iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68194

Audio Transmission Using Light Fidelity

Anandhu MT[1], EvelinaD[2], Ilyas Mubarack[3], Zaahil P Rawther[4], MohithaThomas[5], ReenuGeorge[6]
Department of Electrical And Electronics Engineering, Mar Athanasius College Of Engineering, Kerala, India

Abstract: Li-Fi(LightFidelity)technologyisaninnovativewirelesscommunicationsys- tem that utilizes visible light for data transmission, offering an alternative to traditional radio frequency-based methods like Wi-Fi.In this approach, audio signals are transmitted through modulated LED light and received by a pho- todiode, whichconvertsthe lightbackintoaudio signals. Thesystemallows forreal-time,high-speed audiotransmissionwithminimalinterference,aslightwavesdonotoverlap withradio signals,makingitidealforenvironmentswhere radio frequencies are either restricted or congested.The implementation in- volves key components such as an LED transmitter, photodiode receiver, and circuitsformodulationanddemodulation. Li-Fioffershigh datasecurity, since light cannot pass through walls, reducing the risk of eavesdropping.Despite challenges such as line-of-sight dependency and susceptibility to ambient light interference, Li-Fi shows immense potential for secure, fast, and interference-free audio transmission, paving the way for advanced communication systems in both public and private sectors.
Keywords: Li-Fi Technology AudioTransmission, Visible Light Communication Optical Wireless Communication Signal Amplification.

I. INTRODUCTION

Wireless communication technology has revolutionized the way data is transmitted across various platforms. Therapidincreaseinthenumberofconnecteddeviceshasledtocongestionintheradiofrequency(RF)spec- trum, making it necessary to explore alternative communication methods.Light Fidelity (Li-Fi) has emerged as an innovative solution, utilizing visible light for high-speed, secure, and interference-free data transmis- sion. UnlikeWi-Fi,whichoperatesusingRFwaves,Li-Fiemploysmodulatedlightsignalsemittedfrom LEDs to transfer data, offering a promising alternative in environments where RF communication is limited or un- desirable.Li-Fi technology operates within the visible light spectrum, which is approximately 10,000 times larger than the RF spectrum.This expanded bandwidth allows for higher data transmission rates and reduces congestion in wireless networks.Additionally, Li-Fi is highly secure, as light waves do not penetrate walls, preventing unauthorized access and making it ideal for secure communication applications.This inherent ad- vantagemakesLi-Fiparticularlysuitableforenvironmentssuchashospitals,airplanes,andmilitaryoperations where electromagnetic interference must be minimized.

TheapplicationofLi-Fiinaudiotransmissionisanotableadvancement, offeringaseamlessmethodforsending audio signals without relying on conventional RF technologies.The process involves converting an audio signal into modulated light pulses, which are transmitted via an LED and received by a photodetector.

The receivedsignalisthenconvertedbackintoanaudioformat,ensuringclearandreliablesoundreproduction.

Thetechnologyprovidesanalternativefortransmittingsoundinsituationswheretraditionalwirelessmethods are impractical or compromised by interference.

In this project, Li-Fi has been implemented for audio transmission, demonstrating its efficiency in real-time communication.The study investigates the effectiveness of using modulated LEDs to transmit sound signals. Theexperimentfocusesonoptimizingthetransmissionprocesstoensureminimalsignaldegradationandhigh fidelity in audio output.Additionally, the implementation of an amplification circuit ensures adequate signal strength for playback.

The development of Li-Fi-based audio transmission systems has the potential to transform the way sound is communicatedinenclosedenvironments. Thispaperexploresthemethodology,systemarchitecture,hardware implementation,andresults obtainedfromtheexperimentalsetup. Thefindingscontributetoongoingresearch in optical wireless communication and highlight the feasibility of Li-Fi in audio applications.

II. LITERATU REREVIEW

Alietal. [1]onVLCpresentedattheTexasInstrumentsIndiaEducatorsConferenceexploresthepotentialof using light-emitting diodes (LEDs) for high-speed, short-range data transmission.VLC leverages the visible light spectrum to enable wireless communication, presenting an alternative to radio frequency technologies. Assabiretal.

