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Lifi Based Underwater Communication System

Mrs.Shobhika.P.Gopnarayan[1], Ritesh Patil[2], Abutwalha Sayyad[3], Armaan Sayyad[4], Aryan Kadam[5]
[1]Lecturer, [2, 3, 4, 5]Student, Department of Electronics & Telecommunication Engineering, AISSMS's Polytechnic, Pune, Maharashtra, India

Abstract: The primary objective of this project is to develop an efficient and sustainable underwater communication system using Li-Fi (Light Fidelity) technology. The system utilizes light waves for data transmission, offering an alternative to conventional radio frequency-based communication systems. The key components employed in this project include the IC 7805 voltage regulator, APR 9600 voice recorder and player, Arduino Uno microcontroller, 16x2 LCD display, and a battery for energy harvesting. The system enables communication between devices placed underwater by using light pulses transmitted through water, providing a reliable solution for underwater data transfer with minimal interference. This project showcases the integration of wireless communication with renewable energy sources, demonstrating the potential of Li-Fi for future underwater communication applications.

I. INTRODUCTION

Underwater communication systems have long been a challenge due to the inherent limitations of traditional radio frequency (RF) signals in aquatic environments. These signals suffer from significant attenuation, making reliable communication difficult over long distances. As technology evolves, there has been a growing interest in utilizing optical communication methods to overcome these challenges. Li-Fi, or Light Fidelity, is an emerging technology that uses light to transmit data, offering a potential solution for underwater communication due to its higher data transmission capabilities and less interference compared to RF-based systems.

This project focuses on the design and implementation of a Li-Fi-based underwater communication system. By employing light waves for data transmission, the system aims to provide an efficient, low-cost, and sustainable method for underwater communication. The use of components such as the Arduino Uno, IC 7805 voltage regulator, APR 9600 for voice recording and playback, and a 16x2 LCD display contributes to the overall functionality of the system. Additionally, a battery for power supply. The combination of these components allows for a reliable and practical solution for underwater communication, demonstrating the potential of Li-Fi technology for real-world applications in marine research, underwater robotics, and more.

II. THEORY OF OPERATION

The Li-Fi underwater communication system operates based on the principle of using light waves for data transmission, instead of conventional radio frequency (RF) waves. Light waves, particularly visible light, are less affected by water absorption compared to RF signals, making them ideal for underwater communication.

The system utilizes an LED (Light Emitting Diode) to emit modulated light signals which carry the data. The receiver, typically a photodiode or light sensor, captures the modulated light signals and converts them into electrical signals. These signals are then processed to extract the transmitted data. For data encoding and decoding, the system uses a modulation technique where the light intensity is varied to represent digital data (1s and 0s). The Arduino Uno microcontroller controls the transmission and reception of the light signals and processes the data accordingly.

The IC 7805 voltage regulator ensures that the system components operate at the appropriate voltage levels, providing a stable power supply. The APR 9600 is used for recording and playback of voice or other audio data, which is also transmitted via light pulses. The 16x2 LCD display provides real-time information such as the communication status or distance to the target. Finally, the battery charges the system, making it independent of external power sources and suitable for long-term deployments in underwater environments.

The entire system is designed to operate in harsh underwater conditions, offering a robust and energy-efficient solution for underwater communication by using light-based technology.

III. METHODOLOGY

The design and implementation of the Li-Fi underwater communication system follows a systematic approach, incorporating both hardware and software components to achieve seamless communication.

The methodology can be divided into several key stages:

1) *Component Selection and Setup:* The primary components used in this system include the Arduino Uno, IC 7805, APR 9600, 16x2 LCD, and a battery. The Arduino Uno microcontroller is the central processing unit, controlling the transmission and reception of data. The IC 7805 regulates the voltage supply to ensure proper functioning of the components. The APR 9600 is used for recording and playback of audio signals, while the 16x2 LCD provides visual feedback for system status. The battery provides a sustainable power source.
2) *Light-based Data Transmission:* The communication between the sender and receiver is established using modulated light signals. An LED (Light Emitting Diode) is used to transmit data, where the intensity of the light is modulated to encode digital information. The data is encoded in the form of binary signals, with variations in light intensity representing '1' and '0'. The receiver, a light sensor, detects these modulated light signals and converts them back into electrical signals for further processing by the Arduino.
3) *Data Encoding and Decoding:* The data encoding process is achieved through modulation techniques, where the Arduino controls the LED's light intensity to represent binary data. The APR 9600 records audio or other data, which is then converted into modulated light signals. The receiver decodes the signals by measuring the light intensity and translating the variations into digital data, which can be displayed on the LCD or processed further.
4) *Power Management:* The system is powered by a battery, to provide continuous power to the system. This energy-efficient design ensures that the system can operate independently in remote or underwater environments without reliance on traditional power sources.
5) *Testing and Calibration:* Once the system components are integrated, the communication system is tested in various underwater conditions to evaluate the effectiveness and reliability of the Li-Fi transmission. The performance of the system is measured by analyzing the range, speed, and stability of the communication link. Calibration of the sensor and modulation techniques is carried out to ensure accurate data transmission.

