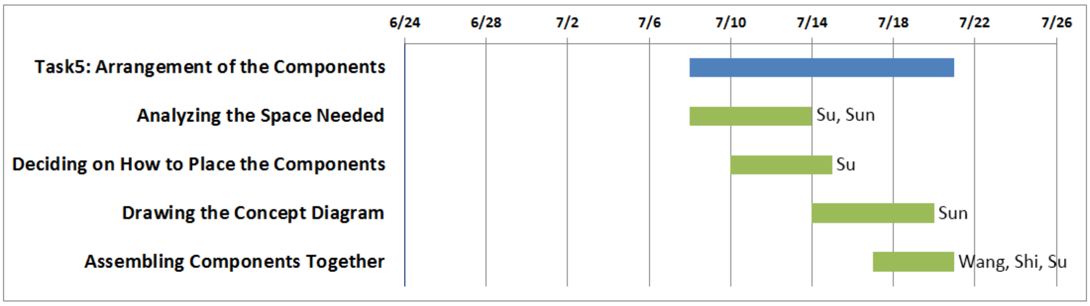

Figure 27: (Gantt Chart for Task 5) Arranging the Components

Task 5 was to arrange the position of all components. The whole process was finished on July 21^{rd}.

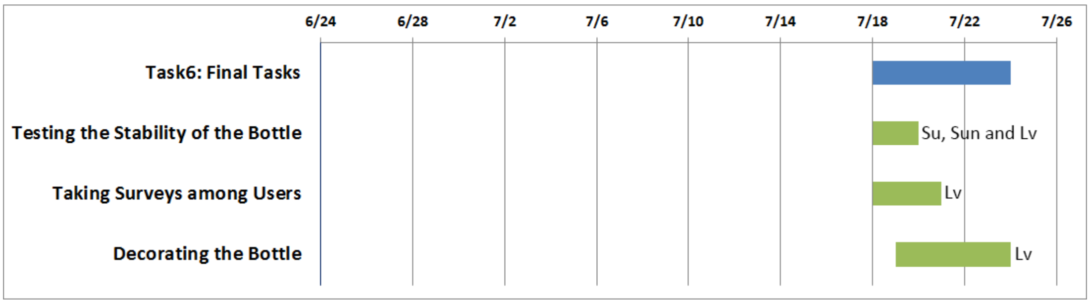

Figure 28: (Gantt Chart for Task 6) Final Tasks

Task 6 was to finish the final improvement and have surveys among users. The whole process was finished on July 21^{rd}.

9 Budget

Items	Quantities	Prices (RMB)
Semi-conductor Cold Plate	1	10.00
Temperature Sensor	1	4.50
Cooling Fin	1	40.00
Arduino Nano Board	1	16.00
TFT Screen	1	28.00
Battery Pack	1	79.80
Relay Modules	2	5.90
MOS Controlling Board	2	14.00
Other Small Electric Devices	/	10.00
Fan	1	8.40
Inner Cup	1	38.00
Outer Cup	1	69.00
Bottom	1	30.00
Total	/	353.60

Table 5: Budget

This budget table shows prices of all components of our bottle. Among them, electric devices dominates the cost. The material of the bottle is also costly. The total cost is ¥353.60. The retail prices of the electronic devices are relatively high, and it can be significantly reduced if we can put the bottle into mass production in the future. The budget for mass production can be as low as ¥100.00 according to our estimate.

10 Conclusion

10.1 Experience Sharing

10.1.1 The Transformation of the Heat

Air exists between the inner layer of the bottle and the semi-conductor and makes the heat transformation a convection process. Due to this reason, the efficiency of the heat transformation cannot satisfy the need of heating and cooling.

In order to solve this problem, heat conductive adhesive should be used to stick components involved in heat transformation together to change the process of convection into heat conduction. The efficiency of heat transformation will be significant improved after this [4]. And the inner layer is made of copper, which performs will in heat conduction.

On the other hand, the material of the inner layer should have good thermal conductivity. We first chose the 304-Type stainless steel, which was widely used as bottle's material.

