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IOT-Enabled Smart Plant Monitoring System with Automated Fertilization

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Abstract: The increasing need for efficient and sustainable agricultural practices has led to the adoption of smart technologies in farming. This project presents an IoT-enabled Smart Plant Monitoring System with an automated fertilization mechanism to optimize plant health and growth. The system integrates sensors to monitor key environmental parameters such as soil moisture, temperature, humidity, pH level, and nutrient concentration. These real-time data points are transmitted to a cloud-based platform for analysis and remote monitoring. Based on the collected data, an automated fertilization system precisely delivers the required nutrients, reducing manual effort and preventing excessive fertilizer use. The system utilizes wireless communication for seamless connectivity, ensuring real-time alerts and decision-making via a mobile or web-based interface. The proposed solution aims to enhance crop yield, conserve resources, and promote sustainable farming by minimizing waste and optimizing plant care.

Index Terms: Internet of Things (IoT), smart plant, automated fertilization.

I. INTRODUCTION

Agriculture plays a vital role in global food security, yet traditional farming methods often face challenges such as inefficient water usage, soil degradation, and improper fertilization. The advancement of Internet of Things (IoT) technology offers innovative solutions to these problems by enabling real-time monitoring and automated decision-making in agricultural systems.

The IoT-Enabled Smart Plant Monitoring System with Automated Fertilization is a cutting-edge innovation that integrates sensor technology, artificial intelligence, and automation to optimize plant growth and health. This system enables real-time monitoring of soil moisture, temperature, pH, and nutrient levels, triggering automated fertilization and irrigation adjustments to create a personalized and optimal growing environment. By harnessing the power of IoT and AI, this system aims to increase crop yields, reduce water and fertilizer consumption, and enhance the overall efficiency of plant care. This project explores the design, development, and implementation of this innovative system, highlighting its potential to transform the future of agriculture and plant cultivation.

The system incorporates various sensors to measure key environmental factors such as soil moisture, temperature, humidity, pH levels, and nutrient content**.** These sensors continuously collect data, which is transmitted to a cloud-based platform for real-time analysis and remote monitoring**.**

Based on the collected data, a microcontroller-based automated fertilization system determines the precise amount of nutrients required by the plants and delivers them efficiently, preventing both over-fertilization and nutrient deficiency. The system supports wireless communication protocols (such as Wi-Fi, Bluetooth, or LoRa) for seamless connectivity, allowing farmers to access information and receive alerts via a mobile or web-based application.

The implementation of this system aims to enhance agricultural productivity, reduce resource wastage, and promote sustainable farming practices. By leveraging IoT, this solution provides farmers with data-driven insights, enabling them to make informed decisions that improve plant health, conserve water, and optimize fertilizer usage.

In India, horticulture assumes a significant part for enhancement in food creation. There's an extraordinary need to robotizing the customary husbandry practices for the great profitability. Because of robotic application of water asset the ground water position is dwindling surely, absence of cloudbursts and deficit of land water also brings about diminishment in volume of water on earth. We need water in every single field. In our day by day life water assumes a significant part. Horticulture is one of fields where water is demanded in enormous quantum. Wastage of water is the serious issue in agribusiness. The practice of adding extraneous material to a standard toxin to lower its quality. Agriculture has been the backbone of human civilization for centuries, providing food, raw materials, and economic sustenance.

However, traditional farming practices often suffer from inefficiencies, including improper irrigation, excessive fertilizer usage, and a lack of real-time monitoring. With the rise of smart agriculture, technological advancements such as the Internet of Things (IoT), artificial intelligence (AI),, and automation are transforming traditional agricultural practices into efficient and data-driven solutions. The IoT-enabled Smart Plant Monitoring System with Automated Fertilization is an innovative approach that integrates sensor technology, wireless communication, cloud computing, and automation to enhance plant growth while optimizing resource usage. By providing real-time data on environmental conditions and automating fertilization, this system enables precision agriculture, reducing human effort and improving crop yield.

