Indian Institute of Technology Bombay

EE 334

Electronic Design Lab

Visual Light Communication Link

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1 Abstract

Current wireless communication systems pose great challenges in terms of capacity, reliability, infrastructure and power consumption. The radio waves that are predominantly used today for the wireless communication is approaching its bottleneck in terms of the above mentioned constraints. Alternatives such as visible light could prove vital for the advancements in future communication technologies. Our project seeks inspiration from Professor Harald Haas' work on Li-Fi. Prof. Haas in his TED talk explained and demonstrated a communication system based on visible light.

Visible light constitute one of the most crucial part of EM Spectrum. We want to develop a communication system using this visible light. It's advantageous over Radio wave in many terms including its capacity and safety concern. Visible light spectrum is nearly 10000 times that of radio frequency spectrum i.e. theoretically a lot higher data rate can be achieved. Unlike other bands of electromagnetic wave

spectrum such as UV or gamma, visible light is safe to use in public. Unlike WiFi which requires routers to be installed, LED lamps are already present everywhere.

The project seeks to explore a mechanism through which packets of data could be transmitted from one point to other. We are primarily working on making a downlink communication channel where in we would be sending data through LED and receiving and decoding this data.

2 Aim

We aim to establish a fast and reliable communication system which would be based on visible light. We aim to facilitate a downlink communication using visible light. We are aiming at the specifications of 1 Kbps and a distance of 1 feet.

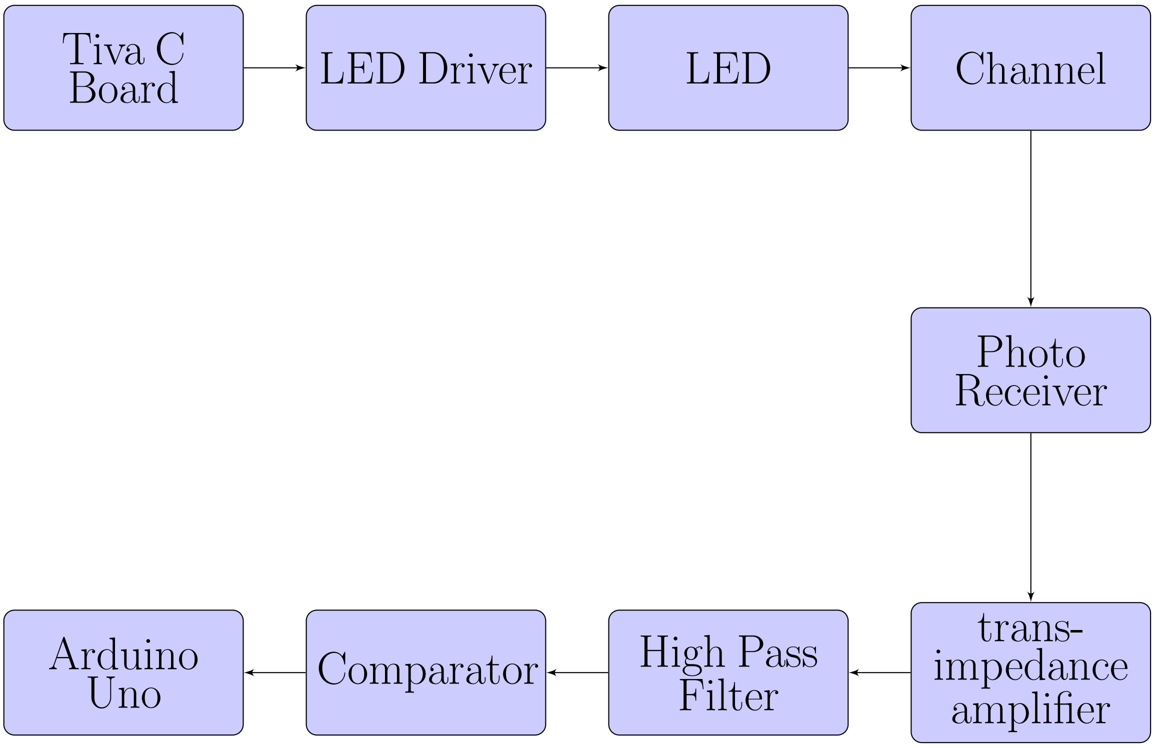
3 Introduction

As the name suggests, our project aims to transmit data from one point to other. For this, we first modulating a signal, then transmit it using an LED. The fast blinking LED transmits the generated signal. Before transmitting, this signal is modulated using on -off keying in which we are sending a high pulse(light on) for 1 and low pulse(light off) for 0.

