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Design and Implementation of Vehicle Identification Using Li-Fi Technology

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Abstract: The project titled "Design and Implementation of Vehicle Identification Using Li-Fi Technology" addresses the limitations of existing vehicle identification systems, which typically rely on RFID and camera-based solutions. These systems face challenges such as limited bandwidth, interference from radio signals or lighting conditions. To overcome these issues, we propose a Li-Fi-based vehicle identification system, leveraging light as the medium for data transmission. LI-FI is a wireless communication technology that uses light, specifically LED bulbs, to transmit data, offering potentially higher speeds and bandwidth. Li-Fi offers several advantages, including higher bandwidth, faster data rates, and immunity to radio frequency interference. In our system, vehicle data is transmitted via LED lights to a photo-detector placed on the road, ensuring efficient, real-time identification even in challenging environments. The system is designed to minimize the effects of ambient light and other interferences, offering a reliable and scalable alternative for modern traffic management.
Keywords: Li-Fi, vehicle identification, Manchester encoding, noise filtering, photodiode, high-pass filter, optical communication, modulation.

I. INTRODUCTION

Li-Fi is a wireless communication technology that uses visible light, instead of radio waves, to transmit data. It leverages LEDs (light-emitting diodes) to send information by modulating light at frequencies too fast to be detected by the human eye. A photo detector at the receiver end captures these modulated light signals and converts them back into data. First proposed by Professor Harald Haas in 2011, Li-Fi has gained significant attention as a potential alternative or complement to traditional RF-based communication technologies like Wi-Fi [7]. Li-Fi is a derivative of optical wireless communications (OWC) technology, which uses light from light-emitting diodes (LEDs) as a medium to deliver network, mobile, high-speed communication in a similar manner to Wi-Fi. The Li-Fi market was projected to have a compound annual growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018. However, the market has not developed as such and Li-Fi remains with a niche market. Visible light communications (VLC) works by switching the current to the LEDs off and on at a very high speed, beyond the human eye's ability to notice. Technologies that allow roaming between various Li-Fi cells, also known as handover, may allow to seamlessly transition between Li-Fi. The light waves cannot penetrate walls which translates to a much shorter range, and a lower hacking potential, relative to Wi-Fi. Direct line of sight is not always necessary for Li-Fi to transmit a signal and light reflected off walls can achieve 70 Mbit/s. Li-Fi can potentially be useful in electromagnetic sensitive areas without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible, ultraviolet, and infrared light. Researchers have reached data rates of over 224 Gbit/which was much faster than typical fast broadband in 2013. Li-Fi is expected to be ten times cheaper than Wi-Fi. The first commercially available Li-Fi system was presented at the 2014 Mobile World Congress in Barcelona.

Li-Fi technology offers several advantages that make it ideal for your vehicle identification project. It provides high data transmission speeds, enabling real-time data transfer between vehicles and roadside receivers. This is crucial for managing large volumes of data in traffic conditions without delays. Unlike radio frequency-based systems, Li-Fi is immune to electromagnetic interference from devices like Wi-Fi and cell phones, ensuring more reliable communication in busy urban areas. Li-Fi also offers enhanced security since light signals cannot penetrate walls, reducing the risk of data interception. Additionally, the technology supports high spatial reuse, meaning multiple vehicles can transmit data simultaneously without interference. Its operation outside the congested radio-frequency spectrum eliminates the issue of spectrum overcrowding, further improving system performance. Li-Fi's low latency ensures that vehicle data is transmitted with minimal delay, critical for real-time identification. Moreover, the technology can be integrated with existing LED-based infrastructure, such as streetlights and vehicle headlights, making it cost-effective and easy to deploy. These features make Li-Fi an efficient, secure, and scalable solution for your project, addressing key challenges like interference, data accuracy, and real-time performance in vehicle identification.

