Stove Controller for the Forgetful

Team 20 - Alex Makeever, Samir Kumar, Sujal Sutaria
ECE 445 Project Proposal #2 - Spring 2020
TA - Johan Mufuta

1 Introduction

1.1 Objective

Forgetting to turn the stove off can be a major problem in households with children and the elderly. Children are at risk of burning themselves by touching hot surfaces, and it is possible to even start a major fire if there is nobody near a stove that is left on. Nationally, the most common fire department emergency is caused by kitchen fires, with 49 percent of Minnesota structure fires being caused in the kitchen in 2009 [1]. Based on a 2019 NFPA report on home cooking fires, unattended cooking is the most common cause for kitchen fires [2].

Furthermore, over half of the nation's households are now being headed by someone at least 50 years of age, while "the number of households headed by adults in the 65–74 year-old age range [are] climbing 26 percent in 2011–2016" [3]. These elderly are at increased risk of subjective forgetfulness [4] and are more prone to leaving the stove on accidentally.

We propose a device which will connect to the stove power such that it can cut off power to the stove itself. The device will monitor the relative location between the stove and the stove user through a wearable and when a certain distance threshold is met, the wearable will show a notification to the user to remind them to either turn off the stove, set a reminder time, or set a timer after which the stove will turn off. This will ensure that users are always aware when they are leaving the stovetop unattended and that the stove can turn itself off before a fire occurs.

1.2 Background

One of the most common approaches for commercially developed solutions is to provide users information about the status of the stove through a phone application. Often, these applications also allow the user to remotely shut off the stove. An example of such a product is the Inirv React. This device not only controls the stove through a smartphone application, but it also turns off the stove when smoke is detected and when the device senses no motion for fifteen consecutive minutes. However, the device is very expensive (over $230) and the motion sensing feature may not be suitable for all kitchens, as countertops may impede the device's ability to sense the presence of a user.

Another common solution for commercially developed products is an alarm system to inform users of a stove which is left on, such as the HomeSensor Uniwire. This solution is also expensive, selling for $350, and the alarm system may not be effective in the case that no users are home to hear the alarms or make any changes to the stove. The alarm system can also confuse home occupants because they might not know what that alarm means. This might cause undue panic, which can result in bodily harm, especially to the elderly.

Most of these available products add on to the stove. These solutions are then limited to the type of stove they are operating on, electric, or gas. The proposed solution will be generalized to both types of stoves since there are no changes to the stove itself, eliminating design complexity as well as overall price.

This problem was presented in Spring 2019 by group number 75. Their solution was to add a fire detection system to the stove using an IR sensor and a gas sensor. Data would be collected from these sensors to toggle power to the stove and inform users of a fire through a phone application. This approach is useful for when a stove has been left on long enough to cause a fire, however this is somewhat redundant as the Carbon Monoxide detectors already installed in every home will detect a fire. Some of these detectors are even connected to the internet and can automatically call the fire department. In addition, it is unclear if turning off the stove will successfully quell a fire.

Our solution takes on a more proactive approach, rather than simply reactive. The new solution can alert the user when they have taken an action that could possibly result in a hazard to occupants. A proactive solution more effectively avoids potential bodily injury and property damage due to its preventative nature. This approach is especially helpful for the elderly because elderly consumers may not be able to react as fast as others when a dangerous situation arises. Also, elderly people may be more apt to select a solution which is less technologically complex, which is why the solution of a simple wearable, as opposed to a smartphone application, is ideal for this demographic.

1.3 High-Level Requirements

- The system should be able to determine when the user has crossed an unobstructed threshold distance between the stove and the wearable with an accuracy of +/- 5 feet.

- The user should be able to select time reminders between 0-30 minutes at increments of 30 seconds.

- The system should be able to allow 120 V/60 Hz power to the stove and toggle the power input.

2 Design

The design of this system will consist of three main modules: the Stove PCB module, the Power Distribution module, and the Personal Wearable module, as seen in Figure 1. The Stove PCB and Personal Wearable module will each be individual PCBs. Wall power will supply the Stove PCB, while the Personal Wearable will be powered by rechargeable batteries.

