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# DESIGN OF AN INTELLIGENT HELMET FOR MINE WORKERS

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***Abstract***- *This paper presents the design of an intelligent helmet for mine workers. It focuses mainly on the automation portion. There are many environmental hazards that can happen in mines which can be very dangerous for the mine workers. The proposed helmet will not only protect the head of the mine workers, but also will aware himself about any sudden atmospheric change such as sudden rise of temperature, humidity and presence of harmful gases. Moreover, after any massive accident the heartbeat detecting sensor can notify whether the worker is dead or alive. If any atmospheric change tends to happen the workers can be alerted and signals can be sent outside by zigbee module.*

**Keywords:** Intelligent Helmet, Automation, Temperature Sensor, Humidity Sensor, Gas Sensor, Heartbeat Detecting Sensor, Zigbee Module

## 1. INTRODUCTION

Air pollution and gas explosion are increasing day by day and become foremost crisis in the coal mines and other industries. Safety of the human being is an essential aspect in any industry, especially in the field of mining and underground industry. The coal mine has been a very precarious activity which results in a number of detrimental effects on the environment such as suffocation, roof collapse, gas poisoning, gas explosions and hazardous greenhouse gases may be released into the air [1].

The major accidents occur in the mines are cave-ins or blockage, sudden rise of temperature, sudden change of humidity, gas explosions, chemical leakage etc. Air pollution leads to the personal and health impacts on lots of people causing illness and fatality. Explosive gas emission panics the human health, occupational safety of the coal mines workers. Consequently these pollutions cause hazardous effects on the coal mines workers. There are a lot of works are carried out in the same manner in the case of coal mine monitoring. However existing and extant security monitoring systems cannot monitor all environmental parameters, therefore workers cannot be monitored properly. The remedy for this issue is a wearable cost effective protection system with low power consumption and high performance. This venture aims to increase the occupational safety and to protect the workers effectively in the hazardous air polluted environment.

Traditional safety helmets have been used extensively from an early period of time in large and medium-sized coal mines due to their light weight and low power consumption. Meanwhile ZigBee based wireless sensor networks are recently given emphasis for having remote environment monitoring capabilities. This kind of network collects sensor data and transmits by radio. So it is proposed to design a Smart Helmet as a mobile node ZigBee wireless sensor network. It not only collects underground parameters quickly and easily but also allows an easier information exchange between miners and control centre through wireless communication. It helps the centralized management to build up real time surveillance on environment parameters. Thus potential safety problems can be avoided by early warning intelligence. On the other hand, it can ensure the physical safety of the worker by protecting his head. The design includes implementation of heart rate detecting sensor which ensures new dimension to the design. The worker's heart bit can be continuously measured and the relevant data can be sent to the control room via Zigbee. It helps to inform the controller of the control room whether the worker is dead or alive after massive accidents in the mine. There is a buzzer on the helmet which can alert the worker from sudden change of atmosphere such as abnormal temperature rise, sudden change of humidity or any leakage of harmful gases like $CO_2$, CO, $SO_2$ etc.

## 2. PREVIOUS WORKS

T. Hemalatha represented a safety system for coal mine workers. The safety system was designed with GPS tracking process. They implemented different kind of sensors in the mining helmet and transmitted the signal through ZigBee technology. In addition they used GPS tracker to locate the particular worker which enhances the cost [2].

A. Geetha proposed a system for enhanced safety of mine workers by implementing voice control command over ZigBee module. A microphone and a headphone have been implemented in the system [3].

In the year of 2002, K. Galatsis proposed a design called "Investigation of gas sensors for vehicle cabin air quality monitoring", this paper focuses on car cabin air quality monitoring can be effectively analyzed using metal oxide semiconducting (MOS) gas sensors. In this paper, commercially available gas sensors are compared with fabricated sensors possessed with comparable gas sensing properties [4].

V. Ramya designed a system to detect the air quality of the mine. Emphasis has been given on the detection of LPG gas only. Detection of sudden changes of temperature and humidity changes has been neglected. The signal is transmitted by GSM technology [5].

