

VIDEO TRANSMISSION USING LI-FI FOR PATIENT MONITORING

Submitted in partial fulfillment of the requirements for the award of Bachelor of
Engineering degree in Electronics and Communication Engineering

By

PUVVADA BALA DIWAKAR GUPTA (37130331)

MUNAGANURI VENKATA SAI RANGA MANIDEEP (37130261)



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this project report is the bonafide work of **MUNAGANURI VENKATA SAI RANGA MANIDEEP (Reg.No.37130261)** and **PUVVADA BALA DIWAKAR GUPTA (Reg.No.37130331)** who carried out the project entitled “**VIDEO TRANSMISSION USING LI-FI FOR PATIENT MONITORING**” under our supervision from December 2020 to April 2021.

Internal Guide

MS. D. JAMUNA RANI M.E., (Ph.D.,)

Head of the Department

Dr. T. RAVI M.E., Ph.D.

Submitted for Viva voce Examination held on _____

INTERNAL EXAMINER

EXTERNAL EXAMINER

DECLARATION

We **MUNAGANURI VENKATA SAI RANGA MANIDEEP (Reg.No.37130261)** and **PUVVADA BALA DIWAKAR GUPTA (Reg.No.37130331)** hereby declare that the Project Report entitled “**Video Transmission Using LI-FI For Patient Monitoring**” done by us under the guidance of **MS. D. Jamuna Rani, M.E., (Ph.D.,)** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **ELECTRONICS AND COMMUNICATION ENGINEERING.**

DATE:

PLACE:

M. V. S. R. MANIDEEP (37130261)

P. BALA DIWAKAR GUPTA (37130331)

SIGNATURE OF THE CANDIDATES

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ABSTRACT

The aim of this work is to achieve surveillance of the patient using LI-FI (light fidelity). Li-fi is an advanced and promising technology can be used in many medical applications. A prototype of live video broadcast using LEDs is proposed. The prototype presented transfers the data with single LED, and is capable of illumination as well as data broadcast. Whole process is kick started by converting analog signal into digital form in transmitter section. This project demonstrates the patient monitoring system using Li-Fi technology. Li-Fi stands for Light Fidelity. Li-Fi technology provides transmission of data through illumination by sending data through varies intensity faster than human eye can follow. Li-Fi is a bidirectional, high speed and fully networked wireless optical communication and is a form of visible light communication. The proposed model helps in the patient monitoring in the hospitals and can be done by using the concept of Li-Fi instead of Wi-Fi technology to avoid the frequency interference with the human body.

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CHAPTER 1

INTRODUCTION

Light Fidelity (Li-Fi) is a new technology that was introduced alongside Wi-Fi (wireless fidelity) as a solution or alternative (capacity, efficiency, availability and security). For signal exploration, Li-Fi primarily transmits data via LEDs and a photo detector via lighting. Li-Fi is called a healthy environment because it is less expensive and much more impressive as a healthy environment than Wi-Fi. For data relocation, Li-Fi uses visible light (VL) radio waves in the infrared (IR) to ultraviolet (UV) spectrum of light. This technology, also known as visible VLC light communication, is a short-range, secure light-by-wireless communication. VLC and Li-Fi have shown to be the most promising inventions. VLC can provide a higher data rate, higher data density, and physical layer protection, according to various studies. The most recent standardisation resulted in in-depth analysis. VLC enhances Li-Fi to provide high-speed, reliable, bi-directional, and fully connected wireless networking. It's worth noting that Li-Fi allows for multiple users and user versatility. The key advantages of a Li-Fi wireless networking layer are:

- Three orders of increased data densities of magnitude;
- Unique properties to improve security of the physical layer;
- Three Orders of Improving Energy Efficiency Magnitude;
- Intrinsically safe applications in which Rf is always banished, such as petrochemical plants And oil platforms;
- The required backhaul links between light sources and the interconnected Li-Fi modem and Internet are provided by means of Advent OF Power Over Ethernet (Poe).
- There is the potential to re-energize accessible data network architectures.

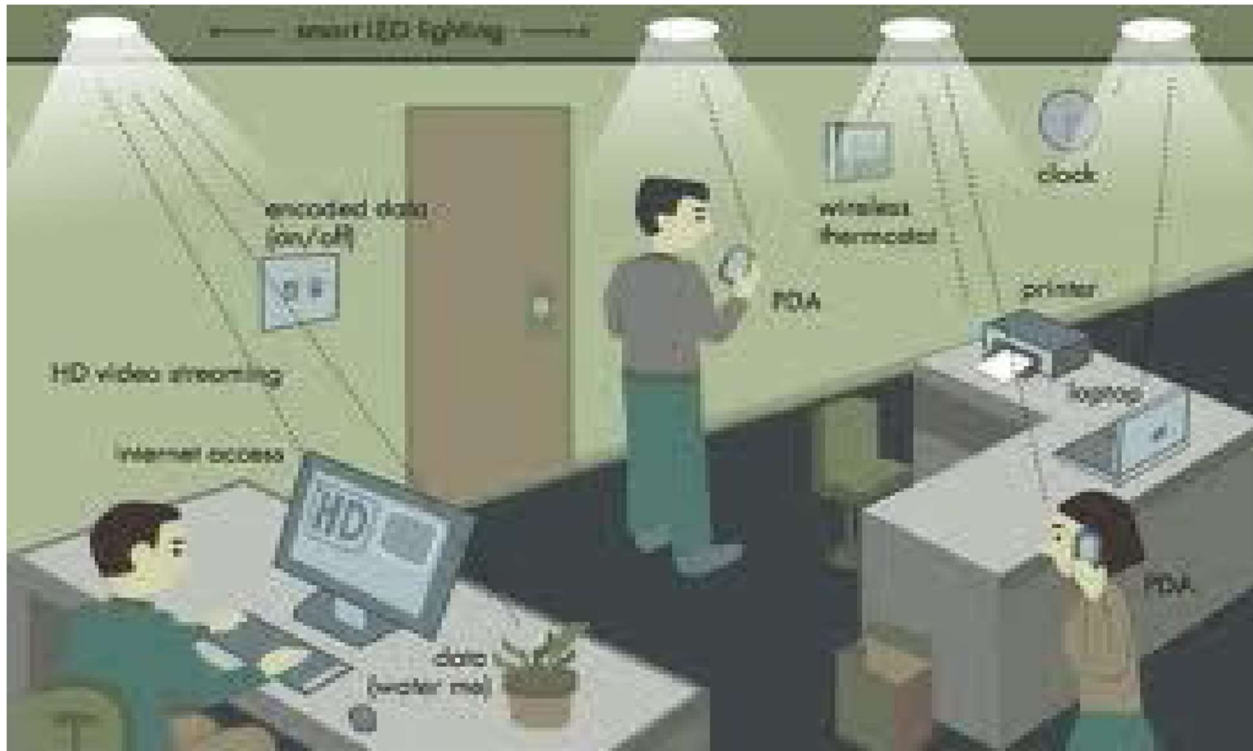


Fig.1.1: Li-Fi Environment

In October 2011, a Li-Fi alliance was created to support the high-speed optical cable networks of a variety of companies and organizations. To compensate for the limited amount of available wireless radio-based bandwidth, various electromagnetic spectrum parts are used. The consortium will download a high-resolution video in 30 seconds and hit data rates of over 10Gbit/s.

1.1. Working Technology

Harald Haas of Edinburgh University, UK, initially suggested this brilliant idea in his TED VLC lecture. He made it clear, "You can send a digital 1 signal if your LED is enabled. The LEDs can be easily activated and deactivated so that the data can be transferred." Consequently, some LEDs and a controller are required to code data on these LEDs. We only need to modify the rate at which the LED flicker is coded to correspond to the data we like. Additional modifications, such as using a sequential LED sequence of transmissions or changes in the light frequency, can be carried out using red, green and black LED mixtures, by encoding each frequency with a different data channel.

These advances pledge a possible 10 Gbps transmission speed that means you can access the entire high-definition film within 30 seconds. Just awesome! However, not the only factors behind this technology are flagrantly high download speeds and global network failure. Li-Fi can be used in aircraft and hospitals that are vulnerable to interference with radio waves since only light is used. This will continue to operate underwater, where there is no Wi-Fi, which offers infinite choices for military operations.

Think of floating under a street light to look at or watch a film from your desk lamps. On the block there is new technology available to "flash" how to metaphorically and practically explain the growing need for high-speed wireless networking. In a modern data transmission system known as Li-Fi, radio waves are replaced with light waves. Light diodes can be turned on and off more quickly than the human eye can see, leading to continuous activation of the light source. It may seem incredible, but it turned out to be a blinding light, which enables the transfer of wireless data by light.

Lighting diodes can be turned on and off more quickly than people see, which leads to a constantly active source of light, although it is 'splashful' (usually known as lighting devices and used on traffic and street lamps, vehicle brake lights, remote control systems, and numerous other applications). This intangible process calls for the use of binary codes to send data: the logical LED switch is '1' and the logical '0' switches off light. Change of rate for encrypting data by using different strings of 1s and 0s on/off. This method is known scientifically as visible light communication by using brief bursts of light to wirelessly transfer information.

As a means of teamwork, LED illumination may be used. The LED performance appears to man constantly because of its rapid flashing speed. With high speed LEDs and effective multiplexing techniques, a data rate of over 100Mbps can be achieved. Because each LED sends a different data stream, the LED arrays have a higher VLC data rate for parallel data transmission. There are reasons why LEDs are preferred as a light source in VLC when a wide range of external lighting devices, such as fluorescent lamps, light bulbs, etc., are available.

The LI-FI term refers to technologies that use visible light communication for high speed wireless networking. The word "radio" was given instead of "light" because of the similarity to WI-FI. WI-FI is the ideal solution for general Internet networking in households, while Li-Fi is ideally suited to broadband data coverage in adjacent environments.