II. LITERATURE SURVEY

We started our literature survey with the “Enhancing Crop Yields through IoT-Enabled Precision Agriculture” 2023, IEEE conference, IoT-enabled precision agriculture system faces several backlogs that require further improvement. Hardware limitations include sensor calibration issues, durability concerns due to environmental exposure, and high power consumption, necessitating the integration of energy- efficient components like solar panels. Communication challenges arise from unreliable network connectivity in rural areas, latency in cloud-based data processing, and signal interference affecting wireless communication protocols such as LoRa, Zigbee, and Wi-Fi. Additionally, data management and security concerns involve the need for efficient storage and processing of large datasets, protection against cyber threats, and ensuring data integrity for accurate decision-making. Addressing these limitations is crucial to optimizing system performance, enhancing reliability, and ensuring widespread adoption of IoT-enabled precision agriculture. In this paper “IoT-based Smart Agriculture system for the detection of plant decay” 2023, IEEE conference, that need further improvement. Sensor limitations such as inaccuracies in detecting early-stage plant diseases and sensitivity to environmental conditions can affect the reliability of decay detection. Image processing and machine learning challenges include the need for large, high-quality datasets to improve model accuracy and difficulties in distinguishing between disease symptoms and natural plant variations. Connectivity issues in rural areas may cause delays in transmitting real-time disease alerts, impacting timely intervention. Additionally, energy constraints arise due to continuous data collection and processing, necessitating efficient power management solutions. Data security and privacy concerns also persist, as transmitting plant health data over cloud networks exposes the system to potential cyber threats. Addressing these limitations is essential to enhancing the accuracy, efficiency, and reliability of IoT-based plant decay detection systems.

In this paper “IoT-based monitoring system for chili plant growth” 2023, IEEE conference, that impact its efficiency and accuracy. Sensor-related challenges, such as calibration issues, limited detection range, and susceptibility to environmental factors like humidity and temperature fluctuations, can affect data accuracy. Connectivity constraints, especially in rural areas, may cause delays in real-time data transmission and remote monitoring. Power management issues arise due to continuous sensor operation, requiring energy-efficient components or renewable energy sources. Data processing limitations, including the need for advanced algorithms to analyze growth patterns accurately, can affect decision-making. Additionally, environmental variability, such as unexpected weather changes, pests, and soil condition fluctuations, may require adaptive models for better yield prediction. Overcoming these limitations is essential for enhancing the precision, reliability, and scalability of IoT-based chili plant growth monitoring systems.

In this paper “IoT-based Soil Nutrients Analysis and Monitoring System for Smart Agriculture” 2023, IEEE conference, aims to enhance precision farming by continuously monitoring soil parameters such as nitrogen (N), phosphorus (P), potassium (K), moisture, and pH levels. However, key backlogs in this system include sensor accuracy and calibration issues, which can lead to inconsistent readings affecting decision- making. Additionally, real-time data transmission faces challenges due to network connectivity issues in remote agricultural areas. The integration of AI for predictive analysis is still in its early stages, limiting the system’s ability to provide advanced insights. Furthermore, energy efficiency remains a concern, as IoT devices require reliable power sources for uninterrupted operation. Lastly, the high initial cost of deployment and maintenance of IoT-based monitoring systems makes adoption challenging for small-scale farmers, highlighting the need for cost-effective solutions. Scalability and interoperability issues emerge when integrating different sensors and platforms, often lacking standardized communication protocols. High implementation and maintenance costs.

III. METHODOLOGY

The hardware setup of the system consists of multiple IoT-enabled sensors integrated to monitor key environmental and soil parameters. Sensors such as soil moisture, temperature, humidity, pH, and NPK (Nitrogen, Phosphorus, and Potassium) sensors are deployed in the soil to collect real-time data. These sensors are connected to a microcontroller (such as Arduino or ESP32), which processes the data and transmits it wirelessly using communication technologies like Wi-Fi, LoRa, or GSM.

The system also includes a solenoid valve-controlled irrigation and fertilization mechanism, where liquid fertilizers are automatically dispensed based on sensor readings and predefined thresholds. A power supply, including solar panels or rechargeable batteries, ensures uninterrupted operation in remote areas.

The data processing and cloud integration play a crucial role in the system's functionality. The collected data is transmitted to a cloud-based platform such as Firebase, AWS IoT, or ThingSpeak, where it is stored, analyzed, and visualized through a user-friendly dashboard. Machine learning algorithms or rule-based decision models process the data to determine the optimal amount of water and fertilizer needed for plant growth. If nutrient deficiencies or inadequate soil moisture levels are detected, the system triggers automated fertilization and irrigation, ensuring efficient resource usage. A mobile or web application allows farmers to remotely monitor real-time plant health, receive alerts, and manually override the automated functions if necessary.

