

REAL TIME GAS MONITORING USING WIRELESS SENSOR NETWORK

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Real Time Gas Monitoring System Using Wireless Sensor Network

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Supervisors' Certificate

This is to certify that the work presented in the dissertation entitled *Guidelines for Real time gas monitoring system using wireless sensor network* submitted by *Varsha Chandravanshi*, Roll Number *214MN1509*, is a record of original research carried out by him under our supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Technology in Mining Engineering*. Neither this dissertation nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

Dr. B. K. Pal
Professor

Dedication

Dedicated to my Parents.

Signature

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ABSTRACT

Miner's safety is the main issue in the present era. Miner's health is affected by many means which includes unstable and cumbersome underground activities and awkward loads, heavy tools and equipment, exposure to toxic dust and chemicals, gas or dust explosions, improper use of explosives, gas intoxications, collapsing of mine structures, electrical burn, fires, flooding, rock falls from roofs and side walls workers stumbling/slipping/falling, or errors from malfunctioning or improperly used mining equipment.

In earlier days for detection of gases canary and small animals are used but they didn't provide the exact condition of the mines so safety in mine is not guaranteed. Hence there is a need of monitoring system which utilized the ZigBee wireless sensor network technology.

There are two units of the monitoring system Sensor unit and Monitoring unit. Sensor unit will be placed in the underground section and Monitoring unit will be placed in the above the mines from where monitoring is done.

Firstly, the Sensor unit is placed in the underground section of the mine. Where input is taken from the sensors in terms of Methane (CH_4) i.e. MQ-2 sensor, Hydrogen Sulphide (H_2S) i.e. MQ-136 sensor, and Natural Gases i.e. MQ-5 sensor. Then they are compared with their threshold value by the Microcontroller Module and if the value is above the threshold value, the Buzzer starts ringing meanwhile data is displayed in the Display module and sent to the Wireless Communication Module of the Monitor unit i.e. end device or coordinator through the Wireless Communication Module of the Sensor unit i.e. router.

In this way the study can help the miners get relief from any casualty and ultimately save their lives. The device encompasses a large range of networking. The data can also be stored for future investigation. The device is also durable and cost effective with a price of approx. Rs. 6,500 to 7,000/-.

Keywords: ZigBee Technology; Wireless Sensor Network; Sensor Unit; Monitoring Unit; Mine Safety; Microcontroller Module; Data Acquisition Module

ACRONYMS

WSN	Wireless Sensor Network
XBee	ZigBee
MAC	Media Access Control
ADO	Active Data Object
CAN	Controller Area Network
ARM	Advanced Risk Machine
CPU	Central Processing Unit
ASK	Amplitude Shift Keying
F-ASK	Frequency Amplitude Shift Keying
D-ASK	Digital Amplitude Shift Keying
IC	Integrated Circuit
IR	infra-red
GSM	Global System for Mobile Communication
GPRS	General Packet Radio Service
RF	Radio Frequency
A	Ampere
V	Volt
KW	Kilo Watt
PPM	Parts Per Millions
PPB	Parts Per Billions
USART	Universal Synchronous Asynchronous Receiver and Transmitter
KB	Kilo Byte
TTL	Transistor Transistor Logic
LCD	Liquid Crystal Unit
IDE	Integrated Development Environment

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Chapter 1

INTRODUCTION

1.1 INTRODUCTION

The extraction of minerals has been going ahead since ancient time, in numerous parts of the world. Today, mining exists in many nations and incorporates investigation for minerals, extraction of minerals, and planning, including pulverizing, crushing, focus or washing of the separated material.

The conventional picture of the working conditions in mining and quarrying is that the work is physically requiring and risky because of unstable underground, cumbersome and awkward loads, heavy tools and equipment, exposure to toxic dust and chemicals, gas and dust explosions, inappropriate use of explosives, gas intoxications, subsiding of mine structures ,electrical burn, fires, flooding, rock falls from roofs and side walls workers stumbling/slipping/falling, or errors from failing or inappropriately used mining apparatus.

The safety society in mine activities demands serious action. Education to workers to do their job in protected way, but however supported devices and safe guidelines also important aspects of the safety society.

Table 1.1: Statistics of Accidents [25]

Sr. no.	Date of Accident	Name of Mines	Fatalities	Cause
1.	14/03/1954	Damra	10	Explosion of Fire Damp
2.	05/02/1955	Amlabad	52	Explosion of Fire Damp
3.	19/02/1958	Chinakuri	175	Explosion of Fire Damp
4.	28/05/1965	Dhori	268	Coal Dust Explosion
5.	18/03/1973	Jitpur	48	Explosion of Fire Damp
6.	04/10/1976	Suhamdih	43	Explosion of Fire Damp
7.	04/10/1976	Baragolai	16	Ignition of Fire Damp
8.	24/08/1981	Jagannath	10	Water Gas Explosion
9.	25/01/1994	New Kenda	55	Fire / Suffocation by Gases

In coal mines major no. of accidents occur due to gas explosion. With the knowing of the exact gas concentration these accidents would have been avoided. In Dhori colliery (1965) Dhanbad (India), 375 miners died due to firedamp and coal dust explosion and in Chasnala (1975) colliery Dhanbad, 372 people died because of coal dust explosion under the deep mine. Statistics of accident due to gas explosion is shown in the above table. So the designed Real Time Monitoring System provide the concentration of gases more precisely.

1.2 BACKGROUND AND MOTIVATION FOR THE PRESENT RESEARCH WORK

Underground mine ventilation gives a discharge of air to the underground workings of a mine of adequate volume to mitigate and expel dust and toxic gasses (commonly NO_x, methane, SO₂, CO₂, and CO) and to adjust the temperature. The origins of these gasses are apparatus that runs on diesel motors and blasting with explosives and the ore body itself. The biggest part of the operating expense for mine ventilation is power to control the ventilation fans, which may represent 33% of a run of the mill underground mine's whole electrical force cost.

Early days, miners convey animals like a bird or canaries with him while he comes under the mine. The miners will plainly comprehend the circumstance of mine, for ex. Gas spillage by the method for the feeling of the smell from animals. Now a day's Gas detection instrumentation is utilized, for example, gas monitor, atmospheric monitoring system, hand-held gas indicator, and so on. The handheld gas detector is currently used by a few mineworkers to make intermittent estimations of gases in the working surface, but the hypothetically explosive of gases is cannot be avoidable. Since it is not viable placing gas monitors in all regions where miners may travel or work. Handheld gas monitors are commonly just utilized by a few miners for occasional estimations of gases close to the working surface.

Regarding monitoring, we have two type of monitoring i.e. online monitoring and Real-time monitoring. Real-time monitoring is advantageous over online monitoring. Real-time data monitoring (RTDM) is a procedure through which an administrator can survey, assess and change the expansion, erasure, alteration and utilization of information on programming, a database or a system. It empowers information managers to audit the general procedures and capacities performed on the information progressively, or as it happens, through graphical outlines and bars on a focal interface/dashboard.

Environment monitoring in underground mining (which are typically long and narrow, with lengths of many kilometres and widths of a few meters) has been a vital task to assure safety of the working circumstances in coal mines where numerous environmental factors, including the measure of water, gas and dust, should be monitored. And to attain a monitoring of the mine surroundings, test information should be gathered at various places. A rigorous background summary requires a high testing thickness, which includes a huge number of devices. Existing strategies for coal mine surroundings observing are usually led in a short and manual way, because of the absence of relating methods for designing a programme enormous scale sensing system.

Using wires to associate detecting focuses to the preparing server requires a significant number of cable deployments, which are arduous on account of high maintenance costs and poor working conditions in underground. Also, the wired communication system makes system less versatile; as tunnel propels, all the detecting device should be conveyed. In this circumstance, wireless monitoring exploits advantageous furthermore, adaptable modification. Because of the unpredictable interference brought about by the concurrence of working equipment and excavators. However, it is usually impractical to continue direct wireless communication channels among the processing server and sensing device. With the type of tunnels make wireless communications directly impossible too.

A wireless network, which utilizes high-frequency radio waves as a replacement for wires to communicate between nodes, is an another choice for corporate or home networking. Organizations can use this option to extends their existing wired network or to go totally wireless. Wireless takes into consideration for devices to be shared without networking wire which expands mobility, however, decreases range. There are two primary short of wireless networking; infrastructure and peer to peer or ad-hoc.

A sensor network encompasses of different detection stations called as sensor node, each of which is lightweight, small and adaptable. Each sensor node is outfitted with a microcomputer, transceiver, transducer and power source. The sensor creates electrical signals given detected physical effects. The microcomputer processes and stores sensor yield. The transceiver gets the summons from a central PC and transmits information to that PC.

The power for each sensor node is given by a battery. Wireless system has advantage over wired system in terms of Installation, Visibility Node to Node, Visibility Network to Network,

Time to Installation, Cost, User Connectivity, Mobility, Reliability, Speed and, Bandwidth Cables Ethernet, Hubs and Switches, Security, Types Local Area Network(LAN), Standards, Signal Loss and fading, Interference Less, Connection Setup time, Quality of Service. In WSNs, the quantity of nodes is much greater than any conventional wireless network. Contingent upon the application, nodes may be in an order of millions. In this manner, it requires a particularly adaptable solution to ensure sensor network operation with no interruption.

WSNs have a collection of sensor nodes because this location is not allowed to them. Rather than address-centric sensor networks are information-centric. Operations of sensor systems are concentrated on information rather than individual sensor node. In this manner, sensor nodes need cooperative endeavours. Most of the conventional wireless networks utilizes point-to-point communication while sensor network uses telecast communications. Sensor node is much cheaper than nodes in ad-hoc network. WSNs are environment-drive or event-driven. Sensor networks create or gather data when any event happens on the other hand environment changes while human produces data in conventional systems. Thus, activity pattern changes with time.

Mobile ad-hoc Networks (MANETs) are intended for distributed processing while sensor networks are mostly used to accumulate data. Information collected from neighbouring sensor nodes is exceedingly connected. It has additionally been observed that ecological quantities changes gradually and some successive readings, detected from sensor nodes are correlated. And it is a one of kind of sensor networks, which give a chance to develop proficient energy protocol for transmitting and collection.

This protocol lessens redundant and traffic information in the network and draw out network lifetime.

Wireless communication has the accompanying points of interest:

- I. Communication has upgraded to pass on the data quickly.
- II. Working experts can work and get to Internet anyplace and at whatever time without conveying links or wires wherever they go. This additionally helps to finish the work on time and enhances the efficiency.
- III. Urgent circumstance can be cautioned through wireless correspondence.
- IV. Wireless systems are less expensive to introduce and keep up.

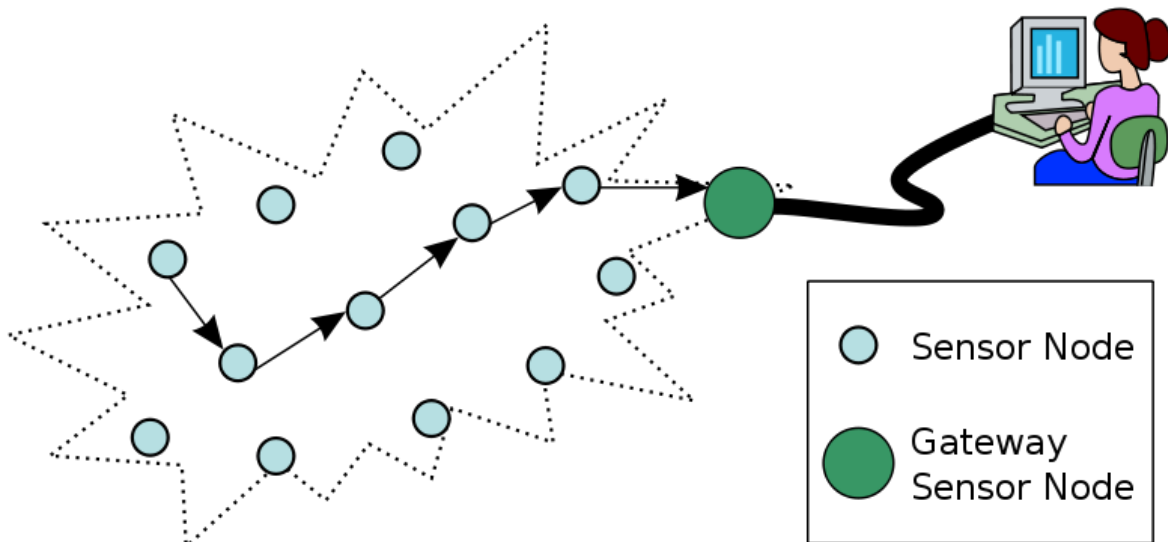


Figure 1.1: wireless system network [26]

ZigBee, a wireless communications protocol, with a safe, reliable and short distance, one can use ZigBee for collecting the several parameters of the station transmitted to a sensor, and then use wired data transmission on the ground principal control computer, and from computer observation and the comparison of the data for examination the security situation under the Mines. To accomplish the objective area underground, ecological and other constraints of the remote accumulation can give exploratory premise to relief. Underground mine environment, interference immunity, the difficulty of the power utilization, and thus has more rigorous requirements. Consequently, based on ZigBee innovation, mine security observing framework has an exceptionally vital criticalness.

1.3 OBJECTIVES OF THE PROJECT

The main objective of the project was to design monitoring equipment which can senses and monitor some gases and take action accordingly.

The research investigations were accomplished with the following objectives:

- Create an Arduino, ZigBee-based real-time monitoring system for improving the safety of the mine.
- Detection of various toxic gases inside mining environment.
- Trigger the alarm according to the data if data crosses the specified dangerous level.
- Gather the data from the ground node and send it to monitoring node using ZigBee.

1.4 LAYOUT OF THE THESIS

Chapter-1: Gives the brief review of the research work, motivation & background for research work, motivation & background for the work, objective, analysis & organization of thesis.



Chapter-2: Involves the literature review for comprehensive analysis of ideas associated with the design of WSNS.



Chapter-3: Give details about different gas present in mine environment and their impacts.



Chapter-4: Consists of detail idea about methodology & implementation of WSN, with a brief discussion of each component associated with it.



Chapter-5: Shows the results acquire from the measuring & monitoring under the mine environment.



Chapter-6: Concludes with the results of the study & suggest the future scope of work.

1.5 CONCLUSION

This chapter gives the brief review of the research work, motivation & background for research work, motivation & background for the work, objective, analysis & organization of the thesis.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter includes all the overview and previous work has been done in the field of monitoring system using wireless sensor network.

2.2 OVERVIEW OF PREVIOUS RESEARCH WORK

Many studies have been attempted on the monitoring system using wireless sensor network in mines and the corrective measures to mitigate the problem. The following portion presents past inspection lives up to desires completed by distinctive researchers in India and abroad. It gives a reasonable idea regarding control element, its amendment techniques, and different approaches to mining.

