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PLC Automation for Industrial Process Control and Monitoring

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Abstract: PLC-based automation is critical for industrial process control and monitoring because it increases efficiency, reliability, and precision. This paper describes the design and construction of a PLC-based automation system for industrial applications, with a focus on a color sorting process utilizing a conveyor mechanism. The system combines a Siemens S7-1200 PLC and an Arduino Uno to provide effective control and real-time operation. The TCS34725 RGB Colour Sensor is used to identify object colour, and the PLC uses the processed data to regulate sorting via an SG90 Servo Motor. The suggested approach improves automation by reducing manual involvement and ensuring accurate and efficient sorting.
Keywords- PLC, Industrial Automation, Process Control, Monitoring, Colour Sorting, Conveyor System, Arduino

I. INTRODUCTION

Industrial automation has become a fundamental requirement in modern manufacturing systems to achieve higher productivity, accuracy, and reliability. The use of Programmable Logic Controllers (PLCs) enables efficient process control and real-time monitoring, reducing human intervention and operational errors. PLC-based systems are widely adopted in industries due to their robustness, flexibility, and ability to handle complex control operations.[2]

This paper focuses on the application of PLC automation in industrial process control and monitoring, with a specific implementation of a color-based object sorting system. The proposed system utilizes a Siemens S7-1200 PLC as the main control unit, integrated with an Arduino Uno for sensor data processing. A TCS34725 RGB Color Sensor is employed to detect the color of objects moving along a conveyor belt. Based on the detected color, the system classifies objects and directs them to appropriate locations using an SG90 Servo Motor.

The integration of PLC and microcontroller technologies provides a hybrid solution that combines industrial reliability with flexible data processing capabilities. This approach enhances system performance, improves sorting accuracy, and enables real-time monitoring of the process.[5]

The developed system is suitable for applications in packaging, quality inspection, and material handling industries. It demonstrates how automation can optimize industrial operations while maintaining consistency and reducing manual effort, making it an effective solution for modern smart manufacturing environments.

II. OBJECTIVE

The primary objective of this work is to design and develop a PLC-based automation system for industrial process control and monitoring, aimed at improving operational efficiency, accuracy, and reliability. The project focuses on implementing an automated color sorting mechanism using a conveyor system, reducing the need for manual intervention and ensuring consistent performance in industrial applications. The integration of industrial control and embedded systems enhances system flexibility and real-time response. To design and implement an automated control system using a Siemens S7-1200 PLC.

- To design and implement a PLC-based automation system for industrial process control and monitoring using a Siemens S71200 PLC.
- To develop a color-based object sorting mechanism using a conveyor system integrated with an Arduino Uno and a TCS34725 RGB Color Sensor.
- To improve sorting accuracy and reduce manual intervention through efficient control and real-time operation.

III. LITERATURE REVIEW

A. Industrial automation and PLC Systems

K. Bolton and F. D. Petruzella explain that industrial automation has become a key component in modern manufacturing systems, improving efficiency, accuracy, and reliability.

Industrial automation has become a key component in modern manufacturing and production processes, enabling improved efficiency, accuracy, and reliability.[4] The increasing demand for high productivity and reduced operational costs has led to the widespread adoption of automated control systems in various industries. Among these, Programmable Logic Controllers (PLCs) play a crucial role in process control and monitoring due to their robustness, flexibility, and ease of programming.

PLCs are widely used to control machinery, production lines, and industrial processes by continuously monitoring input signals and executing predefined control logic to generate appropriate outputs. Systems such as the Siemens S7-1200 PLC are commonly implemented in industrial environments because of their high performance, real-time operation, and ability to handle complex control tasks. PLCs support multiple programming languages, including Ladder Logic, which simplifies the design and implementation of control algorithms.

In addition to control functions, PLCs also provide monitoring capabilities that allow operators to track system performance and detect faults in real time. This enhances system reliability and reduces downtime. Due to these advantages, PLC-based automation systems are extensively used in applications such as material handling, conveyor systems, packaging, and quality control processes.

Overall, the integration of PLCs in industrial automation has significantly improved process efficiency and operational safety, making them an essential component in modern automated systems.

B. Automated Conveyor and Sorting Systems

S. Patil and M. Kulkarni describe that automated conveyor systems are widely used in industries for efficient material handling and sorting applications. Automated conveyor and sorting systems are widely used in industrial applications for efficient material handling and product classification. These systems are designed to transport objects from one location to another while performing operations such as sorting, packaging, and inspection. The use of automation in conveyor systems significantly reduces manual effort, increases processing speed, and ensures consistent performance.

