ECE 445

SENIOR DESIGN LABORATORY

FINAL REPORT

---

# Tea Blend Distributor

---

**Team #14**

Zhenzuo Si
(zsi2@illinois.edu)
Zhiyuan Wang
(zw39@illinois.edu)
Ruiqi Ye
(ruiqiye3@illinois.edu)
Anyu Ying
(anyuy2@illinois.edu)

TA: Xinyi Xu

Sponsor: Timothy Lee

May 23, 2023

# Abstract

This project is a tea brewing system with Internet of Things, aimed to get user input from touch screen and WeChat mini program, parse the input to amount of tea ingredients, and finally produce a cup of tea as user desired. We have implemented a system fully achieved our goals.



Keywords: Internet Of Things; Tea; Dispenser

# Contents


**1 Introduction** **1**
- 1.1 Purpose . . . 1
- 1.2 High-level Functionality . . . 1
- 1.3 Block Diagram . . . 2
- 1.4 Subsystem Overview . . . 2
  - 1.4.1 Power System . . . 2
  - 1.4.2 Control System . . . 2
  - 1.4.3 Solid/Liquid Dispensing System . . . 3
  - 1.4.4 Tea Brewing System . . . 3

**2 Design** **4**
- 2.1 Power System . . . 4
  - 2.1.1 Demand Analysis . . . 4
  - 2.1.2 Design Decisions . . . 4
  - 2.1.3 Test and Analysis . . . 4
  - 2.1.4 Schematic of Power System . . . 5
  - 2.1.5 Simulation and Analysis . . . 5
- 2.2 Remote Control Subsystem . . . 6
  - 2.2.1 Frontend Part . . . 6
  - 2.2.2 Backend Part . . . 8
- 2.3 Local Control Subsystem . . . 9
  - 2.3.1 Demand Analysis . . . 9
  - 2.3.2 Design Decisions . . . 9
    - 2.3.2.1 Choose MCU between Arduino and STM32 . . . 9
    - 2.3.2.2 Choose LCD Module . . . 10
    - 2.3.2.3 Choose Wi-Fi Module . . . 10
  - 2.3.3 Software Design of Local Control Subsystem . . . 10
    - 2.3.3.1 WeChat-Alibaba Cloud-MCU Message protocol . . . 10
    - 2.3.3.2 Temperature Control . . . 10
    - 2.3.3.3 GUI Design . . . 12
    - 2.3.3.4 Controlling Dispensers . . . 14
- 2.4 Solid Dispensing System . . . 14
  - 2.4.1 The Solid Dispenser . . . 14
  - 2.4.2 The Supporter of Solid Dispenser . . . 15
- 2.5 Liquid Dispensing System . . . 15
- 2.6 Tea Brewing System . . . 16
  - 2.6.1 The Bottom Supporter . . . 16
  - 2.6.2 The Major Vessel . . . 16
  - 2.6.3 The Top Supporter . . . 17
  - 2.6.4 The Minor Vessel . . . 17

**3 Verification** **18**
- 3.1 Remote Control Subsystem . . . 18

3.2 Local Control Subsystem . . . . . 19
3.3 Solid Dispensing System . . . . . 19
3.4 Liquid Dispensing System . . . . . 20
3.5 Tea Brewing System . . . . . 20

**4 Cost and Schedule** **21**
4.1 Cost Analysis . . . . . 21
4.2 Schedule . . . . . 22

**5 Conclusions** **23**
5.1 Accomplishments . . . . . 23
5.2 Uncertainties . . . . . 23
5.3 Ethical Considerations . . . . . 23
5.3.1 Ethics . . . . . 23
5.3.2 Safety Considerations . . . . . 23
5.4 Future Work . . . . . 24

**6 References** **25**

# 1 Introduction

## 1.1 Purpose

Recently, coffee makers have become popular among coffee lovers as emerging home appliances. Even people who do not know much about coffee are able to use coffee machines to get a cup of coffee that meets their taste requirements conveniently and quickly. Figure 1 shows that the market size of coffee machines are increasing from 2017 to 2021 and there is a continuing upward trend. Similarly, tea is also a popular beverage over the world. However, the procedure of brewing tea is very complicated. It is not an easy task for people to obtain a good cup of tea. Thus, a highly automatic tea brewing machine is urgently needed in the market.

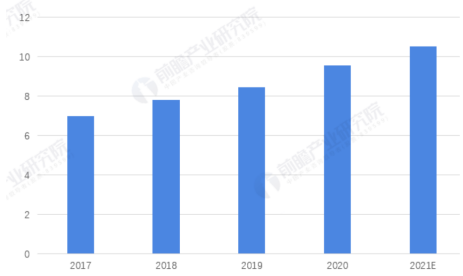


**Figure 1. The Market Size of Coffee Machines in China from 2017 to 2021[1]**

In attempt to solve the problem stated above, we designed a tea brewing machine whose usage is part of similar to the coffee machine. In general, this tea brewer can make the proper tea according to the preferences input by the user. All the brewing process is automatic, and users only need to wait for a while to get a good cup of brewed tea. It allows tea lovers to save the energy needed to brew tea and will enable people new to tea to have a chance to try it.

## 1.2 High-level Functionality

- WeChat Mini Program should allow users to input their requirements and transmit data to the machine through the server. Besides, the user input from WeChat Mini Program includes the type of tea, the flavor requirements, and the strength of the tea and ingredients.
- Tea and Supplement Dispensers should accurately distribute set amount of ingredients into the container. For example, tea leaves and small flowers like osmanthus should be dispensed in units of 1 g and large flowers like roses should be dispensed in units of a single flower.
- Server should transmit user input from WeChat Mini Program to Local Control Subsystem.
- Tea Brewing System should maintain the water temperature at 85 °C and the tea brewing time at least 2 minutes.

## 1.3 Block Diagram

The block diagram of Tea Blend Distributor is shown in Figure.1.

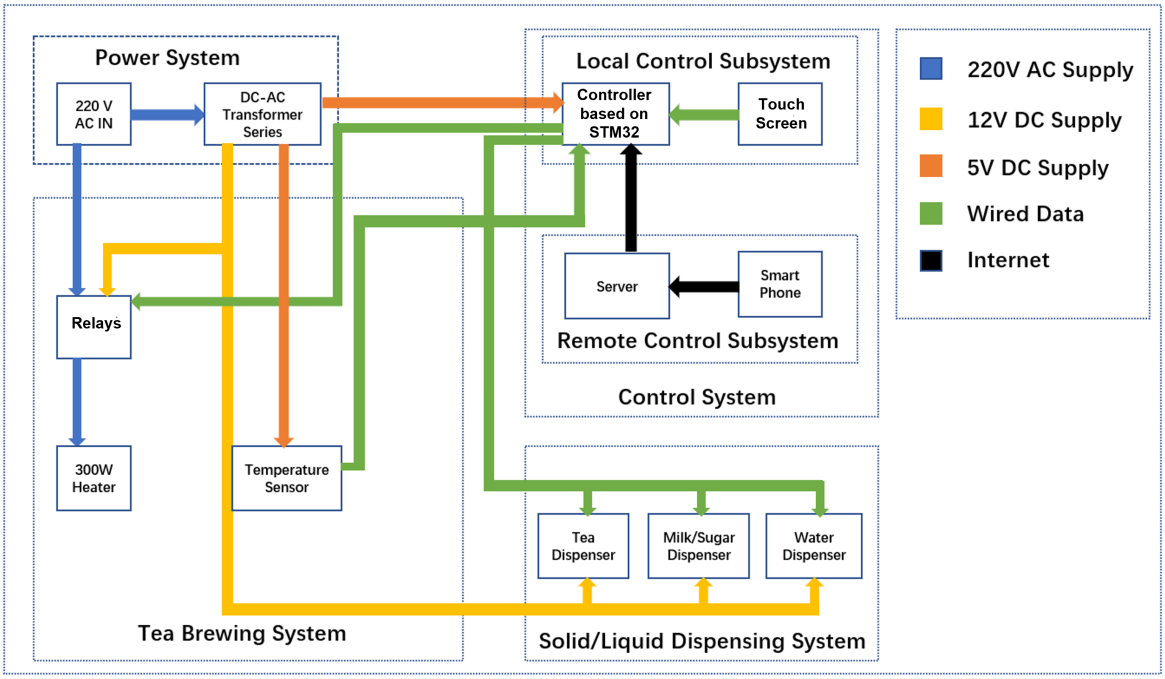


**Figure 2. Block Diagram of Tea Blend Distributor**

## 1.4 Subsystem Overview

### 1.4.1 Power System

The Power System is used for supplying power to all other systems, which contains a 220 V AC input, DC-AC transformer series, three 5 V outputs, output and six 12 V outputs. The 220 V AC input comes from a socket, the two 5 V outputs are connected to Temperature Sensor in Tea Brewing System and Controller based on STM32 in the Local Control Subsystem of the Control System as a power supply. The six 12 V outputs are connected to the Tea Dispenser, Tea Ingredients Dispenser and the other 5 V output are connected to the two Liquid Dispensers of the Solid/Liquid Dispensing System as a power supply.

