A practical Approach to Light Fidelity

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Abstract: *With increasing demands for efficient, faster and more secure wireless communications, there is a pressing need for a new epoch of wireless communication.The radio spectrum is getting clogged day by day limiting the speed and user density. Optical Communication using Visible Light or Infrared rays is a medium that can address all these requirements. Professor Harald Hass first showcased the interconnection of internet with optical communication through LEDs. Hence the solution for the future is in the technology named Li-Fi i.e. Light Fidelity. Li-Fi is a relatively better technology with great potential. Li-Fi has the data rate in range of Gbps (Giga bits per second). Moreover it also provides security as the light is unable to penetrate the obstacles. The concept of data transfer through LED and photodiode pair was applied practically through various techniques. Li-Fi technique is being practically implemented using DTMF and USART technology. This paper will focus on the implementation of data transfer using LEDs and data detection by photodiodes using two modules through flow charts and circuit schematics. One module works on DTMF technique to transmit numeric data and other one transmits images using a microcontroller USART feature. The Li-Fi technology has evolved from infant stage to adolescent but still the better is yet to be developed.*

Key Words: *Li-Fi, Wi-Fi, LED, Photodiode, DTMF, USART*

1. INTRODUCTION:

Radio spectrum is getting clogged day by day resulting in a restriction on data transfer rates and number of users. Li-Fi is proposed as an helping technique for short range to the long ranged Wi-Fi technology. The idea is to modulate LEDs transmitting electromagnetic waves in the visible light frequencies to communicate between devices at line of sight[1,6]. Transmitting data through light is achieved by having the light source flicker on and off to represent a logic high and logic low signal respectively. A receiver consists of either photodiodes or a digital camera to detect the light coming from the transmitter and it will interpret the signal coming from the transmitter. The working principle of Li Fi is very simple – if led is off it transmits binary 0 and if LED is on[2,5,6]. LEDs can be made to switch off and on so quickly by using a such controller so that it can be used to transfer message signals. Data from a network is used to modulate the intensity of LED source rapidly by tiny changes in amplitude of signal which is too fast to be sensed by a human eye. A photosensitive device like a photodiode receives up signal in the form of light and then transfers electrical equivalent data to receiver. Therefore every light source can work as hub for data transmission[3,4].
Li-Fi has a very vast scope in upcoming era, not only at a global level but for India as a most. With the concept of "Digital India" in progress Li-Fi concept could be implemented with more ease here. The initiatives like promoting LED bulbs, solar panels and LED street lamps with proposal of implementation of Wi Fi technique could be well complemented by Li-Fi towards betterment. Further in this section we have describe the two modules used in our system design namely DTMF & uc.

2. DTMF Technology- Dual Tone Multiple Frequency :

Each key pressed on phone (keypad) generates two tones of specific frequency where column frequency is higher than row frequency. The tones formed when dialing on the keypad on the phone can be used to characterize the digits and a voice or a random signal cannot mimic DTMF signaling tones. The principle is to convert an analog signal to digital using DTMF decoder. IC 9121B generates DTMF signal and its counter part IC CM 8870 is a DTMF receiver. The following table shows the standard DTMF frequencies generated by the keys used in our modules.

Table 1 : Standard DTMF frequencies with the Key Generating them used in the circuit

