EE304 DESIGN PROJECT REPORT

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Project Title	Wireless Data Communication using Laser		

WIRELESS DATA COMMUNICATION USING LASER

Introduction

High speed data communication systems form the backbone of the present technological era with some of the popular system being Wi-Fi, Bluetooth and Radio Frequency (RF) etc. However, in a resource constraint scenario, neither of these systems are easy-to-realize and cost-efficient.
Thus, as an alternative to these systems the field of wireless data communication has witnessed the growth of visible light communication (VLC).
Li-Fi or "Light Fidelity" is a data communication variant which uses visible light between 400 and 800 THz (780–375 nm) to transmit high speed data. Typically, this technology uses fluorescent bulbs or LEDs to transmit signals over short distance. But laser light can be used as an alternative to increase the range of communication system as it has a much lower transmission loss per unit length (0.15-5db/km).
Inspired with this concept, we propose a 'Wireless Communication System using Laser (Line-of-sight)'. The main aim of this project is to efficiently transmit digital data (images and text files) over Laser beam.

An immediate question will be "Why to use laser based system in place of Wi-Fi, Bluetooth or Radio Frequency systems?".
Well, it is not always possible to lay down the required infrastructure (mainly wiring, antennas and high power supply) for these conventional systems, for example, for satellite communication and in emergency combat zones, etc. FCC licensing is not a prerequisite for Laser based communication systems. The intensity of laser light is higher and is much less susceptible to electromagnetic interference than RF or Bluetooth.
Thus, laser based communication systems provides a much simpler system at low-costs with reasonably high data rate and transmission range.

BLOCK DIAGRAM

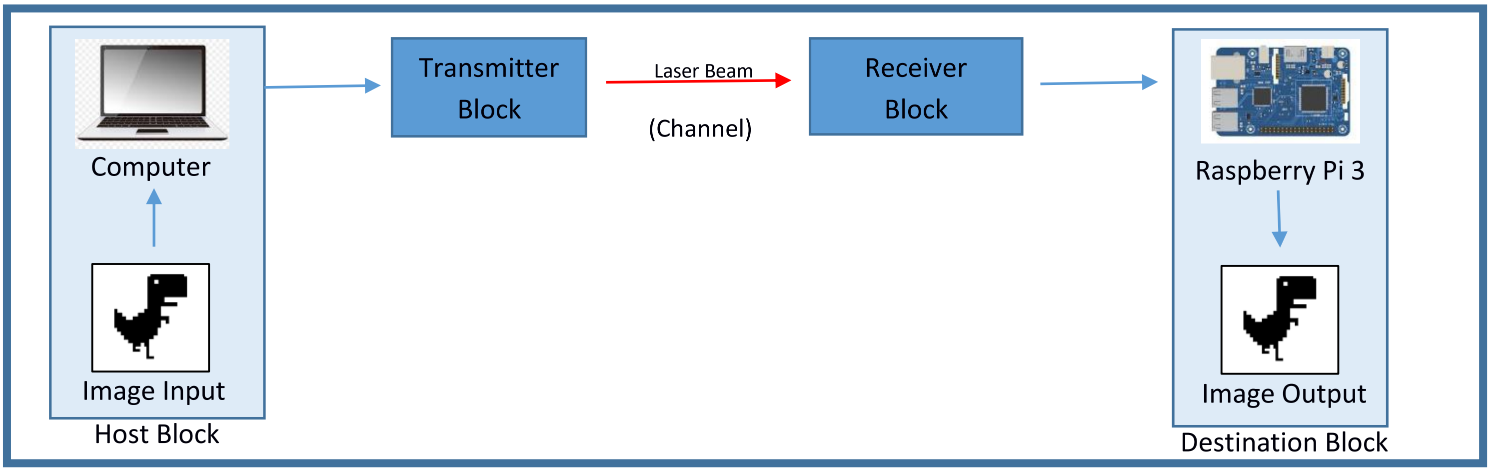


Figure 1. Functional Block Diagram

DESCRIPTION:

We aim to send .jpeg image from a host computer to destination computer using wireless laser data communication system.

