Indian Institute of Technology Bombay
Department of Electrical Engineering
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Course Project Report

Course: EE 344: Electronic Design Lab

Project Group No: TUE-JJ-6-2

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Project Title: Data Transmission using Visible Light Communication

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Abstract:

Visible Light Communication(VLC) is a data communication technique where the visible range is used as a medium of communication. VLC uses white Light Emitting Diodes (LED), for transmission, which sends data by flashing light at speeds undetectable to the human eye. The visible range is much larger in size than the range used by Wi-Fi systems. VLC systems can be useful in scenarios where data security is very important since visible light transmission cannot cross walls. These systems can also be useful in places like flights where EM waves are not allowed to be used due to the interference it can cause to other electronics systems.
In this project, we complete a simplex VLC communication link capable of transmitting upto 100Kbps at 50cm, 200Kbps at 30cm, 500Kbps at 10cm. We have also transmitted text using the VLC link.

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1 Introduction

With the ever increasing demand for wireless communication , it has become necessary to innovate and utilize parts of the electromagnetic spectrum other than the radio frequencies. One such promising candidate is the visible spectrum (wavelengths in the range of 400 nm to 700 nm). Communication using this spectrum is called as Visible Light Communication(VLC). VLC is definitely an answer for the problems posed by RF communication. It can be achieved through the already existing resources except for an additional photodiode which is inexpensive. Since visible light does not have the ability to escape a room or pass an obstacle , secure communication in indoors can be achieved. It also operates at frequencies much higher than the radio spectrum which is a solution for RF's bandwidth problems.

In this project, we attempt to implement Visible Light Communication to achieve data transmission rates of 1 Mbps at a distance of one metre. We also attempt to demonstrate a practical application using the link by performing text transmission and reception.

2 System Overview

The following, as shown in 2, are the various block components we use-

1. **Data Input:** Input bits are obtained from the laptop for text transmission and for general link testing we use a Pseudo Random Bit Sequence (PRBS) generator.
2. **USB to UART :** USB UART module PL2303 is used to convert the bits into TTL logic levels and serially communicate them to the LED driver IC.
3. **LED Driver:** The output digital signal from the UART is passed to the open-collector hex inverter(7404) which is used for driving the LED.
4. **LED:** A 3 V , 1 A rated white LED is used as our light source.
5. **Photo Diode:** The photodiode (BPW34) would receive the flashing LED signal and generate a current proportional to the intensity of the received light.
6. **Trans-Impedance Amplifier:** We use TL081 in the inverting configuration, which would convert the generated current to a voltage signal.
7. **Active High Pass Filter:** We use HPF to centre the incoming signal to 0 mean so that we can use 0 as the threshold for the comparator. An active HPF of gain 10 was designed so that the received signal can be amplified for easy usage of comparator.
8. **Comparator:** The voltage signal is now converted to a square wave by thresholding with 0 voltage. We use LM311 IC for this.
9. **UART to USB:** The binary output from the comparator is fed to the Laptop using UART to USB module and the text is generated back.

3 Project Implementation

3.1 Pseudo Random Bit Sequence generation

Initially, we developed a PRBS generator using shift register(74195) and XOR gate(7486). This generator is used to validate whether the link works for all types of data. We have given the clock signal using an AFG which determines the output bit rate. The XOR gate takes Q0 and Q3 bits of the shift register as input and the output of the XOR gate is fed back into J,K pins of 74195. Initial trigger is provided by disconnecting and reconnecting the feedback path.

3.2 Text Transmission

In order to transmit text we have used PL2303 USB UART module that produces TTL output and thus can directly be interfaced with the hex inverter. We used Realterm software to set the baud rate, to read and to write the text.

3.3 Transmitter

As part of the transmitter we used a 3V,1A rated white LED and this LED was driven using hex inverter 7404. The bits to be transmitted are given as input to the hex inverter and the output of the hex inverter is connected to the cathode of the LED through 120 Ω resistors. The anode of the LED is connected to 5V. All 6 channels in the hex inverter have been used to maximize intensity of the LED.

3.4 Receiver

The receiver consists of a trans-impedence amplifier which is used in the inverting configuration and takes input from the photodiode. The optimal feedback resistor and capacitor values were found to be 40 kΩ and 10 pF. An active HPF of gain 10 is designed using LM741. This helps in amplifying the signal and also in removing any offset due to ambient light. The output of the filter is given as input to the comparator LM311. An inverter may be used to flip the bits back to original configuration.

4 Testing and Evaluation

Initially we had tested each and every block individually before interfacing with the neighbouring blocks. Integrated link testing was done using AFG and PRBS generator.

