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Automated Metal & Non-Metal Segregation System

Dr. A.Murugurajan, V.Aswaddhaman, E.Angelpriya, G.Yuvashree
Department of Robotics & Automation Engineering, Sri Ramakrishna Engineering College, Coimbatore, Tamil Nadu, India - 641022

Abstract: ***Efficient waste management and material sorting are essential for modern industries and recycling facilities. Manual segregation of metal and non-metal materials is time-consuming, labour-intensive, and prone to human error. The Automated Metal and Non-Metal Segregation System is designed to improve sorting accuracy, reduce human effort, and increase operational efficiency through automation. The proposed system uses a conveyor mechanism integrated with sensors to automatically detect and separate metallic and non-metallic objects. A metal detection sensor identifies metallic materials as they pass along the conveyor belt, while non-metal objects continue along the default path. Based on the sensor output, a control unit processes the signal and activates a mechanical actuator or diverter mechanism to segregate the detected material into separate collection bins. The system is controlled using a microcontroller platform that coordinates the conveyor movement, sensor input, and actuation process. This automated approach ensures continuous operation, higher sorting speed, and improved reliability compared to traditional manual methods. The proposed system can be applied in recycling plants, scrap yards, manufacturing industries, and waste management facilities to streamline material handling and improve resource recovery. By implementing automation in the segregation process, the system contributes to increased productivity, reduced operational costs, and more effective waste management practices.***

Keywords: Automated Segregation, Metal Detection, Non-Metal Sorting, Conveyor Belt System, Sensor-Based Detection, Microcontroller Control, Industrial Automation, Waste Management, Material Classification, Smart Recycling System

I. INTRODUCTION

Material segregation plays a critical role in industrial manufacturing, recycling plants, and waste management systems. In many industries, large quantities of mixed materials containing both metallic and non-metallic components must be sorted before further processing. Traditionally, this segregation process is performed manually, which is time-consuming, labour-intensive, and prone to human errors. Manual sorting also reduces efficiency and may lead to safety risks when workers handle sharp or hazardous materials.

With the advancement of automation and sensor technologies, industries are increasingly adopting automated systems to improve productivity and accuracy. Automated segregation systems can detect and classify materials quickly and consistently without continuous human intervention. These systems help industries maintain higher operational efficiency while reducing labour costs and improving workplace safety.

The Automated Metal and Non-Metal Segregation System is designed to automatically identify and separate metallic and non-metallic objects using sensor-based detection and a conveyor mechanism. In this system, materials placed on the conveyor belt move through a detection zone where sensors identify the presence of metal. Based on the detection result, a control unit activates a sorting mechanism that directs the material into the appropriate collection bin.

This project focuses on developing a reliable and cost-effective automated segregation system suitable for small-scale industries, recycling units, and educational demonstrations. By integrating sensors, microcontrollers, and mechanical sorting mechanisms, the system improves sorting accuracy, reduces manual effort, and enhances overall material handling efficiency.

II. LITERATURE REVIEW

Several researchers have worked on automated material sorting systems to improve efficiency in recycling plants, manufacturing industries, and waste management. Traditional manual segregation methods are slow, labour-intensive, and prone to human error. As a result, many studies focus on developing automated conveyor-based sorting systems using sensors, controllers, and actuators to improve sorting accuracy and productivity.

A study on the design and manufacturing of a metal and non-metal sorting system proposed the use of a metal detector sensor integrated with a conveyor belt mechanism.

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In this system, objects move along the conveyor, and when metallic material is detected, a motor-controlled mechanism diverts the metal object into a separate container while non-metal materials continue along the conveyor path. This approach demonstrated that sensor-based detection combined with mechanical separation can effectively automate the sorting process.

Another research work developed a PLC-based automated sorting system that uses metal detection along with colour sensors to classify different objects. The system employed servo motors and actuators to direct materials into different bins based on sensor outputs. The study showed that automation reduces human involvement and improves sorting accuracy in industrial production lines.

