DESIGN AND IMPLEMENTATION OF AN AUTOMATIC FIRE ALARM SYSTEM USING GSM MODULE

BY

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CERTIFICATION

This project with the title

DESIGN AND IMPLEMENTATION OF AN AUTOMATIC FIRE ALARM SYSTEM USING GSM MODULE

Submitted by

JAYEOBA, MERCY MONISOLA (CPE/13/1077)

Has satisfied the regulations governing the award of degree of

BACHELOR OF ENGINEERING (B.Eng.) IN COMPUTER ENGINEERING,

Federal University Oye-Ekiti, Nigeria.

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DECLARATION

This project is a result of my own work and has not been copied in part or in whole from any other source except where duly acknowledged. As such, all use of previously published work (from books, journals, internet etc.) has been acknowledged within the main report to an entry in the References list.

JAYEOBA MONISOLA MERCY
Student's Full Name

11/04/19
Signature & Date

DEDICATION

I dedicate this project to my father, the Almighty God – The Alpha and Omega of my life and my amiable parents.

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ABSTRACT

Fire disaster is a great threat to lives and properties, and it accounts for over 70% of total loss of properties and about 20% of total loss of lives every year in Nigeria. Although some conventional fire preventive systems have been developed which are not enough to take prompt action during fire, save properties, and ultimately save lives. Hence, the need to develop an automatic wireless-based fire monitoring, detection and alarm system which is accurate, scalable and energy efficient. This report presents the design and implementation of an automatic fire alarm system which is able to detect and mitigate fire accidents even before its outbreak by alerting residents of the building.

In implementing this project, flame sensor, temperature sensor, and smoke sensor have been incorporated to monitor and detect flame, heat, and smoke/gas leakage which are considered as the three most probable symptoms of an erupting fire. In situation of an erupting fire, this project is designed to promptly alert neighbors, property owners and the fire service department by sounding a loud buzzer and also reporting the status of the abnormal situation via Short Message Service over a wireless GSM network. A microcontroller (ATMega328) was used which served as the processing unit of the project. This project was implemented on a Veroboard and tested under different experimental conditions to evaluate its performance.

The performance of the developed system was evaluated using three metrics which are hardware testing, functional requirements and system response time. The system was found to be accurate, scalable, low cost, energy efficient and portable with a good enough response time of 28-40 secs.

This design system was able to detect an erupting fire, alert occupants of the building, notify the concerned recipient, eliminate false positive and true negative results, thereby proffering an eventual prevention of fire outbreaks and its fatalities, hence, saving lives and properties.

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LIST OF ACRONYMS

ADC:	Analog to Digital Conversion
AVR:	Automatic Voltage Regulator
CCD:	Charged Couple Device
CCTV:	Closed Circuit Television
CDMA:	Code Division Multiple Access
C02:	Carbon Dioxide
CPU:	Central Processing Unit
EEPROM:	Electrically Erasable Programmable Read Only Memory
FACU:	Fire Alarm Control Unit
GPRS:	General Packet Radio Service
GSM:	Global System for Mobile Communication
HSDPA:	High Speed Downlink Packet Access
HTTP:	Hypertext Transfer Protocol
IDE:	Integrated Development Environment
IEEE:	Institute of Electrical and Electronics Engineers
IMEI:	International Mobile Equipment Identity
I/O:	Input/output
IR:	Infra-Red
JTAG:	Joint Test Action Group
LCD:	Liquid Crystal Display
LED:	Light Emitting Diode

LPG:	Liquefied Petroleum Gas
MODEM:	Modulator-Demodulator
PAN:	Personal Area Network
SIM:	Subscriber Identification Module
SMS:	Short Message Service
SRAM:	Static Random-Access Memory
UMTS:	Universal Mobile Telecommunication Service
USART:	Universal Synchronous/Asynchronous Receiver Transmitter
USB:	Universal Serial Bus
UV:	Ultra-Violet
WHO:	World Health Organization
KNN:	K-Nearest Neighborhood Algorithm
MRF:	Markov Random Field
NN:	Neural Network
ONH:	Optic Nerve Head
PCA:	Principal Component Analysis
RGB:	Red, Green, Blue
SLO:	Scanner Laser Ophthalmoscopy
SVM:	Support Vector Machine
TP:	True Positive
TN:	True Negative
WHO:	World-Health-Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Fire disaster is a great threat to lives and properties, and it accounts for over 70% of total loss of properties and about 20% of total loss of lives every year in Nigeria (Izuora, 2017). The major causes of such percentage have ranged from insufficient fire defense materials, to electric short circuit in faulty electrical wiring, leakage of flammable materials, violation of fire safety and most especially, lack of adequate awareness etc. (Izuora, 2017). Although some factories and recent buildings have now incorporated installations of fire safety arrangements such as fire alarm, fire extinguishers, water supply system etc.; the limitation is that these conventional fire extinguishing systems are not enough to take prompt action during fire, save properties, and ultimately save lives. It is thoughtful that an automatic fire detection and mitigation system, in such scenario, will provide real-time surveillance, monitoring, and automated notification.

Nowadays, securing one's property and business against fire is becoming more and more important. Monitoring commercial and residential areas all-round is an effective method to reduce personal and property losses due to fire disasters. Automatic fire alarm system is widely deployed in those sites recent years. Large numbers of small fire detectors should report their information to the control Centre of a building or a block. But the cost of wiring is very high in traditional wired fire alarm systems. Networking without pre-exist infrastructure reduces the wiring cost greatly. In recent years, wireless sensor networks (WSNs) are widely deployed in environmental monitoring, structural health monitoring and industrial monitoring. It provides low cost solutions for such applications. It consists of small size, low-power, and low-cost devices that integrated with limited computation, sensing, and radio communication capabilities. So WSN is very suitable for communication between detectors in fire alarm system (Mobin, Rafi, Islam, & Hassan, 2016).

This project therefore is designed to automatically detect fire-outbreaks symptoms, and further send notifications to concerned recipients over a wireless network.

1.2 Statement of the Problem

According to WHO (2015), statistics of number of death caused by fire between 2005 and 2014 (10-year period) show that Africa is the continent with most number of deaths by fire, while Nigeria tops the chart with the total number of deaths caused over the years (until 2014) reaching about 210,000. Designing a system to detect and mitigate fire accidents even before its outbreak by alerting residents of a building and the fire department of the fire would really help combat such issues in the nation. This design system will be able to detect an erupting fire, both in its active or potential stage (such as flames, smoke, heat), and then alert occupants of the building or concerned recipients, notify the fire department (via text) using a wireless network, thereby helping the prevention of fire outbreaks and its fatalities, hence, saving lives and properties.

1.3 Aim and Objectives

The aim of this project is to design and implement an automatic fire monitoring, detection and alarm system using GSM module. The specific objectives are to:

i. design a wireless-based automatic fire alarm system

ii. implement the fire alarm system using hardware prototype.

iii. evaluate the effectiveness and efficiency of the developed system.

1.4 Significance of the Project

Over the years, monitoring of fire outbreak and fire symptoms within residential buildings, offices and factories have ever being the challenges encountered by users, but with the knowledge of GSM communication via Short Message Service protocol, they can have knowledge of what is happening in their houses, offices and factories without any stress just by communicating to the system installed at the houses, offices and factories and the system replying the situation on ground back to them through an SMS. The result of this project will reduce fire outbreak, the cost of damages caused by fire outbreak in houses, offices and factories.

1.5 Scope of Study

This work is designed to prevent fire outbreak by detecting fire symptoms such as smoke, flames, temperature rise and gas leakage using wireless sensors in residential building or office or factories to a certain benchmark and sending SMS to the occupants whenever there are changes in the logic parameters of the sensors.

CHAPTER TWO

Literature Review

2.1 Embedded and Real Time systems

An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts (Tancreti, Hossain, Bagchi, & Raghunathan, 2011). Embedded system is a field in which the terminology is inconsistent. A real time system is one in which the correctness of the computations not only depends on the accuracy of the result, but also on the time when the result is produced. This implies that a late is a wrong answer. A Hard-Real time system should always respond to an event within the deadline or else the system fails and endangers human lives but in soft real time system, failing to meet the deadline produces false output and does not endanger the human lives. (Radhakrishnan & Angayarkkani, 2009).

2.1.1 Features of Embedded Systems

- Multiple operations can be performed using single chip
- Fully automatic.
- Compact and Faster

2.1.2 Components of Embedded System

- Hardware specifically built for that application
- An embedded operating system
- User interface like push buttons, LCD, numeric displays

The major part of this project is the hardware model consisting of sufficient sensor with embedded system. Embedded systems are computer in the widest sense. Based on functionality and performance requirements, embedded systems can be categorized as, Stand-alone system, Real time system, Networked information appliances and Mobile devices. Every embedded System consists of custom-built hardware built around a central processing unit (CPU). This Hardware also contains memory chips onto which the software is loaded. The software residing on the memory chip is also called as the firmware (Radhakrishnan & Angayarkkani, 2009).

2.2 Fire Alarm Systems

A fire alarm system has a number of devices working together to detect and warn people through visual and audio appliances when smoke, fire, carbon monoxide or other emergencies are present. These alarms may be activated automatically from smoke detectors, and heat detectors or may also be activated via manual fire alarm activation devices such as manual call points or pull stations (Bahrepour, Meratnia, & Havinga, 2008). Alarms can be either motorized bells or wall mountable sounders or horns. They can also be speaker strobes which sound an alarm, followed by a voice evacuation message which warns people inside the building not to use the elevators. However, recent fire alarm systems have even been made better through the integration of notification medium in order to automated the alarm process. The major Fire alarm system types are Conventional fire alarm system and addressable, with the third being the hybrid of the two.

2.2.1 Conventional Fire Alarm Systems

Conventional alarms have a radical circuit with a limited coverage. Every room needs a different alarm, each separately connected to the control panel. A single alarm, if disconnected from the control panel, can disconnect the whole system. A conventional fire alarm system is less expensive and can be a good option for small areas (Chenebert, Breckon, & Gaszczak, 2013). The only drawback of these alarms is that the signal for the mishap appears directly on the control panel, making it difficult to understand which alarm is giving the signal to the entire premises.

2.2.2 Addressable Fire Alarm Systems

An addressable fire alarm system has a loop circuit and has a wide area coverage. It connects multiple alarms to a single circuit and can detect fire around each alarm individually. They are highly reliable as each alarm has its own address making it easy to identify which alarm is working. These are a costlier option to go for but provide for a better alarm system. These 'intelligent systems' are highly recommended for large industrial and commercial areas (Chenebert, Breckon, & Gaszczak, 2013).

2.2.3 Hybrid Systems

A hybrid fire alarm system is a combination of both conventional and addressable fire alarm system. The hardwired zone feature of the conventional alarm system and the loop circuit feature of addressable fire alarm system is connected to a single panel. This slowly helps in upgrading from conventional to addressable fire alarm system, reducing the cost of complete replacement (Chenebert, Breckon, & Gaszczak, 2013).

In summary, there are many types of fire alarm systems each suited to different building types and applications. A fire alarm system can vary dramatically in both price and complexity, from a single panel with a detector and sounder in a small commercial property to an addressable fire alarm system in a multi-occupancy building. The **Fire Industry Association** (FIA, 2015) Classifies Fire Alarm Systems as follows:

"M" manual system (no automatic fire detectors so the building is fitted with call points and sounders),

"L" automatic systems intended for the protection of life, and

"P" automatic systems intended for the protection of property.

2.3 Fire Alarm Systems Designs

After the fire protection goals are established, the next thing, usually, is to develop the fire alarm system design, which involves paying attentive detail to specific components, arrangements, and interfaces necessary to accomplish these goals. Equipment specifically manufactured for these purposes is selected and standardized installation methods are anticipated during the design. Considered fire alarm systems design in this review includes Smoke detector based and flame detector based design (Shunxia & Yanda, 2012).

2.3.1 Smoke Detector-based

In the late 1930s Swiss physicist Walter Jaeger tried to invent a sensor for poison gas. He expected that gas entering the sensor would bind to ionized air molecules and thereby alter an electric current in a circuit in the instrument. His device did not meet its purpose. Smoke particles from his cigarette had apparently done what poison gas could not. Jaeger's experiment was one of the advances that paved the way for the modern smoke detector (Shunxia & Yanda, 2012).

