Self-Heating Cup

ECE 445 Design Document

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1 Introduction

1.1 Objective

Coffee and tea culture are long living both in the east and the west. Either of them requires warm or hot water to make. These days, although cafes like Starbucks or even the Daily Byte in ECEB are everywhere in the United States, the temperature of the coffee or tea usually does not hold for a long time. Especially for people who work in the office, they don't want to walk in and out to reheat their drinking. Scenarios like a long meeting and your coffee was totally cold after one hour and you don't have access to a microwave at that awkward moment. Therefore, our objective is to always keep your coffee or tea warm whenever you drink it with our designed mug with a self-heating coaster.

1.2 Background

Our design is specific for people who work in offices and probably will spend much time in their seats. As we briefly explained above, there are for sure products that could heat your beverage like a microwave. However, they are not everywhere. The microwave in ECEB was in the lounge on the 3rd floor. We do see some professors heat their beverage occasionally but more often they don't want to walk up and down stairs to just heat their coffee. The first point of our design is to allow people to stay focused on their stuff and don't have to walk around when working.

The previous project idea Electric Thermos Box, contributed by Celine Chung, Tingfeng Yan and Zerui An is a good approach for solving this problem, but we think that it is still too large to prevent more convenient usage. Their design looks like a small-scale microwave, which like we explained above, you mostly don't want to bring a microwave in scenarios like in-person meetings etc. This comes with our second point that makes the design portable.

There's also a similar product on the market called Ember[1], which is a self-heating mug that has a fully-integrated design. But it also has several problems: according to user reviews, it suffers limited heating ability and potential failure due to integrated design in one mug. Putting the battery, sensors and controllers underneath the hot mug may not be a safe and efficient approach. Based on that, we decided to use a constant power supply since the heating part is only the coaster instead of the mug.

Our design will consist of two parts: a cup for heating and drinking as well as a coaster that provides the power for the cup. For one cup, we can have several coasters in different areas for more portable heat-and-drink experience. The coaster can provide some functionalities like power and controlling, to help simplify the cup's design that makes it safer and more reliable.

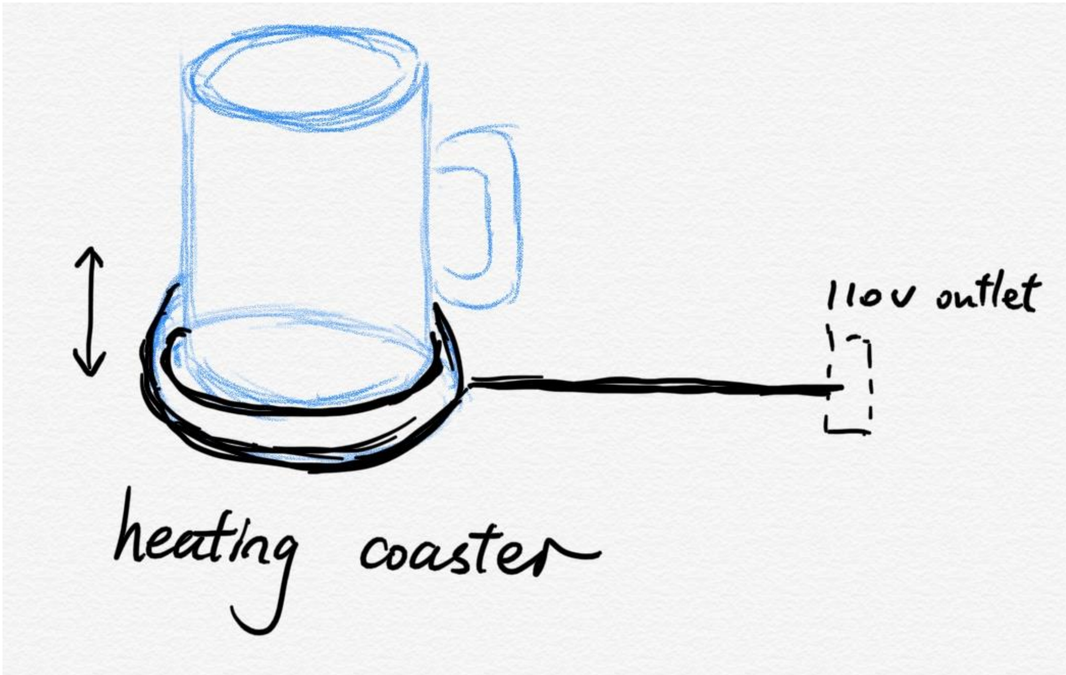

Figure 1. Physical Design for Self-Heating Cup

1.3 High-level Requirements

- The heating process within 10 mins to heat the liquid to certain temperature.
- The difference between the temperature we set and the temperature of the liquid after heating should be less than 5 Fahrenheit.
- The whole design should be fit in a bag and can be carried to anywhere conveniently.

