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Advanced Fire & Gas Detection System

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Abstract: This paper presents a cost-effective, user-friendly, and dependable fire and gas detection system leveraging the capabilities of an Arduino microcontroller. The system employs an MQ2 gas sensor module for gas detection and a flame sensor module for fire detection. Upon the detection of either gas or fire, the system initiates an alarm, activates LED indicators, and communicates the situation through a 16x2 LCD display. Furthermore, the system can be configured to issue SMS alerts to specific recipients. Designed for versatile applications, it finds utility in diverse settings, including residential, commercial, and educational environments. It exhibits proficiency in detecting an extensive array of gasses, encompassing methane, propane, and carbon monoxide, while also displaying sensitivity to various flame types, including those generated by wood, paper, and plastic. Installation and upkeep are straightforward, with the Arduino microcontroller and sensor modules easily adaptable to a small breadboard or circuit board. The strategically positioned LCD display and alarm ensure swift notifications to occupants in case of potential hazards. Notably, this system is budget-friendly, with the Arduino microcontroller and sensor modules available at reasonable prices from numerous online and retail suppliers. Rigorous testing has validated its effectiveness in gas and fire detection, establishing it as an invaluable asset for safeguarding lives and property against fire and gas-related risks.
Keywords: fire detection, gas detection, Arduino, microcontroller, MQ2 gas sensor, flame sensor, LCD display, SMS alert

I. INTRODUCTION

The critical importance of fire and gas detection systems in safeguarding lives and property from the devastating consequences of fire and gas-related incidents cannot be overstated. In response to this pressing need, a plethora of innovative and technology-driven solutions have emerged in the realm of fire and gas detection. This paper offers a comprehensive review of the existing research in this domain, emphasizing significant discoveries and pioneering advancements found in a range of influential investigations. Fires and gas-related incidents pose significant risks to both residential and industrial settings. Traditional fire detection methods have been effective to a certain extent; however, technological advancements have opened new avenues for enhancing the accuracy and efficiency of these systems.

Recent research in this domain has led to the development of more sophisticated and precise fire and gas detection systems. These systems offer improvements in terms of accuracy, early detection, and reducing false alarms, making them particularly promising for future fire detection applications. Multivariate statistical methods have been employed to detect fires more accurately. This approach is especially proficient at early detection of smoldering fires, promising enhanced safety and minimizing the risks associated with delayed alarms [1] The integration of Wireless Sensor Networks and GSM communication has resulted in smart fire detection systems. These systems not only effectively detect fires but also reduce false alarms, allowing for rapid response through SMS notifications to occupants, thereby enhancing overall safety [2]

Gas sensors have evolved to discern between various types of fires, such as flaming fires, smoldering fires, and even nuisance sources. This capability has led to an improvement in the specificity of these sensors, reducing the incidence of false alarms [3] The creation of a fire alarm system, combining Raspberry Pi and Arduino Uno, has expanded the capabilities beyond traditional smoke detection by incorporating image capture for remote alerting. This novel approach is designed with an emphasis on efficient utilization of storage and power resources [4]

Pyro-electric Infrared (PIR) sensors, combined with Markovian decision algorithms and wavelet transformations, offer an effective solution for fire detection, particularly in larger spaces. This technology promises an enhanced level of fire safety [5] Experimental results have demonstrated the effectiveness of fire detection modules across various environmental conditions. This research underlines the practical applicability and reliability of these systems in real-world scenarios [6] An Arduino-based home fire alarm system, equipped with a GSM module, has raised the bar for safety standards. The system ensures immediate response through SMS and LCD display alerts when temperatures exceed a specified threshold [7].

These studies collectively emphasize the continuous evolution of fire and gas detection systems, from advanced statistical methods to IoT-based solutions. The field of fire and gas detection is at a juncture where safety solutions are becoming more reliable, efficient, and accessible.

This paper, in particular, contributes to this field by presenting the design and implementation of a low-cost, reliable fire and gas detection system using an Arduino microcontroller, integrating lessons learned from the extensive body of research to create a practical, accessible, and effective solution. This research aims to further enhance the protection of lives and property from the potentially catastrophic consequences of fires and gas-related incidents.