Another fabulous technology in this particular field has been proposed by S. Jayabratha. Various kinds of sensors have been applied to ensure the security. On addition, fire detector and fall detector has been successfully implemented in this design which enhanced the overall safety. But due to uses of various sensors the cost has been increased [6].

### 2.1 Advantages of Proposed System over Previous Works

This design is better than previous works for many aspects. They are:-

- The used temperature and humidity sensors are sensitive enough to respond in slightest atmospheric change.
- The implemented gas sensor not only detects LPG, it detects CO, $CO_2$ and smoke also.
- The extra dimension in this design is implementation of heartbeat detecting sensor which has not been used anywhere in the previously discussed works. This sensor creates opportunity to measure the heart rate of the worker during working hour. Moreover, after any sudden accident whether the worker is dead or alive can be detected by this sensor.

## 3. SYSTEM DESIGN

The proposed protection system covers the most significant and primary necessity aspects of the coal mine workers. This rescue system for coal mine workers is divided into two segments. Miner module and ground station unit. The wearable hardware device (miner module) is attached to the helmet of the mine workers.

### 3.1 Miner Module

The miner module consists of different elements. They are helmet, gas sensor, humidity sensor, temperature sensor, heartbeat detecting sensor, power supply, buzzer etc. The sensors are mounted on the helmet.

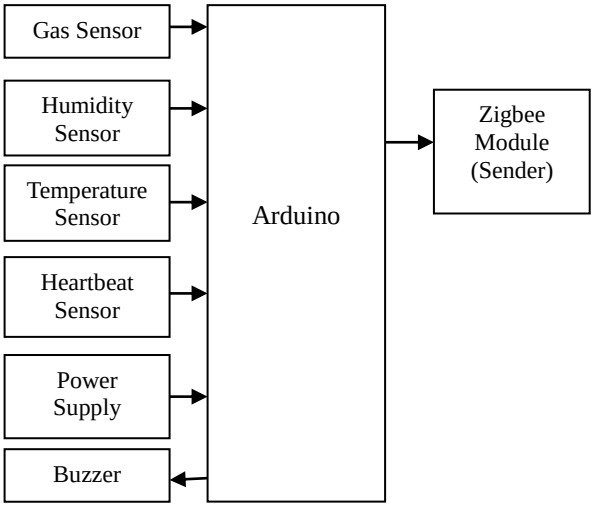


Fig.1: Miner Module Block diagram

#### 3.1.1. Gas Sensor

MQ5 is a semiconductor type gas sensor which detects the gas leakage. The sensitive material of MQ-5 is tin dioxide ($SnO_2$). It has very low conductivity in clean air. This Gas sensor not only has sensitivity to propane and butane but also to other natural gases, low sensitivity to cigarette smoke and alcohol. This sensor can also be used for detection of other combustible gas such as methane. The concentration range of MQ-5 gas sensor is 300-1000 ppm. This sensor is available in 6 pins package, out of which 4 pins are used for fetching the signals and other 2 pins are used for providing heating [7].

#### 3.1.2. Humidity and Temperature Sensor

The module of HSM-20G is essential for those applications where the relative humidity can be converted to standard voltage output. It is a sensor that senses the amount of water vapor in the air. The module of HSM-20G is essential for those applications where the relative humidity can be converted to standard voltage output [8].

#### 3.1.3. Heartbeat Detection Sensor

The Heart Rate Ear clip kit contains an ear clip and a receiver module. The heart rate measure kit can be used to monitor heart rate of patient and athlete. The result can be displayed on a screen via the serial port and can be saved for analysis. The entire system is highly sensitive and consumes low power.

#### 3.1.4. ZigBee Module

The Zigbee Modules used in the interfacing boards are engineered to meet IEEE 802.15.4 standards. It is low-cost, low-power, reliable 20 pin device that operates

within the ISM 2.4 GHz frequency band. It has 30 to 100 metre data transmission capability with rate of 250,000 bps. Zigbee modules operate in five modes. When not receiving or transmitting data, the RF module is in Idle Mode. The RF module shifts into the other modes of operation under various conditions [9]. It can send or receive any kind of signal.

