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Harmful Gases Monitoring with Smart Helmet and Alerting System

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***Abstract:** A Coal mining is a hazardous occupation where workers are regularly exposed to toxic gases such as carbon monoxide, methane, and LPG, which pose serious health risks and can lead to fatal incidents if undetected. To address this issue, this project introduces a Smart Helmet integrated with a harmful gas monitoring and alerting system designed to enhance miner safety through real-time gas detection. The core of the system relies on MQ2 and MQ5 gas sensors, where MQ2 is highly sensitive to LPG and smoke, and MQ5 is effective in detecting methane and carbon monoxide. These sensors continuously monitor the air quality, and the data is processed by an ESP32 microcontroller. When the concentration of any harmful gas exceeds predefined safety limits, the system immediately triggers alerts using a buzzer and a red LED, while a green LED indicates normal conditions. In addition to on-site alerts, the system also enables remote monitoring and notifications via the Blynk IoT app, allowing for timely response even from a central control room. To further enhance the functionality of the helmet, additional sensors are incorporated. An LDR controls the headlight automatically based on ambient lighting, ensuring visibility in dark environments. A BMP180 sensor is included to monitor atmospheric pressure and altitude, useful in underground conditions. The MPU6050 sensor detects falls or abnormal motion, indicating potential accidents, and an IR sensor ensures the system operates only when the helmet is worn. Though these additional features contribute to overall worker safety, the primary focus of the project remains on the accurate and reliable detection of harmful gases and the immediate alerting of workers and supervisors to prevent accidents and health hazards in coal mining environments.*
***Keywords:** MQ5 sensor, Internet of Things, ESP32, BMP180. LDR, Blynk IOT, MQ2 sensor, IR sensor.*

I. INTRODUCTION

Coal mining is an essential yet hazardous industry where workers often operate in confined and poorly ventilated environments. One of the most critical dangers miners face is exposure to toxic gases such as carbon monoxide (CO), methane (CH_4), and liquefied petroleum gas (LPG). Prolonged or high-level exposure to these gases can cause serious health issues, unconsciousness, and even fatalities. Conventional safety measures such as manual checks and stationary detectors are not sufficient to ensure real-time, individual-level safety. This project proposes the development of a Smart Helmet embedded with harmful gas sensors and real-time alerting capabilities. By leveraging gas sensors (MQ2 and MQ5), microcontroller technology (ESP32), and IoT platforms (Blynk), the helmet ensures timely detection of toxic gases and immediate alert generation to prevent accidents and loss of life. The system also includes additional sensors such as an LDR for automatic lighting, BMP180 for pressure monitoring, MPU6050 for fall detection, and an IR sensor for helmet-wear validation, further enhancing safety and operational intelligence.

Mining is the process of extracting valuable minerals from the earth. It plays an important role in today’s world due to need for metals and other materials caused by rapid urbanization and industrialization. India is a land with many natural reserves of mineral and valuable rocks .Underground mining, surface mining, high wall mining, quarrying are some of the mining techniques used in the country. There are about 11 coal mines, 13 iron ore mines, 9 bauxite (aluminum ore) mines, 5 manganese mines, 5 copper mines, 3 diamond mines and 2 gold mines in India. The mining industry there is a high safety risk due to problems like mine ventilation, danger from hazardous gases, incidents like rock fall and head injuries.

These are direct threat to the safety of miners. Some small incidents often occur in the mining industry but two major mining hazards that occurred in India lead us to think about the safety of miners more deeply. The Chasnala mining disaster killing 372 miners and the Jharkhand coal mine incident that killed 11 miners and trapped over 50.Thus a safety device is necessary to protect miners and rescue them even in case of such incidents. Sensors can be used to detect the changes in the environment that affect safety of miners and communicate them with the ground center. Under the mines, due to the labyrinth of tunnels it is inconvenient to use wired communication system. The installation and maintenance cost are also high.