Further research on automated segregation systems used Arduino microcontrollers with multiple sensors such as inductive sensors, IR sensors, and cameras to detect different types of materials. These systems demonstrated that integrating sensors with microcontrollers and conveyor mechanisms can achieve fast and efficient sorting while minimizing manual labour.

In addition, some researchers proposed parameter-based auto-segregation systems that combine metal detection and colour sensing techniques. These systems can classify objects based on their physical properties and material composition, thereby improving productivity and ensuring accurate classification in industrial environments.

Overall, previous studies indicate that sensor-based automated sorting systems using conveyors and control units provide a reliable solution for separating metal and non-metal materials. However, many existing systems focus only on basic detection or require expensive industrial equipment. Therefore, the development of a cost-effective and efficient automated metal and non-metal segregation system is important to enhance industrial material handling and recycling processes.

III. SYSTEM METHODOLOGY

The Automated Metal and Non-Metal Segregation System is designed to automatically detect and separate metallic and non-metallic materials using sensors, a conveyor mechanism, and a control unit. The system integrates sensing, processing, and actuation to ensure efficient and accurate material sorting.

1) Material Feeding

Mixed materials containing metal and non-metal objects are placed on a conveyor belt. The conveyor continuously moves the materials toward the sensing section.

2) Material Detection

AnInductive sensor is placed along the conveyor path. As objects pass through the sensing zone, the sensor checks whether the material contains metal.

3) Signal Processing

The sensor output signal is sent to a ESP32 microcontroller. The controller analyses the signal and determines whether the object is metallic or non-metallic.

4) Sorting Mechanism

Based on the detection result, the controller activates an actuator such as a servo motor or mechanical diverter.

- If metal is detected, the actuator pushes the object into the **metal collection bin**.
- If no metal is detected, the object continues along the conveyor into the **non-metal bin**.

5) Collection

The segregated materials are collected in separate containers for further recycling, processing, or disposal.

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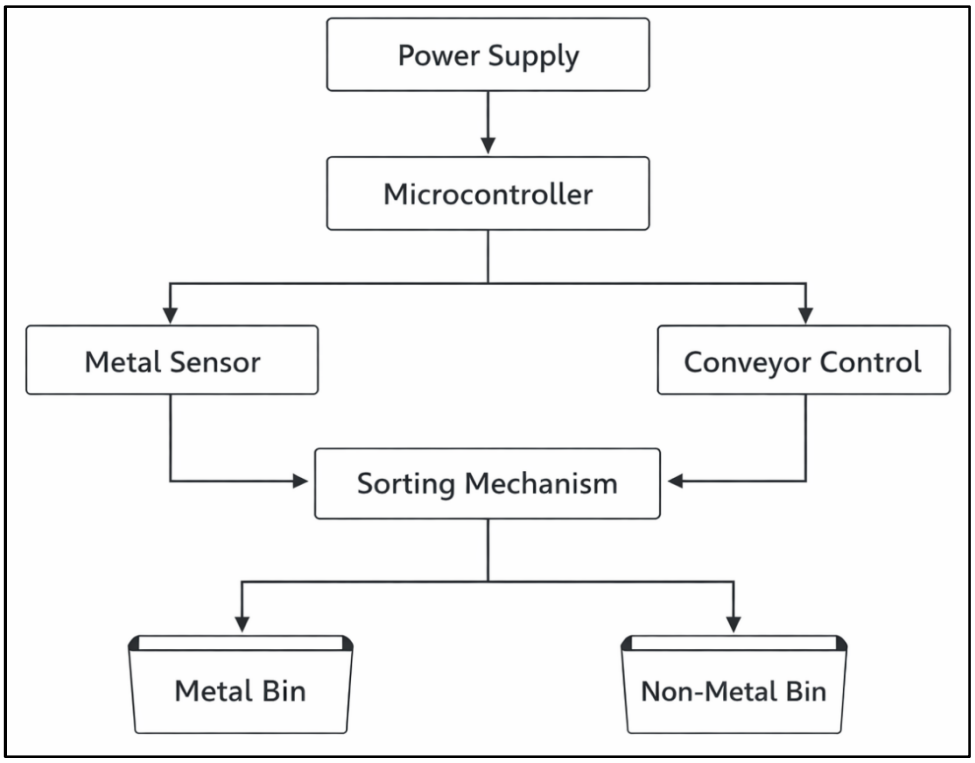


Fig.1Block Diagram of the System Methodology

The working principle of the system is based on inductive proximity sensing technology. An inductive proximity sensor is capable of detecting only metallic objects without any physical contact.