A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial security devices issue a signal to a fire alarm control panel as part of a fire alarm system, while household detectors, known as smoke alarms, generally issue a local audible or visual alarm from the detector itself. Smoke detectors are housed in plastic enclosures, typically shaped like a disk about 150 millimeters (6 in) in diameter and 25millimetre (1 in) thick, but shape and size vary. Smoke can be detected either optically (photoelectric) or by physical process (ionization), detectors may use either, or both, methods. Smoke detectors in large commercial, industrial, and residential buildings are usually powered by a central fire alarm system, which is powered by the building power with a battery backup. Domestic smoke detectors range from individual battery-powered units, to several interlinked mains-powered units with battery backup; if any unit detects smoke, all trigger even in the absence of electricity (Shunxia & Yanda, 2012).

2.3.1.1 Ionization Smoke detector sensor

In 1939 Swiss physicist Ernst Meili devised an ionization chamber device capable of detecting combustible gases in mines. He also invented a cold-cathode tube that could amplify the small signal generated by the detection mechanism which is strength sufficient to activate an alarm (Shunxia & Yanda, 2012).

An ionization smoke detector uses a radioisotope, typically americium-241, to ionize air; a difference due to smoke is detected and an alarm is generated. Ionization detectors are more sensitive to the flaming stage of fires than optical detectors, while optical detectors are more sensitive to fires in the early smoldering stage. The smoke detector has two ionization chambers, one open to the air, and a reference chamber which does not allow the entry of particles. The radioactive source emits alpha particles into both chambers, which ionizes some air molecules (Shunxia & Yanda, 2012).

Fig 2.1: Ionization smoke detector sensor

2.3.1.2 . Photoelectric Smoke Detector

The photoelectric or optical smoke detector was invented by Donald Steele and Robert Enmark of Electro Signal and patented in 1972 (Bahrepour, Meratnia, & Havinga, 2008). A photoelectric smoke detector or optical smoke detector contains a source of infrared, visible, or ultraviolet light (typically an incandescent light bulb or light-emitting diode), a lens, and a photoelectric receiver (typically a photodiode). In spot-type detectors all of these components are arranged inside a chamber where air, which may contain smoke from a nearby fire, flows. In large open areas such as atria and auditoriums, optical beam or projected-beam smoke detectors are used instead of a chamber within the unit: a wall mounted unit emits a beam of infrared or ultraviolet light which is either received and processed by a separate device or reflected to the receiver by a reflector (Bahrepour, Meratnia, & Havinga, 2008). According to the National. Fire Protection Association (NFPA), "photoelectric smoke detection is generally more responsive to fires that begin with a long period of smoldering" (Bahrepour, Meratnia, & Havinga, 2008).

Fig 2.2: Photo electric Smoke Detector (Wike, 2015)

2.3.1.3 Carbon Monoxide and Carbon Dioxide Detector

Carbon monoxide sensors detect potentially fatal concentrations of carbon monoxide gas, which may build up due to faulty ventilation where there are combustion appliances such as heaters and cookers, although there is no uncontrolled fire out with the appliance. High levels of carbon dioxide (CO_2) may indicate a fire and can be detected by a carbon dioxide sensor. Such sensors are often used to measure levels of CO_2 which may be undesirable but not indicative of a fire; this type of sensor can also be used to detect and warn of the much higher levels generated by a fire. One manufacturer says that detectors based on CO_2 levels are the fastest fire indicators, and, unlike ionization and optical detectors, detect fires that do not generate smoke, such as those fueled by alcohol or gasoline. CO_2 fire detectors are not susceptible to false alarms due to particles, making them particularly suitable for use in dusty and dirty environments (Bahrepour, Meratnia, & Havinga, 2008).

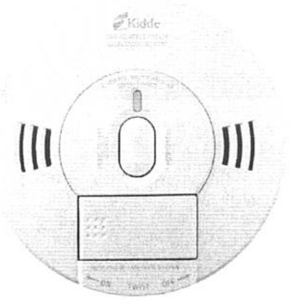

Fig 2.3: Carbon-Monoxide & Dioxide Smoke Detector (Wike, 2015)

2.3.2 Flame Detector-based

A flame detector is a sensor designed to detect and respond to the presence of a flame or fire. Responses to a detected flame depend on the installation, but can include sounding an alarm, deactivating a fuel line (such as a propane or a natural gas line), and activating a fire suppression system (Srivastava & Prabhukar, 2013). When used in applications such as industrial furnaces, their role is to provide confirmation that the furnace is properly lit; in these cases, they take no direct action beyond notifying the operator or control system. A flame detector can often respond faster and more accurately than a smoke or heat detector due to the mechanisms it uses to detect the flame. There various flame sensors available in market based on principles for working. Some of the flame detector or sensors available are explained below

2.3.2.1 Infrared flame

Infrared (IR) flame detectors monitor the infrared spectral band for specific patterns given off by hot gases. These are sensed using a specialized fire-fighting thermal imaging camera (TIC), a type of thermographic camera. False alarms can be caused by other hot surfaces and background thermal radiation in the area. Water on the detector's lens will greatly reduce the accuracy of the detector, as will exposure to direct sunlight (Srivastava & Prabhukar, 2013). A single frequency IR flame detector is typically sensitive to wavelengths around 4.4 micrometer, which is a spectral characteristic peak of hot carbon dioxide as is produced in a fire. The usual response time of an IR detector is 3–5 seconds.

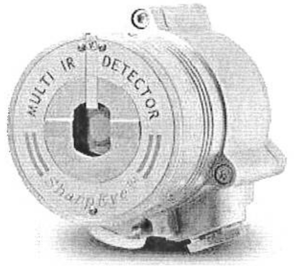

Fig 2.4: Infrared flame detector (Byungrak, Yong-sork, & Jung-Gyu, 2016)

2.3.2.2 Ultraviolet

Ultraviolet (UV) detectors work by detecting the UV radiation emitted at the instant of ignition. While capable of detecting fires and explosions within 3–4 milliseconds, a time delay of 2–3 seconds is often included to minimize false alarms which can be triggered by other UV sources such as lightning, arc welding, radiation, and sunlight. UV detectors typically operate with wavelengths shorter than 300 nm. The solar blind UV wavelength band is also easily blinded by oily contaminants.

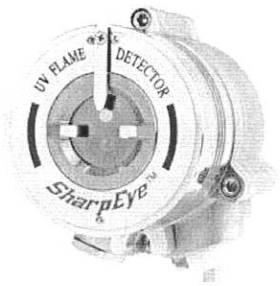

Fig 2.5: Ultraviolet Flame detector (Byungrak, Yong-sork, & Jung-Gyu, 2016)

2.3.2.3 Visual Flame Imaging Flame Detector

Visual flame detectors employ standard charged couple device (CCD) image sensors, commonly used in closed circuit television cameras (CCTV), and flame detection algorithms to establish the presence of fires (Toreyin, Dedeoglu, & Cetin, 2005). The difference between UV and IR flame detectors and the visual imaging, is that, visual imaging does not depend on the emission of the products of combustion like carbon monoxide, water or the radiant heat from combustion of HC, rather it works by processing the live image from the CCD array, analyzing the shape and progression of would be fires to differentiate between actual flame and non-flame sources. As a result, they are good for areas where it is required to differentiate between actual fire from accidental release of HC or combustible materials and process fire from normal operations. Visual imaging flame detector has its own limitations, they cannot detect flames that are non-visible to naked eye like hydrogen flames, and heavy smoke can prevent it from detecting flame as they depend on visible radiation from the fire for detection (B.C & Ahuja, 2004).

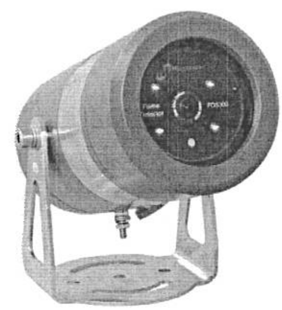

Fig 2.6: Visual Flame Imaging detector (Arduino flame sensor digital sensor, 2015)

2.4 Fire Alarm Parts

Every standard Fire Alarm System has some key parts and standard components that makes it work altogether. An ordinary man will think his building's fire alarm is all about the red and white strobe lights on his walls or the pull stations by the doors. But there's a lot more to it than that!

2.4.1 Fire Alarm Control Panel

Also known as the fire alarm control unit (FACU), this component, the hub of the system, monitors inputs and system integrity, controls outputs and relays information.

2.4.1.1 Arduino

Arduino Is an open-source computer hardware and software company, project and user community that designs and manufactures microcontroller-based kits for building digital devices and interactive objects that can sense and control the physical world. The project is based on a family of microcontroller board designs manufactured primarily by Smart Projects in Italy, and by several other vendors, using various 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors. These systems provide sets of digital and analog I/O pins that can be interfaced to various expansion boards ("shields") and other circuits. The boards feature serial communications interfaces, including USB on some models, for loading programs from personal computers (Byungrak, Yong-sork, & Jung-Gyu, 2016).

For programming the microcontrollers, the Arduino platform provides an integrated development environment (IDE) based on the Processing project, which includes support for C, C++ and Java programming languages. The first Arduino was introduced in 2005, aiming to provide an inexpensive and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators Common examples of such devices intended for beginner hobbyists include simple robots' thermostats, and motion detectors. Some of the advantages of Arduino as control panel includes:

Simple and accessible user experience: Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. (Bahrepour, Meratnia, & Havinga, 2008). There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Net media's BX-24, Phi gets, MIT's Handy board, and many others offer similar functionality. All these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers. (Bahrepour, Meratnia, & Havinga, 2008).

Economical: Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50 Cross-platform

Open source and extensible software: The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to. The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module to understand how it works and save money.

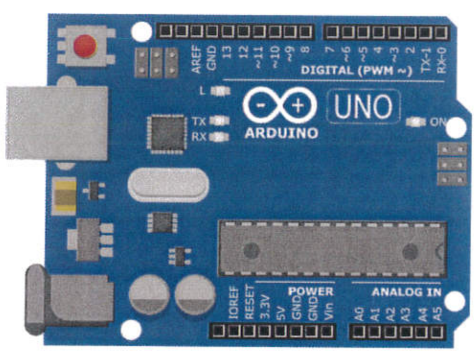

Fig 2.7: Arduino Board (Arduino flame sensor digital sensor, 2015)

2.4.1.2 Raspberry pi

Raspberry Pi project development started on 2006. It is an inexpensive computer that uses Linux-based operating system, equipped with a 700 MHz ARM-architecture CPU, having a 512 MB RAM and featured with two USB ports and an Ethernet controller. It can handle full HD 1080 video playback and by using the onboard Video core IV graphics processing unit (GPU), it was able to demonstrate the ported version of the Quake 3 game. It allows flexibility in the choice of programming languages and installation of software that could be used (Krstinic, Stipani, & Jakov, 2015). It can serve webpage by installing Apache HTTP Webserver on it (B.C & Ahuja, 2004)

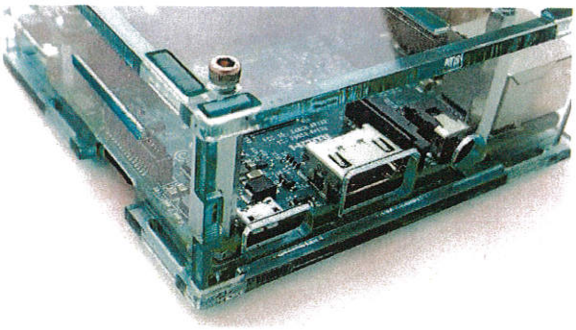

Fig 2.8: Raspberry pi board (B.C & Ahuja, 2004)

2.4.2 Power Supply

For the sake of efficiency and effectiveness, the best practice has always been to have two source of power supply to fire alarm systems: Primary and Secondary.

2.4.2.1 Primary Power Supply

Commonly the non-switched 120 or 240-volt alternating current source supplied from a commercial power utility. In non-residential applications, a branch circuit is dedicated to the fire alarm system and its constituents. "Dedicated branch circuits" should not be confused with "Individual branch circuits" which supply energy to a single appliance.

