Project Report on

Wireless Surveillance and Safety System for mine workers using ZigBee

Submitted in partial fulfillment of the requirement of the degree of
Bachelor of Engineering in Electronics and Communication Engineering,
Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur

By

Namrata B. Bhagat (EC12015)
Navratan Lal Gupta (EC12016)
Shalaka P. Pokley (EC12040)

Under the guidance of
Mr. S. M. Kharad

2015-2016
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
KAVIKULGURU INSTITUTE OF TECHNOLOGY &SCIENCE
RAMTEK - 441 106

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CERTIFICATE

This is to certify that it is a bonafide record of project work entitled

WIRELESS SURVEILLANCE AND SAFETY SYSTEM FOR MINE WORKERS USING ZIGBEE

Carried out by

Namrata Bhagat (EC12015) **Navratan Lal Gupta (EC12016)**

Shalaka Pokley (EC12040)

Of the B.E final year **Electronics & Communication Engineering**, during the academic year **2015-2016**, in partial fulfillment of the requirement for the award of the degree of **Bachelor Of Engineering** offered by the **Rashtrasant Tukdoji Maharaj Nagpur University**, Nagpur.

Mr. S. M. Kharad
Project Guide

Mr. S. M. Kharad
Head of Department

Dr. Bhaskar Patel
Principal

Date:

Place: Ramtek

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Finally, Lots of love & respect to our family who has always helped us with our work directly and indirectly.

Projectees

INDEX

ABSTRACT

"Wireless surveillance and safety system for mine workers using ZigBee"

This project addresses a cost effective, flexible solution of underground mine workers' safety. A module of MEMS based sensors are used for underground environment monitoring and automating progression of measurement data through digital wireless communication technique is proposed with high accuracy, smooth control and reliability. A microcontroller is used to collecting data and making decision, based on which the mine worker is informed through alarm as well as voice system. ZigBee, based on IEEE 802.15.4 standard is used for this short distance transmission between the hardware fitted with the mine worker and the ground control Centre.

Industrial safety is one of the main aspects of industry specially mining industry. In the mining industry safety is a very vital factor. To avoid any types of unwanted phenomena all mining industry follows some basic precaution and phenomena. Communication is the main key factor for any industry today to monitor different parameters and take necessary actions accordingly to avoid any types of hazards. To avoid loss of material and damaging of human health, protection system as well as faithful communication system is necessary inside the underground mines. To increase both safety and productivity in mines, a reliable communication must be established between workers, moving in the mine, and a fixed base station.

Inside mines, the wired communication system is not so effective. Due to uncomfortable situation inside mines the installation cost as well as maintenance cost is high for wired communication networks. It is very difficult to reinstall the wired communication system inside mines after a landslide or damage due to any reason. To monitor other parameters during this condition it is very much necessary to maintain the communication system as usual. Accordingly, development of mine monitoring system to accurately detect temperature, pressure, flammable and poisonous gas and to track underground miners has significant meaning to safety production and rescue of coal mine disaster.

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

- O-QPSK: Offset Quadrature Phase Shift Keying
- IEEE: Institute of Electrical & Electronics Engineering
- VOIP: Voice Over Internet Protocol
- IP: Internet Protocol
- MEMS: Micro Electro-Mechanical Systems
- UART: Universal Asynchronous Receiver/Transmitter
- PWM: Pulse Width Modulation
- I2C: Inter-Integrated Circuit
- SPI: Serial Peripheral Interface
- COM: Communication
- NRZ: Non-Return to Zero
- LOS: Line Of Sight

CHAPTER 1

INTRODUCTION

Engineers have worked for a long time for safety of human resources. They developed many advanced new technologies to warn surface monitoring station before any threatening situation happens.

Many hazardous disasters take place inside mines such as fire, leaking of gases and flooding.

In India mining industries, mostly leaky feeder based communication system is used in underground mines. Coaxial cables are the backbone of the whole system and it runs along the underground mines. Coaxial cable emits and receives radio waves for communication purpose, and it behaves as an extended antenna. The radio waves signal is usual1y used by portable transceivers, which are carried by miners. Leaky feeder based system are more complex and unreliable data communication between underground mine workers and on the surface control room.

IEEE 802.15.4/ZigBee global standard protocol defined for low-power, low-rate and cost-effective wireless sensor network is developed for automation and wireless environment monitoring. Many applications have been designed based on the ZigBee 2003, ZigBee 2006 version of device such as building automation, security systems, remote control, and smart energy metering. The ZigBee standard utilizes of IEEE 802.15.4 standard and that combinations are made a complete stack.

Coal mine safety monitoring system based on wireless sensors can timely and accurately reflect dynamic situation of staff in the underground regions to ground computer system. In this project, MEMs based sensors have been used to sense environmental parameters such as temperature to detect fire, humidity to detect flooding and methane gas to detect leakage of organic harmful gases. The parameters are sensed, analysed and processed before transmission. If any of the mentioned factors exceeds the specified limits, then workers inside the mines are warned through indicators as well as sound.

The parameters are then transmitted through ZigBee. ZigBee is a very reliable, low-range wireless technology and uses IEEE 802.15.4 Specification. This specification is a very modern, robust radio technology built on over 40 years of experience by IEEE.

1.1 Background

Throughout many years there were investigations on safety of mine workers to overcome major limitation set by coaxial wired cable. Coal mine safety monitoring system based on wireless sensors can timely and accurately reflect dynamic situation of staff in the underground regions to ground computer system.

The cable of a mine cage is a critical element in miner safety. Maximum allowable loads and cable lifespans are governed by strict standards laid by the health and safety commission. Although cable breaks are extremely rare, it is nonetheless necessary to conduct periodic checks.

A continuous monitoring system for winch cables in underground mines has been developed by research consortium. The system establishes the amount of wear in real time and determines the precise moment the cables should be replaced, thanks to an electromagnetic coil that induces the field in the cable.

The clothing used in the mining industry is becoming increasingly sophisticated, allowing greater comfort and safety for the wearer. Among recent improvements is a series of microclimate conditioning garments that use a membrane technology; a liquid coolant gradually evaporates thereby cooling the person wearing the clothing, vest or head/neck/shade. The garments combat the heat found in deep mines where it can get very hot, sometimes reaching more than 60 degree Celsius.

Communicating underground is difficult. For a long time, whistles were the only means of exchanging messages. The arrival of wireless telephones and Wi-Fi antennas revolutionized communication in mines. Installing relays made it possible to communicate using wireless VOIP type telephones in the tunnels. VOIP, however, is costly and IP doesn’t show satisfactory performance inside deep mines.

1.2 Rationale

Inspite of technological improvement and stricter safety regulation, many loss of life happens due to mine disasters in underground mine, all due to lack of proper monitoring system and lack of communication through deep mines.

China holds the record of worst mining disaster ever happened where 1,549 workers died in Benxihu Colliery due to coal dust explosion on 26 April 1942.
In India, worst coal mine disaster happened in Dhanbad where 375 miners were killed due to coal mine fire.

According to information sought under RTI Act-2005 (Ref No. WCL/PIO/2015/6(3)/491 dt. 07/10/2015) to Western Coalfield Limited (WCL), 6 people died in different event ONLY due to toxic gases, fire and flooding inside mine of Western Coalfield Limited in between year 2006 to 2015. There are many similar mine working legally and illegally in India.

According to information sought under RTI Act-2005 (Ref No. CCL/PIO/15/282-83 dt. 30/09/2015) to Central Coalfield Limited (CCL), 5 people died ONLY due to toxic gases, fire and flooding inside mine of CCL in last 10 years.
While the mentioned figure may range to more number of deaths as there are more than 500 mines in India and much more if taken as whole world.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

It includes the brief schematic of general study of related topics .It include brief description of technologies used. We will be discussing about ZigBee technology, Arduino microcontroller board and sensors used in our project. We will be explaining components used for voice in our project.

2.2 ZigBee

ZigBee is relying on a very reliable, low-range wireless technology, the IEEE 802.15.4 Specification. This specification is a very modern, robust radio technology built on over 40 years of experience by IEEE.

It uses Offset-Quadrature Phase-Shift Keying (O-QPSK) and Direct Sequence Spread Spectrum (DSSS), a combination of technologies that provides excellent performance in low signal-to-noise ratio environments.

ZigBee uses Carrier Sense Multiple Access Collision Avoidance (CSMACA) to increase reliability. Before transmitting, ZigBee listens to the channel.

When the channel is clear, ZigBee begins to transmit. This prevents radios from talking over one another, causing corrupted data. CSMA-CA is similar to what people do in conversations. They wait for the other speaker to finish, and then talk.

ZigBee uses a 16-bit CRC on each packet, called a Frame Checksum (FCS). This ensures that the data bits are correct. Each packet is retried up to three times (for a total of four transmissions). If the packet cannot get through after the fourth transmission, ZigBee informs the sending node so something can be done about it.

Another way that ZigBee achieves reliability is through mesh networking.

Mesh networking essentially provides three enhanced capabilities to a wireless network: extended range through multi-hop, ad-hoc formation of the network, and most importantly automatic route discovery and self-healing. This method is used in wireless sensor network which can be used to extend our project to practical level.

We are using 2.4GHz band ZigBee in which 16 channels are allocated. Each channel has bandwidth of 2MHz and band gap between two channels of 5MHz.
It can programmed using windows based application called X-CTU.

Fig 2.1: ZigBee module

ZigBee is of two types based on range type i.e. ZigBee and ZigBee pro. ZigBee pro is advanced version of ZigBee which is having long range than ZigBee.

ZigBee is of two types based on type of networking; they are ZigBee series 1 and ZigBee series 2. Series 1 is only used for point-to-point networking and star networking. This is simple to use. Whereas series 2 are little complex to use and can be used to form any type of networking.
We are using ZigBee series 2 for our project, so that our project can be extended as mesh networking.