- AFG was used for generating a square wave which was used to drive the LED. It was checked whether the output of the trans-impedence amplifier was indeed a square wave. The test was performed at various frequencies to confirm the link's working.
- Same test as above was performed except that PRBS was used as input to the LED. We had performed this test multiple times varying frequency and distance between transmitter and receiver.

Final evaluation of the link was done using text transmission at multiple baud rates and the optimal baud rate for transmission was found. PCBs were designed , printed and tested for PRBS based transmitter.

5 Experiments and Results

Table 1 shows the transmission rates achieved at various distances while using PRBS.
Figure 9 shows the PRBS output waveform when the PRBS block was tested individually.
Figure 10 and Figure 11 show the output waveform observed when a square wave is given as input to the transimtter at 100 kHz and 1 MHz respectively.
Figures 12, 13 and 14 show the received waveform according to the PRBS input at various frequencies and distances.
Text to text transmission was achieved at a distance of 30 cm and baud rate of 57600.

6 Conclusions

A Visible Light Communication link was successfully setup and transmission rates upto 1 MHz and distances upto 50 cm have been achieved. A practical application of the link , that is text transmission ,was demonstrated in live.
Going further bulkier data such as audio and video can be transmitted using the link. Greater distances can be achieved by using more intense light source and optical concentrators. Various encoding schemes can be elaborated to improve performance. Optical filters may be used to remove ambient light.

Acknowledgements

We would like to thank Prof. Joseph John for believing that we are capable to do this project and for providing invaluable guidance at every step. We would also like to thank Prof. Tallur , Prof. Pandey and Prof. Tuckley for explaining how various design choices are made. We are grateful to Maheshwar sir , Sekhar sir and all the WEL RAs and TAs for helping us with all types of problems and also for allowing us to work late in the night.

References

[1] Datasheets of components used

[2] Visible light communication: Applications, architecture, standardization and research challenges, Available online: https://www.sciencedirect.com/science/article/pii/S2352864816300335

Appendix: Bill Of Materials

S. No.	**Items**	**Quantity**	**Approx. Cost(Rs)**
1	Hex inverter(7404)	2	Available in wel
2	7486	1	Available in wel
3	74195	1	Available in wel
4	Op-amps(TL-081)	1	Available in wel
5	LM741	1	Available in wel
6	Comparator (LM311)	1	Available in wel
7	Photodiode(BPW34)	1	Available in wel
8	PL2302 USB UART Modules	2	Available in wel

Figure 1: Bill Of Materials

Tables

Table 1: Transmission rates achieved

Sl	Distance (in cm)	Transmission rate (in kbps)
1	4	1000
2	10	500
3	30	200
4	50	100