2.4.2.2 Secondary Power Supply

This component, commonly consisting of sealed lead-acid storage batteries or other emergency sources including generators, is used to supply energy in the event of a primary power failure. The batteries can be either inside the bottom of the panel or inside a separate battery box installed near the panel.

2.4.3 Hardware

It has been established earlier that a fire alarm system has a number of devices or components working together to detect and warn people through visual and audio appliances against fire. A great deal of these devices are hardware, and this review takes a look at few.

2.4.3.1 Flame Sensor

The essence of flame sensor is to detect the presence of smoke. This module is sensitive to the fire and basically flame spectrum. The way it works it just detects the light wave length between the range of 760nm-1100 nm which is the range of typical infrared light. It is very low-cost sensor, light weight only 8-gram, response time is very fast and easy to use, which makes it a right choice to work with, for prototyping and experiment (Arduino flame sensor digital sensor, 2015). There are digital and analog pin output with the module and a potentiometer to change the flame sensitivity. If temperature reaches very high, then output high and low threshold needs to be adjusted accordingly.

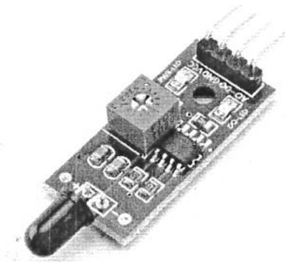

Fig 2.9: Flame Sensor (Arduino flame sensor digital sensor, 2015)

2.4.3.2 MQ-2 Sensor

LPG sensor is an ideal sensor to detect the presence of a dangerous LPG leak in our home or in a service Station, storage tank environment and even in vehicle which uses LPG gas as its fuel. This unit can be easily incorporated into an alarm circuit/unit, to sound an alarm or provide a visual Indication of the LPG concentration. The sensor has excellent sensitivity combined with a Quick response time. When the target combustible gas exists, the sensor's conductivity is higher along with the gas concentration rising. Figure 2-5 below shows an example of a gas sensor (Çelik, Ozkaramanli, & Demirel, 2007).

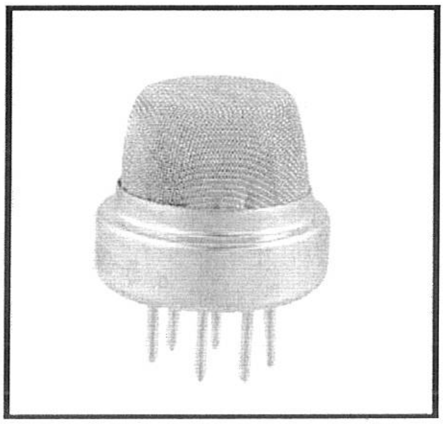

Fig 2.10: Gas sensor (Krstinic, Stipani, & Jakov, 2015)

A simple electronic circuit is used to convert change of conductivity to its corresponding output Signal of gas concentration. MQ-2 gas sensor shown in figure 2.5 is used to sense the poisonous Gas and has high sensitivity to LPG, and response to Natural gas. The sensor could be used to detect Different combustible gas, especially Methane and it is a low-cost sensor and suitable for different applications (Çelik, Ozkaramanli, & Demirel, 2007)

2.4.3.3 Heat Sensor.

A Heat sensor, for example, SEN11301P model sensor is a sensor that can be used to determine the presence and intensity of heat . It can provide temperature and humidity reading simultaneously (Wike, 2015). SEN11301P sensor has accuracy of ±2 ◦C for temperature measurement.

Fig 2.11: Heat Sensor (Krstinic, Stipani, & Jakov, 2015)

2.4.3.4 Buzzer

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input such as a mouse click or keystroke. Buzzer is an integrated structure of electronic transducers, DC power supply, widely used in computers, printers, copiers, alarms, electronic toys, automotive electronic equipment, telephones, timers and other electronic products for sound devices. 3Active buzzer 5V Rated power can be directly connected to a continuous sound, this section dedicated sensor expansion module and the board in combination, can complete a simple circuit design, to "plug and play."

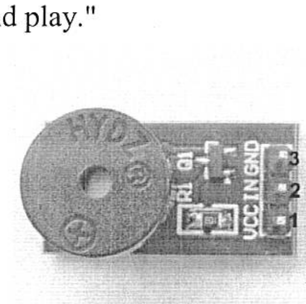

Fig 2.12: Buzzer (Kewei, Weisong, & Watkins, 2010)

2.4.3.5 Relay

The relay module is an electrically operated switch that allows you to turn on or off a circuit using voltage and/or current much higher than a microcontroller could handle. There is no connection between the low voltage circuit operated by the microcontroller and the high-power circuit. The relay protects each circuit from each other. Each channel in the module has three connections named NC, COM, and NO. Depending on the input signal trigger mode, the jumper cap can be placed at high level effective mode which 'closes' the normally open (NO) switch at high level input and at low level effective mode which operates the same but at low level input.

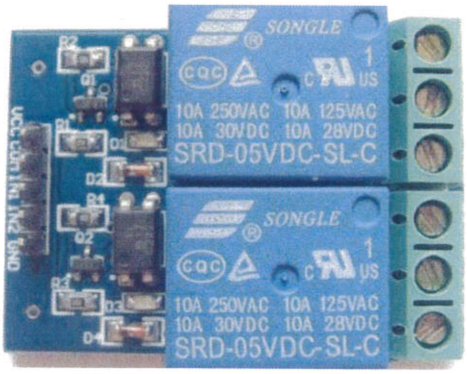

Fig 2.13: Relay (Bahrepour, Meratnia, & Havinga, 2008)

2.5 Initiating Devices

There are two major types of Initiating devices – Manually activated, and Automatically activated Devices.

Manually Activated Devices: also known as fire alarm boxes, manual pull stations, or simply pull stations, break glass stations, and (in Europe) call points. Devices for manual fire alarm activation are installed to be readily located (near the exits), identified, and operated. They are usually actuated by means of physical interaction, such as pulling a lever or breaking glass (J. Hou, et al., 2008).

Automatically actuated devices: Can take many forms intended to respond to any number of detectable physical changes associated with fire: converted thermal energy; heat detector, products of combustion; smoke detector, radiant energy; flame detector, combustion gasses; fire gas detector, and release of extinguishing agents; water-flow detector. The newest innovations can use cameras and computer algorithms to analyze the visible effects of fire and movement in applications inappropriate for or hostile to other detection methods. (J. Hou, et al., 2008)

2.6 Notification Medium - Wireless Communication Technologies and Standard

In a sensor network, dozens, hundreds, or thousands of tiny, battery-powered computing devices are scattered throughout a physical environment. In a WSN, each device is capable of sensing—and/or displaying—actuating information. Sensing may include data collection, such as heat, smoke, vibration, etc. An actuating device may cause an LED to blink, turn on lights, display textual information, or other action that prompts a response or informs a human.

A WSN device is a node in a wireless sensor network that is capable of gathering sensory information, processing it in some manner, and communicating with other nodes in the network. The majority of wireless sensor platforms share a common set of *system components* (J. Hou, et al., 2008):

i. *Microcontroller:* provides the computational capabilities to the platform;
ii. *Radio transceiver:* provides low-power wireless communications;
iii. *Sensor interfaces:* hardware interfaces to external sensors;
iv. *Actuator interfaces:* provide human interaction interface (LED, displays, etc.);
v. *Antenna*;
vi. *Power:* through batteries, capacitors, or solar arrays.

Often these devices for business or engineering reason are broken down into *modules*. These modules are themselves broken into a sensing or display module and a transceiver module. Transceiver modules are convenient in a design because they provide a common radio stack and embedded processor for a cluster of different WSN devices. Common examples of transceiver devices include the WINS (Rockwell), and Mica/Mica2/Mica2DOT (Berkeley/XBOW).

2.6.1 Bluetooth Module

Bluetooth is a low-cost, low-power, robust, short-range wireless communication protocol. It was first developed as a cable replacement between mobile phones, headsets, PDAs, laptops, and so forth, but it has evolved to solve more general applications in the personal area network (PAN) domain. The Bluetooth stack is quite complex, giving it a rather large footprint, which means that it cannot be used in devices constrained in terms of processing-power and memory. A collection of devices communicating using Bluetooth is referred to as a piconet (J. Hou, et al., 2008).

Bluetooth operates in the license-free 2.4-GHz ISM band. It uses 79 1-MHz channels to transmit data. Interference between other ISM band devices (802.11 and 802.15.4 devices) and other Bluetooth piconets is minimized using frequency hopping spread spectrum (FHSS), where the carrier is rapidly switched (hops) among the 79 available channels. The frequency hopping sequence is controlled by the master device within the piconet. Other Bluetooth interference reduction techniques include adaptive power control, channel quality driven data rate (CQDDR), and adaptive frequency hopping (AFH). The Bluetooth core system consists of an RF transceiver, baseband, and protocol stack. The system is usually implemented partly in hardware and partly in software running on a microprocessor (J. Hou, et al., 2008).

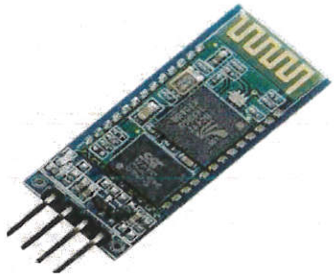

Fig 2.14: Bluetooth Module (J. Hou, et al., 2008)

2.6.2 GSM/GPRS Module

GSM/GPRS module is used to establish communication between a computer and a GSM-GPRS system. Global System for Mobile communication (GSM) is an architecture used for mobile communication in most of the countries. Global Packet Radio Service (GPRS) is an extension of GSM that enables higher data transmission rate. GSM/GPRS module consists of a GSM/GPRS modem assembled together with power supply circuit and communication interfaces (like RS-232, USB, etc) for computer. (J. Hou, et al., 2008).

A GSM/GPRS module assembles a GSM/GPRS modem with standard communication interfaces like RS-232 (Serial Port), USB etc., so that it can be easily interfaced with a computer or a microprocessor / microcontroller based system. The power supply circuit is also built in the module that can be activated by using a suitable adaptor.

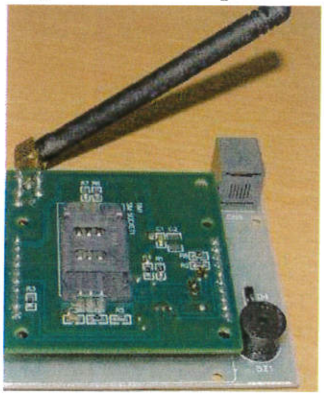

Fig 2.15: GSM/GPRS Module (J. Hou, et al., 2008)

2.6.3 802.15.4/ZigBee

802.15.4/ZigBee is built on the IEEE 802.15.4 standard and specifies the MAC and PHY (physical) layers. "ZigBee" comes from higher-layer enhancements developed by a multivendor consortium called the ZigBee Alliance. For example, 802.15.4 specifies 128-bit AES encryption, while ZigBee also specifies how to handle encryption key exchange. 802.15.4/ZigBee networks are designed to run in the unlicensed frequencies, including the 2.4-GHz band in the United States. IEEE 802.15.4/ZigBee is intended for uses such as the control of lights, security alarms, motion sensors, thermostats and smoke detectors, and environmental monitoring (J. Hou, et al., 2008).

There are plans for ZigBee integration with residential network gateways that merge traffic onto a broadband Internet connection. ZigBee has specific advantages over other short-range protocols such as 802.11 and 802.15 for WSN applications; devices based on these latter protocols use too much power and the protocols are too complex (and thus more expensive) to be embedded in devices on very large scales. Unfortunately, the ZigBee Alliance has not yet made its protocol available as an open standard; additionally, it adds another protocol between the device and the global IP-based network (J. Hou, et al., 2008).

2.7 Related Works

Numerous Fire Alarm Systems and security surveillance systems have been developed using various platforms over the years. Recent improvements in GSM, web server and microcontroller technologies have led to the developments of various Automated versions of fire alarm systems.

