iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.70913

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 V May 2025- Available at www.ijraset.com

# Li-Fi Data Transfer System using ATmega 32

Neeraja Surati[1], Shantanu Neve[2], Aayush Tarjule[3], Vedaang Chaudhari[4]
*Dept. Electronics and Telecommunication, Vishwakarma Institute of Information Technology,* Pune, India

***Abstract: Light Fidelity (Li-Fi) is an emerging wireless communication technology that utilizes the visible light spectrum to enable high-speed data transfer. This research proposes a microcontroller-based Li-Fi system using the ATmega32 to demonstrate low-cost, efficient, and short-range data communication. The transmitter modulates binary data through light-emitting diodes (LEDs), while the receiver employs a photodiode for data detection and demodulation. Experimental results show successful transmission of digital information over a limited distance under controlled conditions, with observations on system limitations and performance factors. This work contributes toward the development of cost-effective, visible light-based wireless networks, suitable for specific low-range applications.***
***Keywords: Li-Fi, ATmega32, Visible Light Communication, Wireless Data Transfer, Photodiode, Microcontroller-based Communication.***

## I. INTRODUCTION

The exponential increase in wireless data traffic has necessitated the exploration of alternative communication technologies beyond conventional radio frequency (RF) systems. Light Fidelity (Li-Fi) represents a significant advancement in this domain, leveraging visible light for data transmission. Introduced by Harald Haas, Li-Fi offers advantages such as abundant bandwidth, reduced interference, and enhanced security.

This paper presents the design and implementation of a Li-Fi-based data transfer system utilizing the ATmega32 microcontroller. The objective is to build a prototype capable of transmitting serial data through an LED-photodiode pair and evaluate its performance under varying conditions.

## II. LITERATURE REVIEW

The rapid expansion of wireless communication technologies has placed a significant burden on the available radio frequency (RF) spectrum. To address this challenge, researchers have explored alternative mediums for data transmission. Light Fidelity (Li-Fi), introduced by Harald Haas in 2011, utilizes the visible light spectrum (VLC - Visible Light Communication) for wireless data transfer, offering significant advantages such as large unlicensed bandwidth, minimal interference, and improved security [1].

Several studies have investigated the theoretical and practical aspects of VLC systems. Komine and Nakagawa [2] conducted fundamental analyses on VLC systems using light-emitting diodes (LEDs) for both illumination and communication. Their work laid the foundation for understanding key parameters such as optical signal strength, modulation methods, and receiver sensitivity. They demonstrated that LEDs could be effectively modulated at high speeds without noticeable effects on illumination quality.

Further studies by Rajagopal et al. [3] explored the modulation schemes suitable for VLC systems, particularly within the IEEE 802.15.7 standard. They discussed various schemes such as On-Off Keying (OOK), Variable Pulse Position Modulation (VPPM), and Color Shift Keying (CSK), highlighting the trade-offs between complexity, robustness, and achievable data rates.

Despite the progress, challenges such as limited communication range, requirement for line-of-sight, and vulnerability to ambient light interference have been major concerns in the practical deployment of Li-Fi systems. Researchers like Zhang et al. [4] have proposed adaptive filtering techniques and dynamic gain control at the receiver side to mitigate the impact of background noise, thereby improving signal-to-noise ratios.

