iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.81379

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

IOT-based Coal Mine Safety and Security Cap

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Abstract: ***Coal mining is a high-risk industry prone to unexpected dangers that threaten worker safety. To address these challenges, an IoT-based Coal Mine Safety and Security Cap has been designed to monitor and protect miners in hazardous underground environments. Built around the ESP32 microcontroller, the cap integrates sensors like DHT11 for temperature and humidity, gas sensors for detecting harmful gases such as methane and carbon monoxide, and an ultrasonic sensor to identify nearby obstacles. A GPS module provides real-time location tracking, while a panic button triggers emergency alerts with a buzzer and LCD display. All sensor data is transmitted via Wi-Fi to a web interface, allowing remote supervisors to monitor conditions live. This innovative solution enhances worker safety by enabling timely alerts and quick responses in emergencies. It offers a cost-effective, scalable approach to reducing injuries and improving health monitoring in coal mines.***

Keywords: IoT (Internet of Things), Safety helmet, Methane sensor, Heartbeat sensor, Temperature sensor, Personal Protective Equipment (PPE), System-on-a-Chip (SoC), Microcontroller unit (MCU).

I. INTRODUCTION

Thecoal miningindustry is thereason for the growth of thecountry's economy. Coalplays an exuberant role in generating the electricitythroughouttheworld. Inthefiscal year2023,approximately1.3 million individualswereemployed in India's mining industry. Thereare3,37,400minersintheminingindustry. India,thesecond-biggestcoalproducerintheworld,employsroughly half as many people as the Shanxi province of China. Every year thousands of mining workers die due to circumstances in the mining area where they face lot of problems while working in the mining area. Where some of the difficulties are suffocation, reeling sensation due to Suffocation, a whirling feeling brought on by the dangerous gasses in the mining area, and the temperaturearesomeofthechallenges. Keepingall oftheseparametersinviewthisproject cameup withanideaofdeveloping anIoT-enabledsafetyhelmetforminers.Heretheprojectisaboutusingdifferentsensorsneededforcollectingdatainthemining area and send the data in real time to the cloud of IoT. Fundamentally here the Sensors which are being used in the project are LPG sensor that is employed to identify hazardous gases in the mining area, which this LPG Sensor is also called as (MQ-2) combustible Gas and smoke Sensor. And also, a Temperature sensor (DHT11), a cheap digital sensor, is used to monitor temperature and humidity. The heart rate sensor is then utilized to determine the heartbeat rate ratio between two consecutive heart beats and MethaneSensor (MQ-3) which is made using alcohol gas sensor which identifies the methane gas and a buzzer which is used for sending an alarm sound and a LCD display which exhibits the required data, Signage etc. Now, the main componentofthisprojectisESP8266Node-MCU,whereallofthebovecomponentsareintegratedtothisNode-MCU.Where from here the data is fetched and is transmitted to the IoT cloud. Where, the blynk software app is used to collect all the data which is given to Node-MCU and right after the data assembling theblynk software sends theinformation to the worker in the miningareawhereheretheworkercan getinformationofriskandalsoiftheworkerclicksontheBuzzerThenNode-MCUtake the command and sends the Alert to the IoT cloud where immediately the information is passed to the Blynk app where the workerwhoisinriskcanbeextricatedrightaway.Theworkerwhoisindangercanbeimmediatelyrescuedusingthe Blynkapp.
Blynkwascreated asan Internet ofThingsapp.Ithastheabilitytoremotelycontrolhardware,showsensordata,savedata,and visualize. Here the Blynk app is a platform that allows users to effortlessly create IoT (Internet of Things) projects and control themthroughamobileapp.Itprovidesadrag-and-dropinterfacetodesigncustomuserinterfacesforcontrollinghardware'ssuch asESP8266,Arduino,Raspberry PI and others,withoutanyrequirement of extensiveprogrammingknowledge.Users here can remotely monitor and control their devices which are connected via the Blynk app, which provide features like real-time data visualization, notifications, and integration with numerous sensors and actuators.

II. LITERATURE SURVEY

[1] T. Kaur and R. Kaur,et al., 2019In this project the authors developed a smart helmet system aimed at increasing miner safety through real-time monitoring of environmental hazards. The helmet was equipped with a range of sensors including temperature, pressure, and gas sensors to detect dangerous gases like methane. A Wi-Fi-enabled microcontroller was used to process sensor data and transmit alerts to a central monitoring system. The system also included a panic button, allowing workers to send manual distress signals. Their prototype was successfully tested in simulated environments, showcasing the feasibility of integrating multiple safety features into a wearable platform. This research highlighted the importance of live monitoring and immediate alert mechanisms in underground mining operations, aligning closely with your cap's approach using ESP32 and real-time communication.

