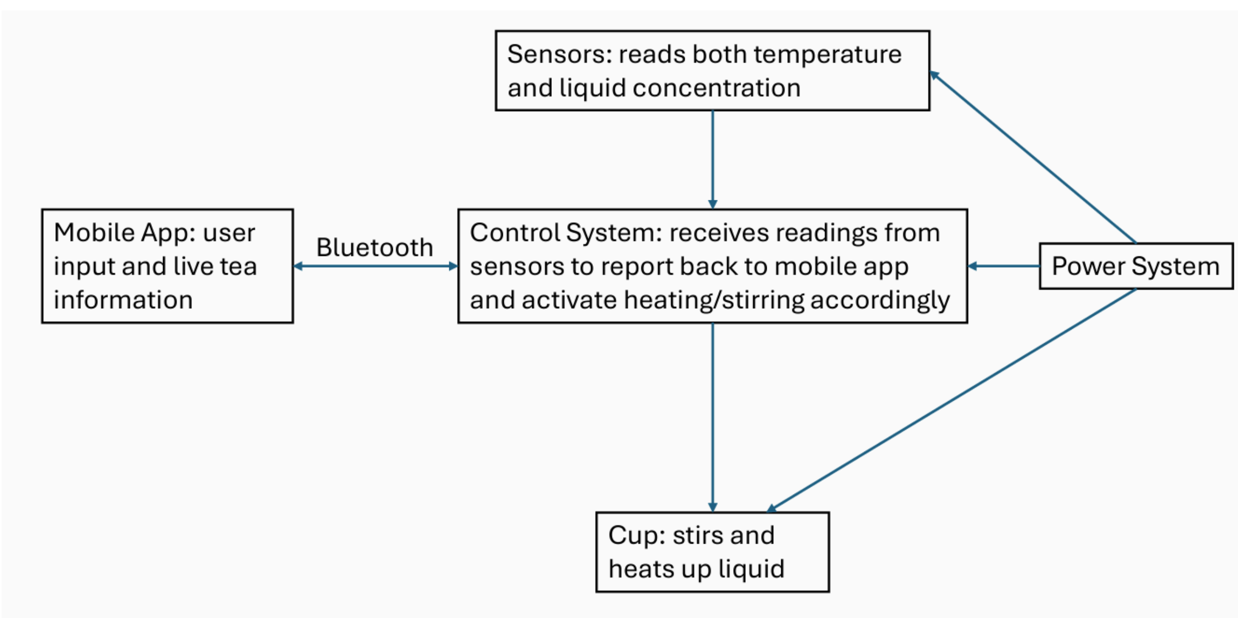
Introduction

Current methods to brew tea lack ways to handle different tea leaves and maintain temperature. For instance, tea is usually brewed by adding boiling water to a cup of tea leaves. This is effective for tea leaves like black tea, however, for more delicate teas like green tea, this would bring out more bitterness as it burns the green leaves. Adding boiling 100°C water is way over green tea's preferred temperature range of 70-80°C. Temperature is important in brewing tea because different tea leaves require different temperatures to effectively bring out its aromatic compounds. The ability to heat different tea leaves to its optimal temperature and maintain its warmness would provide the best possible tea drinking experience.

We propose a cup that can heat liquid optimal to the type of tea leaf chosen and maintain the liquid to a user-specified temperature. Our system provides a precise temperature control to combat inconsistencies in conventional tea brewing methods. Our cup integrates multiple subsystems to ensure optimal flavor extraction, temperature retention, and ease of use.