Li and Liu (2001) aimed the safety in coal mines and gave a Structure-Aware Self-Adaptive (SASA) WSN system. And by balancing mesh sensor network distribution and constructing a cooperative mechanism which is based on a regular inspirational strategy. SASA can detect structure variations because of underground collapses and develop a sturdy and robust mechanism for effectively handling of queries under the unstable circumstances. For better evaluation of the reliability and scalability of SASA, a large-scale trace-driven simulation which is established on data composed by the experiments is conducted. [1]

Si-Yuan (2008) analyses the energy efficiency of MAC protocols and compares the S-MAC protocol with T-MAC protocol by their working principles for energy efficiency and established a mathematical model and perform the simulation with NS-2 and gives the result that T-MAC protocol utilized less energy, also satisfies the invisibility of communication. [5]

Zhang (2008) described hardware architecture for mini intelligent methane sensor algorithm which is used for maintenance free technique and technology in WSN with the help of intelligent methane sensor real-time methane monitoring network is formed, and it is used for data collection along with calibration and diagnosis of the data through sensing node. As conventional calibration system in this system no need to make standard gases. [4]

Hongjiang et al. (2008) proposed a system for coal mine safety. This system uses communication technology CAN bus and ZigBee technology with low power ARM processor chip S3C2401. Given system improves scalability, enhances the flexibility and

reduces the cost. This paper gives knowing about ZigBee standard topology (Star, Mesh, Cluster). [3]

Wenge et al. (2009) proposed a mine safety system on the principle of B/S and C/S mixed mode by use of the network technology, virtual instrument technology and data base technology. The system has the underground substation, sensors, ground monitoring center for remote clients, throughout internet explorer. Client can check the data such as (wind speed, gas, carbon monoxide etc.). Data is stored in the system by ADO in LabVIEW for web application interface ASP technology is used. [6]

Wei and Li Li-Li (2009) designed a multipara meter WSN monitoring system which works on the ZigBee technology for the coal mine. This system gives real-time monitoring for underground mine and production parameter, warning by the variety of sensors and WSN. This system utilized the RS-285 communication protocol and hardware modular. This is the expansion of wired coal mine security system. [8]

Weng et al. (2009) presented a Mine-Auxiliary Sensor System (MASS) that system monitors all situation in mines which is named as Real-Time Mine Auxiliary Monitoring System (RMAMS) and for communication D-ASK and D-FSK is used. This system has Mine Auxiliary Sensor System (MASS) in which System Main Control Computer (SMCC), System Control Interface Unit (SCIU) are there. MASS involved CPU, RF transceiver IC, a gas sensor (water check sensor, a microphone sensor, pressure sensor), rechargeable battery, LED, AC to DC converter, a mercury switch, speaker, active sensor, and repeater. Comparison for various communication protocol standard is done i.e. for Wi-Fi, D-ASK, ZigBee, Bluetooth, and D-FSK in terms of speed, band, distance, consumption, capacity and cost and application. As for mine system real time monitoring and power system play the important role. So RMAMA D-ASK is used in these system as it spends less power and cost. [6]

Bin and Huizong (2011) elaborated a method of Mine Safety Monitoring System depend on ZigBee, and the hardware outline of the ZigBee sensor node and software system design takes up. The self-organizing routing algorithm for ZigBee systems and the gateway configuration and systems integration are also studied. ZigBee-based Mine Safety Observing System can accomplish an assortment of wellbeing variables of creation, and underground environment, (for example, gas, temperature, moistness and other natural markers) for observing, controlling mine generation, safety administration for providing a good source for decision creating. [11]

Molina S. et al. (2011) pointed out the accident causes in coal mines and issues while implementation of an efficient monitoring in the presence of gases (carbon monoxide, carbon dioxide, methane) and micro seismic events in underground mines. This paper explores identification of unstable areas, different types of gasses (electrochemical gas sensor, solid state gas sensor), micro seismic monitoring sensors transducer; location algorithm and WSN character) benefit, opportunity, cost, risk, range of variables, range of measurements, principles of operation, accuracy, location and time of request for booth cases. [9]

Vandana and Sundheep (2011) compared the different transmission media and came out with an automatic real-time monitoring system for coal mine. The underground module of the system assembles humidity, temperature, methane values and number of persons inside the coal mine by an IR sensor, transmits the information to information processing terminal which is based on ARM. The node sends the data for the ground section via ZigBee, and the processing terminal monitors the data in the ground section and transmits the data to the PC and the data can be saved for remote users to examine as well as a SMS is send to the member via GSM modem which is connected to a controller. After data reception, data is matched with the certain threshold values, if the data exceeds than the threshold value then buzzer will start alarming and warning to the person will occur. [20]

Zhu et. al. (2011) described a Mine Safety On-line Monitoring System for coal mine with the low cost, simple structure and low power consumption with improved production safety, level of monitoring and reduced accidents. It is build up by nRF905 and MSP430 and working principle, structure of the system, flow chart of software and hardware design of the sensor nodes is described. In this paper whole system is divided into three parts i.e. Data Acquisition Module comprises of KGS-20 such as the gas sensor, SHT11 as temperature/humidity intelligent sensor, EC21B such as wind speed sensor, Data Processing Module (16-bit ultra-low power microcontroller MSP430F149), and Wireless Communication Module (nRF905). [13]

Xuwen and Yun (2012) carried out wireless sensor networks (WSNs) for the tungsten mine environment monitoring system. In this system, Sensor nodes are arranged under tungsten mine. Which transfers several safety indicators in the mine by the gateway node via the cluster head nodes i.e. indirectly or directly, then by transmission network data is uploaded to the ground monitoring centre via the gateway node. The system has ATmega128L low-power single-chip (microprocessor), SHT11(temperature sensor), KE-25 (humidity sensor) and T6004 (Oxygen (O₂) and Carbon dioxide (CO₂) sensor) and LED module (display unit), buzzer (such as sound component for alarming), CC2420 wireless transceiver chip (for the

core in the communication module), AA batteries. It efficiently took used of the microcontroller that has the characteristics of strong function, high assimilation, low power consumption, small capacity, reliable performance, and sending and the monitoring of the data via WSNs. [14]

Bo et.al. (2012) gave a RESTful Web services mashup enhanced coal mine safety monitoring and control automation system using ZigBee WSN, which can collect the underground humidity, temperature, methane values and position via sensor nodes inside the coal mine and then implementation of a RESTful Application Programming Interface (API) for sensor nodes to avail access to sensors and actuators, allowing them to be easily combined with other information resources which are based on the success of the mashup applications. three different conditions for RESTful Web service mashups showing for coal mine safety monitoring and the control automation. [15]

Yi-Bing (2012) offered a computer-controlled monitoring system for coal mines. The system integrated three subsystems that are monitoring subsystem, communication subsystem, and control subsystem. Monitoring subsystem is consisting of wind speed, gas, temperature and negative pressure sensors, which are present in the mine and used for developing a real-time monitoring. The communication subsystem composed of Coordinator node, Router node and End node for performing wireless communication. communication subsystem and monitoring subsystem enact a network with a central controlled computer which is located on the surface via CAN buses. The system simultaneously transmits real-time data to the host computer which is located in the management centre and the mobile phone of the authorized employees via GPRS module, when the data exceeded by the limited values, buzzer will ring. It reduces maintenance difficulties, venture on underground lines-laying and ensures accurate, appropriate and rapid transmission of information in all underground mining zones and improves the productivity of the system with powerful function, easy building up, good-extendibility and high-reliability etc. [18]

Garde and Kotgire (2013) provided a better solution of safety system in the coal mines using ZigBee WSN. The proposed system assembles humidity, temperature, and methane values in an underground section of the coal mine by ZigBee sensor nodes and then sends the same data to the receiver, present at the ground section of a coal mine. If the received value crosses the threshold level, then buzzer starts alarming, and the same data will be display on the LCD screen, present at both underground and ground section. [14]

Dange and Patil (2013) explored critical situations in the coal mine. For reducing the cost and improving the productivity with product quality the automation in the coal mine is

necessary. This paper gave a design of a WSN which comprises of MSP430xx controller (low power, cost effective) for monitoring the temperature (LM35 sensor), gas, humidity (SYSH220), and smoke in underground mine. This system also supervises the ventilation claim to miners according to the present climate conditions in the mine field. a wireless ZigBee transceiver for wireless transmission of data at the central location for controlling the climate state by the help of valve and motor control circuitry. [19]

Doddi and Anuradha (2013) proposed a coal mine monitoring system using ZigBee WSN. This comprises of two sections i. e. Underground section (sensors for humidity, temperature, gas, and microcontroller, LCD and ZigBee transmitter) and ground section (ZigBee receiver, GSM modem, LCD). [21]

Ashish Kumar et al. (2013) suggested a wireless sensor node architecture for mines. Which comprises of sensing unit, the processing unit, and a transmission unit. Sensing unit has a sensor at the node (for collecting data on the ground). Sensing units are composed of two subunits: sensors (translate physical changes to electrical signals) and analog to digital converters. Sensors can be either analog or digital which can measure temperature, image, magnetic fields, light intensity, sound, etc. The processing unit provides commands to the sensor node. The processing unit comprises a microprocessor for controlling the sensors, executing the communication protocols and processing the signal algorithms by the gathered sensor data. Transmission Unit has all the transmission related data that transceivers can be operated in Transmit mode, Idle mode Receive mode, and Sleep mode. [22]

Archana and Mudasser (2013) developed an ARM based embedded system which is used for monitoring the parameters inside the mine and transmitting the data in the wireless form for better monitoring and visualization with the help of XBee module with LPC2148, Methane, and CO Gas Sensor, Light intensity sensor TSL235R. [23]

Shrivastav and Ranjan (2013) studied the wireless sensor network and different topologies to be chosen for the wireless sensor system relies on upon the premise of the data redundancy, area to be covered and energy optimization issues like star topology, ring topology, and mesh topology. [10]

Yao and Tian (2014) gave a design of a roof abscission layer using wireless monitoring system 433MHz RF technology. The nodes under the ground form a distributed wireless network and Monitoring sub-stations, communicate with each other by wireless data transmission module. In this system sub-stations, connecting to the remote monitoring centre through underground fiber-optic ring network, and are the network gateway, which is liable for managing nodes across the sub-station and for collecting monitoring data. Nodes use the

displacement sensor for monitoring the roof separation displacement data and MSP430 chip as a microprocessor which has an auto sleep function, low power, and several ways to wake up characteristic. It monitors the roof separation displacement information in real-time as well as send the warning message and but reduces the installation and maintenance cost. [16]

2.3 CONCLUSION

The chapter clarifies all of the previous work done related to the monitoring of mine safety. The different analysts have done their work in this field and came out with their particular systems of reconnaissance for the mine gases. By referring their study, the accompanying work is a spontaneous creation on the ongoing checking of the real-time monitoring system with wireless system technology of data transmission.

Chapter 3

MINE GASES WITH THEIR IMPACT

3.1 INTRODUCTION

The air in Earth's atmosphere is composed of the mixture of different gases and each gas has its inheritance. The mixture comprises gases of constant concentrations and variable concentrations of both time as well as space.

3.2 COAL MINE GASES

Mine gases are the harmful vapours that are produced during mining operations. At the same time, this released gas is 30% diluted with the environmental air and changes the mine environment. The impurity is formed as the result of repeatedly blasting of hard rock with explosives, drilling, burning of light, gases are given off from strata, underground fire and barring, the underground mine becomes restricted and dangerous owing to the presence of noxious and poisonous explosive gases.

There is certain mining term for explosive mixture and are frequently called as damp.

They are generally differentiated into the following categories:

- **Fire damp** is synonyms for an inflammable gas in coal mine specially for methane. It also has the small amount of ethane and propane.
- **After damp** is the toxic combination of gases left in the mine after an explosion caused by coal dust and firedamp. This leads to black damp. It consists of carbon monoxide carbon dioxide, and nitrogen.
- **Black damp**, is also known as "choke damp" or "stythe" when the high concentration of carbon dioxide is mixed with nitrogen then black damp is generated and is an atmosphere in which a flame lamp will not burn. Their mixture in the air can cause physical effects or death by suffocation by taking place of environmental oxygen but it is neither poisonous nor combustible by itself.
- **White damp** is a noxious composite of gases given off by the combustion of coal, in an enclosed environment like the coal mine. Mainly used for carbon monoxide(CO) and is an illuminating gas, very poisonous and supports combustion.
- **Stink damp** is usually referred for hydrogen sulphide (H₂S).

Source of toxic gasses in mining can be divided into five categorise as follows:

1. Gases by Blasting:

Blasting operations yield both poisonous and nontoxic gases; the poisonous gases consist of most part the oxides of nitrogen (NO_x) and carbon monoxide (CO). The amount of poisonous gases delivered by a blasting is influenced by confinement, formulation, and contamination of the explosive with water, an age of the explosive, or drill, cuttings, etc. As oxygen is expended in any such blast, oxygen inadequacy may also be an issue.

2. Methane by Coal Beds:

Exceptionally ignitable methane (CH₄)/firedamp, is enclosed in the last segments of coal organization, and due to depths and pressure, it grows to be entrenched in the coal. Methane gas is given off into the air. As excavations are done along with from the coal transportation from the surface.

3. From Vehicle Exhaust:

Flue gas or exhaust gas is discharged as the result of the burning of fuels, for example, regular gas, petrol, gasoline, diesel fuel, biodiesel blends, fuel oil, or coal. As per the kind of engine, it is released into the environment through a flue gas stack, an exhaust pipe or propelling nozzle. It regularly disperses downwind in an arrangement called an exhaust plume. In mining diesel vehicles are utilised and nitrogen dioxide and carbon monoxide and additionally oxygen insufficiency are of concern.

4. Underground Explosions and Fires:

A gas explosion is a combustion coming out because of a gas leak within the presence of an ignition source. The principal hazardous gases are methane, natural gases, Propane and butane since they are utilized for heating purposes. But many other gases, like methane and hydrogen, are combustible and are caused because of explosions in the past.

5. Drilling into Still Water:

Pockets of the stagnant water can also contain a bulk amount of hydrogen sulphide coming about basically from the interruption of pyrites.

Some mining gases with their impacts are as follows:

3.2.1 NATURAL GASES

Natural gas is a volatile mixture of hydrocarbon gases and is considered a fossil fuel. In the earth when gases are discharged from the decaying entity and under pressure over billions of years. Gas is a colourless, tasteless, odourless, and non-toxic gas. An intense chemical called mercaptan should be added in a very small amount of the gas, for giving the gas a particular odour of the rotten eggs as the gas is odourless. Natural gas is, for the most part, aggregated of methane (up to 90%) with the rest comprising of ethane, butane, propane, hydrogen sulphide carbon dioxide, nitrogen, oxygen, and trace measures of rare gases. It comes in four forms:

- Liquefied Natural Gas, (LNG)
- Regasified Liquefied Natural Gas, (RLNG)
- Compressed Natural Gas, (CNG)
- Piped Natural Gas, (PNG)

Sources of Natural gases

Natural gas sources can be differentiated into two types based on the production of the rock characters: conventional natural gas and nonconventional natural gas. The conventional natural gas is released by an all-around bore in a geologic development in which the cistern and fluid qualities allow the natural gas to flow promptly to the wellbore. Nonconventional natural gas does not exist in these traditional supplies and this regular gas takes another structure or is available in a distinct development that makes its different extraction compare to conventional sources.

Uses of Natural gases

It is used for the production of electricity, as vehicle fuel, pipeline and distribution, preheating glasses, waste treatment and incineration, melting glass, drying and dehumidification and in many processes (like metals, pulp and paper, stone, petroleum refining, chemicals, glass, clay, plastic and food processing industry).

3.2.2 METHANE (CH₄)

Methane is an odourless, colourless, flammable gas, tasteless, and lighter than air with a wide distribution in nature. It burns promptly in air, producing carbon dioxide and water vapour.

Sources of Methane

- **Underground Mining:** Methane gas released in all coal mines, given off in pores inside the coal seam.
- **Surface Mining:** it also results by surface mining
- **Post-Mining Activities:** coal mining activity like transportation, extraction, distribution, crushing it is released.
- **Abandoned Mines:** Methane releases from the breakdown of the surrounding rock strata after an area of coal seam have been mined and the artificial rooftop and wall support are expelled as mining advances to another area.

Impact of CH₄

Methane is poisonous and highly combustible. It may produce explosive mixture with air. It may lead to oxygen deficiency in air, and cause suffocation because of the High concentration of methane. Breathing high amounts of the methane can also lead nausea, slurred speech, vomiting, agitation, flushing and headache. Breathing coma, heart complications and death may cause in severe cases. Frostbite may be caused when skin is contacted with liquefied gas. Asphyxia may be the result if the oxygen percentage is decreased to beneath 19.5%.

