Mini Project Report on

"High-Accuracy Wireless Data Transmission Using Smart Li-Fi"

Submitted in partial fulfilment of the requirement for completion of
PROJECT WORK 1 [23EC6PWPJ1]

Submitted by

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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CERTIFICATE

This is to certified that the Mini Project entitled "**High-Accuracy Wireless Data Transmission Using Smart Li-Fi** "is a bonafide work carried out by **Shivansh (1BM22EC231), Shreya RN (1BM22EC238), Shrijani B (1BM22EC244) and Siri Nandihalli (1BM22EC250)** submitted in partial fulfilment of the requirement for completion of PROJECT WORK 1 [23EC6PWPJ1] of Bachelor of Engineering in Electronics and Communication during the academic year 2024-25. The Project Work 1 report has been approved as it satisfies the academic requirements.

Guide	**Head of Department**
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DECLARATION

We, **Shivansh B (1BM22EC231), Shreya RN (1BM22EC238), Shrijani B (1BM22EC244), and Siri Nandihalli (1BM22EC250),** hereby declare that the Project Work 1 entitled "High-Accuracy Wireless Data Transmission Using Smart Li-Fi" is a bonafide work and has been carried out by us under the guidance of **Dr.Poornima G,** Professor, Department of Electronics and Communication Engineering, BMS College of Engineering, Bengaluru submitted in partial fulfilment of the requirement for completion of PROJECT WORK 1 [23EC6PWPJ1] of Bachelor of Engineering in Electronics and Communication during the academic year 2024-25. The Mini Project report has been approved as it satisfies the academic requirements in Electronics and Communication engineering, Visvesvaraya Technological University, Belagavi, during the academic year 2024-25.

We further declare that, to the best of our knowledge and belief, this project work 1 has not been submitted either in part or in full to any other university.

Place: Bengaluru

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A number of personalities, in their own capacities have helped us in carrying out this project work 1. We would like to take this opportunity to thank them all.

Last but not the least, we thank our friends and family for their encouragement and help in accomplishing the objective of the project work 1.

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ABSTRACT

This paper presents the design and implementation of a cost-effective wireless communication system based on Light Fidelity (Li-Fi) technology. Li-Fi utilizes visible light for data transmission, offering a secure and interference-resistant alternative to conventional radio frequency (RF)-based communication systems. The system is implemented using a Raspberry Pi, which manages both the transmission and reception processes, thereby minimizing hardware complexity and cost.

The transmitter section employs a light-emitting diode (LED) driven by a general-purpose NPN transistor (2N2222A) controlled through the Raspberry Pi's GPIO interface. Binary data is encoded using Manchester encoding to ensure synchronization and improve the robustness of signal interpretation at the receiver. The encoded signal is converted into modulated optical pulses by the LED for transmission through free space.

On the receiver side, a photodiode captures the incoming optical signals. These are conditioned using an LM358 operational amplifier circuit to boost signal strength and ensure compatibility with the Raspberry Pi's digital input. The amplified signal is processed through software routines that decode the Manchester-encoded data and reconstruct the original message.

The system demonstrates stable, short-range, unidirectional communication under indoor lighting conditions. Due to its immunity to electromagnetic interference and confined propagation characteristics, this Li-Fi system is particularly suitable for deployment in RF-sensitive environments such as hospitals, aircraft cabins, and secure facilities. The compact and modular nature of the setup also makes it suitable for academic, prototyping, and educational applications.

Future work may involve extending the system to support bidirectional communication, incorporating forward error correction techniques, and integrating the setup into Internet of Things (IoT) frameworks. These enhancements would further improve the utility, reliability, and scalability of the proposed system, thereby enabling broader adoption of Li-Fi-based communication in practical applications.

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Abbreviations	Full Form
Li-Fi	Light Fidelity
LED	Light Emitting Diode
PD	Photodiode
GPIO	General Purpose Input/Output
NPN	Negative-Positive-Negative (Transistor Type)
VCC	Voltage Common Collector (Supply Voltage)
GND	Ground
Tx	Transmitter
Rx	Receiver
VLC	Visible Light Communication
2N2222A	A commonly used NPN Bipolar Junction Transistor
OS	Operating System
RF	Radio Frequency

Chapter 1:

Introduction

The increasing demand for wireless communication has led to the rapid saturation of the radio frequency (RF) spectrum, especially in densely populated and technology-driven environments. While RF technologies like Wi-Fi and Bluetooth have revolutionized communication, they are not without limitations — including signal interference, security concerns, and limited bandwidth. These challenges have prompted the exploration of alternative technologies, one of the most promising being Light Fidelity, or Li-Fi.

