Automation of Gas Valves and Wireless Detection of Gas and Flame in Household Using Arduino Microcontroller

Syed Kamran Ali Rizvi
(0000277737)

A thesis submitted in partial fulfilment of

the requirements for the degree

Master of Science
in

Disaster Management

MILITARY COLLEGE OF ENGINEERING (MCE) RISALPUR

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY(NUST) SECTOR H-12, ISLAMABAD PAKISTAN.

(2022)

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS thesis written by **Syed Kamran Ali Rizvi Reg. No. 00000277737** of **Military College of Engineering**, National University of Sciences & Technology, Risalpur Campus, has been vetted by the undersigned, found complete in all respects as per NUST Statutes / Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfilment for the award of **MS degree in Disaster Management.** It is further certified that necessary amendments, as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

Signature: ______________________________

Name of Supervisor: **Maj. Dr Naeem Shahzad**

Date: __________________________________

Signature **(HOD)**: ________________________

Date: __________________________________

Signature **(Dean/Principal)**: ________________

Date: __________________________________

Automation of Gas Valves and Wireless Detection of Gas and Flame in Household Using Arduino Microcontroller

By

Syed Kamran Ali Rizvi

(00000277737)

A Thesis

of

Master of Science
Submitted to

Department of Disaster Management

Military College of Engineering (MCE) Risalpur

National University of Sciences and Technology (NUST)
Islamabad

In partial fulfillment of the requirements for the degree of

Master of Sciences in Disaster Management

2022

DEDICATION

This thesis is dedicated to **Muhammad wa Aal e Muhammad (Peace be Upon Him)**; minaret of knowledge and wisdom, my beloved **Mother** and my beloved **Father** who always supported me through thick and thin of my life gave me a lot of inspiration, moral courage, and my respected **advisor Maj Dr. Naeem Shahzad**, who's guidance made me able to finish my research work.

Acknowledgement

I am grateful to Almighty Allah, who enabled me to complete this research. The author would first like to acknowledge the Military College of Engineering for sponsoring this research project.

I would like to extend much appreciation and gratitude to my advisor, Maj. Dr Naeem Shahzad, whose countless inspirations, and guidance made it possible to complete my research work. In addition, Lecturer Somana Riaz and Dr Muhammad Amjad in the capacity of the committee member, gave me advice and feedback throughout the thesis process. I would like to pay gratitude to the academic members of the Military College of Engineering who provided a lot of knowledge during the academic session in the postgraduate program.

In the end, I express my solemn gratitude with a genuine sense of reverence to my parents for their encouragement, heartfelt prayers, and kind wishes for the successful completion of my studies along with this research work. I want to thank my parents from all my heart for always being with me and for motivating meat every point of my life. Without their support, nothing would have been possible.

(*Syed Kamran Ali Rizvi)*

ABSTRACT

During the past decade there has been a significant increase in number of gas leakage incidents on domestic and industrial scale claiming valuable lives and property. Keeping in view the nature of these incidents there is dire need for a mechanism which can minimize the frequency and impact of these incidents. Internet of things IOT has played a vital role in automation of various household equipment's using the readily available sensors in the market. One such automation device is the Microcontroller Arduino Esp32. which has 30 input points and a built in Wifi Module. Arduino has pre-installed multiple opensource libraries which can be loaded to the simulator as per requirement. The sensors which are connected to this microcontroller are MQ2 Gas Sensor, LM-35 Temperature Sensor, Flame sensor and a 12V solenoid valve is installed with the input gas pipeline. These sensors record the values at normal room temperature and transmits analogue output to the microcontroller which converts these values into digital output using the pre-installed algorithm and sends signal using a specific IP address using the in-built Wi-Fi module. These digital outputs converted by the microcontroller are then checked with the programmed thresholds for each sensor, if the value exceeds the threshold of any sensor the microcontroller sets off an alarm and cuts off the gas supply using a 12V solenoid valve. A user-friendly android application is developed which monitors readings from all the sensors and user can check the status of all sensors anytime. The developed prototype cuts off the gas supply and set off an alarm when the outputs exceed the thresholds values defined in the Algorithm.

LIST OF ABBREVIATIONS

IOT	-	Internet of Things
GSM	-	Global system for mobile communications
IBM	-	International Business Machines Corporation
NODE MCU	-	Node Combined with Micro-controller Unit
ARDUINO IDE	-	Arduino Integrated Development Environment
IP	-	Internet Protocol
MQTT	-	Message Queuing Telemetry Transport
PPM	-	Parts per Million
PCB	-	Printed Circuit Board
EDA	-	Electronic Design Automation

Table of Contents

List of Tables:

List of Figures:

Chapter 1 Introduction

1.1 Background Information

The history of microprocessors includes an increasing upward trend in terms of size and performance of various micro-controllers. These microcontrollers are vastly used for industrial and domestic applications. Modern day microcontrollers are low-cost and have a tendency to perform multiple functions using a basic algorithm, these microcontrollers can be used for the automation of various small and huge household appliance e.g., electrical switch to washing machine. These houses are usually called sensible homes. The Internet of things IOT enables these devices to be controlled and monitored wirelessly from anyplace or anyone using the specific defined network pathway. These include the automation of lights, Doors, vehicles, and even water sprinklers installed in the gardens. Objects make themselves recognizable and they obtain intelligence by making or enabling context related decisions thanks to the fact that they can communicate information about themselves. (Vermesan, 2013)

These smart microcontrollers have the capacity to transmit data signals and communicate with the connected devices using various means like GSM, Bluetooth and Wifi. Microcontrollers have extended the problem-solving capabilities of today's world one of which is the domestic fire outbreaks. These domestic gas leakage incidents have been drastically increased during the past 2 decades, majorly these incidents occur as a result of leakage caused by negligence during cooking and explosion of gas cylinders some other reported cases include the fire incidents caused as the result of the faulty electrical wiring, storage of flammable fluids near the cooking spaces, and minors playing in the cooking spaces.

Because of an increasing urban migration trend in search of better employment opportunities and livelihood has created a congestion in the cities so they have limited routes to access main roads, lack of special emergency lanes on highways and motorways, limited technical support mechanism for firefighting services, and very less personal or individual level firefighting skills. Excessive urban migrations have caused the congestion on the highways which also results in the response time by the firefighting authorities. In Pakistan specially no residential infrastructure is equipped with firefighting equipment's and emergency exits which increase the risk of massive losses in case of any fire incident. The residential apartment blocks in the metropolitans are not even equipped by any firefighting equipment, the high cost of these equipment's and lack of awareness is also a hindrance.

The timely detection of fire or any other gas leakage can minimize the loss to property and lives of citizens. If the readily available devices or sensors in the market are used in sensible way, then a reliable and accurate system can be developed which will enhance the capacities of communities. The fire detection equipment's that are available in the market have a really high rate of false alarms and lack of intelligence that these automated modern devices seek to incorporate. Even the western countries that have installed this fire detection mechanism have a ratio of 85% false alarms and only 15% is the success ratio. (Rutimann, 2014, March 07)

The solution to this problem is clearly an introduction of smart and intelligent detection mechanism which incorporates these smart sensors and allows them to communicate with each other using microcontrollers. An intelligent prototype needs to be developed that can be embedded in any modern home using a user-friendly software, which can increase the coping capacity and timely detection of these residential fire incidents. The evolution of Internet of things have introduced various low-cost hardware that can be connected with multiple sensors at the same time and can communicate simultaneously with all of them, which not only monitors the conditions of these sensors but also provide the set of instruction about their operation mechanism.

1.2 Problem Statement

Domestic gas leakage incidents have increased tremendously during the past 10 years in Pakistan and no residential unit is properly equipped with the fire detection, gas detection mechanisms. These high-end systems are installed by various private companies at a remarkably high cost, so the majority of the community cannot afford to pay of these hefty systems. The slow and no response by the fire department also increase the vulnerability of the communities. Lack of awareness and technical trainings in the individual homeowners is also one of the factors. These incidents cause various causalities and damage to the property, these incidents can be mitigated by using a multisensory smart detection system.

1.3 Research Objectives

- To review the existing techniques in the detection of domestic gas leakages and fire outbreaks and Review its Challenges.
- To develop a prototype that incorporates multiple sensors to detect domestic gas leakages and fire outbreaks.
- To develop a user-friendly Android Application that generates alert based on signal received from Arduino Esp.32
- To test the developed Prototype

1.4 Scope and Limitation

Various categories of infrastructures are widely used in our country, but this research only encompasses the residential spaces, i-e rooms, houses, and residential buildings. Business and other mega projects require high-end performance standards thus the equipment's that are used for industrial usage are very costly and development of such a prototype is out of the scope of this study. This proposed and developed prototype was only checked for small fires and gas leakages of domestic scale because of the risk to attracting large fires in the buildings/spaces.

Chapter 2 Literature Review

2.1 Introduction

The concept of smart technology is emerging in Pakistan, with the development of mega infrastructure projects like the smart motorways network, smart city Lahore and Islamabad, smart cars, and smart homes. The Major companies like IBM and Other research associations are contributing a lot to the innovation of Internet of things and have introduced extensive projects like Cisco till 2019 have introduced more than 24 billion internet-connected objects. (Obanda, 2017).

Internet of things is the hub for connecting all these multi-sensors and all these physical sensors and electronic devices are interconnected with each other using this same technology. These devices can include cars, electronic doors, sprinkler systems, software's, and switches etc. they can communicate with each other and exchange data not only with each other but also sends this data across different internet servers which helps in the wireless operations of these devices. (The Internet of Thigs:, 2015)

IOT can be used to prevent and mitigate the enormous incidents and disasters that are caused because of domestic gas leakage and help in generation of early warning mechanism for these residential units. A fire outbreak is silent, and people will know about the fire when it has spread across a large area. (Today C. , 2015). Fire and gas leakage incidents have claimed hundreds of lives and have caused damage of Million to property and infrastructure.

Smart gas detection mechanism to measure the air and water quality in all parameters that can be outliers by an eventual gas leak in the atmosphere. This detection mechanism monitors CH4 and CO2 and for water parameters like PH, Temperature and electrical conductivity. The system uses Arduino Uno Micro-controller and Integration module is Raspberry Pi 3. (Ilie & Vaccaro, 2017)

IOT based domestic gas leakage detection mechanism is another project designed to integrate sensors in a smart automation module Node MCU, the data is acquired by the gas sensor and is uploaded to the cloud server associated with it, the stored data can be used to analyze the pattern of leakage and decimals. The gas detector sends analogue data to the connected NODE MCU and it converts this into digital output. (Subramanian, Selvam, Rajkumar, Mahalakshmi, & Ramprabhakar, 2020)

A multi sensor fire detection mechanism that uses smoke sensor and gas sensor are connected with the Arduino Uno micro-controller. The monitored data for gas is in PPM, and threshold for gas sensor is set at 300ppm in order to get more accurate results. A GSM module is connected with the micro-controller which enables the generation of alert using GSM module in case the threshold exceeds for any sensor. The smoke sensor has high ratio of false alarms as it triggers with cigarette smoke and even cooking fumes in the kitchen. (Obanda, 2017)

2.2 Nature of Fire/leakage

A chemical reaction in which a carbon-based material (fuel) mixes with oxygen and is heated to a point where flammable vapors are produced is called a fire. (Center:, 2015). These flammable vapors then if encounter some elevated temperature substance that can make it ignite and result in generation of fire. The residential units usually are full of numerous fuels in various forms that include clothing, bedding items, wooden furniture, other plastic, and electronic equipment. The installed appliances like Air conditioners, refrigerators, and electric lighting in the residential units also contains various gases that are flammable and thus increase the intensity and loss in case a fire is erupted in the Residential unit.

The fire in residential units starts at a slow pace usually and when it gets in contact with other substances that can act as the fuels then it increases the intensity. The development of fire in any residential unit depends on several factors that include the physical arrangement of assorted items that are placed in the domestic unit and the quantity of available oxygen. This fire generates an enormous amount of heat and light, also emits moderate amount of smoke. During this time when the fire is growing slowly there is a need generate a timely response either human or automatic which can be used to control the fire before significant loss takes place. (Hartin, 2005)

Once the flames starts to appear then this fire changes it form from a minor to major situation and increase the temperature of the surrounding to several hundred degree within the spam of minutes, the temperature of surrounding and ceiling exceeds 1000 degree and these flames takes all the available fuels in the room/ space available and within a span of 3 to 5 minutes the room starts to act like a boiler and it starts to ignite all the combustibles of the room. At this point it becomes too impossible for human survival and almost of the contents of the room are lost. Another important factor is the structure of the building if the structure is strong enough to hold the fire, then the fire will burn out on its own in some time and less damage is occurred to the structure of the building but in case the structure of the building is not good then it may cause the building structure to collapse as the high temperature of because of fire will melt down the reinforcements.

The individual with a portable fire extinguisher might function as the first or primary line of defense in the process, but only when the fire is erupted and no major combustibles of the room are utilized by fire, this can mitigate the loss and can extinguish the fire within time. If there is no one present in the room and fire grows rapidly, the extinguisher capability is only valid for a first few minutes. If these capabilities are surpassed, then more powerful fire suppression methods might be needed which can be provided either by the fire department or automatic fire systems.

2.3 Gas Leakage Incidents and Challenges

Several incidents have been reported in the last two years that are caused as the result of the domestic gas leakages. These horrific disasters can be controlled using the mechanism described in the previous chapters.

Few of the reported cases during the last two years are described.

2.3.1 Domestic Gas Leakage Incidents

- **January 13, 2019,** three members of the family including a woman were injured as the result of explosion caused by gas leakage. The house was located at Chakri road Rawalpindi, the family members were trapped under the rubble and suffered several injuries. The Rescue personnel pulled up the injured from the debris and shifted them to the hospital for treatment.
- **November 21st, 2017:** Quetta. Gas leakage in the house caused fire which resulted in the death of two members of the family.

- **September 1st, 2018:** Lahore. The house caught fire due to leakage of gas, killing four family members.
- **December 31st, 2018:** Lakki Marwat, KPK. Gas leakage explosion killed an infant girl, and the mother was critically injured.
- **January 25th, 2019:** Lahore. Domestic gas explosion set a minor to burn alive, while four other family members sustained serious injuries.
- **January 13th, 2019:** Chakri road, Rawalpindi. The roof of the house collapsed due to an explosion caused by gas leakage. The explosion resulted in the death of three family members.
- **February 8th, 2019:** Pashtunabad, Quetta. Gas Leakage in the house poisoned four family members to death.
- **April 20th, 2019:** Dir colony, Ring Road, Peshawar. Gas leaked in the religious seminary. 17 girls fainted and were immediately hospitalized.

2.3.2 Industrial Gas Leakage Incidents

- **October 25th, 2017:** Haripur, District Hazara. Approximately 15 laborers were injured as a result of the blast caused by the leakage of gas in the factory.
- **March 6th, 2020:** Port Qasim, Karachi. Gas leakage by a chlorine gas pipeline in Engro Polymers and Chemicals Limited resulted in the injury of more than 90 employees.
- **February 18th, 2020:** Keamari, Karachi. The factory underwent a big scale gas leakage causing the death of 14 people and sickening of hundreds. (Jawad, 2020, February 18)
- **January 10th, 2020:** Karachi. Gas Leakage in the warehouse of a hotel caused multiple explosions. This killed five people.

2.4 Existing Preventive Measures

Residential buildings in Pakistan are not equipped with any fire detection systems only some of the modern housing schemes have buildings equipped with fire detection systems, even amongst these buildings because of high ratio of false alarms these systems are disconnected or forged, and they have only sensors visible but nonfunctional. There is a regulation for industrial units to obtain license from the civil defense authority and the competent authority only provides the certification after the physical inspection of the placed fire detection and extinguishing mechanism but unfortunately there are very fewer industrial units functional which have cleared this certification.

Fire Alarm system and smoke detection modules are the systems that are intended only for the detection of the fire and smoke in the premises, they can trigger the alarm but have limited capacity to provide mitigation mechanism to avoid the loss of life and damage to property. These fire detection and smoke detection modules have high rate of false alarms and they can be triggered by various activities in the residential unit like cooking and smoking in some cases. Few of the readily available systems in the market have water sprinklers systems connected with these modules that starts operations automatically if they detect fire or smoke in room, thus false alarms can trigger these sprinklers and cause damage to installed appliances as well. These systems have the capacity to extinguish the fire erupted in some cases, but they cannot cut off the potential source of these fires.

2.5 Conceptual Model

The figure below represents the main idea on how the proposed system is supposed to work. For this purpose, an acrylic box is prepared, and multi-sensor detection system is installed in that box, this multi-sensor prototype at the core has an Arduino Esp.32 Microcontroller installed MQ2 Gas sensor, a flame sensor and LM35 temperature sensor with a build in Wifi module. The Sensors installed will record the data and sends analogue signal to the Arduino Esp.32 which converts the analogue signal to digital output and sends this signal to the allocated web server with this micro-controller, the webserver is connected with the microcontroller, which monitors the digital output and compare the value with the designated thresholds within the Algorithm. If the received output valve exceeds the threshold, then it will send the signal to the buzzer, which set off the alarm and shuts off the solenoid valve connected with the central gas supply valve.