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The mining industry is recognized for its hazardous working environment, where workers are consistently exposed to unsafe conditions such as poor air quality, high gas concentrations, and risks due to improper safety gear usage. With the advancement of wearable technology and the integration of Internet of Things (IoT), a smart helmet has been developed to detect and alert against critical hazards in real-time. This helmet primarily focuses on three major hazards: air quality, helmet removal, and ventilation monitoring. The air quality is compromised due to harmful gases such as Carbon Monoxide (CO), Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2), and Methane (CH4) emitted during mining operations. The second risk is associated with helmet removal, where miners expose themselves to potential head injuries and environmental dangers. The third includes monitoring the operational status of the exhausting fan, essential for maintaining breathable air in underground mines. By incorporating sensors such as MQ-2 for gas detection, IR for helmet presence, BMP180 for environmental monitoring, and LDR for automated lighting, the system ensures miner safety. An ESP32 microcontroller processes sensor data and transmits it via Wi-Fi using the Blynk IoT platform to notify supervisors. This paper presents the design, implementation, and analysis of the smart helmet, highlighting its effectiveness in bridging the gap between theoretical concepts and real-world applications.

II. LITERATURE SURVEY

Several studies and innovations have addressed the need for smart safety gear in hazardous environments like mines. Research by Kumar et al. (2019) introduced an IoT-based mining safety system using Arduino and basic gas sensors, but lacked real-time remote monitoring. Another project by Singh and Sharma (2020) implemented a gas detection helmet with SMS alerts but did not incorporate additional environmental sensing or headwear validation. A recent advancement by Bansal et al. (2021) focused on wearable technology for gas detection, integrating it with cloud-based platforms, but the system suffered from high power consumption and lacked fall detection capabilities.

While previous models emphasized gas detection, most lacked comprehensive alert mechanisms or ignored practical miner behaviors, such as whether the helmet is worn. Furthermore, few systems integrated pressure, lighting, and motion sensors, which are crucial for deep mining environments. This project bridges these gaps by combining multiple safety sensors with real-time alerts and IoT-based monitoring, offering a holistic and practical solution for miner safety.

The mining industry mostly uses cables and wired network to communicate with the ground center. In mines, if an accident happens, the sensors and cables were usually damaged fatally by the explosion, and so we couldn't provide information for rescue search and detection events. We used wireless sensor network to communicate at times of such accidents and to detect a number of activities like helmet removal, collision detection and air quality measurement by using PIC microcontroller. For our paper, we observed from different reference papers developed by researches.

Michael Zuba, Carlos Villa, Alexandria Byrd proposed about an Autonomous Coalmine System (AUV) networks are becoming increasingly popular in scientific, commercial, and military applications. In undersea exploration and environmental monitoring AUVs are used for tasks such as detection of oilfields and marine life, distributed tactical surveillance for offshore and seaport defense and mine reconnaissance. AUV networks are also becoming an important interest in an effort to enhance the capabilities of coalmine sensor networks (UWSNs). In this paper we propose a control system for networked autonomous coalmine systems that includes both hardware and software modules.

Several research efforts have explored safety enhancements in the mining sector using wearable and sensor-based technology. Studies indicate that most mining accidents occur due to gas poisoning, equipment malfunction, and neglecting safety protocols. Prior works like gas sensor arrays integrated into helmets focused on detection of toxic gases like CO and CH4. However, real-time alerts and cloud-based monitoring were limited. Other works included smart helmets with GPS and GSM modules for location tracking, yet they lacked helmet removal detection and proper environmental parameter monitoring. While IR sensors have been used in healthcare to detect human presence, their application in helmet detection is novel in this context. In terms of air quality, MQ series sensors, particularly MQ-2 and MQ-135, have shown reliability in detecting various gases in controlled environments, but limited studies have validated them in actual mining conditions. The inclusion of temperature and pressure monitoring via BMP180 is also underutilized in existing helmet designs. Some proposals suggest machine learning-based data interpretation to predict accidents, but most of these remain at the prototype stage. In conclusion, while existing literature provides a foundation for sensor integration in helmets, there exists a significant gap in combining multiple safety parameters like helmet status, air quality, temperature/pressure conditions, and IoT-based alert systems into a single, robust, and field-tested solution. This research aims to address these gaps with a comprehensive, real-world tested smart helmet design.