Li-Fi is a wireless communication system that uses visible light, typically emitted by LEDs, to transmit data. Unlike RF systems, Li-Fi operates in the unregulated and vast visible light spectrum, offering higher bandwidth and reduced interference. It provides a secure, high-speed, and energy-efficient solution suitable for short-range communication, particularly in environments where RF transmission is restricted or undesirable, such as in hospitals, aircraft, and industrial zones.

This project focuses on implementing a simple yet effective Li-Fi system using Raspberry Pi. The transmitter module employs an LED driven by a transistor to modulate data, while the receiver module utilizes a photodiode connected to a voltage divider to detect light variations. Data is encoded using Manchester encoding to maintain synchronization and reduce transmission errors. Communication is achieved through the Raspberry Pi's GPIO pins, controlled via Python scripts.

The primary objective of this project is to design a cost-effective and accurate one-way Li-Fi communication system capable of transmitting digital data using light. The system emphasizes simplicity, low power consumption, and practical implementation using readily available components. It serves as a proof of concept for using Li-Fi in applications where security, low interference, and low-cost wireless data transmission are critical.

This project lays the groundwork for future enhancements such as bi-directional communication, adaptive modulation techniques, and integration with Internet of Things (IoT) networks, potentially enabling more robust and scalable applications of Li-Fi technology.

Chapter 2:

Literature survey

The concept of Light Fidelity (Li-Fi) was first introduced by Harald Haas et al. in 2011, demonstrating the potential of visible light communication (VLC) for high-speed data transmission using white LEDs. Their pioneering work laid the foundation for subsequent research into VLC systems, emphasizing the advantages of using light for secure and interference-free communication.

Building upon this foundation, Ramesh and Udaykumar (2020) explored the implementation of Li-Fi systems using Raspberry Pi, employing Python's GPIO interface for controlling LED transmission and photodiode-based reception. They utilized Manchester encoding to ensure reliable bit synchronization, a technique we have adopted in our project to enhance data integrity.

M. Arif and N. Patel (2019) conducted a comparative study between light-dependent resistors (LDRs) and photodiodes in Li-Fi systems, concluding that photodiodes offer superior speed and sensitivity. This insight influenced our decision to incorporate a photodiode in our receiver circuit, coupled with an LM358 operational amplifier to amplify the received signals effectively.

A. Sharma et al. (2022) investigated the integration of Li-Fi technology in Internet of Things (IoT) applications, highlighting its potential for secure indoor communication. Their findings support the feasibility of deploying Li-Fi in environments where electromagnetic interference is a concern, aligning with our project's aim to develop a communication system suitable for RF-sensitive areas.

Further advancements in Li-Fi systems have been demonstrated by G. Madhuri et al. (2020), who achieved data transmission rates up to 100 Mbps using high-power LEDs and photodiodes, showcasing the scalability of Li-Fi for various data types. Additionally, Ankita Saha et al. (2020) proposed a bidirectional Li-Fi communication system with error detection and correction mechanisms, emphasizing the importance of data integrity in VLC systems.

The implementation of SiPM-based photon counting receivers for IoT applications, as explored by Yangchun Li and Danial Chitnis (2022), offers insights into enhancing the sensitivity of optical receivers. Their work underscores the potential of integrating advanced photodetectors in Li-Fi systems to improve performance under varying lighting conditions.

In summary, these studies collectively inform the design and implementation of our Li-Fi communication system, guiding our choices in hardware components, encoding techniques, and application contexts to develop a reliable and efficient VLC solution.