Qiongfang *et al.* (2009) proposed an intelligent fire alarm system using fuzzy neural network. It processes data from the sensors and calculates model of fuzzy neural network based on the characteristics of fire detection signal so it will have a self-learning and adaptive capability. However, it is only a study on proposing a new approach for fire detection.

Shunxia & Yanda (2012) designed a wireless intelligent home alarm system consisting on anti-theft feature, anti-fire feature, and anti-harmful gas leak feature using Single Chip Microcomputer (SCM) AT89C51 and voice chip ISD1420. Two SCMs were used to display the gas concentration and alarm host as the alarm signals were sent by using wireless transmission. When the sensor detects smoke, a voice message will be sent to the relevant department. However, if an error occurs during the detection, a false alarm will be submitted because this system did not include any user confirmation.

Hou, *et al.* (2008) proposed an intelligent home security system using Zigbee to monitor important locations inside a home through a surveillance camera. When the system was triggered by any penetration, the user will be notified through SMS and Multimedia Message Service (MMS). The temperature and gas sensor were connected to the system motherboard using Zigbee modules and forming a Wireless Sensor Network (WSN). Even though it can be included as one of the most advanced system, the system motherboard used to manage the WSN was too expensive.

San-Miguel-Ayanz & Ravail (2005) pointed out an "Intelligent Residential Security Alarm and Remote-Control System Based on Single Chip Computer". Their work focused on the intelligent residential burglar alarm, emergency alarm, fire alarm, toxic gas leakage remote automatic sound alarm and remote-control system, which is based on 89c51 single chip computer. The system can perform an automatic alarm, which calls the police hotline number automatically. It can also be a voice alarm and shows alarm occurred address. This intelligent security system can be used to control the electrical power remotely through telephone.

Peijiang & Xuehhua (2008) developed a system namely "Design and Implementation of Remote Monitoring System Based on GSM", which has focused on the wireless monitoring system; a remote monitoring system based on SMS through GSM. The hardware and software architectures of the system are designed. In this system, the remote signal is transmitted through GSM network.

Srivastava & Prabhukar (2013) developed a GSM-based embedded system which helps detect leakages in gases. This work was tailored majorly towards elimination of the fire accidents caused by toxic gas leakages in offices and homes by automating an alarm system over a GSM-module. This system uses a remote automatic alarm over the GSM. The system can perform an automatic alarm, which calls the Fire / Emergency department, or the concerned party as the case may be, automatically.

Byungrak, Yong-sork, & Jung-Gyu (2016) developed an automated fire alarm system that uses various sensors like AS-MLC, MQ 6, MQ2, LM 35, IR sensor, door vibration sensor in preventing fire outbreak, thefts, etc. In this work, the LPC 2148 ARM7TDMI-S microcontroller was used in the information receiving process. The LPC2148 microcontroller is based on 32/16 bit ARM7TDMI-S CPU with real-time emulation and embedded 8 trace support, that combines the microcontroller with embedded high speed flash memory ranging. GSM modem is also attached with microcontroller which would send the SMS to the home user as well as the emergency service providers like fire brigade or police. This system use C-Language program to developed with help of Keil compiler. This program is transferred to the microcontroller using Flash Magic software. This system not only sends a message to alert a home user, but it also has an added function of making a phone call to home users. However, the major disadvantage of this work is the fact that it can only quickly detect smoke and fire, not flame. Moreover, a mini vibration on door by a friendly face could trigger an unnecessary alarm.

Kewei, Weisong, & Watkins (2010) developed an embedded system that uses an automated approach for homes and industrial security using GSM. This developed system is fully controlled by an 8 bit P89V51RD2 microcontroller. All the sensors and detector are interconnected to microcontroller by using various types of interface circuits. This system involved various sensors like PIR sensor, gas and smoke sensor and fuse failure detector. The PIR (Passive Infra-Red) sensor is a pyroelectric device that detects motion by measuring changes in the infrared level emitted by surrounding objects and the fuse failure detector is a special type of sensor, which will be activated when the security areas fuse breakdown by some unwanted person or by artificial means. The major drawback of this project is that the system automatically sends a message to police station even when the smoking is not coming from inside of house, maybe smoke from outside. So it trips and send an unnecessary alarm to police and fireman.

Wen-hui, Li, Guang-zhi, & Zhi-bin (2017) developed an embedded system for hazardous gas detection and alarm. In this work, the hazardous gases like Liquefied petroleum gas (LPG) and propane were sensed and displayed each and every second in the liquid crystal display (LCD). If these gases exceed the normal level, then an alarm is generated immediately and also an alert message (SMS) is sent to the authorized person through the Global System for Mobile communications (GSM), which leads to faster diffusion of emergency situation. The system also supports to provide real-time monitoring of concentration of the gases, which presents in the air. As this method is automatic the information can be given in time such that the endangering of human lives can be avoided. However, the major drawback of this work is that the system cannot detect heat, flame or smoke. Moreover, it can only send a message only to a user.

2.8 **Review of Related Works**

Table 2.1: Review of Related Works

AUTHOR	WORK	SYSTEM COMPOSITION	MERIT	DRAW BACK
San-Miguel-Ayanz & Ravail (2005)	Residential Security Alarm and Remote-Control System	Single Chip Computer, Automatic Sound alarm	Voice alarm, Can control electrical power remotely through telephone	No wireless notification
Hou et al (2008)	Intelligent home monitoring security system	Zigbee MC, WSN, SMS	Robust WSN	Expensive
Peijiang & Xuehhaua (2008)	Design & Implementation of Remote monitoring system	GSM, SMS	Wireless monitoring	No user confirmation
Qiongfang et al (2009)	Intelligent fire alarm system using fuzzy neural network	Neuro-fuzzy	Self-learning and adaptive capability	Still Relatively new
Shunxia & Yanda (2012)	Wireless intelligent home alarm system	Wireless, Single chip microcomputer	Voice messaging included	No user confirmation, hence, false alarm
Srivastava & Prabhukar (2013)	GSM-based gas leakage alarm system	GSM	Automatic alarm, automatic calling	It can only detect gas leakage and not heat
Byungrak et al (2016)	Automated fire alarm system	Sensors, GSM, SMS	SMS + Phone call	Mini vibration could trigger a false alarm
Kewei et al (2016)	Automated security for homes and industry using GSM	PIR, Gas sensor, GSM	SMS, Interconnected sensors	Sends false alarm when smoke is coming from outside the house
Wen-hui et al (2017)	Embedded system for hazardous gas detection and alarm	LPG, SMS, GSM	Real time monitoring	It cannot detect heat or smoke.

CHAPTER THREE
METHODOLOGY

3.1 Architecture of the Automatic Fire Alarm System

The Fig. 3.1 shows a block diagram which describes the Automatic Fire Alarm System using GSM module. The architecture of this system is based on the Wireless Network and it composes of both software and hardware resources; The system is made up of three major sections namely: Sensor Interface, Control Panel/Transmission, and Displaying/Alert/Notification.

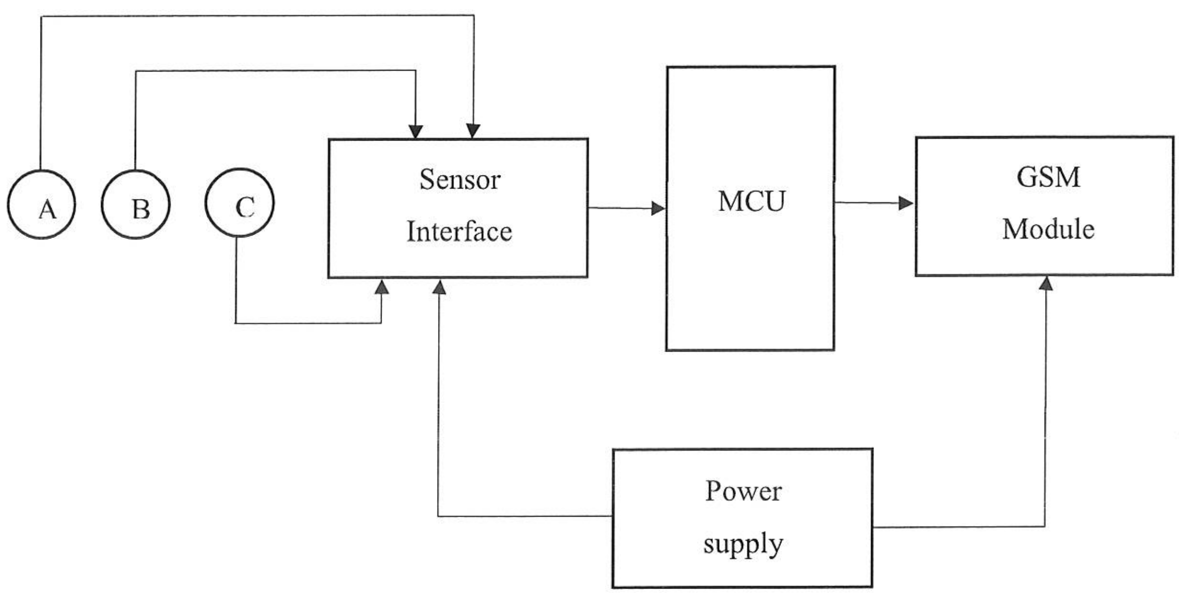

Fig 3.1: Architecture of the automatic fire alarm system

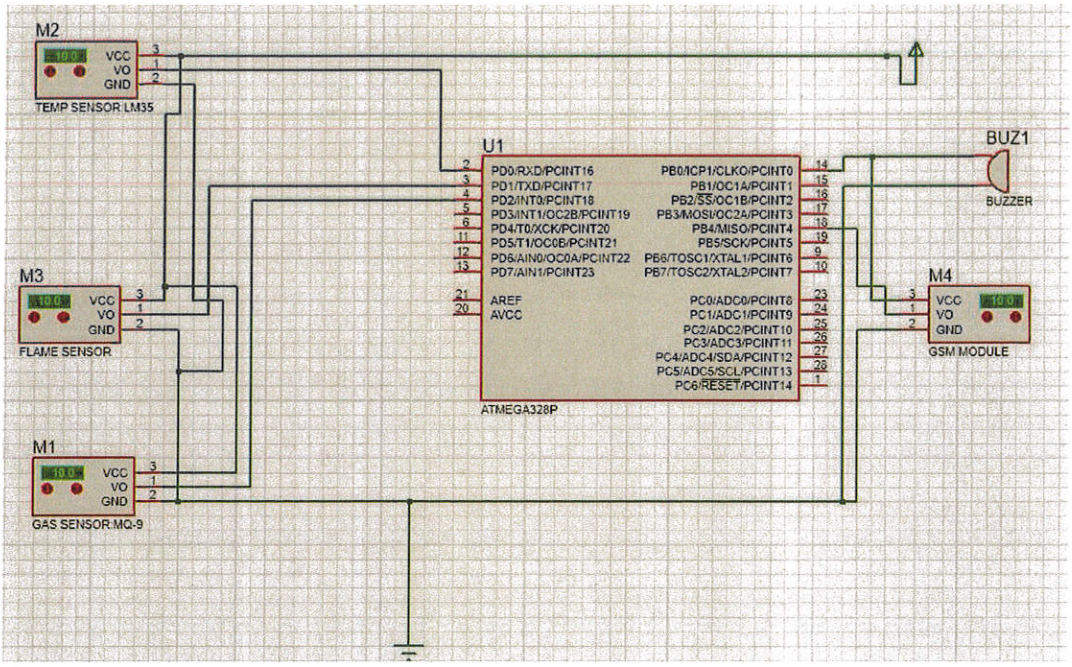

Fig 3.2: Circuit Diagram Obtained Using Proteus

It contains units M1, M2, M3, M4, U1 as Gas sensor, Temperature sensor, Flame sensor, GSM module and Arduino ATMEGA328P respectively.

