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A Smart Helmet for Secure Monitoring of Miner Data to Improve Safety

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Abstract: In recent times, mining has been a dangerous activity taking a severe toll on the lives of miners. Underground mining hazards include gas poisoning, suffocation, roof collapse, and gas explosion. This project aims to develop a smart helmet based on Zigbee wireless technology to build wireless sensor networks for real-time surveillance and monitoring hazardous gases and abnormal levels of temperature and humidity in the mine.

These three parameters are continuously being detected using the gas sensor(s), temperature and humidity sensor, and if the pre-defined limit is crossed, a buzzer and LED will be initiated.

Two infrared sensors, one inside and one on the surface of the helmet, are placed to check if the helmet is properly placed and to detect collision from falling debris, respectively. These values are continuously being transmitted to the control room for monitoring.

In case of any hazardous situation, the led and buzzer are activated in the control room as well as on the miner's helmet. The helmet is powered by the energy generated from piezoelectric sensors placed in the miner's shoes, which work on the principle of vibration detected from the miner's movement. The safety measures included in our project can drastically help us avoid mining accidents and thus saving invaluable lives.

Keywords: Smart helmet, Zigbee Technology, Gas sensor, Temperature and Humidity sensor, Infrared Sensor, Coal mines, Safety

I. INTRODUCTION

In every industry, safety is a significant factor, and coal mines are no exception. The Chasnala mining tragedy, one of the greatest mining disasters in history, occurred on December 27, 1975, in a coal mine near Chasnala, Jharkhand, when an explosion followed by floods killed 375 men.

Miners working in the mine face a lot of danger from greenhouse gases, rising temperature, and falling debris. In such situations, miners are unable to contact with the outside world.

A lot of systems have been designed to ensure the safety of the miners, such as sensors being employed in the mines and wired communication systems. They were found ineffective due to plenty of reasons, including natural calamities or roof collapse. The severe environmental conditions in the mine make the installation and maintenance of wired systems complicated.

This project aims at designing a smart helmet based on Zigbee-based wireless sensor networks for hazardous event detection, monitoring environmental conditions, and updating sensor data to the base station.

A buzzer and LED are activated to alert the central console and the miner if the sensor data crosses any pre-defined value or if there is any collision with the miner.

II. WORKING PRINCIPLE

The system consists of a helmet with all the sensor networks mounted on it. There are two sections: the transmitter and receiver section. The transmitter section includes an Arduino, which takes input from various sensors like gas sensors, temperature and humidity sensor, infrared sensor, and a panic switch and displays the values on an LCD placed on the helmet and the control room. This information is transmitted by the helmet via Zigbee and received by another Arduino in the control room for monitoring and sending alerts in case of emergency.

A buzzer is placed on the helmet, and the control room to that is initiated when abnormal environmental conditions are detected or the panic switch is pressed.

III. PROPOSED BLOCK DIAGRAM

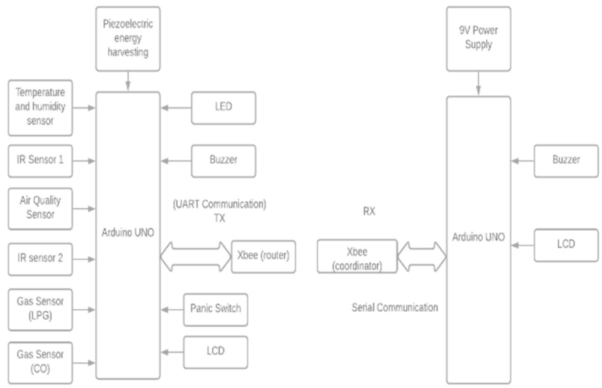

Figure 1. Block Diagram

The transmitter section on the helmet consists of an Arduino Uno (Atmel Mega 328p u-kr) taking inputs from values of Gas sensors (MQ6 - LPG, MQ7 – Carbon Monoxide, MQ135 – Ammonia, Sulphide, etc.), Temperature and Humidity Sensor (DHT11), Infrared Sensors, and a panic button. Output pins of the Arduino are connected to LED, buzzer, LCD display, and Zigbee module for wireless communication. The helmet is powered by the energy generated from piezoelectric sensors placed in the miner's shoes, which work on the principle of vibration detected from the miner's movement. The receiver section receives data through another Zigbee module connected to an Arduino on the receiver side and displays it on an LCD display and, activates a buzzer in case of abnormal environmental conditions detected by sensors in the mine.