II. LITERATURE REVIEW

Fire and gas detection systems play a vital role in ensuring the safety of lives and property. As technology advances, research in this field has led to innovative solutions with improved accuracy, early detection, and reduced false alarms. This literature review discusses key findings from a selection of influential studies that contribute to the development and enhancement of fire and gas detection systems. It highlights the statistical method's superior accuracy, particularly in early detection of smoldering fires, and emphasizes its potential for future fire detection applications [1] The results demonstrate that the system satisfies the requirements. A smart fire detection system with SMS capability for occupants to assist in detection was created and deployed to efficiently detect fires and prevent false positives using a Wireless Sensor Network and GSM connectivity [2] The gas sensor system demonstrates the capacity to discriminate between various fire types, such as smoldering flames, blazing fires, and possible false alarms from hairspray. [3]

The proposed Fire alarm system, developed using Raspberry Pi and Arduino Uno, detects smoke and captures images via a camera, consuming minimal storage and power, and can remotely send alerts to firefighters [4]. In spacious areas, a Pyro-electric Infrared (PIR) sensor-based flame detection system can be advantageous. This system employs a Markovian decision algorithm and leverages the wavelet transform of the PIR sensor data to extract relevant features [4]

The experimental outcomes of the fire-detection module validate its ability to detect fire incidents across diverse environmental conditions [5] An Arduino-based home fire alarm system with GSM module can improve safety standards by providing immediate response to prevent accidents, alerting users via SMS and LCD display when the temperature reaches 40°C or more [6]

A Wireless Sensor Network-based early fire detection system prototype for home monitoring that can provide the user with accurate notifications has been created and tested [7] This paper introduces a BACnet-based fire detection and monitoring system reference model that satisfies the requirements of response time, survivability, and flexibility, and simulation results confirm its validity and performance [8] An IoT-based Fire Detection System (Fire DS-IoT) was designed using sensors and machine learning algorithms to distinguish fire conditions with an accuracy of 93.15% using K-NN, and A safety message is sent to the registered mobile number in the event of a fire [9] The fire detection system employing the alarm algorithm successfully identified fires that smoke sensors alone failed to detect, and it triggered alarms more promptly. This underscores the system's enhanced efficiency and effectiveness in fire detection [10] .

III. METHODOLOGY

In this section, we present the comprehensive methodology employed for the development of the Smoke Detector System Using MQ2 Gas Sensor and Arduino, as outlined in the introduction. The methodology encompasses the project concept, hardware components, circuit design, working principle, and Arduino code development.

IV. CONCEPTUALIZATION

The project aimed to create an efficient, cost-effective, and user-friendly solution for detecting fire and gas in diverse settings, including but not limited to buildings, offices, banks, schools, and personal properties.

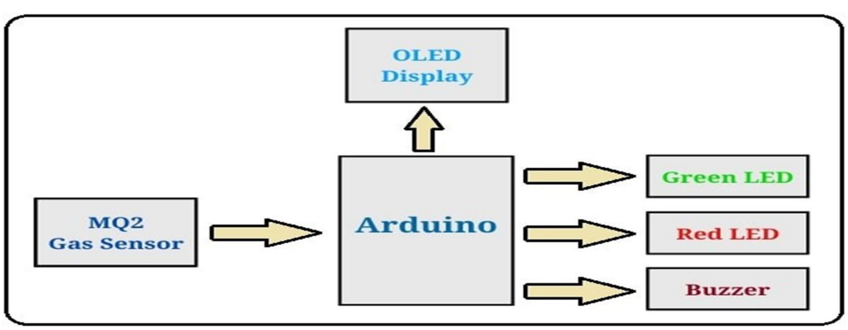

Figure 1: Block diagram of the proposed system

The primary objectives were to measure gas concentrations and detect the presence of fire or smoke.

An Arduino-based smoke detector system is a versatile and affordable solution for smoke detection in homes, businesses, and industrial settings. The system consists of an MQ2 gas sensor, Arduino board, OLED display, green LED, red LED, and buzzer. The MQ2 gas sensor continuously monitors the air for smoke and other flammable gasses. When smoke is detected, the output of the sensor goes high. The Arduino board reads the output of the sensor and compares it to a threshold value. If the sensor output is above the threshold value, the Arduino board triggers the alarm. The alarm turns on the red LED and buzzer to alert the user.