III. METHODOLOGY

The proposed Smart Helmet system is designed to ensure real-time detection and alerting of harmful gases commonly present in coal mining environments. At the core of the system are the MQ2 and MQ5 gas sensors. The MQ2 sensor is highly sensitive to LPG and smoke, while the MQ5 sensor effectively detects gases like methane and carbon monoxide. These sensors are strategically placed on the helmet to continuously monitor the surrounding air. The data from these sensors is fed into an ESP32 microcontroller, which acts as the brain of the system. The ESP32 processes the sensor readings and compares them against predefined safety thresholds. If the gas levels exceed safe limits, the system immediately activates a buzzer and switches on a red LED to alert the wearer on-site. A green LED remains on under safe conditions, providing a quick visual indication of air quality.

In addition to the core gas monitoring functionality, the helmet is equipped with supporting sensors to improve overall safety. An LDR (Light Dependent Resistor) is used to automatically control the headlight of the helmet based on ambient lighting conditions, ensuring visibility in dark environments. A BMP180 sensor monitors atmospheric pressure and altitude, which is particularly useful in underground mining scenarios. For detecting falls or abnormal movement patterns that may indicate an accident, the MPU6050 sensor is used to monitor acceleration and orientation. Furthermore, an IR sensor is integrated to detect whether the helmet is being worn; the system only functions when the helmet is properly in place, preventing false alerts and conserving power.

To enable remote monitoring and alerts, the system uses the Blynk IoT platform. The ESP32 connects to Wi-Fi and transmits real-time sensor data to the Blynk app, which allows supervisors or safety officers to remotely view gas levels and receive notifications if dangerous conditions are detected. The entire system is powered by a compact, rechargeable battery, and the components are embedded within the helmet in a way that ensures user comfort and mobility. This integrated approach provides a comprehensive, wearable safety solution for coal miners, combining gas detection, local and remote alerts, and environmental awareness in one smart helmet.

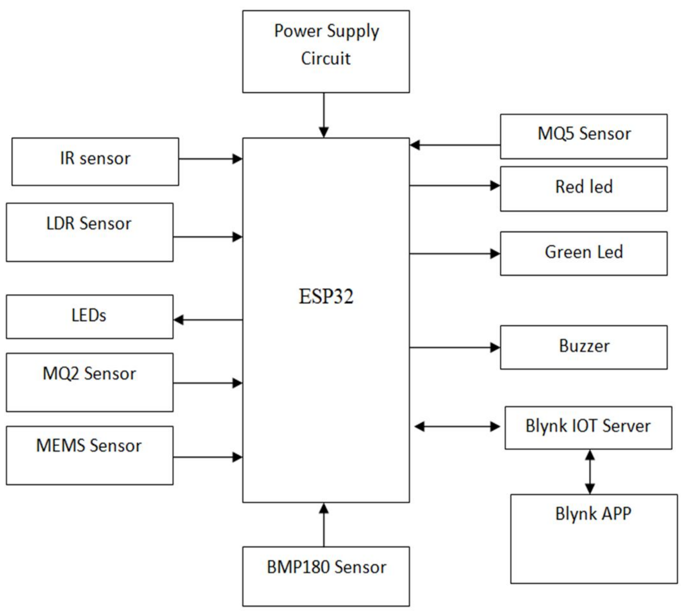

Fig 1: Block Diagram

A. Gas Detection Module (MQ2 & MQ5 Sensors)

This is the core module of the project, responsible for detecting harmful gases such as LPG, methane, smoke, and carbon monoxide.

MQ2: Detects LPG, propane, hydrogen, smoke, and alcohol vapor. It is used for identifying flammable gas leaks in the environment.

MQ5: Detects methane, natural gas, and carbon monoxide. It has a fast response time and high sensitivity, making it ideal for underground conditions.

These sensors output analog values which are read by the ESP32 microcontroller. If the gas concentration exceeds safe thresholds, the system triggers visual (LED) and audio (buzzer) alerts.

