Visible Light Communication

Capstone Project Report
FINAL REPORT EVALUATION

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Declaration

We hereby declare that the working prototype, design principles and model of the project entitled Visible Light Communication is an authentic record of our own work carried out in the Electronics & Communication Engineering Department, TIET, Patiala, under the guidance of Dr. Hem Dutt Joshi during 6th Semester (2022).

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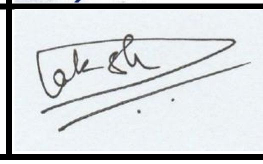
101906047	Daksh Krishna Khanna	

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Designation

ECED
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Acknowledgement

We would like to thank Dr. Hem Dutt Joshi, who served as our mentor. He has been a crucial source of technical knowledge for our project and has been of great assistance.

Additionally, we would like to express our gratitude to the entire faculty and staff of the Electronics & Communication Engineering Department as well as our friends for volunteering their time and assisting us in any way they could to complete this project successfully. We appreciate each and every person who made a direct or indirect contribution to this project.

Finally, we would like to express our gratitude to our families for their unwavering support and love. We are in awe of their tenacity and commitment because they always wanted the best for us.

Date:

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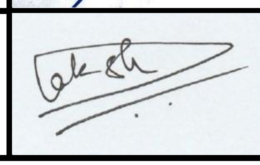
101906047	**Daksh Krishna Khanna**	

Abstract

Internet of Things enables devices to communicate across networks, with growth in the number of devices, the demand for bandwidth increases. Furthermore, GPS cannot provide satisfactory accuracy in an indoor environment, location estimation in an indoor environment necessitates the use of appropriate technology. As a result, visible light communication (VLC) technology is introduced to supplement an existing radio frequency infrastructure, improve bandwidth and eliminate interference from electromagnetic sources. VLC is acknowledged globally as an advanced and promising technology for achieving short-range, high-speed, large-capacity wireless data transmission as the demand for lighting devices with fixed feature sets rises.

Table no	**Caption**	**Page no**
Table 1.1	Assumptions	2
Table 1.2	Constraints	2
Table 2.1	Sample Table for Literature Survey	6
Table 2.8	Cost Analysis	10
Table 4.3	Pin Configuration of LM358	22
Table 4.4	Microcontroller Comparison	23

List of Figures

Figure no	Caption	Page no
Fig. 3.1	System Architecture	12
Fig. 3.2	Flowchart	13
Fig. 3.3	Working of LDR	14
Fig. 3.4	Working of Solar Panel	14
Fig. 3.5	Working of LED	15
Fig. 4.1	LDR	19
Fig. 4.2	Solar Panel	21
Fig. 4.3	Light Emitting Diode	22
Fig. 4.3	LM358 Pin Configuration	24
Fig. 5.1	Work Breakdown Structure	29
Fig. 5.2	Gantt Chart	30

IoT	Internet of Things
Li-Fi	Light Fidelity
VLC	Visible Light Communication
PCB	Printed Circuit Board
RF	Radio Frequency
LED	Light Emitting Diode
UI	User Interface
OBJ	Object
USB	Universal Serial Bus
PWM	Pulse Width Modulation
IEEE	Institute of Electrical and Electronics Engineers

TABLE OF CONTENTS

DECLARATION..i
ACKNOWLEDGEMENT..ii
ABSTRACT..iii
LIST OF TABLES..vii
LIST OF FIGURES..viii
LIST OF ABBREVIATIONS..ix
CHAPTER 1- INTRODUCTION..1
1.1 PROJECT OVERVIEW..1
1.2 MOTIVATION..1
1.3 ASSUMPTIONS AND CONSTRAINTS..2
1.4 NOVELTY OF WORK..2
CHAPTER 2 – LITERATURE SURVEY..3
2.1 LITERATURE SURVEY..3
2.1.2 SAMPLE TABLE FOR LITERATURE SURVEY..5
2.2 RESEARCH GAPS..7
2.3 PROBLEM DEFINITION AND SCOPE..7
2.4 REQUIREMENTS SPECIFICATION..7
2.4.1 INTRODUCTION..7
2.4.1.1 PURPOSE..7
2.4.1.2 INTENDED AUDIENCE AND READING SUGGESTIONS..7
2.4.1.3 PROJECT SCOPE..8
2.4.2 OVERALL DESCRIPTION..8
2.4.2.1 PRODUCT PERSPECTIVE..8
2.4.3 EXTERNAL INTERFACE REQUIREMENTS..8
2.4.3.1 HARDWARE INTERFACES..8
2.4.3.2 SOFTWARE INTERFACES..8
2.4.4 OTHER NON-FUNCTIONAL REQUIREMENTS..9
2.4.4.1 TECHNICAL FEASIBILITY..9
2.4.4.2 ECONOMIC FEASIBILITY..9
2.4.4.3 OPERATIONAL FEASIBILITY..9
2.5 APPROVED OBJECTIVES..9
2.6 PROJECT OUTCOMES AND DELIVERABLES..9
2.7 COST ANALYSIS..10
2.8 RISK ANALYSIS..10
CHAPTER 3 – FLOW CHART..11
3.1 SYSTEM ARCHITECTURE..11
3.2 FLOWCHART..12
3.3 TOOLS AND TECHNOLOGIES USED..13
CHAPTER 4 – PROJECT DESIGN AND DESCRIPTION..17
4.1 DESCRIPTION..17
4.2 U.G SUBJECTS..17
4.3 STANDARDS USED..17

4.4 SURVEY OF TOOLS AND TECHNOLOGIES ... 18
4.4.1 LDR Module (Photoresistor) ... 18
4.4.1.1 INTRODUCTION ... 18
4.4.1.2 BENEFITS OF LDR ... 18
4.4.1.3 APPLICATION OF LDR ... 18
4.4.1.4 SPECIFICATIONS ... 19
4.4.1.5 SYMBOL/IMAGE ... 19
4.4.2 SOLAR PANEL ... 19
4.4.2.1 INTRODUCTION ... 19
4.4.2.2 WORKING PRINCIPLE ... 19
4.4.2.3 BENEFITS OF SOLAR PANEL ... 20
4.4.2.4 APPLICATION OF SOLAR PANEL ... 20
4.4.2.5 SPECIFICATIONS ... 20
4.4.2.6 SYMBOL/IMAGE ... 21
4.4.3 LIGHT EMITTING DIODE (LED) ... 21
4.4.3.1 INTRODUCTION ... 21
4.4.3.3 BENEFITS OF LED ... 21
4.4.3.4 APPLICATION OF LED ... 22
4.4.3.5 SPECIFICATIONS ... 22
4.4.3.6 SYMBOL/IMAGE ... 22
4.4.4 IC LM358 ... 23
4.4.4.1 INTRODUCTION ... 23
4.4.4.3 BENEFITS OF LM358 ... 23
4.4.4.4 APPLICATION OF LM358 ... 23
4.4.4.5 SPECIFICATIONS ... 23
4.4.4.6 PIN CONFIGURATION ... 24
4.4.5 MICROCONTROLLER COMPARISONS ... 25
4.4.5.1 PROS AND CONS ... 26
4.4.5.1.1 PROS AND CONS OF RASPBERRY PI ... 26
4.4.5.1.2 PROS AND CONS OF ARDUINO ... 26
4.4.5.1.3 PROS AND CONS OF NODE MCU ... 27
4.4.5.2 NODE MCU Vs RASPBERRY PI ... 27
4.4.5.3 RASPBERRY PI Vs ARDUINO ... 27
4.4.5.4 ARDUINO UNO SPECIFICATIONS ... 28
CHAPTER 5 – IMPLEMENTATION & EXPERIMENTAL RESULT ... 29
5.1 CIRCUIT SIMULATION ... 29
5.2 RECEIVER SENSOR SIMULATION ... 30
5.3 TRANSMITTER SIMULATION ... 31
5.4 DISTANCE VS DATA LOSS ... 33
5.5 HARDWARE VS SOFTWARE UPDATE TRIALS ... 33
5.6 FLOW CHART OF CODE APPROACH ... 34
5.7 FUNCTIONS USED IN THE CODE ... 34
5.8 OUTPUT ... 36

CHAPTER 6 – OUTCOME AND PROSPECTIVE LEARNING ... 38

6.1 ENVIRONMENTAL AND ECONOMIC BENEFITS 38
6.1 CONCLUSION 38
CHAPTER 7 – PROJECT TIMELINE 39
5.1 WORK BREAKDOWN & GANTT CHART 39
REFERENCES 41

1.1 Project Overview

Since LEDs operate at a speed of less than 1 s, a light source appears to be on all the time. Binary codes are used for data transmission through this inconspicuous on-off process. A digital value of 1/0 is transmitted when an LED is turned on or off, making it possible to encode data by controlling how quickly the LEDs turn on and off to produce different strings of 1s and 0s. The signal is then captured by a photo detector, which converts it back into its original form.

Technically speaking, this method of wireless information transmission through quick light pulses is known as VLC. Because Li-Fi has the potential to rival traditional Wi-Fi, the term has been inspired. Between 400 THz and 800 THz of visible light are used by the VLC as the optical carrier for data transmission and illumination. By combining high-speed LEDs with effective multiplexing, this results in data rates of up to 100 Mbps. The VLC data rate can be increased by using arrays of LEDs where each LED transmits a different stream of data in parallel.

1.2 Motivation

As they currently stand, transmission systems cannot be used modularly, that is, as a package that only needs to be deployed at the point of action, because they are fundamentally slow and occasionally only allow transmission of data that has been pre-coded into the system. Since the system generally operates using visible light, which most people can not even detect undergoing a switching action, providing a secure mode of transmission over and above all other details, VLC, and by extension, Li-Fi, helps tackle these issues by providing modularity, and an ease of deployment. At the same time, since visible light is a natural substitute for the radiation transmissions made by Wi-Fi and other common methods, this is a cost-effective, energy-efficient alternative that has no negative environmental effects.

1.3 Assumptions and Constraints

The Assumptions are listed in Table 1, and Constraints are listed in Table 2.

Table 1.1: Assumptions

Serial Number	Assumption
1st	It has been assumed that the photoresist is kept nearby (in the range of) the light emitting sensor.
2nd	It has been assumed that the space between transmitting and receiving antenna is not obstructed.
3rd	It has been assumed that no interfering action will take place on the input signal being transmitted.

Table 1.2: Constraints

Serial Number	Constraint
1st	Sensitivity range of photoresist is fixed.
2nd	External light sources are present.
3rd	There is an interference action on the input signal transmission.
4th	Constant power supply is required.

1.4 Novelty of Work

Corresponding to this project, there are two major unique contributions to the endeavors hitherto.

1. Li-Fi Transmitter and Receiver System: A device that transmits and receives data by switching an LED's state between on and off based on the general principle of data transmission, encoding, decoding, and receiving.
2. The revolutionary technologies that are reshaping today's industry are the subject of this research. In this project, Visible light communicated to the LDR Module via a 5G Li-Fi band.

2.1 Literature Survey

Visible light communication systems have recently attracted a lot of interest from the academic and industrial worlds and have primarily been used indoors. A wider range of applications, such as Li-Fi, vehicle-to-vehicle communication, hospital robots, underwater communication, and information displayed on billboards, are currently where they are used. Due to the rising demand for extremely high data transfer rates and broadband wireless services, researchers have been forced to investigate feasible methods to optimize the use of the wireless medium. There has already been some noteworthy work in this field.

