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IOT Based Coal Mine Safety Monitoring and Alerting Smart Helmet

Harshada R. Rokade[1], Priyanka G.Ghagre[2], Vaibhav M. Mandade[3]
Department of Electronics and Telecommunication Engineering, Wainganga College of Engineering and Management Nagpur, India

Abstract: ***"Coal mining remains one of the most hazardous occupations, with workers exposed to numerous safety threats such as toxic gases, high temperatures, low visibility, and potential structural collapses. This research presents the design and development of a smart helmet aimed at enhancing coal mine safety through real-time environmental monitoring and communication capabilities. The helmet integrates sensors for gas detection (e.g., methane, carbon monoxide), temperature and humidity monitoring, and an accelerometer for fall or impact detection. It also features wireless data transmission to alert supervisors in case of abnormal conditions or emergencies. The proposed system seeks to minimize risk and improve response times during incidents, contributing to a safer mining environment. Experimental validation in simulated mining conditions demonstrates the system's effectiveness and reliability.***

Keywords: Node MCU ESP- 32 , DHT11 Temperature and Humidity Sensor , MQ3 Gas Sensor , BMP180 Pressure Sensor , etc.

I. INTRODUCTION

Our provocation behind this design is that numerous workers work in the lair and may get dangerous feasts, pressure and high temperature moisture. It also helps to the control room to take the immediate action help for the worker and can cover the data of each lair.

Mine helmet system, is used to descry the dangerous feasts of a worker in which lair he's working. The detectors are attached on the Helmet of the worker.

When worker moves through the lair, the detectors on the helmet will descry the ignitable gas(LPG) and shoot the signal to the eschewal station via wifi. To the external control room is connected to the lair via wifi. For our rally design we use the ESP32 as the regulator and detectors guard is use to connect the system via wifi. The whole system will be on the helmet. For the rally use are using the system which is big but if we go for mass product the system will be compact and easy to wearable

Every lair is wifi enabled by the repeater so as to increase the network range. The Gas and the temperature & moisture detector shoot the signal to the control room so that the control room will get announcement and condition of each lair.

In case if any ignitable gas(for rally we use LPG) occurs also the signal sends to the control room and the aleart alaram will ring in the complete lair to void the area. Also if the temperature grows also the same action will takesplace.

Each helmet have the exigency button so that the worker when pressed the button also the control room will take immediate help for the worker.

II. LITERATURE REVIEW

Coal mining remains one of the most dangerous occupations encyclopedically, with pitfalls stemming from falling debris, gas explosions, low visibility, and underground defeats. particular Defensive outfit(PPE), especially safety helmets, plays a pivotal part in securing miners from head injuries and losses. This literature review explores the elaboration, technological integration, and exploration progress in coal mine safety helmets.

A. Literal Background and Helmet Design Evolution

Traditional mining helmets, frequently made from hard plastic or fiberglass, were primarily designed for mechanical protection against falling jewels or bumps(Singh et al., 2009). Beforehand designs emphasized continuity and comfort but demanded technological integration. Over time, standard designs have been bettered with better accoutrements similar as high- viscosity polyethylene(HDPE) and thermoplastics, offering increased impact resistance(Zhou et al., 2013).

B. Technological Advancements

Recent studies have stressed the integration of smart technologies into helmets to ameliorate overall mine safety. For case, helmets bedded with wireless communication bias, environmental detectors, and position shadowing modules have come decreasingly common(Chen et al., 2017). These smart helmets cover gas situations(e.g., methane, CO), temperature, moisture, and air pressure to warn miners of dangerous conditions in real time.

Gas Discovery Systems Smart helmets are frequently equipped with detectors able of detecting poisonous feasts like methane and carbon monoxide. exploration by Li et al.(2018) showed that real- time gas monitoring helmets significantly reduce losses from gas explosions.

Communication and Tracking Integration of RFID and GPS modules allows real- time shadowing of miners' locales. This is vital during extremities, similar as defeats or explosions, enabling faster deliverance operations(Park & Lee, 2020).

Wearable Health Monitoring Some helmets are now paired with biometric detectors that cover heart rate, fatigue, and body temperature to assess the miner's physical condition and alert for signs of prostration or heat stroke(Rajput et al., 2021).

C. Ergonomics and mortal Factors

Helmet comfort and weight distribution are pivotal in icing prolonged operation compliance. Studies by Ahmed et al.(2016) noted that inaptly fitted helmets contribute to discomfort and long- term health issues similar as neck strain. therefore, ultramodern designs concentrate not only on defensive features but also on ergonomics and ventilation to ameliorate wearability.

