Real Time Monitoring System for Mine Safety using Wireless Sensor Network (Multi-Gas Detector)

A Thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY

by

Sumit Kumar Srivastava

DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769 008

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Under guidance of

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Certificate

This is to certify that the thesis entitled "**Real Time Monitoring System for Mine Safety using Wireless Sensor Network (Multi-Gas Detector)"** submitted by **Sumit Kumar Srivastava** to the National Institute of Technology, Rourkela, for the partial fulfilment of the reward of the degree of Master of Technology in Mining Engineering is an authentic work carried out by him under my guidance and supervision.

The thesis in my opinion, is worthy of consideration for the award of the degree of Master of Technology in accordance with the regulations of the Institute. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:

Dr. B. K. Pal
Professor
Department of Mining Engineering
National Institute of Technology
Rourkela-7690 08

Declaration

I certify that

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Sumit Kumar Srivastava

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I wish to express my profound gratitude and indebtedness to Dr. B. K. Pal, Professor, Department of Mining Engineering, and NIT Rourkela who gave me the golden opportunity to do this wonderful project on the topic "**Real Time Monitoring System for Mine Safety using Wireless Sensor Network (Multi-Gas Detector)**". I find words inadequate to thank him for his encouragement and valuable suggestions during the course of this work.

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Sumit Kumar Srivastava

Date:

Abstract

Today safety of miners is a major challenge. Miner's health and life is vulnerable to several critical issues, which includes not only the working environment, but also the after effect of it. Mining activities release harmful and toxic gases in turn exposing the associated workers into the danger of survival. This puts a lot of pressure on the mining industry. To increase the productivity and reduce the cost of mining along with consideration of the safety of workers, an innovative approach is required.

Miner's health is in danger mainly because of the toxic gases which are very often released in underground mines. These gases cannot be detected easily by human senses. This thesis investigates the presence of toxic gases in critical regions and their effects on miners. A real time monitoring system using wireless sensor network, which includes multiple sensors, is developed. This system monitors surrounding environmental parameters such as temperature, humidity and multiple toxic gases. This system also provides an early warning, which will be helpful to all miners present inside the mine to save their life before any casualty occurs. The system uses Zigbee technology to establish wireless sensor network. It is wireless networking standard IEEE 802.15.4, which is suitable for operation in harsh environment.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

This chapter serves as introduction to the thesis. It presents the problems of communication in underground mines and safety issues. The need for the detection and real time monitoring of the system is also discussed briefly. It also presents objectives and organization of the thesis.

1.1 Introduction

Underground mining operations proves to be a risky venture as far as the safety and health of workers are concerned. These risks are due to different techniques used for extracting different minerals. The deeper the mine, the greater is the risk. These safety issues are of grave concern especially in case of coal industries. Thus, safety of workers should always be of major consideration in any form of mining, whether it is coal or any other minerals.

Underground coal mining involves a higher risk than open pit mining due to the problems of ventilation and potential for collapse. However, the utilization of heavy machinery and the methods performed during excavations result into safety risks in all types of mining.

Modern mines often implement several safety procedures, education and training for workers, health and safety standards, which lead to substantial changes and improvements and safety level both in opencast and underground mining.

Coal has always been the primary resource of energy in India, which has significantly contributed to the rapid industrial development of the country. About 70% of the power generation is dependent on it thus, the importance of coal in energy sector is indispensable. But the production brings with it the other byproducts, which proves to be a potential threat to the environment and the people associated with it. In lieu of that the present work is a sincere attempt in analyzing the graveness and designing a real time monitoring system of detection by using the ZigBee technology.

1.2 Background and Motivation

In underground mine, ventilation systems are critical to supply adequate oxygen, keeping up non-dangerous and non-lethal environments and an effective working mine. To monitor an underground mine, can help killing high hazard environments. Primitive procedures of monitoring a mine's air can be followed back to the utilization of canaries and different creatures to ready diggers when the climate gets to be lethal. Incorporating ventilation monitoring systems empowers a mine to insightfully roll out ventilation improvements in view of the far reaching information given by the monitoring systems. Sudden changes in the ventilation system are identified by the monitoring system, permitting quick move to be made. New and creating correspondence and following systems can be used to monitor mines more proficiently and transfer the information to the surface.

The progression of technology has allowed mine monitoring techniques to become more sophisticated, yet explosions in underground coal mines still occur. The safety issues of coal mines have gradually turned into a major concern for the society and nation. The occurrence of disasters in coal mines is mainly due to the harsh environment and variability of working conditions. So, it makes the implementation of mine monitoring systems essential for the safety purpose. Wired network systems used to be a trend for traditional coal mines, which have really played a significant role in safely production in coal mines. With the continuous enlargement of exploiting areas and depth expansion, laneways have become blind zones, where numerous unseen dangers are hidden out. Moreover, it is not possible there to lay expensive cables, which is also time consuming. So, it is essential to have a wireless sensor network mine monitoring system, which can be disposed in such mines in order to have a safe production within.

Wireless sensor networks (WSNs) have earned a significant worldwide attention in current scenario. A WSN is a special ad-hoc, multi-hop and self-organizing network that consists of a large number of nodes arranged in a wide area in order to monitor the phenomena of interest. It can be useful for medical, environmental, scientific and military applications. Wireless sensor networks mainly consist of sensor nodes or motes responsible for sensing a phenomenon and base nodes, which are responsible for managing the network and collecting data from remote nodes. The design of the sensor network is influenced by many factors, including scalability, operation system, fault tolerance, sensor network topology, hardware constraints, transmission media and power consumption.

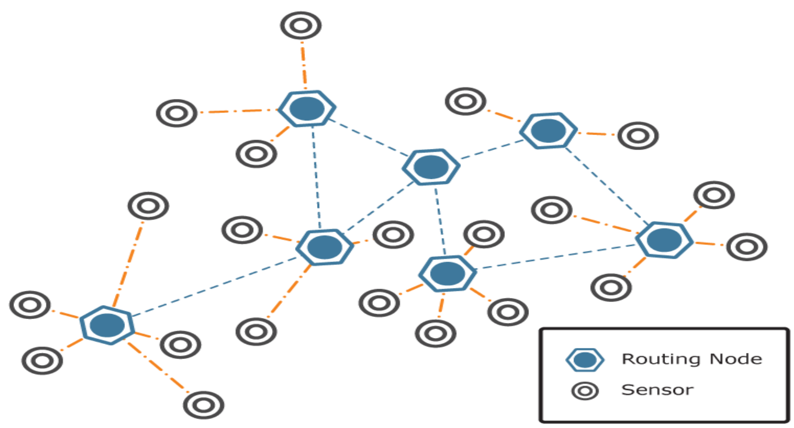


Figure 1-1 Wireless Sensor Network
(http://www.purelink.ca/en/technologies/related-technologies.php)

These small sized sensors are quite inexpensive compared to traditional sensors and also require limited computing and processing resources. These sensor nodes can detect, measure and collect information from the environment and based on some local statistical decision process, they can convey the collected data to the control room.

It has three major advantages over wired monitoring network systems:

1. There is no need of cables to lay and easy installation in blind areas, reducing cost of the monitoring system. The number of nodes can be increased to eliminate blind areas. Also, it offers a general communication and allocation of the goal.
2. The dense nodes ensure the data acquisition with high accuracy and optimum data transmission, and further realization of real-time monitoring system for mine environment.
3. A little computing ability, storage capacity with data fusion of sensor nodes make them suitable for the remote monitoring system.

The above mentioned advantages make wireless sensor network ideal for monitoring of safely production of coal mines.

1.3 Objective

Mining environment often has hidden dangers within such as toxic gases, which may present severe health exposures to the people working within mining. These gases need to be detected at times and informed the dangerous situation in right time for the safety of miners. Wired network monitoring systems have assisted the mine safety significantly, but it is not idea for all types of mining environment.

A real-time monitoring systems may assist in monitoring and control over the mining environment. Zigbee technology offers its most of the advantages ideal for the real-time monitoring system. Thus, the primary objective of this project is decided to design an efficient real-time monitoring system so that various leaked mine gases could be identified at times and preventive measures could be devised accordingly. The research investigations to be carried out with the following objectives:

1. Detection of different toxic gases within mining environment
2. Communication establishment between sensors and Zigbee
3. Establishment of Wireless Sensor Network
4. Design of a real-time monitoring system

1.4 Organization of the Thesis

The present work is an attempt to analyze the safety scenario of a mine. The idea is an improvisation on previous related works where WSN is used to detect the toxic gases present in the mine. The real time monitoring which is the requirement now a days is designed for the purpose. The thesis presents all the related technologies such as ZigBee and embedded designing etc. the work can be summarized as follows:

- Introduction
- Literature Review
- Mine gases and their Impacts
- System Design
- Experiments and Results
- Conclusion

Chapter 2

Literature Review

In underground mining, ventilation systems are crucial to supply sufficient oxygen, maintaining non-explosive and non-toxic atmospheres and operating an efficient mine. Mine ventilation system can help in eliminating high risk atmosphere. Primitive techniques to monitor the mining atmosphere can be traced back to the use of canaries and other animals to alert miners, when the atmosphere becomes toxic. Integrating ventilation monitoring system enables mine to intelligently make ventilation changes based on the extensive data, the monitoring system provides. Unexpected changes in the ventilation system are noticed by the monitoring arrangement, allowing prompt action to be considered. New and developing communication and tracking systems can be utilized to monitor mines more efficiently and relay the data to the surface.

2.1 Previous Work

These are the previous research work on different systems using different technologies for the safety of the environment.

Yu *et al.* (2005) proposed a real-time forest fire detection system based on wireless sensor network. The system collects the data and processes it in the WSN for detecting the forest fire. They designed the monitoring and detecting sensor networks using neural network.

Joseph *et al.* (2007) focused on the problems and hazards of fire in libraries or archives and described the necessary preventive steps to be adopted. They identified the diverse parts which are applied for fire detection and alert system and also provided necessary strategies for the selection and installation of an ideal fire alarm system.

Fischer (2007) considered the simulation technique and applied this technique to design a fire detection system. This system detects the fire as well as differentiates fire and non-fire spot to decrease the false alarm rate in the non-fire event.

Tan *et al.* (2007) designed a system, which is applied for mine safety monitoring. They called the system WSN based Mine Safety System. This system is capable of real time monitoring of the mine environment and provide the pre-warning for the fire or explosion.

Niu Xiaoguang *et al.* (2007) presented a distributed heterogeneous hierarchal mine safety monitoring prototype system (HHMSM) which is based on features of the underground mine gallery and necessities of mine safety. This system monitors the methane concentration and the location of miner. They proposed an overhearing-based adaptive data collecting system, which makes use of the redundancy and the correlation of the sampling readings in both time and space to ease the traffic and control.

He Hongjiang *et al.* (2008) designed a system using low power ARM (Advanced RISC Machines) processor chip S3C2410 as the control of core and Zigbee as a communication platform of WSN. This system composed of network mode, communication network of CAN BUS as well as monitoring sensors.

Zheng Sun *et al.* (2008) analyzed the problems of mine safety monitoring and an improved TinyOS Beaconing-based WSN. This protocol can not only aware Energy and repair route automatically, but also can prevent the number of child nodes and that of system levels. The features are small routing Table, high stabilization, high self-repairing and long lifetime. It may be suitable for coal mine data acquisition and applied to mine safety monitoring.

Lin-Song Weng *et al.* (2009) planned a framework, which is viably observing all circumstances in mine, particularly for the wellbeing of mineworkers. They named the system the real-time mine auxiliary monitoring system (RMAMS), which is embraced for a real-time mine-monitoring system. Mine auxiliary sensor system (MASS) consists of an intelligent activity sensor and repeater and arrives at decision to resolve the procedure of processing.

Hua Fu *et al.* (2009) studied the fuzzy theory and neural network technology and by using this information they designed an intelligent fuzzy neural network sensor system for coal mine. This technology can make accurate detection of different parameters.

Shi Wei *et al.* (2009) designed a multi parameter monitoring system for coal mine tunnel, which is based on WSN network. This system uses the RS-485 communication protocol and hardware modular. It automatically sends warning signals to the main control room and accomplishes corresponding control.

Wenge Li *et al.* (2009) designed a system for remote monitoring and analysis of mines using virtual instrument technology, network technology and database technology. This organization consists of sensors, remote clients, the ground monitoring center and the underground substation. The remote client, through internet explorer, can browse the real time monitoring data of mine safety such as temperature, gasoline, wind velocity, carbon monoxide and so on. The system stored the data using ADO in LabVIEW.

Shao Chang'an *et al*. (2009) studied the coal mine safety information and based on this information such as dynamic changes, activity, closely related to the space, they used special data mining and GIS technology for designing a coal mine safety monitoring.

Hongmei Wu *et al.* (2010) proposed a remote monitoring system for mine vehicle based on wireless sensor technology. This scheme uses the sensor nodes, deployed on the vehicles to collect speed, mileage, pressure, oil level value, and data to the ARM based information processing terminal.

Li-Chien Huang *et al.* (2011) designed a system for building electrical safety. No-fuse breakers (NFBs) and electrical wall plugs are the main components of traditional distribution, which is used for power transmission and overload protection. NFBs have the utilization of over-burden security and are not completely compelling in forestalling electrical flames created by poor contact or dust pollution. This plan is built with assurance instruments so as to upgrade the parts of customary circulation frameworks. The effects on other equipment in the same branch circuit can be avoided by the threshold limit of the system when the outlet disconnects the power.

Ge Bin *et al.* (2011) suggested a method for monitoring coal mine using Zigbee technology. This system measures the various safety factor of production such as gas, temperature, humidity and other environmental indicators.

Cheng Bo *et al.* (2012) proposed a restful web services mashup improved coal mine safety monitoring and control automation using WSN network. This system can collect the values of methane, temperature, humidity and personal position information inside the mine.

Rajkumar Boddu *et al.* (2012) designed a coal mine monitoring system using Zigbee based on GSM technology. The degree of monitoring safety can be improved using this scheme and reduce misfortune in the coal mine. They purposed a solution suitable for mine wireless communication, and safety monitoring using this scheme.

Isaac O. Osunmakinde (2012) studied the different types of toxic fumes in dangerous regions and their conditions and trends in the air for preventing miners from contracting diseases. They developed an autonomous remote monitoring system of WSNs which combines Ohm's law and mobile sensing coupled with ambient intelligence governing decision-making for mine workers. The system has been monitored the indoor scenarios which is successfully deployed in underground mines. The system provides pre warning for safety purpose.