When an object moves on the conveyor belt and enters the sensing range of the inductive proximity sensor, the sensor generates a high-frequency electromagnetic field. If a metallic object (such as iron, steel, or aluminium) comes within this field, eddy currents are induced in the metal surface, which causes a change in the sensor's oscillation. This change is detected by the sensor's internal circuit and converted into an electrical output signal.

The output signal from the inductive sensor is sent to the ESP32 microcontroller. Based on the sensor signal:

- If metal is detected, the controller activates a sorting actuator (servo motor or diverter mechanism) which pushes the object into the metal collection bin.
- If no metal is detected, the object is considered non-metal and continues moving along the conveyor to the non-metal bin.

This method allows contactless, fast, and reliable detection of metallic materials, making the system suitable for automated material segregation in recycling and industrial environments.

IV. HARDWARE & SOFTWARE IMPLEMENTATION

1) Conveyor System: A conveyor belt is used to transport mixed materials from the input section to the detection area. The conveyor is driven by a DC motor to ensure continuous movement of objects.

2) Inductive Proximity Sensor: An inductive proximity sensor is placed near the conveyor to detect metallic objects. When a metal object enters the sensing range, the sensor generates an output signal.

3) Microcontroller Unit: A ESP32 microcontroller acts as the main control unit. It receives signals from the sensor and processes the data to determine whether the object is metal or non-metal.

4) Motor Driver: A motor driver is used to control the conveyor motor. It receives control signals from the microcontroller to operate the motor.

5) Sorting Actuator: A servo motor or mechanical diverter mechanism is used to separate the materials. When metal is detected, the actuator diverts the object into the metal bin.

6) Collection Bins: Two bins are provided at the output section: one for metallic materials and another for non-metallic materials.

7) Power Supply: A regulated power supply provides the required voltage for the microcontroller, sensors, and motors.

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8) Control Software: The system is programmed using the Arduino IDE. The program continuously reads the sensor signal and executes the sorting operation using conditional logic.

9) Continuous Operation: The software runs in a loop, enabling automatic detection and segregation of materials as they move along the conveyor belt.

V. RESULT& DISCUSSION

The Automated Metal and Non-Metal Segregation System was successfully designed, developed, and tested to evaluate its capability in automatically separating metallic and non-metallic materials. The system integrates a conveyor mechanism, an inductive proximity sensor, an ESP32 microcontroller, and a sorting actuator to perform the segregation process. During testing, mixed materials containing both metal and non-metal objects were placed on the conveyor belt. As the conveyor moved the materials through the sensing region, the inductive proximity sensor continuously monitored the objects passing in front of it.

The inductive proximity sensor effectively detected metallic materials such as iron and steel without making physical contact with the objects. When a metal object entered the sensing range of the sensor, it generated an output signal which was transmitted to the ESP32 microcontroller. The microcontroller processed this signal and executed the programmed logic to control the sorting mechanism. Once metal was detected, the controller activated the actuator mechanism, such as a servo motor or mechanical diverter, which redirected the metallic object into the designated metal collection bin. In contrast, objects that did not trigger the sensor were identified as non-metal materials and continued moving along the conveyor until they reached the non-metal collection bin.

Throughout the testing process, the system demonstrated stable and consistent performance. The conveyor mechanism ensured a continuous flow of materials, allowing the detection and sorting process to occur without interruption. The sensor response was quick and reliable, enabling the system to accurately detect metallic objects and activate the sorting mechanism at the correct time. The integration of the ESP32 microcontroller provided efficient processing of sensor signals and smooth coordination between the sensor, conveyor motor, and actuator. As a result, the system was able to perform automatic segregation with minimal delay.

