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Investigation of Visible Light Technique

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Annotation: The rapid expansion of mobile applications utilizing radio frequencies (RFs) has raised concerns about spectrum limitations, security vulnerabilities, and transmission capacity. This study explores Visible Light Communication (VLC) as an alternative optical wireless communication method, leveraging light in the visible spectrum (375nm–780nm) for secure, high-speed data transmission. Despite its potential, existing research lacks practical implementations addressing range limitations and hardware constraints. This study employs an experimental design to develop and test a VLC system using LEDs and phototransistors. Findings indicate that VLC offers significant security and data rate advantages over RF systems, although challenges such as line-of-sight dependency and transmission range must be optimized. The results suggest that VLC can be a viable solution for indoor wireless communication and intelligent transport systems. These findings have implications for future research and the

integration of VLC in smart environments.

Keywords: Visible Light Communication, Optical Wireless Communication, Data Security, High-Speed Transmission, Intelligent Transport System.

Introduction

1.1 statement of the problem

Nowadays people are using several types of communication system such as infrared, radio communication, Bluetooth …… etc. these types face some problems including limited transmission power, security, limited data rates …etc. in our project we are developing a new communication system that will solve almost all these problem. This system is called visible light communication.

Visible Light Communication (VLC): is free space optical communication, and line of sight (LOS) is the common link between two points in optical wireless communication system, where the transmitter directs the visible light beam in a straight and unobstructed path to the receiver [1]. In this technology LEDs are used as transmitter, the Air as a transmission medium and the Photodiodes as a receiver.

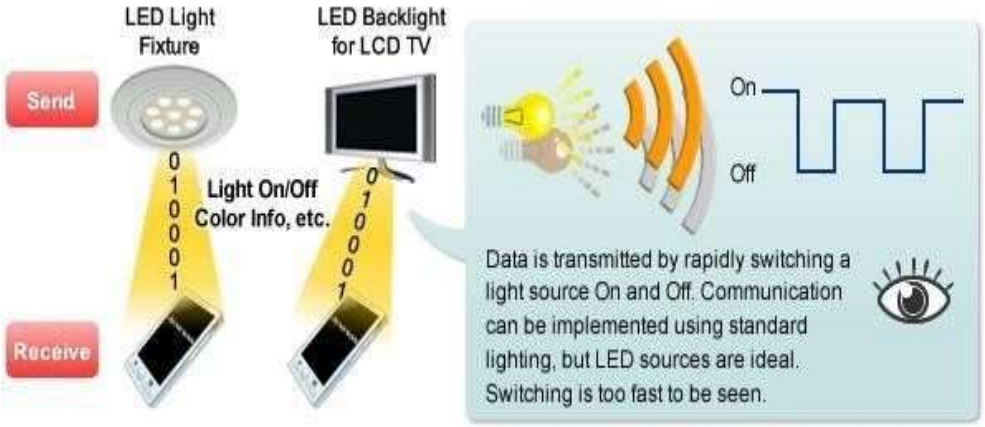

Fig.1.1 VLC system. [1]

1.2 Motivation and Objectives

From our review of the literature, it became evident that work should be done to look into the possibility of designing a new model that could fit the present infrastructure for indoor applications [2]**.** Therefore, the objectives of the research presented in this thesis can be summarized as follows:

- ✓ Build a circuit for **VLC** by using LED to LED.
- ✓ Test the circuit then take notes and discus the performance.
- ✓ Suggest a guideline for the design and implementation of future development of the prototypes.

1.3 Scope of the work

we hope that the achievement of this project in reality will make everyone in everywhere and at all times be able to send and receive text, image, audio and video with lowest cost, reasonable rate and more security without using the internet.

