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A Smart Helmet for Air Quality and Hazardous Event Detection for The Mining Industry

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Abstract:

Industrial safety plays a vital role in protecting workers and maintaining smooth industrial operations. In many industries such as mining, chemical plants, and manufacturing units, workers are exposed to dangerous conditions including toxic gases, high temperature, low oxygen levels, and poor air quality. These hazards can cause serious health problems, accidents, or even loss of life if not detected at an early stage. Therefore, continuous monitoring of the working environment is essential.

The proposed system focuses on real-time monitoring of environmental parameters using a wireless sensor network. Sensors are installed in the working area to continuously measure temperature, humidity, and gas concentration. The collected data is transmitted wirelessly to a

central monitoring station using Wi-Fi technology, allowing supervisors to monitor conditions remotely without being physically present at the hazardous site. When the sensor readings exceed safe limits, the system automatically generates an

emergency alert. This alert helps authorities take immediate preventive actions such as evacuating workers or shutting down machinery, thereby reducing the risk of accidents like gas poisoning or explosions. In addition to automatic alerts, a manual emergency switch is provided at the worksite so that workers can instantly report dangerous situations.

Worker safety equipment compliance is also addressed in this system. Many accidents occur because workers do not wear safety helmets properly. To overcome this issue, an IR sensor is used to detect whether a worker is wearing the helmet correctly. If the helmet is not worn, the system can send a warning or alert to the monitoring station.

Overall, the proposed system enhances industrial safety by providing real-time monitoring, early hazard detection, and quick emergency response. It helps reduce industrial accidents, improves worker awareness, and ensures a safer working environment through the use of IoT and wireless communication technologies.

1.INTRODUCTION:

The Internet of Things (IoT), sometimes referred to as the Internet of Everything (IoE), is an advanced technological paradigm that enables physical objects to be connected to the internet for data exchange and intelligent decision-making. IoT devices are embedded with various sensors, microcontrollers, processing units, and communication modules that allow them to sense physical conditions, analyze the collected data, and transmit information to other devices or centralized systems. These smart devices operate with minimal human intervention and are capable of autonomous functioning through machineto-machine (M2M) communication.

The rapid development of compact electronic components, low-power sensors, and high-speed wireless communication technologies has significantly contributed to the expansion of IoT applications. Continuous internet connectivity in industrial and commercial environments has further enhanced the reliability of IoT systems. Humans interact with IoT systems mainly to configure device settings, monitor data, or issue control commands, while the actual sensing, processing, and response actions are performed automatically by the devices.

Mining is widely regarded as one of the most dangerous industries in the world due to its harsh and unpredictable working conditions.

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Underground mining environments are particularly hazardous because of limited ventilation, poor lighting, and confined spaces. Miners are exposed to serious risks such as toxic gas accumulation, oxygen deficiency, excessive heat, humidity variations, and structural failures. In many developing regions, miners lack adequate safety equipment, proper monitoring systems, and immediate medical assistance, which increases the severity of accidents.

Statistical studies show that the mining sector has the highest rate of occupational fatalities among all industries. Common causes of mining accidents include rock collapses, underground fires, methane gas explosions, toxic gas inhalation, and electrical faults. These accidents often occur due to the absence of real-time monitoring systems and delayed communication between miners and control rooms.

To address these challenges, there is a strong need for a reliable communication infrastructure combined with intelligent sensing and early warning systems. IoT technology provides an effective solution by enabling continuous monitoring of critical environmental parameters within mining areas. Sensors deployed throughout the mine can detect hazardous gases, temperature changes, and humidity levels in real time. The collected data is transmitted wirelessly to a centralized monitoring station for analysis and decision-making.

In case of abnormal or dangerous conditions, the IoT system can automatically trigger alerts and warnings, allowing quick evacuation and preventive measures. By integrating IoT-based communication and sensing technologies, mining industries can significantly improve worker safety, reduce accident rates, and enhance operational efficiency. Thus, IoT plays a crucial role in transforming traditional mining operations into safer and smarter industrial environments.

