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Semi Rotating Solar Panel with Inverter Circuit For Optimum Power Generation With Monitoring Over IOT Platform

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Abstract: ***The Dual Axis Solar Tracker is an innovative and efficient solution aimed at maximizing solar energy capture by dynamically adjusting the orientation of solar panels. Solar energy has emerged as one of the most promising renewable energy sources, but its effectiveness is directly influenced by the positioning of solar panels relative to the sun's movement. Traditional fixed solar panel systems can only generate peak energy when the sun is directly overhead, leading to suboptimal energy capture during other parts of the day. To address this limitation, the Dual Axis Solar Tracker is designed to continuously track the sun across both horizontal (azimuth) and vertical (elevation) axes, ensuring optimal exposure to sunlight throughout the day and across varying seasons. At the core of this system is the NodeMCU microcontroller, which processes real-time data from Light Dependent Resistor (LDR) sensors to determine the intensity and direction of sunlight. The NodeMCU then controls servo or DC motors to adjust the solar panels' orientation accordingly, allowing them to follow the sun's path from sunrise to sunset. This real-time adjustment ensures that the panels remain aligned with the sun's changing position, significantly improving energy collection efficiency by up to 30-40% compared to fixed systems.***

I. INTRODUCTION

Solar energy has emerged a sone of the most promising and sustainable sources of energy in the modern era. Its ability to reduce dependence on fossil fuels and minimize environmental damage has driven significant innovation on solar technology. However, the efficiency of solar panels, which capture sunlight and convert it into electricity, depends heavily on their orientation towards the sun. To fully harness solar power, solar panels must maintain optimal alignment with the seasons. Conventional solar panels systems are typically fixed in a stationary position, limiting their ability to capture maximum solar energy, These fixed installation are only able to generate peak power when the sun is directly overhead, leading to reduced efficiency as the sun moves across the sky, thus maximum energy capture. At the heart of this system is the Node MCU microcontroller, Which Processes data from Light Dependent Resistor (LDR) sensors that detect Sunlight intensity and direction. Based on the sensor inputs, the microcontroller drives servo or DC motors to reposition the solar panels, ensuring they remain aligned with the sun in real time.

The Dual axis Solar Tracker system provides an advanced solution to this problem by dynamically adjusting the position of solar panels along both the horizontal and vertical axes. This allows the panels to follow the sun from sunrise to sunset, ensuring optical exposure throughout the day and maximizing energy collection.

In addition to the tracking mechanism, the system features a buck converter to monitor and regulate battery's charge level, ensuring a stable power supply and extending the battery's lifespan. The Blank IOT platform allow surest monitor the battery status and overall system performance remotely via a mobile app , providing real-time data on energy levels, environment condition, and systems health. Moreover, the solar tracker incorporates a temperature and humidity sensors to monitor the operational environment, offering insight that can help schedule maintenance and optimizing the system's performance.

II. PROBLEM STATEMENT

Solar panels' efficiency in converting sunlight to electricity is highly dependent on their orientation relative to the sun. Fixed solar panel installations, which maintain a constant angle, cannot adjust to the changing position of the sun throughout the day or across seasons. As a result, these static systems capture less solar energy than systems that can dynamically adjust their position to face the sun directly. The primary problem is that traditional fixed solar panels suffer from reduced efficiency and energy output because they do not follow the sun's path. This limitation results in a suboptimal capture of solar energy, reducing the overall effectiveness of solar power systems and leading to lower returns on investment in solar technology.

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To address this issue, a solution is needed that allows solar panels to automatically adjust their orientation in both horizontal and vertical directions to continuously track the sun. This dynamic adjustment would ensure that the panels are always positioned for optimal sunlight exposure, thereby maximizing energy capture and improving overall system efficiency. Additionally, there is a need for a comprehensive monitoring system that can track and display real-time data on the solar tracker's performance, battery status, and environmental conditions. This data is crucial for maintaining the system's efficiency, scheduling maintenance, and ensuring long-term reliability. The Dual Axis Solar Tracker system aims to solve these problems by providing a mechanism for precise solar panel alignment and integrating real-time monitoring capabilities. This solution addresses the inefficiencies of fixed solar panel systems, enhances energy capture, and offers valuable insights into system performance and environmental conditions.