3.2 Design calculation

Selecting switch transistor for the buzzer

Buzzer parameters: Voltage = 5v, current consumption = 70mA

From ohms law $V = I * R,\ therefore\ I = \frac{V}{R}$

V is the Voltage, I is the Current (A) and R is Resistance, hFE is current Amplification

The current (I) required to drive the buzzer is 70mA

bc547 was chosen to drive the relay

$where\ I_C = hFE * I_b$

$I_b = I_c/hFE$

$I_b = \frac{70mA}{120} = 566.6uA$

From Ohms law $R = \frac{V}{I}$

$R_b = \frac{V_s - V_b}{I_b} = \frac{5-0.7}{566.6*10^{-6}} = 7589.12\Omega$

$R_b = 7.5k\Omega$ Bias the base of both transistors correctly.

3.3 Operational sequence of the designed system

The figure 3.3 is the schematic diagram of the project; the ATMEGA328 is the heart of the system. Upon power up, it initializes all the sensors after a time out of a few seconds, it begins calibration of the sensors; it then goes into the active monitoring mode, analyzing sensor data for a potential fire or emergency situation.

When there is a fire/smoke/pollution incident, the microcontroller initializes the SIM808 module and waits for it to acquire the network, it then forwards the programmed SMS to the assigned Response Center numbers, repeating the message once just in case there is a network issue. After this sequence, it reverts to the active monitoring mode. The operational sequence is clearly portrayed in the flowchart in figure 3.3.

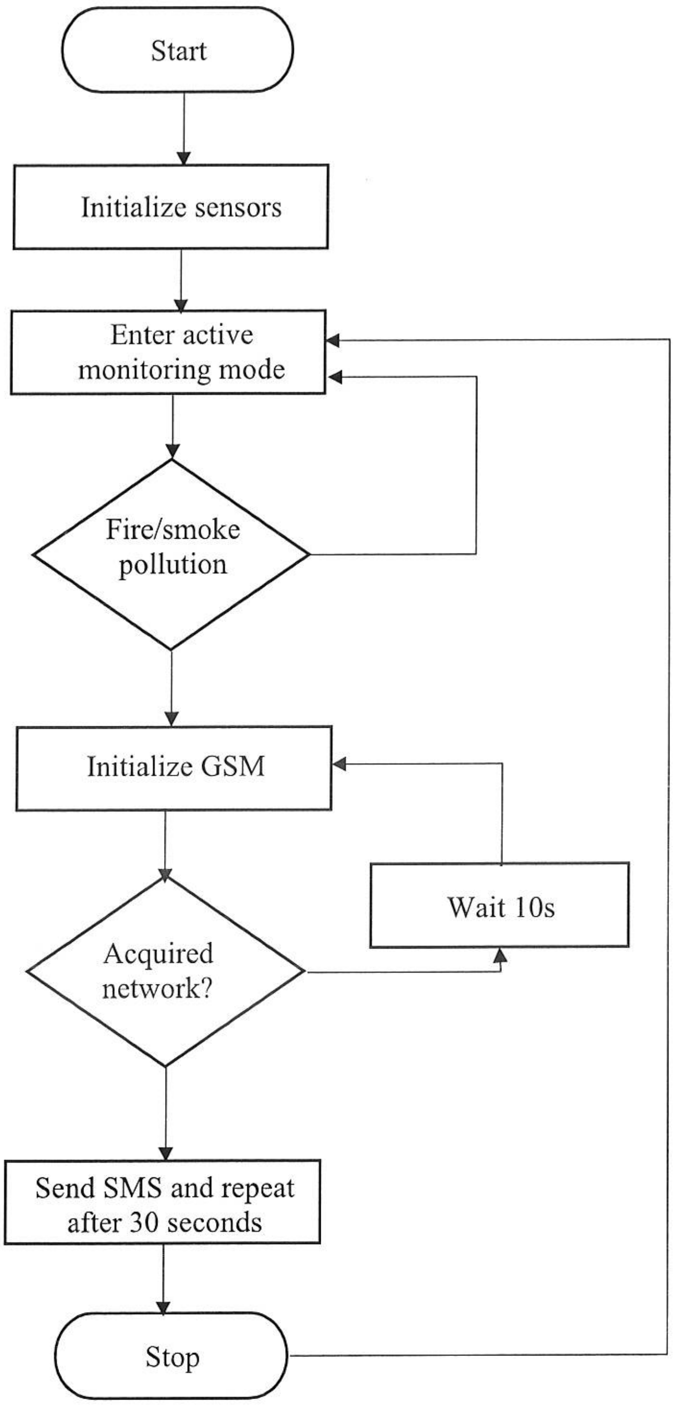

Fig 3.3: Operational flowchart of the design

3.4 Requirements and Specification of the design

The Fire Alarm system design specification involves the following:

1. Capable of measuring temperature variation over a wide. Also, it must be able to detect temperature over a preset limit and perform specified actions when this limit is crossed.
2. Capable of detecting smoke in a room compartment and performing a specified action.
3. Operated via a rechargeable battery for standby operation.
4. Capable of sending an SMS alert to designated numbers as soon as smoke or temperature level crosses a preset limit.
5. Capable sounding an alarm as soon as smoke or temperature level crosses a preset limit.

3.5 Hardware Composition and Implementation of the Automatic Fire Alarm System

At the core of the system is the enclosed environment being monitored, which can also be referred to as the "subject" in this case. The subject is primarily monitored by flame, gas and temperature sensors which are embedded on a microcontroller, and triggered by the presence of fire symptoms, ranging from flame, to smoke, or heat.

The information gathered by the sensor will then be sent to the Control Panel, which in this case is the Arduino, as the two hardware components are directly connected together on the hardware part of this project. So, at any point in time that the sensor receives an input that exceeds the preset critical value or safe level, it triggers an alarm which is processed by the Arduino, and then the Arduino launches a transmission process in order to send an alarm via the Wireless Notification Medium to the building occupants or Fire Emergency Services, as the case may be (depending on the configuration).

The method used in the execution of this project comprises the combination of serial communication protocols, signal processing, programming logics with embedded system. In other to establish the aim of the project these methods were combined from the design stage to the construction and performance results of the system. Using carefully selected materials and software implementation to drive the complete system as seen in the final construction. This chapter entails the design procedure of the system detailing the theoretical analysis, choice of components and values and construction and packaging materials. Indicating calculations, schematics and drawings. The materials that are in this project will include the following:

i. Li-ion battery
ii. Sim800L GSM module
iii. MQ-2 Gas Sensor
iv. LM35 Temperature Sensor
v. ATMega328 (mini) Microcontroller
vi. Flame Sensor
vii. Resistors
viii. Capacitors
ix. LEDs
x. Piezoelectric buzzer
xi. USB Ports
xii. Connecting wires, soldering lead, hot melt sticks, veroboard, cable wires, etc

3.5.1 Sensing Interface

1. Flame Sensor

A flame detector is a sensor designed to detect and respond to the presence of a flame or fire. Responses to a detected flame depend on the installation, but can include sounding an alarm, deactivating a fuel line (such as a propane or a natural gas line), and activating a fire suppression system (Srivastava & Prabhukar, 2013). A flame detector can often respond faster and more accurately than a smoke or heat detector due to the mechanisms it uses to detect the flame. When used in applications such as industrial furnaces, their role is to provide confirmation that the furnace is properly lit; in these cases, they take no direct action beyond notifying the operator or control system.

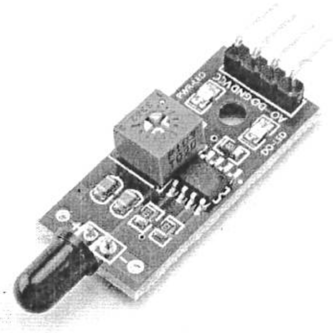

Fig 3.4: Flame Sensor

2 MQ-2 Sensor

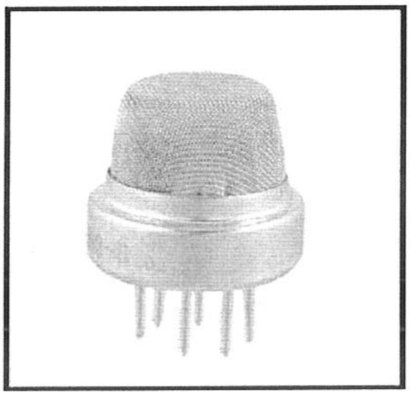

Fig 3.5: Smoke sensor

MQ-2 smoke sensor is an ideal sensor to detect the presence of a dangerous LPG leak in our home or in a service Station, storage tank environment and even in vehicle which uses LPG gas as its fuel. This sensor can be easily incorporated into an alarm circuit/unit, to sound an alarm or provide a visual Indication of the LPG concentration. The sensor has excellent sensitivity combined with a quick response time. When the target combustible gas exists, the sensor's conductivity is higher along with the gas concentration rising. The sensor can detect smoke in the range of 300-10,000 ppm, giving an analog output voltage of between 0v to 5v depending on the quantity of smoke detected. The sensitive material used is SnO2, whose conductivity is lower in clean air. Its conductivity increases as the concentration of combustible gases increases, hence generating a corresponding analog voltage at the output.

3. **Temperature Sensor**

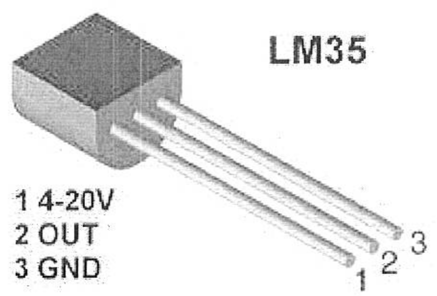

Fig 3.6a: Temperature Sensor

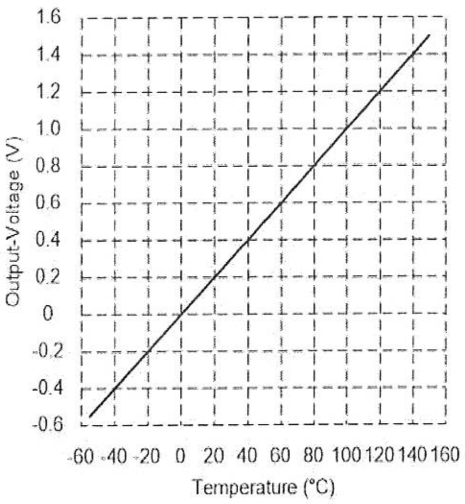

Fig 3.6b: LM35 sensitivity graph

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C). It can measure temperature more accurately than a using a thermistor. The sensor circuitry is sealed and not subject to oxidation. The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified. The LM35 has an output voltage that is proportional to the Celsius temperature. The scale factor is .01V/°C.

The LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4°C at room temperature and +/-0.8°C over a range of 0°C to +100°C.Another important characteristic of the LM35 is that it draws only 60 micro amps from its supply and possesses a low self-heating capability. The LM35 comes in many different packages such as TO-92 plastic transistor-like package, T0-46 metal can transistor-like package,8-lead surface mount SO-8 small outline package. This project uses the To-92 small transistor package type.

3.5.2 Control Panel – ATMega328 Microcontroller

For programming the microcontrollers, the Arduino platform provides an integrated development environment (IDE) based on the Processing project, which includes support for C, C++ and Java programming languages. Using various 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors, the Arduino Microcontroller provide sets of digital and analog I/O pins that can be interfaced to various expansion boards ("shields") and other circuits. The boards feature serial communications interfaces, including USB on some models, for loading programs from personal computers.

Taking into account its several advantages namely, the simple user experience, economical nature, together with its open source and extensible nature; this project relies on the Processing capability and prowess of Arduino board as the best choice for its Control Panel.

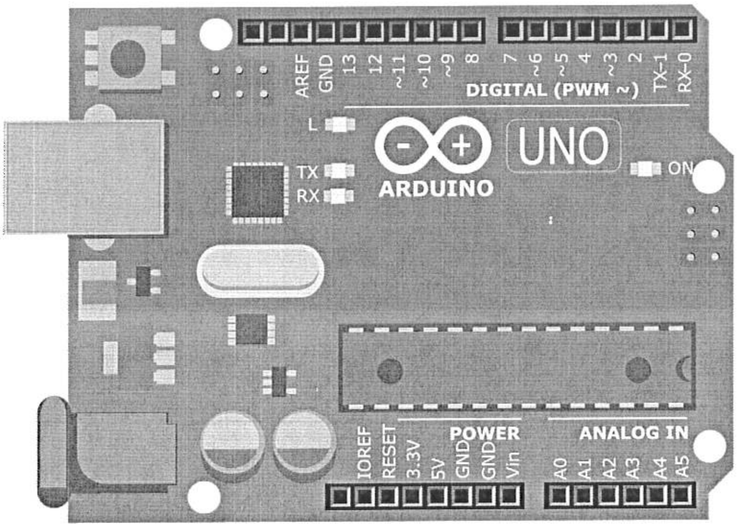

Fig 3.7: A typical Arduino Board

The ATmega328 provides the following features: 32 kilobytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 1024 bytes EEPROM, 2 kilobyte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for boundary-scan, On-chip Debugging support and programming, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain (TQFP package only),a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes.

