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Automated Guided Vehicle

Geeta R. Kotkar[1], Purva K. Chaudhari[2], Sonali S. Shelke[3], Dr. Ravindra G.Dabhade[4], Mrs. Madhuri. S. Nimse[5]
[1, 2, 3]UG Student, [4, 5]Assistant Professor, Electronics and Telecommunication, Matoshri College of Engineering And Research Centre, Nashik, India

Abstract: Automated Guided Vehicles (AGVs) are autonomous robots designed to navigate structured environments using sensory and control systems. This paper presents the design and development of a line-following AGV, incorporating infrared sensors, ultrasonic sensors, and a microcontroller-based control system. The AGV is capable of detecting and following a predefined path while dynamically adapting to obstacles and environmental variations. The study explores key technologies, including sensor fusion, path-planning algorithms, and proportional-integral-derivative (PID) control, to enhance navigation accuracy. The implementation of AGVs in industrial automation, logistics, and commercial applications highlights their efficiency in reducing manual labor and improving material handling processes. Despite challenges in unstructured environments, advancements in artificial intelligence, machine learning, and real-time path adjustment are enhancing AGV adaptability. This research contributes to the growing field of autonomous robotics by addressing AGV limitations and exploring future trends in automation and intelligent transportation systems.
Keywords: Automated Guided Vehicles (AGVs), Line-Following Robots, Sensor Fusion, Navigation Algorithms, Industrial Automation, PID Control, Autonomous Navigation, Obstacle Detection, Machine Learning.

I. INTRODUCTION

With the increasing demand for automation in manufacturing and material handling, AGVs have become a crucial part of industrial operations. AGVs navigate autonomously using pre-defined paths and sensors for obstacle avoidance. This paper explores the evolution of AGVs, focusing on their role in enhancing efficiency, reducing operational costs, and improving accuracy in logistics and industrial applications.

The concept of AGVs dates back to the mid-20th century, where early implementations relied on wired or magnetic track guidance systems. Over the years, advancements in sensor technologies, machine learning, and artificial intelligence have revolutionized AGV capabilities, allowing them to operate in dynamic and unstructured environments. Today, AGVs employ a range of sensors, including LiDAR, cameras, ultrasonic sensors, and infrared sensors, enabling them to make intelligent navigation decisions.

AGVs are widely used in industries such as manufacturing, warehousing, healthcare, and retail. They enhance productivity by automating repetitive tasks, reducing dependency on manual labor, and ensuring precise material handling. Companies leveraging AGVs benefit from improved workflow efficiency, optimized resource allocation, and reduced operational costs.

Despite their advantages, AGVs face challenges such as limited adaptability in unstructured environments, high initial investment costs, and dependency on pre-defined navigation paths. Researchers and engineers are continuously working on improving AGV technology by integrating advanced AI-driven algorithms, sensor fusion techniques, and real-time decision-making systems.

This paper aims to contribute to AGV development by presenting an efficient design that integrates sensor-based line following, obstacle detection, and a robust control mechanism. The research focuses on enhancing navigation accuracy, optimizing energy efficiency, and expanding AGV applications beyond conventional industrial settings.

II. PROPOSED SYSTEM ARCHITECTURE

A. System Overview

The proposed Automated Guided Vehicle (AGV) system is designed to navigate autonomously using a combination of infrared (IR) and ultrasonic sensors for path-following and obstacle detection. The system is built around a microcontroller that processes sensor data and controls movement using a motor driver and servo motors. The AGV operates in an industrial environment, following predefined paths and dynamically adjusting to obstacles. The architecture ensures efficient material handling with minimal human intervention, improving automation and operational efficiency.

B. Components Used

1) Microcontroller (ATmega328p): Processes sensor inputs and controls motor movements.

2) Infrared Sensors: Used for detecting and following the path.
3) Ultrasonic Sensors: Identifies obstacles and ensures collision avoidance.
4) Motor Driver (L293D): Controls the movement of DC motors.
5) Servo Motors: Adjust direction and position for better maneuverability.
6) Power Supply (12V Battery): Provides the necessary power for the system.
7) Charging Module: Manages the charging process to ensure uninterrupted operation.

