CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Light Fidelity (Li-Fi) is an innovative technology in the field of wireless communication sector that utilizes the visible light communication (VLC) providing high speed data-rates and wireless data transmission. Li-Fi uses LED bulbs that can be switched on and off at high speeds, beyond the human eye's ability to notice. This modulation of the light intensity encodes the data, which is then received and to be decoded by the photodiodes. In this technology, the light communication systems that are capable of transmitting the data at very high-speed over the Visible-light, ultraviolet and infrared light-ray spectrums that is used for the wireless data transmission. In developing state as of 2011 information, only LED Lamps can be used for the transmission of data in visible light. In terms of its end user, the technology is similar to Wi-Fi – the key technical difference being that Wi-Fi uses radio frequency to induce an electric tension in an antenna to transmit the data, whereas Li-Fi uses the modulation of light intensity to transmit the data. Li-Fi is able to function in areas susceptible to electromagnetic interference like in case of aircraft cabin, hospitals, or the military. The Li-Fi is still an emerging technology, but it holds a great potential for providing high-speed, secure, and interference-free wireless communication in specific environments like corporates, governments, and even for the general-public networking usage. The Li-Fi market was projected to have a Compound growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018. However, the market has not developed as such and Li-Fi remains with a niche market.

The concept of Li-Fi is a Wireless Communication technology was first introduced by Professor Harald Haas in 2011, TED-Global talk in Edinburgh, Scotland, UK and since then it has gained significant attention due to its potential to provide faster and more secure data communication as the Li-Fi employs light-emitting diodes (LEDs) to modulate the light signals for high-speed data transfer and also for the positioning between electronic devices. Li-Fi can potentially be useful in electromagnetic sensitive areas without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic Spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible, ultraviolet, and infrared light. Researchers have reached data rates of over 224 Gbit/s, which was much faster than typical fast broadband in 2013. Li-Fi is expected to be ten times cheaper than Wi-Fi. The first commercially available Li-Fi system was presented at the 2014 Mobile World Congress in Barcelona. Li-Fi is a derivative

of Optical Wireless Communication (OWC) technology, which uses the light from Light-emitting Diode (LEDs) as a medium to deliver mobile-network, high-speed communication in a similar manner to Wi-fi. The Li-Fi technology used in the field of wireless communication system offering higher bandwidth, reduced electromagnetic interference, and enhanced security, and the Li-Fi can leverage existing lighting technological infrastructure which makes it a cost-effective solution for several applications. With the increasing demand for the high-speed internet connectivity for the data transmission with the growing number of connected devices through Internet of Things (IOT), and with the limitations in the traditional Radio-frequency RF wireless-communication systems that are becoming outdated with the development of upcoming wireless-communication technologies. With the challenges faced by the RF-based technological system such as limited bandwidth, signal interference, and security vulnerabilities, an alternative communication technology that can addresses these issues providing reliable and efficient data transmission is the Li-Fi presenting a promising solution to these challenges.

1.2 OBJECTIVES

- To provide an overview of Li-Fi technology and its working principles.
- To identify the required hardware components and software for a Li-Fi-based text transmission system.
- To design and implement a prototype system for text transmission system using Li-Fi.
- To test the performance of the Li-Fi system in terms of data transmission speed, reliability, and security.
- To discuss and solve the Li-Fi system problems faced during the testing phase.

1.3 ADVANTAGES

- **High Speed:** Li-Fi can achieve data rates much higher than traditional Wi-Fi.
- **No Electromagnetic interference:** It doesn't cause electromagnetic interference, making it suitable for use in sensitive areas like hospitals and aircraft cabins.
- **Enhanced Security:** Since light cannot penetrate walls, Li-Fi offers better security compared to Wi-Fi.

- **Large Bandwidth:** The visible light spectrum offers a much larger bandwidth than radio waves used by Wi-Fi.

1.4 DISADVANTAGES

- **Line of Sight**: It requires a direct line of sight between the transmitter and receiver, which can limit its range.
- **Light Dependency**: The system needs the LEDs to be ON while transmitting and receiving the data, which can be a limitation in some scenarios.
- **Interference**: Other light sources, like sunlight, can interfere with the signal.

1.5 APPLICATIONS

- **Medical Applications**: Secure and interference-free communication in hospitals and healthcare facilities.
- **Aircraft Cabins**: Providing the internet connectivity without interfering with the other internal aircraft systems.
- **Underwater Communication**: Since RF signals cannot propagate underwater, Li-Fi can be used for underwater data transmission.
- **Indoor Wireless Communication**: High-speed internet access in homes, offices, and public spaces.
- **Smart Lighting**: The Integration of lighting and communication systems in the smart cities and buildings.
- **Secure Facilities**: Such as military bases or nuclear power plants.

CHAPTER 2

LITERATURE SURVEY

2.1 KEY STUDIES AND CONTRIBUTIONS

- In 2011 Professor Harald Haas introduced the concept of Li-Fi in the TED-Global Talk, demonstrating the use of LED light bulbs for the wireless data transmission and reception. Harald Haas was the first person to introduce "Information conveyed through luminous" in front of the world at the global TEDx.