2.LITERATURE SURVEY:

Ravi and Kuldeep focused upon prevention of casualties by ensuring the safety in their work [1]. They developed a system such that in the case of the drunken, the ignition in the combustion chamber would not occur. The system is directly connected to the two-wheeler ignition system by electronics. The system has the main components as stated – a proximity sensor, alcohol sensor, accelerometer, and a keypad.

At the receiver end, on the twowheeler, a microcontroller controls the ignition. The ignition system is incorporated with a diode acting as cut off and on region connector. Upon the reception of the signal from the system, the microcontroller takes care of the ignition starting the vehicle. While the idea of this system is noble and very much the need of the hour, the implementation would be completely infeasible because of the ignition system has to be tampered with, in every single model of every single twowheeler manufacturer for this idea to come to function [1].

Kodanda Ramaiah focused on cooling the inside of a helmet [3] using a thermoelectric cooler working on solar energy Bluetooth headset inside the helmet to handle calls ensuring that the rider is wearing a helmet while on a trip GPS and GSM modules to send the precise location of the rider in case of an accident.

On the other hand, consists of GSM, GPS, vibration sensor, RF Receiver, and microcontroller. The RF Transmitter sends the trigger signals about the status of switches to the bike module. When the RF receiver receives an alert signal from the helmet module, the same is sent to the controller to take necessary actions. The vibration sensor along with the GSM and GPS modules works with the micro controller to send alerts regarding an accident to the specified contacts and emergency vehicles/hospitals proposed a smart helmet [3].

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Indranil Nikose proposed the smart system [7], which detects an accident using an accelerometer sensor, GPS and GSM modules, and prevention of accidents by the detection of alcohol levels of the rider using an alcohol sensor. The working of accident detection is simple. When the bike hits the ground, the accelerometer sensors note this data and send it to a CMOS 8-bit microcontroller.

The controller then extracts the longitude and latitude of the location using the GPS module and initiates a timer counting to 10 minutes. If the rider does not start riding in those 10 minutes, then the controller sends the location details as an SMS to the ambulance and parents. The alcohol is detected using an alcohol sensor, which measures the amount of alcohol present in the surrounding environment. When the alcohol level crosses a predefined value, it triggers off an alarm, notifying the makers. While the accident detection feature in this system is feasible, the alcohol detection system does nothing on detection and hence is not very useful [7].

Priyanka C focused on Accident Prevention [5] and Detection proposed on a smart bike. If there is, alcohol content found in rider's breath, the bike remains off. The bike will not start until the rider wears the helmet and there is no alcoholic content present stating that rider did not consume alcohol. When the rider crashes, and hits the ground and sensors detect the motion, tilts of bike, reports the occurrence of an accident, and sends information of the location of accident to the family members of the rider and the emergency contact numbers [5].

Asad Ali, Mohamad Eid [6] proposed a Automatic Smart Accident Detection (ASAD) is an auto-detection unit system that immediately notifies an Emergency Contact through a text message. When an instant change in acceleration, rotation and an impact force in an end of the vehicle is detected by the system, detailing the location and time of the accident. The system involves the use of fuzzy logic as a decision support built into the Smartphone application that analyses the incoming data from the sensors and makes a decision based on a set of rules. The simulated results show a 98.67% accuracy of the system [6].

3.EXISTING SYSTEM:

The problem addressed in this project was the improvement of a mining helmet in order to ensure more safety awareness between miners. When working with noisy equipment, being aware of one's surroundings can sometimes be challenging. In the mining trade miners tend to get rid of some of their safety gear as aresult of the gear is just too significant, warm or uncomfortable to work with. So this system is developed to intimate the authorities in critical conditions.

