DATA TRANSMISSION THROUGH LIFI USING ARDUINO

[Mini Project Report submitted for the partial fulfillment of the requirements of **Bachelor of Technology** in Electronics and Communication Engineering of Maulana Abul Kalam Azad University of Technology, West Bengal]

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SESSION: 2022 - 2026

Kalyani Government Engineering College

[Govt. of West Bengal]

Certificate of Approval

This is to certify that Akash Poddar, Prantik Roy, Ritika Priya, Soumali Sau have completed the Mini project work entitled **DATA TRANSMISSION THROUGH LIFI USING ARDUINO** under **Dr. SANDIP NANDI** sir supervision. This project work is submitted fulfilling the norms of academic standard for **B.Tech Degree** in **Electronics and Communication Engineering** of the **Maulana Abul Kalam Azad University of Technology**.

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ACKNOWLEDGEMENT

A project is the partial implementation of our technical knowledge and it was a golden opportunity for having a confidence and self-confident. We felt very lucky, blessed and honoured to have so many wonderfully talented people, who always inspired us. Their proper guidance and technical support lead us in completion the project successfully.

We are really grateful and thankful to **Dr. Sandip Nandi** faculty, Dept. of **Electronics and Communication Engineering** of **Kalyani Govt. Engineering College** for his spontaneous guidance and encouragement, which help us to go to the proper path. We are sure about a thing that without his support and technical reason we could not complete this project.

We are grateful to **Dr. Angsuman Sarkar,** Professor and Head of the Department of **Electronics and Communication Engineering of Kalyani Government Engineering College** for allowing us the necessary instruments in the laboratory for basic experiments for carrying out this project properly.

We are also thankful to all the faculty members of the Department of **Electronics and Communication Engineering** of **Kalyani Government Engineering College** for giving us the proper technical support and valuable time, which helped us to complete the work properly. We always got the enthusiasm from them to take the bold step for taking the project. Last but not the least; we got lots of favour from the non-technical faculty members of the Department of Electronics and Communication Engineering of Kalyani Government Engineering College. Thanks to all the friends and mates who has also guided us for project.

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Abstract

This project presents the development of a low-cost Data transmission through Li-Fi (Light Fidelity) using Arduino for wireless data transmission using visible light. The concept replaces traditional radio-based communication with LEDs and photodiodes to achieve short-range, high-speed data transfer. The transmitter modulates data onto a light-emitting diode (LED), and the receiver uses a photodiode to decode the light pulses. This project demonstrates the feasibility of Li-Fi as a secure, interference-free communication method and highlights its application in areas where RF communication is restricted.

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Introduction

Li-Fi stands for Light Fidelity. The technology is very new and was proposed by the German physicist Harald Haas in 2011 TED (Technology, Entertainment, Design) Global Talk on Visible Light Communication (VLC), by referring to it as "data through illumination". He used a table lamp with an LED bulb to transmit a video of a blooming flower that was then projected onto a screen. LiFi is a wireless optical networking technology that uses light emitting diodes (LEDs) for transmission of data.

The technology is similar to Wi-Fi – the key technical difference being that WiFi uses radio frequency to induce an electric tension in an antenna to transmit data, whereas Li-Fi uses the modulation of light intensity to transmit data. Li-Fi is capable of transmitting data at high speeds over the **visible light**, **ultraviolet**, and **infrared spectrums**. Thus, it may offer additional frequency band of the order of **400 THz** compared to that available in RF communication which is about 300 GHz. Researchers have reached data rates of over 224 Gbit/s.

So, by adding new and unutilized bandwidth of visible light to the currently available radio waves for data transfer, Li Fi can play a major role in relieving the heavy loads which the current wireless system is facing.

By Communication through visible light, Li-Fi technology has the possibility to change how we access the Internet, stream videos, receive emails and much more. Security would not be an issue as data can't be accessed in the absence of light. As a result, it can be used in high security military areas where RF communication is prone to eavesdropping.

So, in the era of overcrowded (data communication) world, Li-Fi is a new way of wireless communication that could light a room as well as transmit and receive information.

The main components of a basic Li-Fi system may contain the following:

a) A high brightness white LED which acts as transmission source.

b) A silicon photodiode with good response to visible light as the receiving element.

Switching the LEDs on and off can make them generate digital strings with different combination of 1s and 0s. To generate a new data stream, data can be encoded in the light by varying the flickering rate of the LED. In this way, the LEDs work as a sender by modulating the light with the data signal. The LED output appears constant to the human because they are made to flicker at a phenomenal speed (millions of times per second) and it's impossible for human eye to detect this frequency. Communication rate more than 100 Mbps can be achieved by using high speed LEDs with the help of various multiplexing techniques.

The main objective of our project is to transfer data through Li-Fi for which we are using Arduino on both transmitter and receiver side.

The Arduino at transmitter side is responsible for modulating the intensity of the LED light to generate data and the Arduino at receiver side is doing the work of detecting these light variations using light sensor and therefore decoding the received data.

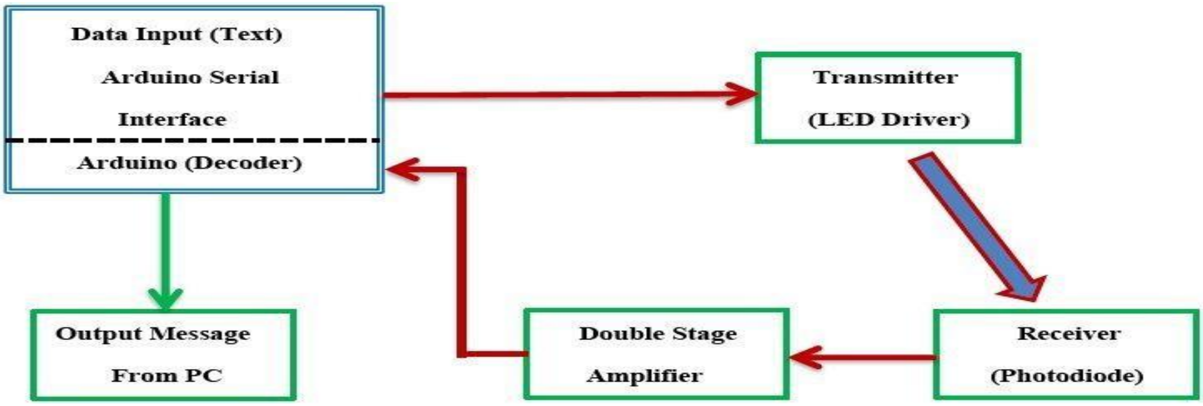

Fig.1: Li-Fi basic block diagram

System Design

Block Diagram:

At transmitter side:

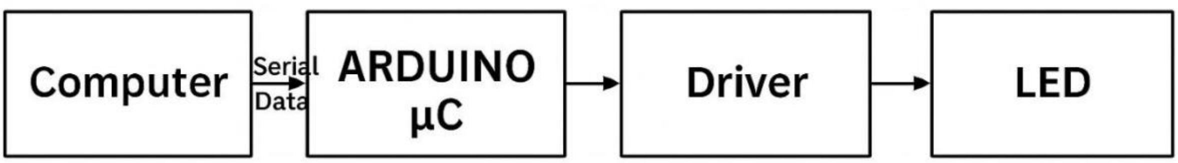

Fig.2: Block Diagram of Transmitter side At receiver side:

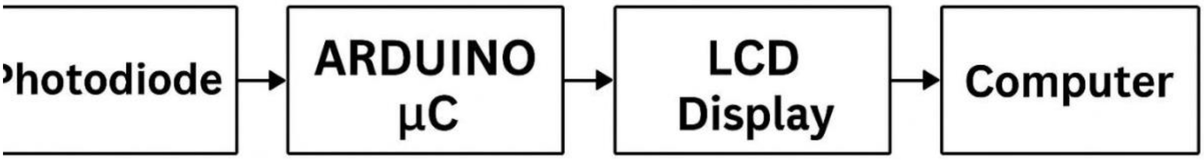

Fig.3: Block Diagram of Receiver side

Complete block diagram:

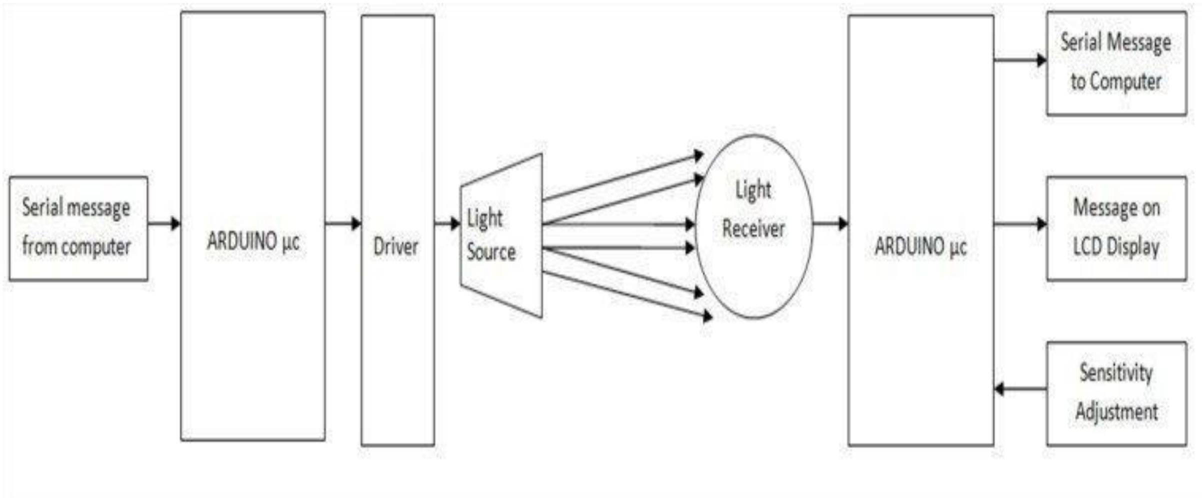

Fig. 4: Complete Block diagram of the Li-Fi system

The above block diagram represents a light-based communication system using Arduino microcontrollers. Let's break down each block:

1. Serial Message from Computer
    - This is the input where a computer sends a serial message to the first Arduino microcontroller.
2. Arduino µC (Microcontroller)
    - The first Arduino receives the serial data and processes it for transmission.
    - The second Arduino processes the received light signal, decoding the data.
3. Driver
    - This circuit acts as an interface between the Arduino and the Light Source, ensuring correct voltage and current levels.

4. Light Source ○ This component transmits data via modulated light signals.
5. Light Receiver
   - ○ A photodetector captures light pulses and converts them back into electronic signals.
6. Serial Message to Computer ○ The decoded signal is sent back to the computer as a serial message.
7. Message on LCD Display ○ The received data is displayed on an LCD screen for visibility.
8. Sensitivity Adjustment ○ This block allows fine-tuning of the light receiver's sensitivity, improving transmission efficiency.

Components used

1. Arduino Nano
2. Arduino UNO
3. LED
4. Mini solar panel
5. Breadboard
6. LCD display 16*2
7. Connecting wires
8. Resistor (220 ohm)
9. 9v battery
10. 2N2222 transistor

Let's understand the use of each component:

1. Arduino Nano

The Arduino Nano is a compact, powerful microcontroller based on the ATmega328P. It is widely used in embedded systems due to its small size, low power consumption, and ease of programming.

Key Features of Arduino Nano

Operating Voltage: 5V Digital I/O Pins: 14 (6 PWM)

Analog Input Pins: 8 Flash Memory: 32 KB

Role in Li-Fi Data Transfer System

In our Li-Fi project, the Arduino Nano plays a crucial role in both the transmitter and receiver sides:

Transmitter Side

- Encodes data from the computer.
- Modulates LED intensity to transmit binary signals.
- Controls the driver circuit to ensure proper voltage levels.

Receiver Side

- Processes signals from the photodiode.
- Decodes light pulses into meaningful data.
- Displays received data on an LCD screen.

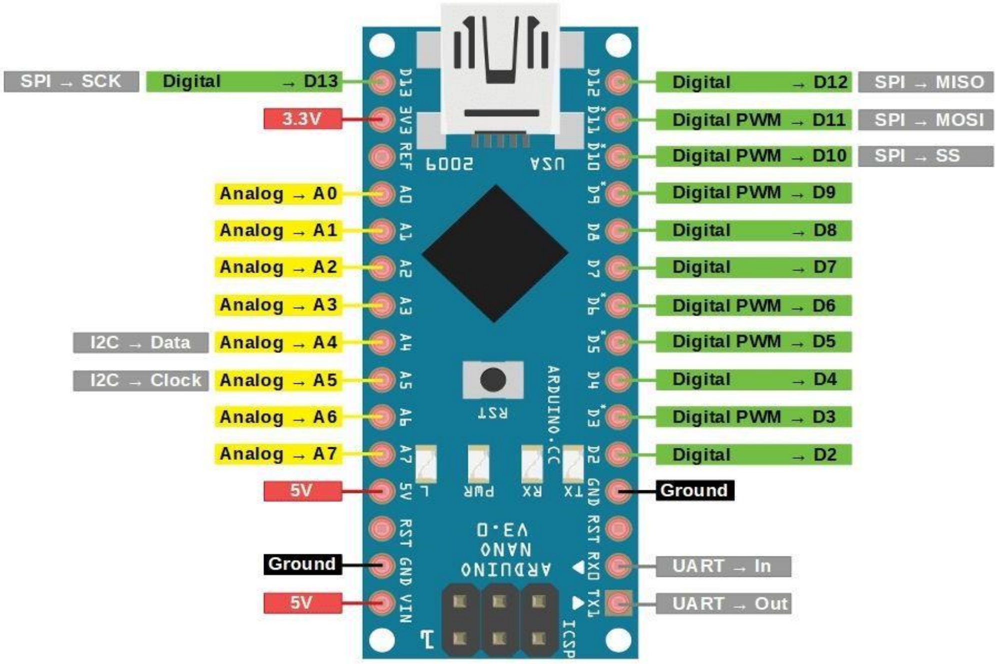

Fig. 5: Arduino Nano

2. Arduino Uno:

Microcontroller: ATmega328P (8-bit AVR)

