Design Document

Project 75

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Electric Stove Safety Control

1. Introduction

1.1

Objective: People, especially old people, tend to forget that they have left their stove on. If there are children in the house, it gets worse. If fire starts while they are not attending the stove or if people are outside, the materialistic loss would be catastrophic. The goal of this project is to prevent hazards on the electric stove, specifically fires, from becoming disasters, and if they do happen, users should be informed so they can react quickly. The system needs to be cost-efficient, as well as applicable for most households.

Our solution would be to create a system that can detect carbon monoxide and fires using an IR detector and Gas sensor. These sensors will send information to a mobile application. There are three main functions we would like to accomplish with this. Firstly, users could remotely turn the stove off through the application. Next, users would be informed if they left their houses and power to the stove will be automatically cut. Lastly, if a fire starts while they are away from the stove but still in the house, their stove will automatically turn off and the user will be notified to extinguish it.

1.2

Background: As the technologies develop more and more, companies make their appliances to be controllable by mobile devices. For example, Samsung has an application called Samsung Smart Home which controls all the home appliances that are made by Samsung. Another one is from GE and is called kitchen- GE Appliances. They can control the time, temperature, alarms, etc. However, we thought that they can only be used if the customers were using the companies' brand. If there was a device that can control for any companies' device, it would be very convenient for the user.

Among all the appliances, we thought that the stove was the most important thing out of all the appliances in the kitchen because it is directly related to fire, which could potentially damage the owner's property by a lot. If the user can control their stove from the mobile application, it will be safer, and users don't have to worry about not turning off the stove ever again. In addition, since it can be used for all electric stoves, users don't have to spend money on new stove in order to control their appliances.

1.3

High-level requirements list:

- Should be able to detect a fire within 10-15 seconds when it emits light wavelengths above the visual spectrum as well as when smoke starts coming out.
- There needs to be a wireless connection and communication between the stove, sensors, and application using a ESP chip.
- Our system needs to be able to stop power to electric stove when fire starts or user remotely turns stove off. Relay should turn off stove within 5 seconds after application turns it off.