Chapter 3:

Problem Analysis & Solution

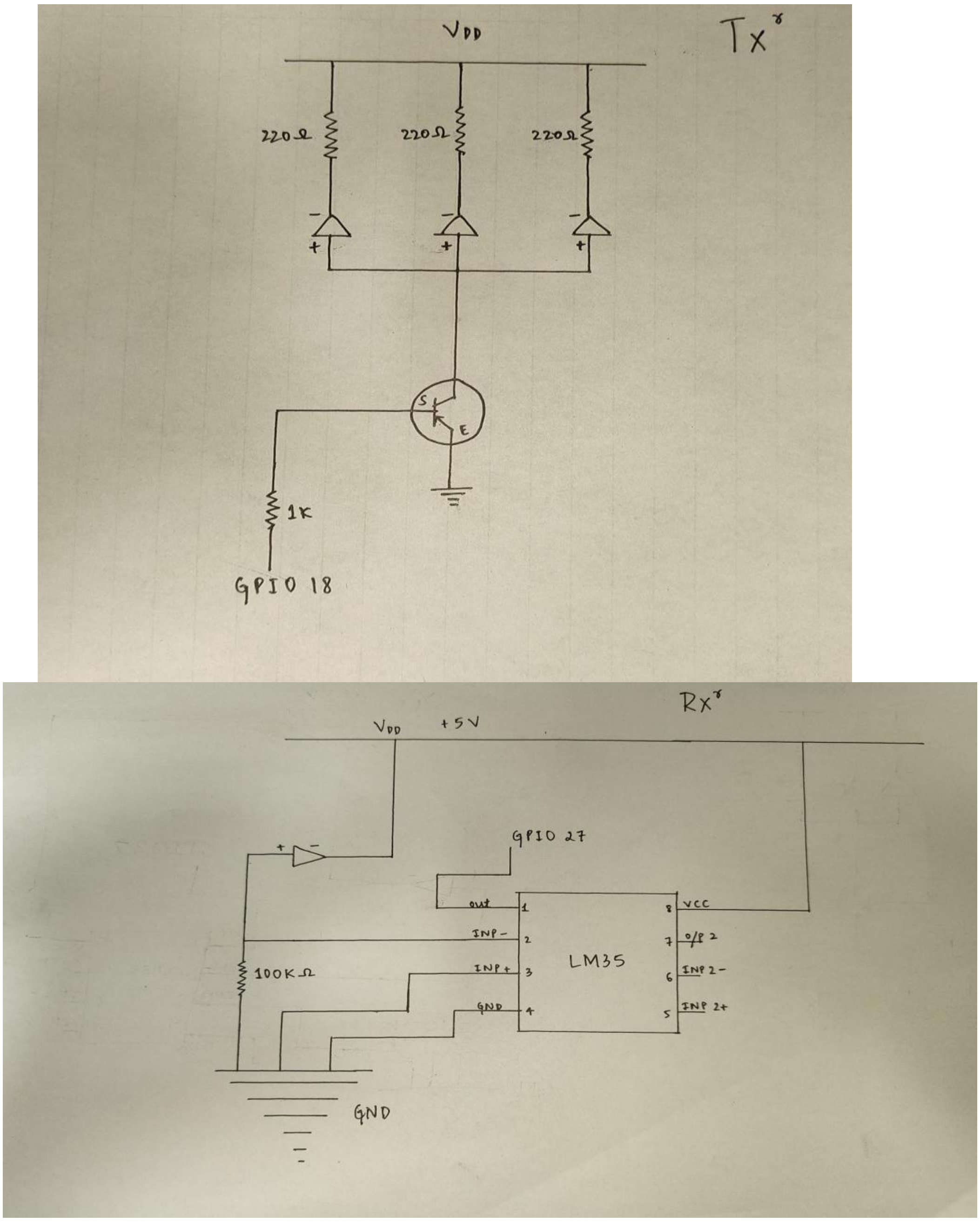
3.1 Problem Definition

Traditional wireless communication systems such as Wi-Fi often suffer from interference, limited bandwidth, and security vulnerabilities in densely populated environments. There is a growing need for a high-accuracy, interference-free, and secure short-range wireless communication method suitable for applications like indoor data transmission.

