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Automated Vermicompost Production and Monitoring System

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Abstract: Vermicomposting is a sustainable method for organic waste management, but traditional approaches require continuous monitoring to maintain optimal conditions for worm activity and compost quality. This paper presents the design and implementation of an automated vermicomposting system that integrates embedded sensors and microcontroller-based real-time control to optimize environmental parameters. The system uses an ESP32-S3 microcontroller as the core controller, along with soil moisture and temperature sensors, to monitor and regulate irrigation and ventilation through relays and actuators.
Moisture and temperature thresholds are set based on optimal worm activity (60–80% soil moisture and 18–28°C temperature range), and real-time data processing dynamically adjusts system operations to maintain ideal composting conditions.
Collected data are logged and transmitted wirelessly via WiFi/Bluetooth, enabling remote monitoring and analysis through mobile or web applications. Experimental results demonstrate that the automated system consistently maintains optimal conditions, resulting in improved worm productivity and a 15–20% increase in compost yield compared to manual methods. The proposed design offers a reliable, scalable, and energy-efficient solution for high-quality vermicomposting, reducing manual intervention while enhancing sustainability.
Keywords: Vermicompost Automation, IoT Composting, Environmental Monitoring, Organic Waste, Embedded Systems.

I. INTRODUCTION

Vermicomposting represents a sustainable and environmentally conscious method for transforming organic waste into nutrient-dense compost. The process's effectiveness is significantly influenced by the maintenance of optimal environmental conditions, such as soil moisture, temperature, and aeration, which directly impact worm activity and the quality of the compost produced.

Traditional manual monitoring techniques are often labour-intensive, time-consuming, and susceptible to inaccuracies, particularly in large-scale operations where uniform condition maintenance proves challenging.

To address these shortcomings, automated vermicomposting systems have been developed, incorporating microcontrollers and sensors to monitor temperature, moisture, and other environmental parameters.

These systems facilitate continuous monitoring and real-time adjustments, thereby ensuring stable conditions for worm growth. By minimizing manual intervention, improving process control, and optimizing environmental factors, automated vermicomposting not only enhances compost quality and worm productivity but also provides scalable and efficient solutions for organic waste management.

II. LITERATURE REVIEW

Recent studies indicate that IoT-based vermicompost bins significantly outperform traditional manual bins in both compost quality and worm growth [1]–[3]. These systems typically employ microcontrollers such as ESP32-S3, combined with soil moisture and temperature sensors, enabling data-driven control of irrigation and ventilation [4]–[6].

Despite their advantages, key technical challenges remain, including ensuring sensor accuracy, maintaining stable environmental conditions, achieving reliable cyber-physical integration, and implementing automated data logging for performance tracking [6], [7].

Comparative research demonstrates that such automated approaches produce higher quantities of vermicompost and maintain more consistent worm populations by precisely regulating the critical conditions necessary for optimal vermicomposting [2], [5], [8].