III. OBJECTIVES

1) Optimize Solar Energy Capture: Develop a Dual Axis Solar Tracker system that dynamically adjusts the orientation of solar panels in both horizontal and vertical axes to maximize solar energy absorption throughout the day and across seasons.
2) Enhance System Efficiency: Improve the overall efficiency of solar energy systems by ensuring that solar panels maintain optimal alignment with the sun, thus increasing energy output and reducing reliance on fixed panel installations.
3) Real-time Monitoring and Control: Implement a comprehensive monitoring system using the NodeMCU microcontroller and the Blynk IoT platform to provide real-time data on the solar tracker's performance, including battery status, environmental conditions, and system health.
4) Battery Management: Integrate a buck converter to continuously monitor and regulate the battery's charge level, ensuring a stable power supply and extending the battery's lifespan.
5) Environmental Monitoring: Incorporate temperature and humidity sensors to track environmental conditions that may impact the solar tracker's performance, providing users with valuable data for maintenance and optimization
6) User-Friendly Interface: Utilize the Blynk IoT platform to offer a user-friendly interface for remote monitoring and control, enabling users to access real-time insights and manage the solar tracker efficiently.
7) Reliability and Longevity: Design the system to be robust and reliable, with features that enhance its operational longevity and reduce the need for frequent maintenance or adjustment.

IV. LITERATURE REVIEW

A. *Fixed Solar Panels and Their Limitations*

Several studies have highlighted the limitations of fixed solar panel systems. **Kalogirou (2004)** discussed how fixed panels are only able to generate peak power when the sun is directly overhead. As the sun moves across the sky, the angle of incidence decreases, resulting in a reduction in the amount of solar energy captured. According to Kalogirou, this loss of efficiency can range from 15-25%, depending on geographical location and the time of year. The in ability of fixed systems to adjust their position in response to the sun's movement has led to increased interest in solar tracking technologies.

B. *Single-Axis and Dual-Axis Solar Trackers*

To overcome the limitations of fixed solar panels, single-axis and dual-axis tracking systems have been developed. Gupta & Mittal (2017) and Chin, Babu &McBride (2011) compared the efficiency of single-axis and dual-axis trackers. Single-axis trackers allow panels to rotate along one axis, typically either horizontally or vertically, improving energy output by 10-20%. However, dual-axis systems offer superior performance by enabling the panels to follow the sun's path both horizontally and vertically throughout the day, leading to apotential30- 40%increase in energy capture compared to fixed systems. Chantal also emphasized that dual-axis trackers are particularly effective in region with high solar exposure, where the sun’s angle varies greatly over the course of the day.

C. *Design of Dual-Axis Solar Trackers*

Several prototypes of dual-axis solar tracking system shave been developed, using various components such as LDR sensors, microcontrollers, and servo motors. Patel and Agarwal(2013) introduced a dual-axis tracking system that utilized Light Dependent Resistor (LDR) sensors to detect the sun's position. The LDR sensors provided real-time data about the intensity and direction of sunlight, allowing the system to adjust the solar panel’s orientation through servo motors. This design significantly improved the efficiency of the system compared to fixed panels, demonstrating that LDR-based solar trackers could effectively enhance energy capture throughout the day. Yogesh and Rahatkar (2016) also explored the use of LDR sensors in combination with microcontrollers, showing that automation of the tracking system can further optimize performance.

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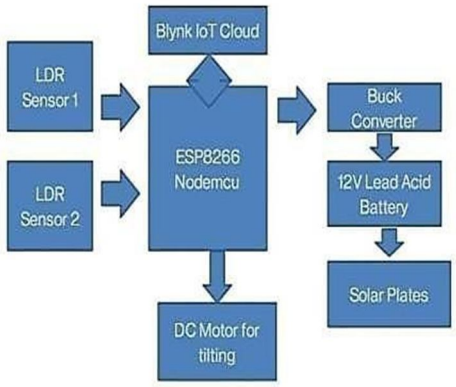
D. Battery Management Using Buck Converters

In solar tracking systems, managing the energy generated and stored in batteries is critical to ensure consistent operation. Singh and Rao (2018) discussed the importance of using buck converter store battery charge levels in renewable energy systems. Buck converters are capable of stepping down voltage levels, preventing overcharging, and ensuring a stable power supply. Gnanavel et al. (2019) further emphasized the role of buck converters in extending battery life, noting that by continuously monitoring and regulating the battery, users can prevent damage caused by overvoltage or undervoltage, thus enhancing the reliability of the system.