It has been considered the use of light waves for data exchange. Today, efforts to introduce this technology and to improve its tools in Li-Fi technology, such as Haas and its partners. This technology was compared with Wi-Fi technology by Zhou and partners. The types of Li-Fi lights were studied by Mr. Richard Gilliard. Area data rate analysis was carried out on the LIFI and RF hybrid networks with shadowing effects. Hu and collaborators have been working on prototyping and Li-Fi measurements. In this project, the technology that exchanges data at high speed will be implemented.

Li-Fi depends on light modulation at frequencies that in most lighting systems are inaudible to the human eye. As semiconductors, up to one million times a second are on and off, enabling diodes to retransmit data rapidly. The PAM8403 is an audio amplifier of 3W Class D. AUX OR microphone can be used to enhance sound from PAM8403. This circuit is suitable for LCD and TV projection systems, tablets, handheld laptops, notebooks, game or mobile devices

The table also contains the latest data sharing technologies available today (Wi-Fi, Bluetooth and IrDA). Only Wi-Fi currently has rapid data speeds. The specification IEEE 802.11n allows up to 150 Mbits/s, but you get even less, in reality (the standard allows up to 600 Mbps). Notice that only one of three choices is optical equipment.

For data transmission, LEDs shall be used in the Li-Fi networks. All kinds of lighting will relay the data regardless of the wavelength. This means that the light, whether translucent, ultraviolet or fluorescent, will come out of the spectrum. You can use the internet very quickly to watch, among other things, videos, sports and music. The technology also eliminates Wi-Fi networking user limitations. You don't have to be in a Wi-Fi zone anymore. If the relationship is bright, it actually stands under some kind of light and looks at the internet. What would be better than this technology?

Similarly, Li-Fi and light fidelity apply to networks that use LEDs as means of networking, telephone and high-speed networking in the 5G visible light communications system. LEDs are the kind of diode that emits light. Li-Fi is able to assist with the Internet of Things, and does everything with remote Internet connections and electronic LED lamps act as Internet access points. The Li-Fi market is anticipated to grow by 82% to over \$6 billion annually by 2013 and 2018.

Visible Light Communications (VLC), which is too fast for the human eye to detect, are controlled by activating and disabled light in nanoseconds. Along with Li-Fi lamps, they can be dimmed to the degree that they are no longer available to humans and remain usable. They are also not available. As light waves cannot cross walls, they are much narrower than Wi-Fi, but more safe from hacking. Li-Fi does not have to transmit a signal from a direct line of view and the light from the walls can exceed 70 Mbps.



Fig. 1.2: Li-Fi Tx and Rx

The advantage of Li-Fi is that it does not cause radio interference in sensitive areas such as aircraft cabins, hospitals and nuclear plants. Although the US FCC has advised that there might be a lacking spectrum due to Wi-Fi limitations in bandwidth, Li-Fi does not have any bandwidth limitations. The visible light has been outnumbering the entire range of radio frequency for 10,000 years. Researchers have attained speeds of more than 10 Gbps (Gbps) a second, 250 times faster than super-fast broadband. Li-

Fi is said to be ten times more costly and eco-friendly than Wi-Fi. Potential disadvantages are also short reach, poor reliability and high installation cost.

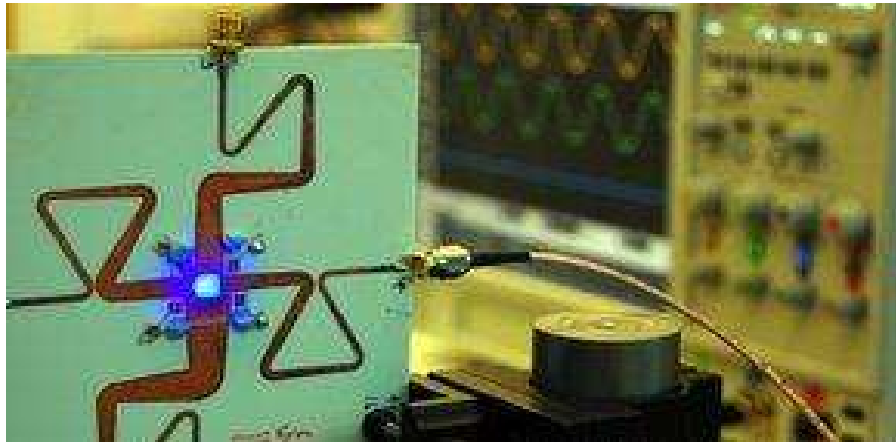


Fig.1.3: Micro-LEDs

The Universities of Edinburgh, St. Andrews, Strathclyde, Oxford and the Council of Engineers and Physics of Cambridge are jointly developing and finance them (ERC). Glasgow's Strathclyde University has created a small micro-LED light bulb that allows the transmission of light streams simultaneous with the multiplication of data flows.

"This is how we can make light look like when you think a shower is separating water into simultaneous streaming, Professor Harald Haas, expert in optical Wireless Networking at the University of Edinburgh and a team members. In order to handle million light intensity variations a second and to function effectively as a rapid on and off, researchers used a digital modulation technique known as the Orthogonal Frequency Division Multiplexing (OFDM).

- Over the last ten years, Professor Harald Haas has pioneered 'li-fi' science.
- In 2011, Prof. Haas showed how a High Resolution video could be transmitted through signal processing equipment and LED lamp to a screen.
- He coined "light fidelity" (VLC) for its marketing purpose and formed a private company, PureVLC.

- By using LED bulbs and the modern luminaire grid, Li-Fi promises to be less expensive and energy-efficient compared to existing wireless radios.
- Visible light is 10,000 times broader than conventional television systems and has much more power than radio frequency spectrum. In addition, Prof. Haas points out that there are far more secure and local Internet accesses in both houses for LED broadcasters.
- The downside of conventional wireless routers is that, as you get farther, the signal weakens and incoherently networks in workplaces and homes are created.
- Professor Haas also argues that VLC technology is theoretically safer than standard WLAN since light cannot penetrate walls. Chinese scientists suspect LED light bulb 'li-fi.'
- If "li-fi" technology starts off, both LEDs can provide internet access. The wireless contact from a bulb – or "li-fictio" – is a step closer, according to Chinese physicists.
- Xinhua News said that a bulb will generate data up to 150 Megabit/sec, a Professor of IT in Fudan Shanghai University, Chi Nan. Xinhua News. Xinhua News. Xinhua News. Xinhua News.
- Li-fi can be faster – and cheaply – at such rates, which is also called visible light communications (VLC) than the standard broadband connection in China.

1.2 Unlimited Capacity

Li-Fi promises less costly and more powerful than current wireless radio with the omnipresence of the LED bulbs and a modern lighting grid. Electromagnetic spectrum can be 10,000x larger than a radio frequency with an infinite bandwidth for visible light. There are however inconveniences: the light is darkened and the sound is blocked, too. There is, however, a possible safety advantage here.

CHAPTER 2

LITERATURE REVIEW

Jabin Tuo.et.al proposed Visible light communication by using commercial phosphor based white Led's. A high-speed visible light transmission system based on phosphorus White LEDs is demonstrated in commercial form. The passive post-equalization circuit configuration of the blue LED is used to achieve a high 3-dB modelling bandwidth of up to 85 MHz, and a transfer rate of 250 Mbps is shown with diagrams obtained. A transparent HD lighting platform focused on the most powerful white-light phosphorus LED on the market.

Mithun P.et.al. discussed Patient Monitoring System using Li-Fi. The Li-Fi unit displays the patient surveillance system. Light Fidelity is Li-Fi. By the transmission of data at different intensities faster than the human eye can perceive, Harold Haas's li-foil technology enables the data to be transmitted by illumination. Li-Fi is a form of two-way, swift and completely networked visible light communication. The theory used the Li-fi principle to track patients in hospitals and prevent repeated interactions with the human body instead of Wi-Fi technology.

These sensors capture and digitalize data from the human body using an analogue to synthes converter. The sensors' data is supplied into the microcontroller. The microcontroller that is used in this case is the AVR microcontroller. The Li-Fi module, where data are transmitted in light form and receiver end data are collected, transmits the microcontroller output, while the patient data is transmitted by the cell computer.

Sudha.et.al Patient Monitoring In Hospital Using Li-Fi. Li-Fi is a form of two-way, swift and completely networked visible light communication. Instead of Wi-Fi technology, the proposed model uses Li-Fi to track patients at 13 hospitals and to prevent frequent contact with the human body. The sensors in this model include temperature, heartbeat, oxygen and breathing.

These sensors capture and translate data from the human body into digital form by using analogue to digital conversion devices, and then pass sensor outputs to the microcontroller. The PIC16F877A is the microcontroller. The microcontroller input is fed into the Li-Fi module, where data is transmitted in light shape and the receiving end graph is shown on the PC. You can send this report to the patient by e-mail.

Hasnain Ali.et.al Li-Fi Based Patient Monitoring System Presents Li-Fi based patient surveillance unit. Light Fidelity is Li-Fi. A German physicist, Harold Haas invented and patented Li-Fi technology that transmits data faster than human beings can be followed, at different speeds. Li-Fi is an electronic, two-way, high-speed and completely networked optical wireless connectivity communication.

In order to avoid messing with frequencies in the body, the proposed model helps patient monitoring in hospitals and can be achieved by using li-fi instead of wireless internet. The prototype functions are executed using sensors such as temperature, heart beats, rotation and an ECG cardiogram. These sensors collect information and pass it on to the microcontroller ATmega8. The digital signal will be transformed into an optical signal transmitted through leds or lasers and photo detectors will be used to transmit the data to a new microcontroller at the end of the reception.

Y. P. Singh Presented a paper on Comparative and Critical technical study of the Li-Fi for some days now, connectivity was the fundamental pillar of ICT. ICT turned our world into a town. In order to get the right details at a proper time and place in today's world (companies, organisations, companies and entrepreneurs). This offers high technology Internet access and a wide range of network infrastructure. This paper discusses LI-FI, which can influence the lives of all. In the future, communication.