2.1 Block Diagram

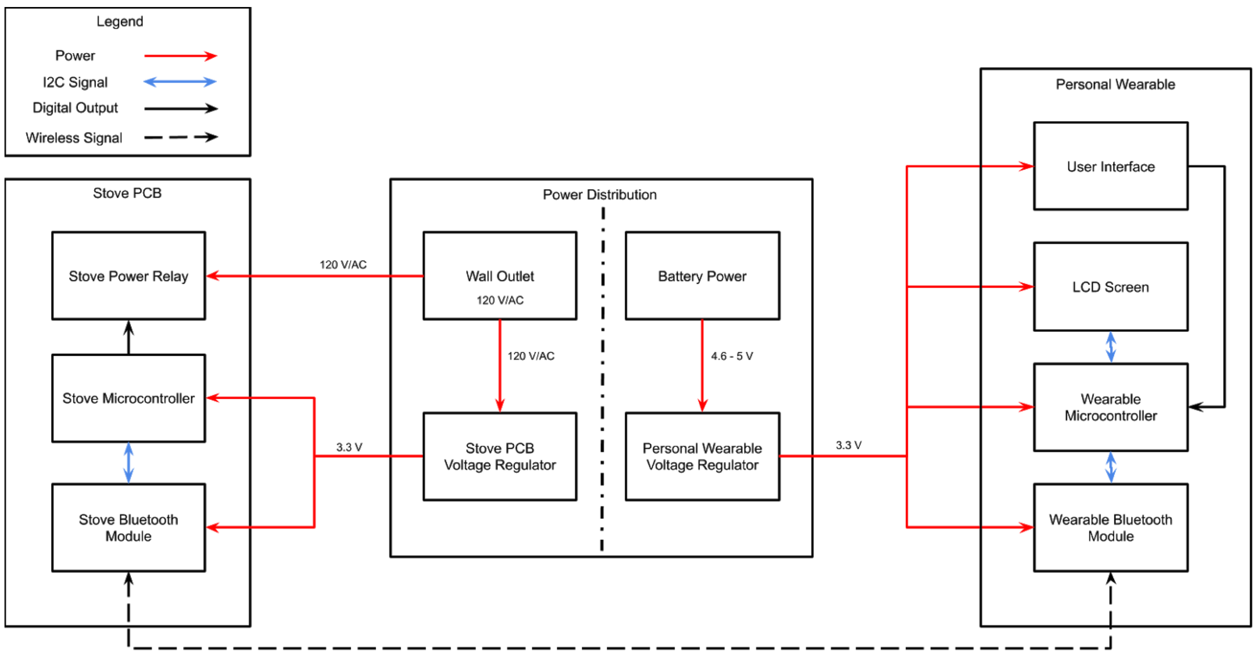

Figure 1. Block Diagram

2.2 Power Distribution

The power distribution module will be the system that supplies all the necessary voltages to the integrated circuits for efficient power transfer.

2.2.1 Stove PCB Voltage Regulator

Stoves are typically powered from a standard 120 V/60 Hz outlet, so we will use the same power for the input to the Stove PCB to decrease design complexity. This voltage will need to be rectified and stepped down in stages in order to reach the low voltages required by the integrated circuits.

Must step down wall power to 3.3V +/- 10%
Must be able to provide at least 500 mA of current.

2.2.2 Battery Power

The wearable device will be powered solely off of battery power. These batteries will be rechargeable so that the device can be charged when not in use. This means that the battery capacity can be low as extended use periods will be infrequent. The integrated circuits on the wearable will primarily use 3.3 V so there will be voltage regulators to transition the input battery voltage to the desired value.

Must be able to provide at least 200 mA of current for up to eight hours.
Must have a nominal battery voltage of at least 3.8 V.

2.2.3 Personal Wearable Voltage Regulator

The Personal Wearable Voltage Regulator will take the battery voltage and convert it to 3.3 V in order to power the integrated circuits on the wearable device.

Must provide 3.3 V +/- 0.2 V.
Must be able to provide at least 200mA of current.

2.3 Stove PCB

This module will regulate power to the stove. It will communicate with the wearable module to determine whether or not to power the stove off.

2.3.1 Stove Bluetooth Module

This module will send notifications to, and receive acknowledgements from the wearable. This module will also calculate the relative signal strength between the stove and the wearable. This will be used to determine whether the user is too far away from the stove.