### 3.1.5. Arduino

Arduino Mega is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins. 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila [10].

### 3.2 Ground Station Unit

Ground station unit contains ZigBee receiver module, LCD display, laptop /desktop and arduino. Most of the components have been discussed earlier.

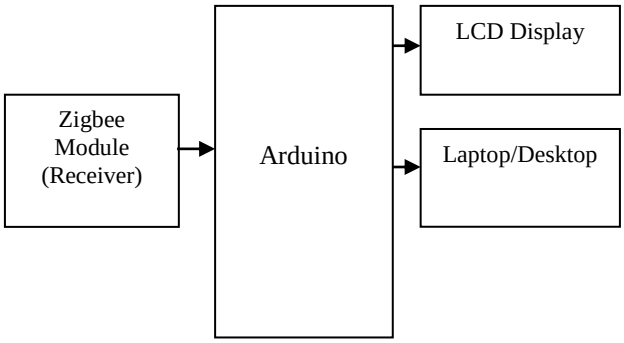


Fig.2: Ground Station Unit Block Diagram

### 3.2.1. LCD Display

A Liquid Crystal Display (LCD) is a flat panel display, electronic visual display or video display that uses the light modulating properties of liquid crystal. Liquid crystals do not emit light directly. LCDs are available to display arbitrary images or fixed images which can be displayed or hidden such as preset words, digits and seven segment displays as in digital clock. They use the same basic technology except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

## 4. WORKING PROCEDURE

The working procedure of smart helmet is very simple. The miner module and the ground station units are connected by a network using Zigbee module. The base of the miner module is the helmet which a miner needs to protect his head. The sensors and other elements are installed on the helmet. To analyze the perfect surroundings, the sensors are implemented on the top of the helmet. The arduino microcontroller system and power supply can be placed inside the helmet creating a different chamber. A buzzer is placed on the top of the helmet to alert the miner about any certain change of atmosphere in the mine.

The tolerable temperature range of human body is 34°c-41°c. But if the temperature crosses 39°c, it can affect human body. So, the maximum tolerable temperature of human is 39°c [11]. If the temperature crosses 41°c the human cells stop functioning. So, when the temperature inside the mine rises to 34°c the temperature sensor senses it and the buzzer will buzz to alert the miner about sudden temperature change. By Zigbee module the value of change of temperature is sent to the ground station unit.

The tolerable range of humidity for human being is 25%-60%RH [12]. In the mine the humidity can change suddenly. But if the humidity crosses the upper limit of tolerance 60%RH, then the sensor will alert the miner by the buzzer and sequentially it will send the signal to the ground station unit by Zigbee.

The MQ5 gas sensor works according to following procedure:-

Table 1: Butane Gas Concentration and voltage levels according to UK safety standards

| Gas Concentration | Voltage Range |
|---|---|
| ≤ 400ppm | ≤ 1.2V |
| 400-600ppm | ≥ 1.2V to ≤ 4V |
| ≥ 600ppm | ≥ 4.0V |

So, if the concentration of $CO_2$, CO, LPG or smoke increases then buzzer will alert the worker. Meanwhile the value will be sent to the ground station unit.

The heart rate detecting sensor is an ear clip sensor. It will be attached to ear lobe of the worker and heart rate will be measured. The value of heart rate of the worker is sent to the controller of the ground station unit. It can be useful after a massive accident in the mine. It helps to determine whether the worker is dead or alive. If no value is found from the heart sensor, then it can be decided that the worker is dead. Moreover, it helps to know about the worker's health condition during mining. Steps can be taken from outside if a worker suffers from sudden heart disease.

The arduino is coded with arduino code which has been originated from basic AVR coding. Three arduino systems are used to control the system. One is used to gather all the sensor values, second one is used to receive the sensor values transferred by zigbee module and the third one is used to analyze the data collected from different sensors.

## 5. SOFTWARE DESCRIPTION

Three software have been used to implement this design. They are discussed below:-

### 5.1 Arduino

Arduino is an open source software that makes it easy to write code and upload it to the board. The environment is written in JAVA. It's an AVR based programming software.