A more cost-effective, efficient and convenient choice to use Wi-Fi at 550 MBPs is the new 14 platform (30 GBPS per minute). The visible light communication might be the future of the Internet.

M.Goyal published a paper on New Epoch of Wireless Communication Free Wi-Fi is available in our homes, coffee shops, restaurants, malls and even towns and a fast expansion of the Wi-Fi network. This leads to a regular blockade of radio spectrum and an exponentially growing annual wireless data demand. Wireless data is highly requested, but bandwidth is scarce. RF complexity and interference are growing, as is the frequency of Wireless Radio. Light Faithfulness Technology (LiFi) is in use since 2011 to tackle this problem in the future.

Li-Fi is a Wi-Fi device using light instead of standard radio frequencies as a carrier signal. Li-Fi is a device which transmits data wirelessly using light-emitting diodes. In the Visible Light Transmission (VLC), high-speed light waves are used to wirelessly relay information that is not observable by the human eye. This article focuses on LiFi technology and developing problems with VLC technology via Wi-Fi.

Kelvin Guobadia discussed on Implementation of Wi-Fi Network Using Windbelt this paper evaluates how the technology for wind belt-cantennas can be used in improving the rural Wi-Fi network. The paper assesses the main aspects of the implementation process. The paper tests. The paper first mentions rural areas as one of the places where wind belt-cantenna technology can be applied to improve the Wi-Fi network. Secondly, the paper evaluates the different parties involved in the implementation process.

CHAPTER 3

AIM AND SCOPE

3.1. Existing System

In the field of hospital monitoring, many critical care devices are installed. In order for hospital officers to monitor the condition of the patient and share details, electronic devices, such as cellphones or laptops, may be used. Wi-Fi is used in almost every hospital in the world (Wireless Fidelity). For example, low electromagnetic gigahertz frequencies make Wi-Fi risky. This allows for accidents involving procedures involving emergency equipment. Electromagnetic interference is a term for electromagnetic interference describing the phenomenon.

20% of patients suffer from insomnia according to the effects of nuclear radiation. The wired patient would be exposed to electromagnetic frequencies on these routers 24 hours a day, seven days a week. The deterioration of intensive care services jeopardises the lives of certain patients. In certain areas of the hospital complex, Wi-Fi access is also strictly forbidden. In order to transmit the video transmission from your room to the doctor or staff member, CCTV is linked to wireless routers in the hospital area. Li-Fi will help solve these problems (light fidelity).

The light faithfulness can be used both as lighting and as data transfer replacement. LEDs, which function as a transmitter source, are the key components of the communication system. The visible sensitive areas of the wavelength create a positive photodiode reaction. This computer slows down the data transmission and limits the complexity of this machine with a built-in platform. The light fidelity system is transmitted to hospitals only data, audio and imagery from sensing components, including pulse sensors, EEG sensors, temperature, respiratory sensors, blood glucose and related sensors.

3.2. Proposed System

The application of light-faithfulness CCTV monitoring in hospitals, in particular ICUs, decreases health issues for patients. The photo seen in hospitals conveys all detail to doctors (in intensive care).

The transmission power alternative is Light Fidelity (LiFi) technology. Choosing the best access solution in a multi-user setting is a challenge in terms of light fidelity. In this article, we are examining LI-FI video transmission, which needs a higher transmission frequency and a need to carry the high frequency signal in a receiver circuit. It's attached to a TV that displays the video feed with an RCA input jack.

3.2.1 Proposed Block Diagram

Transmitter:

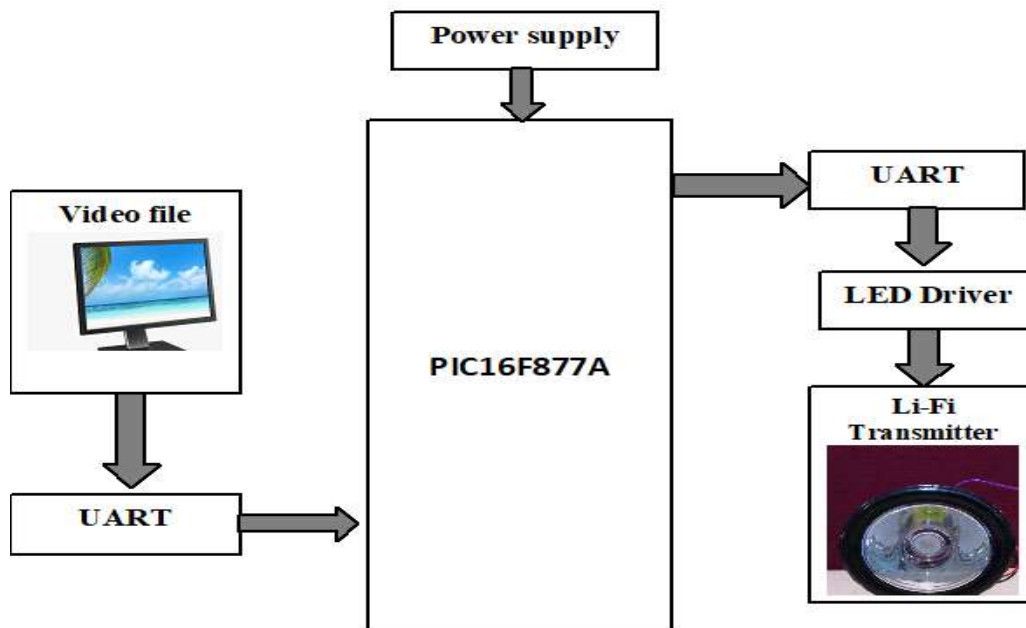


Fig.3.1: Li-Fi Transmitter

Receiver:

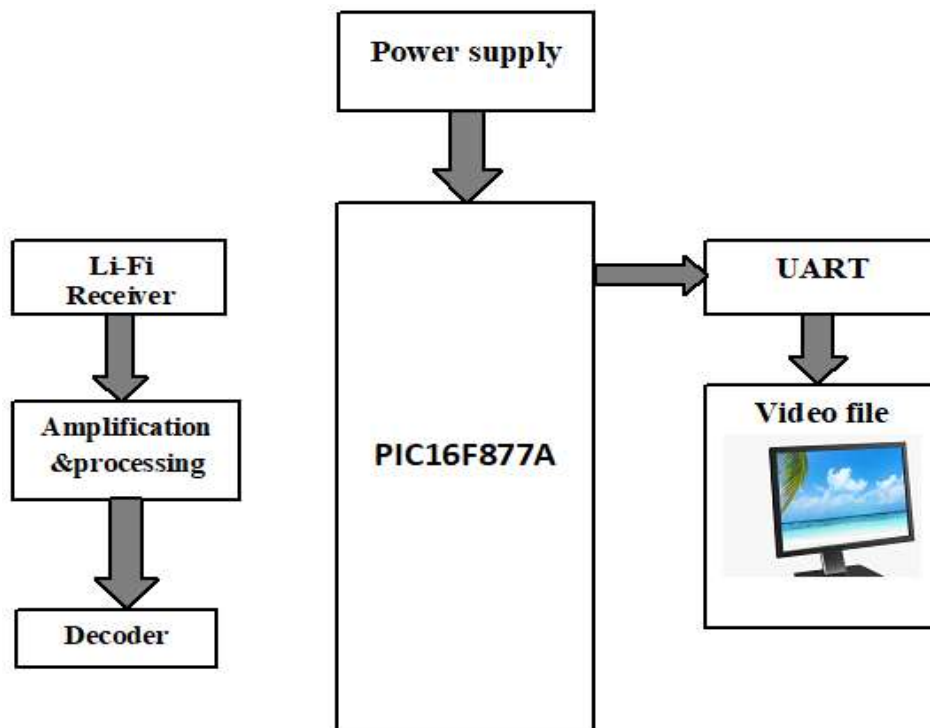


Fig.3.2: Li-Fi Receiver

3.3. Working Principle:

LIFI is a new type of solid-state light source of high intensity that provides both general and specialized lighting with a clean illumination solution. It produces electricity, has a long lifetime and a wide range of options for dimming. LIFI luminaires exceed traditional methods of illumination. The brief describes the building blocks of LIFI luminaries in general.

3.3.1. Li-Fi Construction

The inputs and outputs of the lamp are handled by the PCB, where the microcontroller also holds different lamp functions. The solid-state PA, which pushing the bulb into an electrical field, produces an RF signal (radio-frequency). This guided plasma creating intense light source transforms the energy content in the electrical field to a plasma state at the centre of the bulb. Many of them are contained in a jar of aluminium.

3.3.2. Function Of The Bulb Sub-Assembly

The centre of the LIFI is a bulb sub mounted on a dielectric medium and includes a sealed bulb. This configuration is more precise for degradable electrodes than traditional in the bulb. The dielectrical material serves two purposes: one, as a concentrator of the electric field, which concentrates energies in the lamp and, second, as a guide to the dispersion of wavy PA RF capacitance. The power of the electric field heats the material quickly in a plasma lamp providing a wide spectrum of light.