Mohit Kumar *et al.* (2013) proposes a wireless control and monitoring system for an induction motor based on Zigbee communication protocol for safe and economic data communication in industrial fields, where the wired communication is more expensive or impossible due to physical conditions. This system monitors the parameters of induction machine and transmit the data. A microcontroller based system is used for collecting and storing data and accordingly generating a control signal to stop or start the induction machine wireless through a computer interface developed with Zigbee.

Mr. Kumarsagar *et al.* (2013) designed a wireless sensor network with the help of MSP430xx controller, which is monitor the smoke, gas, temperature and humidity in an underground mine. This system also controls the ventilation demand to miners depending using upon the monitoring data from the mine. This system utilizes a wireless Zigbee transceiver for remote logging of data at a central location to control the environmental state with the assistance of a motor and valve control circuitry.

Berardo Naticchia *et al.* (2013) proposed the infrastructure less real-time monitoring system to provide prompt support for inspecting the health and safety management on construction sites. They tested the specific applications of monitoring, interference between teams working on large construction sites. The system is capable of alert in the occurrence of interference and to log any unexpected behavior.

Zhang Xiaodong *et al.* (2014) presented the problems and faultiness of current coal mine monitoring system. They examined the plan and implementation of a platform to remotely monitor and control coal mine production processes over Industrial Ethernet based on the embedded engineering. Integrated with each lower computer terminal are S3C2410 microprocessors that can be utilized for linking up to the monitoring network effectively.

2.2 Conclusion

The chapter explains all the previous work related to the monitoring of mine safety. The different researchers performed their work in this regard and came out with their own systems of surveillance for the mine gases and fires. Based on their study the following work is an improvisation on the real time monitoring system with wireless technology of data transfer.

Chapter 3

Mine Gases and their Impacts

The air of the atmosphere that we breathe is a mixture of several gases and its composition is practically constant over the whole surface of the earth. Because air is mixture and not a chemical substance, the components can be separated.

3.1 Mine Gases

In mine, gases are released during mining operations. It will be observed that return air is depleted in oxygen content and contaminated by mine gases. Impurities come from exhalation by men, blasting, and underground fires, burning of lights, bacterial action and gases given off from strata. It also contains moisture and dust of coal and rock.

When referring to noxious and poisonous gases met with in a mine the commonly used names are as follows:

- **Blackdamp:** It is a mechanical mixture of the extinctive gases, carbon monoxide and excess nitrogen; sometimes it is referred to as chokedamp or stythe.
- **Firedamp:** It is used either as synonymous with methane or referring to the mechanical mixture of the gases, chiefly inflammable, given off naturally from coal and consisting for the most part of methane.
- **Whitedamp:** It is synonymous with carbon monoxide.
- **Stinkdamp:** It is synonymous with sulphureted hydrogen (H_2S).
- **Afterdamp:** This is a mechanical mixture of gases existing in a mine after an explosion of firedamp or coal dust. Its composition is extremely variable, but usually includes carbon monoxide, carbon dioxide, nitrogen and sometimes H_2S and SO_2 with a very small percentage of oxygen.

The necessities for gas distinguishing proof can move massively, on the other hand, there are five fundamental sources of hazardous gas in mining applications.

1. **Gasses from Blasting:**

   Blasting generates toxic and harmful gases. These harmful gasses include carbon monoxide and nitrogen dioxide. As a result of the utilization of oxygen in any such impact, oxygen deficiency might likewise be an outcome.

2. **Methane from Coal Beds:**

   Profoundly flammable methane (CH4) or firedamp, as it is brought in numerous coal-fields, is framed in the last phases of coal arrangement, and due to the profundities and weights, it gets to be imbedded in the coal. As unearthings are made, methane gas is freed into the air. Gas is transmitted from the purpose of unearthing, as well as from the coal being transported to the surface.

3. **Vehicle Exhaust:**

   Vehicles are also generated various toxic and poisonous gases. These poisonous gases are an aftereffect of the operation of burning motors.

4. **Underground Explosions and Fires:**

5. **Penetrating into Stagnant Water:**

   Pockets of stagnant water can contain a lot of hydrogen sulfide coming about essentially from the breakdown of pyrites.

These are some harmful gases and their effects:

3.1.1 Nitrogen Dioxide (NO_2)

NO2 is a reddish brown gas with a sharp and chafing scent. It changes noticeable all around to shape vaporous nitric corrosive and harmful natural nitrates. NO_2 additionally assumes a noteworthy part in climatic responses that create ground-level ozone, a noteworthy segment of brown haze. It is additionally an antecedent to nitrates, which add to expanded respirable molecule levels in the climate.

Sources of NO_2

All burning in air produces oxides of nitrogen (NOx) such as NO, NO_2, N_2O_3 and have choking smell. These oxides are easily dissolved by moisture in the mine air. NO_2 are formed during the blasting of explosives containing nitroglycerine as one of the constituents if the explosives is not detonated completely.

Impacts of NO_2

NO_2 can chafe the lungs and lower impervious to respiratory contamination. Affectability increments for individuals with asthma and bronchitis. NO_2 artificially changes into nitric corrosive and, when stored, adds to Lake Acidification. NO_2, when artificially changed to nitric corrosive, can consume metals, blur fabrics and corrupt elastic. It can harm trees and products, bringing about considerable misfortunes.

Table 3-1 Health effects and Pollutant concentration breakpoints caused by NO_2

Category	Pollutant Concentration Breakpoints (ppb)	Health Effects
Very Good	0 -50	No health impacts
Good	51 -110	Slight smell.
Moderate	111 - 200	Smell.
Poor	201 - 524	Air smells and looks brown. Some increment in bronchial hyperactivity in asthmatics people.
Very Poor	525 or over	Expanding affectability for asthmatics and individuals with bronchitis.

3.1.2 Sulfur Dioxide (SO_2)

SO_2 is a colourless gas with a strong sulphurous smell, neither combustible nor a supporter of combustion. It is 2.21 times heavier than air. It can be oxidized to sulfur trioxide, which in the region of water vapor is instantly changed to sulphuric corrosive fog. SO_2 can be oxidized to shape corrosive vaporizers. SO_2 is a forerunner to sulfates, which are one of the principal segments of respirable particles in the air.

Sources of SO_2

It may be produced in small quantities during blasting in mines, and after a fire or coal dust explosion.

Impacts of SO_2

This gas is very poisonous and extremely irritating to the eyes and respiratory passages. Health impacts brought about by the presentation to abnormal amounts of SO_2 incorporate breathing issues, respiratory sickness, changes in the lung's safeguards, and intensifying respiratory and cardiovascular ailment. Individuals with asthma or perpetual lung or coronary illness are the most delicate to SO_2. It also harms trees and harvests. SO_2, alongside nitrogen oxides, is the principle antecedents of corrosive downpour. This adds to the fermentation of lakes and streams, quickened consumption of structures and diminished deceivability. SO_2 additionally causes development of minute corrosive mist concentrates, which have genuine wellbeing ramifications and adding to environmental change.

Table 3-2 Health effects and Pollutant concentration breakpoints caused by SO_2

Category	Pollutant Concentration Breakpoints (ppb)	Health Effects
Very Good	0 - 79	No health impacts
Good	80 - 169	Damages some vegetation in combination with ozone.
Moderate	170 - 250	Damages some vegetation.
Poor	251 - 1999	Smell; increasing vegetation damage.
Very Poor	2000 or over	Increasing vulnerability for asthmatics and individual with bronchitis.

3.1.3 Carbon Monoxide (CO)

Carbon monoxide gas is colourless, odourless, tasteless and nonirritating. It is only slightly higher than air. It is combustible but does not support combustion. It is soluble in water. In air it burns with a light blue flame to CO_2.

Sources of CO

The production of the CO in a mine may be due to any one or more of the following cases:

- **Oxidation of coal and other carbonaceous matter:** Incomplete oxidation may result in its formation and under normal mining condition, the percentage found is negligible and harmless in return of a coal mine.
- **Explosives:** Explosives contain the amount of oxygen required for complete chemical reaction, but the chemical reaction when the explosive is blasted is seldom perfect and this results in the formation of CO.
- **Spontaneous Combustion:** This is a main source of production of dangerous percentage of CO in a coal mine. Active fire in an underground mine also forms CO in dangerous percentage.
- **Methane or Coal dust Explosion:** Gases produced by the explosion of methane coal dust invariably contain a large percentage of CO.
- **Underground Machinery:** Air compressor, run faultily, and exhaust gas of internal combustion engines like diesel locomotives, are common sources of production of CO. In fact, every machine some CO if proper lubricants are not used.

Impacts of CO

CO is a very poisonous gas and its affinity for the hemoglobin of the blood is nearly 300 times that of oxygen. If CO is present even in small quantities in the inhaled air, it is difficult for blood to absorb proper quantities of oxygen to support life. CO enters the circulation system and lessens oxygen conveyance to the organs and tissues. Individuals with coronary illness are especially touchy. Introduction to abnormal states is connected with weakness of vision, work limit, learning capacity and execution of troublesome undertakings.

Table 3-3 Health effects and Pollutant concentration breakpoints caused by CO

Category	Pollutant Concentration Breakpoints (ppb)	Health Effects
Very Good	0 - 12	No health Impacts
Good	13 - 22	No health impacts.
Moderate	23 - 30	Blood chemistry changes, but no noticeable damage.
Poor	31 - 49	Increased warning sign in smokers with heart disease.
Very Poor	50 or over	Increasing warning sign in non-smokers with heart disease; blurred vision; some clumsiness.

Typical sickness symptoms due to the high concentration of the CO are mild headache, fatigue, nausea and dizziness. A CO concentration of 12-13000 ppm is dead after 1-3 minutes. A CO concentration of 1600 ppm is deadly after one hour.

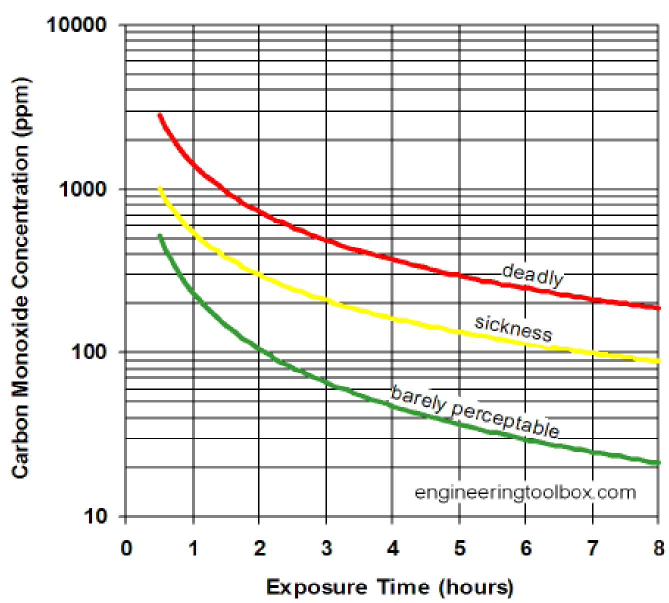


Figure 3-1 Concentration and Its exposure time

Table 3-4 Concentration of CO and Its exposure time

Conc. of CO in the air (ppm)	Breathing Time	Toxic Symptoms
9	Short term exposure	ASHRAE recommended maximum allowable concentration in living area.
35	8 hours	The maximum exposure allowed by OSHA in the workplace over an eight hour period.
200	2-3 hours	Slight headache, tiredness, fatigue, nausea and dizziness.
400	1-2 hours	Serious headache-other symptoms intensify. Life threatening after 3 hours.
800	45 minutes	Dizziness, nausea and convulsions. Unconscious within 2 hours. Death after 2-3 hours.
1,600	20 minutes	Headache, dizziness and nausea. Death within 1 hour.
3,200	5-10 minutes	Headache, dizziness, nausea. Death within 1 hour.
6,400	1-2 minutes	Headache, dizziness, nausea. Death within 25-30 minutes.
12,800	1-3 minutes	Death within 1-3 minutes

3.1.4 Methane (CH_4)

Methane is a colorless, odorless, tasteless, flammable gas and lighter than air. Because of the largest component of fire damp, it is commonly known as firedamp. Firedamp refers to the mixture of gases. Such mixture consists of practically methane with small traces of ethane (C_2H_6), and other hydrocarbons, such as propane (C_3H_8) and butane (C_4H_{10}).

Sources of CH_4

Methane in mine is mainly released from five sources:

1. To recover methane in advance of mining from gob or goaf wells.
2. From ventilation air in underground mines (dilute concentrations of methane).
3. From an abandoned or closed mines, from which methane may leak out through the vent holes or through fissures or crevices in the earth.
4. Extremely flammable methane (CH_4) or firedamp, as it is brought in numerous coal-fields, is framed in the last phases of coal arrangement, and due to the profundities and weights, it gets to be imbedded in the coal. As unearthings are made, methane gas is freed into the air.
5. Fugitive emissions from post-mining operations, in which coal keeps on give off methane as it is stacked away in pores and transported.

Impacts of CH_4

Methane is a very poisonous gas. Methane gas causes headaches, reduces the oxygen level in the physical structure. If the oxygen level reduces to less than 12%, the individual can get to be unconscious and turn out to be dead in some cases. This gas symptoms are Nausea and vomiting, heart palpitations (which causes a painful sensation of the heart beating), memory loss, poor judgment, dizziness and blurred vision. Some patients also display flu-like symptoms. Methane gas is extremely inflammable. When it is burnt, carbon monoxide will be brought forth.

All above toxic gases summarized in Table 3.5.

Table 3-5 Classification of Toxic gases and their hazardous limit

Name	Primary sources in mines	Hazards	Guidelines TLVs	Flammability limits in air (%)
Methane (CH_4)	Strata	Explosive, Breathing problem	1%;isolate electrical power 2%remote personnel	5 to 15
Carbon dioxide (CO_2)	Oxidation of carbon, fires, explosions	Increased heart rate and breathing	TWA=0.5% STEL=3.0%	
Carbon monoxide (CO)	Fires, Explosions, blasting, incomplete combustion of carbon compounds	Highly toxic, Explosive	TWA=0.05% STEL=0.04%	12.5 to 74.2
Sulphur dioxide (SO_2)	Oxidation of Sulphides, acid water on sulphide ores	Toxic, irritant to eyes, Throat and lungs	TWA=2 ppm STEL=5 ppm	
Nitrogen dioxide (NO_2)	IC engines, blasting, fumes, welding	Toxic, Throat and lung infections	TWA=3 ppm Ceiling: 5ppm	
Hydrogen Sulphide (H_2S)	Acid water on sulphides, Strata decomposition of organic materials	Highly Toxic, irritant to eyes and explosive	TWA= 10ppm STEL= 15ppm	4.3 to 45.5

TWA-- Time-weighted average (8 h shift and a 40 h work week)

STEL-- Short-term exposure limit (TWA concentration occurring more than 15 min).