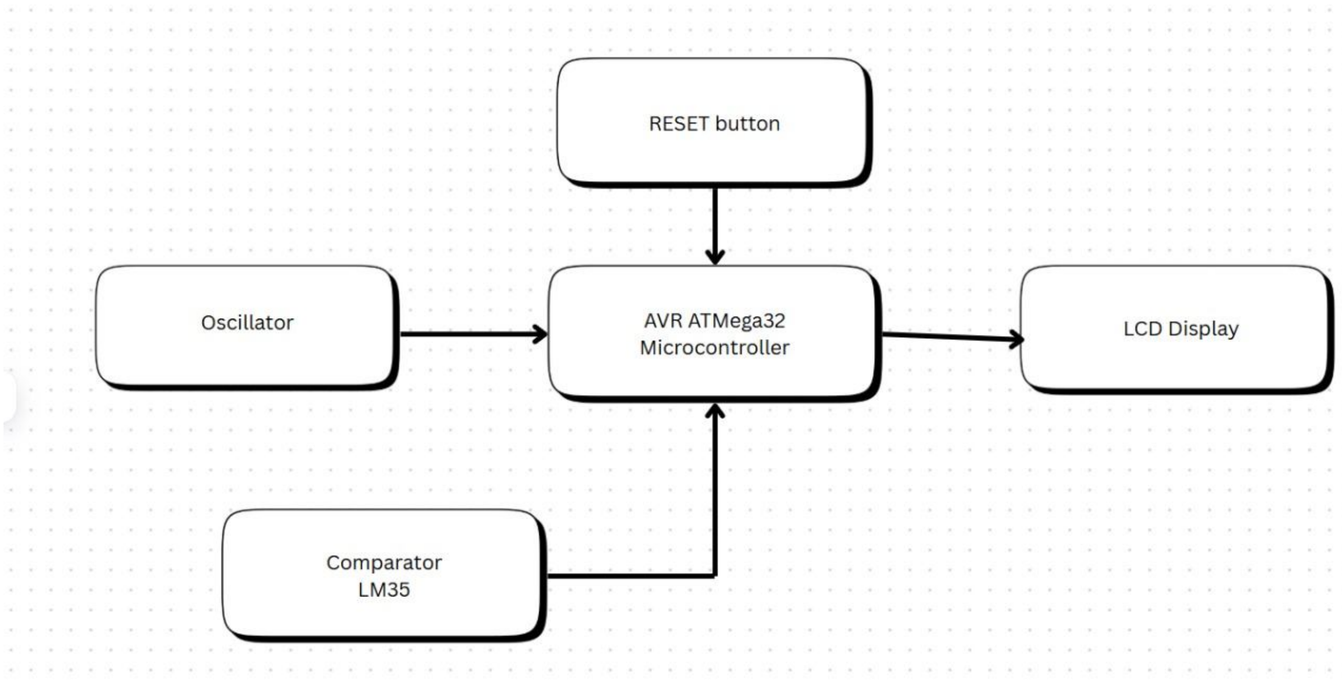
Most existing works have highlighted the importance of system parameters — LED intensity, photodiode sensitivity, ambient light mitigation, modulation depth, and microcontroller baud rates — as critical factors influencing performance.

Thus, building on the existing body of research, this study focuses on developing a cost-effective, microcontroller-based Li-Fi data transfer system using ATmega32. By adopting simple circuit designs and low-complexity modulation, the work aims to demonstrate reliable serial communication under constrained laboratory conditions, while addressing basic limitations identified in prior works.

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 V May 2025- Available at www.ijraset.com

## III. SYSTEM DESIGN AND ARCHITECTURE

### *A. Block Diagram of the System*




1.1 Block diagram

1. Transmitter:

Keyboard/Predefined data → ATmega32 (USART encoding) → LED (Light emission)

2. Receiver**:**

**Side:**

Photodiode → Signal Conditioning (Amplifier) → ATmega32 (USART decoding) → LCD Display (output)

### *B. Functional Description*

The transmitter encodes characters using UART and modulates an LED. The receiver detects variations in light intensity through a photodiode, processes it via amplification, decodes UART signals, and displays received text on an LCD module.

## IV. HARDWARE COMPONENTS

### *A. ATmega32 Microcontroller*

ATmega32 is an 8-bit AVR microcontroller featuring USART, ADC, and multiple I/O ports. It handles data encoding, light signal generation, and reception.

### *B. Light Source: LED*

High-intensity white LEDs are used for transmitting the modulated data.

.

### *C. Photodiode as Receiver*

A photodiode detects incident light and converts it into a small current proportional to light intensity, used for receiving data.

### *D. Signal Conditioning Circuit*

Operational amplifiers are used to amplify the weak current from the photodiode into readable voltage levels for the microcontroller.

.

### *E. Display Unit*

A 16x2 LCD is interfaced with ATmega32 to display received characters in real time.