Figures

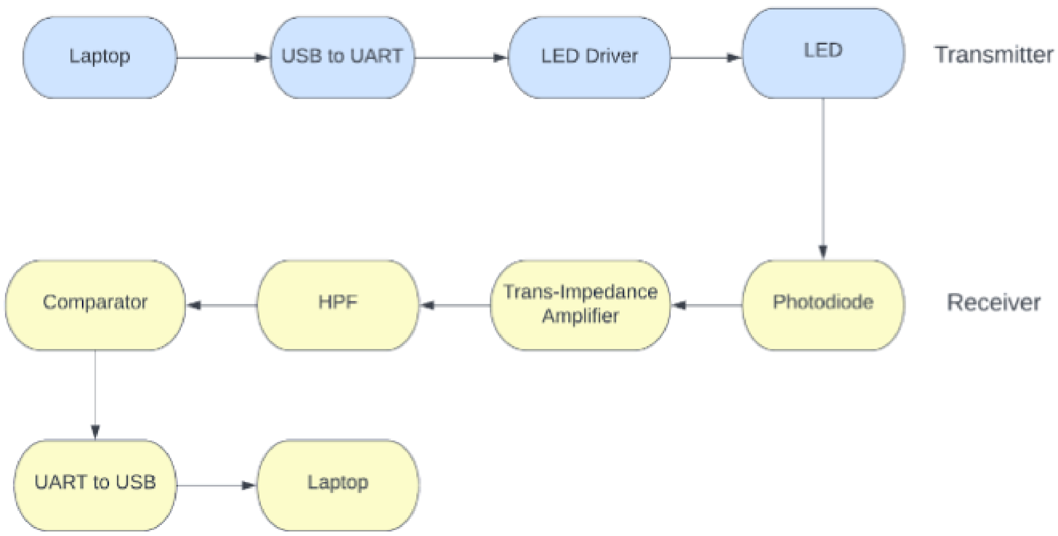

Figure 2: Block Diagram

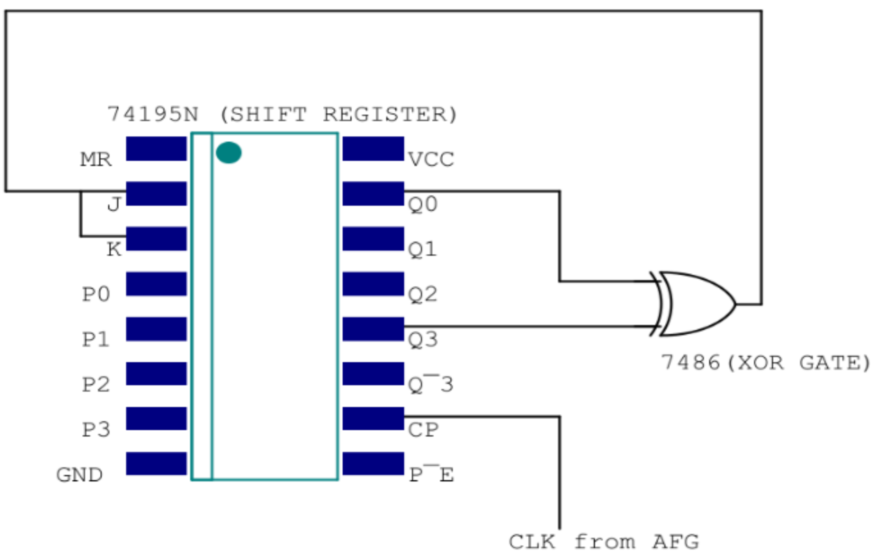

Figure 3: PRBS

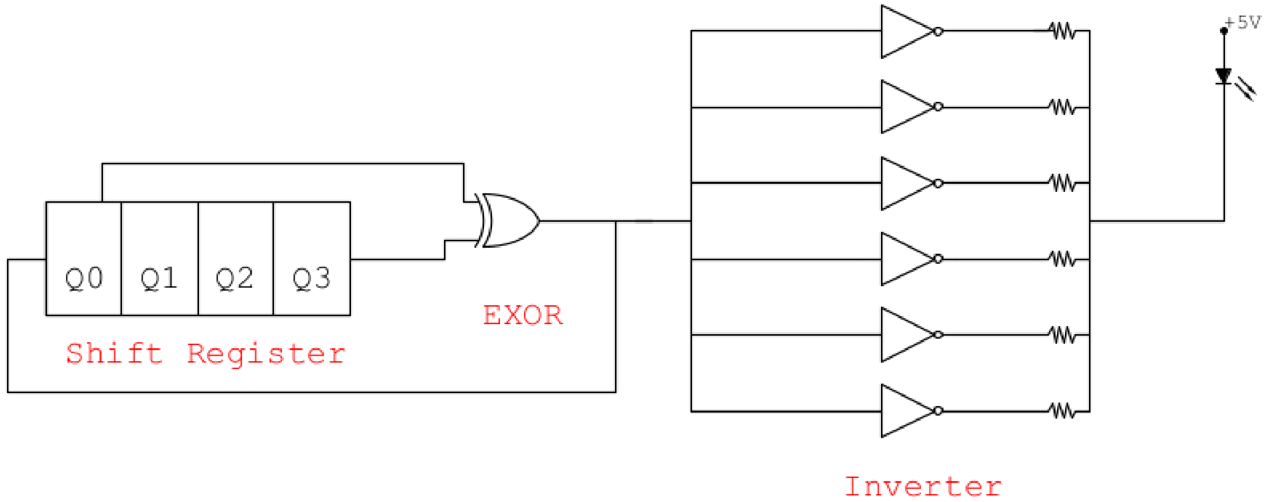