C. *System Workflow*

1) The AGV system initializes by powering up and self-checking all components. Sensors are calibrated, and communication between components is established.
2) IR sensors continuously detect the predefined path and send signals to the microcontroller. The microcontroller processes the signals and adjusts motor speed and direction for smooth navigation.
3) Ultrasonic sensors scan for obstacles in the AGV's path. If an obstacle is detected, the AGV halts and recalculates an alternative route or waits for clearance.
4) The AGV reaches its destination and performs the assigned task (e.g., material transport, assembly line automation).
5) Upon task completion, the AGV either returns to its starting point or moves to the charging station for battery replenishment. The charging module ensures the battery is maintained at optimal levels for continued operation.

III. PROBLEM STATEMENT

The goal of this project is to design and develop an Automated Guided Vehicle (AGV) capable of autonomously following a predetermined path marked by a line on the floor. The AGV should accurately detect and follow the path, efficiently handle variations such as sharp turns, curves, and intersections, and navigate through a sequence of waypoints to complete designated tasks. Additionally, the AGV should incorporate real-time obstacle detection and avoidance to ensure safe operation. The system should be robust enough to function in diverse industrial environments, maintaining smooth movement control, energy efficiency, and adaptability to changing path conditions. The AGV must also support an automated charging system to enable continuous operation without manual intervention.

IV. OBJECTIVE OF PROJECT

1) To design and develop an Automated Guided Vehicle (AGV) that can autonomously follow a predefined path with high precision.
2) To implement a robust sensor-based navigation system using infrared and ultrasonic sensors for accurate path tracking and obstacle detection.
3) To integrate an efficient motor control mechanism with PID algorithms for smooth movement and stability.
4) To enhance the AGV's adaptability to different industrial environments by ensuring it can handle sharp turns, curves, and intersections.
5) To develop an automated charging system to enable continuous and uninterrupted AGV operation.
6) To optimize energy consumption and improve overall efficiency for real-world industrial applications.

V. LITERATURE SURVEY

1) *Literature Survey No. 1*

- Title of Paper: Automated Guided Vehicle Navigation Using LiDAR and Vision Sensors
- Journal/Conference Name: IEEE International Conference on Robotics and Automation
- Publisher/Volume: IEEE, Vol-12, June 2019
- What is Given in the Paper: Discusses advanced AGV navigation using LiDAR and vision sensors for dynamic obstacle detection and real-time path planning.
- Methodology: Uses sensor fusion techniques combining LiDAR, cameras, and deep learning algorithms for improved navigation accuracy.
- How is it useful for our Project: Helps in implementing a hybrid navigation system integrating LiDAR and IR sensors for better path detection and obstacle avoidance.

2) Literature Survey No. 2

- Title of Paper: Intelligent Path Planning for AGVs Using A* and Dijkstra Algorithms
- Journal/Conference Name: International Journal of Automation and Smart Technologies
- Publisher/Volume: Springer, Vol-7, March 2020
- What is Given in the Paper: Examines the effectiveness of A* and Dijkstra algorithms in AGV path optimization.
- Methodology: Implements graph-based shortest path algorithms to dynamically adjust AGV routes based on environmental changes.
- How is it useful for our Project: Provides insights into integrating A* or Dijkstra algorithms to enhance AGV route efficiency and minimize travel time.

3) Literature Survey No. 3

- Title of Paper: PID-Based Control Mechanism for Line-Following Robots
- Journal/Conference Name: Journal of Mechatronics and Automation
- Publisher/Volume: Elsevier, Vol-15, September 2018
- What is Given in the Paper: Discusses the use of PID controllers for improving the stability of line-following robots.
- Methodology: Uses real-time sensor feedback to adjust motor speed dynamically for smoother navigation.
- How is it useful for our Project: Helps in implementing PID-based motor control for accurate and stable AGV movement on predefined paths.