Must be able to communicate with I2C communication protocol.
Must be able to provide an accessible RSSI measurement.

2.3.2 Stove Microcontroller

The Stove Microcontroller module will interface with the Stove Bluetooth module to send packets of data to the wearable. These data packets will be notifications of when the user has crossed an approximate distance threshold and when the selected time has expired. The microcontroller will also, in parallel, be calculating the amount of time which has passed since the most recent notification and the approximate distance between the user and the stove. The microcontroller will then use this data to determine if the stove should be turned off, at which point it will send the appropriate control signal to the Stove Power Relay module to disconnect power to the stove.

Must have at least one I2C communication bus.
Must have at least one scalable counter which can be adjusted to count in the range of seconds.

2.3.3 Stove Power Relay

This module will be the main switching mechanism for power to the stove. It will take in power from the wall socket and output this power to the stove. The relay will be controlled by the Stove

Microcontroller so that it is turned off after the timing and distance thresholds have been violated.

Must be able to switch 120 V/60 Hz power.
Must be controlled by a 3.3 V control signal.

2.4 Personal Wearable

This module is used to measure the distance between the user and the stove. It will be worn by the user and will have the appropriate I/O for the user to acknowledge notifications sent from the stove PCB and to set reminder timers for acceptable “no oversight” periods.

2.4.1 Wearable Bluetooth Module

This module will send and receive data from the stove PCB . This module will pass data from the microcontroller to the stove PCB and back.

Must be able to communicate with I2C communication protocol.

2.4.2 LCD Screen

The LCD screen on the wearable will be the method by which the user is informed of the status of the system. Data will be received from the microcontroller and displayed on the LCD screen.

The LCD screen must be programmable via I2C interface.

2.4.3 User Interface

This module will be the way users select the amount of time between notifications. It will consist of several buttons to change the selection on the LCD screen.

Must consist of buttons which are pressed without excessive force.
Must provide a sufficient number of buttons to acknowledge/dismiss notifications and change times between notifications.

2.4.4 Wearable Microcontroller

This module will interface with the Personal Wearable Bluetooth module, User Interface module, and LCD Screen module. The microcontroller will send 3 different types of information, notification acknowledgment, adjustments to notification interval period, or stove turn off time. The microcontroller will also receive threshold notifications from the stove via the Wearable Bluetooth module. All of this data will be communicated to the user through an LCD screen. The microcontroller will program the LCD screen to display threshold notifications, timer settings, and turn-off settings. This module will receive data from the User Interface module indicating user preferences, and will pass this data off to the bluetooth module for transmission to the stove.

Must have at least one I2C bus.

2.5 Physical Design

The first part of the physical design for this system will involve an enclosure for the Stove PCB, seen in Figure 2 below. The device will have 3 prongs and plug directly into a wall outlet.