IV. LITERATURE SURVEY

Underwater communication has been a challenging task for many years due to the limitations posed by water's absorption of radio frequency (RF) signals. The traditional methods of underwater communication, such as acoustic and RF-based systems, have been widely used but come with inherent issues, including limited bandwidth, high energy consumption, and slower data transmission speeds. This has led researchers to explore alternative communication methods, such as optical or light-based systems, which offer potential advantages in underwater environments.

1) *Acoustic Communication Systems*

Acoustic waves have been the standard method of underwater communication, widely used in sonar systems and submersible communication. However, they suffer from low bandwidth, long propagation delays, and significant attenuation in deeper waters, making them less efficient for high-speed data transmission. Studies have shown that while acoustic systems work well for long-range communication, they are limited in terms of data rate, especially in crowded underwater environments (e.g., near coastal areas with high shipping traffic).

2) *Radio Frequency (RF) Communication*

RF communication has seen limited success in underwater applications due to high attenuation of electromagnetic waves in water. Radio waves, especially in the higher frequencies required for data transmission, are absorbed quickly, rendering the communication range short. Several studies have attempted to overcome this challenge by using low-frequency RF waves, but the results have been suboptimal, with poor data rates and high energy consumption.

3) *Optical or Li-Fi Communication*

Light-based communication has emerged as a promising alternative to acoustic and RF systems. Optical communication using visible light or infrared (IR) waves has advantages, including higher bandwidth, lower energy consumption, and less interference from environmental noise. The concept of Light Fidelity (Li-Fi), where data is transmitted using light waves, has been explored for underwater communication. A study by Ahmed et al. (2019) highlighted the potential of Li-Fi for underwater environments, demonstrating that light waves can propagate with less attenuation than RF signals.

4) Li-Fi Underwater Communication Systems

Several studies have explored the feasibility of using Li-Fi for underwater communication, focusing on the advantages of optical systems. For instance, a research paper by Yang et al. (2020) proposed a Li-Fi-based system for underwater communication, showing that visible light communication (VLC) can achieve data rates up to several Mbps. The system used an LED as the light source and a photodiode as the receiver. The key challenge identified was the effective modulation of the light signals to overcome water's scattering effects and to ensure stable communication in various water conditions.

5) Power Consumption and Sustainability

One of the key challenges in underwater communication is ensuring a reliable power supply. Traditional systems, such as those using acoustic or RF communication, require high-power transmitters, limiting their use in remote or autonomous underwater applications. Li-Fi systems, however, offer the potential for energy-efficient communication, especially when powered by sources such as battery. This is an essential advantage in applications like underwater sensor networks, where long-lasting and low-maintenance systems are required.

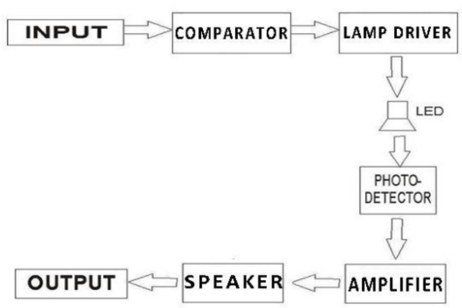
6) Recent Advancements in Li-Fi for Underwater Communication

More recent studies have focused on improving the efficiency and range of Li-Fi systems in underwater settings. Researchers have developed advanced modulation techniques to increase data rates, as well as methods for reducing the effects of scattering and absorption in water. Some studies also explore hybrid systems that combine optical and acoustic technologies to achieve better performance across varying depths and environmental conditions.