## V. SOFTWARE DESIGN AND IMPLEMENTATION

### A. Programming Environment
Code was written in Embedded C using Atmel Studio. Proteus simulation was used for pre-testing.

### B. USART Data Encoding and Transmission
The ATmega32's USART module is configured for 9600 baud rate. Characters are transmitted by toggling the LED based on bit patterns.

### C. USART Reception and Data Decoding
The receiver's microcontroller detects the incoming data stream through interrupts and reconstructs characters.

### D. Error Detection Techniques
Basic start/stop bit checking is used. More sophisticated error checking (e.g., CRC) can be added in future enhancements.

## VI. CIRCUIT DESIGN
The circuit design of the Li-Fi data transfer system is divided into two major blocks:

A. *Transmitter Circuit (LED Driver Section)*

B. *Receiver Circuit (Photodiode + Signal Processing Section)*

This section focuses on the receiver-side circuit design, where a Voltage Divider and Comparator circuit are critical.

The Li-Fi data transfer system consists of two main circuits: a transmitter and a receiver. On the transmitter side, the ATmega32 microcontroller controls a high-intensity LED, modulating it through On-Off Keying (OOK) based on the digital data. A current-limiting resistor is used in series with the LED to ensure safe operation. This allows the LED to transmit digital signals as visible light.

The receiver circuit uses a photodiode to detect the transmitted light. The small photocurrent generated by the photodiode is converted into a voltage using a simple voltage divider, where a high-value resistor (typically 1 MΩ) is connected across the photodiode. This passive arrangement creates a voltage proportional to the intensity of the received light.

To convert this variable voltage into a clean digital signal, a comparator circuit based on an operational amplifier (such as LM358) is used. The comparator compares the photodiode voltage with a fixed reference voltage, which is set using a resistive divider. When the photodiode voltage exceeds the reference, the comparator outputs a logic high; otherwise, it outputs a logic low. This sharpens the analogue signal into a digital format suitable for microcontroller input.

The ATmega32 reads the comparator’s output and reconstructs the transmitted data, which is then displayed on a 16x2 LCD. Throughout the design, stable +5V regulated power is supplied to all components, and resistor values are carefully chosen to balance sensitivity with noise rejection.

## VII. WORKING PRINCIPLE
The proposed Li-Fi data transfer system utilizes visible light communication (VLC) to transmit data between two ATmega32 microcontrollers using modulated LED illumination and a photodetector-based receiver.

At the **transmitter side**, digital data input is provided to the ATmega32 microcontroller via a serial communication interface (UART). The microcontroller processes this data bitwise and modulates the LED’s state accordingly: logical '1' is represented by turning the LED ON, and logical '0' by turning the LED OFF. This technique, referred to as **On-Off Keying (OOK) modulation**, is employed due to its simplicity and suitability for low-complexity embedded systems.

The LED, driven through a current amplifier circuit (typically a transistor-based switch), emits light pulses corresponding to the data bits. The emitted optical signals propagate through free space and are incident upon the receiver.

At the **receiver side**, a photodiode or solar cell converts the received optical signal into a weak analog electrical current. This current is subsequently amplified and filtered through a signal conditioning circuit comprising a transimpedance amplifier and a low-pass filter. The conditioned signal is then fed into the input pin of the receiving ATmega32 microcontroller.

The receiver microcontroller continuously monitors the input signal. Detection of light intensity variations allows the microcontroller to reconstruct the transmitted data bitstream. Internal UART logic is utilized to reformat the incoming bits into bytes, ensuring synchronized data reception. In the presence of noise or fluctuating ambient light, thresholding techniques at the software level are employed to differentiate between legitimate signal transitions and interference.

Throughout the transmission process, synchronization between the transmitter and receiver is maintained using start and stop bits inherent to UART communication protocols. Simple error detection mechanisms, such as parity checking, are optionally incorporated to improve reliability.

This system operates effectively under direct line-of-sight conditions and is capable of achieving short-range communication with moderate data rates (typically 9600–19200 bps). The design prioritizes low hardware complexity, minimal energy consumption, and cost-effectiveness, making it suitable for educational purposes, prototype development, and demonstrating the core principles of Li-Fi technology.