N. T. Surajudeen-Bakinde, E. Ifada, N. Faruk, O. O. Mohammed, A. O. Otuoze, A. Abdulkarim and A. A. Oloyede proposed an idea on A Li-Fi Based Technology for PC-PC Data Transmission for Wireless Communications. With the help of a single Micro Controller - Arduino board, which is used to encode, decode, and supply power to the transmitter and receiver circuits, which were implemented on a single breadboard with an LED and photodiode, this work aimed to design a Li-Fi Data Transmission system to send data (limited to text - strings) from a PC to another PC. When tested, the Data Transmission system produced satisfactory results. Because of its low cost, the Li-Fi data transmission system achieved the project's main goal of incorporating a Li-Fi medium using commercially available electronic devices and components. However, to demonstrate how this technology could be used in the workplace, we used not one, but two Arduinos that were linked to two computers.

Dr. Hema Kale in their work on Communication using Li-Fi between two computers: Similar to Wi-Fi, Li-Fi is a bidirectional, fast, and fully networked wireless communication technology. White LED-based visible light communication (VLC) has several benefits over RF-based wireless systems, including license-free spectrum, low power consumption, and increased privacy.
VLC operates by rapidly turning off and on the current to the LEDs—too quickly for the human eye to notice. Li-Fi LEDs could be dimmed to below human visibility while still emitting enough light to carry data, even though they would need to be kept on to transmit data. Li-Fi does not require a direct line of sight to transmit a signal; light reflected off of walls can reach 70 mbps. This helped us understand how the Li-Fi systems operate and what its capabilities are.

Kalai Vendhan.S, Dr. Azha Periasamy, Karuppiah.T, Gopinath.S, Anandraj.V propose an idea to create a potential replacement for wireless communication in which a two-sided transmission system can successfully transmit both text and images using Li-Fi technology. If this technology can be put to practical use, each bulb can be used as a light source in conjunction with VLC-based Wi-Fi hotspots. Therefore, it is only employed for broadcasting. By using a more sophisticated device, the limitations of this work can be overcome. We use RF waves to communicate while minimizing the impact of radiation on human health. Because Li-Fi is a short-range technology, data traffic is reduced while also being easier to send and receive at high speeds.

Nischay, 2017 highlights the need for an alternative communication system, which comes in the form of Li-Fi, due to current infrastructure not being sufficient, and there being overcrowding. As a conclusion, the impact of Li-Fi technology, and the vast research going on in-between individual researchers, and also companies, to improve this technology, and field, to make it a commercial success, and to widely implement it, as an alternative means to existing technologies is highlighted. This paper provides a fundamental understanding, and base on which the project is developed, and takes a standpoint from.

Yaseein Soubhi Hussein and Amresh Chetty Annan 2019, show the benefits and advantages of Li-Fi, and the secure transmission methods it offers, transmitting varying amounts of data, with any encryption, and decryption standard set, with the transmission being invisible to the naked eye, and to normal radio scanners, since transmission occurs using the feature of lights instantaneous switching action, invisible to the naked eye. The paper has provided a base for secure communications, and transmission of data, giving a vast range of applications where the technology can be implemented.

Safwan Alfattani, J. Opt. Comm., 2018; highlights the future scope of Li-Fi, and how where RF use is limited, or restricted, it can be used an alternative, since visible light has a much larger band, and does not suffer from the same blockages, and restrictions that RF, and Wave communications suffer from. Data about the current, and future applications of this technology, along with implementation details, and custom requirements, such as unique modulation techniques, have helped improve the project working.

Jyothsna, and Saurabh Sambhav, 2020, highlights the prospective implementation of 6G networks using Li-Fi technology since current technology still lacks in providing adequate infrastructure and support for the implementation of modern networks, and IOT technologies. An understandingof future implementations, and technological requirements, improving the landscape of Li-Fi provide a better grasp, and base for the implementation, and working of the project.

Buvaneswari S, Tanishka Raghu, Saranraj S highlights the prospective implementation with modern vehicles, which are overloaded with sensors, to ensure there is no hassle, Li-Fi is used to provide driver safety, and monitoring of the vehicle by interfacing a Li-Fi system with the sensors. This same implementation is used as a base to work on automation and large scale industrial deployment in the implementation being developed.

R. Reka, R. Maheswari, Dr. R. Anitha, R. Malathy, in their paper highlight how there is widespread expenditure and infrastructure to setup new communication centers across a city, or state, in the forms of antennas, and communication poles, while at the same time the loss incurred due to the street lighting, and then being switched on and off continuously. These street lights integrated with Li-Fi can reduces these incurred costs, since they can be used for data communication, while still providing lighting.

Sudharshan B, Jahnavi A P, Jhanavi V, in IARJSET 2021, highlight how Li-Fi is an improved method for text transmission, and an alternative to Wi-Fi which can be utilized, even when Wi-Fi access is restricted or banned. Li-Fi is also a secure communication method, since the data cannot be intercepted till the time illuminated light is not seen, and intercepted by a receiver, and does not offer the same adverse health effects as Wi-Fi, with the use of EM waves.

2.1.1 Sample Table for Literature Survey

Sr. No.	Author Name	Paper Title	Tools/Tech.	Description
1	N. T. Surajudeen-Bakinde; E. Ifada; N. Faruk; O. O. Mohammed; A. O. Otuoze; A. Abdulkarim; A. A. Oloyede	Li-Fi Based Technology for PC-PC Data Transmission	Li-Fi, Arduino	Using commercially available electronic components, the Li-Fi Data Transmission system allows data (limited to text-strings) to be sent from one PC to another PC.
2	Dr. Hema Kale	PC - PC Communication using Li - Fi	Li-Fi, Laser, Solar Panel, LM386	Li-Fi allows electronic devices to connect wirelessly to the internet. With speeds of 224 gigabits per second, it has been determined to be approximately 100 times faster than Wi-Fi.
3	Kalai Vendhan.S; Dr. Azha Periasamy; Karuppiah. T; Gopinath.S; Anandraj.V	Li-Fi Based Security System for Defense and Commercial Purpose	VLC, LED, Photoresistor	The goal of this project's conclusion is to use RF wave communication to mitigate the effects of radiation. Li-Fi has made communication more secure, affordable, and health-safe.
4	. Nischay	Li-Fi Technology	Li-Fi	An overworking and the impact and vast research going on into Li-Fi technology is highlighted throughout

5	Yaseein Soubhi Hussein and Amresh Chetty Annan	Li-Fi Technology: High data transmission securely	Li-Fi	The paper undergoes research on the secure transmission methods provided by Li-Fi
6	Safwan Alfattani, J. Opt. Comm	Review of Li-Fi Technology and Its Future Applications	Li-Fi	The paper highlights the future scope of Li-Fi, and the varying places Li-Fi is/can be utilized, as an alternative to RF methods
7	Jyothsna, and Saurabh Sambhav	Li-Fi in Future Technology – Working, Application, and Limitation	Li-Fi	The paper undergoes highlighting how Li-Fi can be used to provide better infrastructure for future technologies
8	Buvaneswari S, Tanishka Raghu, Saranraj S	Vehicle to Vehicle Communication using LI-FI Technology	Li-Fi	The paper highlights interfacing of vehicle sensors with a Li-Fi system, for monitoring and ensuring driver safety.
9	R. Reka, R. Maheswari, Dr. R. Anitha, R. Malathy	Li-Fi Enhanced Street Lights	Li-Fi	The research paper highlights how street lights can be an alternative method to Wi-Fi hotspot
10	Sudharshan B; Jahnavi A; Jhanavi V	Text Transmission using Li-Fi	Li-Fi	The paper highlights how data, specifically text can be transmitted via a Li-Fi system

Table 2.1 Sample Table for Literature Survey

2.2 Research Gaps

Despite the advancement in technology and efforts made to control and counter the problem of communication through this method, it is still not as well-known and hasn't been studied to the same extent as other transmission methods.

The energy consumption and environmental impact of this system are not adequately covered in current research, making it a better alternative in many ways and one that calls for additional study and coverage.

Several studies and research projects have recently brought Li-Fi to light, demonstrating its advantages over other transmission methods.

2.3 Problem Definition and Scope

A warehouse requires a lot of labor to run, from security to clearance to warehouse necessities. However, a large portion of this labor force can be eliminated with the right preparation, funding, and application. Trucks can be installed with a transmitter and a warehouse gate can be automated with a receiver using a VLC/Li-Fi system.

All modern cars have an always working light called Daytime Running Lamps (DRL) in their headlights, so when a truck approaches, the VLC system can automatically verify that it belongs in the warehouse and automate the entry and exit procedures. With more research and IOT technology, this system can also be expanded to automate warehouse processes such as loading trucks after entry, emptying them at exit, refueling, and smart vehicle system monitoring, which would prevent exit when the vehicle is not in fit condition.

2.4 Requirement Specification

2.4.1 Introduction

2.4.1.1 Purpose

Our project's objective is to use Li-Fi principles to transmit data through a visible light source in order to establish a quicker communication channel.

Additionally, real-time data sent by a vehicle equipped with this transmitter can be understood and customized by using sensors. A room indoors without interfering activities will be preferred to produce the best results.

2.4.1.2 Intended Audience and Reading Suggestions

Our module can be used by both individuals and organizations to minimize labor-intensive tasks in commercial settings and domestic settings. Additionally, automation can benefit other places rather than wasting human labor. Researchers working in this field and other relevant fields can gain a great deal of insight from all the research studies, observations, and findings included in our project, enabling them to conduct additional research and experiments.

2.4.1.3 Project Scope

This module could be helpful in effectively addressing the long-standing problem of excess labor/manpower and the rising tide of negligence among people, especially in the commercial sector. The main goal of the project is to automate the parking system for a commercial/residential building. The project will raise both the standard of living and the working environment. This technology is not just applicable to the project; it can also be used in a number of other areas, such as street lighting, indoor communication, and military applications. The technology transmits information very quickly because it communicates using visible light.

2.4.2 Overall Description

2.4.2.1 Product Perspective

Our idea aims to use a visible light source to transfer data significantly and fairly accurately. This project also includes an LED that transmits the data, which the photoresist then receives and sends on to be decrypted. The objective of this project is to develop a prototype system based on cutting-edge, straightforward methods that will enable much faster data transmission and better fidelity connectivity between appliances.

2.4.3 External Interface Requirements

2.4.3.1 Hardware Interfaces

- LED
- Arduino Uno
- LDR
- Solar Panel
- Potentiometer
- Tactile Button
- IC LM358

2.4.3.2 Software Interfaces

- Arduino IDE
- EAGLE
- XCTU

2.4.4 Other Non-functional Requirements

Technical feasibility

Since the proposal can be implemented using current technologies, it is technically feasible.

The project is technically feasible because the necessary technology is easily accessible.

Economic feasibility

We use a cheap light source, which may be less expensive than other options, making it economically feasible in comparison to other technologies like Wi-Fi modules.

Operational feasibility

Because sensors can clearly show whether a signal is received or not, the idea is operationally feasible.

2.5 Approved Objectives

- To investigate Li-Fi systems and the contemporary communication landscape.
- To present Li-Fi's advantageous position and energy usage and to explore new areas of research into this system.
- To create a contemporary communication method that simplifies transmission systems.
- To assess the performance of the suggested prototype using a variety of performance metrics and cutting-edge methods.

