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Intelligent safety system for coal miners

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***Abstract*— Disasters are common in coal mine due to the complexity of its natural Environment. These frequent disasters bring huge loss of possession and life. Therefore, the safe production of coal in the mine is inevitable. A cost effective ZigBee-based wireless supervising system for coal mine is presented. An intelligent helmet is used as a mobile safety system with sensor network. The system adopted a ZigBee wireless technology to build wireless sensor networks, realized real-time surveillance with early-warning intelligence on methane, temperature, humidity in mining area to reduce potential safety problems in coal production. PIC16F877A micro-controller is used for controlling all the operations. Sensors, an RF receiver and transmitter for location identification, LCD (Liquid-crystal-display) and a keyboard with alert buttons are used as input/output devices. As a result of this project, we obtained the desired system having a range of communication of 8 meters which give proper results in normal atmospheric conditions.**

***Index Terms*— Dock light, Sensors, ZigBee.**

I. INTRODUCTION

The disasters in underground coal mine are very serious issues today. So the safe production of coal in the mine is an important factor to be considered. To improve the safety system in the mines, a reliable communication system must be there, between the workers of the mine, and the control base station.

Wired communication system was used inside the mines, which is found to be ineffective mainly when a natural calamity or a roof fall occurred. So the reliability and long life of this conventional communication system is very poor. Due to the harsh environment inside the mine, the installation and maintenance of this wired system is very difficult. Also it is very difficult and costly to reinstall the entire system inside the mine after a landslide or any other damage occurred. If the workers get trapped inside mines due to any reason, a continuous and reliable communication system is required to monitor the actual position and condition of the workers. The development of a wireless mine monitoring system accurately detect the temperature, pressure, flammable and poisonous gas inside mine. Also it will track the underground miners and vehicles on real-time, to ensure the safety production and rescue of coal mine disaster [1]. So a cost-effective and flexible solution for the safety of underground mine workers is necessary.

II. WORKING

The intelligent security system consists of a helmet, which is mounted with the sensor circuits. The transmitter section has a microcontroller which receives input from various sections like gas sensor, temperature sensor, humidity sensor, alert buttons and RF receiver.

RF (Radio Frequency) receiver receives RF signals produced by RF transmitters fixed on various spots in the coal mine to identify the location of miner. These RF transmitters will emit RF signals containing corresponding location information. These signals are received by the RF receiver placed in the helmet and it will decode this location information and fed into the microcontroller. For the simplicity to demonstrate, here in this project, four different locations are chosen and corresponding information is given through a single RF transmitter with the help of a DIP-4 switch. Four switch positions are predetermined for four locations. On receiving a signal corresponding to a particular location, the microcontroller will be able to identify the position of the coal miner.

The humidity, temperature and gas sensors will sense the corresponding parameters [2]. The LDR (Light-dependent resistor) module consists of an LED (Light-emitting diode) which glows automatically when sufficient light is not available. All the sensed parameters are displayed in an LCD which is worn on the wrist of the coal miner. By this arrangement, the coal miner itself will be able to know the environmental variations and in case of any emergency, he can send alert messages to the outside world using the alert buttons.

The sensed parameters or alerts along with the location information are communicated to the outside world through a ZigBee module. The receiver of the ZigBee is connected at the RS232 terminal of the computer of the control room. The information send by the helmet are received by the control room at a fixed base station and displayed in a computer using Docklight software. Docklight will work with the COM communication ports of the computer. This software will detect the data sequence received through the RS232 terminal and display it in the monitor. The computer will displays the values of temperature, humidity, gas and also the location of the miner. The Alert message is also displayed on the screen in case of emergency.

A. Block diagram

The helmet section consists of gas, temperature, humidity, and light sensors, RF receiver, LCD Display, and ZigBee for communication. PIC16F877A is used as the processor [1]. Inputs to the microcontroller are humidity, gas and temperature sensors outputs, LDR, control button and RF receiver. Output pins of the controller are connected to LCD display and ZigBee module as shown in the fig.1. MQ-3 is the gas sensor used which has the sensitive material SnO2. Humidity sensor is HS1101LF. LM35 is used as the temperature sensor. An alert keypad consisting of 4 buttons are given to the input of microcontroller so that the miner can directly convey the emergency messages to the control room [2]. 7 segment LCD is used for displaying the sensed parameters and alerts. ZigBee is used for wireless communication which is interfaced through MAX 232.