Figure 29: 304-Type Stainless Steel Cup

We tested the thermal conductivity of this material. We put the semi-conductor under the inner cup and connect the semi-conductor with battery. After 30 seconds, the temperature rose only 0.2 $°C$, which meant that the stainless steel cup had poor thermal conductivity. So we needed to change the material.

We considered using aluminum because of its good thermal conductivity.

Figure 30: Aluminum Cup

We found it soft and easy to change the shape. Unfortunately, it is harmful to people's health. It does harm to people's brain [5] and is not a good choice for a reusable bottle.

We finally chose copper as the material of the water container.

Figure 31: Copper Cup

Copper has excellent thermal conductivity and does no harm on people's health [6]. So this was our final choice.

10.1.2 The Dissipation of the Heat

The semi-conductor cold plate gives out a lot of heat during the cooling process, and the whole bottle gradually be heated and the effect of cooling will be seriously influenced.

To solve this problem, we should introduce more ways to dissipate the heat. A fan will help to blow the heat out of the bottle. In order to direct the heat out, holes are needed on the wall of the outer layer. The holes should be at different heights to speed up the air circulation.

Figure 32: The Position of Holes on the Outer Layer

10.1.3 The Control of the Current

Since we need to change the current passing through the semi-conductor cold plate to change the direction of heat transformation, we need to design a circuit to realize it. After careful consideration, we decide to use two relay modules to realize this function.

This device can change the structure of the circuit from the programming signal. When it receives HIGH signal, NO side will be connected and NC side will break. When it receives LOW signal, NC side will be connected and NO side will break. The whole circuit is shown below.

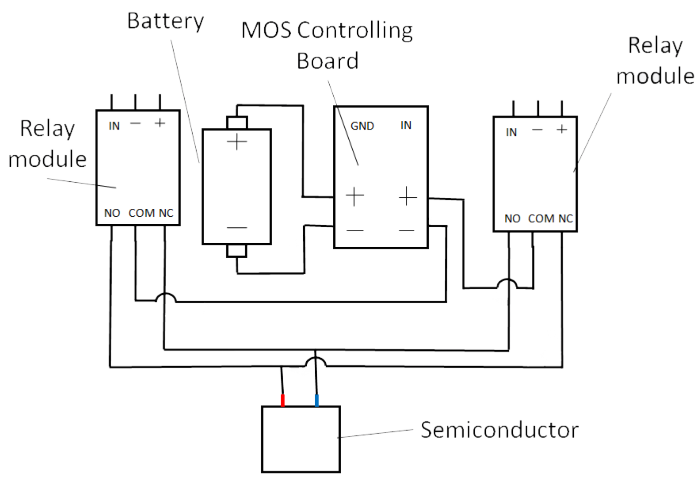

Figure 33: The Circuit Design

We designed the circuit like this so the current passing through the semi-conductor cold plate would change as the signal changes. Details have been discussed in the Procedure Part. We used only two relay modules to change the current. This design can be applied to this project as well as any situations of current changing. The method is easy to understand and it doesn't occupy much room.

10.2 Suggestions for Future Work

Our project succeeds in serving people's need; however, there is still a lot to improve. These are suggestions for the future work of our project:

1. Solve the heat dissipation issue and battery-size issue to use $15.4V$ instead of $12V$ to power the semi-conductor cold plate. This can increase the rate at which the water bottle cool or heat the water.
2. Design a circuit that integrate all the Arduino modules we use together to decrease the size of our water bottle and make the circuit simple and clean to enhance our product's stability.
3. Design a battery whose shape fits our project to decrease the size of the bottle.
4. Make the water hold part and the electrical part of our water bottle separable by users so that they can wash the water bottle easily without water accidentally going into circuits.
5. Find an alternative material for the copper cup to avoid the smell.
6. Decrease the noise produced by the heat-dissipation fan.
7. Enhance water bottle's endurance against impact such as falling onto the ground.