3.2.3 HYDROGEN SULFIDE (H₂S)

Hydrogen sulphide is a colourless, highly poisonous and combustible gas. As it is heavier than air, it has a tendency to collect at the base of inadequately ventilated spaces. Its smell is like rotten eggs and is in some cases called hydro-sulphuric acid, stink gas or sewer gas.

Sources of H₂S

It normally found in raw petroleum, hot springs, and natural gas and is released by bacterial breakdown of natural materials and animals and human wastes (like sewage). Modern industrial activities that can also produce the gas which are wastewater treatment, petroleum and natural gas drilling and refining, coke boilers, Kraft paper plants and tanneries. It can be existing as a liquid compressed gas.

Impact of H₂S

Hydrogen sulphide is a concoction asphyxiates and irritant with consequences for both oxygen use and the central anxious system.

Low concentration of gas irritates the nose, eyes, throat and the respiratory system (as squatness of breath, burning or slitting of eyes, cough,). Even asthmatics may feel some breathing problems.

The moderate concentration of gas results more severe respiratory and eye irritation (like an accumulation of fluid in lungs, coughing, difficulty breathing), dizziness, headache, vomiting, nausea, staggering and excitability.

High concentration can cause extremely rapid unconsciousness, convulsions, shock, inability to breathe, coma and death. Effect can happen possibly in the few breaths or even within single breath.

Table 3.1: Concentration of H₂S in the air with their Health Effect and Category [27]

Concentration of H ₂ S in the air (in ppm)	Health Effect	Category
0 -10 ppm	Irritation of the nose, eyes, and throat	Good
10 – 50 ppm	Headache, Coughing and Breathing problem, Nausea and Vomiting Dizziness	Moderate
50 – 200 ppm	Eye irritation or acute conjunctivitis Severe respirational tract irritation, Convulsions, Shock, Coma, Death in severe cases	Very poor

3.2.4 CARBON MONOXIDE (CO)

Carbon Monoxide is tasteless, colourless, and odourless and it has specific gravity same as air. It is very noxious at low concentrations too and in the blood stream. It is combustible in the air between 12.5% and 74%. It is poisonous because of the fact that it blocks the capacity

of the haemoglobin in the blood to convey oxygen from the lungs to the muscles and other tissue in the human body.

Sources of CO

Carbon monoxide may be found in underground and surface mines in inadequately ventilated or confined spaces. In different mining operations, the most frequent sources of CO are inner combustion motor exhaust and explosives explosion and the low-temperature oxidation of coal can also deliver CO. the main source of CO is

- diesel emissions
- underground machinery
- blasting operations
- incomplete combustion of carbonaceous materials, and
- spontaneous combustion (coal mines)
- fires
- Methane and dust emission

Table 3.2: Concentration of CO in the air with their Health Effect and Category [28]

Concentration of CO in the atmosphere (in PPM)	Breathing Time	Toxic Symptoms
9	Short Term Exposure	ASHRAE suggested maximum permissible concentration in living area.
35	8 hours	The maximum revelation permissible by OSHA in the factory over an 8 hour period.
200	2–3 hours	Minor headache, fatigue, tiredness, nausea and dizziness
400	1–2 hours	Severe headache and other symptoms intensify. Life frightening after 3 hours.
800	45 minutes	Nausea, Dizziness, and convulsions Unconscious within 2 hours. Death subsequently 2 – 3 hours.
1,600	20 minutes	Dizziness ,headache, and nausea. Death within 1 hour.
3,200	5–10 minutes	Dizziness headache, and nausea.

		Death within 1 hour.
6,400	1–2 minutes	Dizziness ,headache, and nausea. Death within 25-30 minutes.
12,800	1–3 minutes	Death within 25-30 minutes.

Impact of CO

When miner get exposed to CO, the early indications of intense CO harming include a headache, dizziness, blurry vision, drowsiness, confusion and weakness. At first, the victim may have greyish skin. Because of the CO joining with blood haemoglobin later the skin and mucous layers turn cherry red. If exposure continues they proceed with vomiting, nausea, breathing difficulty and ringing in the ears., At last, the victim loses awareness and enters a state of extreme lethargy or cause permanent brain damage even death can occur in a couple of minutes.

3.2.5 CARBON DIOXIDE (CO₂)

Carbon dioxide is odourless, colourless gas at the room temperature, which is inflammable in typical conditions. CO₂ can be constrained into a solid form, and known such as dry ice. It is part of black damp and after damp both.

Sources of CO₂

Mining release gas from the coal where gas can concentrate in hazardous amounts, particularly in underground mines. It is created through decay of organic materials and also through respiration and ignition. It is too created as a by-result of the ignition of fossil fuels, lime and cement manufacture, beverage carbonation, explosions, chemical reactions with certain rocks/minerals, even the decay of timber and waste combustion.

Effect of CO₂

CO₂ is a potential inward breath toxicant and a simple suffocate. It enters in the body by the air via the lungs and is dispersed into the blood, and may results from an acid-base imbalance which is called acidosis. Acidosis is brought on by an excess of CO₂ in the blood. There is a higher convergence of CO₂ into the blood than in the lungs, framing a fixation inclination, where blood CO₂ spreads into the lungs and after that is breathed out under ordinary

physiological circumstances. An increase in breathed in CO₂ and ensuing response with water into the blood produces carbonic acid (as H₂CO₃).

Table 3.3: Concentration of CO₂ in the air with their Health Effect and Category [29]

Percentage of CO ₂ (%)	Symptoms	Category
2-3 %	Shortness of breath, deep breathing	Very Poor
5%	Breathing becomes heavy, sweating, pulse quickens	Good
7.5%	Headaches, restlessness, dizziness, breathlessness, increased heart rate and blood pressure, visual distortion	Moderate
10%	Impaired hearing, vomiting, nausea, loss of consciousness	Poor
30%	Convulsions,coma, death	Very Poor

Table 3.4: Concentration of Different Gases in the air with their Source, Route of Entry, TLV and Toxic Health Effect [30]

Gas	Source(s)	Route Of Entry	TLV (ppm)	Toxic Effects
Nitrogen (NO ₂)	About 4/5 th of atmosphere, Rock strata form some mines.	Inhalation	-	Asphyxia from oxygen deficiency.
Carbon Dioxide (CO ₂)	Oxidation of coal, Rotting timbers, blasting, Breathing, explosions, fires diesel engines and rock strata in some mines.	Inhalation	5,000	Concentration of 5% can produces shortness of breath and headaches. Concentration of 10% can produces death due to oxygen deficiency.
Methane (CH ₄)	Coal and rock strata, carbonaceous shale, and rotting mine timbers.	Inhalation	-	Oxygen deficiency

Carbon Monoxide (CO)	Diesel engines, explosions, fires, and blasting	Inhalation	50	Low concentration can produce headache, dizziness and drowsiness. Higher concentration can produces nausea, collapse, vomiting, coma and death.
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3.3 CONCLUSION

The chapter gives information about mine gases along with their generation and the effect. Different dangerous gases like natural gases, CO, CO₂, CH₄ etc. has been discussed. The health impacts, toxic effect, the maximum exposure limit, source with their characteristic each of them is described. With consideration of all of these suitable monitoring systems has been designed.

Chapter 4

DESIGN

MEHTODOLOGY

4.1 INTRODUCTION

This chapter comprises of the methodology of the monitoring system with the design implementation. In methodology block diagram, flow chart and algorithm will be explained in length. and in design implementation step by step implementation of hardware system after that software implementation and with the brief discussion of the component used in the monitoring system.

4.2 METHEDODOLOGY

There are two units of the monitoring system Sensor unit and Monitoring unit. Sensor unit will be placed in the underground section and Monitoring unit will be placed in the above the mines from where monitoring is done.

Sensor unit comprises of Data Acquisition Module (sensors), Micro Controller Module (Arduino UNO), Wireless Communication Module (ZigBee Pro SB), Display Module (LCD), Buzzer, Power Module(batteries).

Monitor unit comprises of Wireless Communication Module (ZigBee Pro SB), Microcontroller Module (Arduino UNO), Display Module (LCD), Power Module (batteries).

Firstly, the Sensor unit is placed in the underground section of the mine. Where input is taken from the sensors in terms of Methane(CH_4) i.e. MQ-2 sensor, Hydrogen Sulphide (H_2S) i.e. MQ-136 sensor, and Natural Gases i.e. MQ-5 sensor. Then they are compared with their threshold value by Microcontroller Module and if value is above the threshold value Buzzer start ringing meanwhile data is displayed in the Display module and sent to the Wireless Communication Module of the Monitor unit i.e. end device or coordinator through the Wireless Communication Module of the Sensor unit i.e. router.

In the Monitor unit data is taken by Wireless Communication Module and displayed in the Display Module through Microcontroller Module.

4.3 ALGORITHM

Step 1: Take input through sensor.

Step 2: Input data is compared with their threshold value.

Step 3: If data is above the threshold value buzzer start ringing.

Step 4: Input data is displayed in the LCD.

Step 5: Data is transmitted to the Monitor unit through Wireless sensor.

Step 6: Data is received from Sensor unit.

Step 7: Data is displayed through LCD in the Monitor Unit.

