ECE445
Senior Design Laboratory
Project Proposal

Smart Kettle Module

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Contents:

1. Introduction

1.1 Objective

Nowadays, people are living a fast-paced life. “One of the characteristics of modern life seems to be that we are moving at an ever-increasing rate, regardless of turbulence or obstacles. [1]” We are always trying to improve the efficiency of everything. “It seems that a lot of people, to be exact 432,300,000 of them, want to learn how to be better at executing their activities.The reason for this is, even with all the technology we have, we’ve never been busier. [2]” Boiling water is one of the time-consuming activity that people may want to improve. Although there are already some types of smart kettle existing in the market like “Black + Decker™ 1.7-Liter Rapid Boil Electric Kettle, [3]” the functionalities of these kettles are not ideal enough. The regular kettles require the users to stand aside and wait until the kettle is fully filled otherwise the kettle might be overfilled. “Three-quarters of British households overfill their kettles, wasting a total of £68m each year, an Energy Saving Trust (EST) report has suggested. [4]” There are scenarios when the users go back to the kettle and see the water is not ready yet. They will either wait next to the kettle until the water is ready or go back to work. Both ways are a waste of time. It would be ideal if we can have some new features that can save us time from keeping checking the kettle.

We propose a kettle-module that provides users with better experience. In the application, the module would be connected to the kettle. The kettle-module has three main features. The first one is filling water automatically. Weight sensors would be implemented and control the amount of water to prevent overflow. Next, to avoid the situations when users get back to the kettle and see the water has not fully boiled yet, the kettle-module would display the remaining time required for the water to reach the target temperature on a LCD screen. Finally, the kettle-module would introduce a new way to keep warm. Different from the traditional way of keeping warm, which is maintaining the temperature at a specific level, our kettle-module will not reheat the water until it is 5 °C lower than the target temperature. The time of keeping warm is also controllable.

1.2 Background

Our idea comes from our own experiences in daily life. Most people also have the same experience waiting in front of a water kettle just to let it refill, and boiling water. Take one of our group member’s electrical kettle as an example, which is a 2-liter stainless steel hamilton beach electric kettle. It takes him 2 mins to let the kettle fully fill the water and 10 mins to boiling water. If he decides to make tea with boiling water, that would be another 10 mins for tea to cool down at a servable temperature. It is hard to give a precise value for one’s time, but “The average salary in the UK is now £26,500 which equates to £14.56 an hour for a standard 35 hour week. This means that if a typical worker makes six cups of tea or coffee in a day and spends three and a half minutes away from their desk for each cup it all adds up to 21 minutes a day and a staggering one and three-quarters of an hour over the whole week. That’s £25.50 a week in lost time.”[5]

In fact, not only us come with the smart electrical kettle idea. A website called smarthomebit already predicted the best selling smart kettle for 2021. From its opinion, the overall best smart kettle is called smarter ikettle 3rd generation. Its signature features are operation “at a diverse temperature ranging from 68-212 degrees Fahrenheit” [6], remote accessing, and preparing the steaming water at a certain time.

Our project can also preset different temperature levels and keep the kettle at that temperature for a certain amount of time no longer than one hour. One of the advantages of our product is minimizing manual operation. We combined adding water, boiling water, temperature controlling, data recording all in one place. For adding water, Weight sensor will detect the water level in our kettle. As long as the water volume is less than 20 percent of the kettle containing volmen, the kettle will be refilled to a certain water level controlled by us from water pumped out of the water tank. Each time, after our product automatically adds water in, the kettle starts to boil water to 100 degree Celsius. After water boils, It comes to temperature control mode. Water will be cooled down to our setting temperature for a set amount of time, and the limitation is one hour. As previously mentioned, our product has four stages: Adding water stage, boiling water stage, cooling down stage, and keeping warm stage. The LCD panel in our product is completely responsible for displaying data recorded. It will show us at what stage the product is at, how long it stays in this stage, how long time left, and basic status of the water in our kettle like temperature and weight.

