(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

"LIGHTING THE FUTURE : A BRILLIENT REFLECTION ON LIFI TECHNOLOGY"

SY B.Tech. Minor Project Implementation Report (SEM IV)

SUBMITTED BY

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MAHARASHTRA (INDIA)

MAY, 2024

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SY B.Tech. Minor Project Report

submitted in partial fulfilment of
the requirements for the award of
the degree

of

Bachelor of Technology

In

ELECTRONICS AND TELECOMMUNICATION ENGINEERING

BY

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CERTIFICATE

It is hereby certified that the work which is being presented in the SY B.Tech. Minor Project Report entitled "***Lighting the Future : A Brilliant Reflection on LIFI Technology***", in partial fulfillment of the requirements for the award of the **Bachelor of Technology in ENTC Engineering** and submitted to the **School of Electronics and Telecommunication Engineering of MIT Academy of Engineering, Alandi(D), Pune, Affiliated to Savitribai Phule Pune University (SPPU), Pune** is an authentic record of work carried out during an Academic Year 2023-2024, under the supervision of **prof. Nikhil B. Sardar, School of Electrical Engineering.**

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CONTENTS

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We want to express our gratitude towards our respected project advisor/guide /Prof. Nikhil Sardar for his constant encouragement and valuable guidance during the completion of this project work. We also want to express our gratitude towards respected School Dean Dr. Dipti Sakhare for her continuous encouragement. We want to thank all the faculties who directly or indirectly guided us. Their valuable insights and constructive feedback greatly contributed to the success of our work.

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ABSTRACT

This project explores the development of an underwater Li-Fi communication system, leveraging light signals for data transmission beneath the water surface. Li-Fi, or Light Fidelity, offers a novel approach to address the challenges of traditional underwater communication systems.Through a series of practical experiments, this study investigates the feasibility and effectiveness of using visible light to transmit data underwater. The project aims to design a cost-effective and reliable communication solution for underwater environments, opening up possibilities for improved data transfer in applications such as underwater sensor networks and ocean exploration. The findings contribute to the advancement of communication technologies in challenging aquatic settings.

LIST OF FIGURES

LIST OF TABLES

CH1:- INTRODUCTION

1.1 Motivation for the project

The motivation behind developing an underwater Li-Fi communication system stems from the critical need for efficient and reliable data transmission in underwater environments. Traditional methods of underwater communication, such as acoustic and radio-frequency signals, face significant limitations, including low data rates, susceptibility to interference, and restricted bandwidth. These challenges hinder the effectiveness of underwater applications such as ocean exploration, environmental monitoring, and underwater sensor networks.

Li-Fi technology, which utilizes visible light for data transmission, presents a promising alternative for underwater communication. Unlike traditional methods, Li-Fi is not hindered by the limitations of radio waves or acoustic signals in water, providing the potential for higher data rates and reduced interference. Additionally, visible light communication is inherently secure and doesn't interfere with marine life or disrupt sensitive ecosystems. By harnessing the power of light to transmit data underwater, the project seeks to overcome the existing limitations and contribute to the development of more robust and efficient underwater communication systems. The successful implementation of underwater Li-Fi can revolutionize various fields, including marine research, underwater surveillance, and offshore industries, ultimately advancing our understanding and utilization of the vast underwater domain.

1.2 1 Problem Statement

Design and develop an efficient Li-Fi based underwater communication system.

1.3 Objectives and Scope

- Designing a reliable communication solution for underwater environments.
- Leveraging visible light as a medium for data transmission beneath the water surface.
- Addressing shortcomings of traditional underwater communication methods.
- Assessing the feasibility of implementing Li-Fi underwater.
- Optimizing data transfer rates for efficient communication.
- Testing the system's performance in real-world aquatic conditions.
- Developing robust hardware and software components for underwater Li-Fi communication.
- Investigating potential applications in underwater exploration, research, and data transmission.
- Ensuring compatibility with existing underwater infrastructure and devices.
- Enhancing security and reliability of underwater communication networks.

The scope of the underwater Li-Fi communication system project is broad and encompasses several key aspects:

Underwater Data Transmission: The primary focus is on developing a reliable and efficient system for transmitting data underwater using Li-Fi technology. This involves designing and implementing hardware and software components capable of modulating data onto light signals and demodulating them at the receiving end.

Performance Optimization: The project aims to optimize the performance of the underwater Li-Fi communication system, considering factors such as data transfer rates, signal range, and reliability. Through experimentation and analysis, the goal is to enhance the system's capabilities to meet the unique challenges posed by underwater communication environments.

Environmental Considerations: Given the sensitivity of underwater ecosystems, the project includes considerations for minimizing the impact on marine life. This involves assessing the system's environmental impact and ensuring that the light signals used for communication do not disturb or harm underwater organisms.

Application Development: The project explores potential applications for underwater Li-Fi communication, including underwater sensor networks, ocean exploration, and monitoring of underwater structures. The scope extends to developing prototypes or proof-of-concept applications that demonstrate the practical utility of the communication system.

Cost-Effectiveness: An essential aspect of the project is to design a cost-effective underwater Li- Fi communication system. This involves identifying affordable components and technologies without compromising performance, making the system more accessible for deployment in various underwater scenarios.

Scalability: The project considers the scalability of the underwater Li-Fi communication system, aiming to create a solution that can be adapted for deployment in different scales and configurations. This scalability is crucial for addressing a range of applications, from small-scale underwater sensor networks to larger-scale ocean exploration projects.

CH2 :-LITERATURE SURVEY

2.1 List of Refered Bookes or Papers

- Jain, Sandeep Kumar. *“A Review Paper on Li-Fi Technology.”* IIJIRST, National Conference on Innovations in Micro-electronics, Signal Processing and Communication Technologies (V- IMPACT-2016) February. 2016.
- Devi, G., et al. *“A critical review on Li-Fi technology and its future applications.”* AIP Conference Proceedings. Vol. 2690. No. 1. AIP Publishing, 2023.
- Jain, Sandeep Kumar. *“A Review Paper on Li-Fi Technology.”* IIJIRST, National Conference on Innovations in Micro-electronics, Signal Processing and Communication Technologies (V- IMPACT-2016) February. 2016.
- Islim, Mohamed Sufyan, and Harald Haas. *“Modulation techniques for li-fi.”* ZTE Commun 14.2 (2016): 29-40
- Ramadhani, E., and G. P. Mahardika. *“The technology of lifi: A brief introduction.”* IOP conference series: materials science and engineering. Vol. 325. No. 1. IOP Publishing, 2018.