2 Design

High level description of the design

Our design is located heavily on the heating coaster, which requires a power supply, a heating unit and a control unit. The power supply takes in the standard 110V voltage input and powers the rest of the design using several linear regulators. The heating unit will heat the mug to a comfortable temperature to use. The control unit takes the responsibility to monitor display the temperature measurements and communicates with the control panel, temperature sensors and the heating unit.

Block Diagram

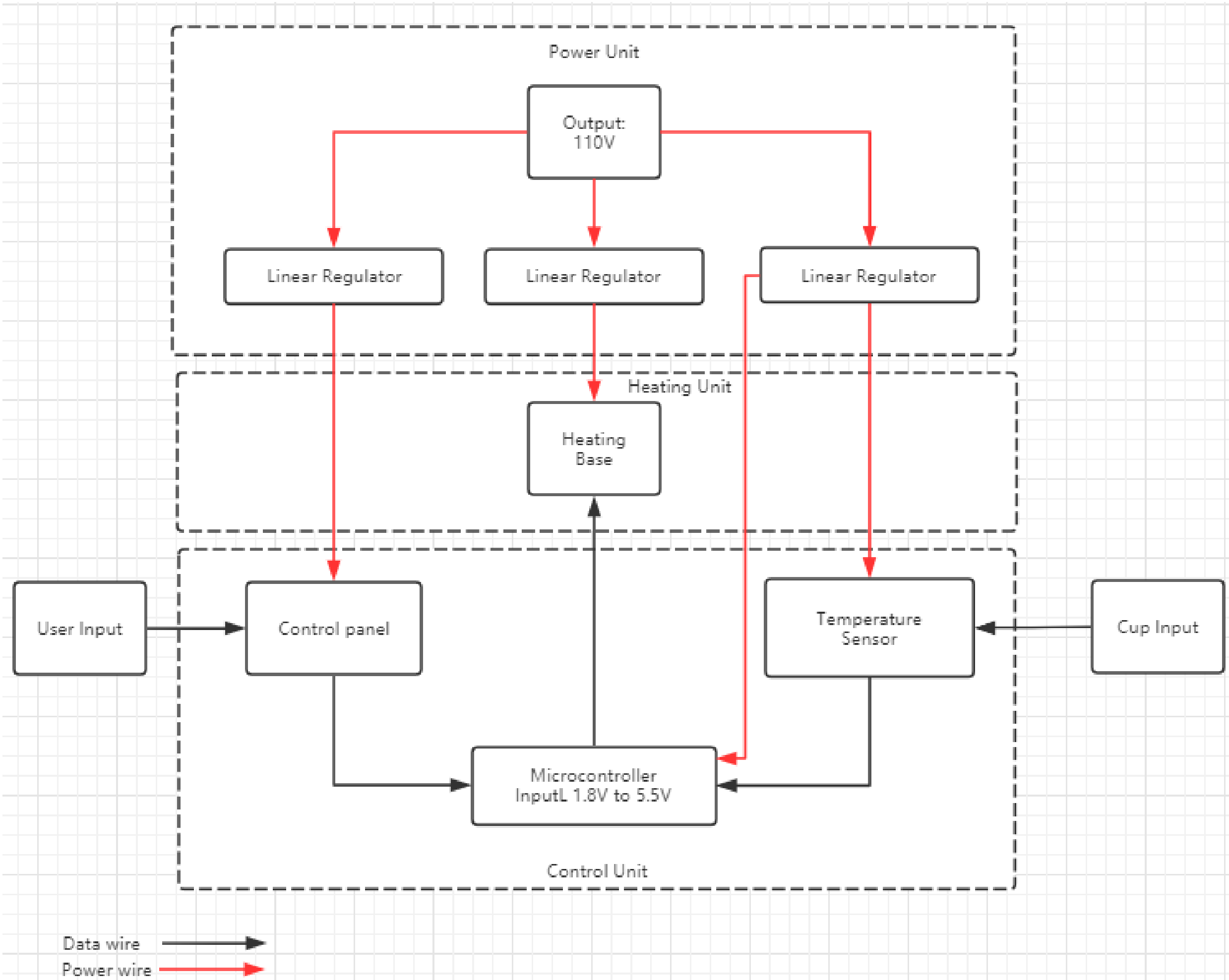

Figure 2. Block Diagram for Self-Heating Cup

2.1 Power Unit

The heating-base will use the 110V standard outlets as power supply and linear voltage regulators to deliver power to the heating unit and control unit.