In many industrial setups, conveyor-based sorting systems are controlled using Programmable Logic Controllers (PLCs), which enable precise coordination between sensors, actuators, and control logic. The Siemens S7-1200 PLC is commonly employed for such applications due to its ability to handle real-time control and multiple input/output operations efficiently.[3][6] These systems typically use sensors to detect object properties such as size, shape, or color, and actuators to direct objects to designated locations.

Sorting mechanisms in conveyor systems can vary depending on the application, including mechanical diverters, pneumatic systems, and servo motorbased actuators. The use of compact actuators like the SG90 Servo Motor allows precise positioning and quick response, making them suitable for smallscale automated sorting applications.

Despite their advantages, existing conveyor sorting systems may face challenges such as limited flexibility, high cost, and complexity in integration. Therefore, there is a need for efficient and costeffective solutions that can provide accurate and reliable sorting while maintaining simplicity in design and operation.

C. Color Detection and Sensing Techniques

N. Patel and K. Shah explain that color detection is essential in automated sorting systems, particularly in quality inspection and packaging industries. Color detection plays a significant role in automated sorting systems, especially in applications such as packaging, quality inspection, and material classification. Accurate identification of object color is essential for ensuring proper sorting and maintaining product consistency. Various techniques have been developed for color detection, ranging from basic optical sensors to advanced vision-based systems.

One of the most commonly used approaches in small- to medium-scale automation systems is the use of RGB color sensors. Devices such as the TCS34725 RGB Color Sensor are capable of detecting red, green, and blue light components and converting them into digital signals for processing. These sensors also include an infrared filter and high sensitivity, which improves accuracy under varying lighting conditions. The sensor outputs are typically processed using microcontrollers like the Arduino Uno, which classify objects based on predefined color thresholds.

Compared to image processing techniques, RGB sensors offer a cost-effective and simple solution for real-time color detection. They require less computational power and are easier to integrate with control systems such as PLCs.[8] However, their performance can be affected by external lighting conditions, object surface properties, and sensor calibration.

Despite these limitations, color sensor-based systems are widely adopted in industrial automation due to their simplicity, reliability, and suitability for real-time applications. These characteristics make them an effective choice for implementing colorbased sorting systems in conveyor-based automation.

D. Microcontroller Integration in Automation Systems

M. Margolis states that the integration of microcontrollers in automation systems enhances flexibility and efficiency by enabling advanced data processing and sensor interfacing. Theintegration of microcontrollers in industrial automation systems has significantly enhanced the flexibility, efficiency, and functionality of modern control applications.[2] Microcontrollers are widely used for handling sensor data, performing intermediate processing, and enabling communication between different components of an automated system. Their ability to execute complex operations at low cost makes them suitable for hybrid automation solutions.A single PLC can be programmed as a replacement as a substitute for many relays. PLC control systems have been designed to be easily installed and maintained.[1]

In many applications, microcontrollers such as the Arduino Uno are used alongside Programmable Logic Controllers (PLCs) to improve system performance. While PLCs are responsible for robust control and real-time operation, microcontrollers handle tasks such as data acquisition, signal processing, and sensor interfacing. This division of tasks results in a more efficient and scalable system.

In the proposed system, the microcontroller processes data from the TCS34725 RGB Color Sensor to identify object color accurately. The processed information is then transmitted to the PLC, which executes control actions based on predefined logic. This integration allows for better accuracy in sensing while maintaining the reliability of PLC-based control.

The combination of microcontrollers and PLCs provides several advantages, including reduced system complexity, improved response time, and cost-effectiveness. As a result, such hybrid systems are increasingly used in industrial automation applications such as sorting, monitoring, and process control.

IV. METHODOLOGY

A. System Overview

The proposed system is an automated color-based object sorting system designed for industrial process control and monitoring applications. The system consists of a conveyor belt mechanism, a sensing unit, a control unit, and a sorting mechanism integrated to perform real-time sorting operations. The conveyor belt is used to transport objects from one point to another, ensuring continuous movement within the system.

The sensing unit includes a TCS34725 RGB Color Sensor, which detects the color of objects as they pass through the detection zone. The sensor data is processed using an Arduino Uno, which identifies the color based on predefined parameters. The processed information is then transmitted to the control unit.