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III. PROBLEM STATEMENT

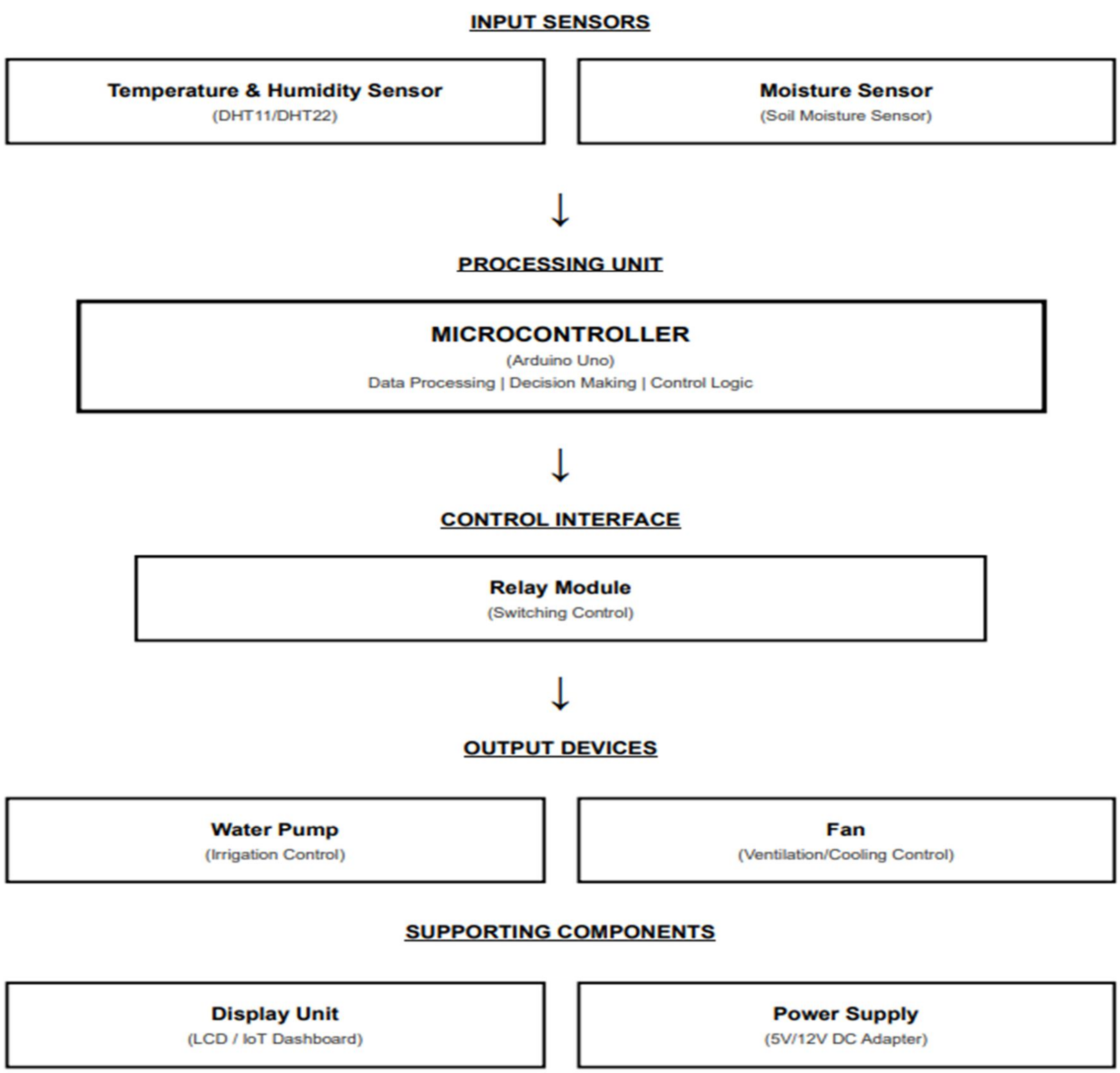
Traditional vermicomposting methods can sometimes struggle due to inconsistent monitoring and changing environmental factors like temperature, moisture, and aeration. These fluctuations can interfere with worm activity, slow down the breakdown of organic waste, and ultimately lead to lower-quality compost. Manually keeping these conditions optimal can be quite labour-intensive, time-consuming, and often impractical, especially for larger-scale operations, where achieving uniformity across the composting bed can be challenging.

To tackle these issues, there is a growing interest in creating reliable and scalable automated solutions using embedded systems. By using sensors, microcontrollers, and actuators, these systems can continuously keep an eye on key parameters and make real-time adjustments to things like irrigation and ventilation. This kind of data-driven control not only maintains ideal conditions but also boosts worm health, speeds up the composting process, and produces high-quality vermicompost consistently.

Additionally, advanced features such as wireless data transmission, remote monitoring via mobile or web apps, and automated data logging allow for precise performance tracking, predictive maintenance, and long-term optimization. By minimizing manual labour, enhancing process efficiency, and enabling scalable operations, automated vermicomposting offers a practical and sustainable way to manage organic waste, helping to support environmental conservation and resource recovery efforts.