Figure 4: Transmitter Circuit Diagram

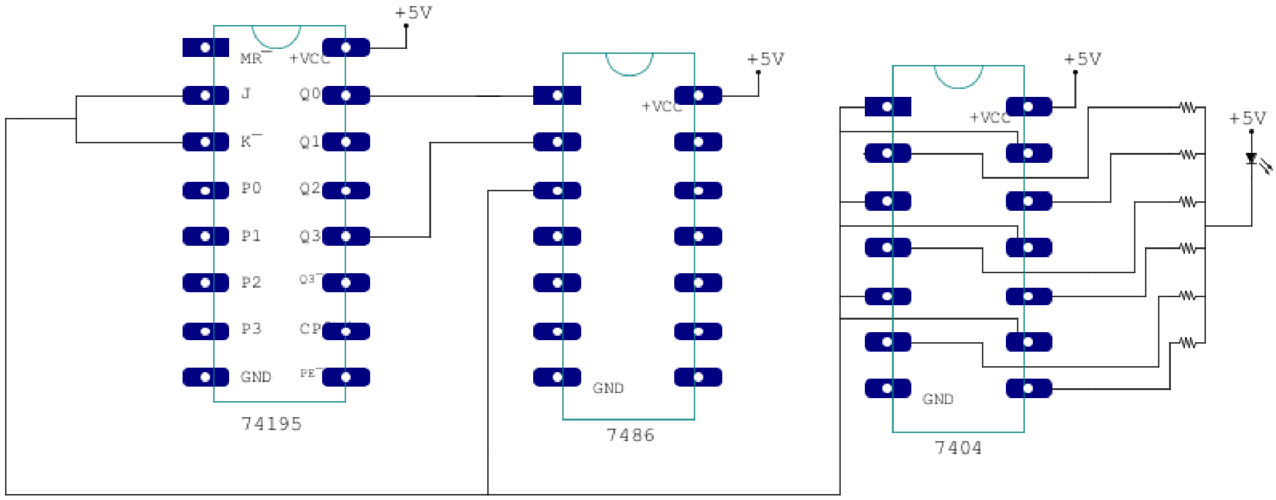

Figure 5: Transmitter

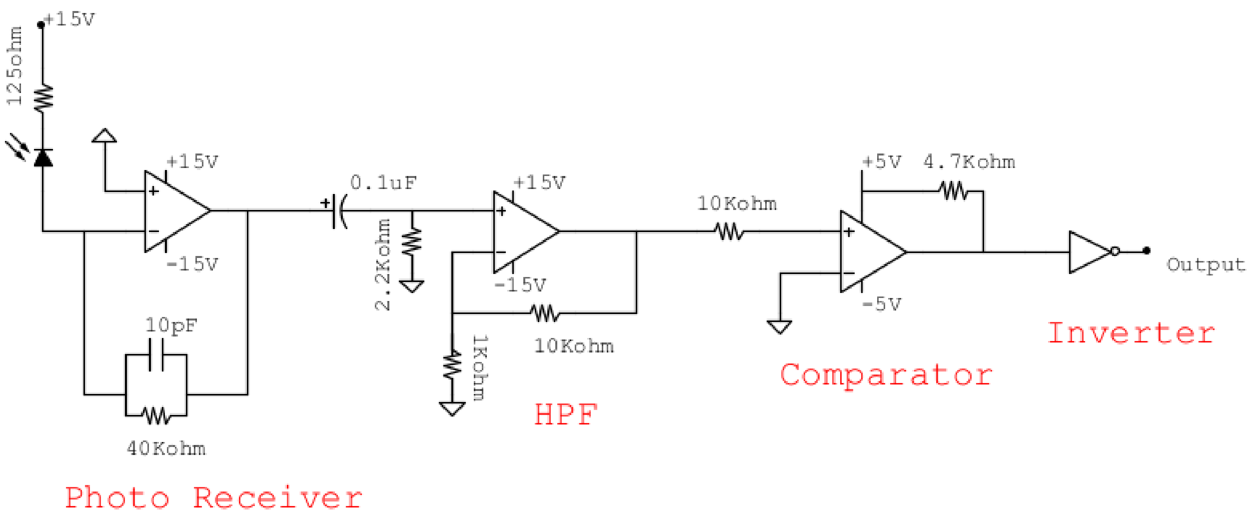

Figure 6: Receiver Circuit Diagram

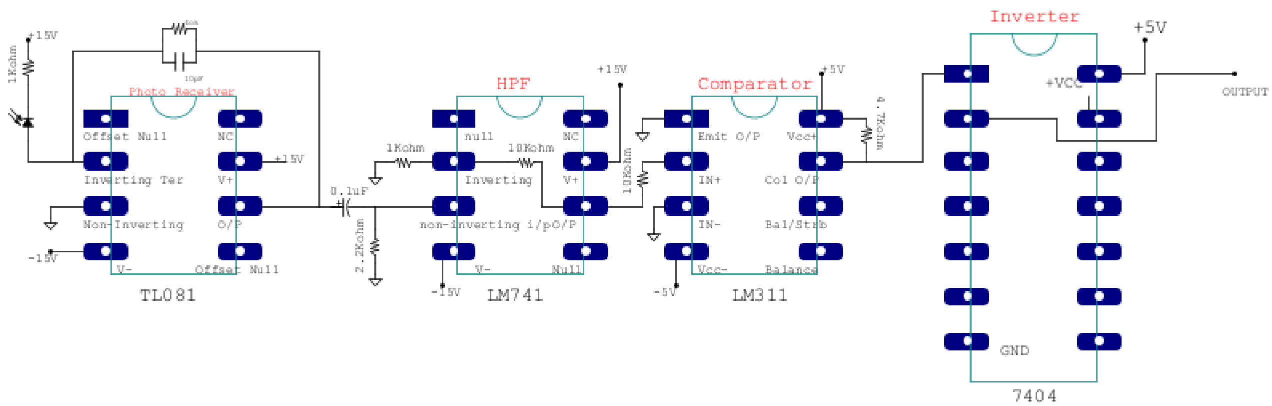

