Stove Controller for the Forgetful

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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.

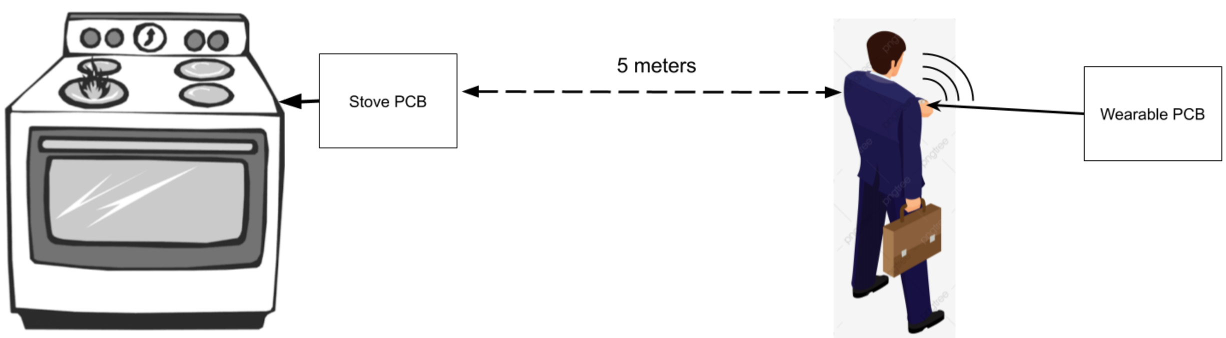

Figure 1. Visual Aid

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 are add-ons to the stove. These solutions are then limited to the type of stove they are operating on whether it be electric or gas. The proposed solution will be generalized to both types of stoves since there are no modifications to the stove itself, eliminating design complexity as well as overall price.

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 +/- 1.5 meters.

- 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 2. 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

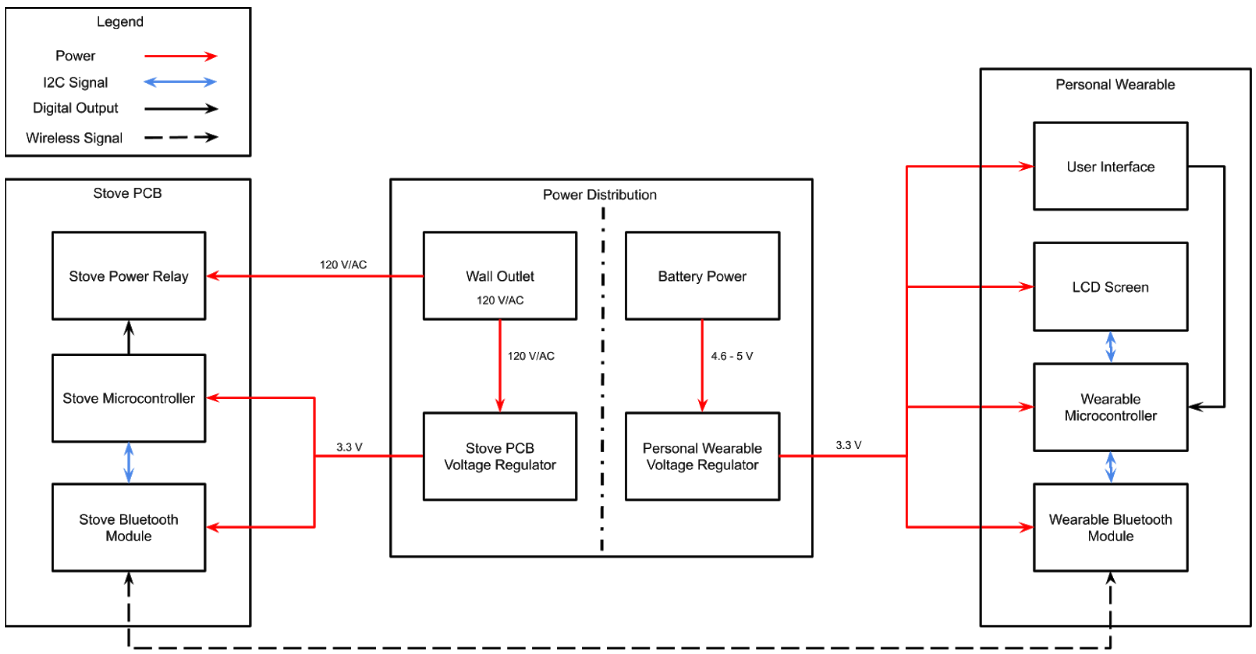

Figure 2. Block Diagram

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 Regulation

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. To protect the stove PCB, wall power will first pass through an external fuse as seen in Figure 3. This will prevent a current surge from destroying the circuit. After passing through the fuse, the 120 V/AC power will be rectified into a 12V DC signal using a RAC_05_12SK AC/DC converter. It is rectified to 12 V because the coil voltage on the power relay, seen in section 2.3.3, is switched with 12 V. This 12 V DC power is then further stepped down by a voltage regulator to output a constant 3.3 V that powers the components on this board. We will use a UA7BMCDCYR voltage regulator. There will be a manual switch that controls power to the system for debugging purposes.

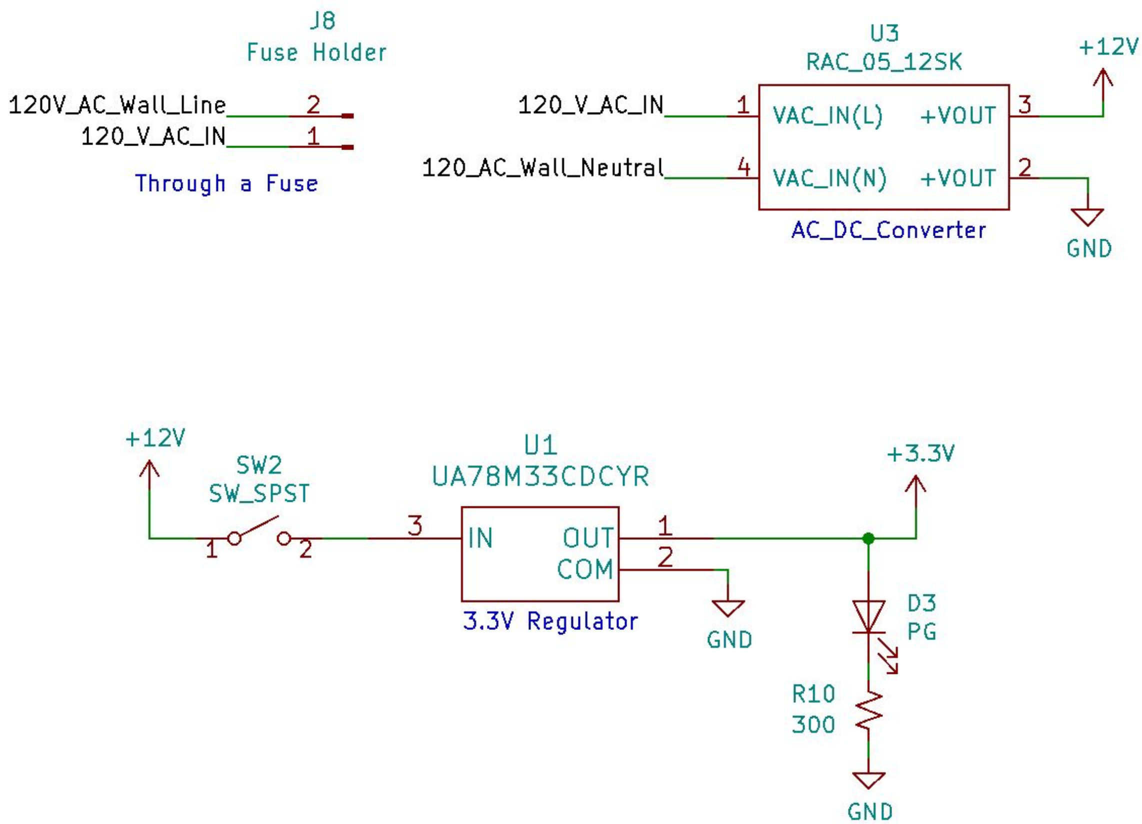

Figure 3. Wall Voltage Regulation Sub-Circuit

Requirement	Verification
1. The Stove Voltage Regulation circuit must be able to provide at least 500 mA of continuous current to the board with an output of 3.3V +/- 10%	1. a. Connect a multimeter to the output of the 3.3 V regulator. b. Connect a DC electronic load to the output of the 3.3 V regulator. Set the load to constant current mode with a setpoint of 500mA. c. Ensure the output voltage is a constant 3.3 V +/- 10%.