Something transmitted should be received as well. So for this, we are using a photo-detector for receiving the signals. Then after some enhancement to this received signal by passing it through a high pass filter and comparator, we demodulate the signal using arduino board.

Summarizing what is said, to make a successful Visual Light Communication link we need a transmitter, which can transmit light at sufficiently high frequency, and a receiver which should be able to receive detect this blinking light, decode the data and send it to the front-end application.

4 Block Diagram



5 Block Description

TIVA C Board: The function of this board is to modulate the encoded data (Message signal in Binary) using OOK. The resulting signal is transmitted through on board GPIO pin to the LED Driver. This Board can send data up to 100 kbps (kilo bits per second) speed. High Value of Bit is 3.7V, white low value is 0V. We would be sending bit stream stored in the memory of the board using this channel.

LED Driver: We are using IRF 840 based LED Driver with a drain current of 8A. It is MOS-FET with a typical rise and fall time of 20 ns. This circuit could be operated reasonably up to 50 MHz.

LED: We are using a 1W LED which has a voltage drop of 3.2V. These LED were bought from Digibay. This LED is working reasonably good for switching frequency up to 100 kHz.

Channel: The channel for the communication link is predominantly the air channel. The noises added in the channel is in the form of 50Hz light from the light source in the room, sunlight and other light sources in the vicinity. The biggest problem is that of the 50Hz noise. For removing this noise, we tried implementing a second order high pass filter which worked well only up to 1 KHz.

Photo Receiver: The photo receiver circuit consist of a reverse biased photo-diode. We are using BPW34 photo-diode which has a reverse current of 75 μA ($E_A = 1$ klx, $V_R = 5$V). This photo-diode has a spectral bandwidth of 430 - 1100 nm.

Trans-impedance amplifier: he photo-current from the photo-diode is amplified through a trans-impedance amplifier which converts it into suitable voltage range. We are using TL-082 which is a CMOS based Op-Amp for this purpose which has a slew rate of 13 V/μs as compared to 0.5 V/μs of LM 741. This trans-impedance amplifier has a gain of 10^6.

High Pass Filter: The High Pass Filter is to be used to reduce the 50 Hz noise in the circuit. We implemented a first order high pass filter with cut off frequency 500Hz and gain of 10.

Comparator(followed by Zener Diode): The comparator circuit is used here to generate waveform that does not vary as the distance between them changes and send the positive bit to +5 V and negative bit to 0 V. It is a zero volt threshold which returns high when voltage is greater than 0.15 V and gives 0 V when voltage is less than 0.15 V.

Arduino Uno: The Arduino Uno board is used for demodulating signal and decoding the received signal.