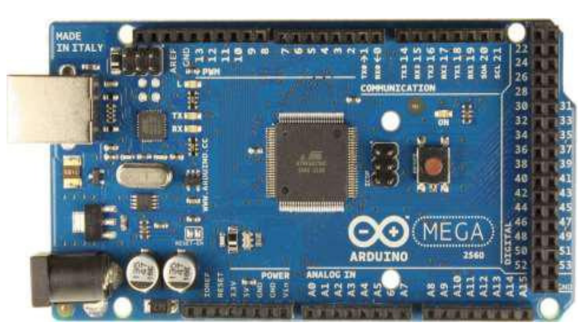
The literature reveals that while acoustic and RF communication systems have dominated underwater communication for years, Li-Fi is emerging as a highly efficient and promising alternative, particularly for applications requiring high data rates and low power consumption.

V. PRODUCT ARCHITECTURE

Block Diagram:

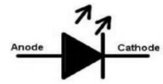


1) Microcontroller (Arduino Uno)



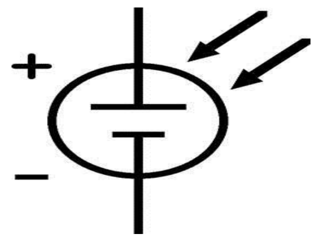
The core of the system is the Arduino Uno, which serves as the central controller for the entire system. It processes inputs from sensors, controls the light-emitting diode (LED) for signal transmission, and receives feedback from the photodiode to decode received signals. The Arduino Uno interfaces with various components such as the APR9600 (audio recording and playback module), the LCD display, and the battery for power supply.

2) Li-Fi Transmitter (LED)



The Li-Fi transmitter is an LED that emits modulated light signals. These light signals encode the data, which can be transmitted to a receiver (located at a distance). In the underwater environment, the LED will be controlled by the Arduino to send light signals at specific frequencies. The modulated light signals carry the data and are transmitted through the water medium.

3) Li-Fi Receiver (Photodiode)



The receiver consists of a photodiode that detects the modulated light signals transmitted by the LED. The Arduino processes the received signal, decodes the information, and displays the received data on an LCD screen. The photodiode is connected to the Arduino to read the intensity of the incoming light, which is then used to determine the transmitted data.

1. APR9600 Audio Module

The APR9600 module is used to record and play back audio data. In the context of this project, it can be used to encode audio signals into the light transmission or to provide an interactive interface for communication. The APR9600 module is integrated with the Arduino, allowing it to capture and play sound recordings through the system.

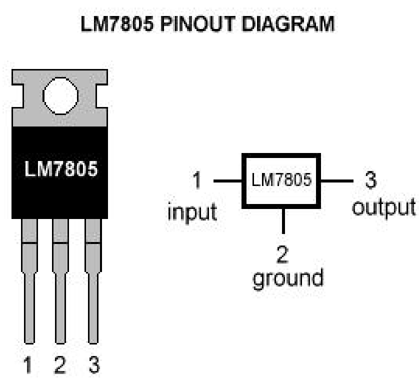
4) 16x2 LCD Display:

A 16x2 LCD screen is used to display the data transmitted and received by the system. The LCD allows users to visually monitor the communication process, making it easier to debug and observe the transmitted information in real time.

5) Power Supply

The system is powered by a battery, which provides energy to the components. The battery supplies power to the Arduino, LED, photodiode, APR9600, and other components of the system.

6) IC 7805:



The IC 7805 is used to regulate the voltage from the power supply to a stable 5V, which is required by the Arduino and other components. It ensures that the system receives a consistent and appropriate voltage for optimal performance.

7) Resistors:

Resistors are used throughout the circuit to limit current and protect the components from overloading. They are strategically placed in the circuits of the Arduino, LED, photodiode, and other components to ensure proper functionality and safety.

