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LIFI SYSTEM FOR AUTOMATION WITH DEVICE CONTROL AND DATA TRANSMISSION USING LED AND SOLAR PANEL

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ABSTRACT
Light has been around for millions of years. It has created us, has created life and has created all stuffs of life. WiFi has become indispensible part of our daily life. We can't imagine life without these, be it at home, at work place, meeting hall, hospitals, aircrafts, street lights, vehicles, traffic lights and so on. In recent years, the rapid development in solid state Light emitting diodes(LED's) material has given rise to next generation 5G data communication called LiFi it is faster in transmission of data, more secure and immune to EMI relative to radio waves unlike radio waves. This paper presents a implementation of LiFi system, how its different, different application scenarios and a prototype is been developed to demonstrate the implementation of LiFi in industrial automation system for device switching and audio transmission system. The Design is accomplished using Optocoupler, PC and serial interface along with LiFi transmitter an LED, LiFi receiver solar panel, the LED light is modulated with data signal, converted to binary form in order to support transmission over light, on and off modulation is used and the signal is received at receiver side by a photo detector i.e. solar panel, given to MCU received signal is demodulated to get back original transmitted data and corresponding devices are turned on. Experimental analysis of LED output is one, simulation of LED driver circuit, amplifier circuit is done using Proteus software. Thus a Prototype is been developed
Keywords: LED(light emitting diode), solar panel, photo detecctor, Light Fidelity (LiFi), Wireless fidelity (WiFi), LED driver circuit, amplifier.

I. INTRODUCTION

Undoubtedly, Wi-Fi is very eminent technology having vast applications encompassing both our personal and professional life. Like water and electricity wireless networks have become basic utility of our day to day life. RF communication has both pros and cons, on one side it provides connectivity among 5 billion cellular phones and 70,000TB of data transfer every year [1] on other hand due to its tremendous usage the RF bands are getting scarce, also RF signals are restricted at hospitals and aircrafts because of its hazardous effects. Several issues related to radio waves are listed below:

1) *Capacity :* We transmit wireless data through radio waves which are limited.
2) *Efficiency :* There are 1.4 million cellular radio base station's which consume massive amount of energy.Most of this energy is not use for transmission but for cooling down the base stations.Efficiency of such a base station is only 5% and that raise a very big problem.
3) *Availability :* Availability of radio waves or RF signals causes another concern as we have to switch off our mobiles in aero planes, industries etc.
4) *Security :* Radio waves penetrates through walls and they can be intercepted.

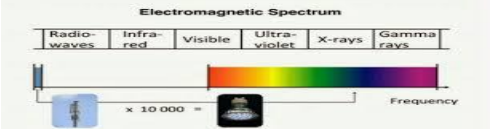

Fig 1 Electromagnetic spectrum

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We have 40 billions of light box already installed and light is part of electromagnetic spectrum. Looking up at this in context of EM spectrum we are left with only visible light spectrum as other cannot be used due their shortcomings and harmful effects as listed in fig 1. Thus an alternative technology "Visible Light Communication/Light Fidelity(LiFi)" is been developed for short range communication(1000meters) [1].

I. METERIALS AND METHEDOLOGY

This section outlines the entire design process. An overview of the system is discussed, different materials/components used, how components are selected, designing and working of system, transmitter & receiver design, led driver design, amplifier circuit design and finally, about the coding and software's used by the LiFi system.

Design Overview

When designing and creating a LiFi System, a number of steps are required. Fig 2 shows complete block diagram of the system Steps are illustrated below

- Introduction to the system : Defining the system, typical components and characteristics of embedded system.
- Hardware and software requirements
- Components selection and testing
- Transmitter and Receiver circuit design and testing
- Hardware Interfacing and Programming

LiFi system for automation and audio, text communication block daigram is shown in fig below

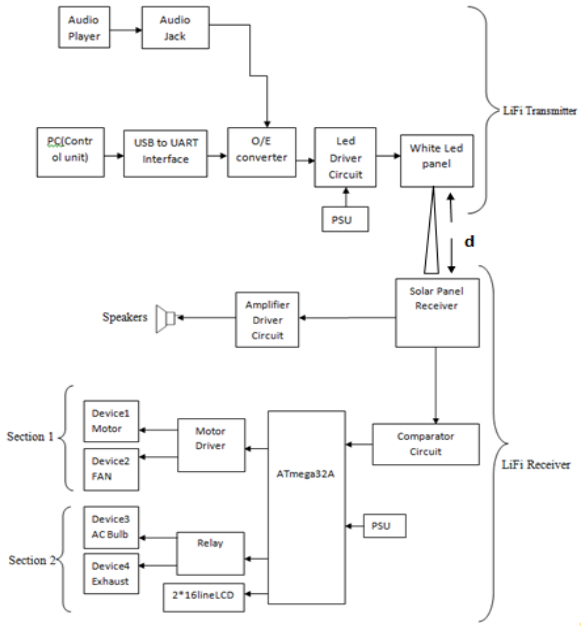

Fig 2 Block Diagram of LiFi enabled system for automation and audio communication