IV. METHODOLOGY

Block Diagram and System Overview:



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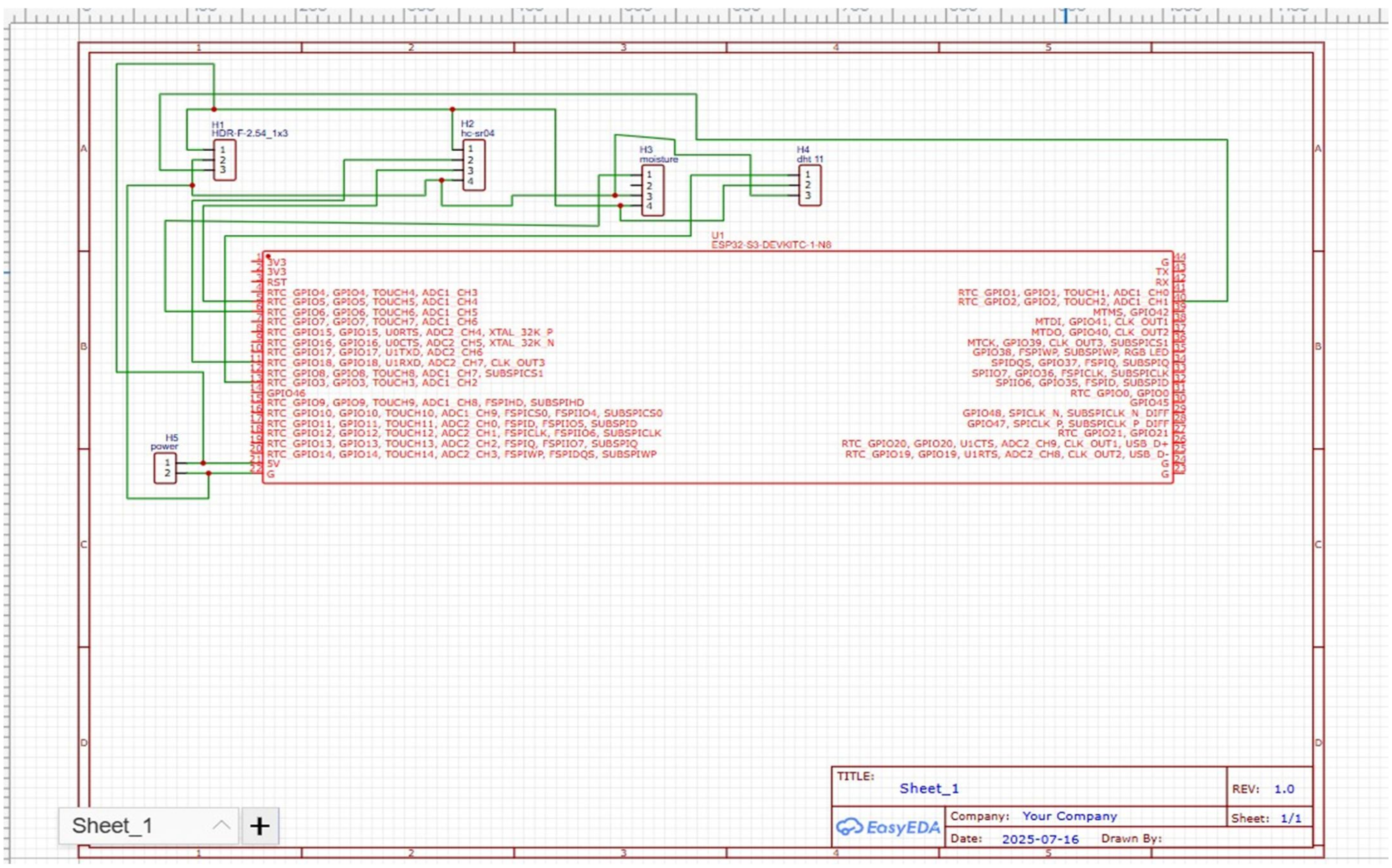
The automated vermicomposting system is built around the ESP32-S3 microcontroller, which serves as the main controller for all its operations. This system comes equipped with soil moisture and temperature sensors that keep an eye on environmental conditions, offering both analog and digital data for accurate evaluation. It also uses relays and actuators to manage essential functions like irrigation—with a solenoid valve—and ventilation, ensuring the perfect conditions for worm activity and composting effectiveness. The sensor data is processed in real time, allowing for on-the-fly adjustments to irrigation and aeration, so all crucial parameters stay within ideal ranges. Plus, the system is set up with data logging and wireless transmission features via Wi-Fi and Bluetooth, which means users can easily monitor system performance remotely and check historical data through mobile or web applications.