[2]discussedVLC’sapplicationsinvariousfields,suchasindoornavigation,vehicularcommu- nication, andsecureddatatransmission, whereRFinterferenceposeschallenges.Ithighlightskeycomponents like photodetectors, modulation techniques, and microcontroller integration, enabling data transfer through LED flickering, imperceptible to the human eye.Through this approach, VLC provides an efficient and low- costcommunicationmethodsuitableforsmartenvironments,demonstratingthescopeforinnovationindigital communication through light.

Saranya et al.[3] presented a high-sensitivity, universal LiFi receiver designed to improve data communica- tion efficiency.LiFi technology uses visible light for data transmission, offering an alternative to traditional radio-frequency communications with potential for faster,more secure connections.The proposed receiveris optimized for low-light environments, enhancing its adaptability across diverse applications and enabling reliable communication in settings where conventional wireless options may struggle.Madhuri et al.[4] dis- cussed the design methodology, sensitivity improvements, and the system’s ability to handle various lighting conditions.Additionally,thereceiver’suniversalcompatibilityallowsittofunctionwithdifferentlightsources and modulated signals, making it a versatile solution for both indoor and outdoor environments.The results demonstrate the potential of this advanced LiFi receiver to support green technology initiatives by enabling energy-efficient, high-speed data communication while reducing the electromagnetic interference associated with RF-based systems.

Bollaetal. [5]exploredreal-timeaudiostreamingusingvisiblelightcommunication(VLC),showcasingVLC asaninnovative alternativeto conventionalradio-frequencycommunicationforaudiotransmission.Bylever- aging visible light, VLC provides highspeed, interference-free data transfer, offering a secure and energy- efficient means of streaming audio.Sharmila et al.[6] covered the technical framework for implementing audiotransmissionthroughmodulated lightsignals,addressingkey challengeslikemaintaining signalfidelity and optimizing data rates in real-time applications.Experimental results validate the system’s performance, highlightingitspotentialforseamless,low-latencyaudiostreamingindiverseenvironments. Thisstudyunder- scores VLC’s capabilities, promoting its use for secure, high-quality audio streaming in indoor settings such asconferencerooms, hospitals,andpublicspaces, wheretraditionalwirelesssolutionsmayfaceconstraintsor interference.

Seungjik et al.[17] discussed about the sustainable energy-efficient wireless applications using light, also knownasVisibleLight Communication(VLC)orLi-Fi,leverageLEDstotransmitdatawhilesimultaneously providingillumination.Thisdual-purposeapproach reduces powerconsumption, asLEDsarehighlyenergy- efficientandcanserveasbothlightinganddatasources. Unlikeradiofrequencies, ight-based communication does not cause interference, allowing for dense network deployments with lower energy overhead.Applica- tionsincludesmartcityinfrastructure(suchasstreetlightstransmittingenvironmentaldata),healthcare(secure, confineddat at ransferinhospitals),andhigh-speedindoornetworks,providinganeco-friendlyalternativefor wirelesscommunication. Asmathunnisaetal. [8]discussedaboutthebroadbandaccessovermediumandlow- voltage powerlines which enables high-speed internet connectivity by using existing electrical infrastructure, bringing broadbandtoareaswithout traditionalcabling.Thisapproach,knownasPowerline Communication (PLC),offersanefficient,cost-effectivewayto expandbroadbandaccess, particularlyinruralorunderserved regions.When combined with White Light Emitting Diodes (LEDs) for indoor communication, PLC en- ablesVisibleLightCommunication(VLC)withinbuildings, whereLEDlightingcan transmitdatawirelessly. Sabareeswaran et al.[16] discussed the integration that provides a sustainable solution for high-speed indoor communications, improving connectivity in smart homes and offices.

III. PROPOSED METHODOLOGY

The methodology involves the conversion of an audio signal into an optical signal using an LED transmitter, followed by its reception and demodulation by a photodetector.The system starts with an audio source, such asamicrophoneormusicplayer,whichgeneratesananalogsignal. Thissignalisfedintoamodulationcircuit that varies the intensity of an LED on the basis of the audio input.The light variations [9] are captured by a solarpanelorphotodiode, whichconvertstheoptical signalbackintoanelectrical form.Finally, thesignalis amplifiedandsenttoaspeakerforaudioplayback. Thisprocessensures thatthetransmittedsoundisclearand free from significant distortion.

