ES116: Laser-based Communication Module

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***Abstract*: This paper describes the project developed deriving inspiration from demonstration in class where Professor Chakraborty and Rituparna Ma'am communicated 1's and 0's by manually turning their laser pointers On and Off. We built a robust system capable of communicating using laser to transmit information encoded by Arduino and our code. After countless rounds of building, debugging, rebuilding and modifications we have built an electronic system that does what we first conceptualized and much more.**

Keywords—Laser, Light Detection, Binary Encoding and Communication.

I. Introduction

A. Aim

To develop a transmitter-receiver system that takes a string input from the user and transmits it to the receiver using **laser pulses** corresponding to a 6-bit binary dictionary. Decoding the pulses gives the transmitter's operator the initial string message. The system must be capable of **automatic synchronization** (clock signals), alignment and should function in **Medium-Long Ranges** effectively.

B. Apparatus

1. Arduino UNO Boards (x2)
2. Laptops with Arduino IDE Interface (x2)
3. Photodiodes (x2)
4. Laser diodes (x2)
5. Servo Motor
6. LED Light
7. 10K Ohm Resistors (x2)
8. Jumper Wires, Breadboards.
9. Material for Breadboard Stands

II. Theory

A. Photodiodes

A photodiode is a semiconductor-based photosensor that is used to **detect and measure the intensity of light**. It allows current to pass through it when light falls on it. Practically, the more intense the light, the more current passes through it. It consists of a PN Junction Diode operating under reverse-biased conditions.

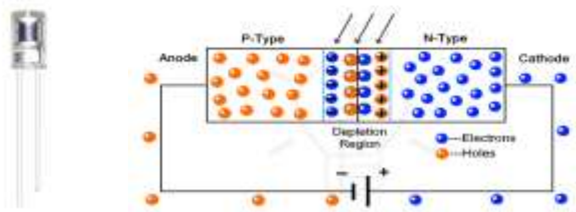

Image 1,2: Semi-Cylindrical Photodiode and Working of Photodiode

Working: When light with photons of energy (hv) higher than that of the Energy Gap of the semiconductor falls on the depletion layer of the PN Junction, electrons are freed and electron-hole pairs are generated They move in opposite directions (electron towards the +ve terminal, holes towards the -ve terminal) resulting in photocurrent. [1]

Role here: Acted as the **main cell of the receiver** to detect pulses. Also used for **alignment and clock signals**. We used this instead of a LDR since its readings were consistently high compared to the alternatives.

B. Laser Diode

The Laser is one of the only successful engineering products that was developed before its application was devised. Laser diode is a semiconductor-based device used for producing light that is **coherent** (of a particular frequency, this is the reason it **does not lose a lot intensity over distance**) and focused at a small point. It is extensively used in fiber optical communication, bar code reader, laser printing and scanning, etc.

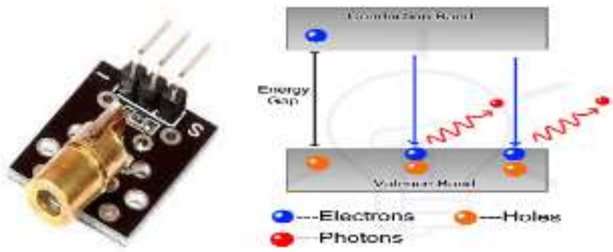

Image 3,4: 3-Pin Laser Diode and Working of Laser Diode

Working: The PN Junction is operated under forward bias which forces the recombination of electron-hole pairs upon which energy equivalent to the bandgap is released as photons. To maintain coherency and make sure light is released (and not heat), it is critical to ensure that the materials used so that Direct Band Gap (i.e. energy equal to exactly Energy Gap) is in use, else heat shall be released. [2]

Role here: To **release focused light on the opposite photodiode** for clock signals, alignment, and actual communication. LED lights were not used here as they are not intense enough over long distances.

III. Circuit and Setup

Transmitter Circuit: Photodiode and resistor were connected in series, and the voltage across the resistor is measured using the analog A0 pin. The LED Light (for Unsupported Character Notification) is connected to digital pin 7. The Laser (meant to transmit information via pulses) is operated from the 8th Digital Pin.

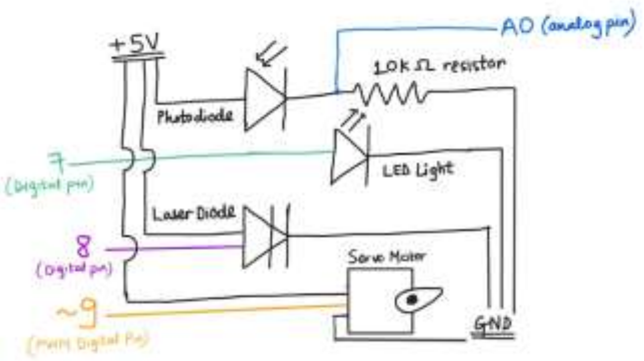

Image 5: Transmitter Circuit Diagram

The 9th Digital Pin, a PWM (Pulse Width Modulation) capable pin, operates the Servo Motor. All these pins come from a Arduino UNO Board running the transmission code. All of this is set up on a breadboard sitting atop the said servo motor.

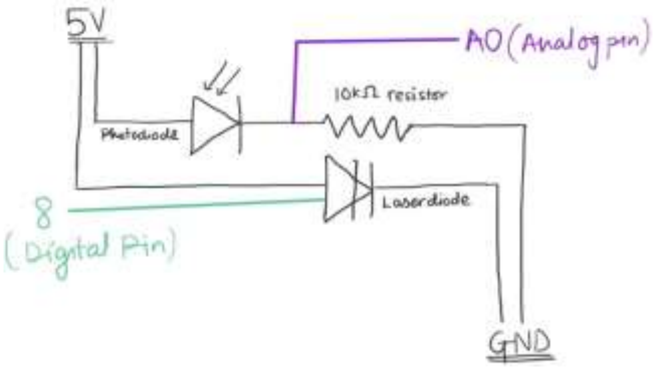

Image 6: Receiver Circuit Diagram

Receiver Circuit: The Arduino UNO Board operates the Receiver by taking readings of voltage across the resistor through the A0 pin. The Laser is run through the Digital Pin No. 8. All of this is set up on a breadboard only.

IV. WORKING OF THE SYTEM

Preparation: Both the modules must be connected to one laptop each with the appropriate transmitter/receiver running code on the Arduino IDE. **Vertical alignment** of the height of the laser pointers and photo diodes to be ensured.

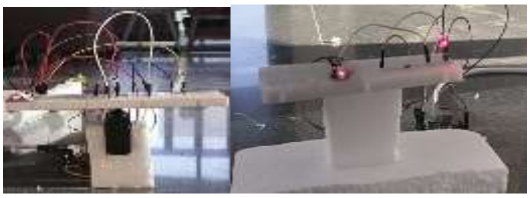

Image 7: Actual Photos of Receiver and Transmitter

1. Receiver turns on. Its clock line and signal line is turned on for the next 30 seconds. (This is T -30)
2. User enters the message into the Serial Monitor. After pressing enter, the alignment process starts.
3. The servo-motor scans 180 degrees of horizontal range. The code records the position where the photodiode received maximum intensity of light (ideally, when it faces the receiver's laser line) and returns the module to that position after the first sweep.
4. After waiting for 4 seconds, it waits for the photodiode to detect the absence of light (i.e. the end of the 30 seconds countdown given by receiver) and this marks T0 for the system.
5. The transmitter laser shoots 2-second-long pulses for every 1 and shuts off for 2 seconds for every 0. There is no demarcation between subsequent characters, but instead a continuous string which the receiver is trained to break into 6-bit sub strings. The same custom-made dictionary on both ends achieves the encoding and decoding.
6. In case one of the characters to be transmitted is not a part of the dictionary, the transmission stops and the LED Light indicating failure lights up. The process must then be restarted.

V. BUILDING PROCESS

We made two channels in the team initially, one to work on the transmitter and the other receiver. Both were built in an incremental fashion and additional features were added as we went along the way.

Stage 1: Transmitter that takes binary string input and gives corresponding output via the Laser. Receiver that is capable of printing continuous binary strings (at 2 second interval per bit) on the basis of a predefined threshold value.

Stage 2: Transmitter that takes a single character input (and then complete string) for input. Receiver that breaks the continuous string into 6-bit binary strings and converts it back to a character. Manual syncing and alignment.

Stage 3: Addition of servomotor which: a. initially stopped at a position above a threshold value; changed since the value was often reached before the best value was even scanned b. scans 180 degrees of horizontal range and aligns at max position. Clock that triggers immediately after alignment; clock system changed due to the delay in the mechanical alignment of the system.

Stage 4: Alignment line of the receiver serves as the clock signal. After alignment is complete, T0 is marked when receiver shuts off its laser.

Features explored: LED Light/Buzzer for unsupported characters (Added), Multiple Receiver Systems (can be integrated into current model), lens integration (Rejected after trials suggested it was an unnecessary hindrance)

VI. RESULTS AND CONCLUSION

We largely achieved our objectives of developing a system that can operate on **Medium-Long Distances and has an inbuilt clock, while adding features like auto-alignment** and making the project robust enough to operate even in daytime conditions. In the process, we learnt the harsh realities of executing code on real electrical devices.

The simplest example of this would be the difficulties we faced in aligning the Laser vertically on the opposite

Photodiode. Using **a photodiode with a larger receiving** surface will mitigate this situation. We used lens to focus the light on the photodiode but realized it was unnecessary due to the distance we operated at.

The clock system was changed multiple times to overcome the time the servomotor takes to reach the correct position. We can add multiple receivers, which the servomotor will align itself to one-after-the-other. The speed of the transmission can reached 50 ms/bit but were then slowed down to 2 seconds/bit to visually inspect every signal.

Future Scope: We can use Optic Fibre Cables to further increase the speed of communication. It will take away the Wireless Ability of the system, but the tradeoff is that signals cannot be interfered with and will travel a longer distance.

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