IV. HARDWARE

A. Arduino Uno – ATmega328P Microcontroller

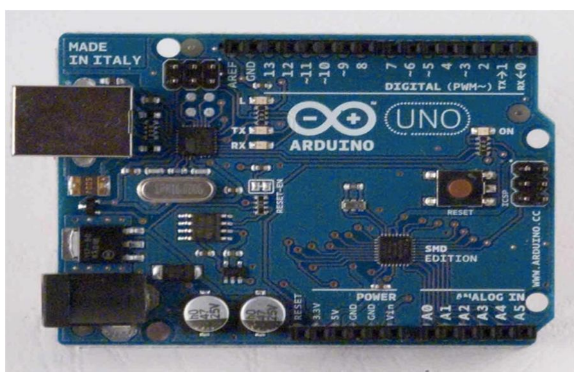

Figure 2. Arduino Uno

The microcontroller board Arduino Uno is based on ATmega328P. There are 14 digital input/output pins (out of which six can be used as PWM outputs), 6 analog input pins, a 16 MHz quartz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It can be connected to a computer with a USB cable or powered with an AC-to-DC adapter or battery to get started.

Operating Voltage	+5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
DC Current per I/O pin	40mA
Clock speed	16MHz

B. Gas Sensor Unit

MQ-6: Used to detect gas leakage, suitable for detecting LPG, iso-butane, propane, LNG, etc.

Figure 3. MQ6 gas sensor

Operating Voltage	+5V
Analog Output Voltage	0V to 5V
Digital Output Voltage	0V to 5V (TTL Logic)

MQ-7: Used to detect carbon monoxide (CO) levels in the air.

Figure 4. MQ7 gas sensor

Operating Voltage	+5V
Analog Output Voltage	0V to 5V
Digital Output Voltage	0V to 5V (TTL Logic)

MQ-135: Used to detect gases like Ammonia (NH3), sulphur (S), Benzene (C6H6), CO2, and other harmful gases and smoke.

Figure 5. MQ135 gas sensor

Operating Voltage	+5V
Analog Output Voltage	0V to 5V
Digital Output Voltage	0V to 5V (TTL Logic)

C. Temperature and Humidity Sensor (DHT11):

It is the most used sensor to measure temperature and humidity levels in the air. It consists of an NTC thermistor and a humidity measuring component. The temperature range is from 0 to 50 degrees Celsius with a 2-degree accuracy. The humidity range is from 20% to 80% with 5% accuracy. The sensor gives one reading every second as its sampling rate is 1Hz.

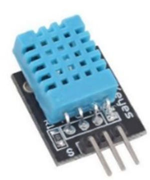

Figure 6. DHT11 sensor

Operating Voltage	3.5V to 5.5V
Operating Current	0.3mA (measuring) 60uA (standby)

D. Infrared Sensor

Active IR sensor consists of a LED and a receiver. When an object is near the sensor, infrared light from the LED is detected by the receiver, and it acts as a proximity sensor.

Figure 7. Infrared sensor

1) Detecting if the helmet is on the head of the miner: An IR sensor is placed inside the helmet to alert the control room if the miner has taken the helmet off by initiating the buzzer.
2) Detecting collision from falling debris: Another sensor is placed on top of the helmet to alert the control room in case of mine collapse or falling debris.

Operating Voltage	5V DC
Operating Current	20mA
Range	Up to 20cm

E. Panic Switch

Placed on the helmet to assist the miner in alerting the control station in case of an emergency by initiating the buzzer.

Figure 4. Panic Button

Operating Force	2.55±0.69N
Power Rating	Max 50mA 24V DC
Contact Resistance	Max 100mOhm

F. XBee S2C

It is an RF module designed for wireless communication between end-point devices in a Zigbee mesh network. The smart helmet wirelessly transmits sensor data from the mine to the control station to help monitor the mine conditions.

Figure 5. XBee module

Supply Voltage	+2.1V to +3.6V
Operating Current	33mA (at 3.3V) and 45mA (at 3.3V)

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G. LCD Module (16x2 and 20x4)

Figure 6. LCD

A 16x2 LCD is placed on the helmet, and a 20x4 LCD is placed in the control station. Both LCD display values from Gas sensors and Temperature and Humidity Sensor continuously for monitoring the mine's environmental conditions.