. Basically 2 things areaccomplished:

1. Audio is played in played from PC or phone, proccessed given to LED driver unit which in turn drives and glows LEDs accordingly.
2. Text and Control signals are transmitted using LED light, simulataneosly received by solar panel, displayed onto the LCD screen at reciever side and corresponding devices are turned on. Different devices used are motor, AC buld, Fan and Exhaust.d-> distance between transmitter and reciever. The figure below shows bloack diagram of.

Components Selection and Testing

Once a rough idea of what the LiFi system would be like is got, the components required for the circuit must be tested, comparative study is done before making a final selection. The selection process comprises of analysis of various parameters and emphasis is placed on certain desirable features of each component so that the best component of its group is selected for the circuit. Once the initial components were selected, both the receiver and transmitter circuits were designed and tested in simulations.

LED's And Photo Detector Selection Aspects

The purpose of the LEDs in the LiFi system is to allow light to be used to transmit data. Any data needs to converted to binary 1's & 0's form to support transmission, LEDs accomplish this by switching on which represents a logic 1 and turning off which represents a logic 0.

In order to choose the most optimal and appropriate LEDs, the important parameters are shown in following Tables below were considered. The importance of each parameter in the table is to aid in the selection of the best LED. For the LiFi project, there are two goals: to transmit CD quality audio, control signal and text data from the transmitter to the receiver, and have it transmitted across three meter. With above goals in mind, the brightness/intensity and frequency of operation very important while choosing a LED. As shown in table 1,2, 3 qnd 4.

Table 1 LED Selection Parameters

Parameters	Importance	Desirable	Undesirable
Brightness/intensity	1	Greater than 10000mcd	Less than 10000mcd
Operating Frequency Speed	1	At least 1MHz	Less than 100Khz
Color of LED	2		

Table 2LED Comparisons

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Device no	Intensity	Field of Viewing Angle	Frequency of operation	Color	Max current through LED
YSL-R5342G5C-A14	10000 - 13000 mcd	10°	Greater than 1 MHz	Pure Green	20mA Peak: 30mA
09855-04	200 mcd	Not listed	Not listed	RED	20 mA
LWS14	35000 mcd	15°	> 1MHz	White	Peak:30mA 100mA

Table 3 Photo detector Selection

Parameters	Importance	Desirable values	Undesirable
Response time	1	Greater than 10ns	Less than 100ns
Wavelength of operation	3	Difference of 700nm or more	Difference of 700nm or less
Field of Vision(FOV)	2	Greater than 30 deg	10 deg

Table 4 Photo detectors comparisons

Part NO	Response Time(ns)	Wavelength Range (nM)	FOV	Surface mount	Photo current
SFH 203	5	400-1100	40°	N	50uA
SFH 213	5	400-1100	20°	N	135uA
TEFD4300	100	350-1120	40°	N	17uA
OP993	5	600-1100	118°	N	15uA
SFH2701	2	400-1100	120°	Y	1.4uA
TPS-12-5	2	300-750	Wide (8.7 -10.6)	Y	0.34uA

For reference, all data organized in tables dealing with different models for a specific component are highlighted in green, yellow, and red. Green means that It was the best choice based off of specifications and pricing while yellow means it is a fair choice while red means it was a unwise choice.

Each of the features was rated for its importance. The most important feature was the response time. If the photodiode was incapable of detecting the flashing of the LED fast enough, then it would be incapable of meeting our design requirement. A response time of less than 10 ns is desirable as a shorter response time means that the photodiodes can react faster to each bit that is transmitted.

Microcontroller

With light being transmitted by the LEDs and being received by the photodiodes, the raw analogy signal itself is not of much use. A DAC is needed to take the binary values that the data stream is represented in and turn it into a signal that can control the LEDs' flickering rate. On the other side of the system, an ADC is needed to convert the photocurrent back into a binary format that can be digitally processed. The transmitter and receiver microcontroller is arguably one of the biggest bottlenecks in the system. While the analogy circuitry may introduce quite a bit of noise and be difficult to tune properly, a fast digital board can get around this by digitally processing the data and outputting accurate results to the computer to finish processing. Since AVR can perform single cycle execution, it means that AVR can execute 16 million instructions per second if cycle frequency is 16MHz. The higher is the operating frequency of the controller, the higher will be its processing speed. We need to optimize the power consumption with processing speed and hence need to select the operating frequency accordingly. ATMEGA32A MCU is been used. Table 5 and 6 Important Selection parameters for Microcontroller.