Ceiling limit is the concentration that should not be exceeded at any time. This is relevant for the most toxic substances or those that produce in an immediate irritant effect.

3.2 Conclusion

The chapter deals with generation and the effects of mine gases. Different hazardous gases such as NO_X, SO_2, CO, CH_4 etc. has been discussed at length. The health impacts and the maximum exposure limit of each of them is described. In lieu of that a suitable monitoring system for these gases has been designed, which is mentioned in the next chapter.

Chapter 4

System Design

This chapter consists of the design of the system. This chapter mainly contains the details of required hardware and software. The appropriate working environment is setup with all required components to develop the system. After developing the system, it tested in the particular environment. This chapter explains the step-by-step development of hardware system followed by software development and its implementation.

4.1 System Hardware Design

This monitoring system contains several components like boards (Arduino board, Xbee module and Zigbee USB interfacing board), LCD (Liquid crystal display), different sensors and other small electronic components. This chapter gives a detailed review of each of this part along with its working principle.

4.1.1 Arduino

Arduino is an open source hardware and software based on microcontroller which is very easy to use. Arduino is an inexpensive control board that's easy to program and can hook up to a wide variety of hardware. It is intended for anyone making project. Arduino senses the environment by receiving input from many sensors and affects its surroundings. In the market, various types of Arduino board are available such as Arduino UNO, Arduino Leonardo, Arduino due, Arduino Yun, Arduino Mega etc. But I am using Arduino UNO for this system.

Arduino UNO

The Arduino board is a specially designed circuit board for programming and prototyping with Atmel microcontrollers. The microcontroller on the board is programmed using the Arduino Programming Language (based on Wiring) and the Arduino development environment (based on Processing). It is relatively cheap and plug straight to computer’s USB port or power it with an AC-to-DC adapter or battery to get started.

Figure 4-1 Arduino UNO Board
(http://www.lextronic.fr/P4124-platine-arduino-uno-rev-3.html)

Table 4-1 Technical specification of Arduino UNO

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

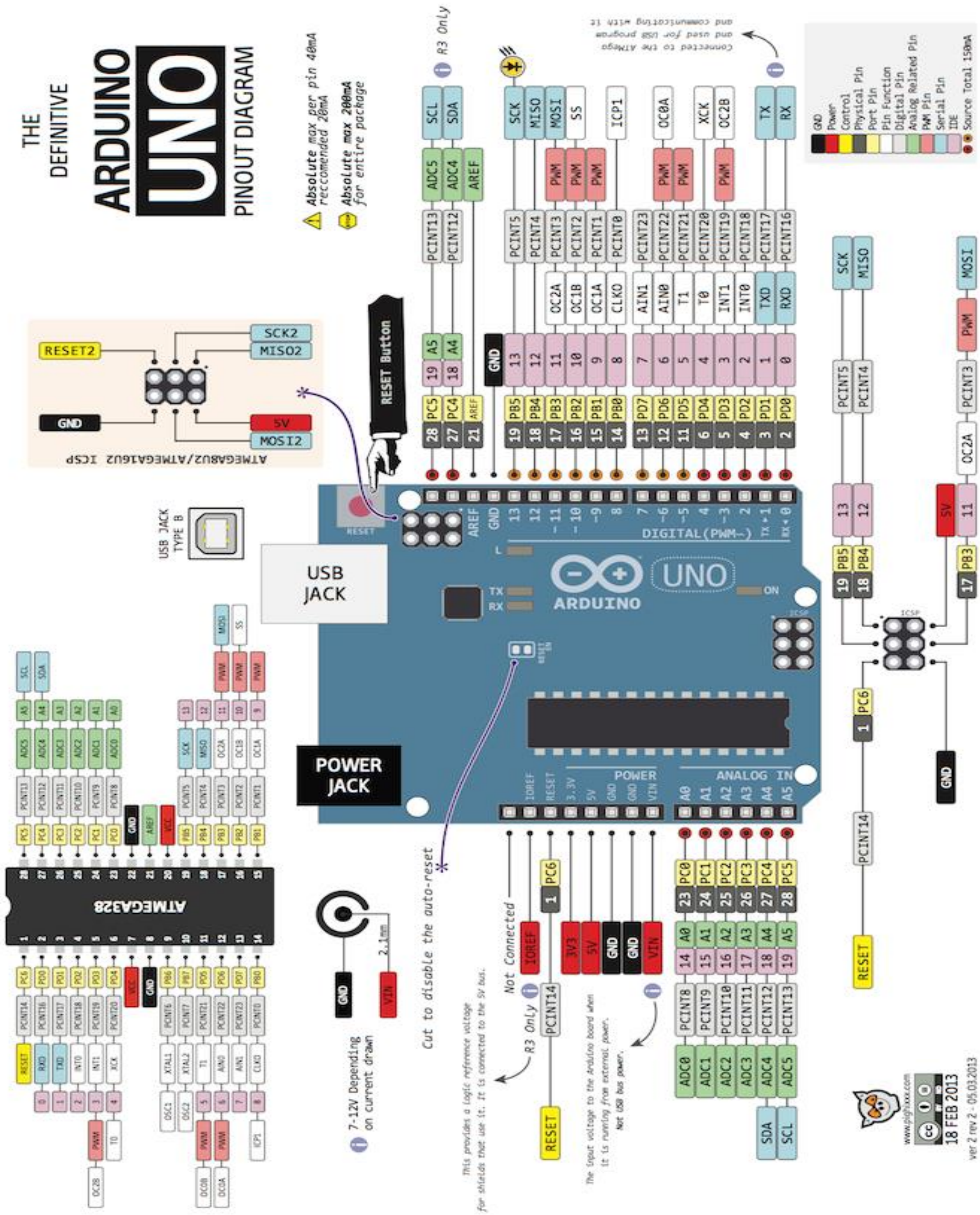


Figure 4-2 Arduino UNO Pin out diagram
(http://www.dominicdube.com/wp-content/uploads/Arduino-uno-Pinout.png)

Arduino UNO has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The Atmega328 has 32 KB of flash memory for storing code (of which 0.5 KB is used for the bootloader). Each of the 14 digital pins can be used as input or output and these operate at 5V.

The functions of these digital pins are predefined like 0 and 1 pins wok for receiving and transmitting data, 2 and 3 pins act as external interrupts which can be configured to trigger an interrupt on a low value and a rising or falling edge, 3, 5, 6, 9, 10, and 11 pins provide 8-bit PWM output, 10, 11, 12 and 13 pins support SPI communication.

Each of 6 analog pins can be used as analog input, which provides 10 bits of resolution (1024 different value). These pins measure from ground to 5V.

Arduino UNO can communicate with a computer or other Arduino or other microcontrollers. It communicates via serial communication (UART TTL). This serial communication appears as a virtual com port to software on the computer.

4.1.2 Xbee Pro S2B

The Xbee Pro S2B module is a wireless sensor network, which operates within the Zigbee protocol and support the unique need of low cost and low power. This module requires minimum power and provide reliable delivery of data between devices. It operates at 2.4GHz frequency band.

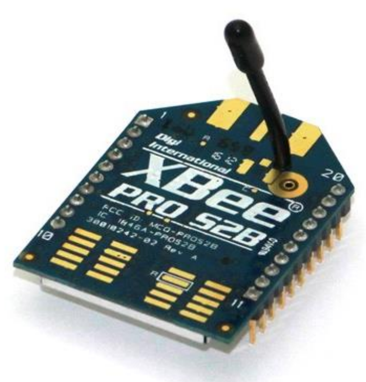


Figure 4-3 Xbee Pro S2B 63mw – series 2
(http://www.jayconsystems.com/xbee-pro-s2b-63mw-wire-antenna-series-2.html)

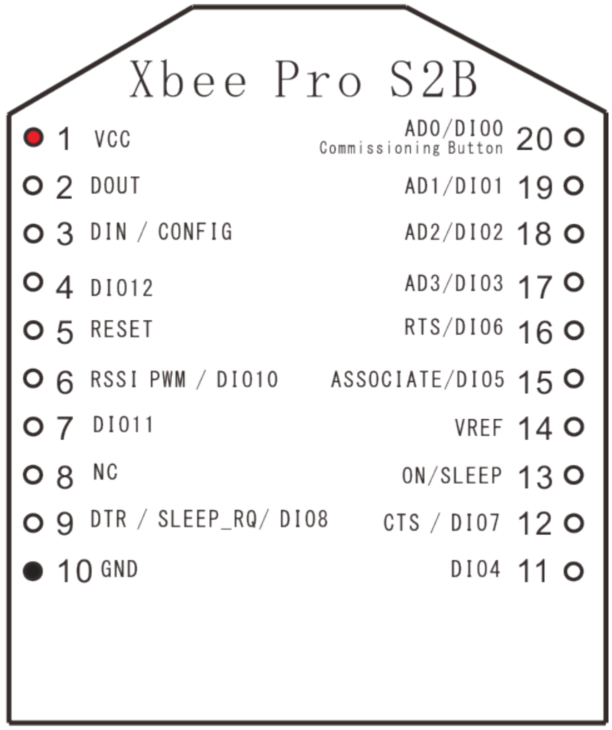


Figure 4-4 Xbee Pro S2B Pin Configuration
(http://www.inetclub.gr.jp/Total_collection_volume.html)

Table 4-2 Performance of the Xbee PRO S2B RF Module

Indoor/Urban Range	Up to 300 ft. (90 m), up to 200 ft (60 m) international variant
Outdoor RF line-of-sight Range	Up to 2 miles (3200 m), up to 5000 ft (1500m) international variant
Transmit Power Output	63mW (+18 dBm) 10mW (+10 dBm) for International variant
RF Data Rate	250,000 bps
Data Throughput	up to 35000 bps
Serial Interface Data Rate	1200 bps - 1 Mbps (non-standard baud rates also supported)
Receiver Sensitivity	-102 dBm

Table 4-3 Power requirement of Xbee Pro S2B

Supply Voltage	2.7 - 3.6 V
Operating Current (Transmit, max output power)	205mA, up to 220 mA with programmable variant (@3.3 V) 117mA, up to 132 mA with programmable variant (@3.3 V), International variant
Operating Current (Receive)	47 mA, up to 62 mA with programmable variant (@3.3 V)
Idle Current (Receiver off)	15mA
Power-down	3.5 □A typical @ 25ºC

Table 4-4 General features of Xbee Pro S2B

Operating Frequency Band	ISM 2.4 GHz
Dimensions	0.960 x 1.297 (2.438cm x 3.294cm)
Operating	-40 to 85º C (industrial)
Antenna Options	Integrated Whip Antenna, Embedded PCB Antenna, RPSMA or U.FL Connector
I/O Interface	3.3V CMOS UART (not 5V tolerant), DIO, ADC

Table 4-5 Network and Security of Xbee Pro S2B

Supported Network Topologies	Point-to-point, Point-to-multipoint, Peer-to-peer, and Mesh
Number of	15 Direct Sequence Channels
Channels	11 to 25
Addressing Options	PAN ID and Addresses, Cluster IDs and Endpoints (optional)

4.1.3 Zigbee USB Interfacing Board

ZigBee (Xbee) USB Interfacing Board is used to interface Xbee wireless module with computer systems. This Board is used to connect ZigBee modules to make communication between PC to PC or laptop, PC to Mechanical Assembly or robot, PC to embedded and microcontroller based Circuits. As ZigBee communicates through Serial Communication so other end of USB which is connected to a PC, treated as COM port for Serial Communication. It is provided with indication LEDs for ease.

Figure 4-5 Zigbee USB interfacing Board
(http://www.campuscomponent.com/media/download/ZigBee%20USB.pdf)

It supports both AT and API mode. Its baud ranges from 2400 bps to 115200 bps. On this interfacing board, CP2102 IC is used for converting TTL logic to USB logic.

4.1.4 Carbon Monoxide Sensor (MQ7)

Various types of sensors are available in the market in which semiconductor sensors are considered to have fast response. MQ7 semiconductor sensor is mainly used for detecting carbon monoxide (CO).

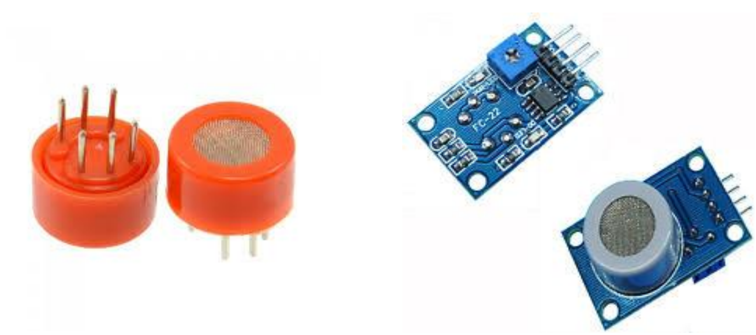


Figure 4-6 MQ-7 sensor, MQ7 Module
(http://www.ebay.com/itm/New-MQ-7-Carbon-Monoxide-CO-Gas-Sensor-Detection-Module-For-Arduino-/281487761087)

MQ-7 gas sensor composed of micro Al_2O_3 ceramic tube and Tin Dioxide (SnO_2). Electrode and heater are fixed into a crust. The heater provides required work conditions for the work of sensitive components.

The conductivity of sensor is higher along with the gas concentration rising. When the sensor, heated by 5V it reaches at high temperature, it cleans the other gases adsorbed under low temperature. The MQ-7 have 6 pins in which 4 of them are used to fetch signals and other 2 are used for providing heating current.

	Parts	**Materials**
1.	Gas sensing layer	SnO_2
2.	Resin base	Bakelite
3.	Electrode line	Pt
4.	Tube Pin	Copper plating Ni
5.	Tubular ceramic	Al_2O_3
6.	Electrode	Au
7.	Clamp ring	Copper plating Ni
8.	Heater coil	Ni-Cr alloy
9.	Anti-explosion	network Stainless steel gauze

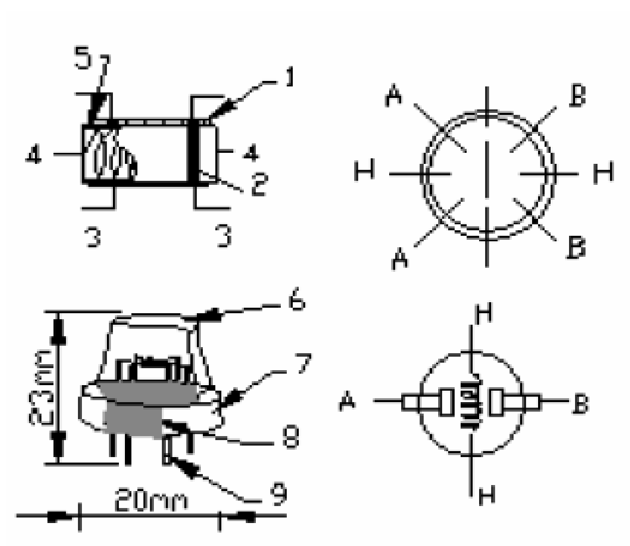


Figure 4-7 Structure and Configuration of MQ-7
(https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf)

MQ-7 sensor consist of 2 parts. One is heating circuit and the other one is the signal output circuit. In which heating circuit is used for time control and signal output circuit is accurately respond changes of surface resistance of the sensor.