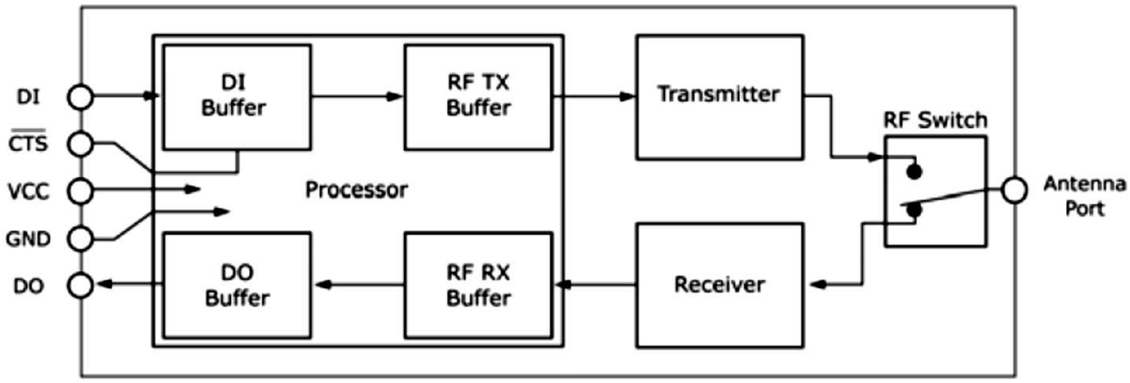


Fig 2.2: Internal flow block diagram of ZigBee

XBee

XBee Product Registered Brand name of ZigBee Standard Module by Maxstream now it changed to Digi

Few specifications of XBee series 2 are:

- Indoor Range : up to 40m
- Outdoor RF LOS range : up to 120m
- Transmit Power output : 2mW (+3dbm)
- RF data rate : 250kbps
- Receiver sensitivity : -98dbm
- Supply voltage : 2.8-3.6 V
- Transmit current : 40 mA
- Received current : 40 m
- Frequency : ISM 2.4 GHz
- Operating Temperature : -40 to 85 degree
- Antenna : wired antenna
- Network Topology : Point to point, star, mesh
- No. of channels : 16 direct sequence channels

Pin description:

Pin	Name	Direction	Description
1	VCC	-	Power Supply
2	DOUT	Output	UART Data Out
3	DIN/ $\overline{\text{CONFIG}}$	Input	UART Data In
4	DO8	Output	Digital Output 8
5	$\overline{\text{RESET}}$	Input	Module Reset
6	PWM0/RSSI	Output	PWM output 0/Rx Signal Strength Indicator
7	PWM1	Output	PWM output 1
8	[reserved]	-	Do not Connect
9	$\overline{\text{DTR}}$ /SLEEP_RQ/DI8	Input	Pin Sleep Control Line Or Digital Input 8
10	GND	-	Ground
11	AD4/DIO4	Either	Analog Input 4/Digital I/O 4
12	$\overline{\text{DTS}}$ /DIO7	Either	Clear to Send Flow Control Or Digital I/O7
13	ON/ $\overline{\text{SLEEP}}$	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D input
15	Associate/AD5/DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	$\overline{\text{RTS}}$ /AD6/DIO6	Either	Request-to-send flow control ,Analog input6 or Digital I/O 6
17	AD3/DIO3	Either	Analog Input 3or Digital I/O 3
18	AD2/DIO2	Either	Analog Input2or Digital I/O 2
19	AD1/DIO1	Either	Analog Input 1or Digital I/O 1
20	AD0/DIO0	Either	Analog Input 0or Digital I/O 0

Table 2.1: Pin Description of ZigBee

AT mode of Operation

AT mode is synonymous with “Transparent” mode. In AT mode, any data sent to the XBee module is immediately sent to the remote module identified by the Destination Address in memory. When the module is in AT mode, it can be configured in by the user or a host microcontroller by first placing the module in Command mode and then predefined AT commands through the UART port. This mode is useful when we don’t need to change destination address very often, or we have a very simple network, or simple point to point communication.

2.2.1 Offset-Quadrature Phase Shift Keying

O-QPSK is a special version of QPSK in which the transmitted signal has no amplitude modulation. This disadvantage of amplitude modulation is a result of 180 degree shifting in the phase.

In O-QPSK the incoming signal is divided in the modulator into two portions I and Q which are then transmitted shifted by half symbol duration. There is no phase shift through the zero crossing which means there is no phase shift by 180 degrees. Taking four values of the phase (two bits) at a time to construct a QPSK symbol can allow the phase of the signal to jump by as much as 180° at a time. When the signal is low-pass filtered, these phase-shifts result in large amplitude fluctuations which are an undesirable quality in communication systems. By offsetting the timing of the odd and even bits by one bit-period, or half a symbol-period, the in-phase and quadrature components will never change at the same time. In the constellation diagram shown on the right, it can be seen that this will limit the phase-shift to no more than 90° at a time. This yields much lower amplitude fluctuations than non-offset QPSK and is sometimes preferred in practice.

The picture below shows the difference in the behaviour of the phase between ordinary QPSK and OQPSK. It can be seen that in the first plot the phase can change by 180° at once, while in OQPSK the changes are never greater than 90°.

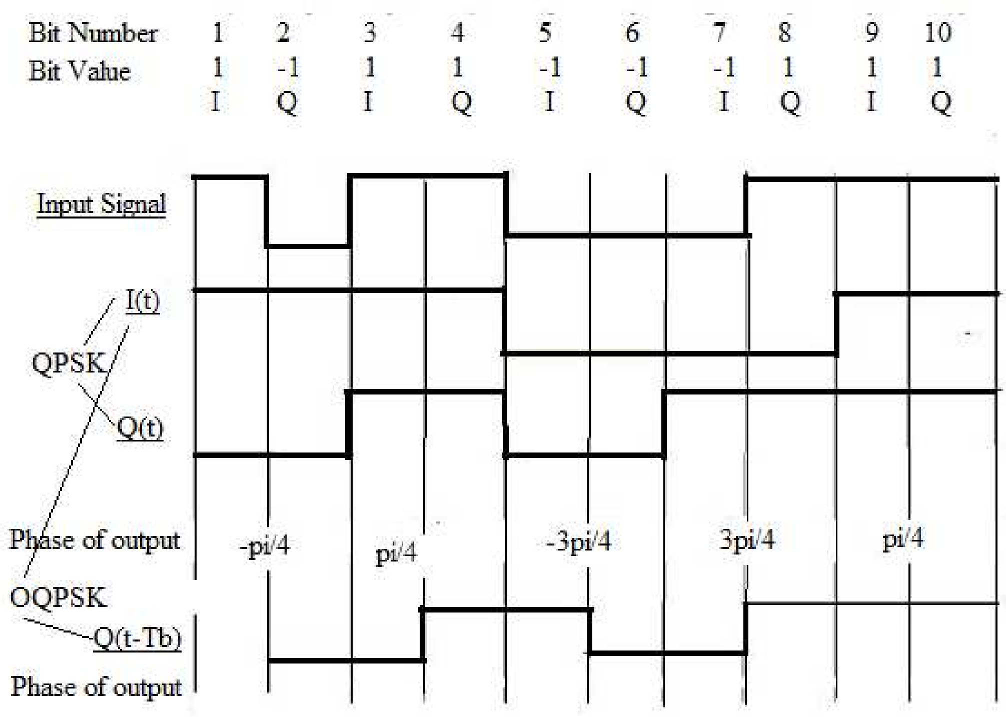


Fig 2.3: QPSK and OQPSK Time Domain Waveform

The sudden phase-shifts occur about twice as often as for QPSK (since the signals no longer change together), but they are less severe. In other words, the magnitude of jumps is smaller in OQPSK when compared to QPSK.

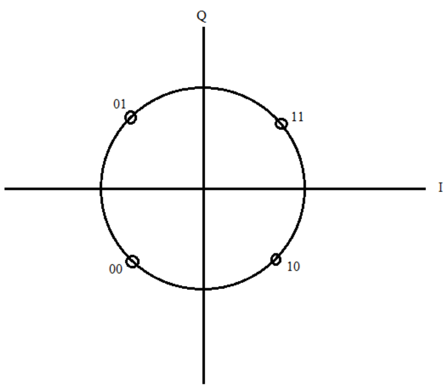


Fig 2.4: Constellation Diagram of O-QPSK

2.2.2 Direct Sequence Spread Spectrum

In Direct Sequence Spread Spectrum, the stream of information to be transmitted is divided into small pieces, each of which is allocated across to a frequency channel across the spectrum. A data signal at the point of transmission is combined with a higher data-rate bit sequence that divides the data according to a spreading ratio. The redundant chipping code helps the signal resist interference and also enables the original data to be recovered if data bits are damaged during transmission.

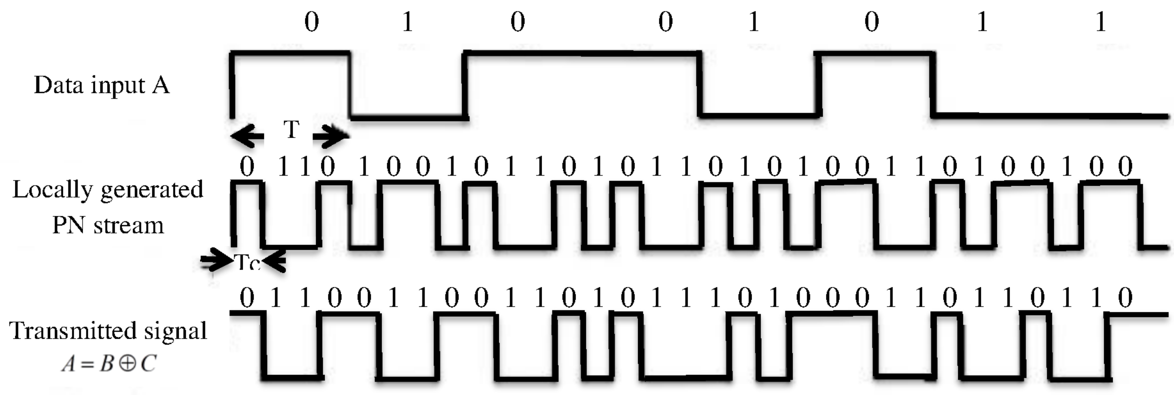


Fig 2.5: DSSS transmitted signal waveform

Direct sequence contrasts with the other spread spectrum processes, known as frequency hopping spread spectrum, in which a broad slice of bandwidth spectrum is divided into many possible broadcasts frequencies. In general, frequency hopping devices use less power and are cheaper, but the performance of DSSS system is usually better and more reliable.

2.3 Arduino Board

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

"Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or out-dated boards see the Arduino index of boards.