## VIII. EXPERIMENTAL SETUP AND TESTING

### A. *Experimental Setup*

The experimental setup for the Li-Fi data transfer system was designed to demonstrate the successful transmission and reception of data using visible light. The system consists of two primary blocks: the transmitter and receiver.

1) *Transmitter Setup*: The transmitter circuit consists of an ATmega32 microcontroller programmed to transmit data using On-Off Keying (OOK) modulation. The microcontroller controls an LED to represent digital data, turning the LED on for a logic ‘1’ and off for a logic ‘0’. A current-limiting resistor is placed in series with the LED to prevent excessive current flow. The system operates on a regulated 5V DC supply, ensuring stable power for the microcontroller and LED. The transmitted light signal carries the modulated data, which can be detected by a receiver.
2) *Receiver Setup*: The receiver circuit consists of a photodiode placed to detect the light signals from the transmitter’s LED. The photodiode is connected to a voltage divider circuit, which converts the photocurrent into a measurable voltage. This voltage is compared with a fixed reference voltage by a comparator (LM358 op-amp), which outputs a digital signal when the photodiode voltage exceeds the reference. The digital output is then sent to the ATmega32 microcontroller, which processes the received data and displays it on a 16x2 LCD. The receiver also operates on a regulated 5V DC supply, ensuring consistent power for all components.

### B. *Testing Methodology*

#### 1) *Transmitter Testing:*

The **ATmega32 microcontroller** was programmed to transmit a simple binary data stream using OOK modulation. The transmission was started by activating the LED with a high signal (for logic '1') followed by a low signal (for logic '0').

The LED transmission was monitored using a photodiode at the receiver's end, ensuring that the light pulses corresponded to the data stream.

#### 2) *Receiver Testing*

The photodiode output was observed to ensure that the incoming light signals were being converted to a corresponding voltage level. The comparator was tested by adjusting the reference voltage to ensure that it correctly discriminated between the transmitted light signal and any ambient noise. The output from the comparator was verified using an oscilloscope to confirm that the voltage was being converted into clean digital pulses.

#### 3) *Data Integrity*

The received data was compared to the transmitted data on the LCD display to verify the accuracy of the transmission. Any errors or discrepancies were noted and analysed to determine the impact of factors such as signal strength, ambient light interference, and distance between the transmitter and receiver.

Bit error rate (BER) was measured by introducing controlled noise and analysing the number of errors in the received data. Testing was performed under different lighting conditions, including both artificial and natural light, to evaluate the system's robustness.

#### 4) *Range Testing*

The system was tested at different distances, ranging from 0.5 meters to 3 meters, to determine the effective communication range. The signal strength and data integrity were measured at each distance to identify the maximum operational range where the system could reliably transmit and receive data without significant errors.

*5) Angle of Reception*

The receiver's performance was tested by varying the angle of the photodiode with respect to the transmitter's LED. The alignment of the transmitter and receiver was adjusted, and the system's ability to receive and decode the data at different angles was evaluated.

*6) Noice and Interface Testing*

The effect of ambient light on system performance was tested by operating the system under various light conditions. Fluorescent lights, sunlight, and other artificial light sources were used to simulate real-world environments. The system's robustness to noise was evaluated by testing it in rooms with varying light levels.

## IX. RESULT AND OBSERVATION

The system successfully transmitted data with minimal error over a distance of upto **2 meters** under ideal conditions. As the distance between the transmitter and receiver increased, signal degradation occurred, leading to occasional bit errors. The performance was significantly impacted when the angle of alignment between the LED and photodiode deviated from the optimal position.

Ambient light caused minor interference, but the use of the comparator circuit effectively filtered out noise, allowing the system to function reliably under moderate light conditions. However, under strong ambient light (such as direct sunlight), the signal quality was reduced, and data errors increased.