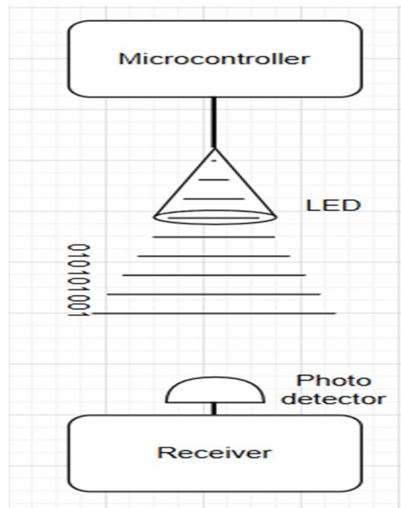

Fig.1.1 Basic concept diagram of Li-Fi

Li-Fi works on the principle of Visible Light Communication (VLC). It uses the rapid modulation of the light emitted by LEDs to encode and transmit data. It enables high-speed wireless communication using visible light from LED bulbs, offering a faster and more secure alternative to traditional Wi-Fi. Li-Fi works by modulating the LED light at extremely high speeds to encode data in binary form, where "ON" represents a binary '1' and "OFF" a binary '0'. Although this flickering happens too quickly to be visible, it transmits data to a photo-detector at the receiver end, which interprets the changes in light as digital information. The LED light source is modulated at high speeds corresponding to binary data (1s and 0s). The modulated light is transmitted through the visible light spectrum, covering a broad frequency range. A photo detector (typically a photodiode) receives the modulated light, converts it back into electrical signals, and decodes it into data that can be understood by digital devices [7].

II. METHODOLOGY

Li-Fi-based vehicle identification systems utilize the headlights of vehicles as transmitters, sending data encoded in modulated light signals. On the receiving end, photo detectors or optical receivers are installed on roadsides, toll booths, or speed breakers to capture the transmitted data. Each vehicle is equipped with a Li-Fi transmitter (typically an LED) that modulates light to transmit a unique identifier (vehicle ID) along with additional data such as timestamps, vehicle speed, and owner information. The light signals are detected by photodiodes or Li-Fi receivers installed at strategic points on the road. These receivers decode the light signals back into digital data. Once the data is received, it can be processed by a central system for vehicle identification, tracking, and management purposes, such as toll collection, traffic monitoring, or law enforcement.

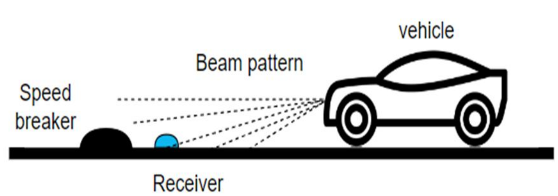

Fig.2.1 Vehicle Identification using Li-Fi method

The fig.1.2 shows a Li-Fi-based vehicle identification system. The vehicle transmits its unique ID using modulated light from its headlights, creating a beam pattern directed toward a receiver on the road. The receiver, placed near a speed breaker, captures this light signal and demodulates it to extract the vehicle's ID. The speed breaker slows down the vehicle, improving the accuracy of data transmission. The decoded information is then sent to a central system for vehicle identification and further processing [6]. Fake Number Plate Detection LiFi can be used to verify the authenticity of a vehicle's number plate by cross-referencing the transmitted data with a central database. This can help in identifying and addressing cases of fake or duplicate number plates.

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III. SYSTEM ARCHITECTURE

In the Li-Fi-based vehicle identification system, the vehicle microcontroller modulates vehicle data, such as its unique ID, and sends it through the LEDs as light signals. This data is modulated at a high frequency to ensure smooth and rapid transmission.

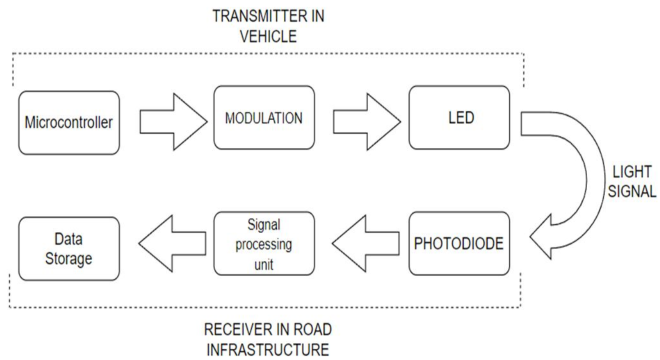

Fig.3.1Architecture of li-fi based vehicle identification

The light signals are then captured by a photodiode receiver installed on the roadside, which detects the modulated light. The signal processing unit filters out unwanted light, demodulates the signal, and decodes the transmitted vehicle data. Finally, the decoded information is either stored or transmitted to a central system for further use, such as logging or identification.