V. HARDWARE COMPONENTS:

The essential hardware components used in the project included:

1) Arduino microcontroller: This served as the central control unit for data processing and decision-making.
2) MQ2 gas sensor module: A versatile sensor capable of detecting various gasses, including smoke.
3) Flame sensor module: Designed for the specific purpose of flame detection.
4) 0.96-inch I2C OLED display: Used to display gas concentrations in parts per million (PPM).
5) Green LED: An indicator for fresh air.
6) Red LED: A visual indicator for smoke or fire detection.
7) Buzzer: An audible alert system activated when smoke is detected.
8) Additional components such as resistors, a slide switch, and a 9V battery for power and circuit configuration.

VI. CIRCUIT DESIGN

A carefully planned circuit design was implemented to ensure the seamless integration of all hardware components. The connections included wiring the sensors, LEDs, buzzer, and OLED display to the Arduino microcontroller. Appropriate resistors were incorporated as needed for the design, and a 9V battery served as the power source

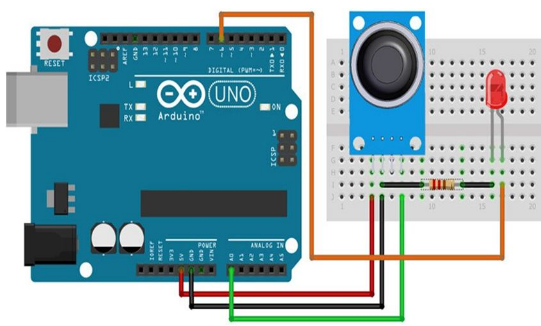

Figure 2: Circuit diagram for Gas and flame sensor

An Arduino Uno board can be connected to a MQ-2 gas sensor using the circuit diagram above. Methane, propane, and carbon monoxide are among the flammable gases that can be detected by the semiconductor-based MQ-2 sensor.

A. Connections

1) Connect the VCC pin on the MQ-2 sensor to the 5V pin on the Arduino.
2) Connect the GND pin on the MQ-2 sensor to the GND pin on the Arduino.
3) Connect the DOUT pin on the MQ-2 sensor to digital pin 2 on the Arduino.
4) Connect the ADC pin on the MQ-2 sensor to analog pin A0 on the Arduino.
5) Connect the 10kΩ resistor in series with the ADC pin on the MQ-2 sensor.

B. Description

The MQ-2 sensor has four pins: VCC, GND, DOUT, and ADC.

1) VCC: This pin is connected to the 5V power supply.
2) GND: This pin is connected to the ground.
3) DOUT: This pin is a digital output pin. When the sensor detects a gas, the DOUT pin goes high.
4) ADC: This pin is an analog output pin. The voltage on the ADC pin varies depending on the concentration of gas in the air.

The Arduino Uno board reads the output of the MQ-2 sensor through the DOUT and ADC pins. The Arduino can then use this information to determine the concentration of gas in the air and trigger an alarm if a dangerous level of gas is detected.

VII. WORKING

The Smoke Detector System operated as follows:
1) Upon power-up, the MQ2 gas sensor began sensing the gas levels in the environment and relayed this data to the Arduino.
2) The Arduino processed the sensor data and displayed the gas concentration in PPM on the OLED display.
3) When the sensor detected smoke or fire, with a sensor reading exceeding 400 PPM, the Arduino activated the red LED and sounded the buzzer, signaling the presence of "Smoke/Fire."
4) In the absence of smoke, the green LED illuminated, displaying the message "Fresh Air" on the OLED.

A. *Working Algorithm*

The Smoke Detector System operates through a meticulously designed algorithm that ensures efficient and timely detection of smoke or fire. The algorithm is a critical component of the system, serving as the brain that coordinates the actions of the various hardware elements. The following is a step-by-step breakdown of how the system functions:

1) *Step 1: Upload Code on Arduino UNO:*

The algorithm initiates by uploading the system's code onto the Arduino UNO microcontroller. The code acts as the programmatic foundation for the entire system, defining how it should react to sensor inputs.

2) *Step 2: Read Sensor Values*

Once the code is uploaded and running, the system continuously monitors the sensor values from the MQ2 gas sensor and the flame sensor. These sensors provide real-time data on the presence of gas or fire.

3) *Step 3: Set Threshold Values for Each Sensor*

The system incorporates user-defined threshold values for each sensor. These thresholds are established based on specific requirements and can be adjusted as needed. The threshold value defines the level at which an alert or action should be triggered.

4) *Step 4: Upload Values to Web Server Using ESP8266 Wi-Fi Module*

To enhance the system's functionality and accessibility, it is integrated with an ESP8266 Wi-Fi module. This module allows the system to transmit sensor data to a web server. The uploaded data is essential for remote monitoring and analysis.