- The VLC-based Communication "Light-Fidelity that how visible light communication (VLC) technology is applied to high-speed wireless communication," according to Singh AJ & Veerahgari (2014) the most popular form of communication on the planet is wireless data transmission using radio waves, however, due to its narrow frequency bandwidth, its use has been constrained. To solve this problem, VLC is introduced. The spectrum of visible light is 10,000 times greater than the spectrum of radio frequencies. Kartika R & Balakrishnan, 2015 discussed Li-Fi technology-based on the wireless communication focusing on the modulation techniques, data rates, and the impact of ambient light on system performance.

- Every-day the number of people accessing the internet which makes the demand for the internet access exponentially increase day-by-day eventually. The Wi-Fi (wireless fidelity) is a more expensive and exhibits sluggish data speeds when more than two routers are connected, the Li-Fi (light-fidelity) is a good solution to solve these problems. It is a wireless technology that uses LED or infrared light to transfer the information which uses a light source to transmit the data while using VLC for the Li-Fi under varying limitations such as light intensity, output quality and distance. The Li-Fi uses the LED for up to 500 Mbit/s of communication over short distances or regular lamps for transmissions at 10 Kbit/s.

- Among the other transmission methods that are now in use, the visible light communication is one of the most cutting-edge improving advance technologies. When the substantial data transfer is required, its high bandwidth, quick data rate, and resilience to interference has made this technology set it apart from other technologies. According to a newly released CISCO estimate on data traffic, mobile data traffic will increase 11-fold in 2018 compared to 2013. The main cause of the significant increase in mobile data traffic is the rise in the

number of smartphone devices connecting to mobile networks for the access of internet services for the use of various types of corporate offices, numerous industries, including the hospitals, aviation, communication, industrial automation, information displayed on sign boards(for advertising), home and building automation, telecommunication and education, also make use of the visible light communication technology. By alerting the traffic signal, VLC is utilized in vehicle-to-vehicle communication to prevent accidents, as this type of communication requires the minimal latency for the communication between the short-range distances, which the VLC is able to provide as its core domain technology as compared to other technologies.

- In areas that are extremely sensitive to electromagnetic waves, such as aircraft and hospitals, where radio waves interfere with the waves of other machinery, the visible light communication is also an option provided by Ashoke Nath, et al 2015. Even for the real-time audio & video transmission system based on visible light communication presented by He Y, et al. 2013. Li-Fi system for data communication for either audio or a text file transmission is utilizing visible light communication technology. The demodulation signals are used to recover the original information from the received signal in which the noise is being supplied by which the bit size gradually increases the bit error rate and to set up the demodulation for bringing this error down to about zero. In the hybrid Li-Fi/RF systems the research has explored the integration of Li-Fi with existing RF-based systems, aiming to enhance overall network performance and provide seamless connectivity.

- The worlds' demand for the internet connections and services is growing rapidly and also largely dependent on wireless communication. The worldwide sales of cell phones were approximately 122.32 million in 2007. In 2013, the amount reaches 969.72 million. Additionally, the population will reach 1.524 billion in 2019 and is projected to rise to 1.582 billion in 2021. From this data, it is inferred that there's a huge significant growth and development for the demand and supply for the wireless communication and telecommunication field with technological improvements.

CHAPTER 3

HARDWARE AND SOFTWARE

3.1 HARDWARE COMPONENTS

1 Arduino Uno

The Arduino UNO as shown in figure 3.1 is a microcontroller board based on the ATmega328P. Its features are:

- 14 digital input/output pins.
- 6 analog inputs.
- 6 output pins used for PWM signal generation.
- A 16 MHz quartz crystal.
- A USB connection, a power jack, an ICSP header, and a reset button.

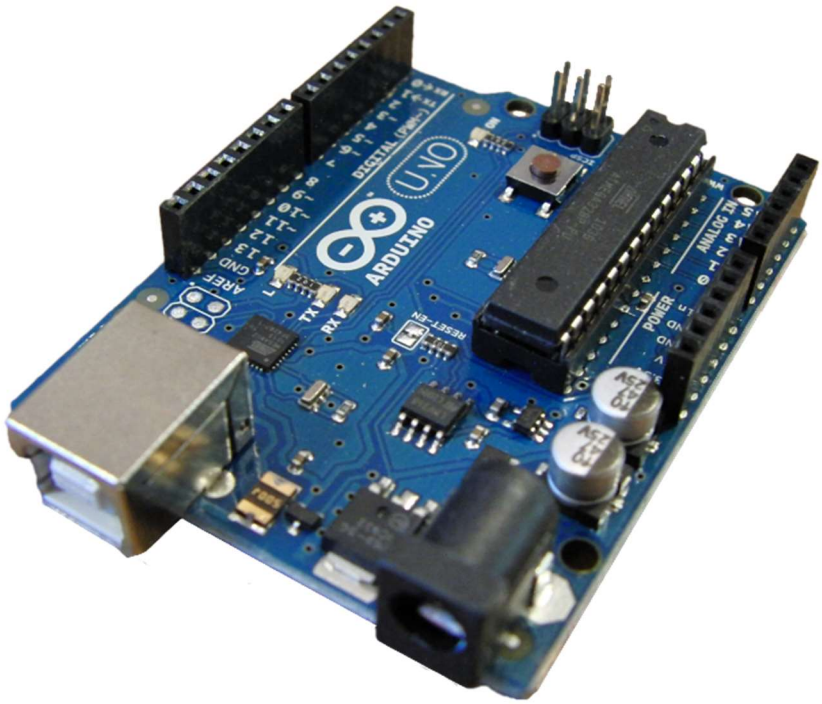

FIGURE 3.1: Arduino Uno

2 Arduino Nano

The Arduino Nano as shown in figure 3.2 is a compact, versatile microcontroller board designed for its ease of use in small projects and embedded systems. It is based on the ATmega328P microcontroller that offers similar functionality to the Arduino UNO but in a smaller performance-oriented version, making it an ideal choice for space-constrained projects. The key features of Arduino Nano are as follows:

- **Microcontroller:** The ATmega328P is an 8-bit microcontroller with 32 KB of flash memory for storing the code, 2 KB of SRAM, and 1 KB of EEPROM.
- **Analog Input Pins:** The 8 analog-pins, which can read signals from the analog sensors and converting them into the digital values with each analog pin providing 10-bit resolution.
- **Digital I/O Pins:** The Arduino Nano consists of 14 digital pins, these pins can be configured as input or output and are used to interface with other electronic components like sensors, LEDs, in which the 6 pins are the output pins used for the generation of PWM signals.
- **Clock Speed:** The microcontroller provides 16 MHz processing clock speed for efficient execution oftheinstructionsandsynchronisedtimelyresponseforthecontrolapplications.**USB Connectivity:** The mini-USB port is used to dumb the program onto the MC-board and also provides with the power supply for the circuit. The USB connection also allows for serial communication with the electronic device or any other embedded system.

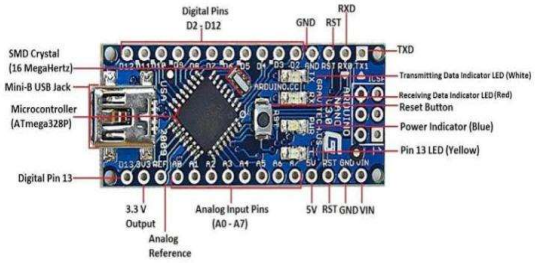

FIGURE 3.2: Arduino Nano Board.

3 Light Emitting Diode

A Light Emitting Diode (LED) as shown in figure 3.3is a semiconductor device that emits light when an electric current pass through it. LEDs are widely used in various applications due to their efficiency, long lifespan, and fast switching capabilities. In a Li-Fi system, LEDs serve as the primary light source for transmitting data. The key features of the LED include the following:

- High Efficiency: LEDs convert a significant portion of electrical energy into light, making them energy-efficient.
- Long Lifespan: LEDs have a long operational life, often exceeding 50,000 hours.
- Fast Switching: LEDs can switch on and off rapidly, enabling high-speed data transmission in Li-Fi systems.
- Variety of Colours: LEDs are available in various colours and wavelengths, suitable for different applications.

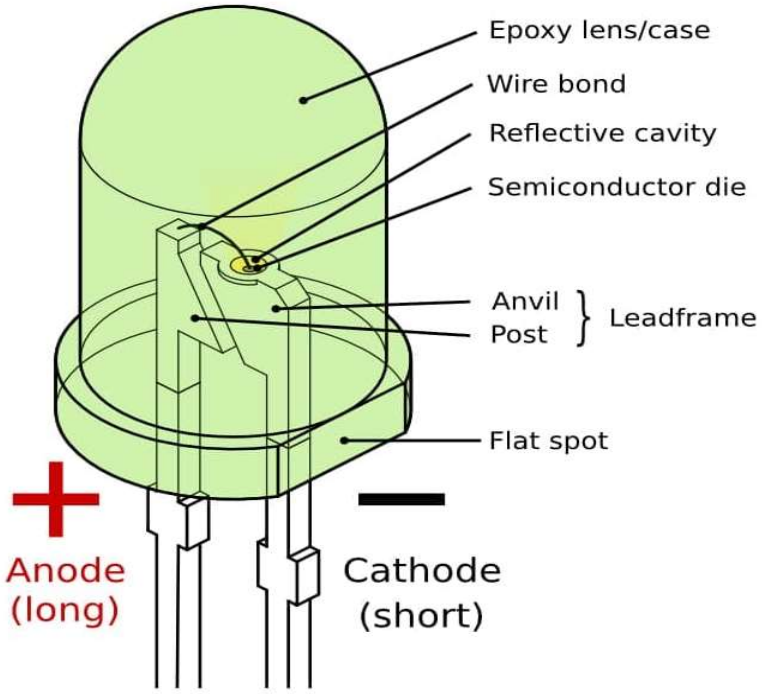

FIGURE 3.3: LED.

4 Photodiode Sensor

The Photodiode (Light Dependent Resistor) as shown in figure 3.4 is a semiconductor device that converts the light energy into the electrical current signals. It is used in various applications, including the light sensing technology and optical communication. In a Li-Fi system, a photodiode acts as the receiver, detecting the modulated light signals transmitted by the LED.

- **High Sensitivity:** Photodiodes are highly sensitive to light, enabling accurate detection of light signals.
- **Fast Response Time:** Photodiodes can quickly respond to changes in light intensity, making them suitable for high-speed data reception.
- **Low Dark Current:** Photodiodes have a low dark current, ensuring minimal noise when no light is present.

