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Dual Axis Solar Tracking System Using Arduino

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Abstract: The growing demand for clean and renewable energy has increased the need to improve the efficiency of solar power systems. Conventional solar panels are usually installed in a fixed position, which prevents them from continuously facing the sun as it moves across the sky during the day. As a result, a significant portion of available sunlight is not effectively utilized, leading to reduced power generation.To address this limitation, this project presents the design and development of a dual-axis solar tracking system that automatically follows the movement of the sun to maximize energy output. The system is controlled by an Arduino Uno, which acts as the central processing unit. Four BPW34 silicon photodiodes are used as light sensors to detect sunlight intensity from different directions. The Arduino continuously compares the sensor readings and determines the direction in which the solar panel should move.Two servo motors are used to achieve movement in both axes: the MG996R servo motor controls horizontal rotation, while the SG90 servo motor controls vertical movement. A tolerance-based control algorithm is implemented to ensure smooth operation and to prevent unnecessary motor movement. By continuously aligning the panel with the sun, the proposed system improves energy capture compared to fixed solar panels. The developed model offers a practical, low-cost solution suitable for small-scale solar applications and educational purposes.

I. INTRODUCTION

Nowadays, the demand for energy is increasing rapidly, and the environmental issues caused by fossil fuels have increased the importance of renewable energy sources. Among the available renewable options, solar energy is considered one of the most reliable and widely used because it is clean, abundant, and naturally available. Solar panels convert sunlight into electrical energy using photovoltaic (PV) technology, but their efficiency mainly depends on the amount of sunlight they receive. In many solar power systems, the panels are installed in a fixed position since the design is simple and cost-effective. However, this approach has a limitation because the sun continuously moves from east to west during the day, and a fixed solar panel cannot always face the sun directly, which reduces the overall energy produced [1]. To overcome this limitation, solar tracking systems are used to adjust the position of the panel so that it can follow the movement of the sun and capture more sunlight throughout the day. Among the different tracking methods, dual-axis tracking systems are more effective because they allow the panel to move in both horizontal and vertical directions, helping it maintain better alignment with sunlight and improve the overall efficiency of the photovoltaic system [3].

II. HARDWARE AND COMPONENCES

A. Hardware

The proposed system aims to improve the efficiency of solar power generation by allowing the solar panel to follow the movement of the sun throughout the day. This is achieved through a dual-axis tracking mechanism controlled by an Arduino microcontroller, which continuously adjusts the panel’s position based on the direction of sunlight. The system includes several main components such as a solar panel, silicon diode sensors, an Arduino microcontroller, servo motors, and a mechanical support structure. The silicon diodes act as light sensors that help detect the direction of maximum sunlight. When exposed to sunlight, these diodes produce a small voltage that indicates the intensity of light, helping the system determine the direction in which the panel should move. The signals produced by these sensors are sent to the Arduino microcontroller, where they are processed to decide the required movement of the solar panel. Based on this processed information, the Arduino sends control signals to the servo motors that adjust the panel’s orientation. Two servo motors are used in this setup: one controls the horizontal movement of the panel (east–west direction) and the other controls the vertical movement (north–south direction). By coordinating these two movements, the solar panel can continuously align itself with the sun’s position. This continuous tracking allows the panel to receive maximum sunlight during the day, thereby increasing the overall efficiency and energy output of the solar power system, which is consistent with the operation of automated dual-axis solar tracking systems reported in previous studies [6], [11].