E. Cost and Energy Efficiency

The cost-effectiveness of dual-axis solar trackers has been a subject of numerous studies. **Aly & Fayek (2020)** conducted an analysis comparing the up front costs and long-term benefits of fixed, single-axis, and dual-axis tracking systems. While dual- axis trackers involve a higher initial investment, their ability to generate up to 40% more energy than fixed systems significantly reduces the payback period. Over the lifespan of the system, the increased energy output leads to greater savings, particularly in regions with consistent sunlight exposure

Block Diagram



Description

1) Solar Panel Array: Converts sunlight into electrical energy. The array's position is continuously adjusted to maintain the optimal orientation with respect to the sun.
2) Servo/DC Motors: These motors are responsible for controlling the movement of the solar panel along both the horizontal (azimuth) and vertical (elevation) axes. The motors are driven by the signals from the Node MCU based on inputs from the LDR sensor array.
3) LDR Sensor Array: Light Dependent Resistor (LDR) sensors detect the intensity and direction of sunlight. The data collected from these sensors is sent to the Node MCU, which processes it and commands the motors to adjust the solar panel's position to face the sun.
4) Node MCU Controller: Acts as a brain of the system. It processes the signals from the LDR sensors, temperature and humidity sensors, and control the servo/dc motors. The NodeMCU is also responsible for sending data to the IoT cloud (Blynk platform) and receiving commands fir remote monitoring and adjustments.
5) Temperature & Humidity Sensor: Monitors the environmental conditions (temperature and humidity) around the solar panel system. This data helps optimize performance and ensure that the system operates with in ideal conditions.
6) Buck Converter: A voltage regulation component that steps down the voltage to charge the battery efficiently. Iten sures that the battery is charged safely and optimally, preventing overcharging or undercharging.
7) Battery Storage: Stores the energy generated by the solar panel to be used when sunlight is not available. The energy stored is regulated through the buck converter to maintain battery health.
8) Blynk IoT Cloud/App: This cloud platform allows users to remotely monitor and control the solar tracker system. The real-time data from the solar tracker, such as battery levels, motor operation status, and environmental conditions, are transmitted to the Blynk app, where users can track performance.

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V. SYSTEM DEVELOPMENT

A. Design and Component Selection

The system is designed to track the sun's movement in both the horizontal (azimuth) and vertical (elevation) axes. For this purpose, essential components are selected as follows:

1) Hardware Components

- Solar Panel Array: Converts sunlight into electrical energy.
- Node MCU: Serves as the microcontroller for processing sensor data and controlling the motors.
- LDR Sensors: Detect sunlight intensity and provide data for adjusting panel orientation.
- Servo / DC Motors: Responsible for moving the solar panels on both axes (horizontal and vertical).
- Buck Converter: Regulates and manages the voltage supplied to the battery.
- Battery (12V): Stores energy generated by the solar panels for later use.
- Temperature & Humidity Sensor: Monitors environmental conditions to ensure optimal operation.
- Blynk IoT Cloud / App: Provides remote monitoring and control functionality.
- Mounting Frame: Mechanical support to hold the solar panel and motors.

2) Software Components

- Arduino IDE: Used for programming the Node MCU microcontroller.
- Blynk IoT Platform: For remote monitoring and control of the solar tracker.
- Sensor Libraries: Include libraries for LDR, temperature, and humidity sensors.
- Servo Motor Control Libraries: To facilitate motor control using the Node MCU.

B. Circuit Design and Wiring

The circuit design for the dual-axis solar tracker involves connecting the selected hardware components. Key connections include:

1) NodeMCU and LDR Sensors: Four LDR sensors are placed in different quadrants around the solar panel to detect the intensity of light. These sensors are connected to analog pins of the MCU.
2) Node MCU and Servo/DC Motors: wo servo / DC motors are connected to digital pins of the Node MCU for controlling the horizontal and vertical movement of the solar panels.
3) Node MCU and Buck Converter: The buck converter is connected to the battery and ensures regulated charging through solar energy.
4) Node MCU and Temperature/Humidity Sensor: This sensor is wired to the Node MCU for environmental monitoring.
5) Battery and Solar Panel: The solar panel is wired to the battery through the buck converter to store generated power.