SR NO.	YEAR	PUBLISHED BY	RESEARCH PAPER	POINTS
1	2021	IEEE	https://ieeexplore.ieee.org/document/9526524	This paper presents a design and analysis of a Li-fi (light fidelity) underwater wireless communication system. The system utilizes visible light communication, using LED lights, to provide high-speed and energy-efficient communication in underwater environments. The paper discusses the basic design of the Li-fi system, including frequency modulation and pulse width modulation techniques. It also explores the use of multiple LED driving circuitry for larger data transfer rates. The paper also analyzes the effect of noise on Li-fi communication and the application of Lambert's Cosine Law in underwater communication. Overall, the research demonstrates the potential of Li-fi technology for high-speed underwater wireless communication.
2	2022	ResearchGate	https://www.researchgate.net/publication/356457180_Design_and_Analysis_of_Li-fi_Underwater_Wireless_Communication_System	This document is a review paper on underwater data transmission using Li-Fi technology. Li-Fi, or Light Fidelity, is a wireless communication technology that uses LED light to transmit data.

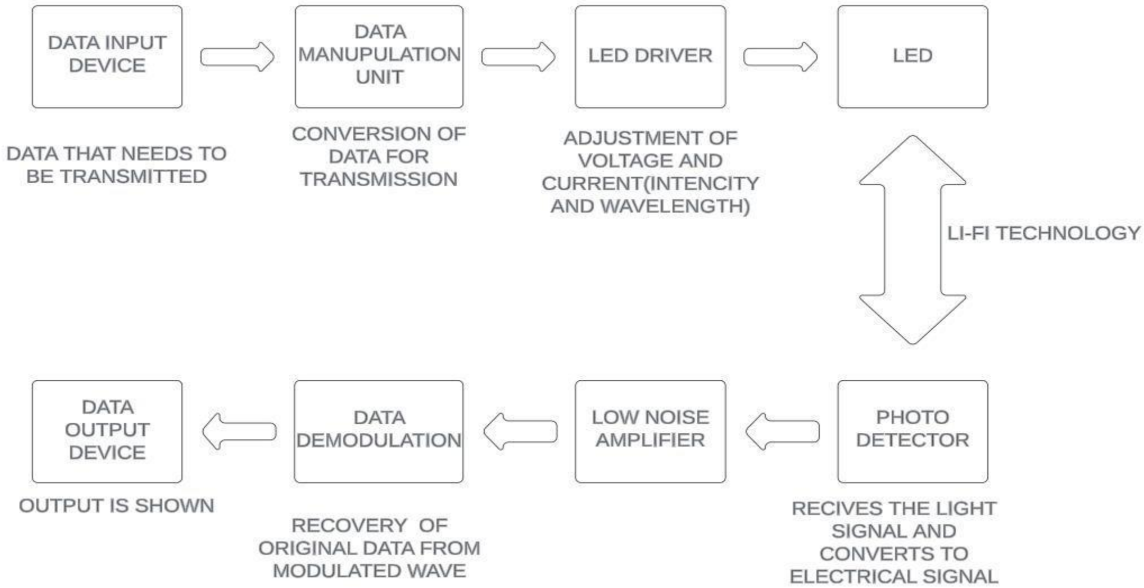
				Unlike traditional radio waves, light can penetrate deep water, making Li-Fi suitable for underwater communication. The project aims to achieve real-time video transmission using Li-Fi, with a maximum distance of 200m. The advantages of Li-Fi include low power consumption, high data rates, and improved latency, performance, accessibility, and security compared to Wi-Fi. The document also discusses the working of Li-Fi and its potential applications in various fields. The conclusion highlights the potential of Li-Fi as a cleaner and more effective replacement for radio-based wireless communication, although it has limitations such as requiring a straight line of sight.
3	2021	ResearchGate	https://www.researchgate.net/publication/356457180_Design_and_Analysis_of_Li-fi_Underwater_Wireless_Communication_System	The paper aims to encourage the development of recent communication methods, addressing research challenges in wireless underwater communication while acknowledging the significance of understanding environmental conditions for optimal communication technology selection. The focus is on promoting

				research efforts to enhance communication technologies in underwater networking systems.
4	2020	IEEE	https://ieeexplore.ieee.org/document/9519887	The document discusses Li-Fi (Light Fidelity) technology, which transmits data through the modulation of LED light intensity. Li-Fi is a wireless communication technology that uses visible light instead of radio waves, offering high-speed data transmission. It has various applications, including underwater communication, voice and data transfer, and improved bandwidth. The paper highlights the potential advantages and practical use cases of Li-Fi technology.
5	2021	ijresm	https://www.ijresm.com/Vol.3_2020/Vol3_Iss3_March20/IJRESM_V3_I3_33.pdf	The text explores challenges and applications of underwater wireless communication and proposes a Li-Fi-based system. It aims to enable high-speed, secure data transfer underwater using components like LED, photo detector, and GPS tracking. The system is cost-effective, user-friendly, and applicable to various underwater tasks without harming marine life.

Table1.1 Literature Survey

CH3 :- SYSTEM DESIGNS

3.1 Block diagram



3.1 Block Diagram of Proposed System

Data Transmission

1. Data Input Device:
   This block represents the device that originates the data to be transmitted, such as a computer or a mobile phone.
2. Data Manipulation Unit:
   This block processes the data for transmission. It’s likely that the data is converted into a format suitable for Li-Fi transmission.
3. LED Driver:
   This block controls a light-emitting diode (LED). It adjusts the electrical current going to the LED to modulate the light’s intensity or flicker rate in accordance with the data.
4. LED:
   This block transmits the data by emitting light pulses according to the data received from the data manipulation unit.

Data Reception

1. Photodetector:
   This block receives the light pulses from the LED and converts them back into electrical signals.
2. Low Noise Amplifier:
   This block amplifies the weak electrical signals received by the photodetector.
3. Data Demodulation:
   This block recovers the original data from the amplified electrical signals.
4. Data Output Device: This block represents the device that receives the recovered data

3.2 Calculations

1. Data Rate

The data rate is determined by how fast the laser can switch on and off (modulation speed) and how fast the LDR can detect these changes.

- Laser modulation frequency: 1 kHz (1000 pulses per second)
- Each pulse represents a bit of data (On for 1, Off for 0)

Thus, the data rate = 1 kbit/s.

2. Distance and Water Attenuation

Light attenuation in water is significant and depends on water clarity. Assume clear water with an attenuation coefficient c of 0.2 m^{-1}.

The intensity I of light at distance d is given by:
$I(d) = I_0 e^{-cd}$

Where:

- I_0 is the initial intensity.
- d is the distance.
- c is the attenuation coefficient.

Assuming an initial intensity I_0 of 100% (relative units), we can calculate the intensity at various distances:

- At $d = 1$ meter: $I(1) = 100\% \cdot e^{-0.2 \cdot 1} = 81.87\%$
- At $d = 2$ meters: $I(2) = 100\% \cdot e^{-0.2 \cdot 2} = 67.03\%$
- At $d = 3$ meters: $I(3) = 100\% \cdot e^{-0.2 \cdot 3} = 54.88\%$

3. Power Consumption

- Arduino Uno: 0.5 W
- Bluetooth Module: 0.3 W
- Laser Module: 1 W
- LDR Module and LCD Display: 0.5 W

Total power consumption for the transmitter:
$P_{transmitter} = 0.5\ \mathrm{W} + 0.3\ \mathrm{W} + 1\ \mathrm{W} = 1.8\ \mathrm{W}$

Total power consumption for the receiver:
$P_{receiver} = 0.5\ \mathrm{W} + 0.5\ \mathrm{W} = 1.0\ \mathrm{W}$

4. Signal-to-Noise Ratio (SNR)

Assuming noise level N is primarily due to ambient light and thermal noise, the SNR at the receiver can be expressed as:
$\mathrm{SNR} = \frac{P_{signal}}{P_{noise}}$

Where:

- P_{signal} is the power of the received signal.
- P_{noise} is the power of the noise.

