Smart Stove

ECE445 Final Report | Spring 2019 | Team 75

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Abstract

This paper documents the design and testing of our smart stove setup. The inspiration of our project comes from attempting to make the kitchen, specifically a stove, a safer environment for the elderly and children. We will highlight how we accomplish this by detecting hazards with multiple sensor, notifying users wirelessly, and controlling power to a stove remotely. This done through 4 main modules, the sensor module, wifi module, control module, and power module. We hope that this is something that can be easily implemented in most home to make the lives of people safer.

Contents

1 Introduction

The kitchen has many different appliances, such as a microwave, refrigerator, dishwasher, and stove. They are to to an extent dangerous, but we believe the stove is the most dangerous. This is because it has a surface which exposes high heat and flames. 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 is cost-efficient, and applicable for most households. 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 and cheaper for the user. Our solution is 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 can remotely turn the stove off through the application. Then 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 through the application.

2 Design

2.1 Block Diagram

Our design is mainly divided into four parts: Wi-Fi Module, Control Module, Sensor Module and Power Module. Each can run on its own; However, they can interact with each other to achieve greater things in our project. This part will tell us the specific details about the modules and its components as well as its verification.

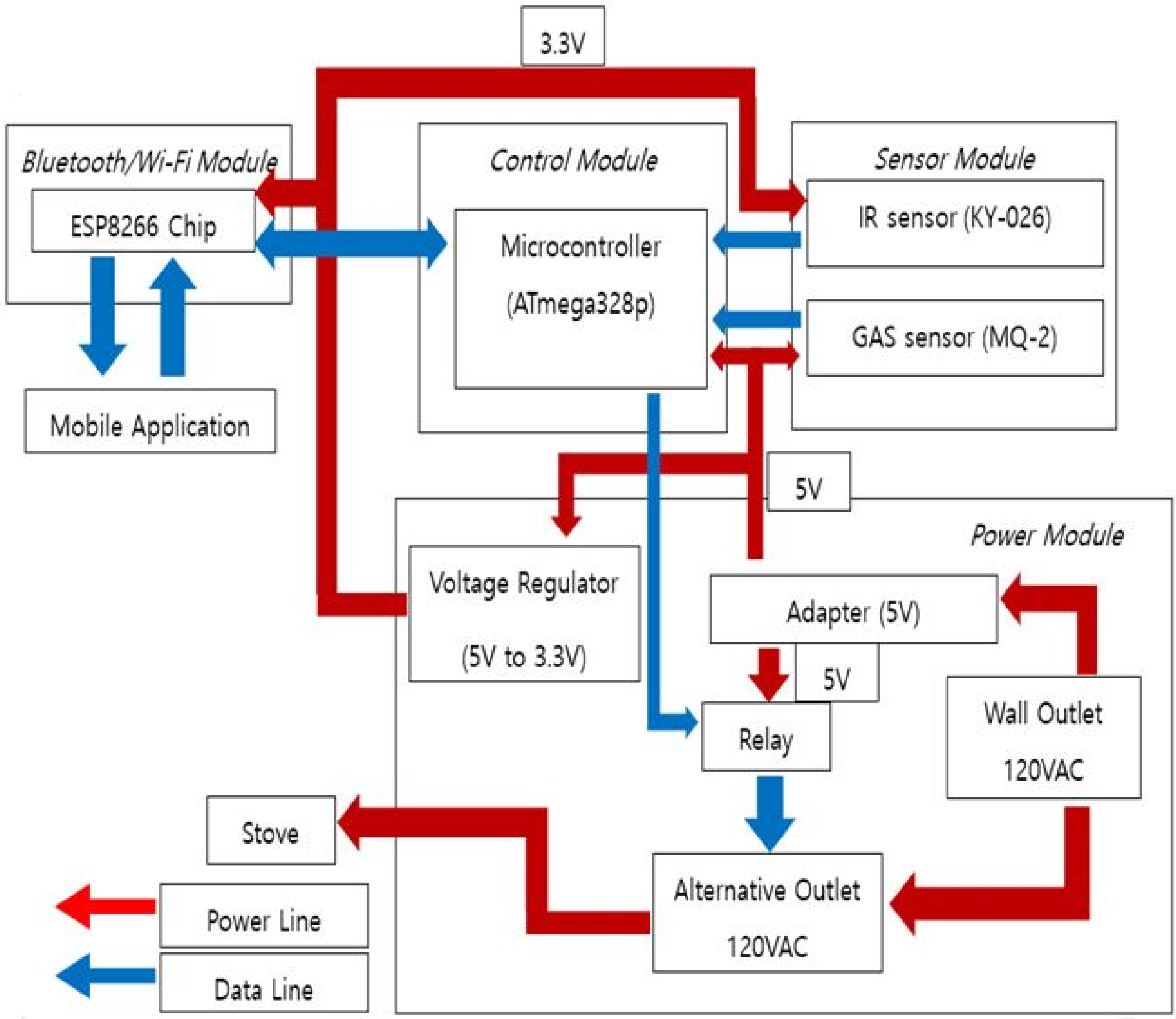

Figure 1. Block Diagram

2.2 Physical Design

We have two different parts for the physical design: one for the demonstration purpose and one for the actual usage visualization. Since the stove couldn't be brought to the actual demo place, we had to make a similar version of the setting to apply the tests. The main differences between the two physical designs are exact positioning of the sensors, size of the stove and the placement of the parts within the area of the design.

Figure 2. Physical Design – Demonstration

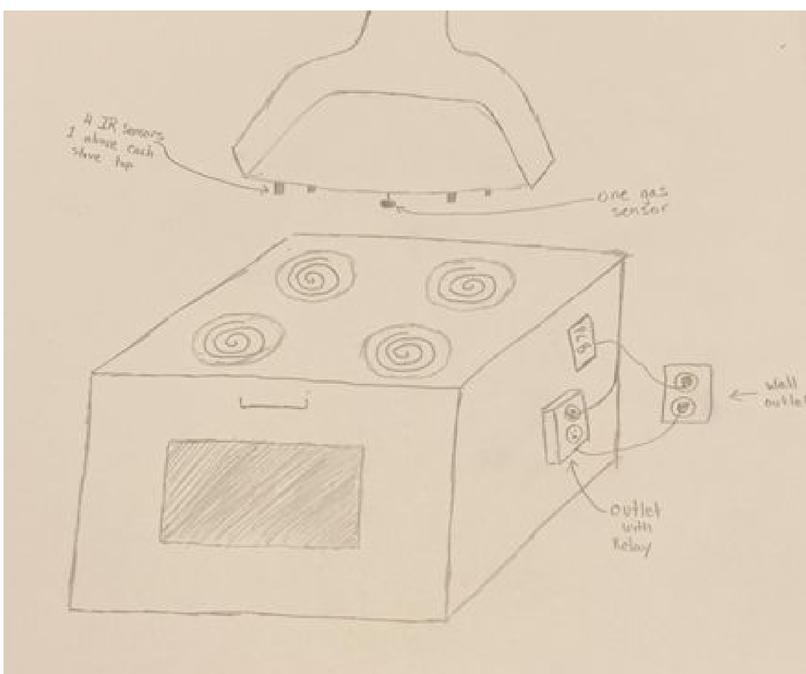

Figure 3. Physical Design – Reality visualization

2.3 Power Module