[2] N. Dey et al., 2019, in this project the authors designed a smart helmet using IoT technology for real-time health and safety monitoring of coal mine workers. Their system utilized an ESP8266 microcontroller integrated with gas sensors, a temperature sensor, and a panic switch. Sensor data was transmitted wirelessly to a web server for live tracking. The helmet generated automatic alerts when abnormal conditions like high gas concentrations or overheating were detected. Field tests confirmed that the system could effectively detect multiple hazards and communicate alerts with minimal latency. The device was low-cost and energy-efficient, emphasizing its potential for mass deployment in mines. Their work strongly supports the architecture of your cap, which enhances safety with the addition of GPS, ultrasonic sensing, and ESP32-based control.

[3]. S. P. Mohapatra and A. Mahapatra, et al., 2018 this research introduced a GPS-enabled coal mine safety system that leverages wireless sensor networks (WSNs) to collect and transmit data on environmental parameters. Gas sensors were used to detect methane and carbon monoxide levels, while GPS modules provided real-time location data of miners underground. The sensor data was transmitted to a surface-level monitoring center using low-power RF communication. The system's routing protocol was optimized for underground conditions, improving reliability. The integration of geolocation with hazard detection provided enhanced situational awareness for supervisors. Your proposed 20 ESP32-based cap builds on this by including onboard alert systems and a web dashboard for real-time visualization, improving user interaction and response time.

[4] S. Roy, P. Basak, and S. Sarkar, et al., 2020 in this paper, the authors developed a compact IoT system to monitor hazardous gas levels in underground coal mines. Their system used MQ-series gas sensors for detecting combustible and toxic gases, including methane and carbon monoxide. A NodeMCU board collected the sensor data and transmitted it via Wi-Fi to an IoT dashboard. The dashboard allowed supervisors to observe gas concentrations in real time and set alert thresholds for immediate response. The prototype emphasized low power consumption and ease of deployment. This design supports your project's use of ESP32 and web-based interfaces for live safety updates. However, your solution adds significant value by integrating location tracking, panic alerts, and an LCD for local display.

[5] P. Bhattacharjee and S. De, et al., 2020the authors proposed an IoT-based underground coal mine monitoring system that employed ESP8266 microcontrollers to gather data from DHT11 temperature-humidity sensors and gas sensors. The collected data was sent to a remote server via Wi-Fi and could be accessed through a web-based dashboard. The system provided real-time data visualization, helping supervisors assess the mine's conditions. The research focused on developing a scalable, low-cost, and easily maintainable solution. The study showed high responsiveness and accuracy in sensor output. Compared to this, your project uses a more capable ESP32, adds location services with GPS, a panic button, and obstacle detection, thereby offering a comprehensive solution in a wearable form factor.

[6] R. K. Megalingam et al., (2021) this paper explored the use of wireless sensor networks to enhance mine safety through distributed environmental monitoring. The system deployed multiple sensor nodes equipped with gas and temperature sensors. Each node communicated wirelessly with a central base station, ensuring full mine coverage. The system was designed for fault tolerance, energy efficiency, and scalability. Alerts were generated automatically when sensor readings crossed predefined thresholds. The work proved the effectiveness of decentralized monitoring systems in reducing risk to miners. While their system was stationary and centralized, your wearable cap system offers more mobility and direct user alerts, increasing personal safety.

III. PROPOSED SYSTEM

In this project we would redefine industry safety standards by developing an ultra-modern protective helmet with advanced IoT (Internet of Things) technologies, especially made for miners.