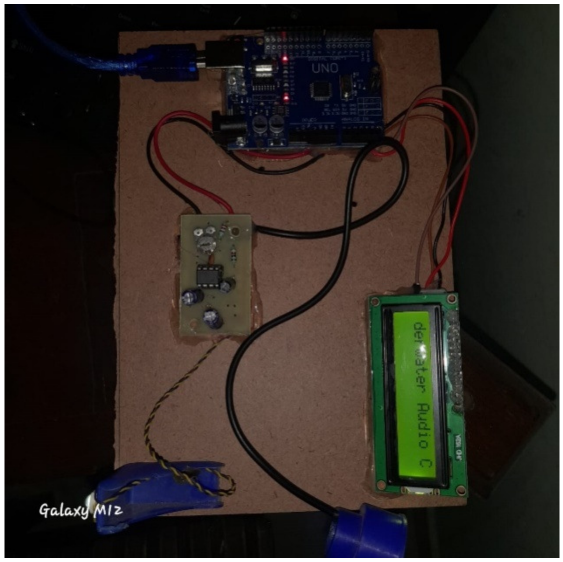
VI. SYSTEM DIAGRAM

The system's architecture can be depicted in the following steps:

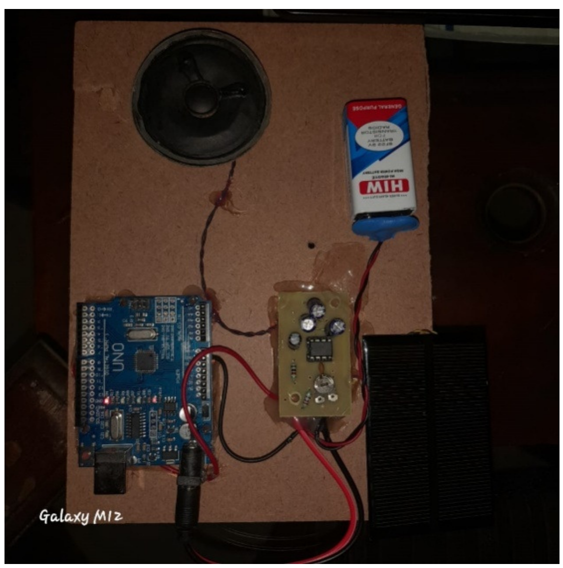
1) The Arduino Uno receives inputs from the sensors (e.g., ultrasonic sensors or any other sensors used for data collection).
2) Based on the inputs, the Arduino modulates the LED to send light signals encoded with data.
3) The photodiode at the receiver end detects the light signals and sends them to the Arduino.

4) The Arduino processes the received signals, decodes the data, and displays it on the 16x2 LCD.
5) Power is supplied to the system via a battery that powers the Arduino and other components.
6) The APR9600 audio module can be used to record and play back audio signals, which can be transmitted or received through the Li-Fi system.

Real Images:



Transmitter Section



Receiver Section

VII. PROGRAM USED

In the Li-Fi underwater communication system, the program is designed to control the transmission and reception of light signals using the Arduino Uno. The Arduino will modulate the LED for transmitting signals and read the incoming signals from the photodiode for decoding. The program also interfaces with the APR9600 audio module for recording and playing back audio signals.