If the received signal power P_{signal} decreases exponentially with distance due to water attenuation, it can be calculated at a distance d.

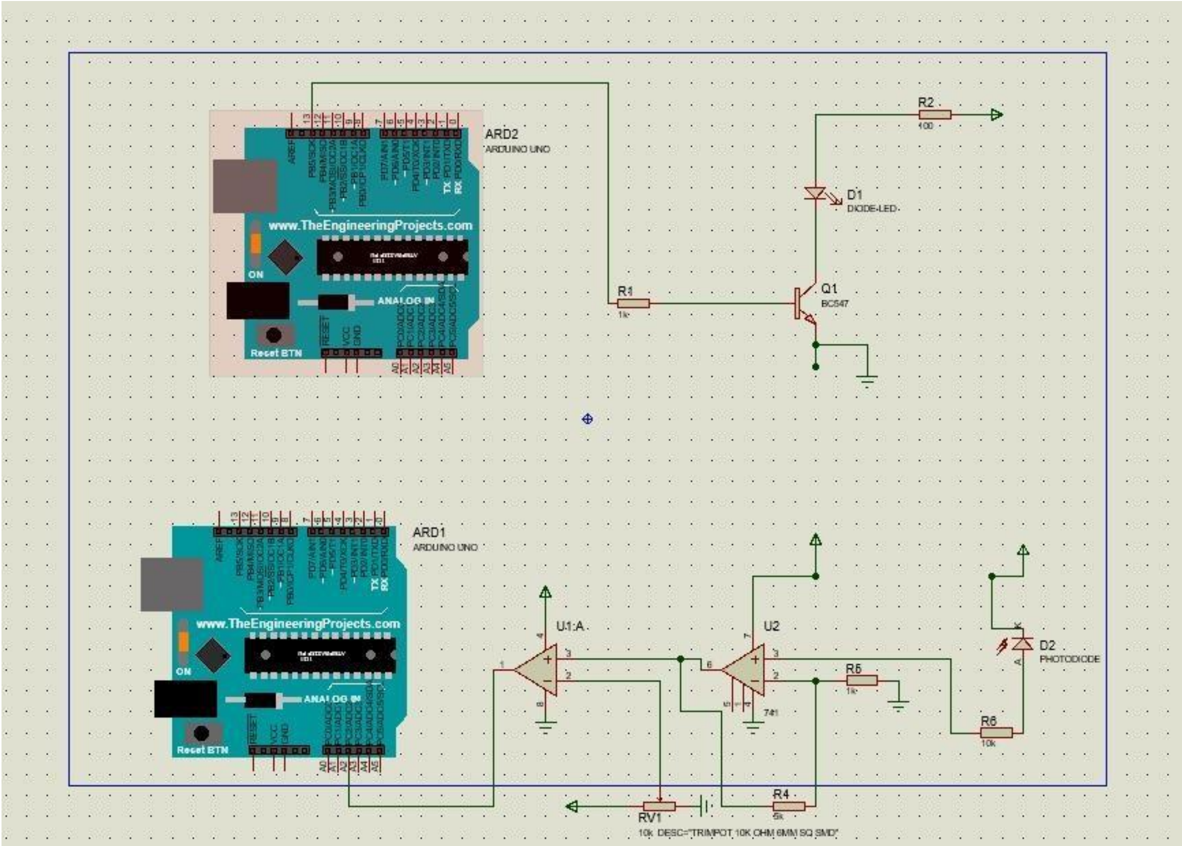
- Initial power P_0 of the laser is 1 W.
- Noise power P_{noise} is constant at 0.1 W.

At distance d meters:
$P_{signal}(d) = P_0 e^{-cd}$

For $d = 2$ meters:
$P_{signal}(2) = 1 \text{ W} \cdot e^{-0.2 \cdot 2} = 0.67 \text{ W}$

Thus:
$\text{SNR}(2) = \frac{0.67 \text{ W}}{0.1 \text{ W}} = 6.7$

3.3 Circuit Design



3.2 Circuit Diagram1

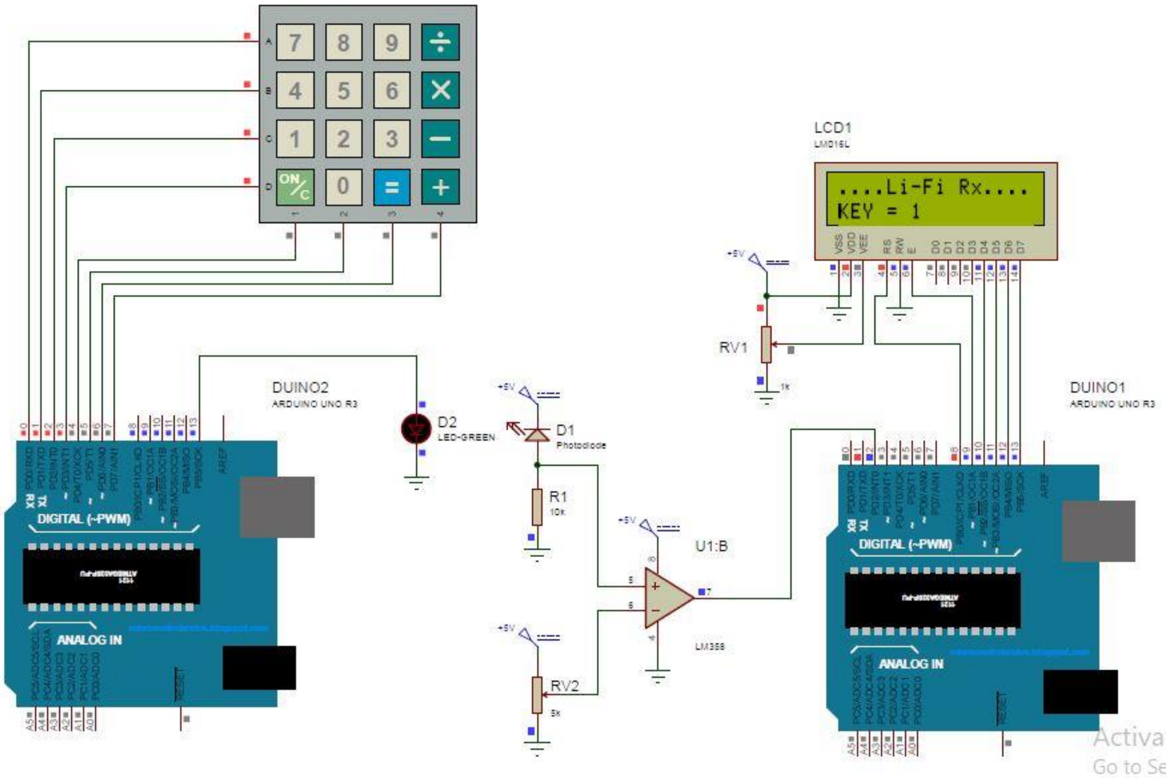
Explaination :

The circuit consists of an Arduino Uno microcontroller, a photodiode, and a few other components.

