iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.69430

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

IOT Based Water Quality Monitoring System using ESP32

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Abstract: The rapid growth of the human population, combined with environmental degradation and climate changes, is turning clean water into an increasingly scarce resource. As a result, monitoring water quality, especially for drinking purposes, has become crucial. Traditional methods of laboratory testing are time-consuming, costly, and fail to provide real-time results. Moreover, systems based on Wireless Sensor Networks (WSN) technology often face challenges in areas like data security, energy management, and communication coverage. Critical sectors, such as flood warning systems, irrigation networks, power generation, and research, rely heavily on accurate flood-level data. Historically, water levels have been measured manually, but this approach is prone to inaccuracies due to difficulties in accessing the measurement sites and human error. To address this, data can be transmitted to a central server via a web interface for database management. Access to this data is secured by passwords, ensuring that only authorized users can view it. Additionally, customers are billed based on their water consumption, which is monitored through a flow sensor connected to an ESP32, providing measurements in liters per minute or other volumetric units.
Keywords: ESP32, pH Sensor, dht11 Sensor, Turbidity Sensor, TDS Sensor, GSM.

I. INTRODUCTION

Access to clean and safe water is essential for environmental sustainability, economic growth, and human health [1-5]. According to the World Health Organization (WHO), water contamination from microbial diseases, chemicals, and pollutants leads to over 5 million deaths annually, posing significant risks to ecosystems and public health [6-9]. To effectively monitor, regulate, and safeguard water quality, there is a pressing need for innovative technologies and solutions [10-11]. This research introduces an IoT-based water quality monitoring and management system aimed at addressing these challenges [12-13]. By leveraging advanced sensors, wireless communication technologies, and IoT platforms, the system provides real-time data on key water quality parameters such as pH, temperature, turbidity, and total dissolved solids (TDS), enabling comprehensive monitoring, analysis, and management of water resources [14-15].

II. FLOW CHART

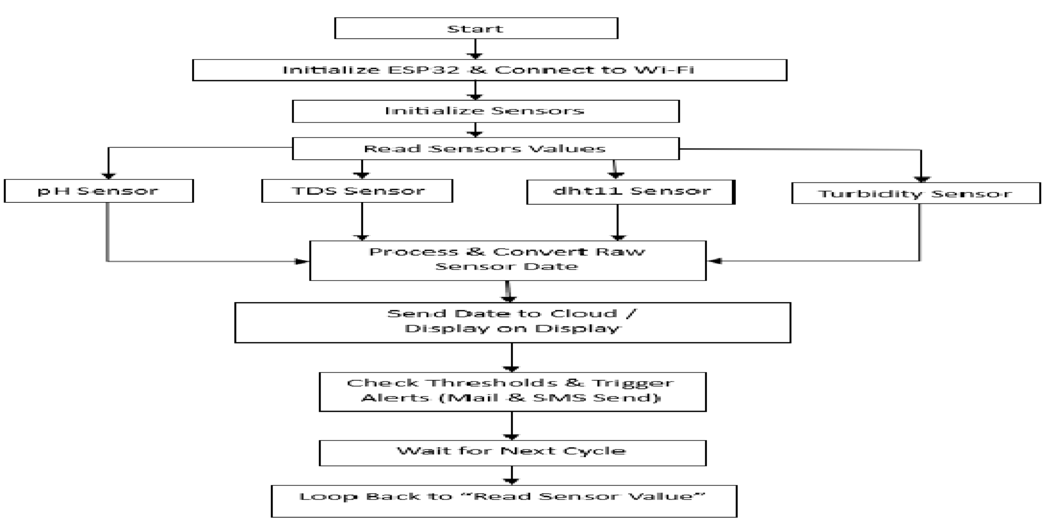

Fig.1. Flow Chart

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1) *System Startup*
- The process begins when the ESP32 is powered on.
- Basic initialization routines run to set up the microcontroller for further operations, including preparing connections with sensors and cloud services.

2) *ESP32 Initialization & Wi-Fi Connection*
- The ESP32 sets up its hardware modules and begins initializing required libraries.
- It then attempts to connect to a specified Wi-Fi network using saved credentials.
- Establishing this connection is essential for sending data to cloud platforms and enabling remote access.

3) *Sensor Initialization*
- All connected sensors, such as those for pH, turbidity, TDS, and dht11, are set up.
- The ESP32 configures the necessary GPIO pins (Analog/digital) and begins communication with each sensor.
- It ensures that all sensors are functioning and ready to provide accurate readings.