2. Design

2.0.1
Block Diagram

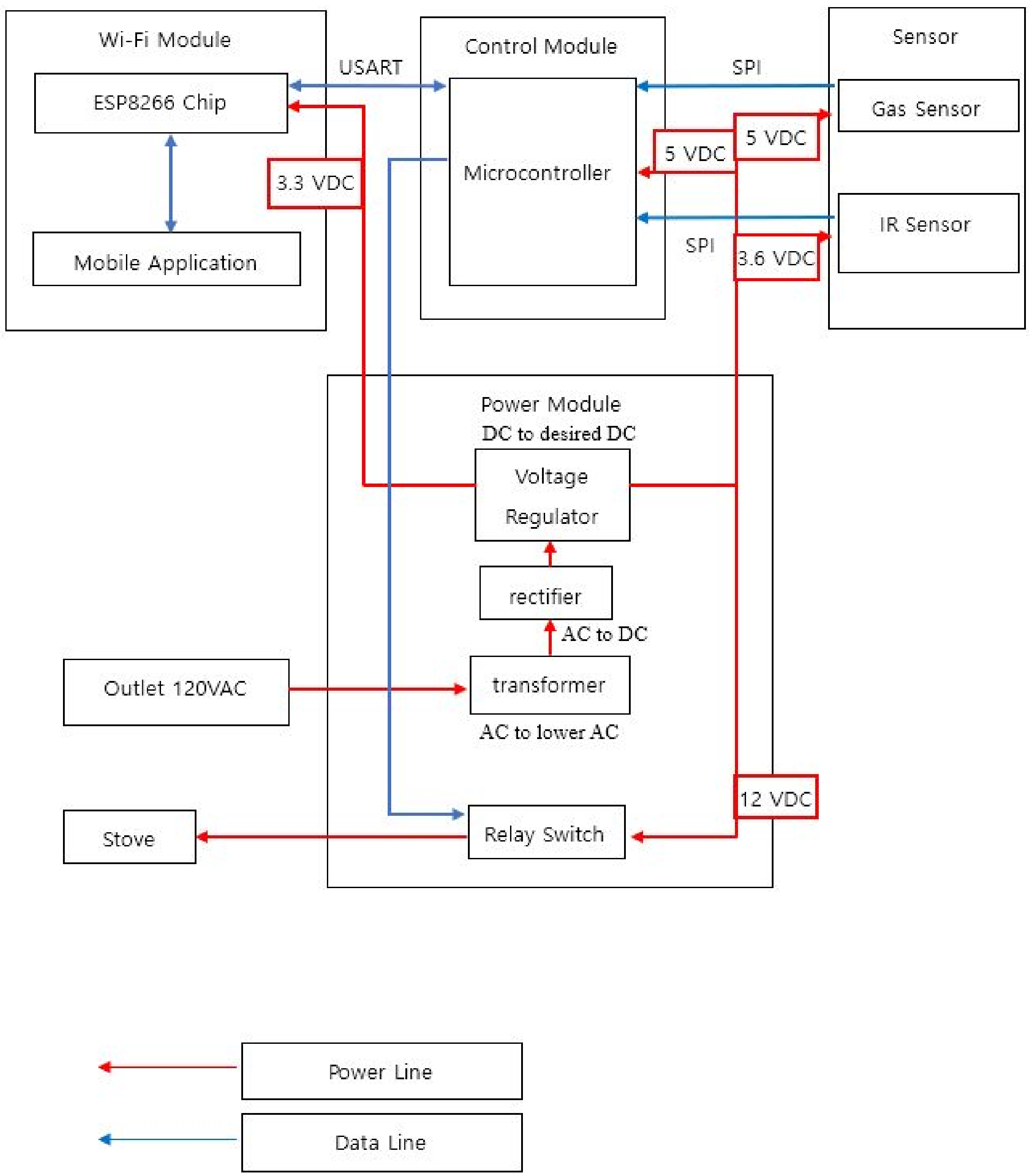

Figure 2.1 Detailed Block Diagram

2.0.2
Physical Diagram

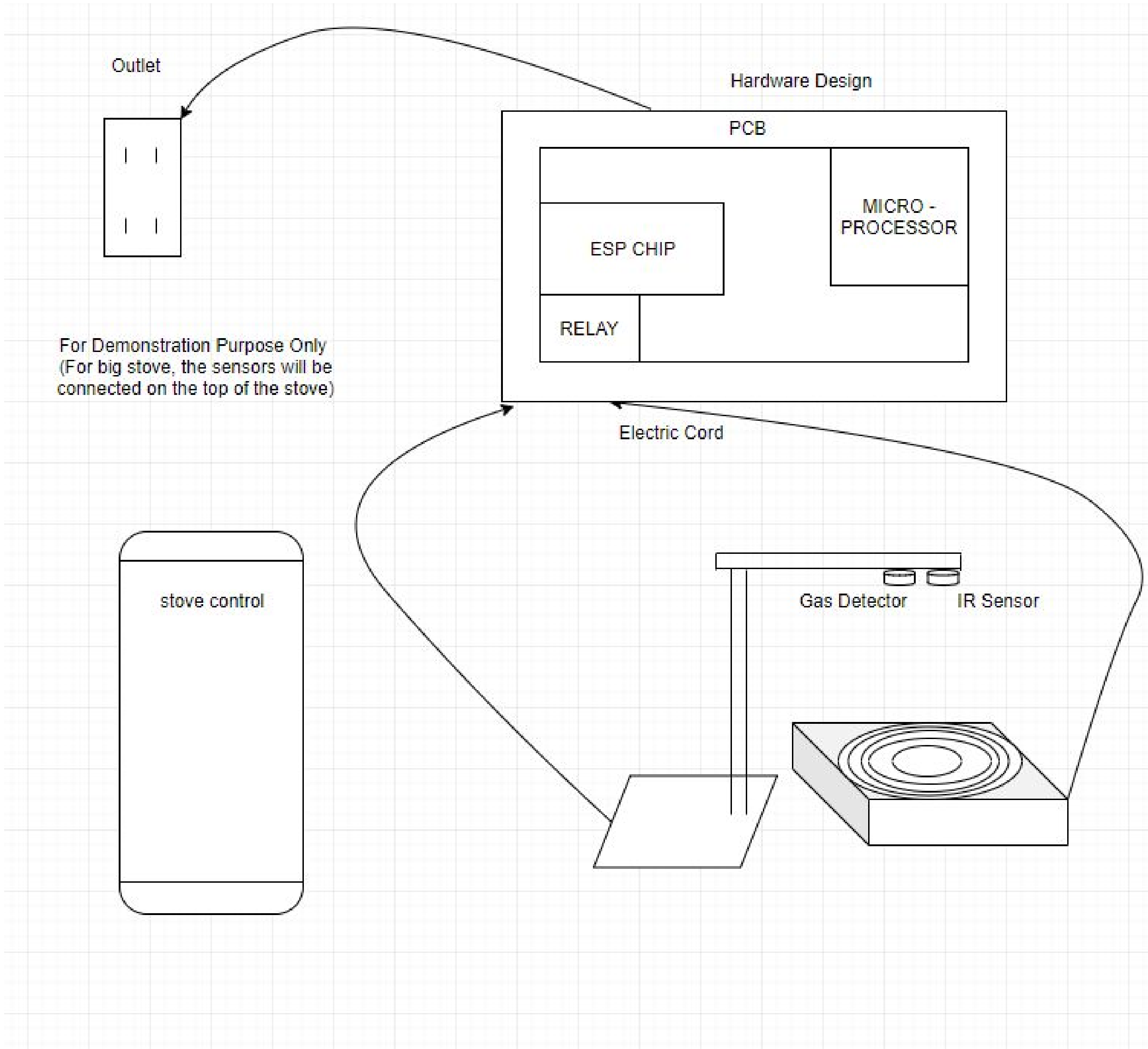

Figure 2.2 Physical diagram

2.1 Power Module

We will be using 120VAC from the outlet. This is the main power source that are to distribute power to other modules such as microcontrollers, wifi chip, and sensors. This will have to be regulated through transformer and the voltage regulator to have constant DC voltages running to each of the Without this, we won't be able to power our system.