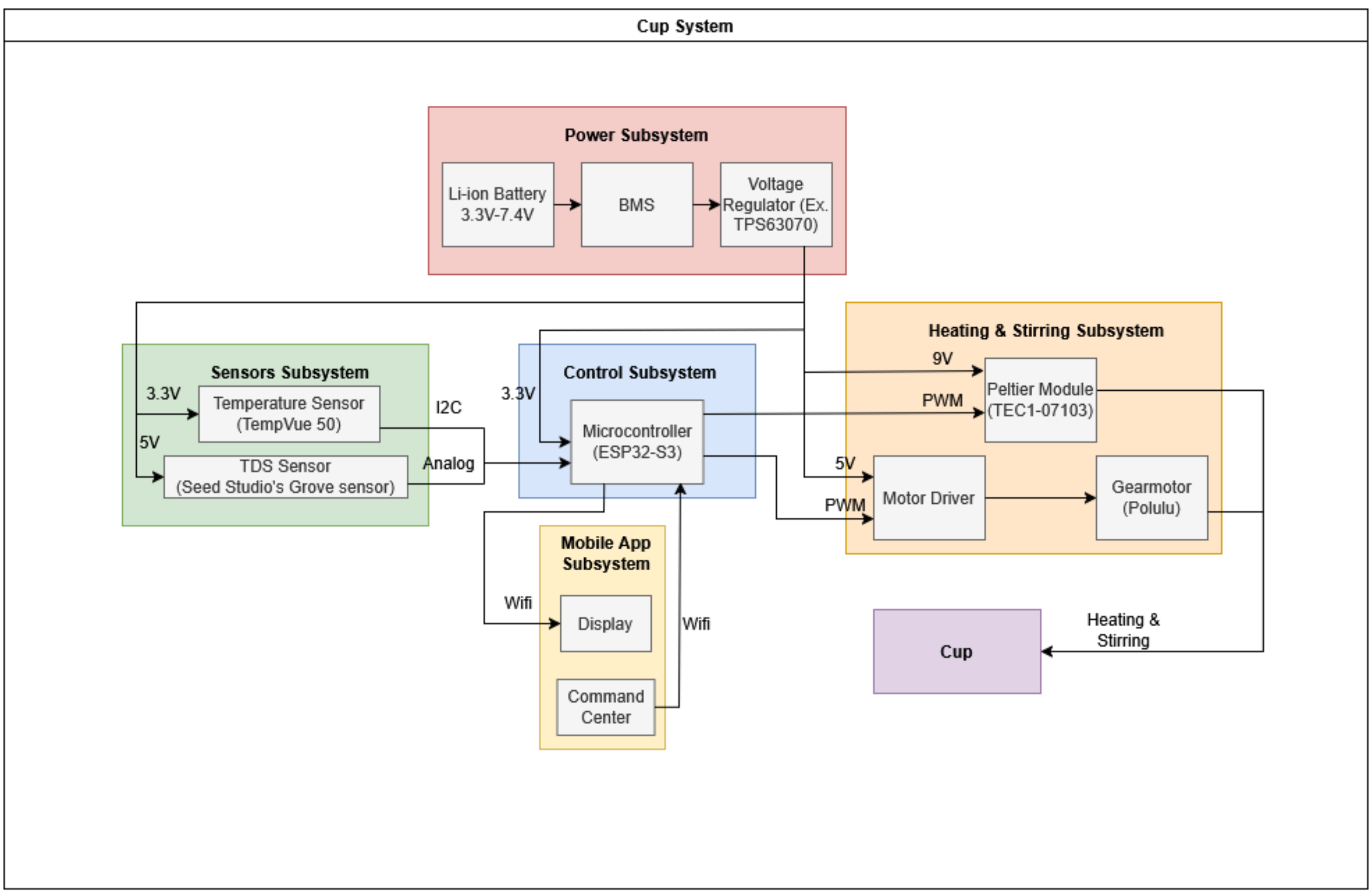
These include sensors to measure temperature as well as a TDS sensor to measure tea strength/bitterness. Of course, we will also have a power subsystem, which will be provided via a battery. Two of the functionalities we want to provide are temperature heating and control, as well as stirring, both of which are important for the tea making process. The user can interact with the cup through a mobile application through Bluetooth - the cup will communicate information from the sensors, while the application can be used to change settings and the like. Here is a visual aid to demonstrate the general overview of our project:



We believe our project must display these three high-level characteristics to solve the problem:

1. The cup should be able to maintain the desired temperature for at least six hours. Given that this is designed to be portable, it would be important for the tea to be kept warm as long as the user is outside, which of course varies, but could be at least the length of a working day. This also means that we would want other subsystems to be as efficient as possible, to minimize the energy loss.
2. The cup should be able to maintain the temperature within 1-2°C of the desired user temperature. This requires precise sensors that can communicate effectively with the user application which in turn needs to communicate with the heating element to control its behavior.
3. Ideally, the cup should not be too heavy. Some of the heavier water bottles that people carry around are about 0.3kg, and ours should also fall within a similar weight range. One can consider that people might use this in situations when they are outside in a cold area, perhaps doing tourism, and it is important to travel a little light.

Design



Subsystem 1: Sensors

The sensor's subsystem is responsible for reading the necessary data from the liquid to be used to maintain its tea qualities and temperature. Specifically, it will consist of a Total Dissolved Solids (TDS) sensor for tea strength and a temperature sensor. This data will be relayed to the control system to be analyzed and acted upon. These sensors will also be connected to the power system.