Circuit Diagram

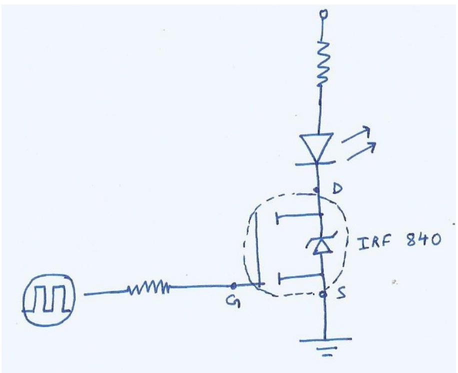


Figure 1: Transmitter Circuit

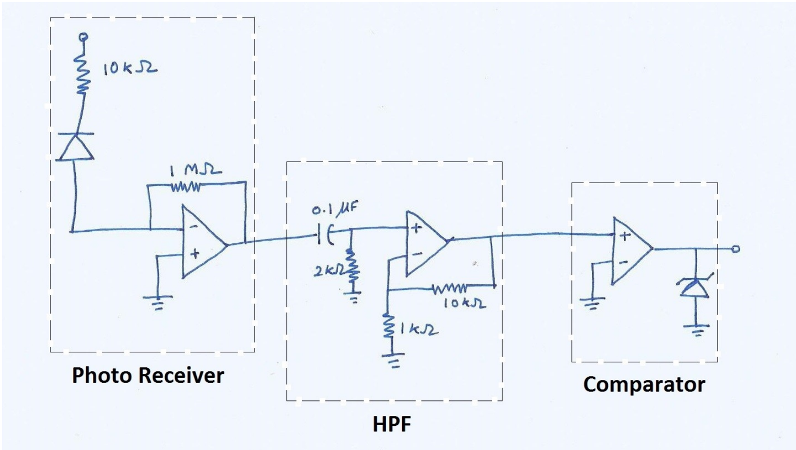


Figure 2: Receiver Circuit

6 Waveforms

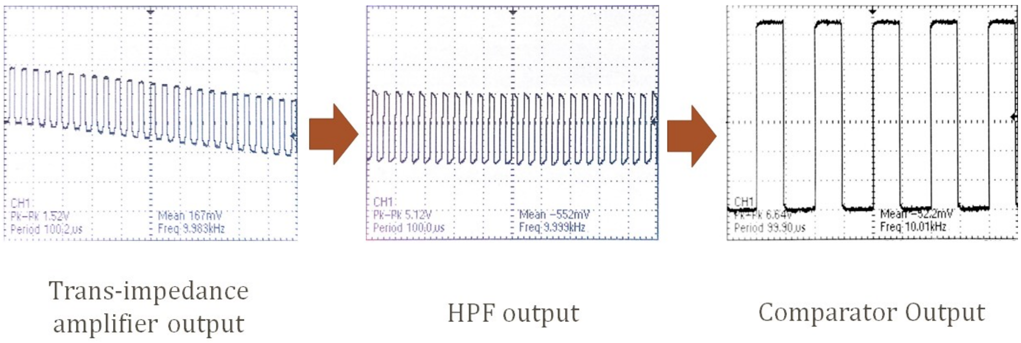


Figure 3: Receiver Circuit

7 Components Used

Item	Quantity	Price (in Rs.)
Tiva C Board	1	1200
Arduino Uno	1	700
1W LED	1	50
BPW34	1	40
TL 082	2	-