Table 5 Important Selection parameters for Microcontroller

Category	Importance	Desirable	Undesirable
Interface	5	As many different types of I/O ports as possible	Very limited or not having USB the very least
Cost	4	Less than 1000	More than 1500
Clock Speed	2	> 5 MHz	< 1 MHz
Ease of Use	6	Libraries, Documentation, Help Forums	Rarely used in the real environment
Sample Rate/Reliability	1	> 1 Megasamples	< 500 Kilosamples
Memory	3	> 1 Mb	< 512 kB

Table 6 Comparison Between various shortlisted microcontrollers family

	8051	PIC	AVR
SPEED	Slow	Moderate	Fast
MEMORY	Small	Huge	Huge
ARCHITECTURE	CISC	RISC	RISC
ADC	Absent	Built-in	Built in
Timers	Built in	Built in	Built in
PWM Channels	Absent	Built in	Built in

The interfacing circuit diagrams are shown in figures 3 and 5below.

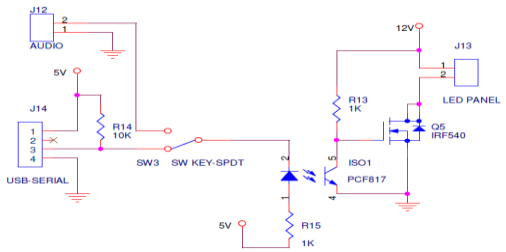

Fig 3 LiFi system interfacing Diagram of transmitter

UART Protocol:

Fig 4 shows the expected waveform from the UART when using the common 8N1 format. 8N1 signifies 8 Data bits, No Parity and 1 Stop Bit. The RS-232 line, when idle is in the Mark State (Logic 1).

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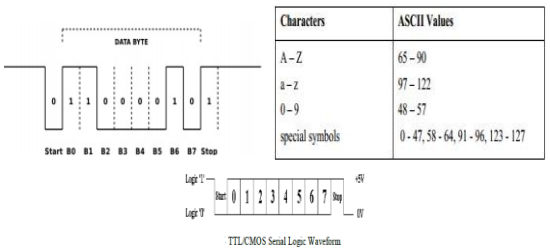

Characters	ASCII Values
A – Z	65 – 90
a – z	97 – 122
0 – 9	48 – 57
special symbols	0 - 47, 58 - 64, 91 - 96, 123 - 127

Fig 54TTL/CMOS Serial Logic Data Transfer

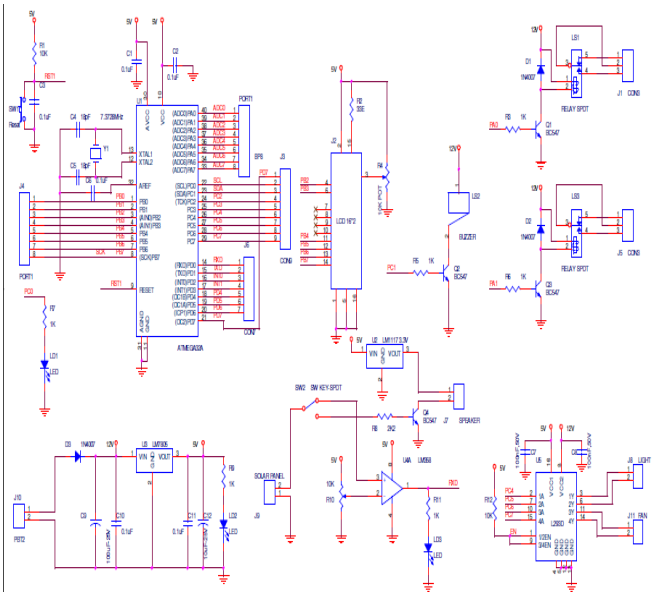

Fig 5 LiFi system interfacing Diagram of Receiver

Amplifier Driver Circuit:

Originally, a MOSFET was used but was found to be unsuitable, which lead to use BJT. During the testing of transistors, it was decided to use the 2N3906 or 2N2222A BJT; however, it was not adequate and it was finally decided to use the BJT, which is very similar to the 2N3906/2N2222A BJT but is made for slightly higher power usage circuits such as ours. The BC547 transistor turns itself on (the resistance between the collector and emitter essentially become 0Ω) when a 0.7 V or higher signal is at coming from the MCU pin. Designed circuit is shown in figure 3

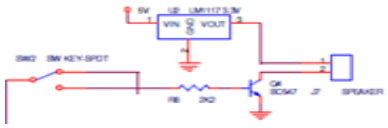

Fig 6 Amplifier Driver Circuit

Device Switching in Industrial Automation and Text Transmission:

GUI is created as shown in fig8 depending on the operation to be performed user can select the blocks like turn on device or type text to be transmitted in GUI created in PC. The analog signals are transmitted to OptoCoupler then to driver circuit and finally reaches LEDS and switch the LEDs accordingly, using the illumination LEDs in the transmitter. The photo detector solar panel at the receiver senses optical signals from the LEDs and is converted into electrical signals. The electrical signal is then compared and amplified using comparator circuit with a reference of 5V, this signal is given to Rxd pin of microcontroller which is pre-programmed to switch the devices depending on what operation was selected at transmitter side and display characters typed in GUI onto LCD attached

In this paper we are discussing use of Light as a source of medium to transmit the signals as we know that light is ambient and it doesn't affect the human's life or nature here we are transmitting the audio signals via light.

