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Automatic Street Light Controller using LDR and IOT

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Abstract: The IoT-based street light controller and monitoring system represent a revolutionary advancement in urban lighting infrastructure, leveraging cutting-edge technologies to transform traditional street lighting into intelligent, adaptive, and energy-efficient systems .This comprehensive solution integrates a myriad of components, including Node MCU microcontrollers, relay modules, Light Dependent Resistors (LDRs), motion sensors, and environmental sensors, to create a dynamic and responsive lighting network. By strategically deploying sensors throughout urban areas, the system continuously collects real-time data on ambient light levels, traffic density, pedestrian activity, and environmental conditions. This wealth of data serves as the foundation for intelligent lighting control algorithms that dynamically adjust street lighting levels to optimize energy consumption while ensuring adequate illumination for safety and visibility. Moreover, the implementation of remote monitoring and management capabilities enables proactive maintenance, fault detection, and performance optimization, thereby reducing downtime and operational costs. Through rigorous field trials and simulations, the system's efficacy in enhancing energy efficiency, safety, and sustainability has been thoroughly validated. Experimental results demonstrate significant reductions in energy consumption, improvements in lighting efficiency, and enhancements in maintenance effectiveness. Furthermore, the system's adaptability to varying environmental conditions and its ability to respond dynamically to changing requirements underscore its versatility and effectiveness in diverse urban settings. Overall, the IoT-based street light controller and monitoring system represent a groundbreaking solution that promises to revolutionize urban lighting management, paving the way for smarter, safer, and more sustainable cities in the future. Keywords: Node MCU ESP8266, LDR, Relay, ThingSpeak integration, LED.

Keywords: Smart street light systems, Internet of Things, Temperature sensor, Weather sensor, Raspberry Pi, Arduino UNO

I. INTRODUCTION

Street lighting is a critical public infrastructure that supports nighttime visibility, traffic safety, and public security in urban environments. However, traditional street lighting systems often operate on fixed schedules, remaining fully ON from dusk to dawn regardless of actual usage conditions. This leads to excessive energy consumption, increased operational costs, and reduced lifespan of lighting components ([3],[5]).

With the advancement of smart technologies, intelligent street lighting has emerged as an essential component of smart city development. IoT-enabled systems allow real-time monitoring, remote control, and automated decision-making, improving both efficiency and reliability ([6],[8]). These systems integrate sensors such as Light Dependent Resistors (LDRs) and motion detectors to dynamically adjust lighting levels based on environmental conditions and user activity ([10],[12]).

Recent studies have shown that adaptive lighting systems significantly reduce energy consumption while maintaining adequate illumination for safety and visibility ([12],[14]). Furthermore, wireless sensor networks and IoT platforms enable large-scale deployment and centralized control of street lighting systems ([10],[12]).

Despite these advancements, many existing systems focus more on communication architecture rather than practical implementation and control logic. Issues such as threshold selection, response time, and system stability are often not addressed in detail, limiting real-world applicability ([1]).

To address these challenges, this study proposes an IoT-based automatic street lighting system using LDR and microcontroller technology. The system is designed to dynamically control lighting intensity based on ambient conditions, thereby improving energy efficiency, reducing operational costs, and supporting sustainable urban development.

II. LITERATURE REVIEW

A comprehensive review of existing research reveals significant progress in the development of automatic street lighting systems using LDR and IoT technologies. Early work by ([13])demonstrated the use of microcontrollers for automatic street light control, highlighting the potential for energy savings through automation. Similarly, ([5]) designed a microcontroller-based system using LDR sensors, showing effective switching based on ambient light conditions.

Several researchers have focused on integrating IoT into street lighting systems to enhance monitoring and control capabilities. ([6]) proposed an IoT-based smart street light management system that enables remote access and real-time data monitoring. ([8]) further improved this approach by incorporating fault detection mechanisms, enhancing system reliability and maintenance efficiency.

Sensor-based approaches have also been widely explored. ([10]) developed a system combining LDR and IR sensors to automate lighting based on both light intensity and motion detection. Similarly, ([12]) demonstrated an LDR-based automatic lighting system that significantly reduces power consumption.