The results obtained from the experimental setup indicate that the proposed automated system can significantly improve the efficiency of material sorting when compared to traditional manual segregation methods. Manual sorting processes often require considerable human effort and time, and they may lead to errors due to fatigue or inconsistent judgment. In contrast, the automated system performs the segregation process continuously and consistently, thereby reducing human intervention and improving productivity. The system also enhances safety by minimizing direct human contact with industrial waste or scrap materials.

Another important advantage of the system is its relatively simple design and cost-effective implementation. The use of commonly available components such as an inductive proximity sensor, ESP32 microcontroller, and basic motor control circuits makes the system suitable for small-scale industries, recycling centres, and educational demonstration purposes. The design can also be scaled or modified to meet the requirements of larger industrial applications.

Despite the successful implementation and performance of the system, certain limitations were observed. The current system is capable of detecting only the presence of metallic objects and cannot differentiate between different types of metals such as aluminium, copper, or steel. In addition, non-metal materials are treated as a single category and are not further classified into different groups such as plastic, rubber, or wood. This limitation may reduce the effectiveness of the system in applications that require detailed material classification.

Future improvements can focus on integrating additional sensing technologies such as optical sensors, weight sensors, or camera-based vision systems to enhance the material identification capability. Advanced algorithms or artificial intelligence techniques can also be incorporated to enable multi-material classification and improve overall sorting accuracy. By implementing such enhancements, the system can be transformed into a more advanced automated material segregation solution suitable for modern recycling and waste management industries.

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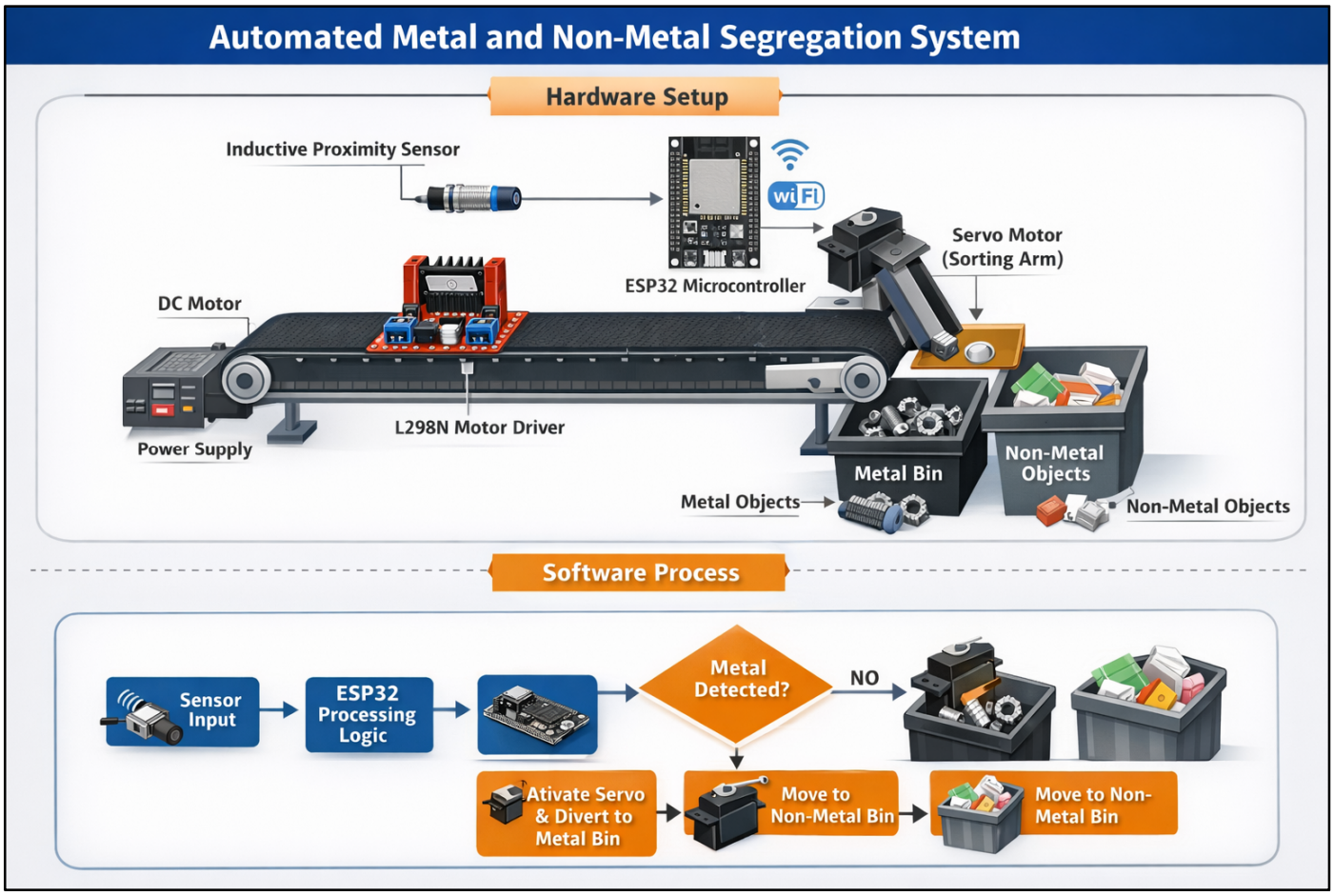