B. Alerting Module (Red LED, Green LED, Buzzer)

This module provides immediate, on-site alerts to the worker based on the gas levels.

Red LED: Lights up when harmful gas levels exceed the safety limit, signaling danger.

Green LED: Indicates that the air quality is within a safe range.

Buzzer: Emits a loud beeping sound when toxic gas is detected, ensuring the worker is immediately alerted even if visual cues are missed.

C. Microcontroller Module (ESP32)

The ESP32 is the brain of the system. It collects data from all sensors, processes the values, makes decisions based on thresholds, controls the alerting module, and handles wireless communication.

Key features include:

Built-in Wi-Fi for IoT connectivity.

Multiple GPIO pins for interfacing sensors.

Low power consumption, ideal for wearable devices.

D. IoT Communication Module (Blynk Integration)

This module enables remote monitoring and real-time alerts using the Blynk IoT platform.

The ESP32 connects to a Wi-Fi network and sends sensor data to the Blynk app.

Safety officers can monitor gas levels in real-time and receive push notifications on their smart phones if dangerous conditions are detected.

This feature ensures that action can be taken even if the miner is unable to respond immediately.

E. Light Control Module (LDR Sensor)

The LDR (Light Dependent Resistor) is used to automate the headlight of the helmet.

In low light conditions (like underground mines), the LDR detects darkness and turns on the headlamp automatically.

In bright conditions, it turns the light off, conserving battery power.

This improves visibility without requiring manual control from the worker.

F. Pressure and Altitude Monitoring Module (BMP180 Sensor)

The BMP180 sensor measures atmospheric pressure, temperature and altitude.

Useful in underground mining to understand the depth and environmental pressure, which can indicate potential hazards like cave-ins or air pressure changes.

Provides additional environmental context to help supervisors monitor safety.

G. Fall Detection Module (MPU6050 Sensor)

The MPU6050 is a 6-axis motion sensor (accelerometer + gyroscope) that detects movement and orientation.

It identifies sudden changes in motion, such as a fall or collapse.

If a fall is detected, the system can trigger alerts through the buzzer and notify remotely via Blynk.

This module ensures timely response to accidents or health emergencies.

H. Helmet Wear Detection Module (IR Sensor)

This module ensures the smart helmet is only active when worn.

An IR sensor detects the presence of the user's head inside the helmet.

If the helmet is not worn, the system disables sensor readings and alerting mechanisms to avoid false data and save power. This also acts as a safety and power management feature.

I. Power Supply Module

All modules are powered by a rechargeable Li-ion battery pack.

Ensures portability and uninterrupted functioning.

The system is designed to be lightweight and energy-efficient to avoid discomfort during long working hours.

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IV. RESULT ANALYSIS

The Smart Helmet system was tested under various controlled and real-time conditions to evaluate its effectiveness in detecting harmful gases and providing timely alerts. The gas detection module, featuring MQ2 and MQ5 sensors, successfully identified the presence of LPG, methane, and carbon monoxide when exposed to different sources such as cigarette smoke, gas lighters, and controlled gas leaks. The system reliably activated the buzzer and red LED when gas concentrations exceeded the defined safety thresholds, ensuring immediate local alerts. In safe conditions, the green LED remained on, indicating normal air quality, which confirms the system's ability to differentiate between safe and hazardous levels accurately.

The integration with the Blynk IoT platform also performed effectively. Real-time gas level data was successfully transmitted to the Blynk app, where it was displayed in an intuitive dashboard. When gas levels crossed safe limits, push notifications were promptly received on a remote smartphone, demonstrating the feasibility of real-time remote monitoring. This feature is particularly useful for supervisors overseeing multiple workers across large mining sites.