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1) *Block Diagram*

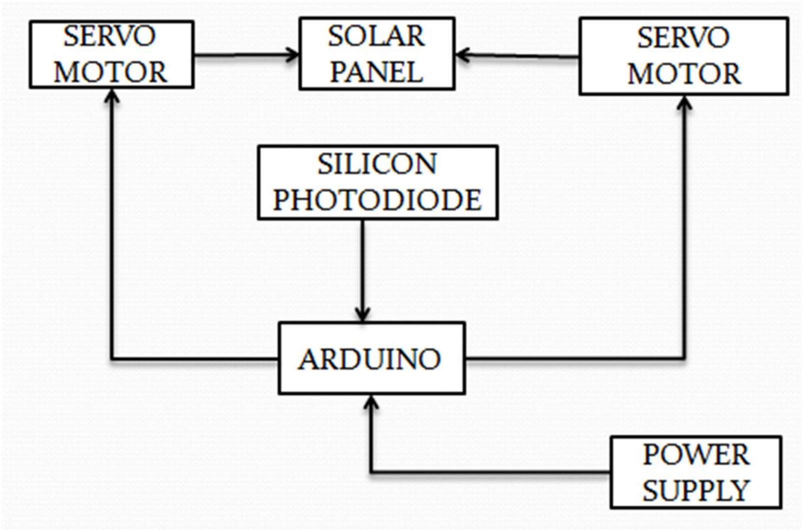

Fig-1- Block Diagram

2) *Circuit Diagram*

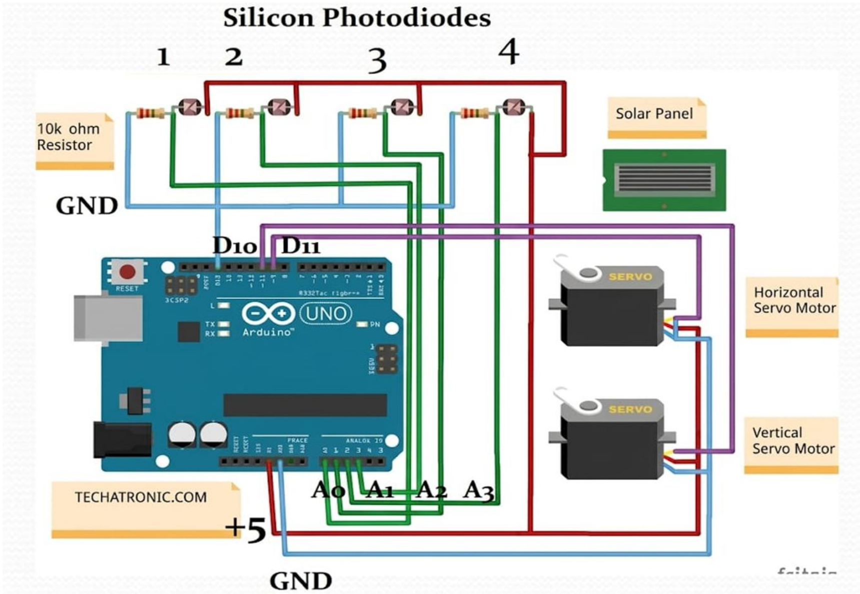

Fig-2- Circuit Diagram

The circuit diagram represents a practical solar tracking setup built using an Arduino Uno and four silicon photodiode sensors. In this system, the Arduino acts as the main controller or “brain,” coordinating the operation of all connected components. The four photodiodes are placed at the top of the circuit and labeled 1, 2, 3, and 4, each positioned to detect sunlight from different directions. When light falls on these sensors, they generate small voltage variations depending on the intensity of the light. These voltage signals are then sent to the analog input pins of the Arduino (A0, A1, A2, and A3), where the microcontroller reads and compares the values to determine the direction of the strongest light. The +5V and GND pins of the Arduino provide the necessary power supply for the sensors and other electronic components in the circuit. On the output side of the system, motor driver components are connected to DC motors, which are controlled by signals from the Arduino. Based on the sensor readings, the Arduino processes the data and sends commands to the motors so that the connected mechanism moves toward the direction of maximum sunlight. In simple terms, the sensors detect the light, the Arduino processes the information, and the motors adjust the position of the system accordingly. This type of sensor-based control circuit is widely used in solar tracking applications to automatically orient solar panels toward the sun and improve the overall energy efficiency of photovoltaic systems [8], [10].