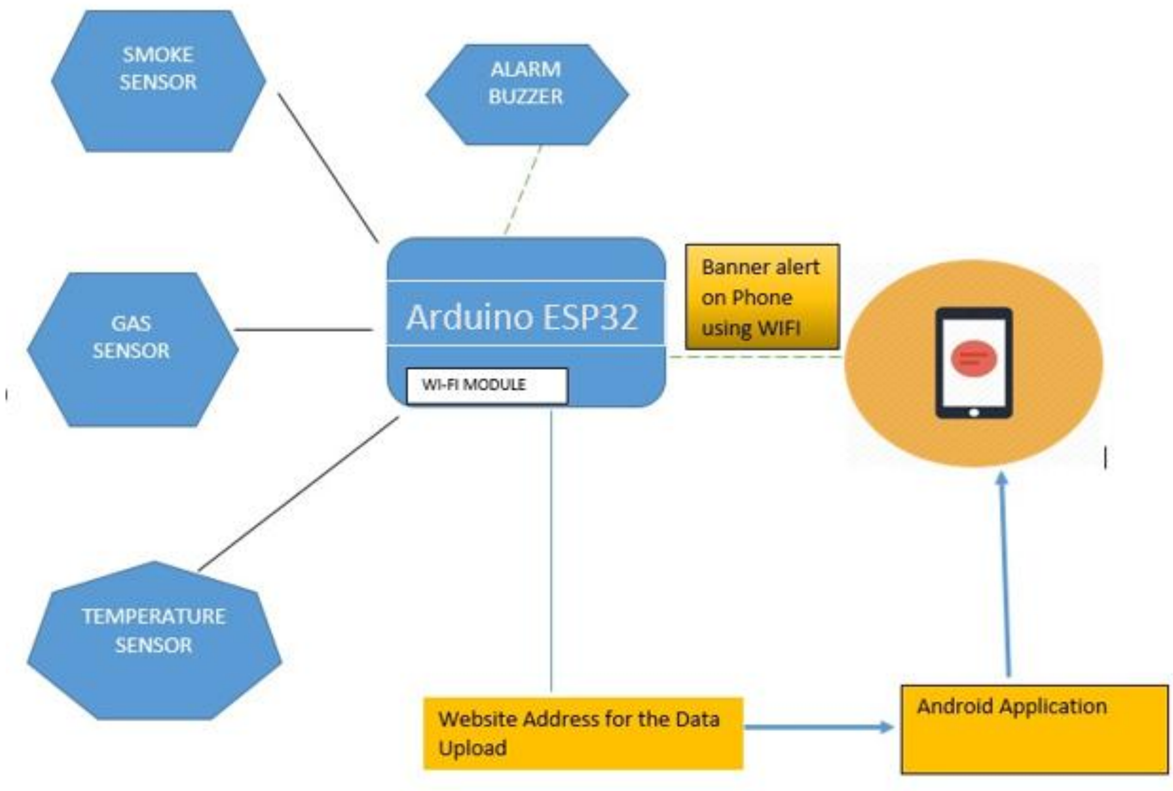


Figure 2. 1 Conceptual Model for Prototype Development

Chapter 3 Research Methodology

3.1 Introduction

The procedures by which researchers go about their work of describing, explaining, and predicting phenomena are called research methodology (Rajasekar, 2013). This chapter covers the idea and design of the research, the methods for the data collection and presentation.

3.2 Research Idea and Design

The idea of is research is derived from the concept of applied research that is designed to solve the technical problems that are faced in the modern world. (National, 2014). The problem identified was the residential fire incidents where there is need to incorporate an innovative mechanism that can inform and mitigate the fire or gas leakage incident that can occur within a domestic household with more accuracy and a low rate of false alarms.

The researcher after analyzing the available literature about the concept, theories and application of these modernized microcontroller programs that are user friendly and have a huge built-in library of various functions that they can perform. All these libraries and literature aided a lot in understanding the core concept of developing a smart prototype which can be incorporated in any residential or domestic household.

3.2.1 Data Collection and Analysis

The methods used in this research is the combination of primary and secondary both data. Primary data refers to the information which is acquired through firsthand investigations that include the data collection using surveys, questionnaires, focus groups and measurements. (Sapsford, 2006). The primary data in case of this research is the data collected from all the sensors that are installed on the PCB, this includes the data collected from MQ2 gas sensor, flame sensor and LM35 temperature sensor. All these sensors have a pre-defined data sheets which exhibits the characteristics of these sensors under different conditions, like the data sheet for the temperature sensor will exhibit the operations of sensor at different temperatures.

Secondary data is the data that is used in the literature review, which includes the qualitative and quantitative data that has been already collected by other parties. (Sapsford, 2006), secondary data in this research includes the mechanism that are previously used for detection of fire and gas leakage in residential households which incorporates the IOT and smart usage of modern-day microcontrollers.

3.2.2 Development of Proposed Prototype

Prototype building and architecture is a developing process in order to get the desired output and clarify the requirement. Rapid prototyping is being used in this project as methodology. The process of rapid prototyping is selected because of its two core advantages time and cost saving and easy incorporation of changes in the prototype.

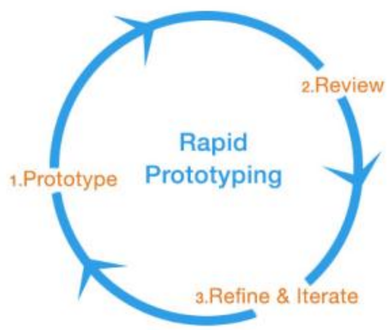


Figure 3. 1 Rapid Prototyping Cycle (Adapted from: Chua, 2010)

The prototype will be built with one sensor unit at a time. The following procedure will be adopted in order to obtain the specified results

- Incorporating a Single sensor (MQ2 Gas Sensor)
- Testing and validation of the incorporated sensor
- Setting the Threshold for the Sensor
- Implementation of Second sensor in the same fashion

Chapter 4 System Analysis and Design

4.1 Introduction

This chapter incorporates the techniques and development process about what functions will the prototype performs and the specified outputs under different operational conditions. This chapter also provides information about functions that are being performed by various components that are installed in the prototype.

4.2 Specifications of Prototype

The requirement of the prototype describes complete information about the behavior of the prototype. These requirements can be classified into two distinct types which are described in this section.

4.2.1 Functional and Non-functional requirements.

Functional requirement is the set of information that are the intended outputs of the prototype, these include the activity, task, and what regulation of required action according to the defined scenario. These include

I. The developed prototype should be able to read and process the Analogue data obtained by various sensors that are connected to it. These include the data from the LM35 temperature sensor, MQ2 gas sensor and Flame Sensor.

II. The collected analogue data should be converted to digital signal by the Arduino ESP32. And should send this digital data to the Arduino web server that connects the hardware with the developed android application.

III. The prototype then processes the digital data received from the microcontroller with the predefined set of instructions provided in the microcontroller algorithm.

IV. If the data exceeds the threshold set in the algorithm, then the prototype will shut the solenoid valve and set off the buzzer alarm.

V. The connected web server of Arduino should reflect the readings from the prototype into the developed android application so the user can monitor the state of sensors anytime from anywhere.

VI. The non-functional requirement of the prototype refers to the specific set of instructions that can be used to judge the overall progress of the system which is independent of the specific behaviors of various modules connected with the system.

VII. These non-functional requirements include the performance, market availability, and reliability of the prototype.

4.3 Analysis of system thresholds

The section will cover the defined set of instructions provided to the Arduino Esp32. For processing of data received from the prototype. The connected modules in the prototype have their own data sheets to monitor the characteristics of sensors under different circumstances, these sensors have a built-in calibration module that is physically accessible and is used by hit and trial method to set in the calibration.

MQ2 Gas sensor detects the H2, LPG, methane (CH4), alcohol and Propane, the sensor have a calibration setting module connected with it which can be adjusted from 300ppm (parts per million) to 10000 ppm, the sensitivity of this module is set at most sensitive in the prototype so that the leakage can be detected timely, another reason to set this sensor at high sensitivity is the size of room in which the sensor is installed, regardless of the size of room this sensor because of its high sensitivity will detect the leakage and will provide a more timely response(set off the buzzer alarm and cut off the gas supply in the room with the help of the solenoid connected with it.

The temperature sensor in the prototype provides information about the temperature conditions in the room during different hours of the day. The average room temperature is 21 to 26 degrees generally but because of the global warming effect, harsh summer, and winter conditions the temperature is set maximum at 41, mean room temperature 37.5and lowest is 33. This temperature sensor is set up individually in the prototype so that the ratio of false alarms can be controlled. This sensor provides the temperature conditions of the room to the user and is meant to display the readings only, this does not set off the alarm when temperature is high in the room.

Temperature	Time of the Day
34	10am
34	11am
37	12pm
38	1pm
38	2pm
41	3pm
40	4pm
39	5pm
38	6pm
38	7pm
37	8pm
37	9pm
36	10pm
36	11pm
35	12am
35	1am
35	2am
34	3am
34	4am
33	5am
33	6am
34	7am
34	8am
34	9am

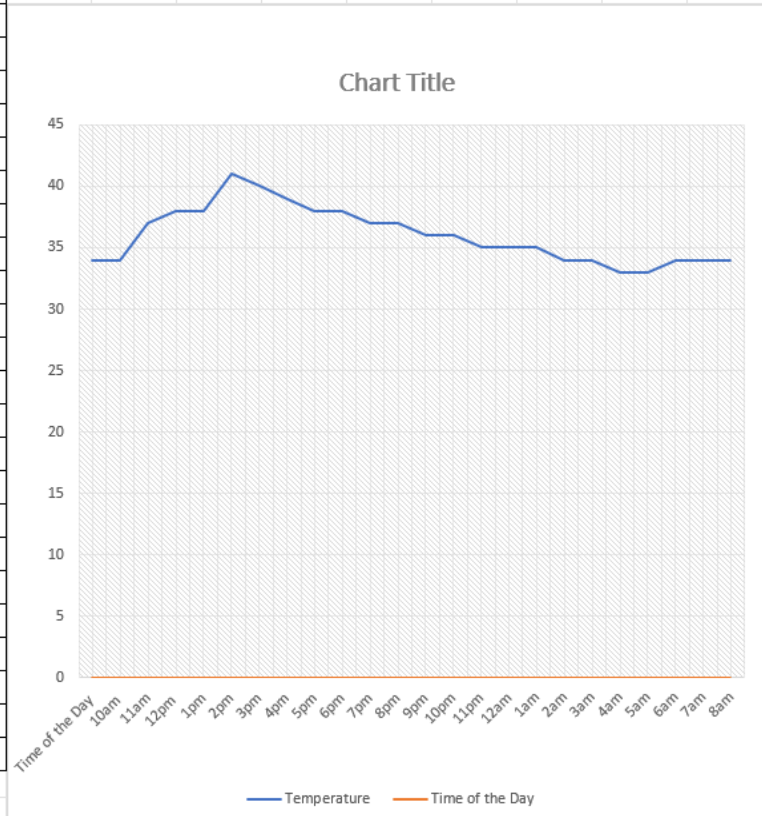


Figure 4. 1 Variable Temperatures during the day

Flame sensors are equipped with UV detectors that functions on the principle of Infrared; it detects the high intensity of light produced by certain object. Whenever any material ignites it emits the Ultraviolet radiations at the ignition which are less than 300nm wavelength and are detected by this flame sensor.

4.3.1 Challenges of Various Flame gas and gas detection sensors

The existing preventive measures that are mentioned in the literature review have several limitation and challenges and the table below describes how the proposed system will try to solve these limitations and challenges.

Table 4. 1 Challenges with Existing and Proposed Systems

List of Challenges	Existing Fire and Smoke detection systems in Market	Proposed System Support

Incorporation of Multiple Sensors	Yes	Yes
Relies on a single Sensor for detection	Yes	No
Generates alert on Fire Detection (Buzzer)	Yes	Yes
Ability to notify the User	No	Android Application for Alerting the User
Detection of LPG gas	No	Yes
Generates Alarm on Smoke of Cigarette	Yes	Yes
Steam and Cooking Vapors can Triger the system	Yes	No
Chemical Leakage and fumes detection	Yes	CO, Alcohol, and other gases like Propane butane.

4.4 System Architecture

The system architecture of the prototype refers to the conceptual model described in the chapter 2. The MQ2 gas sensor, Smoke/Flame Sensor and Temperature Sensor are all connected with the Arduino Microcontroller, which collects all the data/readings from these sensors and provides a user-friendly interface to check the readings.

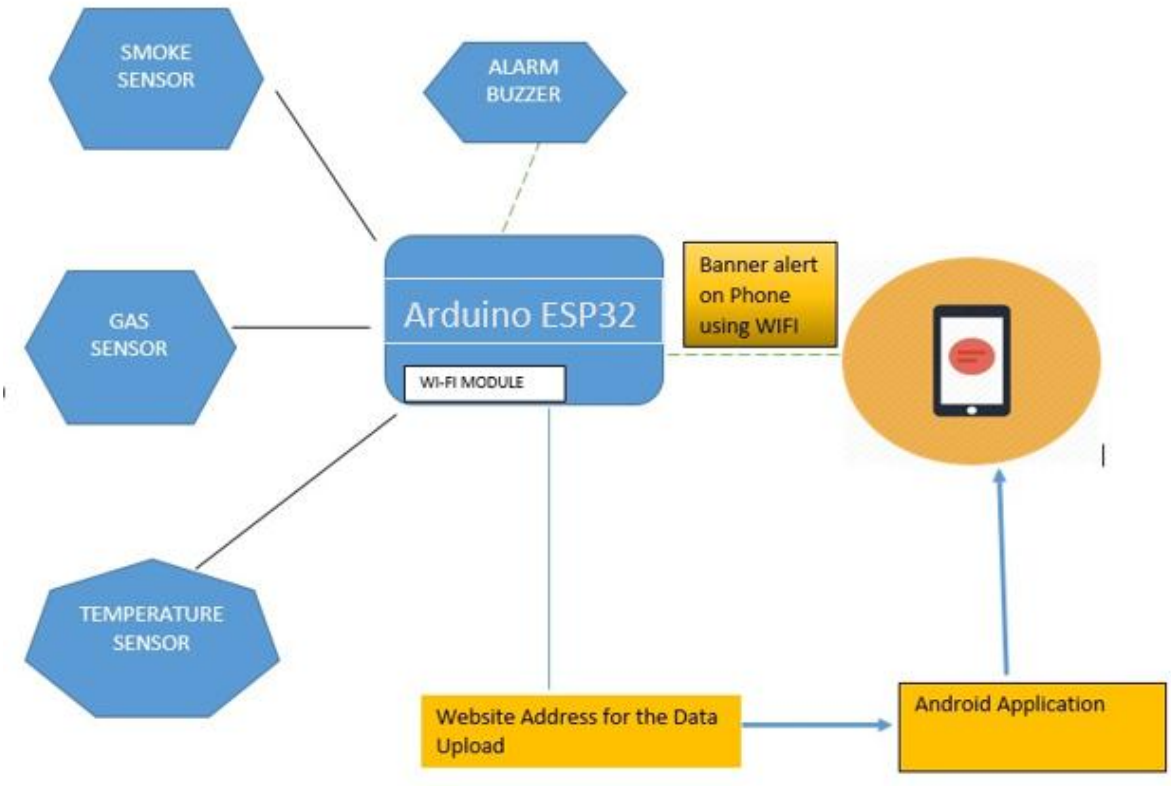


Figure 4. 2 System Architecture diagram

4.4.1 Flow-chart representation

The flowchart represents the sequence of events and the functional model of the proposed prototype, it provides information about how the proposed system will operate and interact with other components of the system and how the user will make an interaction with all the modules that are connected in the system.