Figure 7: Receiver

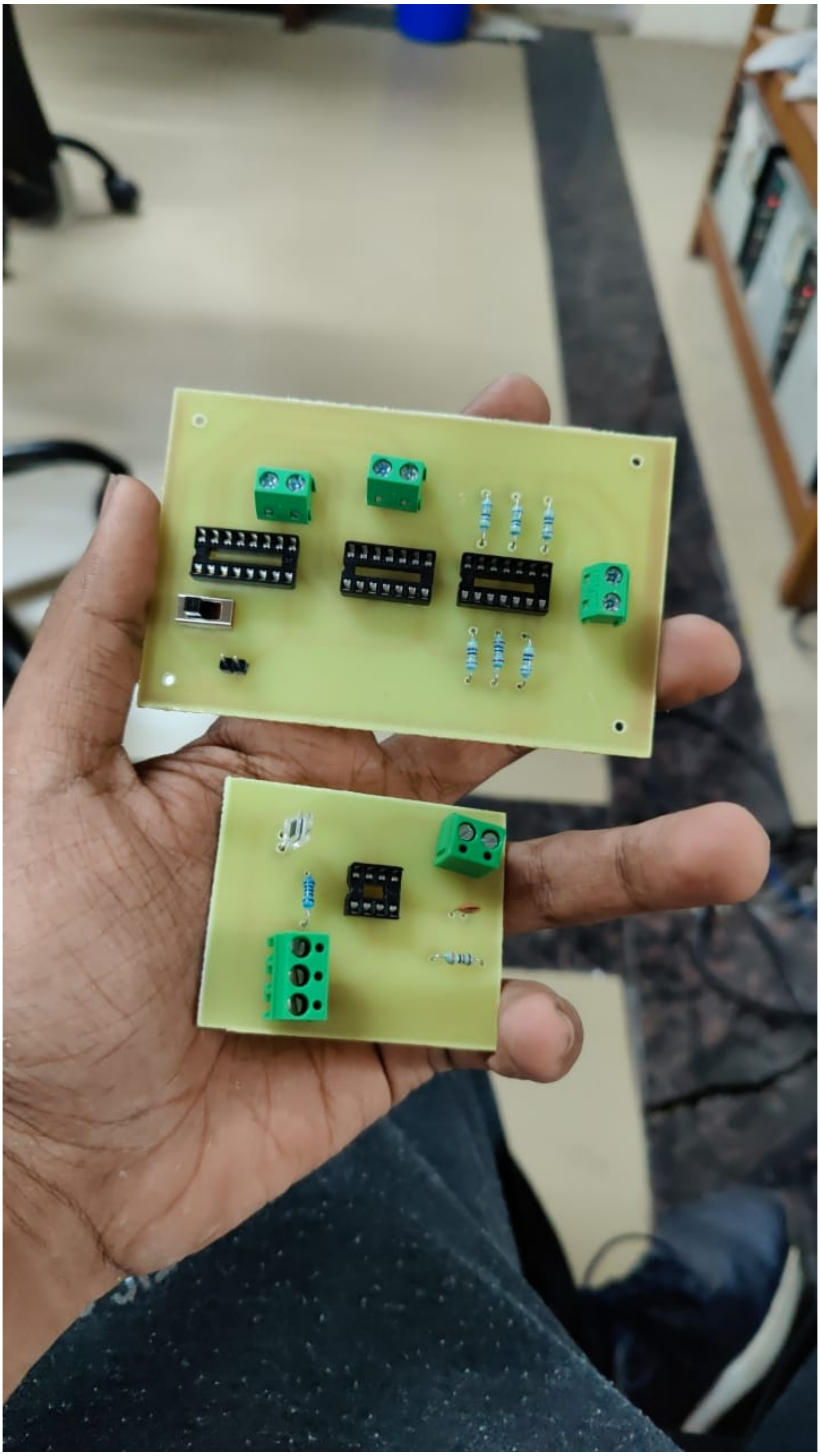

Figure 8: Soldered PCBs

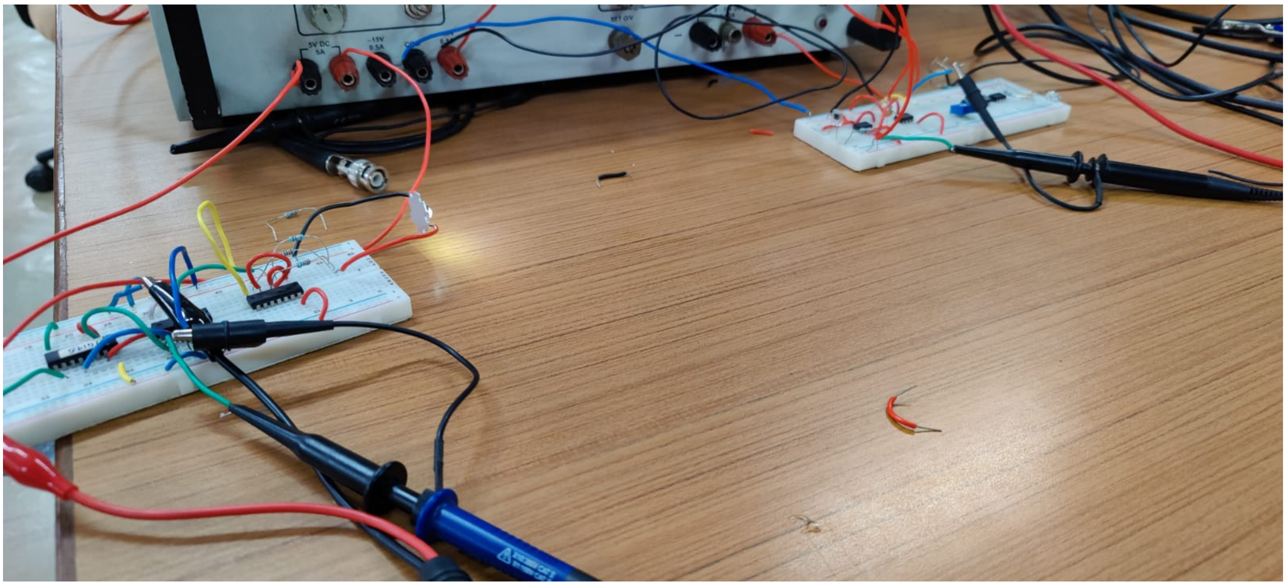

Figure 9: Experimental setup used