The main purpose of the power module is to supply power to other modules. It consists of the wall outlet, adapter, voltage regulator, relay and alternative outlet. For the power module, wall outlet is the main source in distributing appropriate power. Adapter is used as AC/DC converter to step down the outlet voltage to DC voltage so that it could be used for other parts. Voltage regulator is used to regulate the voltage from the adapter to appropriate voltage to be used for ESP chip and the IR sensor. Relay is used to control the alternative outlet's power and the alternative outlet is used as a bridge to power stove.

2.3.1 Adapter

For transforming the AC voltage from the wall outlet to DC voltage, we decided to use adapter instead of AC/DC converter. It would convert 120VAC to 5VDC with 2A connector. The reason why we decided not to use the transformer was that, since we are using high-voltage, there was a safety issue with our design. Having a transformer would require us to put the 120VAC directly into our PCB design, which could lead to some potential danger. For this reason, AC/DC adapter was our best candidate to replace the transformer. This would generate enough power to supply it to our microcontroller, two sensors, ESP chip and the relay.

2.3.2 Voltage Regulator

5V to 3.3V voltage regulator was essential in our design because it would not only power the appropriate voltage to the ESP chip and IR sensor but also reduce the complexity of our design. The voltage regulator that we used was LD1117V33 voltage regulator. The maximum current it could output was 800mA, which was well over the required current for the ESP chip and the IR sensor [10]. Since this part of our design was to transform 5V to 3.3V we needed to verify that it would output the correct voltage with the voltmeter. The two capacitors that we added in the V_{in}, 100nF, and the V_{out}, 10uF, were for stability of the in/out of the voltages.

2.3.3 Relay

The relay was an effective tool to control the alternative outlet that was powering the stove through the wall outlet. Three data through the microcontroller control the relay on/off switch: fire/smoke presence with the help from the sensors, on and off button from the mobile application. The main requirement for the relay was to check if the relay turns on/off according to the instructions from the mobile application and the sensors detecting hazards.

