# A low cost solution to remotely refresh displays by using LED lights for communication

*A Project Report*

*submitted by*

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# THESIS CERTIFICATE

This is to certify that the thesis titled **A low cost solution to remotely refresh displays by using LED lights for communication**, submitted by **Mohit Parihar**, to the Indian Institute of Technology, Madras, for the award of the degree of **Master of Technology**, is a bonafide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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# ABSTRACT

KEYWORDS: VLC, Differential Signaling, Low refresh rate display

White LED offers advantageous properties such as high brightness, low power consumption and long lifetime. The use of white LEDs for communication has been proposed, but it is very difficult to install many such "visible light communication" solutions in public places because of high cost of the specialised components required to assemble these solutions

The presence of abundant light sources which are slowly replaced by LED light sources and presence of various low refresh rate displays sitting under such light sources gives the opportunity to use light for dual purpose of data transmission as well as illumination. Here, the data rate is not an important factor instead it is cost.

The aim of the project is to design an end to end system that can demonstrate remote (contactless) display refresh in a reasonable time using LED lights for communication keeping the design cost as low as possible. The transmission scheme involves transmitting differential signal via pair of low cost high brightness LEDs. The focus is to develop a transmission scheme where pixel level data transmission is done instead of sending compressed data so that it is efficient for applications which refresh only a few pixels. Considering the need for Low cost solution the transmitter and receiver circuit are made with commercially available components to keep the cost as low as possible.

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# ABBREVIATIONS

| | |
|---|---|
| **IITM** | Indian Institute of Technology, Madras |
| **VLC** | Visible Light Communication |
| **Li-Fi** | Light Fidelity |
| **SPI** | Serial Peripheral Interface |
| **LED** | Light Emitting Diode |
| **MOSI** | Master Out Slave In |
| **MISO** | Master In Slave Out |
| **UTP** | Un-shielded Twisted Pair |
| **LDR** | Light Dependent Resistor |
| **GPIO** | General Purpose Input Output |
| **SCLK** | System Clock |
| **MSB** | Most Significant Bit |
| **LSB** | Least Significant Bit |
| **SFD** | Start Frame Delimiter |
| **EOP** | End of Packet |
| **CCF** | Command Control Field |
| **LVDS** | Low Voltage Differential Signaling |
| **DSI** | Display Serial Interface |
| **HDMI** | High Definition Multimedia Interface |
| **LCD** | Liquid Crystal Display |

# CHAPTER 1

# INTRODUCTION

Consider today's scenario where use of LED lighting is increasing very rapidly as a cheap and efficient lighting source in places like shopping malls, classrooms, offices and various other public places. One can make use of this advancement in technology to transmit data owing to the fact that Visible light Communication is an emerging technique for wireless data transmission. One of the things that most of the above mentioned places have in common is various kinds of display devices which are placed and need for wireless data transmission, whether it is in the form of a electronic shelf display, digital clock, electronic calendars or digital picture frame lying on the desk of an office or the LCD displays in shopping malls displaying various information like offers, timings etc. which are updated regularly. These updates can be done by taking advantage of LED lighting which are available at these places by transmitting data through visible light as a carrier. The updates that are made on these displays usually require refreshing of only few numbers of pixels rather than the whole screen. So if we can somehow manage to refresh those particular pixels then this updating process will become much easier and efficient.

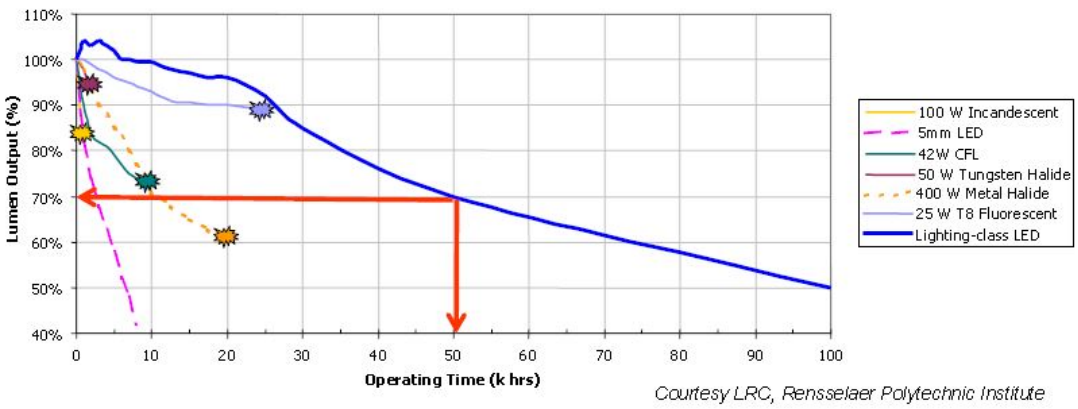



Figure 1.1: Lifetime of various light sources

## 1.1 Visible Light Communication

Visible light communication is communication medium using visible light between(400nm-800nm). Use of visible light is less harmful for high power applications because humans can perceive it. The technology uses fluorescent lamps to transmit at low rates or LEDs for up to 500 Mbits/s. VLC has following advantages which attracts attention of researchers and scientists.

- Large bandwidth and already present infrastructure.
- Poses no health hazards.
- No interference.
- Data Security.

### 1.1.1 Li-Fi Technology

Li-Fi or "light fidelity", is a technology, that can be complement of RF communication or replacement in context of data broadcasting. Li-Fi like Wi-fi is wireless and it uses visible light communication ( instead of radio frequency waves ) which carries much more information and has been proposed as a solution to RF-bandwidth limitations.

Professor Harald Haas from University of Edinburg in United Kingdom,is the founder of this technology and he is the one who coined the term Li-Fi after Wi-Fi. The general term Visible Light Communication (VLC), includes use of visible light portion of electromagnetic spectrum to transmit information. Professor Harald Haas promoted this technology in his global TED talk and helped start a company to market it.

In recent time Li-Fi has become one of the very important technology because of several reasons.For example user are always looking for better performance, and VLC promises high data rates. Also, the technology works with LED lights, which are becoming increasingly popular.

Demand for wireless communication is continuing to increase, but spectrum available for traditional, radio-based mobile approaches is shrinking rapidly. Also, using radio communications equipments can be hazardous at various type of locations. For example it can cause sparks, which makes it dangerous for use on oil platforms and also it can interfere with other radio equipments, which makes it inappropriate to use in airplanes.

Doctors are increasingly using wireless technology to transmit data from medical devices to their PCs or Laptops for analysis. However there are powerful magnetic fields around devices such as magnetic resonance imaging scanners, so physicians can't use radio-based wireless technology to transfer MRI data they collect.

### 1.1.2 Current State Of Art

There are numerous VLC research projects and products beginning to appear, signaling the technologies growing importance.

**OMEGA:** The European Union-funded OMEGA project is an interdisciplinary effort with participants from industry and academics that ran from 2008 to 2011 in which research was focused user-friendly, high-bandwidths, home-area networks. The project options such as optical, power-line, infrared and VLC networking.
OMEGA's VLC demonstration used 16 high-power,ceiling mounted LED lamp's. The researchers aggregated the output of four video players into an Ethernet stream, which they then modulated onto electrical current sent to the lamps. The light then continuously broadcast four high-definition videos at 100 Mbits per second.

**US National Science Foundation:** The NSF operates the Smart Lighting Engineering Research Center in partnership with several US universities. As a part of this program, Boston University Professor Thomas Little noted that he is working on a project that uses VLC to provide network connectivity and control among distributed light sensors. He is also researching data-delivery approaches that use both VLC and radio communications.

**RONJA:** The Reasonable Optical Near Joint Access Free Space Optics Device, which Czech Republic-based Twibright labs developed, uses red light to transmit data up to 1.4 Kilometers. It also uses infrared light, which has a wavelength longer than that of visible light for transmission up to .78 km.

**Siemens:** The German Company is primarily developing high speed VLC links based on commercial LEDs, focusing on modulation techniques, as well as LED driver circuitry and analog receivers. It has been working with one of the brightest LEDs available commercially, made by its Osram subsidary.

**Klipsch:** This is a US manufacturer of sound equipment has introduced speakers that can receive music via data transmitted from LED light bulbs.
The Light Speaker system combines 10-watt LED lighting and a 20-watt wireless sound speaker into a unit that installs like a standard light bulb. a music source is plugged into a centrally located transmitter, which then sends different music streams to as many as four pair of speakers.

**LVX System:** The company has developed an LED lighting fixture that offers an access point to whichever network an individual or an organization is using.
The system is installed as a part of the 2x2 foot lighting panels used in many commercial buildings, although LVX hopes to offer the system in other fixture models soon.

### 1.1.3 Illuminating The Road Ahead

If and when visible light communication implemented more widely, it could be used in many settings and many purposes.
**Healthcare:** Because, unlike radio communications, VLC doesn't experience problems with magnetic interference, the technology could enable doctors to wirelessly transmit data from magnetic-based medical devices, such as MRIs, to PCs or laptops for analysis.
**Hazardous settings:** VLC could enable wireless data communications in oil fields and mines, near gas pipelines, and in other environments where using RF equipment which can create sparks that could be dangerous.
**Commercial aviation:** Because, unlike radio communications, VLC doesn't interfere with flight-related radio signals, it could enable wireless data communications by passengers on aircraft. Airlines generally don't let passengers use RF-based equipment on planes when in flight. VLC could also let airlines wirelessly offer entertainment and other content to passengers.
**Green computing:** VLC offers more energy efficiency than radio communications.
**Military applications:** VLC could enable fast, secure transmissions within vehicles and aircraft.
**Underwater communications:** RF doesn't work optimally underwater, but VLC functions well in such settings over short distances.
**Automobiles:** LED stoplights or railroad signals could transmit information to cars or

trains. Cars could use LED lights to help occupants communicate with other vehicles, noted Siemens spokesperson Sebastian Webel.

**Smart lighting:** This approach, designed to create intelligent lighting systems that can be operated in an energy-efficient way, could use VLC as the infrastructure for illumination, control, and communications. VLC would require less wiring and energy than typical smart-lighting systems.

**Sensors:** VLC could be useful for communications in various types of sensor systems, noted Boston University professor Thomas Little. Museums. VLC systems could illuminate an object in an exhibit and at the same time wirelessly provide information about it, noted University of Edinburgh professor Harald Haas.

## 1.2 Goal

The goal is to design an end to end system that can demonstrate remote (contactless) display refresh in a reasonable time using Lifi keeping the design cost as low as possible. The transmission scheme involves transmitting differential signal via pair of low cost high brightness LEDs. The focus is to develop a transmission scheme where pixel level data transmission is done instead of sending compressed data so that applications where only few pixels need refreshments, this technology can be used effectively. Considering the need for Low cost solution the transmitter and receiver circuit are made with commercially available components to keep the cost as low as possible.

## 1.3 Components of the system

The transmission system which needs to be demonstrated for wireless transmission using LED light will consist of various components or subsystems which are given below.

- Transmitter and Receiver circuit
- Display device
- Miro-controller

### 1.3.1 Hardware Circuit

The communication scheme will use differential signal so the design of transmitter circuit should be such that it can transmit the differential signal therefore, use of single LED is not enough instead a pair of LEDs are used for transmitting differential signal. The circuit is design similar to concept of multi-vibrator circuit where both the LEDs are glowing but the light intensity is different because of different amount of current flowing as the intensity of light through an LED is directly proportional to amount of current flowing through it. The differential signal that needs to be transmitted is fed to a centre tap or pulse transformer and the output pins are connected to a pair of capacitors connected to gate of MOS transistors of multi-vibrator circuit. The use of capacitor is to remove any noise and the transformer are used to make sure that the capacitors get complimentary pulses. So, as soon as the pulse is applied the LED's start blinking with intensity of one LED more than the other.