A wide range of sensors, including gas detectors, temperature and humidity sensors, and others, will be integrated into this state-of-the-art helmet to enable real-time monitoring of critical physiological and environmental variables. These sensors will gather data, which will be evaluated by advanced algorithms that can recognize anomalies that could be signs of danger or emergencies. In addition, a strong communication system will make it easier to transmit this data to a central monitoring station, which will guarantee prompt attention to any safety issues. The integration of aural, and haptic feedback systems will enhance workers' situational awareness and facilitate prompt response in crucial situations by providing instant alerts. A user-friendly monitoring app (Blynk) will also be created, giving managers the ability to keep an eye on employees' safety conditions and take proactive measures to address any threats before they arise. We hope to provide a complete solution that not only satisfies but surpasses the industry's strict safety standards. This project sets new standards for safety in dangerous work conditions and significant improvement in the safety and health of mine workers. Modern mines often employ a variety of safety procedures, worker education and training programs, and health and safety laws, which greatly changes and raises, which significantly alters and raises the bar for safety in both opencast and underground mining. The removal of high-risk environments can be aided by mine ventilation systems. The use of canaries and other animals are used to alert miners when turns hazardous in the origin of early methods for monitoring the atmosphere in mining operations. A "safety helmet" is the most basic device that mine workers take with them. As a result, this helmet is chosen as the focal point for the improvisation, keeping the helmet's features intact. Only accurate environmental sensing will be able to address the issues raised. A microcontroller is interfaced with a variety of sensors for this purpose. The structure of industrial helmets is said to include a vacuum between the inner and outer layers, which may be the best location for the electronic components. The issue of data transmission from the helmet to the control room also exists. Due to the variable dimensions of mines, routers cannot be installed inside of them. This might be accomplished by connecting every helmet to a wireless network so that data from the end nodes can be sent to the coordinator via a mesh network. Monitoring the mine's internal conditions is the final task to be completed. Using the idea of IoT might potentially lower the enormous cost required to set up a separate control Centre. Mining serves as essential for the development of goods, services, and infrastructure that raise people's standard of living. Because industry combines raw materials to create manufactured items, we as a society are lucky to have access to their many advantages. The temperature, heart rate, and GPS sensors on the helmet allow for real-time monitoring of the miners' well-being. The heart rate sensor tracks the miners' heart rates to identify any unusual activity and notify the safety crew if there are any health concerns.

This is particularly crucial in hazardous and physically taxing jobs like mining. The temperature sensor keeps track of both the ambient and the miner's body temperatures. It can identify whether a miner is experiencing heat exhaustion or whether the high temperatures are making the surrounding area dangerous. Overall, by offering real-time monitoring and notifications for potential hazards or health issues, an IoT-based safety helmet for miners can greatly enhance their safety and well-being. So, we here designed a block diagram keeping all of these parameters in mind. The proposed architecture is provided in the fig.1

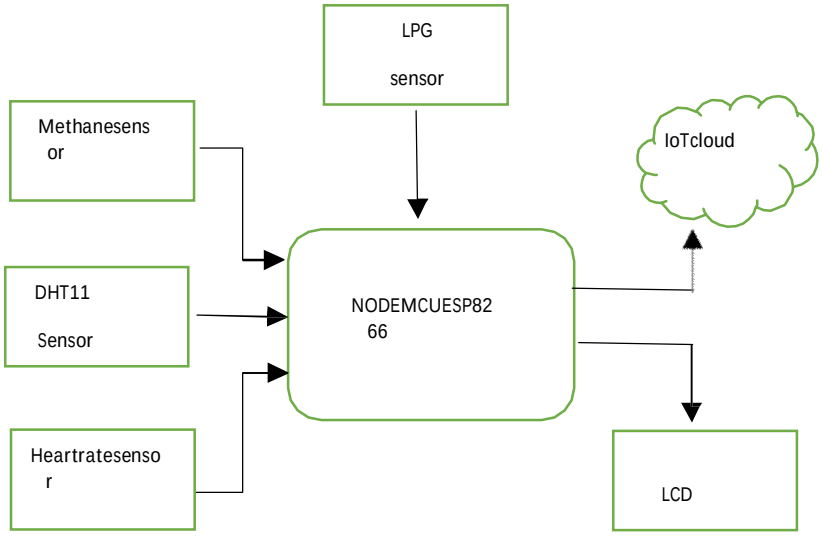

Fig.1 Proposed block diagram of safety helmet for mining worker using IOT

So, now we here use a software called proteus which is one software tool for electronic design automation (EDA) is called Proteus. The main applications for it are PCB (printed circuit board) design, simulation, and schematic capture. Electronic engineers and enthusiasts alike use Proteus to build and test circuits prior to actual implementation. It enables users to efficiently and accurately design, test, and layout PCBs. The program is a useful tool for embedded system development since it has a simulation module that can mimic the behavior of designs based on microcontrollers. Proteus is a flexible tool for electronics design and prototyping all around. Simulation of microcontrollers is done. The Proteus micro-controller simulations are run by attaching a hex file or a debug file to the schematic's microcontroller section. All electronic devices, both digital and analog attached to it are then co-simulated with it. This makes it possible to utilize it for a wide range of project prototyping, including