The control unit is implemented using a Siemens S71200 PLC, which executes the control logic based on the input received from the Arduino. Depending on the detected color, the PLC activates the sorting mechanism through output signals.

The sorting mechanism utilizes an SG90 Servo Motor to direct objects into designated bins. The overall system ensures efficient, accurate, and realtime sorting of objects while minimizing manual intervention and enhancing industrial automation performance.

B. System Architecture

The system architecture of the proposed automated color sorting system is designed to ensure smooth coordination between sensing, processing, and control units. It consists of four main sections: the conveyor system, sensing unit, processing unit, and control and actuation unit.

The conveyor belt mechanism is responsible for transporting objects through different stages of the system. As the objects move along the conveyor, they pass through the sensing zone, where a TCS34725 RGB Color Sensor detects the color of each object. The sensor outputs are received by the Arduino Uno, which processes the data and determines the color category based on predefined thresholds.

The processed signal is then transmitted to the control unit, which is the Siemens S7-1200 PLC. The PLC acts as the central controller and executes the sorting logic based on the input received from the Arduino. It generates appropriate output signals to control the actuators.[6][8]

The actuation unit consists of an SG90 Servo Motor, which directs the objects into different bins according to their color. The overall architecture ensures efficient communication and synchronization between all components, enabling accurate and real-time sorting operations.

Fig.1.1 represents the block the flow of data from the sensor to the Arduino, then to the PLC, and finally to the actuator, illustrating the complete working of the system.

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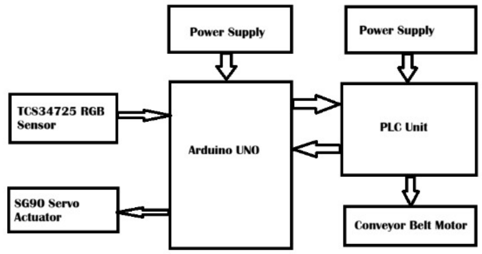

Fig1.1 Block Diagram of system

C. Hardware Implementation

The hardware implementation of the proposed system consists of several key components that work together to achieve automated color-based sorting. The main control unit is the Siemens S7-1200 PLC, which is responsible for executing the control logic and managing the overall operation of the system.[2] It receives input signals from the processing unit and generates output signals to control the actuators.

The sensing and preprocessing unit is implemented using an Arduino Uno, which interfaces with the TCS34725 RGB Color Sensor. The sensor detects the color of objects placed on the conveyor belt by measuring RGB values, and the Arduino processes this data to classify objects into different categories based on predefined thresholds.

The actuation mechanism is achieved using an SG90 Servo Motor, which directs the objects into specific bins depending on the control signals received from the PLC. The servo motor provides precise angular movement, enabling accurate positioning for sorting operations.

The circuit diagram of the proposed system is shown in Fig 1.2. The TCS34725 RGB Color Sensor is connected to the Arduino Uno using I2C communication (SDA and SCL pins). The Arduino processes the sensor data and sends output signals to the Siemens S7-1200 PLC through interfacing circuits such as relays or digital input modules. The PLC then controls the SG90 Servo Motor by generating appropriate output signals to perform the sorting operation. A conveyor belt system is used to transport objects through the sensing and sorting zones, ensuring continuous operation.

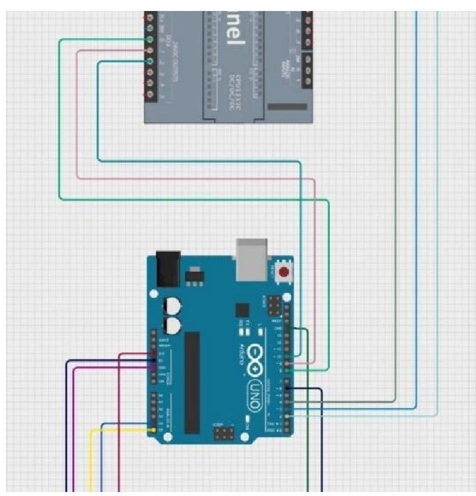

Fig1.2 Circuit Diagram of proposed system.

D. Working Methodology

The working methodology of the proposed system is based on the sequential operation of sensing, processing, and control units to achieve automated color-based sorting. The system operates in real time and ensures continuous and efficient handling of objects on the conveyor belt.