Fig.2 Complete Hardware & Software Setup

VI. CONCLUSION

The Automated Metal and Non-Metal Segregation System was successfully designed and implemented to automatically identify and separate metallic and non-metallic materials. The system integrates an inductive proximity sensor, ESP32 microcontroller, conveyor mechanism, and a sorting actuator to perform the segregation process in an efficient and automated manner. The inductive proximity sensor plays a crucial role in detecting metallic objects without physical contact, while the ESP32 processes the sensor signals and controls the operation of the sorting mechanism.

During the testing phase, the system demonstrated stable and reliable performance. Mixed materials placed on the conveyor belt were transported through the sensing area, where the inductive sensor detected metallic objects accurately. Based on the detection result, the ESP32 activated the sorting actuator to divert metal objects into the metal collection bin, while non-metal objects continued along the conveyor path into the non-metal bin. This automated process ensured consistent and continuous segregation of materials without the need for manual intervention.

The implementation of this system highlights the advantages of automation in material sorting applications. Compared to traditional manual segregation methods, the automated system reduces human effort, increases operational efficiency, and minimizes the chances of sorting errors. The use of widely available and affordable components such as the ESP32 microcontroller and inductive proximity sensor also makes the system cost-effective and suitable for small-scale industrial applications, recycling units, and educational demonstrations.

Although the system performs effectively in separating metal and non-metal materials, it currently detects only the presence of metal and does not differentiate between different types of metals or other materials. Future enhancements can focus on integrating additional sensors or advanced technologies such as vision-based systems to improve the classification capability and expand the range of materials that can be sorted.

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Overall, the developed Automated Metal and Non-Metal Segregation System demonstrates that sensor-based automation can provide an efficient, reliable, and scalable solution for material segregation in industrial and recycling environments.

VII. FUTURE UPGRADES

1) Multi-Material Detection: Additional sensors such as capacitive sensors, colour sensors, or weight sensors can be integrated to classify different types of non-metal materials like plastic, glass, and rubber.
2) Metal Type Identification: Advanced sensing techniques can be used to differentiate between various metals such as aluminium, copper, and steel for more precise sorting.
3) Vision-Based Sorting System: A camera module with image processing or artificial intelligence algorithms can be added to identify objects based on shape, colour, and material type.
4) Industrial Conveyor Integration: The system can be upgraded with a larger and faster industrial conveyor to handle higher volumes of materials for large-scale industrial applications.
5) IoT-Based Monitoring: By utilizing the Wi-Fi capability of the ESP32, the system can be connected to an IoT platform to monitor system performance, sorting data, and operational status remotely.
6) Automated Counting and Data Logging: The system can be enhanced to count the number of metal and non-metal objects sorted and store the data for analysis and performance monitoring.
7) Improved Sorting Mechanism: More advanced actuators such as pneumatic or robotic arms can be implemented to improve sorting speed and accuracy in industrial environments.