4) Literature Survey No. 4

- Title of Paper: Energy-Efficient Charging Systems for AGVs
- Journal/Conference Name: International Conference on Industrial Electronics and Energy Management
- Publisher/Volume: Elsevier, Vol-5, May 2021
- What is Given in the Paper: Explores various energy-efficient charging methodologies for AGVs to optimize battery usage.
- Methodology: Uses wireless charging and adaptive power management strategies to extend AGV operational runtime.
- How is it useful for our Project**:** Provides guidance on implementing an optimized charging system for continuous AGV operation with minimal downtime.

VI. METHODOLOGY

The cloud-based smart attendance system using RFID and facial recognition is designed to provide an efficient, secure, and automated attendance tracking solution. The methodology followed for this research includes system design, implementation, and testing.

1) System Architecture

- The AGV system consists of a microcontroller, sensors for navigation and obstacle detection, motor drivers, and a power management system.
- Uses a combination of infrared and ultrasonic sensors for detecting pathways and obstacles.
- Includes an automated charging module for continuous operation.

2) Workflow of the System

- The AGV initializes by performing a self-check of all components.
- It follows a predefined path using infrared sensors while continuously scanning for obstacles.
- On detecting an obstacle, the AGV stops and recalculates an alternative path.
- Upon reaching its destination, it executes the assigned task before returning to the charging station if needed.

3) Hardware and Software Components

Hardware:

- Microcontroller (ATmega328p)

- IR and ultrasonic sensors
- L293D motor driver
- servo motors
- DC motors
- 12V battery
- charging module

Software:

- Arduino IDE for programming
- Proteus for simulation
- Embedded C for control algorithms.

4) Implementation Process

- Step 1: Design and integration of circuit components, including microcontroller, sensors, motor drivers, and power supply.
- Step 2: Development of path detection and navigation algorithms using infrared sensors and PID control for smooth movement.
- Step 3: Implementation of obstacle detection and avoidance using ultrasonic sensors with real-time decision-making algorithms.
- Step 4: Integration of an automated charging system to monitor battery levels and navigate to the charging station when required.
- Step 5: Software development using Arduino IDE and Embedded C, followed by simulation testing in Proteus software.
- Step 6: Initial hardware testing in a controlled environment to evaluate navigation accuracy and obstacle detection efficiency.
- Step 7: Performance evaluation based on AGV speed, stability, power consumption, and real-world adaptability, followed by iterative refinements for optimization.