Recent advancements include the use of intelligent algorithms and predictive models. ([11]) introduced a smart street lighting system with predictive capabilities, enabling optimized lighting based on traffic patterns. ([14]) emphasized energy-efficient designs using adaptive lighting techniques.

Wireless communication technologies have also been investigated to improve scalability. ([13]) proposed a wireless sensor network-based system for street lighting control, allowing efficient communication between nodes. Additionally, ([7]) developed an Arduino-based system using LDR sensors, demonstrating cost-effective implementation suitable for real-world deployment.

Overall, the literature indicates that IoT-based street lighting systems offer significant advantages in terms of energy efficiency, automation, and scalability. However, there remains a need for simple, low-cost, and easily deployable solutions that can be implemented in both urban and rural areas. This research aims to bridge that gap by proposing a practical and efficient automatic street light controller using LDR and IoT.

III. PROPOSED SYSTEM

A. Overview of the Proposed System

The proposed system aims to develop an energy-efficient and adaptive street lighting solution using IoT principles and low-cost hardware components. Unlike traditional timer-based systems, which operate irrespective of environmental conditions, the proposed model dynamically responds to real-time ambient light levels using sensor-based automation ([12]). The system primarily utilizes a Light Dependent Resistor (LDR) sensor for detecting light intensity and an Arduino Uno microcontroller for processing and control operations.

The integration of IoT concepts enables intelligent decision-making and enhances system efficiency by minimizing unnecessary power consumption ([8]). The objective is to ensure that street lighting is provided only when required, thereby improving energy efficiency while maintaining safety and visibility in public areas.

B. Overall System Architecture

The system architecture consists of four major components: the sensor module, control unit, output module, and power supply. The sensor module includes an LDR that continuously monitors ambient light intensity and sends analog signals to the Arduino microcontroller. Based on predefined threshold values, the control unit processes the input data and determines the appropriate lighting level ([5]). The Arduino Uno acts as the central processing unit, executing decision-making algorithms and controlling the lighting output. Pulse Width Modulation (PWM) is used to regulate LED brightness, enabling smooth transitions between different lighting levels instead of simple ON/OFF switching ([7]).

The output module consists of LEDs that simulate street lighting, while a stable power supply ensures uninterrupted system operation. This modular architecture allows efficient automation and adaptability to changing environmental conditions, aligning with modern smart lighting requirements ([14]).

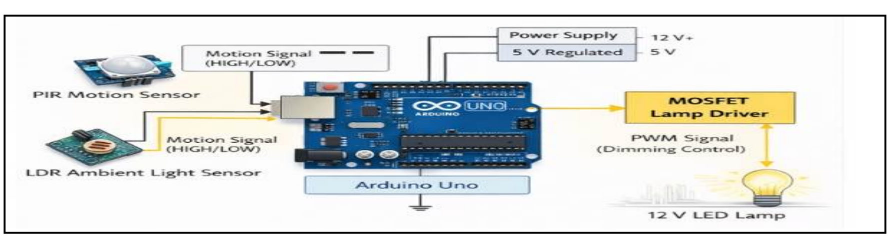

Fig. 1 Block diagram of the intelligent street lighting system using Arduino, PIR, and LDR

C. Ambient Light Detection Module

The ambient light detection module uses an LDR sensor to measure the intensity of light in the surrounding environment. The resistance of the LDR varies inversely with light intensity—decreasing in bright conditions and increasing in darkness. This variation is converted into an analog voltage signal and sent to the Arduino for processing ([3]).

The Arduino reads the sensor values and compares them with predefined thresholds to determine whether lighting is required. When ambient light falls below a certain level, such as during nighttime or cloudy conditions, the system automatically activates the streetlights. Conversely, during daylight, the system keeps the lights OFF, thereby conserving energy ([1]).

D. Microcontroller-Based Decision Engine

The Arduino Uno functions as the central control unit of the system. It continuously monitors the input from the LDR sensor and processes it using programmed logic to determine the appropriate lighting condition. Based on this analysis, the microcontroller adjusts the brightness of LEDs using PWM signals ([10]).

