Modeling and Simulation of a Gas Detecting Device for providing safety; and reducing the risk of accidents due to gas explosion or fire

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Electrical and Electronic Engineering

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DECLARATION

We hereby declare that research work titled "**Gas Leakage Safety Alarm**" is our work. The thesis does not contain material that has been accepted or submitted for any other degree or diploma at a university or other institution.

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APPROVAL

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DEDICATION

This work is dedicated mainly to our parents for all their efforts and encouragement they have invested in us up until now. We also dedicate the work to our supervisor, who has been more than a pillar in the development of the final work output.

ABSTRACT

The Internet of things (IoT) has been a current topic of interest. It creates an interconnection between electronic devices, computers, and human beings. Implementing IoT can be highly beneficial for humanity for various reasons, such as safety. The accidents which occur due to flammable gas explosions and leakage have been an ongoing problem in Bangladesh. While many settlements possess safety anti-fire alarms, it is noteworthy that such facilities are not accessible by the majority of the people in our country. Thus, we developed a gas detecting device that acts according to how it is programmed to systematically let the user know of an abrupt change in gas concentration in the surroundings where the device operates and, hence, work accordingly to lower the risks of any adverse development as explosions or fire. Ideally, the device is placed around stoves, machines, or any place where flammable gas exposure is present. The whole architecture has four parts – 1) Simulation, 2) Mechanical, 3) Electrical, and 4) Software. In this thesis, to prove our whole concept, we will simulate the software, hardware, and electrical parts in depth.

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Chapter 1

Introduction

1.1 Aim of the project

We cannot depart from gas stoves any time soon, so we created a safety device that alerts people to potential fire risks, known and referred to as the gas stove safety device. We define these fire risks in our high-level requirements as:

- The device must be able to detect when the stove is on, issuing an intermittent warning.
- After issuing an intermittent warning, it will warn a dedicated person by a CALL/SMS from the GSM module.
- The device must detect when a dangerous amount of flammable gas is in the air, defined as 5,000ppm methane, 2,100ppm propane, or 1,600ppm butane, triggering an immediate alert.
- After that, it will cut off the gas supply from the mainline by using a servo motor to rotate the valve by 90 degrees, and the exhaust fan will start.
- After cutting off the gas, it will start an exhaust fan which will take out the remaining gas from the place.

1.2 Background

The alarming situation of accidents due to gas leakage is evident by recent events which occurred. In June 2021, a three-storied settlement was destroyed due to a severe gas explosion in the capital of Dhaka, resulting in several casualties and serious injuries. In 2020, Narayanganj, deaths due to fire were recorded, which concluded deaths due to this matter were higher than casualties due to Covid-19 during the peak stages of the pandemic. A total of 94 blasts occurred during that period, during which 44 people faced death. One of the most tragic incidents occurred at a Mosque, when 37 people were reportedly affected by a gas explosion which occurred when a gas line erupted underneath the mosque, resulting in several casualties. Moreover, several deaths went by undocumented as victims of gas explosions underwent medical proceedings in hospitals before facing their inevitable demise. Finally, the data and statistics trend of deaths due to gas leakage convey that this problem has been ever-existing and has been consistently occurring in Bangladesh, mainly due to the unawareness of concerned citizens, authorities, and the governing bodies of those areas.

1.3 Motivation

The Internet of things (IoT) has been a current topic of interest. It creates an interconnection between electronic devices, computers, and human beings. In modern times, technology benefits humanity in various ways and builds systems that ensure its users' safety from dangers that may unwantedly arise. Accordingly, leakage of gas is one of the significant problems in the present era. In this modern technological world, almost everything we use contains gases like Methane, Propane, Carbon Monoxide, Liquefied Petroleum Gas (L.P.G.), and other fuel sources. Both in industrial and residential sites, these gases are being used grandly. As a result, accidents due to gas leakage have become very frequent. Dangerous gases can bring harmful effects as they may cause explosions and fire, resulting in severe burns, damage of property, injuries, and even death of people. Several accidents have already taken place in different areas of Bangladesh. A gas detecting device could be the key to reduce such catastrophic situations from occurring again. Accordingly, we wanted to create a system that can solve the problems by detecting gas leakage, alerting the users, and automatically shutting the system down to prevent serious accidents.

1.4 Literature Review

As discussed above, gas leakage has become a significant problem as it can bring harmful effects to humans and the environment. Hence important research was conducted, and papers such as the following made a substantial contribution.

For example, “Gas sensors based on nanostructured materials" by Giselle Jimenez-Cadena, Jordi Riu and F. XaveRius (2007), “Design and Development of Gas Leakage Monitoring System using Arduino and Zigbee” by Huan Hui Yan from University of Malaya and Yusnita Rahayu from Universitas Riau (2014), “Gas Leakage Detection System (GLDS)” by D. Simbeye from Dares Salaam Institute of Technology (2013), “Sensor- Based Gas Leakage Detector System" by Mohammad Monir Ujjaman Khan (2020), “L.P.G. Gas Leakage Detection and Alert System" by E. J Leavline, D. Asir Antony Gnana Singh, B. Abinaya, H. Deepika from Anna University, BIT Campus, Tiruchirappalli-24 (2017), “FPGA-GSM based gas leakage detection system” by T. Arpitha, D. Kiran, V.S.N. S. Gupta, Punithavathi Duraisamy (2016) are some of the significant ones on this topic.

In their research “Design and Development of Gas Leakage Monitoring System using Arduino and Zigbee” done by Huan Hui Yan from the University of Malaya and Yusnita Rahayu from Universitas Riau (2014), they have built a system that can detect and monitor leakage of gas using Arduino UNO Microcontroller, MQ-9 gas sensor, Zigbee and LEDs. They designed the sensor in such a way so the sensor can immediately detect the leakage of gas, obtain data from that place and display it in the monitoring system. Based on the sensor's voltage output, this sensor will detect the gas concentration and will be used in the alarm system, control system, and monitoring system.

D. Simbeye from Dares Salaam Institute of Technology (2013), in his study “Gas Leakage Detection System (GLDS),” mainly focused on detecting gas leakage and providing security using short message service (CALL/SMS) and wireless technology.

Mohammad Monirujjaman Khan (2020) proposed a sensor-based system that detects, alerts, and controls gas leakage. In his study, he used Arduino Uno, an MQ-6 gas sensor in order to detect the leakage of gas, and a buzzer as an alarm system to alert the users about gas leakage. MQ-6 can detect gas from 200ppm to 10000ppm. The system will trigger the buzzer to notify the users if the gas in the air exceeds the safety threshold. LCDs have been added to show whether or not a gas leak has been observed.

In their paper “LPG Gas Leakage Detection and Alert System,” E. J. Leavline, D. Asir Antony G. Singh, B. Abinaya, H. Deepika (2017) have simply represented a battery-operated portable system which can spot the leakage of gas and can alert by the aid of a buzzer. They utilized a sensor with a high sensitivity MQ-6 gas sensor with a quick reaction time which can detect LPG concentrations between 200ppm and 10,000ppm.

In the paper “FPGA-GSM based gas leakage detection system” by T. Arpitha, Divya Kiran, V.S.N. Sitaram Gupta, Punithavathi Duraisamy (2016), they have presented a system that can detect leakage using

FPGA and warn the users by sending short message service (CALL/SMS). They have used an 8-bit ADC to convert the sensor analog voltage into digital. In FPGA, the data from ADC is analyzed, and if any leakage is detected GSM module sends a CALL/SMS to the stored number to warn the consumer. Universal Asynchronous Receiver Transmitter (UART) has been used as the interface between the FPGA and GSM modules.

Gas detectors are now available in a variety of forms, including a gas sensor made of nanostructured material, gas leakage detection with monitoring and alarm system, wireless installation, and so on. In our study, we have added several useful features to innovate the gas detector so that the system can automatically prevent any kind of accident without any human interaction. We have added a buzzer that will alert the users when the gas concentration is higher than usual, LEDs, and LCDs to show the detection. GSM module (SIM800L) will notify the users by calling them on the given number if any gas leakage is detected. A DC motor powers an exhaust fan for removing excessive and unwanted gas, fumes, and smoke from the area.

Chapter 2

Components

2.1 Hardware Components

2.1.1 Arduino UNO R3

The Arduino Uno is an open-source microcontroller board designed by Arduino.cc and based on the ATmega328P microprocessor. The Arduino UNO has 14 digital pins that can receive and transmit signals. Using the Arduino Integrated Development Environment (IDE) on a computer, six pins send PWM output, and six pins receive analog and programmable inputs. An Arduino's primary source of power is a 9-volt battery or a USB connection. The Arduino can function with a voltage range of 7 to 20 volts.

In our project, we made use of Arduino’s Analog Input pins. Prompts from the MQ-2 Gas Sensor reach the Arduino Microcontroller. Next, signals to a servo motor (Connected to the gas knob) operate to cut the connection from the gas source. Simultaneously, an exhaust fan replaces the accumulated gas inside the kitchen; a message is delivered to the user via a GSM Module to notify him of gas leakage. In contrast, the buzzer alarm and LCD receive signals to be switched on and let users nearby of the occurrence of gas leakage.

Figure 2.1 – Arduino UNO R3

2.1.2 Ball Valve

The ball valve is primarily known as a flow control device that makes use of a rotary ball with an opening in the center of the ball. This device either allows gas flow through it while it is open or completely shuts down the flow of gas through it once rotated by an angle of 90 degrees. We have used the ball value as it is very sturdy and, over a long period, can still perform its duty without faults whatsoever. Since we are installing a ball valve in the gas carrying pipe, we have made sure the ball valve can withstand the flowing gas pressure. A ball valve can handle pressure up to 100MPa/ 15,000 psi while working in conditions where the temperature may rise to about 400 °C; hence, through research and studies, we have selected the ball valve as the most suitable instrument which would aid us to stop the flowing gas through a gas line once a leakage activates the device.

Figure 2.2 – Ball Valve

2.1.3 GSM Module

The GSM module, or global system for mobile communication, is the communication channel that establishes a link between different system sites. It is a wireless system that uses mobile technology to transmit data from one distant network to another. The GSM module comes in a variety of configurations, including SIM900, SIM300, and SIM800. We utilized the SIM900A GSM module, which offers a variety of services including voice, CALL/SMS, data, and fax, all of which are associated with a specific frequency or quad-band of 850MHz, 900MHz, 1800MHz, and 1900 MHz assigned by the GSM module. It operates in the 5V supply voltage range. It has a power consumption of 2A and can operate at temperatures ranging from -40 to +85 degrees Celsius. To use the GSM module, a SIM card is needed. We can connect the TX pin of the GSM module to the RX pin of Arduino and the RX pin of the GSM module to the TX pin of Arduino to link the GSM module with Arduino. When the system detects any leakage, the suggested GSM module gets a signal and transmits text and voice calls to the specified number.

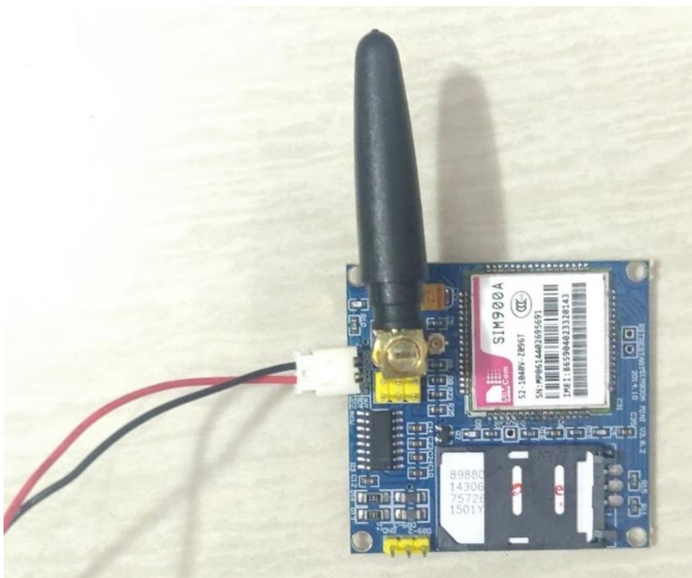

Figure 2.3 – GSM Module

2.1.4 Gas Sensor

The MQ-2 sensor can detect a wide range of gases, including methane, carbon monoxide, alcohol, hydrogen, LPG (Liquefied Petroleum Gas), propane, and smoke. Metal Oxide Semiconductor (MOS) type Gas Sensor is sensitive to small changes in gas concentration and quick time response. Gas concentrations can be recorded using a simple voltage divider network. The MQ-2 sensor module comes with four male headers, allowing it to be readily connected to an Arduino Uno with jumper wires. The operating voltage of the MQ-2 sensor is 5V. It can detect concentrations of Methane**,** Carbon Monoxide, LPG**,** Alcohol**,** Propane**,** Hydrogen, and smoke anywhere from 200 to 10000ppm. The sensor has two layers of fine stainless-steel mesh, which are called an Anti-explosion network. It protects the sensor and ensures the particles inside the sensor are not causing any explosion because of the flammable gases. The MQ-2 sensor's construction materials contain SnO2 (Tin Dioxide), which is the most significant substance sensitive to combustion gases. When any gas leakage is detected, the sensor’s conductivity rises proportionately with the increasing gas concentration. The MQ2 Gas sensor module is simple to connect to the Arduino. VCC pin connected to the Arduino's 5V pin and the GND pin to the Arduino's Ground pin. AO pin connected with the Arduino's A1. When the sensor detects any leakage or senses a higher amount of gas concentration than usual, it will signal the microcontroller to monitor it and send it to the buzzer, LED, GSM module, and an exhaust fan.