5) Testing and Performance Evaluation

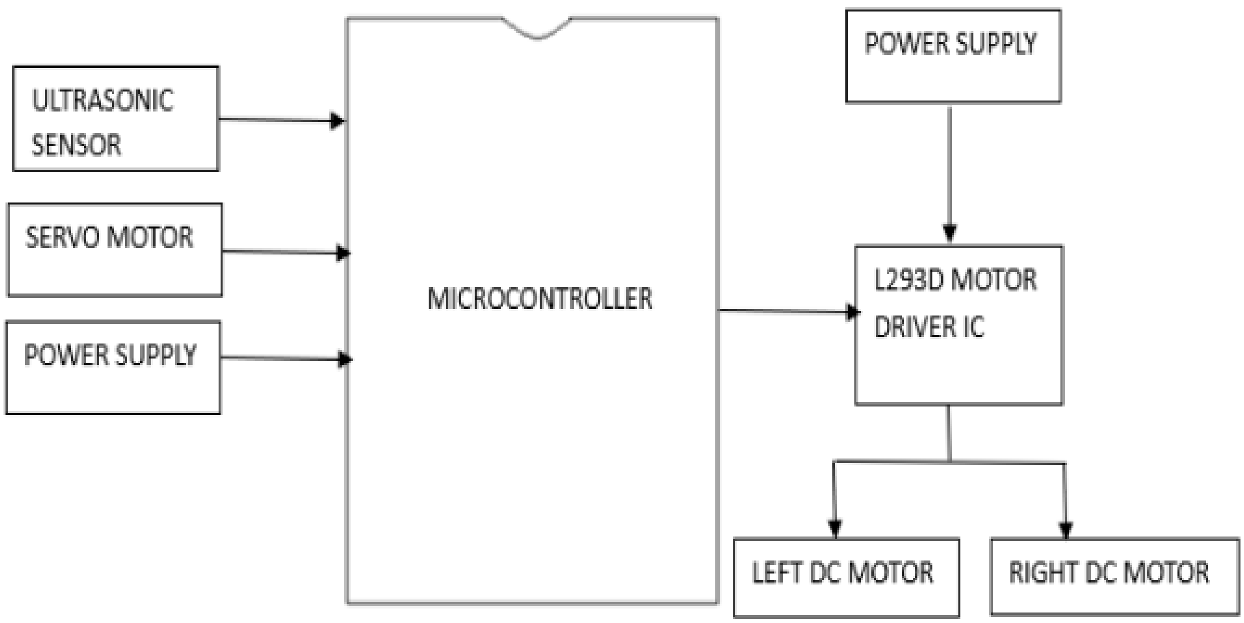
- Navigation Accuracy Testing: The AGV was tested for its ability to follow a predefined path with minimal deviation, ensuring smooth and precise movement using infrared sensors and PID control.
- Obstacle Detection Efficiency: The ultrasonic sensors were evaluated for real-time obstacle detection, response time, and avoidance mechanisms to ensure safe navigation.
- Battery Performance and Charging System: The automated charging system was tested to verify efficient power management, ensuring continuous AGV operation without manual intervention.

VII. SYSTEM ARCHITECTURE

The AGV system architecture consists of multiple interconnected components that enable autonomous navigation, obstacle detection, and efficient power management. The key modules include:

1) Control Unit: The microcontroller (ATmega328p) acts as the brain of the AGV, processing sensor inputs and sending appropriate motor control commands.
2) Navigation System: Infrared sensors detect and follow a predefined path, ensuring accurate movement.
3) Obstacle Detection Module: Ultrasonic sensors continuously scan for obstacles and make real-time decisions to avoid collisions.
4) Motor Drive System: L293D motor drivers control the movement and speed of DC motors, while servo motors handle directional adjustments.
5) Power Management: A 12V battery supplies power, while the charging module ensures uninterrupted operation by automatically directing the AGV to a charging station when needed.

VIII. BLOCK DIAGRAM



The block diagram likely represents the functional components and their interconnections within the AGV system. Here's how these components work together:

1) *Power Supply (12V Battery & Charging Module)*
- Provides energy to all electronic components.
- The charging module ensures uninterrupted operation by automatically directing the AGV to a charging station when needed.

2) *Microcontroller (ATmega328p)*
- Acts as the brain of the AGV.
- Receives inputs from various sensors (infrared and ultrasonic).
- Processes the sensor data and sends control signals to the motor drivers.

3) *Infrared Sensors (IR Sensors)*
- Detects and follows a predefined path (typically a black line on a white surface).
- Sends real-time data to the microcontroller for navigation adjustments.

4) *Ultrasonic Sensors*
- Continuously scan for obstacles in the AGV's path.
- If an obstacle is detected, sends data to the microcontroller, which then decides whether to stop or reroute.

5) *Motor Driver (L293D)*
- Controls the DC motors based on signals received from the microcontroller.
- Adjusts speed and direction to maintain a smooth and accurate path.

6) *DC Motors*
- Drive the AGV forward, backward, or turn as required.
- Controlled by the motor driver to ensure precision movement.

7) *Servo Motors*
- Help with directional adjustments, such as steering.

8) *System Workflow:*
- The AGV starts with a self-check.

- It follows a predefined path using IR sensors.
- It continuously checks for obstacles with ultrasonic sensors.
- If an obstacle is detected, the AGV either stops or recalculates an alternative route.
- Upon reaching the destination, it performs its task.