1.3 Physical Design

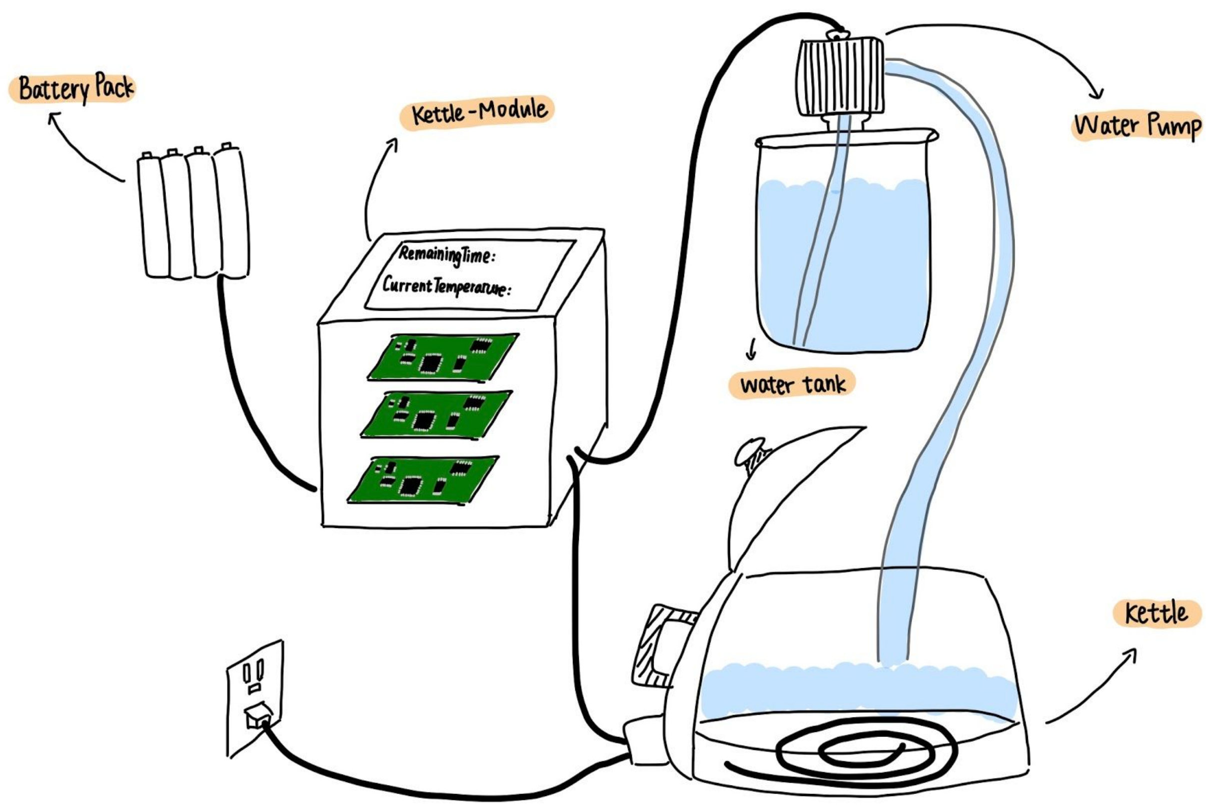

Figure1. The connection of kettle, water pump and kettle-module.

1.4 High-level requirements list

- Water has to be automatically stopped pumping, when the water level reaches our expectation, could be full or half full. The difference between our expectation weight and the real weight of the water bottle can’t be larger than 100g.
- The temperature controlled unit has to control the water temperature in less than 5 degrees error from our setting temperature, and keep it from 0 to 60 mins as what we pre-set.
- The LCD panel has to be fast respond within 2 secs when the temperature and weight inside the kettle rapidly changes.