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B. Componences

1) Silicon Photo Diode

In the dual-axis solar tracking system, four BPW34 silicon photodiode sensors are used to detect the direction and intensity of sunlight. These photodiodes are placed at four different positions—Top Left, Top Right, Bottom Left, and Bottom Right—so that the system can sense sunlight from both the horizontal and vertical directions. Each photodiode operates in reverse-bias mode, which allows the sensor to respond quickly and detect even small variations in light intensity. When sunlight falls on the photodiode, it generates a small photocurrent that increases as the light intensity becomes stronger. Since the Arduino Uno (ATmega328P) cannot directly measure current, a 10 kΩ resistor is connected to convert the generated current into a corresponding voltage signal that can be read through the Arduino's analog input pins. The Arduino continuously monitors and compares the voltage values from all four sensors. If one sensor detects higher light intensity than the others, the controller identifies the direction of the sun and commands the servo motors to rotate the solar panel toward that brighter side. By continuously adjusting the panel's orientation in this way, the solar tracking system ensures that the panel remains aligned with the sun throughout the day, thereby increasing the amount of solar energy captured and improving overall system efficiency compared to a fixed solar panel system. [14].

Fig-3- Silicon Photo Diode

2) MG996R Servomotor

The MG996R servo motor is a strong and reliable actuator that is widely used in robotics and automation projects where higher torque and precise movement are required. It normally operates within a voltage range of 4.8 V to 7.2 V and is capable of producing enough torque to move mechanical structures such as robotic arms, solar panels, and other positioning mechanisms. In solar tracking applications, servo motors play an important role in adjusting the orientation of the solar panel so that it can follow the movement of the sun and capture maximum sunlight throughout the day [10]. The MG996R servo motor has three connection wires: the brown wire for ground, the red wire for the power supply, and the orange or yellow wire for the control signal. Inside the motor, several components work together, including a DC motor, a set of durable metal gears, a control circuit, and a potentiometer that helps detect the position of the motor shaft. The use of metal gears makes the motor stronger and more durable compared to small servos that use plastic gears, allowing it to handle heavier loads and operate reliably in practical systems. The motor works using Pulse Width Modulation (PWM) signals, which are typically generated by microcontrollers such as the Arduino Uno (ATmega328P) to control the rotation angle of the motor shaft, usually within a range of 0° to 180°. An internal feedback mechanism continuously monitors the shaft position and adjusts the motor until the required angle is reached and maintained. This feedback control allows the servo motor to produce smooth, accurate, and stable movement, making it suitable for automated systems such as Arduino-based dual-axis solar tracking systems [11].

Fig-4- Mg996r Servomotor

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TABLE I.
Servo Motor MG996R Specification

Rotation angle	180°
Weight	55 g
Operating voltage	4.8 – 6.6 v
Dead band width	1 us

3) SG90 Servomotor

The SG90 micro servo motor is a small, lightweight, and easy-to-use actuator that is commonly used in electronics and robotics projects, especially in systems controlled by microcontrollers such as the Arduino Uno (ATmega328P). It usually operates within a voltage range of 4.8 V to 6 V and can rotate approximately 0° to 180°, which makes it suitable for applications that require controlled and accurate movement. In many automated systems, including solar tracking systems, small servo motors are used to adjust the position of solar panels so that they can follow the movement of the sun and improve energy collection efficiency [10]. The SG90 servo motor has three connecting wires: the brown wire for ground, the red wire for the power supply, and the orange or yellow wire for the control signal. Inside the motor, there are several important components such as a small DC motor, a gear mechanism, a control circuit, and a potentiometer, which helps in detecting the position of the motor shaft. The gear mechanism helps reduce the speed of the motor while increasing torque, allowing the shaft to move smoothly and reach the required angle accurately. The SG90 operates using Pulse Width Modulation (PWM) signals that are usually generated by controllers like the Arduino. These signals determine the rotation angle of the motor shaft. The internal feedback system continuously monitors the shaft position through the potentiometer and adjusts the motor until the desired angle is reached and maintained. Because of its simple design, reliable performance, compact size, and low cost, the SG90 servo motor is widely used in Arduino-based automation projects, robotics systems, educational experiments, and solar tracking applications where precise and controlled movement is required [11], [12].