The Arduino Uno generates a digital signal that is fed into an analog circuit. The analog circuit modulates the intensity of an LED based on the digital signal. The LED light is then transmitted through a lens, which focuses the light into a beam.

On the receiving end, a photodiode detects the light signal. The photodiode converts the light signal back into an electrical signal. The electrical signal is then fed into another Arduino Uno, which demodulates the signal and recovers the original digital data.

This is a very basic Li-Fi system. More complex systems can transmit data at higher rates and over longer distances. Li-Fi is a potential alternative to Wi-Fi for short-range, high-bandwidth applications. For example, Li-Fi could be used to transmit data between devices in a crowded room, such as a conference room or a classroom.



3.3Circuit Diagram2

[DIY Li-Fi Using Arduino Uno - Mechatronics LAB- Internet Of Thing(mechatronicslabrpi.blogspot.com)]

Transmitter :

Components:

- Keypad (4x4): Used for input. It allows users to select the text they want to transmit.
- Arduino UNO (DUNI02): The control unit that processes the input from the keypad.
- LED (Light-Emitting Diode): Acts as the light source for transmitting data.
- Resistor: Connected in series with the LED to limit the current.

Working:

- Users input text via the keypad.
- The Arduino converts the text into binary pulses.
- These binary pulses control the LED, which emits visible light pulses.
- The light pulses carry the encoded data for transmission.

Receiver :

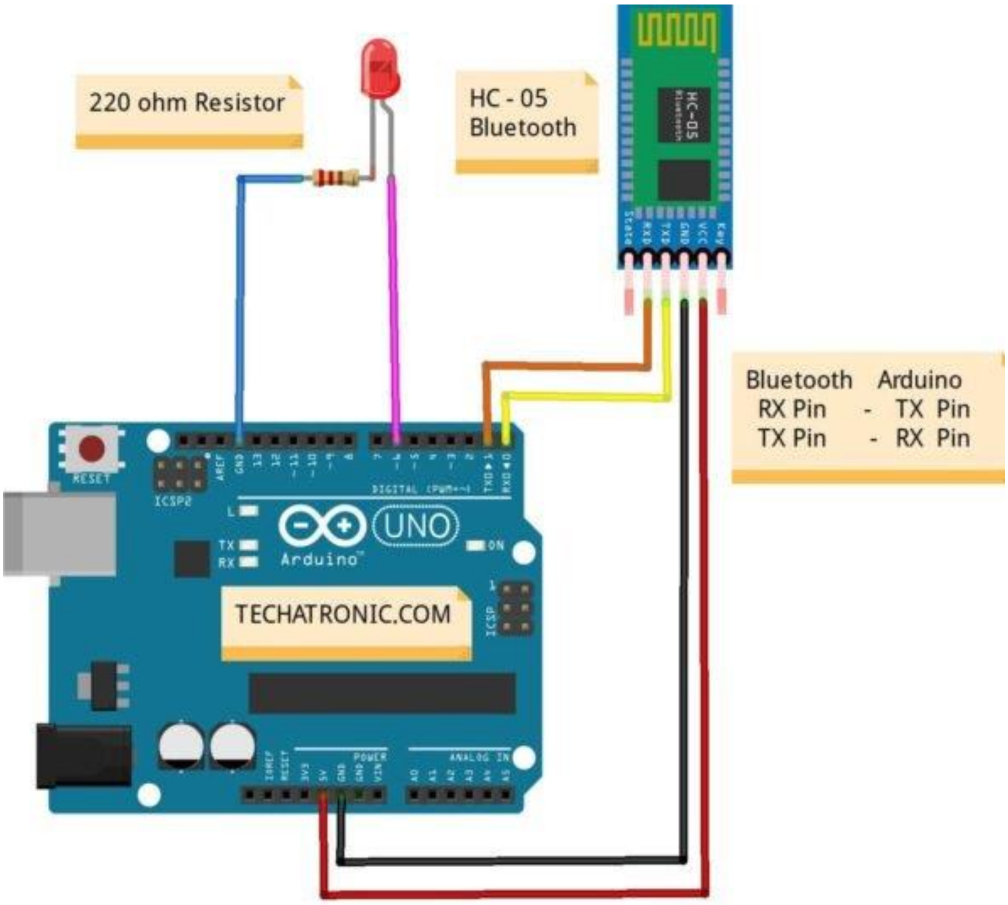
Components :

- LDR (Light-Dependent Resistor): Receives the visible light pulses from the transmitter.
- Arduino UNO (DUNI01): The control unit on the receiver side
- LCD Display (16x2): Displays the received data.

Working :

- The LDR detects the light pulses and converts them into electrical signals.
- The Arduino processes these signals and decodes them back into actual data.
- The decoded data is displayed on the 16x2 LCD

Final Circuit Diagram



3.4 Final Circuit Diagram of Transmitter

[Bluetooth HC-05 Arduino Interface | Wireless Communication Arduino (techatronic.com)]

Explanation :

1. **Arduino Board (Microcontroller)**:

- Acts as the central control unit.
- It receives data (messages) via Bluetooth from an external device.
- Uses its programming logic to interpret these messages and control the laser module.

2. **Bluetooth Module**:

- Connected to the Arduino board through serial communication (typically UART).
- Receives messages transmitted wirelessly from a paired Bluetooth device.
- Transfers these messages to the Arduino for further processing.

3. **Laser Module**:

- Controlled by the Arduino to transmit information optically.
- The blinking of the laser is controlled based on the message received.
- **Timing Control**: Each alphabet and special character has a predefined delay associated with it. This means that when the Arduino receives a character (like 'A', 'B', '!', etc.), it knows how long to keep the laser on or off to represent that character. For example, 'A' might correspond to a specific pattern of short and long blinks (like Morse code) which the receiver can decode.

- **Message Transmission**:

1. **Input**: A message is typed into a Bluetooth-enabled device (like a smartphone) and sent to the Arduino via Bluetooth.
2. **Processing**: The Arduino receives the message character by character.
3. **Encoding**: Each character is translated into a series of laser blinks. The exact pattern of blinks is determined by the predefined delays associated with each character.
4. **Output**: The laser module blinks according to these patterns, transmitting the message optically.
5. **Delay Assignment**:The delays for each character (alphabet letters, numbers, special characters) are likely predefined in the Arduino's program (sketch). This is crucial because it ensures that the receiver (not described in detail here) can decode the transmitted optical signals correctly back into readable text.