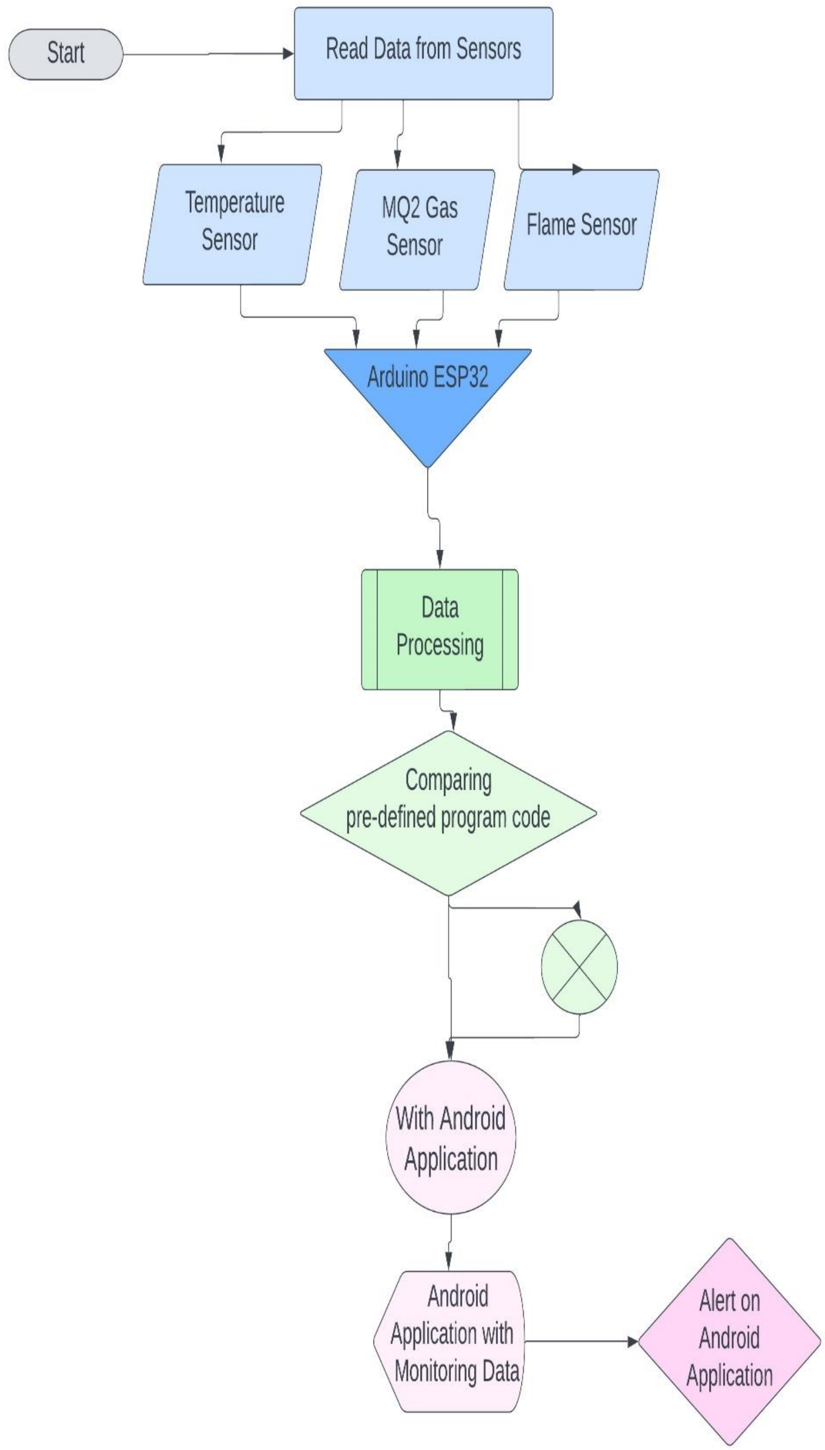


Figure 4. 3 Flow-chart diagram describing functionality of Prototype

Chapter 5 Development and Testing

5.1 Introduction

This section refers to the development and testing of the prototype, the design of circuit and PCB using EasyEDA online platform, the conditions and processing of the values that are recorded by the prototype are also discussed in this chapter. The developed prototype's response time for monitoring the temperature, presence of gas and flame intensity are also discussed in this chapter.

5.2 Components Required

The first step in the development of the prototype includes the procurement of required sensors that are available in the market, then these sensors are assembled on the designed circuit and PCB with hardware configuration and Integration with the Arduino webserver, this data from the server is then displayed on the Android application.

5.3 Material Assemblages and List

The list of materials that are required to build the prototype are discussed with their salient features below. The mentioned specifications include the power supply that is required by each sensor, which is considered to be a key factor in developing the PCB and Circuit design. These mentioned components are selected because they are easily available in the market and are cheap compared to other sensors that are available.

Table 5. 1 List of Materials

Hardware Name	**Technical Specifications**	**Description**
Bread Board with PCB Design and Circuit	• Dimension: • Wire size: Suitable for 29-20 AWG wires	The bread board serves as a connection point for the electrical devices such as the Sensors, capacitors, and resistors. It enables the creation of the circuit and

		provides pins that can also be used for Data transfer. The Circuit is developed on this PCB using an Online Platform called Easy EDA (A free Platform which allows to develop a circuit diagram based on your requirements)
Jumper Wires	• Red, blue, black, and yellow color codes	An assortment of female-female, male male and female-to male jumper Cables were purchased for the Wiring.
Buzzer	• Operating Voltage: 3 -24V • Rate Voltage: 12V DC	Standard Piezo buzzer.
MQ 2 Gas Sensor	• Concentration: 300-10000ppm • Voltage: 5V	The Grove - Gas Sensor (MQ2) module is useful for gas leakage detection (home And industry). It is suitable for detecting H2, LPG, CH4, CO, Alcohol, Smoke or Propane. Due to its high sensitivity and fast response time, measurement can be Taken as soon as possible.
Flame Sensor	• Operating Voltage: 3.3V to 5.3V • UV/IR Flame	High photosensitivity, Quick Response time, the angle of detection if 600 degrees, with an adjustable sensitivity option, this sensor is also used in industrial boilers to check whether the boiler is working properly or not because of its

	Detector • From 350nm to 1100nm	quick response time.
ARDUINO WROOM ESP32 (NODE MCU) Wifi Based Micro-Controller	• Current – Receiving: 80 mA • Voltage – Supply: 2.2 V ~ 3.6 V • Current – Transmitting: 80 mA • Number of pins supported: 30 • Data Rate: 54 Mbps • Frequency: 2.4 GHz. • Mounting Type: Surface Mount • Operating Temperature: -40°C ~ 85°C. • Power – Output: 16.5dBm.	This micro-controller can be directly plugged into the center of your breadboard, and you are ready to build a circuit around it. You will be able to plug it into your computer via a micro-USB socket at the far end, and there are two buttons on the top: one for resetting the device, the other for programming.
12 V Dc Solenoid Valve	• Operating Voltage: 12V DC • 2 ways	It works on the principle of 0/1 for opening and closing of the valve, it requires a 12V Dc current for its operation, one wire is connected with the Relay and Other with the 12V adapter, it connects

		the relay with the microcontroller and controls the valve operation as per defined criteria in the algorithm.
Relay Switch	• Operating Voltage: 12V DC	This relay switch connects the solenoid valve with the micro-controller and controls its operation i-e opening and closing with respect to the provided conditions
12V Dc Adapter	• Operating Voltage: 220AC • Converts 220AC to 12 DC	The function of adapter is to provide 12V DC to the solenoid value.

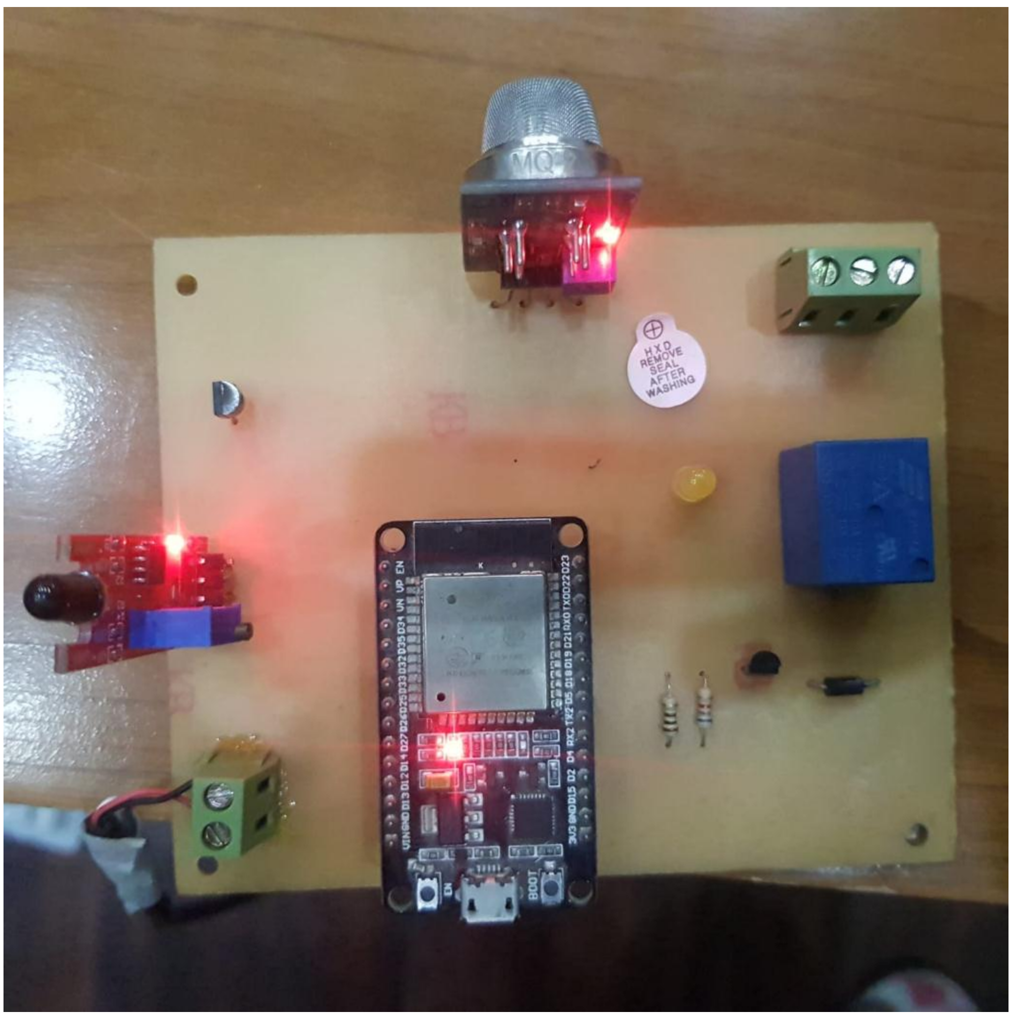


Figure 5. 1 Circuit with installed sensors

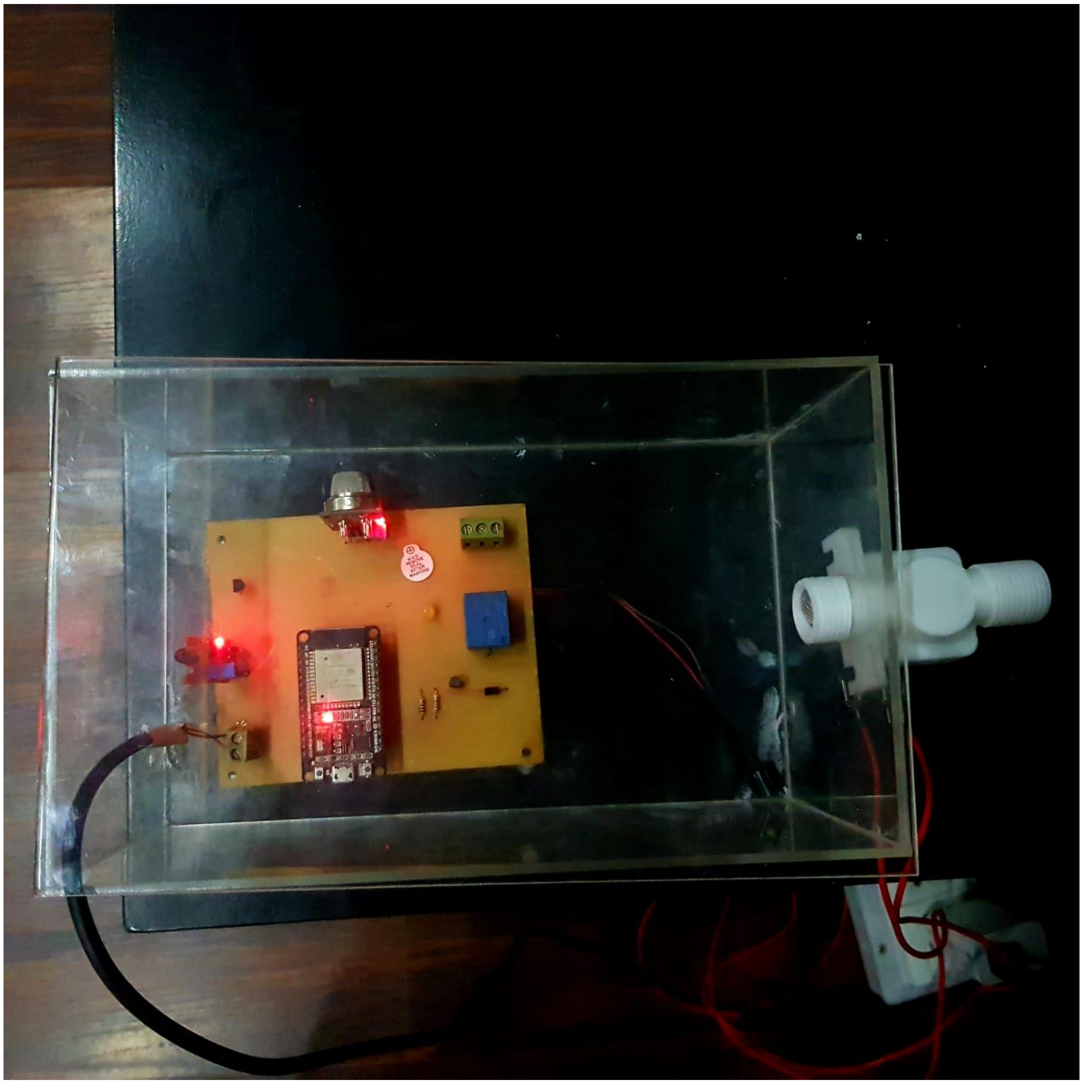


Figure 5. 2 Complete Prototype with connected Solenoid Valve

5.4 Development of Hardware and PCB

The PCB is designed using an online free tool which allows user to build up the circuit diagram and allow user to export the pdf file to develop the constructed circuit. This PCB is designed on Easy EDA platform for the purpose of transforming the conceptual model and its integration with the hardware components. The circuit diagram of the proposed prototype is explained below.

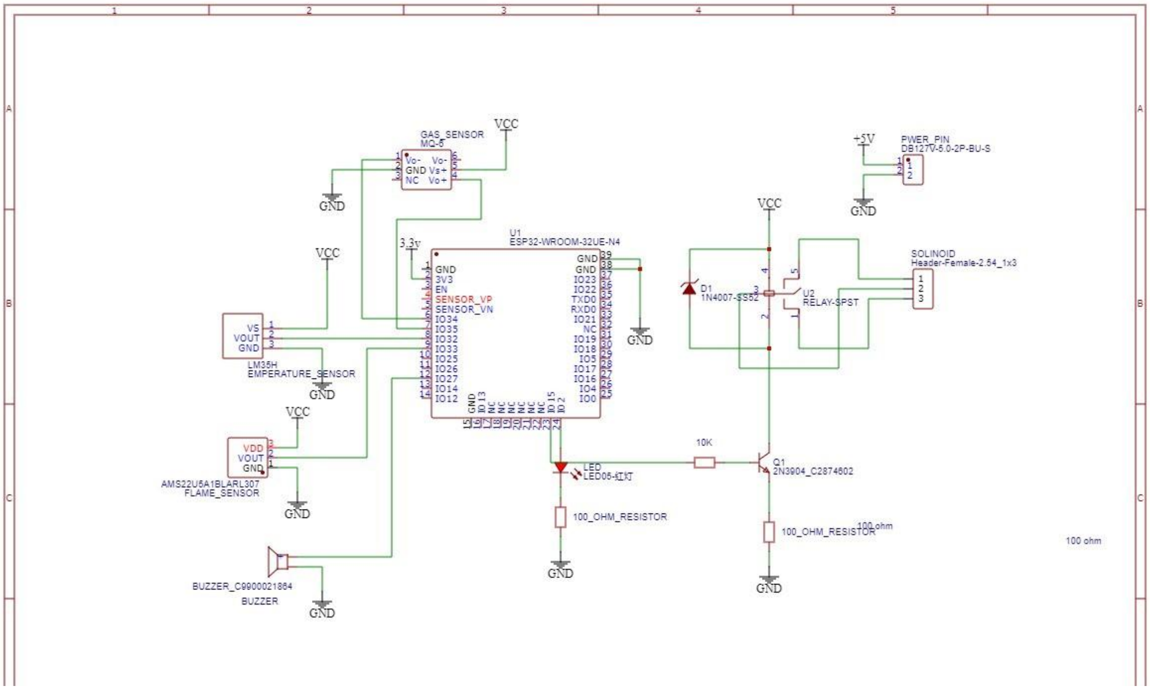


Figure 5. 3 Circuit design Using Easy EDA (Online Platform)

The working principle of the circuit is as follows.

- The Power pin is the 3.3V primary source of current for all the modules that are placed on the PCB.
- The VS+ on the MQ2 Gas Sensor is connected to the Primary Current source VCC, while the GND is Ground line for this sensor, VO+ and VO+ are the analogue outputs, which are connected to the Arduino Esp. 32, which converts the analogue signal to digital output.
- The VS on the LM35 Temperature sensor is connected to the VCC, which provides the Primary Current to the Sensor, GND is the ground Wire for this sensor, VOut is connected to the IO32 of the Arduino Esp. 32 which converts the analogue signal to digital signal.
- VDD on the Flame sensor is connected to the VCC which provides the Primary current source, GND is the Ground/Neutral wire for this sensor, Vout2 is the Analogue output signal which is connected with the IO33 of the Arduino Esp. 32, which converts the analogue signal to digital output.