Fig-5 - SG90 Servomotor

TABLE 2.
Servo Motor SG90 Specification

Operating voltage	4.8 – 6 v
weight	10.5 g
Rotating angle	180°
Operating Temperature	-30 to 60°C
Dead band width	7 us

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4) Arduino Uno

The Arduino Uno (ATmega328P) is a simple and widely used microcontroller board that helps students and beginners learn electronics and create practical projects. It uses the ATmega328P microcontroller as its main controller, which works at 16 MHz and operates on a 5 V power supply. The board has 14 digital input/output pins for controlling devices, 6 analog input pins for reading values from sensors like light or temperature sensors, and 6 PWM pins that allow smooth control of motors and LEDs. It also has 32 KB of flash memory to store programs, along with 2 KB of SRAM and 1 KB of EEPROM for storing data. The Arduino Uno can be easily connected to a computer using a USB cable and programmed through the Arduino IDE, which makes it very convenient for beginners to write and upload programs. It also supports communication methods such as Serial, SPI, and I2C, allowing it to connect with modules like Bluetooth, Wi-Fi, and displays. Because it is affordable, easy to use, and supported by a large community, the Arduino Uno is commonly used in many student projects such as solar tracking systems, home automation, robotics, and other simple electronic applications.

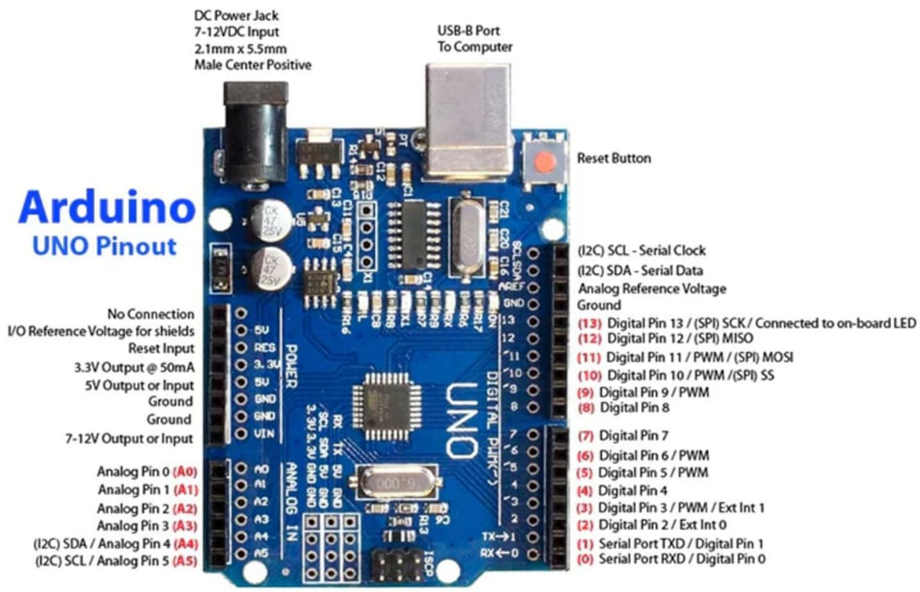

Fig-6- Arduino Uno

III. RESULT AND DISCUSSION

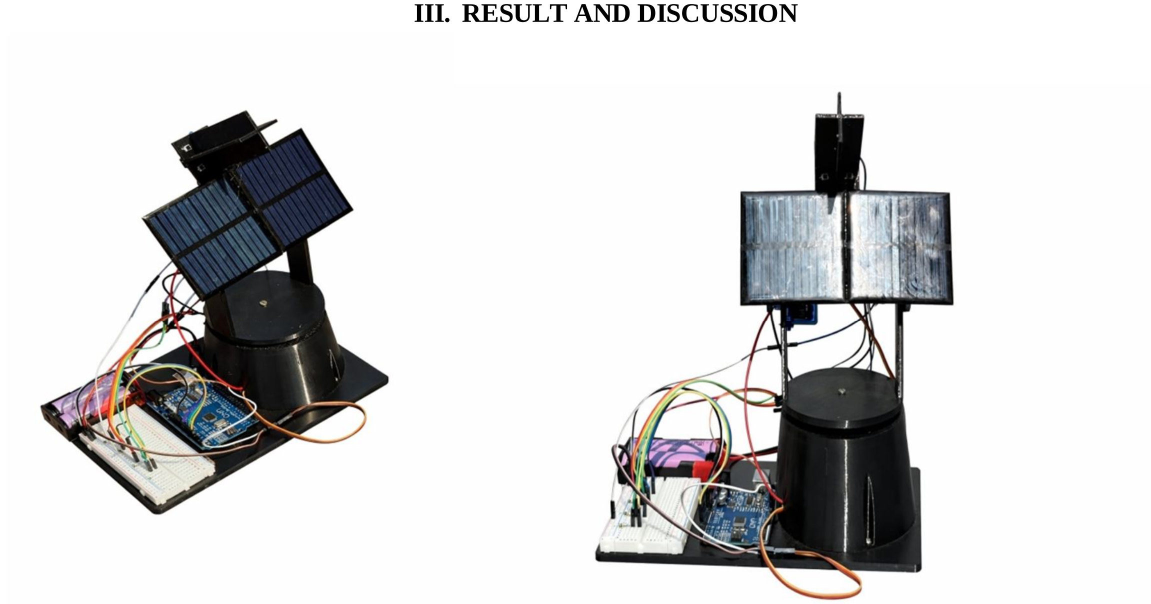

Fig-7- Hardware Model

The Dual Axis Solar Tracking System using Arduino Uno is developed to improve the efficiency of solar panels by automatically following the movement of the sun. In this project, silicon photodiodes are used as light sensors instead of LDRs. These photodiodes detect the intensity of sunlight from different