11 Key Personnel

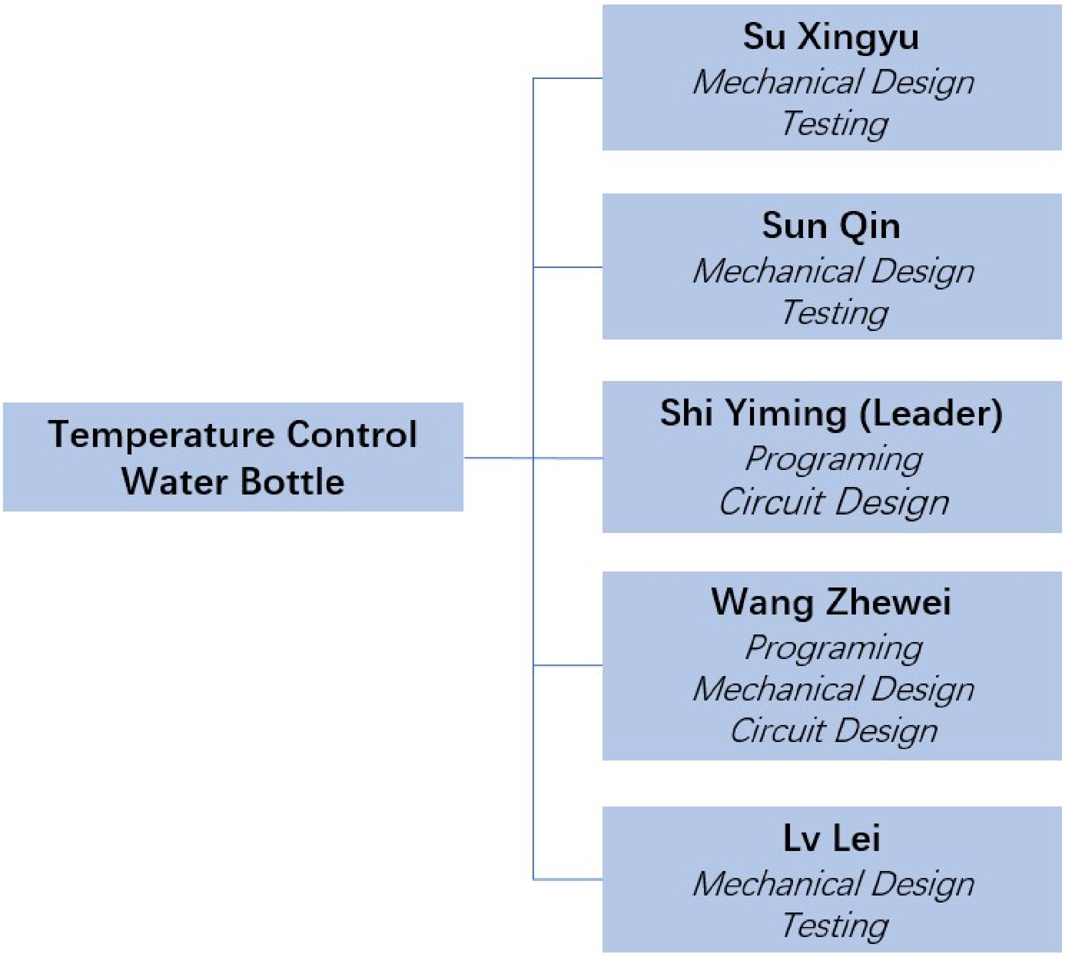

Figure 34: Key Personnel

Shi Yiming, our group leader, was responsible for the programming of the screen and buttons and the circuit design.

Wang Zhewei contributed to most Tech parts in Project II including electrical and mechanical design. He was also responsible for programming of the relay modules.

Su Xingyu took charge of main parts in mechanical design and helped different members to communicate with each other.

Sun Qin took part in mechanical design and was responsible for drawing the concept diagram. She helped with the testing part.

Lv Lei was responsible mechanical design and testing.

Although the task assignments were roughly as above, all members took part in purchasing materials and assembling.