A. System Architecture

The system comprises key components such as an LED transmitter, a photodetector-based receiver,[10] an amplificationcircuit,andaspeaker.TheLEDfunctionsasthelightsourcethatencodestheaudiosignalthrough intensitymodulation. Thereceiversectionconsistsofaphotodetector,whichcapturesthelightfluctuationsand converts them into an electrical signal. The amplified signal is then fed into a speaker for output.

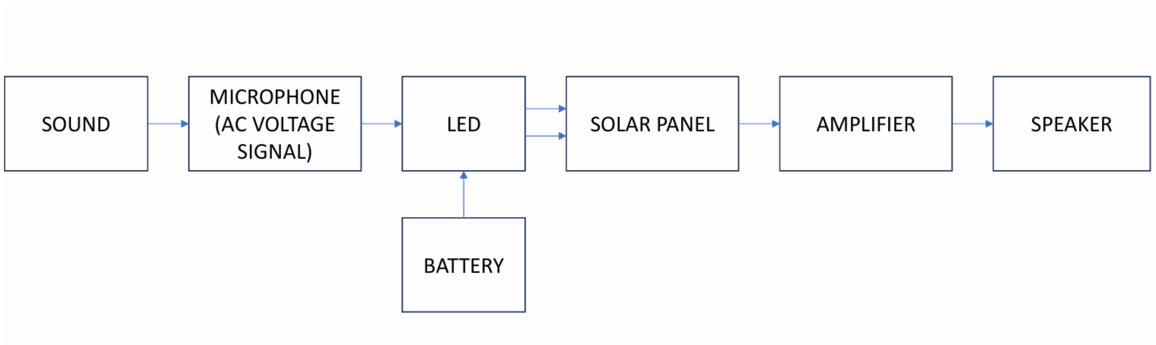

Figure1.BlockdiagramofaudiotransmissionusingLi-Fi

Theblockdiagramofthesystemincludesanaudiosource,LEDdrivercircuit,LEDtransmitter,photodetector,signalamplificationstage,andoutputspeaker.Themodulationanddemodulationprocessesplayacrucialroleinensuringthefidelityofthetransmittedsignal.Propersynchronizationbetweentransmissionandreception[13]isnecessarytominimizesignallossanddistortion.

The amplification stage is particularly important in this setup.After the audio signal is converted back into electrical form, it is relatively weak and requires amplification to restore its original clarity and volume.An operational amplifier (IC-based amplifier) [15] is used to boost the signal before feeding it into the speaker. This ensures that the received audio maintains high quality.

IV. HARDWARE IMPLEMENTATION

The hardware implementation of the LiFi-based audio transmission system involves multiple components working together to successfully transmit and receive audio signals using light as the transmission medium. The key steps in this process include signal transmission, light modulation, reception, and amplification to ensure clear audio output.

A. Audio Signa Transmission

The process begins with an audio source, such as a smartphone, computer, or music player, which serves as theinputdevice. Theaudiosignalistransmittedfromthesourcethroughanauxiliary(AUX)cable,whichisastandardmethodfortransferringanalogaudiosignals. TheAUXcablecarriestheleftandrightaudiochannels, maintaining signal fidelity and minimizing noise or interference during transmission.

B. Conversion of Audio Signal into Light

Once the audio signal is transmitted through the AUX cable, it needs to be converted into an optical signal. ThisisachievedbymodulatingtheintensityofanLED(LightEmittingDiode).TheLEDservesastheopticaltransmitterintheLiFisystem.Insteadofcontinuouslyglowingatafixedintensity,theLEDvariesitsbrightnessrapidlyinresponsetotheaudiosignal.

Thesevariationsoccuratahighfrequency,makingthemimperceptible to the human eye but easily detectable by a light-sensitive receiver.This modulation technique enables the conversion of electrical audio signals into light pulses, which then travel through the air as the medium of transmission. TheLED'sfastresponsetimeensuresthatthetransmittedaudioisaccuratelyencodedwithinthe fluctuations of light intensity.