4) *Data Acquisition from Sensors*
- The ESP32 collects data from the attached sensors.
- Typical sensors include:
  - pH sensor – to measure acidity or alkalinity.
  - Turbidity sensor – to assess the clarity of the water.
  - TDS sensor – to determine the level of dissolved solids.
  - DHT11 sensor – to measure the temperature of the environment or water (if waterproofed).

5) *Data Processing & Conversion*
- The ESP32 processes the raw sensor output.
- This step involves converting voltage levels or digital values into real-world units (like pH levels, NTU for turbidity, °C for temperature, PPM for TDS.).
- Calibration formulas or correction factors are applied to improve accuracy.

6) *Cloud Transmission / Dashboard Display*
- The refined sensor data is uploaded to a cloud platform (such as ThingSpeak).
- This allows users to view real-time water quality stats remotely via apps or web interfaces.
- Optionally, the data can also be shown locally on an LCD screen.

7) *Threshold Monitoring & Alerts*
- The ESP32 continuously evaluates if the collected values fall within safe and acceptable ranges.
- If any reading exceeds its threshold (e.g., too high TDS or very low pH), the system triggers alerts.
- Alert methods may include:
  - Smartphone notifications using services like SMS or Mail Alert

8) *Delay Before Next Reading*
- To avoid excessive power usage and prevent data flooding, the system waits for a defined interval before restarting the cycle.
- After this pause, it loops back to read new data from the sensors again.

III. PROPOSED SYSTEM

Access to clean and safe water is essential for environmental sustainability, economic growth, and human health. According to the World Health Organization (WHO), water contamination from microbial diseases, chemicals, and pollutants leads to over 5 million deaths annually, posing significant risks to ecosystems and public health.

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To effectively monitor, regulate, and safeguard water quality, there is a pressing need for innovative technologies and solutions. This research introduces an IoT-based water quality monitoring and management system aimed at addressing these challenges. By leveraging advanced sensors, wireless communication technologies, and IoT platforms, the system provides real-time data on key water quality parameters such as pH, temperature, turbidity, and total dissolved solids (TDS), enabling comprehensive monitoring, analysis, and management of water resources.

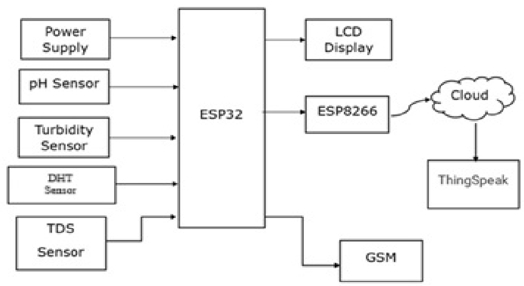

Fig.2. Block diagram of proposed system

IV. HARDWARE IMPLEMENTATION

A. ESP32 Microcontroller

The ESP32, developed by Expressif Systems, is an upgraded version of the ESP8266 and is widely used in various embedded system and Internet of Things (IoT) applications due to its integrated Bluetooth and Wi-Fi capabilities. The chip, built using TSMC's 40-nanometer process, offers a compact footprint on the PCB while delivering excellent RF performance, stability,and low power consumption. It incorporates several components, such as antenna switches, RF modules, poweramplifiers,low noise amplifiers, filters, and power management modules, to optimize its functionality.

Fig.3. ESP32 Microcontroller

This allows developers to choose the approach that best suits their needs, making DIY projects more flexible and accessible. Its open-source nature, combined with extensive documentation, makes it beginner-friendly, lowering the entry barrier for new developers.

B. ESP8266 Microcontroller

The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capabilities, widely used in Internet of Things (IoT) applications.

Fig.4. ESP8266 Microcontroller

It operates at 3.3V and can be integrated with Arduino development boards to provide Wi-Fi connectivity, as most Arduino boards lack built-in Wi-Fi. The ESP8266 comes preprogrammed with AT command set firmware, allowing it to function as a Wi-Fi shield when connected to other development boards.

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C. LCD Display with I2C

A Liquid Crystal Display (LCD) is a type of flat-panel display that utilizes polarized liquid crystals to present content. It functions by modulating light to display images or text. An I2C LCD communicates using the I2C interface, requiring only two lines—SDA (data) and SCL (clock)—for data transmission. This simplifies the circuit and reduces wiring complexity.

Fig.5. LCD Display with I2C

D. pH Sensor Module

A pH sensor detects the concentration of hydrogen ions in a solution and translates it into a usable output signal. It consists of both a chemical sensing element and a signal transmission component. This sensor is used to determine the acidity or alkalinity of a liquid, typically within a standard range of 0 to 14. A pH value of 7 signifies a neutral substance.