3.5.3 Transmission and Notification System – GPRS Module Wireless Network

GSM/GPRS module is used to establish communication between a computer and a GSM-GPRS system. Global System for Mobile communication (GSM) is an architecture used for mobile communication in most of the countries. Global Packet Radio Service (GPRS) is an extension of GSM that enables higher data transmission rate. GSM/GPRS module consists of a GSM/GPRS modem assembled together with power supply circuit and communication interfaces (like RS-232, USB, etc) for computer. The MODEM is the soul of such modules.

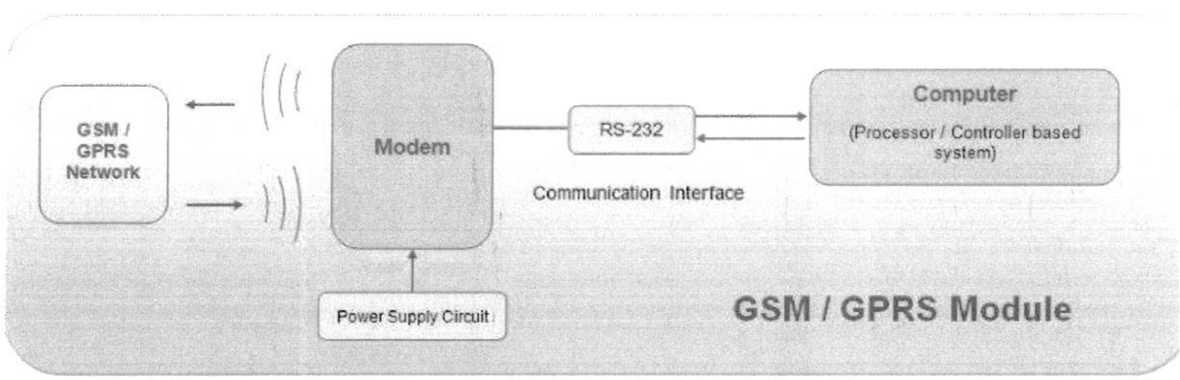

Fig 3.8a: GSM/GPRS Module Architecture

Wireless MODEMs are the MODEM devices that generate, transmit or decode data from a cellular network, for establishing communication between the cellular network and the computer. These are manufactured for specific cellular network (GSM/UMTS/CDMA) or specific cellular data standard (GSM/UMTS/GPRS/EDGE/HSDPA) or technology (GPS/SIM). Wireless MODEMs like other MODEM devices use serial communication to interface with and need Hayes compatible

AT commands for communication with the computer (any microprocessor or microcontroller system).

GSM/GPRS MODEM is a class of wireless MODEM devices that are designed for communication of a computer with the GSM and GPRS network. It requires a SIM (Subscriber Identity Module) card just like mobile phones to activate communication with the network. Also they have IMEI (International Mobile Equipment Identity) number similar to mobile phones for their identification. A GSM/GPRS MODEM can perform the following operations:

1. Receive, send or delete SMS messages in a SIM.

2. Read, add, search phonebook entries of the SIM.

3. Make, Receive, or reject a voice call.

The MODEM needs AT commands, for interacting with processor or controller, which are communicated through serial communication. These commands are sent by the controller/processor. The MODEM sends back a result after it receives a command. Different AT commands supported by the MODEM can be sent by the processor/controller/computer to interact with the GSM and GPRS cellular network.

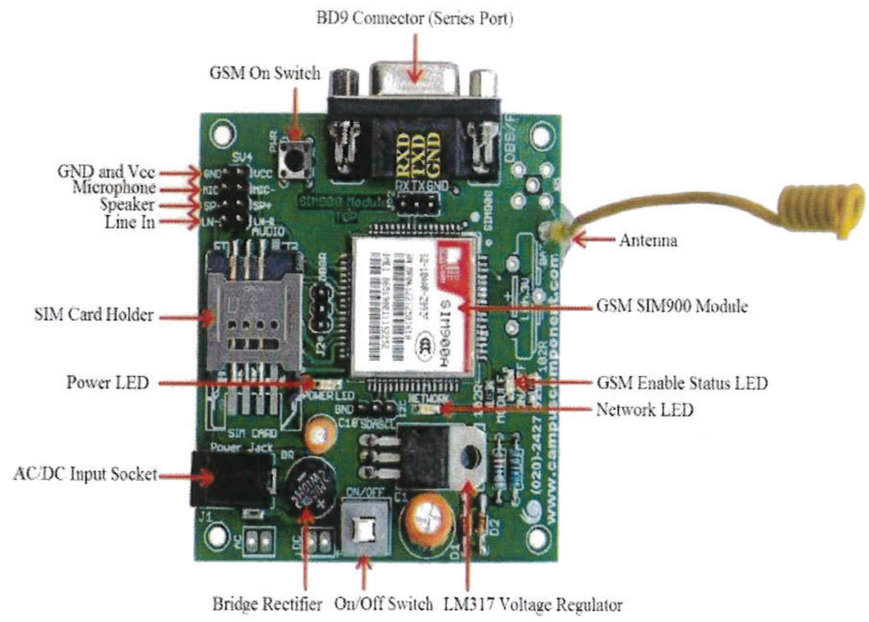

Fig. 3.8b SIM800L GSM Module (Srivastava & Prabhukar, 2013)

The GSM/GPRS module assembles a GSM/GPRS modem with standard communication interfaces like RS-232 (Serial Port), USB etc., so that it can be easily interfaced with a computer or a microprocessor / microcontroller based system. The power supply circuit is also built in the module that can be activated by using a suitable adaptor.

3.5.4 Power supply

The device is powered by a 4.2v 3000mah lithium polymer rechargeable battery which is charged by a normal 5-volt cell phone charger through an on-board USB charging port. This arrangement has a major advantage which is that even when there is no electrical power, the operation of the device is not impeded. Different voltages are required for different modules, the microcontroller uses 5v, the GSM module uses 3.7v to 4.2v. Therefore, two converters are used to provide necessary voltage to the devices. The GSM module is connected to the battery directly, a boost converter is used to boost 4.2v to 12v to drive the relay and also serves as input to the regulator IC (7805) which regulates the 12v input to give 5v output which is connected to the microcontroller. Below is a simple block diagram of the power supply unit:

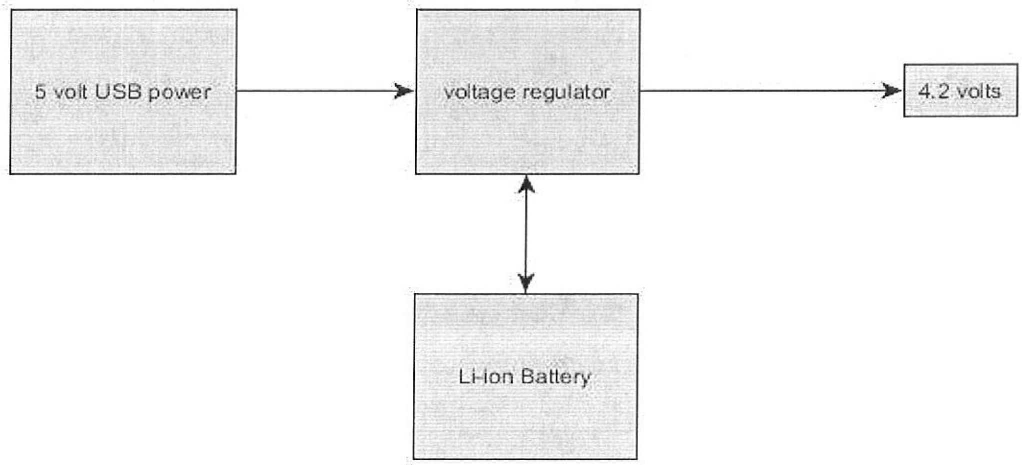

Figure 3.9: Power Supply Unit

Fig 3.10: Lithium Ion Battery

A Lithium-ion battery is made up of an anode, cathode, separator, electrolyte, and two current collectors (positive and negative). The anode and cathode store the lithium. The electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator. The movement of the lithium ions creates free electrons in the anode which creates a charge at the positive current collector. The electrical current then flows from the current collector through a device being powered (cell phone, computer, etc.) to the negative current collector. The separator blocks the flow of electrons inside the battery. While the battery is discharging and providing an electric current, the anode releases lithium ions to the cathode, generating a flow of electrons from one side to the other. When plugging in the device, the opposite happens: Lithium ions are released by the cathode and received by the anode.

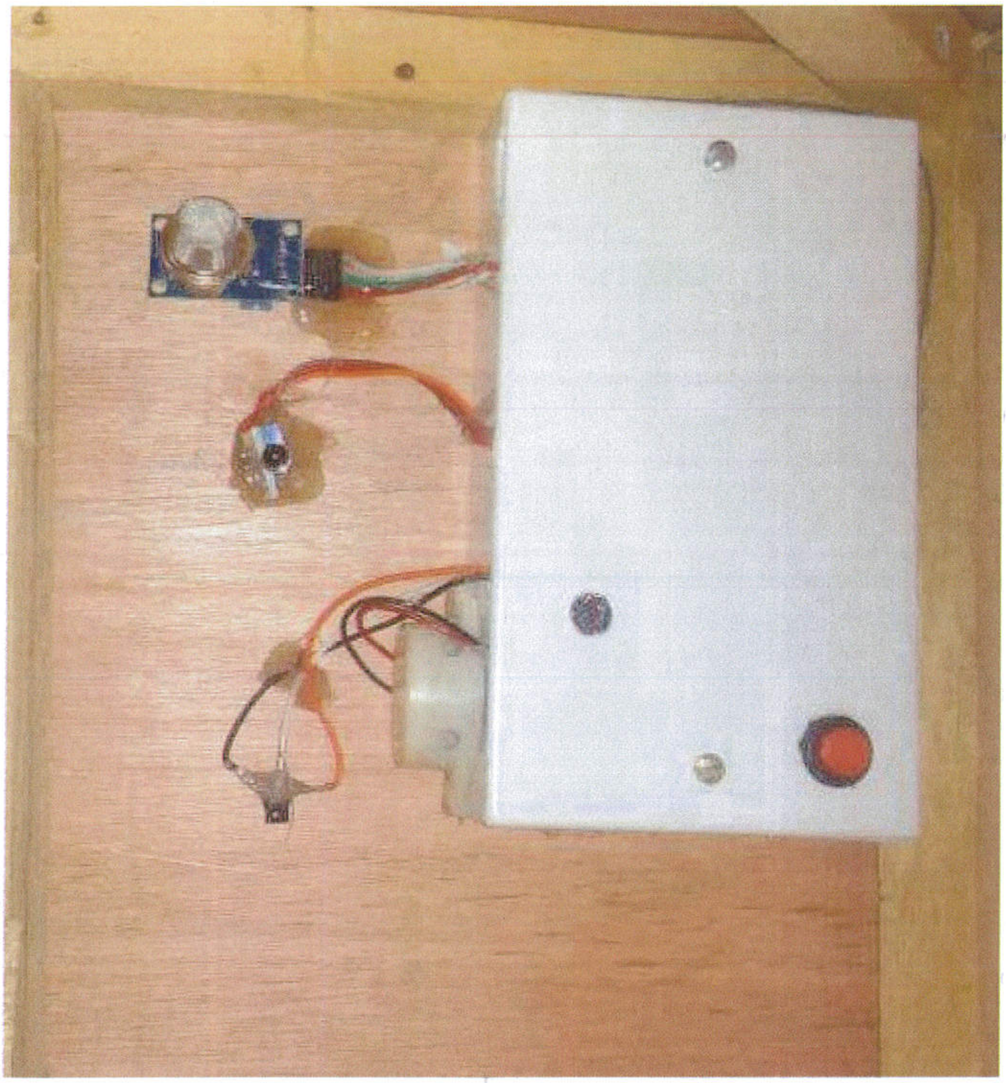

Figure 3.11: The Fire Alarm System Hardware.