Figure2.TransmitterCircuit

C. Reception of Light Signal

At the receiving end,a solar panel is used as a light detector to capture the transmitted light signals. Thesolarpanelactsasaphotodetector, convertingthevaryingintensityoflightbackintoelectricalsignals. When lightfallsonthepanel, itgeneratesasmallelectricalcurrentcorrespondingtothevariationsinlightintensity.
SincetheLEDwasmodulatingtheaudiosignalintothelight,thereceivedelectricalsignalcarriestheoriginal audioinformation. Theuse ofasolar panelinsteadofaconventionalphotodiodeprovidesalargersurfacearea for capturing light, improving signal reception and allowing the system to function effectively even when the alignment between the transmitter and receiver is not perfect.

D. Signal Processing and Amplification

The output signal from the solar panel is weak and requires further processing to ensure clear audio output. This is where the TPA3110 Class D amplifier plays a crucial role.The TPA3110 is a highly efficient audio amplifier IC capable of delivering 15W per channel.It takes the weak electrical signal from the solar panel, processesit,andamplifiesittoalevelsufficienttodriveaspeaker. Fig. 4istheamplifiercircuitthatamplifies the output signal from the solar panel.
Fig3showsthepinoutdiagramoftheTPA3110amplifierIC,accordingtowhichtheconnectionsweremade. The signal captured by the solar panel may include noise, distortions, or signal losses due to environmental factors such as ambient light interference or weak signal reception.To ensure a clear and strong audio out- put, the TPA3110 amplifier plays a crucial role in signal processing and amplification.This Class D audio amplifiereffectivelyboosts theweak electricalsignal whileminimizing powerconsumption,makingithighlysuitableforlowpower,highefficiencyapplicationslikeLiFibasedaudiotransmission systems. Additionally, the TPA3110 provides stable performance, reduces heat generation, and enhances audio clarity, ensuring that the transmitted sound is accurately reproduced at the receiving end.

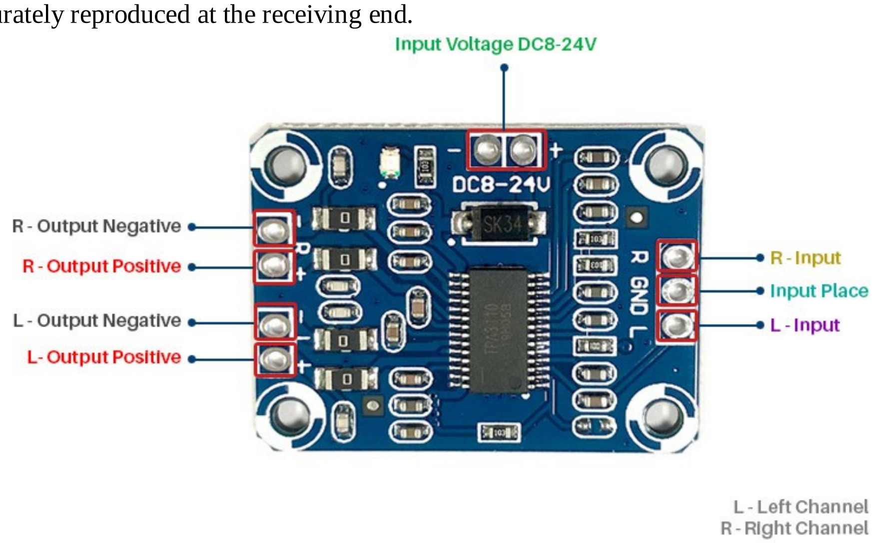

Figure3.PinoutDiagramofTPA3110

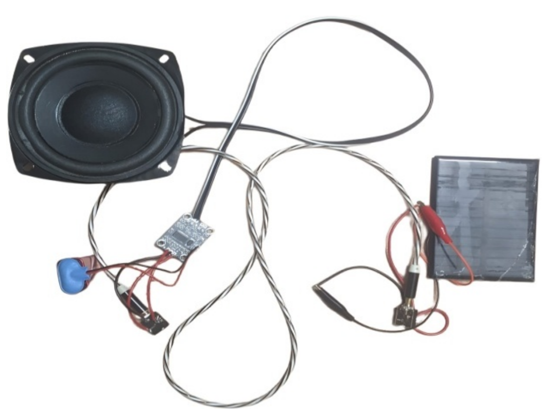

Figure4.AmplifierCircuit

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

E. Audio Output

Oncetheaudiosignalhasbeenamplified,itisfinallysenttoa15Wspeaker,whichservesastheoutputdevice.Thespeakerconvertstheelectricalsignalsbackintoaudiblesoundwaves,allowinguserstohearthetransmit-tedaudio.