### 5.2 Cool Term

Cool Term is a software that can collect values from different sensors and preserve them in a text file.

### 5.3 MATLAB

MATLAB is a multi-paradigm numerical computing environment and fourth generation programming language. It allows matrix manipulation, plotting of functions and data, implementations of algorithms and interfacing with programs written in other languages.

## 6. DATA ANALYSIS

To analysis the value of different sensors, different environmental change can be created. Temperature, humidity can be changed artificially inside a room. Again, different types of gases like $CO_2$, LPG and smoke can be produced artificially. It is noted that the value of different sensors is sent by serial print by zigbee module to the controlling unit. In the controlling unit the values are shown in LCD monitor or in the computer screen. To plot the data to obtain the atmospheric change, "Cool Term" and "MATLAB" are used. "Cool Term" is a software that collects the data taken from zigbee receiver continuously and saves them in a text file. Then from the text file the values can be replaced in a MATLAB "blank M file" and graphs can be plotted.

'Figure-3' indicates the plot between relative humidity and time. During the experimental procedure the relative humidity of the environment remained constant almost and it varied slightly within the range 62%-82%.

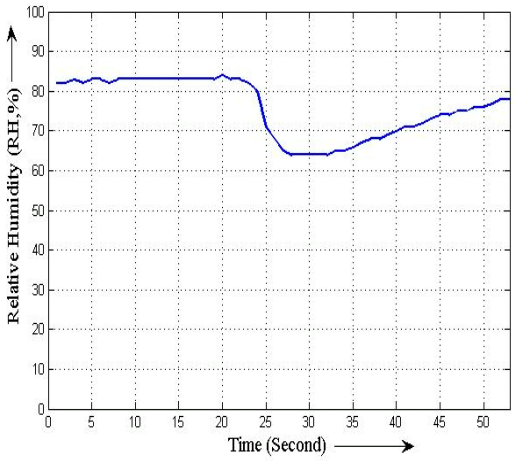


Fig.3: Relative Humidity vs. Time

'Figure-4' indicates the temperature variation with time. The temperature varied within 26°c-29°c.

'Figure-5' shows the fluctuation of amount of methane (in ppm) with time. During the experiment the amount of methane varied within the range 0 ppm-600 ppm.

'Figure-6' indicates the variation of amount of $CO_2$ (in ppm) within the working period. During the experimentation the amount of $CO_2$ varied within 0 ppm -420 ppm.