2.3.4 Alternative Outlet

This was our best option control the power to the stove with the help from the relay. Since it would require too much work for the users to install the relay on to the wall outlet, we decided to make another outlet with the relay so that it would directly control the stove's power.

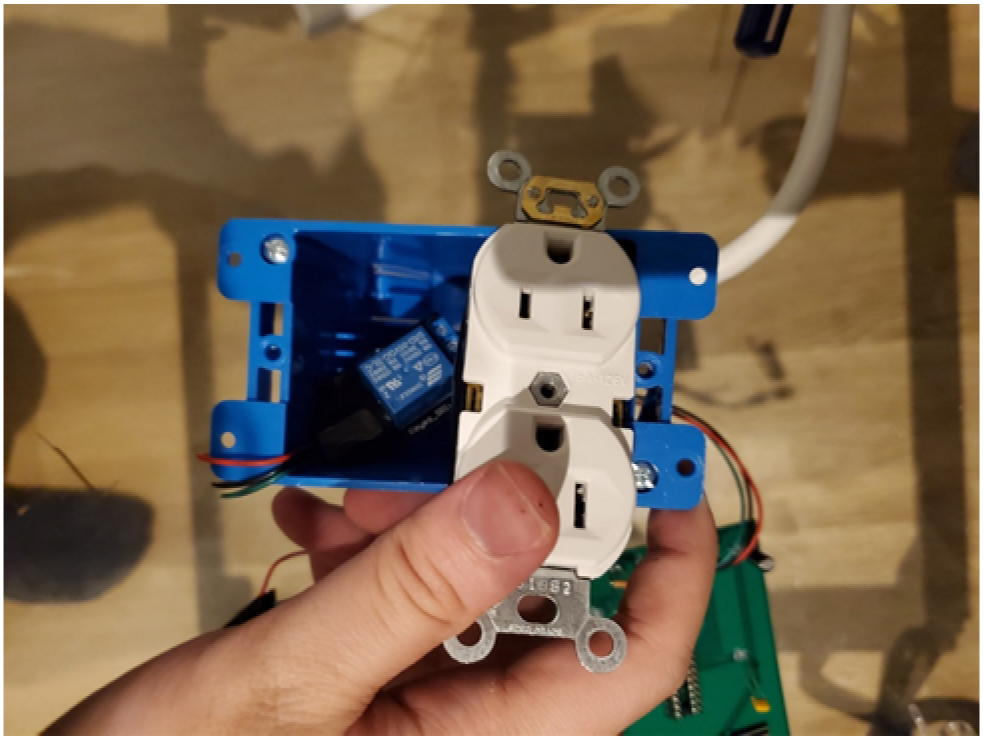

Figure 4. Alternative outlet with relay connected to one piece

2.4 Control Module

2.4.1 Microcontroller

The microcontroller that we used was the ATmega328p with 28-PDIP. This microcontroller was used because of three reasons: very cheap, accessibility to code on Arduino, and functionality to communicate with other devices. It had maximum clock speed of 16Mhz, which was more than enough to process all the data flow for our design. In addition, the microcontroller requires very low current even when it's on power mode, about 0.2mA [11]. Lastly, it has the easiest accessibility to programming with the usage of Arduino Uno. Using Arduino Uno, with DIP socket, we would just have to put it on and start programming. As it will be shown on the next page, the DIP socket was mounted on our PCB design for the accessibility of people on microcontroller.