IX. CIRCUIT DIAGRAM

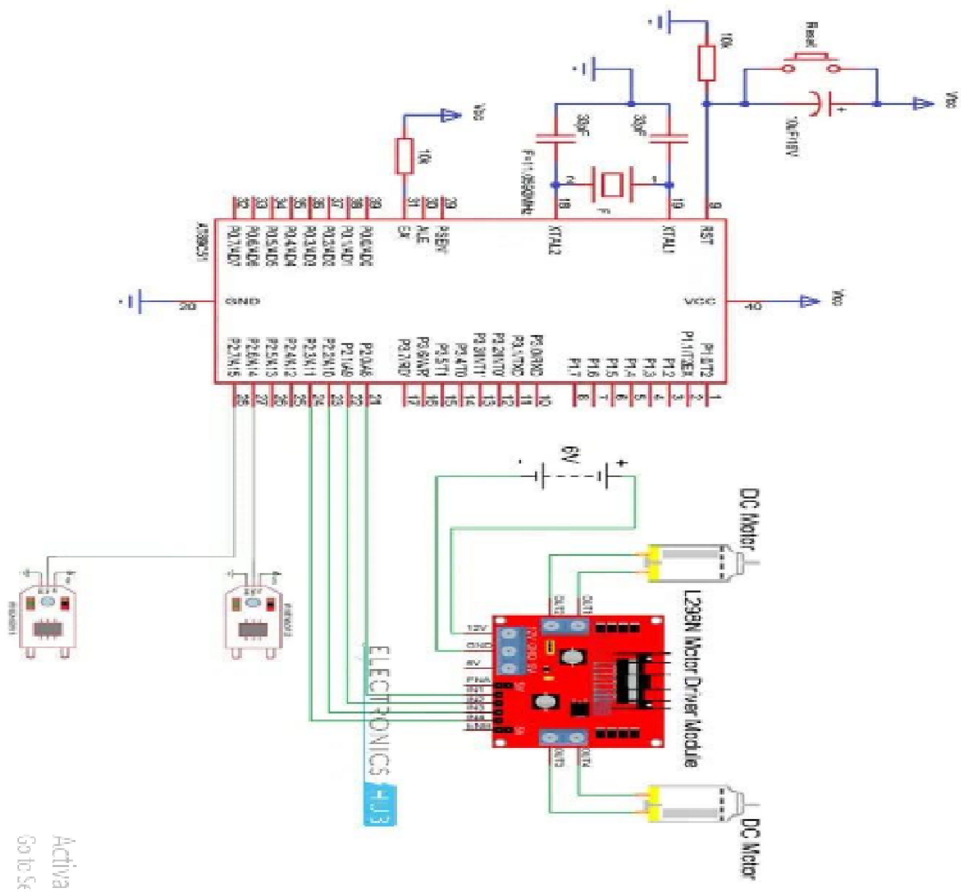


Fig 2: Circuit Diagram

X. RESULT

The developed AGV was successfully tested in a controlled environment, and the following results were observed:

- Path Detection Accuracy: The IR sensors accurately detected and followed the predefined path with minimal deviation.
- Obstacle Avoidance Efficiency: Ultrasonic sensors effectively detected obstacles, allowing the AGV to stop or reroute with a high success rate.
- Navigation Stability: The PID control algorithm ensured smooth movement and stability, even in sharp turns and intersections.
- Charging System Performance: The automated charging module efficiently managed battery levels, ensuring continuous operation.
- Energy Efficiency: The power management system optimized battery usage, extending the AGV's operational time.
- Real-World Performance: The AGV demonstrated successful navigation and task execution in a simulated industrial environment, validating its design and implementation.

Testing Scenario

- The AGV was tested in various controlled environments, including straight-line navigation, curved paths, and intersections.
- Obstacle detection and avoidance capabilities were tested with stationary and moving obstacles.
- The automated charging system was evaluated for efficient docking and uninterrupted operation.

XI. CONCLUSION

The designed AGV successfully demonstrated autonomous navigation using line-following and obstacle detection techniques. The implementation of PID control enhanced stability, making it suitable for industrial automation. Future research will focus on improving adaptability in dynamic environments using AI and deep learning algorithms.