Input Voltage	+5V
Supply Current	10mA

H. LED and Buzzer

Figure 11. LED

Figure 12. Buzzer

LED and buzzer are placed on the helmet and the control station and are initiated due to the following reasons:

1) To alert when the helmet is off the head.
2) In case of falling debris or collision with a rock.
3) When the panic switch is pressed.

Forward Current	30mA
Forward Voltage	1.8V to 2.4V
Reverse Voltage	5V

Operating Voltage	4-8V DC
Rated Current	<30mA

I. Piezoelectric Energy Harvesting

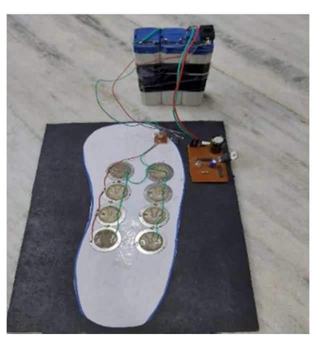

Figure 13. Piezoelectric Energy Harvesting

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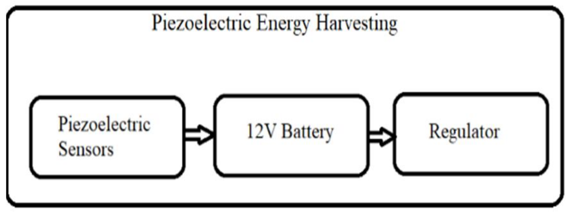

Figure 14. Piezoelectric Energy Harvesting Block Diagram

The piezoelectric energy harvesting consists of piezoelectric sensors, a 12V Lead Acid battery, and regulator.
A piezoelectric sensor is a device that converts changes in pressure, acceleration, temperature, strain, or force to an electrical charge using the piezoelectric effect. They've been utilized successfully in various applications, including medical, aerospace, and nuclear instruments, as well as a tilt sensor in consumer electronics and a pressure sensor in mobile phone touchpads.
An electric charge is created across the faces of a piezoelectric crystal when a force is applied to it. A voltage proportional to the pressure can be used to measure this. These sensors have an inbuilt charge amplifier that provides a voltage output to simplify the electrical interface.
The piezoelectric energy generated is fed into a 12V battery and from the battery to the regulator. Finally, the energy is transferred to the transmitter side.

V. ADVANTAGES AND APPLICATIONS

A. Advantages

1) Monitoring the environment safely.
2) Enhanced services in the coal mining industry.
3) Prevent miners from high temperature, humidity, and harmful gases.
4) Sending alerts to avoid disasters.
5) Provides reliable wireless communication.

B. Applications

1) Prevent disasters and save lives of people working in mines.
2) Communicate wirelessly and in any environmental condition.

VI. RESULT

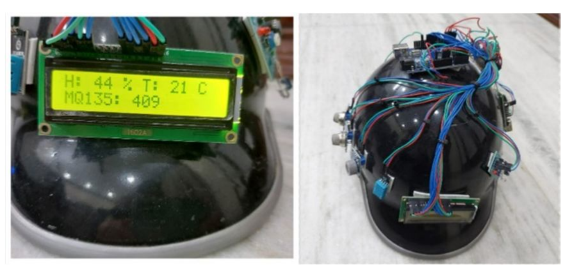

Figure 15. Transmitter section and sensor values

Figure16. Alert generation and sensor values

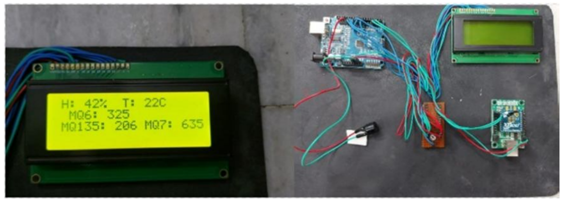

Figure 17. Receiver section and received data

VII. CONCLUSION

The primary purpose of this project is to design a smart helmet to enhance the safety of a miner and avoid unforeseeable disasters. Miners face various dangers from environmental conditions and falling debris in the mine. The smart helmet monitors these conditions and sends alerts to prevent hazardous situations, communicating wirelessly with the control station using Zigbee module by sending data continuously.