user interface design, temperature control, motor control. It is also useful for general hobbyists and is convenient to use as a training or teaching tool because no hardware is needed. By this we here design a schematic circuit using the proteus software app. Now here we also use Blynk app with NodeMCU for safety helmets in mining. With this configuration, we here monitor the environment and conditions inside the mine by integrating sensors like temperature, humidity, and even gas detectors. This can also incorporate features like real-time location tracking and panic buttons that let employees to notify supervisors in the event of an emergency. It's an effective technique to improve safety protocols in dangerous areas, such as mines. One useful way to monitor environmental conditions with IoT technology is by using a Blynk app and a DHT11 sensor incorporated into mining safety helmets. The temperature and humidity can be measured using the DHT11 sensor, which offers useful information to guarantee the comfort and safety of miners. Supervisors may remotely monitor the temperature and humidity levels experienced by workers in real-time by attaching the DHT11 sensor to a NodeMCU board and combining it with the Blynk app.This makes it possible to take preventative action to lessen the hazards brought on by harsh environments, protecting the safety of mining workers. The critical safety precaution for mining workers utilizing IoT technology where here we integrated a Blynk app with a methane sensor in their safety helmets. Methane gas is a common concern in mining sites, and methane sensors can detect potentially harmful levels of the gas. So, by integrating methane sensor in their helmets this makes it possible to respond quickly in the event that dangerous levels are found, allowing for the evacuation of employees or the installation of ventilation techniques to lessen the possibility of explosions or health problems from methane exposure. The safety procedures in mining operations will be greatly improved by this application. Now we integrated an LPG (liquefied petroleum gas) sensor in their safety helmets. Potentially dangerous gas leaks, which can present significant concerns in mining operations, can be detected by LPG sensors. We here can remotely check gas levels in real-time by attaching the LPG sensor to a NodeMCU board and connecting it to the Blynk app. In the event that a gas leak is discovered, this enables prompt action to be taken, such as worker evacuation or equipment shutdown to avoid mishaps or explosions. By putting such a system in place, safety precautions are greatly improved, and mining workers' wellbeing is protected. A heart rate sensor is integrated into safety helmets for miners, important information about the health and welfare of workers in hazardous conditions will be obtained. This makes it possible to identify possible health concerns or emergencies like overdoing it, stress, or heart-related issues. This helps safeguarding the mining workers' physical health and improves safety protocol. The Blynk app has an ability to log sensor data over time. The mine's working conditions can be improved or safety audits and compliance reporting can be conducted using this data. So, by this we may improve safety protocols and guarantee the wellbeing of mining staff by remotely monitoring environmental conditions and worker health in real-time by integrating the Blynk app software into the safety helmet used by workers.

IV. RESULT AND DISCUSSIONS

In accordance to this principle, the helmet functions as a multifunctional equipment to detect potentially hazardous gases in a mining area, such as methane or excessive CO2. To more accurately monitor the standard of life for coalmine miners and estimate the amount of hazardous fumes present, we utilized four sensors. An ESP8266 NODE MCU, incorporated within this helmet, serves as an intermediary in the conveyance of the concentrations of chemicals of all the gases it comprises. Sensor data acquisition is facilitated by the microcontroller's built-in Wi-Fi module. The Blynk app simplifies this process and can be installed easily from the Google Play Store. In today's modernized world, the safety and health of workers should be protected especially when dealing with circumstances where there are several possible risks at work. The mining industry is intrinsically hazardous because toxic gases like CO2 and methane constantly jeopardize both the well-being of coalmine miners and their ability to sustain themselves.