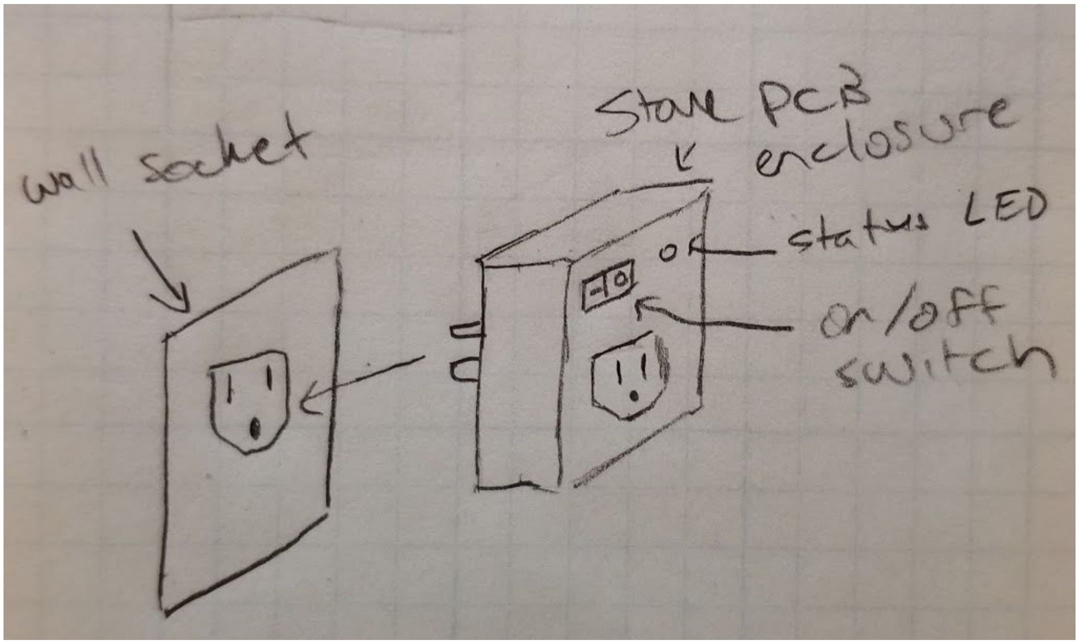

Figure 2. Stove PCB Enclosure

The second physical design will be for the wearable device. This device will be worn on the wrist of the user and will consist of an LCD screen and several buttons, composing the User Interface. See Figure 3.

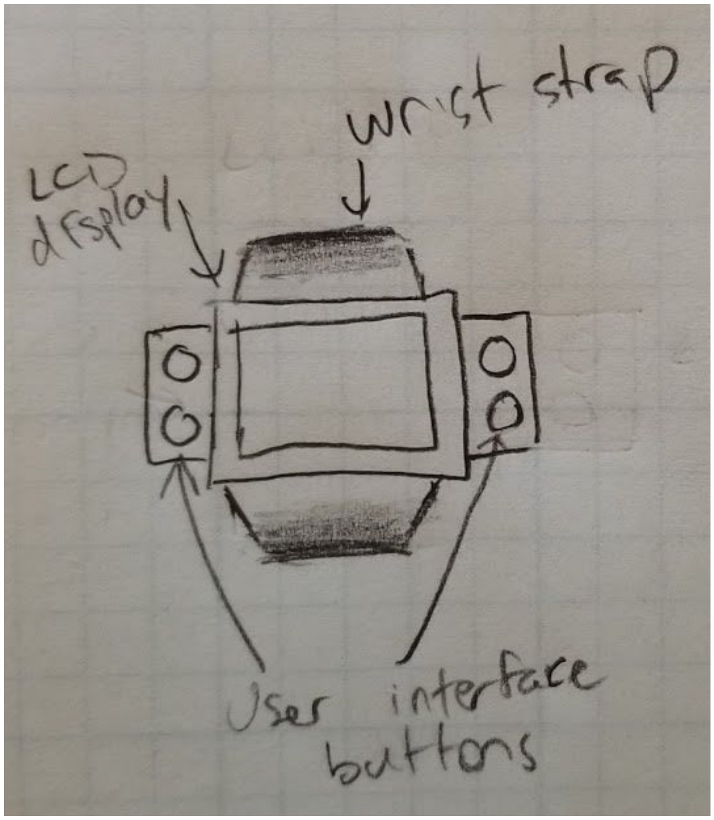

Figure 3. Personal Wearable Physical Design

2.6 Risk Analysis

The interface which poses the greatest risk to this project is the bluetooth communication. We will be using the bluetooth devices to approximate the relative distance between the user and the stove through the measurement of the Relative Signal Strength Indicator (RSSI). Although we will not be using this measurement to provide an exact distance measurement, we will need this approximation to be free of major changes in the calculation while the user is still near the stove. RSSI is known to be affected heavily by obstacle obstructions, so a large part of the project will involve determining a method of using the measurement which provides a good user experience while still accomplishing the goals of the project. This will involve lots of research during the design phase of the project to determine the best and most accurate methods of approximating distance between two bluetooth devices. We will also need to perform extensive testing and verification with the chosen algorithm so that we can optimize it for the specific use case.

Incorrect threshold calculation can result in improper communication with the user. The system could be too sensitive to change and might notify the user more than necessary. This would result in the user not taking notifications seriously, ignoring the system all together. On the other hand, if the system overcompensates for the fluctuations in the distance calculation, safety issues can be caused when the user steps away from the stove without the system noticing.

3 Ethics and Safety

3.1 Ethics

This project deals very closely with the safety of the public in the household, which is covered in the IEEE Code of Ethics #1: “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment.” In order to comply with this code, we will test our system very thoroughly in a variety of situations and environments before releasing it to the market. We will also be sure to provide ample documentation and warnings to ensure its proper use. If ever we discover a flaw in our design, we will ensure that this is known to the users of the system before we work tirelessly to fix it.