The above figure is the image of the designed and implemented fire alarm system attached to a wooden structure. The sensors are kept outside the plastic casing to allow for optimal sensing of gas, smoke and high temperature

3.6 Method of Evaluation

The system is evaluated based on three major metrics namely: Accuracy, Energy utilization and Scalability.

Accuracy: This term refers to the ability of the system to correctly sense when there is any slight change in the environmental variables of the subject. The accuracy will be determined by the percentage of cases in which the sensor senses the presence of heat, smoke, flame, or fire accurately and successfully transmits it to the control panel.

Energy consumption: The energy consumed by the microcontroller and GSM Module during the transmission can be measured and the efficiency of the energy harvest. Due to possible variation in supply voltage (VL), a fixed 1.223 VDC voltage reference can be used to determine the router node VL and microcontroller 10-bit A/D reference voltage (VREF). This voltage reference would consist of a 1.223 VDC zener diode.

Scalability: This system is physically tested using a house-model, a close environment to a real house environment; and its behavior is evaluated to see its scalability and see how it will work in the case of real-life scenario.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Testing the Designed and Implemented Automatic Fire Alarm System

The project was put together and tests were conducted to verify functionality. Before the device was powered a thorough check was conducted on the circuit board using multimeter to make sure that all connections are done correctly to avoid any form of casualty due to wrong connection. When the switch was toggled, the buzzer sounded an alarm indicating system power up. The MODEM connected to Network in five seconds on powering ON.

In testing the functionality of the system, a smoking ember was placed 15cm away from the device, the increment of the smoke level was seen on the display. As soon as the smoke level got to the preset critical value of 3800ppm, the system immediately sounded the buzzer and sent SMS to the registered phone numbers provided in the code stating that "High Smoke and Pollution Levels Detected". The message was delivered within a minute, this time is early enough for a response and action to be taken before the spread of the fire and damage to lives and properties.

The temperature test was also conducted by placing a burning ember 15cm towards the sensor, when the temperature had risen beyond the 40^0C preset level, the device sent an SMS to the registered phone numbers stating that "Temperature above safe levels" and sounded the buzzer. These test results showed a successful implementation of the project in accordance to the design specification and requirements.

The flame test was conducted by testing the system in the presence of flame, a burning ember was placed 15cm towards the sensor, when the flame had risen beyond the preset level, the device sent an SMS to the registered phone numbers stating that "Flame detected" and sounded the buzzer. These test results showed a successful implementation of the project in accordance to the design specification and requirements.

4.2 Results of the Designed and Implemented Automatic Fire Alarm System

The results obtained from tests are presented in the tables 4.1 below. The three sensors were tested individually. The delay between the initiating or trigger condition and the SMS report is about 40 seconds. This delay is mostly due to the time needed for the GSM Module to acquire the network and send the messages. Sometimes, due to network issues, there could be a longer delay, although such was not observed during the Tests. To eliminate the possibility of SMS not being received, there are several backup mobile numbers to which the GSM Module reports.

Table 4.1: Results of the Designed System Functionality

Subject	Test Condition	Sensor under Test	Response SMS to mobile numbers: +2348107211102; +2348038457998; +2348063068173	Remarks
1	Burning ember at 20cm distance	Flame Sensor	Flame detected in Apartment	
2	Smoking Ember at 15 cm distance	Smoke and Pollution Sensor MQ-2	High Smoke and Pollution Levels Detected	This occurred when the smoke level had exceeded the preset critical value of 3800ppm
3	Burning match at 5cm	Temperature Sensor LM35	Temperature above safe levels	This occurred when the temperature level had exceeded the preset critical value of 40 C

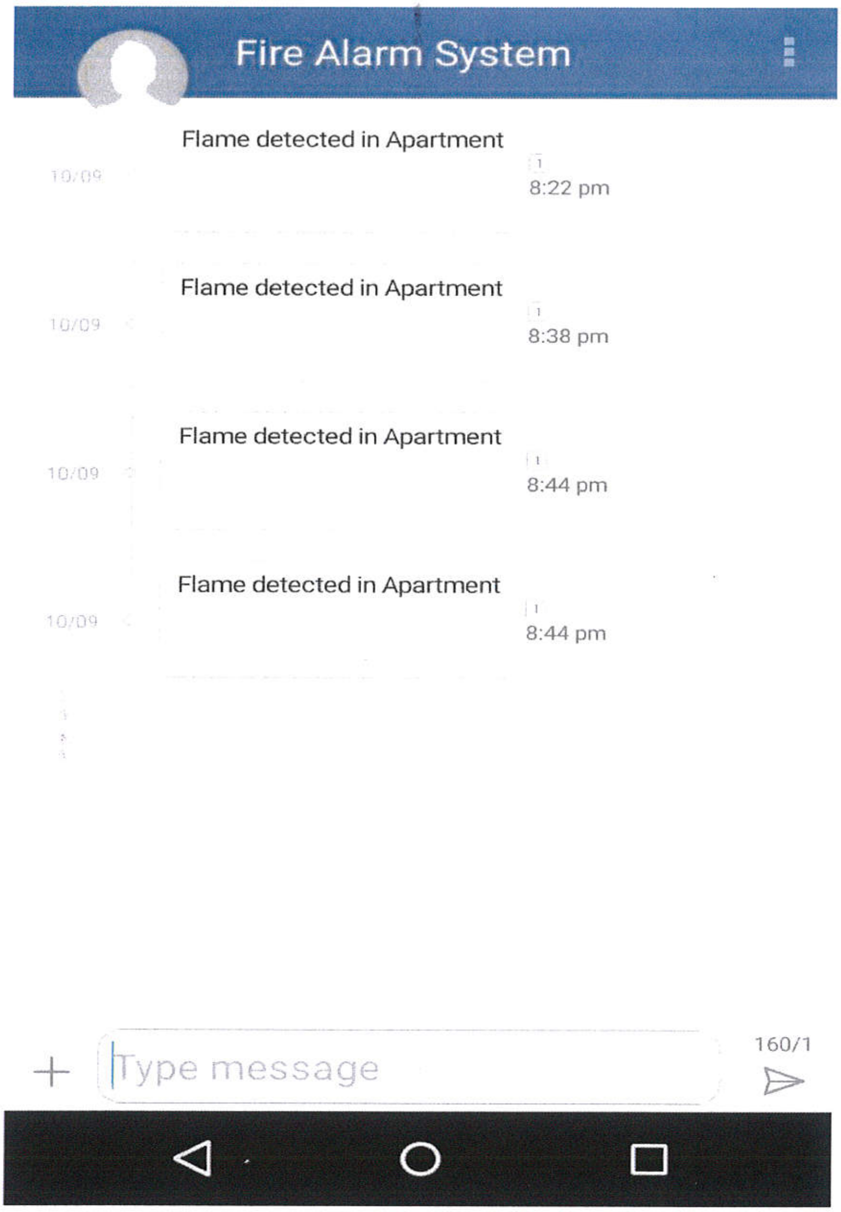

Fig 4.1: SMS Alert received stating "Flame detected' during testing

The above image was taken when the system was being tested in the presence of flames. Flame was detected which denotes the erupting of a burning fire and thus the GSM module was triggered to send an alert SMS to the registered emergency lines.

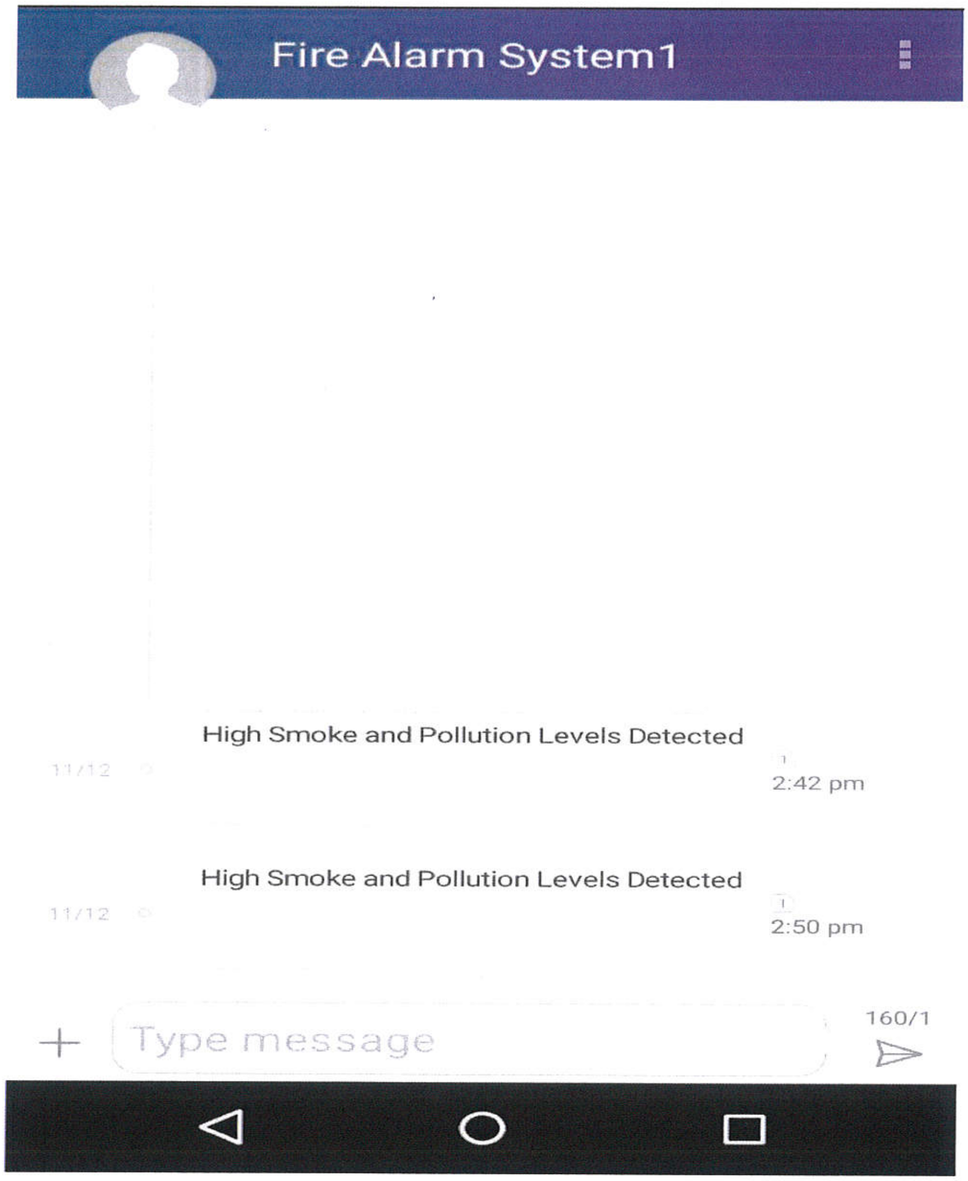

Fig 4.2: SMS alert received stating "High Smoke and Pollution Levels Detected"

The above image was taken when the system was being tested in a smoky environment. Smoke was detected to be above the preset critical value of 3800ppm and thus the GSM module was triggered to send an alert SMS to the registered numbers.