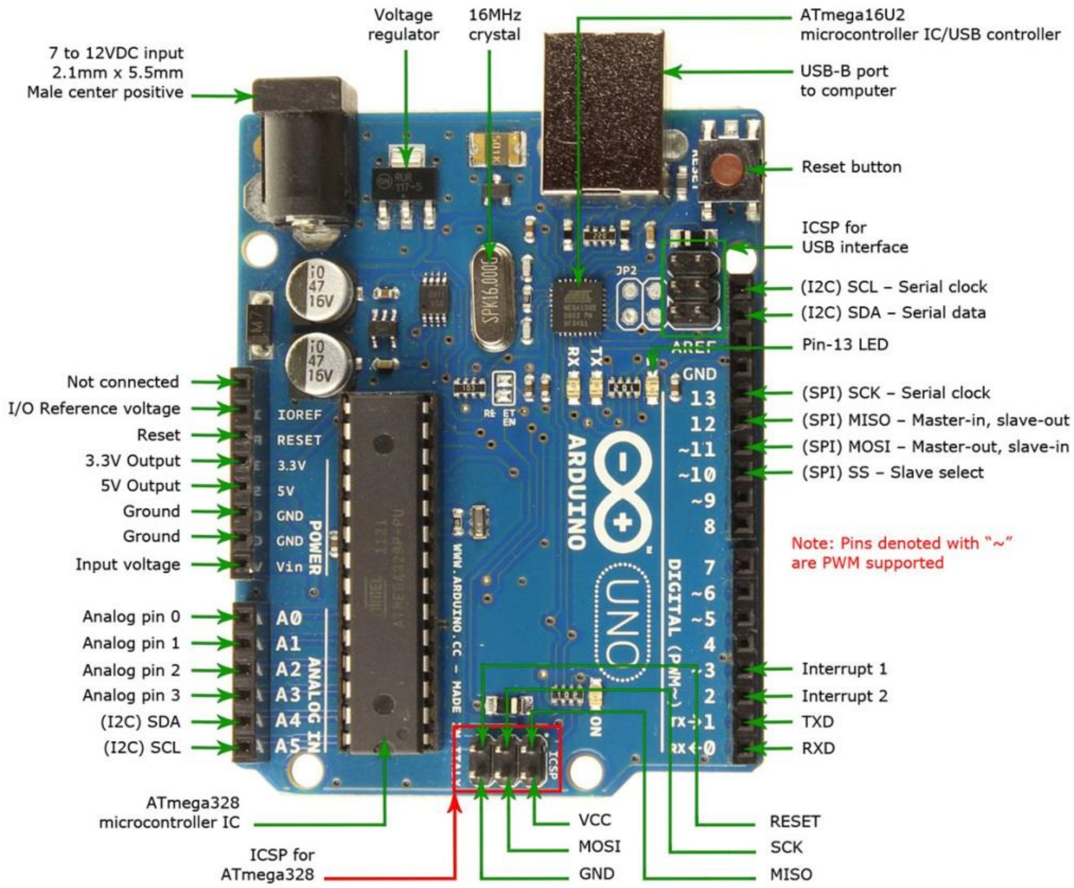


Fig 2.6: Arduino Uno board

Technical specifications:

- Microcontroller : ATmega328P
- Operating Voltage : 5V
- Input Voltage (recommended) : 7-12V
- Input Voltage (limit) : 6-20V
- Digital I/O Pins : 14 (of which 6 provide PWM output)
- Analog Input Pins : 6
- DC Current per I/O Pin : 20 mA
- DC Current for 3.3V Pin : 50 mA
- Flash Memory : 32 KB (ATmega328P) of which 0.5 KB used by boot loader
- SRAM : 2 KB (ATmega328P)
- EEPROM : 1 KB (ATmega328P)
- Clock Speed : 16 MHz

The Arduino Uno can be programmed with the Arduino Software (IDE). The ATmega328 on the Arduino Uno comes preprogramed with a boot loader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the boot loader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header using Arduino ISP or similar; see these instructions for details.

Arduino Uno has a number of facilities for communicating with a computer, another Arduino board, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The 16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an .inf file is required. The Arduino Software (IDE) includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows serial communication on any of the Uno's digital pins.

The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino Software (IDE) includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

2.4 Sensors

We are using two different sensors: DHT11 and MQ4.

DHT11

This DFRobot DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.

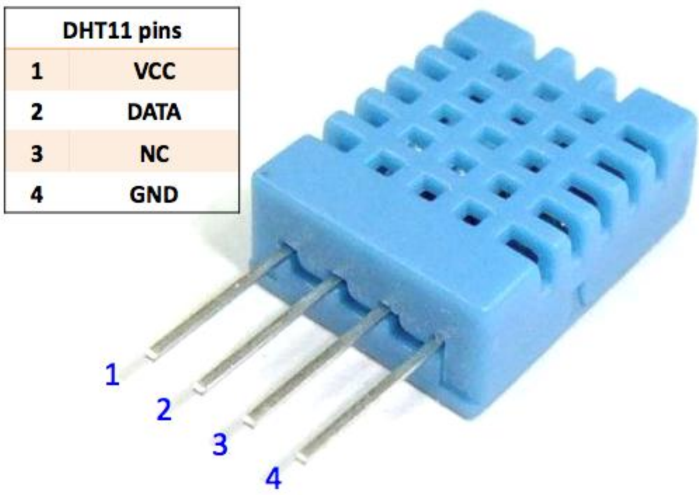


Fig 2.7: DHT11 sensor module

Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programmes in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20 meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package. It is convenient to connect and special packages can be provided according to users' request.

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50 ℃	±5%RH	±2℃	1	4 Pin Single Row

Table 2.2: Technical specification of DHT11

MQ4

Sensitive material of MQ-4 gas sensor is SnO_2, which with lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is higher along with the gas concentration rising. Please use simple electro circuit, Convert change of conductivity to correspond output signal of gas concentration.

MQ-4 gas sensor has high sensitivity to Methane, also to Propane and Butane.

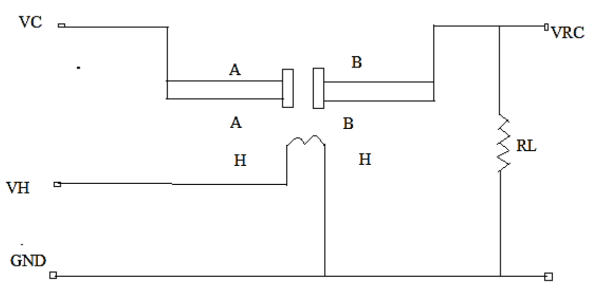


Fig 2.8: Basic circuit of MQ4

The sensor could be used to detect different combustible gas, especially Methane; it is with low cost and suitable for different application.

Character Configuration

- Good sensitivity to Combustible gas in wide range
- High sensitivity to Natural gas
- Long life and low cost
- Simple drive circuit

Application

- Domestic gas leakage detector
- Industrial Combustible gas detector
- Portable gas detector

2.5 MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, we can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN.

We can use MATLAB in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modelling and analysis, and computational biology. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas.

MATLAB provides a number of features for documenting and sharing our work. We can integrate our MATLAB code with other languages and applications, and distribute our MATLAB algorithms and applications. Features include:

- High-level language for technical computing
- Development environment for managing code, files, and data
- Interactive tools for iterative exploration, design, and problem solving

- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration
- 2-D and 3-D graphics functions for visualizing data
- Tools for building custom graphical user interfaces
- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java™, COM, and Microsoft® Excel

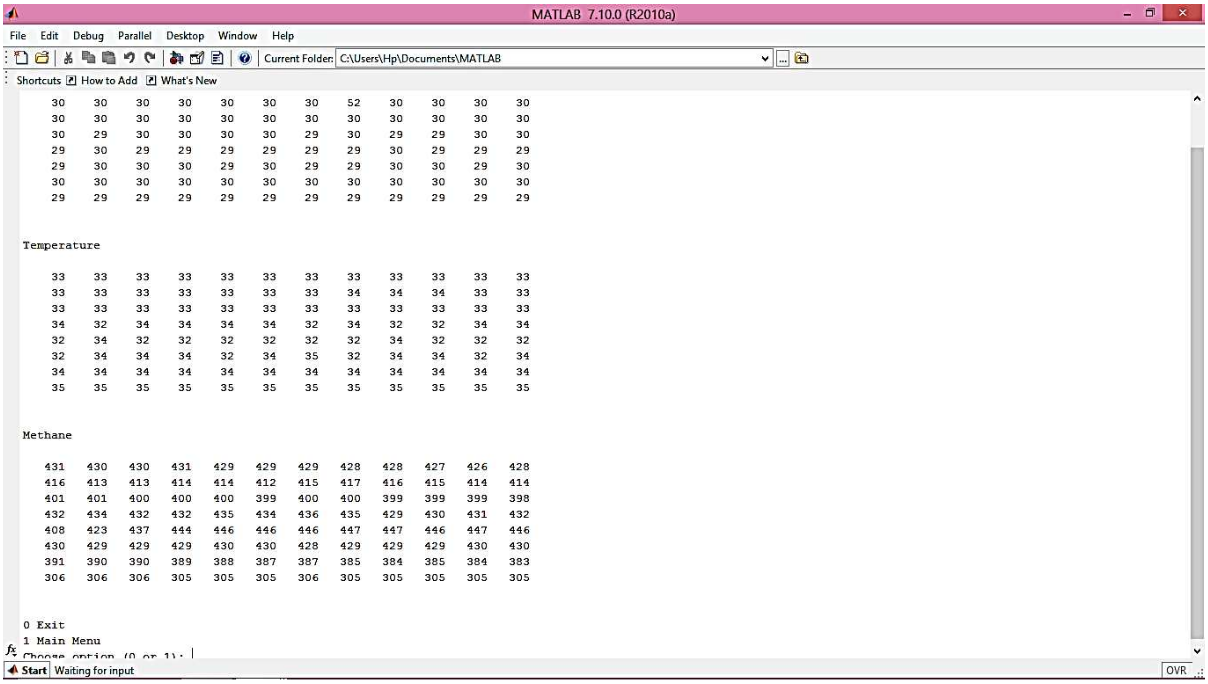


Fig 2.9: MATLAB window

2.5.1 The MATLAB System

The MATLAB system consists of these main parts:

Desktop Tools and Development Environment

This part of MATLAB is the set of tools and facilities that help us use and become more productive with MATLAB functions and files. Many of these tools are graphical user interfaces. It includes: the MATLAB desktop and Command Window, an editor and debugger, a code analyser, and browsers for viewing help, the workspace, and folders.

Mathematical Function Library

This library is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

The Language

The MATLAB language is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick programs we do not intend to reuse. We can also do "programming in the large" to create complex application programs intended for reuse.

Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow us to fully customize the appearance of graphics as well as to build complete graphical user interfaces on our MATLAB applications.

External Interfaces

The external interfaces library allows us to write C/C++ and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), for calling MATLAB as a computational engine, and for reading and writing MAT-files.

2.6 Serial Communication

In communication, serial communication is the process of sending data one bit at a time, sequentially, over a communication channel or computer bus.

Baud rate

The term “baud” originates from the French engineer Emile Baudot, who invented the 5-bit teletype code. Baud rate refers to the number of signal or symbol changes that occur per second. A symbol is one of several voltage, frequency, or phase changes.

NRZ binary has two symbols, one for each bit 0 or 1, that represent voltage levels. In this case, the baud or symbol rate is the same as the bit rate. However, it’s possible to have more than two symbols per transmission interval, whereby each symbol represents multiple bits. With more than two symbols, data is transmitted using modulation techniques.