### 1.4.2 Control System

The Control System is used for controlling the remaining parts of this machine, consisting of the Local Control Subsystem and the Remote Control Subsystem.

The Local Control Subsystem is the core part of the Tea Blend Distributor, which receives user input and internal signals and sends out control signals. This system contains a Controller based on STM32 and a touch screen. It has a 5 V DC input, an Internet data

input, a wired data input, and four wired data outputs. The 5 V DC input, which is the power supply, is given by the Power System. The Internet data input is connected from the Server in the Remote Control Subsystem of the Control System, transferring user input. The Wired Data input is connected from the Temperature Sensor of the Tea Brewing System as temperature input. The first Wired Data Output is connected to the Thermo Switch of the Tea Brewing System as temperature input, and the other three are connected to the Tea Dispenser, Tea Ingredients Dispenser and Liquid Dispenser of the Solid/Liquid Dispensing System as order input.

The Remote Control Subsystem, containing a server and a smart device, which is used for getting user input by smart devices, has only an Internet data output which is connected to Controller based on STM32 as user input.

### 1.4.3 Solid/Liquid Dispensing System

The Solid/Liquid Dispensing System is used to dispense material. It consists of two tea dispensers, four tea ingredients dispensers, a milk dispenser, and a water dispenser. They are linked with containers that restore the necessary materials to make a cup of tea. Each solid dispenser has a wired data input and a 12 V power input, on the other hand, two liquid dispensers have a 5 V power input. The wired data inputs are connected from the Controller based on STM32 of Local Control System. The power inputs are connected from the DC-AC Transformer Series of the Power System. In general, when working, the dispensers can receive wired data inputs from the Local Control Subsystem and do corresponding responses by dispensing a precise amount of items into the vessel. For liquid dispensers, they can pour the required volume of corresponding liquid into the major vessel. In the test, the fluid flow rate is essentially a constant. So the amount of liquid output can be fixed by controlling the running time of the dispensers, and the Local Control Subsystem gives this signal. For solid dispensers, they can drop a settled amount of materials into the minor vessel. The dispenser device receives a single electrical signal, causing the container to drop a fixed amount of items. This quantity is the smallest unit of dispensing. The number of received signals determines the total amount and is an integer multiple of the smallest unit.

### 1.4.4 Tea Brewing System

The Tea Brewing System is used for heating and brewing water and other materials to make a cup of tea. It contains relays, 300 W Heater, and Temperature Sensor. This system has a wired data input, a wired data output, a 5 V DC input, a 12 V DC input, and a 220 V AC input. The 220 V AC input is connected from the 220 V AC inputs of the Power System, and the DC inputs are connected from the proper DC outputs of the DC-AC Transformer Series of the Power System. The wired data input is connected from the Controller based on STM32, receiving temperature settings for the relays, and the wired data output is connected to the Controller based on STM32, sending the temperature information to the Controller based on STM32.

# 2 Design

## 2.1 Power System

### 2.1.1 Demand Analysis

To design a usable Power System, we have analyzed power demand from all devices. All demands were listed as below:

- 6x 12 V 2 A DC Supply for motors of Solid Dispensers
- 1x 12 V 500 mA DC Supply for driving 10 relays in Control System
- 1x 5 V 500 mA DC Supply for the STM32F103VET6 Micro Controller
- 1x 5 V 500 mA DC Supply for DS18B20 Temperature Sensor
- 1x 5 V 500 mA DC Supply for 3 motors of Liquid Dispensers and Pump

### 2.1.2 Design Decisions

During the choose among AC-DC Transfomers on sale, we have made these decisions:

- Using 2x 12 V 20 A DC Power Source instead of 6x 12 V 700 mA AC-DC Transform Module for Solid Dispensers.
- Using 2x 5 V 700 mA AC-DC Transform Module for MCU and Temperature Sensor instead of using only one.

Reasons are in the Test and Analysis part.

### 2.1.3 Test and Analysis

When building the Power System, we have tested several times with different combinations of devices to utilize the Power System's stability.

- Test for one 775 Motor with locked-rotor state:
  - Test: Using the 12 V 700 mA AC-DC Transformer Module to drive a 775 direct motor. Test performed for both spinning and locked-rotor conditions.
  - Result: The AC-DC Transform Module performs well when the motor is normally spinning.
    However, when the motor was locked, the AC-DC Transform Module released several sparks then broke.
  - Analysis: The locked-rotor current of 775 motor is 2 A, which exceeded the maximum current of 12 V 700 mA AC-DC Transformer Module.
  - Decision Made:Use 2x 12 V 20 A DC Power Source instead of 6x 12 V 700 mA AC-DC Transform Module for Solid Dispensers.
- Test for supplying power to Micro Controlling Unit (MCU) and Touch Screen:

- Test:Using the 5 V 700 mA AC-DC Transformer Module to supply power for the STM32F103VET6 MCU.
- Result: The AC-DC Transform Module performs well and all parts of MCU functions properly.

- Test for adding a DS18B20 Temperature Sensor:
  - Test:Using the 5 V 700 mA AC-DC Transformer Module to supply power for the STM32F103VET6 MCU and use the power pin on MCU to drive a DS18B20 Temperature Sensor.
  - Result: The module performs well and all parts of MCU functions properly. However, when the sensor was plugged in, the MCU immediately broke.
  - Analysis: The working current of DS18B20 exceeded the maximum power supply ability of MCU.
  - Decision Made:Use 2x 5 V 700 mA AC-DC Transform Module separately for MCU and Temperature Sensor instead of using only one.

### 2.1.4 Schematic of Power System

The schematic of Power System is in Figure 3.

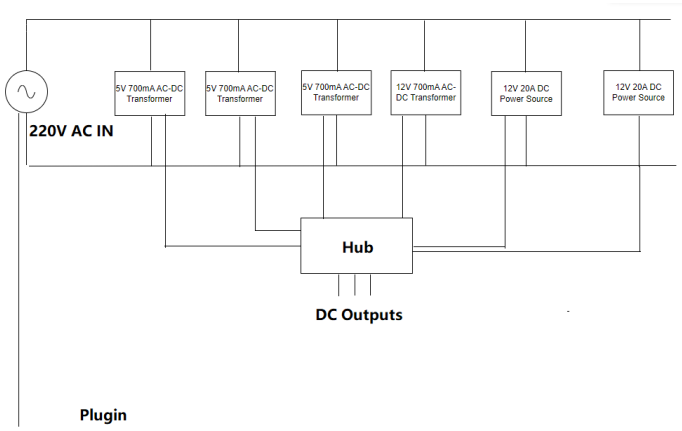


**Figure 3. Schematic of Power System**

### 2.1.5 Simulation and Analysis

- How to drive 10 relays with one 12 V 700 mA AC-DC Transform Module :
  A relay has working current 10 mA, so the net current will be 10x10=100 mA, which will never cause overload.
- Analysis of Total Current at Plugin: The maximum net current at plugin is $I_m$.

$$I_m = \frac{300\ W}{220\ V} + 100\ mA + 3 \times 700\ mA = 3.58\ A \tag{1}$$

This value is smaller than the maximum current that can be tolerated by 0.5 $mm^2$ copper wire we used as power wire, which is 10 A.

