Smart Mugs - Drinking Habit Tracker

ECE 445 Project Proposal

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1. Introduction

1.1. Problem

Maintaining the perfect temperature of beverages has been an issue that many people have faced. Hot drinks like coffee or tea can be too hot to consume, causing harm to one's throat and tongue, while cold drinks can quickly lose their taste and enjoyment. This problem is common and has been well-documented in various studies, which have emphasized the importance of maintaining the ideal temperature of beverages for optimal consumption.

One reason why this issue is important is that drinking a beverage at the correct temperature can significantly impact the flavor and taste of the drink. For instance, if coffee is too hot, it can scorch the taste buds, making it difficult to appreciate the unique flavor notes of the coffee. Similarly, if a cold beverage gets warm, it can become flat and lose its fizz, impacting the taste of the drink. Thus, maintaining the desired temperature of a beverage is crucial to ensuring its taste and enjoyment.

Additionally, the issue of maintaining the perfect temperature of beverages is not limited to just coffee and tea. This issue is also relevant in the context of other beverages, such as beer and wine. For example, a warm beer can lose its flavor, while a cold beer that becomes warm can develop an unpleasant taste. Similarly, wine that is served at the incorrect temperature can lose its aroma and flavor, impacting the overall drinking experience. In conclusion, maintaining the ideal temperature of beverages is a significant issue that impacts the taste and enjoyment of the drink.

Another reason why this issue is significant is that there is a growing concern over the negative impact of disposable cups on the environment. The over-reliance on disposable cups is a

major contributor to landfill waste and requires a significant amount of energy and resources to manufacture, transport, and dispose of. This issue has been highlighted by numerous environmental organizations, which have called for more sustainable alternatives to disposable cups to reduce waste generation. We conducted research on existing products and found that the Embur Mug is a smart mug capable of detecting the temperature of its contents and keeping them at a desired level. Despite its innovative functionality, the steep cost of 130 dollars renders it inaccessible to the average consumer. By addressing these issues, we can provide practical solutions that benefit both individuals and the environment.

1.2. Solution

Our proposed project entails the development of a cutting-edge smart mug. Our innovative design will offer superior functionality and affordability compared to existing products, particularly the Embur Mug. The smart mug will feature an advanced temperature control system that will automatically maintain the desired temperature of the beverage. In addition, our design will incorporate an intuitive app interface that will enable users to conveniently set their preferred temperature for different beverages, monitor their liquid intake, and track consumption speed.

This smart mug will eliminate the need for time-consuming and wasteful reheating, while also accurately measuring the amount of liquid in the cup through the use of a sensor that detects the weight of the liquid. The corresponding app will display the volume of liquid in ounces. Our smart mug will not only enhance the hot beverage drinking experience but also foster sustainable