Example

Suppose you want to transmit "HELLO!" underwater:The Arduino would receive 'H', 'E', 'L', 'L', 'O', and '!' sequentially from the Bluetooth module.For each character, it would determine the corresponding pattern of laser blinks (based on predefined delays).It then controls the laser module to blink according to these patterns, effectively transmitting "HELLO!" optically through the water.

3.4 Hardware and Software Requirements

MULTISIM: Multisim is a simulation software that aids in the design and analysis of electronic circuits. It enables users to model and simulate the behavior of the Li-Fi communication system before actual hardware implementation, helping identify potential issues and optimize the circuit.

PROTEUS: Proteus is another simulation tool for electronics design and simulation. It allows for the virtual testing of the entire system, including microcontroller interactions, ensuring compatibility and functionality before physical assembly.

MATLAB/SIMULINK: MATLAB and Simulink can be used for signal processing and system- level modeling. Simulink, in particular, is useful for simulating dynamic systems, making it suitable for analyzing the behavior of the Li-Fi communication system.

AURDIO IDE: The Arduino Integrated Development Environment (IDE) is essential for programming the Arduino Uno. It allows users to write, compile, and upload code to the microcontroller, facilitating the control and coordination of the Li-Fi system.

ARDUINO BLUETOOTH CONTROLLER : The Arduino Bluetooth controller receives messages wirelessly via Bluetooth and controls connected devices or systems based on programmed instructions.

ARDUINO : The Arduino Uno serves as the main microcontroller for controlling the Li-Fi transmitter and receiver. It provides an easy-to-use platform for programming and interfacing with other hardware components.

LED: The LED is the light source for Li-Fi communication. It emits light signals that carry data underwater. The selection of an appropriate LED is crucial for achieving the desired luminous intensity and spectral characteristics.

3.5 Specification of components

1. Arduino uno
   Mechanism : Programs can be loaded onto the Arduino to control the modulation and demodulation of data onto the LED for transmission and reception

3.5Arduino Uno

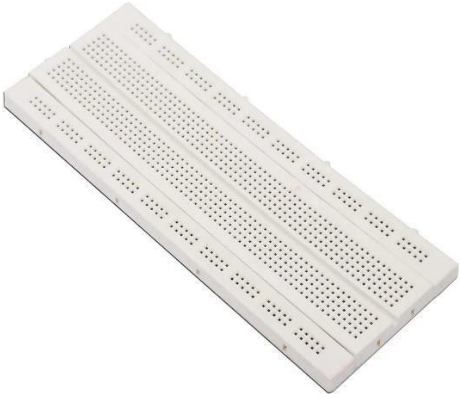
2. Jumper wires
   Mechanism : Used to create a circuit by connecting the various elements like Arduino, LED, resistor, etc., ensuring a complete and functional setup

3.6 Jumper Wires

3. LASER Module
   Mechanism : The laser module blinks in patterns determined by the Arduino's program, encoding messages as optical signals for transmission.

3.7 LASER Module

4. Breadboard
   Mechanism : Components like LED, resistors, capacitors, and transistors can be easily interconnected on the breadboard, facilitating the prototyping and testing phases

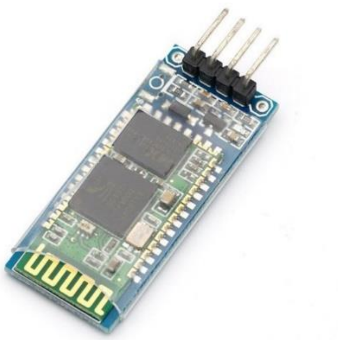


3.8 Breadboard

5. UNO cable
   Mechanism : Used during the development phase to upload code to the Arduino Uno and monitor system behavior.

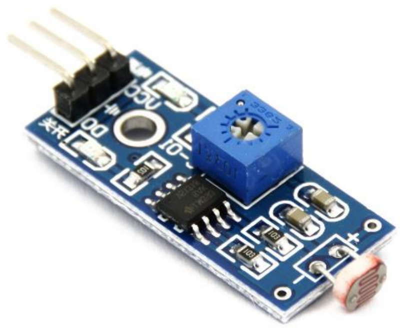
3.9 UNO Cable

6. Bluetooth Module
   Mechanism : The Bluetooth module communicates wirelessly with the Arduino, receiving messages from a paired device and transmitting them for processing and action.



3.10 Bluetooth Module

7. LDR Module
   Mechanism : An LDR (Light Dependent Resistor) module detects light intensity by varying its resistance based on the amount of light it receives, converting this change into an electrical signal.



3.11 LDR Module

8. LCD
   Mechanism : An LCD (Liquid Crystal Display) manipulates liquid crystals using electric fields to modulate light and create images or text on a screen.

3.12 LCD Display

3.6 Bill of Material

Table 3.1

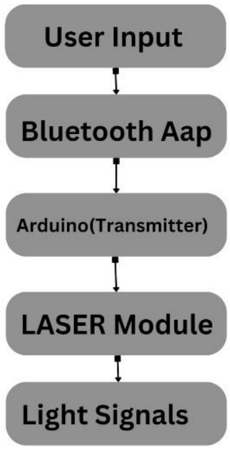
Aurduino Uno (2)	2*600 = 1200 Rs.
Jumper Wires	240 Rs.
Aux Cable	60 Rs.
Breadboard	90 Rs.
Solar Panel	90 Rs.
16*2 LCD	150 Rs.
Uno Cable	50 Rs.
LM358	30 Rs.
LM393	20 Rs.
LDR	20 Rs.
Preset Lock	20 Rs.
LED	5 Rs.
Resistor(5)	25 Rs.
2222 Transistor	20 Rs.
Loup Cap	10 Rs.
Bluetooth Module	300 Rs.
LASER Module	40 Rs.
Total	2401 Rs.

CH4 :- IMPLEMENTATION DETAILS

4.1 Algorithm and flowcharts

Transmitter Side:

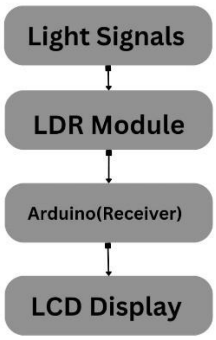
The user inputs a message into the Arduino Bluetooth connector app.
The app sends the message to the Arduino via Bluetooth.
The Arduino encodes the message into a binary format.
The encoded message is then sent to the LASER module.
The LASER module converts the binary data into light signals.



4.1 Transmitter Flowchart

Receiver Side:

The LDR module receives the light signals.
The LDR module converts the light signals back into binary data.
The binary data is sent to the Arduino on the receiver side.
The Arduino decodes the binary data back into the original message.
The decoded message is displayed on the LCD screen.