## 2.2 Remote Control Subsystem

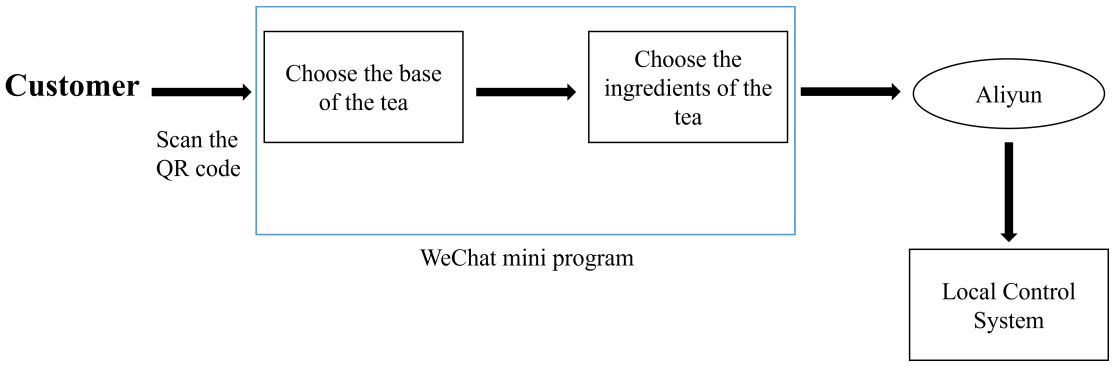


**Figure 4. Diagram of Remote Control System**

The Remote Control System contains WeChat mini program and Alibaba Cloud. Figure 4 shows the diagram of the Remote Control Subsystem.

### 2.2.1 Frontend Part

The customers can use the WeChat mini program to order the tea they want. In general, the customers first scan the QR code of the WeChat mini program to access it. After that, they can choose the base and the ingredients of the tea in the program. When they submit the order, the program will send the information of the tea to Alibaba Cloud, which will transmit it to the Local Control Subsystem.

The WeChat mini program has mainly three interfaces. The first interface contains an introduction and a picture to each type of tea base. Customers will choose one from green tea, black tea, and milk tea and proceed to the next step of personalized selection. Besides, it contains a button for switching between Chinese and English. Clicking it can switch the language of the whole WeChat mini program's pages from Chinese to English, and vice versa. The first two pictures in Figure 5 show the Chinese and English versions of the homepage. In addition, the WeChat mini program provides a function that recommends tea based on the user's selected mood. Users can choose their own mood to view our recommended tea and place an order. For example, the third picture in Figure 5 shows that the program recommends a cup of green tea with jasmine for a user with happy mood.

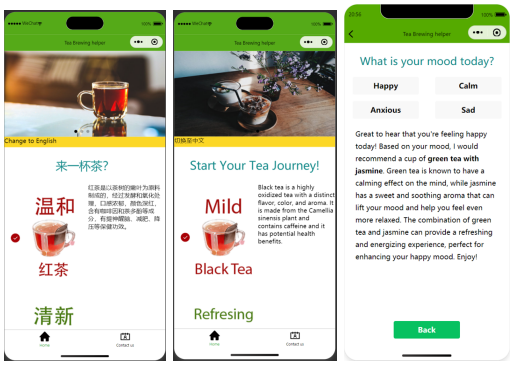


**Figure 5. The Screenshots of the Homepage**

The second interface contains the selection of tea ingredients, where customers can choose one or more ingredients from jasmine, rose, and osmanthus (users who choose milk tea as the base can choose milk). For these three types of flowers and milk, users can choose three different doses: no addition, normal amount, and large amount, which can maximize the personalization of each person's tea selection. Figure 6 shows the pictures and the choices of each ingredient. Considering that some people might be allergic to tea ingredients, we added a reminder to advise allergic users not to add them.

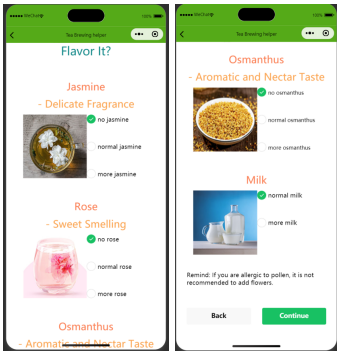


**Figure 6. The Screenshots of the Second Page**

The third interface contains the selection of tea concentration and sweetness. The concentration of tea includes two options: strong and normal and the sweetness level includes unsweetened and sweetened with Stevia rebaudiana leaves, which contain abundant sweetening compounds, mainly stevia, which have high sweetness and can replace sugar and other sweeteners. We choose to use Stevia rebaudiana leaves instead of cube sugar because Stevia rebaudiana leaves are more suitable for dispensing and controlling the amount of addition. However, granulated sugar can easily remain on the dispenser, which can affect its mechanical function.

When the users have completed their selection, they can submit their orders. Before officially submitting the order, in order to prevent customers from changing their minds and wanting to choose the tea again, the WeChat mini program will pop up a window to remind customers whether they confirm to place an order. After the customer confirms

the order in the pop-up window, the mini program will send the information about the personalized tea to Alibaba Cloud and display the successful order interface.

The above is the entire tea-making process and frontend interface design of our WeChat mini program. In addition, our WeChat mini program also has a "contact us" page, which includes our project name, team members, and the email addresses of us. If the customers have any questions about the tea-brewing machine or the WeChat mini program, they can contact us through email.

### 2.2.2 Backend Part

We use Alibaba Cloud IoT Platform as our server. Alibaba Cloud IoT Platform is a cloud-based IoT solution that provides a complete set of IoT services, including device access, data storage, device management, rule calculation, message routing, and application development. It supports multiple protocols, including MQTT, CoAP, HTTP, and WebSocket, which can help businesses quickly build stable and efficient IoT platforms.

The transmission of the information from WeChat mini program and Alibaba Cloud is based on MQTT protocol, using a subscription and publication mode, as well as the communication between STM32 controller and Alibaba Cloud. For each device, WeChat mini program and the controller based on STM32, it can subscribe to some topics on the server; publish and receive messages from these topics. Between topics, forwarding rules are used for messaging, as shown in Figure 7.

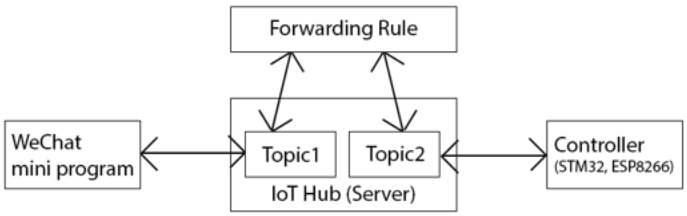


**Figure 7. The Data Route between Server and Devices**

WeChat mini program can send and receive messages from the server. Messaging between the mini program and the server is in the form of MQTT packet, as shown in Figure 8. Each time the mini program wants to connect the server, it sends its productKey, deviceName, and deviceSecret to the server, and the server sends back port, clientId, password and some other information. Then, the mini program can send a packet containing all these information to establish a connection. After that, the mini program can send and receive messages from the server.

| MQTT packet<br>CONNECT | |
|---|---|
| clientId | (name) |
| cleanSession | (importance) |
| keepAlive | (time/sec) |

**Figure 8. The Structure of MQTT Packet**

## 2.3 Local Control Subsystem

### 2.3.1 Demand Analysis

All demands of Local Control Subsystem are shown below:

- Controlling Solid/Liquid Dispensing System and Tea Brewing System.
- Receiving user input from Liquid Crystal Display (LCD) Touch Screen using a GUI.
- Receiving user input from WeChat mini program, and respond to both LCD Screen and other systems.

### 2.3.2 Design Decisions

#### 2.3.2.1 Choose MCU between Arduino and STM32

Based on demand of Local Control Subsystem, it should be able to drive 10 relays, using 10 pins. The LCD plugin costs 34 pins, and Wi-Fi module costs 2 pins. Totally, at least 46 IO pins should be used, which exceeded the maximum amount of IO pins Arduino Uno can supply. On top of that, we have chose STM32F103VET6 as MCU of Local Control Subsystem. The pin map of STM32F103VET6 is shown in Figure 9 below, which has at least 64 IO pins.So STM32F103VET6 satisfies our requirement.