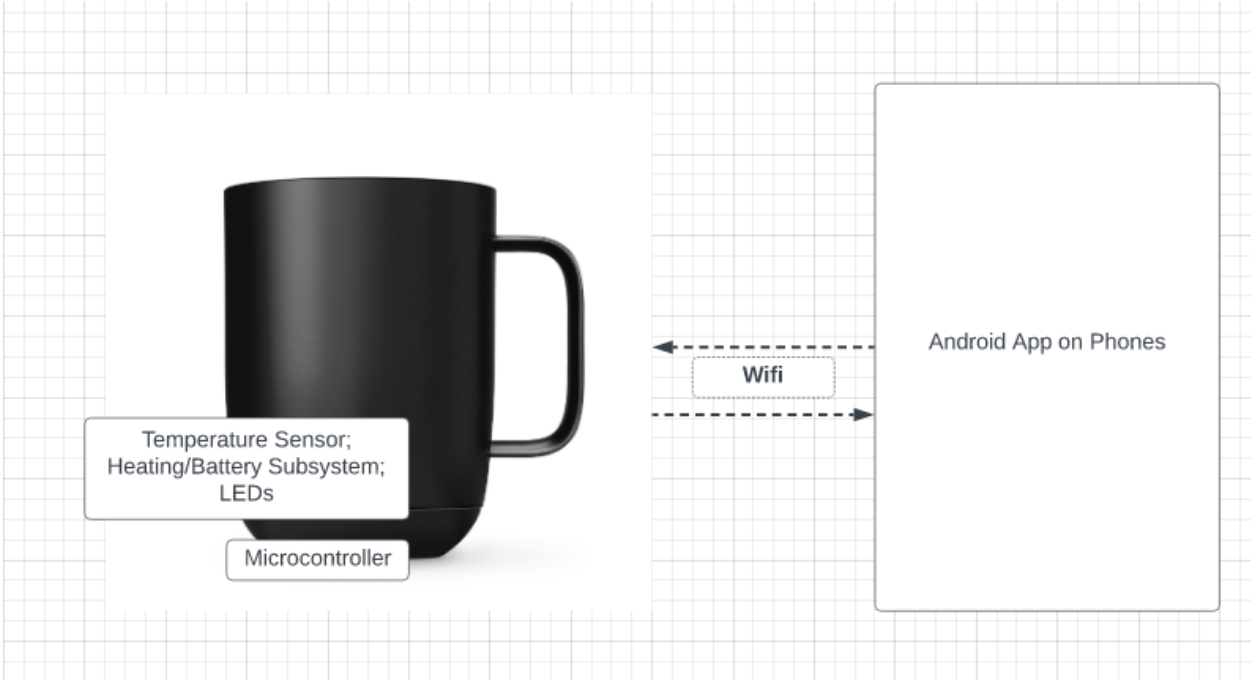
habits by reducing waste from disposable cups and promoting efficient beverage consumption. By leveraging cutting-edge technology and design principles, our project aims to create a smart mug that offers a superior user experience at an affordable cost, while promoting sustainability and minimizing waste

1.3. High-level Requirements

Accurate and precise temperature control	The smart mug must be able to accurately and precisely control the temperature of the liquid it contains. The heating subsystem and sensor subsystem must work together to ensure that the temperature of the liquid is maintained at a desired temperature within ±1°C range.
Reliable and consistent connectivity	The microcontroller with Wi-Fi transceiver must provide reliable and consistent connectivity to the Android application subsystem. The mug must be able to connect to the internet and communicate with the application without interruption or dropped connections.
Robust and easy-to-maintain design	The smart mug must be designed in a manner that enables easy washing and charging of the device without any damage to its electronic systems.