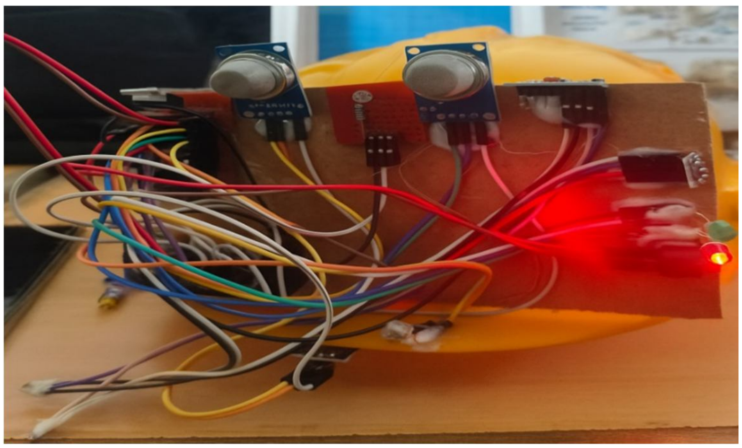


Fig2: Hardware Setup of Smart Coal Mine Helmet

Other modules, including the LDR, MPU6050, IR sensor, and BMP180, were also tested for their respective functionalities. The LDR accurately turned the headlight on in dark conditions and off in bright areas. The MPU6050 effectively detected sudden movements simulating a fall, triggering alerts. The IR sensor correctly identified whether the helmet was worn, ensuring the system only operated when in use. The BMP180 sensor provided consistent altitude and pressure readings, validating its support for environmental monitoring. Overall, the system proved to be robust, responsive, and suitable for hazardous environments like coal mines. It offers a compact, reliable, and cost-effective solution for enhancing worker safety through continuous gas monitoring and real-time alerting, both locally and remotely.