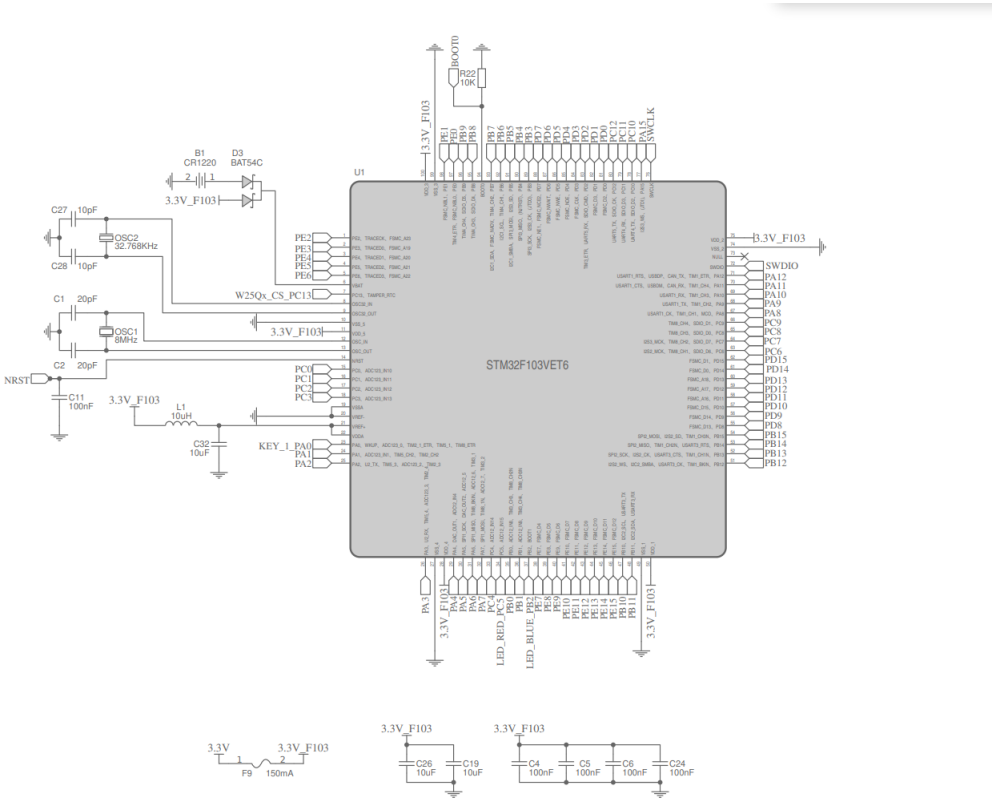


**Figure 9. Pin Map of STM32F103VET6**

#### 2.3.2.2 Choose LCD Module

The LCD Module should have high fresh rate, enough size and way to connect to MCU. Among some LCD module on sale, we chose ATK-MD7000 TFT LCD Module for our project. It has a 83 fps flash rate, with 16-bit RGB, SSD1963 display chip and FT5206 touch chip. The size of this module is 7 inch which make it easy for users to touch. The maximum working temperature of SSD1963 and FT5206 is $70°C$, so we have isolated the Local Control Subsystem and Tea Brewing System.

#### 2.3.2.3 Choose Wi-Fi Module

For Wi-Fi Module we chose on-board ESP8266 module. It is because ESP8266 with AT flash can easily connect to and receive message from Alibaba Cloud server with MQTT protocol. The ESP8266 module supports WPA2 authentication and 2.4 G Wi-Fi signal, which is suitable for connecting to most of Wi-Fi hotspot.

### 2.3.3 Software Design of Local Control Subsystem

#### 2.3.3.1 WeChat-Alibaba Cloud-MCU Message protocol

To transfer any message from Alibaba Cloud Server to MCU, we have wrote AT flash to the ESP8266 module. Then we have hardcoded some AT commands into the main control program to make the ESP8266 module automacticly link to Wi-Fi hotspot and Alibaba Cloud Server. The AT commands comes from official AT command instruction. As result, any message with length up to 1023 Bytes can be transferred from WeChat mini program to MCU.
The format of sent message should be {Base:x,Strength:x,Milk:x,Sugar:x,Osmanthus:x, Rose:x,Jasmine:x} with x as a number from 0 to 2. For the tea base part, the x should be 0 or 1, representing green tea or black tea. Then the message in this format will be parsed by the parser and corresponding amount of ingredients will be stored in a tea_struct global variable to make the consequence of online order same as offline order.
After a message received and parsed, a summary page will be constructed and shown to user.

#### 2.3.3.2 Temperature Control

To implement temperature control, we have chosen DS18B20 temperature sensor and a relay to control our 300 W Heater. The schematic of the subsystem controlled is shown below in Figure 10.

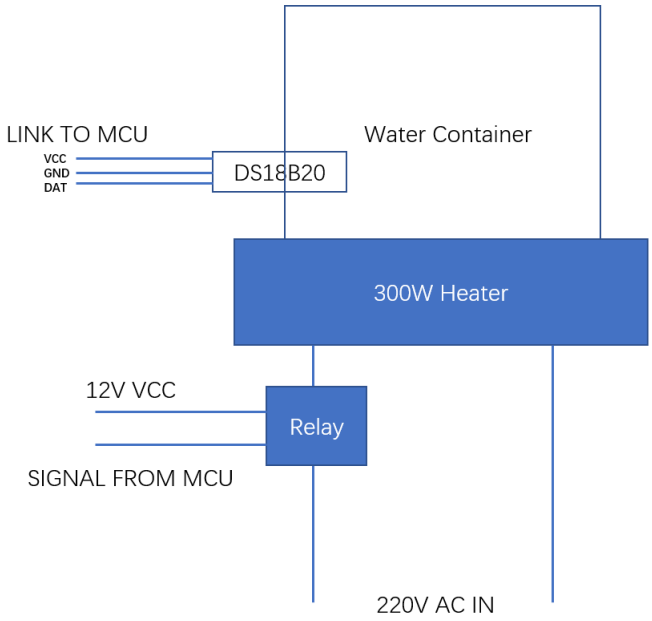


**Figure 10. A part of Tea Brewing System Controlled by Local Control Subsystem**

Since the heating and cooling speed of our heater itself is relatively fast, we have chosen a simple algorithm to control the temperature of the tea. The algorithm is shown below in Figure 11.

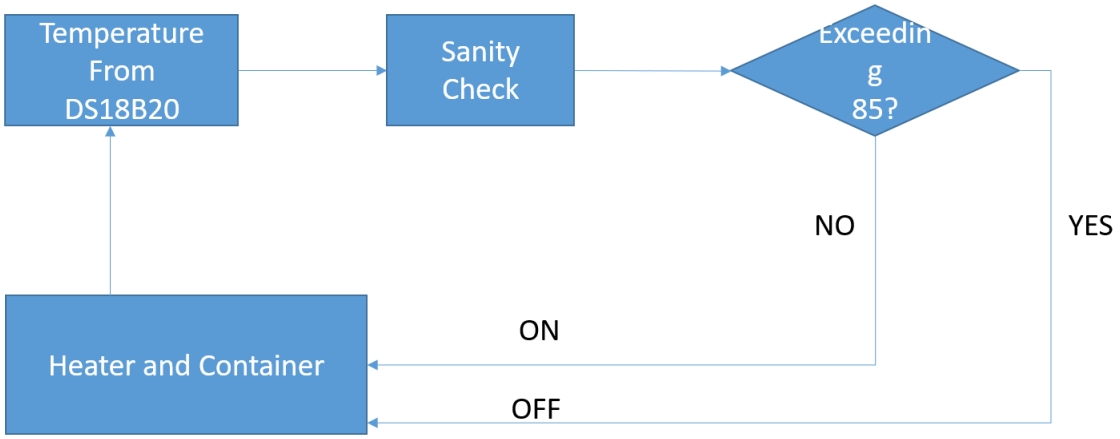


**Figure 11. Temperature Controlling Algorithm**

The sanity check part is for filtering bad data since DS18B20 sometimes will produce some bad data, e.g. $2000\ ^{\circ}\mathrm{C}$. This procedure removed all data out of the range from $0\ ^{\circ}\mathrm{C}$ to $100\ ^{\circ}\mathrm{C}$ The temperature of tea measured at the first 5 seconds after the tea firstly reached $85\ ^{\circ}\mathrm{C}$ is shown below.

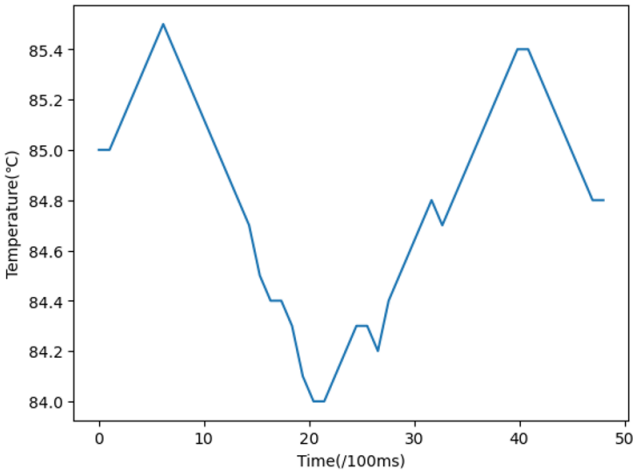


**Figure 12. Temperature Curve Measured**

As the Figure 12 shows, the temperature can be controlled around $85\ ^{\circ}\mathrm{C}$ with maximum error $1\ ^{\circ}\mathrm{C}$.