HOST BLOCK:

UART (Universal Asynchronous Receiver/Transmitter) serial communication protocol is used to send data from host computer to the transmitter. In Asynchronous serial communication, a byte of data is transferred at a time.

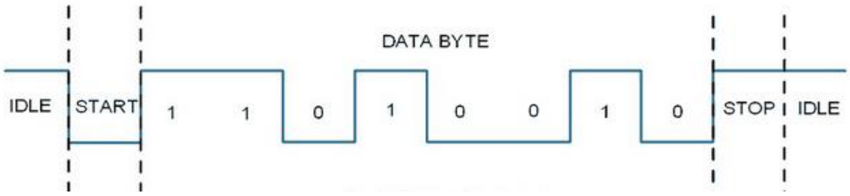


Figure 2. Basic Frame Structure of UART Serial Communication Protocol

The image file(.jpeg) on the host computer is first encoded by Base64 algorithm into a text(.txt) file with the help python programming language (function- " base64.b64encode () "). Base64 algorithm is used basically for representing data in an ASCII string format and encoding-decoding arbitrary binary strings into text strings that can be safely sent over the transmission channel.

Python Library “pySerial” is used to configure the serial data communication at the desired port of the computer. This configuration primarily includes specifying data file, baud rate and port address.

A USB-to-TTL Converter receives the data from the USB port of the host computer and converts the stream of data bits into square wave signal with amplitude of 3.3 V. This signal is fed as an input to the transmitter block.

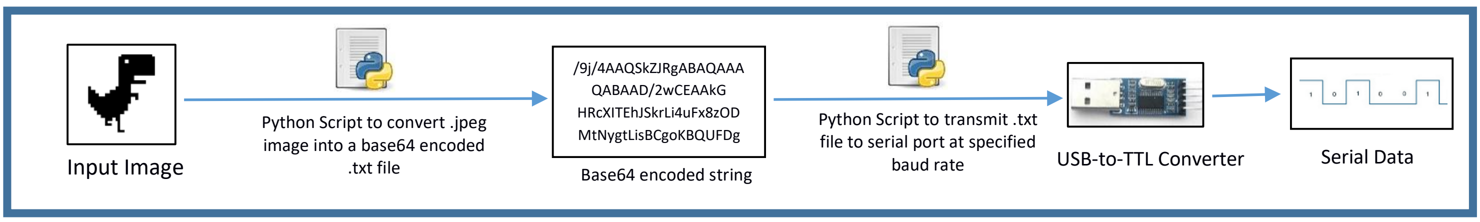


Figure 2. Host Block (Serial data conversion and encoding)

TRANSMITTER BLOCK:

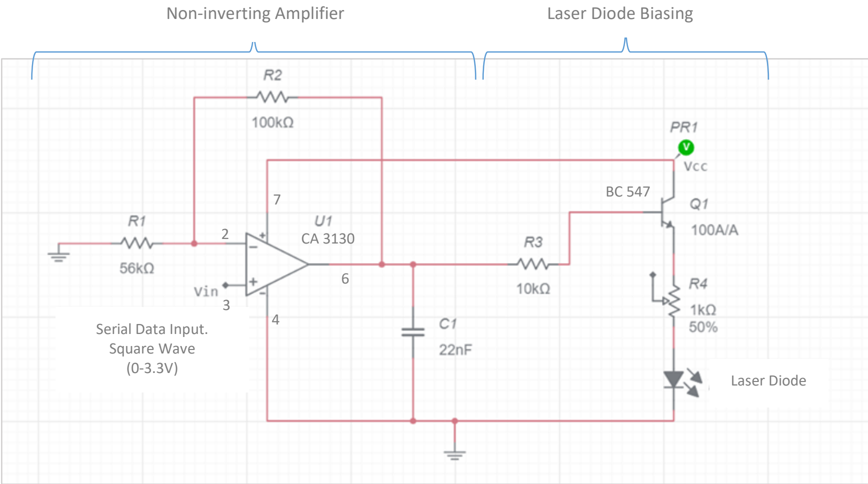


Figure 3. Transmitter Circuit Diagram

The output of the USB-to-TTL converter is a stream of bits depicting square wave with amplitude varying between 0 V to 3.3 V (Graph 1), but to properly modulate the laser diode 4.5 V power is required. Thus, the input data signal is amplified using CA3130 Op-Amp IC in non-inverting amplifier configuration.
Gain of the amplifier = 1+ R2/R1 = 2
Apparent Output swing of the amplifier = Gain * Input amplitude = 6.6 V
CA3130 Op-Amp IC (U1) used because of its following characteristics to high speed input data: high closed loop slew rate (10V/us), high gain crossover frequency (4Mhz –Closed Loop) and operation at single power supply.
It is observed that after connecting the laser diode directly at the output of amplifier the intensity of the laser beam is very low owing the low output current of CA3130 at 0V-8v power supply.
This is overcome by using an intermediate stage of switching circuit that can properly power the diode.
BC 547 npn transistor (Q1) is used (in switch configuration) as it has high gain bandwidth product (300 MHz) that is ideal for high frequency applications. Variable resistor (R4, 1kOhm) is used to provide adequate current to the laser diode. (Graph 1)
Modulation Technique: The input serial data signal is amplified and then fed to the base of Q1 which acts as a switch to toggle laser diode on or off. This method of representing data is called On-off keying (OOK). The logic value zero corresponds to LOW (0 V) and the logic value one to HIGH (4.5 V). This means that when the data bit 0 is being transmitted the base of Q1 will be at logic low and laser diode will be off and vice versa in case of data bit.

RECIEVER BLOCK:

On the receiver side, solar panel receives the laser beam and converts the light signal into voltage signal. If the channel is idle, that is, if no data is being transmitted, then output of the solar panel is a 100 Hz, 0.2V amplitude noisy sinusoidal signal with a DC offset (Graph 2). A high pass filter is used to attenuate the noise and remove DC offset. (Graph 3)

High Pass Filter Parameters: Design for fc=250 Hz and C1=1 uF

Cut off frequency = $\frac{1}{2*pi*RC}$ Hz => R1=6 kOhm (used 22 k potentiometer)

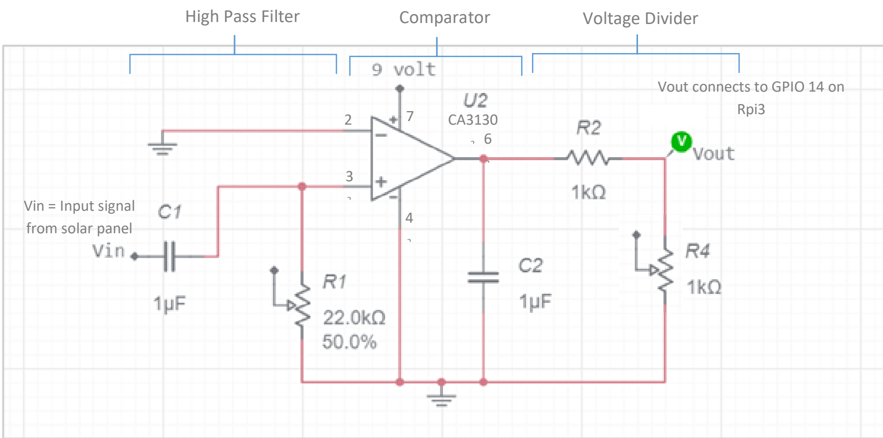


Figure 4. Receiver Circuit Diagram

During transmission of the data, on comparison of filter output with original signal it is observed that the square wave signal from transmitter is attenuated by the channel and the filter output is below 0 V for logic low bit and above 0 V for logic high bit (Graph 3). Thus, a comparator (CA 3103 Op-Amp IC) is used on the transmitter side to retrieve back the serial square wave signal from the received signal. (Graph 4).
The output of the comparator differs from the original signal only in amplitude.

As the destination device is Raspberry Pi 3 that receives serial data with the logic level of 0 V (LOW) and 3.3 V (HIGH), a voltage divider circuit (resistor R2 and potentiometer R4) is used to reduce the amplitude of received serial data signal (Graph 5 and Graph 6).