directions and send signals to the Arduino. The Arduino processes these signals and controls the servo motors, which rotate the solar panel in two directions: East–West (azimuth) and North–South (elevation). By adjusting the panel position continuously, the system helps the solar panel face the sun directly throughout the day and capture more sunlight The proposed system successfully demonstrates automatic solar tracking using silicon photodiodes and an Arduino controller. The solar panel is able to adjust its position according to the direction of sunlight, which helps it absorb more solar energy compared to a fixed panel. The dual-axis tracking system can increase energy generation.

IV. CONCLUSION

The Arduino Uno (ATmega328P) is a very popular microcontroller board that is widely used by students and beginners to learn electronics and develop simple projects. It is based on the ATmega328P microcontroller, which runs at a speed of 16 MHz and works with a 5 V power supply. The board provides 14 digital input/output pins for controlling electronic devices and 6 analog input pins for reading signals from sensors such as light or temperature sensors. It also includes 6 PWM pins, which help in smoothly controlling devices like motors and LEDs. The Arduino Uno has 32 KB of flash memory for storing programs, along with 2 KB of SRAM and 1 KB of EEPROM for handling data. It can be easily connected to a computer using a USB cable and programmed through the Arduino IDE, which makes it very convenient for beginners. In addition, it supports communication methods like Serial, SPI, and I2C, allowing it to connect with modules such as Bluetooth, Wi-Fi, and display devices. Due to its simplicity, low cost, and strong community support, the Arduino Uno is commonly used in student projects such as solar tracking systems, small robots, and home automation applications.