The receiver section receives the data and displays it in the computer of the control room as shown in fig. 2 An RF receiver is given at the input section and it is used to receive RF signals transmitted by RF transmitters at different locations of the coal mine. The receiver section receives the data and displays it in the computer of the control room.

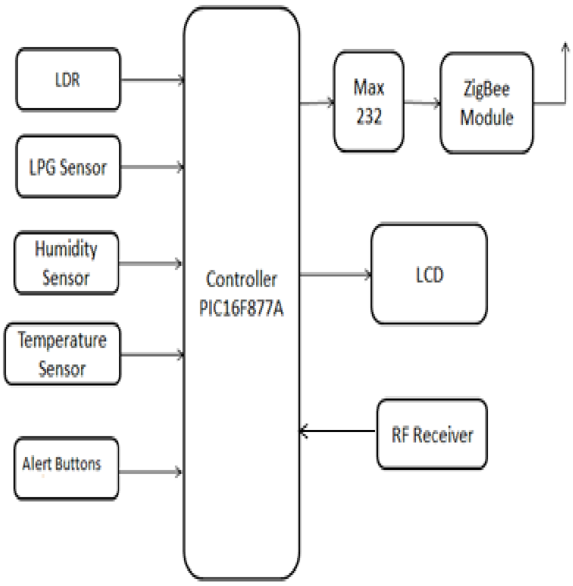

Fig. 1: Block diagram of the transmitter

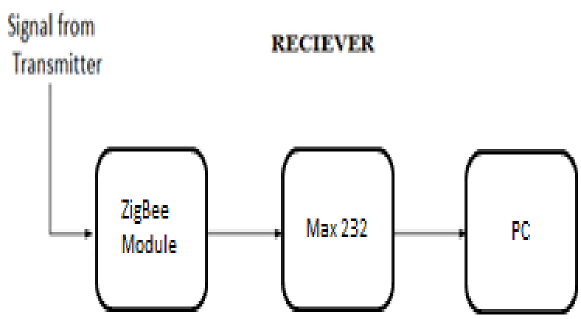

Fig. 2: Block diagram of the receiver

B. Circuit diagrams

The circuit diagram of the helmet is shown in fig. 3 and the circuit diagram of the RF transmitter section is shown fig. 4.

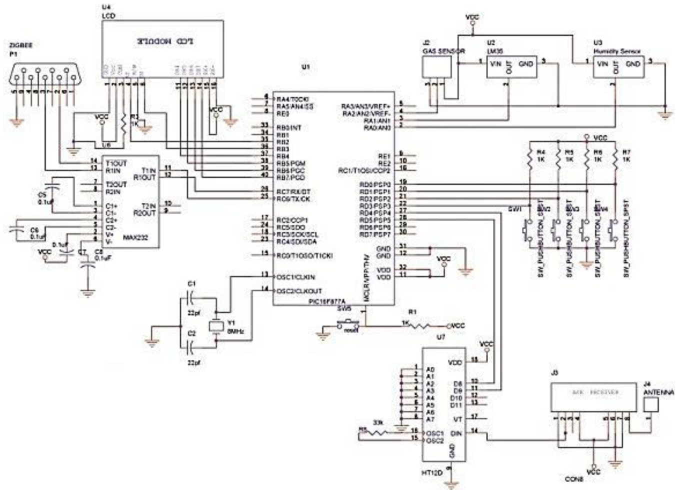

Fig. 3: Circuit diagram of the coal mine helmet as transmitter section

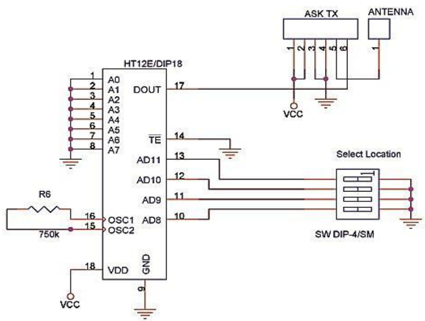

Fig. 4: Circuit digram of the RF transmitter

III. HARDWARE

The main hardware components used are discussed here.