Final Program Used:

```
unsigned long StartTime = millis();
unsigned long Value; unsigned long EndTime;
```

```
int Message;
booleanStartedCounting = false; //this is used to determine if the counting has started
void setup() { Serial.begin(9600); }
void loop() {
int sensorValue = analogRead(A0); //read the sensor value
delay(1); // to stabilize
// Serial.println(sensorValue); // this can be used to determine the threshold in your lighting conditions
if (StartedCounting==false &&sensorValue>850){ //if the counting has not yet started and the light is on
StartTime = millis(); // This saves the current time in milli seconds
StartedCounting= true; }
if (StartedCounting== true &&sensorValue<850){ // if the counting has started and the light is off
Value = millis() - StartTime; // subtract the starting time from the current time to get message time Message= Value/1000;
StartedCounting= false;
Serial.print ("Message: ");
if (Message == 1){ // change these to your own messages. the sender should also have this list so they know what they send.
Serial.println("hi"); }
else if (Message == 2){
Serial.println("wazzup?"); }
else if (Message == 3){
Serial.println("HELP"); }
else if (Message == 4){
Serial.println("top secret"); }
else if (Message == 5){
Serial.println("Penguins"); } '
else if (Message == 6){
Serial.println("LI-FI is the future"); }
else if (Message == 7){
Serial.println("#notreallythough"); }} }
int sensorPin = A0; // select the input pin for ldr
int sensorValue = 0; // variable to store the value coming from the sensor
int light=0;
int i=0;
int d[32];
int temp=1;
int k=0; int add=0;
int a=1001;//-------------- replace with any value of your choice
void setup()
{ pinMode(13, OUTPUT); //pin connected to the relay
Serial.begin(9600); //sets serial port for communication
Serial.println(sensorPin);
int b;
while(a!=0)
{
b=a%2; //converts binary to decimal
a=a/2;
if(b==1)
{
digitalWrite(13,HIGH);
delay(2);
sensorValue=analogRead(sensorPin);
```

```
d[i]=sensorValue; }
else
{
digitalWrite(13,LOW);
delay(2);
sensorValue=analogRead(sensorPin);
d[i]=sensorValue;
}
i++;
} i--;
// for converting binary to decimal
while(i>=0)
{
if(d[i]>=75&&d[i]<700)
{
k=i;
while(k!=0)
{
temp=temp*2;
k--;
}
add=add+temp;
temp=1;
}
i--;
}
Serial.println(add); // Final recieved value gets printed
digitalWrite(13,LOW); }
void loop()
{
}
int Message1 = 6; // set the number of the first message you want to convey
int Message2 = 2; // set the number of the second message you want to convey boolean Message1done = false; // this will be used to determine if the first message has been sent
int i=0;
int j=0;
void setup()
{ pinMode(10, OUTPUT); //pin connected to the led Serial.begin(9600); //sets serial port for communication }
void loop(){
if ( i< Message1) { // Sending the first message. this will loop until i has reached the value of message1
digitalWrite(10,HIGH); // turn on the LED
i++; //increase i with 1
delay (1010); // wait for a second (1010 mili seconds, a little more than a second to correct inaccuracies) }
else if (Message1done == false){ // once the led has been lit long enough it will be turned off a
digitalWrite(10,LOW);
delay(1000); // wait a second before sending the next message
Message1done= true; // note that message one has been sent }
if (( j< Message2) && (Message1done == true)) { // sending the second message only if message one is done
digitalWrite(10,HIGH); //this code is in priciple the same as for message 1
j++;
```

```
delay (1010); }
else if (Message1done == true) { digitalWrite(10,LOW);
exit(0); // stop the execution of the code when both messages are sent } }
```

VIII. FUTURE SCOPE

1) *Improved Communication Range and Speed*

Problem: In current systems, the range of Li-Fi underwater communication is limited by the absorption and scattering of light in water.

Future Scope: Developing more powerful and efficient light sources, such as high-intensity LEDs or lasers, and designing more sensitive photodetectors will significantly improve the range and speed of data transmission underwater. Also, adaptive algorithms that adjust transmission power based on water quality could optimize communication performance.

2) *Use of Different Wavelengths for Better Penetration*

Problem: Different wavelengths of light have varying abilities to penetrate water. Visible light, for instance, is absorbed quickly, limiting the communication distance.

Future Scope: Researching into the use of different wavelengths of light, such as infrared or ultraviolet, which can penetrate water more effectively, could open up new possibilities. Using wavelength-division multiplexing (WDM) could also allow multiple channels of communication in the same environment, thus improving the overall bandwidth.

3) *Integration with Wireless Communication Networks*

Problem: Current systems primarily rely on direct line-of-sight communication, which can be disrupted by obstacles in the water.

Future Scope: Integrating Li-Fi with wireless communication networks (like Wi-Fi, 5G, or satellite communication) can enable seamless communication between underwater and terrestrial environments. For example, a relay system could be established to maintain communication between the underwater devices and surface stations.

4) *Miniaturization and Power Efficiency*

Problem: Many underwater sensors and communication devices are bulky and require significant power for operation.

Future Scope: Focus on miniaturizing the communication hardware and making the system more power-efficient. This would allow for compact devices that can be used for long-duration underwater monitoring without frequent recharging or maintenance, making it ideal for deep-sea exploration or long-term oceanographic studies.

5) *Improved Signal Modulation and Data Encoding Techniques*

Problem: Current data encoding techniques may not be optimal in terms of error correction and efficiency in challenging underwater environments.

Future Scope: Advancements in modulation techniques, such as Orthogonal Frequency-Division Multiplexing (OFDM) or advanced error-correcting codes, can allow for more robust and efficient communication even in murky or turbulent water. These techniques could minimize data loss and improve the reliability of data transmission.