Figure 2.4 – Gas Sensor

MQ Gas detectors come in different varieties which sense different types of gas as follows:

Gas Sensors	**Gas Detected**
MQ-2	Methane, Butane, LPG, smoke
MQ-3	Alcohol, Ethanol, smoke
MQ-5	Natural gas, LPG
MQ-6	LPG, butane gas
MQ-7	Carbon Monoxide
MQ-9	Carbon Monoxide, flammable gasses
MQ-131	Ozone
MQ-135	Air Quality (CO, Ammonia, Benzene, Alcohol, smoke)
MQ-136	Hydrogen Sulfide gas
MQ-137	Ammonia
MQ-138	Benzene, Toluene, Alcohol, Acetone, Propane, Formaldehyde gas, Hydrogen
MQ-214	Methane, Natural gas

Table 2.1. Types of MQ Gas Sensor

2.1.5 Exhaust Fan:

Exhaust fans extract smoke, fumes, and pollutants from an area and expel them outside for disposal. Increasing amounts of gas fumes may cause severe accidents in the area. Therefore, exhaust fans are instrumental in avoiding them and getting rid of unnecessary and excessive gases. The blades of the fan, which draw air out of the area, are turned on using a motor.

Figure 2.5 – Exhaust Fan

2.1.6 I2C (Inter-Integrated Circuit)

It is also known as I2C (Inter-Integrated Circuit) or IIC (Inter-Integrated Circuit); which is a synchronic, multi-master, multi-slave, single-ended serial communication bus developed by Philips Semiconductors in 1982. It is commonly used to connect lower-rate peripheral ICs to CPUs and microcontrollers in short-range inter-board communication. We used Inter-Integrated Circuit to reduce the LCD connection and make the circuit comfortable to work with, and relieve some tension.

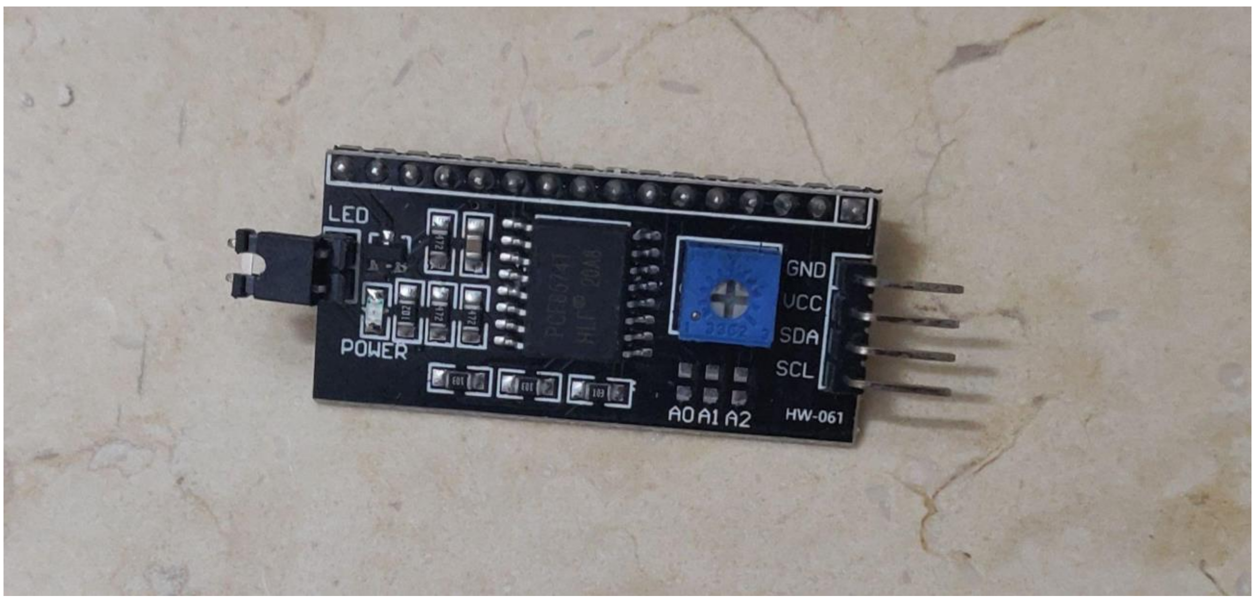

Figure 2.6 – I^2C (Inter-Integrated Circuit)

2.1.7. Servo Motor

A servo motor is an electromechanical device that creates torque and speed based on the current and tension provided. A servo motor functions as part of a closed-loop, giving torque and speed control from a servo controller that uses feedback equipment to close the loop. Servos are used primarily for the angular or linear position and specific velocity and acceleration.

After detecting the gas by MQ2 sensor, a signal from the Arduino is delivered to the servo which will fix the direction of the valve. The valve will rotate 90 degrees, and the gas supply will be cut off.

Figure 2.7 – Servo Motor

2.1.8 LED and Buzzer

An LED bulb generates light by sending an electric current through a semiconducting material, the diode, which subsequently emits photons (light) using the concept of electro-luminescence, which simply says that when electricity is supplied to a material (in this example, the diode), it emits light.

The buzzer is made out of an exterior casing with two pins for power and ground connections. It comprises a center ceramic disc surrounding by a metal (typically bronze) vibration disc found inside. The ceramic disk contracts or expands when electricity is delivered to the buzzer.

Figure 2.8 – LED and Buzzer

2.1.9 Breadboard

Before finishing any circuit design, a breadboard is used to quickly develop and test circuits. Connection points on the breadboard allow circuit components like as ICs and resistors to be added. A breadboard is a construction platform for electronics prototyping. Originally, the term meant to a physical breadboard, and translucent principally refers to a flexible, polished piece of wood used for bread slicing. This makes it simple to use for making temporary prototypes and circuit design experiments.

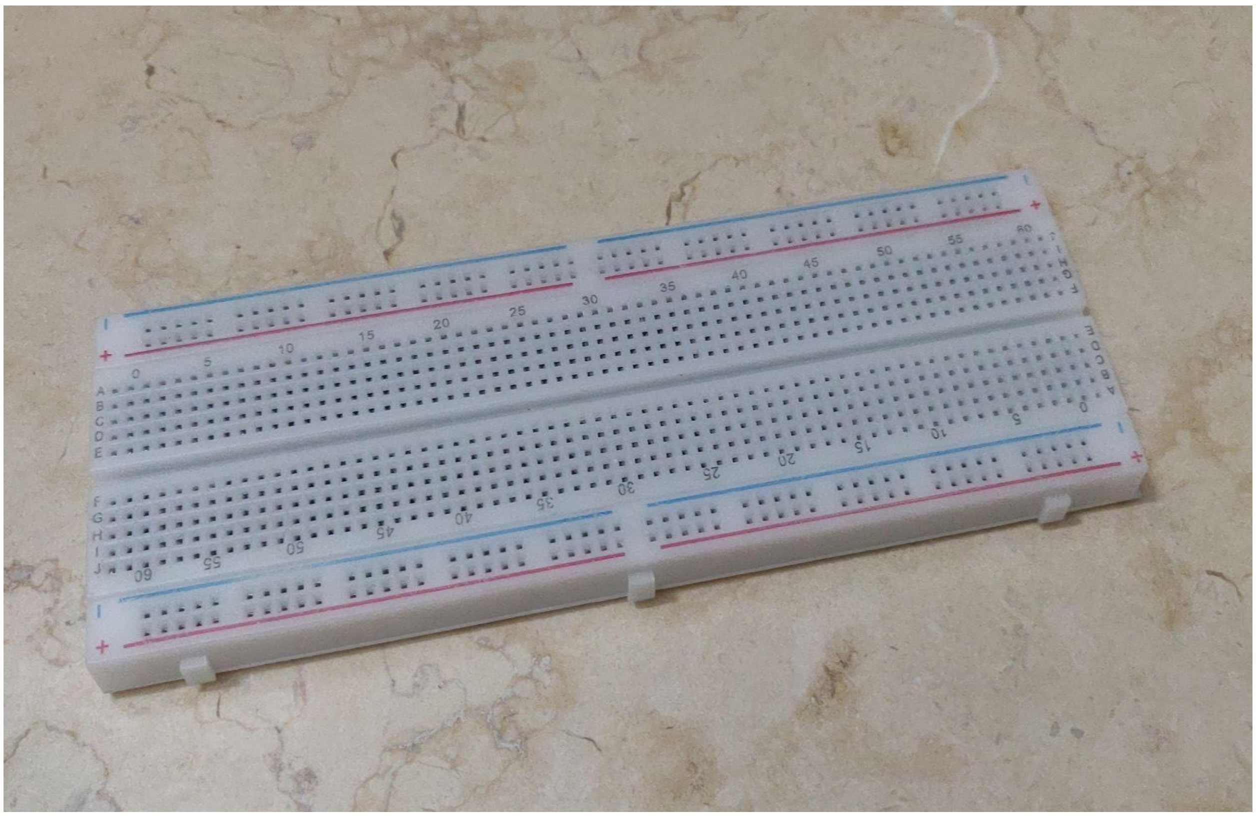

Figure 2.9 – Breadboard

2.1.10. LCD

LCD is a type of electronic display device that shows messages and information. As the name implies, it has 16 columns and 2 rows, allowing it to display a total of 32 characters, each of which is made up of 40 Pixel Dots. As a result, the total pixels in this LCD are 1280 pixels.

Multi-segment LEDs are used extensively in 16 X 2 screens. Various types of displays are available in the market with various combinations; however, LCD 16 x2 is widely used in devices, DIY circuits, and electronic projects due to its low cost, programmability, and ease of use.

Figure 2.10 – LCD

2.2 Software Components

2.2.1 Arduino

The Arduino Software (IDE) is user-friendly for beginners. It is very much easy to write code with the software and upload it to the Arduino board. This software supports many operating systems. It's compatible with Mac, Windows, and Linux. It is used to make low-cost scientific equipment, prove various subject-oriented notions, and learn programming and robotics. Using the IDE platform, we create the main code, also known as a sketch, which will generate a 'Hex File,' and the hex file is then uploaded in the controller on the board.

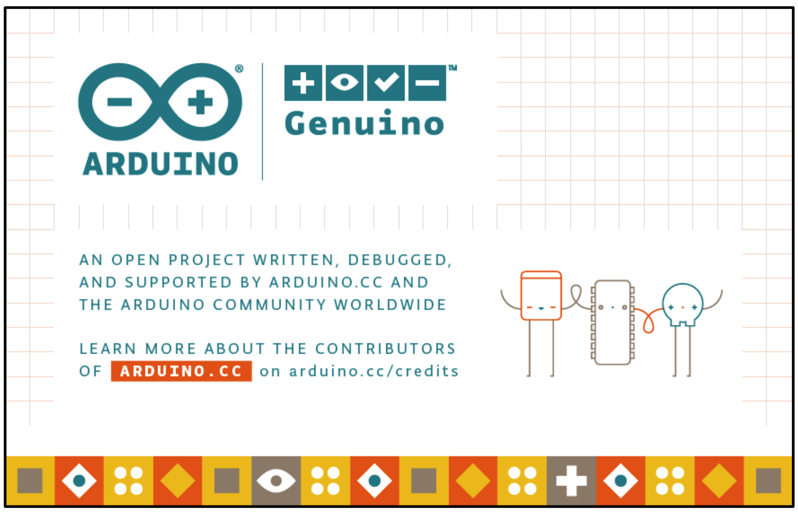

Figure 2.11 – Arduino Software

We have used Arduino software for our project as our project is totally Arduino-based, so we did not have any other option. While doing this project, we found that some libraries were not pre-installed in Arduino Software like LCD integrated with I2C module, different types of gas sensor, GSM module etc.

We had to install those libraries for creating our desired code. For this reason, we had to visit various websites and learn how to add or install those library files to the Arduino software. When we used Arduino software to create code for the software simulation, we did not have to install those library files externally.

2.2.2 Proteus Design Suite

Labcenter Electronics Ltd. designs Proteus Design Suite. It is a software tool mainly used to create schematics for different projects, simulates electronic circuits, and design PCB layouts. This Design Suite combines excellent ease of use with different features set to enable' design, test, and layout of printed circuit boards.

For our project, we used Proteus for designing our software circuit. We used some of Proteus' built-in components, however some of the components we needed for our project were not installed or added by default, such as gas sensors and GSM module, and, above all, the Arduino UNO board.

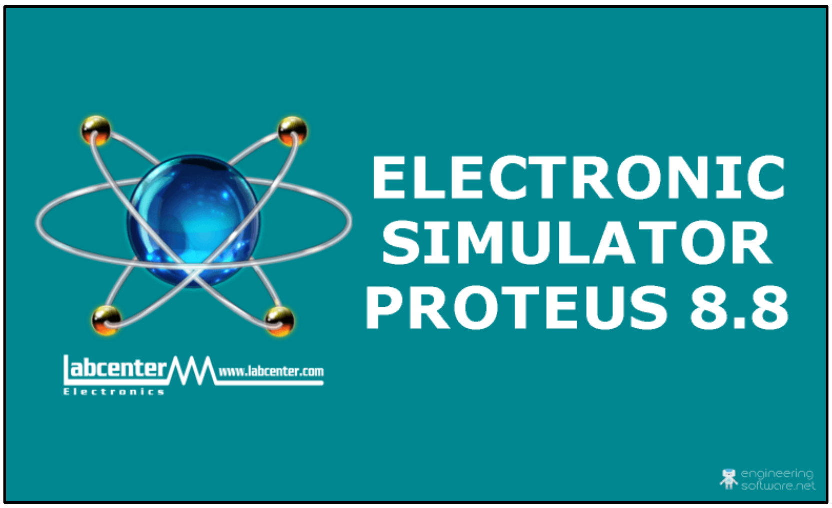

Figure 2.12– Proteus Design Suite

We have manually added these libraries in the library file of Proteus in order to use these components in our project. Proteus is quite lenient in the case of designing circuits which helped us a lot. While designing the hardware circuits, we observed how Proteus helped us create the software circuits earlier as we did not face such problems then.