1.4 Significance (importance) VLC Advantages:

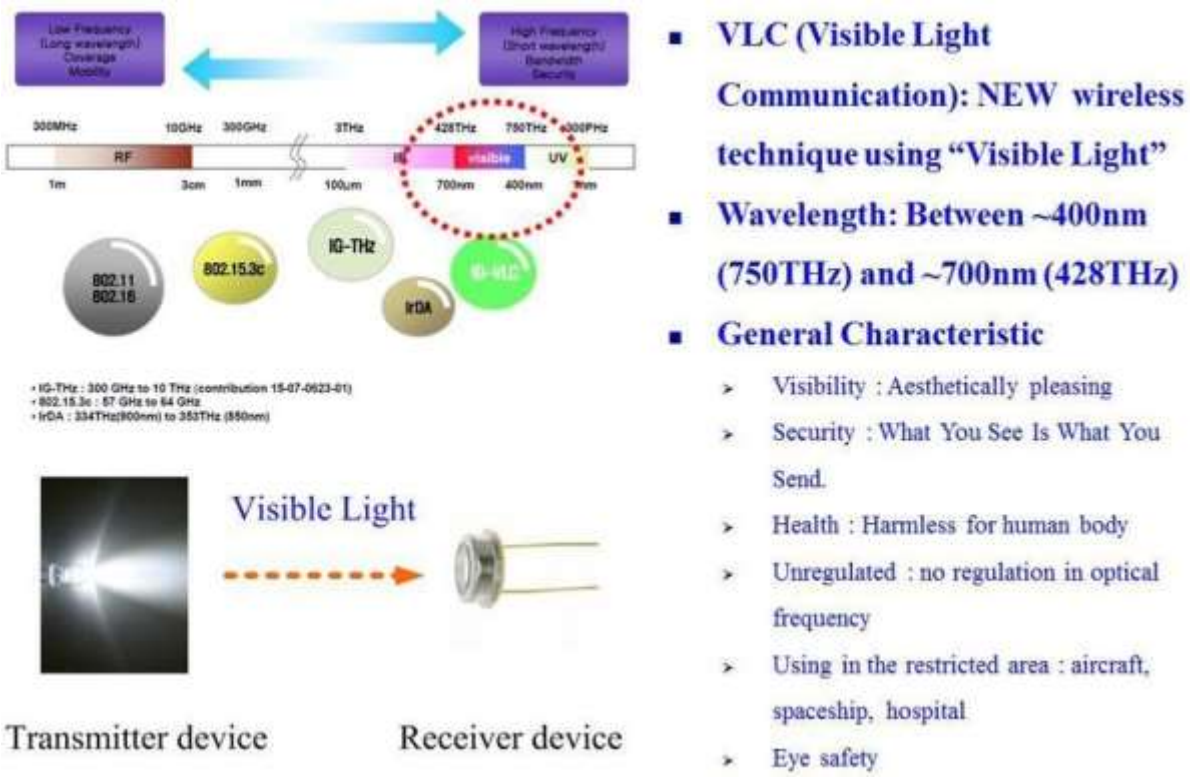

Fig.1.2 VLC Advantages [3]

VLC System has many advantages over the other Communication Systems:

1- **Security:** VLC is use light communication and it's visible so in this case it's easy to determine who can receive the message and it's impossible to tap the communication without breaking the link.

2- **Human Safety:** VLC doesn't effect at the human body. Thus, the transmission power can be kept high if needed.

3- **Bandwidth**: VLC has a bandwidth range from 430 THz to 750 THz and this range is larger than the bandwidth in the RF Communications from 3 kHz to 300 GHz.

4- **High Data Rates.**

5- **Unlicensed Spectrum**: No company owns property rights for visible light and thus no royalty fees have to be paid nor does expensive patentlicense have to be purchased in order to use visible light for communication purposes[4].

6- **Ubiquitous Nature**: visible light is present in many places, so there is the opportunity to combine light communication with lighting design to let Visible Light Communication (VLC) coexist with the lighting setup present in many offices, homes, or institutions.

1.5 : Organization of the Report

Chapter 1 of this thesis serves to provide an overview of the basic concepts and techniques in physics and engineering and also shows several designs that are required for the implementation of VLC. Chapter 2 provides the constraints, standards /codes and earlier course work. Chapter 3 literature review. Chapter 4 methodology .Chapter 5 results and analysis. Chapter 6 discussion the results. Chapter 7 presents recommendations for improving the designs, as well as the conclusion with suggestions for further improvements in the work.

2.1 Constraints

The main problem was with dealing with the Arduino Where we encountered a problem in writing the code. Also we had two problems with the hardware circuit. The first one is LOS Communication which means that we need line of sight communication. The second problem was the short Range i.e. this technology usually works over a short distance range. Also we faced many other problems such as:

1. Important elements of the circuit were unavailable in Palestine so we had to order them from other countries. They took a lot of time to be available in our hands and thus there was a very short time for the implementation of the circuit.
2. The size of the elements is very small, so we needed special equipments for the implementation.
3. Part of the project needed new software which required us to learn a new software programs.

2.2 Standards

- the Visible Light Communication Consortium was established in 2003 by Japanese tech-companies
- aims to standardize VLC technology
- ✓ avoid fragmentation of different protocols and implementations – two standards are proposed:
- ✓ JEITA CP-1221
- ✓ JEITA CP-1222
- also tries to raise public awareness for VLC and promote its applications
- Standardization efforts for physical and media access layer are also done by IEEE 802.15, Task Group 7.
- in 2007, the VLCC proposed two different standards:
- ✓ Visible Light Communication System Standard
- ✓ Visible Light ID System Standard
- JEITA (Japan Electronics and Information Technology Industries Association) accepted these standards as JEITA

CP-1221 and JEITA CP-1222

JEITA CP-1221 (1/2)

- motivation:
- ✓ avoid fragmentation and proprietary protocols
- ✓ prevent interference
- light that is used for communication purposes must be within a range of 380nm to 750nm emitted light must be within a particular range with an accuracy of 1nm sub-carrier (SC) modulation is proposed (as opposed to modulating the frequency of the actual light)

JEITA CP-1221 (2/2)

- there are three major frequency ranges:
- ✓ range 1 (15 kHz to 40 kHz): - communication purposes
- ✓ range 2 (40kHz to 1 MHz):
- fluorescent lights cannot use this range - they are too slow and generate too much noise

- ✓ range 3 (> 1 MHz):
- ➢ should only be used for vast data transmission with special LEDs19 JEITA CP-1222
- ➢ according to Shinichiro Haruyama (vice chairman of the VLCC) the following recommendations are proposed by JEITA CP-1222 :
- ✓ SC frequency: 28.8 kHz
- ✓ transmission rate: 4.8 kbps
- ✓ modulation: SC-4PPM (chosen to avoid flickering)
- ✓ cyclic redundancy checks (CRC) for error detection/correction .[5]

2.3 Earlier Coursework

In this project we made use in some subjects such as electronic, digital communication,……. Etc.