When the transmission medium can’t handle the baseband data, modulation enters the picture. Of course, this is true of wireless. Baseband binary signals can’t be transmitted directly; rather, the data is modulated on to a radio carrier for transmission. Some cable connections even use modulation to increase the data rate, which is referred to as “broadband transmission.”

By using multiple symbols, multiple bits can be transmitted per symbol. For example, if the symbol rate is 4800 baud and each symbol represents two bits, that translates into an overall bit rate of 9600 bits/s. Normally the number of symbols is some power of two. If N is the number of bits per symbol, then the number of required symbols is S = 2N. Thus, the gross bit rate is:

$R = \text{baud rate} \times \log_2 S = \text{baud rate} \times 3.32 \log_{10} S$

If the baud rate is 4800 and there are two bits per symbol, the number of symbols is $2^2 = 4$. The bit rate is:

$R = 4800 \times 3.32 \log(4) = 4800 \times 2 = 9600$ bits/s

If there’s only one bit per symbol, as is the case with binary NRZ, the bit and baud rates remain the same.

CHAPTER 3

METHODOLOGY

3.1 Block diagram

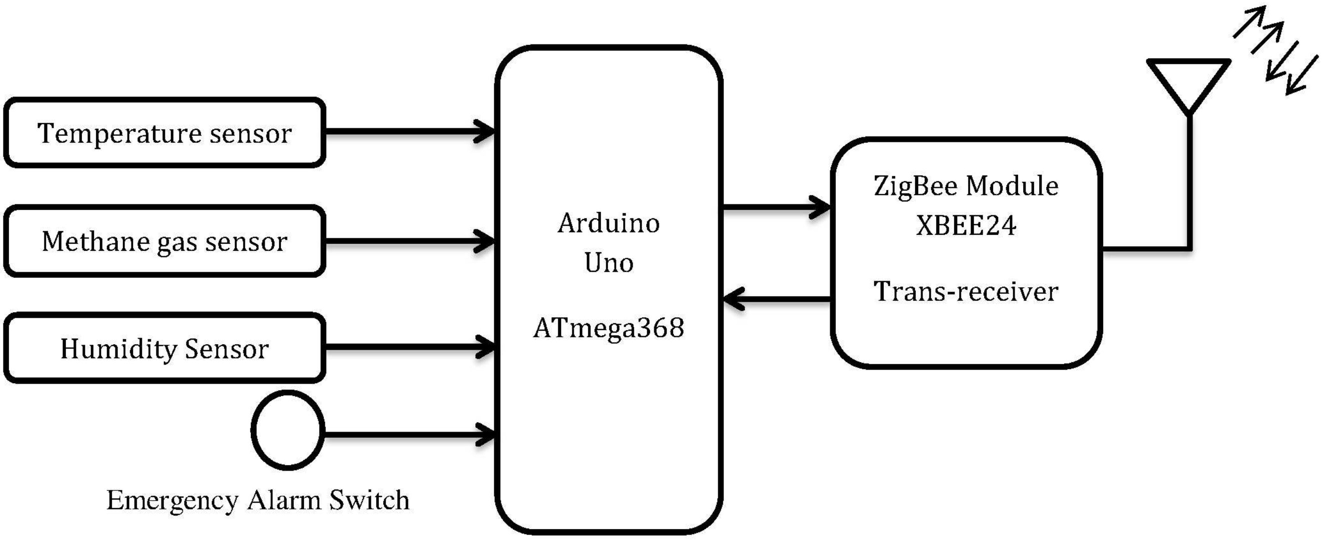


Fig 3.1a: Block diagram of Underground module

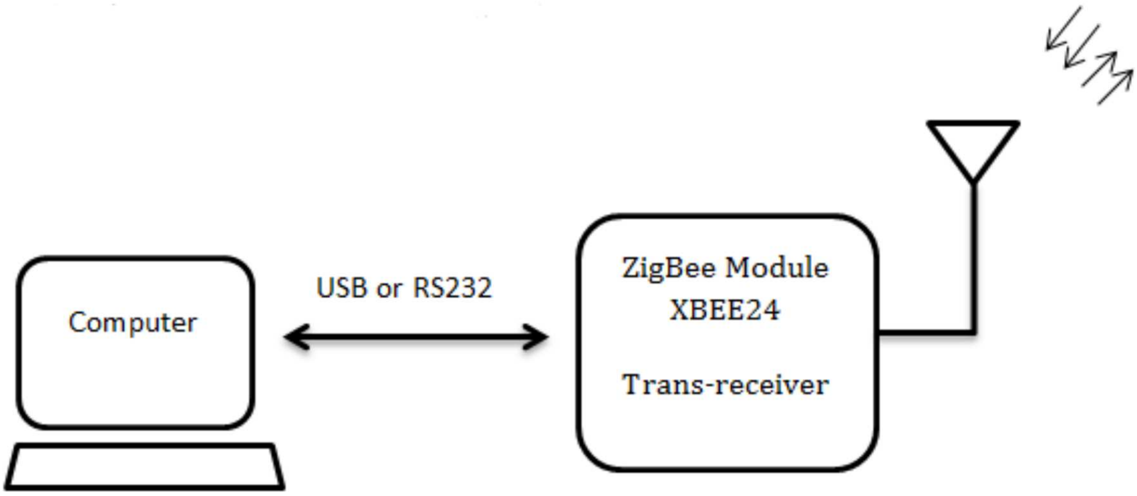