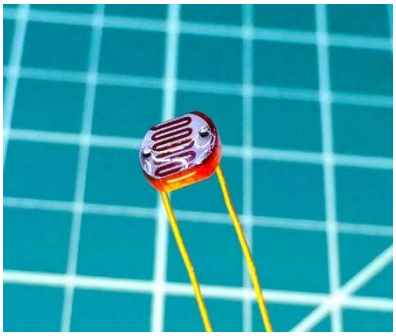

FIGURE 3.4: Photo-diode Sensor.

5 Liquid Crystal Display

A Liquid Crystal Display (LCD) as shown in figure 3.5 is an electronic display module that uses liquid crystals to produce visible images or text. LCDs are commonly used in a wide range of applications due to their low power consumption, compact size, and versatility. In a Li-Fi system, an LCD can be used to display transmitted text or status information. The key features are as follows:

- **Low Power Consumption:** LCDs require minimal power to operate, making them ideal for battery-powered devices.

- **High Contrast:** LCDs provide clear and sharp images with high contrast, ensuring good readability.
- **Compact and Lightweight:** LCD modules are thin and lightweight, suitable for portable and embedded systems.
- **Versatile Display Options:** Available in various sizes and formats, including character and graphic displays.

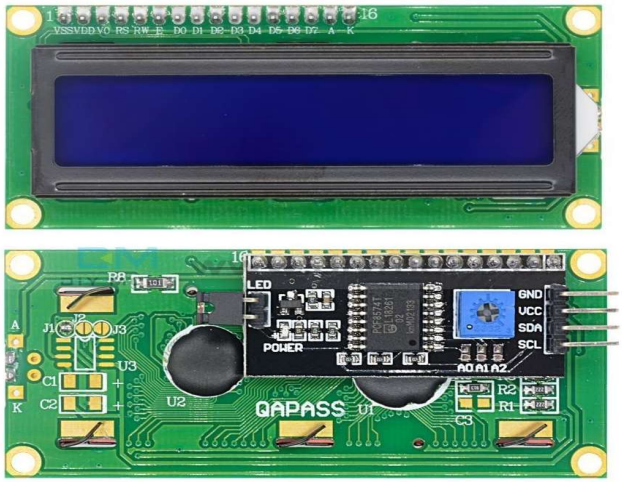

FIGURE 3.5: LCD Display (16*2).

6 Resistor

Resistor as shown in figure 3.6 is the basic electronic component used to control current in the circuit. The resistor value is 10k ohm used for biasing, filtering, and stabilizing the circuit.

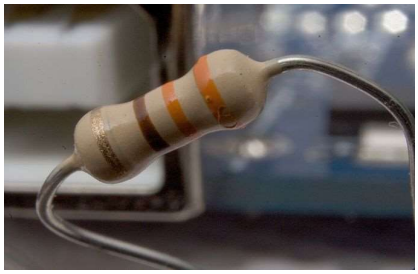

FIGURE 3.6: 10k ohm Resistor.

CHAPTER 4

SOFTWARE COMPONENTS

4.1 SOFTWARE

- **ARDUINO IDE**

  The Arduino Integrated Development Environment (IDE) is an open-source platform that is being used for developing and uploading the code in the case of different types of Arduino boards. The Arduino uses a simplified version of C/C++ programming language. The code developed after compiling, is to be uploaded onto the Arduino Uno board for the control signals to get activated for the data transmission using the LED as transmitter and the photodiode used as receiver for the data reception, and subsequently displays the data on the LCD screen. The key features of using the Arduino IDE are as follows:

  - Code Editor: Provides syntax highlighting, auto-formatting, and debugging tools.
  - Serial Monitor: Allows communication with the Arduino board via USB.
  - Library Manager: Facilitates the inclusion of additional libraries for extended functionality.

- **LIBRARIES USED IN ARDUINO**

  The programs can get very long and have many lines of code. The functions help the program to stay in an organized and structured way by letting them to integrate with the logic and flow of the code and segment onto the code by using different the groups that can be used over and over again in the same program for various functionalities in the rest of the program. The Arduino libraries used are as follows:

  - **setup ()** initializes variables, pin modes, and starts using libraries.
  - void setup () will only run once, and that will be at the beginning of your program.
  - void loop () the code will repeat over and over again.

- **serial. printing ()** description the print data to the serial port as human-readable ASCII text followed by a return character (ASCII 13, or '\r') and a newline character (ASCII 10, or '\n') that takes the command which is same as in the form of the **serial. Print ().**

- **loop ()** contains the main code to be executed repeatedly after the setup.

FIGURE 4.1: Arduino Software Logo.

CHAPTER 5

SYSTEM DESIGN AND DESCRIPTION

5.1 TRANSMITTER

The block diagram of the transmitter is as shown in figure 5.1 that consists of the following:

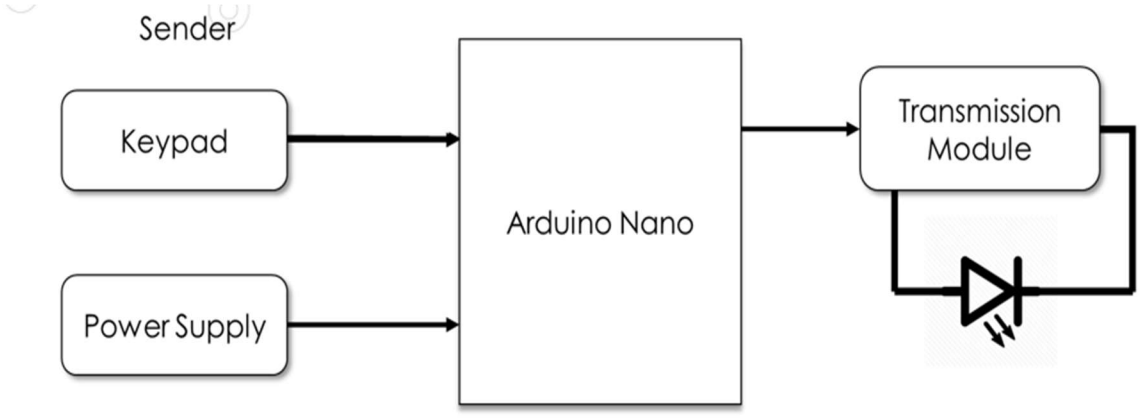

FIGURE 5.1: Block diagram of the transmitter.

The keypad acts as an input device for the user to enter data, commands, or codes. It sends input in the form of pressing the button from the user's end and sends the input signals to the transmission module through the Arduino Nano as shown in the figure 5.2 and the Arduino Nano processes the input from the keypad and it generates the control signals to send the coded data through the transmission module. The transmission module includes an LED or IR transmitter through which the processed signal from the Arduino Nano passes into an optical cable or through wireless for message transmission. The diode is the most used semiconductor device for the electronic circuits. It is a two-terminal electrical check valve so that allows for the flow of current in one direction. They are mostly made up of silicon and germanium is also used and usually, they are used for rectification and there are many different properties & various characteristics of diodes which make them to be suitable for different commercial and industrial applications. These characteristics are modified to form different types of diodes. Nowadays, there are several different types of diodes that are having different properties are made available through various modification and tuning methodological techniques. A modulator's photo-diode is one of the types of the transmitter diode that is capable of switching a light-emitting diode, or LED for short, on and off very quickly so that the human eye does not perceive it, for the photodiode placed at the receiver end for picking up the transmitted light so that it gets converted it into electrical pulse signal for the transmitted message to be decoded. The power supply that provides the circuitry

with the necessary electrical energy to the connections containing the Arduino Nano, keypad, photo-diode and the transmission module as shown in figure 5.2.

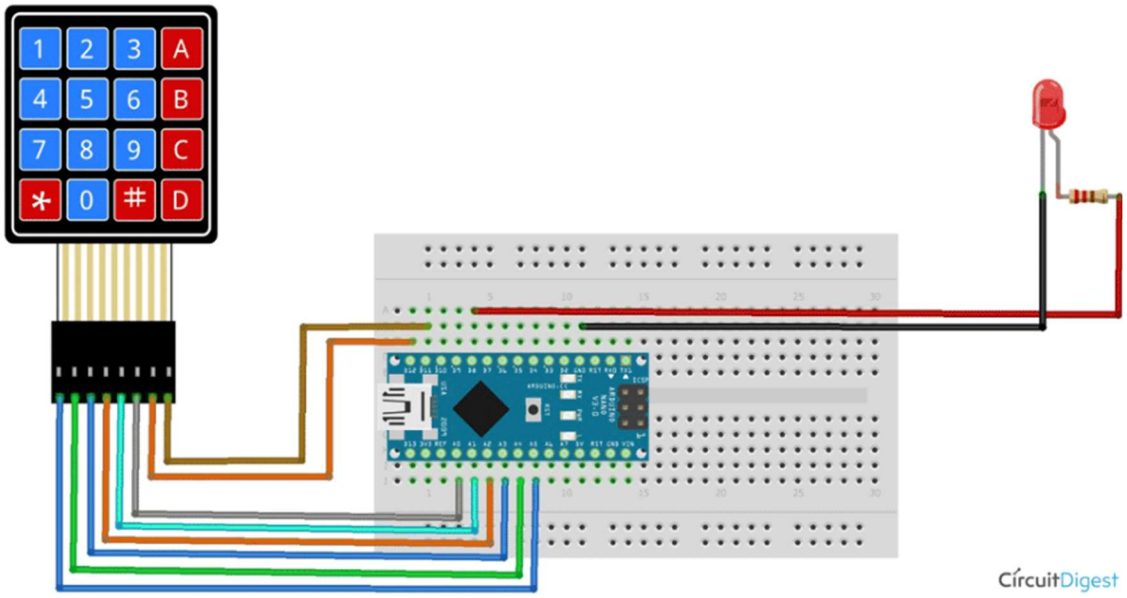

FIGURE 5.2: Transmitter circuit.