- Buzzer is connected to the IO27 of the Arduino Esp. 32, which is coded in the Program in order to set off the Alarm when the output value exceeds the decimals in place.
- LED is connected to the IO2 of the Arduino Esp. 32, and GND for the Neutral wire for this, LED is programmed in Arduino to provide signal when the Sensors are functional, LED is turned On/OFF at the interval set in the Arduino.
- The Solenoid valve is connected to 12V DC adapter at one end, the second end of the adapter is connected to the 2 Marked at solenoid, which acts as ON/OFF function for the Relay connected to the Solenoid. The second wire from the solenoid is connected to the 3 marked on the PCB which provides the connection of the Solenoid to the Relay and the Entire PCB, the Arduino is programmed to Switch ON/OFF the Relay based on the Decimals received from the MQ2, LM35 and Flame sensors connected to the Arduino.

5.5 Software and Hardware Integration

The hardware components of the proposed prototype are interlinked with each other using the software of Arduino integration named as Arduino IDE (Integrated Development Environment). This software allows to integrate the built-in libraries of Arduino Esp32, these libraries and software tool is open-source program and is compatible with Windows, MAC OS, and Linux. The integration software allows the programming environment for writing up the functions and operation brief that is required to run the prototype. Arduino uses a simple C++ programming complier and language for coding.

The Built in (MQTT) Libraries for the Arduino Esp32 are then loaded to the microcontroller that is integrated with the Arduino IDE, they are integrated with the system following these steps.

I. The library is Downloaded from Internet, from GitHub or any other free online platform.

II. Run the Arduino IDE and open the Sketch menu, it will show the option to manage libraries of the compiler, this will show the list of already downloaded libraries in the system.

III. Locate the MQTT file from the Downloaded section and install it from manage libraries setting.

Once the Libraries are loaded in the System then there is a need to write up the instructions which will be needed by the microcontroller to perform the designated tasks. As the microcontroller works on the principle and programming language C++ so the instructions that are required by the microcontroller to perform the analysis is provided in below mentioned steps.

I. The Microcontroller Arduino ESP32 has a series of Built Inn directories for Multiple Functions that can be performed by it, these libraries are open source and at the start of Program code, these libraries are loaded for functioning of all operational parameters.

II. Once the Libraries are loaded the #define function in the Program Code is Used to Define the values of Current and input of all the sensors that are connected with the Microcontroller.

III. The Float defines the decimal value of an analogue signal, these include which value from the LM35 in Degree centigrade.

IV. String is used to provide the Characters in the microcontroller code, this will display the characters as needed in the interface.

V. Reading is the function in the program which collects the analogue signals and convert it to digital output and compare it the with the specific data sheet for each sensor and displays the output.

VI. Void setup will define the functions of the digital Outputs generated by the Arduino; it will provide the signal that which output refers to what function in the program.

VII. Serial and IP address will connect the Wifi module of Arduino with the Defined internet server, it will send the digital signal to the Interface model which will reflect the Value as per input obtained by all connected sensors.

VIII. Void Loop is the interval defined at 2000 milliseconds for each sensor to secure the readings and operations of the Outputs from the Arduino Esp.32, these operations include the conversion of analogue signal to digital signal and sending this value to the pre-defined server and IP Address. In Addition to sending this to server, it will also send back the signal to the Solenoid valve connected which works on the Digital output of 0 and 1 (run/off) which can cut off the supply of Gas to any appliance connected with it.

5.6 Android Application Integration and Development

The android application is linked the Arduino webserver using the WebView platform, which is designed to link the android applications with their integrated webservers. The android code is developed using the android studio application, which provides platform for smart application development. The IP address of the ESP module is connected with the Web-View Android Testing platform which displays the information that is associated with the designated IP address. The interface and layout for the android application is loaded in the Android Studio. the layout will display the specific information that is provided in the Algorithm which in current case is the valves for the temperature, MQ2 gas sensor and Flame sensor. The Monitoring data which is displayed at the selected IP address of the ESP is connected with the android application. Whenever an alert is generated, or the system detects the flame or gas. It triggers the alarms, and the android application displays a toast message indicating the provided string provided in the Algorithm. The toast message which is displayed on the phone will continuously notify the user about the detection of gas or flame till the thresholds are lowered down.

5.7 System detection Module Rules

The system is designed to perform the tasks associated with the connected sensors which include the

- MQ2 Gas Sensor
- Temperature Sensor
- Flame Sensor

The parameters for all these sensors which are used to define the various scenarios that are taking place in the prototype are listed below.

Table 5. 2 Parameters and Operations in Detection

Parameters (Set of Instructions)	Criteria to Perform Various operations
LM35 Temperature	Normal: 23-27 Degree, Abnormal: >43 Degree (this will only display the temperature conditions

Sensor	of the space where the Prototype is Installed and will not generate any alert)
MQ2 Gas Sensor	Concentration of the Gas is Set 300ppm, as the concentration of gas will increase in the designated space, the solenoid valve will cut off the gas supply and will set off the buzzer.
Flame Sensor	The Normal Value for detection of UV/IR light is 0-499nm, when the valve of UV or IR exceeds 500nm, the flame sensor will set of the buzzer.

The below mentioned are the set of rules for Arduino Esp32, which defines the state of Gas Leakage and high Temperature in the Proposed prototype. These rules are defined as the functions for Arduino Esp32.

I. If the Temperature exceeds 42 degrees, the LED will blink on the system, and user will get an alert on the Android Application.
II. If the concentration of Gas increases, then microcontroller will cut off the supply to the solenoid valve and set off the buzzer, the user will get a toast message alert on android application about the excess gas concentration in the premises.
III. If the flame sensor identifies high radiation or light using the UV/IR detector installed with it, this will turn on the Led on the Prototype and Also generate a toast message Alert on the Android application.

5.8 System Testing

Each sensor was tested individually to ensure the accuracy and working environment of each sensor. The calibration switches on each sensor are calibrated with comparison to the data sheets of each sensor and then tested for the errors related to the calibrations using hit and trail method. The power supply to each sensor is checked after connecting all sensors and microcontroller to the PCB circuit broad. The functionality of Solenoid valve is checked carefully, its connection to a 12V Dc source and trip function of the valve is checked by turning the gas on. Buzzer is checked by making the connection to the microcontroller and the check button in the android application interface to check the functionality. Complete prototype functionality is checked by leaving in the cooking fumes, humidity, steam, and cigarette smoke to check the system for reliability and false alarm detection. The Flame sensor in the Prototype is found to detect 5 out of 6 times the flame is introduced in the chamber, Gas sensor detected the gas and Smoke in the chamber 6 times when assessed.

5.8.1 Prototype Testing:

To check the performance of the developed prototype, the project was piloted in Faisalabad City and values are monitored hourly, the below mentioned table and chart provides information about the temperature conditions in the room, with the status of gas and flame.

- For evaluating the workability of the developed prototype gas and flame are introduced in the enclosed environment at various times during the day. The graph shows the triggered alarm and notification generated as a result of detection of gas and flame in the premises.
- Gas cylinder was connected with the solenoid value and gas is turned on 6 times throughout the day, the developed prototype successfully detected the gas in the environment and performed the pre-set functions as per Algorithm i-e shutting off the gas supply using the solenoid value, trigging the alarm buzzer on the prototype, and generating a banner alert for the user using the developed android application.
- Flame was introduced in the chamber 6 times, but the sensor detected flame 5 times and missed one alarm, the sensitivity of the flame sensor is then increased.
- The Blue points in the graph represents the detection of gas in the chamber while the blue points indicate the flame detection.
- The gray line represents the fluctuating temperature throughout the day.

Table 5.3.1 Testing Prototype Day 1

Disaster Management Project (Prototype Testing Day 1)					
Time of the Day	**Condition**	**Temperature**	**Gas Sensor**	**Flame Sensor**	**Results**
12:00:00 AM	Flame Introduced	28		Detected	Functional Flame Sensor
1:00:00 AM		27			
2:00:00 AM		27			
3:00:00 AM		27			
4:00:00 AM	Gas Introduced	26	Detected		Functional Gas Sensor
5:00:00 AM		26			
6:00:00 AM	Flame Introduced	27		Detected	Functional Flame Sensor
7:00:00 AM		27			
8:00:00 AM		28			
9:00:00 AM	Gas Introduced	28	Detected		Functional Gas Sensor
10:00:00 AM		28			
11:00:00 AM	Flame Introduced	29		Detected	Functional Flame Sensor
12:00:00 PM		30			
1:00:00 PM		30			
2:00:00 PM	Gas Introduced	31	Detected		Functional Gas Sensor
3:00:00 PM		32			
4:00:00 PM		32			
5:00:00 PM	Flame Introduced	32		Detected	Functional Flame Sensor
6:00:00 PM		32			
7:00:00 PM	Gas	31	Detected		Functional Gas

	Introduced				Sensor
8:00:00 PM		31			
9:00:00 PM	Flame Introduced	31		Detected	Functional Flame Sensor
10:00:00 PM	Gas Introduced	30	Detected		Functional Gas Sensor
11:00:00 PM	Gas Introduced	29	Detected		Functional Gas Sensor

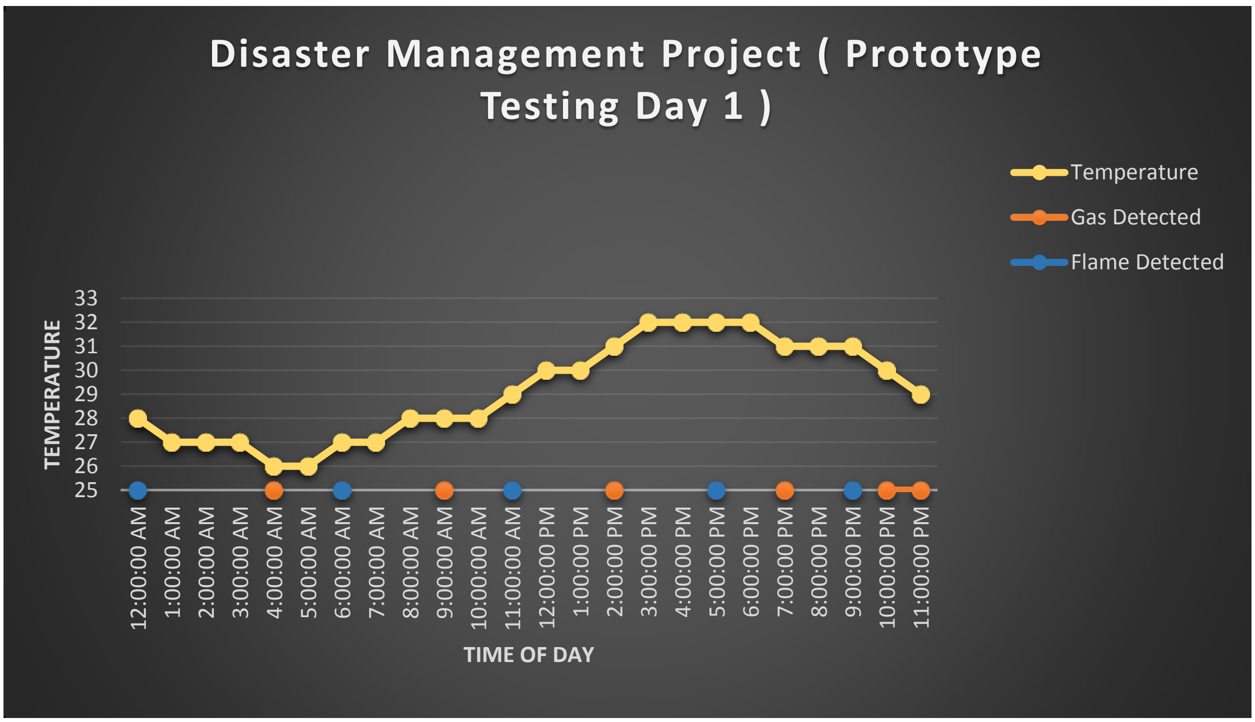


Figure 5. 4 Graph showing the fluctuation of Temperature and detection of Gas and Flame

Prototype testing day 2

The Second testing day was conducted in Islamabad where the comparative room temperature conditions are better than was in Faisalabad. The process used was the same as it was done in Faisalabad. Below mentioned are the core findings of testing day 2

i. Throughout the day the conditions are monitored hourly, gas and flame are introduced at various times.

ii. Whenever the Gas is introduced in the chamber, the sensor detected the gas and shutoff the solenoid valve connected. There is no false alarm detected as a result of alcohol. Vape or cigarette smoke in the room.

iii. Flame sensor missed alarm twice throughout the day, the sensitivity of the flame sensor is adjusted but still it misses alarm.

iv. The graph provides information about the temperature conditions in the room, with marked points indicating the gas and flame detections at various times throughout the day.

Table 5.3.2 Table showing results of Prototype testing Day 2

Disaster Management Project (Prototype Testing Day 2)					
Time of the Day	**Condition**	**Temperature**	**Gas Sensor**	**Flame Sensor**	**Result**
12:00:00 AM	Gas Introduced	25.8	Detected		Functional Gas Sensor
1:00:00 AM	Gas Introduced	25.7	Detected		Functional Gas Sensor
2:00:00 AM	Flame Introduced	25.1		detected	Functional Flame Sensor
3:00:00 AM		25.3			
4:00:00 AM	Gas Introduced	25.6	Detected		Functional Gas Sensor
5:00:00 AM		25.4			
6:00:00 AM		25.9			
7:00:00 AM	Gas and Flame Introduced	25.8	Detected	not detected	Gas Sensor Functional and Flame Sensor Missed
8:00:00 AM		25.6			
9:00:00 AM	Gas Introduced	25.4	Detected		Functional Gas Sensor
10:00:00 AM		25.7			
11:00:00 AM	Flame Introduced	25.4		not detected	Flame Sensor Missed
12:00:00 PM		25.2			
1:00:00 PM	Gas Introduced	25.6	Detected		Functional Gas Sensor
2:00:00 PM	Flame Introduced	25.1		detected	Functional Flame Sensor

3:00:00 PM	Gas Introduced	25.9	Detected		Functional Gas Sensor
4:00:00 PM	Gas Introduced	25.4	Detected		Functional Gas Sensor
5:00:00 PM	Flame Introduced	25.2		detected	Functional Flame Sensor
6:00:00 PM		25.6			
7:00:00 PM		25.7			
8:00:00 PM	Gas Introduced	25.1	Detected		Functional Gas Sensor
9:00:00 PM	Flame Introduced	25.9		Detected	Functional Flame Sensor
10:00:00 PM	Gas Introduced	25.7	Detected		Functional Gas Sensor
11:00:00 PM	Gas and Flame Introduced	25.8	Detected	detected	Gas and Flame Sensor Functional

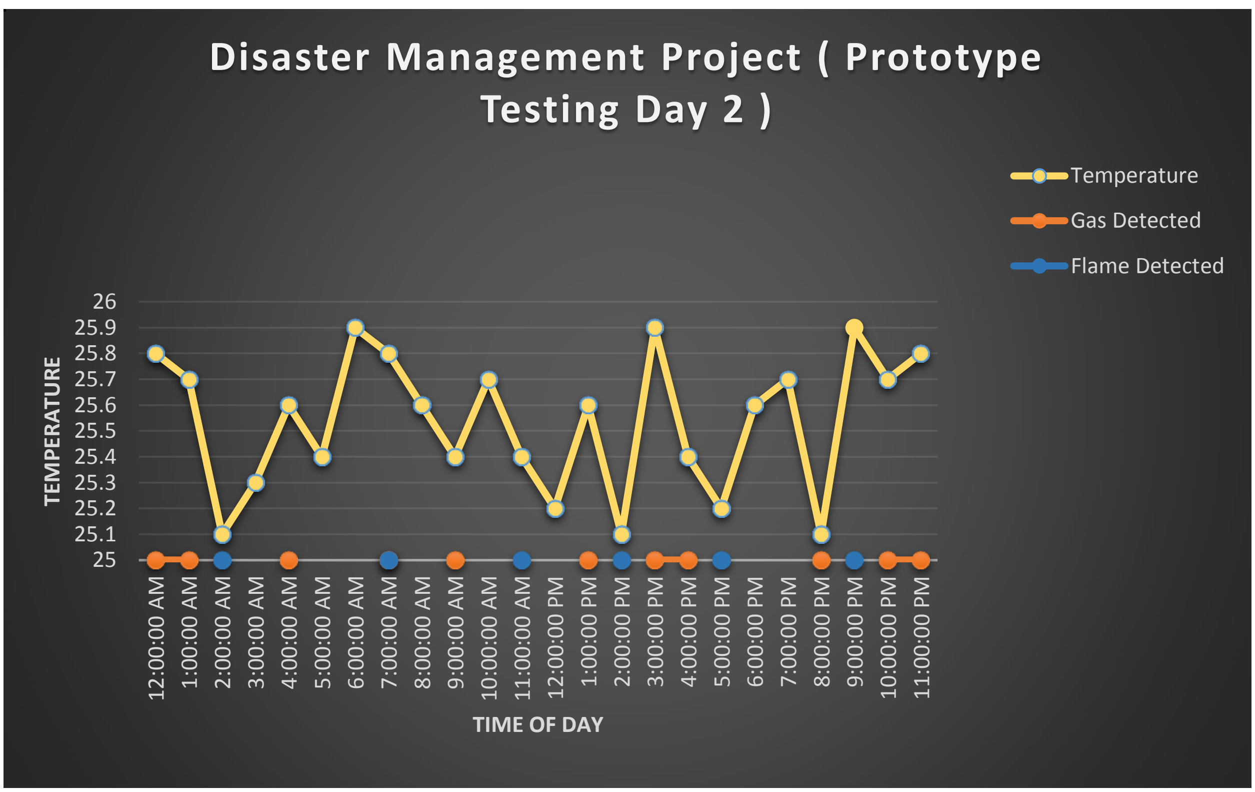


Figure 5. 5 Graph testing Prototype Day 2

Prototype Testing Day 3

Table 5.3.3 Table showing results of Prototype testing Day 3

Disaster Management Project (Prototype Testing Day 3)					
Time of the Day	**Condition**	**Temperature**	**Gas Sensor**	**Flame Sensor**	**Result**
12:00:00 AM	Gas and Flame Introduced	25.3	Detected	detected	Gas and Flame Sensor Functional
1:00:00 AM	Flame Introduced	25.8		detected	Functional Flame Sensor
2:00:00 AM	Gas Introduced	25.9	Detected		Functional Gas Sensor
3:00:00 AM		25.6			
4:00:00 AM		25.1			
5:00:00 AM		25.4			
6:00:00 AM		25.6			
7:00:00 AM	Gas Introduced	25.7	Detected		Functional Gas Sensor
8:00:00 AM		25.3			
9:00:00 AM		25.9			
10:00:00 AM		25.5			
11:00:00 AM	Gas and Flame Introduced	25.9	Detected	detected	Gas and Flame Sensor Functional