This study introduces a multifunction safety helmet that employs contemporary sensor technology to detect and manage the number of toxic gases, resolving the issue of improving precautions for miners. As part of our research, we are monitoring the quantities of toxic substances using a total of four different sensors. The aforementioned sensors have become crucial since they provide precise data on concentrations of gases that preserve human health while assessing the air quality in the mining zone. It is essential to use this quick reaction system in order reduce the risks of toxic gas inhalation while safeguarding the health and safety of workers. The integration of interface modules and gas sensors with the ESP8266 microcontroller facilitates continuous surveillance and data retrieval. The Blynk program, that enables users to track and interpret gas concentration data remotely, significantly broadens the project's scope. An industrial safety management system might be supplied by our safety helmet's data from sensors, Wi-Fi connectivity, and real-time monitoring operations. The interface between the Blynk App and the microcontroller unit, executed in the Arduino IDE, plays an important role in establishing a seamless communication channel. An application known as an integrated development environment (IDE) gives computer-based developers all the tools they need to create software. Generally, an IDE contains at least source code. editor, debugger, and build tools for automation. Several IDEs, such as Lazarus and Sharp Develop, aren't provided with the necessary compiler or interpreter; other IDEs, as NetBeans and Eclipse, do. It can be hard to determine where an IDE often includes at least source code, editor, debugger, and automated building tools. This helps to meet specific requirements; the code relies on built-in libraries and functions for optimal functionality. Once transposed onto the ESP8266 microcontroller, this code establishes a connection between the microcontroller unit and the cloud. By handling the sensor data, the system not only enhances the safety of mining operations but also contributes to the environmental protection. By generating real-time insights into sensor readings, the Blynk mobile application allows users to take preventive actions in response to potentially dangerous circumstances. In simple terms, The Blynk application's integration with the Arduino development environment and esp8266 microcontroller establishes an infrastructure that assists in reading sensor values and protecting mining workers. This technology not only strengthens operational effectiveness but also indicates a commitment to environmental accountability and safety at coalmine work zones.

V. OUTCOMES OF THE SAFETYHELMET

To precisely measure the concentration of gases in the environment, a variety of gas sensors have been incorporated with the ESP8266, which is the primary microcontroller. This comprehensive sensing system ensures real-time gas level monitoring, providing crucial details to assess worker safety. This data can be accessed remotely according to the interface with a Wi-Fi module, which also makes connecting to the Blynk App easy. Users may immediately obtain gas concentration measurements through the Blynk App interface, which enables them to track and assess the environmental factors affecting the workforce.

FIG: 2Sensors Output displaying in the LCD

Additionally, the microcontroller is configured to obtain gas concentration threshold values that have been predefined. The system initiates a warning process in the event that the concentration being measured surpasses the limits that have been established. The sensors mounted on the helmet are tested for their capabilities within predetermined bounds as well as for particular tasks such as temperature, humidity, and dangerous chemical detection. Furthermore, functioning properly is the buzzer system, which receives its input from sensors. The buzzer begins to sound and the status is shown on the LCD display when the sensor values surpass their designated limits. The buzzer that is attached to the microcontroller produces an audible noise to notify individuals about elevated gas levels instantaneously. As a crucial safety attribute, this audible indicate makes sure workers are apprised of potential hazards right away and can implement precautions that are necessary. A thorough grasp of the work environment is made possible for both on-site and remote users by the incorporation of data collected by sensors, wireless internet access, and continuous surveillance abilities.

This revolutionary device delivers an effective solution for proactive gas tracking and cautioning in workplaces, while additionally enhancing security for workers. Here in the project, we used Proteus where Proteus is an all-around versatile tool for electronics designing and development. The way Proteus works its microcontroller simulation is by attaching a file with a hex extension or a debugging file to the schematic's microcontroller area. It then co-simulates with any correlated analog and digital electrical circuits. This makes it possible it to be utilized in a variety of project prototyping, such as motor control, temperature control, and user interface creation.

Because no additional equipment is required, it can be utilized readily as a training or instructional device and is also useful for regular enthusiasts. In this case, we use the Proteus software program to construct a schematic circuit. Now integrating all the sensors of the Node MCU we used the proteus software to design a circuit diagram.

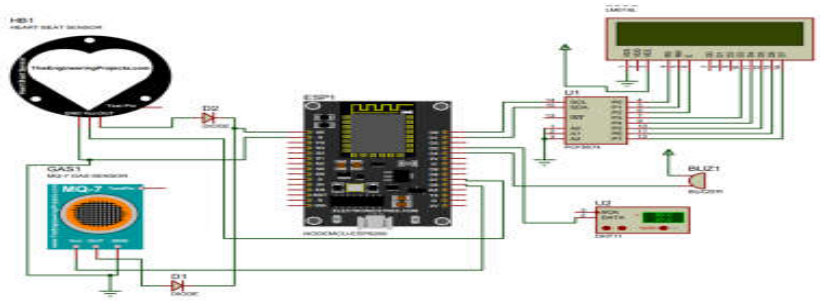

FIG: 3Proteus circuit diagram

Consequently, the integrated sensors' ultimate output, which has been incorporated in the helmet, is shown belowfigure:

FIG: 4Safety helmet completely embedded with sensors

VI. CONCLUSION

The proposed IoT-based Coal Mine Safety and Security Cap offers an effective and real-time solution for enhancing the safety of mine workers in hazardous underground conditions. By integrating multiple sensors including DHT11 for environmental monitoring, gas sensors for toxic gas detection, ultrasonic sensors for obstacle awareness, and a GPS module for location tracking this wearable device ensures comprehensive monitoring of both environmental and personal safety parameters. The inclusion of a panic button and buzzer facilitates quick emergency alerts, while the LCD display provides instant on-site feedback to the user. Furthermore, the system's ability to transmit live data to an HTML-based web dashboard allows remote supervisors to make informed decisions in real time. This smart, low-cost, and scalable solution has significant potential to reduce risks in mining operations and can be adapted for broader industrial safety applications in the future.