5.2 RECEIVER

The block diagram of the receiver is as shown in figure 5.3 that consists of the following:

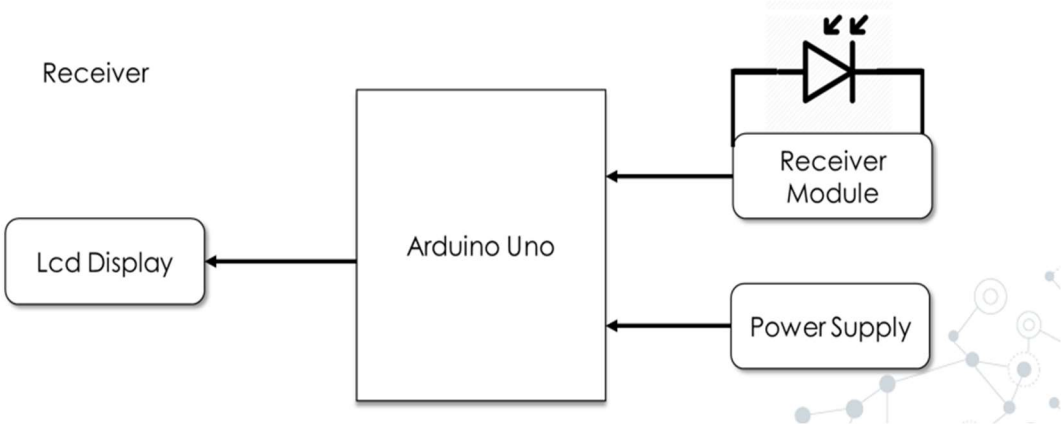

Figure 5.3: Block diagram of the receiver.

The receiver module includes a photodiode or IR receiver that is able to capture the transmitted signal and convert it into electrical signals for further analysing and processing for the Arduino Uno to process the received signal. An LED lamp that emits the modulated visible light communicated channeled cable which also acts as a data transmission medium. The standard high-

brightness white LEDs that can be used for better coverage for the transmitting range to have greater illumination capacity and these circuits are capable of driving the LEDs for modulation and to manage the timing of data transmission and for the correct and proper reception for the message to decode using the software stack that it handles the aspects like encoding, error control, encryption, and connectivity at the transmitter module and also for the decoding and even for the error correction to be done at the receiver module. The centralised software is required to manage the Li-Fi integrating the lighting infrastructure for greater optimal performance which should support handover when moving between optical access points. During the backhaul integration using the wired-backhaul connectivity that will be needed between the optical wireless access points, which can be connected to local LAN and internet. The photodiodes sense the transmitted light signals, which are then demodulated to extract the encoded data consisting of the high-sensitivity avalanche photodiodes offering higher data-rates. It also decodes the data and prepares it for the display on the LCD screen. The LCD displays the light intensity level as processed by the reception from the control unit. The output is shown in form of numerical method for user interpretation. The LCD screen displays the processed data or decoded message received from the sender as shown in figure 5.4 and the power supply is to power up the energy supply for the circuitry connections consisting of the Arduino Uno, receiver module, and LCD display.

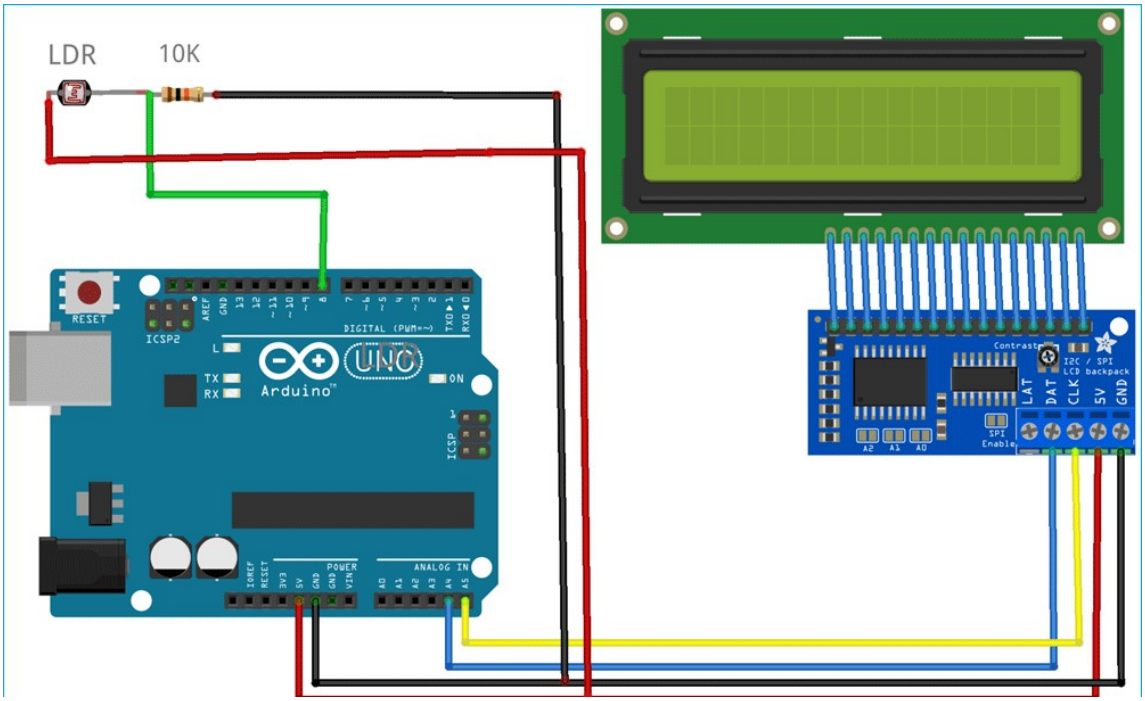

Figure 5.4: Receiver circuit.