2.2.2 Battery Power

The wearable device will be powered by a battery. The battery will be rechargeable so that the device can be charged when not in use. A Lithium-ion rechargeable battery will be used because it is eco-friendly and contains a high energy density. Based on the calculation in Section 2.6.1, this battery will need to have a capacity of at least 950.4 mAh.

For safety, a commercially produced Lithium-ion battery charger and power management integrated circuit will be used to connect the battery to the system and the charging adapter. As seen in Figure 4, this device will be the BQ24075T because it has programmable fast charge current, utilizes an integrated Power Path to supply the system when the adapter is plugged in, and comes in a package which can be soldered by hand with reasonable difficulty.

In order to prevent damaging the battery, the charge rate will be set to approximately C/2. This means we will charge the battery with a constant fast charge current of about 500 mA. This rate is set by the resistor connected to the ISET pin of the BQ24075T. See Section 2.6.2 for the sizing of this resistor, R10.

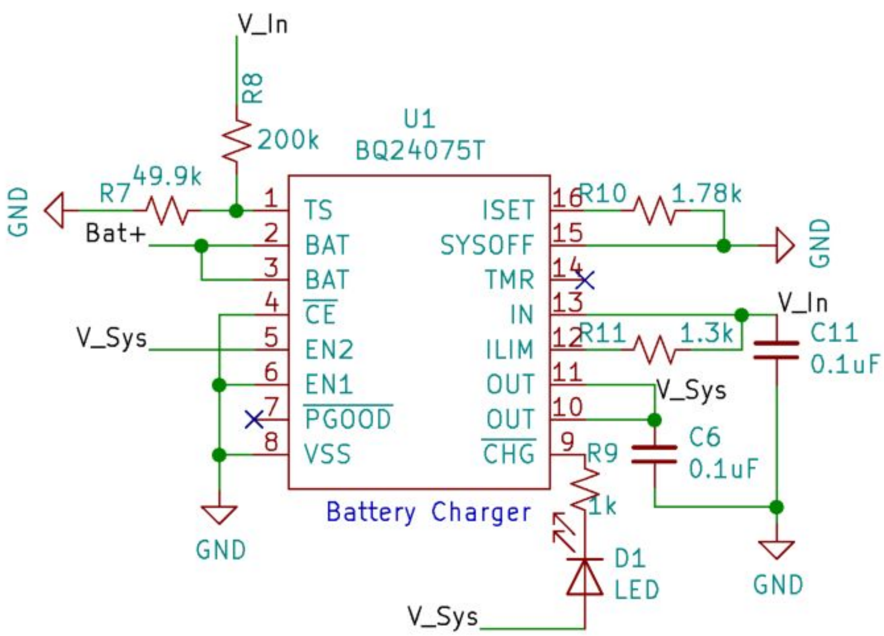

Figure 4. Battery Charging Circuit

Requirement	Verification
1. The battery can be used for at least 6 hours continuously at normal load after a 3 hour charge time.	1. a. Ensure that the battery is fully discharged by using a constant current load on the V_Sys node. b. Start a timer and charge the battery for 3 hours or until full. c. Use a DC electronic load to sink a constant 120 mA from the battery at the V_Sys node. Ensure that the battery is able to provide this current for at least 6 hours.

2.2.3 Personal Wearable Voltage Regulator

Figure 5 shows the circuit schematic for the Personal Wearable Voltage Regulator module. This module will provide a smooth 3.3 V output signal with which the other circuitry on the Wearable module will be powered. The input of the regulator will be the output provided by the battery charger circuit. With the Power Path technology used, this means that the input of the voltage regulator will be either power from the 5 V adapter (when plugged in) or from the battery. The enable pin functionality will also be used as the power switch to the device. In order to save battery life, the user can switch off the SYS_PWR switch, which turns off the voltage regulator so that negligible battery power is drained.

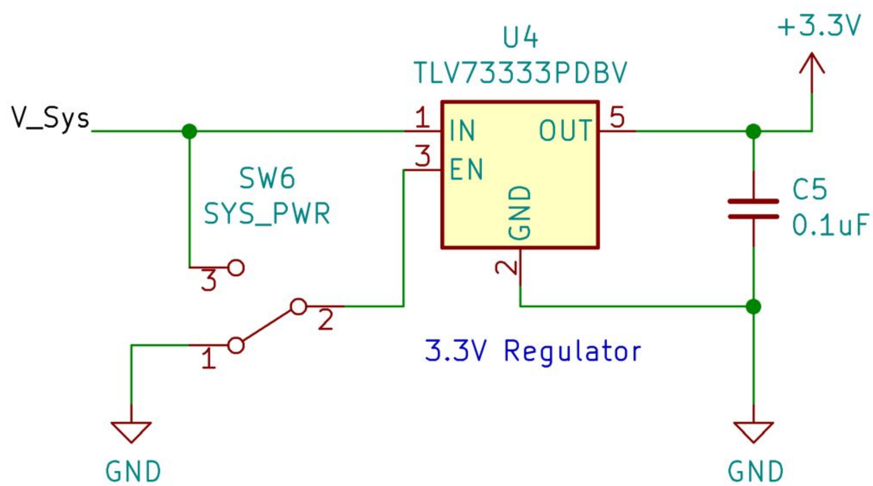

Figure 5. Wearable Voltage Regulator Sub-Circuit

Requirement	Verification
1. Power switch must be able to toggle all device power within 500ms of being pressed.	1. a. Place an oscilloscope probe on the EN pin of the voltage regulator and on the power pin of the IC physically furthest from the regulator. b. Toggle the switch and use the oscilloscope to measure the time between the EN pin voltage changing and the power pin changing.

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. This PCB will take in 120 V/AC power, and step this voltage down to power the circuitry. This board will also pass the wall power through the board to the stove via a controllable relay. The PCB will plug into the normal outlet the stove connects to. The Stove power cable will then be connected to the PCB, so the board is able to regulate power to the stove. There will also be a button onboard in case stove shutdown occurs. This button will serve as a reset input to turn the stove back on.

2.3.1 Stove Bluetooth Module

This module will communicate wirelessly with the wearable PCB via the Bluetooth protocol. The module will be the master module, which sends requests to the wearable module. The data it sends and receives will be processed by the microcontroller. The chosen Bluetooth module is the Laird BT730-SC, as it has a large communication range of up to 1000m, a fast data rate of up to 1.0 Mbps, and an external antenna. The most essential function of this module will be measuring the received signal strength between the stove and wearable Bluetooth module. This will determine the wearables approximate distance away from the stove.

Figure 6 shows the circuit schematic for the Stove Bluetooth module. As shown, the module will communicate with the Stove Microcontroller via the UART digital communication protocol. This line of communication will provide the Bluetooth module with the necessary AT commands to execute the desired functionality.

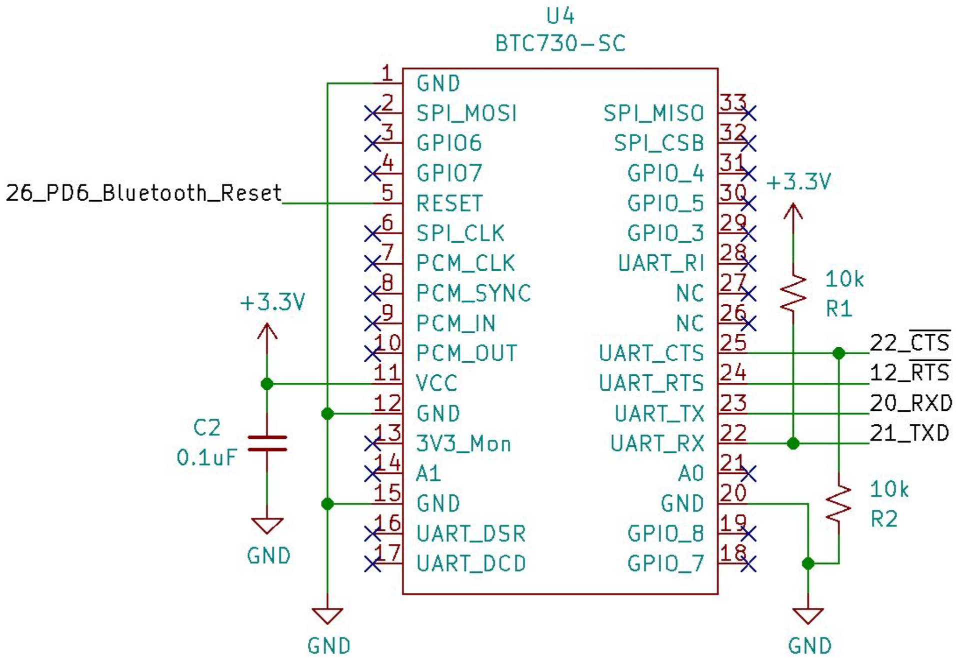

Figure 6. Stove Bluetooth Module Sub-Circuit

Requirement	Verification
1. Must be able to measure Received Signal Strength between this module and the Wearable Bluetooth module and communicate this via I2C to the microcontroller	1. a. Create a serial connection between the Stove Bluetooth module and a PC. b. Send the proper AT commands such that the module is measuring RSSI. c. Verify that the PC receives the RSSI values. d. Repeat Steps a-c for different distances to verify accuracy.