Chapter 3

System Design

In this chapter, we have divided our project into eight parts which are:

1. Design Concept
2. Interfacing LCD and I^2C Module with Arduino
3. Connecting MQ2 Gas Sensor with Arduino
4. Attaching Buzzer, LEDs, and Resistors to the circuit
5. Connecting SIM900D, which works as signal transmission
6. Interfacing Servo Motor with clamp and Gas ball valve, which is the primary safety protocol
7. As a secondary safety, an exhaust fan is connected to the Arduino
8. Discussion regarding working procedure of the whole circuit

3.1 Design Concept

The whole project is mainly run by the Arduino. Power is provided to the Arduino through USB or AC/DC Power supply. MQ2 gas sensor is installed and connected to the Arduino. Sensing the presence of gas, a signal is sent to the Arduino, and from the Arduino, different types of instructions are sent to all the other components like the buzzer, LED, GSM module, servo motor, and the Arduino exhaust fan. In the given block diagram, the design concept of the project is demonstrated. The connections and the whole working procedure are described in the upcoming segments.

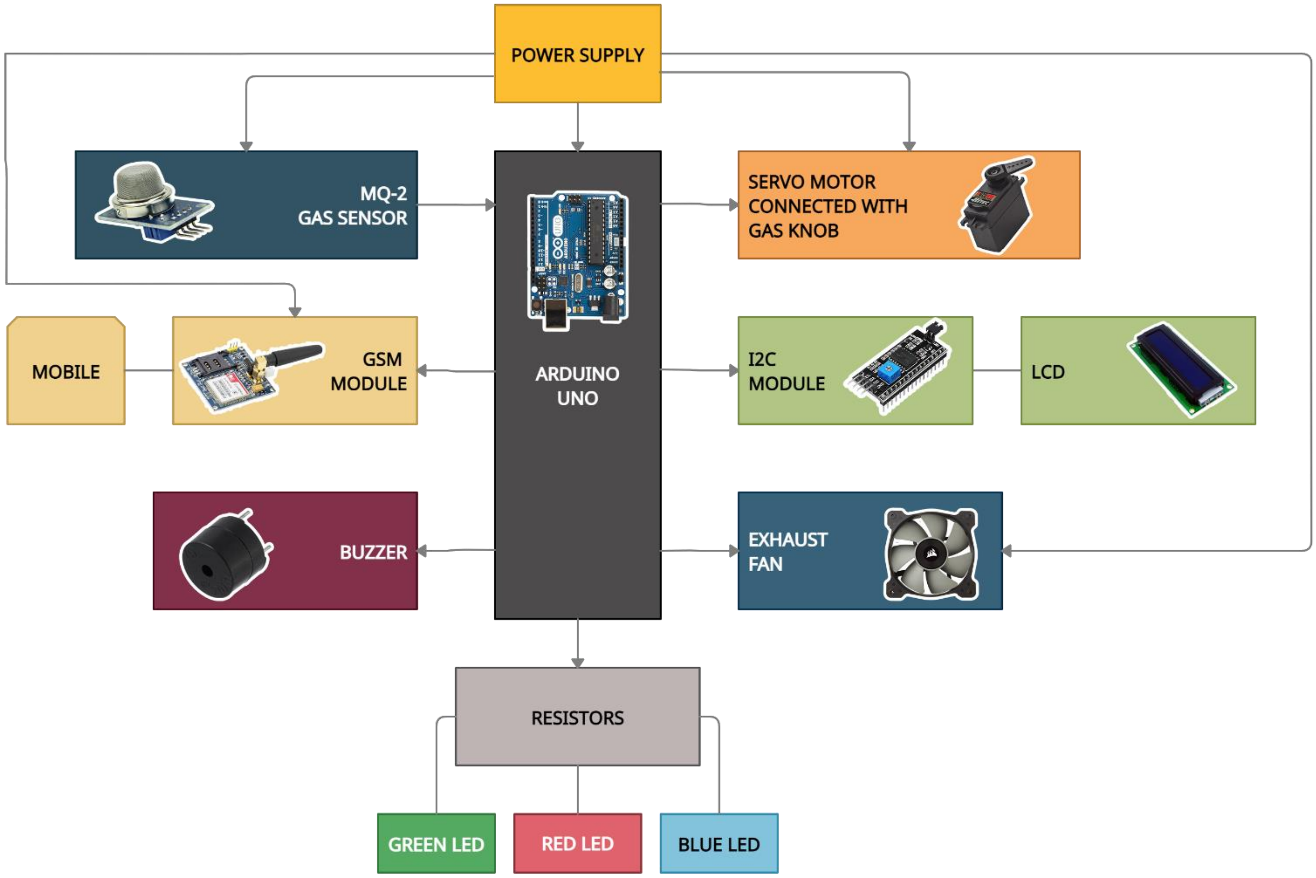

Figure 3.1 – Design Concept of Gas Detecting Device

3.2 Interfacing LCD and I2C Module with Arduino

For the project, an I^2C module incorporated with the LCD is installed. As the project consisted of complicated wiring, the number of wires has been minimized using the I^2C module with the LCD. There are four pins in the module; GND, VCC, SDA & SDL. The GND and VCC are connected to the Arduino ground pin and 5V pin, respectively. The SDA of the I2C module is connected to Pin 16, and SCL is connected to Pin 17 of Arduino UNO.

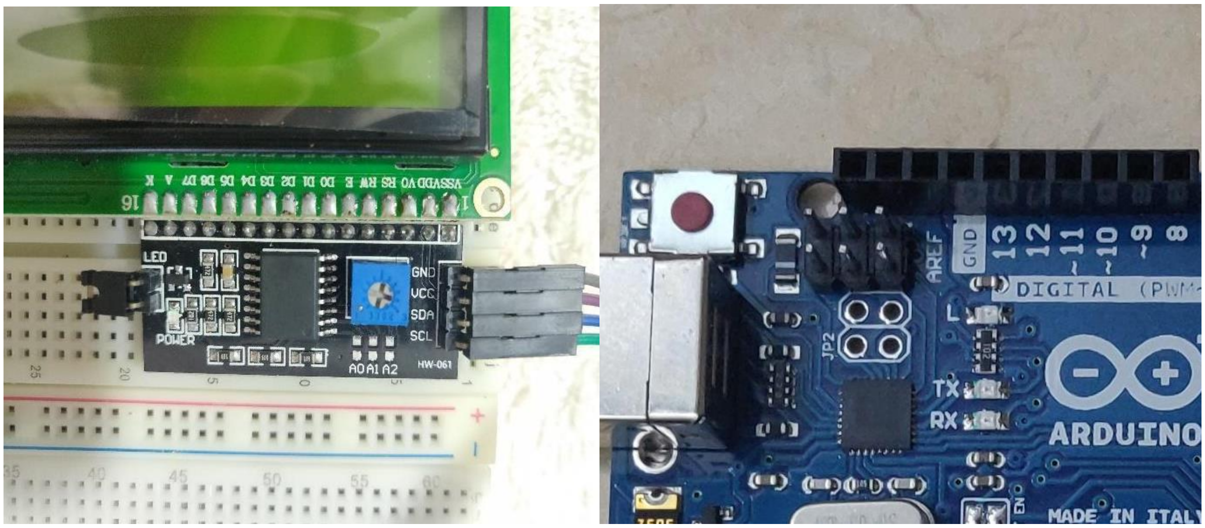

Figure 3.2 – LCD and I^2C connection with Arduino

3.3 Connecting MQ2 Gas Sensor with Arduino

The MQ2 Gas sensor is one of the main components of the project. There are four pins in the MQ2 gas sensor. They are AO (Analogue Output), DO (Digital Output), GND and VCC. The VCC and GND are connected to the Arduino 5V pin and ground pin, respectively. The AO pin of MQ2 is connected to the AO pin of Arduino.

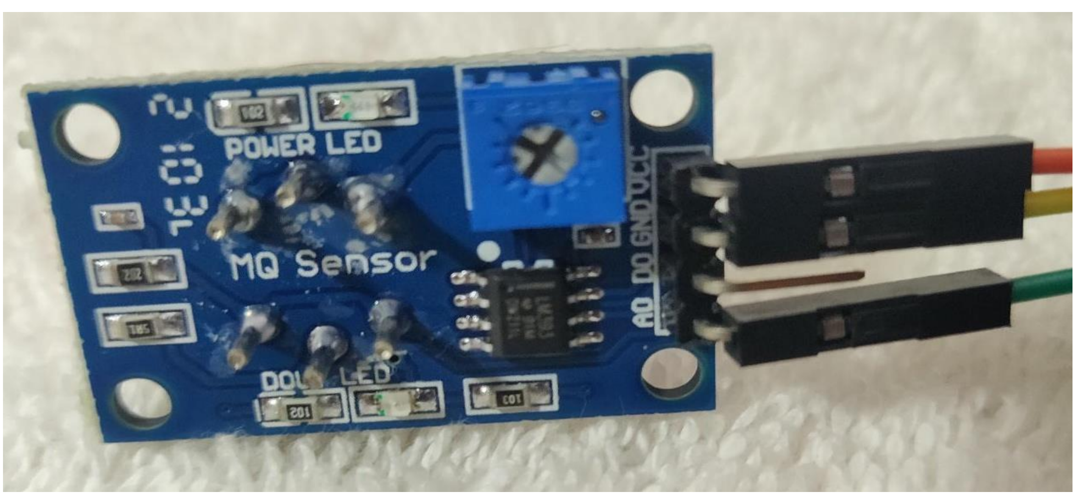

Figure 3.3 – Wire Connections of MQ-2

3.4 Attaching Buzzer, LEDs, and Resistors to the Circuit

The buzzer and LEDs are mainly used as notification signals. The resistors are used in series with the LEDs. In this project, 3 LEDs have been used for different notification signals: green, red, and blue. The Arduino Pin 8 is connected to the buzzer, Pin 12 to the green LED, Pin 13 to the red LED, and Pin 4 to the blue LED.

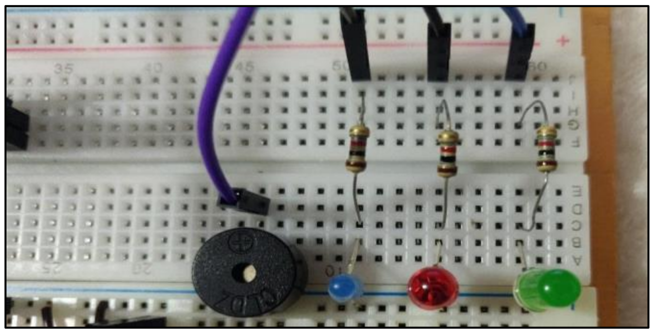

Figure 3.4 – Connections of Buzzer and LED

3.5 Connecting SIM900A, which works as Signal Transmission

The signal transmission of our project is mainly done by SIM900A, which is also known as the GSM module. There are 9 pins in the SIM900A, but only 3 pins are used for our project: RXD, TXD, and GND. The RXD is connected to Arduino Pin 11, and the TXD is connected to Arduino Pin 10.

Figure 3.5 – Design Concept of SIM900A

3.6 Interfacing Servo Motor with Clamp and Gas Ball Valve

There are three functional wires in the servo motor; 2 of them are for positive and ground. The last one is for receiving the signal from Arduino. Pin 6 of the Arduino is connected to the servo motor. Once prompted via a signal, the motor provides the necessary amount of torque to rotate a ball valve by 90 degrees with the help of a clamp attached to it which shuts the flow of gas completely; this ensures that gas is cut off from the line to the stove hence, further gas accumulation around the stove is stopped.

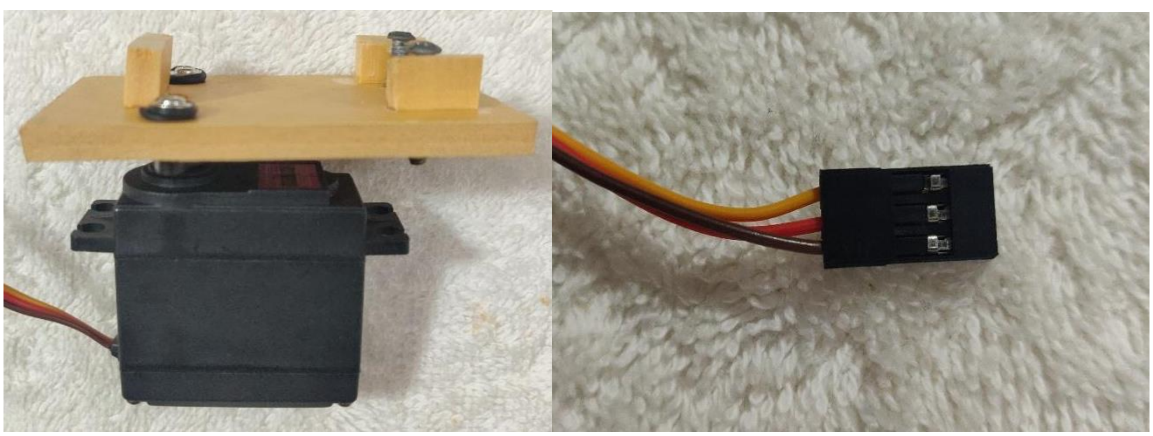

Figure 3.6 – Servo Attached with Clamp

3.7 As a Secondary Safety, Exhaust Fan is connected to the Arduino

An exhaust fan is connected to eliminate any odd chances of gas accumulation and be confined inside the kitchen room for explosions to occur later. The one wire of the exhaust fan is simply connected to Arduino Pin 7, and the other wire is connected to the ground.