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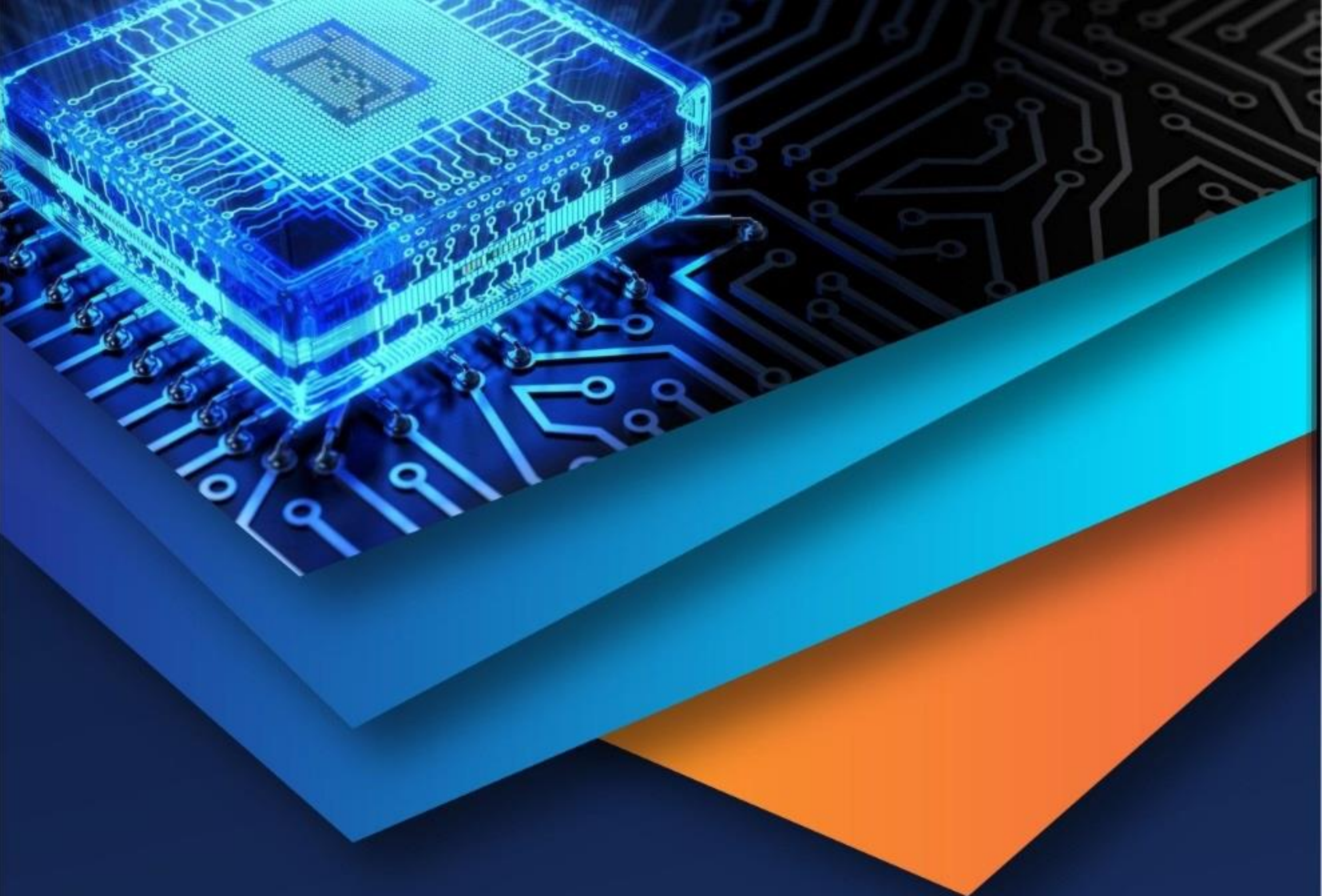

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