2.3.2 Stove Microcontroller

As shown in Figure 7, the Stove Microcontroller will communicate with the Stove Bluetooth module via UART. The microcontroller, chosen to be the ATMega32U4, will be flashed with code through an onboard micro-USB port. Various GPIO pins on the microcontroller will also control the reset functionality of the Bluetooth, LEDs, and relay. The reset functionality of the microcontroller itself will be controlled by a button. This button will reset the entire stove PCB, reverting any action taken to shut the stove power off and removing any notifications.

Figure 17 shows a flow chart of the microcontroller code functionality. It will use AT commands to first set up the Bluetooth device address and establish a connection between the Stove Bluetooth module and the Wearable Bluetooth module. When a connection is established it will begin measuring the relative power between the stove and wearable bluetooth modules. When the Stove Bluetooth module receives an indication that the Received Signal Strength between itself and the Wearable Bluetooth module has reached a significantly low level, this indication will be passed onto the microcontroller. The microcontroller will then start a default timer that will begin to count down. The wearable might update the timer with a given timer value and notification interval. The microcontroller will reset the timer accordingly. If no notification acknowledgement is received from the wearable within the specified time, the microcontroller will send a stove shut off signal to the relay. This will cause power to the stove to be disconnected. To reconnect stove power, the reset button on the Stove PCB must be pressed.

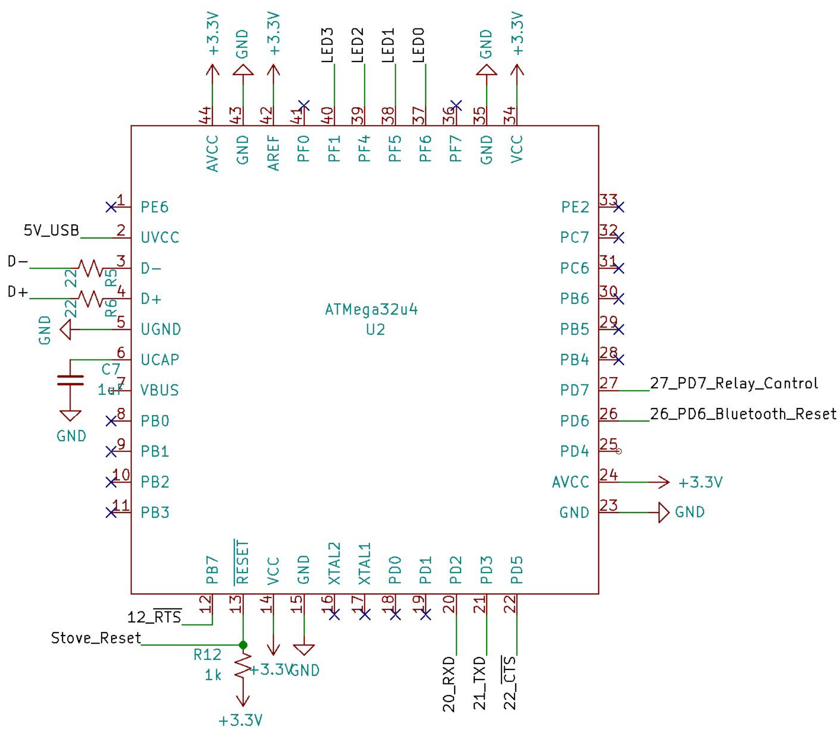

Figure 7. Stove Microcontroller Sub-Circuit

Requirement	Verification
1. The microcontroller must be able to program the Bluetooth chip on startup within 5 seconds.	1. a. Power cycle the Stove PCB. b. Verify that the Bluetooth chip is sending RSSI measurement data to the microcontroller. c. Using a timer, time how long it takes for data to be transmitted to the microcontroller.
2. The microcontroller must be able to set and reset at least one scalable counter which can be adjusted to count in the range of seconds	2. a. Create a test program that starts a timer and turns on the User Interface LEDs when the timer starts and turns them off when the timer finishes, with the onboard button serving as a reset for the timer. b. Verify that the microcontroller is able to set a timer and count down 1 unit per second. c. Verify that the microcontroller is able to perform a reset of the timer.
3. The microcontroller must be able to shut power off to the stove within 5 seconds of end of timer notification	3. a. Move the wearable past the acceptable distance threshold. b. Wait for the timer within the microcontroller to count down to zero. c. Once the timer hits zero, record the time taken to shut the stove off.
4. The microcontroller must be able to read the RSSI value to determine when the user has crossed the designated distance threshold, +/- 1.5 meters.	4. a. Move the wearable away from the stove until the distance threshold is violated. b. Measure the distance between the stove and the wearable to verify that this value is within 1.5 meters of the threshold distance.

2.3.3 Stove Power Relay

This module will be the main switching mechanism for 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. This module will be in a normally open operation mode. When the relay is closed, power will be passed from the wall to the stove. The microcontroller will control the gate of the MOSFET in Figure 8 and when the signal is set high, will pull the switch low, turning on the relay. This will enable power to the stove. If the stove does not power the relay, no power gets transferred to the stove. This prevents PCB malfunction causing potential harm.

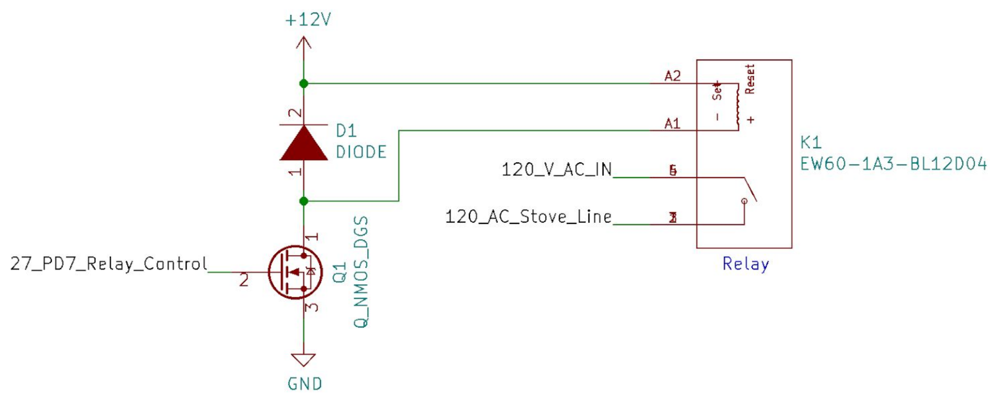

Figure 8. Stove Relay Control Sub-Circuit

Requirement	Verification
1. The relay must be able to toggle 120 V power to the stove within 2 seconds of the Stove PCB Microcontroller sending a stove shutdown signal.	1. a. Use a high voltage probe connected to an oscilloscope to measure the output of the relay. b. Use an oscilloscope probe to measure the output of a specified GPIO pin. c. Program the microcontroller to send the shut off signal to the relay, and pull a GPIO pin high. d. Measure the time it takes the relay to switch 120 v power after the shut off signal is sent.

2.3.4 Stove PCB User Interface

This module allows the user to view the system operation mode as well as reset the system in case a stove shutdown event occurs. There are 4 LEDs as seen in Figure 9. Two of these LEDs show whether the relay is open or closed. Another one displays whether the Stove PCB is powered. The final one is a notification LED that the system needs to be reset before power to the stove is restored. If this last LED is on, the correct reset procedure is pressing the reset button as seen in Figure 10. This button will reset any timers as well as close the relay.