Working Principle and Test Circuit for the MQ-7 Sensor

The surface resistance of the sensor is measured through the voltage signal output of the load resistance.

$$\textbf{Resistance of sensor } (R_S): R_S = R_L \times (V_c - V_{RL}) / V_{RL}$$

The sensor needs to be put 2 voltages for detecting CO in which, the heater voltage used to supply certified working temperature of the sensor and the test voltage used to detect voltage (V_{RL}) on load resistance (R_L) whom is in series with the sensor. In order to make the sensor with better performance, suitable R_L value is needed:

$$\textbf{Power of Sensitivity body } (P_S): P_S = V_C^2 \times R_S / (R_S + R_L)^2$$

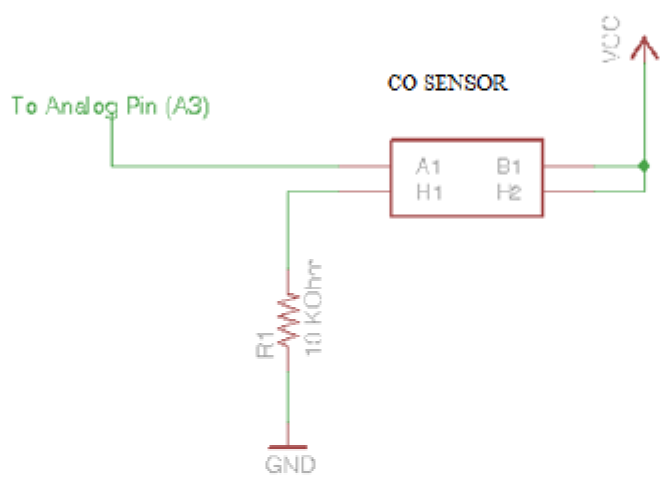


Figure 4-8 Measuring circuit of MQ-7

Table 4-6 Specification of MQ-7
(https://www.pololu.com/file/download/MQ7.pdf?file_id=0J313)

Model No.			MQ-7
Sensor Type			Semiconductor
Standard Encapsulation			Plastic
Detection Gas			Carbon Monoxide
Concentration			10-10000ppm CO
Circuit	Loop Voltage	V_c	≤10V DC
	Heater Voltage	V_H	5.0V±0.2V ACorDC（High） 1.5V±0.1V ACorDC（Low）
	Heater Time	T_L	60±1S（High）90±1S（Low）
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3Ω（Room Tem.）
	Heater consumption	P_H	≤350mW
	Sensing Resistance	R_s	2KΩ-20KΩ(in 100ppm CO)
	Sensitivity	S	Rs(in air)/Rs(100ppm CO)≥5
	Slope	α	≤0.6（R_{300ppm}/R_{100ppm} CO）
Condition	Tem. Humidity		20℃±2℃；65%±5%RH
	Standard test circuit		Vc:5.0V±0.1V; V_H（High）：5.0V±0.1V; V_H（Low）：1.5V±0.1V
	Preheat time		Over 48 hours

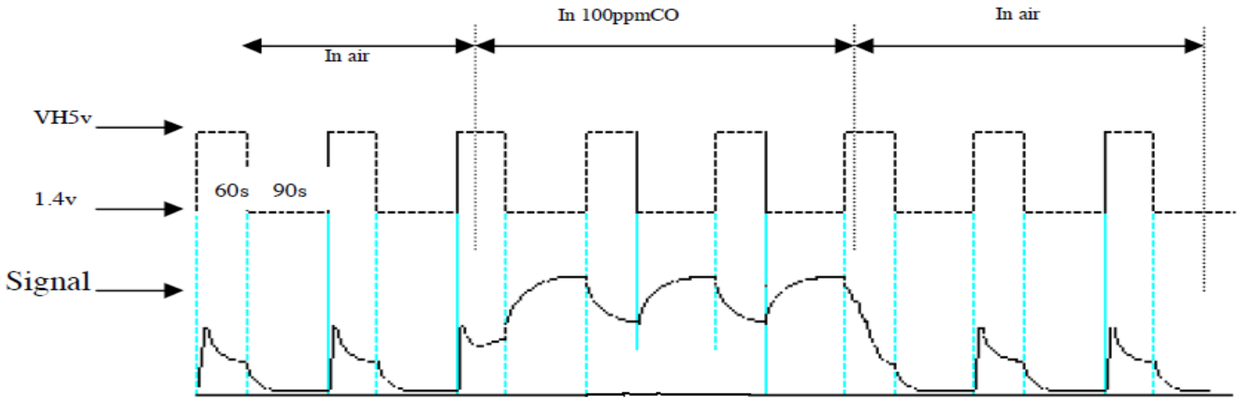


Figure 4-9 Alterable situation of R_L
(https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf)

Figure 4-9 shows the output signal of the sensor when it is moved from clean air to CO laden air. The readings are taken at one or two complete heating cycle.

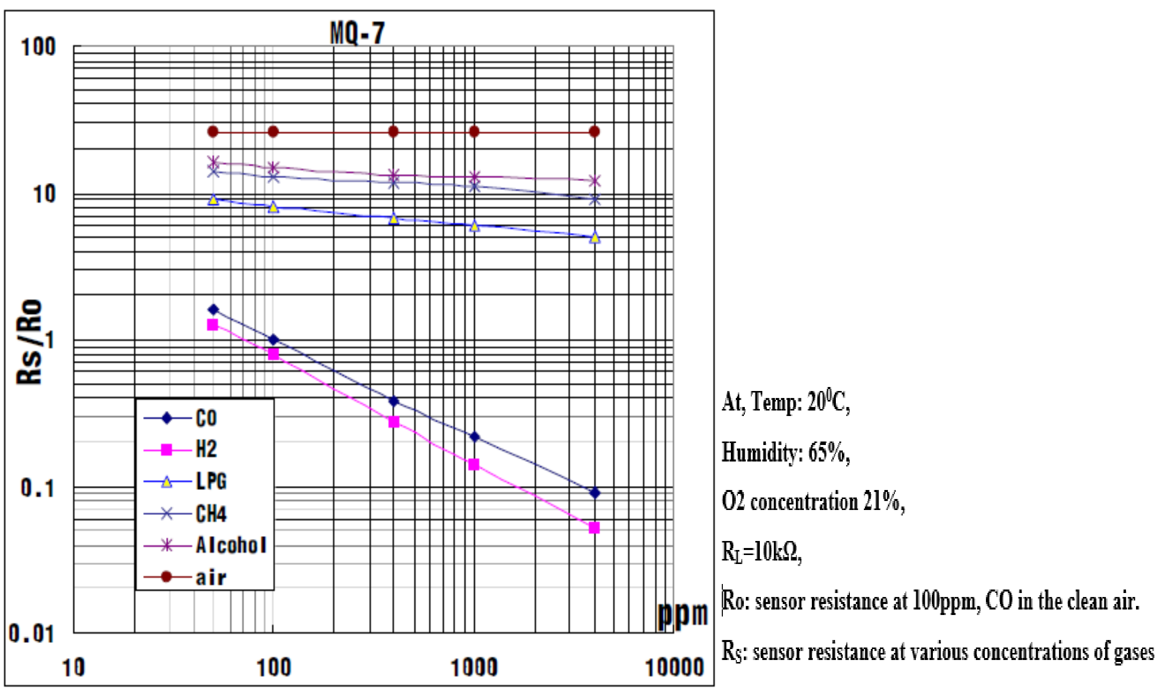


Figure 4-10 Sensitivity Characteristics curve of the MQ-7 for several gases
(https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf)

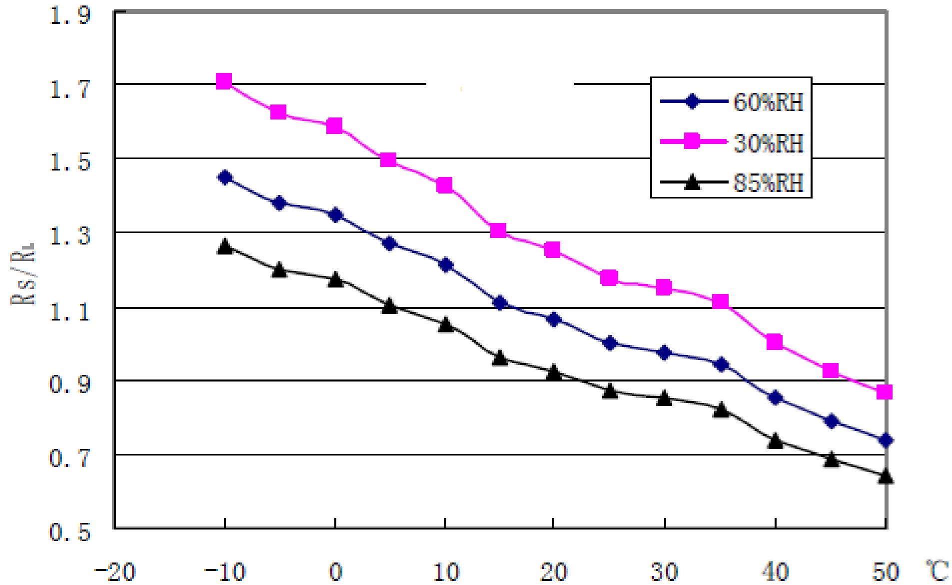


Figure 4-11 Influence of Temperature and Humidity
(https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf)

Features

1. Simple drive circuit
2. Sensitivity to flammable gas in wide range
3. Long life and low cost
4. High sensitivity to Natural gas

Application

1. Domestic gas leakage detector
2. Industrial CO detector

4.1.5 Methane Gas Sensor (MQ-4)

MQ-4 gas sensor composed of ceramic tube and Tin Dioxide. Electrode and heater are fixed into a layer. The heater provides required work conditions for the work of sensitive components.

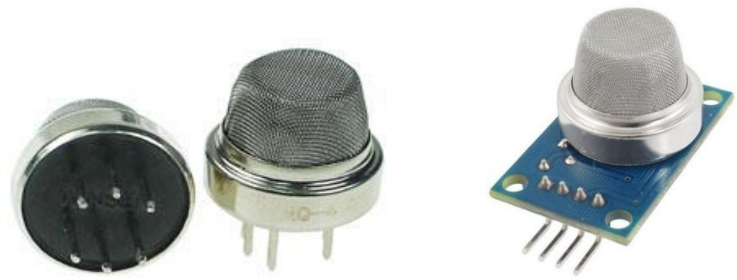


Figure 4-12 MQ-4 Sensor and MQ-4 Module
(http://smart-prototyping.com/MQ4-High-Sensitivity-Gas-Sensor-Natgas-Methane-Sensor.html)

When the target combustible gas present, the conductivity of sensor is higher along with the gas concentration rising. The MQ-4 sensor has 6 pins in which 4 of them are used to fetch signals and other 2 are used for providing heating current.

Parts Materials

1. Gas sensing layer SnO_2
2. Clamp ring Copper plating Ni
3. Heater coil Ni-Cr alloy
4. Electrode Au
5. Tubular ceramic Al_2O_3
6. Anti-explosion Network Stainless steel gauze
7. Electrode line Pt

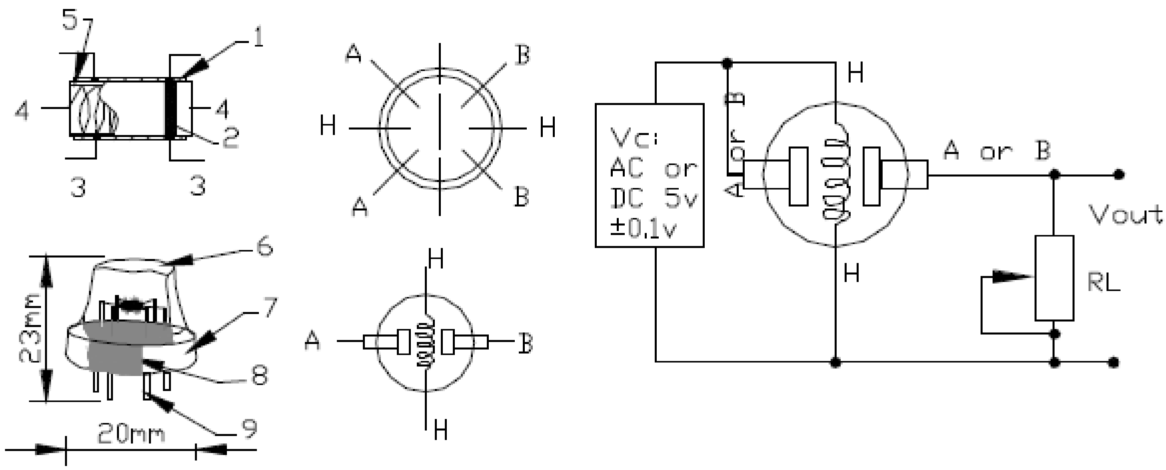


Figure 4-13 Structure and Configuration of MQ-4 Sensor
(https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-4.pdf)