BUTTON	LOW DTMF (Hz)	HIGH DTMF (Hz)
1	697	1209
2	697	1336
3	697	1477
4	770	1209
5	770	1336

6	770	1477
7	852	1209
8	852	1336
9	852	1477

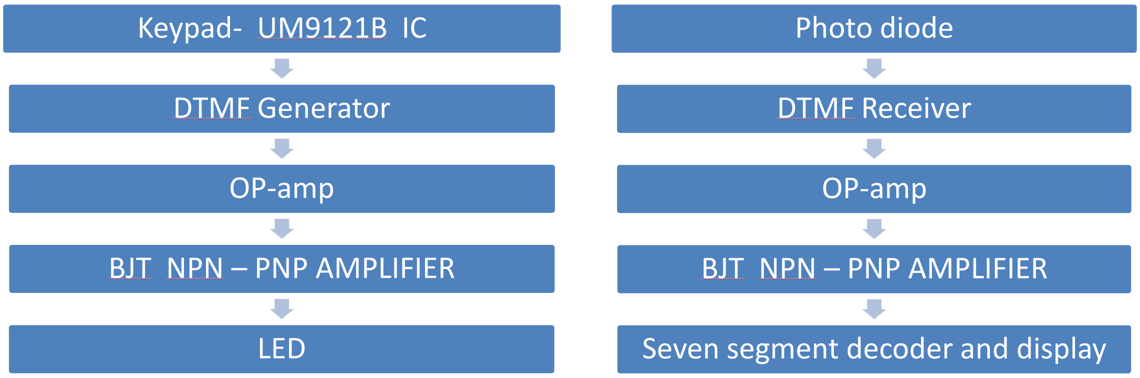


Figure 1: Flow Diagram for DTMF Transmitter (Left) and Receiver (Right)

In digital transmission we use one numeric keyboard and at the receiver section we use one numeric display circuit. In transmitter section we use 9 switches for the nine decimal number's and the output circuit we use one seven segment display for the numeric display. In transmitter section we use one DTMF signal generator for generating a signal in the form of PWM (pulse width modulation) for this purpose we use IC UM 91513 as a transmitter. All the nine switches are connected to the input of this IC . All the switches are connected together as a matrix network and are divided in three rows and three columns i.e. R-1,R-2, R-3 and C-1, C-2, C-3. Resistance of 150 ohm limit the current and 3.3 volt zener regulate the input supply voltage. This output signal is directly connected to the operational amplifier circuit. Further NPN-PNP BJTs are used as class B Power amplifier for output signal. In receiver circuit we use one photodiode. When light falls on the photodiode then photodiode sense the light and convert it into a very small electrical equivalent. This small signal is amplified by the operational amplifier and further connected to the DTMF decoder circuit.For the DTMF decoder circuit we use IC 8870. This IC Receive the signal and demodulate the frequency and this frequency is available on the pins 11,12,13,14 in the form of BCD signal. If we use this BCD signal in further then we can control many electrical appliances through this circuit. Here we use IC 7447 as a seven segment decoder circuit.

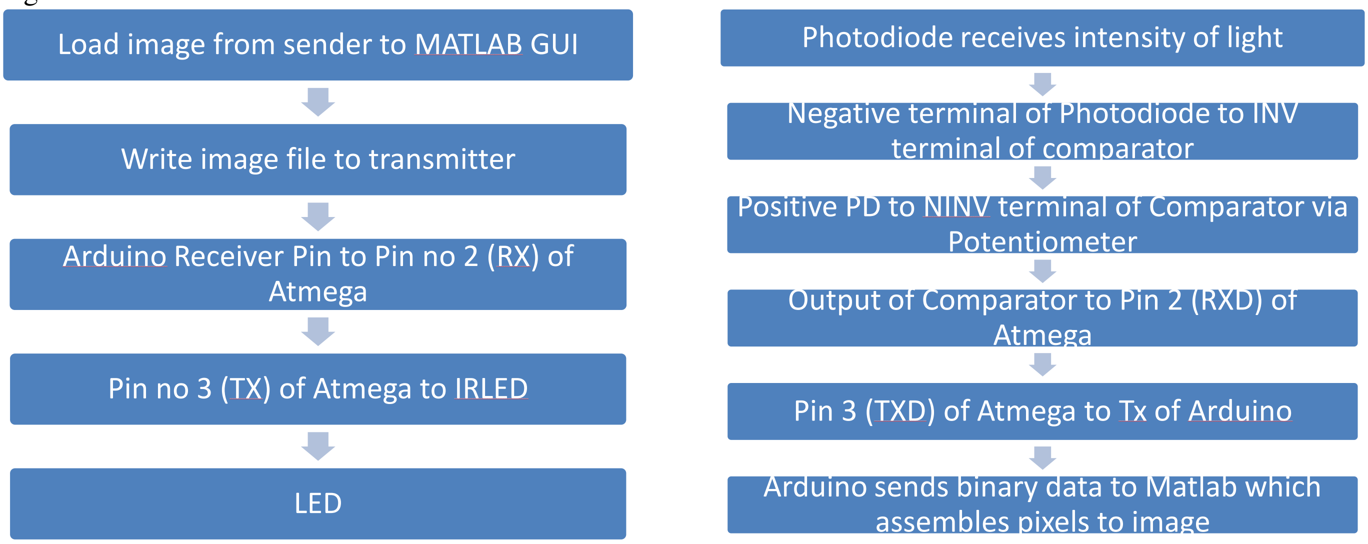


Figure 2: Flow diagram forUSART Transmitter (Left) and Receiver (Right)