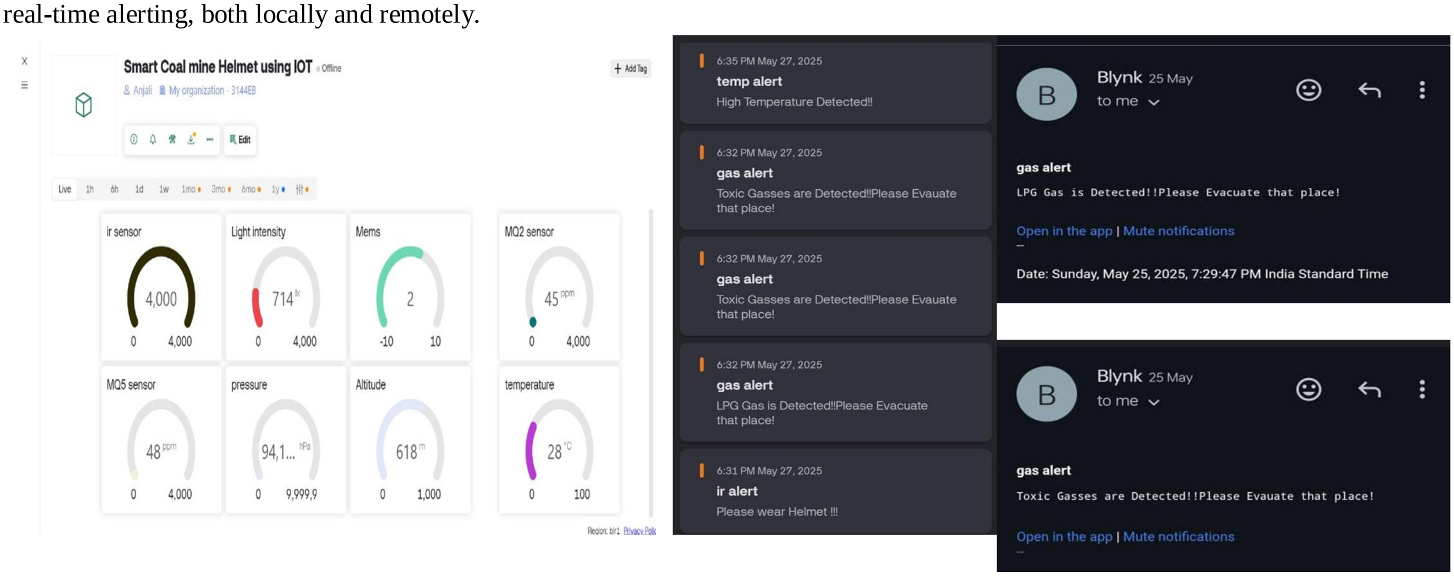


Fig 3: Blynk App Monitoring and Alerting

V. CONCLUSIONS

The Smart Helmet for Harmful Gas Monitoring and Alerting System successfully addresses a critical safety challenge faced by workers in hazardous environments such as coal mines. By integrating MQ2 and MQ5 gas sensors with a microcontroller-based alert system, the helmet provides real-time detection of toxic gases like LPG, methane, and carbon monoxide. The use of visual and audio alerts ensures that the worker is immediately notified of dangerous conditions, while IoT integration through the Blynk platform enables remote monitoring, allowing supervisors to respond promptly to emergencies. Additional features like automatic headlight control (LDR), fall detection (MPU6050), helmet-wear detection (IR sensor), and pressure sensing (BMP180) enhance the functionality and safety of the device. The compact and wearable design, coupled with low power consumption, makes this system a practical and effective solution for improving occupational safety in mining and other high-risk industries.

While the current prototype demonstrates high reliability and functionality, several improvements can be made to further enhance the system's capabilities:

The Smart Helmet system demonstrates great potential for enhancing safety in hazardous working environments, particularly in mining operations. However, there are several areas where the system can be further improved to increase its effectiveness and adaptability. One promising enhancement is the integration of a GPS module to enable real-time location tracking of workers, which can be crucial during emergency situations or rescue operations. Additionally, the reliance on Wi-Fi can be replaced or complemented with long-range communication protocols like LoRa or Zigbee to ensure reliable data transmission in areas with poor internet connectivity. Another key improvement would be optimizing power consumption and incorporating a solar charging module, which would extend the operational time of the helmet and make it more sustainable for long-term use in remote locations.

To improve alert mechanisms, the inclusion of voice alerts or vibration feedback can ensure notifications are noticed even in noisy environments or by workers with hearing impairments. Furthermore, cloud-based data logging can be implemented to store historical sensor data for analysis, enabling predictive maintenance, hazard pattern identification, and compliance reporting. Finally, integrating the system with a broader personal protective equipment (PPE) compliance framework could ensure that workers are fully geared before entering high-risk areas. With these future enhancements, the smart helmet system can evolve into a more intelligent, autonomous, and comprehensive safety solution adaptable to a wide range of industrial applications.

REFERENCES

[1] C.J. Behr, A. Kumar and G.P. Hancke ―A Smart Helmet for Air Quality and Hazardous Event Detection for Mining Industry‖, Department of Electrical, Electronic and Computer Engineering University of Pretoria, South Africa gerhard.hancke@up.ac.za .

[2] C. Qiang, S. J. Ping, Z. Zhe, Z. Fan, ―ZigBee Based Intelligent Helmet for Coal Miners, Proc. IEEE World Congress on Computer Science and Information Engineering, pp. 433-35, 2009.

[3] Tanmoy Maity, Partha Sarathi Das, Mithu Mukherjee ―A Wireless Surveillance and Safety System for Mine Workers based on Zigbee.

[4] S. Wei, L. Li-li, ―Multi-parameter Monitoring System for Coal Mine based on Wireless Sensor Network Technology, Proc. International IEEE Conference on Industrial Mechatronics and Automation, pp 225-27, 2009.