12:00:00 PM	Gas Introduced	25.1	Detected		Functional Gas Sensor
1:00:00 PM		25.4			
2:00:00 PM	Flame Introduced	25.4		detected	Functional Flame Sensor
3:00:00 PM	Gas Introduced	25.2	Detected		Functional Gas Sensor
4:00:00 PM		25.5			
5:00:00 PM		25.1			
6:00:00 PM	Gas Introduced	25.7	Detected		Functional Gas Sensor
7:00:00 PM		25.4			
8:00:00 PM	Gas and Flame Introduced	25.6	Detected	detected	Gas and Flame Sensor Functional
9:00:00 PM	Gas Introduced	25.3	Detected		Functional Gas Sensor
10:00:00 PM		25.5			
11:00:00 PM	Gas and Flame Introduced	25.8	Detected	detected	Gas and Flame Sensor Functional

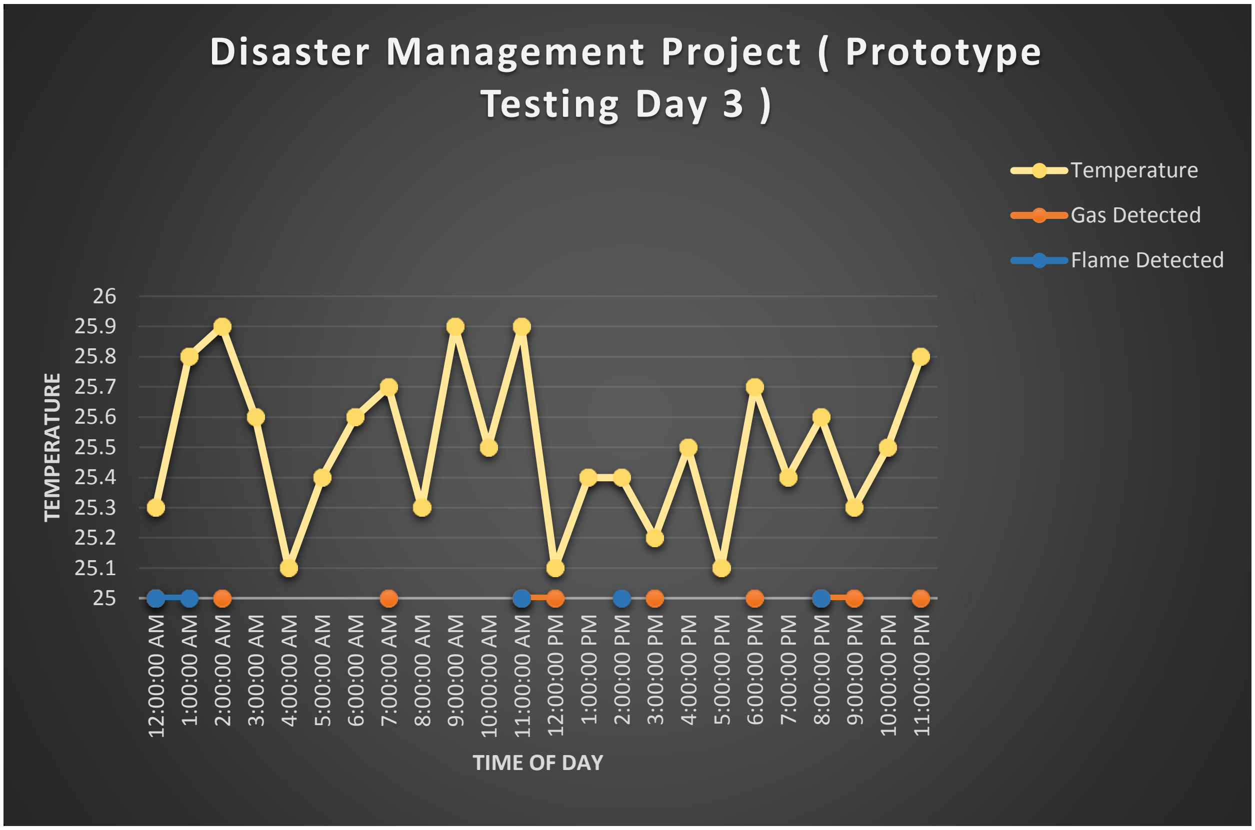


Figure 5. 6 Graph Prototype testing Day 3

5.8.2 Prototype Testing Results

The prototype was tested for 3 days under different conditions, the major purpose of this testing was to check the performance of all the sensors that are installed and programmed in-order to monitor the physical atmospheric conditions of the Room or place in which the prototype is installed. These sensors were individually tested before they are installed on the PCB Board, but these tests were to only to verify the current and functionality. All the sensors are installed and programmed in a way that each of the module will act and trigger the over-all response of the prototype. The conditions and thresholds are different for each sensor, MQ2 Gas sensor is the primary sensor in the prototype while the flame sensor, and temperature monitoring is meant for the analysis of the atmospheric conditions.

When the prototype detects gas in the atmosphere it generates a buzzer on-site for alarming the users on site, and also generates an alert on the connected android device of the user. This multiple mechanism notifies the user regarding the unsuitable atmospheric conditions, thus alerting the user to monitor the data on the device. These conditions trigger the solenoid valve connected with the gas appliance in the room and cut-off gas supply. Throughout the testing process of three days the primary gas valve in the prototype haven’t missed a single time and have performed according to the provided instructions in the programmed code. The integrated android application continues to provide the alert to the user till the gas sensors comes back to its original state, these alerts are programmed in a way that it won’t affect the cellphone usage of user and will be popped up even if the application is not running on the screen. This pop-up message will be repeated at set intervals till the gas concentration is decreased in the prototype premises and buzzer will also continue the alarm till concentrations decreases. The flame sensor on the prototype is programmed in way that it also generates a buzzer alarm and android alert, this message is also flagged in the same manner as gas sensor, the flame sensor is sensitive to high intensity radiation and the sensor used in the prototype is infrared based, thus detection is done when the flame comes near the sensor, the threshold is set at most sensitive, the flame sensor was tested by introducing flame in the chamber and when it’s near the infrared sensor it acts according to the instructions provided in the programmed code. The flame sensor missed the flame twice on the second ay of testing as the sensitivity was lowered and flame proximity wasn’t in the defined thresholds which was later adjusted and re-programmed in the code, thus the sensor worked perfect on third day.

5.9 Performance Evaluation

Performance of the prototype is evaluated by checking the response time on the android application developed the test was performed to check the timely response and alert generated by the android application. The response time is measured using a stopwatch, to check how long it takes to generate the alert and system return state time, which refers to the return to original state after performing the desired functions.

Table 5. 4 Performance Evaluation (Alerts and Response)

Alert and test	Response time
Alert 1 (opening the Gas valve on Lighter)	15 seconds till the system changes the state on the application that gas has been detected in the system. The buzzer will set off the moment it detects the gas in the chamber and will shut off the solenoid valve. Android Application will generate an alert on the User Android application
Alert 2 (Return to normal Condition)	<5 Seconds (to return back to the original state and changing the gas status to No Gas, if the gas valve is turned off
Alert 3 Temperature Sensor (LM35)	If the temperature in the chamber is increased to 43 degrees, the LED on the prototype will start to blink the moment the temperature rises. This will not trigger the alarm neither will generate a text alert.
Alert 4 (Flame Sensor)	Once high intensity light is detected within 15 seconds the android application will show the flame status and LED will blink on the Prototype and solenoid valve will shut down the gas connection.
Alert 5 (Return to Normal)	Within <5 seconds if the light intensity of decreased the system will return to normal and NO flame status will be displayed on the Android application interface and the LED will be stop blinking.

5.10 Challenges and Limitations

I. The proposed prototype can only be used for residential units, and it does not have any industrial capabilities. High sensitivity sensors are required for industrial operations.

II. The voltage required to operate the PCB can be obtained with a normal Charger and it's connected to the circuit via USB Cable, if any fast charger or high watt charger is connected with the circuit it will burn the temperature and flame sensor.

III. The integration of android application and the microcontroller requires the Gateway of the router to which the prototype is connected, disconnection to the router will cause the android application to halt the program from running, but it will disconnect the solenoid valve and set off the buzzer in case of gas leakage in the premises.

IV. Constant supply of 3.3V is required to run the circuit, for this purpose an alternate power source can also be connected with the circuit so the prototype can work independent of the house electricity.

Chapter 6 Conclusions

6.1 Conclusion

The existing mechanism for the detection of fire and gas leakages in the domestic households have numerous challenges, the major challenge in these systems is the high ratio of false alarms caused because of smoke of cigarette, the steam from cooking inside the house, affordability of multi sensor operation mechanism, and lack of awareness in the community. The identified major challenge was the lack of mechanism for detection of gas leakage in the residential units, the existing systems are more focused on fire and smoke detection.

The agenda for this research was to provide a sustainable and affordable solution to this problem and to decrease the ratio of false alarm. Incorporation of multiple sensors to perceive the environment in which the prototype is installed and to provide timely response under different circumstances. The three major percepts that are identified and investigated which can result in the emission of fire and can also cause the death of residents by saturation of gases in the environment. They are Gas leakage, Flame detection and temperature monitoring.

The analysis of the secondary data provides information that the major potential cause of fire at domestic scale is the natural and LPG gas leakage. The incorporation of multi-sensors in the prototype have aided in getting more timely and accurate responses that can mitigate the potential hazard. This multi-sensor detection prototype is implemented and tested under different circumstances and at various times of day.

The existing residential megaprojects and stakeholders in the fire department should incorporate the proposed mechanism as a steppingstone in timely detection and response to fire and gas leakage hazards. This can mitigate the major life and property damages, the data acquired from these multi-sensors can also provide an opportunity to investigate better advancements in fire and gas leakage detection services in Pakistan where we have lack of awareness and recording mechanism for these disasters.

6.2 Recommendations

This section covers the recommendations based on the implementation, testing and challenges that are faced during the process of development.

I. Multi-sensors can be interconnected in the system and can function as One unit to describe the overall environment.
II. Rechargeable portable power source can be connected to the prototype which can ensure the operations in all conditions.
III. The developed prototype can be incorporated with the department of fire as well, once the alert is generated it can provide the Navigation and signal to fire department using Google Maps.

6.3 Future Extensions and Integrations

The project can further be extended by upgrading the system, few of the future extensions are mentioned below

I. The incorporation of Fire extinguishing Mechanism i-e the water sprinkler system can be connected to the Arduino ESP32.
II. The modern electronic switches can be connected with the micro-controller which can act to furthermore eliminate the fire and leakage hazards. For example, if an electronic switch for the exhaust mechanism is connected with the microcontroller, then it can filter out the saturation of gases inside the room as the alert is generated.
III. GSM Module can also be connected to this Arduino Microcontroller which will incorporate Text message alert using mobile network sim card, this can also function as an alternate alert mechanism in case of Internet dysconnectivity.
IV. Light intensity sensor and other sensors can be connected to this prototype as it has a capability of managing an overall thirty input and output ports.

V. The prototype can also incorporate image processing once the alert, the android application can also be incorporated with the wireless camera on the location which can substantially increase the accuracy of the threat.

References

Azmil, M. S. 2015. "Wireless Fire Detection Monitoring System for Fire and Rescue Application." *Universiti Teknologi MARA (UiTM), Faculty of Electrical Engineering. Kuala Lumpur: IEEE.*

Boeije, H. R. 2009. "Analysis in Qualitative Research." *SAGE Publication LTD*.

Center:, N. D. (2015). An Introduction to Fire Detection, Alarm, and Automatic Fire Sprinklers. Retrieved from www.nedcc.org: https://www.nedcc.org/free-resources/preservation-leaflets/3.-emergency-management/3.2-an-introduction-to-fire-detection,-alarm,-and-automatic-fire-sprinklers

Doiron, T. 2007. "A Short History of the Standard Reference Temperature for Industrial Dimensional Measurements , 112." *Journal of Research of the National Institute of Standards and Technology*.

Goh, R. 2014. "Fire Safety and Protection Systems.": *Http://Finalprojectfyp.Blogspot.Co.Ke/2014/01/Unit-4-Heat-Detectors.Html*.

Gorli, R. 2017. "World Laying Steps towards Smart Ideas." *Journal of Advanced Research in Computer and Communication Engineering*.

Grinberg, M. 2012. "Robotics, Arduino." *Rom Miguel Grinderg Blog: Https://Blog.Miguelgrinberg.Com/Post/Building-an-Arduino-Robot-Part-i-Hardwarecomponents*.

Hartin, E. 2005. "Fire Development in a Compartment. Review of Basic Fire Behavior."

Ilie, A. M., & Vaccaro, C. (2017). Design of a smart gas detection system in areas of natural gas storage. *IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*.

Jan Holler, V. T. 2014.: ": Introduction to a New Age of Intelligence." *Oxford: Elservier.*

Jawad, A. (2020, February 18, 02 18). *Toxic gas kills 4 more people in coastal area*. Retrieved from www.usnews.com/news/health-news/articles/2020-02-18.

Lewes, E. 2015. . . *Fire Safety*. Sussex,

Mahalank, S. N. 2016. "Non-Functional Requirement Analysis in IoT Based Smart Traffic Management System." *International Conference on Computing Communication Control and Automation (ICCUBEA) (p. 10). IEEE*.

Mitrani, A. C. 2003. "Fuzzy Logic Methodology for The Comparison of Costruction Firms." *IAARC: Http://Www.Iaarc.Org/Publications/Fulltext/Isarc2000- 008_TE2.Pdf*.

Nisha Ashok Somani, Y. P. 2012. "ZIGBEE: A LOW POWER WIRELESS TECHNOLOGY FOR INDUSTRIAL APPLICATIONS." *International Journal of Control Theory and Computer Modelling, 2 (3).*

National, L. B. (2014). *Basic vs Applied research*. Retrieved from https://www.sjsu.edu/people/fred.prochaska/courses/ScWk170/s0/Basic-vs.-Applied-Research.pdf

Obanda, Z. S. (2017). *Multi-sensor fire detection system using an.* Strathmore University.

Palys, T., ed. 2008. *The Sage Encyclopedia of Qualitative Research Methods (Vol. 2)*. Vol. 2. Carlifornia: Sage Publishers.

Pyror, G. 2012. "Managing Research Data." in *Managing Research Data.* London: Facet Publishing.

Rajasekar, S., &. Philominathan, P. 2013. "Research Methodology." Bharathidasan University, Mumbai.

Rutimann, L. (2014, March 07). *Reducing False Alarms(A study of selected European Countries).* Europe: Siemens Switzerland Ltd.

Sapsford, R. 2006. *Data Collection and Analysis.* New Delhi: Sage publications India.

Smith, F. 2014. *Microsoft Dynamics. Manufacturing Bill of Materials in Microsoft Dynamics.* United States.

Subramanian, M. A., Selvam, N., Rajkumar, S., Mahalakshmi, R., & Ramprabhakar, J. (2020). Gas Leakage Detection System using IoT with integrated notifications using Pushbullet-A Review. *Fourth International Conference on Inventive Systems and Control (ICISC)*.