2.1.1 Transformer

This will the part where we take in the 120VAC from the outlet and lower down their voltages using the transformer. Transformer, as we know, can vary voltages based on the number of coils between primary and secondary.

Requirement	Verification
1. From the transformer, we change the 120VAC to 6.3VAC with about 0.68A of load current as our output.	1. Measure the output of the transformer to the oscilloscope to see the AC voltage output

2.1.2 Rectifier

This is the part where the output from the transformer will be converted into DC voltage. Here, diodes are connected in a such way so that the current flows in one direction. After the voltage has been converted into DC voltage, the load current will be controlled by adding corresponding resistor.

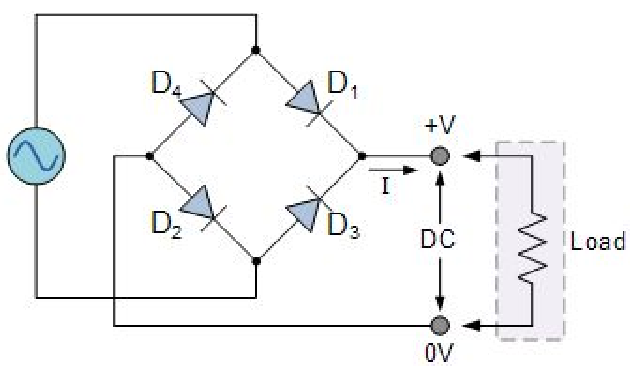

Figure 2.3 Diode Bridge Rectifier

2.1.3 Voltage Regulator

This is the part where we get desired voltage for our parts. Each part, including microcontroller, ESP chip, sensors and relay require different amount of voltages and current flowing. We would have to use voltage regulator and resistor to successfully have them.

Requirements	Verification
1. The voltage regulator will have to specifically convert the DC voltages to corresponding voltages as follow, Microcontroller & gas sensor – 5V +/- 5% 0.2mA for microcontroller 150mA for gas sensor ESP8266 WiFi Module – 3.3V +/- 5% 170mA for ESP chip IR detector – 3.6V +/- 5%	1. Since we are using voltage regulator to output the desired voltages, we will use a voltmeter to measure the output voltage to prove that the desired voltages are measure for each of the parts and they are steady. This will be measured through either oscilloscope or voltmeter.

2.1.4 Relay

This will be used as a switch for the stove. The data from the microcontroller will control the switch of the stove. Whenever the fire is on or the user acts on the application, the switch will be switched to off position so that the stove will be turned off.

Requirements	Verification
1. When the relay is switched off, the voltage or current must measure around 0 so that the stove is powered off. If the relay is switched on, the current should flow and we should have the stove working.	1. Use voltmeter or multimeter to observe the change in the voltage and current to make sure that the stove is not powered with anything once the switch is off and vice versa.

2.2 Sensors

The purpose for this module is to be able to respond to outside stimulus. Each of the sensor will check with each other so that they wouldn't cause a false signal to be sent out through the microcontroller. This module will serve as a crucial component for our design because these will have to detect the actual fire in case it happens.

2.2.1 IR Sensor

The Infrared detector will visually detect the fire at an infrared level. When the fire displays wavelengths between 760-1100 nm, the sensor will send a signal saying that a fire exists. The sensor has a detection angle of 60 degrees. While for the most part the gas sensor will be the main detector for a fire, having this sensor as well ensures that there will be little to no false alarms.

Requirements	Verification
1. The sensor must be able to detect a fire from anywhere on a stovetop of size 30 by 25 inches from a distance of 2 feet away having run at 3.3 V.	1.1 Wire sensor to arduino device and make sure readings from it are possible. 1.2 Create a small fire, emitting 760- 1100 nm, about 80 cm away from the sensor. 1.3 Make sure there are readings and adjust intensity and distance of fire accordingly.

2.2.2 Gas Sensor

The gas detector will detect the smoke that fires produce, much like most smoke alarms. An LED will shine in a straight line through the room; the smoke will deflect this light into another chamber holding this photoelectric sensor. This triggers the gas sensor. The ppm necessary to trigger it could be as low as 300 ppm, which is about the amount of CO necessary to be a danger to humans.

Requirements	Verification
1. Will detect CO levels of 300 ppm	1.1 Connect sensor to Arduino to read resistance of sensor. 1.2 Place the sensor in a container of one of the gases at least 300 ppm mentioned in the graph(Figure 2.4) and make sure resistance changes.