***Light Emitting Diode (LED)**

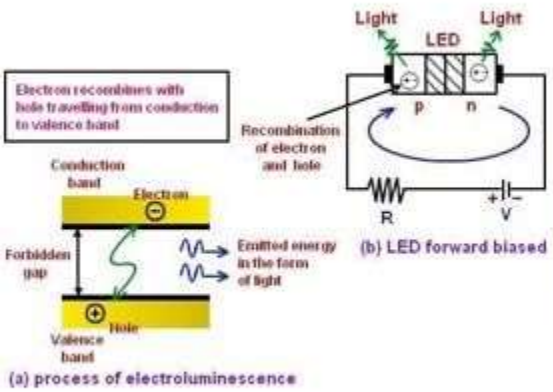

Fig 2.1 How LED work [6]

Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

Fig 2.2 Typical Led Characteristics [7]

***Phototransistor:**

the st -1kla is a high -sensitivity phototransistor mounted in durable , hermetically sealed TO -18 metal can which provide years of reliable performance even under demanding conditions such as use outdoors. It has two leads. It can be used in various applications such as smoke detectors, infrared sensor, optical switches and optical detectors [ ]

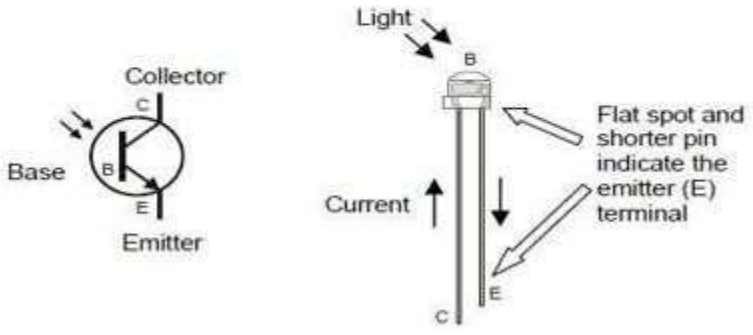

Fig .2.3 Phototransistor [9]

Arduino UNO

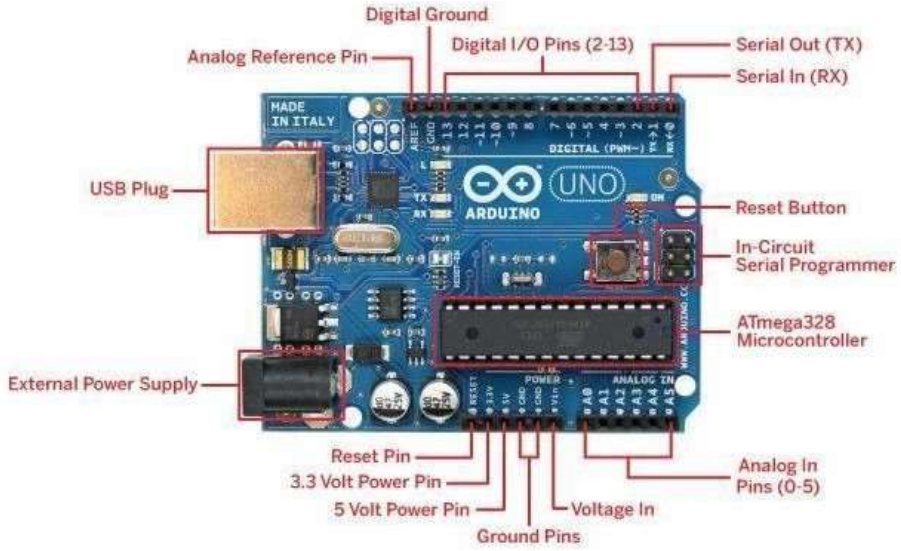

Fig.2.4 Arduino UNO pins [10]

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver [6]

*** Universal Serial Bus (USB)**

Used to communicate via the USB protocol with a host computer (for programming or sending/receiving serial data).

Fig.2.5 Universal Serial Bus (USB)

***Resistors:**

Resistor is an electrical component that reduces the electric current. The resistor's ability to reduce the current is called resistance and is measured in units of ohms (symbol: Ω). [7]

Fig.2.6 220 Ω resistor Fig.2.7 1 K Ω resistor

OPA847

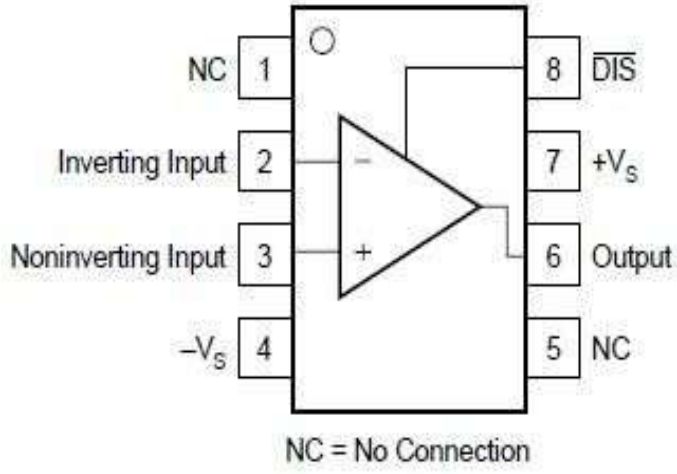

Fig.2.8 Pin Configurations for opa847 [8]**.**

OPA358:

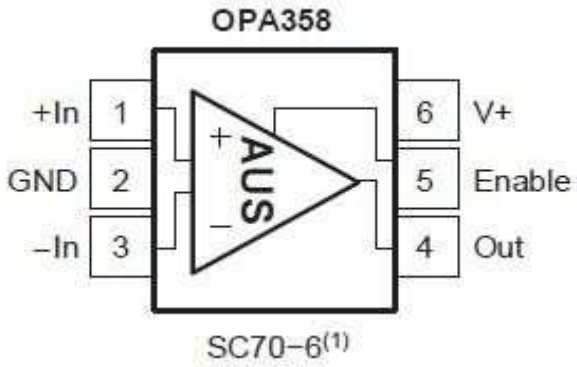

Fig.2.9 Pin Configurations for opa358 [9]

Literature Review

This chapter provides an overview of the topics that supplied the ideas for this report and the following sections examine the previous works which have been done on implementing Visible Light Communication technology.