2.6 Project Outcomes and Deliverables

- Development of a system that can receive data from a visible light source.
- Improving the effectiveness of communication among different sensors.
- With less human effort, providing a better and more cohesive solution to the problems related to identification in parking.
- A VLC system that can be deployed at points of access, integrated with vehicle headlights, and more with comparatively little effort and setup expense.
- Thorough organizational control and automation of warehouses.
- An effective data transmission system that aids in workflow automation, manpower reduction, and cost-cutting.

2.7 Cost Analysis

Description	Price per unit (₹)	Quantity
Arduino UNO R3	**500**	**2**
Photoresist	**10**	**2**
LED	**10**	**2**
Solar Panel	**400**	**2**
IC LM358	**10**	**2**
Push Button	**5**	**1**
Potentiometer	**10**	**1**
5mm LED	**10**	**2**
Jumper Wires	**10**	**N/A**
Breadboard	**100**	**1**

Total Cost: ₹2105

2.8 Risk Analysis

- **Sensor Fault**: Any imperfections or errors in the hardware framework and sensors used could result in inconsistent signal detection from the LED, which would then either result in incorrect signal transmission or signal loss.

- **Communication Break**: Communication barriers may result from the transceiver failing.

3.1 SYSTEM ARCHITECTURE:

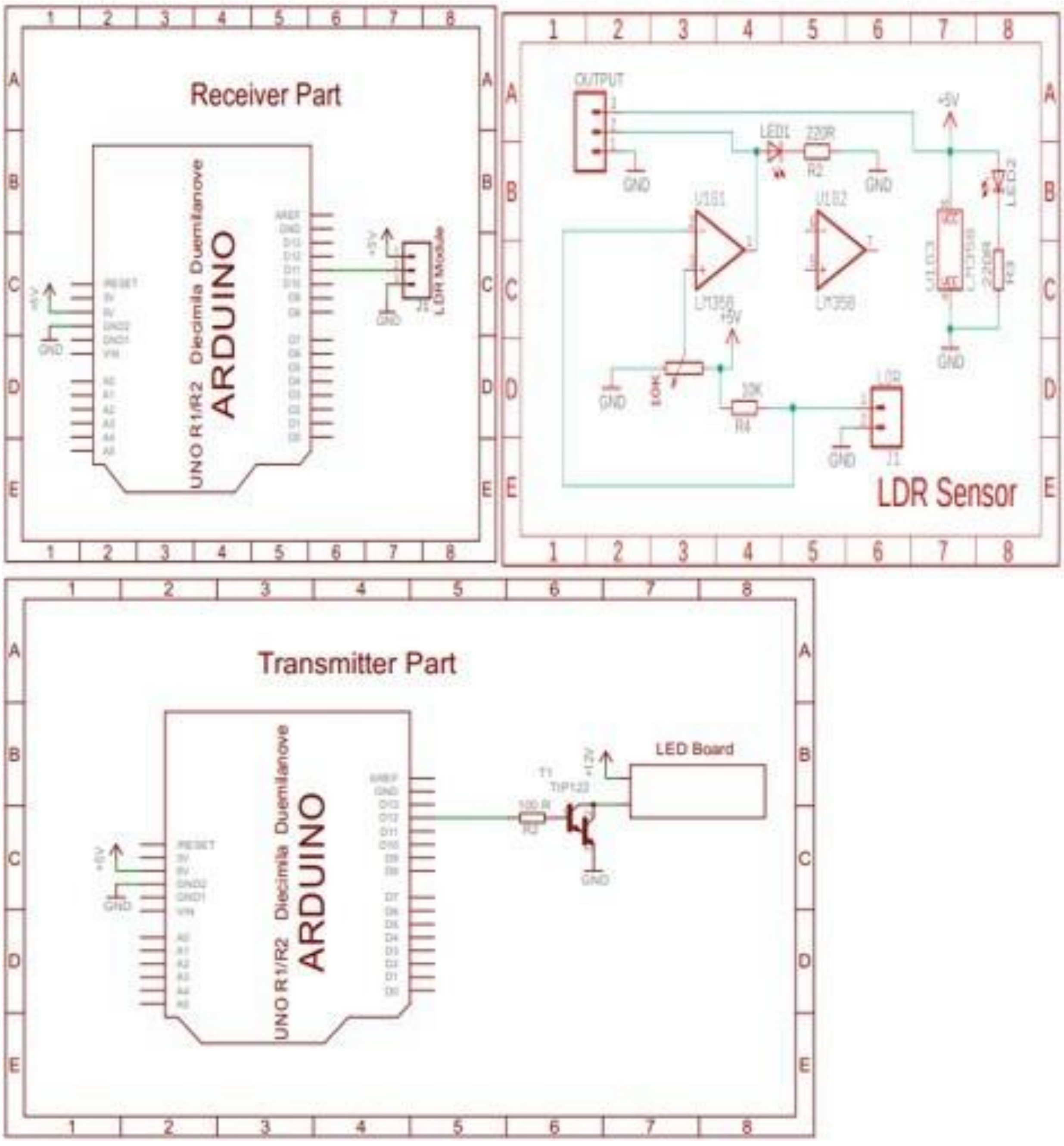


Fig 3.1 System Architecture

3.2 Analysis

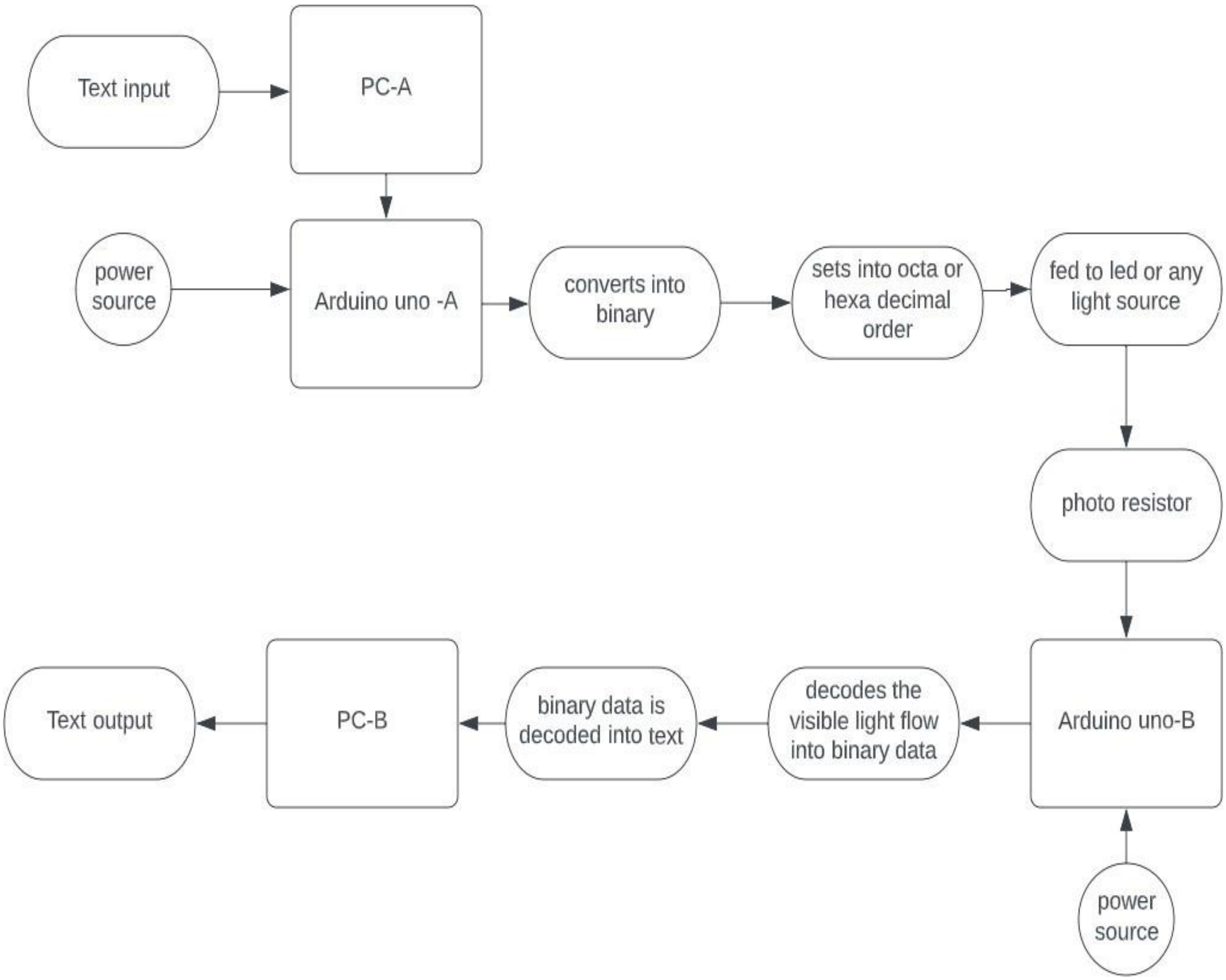


Fig. 4.2 Flowchart

The Flow of our Project is:

1. **1.** We connect the module as shown in the figure below and the first laptop (source) sends the signal by converting text to binary and forwards it according to our code to the Arduino-1.
2. **2.** Arduino-1 converts the signal into octa-decimal and sends it forward to the bread board module which inherently sends it to the LED.
3. **3.** The LED beam flashes accordingly to transmit the signal through visible light in the same pattern as the octa-decimal for the receiver to pick it up.
4. **4.** The LDR module receiver picks up the LED signal which is also connected to a potentiometer which can vary the sensitivity of the signal.
5. **5.** The LDR module is connected to another Arduino-2 and send the signal to it for the decoding to happen into the original format so as to receive the actual message.
6. **6.** The original message is displayed on the designated screen.

3.3 Tools and Technologies Used

The development of a Smart Workspace to turn off electronic appliances using a beam switching antenna itself is an important aspect to save electricity and reduce human efforts. And to accomplish this, it requires a certain design, sensors, tools, and algorithms for proper implementation. The following tools and technologies are required to make this project successful:

1. **Sensors and Modules:**

   a. **LDR Module (Photoresistor):**

   A photoresistor, also known as a light-dependent resistor, is a light-sensitive electronic component. It changes in resistance when light strikes it. LDR resistance values can vary by many orders of magnitude, and as light levels rise, the resistance value falls. An LDR or photoresistor frequently has resistance values of a few megohms in darkness and drops to a few hundred ohms in bright light. LDRs are simple to use and there are many LDR circuits available even though they have such a wide range of resistance. The wavelength of the incident light affects how sensitive light-dependent resistors or photoresistors are. Such sensors can be mass produced for a low price and only need to meet a few requirements.

   There are two types of Sensors available:

   1. Intrinsic photoresistors
   2. Extrinsic photoresistors

   No matter the kind of photoresistor or light dependent resistor, both types show a rise in conductivity or a fall in resistance with increasing levels of incident light.