CHAPTER 6

RESULTS

The Light Dependent Resistor LDR detects the intensity of the ambient transmission light that converts the light levels into the corresponding electrical signals using the control unit which is then able to process the electrical signals received from circuitry which includes the Arduino microcontroller, LDR sensors, or any other processing unit responsible for analysing the data and the processed data is then prepared for output. The ambient light interference especially, the sunlight or artificial lighting, which will be introduced as the external or some times within the internal noise's into the system, which is affecting the photodiode's ability to be accurately detect the modulated light signals and this interference was more pronounced in the brightly challenging environments to the adaptiveness for the changes in the environmental deployment for the changing external factors that will lead to the higher error-rates and also the increase in the error rate over the longer distance is being attributed for the signal attenuation and dispersion are the main challenges to be encountered and the potential improvements are as follows:

- While implementing the adaptive modulation techniques that help to mitigate the effects of the ambient light interference and also the signal attenuation by dynamically adjusting the modulation scheme based on real-time conditions while the system could maintain higher data transmission rates and lower error rates.

- Incorporating with the error correction algorithms, such as forward error correction (FEC), could improve the reliability of data transmission. These algorithms can detect and correct errors in the received data, reducing the overall error rate.

- When developing the more robust alignment mechanisms, such as the motorized or automated alignment systems, that could ensure optimal positioning of the LED and photodiode, while improving the signal strength and also in the reduction with the number of the error rates.

- Using the higher power LEDs could enhance the signal strength, allowing for longer transmission ranges and even provides with better performance in the presence of the ambient lighting. However, this would need to be balanced against power consumption and heat dissipation considerations.

The signal integrity is to be assessed by examining the clarity of the transmission signal and the strength of the received signal for maintaining the signal's higher integrity rate for the short and medium ranging distances, but needs more and more experienced degradation for the longer ranging distances for the ambient light interference that will also affect the signal integrity that is particularly required in the brightly enlightened changes in the external environmental. When there is any of the alignment sensitivity in the changing environment for the alignment changes in-between the LED bulb and the photodiode is mainly crucial for maintaining a clear line-of-sight communication. Misalignment reduced the signal strength and increased the error rate. This sensitivity to alignment posed challenges for maintaining stable communication over longer distances. When there is a gradual increase in the signal attenuation, then the distance between the transmitter and receiver end's light signals will get weakened, resulting in higher error rates and reduced transmission speeds. Hence the signal attenuation is a significant factor limiting the effective and efficient range of the system as shown in the figure 6.1.

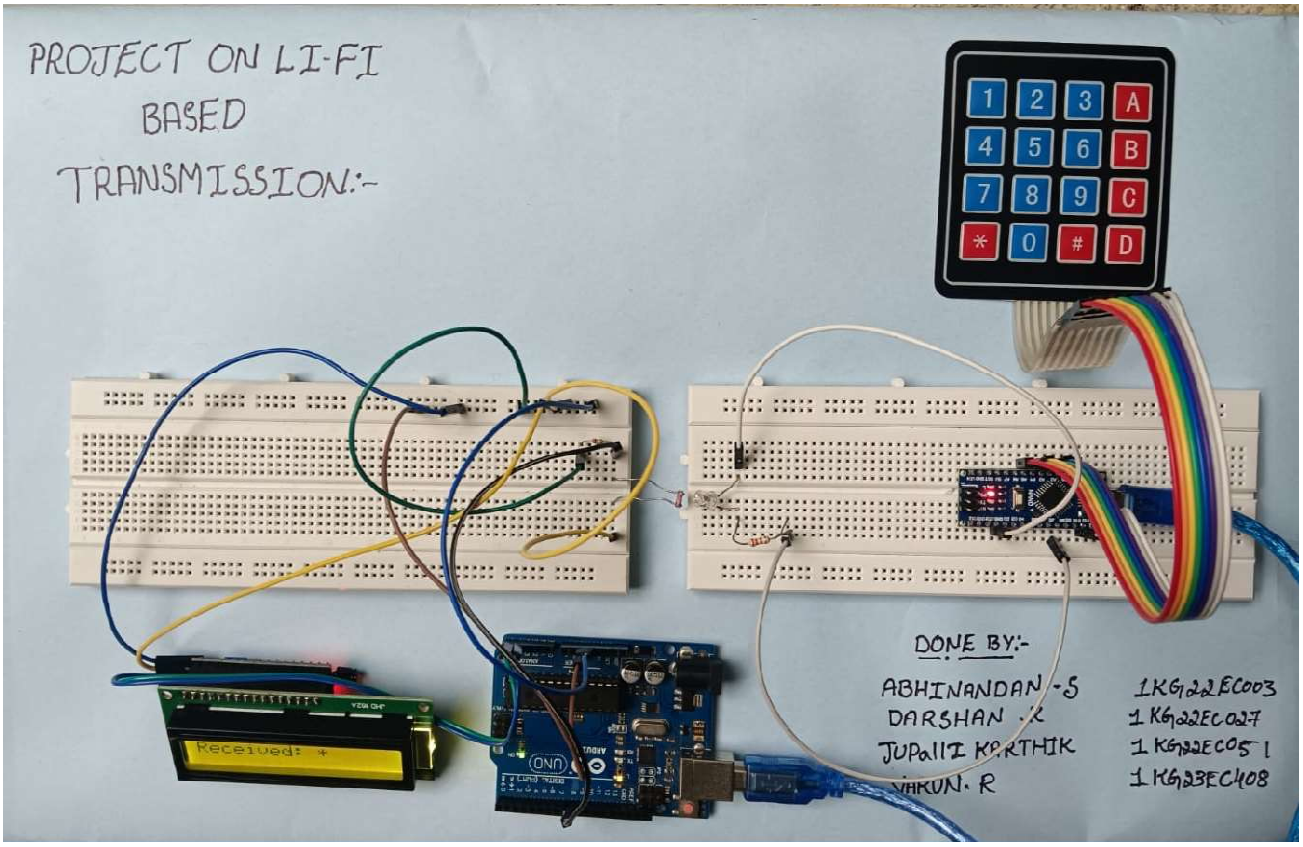

FIGURE 6.1: Output.

