Implementation of LiFi prototype in Indoor Scenario

Project report submitted in partial fulfillment
of the requirements of Mini Project for the degree of

Bachelor of Technology
in
Electronics and Communication Engineering

by

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December 2018

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CERTIFICATE

This is to certify that the project entitled Implementation of LiFi prototype in Indoor Scenario, submitted by Anubhuti Jain (16UEC019), Jyoti Kumari (16UEC052) and Shrutika Bansal (16UEC064) in partial fulfillment of the requirement of Mini Project for the degree in Bachelor of Technology (B. Tech), is a bonafide record of work carried out by them at the Department of Electronics and Communication Engineering, The LNM Institute of Information Technology, Jaipur, (Rajasthan) India, during the academic session 2018-2019 under my supervision and guidance and the same has not been submitted elsewhere for award of any other degree. In my opinion, this report is of standard required for the submission of Mini Project.

______________ Dr. Nikhil Sharma

Date Adviser: Name of Mini Project Supervisor

Dedicated to My Family and Friends

Acknowledgments

This report would not have been possible without the constant guidance and nurturing provided by our Mentor and guide Dr. Nikhil Sharma. We are grateful to Dr. Divyang Rawal for his constant support. We also acknowledged the support provided by all the Lab Staff, specially Dharmpal Yadav Sir.

Abstract

The rising popularity of LEDs in our day to day life has opened the doors to untapped potential of Visible Light Communication(VLC). VLC is an fast upcoming field of prominence in the area of Optical Wireless Communication which utilizes the superior modulation bandwidth of Light Emitting Diodes (LEDs) to transmit data. RF systems have been the backbone of modern day communication due to its low interference and high coverage. However, the rapidly dwindling RF spectrum along with increasing wireless network traffic has substantiated the need for greater bandwidth and spectral relief. VLC is at the forefront of dealing with these challenges since it will provide for both illumination and communication; with the present day installation of LEDs playing a major role in its popularity. This report aims to characterize the physical implementation of VLC in indoor conditions by making use LEDs and photodiode. The physical implementations along with practicality is to be studied. Also the aim of the project is to provide a basic understanding of the LiFi technology which will allow for further exploration in this domain.The proposed work involves making use of basic electronic components to transmit data from LEDs to photodiode by making use of the on-off modulation scheme. This is facilitated by making use of Arduino and LCD to both control and display the data trasmitted.

Contents

Chapter *1*

Introduction

1.1 The Area of Work

Communication has been an integral part of the human evolution. It's most important aspect being the medium of communication. Communication means have now evolved to be fast, over long distances and convenient. This has largely being possible by use of Radio Frequencies to transmit data over long distances and instantaneously. But now in this age of data explosion and consumption the spectrum provided by RF is dwindling and is insufficient to cater to the next revolution of 5G and IoT. In view of the above it is essential to explore the possibilities opened by Visible Light Communication. The area of work dealt with in this project Light Fidelity which is an application of VLC. The proposed project is to implement a basic prototype of LiFi.

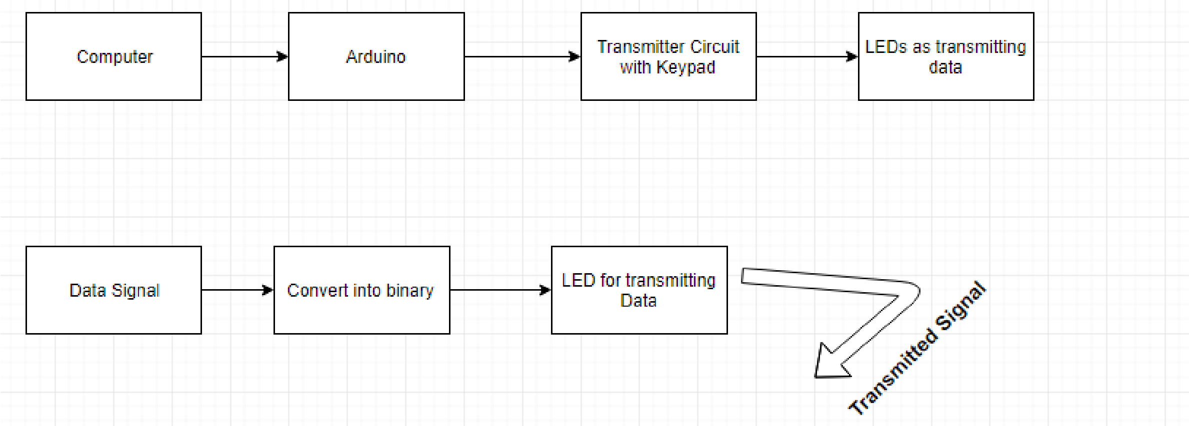
1.2 Problem Addressed

As referred to in the area of interest; the surge in demand for data has posed a number of challenges which need to be overcome. The challenges include:

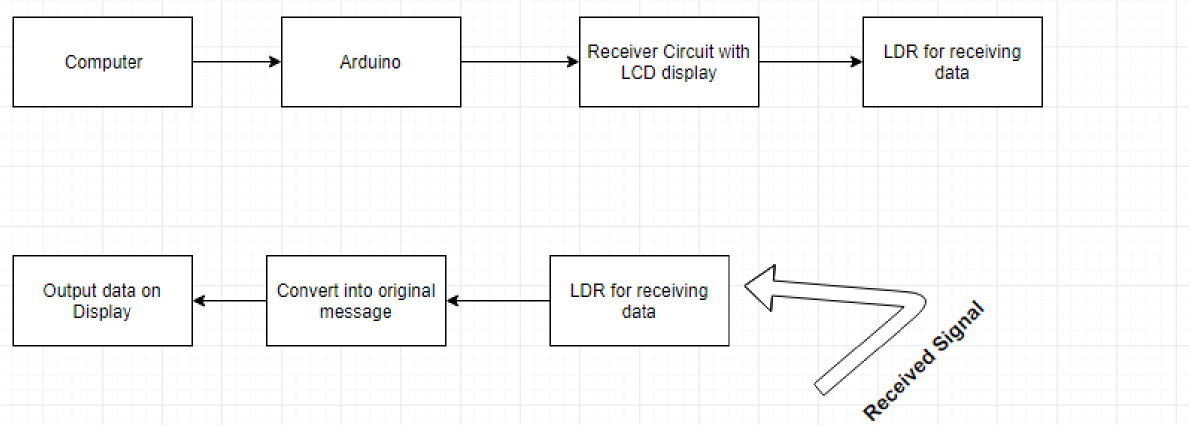
1. Diminishing RF Spectrum
2. Capacity Crunch
3. Interference
4. Security
5. Energy Efficiency

VLC has inert tendencies to overcome these challenges and can be used in collaboration with RF to deliver optimum data transmission. One specific application is LiFi which makes use of LEDs to transmit data. This report aims to implement a basic LiFi design and help further an understanding so as to spur development to overcome the above challenges.

1.3 Block Diagram



Block Diagram for Transmitter



Block Diagram for Receiver

Chapter *2*

Litrature Survey

2.0.1 Introduction

Li-Fi (Light-Fidelity) technology, was proposed by the German physicist—Harald Haas.[1A] Li-Fi is high-speed bi-directional networked and mobile communication of data using light. Li-Fi comprises of multiple light bulbs that form a wireless network, offering a substantially similar user experience to Wi-Fi except using the light spectrum. Connectivity is evolving. The spectrum now has to accommodate more mobile users. Connected devices are forecasted increase to 20 Billion IoT devices by the year 2020. It is time to future proof our networks to enable the connectivity demands of tomorrow. With Li-Fi, we can utilise spectrum more than 1000 times greater than the spectrum utilised for radio frequencies. Li-Fi is now unlocking unprecedented data and bandwidth.[1B]

2.0.2 Working principle

Li-Fi is a category of Optical Wireless Communications (OWC). OWC includes infrared and ultraviolet communications as well as visible light. However, Li-Fi is unique in that the same light energy used for illumination may also be used for communication. In a paper by Harald Haas,[2]the physicist has clarified the difference between visible light communication (VLC) and light-fidelity (Li-Fi). In particular, the paper showed how Li-Fi takes VLC further by using light emitting diodes (LEDs) to realise fully networked wireless systems. Synergies are harnessed as luminaries become Li-Fi attocells resulting in enhanced wireless capacity providing the necessary connectivity to realise the Internet-of-Things, and contributing to the key performance indicators for the fifth generation of cellular systems (5G) and beyond. It covers all of the key research areas from LiFi components to hybrid Li-Fi/wireless fidelity (WiFi) networks to illustrate that Li-Fi attocells are not a theoretical concept any more, but at the point of real-world deployment.

2.0.3 Advantages over RF communication

The way Li-Fi works is simple but powerful. Radio frequency communication requires radio circuits, antennas and complex receivers, whereas Li-Fi is much simpler and uses direct modulation methods similar to those used in low-cost infrared communications devices such as remote control units. LED light bulbs have high intensities and therefore can achieve very large data rates. Another paper titled " VLC : Beyond Point-to-Point Commmunication" by Haas states that furthermore, energy efficient indoor lighting and the large amount of indoor traffic can be inherently combined. In this paper, VLC is examined as a viable and ready complement to radio frequency (RF) indoor communications, and advancement toward future communications. Various application scenarios are discussed, presented with supporting simulation results, and the current technologies and challenges pertaining to VLC implementation are investigated.