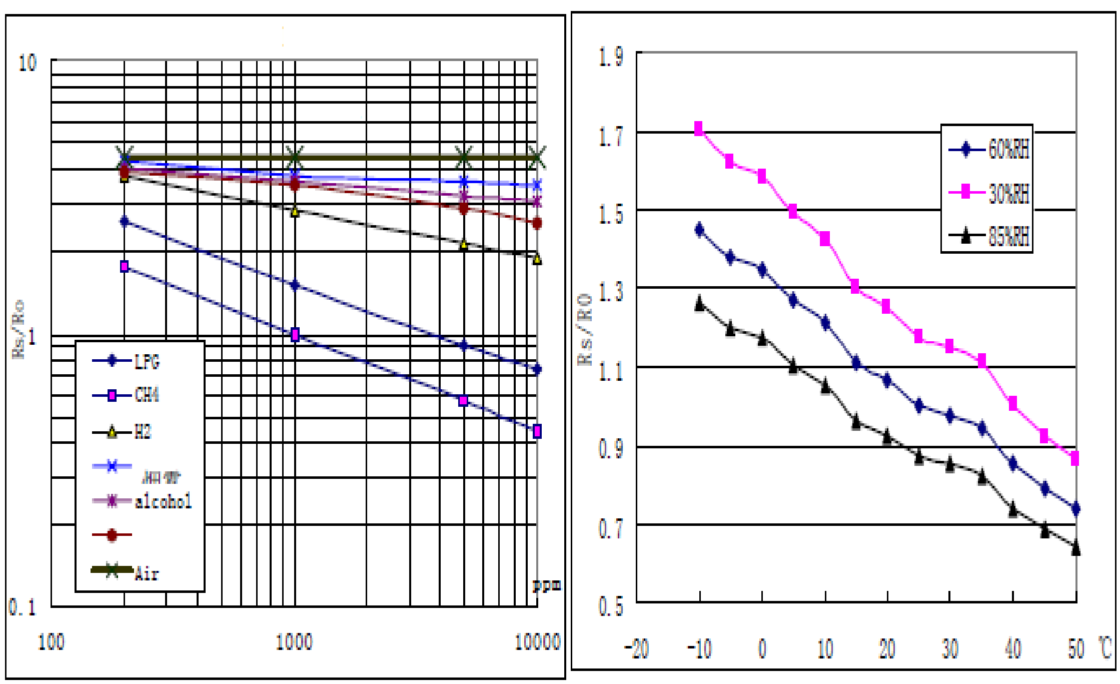


Figure 4-14 Influence of Temperature and Humidity and Sensitivity characteristics of MQ-4 for several combustible gases
(https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-4.pdf)

Table 4-7 Technical Specification of MQ-4
(https://www.pololu.com/file/0J311/MQ4.pdf)

Model No.			MQ-4
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Detection Gas			Natural gas/ Methane
Concentration			300-10000ppm (Natural gas / Methane)
Circuit	Loop Voltage	V_c	≤24V DC
	Heater Voltage	V_H	5.0V±0.2V ACorDC
	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 5000ppm CH_4)
	Sensitivity	S	Rs(in air)/Rs(5000ppm CH_4)≥5
	Slope	α	≤0.6($R_{5000ppm}$/$R_{3000ppm}$ CH_4)
Condition	Tem. Humidity		20℃±2℃；65%±5%RH
	Standard test circuit		Vc:5.0V±0.1V； V_H: 5.0V±0.1V
	Preheat time		Over 48 hours

Features

- High sensitivity to CH_4.
- Small sensitivity to alcohol and smoke.
- Fast response
- Stable and long life

Application

- Domestic gas leakage detector
- Industrial Combustible gas detector

4.1.6 Carbon Dioxide Sensor (MG811)

This CO2 sensor is designed by DFRobot engineer. The MG-811 sensor is highly sensitive to CO_2 and less sensitive to alcohol and CO. The MG-811 sensor has low humidity and temperature dependency. Its structure same as MQ-7 but parts material are different. This sensor composed by solid electrolyte layer, Heater, Platinum Lead, Gold electrodes, Porcelain Tube, 100m double-layer steeliness net, Nickel and copper plated ring.

Figure 4-15 MG-811 sensor and Module
(http://www.dfrobot.com/index.php?route=product/product&product_id=1023#.VWyS9s-qqko)

Working Principle

Sensor adopts solid electrolyte cell Principle. It is composed by the following solid cells：

Air, Au (NASICON) carbonate Au, air， CO_2

When the sensor exposed to CO_2， the following electrode reaction occurs：

Cathodic reaction： $2Li^{+} + CO_2 + 1/2O_2 + 2e^{-} = Li_2CO_3$

Anodic reaction： $2Na^{+} + 1/2O_2 + 2e^{-} = Na_2O$

Overall chemical reaction： $Li_2CO_3 + 2Na^{+} = Na_2O + 2Li^{+} + CO_2$

The Electromotive force (EMF) results from the above electrode reaction, accord with according to Nernst's equation：

EMF = Ec - (R x T) / (2F) ln (P (CO2))

P (CO2) = CO2- partial Pressure

Ec = Constant Volume

R = Gas Constant volume

T = Absolute Temperature (K)

F—Faraday constant

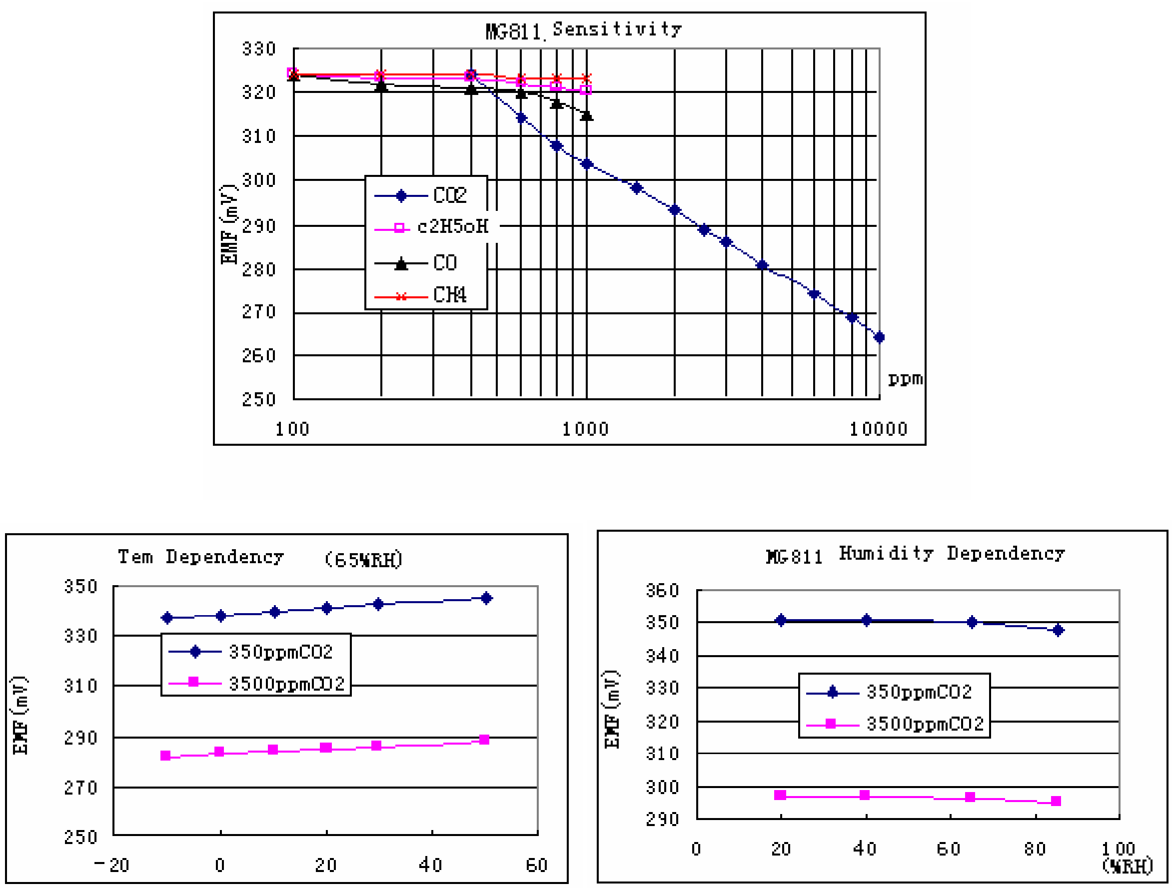


Figure 4-16 Sensitivity and its Temperature and Humidity dependency
http://www.dfrobot.com/image/data/SEN0159/CO2b%20MG811%20datasheet.pdf)

4.1.7 DHT-11 Sensor

This DHT11 Sensor measures the temperature and humidity. The sensor has greater reliability and very good stability. A resistive-type humidity measuring component with negative temperature coefficient is used. It connects to a microcontroller and shows excellent quality, anti-interference and fast response ability.

Figure 4-17 MQ-135 Sensor and Module
(Source: http://www.vascolabstore.com/wp-content/uploads/2014/12/Jual-DHT11-Digital-Humidity-and-Temperature-Sensor-Murah-Vascolabstore.jpg)

Application of DHT-11

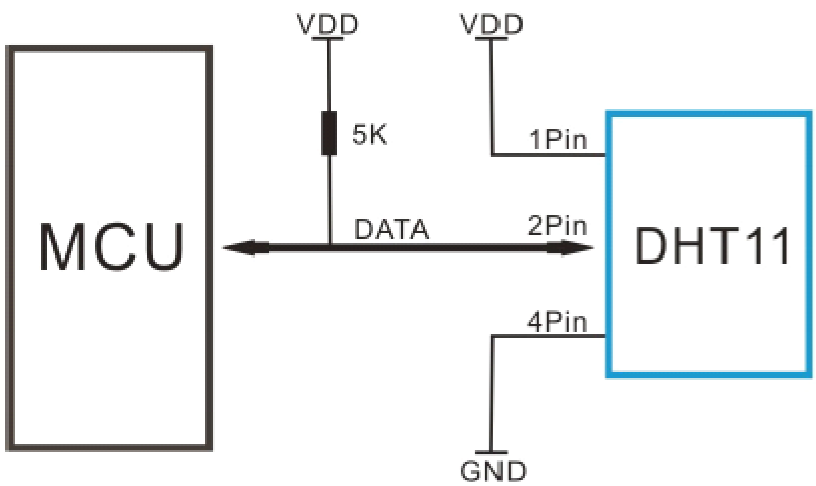


Figure 4-18 Typical application of DHT-11
(http://www.micropik.com/PDF/dht11.pdf)

Table 4-8 Specifications of DHT-11 sensor
(http://www.micropik.com/PDF/dht11.pdf)

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Accuracy	25℃		±4%RH	
	0-50℃			±5%RH
Measurement Range	0℃	30%RH		90%RH
	25℃	20%RH		90%RH
	50℃	20%RH		80%RH
Response Time (Seconds)	1/e (63%) 25℃，	6 S	10 S	15 S
Long-term Stability	Typical		±1%RH/year	
Temperature				
Accuracy		±1℃		±2℃
Measurement Range		0℃		50℃
Response Time (Seconds)	1/e (63%)	6 S		30 S

4.2 System Architecture

This monitoring system mainly consists of two units. First one is Sensor Unit another one is Monitoring unit.

Sensor unit contains two parts.

1. Display Unit
2. Transmitter Unit

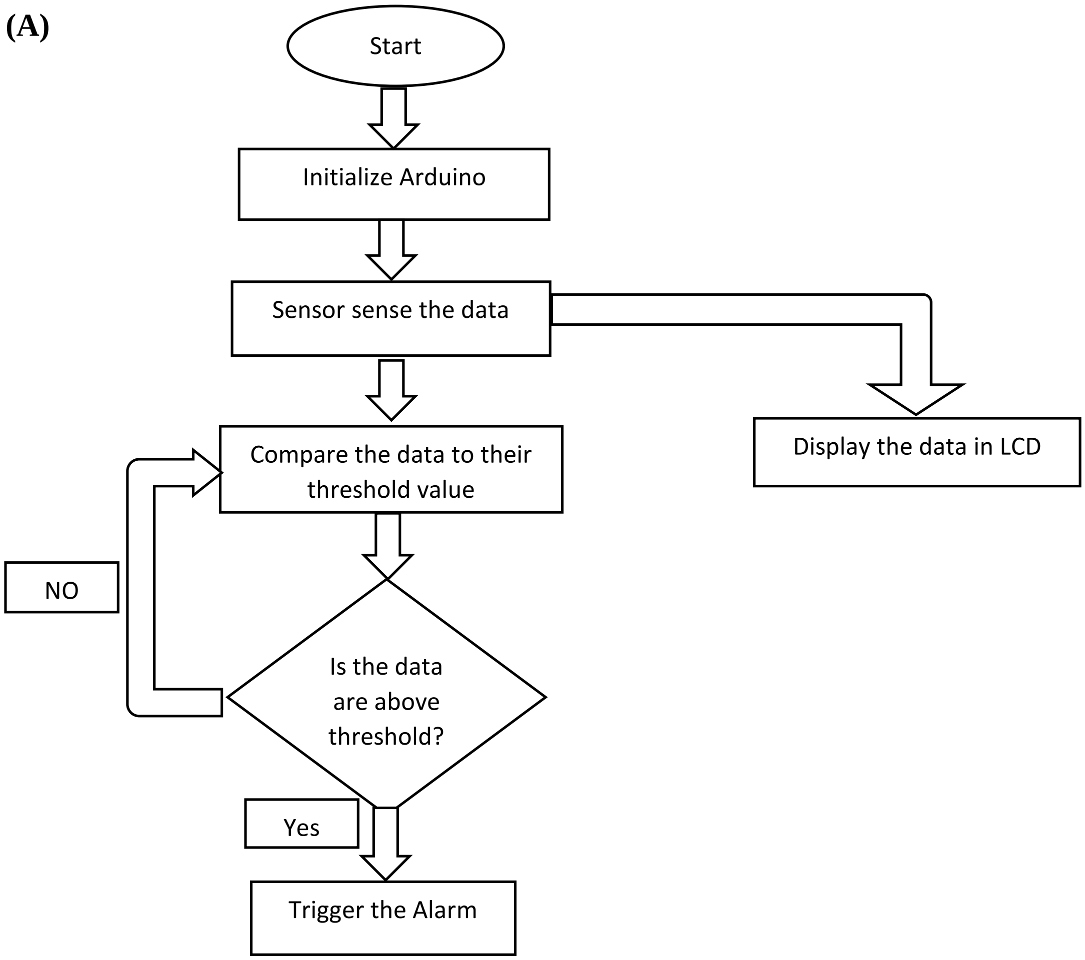
Display unit consist of the Arduino board, sensors and the LCD. The transmitter unit consists of a router and the sensors.

In 4.2.1 section shows the flow chart of the Sensor unit in which (A) is the flow chart of a display unit and (B) is the flow chart of transmitter unit.

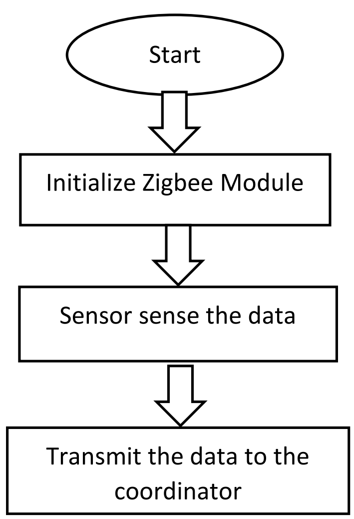
In 4.4.2 section shows the flow chart of the monitoring unit.