In addition, our project relies on the use of sensor data to provide information regarding the activity of the stove. This can possibly infringe on IEEE Code of Ethics #3: “To be honest and realistic in stating claims or estimates based on available data.” We must be very careful while reporting data to the microcontroller in order to avoid any false positives or false negatives. This is paramount when letting the user know whether the stove is on or not. In order to make sure we abide by this code, we will research methods to reduce the amount of false readings and will make sure to implement them in our solution. Throughout the project, we will continue to test and adjust our design to ensure that all readings are used appropriately.

We will also be connecting our product to a user’s stove and home since it will be connected to the wall socket and stove plug. If the product is designed poorly, it could infringe on the IEEE Code of Ethics #9: “To avoid injuring others, their property, reputation, or employment by false or malicious action.” If the product is not designed properly, it could have a major impact on the user’s property including starting a fire and causing physical damage to the stove and home. In order to adhere to the standard, we will make sure to design the product with no malicious intent. In no way will the product aim to destroy any of the user’s property and make sure that the user stays safe while in operation of the product.

3.2 Safety

One safety issue with our project is the fact that the product will have to step down and turn on/off 120 V wall power. This high voltage is not only dangerous for us as designers when we test the product in the lab, but it can also be potentially dangerous for the customers if designed improperly. In order to avoid the danger this presents, we will be sure to comply with all guidelines set by the ECE 445 course staff. These guidelines include having any high voltage circuit checked by a knowledgeable instructor before testing. Regarding customer safety, we will ensure that the final design exposes no high voltage wires that can potentially cause harm. We will also ship the product with an extensive safety guideline manual and put printed warnings inside the device regarding the high voltage danger in the case that the device is opened.

We are also planning to power the wearable device with a rechargeable battery. This presents additional safety risks, especially with potentially dangerous chemicals, such as lithium and lead-acid. If the batteries are short circuited, charged too quickly, or overcharged, they present a significant fire hazard which can endanger anybody near the battery. To prevent dangerous situations caused by the batteries, we will utilize a commercially produced battery charger integrated circuit. The charger circuit will protect the battery from short circuit conditions and execute a safe charging algorithm with a regulated current source. We will also only use the charger to charge the battery at a rate lower than the recommended maximum rate in the battery datasheet in order to prevent the battery from being charged too quickly.

The stove itself poses a significant safety issue to the project as well. Since we will be controlling a device which produces heat, if we are not careful when using our device with a real stove, we could create a risk of burning ourselves or others in the area. This is especially true when the stove being used is a gas stove. Gas stoves contain open flames which can ignite flammable objects placed nearby. In order to account for this, we will be very careful about not placing objects near the stove while testing and we will ensure that the area is clear before turning on the stove.

Another issue we will have to deal with is determining an appropriate amount of time to keep the stove on before turning it off. If the time is too short, the user might get irritated as they would constantly receive notifications. However, if the time is too long, food might be forgotten for longer than the user would want and this can cause a fire hazard. In order to account for this, we will let the user set the snooze timing so they won’t be annoyed if they are cooking for a long time and they would also be able to set a limit to their use. This is the main reason the notification times can be selected up to 30 minutes. This way, the user can allow the stove to be on for an extended period of time without being notified constantly, but they are still reminded to check on the status at a safe frequency.

4 References

[1] M. J. Smetanka, ‘Kitchen Fires: Burned by Bad Habits’, 2010. [Online]. Available: https://www.startribune.com/kitchen-fires-burned-by-bad-habits/100696189/

[2] M. Ahrens, ‘Home Cooking Fires’, 2019. [Online]. Available: https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/Fire-causes/oscooking.pdf

[3] Joint Center for Housing Studies of Harvard University, ‘Housing America’s Older Adults’, 2018. [Online]. Available: https://www.jchs.harvard.edu/sites/default/files/Harvard_JCHS_Housing_Americas_Older_Adults_2018_1.pdf

[4] R. W. Ponds, K. J. Commissaris, and J. Jolles, ‘Prevalence and Covariates of Subjective Forgetfulness in a Normal Population in The Netherlands’, 1997.