The vermicomposting journey starts with shredding and loading organic waste into the compost chamber. Sensors continually monitor soil moisture levels, triggering irrigation automatically whenever moisture falls below a set threshold. Temperature sensors control ventilation to keep the environment just right, ensuring the worms stay active while preventing overheating.

When it's time to harvest, sensor readings identify the perfect moment for worm separation and compost extraction, leading to top-notch vermicast production. By automating these vital steps, the system reduces manual effort, keeps environmental conditions steady, and streamlines the entire vermicomposting process for better productivity and efficiency.

V. DESIGN & EXPERIMENTATION



The system is thoughtfully crafted to keep the soil moisture and temperature just right for optimal worm activity. It usually maintains moisture levels between 60% and 80%, and temperatures between 18 and 28°C. The sensor circuitry is designed to consume low power while ensuring safe and continuous operation, which allows for reliable and long-term monitoring of the composting environment.

With real-time data processing, the system can make timely adjustments to irrigation and ventilation, ensuring conditions that nurture healthy worm growth and efficient decomposition. Plus, our in-line energy and performance analyses show that this automated approach greatly reduces the need for manual labour while boosting compost yield per cycle, making it a more efficient and scalable solution compared to traditional vermicomposting methods.

VI. RESULTS

Experimental and simulation results demonstrate that IoT-based vermicomposting systems maintain optimal composting conditions more consistently than manual approaches, achieving 15–20% higher vermicompost yield in test trials. Data logs confirm that environmental parameters remain stable throughout composting cycles, with rapid recovery from any deviations thanks to real-time actuation. Additionally, the user interface provides remote access for monitoring system status and reviewing operational history, enhancing convenience and process control.