The automated fertilization and irrigation control mechanism is designed to optimize plant growth and minimize resource wastage. Based on the analyzed data, the system activates the nutrient and water delivery system only when necessary, preventing overuse of fertilizers that can lead to soil degradation. IoT-based actuators control the release of liquid fertilizers through drip irrigation or sprinklers, ensuring precise application to the root zone. Additionally, historical data and weather forecasts are considered to enhance decision-making and avoid unnecessary watering or fertilization before rainfall. This smart automation not only reduces manual labor but also promotes sustainable farming by conserving water and optimizing fertilizer usage.

The primary sensors include soil moisture, temperature, humidity, pH, and NPK sensors to measure the nutrient levels in the soil. These sensors are deployed at different depths in the soil to ensure accurate readings and comprehensive analysis. The sensors are connected to a microcontroller unit (MCU) such as an ESP32, Arduino, or Raspberry Pi, which serves as the central processing unit of the system.

IV. BLOCK DIAGRAM

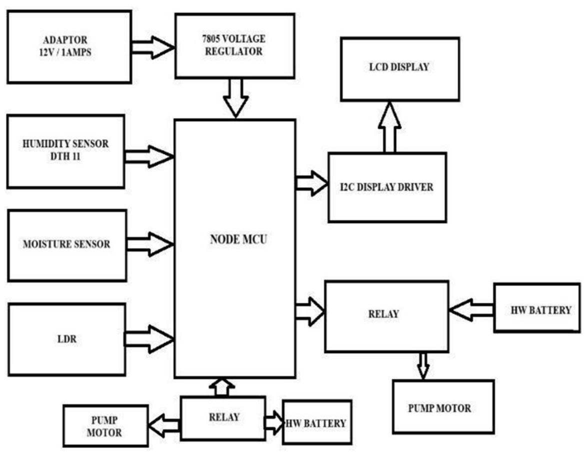

Fig.1 Overall Block diagram of the system

This block diagram represents an IoT-based smart irrigation system using a NodeMCU (ESP8266/ESP32) microcontroller. The system monitors environmental conditions and automates the operation of a water pump based on sensor data. The primary components and their functions are as follows:

1) Adaptor (12V / 1A)

The 12V/1A adaptor serves as the primary power source for the system. It converts AC mains power into a 12V DC supply, which is then regulated to power different components of the circuit. This adaptor ensures a stable power supply for sensors, microcontrollers, and actuators, preventing voltage fluctuations that could damage sensitive electronic components. Converts the 12V input to a stable 5V output required by the NodeMCU and sensors.

2) 7805 Voltage Regulator

The 7805 voltage regulator is used to step down the 12V DC from the adaptor to a stable 5V DC, which is the required operating voltage for the NodeMCU, sensors, and other low-power components. This regulator prevents overvoltage damage and ensures consistent performance of the circuit by eliminating voltage spikes.

3) Humidity Sensor (DHT11)

The DHT11 sensor is used to measure the temperature and humidity of the surrounding environment. It provides real-time atmospheric conditions, which can help optimize irrigation schedules based on humidity levels. The sensor outputs data in digital form, which is processed by the NodeMCU for decision-making.

4) Moisture Sensor

The soil moisture sensor is a key component that detects the water content in the soil. It operates by measuring the resistance of the soil – dry soil has high resistance, while wet soil has low resistance. If the soil moisture drops below a predefined threshold, the NodeMCU triggers the water pump to supply water automatically, ensuring proper irrigation.

5) Light Dependent Resistor (LDR)

The LDR sensor measures ambient light intensity. It is useful in detecting daylight conditions and can be integrated into the system to schedule irrigation based on sunlight availability. For example, watering plants in the evening or early morning reduces water evaporation, improving water efficiency.

6) NodeMCU (ESP8266/ESP32)

The NodeMCU is the central processing unit of the system. It collects data from the humidity sensor, moisture sensor, and LDR, processes the information, and makes real-time decisions. It also controls the relay module to turn the pump motor ON/OFF based on soil moisture levels. Additionally, it can transmit data to the cloud or a mobile application for remote monitoring.

7) I2C Display Driver

The I2C display driver allows efficient communication between the NodeMCU and the LCD display using the I2C protocol. This reduces the number of required connections and simplifies wiring. The driver ensures smooth and reliable display updates without overloading the microcontroller.