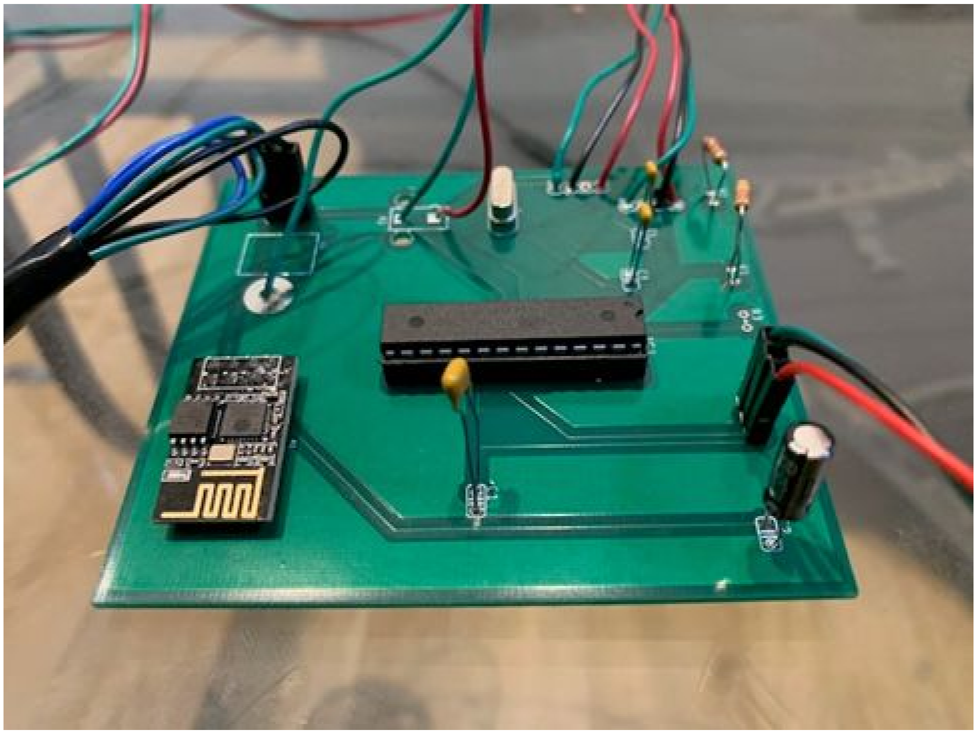

Figure 5. ATmega328p on PCB design with DIP socket

2.5 Sensor Module

We use two sensors in order to detect hazards. IR sensor is used to detect the IR wavelength while gas sensor is used to detect the smoke level. IR sensor uses digital signal so that it would sense the presence of IR or not while gas sensor uses analog signal to detect the hazardous gas level around the sensor. The data are then sent over to the microcontroller to be evaluated to send data accordingly, to mobile application and/or relay.

2.5.1 IR sensor (KY-026)

The first method to detect a fire is visually through infrared wavelengths. Fire emits many different kinds of wavelengths all throughout the electromagnetic spectrum, and many different light sensors could be used to detect these wavelengths.[4] However, the easiest and most cost effective way was to detect wavelengths of narrower infrared, just above the visual spectrum. The cost of making such a sensor currently is very low and abundant in every market. There are certain wavelengths that CO_2 and H_2O, created from fire, emit that are specific to those compounds. It is possible to detect those wavelengths, but as it stands now, those sensors are specially made and expensive. The sensor used in this project detects wavelengths through a phototransistor and compares with a certain threshold set on the comparator on the sensor, returning output when a fire is detected

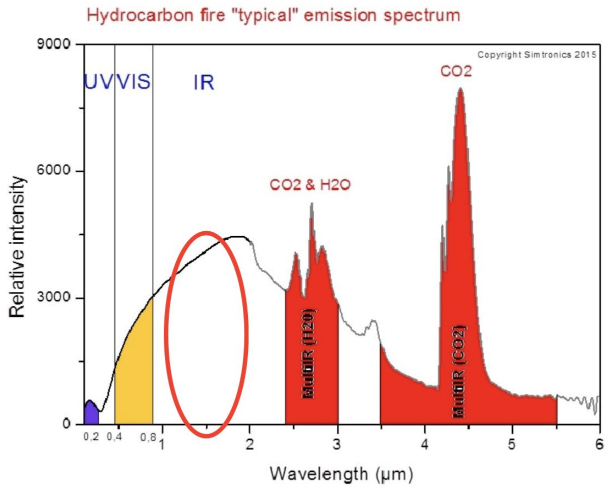

Figure 6. Electromagnetic Spectrum for Fire

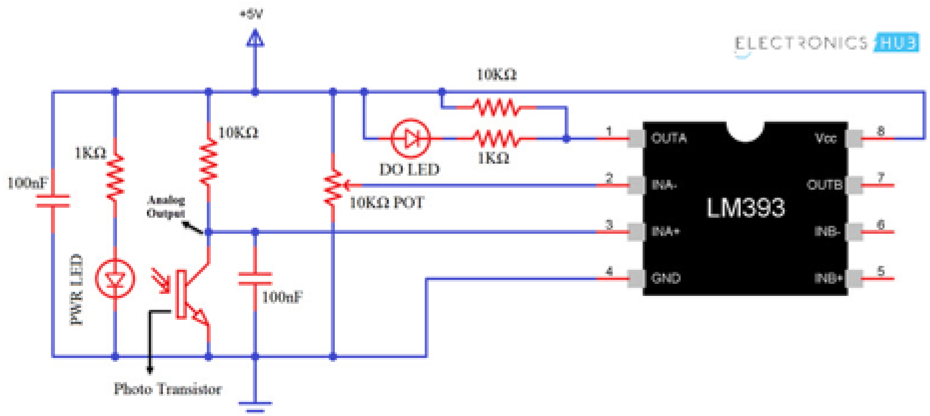

Figure 7. Flame Sensor Circuit [9]