3.1 The Visible Light Communication System Considered

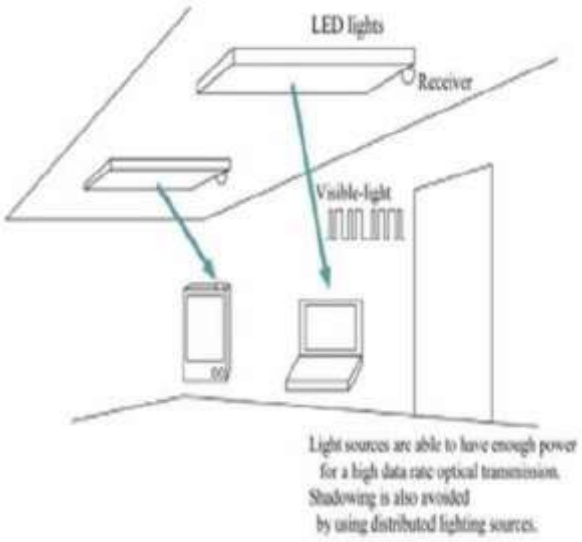

Fig 3.1: Arrangement of LEDs & receivers

In an indoor system [10]**. Fig 3.2: Distribution of LEDs Inside model room** [11]**.**

The final objective of VLC development is the application of off-the-shelf LEDs in home environment wireless network to satisfy the needs of both illumination and data transmission. An indoor visible light communication system using white LEDs under consideration is shown in Fig. 3.1& 3.2[12]. All the lights in the room are replaced by LEDs. The LEDs are not only used for illuminating the room but also for an optical wireless communication system.[13]

3.2 Traffic Lights

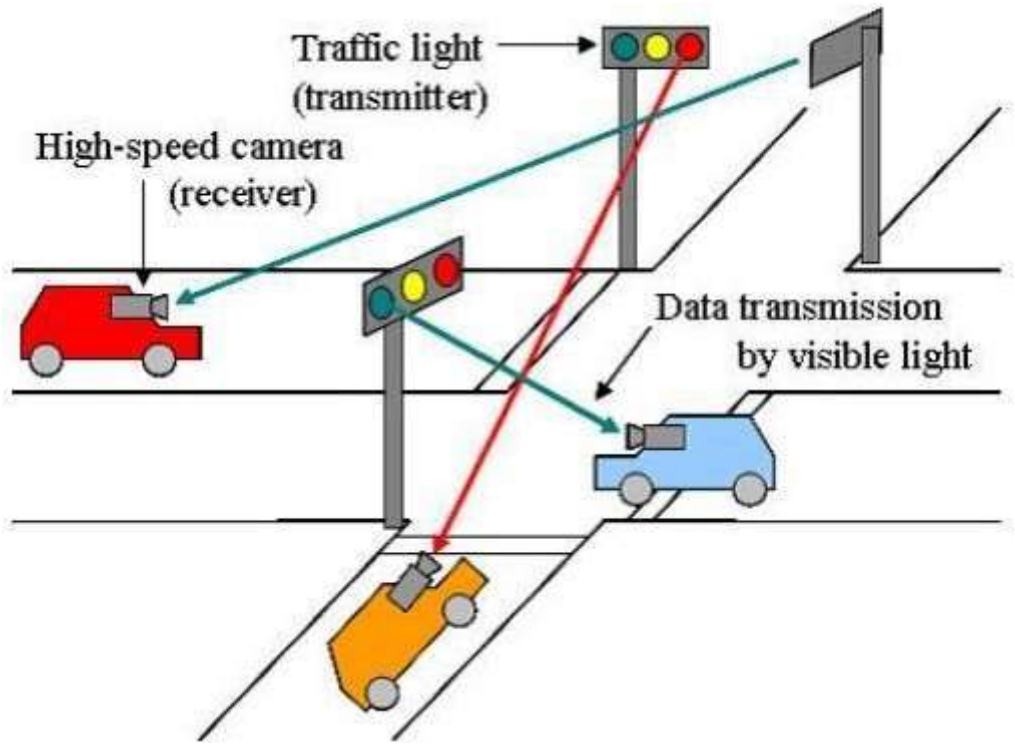

Figure 3.3: Road-to-vehicle visible light communication [14]**.**

The above Fig. 3.3 shows the basic usage of LED as a transmitter and CAMERA as a Receiver. In this model, they mounted a camera before the front end of the car. The Camera is used as the information receiver from traffic signal lights. The advantage of using the camera is that multiple data can be transmitted by the LEDs and received by High-speed cameras [15].