#### 2.3.3.3 GUI Design

The GUI should be multi-page, touchable and contains at least these widgets below:

- Static Text
- Check
- Button
- Dynamic Text

Due to the limitation of RAM and ROM of STM32F103VET6, we have designed and implemented a GUI library for STM32F103VET6 and the LCD module we used. The library contains functions and variables listed below.

- GUI- A tasklet with information of pages and widgets containing locations, function pointer of onclick functions.
- gui_sketch: Sketch current page.
- widget_refresh: Refresh a widget in current page. Used for dynamic text.
- page_jump: Jump to another page.

The implementation of touch is shown below in Figure 13.

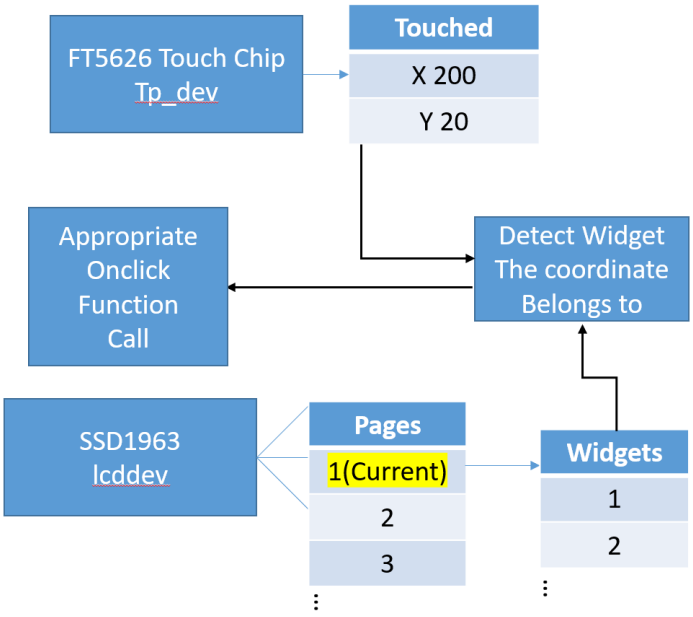


**Figure 13. Implementation of Touch**

Some photos of the GUI and is shown below.Firstly, user can choose their tea base at page 1 shown in Figure 14.

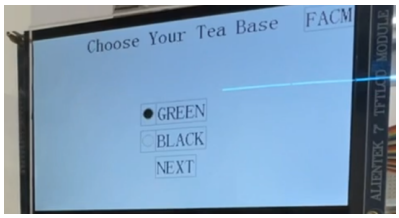


**Figure 14. Page 1**

User can choose their amount of ingredients at page 2 shown in Figure 15.

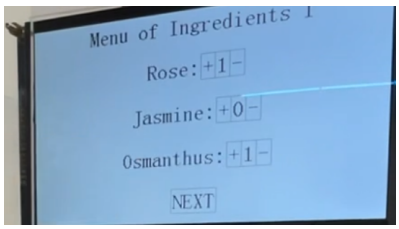


**Figure 15. Page 2**

After chose base and ingredients, user will obtain a summary page for final check. Same page will appear when make order using WeChat. The summary interface is shown in Figure 16.

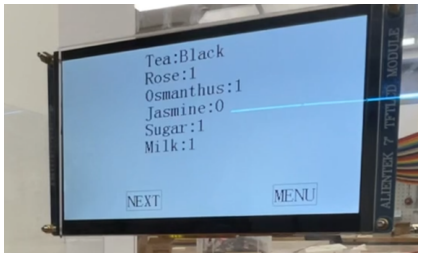


**Figure 16. Summary Page**

#### 2.3.3.4 Controlling Dispensers

For controlling dispensers, we need to control the solid dispenser to spin half a circle and liquid dispenser to release 50 mL liquid. This can be easily implemented with step motors. However, we are aimed to develop a machine that is affordable to users, while step motors are too expensive. Instead, we chose to use normal direct motor and control them to spin for a fixed time. By measurement, the liquid dispenser needs 1475 ms to release 50 mL liquid. The solid dispenser needs 2805 ms to dispense a piece of solid.

## 2.4 Solid Dispensing System

The Solid Dispensing System used to distribute certain amount of solid ingredients when receiving electric signal. Therefore, the output of the material needs to be quantified each time, and the tolerance should be small enough. Depends on the fact that all of the ingredients have stable density, the amount of mass could be changed into corresponding volume. It consists of two parts, one is the solid dispenser, the other is the supporter.

### 2.4.1 The Solid Dispenser

The Solid Dispenser is the main part of this system. It distributes the ingredients when receiving electric signal. It has four subparts, and their models are shown from the Figure 17. The assembling view is shown in Figure 18.

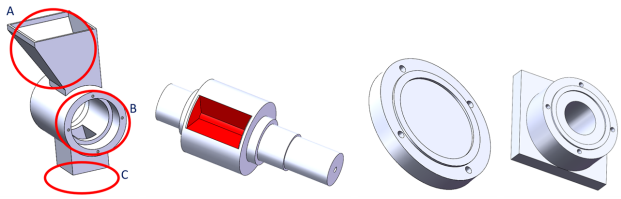


**Figure 17. The Figure of Hopper, Down Feed Roller, Baffle and Motor Mounting Plate**

Hopper is the main subpart of the solid dispenser. Segment A is the container of the solid ingredients. Segment B is the place for down feed roller. Segment C is the hole for dropping the ingredients.

The down feed roller dispenses the ingredients. Firstly, the materials fall in the hole from the container because of the gravity. After rolling half turn, the materials go to

the downside of the dispenser, and one defined amount of ingredient can be accurately outputted.

The baffle fixes the left side of the down feed roller. Between the down feed roller and the baffle, a 6204-2Z bear is used for reducing friction and stability.

The motor mounting plate fixes the right side of the down feed roller, and the connecting structure is a reflection from the baffle. What is different is that the outside of this plate connects with the motor. The motor generates the force for rotating the roller.

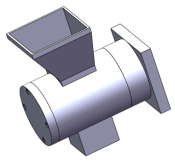

**Figure 18. The Solid Dispenser after Assembling**

### 2.4.2 The Supporter of Solid Dispenser

The supporters enable the dispenser to work at a correct place. It has two subparts, funnel and support column. The support columns are only ordinary cylinder for adjusting height, and it will not be discussed in the following paragraphs. The detail of funnels will be discussed below.

The funnel has two versions, which are shown in Figure 19. Version A is designed for the Tea Brewing System, and version B is for the whole output part of the machine. For version A, its topside is the platform for 4 solid dispensers, and the output exit is at the bottom side. The version B only works for 2 solid dispensers. An extra hole at around the bottom side is designed for the pipe of outputting tea.

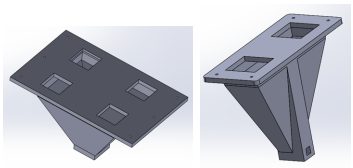

**Figure 19. Funnel Version A and B**

## 2.5 Liquid Dispensing System

The Liquid Dispensing System is used to distribute required amount of liquid, including water and milk, to the Tea Brewing System.

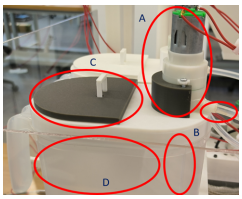


**Figure 20. The Liquid Dispenser**

The photo of the liquid dispenser is shown in Figure 20. Circle A represents the combination of the pump, fixing structure and the pipes. B are two pipes, one connects with the Tea Brewing System, the other attaches to the water. C is the lid, D is the container.

## 2.6 Tea Brewing System

The Tea Brewing System consists of two parts. One is the mechanical part; the other is the heater and temperature controller. This report only discusses the mechanical part. The primary functions are providing a place for brewing the tea, separating the tea and liquid, and adapting the heated main container to the heating weaver.

### 2.6.1 The Bottom Supporter

It is the supporter of the major vessel. The screenshot of model is shown in Figure 21. The blank area is the place for connecting with the major vessel. At the bottom, there are 4 circular holes with 4 mm diameter. These holes allow it to link with the base plate by M4 screws. At the top, there are also circular holes with 3 mm diameter. These holes allow it to link with the top supporter by M3 screws. It is made of ABS for the structure strength. It does not need to be food-level because it does not directly contact with the ingredients or liquid.