2.5.2 Gas sensor (MQ-2)

The second method which to detect fire would be through the by-products of fire, namely smoke. Of course, cooking can provide smoke as well, so there are countermeasure against this. This sensor's main goal is to detect an abundance of smoke in an unnatural area. Fire detection through light should be the main method, while this sensor acts as a secondary method for when the fire could be obstructed visually. The sensor functions by heating up the air around it and, based on the obstruction of gases heated, relays a number depending on how much voltage is getting through the circuit. The sensor we chose was the MQ-2, which is able to detect smoke along with flammable gas. While the flammable gas feature is not necessary in this project, it would be helpful to detect gas leaks in the household as well, making this even more useful than initial assessment. The gas sensor does have a digital output and analog output, but only analog output was used as it may provide more information as to what exactly to call a hazard.

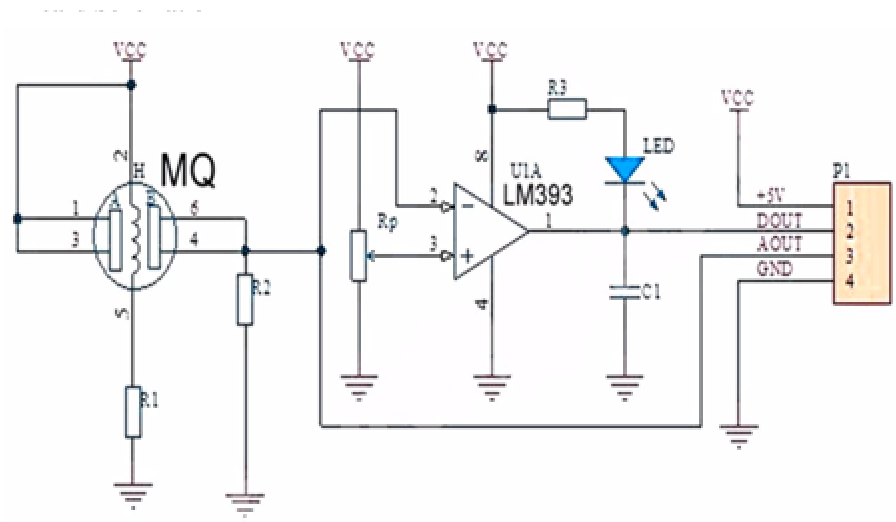

Figure 8. Gas Sensor Circuit [6]

2.6 Wi-Fi Module

The project utilizes WiFi from an ESP8266-01 as the connection between user and system. Bluetooth was an option to pair with the user as well, but there may be cases where the bluetooth distance limitations could be an issue to the entire system. In this case, the stationary circuit will have a stable connection to a WiFi network, and thus the phone will always be able to establish connection with the circuit through the network. The user, through this network, will be able to be alerted of hazards as well as control the stove remotely. This will be done by relaying messages from an app to the microcontroller.

2.6.1 Application Module

The app designed for this project has three purposes: to manually control the stove, alert the user of danger, and disable the utility of the circuit. Considering many scenarios of stove usages, these seem to cover the majority of things that can be done from the phone. Alerting the user is straightforward to explain; there needs to be a way the user is notified of danger. Then the user can turn off the stove if he wants. The disable function was thought of later, as disabling the automatic shutting off of the stove can be beneficial in some situations, such as when the user is cooking at the time or when the user is utilizing the stove for a longer period of time, i.e. simmering food. In order to detect a fire accurately, there has to be a consideration for possible spikes in the value readings. Fire has a flicker rate of at most 5 hz; reading the flame sensor every .1 second would appropriately catch the readings reliably. The smoke has no such flicker rate, but setting it to the same amount of readings should do no harm.To guarantee there is a fire read, there needs to be at least 2 positive readings every second, rather than 1, to ensure that spikes do not lead the system to trigger.

3 Design Verification

3.1 Power Module

3.1.1 Relay

In order to test the relay is getting the correct data to power on/off the alternative outlet, we used voltmeter and mobile application along with the sensors to test its functionality. When the hazard was present or button was pressed to turn off the stove, the relay would turn off and there will be no voltage/current flowing to relay.