3.3 Intelligent Transport System

This technology can be used to design an intelligent transport system to ensure road safety. Nowadays, solid state lighting is widely used in traffic signals and vehicle lights. So, these sources can also be used for both car-to-car and car-totraffic signal information communication.

3.5 Visible Light Communication Link for Video & Audio Transmission

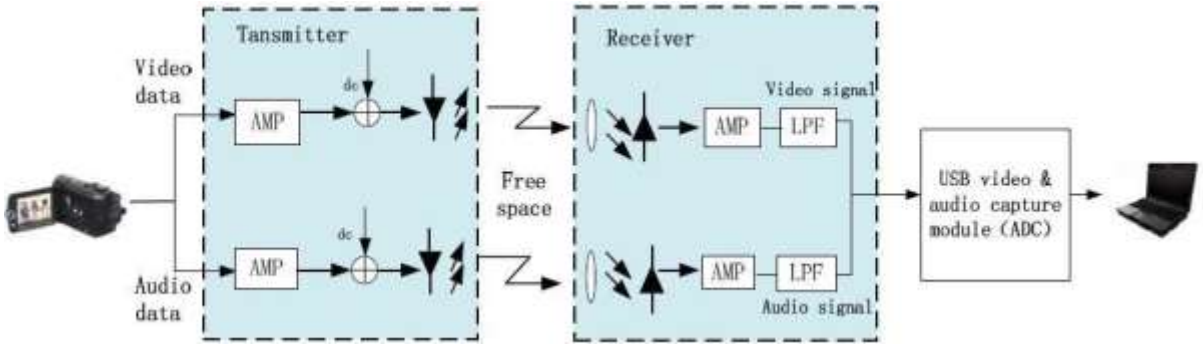

Fig.3.6 Block diagram of real-time video/audio VLC transmission system.

Video and audio signal captured by video camera are amplified by a selfdesigned amplifier and then superimposed onto two LED lamps. Thus, the output light rays changes in intensity corresponding to the variation in signal, which however is insensitive to human eyes due to the rapid frequency response of LED devices. The distance between two LEDs was about 10 cm in order to avoid mutual interference caused by light sources. At the receiver, two highly sensitive photodiodes are used to detect light transmitted over two separate optical channels. And the directionality of the PDs is required to be aligned with the most intense portion of the emitted light beams. After detection, optical signals are converted into photo electric current proportional to the variation of incident light which then is amplified and filtered by a low pass filter (LPF)[16].

Materials and Methods

VLC is typically implemented using white LED light bulbs at the transmitter. These devices are normally used for illumination only by applying a constant current. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This very property of optical current is used in VLC setup. The operational procedure is very simple, if the

LED is on, you transmit a digital 1, if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data. Hence all that is required is some LEDs and an Arduino that code data into those LEDs. All one has to do is to vary the rate at which the LED's flicker depending upon the data we want to encode. Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission to transmit larger data like, videos, audios and pictures.

After building the previous circuit that shown in Fig.4.1 and sending a message from 5cm distance between the transmitter and receiver circuits we worked to improve our VLC system in order to increase the distance and to send more types of data in addition to the message such as images and voice.

At first, we tried to build the circuit shown in fig.4.2 but unfortunately it didn't work as we wanted.

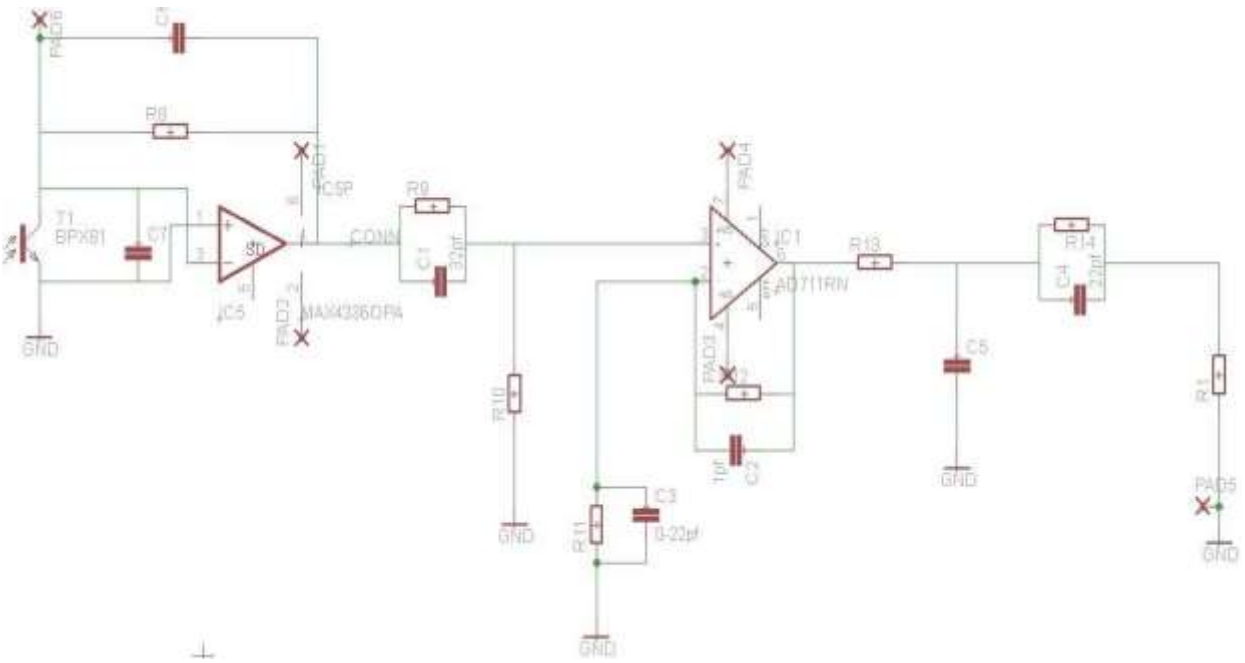

Fig.4.2 Experimental circuit

Because of that we tried other ways to make the distance larger as:

1. Changing resistors values in the transmitter and receiver circuits and put instead of old ones smaller values. So we put a 60Ω resistor at the transmitter circuit and 20Ω resistor at the receiver circuit. This increased the distance from 5cm to 30cm.
2. Put two convex lenses, one (30cm focal length) after the white LED and the other (taken from car) before the photo transistor.

And this way increased the distance between the transmitter and the receiver to 1.6m.

4.2 Software Design

In order to send more data such as, images we designed a new applications (transmitter and Receiver) using C sharp programme.

The figures below show the two applications:

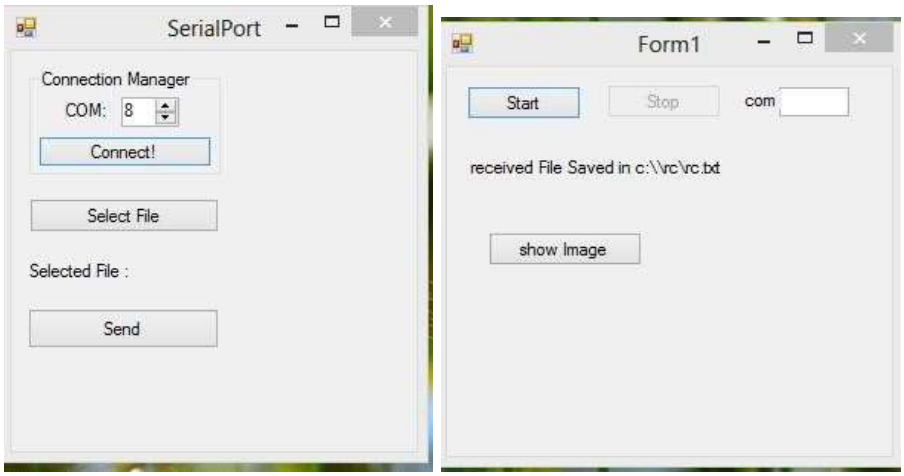

Fig.4.5 Transmitter application Fig4.6 Receiver application

4.3 Flow Chart

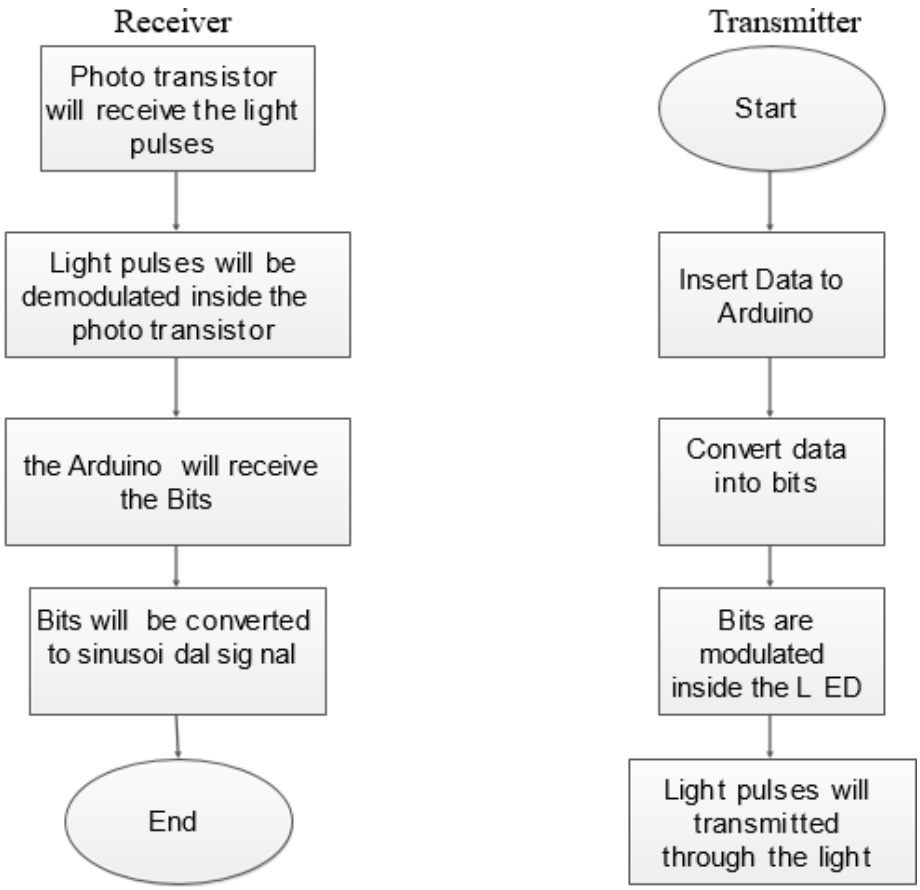

Fig 4.7 the Flowchart

Arduino

We used it to convert the input data into bits in order to transmit it into the LED.