There are therefore four main issues, namely power, performance, availability, radio wave safety. In the other side, though, we do have 40 billion light boxes

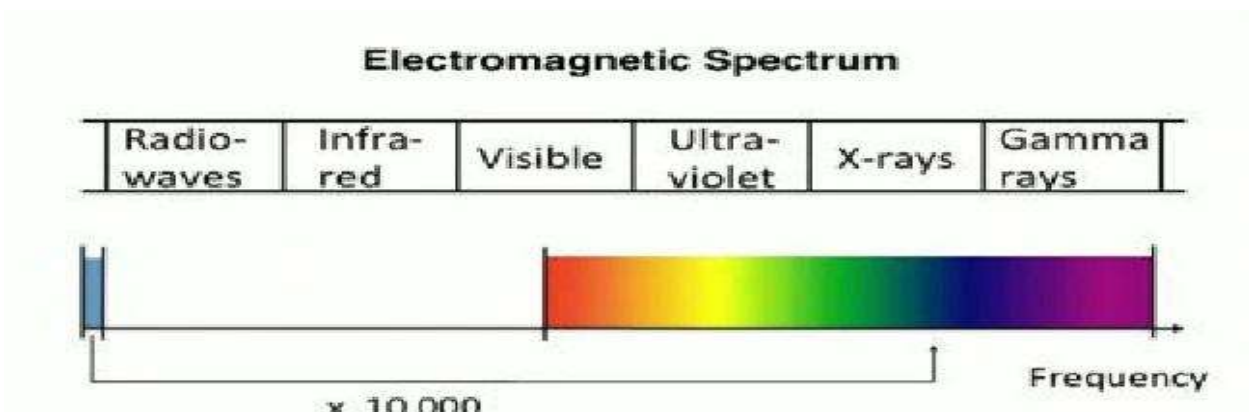


Fig.3.3: Electromagnetic Spectrum

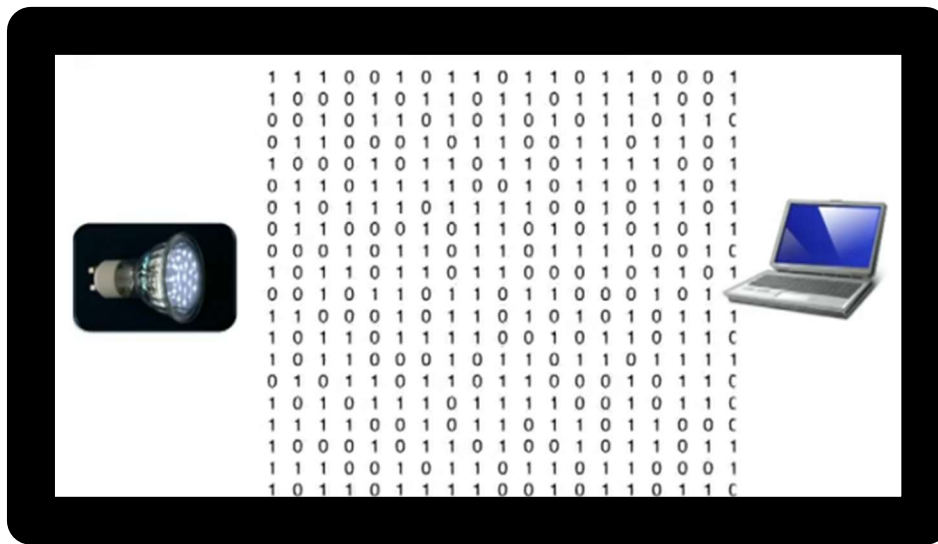


Fig.3.4: Transmission of bits to PC

3.3.3 Hardware Requirements:

- PIC16F877A
- LED Driver
- UART Port
- LI-FI Transmitter
- Power Supply Module
- Relay for power supply
- LI-FI receiver
- Decoding unit

3.3.4 Software Requirements:

- Arduino IDE
- Li-Fi Tx and Li-Fi Rx

3.4. Embedded Systems

3.4.1. Overview Of Embedded Systems

An embedded system is a computer device that has been designed to perform one or more basic functions, often with real-time computational constraints. It is usually combined with hardware and mechanical parts to form a complete device. In addition, a general-purpose computer, such as a personal computer, can perform a variety of tasks depending on the programming. Embedded systems are becoming increasingly important as more and more of our everyday gadgets are powered by them.

Because of special operations, the embedded system can be streamlined, resulting of a reduction in package size and expense, or an improvement in performance and efficiency. Engineers who specialize in design. Any embedded system is very useful, resulting in size reductions.

Mobile devices such as digital watches and MP3 players are examples of embedded systems, as are large, fixed systems such as traffic lights, plant controllers, and nuclear power plant control systems. The complexity of a single microcontroller chip that is installed within a large frame with various modules, peripherals and nets ranges from low to extremely high.

Since certain applications have a programming element, the term "embedded system" is not a fixed definition. Handheld computers, for example, Share some characteristics of Embedded systems like operating systems, microprocessors, but not embedded systems,since several programs can be loaded and connected.

Embedded systems provide several functions

- Environmental monitoring; input sensor data read systems. This data are then analyzed and reports are shown to a server or user in any format
- Environmental control; embedded systems produce and relay actuator commands.
- Transform the information; embedded systems transform the collected data, such as compression/decompression, in some practical way

In general, the embedded system runs programmes such as monitoring rules, terminating state machines, and signal processing algorithms. These systems are needed to detect and respond to failures in both internal and external computing environments. Embedded applications, from communications equipment to home electronics to control systems, come in various types.

3.4.2 Block Diagram Of An Embedded System:

Usually, an integrated processor is used in an integrated configuration. Integrated instruments, such as microwaves and VCRs, are used by many digital appliances. A digital interface is available for them. There is an operating system for every embedded software. Others are more advanced and contribute to the argument in its entirety.

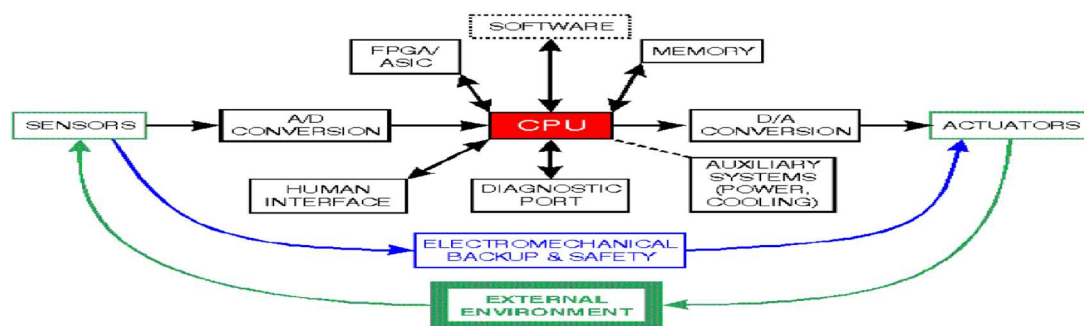


Fig.3.5: Typical embedded system

3.4.3. Characteristics Of Embedded Systems

A specific collection of capabilities is available with the integrated system. A collection of design constraints was placed on embedded product designers by each feature. Embedded systems meet the requisite imposition requirements and are difficult to build.

3.4.4. Application Specific Systems:

Not general purpose computers are the embedded machine. The embedded architectures of the device are adapted to a particular function. Until the hardware is assembled, several working functions are unknown. The designer may therefore concentrate

on the particular design restrictions of a given scheme. The reprogrammability of users is therefore limited. On the other hand, any embedded equipment requires versatility reprogramming. For such applications, programmable DSPs are popular.

3.4.5. Reactive Systems

As discussed above, a typical embedded system model responds with sensors and actuators to the environment. Integrated systems are needed to operate at the speed of setting. The term 'response' refers to this part of the integrated process. Reactive calculation signifies that in response to external events the device (primarily the software component) operates. International activities can be planned or unplanned. Normal activities simplify production cycles to ensure performance. Preparing for aperiodic phenomena is harder. To deal with worst-case situations, the optimal arrival rate for events must be calculated. A significant reactive factor for most embedded systems.

The effective case design analysis of predictive applications is one of the key challenges for integrated device designers. When a real time approach is used, the precise calculation is based in part on the time of execution. Sometimes this helps to make alarm figures extremely gloomy. In order to satisfy external I/O and reliable control parameters, many embedded devices have essential real-time specification. Many processes are reactive in real time.

3.4.6. Distributed Systems

One of the most difficult problems for connected system designers with distributed systems with predictive performance characteristics is a successful case design study. (e.g., DSP or other embedded processors cache memory). The accuracy of a measurement depends partly on the completion time when using a real-time method. This often contributes to unnecessary bad alerts. Many embedded devices have necessary real-time specifications to Meets external I/O specifications and robust management needs. Often reactive are real-time applications.

CHAPTER 4

MATERIALS AND METHODS

4.1. Pic Microcontroller

One of the best-known microcontrollers on the market is the PIC PIC16f877a. The microcontroller is very easy to use, and coding or programming is often easier. One of FLASH Memory System's many benefits is that it enables the greatest possible deletion. A total of 40 pins and 33 input and output pins are present. In several microcontroller companies PIC16F877A is used. In optical circuits PIC16F877A is still commonly used.

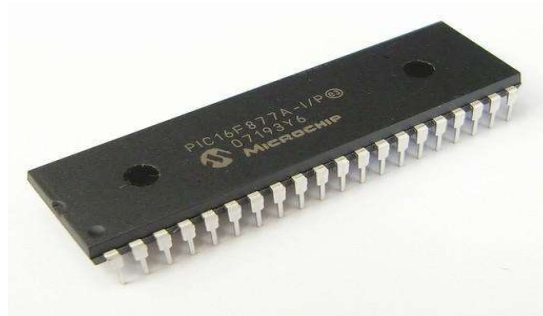


Fig.4.1: Pic Microcontroller

A wide variety of cameras are used in PIC16f877a. It is all used by remote control, safety equipment, household equipment and diverse industrial machinery. Any details, such as the frequency codes of the transmitter and the recipient and similar data can be stored with EEPROM indefinitely. This is a low-cost and easy to use controller. It is modular and can therefore be used where there was no previously existing microcontroller, timer or other unit.

- It has a range of smaller 35 commands.
- Up to 20MHz frequency can be operated.
- The frequency of the running voltage is from 4.2 to 5.5 volts. It can be permanently disabled if you supply it with more than 5.5 volts.
- It doesn't have a PIC18F46K22, PIC18F4550 internal oscillator.
- Each PORT can sink or source has a maximum current of about 100mA. The present limit is therefore 10 milliampere for each PIC16F877A GPIO pin.