IX. CONCLUSION

In conclusion, the LiFi underwater communication system demonstrates a significant advancement in communication technology for submerged environments. By utilizing visible light for data transmission, this system overcomes the limitations of traditional radio frequency communication, such as attenuation and interference in underwater conditions. The integration of components like the IC 7805, APR 9600, Arduino UNO, 16x2 LCD, Photo detector, and power supply ensures that the system operates efficiently and can be powered sustainably. This project not only showcases the feasibility of using LiFi technology in underwater communication but also highlights its potential for future applications in marine research, underwater exploration, and environmental monitoring.

X. ACKNOWLEDGEMENT

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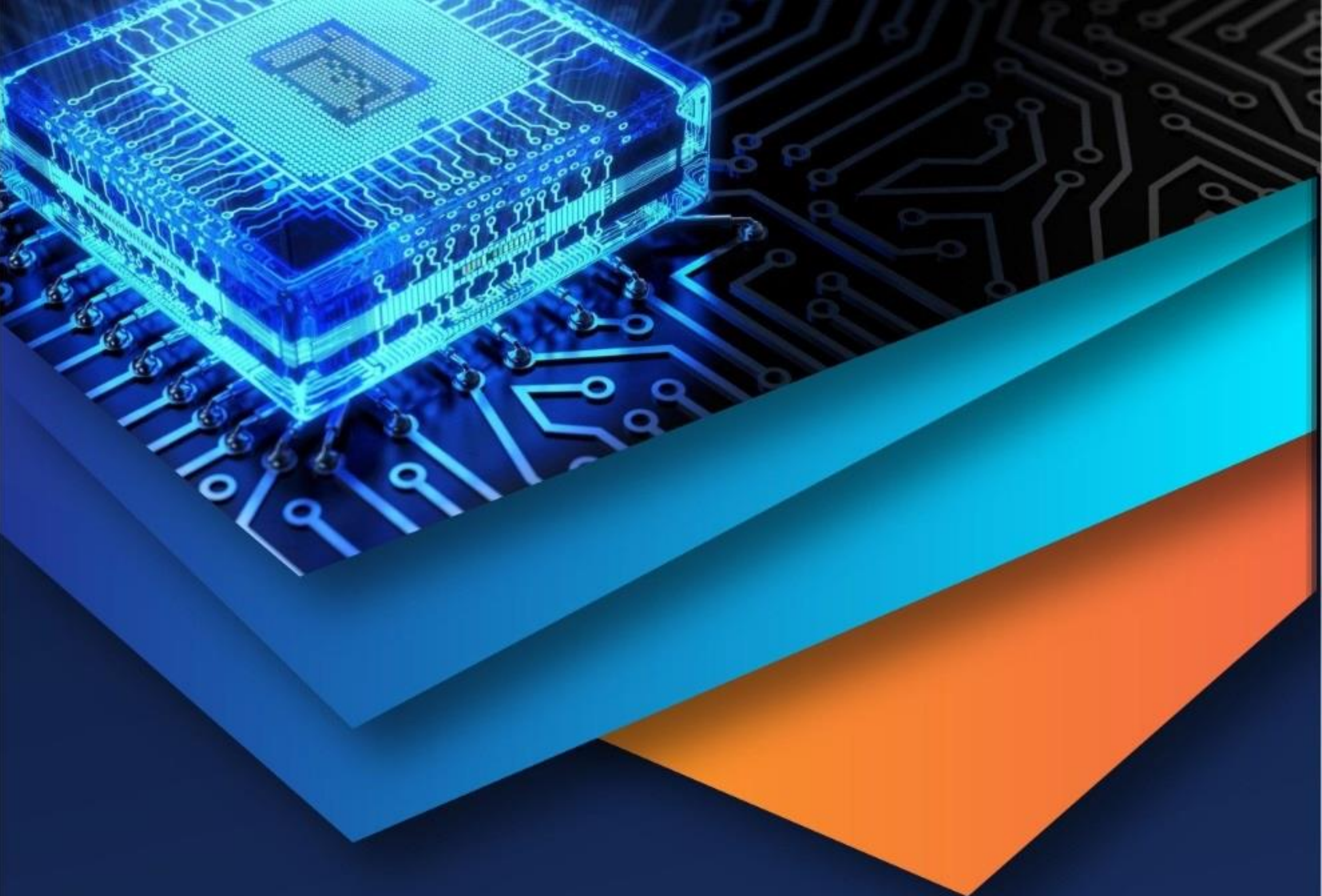

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