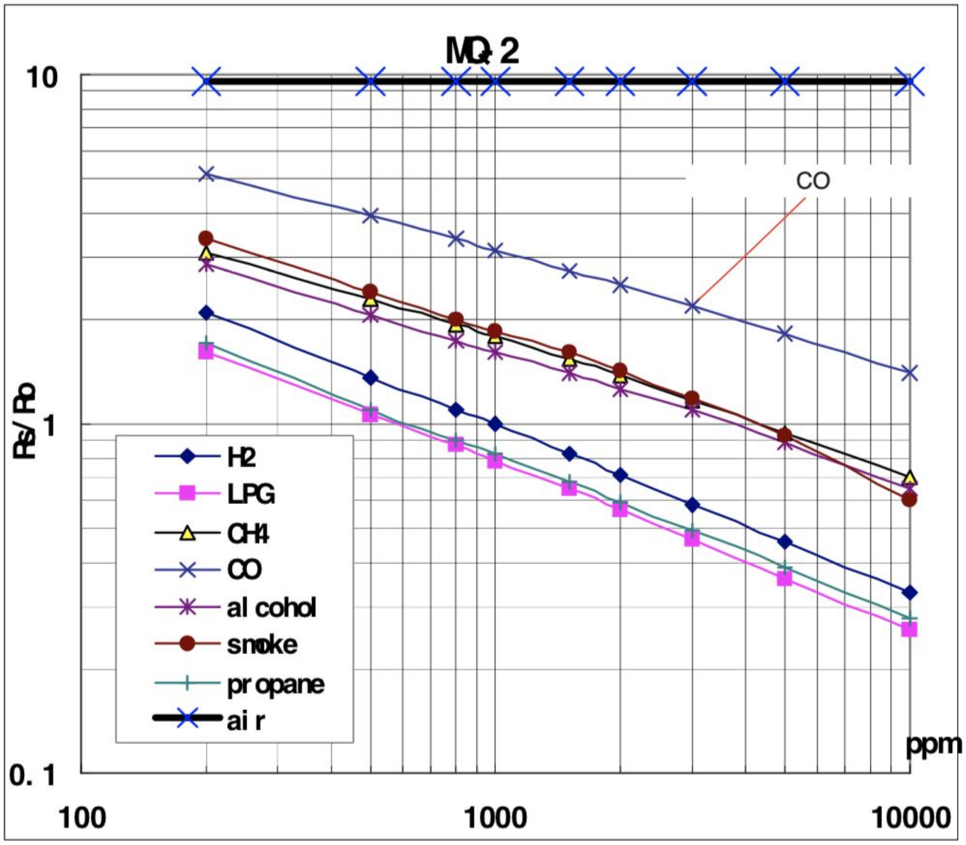

Figure 2.4 Sensitivity Characteristics of the Gas Sensors

X Axis: Parts Per Million of the gas measured
Y Axis: Rs/Ro. Rs represents the resistance of the sensor at the time of that much gas. Ro represents the resistance at 1000 ppm of hydrogen. Rs/Ro is the ratio.

2.3

Control Module - Microcontroller

The control unit will be responsible for determining whether the stove is on. In addition, it will be able to tell if the stove is on fire based on the information from the two sensors. This will be a real-time data into the mobile application through the usage of ESP8266 chip and then let the user decide to take action accordingly.

Requirements	Verification
1. The microcontroller must be running with maximum voltage 5V with approximation error of +/- 5%	1. We will check the Vin of the part with voltmeter to ensure that the microcontroller is getting the correct voltage within the range.
2. The microcontroller will have the current of 0.2mA when it is active.	2. The current of .2mA will be shown through the oscilloscope.
3. The microcontroller will run at typically 9600 baud, the transfer rate in bit per seconds.	3. We will calculate the oscillating frequency and using the formula for equation for calculating Baud rate and UBRRn value, the rate will be calculated.

2.4

Wifi Module

This module is responsible is for all wireless data transfer. Wireless communication will be between microcontroller, ESP chip, and a mobile application. This will allow wireless control of the stove.

2.4.1

ESP Chip

A ESP8266 chip will be used for this project. It is responsible for communicating all data between mobile application and the controller. So if a fire has been detected, it is the chip's job to communicate that to the application, and then when the user wants to turn the stove off through the app, the chip must tell that to the controller so the power module can be adjusted accordingly.

The ESP8266 has 8 pins with the following functions:

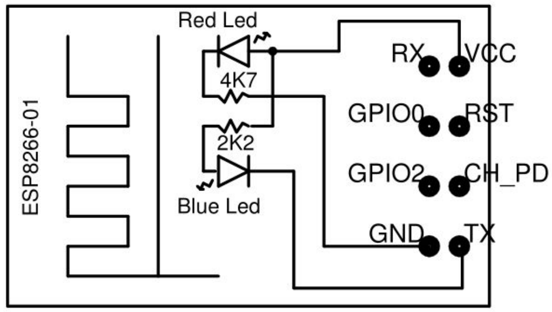

Figure 2.5 ESP8266-01 Pins and Basic Circuitry

Label	Signal
VCC	3.3V (3.6V max) supply voltage
GND	Ground
TXD	Transmit Data (3.3V level)
RXD	Receive Data (3.3V level!)
CH_PD	Chip Power down: (LOW = power down active)
GPIO0	General Purpose I / O 0
GPIO2	General Purpose I / O 2
RST	Reset (reset = LOW active)

Figure 2.6 ESP8266-01 Pin Specification

Requirement	Verification
1. The ESP chip needs 3.3V to function. 2. When not active, it requires 15mA +/- 10% 3. When receiving data, it requires 55mA +/- 5% 4. When transmitting data it requires 150mA +/- 5% 5. Transmission rate up to 100ft	1. Use voltmeter to show 3.3V 2. Use ammeter to show 15mA when no data transfer. 3. Receiving can be seen through a notification on the application. 4. Transmitting data can be seen by a test led that lights up based on command from the application. 5. Walk around the area to demonstrate range of chip.