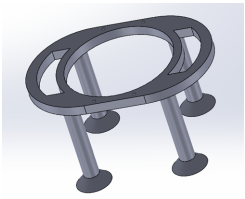

**Figure 21. The Bottom Supporter**

### 2.6.2 The Major Vessel

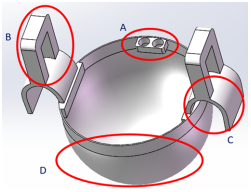


**Figure 22. The Major Vessel**

The major vessel is the container for heating the liquid during tea brewing and its model is shown in Figure 22. It is made of stainless steel, which is food-level. Its volume is 300 ml, and the maximum brewing liquid is 200 ml. Section A is the structure for fixing the pipes. Section B is a handle for better lifting. Section C can connect with the bottom supporter. Section D can be just surrounded by the heating jacket.

### 2.6.3 The Top Supporter

Figure 23 is the model of the top supporter. It is the supporter of the minor vessel, and it is hardwired to the major vessel with M3 screws. Section A is the place for minor vessel. Section B is for the pump. Section C fixing the pipes from the liquid dispenser. Section D is the hole for temperature probe. It is also made of ABS for structure strength. It does not need to be food-level because it does not directly contact with the ingredients or liquid.

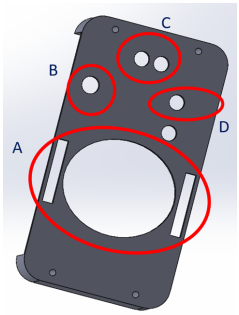


**Figure 23. The Top Supporter**

### 2.6.4 The Minor Vessel

Figure 24 is the model of a minor vessel. It is made of PLA, and a steel sieve surrounds it. Both of the vessels and sieves are food level. It is a container of tea leaves, petals, and stevia leaves when brewing the tea. Liquid can be passed through steel sieves, but not ingredients.

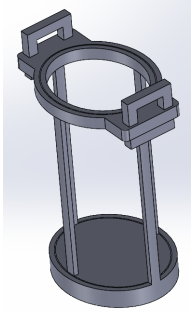

**Figure 24. The Minor Supporter**

# 3 Verification

## 3.1 Remote Control Subsystem

The requirement of the Remote Control Subsystem is that WeChat mini program should allow users to input their requirements and transmit data, including the type of tea, the flavor requirements, and the strength of the tea and ingredients to the machine through the server.

Figure 25 shows the screenshot of the debugger of the WeChat Developer Tools, which can show the values of all the variables and check if the variables are changed when the users change their choices of tea/ingredients. We can see after the previous interfaces the results of the users' choice will be summed in this page, the variables: jasmine, milk, osman (osmanthus), rose, sugar (stevia), tea_id, tea_strength are set to 1, 0, 0, 2, 1, 2, 0.

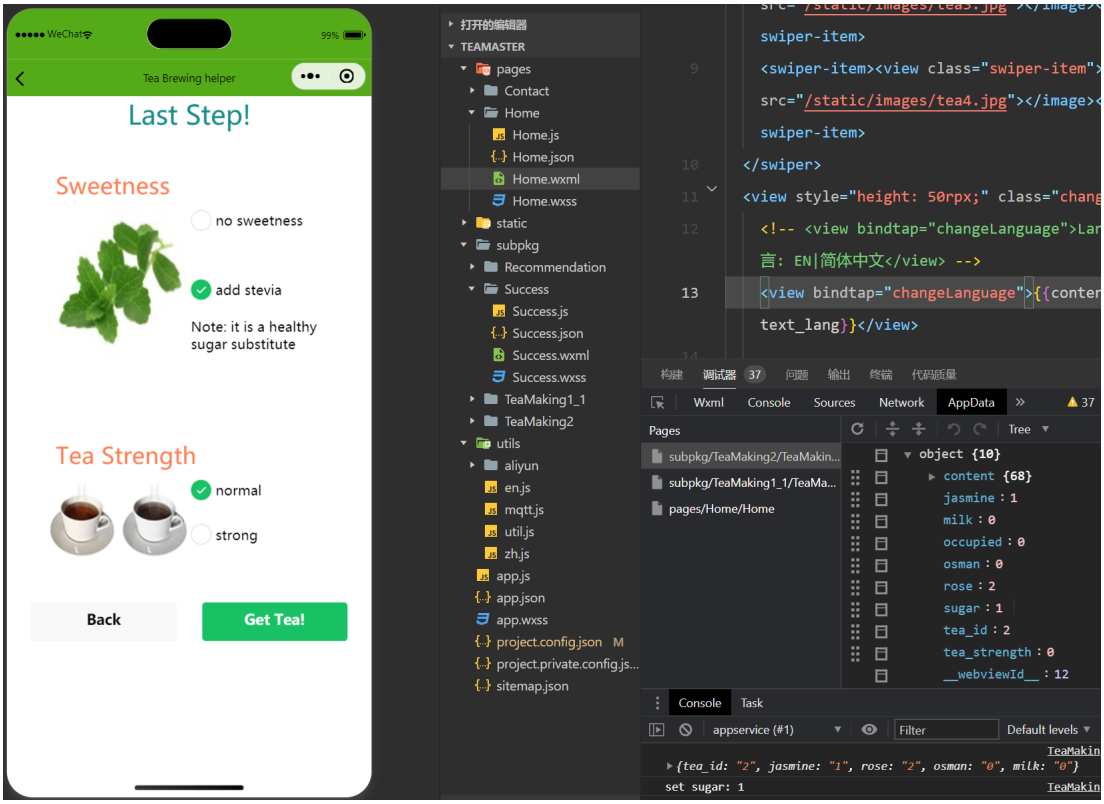


**Figure 25. The Screenshot of the AppData**

Figure 26 shows the message sent by the server when it receives information from the WeChat mini program. After the user confirms their order, the information of the tea would be sent to Alibaba Cloud server and the receive massage would be printed.


**Figure 26. The Screenshot of the Receive Infomation**

## 3.2 Local Control Subsystem

The requirement of the Local Control Subsystem is that the server should transmit user input from WeChat mini program to Local Control Subsystem.

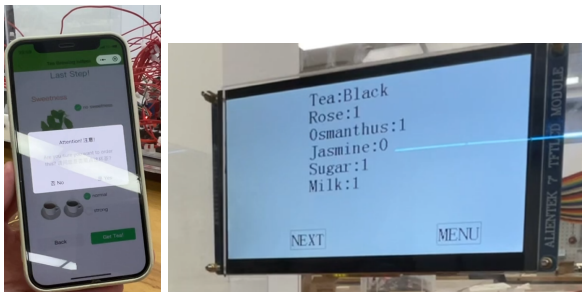


**Figure 27. WeChat mini program and the Summary Page**

After we confirm the order of tea in the WeChat mini program, the touch screen would show the details of this order as shown in Figure 27.

## 3.3 Solid Dispensing System

The requirements of the Solid Dispensing System are: the dispenser can correctly output one copy of ingredients, and the ingredients can correctly fall into the minor vessel.

For the first requirement, the motor we use is 10 r/min. As a result, with the consideration of inertial, 2805 ms is a suitable value. It passes our test successfully.

For the second requirement, as the velocity of falling is not vertical, sometimes ingredients will fall out of the minor vessel. An extra horn-like limiter was set on the top supporter, and its model is shown in Figure 28. Then the whole system passes the test.

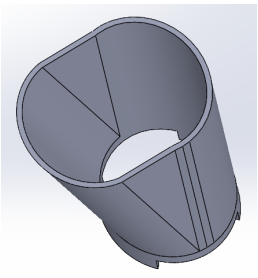

**Figure 28. Summary Page of Touch Screen**

## 3.4 Liquid Dispensing System

There is one requirement for the Liquid Dispensing System: the dispenser should output correct volume of liquid with the guidance of tea recipe. It needs to dispense 100 ml or 200 ml liquid, and the output volume should be within the required tolerance: 5 ml for 100 ml. With our experiment, 3750 ms is a suitable working time for motor to dispense 100 ml, and 7500 ms is for 200 ml. It passes our test successfully.

## 3.5 Tea Brewing System

The requirement of the Tea Brewing System is that it should maintain the water temperature at $85°C$ and the tea brewing time at least 2 minutes.