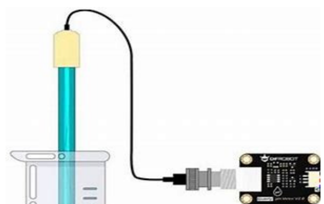

Fig.6. pH Sensor Module

E. Turbidity Sensor Module

Turbidity sensors, also known as turbidity meters, are used to measure the clarity of a liquid. Their accuracy and reliability have improved over time. To obtain precise measurements, it is essential to keep both the sensor and the measuring cell or detector clean.

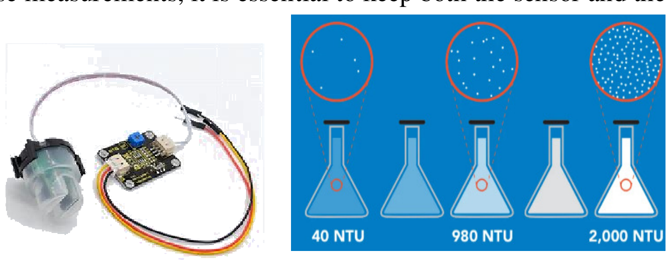

Fig.7. Turbidity Sensor Module

The detection range for this sensor spans from 0% to 3.5% (0 to 4550 NTU or Nephelometric Turbidity Units) with a tolerance of ±0.5%. It supports two modes of operation, allowing it to function with both analog and digital outputs.

F. TDS Sensor Module

TDS (Total Dissolved Solids) measures the concentration of dissolved solids in water, expressed in milligrams per liter. A higher TDS level indicates a greater presence of dissolved substances, which reduces the water's purity.

Fig.8. TDS Sensor Module

G. DHT11 Sensor Module

A DHT sensor is a device designed to measure the temperature of an environment. It is commonly used in various applications such as air conditioners, water heaters, refrigerators,and for monitoring temperatures in water, and buildings.

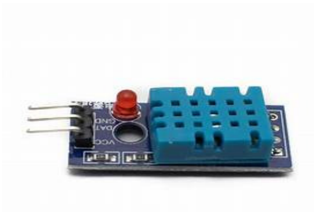

Fig.9. DHT11 Sensor Module

H. GSM Module

GSM, or Global System for Mobile Communication, is a widely used digital mobile network worldwide. It operates using a combination of FDMA and TDMA and is one of the primary digital wireless telephony systems alongside TDMA and CDMA. GSM functions across four frequency bands: 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz. It processes data by compressing and converting it before transmitting it over a channel shared with two other user data streams, each assigned a specific time slot.

Fig.10. GSM Module

V. CIRCUIT DIAGRAM

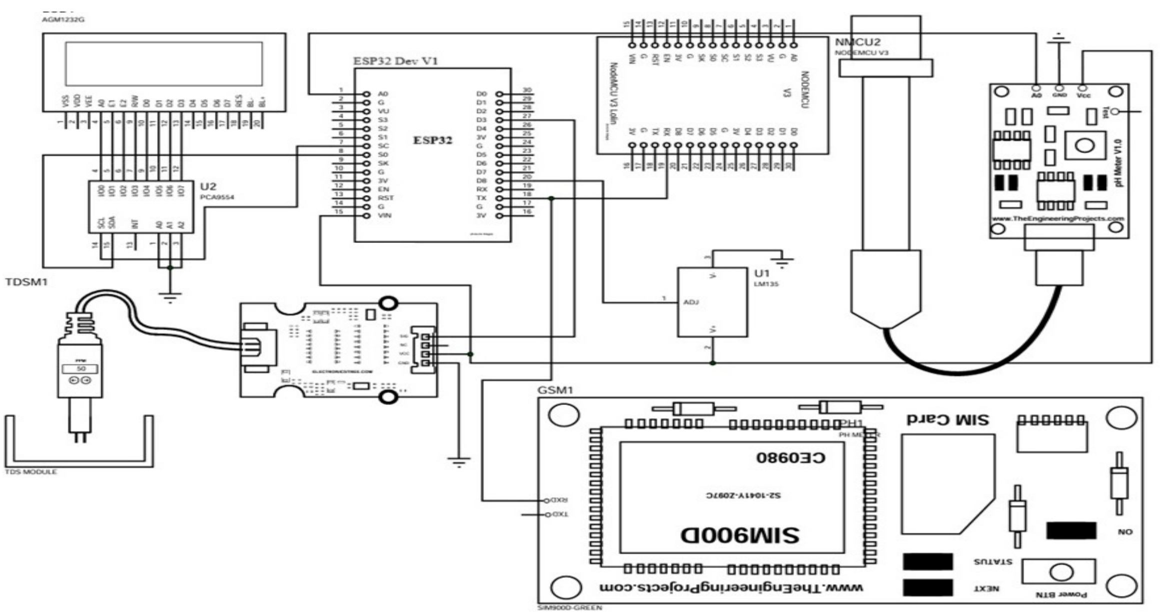

Fig.11. Circuit Diagram

VI. WORKING METHODOLOGY

This paper presents the design and functionality of an IoT-based water quality monitoring and filtration system to ensure access to clean and safe water. The proposed methodology includes the following key components:

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1) Sensor Integration: Advanced sensors, including temperature, turbidity, pH, and total dissolved solids (TDS) sensors, are integrated with an ESP32 microcontroller to enable real-time water quality monitoring.
2) Data Collection and Transmission: Water quality data is continuously gathered and transmitted wirelessly to an IoT application for analysis and visualization. This application serves as a central hub for real-time monitoring and data management.
3) Smart Pumping and Filtration: The system incorporates smart pumping and multi-stage filtration processes to effectively distribute water while maintaining its quality. These filtration stages help remove impurities and contaminants, ensuring the delivery of clean water.
4) Feedback Mechanism: Additional TDS sensors placed at water usage points provide continuous feedback on water quality, allowing for ongoing monitoring and improvements across the distribution network.
5) Blynk Integration: The system utilizes the Blynk IoT platform to enable seamless mobile device connectivity, allowing users to remotely monitor water parameters, control the system, and receive real-time alerts. Notifications about filter damage can be sent via SMS or Mail.

By implementing this IoT-based water monitoring and filtration system, water quality can be continuously tracked, analyzed, and managed. This approach supports the sustainable management of water resources while promoting community health and well-being.

VII. HARDWARE OUTCOME

The prototype hardware has been successfully developed, and its visual interface is depicted in Figure 10. Accompanying this, the corresponding message and image outputs are illustrated in Figure 11, respectively. Notably, this innovative system extends beyond mere water quality detection, as it effectively displays real-time data on the integrated display and concurrently transmits this information to a mobile application.