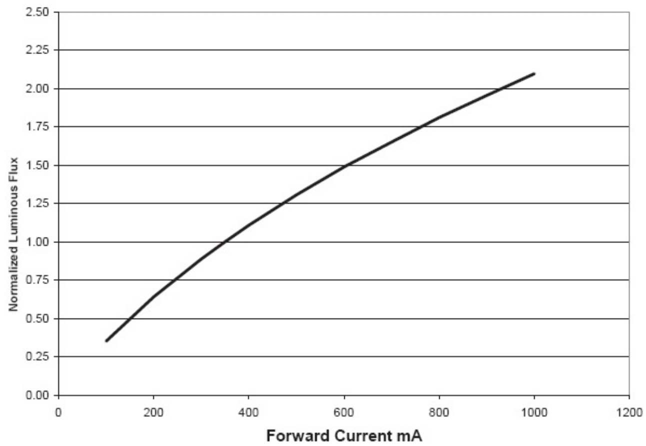



Figure 1.2: Brightness of LED Vs Current

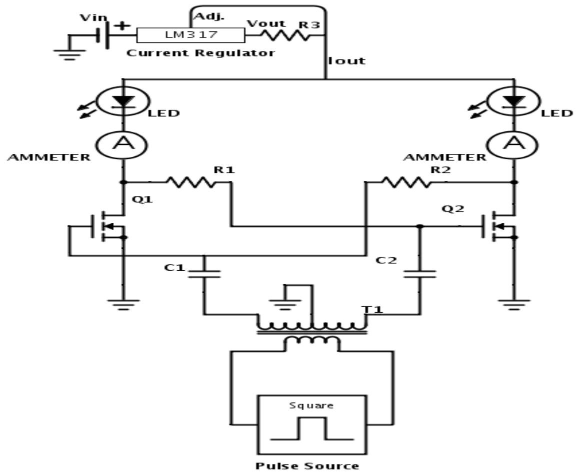



Figure 1.3: Transmitter Circuit

Once the LED's start transmitting the differential signal the challenge is to receive the differential signal by designing a low cost receiver circuit. Therefore, Light Dependent Resistor are used to detect the transmitted signal. The LDR has characteristics that when light falls on it the resistance of the LDR decreases and the decrease in resistance is dependent on light intensity. So, the LDR on which high intensity light is falling will make the base of respective transistor shorted to ground and thereby making that transistor of and the other on.

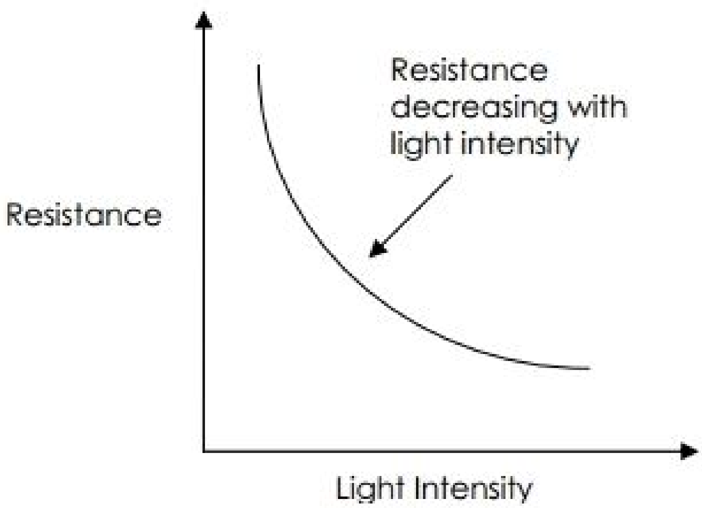



Figure 1.4: Characteristic of a LDR

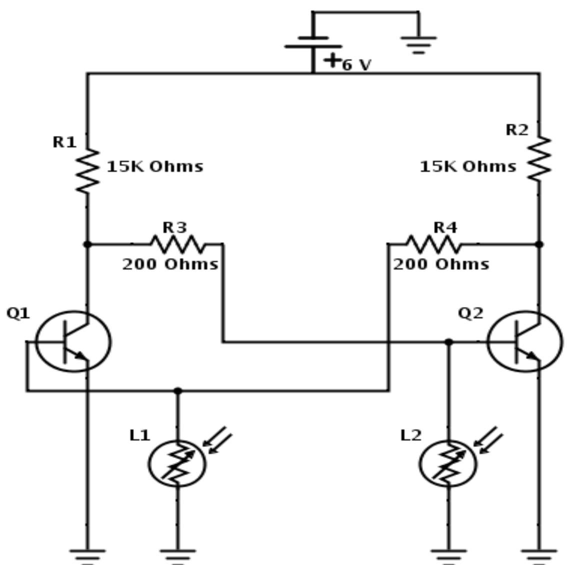



Figure 1.5: Receiver Circuit

### 1.3.2 Display System

A SPI display is used for displaying the data which is sent using the above mentioned transmission scheme.The SPI(Serial Periferal Interface) is a synchronous serial interface in which data in a byte can be shifted in and/or out one bit at a time. It can be used to communicate with a serial peripheral device or with another microcontroller with an SPI interface. The SPI system contains the four signals as shown in Fig.

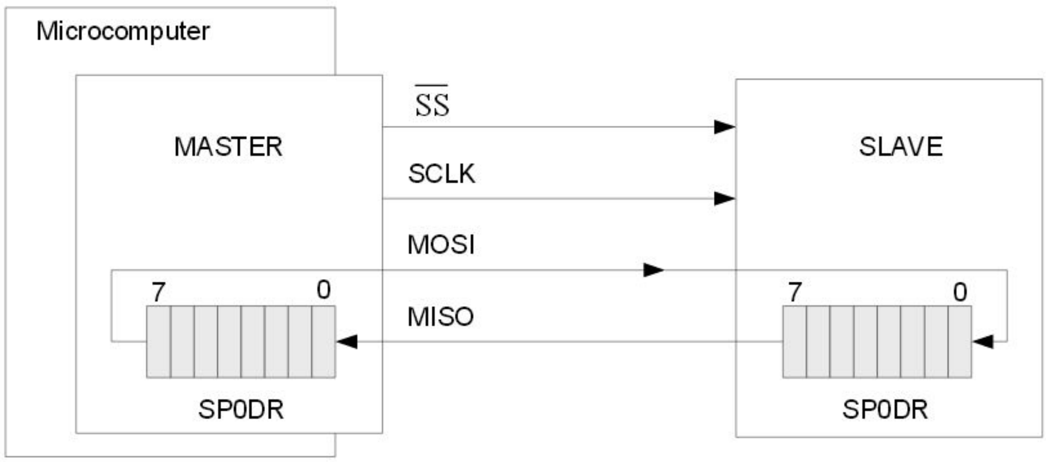



Figure 1.6: Two SPI modules connected in master slave configuration

| SPI Signal | Name |
|---|---|
| MISO | Master in Slave out |
| MOSI | Master out Slave in |
| clk | clock signal |
| SS | Slave Select |

Table 1.1: SPI signal description

**Operation:** In the master SPI, the bits are sent out of the MOSI pin and received in the MISO pin. The bits to be shifted out are stored in the SPI data register,SP0DR, and are sent out most significant bit (bit 7) first. When bit 7 of the master is shifted out through MOSI pin, a bit from bit 7 of the slave is being shifted into bit 0 of the master via the MISO pin. After 8 clock pulses or shifts, this bit will eventually end up in bit 7 of the master.

### 1.3.3 Communication Between Source and Display

The received data needs to be synchronized with the transmitted data for proper functioning of display therefore, a clock needs to be sent along with data for synchronization and that is done by appending preamble bits with data itself which will serve the purpose of generating clock. Displaying any text or image requires first sending command and that data so the controller at receiver end should be able to distinguish between the data bits and command bits. Therefore, the data is sent in frames of fixed size containing various information needed like whether the data is text or image, font, address of start and end pixel, device address in case of broadcasting data for multiple devices and various other information needed for proper functioning. So, different kinds of frames required for faster refresh are

- Command frame
- Text data frame
- Image data frame

**Command frame:** The command frame which contains the data bits for command consists of various other fields apart from command data which includes SFD(start frame delimiter) for bit synchronization, FCF( frame control field), end of frame byte etc. So, a command frame looks like one shown below:

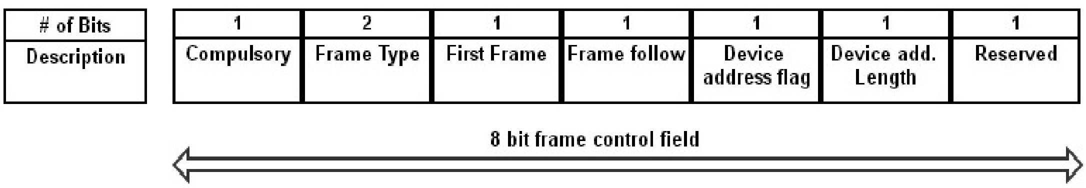



Figure 1.7: Frame control field

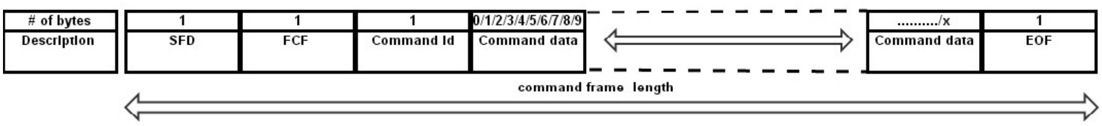



Figure 1.8: command frame when only one device is present

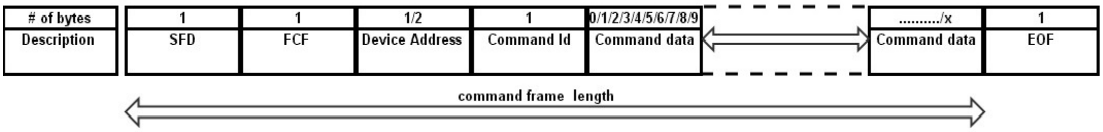



Figure 1.9: Command frame when multiple devices present

The SFD which is chosen for bit synchronization is 0xA7 and the EOF will be 0xA6 to know the frame is ended or not. The frame control field will contain various information like whether the frame is first frame, whether there will be a frame to follow after the current frame, whether device address will be present i.e multiple devices or single device, type of frame whether text, command, image.

**Text data frame:** The data frame for text contains various information like device address, start coordinates of text, type of font to be used, color of the text and length of data. The subsequent frames of text after first frame will not contain the start coordinates, color, font type.

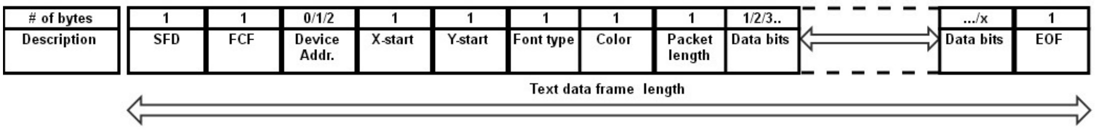



Figure 1.10: First frame of Text data

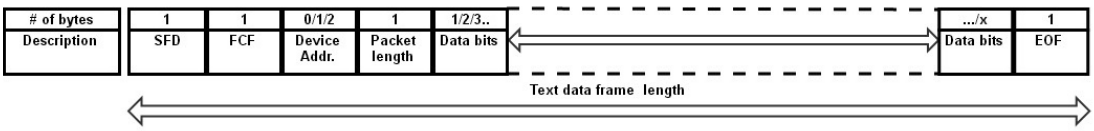



Figure 1.11: Text data frame after first frame

**Image data frame:** The data frame for image contains various information like device address, start coordinates, end coordinates of image, data length and rest other necessary fields. The device address can be of one byte to address 256 devices or 2 bytes to address 65536 devices.

| # of bytes | 1 | 1 | 0/1/2 | 1 | 1 | 1 | 1 | 1 | 1/2/3.. | | .../x | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | SFD | FCF | Device Addr. | X-start | Y-start | X-end | Y-end | Packet length | Data bits | | Data bits | EOF |

Image data frame length

Figure 1.12: First Image data frame

| # of bytes | 1 | 1 | 0/1/2 | 1 | 1/2/3.. | | .../x | 1 |
|---|---|---|---|---|---|---|---|---|
| Description | SFD | FCF | Device Addr. | Packet length | Data bits | | Data bits | EOF |

Image data frame length

Figure 1.13: Image data frame after first frame

### 1.3.4 Overall System

To increase the bandwidth and the distance of transmission, reflectors and lenses are used at both transmission and receiver side so that light can be concentrated on ldr and distance can be increased. Also, as there is no uplink the error during transmission is reduced by using forward error correction techniques so that the error in signal during transmission can be minimized. So, the overall set up will look like as shown in below figure.