Thepowerandefficiencyofthespeakerensurethattheaudioisloudandclear.Thechoiceofa15Wspeakerstrikesabalancebetweenpowerconsumptionandaudiooutput,makingitsuitableforbothindoorand portable applications.

By carefully integrating these hardware components, the LiFi-based audio transmission system effectively demonstrateshowlightcanbeusedasamediumforwirelessaudiocommunication.ThisimplementationhighlightsthepotentialofLiFitechnologyinapplicationswheretraditionalradio-frequency-basedcommunication is limited or interference needs to be minimized.Additionally, the use of LiFi for audio transmission opens new possibilities for secure communication, as light-based signals do not penetrate walls, ensuring restricted accesstotransmitteddata. Withfurtheradvancements, LiFitechnologycouldrevolutionizevariousindustries,includinghealthcare,aviation,andunderwatercommunication,offeringhigh-speedandinterference-freedata transmission.

Figure5.OverallCircuit

V. RESULTS

The Li-Fi system successfully transmitted audio from the LED to the solar panel-based receiver, resulting in the given signal [14].The transmitted signal showed minimal delay showcasing Li-Fi's capability for real- timeaudiotransmission. Thesetupdemonstratedreliableperformancewithstableconnections,confirmingthe suitability of Li-Fi for simple audio data transmission applications.

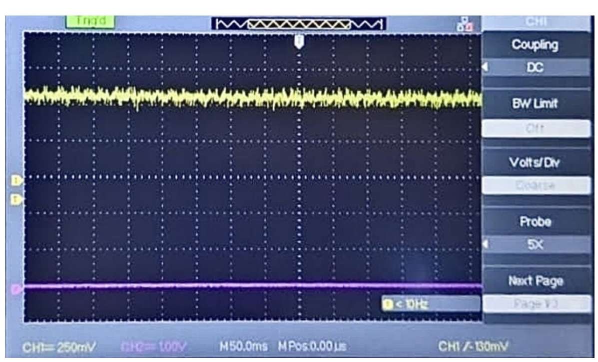

Figure6.AudioSignalwithMusic

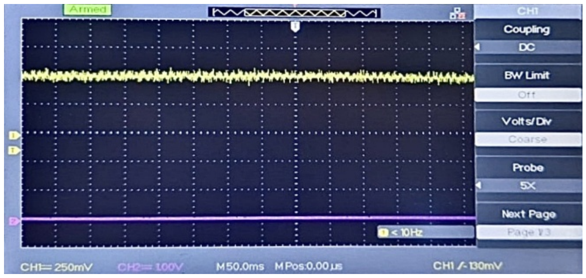
Figure7.AudioSignalwithoutMusic

The use of an amplification circuit [12] played a vital role in enhancing the received audio signal.Without amplification,thesoundoutputwasweakandbarelyaudible.However,theinclusionofanicbasedamplifier significantly [11] improved the clarity and volume of the transmitted audio, demonstrating the importance of post-processing in Li-Fi-based audio systems.

VI. CONCLUSION AND FUTURE SCOPE

The audio transmission using LiFi successfully demonstrated the feasibility of transmitting an audio signal, fromasmartphonethroughanauxcablewithapeakoutputvoltageof0.447V,whichwasthenusedtomodulateanLED.Thesolarpanel,actingasap hotodetector,capturedtheweakopticalsignal,whichwasthenamplified by the TP3110 IC to drive a 15 W speaker, reproducing the audio with minimal distortion.LiFi's directional nature ensures secure one-to-one data transfer, minimizing interference risks compared to RF-based systems. The setup highlights LiFi's potential for short-range, interference-free communication, particularly in EMI- sensitiveenvironments. Furtherimprovementsin LEDmodulationand photodetector sensitivitycouldenhance performance.This experiment validates LiFi's viability as a high-bandwidth, secure alternative for localized wireless audio and data transmission.