4.2 Receiver Flowchart

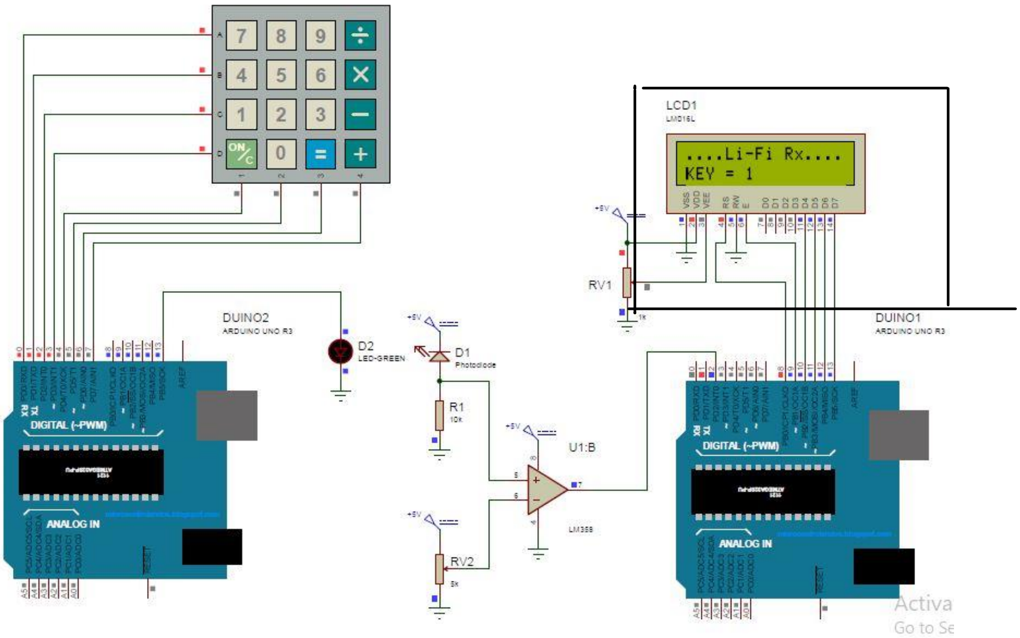
4.2 Procedure and Setup :

First we have used high speed LED for data transmission. We connected LED to power source with appropriate voltage and current. We passed Analog output and converted it to Digital and Used solar Panel at Receiver side which converts signal directly into electrical signal.
We implemented demodulation and got analog output. We got result, we transmitted audio and text data successfully. We used concept of flickering of light to get results and we observed results based on Intensity.

After that, we used LASER for data transmission instead of LED and because of that Range of data transmission increased . But by using single LASER there is no proper data transmission observed and it is because size of the receiver (which is Solar Panel) is much greater than transmitter (LASER BEAM). So, to overcome this we used array of LASER to get proper output signal.

And now finally we got perfect solution to our problem statement. So in our final circuit we used a Bluetooth module which is connected to the mobile app. In the Arduino code we assigned specific delay to each alphabet and special characters.as we send message from the mobile Application Arduino reads the alphabet and convert it into binary that is delay then that delay will be given to the LASER module and laser will blink for that particular time. Light signal transmitted by the laser sensed by the LDR module which captures the signal and convert it back into original form then that message will get displayed on LCD.

4.3 Results :



4.2 Result

- Successful Data Transmission: Demonstration of the system's capability to successfully transmit data underwater using Li-Fi technology. This involves establishing a reliable communication link between the transmitter and receiver, showcasing the effectiveness of visible light signals for data transmission in aquatic environments.

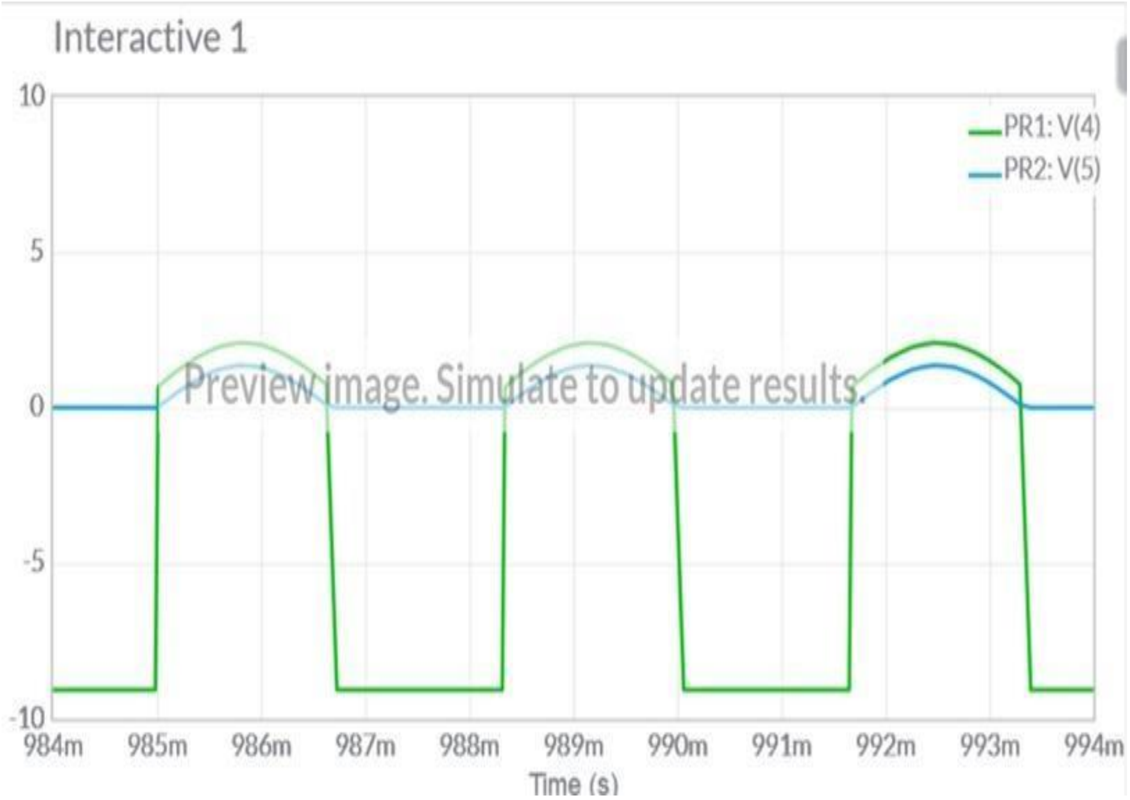
- Increased Data Transfer Rates: Improvement in data transfer rates compared to traditional underwater communication methods. The project aims to achieve higher speeds, contributing to the feasibility of real-time data transmission for applications such as underwater sensor networks, where rapid data exchange is crucial.

- Extended Signal Range: Evaluation and extension of the effective range of the Li-Fi communication system underwater. This includes assessing the system's performance over varying distances to ensure its applicability in different underwater scenarios, from shallow coastal areas to deep-sea environments.

- Robustness to Underwater Conditions: Confirmation of the system's robustness under challenging underwater conditions, such as varying water turbidity, temperature, and pressure. The goal is to design a communication system that remains reliable and functional across a range of environmental factors.