Unlike conventional systems that rely on binary switching, the use of PWM allows gradual adjustment of brightness levels, enhancing both energy efficiency and system performance. This intelligent control mechanism ensures optimal lighting under varying environmental conditions ([11]).

E. Smart Brightness Control Logic

The proposed system employs a dynamic brightness control mechanism based on real-time ambient light conditions. During daytime, the system keeps the lights OFF to eliminate unnecessary energy usage. During low-light conditions such as dusk or cloudy weather, the system operates at medium brightness, while in complete darkness, it switches to full brightness to ensure visibility and safety ([14]).

This adaptive behavior makes the system more efficient compared to traditional fixed-intensity lighting systems. Additionally, the system can be extended to include motion sensors or IoT-based monitoring for further optimization and automation ([6]).

F. Benefits of the Proposed System

The proposed system offers several advantages over conventional street lighting systems. It significantly improves energy efficiency by ensuring that lights operate only when necessary. The use of low-cost components such as Arduino and LDR makes the system economically viable for large-scale deployment ([7]).

Furthermore, the integration of IoT technologies enables remote monitoring and control, reducing maintenance efforts and operational costs ([8]). The system also enhances environmental sustainability by reducing energy consumption and carbon emissions, contributing to the development of smart and eco-friendly cities ([13]).paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

IV. HARDWARE REQUIREMENTS

A. Raspberry Pi

Raspberry Pi is a small-sized computer used Linux operating system. It is a small size computer used to run larger and smart programs to achieve output quickly. RPi 4 B+(RP4) is the latest model developed by the company, which has all the essential latest wired and wireless communication system used in most of the smart projects. A Raspberry Pi 4 comes to a Quad-core Processor but it has three various versions which give three various sizes of RAM.

Fig. 2 Raspberry Pi

B. Infrared Sensors

An IR sensor is an electronic device that is used to sense some aspects of the surrounding environment. An IR sensor can measure the heat of an object as well as detects the movement as well as the presence of an object due to interruption. These type of sensors measure only infrared radiation, rather than emitting it that is called as a passive infrared sensor, an IR sensor is simply a device which detects infrared radiation falling on it.

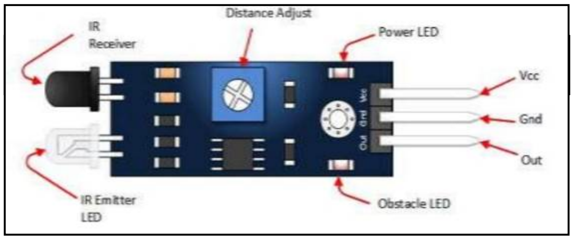

Fig. 1 *IR Sensor*

C. Light Dependent Resistance

Light Dependent Resistors are very useful especially in light or dark sensor circuits. Light dependent resistor as the name suggests depends on light for the variation of resistance. Normally the resistance of an LDR is very high, sometimes as high as 1000000 ohms, but when they are illuminated with light resistance drops dramatically. Electronic onto sensors are the devices that alter their electrical characteristics, in the presence of visible or invisible light.

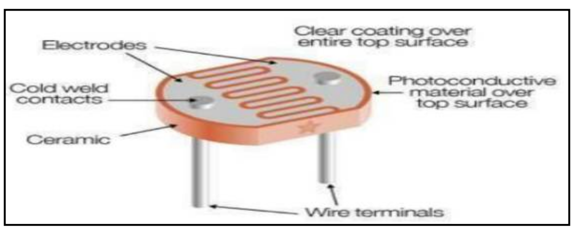

Fig. 4 *LDR Sensor*

D. Passive Infrared Sensor

A passive Infrared Sensor (PIR sensor) is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view. They are most often used in PIR based motion detectors. PIR sensors use a pair of piezoelectric sensors to detect heat energy in the surrounding environment. PIR sensors are commonly used in security alarms, motion detection alarms and automatic lighting applications.