4.4 BLOCK DIAGRAMS

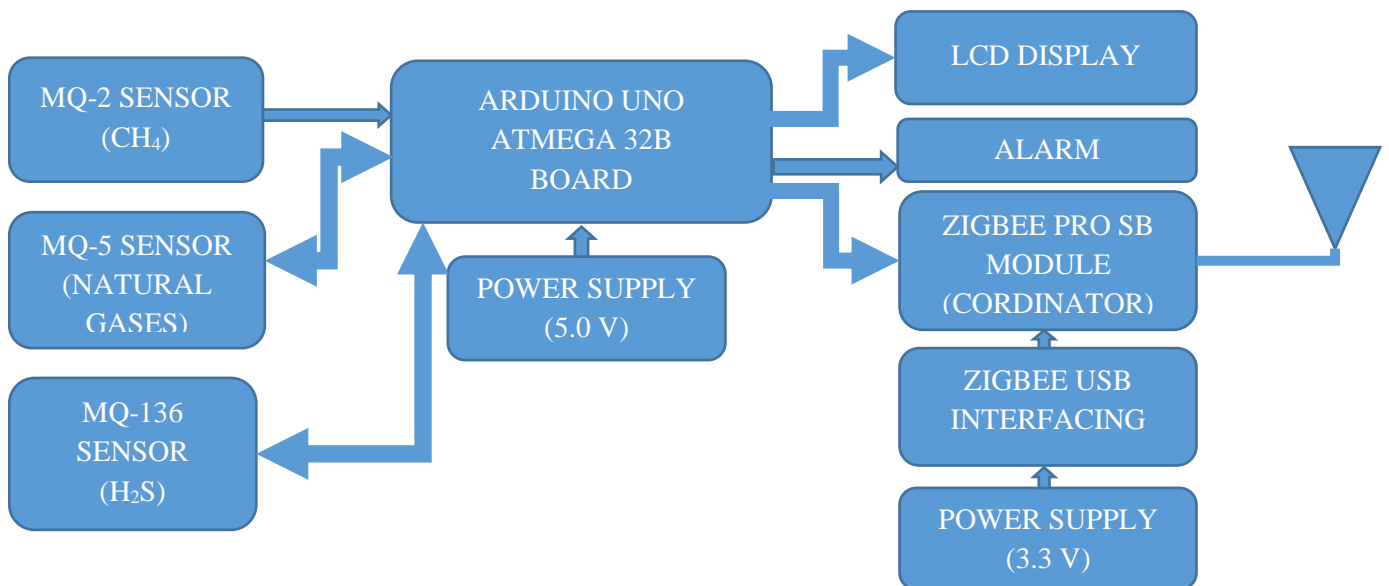


Figure 4.1: Block Diagram of Sensor Unit

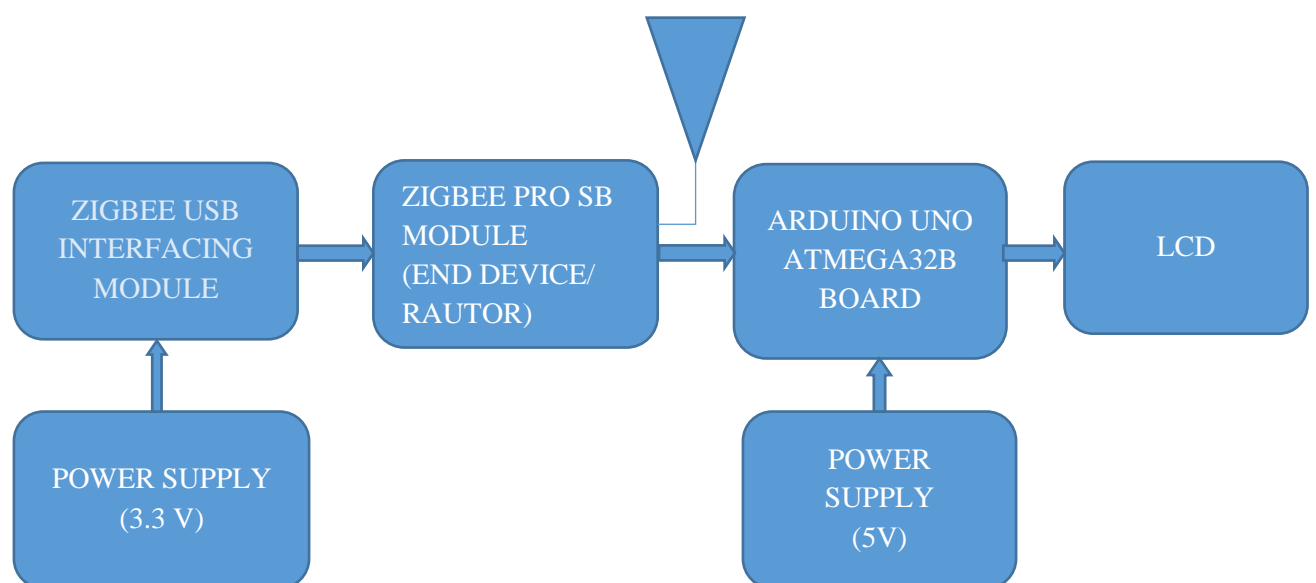


Figure 4.2: Block Diagram of Monitoring Unit

4.5 FLOW CHARTS

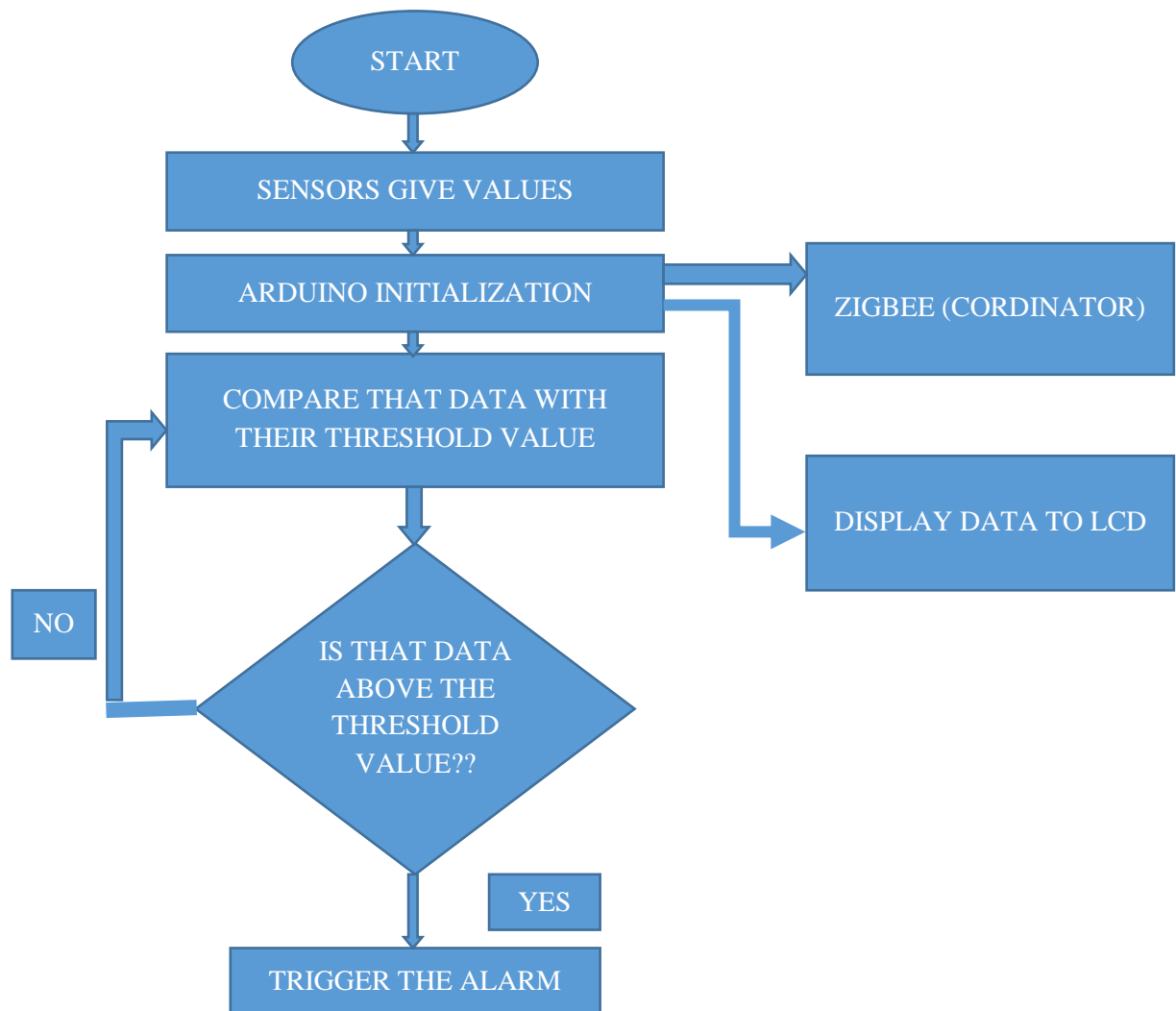


Figure 4.3: Flow Chart of Sensor Unit

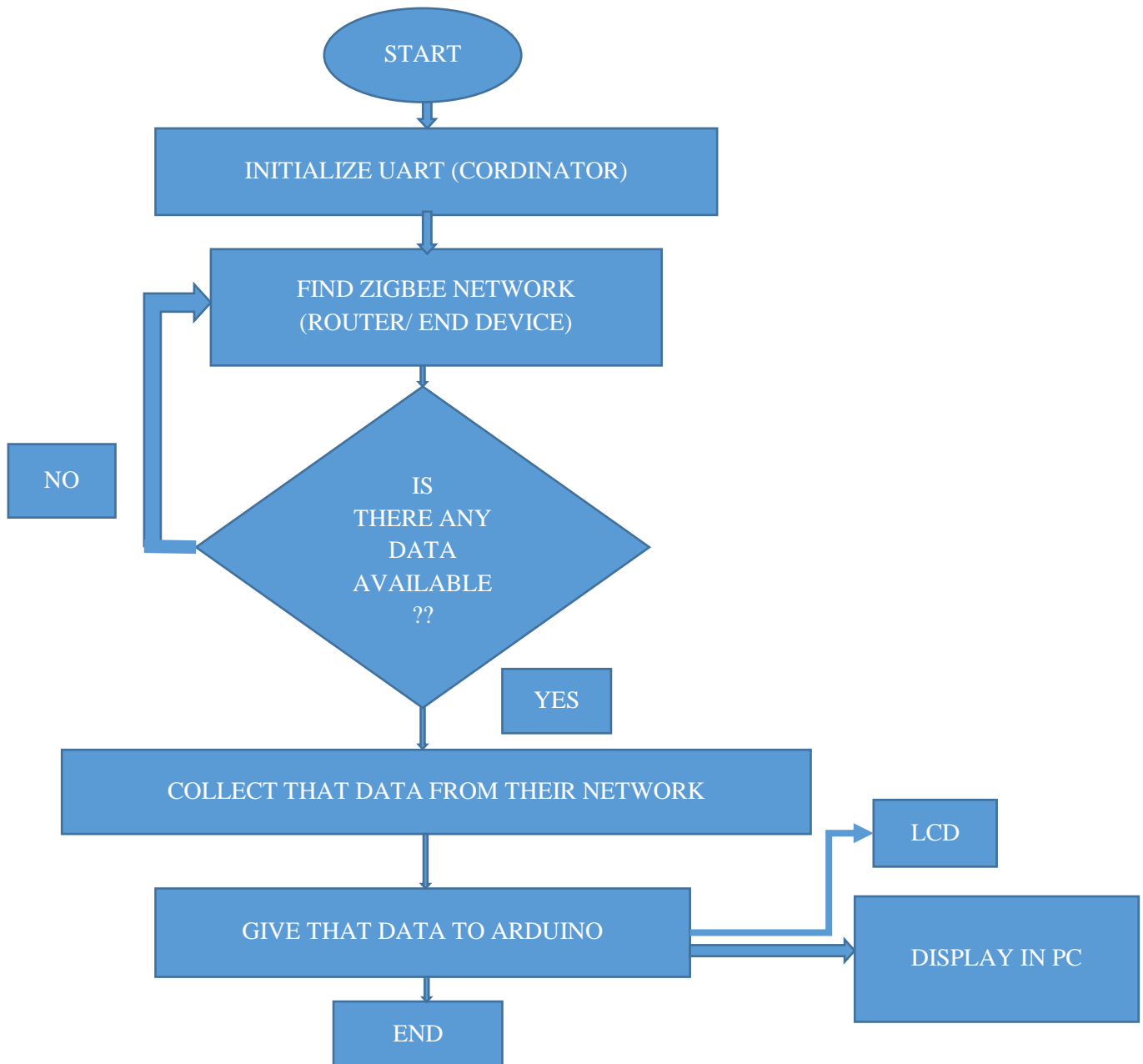


Figure 4.4: Flow Chart of Monitoring Unit

4.6 SYSTEM HARDWARE DESIGN

This monitoring system consists of different sensors, Arduino UNO, ZigBee SB Module, ZigBee USB interfacing Board, Buzzer and other small electronic components. They are discussed here in length with their specific working.

4.6.1 Arduino

Arduino is an open-source precursor which is very easy-to-use in terms of hardware and software. Arduino boards are able to read inputs , a finger on a button, light on a sensor, publishing something online , turning on an LED. Arduino has 17 versions of it those are Arduino Diecimila in Stoicheia, Arduino Duemilanove (rev 2009b), Arduino UNO, Arduino Leonardo, Arduino Mega, Arduino MEGA 2560 R3 (front side), Arduino MEGA 2560 R3 (back side), Arduino Nano, Arduino Due (ARM Cortex-M3 core), Lily Pad Arduino (rev 2007), Arduino Yun and Arduino UNO is used in this system.

Arduino UNO

The Arduino UNO is a microcontroller board which is based on the ATmega328. For supporting the microcontroller Arduino UNO has variety of functions. by simply connecting it to a computer through a USB cable and one can power it through a AC-to-DC adapter or required a battery to start it. Arduino has advantages in terms of memory, clock speed, USB interface, input output interface, communication Small, Portable, No Computer required, Programmable logic, Vast range of applications, Cheap.

Features

- High Performance and Low Power Microcontroller
- Advanced RISC Architecture32 x 8 General Purpose Working Registers
 - 131 Instructions
 - Single Clock Execution
 - Fully Static Operation
 - On-chip 2-cycle Multiplier
- Mode
- Temperature Measurement
- Programmable Serial USART
- Power-on Reset
- Programmable Brown-out Detection
- Internal Calibrated Oscillator
- External and Internal Interrupt Sources
- I/O and Packages
- Temperature Range (-40°C to 85°C)
- Speed Grade
- Low Power Consumption

Table 4.1: Technical specification of Arduino UNO [31]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

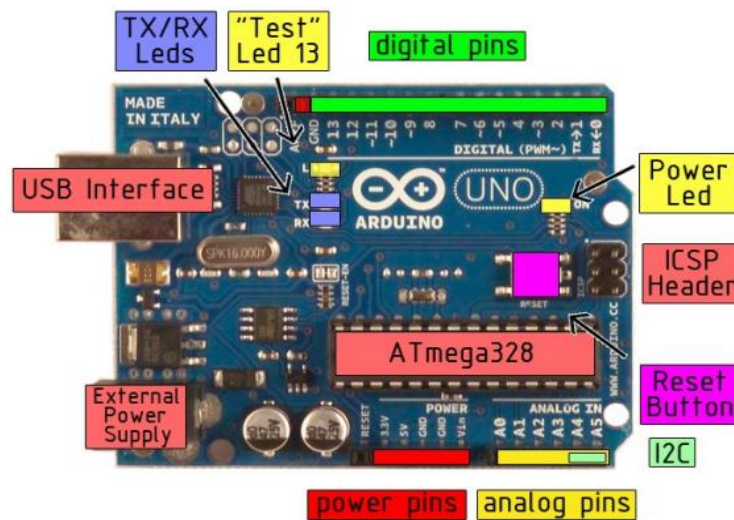


Figure 4.5: Arduino UNO Board [31]

It has 14 digital input/output pins (of which 6 can be used as PWM outputs), a 16 MHz crystal oscillator, an ICSP header, 6 analog inputs, a power jack, a USB connection, and a reset button. The Atmega328 has a 1 KB of EEPROM and 2 KB of SRAM (these can be read and written by the EEPROM library). It also has 32 KB of flash memory only for storing the code (from which 0.5 KB is used for bootloader).

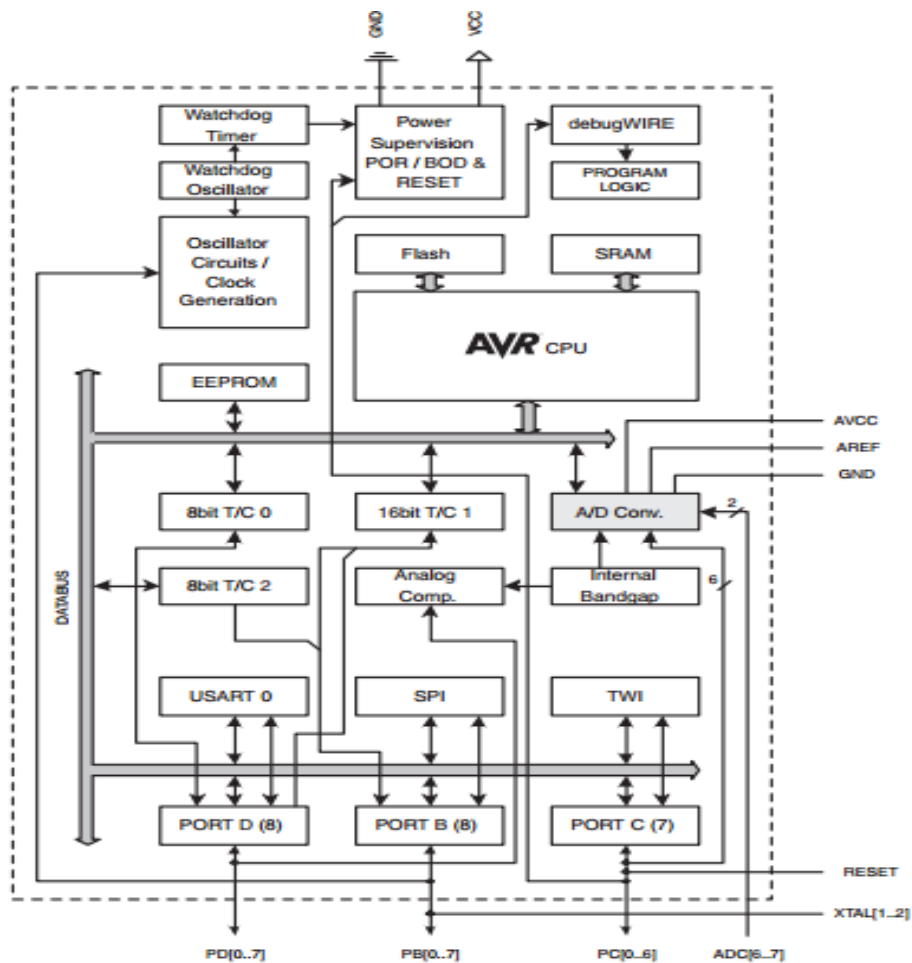


Figure 4.6: Block Diagram of ARDUINO UNO [32]

Each 14 digital pins can be utilized as an input/output pins using the command pin Mode (), digitalRead() and digitalWrite(). They are operated at 5 volts. Each of that pin can give or receive maximum of 40 mA with an internal pull-up resistor of 20-50 kOhms (which is by default disconnected).

The 1024 various values are obtained using 6 analog inputs that provide resolution of 10 bits. they can measure by default from ground to 5 volts however upper range can be changed using the analogReference() function and the AREF pin .

The Arduino Uno has many ways to communicating with another Arduino, a computer, or other microcontrollers. The ATmega328 supports UART TTL serial communication(5V), which is given by digital pin 0 (RX) and digital pin 1 (TX) and an ATmega8U2 given on the board channels the serial communication on the USB and it give an appearance like a virtual com port for software on the computer. No external drivers are needed, though an *.inf file is required for windows.”