VIII. FUTURE SCOPE

This project can be further modified by adding a GPS module to track the miner's location at all times. Two-way communication can also be set up to help send messages from the control station to the miners. The energy generated by piezoelectric sensors is not sufficient to drive the whole system. So, an alternate to this is a boost converter circuit that will step up the dc voltage. Hence, sufficient power will be generated to drive the whole system.

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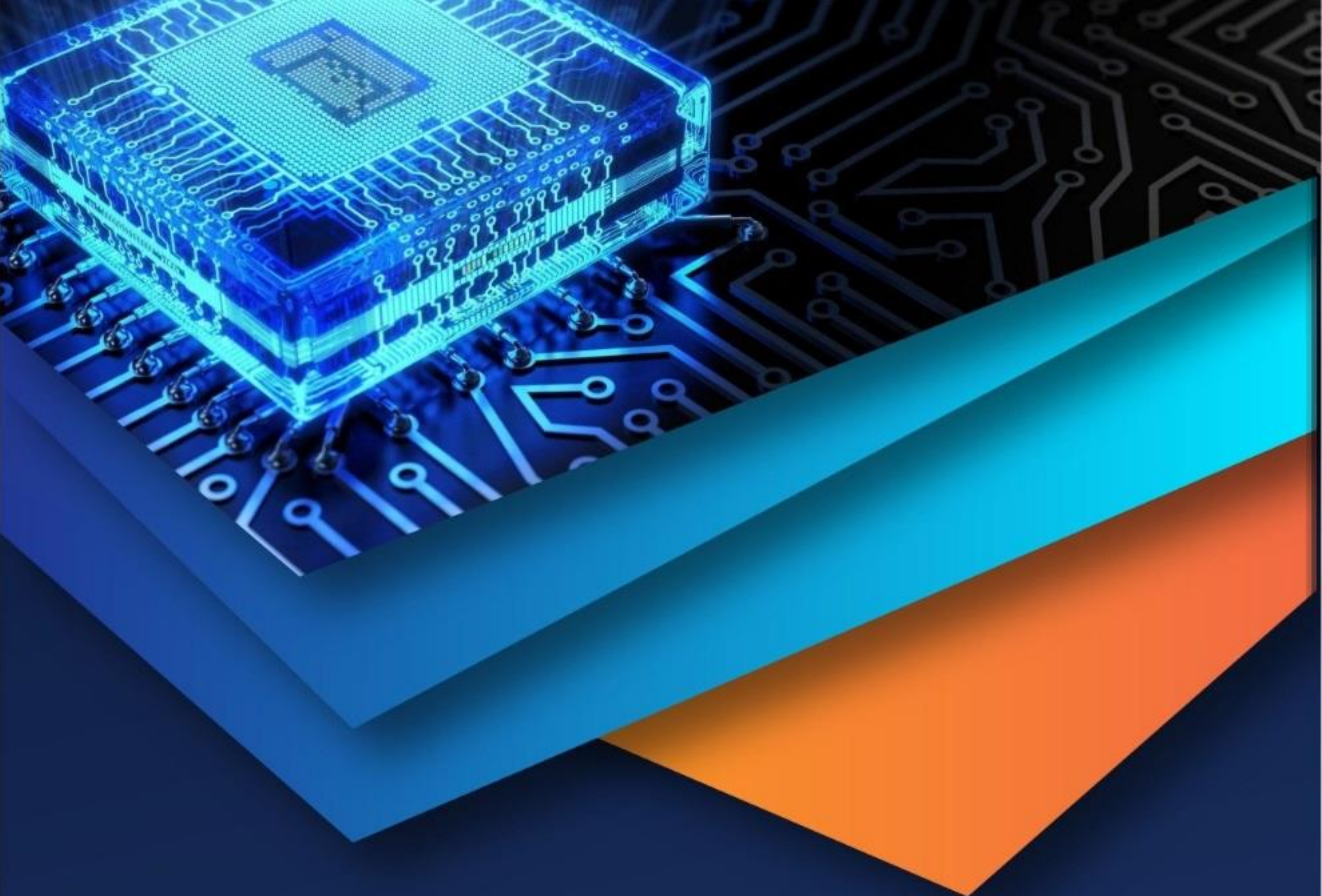

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