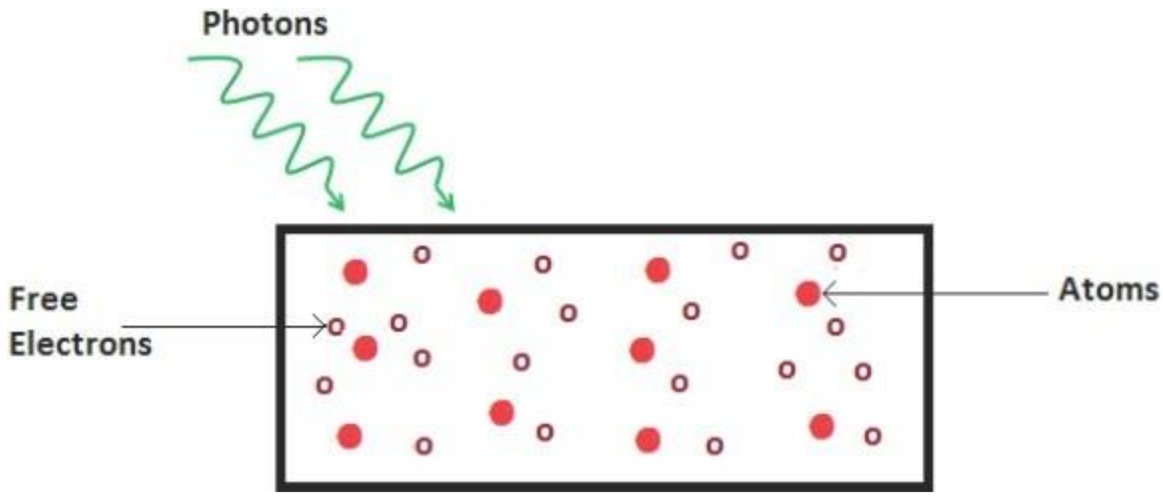


Fig 3.3 Working of LDR

b. Solar Panel:

Sunlight from solar panels is captured as clean, renewable energy and transformed into electricity, which is then used to power electrical loads. Solar panels are made up of many different solar cells, each of which is made up of layers of silicon, phosphorous, and boron. Photons are absorbed by solar panels, which then start an electric current. Electrons can be thrown out of their atomic orbits and released into the electric field produced by the solar cells, which then pulls these free electrons into a directional current. This process is made possible by the energy produced when photons strike the surface of the solar panel. The Photovoltaic Effect is the name given to the entire process.

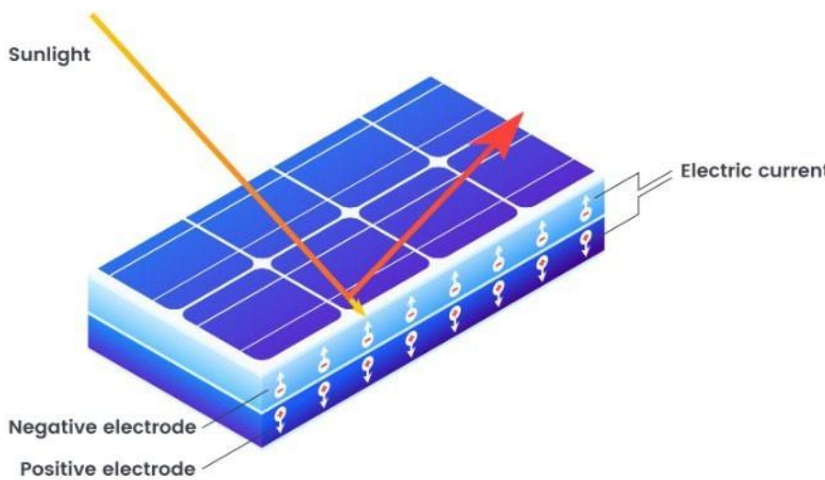


Fig 3.4 Working of LDR

c. **Light Emitting Diode (LED):**

When an electric current passes through a semiconductor device called a light-emitting diode (LED), the LED emits light. When current flows through an LED, the electrons and holes recombine and produce light. LEDs only let current flow in one direction—forward—and stop it from going the other way.

P-n junctions in light-emitting diodes are highly doped. When forward biased, an LED will emit a colored light at a particular spectral wavelength depending on the semiconductor material used and the amount of doping. An LED is enclosed with a transparent cover, as seen in the figure, to allow the light that is emitted to escape.

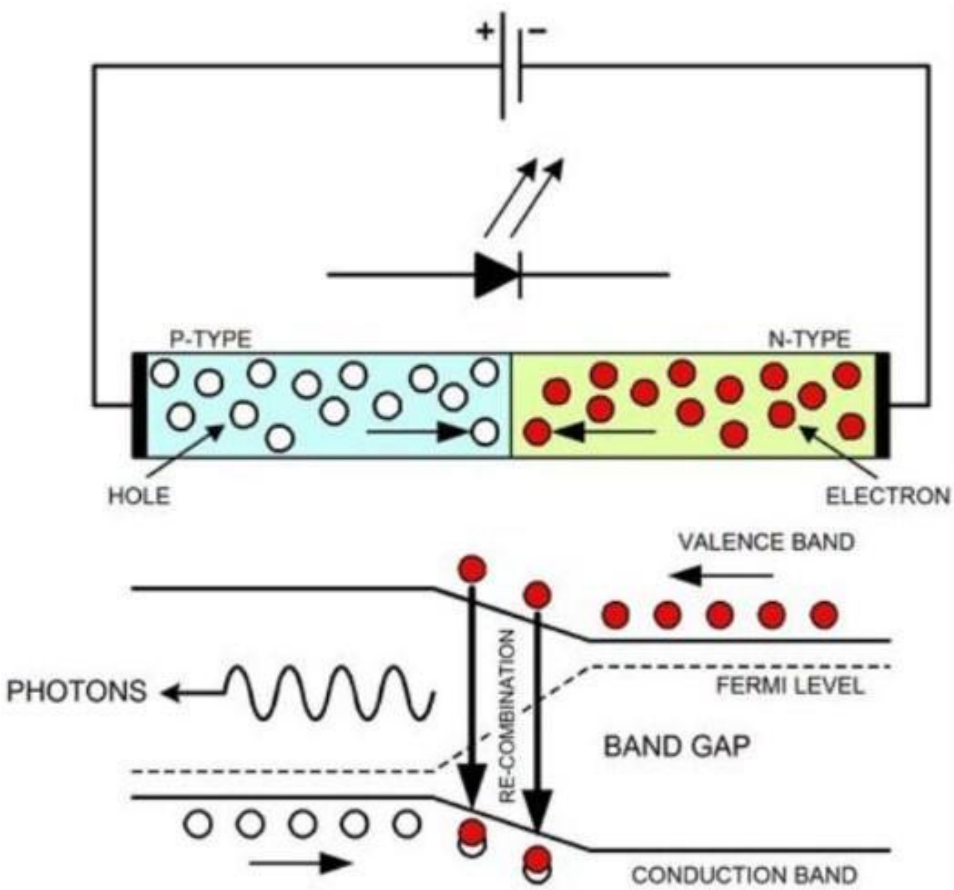


Fig 3.5 Working of LED

2. **Softwares/Libraries:**

   a. **Arduino IDE**

   The Arduino Software (IDE) includes a text editor for writing code, a message box, a text console, a toolbar with buttons for basic functions, and a series of menus. It communicates with the Arduino hardware and uploads applications to it.

   b. **Eagle**

   EAGLE is an electronic design automation (EDA) programme that can be scripted and has features like schematic capture, PCB layout, autorouter, and computer-aided manufacturing (CAM). EAGLE stands for Easily Applicable Graphical Layout Editor.

   For editing, managing projects, and personalizing design interfaces and parameters, EAGLE offers a multi-window graphical user interface and menu system. Using the mouse, keyboard shortcuts, or by entering specific commands on the built-in command line, the system can be managed. The user can specify hotkeys. Script files can be created by combining numerous repeating commands (with the .SCR extension). The object-oriented programming language developed specifically for EAGLE can also be used to explore design files (with a .ULP extension).

   c. **XCTU**

   Using a user-friendly graphical interface, the free multi-platform application XCTU enables developers to communicate with Digi RF modules.

4.1 Description

The goal of this project is to advance research and knowledge in the fields of Li-Fi and VLC. While this is the overall goal, we can improve the performance of contemporary communication systems overall, introduce cost-cutting, optimize workforce management and manpower hours, and more with the applications and implementations that already exist and use Li-Fi as their foundation.

This project also aims to introduce the numerous benefits and use cases of Li-Fi, and if carried out successfully, to be implemented on a large scale, can lessen the harm that existing systems' EM waves cause to the environment and living things. Additionally, it will introduce a new framework for Li-Fi applications and ideas, broaden public understanding of this area, and advance research and development in it.

4.2 Undergraduate Courses used in this project

- Embedded System
- Antenna and Wave Propagation
- Computer Architecture
- Engineering Design 1
- Engineering Design 2
- Circuit Analysis & Synthesis

4.3 IEEE Standards used in this project:

- 1118.1-1990 - IEEE Standard for Microcontroller System Serial Control Bus.
- IEEE 802.15.7 is a high-speed, bidirectional and fully networked wireless communication technology-based standard.
- IEEE 802.11bb—Standard for Information Technology—Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Networks

4.4 Survey of Tools and Technologies

4.4.1 LDR Module (Photoresistor)

4.4.1.1 Introduction

A photoresistor, also known as a light-dependent resistor, is a light-sensitive electronic component. It changes in resistance when light strikes it. LDR resistance values can vary by many orders of magnitude, and as light levels rise, the resistance value falls. An LDR or photoresistor frequently has resistance values of a few megohms in darkness and drops to a few hundred ohms in bright light. LDRs are simple to use and there are many LDR circuits available even though they have such a wide range of resistance. The wavelength of the incident light affects how sensitive light-dependent resistors or photoresistors are. Such sensors can be mass produced for a low price and only need to meet a few requirements.

There are two types of Sensors available:

1. ***Intrinsic photoresistors***
2. ***Extrinsic photoresistors***

No matter the kind of photoresistor or light dependent resistor, both types show a rise in conductivity or a fall in resistance with increasing levels of incident light.

4.4.1.2 Benefits of LDR

1. It had high sensitivity due to the large area it can cover.
2. They are mass produced and hence incur a very low cost.
3. The lack of union potential makes it even more functional.
4. It has a high light-dark resistance ratio.
5. It’s small in size and can be used in little circuits.
6. Its easy to connect and simple to place anywhere.