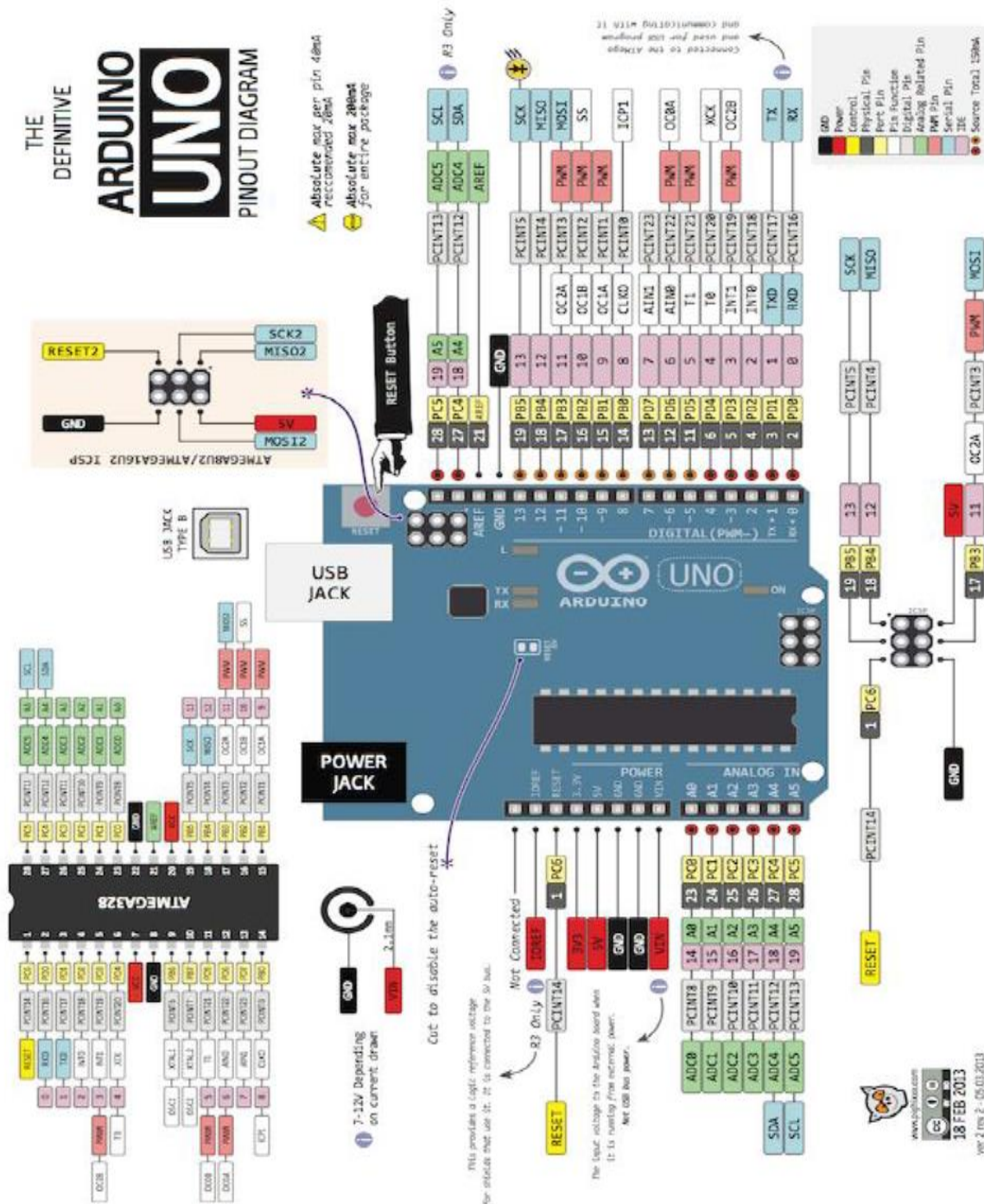


Figure 4.7: Pin diagram of ARDUINO with their function [32]

4.6.2 ZigBee Pro SB

ZIGBEE is a new wireless communication technology which is guided by the IEEE 802.15.4 (Personal Area Networks standard). And full fill the requirement of low-power, low-cost, self-healing system for redundant, self-configuring, battery-free nodes which enable ZigBee's unique mobility, flexibility, and ease of use of wireless sensor networks. This XBee module

requires minimal power and support reliable data delivery between devices. It operates in the ISM 2.4 GHz frequency band.



Figure 4.8: XBee PRO SB Series [33]

Key Features

- Long range data integrity
- Low power
- Advanced security and networking system
- ADC and I/O support line
- Easy to use

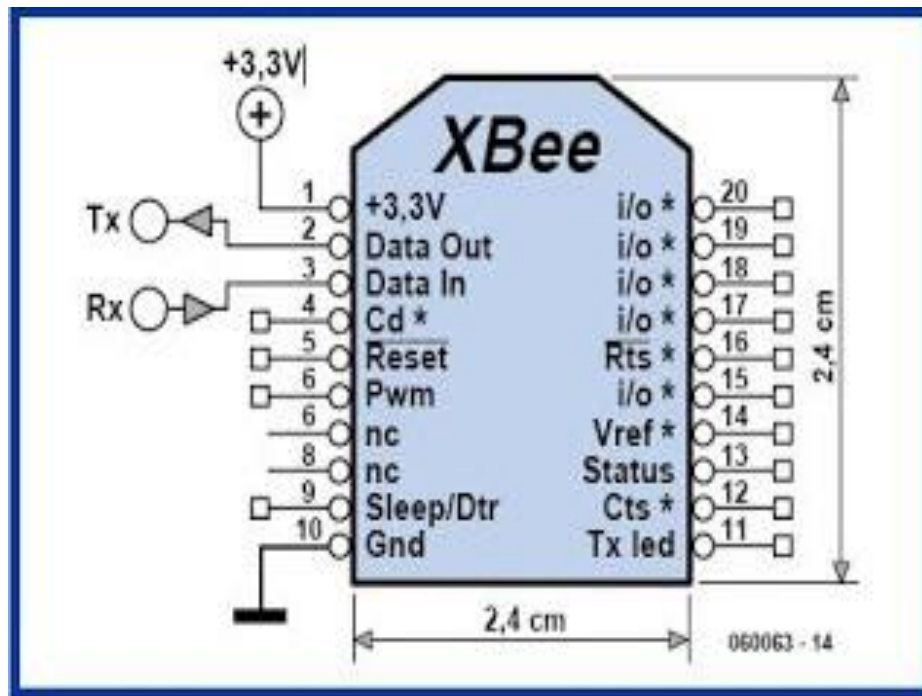


Figure 4.9: Pin Specification of XBee PRO [33]

4.6.3 XBee USB interfacing Board

XBee USB Interfacing Board is used to interface XBee wireless Module with Laptop and Desktop computer systems. It also can be used to connect raw module of XBee to develop communication between PC to Mechanical Assembly, PC to PC, PC to embedded and microcontroller based Circuits and configure XBee according to the required application. As for XBee Serial Communication is used other end of USB, is connected to PC and treated as COM port for that Serial Communication.

Features:

- Power booster which is responsible for interfacing suitability for all types of modules.
- USB 2.0 protocol
- 3.3V and 5V dual power output
- easy interface using Digi's X-CTU software
- Pin-out compatible with other XBee Adapter board
- Provides easy pluggable solder and wire connections
- 6 different status indicator LEDs that is for SUSPEND, ASSOC, RSSI, Power, TX, RX
- Reset button

- Supports AT and API commands



Figure 4.10: XBee USB interfacing board [36]

4.6.4 Hydrogen sulphide sensor (MQ-136)

In MQ-136 gas sensor SnO_2 is used as sensitive material with the lower conductivity in the clean air. When the target H_2S gas exist, the sensor's conductivity increases along with the gas concentration increase.



Figure 4.11: MQ-136 Sensor and MQ-136 Module [37]

Features

- Good sensitivity

- Simple drive circuit
- Long life and low cost

MQ-136 sensor comprised of by micro Al_2O_3 as ceramic tube, Tin Dioxide (SnO_2) as sensitive layer, heater and measuring electrode are fixed into the crust which is made by stainless steel net and plastic. Necessary working conditions is provided by the heater for working of sensitive components. The MQ-136 has 6 pin in which 4 are used to fetch the signals and for providing heating current other 2 pins are used.

Table 4.2: Technical Parameters of MQ-136 [37]

Model			MQ136
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite, Metal cap
Target Gas			Hydrogen Sulfide(H_2S gas)
Detection range			1~200ppm
Standard Circuit Conditions	Loop Voltage	V_c	$\leq 24V$ DC
	Heater Voltage	V_H	$5.0V \pm 0.1V$ AC or DC
	Load Resistance	R_L	Adjustable
Sensor character under standard test conditions	Heater Resistance	R_H	$29\Omega \pm 3\Omega$ (room tem.)
	Heater consumption	P_H	$\leq 900mW$
	Sensitivity	S	$R_s(\text{in air})/R_s(50ppm H_2S) \geq 3$
	Output Voltage	ΔV_s	$\geq 0.5V$ (in 50ppm H_2S)
	Concentration Slope	α	$\leq 0.6(R_{200ppm}/R_{50ppm} H_2S)$
Standard test conditions	Tem. Humidity		$20^\circ C \pm 2^\circ C$; 55% \pm 5%RH
	Standard test circuit		$V_c: 5.0V \pm 0.1V$; $V_H: 5.0V \pm 0.1V$
	Preheat time		Over 48 hours

Parts

- 1 Gas sensing layer
- 2 Electrode
- 3 Electrode line
- 4 Heater coil
- 5 Tubular ceramics
- 6 Anti-explosion network
- 7 Clamp ring
- 8 Resin base
- 9 Tube Pin

Materials

- 1 SnO_2
- 2 Au
- 3 Pt
- 4 Ni-Cr alloy
- 5 Al_2O_3
- 6 Stainless steel gauze (SUS316 100-mesh)
- 7 Copper plating Ni
- 8 Bakelite
- 9 Copper plating Ni

MQ-136 sensor comprises of 2 parts; the heating circuit and the signal output circuit. heating circuit is responsible for time control and accurately respond changing in the surface resistance of the sensor is done by the signal output circuit.

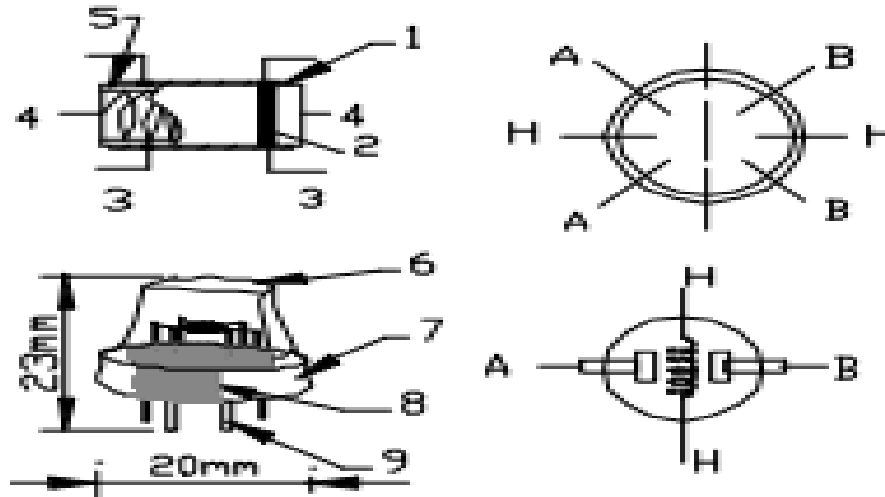


Figure 4.12: Structure and Configuration of MQ-136 [37]

Working and testing of MQ-136 sensor

The sensor needed two voltages, a heater voltage (V_H) and a test voltage (V_C). V_H is supplied voltage to the sensor at working temperature, while V_C used to measure voltage (V_{RL}) on the load resistance (R_L) which is in series with the sensor. The V_C need DC power. V_C and V_H can use same power circuit to assure performance of sensor with precondition. suitable R_L value is needed for better performance of the sensor.

Power of Sensitivity the body(P_s): $P_s = V_C^2 \times R_s / (R_s + R_L)^2$

Resistance of sensor (R_s): $R_s = (V_C / V_{RL} - 1) \times R_L$

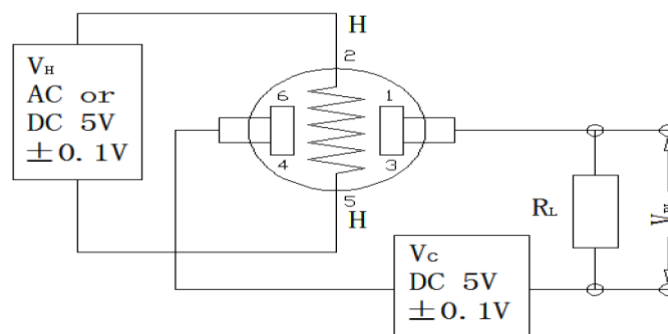


Figure 4.13: MQ-136 Test Circuit [37]

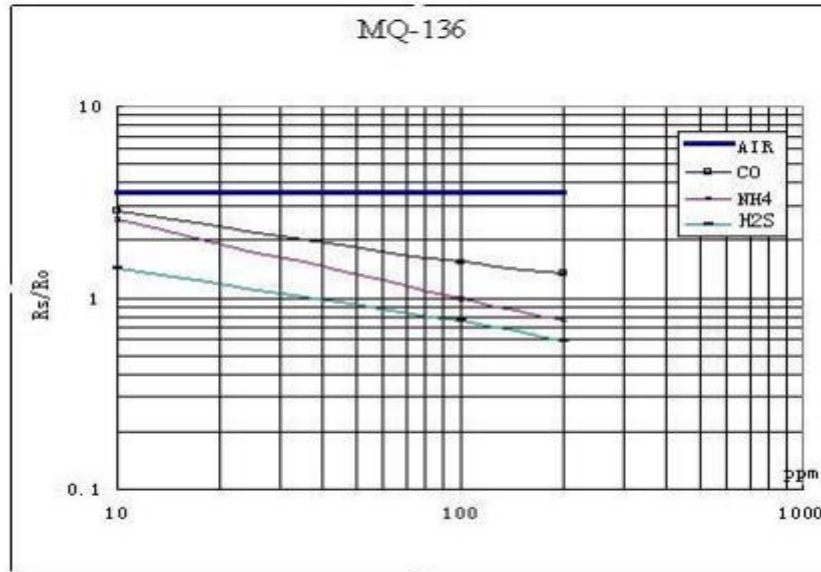


Figure 4.14: MQ-136 sensitivity characteristics for several gases in the condition [37]

At Temp: 20°C, O₂=21%, Humidity=65%, R_L=20kΩ, R_o=sensor resistance of H₂S at 10ppm in the clean air, R_s= sensor resistance at various concentrations of gases.

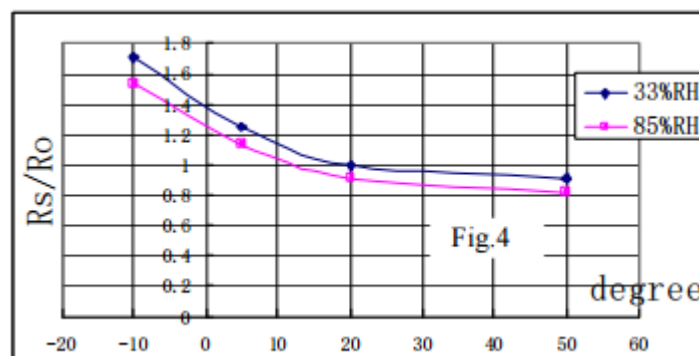


Figure 4.15: MQ-136 characteristic for temperature and humidity. [37]

R_o= sensor resistance of H₂S at 10ppm at 33%R_H and 20 degrees, R_s= sensor resistance of H₂S at 10ppm for different temperatures and humidity

4.6.5 Methane sensor (MQ-2)

It is used for detecting methane.

Features

- Good sensitivity for Combustible gas
- High sensitivity to Methane
- Long life and low cost
- Simple drive circuit



Figure 4.16: MQ-2 Sensor and MQ-2 Module [34]

In the wiring of the sensor is both 'A' pins and both 'B' pins are connected together. It is a safer phenomenon and it is having more reliable output results.