2.4.2

Mobile Application

This will be the primary module for user to communicate with the stove indirectly. The application should be able to relay message to microcontroller to cut power from the stove through the ESP chip. It should also give notifications when a fire has occurred.

Here is a flow chart of how the application should function.

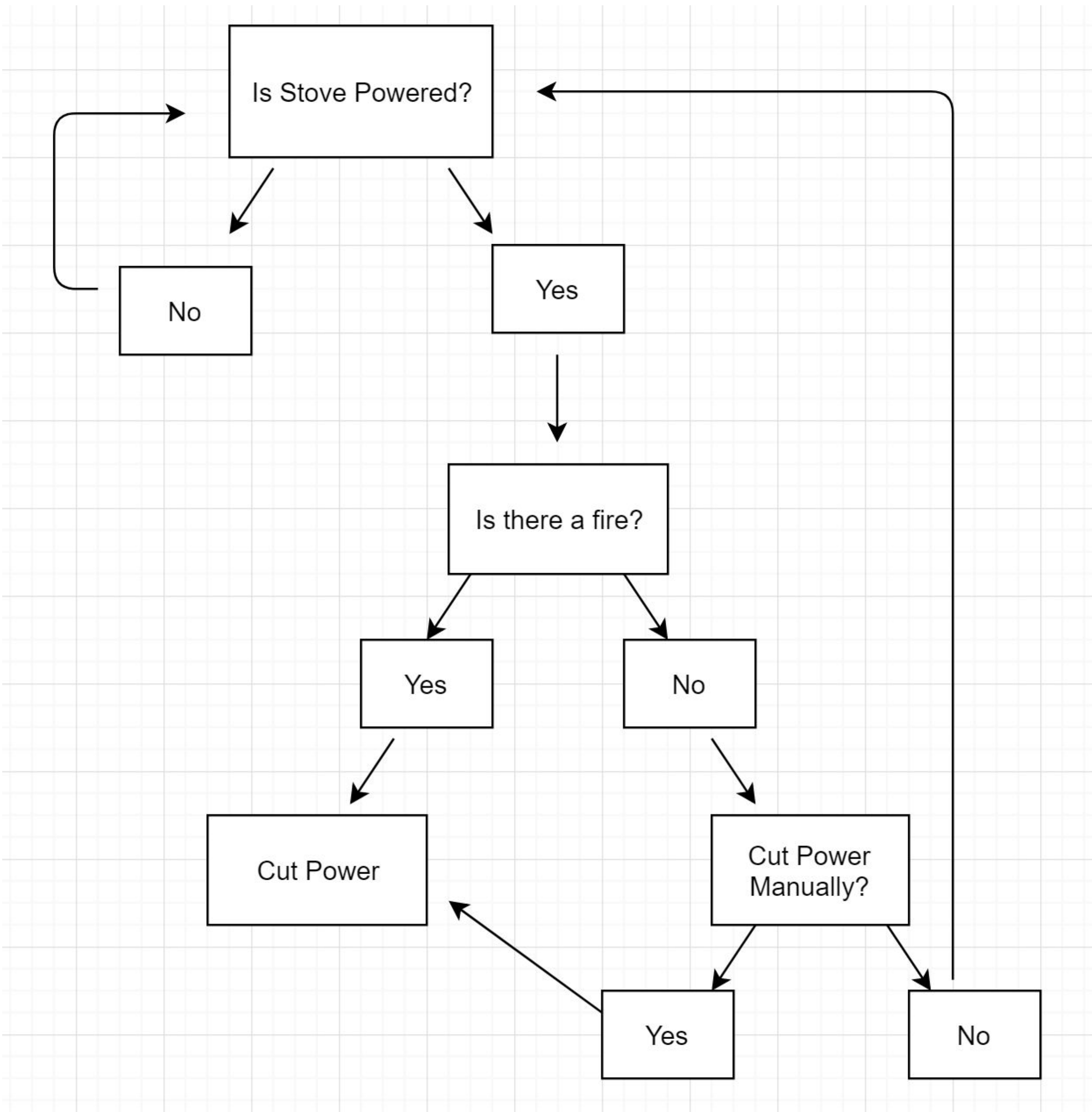

Figure 2.7 Software Flow Chart

Requirement	Verification
1. Should be able to communicate with microcontroller by sending and receiving data.	1. Show notification on phone to show receiving data, and turn stove off to show transmitting data.