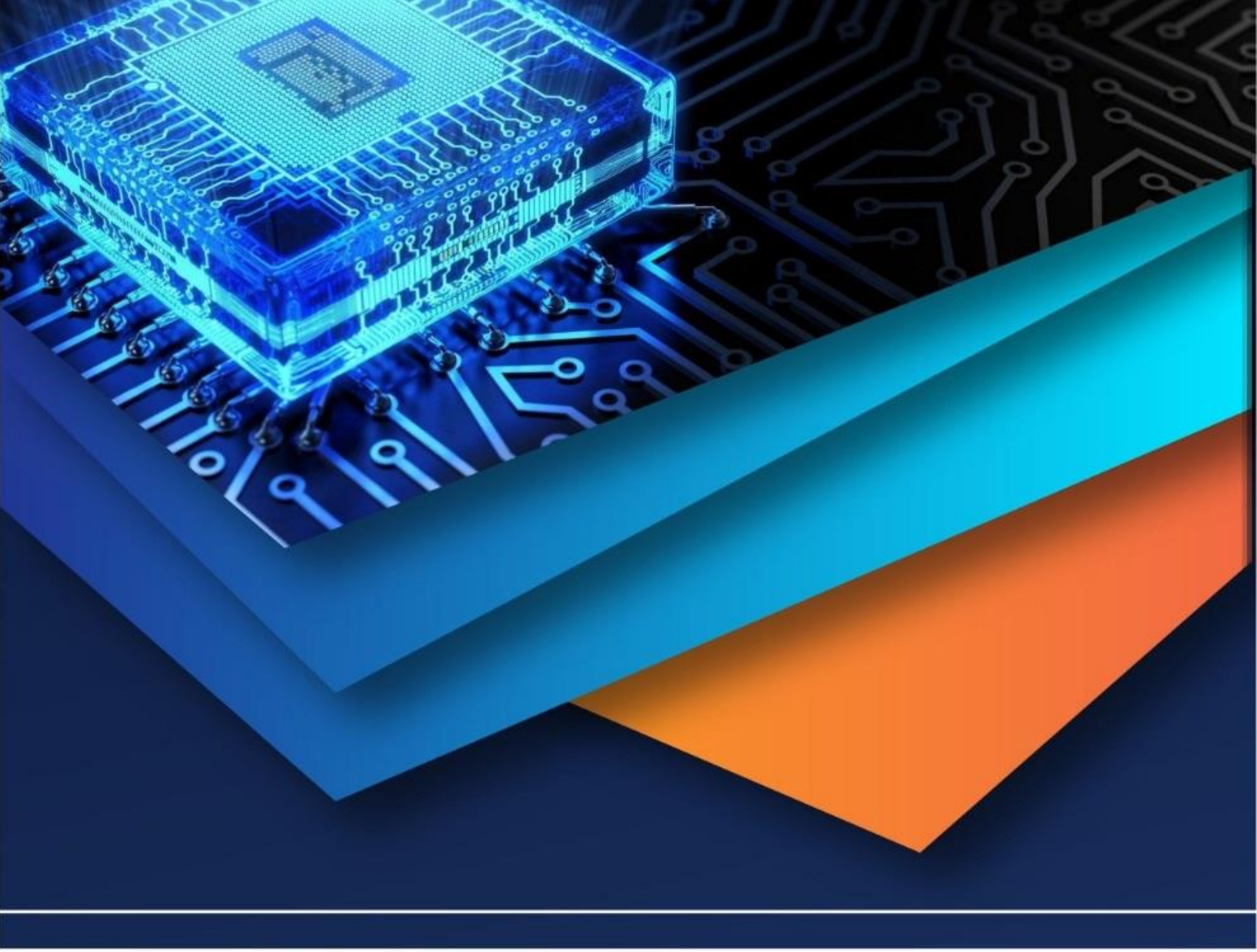
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