The vehicle is equipped with LED headlights modified to act as the Li-Fi transmitter. These LEDs will transmit encoded vehicle data in the form of modulated light. A microcontroller (e.g., Arduino) processes the vehicle's unique ID and other information (like time stamps) and sends it to the Li-Fi transmitter (LED. The vehicle transmits its identification data, such as registration number, model, and owner details, using modulated light from the headlights. This data can be transmitted constantly.[4]

Fig.3.2 Li-Fi transmitter in vehicle

The transmitter is designed to operate seamlessly with the vehicle's existing power systems, ensuring low energy consumption while maintaining high performance. It can be configured to continuously transmit data as the vehicle approaches the designated receiver location, facilitating real-time identification. To enhance reliability, the transmitter incorporates error detection and correction algorithms, allowing for accurate data interpretation despite potential interference. Overall, the transmitter plays a pivotal role in enabling effective communication between vehicles and infrastructure, contributing to smarter transportation systems.

The Receiver on Roadside Infrastructure is a crucial component in the Li-Fi-based vehicle identification system. It typically consists of a photodiode or light sensor that captures modulated light signals transmitted from vehicles' LEDs. Positioned near or on speed breakers, the receiver is strategically placed to ensure proximity to the vehicle for accurate detection. It is equipped with filters to eliminate interference from ambient light sources, such as sunlight or headlights, ensuring only the modulated Li-Fi signals are captured. Once detected, the signals are processed, demodulated, and decoded, enabling the system to extract and log vehicle identification data for further processing.

Fig.1.2 show that the position of the receiver. Two or more receiver are fixed on the road on same place to avoid missing out of vehicle in traffic condition. By fixing more receiver on the same place with some distance can help us to identify every vehicle which going on the road without missing. By placing the receiver on the road will help to reduce the distance between the transmitter and receiver and help to read the information without missing.[13]

IV. DATA TRANSMISSION PROCESS

The Data Transmission Process in a Li-Fi-based vehicle identification system begins with the vehicle's microcontroller encoding its unique identification information, such as the vehicle ID, into modulated light signals. These signals are transmitted using the vehicle's LED headlights, which flicker at a high frequency, invisible to the human eye. As the vehicle approaches a designated roadside infrastructure, typically located near speed breakers, a photodiode receiver on the roadside captures these modulated light signals. Data transmission also enables autonomous vehicles to make decisions based on real-time traffic data and communicate intentions with surrounding vehicles. By integrating data from various sources, vehicles can achieve smarter navigation, improve fuel efficiency, and enhance safety on the roads. As vehicle technology evolves, reliable and secure data transmission will become increasingly critical in advancing connected and autonomous transportation systems

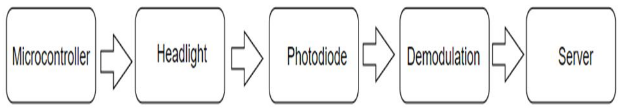

Fig. 4.1 Data Transmission Process of Li-Fi

The receiver is specially designed to filter out ambient light, including sunlight or other artificial light sources, ensuring that only the modulated data from the vehicle's LEDs is processed. Once the light signal is detected, it is sent to a signal processing unit. This unit demodulates the signal, converting the light data back into its original digital form. The decoded information, which contains the vehicle's ID and potentially other relevant details like timestamps, is either logged in a data storage system or transmitted to a central server for further processing. This real-time transmission process enables accurate vehicle identification, which can be used for various applications such as toll collection, traffic monitoring, or security checkpoints, ensuring efficient, contactless data exchange between vehicles and roadside systems.