C. System Assembly :

The system assembly focuses on the physical setup: Mount the Solar Panel on a rotatable platform that can be moved by the servo / DC motors. Install LDR Sensors at different points around the panel to ensure accurate detection of sunlight direction.
Attach Servo / DC Motors to the platform so that they can move the panel in both horizontal and vertical directions.
Place the Node MCU and Battery inside an enclosure box to protect from environmental elements.

VI. SOFTWARE DEVELOPMENT AND PROGRAMMING

A. Microcontroller Programming (NodeMCU)

Using the Arduino IDE, you will program the Node MCU to:

1) Read LDR Sensor Data: Determine the direction of sunlight by comparing the intensity of light from different sensors
2) Control Motors: Based on sensor data, adjust the position of the solar panel by sending appropriate signals to the servo motors to align the panel with the sun.
3) Monitor Temperature and Humidity: Continuously record and monitor environmental conditions.
4) Battery Management: Monitor battery voltage using the buck converter and display data on the Blynk

Blynk IOT Integration:

- Blynk Dashboard: Create a dashboard on the Blynk app to monitor:
  a) Panel orientation (servo motor position).
  b) Battery voltage(real-time).
  c) Environmental conditions (temperature and humidity).

- Alert sand Notifications*:* Setup notifications for battery voltage there should so environmental changes for remote user intervention if needed

B. Testing and Calibration

After assembly and programming, testing and calibration are essential steps:

1) Servo Motor Calibration: Adjust the motor movement range to ensure the solar panel rotate optimally without hitting mechanical limits .
2) LDR Sensitivity Testing: Ensure the LDR sensors are accurately detecting sunlight From different angles.
3) Battery Charge Monitoring: Verify that the buck converter is efficiently charging the battery, and Blynk is displaying the correct voltage levels.
4) IoT Monitoring: Test remote monitoring and control via the Blynk app.
5) Periodic Calibration: Ensure the system is recalibrated over time to maintain tracking accuracy.
6) Firmware Updates: Continuously improve the system's performance through Node MCU firmware updates, optimizing sensor response and motor control.
7) Regular Maintenance: Check the servo motors and LDR sensors periodically for wear and tear, and ensure the system is dust-free for accurate operation.

C. Software Development

Software Development for Dual Axis Solar Tracker

The software development of a Dual Axis Solar Tracker revolves around the programming of the NodeMCU microcontroller to manage sensor data, control motors for tracking, and interface with the Blynk IoT platform for remote monitoring. The system relies on inputs from light sensors (LDRs) and environmental sensors (temperature and humidity) to continuously adjust the orientation of solar panels for optimal solar energy capture. The software also incorporates logic for power management and data visualization on a cloud platform.

1) Software Design

The software design is divided into several functional blocks:

a) Sensor Data Acquisition:
  - Read light intensity values from the LDR sensors to determine the position of the sun.
  - Read environmental data (temperature and humidity) from the DHT11 sensor.

b) Decision-Making Logic:
  (a) Compare LDR values from different axes to determine whether the solar panel needs to rotate horizontally (azimuth) or vertically (elevation).
  (b) Adjust the solar panel's position accordingly using servo/DC motors

c) Motor Control:
  Use pulse-width modulation (PWM) to drive servo motors based on the directional data calculated from the LDR sensors.

d) Power Management:
  - Monitor the battery voltage through the buck converter and ensure the solar panel is functioning efficiently.
  - Display battery status on the Blynk IoT platform for real-time monitoring.

e) IoT and Remote Monitoring:

- Integrate with Blynk IoT for real-time data visualization, alerts, and control.
- Provide users with data such as:

Battery voltage levels.
Panel orientation (horizontal and vertical angles).
Temperature and humidity readings.

D. Software Tools and Libraries

He following tools and libraries are utilized for software development:

1) Development Environment

- **Arduino IDE**: This is the primary environment for programming the NodeMCU using the C++ programming language.