A. Hardware Design

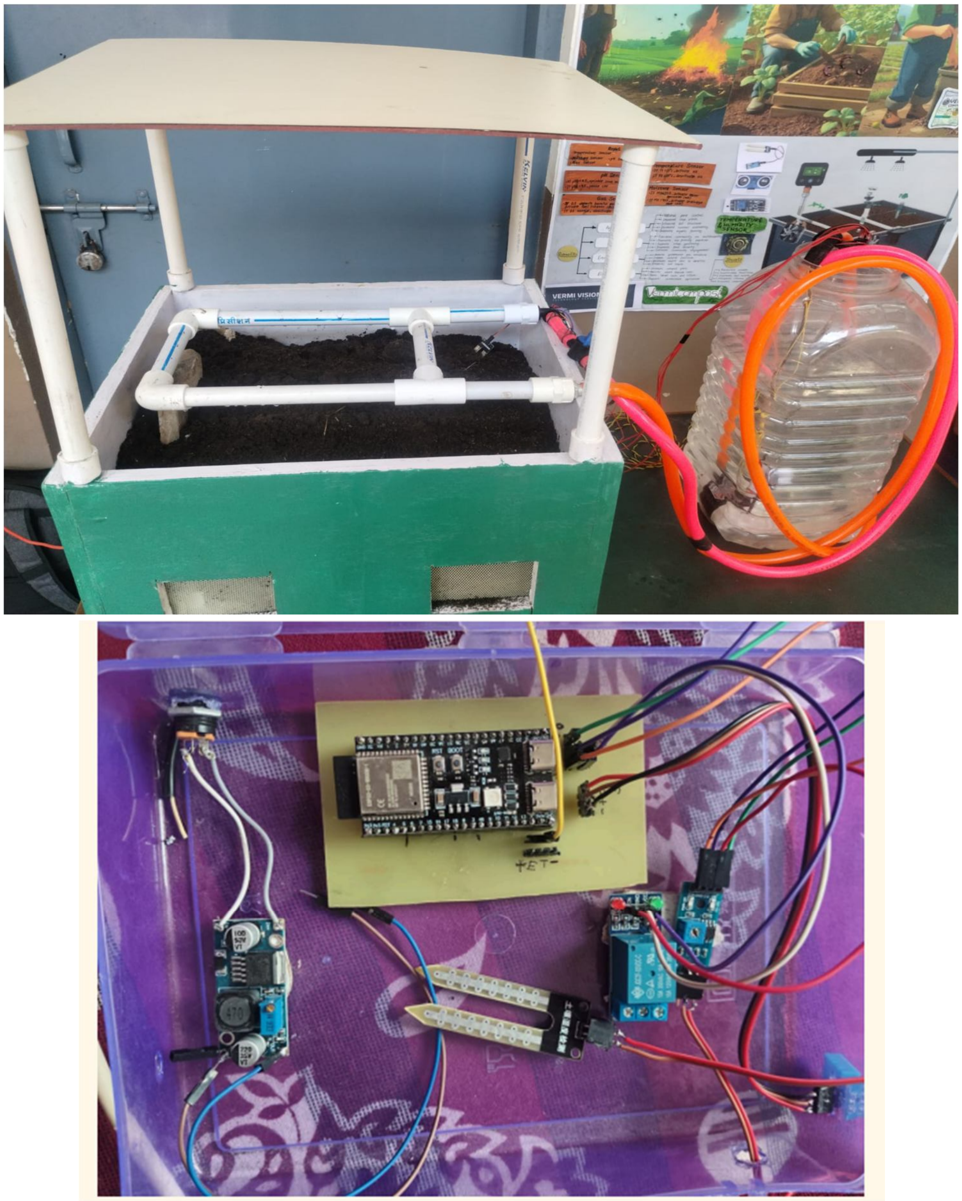


Figure 6.5 Hardware Design

The automated vermicomposting system is built around the ESP32-S3 microcontroller, which processes data from soil moisture and temperature sensors to maintain optimal composting conditions. Relays and actuators, including a solenoid valve for irrigation and ventilation fans, are controlled in real time to ensure soil moisture stays between 60–80% and temperature within 18–28 °C. Sensor data are logged and transmitted via WiFi or Bluetooth for remote monitoring through mobile or web applications. The system is powered by a 12 V DC supply, with circuitry designed for low power consumption, safe operation, and continuous autonomous functioning, enabling efficient and high-quality vermicompost production with minimal manual intervention.

B. Simulation result (MATLAB)

Figure 6.2Humidity Plot

Figure 6.3 Temperature Plot

Figure 6.4 Moisture Plot

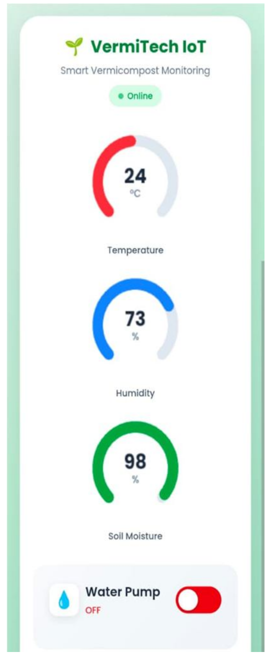


Figure 6.5 Web Interface

VII. CONCLUSION

Automated vermicomposting systems, driven by embedded sensors and real-time control, enhance both the output and consistency of compost while significantly reducing operational overhead. Future developments could incorporate advanced data analytics, including machine learning for predictive optimization, modular scalability for larger or distributed operations, and further cost reductions to encourage wider adoption of these sustainable systems.