2. Design

2.1 Block Diagram

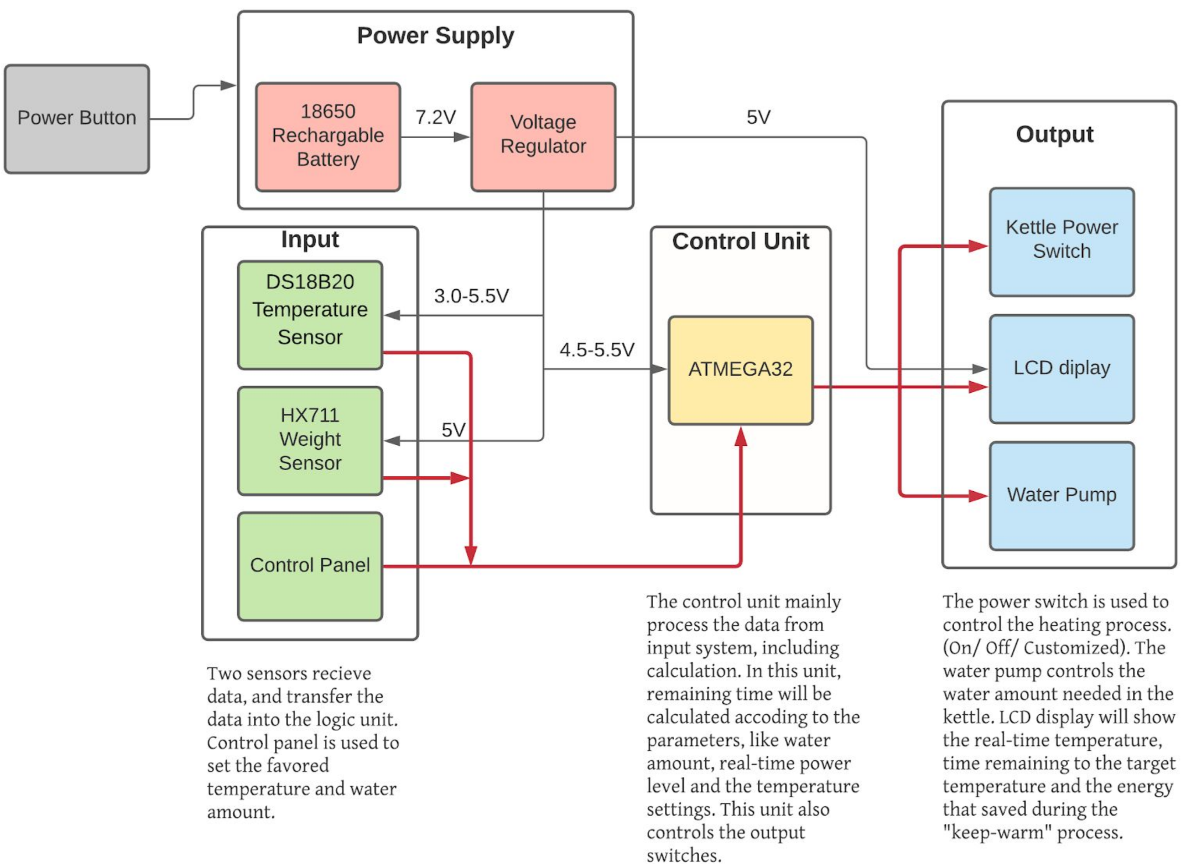

Figure2. The block diagram of the whole project.

2.2 Power Supply Subsystem

2.2.1 Voltage regulator

The battery we choose to use is 7.2V, but we actually need different voltage inputs from 3v to 5.5v. A buck converter can do the trick. a buck converter with PWM signal to control the duty circle of the switch(probably a NMOS). Then, we get feedback error signals to adjust our PWM signal. The feedback error voltage is the difference between the desired voltage output and the actual voltage from that converter. We also need a high side gate driver for the NMOS switch to make sure the input signal is not floating. The specified design was shown at the following figure. Since we need to provide different dc voltage levels, we can just set the expected output voltage on the DE10-lite which will control the PWM and give error feedback to adjust the output voltage to what we want.

Requirement: Must stabilize the input voltage at 5V with the error less than 0.5V.