2) Libraries

- ESP8266WiFi.h: Enables Wi-Fi connectivity for NodeMCU.
- BlynkSimpleEsp8266.h: Facilitates communication with the Blynk cloud platform.
- Servo.h: Provides functions to control the servo motors.
- DHT.h: Supports the reading of temperature and humidity data from the DHT11 sensor.
- Wire.h: Used for I2C communication (if needed for additional sensors or peripherals).

3) Testing and Debugging

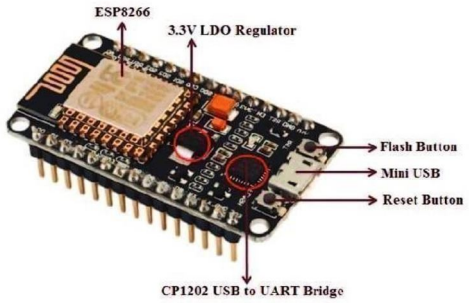
After writing the firmware, the system to undergo extensive testing and debugging:

- Motor Movement Calibration: Fine-tune motor to prevent over-adjustments.
- IoT Monitoring: Ensure accurate data is displayed on the Blynk platform for battery voltage and environmental conditions.
- Error Handling: Implement logic to handle scenarios like sensor failure or weak Wi-Fi signals.

VII. COMPONENTS INFORMATION

1) Node MCU Microcontroller

It receives signals from LDR sensors, processes them, and sends output commands to motors



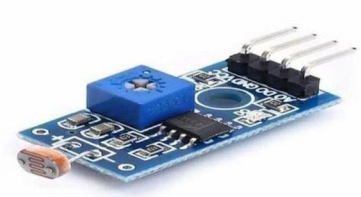
2) Power Supply (Including Buck Converter):

A buck converter is typically used to step down the voltage from a higher source, like a solar panel, to power the electronics without damaging them.



3) LDR Sensors (Light Dependent Resistor):

Placed strategically at different corners of the solar panel, the sensors' varying resistance based on light exposure is read by the Node MCU. This data allows the system to determine the sun's position and angle.



4) Solar Panels

These are mounted on the structure, and their orientation is constantly adjusted by the tracker system for optimal exposure to sunlight.



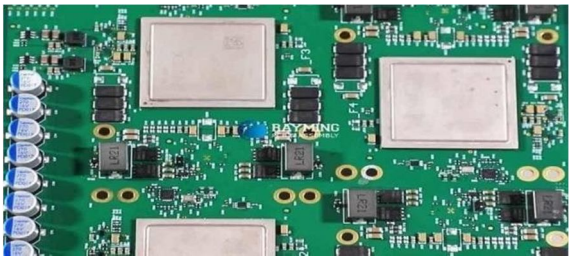
5) Battery Energy storage

This energy can be used for powering devices or fed back into the system to keep the tracker operational.



6) Wiring and Circuit Assembly

Wire the motors to motor drivers, which are controlled by the digital outputs of the Node MCU. Ensure proper power distribution using a buck converter to provide safe voltage levels for the components.



VIII. RESULT

A. Remote Monitoring and Control

The system was successfully connected to the Blynk IoT platform, allowing real-time monitoring of parameters such as battery voltage, temperature, and humidity. Users could remotely access system data, ensuring easy maintenance and troubleshooting.

B. Environmental Adaptability

The temperature and humidity sensors provided useful insights into system performance under different weather conditions.
The system operated effectively in varying lighting conditions without significant performance drops.

IX. CONCLUSION

1) The Dual-Axis Solar Tracker system represents a significant leap forward in the realm of solar energy technology, offering an effective and sustainable solution to the challenges of optimizing solar panel efficiency. Unlike traditional fixed solar installations, this advanced tracking system continuously adjusts the position of solar panels in both horizontal (azimuth) and vertical (elevation) directions, ensuring that they maintain optimal alignment with the sun throughout the day and across different seasons.

2) At the heart of this system is the NodeMCU microcontroller, which seamlessly processes data from Light Dependent Resistor (LDR) sensors to detect sunlight intensity and direction. The NodeMCU drives servo or DC motors to accurately reposition the panels, enabling real- time adjustments that maximize energy collection.

3) The integration of additional features such as a buck converter for battery management, and environmental sensors for temperature and humidity monitoring, further enhances the system's efficiency, durability, and ease of maintenance. The buck converter regulates battery charge levels, preventing overcharging or depletion, thereby extending the overall lifespan of the battery.