***The Internet of Thigs:*. (2015, october 16).** Retrieved from www.internetsociety.org.

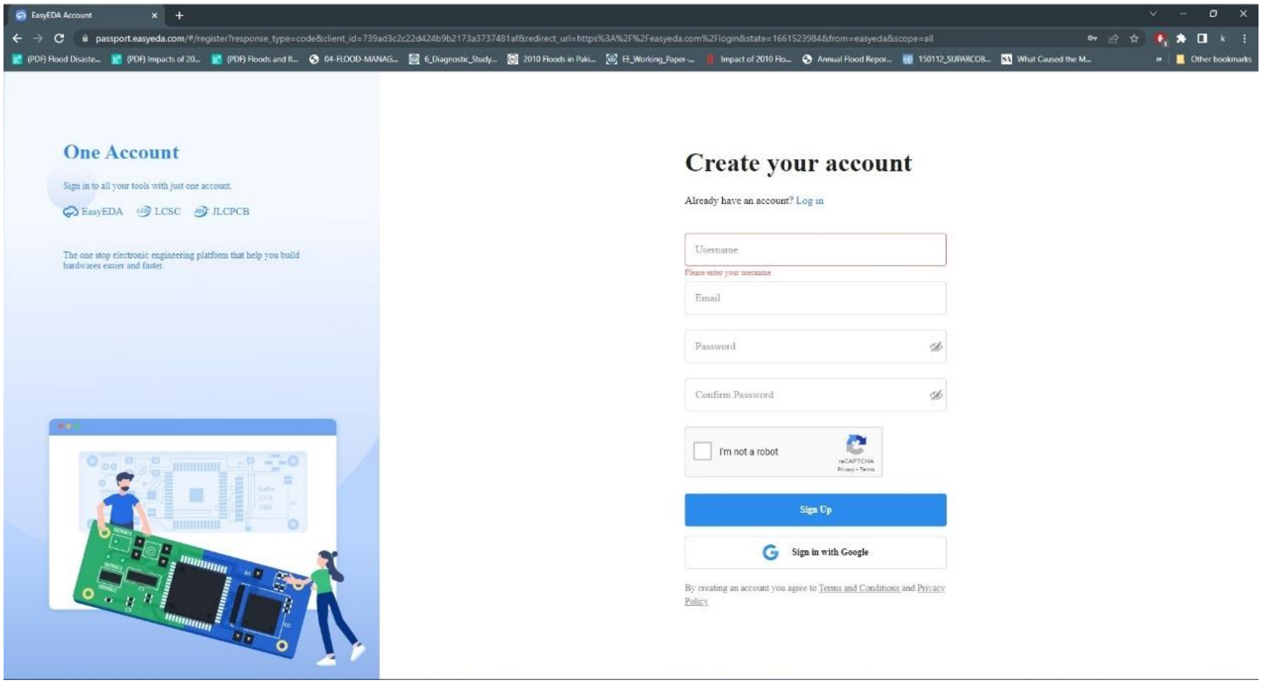
Today, C. (2015, October). Retrieved from http://www.circuitstoday.com/gsm-based-fire-alarmsystem-using-arduino: http://www.circuitstoday.com/gsm-based-fire-alarmsystem-using-arduino

Today, P. (2020, may 7). Retrieved from https://www.pakistantoday.com.pk/tag/gas-leakage/ .

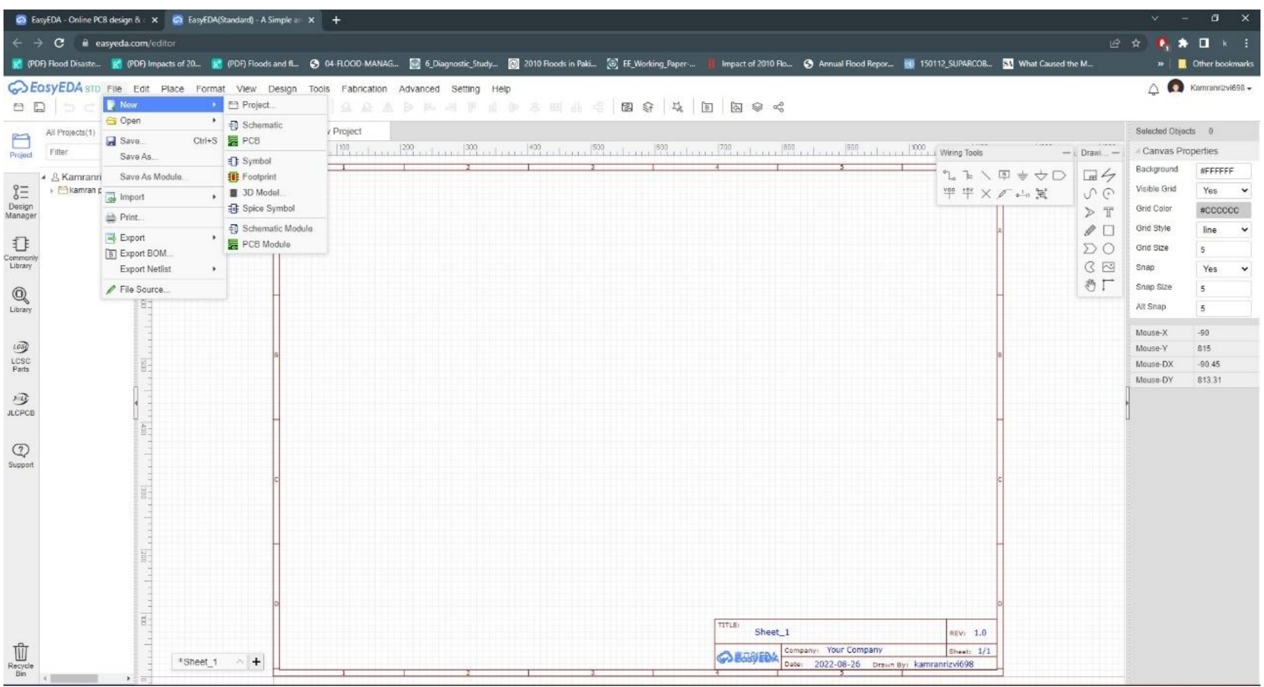
Tribune, T. E. (2019, November 12). *gas leak blast kills sisters,injured parents in Rawalpindi*. Retrieved from https://tribune.com.pk/story/2097857/gas-leak-blast-kills-sisters-injures-parents-rawalpindi .

Vermesan, D. O. 2013. *Internet of Things:* *Converging Technologies for Smart Environments and Integrated Ecosystems*. Aalborg, Denmark: River Publishers.

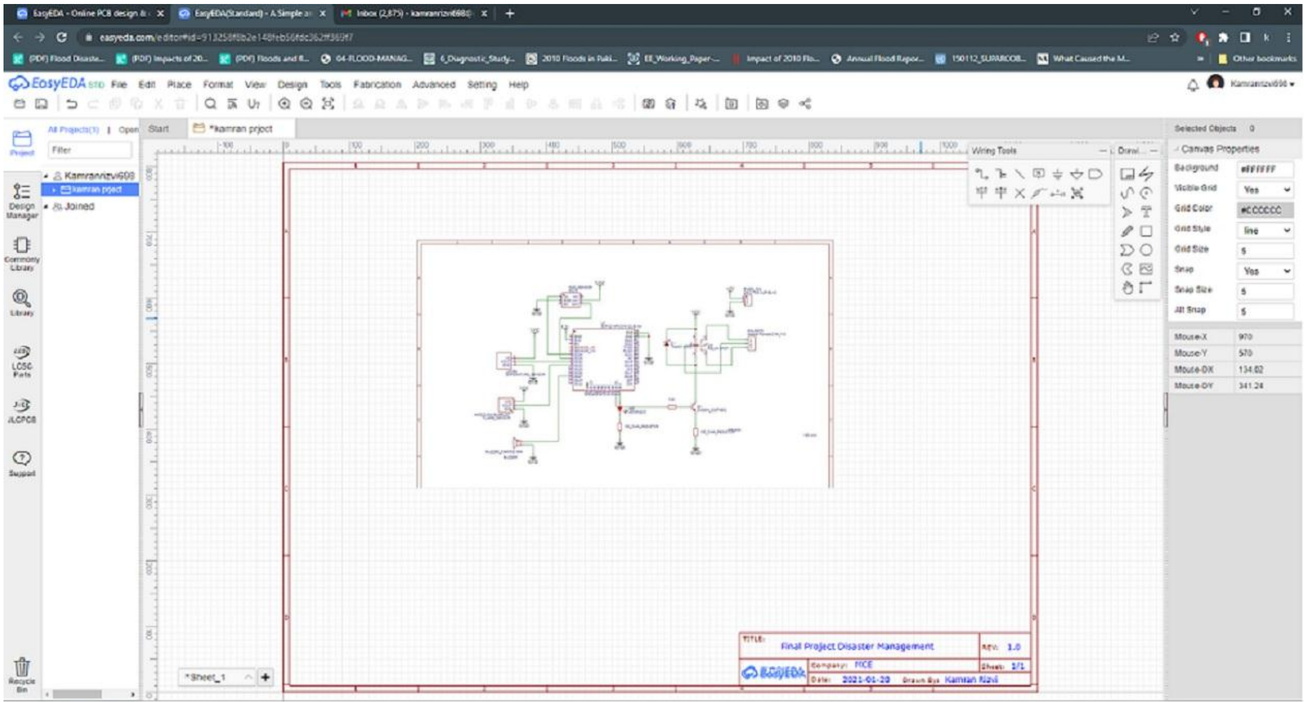
Appendices



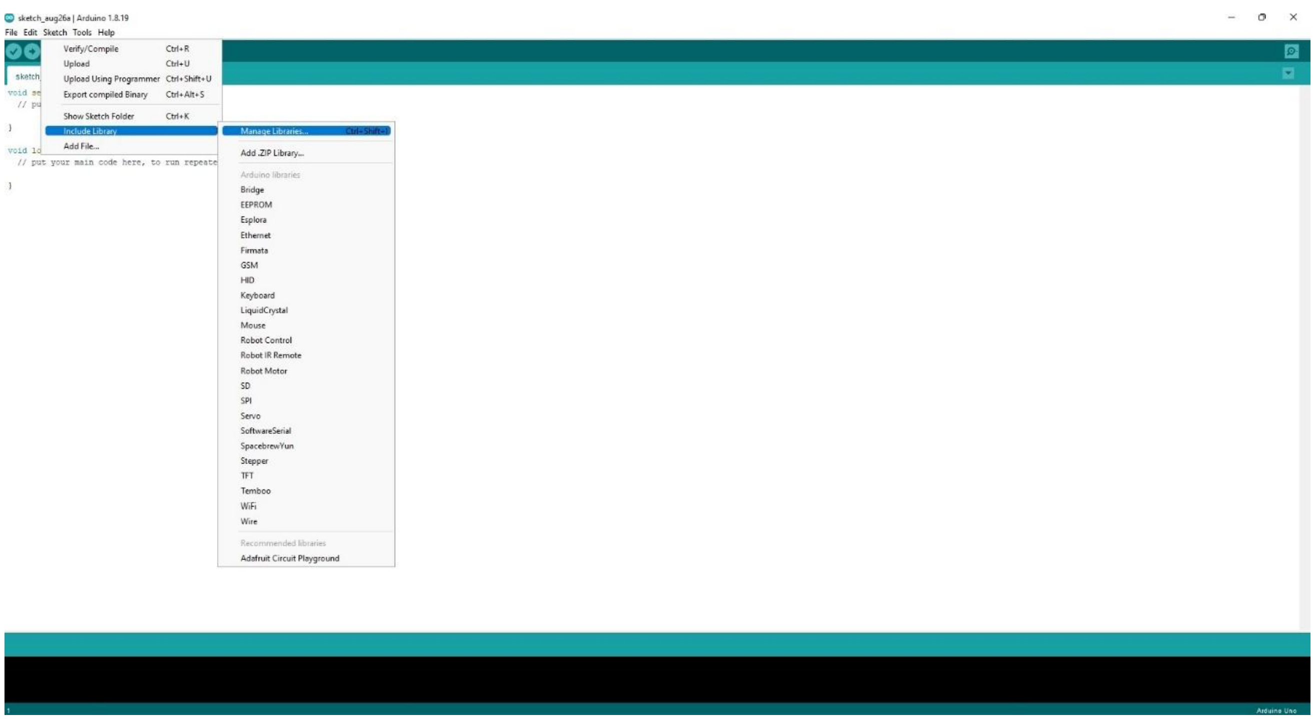
Appendix A: Setting up an Account on EasyEDA