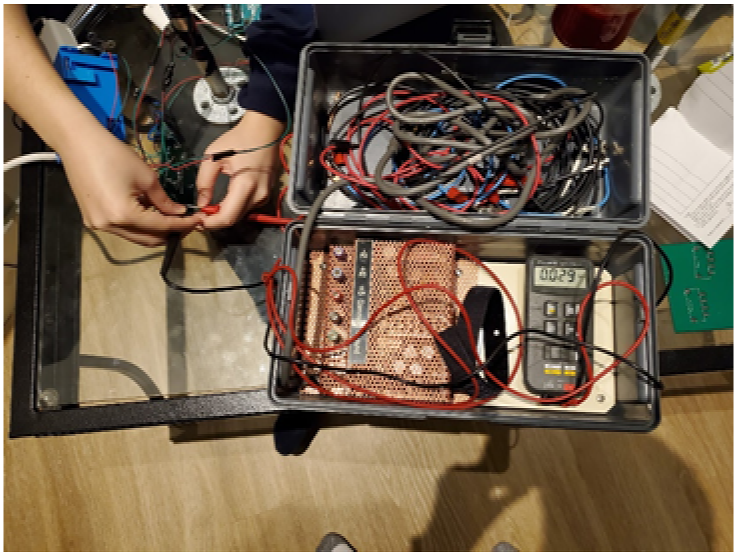

Figure 9. Relay powered off

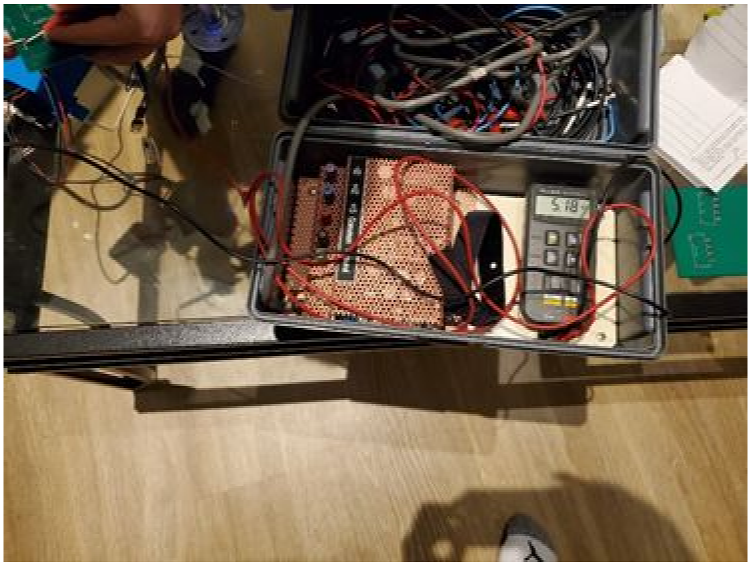

Figure 10. Relay powered on

3.1.2 Voltage Regulator

In order to test the voltage regulator’s functionality, we needed to make sure that the regulator would flow out the 3.3V with the approximate error of +-5%.

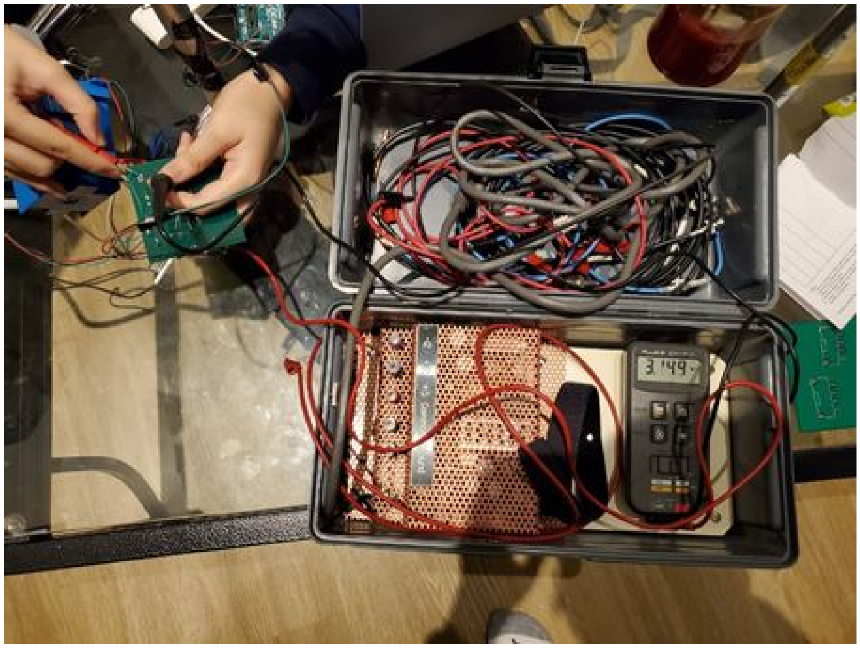

Figure 11. Output voltage, 3.149V, of Voltage Regulator

3.2 Control Module

3.2.1 Microcontroller

Microcontroller was the crucial part of our design in that it had to analyze all the data coming in from the sensors and the Wi-Fi module and act accordingly. It had two major requirements to be taken care of; It had to run at 5V with the approximate error of +-5% and run at 9600 baud rates, the transfer rate in bits per second.

```
SoftwareSerial ESPCom(4,5);

void setup() {
Serial.begin(9600);
 ESPCom.begin(115200);
 pinMode(flame_sensor, INPUT);
 pinMode(relayPort, OUTPUT);
 digitalWrite(relayPort, toggle);
```