The packages include 44-pin PDIP 44-pin PLCC, 44-pin TQFP, and 44-pin QFN packing.

4.2. Pin Configuration Of PIC16f877a Microcontroller

As already mentioned, this IC microcontroller has 40 pins. There are two 8-bit clocks and a 16-bit clock. Serial ports and parallel ports and five ports for input and output are also available as well as capturing and comparing modules. The PIC16F877A schematic is presented in this image.

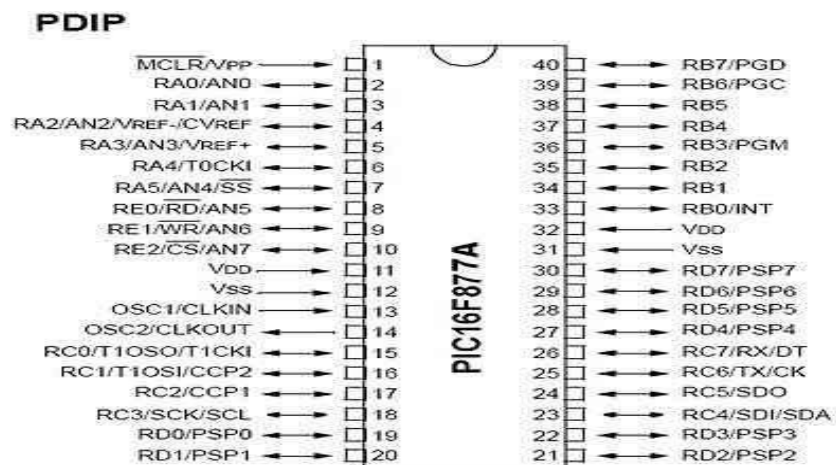


Fig.4.2: Pin Diagram of PIC16F877A

- **PIN 1: MCLR:** The first pin of this IC is the most transparent. The microcontroller is reset and triggered low, which ensures that a 5V voltage must be provided continuously, and if 0 V is provided, the controller will be reset. The controller is restored to the first line of the IC software as it is reset.
- A push button and a resistor are connected to the pin. The pin also has a constant 5V supply. We simply need to push the button to reset the controller with an MCLR pin of 0 to restart the IC.
- **PIN 2: RA0/AN0:** PORTA has 6 pins, all of which are bidirectional input/output pins from pin 2 to pin 7. Pin 2 is this port's first pin. This pin is also available as an analog AN0 pin. It's made in hybrid analog transformers.
- **PIN 3: RA1/AN1:** This can be the analog input 1.
- **PIN 4: RA2/AN2/Vref- :** The analog input can also be used². Negative analog reference voltage can also be given.
- **PIN 5: RA3/AN3/Vref+:** It works with analog input 3. Or it will function as an analog positive reference voltage.
- **PIN 6: RA0/T0CKI:** This pin can be used as the input clock pin, and the output form would be opened drain.
- **PIN 7: RA5/SS/AN4:** This could be analog input 4. The control device also has a synchronous serial port, so this pin will be used as the slave pick for that port.
- **PIN 8: RE0/RD/AN5:** PORT E begins with pin 8 to pin 10 and is also a two-way output port. It can be an analog input 5, or it can serve as a low read pin for parallel slave port.
- **PIN 9: RE1/WR/AN6:** The analog input can be 6. It can be the 'writing control,' which is active low, for the parallel slave port.
- **PIN 10: RE2/CS/A7:** It can be an analog input 7 or it can be used as the 'power pick' for parallel slave ports that are also short, much like control pins for read and write.
- **PIN 11 and 32: VDD:** The input/output and the logical pins are supplied positive. Both should be linked to 5V.

- **PIN 12 and 31: VSS:** These pins are the basis for input/output and logical pins. The opportunity should be 0-linked.
- **PIN 13: OSC1/CLKIN:** It's the input of the oscillator or the external pin of the clock.
- **PIN 14: OSC2/CLK OUT:** An external clock provides the microcontroller with a crystal resonator between pins 13 and 14. In the RC mode, OSC2 output is 14 times the frequency of OSC1. This graph depicts the teaching period rate.

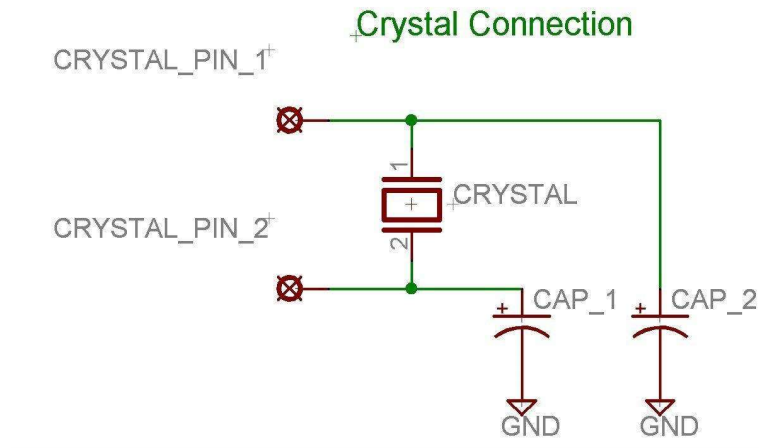


Fig.4.3: Crystal Connection

There are a lot of features on both pins. UART and I2C connectivity digital output pines can also be used, as well as PORTC pins, as digital input pins. However, you can only use only one part of every port at a time or cleverly adjust it to allow you to switch between functions. Set it to analogue and then move it on to other features like digital output to read an analogue signal first. When you gain programming knowledge, we recommend using a single pin for beginners and multi-function mode.

4.3. Program For Input And Output Ports

- Port A, Port B, Port C, Port D, and Port E are five incoming and outgoing ports that can be optical or analog.
- In such instances, an A-D converter is built-in. Multiplexers use circuits as well. The digital mode, on the other hand, has no restrictions.

- The ports may be set to either input or output. The programming has been finished. Importing the micro C pro from your website is preferred for PIC.
- The ports route is regulated by a register called "TRIS." TRIS B, and so on.
- if a little of the register of TRIS is set 0, it acts as a digital output to the corresponding port bit.
- When a TRIS register bit is set to 1, it becomes a digital entry for the corresponding port bit.

4.3.1. Compiler For PIC16F877A Microcontroller

- MPLAB XC8, MikroC for pic, PIC CCS compiler, and Hi-Tech compiler are three common compilers that are used to program pic microcontrollers.
- The MPLAB XC8 is the official compiler that is produced by PIC16F877A manufacturers.
- We usually suggest MikroC for beginners and MPLABXC8 for those who want to learn the programming of peak microcontrollers from bare metal principles at register stage.
- For more information please visit our list of microcontroller compilers.

4.4. Features Of PIC16F877A

PIC16F877A also provides useful features like all other microcontrollers, as described in this list.:

- **Analog to digital converter module:** It consists of 8 channels with 8 bit ADC module. With this microcontroller, we can use 8 analog sensors.
- **Timers:** You are given three minutes, a minute and a minute 2. Either time or counter mode can be set by either of the timers. These timers are used to interrupt, modulate pulse amplitude, count external events and disturb time flow. TIMER0 is an 8-bit timer for setting the clock frequency inside or outside. We normally run Timer0 in timer modes with internal frequency and counter mode with an external

clock source. Even TIMER1 can be used for all modes as a 16-bit timer. This is a TIMER2 just 8-bit. The time base for CCP modules is PWM.

- **EEPROM:** It also has an embedded, electrically erasable read memory of just 256 x 8 bytes, allowing data to be stored indefinitely even when the microcontroller is turned off. It's most often used for tasks involving electronic locks.
- **PWM modules:** There are two CCP units as well. For Capture, compare PWM and CCP modules. This microcontroller enables us to generate two PWM signals in a short amount of time. A maximum resolution of 10 bits is supported.
- **Serial or UART communication pins:** There is only one UART channel available. UART pins are used for serial connectivity over optical networks. The RC7 pin is a transmitter or RX pin with 26 pins. RC6 is a Tx Pin number 25 receiver. For further details, refer to the pic16f877 microcontroller for complete serial communication guide.
- **I2C Communication:** The PIC16F877A also has an I2C networking module and supports I2C connectivity. The SCL and SDA pins are 18/RC3 and 23/RC4 pins, respectively.
- **Interrupts:** In the field of embedded system, interrupts are extremely useful. I suggest that you understand all of the interrupts because if you don't, you won't be able to get the order on the embedded software. External interrupts, interruptions in the counter, interrupts in the port status, interrupts in the UART, I2C, and interrupts in the PWM are all available on the PIC16F877A. Read this guide on interrupts for the peak microcontroller for more details.
- **Comparator module:** It has a module with two comparators in it. They're used to compare analog signals in the same way as electrical circuit comparators are used to compare electronic circuits.
- **Watchdog timer:** WDT is an independent, freely functioning oscillator on a computer. It is an independent OSC1 / CLKIN oscillator. And if the device is sleepy, the WDT works too. The unit is used for sleeping and for resetting the watchdog timer.
- **Sleep mode:** PIC16F877A also has sleep mode operations. In this mode, the machine uses very little fuel. Both peripherals draw the bare minimum of current.

Interrupt sleep mode tools such as timer1, interrupt, EEPROM write-out, and others can be used to wake you up.

- **Brown out reset:** The system will be reset when the brown-out BODEN signal is detected. If the voltage supply is lower than 100 microseconds below the threshold
- Brown-out reset and device reset can occur until the nominal voltage rises in voltage, and security code can be programmable. The voltage is regulated by the device every 72 milliseconds.

4.5. Li-Fi Technology

Wireless networks have now been used enormously, researchers still attempt to speed up the exchange of data within wireless networks. Light waves are usually high-speed and they can finally be used to transmit data. Light waves.