8 Apparatus

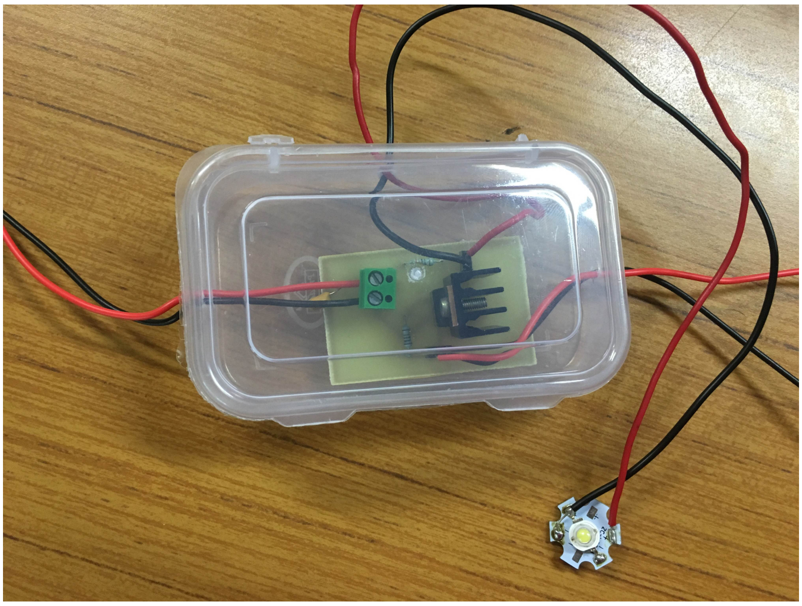


Figure 4: Transmitter Circuit

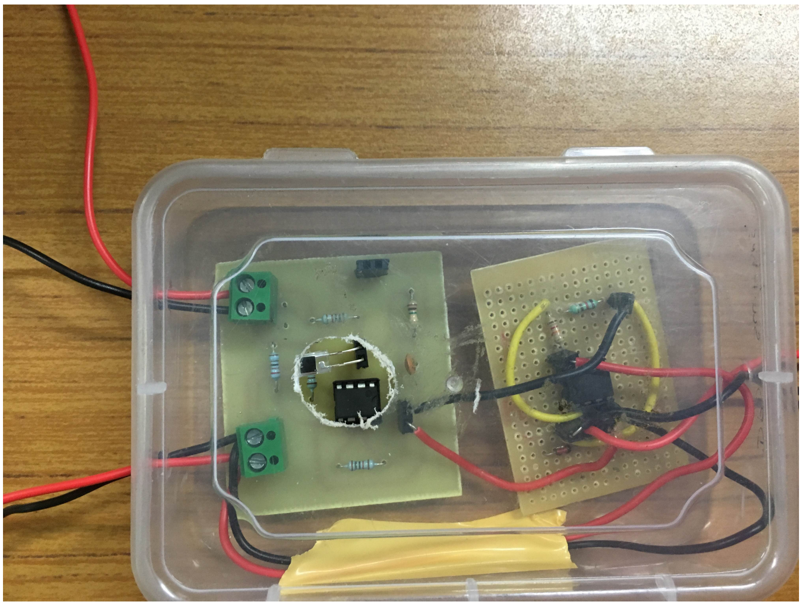


Figure 5: Receiver Circuit

```
[0111011011000010100000101110111010000010111011101100001010000101110111010000010111001101110001010000]
/01/
[0111011011000010100000101110111010000010111011101100001010000101110111010000010111001101110001010000]
/01/
[0111011011000010100000101110111010000010111011101100001010000101110111010000010111001101110001010000]
/01/
```

Figure 6: Received Binary Bit Sequence 1

```
[0111110000000100001111100000100000001110111111000000100001111110100010000001110011111000000100001111]
/11/
[0111110000000100001111100000100000001110111111000000100001111110100010000001110011111000000100001111]
/11/
[0111110000000100001111100000100000001110111111000000100001111110100010000001110011111000000100001111]
/11/
```

Figure 7: Received Binary Bit Sequence 2

9 Results

We have achieved the following objectives:

- Successfully able to send modulated data up to a speed of 100 Kbps
- Able to receive and detect data at the receiver for a distance of 1 feet with a speed of 10 Kbps
- Integrated the modulator, transmitter and receiver circuit
- We are able to remove the ambient noise and able to recover the exact rectangular signals
- Ambient light is not causing an issue as it is getting filtered by the HPF
- We have made the Printed Circuited Board for the entire working circuit
- Have designed a primitive demodulator which is capable of reading square wave till about 10 Kbps
- Developed a mechanism for receiving bits. Decoded binary stream of data(00,01,10,11) using Arduino Uno board

10 Problem Faced

- Ambient 50 Hz noise was needed to be removed. Optimum High pass filter design was a challenge

- The photo-current in receiver was changing as the distance between the LED and photo-diode was being varied. We used a Zero crossing comparator to solve this problem
- Clock synchronization between the receiver and transmitter
- The receiver works well for a square wave of 10 KHz, but gives big errors when the modulated signals are sent
- The receiver circuit faces high error rates as we increase the number of bits which limit our ability to detect bit sequences of larger bit size

11 Conclusion

Using this project, we demonstrated the ability to establish a communication link using visual light. We were able to devise the communication link using simple analog circuits which gave appreciable performance.

12 Future Work

Visual Light Communication link can prove to be great complement to the existing wireless communication system. Great deal of work can be done to improve upon the system. Other modulation and demodulation techniques like FSK, PPM, OFDM and so on can be evaluated for this channel. Availability of resources has been a constraint which can be overcome by using faster and brighter LEDs and faster photo-diodes.

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