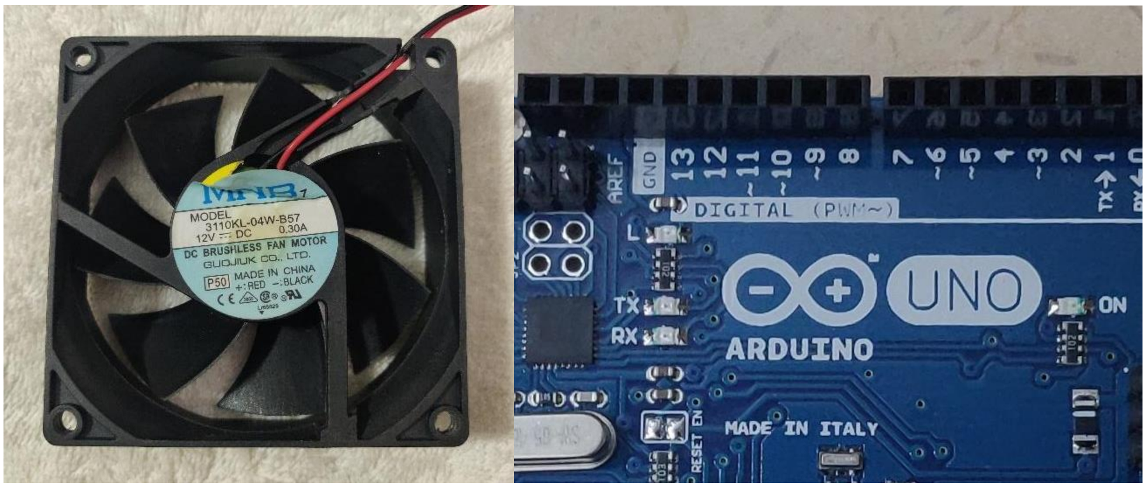

Figure 3.7 – Connections of Exhaust Fan

3.8 Discussion about Working Procedure of the Whole Circuit

At the very first, after completing the circuit setup, the LCD is going to turn on, and it will show the percentage of gas level in the air and determine whether the level is average. After that, the MQ2 gas sensor will try to sense any gas present in the room or kitchen. If the sensor does not sense any leaked gas, which will show a standard signal, the green LED, and the LCD will continuously display the gas level during this whole process. However, if the sensor senses any gas, it sends a signal to the Arduino, and the Arduino will send a password to the buzzer and the red LED. At this point, the Arduino will also make the SIM900D to send a CALL/SMS or call the owner’s mobile number. After 5 seconds of sensing the gas, the Arduino will send a signal to the servo motor, and then the servo motor will turn 90 degrees, making the ball valve connected to the main gas line shut so that no more gas leakage occurs. After doing so, the blue LED will turn on after 2 seconds to verify the situation. During this period of time, some amount of gas has already been accumulated in the kitchen. To eliminate that gas just after 5 seconds, a signal from the Arduino will reach the exhaust fan and turn it on.

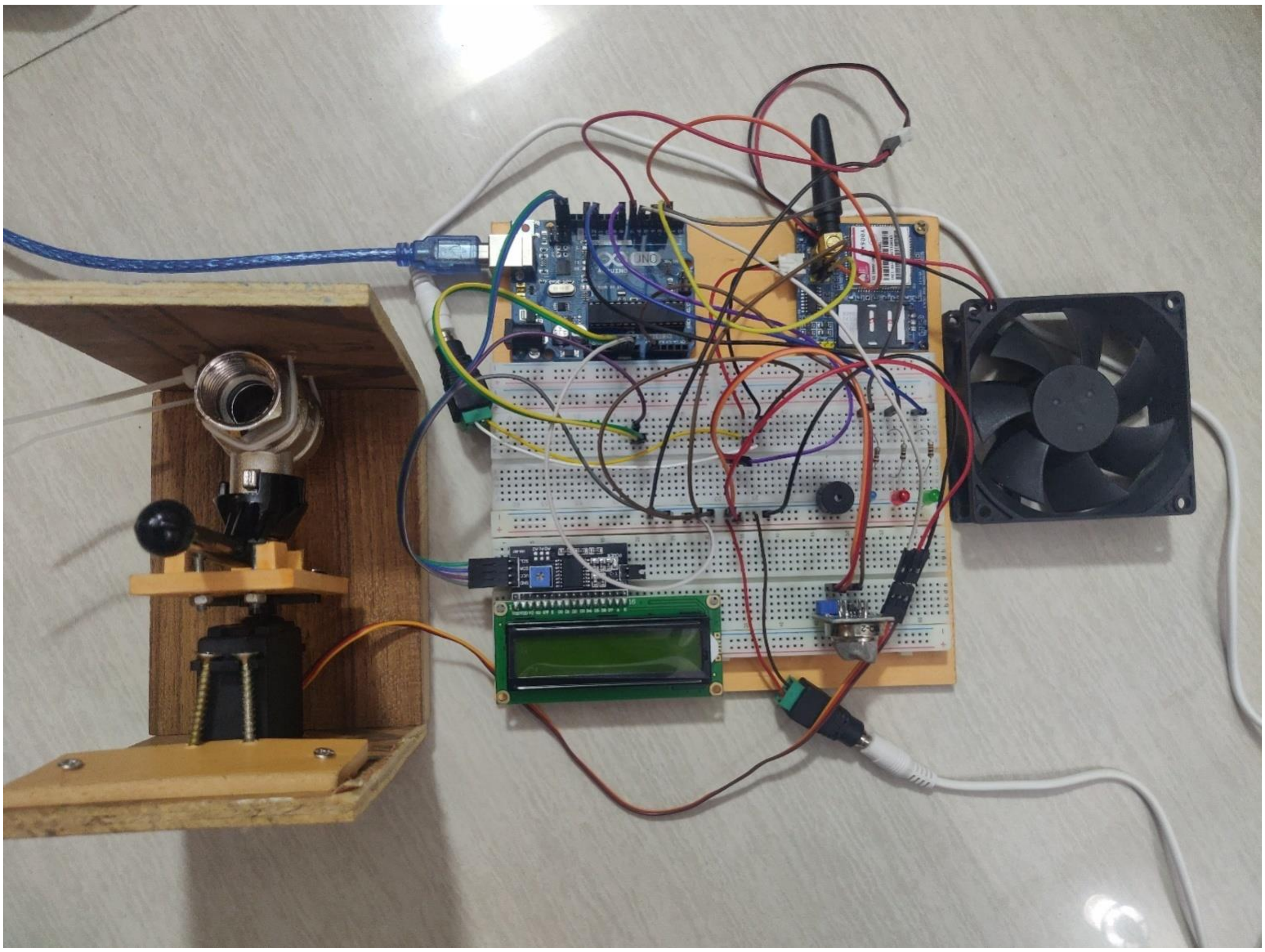

Figure 3.8 – Structure of Entire Circuit

Chapter 4

Result and Analysis

4.1 Supply Voltage and Current

Components	Operating Voltage	Operating Current
Gas Sensor	5V	160 mA
LCD	4.7 ~ 5.3 V	1.2 ~ 1.5 µA
I^2C	3 ~ 5 V	4 ~ 10 A
LED	1.2 ~ 3.6 V	10 ~ 20 mA
Buzzer	1.5 ~ 5 V	>20 mA
Exhaust Fan	Up to 12 V	300 mA
SIM900A	5 V	2 A
Arduino	5 V	150 mA

Table 4.1: Operating Voltages and Current

In this part, we have divided our result and progression into 6 parts which are:

1. Detection of changing gas level
2. Primary Indication of danger to surroundings
3. Systematic CALL/SMS sent to the user to notify of danger
4. Signaling through a LED light that ensures gas connection has been cut off
5. Primary safety protocol
6. Secondary safety fan

4.1.1 Gas Sensor Detects Changes in Gas Level

When gas is detected in normal conditions, the LCD and the LCD light indicate that the user knows the surrounding conditions and gas level. As the level of gas is average, the LED is Green.

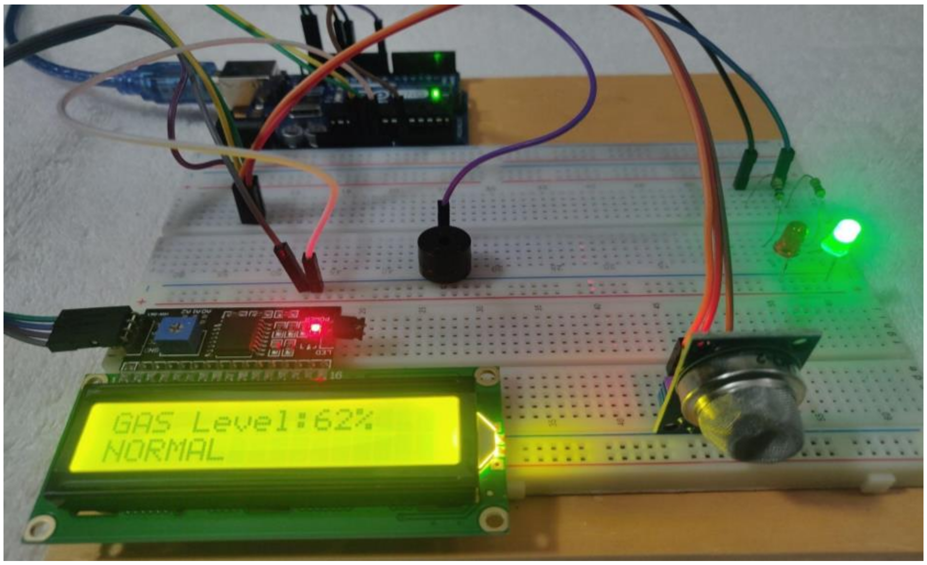

Figure 4.1 – Gas Sensor Detects Changes in Gas Level

We used an MQ-2 sensor to detect a wide range of gas, including methane, carbon monoxide, alcohol, hydrogen, LPG (Liquefied Petroleum Gas), propane, and smoke.

4.1.2 Primary Indication of Danger to Surroundings

Now, as the Gas level rises rapidly, due to leakage or for stove being kept unwarily by the user; this prompts the gas sensor to send a signal to Arduino, and the LED turns RED, Simultaneously the buzzer goes on.

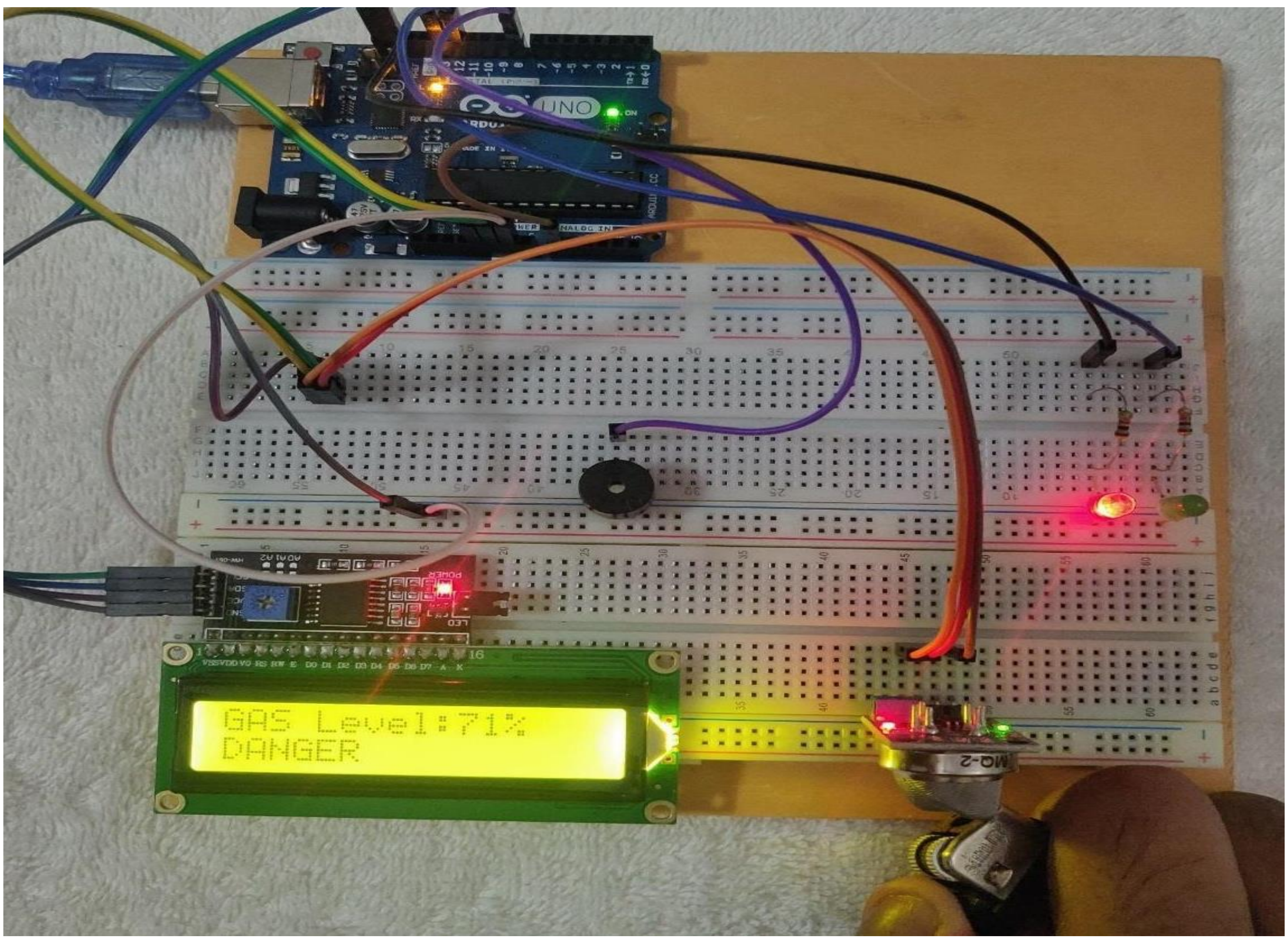

Figure 4.2 – Primary Indication of Danger to Surroundings

4.1.3 Systemic Call/SMS Sent to User to Notify of Danger

We have used the SIM900A GSM module, which provides various services such as voice, CALL/SMS, data, fax, each associated with a specific frequency or quad-band of 850MHz, 900MHz, 1800MHz, and 1900 MHz assigned by the GSM module.