Resistors

To protect the LED and Phototransistor from the high current.

LED:

It modulates the Bits received from the Arduino by converts the electrical current into light pulses

Why we used LEDs ?

With LEDs, it is possible to control light brightness at a frequency much higher than conventional light bulbs: LEDs can be switched on and off at very high rates. As result, LED-based lighting can be used for wireless communication services by modulating the intensity of the emitted light. Further, LEDs can also be used as receivers just like photodiodes. We call this concept Visible Light Communication (VLC) with LED-to-LED networking .

Phototransistor

In order for data transmission to have any significance there must be a way to receive the signal at the other end of the design. This is the purpose of the photodiodes as they react to the light emitted from the LEDs and allow for current to flow to the rest of the receiver circuit. When there is no light emitted from the LEDs the photodiodes do not allow current to flow through to the Arduino on the receiver.

USB

It used to transmit the data from the device to Arduino.

Results

After research we found that the VLC system is different from the other Communication systems and we summarize these differences in the following tables:

	GPS	RFID	WIFI	QR code	Visible light communication
Position accuracy	Several meters	Several Millimeters to Several meters	Several Meters to Several hundred meters	Several Millimeters to Several meters	Several meters
Measurement time	A few minutes	Less than a second	Several seconds	Several seconds	Less than a seconds
Measurement device	GPS receiver	RFID reader	WIFI transceiver	Image sensor	Visible light receiver
Database	Not necessary	necessary	necessary	necessary	Not necessary
The use of indoor and underground	impossible	possible	possible	possible	possible
Recognition of building floors	Impossible	possible	difficult	possible	possible
Applications	Outdoor	In\outdoor	In\outdoor	In\outdoor	In\outdoor
Possibility of widespread use	Already widely used for outdoor	Need to install RFID tags all over the place	Need to install WIFI base stations all over the place	Need to install QR code stickers all over the place	Need to install Visible light transmitters all over the place illumination lights can be used as transmitter

Table 2: Comparison Between VLC System and other Communication system.

Property	VLC	RF
Visibility	Yes	NO
Frequency	400THZ-790THZ	850-950nm
Data rate	3.25 Gb/s	1-2 mb/s
Security	More	Less comp. to VLC
Power Consumption	Relative low	Medium
Coverage Distance	Short	Medium
Harmless for human body	NO	Yes

Table 3: Comparison Between VLC System and RF.

After building the basic circuit of the VLC system we test it by connect the receiver to an oscilloscope and got the following result:

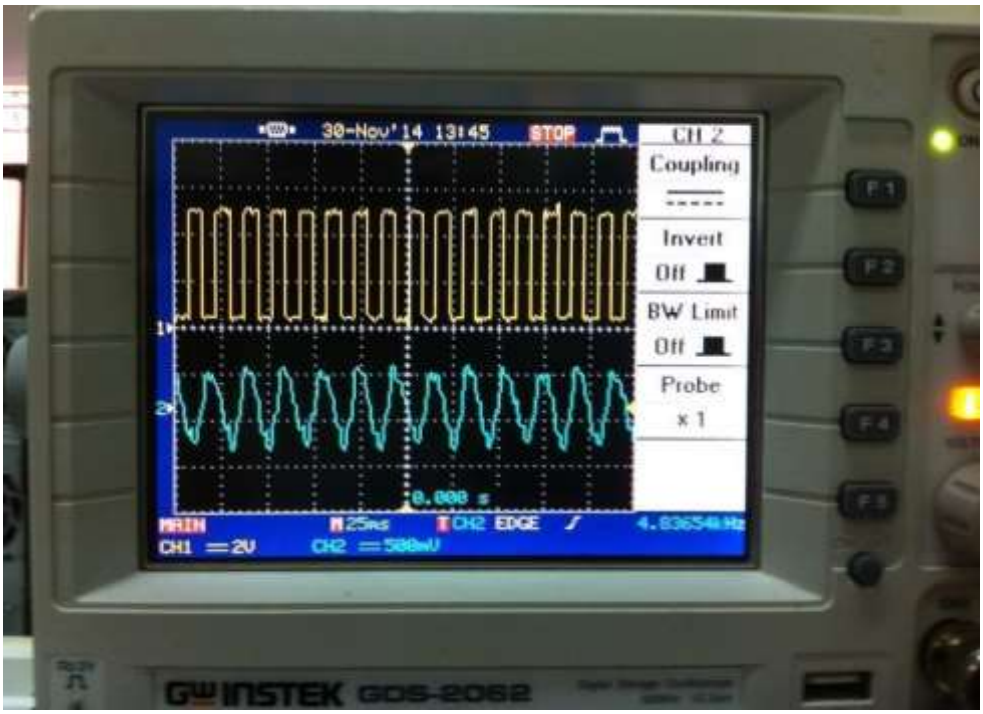

Fig.5.1 testing result

This result mean that the message was sent from the transmitter should be the same at the receiver in order to make sure that the phototransistor receives data from the LED.

Next, a measurement was made on the voltage at several distances in order to know at what distance the receiver (phototransistor) will not receive any data from the transmitter (LED). The results are showed in the following table:

Distance	Output Voltage (p)
2cm	400 mv
4cm	178 mv

Table 1: The Voltage at Photo transistor

After measuring the voltage, the code was downloaded into the arduino and a text message was inserted into it then the transmission operation begun. The photo below shows transmission and reception operations

Fig.5.2 Transmission and Reception operations

As we mentioned earlier we tried to send other types of data like images by writing C# code.