4.PROPOSED SYSTEM:

The proposed system uses Wi-Fi technology to transfer data from the working environment to the remote monitoring unit. The merit in using Wi-Fi as a medium of transfer is that it covers wider area and it is the latest modern technology that has been emerging worldwide for transferring data. In this system the transferred data is collected ,stored and analyzed using Thing speak application. Thing speak is one of the recently developed application in the field of IoT for analyzing data transferred by wireless sensor networks.

5.BLOCK DIAGRAM:

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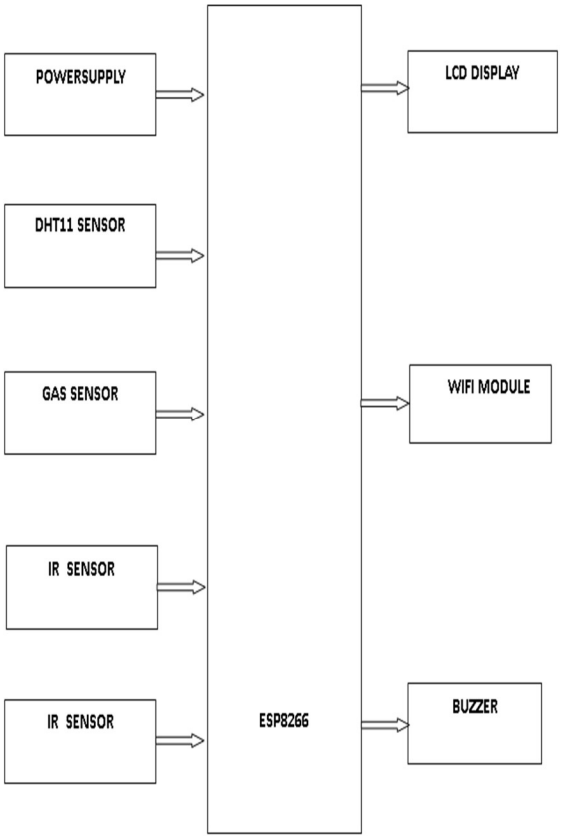
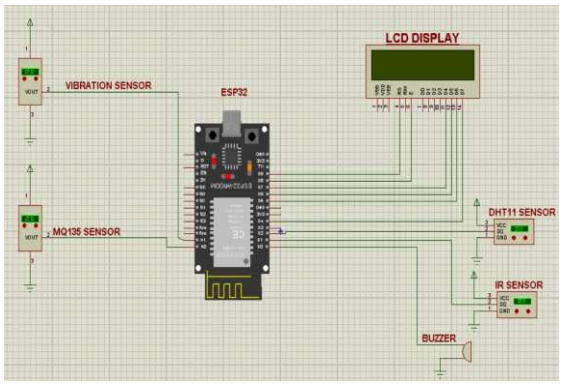


6.CIRCUIT DIAGRAM:



7.WORKING PRINCIPLE:

This unit is placed at various places in mining industry to absorb the working environment. The Fig.1 shows the block diagram of mining unit which consist of sensors and display unit. The sensed values are absorbed by the NODEMCU and stored to the cloud. If the mining parameters increased beyond the threshold level an alert message is sent to the control room. The safety system consist of DHT11 (Temperature and Humidity sensor), vibration sensor and ir sensor to monitor the physical parameters of mine unit which is difficult to predict for human beings. Along with it consist of buzzer, LCD display, wi-fi module.