## X. APPLICATIONS

The Li-Fi data transfer system has several promising applications, particularly in environments where radio frequency (RF) communication is limited or undesirable. It can be used for secure communication in places such as hospitals, aircraft, and data centers, where RF interference needs to be minimized. Additionally, Li-Fi can be utilized in smart homes and industrial automation for efficient data transmission, providing high-speed, low-latency communication while avoiding congestion in traditional wireless networks. Moreover, its applications extend to underwater communication and high-speed internet access in environments with challenging RF conditions.

Li-Fi also holds significant potential in education and entertainment sectors, offering a means to deliver high-speed internet in classrooms, conference rooms, and theaters without the risk of RF interference. In public transportation, such as buses and trains, Li-Fi can provide secure, high-speed internet access to passengers, enhancing the travel experience. Moreover, in smart cities, Li-Fi can be integrated with street lighting systems to enable data transmission, reducing the need for additional infrastructure and improving overall energy efficiency. Its ability to provide secure, interference-free communication in both commercial and residential environments makes it an attractive option for a wide range of industries.

## XI. CONCLUSION

The Li-Fi data transfer system using the ATmega32 microcontroller successfully demonstrates the feasibility of using visible light for data communication.

The system proved to be effective in transmitting and receiving data over short distances with minimal error, showcasing the potential of Li-Fi as a high-speed, secure alternative to traditional RF communication. Despite its limitations with distance and ambient light interference, the system's performance highlights the effectiveness of low-cost components like LEDs, photodiodes, and microcontrollers in implementing visible light communication.

## XII. FUTURE SCOPE

Future developments of the Li-Fi system can focus on improving its range and robustness against ambient light interference by incorporating more advanced modulation techniques and signal processing algorithms. Research into multi-channel Li-Fi systems could enhance data transmission rates, making the technology more suitable for high-demand applications like video streaming and real-time data transfer.

Additionally, the integration of Li-Fi with 5G and IoT technologies could pave the way for the next generation of wireless communication systems, offering a reliable and secure solution in smart cities and industrial networks.

## REFERENCES


[1] Z. T. Aldarkazaly, M. F. Younus, and Z. S. Alwan, "Transfer Data from PC to PC Based on Li-Fi Communication Using Arduino," Int. J. Adv. Sci. Eng. Inf. Technol., vol. 11, no. 2, pp. 433–439, Apr. 2021. [Online].

[2] R. Anbalagan, M. Z. Hussain, D. Jayabalakrishnan, D. B. N. Muruga, and M. Prabhahar, "Vehicle to vehicle data transfer and communication using LI-FI technology," Mater. Today: Proc., vol. 45, pp. 5925–5933, 2021. [Online].

[3] Y. Perwej, "The Next Generation of Wireless Communication Using Li-Fi (Light Fidelity) Technology," J. Comput. Netw., vol. 4, no. 1, pp. 20–29, 2017. [Online].

[4] M. U. A. Khan, M. I. Babar, S. U. Rehman, D. Komosny, and P. H. J. Chong, "Optimizing Wireless Connectivity: A Deep Neural Network-Based Handover Approach for Hybrid LiFi and WiFi Networks," Sensors, vol. 24, no. 7, p. 2021, 2024. [Online]. Available:

[5] X. Wu, M. D. Soltani, L. Zhou, M. Safari, and H. Haas, "Hybrid LiFi and WiFi Networks: A Survey," arXiv preprint arXiv:2001.04840, 2020. [Online].

[6] C. Cheng et al., "100 Gbps Indoor Access and 4.8 Gbps Outdoor Point-to-Point LiFi Transmission Systems using Laser-based Light Sources," arXiv preprint arXiv:2402.16144, 2024. [Online].

[7] H. Abumarshoud et al., "LiFi Through Reconfigurable Intelligent Surfaces: A New Frontier for 6G?," arXiv preprint arXiv:2104.02390, 2021. [Online].

[8] C. Chen et al., "NOMA for Energy-Efficient LiFi-Enabled Bidirectional IoT Communication," arXiv preprint arXiv:2005.10104, 2020. [Online].

[9] S. Paramita, A. Srivastava, V. A. Bohara, and A. Mitra, "Demo of Hybrid LiFi/WiFi Network for an Indoor Environment," in Proc. IEEE COMSNETS, 2023.