4.2.1 Flow chart of the monitoring System for Sensor Unit

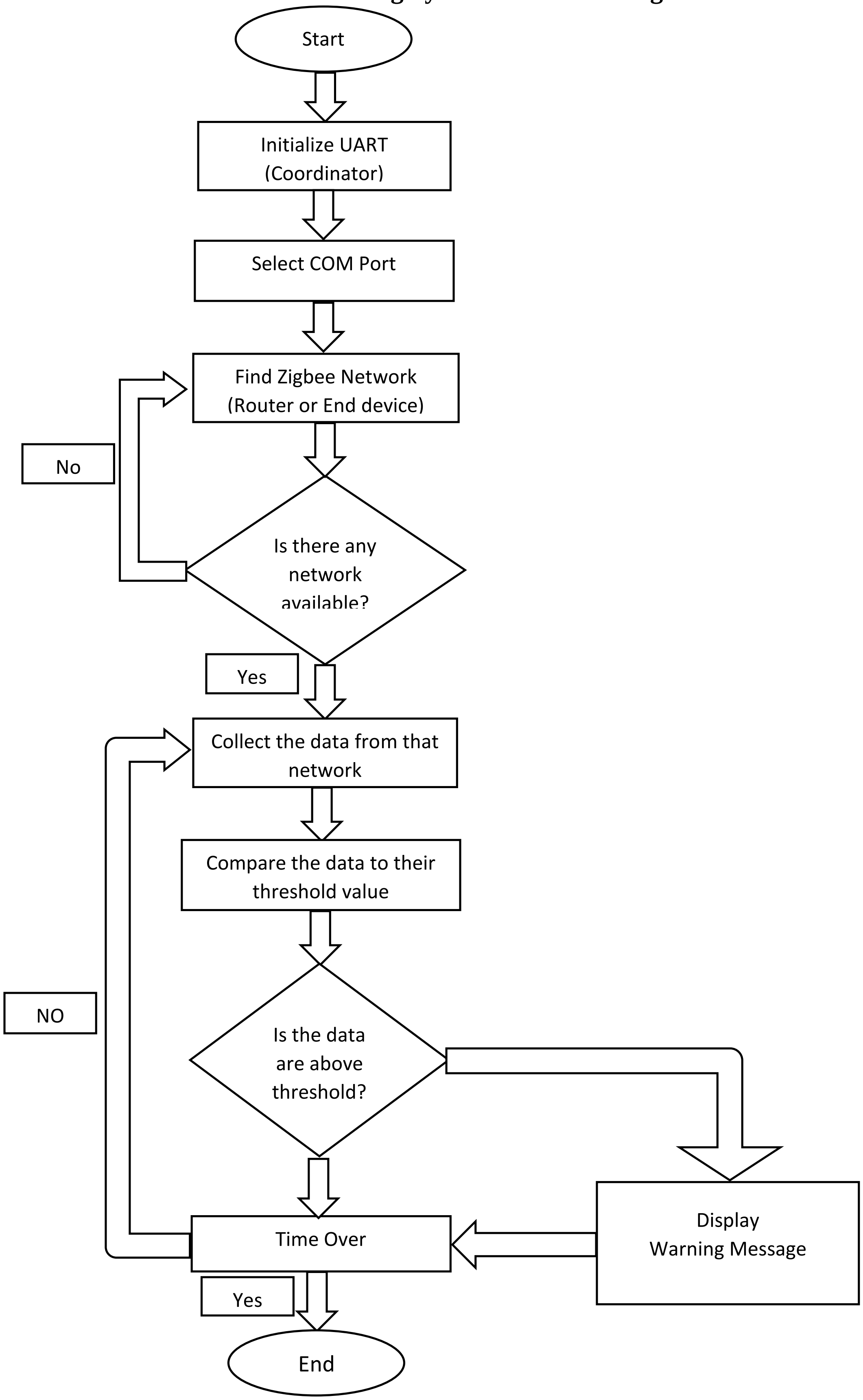
(A)



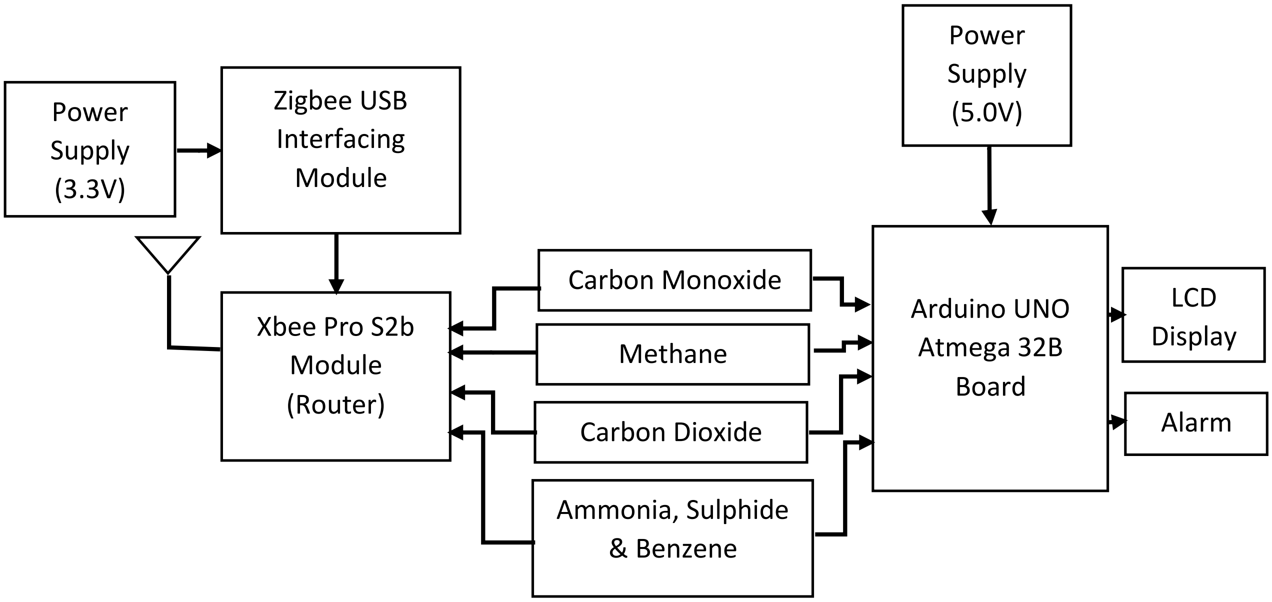
(B)



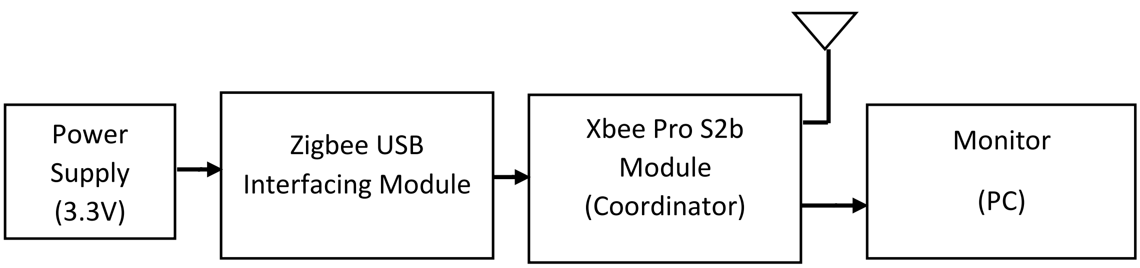
4.2.2 Flow chart of the monitoring System for Monitoring Unit



4.2.3 Block diagram of Sensor Unit



4.2.4 Block Diagram of Monitor Unit



4.3 Conclusion

This chapter deals with the hardware implemented for the real time monitoring system. The details of each components used were described briefly based on its functionality and specifications. The flow chart and block diagram shows the organization and working of the system. The above mentioned hardware and design plan has been described in the subsequent chapter which explains the implementation part.

Chapter 5

Experiment and Results

5.1 Hardware Implementation

To test the designed real time monitoring system using wireless sensor network, an artificial mining environment is simulated inside the laboratory. As a first implementation, we designed the complete system on a breadboard which is presented in Figure 5-1.

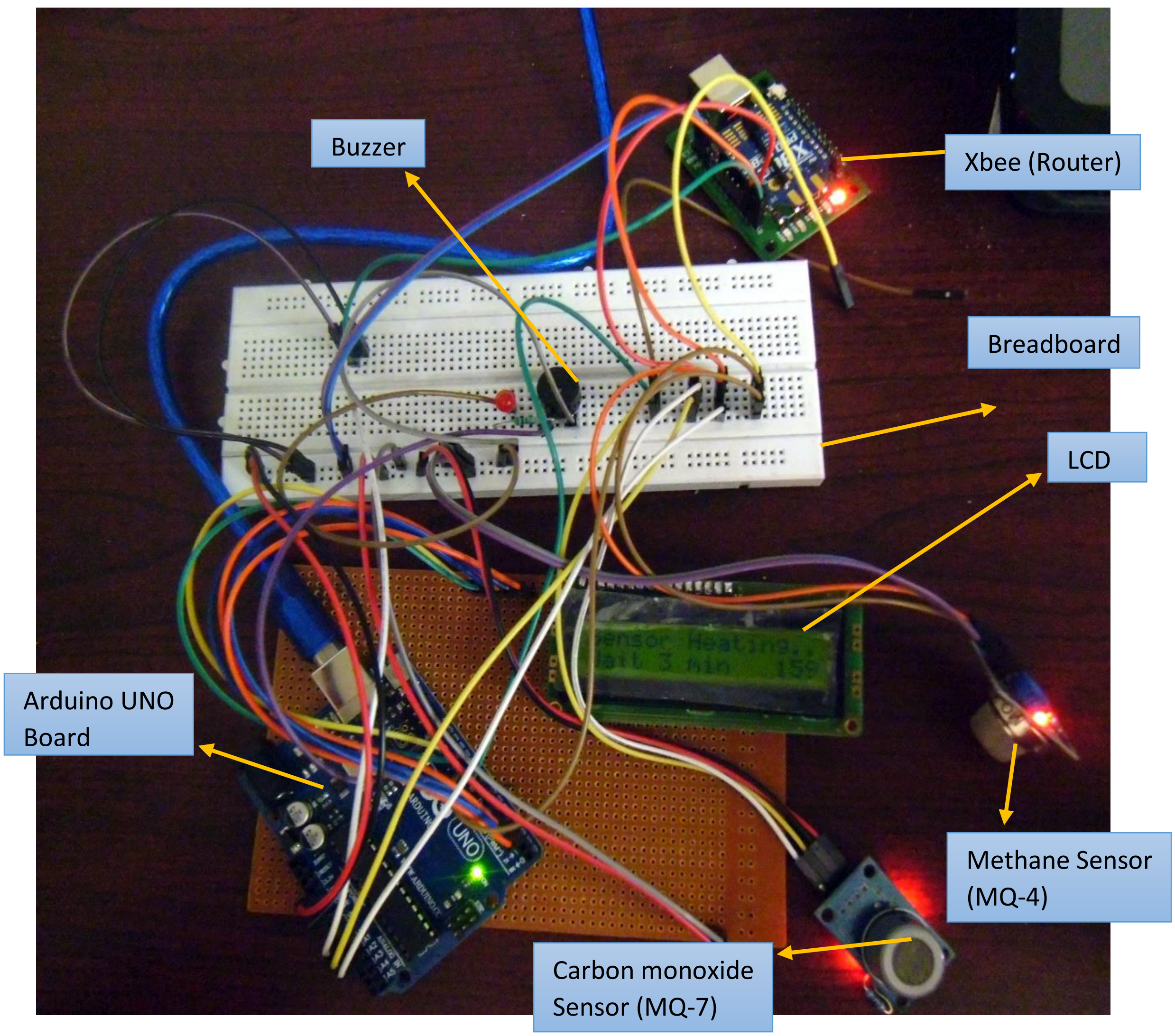


Figure 5-1 Sensor Unit of Monitoring System using Breadboard

The system consists of following components:

1. Arduino Board – Model Arduino UNO
2. Xbee – Model Xbee Pro S2B
3. LCD (Liquid crystal display) – 16*2 LCD
4. Carbon monoxide Sensor – Model MQ-7
5. Methane Sensor – Model MQ-4
6. Buzzer

The final design of the sensor unit consists of the all above components as well as additional sensors:

1. Carbon Dioxide Sensor – Model MG-811
2. Temperature and Humidity Sensor – DHT-11

Figure 5-2 shows the schematic diagram of the sensor unit of the monitoring system. This schematic diagram is designed in the eagle 7.3.0 PCB design software.

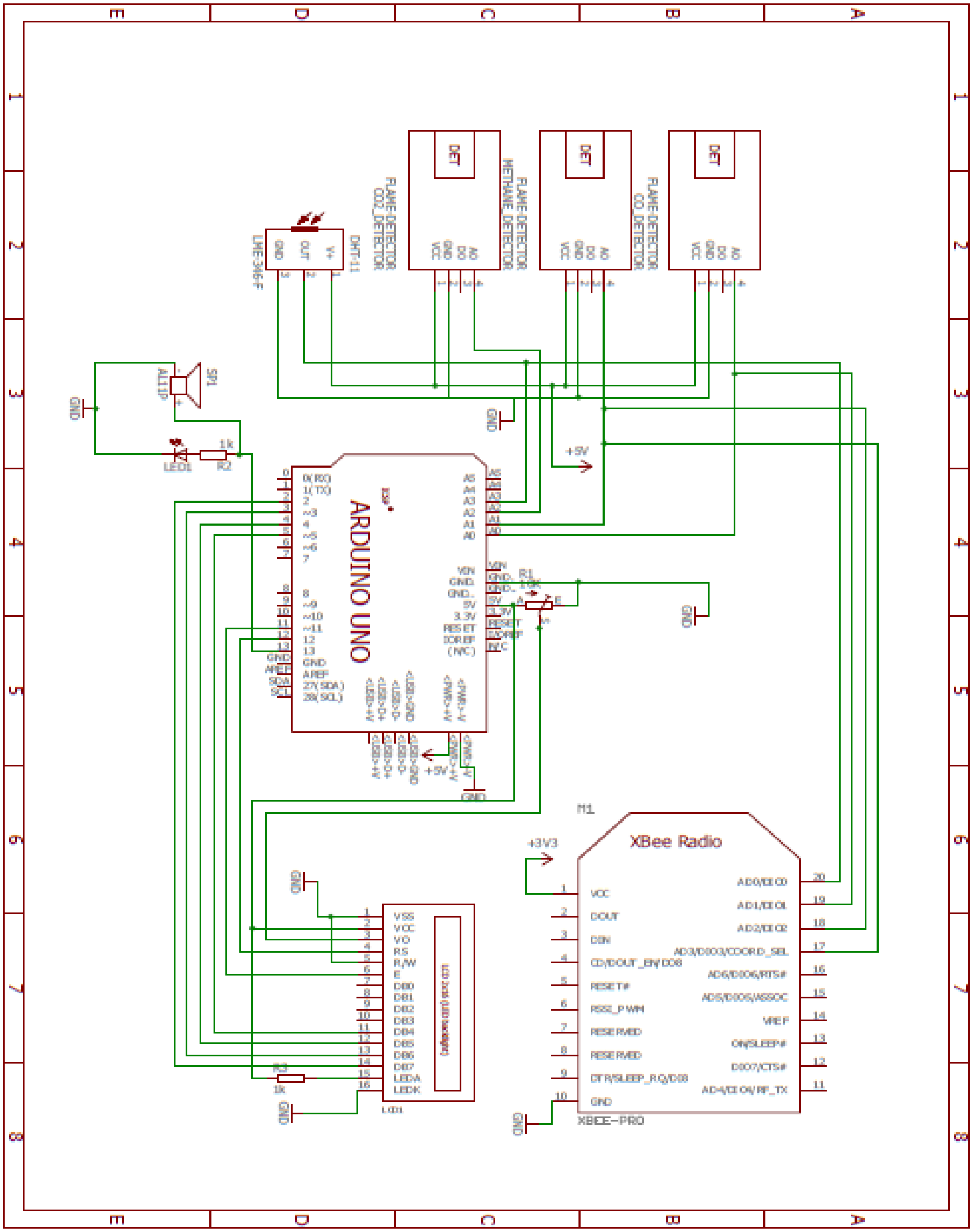


Figure 5-2 Schematic Diagram of Sensor Unit

By using above circuit, we designed complete real time monitoring system, which is shown in Figure 5-3.