4) Remote control and monitoring via the Blynk IoT platform offer unparalleled user convenience, allowing for real-time access to system performance data, battery levels, and environmental conditions. This level of connectivity ensures that users can manage and troubleshoot the system from virtually anywhere, reducing downtime and enhancing operational reliability.

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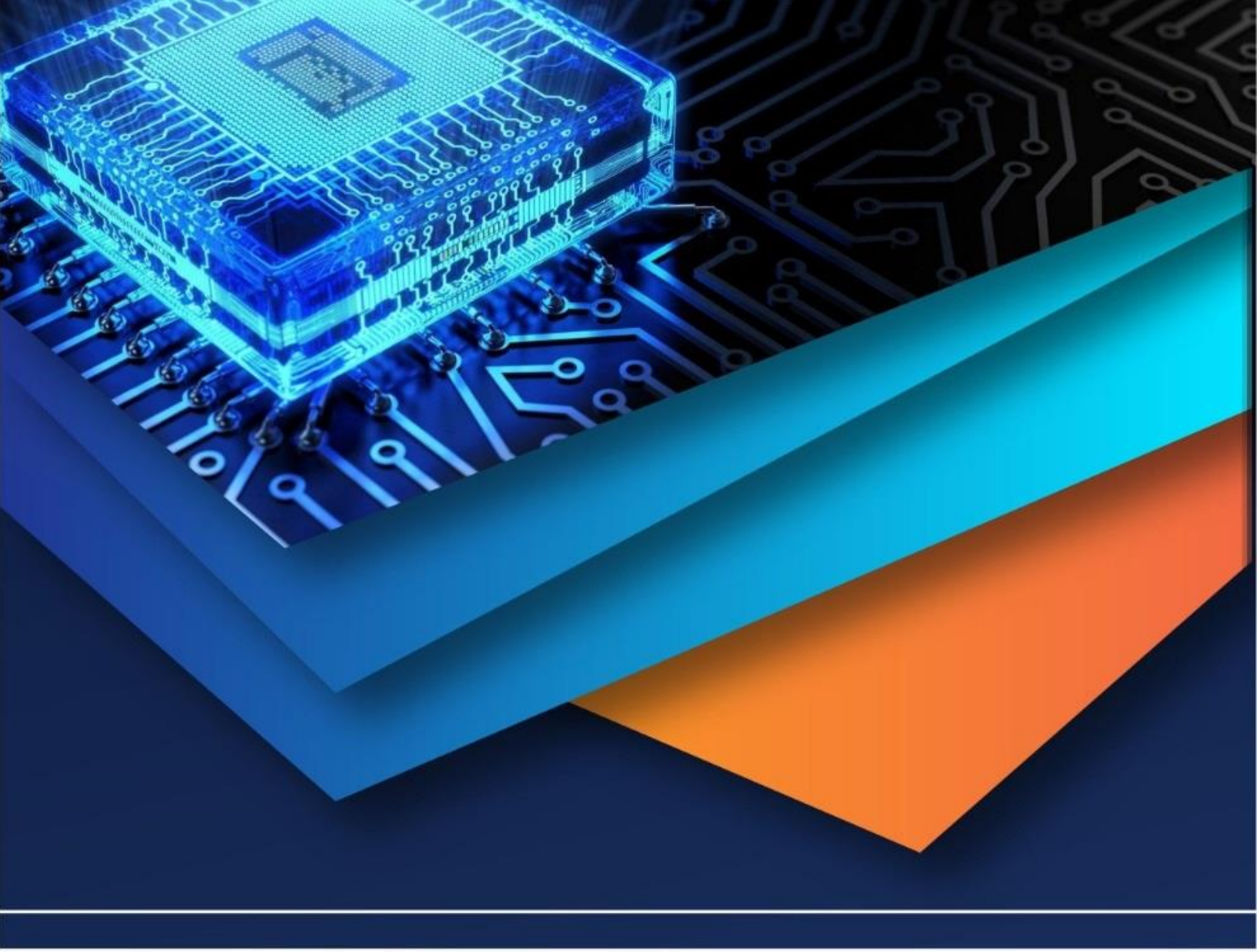
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