A. PIC16F877A Microcontroller

The microcontroller unit used here is a PIC16F877A. The core controller is a mid-range family. PIC16F877A have enough I/O (Input/output) lines for current need. It is capable of initiating all intersystem communications. The master controller controls each functions of the system with a supporting device. It is also responsible for reception of commands from the host and taking necessary actions. This powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS (Complementary metal-oxide semiconductor) FLASH-based 8-bit microcontroller packs Microchip's powerful PIC architecture into a 40 or 44-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI) or the 2-wire Inter-Integrated Circuit bus and a Universal Asynchronous Receiver Transmitter (USART) [6]. All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

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B. *ZigBee Module*

ZigBee is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. Though its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics, ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128 bit symmetric encryption keys). ZigBee has a defined rate of 250kbit/s, best suited for intermittent data transmissions from a sensor or input device. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that require short-range low-rate wireless data transfer [3].

C. *Gas sensor MQ-3*

Sensitive material of MQ-3 gas sensor is SnO_2, which with lower conductivity in clean air. When the target LPG (Liquefied Petroleum Gas) exist, the sensor's conductivity is higher along with the gas concentration rising. MQ-3 gas sensor has high sensitivity to LPG, and has good resistance to disturb of gasoline, smoke and vapour. The sensor could be used to detect LPG with different concentrations; it is with low cost and suitable for different applications.

D. *Humidity Sensor HS1101LF*

Humidity is the presence of water in air. The amount of water vapour in air can affect human comfort as well as many manufacturing processes in industries. The presence of water vapour also influences various physical, chemical, and biological processes. Humidity sensors relying on this principle consists of a hygroscopic dielectric material sandwiched between a pair of electrodes forming a small capacitor. Most capacitive sensors use a plastic or polymer as the dielectric material, with a typical dielectric constant ranging from 2 to 15. In absence of moisture, the dielectric constant of the hygroscopic dielectric material and the sensor geometry determine the value of capacitance. At normal room temperature, the dielectric constant of water vapour has a value of about 80, a value much larger than the constant of the sensor dielectric material. Therefore, absorption of water vapour by the sensor results in an increase in sensor capacitance.

E. *Temperature sensor LM35*

Thermistors are thermally sensitive resistors whose prime function is to exhibit a large, predictable and precise change in electrical resistance when subjected to a corresponding change in body temperature. Negative Temperature Coefficient (NTC) thermistors exhibit a decrease in electrical resistance when subjected to an increase in body temperature and Positive Temperature Coefficient (PTC) thermistors exhibit an increase in electrical resistance when subjected to an increase in body temperature.

F. *RF transmitter*

The RF transmitter is ideal for remote control applications where low cost and longer range is required. The transmitter operates from a 1.5 to 12V supply, making it ideal for battery-powered applications. The transmitter employs a SAW stabilized oscillator, ensuring accurate frequency control for best range performance. Output power and harmonic emissions are easy to control. The manufacturing friendly SMT (Surface-Mount Technology) style package and low cost make the RF module make it suitable for high volume applications.

G. *RF receiver*

RF receivers are ideal for short-range remote control applications where cost is a primary concern. The receiver module requires no external RF components except for the antenna. It generates virtually no emissions. The super regenerative design exhibits exceptional sensitivity at a very low cost. A SAW filter can be added to the antenna input to improve selectivity for applications that require robust performance. The friendly SIP (Single in-line pin) style package and low-cost make it suitable for high volume applications.

H. *Light Dependent Resistor*

The upper surface of the light dependent resistor (LDR) consist of a photo conductive material. When light exposed on the upper area of the device, its resistance changes. That is, resistance increases when the intensity of light decreases. So the device gives very high resistance if there is no light incident on it. Resistance of the component decreases when the intensity of incident light increases. Commonly used photo conductive material for making Light Dependent Resistor is Cadmium Sulphide (CdS).

IV. EXPERIMENTAL SETUP AND RESULTS

The fig. 5 shows the main module which is the control unit of the system. PIC16F877A is used as the control unit. Clock to the PIC is given by 8 MHz crystal along with two 22pF capacitors.