Appendix B: Services of EasyEDA

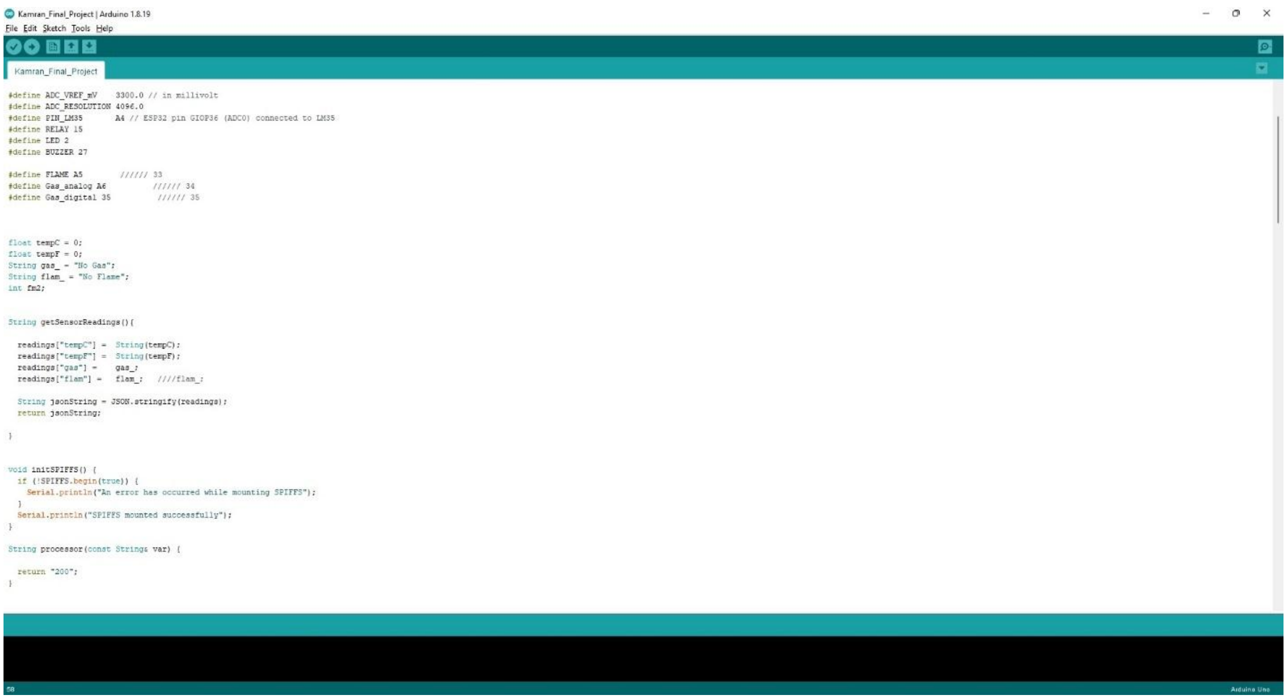


Appendix C: Design Schematic for the Circuit

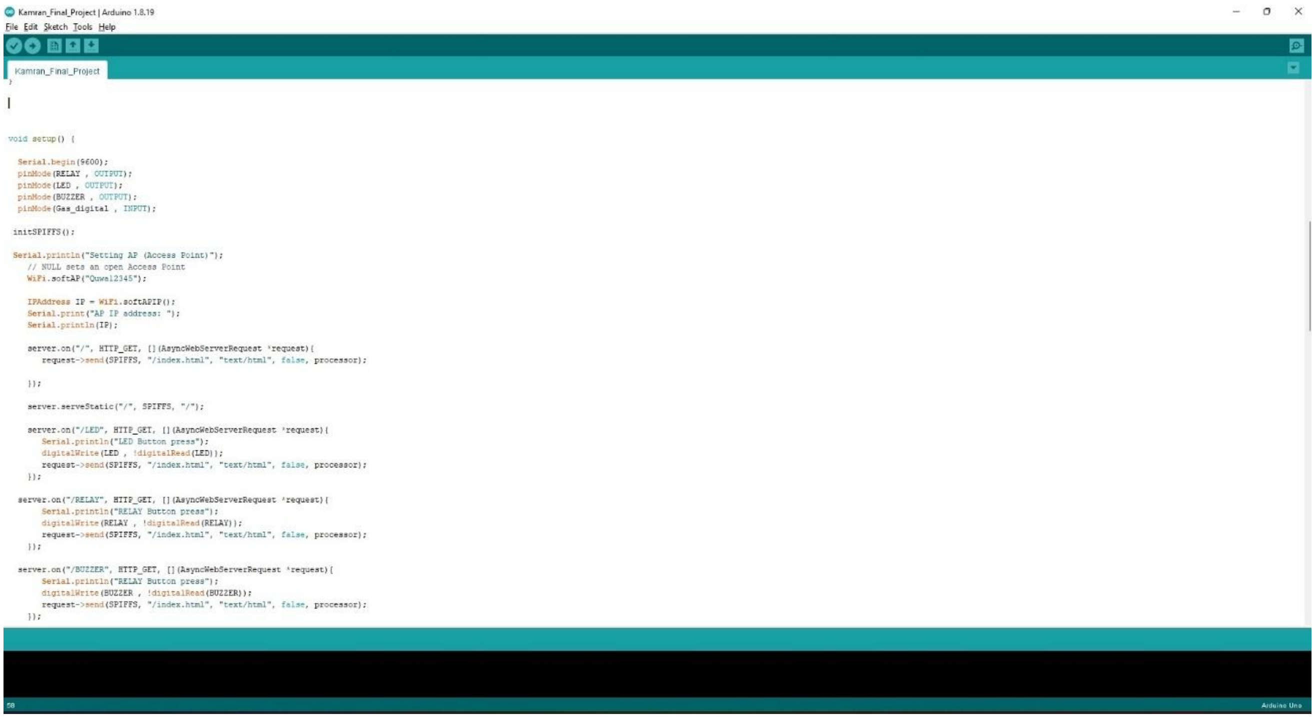


Appendix D: Sketch MQTT libraries to Arduino IDE

Appendix E: MQTT Library Added and connected to Web Server

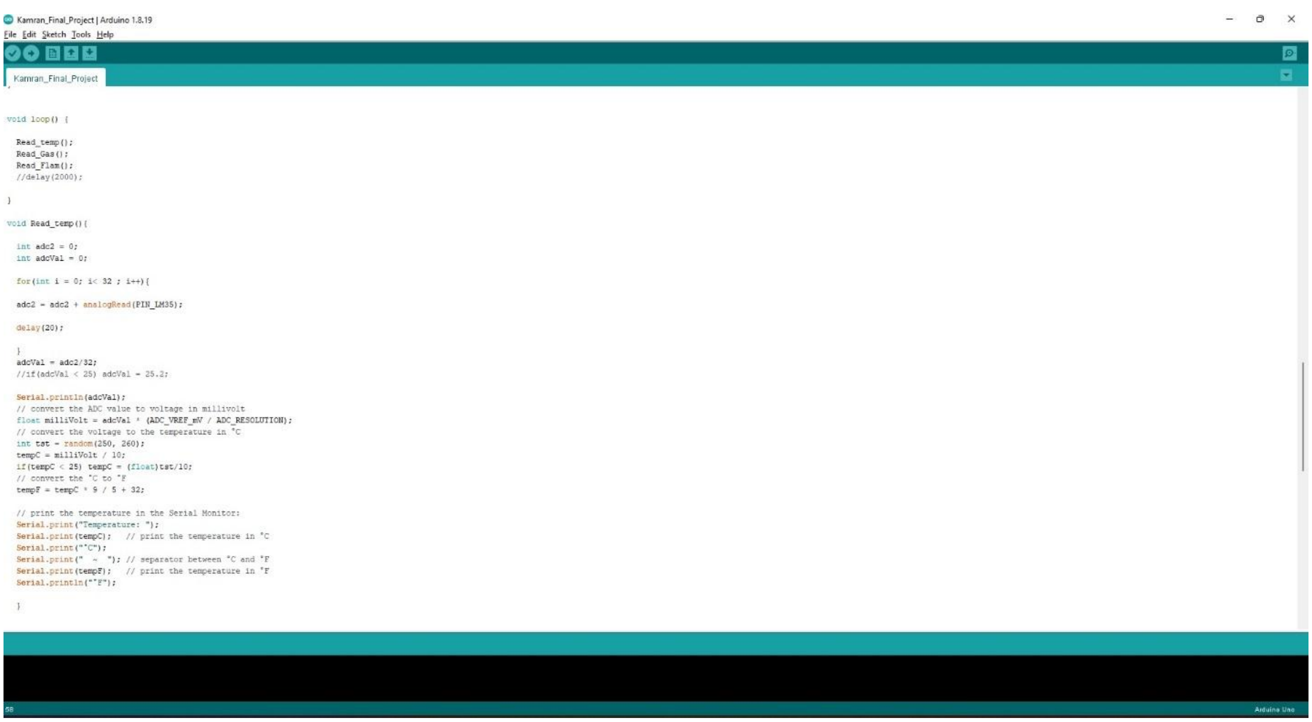


Appendix F: Defining functions and Input Values



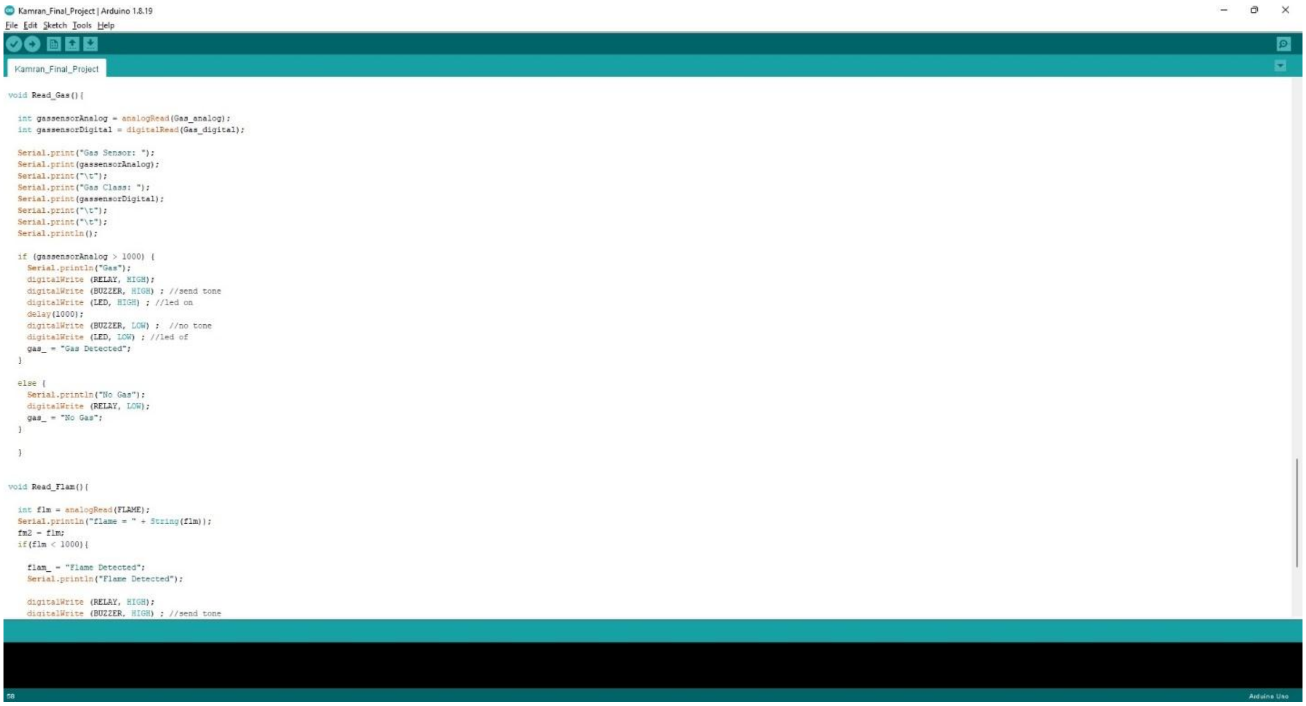
```
Kamran_Final_Project | Arduino 1.8.19
File Edit Sketch Tools Help
Kamran_Final_Project
}

void setup() {

  Serial.begin(9600);
  pinMode(RELAY , OUTPUT);
  pinMode(LED , OUTPUT);
  pinMode(BUZZER , OUTPUT);
  pinMode(Gas_digital , INPUT);

 initSPIFFS();

 Serial.println("Setting AP (Access Point)");
    // NULL sets an open Access Point
    WiFi.softAP("Quwa12345");

    IPAddress IP = WiFi.softAPIP();
    Serial.print("AP IP address: ");
    Serial.println(IP);

    server.on("/", HTTP_GET, [](AsyncWebServerRequest *request){
       request->send(SPIFFS, "/index.html", "text/html", false, processor);

    });

    server.serveStatic("/", SPIFFS, "/");

    server.on("/LED", HTTP_GET, [](AsyncWebServerRequest *request){
       Serial.println("LED Button press");
       digitalWrite(LED , !digitalRead(LED));
       request->send(SPIFFS, "/index.html", "text/html", false, processor);
    });

  server.on("/RELAY", HTTP_GET, [](AsyncWebServerRequest *request){
       Serial.println("RELAY Button press");
       digitalWrite(RELAY , !digitalRead(RELAY));
       request->send(SPIFFS, "/index.html", "text/html", false, processor);
    });

  server.on("/BUZZER", HTTP_GET, [](AsyncWebServerRequest *request){
       Serial.println("RELAY Button press");
       digitalWrite(BUZZER , !digitalRead(BUZZER));
       request->send(SPIFFS, "/index.html", "text/html", false, processor);
    });
58                                                          Arduino Uno
```

Appendix G: Defining Output Functions



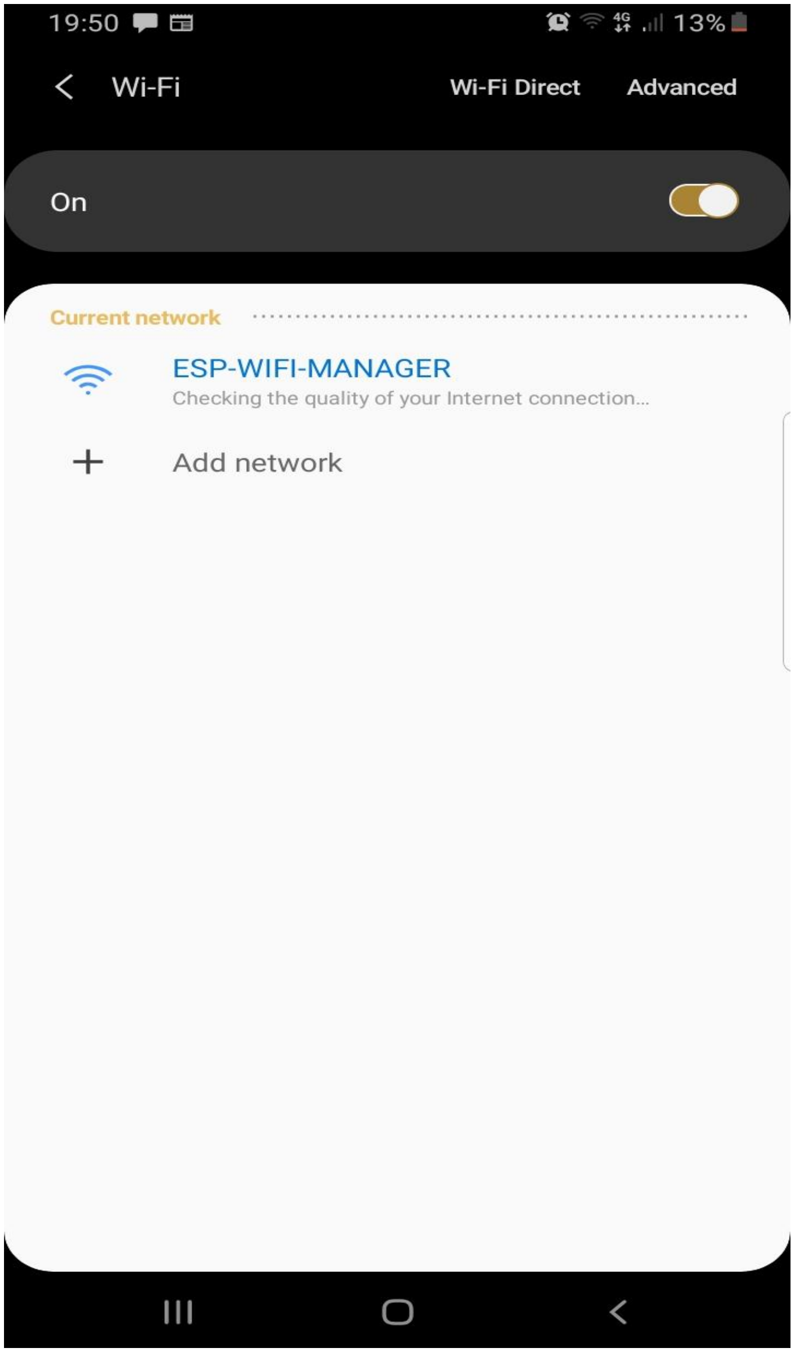
```
Kamran_Final_Project | Arduino 1.8.19
File Edit Sketch Tools Help
Kamran_Final_Project

void loop() {

  Read_temp();
  Read_Gas();
  Read_Flam();
  //delay(2000);

}

void Read_temp(){

  int adc2 = 0;
  int adcVal = 0;

  for(int i = 0; i< 32 ; i++){

  adc2 = adc2 + analogRead(PIN_LM35);

  delay(20);

  }
  adcVal = adc2/32;
  //if(adcVal < 25) adcVal = 25.2;

  Serial.println(adcVal);
  // convert the ADC value to voltage in millivolt
  float milliVolt = adcVal * (ADC_VREF_mV / ADC_RESOLUTION);
  // convert the voltage to the temperature in °C
  int tst = random(250, 260);
  tempC = milliVolt / 10;
  if(tempC < 25) tempC = (float)tst/10;
  // convert the °C to °F
  tempF = tempC * 9 / 5 + 32;

  // print the temperature in the Serial Monitor:
  Serial.print("Temperature: ");
  Serial.print(tempC);   // print the temperature in °C
  Serial.print("°C");
  Serial.print("  ~  "); // separator between °C and °F
  Serial.print(tempF);   // print the temperature in °F
  Serial.println("°F");

  }
58                                                          Arduino Uno
```

Appendix H: Reading Data from Temperature, Gas and Flame Sensors

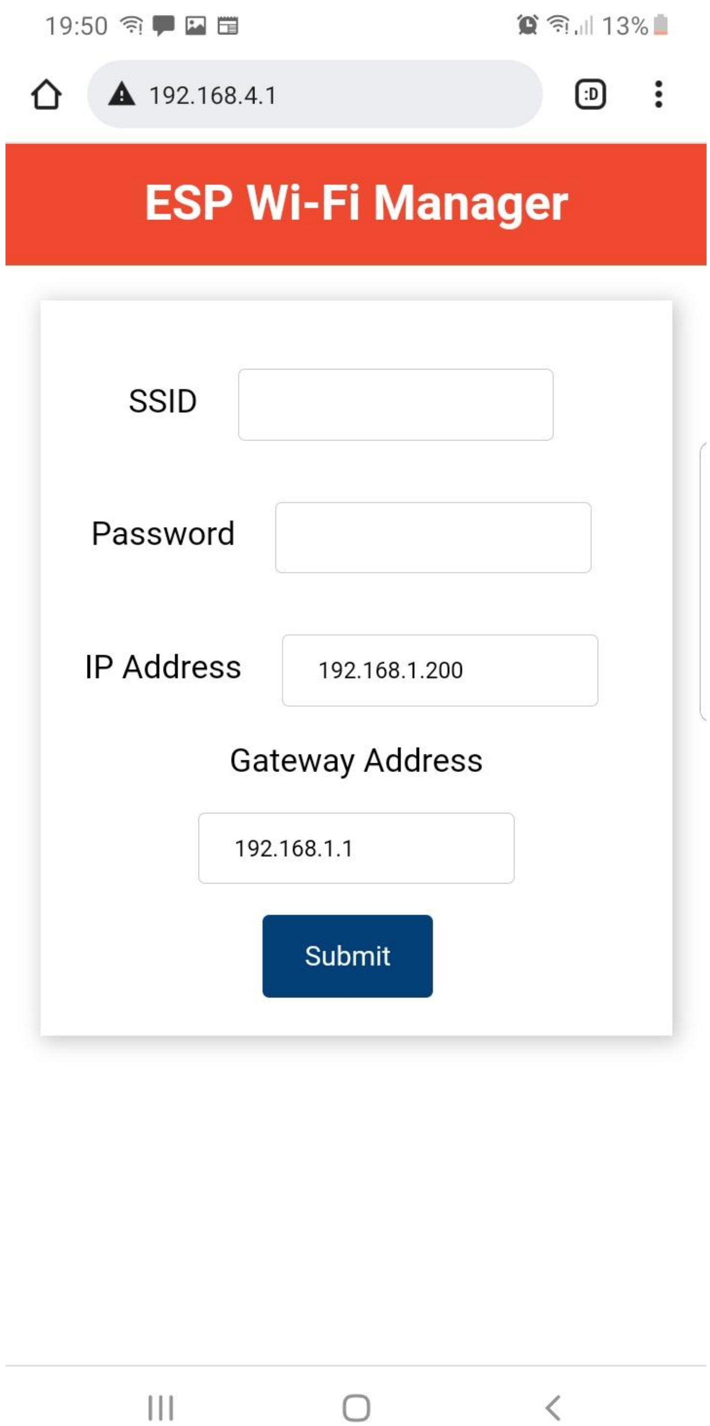


```
void Read_Gas(){

  int gassensorAnalog = analogRead(Gas_analog);
  int gassensorDigital = digitalRead(Gas_digital);

  Serial.print("Gas Sensor: ");
  Serial.print(gassensorAnalog);
  Serial.print("\t");
  Serial.print("Gas Class: ");
  Serial.print(gassensorDigital);
  Serial.print("\t");
  Serial.print("\t");
  Serial.println();

  if (gassensorAnalog > 1000) {
    Serial.println("Gas");
    digitalWrite (RELAY, HIGH);
    digitalWrite (BUZZER, HIGH) ; //send tone
    digitalWrite (LED, HIGH) ; //led on
    delay(1000);
    digitalWrite (BUZZER, LOW) ;  //no tone
    digitalWrite (LED, LOW) ; //led of
    gas_ = "Gas Detected";
  }

  else {
    Serial.println("No Gas");
    digitalWrite (RELAY, LOW);
    gas_ = "No Gas";
  }

  }


void Read_Flam(){

  int flm = analogRead(FLAME);
  Serial.println("flame = " + String(flm));
  fm2 = flm;
  if(flm < 1000){

    flam_ = "Flame Detected";
    Serial.println("Flame Detected");

    digitalWrite (RELAY, HIGH);
    digitalWrite (BUZZER, HIGH) ; //send tone
```