The overall process flow of the system is illustrated in Fig. 1.3

Initially, objects are placed on the conveyor belt, which transports them through the sensing zone. As each object passes through this region, the TCS34725 RGB Color Sensor detects its color by measuring the intensity of red, green, and blue components.

The detected data is then transmitted to the Arduino Uno, where it is processed and compared with predefined threshold values to identify the color category of the object. Once the color is identified, the Arduino sends a corresponding signal to the Siemens S7-1200 PLC through the interfacing circuit. The PLC receives this input and executes the programmed control logic to determine the appropriate sorting action. Based on the received signal, the PLC activates the sorting mechanism.

The sorting operation is performed using an SG90 Servo Motor, which rotates to specific angles corresponding to different color categories. As the object reaches the sorting position, the servo motor directs it into the designated bin. After the sorting process is completed, the system resets and waits for the next object.

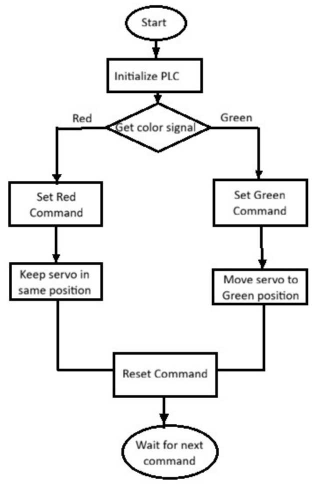

Fig1.3 Flow Chart of System Working

E. *Communication Interface*

The communication interface in the proposed system plays a crucial role in ensuring proper coordination between the sensing, processing, and control units.Networking system can be well incorporated with the PLC application for various functions.[1] It enables reliable data transfer between the Arduino Uno and the Siemens S7-1200 PLC, allowing accurate execution of sorting operations.

In the system, the TCS34725 RGB Color Sensor is interfaced with the Arduino using I2C communication, where the sensor transmits color data in digital form. The Arduino processes this data and determines the color category of the object based on predefined threshold values.

After processing, the Arduino sends corresponding output signals to the PLC through digital output pins. These signals are interfaced with the PLC using relays or suitable interfacing circuits to ensure proper voltage level matching and electrical isolation. The PLC reads these signals as input conditions and executes the control logic accordingly.

The communication between the Arduino and PLC is designed to be simple and reliable, ensuring fast response and minimal delay in operation. Proper synchronization between these units is maintained to avoid signal mismatch and ensure accurate sorting.[4]

Overall, the communication interface enables seamless integration of microcontroller-based sensing with PLC-based control, enhancing system performance and reliability in industrial automation applications.

V. FUTURE SCOPE

The proposed system can be further enhanced to improve its performance, flexibility, and applicability in advanced industrial environments. Future developments may focus on integrating highspeed and high-precision sensors to increase sorting accuracy and efficiency. The use of machine vision systems and image processing techniques can enable more complex object recognition based on shape, size, and defects in addition to color.

The system can also be upgraded by implementing wireless communication or industrial networking protocols for remote monitoring and control. Integration with Human Machine Interface (HMI) systems and Supervisory Control and Data Acquisition (SCADA) can provide better visualization, data logging, and real-time system analysis.

Additionally, replacing conventional control logic with intelligent algorithms or artificial intelligence techniques can further enhance decision-making capabilities. The scalability of the system can be improved to handle larger volumes of objects and multiple sorting categories, making it suitable for large-scale industrial applications.

VI. ADVANTAGES

The proposed PLC-based color sorting system offers several advantages in industrial automation applications. It improves overall system efficiency by automating the sorting process, thereby reducing the need for manual labor. The use of the Siemens S7-1200 PLC ensures reliable and robust control, making the system suitable for continuous industrial operation.

The integration of the Arduino Uno with the TCS34725 RGB Color Sensor provides accurate and real-time color detection, enhancing sorting precision. The system also offers fast response time due to efficient communication between the sensing and control units.

Additionally, the use of an SG90 Servo Motor enables precise positioning for sorting, ensuring consistent output. The system is cost-effective, easy to implement, and can be scaled or modified according to different industrial requirements.

VI. APPLICATION

The proposed PLC-based color sorting system has a wide range of applications in various industrial and commercial sectors. It can be effectively used in manufacturing industries for automated material handling and sorting processes, where accurate and fast classification of objects is required. The use of the Siemens S7-1200 PLC ensures reliable control, making the system suitable for continuous industrial operations.