[10] P. Singh, V. A. Bohara, and A. Srivastava, "Reliable and Cost Effective All Optical Wireless Architecture for Broadband Access Network," IEEE/OSA J. Opt. Commun. Netw., 2023.

[11] A. Gupta et al., "Traffic Prediction Assisted Wavelength Allocation in Vehicle-to-Infrastructure Communication: A Fiber-Wireless Network Based Framework," Veh. Commun., 2023.

[12] G. Singh, A. Srivastava, and V. A. Bohara, "Visible Light and Reconfigurable Intelligent Surfaces for Beyond 5G V2X Communication Networks at Road Intersections," IEEE Trans. Veh. Technol., 2022.

[13] A. Singh, A. Srivastava, V. A. Bohara, and G. S. V. R. K. Rao, "Performance of Indoor Visible Light Communication System Under Random Placement of LEDs," in Proc. 21st Int. Conf. Transparent Opt. Netw. (ICTON), 2019, pp. 1–5.

[14] R. Ahmad and A. Srivastava, "Optimized User Association for Indoor Hybrid Li-Fi Wi-Fi Network," in Proc. Int. Conf. Transparent Opt. Netw. (ICTON), 2019.

[15] W. Ma and L. Zhang, "QoE-Driven Optimized Load Balancing Design for Hybrid LiFi and WiFi Networks," IEEE Commun. Lett., vol. 22, no. 11, pp. 2354–2357, 2018.

[16] V. V. Andreev, "Wireless Technologies of Information Transmission Based on the Using of Modulated Optical Radiation (Li-Fi Communication System): State and Prospects," in Proc. 2018 Systems of Signal Synchronization, Generating and Processing in Telecommunications (SYNCHROINFO), Minsk, Belarus, 2018.

[17] G. Albert et al., "Which LiFi's apps may fit mostly to 5G and beyond-5G Technology?," in Proc. 2019 Global LIFI Congress (GLC), Paris, France, 2019.

[18] S. Murawwat et al., "An Overview of LiFi: A 5G candidate Technology," in Proc. 2018 Int. Symp. Recent Advances in Electrical Engineering (RAEE), Islamabad, Pakistan, 2018.

[19] L. I. Albraheem et al., "Toward Designing a Li-Fi-Based Hierarchical IoT Architecture," IEEE Access, vol. 6, pp. 40811–40825, 2018.

[20] V. Swetha and E. Annadevi, "Survey on Light-Fidelity," in Proc. 2018 Int. Conf. Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2018, pp. 355–358

[21] C. Chen, D. Basnayaka, A. A. Purwita, X. Wu, and H. Haas, "Physical Layer Performance Evaluation of Wireless Infrared-based LiFi Uplink," arXiv preprint arXiv:1904.13163, 2019. [Online].

[22] M. D. Soltani et al., "Terabit Indoor Laser-Based Wireless Communications: LiFi 2.0 for 6G," arXiv preprint arXiv:2206.10532, 2022. [Online].