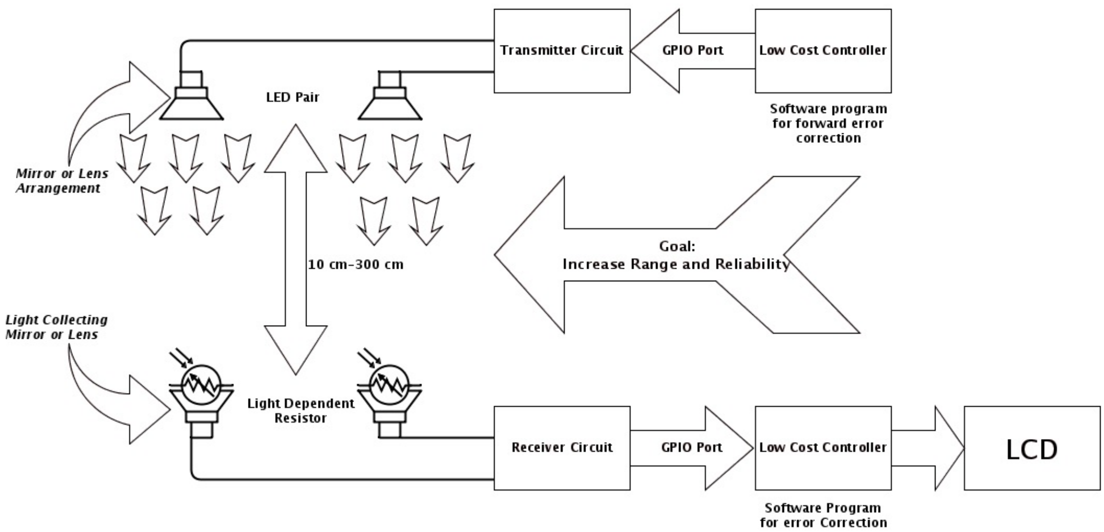



Figure 1.14: Final transmission scheme

# CHAPTER 2

# Literature Survey

Broadcasting of data can be done using various other technologies apart from Li-Fi but there are applications which uses need of cheap transmission scheme and moderate data rates. The technologies are mostly focused on getting higher data rates even if the cost involved is high. The various non lifi wireless schemes which are used these days are like bluetooth, wifi, zigbee etc.

## 2.1 Wireless Fidelity

Wi-Fi, is a local area wireless technology that allows an electronic device to exchange data or connect to the internet using 2.4 GHz UHF and 5 GHz SHF radio waves. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards". Many devices can use Wi-Fi, e.g., personal computers, video-game consoles, smartphones, some digital cameras, tablet computers and digital audio players. These can connect to a network resource such as the Internet via a wireless network access point. Such an access point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hotspot coverage can comprise an area as small as a single room with walls that block radio waves, or as large as many square kilometres achieved by using multiple overlapping access points.

Wi-Fi can be less secure and has limited bandwidth which is a constraint for its usage at various places also, the radio waves which are used can cause interference when used at certain places with other equipments like it cant be used in airplanes, hospitals etc. The wifi is basically designed to get high data rates and the cost involved in setting up is also quite high.

## 2.2 ZigBee

ZigBee is a specification for a suite of high level communication protocols used to create personal area networks built from small, low-power digital radios. ZigBee is based on an IEEE 802.15 standard. Though low-powered, ZigBee devices can transmit data over long distances by passing data through intermediate devices to reach more distant ones, creating a mesh network; i.e., a network with no centralized control or high-power transmitter/receiver able to reach all of the networked devices. The decentralized nature of such wireless ad hoc networks make them suitable for applications where a central node can't be relied upon.

ZigBee is used in applications that require only a low data rate, long battery life, and secure networking. ZigBee has a defined rate of 250 kbit/s, best suited for periodic or intermittent data or a single signal transmission from a sensor or input device. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range wireless transfer of data at relatively low rates. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi.

## 2.3 Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs). It was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization. Since the distance of transmission is very less in this technology it cant be used in display application under consideration.

## 2.4 Li-Fi Technology

### 2.4.1 Experimental evaluation of Video transmission

An implementation of a prototype of an optical wireless system based on visible white LED lamps done by J. Rufo and J. Rabada, which allows a video broadcasting to reach a bit rate of 2 Mbps and for the uplink channel an infrared transceiver at 115 kbps is included in prototype. The VLC system developed could be used for supporting data transmission applied to low-speed sensor network connections as well. PPM scheme is used to ensure correct data transmission in both operating modes i.e when the LED lamps are switched on and when they are turned off. This is achieved by emitting "positive" or "negative" pulses. "Positive" means that the lamp is in off state and use of short light pulses to ensure it is under eye sensitivity, while "negative" represents cutting the light flux during a short interval. About 85% of the nominal optical power was selected for the "turn on" mode and 15% for the "turn off" one. This modulation technique reduced (almost completely in the "turn off" state) the lowest frequency components of the spectrum, making it suitable for avoiding interferences from incandescent and/or fluorescent lamps. The main drawback of this modulation technique is the necessity of a complex synchronism system to ensure correct detection. To alleviate this, Constant Rate-Differential Pulse Position Modulation (CR-DPPM) is used. This technique combines the noncoherent detection capability of classical DPPM schemes with a constant bit rate.

Different driver configurations were tested, based on open collector-logical gate chips. They were able to switch current values up to 100s of mW, as required for the illumination LED (especially in a parallel configuration). Finally the implemented scheme makes use of several gates, each of them driving a group of 5 parallel connected LEDs, as is shown in figure. This configuration improves the current control and reduces the capacitive charge introduced by the LEDs, which decreases the available transmission bandwidth. The same circuit scheme can be used with other lamp configurations, as those which use groups of series-connected LEDs. The open collector output makes it possible to work with the needed voltages for the polarization of each group of LEDs (10-20 V). Receiver structure is depicted below. Two PIN photodiodes, with 15 MHz bandwidth, 0.45 A/W optical sensitivity at a 660 nm wavelength and an active area of

66 mm$^2$, perform the optical signal reception. After the photodiodes, there was a pre-amplifier in a trans-impedance configuration connected to a boost-trap circuit. Boost-trap was used to reduce the effect of spurious capacities in the photodiodes improving the frequency response, if a single photodiode was used, or maintaining the reception bandwidth, when several parallel connected photodiodes are needed to increase reception area. The second stage is composed by an amplification block and an active filter in sallen-key configuration for noise reduction and the received signal is delivered to a ML detector.

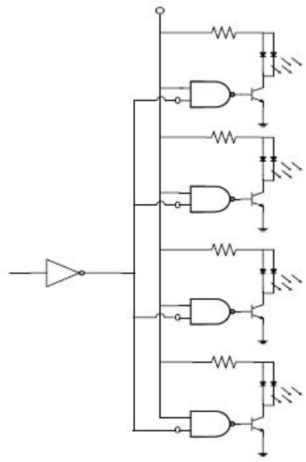


Figure 2.1: Driver scheme for LED Lamp

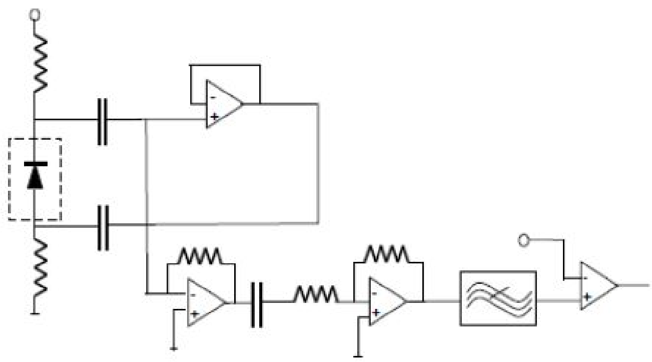


Figure 2.2: Optical receiver Block Diagram

### 2.4.2 Demonstration Of VLC link For Audio and Video Transmission

The illumination LED has a problem of the limitation in modulation bandwidth. The maximum modulation frequency of ordinary high-brightness LED is not very high ( 20

MHz). Therefore, use of analog-to-digital conversion (ADC) for video transmission, the very high bit rate is required. For example, with an 8-bit ADC, the sampling rate is 10 Msamples/s; the ADC for video transmission output 80 Mb/s data stream. High-brightness LEDs cannot support this high bit rate. Therefore, to lower the bit rate, the PWM is us ed for video transmission.

In the transmitter,the analog video signal is PWM modulated through a video amplifier and the analog audio signal is converted to a digital signal through an audio amplifier. The S/PDIF audio and PWM video signals are multiplexed. Then the multiplexed digital signal drives the LED transmitter by using on-off-keying (OOK) modulation. The transmitter block diagram shown below shows the analog input audio signal is amplified to a suitable level for analog-to-digital converter (ADC). A noise filter used to rejects noises from the analog audio signal before digital converting. The output of ADC is Inter-IC Sound (I2S) signal which includes master clock, bit clock, left right clock, and data clock. The I2S signal is converted to Sony/Philips Digital Interconnect Format (S/PDIF) signal. The S/PDIF signal has a data stream of a series of 1 and 0 digital bits that describe the audio waveform. The video signal also is amplified and the noise filter rejects noise components. An ultra high-speed comparator is used to generate a PWM signal by comparing the video signal with a saw-tooth waveform at 15 MHz. This PWM frequency is high enough to keep the analog video signal quality.

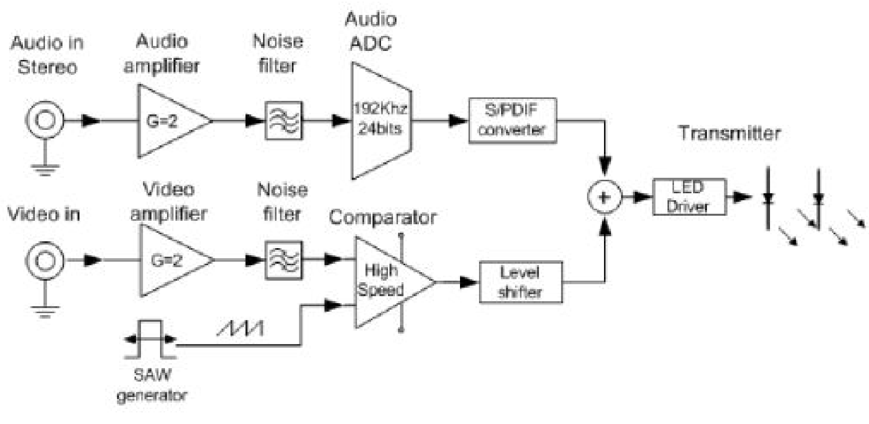



Figure 2.3: Transmitter Module block diagram

The receiver side shown below with the help of block diagram is mainly composed of photo-detectors and signal conditioning devices. A high speed photodiode receives the transmitted optical signal and converts the optical signals into the electrical signals. Then, the electrical signal is fed into the S/PDIF recovery circuit and PWM recovery circuit to recover the S/PDIF audio and PWM video signals,respectively.A high quality stereo audio digital-to-analog converter (DAC) converts the S/PDIF signal to the analog audio signal.The analog audio signal after the DAC is filtered and amplified to provide an appropriate audio output level.The PWM video signal goes to 3 MHz filter and we have analog video signal at the output. The analog video signal is amplified to provide an appropriate video output level.

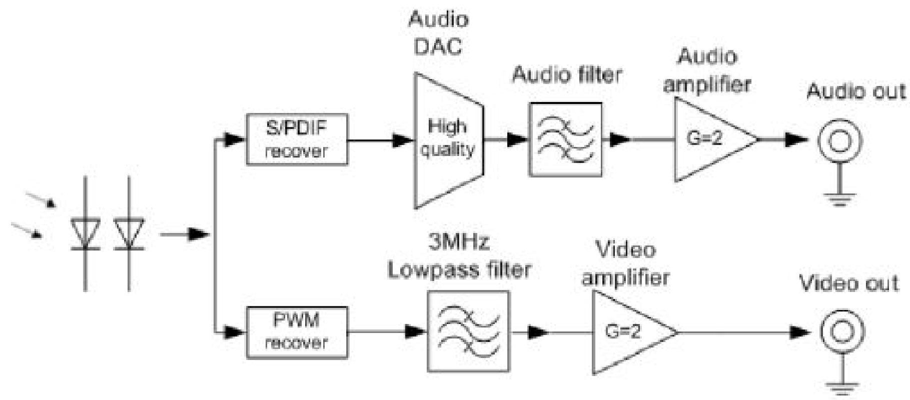



Figure 2.4: Receiver module block Diagram

Other experiments considered a combination of various technologies such as radio-frequency and wireless optical links operating at infrared and visible wavelengths. When combined with power-line communications (PLC), this enables a home backbone that meets the requirement"without new wire" vision. The experimental demonstration of an indoor visible-light wireless link including a MAC layer protocol adapted to optical wireless communications systems. The system operates at 84 Mb/s broadcast and was successfully used to transmit three high definition.

### 2.4.3 Conclusion

All the above mentioned technologies have some drawback and are not suitable for general cheap display applications. Also the Li-Fi technology experiments conducted by various researchers showed that high data rates can be achieved but at very high cost due to involvement of high cost photo detectors able to work at very high frequencies and using complex modulation schemes. So, there is a need for some technology which is simple, cheap and targets low refresh rate display applications.