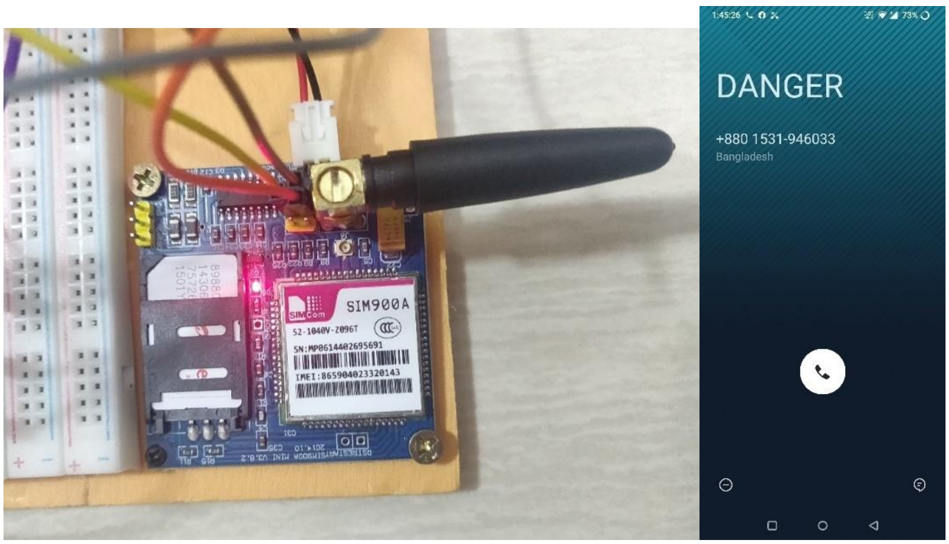

Figure 4.3 – Systemic Call/SMS Sent to User to Notify of Danger

4.1.4 Primary Safety Protocol Servo Motor Turns to Shut Knob OFF

A servo motor is connected to the Arduino (input PIN). Once prompted via a signal, the motor provides the necessary torque to rotate a ball valve by 90 degrees, which ultimately shut the gas flow; this ensures that gas is cut off from the line to the stove. Hence, further gas accumulation around the stove stops.

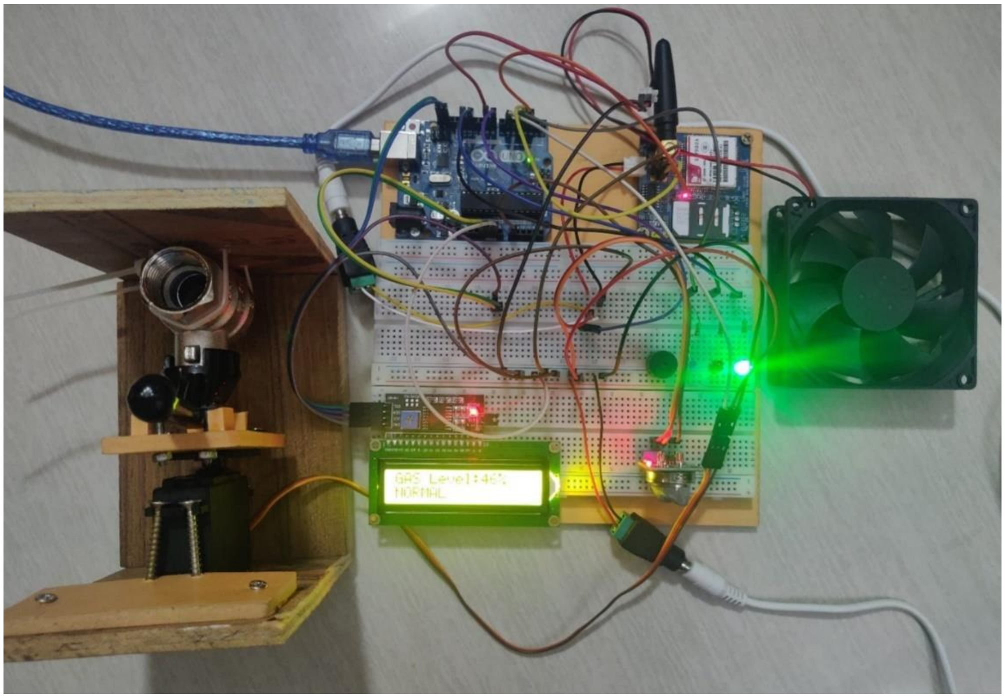

Figure 4.4 – Primary Safety Protocol Servo Motor Turns to Shut Knob OFF

4.1.5 Signaling through a LED Light that Ensures Gas Connection Has Been Cut off

After disconnecting from the gas line, the server gets a signal by giving a blue light, which will signal that the gas has been cut off, so there is no point in danger now.

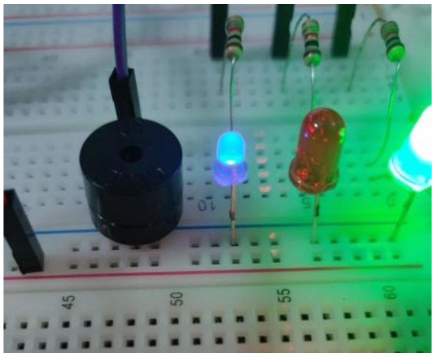

Figure 4.5 – Signaling through a LED Light that Ensures Gas Connection Has Been Cut off

4.1.6 Exhaust Fan Removes Stored Gas from the Room

To eliminate any odd chances of gas accumulation to occur and be confined inside the kitchen room for explosions to occur later, we have also added an exhaust fan to the system. Once a signal reaches the Arduino (input PIN) during its operation, the exhaust fan switches on; this ensures any remaining gas initially built up around the stove is directly sucked out of the confined room and hence is released outside to ensure safety further.

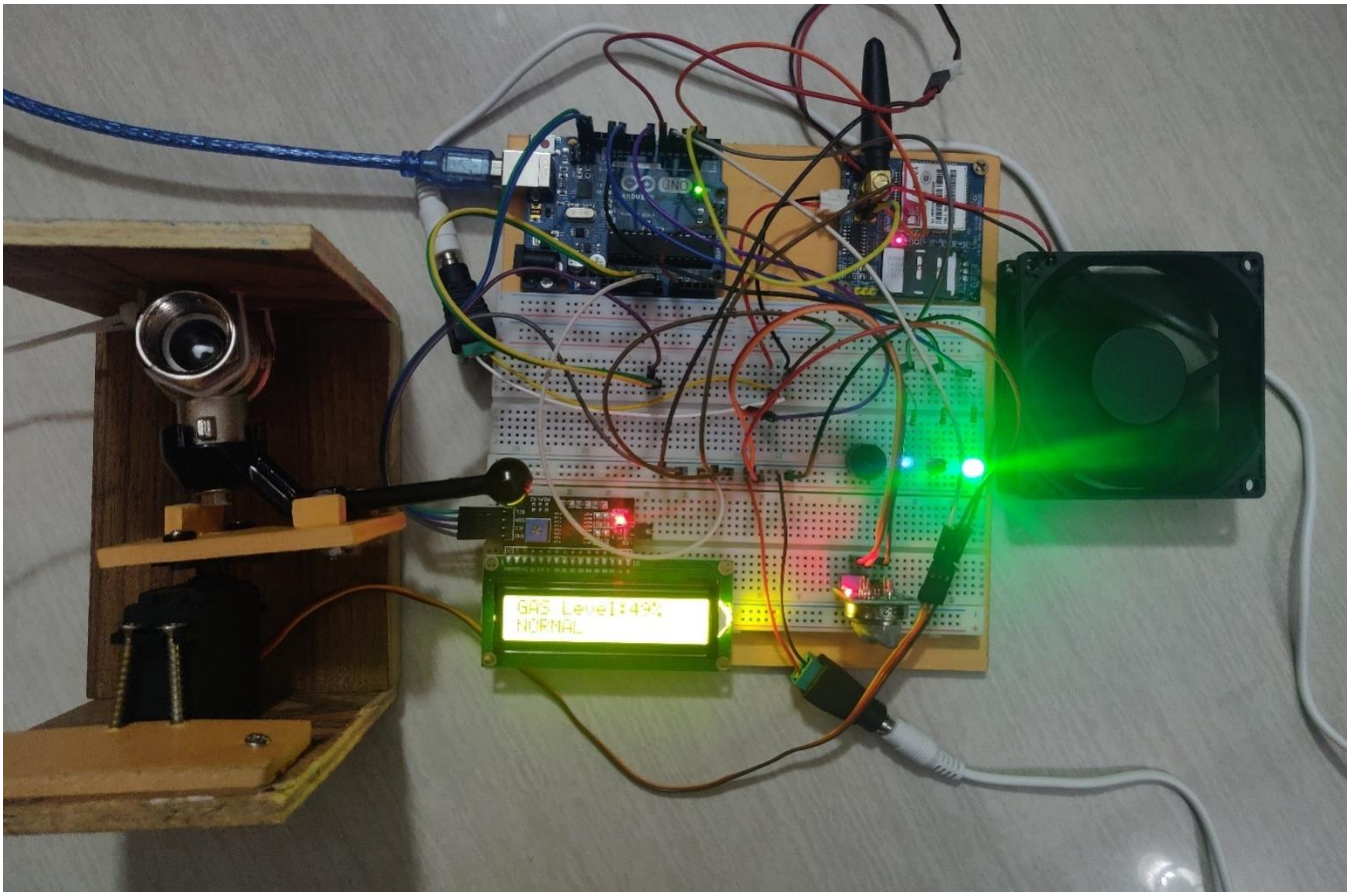

Figure 4.6 – Exhaust Fan Removes Stored Gas from the Room

4.2 Data Table of Gas level readings vs Time

Time	*Gas Level of Propane (Gas Stove) in percentage*	*Gas Level of Butane (Lighter) in percentage*
1	21	39
2	23	41
3	25	44
4	28	47
5	33	51
6	40	55
7	46	59
8	52	63
9	58	65
10	64	70
11	69	74
12	75	77
13	79	76
14	86	76
15	86	75
16	85	71
17	85	71
18	84	72
19	81	71
20	77	65
21	71	61
22	64	58
23	58	55
24	51	53
25	43	49
26	34	47
27	24	43
28	18	41
29	11	38
30	5	36

Table 4.2: Gas level readings vs Time

The above table represents the readings of gas level of both propane and butane with respect to time. The readings are taken from the Serial Monitor of Arduino software. The graphical representation of this table is also shown below separately.