12 References

[1]Hu, Z., 2012, “The Path that Electrons in Semi-conductors Follows,” School of Engineering, National Taiwan University. <`http://ee.ntu.edu.tw/upload/hischool/doc/2012.02.pdf`>

[2] "Telluride Crystals," Alfa image. <https://alfa-img.com/show/telluride-crystals.html>

[3] Hajmohammadi, M.R., Poozesh, S., Nourazar, S.S., and Manesh, A.H., 2013, "Optimal Architecture of Heat Generating Pieces in a Fin," Journal of Mechanical Science and Technology, 27(4), pp. 1143-1149.

[4] Jiji, L.M., 2006, *Heat Convection*, Dept. of Mechanical Engineering, School of Engineering, City University of New York, the United States, pp. 1-12. <https://link.springer.com/content/pdf/10.1007/978-3-540-30694-8.pdf>

[5] Kawahara, M., Muramoto, K., Kobayashi, K., Mori, H., and Kobayashi, Y., 1994, "Aluminium Promotes the Aggregation of Alzheimer's Amyloid β-Protein in Vitro," Biochemical and Biophysical Research Communications, 198(2), pp. 531-535.

[6] "Copper," 2017, *Encyclopaedia Britannica*, the United Kingdom. <https://www.britannica.com/science/copper>