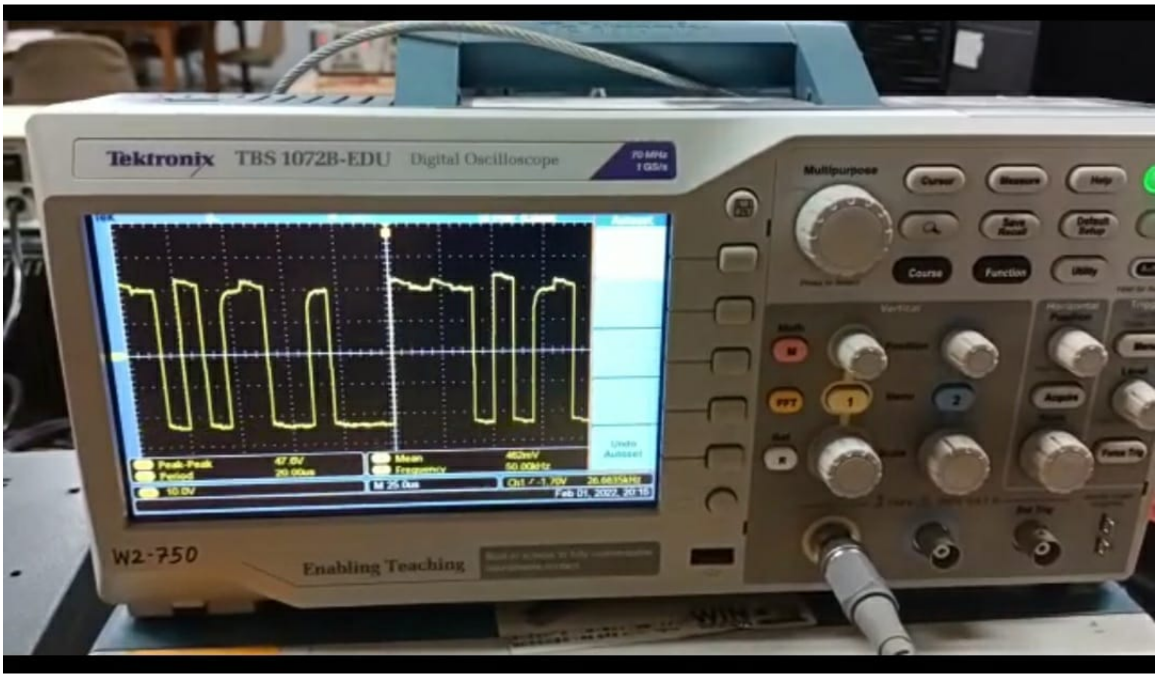

Figure 10: PRBS output waveform

Figure 11: Received signal when input is 100kHz square wave

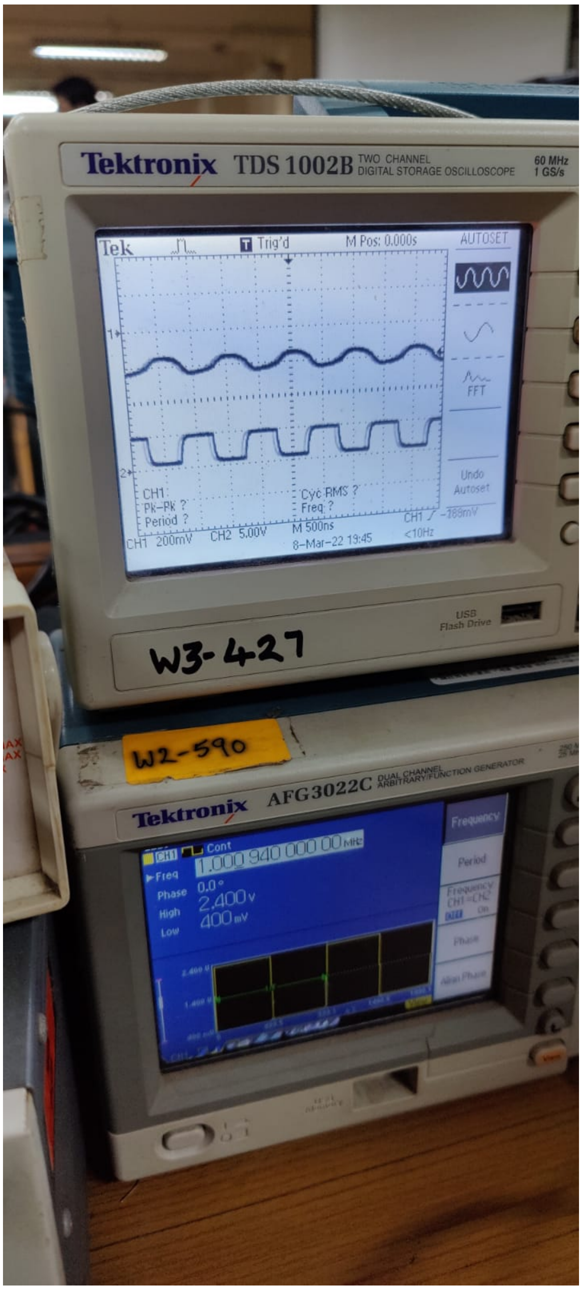