In the packaging industry, the system can be used to sort products based on color for quality control and proper categorization. It is also applicable in food processing industries for sorting items such as fruits, candies, or packaged goods according to color specifications. The integration of the Arduino Uno and TCS34725 RGB Color Sensor enables accurate detection, which is essential in maintaining product standards.

Additionally, the system can be utilized in recycling plants for segregating materials based on color, improving efficiency and reducing manual effort. It can also be applied in educational and research laboratories for demonstrating industrial automation concepts.

VII. RESULT

The proposed system was successfully designed and implemented to achieve PLC-based automation for industrial process control and monitoring using the Siemens S7-1200 PLC. The PLC effectively controlled the entire operation of the system, including conveyor movement, signal processing, and actuation of the sorting mechanism. The system demonstrated stable and reliable performance under continuous operation, confirming the suitability of PLC-based control for industrial automation applications.

The development of a color-based object sorting mechanism was achieved using a conveyor system integrated with an Arduino Uno and a TCS34725 RGB Color Sensor. The sensor successfully detected the color of objects passing through the sensing zone, and the Arduino processed the RGB values accurately based on predefined threshold conditions. The processed signals were transmitted to the PLC without significant delay, enabling smooth communication between the sensing and control units.

Based on the received input, the PLC executed the control logic and activated the SG90 Servo Motor to perform the sorting operation. The servo motor responded accurately by rotating to specific positions corresponding to different color categories, ensuring correct placement of objects into designated bins. The coordination between the conveyor system, sensor, Arduino, and PLC resulted in a synchronized and efficient sorting process.

The system demonstrated improved sorting accuracy and reduced manual intervention, thereby fulfilling the primary objective of automation. The real-time operation ensured quick response and continuous processing of objects, making the system suitable for small-scale industrial applications. The overall performance was consistent, and the system was able to handle multiple sorting cycles without failure.

A. Case Study

In many small-scale manufacturing and packaging industries, object sorting is still performed manually. For this case study, consider a packaging unit where products are sorted based on color using human labor. Workers visually inspect each object and place it into designated bins. This process is timeconsuming, prone to human error, and requires continuous manual effort.

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In the manual system, sorting speed is limited due to human fatigue, and accuracy varies depending on worker concentration and lighting conditions. Additionally, multiple workers are required to maintain productivity, increasing labor costs and reducing efficiency.

To overcome these limitations, the proposed automated system using a Siemens S7-1200 PLC, Arduino Uno, and TCS34725 RGB Color Sensor was implemented. The system automates the detection and sorting process using a conveyor belt and a servo-based mechanism.

After implementation, the automated system demonstrated significant improvements. The sorting speed increased due to continuous conveyor operation, and accuracy improved because of precise sensor-based detection. The system also reduced the need for manual labor, requiring only minimal supervision.

Comparative Analysis:

Parameters	Manual System	Automated System
Sorting speed	Low (~100–150 items/hr)	High (~250–300 items/hr)
Accuracy	Moderate (~80–85%)	High (~90–95%)
Labour Requirement	2–3 workers	1 operator
Efficiency	Low	High

Fig 2.1 shows the comparison between manual and automated color sorting systems. It can be observed that the automated system significantly improves sorting speed and accuracy while reducing labor requirements. The manual system shows lower performance due to human limitations, whereas the automated system ensures consistent and efficient operation. This comparison clearly demonstrates the effectiveness of the proposed PLC-based automation system.

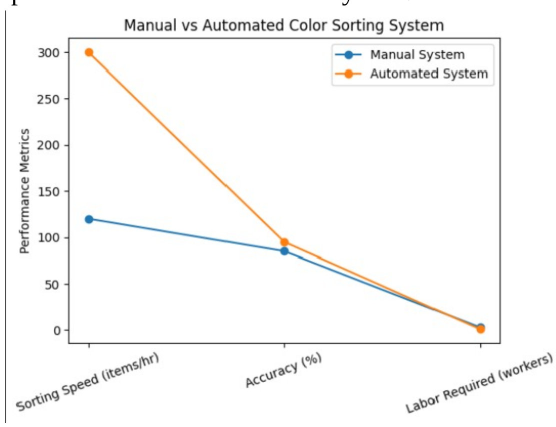

Fig 2.1 Graphical Representation of Comparative Analysis

VIII. CONCLUSION

This paper presented the design and implementation of a PLC-based automation system for industrial process control and monitoring, with a specific focus on color-based object sorting. The system was successfully developed using a Siemens S7-1200 PLC as the main control unit, integrated with an Arduino Uno for sensor data processing. The use of the TCS34725 RGB Color Sensor enabled accurate detection of object colors, while the SG90 Servo Motor provided precise sorting based on control signals from the PLC.