4.4.1.3 Applications of LDR

1. Fire alarm circuits
2. Burglar alarm circuits
3. Photosensitive Relays
4. Street lights
5. Automatic brightness control in computers
6. Clock Radios

4.4.1.4 Specifications

PARAMETER	EXAMPLE FIGURES
Power Dissipated MAX	200mW
Voltage MAX @ 0 lux	200V
Wavelength (Peak)	600nm
Resistance MIN @ 10lux	1.8kΩ
Resistance MAX @ 10lux	4.5kΩ
Resistance Typical @ 100lux	0.7kΩ
Dark resistance (1 sec)	0.03MΩ
Dark resistance (5 sec)	0.25MΩ

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4.4.1.5 Symbol

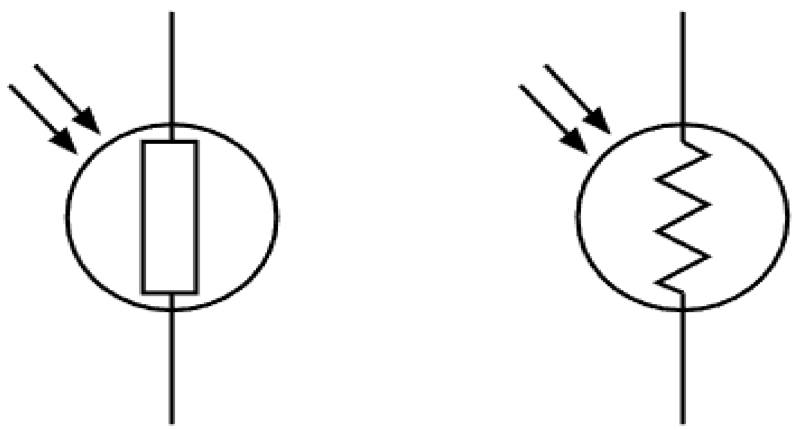

Fig. 4.1 LDR

4.4.2 Solar Panel

4.4.2.1 Introduction

Sunlight from solar panels is captured as clean, renewable energy and transformed into electricity, which is then used to power electrical loads. Solar panels are made up of many different solar cells, each of which is made up of layers of silicon, phosphorous, and boron. Photons are absorbed by solar panels, which then start an electric current.

4.4.2.2 Working Principle

Electrons can be thrown out of their atomic orbits and released into the electric field produced by the solar cells, which then pulls these free electrons into a directional current. This process is made possible by the energy produced when photons strike the surface of the solar panel. The Photovoltaic Effect is the name given to the entire process.

4.4.2.3 Benefits of Solar Panels

1. Renewability - The fact that solar energy is a truly renewable energy source is the most significant advantage of solar panels among all their other advantages. It is available every day and can be used everywhere in the world. Unlike some other energy sources, solar energy will never run out.
2. Power Consumption – Since it doesn’t require actual current, it uses less power and doesn’t require a power supply to work.
3. Low Maintenance - In general, solar energy systems don't need much upkeep. They only need to be kept moderately clean, so a few times a year of cleaning will do.

4.4.2.4 Applications of Solar Panel

1. Water Heating
2. Distillation of water
3. Pumping of water
4. Furnaces
5. Cooking
6. Electricity Generation
7. Green Houses

4.4.2.5 Specifications

Power MAX(Pmax)	0.3W
Power Voltage MAX(Vmp)	6V
Power Current MAX (Imp)	42mA
Voltage Open Circuit (Voc)	6.706V
Current Short Circuit (Isc)	0.055A

4.4.2.6 Symbol/Image

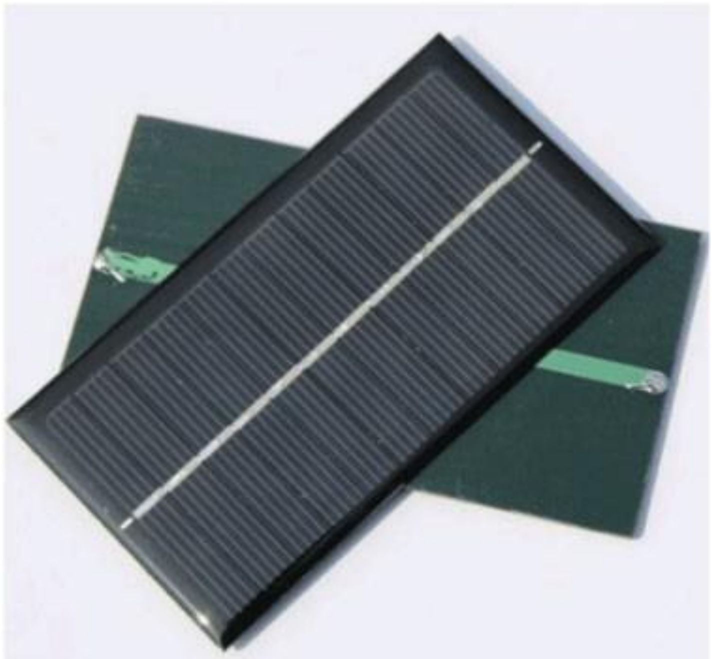

Fig. 4.2 Solar Panel

4.4.3 Light Emitting Diode (LED)

4.4.3.1 Introduction

When an electric current passes through a semiconductor device called a light-emitting diode (LED), the LED emits light. When current flows through an LED, the electrons and holes recombine and produce light. LEDs only let current flow in one direction—forward—and stop it from going the other way. P-n junctions in light-emitting diodes are highly doped. When forward biased, an LED will emit a colored light at a particular spectral wavelength depending on the semiconductor material used and the amount of doping. An LED is enclosed with a transparent cover, as seen in the figure, to allow the light that is emitted to escape.

4.4.3.2 Benefits of LED

1. Lifespan - The lifespan of an LED light is significantly longer than that of the typical incandescent bulb. An incandescent light bulb typically lasts a thousand hours.
2. Power Consumption - LEDs typically have very low power requirements.
3. Safety - Perhaps the most frequently disregarded benefit of LED lighting is safety. When it comes to lighting, heat emission is the biggest risk. Unlike conventional incandescent bulbs, LEDs almost never produce forward heat.
4. Compact size and low price – Offer necessary functions in a housing design that saves space, combining lower cost with higher value and performance.

4.4.3.3 Applications of LED

1. TV Backlighting
2. Smartphone Backlighting
3. LED Displays
4. Automotive Lighting
5. Aviation Lighting
6. Traffic Signals and Burglar Alarms

4.4.3.4 Specifications

1. Intensity: 6,000mcd
2. Color Frequency: 6000-6500
3. Viewing Angle: 28º
4. Lens: Water Clear
5. Voltage: 2.6v-2.9v
6. Typical: 2.8v
7. Current: 18mA

4.4.3.5 Symbol/Image

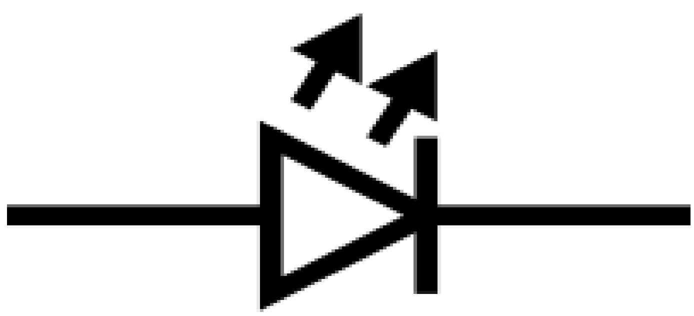

Fig. 4.3 Light Emitting Diode

4.4.4 IC LM358

4.4.4.1 Introduction

Two independent high gain frequency compensated operational amplifiers make up the LM 358. (Op-amp). These are made to operate with either a single supply or two separate supplies at a variety of voltages.

4.4.4.2 Benefits of LM358

1. Internal compensation is used with two operational amplifiers.
2. Direct sensing is permitted when close to GND and VOUT.
3. All logic methods suit it well.
4. Battery and power consumption is appropriate.
5. The need for dual supplies is eliminated.

4.4.4.3 Applications of LM358

1. Used in the DC gain block.
2. Used in Signal Conditioning.
3. Used for active filters.
4. Shock Alarm Circuits
5. Dark Sensor Circuits
6. Operational Circuits

4.4.4.4 Specifications

1. Number of channels (#): 2
2. Total supply voltage (Max) (+5V=5, +/-5V=10): 32
3. Total supply voltage (Min) (+5V=5, +/-5V=10): 3

4.4.4.5 Pin Configuration

Pin	Name	Description
1	OUTPUT 1	First Operational Amplifier Output
2	INPUT 1-	Inverting Input of First Operational Amplifier
3	INPUT 1+	Non-Inverting Input of First Operational Amplifier
4	GND	Ground or Negative Supply to Operational Amplifier
5	INPUT 2+	Non-Inverting Input of Second Operational Amplifier
6	INPUT 2-	Inverting Input of Second Operational Amplifier
7	OUTPUT 2	Second Operational Amplifier Output
8	VCC	Positive Voltage Supply to both Amplifiers

Table 4.4 Pin Configuration of LM358

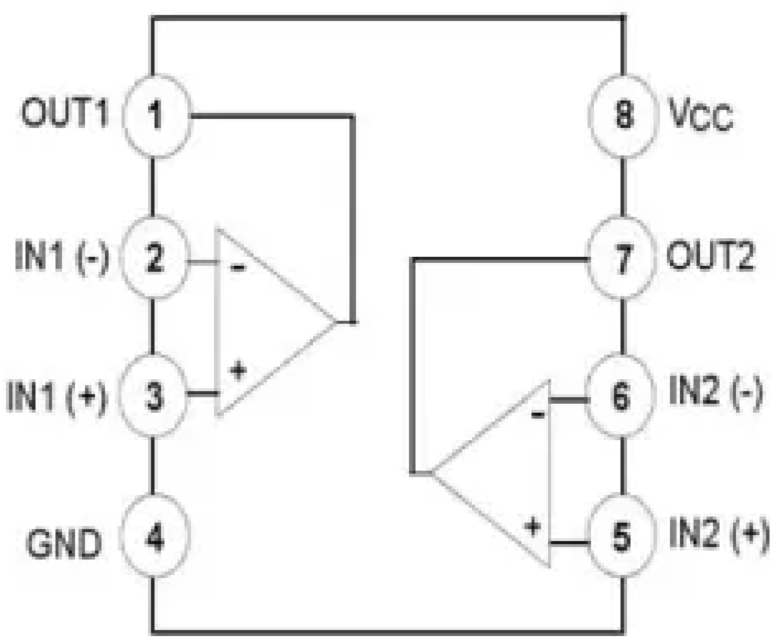

Fig. 4.4 LM358 Pin Configuration

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4.4.5 MICROCONTROLLER COMPARISON

The following is a comparison of the various microcontrollers available on the market.

Parameters	Raspberry Pi	Arduino Uno	Node mcu
Control unit	The Control Unit for the Raspberry Pie is an ARM device.	The ATmega family includes the Control Unit for the Arduino.	The ESP8266 microcontroller chip houses the Control Unit of the Node mcu.
Use	For the purpose of producing useful outputs, the Raspberry Pi is primarily used to compute data and information. It also controls the many parts of any given system based on the outcome.	All of the electrical parts of a system's circuit board are connected to the Arduino, which is used to control them all.	For creating internet-dependent embedded and Internet of Things applications, use Nodemcu.
Type of CPU Architecture	64-bit	8-bit	32-bit
Clock Frequency	1.4GHz - 1.5GHz	16MHz	80MHz
Operating Voltage	5V	5V	3.3V
RAM	>1GB.	>2kB.	SRAM:128 kB; EEPROM: 512 bytes.
Memory	32GB or more. (External SD card)	32 KB (Flash Memory)	4MB (Flash Memory)
Storage	Micro SD Slot	1KB	4MB
CPU	ARM Cortex	Atmel, ARM, Intel	LXT106
Applications	Smart TV, a 3D scanner, a wireless printer, a pirate radio, and a Raspberry Pi oscilloscope	Parking lot counter, H-bridge-based DC motor control testing for water quality, Industrial and domestic automation	IoT device prototyping, network initiatives, and battery-powered, low-power applications

Table 4.5 Microcontroller Comparison

4.4.5.1 PROS AND CONS

4.4.5.1.1 Pros and Cons of Raspberry Pi

Pros -

- The product enables extensive experimentation and transformation into entirely new forms. The user can change the device's capabilities without having to reinstall the software thanks to the easily replaceable SD cards on the board.
- The Raspberry Pi is excellent for adaptive technology because it can play high-definition movies or display visuals, which makes it perfect for prototyping embedded systems. You can build complex, useful structures with this tool at a lower cost.
- Small businesses with limited resources can use this microcomputer to use their product or develop new technology that is integrated into the product. The Raspberry Pi can be used by small business owners to automate any minuscule task, including running a website or acting as a video and database server.