Figure 12: Received signal when input is 1MHz square wave

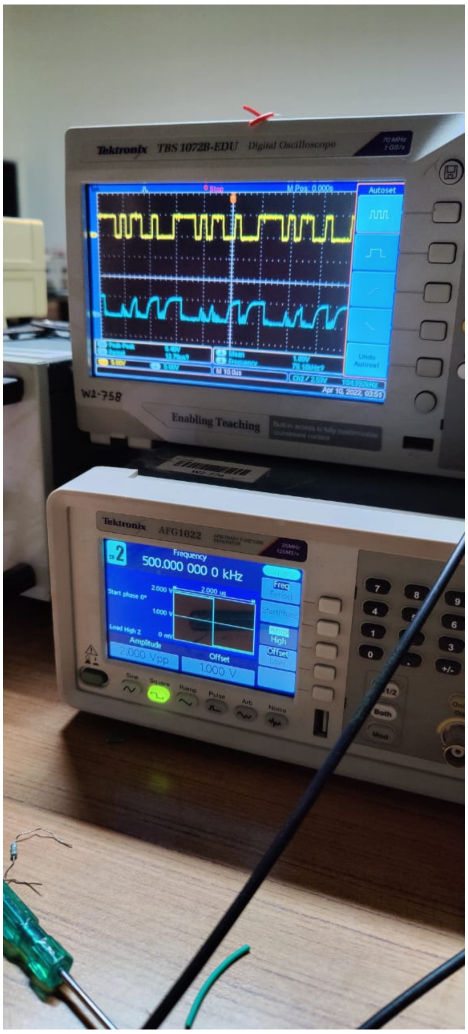

Figure 13: Received signal with PRBS input at 500 kHz and 40 cm distance

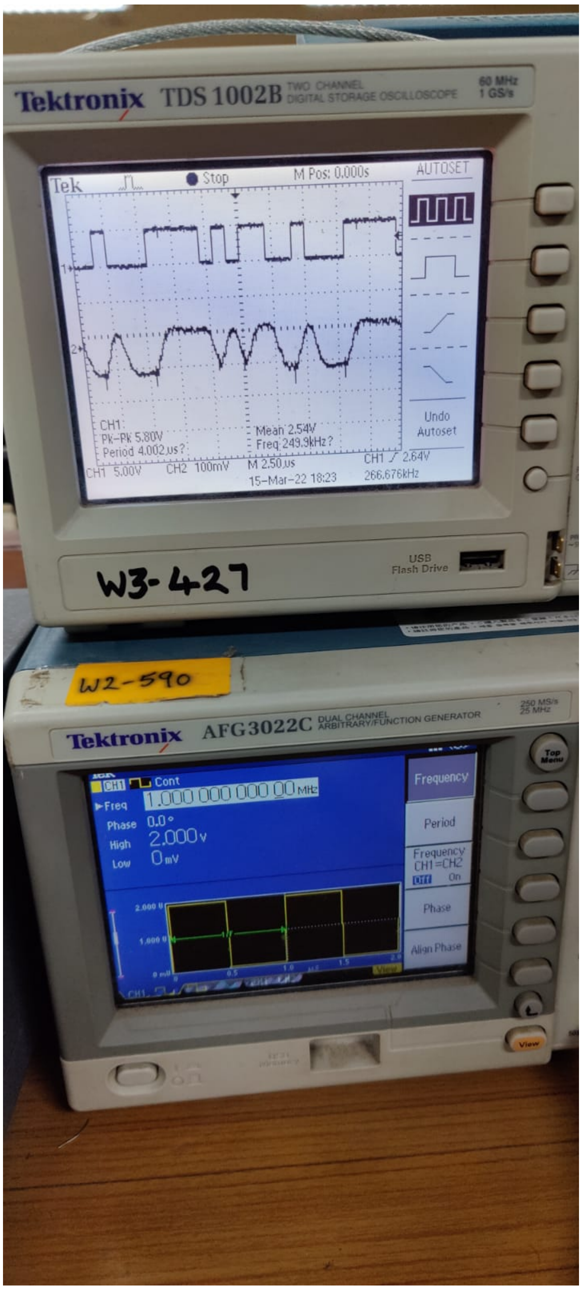