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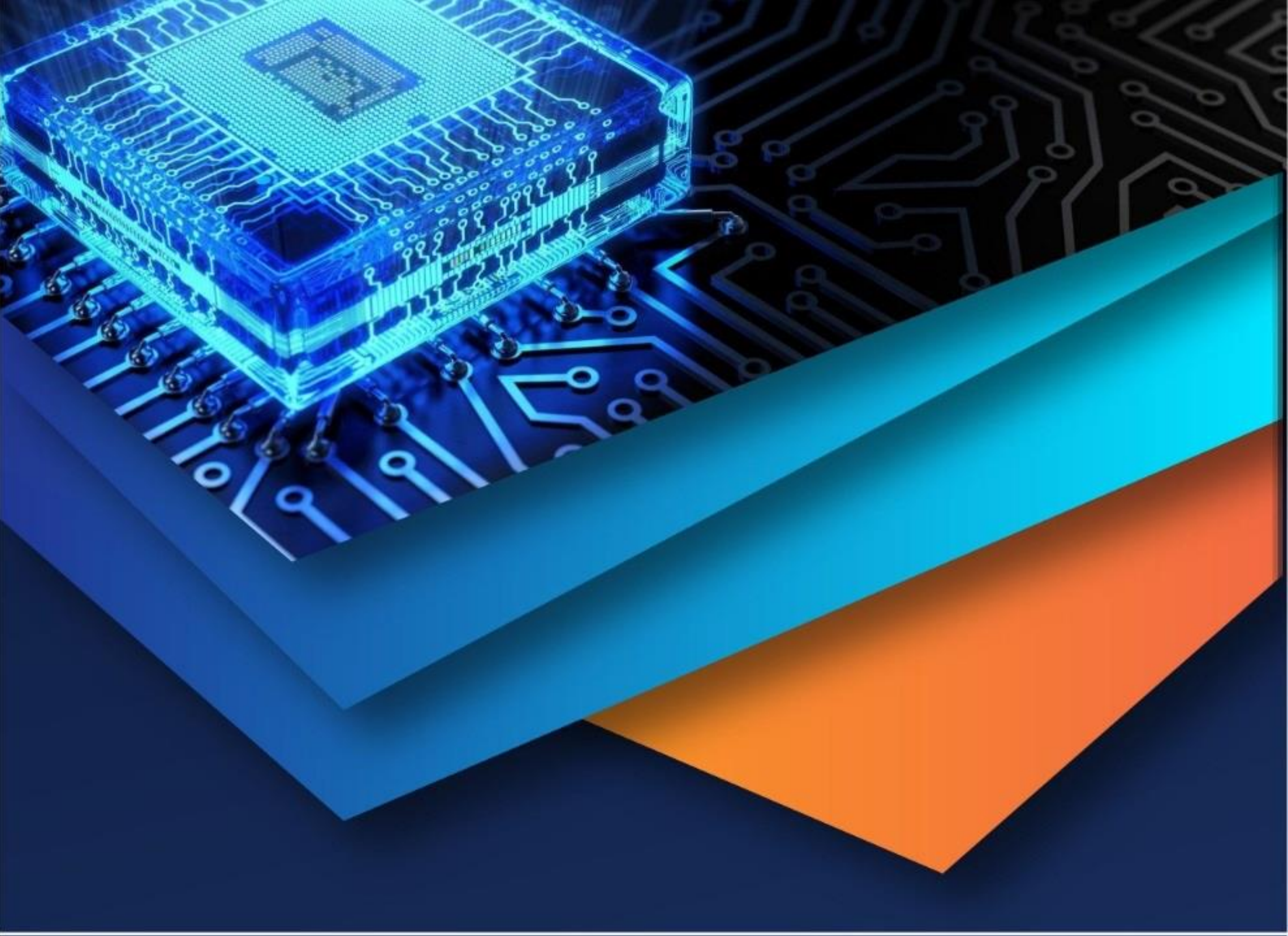

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