Arduino based mine safety system consists of various sensors which are connected to controller and sensed values from these sensors are send to the cloud server. Workers start to utilize various monitoring and controlled system in order to increase the working condition. Help of automation of environmental parameters like temperature, humidity and poisonous gases are monitored and control the system which can help the workers to secure their life. The design implements IoT technology using an android device, a main controlling unit (MCU), sensors to measure various parameters and alert system, which will be used to ensure the security of workers. When a significant impact occurs, the fall detector will start diagnosing the fall. Before the alert is transmitted, a vibration pre-alarm starts. During this time, the alarm can be cancelled by moving the arm. This avoids false alarms. The device is also able to avoid any false alarm by analyzing the fall and detecting if it should send an alarm or not. The automatic trigger will only be activated if the person wearing the detector is unable to push the button, for example in case of unconsciousness or immobility. The detector is not activated in all fall situations, such as, where no significant impact occurs. The fall sensor which integrated into the Arduino uno is given to the individual worker to monitor their health condition

8. COMPONENT:

HARDWARE CONFIGURATIONS:

- ESP8266
- Power Supply
- DHT11 Sensor

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- IR Sensor
- GAS sensor
- Vibration sensor
- Lcd Display
- WIFI Module
- Buzzer

SOFTWARE CONFIGURATIONS:

- Arduino IDE
- embedded C.

9.COMPONENT DETAILS:

Node MCU:

NodeMCU is an open-source firmware for which open-source prototyping board designs are available. The name "NodeMCU" combines "node" and "MCU" (micro-controller unit). The term "NodeMCU" strictly speaking refers to the firmware rather than the associated development kits. Both the firmware and prototyping board designs are open source. Nodemcu ESP8266 and Nodemcu ESP32 are becoming very popular and are almost used in more then 50% IoT based projects today.

The firmware uses the Lua scripting language. The firmware is based on the eLua project and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson and SPIFFS. Due to resource constraints, users need to select the modules relevant for their project and build a firmware tailored to their needs. Support for the 32-bit **ESP32** has also been implemented.

The prototyping hardware typically used is a circuit board functioning as a dual in-line package (DIP) which integrates a USB controller with a smaller surface-mounted board containing the MCU and antenna. The choice of the DIP format allows for easy prototyping on breadboards. The design was initially was based on the ESP12 module of the ESP8266, which is a WiFi SoC integrated with a Tensilica Xtensa LX106 core, widely used in IoT applications.

NodeMCU ESP8266 Specifications & Features:

- Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- Operating Voltage: 3.3V
- Input Voltage: 7-12V
- Digital I/O Pins (DIO): 16
- Analog Input Pins (ADC): 1
- UARTs: 1
- SPIs: 1
- I2Cs: 1
- Flash Memory: 4 MB
- SRAM: 64 KB
- Clock Speed: 80 MHz
- USB-TTL based on CP2102 is included onboard, Enabling Plug n Play
- PCB Antenna
- Small Sized module to fit smartly inside your IoT projects **Applications**:

- Prototyping of IoT devices
- Low power battery operated applications
- Network projects

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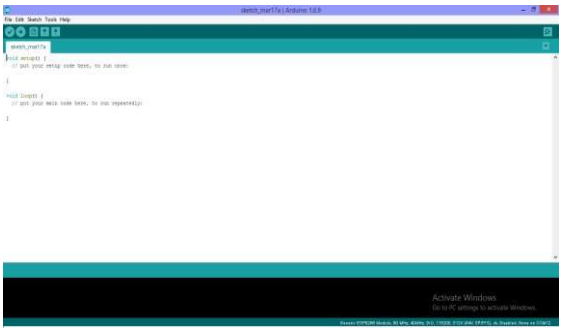
- Projects requiring multiple I/O interfaces with Wi-Fi and Bluetooth functionalities

ARDUINO IDE:

The Integrated Development Environment (IDE)is a combination of editor, linker and a compiler which helps the developer to make their Firmware for their Innovative Projects. Arduino IDE play a major role in open source platform for fast prototyping and easy to access of library. It is user friendly tool for beginners and it supports programming language like embedded C, Luna etc. Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. Its supports all the variant of Arduino boards like Arduino Uno, Nano and Mega etc. As soon as it reaches a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments

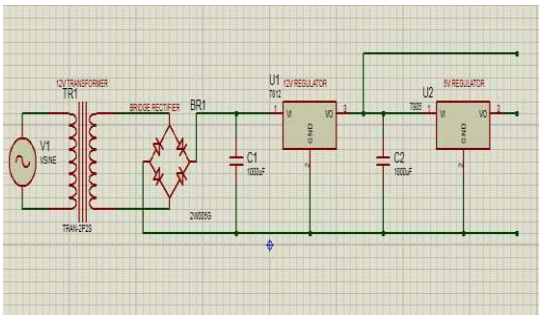
ARDUINO IDE SOFTWARE:

With this Arduino Integrated Development Environment you can edit, compile and upload Arduino sketches to the Arduino boards.



POWER SUPPLY:

This is a simple approach to obtain a 12V and 5V DC power supply using a single circuit. The circuit uses two ICs 7812 and 7805 for obtaining the required voltages. The AC mains voltage will be stepped down by the transformer, rectified by bridge and filtered by capacitor to obtain a steady DC level.The 7812 regulates this voltage to obtain a steady 12V DC. The output of the IC1 will be regulated by the 7805 to obtain a steady 5V DC at its output. In this way both 12V and 5V DC are obtained.



Initially small stepdown transformer is used to reduce the voltage level 230V AC into 12V AC. The output of the transformer is a pulsating sinusoidal AC voltage, which is converted to pulsating DC with the help of a rectifier. This output is given to a filter circuit which reduces the AC ripples, and passes the DC components. 7812 regulator is used to converts 12V DC study voltage. And 7805 regulator is converts constant 5V DC voltage.

DHT11 SENSOR:

This DHT11 Temperature and Humidity Sensor features a calibrated digital signal output with the temperature and humidity sensor capability. It is integrated with a high-performance 8-bit microcontroller. Its technology ensures the high reliability and excellent long-term stability. This sensor includes a resistive element and a sensor for wet NTC temperature measuring devices. It has excellent quality, fast response, anti-interference ability and high performance.

Each DHT11 sensors features extremely accurate calibration of humidity calibration chamber. The calibration coefficients stored in the OTP program memory, internal sensors detect signals in the process, we should call these calibration coefficients. The single-wire serial interface system is integrated to become quick and easy. Small size, low power, signal

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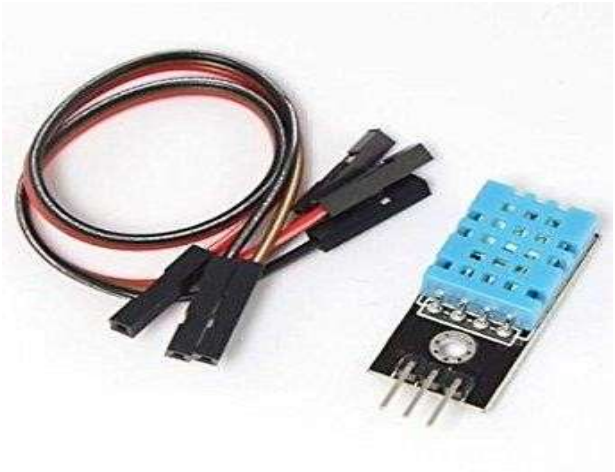
transmission distance up to 20 meters, enabling a variety of applications and even the most demanding ones. The product is 4-pin single row pin package. Convenient connection, special packages can be provided according to users need.



The DHT11 sensor provides the current temperature is humidity readings. The DHT11 gives out analog output and is connected to the analog input of the Arduino micro-controller A0. The dht11 sensor has 3 pins. Along with temperature and humidity the other values that are calculated or derived from the dht11 sensor is the dew point, heat index etc. The dew point is the temperature at which air in the atmosphere freezes to become water droplets and the heat index is the heat felt by the human skin from the environment. This is important in places with high humidity. Even though the temperature maybe lowers, the body still feels warm. This is due to the high humidity in the air. Humidity is the moisture content in the air. High humidity in the air generally makes one to sweat or perspire.