Cons -

- Its processor is slower and it cannot replace a computer. There is no complex multitasking possible while downloading and installing software because it takes time.
- Incompatibility with Windows and other operating systems.
- Instead of those who just want a job done quickly, this is for those who want a device that they can customize to their own needs and preferences. Owners of businesses must decide whether the extra work is worthwhile.

4.4.5.1.2 Pros and Cons of Arduino

Pros -

- It has strong community support
- It has a large number of GPIOs with PWM capabilities, and both analogue and digital pins.
- It is completely open-source.
- It is also user-friendly for beginners.

Cons -

- Large projects cannot be handled by Arduino. On Arduino, there are only a certain number of available inputs and outputs. Additionally, Arduino lacks the power to handle larger projects.
- Arduino can only use a certain amount of power, so it is only suitable for small projects. That implies that it is also less effective and powerful in terms of computation.

4.4.5.1.3 Pros and Cons of Nodemcu

4.4.5.1.4 <u>Pros</u> -

- ❖ It has good speeds of Processor & Memory.
- ❖ It has inbuilt Wi-Fi System.
- ❖ It is compact.
- ❖ It needs low power to operate.

<u>Cons</u> -

- ❖ Needs a lot of computation.
- ❖ May not work with some devices as its only 3.3V.
- ❖ Need to keep the structure small while building the project.

4.4.5.2 Which is better - Nodemcu or Raspberry Pi

The Raspberry Pi easily outperforms the NODEMCU in terms of performance.
The NODEMCU is in front of a two core CPU on the Raspberry Pi, which will enhance the project's quality. The Raspberry Pi's 64 bit ARM Cortex M0+ CPU boosts processor performance in comparison to the NODEMCU, speeding up the production process.
The 32-bit LX106, on which NODEMCU is based, is suitable for projects but appears to operate more slowly than the Raspberry Pi Pico.

4.4.5.3 Which is better - Raspberry Pi or Arduino

Arduino is anytime better because of the following reasons:

- ❖ The Arduino Uno is less expensive than the Raspberry Pi
- ❖ Arduino comes with a number of highly developed libraries for various communication interfaces and devices. The Arduino allows for faster code construction than the Raspberry Pi.
- ❖ Analog inputs are supported by the integrated ADC on the Arduino Uno, whereas analogue inputs on the Raspberry Pi require an external ADC to be connected.
- ❖ Because the Raspberry Pi runs an operating system, shutting it down is necessary if you want to turn it off. Otherwise, the OS risked getting damaged. There is no such problem with the Arduino Uno.

4.4.5.4 Arduino UNO Specifications

- ❖ Microcontroller: ATmega328P
- ❖ Length: 68.6 mm
- ❖ Width: 58.4 mm
- ❖ Weight: 25 g
- ❖ Operating Voltage: 5V
- ❖ Input Voltage (recommended): 7-12V
- ❖ Input Voltage (limit): 6-20V
- ❖ DC Current per I/O Pin: 20 mA
- ❖ DC current for 3.3V Pin: 50 mA
- ❖ Flash Memory: 32 KB
- ❖ SRAM: 2 KB
- ❖ EEPROM: 1 KB
- ❖ Clock Speed: 16 MHz
- ❖ LED_BUILTIN: 13
- ❖ Digital I/O Pins: 14 (6 - PWM O/P)
- ❖ PWM digital I/O Pins: 6
- ❖ Analog Input Pins: 6

BEGINNING TRIALS ON HARDWARE AND SOFTWARE MODEL
(5.1Circuit Simulation , 5.2 Receiver Simulation, 5.3 Transmitter Simulation)

For communication between these two Arduinos using visible light, we created a simple hardware setup using a 3V LED connected to a resistor with an Arduino (Tx) and an Arduino (Rx) with a variable resistor (for range and data loss calibration) to a photo diode (for light detection). We thenbuilt a code with 8-bit data transfer using 0s and 1s (o being light turned off and 1 saying the lighthas turned on).

Receiver code(model 1):

```
#define LDR_PIN A6
#define LED A4
#define SAMPLING_TIME 20


//Declaration
bool led_state = false;
bool previous_state = true;
bool current_state = true;
char buff[64];
void setup()
{
  pinMode(LED,OUTPUT);
  Serial.begin(9600);

}

void loop()
{
  current_state = get_ldr();
  if(!current_state && previous_state)
  {
    sprintf(buff, "%c", get_byte());
    Serial.print(buff);
  }
  digitalWrite(LED, current_state);
  previous_state = current_state;
}
bool get_ldr()
{
  bool val = analogRead(LDR_PIN) > 90 ? true : false;
  digitalWrite(LED, val);
  return val;
}
```

```
char get_byte()
{
  char data_byte = 0;
  delay(SAMPLING_TIME * 1.5);
  for(int i = 0; i < 8; i++)
  {
    data_byte = data_byte | (char)get_ldr() << i;
    delay(SAMPLING_TIME);
  }
  return data_byte;
}
```

Transmitter code(model 1):

```
#define TRANSMIT_LED 11
#define BUTTON 3
#define SAMPLING_TIME 20

char* text = "Li-Fi is wireless communication technology which utilizes light
to transmit data and position between devices. The term was first introduced
by Harald Haas during a 2011 TED Global talk in Edinburgh.";

//Declaration
bool led_state = false;
bool button_state = false;
bool transmit_data = true;
int bytes_counter = 20;
int total_bytes;
void setup() {
  // put your setup code here, to run once:
  pinMode(TRANSMIT_LED,OUTPUT);
  //pinMode(BUTTON,INPUT_PULLUP);
  total_bytes = strlen(text);
}void loop() {
 //button_state=!digitalRead(BUTTON);

   while(transmit_data)
   {
    transmit_byte(text[total_bytes - bytes_counter]);
    bytes_counter--;
      if(bytes_counter == 0)
      {
        transmit_data = false;
      }
     //delay(100);
   }
   transmit_data = true;
   bytes_counter = total_bytes;
   delay(1000);
 }

void transmit_byte(char data_byte)
{
```

```
  digitalWrite(TRANSMIT_LED,LOW);
  delay(SAMPLING_TIME);
  for(int i = 0; i < 8; i++)
  {
    digitalWrite(TRANSMIT_LED,(data_byte >> i) & 0x01);
    delay(SAMPLING_TIME);
  }
 digitalWrite(TRANSMIT_LED,HIGH); //Return to IDLE state
 delay(SAMPLING_TIME);
}
```

5.4 Distance Vs Data Loss

Compared to conventional RF communication, visible light communication has some disadvantages. The biggest disadvantage is that as connection distance rises, the possible data rate progressively decreases. This restricts the bandwidth for use cases involving high data rate VLC. Distance has an inverse relationship with loss. When the photodiode receiver is exposed to direct sunlight, shot noise reduces the data rate of the VLC link, restricting high data rate VLC communication mostly to indoor settings. The requirement to turn on the lights in order to transfer data at connection speeds similar to WiFi is another drawback of VLC. VLC cannot replace high-speed RF transmission due to these factors. In circumstances where long-range, non-line-of-sight, and/or outdoor connectivity are necessary, high-speed RF communications are always used. VLC and HF communication are, in fact, complementary technologies that, when used together, can significantly boost the performance of your wireless network.

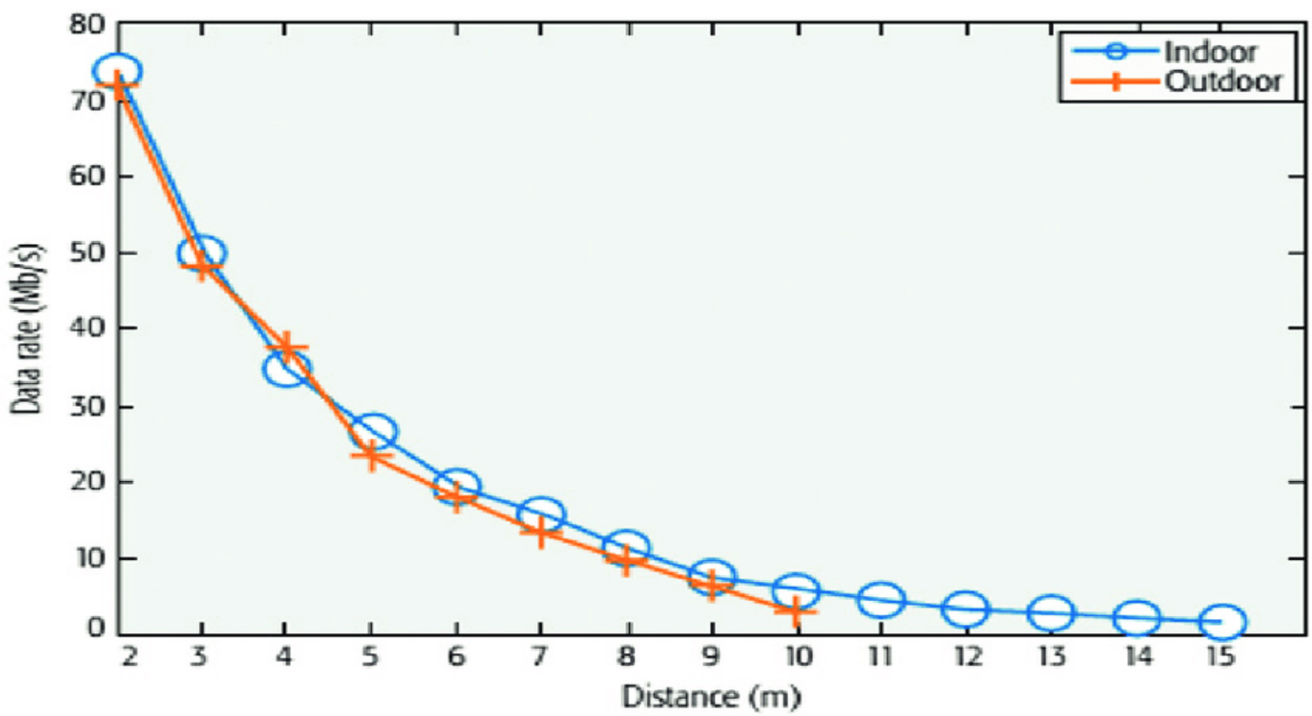


Fig 5.3 diatance vs data loss

5.5 Hardware and Software Final Update Trials

ATTINY85 Trial:

We tried to use the ATTINY85 instead of Arduino to reduce the size of the system but had difficulties and eventually decided against it. In our testing with the ATTINY85, we discovered that it is unable to communicate with the XCTU. In addition, we are using a 12v led as a source to extend the range, but the ATTINY85 only outputs 5v. Therefore, we chose not to employ it.