D. Challenges in Adoption

Despite technological advancements, several walls hamper the wide relinquishment of smart safety helmets in coal miningCost Smart helmets are significantly more precious than traditional bones , limiting their deployment in small- scale or underfunded operations(Gupta & Sharma, 2019).continuity Harsh underground surroundings challenge the continuity of bedded electronic factors, challenging robust and leakproof designs(Patel et al., 2020).

Battery Life Limited battery capacity can circumscribe the functional hours of smart helmets, raising enterprises in long- shift operations.

E. Current Trends and unborn Directions

Recent exploration focuses on Internet of effects(IoT)- enabled helmets, AI- grounded hazard vaticination, and stoked reality(AR) for real- time hazard visualization. Blockchain integration for secure miner data operation and machine literacy algorithms for prophetic safety cautions are also arising(Zhang et al., 2022). Sustainability is another growing concern, with sweats directed at developing helmets from recyclable or biodegradable accoutrements ..

III. METHODOLOGY

This research investigates the design, materials, technologies, and effectiveness of coal mine safety helmets. A structured and multi-faceted methodology is employed, which incorporates literature reviews, experimental testing, material analysis, technology integration, and practical field trials. The following steps outline the approach taken in the study:

The major Components serves important role in system ability, as shown in Block Diagram .coal mine safety helmet, for this we going to use the following hardware and software to meet our requirements.

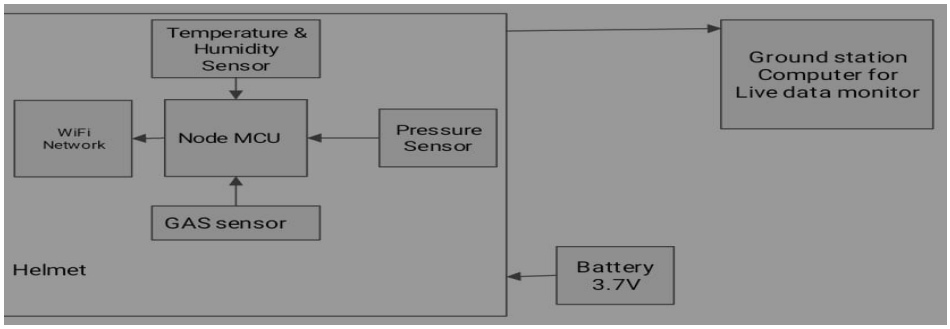


Fig 2.1 System Block Diagram

A. The NodeMCU ESP32

The NodeMCU ESP32 is a important development board erected around the ESP32 microcontroller, specifically designed for bedded systems and Internet of effects(IoT) operations. As a successor to the popular ESP8266, the ESP32 offers significant advancements, including enhanced processing power, further memory, and a broader range of integrated features. These advancements make it a protean choice for inventors working on smart bias, wireless communication systems, and other connected operations.

The ESP32 microcontroller offers roughly 36 GPIO legs, which support a wide range of functionalities including PWM(palpitation range Modulation), ADC(Analog- to- Digital Conversion), DAC(Digital- to- Analog Conversion), as well as communication protocols like I2C, SPI, and UART. Operating at 3.3 V, it's important to note that the ESP32 is n't tolerant to 5V signals. The chip also integrates several onboard detectors, similar as a hall effect detector, capacitive touch seeing inputs, and a introductory temperature detector, adding to its versatility

B. Ai-Thinker (A9) GSM+GPRS Module

The AI-Thinker A9G is a compact, all-in-one module that integrates GSM and GPS capabilities. This module combines a quad-band GSM/GPRS engine with a high-sensitivity GPS receiver, enabling simultaneous voice, SMS, and data communication, as well as precise location tracking.

The A9G supports TCP/IP, HTTP, and FTP protocols, making it suitable for IoT applications, vehicle tracking, and personal safety devices. Its small form factor, low power consumption, and easy-to-use AT command set make it a popular choice for developers and makers.

C. DHT11 Temperature & Moisture Detector

The DHT11 is a compact and cost-effective detector designed to measure both temperature and moisture, making it a popular choice for IoT systems, environmental monitoring, and introductory rainfall station operations. Known for its simplicity and decent trustability, the detector is well- suited for systems that bear moderate delicacy without complex estimation processes.

The DHT11 delivers digital affair, barring the need for analog- to- digital conversion and allowing for straightforward integration with microcontrollers. It measures temperatures in the range of 0 °C to 50 °C with an delicacy of ± 2 °C, and relative moisture situations from 20 to 90 with an delicacy of ± 5 RH. The detector updates its readings roughly formerly per second, which is sufficient for numerous real- time operations.