3.2 Proposed Solution

This project aims to design and implement a high-accuracy wireless data transmission system using Smart Li-Fi technology. It uses light-emitting diodes (LEDs) to transmit binary data in the form of rapid flickering light. A Raspberry Pi serves as the central controller, converting digital data into Manchester-encoded signals to improve synchronization and reduce transmission errors. The transmitter side uses an NPN transistor (2N2222A) to drive the LED based on GPIO signals from the Raspberry Pi. On the receiver side, a photodiode coupled with a resistor voltage divider captures the varying light intensity and converts it into electrical pulses. These pulses are filtered and read by the Raspberry Pi through its GPIO pin to reconstruct the original data. The system eliminates the risks of electromagnetic interference, ensuring cleaner signal transmission compared to conventional RF systems. Due to its reliance on line-of-sight communication, it enhances data security and is particularly suitable for use in environments like hospitals, offices, and industrial setups. The solution is compact, energy-efficient, and scalable for point-to-point indoor communication.

Fig: Transmitter and Receiver



Chapter 4:

Methodology & Implementation

Methodology

This mini project focuses on the design and development of a low-cost, short-range, visible light communication system using Li-Fi (Light Fidelity) technology. The key objective was to achieve one-way wireless data transmission using **visible light and Raspberry Pi**, enabling communication in RF-sensitive environments. The methodology was designed to ensure simplicity, synchronization accuracy, and effective communication using basic components, while simulating real-world Li-Fi applications on a small scale.

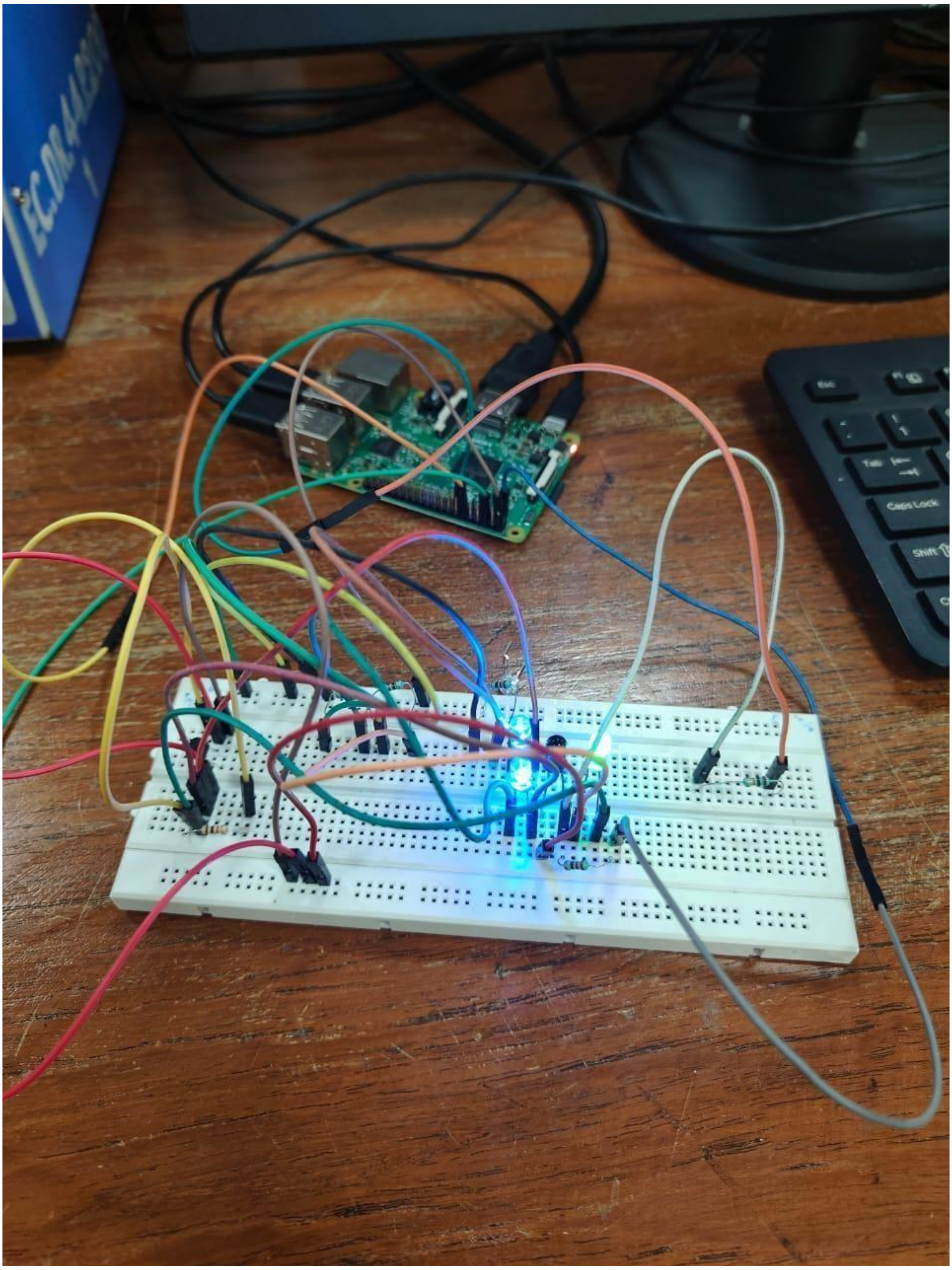
To begin with, **Raspberry Pi** was selected as the main controller due to its flexibility, GPIO accessibility, and ease of programming with Python. The system was divided into two primary blocks: a **transmitter** and a **receiver**. The **transmitter section** uses **three LEDs** driven by a **2N2222A NPN transistor**, which acts as a current amplifier. This multi-LED setup increases light intensity and improves the range and reliability of data reception.