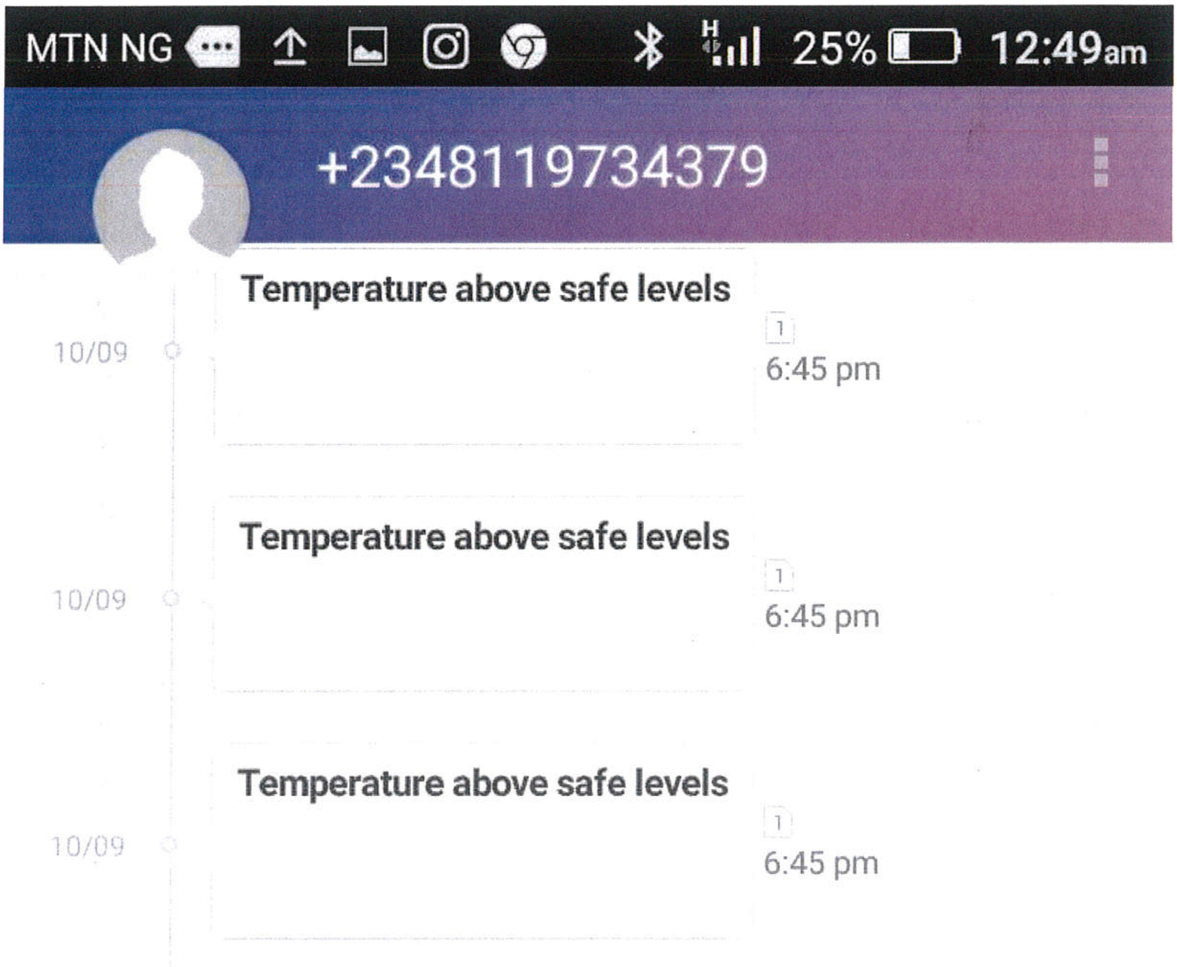

Fig 4.3: SMS alert received stating "Temperature above safe levels"

The above image is a screenshot taken when the system was being tested in a heated environment. Temperature was detected to be above the preset critical value of 70 C and thus the GSM module was triggered to send an alert SMS to the emergency lines.

4.3 Evaluation of the Designed and Implemented Automatic Fire Alarm System

The three sensors worked as per specifications, and reports were received by the three mobile numbers. It can be seen that the environmental triggers were held at varying distances from the sensors. This was to protect the target sensors from possible heat damage. This also shows that the sensors are quite sensitive to the environmental triggers, such as smoke/pollution, heat and flames.

In this model, the sensors were mounted at the apex of the structure for better performance, since warm air and smoke tend to rise high in an enclosed space. This arrangement improves the sensitivity and performance of the sensors.

In order to ensure that all the necessary specifications and requirements are met, the performance of the system was evaluated according to real life situations. Both the simulation program and the hardware have been tested in real scenarios by many users. The three major metrics that have been used are hardware testing, functional requirements and system response time

4.3.1 Hardware Testing

Under this section, components in the system hardware were tested independently using a Multimeter to ensure that every component is in good working condition. The system hardware components that were tested are the power source, GSM module, microcontroller, and sensors.

1. Testing the Power Source

It is important that the power source must be tested since it provides power to the entire system. Any damage that results from the power source may damage the entire system. The result of testing the power source shows us that, the voltage of the power source must be 5V, as any voltage that is less than or greater than 5V will not make the system work or will damage the system respectively. Also, the AC current to be used to power the power source must be within the range of 110-240V; any voltage greater than 240V will damage the power source itself.

2. Testing the GSM Module

The power consumption of the system based on measurements is approximately 5Volts x 200 mA= 1 watts on average, rising to 5 watts peak when the GSM module connects to the network to send SMS. With a 1000mah battery, this translates to approximately 1000/200 =5 hours in standby mode, but much less than that when there are frequent SMS dispatches due to environmental triggers. One of the contributors to a longer booting cycle is the fact that the GSM Module is switched off completely when there are no triggers.

This algorithm was adopted to conserve power and extend battery run time. Thus, the GSM Module does a cold reboot every time there is a trigger. Thus, power requirement is brought down to 1 watt in standby mode.

4.3.2 Functional Requirement

The system has been evaluated by different users using different GSM devices, and based on its response to different mobile devices, whether or not it sends correct information after detecting any of the physical properties, whether or not it sends notification in time, data management, user friendly and theft tolerance. See Table 4.2 below

Table 4.2: Performance evaluation of the designed automatic fire alarm system

Functional Requirements	**Yes**	**No**
Response to diverse mobile phones	Yes	
Send correct information	Yes	
Read correct soil properties	Yes	
Send notification	Yes	
Data management		No
Theft tolerance		No
User friendly	Yes	

According to the diverse users who tested the system, the system performance is excellent; the system has no tolerance for theft and its data cannot be altered. The system is user friendly and it can easily be used by everyone

4.3.3 System Response Time

To observe the performance and response of the system to adverse fire situations, 10 individual simulation tests were performed with varying smoke, gas, and temperature conditions. The result of the tests suggests the system renders desired alert responses under different test conditions reliably. The experimental set-up of the tests is shown in figure 4.4. During the tests, the time taken from fire detection to alert message (SMS) delivery via GSM network by the system was noted. The maximum time taken by the system to deliver alert SMS was 40 seconds (test no. 6), and the minimum time was 28 seconds (test no. 2) approximately. As it is seen, on an average, the designed system takes about 28 – 40 seconds to deliver alert SMS to the emergency lines, which is quick enough to undertake necessary measures to avert and mitigate fire hazards.

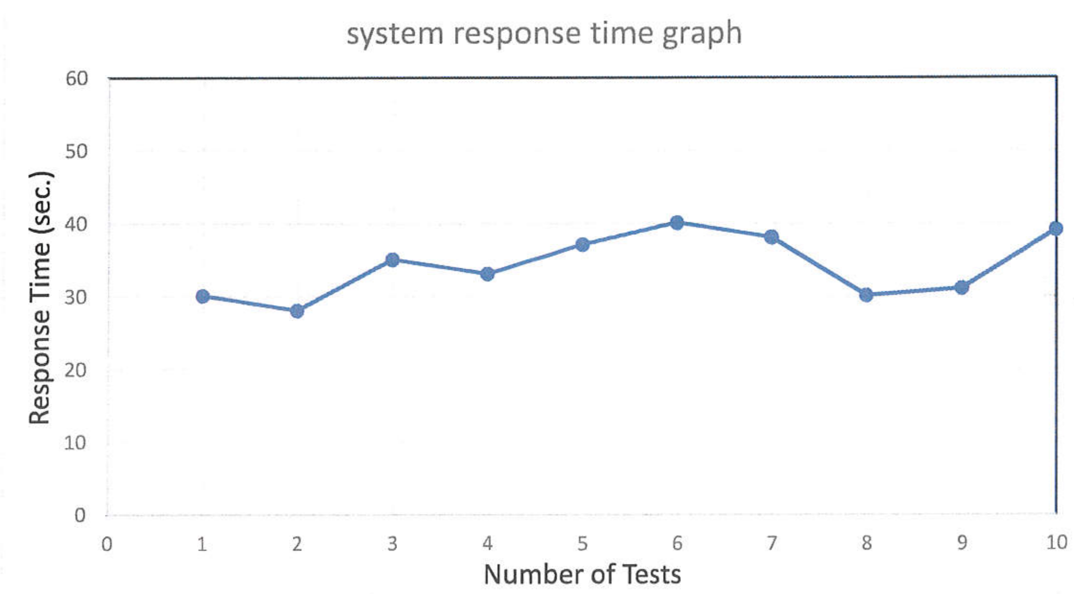

Fig. 4.4: system response time graph

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This design system is be able to detect an erupting fire, alert occupants of the building, notify the concerned recipient, extinguish the source of the fire before the occurrence of such hazard, thereby proffering an eventual prevention of fire outbreaks and its fatalities, hence, saving lives and properties. The objective of this project was met since the system works effectively.

During the implementation of this project, the problems and weaknesses of earlier similar systems were reviewed in detail with the sole aim of having a better and more desired product quality. This project is implemented as a hardware, of which the major components include Arduino microcontroller, phone device, Wireless Adapter and flame sensor. The result from this project has proven that the system is scalable, accurate and energy efficient therefore, it is useful in homes and industrial environments to help reduce the risk of death and injuries caused by fire, and furthermore to avoid the losses that need to be borne by the victims.

This project is of significant benefit as an automatic notification system in situations of erupting fire. A major advantage of this project is that it explores the weaknesses of earlier similar systems by measuring simultaneously three physical environmental quantities which are the most probable symptoms of fire as a means of intensifying fire outbreak prevention measures. Furthermore, the simultaneous measure of these three quantities, help to reduce the probability of false-positive alerts.

The cost of implementing this system is relatively low since the components used are relatively cheap and are easily available in the market. This system is designed with a rechargeable power unit that can be directly plugged to the mains (240V AC) source given the appropriate operating voltage.

5.2 RECOMMENDATIONS

Human safety is a very crucial aspect in both domestic and industrial setting, hence use of an automatic fire alarm system is inevitable in addition to other more sophisticated security systems.

This system should be placed in a cool and dry place in order to ensure a longer life span. It should also be placed in a high position in the room and in the direction of the window which is most likely to be the direction of the wind to facilitate the contact of the sensor with the smoke or gas.

Further mitigation measures such as overhead water or sand sprinkler and automated fire extinguishers were not explored in this project due to time constraints. These can be implemented in future designs.

5.3 LIMITATION AND CHALLENGES

While this project is designed to protect human lives and valuable properties from fire hazards, it has a limitation and challenges which are as follows;

I. Prompt notification of erupting fire incidence is dependent on availability of good and fast internet network connection at both the system' and receiver' locations.

II. When components got destroyed, it resulted to incurring some extra costs and the need to ship the replacements thereby causing delay in implementation time usually running into a month or two for arrival of replacements.

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Appendix A

BILL OF ENGINEERING MATERIALS

S/N	ITEM DESCRIPTION	QUANTITY	UNIT COST (NAIRA)	TOTAL COST (NAIRA)
1	Air Quality Sensor (MQ-9)	1	800	800
2	Temperature Sensor (LM35)	1	80	80
3	Flame Sensor	1	2500	2500
4	ATMEGA328 microcontroller	1	800	800
5	SIM808L GSM module	1	15000	15000
6	Lithium Ion Battery	1	800	800
7	USB Port	1	300	300
8	Power switch	1	70	70
9	Arduino Uno board	1	4000	4000
10	Resistors	25	5	125
11	Capacitors	10	30	300
12	Potentiometer	2	150	300
13	Veroboard	1	350	350
14	Buzzer	1	200	200
	TOTAL			25,625