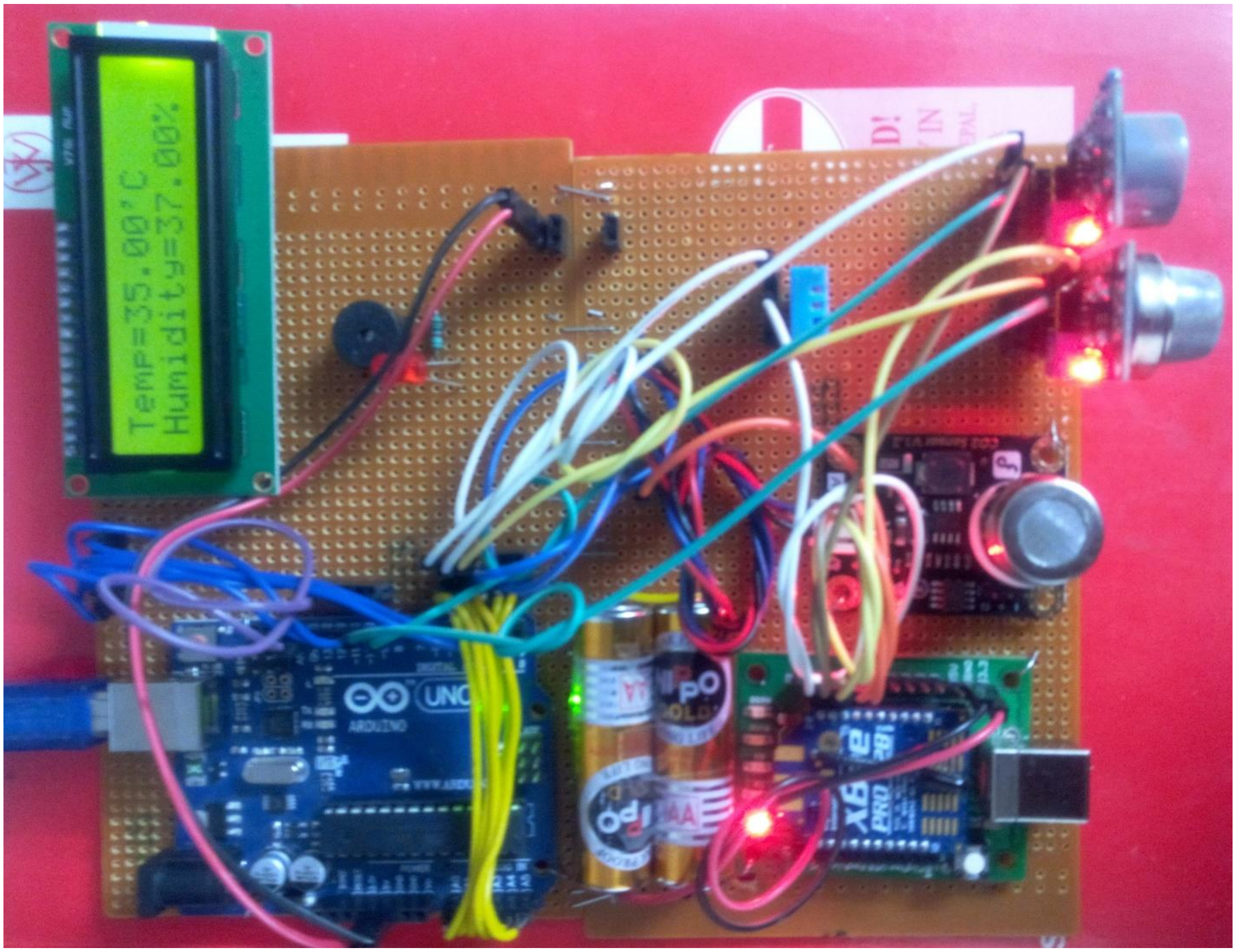


Figure 5-3 Final Real Time Monitoring System

5.2 Software Implementation

It is essential to configure Xbee, when it is brought new from the market. To assign Xbees as transmitter and receiver or as coordinator and router, X-CTU software is used. Any wireless system using Xbee can be defined in following categories:

1. **Coordinator:** For any wireless system using Xbee, one Xbee is required in every network. This Xbee is called as Coordinator. It is in charge of setting up the network. If it goes down, the network goes down. It can never sleep.
2. **Router:** In any network multiple router may exist. It can relay signals from other routers or End point signals. It can never sleep either.
3. **End Point:** In any network multiple end point may exist. It can't relay signals. It can sleep to save power.

There are two modes of X-bee, which are AT Mode and API mode. In AT mode (transparent mode) we can communicate with the Xbee through serial data and in the API mode we can communicate with the Xbee by sending and receiving packets.

Figure 5-2 illustrates the configuration of Xbee coordinator and Figure 5-3 illustrates the configuration of Xbee router.

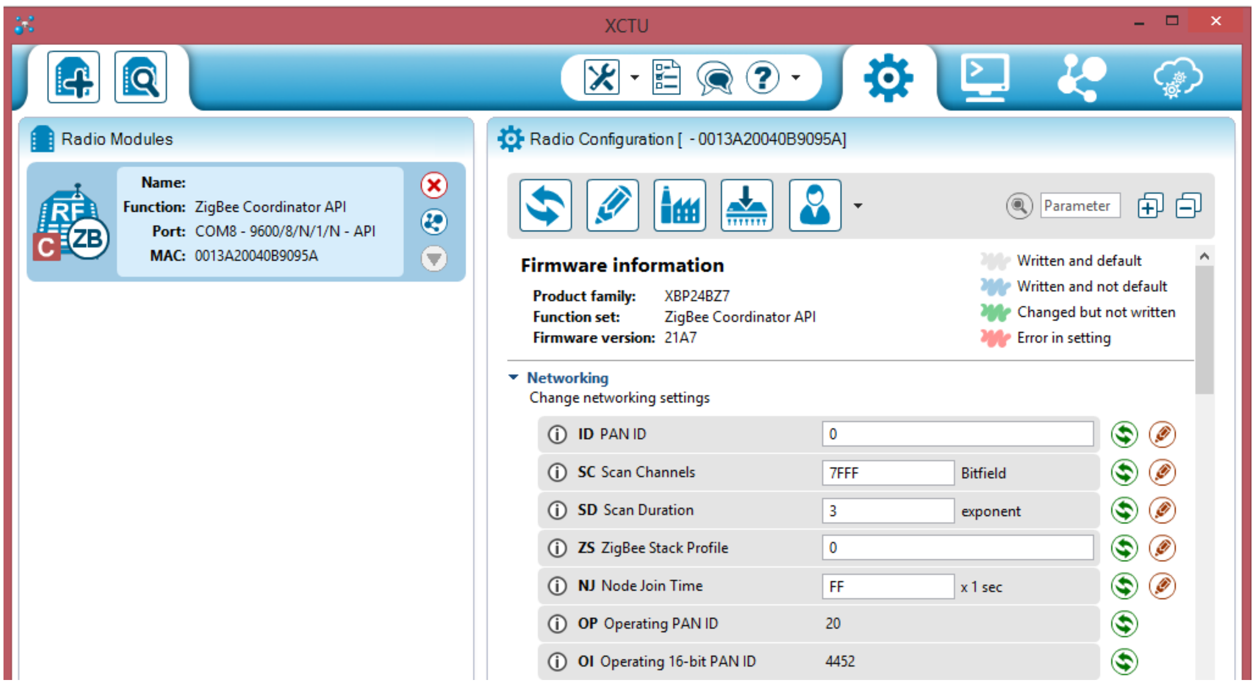


Figure 5-4 Configuration of Coordinator

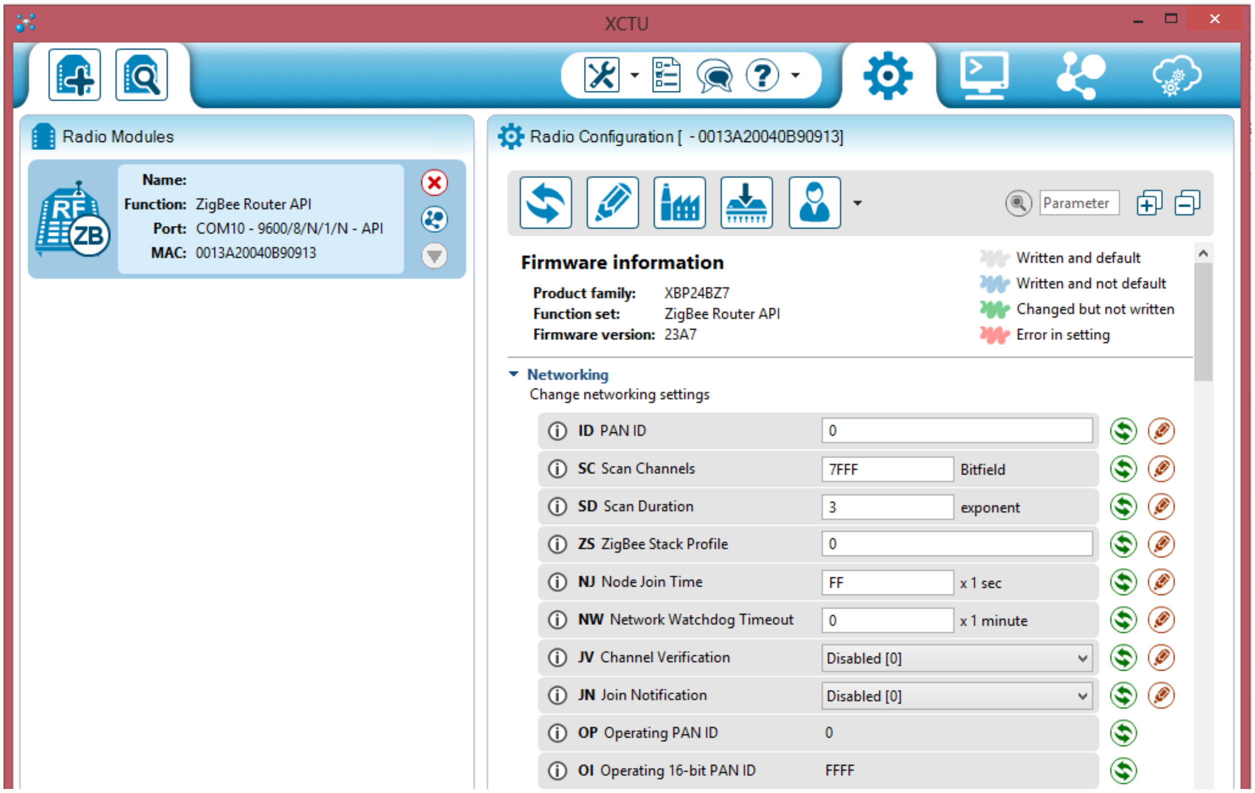


Figure 5-5 Configuration of Router

Sensor unit Xbee (router) and the monitor unit Xbee (coordinator) both are should be in API mode. For communication between both coordinator and router Xbee, PAN ID (Personal Area Network identifier) should be same. For this system we set the PAN ID as 0 for both Xbee.

As mentioned earlier, Arduino UNO is microcontroller based board. So for programming the Arduino board, Arduino IDE 1.6.1 (Integrated Development Environment) software is used which supports C and C++ programming languages. This software makes it easy to write code. Figure 5-5 shows the different sensors value in serial monitor using Arduino IDE 1.6.1 software.

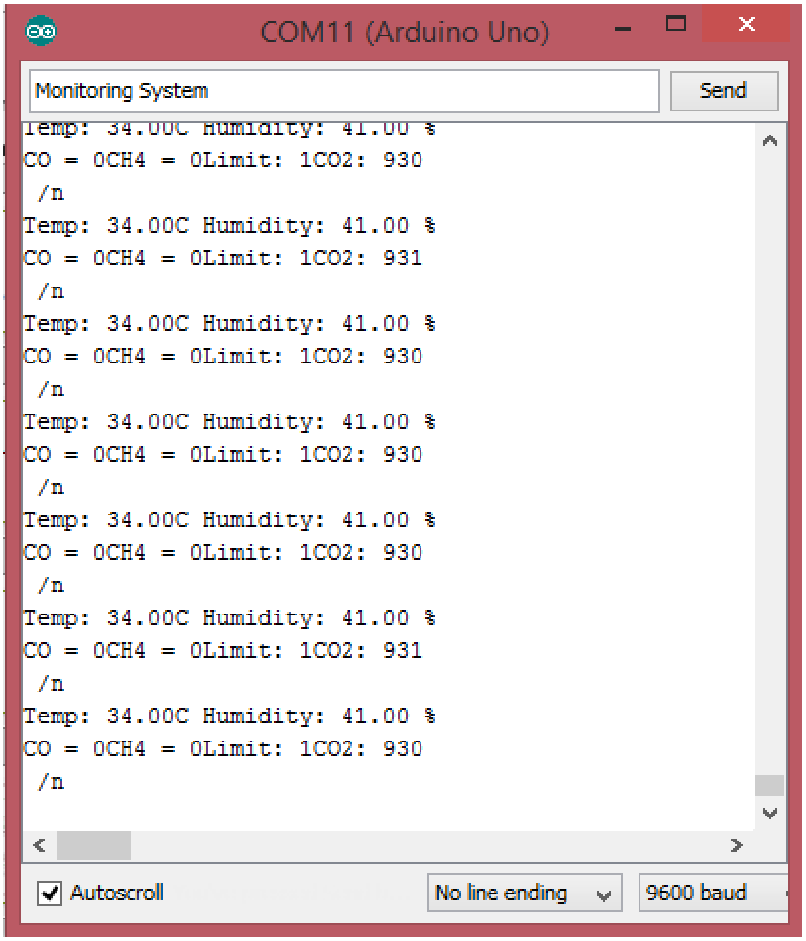


Figure 5-6 Different sensors value using Arduino IDE Software.