2.5

Tolerance Analysis

The objective of the smart stove fire detector is to detect a fire on the stove, notify the user, and turn off the stove accordingly. This requires many parts for it to function correctly, such as the functionality of the sensor, the relay switch reliability, and the communication through the wifi module.

One of the most crucial parts of this design is the reliability and speed of the fire detection. In order for the fire to not spread and cause damage, the sensors must be able to quickly relay that the fire exists. In order to do this, the levels of carbon monoxide as well as the fire wavelength emittance must be at adequate levels for a period of time. However, if these levels vary a bit during the fire, the sensor must still be able to sense this and recognize that it is still a fire, although the values may be varied.

Therefore, in the program we will be writing for the microcontroller, the signal should be read for a duration of time, around 10 seconds, so that the device will be responsive as well as have little false alarms. The range needs to be large as well; 400 ppm of CO is a dangerous amount for humans, but having a range between 300 ppm and beyond allows the device to consistently detect the hazard even at levels below that. As for the flame sensor, the levels of wavelength varying is a common occurrence, as fire has a flicker rate of about 1 - 5 hz. It is imperative for the program to be able to account for this. An appropriate check for this would probably be at least twice the fastest flicker rate, which is 10 times a second. Checking this much in a span of 10 seconds as well should be an adequate detection time.

A range of 760 nm to 1100 nm for wavelength detection is very broad, but a change in these wavelengths should not matter as fire emits wavelengths above and below these wavelengths as well. Upon analysis, it seems that these numbers are broad enough such that detection is ensured, but the time for registering the fire could be adjusted based on how responsive this device.

3.1 Costs

For our project, we will calculate the costs of the whole project. The costs are divided into the parts and the labor. The costs of the parts are described as follows,

Parts	Details	Cost per unit	Quantity	Total Cost
Microcontroller	ATmega328P	$2.14	1	$2.14
Stove	Electric Single Burner Hot Plate	$19.99	1	$19.99
ESP chip	ESP8266 WiFi module	$7.00	1	$7.00
Sensor	IR detector KY-026	$6.99	1	$ 6.99
Sensor	Gas Sensor MQ2	$5.50	1	$5.50
Relay Switch	SLA-12VDC-SL-C	$0.94	1	$0.94
Regulator	5V – 576-2770-2-ND	$0.92	1	$0.92
Regulator	3.3V – TCR2EF33LM	$0.39	1	$0.39
Regulator	3.6V - FAN1585AT-ND	$0.47	1	$0.47
Regulator	12V - COM-12766 ROHS	$1.50	1	$1.50
Transformer	237-1911-ND	$9.25	2	$18.50

The Total cost of parts will be approximately, $ 64.34

The costs of labor will be such that we will be working at least 10 hours a week. Average starting salary of UIUC students is $71,166.

$\frac{\$71{,}166}{1\ year}$ x $\frac{1\ year}{52\ weeks}$ x $\frac{1\ week}{40\ hrs}$ = $34.21/hr.

Since we have three members in our group and we will each be working 10 hours a week for 12 weeks, excluding the first two weeks that we spent individually,

$\frac{\$34.21}{1\ hour}$ x 120 hours x 3 people = $12,315.60

Combining them together, the costs for the whole project will be approximately, $12,379.94

3.2 Schedule

Week	Kyung-Hoon	Shubhit	Alan
Week 2/18	-Finish design doc -Research relay specs -How to use regulators	-Finish design doc -How to connect ESP chip to microcontroller	-Finish design doc -Figure out how sensors will detect fire and connect to microcontroller
Week 2/25	-Start buying parts -Finish research on pin configuration of microcontroller	-Start buying parts -Finish research on pin configuration of ESP	-Start buying parts -Finish research on pin configuration of sensors
Week 3/4	-Set up power transformer and regulators	-Set up power transformer and regulators	-Set up power transformer and regulators
Week 3/11	-Power microcontroller -Try connecting relay -Start PCB design	-Power microcontroller -Try connecting ESP chip to controller -Start PCB design	-Power microcontroller -Try connecting sensors to controller -Start PCB design
Week 3/18	**Spring Break (research any additional parts that need to be bought)**	**Spring Break (research any additional parts that need to be bought)**	**Spring Break (research any additional parts that need to be bought)**
Week 3/25	-Finish PCB design	-Start mobile application -Finish PCB design	-Start mobile application -Finish PCB design
Week 4/1	-Start testing project with mock fires -Figure out what changes need to be made	-Start testing project with mock fires -Figure out what changes need to be made	-Start testing project with mock fires -Figure out what changes need to be made
Week 4/8	-Make changes from simulations	-Make changes from simulations	-Make changes from simulations
Week 4/15	-Bug fixes -Mock demo	-Bug fixes -Mock demo	-Bug fixes -Mock demo
Week 4/22	-Prepare presentation -Work on final paper	-Prepare presentation -Work on final paper	-Prepare presentation -Work on final paper
Week 4/29	-Present -Finish final paper	-Present -Finish final paper	-Present -Finish final paper

3.3 Calculation

$$V_{ripple} = \frac{V_p}{RL \times C} \times \Delta T$$

Since we are using full-wave rectifier, we would have 120Hz of frequency. We plan to use transformer, which outputs 6.3VAC and maximum load of 0.68A.