The result we got is shown in the figures below:

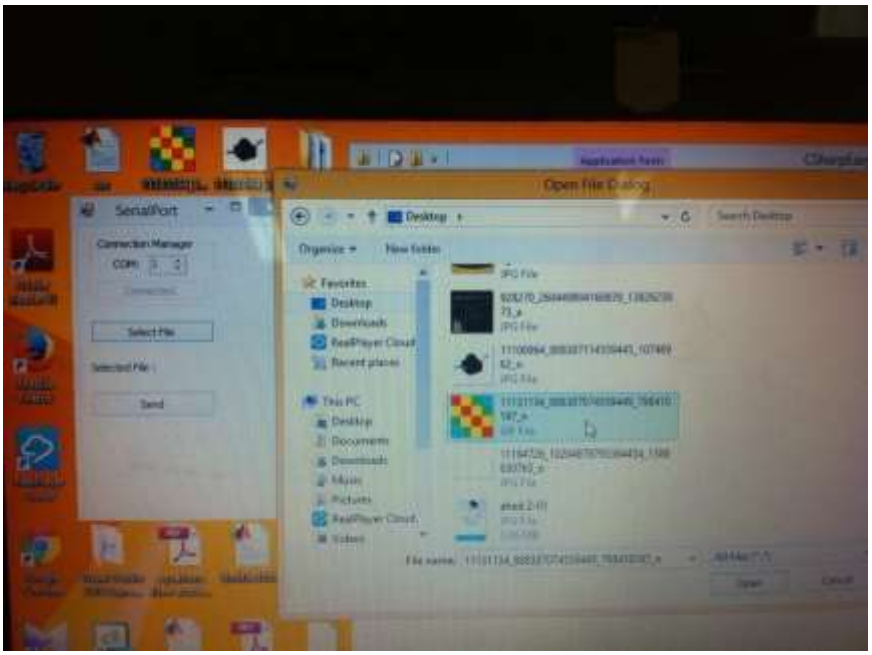

Fig.5.3 Selecting Image

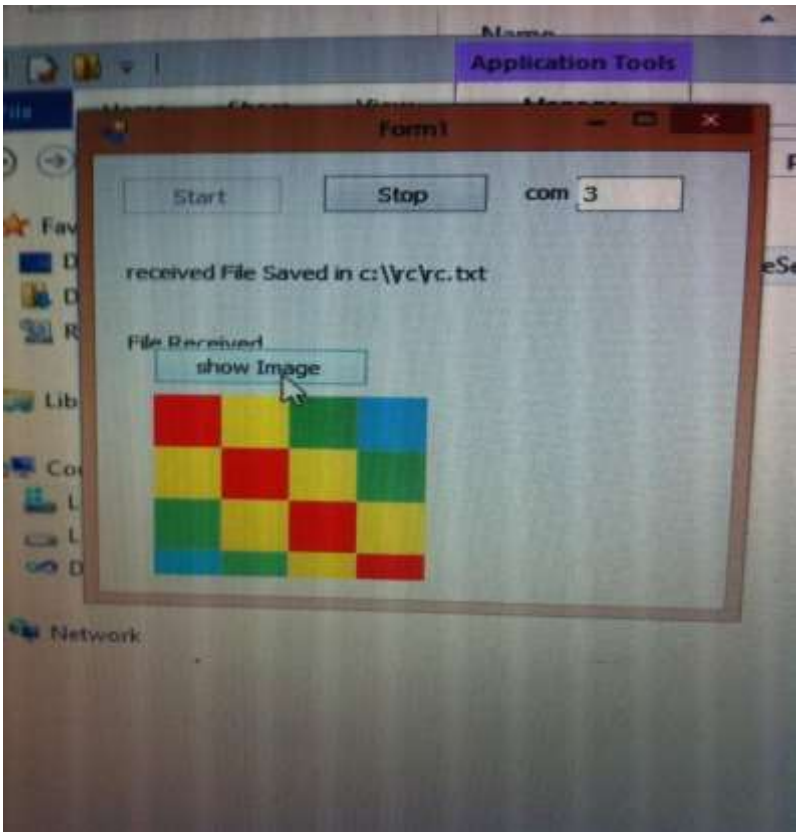

Fig.5.4 Show Receiving Image

Then after increasing the distance we test the circuit and we succeed to send messages from 1.6m distance

Fig.5.5 Distance testing

Discussion

At the beginning of our project we hoped (or expected) that we will be able to send and receive data through light with relatively high data rate and at acceptable distance (at first we looked forward to send and receive data at least at 3 meters). on one hand, we succeeded to send receive

the data. But on the other hand, there was a problem in the distance, i.e. the highest distance the receiver was able to receive data from the transmitter with relatively low error is 5 cm. There were two suggested problems; the first problem is that the LED needed relatively high power in order to send the data to high distance, the second problem is that the light distract along high distances.

We solved these two problems by decreasing the resistors values in the transmitter and receiver circuits and by adding two convex lenses after the white LED and before the photo transistor.

Conclusion and Recommendation

At the end of this project we were able to send and receive text message through led-to-led communication. This proved that at the future we will be able to send hotspots.

and receive any kind of data using every light bulb everywhere like the Wi-Fi

In the future we hope to send and receive all kind of data such as video and audio. In addition, we hope to have mobile-to-mobile communication instead of computer-to-computer communication.

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