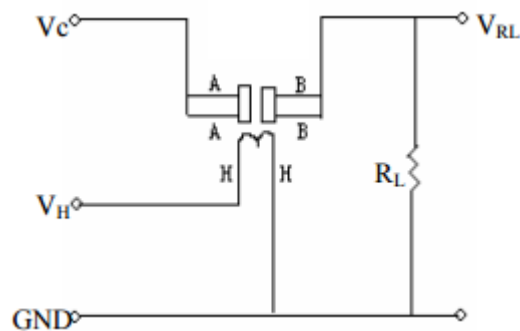


Figure 4.17: MQ-2 Sensor Wiring Circuit [34]

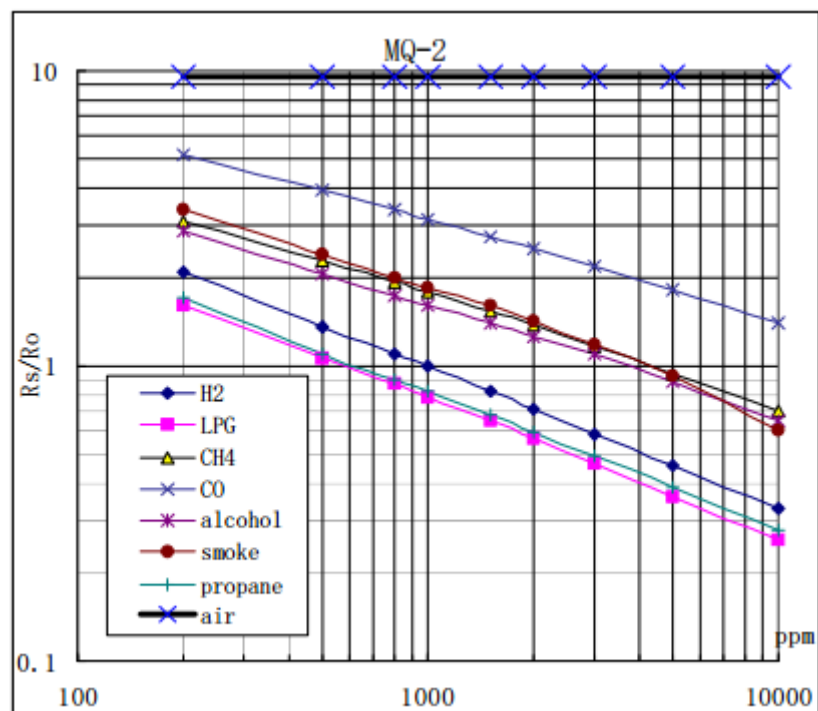


Figure 4.18: The MQ-2 sensitivity characteristics for several gases. [34]

at Temp=20°C, Humidity=65%, O₂=21%, R_L=5kΩ, R_o=sensor resistance of H₂ at 1000ppm in the clean air, R_s= MQ-2 sensor resistance at various concentrations of gases.

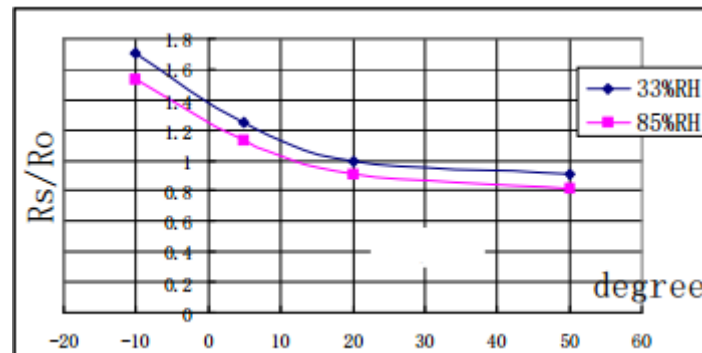


Figure 4.19: Typical dependence curve on temperature and humidity of the MQ-2. [34]

R_o=sensor resistance of H₂ at 1000ppm in air at 33%R_H and 20 degrees. R_s=sensor resistance of H₂ different temperatures and humidity at 1000ppm.

Table 4.3: Technical Parameters of MQ-2 [34]

Model No.			MQ-2
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Detection Gas			Combustible gas and smoke
Concentration			300-10000ppm (Combustible gas)
Circuit	Loop Voltage	V _e	≤24V DC
	Heater Voltage	V _H	5.0V±0.2V AC or DC
	Load Resistance	R _L	Adjustable
Character	Heater Resistance	R _H	31Ω±3Ω (Room Tem.)
	Heater consumption	P _H	≤900mW
	Sensing Resistance	R _s	2KΩ-20KΩ(in 2000ppm C ₃ H ₈)
	Sensitivity	S	R _s (in air)/R _s (1000ppm isobutane)≥5
	Slope	α	≤0.6(R _{5000ppm} /R _{3000ppm} CH ₄)
Condition	Tem. Humidity		20°C±2°C; 65%±5%RH
	Standard test circuit		V _c : 5.0V±0.1V; V _H : 5.0V±0.1V
	Preheat time		Over 48 hours

4.6.6 Natural gas sensor (MQ-5)

The MQ-5 gas sensor uses a small heater inside it with an electro-chemical sensor. According to need it can be calibrated but for this a known concentration of the measured gas or a group

of gasses is needed. Analog output is given by this and can be read by analog input of the Arduino.

The sensor is comprising Tin Dioxide (SnO_2) sensitive layer, micro Al_2O_3 ceramic tube and heater and measuring electrode are fixed within a crust which is made by plastic and stainless steel net. In MQ-5 6 pins are there out of which 4 are used to give signals and remaining 2 are current-availability. For the heater some sensors use 5V, others need 2V. The heater should be on for about 3 minutes After the "burn-in time".



Figure 4.20: MQ-5 Sensor and MQ-5 module [35]

Features

- High sensitivity to natural gas, LPG, town gas.
- Small sensitivity to smoke, alcohol.
- Fast response.
- Stable and long life.
- Simple drive circuit
- Wide detection range

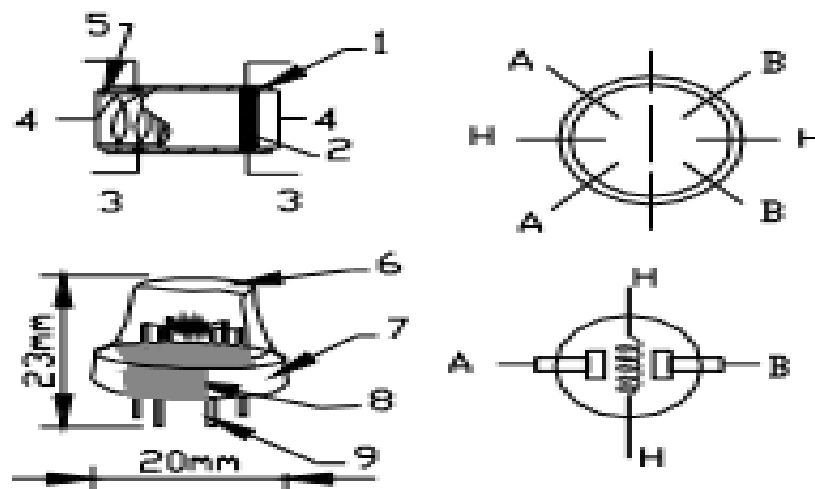


Figure 4.21: Structure of MQ-5 sensor [35]

Parts	Materials
1) Gas sensing layer	SnO ₂
2) Electrode	Au
3) Electrode line	Pt
4) Heater coil	Ni-Cr alloy
5) Tubular ceramics	Al ₂ O ₃
6) Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
7) Clamp ring	Copper plating Ni
8) Resin base	Bakelite
9) Tube Pin	Copper plating Ni

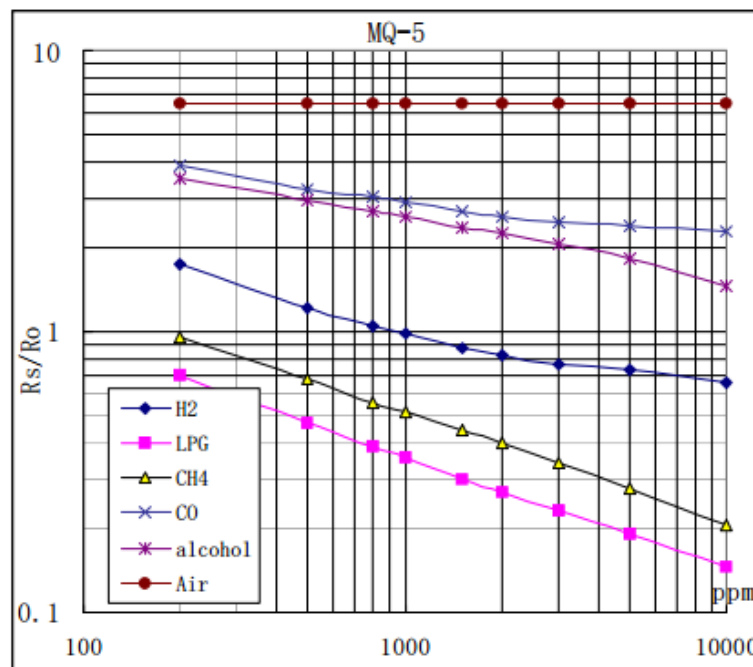


Figure 4.22: The typical sensitivity characteristics curve of the MQ-5 for different gases. [35]

At Temperature=20°C, Humidity: 65%, O₂ = 21% R_L=20kΩ, R_o=sensor resistance of H₂ at 1000ppm in the clean air, R_s=sensor resistance at various concentrations of the gases.

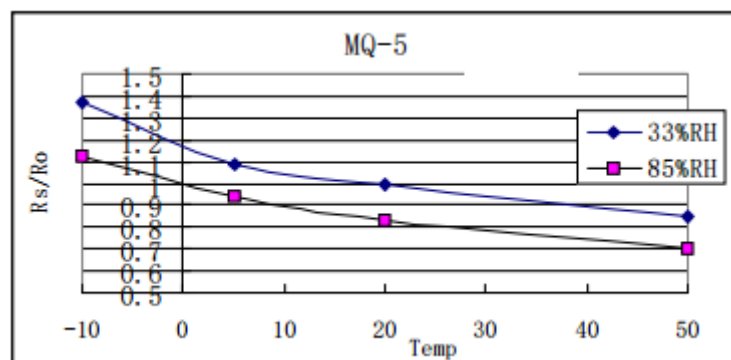


Figure 4.23: The typical dependency curve on temperature and humidity of the MQ-5, [35]

R_o =sensor resistance of H2 at 1000ppm in air at 33% R_H and 20 degrees, R_s : sensor resistance at different temperatures and humidity.

4.6.7 LCD display unit

It is an electronic display module. This is preferable over multi segment and seven segments LEDs. A 16x2 LCD displays 16 characters per line and 2 such lines. Each character is displayed by 5x7 pixel matrix and has two registers: Command and Data.

Data is stored and the commanded instructions which is given to the LCD by the command register. It is an instruction given for LCD to do a predefined task like clearing its screen, initializing it, controlling display, setting the cursor position etc. The data register stores the data which is to be displayed on the LCD. And the data is the ASCII value of the character which is to be displayed on the LCD.

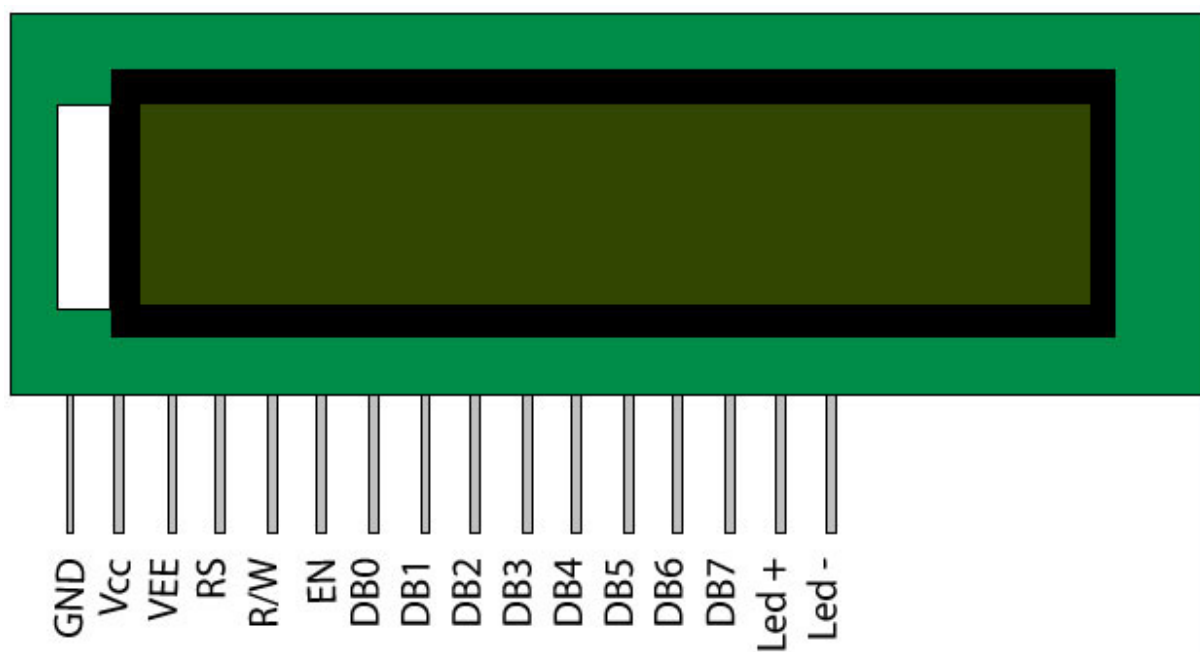


Figure 4.24: Pin Diagram of LCD [38]

Pin Description:

LCD has 16 pins. In which 5 pins are for power the LCD (Ground, V_{CC} , V_{EE} , led+, Led-), 3 pins are for controlling LCD and 8 pins are for data pins.

The three control lines are referred to as RS, EN, and RW.

The EN line is "Enable." This is used to inform the LCD that data is sent to it. This line should be low (0) for sending data to the LCD and then other two control lines is set and/or

data should be put on the data bus. When for data transfer other lines are ready, Enable is bring high (1) and there should be pause of minimum time which is given in LCD and end by bringing EN low (0) again.

The RS line is called "Register Select" line. If RS is low (0), the data is to be taken as a command or a special instruction (i.e. position cursor, clear screen, etc.). if RS is high (1), the data is treated as text data which is now displayed on the screen.

The RW line is called the "Read/Write" control line. If RW is low (0), data on the data bus should be written on the LCD. And When RW is high (1), program querying (or reading) to the LCD.

Table 4.4: Pin No. of LCD along with their Name and Function [38]

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	V _{CC}
3	Contrast adjustment; through a variable resistor	V _{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V _{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

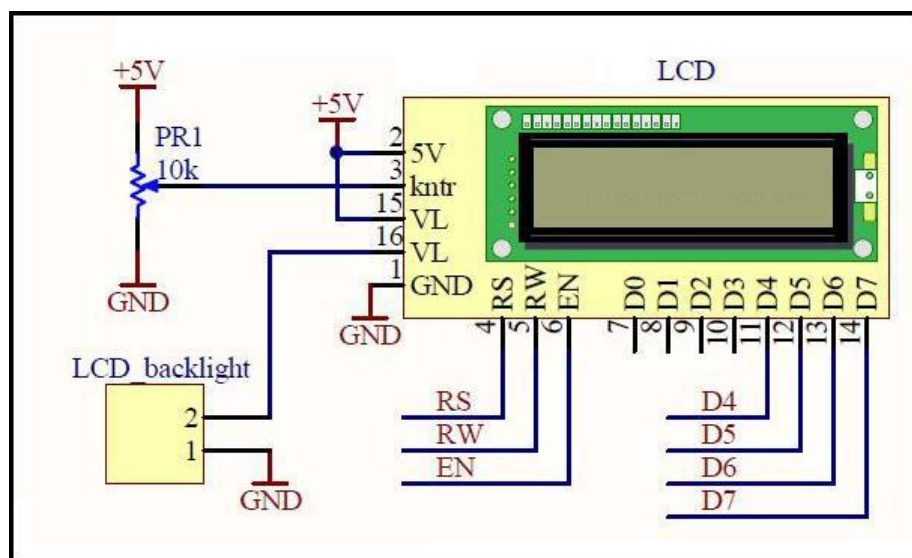


Figure 4.25: Pin Description and Connection Diagram of 16x2 LCD [38]

4.7 HARDWARE IMPLIMENTATION

Testing of designed Real Time Gas Monitoring System module using Wireless Sensor Network is done in an artificial mining environment which is simulated inside the laboratory. As the first, complete system is designed on a breadboard which is presented in Figure 4.26.