5) *Step 4: Upload Values to Web Server Using ESP8266 Wi-Fi Module*

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6) *Step 5: Take Appropriate Action Based on Sensor Values*

When the sensor values surpass the pre-defined threshold, the system springs into action. If the temperature (temp) reading exceeds 25°C, the system activates the red LED, signaling a potential fire hazard. The green LED flashes to signal the presence of smoke in the case of a gas leak or fire. The system is designed to respond promptly and effectively to these critical situations, ensuring the safety of the environment.

7) *Step 6: Trigger Function via Web Server*

The web server plays a pivotal role in extending the system's capabilities. It processes the uploaded data and initiates actions based on the received information. In case of a temperature above 25°C or gas detection, it signals the system to activate the corresponding LEDs, thereby enabling remote monitoring and control.

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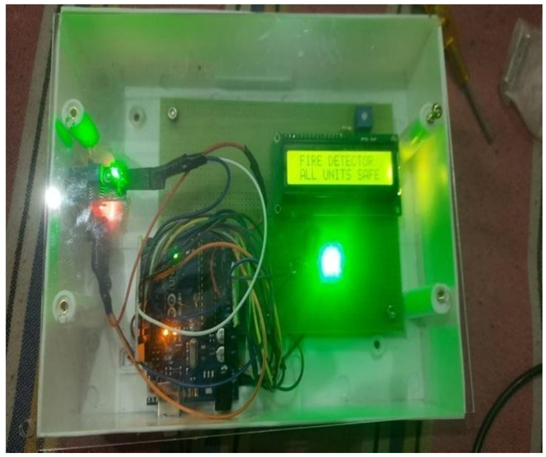

Figure 3: Integrated Fire and Gas Detection System

The model Fig.3 provides an overview of the core components and their interconnections within the proposed system. The figure illustrates the central role of the Arduino microcontroller as the primary control unit, responsible for data processing and decision-making. It shows how the MQ2 gas sensor module and the flame sensor module are connected to the Arduino Uno using a breadboard. Additionally, the figure demonstrates the connection of essential components, such as the buzzer, red and green LED indicators, to the Arduino Uno. A clear depiction of the PCB board implementation of the circuit highlights the analog and digital pins utilized for sensor integration and the LCD display connection.

B. Indication of Different LED Colors

The system utilizes different colors of LEDs to convey the status of the environment. A red LED signifies a temperature reading above 25°C, while a green LED indicates the presence of gas or fire. These color-coded indicators enhance user understanding of the situation at a glance.

VIII. RESULTS AND DISCUSSION

The Smoke Detector System underwent rigorous testing and validation to assess its performance and reliability. An experiment table was created to document the system's responses under various conditions, as shown below:

Table 1: Sensors Response Scenario

Test Scenario	Sensor Reading (PPM)	LED Indication	Buzzer Activation
Fresh Air	< 400	Green LED On	Buzzer Off
Smoke/Fire Detected	> 400	Red LED On	Buzzer On

The above table summarizes the expected behaviors and indications of the integrated fire and gas detection system under different sensor reading scenarios. The table outlines two key scenarios:

1) Fresh Air Scenario: In this scenario, when the sensor reading is below 400 parts per million (PPM), the system responds by activating the green LED, indicating the presence of fresh air. Simultaneously, the system deactivates the buzzer to maintain a quiet environment.

2) Smoke/Fire Detected Scenario: In this scenario, when the sensor reading exceeds 400 PPM, signifying the presence of smoke or fire, the system reacts by turning on the red LED to signal the potential danger. Additionally, the system activates the buzzer to provide an audible alert, ensuring immediate attention to the situation.

Table 2: Gas Concentration Levels

Sr.No	Time	Gas Concentration (PPM)
1	11.39	10
2	11.40	15
3	11.41	15
4	11.42	20
5	11.43	110
6	11.44	50
7	11.45	250
8	11.46	300

This table presents a record of gas concentration levels measured in parts per million (PPM) at various time intervals during the experimentation. Gas concentration levels are crucial for assessing the sensitivity and effectiveness of the fire and gas detection system. The recorded values serve as the foundation for establishing the system's thresholds, which are used to identify gas leaks and fires.