8) LCD Display

The LCD display provides a user-friendly interface for real-time monitoring of sensor data. It shows important parameters such as soil moisture percentage, humidity, temperature, and light intensity. This helps farmers or users manually monitor environmental conditions without needing a mobile app.

9) Relay Module

The relay module acts as an electronic switch that controls the pump motor. When the NodeMCU detects dry soil, it sends a signal to the relay, which then activates the pump motor. Once the soil moisture level reaches the required threshold, the relay turns off the pump, preventing overwatering and saving energy.

10) HW Battery

The HW battery is a secondary power source used to run the pump motor. Since the pump requires higher power, a dedicated battery is used to avoid excessive load on the main power supply. This ensures uninterrupted irrigation even if the main power supply.

11) Pump Motor

The pump motor is responsible for supplying water to the plants. It is activated when the soil moisture level is low and remains ON until the soil reaches the optimal moisture level. This automated irrigation system ensures water conservation and promotes efficient plant growth.

V. RESULTS AND DISCUSSION

The IoT-based smart irrigation system was successfully designed and implemented using NodeMCU, soil moisture sensors, a humidity sensor (DHT11), an LDR, a relay module, and a pump motor. The system effectively monitored soil and environmental conditions in real-time and automated irrigation based on moisture levels. When the soil moisture dropped below a set threshold, the NodeMCU triggered the relay to activate the pump motor, supplying water until the desired moisture level was achieved. The LCD display provided real-time data visualization, showing temperature, humidity, moisture levels, and light intensity.

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This allowed for easy monitoring and manual intervention if necessary. The use of a 7805 voltage regulator and HW battery ensured stable power supply, preventing malfunctions.

In the results, We can see in thingshow application Temperature, Humidity, Moisture detection, P^{H}, Nitrogen and Potassium. That figures are shown in below,