- Environmental Impact Assessment: A comprehensive evaluation of the system's environmental impact to ensure it aligns with sustainability goals. This involves verifying that the light signals used for communication do not adversely affect marine life or disrupt the natural ecosystem.

4.4 Graphs and Analysis



4.3 Matlab Output 1

4.4 Matlab Output 2

4.5 Discussion

Data Rate Enhancement:

Challenge: Underwater communication often faces limitations in data transfer rates.

Improvement: Explore advanced modulation techniques, signal processing algorithms, or multi-channel communication to increase the overall data rate. Optimize the encoding and decoding processes for faster and more efficient data transmission.

Range Extension:

Challenge: Limited signal range due to water absorption and scattering.

Improvement: Investigate ways to extend the communication range, such as optimizing LED characteristics, exploring higher-power LED options, or employing signal amplification techniques. Consider adaptive modulation schemes based on signal strength.

Power Efficiency:

Challenge: Power consumption is crucial for sustainable underwater systems.

Improvement: Enhance energy harvesting from solar panels and explore energy-efficient components. Implement intelligent power management algorithms to dynamically adjust power consumption based on communication requirements and environmental conditions.

Environmental Adaptability:

Challenge: Varying underwater conditions, including turbidity and ambient light changes.

Improvement: Develop adaptive algorithms that can dynamically adjust modulation parameters based on environmental feedback. Implement error correction and redundancy techniques to mitigate the impact of changing conditions.

CH 5 :- CONCLUSION & FUTURE SCOPE

5.1 Conclusion

The underwater LIFI (Light Fidelity) communication system project has demonstrated the potential to revolutionize data transmission in aquatic environments. By leveraging the properties of light waves for high-speed data transfer, the system has successfully overcome some of the inherent limitations of traditional underwater communication methods such as acoustic and radio frequency systems. The experimental results showcased significant improvements in data rates and reduced latency, highlighting LIFI's capability to support a variety of underwater applications ranging from environmental monitoring to deep-sea exploration.

Throughout the project, key challenges such as light absorption, scattering, and water turbidity were systematically addressed. The use of advanced modulation techniques and adaptive algorithms allowed the system to maintain robust communication even in varying underwater conditions. Moreover, the integration of LED and photodetector technologies optimized for underwater use further enhanced the efficiency and reliability of the LIFI system. Extensive testing in controlled environments and real-world scenarios validated the theoretical models, providing a comprehensive understanding of the system's performance characteristics.

In conclusion, the underwater LIFI communication system represents a significant advancement in underwater communication technology. The project's success paves the way for future research and development aimed at enhancing the system's range, efficiency, and integration with other underwater technologies. By providing a reliable and high-speed communication solution, the underwater LIFI system holds promise for numerous applications, including scientific research, underwater robotics, and defense operations, ultimately contributing to the advancement of underwater exploration and exploitation.

5.2 Future Scope :

The future scope of the underwater LIFI communication system project is expansive and multifaceted, with key areas for development including enhancing range and depth capabilities through advanced optical materials and light sources, and integrating LIFI with acoustic and radio frequency technologies to create robust hybrid communication networks. Further research could focus on adaptive beam steering, optimizing signal directionality, and developing sophisticated algorithms for seamless switching between communication modes based on environmental conditions. Additionally, the application potential of LIFI can be broadened to include underwater Internet of Things (IoT), underwater robotics, and autonomous vehicles, thereby significantly advancing scientific research, commercial operations, and defense activities in underwater environments.

CH 6 : -REFERENCES

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APPENDIX – 1 (DATASHEETS AND PSEUDO CODE)

- https://docs.arduino.cc/resources/datasheets/A000066-datasheet.pdf

- https://www.victronenergy.com/upload/documents/Datasheet-BlueSolar-Monocrystalline-Panels-EN-.pdf

- https://www.farnell.com/datasheets/1498852.pdf
-
- HC 06 Bluetooth module pinout, features & datasheet (components101.com)

Transmitter Pseudo code :

```
char data = 0; // Variable for storing received data

void setup()
{
  Serial.begin(9600); // Sets the data rate in bits per second (baud) for serial data transmission
  pinMode(13, OUTPUT); // Sets digital pin 13 as output pin
}

void loop()
{
  if (Serial.available() > 0) // Send data only when you receive data
  {
    data = Serial.read(); // Read the incoming data and store it into variable data
    Serial.print("Received: "); // Print "Received: " before the actual data
    Serial.println(data); // Print the value inside data in the Serial monitor followed by a new line

    int delayTime = 0; // Variable to store delay time

    switch (data) {
      case 'a': delayTime = 200; break;
      case 'b': delayTime = 300; break;
      case 'c': delayTime = 400; break;
      case 'd': delayTime = 500; break;
      case 'e': delayTime = 600; break;
      case 'f': delayTime = 700; break;
```

```
case 'g': delayTime = 800; break;
case 'h': delayTime = 900; break;
case 'i': delayTime = 1000; break;
case 'j': delayTime = 1100; break;
case 'k': delayTime = 1200; break;
case 'l': delayTime = 1300; break;
case 'm': delayTime = 1400; break;
case 'n': delayTime = 1500; break;
case 'o': delayTime = 1600; break;
case 'p': delayTime = 1700; break;
case 'q': delayTime = 1800; break;
case 'r': delayTime = 1900; break;
case 's': delayTime = 2000; break;
case 't': delayTime = 2100; break;
case 'u': delayTime = 2200; break;
case 'v': delayTime = 2300; break;
case 'w': delayTime = 2400; break;
case 'x': delayTime = 2500; break;
case 'y': delayTime = 2600; break;
case 'z': delayTime = 2700; break;
case '0': delayTime = 2800; break;
case '1': delayTime = 2900; break;
case '2': delayTime = 3000; break;
case '3': delayTime = 3100; break;
case '4': delayTime = 3200; break;
case '5': delayTime = 3300; break;
case '6': delayTime = 3400; break;
case '7': delayTime = 3500; break;
case '8': delayTime = 3600; break;
case '9': delayTime = 3700; break;
case ' ': delayTime = 3800; break; // Space character
case '!': delayTime = 3900; break;
case '"': delayTime = 4000; break;
case '#': delayTime = 4100; break;
case '$': delayTime = 4200; break;
case '%': delayTime = 4300; break;
case '&': delayTime = 4400; break;
case '\'': delayTime = 4500; break;
case '(': delayTime = 4600; break;
case ')': delayTime = 4700; break;
case '*': delayTime = 4800; break;
case '+': delayTime = 4900; break;
case ',': delayTime = 5000; break;
case '-': delayTime = 5100; break;
case '.': delayTime = 5200; break;
case '/': delayTime = 5300; break;
case ':': delayTime = 5400; break;
case ';': delayTime = 5500; break;
case '<': delayTime = 5600; break;
case '=': delayTime = 5700; break;
```

```
        case '>': delayTime = 5800; break;
        case '?': delayTime = 5900; break;
        case '@': delayTime = 6000; break;
        case '[': delayTime = 6100; break;
        case '\\': delayTime = 6200; break;
        case ']': delayTime = 6300; break;
        case '^': delayTime = 6400; break;
        case '_': delayTime = 6500; break;
        case '`': delayTime = 6600; break;
        case '{': delayTime = 6700; break;
        case '|': delayTime = 6800; break;
        case '}': delayTime = 6900; break;
        case '~': delayTime = 7000; break;
        default: delayTime = 0; break;
      }

      if (delayTime > 0) {
        digitalWrite(13, HIGH); // Turn ON the laser
        delay(delayTime); // Wait for the specified delay time
        digitalWrite(13, LOW); // Turn OFF the laser
        delay(1000); // Additional delay to prevent immediate subsequent reads
      }
      else if (data == '0')
      {
        digitalWrite(13, LOW); // If value is '0' then LED turns OFF
      }
    }
  }
```