Audio and Text Transmission system Working using LiFi

In the process of voice communication through the visible light on the transmitter side voice is used as the input signal. This signal is converted to an electrical signal through a condenser or microphone. This electrical signal is amplified by the amplifier circuits and fed into the power LED. The light signal from the LED varies according to the intensity of the audio signal. At the receiver side solar panel will receives the light signal and correspondingly generates an electrical signal proportional to it.,.This electrical signal is processed by a demodulator circuit, output is given to amplifier driver circuit Fig 6 and then which is then fed to a speaker and it produces the audio signal which was at the input of the transmitter side. Fig 2 shows the block diagram. Audio played at transmitter is played back at receiver side speakers.

II. RESULTS AND DISCUSSION

In this section various observations made about the LiFi Enabled system are listed in table. Later, simulations and corresponding outputs of basic transmiiting circuit, LED driver circuit and amplifier circuit are shown using proteus software. Lastly numerical modeling is done in order analyze impact of increasing distance on output power and voltage. Figure shows initial brightness test conducted. From tests, the LEDs were capable of modulating at high frequencies (a few MHz) easily and maintaining nearly the same level of intensity. The only concern now was to figure out how reliable the LEDs were when modulation was carried out at high frequencies.

Fig 7 Brightness test for transmitting LED

Snapshots are shown in fig 9. Initially, a basic receiving and transmitting circuits were implemented and simulated. The purpose of implementing the circuits is to understand the main and basic concepts of optical

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wireless communication using LED as transmitter and a photodiode as receiver.

Snapshot of GUI created using VB.NET in PC to enable transmission

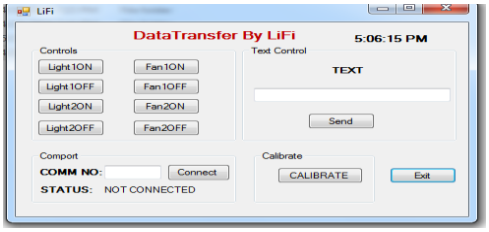
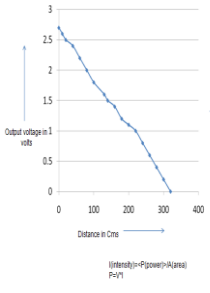


Fig 8 GUI interface

Complete setup of LiFi system is showm in figure below.

Fig 9 LIFI system Set Up

The output optical power from LED decreases with respect to the increase in the vertical distance between the transmitter and receiver. The exponentially decreasing intensity of light versus the distance proving the theory of light that, as the source far apart from the receiver, the intensity becomes low as in the case of photo detector.



Distance in Cms	Output Voltage in volts	Current in mAmps	Power in Watts
10	2.8	300	0.84
50	2.2	300	0.66
100	1.8	300	0.54
200	1.4	300	0.42
250	0.8	300	0.24
300	0.2	300	0.06
350	0	300	0.00

Fig 10 observed output Power output Values

Performance analysis is done by making observations of various parameters associated with LiFi system as listed in table 7 below.

Table 7 Observations of LiFi system

Parameters	***Observations/Attributes to be achieved***
Transmitting Distance Between LED and Solar panel	Upto 3meters
Light allowance	Data transmission occurs at every LED that has a preprogrammed microcontroller attached which determines task to be done
Transmission parameters	Device automation , text and audio
Variation with intensity	Intensity of light doesn't hamper the transmission of data. The data is transmitted even when the light is cold, dull and less intense.
Temperature range	0-70deg Celcius
Transmission frequency	1MHz
Data rates	Very high
Security & safety	Highly secure

CONCLUSIONS

This paper proposes a LiFi system to overcome a the shortcomings of wireless networks Lifi is definitely has the potential and is going to take over WiFi to certain extent in next 10 to 15 years. In the industrial communication, the control message transmission will be required to achieve real-time and accurate delivery of control information to specific devices or machines in the automation factory. Unfortunately, the wireless communication systems normally have well-known delivery problems, such as signal fading, multipath propagation, signal obscured and interference problems, and these will affect the industrial network communications required in immediacy. This mechanism will consider implementing by using industrial wireless Ethernet in the near future.

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