➢ FEATURES

- Full range temperature compensated
- Relative humidity and temperature measurement
- Calibrated digital signal
- Outstanding long-term stability
- Extra components not needed
- Long transmission distance
- Low power consumption
- 4 pins packaged and fully interchangeable

➢ APPLICATIONS:

- Measure temperature and humidity
- Local Weather station
- Automatic climate control
- Environment monitoring

➢ IR SENSOR :

1) IR LED Transmitter:

IR LED emits light, in the range of Infrared frequency. IR light is invisible to us as its wavelength (700nm – 1mm) is much higher than the visible light range. IR LEDs have light emitting angle of approx. 20-60 degree and range of approx. few centimeters to several feets, it depends upon the type of IR transmitter and the manufacturer. Some transmitters have the range in kilometers. IR LED white or transparent in colour, so it can give out amount of maximum light.

2) Photodiode Receiver:

Photodiode acts as the IR receiver as its conducts when light falls on it. Photodiode is a semiconductor which has a P-N junction, operated in Reverse Bias, means it start conducting the current in reverse direction when Light falls on it, and the amount of current flow is proportional to the amount of Light. This property makes it useful for IR detection. Photodiode looks like a LED, with a black colour coating on its outer side, Black colour absorbs the highest amount of light.

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3) LM358 Opamp:

LM358 is an Operational Amplifier (OpAmp) is used as voltage comparator in the IR sensor. the comparator will compare the threshold voltage set using the preset (pin2) and the photodiode's series resistor voltage (pin3).

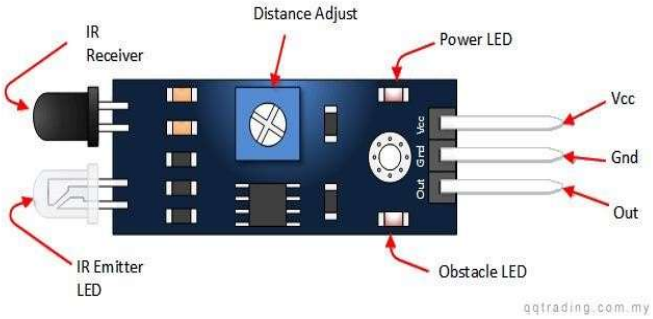
Photodiode's series resistor voltage drop > Threshold voltage = Opamp output is High

Photodiode's series resistor voltage drop < Threshold voltage = Opamp output is Low

When Opamp's output is **high** the LED at the Opamp output terminal **turns ON** (Indicating the detection of Object).

4) Variable Resistor:

The variable resistor used here is a preset. It is used to calibrate the distance range at which object should be detected.



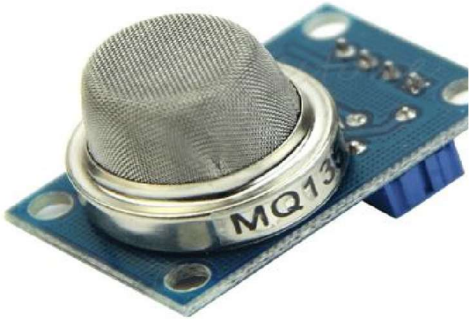
5) APPLICATIONS:

- Obstacle Detection
- Industrial safety devices
- Wheel encoder

GAS SENSOR

The MQ-135 Gas sensors are used in air quality control equipments and are suitable for detecting or measuring of NH3, NOx, Alcohol, Benzene, Smoke, CO2. The MQ-135 sensor module comes with a Digital Pin which makes this sensor to operate even without a microcontroller and that comes in handy when you are only trying to detect one particular gas. If you need to measure the gases in PPM the analog pin need to be used. The analog pin is TTL driven and works on 5V and so can be used with most common microcontrollers.

If you are looking for a sensor to detect or measure common air quality gases such as CO2, Smoke, NH3, NOx, Alcohol, Benzene then this sensor might be the right choice for you.