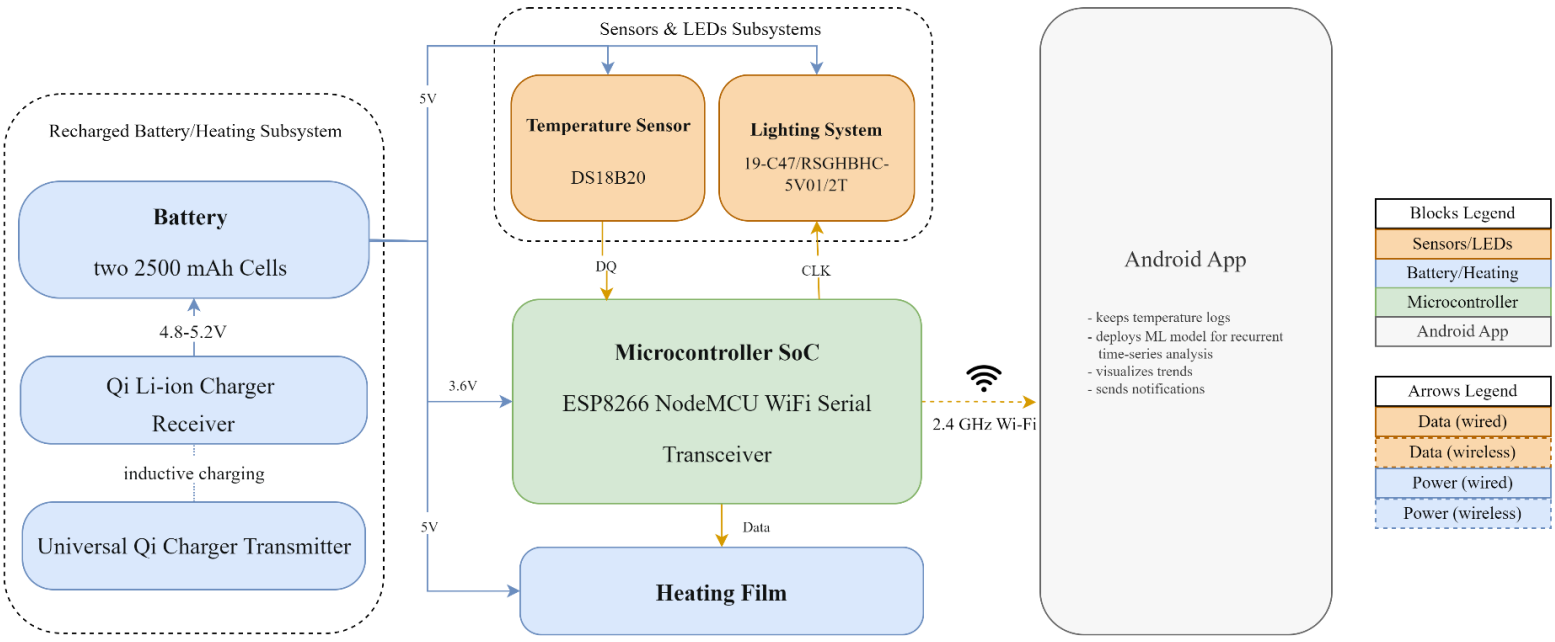
Competitive pricing	The product must be affordably priced and offered at a cost that is 20% less than other comparable smart mugs in the market.
Safe and user-friendly design	The design of the mug must be safe and user-friendly, with features such as spill-proof lids, easy-to-use controls, and heat-resistant materials. The lighting system and Android application subsystem should provide clear and easy-to-understand feedback to the user about the temperature and status of the mug.

1.4. Visual Aid



2. Design

2.1. Block Diagram



2.2. Subsystem Overview

Subsystem 1 Sensor and LEDs Subsystem

This subsystem includes two important components: temperature sensor and LED lights which indicate the temperature range of the input liquid. The sensor module will be implemented with the industry standard temperature sensor by Maxim Integrated (DS18B20). This module takes input from the sensors with the detected temperature and delivers the present output to the microcontroller. For the LEDs, the current preferred option is 19-C47/RSG BHC-5V01/2T, which can address three different lights (Red, Green and Blue). For the LED module, it will be implemented through the microcontroller and change to the corresponding color of different range of temperatures.

Requirements	Verification
Temperature sensor must accurately measure the temperature within ±1°C range	Measure the temperature of a known heat source at different temperatures and compare the readings with a calibrated thermometer
LED lights must change color according to the temperature range of the input liquid. LEDs change to red if the temperature detected is more than 5% above the desired temperature. LED becomes blue if the temperature detected is over 5% below the desired temperature.	Observe the color change of the LED lights when the temperature of the input liquid changes and verify that the LED lights change to the correct color.
The microcontroller must be able to receive the temperature data from the sensor and translate it into the corresponding color of the LED lights accurately and in real-time	Simulate different temperature inputs to the microcontroller and verify that the LED lights change to the correct color in real-time.
The temperature sensor and LED module must be able to withstand an operating temperature up to 80°C	Test the temperature sensor and LED module in an environment with temperature levels within the specified operating range and verify that they can operate properly under these conditions.

Subsystem 2 Control Subystem

This control system manages all the data from other subsystems. It will control the other subsystems, receiving and delivering data, and send logs to a server that visualizes data and handles possible app notifications. The microcontroller used in our project is ESP8266 NodeMCU board, a standard Arduino generic microcontroller with a serial Wifi transceiver to regulate power. The board comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects. NodeMCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface. We will program the board using Arduino IDE.