V. PROTOTYPE OVERVIEW

Transmitter: An LED light source that modulates data (vehicle ID) into light signals.
Receiver: A photodiode or light sensor capable of receiving the light signals and filtering out ambient light.
Microcontroller: Processes the received signals, decodes the data, and handles communication with other components.

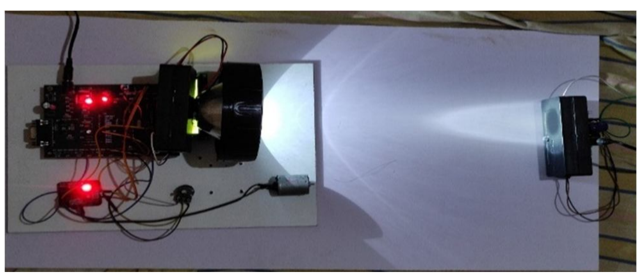

Fig.5.1 Li-Fi Data Transmission

VI. WORKING METHOD

The transmitter continuously emits light pulses representing vehicle identification data. Modulation techniques (Pulse Position Modulation) can be used to encode the information into the light.

Fig.6.1 Prototype of Transmitter

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The receiver detects the modulated light signals. The photodiode converts the light into electrical signals, which may include some noise from ambient light.

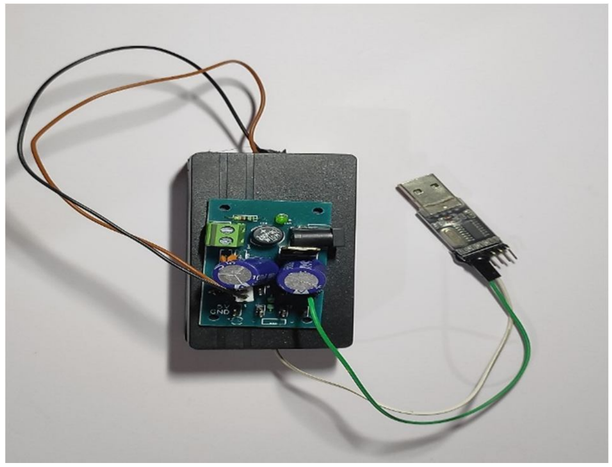

Fig.6.2 prototype of Receiver

Signal filtering is applied to minimize noise and enhance the received signal quality.

The microcontroller processes the filtered signals to decode the vehicle IDs. It checks for errors or transmission issues, such as signal loss or interference.

VII. OUTPUT

The decoded information can be displayed on an LCD, sent to a database, or processed for further action (e.g., logging vehicle entry).