Operating Voltage: 5V

Digital I/O Pins: 14 (6 support PWM)

Analog Inputs: 6 (A0–A5)

Clock Speed: 16 MHz

Flash Memory: 32 KB (with 0.5 KB used by bootloader)

USB Interface: Standard USB-B for programming and serial communication

Power Options: USB or external (7–12V via barrel jack)

Its robust design, easy USB interface, and ample I/O pins make it ideal for prototyping and real-time control tasks

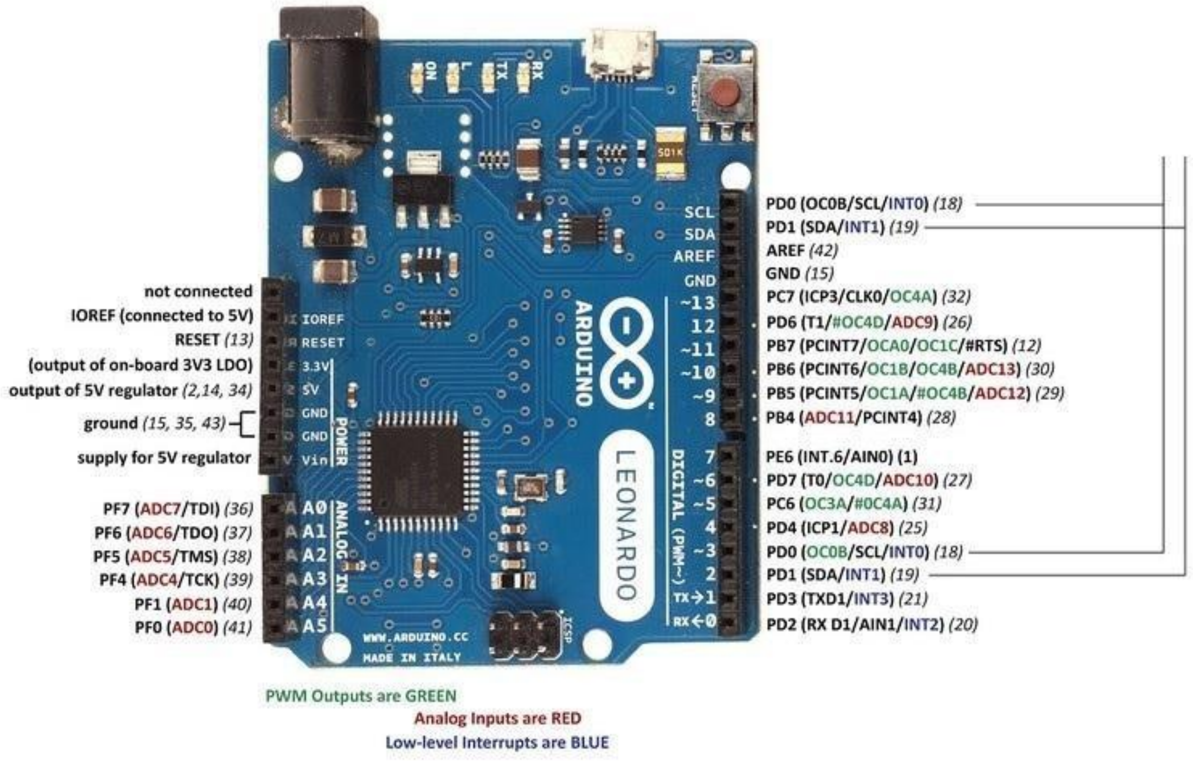

Fig.6: Arduino UNO

Role in our Li-Fi Transmitter:

1. **Serial Data Handling:**
   - Reads user input from the Serial Monitor.
   - Converts characters into binary using your custom protocol.
2. **Bit-Level Modulation:**
   - Controls **digital pin 7** to blink the LEDs in sync with binary data.
   - Implements **On-Off Keying (OOK)** modulation with precise timing (dotDuration).
3. **Signal Control for Driver Circuit:**
   - Sends HIGH/LOW signals to the **base of a transistor** via a resistor.
   - This switches the **dual-LED array** ON and OFF, transmitting data as light pulses.
4. **Timing & Synchronization:**

- Ensures consistent bit duration (100 ms in your code) for reliable decoding at the receiver.

5. **User Feedback:**
    - Sends confirmation messages like "Message Sent!" back to the Serial Monitor.

3. Light-Emitting Diode (LED)

A Light-Emitting Diode (LED) is a semiconductor device that emits light when an electric current passes through it. Unlike traditional bulbs, LEDs are energy-efficient, durable, and capable of high-speed switching, making them ideal for Li-Fi communication.

Key Features of LEDs

- Working Principle: Based on electroluminescence, where electrons recombine with holes to release energy in the form of photons.
- Efficiency: Consumes less power than incandescent bulbs.
- Colour Variations: Different semiconductor materials produce red, green, blue, and white light.
- Switching Speed: Can turn on/off rapidly, enabling data transmission.

Fig.7: LED (light emitting diode)

In our Li-Fi project, the LED plays a crucial role in the transmitter side:

- Encodes data by modulating light intensity.
- Transmits binary signals through rapid switching.
- Ensures high-speed optical communication.

Since LEDs can switch at extremely high frequencies, they enable fast and secure data transmission in Li-Fi systems

4. Mini Solar Panel

A mini solar panel is a compact photovoltaic device that converts sunlight into electrical energy.

In your Li-Fi receiver system, the solar panel functions as a light detector, converting modulated light signals into electrical signals. This process relies on the photoelectric effect, where photons from the transmitted light interact with the solar panel's semiconductor material.

How It Works:

1. Photon Absorption:
   - The solar panel consists of photovoltaic (PV) cells made of semiconductor materials (typically silicon).
   - When light pulses from the transmitter (LED) hit the panel, photons excite electrons in the semiconductor.
2. Electron Excitation & Current Generation:
   - The excited electrons create a potential difference, generating an electrical signal. o The intensity and frequency of the light pulses determine the variation in the output voltage.
3. Signal Processing:
   - The Arduino microcontroller reads the voltage fluctuations.
   - It decodes the modulated light signals into meaningful data.