2.0.4 Applications

Anywhere there is LED lighting infrastructure there can be a wireless Li-Fi communication network. That Li-Fi network can provide added value providing enhanced efficiency and control. Each Li-Fi access point (LED Light) in a Li-Fi network has a unique IP address allowing facility and IT managers the ability to harness the power of a small cell network. Li-Fi could also enable indoor as well as improve city canyon navigation where Global Positioning System (GPS) signal is weak/non-existent. Due to the simplicity of its front-end hardware, it can play a significant role in enabling the Internet of things and machine-to- machine communication in general. Car-to-car communication could be one of the first implementation scenarios as manufacturers are beginning to make a move towards solid- state lighting solutions. Other possible areas that stand to benefit from the practical implementation of VLC include museums, hospitals, and underwater communications.[4,5] Museums could exploit the already present light fixtures to not only illuminate their exposition pieces, but also to continuously transmit information about them. This could redefine the way automated tours are executed. Hospitals could achieve ubiquitous networking without any detriment to equipment that is sensitive to RF radiation. This should improve hospital care and reduce staff workload. Underwater communications stand likely to benefit most. RF and sound communication are unable to provide fast wireless connectivity under water. Although Li-Fi will also face challenges in that particular propagation environment, it should deliver significant data rate improvements when conditions allow, and otherwise fall back to existing technology, for example sound waves, to provide basic connectivity.

2.0.5 Challenges

If Li-Fi is to become widespread, a number of challenges pertaining to its commercialisation must be addressed. In particular, the drive toward an industry standard, possible market penetration and applications must be considered. Being a relatively modern technology, there are, of course, many challenges that Li-Fi systems are currently facing. Apart from the inherent non-linearity of the LEDs and limits of LED bandwidth, aspects such as signal modulation, power delivery to the transceiver, and multiple access pose difficulties for the immediate proliferation of Li-Fi. However, since such technical challenges have already been conquered in RF through decades of research, Li-Fi is well equipped to go along a similar, only much-accelerated, path. Furthermore, while the current abundance and maturity of RF communications may impede the commercialisation and standardisation of Li-Fi technologies, there is no doubt that Li-Fi will be needed in future communications.