13 Appendix

13.1 Gantt Chart

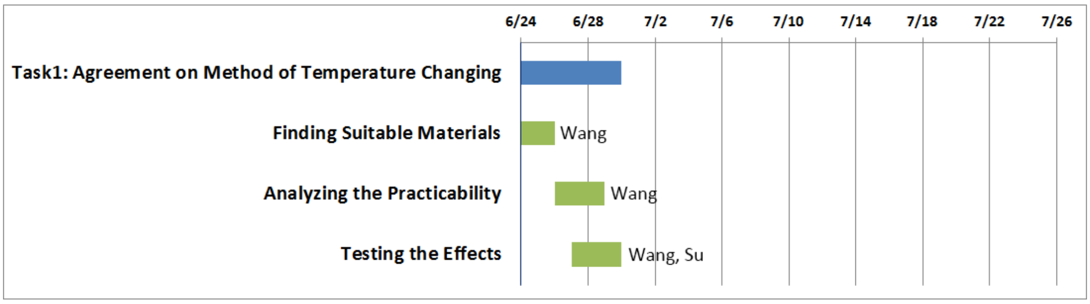

Figure 35: (Gantt Chart for Task 1) Agreement on Method of Temperature Changing

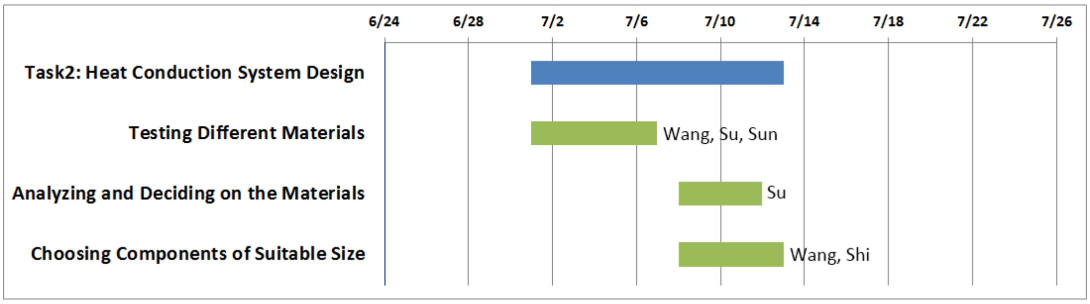

Figure 36: (Gantt Chart for Task 2) Heat Conduction System Design

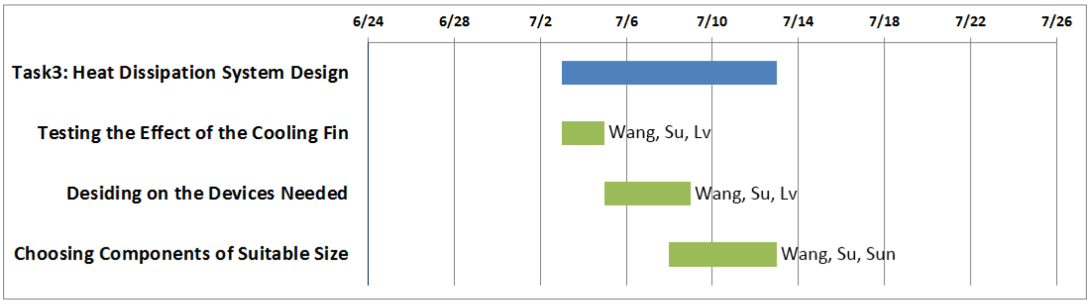

Figure 37: (Gantt Chart for Task 3) Heat Dissipation System Design

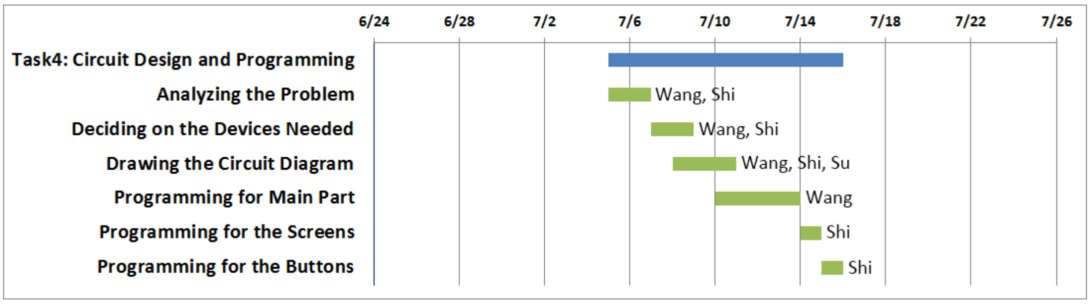

Figure 38: (Gantt Chart for Task 4) Circuit Design and Programming

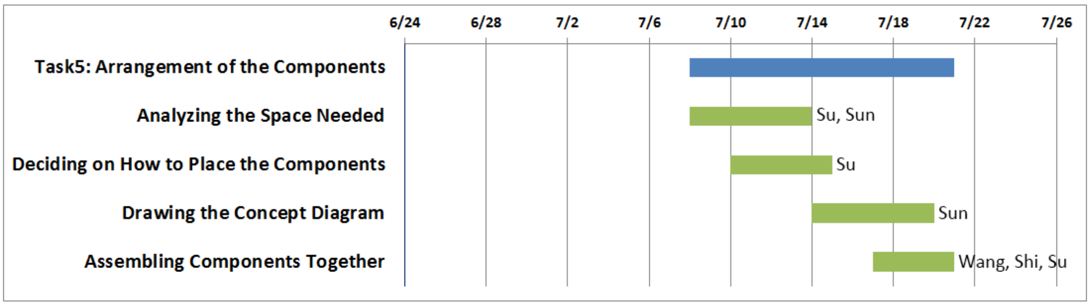

Figure 39: (Gantt Chart for Task 5) Arranging the Components

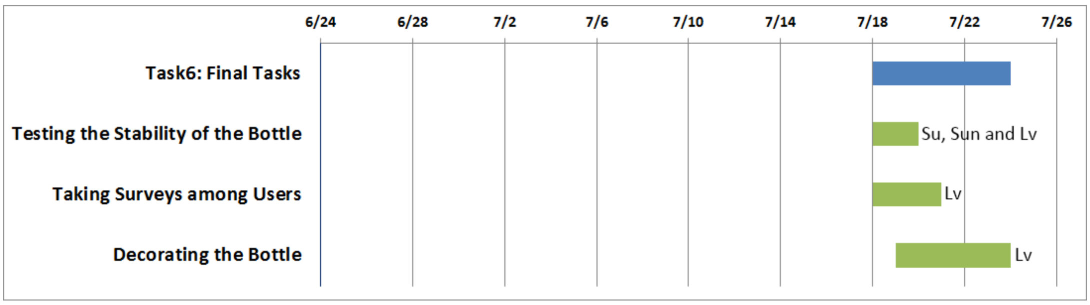

Figure 40: (Gantt Chart for Task 6) Final Tasks

13.2 Coding

```
#include <TFT.h>  //Arduino LCD library
#include <SPI.h>
#include <OneWire.h>
#include <DallasTemperature.h>
//pin definition for the Uno
#define cs   10
#define dc   9
#define rst  8
// create an instance of the library
TFT TFTscreen = TFT(cs, dc, rst);
//Temperature sensor
#define ONE_WIRE_BUS A2
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
//Button set
#define button A1
#define lock A5
unsigned int push = 0;
int set_t = 25;
int state = 1;
// char array to print to the screen
char sensorPrintout[10];
char setPrintout[10];
int t_save = -100;
//cold plate and fan define.
#define CodeplatePowerIN 3
#define FanPowerIN 4
#define RelayIN1 5
#define RelayIN2 6
void CooldownHeatup(int,int);
void standby();
void standby();
void heatup();
void cooldown();
void fanon();
void fanoff();
void setup() {
  Serial.begin(9600);
  //Button Part
  pinMode(button,INPUT);
  //Put this line at the beginning of every sketch that
  //uses the GLCD:
  TFTscreen.begin();
  //clear the screen with a black background
  TFTscreen.background(255, 255, 255);
  //write the static text to the screen
  //set the font color to white
```

```
  TFTscreen.stroke(0, 0, 0);
  //set the font size
  TFTscreen.setTextSize(2);
  //write the text to the top left corner of the screen
  TFTscreen.text("Temperature:\n ", 10, 5);
  //ste the font size very large for the loop
  TFTscreen.setTextSize(4);
  TFTscreen.text(".", 85, 0);
  TFTscreen.text("C", 105, 25);
  TFTscreen.text(".", 85, 65);
  TFTscreen.text("C", 105, 90);
  TFTscreen.setTextSize(2);
  TFTscreen.text("Setting:", 10, 65);
  TFTscreen.setTextSize(4);
  //Set up for cold plate
  pinMode(CodeplatePowerIN,OUTPUT);
  pinMode(FanPowerIN,OUTPUT);
  pinMode(RelayIN1,OUTPUT); //HIGH to heat LOW to cool
  pinMode(RelayIN2,OUTPUT);
  digitalWrite(CodeplatePowerIN,LOW);
  digitalWrite(FanPowerIN,LOW);
  digitalWrite(RelayIN1,LOW);//These two must be the
  //same