4.3 Graphs

4.3.1Time vs Gas Level of propane graph

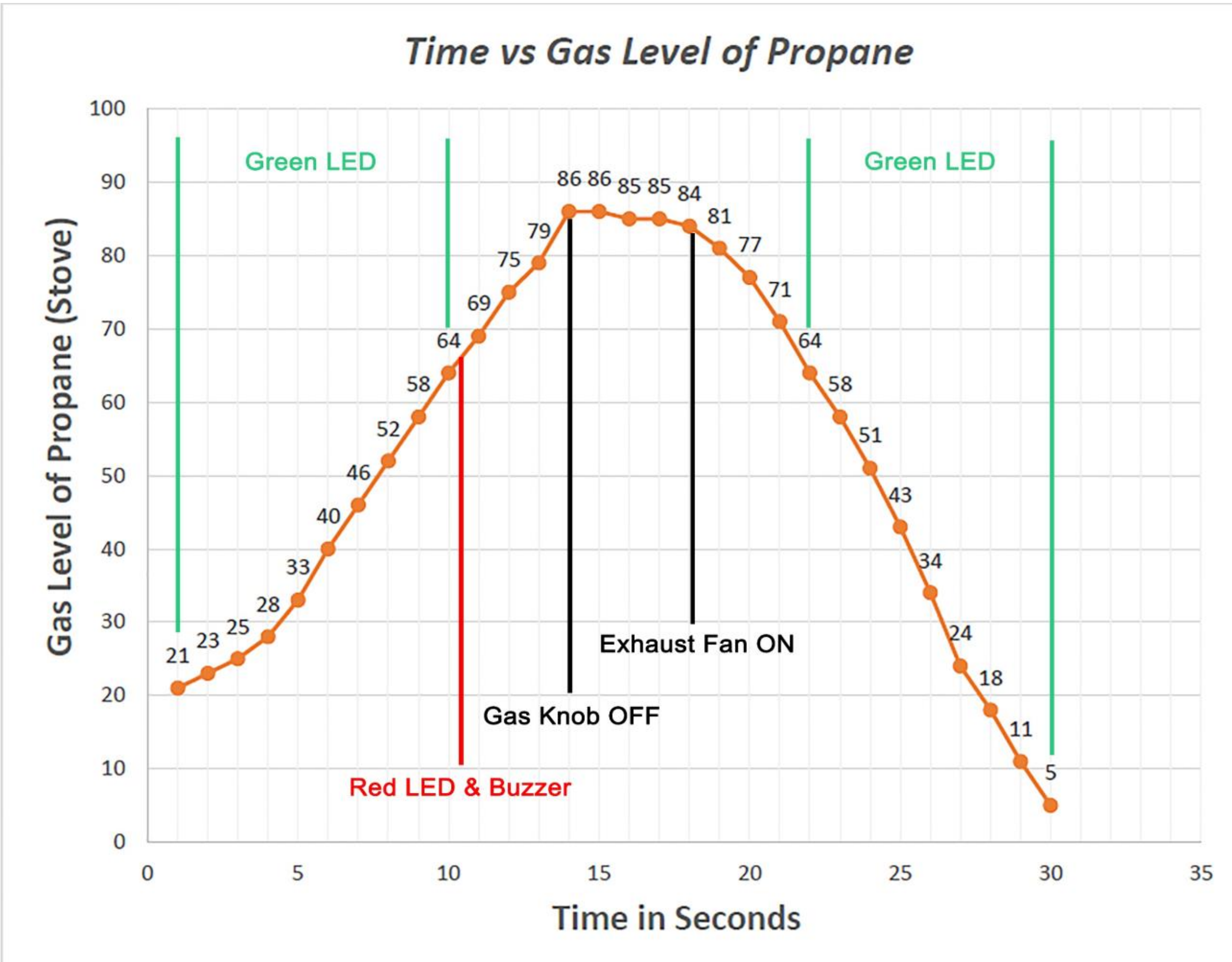

Figure 4.3.1: Time vs gas level of propane graph

The readings of gas level are taken in percentage. The starting value 21 is read by the sensor just after starting the device. This value is considered as the presence of propane in air. After providing the propane gas from the stove, the readings started to increase. When it reached 65+ the buzzer and red LED was ON as shown in the graph. The value rose up to 86 when the gas knob turned OFF. At that moment the leaking of gas was stopped and for that reason the readings were almost stable for 5 seconds without any further arousal. Later on, the exhaust fan is started and the accumulated gas is released in the outer air which is also visible in the decreasing readings of the graph.

4.3.2 Time vs Gas Level of Butane graph

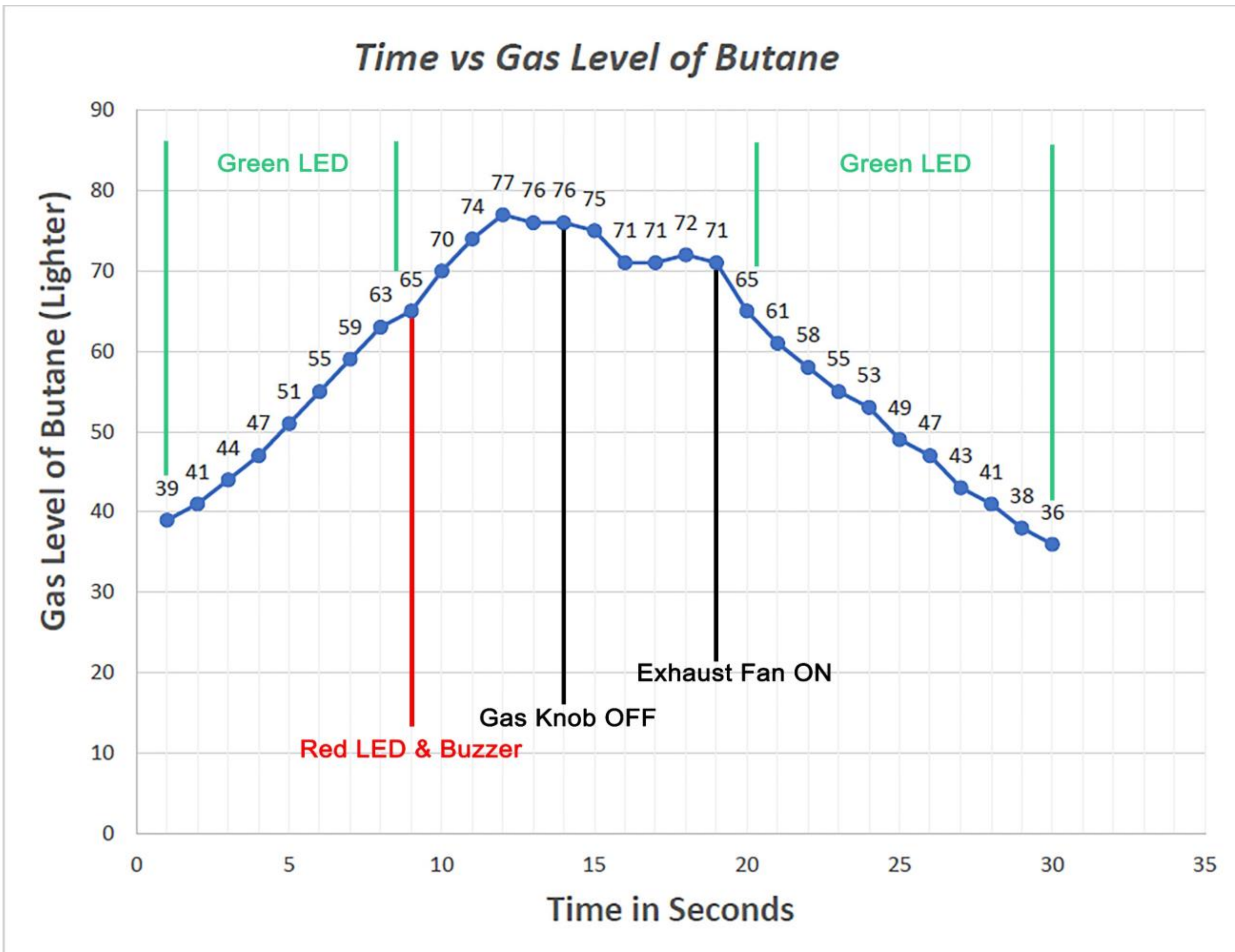

Figure 4.3.2: Time vs gas level of Butane graph

The readings of butane gas are taken by the help of a lighter. The above graph is supposed to be the exact copycat of the graph of time vs propane theoretically. However, there are some changes because of the fluctuated readings in case of butane gas. The butane is slightly above 2 times heavier than air and therefore, it is gathered on the ground level after some time and while taking the readings the device was on the ground which resulted this fluctuation in the readings. Because of this gathered butane on the ground level the starting value and the ending value is also high compared to the readings of propane gas.

Chapter 5

Software Analysis

5. 1. Software Schematics:

We have simulated the system into Proteus 8 Professional software. In the following simulation, we added the Servo motor, which operates to turn the knob of the ball valve though we could not add the closing mechanism of the gas lines in our simulation.

5. 1 .1. Component Library Used in Proteus

The components library used to construct the circuit of the proposed system in Proteus are:

1. SIMULINO UNO

2. SIM900D

3. PCF8574

4. MQ_2 (Gas Sensor),

5. MOTOR-SERVO,

6. MOTOR-PWM SERVO,

7. FAN-DC (Exhaust Fan)

8. LM016L,

9. LED-RED, LED-GREEN

10. BUZZER

11. LOGIC TOGGLE.

5.1.2. Connection Description

We connected the OUT pin to the MQ-2 gas sensor. And Pin ~10 of the Arduino and the test pin of the sensor to the LOGICTOGGLE. Pin 8 and ~9 of the Arduino connects the TXD and RDX pins of the SIM900A, and pin 7, ~6,4,13 and pin AO connect to Buzzer's LEDs and the exhaust fan, respectively. LM016L has been used to display whether gas is detected or not. We have also connected a virtual terminal to the TX and RX pins of the Arduino. After constructing the circuit, we attached the HEX file of code written in the Arduino to the Simulink Uno. Two more HEX files of code for the MQ-2 gas sensor and SIM900A also have been added. Without these HEX files, the system will be unable to simulate in Proteus. After simulation, we observed that when the test pin is LOW (LOGIC TOGGLE is 0), there is no gas detection. When the test pin is HIGH (LOGIC TOGGLE is 1), it indicates we have a higher amount of gas in the area, Buzzer and the LED-RED turn on, and the virtual terminal shows the contact number.

5.1.3. Schematic Interface:

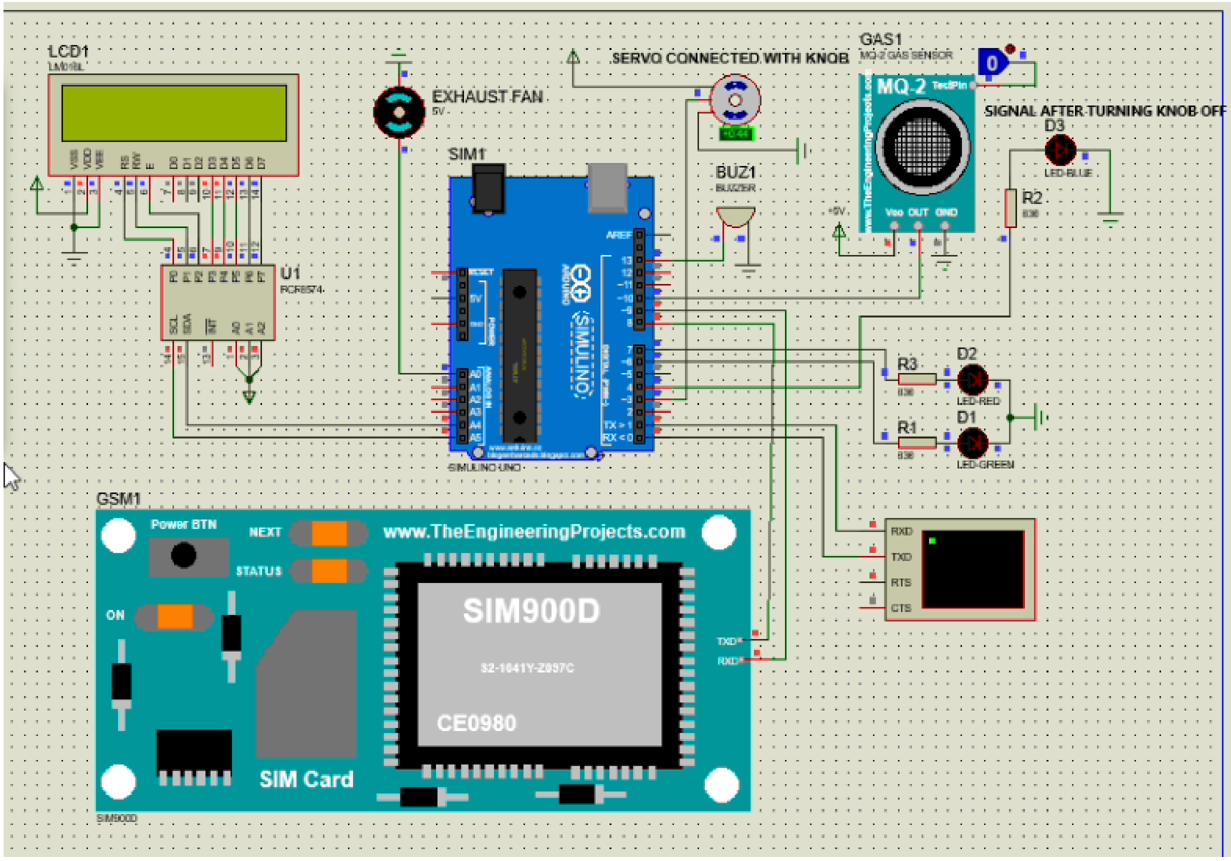

Figure 5.1 – Circuit Schematic of Gas Detector

Once the gas concentration is above the threshold value, the gas detector sends the Arduino Microcontroller to start its systemic work.

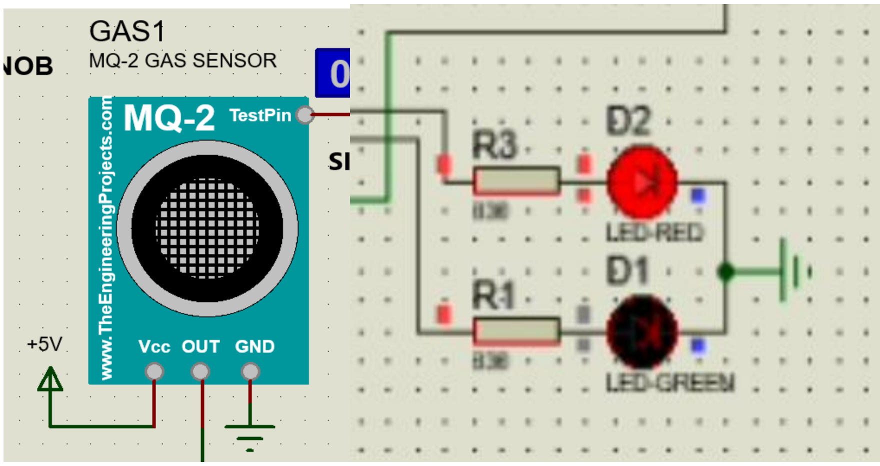

Figure 5.2 – MQ2 Gas detector detects gas above the threshold concentration and the LED Signals RED

As the name implies, the gas sensor detects gas. When the gas concentration rises higher than usual, i.e., the threshold of 2 mg/m3 to 5 mg/m3 (approximately 2ppm – 4ppm) sends the data to microcontroller SIMULINO UNO.