Chapter *3*

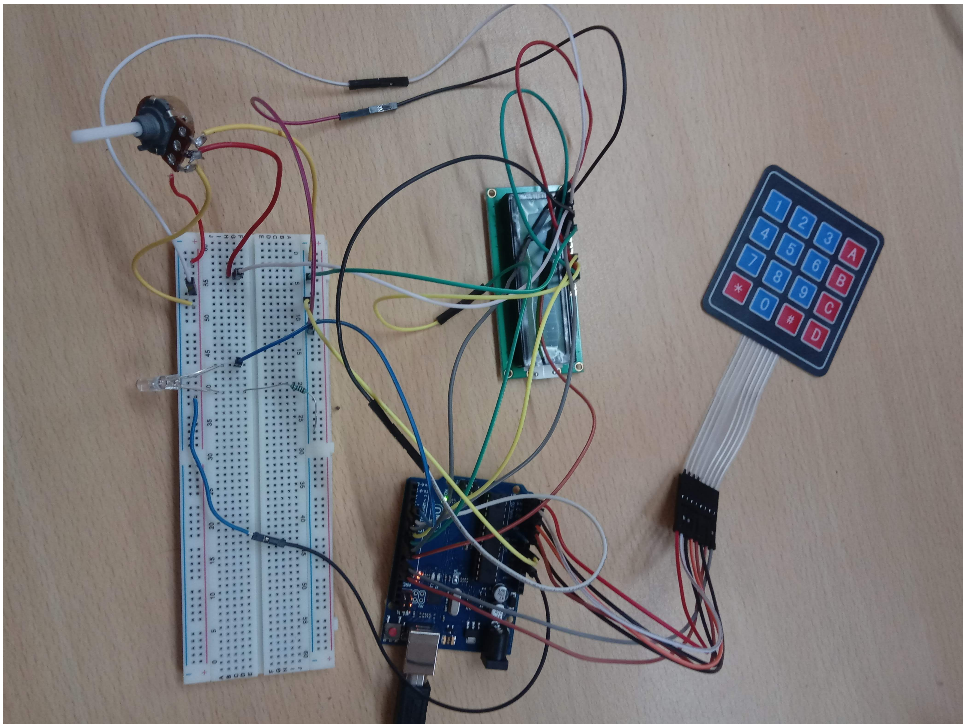
Proposed Work

3.0.1 Working

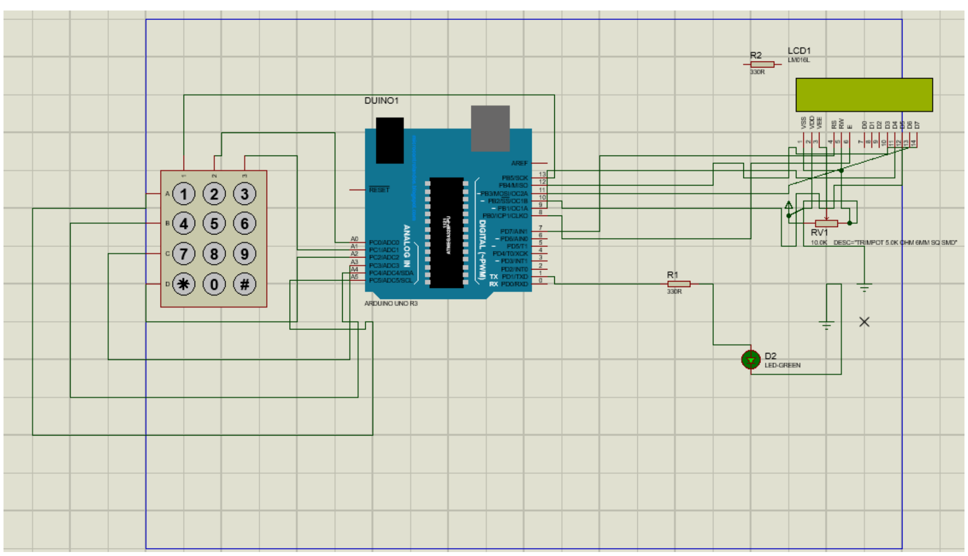
The proposed LiFi prototype consists of a transmitter and receiver. The task of transmitter is to convert digital data into visible light and receiver converts the incoming light into current using a photo-diode. As can be seen from the circuit,input (alphabets and numbers) is given from the keypad; given input can be seen on the LCD connected from the Arduino. There are two infrared LED used as light source. An LED was a suitable component as light source because of its relatively linear relation between current and light intensity. The general idea is to modulate the blinking rate of the LED i.e., the rate at which the LED blinks corresponds to the symbol transmitted. Here rate of blinking is very fast and hence not visible from naked eyes. For a digital signal, the Arduino cannot receive a voltage above 5 V. Therefore, the electrical