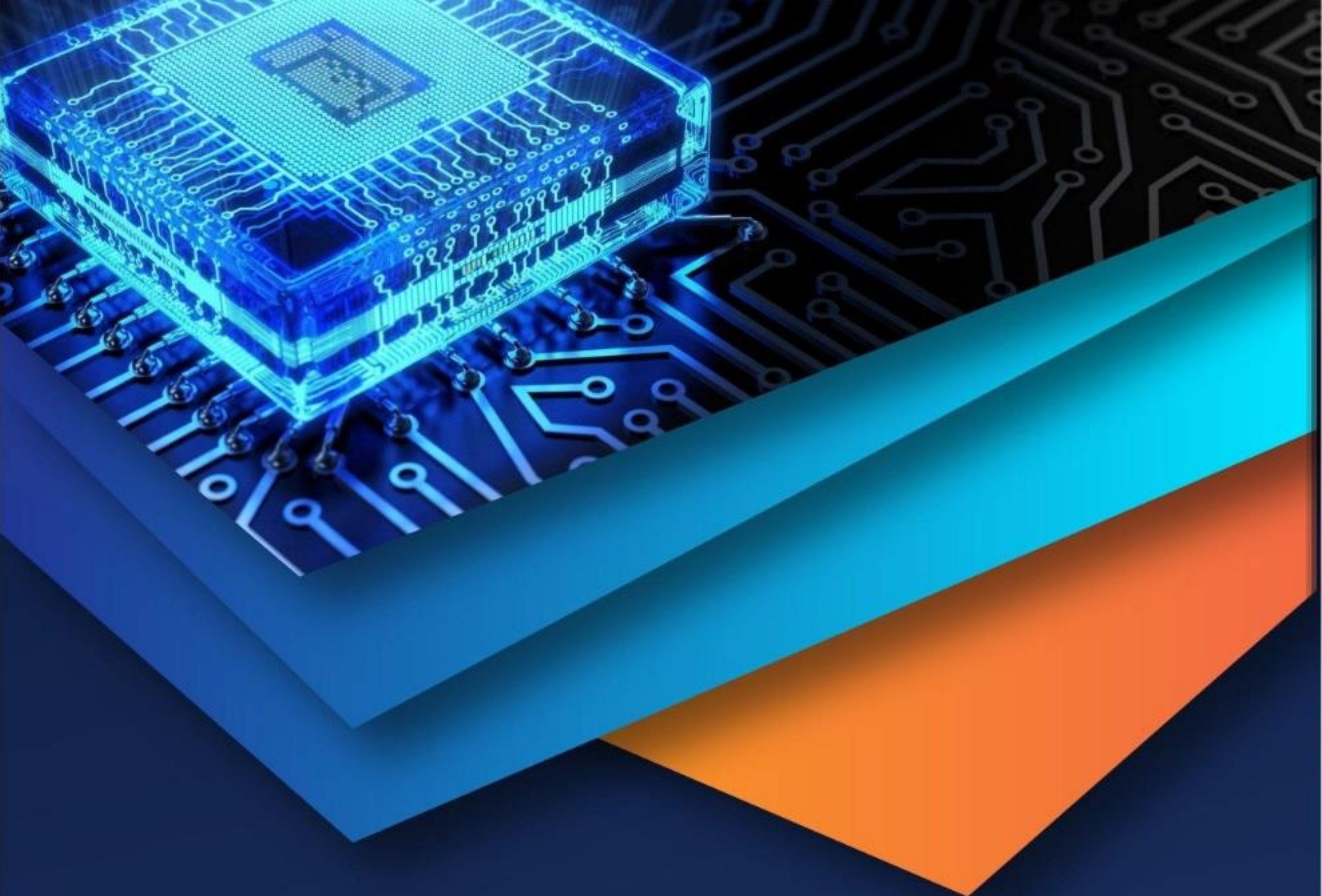
[5] Rajkumar boddu, p.balanagu ―zigbee based mine safety monitoring system with gsm International Journal of Computer & Communication Technology, Volume-3, Issue-5, 2012.

[6] M.A. Hermanus, ―Occupational health and safety in mining status, new developments, and concerns‖, The Journal of The Southern African Institute of Mining and Metallurgy, vol. 107, p. 531-538, Aug 2007.

[7] R. S. Nutter, ―A distributed microprocessor monitoring and control system for coal mines,‖ in Proc. 4th WVU Conf. on Coal Mine Electro technology, Aug. 2-4, 1978.

[8] R. S. Nutter, ―Hazard evaluation methodology for computer-controlled mine monitoring/control systems,‖ IEEE Trans. on Industry Applications, vol. IA19, no. 3, pp. 445-449, May/June 1983.

[9] R. S. Nutter and M. D. Aldridge, ―Status of mine monitoring and communications,‖ IEEE Trans. on Industry Applications, vol. 24, no. 5, pp. 820-826, Sep./Oct. 1998.



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