Next, the microcontroller analyses the data and sends it to the GSM module (sends a CALL/SMS to the user to alert them of the leakage)

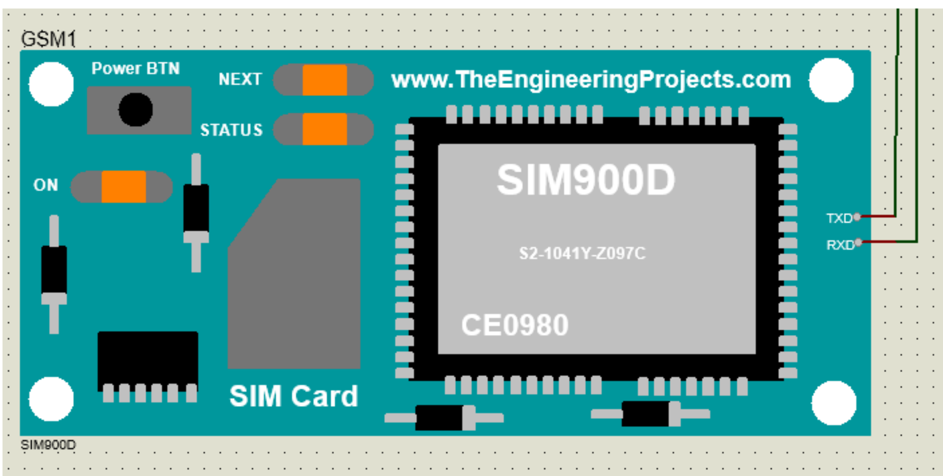

Figure 5.3 – SIM900D receives a message from the microcontroller to send CALL/SMS to notify the user

Simultaneously, a message reaches the user. The LCD shows if gas has been detected and hence via the built-in virtual terminal, displays the receiver/user's phone number.

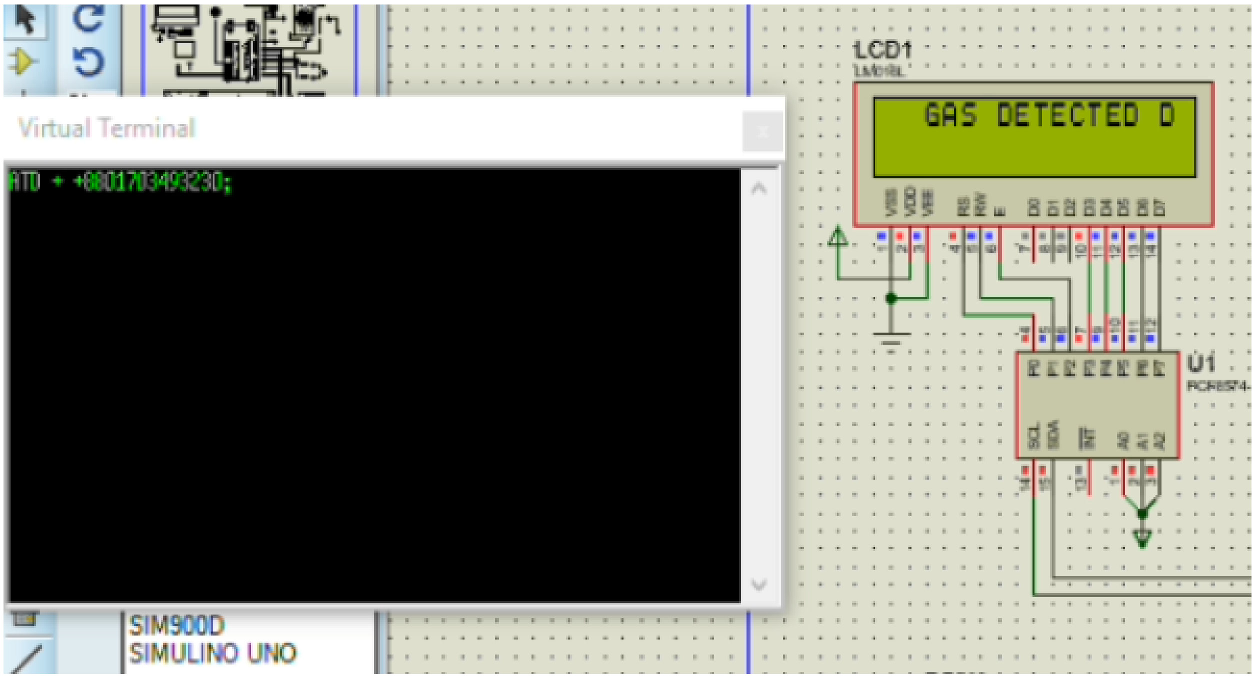

Figure 5.4 – A message sent to the user at the instant detected gas is present

Hereafter, the exhaust fan runs (to remove built-up flammable gas in the kitchen from outside); hence these components simultaneously start running.

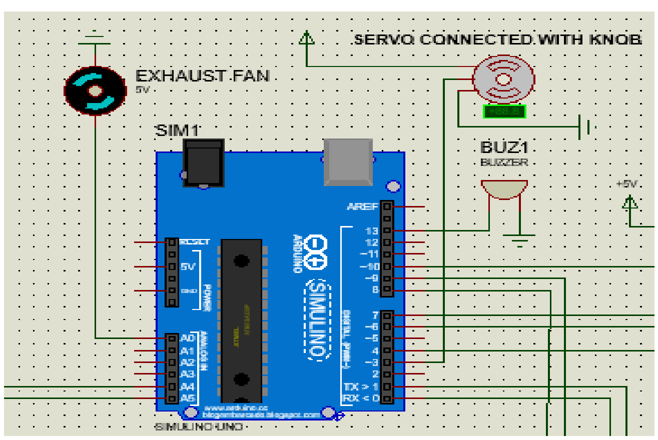

Figure 5.5 – The Exhaust Fan functions to remove gas from the confined room where gas is leaking

Lastly, a servo motor connected to a knob/ ball valve (not shown) connected to the PIN3 input functions to rotate a knob by 90 degrees to cut the gas source from the line reaching the stove; simultaneously, Green LED signifies the elimination of any possible danger.

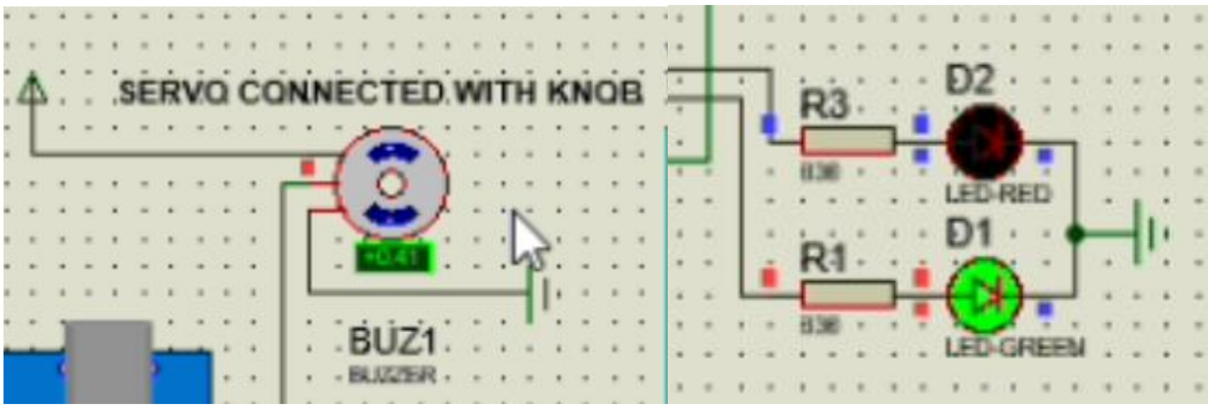

Figure 5.6 – Servo connected to Knob functions to cut access to gas temporarily

Chapter 6

Feasibility Analysis

6.1 Social Sustainability and Impact

This project also has a significant impact on our society. We all know that many of the recent incidents in Bangladesh occurred because of gas explosions. The explosion had affected much of the community. Many people died, and many have suffered the utmost. By this project, a user finds a means of protection from gas leakage and its effects. They can protect their family and their home with this as well. The following project can benefit restaurants, households, factories, and other stakeholders where safety is a significant issue. The requirement of this project for safety is very much. As if a gas explosion occurs, many people lose their lives, and much hamper affects society. Society's safety will be at stake if the explosion keeps happening. This technology may be used in a kitchen, a hostel café, or anywhere else. It is noteworthy that the costs of a Gas Detection device are comparatively low, which will benefit people in our country while preventing accidents and saving many properties and human lives by providing such technology at low costs.

6.2 Ethical Consideration

Resources, data, and other elements used were confidential. We voluntarily completed all the studies and worked as well as monitored and checked our data carefully. Anyone who participates directly or indirectly in this project work was not given any remittance. None of our members have faced any sort of discrimination in the process. We also focus on minimizing and maximizing benefits for human and animal harm as much as possible. In addition, colonizers believe they only did so since indigenous people, who dominated, had the same interests. However, it was so wrong because we can see that there were different protests and riots against these rules.

6.3. Risk Management and Safety

From the beginning of the project, one of our priorities was to ensure the user's safety. Keeping that in mind, we have used the components to provide more security to our project. Our gas sensor can sense different variations of gas and those which is present in the air. We have also done so with excellent supervision. The buzzer and the exhaust fan took a minimal amount of voltage, and they do not take a good amount of current, which cannot cause problems. The components we used do not overheat under any circumstances. We will set the project in a waterproof box to not have to bear any problem. For demonstrating the project, we cared about our safety as well.

6.4 Economical Impact

One of the main goals of our project is to create a cost-efficient system that will ensure safety from any accident caused by gas leakage. In recent days we have seen several accidents due to gas leakage that caused severe explosions, fire, damage of properties, and even the death of hundreds of people. Gas stations, big industries, and firms usually store vast amounts of toxic gases like LPG. Therefore, the risk of serious accidents occurring in these areas is higher than in others. A single accident in a small industry can destroy properties worth millions of dollars. Apart from the destruction of properties, the other significant effects of accidents in industrial areas are loss of productivity, distrust of firms, delayed wage penalties, salary reduction, unemployment, and many more. Such accidents harm the economic condition of an entire country depending on the seriousness of the casualties as the country's production reduces. Besides, unemployment increases as it is not easy for workers to move to a new job that suits their post-injury abilities. All these harmful gases are being used in domestic areas too. We have designed a low-cost system so that people from all walks of life can afford it. Since people have to bear the risks of gas leakage daily, gas detectors are increasing. To tackle producing more advanced gas sensors, creating employment opportunities for many people and impacting the country's economic development. We can also export the gas leakage detection system to other countries at a reasonable price, contributing to our country's economic growth.

6.5 Project Set-Up Cost:

	Components	**Quantity**	**Price**
1.	Arduino UNO R3	1	545
2.	SIM900A Mini GPRS GSM Module	1	1200
3.	MQ- 2 Flammable Gas & Smoke Sensor	1	95
4.	Standard LCD 16x2	1	120
5.	MG996R 10kg Servo	1	350
6.	Buzzer	1	15
7.	Breadboard	1	50
8.	5V 2000 RPM DC Motor	1	35
9.	LED	3	6
10.	Exhaust Fan	1	80
11.	Resistors	3	4
12.	Power Adapter	2	400
13.	SIM	1	100
14.	Ball Valve	1	100
	Total:		**3100**

Table 6.1: Project Set-Up Cost

6.6. Commercial Set-Up Cost

	Components	Quantity	Price
1.	Arduino UNO R3	1	550
2.	SIM900A Mini GPRS GSM Module	1	1200
3.	MQ- 2 Flammable Gas & Smoke Sensor	1	100
4.	Standard LCD 16x2	1	120
5.	MG996R 10kg Servo	1	350
6.	Buzzer	1	15
7.	Breadboard	1	50
8.	5V 2000 RPM DC Motor	1	35
9.	LED	3	6
10.	Exhaust Fan	1	650
11.	Resistors	3	4
12.	Power Adapter	2	400
13.	SIM	1	100
14.	Set-Up Cost	-	500
15.	Ball Valve	1	100
	Total:		**4180**

Table 6.2: Commercial Set-Up Cost

Chapter 7

Advantages and Limitations

7.1 Advantages

7.1.1 Safety Purpose

Recently, the gas detection system has become one of the most critical systems to detect poisonous gases and provide a vital way to monitor the concentration of gases to ensure safety in production. The proposed gas detection system can work as an indicator or alarm system and as a safety device that can automatically prevent any accident like an explosion, fire, damage of property, and loss of human lives without any human interaction. The automatically turning off the gas supply when the gas concentration rises above the safety level has made the system more reliable in domestic and industrial sites. Besides, it is applicable for use in gas stations where lots of gas cylinders are stored.