Communication with the DHT11 is handled through a single- line digital protocol, taking just one data line in addition to power(VCC) and ground(GND). Its ease of use, minimum leg demand, and low price point have made it a chief in DIY electronics, home robotization setups, and educational accoutrements concentrated on environmental seeing

D. The MQ- 3 Gas Detector

The MQ- 3 gas detector is specifically designed to descry alcohol vapors and other unpredictable organic composites similar as ethanol, benzene, and bank in the girding terrain. Due to its high perceptivity to alcohol, it's generally used in breathalyzer bias, inner air quality observers, and artificial safety systems. The detector's capability to descry a wide range of feasts makes it a practical choice for operations where dependable gas monitoring and discovery are essential.

The MQ- 3 gas detector operates using a sensitive semiconductor subcaste composed of drum dioxide(SnO_2), which exhibits high electrical resistance in clean air. When exposed to alcohol vapors or other unpredictable organic composites, the resistance of this subcaste decreases significantly, performing in increased current inflow. This resistance change produces a variable voltage affair that can be measured by a microcontroller to determine gas attention in real time.

E. BMP180 Pressure Detector

The BMP180 is a protean detector designed to measure atmospheric pressure, temperature, and estimate altitude grounded on pressure variations. It's generally used in rainfall stations, environmental monitoring, and elevation shadowing systems.

The BMP180 is a compact digital barometric pressure detector that utilizes MEMS(Micro-Electro-Mechanical Systems) technology to give precise measures of atmospheric pressure changes. At its core, the detector includes a pressure-sensitive element coupled with an onboard analog- to- digital motor(ADC), which converts the analog signals into accurate digital data. To insure dependable measures, the BMP180 also features an intertwined temperature detector, compensating for temperature variations and maintaining stable pressure readings under different environmental conditions.

The detector supports pressure measures in the range of 300 to 1100 hPa with an delicacy of roughly ± 1 hPa. With its low power consumption, the BMP180 operates with a force voltage between 1.8 V and 3.6 V. It's compatible with both I2C and SPI communication protocols, allowing easy integration with popular platforms similar as Arduino, Raspberry Pi, and other microcontroller- grounded systems

F. 3.7 V rechargeable batterie:

3.7 V rechargeable batteries are generally used in a wide array of movable electronic bias similar as smartphones, wireless accessories, and compact DIY electronics. These batteries are generally erected using Lithium- ion(Li- ion) or Lithium-polymer(Li- Po) technology, both of which offer excellent energy viscosity, featherlight construction, and the capability to be recharged multitudinous times. Their compact size and effective performance make them ideal for powering bias where both space and energy effectiveness are consummate. These batteries give a dependable, long- continuing power result for both consumer widgets and layman systems.

IV. SYSTEM ARCHITECTURE AND PROCESS FLOW

" The system is centered around the ESP32 microcontroller, which functions as the core processing unit responsible for gathering and assaying detector data in real time. Designed to enhance plant safety, it continuously monitors crucial environmental parameters and issues cautions when dangerous conditions are detected. This setup features a DHT20 detector to track temperature and moisture situations, while a BMP180 detector measures atmospheric pressure. To assess air quality, an MQ135 gas detector is included, able of detecting dangerous feasts. A drive button is connected to the ESP32 to allow homemade input or system commerce, similar as resetting admonitions or toggling modes. For announcements, a buzzer is integrated into the circuit, furnishing audible cautions in case of dangerous environmental changes. The entire system is powered by a 5V rechargeable battery, supported by a charging module to maintain nonstop operation. also, a DIP switch is incorporated, enabling druggies to modify settings or customize the system's geste grounded on specific requirements.