CONCULSION AND FUTURE SCOPE

Li-Fi requires a direct line of sight between the transmitter and receiver, which can be a limitation in certain environments for the effective range of the Li-Fi when compared to the Wi-Fi, which might necessitate more access points to cover a given area. The possibilities are numerous and can be explored further because the concept of Li-Fi is currently attracting a lot of eye-balls because it offers a genuine and very efficient alternative to radio based wireless. It has a good chance to replace the traditional Wi-Fi because as an ever-increasing population uses the wireless internet connectivity services, and the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. Li-Fi can provide the data transfer rates much higher than Wi-Fi, potentially up to several gigabits per second. This makes it highly efficient for text transmission, ensuring rapid and reliable delivery of data. The visible light spectrum is vast compared to the RF spectrum, which is becoming increasingly congested. The Li-Fi takes advantage of this unutilized bandwidth, reducing the load on existing wireless communication systems. Li-Fi is less susceptible to electromagnetic interference, which can be a significant issue for RF-based communication, especially in environments with a high density of electronic devices. Li-Fi can be easily integrated into existing lighting infrastructure. This dual-use of lighting for illumination and data transmission can lead to cost savings and increased efficiency in smart buildings and cities.

The future scope of Li-Fi-based text transmission is promising, particularly as the demand for faster, more secure, and the efficient communication technologies keep increases. In the future, the data for laptops, smart phones and tablets can be transmitted through light in the room by using Li- Fi. The researchers are developing micron sized LED which are able to flicker on and off around 1000 times quicker than larger LED. If this technology can be put into practical use, every bulb can be used as a Wi-Fi hotspot to transmit wireless data and we will proceed toward the cleaner, greener, safer and brighter future. This concept solves issues such as the shortage of radio-frequency bandwidth and boot out the disadvantages of Wi-Fi. Li-Fi is the upcoming and on growing technology acting as competent for various other developing and already invented technologies. Hence the future applications of the Li-Fi can be predicted and extended to different platforms and various walks of human life. Li-fi have energy saving parallelism.

With growing number of people and their many devices access wireless internet, and the on one-way data transfer at high-speed and at cheap cost. In the future the LI-FI have LED array

besides a motorway helping to light the road, displaying the latest traffic update and also for transmitting the internet information wirelessly to the passenger laptop, notebook and smart phone. This is the kind of extra-ordinary, energy saving parallelism that is believed to deliver by the pioneering technology. Hospitals can use Li-Fi for the secure transmission of medical data and communication between devices, reducing electromagnetic interference. Li-Fi can enable fast and secure alerts and monitoring in operating rooms and patient care systems. Li-Fi can support high-speed text and multimedia content delivery, enhancing e-learning digital platforms. Li-Fi can provide an alternative to Wi-Fi in regions with limited radio spectrum availability in remote areas. Li-Fi can be a potential technology for high-speed text and data communication in the space missions. Unlike the radio waves, visible light can be used effectively to travel under the water, allowing for Li-Fi-based text communication in marine applications. Li-Fi systems can leverage existing LED lighting infrastructure, making text transmission eco-friendly and cost-effectiveness. Li-Fi reduces reliance on radio waves, lowering electromagnetic pollution and its associated risks.

REFERENCES

[1] Li-Fi: Technology, Applications, and Research Trends (2013) – *International Journal of Computer Applications*, Vol. 70, No. 23

[2]A Survey on Li-Fi Technology: Past, Present, and Future (2016) – *International Journal of Advanced Research in Computer Science*, Vol. 7, No. 7

[3] Visible Light Communication using Li-Fi Technology (2014) – *International Journal of Scientific & Engineering Research*, Vol. 5, Issue 6

[4] Li-Fi: A Survey and Future Prospects (2017) – *Journal of Optical Communications*, Vol. 38, No. 3

[5] Li-Fi: Light Fidelity for Wireless Communication (2018) – *International Journal of Engineering and Technology*, Vol. 7, No. 4

[6] A Review on Li-Fi Technology and Applications (2015) – *International Journal of Electrical and Computer Engineering*, Vol. 10, No. 1

[7] Li-Fi Based High-Speed Data Transmission: A Future Perspective (2019) – *Journal of Communications and Networks*, Vol. 21, No. 2

[8] Performance Evaluation of Li-Fi Based Communication Systems (2018) – *International Journal of Computer Networks & Communications*, Vol. 10, No. 5

[9] Wireless Communication with Li-Fi Technology (2017) – *Wireless Personal Communications*, Vol. 97, Issue 1

[10] Text Transmission using Li-Fi Technology: A Practical Approach (2020) – *International Journal of Electrical and Electronics Engineering Research*, Vol. 8, No. 4