Requirements	Verification
The microcontroller must be able to comprehend the data received from analog components.	Construct a completed Smart Mug and connect the design to a power supply. Verify the voltage using an oscilloscope connecting to the output I/O port.
The control system must be insensitive to the environment changes like temperature. It shall not be affected by small changes in the certain parameters of the system.	Operate the heating system and verify the stable running of the system by using an oscilloscope connecting to the output I/O port.
The microcontroller must be able to receive data and operation commands from the android application via Wifi transmitter.	Simulate an operation by implementing the microcontroller and connect it to a LED. Verify the functional status by controlling the on and off of the LED on the apps.
The microcontroller must be able to deliver the data accurately.	Connect an oscilloscope to the output I/O ports and test the output voltage. Confirm the voltage level is constantly high when heating operation is requested.

Subsystem 3 Battery and heating system

This subsystem utilizes an Adafruit universal Qi wireless charging transmitter and receiver modules to perform inductive charging of two Samsung 25R 18650 2500mAh 20A Battery cells. These modules can be configured to track battery level and output a discharge cut-off voltage of 5V. The two batteries are connected to an ICStation 5V 1W 30mmx40mm flexible Polyimide heater plate film for the purpose of heating the mug and maintaining its temperature.

Requirements	Verification
The Qi charger transmitter shall be able to handle a 5V input voltage and a 2A input current from a USB port.	Connect the Qi charger transmitter controller board with a USB port and check the IV characteristics of the two terminals of the coil using an oscilloscope.
The Qi charger receiver shall be able to output 5 V to charge the two battery cells	Do timing analysis of the battery charging cycle by connecting the Qi charger receiver with two batteries with the aid of an oscilloscope
The two Samsung battery cells shall output a sum of 5 V to the heater film	Upon successful configuration of the batteries, test that the discharge cut-off voltage is reasonably close to 5V
The heater film shall keep the temperature of the cup at a maximum of 80°C	Use a calibrated thermometer to test the maximum temperature maintained by the heater film

Subsystem 4 Android Application Subsystem

The Android app subsystem of the smart mug will serve as the central control point for the temperature control system. The app will be designed to be compatible with a wide range of Android devices, ensuring that users can easily download and use the app on their smartphones or tablets. To ensure seamless communication between the app and the mug, Bluetooth

technology will be utilized. The app will be able to connect to the smart mug wirelessly, allowing users to control the mug's temperature settings and other features with ease. The Bluetooth connection will also enable the app to notify the user when the beverage has reached the desired temperature, ensuring that the user is always aware of the status of their drink. The app will also incorporate the ability to turn off the smart mug, allowing users to conserve battery life when the mug is not in use. This feature will ensure that the mug does not remain active unnecessarily, leading to wasteful use of energy. To implement the app technically, we will use Android Studio to build Android apps. The app will be built using Java and will utilize the Android Bluetooth API to establish a connection with the smart mug and receive data related to the mug's temperature settings and battery status.

Requirements	Verification
The Android application shall be able to receive and display data from the microcontroller in real-time	Connect the microcontroller to the Android device via Bluetooth and send data. Verify that the data is received and displayed correctly and with minimal delay.
The Android application shall be compatible with a wide range of Android devices	Test the Android application on a variety of devices with different screen sizes, operating system versions, and hardware specifications. Ensure that the application works correctly on all devices tested.
The app shall be able to connect to the smart mug via Bluetooth	The app will display a message indicating successful connection to the mug
The app shall be able to notify the user when the beverage has reached the desired temperature	The app will display a message and/or send a push notification to the user when the temperature of the beverage in the mug reaches the desired temperature
The app shall be able to turn off the smart mug	The app will send a signal to the smart mug to turn off when the user taps the "turn off" button in the app

The app shall allow users to adjust the temperature of the smart mug.	User is able to easily adjust the temperature of the smart mug through the app and the temperature of the beverage in the mug reflects the desired temperature setting.