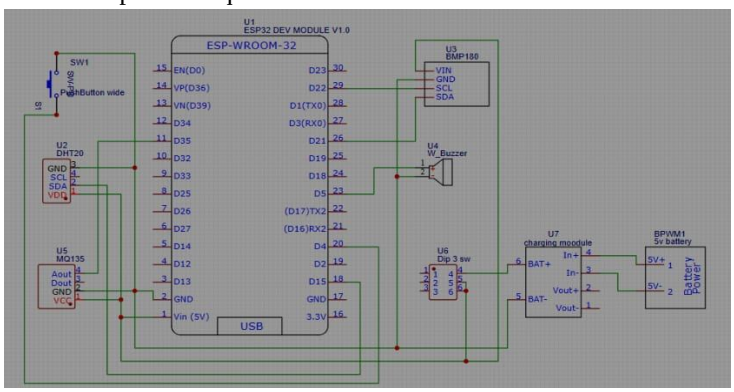


Fig 3.1 Circuit Diagram

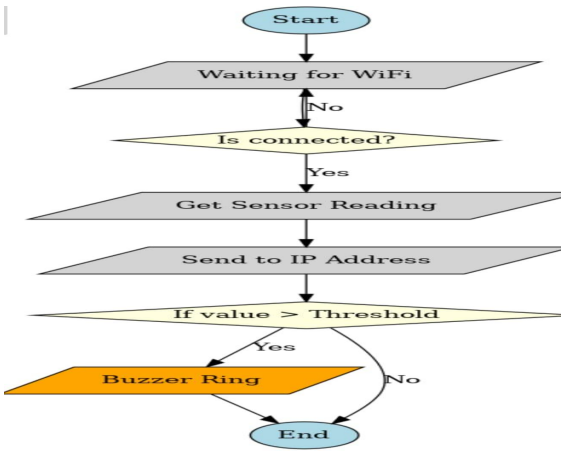
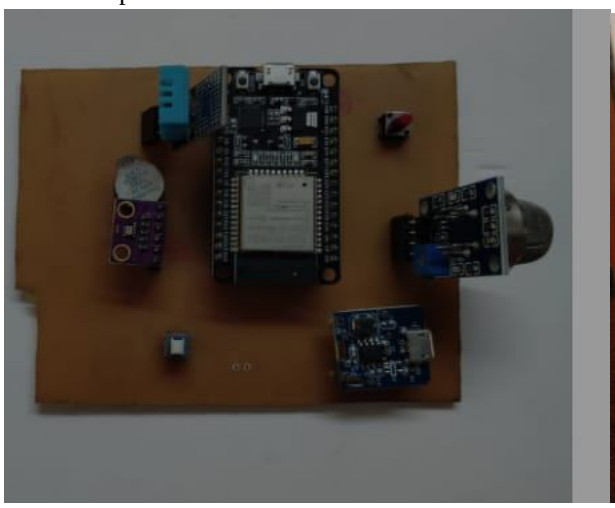


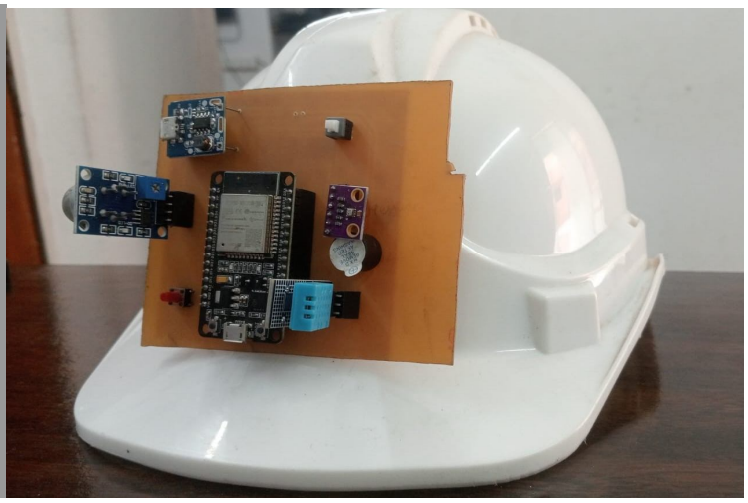
Fig 3.2 process flow

V. RESULTS AND DISCUSSION

The coal mine safety smart helmet effectively monitors environmental conditions in real- time using ESP32, DHT11(temperature & moisture detector), BMP180(pressure detector), MQ- 3(gas detector), and a buzzer for cautions. The system successfully detects dangerous conditions like high temperature, gas leaks, and pressure changes. When peril is detected, it sends cautions via WiFi to a garçon or mobile device and triggers an alarm, perfecting worker safety. Testing shows dependable data transmission, quick response time, and effective hazard discovery.

The future of coal mine safety smart helmets lies in integrating advanced technologies to enhance worker protection, ameliorate communication, and help accidents. One major area of development is the use of artificial intelligence(AI) and machine literacy to dissect environmental data and prognosticate implicit hazards before they come critical. Real- time monitoring of gas attention, temperature, and air quality can be further bettered through more sensitive and compact detectors. The development of further energy-effective and longer- lasting batteries will also play a pivotal part in the future of these helmets. By exercising energy-harvesting technologies, similar as solar cells or kinetic energy conversion, smart helmets could operate for extended ages without frequent recharging. also, ergonomic designs and featherlight accoutrements will ameliorate comfort and usability, making these helmets more practical for diurnal use.