circuit between the photo-diode and the Arduino needs to process the electrical signal so it can be interpreted correctly. The receiver side need to convert the current to voltage in order to amplify and compare it. The distance between the transmitter and the receiver can be varied, but in order to avoid too small or too high signal, a variable resistor is used here. This component amplifies or reduces the input voltage to a selected output voltage. To make sure the signal is digital and stable before the Arduino, an Op-Amp comparator is used here. The transmitted data after being detected by diode and being amplified finally can be seen on LCD connected in receiver side.

3.0.2 Components required

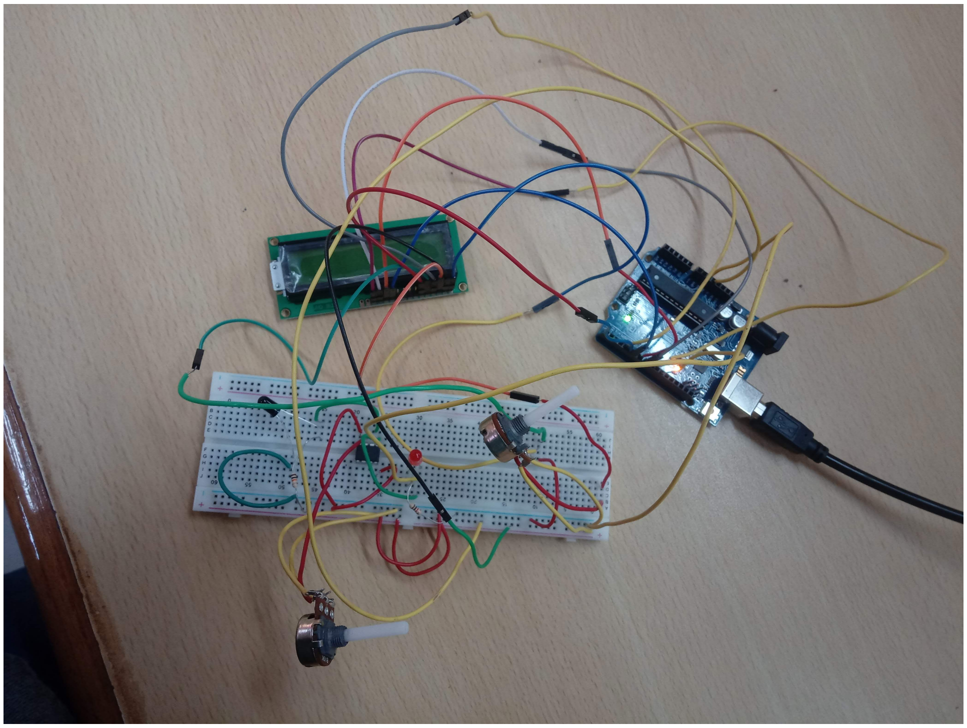
1) 2 x Arduino Uno R3 Board
2) 1 x 16x2 LCD Display
3) 1 x 4x4 Keypad Matrix
4) 1 x 840 Point Bread Board
5) 40 pcs x Male to Male Jumper Wire
6) 5 x LED’s
7) 1 x BMES LDR Module
8) 1 x PCB
9) 1 x Resistor pack