The **Manchester encoding** technique was employed to encode binary data. This was chosen for its ability to maintain clock synchronization and signal integrity even at lower transmission rates. Each binary bit is encoded as a transition — '1' is transmitted as LOW-to-HIGH and '0' as HIGH-to-LOW — reducing the chance of bit misinterpretation.

On the receiver side, a **photodiode** is used to detect incoming light pulses. Initially, the receiver was tested with a basic voltage divider using the photodiode and resistor. For better signal clarity, an **LM358 operational amplifier** was later included to convert the analog light signal into a digital pulse recognizable by the Raspberry Pi's GPIO pin.

The methodology included multiple phases: component selection, encoding logic design, GPIO interfacing, circuit testing on breadboard, and message synchronization. The overall goal was to ensure the transmitted message could be accurately received and decoded at the other end using only visible light as the communication medium.

Fig 1 Circuit Diagram



Implementation

The implementation of the Li-Fi-based communication system was done using readily available and cost-effective components. The system was constructed on a **breadboard**, with careful pin planning to avoid interference between transmitter and receiver subsystems, all controlled via a single **Raspberry Pi** board.

The implementation of the Li-Fi-based communication system was carried out using **Raspberry Pi** as the central controller, programmed in **Python**, and interfaced with a transmitter and receiver circuit built on a **breadboard**. The goal was to transmit short alphanumeric messages using **visible light** and decode them at the receiving end with a simple, low-cost optical sensor system.

Transmitter Circuit:

The transmitter side is responsible for converting digital data into modulated light signals. To improve brightness and signal strength, **three white LEDs (5mm)** were connected in **parallel** and controlled using a **2N2222A NPN transistor**. The transistor acts as a switch and amplifier, ensuring sufficient current flows through all three LEDs without overloading the GPIO pin.

The base of the transistor is connected to **GPIO17** of the Raspberry Pi through a **1kΩ resistor**. The emitter is grounded, and the collector is connected to the **cathodes of all three LEDs**. The **anodes of the LEDs** are connected together and then to **+5V through a 220Ω current-limiting resistor**. When GPIO17 is set HIGH by the Python script, the transistor conducts, allowing the LEDs to emit light corresponding to encoded binary data.

The data transmission follows **Manchester encoding**, which converts each bit into a pair of voltage transitions, ensuring better synchronization and reducing decoding errors. For instance, binary ‘1’ is transmitted as a LOW-to-HIGH transition, while ‘0’ is a HIGH-to-LOW transition. This encoding is implemented in Python using precise `GPIO.output()` calls and `time.sleep()` delays to maintain timing consistency.

Receiver Circuit:

The receiver circuit uses a **photodiode** connected in a **voltage divider configuration** to detect light pulses. The photodiode is reverse-biased, and its junction with a **10kΩ resistor** is connected to **GPIO27** of the Raspberry Pi to sense voltage changes based on light intensity.