In this circuit basically we designed to transfer larger data in the form of image and videos. On the transmitter part, first the image is selected using Graphical user interface program of Matlab and then the image is processed and converted into pixels into some definite size. Once the image is resized it is converted into pixels and serially transmitter using serial ports of Arduino board to Atmega. The microcontroller then correspondingly allows the Infrared LED to transmit data in binary form which is practically not visible to human eye. Here for the transmitter part, the Arduino board is receiving the data from PC or laptop connected via USB hence only RX pin is connected to RX pin of atmega. This is necessary for serial data transmission. Only Atmega microcontroller TX pin is connected to IR LED. While on receiver side first of all the photodiode measures intensity of light but this data is not suitable so it is converted into digital format using a comparator circuit using IC LM 358. This generates the digital data which is received by the microcontroller which further serially transmitts the same to the Matlab receiver software code using USB. The received data enables the Matlab software to reconstruct image as originally transmitted. Moreover, in the receiver circuit the microcontroller as well as arduino both are serially transmitting data hence TX pins are connected as required.The Arduino interface used here eliminates the TTL (Transistor Transistor Logic) logic for connection needed generally for such transmission.

Microcontroller Programming : The whole concept of USART programming was used. The initialisation of various registers were done as required. Transmitter and Receiver pins were programmed with pointers and the whole process was inside an infinite loop indicating that this transmission – reception process keep going on till user wants. The same code was used for both transmitter and receiver parts since each one only receives and transmitts the data directly. Rest of the computations required were done using Matlab software.