Figure 12. Part of the ATmega328p code to run at 9600 baud rates

Figure 13. Input voltage, 5.09V, for microcontroller

3.3 Sensor Module

3.3.1 IR sensor

In the original requirements and verifications, the fire must be detected anywhere on the stovetop. To do this, a lighter was placed at corners of the stovetop while the sensor was placed where the vent is usually. At the time of testing, it became clear that at the lowest threshold setting, the flame sensor was not good enough to detect such a small flames at slight angles. This was assessed and reasoned with: larger fires, most importantly, needed to be detected. Therefore, we produced a larger fire by setting 1/4 of a letter size of paper on fire. The sensor appropriately detected them at all angles. We read this on a serial monitor through an Arduino, printing active low whenever the fire was detected.There seems to be a flicker at the beginning caused by the startup of the lighter; fire was definitely detected.

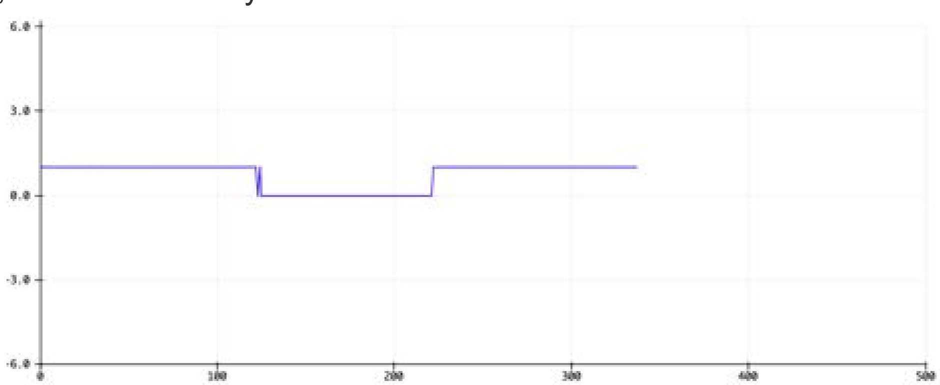

Figure 14. Digital Output for the IR Sensor

3.3.2 Gas Sensor

The gas sensor was also a little bit tricky to produce exact quantities of smoke, and the requirements reflect that. In order to contain smoke to emit on command, we utilized a jar of which we burned a 1/4 letter sized piece of paper. A lid was put on the jar to extinguish the fire, and smoke started building up from the little flames coming from the paper. We read this on a serial monitor through an Arduino, printing converted analog values of which the sensor output.

Each value represents a voltage divided by the maximum voltage 5.0 as a number out of 1024, the factory set intervals for digital conversion. Judging from the readings, it seems that the smoke was read to increase in concentration, steadily decreasing as the smoke dissipated until the sensor was back to neutral state. What is interesting was the slight spike a few seconds afterwards, possibly caused by shifting the sensor. However, spikes such as this will not registered as fire in the program as that is only one instance of a “high” value.

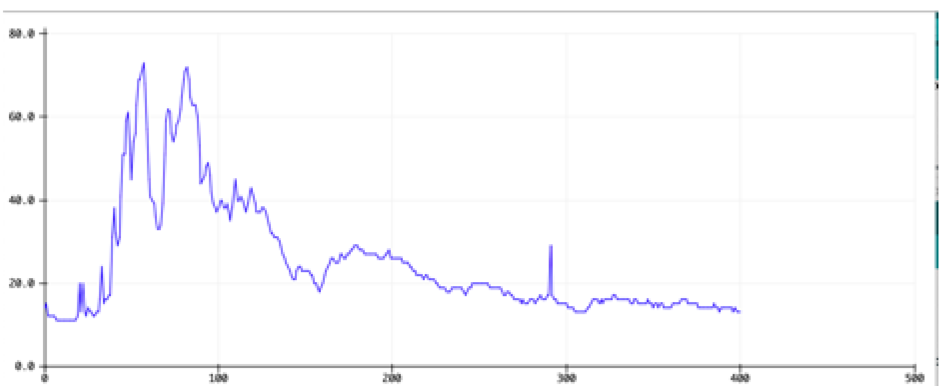

Figure 15. Analog Output for the Gas Sensor
X: Seconds * 1/10
Y: Voltage * 1/5.0 * 1024

3.4 Wi-Fi/Application Module

3.4.1 Mobile Application

We were able to verify our mobile application by making sure the UI is easy to understand and has the two main functionalities of being able to control the power wirelessly, and getting notified during a hazard. On the left, we can see that the application allows you to control the power through the green button. On the right, we see a notification appear when a fire occurs.