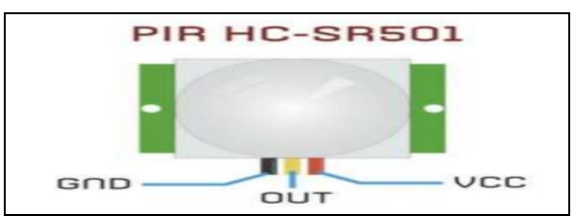

Fig. 5 PIR Sensor

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E. Arduino UNO

Arduino UNO is the microcontroller used in this paper, it is based on ATmega328. It is open source electronic platform based on easy to use software and hardware. It reads input-light on sensor, finger on a button, etc. It has14 input/output and 6 Analog pins. The software used in this microcontroller is Arduino IDE .

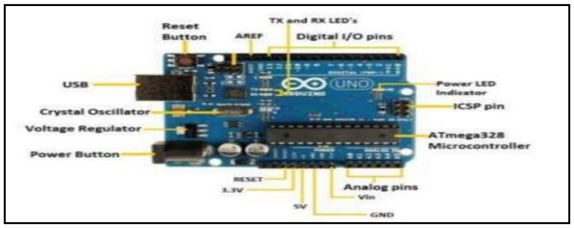

Fig. 6 Arduino UNO

F. Light Emitting Diode

A light Emitting Diode (LED) is a two-lead semiconductor light source. The long terminal is positive and the short terminal is negative. It is p-n junction diode that emits light when activated. When a suitable current is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the colour of the light is determined by the energy band gap of the semiconductor. LEDs are typically small and integrated optical components may be used to shape the radiation pattern.

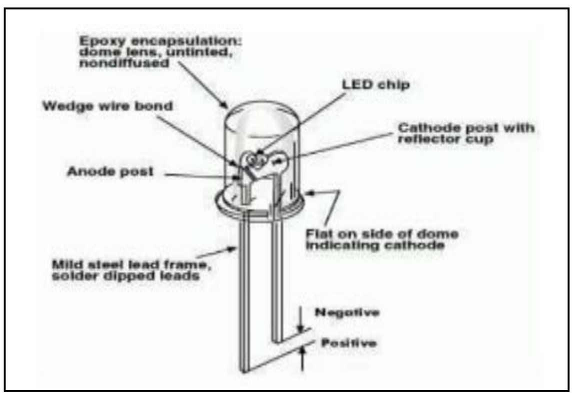

Fig. 7 Light Emitting Diode

G. Solar Panel

Solar Energy begins with the Sun. Solar Panels Are Also Known as "PV Panels" Which Are Used to Convert Light from The Sun, which is Composed of Particles of Energy Called "Photons", Into Electricity That Can Be Used to Power Electrical Loads. Solar Panels Can Be Used for A Wide Variety of Applications Including Remote Power Systems for Cabins, Telecommunications Equipment, And for the Production of Electricity by Residential and Commercial Solar Electric Systems.

Fig. 8 Solar Panel

H. Servo Motor

Servo Motor: Micro Servo Motor SG90 is a tiny and lightweight server motor with high output power. It is an electromechanical device. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. It produces torque and velocity based on the supplied current and voltage.

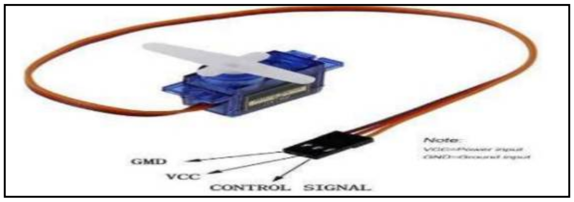

Fig. 9 Servo Motor

V. SOFTWARE REQUIREMENTS

A. Raspbian

Installation of Raspbian OS in Raspberry Pi.
Raspberry Pi Supports C/C++ and Python version 2/3 by default.
However, These Language Compiler or Interpreter can be installed on Raspbian OS.

B. Arduino IDE

Downloading Arduino IDE software and then power up Arduino Board.
Launching Arduino IDE.
The Arduino integrated development environment is a cross platform application, that is written in Java programming language and C/C++.