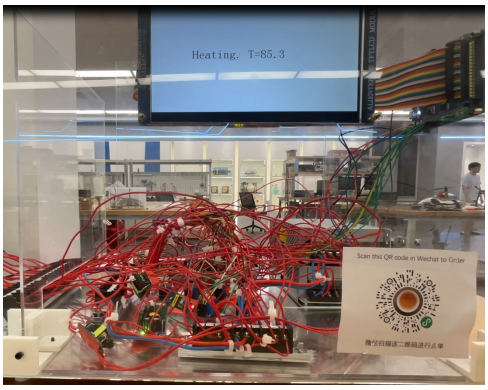


**Figure 29. The Picture of the Temperature When Brewing**

As shown in Figure 29, the temperature during tea brewing can be consistently controlled at around $85\ °C$ and the time of tea brewing is set to 3 minutes.
The detailed Test and Verification Table is in Appendix A.

# 4 Cost and Schedule

## 4.1 Cost Analysis

**Table 1. Labor Costs**

| Name | Hourly Rate ($) | Hours | Total ($) | Total*2.5 ($) |
|---|---|---|---|---|
| Zhenzuo Si | 20 | 200 | 4000 | 10000 |
| Zhiyuan Wang | 20 | 200 | 4000 | 10000 |
| Ruiqi Ye | 20 | 200 | 4000 | 10000 |
| Anyu Ying | 20 | 200 | 4000 | 10000 |
| Total | | | | 40000 |

According to Table 1, we assume that our hourly wage is $ 20 and our working hours are 200 hours, which shows that our labor cost is $ 10,000 per person.

**Table 2. Component Costs**

| Description | Quantity | Cost/unit ($) | Total ($) |
|---|---|---|---|
| Material for 3D Printing | 1 | 42.85 | 42.85 |
| 5V DC power module | 3 | 1.03 | 3.09 |
| 12V DC power module | 1 | 1.61 | 1.61 |
| 12V DC power source | 2 | 6.57 | 13.14 |
| TFT LCD Touch Screen | 1 | 42.57 | 42.57 |
| STM32F407VET6 development board | 1 | 23.43 | 23.43 |
| Heating jacket | 1 | 5 | 5 |
| Temperature probe | 1 | 1.73 | 1.73 |
| Relay | 10 | 1.17 | 11.7 |
| 5m silicon tube | 1 | 0.56 | 0.56 |
| 2500ml plastic kettle | 2 | 1.36 | 2.72 |
| Heated stainless steel vessel | 1 | 20 | 20 |
| 775 direct motor | 6 | 8.57 | 51.43 |
| Pump | 3 | 1.2 | 3.6 |
| Total | | | 223.43 |

Table 2 shows all the component costs of our project.

**Table 3. Sum Cost (Labor & Parts)**

| Section | Total |
|---|---|
| Labor | $40000 |
| Parts | $223.43 |
| Grand Total | $40223.43 |

The sum cost of our project can be calculated by $ 40000+$ 233.43=$ 40223.43, as shown in Table 3.

## 4.2 Schedule

**Table 4. Schedule**

| Week | Task |
|---|---|
| 3/13/2023 | Determined the dosage of each kind of tea, roughly designed Heating System, Control System and WeChat Mini Program |
| 3/20/2023 | Customized heating jacket for the tea brewing system, designed the welcome page of WeChat Mini Program, roughly designed the liquid dispenser |
| 3/27/2023 | Programmed driver for DS18B20, bought and tested the pump, learning how to transmit information between pages |
| 4/3/2023 | Programmed SD driver to record temperature measured, designed and printed first version of liquid dispenser, completed information transmission between pages |
| 4/10/2023 | Tested liquid dispenser and Phone-Server-MCU data transmission, implemented the Power System |
| 4/17/2023 | Printed the solid dispenser and tested with small motor, finished the WeChat Mini Program |
| 4/24/2023 | Did some optimization to WeChat Mini Program, Completed Touch Screen Driver |
| 5/1/2023 | Completed the Control System |
| 5/8/2023 | Tested solid dispenser with 775 motor, measured and marked the positions of installation hole. Added 12 V 20 A power source to Power System |
| 5/15/2023 | Engaged all parts together, thoroughly tested for Final Demo |

The simplified schedule is shown in Table 4. Due to the limitation of number of pages, the detailed schedule assigned to each team member is shown in Appendix B.

# 5 Conclusions

## 5.1 Accomplishments

Our machine allows customers to order their favorite tea through the WeChat mini program or the touch screen. Once the order is received, the information is transmitted to the local control system, which then controls the liquid and solid dispensing systems based on the order details. After that, the tea brewing is activated to make the selected tea. Finally, the finished product is the tea that the customer has chosen.

## 5.2 Uncertainties

In our Heating System, since the available power of the purchased heater is limited, it takes a long time to heat the water, and it is impossible to quickly heat the room temperature water to boiling and maintain it at 85 $^{\circ}\mathrm{C}$ for tea brewing. Besides, our machine is a little bit huge as a tea making machine.

## 5.3 Ethical Considerations

### 5.3.1 Ethics

We have checked the IEEE Code of Ethics and confirmed that we and our product would never violate these rules. Based on the # 1 IEEE Code of Ethics [2], we will put the safety and health of users will always be put first during development. The detailed safety considerations are listed in next part. All materials used in our products are also environmentally friendly. Referring to the # 5 and # 6 IEEE Code of Ethics [2], all the designs and data will be authentic in our reports and presentations, and we would accept criticism and comments with an open mind. In our project, we commit to treat people equally. In our designing process, we will treat each of our members fairly and carefully understand and help each member. For users, we will provide different kinds of options so every user can find his/her satisfactory needs. These follow the requirements of # 7 and # 9 IEEE Code of Ethics [2], which ask us to give fairly treatment and respect to others and not to injure others.

### 5.3.2 Safety Considerations

The safety hazard factors are mainly reflected in the use process, which could be divided into four parts.

The first thing to consider is food safety. As our machine products are tea, to ensure the safety of our customers, the parts of the machine that come into contact with tea must be food-grade and free from any food safety issues.

The second is that part of the machine will be heated internally during the operation. The misuse of our machine might have the risk of scalding. To solve this problem, a caution

label is applied to the product surface, and the Heating System is separated from the product housing by a sufficient distance.

Furthermore, since we use tea leaves and flowers to brew tea, the issue of allergy is considered. In the user selection interface in WeChat mini program and in touch screen, we warn users about allergy problems. Thus, users with pollen allergies or gastrointestinal problems could select appropriate combination of tea leaves and flowers.

Finally, we use electricity as our power supply and use mechanical structures to control some parts of the system. For these parts, safety is ensured. As illustrated in the design block diagram, the electrical and mechanical parts including the power system and the solid/liquid dispensing system which might be dangerous are isolated from the users, so the users will not be hurt by electricity or the mechanical structure. Therefore, the safety of users will always be protected.

In our designing process, we will use 220V power supply for our system and use mechanical and electrical device in the lab to build our heating and dispensing systems. In this process, we can protect our safety, since we have participated in the lab safety training and are familiar with the mechanical and electrical device which will be used in our design. We will always remind each of us to follow the safety instructions. Additionally, we will always check the heating and dispensing systems are operating as we designed, and no unexpected hazard will happen.

## 5.4 Future Work

To reduce the heating time, We can redesign the structure of the heating system and find a more efficient way to heat the tea, for example, heating coil is an option. In addition, the size of the machine can be decreased by structure optimization.

In Wechat mini program, the function of recommending the tea based on the users' moods can be optimized by the ChatGPT API, which can offer better and more personalized advice than the answers we preset.

# 6 References

[1] ”Analysis of the current market situation and competitive landscape of China’s coffee machine industry in 2022.” https://www.qianzhan.com/analyst/detail/220/220602-4b2a1f6b.html. Accessed 19 May. 2023.
[2] ”IEEE Code of Ethics.” www.ieee.org/about/corporate/governance/p7-8.html. Accessed 19 Mar. 2023.