There will be voltage drop of the diodes within the rectifier, so it would have approximately 1.2V.

$$V_p = 6.3 - 1.2 = 5.1V$$

With approximately 10% voltage ripple, C = $\frac{V_p}{R_L} x \frac{1}{V_{ripple}} x \Delta T$

Plugging in the actual numbers, we get the smoothing capacitance to be

C $\approx$ $11111 \mu F$

4 Circuitry Schematics:

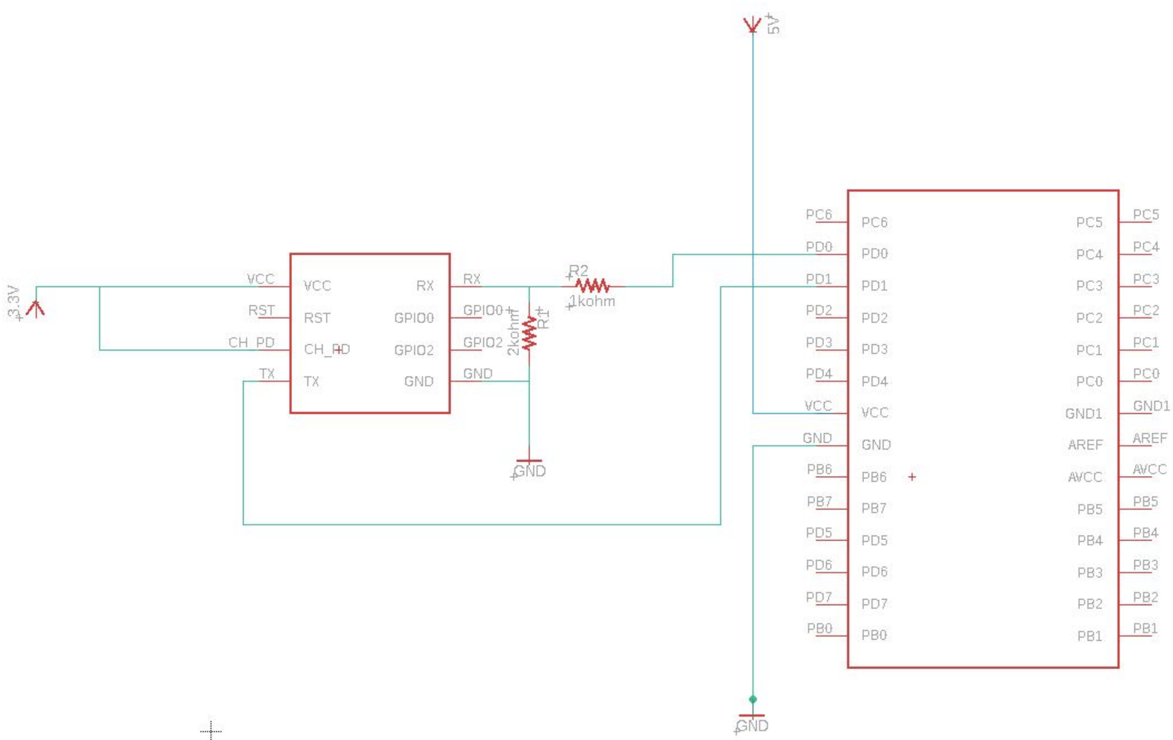

Figure 4.1 circuitry of ATmega328P-PU(right) connected with ESP8266-01(left)