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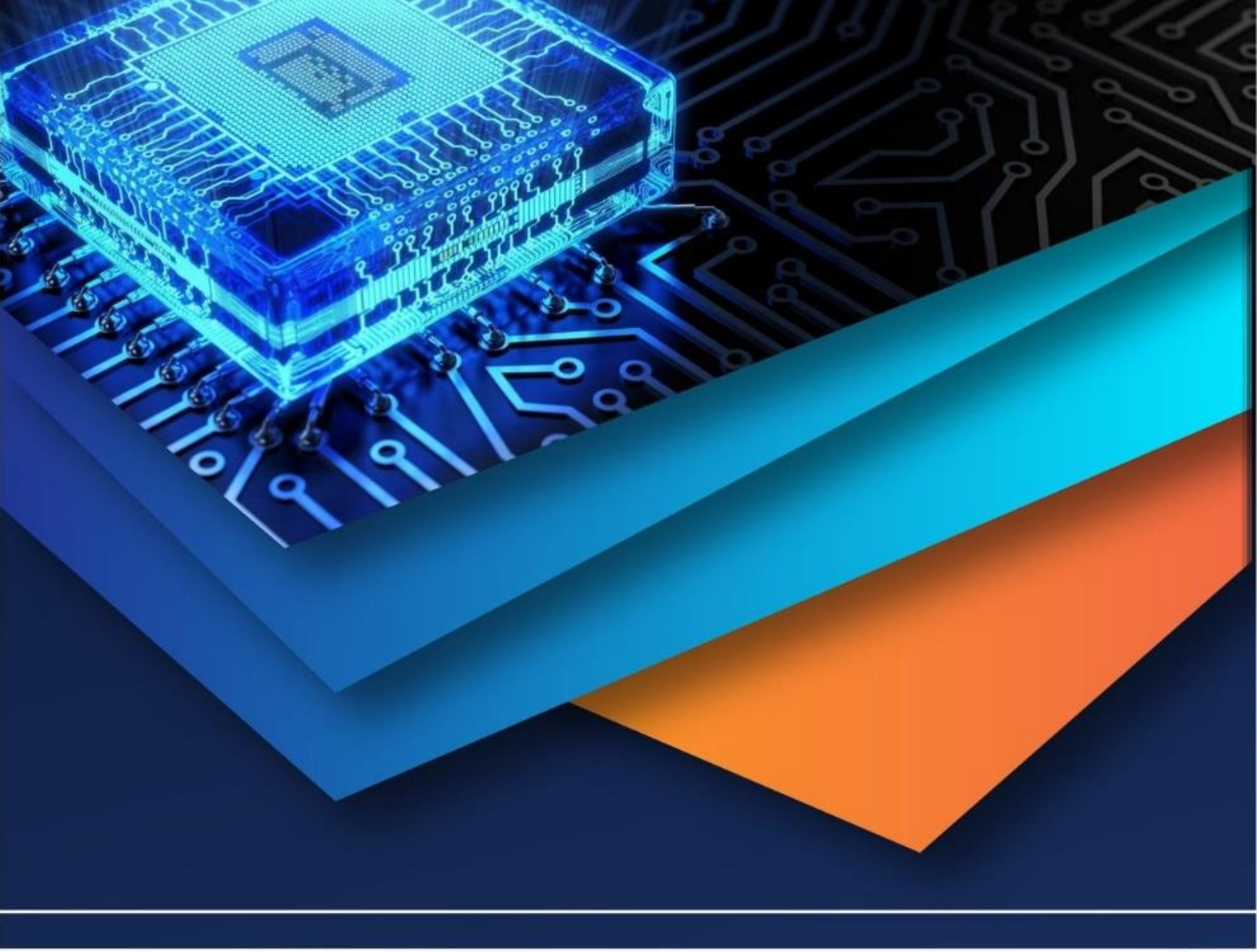

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