Xbee gives the output in digital form which is difficult to understand so it needs to be converted into analog form i.e. Analog samples are returned as 10-bit values. The analog reading is scaled such that 0x0000 represents 0V and 0x3FF represents 1.2V. The analog inputs of the module cannot read more than 1.2V. Analog samples are returned in order, starting with AIN0 and finishing with AIN3, and the supply voltage. To convert the A/D reading to mV, do the following:

AD (mV) = (A/D reading * 1200mV) / 1023

Above designed system is used to test in the laboratory under artificial mining environment. At first when we connect only two sensors carbon monoxide and temperature sensor. Using these sensors in the laboratory following value is shown, which shows in the Figure 5-7.

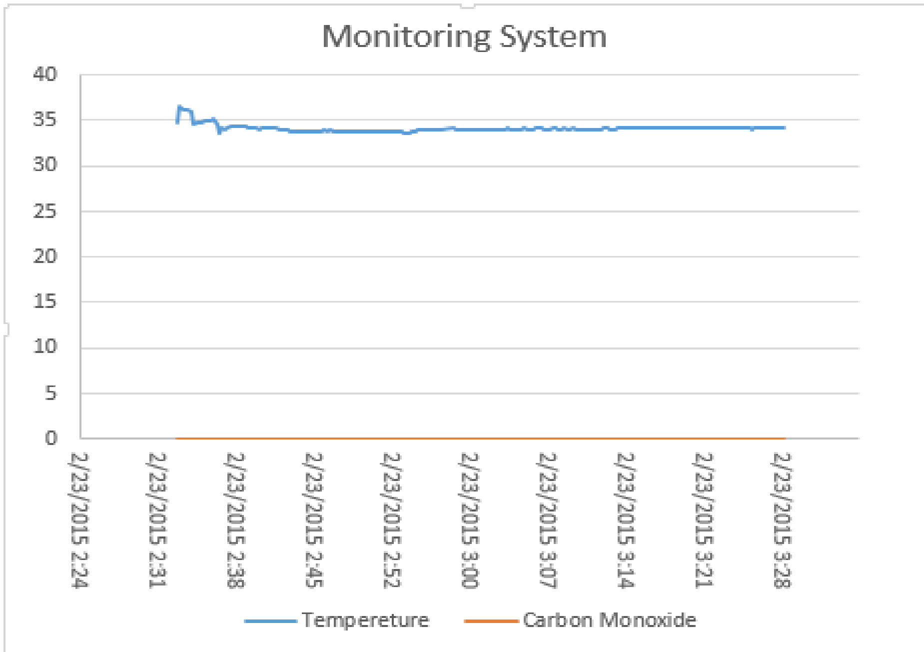


Figure 5-7 Graphical representation of Temperature and Carbon monoxide sensors value. Blue colour curve shows the temperature values and orange colour curve shows the carbon monoxide values in ppm.

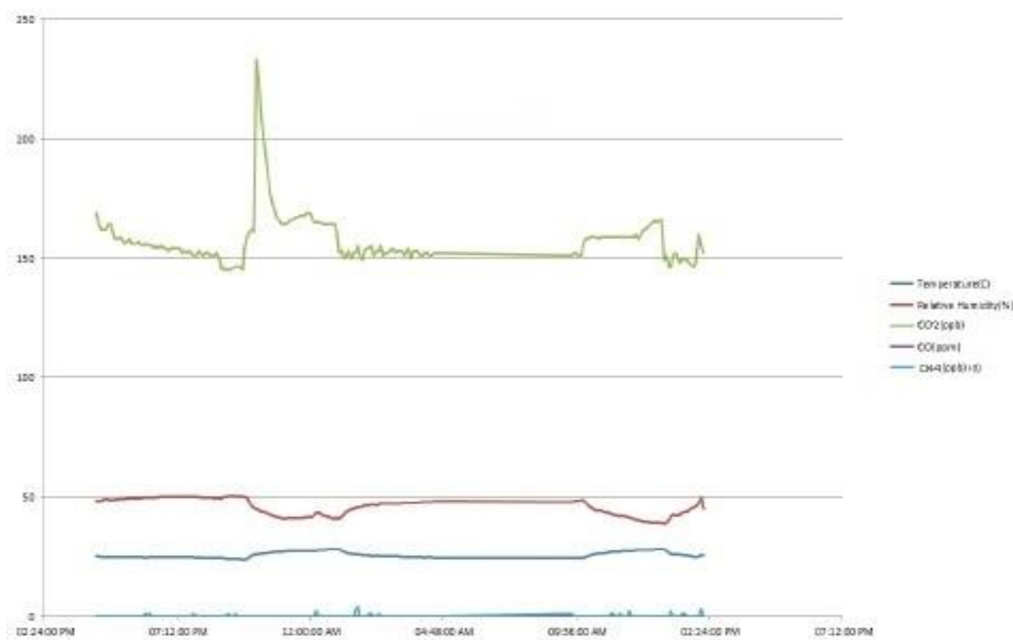


Figure 5-8 Graphical representation of different sensor value (approx 8 hrs.).
Blue colour curve shows the temperature values, brown colour curve shows the relative humidity, light green colour curve shows the carbon dioxide values, violet colour curve shows the carbon monoxide values and sky blue colour curve shows the methane value.

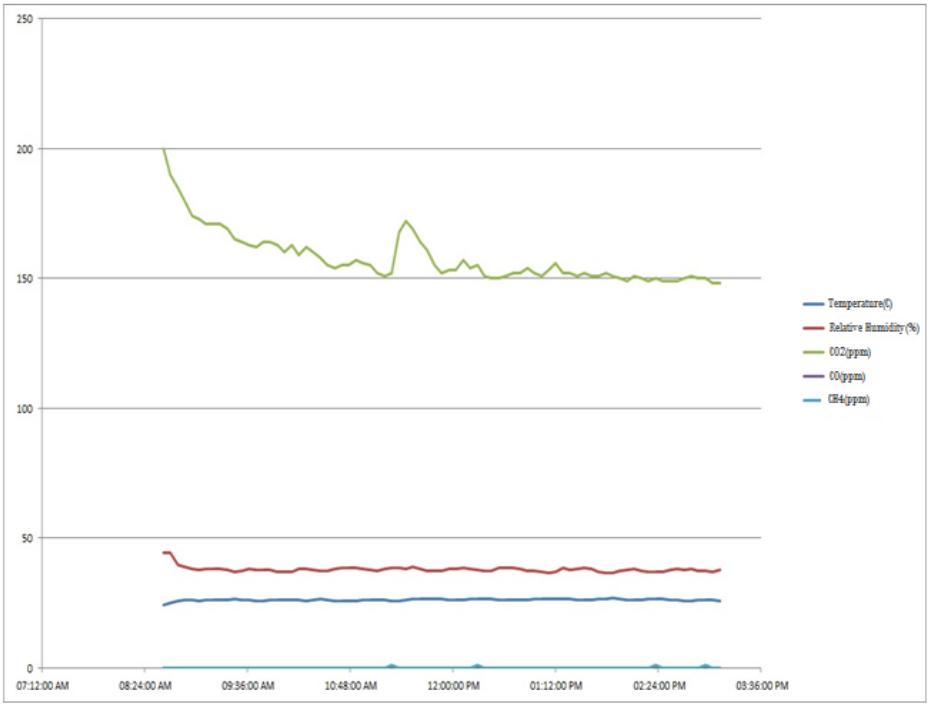
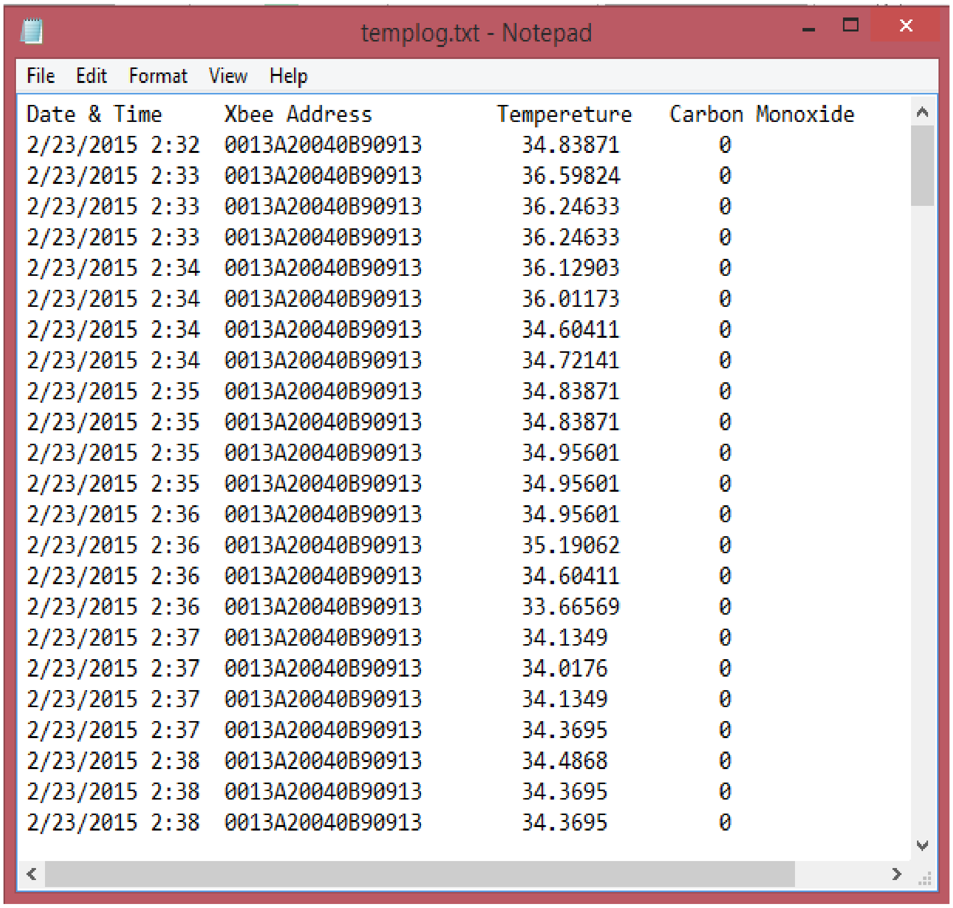


Figure 5-9 Graphical representation of different sensor values (approx 24 hrs.).
Blue colour curve shows the temperature values, brown colour curve shows the relative humidity, light green colour curve shows the carbon dioxide values, violet colour curve shows the carbon monoxide values and sky blue colour curve shows the methane value.

All these data are also automatically stored in the computer for future inspection, which is shown in Figure 5-10.



templog.txt - Notepad

File Edit Format View Help

Date & Time	Xbee Address	Tempereture	Carbon Monoxide
2/23/2015 2:32	0013A20040B90913	34.83871	0
2/23/2015 2:33	0013A20040B90913	36.59824	0
2/23/2015 2:33	0013A20040B90913	36.24633	0
2/23/2015 2:33	0013A20040B90913	36.24633	0
2/23/2015 2:34	0013A20040B90913	36.12903	0
2/23/2015 2:34	0013A20040B90913	36.01173	0
2/23/2015 2:34	0013A20040B90913	34.60411	0
2/23/2015 2:34	0013A20040B90913	34.72141	0
2/23/2015 2:35	0013A20040B90913	34.83871	0
2/23/2015 2:35	0013A20040B90913	34.83871	0
2/23/2015 2:35	0013A20040B90913	34.95601	0
2/23/2015 2:35	0013A20040B90913	34.95601	0
2/23/2015 2:36	0013A20040B90913	34.95601	0
2/23/2015 2:36	0013A20040B90913	35.19062	0
2/23/2015 2:36	0013A20040B90913	34.60411	0
2/23/2015 2:36	0013A20040B90913	33.66569	0
2/23/2015 2:37	0013A20040B90913	34.1349	0
2/23/2015 2:37	0013A20040B90913	34.0176	0
2/23/2015 2:37	0013A20040B90913	34.1349	0
2/23/2015 2:37	0013A20040B90913	34.3695	0
2/23/2015 2:38	0013A20040B90913	34.4868	0
2/23/2015 2:38	0013A20040B90913	34.3695	0
2/23/2015 2:38	0013A20040B90913	34.3695	0

Figure 5-10 Stored sensor output data in the Computer

5.3 Conclusion

The hardware and software for the real time monitoring system of mine gases has been implemented in an artificially created mine environment. The different mine gases were observed through this system and the detection were plotted in the graph as well as the data were stored in PC.

Chapter 6

Conclusion

The study on real time monitoring of toxic gases and other parameters present in underground mine has analyzed using wireless sensor network. A real time monitoring system is developed to provide clearer and more point to point perspective of the underground mine. This system is displaying the parameters on the LCD at the underground section where sensor unit is installed as well as on the monitoring unit; it will be helpful to all miners present inside the mine to save their life before any casualty occurs. Alarm triggers when sensor values crosses the threshold level. This system also stores all the data in the computer for future inspection. From the experiments and observations, the following conclusion can be drawn:

(i) Each node in a particular framework functions as the pioneer robot when all its parameters are configured properly.

(ii) Sensor nodes can reconfigure remotely over a wireless network and most of the processing done in software on computer side.

(iii) The calibration equations of gas sensors may have affected the accuracy of the ppm results.

This is a low cost and lifelong system. The overall cost of this system is around 320-380 $ when using 2 sensor nodes and 250$ extra for each additional sensor node.

Future Scope

1. Using additional sensors all possible safety issues could be monitored such as gases, dust, vibrations, fire etc.
2. Zigbee can also be used for the surveillance of mining operations such as subsidence, water leakage etc.
3. The other important data can be communicated through this system making it feasible where wired communication is a hindrance.
4. The control can be governed from the surface itself as the system provides easy access.

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