7.1.2 Industrial Benefits

As we know, the risk of explosions due to gas leakage in industries is higher as they store a large amount of exceedingly harmful gases for production purposes. Production and mechanisms in the sectors are carried out under a particular concentration of gases and conditions. In the packaging business, the concentration of gases controls to ensure the high quality of products. In these cases, the gas detection system plays an important role.

7.1.3 Sensitivity and Reliability

The sensitivity of the sensor MQ-2 is excellent, combined with a quick response time. It can detect any change in concentration of gases in no time and starts working to alert the users and go back to the safety level. Besides, the high accuracy in results makes the system more reliable.

7.1.4 Preventing Waste of Resources

Apart from providing safety, the system can also reduce unnecessary wastage of gases, and thus it saves the waste of valuable assets in both homes and industrial areas. The system successfully controls the concentration of gases and ensures prolonged longevity without hampering the site's safety measures.

7.1.5 Cost Efficiency

The gas detection system is a small device that can is installable anywhere to ensure safety. Power consumption is deficient compared to current methods. So, the maintenance cost of the system is meager, and it is easy to use.

7.2 Limitations

7.2.1 Power supply:

A gas detection system works at a specific power supply. Without the particular power supply, the sensor does not work correctly; for instance, the GSM module will not work, or the exhaust fan will not start spinning. So, we have to ensure the power supply is appropriate for the dive to work accordingly.

7.2.2 Sensitivity:

Sometimes the sensitivity of the sensor can vary due to the temperature and humidity of the area. At high temperatures and overpressures, the sensor needs more power consumption, and the sensor's sensitivity reduces.

7.2.3 Range:

Gas sensors usually work best near gas supplies or gas storage. Multiple sensors must be installed in larger areas to detect gas leakage since the system cannot detect leaks to a large extent.

Chapter 8

Conclusion

8.1 Future Work:

In recent days, we have seen several accidents occur due to gas leakage, leading to gas sensors' increasing demands. Technology is playing a leading role in the growth of the need for gas sensors. Different kinds of gas sensors, such as catalytic gas, electrochemical, and semiconductor gas sensors, have been constructed. In our proposed system, we have tried to innovate gas sensors by adding several useful features. Different researchers are developing ways to develop the gas detection system as it is a dominant system that provides safety from accidents caused by noxious gases.

Usually, a gas detector or sensor is installable near the gas supply or gas storage. In large industries, multiple sensors ensure the safety of the entire area. More advanced systems should develop to detect leaks of gases in more expansive spaces. A wide range area advanced optical gas sensors or thermal conductivity gas sensors should develop to monitor gas levels in an area.

The typical lifespan of a gas sensor is between 2-3 years. It may also need maintenance to ensure the system is working perfectly. In the future, more advanced techniques with a higher life span will be integrated.

Many industries have stored different kinds of hazardous gases for years. Sometimes, using gases older than a year can cause severe issues like materials damage, health hazards. So, the system is developable by adding a function that can track the age of gases and can detect whether the gas is safe to use or not.

For monitoring gas leaks in a vast range of areas, an advanced mobile application notifies users, who will control the system by switching ON and OFF the gas supply, according to their needs from anywhere, anytime. This application can also get safety alarm notifications, monitor calibration, bump tests, and more.

With increased concern about the environment, it is crucial to pursue harmony between environment-friendly products and human-friendly products. In the future, more environmentally-friendly systems will be produced using low global warming coefficients to prevent polluting the environment. Recycling the leaked gases and filtering them before discharging them into the atmosphere will be significant initiatives to construct an environment-friendly device.

8.2 Conclusion:

The gas sensor we designed is a low-cost, low-power, portable, secure, user-friendly, multi-featured, and highly efficient gas detector. When in a particular area the concentration of gas increases than usual, the system senses the higher concentration, notifies the user, and switches off the gas supply autonomously if the concentration of gas exceeds the safety level. We have seen many tragic accidents occur due to gas leakage that caused serious explosions and fire. Gas leakage contaminates the environment and causes burns, damage to properties, and even death of people. Studies show that preliminary work is present to build an intelligent gas sensor that automatically prevents gas leakage. Our proposed method has tried to integrate more advanced features to make the system more secure and reliable. Therefore, the system will be beneficial in preventing any fatal inferno caused by the leakage of gases. We will monitor the individual members' changes to develop a more productive preparation package for future work. We accept that these advances will promote public interest in spatial design and related fields and under-study them.

Appendix

Software code

```
#include<Wire.h>

#include <Servo.h>

#include<SoftwareSerial.h>

#include<LiquidCrystal_I2C.h>


SoftwareSerial SIM900(8, 9);

LiquidCrystal_I2C lcd(0x27,16,2);

Servo myservo;


int pos = 0;

int Gas = 10;

int buzzer = 13;

intgreenLed = 6;

intredLed = 7;

int FAN = A0;

intresLed = 5;


void setup()

{

pinMode(Gas , INPUT);

pinMode(buzzer , OUTPUT);
```

```
myservo.attach(3);
lcd.begin();
lcd.backlight();
lcd.println(" GAS DETECTOR ");
delay(1000);
lcd.clear();
myservo.attach(3);

SIM900.begin(2400);
Serial.begin(9600);
delay(2000); // give time to log on to network.
}

void loop()
{
if(digitalRead(Gas) == LOW)
  {
lcd.setCursor(1, 0);
lcd.print("NO GAS DETECTED");
delay(500);

digitalWrite(6,HIGH);
digitalWrite(7,LOW);
```

```
digitalWrite(13,LOW);

digitalWrite(5,LOW);

analogWrite(A0,LOW);

  }


if(digitalRead(Gas) == HIGH)

  {

lcd.setCursor(1, 0);

lcd.print(" GAS DETECTED ");

digitalWrite(7,HIGH);

digitalWrite(6,LOW);

digitalWrite(buzzer ,HIGH);

analogWrite(A0, 200);

digitalWrite(5,HIGH);


   SIM900.println("ATD + +8801703493230;"); // Enter mobile number here to call

Serial.println("ATD + +8801703493230;");

delay(100);

   SIM900.println();

delay(30000); // wait for 30 seconds...

   SIM900.println("ATH"); // disconnect after 30 second

Serial.println("ATH");

   do {} while (1); // do nothing
```

```
myservo.write(360);

delay(1000);

  }

}
```

Hardware Code

```
#include <GPRS_Shield_Arduino.h>
#include <MQ2.h>
#include <Wire.h>
#include <Servo.h>
#include <LiquidCrystal.h>
#include <SoftwareSerial.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,16,2); //I2C pins declaration
Servo knob;

#define PIN_TX    10
#define PIN_RX    11
#define BAUDRATE  9600
#define PHONE_NUMBER  "01703493230"
GPRS gprs(PIN_TX, PIN_RX, BAUDRATE);

int pos = 0;
int mq2 = A0;
int buzzer = 8;
int redLed = 13;
int greenLed = 12;
```

```
int fan = 7;
int gasvalue;
int notifLed = 4;

void setup()
{
pinMode(buzzer,OUTPUT);
pinMode(redLed,OUTPUT);
pinMode(greenLed,OUTPUT);
pinMode(fan,OUTPUT);
knob.attach(6);
Serial.begin(9600);
gprs.checkPowerUp();

lcd.begin();
lcd.backlight();
lcd.setCursor(4,0);
lcd.print("WELCOME");
delay(3000);
lcd.clear();
}
void loop()
  {
```

```
  mq2 = analogRead(A0);
  int gasvalue=(mq2-50)/10;

lcd.print("GAS Level:");
lcd.setCursor(10,0);
lcd.print(gasvalue);
lcd.setCursor(12,0);
lcd.print("% ");

  if (gasvalue> 65)
    {
lcd.setCursor(0,1);
lcd.print("DANGER");
digitalWrite(redLed,HIGH);
digitalWrite(greenLed,LOW);
digitalWrite(buzzer,HIGH);

gprs.callUp(PHONE_NUMBER);

delay(20000);
knob.write(370);
digitalWrite(notifLed,HIGH);
delay(5000);
```

```
digitalWrite(fan,HIGH);
    }
    else
    {
lcd.setCursor(0,1);
lcd.print("NORMAL");
digitalWrite(redLed,LOW);
digitalWrite(greenLed,HIGH);
digitalWrite(buzzer,LOW);
    }
delay(1000);
lcd.clear();
    }
```

Reference:

1. Bangladesh police rule out foul play in Dhaka explosion, suspect gas leak, Business Standard, Press Trust of India | Dhaka, Last Updated at June 28, 2021, Available: https://www.business-standard.com/article/international/bangladesh-police-rule-out-foul-play-in-dhaka-explosion-suspect-gas-leak-121062800367_1.html

2. MozibulHaque, Narayanganj, “Gas causes 94 fires, 44 deaths in Narayanganj”, Prothom Alo English, Published: 15 Mar 2021, Available : https://en.prothomalo.com/bangladesh/accident/gas-causes-94-fires-44-deaths-in-narayanganj

3. Death toll in Bangladesh mosque gas pipeline explosion rises, Aljazeera, 6 Sep 2020, Available : https://www.aljazeera.com/news/2020/9/6/death-toll-in-bangladesh-mosque-gas-pipeline-explosion-rises

4. Giselle Jimenez-Cadena, JordiRiu and F.XavierRius, “Gas sensors based on nanostructured materials", December 2007, The Analyst 132(11):1083-99, DOI : 10.1039/b704562j, Source : PubMed, From : https://www.researchgate.net/publication/5890906_Gas_sensors_based_on_nanostructured_materials

5. Huan Hui Yan and YusnitaRahayu, “Design and Development of Gas Leakage Monitoring System using Arduino and Zigbee”, August 2014, DOI : 10.11591/eecsi.1.404, Conference:

International Conference on Electrical Engineering, Computer Science and informatics 2014 (EECSI 2014) At: Yogyakartar, Indonesia, From : https://www.researchgate.net/publication/271517216_Design_and_Development_of_Gas_Leakage_Monitoring_System_using_Arduino_and_ZigBee

6. Daudi S. Simbeye, "Gas Leakage Detection System (GLDS)", June 2013, DOI : 10.52339/tjet.v34i1.457, From : https://www.researchgate.net/publication/262380283_Gas_Leakage_Detection_System_GLDS

7. Mohammad Monirujjaman Khan, "Sensor-Based Gas Leakage Detector System", November 2020, DOI : 10.3390/ecsa-7-08278, From : https://www.researchgate.net/publication/347326171_Sensor-Based_Gas_Leakage_Detector_System

8. E.JebamalarLeavline, D. Asir Antony Gnana Singh, B. Abinaya, H.Deepika, "LPG Gas Leakage Detection and Alert System", International Journal of Electronics Engineering Research. ISSN 0975-6450 Volume 9, Number 7 (2017) pp. 1095-1097 © Research India Publications, From : https://www.ripublication.com/ijeer17/ijeerv9n7_15.pdf

9. T.Arpitha, DivyaKiran, V.S.N. Sitaram Gupta, PunithavathiDuraiswamy, "FPGA-GSM based gas leakage detection system", December 2016, DOI : 10.1109/INDICON.2016.7838952, Conference: 2016 IEEE Annual India Conference (INDICON), From :

https://www.researchgate.net/publication/313449640_FPGAGSM_based_gas_leakage_detection_system

10. Arduino's Official Website, 2021, Retrieved 30 March 2021, From :https://www.arduino.cc

11. Introduction to Arduino IDE, Retrieved 30 March 2021,From: https://www.theengineeringprojects.com/2018/10/introduction-to-arduino-ide.html

12. PCB Design and Simulation Made Easy, Lab center's official website, Retrieved 30 March 2021, From :https://www.labcenter.com

13. Introduction to Proteus, The Engineering Projects, Retrieved 30 March 2021, From : https://www.theengineeringprojects.com/2020/01/introduction-to-proteus.html

14. How MQ2 Gas/Smoke Sensor Works? & Interface it with Arduino, Last Minute Engineers, Retrieved 12 April 2021, From : https://lastminuteengineers.com/mq2-gas-senser-arduino-tutorial/

15. Rhonnel S. Paculanan, Israel Carino,"LPG Leakage Detector using Arduino with CALL/SMS Alert and Sound Alarm", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ,ISSN: 2278-3075, Volume-8, Issue-6C2, April 2019 https://www.ijitee.org/wp-content/uploads/papers/v8i6c2/F10420486C219.pdf

16. The Pros and Cons of Gas Detector, GDS Corp, From : https://www.gdscorp.com/blog/gas-detectors/the-pros-and-cons-of-gas-detector/

17. Advantages and disadvantages of portable and fixed gas detector, Oceanus, Retrieved 4 September 2021, From : https://www.ocgasdetector.com/en/new/portable-fixed-gas-detector.html

18. How to Interface GSM Module to Arduino-Send and Receive CALL/SMS, Circuits Today, From :https://www.circuitstoday.com/interface-gsm-module-with-arduino

19. How to Design an Effective and Future-proof Gas Detection System, MICROWATT, Retrieved 4 September 2021, From :https://microwatt.com/news-resources/design-effective-future-proof-gas-detection-system/

20. A. Anurupa, M. Gunasekaran, M. Amsaveni, Efficient Gas Leakage Detection and Control System using GSM Module, April 2018, International Journal of Engineering Research & Technology (IJERT), Available: https://www.ijert.org/efficient-gas-leakage-detection-and-control-system-using-gsm-module