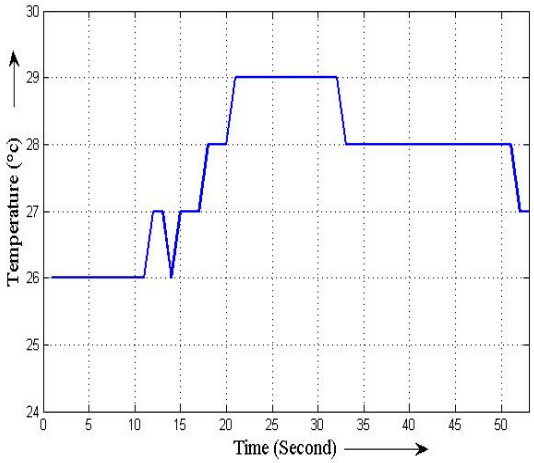


Fig.4: Temperature vs. Time

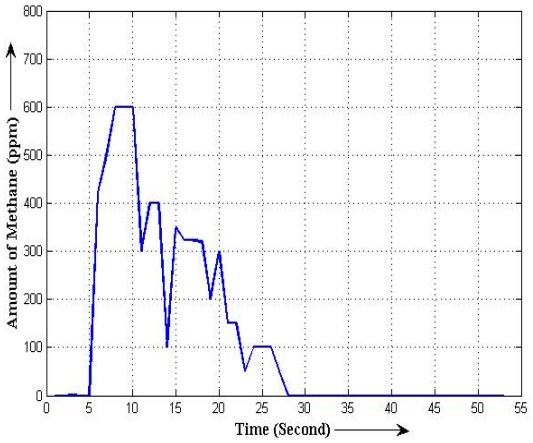


Fig.5: Amount of $CH_4$ vs. Time

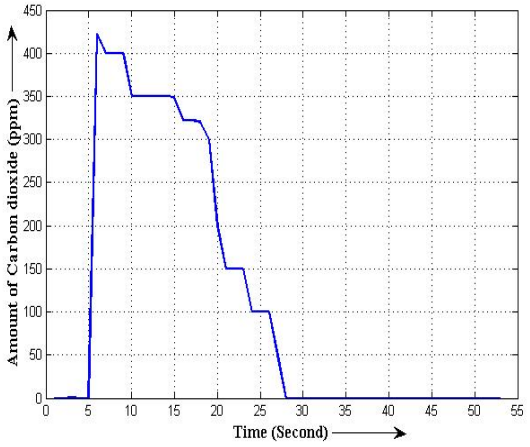


Fig.6: Amount of $CO_2$ vs. Time

'Figure-7' represents the change of amount of smoke (in ppm) over time. From the figure it is stated that, the amount of smoke fluctuated within the range 0 ppm– 420 ppm.

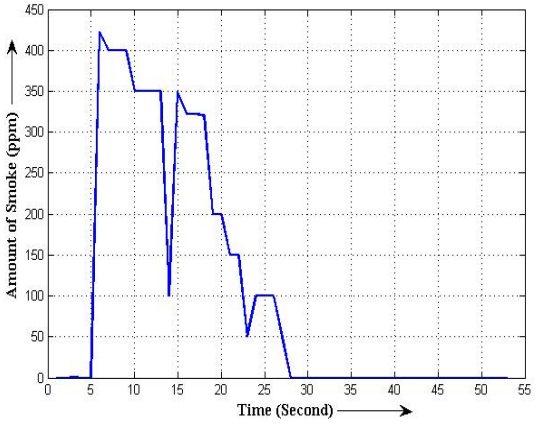


Fig.7: Amount of Smoke vs. Time

'Figure-8' represents the heartbeat of any worker over experimental time. It is clear from the figure that the measured heartbeat remains almost constant. But it slightly fluctuated between 70 bpm–90 bpm (Beats per Minute).

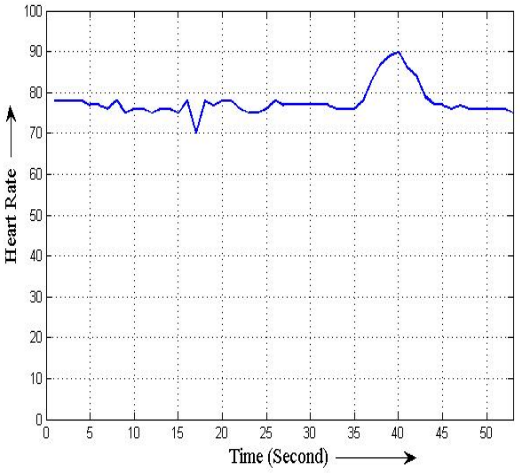


Fig.8: Heartbeat vs. Time

## 7. CONCLUSION

The paper covers all the hardware components and software requirements for the project "Design of an Intelligent Helmet for Mine Workers". This system not only ensures the safety of the mine workers, but also alerts him about any sudden atmospheric change in the mine in a very simple way. Moreover, the values of different sensors can be sent outside through Zigbee technology. Implementing heartbeat detecting sensor adds a great dimension to the safety of the worker. After any massive accident the state of the worker can be known by this sensor. The system contains greater safety with minimum rate of cost. So, if this project can be applied in the respective field it will be a great benefit to the mine workers.

## 8. REFERENCES

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## 9. NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| *V* | Voltage | (V) |
| *ppm* | Parts Per Million | (ppm) |
| *RH* | Relative Humidity | Dimentio-nless |
| $CH_4$ | Methane | |
| $CO_2$ | Carbon Di Oxide | |
| *LPG* | Liquefied Petroleum Gas | |
| $SnO_2$ | Tin dioxide | |