The sensors allow for the tea temperature and strength to be constantly measured to a significant degree of accuracy (within 1-2°C for temperature), which is essential for maintaining the temperature of the liquid at the user's desired point. These sensors are generally lightweight (<50g) and require lower amounts of power compared to the motor and heating element (~5 mW for temperature, ~15 mW for TDS). These sensors will be directly connected to the control subsystem (ESP32-S3) such that the temperature data can be processed and then converted into the necessary output for the heating element to modify the temperature as needed; likewise the TDS sensor will relay information to the ESP32-S3-WROOM, which then notifies the user of the tea readiness/quality via the user interface. The sensors will also receive power from the battery system, however a buck converter or other method of stepping down voltage will likely be needed.

Subsystem 2: Heating and Stirring

The Heating and Stirring subsystem will maintain the liquid/tea at the user's desired temperature and tea strength. The heating element will be under the liquid, conducting through a thin metal layer. The stirring system will consist of an appendage attached to a Pololu DC Micrometal Gear Motor, the shaft of which will be sent through a small hole in the lid of the cup. This system will require power from the power subsystem and it will also receive input from the control subsystem such that temperature and motor speed can be maintained. Given that the motor is just intended to stir liquid, we will not need anything incredibly strong. The low power version of the Pololu Motor uses 6V at 0.36A, which will be sufficient for our purposes. Further, we only need the motor to act for perhaps ten seconds at any time, operating at ~60 RPM.

Subsystem 3: Power

The power subsystem is responsible for supplying power to the sensors, motors, and heating element, as well as monitoring battery level. It will also be connected to the control system such that warnings of low battery level can be sent to the user interface and/or indicated via LED. The battery should supply at least 6V and support current draw of a max of 160 mA. Buck converters/regulators are also needed, with functioning output voltages of 3-6V.

Subsystem 4: Control and Communication

We can use a microcontroller such as ESP32-S3-WROOM to collect the data from the sensors and communicate it to the mobile app / user interface (Subsystem 5). It will also be able to receive information (user settings) from the mobile application and then control the other subsystems as and when needed. It should monitor temperature and TDS regularly, perhaps every thirty seconds or even more frequently. Stirring will also be controlled by this subsystem and done at a regular interval as well.

Subsystem 5: Mobile App/User Interface

We will be using a mobile app rather than something web - based. Given that we want the user to be able to use our device outdoors as well, this will be more convenient and easy to manage. It will display temperature and TDS readings to the user, as well as allow them to control both those values. This data from the sensors will be adjusted before being displayed to the user - the temperature does not need to go into decimal points, and we will map the TDS values to qualitative descriptions (i.e. strong, weak, etc). The app should also alert the user when their tea has reached the desired strength or temperature and allow them to provide settings for stirring. This app will communicate with the microcontroller from Subsystem 4 via Bluetooth. Again, since we want this to be usable outdoors, we chose Bluetooth over Wi-Fi.

Subsystem 6: Cup

The cup/mug will consist of a generic stainless steel mug. The bottom of this mug will be cut off and replaced with a thin sheet of metal to conduct heat through (via welding at the machine shop). Below that, there will be a sizable compartment to hold all electronic components. Additionally, a hole will be cut out of the lid such that the motor shaft from the stirring subsystem can be slotted through. The cup will need to have a large enough radius to have enough space on the lid to place the motor and an orifice for the user to drink from, likely at least 3-4 cm.

Ethics and Safety

There are of course a few safety concerns, specifically in relation to 1.1 from the IEEE Code of Ethics. For instance, since this is meant to be for tea, we will be dealing with very hot water that can seriously scald or burn a person. The lid of the cup should only come off intentionally; in other words, it can not accidentally come off. In essence, we want to make it spill proof. Another potential safety concern is washing the cup. The user will need to do this for hygienic purposes. We want to make sure this is possible to do without the water coming into contact with the electronics, which could be dangerous.

1.2 from the IEEE Code of Ethics is also important to our project. This discusses the importance of improving individuals and society's understanding of smart devices. Our cup would likely fall under this category, as it will communicate with the user's smartphone via Bluetooth. Such connections can be intercepted or interfered with, and it is important for the user to be aware of this. Also, we can envision the application storing data such as user preferences. We need to store user data, no matter how inconsequential it may seem, securely. One last more ethical aspect is more about avoiding waste and proper design. Our cup should be made of a series of parts that can be replaced rather than one singular device. This can avoid waste of materials, and make it cheaper to get one's cup functioning again if something goes wrong.

Tolerance Analysis

Temperature control system is the most crucial part of our design. A successful implementation would allow user's to heat up and maintain their tea at a high temperature. This means that our heating system must be powerful enough to do so as well as being able to conduct heat well through the cup. To meet this requirement, we can use Fourier's Law to calculate heat loss and the heat energy equation to find the estimated energy needed to heat up different liquid temperatures.