Fig 3.1b: Block diagram of surface monitoring station

3.2 Interface Diagram and PCB Layout

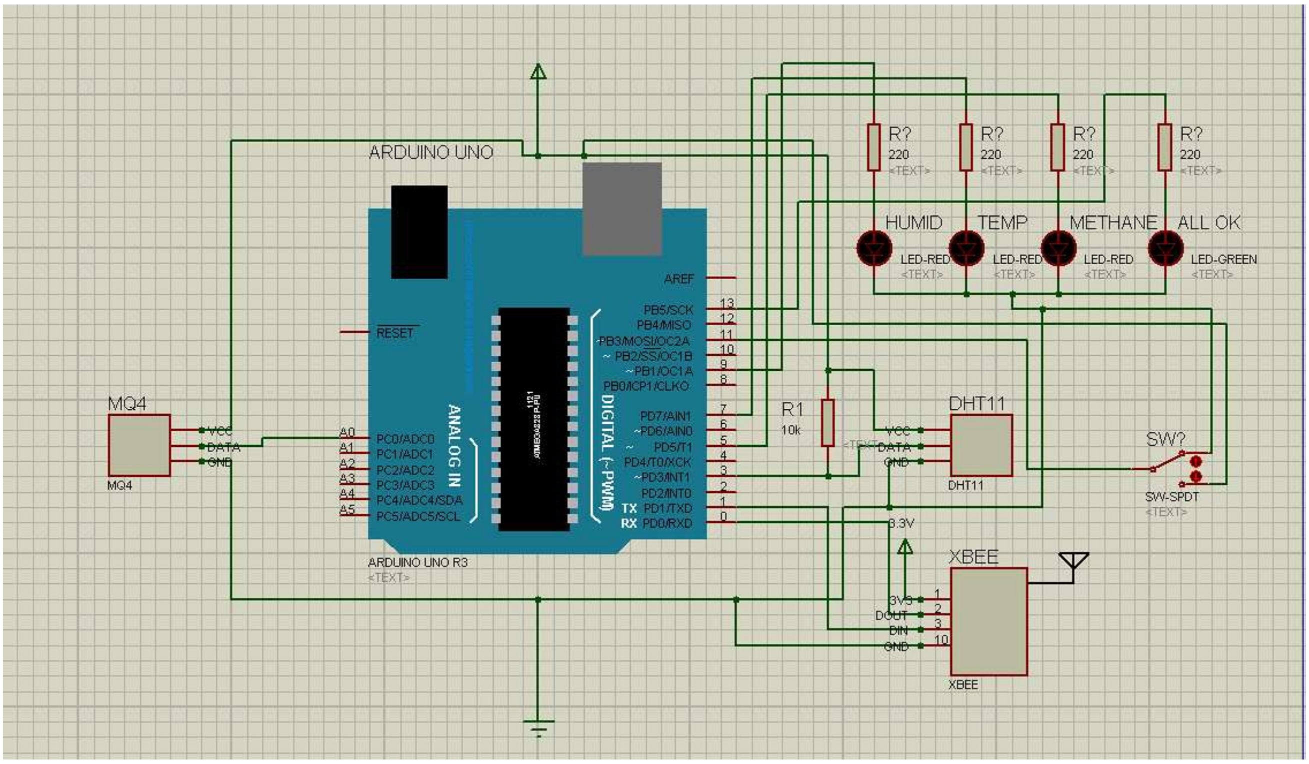


Fig 3.2: Interface diagram

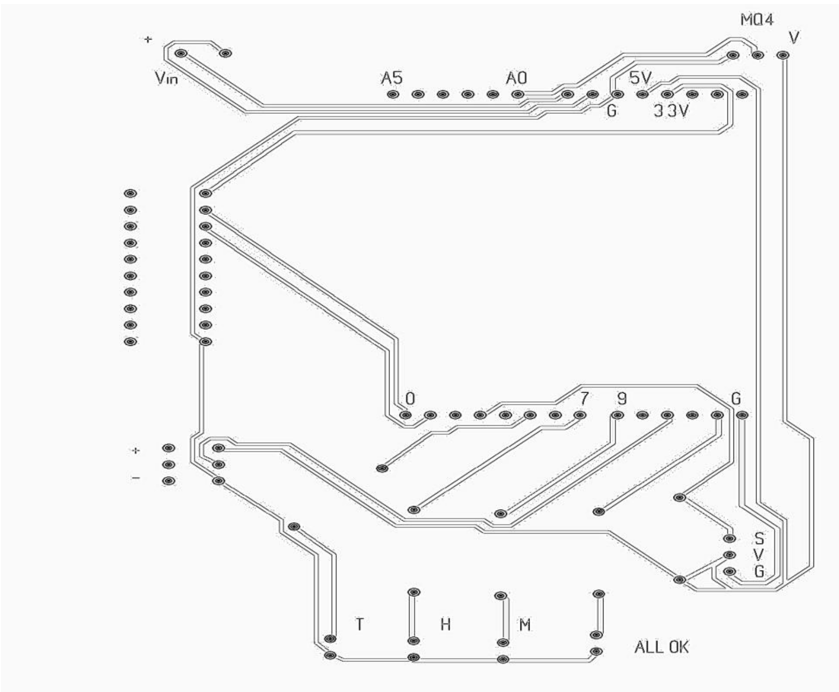


Fig3.3: PCB layout

3.3 Process Flowchart

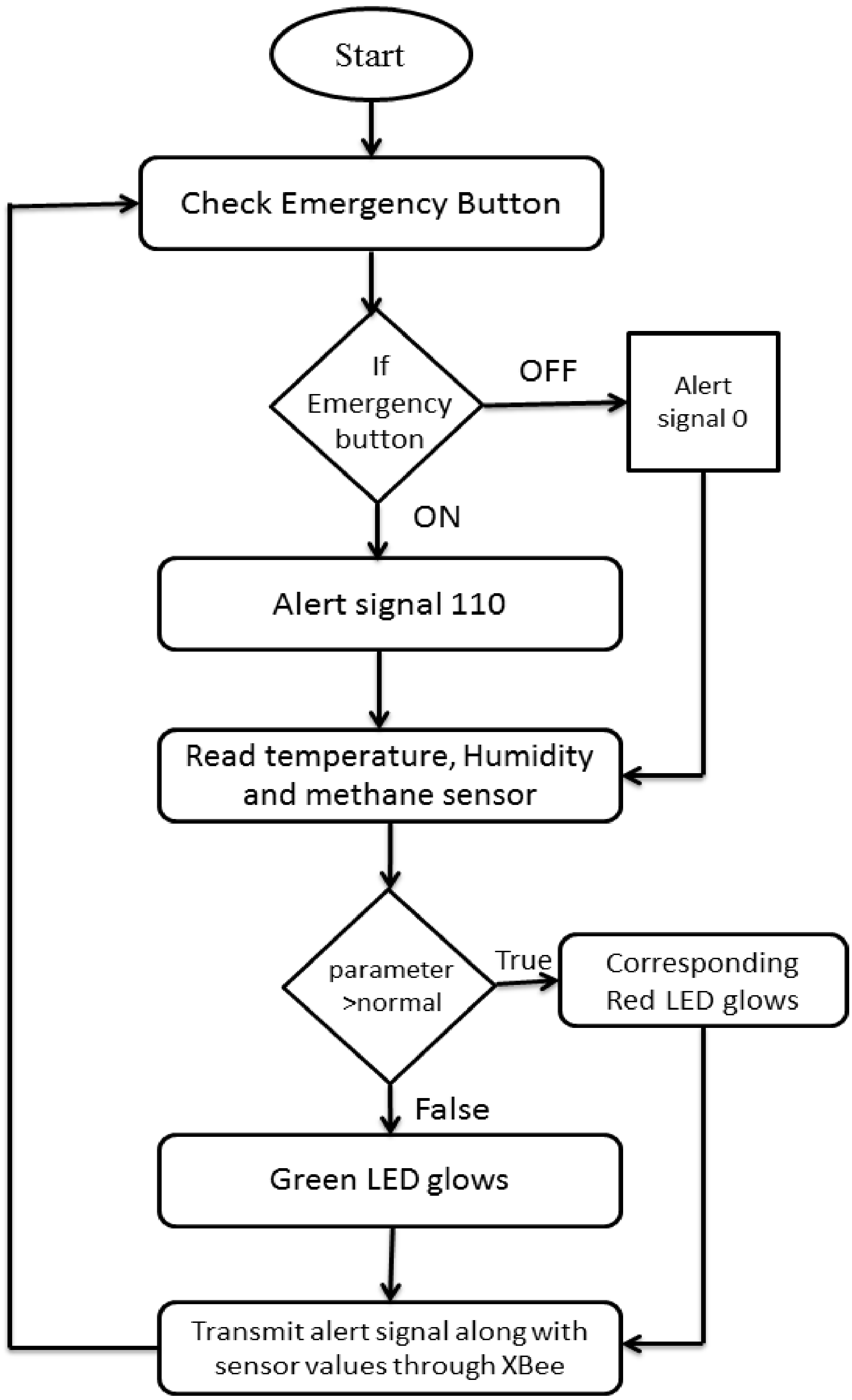


Fig 3.4a: Process Flowchart of underground module

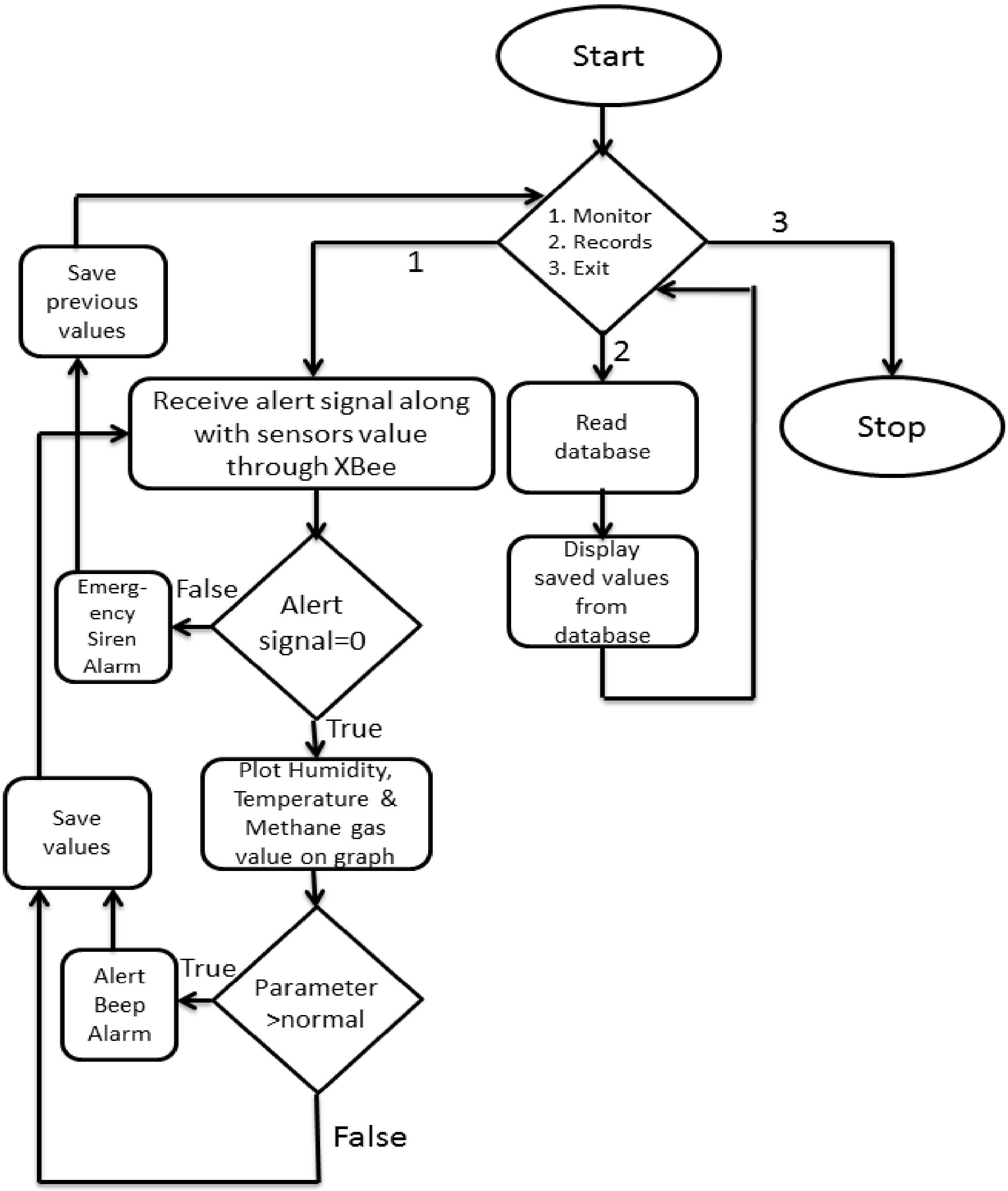


Fig 3.4b: Process Flowchart of surface monitoring station

3.4. Setting Up of XBee

We need to make one of the XBee S2 as **Coordinator**, another as **Router**.

Setup

Plug the XBee S2 module on to XBee USB adapter board. Mind the polarity. Plug the USB cable to it and computer. We will need to have X-CTU software.

Fig 3.5: XBee USB adapter

We have done installing USB driver and X-CTU, and the USB of XBee USB adapter board is plug in properly, we should see the POWER LED on XBee USB adapter board ON. There are two XBee S2 modules needed to be setup, a coordinator and a router.

Coordinator

We can choose either one of the XBee S2 to configure as coordinator. At the end, the host do not know which is which as XBee will become transparent once it is setup correctly.

Launch X-CTU

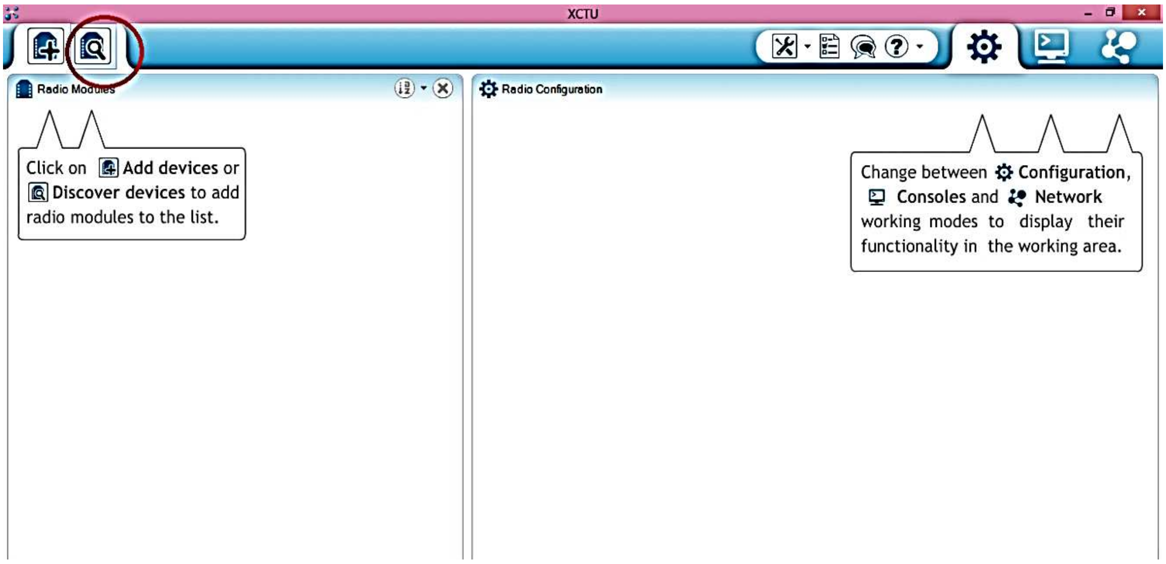


Fig 3.6: X-CTU window

Click on “Discover module” icon shown in red mark above.