DESTINATION BLOCK:

Raspberry Pi 3 is used as the destination device. The output of voltage divider circuit (Vout) is connected to the GPIO15 (UART_RXD0) pin which is the receiving pin of PL011 UART on R Pi3. Using Python, the serial data input is stored into a text file (.txt) which contains the image data in base64 encoded form. After data transmission is over, Python script decodes back the text file into its original .jpeg format. Thus, the image sent by the host is finally received by the destination computer.

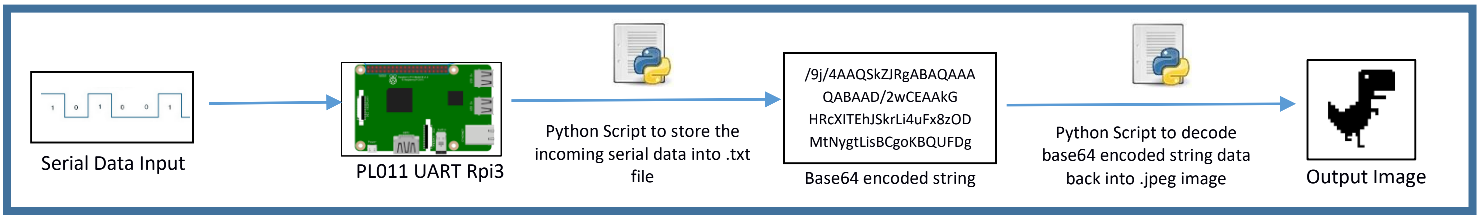


Figure 5. Destination Block (receive, decode and store data)

<u>RESULTS AND PERFORMANCE ANALYSIS</u>

DATA RATE: Baud Rate is the data rate at which information is transferred over a communication channel. 1 baud = 1 bit per second. In the context of Serial Port, "9600 baud" means that serial port is capable of transferring a maximum of 9600 bits per second in a channel.

The performance of the proposed system is being evaluated with respect to two parameters:

1. Baud Rate of successful data receiving.
2. Channel Length: Maximum distance between transmitter and receiver.

ERROR CHECKING MECHANISM: As the proposed system is a simplex system of communication (data travels only from transmitter to receiver), thus there cannot be receiver feedback based (acknowledgement) error control mechanism. However, UART protocol offers parity checking (Odd parity and Even parity) of data frames that can be used to detect the correctly received data frames.

OBSERVATION: Data Rate of system is same as its specified baud rate that can be configured on both the sides by the Python pySerial Module. The distance to which the channel can be extended was limited to 30 feet corresponding to that is the maximum the length of experiment lab.

Experiment No.	Transmitted Data Type	Data Rate (kbps)	Channel Length (feet)	Data Succesfully received and correctly decoded (Yes/ No)
1.	Image/Text	9600	30	Yes
2.	Image/Text	19200	30	Yes
3.	Image/Text	25000	30	Yes
4.	Image	Above 25000	30	No
5.	Text	28000	30	Yes
6.	Text	30000	30	Yes (with error)
7.	Text	35000	30	Yes (with error)

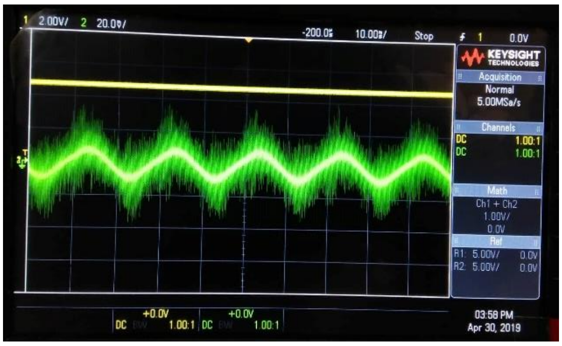
PERFORMANCE CLAIM: The system is capable of successfully transmitting and receiving images files and text files at data rate of 25 kbps for a maximum channel length of 30 feet.