  digitalWrite(RelayIN2,LOW);//These two must be the
  //same
}
void CooldownHeatup(int currentT,int settingT){
  Serial.println("ColddownHeatup?");
  if(currentT > settingT+3){
    cooldown();
  }
  else if(currentT < settingT-3){
    heatup();
  }
  else{
    standby();
  }
}
void standby(){
  Serial.println("standing by");
  digitalWrite(CodeplatePowerIN,LOW);
  fanoff();
}
void heatup(){
  Serial.println("heating");
  digitalWrite(CodeplatePowerIN,LOW);
  digitalWrite(RelayIN1,HIGH);//These two must be the
  //same
```

```
  digitalWrite(RelayIN2,HIGH);//These two must be the
  //same
  digitalWrite(CodeplatePowerIN,HIGH);
  fanoff();
}
void cooldown(){
  Serial.println("cooling");
  digitalWrite(CodeplatePowerIN,LOW);
  digitalWrite(RelayIN1,LOW);//These two must be the
  //same
  digitalWrite(RelayIN2,LOW);//These two must be the
  //same
  fanon();
  digitalWrite(CodeplatePowerIN,HIGH);
}
void fanon(){
  digitalWrite(FanPowerIN,HIGH);
}
void fanoff(){
  digitalWrite(FanPowerIN,LOW);
}
void loop() {
  sensors.requestTemperatures();
  int t = sensors.getTempCByIndex(0);
  if (t_save != t){
  //clear the former charecter
  TFTscreen.stroke(255, 255, 255);
  TFTscreen.text(sensorPrintout, 40, 25);
  //print the new one
  String t_s = String(t);
  t_save = t;
  t_s.toCharArray(sensorPrintout, 10);
  // set the font color
  TFTscreen.stroke(255, 0, 0);
  // print the sensor value
  TFTscreen.text(sensorPrintout, 40, 25);
  }
  //Print the set value;
  String set_t_s = String(set_t);
  set_t_s.toCharArray(setPrintout, 10);
  TFTscreen.stroke(255, 0, 0);
  TFTscreen.text(setPrintout, 40, 90);
  if (analogRead(lock) == 0){
    if (state == 1){
      state = 0;
      TFTscreen.stroke(0, 0, 0);
      TFTscreen.setTextSize(1);
      TFTscreen.text("lock", 120, 70);
```

```
        TFTscreen.setTextSize(4);
        Serial.print(state);
        }
      else {
        state = 1;
        TFTscreen.stroke(255, 255, 255);
        TFTscreen.setTextSize(1);
        TFTscreen.text("lock", 120, 70);
        TFTscreen.setTextSize(4);
        Serial.print(state);
      }
      delay(300);
  }
    if (state == 1){
    if (analogRead(button) == 0){
        //clear set_t;
        TFTscreen.stroke(255, 255, 255);
        TFTscreen.text(setPrintout, 40, 90);
        if (set_t < 60){
        set_t = set_t + 5;
        }
        else {
          set_t = 0;
        }
        String set_t_s = String(set_t);
        set_t_s.toCharArray(setPrintout, 10);
        TFTscreen.stroke(255, 0, 0);
        TFTscreen.text(setPrintout, 40, 90);
        delay(300);
    }
    }
    CooldownHeatup(t,set_t);
}
```