It has been considered the use of light waves for data exchange. Today, efforts to introduce this technology and to improve its tools in Li-Fi technology, such as Haas and its partners. This technology was compared with Wi-Fi technology by Zhou and partners. The types of Li-Fi lights were studied by Mr. Richard Gilliard. Area data rate analysis was carried out on the LIFI and RF hybrid networks with shadowing effects. Hu and collaborators have been working on prototyping and Li-Fi measurements. In this project, the technology that exchanges data at high speed will be implemented.

Li-Fi technology, developed by Prof. H. Hass in 2011, was verified the same year by the IEEE Standards Committee. Many fans noticed this technology from the start, so that it could not match its progression rate with other technologies. After Li-Fi technology was coined at the 2011 global TED Conference, Hass created a pure Li-Fi Company in 2012, which was launched and promoted in the same year. The first attempts to promote

Photo detector information is received through the use of LED lamp information. Before that part Li-Fi-X and Li-Flame were quoted. It was explained in this section that Li-Fi-X

was one of the pure Li-Fi products which connects to any light LED, and a Li-Fi-X and Li-Flame sample is displayed below, which is the following output of Li-Fi technology.

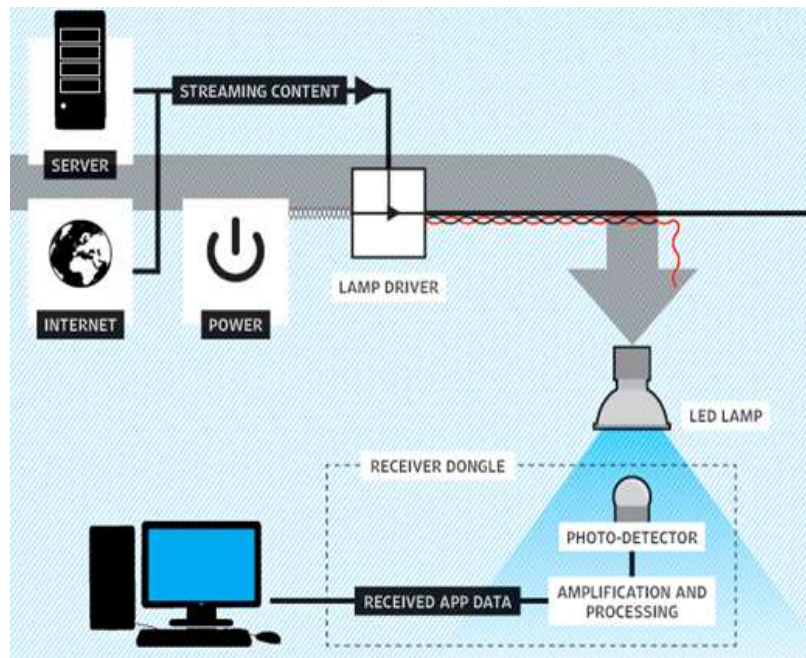


Fig.4.4: Sample Of Li-Fi-X and Li-Flame

In Li-Fi technology, LEDs are used as the recipient of transmitted data both in media transmission and as a photo detector. To make the LED work properly, a lamp driver is required. [8] During amplification and processing, the signal from the picture detector is controlled.

A number of capabilities and objections of Li-Fi technology will express and compare Li-Fi technology with Wi-Fi technology. A number of capabilities of Li-Fi technology are:

- Li-Fi technology is very simple for using.
- Li-Fi waves aren't harmful for humans.
- In Li-Fi technology, density of data is very high.
- The Interference phenomenon doesn't exist between Li-Fi waves.
- Using Li-Fi technology as light waves cause low power consumption.
- This technology, Li-Fi technology has high reliability.
- The Li-Fi technology has personalization capabilities.

This technology has another technologies objection that the following is number of these objections:

- The power of sun waves is very high that hasn't been expected to use this technology against sun severing waves.
- Li-Fi waves haven't ability for crossing of things.
- Most receivers are directly placed to expose the Li-Fi waves without annoying.
- For each place, this technology wants to use which should replace the tools of it instead of before them.

Many studies have been carried out, many study on Li-Fi technology advancement and then they expect to finish these studies. They surely need a high-speed wireless network all over the industry in the future. As a consequence, light waves are used to bind the different industries. Light waves were used in Li-Fi technology, and this technology therefore had many link capabilities between different industries. For networking, Li-Fi technology can be used for the types of connections.

If the RGB laser LEDs are used as part of the Li-Fi technology transmitter, the data exchange rate will be very high, according to the discussion in the last section. Moreover, this technology becomes more unique as it can be overcome by the objections of this technology.

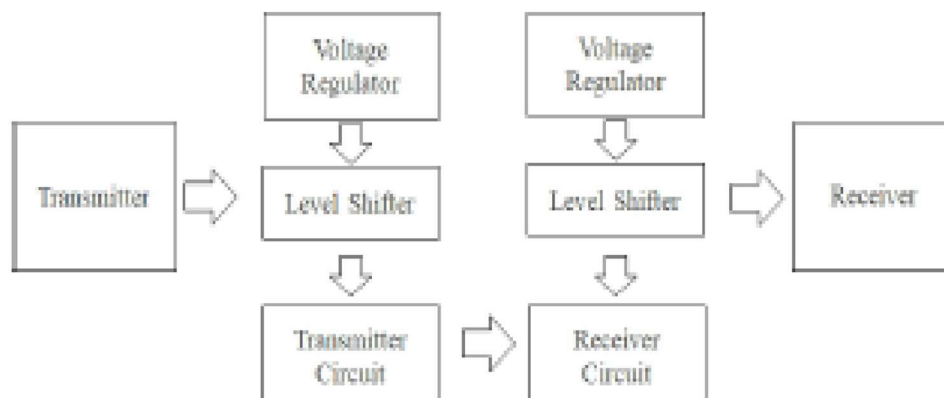


Fig.4.5: The Working Principle Of The Li-Fi

Figure shows the Li-Fi method for data transmission that can be carried out with one single LED or several LEDs. A photo detector transforms the light on the receiver's hand into electrical signs and transmits electric signals. On both sides, tension controls

and level shifter loops are used to transform and sustain tension between the transmitter and the receiver.

4.6. Comparison Between Li-Fi And Wi-Fi

Leistung and Internet security are the key challenges. Li-Fi was created in 2011 by Harold Haas, a British scientist. Fixed the Wi-Fi issue. The maximum speed of Wi-Fi is 1500 mbps which is not adequate for a huge user. A LED, a battery and an AUX (AUX) cable for audio transmission are available in the transmission area. The AUX is also known as an audio jack which receives signals from the system. Which drives the LED with OOK modulation. When the LED is on, the digital 1 is transmitted otherwise the digital 0. Data that can no longer be observed by a human eye are easily turned on and off.

Li-Fi depends on light modulation at frequencies that in most lighting systems are inaudible to the human eye. As semiconductors, up to one million times a second are on and off, enabling diodes to retransmit data rapidly. The PAM8403 is an audio amplifier of 3W Class D. AUX OR microphone can be used to enhance sound from PAM8403. This circuit is suitable for LCD and TV projection systems, tablets, handheld laptops, notebooks, game or mobile devices. Mobile telephones may be used as well. The consumption is cost-effective and low and requires only a small portion to operate. In that case, the photo sensor absorbed the solar panel from the LED source, which demodulates and amplifies these signal(s) (one and zero). The solar panel absorbs the light intensity and the audio is then transmitted through a speaker.

In a commercially available Li-Fi kit a sender and the receiver are included. The transmitter module includes an ultrasound or PIR tracker, an electrical power source and an LED light IC. When the LED light is stronger, the IC is more effective. The data is received on the recipient side by a photodiode and then sent to the decoding microscope.

The aim of our project is to submit data to the recipient photodiode, like '#1.' As a feedback, we use the sensor. When an object is detected, the sensor sends a signal to the microcontroller. If no object is within reach, the data will not be forwarded. The circuit

is powered by the electricity supply AC input. A clock signal from the crystal wobble is sent to the microcontroller. The microcontrollers then transmit the LED lamp signals to the IC. Light transmits light rays to the photodiode of the receiver. The photodiode of the recipient detects light rays from the transmitter and decides whether the data is completely or partially transmitted. When the transmitted data loses their signal, it occurs.

The received signal is sent to another microcontroller to decode it. The details will be shown on an LCD or a monitor for the computer. The result is shown in the hyper terminal on a monitor. It is connected to the receiver side with a serial communication adapter. The hyper terminal shows what the LCD was meant to be shown initially.

The only way to minimize the components is when analysis of Wi-Fi and Li-Fi is seen. The power supply consists of a bridge corrector, a voltage control unit and passive components. Here you can find the connection between the circuit and an AC adapter. A rectifier for the bridge is a device used in the manipulation of different electrical circuits. It converts it to DC and sends it to your computer since we use an AC signal. Depending on the load current requirements, it is equipped with four or more diodes.

The voltage controller we use is the part 7805. Tension is regulated in the circuit. If not, the whole circuit will be destroyed. Both pieces have to be re-sold. The Li-Fi transmitter is an LED lamp and an IC. The IC can be used to monitor the high-energy LED light. Since we needed a powerful LED lamp, a higher range IC was used. It is commercially accessible and concealed upon arrival. Only the manufacturer therefore knows the accurate IC. The Li-Fi Receiver Assembly is a photodiode sent by a light signal. Bits are also sent by a microcontroller to decode the data. In order to display the collected data, the Li-Fi receiver module also has an LCD.

4.7. Arduino Uno

It is an ATmega328P built-in microcontroller board. The 14 optical input/output pins are composed of a 16 MHz ceramic USB, power port, ICSP and reset button. You can

use an input and output computer as well. All the microcontrollers you need to get started are provided; Link it directly to a PC or connect it via an AC-to-DC adapter or charge. You can chip the chip for your Uno and start again without thinking about making a mistake.