# CHAPTER 3

# Basic Communication Scheme

## 3.1 Differential Signaling

Differential signaling is a method of transmitting information electrically with two complementary signals sent on two paired wires, called a differential pair. Since external interference tends to affect both wires together, and information is sent only by the difference between the wires, the technique improves resistance to electromagnetic noise compared with use of only one wire and an un-paired reference (ground). The technique can be used for both analog signaling, as in balanced audio, and digital signaling, as in RS-422, RS-485, Ethernet over twisted pair, PCI Express, DisplayPort, HDMI, and USB. The opposite technique is called single-ended signaling. Differential pairs are usually found on a printed circuit board, in cables (twisted-pair cables, ribbon cables), and in connectors.

## 3.2 Why Differential Signal?

In the electronics industry, and particularly in portable and mobile devices, there is a continuing tendency to lower the supply voltage in order to save power and reduce unwanted emitted radiation. A low supply voltage, however, causes problems with signaling because it reduces the noise immunity. Differential signaling helps to reduce these problems because, for a given supply voltage, it gives twice the noise immunity of a single-ended system. Also, Differential signal are tolerant to ground offsets because at the end of the connection, the receiving device reads the difference between the two signals. Since the receiver ignores the wires' voltages with respect to ground, small changes in ground potential between transmitter and receiver do not affect the receiver's ability to detect the signal.

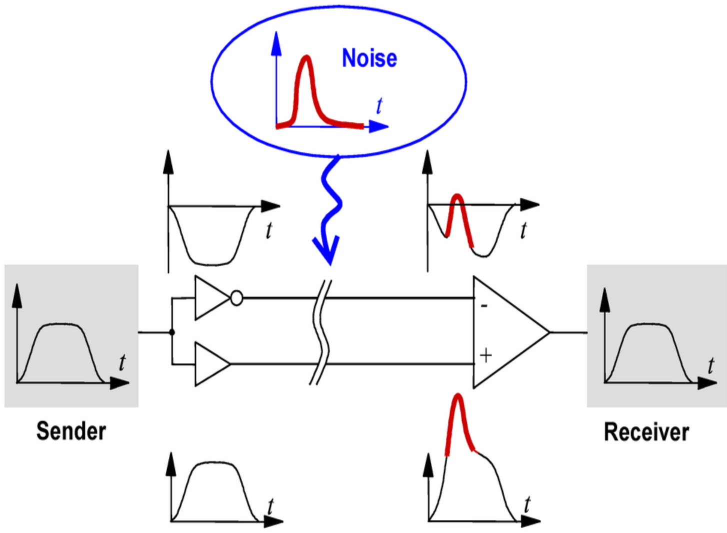
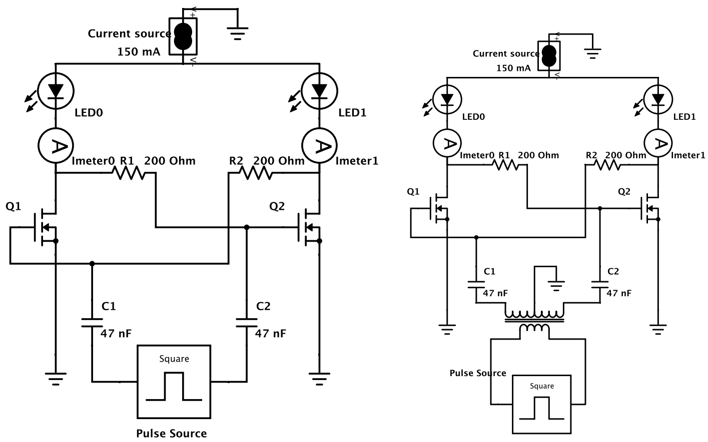



Figure 3.1: Elimination of noise by using differential signal

## 3.3 Design Choices

### 3.3.1 Transmitter circuit choices

The transmitter circuit can have various design choices to transmit differential data two such choices are using a bistable kind of circuit with and without centre tap transformer to give the input data stream. The two design choices are shown below.



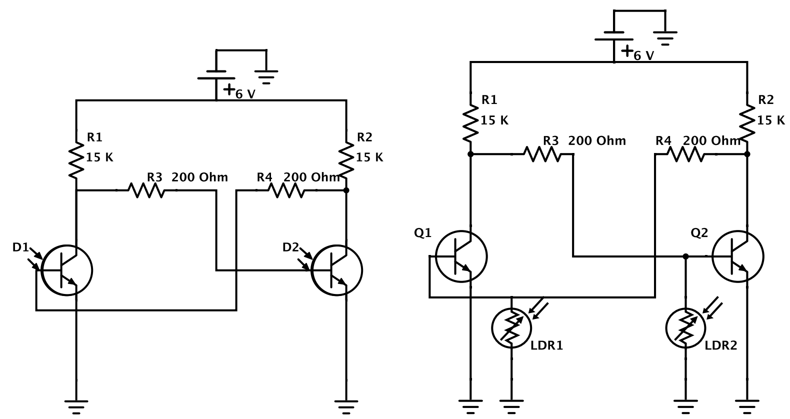

(a) Circuit without transformer (b) Circuit with transformer

Figure 3.2: Two choices for transmitter circuit

The two circuit shown above works very much in the same way when pulse is given to capacitor it gets charged and makes the gate voltage of respective transistor high which turns on the transistor and high amount of current flows through it and remaining current flows through other branch this makes one of the LED with larger current glow brighter then the other LED thereby transmitting differential data in the form of differential light intensity. In case of transformer circuit when input is given to a center tap transformer same and a complimentary signal gets generated at the output pins which are then connected to capacitor helps in making sure that when high pulse is applied to one capacitor a low pulse, different amount of current flows through two branches containing two LEDs and different intensity light is obtained.

### 3.3.2 Receiver Circuit Choices

The receiver should be designed in such a way that it can detect the two intensity and gives the differential output. There can be two possible choices for receiver design one using photo-transistor and the other using light dependent resistor.




(a) Receiver circuit with phototransistor

(b) Receiver circuit with LDR

Figure 3.3: Two choices for Receiver circuit

In case of circuit with photo-transistor then light falls on base of transistor it gets turned on thereby shorting the collector to ground hence collector voltage goes low. When differential light falls on two transistors one collector voltage of one becomes zero while collector voltage of other is sufficiently high this is because of the feedback in the circuit and they get stabilized to that value. The Resistance value are chosen in such a way the transistors are at there sensitive operating point and even small amount of light can make collector voltage go high or low.

In case of LDR circuit the working principle would be same, the ldr which receives higher intensity light will make the corresponding transistor base zero thereby turning it off and the other transistor will be on, the collector voltages will give the received differential data. The voltage level of received signal is very low so to boost up level and get sharp pulse edges the output is fed to comparator which compares the signal and gives an amplified output.

The choice for receiver circuit for prototype is a compromise between data rate and cost. The photo-transistor circuit will give fast switching but the cost will be high due to use of special photo-transistor which can detect visible light whereas, the cost involved in designing the LDR based circuit is very low but with slower switching then the corresponding photo-transistor circuit. But keeping the aim of the project to demonstrate s low cost solution the LDR based circuit is chosen to be the receiver circuit in prototype.

## 3.4 Simulation

The simulation for the choice of transmitter circuit are carried out with the help of an on-line simulator "Do-circuits" which is developed to simulate mixed signal circuits. The choice of simulator is driven by the goal of this project which is to demonstrate the low cost solution for which the cost of components must be known to optimize it. It generates BOM (Bill of Material) for the components used which helps in knowing the cost of designing the circuit. It also helps in saving the time by giving fast simulation results by generating net-list through the use of algorithm.

### 3.4.1 Simulation Result

The circuit with centre tap transformer and without transformer are simulated and the results show the fast switching in case of transformer circuit since the pulse applied at the capacitor are complementary of each other.


Figure 3.4: Current through LED's without using transformer @ 20 Khz


Figure 3.5: Current through LED's without using transformer @ 100Khz


Figure 3.6: Current through LED's using transformer @ 20Khz

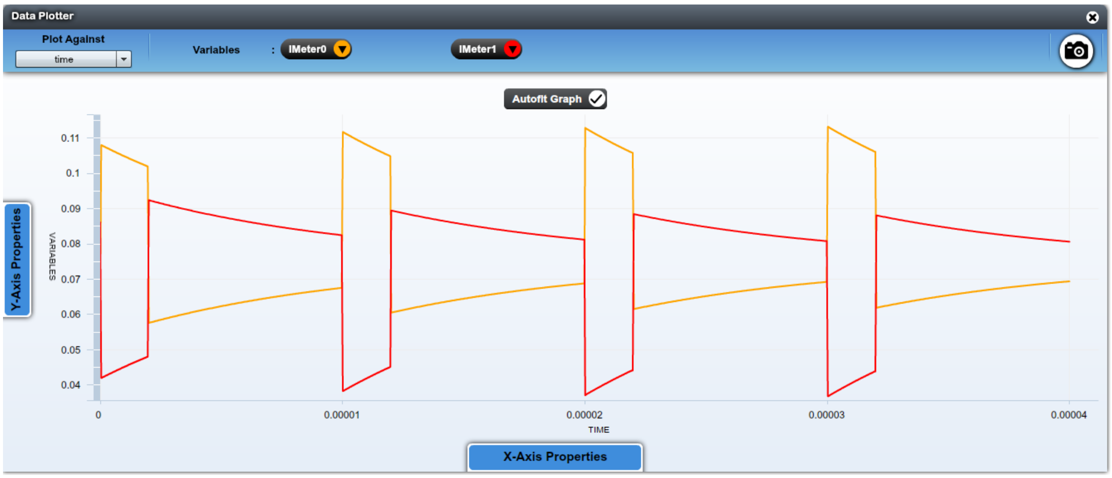



Figure 3.7: Current through LED's using transformer @ 100Khz

The above simulation results shows the desired current swings for both the transmitter design. The difference between the results of simulation for circuit with and without transformer is that the transformer circuit shows deeper and faster current swings which is needed for the purpose of transmitting differential signal easily. The key thing to see from the result is both the LED's have current flowing through them all the time so that high data rates can be achieved.

In case of transformer based design transformer generates a complement pulse of the applied signal at one of the output pins and same pulse at the other this makes sure only one when one transistor is on other is off in the transmitter circuit. The cost involved in including the transformer is very less and is a good idea as the faster switching helps in increasing data rate and transmitting data correctly.

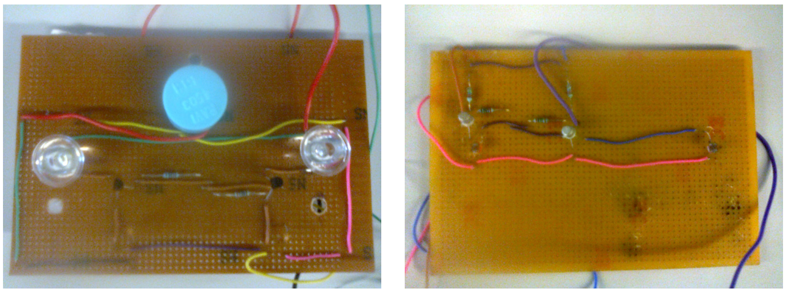
| component | Value | Price(in Rupee per piece) |
|---|---|---|
| Resistor | 15K Ohm | 1.5 |
| Resistor | 200 Ohm | 2 |
| centre tap transformer | 1:1 | 12 |
| LDR | NA | 2 |
| BJT | NA | 5 |
| n-MOSFET | BS170 | 4 |
| HB LED | 1W | 2.5 |

Table 3.1: Component cost

The entire transmitter and receiver circuit design cost turns out to be less than 46 Rupees which is ideal for the type of application which are targeted.

## 3.5 Prototype

The first prototype of the scheme after assembling the transmitter and receiver circuit at a particular distance shows the desired output and that can be seen using an oscilloscope with transmit and received pulse being the same. The lens arrangement is used with LEDs to increase the intensity of light at the receiver end. Same idea can be used at receiver side to focus light on LDR so that the distance between the transmitter and receiver can be increased and still transmission can be achieved. The bit rate depends on distance as well so to get high bit rate the distance should be decreased.