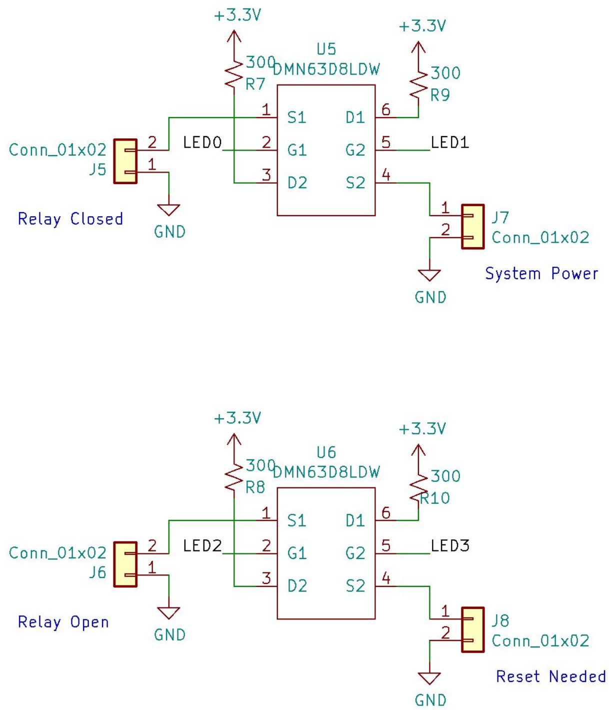

Figure 9. Indicator LEDs

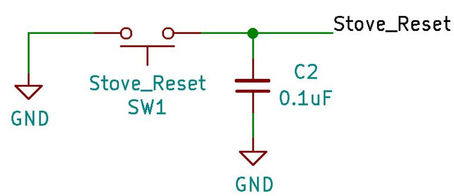

Figure 10. Stove Reset Button

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 communicate wirelessly with the Stove PCB via the Bluetooth protocol. Since the Wearable module is powered by a battery, the Wearable Bluetooth module will act as a slave to the Stove PCB, only sending data as requested. The data it sends will be passed by the microcontroller and will be related to the user selections for notification frequencies and acknowledgments. The chosen Bluetooth module is the Laird BT730-SA, as it has a large communication range of up to 1000m, a fast data rate of up to 1.0 Mbps, and an integrated antenna.

Figure 11 shows the circuit schematic for the Wearable Bluetooth module. As shown, the module will communicate with the Wearable Microcontroller via the UART digital communication protocol. This line of communication will provide the Bluetooth module with the necessary AT commands to execute the desired functionality.

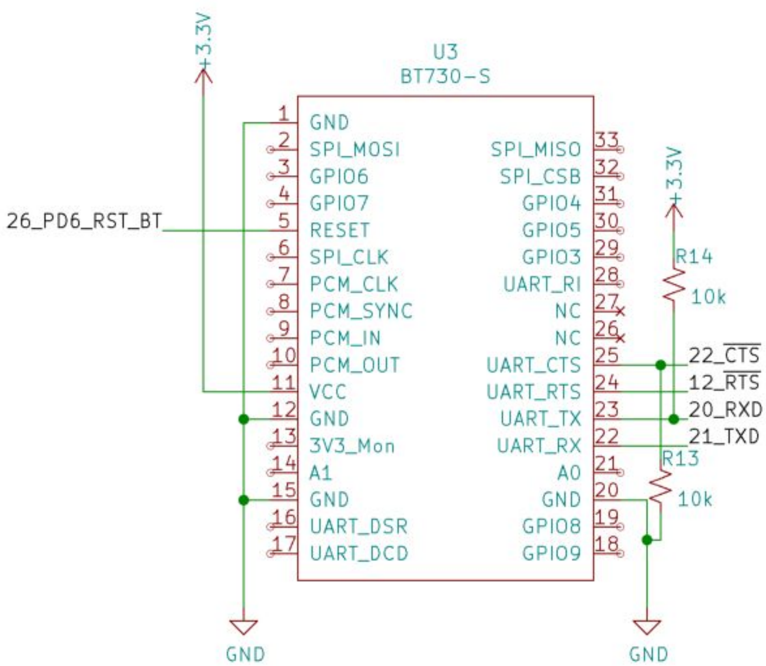

Figure 11. Wearable Bluetooth Module Sub-Circuit

2.4.2 LCD Screen

The LCD Screen module will be the method by which the user is informed of the status of the system. The EA DOGS164B LCD screen was chosen due to its small form factor which can fit on a user's wrist and its I2C compatibility. The microcontroller will utilize the on-board ROM of the LCD screen which contains many pre-programmed characters. See Figure 12 for the schematic design of the LCD module.

The chosen LCD screen also has a backlight which can be programmed to show different colors based on the resistances seen at the C1, C2, and A2 pins. The chosen resistances will give the screen a white backlight with black text, as this should give users the best viewability in most lighting situations.

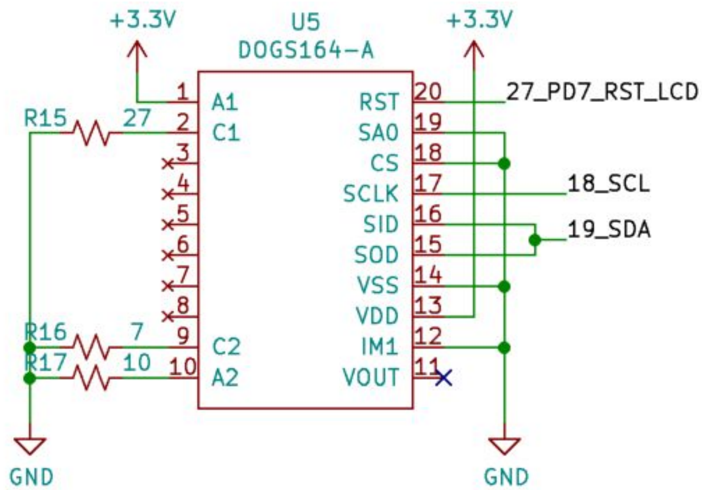

Figure 12. LCD Screen Sub-Circuit

2.4.3 Wearable 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. The buttons will be active low, as seen in the circuit diagram in Figure 13. When the button is pushed by the user, the microcontroller will receive a digital low signal that will indicate that the button is pushed.

The output of each iteration of the User Interface module is also debounced with an RC delay. The goal of this portion of the circuit is to remove any noise seen at the input of the microcontroller due to mechanical bouncing of the button. This will allow the user to push the buttons and not have an undesired response due to the microcontroller picking up digital transitions without additional button pushes.

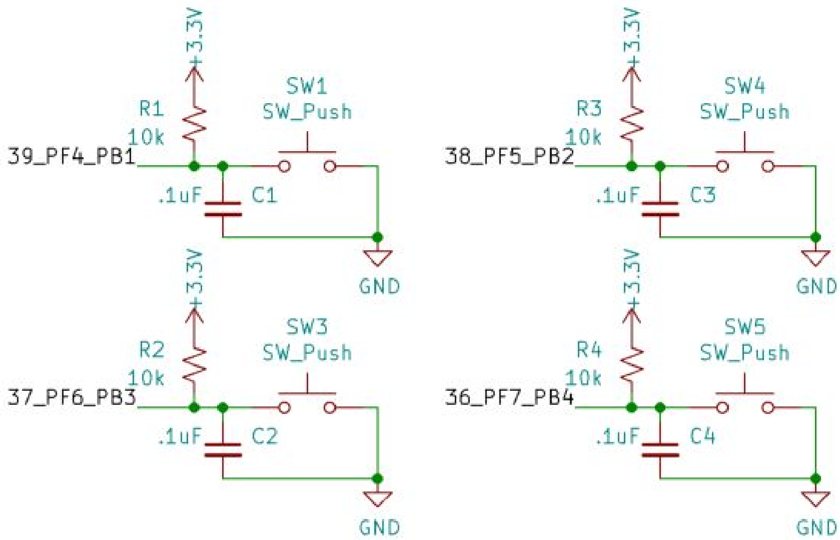

Figure 13. User Interface Sub-Circuit

Requirement	Verification
1. Must provide an output that does not bounce higher than the V_IL (0.56 V) of the microcontroller after a single button press.	1. a. Connect an oscilloscope probe to the output of one of the User Interface circuits. b. Press the button once and use the oscilloscope to ensure that the output voltage does not bounce above 0.56 V until after the button is released.
2. Must provide an output that reaches below 0.56 V within a 10 ms button press.	2. a. Connect an oscilloscope probe to the output of one of the User Interface circuits. b. Press the button once and use the oscilloscope to measure the length of time it takes for the output to go from 3.3 V to 0.56 V.
3. The interface allows users to scroll up and down between notification time options displayed on the LCD screen with a delay of less than 33ms between button presses.	3. a. Create a special microcontroller program that toggles a GPIO pin after the I2C transmission to the LCD screen has finished. Place an oscilloscope probe on this pin.

	b. Place a second probe on the output of the interface circuit and measure the time between the button press and the end of the I2C transmission.