Choose the COM Port. Easily we will see it because it is label as USB Serial Port (COM X). We have COM16. Proceed by clicking on “Next” button.

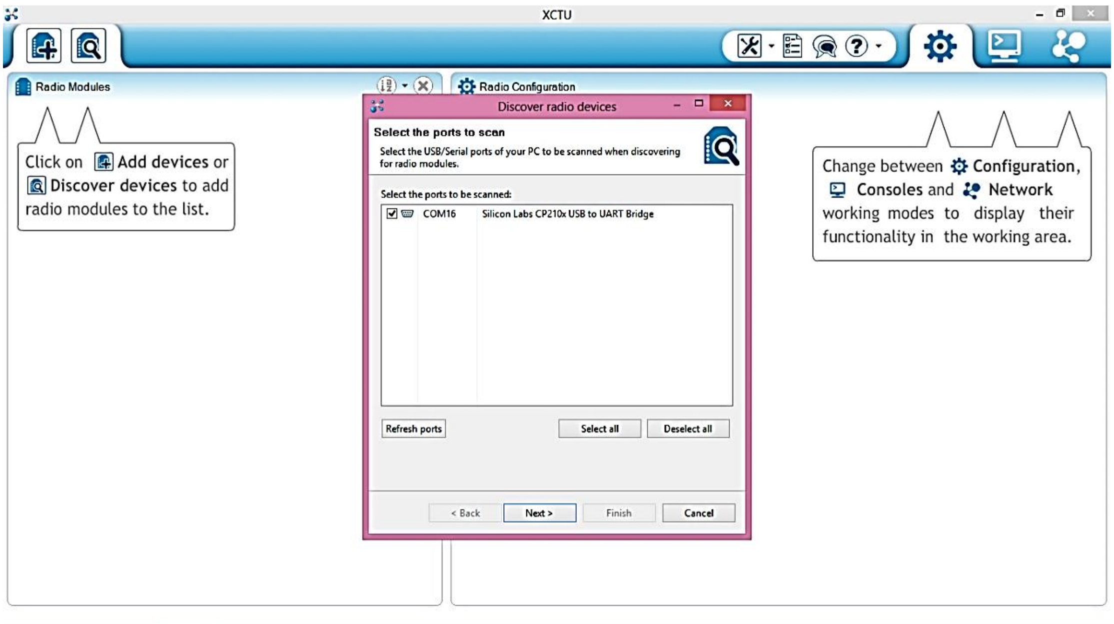


Fig 3.7: Discovering COM port (X-CTU setup)

Tick mark the required field, In our case baudrate 9600, No parity bit, Stop bit 1, Data bits 8, Flow control None. And then proceed.

XBee is discovered.

We Chose "ZIGBEE COORDINATOR AT" under Function Set, set a preferable PAN ID; we set it as "A022". PAN ID is Personal Area Network ID which must be same for all xbee connected in a network.

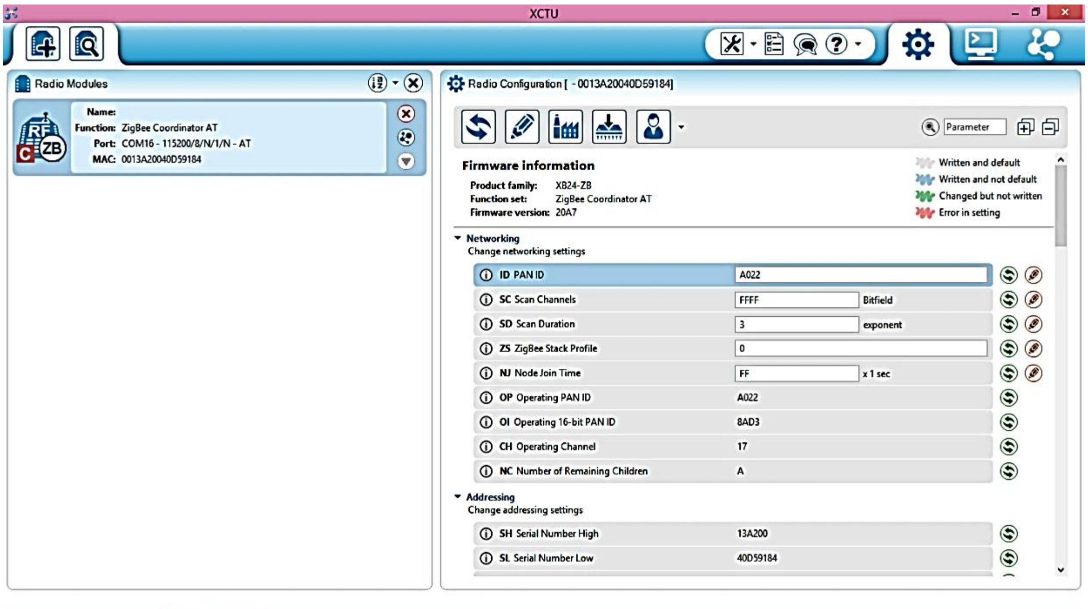


Fig 3.8: Setting up of X-bee

Record the SH and SL ID on this XBee S2 module, we need it to set Router module. In our case, the SH is 13A200, SL is 40D59184. This is Coordinator Source Address.

Click **"Write"** and X-CTU will start loading the parameter we just set.

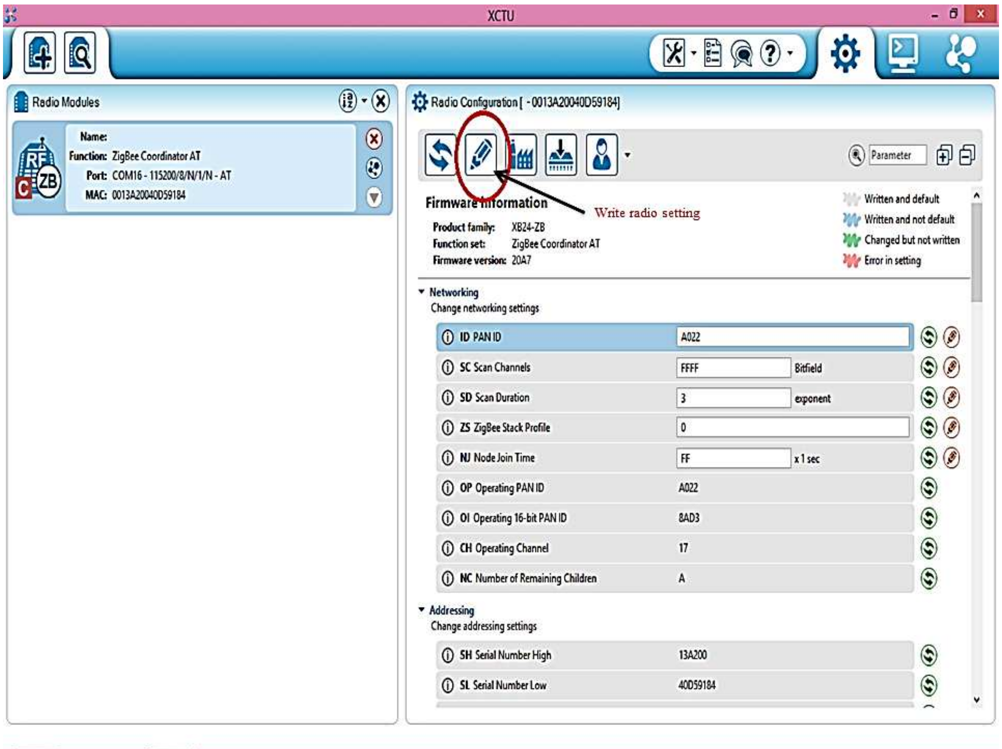


Fig 3.9: Writing radio module

It will take around 30 seconds to 1 minute to complete the loading.

We will need to configure Coordinator again when we get the SH and SL of router . For the time being, we are done for Coordinator.

Router

Now we connect another XBee to USB adapter.

Launch X-CTU

Repeat the same process as in coordinator.

Choose “ZIGBEE ROUTER AT” under Function Set,

Set the same PAN ID, “A022”.

Record the SH and SL ID on this XBee S2 module, you will need it to set Coordinator module. In my case, the SH is 13A200, SL is 40E8B679.

Key in the DH and DL address using the SH and SL from Coordinator module.

Click “Write” and X-CTU will start loading the parameter we just set.

It will take around 30 seconds to 1 minute to complete the loading.

We are done with Router module.

Again, Coordinator

We need to set the DH and DL on Coordinator XBee S2 module. Again, plug in Coordinator XBee S2 module, open X-CTU, read the information, and set the DH and DL that we grabbed from Router's SH and SL. Click "write" to load the parameters into XBee module.

3.5 Reading sensors output

Methane gas sensor

We get output at MQ4 sensor in voltage ranging from 1V to 5V. From the datasheet of MQ4, we obtained the following graph which shows voltage-ppb relationship (sensitivity).

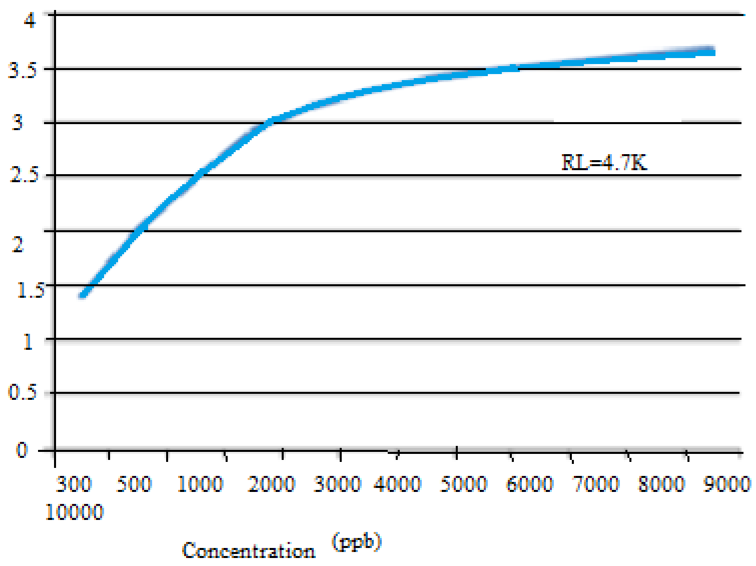


Fig3.10: Sensitivity Curve of MQ4

We divided the whole curve into two parts, First part between 1.3V to 3V and another part from 3V to 3.6V because the variance of slope within the part is very small.