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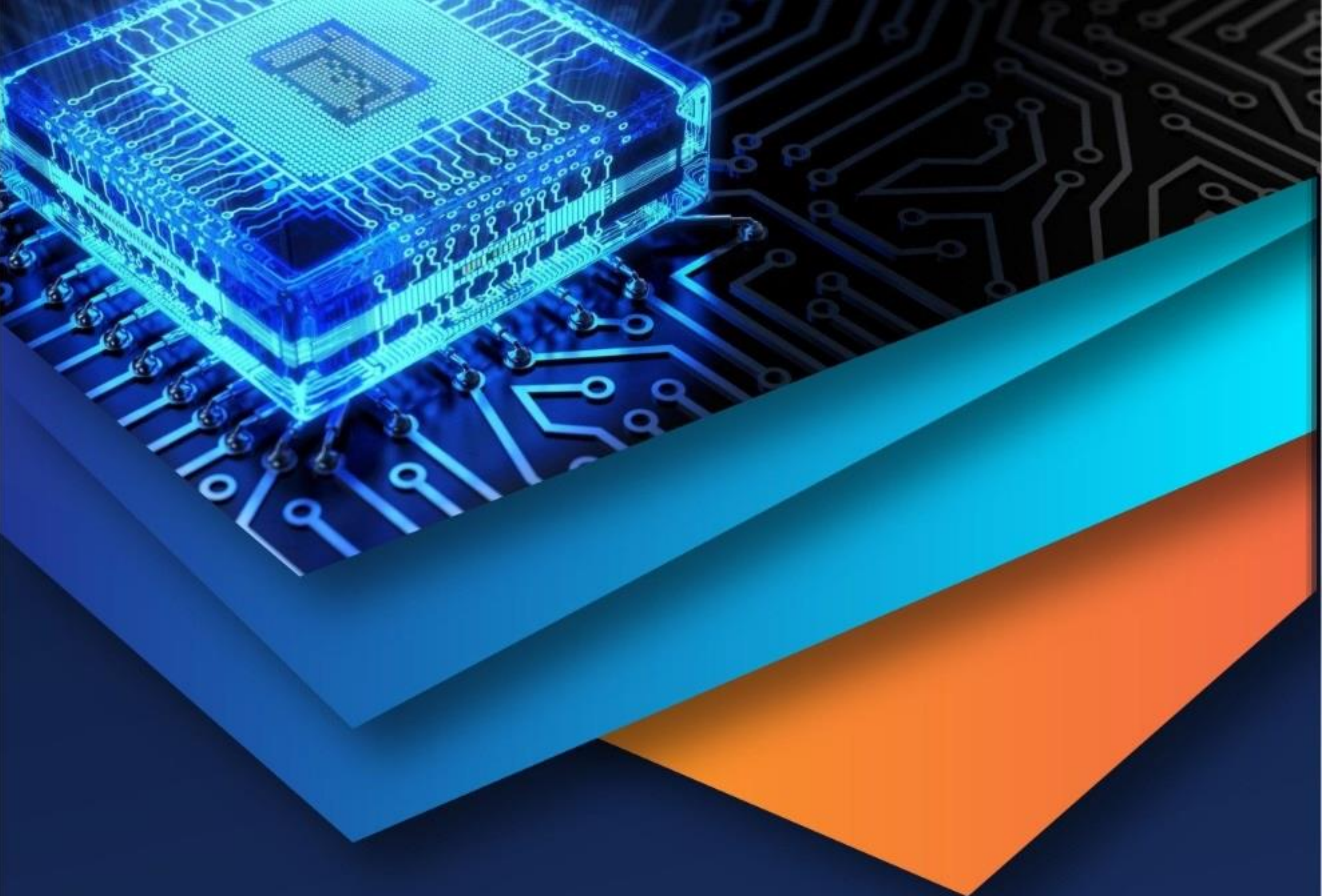

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