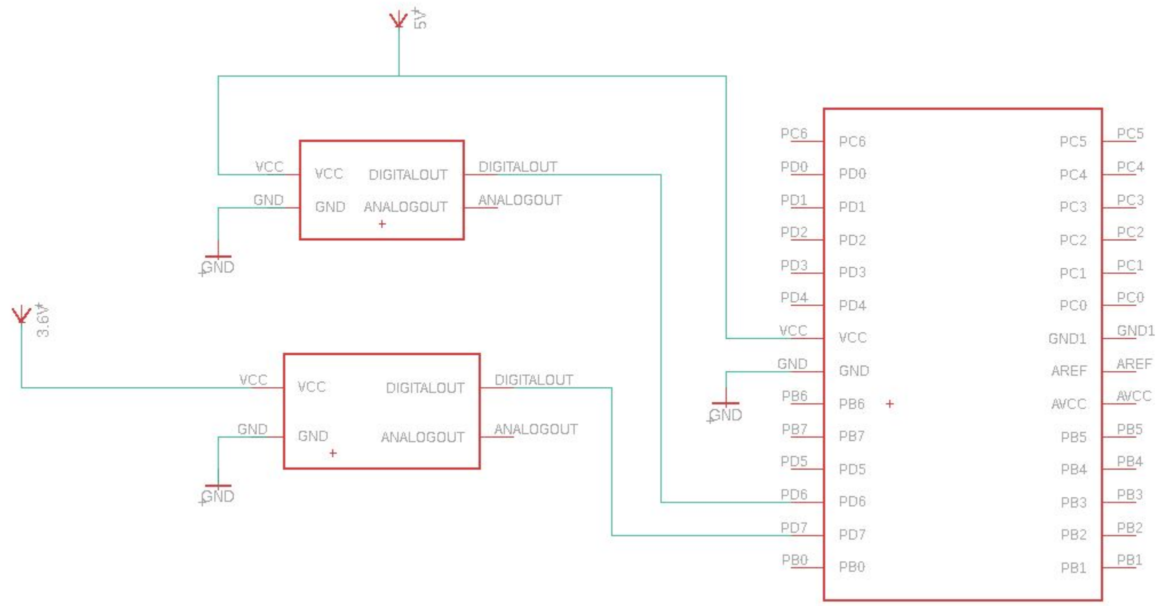

Figure 4.2 Circuitry of Sensors connected to the Microcontroller
Microcontroller(right)
Gas Sensor(upper left corner)
IR detector(lower left corner)

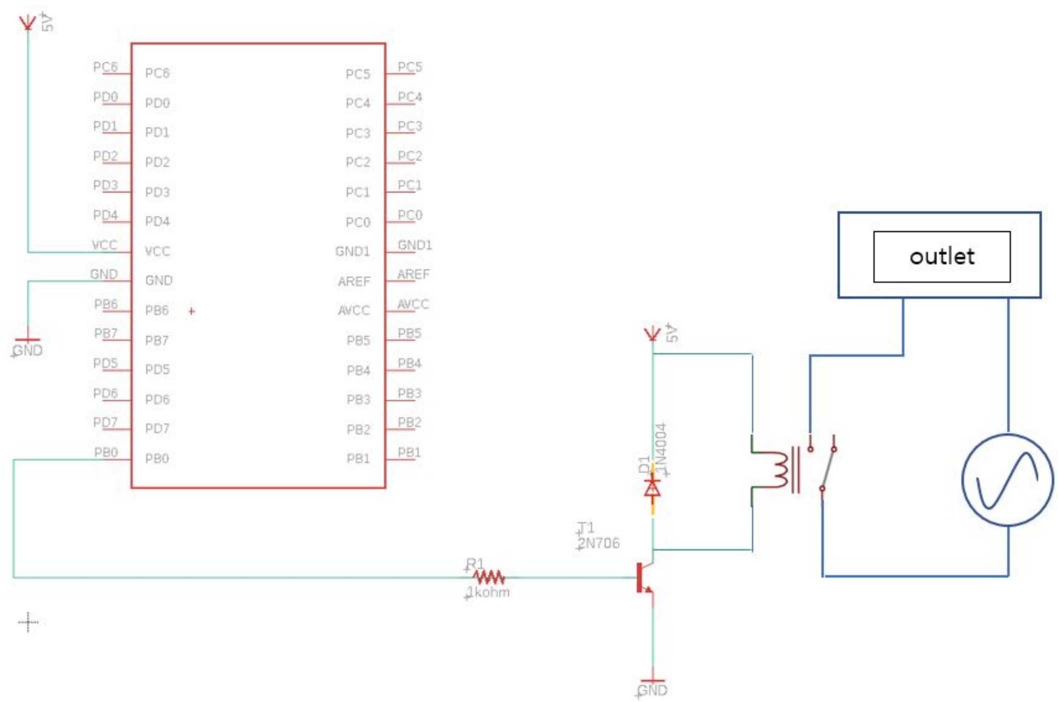

Figure 4.3 Circuit schematic of relay to control outlet and microcontroller to control relay

5 Safety/Ethics:

There will be many safety concerns with this project because of the involvement of the electric stove, which can be a fire hazard. The problem with electric stoves is that there are less physical indications compared to a gas stove [1]. Electric stoves do not use gas, thus it is harder for the user to realize if they have left it on, because there is no gas for them to smell. Compared to a gas stove that has a very visible burning flame, the coil of an electric stove is not always evident of its temperature. Often times, it is difficult for a user to gauge the heat of a coil as the only sign of its temperature is whether or not the coil turns a red color, which is not characteristic of all stoves. Aside from the fire hazard of the stove, we will be doing voltage transformation from a 120V outlet. Dealing with high voltages can be very dangerous if not handled properly. When working with the power module, the capacitors may not function like we expect it to. If we don't deal with this properly, we may get an electric shock. We will also need to make sure we extinguish any fires with a fire extinguisher, not water. When we testing our project, we have to keep the circuit away from water, metal and anything which is conductive. We will follow lab standards [2] and check for damages on outlets and wires, and make sure there are no liquids around that can damage electronics.

When working with this project, we must address all ethical concerns. When using the 120 VAC outlet power, we must ensure that utilizing will be safe and will not damage any circuits we use, such as the PCB or the stove that the circuit will be connected to, or harm any persons using this mechanism, following section one of IEEE code of ethics [3]. Section six of the IEEE code of ethics requires anybody working with this project to have the technological competence and qualifications, which we will follow when dealing with the power and circuits. We will also follow section seven, seeking and correcting errors that might occur when working with this mechanism.

References

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