In first part (For 1.3V<VRL<3V), we obtained the equation as,

$$ppb=1294V_{RL}-1282 \qquad \text{Eq. 3.1}$$

In second part (For 3V<VRL<3.6V), we obtained the equation as,

$$ppb=11667V_{RL}-32800 \qquad \text{Eq. 3.2}$$

Where, ppb=Value in part per billion

V_{RL}= output voltage of MQ4

These equations are used in MATLAB to convert methane voltage value into Parts per Billions before plotting graph.

Humidity and Temperature sensor

The interesting thing in this module is the protocol that uses to transfer data. All the sensor readings are sent using a single wire bus.
Communication Format can be separated into three stages
1) Request
2) Response
3) Data Reading

1) Request: To make the DHT-11 to send us the sensor readings we have to send it a request. The request is, to pull down the bus for more than **18ms** in order to give DHT time to understand it and then pull it up for **40uS**.

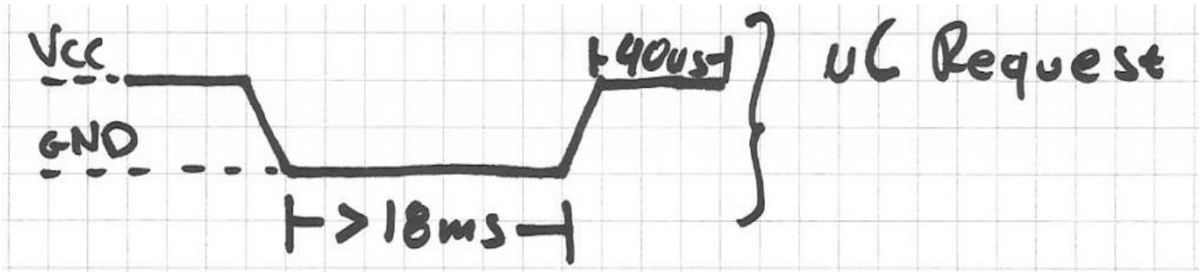


Fig3.11: Request signal sent to DHT11

2) Response: What comes after the request is the DHT-11 response. This is an automatic reply from DHT which indicates that DHT received your request. The response is ~54uS low and 80uS high.

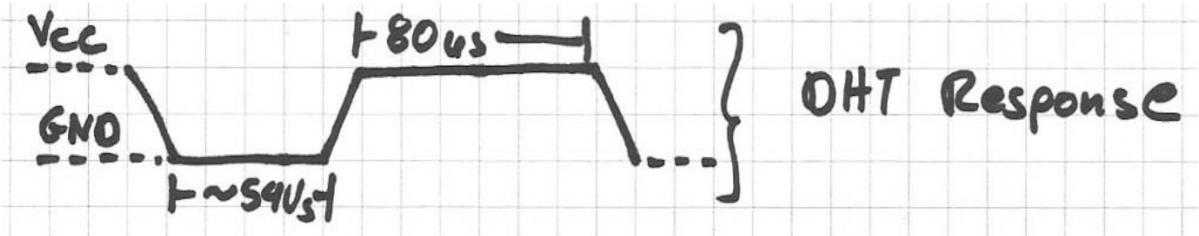


Fig3.12: Response received from DHT11

3) Data Reading: What will come after the response is the sensor data. The data will be packed in a packet of 5 segments of 8-bits each. Totally 5×8 =40bits. First two segments are Humidity read, integral & decimal. Following two are Temperature read in Celsius, integral & decimal and the last segment is the Check Sum which is the sum of the 4 first segments. If Check Sum's value isn't the same as the sum of the first 4 segments that means that data received isn't correct.

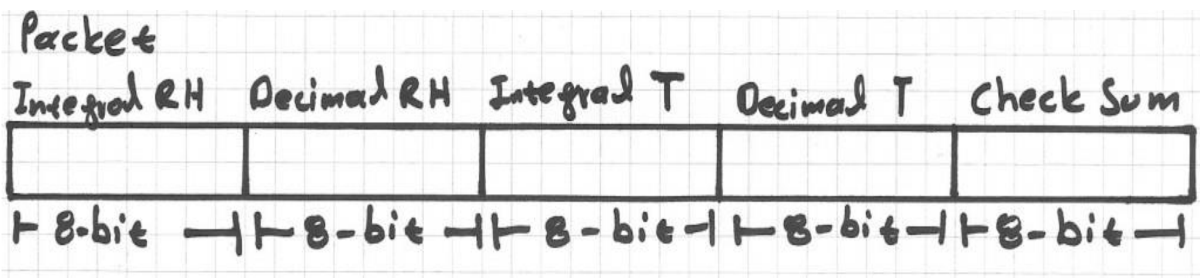


Fig3.13: Sensor data of DHT11

3.6. Working

The whole system works in two parts: Underground module and surface monitoring station.

Underground modules have sensor units which sense the methane gas, temperature and humidity inside the mine. The sensed parameters are processed in Arduino microcontroller and are converted into understandable format i.e. temperature in degree Celsius and humidity in %RH. These values are transmitted through XBee module connected to serial port of Arduino microcontroller. After transmitting, it goes to sleep mode for 5 minutes (5 second in DEMO). If the level of mentioned parameter rises above the specified level, then Red LED on module glows otherwise green LED glows. For Temperature the specified limit is 45ºC, for humidity 60%RH and for methane it is 1500 ppb. These values can be changed in program as required in practical use.

The data are received to surface station through the XBee module. These data are again processed to check the level and to check either it is voice data or sensors parameters. If the sensors parameters rise above specified limit for more than 5 minutes an alert sound beeps. Surface monitoring station has micro-controller board which processes the received data and a windows OS computer. MATLAB installed in computer continuously plots real-time graph for received parameters. We created a function named “project.m” and copied the file in “C:\Users\Hp\Documents\MATLAB”. This makes execution of program easy. The real-time parameters are stored in background in a spread sheet file as a record for future purpose.

Underground module also has a switch which sends an emergency alarm to the ground monitoring station at the time of emergency. The ground monitoring station has Siren alarm designed in MATLAB software which makes aware to the controllers about any emergency happening inside mine. This helps the authorities to take appropriate steps at the time of emergency.

The alert beep sound and emergency siren sound is stored in .wav format in a folder which is accessed during emergency signal or if parameter rises the normal value. Then this file is played using MATLAB in full sound.

CHAPTER 4

ANALYSIS AND SIMULATION RESULT

Here, we will explain the user interface, simulation graph and calculations.

4.1 MATLAB user interface

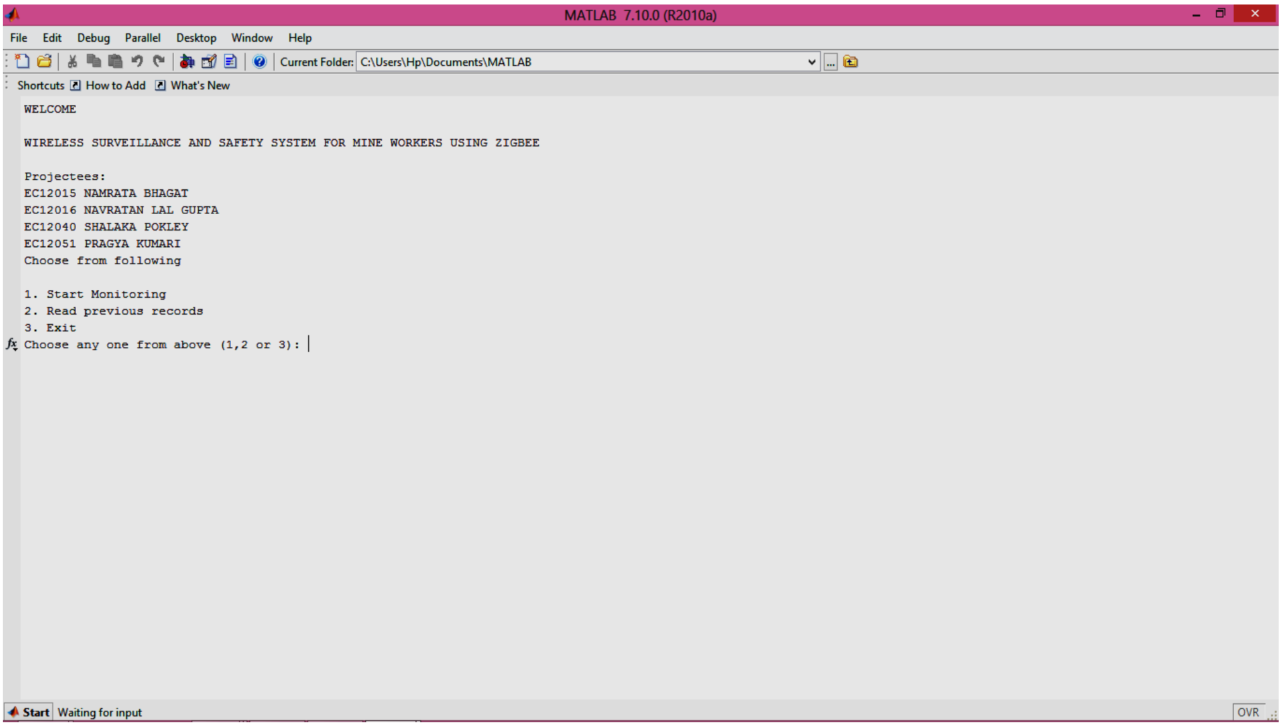


Fig 4.1: MATLAB user interface

Launch MATLAB and type "projectM1" in command window. Above interface opens in MATLAB window. It asks to choose any one option from (1 to 3):

1. Start Monitoring
2. Read Previous record
3. Exit

When “1” is entered, MATLAB starts monitoring the parameters and start plotting on a graph. It also saves the record in spread sheet file.