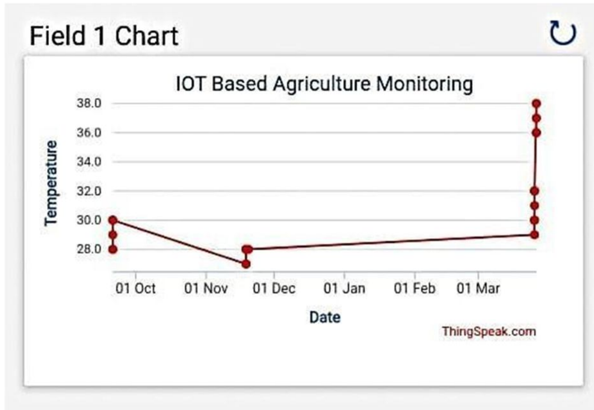

Fig.2 Reserved for Temperature

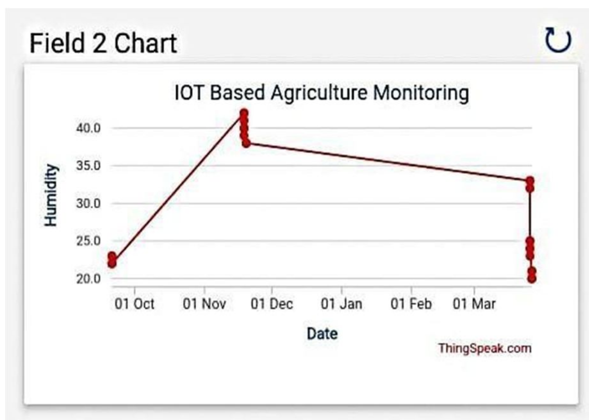

Fig.3 Reserved for Humidity

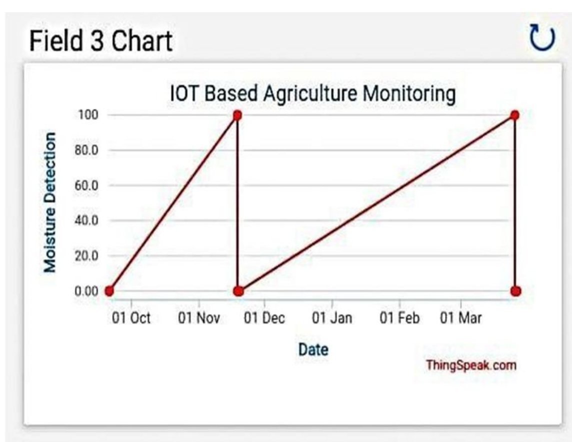

Fig.4 Reserved for Moisture detection

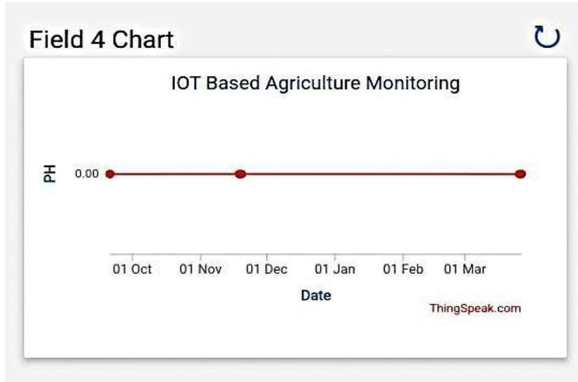

Fig.5 Reserved for PH

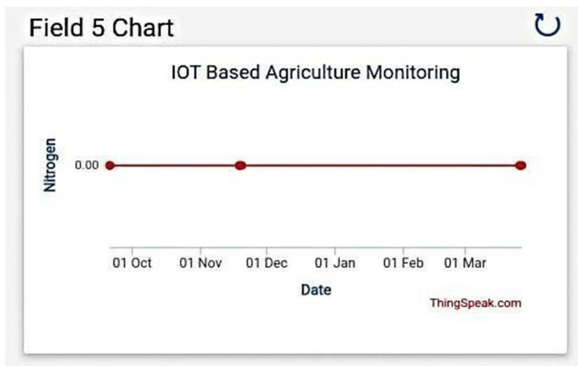

Fig.6 Reserved for Nitrogen

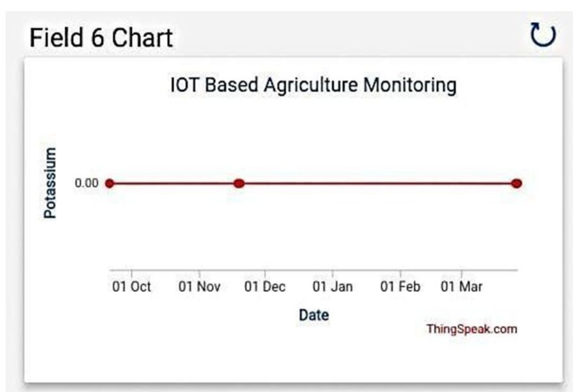

Fig.7 Reserved for Potassium

During testing, the system showed high reliability in detecting soil moisture variations and responding appropriately. The relay-operated water pump functioned efficiently, supplying adequate water without wastage. The integration of light intensity (LDR) and humidity sensors provided additional insights for optimizing irrigation schedules. For example, watering was reduced during high humidity conditions to prevent overwatering. The wireless data transmission capability of NodeMCU allows for remote monitoring, which can be further enhanced by integrating cloud storage and a mobile app for better control. However, network dependency and sensor calibration issues were observed as limitations, requiring occasional recalibration to maintain accuracy.

The automated irrigation system significantly reduces water consumption by ensuring irrigation is done only when needed, compared to traditional manual methods. The real-time monitoring and automation increase efficiency, making it suitable for smart agriculture applications. Future improvements could include AI-based predictive analytics to enhance decision-making, solar-powered energy sources for improved sustainability, and mobile app integration for remote control. Overall, the system proves to be a cost- effective, efficient, and scalable solution for precision farming, improving both crop yield and resource management.

VI. CONCLUSION & FUTURE SCOPE

The IoT-based smart irrigation system presented in this project successfully automates plant watering using real-time sensor data. The system efficiently monitors soil moisture, temperature, humidity, and light intensity using sensors and processes the data through NodeMCU to make intelligent irrigation decisions. The integration of relay-controlled pump motors ensures that water is supplied only when needed, significantly reducing manual intervention and water wastage. The LCD display provides a user-friendly interface for monitoring environmental conditions, while the cloud-based remote monitoring feature can be expanded for better accessibility. Overall, the system enhances agricultural efficiency, conserves water, and supports sustainable farming practices.