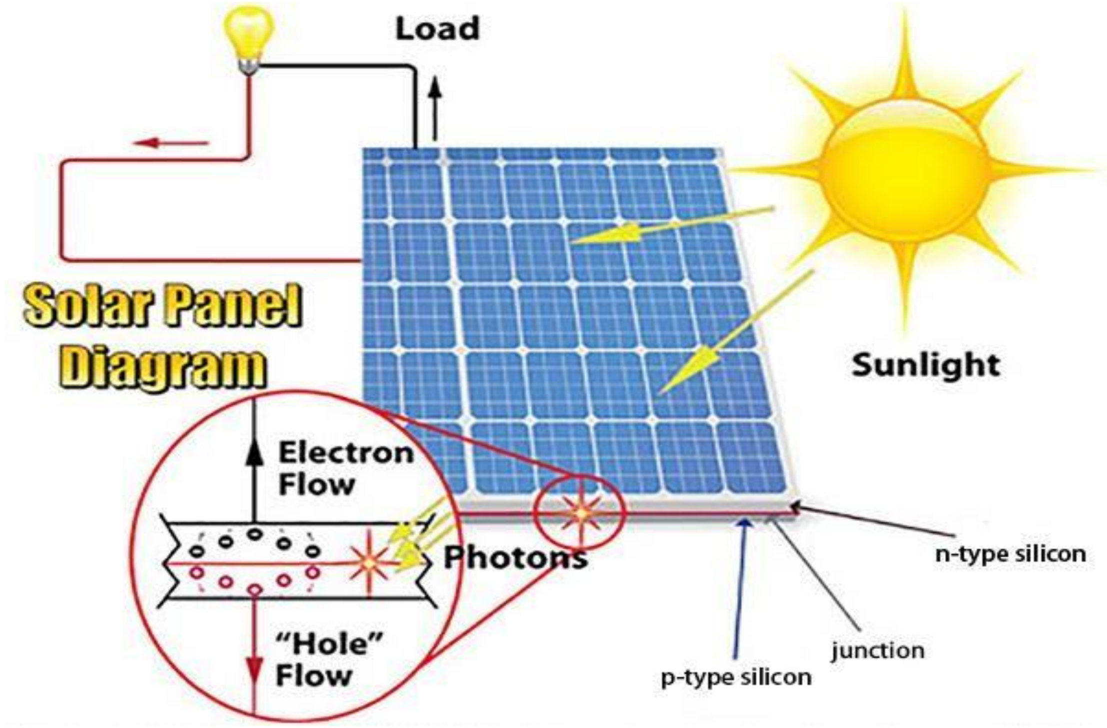

Fig.8. Solar panel

<u>Why Use a Solar Panel Instead of a Photodiode?</u>

- Larger Surface Area: Captures more light, improving signal reception.
- Higher Sensitivity: Can detect small variations in light intensity.
- Efficient Power Conversion: Converts light directly into electrical signals without additional amplification.

4. Breadboard

A **breadboard** is a **solderless prototyping tool** used to build and test electronic circuits without permanent connections. It allows components to be easily inserted and removed, making it ideal for **experimentation and prototyping**

Key Features of Breadboard

□ Plastic **Board with Holes:** The top surface has a **grid of holes** for inserting electronic components and wires.

□ Internal **Metal Strips:** Hidden beneath the holes, these strips **connect specific rows and columns**, allowing electricity to flow.

□ Power **Rails:** Long rows on the edges (often marked **red and blue**) distribute **power and ground** efficiently.

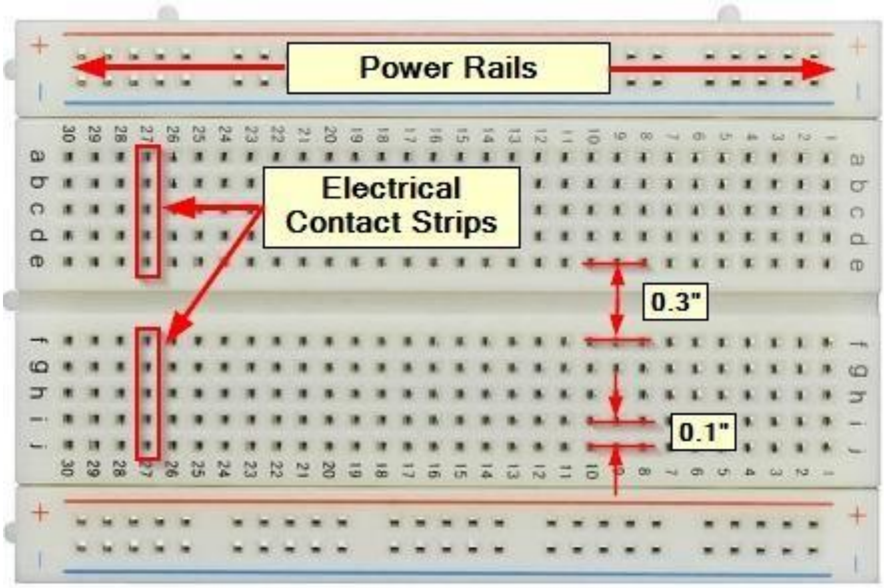

Fig.9. Breadboard

In our Li-Fi project, the breadboard serves as:

- A stable platform for assembling the transmitter and receiver circuits.
- A semi-permanent solution for testing and refining the design.
- An alternative to breadboards, offering better durability and stronger connections.

5. LCD Display

A Liquid Crystal Display (LCD) is a flat-panel display technology that uses liquid crystals to modulate light and create images. Unlike traditional displays, LCDs do not emit light directly but rely on a backlight to illuminate the screen.

Key Features of LCD Displays

- Liquid Crystal Layer: Controls light transmission to form images.
- Polarizers: Manage light direction for better visibility.
- Color Filters: Define pixel colors in color LCDs.
- Low Power Consumption: More efficient than older CRT displays.

Fig.10. 16*2 LCD display

In our Li-Fi project, the LCD display serves as:

- A visual output device to show received data.
- A debugging tool for monitoring transmission accuracy
- An interface for real-time feedback on signal processing.

6. Resistor

A resistor is a passive electrical component that limits current flow and protects sensitive components in a circuit. In the Li-Fi transmitter, the resistor plays a crucial role in ensuring stable operation of the LED.

Key Features of the Resistor

- Resistance Value: Typically, 220Ω to 1kΩ, depending on LED specifications.
- Material: Made of carbon film, metal oxide, or wire-wound.
- Power Rating: Usually, ¼W or ½W for low-power applications.

Fig.11: A Resistor

Role in Li-Fi Transmitter

- Current Limiting: Prevents excessive current from damaging the LED.
- Voltage Regulation: Ensures the LED receives the correct voltage.
- Signal Stability: Helps maintain consistent light modulation for data transmission.

Without a resistor, the LED could overheat or burn out, disrupting the Li-Fi communication system.

7. Battery

A battery is a compact power source commonly used in electronics, communication devices, and embedded systems. It provides a nominal voltage of 9V, though actual voltage can range from 7.2V to 9.6V, depending on the battery chemistry.