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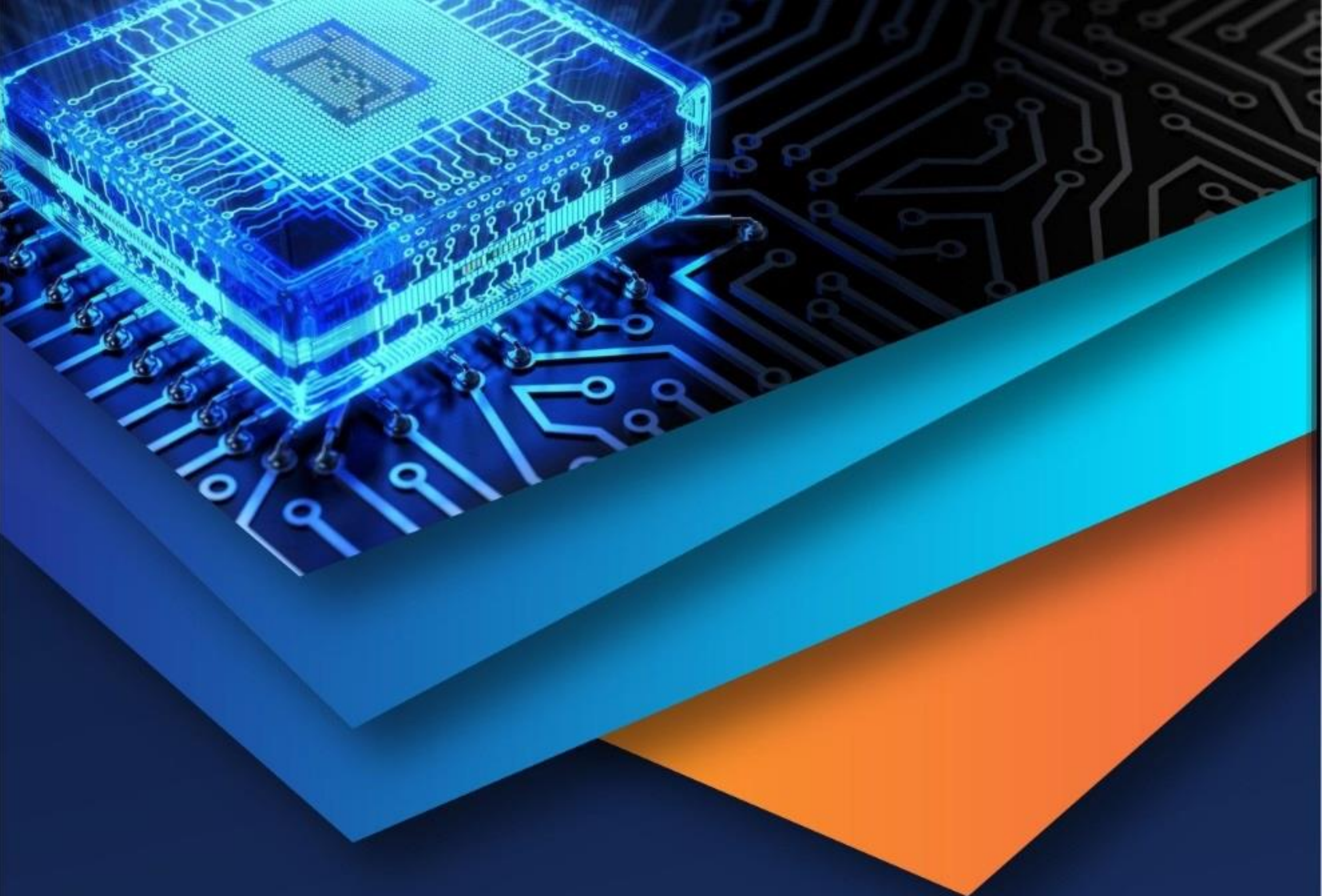

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