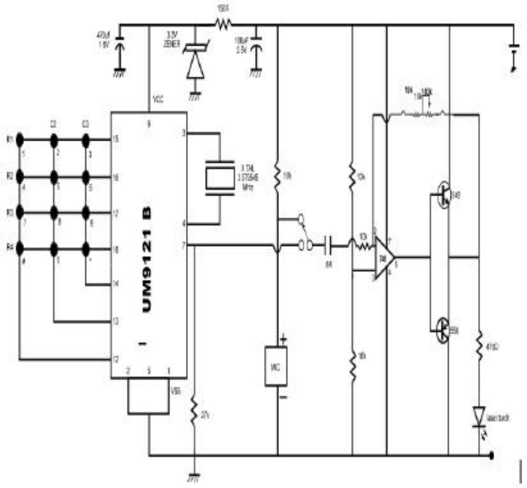


Figure 3
Circuit Diagram DTMF Transmitter

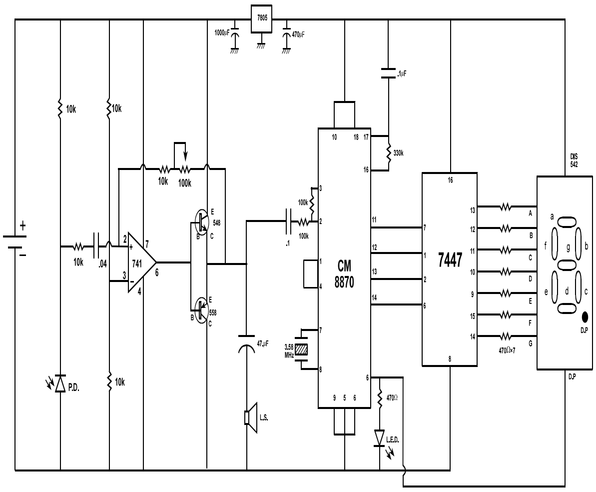


Figure 4
Circuit Diagram DTMF Receiver

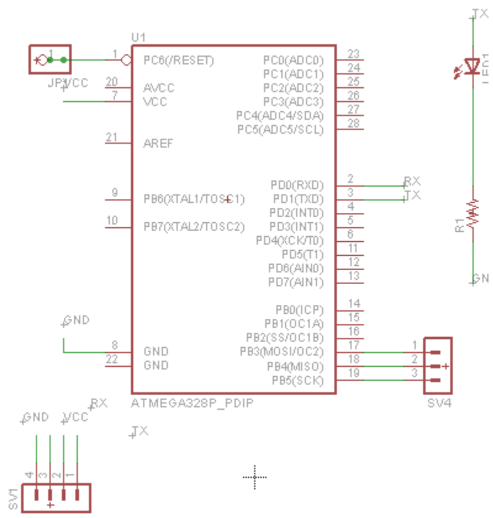


Figure 5 : Transmitter Circuit Diagra

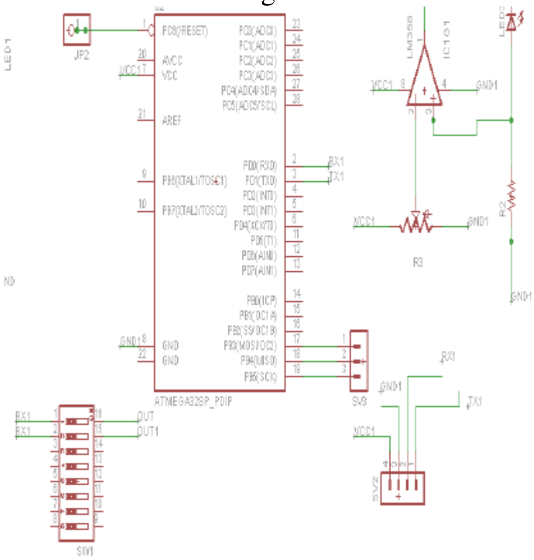


Figure 6 : Receiver Circuit Diagram

Figure 7(a)
DTMF transmitter and Receiver

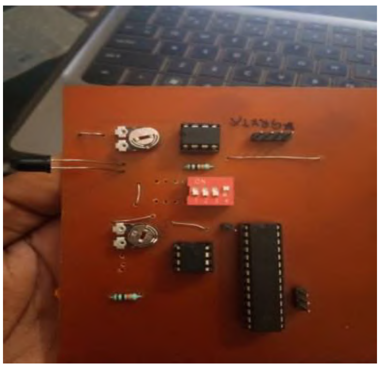
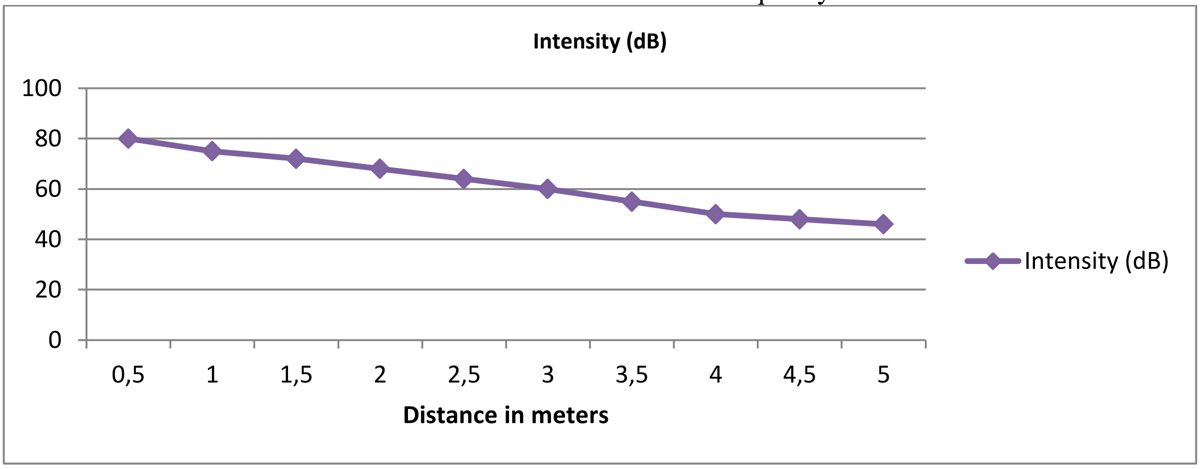


Figure 7(b)
Atmega Receiver

Figure 7(c)
Atmega Transmitter

3. RESULTS AND DISCUSSION:

By the implementation of above stated transmitter and receiver modules, it was observed that the data was transmitted through LED over appreciable ranges. The data in the form of numerals through keypad was successfully received at seven segment display through range of 5 meters. For more practical observations and improvements, we added microphone and speakers to the above circuit for testing the feasibility with the audio data. The audio data was also received successfully. We also added a mobile jack lead so that the recorded audios could also be sent and tested. Finally we observed all the cases of text and audio transmitted over appreciable range. The following graph shows intensity of sound in dB that was measured using a smartphone application against the distance in meters. The intensity of sound decreased as the distance increases and moreover the quality of sound received also deteriorated.