The proposed system effectively achieved its objectives by automating the sorting process, reducing manual intervention, and improving operational efficiency. The integration of PLC and microcontroller technologies ensured reliable communication, real-time response, and consistent performance. The system demonstrated satisfactory accuracy and stability under controlled conditions, making it suitable for small-scale industrial applications.

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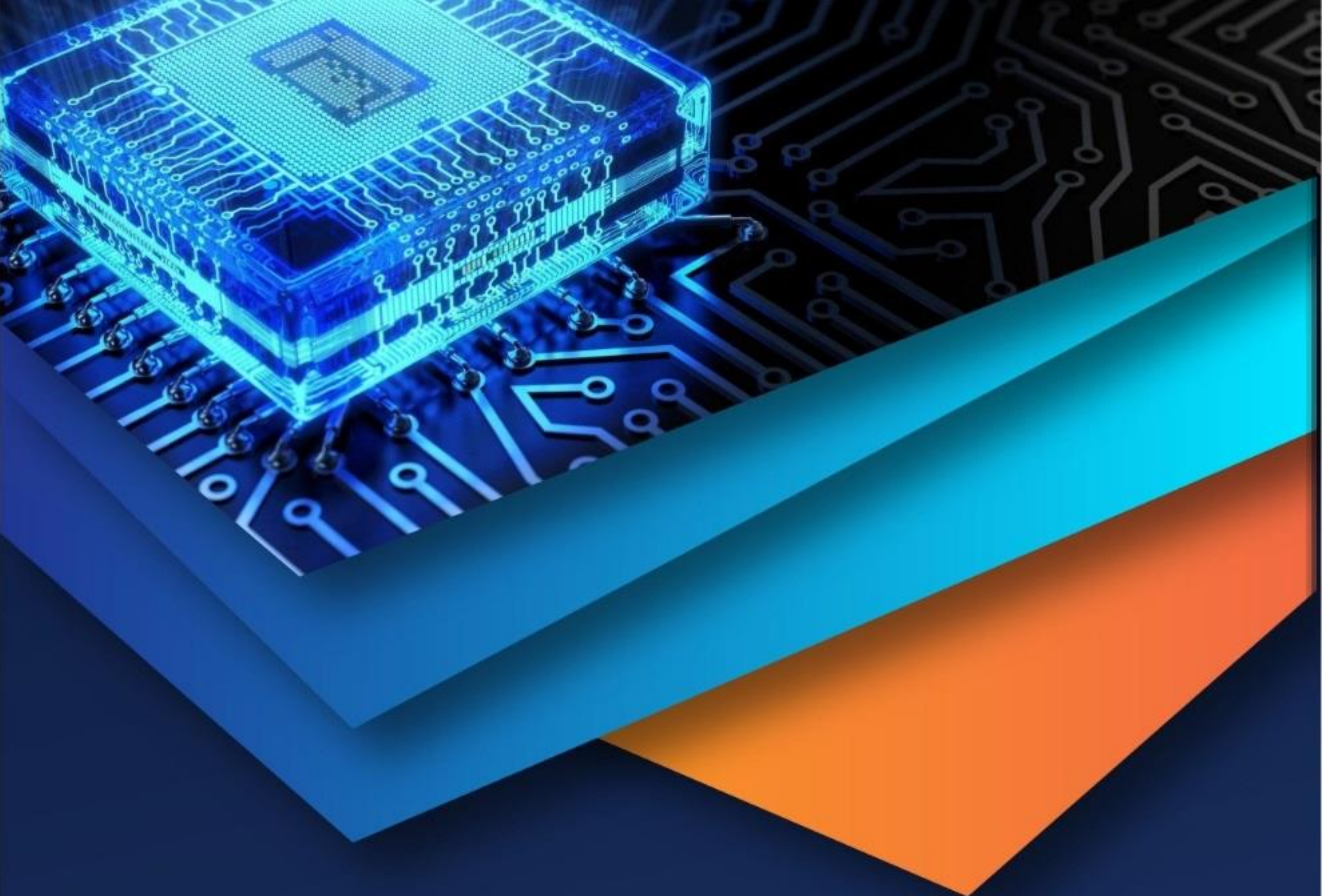

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