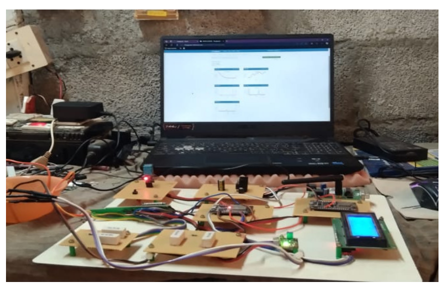

Fig.12. Proto type hardware implementation

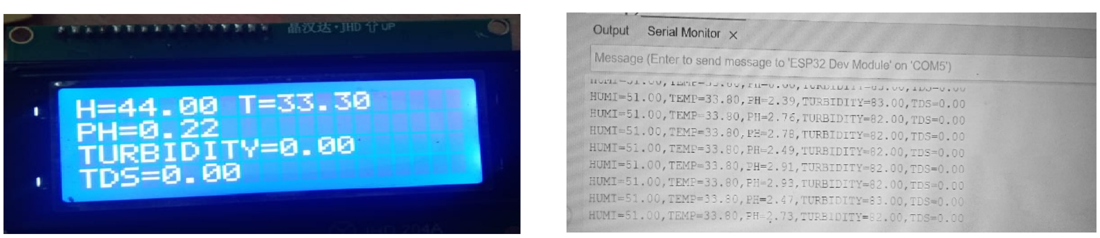

Fig.13. Output in Display and Serial Monitor

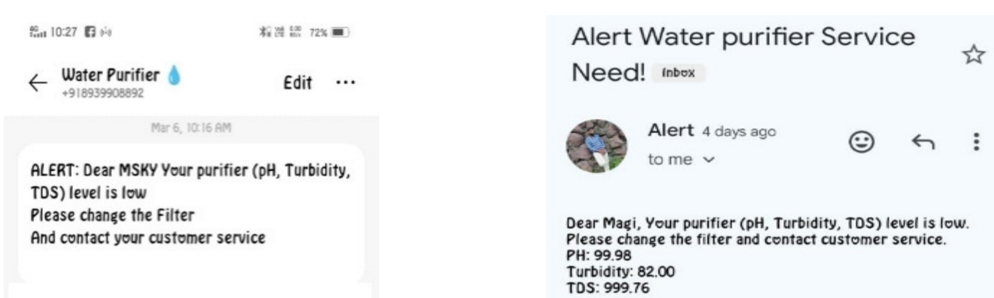

Fig.14. Alert SMS and Mail

VIII. CONCLUSION

In conclusion, integrating the IoT-based Blynk app, pump, and filtration system with TDS, pH, and turbidity sensors connected to an ESP32 provides a reliable approach to ensuring access to clean and safe water. By continuously monitoring key water parameters and leveraging IoT technology, this system enables proactive management and intervention to maintain water quality standards. The real-time data display offered by the Blynk app enhances transparency, allowing users to make informed decisions regarding water usage and management. The pump facilitates efficient water distribution, while the filtration system ensures improved water quality before consumption. Additionally, a feedback loop provided by the TDS sensor at the point of use enables continuous monitoring and optimization. Overall, this integrated solution effectively addresses water quality concerns, promotes sustainability, and helps protect both the environment and public health. Advancements in research and development in this field will further enhance our ability to monitor and manage water resources efficiently, even in the face of evolving environmental and societal challenges.

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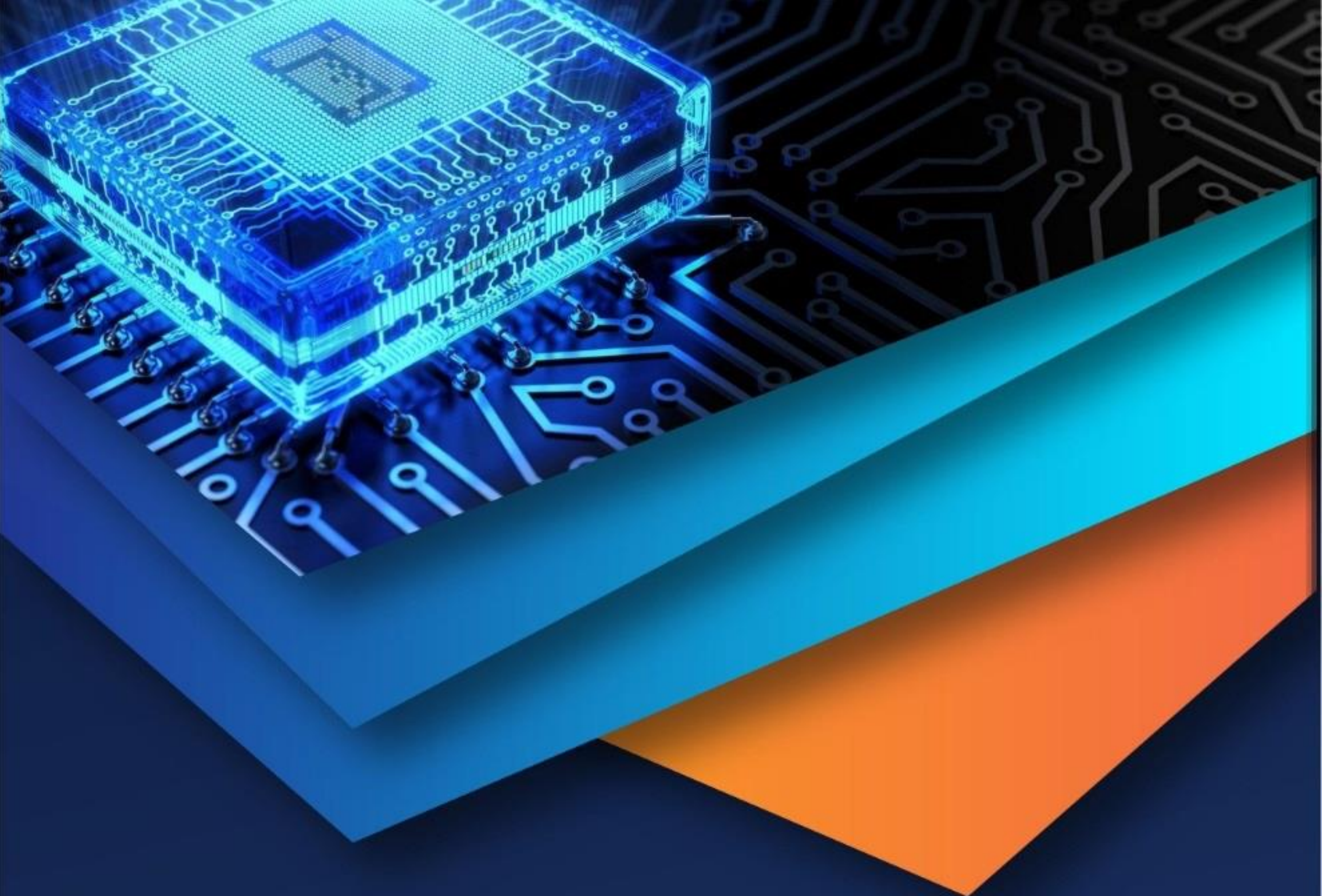

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