MQ-135 SENSOR FEATURES:

- Wide detecting scope
- Fast response and High sensitivity
- Stable and long life
- Operating Voltage is +5V
- Detect/Measure NH3, NOx, alcohol, Benzene, smoke, CO2, etc.
- Analog output voltage: 0V to 5V
- Digital output voltage: 0V or 5V (TTL Logic)
- Preheat duration 20 seconds
- Can be used as a Digital or analog sensor

APPLICATIONS:

- Used to detect leakage/excess of gases like Ammonia, nitrogen oxide, alcohols, aromatic compounds, sulfide and smoke.
- Air quality monitors.

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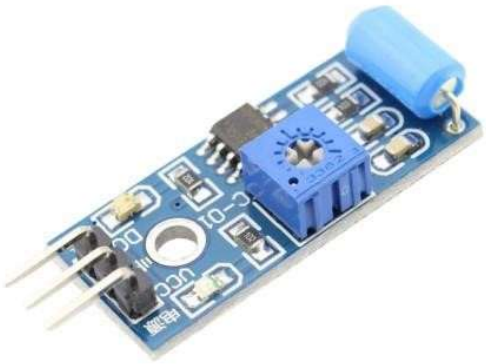
➢ VIBRATION SENSOR

This module features an adjustable potentiometer, a vibration sensor, and a LM393 comparator chip to give an adjustable digital output based on the amount of vibration. The potentiometer can be adjusted to both increase and decrease the sensitivity to the desired amount. The module outputs a logic level high (VCC) when it is triggered and a low (GND) when it isn't. Additionally there is an onboard LED that turns on when the module is triggered.



WORKING

New SW-420 Motion Sensor Module The company produced normally closed type vibration sensor SW-420 The comparator output, signal clean, good waveform, driving ability is strong, for more than 15 ma The working voltage of 3.3V to 5V Output form: digital switch output (0 and 1) Has a fixed bolt hole, convenient Installation Small board PCB size: 3.2cm x 1.4cm Use the LM393 wide voltage comparator Product no vibration, vibration switch is closed on state, the output terminal output low level, the green light is lit Product vibration, the vibration switch instantaneous disconnection, output the output high level, the green light is not bright

Output can be directly connected to microcontroller, through single chip microcomputer to detect the high and low level, thus to detect whether there is a vibration environment, call the police Used to trigger the effect of various vibration, theft alarm, intelligent car, earthquake alarm, motorcycle alarm, etc.

This module is compared with the normally open type vibration sensor module, vibration trigger for longer periods of time, can drive the relay module

FEATURES:

- The working voltage of 3.3V to 5V
- Small board PCB size: 3.2cm x 1.4cm
- Use the LM393 wide voltage comparator
- Output can be directly connected to microcontroller, through single chip microcomputer to detect the high and low level, thus to detect whether there is a vibration environment, call the police

APPLICATIONS:

- Vibration detecting
- Burglary protection system
- Object Movement detecting
- Triggering effect reported theft alarm
- Smart car
- Earthquake alarm

9.METHODOLOGY

The proposed system is designed to improve safety in hazardous industrial and mining environments using Internet of Things (IoT) technology. The methodology involves real-time sensing, wireless data transmission, data processing, and alert generation. The complete working of the system is explained in the following steps.

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9.1. System Design and Architecture:

The system consists of two main units:

- **Worker Unit (Smart Helmet / Field Unit)**
- **Monitoring Station (Control Unit)**

The worker unit is mounted on the helmet and contains various sensors and communication modules. The monitoring station receives, displays, and analyzes the collected data in real time.

9.2. Data Acquisition and Processing:

The microcontroller continuously reads data from all connected sensors. The collected sensor values are:

- Compared with predefined safety threshold levels
- Converted into digital values
- Processed to determine normal or hazardous conditions

If any sensor value exceeds the safe limit, the system identifies it as an abnormal condition.