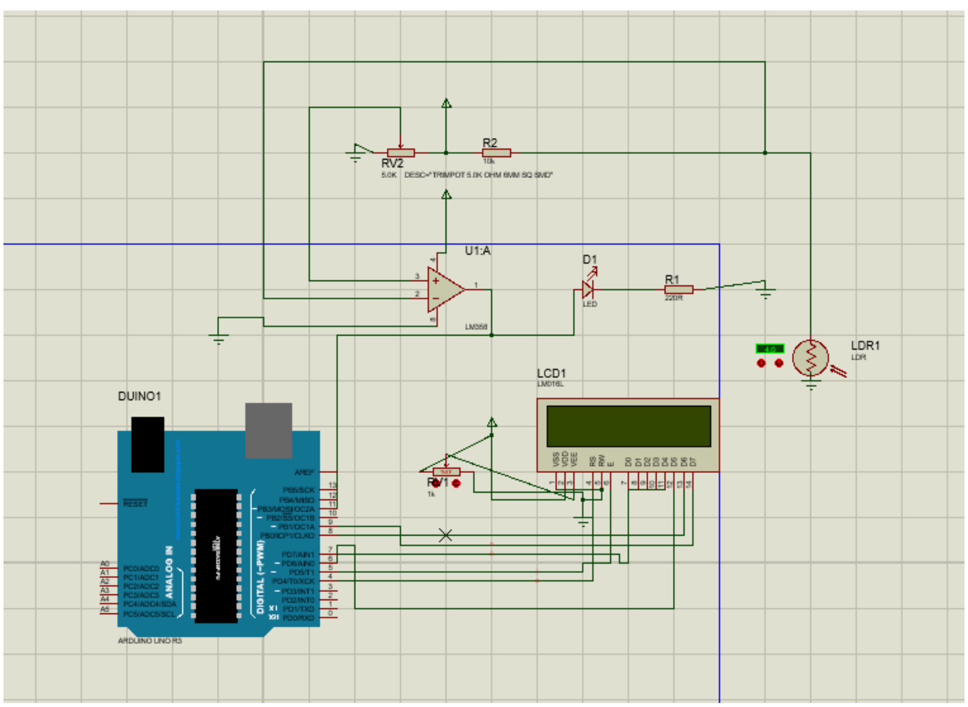
Hardware design of transmitter



Hardware Schematic of transmitter



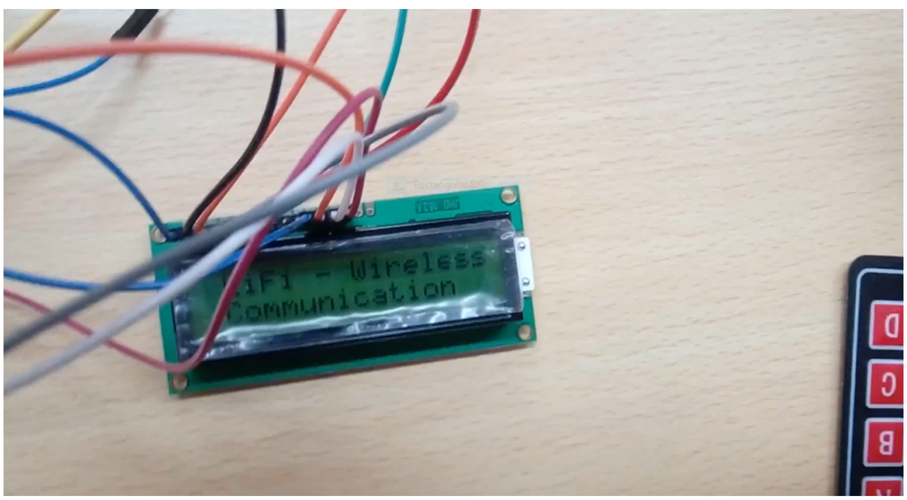
Hardware design of receiver

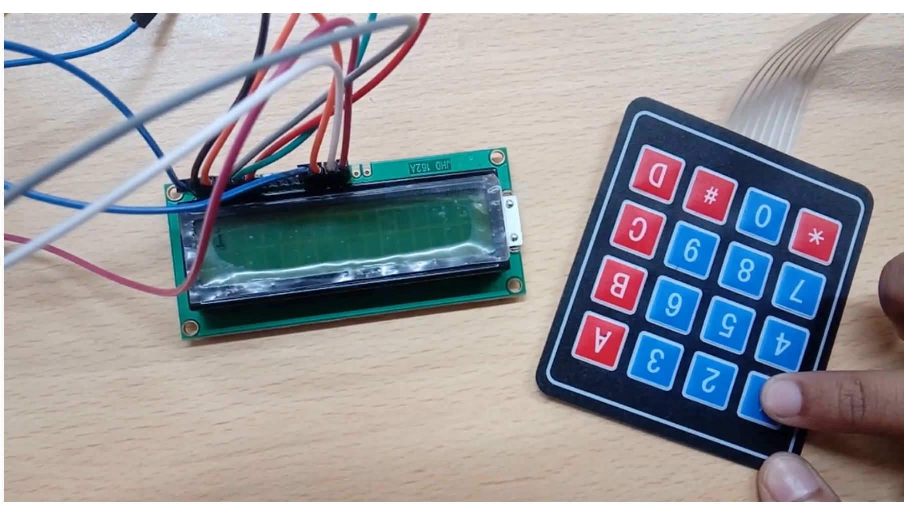


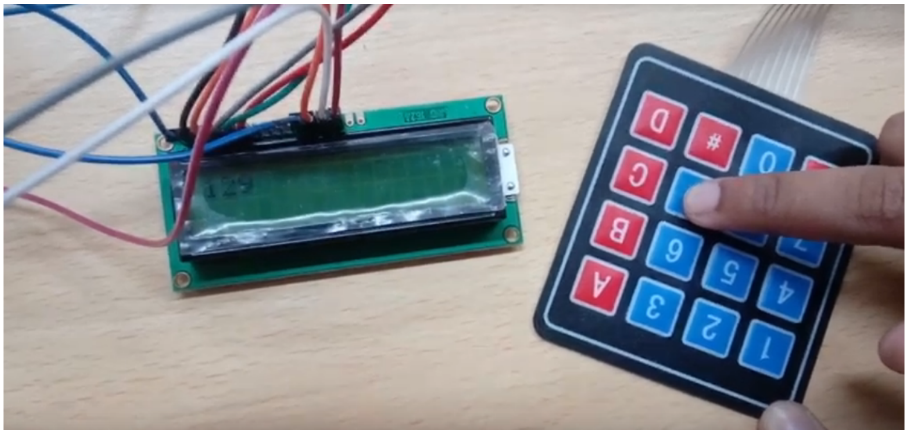
Hardware Schematic of receiver

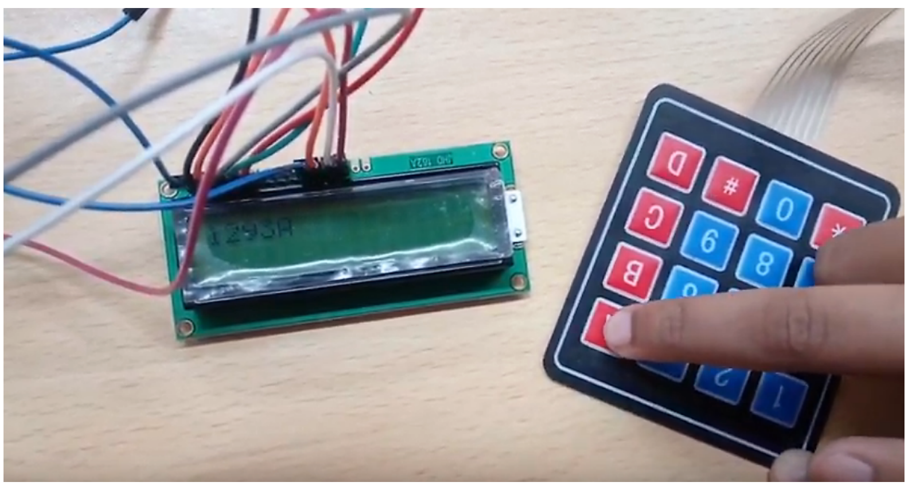
Chapter *4*

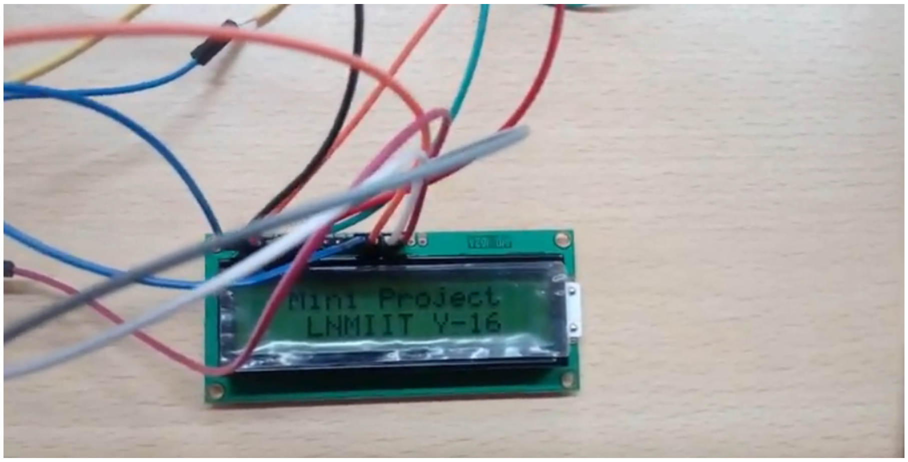
Simulation and Results











Output on LCD of receiver side as key from transmitter side is being pressed

Transmitter Code

```
#include <SoftwareSerial.h>
#include <LiquidCrystal.h>
#include <Keypad.h>
LiquidCrystal lcd(4,5,6,7,8,9);

const byte ROWS = 4;
const byte COLS = 4;

char hexaKeys[ROWS][COLS] = {
  {'1','2','3','A'},
  {'4','5','6','B'},
  {'7','8','9','C'},
  {'*','0','#','D'}
};
byte rowPins[ROWS] = {11,12,A0,A1};
byte colPins[COLS] = {A2,A3,A4,A5};
SoftwareSerial GSerial(2,3);
Keypad customKeypad = Keypad( makeKeymap(hexaKeys), rowPins, colPins, ROWS, COLS);
char keycount=0;
char code[5];


void setup() {
  delay(1000);
  Serial.begin(9600);
  Serial.println("Keyboard Test:");
  GSerial.begin(400);
  lcd.begin(16, 2);

  lcd.setCursor(0, 0);
  lcd.print(" LiFi - Wireless");
  lcd.setCursor(0, 1);
  lcd.print(" Communication  ");
  delay(3000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print(" using Light    ");
  lcd.setCursor(0, 1);
  lcd.print(" TX TESTING ..  ");
  delay(3000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print(" BY Students of  LNMIIT  ");
```

```
  lcd.setCursor(0,1);
  lcd.print("    bm-es.com   ");
  delay(3000);
  lcd.clear();
  GSerial.print('&');
}

void loop()
{
  lcd.clear();
  char customKey = customKeypad.getKey();
  if(customKey && (customKey !='='))
  {
    if (customKey == 'D')
    {
      GSerial.print('1');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);

    }
   else if (customKey == 'C')
    {
      GSerial.print('2');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }
   else if (customKey == 'B')
    {
      GSerial.print('3');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }
      else if (customKey == 'A')
    {
      GSerial.print('A');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }


       else if (customKey == '3')
```

```
{
  GSerial.print('B');
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
}
   else if (customKey == '2')
{
  GSerial.print('C');
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
}
   else if (customKey == '1')
{
  GSerial.print('D');
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
}

   else if (customKey == '*')
{
  GSerial.print('4');
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
}
   else if (customKey == '9')
{
  GSerial.print('5');
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
}
   else if (customKey == '6')
{
  GSerial.print('6');
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
}
   else if (customKey == '0')
{
  GSerial.print('7');
```

```
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }
       else if (customKey == '8')
    {
      GSerial.print('8');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }
       else if (customKey == '5')
    {
      GSerial.print('9');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }
       else if (customKey == '7')
    {
      GSerial.print('0');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }
       else if (customKey == '4')
    {
      GSerial.print('#');
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
    }

   }
 }
```