VI. IMPLEMENTATION OF PROPOSED SCHEME

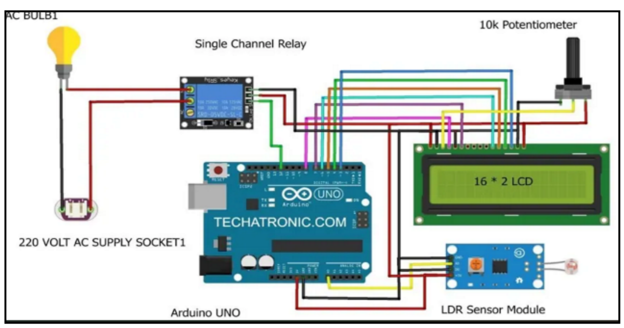

Fig. 10 Schematic Diagram

Raspberry Pi is connected remotely in a hub for automatic turning ON/OFF the street lights. A person is going to control different streets in that hub. In between 6 and 11'O clock at Night, there are huge vehicles on the Roads. So PIR mode of Operation is used for automatic turning ON the whole street lights when Motion is detected for a period of time declared i.e., for 10 sec. During mid night, there are fewer vehicles on the roads. So IR mode of Operation is used for automatic turning ON the respective street light when the motion is detected.
At the time of Festivals, LDR mode of Operation is used i.e., the street lights automatically turned ON at night and turned OFF at day time. Here Manual commands have to be given in the putty software for shifting the mode of Operation. The Solar Module is appended for maintaining less power consumption. There are two manual switches provided to maintain Raspberry pi and Arduino Board. Solar panels are used for charging batteries by changing daylight into electricity. Servo Motor is used to direct the solar

panel. The energy which is stored in battery is used as power supply for the street lights. Whenever there is no charge in the battery then the second switch is used to process the Arduino board.

VII. RESULTS AND DISCUSSIONS

Fig.11 shows PIR mode of Operation, when the motion detected, the whole street lights ON for a period of 10 sec.

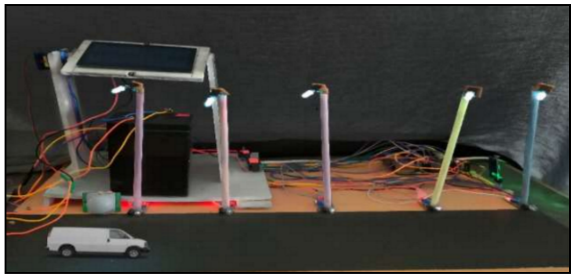

Fig. 11 PIR Mode

Fig.12 shows IR mode of Operation, whenever there is a movement, the respective street lights turns on.

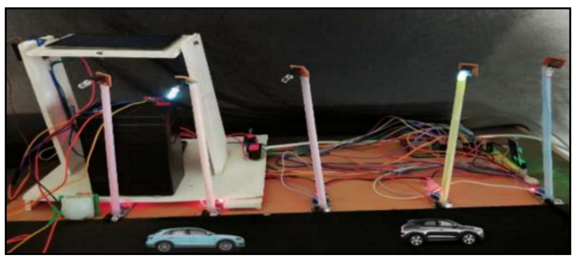

Fig. 12 IR Mode

Fig.13 shows LDR mode of Operation, in the dark condition the street lights will turns on.

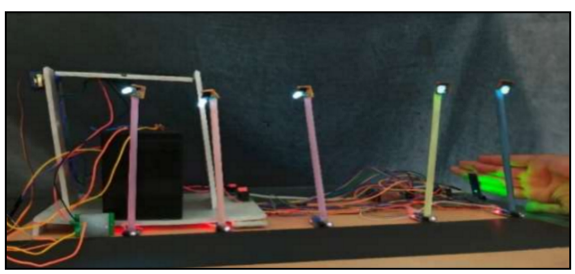

Fig. 13 LDR Mode

Fig.14 shows Solar Panel rotation when it hits by lightning which converts light energy into electricity.

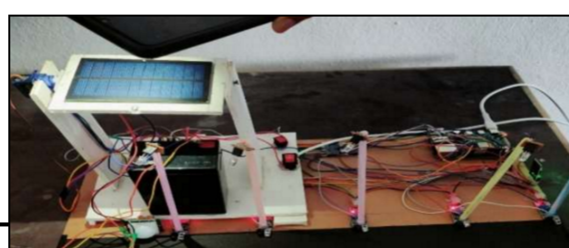

Fig. 14 Solar Model

VIII. ADVANTAGES AND APPLICATIONS

A. Advantages

The proposed street light controller using LDR and IoT offers several advantages:

1) *Energy Efficiency:* Automatically turns ON/OFF lights based on ambient light, reducing unnecessary power consumption.
2) *Cost Saving:* Lower electricity bills and reduced maintenance costs.
3) *Automation:* Eliminates the need for manual operation of street lights.
4) *Remote Monitoring:* IoT enables monitoring and control from anywhere via the internet.
5) *Longer Lifespan*: LEDs last longer due to controlled usage.
6) *Environment Friendly*: Reduces carbon footprint by saving energy.
7) *Low Maintenance*: Minimal human intervention required.
8) *Scalability:* Can be easily expanded for large areas like cities or highways.

B. Real-World Applications

This system can be used in various real-life scenarios:

1) *Street Lighting:* Automatic control of public street lights.
2) *Highways & Roads*: Efficient lighting for highways with reduced energy use.
3) *Parking Areas*: Lights operate only when needed.
4) *Campuses & Institutions*: Schools, colleges, and universities.
5) *Residential Areas*: Gated societies and apartments.
6) *Industrial Zones*: Factories and warehouses.
7) *Parks & Gardens*: Smart lighting based on daylight conditions.

C. Smart City Implementation

In smart cities, this system plays an important role:

1) *Centralized Control:* All street lights can be monitored and controlled from a central system.
2) *Real-Time Data Monitoring:* IoT platforms provide live status of lights.
3) *Fault Detection*: Identifies faulty lights quickly for maintenance.
4) *Adaptive Lighting*: Adjusts brightness based on environment and traffic.
5) *Integration with Smart Systems*: Can be connected with traffic systems, security, and surveillance.
6) *Energy Management:* Helps governments reduce energy consumption at a large scale.
7) *Sustainable Development*: Supports eco-friendly and smart infrastructure goals.

IX. FUTURE SCOPE

A. AI-Based Smart Lighting

In the future, this system can be improved using Artificial Intelligence (AI). With AI, street lights can become smarter by analyzing data such as traffic movement and weather conditions. The system can automatically adjust the brightness of lights based on the number of vehicles or people on the road. This will help in saving more energy and improving efficiency.

B. Integration with Smart City Systems

This project can be connected with smart city infrastructure. All street lights can be controlled and monitored from a central system. It can also be integrated with traffic management and security systems. This will help authorities to manage lighting more efficiently and quickly detect faults in the system.

C. Solar-Based Enhancement

In future, solar panels can be used with this system to make it more energy efficient. Solar energy can be stored during the day and used to power street lights at night. This will reduce dependency on electricity and make the system eco-friendly and cost-effective.

X. CONCLUSIONS

The IoT-based street light controller and monitoring system represent a transformative solution for modernizing urban lighting infrastructure, enhancing efficiency, reliability, and sustainability. Through the integration of advanced sensors, controllers, and data analytics, the system offers numerous benefits, including energy savings, operational efficiency, and improved user experience.

The IoT-based street light controller and monitoring system of feramultifaceted approach to urban lighting management, delivering a wide range of benefits across environmental, economic, social, and policy dimensions. Ascities embrace digital transformation and strive towards sustainability and resilience goals, the adoption of smart lighting solutions becomes increasingly imperative.

The conclusion underscores the transformative potential of the IoT- based street light controller and monitoring system in shaping the future of urban environments and advancing the collective well-being of society.

Beyond the technical and economic benefits, the IoT-based street light controller and monitoring system have a significant social impact on communities. Improved street lighting enhances public spaces, fosters a sense of security, and promotes social inclusion and community well-being. It contributes to creating vibrant, livable cities where residents can thrive and businesses can prosper.

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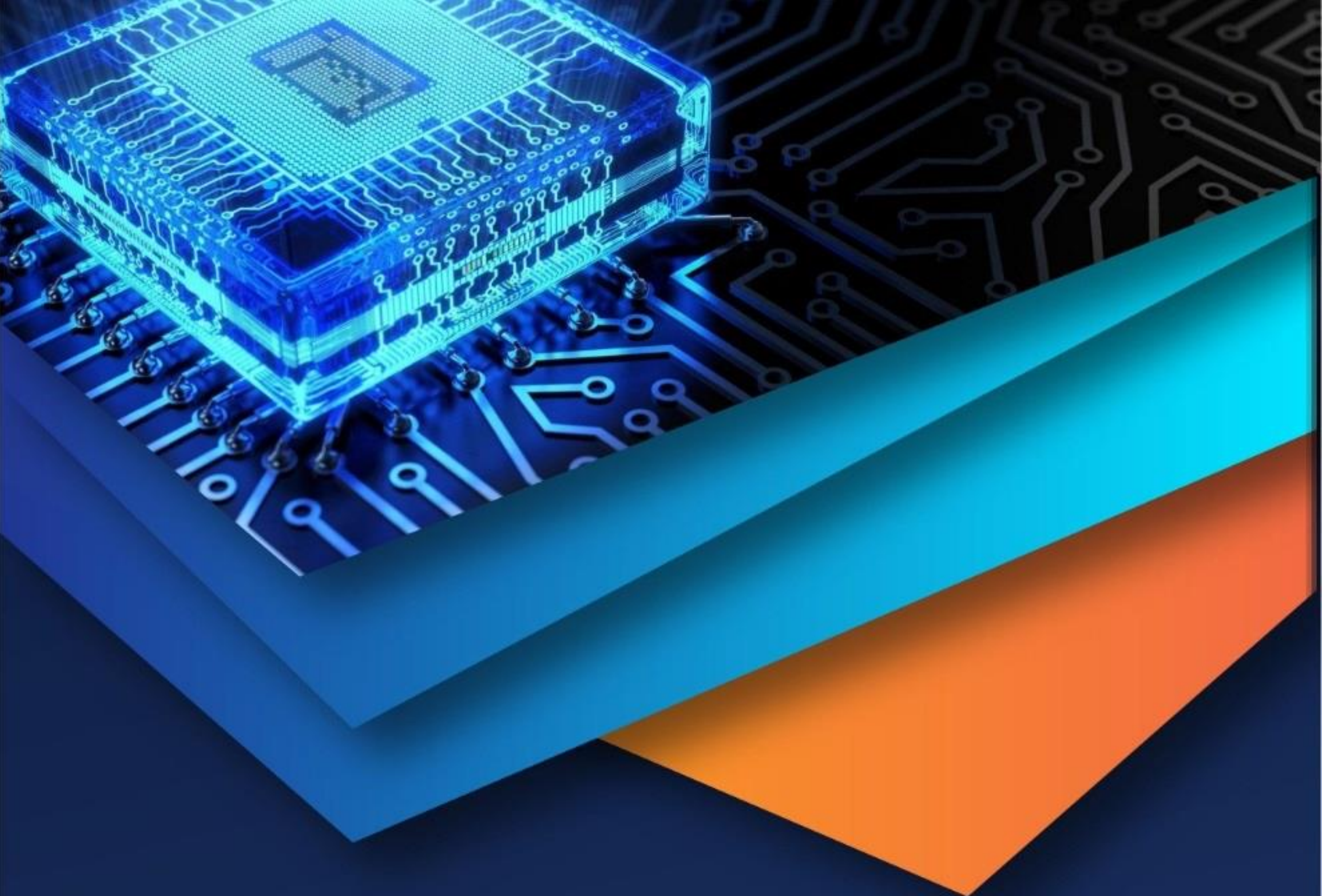

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