In Italian, "uno" means "one," and the Arduino Software (IDE) 1.0 version has been selected. The guide for Arducino is the Uno board and version 1.0 (IDE) of the Arduino software. For a full list of new, previous and obsolete bodies, see the Arduino Board log. It is the reference model for Arduino interface and the first of a number of USB arduino boards.

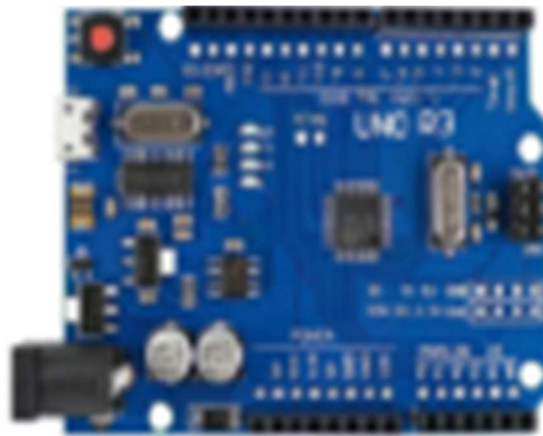


Fig.4.6: Arduino Uno

It is an open sources platform for easy access to and configuration of boards and frames for enhanced functionality. The program that Arduino uses is called IDE, and it takes some technical knowledge to master a free software. C and C++ programming is possible.

There are people who confuse the words Arduino and Microcontroller. The first one consists of a 40-pole chip with an integrated microprocessor, the other of the

microcontroller board on the edge of the plate. The bootloader makes the input and output pins easier.



Fig.4.7: Arduino and Microcontroller

The Arduino Uno is a microcontroller based on an ATmega328 system. All included are a 16 MHz resonator, a USB port, an ICSP header and a reset switch and 20 optical input/output pins (6 PWM outputs and 6 analogue inputs). It comes with all the microcontrollers you will have to run; link them via USB or use an AC-to-DC converter or loader to power them.

The chip from the previous boards is not included in the USB to the serial driver. Rather, it has a USB-to-serial ATmega 16U2 programmed. This secondary controller has a USB Bootstrainer that can be reprogrammed by experienced users.

- The chip has been upgraded from an ATmega8U2 to an ATmega16U2 (8K flash) version (16K flash). This has little impact on the amount of available flash or RAM for drawing.
- Three additional pins, two of which have been previous pin duplicates, have been added. On the side of the board near AREF were the I2C pins (A4, A5). Right next to the reset pin is an IOREF pin twice the 5V pin
- The reset button was inserted to make it more shields available next to the USB connector.

4.7.1 Installing the Software

Follow the directions for the beginning of the website portion of Arduino, <http://arduino.cc/en/Guide/HomePage>. Go all the way before you start to blink the LED pin 13. That means you can now search for your own programmes by effectively upgrading both applications and drivers. Begin the Arduino development atmosphere. Programs in Arduino are called 'sketches,' so we're going to call them. In the editing window enter the next programme and consider where semi-colons are located at the end of the command lines.

```
void setup() {  
    Serial.begin(9600);  
    Serial.println("Hello World");  
}  
void loop()  
{
```

Your window will look something like this



Fig. 4.8: Arduino IDE

4.7.2 Serial Communication:

Serial contact means that only one piece of data is sent or received at a time. Most modern computers use bytes or several bytes to address records. There is an eight-bit byte. Essentially, a bit is one or zero mathematics. Every character on this page is interpreted as one byte internally. The serial port is used both for transforming any byte into a single zero queue and for converting a zero-bytes stream. The serial port has a UART chip which is directly converted into an electric chip. This chip works as a receiver as well as a transmitter. There are a variety of pins in the serial terminal. The transmission is first addressed and a pin is received.

If a logical signal is sent by the serial port, the transmitting pin is electrically supported with a negative voltage. If a logical zero (0) is sent to the serial port, a positive stress is generated. If no data have been transmitted, the serial port pin voltage is negative and indicated as MARK. Notice that the serial port can be pressured, as SPACE and BREAK, to hold the transmission pin (0). (MARK and Space are often used to indicate the transmission pin with a negative tension or positive tension interchangeably. First, the UART serial port transmits the positive 0-voltage START BIT and eight bits of data, followed by the START BIT with a negative one or two bits voltage. For every byte sent, the sequence is repeated. Figure 1 illustrates a scheme about what would be like a byte transmission.

You want to know how long a bit is at this stage. So how much time can the signal be held in a given condition. You can understand the response easily. The baud intensity is determined. The rate of number is transfer in one second the signal is transformed. If 9600 baud is used, 9,600 times a second can be transformed. Every bit lasts $1/9600$ seconds or 100 seconds approximately.

There are many features to be understood or configured in addition to the baud rate when communication to a character. These features describe the entire representation of the data stream. The first attribute is the duration of the byte passed on. This string is between 5 and 8 bits in total length.

Parity is the second function. Oddly enough, parity may be a marker's property, whether it is space or not. If even parity is established, if the data transmitted is evenly distributed 0 bits, the last data bit transferred will be a logical 1.

When the data transmitted were 0 bit odd, the parity was unusual, the last data bit transferred was a logical one. The last data bit transmitted will be a logical one if MARK parity is used. The last data bit transmitted is always a logical 0, if parity SPACE is used. If there was no parity, the parity bit would not be passed. The third feature is the number of stop bits. Typically 1 or 2 is this value. We'll give the letter "A" to the serial terminal, let's say. The binary representation of the letter A is 01000001. Since bits are forwarded from LSB to Most Significant bit (MSB), they will be the following moving bit stream for line features. 8 bit, no parity, one bit delay 9600 baud

4.7.3. Null Modem:

Communications with RS232 are normal. One of the oldest and most comprehensive contact methods in the world of computing. The execution of this form of communication is well described by directives. This is because there is a one-off rule. The communication protocol for DTE/DCE shows how a computer communicates to a peripheral machine, such as a modem. DTE stands for data terminal (computers, etc.) and DCE for data communication equipment for information purposes for your information.

If no modem is present, serial null modems with DTE/DTE communication configuration, especially in the flow control, is one of the most common uses of serial communication. The no term modem became so popular that most people misunderstood what the phrase means and that the relationship with a no modem is an exception rather than a law. In the past, practical applications were created to communicate between two computers using a null modem serial transmission line. In order to shake your device, the original signal line modem is always reused.

Since computers can monitor the transfer of information, handshakes can contribute to the optimal contact time. If you can track this computer, but not if it does

anything, you can get a huge amount of input data. If there is no flow control on the null modem link, the matrix can only be transmitted at a rate that allows the reception side to handle the data even in the worst of circumstances.

When we look at the pin from the RS232 socket, we see two pins which are specifically used to manage the flow. The two pins are CTS and RTS (sending) (clear sending). RTS is an output for DTE and an input for DCE for DTE and DCE communication (i.e. a computer communicating with a modem device).

The signal is the CTS signal of the DCE. The DTE requires permission to set its RTS output before sending a character. No data is transmitted through the CTS line prior to approval by the DCE.

When the DCE cannot meet new demands, the CTS signal will be decreased. This is a basic but efficient control system for one-way flow control. The DTE can process inbound data even more quickly than can be relayed by the DCE. It's been in the past. Three hundred baud modems with 1200 baud high-speed connection were popular.

For further information flow control, both systems may signal their location on the other side. For this purpose ready signals are given in ready-to-use and DSR data collection. The DTE uses the DTR signal for accepting information while the DCE uses the DSR signal for the same purpose. The use of these symbols is not to be ritualised as it is in the RTS/CTS handshake. These are only one way.

The last flow control signal in the DTE/DCE communication is CD carrier detection. It is not used to directly control flow, but mainly to show the ability of the modem system to link. The signal indicates that there is a contact link between two modem devices.

4.7.4. Null Modem Without Handshaking:

How to use the handshake null modem lines Nothing is the easiest alternative. Only the data lines and signal field are linked by the null modem transmission cable. The

other pins are not linked. A cable representation of such a null modem without handshakes is shown in the following figure.

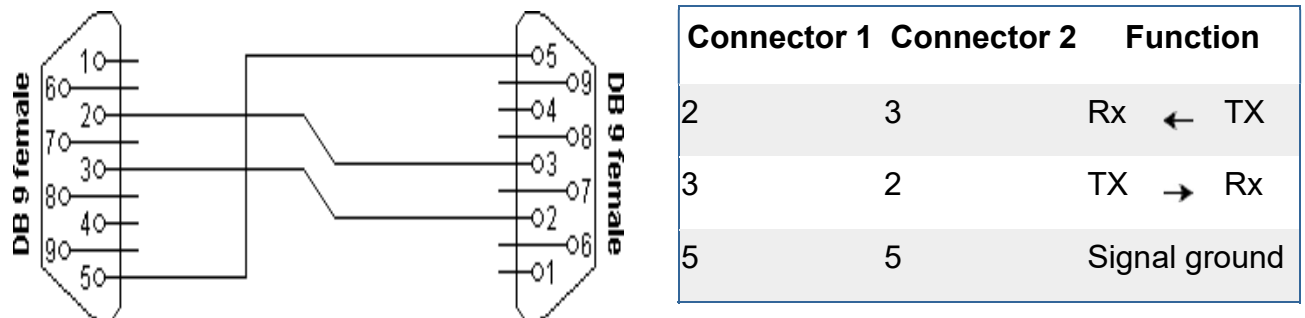


Fig.4.9: Simple null modem without Handshaking

CHAPTER 5

RESULTS AND OBSERVATION

5.1 Li-Fi Transmitter

Arduino Uno – In this project, Arduino Uno is used as a central processing unit. From the source the video signal is transferred to Arduino via VGA cable. From Arduino the video signal is converted to electrical signal and sent to the Li-Fi transmitter. At transmitter electrical pulses are converted to light, the light which is converted is sent to the receiver.

5.2 LED Driver

Enable you to quickly build LED applications and market yourself with our full LED driver portfolio that is combined with our microcontrollers and power management, networking and interface products.