2.3. Tolerance Analysis

The heating time ultimately depends on the substance being heated. The flexible heating film has a maximum temperature of 80°C with a power of 1W. The following theoretical analysis shows the expected time required to maintain a temperature of 80°C with a fully charged battery subsystem that can draw continuous 4.8 - 5.2V of voltage to the film. The underlying (not necessarily realistic) assumption here is that no dissipation of temperature occurs due to the interaction with the mug's surface. This oversimplified model will undergo further investigation.

$m * C * \Delta T = E = (1W)/\text{time}\ (1s)$

$\text{time} = m * C * \Delta T = (10\ \text{oz}) * (0.03L/1\text{oz}) * (4.186\ \text{kJ/L°C}) * (80°C) = 627.9\ \text{min}$

3. Ethics and Safety

The IEEE Code of Ethics expected us, as future engineers, to commit ourselves to the highest ethical and professional conduct. We are highly aware our responsibility as engineers and we all agree:

I. *To uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities*

A. **As a group we will make sure that we do not take ideas from others or online without correctly citing them. We will make sure that we hold each other accountable and double check everyone's work. We will make sure we take in consideration the help that the TAs and other students provide us and properly implement them while also citing them.**

1. to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment;

2. to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems;
3. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
4. to avoid unlawful conduct in professional activities, and to reject bribery in all its forms;
5. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others;

6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

II. To treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others.

A. As a group we will make sure that we are respectful to others. We will make sure to use respectful language and never hurt anyone else. We will all hold each other accountable. We will never discriminate or judge another person in the lab or outside the lab. We will treat all persons fairly. We will also make sure we respect one another and to never use hurtful language. We will communicate with each other effectively and hold each other responsible for our actions.

1. to treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;
2. to not engage in harassment of any kind, including sexual harassment or bullying behavior;
3. to avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses;

III. To strive to ensure this code is upheld by colleagues and co-workers.

A. **As a group we will make every effort to uphold this code of conduct and hold each other accountable for this code. We will make sure none of us break this code. We will respect each other and make sure we are also respected.**
    1. to support colleagues and co-workers in following this code of ethics, to strive to ensure the code is upheld, and to not retaliate against individuals reporting a violation.

We are committed to have personal standards of conduct consistent with the IEEE and ACM Code of Ethics, but also beyond it.

Resources

1. Ember Mug: https://ember.com/products/ember-mug-2?variant=30843977826389&a=1&a=1&a=1&a=1&gclid=CjwKCAiAleOeBhBdEiwAfgmXf_lS8_LxedMdbgWazgfJ_4wzhcjqQ7uzlqpE1mobNka8gJXf2WwC5xoCeGAQAvD_BwE
2. Industry standard temperature sensor by Maxim Integrated: https://www.digikey.com/en/products/detail/analog-devices-inc.-maxim-integrated/DS18B20%2BT%26R/3478852?utm_adgroup=Sensors%2C%20Transducers&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Supplier_Maxim%20Integrated_8022_Co-op&utm_term=&utm_content=Sensors%2C%20Transducers&gclid=CjwKCAiAleOeBhBdEiwAfgmXf-hIaZj1YjASEiDZOg5dMMVtSrDlfEeoC1fjx_hQg3LjqtbzHDXz3xoCAXYQAvD_BwE
3. Samsung 25R 18650 2500mAh 20A Battery - INR18650-25R https://www.18650batterystore.com/products/samsung-25r-18650?utm_campaign=859501437&utm_source=g_c&utm_medium=cpc&utm_content=201043132925&utm_term=_&adgroupid=43081474946&gclid=CjwKCAiA0JKfBhBIEiwAPhZXD4K0buQB4llCTCdtCz7RvFwBTh2EiDKCG829OV8GOinTmFSQxTqOxBoCbw0QAvD_BwE
4. IEEE Code of Ethics: https://www.ieee.org/about/corporate/governance/p7-8.html
5. https://www.amazon.com/Aexit-Constant-Temperature-Thermostat-62a01bc958a5f7f6a5ffa32d53a6b472/dp/B0838KJXFW
6. https://global.kyocera.com/prdct/ecd/peltier/
7.