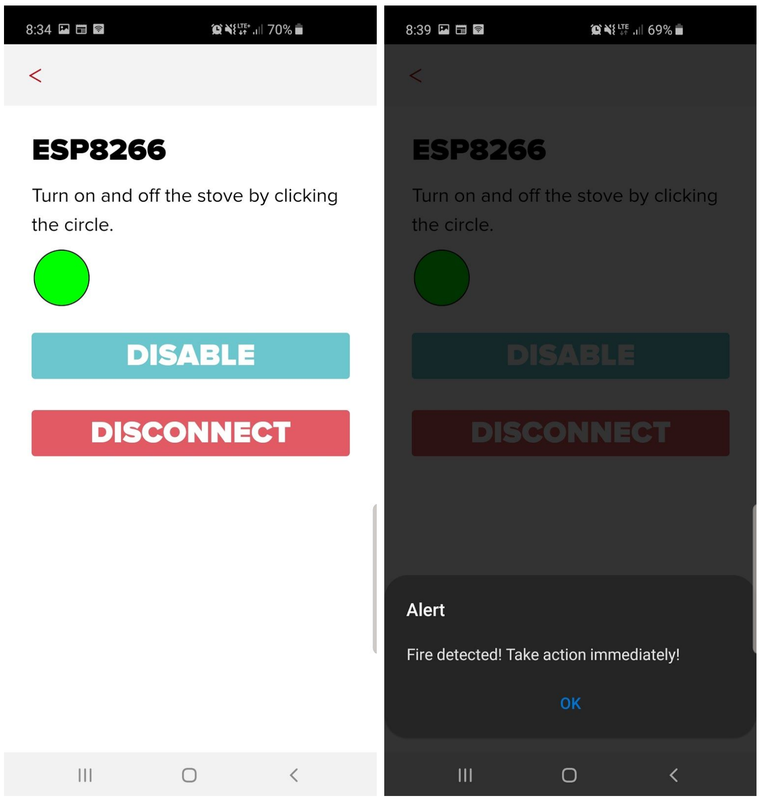

Figure 16. Application UI

4 Costs

4.1 Parts

Parts	Details	Cost per unit	Quantity	Total Cost
Microcontroller	ATmega328P	$9.14	1	$9.14
Arduino	Arduino Uno	$16.12	2	$32.24
Stove	Electric Single Burner Hot Plate	$29.99	1	$29.99
ESP chip	ESP8266 WiFi module	$7.00	1	$7.00
Sensor	IR detector KY-026	$6.99	1	$ 6.99
Sensor	Gas Sensor MQ-2	$7.50	1	$7.50
Relay Switch	SLA-05VDC-SL-C	$4.94	1	$4.94
Regulator	3.3V – LD1117V33	$2.39	1	$2.39
Power Adapter	AC Power Adapter 5V 2A	$6.88	1	$6.88
Sensor Stand	Metal Pipes	$35.00	1	$35.00
Alternate Outlet	120V Wall Outlet	$3.10	1	$3.10
Extension Cord	120V Outlet Extension Cord	$2.23	1	$2.23
Outlet Casing	Plastic Box Outlet Casing	$1.00	1	$1.00

Total Cost of Parts: **$148.38**

4.2 Labor

There were 3 of us working on this project, and we assume we each worked 10 hours a week for the 16 week duration of the class. We are using a base wage of $34 an hour, which is the average salary of graduating ECE students.

3 * 16 * 10 * 34 * 2.5= **$40,800**

5 Conclusion

In the end, our project was fully functioning. Although there were some difficulties along the way, we answered all of them with the best of our abilities. There are definitely things that can be improved upon; however, we properly answered the objectives we set for ourselves at the beginning of this project.

There definitely needs to be a finer line for the program to detect a stove fire versus just a regular cooking procedure, and further testing as well as programming can help work around this issue. There are some upsides to this unspecificity: the fire will be able to detect stove heat radiating from an unoccupied stove. This is actually a beneficial scenario; an empty hot stove can cause many different kinds of dangers.

When working with this project, we must address all ethical concerns. When using the 120 VAC outlet power, we ensured that utilizing the outlet is safe and does 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 follow when dealing with the power and circuits.

In the future, the system can hopefully provide a more direct solution to stopping stove fires. For example, the system can include its own sprinklers to extinguish the fire, but these are messy and might not be compatible with some stoves. The app can also have more functionality, such as being able to figure out the source of what triggered the alarm.

References

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