Key Features of a 9V Battery

- Voltage: 9V (varies slightly based on type).
- Chemistry: Available in alkaline, lithium, nickel-metal hydride (NiMH), and carbon-zinc variants.
- Size: Typically, 48.5mm × 26.5mm × 17.5mm.

Fig.12: Battery

In our Li-Fi receiver circuit, the 9V battery serves as:

- Primary power source for the Arduino and connected components.
- Stable voltage supply to ensure consistent signal processing.
- Portable energy solution for wireless communication setups.

8. 2N2222 NPN Transistor

The 2N2222 is a classic and widely used NPN bipolar junction transistor (BJT), perfect for general-purpose switching and amplification tasks.

Key Specifications:

Parameter	Value
Type	NPN BJT
Package	TO-18 (metal) or TO-92 (plastic)
Collector-Emitter Voltage	30–40V (depending on variant)
Collector Current	Up to 800 mA
Power Dissipation	~500 mW to 1.2 W
DC Gain	30–300

Transition Frequency ~250 MHz

How It Works

- When a small current flows into the **base**, it allows a much larger current to flow from **collector to emitter**.
- This makes it ideal for **switching applications**, where it acts like an electronic on/off valve.

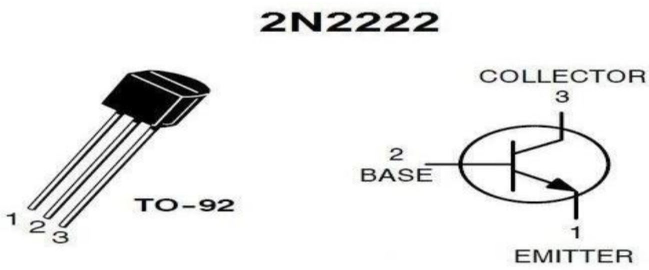

Fig.13: 2N2222 (a NPN transistor) In

our **driver circuit**, the 2N2222:

- **Receives a control signal** from the Arduino at its base.
- **Switches the LED on and off** rapidly to transmit binary data via light.
- **Handles higher current** than the Arduino can directly supply, protecting the microcontroller.

Implementation

This section outlines the step-by-step implementation of the Li-Fi-based data communication system using Arduino. The system consists of a transmitter module that sends data using LED light and a receiver module that interprets the light pulses.

Now to transmit a data, the data must be encoded from digital data to light signal and then that data can easily be transmitted through the LED light. This encoding process is called modulation.

Now let's understand how this process is implemented in our project.

What Is Modulation in Li-Fi?

Modulation is the technique of encoding digital data (like text or numbers) into a light signal that can be transmitted and later decoded. In Li-Fi, this is done by rapidly varying the LED's light output in a way that represents binary data (1s and 0s).

Common Modulation Techniques in Li-Fi are:

1. On-Off Keying (OOK)

2. Pulse Width Modulation (PWM)

3. Frequency Shift Keying (FSK)

4. Orthogonal Frequency Division Multiplexing (OFDM)

In our project we are using the *On-Off Keying (OOK)* technique. Type

of Modulation Used: Serial Bit-Level On-Off Keying (OOK)

This is a form of digital modulation where:

- LED ON represents logic 1
- LED OFF represents logic 0

Arduino is controlling the LED to turn ON and OFF for specific time durations based on the binary representation of each character.

Step-by-Step Breakdown of the Modulation Logic in our Code:

1. Start Bit:

```
digitalWrite(ledPin, HIGH);
delay(dotDuration);
```

- This acts like a wake-up call for the receiver.
- Signals the start of a new character's transmission.

2. 8-bit Binary Data Transmission:

```
for (int i = 7; i >= 0; i--) {
int bitValue = bitRead(c, i);
digitalWrite(ledPin, bitValue);
delay(dotDuration);
}
```

- Each character is transmitted as a sequence of 8 bits (1 byte).
- bitRead(c, i) extracts the i-th bit from the character.
- The LED turns ON or OFF depending on the bit's value.
- Each bit lasts for dotDuration = 100 ms as we have taken dot duration as 100 ms.

3. Stop Bit:

```
digitalWrite(ledPin, LOW);
delay(dotDuration);
```

- Signals the end of the character.
- Ensures spacing before the next byte.

So now we can easily calculate the time needed to transmit 1 character as follows:

Each bit duration is fixed at 10 ms.

So, one character (start + 8 bits + stop) takes:

(1+8+1) ×10ms =100 ms per character

Now after understanding the modulation process which is a part of the transmission process, we return back to the transmission process.

Transmission

- **What it means:** Sending the modulated signal through space using visible light.
- **How it works:**
  - The **LED's brightness** is varied according to the binary signal.
  - A **driver circuit** ensures the LED receives enough current to switch rapidly and brightly. ○ The light beam carries the data across open space to the receiver.

Step by step breakdown of transmission logic in our code:

1. Data Input from Serial Monitor

- The user types a message into the **Serial Monitor**.
- The Arduino reads this message using:

```
String message = Serial.readStringUntil('\n');
```

- This message is then passed to the transmitMessage() function for processing.

2. Character-by-Character Transmission

- Each character in the message is sent one at a time using:

```
for (int i = 0; i < msg.length(); i++) {
transmitChar(msg[i]);
}
```

- This ensures **synchronized and orderly transmission**.

3.Bit-Level Encoding (Modulation):

This is done as per the code discussed above.

4. **Optical Transmission**

- The LED blinks in a pattern that represents the binary form of each character.
- These light pulses travel through open space to the receiver.
- The intensity and timing of the LED's light carry the actual data.

Now we understood the code for transmission but what is a driver cicuit which has been mentioned earlier?

Driver Circuit:

A driver circuit is an interface that connects a low-power control device (like an Arduino) to a high-power component (like an LED, motor, or transistor), ensuring the signal is strong enough to operate the load safely and efficiently.

Purpose of a Driver Circuit in our Li-Fi Project

In our Li-Fi transmitter, the Arduino alone can't supply enough current to drive the LED at the intensity needed for data transmission. The driver circuit:

- **Amplifies the signal** from the Arduino.
- **Protects the microcontroller** from high current draw.
- **Ensures stable modulation** of the LED for accurate data encoding.

Components Used:

Component	Description
NPN Transistor (2N2222)	Acts as a switch to control current to the LED.

Base Resistor (R1)	Limits current from Arduino to transistor base (typically 220Ω–1kΩ).
LED	Emits light for data transmission.
Current-Limiting Resistor	Protects the LED from overcurrent (typically 220Ω).

How It Works

1. Arduino sends a HIGH signal to the transistor's base.
2. The transistor turns on, allowing current to flow from collector to emitter.
3. The LED lights up, transmitting a light pulse.
4. When the Arduino sends LOW, the transistor turns off, and the LED goes dark.

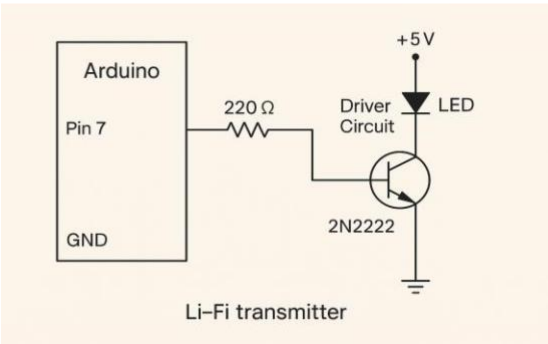

Fig. 14: basic transmitter circuit diagram

Reception

- **What it means:** Capturing the transmitted light and converting it back into usable data.
- **How it works:**
  - A **photodiode** or **solar panel** detects the incoming light pulses. ○ These light variations are converted into **analog voltage signals**. ○ An **operational amplifier (op-amp)** boosts the weak signal for clarity.

- The **Arduino** reads the amplified signal, decodes the binary pattern, and reconstructs the original message.

In our project we are using solar panel for the detection of the light.

Now let's see the step-by-step reception process:

1. Signal Detection (Start Bit)

```
bool detectStartBit() { int value =
analogRead(sensorPin); if (value >
threshold) { delay(dotDuration /
2); return true;
} return
false;
}
```

- Continuously monitors analog input.
- If light intensity **crosses the threshold** (≥175), it assumes a **start bit** is present. In our case we have considered threshold value=175 volts.
- The short delay helps center timing for bit sampling.

2. **Receiving a Character**

```
char receiveChar() {

  byte receivedByte = 0;   for (int i =
7; i >= 0; i--) {
delay(dotDuration);     int value =
analogRead(sensorPin);
    if (value > threshold)
bitWrite(receivedByte, i, 1);
else       bitWrite(receivedByte,
i, 0);
  }
  delay(dotDuration); // Stop bit
delay   return char(receivedByte); }
```

- Reads one bit at a time (from MSB to LSB) at fixed intervals (dotDuration = 10 ms).
- Each bit is reconstructed by comparing light intensity to the threshold.
- Converts the **8 bits** into an ASCII character.

3. **Message Framing Using Start/End Flags**

```
if (receivedChar == '#') receivingMessage = true; else if
(receivedChar == '*') receivingMessage = false;
```

- Messages start with # and end with *.
- Characters between those markers are **appended** to the receivedMessage.

4. **Displaying the Message**

```
lcd.setCursor(0, 0);
lcd.print(receivedMessage);
```

- If the message fits on one line, it's printed directly.
- If it's longer than 16 characters, a **scrolling animation** is triggered by scrollMessage().

5. **Scroll Logic for Long Messages**

```
for (int pos = 0; pos <= displayString.length() - 16;
pos++) {   lcd.print(displayString.substring(pos, pos +
16));   delay(300);
}
```

- Moves a 16-character window across the full string.
- Provides smooth scrolling with configurable speed.

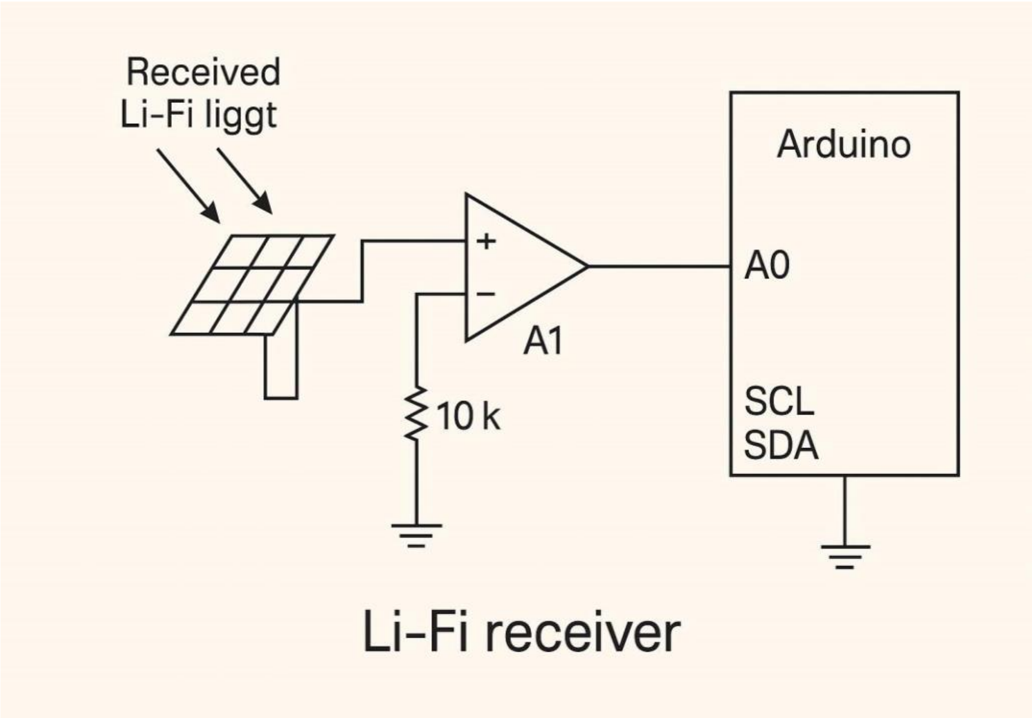

Fig: 15: basic receiver circuit diagram

Output: the output can be clearly seen in the video whose link is given below:

https://drive.google.com/drive/folders/1m8N3WvXmHl4WW3wuRABYoxVQzsRWEJsG

Result & Analysis

Result:

- Successful Data Transmission: Text messages typed into the Serial Monitor were accurately transmitted over a visible light channel using bit-wise LED modulation (via Arduino digital pin 7).

- Receiver Recognition: The solar panel reliably detected rapid ON-OFF light pulses and converted them into analog voltage signals that were processed by the Arduino at the receiver end.
- Accurate Character Decoding: Using your custom protocol with start/stop bits and framing flags (# and *), the system consistently reconstructed the original text.
- Dynamic LCD Output: Messages were correctly displayed on a 16x2 I^2C LCD screen, with longer messages smoothly scrolling across the display.
- Transmission Speed Achieved: With a dotDuration of 10 ms per bit, each character was transmitted in approximately 100 ms, allowing for 10 characters per second under ideal conditions.

Analysis:

Strengths:

- Robust Communication Protocol: Use of start bit, stop bit, and framing characters improved synchronization and reduced decoding errors.

- Effective Use of Solar Panel: As a photodetector, it provided sufficient response time for low-to-moderate transmission speeds, making the system low-cost and energy-efficient.

- Circuit Simplicity with Logical Segmentation: Using a transistor-based LED driver and analog threshold detection kept the design accessible while achieving reliable performance.

- Well-Matched Timing: dotDuration values were symmetrical and consistent across the transmitter and receiver, enabling clean signal interpretation.

Limitations:

- Limited Ambient Light Rejection: Without a filtering system or differential thresholding, bright environmental light could interfere with reception.

- No Error Correction: Noise or missed pulses could result in character misreads, especially at higher baud rates or longer message lengths.
- Speed Constraints: The fixed timing model (bit-by-bit delay and analog sampling) limits the max achievable data rate.

Future Scope of the Project

1. **Higher Data Rates through Advanced Modulation:**
   - Incorporating modulation schemes like **Pulse Position Modulation (PPM)**, **Pulse Amplitude Modulation (PAM)**, or even **Orthogonal Frequency Division Multiplexing (OFDM)** can significantly increase transmission speed.
2. **Bidirectional Communication:**
   - Enhancing your design with a **photodiode or solar cell transmitter** and an **LED receiver** opens the door to **full-duplex data exchange**—essential for two-way communication systems.
3. **Real-Time Audio/Video Streaming:**
   - Upgrading the hardware (e.g., high-speed LEDs and receivers) and optimizing the protocol could allow **live streaming over light**, making Li-Fi practical for IoT or wearable media systems.
4. **Indoor Navigation & Data Broadcasting:**
   - Li-Fi-enabled lighting can be used in **smart classrooms, hospitals, or museums** for location-based information delivery or silent alerts.
5. **Security-First Applications:**
   - Since light doesn't penetrate walls, Li-Fi is naturally confined to a physical space—ideal for **data-secure zones** like banking, defense, or government networks.
6. **Ambient Light Adaptation:**

- Introducing **photodiode arrays**, **IR filters**, and **auto-thresholding algorithms** would make the system adaptable to a variety of lighting conditions—even daylight environments.

7. **Integration with Internet of Things (IoT):**
    - Your system could be embedded into **smart home devices**, enabling fast, localized communication without electromagnetic interference.
8. **PCB-Based Miniaturization:**
    - Transitioning from breadboard/veroboard to a **custom PCB** would allow for **compact, scalable deployment**—essential for real-world productization.
9. **Hybrid Communication Networks:**
    - Future iterations could combine **Li-Fi with Wi-Fi**, creating robust hybrid systems where devices seamlessly switch between mediums for optimized performance.

Conclusion

This project successfully demonstrates a functional **Li-Fi (Light Fidelity) communication system** using an Arduino-based platform. By employing a **LED transmitter** and a **solar panel-based receiver**, data was transmitted through **modulated visible light**, showcasing the potential of optical wireless communication.

The use of **On-Off Keying (OOK)** modulation and **serial bit-level encoding** allowed the system to reliably transmit ASCII characters. The receiver circuit interpreted these light pulses using **analog thresholding** and reconstructed messages with impressive clarity on an **I²C LCD display**. The transmission protocol incorporated **start and stop bits** along with **custom framing characters**, enhancing message integrity.

This project not only highlights the feasibility of low-cost Li-Fi systems for secure, short-range communication, but also opens doors for future enhancements such as **faster modulation schemes**, **error correction**, or **ambient light filtering** for outdoor use.

Overall, the system reflects a well-integrated synergy of **hardware control**, **signal processing**, and **user interface design**, reinforcing your deep interest in innovative communication technologies and hands-on embedded development.

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Appendix

Source Code:

1.Transmitter Code:

```
// Final Transmitter Code with Flags const
int ledPin = 7;
int dotDuration = 10; // Duration for each bit in ms

void setup() {
pinMode(ledPin, OUTPUT);
  Serial.begin(9600);
  Serial.println("Enter text to transmit via Li-Fi:");
}

void loop() {   if
(Serial.available()) {
    String message = Serial.readStringUntil('\n');     message =
"#" + message + "*";  // Add start and end flags
transmitMessage(message);
    Serial.println("Message Sent!");
  }
}

void transmitMessage(String msg) {
for (int i = 0; i < msg.length(); i++) {
transmitChar(msg[i]);
    delay(dotDuration * 3); // Space between characters
  }
}

void transmitChar(char c) {
// Send start bit (HIGH)
```

```
digitalWrite(ledPin, HIGH);
delay(dotDuration);

  // Send 8 data bits   for (int i =
7; i >= 0; i--) {     int bitValue =
bitRead(c, i);
digitalWrite(ledPin, bitValue);
delay(dotDuration);
  }

  //   Send   stop   bit   (LOW)
digitalWrite(ledPin,   LOW);
delay(dotDuration);
}
```

2.Receiver Code

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// Initialize the LCD (Address: 0x27, 16 columns, 2 rows)
LiquidCrystal_I2C lcd(0x27, 16, 2);

const int sensorPin = A0;
int threshold = 175; // Adjust based on your sensor's output int
dotDuration = 10; // Must match transmitter

String receivedMessage = ""; // Store current message bool
receivingMessage = false; // Flag to track message reception bool
newMessageReady = false; // Flag to trigger display
```

```
void setup() {
Serial.begin(9600);
lcd.init();   lcd.backlight();
lcd.setCursor(0, 0);
lcd.print("Listening...");
}

void loop() {   if
(detectStartBit()) {
    char receivedChar = receiveChar();

    if (isPrintable(receivedChar)) {
      if (receivedChar == '#') { // Start of message flag
receivedMessage = ""; // Clear old message         receivingMessage
= true;
      } else if (receivedChar == '*') { // End of message flag
receivingMessage = false; // Message complete         newMessageReady
= true; // Ready to display
      } else if (receivingMessage) { // Only store characters between flags
receivedMessage += receivedChar;
      }
    }
  }

  if (newMessageReady) {
Serial.println(receivedMessage);     lcd.clear();
    if (receivedMessage.length() <= 16) {
lcd.setCursor(0, 0);       lcd.print(receivedMessage);
```

```
    } else {
      scrollMessage(receivedMessage);
    }
    newMessageReady = false; // Message displayed, wait for next
  }
}

bool detectStartBit() {   int value = analogRead(sensorPin);
if (value > threshold) { // Detected a HIGH start bit
delay(dotDuration / 2); // Center timing on the first data bit
return true;
  }   return
false;
}

char receiveChar() {
byte receivedByte = 0;

  // Read 8 data bits   for
(int i = 7; i >= 0; i--) {
delay(dotDuration);
    int value = analogRead(sensorPin);
if (value > threshold) {
bitWrite(receivedByte, i, 1);
    } else {
      bitWrite(receivedByte, i, 0);
    }
  }
```

```
  // Read stop bit (optional)
delay(dotDuration);

  return char(receivedByte);
}

bool isPrintable(char c) {
  return (c >= 32 && c <= 126); // Accept only standard printable ASCII
characters
}

void scrollMessage(String msg) {
int messageLength = msg.length();
  String displayString = msg + "   "; // Add spacing for smooth scrolling

  for (int pos = 0; pos <= displayString.length() - 16; pos++) {
lcd.setCursor(0, 0);
    lcd.print(displayString.substring(pos, pos + 16));
delay(300); // Scroll speed (adjustable)
  }
}
```

Basic Circuit Diagram:

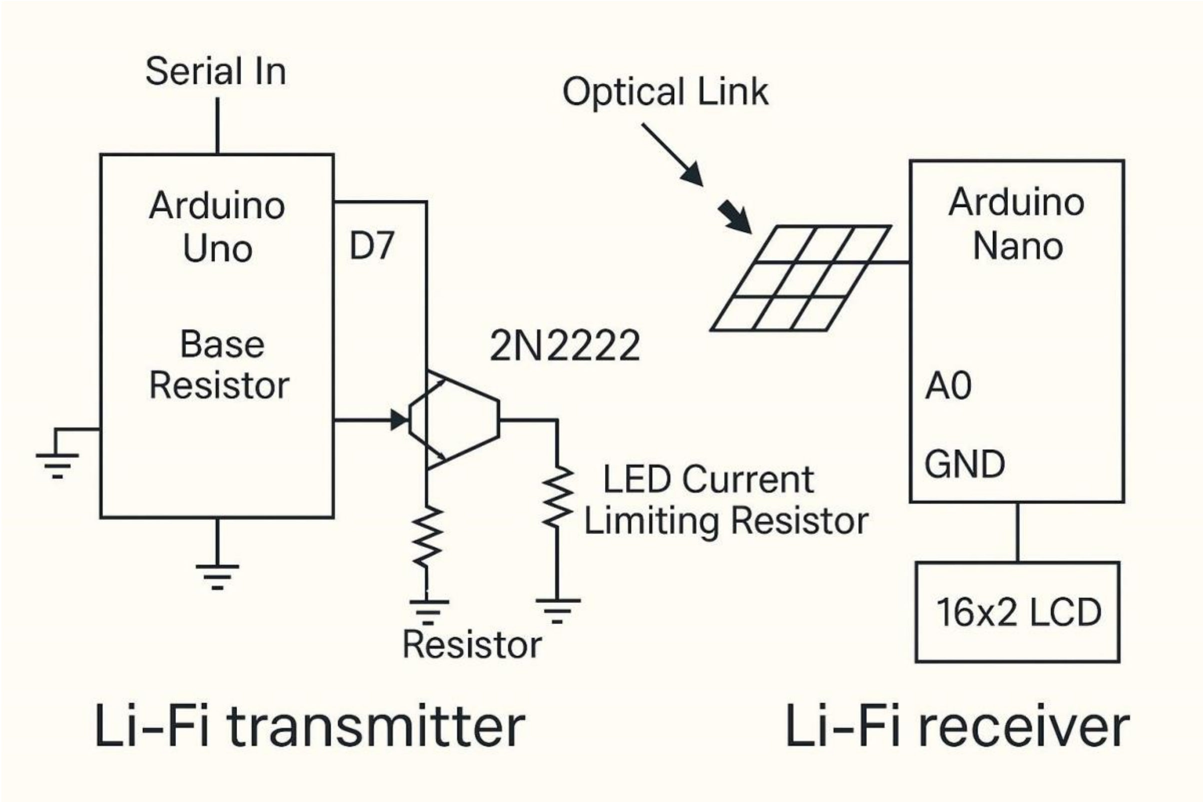

Fig: 16: basic circuit diagram of the project

Real Circuit:

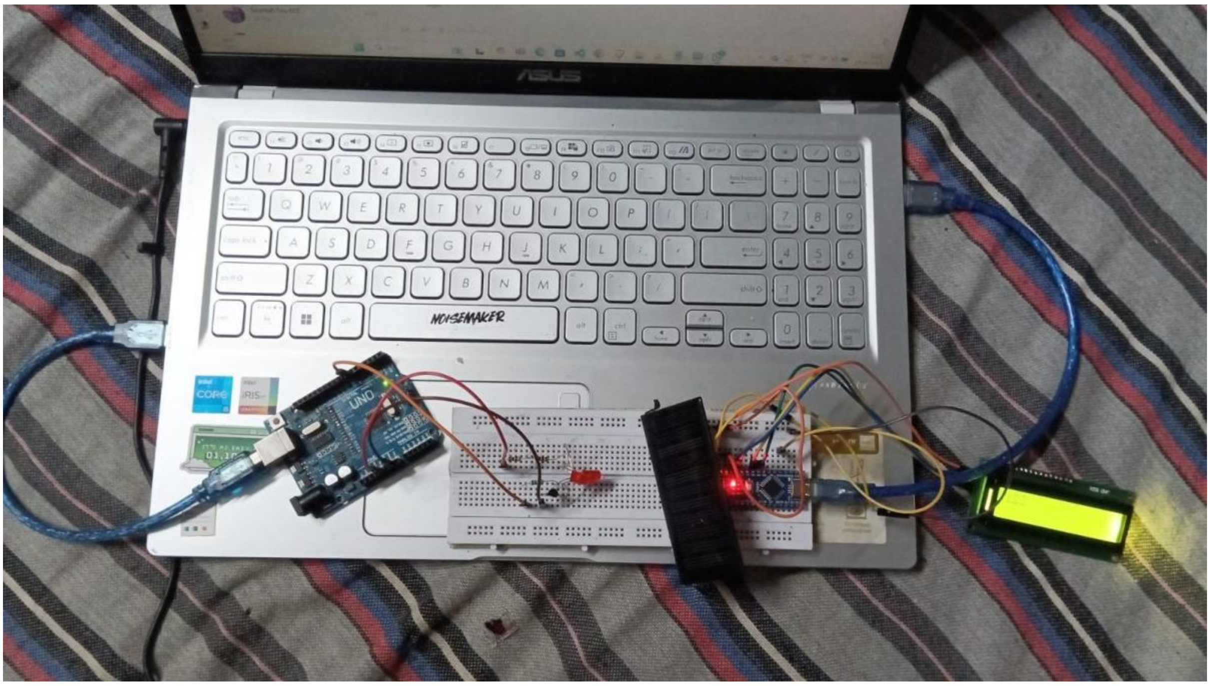

Fig.17: Image of the real circuit

Project Cost:

Transmitter Side (Arduino Uno + Driver + LED)

Component	Quantity	Unit Price (INR)	Total (INR)
Arduino Uno R3 (Clone)	1	₹450	₹450
2N2222 NPN Transistor	1	₹10	₹10
Resistor (Base)	1	₹2	₹2
Resistor (LED)	2	₹2	₹4
High-Brightness LED (5mm)	3	₹5	₹15
Jumper Wires + Breadboard	1 set	₹100	₹100
USB Cable (Type B)	1	₹50	₹50
Subtotal			**₹631**

Receiver Side (Arduino Nano + Solar Panel + LCD)

Component	Quantity	Unit Price (INR)	Total (INR)
Arduino Nano (Clone)	1	₹350	₹350
Solar Panel (Small, 5V)	1	₹80	₹80
16×2 I²C LCD Display	1	₹180	₹180
USB Cable (Mini or Type-C)	1	₹50	₹50
Subtotal			**₹660**

Total Estimated Cost: ₹631 + ₹660 = ₹ 1,291