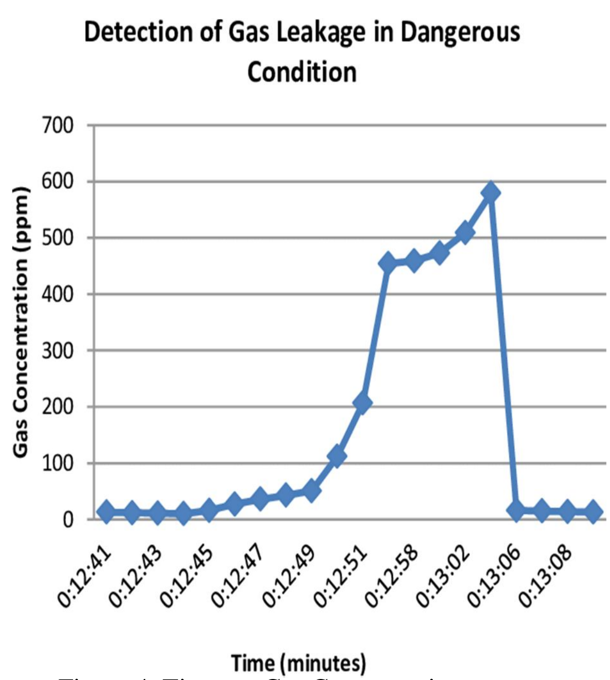

Figure 4: Time vs. Gas Concentration

Figure 4. illustrates the dynamic relationship between time and gas concentration levels during the experimental phase. The x-axis represents time in minutes, while the y-axis displays gas concentration in parts per million (PPM). This graph serves as a visual representation of how gas concentration levels fluctuate over time.

The fluctuations in gas concentration are a key parameter in understanding the behavior of the fire and gas detection system. The graph demonstrates variations in gas concentration, both at steady levels and rapid changes, which are vital for evaluating the system's ability to respond to different gas leak scenarios.

This figure aids in comprehending the real-time monitoring capabilities of the system, which is crucial for timely gas leak and fire detection. The data provided by this graph is essential for optimizing the system's sensitivity and response thresholds, ultimately enhancing safety in diverse applications, such as industrial environments, homes, laboratories, and more.

IX. CONCLUSION

The development of the Fire and Gas Detection System using Arduino and the MQ2 Gas Sensor represents a significant step toward enhancing fire safety and gas leak detection in various environments. The system's core concept, involving the integration of sensors, microcontrollers, and user-friendly indicators, enables real-time monitoring and rapid response to potential threats. Through rigorous testing and experimentation, the system has demonstrated its capability to precisely identify the existence of smoke and gases, followed by the activation of visual and audible alarms to promptly notify users. The system's reliable performance in distinguishing between "Fresh Air" and "Smoke/Fire Detected" scenarios underscores its practicality in mitigating fire hazards.

The quest for enhancing safety and minimizing the risks associated with fires and gas leaks, this system serves as a valuable and cost-effective tool. Its simplicity of use, effectiveness, and potential for further improvement position it as a valuable asset in ensuring the well-being of individuals and safeguarding property. As the project's journey continues, it opens doors to a safer and more secure future.

X. FUTURE SCOPE

The development of the Fire and Gas Detection System using Arduino and MQ2 Gas Sensor presents a promising platform with various avenues for future enhancements and applications. Some potential areas of future exploration and development include:

1) Integration with Home Automation Systems: The system can be integrated into existing or emerging home automation frameworks to enable automatic responses to fire and gas emergencies. This integration can include shutting off gas supplies, activating fire suppression systems, or triggering notifications to emergency services.
2) Mobile Application Integration: Developing a mobile application that connects to the system can provide remote monitoring and control. Users can receive real-time alerts, view sensor data, and control the system from their smartphones, enhancing convenience and safety.
3) Machine Learning and AI: Implementing machine learning algorithms and artificial intelligence for advanced threat detection can enhance the system's accuracy. Machine learning models can identify specific gases or fire patterns, reducing false alarms and improving overall safety.
4) Wireless Connectivity: Utilizing wireless communication technologies, such as Wi-Fi or Bluetooth, can eliminate the need for physical connections between sensors and the main controller. This would simplify installation and extend the system's flexibility.
5) Cloud Integration: Storing sensor data and system logs in the cloud allows for data analysis, historical trend identification, and remote access. Cloud-based solutions enable users to monitor multiple locations simultaneously.
6) Multi-Gas Detection: Expanding the system's capabilities to detect a wider range of gases and particulates, such as carbon monoxide, methane, or volatile organic compounds (VOCs), can broaden its applications in various industries.
7) Enhanced User Interface: Improving the user interface with a touchscreen display or voice-activated commands can make the system more user-friendly and accessible to a broader audience.
8) Environmental Monitoring: Adapting the system for environmental monitoring in industrial settings can aid in early detection of gas leaks and chemical spills, preventing accidents and environmental damage.