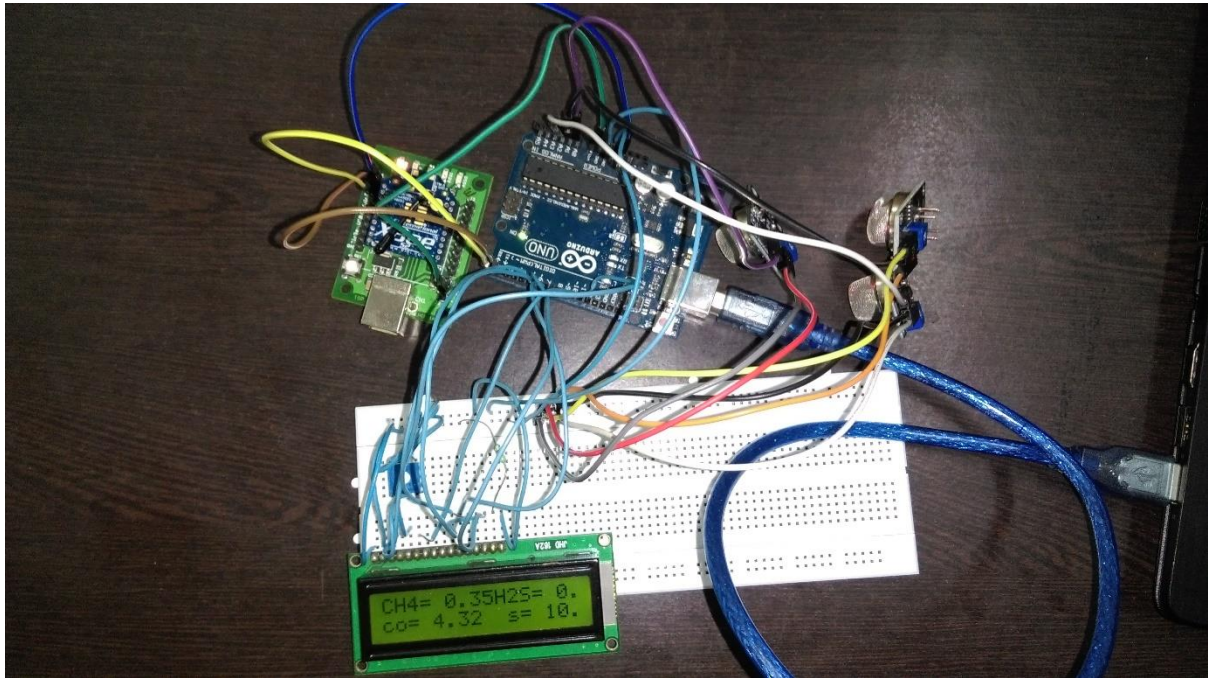


Figure 4.26: Sensor Unit of Monitoring System in Bread board

Designed system consist of:

1. Arduino Board -Arduino UNO Model
2. LCD (Liquid crystal display) - 16*2 LCD
3. Xbee - Xbee Pro SB Model
4. Methane Sensor - MQ-2 Sensor
5. Hydrogen Sulphide Sensor - MQ-136 Sensor
6. Natural Gases Sensor – MQ-5 sensor

Final design is simulated on PCB which additionally consists of Buzzer and shown in the figure 4.27

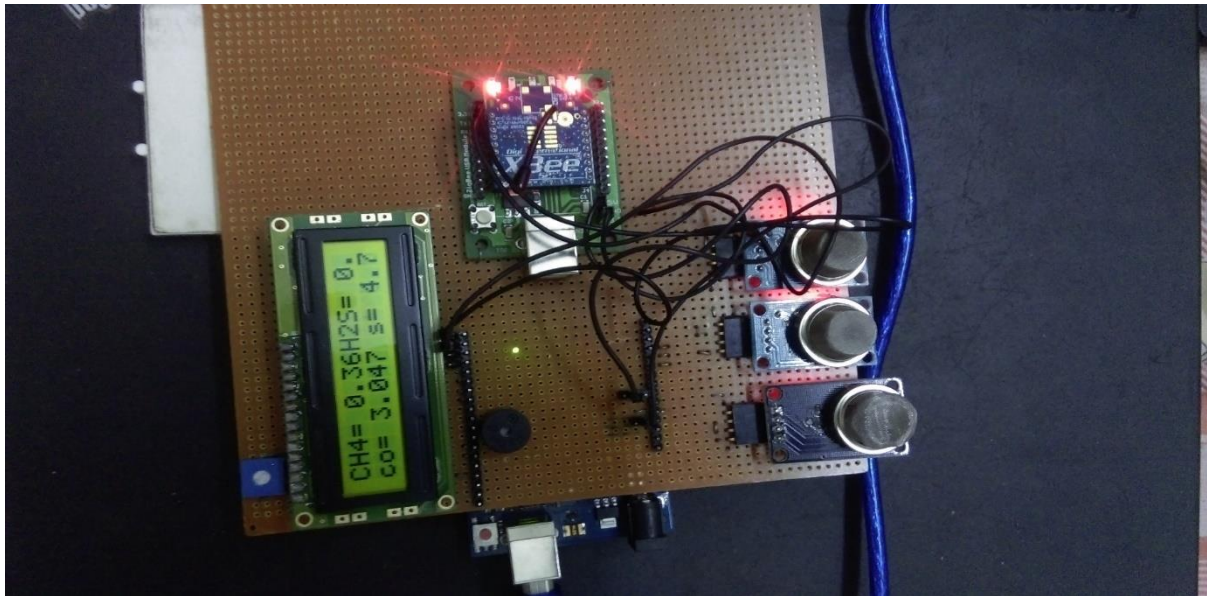


Figure 4.27: final design of monitoring system

4.8 SOFTWARE IMPLEMENTATION

Two software is used in the designing of the following monitoring system. For XBee i.e. XCTU and for Arduino (Arduino IDE 1.6.1) is used.

With help of XCTU software XBee is assigned as transmitter (coordinator) or as receiver (router).

Basically XBee can be defined in the three categories:

- **ZigBee Coordinator:** it forms the root of the any network tree and can connect to other networks. There is specifically one ZigBee Coordinator is present in each network as it is the device which starts the network originally. It cannot go in off mode
- **ZigBee Router (ZR):** in any networks multiple ZigBee Router can be present and a Router acts as an intermediate router, passing the data from one to other device .it also cannot go to off mode.
- **ZigBee End Device (ZED):** it is having enough functionality to connect to the other node (either a Coordinator or the Router). This can go in the off mode which allow to save significant amount of energy and time.it is less expensive as allow less memory section.

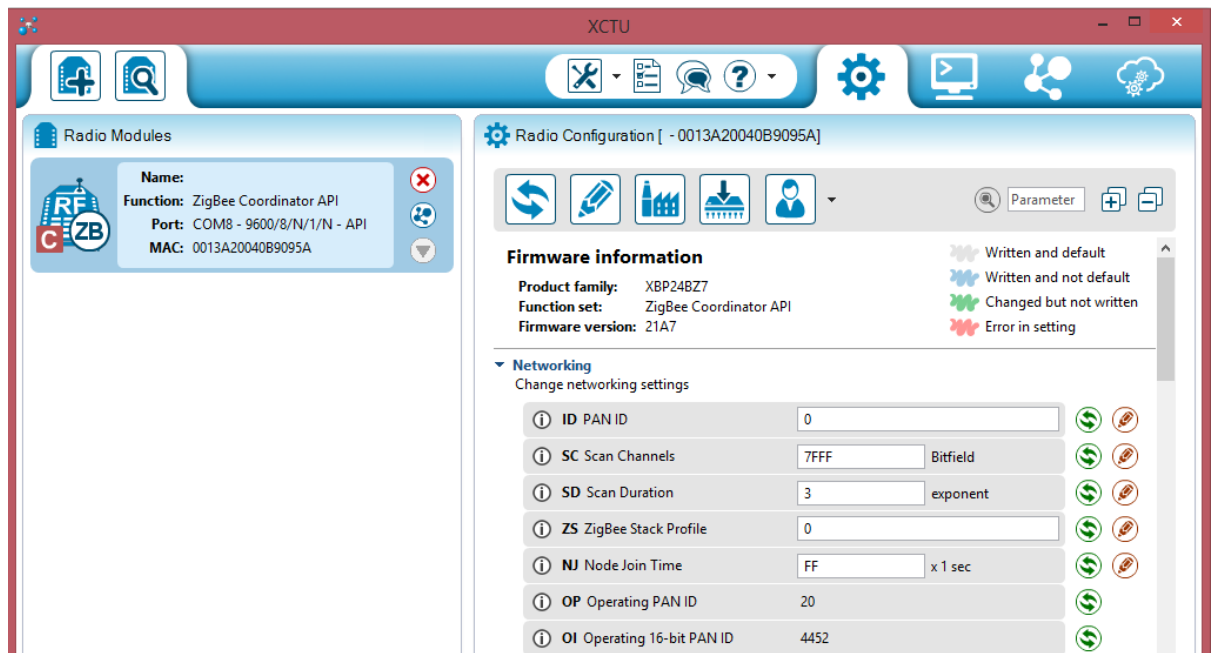


Figure 4.28: Configuration of coordinator on XCTU

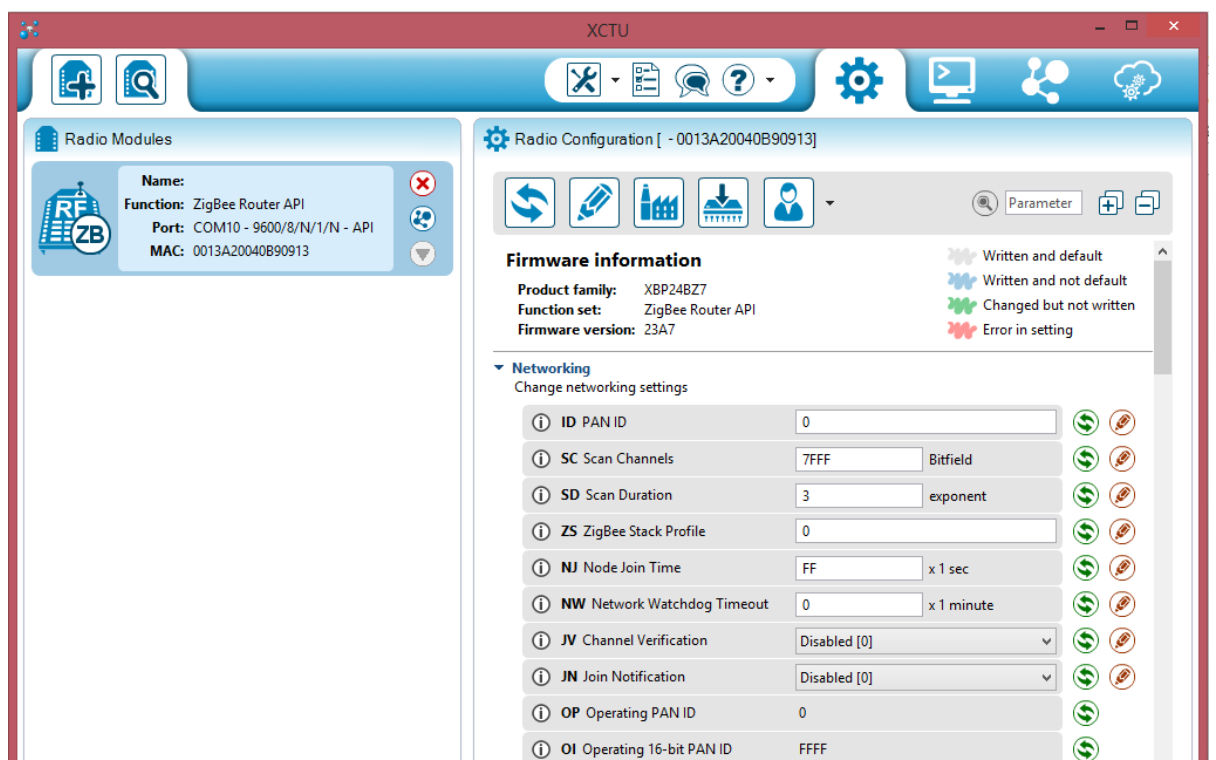


Figure 4.29: Configuration of router on XCTU

PAN ID (Personal Area Network identifier) should be same for stabilizing a network between coordinator and router XBee. For this system we set the PAN ID as 0 for both XBee.

Arduino UNO is microcontroller based board. And programming for the Arduino board, is done in Arduino IDE 1.6.1 (Integrated Development Environment) which supports C and C++ programming languages.

4.9 CONCLUSION

This chapter gives information about the methodology of the Real time monitoring system with the hardware design in length. The algorithm, block diagram and flow chart shows methodology, working and organization of the system. Each component is briefly described here with their specification and functionality. The implementation of the hardware and software is also described here.

Chapter 5

EXPERIMENT RESULT AND DISCUSSION

5.1 INTRODUCTION

The utilization of any module designed can only be verified after it is used and desired results are achieved. After the design of circuit, it is required to verify the working of the module and also it should be verified for desired results. For this purpose, the module should be tested for different gasses accompanied by a regular monitoring of desired output.

5.2 TESTING OF THE MODULE

The module was tested in the laboratory for natural gasses, CH₄ and H₂S individually. The values of each gas was obtained at an interval of 0.5 sec and the obtained value was compared with the atmospheric value of the gas.

5.2.1 TESTING FOR H₂S GAS

The module was tested for H₂S gas. The MQ136 sensor detects the concentration of H₂S gas in the atmosphere and it is displayed in the ARDUINO IDE window as shown in the figure and graph is illustrated in the figure.