(a) Transmitter circuit (b) Receiver circuit

Figure 3.8: Transmitter and Receiver used in prototype

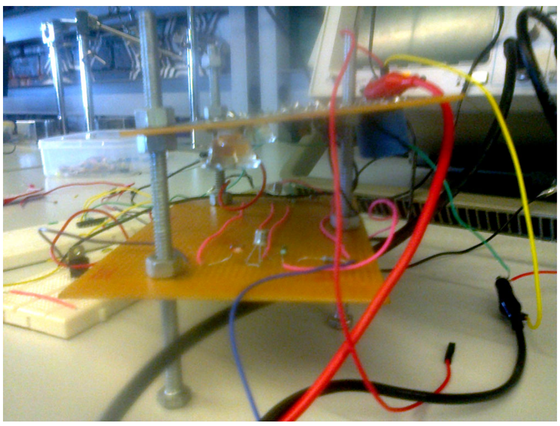


Figure 3.9: Prototype for the transmission scheme

A testing done for various distance between the receiver and transmitter at different frequencies show following output on oscilloscope. As the data rate increases the distance should be reduced but using lens and reflectors to concentrate light can increase distance for same data rate which is one of the major requirement of the display applications being targetted.

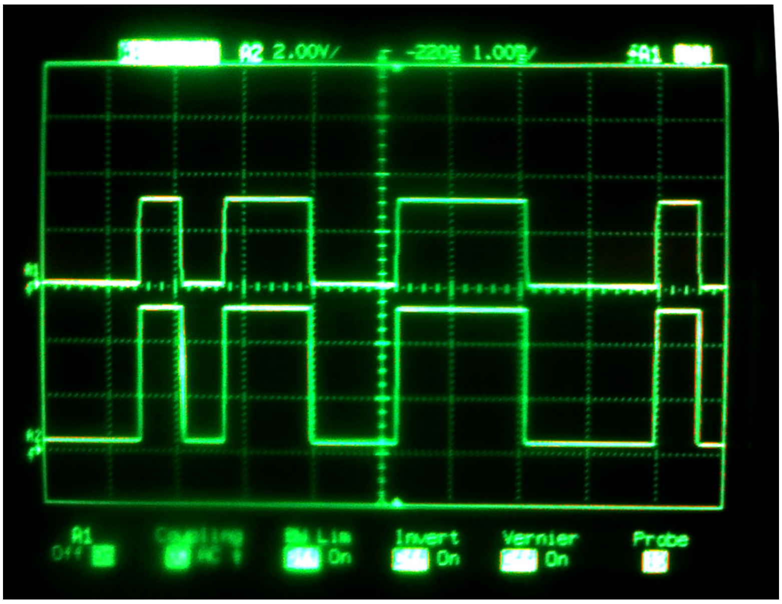



Figure 3.10: Transmitted waveform on top and received waveform below at 1.66 Khz at 8 cm

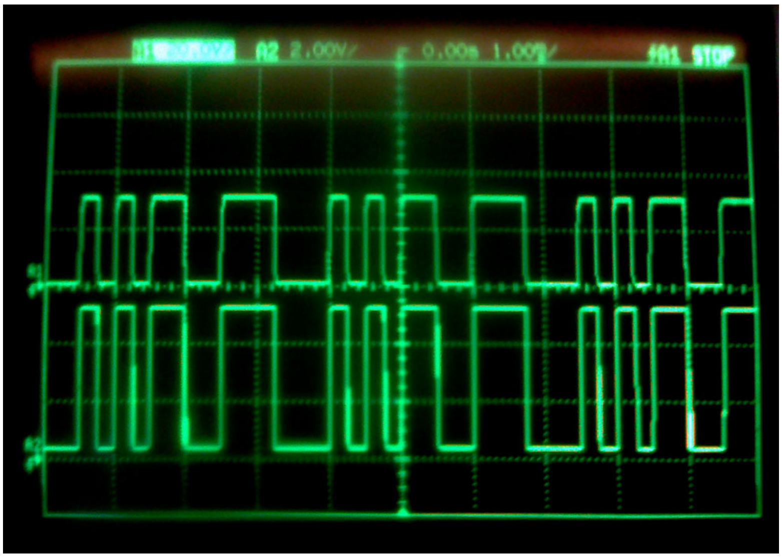



Figure 3.11: Transmitted waveform on top and received waveform below at 4 Khz at 6 cm

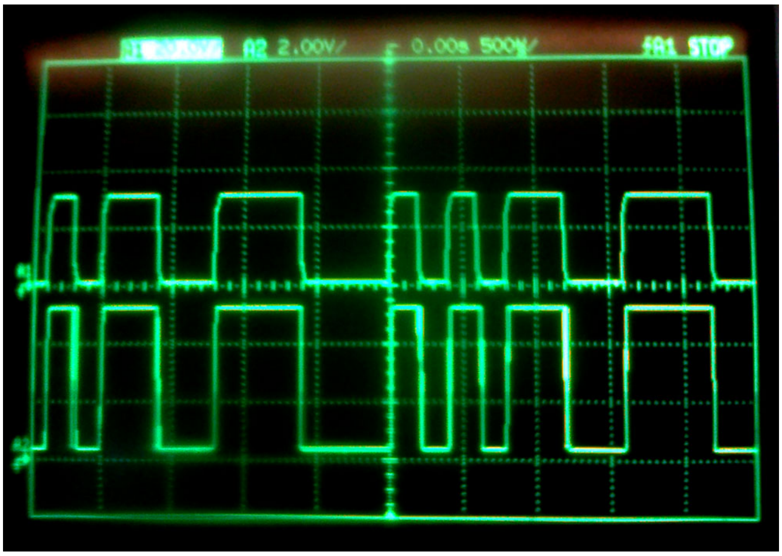



Figure 3.12: Transmitted waveform on top and received waveform below at 5 Khz at 5 cm

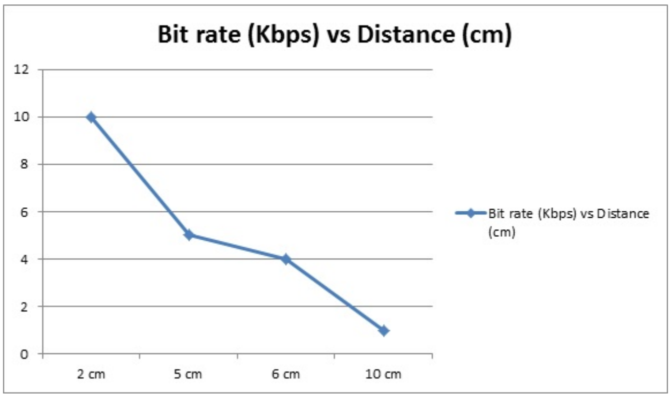



Figure 3.13: Variation of data rate with distance

From the values shown in graph it is evident that the distance should be decreased for getting high data rates. For the testing of prototype we have fixed the distance and data rate to be 5 cm with 2 Kbps as respectively.

**NOTE:** Distance can be increased for the same bit rate if lens and reflectors are used to concentrate light at receiver.

# CHAPTER 4

# Receiver Setup

There are various kinds of displays which support differential signaling like LVDS (low voltage differential signaling) display, HDMI (High Definition multimedia interface)displays ,DSI display. The other kinds of displays that can be targeted are SPI display,LED dot matrix which require low refresh rate and are also suitable for the display applications which are under consideration.

Also since the goal of the project is to demonstrate low cost solution the micro-controller used at receiver side should also be low in cost and should be able to interface with display. LPC Xpresso micro-controller is one choice whichis low cost and has dedicated pins for SPI displays.

## 4.1 Display Choices

### 4.1.1 HDMI

HDMI (High-Definition Multimedia Interface) is a compact audio/video interface for transferring uncompressed video data and compressed or uncompressed digital audio data from a HDMI-compliant source device to a compatible computer monitor, video projector, digital television, or digital audio device. HDMI is a digital replacement for existing analog video standards.

HDMI implements the EIA/CEA-861 standards, which define video formats and waveforms, transport of compressed, uncompressed, and LPCM audio, auxiliary data, and implementations of the VESA EDID. CEA-861 signals carried by HDMI are electrically compatible with the CEA-861 signals used by the digital visual interface (DVI). The CEC (Consumer Electronics Control) capability allows HDMI devices to control each other when necessary and allows the user to operate multiple devices with one remote control handset.

Several versions of HDMI have been developed and deployed since initial release of the technology but all use the same cable and connector. Newer versions optionally support advanced features such as 3D, an Ethernet data connection and improved audio and video capacity, performance and resolution.

### 4.1.2 LVDS

Low-voltage differential signaling, or LVDS, also known as TIA/EIA-644, is a technical standard that specifies electrical characteristics of a differential, serial communication protocol. LVDS operates at low power and can run at very high speeds using inexpensive twisted-pair copper cables. Since LVDS is a physical layer specification only, many data communication standards and applications use it but then add a data link layer as defined in the OSI model on top of it.

LVDS become popular in products such as LCD-TVs, automotive infotainment systems, industrial cameras and machine vision, notebook and tablet computers, and communications systems. The typical applications are high-speed video, graphics, video camera data transfers, and general purpose computer buses.

LVDS works in both parallel and serial data transmission. In parallel transmissions multiple data differential pairs carry several signals at once including a clock signal to synchronize the data. In serial communications, multiple single-ended signals are serialized into a single differential pair with a data rate equal to that of all the combined single-ended channels. For example, a 7-bit wide parallel bus serialized into a single pair that will operate at 7 times the data rate of one single-ended channel. The devices for converting between serial and parallel data are the serializer and deserializer, abbreviated to SerDes when the two devices are contained in one integrated circuit. Embedded clock serializer example.png As an example, FPD-Link actually uses LVDS in a combination of serialized and parallel communications. The original FPD-Link designed for 18-bit RGB video has 3 parallel data pairs and a clock pair, so this is a parallel communication scheme. However, each of the 3 pairs transfers 7 serialized bits during each clock cycle. So the FPD-Link parallel pairs are carrying serialized data, but use a parallel clock to recover and synchronize the data.

Serial data communications can also embed the clock within the serial data stream.

This eliminates the need for a parallel clock to synchronize the data. There are multiple methods for embedding a clock into a data stream. One method is inserting 2 extra bits into the data stream as a start-bit and stop-bit to guarantee bit transitions at regular intervals to mimic a clock signal. Another method is 8b/10b encoding.

### 4.1.3 DSI

The Display Serial Interface (DSI) is a specification by the Mobile Industry Processor Interface (MIPI) Alliance aimed at reducing the cost of display sub-systems in a mobile device. It is commonly targeted at LCD and similar display technologies. It defines a serial bus and a communication protocol between the host (source of the image data) and the device (destination of the image data).

At the physical layer, DSI specifies a high-speed differential signaling point-to-point serial bus. This bus includes one high speed clock lane and one or more data lanes. Each lane is carried on two wires (due to differential signaling). All lanes travel from the DSI host to the DSI device, except for the first data lane (lane 0), which is capable of a bus turnaround (BTA) operation that allows it to reverse transmission direction. When more than one lane is used, they are used in parallel to transmit data, with each sequential byte in the stream traveling on the next lane. That is, if 4 lanes are being used, 4 bytes are transmitted simultaneously, one on each lane. The link operates in either low power (LP) mode or high speed (HS) mode. In low power mode, the high speed clock is disabled and signal clocking information is embedded in the data. In this mode, the data rate is insufficient to drive a display, but is usable for sending configuration information and commands. High speed mode enables the high speed clock (at frequencies from tens of megahertz to over one gigahertz) that acts as the bit clock for the data lanes. Clock speeds vary by the requirements of the display. High speed mode is still designed to reduce power usage due to its low voltage signaling and parallel transfer ability.

The communication protocol describes two sets of instructions. The Display Command Set (DCS) is a set of common commands for controlling the display device, and their format is specified by the DSI standard. It defines registers that can be addressed and what their operation is. It includes basic commands such as sleep, enable, and invert display. The Manufacturer Command Set (MCS) is a device-specific command space whose definition is up to the device manufacturer. It often includes commands required to program non-volatile memory, set specific device registers (such as Gamma correction), or perform other actions not described in the DSI standard. The packet format of both sets is specified by the DSI standard. There are Short and Long Packets, Short Packet is 4 bytes long; Long Packet can be of any length up to $2^{16}$bytes. Packets are composed of a DataID, Word count, Error Correction Code (ECC), Payload and Checksum (CRC). Commands that require reading data back from the device trigger a BTA event, which allows the device to reply with the requested data. A device cannot initiate a transfer; it can only reply to host requests.

Image data on the bus is interleaved with signals for horizontal and vertical blanking intervals (porches). The data is drawn to the display in real time and not stored by the device. This allows the manufacture of simpler display devices without frame buffer memory. However, it also means that the device must be continuously refreshed (at a rate such as 30 or 60 frames per second) or it will lose the image. Image data is only sent in HS mode. When in HS mode, commands are transmitted during the vertical blanking interval.