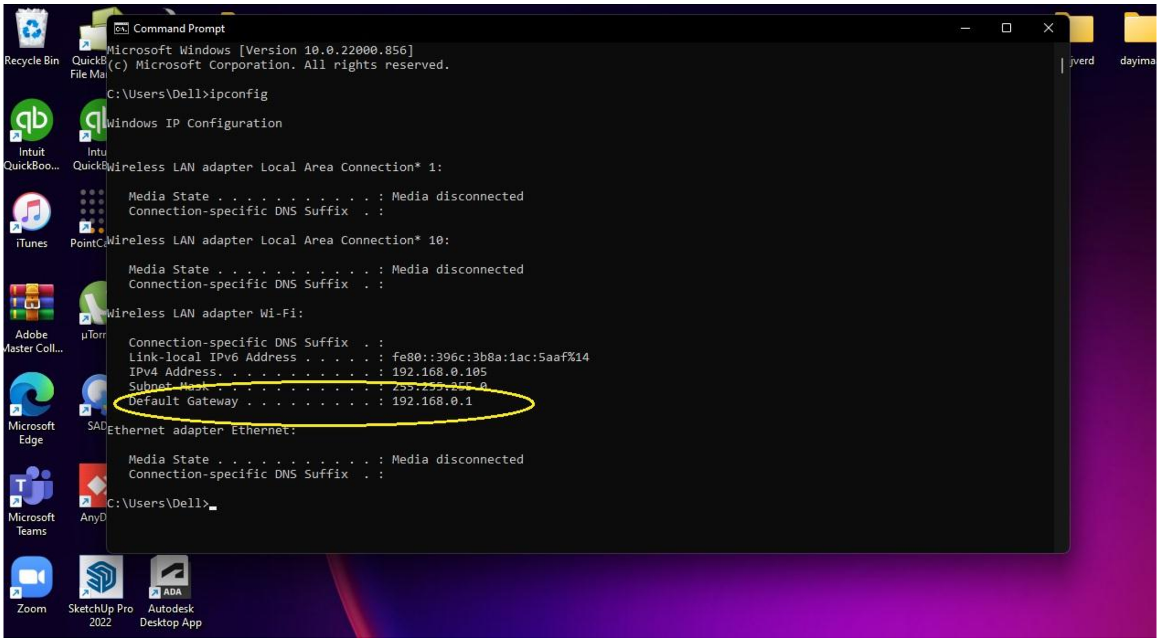
Appendix I: Converting Analogue data to Digital and Operation Conditions



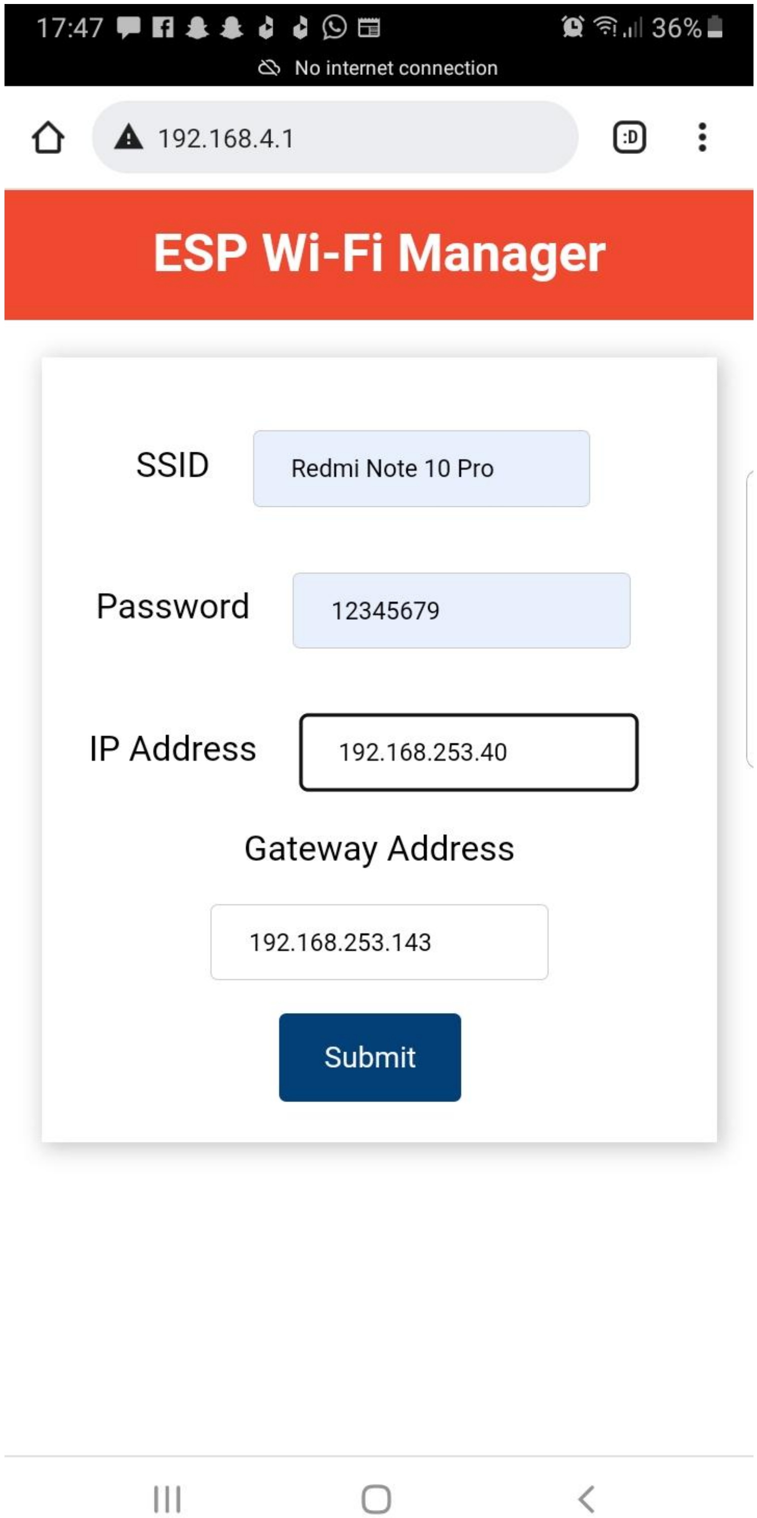
Appendix J: Connection Guide_ Connecting with the ESP Wifi Manager



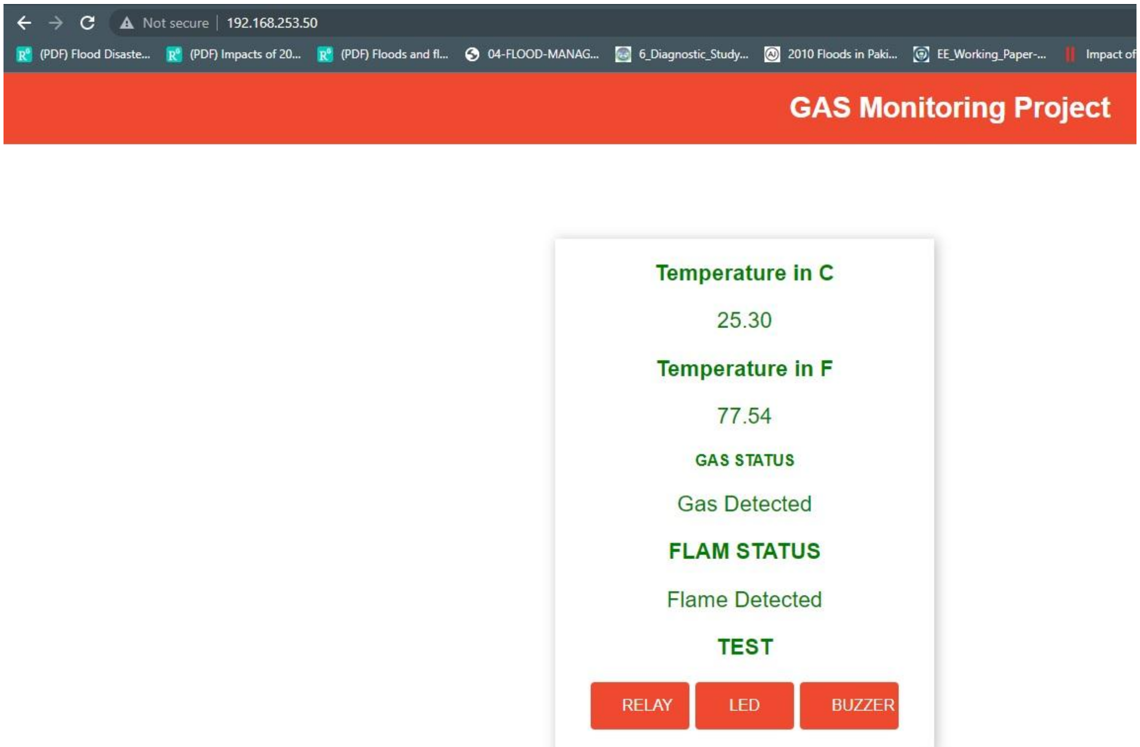
Appendix K: Navigating to ESP Router (Default IP: 192.168.4.1)



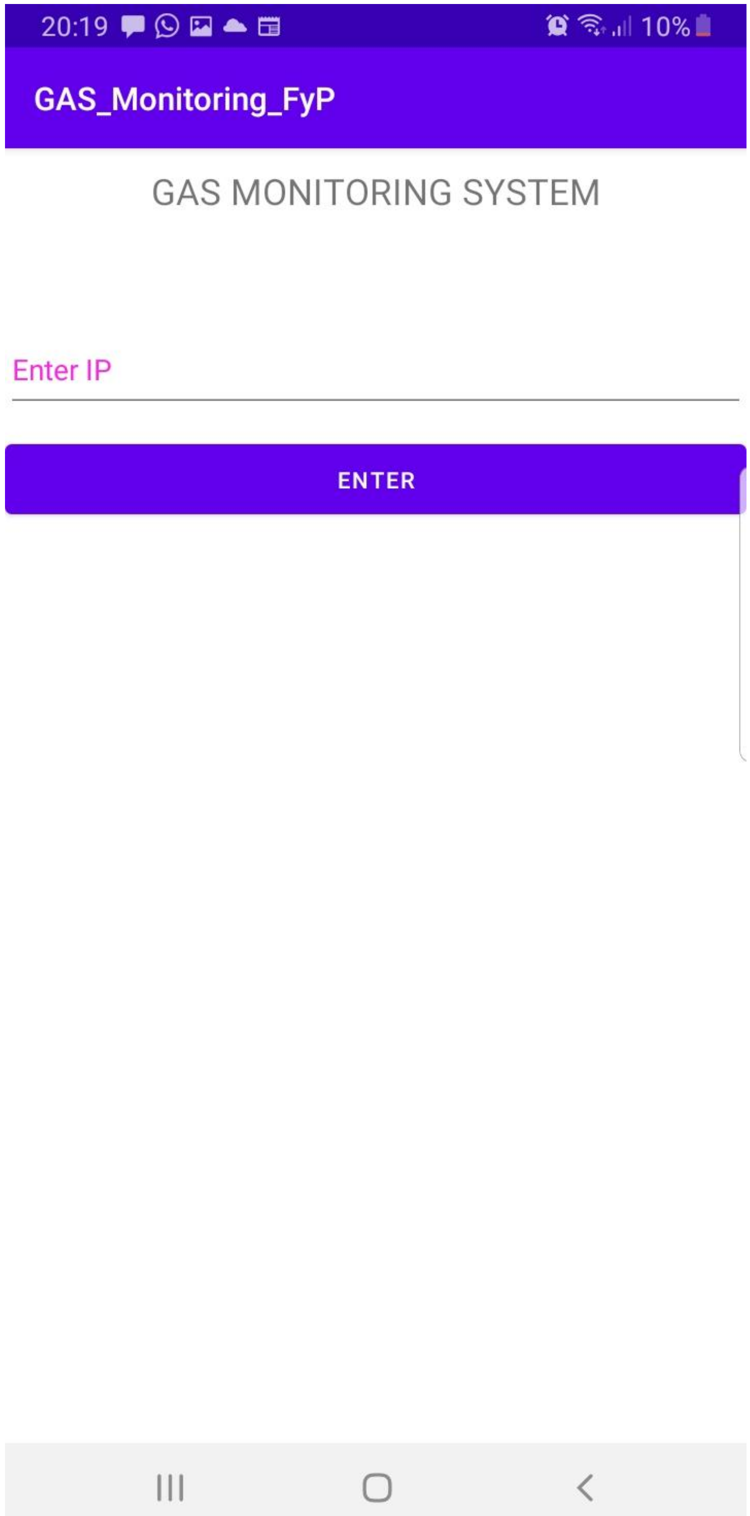
Appendix L: Checking the IP Address of Home Network



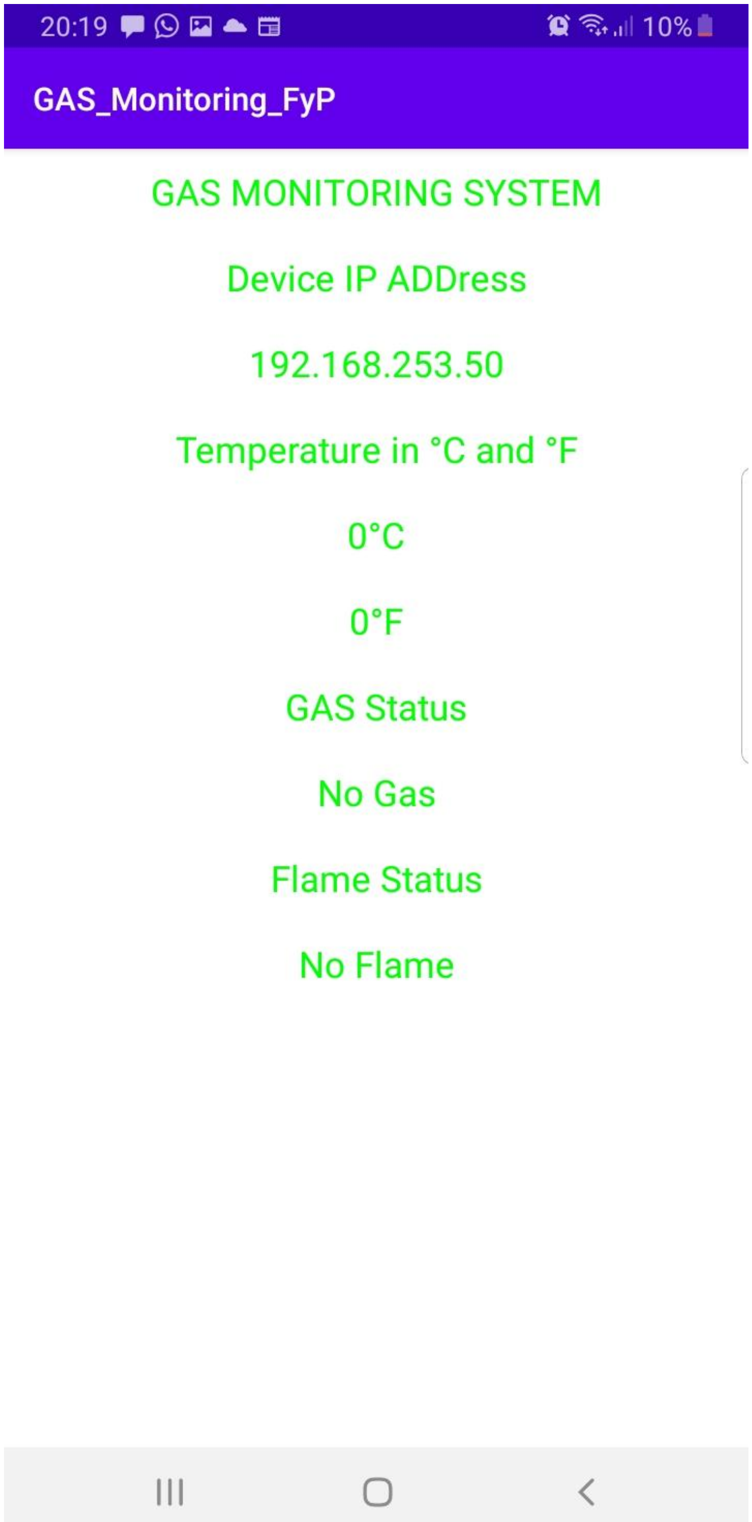
Appendix M: Entering Network Credentials in the ESP WIFI Manager



Appendix N: Navigating to designated IP Address to Monitor the Sensor Values



Appendix O: Android Application Interface (To enter the designated IP Address)



Appendix P: Data Monitoring in Android Application