Requirement: The regulators should be able to deliver enough input voltage to both the heating unit and the control unit. For example, one of the linear regulators should regulate a 110V output voltage to a 1.8V ~ 5.5V input voltage to the microcontroller.

2.2 Heating Unit

2.2.1 Heating base

This is the heater we use to heat the cup and the input of the heater should be 110V.

Requirement: The heater should be able to heat ~200 ml liquid to 40 Celsius in 10 minutes.

2.3 Heat insulator

2.3.1 Insulator layer

There is a heat insulation layer around the handle of the cup to prevent user's hands from overheating.

Requirement: Users can hold the cup safely when the liquid in the coffee cup is around 50 Celsius.

2.4 Control Unit

2.4.1 Control panel

There is a screen to show the current temperature and the temperature set by the user. There are four buttons: the first one is to raise the temperature, the second one is to lower the temperature, the third one is to begin the heating process, the fourth one is to stop the heating.

Requirement: screen and buttons should be waterproof.
Requirement: can resist the extra heat without compromising functionalities.

2.4.2 Temperature sensor

This sensor is fixed on the base and is used to monitor the temperature of the cup.

Requirement: The temperature sensed by the sensor on the base should not be too different from the temperature of the liquid (less than 5 Celsius).

2.5 Risk Analysis

The heating unit is the major risk inside our design since we want to keep a high power within a relatively small coaster. Also, the heating unit is the part that communicates with parts that are in the microcontroller. Therefore, problems like overheating during the heating process should be considered seriously. Since our design will deal with liquid like coffee, making sure that spilled liquid won't affect the full functionality and lead to potential fire.

On the other hand, the temperature measurement could be another risk in that usual mugs are made of ceramics. The reason for that is ceramic retains heat better than materials like glass both in terms of conduction and convection. (i.e. two major ways of heat loss) [2] However, in the case of heating ceramic mug using microwave, the top side of the mug is usually very hot while the bottom side is still cold and hence the temperature measurement in our design is crucial to maintain the mug comfortable to use and temperature-accurate in a range. (i.e. 30 Celsius ~ 40 Celsius is acceptable.)

3 Safety and Ethics

For our project, we have to guarantee safety while using our design to drink. While it involves both powering and heating in a relatively small space, there are several potential safety issues that we need to pay attention to.

The first issue is about heating: while heating the liquid, the extra heat could not only interrupt the functionality of our design but also could destroy other parts if it exceeds the thermal limit. For example, the ATmega328p's operational temperature has a maximum of 85 °C [3]. During our design and building process, we will closely monitor the heating temperature, isolate or dissipate these extra heat as much as we can to prevent thermal issues from happening. We can also set a software temperature barrier using the internal temperature sensor in ATmega328p to cut off the system if it is alarmingly overheated.

The second issue could come from the potential hazard from the liquid, that could cause the water damage to the system. Our solution is to solidify our system, including PCB, to be water-resistant from hot water and moisture. Some post-processing of the PCB can make it waterproof up to IP48 protection level. We will aim for the IP48 protection level, as we should also be safe in events like spilling water accidentally over it. The PCB will be mainly on the heating coaster, so waterproof is mainly about the heating coaster, while the cup itself would be a fully integrated design.

As safety comes first in our design, it also corresponds to the first goal in IEEE Code of Ethics: "hold paramount the safety, health, and welfare of the public..." [4] We will always put the safety as our top priority for our project. It also corresponds to the ninth goal in IEEE Code of Ethics, "to avoid injuring others, their property, reputation, or employment by false or malicious action;" [5], that we will eliminate the possibility of injuring others by false.

We will share our design document and open source all materials needed for this project. This is also aligned with the tenth goal in IEEE Code of Ethics, where it states that “to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.” [6]. Thus, we encourage to learn, share and improve this project further in the future.

References

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