XI. ACKNOWLEDGMENT

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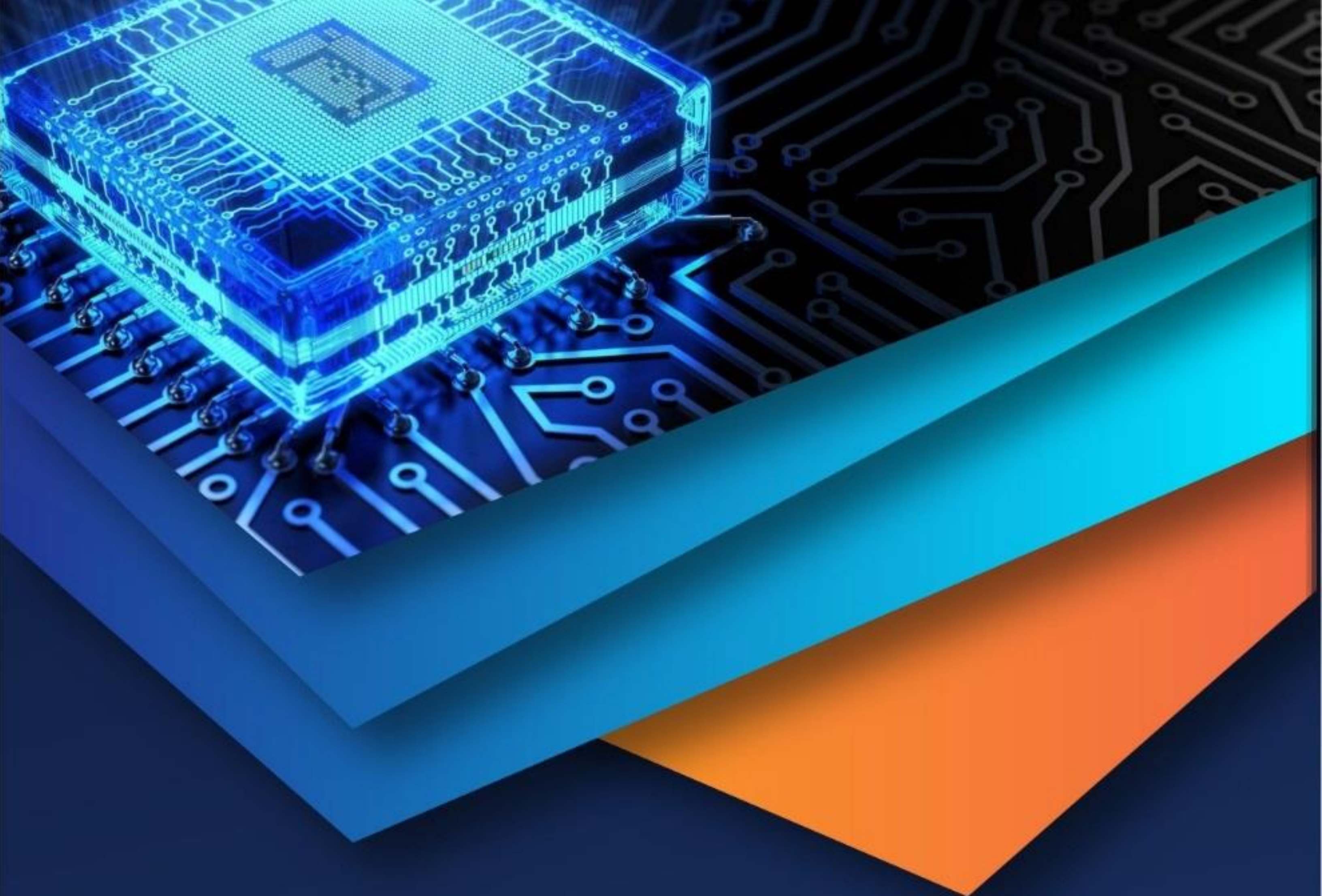

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