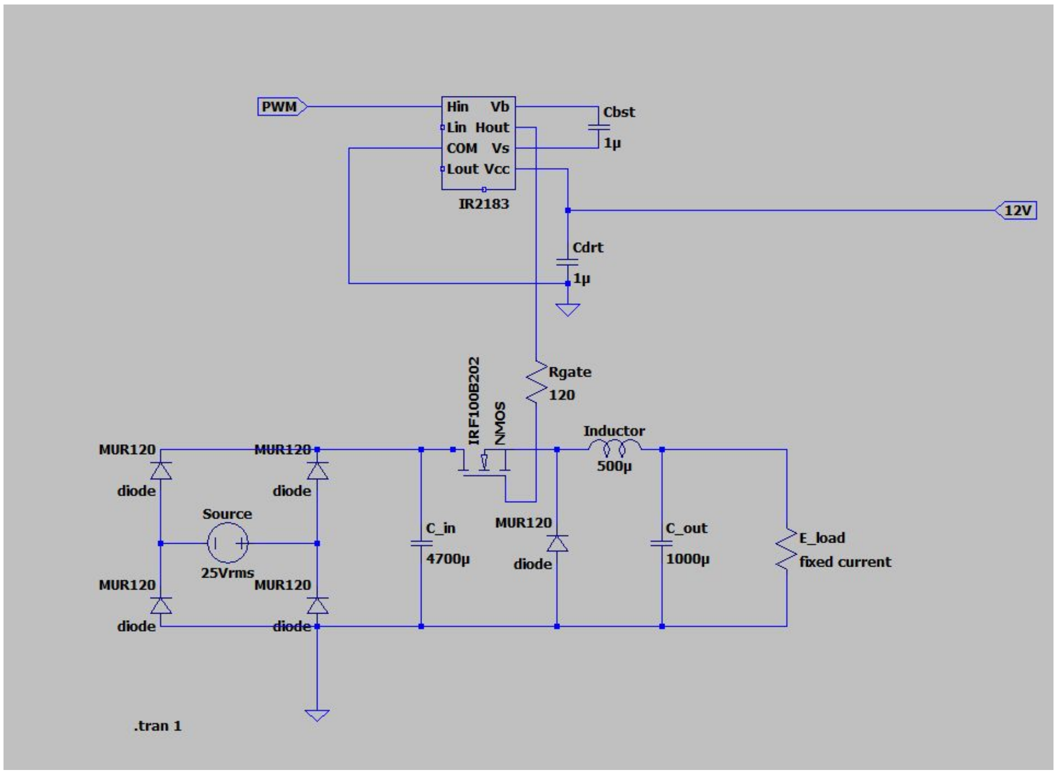

Figure3. Circuit of the voltage regulator

2.2.2 18650 Battery Pack [7]

Battery pack provides power for our project components, not a power source for the electrical kettle. Two 18650 batteries will be connected in series, and will provide 7.2V for the entire system.The voltage regulator will convert the voltage to 5V, which works for all ICs and sensors.

Requirement: Must be able to provide >50mA between 7.2-8.4V and last for a day when daily use.

2.3 Input System

2.3.1 DS18B20 Temperature Sensor [8]

T.his temperature sensor measures temperatures from -55°C to +125°C with the accuracy of ±0.5°C. This is enough for the project since the temperature range for this design is 0-100°C. It takes input voltage at 3.0-5.5V. We decided to use 5V as supply voltage. Water boiling in our smart kettle will have a temperature range of 0°C to 100°C. So the temperature sensor we choose to use completely satisfies the demand.

Requirement: The sensor needs to be waterproof. The accuracy of the sensor should be within ± 2°C when operating in temperature range.

2.3.2 HX711 Weight Sensor [9]

The weight sensor operates at 1.5mA between 2.6-5.5v. It has on-chip active low noise PGA with selectable gain of 32, 64 and 128. Operation temperature range: -40 ~ +85℃. There will be a corresponding load cell with loading range from 0 to 20kg installed with the weight sensor.