9.3. Wireless Communication Using IoT:

Wi-Fi technology is used for wireless communication between the worker unit and the monitoring station. The processed sensor data is transmitted in real time to a cloud server or local monitoring system using IoT protocols.

This enables:

- Remote monitoring
- Continuous data logging
- Instant alert transmission

9.4. Alert and Warning Mechanism:

When hazardous conditions are detected, the system activates multiple alert mechanisms:

- **Buzzer and LED alerts** on the helmet to warn the worker
- **Emergency notification** sent to the monitoring station
- **Visual alerts** displayed on the monitoring dashboard

If the emergency switch is pressed, an immediate distress alert is transmitted regardless of sensor values.

9.5. Monitoring Station Operation:

The monitoring station receives real-time data and displays:

- Gas concentration levels
- Temperature and humidity readings
- Helmet-wearing status
- Emergency alerts

This allows supervisors to take immediate action such as evacuation, ventilation control, or medical assistance.

9.6. Power Management:

The system operates on a lowpower supply suitable for wearable devices. Power optimization techniques are used to ensure long battery life and uninterrupted operation during working hours.

9.7. System Testing and Validation:

The system is tested under various simulated hazardous conditions to verify:

- Accuracy of sensor readings
- Reliability of wireless communication
- Response time of alert mechanisms
- Proper functioning of emergency alerts

Successful testing confirms the reliability and effectiveness of the proposed safety system.

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9.8. Overall Workflow Summary:

1. Sensors collect environmental data
2. Microcontroller processes sensor values
3. Data is transmitted via Wi-Fi
4. Monitoring station receives and displays data
5. Alerts are generated during unsafe conditions

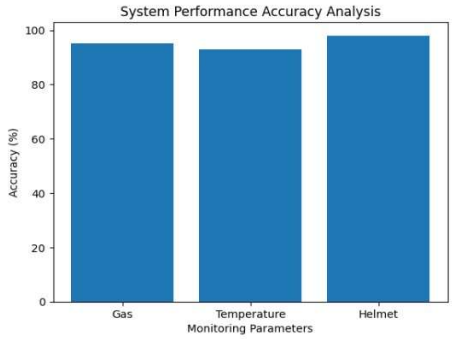
10.RESULTS AND ANALYSIS

The proposed IoT-based industrial safety and smart mining helmet system was successfully implemented and tested under different operating conditions. The system effectively monitored environmental parameters such as gas concentration, temperature, and humidity in real time. Sensor readings were accurately collected and transmitted wirelessly to the monitoring station using Wi-Fi technology.

During testing, when gas levels or temperature exceeded the predefined safety thresholds, the system immediately generated alerts. The buzzer and LED provided instant warnings to the worker, while alert messages were simultaneously displayed at the monitoring station. The emergency push button was also tested and was able to transmit distress alerts instantly, confirming reliable manual emergency communication.

The IR sensor accurately detected whether the helmet was worn properly, helping ensure compliance with safety regulations. The response time of the system was observed to be fast, with minimal delay between hazard detection and alert notification. Continuous monitoring and stable data transmission demonstrated the reliability of the IoT communication framework.

Overall, the results confirm that the proposed system is effective in early hazard detection, real-time monitoring, and rapid alert generation. The analysis shows that the system significantly enhances worker safety, reduces the risk of accidents, and provides a practical and cost-effective solution for industrial and mining safety applications.



10.CONCLUSION:

In this project the proposed project was introduced with a literature review, methodology, system limitations, findings and testing were explained. From the summary points it is seen that the aim related to the project are successfully achieved by designing Automated system that detects the hazardous gas surrounded by the miner's helmet was achieved, designing a monitoring system to update the control room with real time data was achieved and to integrate both design systems and evaluating the power consumption of the proposed system was integrated and achieved

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