### 4.1.4 LED Dot Matrix Display

A dot-matrix display is a display device used to display information on machines, clocks, railway departure indicators and many other devices requiring a simple display device of limited resolution.The display consists of a dot matrix of lights or mechanical indicators arranged in a rectangular configuration (other shapes are also possible, although not common) such that by switching on or off selected lights, text or graphics can be displayed. A dot matrix controller converts instructions from a processor into signals which turns on or off lights in the matrix so that the required display is produced.

## 4.2 LPC1114 Xpresso Microcontroller

### 4.2.1 Why Micro-Controller ?

keeping the goal of project in mind initial idea was to develop the end to end transmission scheme without using any micro-controller because it will add to the cost. But later it was found out that interfacing of LCD display turned out to be bit complicated which leads to the idea of using a cheap micro-controller which can help in easy interfacing with display and gives the added advantage of use in error correction. Due to absence of uplink in the entire scheme the need for error correction is must as the transmission scheme is developed with light as a carrier having very high possibility of picking noise during transmission. The choice of LPC1114 Xpresso micro-controller is driven from the fact that it is very cheap and can be bought from digikey in just Rs 50.

### 4.2.2 Key Features of LPC Xpresso

The LPC1114 is an ARM Cortex-M0 microcontroller and it can operate up to 50 MHz. The peripheral complement of the LPC1114 includes 32 kB of flash memory, 8 kB of data memory, one Fast-mode Plus $I^2$C-bus interface, one RS-485/EIA-485 UART, two SPI interfaces with SSP features, four general purpose counter/timers, a 10-bit ADC, and 42 general purpose I/O pins. In addition, the LPC1114 features unique on-chip API-driven power profiles which provide users with ready-to-use power management templates. Optimized for CPU performance, CPU efficiency and lowest active current, the power profiles enable maximum operating frequency through the entire voltage range from 1.8 V to 3.6 V without compromising speed or functionality.

### 4.2.3 Features and Benefits

- ARM Cortex-M0 processor, running at frequencies of up to 50 MHz
- ARM Cortex-M0 built-in Nested Vectored Interrupt Controller (NVIC)
- Serial Wire Debug
- System tick timer
- 32 kB on-chip flash programming memory and 8 kB SRAM

- In-System Programming (ISP) and In-Application Programming (IAP)
- 42 General Purpose I/O (GPIO) pins with configurable pull-up/-down resistors
- High-current output driver (20 mA) on one pin
- Programmable WatchDog Timer (WDT)
- 10-bit ADC with input multiplexing among 8 pins
- UART with fractional baud rate generation
- Two SPI controllers with SSP features and FIFO and multi-protocol capabilities
- $I^2$ C-bus interface supporting full $I^2$ C-bus specification and Fast-mode Plus.

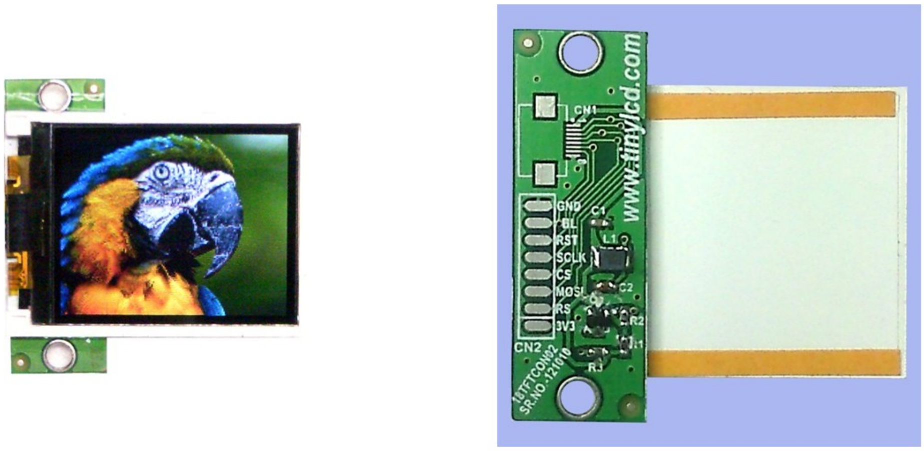
### 4.2.4 SPI Registers

| Name | description |
|---|---|
| SSP0CR0 | Control Register 0. Selects the serial clock rate, bus type, and data size. |
| SSP0CR1 | Control Register 1. Selects master/slave and other modes. |
| SSP0DR | Data Register. Writes fill the transmit FIFO, and reads empty the receive FIFO. |
| SSP0SR | Status Register |
| SSP0CPSR | Clock Prescale Register |
| SSP0ICR | SSPICR Interrupt Clear Register |

Table 4.1: SPI registers

## 4.3 Choice Of Display

The display needed for testing prototype needs to be low in cost. So, a 1.8 Inch Color TFT SPI LCD Display Module with PCB is used for testing which has SPI interface and is easy to program with the help of sample testing codes provided along with it. The display is compatible with 8 to 32 bit processor which gives flexibility for the choice of micro-controller as well. Cost of one such SPI display is around Rs 345 on ebay but if they are purchased in bulk then cost is reduced significantly to Rs 100 for purchase of 100 such displays.




(a) LCD display (b) PCB showing Pin config.

Figure 4.1: TFT Display used for testing

| Name | description |
|---|---|
| SCLK | System Clock. |
| MOSI | Master Out Slave In |
| RS | Register Select (0 for command, 1 for data) |
| CS | Chip Select |
| RST | Reset Pin |

Table 4.2: Display Pin configuration

This display has following key features which make it suitable for use.

- Easy to interface
- Presence of built in controller and memory
- Needs minimum 4 port lines to interface
- No overhead on firmware/processor for refreshing
- Can be easily interfaced to processor from 8 to 32 bits
- No interfacing development cycle as Source code provided
- Low priced demo board for quick reference and affordable
- Low profile can display more information in less area

### 4.3.1 Display Testing

The 1.8 inch TFT SPI display used in this project has 5 lines for display to work. The testing of display is done using bit bagging where bit by bit transmission is done and clock is generated on one of the pins of micro-controller. To display the text or image first command data is sent and then data is sent. Also the Register select pin which is used to distinguish between data and command at display interface. When register select pin is 0 the display takes the incoming data as command and when register select is 1 it is taken as the data. MSB is transmitted first then the subsequent bits.

```
void Write_Command(unsigned char Data)
{
        CS(0);
        RS(0);
        unsigned char i;
        for (i=0; i<8; i++)
        {
                SDIN(((Data & 0x80) >> 7));
                SCLK(0);
                Data = Data << 1;
                SCLK(1);
        }
        CS(1);
}
```

The code for write data will be same except the RS is called with 1.

# CHAPTER 5

# Frame Level Communication Design

The communication between the device and source will be done in the form of frames which contains the necessary data for displaying a text or an image on SPI display along with various other useful fields which helps in bit synchronization, determining the end of data packet, address of pixel where the image will start and end and various other information.

## 5.1 Clock Synchronization

To synchronize the data between transmitter and receiver a clock needs to be present which will help in sampling the data at right intervals. The transmission of clock can be done separately or by sending it with data itself. In this project the clock is sent with data itself as preamble bits and those bits are decoded at the receiver micro-controller by using interrupt subroutine by enabling interrupt at both the edges of data. The preamble used for bit synchronization here is 0xA7 which represents '10100111' in binary where one bit period, twice bit period, thrice bit period is present which helps getting the correct sampling of data. When first interrupt is received the timer counter of controller is set to 0 and at subsequent interrupt, value of timer counters are stored in an array and the timer counter is again made to zero. The value of timer counters are then checked and mean value is set as the period for sampling data at receiver micro-controller. Also, to minimize the effects of pulse widening and compression during transmission the data is sampled at the middle point of bit period.

## 5.2 Text vs Image

The display can support both text and image so in order to have a distinction between these two the receiver should know whether the data received corresponds to a text or an image. This is done by having different frames for both text as well as image. The image frame will contain the information starting address of image on display as well as end address of image. The text frame on the other hand will have different structure with start address , type of font, color of font as its key fields along with data bits.

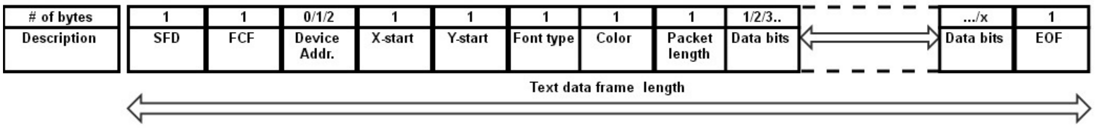



Figure 5.1: First frame of Text data


Figure 5.2: First Image data frame

## 5.3 Addressing Scheme

Since the application which are being targeted in this project involves broadcasting display data to multiple devices. The frame field should also contain the address of the device which needs refreshing. To make the scheme implementable for both single display and multiple display applications the frame control field should have a device address flag which is set to one if more than one devices are targeted and will be set to zero if one one device is present. If the device address flag is 1 than the text frame will have the additional information of device address length i.e what is the length of address and a separate address field which will have the address of the device which needs refreshment. This address can be of 1 byte or 2 byte depending on number of display devices present. Once the frame is received at the receiver the device address will be checked and device corresponding to that address will get refreshed.

## 5.4 MSP430F5438A Experimenter Board

The data which is sent for display application is in form of frames or packets. The formation of the packets for transmission is done with the help of MSP430F5438 Experimenter Board .It is an evaluation board meant to evaluate capabilities of the MSP430F5438A family of micro-controllers built to complement the MSP430's of high degree of mixed signal integration. Also, the experimenter board showcases the external peripherals such as LED Dot matrix LCD, two axis accelerometer, audio output, a serial USB connection.

### 5.4.1 Tool Requirement

An MSP430 Flash Emulation tool or equivalent programming tool is required to download code and debug the MSP430F5438A. The JTAG programmer is connected to the MSP-EXP430F5438 Experimenter Board through the TAG header located in the top center of the board. The MSP430F5438A utilizes the standard 4 - wire JTAG connection. Texas Instrument code composer studio (CCS) is an MSP430 integrated development environment designed specifically to develop applications and program for MSP430 devices.

### 5.4.2 Features

- 100-pin socket for MSP430F5438
- Power Supply sources: USB, FET, 2x AA batteries
- Digital I/O Pins: 34
- Accessible analog inputs (12-bit ADC): 5
- Flash Memory (MSP430F5438): 256KB
- RAM (MSP430F5438): 16KB
- Clock Speed (MSP430F5438): 18MHz
- Communication (MSP430F5438):
  4x UART/LIN/IrDA/SPI
  4x I2C/SPI
- 138x110 grayscale, dot-matrix LCD

- 3-Axis Accelerometer (ADXL330)
- JTAG header for real-time, in-system programming

### 5.4.3 Packetization

In most of the wireless communication scheme when there is no transmission then there is no reception at the receiver whereas, in the case of the scheme developed here even if there is no transmission the receiver still receives string of zero's or one's so its is difficult to know get bit synchronization byte at the receiver therefore a preamble is added with each packet where a high is transmitted followed by a low signal for some specific configurable time and then the packet is send along with bit synchronization byte this helps in detecting Bit synchronization byte correctly at receiver end.

The data which is to be transmitted is taken from user by hyperterminal and once the input is taken packetization of data starts. Various flags are used to know the status of transmission and packetization at various stages of time. once a new line feed is received from the hyperterminal microcontroller starts building packets for transmission for the received data bits.

| Name | description |
|---|---|
| flagTxInProg | Indicates transmission status from microcontroller |
| flagBuildPkt | Idicates recption done , start building packet |
| flagPktBuilding | Indicates status of packet building |
| flagRcving | Indicates data reception from hyperterminal |
| flagLastBit | Indicates whether last bit is transmitted or not |

Table 5.1: Flags involved in packetization of data

### 5.4.4 Packet Testing

The data packets which are sent through MSP430 controller are tested by using the receiver microcontroller where received packets are decoded and stored in an array. The results of which can be seen below when message is sent using hyperterminal with a new line feed indicating start of new packet. Two messages are sent through two packets and received in packet array of receiver controller.