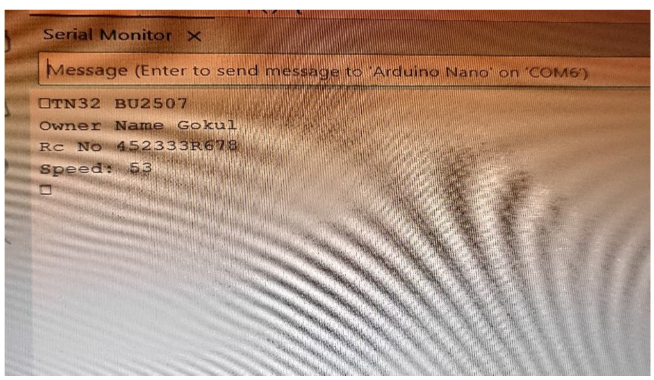

Fig.7.1 Output of the System

VIII. MICROCONTROLLER CODE

```
#include <LiquidCrystal.h>
// Initialize the LCD (RS, E, D4, D5, D6, D7)
LiquidCrystal lcd(13, 12, 11, 10, 9, 8);
// Define pins
const int potPin = A0;         // Potentiometer connected to A0
const int enablePin = 5;       // Enable pin of L293D (PWM)
const int motorPin1 = 2;       // Motor input 1
const int motorPin2 = 3;       // Motor input 2

void setup() {
  // Set motor pins as output
```

```
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(enablePin, OUTPUT);

  // Set motor direction (e.g., forward)
  digitalWrite(motorPin1, HIGH);
  digitalWrite(motorPin2, LOW);

  // Start serial communication
  Serial.begin(9600);

  // Initialize LCD
  lcd.begin(16, 2);
  lcd.print("TN32 BU2507");
}

void loop() {
  int analogValue = analogRead(potPin);          // Read potentiometer value (0-1023)
  int motorSpeed = map(analogValue, 0, 1023, 0, 255); // Map to PWM (0-255)

  analogWrite(enablePin, motorSpeed);            // Control motor speed

  // Send analog value to PC
   Serial.println("TN32 BU2507");
    Serial.println("Owner Name Gokul");
     Serial.println("Rc No 452333R678");
  Serial.print("Speed: ");
  Serial.println(motorSpeed);

  // Display on LCD
  lcd.setCursor(0, 1);                           // Move to second row
  lcd.print("Speed:");
  lcd.print(motorSpeed);
  lcd.print("    "); // Clear leftover digits

  delay(100); // Delay for stability
}
```

IX. FUTURE WORK AND CONCLUSION

The project "Design and Implementation of Vehicle Identification Using Li-Fi Technology" successfully demonstrates the potential of Li-Fi as a reliable and efficient method for vehicle identification. By leveraging light as a medium for data transmission, the system offers an innovative alternative to traditional radio-frequency-based systems, which are often subject to bandwidth limitations and interference. Our prototype effectively transmits vehicle identification data through visible light using LED modulation, while the receiver, placed on strategic points such as speed breakers, captures the transmitted signals, filters out ambient light noise, and decodes the information in real-time. Through simulation and testing, the system has shown robustness in handling environmental challenges such as interference from sunlight and noise. High-frequency modulation, unique vehicle IDs, and error correction mechanisms further enhance its reliability. MATLAB and Simulink simulations confirm that the system can decode vehicle IDs with minimal signal degradation. While the prototype has demonstrated promising results, future work could involve improving transmission distance, optimizing real-world deployment in traffic systems, and addressing challenges posed by varying lighting conditions. Overall, this project highlights the viability of Li-Fi technology in smart transportation systems and opens avenues for its integration into intelligent vehicle management and identification solutions.

In future work, several enhancements can be explored to improve the performance and scalability of the Li-Fi-based vehicle identification system. One key area is optimization of the receiver's sensitivity to better handle varying light conditions, especially in daytime traffic where ambient light may interfere with vehicle signals. Developing more advanced optical filtering techniques and adaptive algorithms could help the system better isolate vehicle data even in bright environments. Another avenue for improvement is expanding vehicle-to-vehicle (V2V) communication. By enabling vehicles to communicate directly via Li-Fi, the system could facilitate real-time traffic updates and improve overall road safety. This would also allow for decentralized data collection, reducing the load on roadside infrastructure. Integration with IoT (Internet of Things) technologies could further enhance the system by enabling seamless communication between vehicles, traffic lights, and other smart city infrastructure

In conclusion, our project on Li-Fi-based vehicle identification offers an innovative solution to the limitations of traditional identification methods, such as RFID and camera-based systems. These conventional systems often face challenges like radio frequency interference, low scanning speeds, visibility issues, and high susceptibility to environmental factors, which compromise accuracy and reliability. By harnessing Li-Fi technology—which uses visible light to transmit data—we achieve a robust, interference-free alternative that leverages the high speed and bandwidth capabilities of light-based communication. Our system transmits unique vehicle data via LEDs to a photodetector positioned on the road, ensuring efficient, secure, and real-time identification. The design addresses common obstacles such as ambient light interference and the need for line-of-sight by employing advanced filtering and modulation techniques. This enhances the accuracy of vehicle identification, even in challenging lighting conditions. The successful implementation of Li-Fi technology in vehicle identification could support better traffic management, enhance safety, and contribute to smart city infrastructure. Overall, our project demonstrates that Li-Fi is a promising technology for future urban mobility solutions, offering high reliability, scalability, and adaptability to complex traffic environments while overcoming many of the limitations of existing systems.