The project has significant potential for further enhancements, making it a scalable and intelligent farming solution. One major improvement is the integration of AI and machine learning to analyze historical data and predict irrigation needs based on weather patterns. Additionally, incorporating cloud connectivity and mobile applications would enable act remote monitoring and control, improving accessibility for farmers. The system could also be powered using solar energy, making it more sustainable and suitable for remote agricultural areas. Furthermore, the inclusion of NPK and pH sensors would allow for automated fertilization, enhancing soil quality and crop yield. To extend its reach, LoRa or Zigbee communication modules can be integrated for long- range data transmission, making the system viable for large-scale farms. By implementing these advancements, this IoT-based smart irrigation system can evolve into a fully autonomous precision farming solution, promoting sustainable agriculture and resource efficiency.

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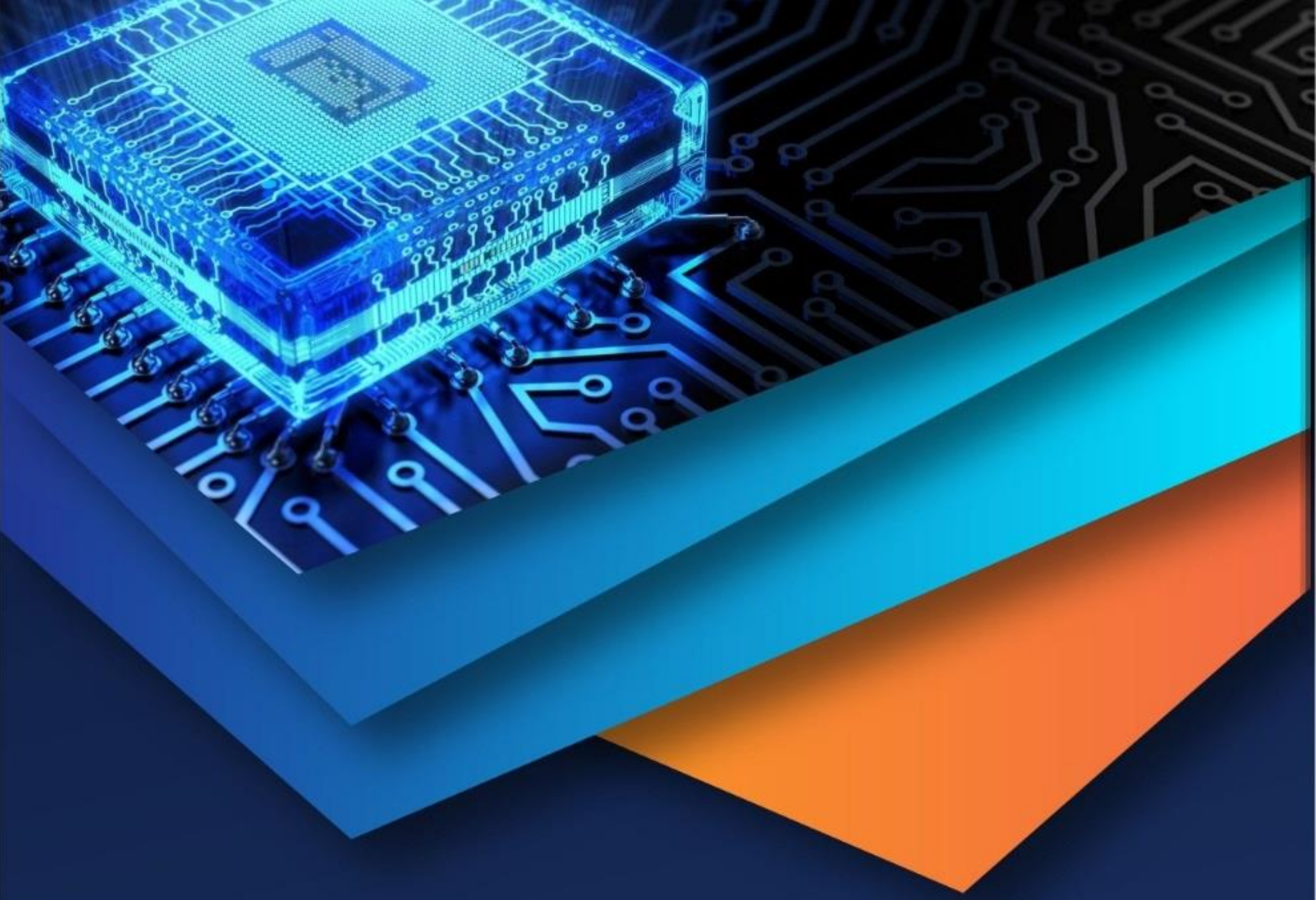

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