ATTINY85 Picture:

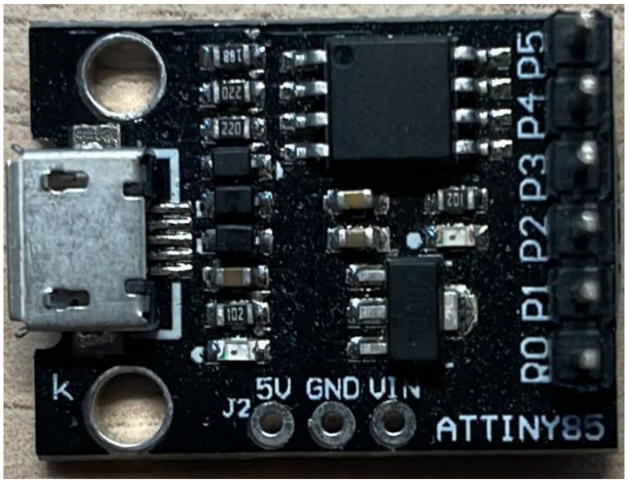


Fig 5.4 ATTINY85

However, we discovered that in order for the Arduino to supply the led with enough power to extend its range, we need a higher voltage led and an additional power source. We were unable to increase the bit rate due to the 8-bit configuration, and even after switching to a 16-bit configuration, we were still unable to achieve sufficient speed and range. As a result, we used an external software (XCTU) with Arduino, which allowed us to transmit data more quickly than in previous tests and extend the range even further by using a solar panel in place of a photo diode.

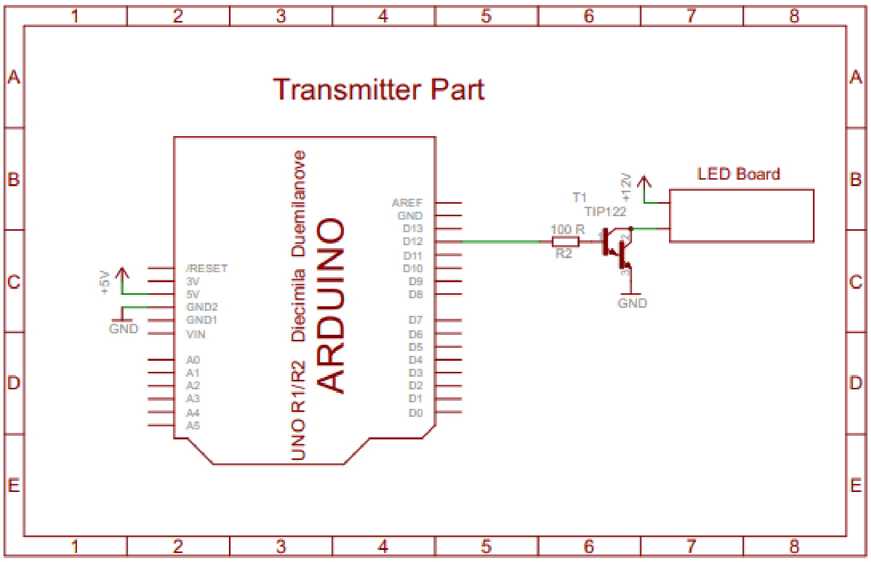
Code:

Tx code:

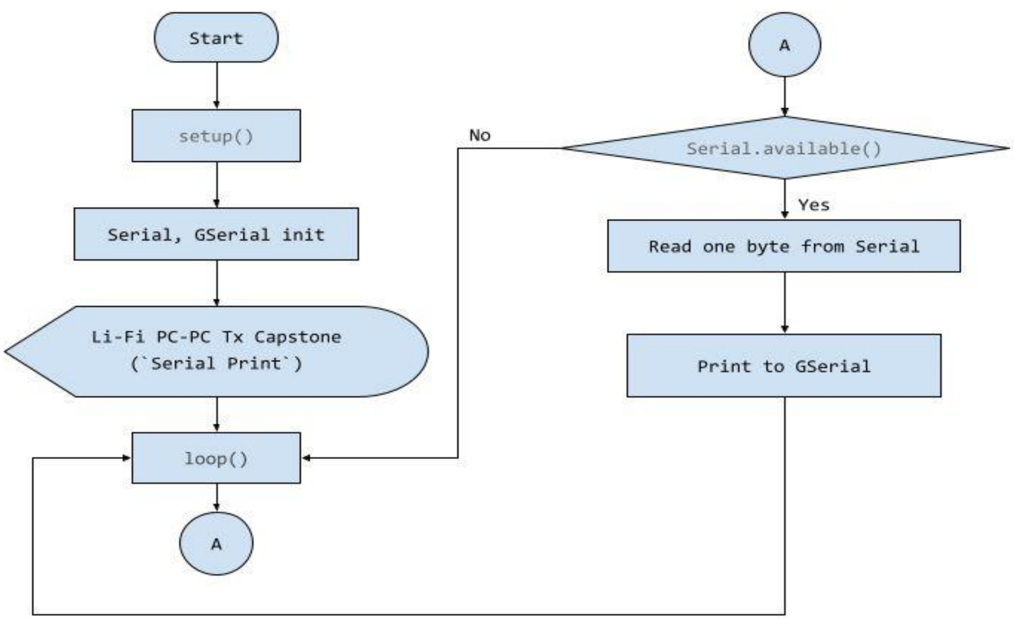
```
#include <SoftwareSerial.h>
SoftwareSerial GSerial(11,12);
void setup()
{
  delay(1000);
  Serial.begin(9600);
  Serial.println("Lifi PC-PC Tx capstone");
  GSerial.begin(400);
}

void loop()
{
```

```
  if (Serial.available())
  {
    // read the next key
    char c = Serial.read();
    GSerial.print(c);
  }
}
```

Schematic:



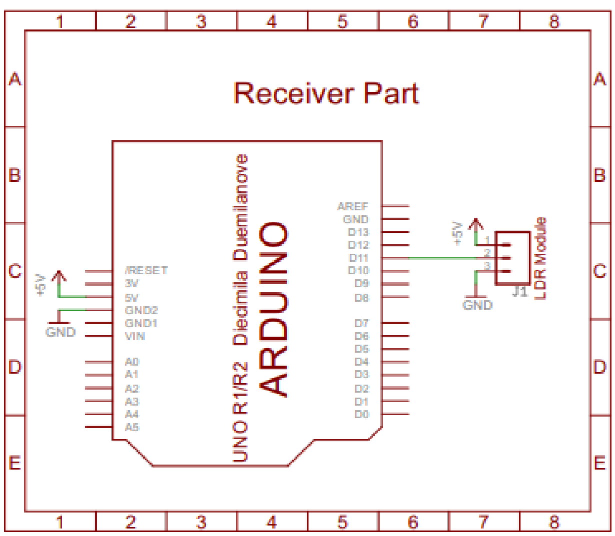
5.61 flow Chart of Code Approach(Tx)

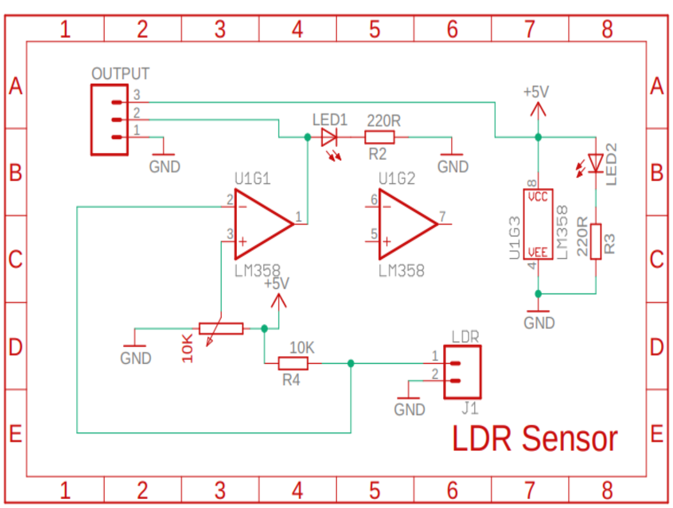


Rx code:

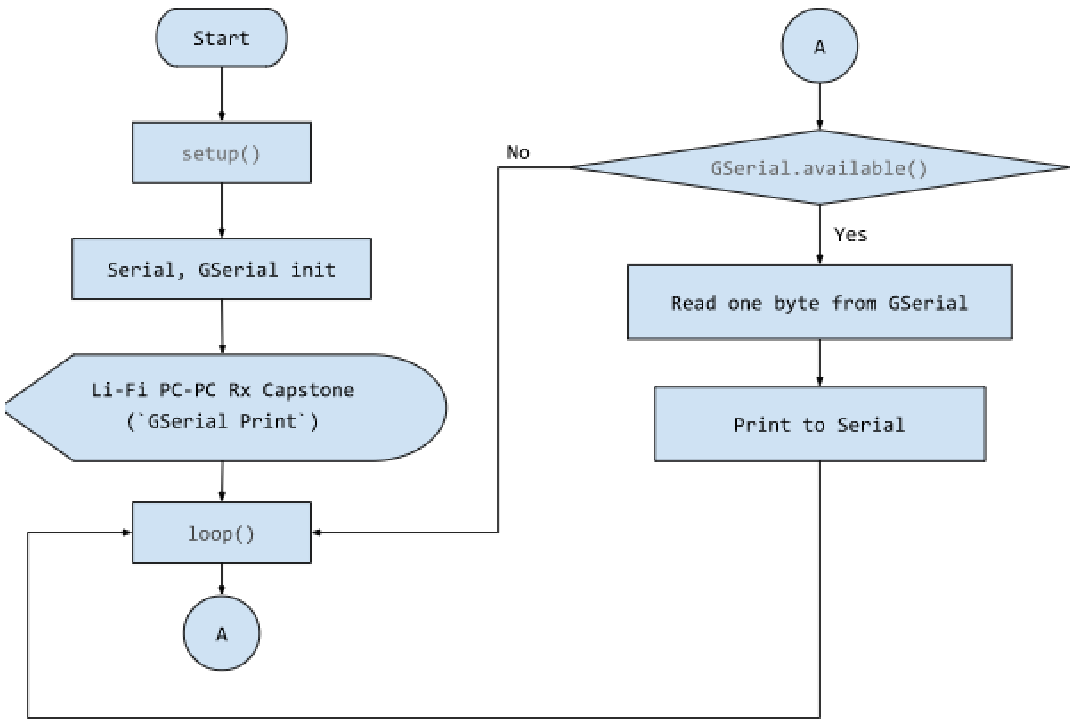
```
#include <SoftwareSerial.h> SoftwareSerial GSerial(11,12);void setup()
{
  delay(1000);
  Serial.begin(9600);
  Serial.println("Lifi PC-PC Rx capstone ");
  GSerial.begin(400);
}
void loop()
{
  if (GSerial.available())
  {
    // read the next key
    char c = GSerial.read();
    Serial.print(c);
  }
  }
```

Schematic:





5.62 Flow Chart of Code Approach(Rx)



5.7Functions used in the Code

5.7.1 SoftwareSerial() - Creates a SoftwareSerial object, and sets the rxPin, and txPin.

5.7.2 setup() and loop() - Standard Arduino functions, which are used to initialize the Arduino [setup], and then code which is to be run continuously without interruption [loop].

5.7.3 delay() - Used to pause program execution, for a given amount of time, specified in ms.

5.7.4 begin() - Starts the serial device, and specifies the initial baud rate.

5.7.5 println() - Prints data to the serial device, followed by a newline, or carriage return.