VI. CONCLUSION

"The development of a smart safety helmet for coal miners significantly improves workplace safety by integrating real- time monitoring, hazard discovery, and wireless communication. Equipped with detectors similar as gas sensors, temperature and moisture detectors, stir detectors, and pressure detectors, the helmet continuously monitors the mining terrain and provides instant cautions in case of peril. The objectification of IoT technology and data analytics enhances prophetic conservation and threat assessment, farther reducing the chances of accidents."

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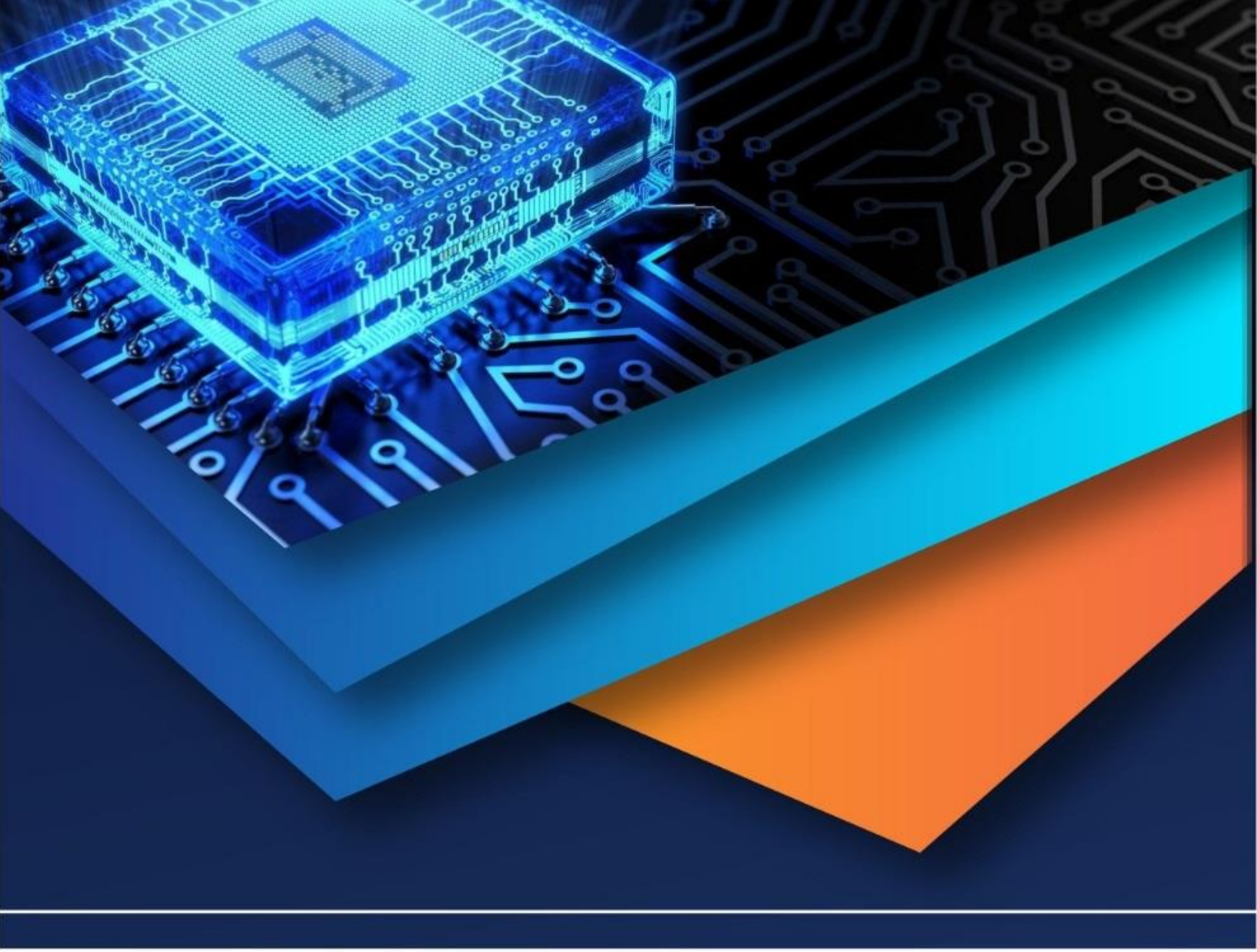

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