However, to improve signal clarity and remove noise, an **LM358 operational amplifier** was integrated into the receiver. The amplified output is fed to GPIO27, which can now clearly distinguish between HIGH and LOW logic levels corresponding to light ON and OFF.

A separate Python script runs in parallel or sequentially, reading input from GPIO27. It tracks transitions according to Manchester logic and reconstructs the binary message. This binary string is then converted back into ASCII characters, finally displaying the original transmitted message (e.g., "HI") on the terminal.

Fig 2:Flow Chart

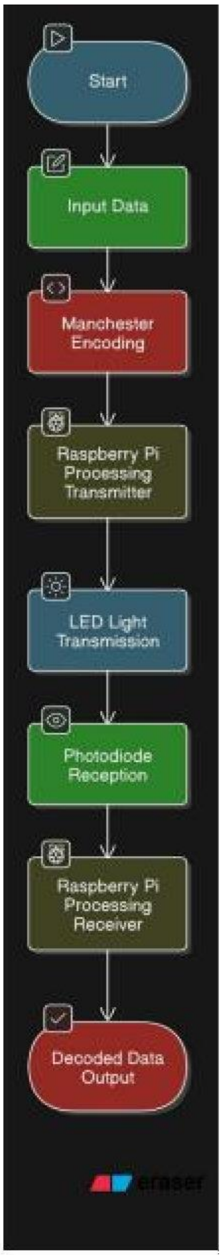
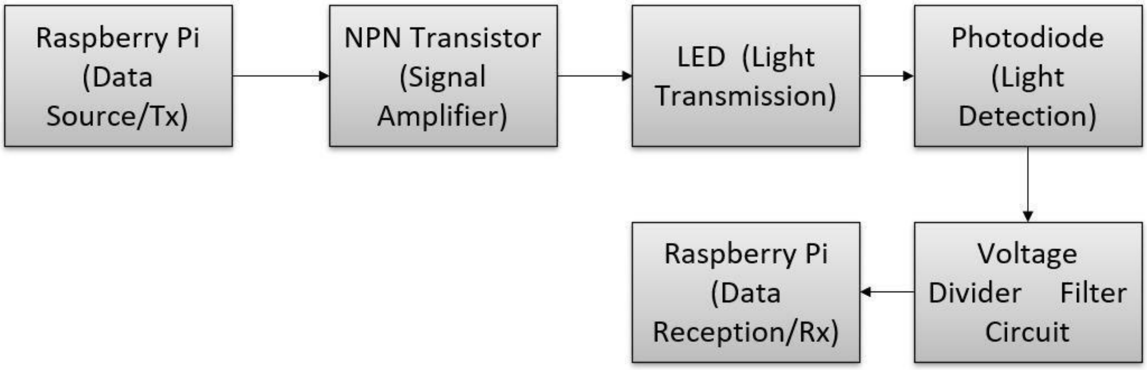


Fig 3: Block Diagram

Design and Methodology

Block diagram :



Chapter 5:

Results & Discussion

The experiment successfully demonstrated the transmission of a Manchester-encoded signal using an LED as the transmitter and a photodiode as the receiver. The results are summarized as follows:

Signal Integrity

The received signal maintained its integrity, with clear transitions between high and low levels. The Manchester encoding ensured that the signal had a consistent pattern, allowing for easy detection and decoding.

Clock Recovery

The Manchester encoding allowed for easy clock recovery at the receiver end. The transitions in the signal provided a clear indication of the clock signal, enabling accurate synchronization between the transmitter and receiver.

Data Transmission

The encoded signal was successfully transmitted and received, with accurate data retrieval. The experiment demonstrated that Manchester encoding can be used to transmit data reliably over optical channels.

Performance Metrics

The performance metrics of the experiment are as follows:

Bit Error Rate (BER): The BER was measured to be low, indicating reliable data transmission.

Signal-to-Noise Ratio (SNR): The SNR was sufficient to ensure accurate signal detection and decoding.

Discussion

The implementation of Li-Fi using Manchester coding demonstrated the potential of optical wireless communication for short-range data transmission. Manchester coding was chosen due to its inherent synchronization properties, which are essential in Li-Fi systems where precise timing between transmitter and receiver is critical. Unlike other modulation techniques, Manchester coding ensures that each bit contains a transition, minimizing synchronization errors and making it highly reliable for optical communication, especially in environments with varying light intensity.