Figure 14: Received signal with PRBS input at 1 MHz and 4 cm distance

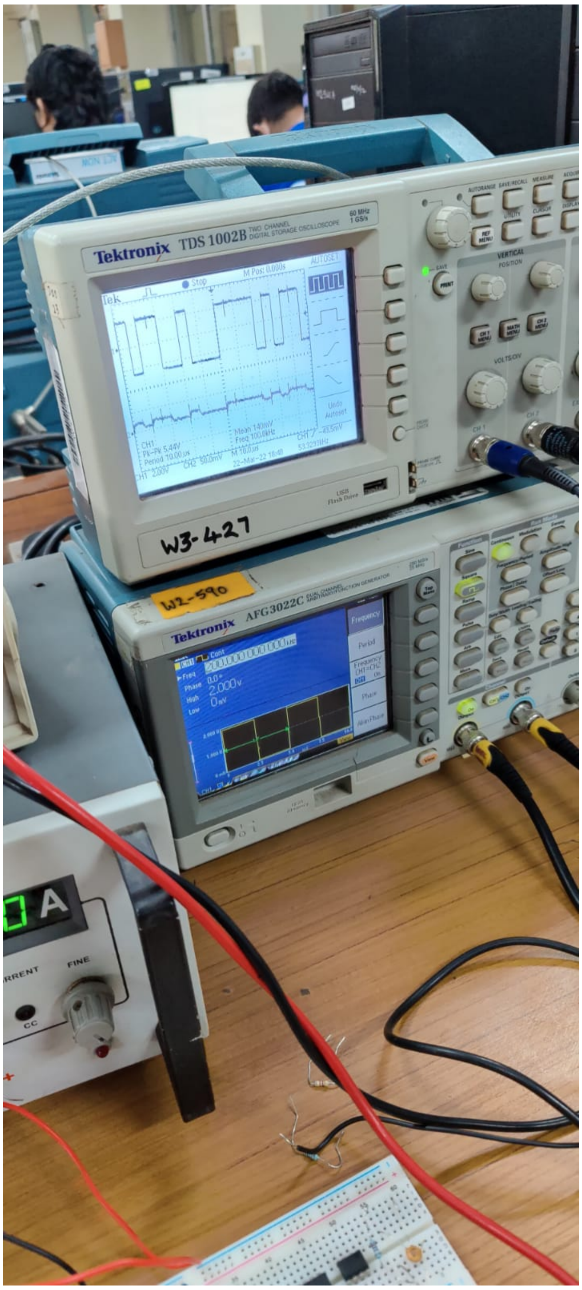

Figure 15: Received signal with PRBS input at 200 kHz and 30 cm distance