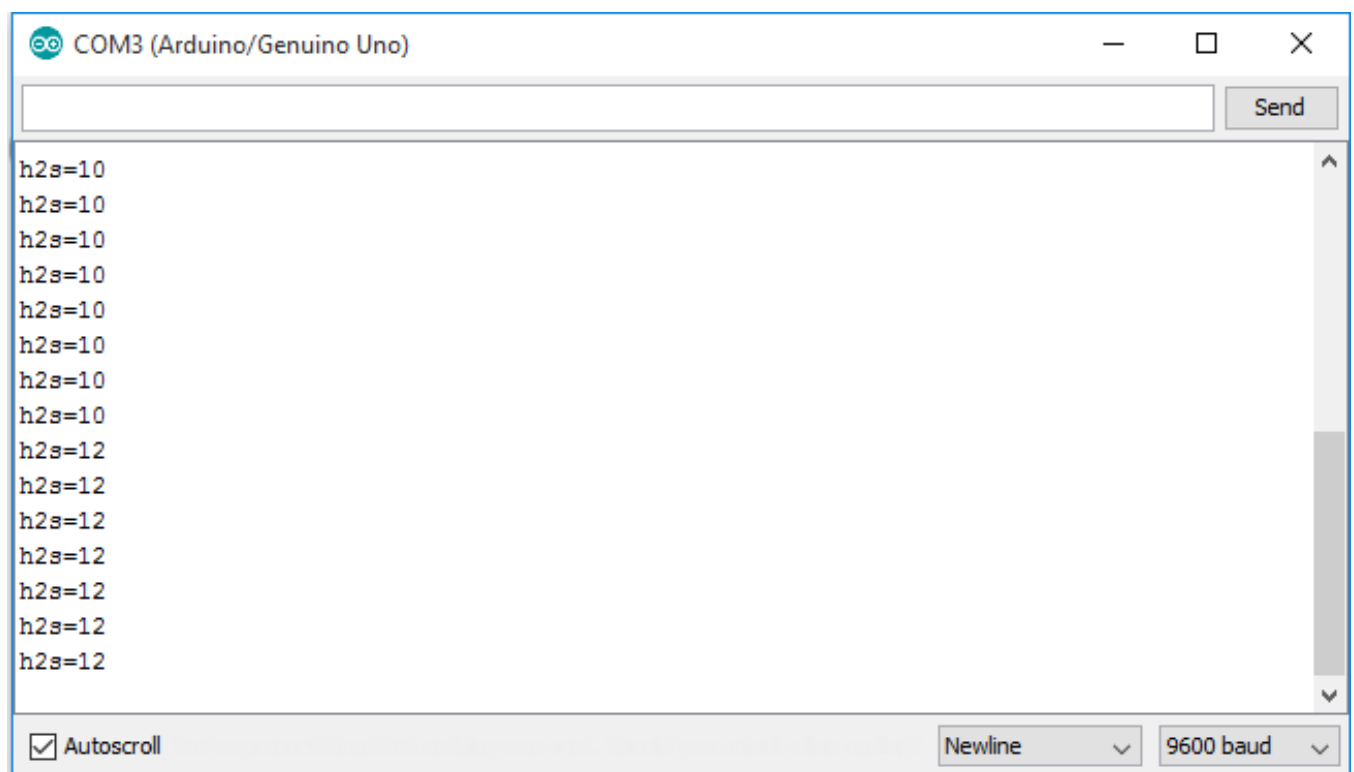


Figure 5.1: MQ-136 value given by Arduino IDE software

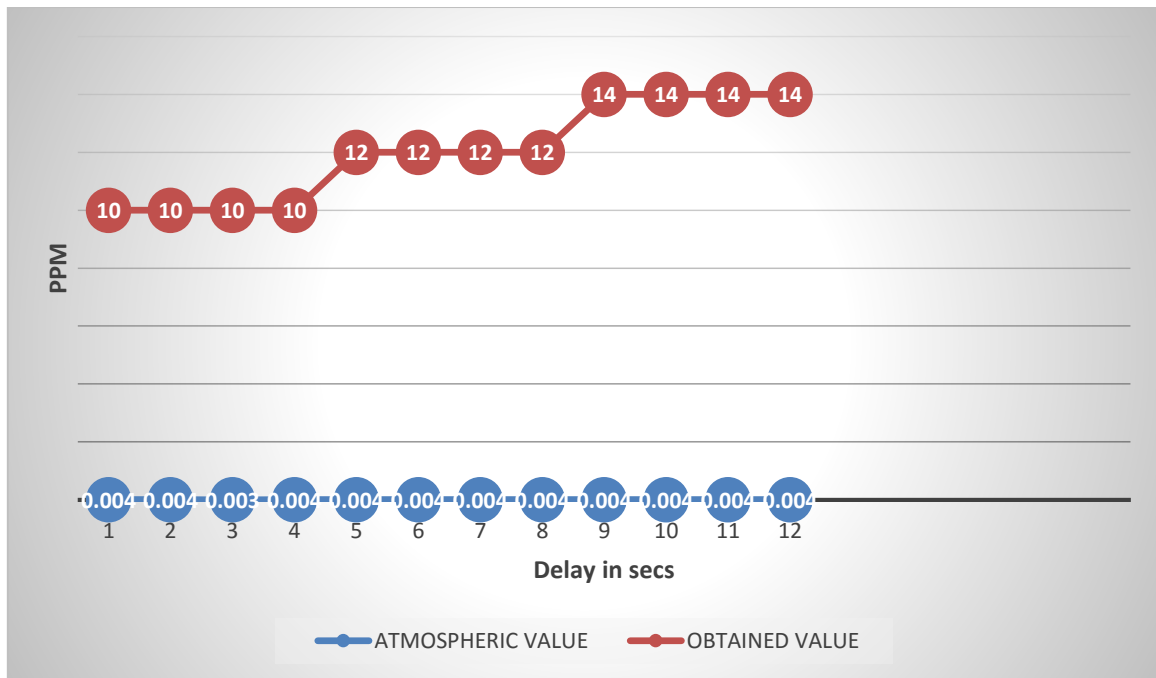


Figure 5.2: Comparison of atmospheric H₂S and Sensor output

5.2.2 TESTING FOR NATURAL GASSES

The module was tested for CO gas. The MQ-5 sensor detects the concentration of CO gas in the atmosphere and it is displayed in the ARDUINO IDE window as shown in the figure and graph is illustrated in the figure.

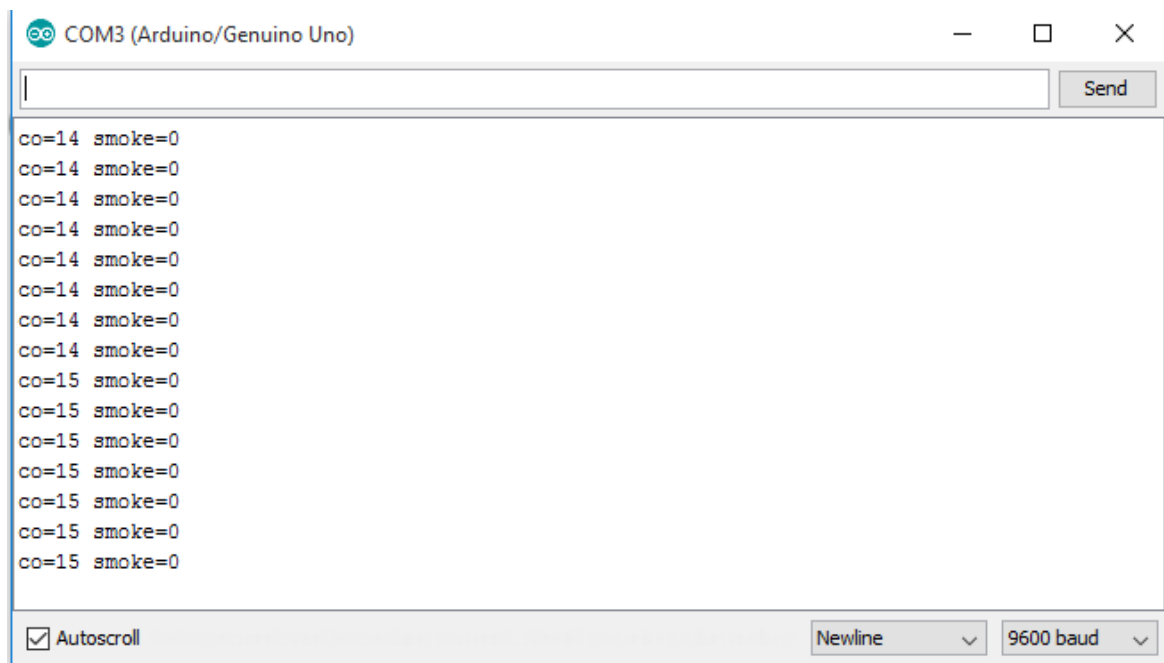


Figure 5.3: MQ-5 value given by Arduino IDE software

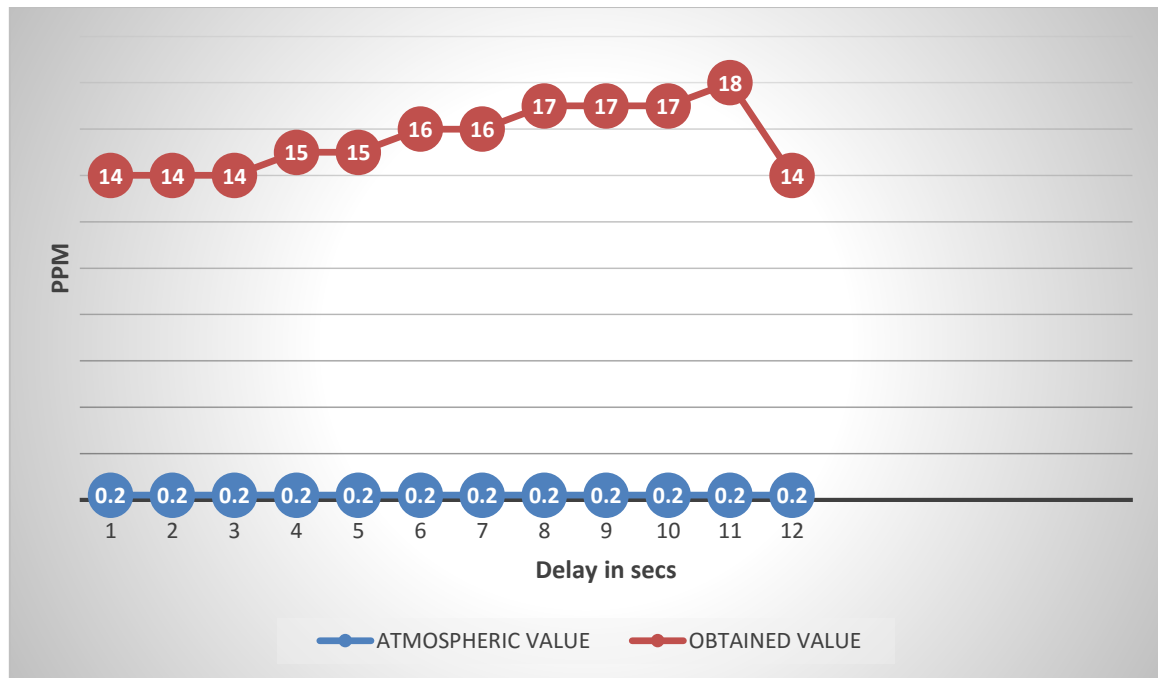


Figure 5.4: Comparison of atmospheric Natural Gas and Sensor output

5.2.2 TESTING FOR CH₄ GAS

The module was tested for CH₄ gas. The MQ2 sensor detects the concentration of CH₄ gas in the atmosphere and it is displayed in the ARDUINO IDE window as shown in the figure and graph is illustrated in the figure.

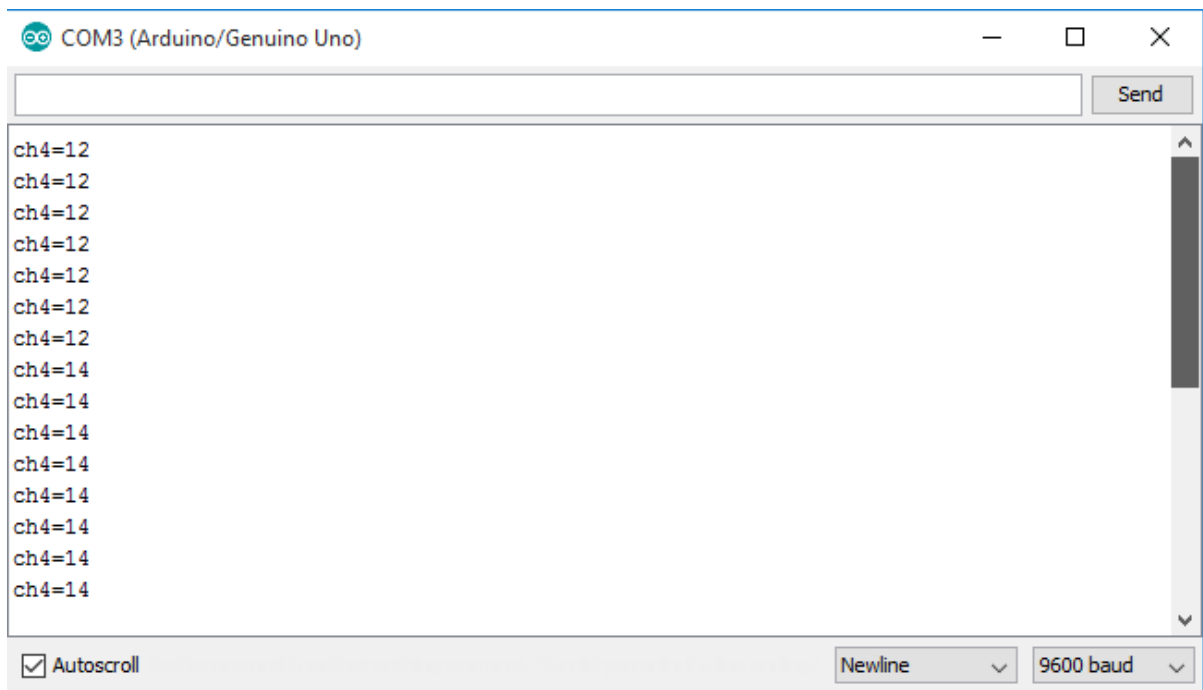


Figure 5.5: MQ-2 value given by Arduino IDE software

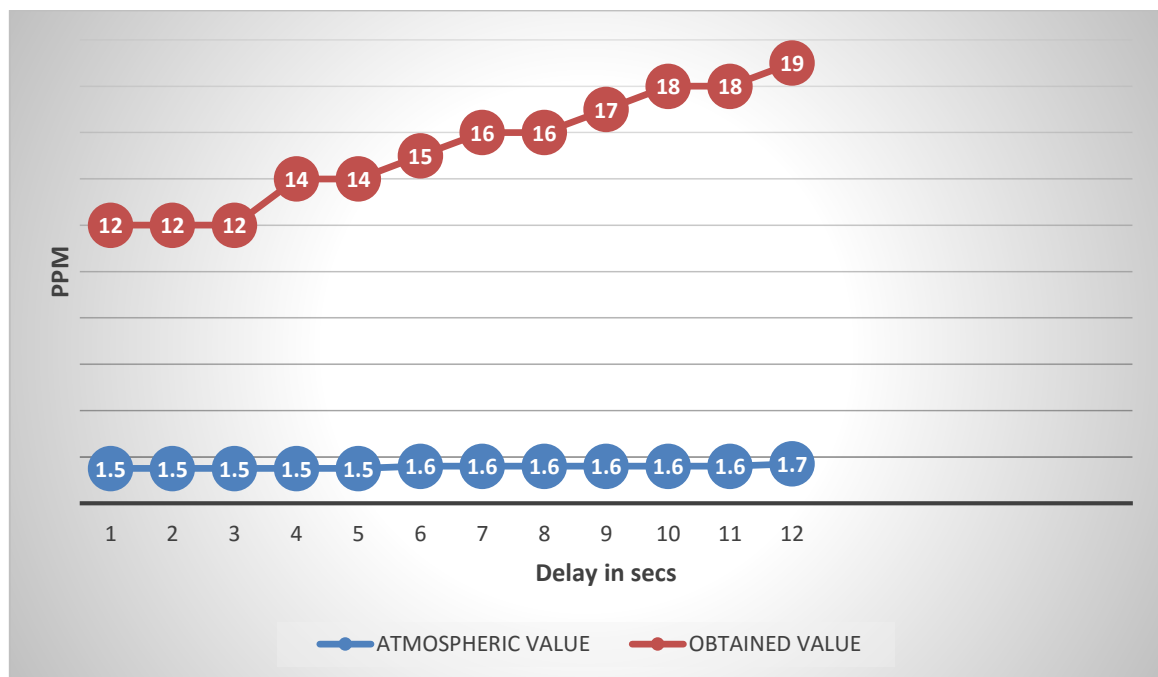


Figure 5.6: Comparison of atmospheric Methane and Sensor output

Chapter 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

The designed real time gas monitoring system is utilized on order to detect the gas concentration and the following conclusions were obtained:

- The designed module gives the precise value of gas concentration.
- Use of XBEE enhances the area of signal coverage and efficiency of data transfer.
- The gas concentration values are displayed at underground section as well as in monitoring unit at the surface in remote area where carrying PC is not possible.
- The designed system is economical that costs Rs. 7500-8000.

6.2 FUTURE SCOPE

- The designed equipment was studied in the laboratory scale; it can be implemented in the mine substations with proper protection to verify the operation in a real time environment.
- Additional sensors can be used for all possible safety issues such as IR sensors (for no. of person inside the mine), pressure sensor, water check sensor, rock collapse sensor.
- The sensor can be made auto calibrated.
- Range of the networking can be extended using more number of ZigBee.

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