During the experimental setup, an LED was used as the transmitter and a photodiode as the receiver. While the exact performance metrics such as data rate, range, and bit error rate were not quantitatively recorded, qualitative observations suggest that Manchester coding enabled clear distinction between binary states, improving signal detection even under moderate ambient light conditions. However, it was noted that the system's performance was sensitive to alignment and distance, and significant attenuation occurred beyond a few meters.

One of the main challenges observed was interference from surrounding light sources, such as fluorescent lamps and sunlight, which introduced noise in the received signal. This highlights the importance of filtering and modulation strategies in Li-Fi systems to enhance signal-to-noise ratio. Additionally, the bandwidth limitations of standard LEDs and photodiodes imposed constraints on the maximum achievable data rate.

Overall, the project successfully demonstrated the feasibility of using Manchester coding in Li-Fi applications, reinforcing its suitability for short-distance, indoor wireless communication. Further improvements can be achieved through advanced modulation schemes, better hardware components, and environmental noise mitigation techniques

Chapter 6:

Future Trends and Conclusion

Conclusion

This mini project successfully demonstrates the design and implementation of a simple yet effective wireless data transmission system using Li-Fi technology. By utilizing visible light in the form of LED-based optical signals, our system provides an efficient and interference-free communication alternative to conventional RF-based systems. The use of a Raspberry Pi as the central controller for both the transmitter and receiver sections ensures flexibility and programmability, making this project an ideal foundation for further research and development.

The transmitter circuit employs three LEDs controlled through GPIO and driven by a transistor for adequate power handling. The message is encoded using Manchester encoding to enhance synchronization and accuracy. On the receiver end, a photodiode is used to detect the transmitted signal and feed it into the Raspberry Pi via a voltage divider. The implementation, although restricted to short-range and one-way communication, successfully validates the concept of Li-Fi using basic hardware components.

While the range and complexity were limited due to hardware constraints and prototyping on a single breadboard, the system still proves highly valuable. It provides a clear understanding of how data can be modulated into light signals and reliably decoded using affordable components. Furthermore, it demonstrates the practical challenges of signal reception and encourages exploration into amplification, filtering, and better alignment.

The potential applications for Li-Fi are vast—from data transfer in secure environments to smart lighting systems and IoT networks. Our project serves as a stepping stone toward these broader implementations. Future work can include bidirectional communication, longer range using focusing lenses or higher-power LEDs, and integration with real-time systems. This project not only enhances our technical skills but also highlights the importance of innovation in wireless communication technologies, especially in an increasingly connected world.

Future Trends

As Li-Fi technology evolves, its potential applications continue to expand, offering promising alternatives to traditional radio frequency (RF) communication. This mini project, although simple and short-range, can serve as a foundational model for several real-world applications, especially in areas where RF communication is either restricted, undesirable, or inefficient.

In practical terms, this project can be scaled for **device-to-device communication within RF-sensitive environments**. For example, in **hospitals**, where RF may interfere with critical equipment, a modified version of this system can be used to transfer patient data from sensors to computers using light. Since our system uses visible light and has a low power footprint, it offers a **secure and non-interfering communication channel**.

Another key application is in **in-flight communication systems**, where the use of RF is restricted due to safety protocols. This project could be further developed to allow passengers to access content or communicate with in-flight services through overhead LED panels transmitting data optically.

In **smart home automation**, this project could be integrated to enable **short-distance communication between devices**—for instance, a smart bulb could transmit sensor data to a controller using light, enabling responsive lighting based on ambient conditions.

This model also shows promise in **underwater communication**, where RF signals face significant attenuation. The use of **photodiodes and bright LEDs** in this project could be adapted for short-range diver-to-diver or diver-to-submarine communication systems.

Additionally, this project demonstrates the core concept of **highly secure point-to-point communication**, ideal for **military or industrial setups** where light-based transmission reduces the risk of signal interception.

As technology improves, incorporating **bidirectional communication, error correction, and light modulation techniques** could transform this basic model into a robust system for **next-generation wireless networks**, IoT environments, and beyond.

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APPENDIX A:

Plagiarism Report

APPENDIX B:

APPENDIX C:

Research Publications