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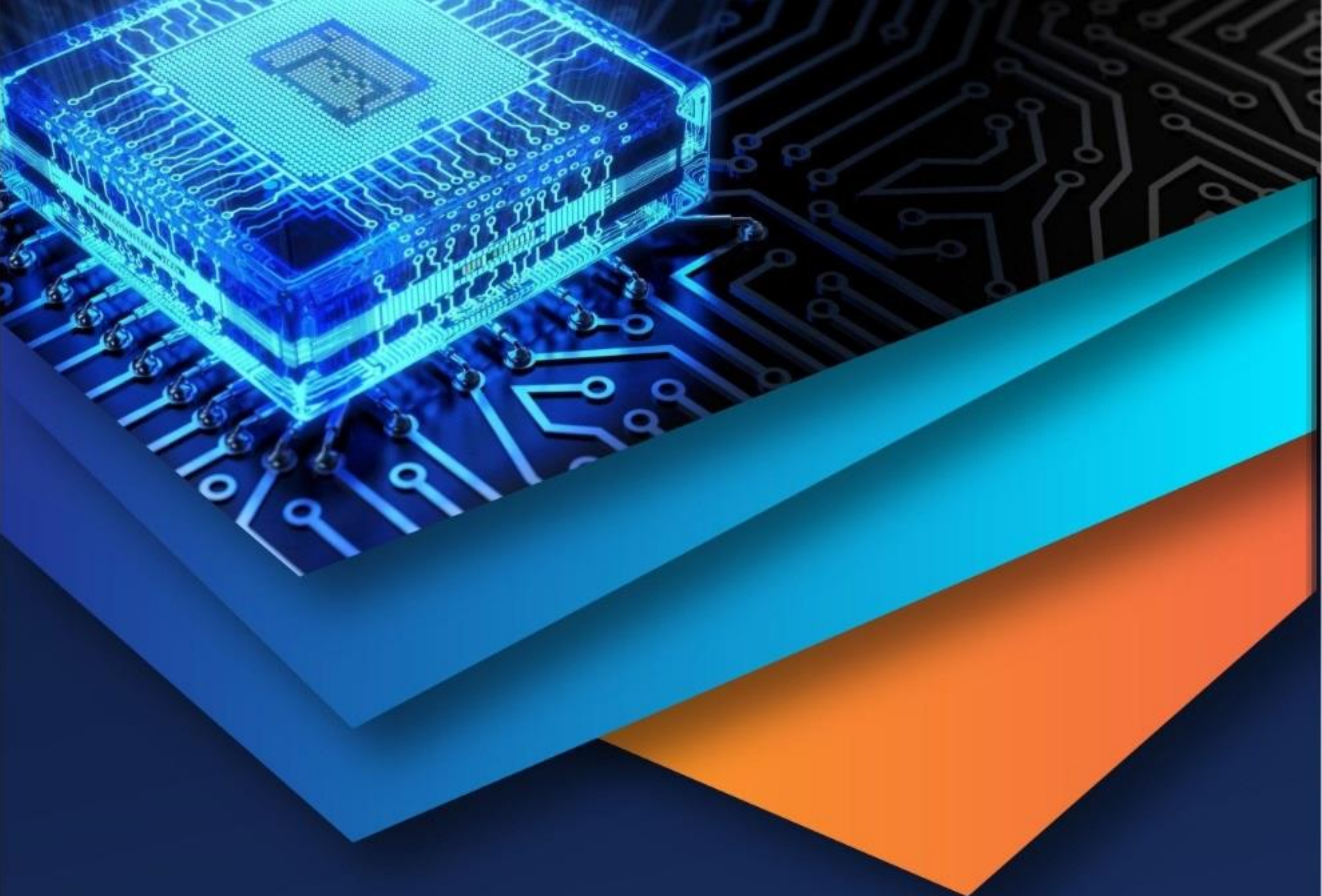

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