5.7.6 available() - Returns the number of bytes available for reading on the Serial device.

5.7.7 read() - Reads one byte out of the incoming data.

5.7.8 print() - Prints data to the port, as ASCII text. Integers, and floats are printed with one ASCII character for each digit, and floats have a two decimal place resolution. All other strings, and characters are printed as is.

5.8 Output

Input Text:

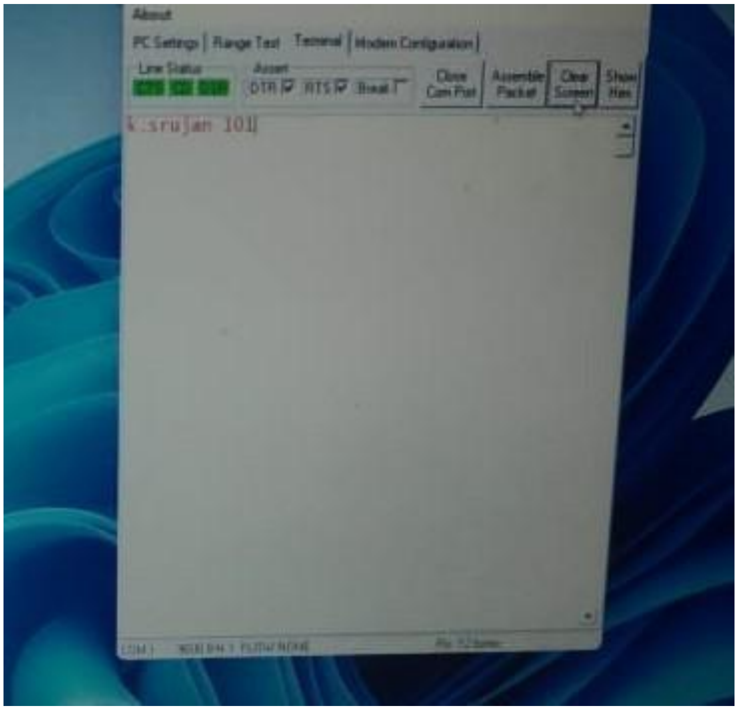


Fig 5.5 Screenshot of Tx terminal in PC

Output Text:

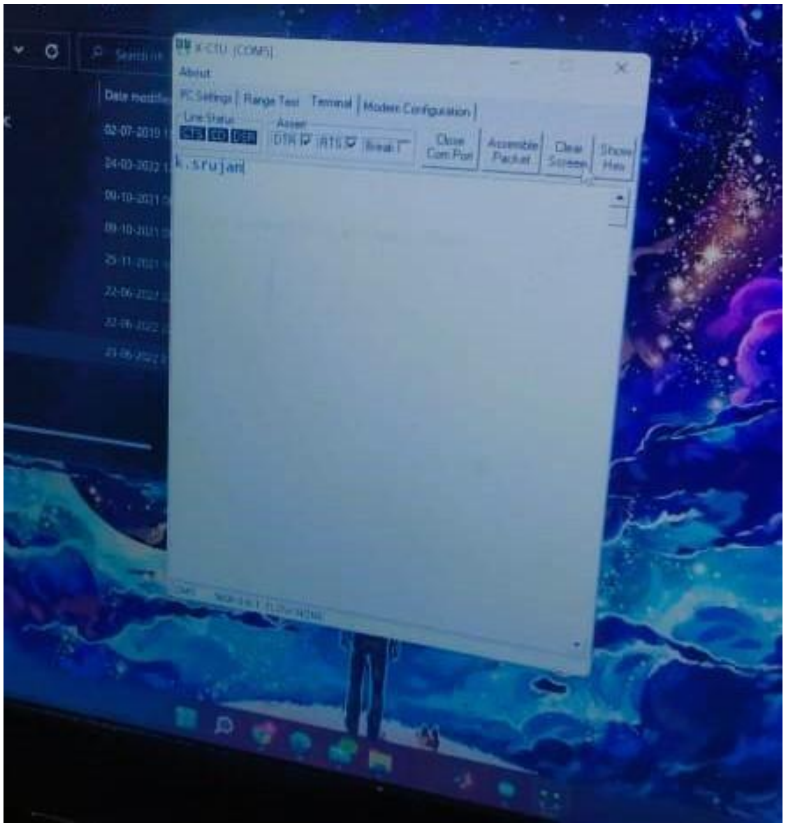


Fig 5.6 Screenshot of Rx terminal in PC

Circuit:

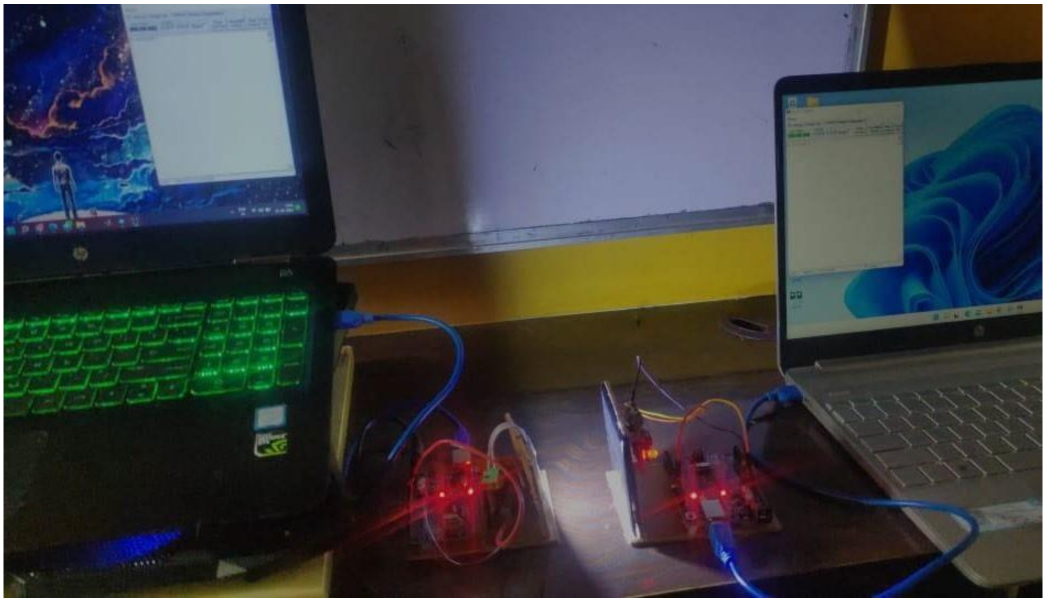


Fig 5.7 Circuit

6.1 Environmental and Economic Benefits

VLC uses less energy since it can be used with LED lighting technology, which uses less electricity. Using LED lighting has several environmental advantages while being more expensive than conventional bulbs. Among them are

- Lifespan: Compared to traditional types of lighting, LEDs can last up to six times longer. As a result, less replacement is required frequently.
- Toxicity: The LED lights don't have any hazardous materials or chemicals in them.
- Bulb Count: For greater light dispersion, LED lighting requires fewer bulbs.

Most users seem to be drawn to VLC speed, but it's remarkable that this cutting-edge technology doesn't pollute the environment by using LED lighting.
These kinds of LED’s and systems area also economically beneficial as mentioned in the cost analysis which prove that its cost and environmentally efficient.

6.2 Conclusion

We have successfully established a link between two devices by using the principle of visible light communication while using Arduino and other components such as LED and have achieved high data link speeds.

7.1 Work Breakdown and Gantt Chart

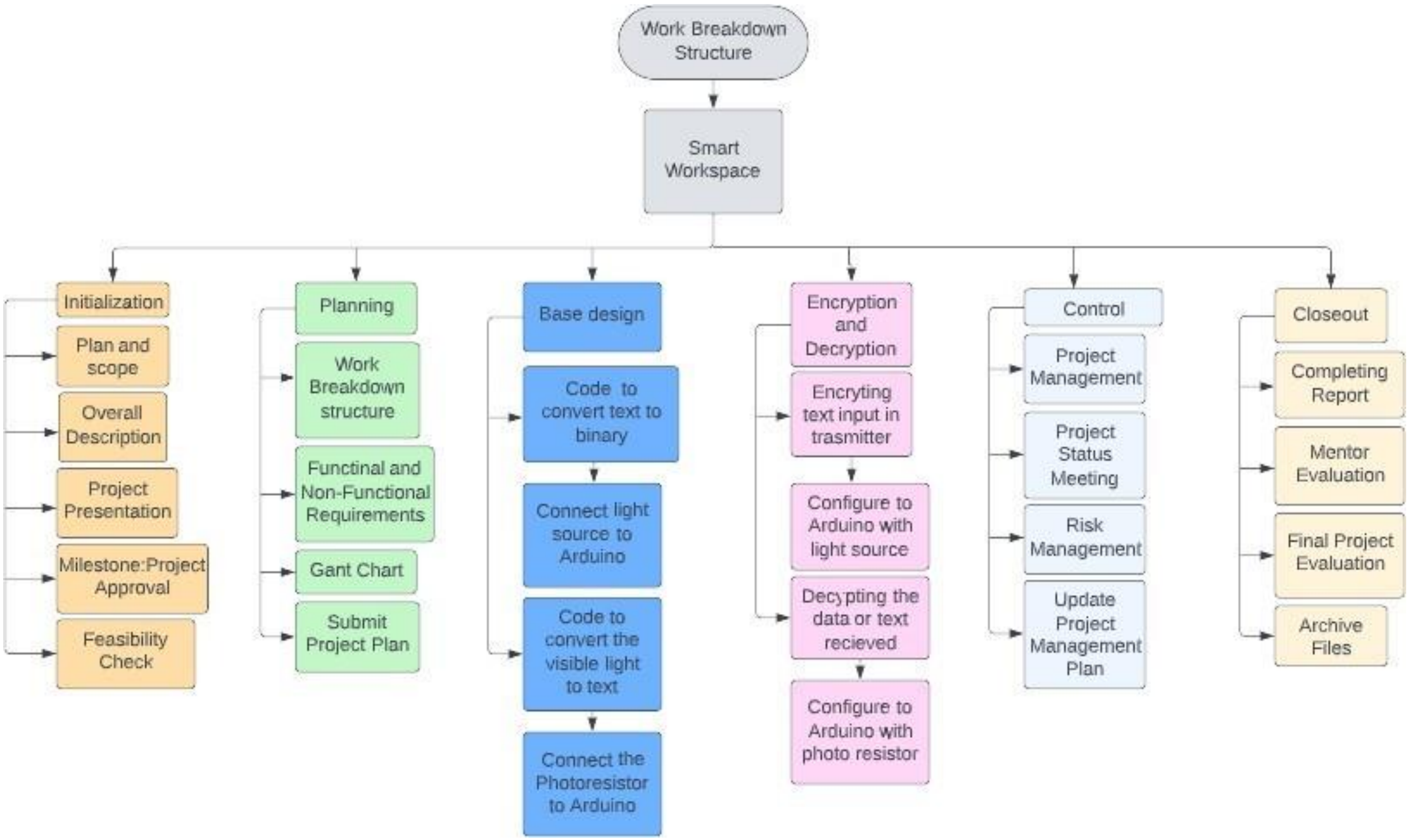


Fig. 5.1 Work Breakdown Structure

Fig. 5.2 Gantt Chart

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