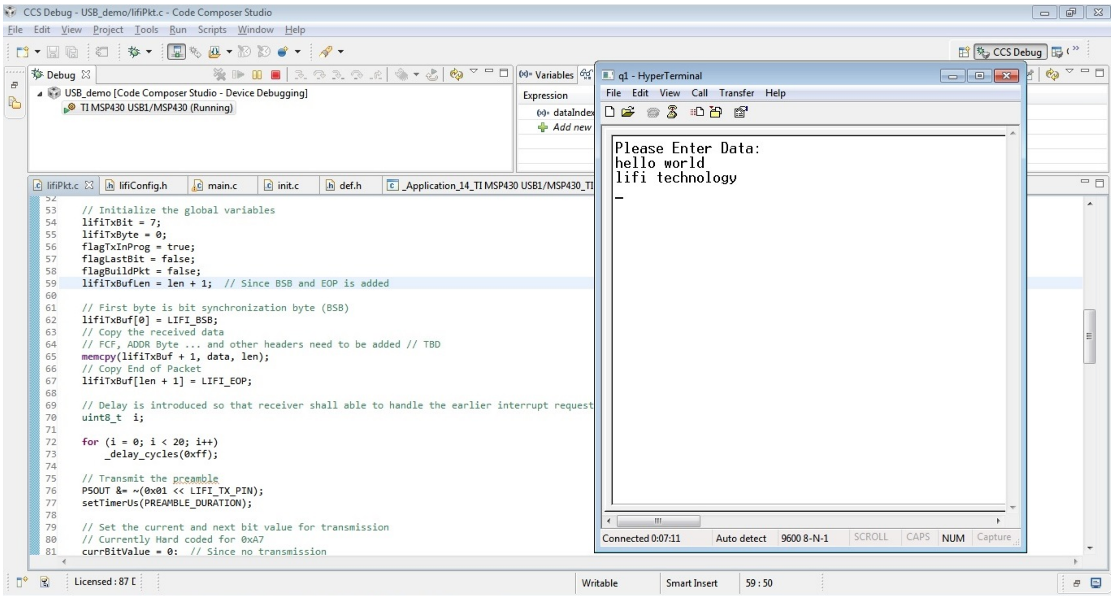


Figure 5.3: Message sent from hyperterminal

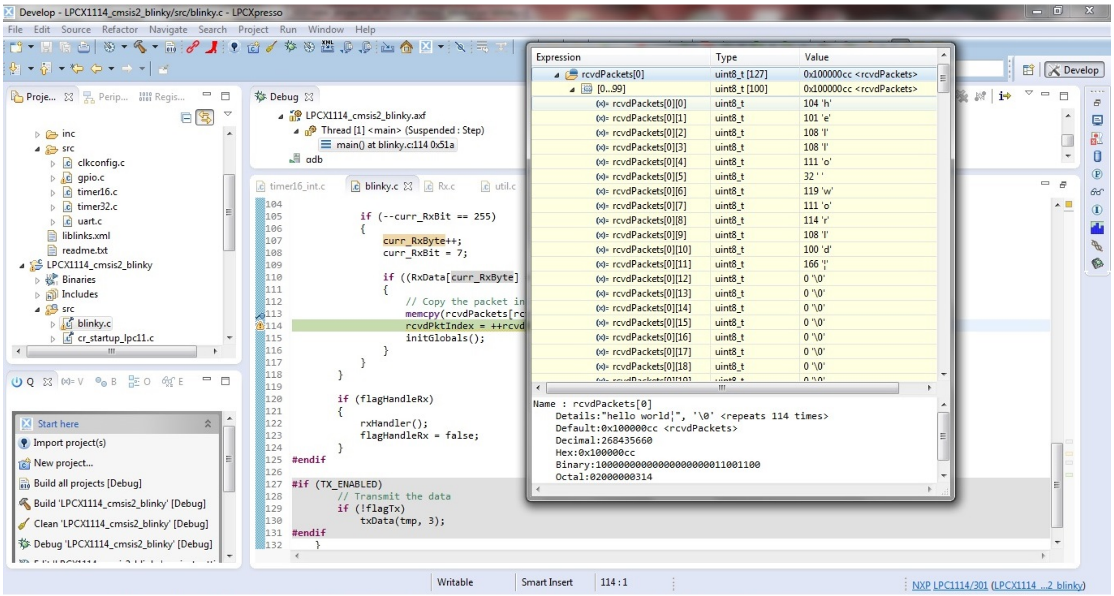


Figure 5.4: Received packet 1 at receiver controller

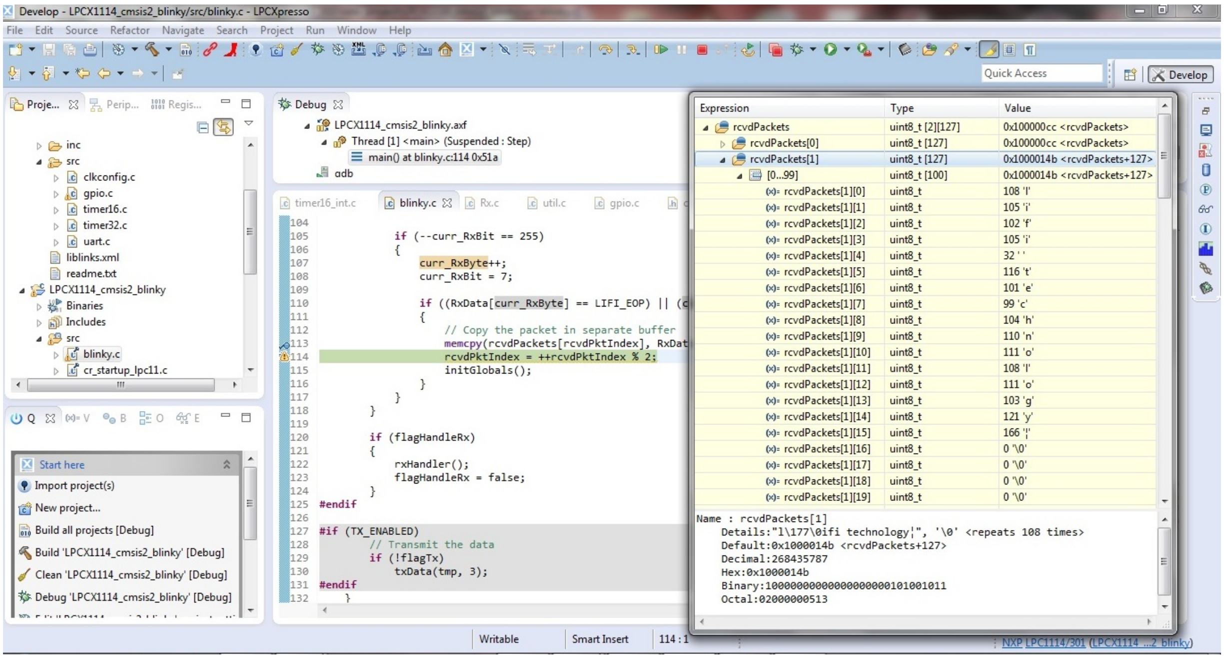


Figure 5.5: Received packet 2 at receiver controller

# CHAPTER 6

# End to End system

So far the following sub-systems have been described:

- The basic communication scheme using a differential signal transmitted using LED lights
- The display system driven by an appropriate microcontroller
- The packetization scheme for carrying different types of display data efficiently and the microcontroller used for this.

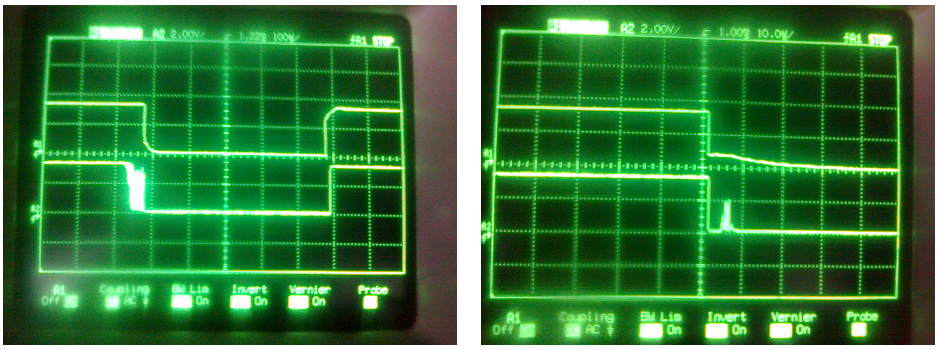
Each of the sub-systems was developed and tested independently. The display system and the packetization scheme was tested using wired connections.

In this chapter the integrated end to end system putting together these sub-systems is described. In order to put together the end to end system, the basic LED light communication scheme had to be inserted between the micro-controller board handling the packetization and the micro-controller board handling the display. But this led to the following challenges:

- The introduction of noise in the LED light channel resulted in the generation of multiple interrupts to the receiving micro-controller board.
- Limitation of scheme for transmission of multiple 1's in presence of other ambient light sources.
- Mismatch in the voltage levels of the different subsystems These required additional circuitry and modifications to be made to make the sub-systems work together.

## 6.1 Noise

The output of the comparator based receiver shows noise at the edges of data. This noise is especially harmful for the integration, since the display board relies on interrupts for bit synchronization (see fig 6.1) So it is necessary to remove this noise by some means, and an obvious choice was to put a low pass filter at output which blocks the high frequency noise. But the addition of the low pass filter, introduced a resistance in series which started to load the comparator circuit. So, the noise part was taken care in the software program itself by putting some time interval for a valid interrupt to occur i.e if an interrupt occurs before a specified interval of time it is ignored and considered as an invalid interrupt. Also, great amount of noise was removed by using a transistor based circuit at the comparator output which is described in detail in later part of this chapter.




(a) Noise causing invalid interrupt (b) Noise causing invalid interrupt

Figure 6.1: Noise captured at comparator output

## 6.2 Effect of Ambient Light

During testing of prototype it was found that sometimes continuous strings of 1's are not received properly which can also affect the transmission scheme because the SFD (Start Frame Delimiter) which is used for bit synchronization was 0xA7 which corresponds to '10100111' contains string of three 1's which are not received properly at the receiver and hence the data bits are not received because of not receiving SFD. This problem of 1's not being transmitted properly is overcome by spreading the bits so that occurence of continuous 1's are avoided. We decided to use a programmable method of encoding, in which 1 and 0 can be represented by any sequence of bits of length 1 to 8. The code that we chose for the implementation is shown below:

| bit | code |
|---|---|
| 0 | ’1000’. |
| 1 | ’1010’ |

Table 6.1: Coding scheme for data bits

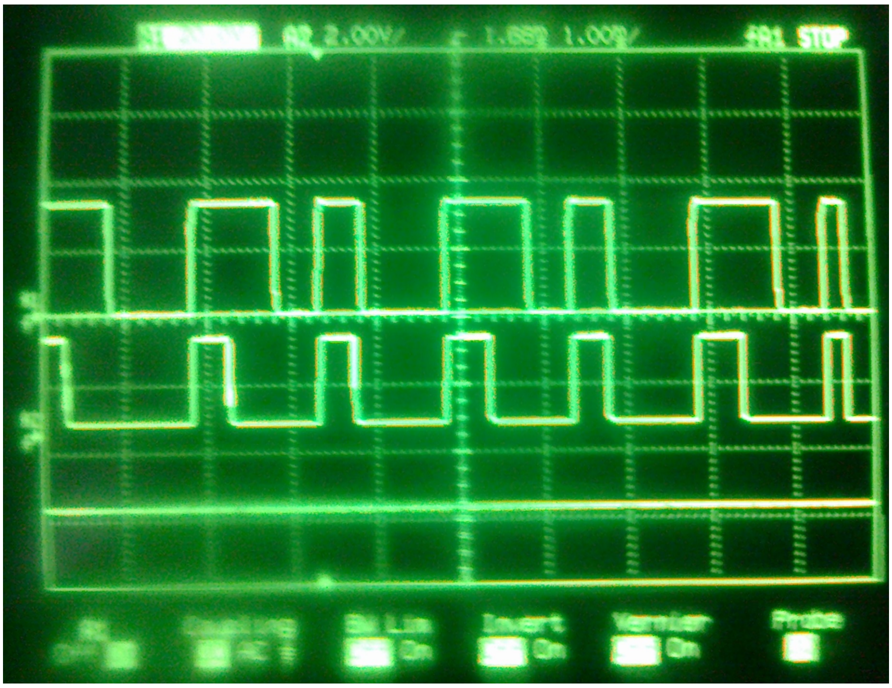


Figure 6.2: waveform showing missing of continuous 1’s

The above coding scheme ensures non-occurrence of consecutive 1’s and thereby removes possibility of occurrence of error to a great extent but at the expense of data rate but since the focus is on low refresh rate devices data rate is not an issue.