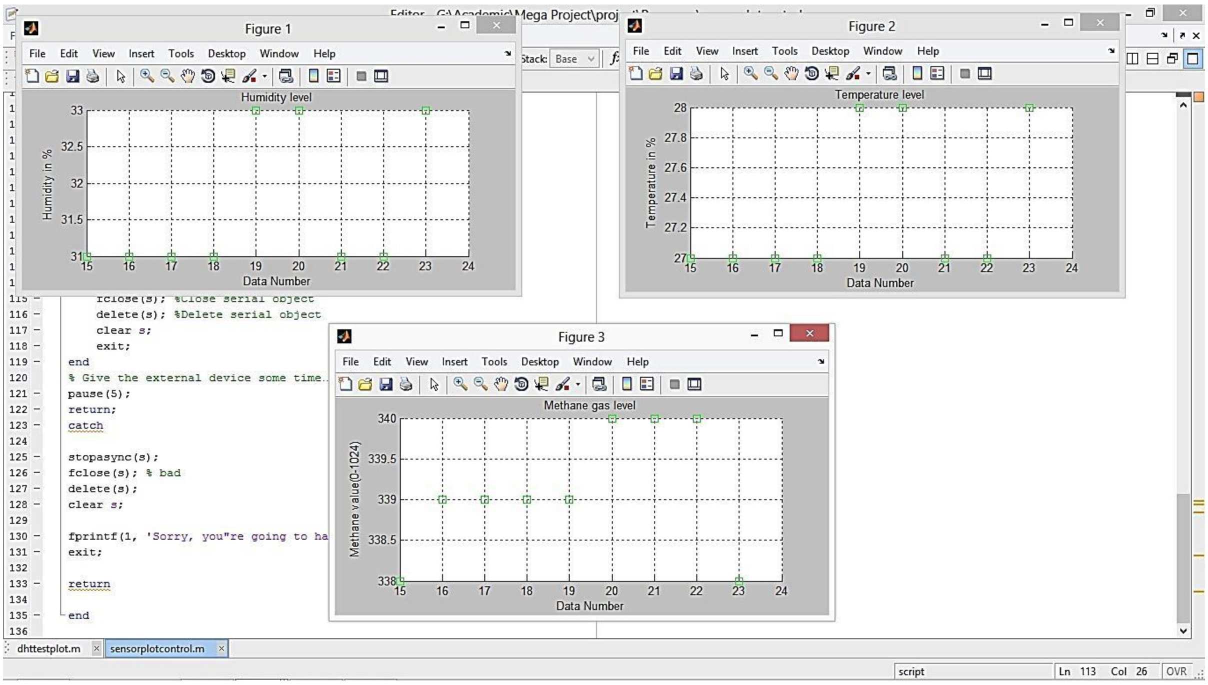


Fig 4.2: Monitoring parameters and graph

When “2” is entered, MATLAB read the previously recorded parameters and displays it on window.

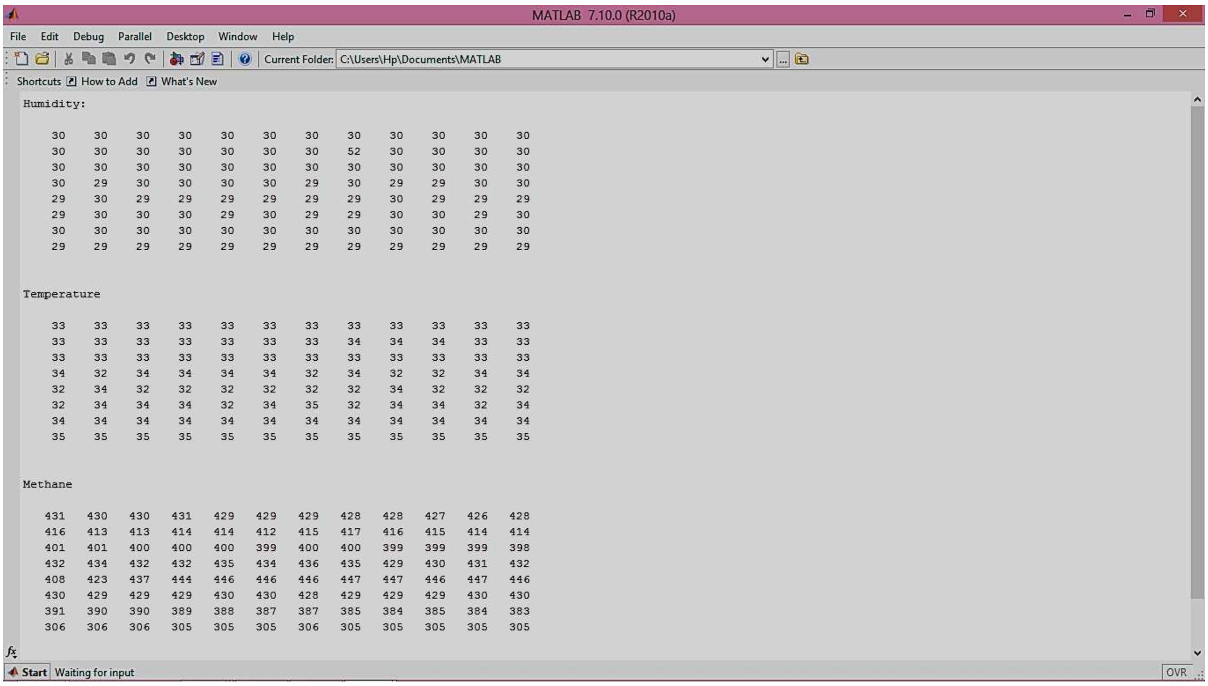
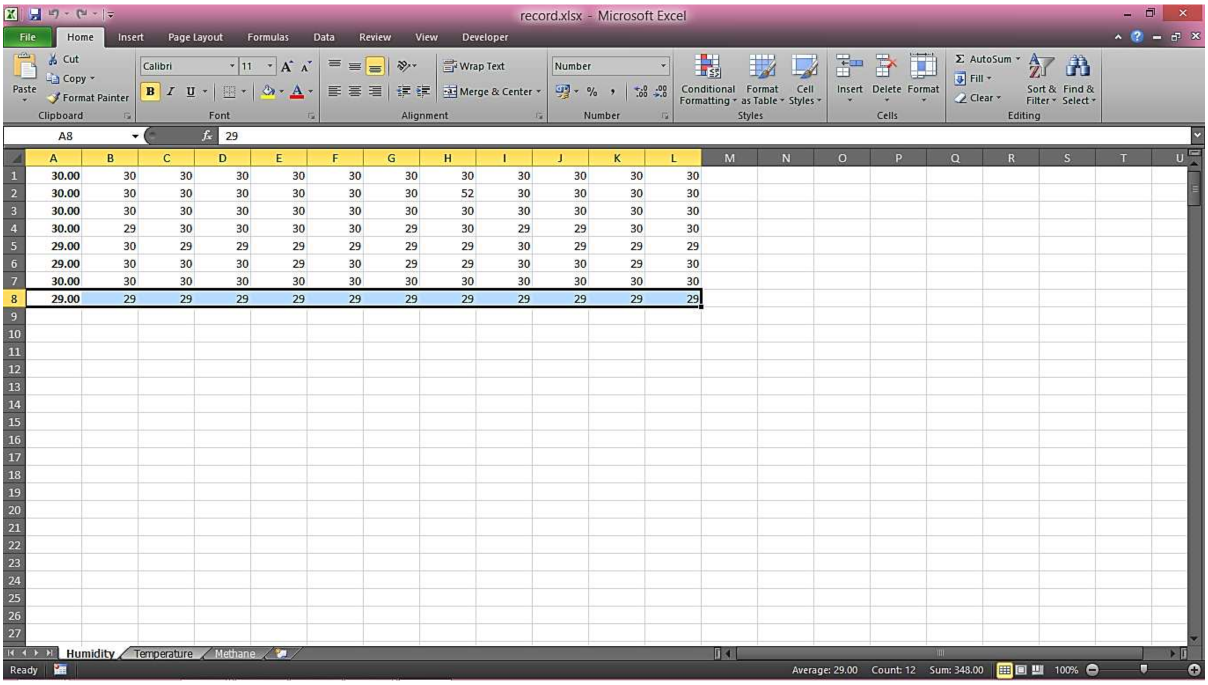


Fig 4.3: Previously recorded parameters



	A	B	C	D	E	F	G	H	I	J	K	L
1	30.00	30	30	30	30	30	30	30	30	30	30	30
2	30.00	30	30	30	30	30	30	52	30	30	30	30
3	30.00	30	30	30	30	30	30	30	30	30	30	30
4	30.00	29	30	30	30	30	29	30	29	29	30	30
5	29.00	30	29	29	29	29	29	29	30	29	29	29
6	29.00	30	30	30	29	30	29	29	30	30	29	30
7	30.00	30	30	30	30	30	30	30	30	30	30	30
8	29.00	29	29	29	29	29	29	29	29	29	29	29

Fig 4.4: Records saved in Spreadsheet file

When we enter “3”, MATLAB closes all the COM ports and exit MATLAB window.

Simulation Graph

MATLAB plots new value after every 5 minutes (5 seconds in DEMO). If values are above limit, Colour of plot automatically turns red, otherwise remains green.

In 5 minutes, 1 value is plotted.

In 24 hours i.e. 24 x 60 = 1440 minutes,

1440/5= 288 values will be plotted.

For DEMO purpose, we considered 1 value to be plotted after every 5 seconds for 1 minute.

Then, Number of points required on graph will be, 60/5 = 12.

4.2 Sensors reading verification

We verified correctness of our sensors output by comparing them with real value. We tested in different time to verify. Due to unavailability of proper methane test bench, we could not able to test methane sensors.

Measurement range:

Temperature: 0 to 50 degree Celsius

Humidity: 20-90% RH

Error:

Temperature: ±2 degree Celsius

Humidity: ±5 % RH

Date	Time	Temperature (In degree Celsius)		Humidity (In %RH)	
		Sensor value	Actual value	Sensor value	Actual value
11/02/2016	09:44 PM	27	25	31	29
15/02/2016	06:13 PM	30	31	31	27
17/02/2016	01:03 AM	30	29	32	27
18/02/2016	02:31 PM	31	34	29	32

Table 4.1: Sensors verification table

4.3 Range Test

Range test can be performed using X-CTU. We have performed the range test in two different conditions, Line Of Sight and Urban Environment. In urban environment, we tested our modules by keeping a fairly large building in between underground module and surface monitoring station.

We found the following result:

LOS: 76 meters to 78 meters

Urban environment: 23 meters to 25 meters

This is fairly good for DEMO purpose. For practical purpose, we can introduce a mesh networking for communication.

CHAPTER 5

CONCLUSION AND FUTURE SCOPES

This project can help underground mine workers, communicate with controller sitting at the monitoring station through alarm. This project is the combination of two individual devices. This project help workers take proper action before disaster grows destructive takes place. Wireless technology can reduce the cost and prevents from instalment the long wired cable. The maintenance of ZigBee is very less than cabled connection. This can be installed at place where wired cables are very tough or impossible to install.

Some of the future scopes of our project are:

- Range of communication can be increased up to 1500 meters by replacing XBee with XBee pro in practical use.
- DHT11 sensors can be replaced with DHT22 or other better sensors for better accuracy, precision and measurement range.
- This module can be used in Industrial purpose also with some advancement.
- Voice communication can be introduced by replacing Arduino with some advanced 10 bit microcontroller.
- This project may replace the wired system.
- A very long and wide communication can be achieved by forming mesh network of XBees.
- Later working on the module will bring great advancement in the wireless communication inside mine and will help miners in various safety and surveillance purpose.

CHAPTER 6

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