2.4.4 Wearable Microcontroller

As shown in Figure 14, the Wearable Microcontroller will communicate with the Wearable Bluetooth module via UART and control the LCD Screen module with I2C while reading the values provided by the User Interface module. The microcontroller, chosen to be the ATMega32U4, will be flashed with code through an onboard micro-USB port. Various GPIO pins on the microcontroller will also control the reset functionality of the Bluetooth and LCD modules, while the reset functionality of the microcontroller itself will be controlled by a button.

Figure 18 shows a flow chart of the microcontroller code functionality. It will use AT commands to first set up the Bluetooth device address and establish a connection between the Wearable Bluetooth module and the Stove Bluetooth module. When a connection is established, it will begin transmitting to the LCD screen the status of the system. As discussed in Section 2.4.2, it will do so by taking advantage of the LCD Screen module's onboard ROM containing the needed characters. When the wearable is within range of the Stove PCB, the microcontroller will first transmit the message "In range." The microcontroller will then continue to poll the Bluetooth module for drastic changes in the distance between the Wearable and Stove modules. When the Wearable Bluetooth module receives an indication that the Received Signal Strength between itself and the Stove Bluetooth module has reached a significantly low level, this indication will be passed onto the microcontroller. At this time, the microcontroller will change the LCD screen to display the notification "Out of range" and will prompt the user to either acknowledge the notification or select a time until the following notification. It will then read the values provided by the buttons to determine what the user has selected, at which point it will pass the information off to the Bluetooth module to be sent to the Stove PCB.

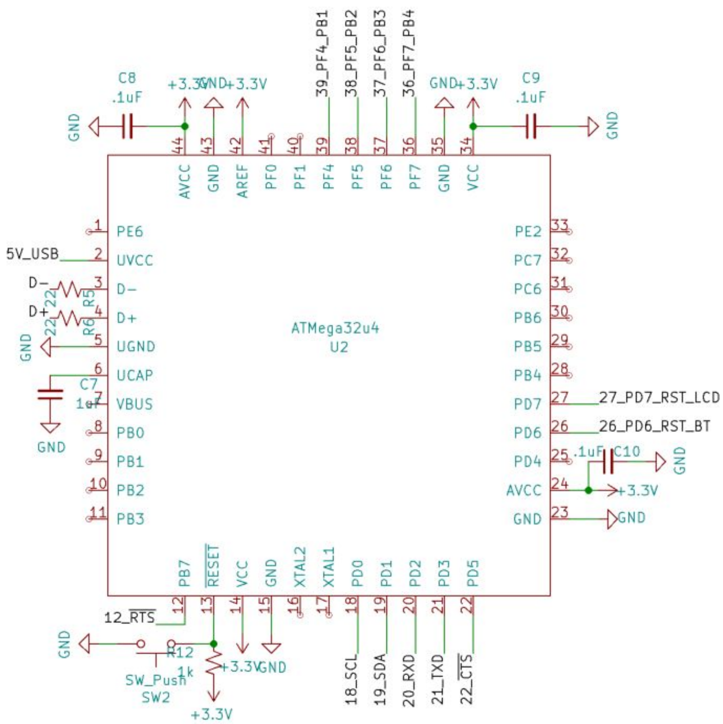

Figure 14. Wearable Microcontroller Sub-Circuit

Requirement	Verification
1. Must be able to provide a notification on the LCD screen when the broken threshold signal is received from the Stove PCB.	1. a. Create a special microcontroller code to toggle a GPIO pin when the broken threshold signal is received. b. Use a multimeter to measure the voltage level on the chosen GPIO pin as the distance between the Wearable module and Stove PCB is increased. c. When the GPIO pin level is toggled, check to ensure that the LCD screen has changed its output.

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 15 below. The device will have 3 prongs and plug directly into a wall outlet.

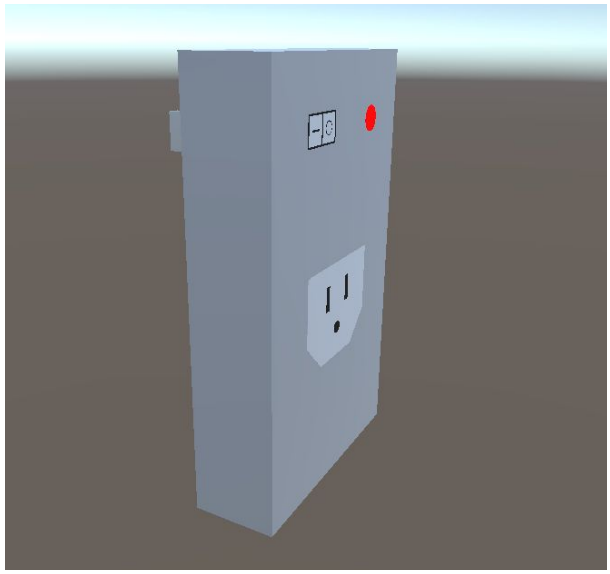

Figure 15. Stove PCB Enclosure

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 16.

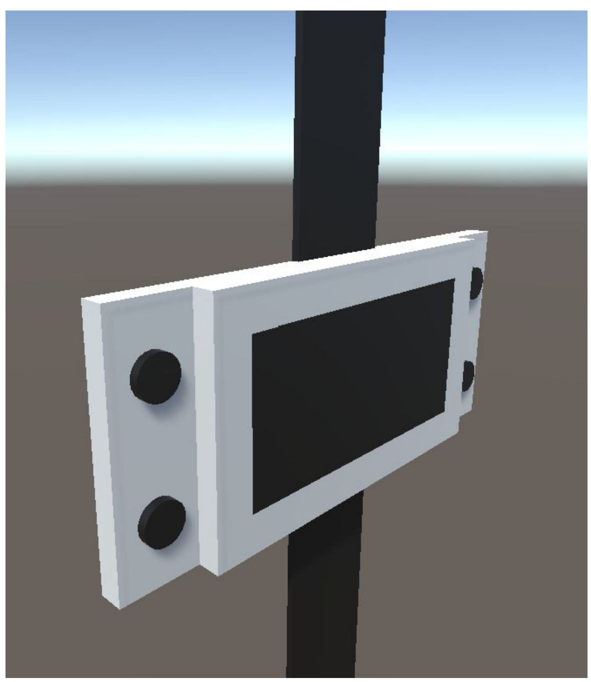

Figure 16. Personal Wearable Physical Design

2.6 Calculations

2.6.1 Wearable Module Battery Capacity

Function	Part to Use	Voltage Input (V)	Max Current Consumption (mA)
Microcontroller	ATMega32U4	3.3	6
Bluetooth Module	BT730	3.3	66
LCD Display	EA DOGS164-A	3.3	45.44
Voltage Regulator	TLV733P	5	0.06
User Interface	Standard Push Button (x4)	3.3	1.3
Total:			118.8

From the table above, the approximate maximum current consumption of the Wearable module is 118.8 mA. Discharging the battery at a rate of C/8, with C being the the total current capacity of the battery), or lower, the current capacity of the battery must be:

$$Battery\ current\ capacity\ (mAh)\ =\ Total\ current\ draw\ (mA)\ *\ 8$$

$$Battery\ current\ capacity\ =\ 950.4\ mAh$$

The battery powering the Wearable module must have a capacity of at least 950.4 mAh. A standard Lithium-ion battery with a capacity of 1000mAh, such as the PRT-13813 fits this requirement.

2.6.2 Resistor Sizing for Fast Charge Current Control

According to the BQ24075T datasheet, the resistor connected between the ISET pin and ground controls the fast charge current based on the following formula:

$$I_{CHG}\ =\ K_{ISET}\ /\ R_{ISET}$$

Where I_{CHG} is the fast charge current, K_{ISET} is the fast charge current factor, and R_{ISET} is the value of the resistor connected to the ISET pin. Rearranging this equation to solve for R_{ISET} yields:

$$R_{ISET} = K_{ISET} / I_{CHG}$$

With the desired fast charge current of 500mA from Section 2.2.2 and the datasheet specified value for K_{ISET} of 890 AΩ,

$$R_{ISET} = 1.78\ k\Omega\ .$$

2.6.3 Relative Signal Strength Threshold Distance

We will be using a maximum distance to calculate a minimum RSSI value to be used as a threshold. This can be done by utilizing the equation to convert the distance value into a RSSI value:

$$Distance = 10^{\frac{MeasuredPower - RSSI}{10 * N}}$$

Where *RSSI* is the Received Signal Strength Indicator in dBm, *Measured Power* is the RSSI value at 1 meter in dBm, *N* is the environmental factor which ranges from a value from 2 to 4, and *Distance* is the distance from the Bluetooth module in meters (m). Since we are calculating the RSSI value, we need to know the maximum distance a user can be before a notification is sent out. The average kitchen size will be used for this value. The average mid sized kitchen ranges from 100 to 200 square feet [6]. The value of 150 square feet will be used. To calculate a linear distance in meters, we will be using the following equation:

$$Distance\ (m) = \sqrt{\frac{Square\ Feet}{10.764}}$$

Where *Square Feet* is the area in square feet and *Distance (m)* is the distance in meters (m). Using this equation, we get a distance of 3.733 meters. If we reorganize the first equation, we get:

$$RSSI = -(10 * N * log_{10} Distance) + Measured\ Power$$

Where *RSSI* is the Received Signal Strength Indicator in dBm, *Measured Power* is the RSSI value at 1 meter in dBm, and *Distance* is the distance from the Bluetooth module in meters (m). For our Bluetooth module, the Measured Power is -87 dBm and for a kitchen, the N value to use will be the average value of 3. Using these values for a range of 3.733 meters, the result is:

$$RSSI = -104.162\ dBm$$

2.7 Flowcharts

2.7.1 Stove Microcontroller Flowchart

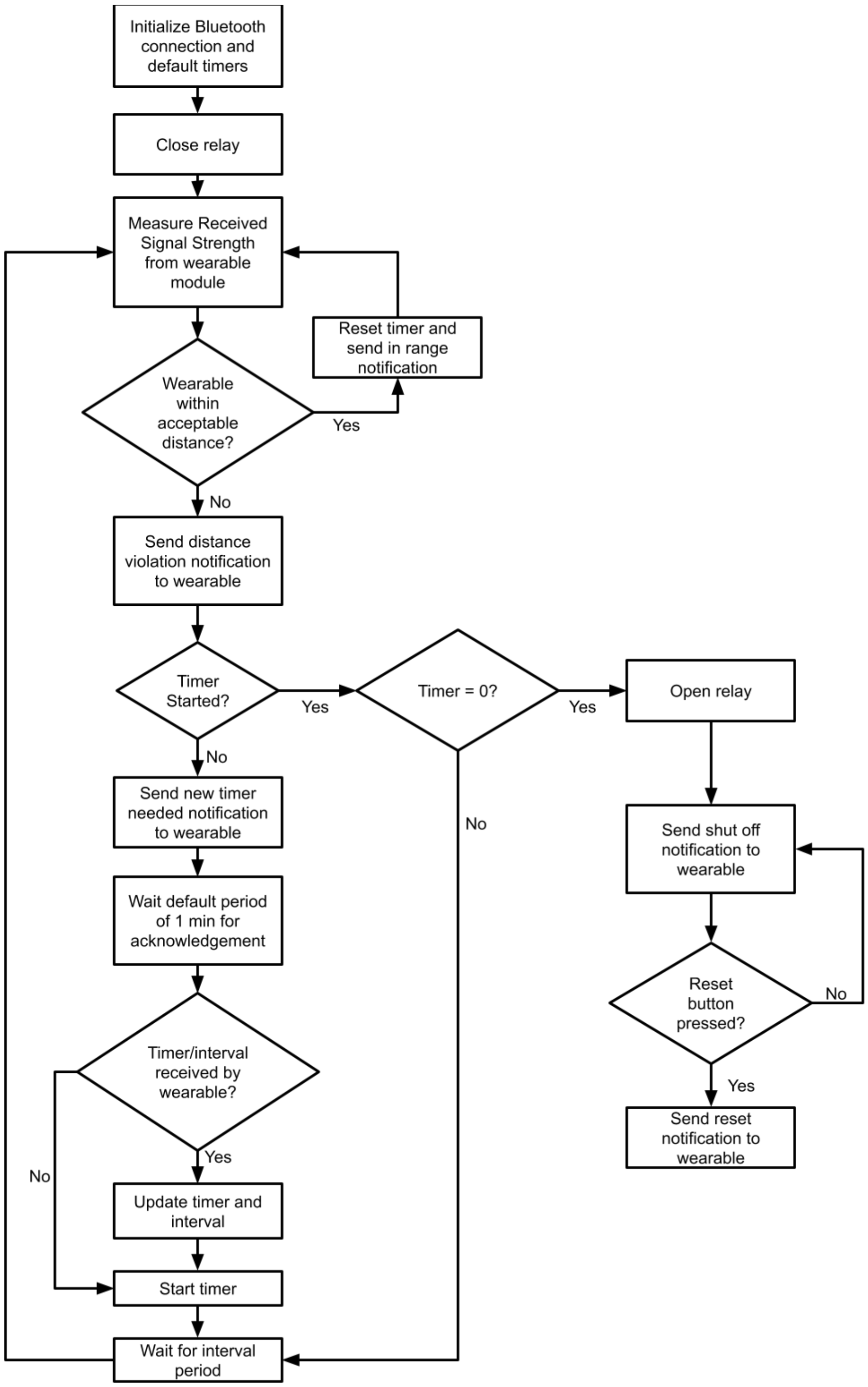

Figure 17. Stove PCB Microcontroller Flow Chart

2.7.2 Wearable Microcontroller Flowchart

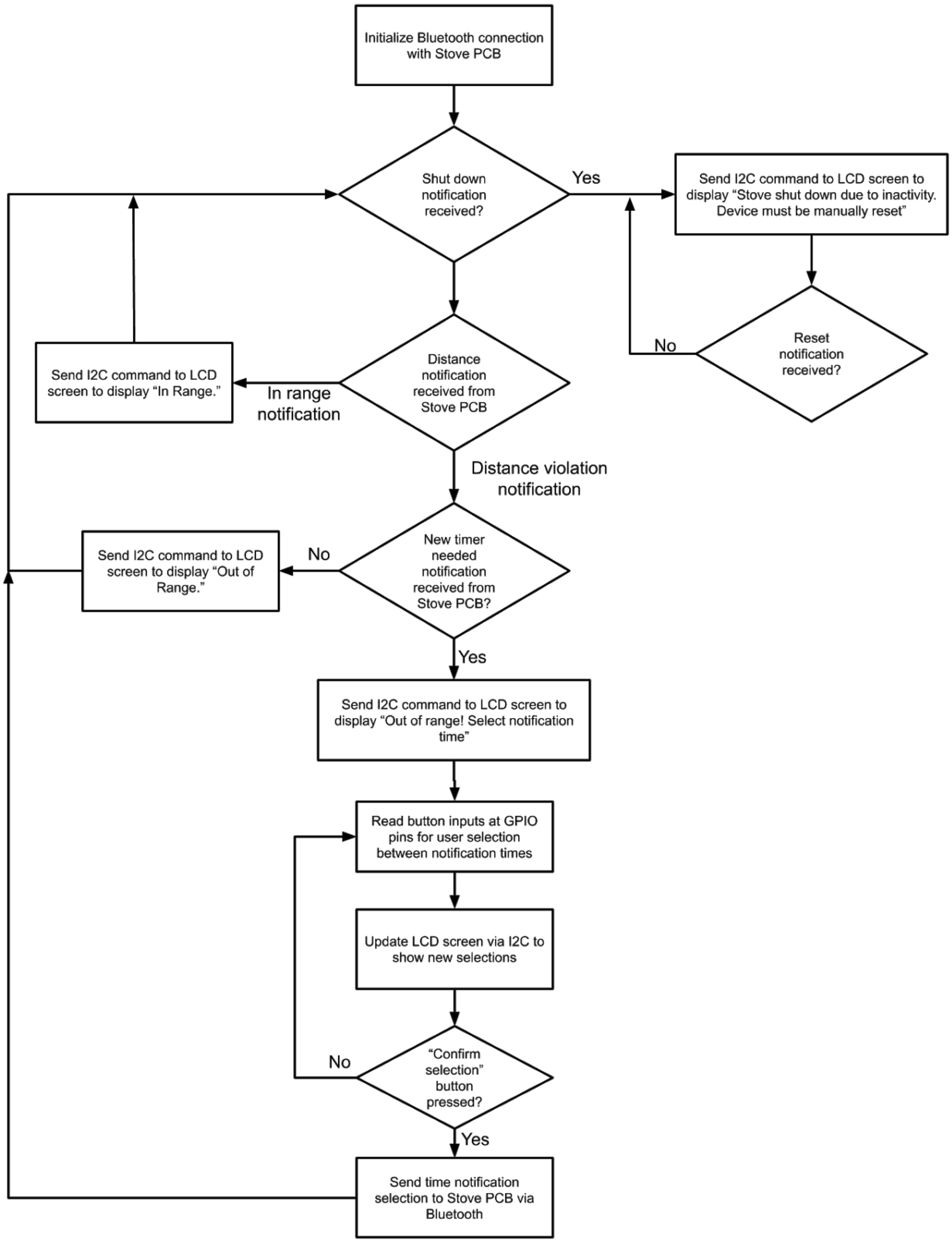

Figure 18. Wearable Microcontroller Flow Chart

2.8 Tolerance 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 Received 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 have time-dependent fluctuations in its measurement which we will need to quantify to determine the error of the signal [8]. We will use the charts in Figure 19, which show the time-varying characteristics of an RSSI measurement between two beacons, to calculate the approximate error in distance.