Fig. 5: Main circuit board

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Voltage regulator 7805 which is followed by 1000µF is given to get a reduced voltage of 5V from 12V battery supply. Max 232, the communication interface along with its four 0.1µF is also fixed on the main circuit board.All the other modules except RF transmitter and ZigBee receiver are connected to the main circuit board. The results are viewed by an LCD which is connected to the port B of the microcontroller.

The RF transmitter will send RF signals with a frequency of 434 MHz contains the location information from various part of the coal mine. By receiving this signal, the position of the miner can be located. The RF transmitter encoder HT12EIP18 has a clock given by 750k resistor. A DIP-4 switch is connected to its data port in order to provide the location information. The receiver has a corresponding HT12DIP18 decoder to decode the location to which a 33k resistor is connected for clock input. Both ASK transmitter and receiver are of the same pair.

Manual emergency alerts for undesirable humidity, temperature, gas and accident alert are given using 4 buttons. They are connected to the port D of microcontroller via 1k resistors.

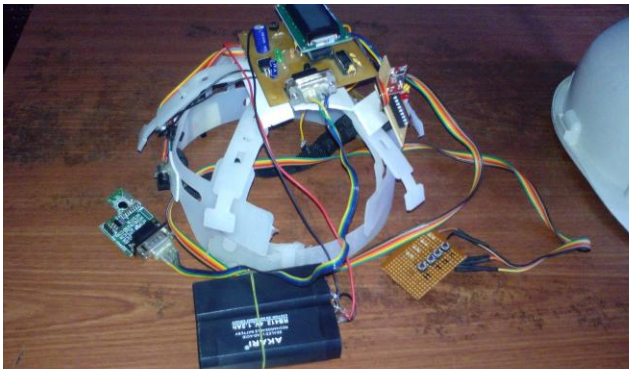

Fig. 6: Final hardware

All the modules were tested separately and mounted on the helmet frame as shown in fig. 6. Communication up to a length of 8 to 9 meters was observed in the final test. The predetermined values and the obtained values are shown in Table I. Temperature is expressed in degree Celsius and humidity and gas are expressed as percentages in air.

Table. I

Parameters	Optimum limit	Test result at room temperature
Temperature	25-40	32
Humidity	15-70	43
Gas	Below 25	2

The serially sent data through ZigBee transmitter fixed in helmet was received by the ZigBee receiver in the control room. Results are displayed in a computer using Docklight software as shown in fig. 7.

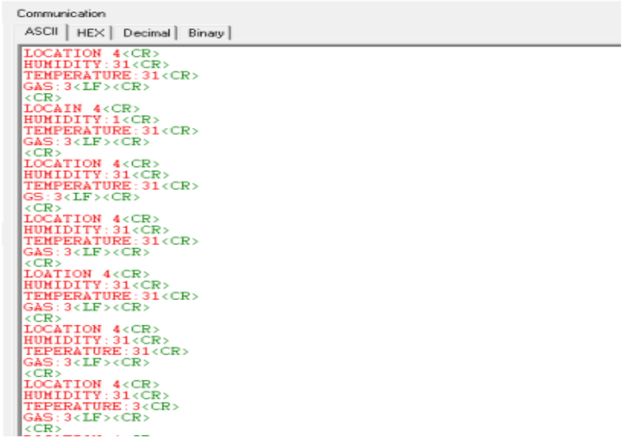

Fig. 7: Dock light view at control room

V. CONCLUSION

As the accidents and hazards inside coal mines are increasing now a day, a coal mine safety system seems to be very useful and relevant. With the help of the coal miner's helmet itself, we could sense the undesirable environmental parameters like temperature, humidity and methane gas inside the coal mine and could communicate efficiently through a most reliable and cost effective wireless communication system. Sensing of different parameters and communication up to a length of 8 to 9 meters was observed in the final test.

By properly fixing appropriate power ratings, this model is expected to fit for practical industrial applications. On time voice communication can also be provided with a microphone - loud speaker set. Alerts can be given along with alarming tones which will be more noticeable. By minimization of all the components, size and weight of the circuit can be reduced to a much comfortable level.

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