13.3 Purchase List

- **Arduino Nano, 16.00RMB**
  https://detail.tmall.com/item.htm?id=44127880320&spm=a1z09.2.0.0.1f30a53fM0AzRd&_u=62jhisje28d4
- **1.8 Inch TFT Screen, 28.00RMB**
  https://detail.tmall.com/item.htm?id=527158777326&spm=a1z09.2.0.0.1f30a53fM0AzRd&_u=62jhisjec1f1
- **DS18B20 Temperature Sensor, 5.90RMB**
  https://detail.tmall.com/item.htm?id=41272469644&spm=a1z09.2.0.0.1f30a53fM0AzRd&_u=62jhisje9a98

- **Copper Cup, 138RMB**
  `https://item.taobao.com/item.htm?spm=a1z09.2.0.0.1f30a53fgoAMXb&id=548253571002&_u=62p3kkpufa0c`

- **Relay Module×2, 2.7×2=5.4 RMB**
  `https://detail.tmall.com/item.htm?id=16513774779&spm=a1z09.2.0.0.1f30a53fgoAMXb&_u=62p3kkpub5b4`

- **MOS Module×2, 5.8×2=11.6 RMB**
  `https://detail.tmall.com/item.htm?id=536770526104&spm=a1z09.2.0.0.1f30a53fgoAMXb&_u=62p3kkpu326a`

- **18650 Battery Set, 79.8 RMB**
  `https://item.taobao.com/item.htm?spm=a1z09.2.0.0.1f30a53fgoAMXb&id=547536074297&_u=62p3kkpue135`

- **Fan, 8.4RMB**
  `https://item.taobao.com/item.htm?spm=a1z09.2.0.0.1f30a53fgoAMXb&id=528806573502&_u=62p3kkpu5333`

- **Heat Dissipation Aluminum Plate, 5.5RMB**
  `https://detail.tmall.com/item.htm?id=535577287726&spm=a1z09.2.0.0.1f30a53fgoAMXb&_u=62p3kkpuae33`

- **TEC12706 Semi-conductor Cold Plate, 8.8RMB**
  `https://item.taobao.com/item.htm?spm=a1z09.2.0.0.1f30a53fgoAMXb&id=19169873178&_u=62p3kkpubba9`

- **Abrasive Paper, 9.00RMB**
  `https://item.jd.com/10254766181.html`

- **Heat Shrink Tube, 26.00RMB**
  `https://item.jd.com/1746192598.html`

- **Electric Soldering Iron, 18.00RMB**
  `https://item.jd.com/10472226552.html`

- **Thermometer, 45.00RMB**
  `https://item.jd.com/1683694565.html`