Fig.5.1: Li-Fi Transmitter

From the source the video signal is transferred to Arduino via VGA cable. From Arduino the video signal is converted to electrical signal and sent to the Li-Fi transmitter. At transmitter electrical pulses are converted to light, the light which is converted is sent to the receiver.

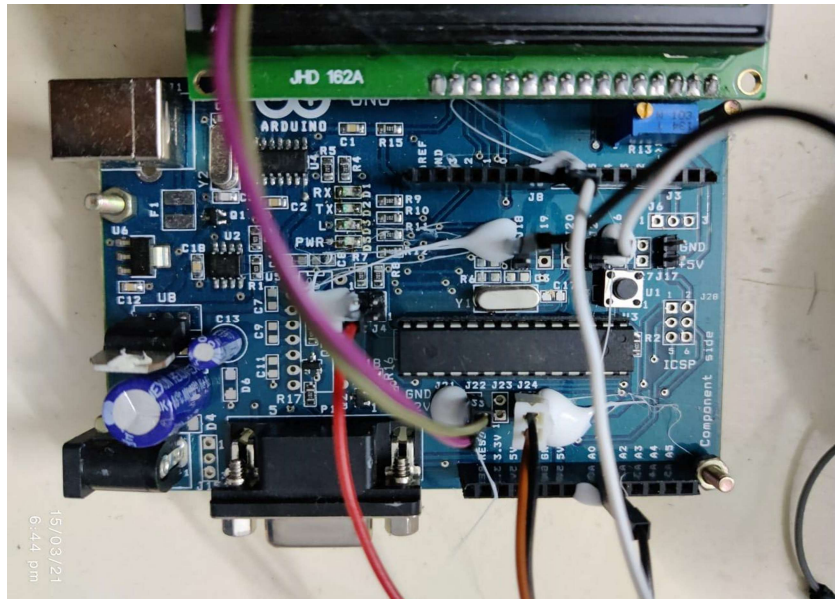


Fig.5.2: Arduino Uno

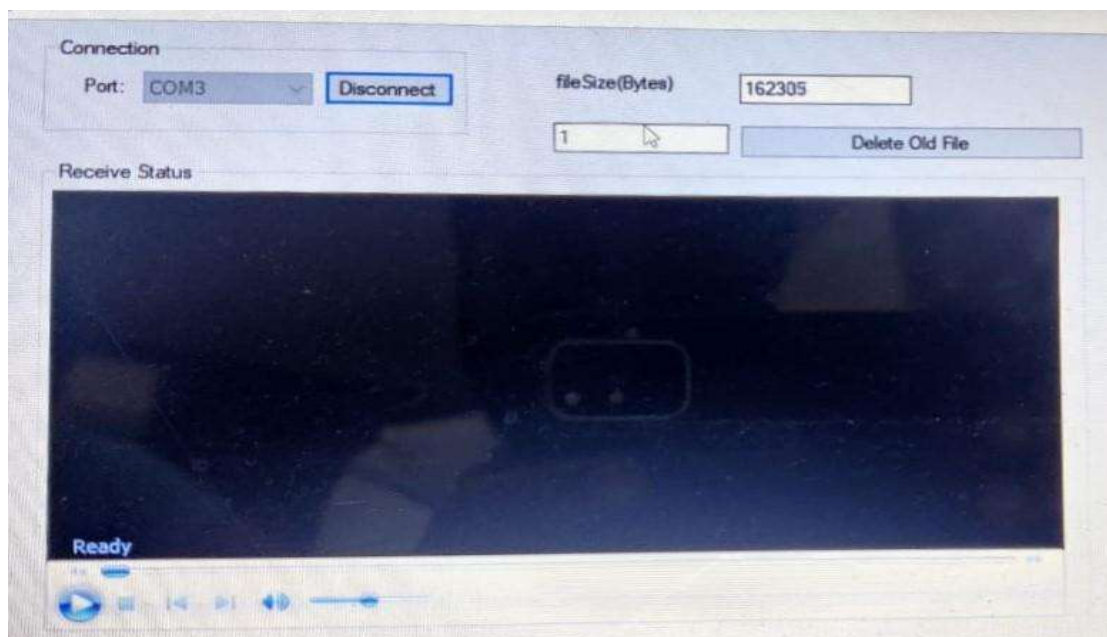


Fig.5.3: Data Transmission

In fig 5.3. we are transmitting the video signal from source to destination, the transfer of bytes were shown during Transmission

5.3 LI-FI Receiver

Li-Fi battery charging and the data receipt can be effectively controlled by visible light waves or visible light transmission (VLC). The receiver is built into the electronic signal provided by LEDs from the visible waves. At receiver the photo diode is present, the diode absorbs the light signal and converts into electrical pulses, these electrical pulses are sent to Arduino, from Arduino the signal is sent to the destination via another VGA cable. Here the transmitted signal is displayed.

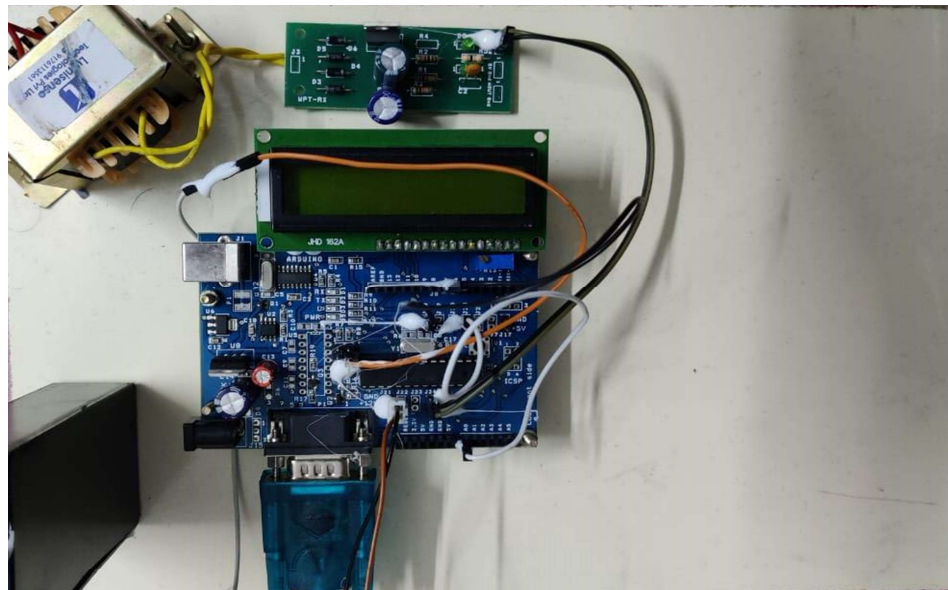


Fig.5.4: Li-Fi Receiver

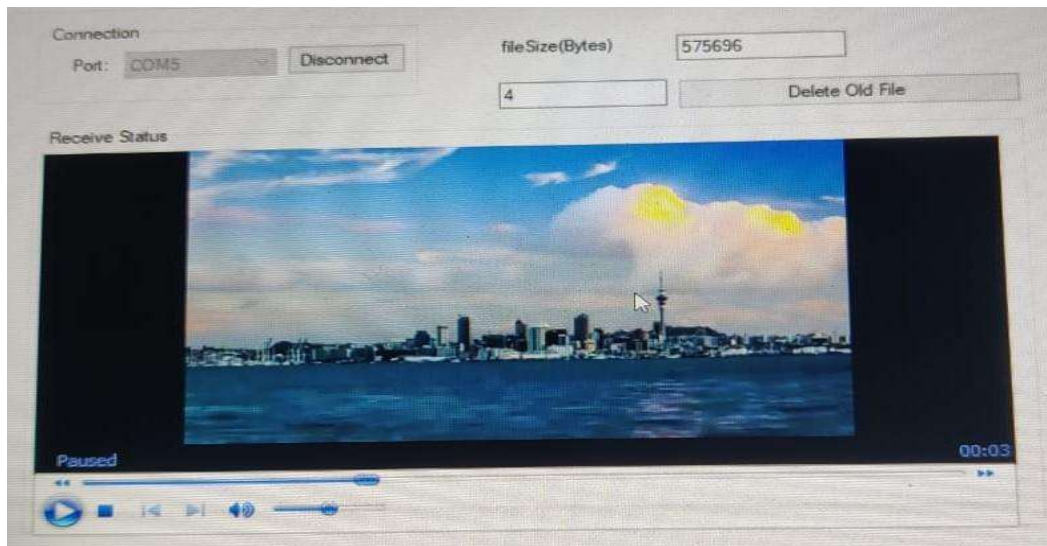


Fig.5.5: Data Receiving

From the source the video signal is transferred to Arduino via VGA cable. From Arduino the video signal is converted to electrical signal and sent to the Li-Fi transmitter. At transmitter electrical pulses are converted to light, the light which is converted is sent to the receiver.

At receiver the photo diode is present, the diode absorbs the light signal and converts into electrical pulses, these electrical pulses are sent to Arduino, from Arduino the signal is sent to the destination via another VGA cable. Here the transmitted signal is displayed.

CHAPTER 6

CONCLUSION

During this study, the LI-FI system has been successfully deployed using visible light as a communication medium in which the dispersed light signal is used as a source of data from which communication devices can transmit and receive the data.

We try to further explore data communication via computer systems and mobile devices so that AUDIO and VIDEO signals are also available. Li-Fi Technology offers many industrial benefits, as it is the best way than any other means to communicate. We have also researched that Li-Fi technology is a safer option to use device-to-device connectivity than Wi-Fi technology.

Here you can see both hardware and software units, as well as the running of the Li-Fi drive. The prototype will send messages to the recipient side. The created architecture shows how a device can help rapidly transmit messages and deliver low-cost network services in a remote environment in real time. The technology will be upgraded and able to work globally across cost-efficient instruments.

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