Signal Observations and waveforms:

Waveform Observation Parameters :	Data Rate: 25 kbps	Channel length: 25 feet	Transmitted data type: Image (.jpeg)	The file was successfully received at the destination device

Graph 1: (Transmitter)
Green: USB-to-TTL serial data signal
Yellow: Laser diode biasing signal

Graph 2: (Receiver)
Green: Solar Panel output signal when the system is idle (notice 100 Hz noise and DC offset)
Yellow: Transmitter idle signal (4.5 V DC)

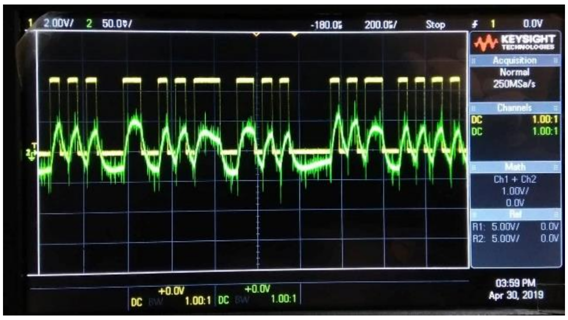


Graph 3: (Receiver)

Green: High Pass filter output when system is idle.

(no DC offset, noise amplitude reduced)

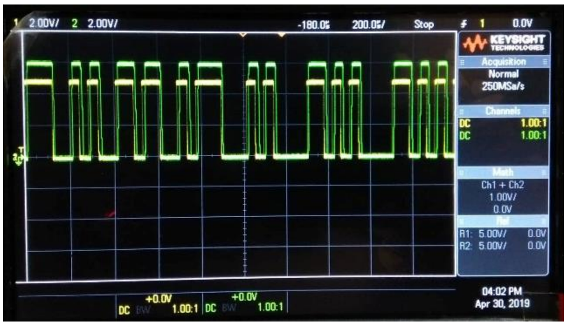
Yellow: Transmitter idle signal (4.5 V DC)



Graph 4: (Receiver)

Green: High Pass filter output while receiving data

Yellow: Transmitter serial data signal



Graph 5: (Receiver)

Green: Comparator serial data output (6 Vpp)

Yellow: Transmitter serial data signal

Graph 6: (Receiver)

Green: Serial Data received after voltage divider

(The logic level is 0-3.3 V; this is given as input to R Pi3 UART pins)

Yellow: Transmitter serial data signal.

SUMMARY:

A Lased based wireless communication system is built as a prototype which is capable of transmission of digital data at 25kbps over a distance of 30 feet and efficiently establish simplex communication network between two computers.

This system is mainly built to establish an economic, long-ranged high speed communication network especially in resource constraint environment (time, money and technology) or emergency situations. It can be efficiently used to transmit data from in remote areas (one hill top to other hill top!) where cell phone communication is not possible due to the lack of mobile operator's network. It can also be used conveniently at conference room, political assembly, class room and for general conversation between two houses.

FUTURE SCOPE:

1. Hardware: By using high quality solar panel (better optical receivers), high speed operational amplifiers and transistors the data rate can be increased to few Mbps or even Gbps. As financial investment is needed to upgrade hardware resources, this is a speed vs price trade-off.
2. Software: With the introduction of encryption and decryption the system can be efficiently used to transmit confidential data that has application in military and satellite communication. In full duplex mode, error checking mechanism can be added in order to improve communication accuracy.

List of Components

#	Item Name	Qty.	Provided by (Dept./Self/Guide)	Price (Rs.)
1.	Raspberry Pi 3	1	Guide	---
2.	CA 3130	2	Self	20
3.	BC 547	1	Self	10
4.	USB-to-TTL Converter	1	Self	150
5.	Solar Panel	1	Self	239
6.	Laser Diode	1	Self	200
7.	Resistor	4	Self	-
8.	Capacitor	3	Self	-
9.	Potentiometer	3	Self	100
10.	9V Battery	2	Self	40
11.	Switch	2	Self	103
12.	Prototype board	2	Self	100

***The Department will provide up to Rs. 2000 per group for the purchase of components. Specialised items like FPGA kit, Kinect, Webcams etc. should be provided by the students or the faculty supervisor.**