# Appendix A Requirements and Verification Table

**Table 5. R&V of Power System**

| Requirements | Verifications |
|---|---|
| (1) The Power System should use a DC-AC transformer series, which transfers 220 V AC input to provide 220 V AC power supply, 12 V $\pm$ 0.2 V DC power supply and 5 V $\pm$ 0.2 V DC power supply.<br><br>(2) The Power System should be able to work correctly even if the current and voltage are too high sometimes. | (1) Measure the circuit voltages at these transformer series respectively by the multimeter in the lab. The results should be 220 V AC, 12 V $\pm$ 0.2 V DC and 5 V $\pm$ 0.2 V DC, which conforms to the requirements.<br><br>(2) First, configure the machine to make tea, and the Power System's wires and components should not heat up and continue to work, which conforms to the requirements. |

**Table 6. R&V of Control System**

| Requirements | Verifications |
|---|---|
| (1) The Remote Control Subsystem should handle user inputs from smartphones and send the inputs to the Local Control Subsystem, and the Local Control Subsystem should get inputs when users push buttons.<br>(2) When the Local Control Subsystem receives a taste requirement profile from buttons or a smartphone, it can control the Solid/Liquid Dispensing System to work.<br>(3) The Local Control Subsystem can alert the Tea Brewing System and set the tea to a calculated temperature (85 $^{\circ}$C in most cases). | (1.1) When the requirement profile is set on the smartphone, the server should show a new record about this new order, which shows the server and smartphones are connected.<br><br>(1.2) Once the server gets a new requirement or the buttons are pushed, the Controller based on Arduino can detect a control signal from the server, which verifies the Controller based on Arduino can detect signals correctly. |

**Table 6 (continued). R&V of Control System**

| Requirements | Verifications |
|---|---|
| (1) The Remote Control Subsystem should handle user inputs from smartphones and send the inputs to the Local Control Subsystem, and the Local Control Subsystem should get inputs when users push buttons.<br>(2) When the Local Control Subsystem receive a taste requirement profile from buttons or a smartphone, it can control the Solid/Liquid Dispensing System to work.<br>(3) The Local Control Subsystem can alert the Tea Brewing System and set the tea to a calculated temperature (85 °C in most cases). | (2.1) When the Controller based on Arduino receive a control signal, it will send a control signal to the Solid/Liquid Dispensing System, and this could be verified by detecting this signal on the sensors or motors in the Solid/Liquid Dispensing System.<br>(2.2) After the Solid/Liquid Dispensing System is built, it should start to make tea when a requirement is set using the buttons or on a smartphone. This means the interaction between the Control System and the Solid/Liquid Dispensing System is functioning properly.<br><br>(3) The Thermo Switch in the Tea Brewing System can detect this alerting signal sent from the Local Control Subsystem, showing that the Control System and the Tea Brewing System are connected. Once the Tea Brewing System is built, the temperature of the tea measured by the thermometer should be the same as the setting one (85 °C in most cases). |

**Table 7. R&V of Solid/Liquid Dispensing System**

| Requirements | Verifications |
|---|---|
| (1) The liquid dispenser, including the milk dispenser and water dispenser, could pour an appropriate amount of liquid into the major vessel according to the signal.<br><br>(2) The solid dispenser, including the tea dispenser and sugar dispenser, could drop an appropriate amount of tea or sugar into the minor vessel according to the signal. | (1) First, configure the machine to output pure water or milk and then use the measuring cylinder to collect the liquid. The volume of collected liquid conforms to the received signal.<br><br>(2) First, configure the machine to output only tea leaves or sugar and then use the beaker to collect them. The weight of dropped tea and sugar measured by the scale conforms to the received signal. |

**Table 8. R&V of Tea Brewing System**

| Requirements | Verifications |
|---|---|
| (1) The 300W Heater should be started to heat the mixture of tea, water, sugar, and milk When receiving signals from Local Control Subsystem.<br>(2) The Thermo Switch should react properly to the water temperature When receiving signals from Local Control Subsystem.<br>(3) The temperature sensor should be sensitive enough to report the actual temperature to Local Control System. | (1) First, insert a thermometer in the water and then configure the machine to brew tea. The tea will be heated, and the temperature shown by the thermometer should be stable at 85 $^{\circ}\mathrm{C}$ eventually. |

# Appendix B Schedule

**Table 9. Detailed Schedule**

| Week | Task | Responsibility |
|---|---|---|
| 3/13/2023 | Roughly designed the structure of Tea Brewing System, bought several heaters and tested | Zhenzuo Si |
| | Draw the rough physical diagram and analyze the structure | Zhiyuan Wang |
| | Bought black tea, green tea, osmanthus, jasmine and rose. Make tea with different proportions of ingredients and test together, and record the result | Ruiqi Ye |
| | Bought stevia. Make tea with different proportions of ingredients and test together, and record the result | Anyu Ying |
| 3/20/2023 | Customized the heating jacket used in the Tea Brewing System, bought DS18B20 temperature sensor for Tea Brewing System | Zhenzuo Si |
| | Built 3D printer, designed the structure of water dispenser | Zhiyuan Wang |
| | Make a prototype of the Wechat mini program including structure and feature of each page, collected the pictured to be used in the WeChat mini program | Ruiqi Ye |
| | Make a prototype of the Wechat mini program | Anyu Ying |
| 3/27/2023 | Programmed the driver of DS18B20 and implemented a simple temperature control algorithm, stabilized the temperature of water in glass container to 85 $^{\circ}\mathrm{C}$ | Zhenzuo Si |
| | Bought and tested the pump of Liquid Dispenser, printed and installed the first version of Liquid Dispenser | Zhiyuan Wang |
| | Learned how to transmit information among pages of WeChat mini program | Ruiqi Ye |
| | Learned how to transmit information among pages of WeChat mini program | Anyu Ying |
| 4/3/2023 | Finished SD driver to record temperature data measured | Zhenzuo Si |
| | Design the solid dispenser, fixed the bug that the cover of liquid dispenser is not fit well | Zhiyuan Wang |
| | Finish the main interface and start the subinterface, completed the information transmission between pages | Ruiqi Ye |
| | Finish the main interface and start the subinterface, completed the information transmission between pages | Anyu Ying |

**Table 9 (continued). Schedule**

| Week | Task | Responsibility |
|---|---|---|
| 4/10/2023 | Tested Liquid Dispenser and the Phone-Server-MCU data transmission, implemented the Power System | Zhenzuo Si |
| | Constructed, tested and adjusted the Liquid Dispenser and early version of Solid Dispenser | Zhiyuan Wang |
| | Designed subinterfaces of the WeChat mini program | Ruiqi Ye |
| | Built the connection between the Aliyun Server and WeChat mini program, tested with Zhenzuo Si | Anyu Ying |
| 4/17/2023 | Tested the Solid Dispenser with small motors, implemented a rough controller | Zhenzuo Si |
| | Completed all mechanical dispenser parts, print and tested the Solid Dispenser together with Zhenzuo Si | Zhiyuan Wang |
| | Finished subinterfaces of WeChat mini program | Ruiqi Ye |
| | Finished subinterfaces of WeChat mini program with Ruiqi Ye, posted the WeChat mini program to Internet | Anyu Ying |
| 4/24/2023 | Programmed the driver of SSD1963 display chip and FT5626 touch chip and implemented GUI | Zhenzuo Si |
| | Designed and constructed the new version of Solid Dispenser with 775 direct moter and its supplements | Zhiyuan Wang |
| | Optimized the appearance of the WeChat mini program, containing better text, smoother pictures and fit different kinds of smartphones | Ruiqi Ye |
| | Optimized the appearance of the WeChat mini program, containing better text, smoother pictures and fit different kinds of smartphones | Anyu Ying |
| 5/1/2023 | Completed and tested the Control System, bought the 775 direct motor and 12 V 20 A power supply | Zhenzuo Si |
| | Manufactured the tea container in the Tea Brewing System | Zhiyuan Wang |
| | Implemented language switch between Chinese and English for WeChat mini program | Ruiqi Ye |
| | Designed the chat page for recommending tea recipes to users | Anyu Ying |

**Table 9 (continued). Schedule**

| Week | Task | Responsibility |
|---|---|---|
| 5/8/2023 | Tested the final version of Solid Dispenser with 775 direct motor, added 12 V 20 A power source to Power System | Zhenzuo Si |
| | Printed all the mechanical components used for the machine, measured and marker the positions of installation hole | Zhiyuan Wang |
| | Collected user feedbacks of WeChat mini program and optimized the WeChat mini program based on these feedbacks | Ruiqi Ye |
| | Collected user feedbacks of WeChat mini program and implemented the chat page | Anyu Ying |
| 5/15/2023 | Engaged all parts together with teammates, tested the Local Control Subsystem for Final Demo | Zhenzuo Si |
| | Engaged all parts together with teammates, tested the Solid/Liquid Dispensing System for Final Demo | Zhiyuan Wang |
| | Engaged all parts together with teammates, tested the Remote Control Subsystem for Final Demo | Ruiqi Ye |
| | Engaged all parts together with teammates, tested the Remote Control Subsystem for Final Demo | Anyu Ying |