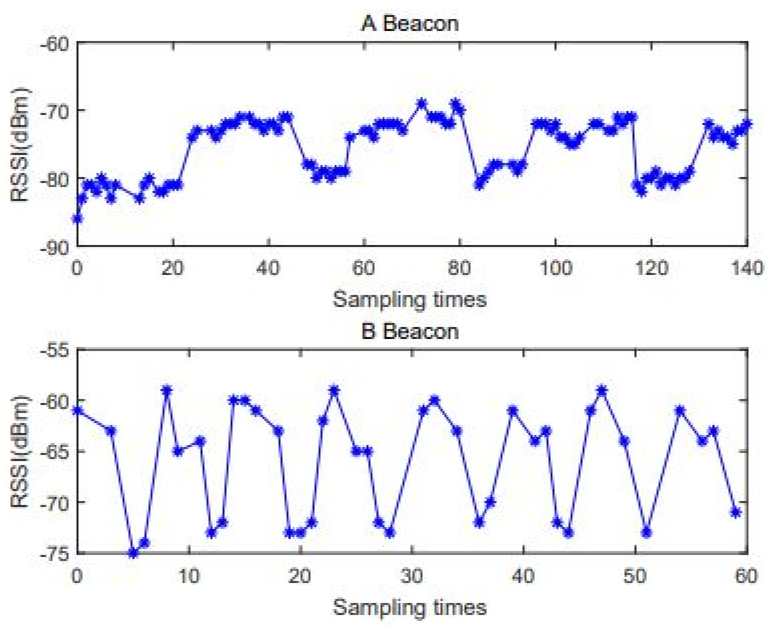

Figure 19. Bluetooth signal strength [8

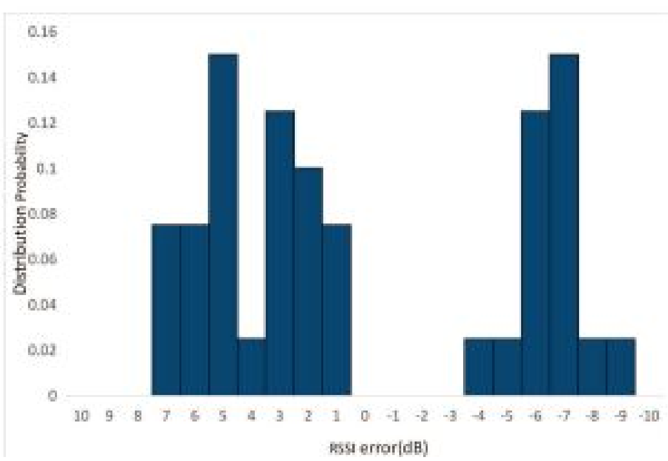

Figure 20. RSSI Error Distribution [8]

The RSSI measurement fluctuates by about 15 dBm over time at this set distance. This can be verified by Figure 20, which shows the error probability distribution for the RSSI signal. Using the equation for distance based on RSSI signal value found in Section 2.6.3,

$$Distance = 10^{\frac{MeasuredPower - RSSI}{10 * N}}$$

Using a measured power value of -87 dBm and an average value of 3 for N, the maximum fluctuation in distance is approximately:

$$Distance\ Error = 0.2722\ m$$

This is well within the requirement of an accuracy of within 1.5 meters.

3 Project Differences

3.1 Overview

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. 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.

One trade off of this new approach is that there is no system to detect if a fire actually occurs. This project leans on a working carbon monoxide detector to detect a fire and there are no backup systems in place.

3.2 Analysis

Based on National Fire Protection Association statistics gathered in 2019, most non-fatal injuries from cooking fires occur when the homeowner tries to control the fire themselves [2]. The main improvement of this project is that if the device is used correctly, users should not have to attempt to control a stove fire themselves because no stove fire should occur. Similarly, smoke alarms only sounded in 41 percent of cooking fires and were found to be present in 70 percent of cooking fire deaths [2]. This shows that a simple warning system telling homeowners of a stove fire is not alway effective in saving lives. In an ideal application of the Stove Controller, users would be at very little risk of injury due to the stove catching fire, and thus a fire-detecting stove control system is not entirely effective.

In the same report, it was found that people aged 55 and older have the highest death rate in home cooking fires. The elderly are also 2.5 times more likely to die in a cooking fire than other members of the general population [7]. This is likely due to the elderly having less physical ability to quickly respond to a rapidly changing fire. One of the target demographics of the Stove Controller is the elderly, and it is therefore unrealistic to expect the users to react appropriately and efficiently to a kitchen fire. Instead, providing frequent notifications about the status of the stove will allow for slower response time without increased risk to the user. This way, even an elderly person with some movement-restricting disability can avoid dangerous situations on their own time.

4 Cost and Schedule

4.1 Cost

4.1.1 Labor

Name	Hourly Rate	Hours	Total	Total * 2.5
Alex	$40	200	$8,000	$20,000
Samir	$40	200	$8,000	$20,000
Sujal	$40	200	$8,000	$20,000
Total:				$60,000

4.1.2 Parts

Wearable Module					
Function	**Part to Use**	**Vendor**	**Individual Cost**	**Quantity**	**Total Cost**
Battery Charger	BQ24075T	Digikey	$2.21	1	$2.21
Linear Regulator	TLV7333PDBVR	Digikey	$0.35	1	$0.35
Microcontroller	ATMega32U4	Digikey	$3.98	1	$3.98
LCD Screen	EA DOGS164B-A	Mouser	$19.14	1	$19.14
Bluetooth Module	Laird BT730-SA	Mouser	$23.65	1	$23.65
Button	Omron B3FS-1000P	Digikey	$0.65	5	$3.25
I/O Header	Molex 0022232021	Digikey	$0.17	2	$0.34
Micro USB Header	Amphenol 10118194-000LF	Digikey	$0.43	1	$0.43

Power Switch	Nidec Copal CSS-1210TB	Digikey	$0.66	1	$0.66
Charge LED	Broadcom Limited 516-1421-2-ND	Digikey	$0.55	1	$0.55
Resistor	-	Digikey	$0.10	16	$1.60
Capacitor	-	Digikey	$0.10	12	$1.20
Total					$57.36

Stove Module					
Function	**Part to Use**	**Vendor**	**Individual Cost**	**Quantity**	**Total Cost**
Micro USB Header	Amphenol 10118194-000LF	Digikey	$0.43	1	$0.43
Outlet Connect	Qualtek Q-710-RA	Digikey	$9.03	1	$9.03
Stove Plug In	Schurter Inc. 6600.3300	Digikey	$1.49	1	$1.49
Stove Reset Button	Omron B3FS-1000P	Digikey	$0.65	1	$0.65
Fuse	Bel Fuse Inc. 5ST 500-R	Digikey	$0.25	1	$0.25
Fuse Holder	Bel Fuse Inc. FC-211-22	Digikey	$0.10	1	$0.10
AC/DC Converter	Recom Power RAC05-12SK	Digikey	$9.63	1	$9.63
Power Switch	Nidec Copal CSS-1210TB	Digikey	$0.66	1	$0.66
Linear Regulator	TI UA78M33CDCYR	Digikey	$0.57	1	$0.57
Power Relay	TE EW60-1A3-BL12D0 4,00000	Digikey	$12.03	1	$12.03
LED controller	Diodes Inc. DMN63D8LDW-7	Digikey	$0.30	2	$0.60

Microcontroller	ATMega32U4	Digikey	$3.98	1	$3.98
External Antenna	Laird MAF94045	Mouser	$2.36	1	$2.36
Bluetooth Module	Laird BT730-SC	Mouser	$23.65	1	$23.65
LED	Broadcom Limited 516-1421-2-ND	Digikey	$0.55	5	$2.75
Resistor	-	Digikey	$0.10	10	$1.00
Capacitor	-	Digikey	$0.10	3	$.30
Total					$69.48

$$Estimated\ Total\ Cost\ =\ Parts\ Cost\ +\ Labor\ Cost$$

$$Parts\ Cost\ =\ \$57.36\ +\ \$69.48\ =\ 126.84$$

$$Estimated\ Total\ Cost\ =\ \$60,126.84$$

4.2 Schedule

The following is a schedule assuming a full 10-week prototype phase:

Week	Item	Responsibility
1	Breadboard design	Sujal
	Design first-round Stove PCB	Samir
	Design first-round Wearable PCB	Alex
2	Order parts	Sujal
	Finalize and order first-round Stove PCB	Samir
	Finalize and order first-round Wearable PCB	Alex
3	Draft test-code for microcontroller	Sujal
	Research for RSSI algorithm	Samir
	Research for LCD screen control	Alex
4	Finalize test-code for microcontroller	Sujal

	Populate and begin testing first-round Stove PCB	Samir
	Populate and begin testing first-round Wearable PCB	Alex
5	Finish testing and debugging first-round PCBs	Sujal
	Begin modifying second-round Stove PCB design	Samir
	Begin modifying second-round Wearable PCB design	Alex
6	Verify Stove PCB RSSI algorithm	Sujal
	Finalize and order second-round Stove PCB	Samir
	Finalize and order second-round Wearable PCB	Alex
7	Order necessary parts for second-round PCBs	Sujal
	Draft Stove Microcontroller code	Samir
	Draft Wearable Microcontroller code	Alex
8	Populate and begin testing second-round PCBs	Sujal
	Finalize and test Stove Microcontroller code	Samir
	Finalize and test Wearable Microcontroller code	Alex
9	Finish debugging PCBs	Alex
	Begin integration testing	Samir
	Draft final report	Sujal
10	Verify all requirements posed in Design Document	Alex
	Prepare presentation	Sujal
	Make last style tweaks to final report	Samir

5 Ethics and Safety

5.1 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.

5.2 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.

6 References

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Appendix A

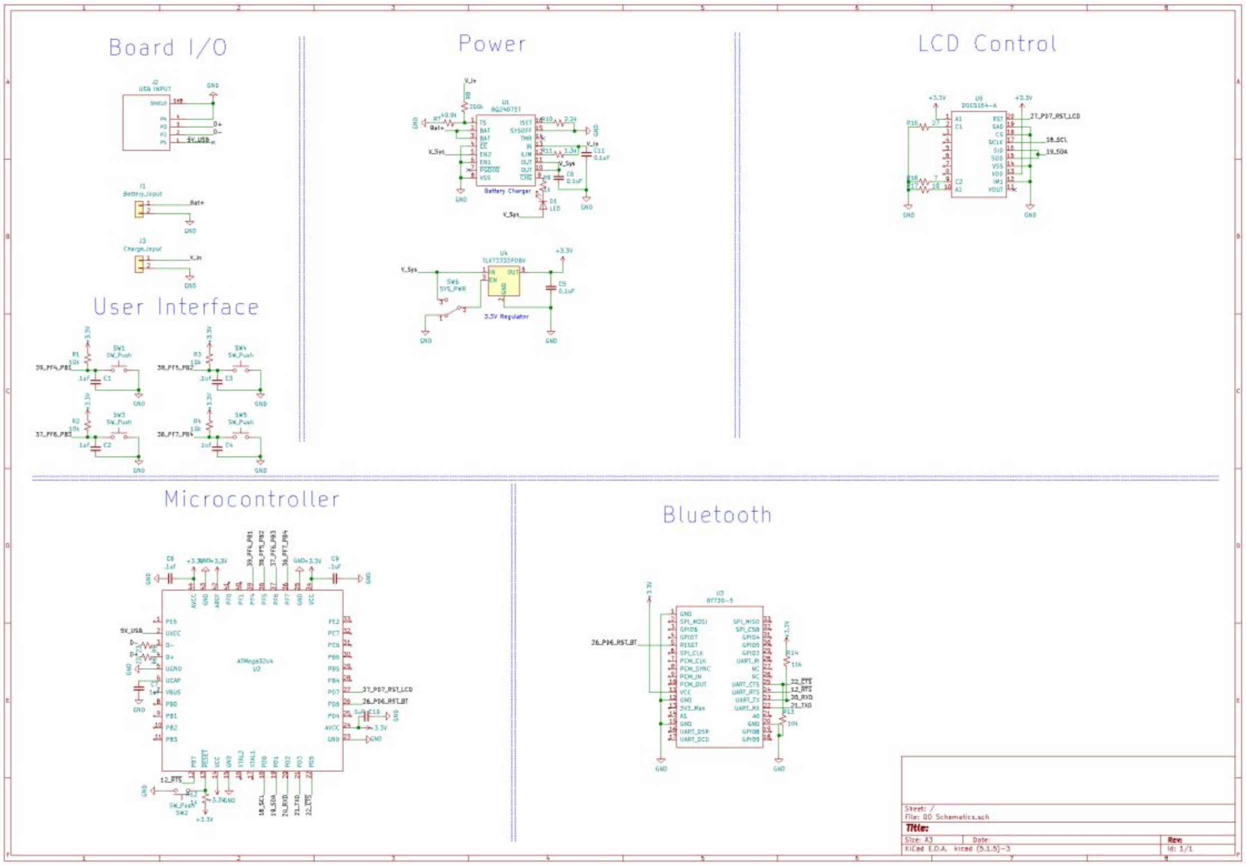

Figure 21. Wearable Module Schematic

Appendix B

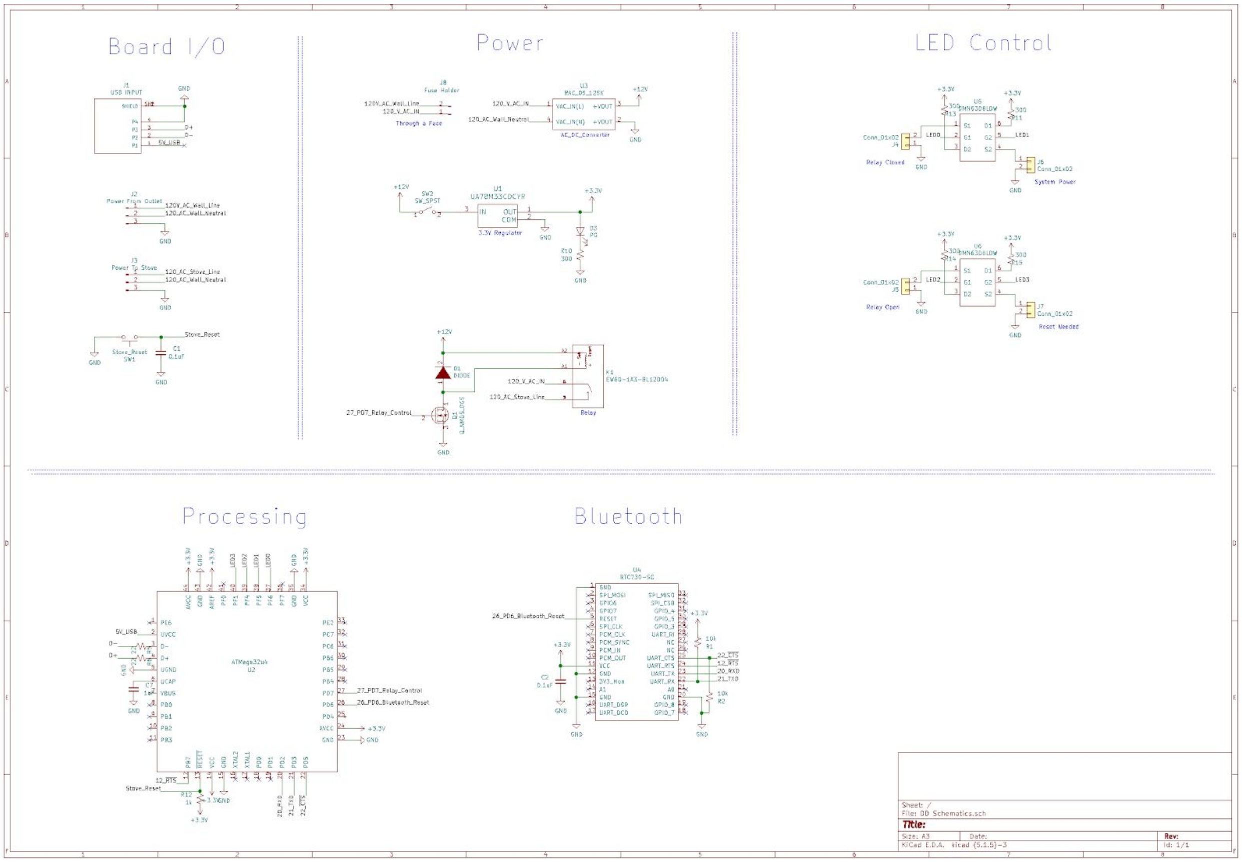

Figure 22. Stove PCB Module Schematic