Receiver Code

```
#include <SoftwareSerial.h>
#include <LiquidCrystal.h>

LiquidCrystal lcd(7, 8, 9, 10, 11, 12);
SoftwareSerial GSerial(5,4);
char rec=0;

void setup()
{
  Serial.begin(9600);
  GSerial.begin(400);
  lcd.begin(16, 2);
  lcd.setCursor(0, 0);

  lcd.print(" LiFi - Wireless");
  lcd.setCursor(0, 1);
  lcd.print(" Communication  ");
  delay(3000);
  lcd.clear();

  lcd.setCursor(0, 0);
  lcd.print(" using LED   ");
  lcd.setCursor(0, 1);

  lcd.print(" RX TESTING ..  ");
  delay(3000);
  lcd.clear();
  lcd.setCursor(0, 0);

  lcd.print("  By students of LNMIIT  ");
  lcd.setCursor(0,1);
  lcd.print("    Y16   ");
  delay(3000);
  lcd.clear();
}

void loop()
{
  if(GSerial.available() != 0)
  {
    rec = GSerial.read();
    if(rec=='^')
    {
      lcd.setCursor(0, 1);
      lcd.print("                ");
      lcd.setCursor(0, 1);
```

```
    }
    else if(rec=='&')
    {
 lcd.clear();
    }

    else
    {
      Serial.print(rec);
      lcd.print(rec);
    }
  }
}
```

Chapter *5*

Conclusions and Future Work

5.0.1 Conclusion

The shortcomings of RF communication in terms of spectral and bandwidth motivates the research into visible light communication. Now with the surge in LED usage has thrown open the door for many VLC potential. One of which is LiFi capability. This in turn has been possible due to its fast switching capabilities. This report has sought to verify its usage as a possible data transmission means which has been successfully collaborated by the results.This report strives to enhance the physical implementation of LiFi technology for indoor purposes by making a working model of such a prototype which can be further improved upon with the basic understanding derived. Certain issues faced in the prototype are interference, noise and shadowing which need to be further investigated. These issues are been dealt with by various research groups to make it a promising technology for the future. The results conclusively proves the versatility of LiFi as an enabling technology for the future deployment of IoT and VLC as the mode of last mile connection in 5G. VLC can also lead to Smart Grid enhancements.

5.0.2 Scope of further work

The proposed work for the future can be broadly divided into 3 categories:
1. Free Space Optical Wireless Communication Infrared, Visible light and Ultraviolet light make up the optical domain. In Free Space Communication this domain can be utilized for very high speed data transmission over moderate distances. This can be achieved by using laser or LED based methods. An important aspect of this method is the security, high speeds and unlicensed spectrum being used. The future works will make use of laser based VLC to achieved its basic understanding, efficiencies and shortcomings. To explore this avenue Koruza units will be used to for physical implementation and further enhancements looked into.
2. Wireless Underwater Optical Communication System Acoustic modems have long been the default wireless communication method for underwater applications due to their long range, the need for high speed communication for underwater applications due to their long range, the need for high speed

communication has prompted the exploration of non-acoustic methods that have previously been overlooked due to their distance limitations. The proposed work aims to setup an optical communication using LED's so as the improve the speed over moderate distances with the use of low power and low complexity communication systems. The proposed work looks to use super bright blue LED based transmitter system and a blue enhanced photo-diode based receiver system with the goal of transmitting data at rates of 1 Mbps over distances of at least 10 meters. This work will be beneficial to assess the effectiveness of Visible Light Communication as an alternative in underwater communication. Its applications include but not limited to Unmanned Vehicle communications with the oil rigs, data transfer at high rates. It will make use a Blue light LED's, LED driver and photo-diode to accomplish the task.
3. Water pollution measurement using Visible Light Chemical composition and physical properties of any water source is measured by water testing which require a lab setup, special equipment, trained personnel and long turnaround time for information. Our aim is to reduce this turnaround time with the use inexpensive equipment by making use of the visible light communication techniques and water properties.Previous research has shed some light as to the achievement of this as shown in the paper by Tamás Szili, Balázs Matolcsy, and Gábor Fekete. The proposed work intends to improve upon these results to achieve higher accuracy and precision by making use of specific light wavelengths to assess the presence of specific components in water. Further improvement based on data models is also an avenue of investigated. A brief overview of the method employed: The channel caused attenuation are measured for different wavelengths of light . If there is a connection between the detected power and the channel type (e.g. it is tap water or salty water), the composition of the medium can be determined. It makes possible the detection of water pollution without any expensive investigations in a laboratory. Future works will investigate the connection between the detected power of the emitted light and the different kinds of polluted water, where it was propagated. To verify this model the setup will include an LED based underwater communication device altered to detect power. .
4. LED based indoor visible light communications. This report exclusively dealt with the LiFi technology by making use of LEDs to transmit data while at the same time acting as a source of light. LEDs due to their unique characteristic of high switching rate can be used for transmission of data by on-off keying which can be perceived by a photodiode. The genesis of further work in this domain makes use of RGB LEDs based on Nitride and aims to achieve indoor a LiFi prototype based on FPGA to augment the LiFi research efforts.

Chapter *6*

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