## 6.3 Voltage Pull Down

The LPC Xpresso micro-controller used at receiver works at 3.3 V so the comparator output which is at 5 V needs to be pulled down before giving it as an input to the microcontroller. One easy choice for this was to use a voltage divider circuit using resistors, but when the resistive circuit was used it started to load the comparator circuit causing the voltage to go down to 2.6. This was very near to the sensitive point of micro-controller so even small peak can cause interrupt to occur and hence the transmission can fail. So, a transistor base circuit is used to get 3.3 V output which can be fed to receiver micro-controller for decoding. The advantage of using a transistor based circuit is it gives the desired output voltage.

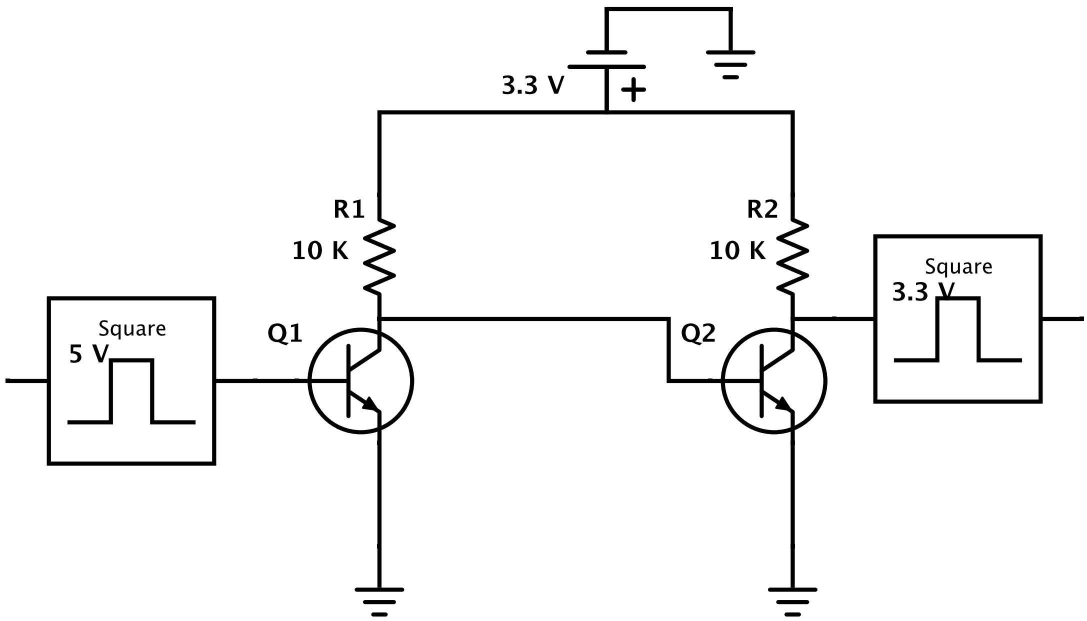
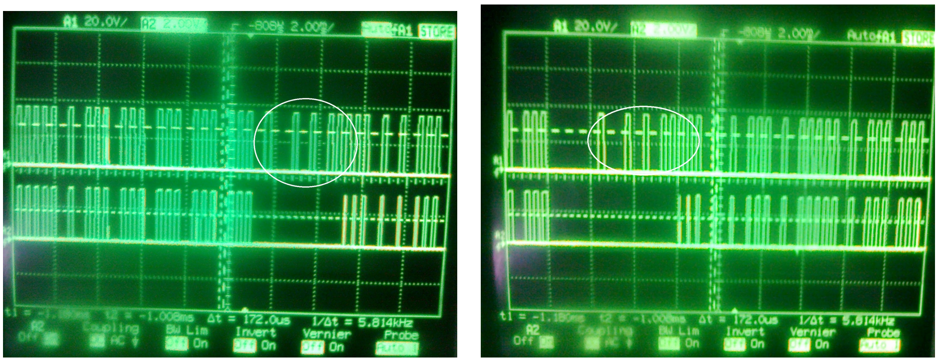



Figure 6.3: Transistor based circuit to get 3.3 V

## 6.4 LDR Effect

The receiver circuit is designed to receive differential data using an LDR for keeping cost low. But since the LDR takes some amount of time to get to a state where it can switch its resistance, this may lead to errors in detection of transmitted signal at the start of a sequence of data.

Because of the time taken by LDR, we observed that a few bits are missed at the start of the data frame in the received signal which can be easily seen in the figure 6.4 below. Therefore, to remove the error seen due to the LDR effect the transmitter program is modified by adding a longer dummy initial sequence.



(a) Missing of first few bits (b) Missing of first few bits

Figure 6.4: Effect of LDR

## 6.5 Modification in Transmission Scheme

Considering the presence of above effect of LDR the coding scheme designed earlier needs some changes so that the data bits are not missed and reception can happen properly.

To neglect the effect of LDR the following scheme is used:

- A continuous stream of '10' is transmitted for 32 times (tried 16 times but didn't work)
- This is followed by preamble which is a high followed by low for four times the data period
- This is followed by a junk byte 0xFF so that so that even if there are more bits after the initial synchronisation sequence, no data loss is there.
- After transmitting junk byte SFD which is 0xA7 is transmitted which signifies the beginning of the actual data
- The data is then transmitted
- After the data to be transmitted is over an EOP byte 0xAA is appended at the end to signify the end of data packet.

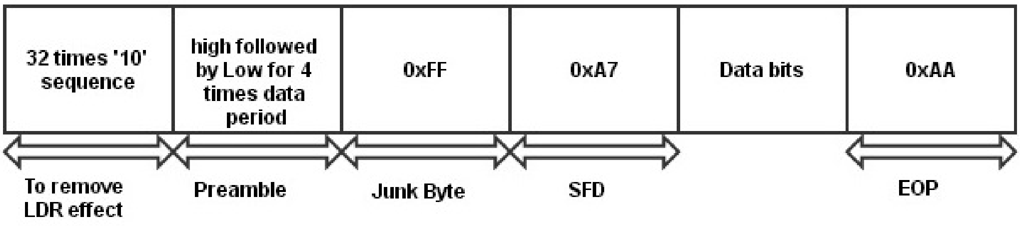



Figure 6.5: Modified packet to remove various errors

## 6.6 Results

After implementing the above changes in the transmission and receiver side, end to end transmission was checked by inserting the LED communication scheme between the transmitter and receiver controller boards. We observed that the transmitted data was received properly most of the times, but there were still occasional errors. The bit error rate was 15-20% . Since we are operating with pixel level refreshes, this could be a barely acceptable error rate not creating visual impairments.

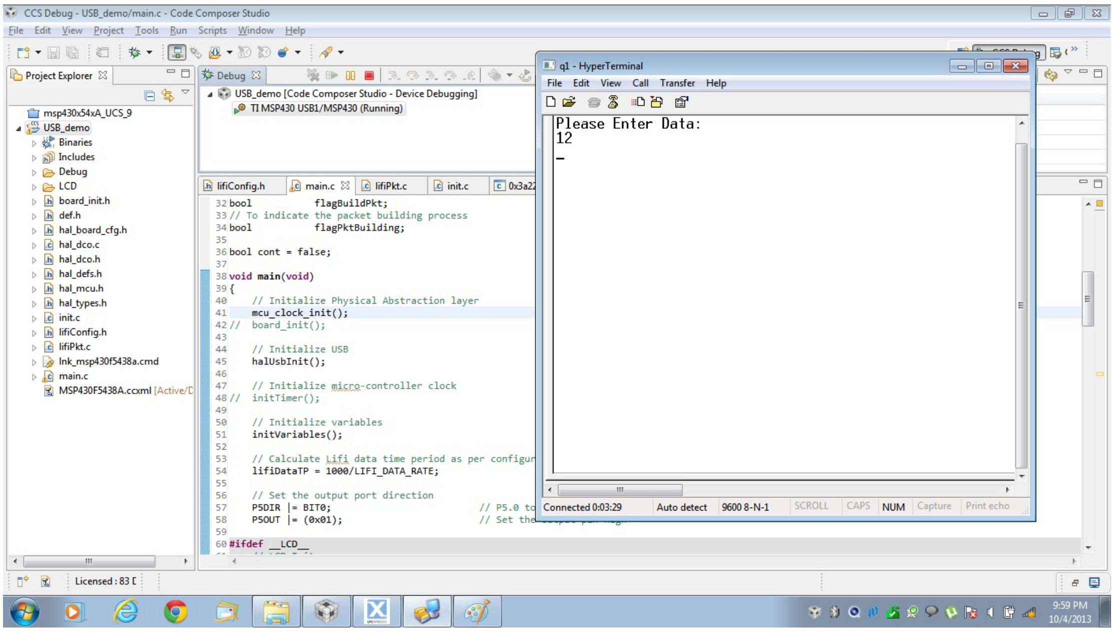



Figure 6.6: Input data for transmission

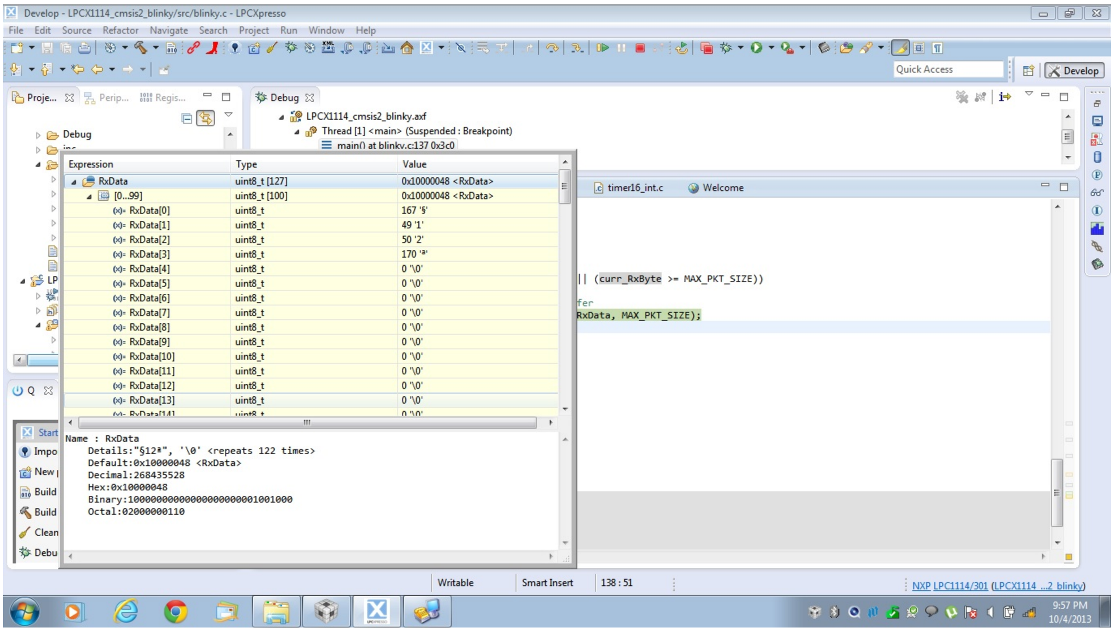



Figure 6.7: Received data at the receiver controller

**Note:** The received message at receiver controller sometimes does not matches because of presence of 1 bit or two bit error in a byte (32 bits because of encoding). Also as the number of bytes transmitted increases the number of errors received increases which still needs to be looked at therefore testing of display device couldn't be done at this stage with error presents as it requires transmission of large number of data bits.

# CHAPTER 7

# Conclusion

Already present infrastructure at various public places gives the opportunity to use light for dual purpose of illumination and data transmission. Since the need for wireless communication is increasing and the excessive use of limited radiowave spectrum is a major cause of concern, Li-Fi technology has a great future as an effective and efficient wireless technology to serve the future need. The high cost involved in setting up a Li-Fi system is the main reason why this technology is not used extensively and is overcome by the prototype designed. The results of this experimental evaluation shows that the Low refresh rate displays can be refreshed by using a very cheap hardware circuitry built by using commercially available low cost components.

The places where broadcasting is needed lifi is first choice and can be implemented using the proposed scheme where each device can be addressed individually.The system designed in this report provides for the following:

- Easy method of entering the refresh data using a simply GUI based system
- Convenient wired interface to carry refresh data to LED lights
- Transmission circuitry embedded in a manner where the LED lights can continue to be lit while transmission is going on.
- A reliable differential signaling method to carry information via LED lights to the receiver circuitry.
- Low cost receiver circuitry using LDRs that can be easily interfaced with displays using a cheap microcontroller framing scheme to deal with multiple displays, where each device can be addressed individually.

The main merit of the proposed method is that it is really low cost, and takes care of any display device where few pixels are refreshed like electronic shelf displays present in shopping marts displaying rates and details of the product.

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