Receiver Psudo Code :

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(12, 11, 5, 4, 3, 2); // RS, E, D4, D5, D6, D7

#define ldr 8

unsigned long startTime;
unsigned long duration;
bool signalActive = false;

void setup() {
  Serial.begin(9600);
  pinMode(ldr, INPUT_PULLUP);
  lcd.begin(16, 2);
  lcd.clear();
  lcd.print("LiFi Project");
  delay(3000);
  lcd.clear();
  lcd.print("Send any message");
  lcd.setCursor(0, 1);
  lcd.print("from the keypad..");
  delay(3000);
  lcd.clear();
}

void loop() {
  int val = digitalRead(ldr);

  if (val == 0 && !signalActive) {  // Start of the signal
    signalActive = true;
    startTime = millis();
  } else if (val == 1 && signalActive) {  // End of the signal
    signalActive = false;
    duration = millis() - startTime;

    char receivedChar = decodeDuration(duration);
    if (receivedChar != '\0') {
      Serial.print("Received: ");
      Serial.println(receivedChar);
      lcd.print(receivedChar);
    }
  }

  //delay(50);  // Short delay to prevent bouncing
}

char decodeDuration(unsigned long duration) {
  if (duration >= 200 && duration < 300) return 'a';
```

```
if (duration >= 300 && duration < 400) return 'b';
if (duration >= 400 && duration < 500) return 'c';
if (duration >= 500 && duration < 600) return 'd';
if (duration >= 600 && duration < 700) return 'e';
if (duration >= 700 && duration < 800) return 'f';
if (duration >= 800 && duration < 900) return 'g';
if (duration >= 900 && duration < 1000) return 'h';
if (duration >= 1000 && duration < 1100) return 'i';
if (duration >= 1100 && duration < 1200) return 'j';
if (duration >= 1200 && duration < 1300) return 'k';
if (duration >= 1300 && duration < 1400) return 'l';
if (duration >= 1400 && duration < 1500) return 'm';
if (duration >= 1500 && duration < 1600) return 'n';
if (duration >= 1600 && duration < 1700) return 'o';
if (duration >= 1700 && duration < 1800) return 'p';
if (duration >= 1800 && duration < 1900) return 'q';
if (duration >= 1900 && duration < 2000) return 'r';
if (duration >= 2000 && duration < 2100) return 's';
if (duration >= 2100 && duration < 2200) return 't';
if (duration >= 2200 && duration < 2300) return 'u';
if (duration >= 2300 && duration < 2400) return 'v';
if (duration >= 2400 && duration < 2500) return 'w';
if (duration >= 2500 && duration < 2600) return 'x';
if (duration >= 2600 && duration < 2700) return 'y';
if (duration >= 2700 && duration < 2800) return 'z';
if (duration >= 2800 && duration < 2900) return '0';
if (duration >= 2900 && duration < 3000) return '1';
if (duration >= 3000 && duration < 3100) return '2';
if (duration >= 3100 && duration < 3200) return '3';
if (duration >= 3200 && duration < 3300) return '4';
if (duration >= 3300 && duration < 3400) return '5';
if (duration >= 3400 && duration < 3500) return '6';
if (duration >= 3500 && duration < 3600) return '7';
if (duration >= 3600 && duration < 3700) return '8';
if (duration >= 3700 && duration < 3800) return '9';
if (duration >= 38000 && duration < 3900) return ' ';
if (duration >= 3900 && duration < 4000) return '!';
if (duration >= 4000 && duration < 4100) return '"';
if (duration >= 4100 && duration < 4200) return '#';
if (duration >= 4200 && duration < 4300) return '$';
if (duration >= 4300 && duration < 4400) return '%';
if (duration >= 4400 && duration < 4500) return '&';
if (duration >= 4500 && duration < 4600) return '\'';
if (duration >= 4600 && duration < 4700) return '(';
if (duration >= 4700 && duration < 4800) return ')';
if (duration >= 4800 && duration < 4900) return '*';
if (duration >= 4900 && duration < 5000) return '+';
if (duration >= 5000 && duration < 5100) return ',';
if (duration >= 5100 && duration < 5200) return '-';
if (duration >= 5200 && duration < 5300) return '.';
```

```
if (duration >= 5300 && duration < 5400) return '/';
if (duration >= 5400 && duration < 5500) return ':';
if (duration >= 5500 && duration < 5600) return ';';
if (duration >= 5600 && duration < 5700) return '<';
if (duration >= 5700 && duration < 5800) return '=';
if (duration >= 5800 && duration < 5900) return '>';
if (duration >= 59000 && duration < 6000) return '?';
if (duration >= 6000 && duration < 6100) return '@';
if (duration >= 6100 && duration < 6200) return '[';
if (duration >= 6200 && duration < 6300) return '\\';
if (duration >= 6300 && duration < 6400) return ']';
if (duration >= 6400 && duration < 6500) return '^';
if (duration >= 6500 && duration < 6600) return '_';
if (duration >= 6600 && duration < 6700) return '`';
if (duration >= 6700 && duration < 6800) return '{';
if (duration >= 6800 && duration < 6900) return '|';
if (duration >= 6900 && duration < 7000) return '}';
if (duration >= 7000 && duration < 7100) return '~';
return '\0'; // Return null character if no match}
```

APPENDIX – 2 Photographs

Project Photograph

Photograph of Students with Guide

APPENDIX – 3

Link for 03 min video on working project

https://drive.google.com/file/d/1soAzTAxjlrBGIo48bHu-ZAV0lZwafEeM/view?usp=drivesdk

Link for Digital Portfolio

https://drive.google.com/file/d/1oRferxBCwhfDqxzUbrSheCcijrXvXVfF/view?usp=drivesdk

https://drive.google.com/file/d/1FKCsReB3eb0Dzp740uK7YcPEzO2TecFr/view?usp=drivesdk

https://drive.google.com/drive/folders/1K8mDe3aK_Dm9kGouO6atngXlLu70BAtV?usp=sharing