Then the concept that reflected light also transmits data was also observed using reflection from plane mirror during testing. Although the intensity in reflection case was less but it was enough to verify the statement that Li-Fi works on the reflecting surfaces. On the other hand for the circuit using Microcontroller firstly the calibration using Arduino Serial Montoring window needs to be done before actually transmitting the image. The image is firstly processed using Matlab and then transmitted serially in the form of pixel by pixel through infrared LED on the principle of USART as shown in following figure. The pixels received through photodiode are again converted into image through the reverse process.

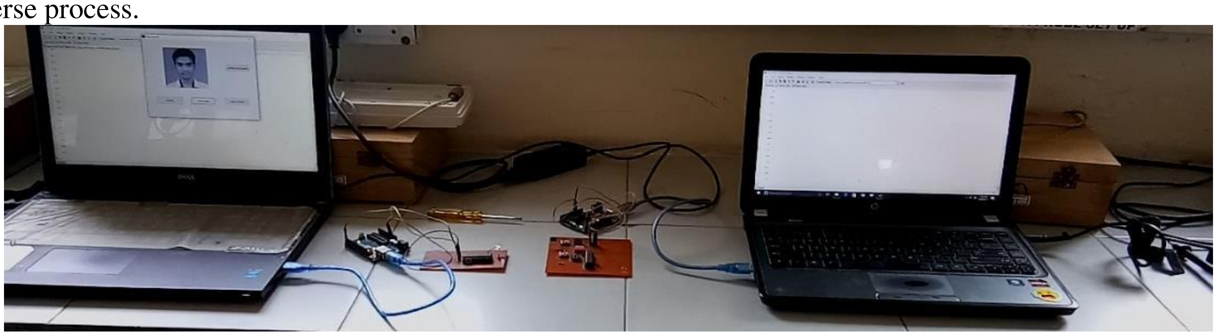


Figure 8 : Image File sending process through LED

Following figures show transmitter(left) and receiver(right) windows of Arduino serial monitor for transmitting data.

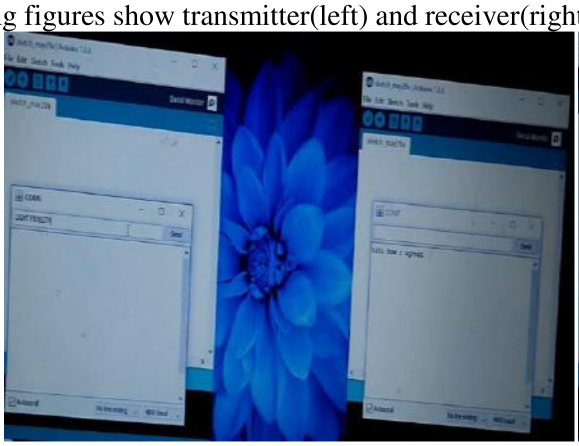


Figure 9(a) : Transmitting Data

Figure 9(b) : Data Received

4. CONCLUSION:

Li-Fi features include benefits to the capacity, energy efficiency, safety and security of a wireless system with a number of key benefits over Wi-Fi but is inherently a complementary technology.[4] The visible light spectrum is not regulated thus can be used for communication at very high speeds. Mobile Connectivity: Laptops, smart phones, tablets and other mobile devices can interconnect directly using Li-Fi.[6] Short range links give very high data rates and also provides security. By the implementation of above stated transmitter and receiver modules, it was observed that the data was transmitted through LED over appreciable ranges. The speed of data transmission is proportional to the encoding of switching speed of LED which can be improved endlessly using various techniques. By this proposed system we concluded that light emitted by a LED is a very good medium of transferring data between systems.

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