Requirement: The sensor will be able to scale weight with +- 10g error within the weight range (0-20kg).

2.3.3 Control Panel

The control panel is used to select favored temperature and water amount according to different needs. We plan to make our own panel with physical buttons.

Requirement: Time delay from out control panel to output unit has to be within 1 sec.

2.4 Output System

2.4.1 LCD Display

A LCD screen will be used to display real-time temperature, remaining time, and water amount. All the data is processed by the control unit. For example, the water temperature (both initial temperature and target temperature), real-time power level, and water amount will be collected by sensors and calculate the time remaining for water to reach the target temperature. The screen would be installed outside the module box, so that the design should be water/dust proof.

Requirement: The screen must be waterproof. The screen has to display all the data with exact value.

2.4.2 Water Pump

A 12V water pump [10] will be implemented to pump water into the kettle. The water pump will be powered by an extra rechargeable battery pack.

Requirement: The water pump can operate within a normal pressure range (60-90 psi) without leaking. The water pump must fill the whole kettle (1.5L) within 30 sec.

2.5 Control Unit

The control unit would be one or more PCBs in a waterproof box. The core of the control unit would be a programmable microcontroller, like ATMEGA32 [11]. All the data will be processed here. The control unit will not only be used to calculate the time, but also be used to make commands for the output system.

Requirement: The unit is programmable and modular. The control unit needs to be able to process input data and send out data with exact value.

2.6 Block Requirements

- **Voltage regulators** must stabilize the input voltage at 5V with the error less than 0.5V.
- **The battery pack** must be able to provide >50mA between 7.2-8.4V and last for a day when daily use.
- **The temperature sensor** needs to be waterproof. The accuracy of the sensor should be within ± 2°C when operating in temperature range.
- **The weight senso**r will be able to scale weight with +- 10g error within the weight range (0-20kg).
- Time delay from **control panel** to output unit has to be within 1 secs.
- The **LCD screen** must be waterproof. The screen has to display all the data with exact value.
- The **water pump** can operate within a normal pressure range (60-90 psi) without leaking. The water pump must fill the whole kettle (1.5L) within 30 sec.
- The **control unit** is programmable and modular. The control unit needs to be able to process input data and send out data with exact value.

2.7 Risk Analysis

Due to the high temperature, the ICs may be damaged easily, which will lead to malfunction of the whole system. Without proper programming and voltage regulation, other components may be damaged as well.

Another challenge for us is precisely controlling the output units which include faucet switch, LCD display, and power switch. Signals come from the weight sensor or the temperature sensor might not have that obvious difference when the weight or the temperature of water increases in a small amount. For example, a temperature sensor might give almost the same signal feedback with 30 degree Celsius and 31 degree Celsius. Thus, it might be very hard to accurately control the temperature and the weight.

3. Ethics and Safety

This device serves for a better, easier, environmental-protected life. Without spending time on trivial things like boiling water, we can put more energy onto things we care about and we love. With the energy saving mode on the smart kettle, everyone who uses this machine can have one step forward on the environmental protection cause.

There are lots of safety issues especially when we operate the control unit to manipulate the 110v household voltage source to boil water in our smart electrical kettle.The IEEE Code of Ethics states that members have a responsibility "to avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses."[12]

Thus, it is important for us to double check the circuit and test the circuit using a low voltage input before we actually put our circuit on that household voltage level. High temperature water would be another issue we have to deal with. Water itself is dangerous when it comes with circuits, especially that our product needs to be attached to many different types of electrical kettle. Different electrical kettle can have different sizes of base. If our product wasn't attached tightly to the kettle, water might flow into the circuit causing hardware damage and then lead to electrical leakage.We will make components of our circuit either waterproof or way apart from water. Temperature could also be a safety issue. High temperature water can scald one's skin and also might dissolve the material of our temperature sensor. So when we choose our components, we have to put thermal stability and waterproof into consideration.

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