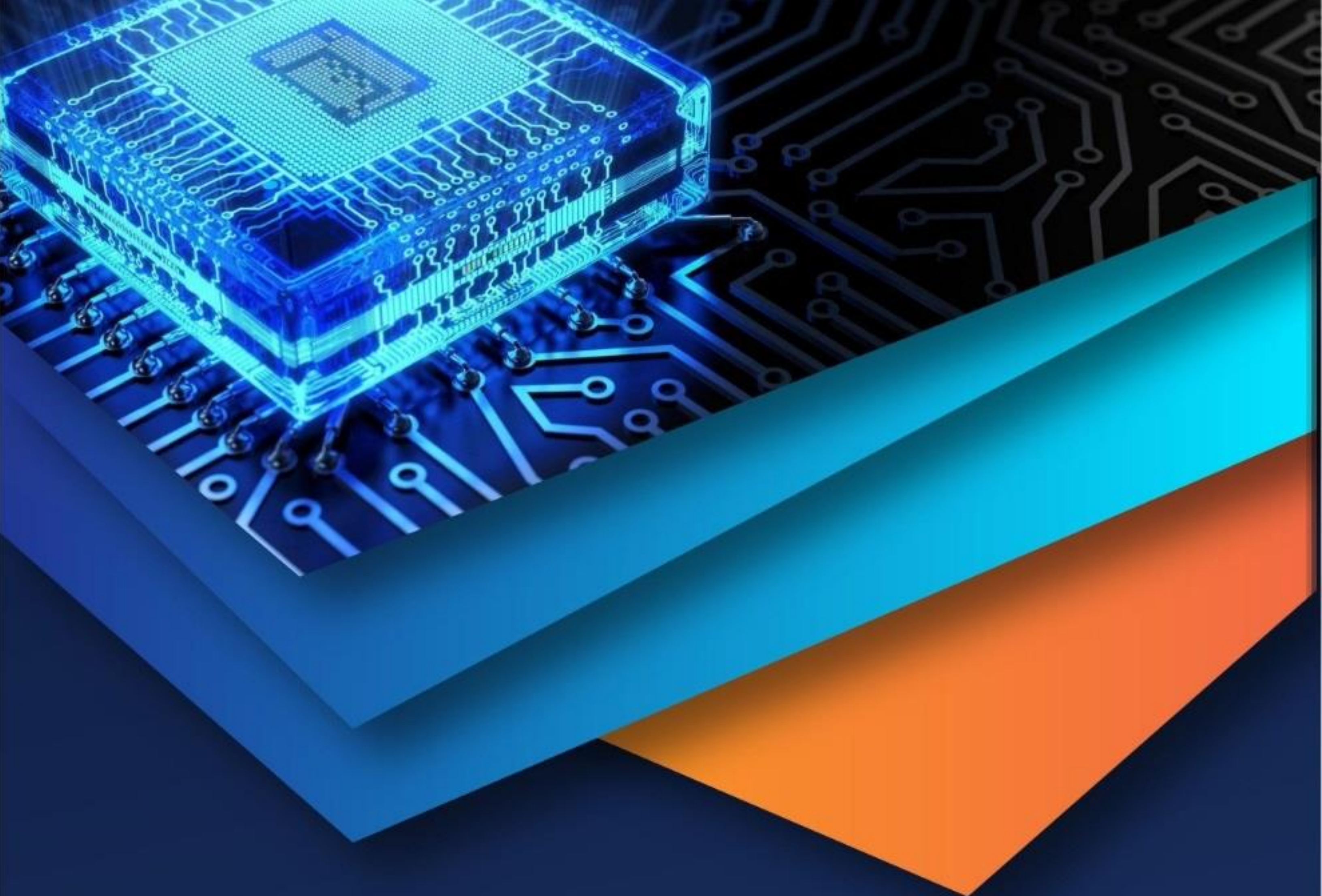
[23] M. D. Soltani, X. Wu, M. Safari, and H. Haas, "Bidirectional User Throughput Maximization Based on Feedback Reduction in LiFi Networks," arXiv preprint arXiv:1708.03324, 2017. [Online].

[24] G. Madhuri, K. Anjali, and R. S. Prabha, "Transmission of Data, Audio and Text Signal Using Li-Fi Technology," in IOP Conf. Ser.: Mater. Sci. Eng., vol. 872, no. 1, p. 012010, 2020. [Online].

[25] N. T. Surajudeen-Bakinde et al., "Li-Fi Based Technology for PC-PC Data Transmission," Int. J. Inf. Process. Commun., vol. 8, no. 1, pp. 153–162, May 2020. [Online].

[26] E. Ifada, N. T. Surajudeen-Bakinde, N. Faruk, A. Abdulkarim, A. O. Otuoze, and A. A. Oloyede, "Implementation of a Data Transmission System using Li-Fi Technology," in Proc. 2019 2nd Int. Conf. of the IEEE Nigeria Computer Chapter (NigeriaComputConf), 2019, pp. 1–6.

[27] H. H. Naser and A. H. Majeed, "Bidirectional Data Transfer via LiFi Technology," in AIP Conf. Proc., vol. 2660, no. 1, p. 020005, Nov. 2022.




10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429


# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY