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Data Transfer between Independent Systems using Visible Light Communication

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ABSTRACT: The following paper explains the implementation of a system developed for wireless visible light communication. The novel approach creates a VLC system that can be used for local communication between two devices. This system is significantly easier to build and is very cost effective. The components used are common, inexpensive and simple to integrate. The system developed was used to transfer textual data from one computer to another at a baud rate of 9.6bps. As mentioned above this is a novel concept and was developed primarily to display its effectiveness and simplicity henceforth has excluded security regarding the data. This paper provides an in detail description of process of development of the system.

KEYWORDS- “Visible light communication”, “Optical Wireless Communication”, “LED”, “Photo Diode”

I. INTRODUCTION

Over the past decade, significant research efforts have been directed towards exploring alternative parts of the electromagnetic spectrum that could potentially offload a large portion of the network traffic from the overcrowded RF domain. One of these alternatives being visible light. The use of the visible light spectrum for high speed data communication is enabled by the emergence of the light emitting diode (LED) which at the same time is at the heart of the next wave of energy-efficient illumination. In that sense, the concept of combining the functions of illumination and communication offers the potential for tremendous cost savings and carbon footprint reductions. VLC is a data communication medium using visible light between 780nm-375nm. The visible light spectrum includes 100s of THz of license free bandwidth, 10,000 times more than the entire RF spectrum up to 30 GHz, including the mmWave spectrum. Also optical radiation, in general, does not interfere with other radio waves or with the operation of sensitive electronic equipment. Therefore, it is ideal for providing wireless coverage in areas which are sensitive to electromagnetic radiation – some examples include: hospitals, airplanes, petrochemical and nuclear power plants, etc.

There are numerous universities and institutions that are developing VLC systems that can be used for multiple applications. This has proven to be challenging as traditional methods used for radio frequency communication cannot be implemented in VLC. Therefore various techniques and methods to efficiently transmit data via light are being researched and tested. One of the popular VLC system developed in recent years is nicknamed “VLC system”, as in Wi-Fi, for Light Fidelity is developed in the University of Edinburgh by a team led by Professor Harald Haas. But there certain drawback to this system. Firstly, the system is complex to build as it involves transmission of multiple streams of data simultaneously to transmit internet to the devices. Also the system then becomes expensive to build and then maintain. A large number of data transfers among systems happen locally i.e. systems within the same room. Therefore, a VLC system setup for such a network would be unnecessary. A solution to problem would be build a simple device that would be sufficient to transfer data between adjacent systems using light at a high speed.

II. COMPONENTS

2.1 Light Emitting Diode

LED is a two lead semiconductor light source. It is a pn-junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. Recently introduced high power LEDs offer a smart solution for flash applications in

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

small form factor portable equipment. Since the diodes are built in tiny packages and not requiring a high voltage, the complete flash solutions can be more cost and space effective. Just as well the same LED can be used for a torch function or a movie light, by just keeping them on continuously at less current.^[1] Most blue and white LEDs use Indium Gallium Nitrite (InGaN) as active material. The wavelength of the generated light of these LEDs shows a strong dependency on the driving current. This special property of InGaN-based LEDs must be considered well in advance for new application solutions. To obtain white light, blue light-emitting die (wavelength 450 nm to 470 nm) is covered with a phosphorous based material that is stimulated by blue light and emits a yellow light. The human eye detects the mixture of blue and yellow light as white. This mixture cannot be described by a simple dominant wavelength but as spectrum. The LED characteristics between diodes vary in manufacturing. The ratio of emitted light and LED forward current is one of the major parameters which change during production. Therefore, LEDs are generally preselected in different groups of similar current to light conversion ratio. However, even among these preselected groups of LEDs, the forward voltage still varies about $\pm 0.8V$ of the nominal value.

A CMOS LED driver for low-cost optical wireless links is presented. The architecture is cellular, with direct optical mapping of arrayed transmitter and receiver elements. The devices are InP-based resonant cavity LEDs and detectors, the driver may be implemented either as a voltage-source or as a current-source. A current-source congregation is preferred for applications in optical systems because: (i) the LED source is a current mode device; (ii) voltage-source drivers are difficult to integrate due to the large speedup capacitors that are required; and (iii) switching between two well-specified voltage levels is also hard to realize in CMOS when driving a large capacitance. For these reasons, the LED driver has been designed to convert a digital (voltage) input signal to a train of current pulses. Table 1 shows the LED configuration of VLC.

VLC SYSTEM PARAMETERS

Parameters	Values
Luxeon LED part number	LXHL-MW1B
LED drive current	200 mA
Optical modulation depth	40%
LED beam angle (Full width half maximum)	45°
Receiver concentration lens diameter	30 mm
Blue filter central wavelength and width	450 nm, 40nm (60% through)
Photodetector (OSD-15T) detection area	15 mm ²
Preamplifier (Max3664) TIA gain	6K Ω
Preamplifier input-referred noise	55 nA _{RMS}
Receiver input dynamic range	28 dB
Optoelectronic receiver bandwidth	77 MHz
Equalizer capacitor	15 pF
Equalizer resistor	750 Ω
Load (oscilloscope-input impedance)	50 Ω
Electrical low pass filter cut-off frequency	0.7×data-rate

Table 1. VLC parameters

2.2 Photo Diode

A photodiode is a type of photo detector capable of converting light into either current or voltage, depending upon the mode of operation. Photodiodes are similar to regular semiconductor diodes except that they may be either exposed (to detect vacuum UV or X-rays) or packaged with a window or optical fibre connection to allow light to reach the sensitive part of the device. Many diodes designed for use specifically as a photodiode will also use a PIN junction rather than the typical PN junction. When a photon of sufficient energy strikes the diode, it excites an electron, thereby creating a free electron and a (positively charged electron) hole. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced.

Critical performance parameters of a photodiode include:

i) Responsivity: The Spectral responsivity is a ratio of the generated photocurrent to incident light power, expressed in A/W when used in photoconductive mode. The wavelength-dependence may also be expressed as a Quantum efficiency, or the ratio of the number of photo generated carriers to incident photons, a unitless quantity.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

ii) Dark current: The current through the photodiode in the absence of light, when it is operated in photoconductive mode. The dark current includes photocurrent generated by background radiation and the saturation current of the semiconductor junction.

iii) Response time: A photon absorbed by the semiconducting material will generate an electron-hole pair which will in turn start moving in the material under the effect of the electric field and thus generate a current. The finite duration of this current is known as the transit-time spread.

iv) Noise equivalent power: (NEP) The minimum input optical power to generate photocurrent, equal to the rms noise current in a 1 hertz bandwidth. NEP is essentially the minimum detectable power.

When a photodiode is used in an optical communication system, all these parameters contribute to the sensitivity of the optical receiver, which is the minimum input power required for the receiver to achieve a specified bit error rate.

2.3 Micro Controller – PIC 16F877A

PIC (Programmable Interface Controllers) microcontrollers are the world smallest microcontrollers that can be programmed to carry out a huge range of tasks. The semi microcontrollers are found in many electronic devices such as phones, computer control systems, alarm systems, embedded systems etc. Various types of microcontrollers exist, even though the best are found in the GENIE range of programmable microcontrollers. These microcontrollers are programmed and simulated by a circuit-wizard software. Every PIC **microcontroller** architecture consists of some registers and stack where registers function as Random Access Memory (RAM) and stack saves the return addresses. The main features of PIC microcontrollers are RAM, flash memory, Timers/Counters, EEPROM, I/O Ports, USART, CCP (Capture/Compare/PWM module), SSP, Comparator, ADC (analog to digital converter), PSP (parallel slave port), LCD and ICSP (in circuit serial programming) The 8-bit PIC microcontroller is classified into four types on the basis of internal architecture such as Base Line PIC, Mid-Range PIC, Enhanced Mid-Range PIC and PIC18

2.3.1 Architecture of PIC Microcontroller

The PIC microcontroller architecture comprises of CPU, I/O ports, memory organization, A/D converter, timers/counters, interrupts, serial communication, oscillator and CCP module which are discussed in detailed below.

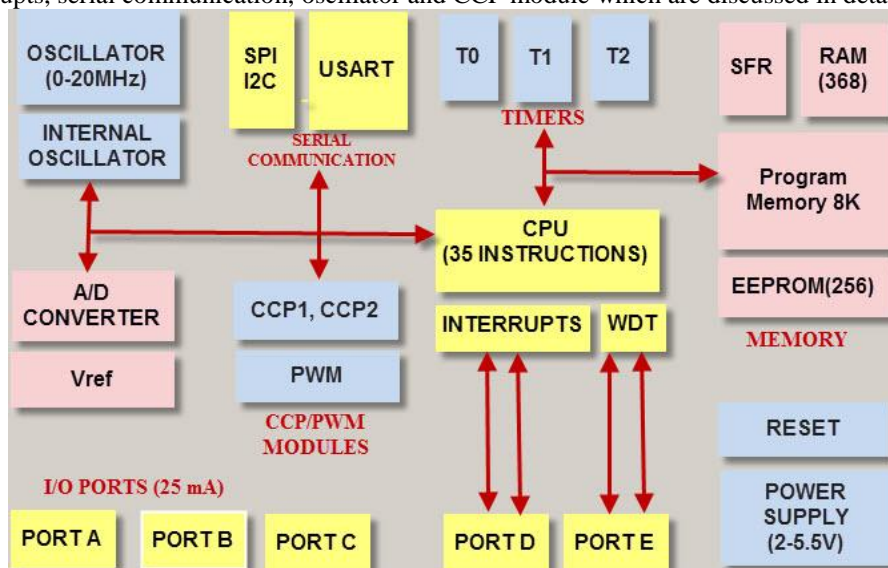


Fig 2.1. Architecture of PIC microcontroller

2.3.1.1 CPU (Central Processing Unit)

It is not different from other microcontrollers CPU and the PIC microcontroller CPU consists of the ALU, CU, MU and accumulator, etc. Arithmetic logic unit is mainly used for arithmetic operations and to take logical decisions.



International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

Memory is used for storing the instructions after processing. To control the internal and external peripherals, control unit is used which are connected to the CPU and the accumulator is used for storing the results and further process.

2.3.1.2 Memory Organization

i) **Random Access Memory (RAM)**: RAM is an unstable memory which is used to store the data temporarily in its registers. The RAM memory is classified into two banks, and each bank consists of so many registers. The RAM registers are classified into two types: Special Function Registers (SFR) and General Purpose Registers (GPR).

a. **General Purpose Registers (GPR)**: These registers are used for general purpose only as the name implies. For example, if we want to multiply two numbers by using the PIC microcontroller. Generally, we use registers for multiplying and storing the numbers in other registers. So these registers don't have any special function, - CPU can easily access the data in the registers.

b. **Special Function Registers**: These registers are used for special purposes only as the name SFR implies. These registers will perform according to the functions assigned to them, and they cannot be used as normal registers. For example, if you cannot use the STATUS register for storing the data, these registers are used for showing the operation or status of the program. So, user cannot change the function of the SFR; the function is given by the retailer at the time of manufacturing

ii) **Read Only Memory (ROM)**: Read only memory is a stable memory which is used to store the data permanently. In PIC microcontroller architecture, the architecture ROM stores the instructions or program, according to the program the microcontroller acts. The ROM is also called as program memory, wherein the user will write the program for microcontroller and saves it permanently, and finally the program is executed by the CPU. The microcontrollers 'performance depends on the instruction, which is executed by the CPU.

iii) **Electrically Erasable Programmable Read Only Memory (EEPROM)**: In the normal ROM, we can write the program for only once we cannot use again the microcontroller for multiple times. But, in the EEPROM, we can program the ROM multiple times.

iv) **FlashMemory**: Flash memory is also programmable read only memory (PROM) in which we can read, write and erase the program thousands of times. Generally, the PIC microcontroller uses this type of ROM.

v) **Stack**: When an interrupt occurs, first the PIC microcontroller has to execute the interrupt and the existing process address. Then that is being executed is stored in the stack. After completing the execution of the interrupt, the microcontroller calls the process with the help of address, which is stored in the stack and get executes the process.

2.3.1.3 I/O Ports

i) The series of PIC16 consists of five ports such as Port A, Port B, Port C, Port D & Port E.

ii) Port A is a 16-bit port that can be used as input or output port based on the status of the TRISA (Tradoc Intelligence Support Activity) register.

iii) Port B is an 8-bit port that can be used as both input and output port.

iv) Port C is an 8-bit and the input of output operation is decided by the status of the TRISC register.

v) Port D is an 8-bit port acts as a slave port for connection to the microprocessor BUS.

vi) Port E is a 3-bit port which serves the additional function of the control signals to the analog to digital converter.

2.3.1.4 BUS

BUS is used to transfer and receive the data from one peripheral to another. It is classified into two types such as data bus and address.

DataBus: It is used for only transfer or receive the data.

AddressBus: Address bus is used to transmit the memory address from the peripherals to the CPU. I/O pins are used to interface the external peripherals; UART and USART both are serial communication protocols which are used for interfacing serial devices like GSM, GPS, Bluetooth, IR, etc.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

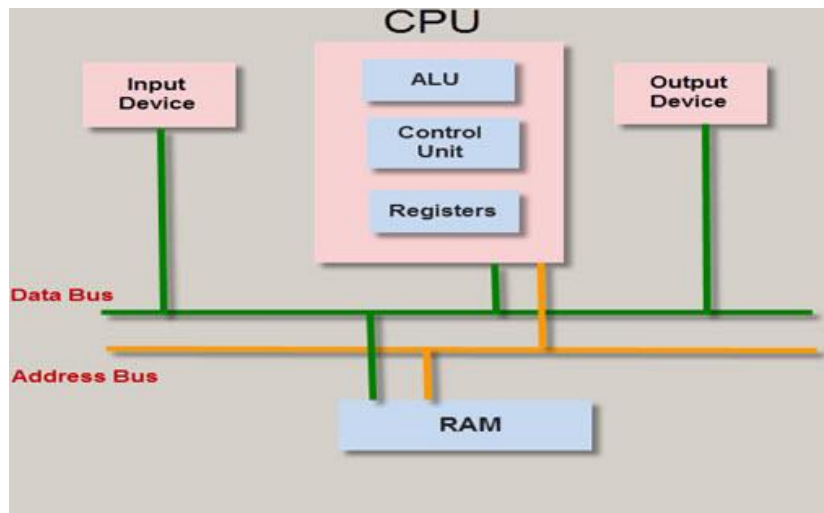


Fig 2.2 BUS Organization

2.3.1.5 A/D converters

The main intention of this analog to digital converter is to convert analog voltage values to digital voltage values. A/D module of PIC microcontroller consists of 5 inputs for 28 pin devices and 8 inputs for 40 pin devices. The operation of the analog to digital converter is controlled by ADCON0 and ADCON1 special registers. The upper bits of the converter are stored in register ADRESH and lower bits of the converter are stored in register ADRESL. For this operation, it requires 5V of an analog reference voltage.

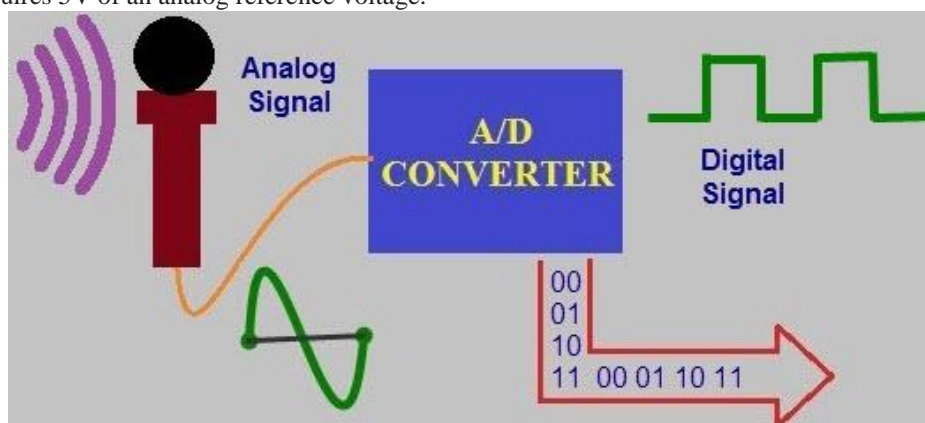


Fig 2.3 A/D Converter

2.3.1.6 Timers/ Counters

PIC microcontroller has four timer/counters wherein the one 8-bit timer and the remaining timers have the choice to select 8 or 16-bit mode. Timers are used for generating accuracy actions, for example, creating specific time delays between two operations.

2.3.1.7 Interrupts

PIC microcontroller consists of 20 internal interrupts and three external interrupt sources which are associated with different peripherals like ADC, USART, Timers, and so on.

2.3.1.8 Serial Communication

Serial communication is the method of transferring data one bit at a time sequentially.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

- i) **USART:** The name USART stands for Universal synchronous and Asynchronous Receiver and Transmitter which is a serial communication for two protocols. It is used for transmitting and receiving the data bit by bit over a single wire with respect to clock pulses. The PIC microcontroller has two pins TXD and RXD. These pins are used for transmitting and receiving the data serially.
- ii) **SPI Protocol:** The term SPI stands for Serial Peripheral Interface. This protocol is used to send data between PIC microcontroller and other peripherals such as SD cards, sensors and shift registers. PIC microcontroller support three wire SPI communications between two devices on a common clock source. The data rate of SPI protocol is more than that of the USART.
- iii) **I2C Protocol:** The term I2C stands for Inter Integrated Circuit, and it is a serial protocol which is used to connect low speed devices such as EEPROMS, microcontrollers, A/D converters, etc. PIC microcontroller support two wire Interface or I2C communication between two devices which can work as both Master and Slave device.
- iv)

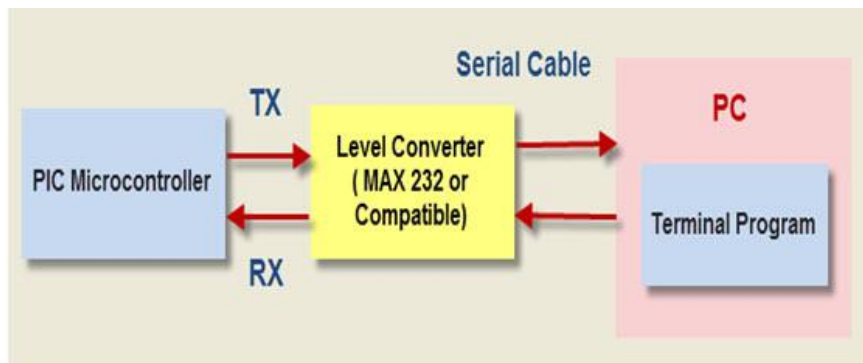


Fig 2.4 Serial Communication

2.3.1.9 Oscillators:

Oscillators are used for timing generation. Pic microcontroller consist of external oscillators like RC oscillators or crystal oscillators. Where the crystal oscillator is connected between the two oscillator pins. The value of the capacitor is connected to every pin that decides the mode of the operation of the oscillator. The modes are crystal mode, high-speed mode and the low-power mode. In case of RC oscillators, the value of the resistor & capacitor determine the clock frequency and the range of clock frequency is 30 KHz to 4MHz.

2.3.1.10 CCP module:

The name CCP module stands for capture/compare/PWM where it works in three modes such as capture mode, compare mode and PWM mode.

- i) **Capture Mode:** Capture mode captures the time of arrival of a signal, or in other words, when the CCP pin goes high, it captures the value of the Timer1.
- ii) **Compare Mode:** Compare mode acts as an analog comparator. When the timer1 value reaches a certain reference value, then it generates an output.
- iii) **PWM Mode:** PWM mode provides pulse width modulated output with a 10-bit resolution and programmable duty cycle.

III. SOFTWARETOOLS

3.1 Proteus 8 Professional

Proteus is one of the most famous simulators. It can be uses to simulate almost every circuit on electrical fields. It is easy to use because of the GUI interface that is very similar to the real Prototype board. Moreover, it can be used to design Print Circuit Board (PCB). Proteus has many features to generate both analogue and digital result.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

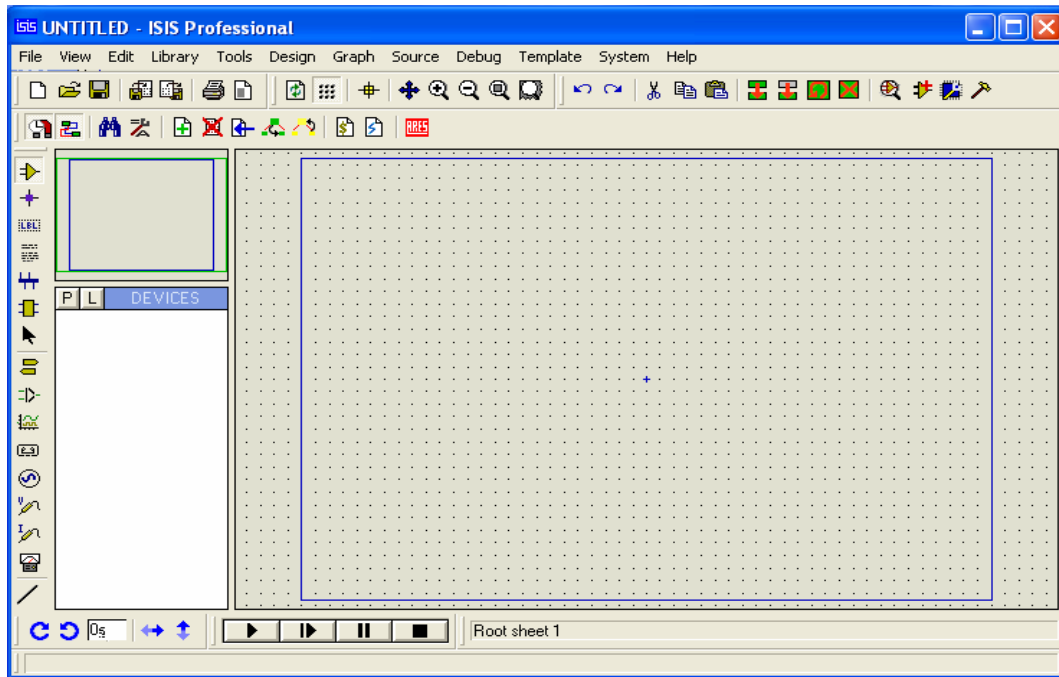


Fig 3.1: Proteus 8 software window.

3.2 MP LAB IDE v8.6

MPLAB IDE is a software program that runs on a PC to develop applications for Microchip microcontrollers. It is called an Integrated Development Environment, or IDE, because it provides a single integrated environment to develop code for embedded microcontrollers.

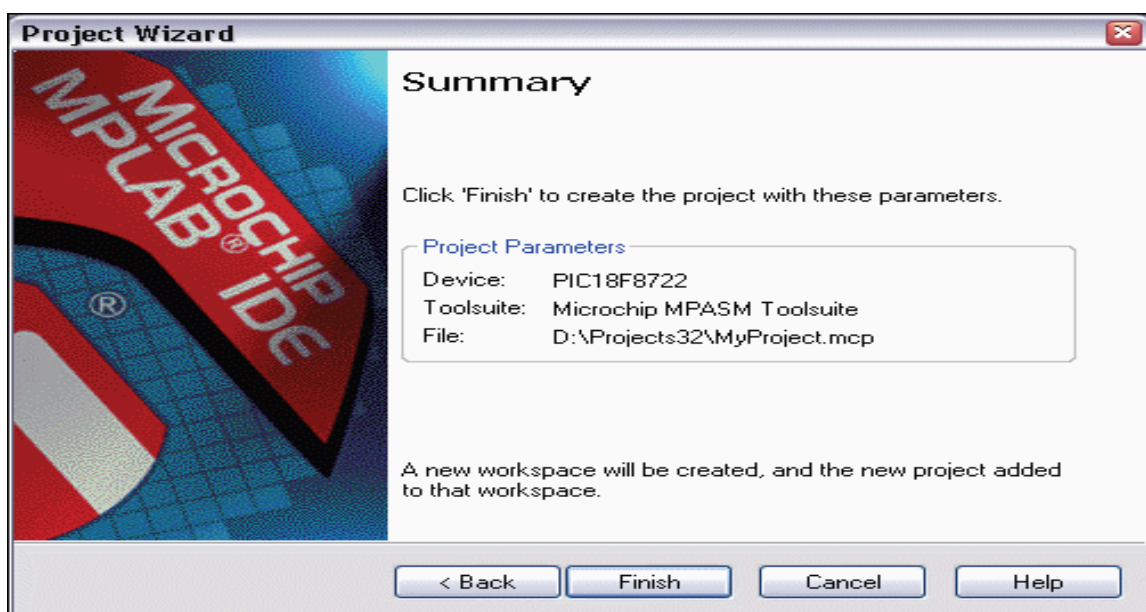


Fig 3.2 Microchip MPLAB IDE



International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

3.2.1 Components of MPLAB IDE

The MPLAB IDE has both built-in components and plug-in modules to configure the system for a variety of software and hardware tools.

The built-in components consist of:

- i) Project Manager:** The project manager provides integration and communication between the IDE and the language tools.
- ii) Editor:** The editor is a full-featured programmer's text editor that also serves as a window into the debugger.
- iii) Assembler/Linker and Language Tools:** The assembler can be used stand-alone to assemble a single file, or can be used with the linker to build a project from separate source files, libraries and recompiled objects. The linker is responsible for positioning the compiled code into memory areas of the target microcontroller.
- iv) Debugger:** The Microchip debugger allows breakpoints, single stepping, watch windows and all the features of a modern debugger for the MPLAB IDE. It works in conjunction with the editor to reference information from the target being debugged back to the source code.
- v) Execution Engines:** There are software simulators in MPLAB IDE for all PICmicro MCU and dsPIC DSC devices. These simulators use the PC to simulate the instructions and some peripheral functions of the PICmicro MCU and dsPIC DSC devices. Optional in-circuit emulators and in-circuit debuggers are also available to test code as it runs in the applications hardware.

Optional components can be purchased and added to the MPLAB IDE:

- i) Compiler Language Tools:** MPLAB C18 and MPLAB C30 C compilers from Microchip provide fully integrated, optimized code. Along with compilers from HI TECH, IAR, microEngineering Labs, CCS and Byte Craft, they are invoked by the MPLAB IDE project manager to compile code that is automatically loaded into the target debugger for instant testing and verification.
- ii) Programmers:** PICSTART Plus, PICKit 1 and 2, PRO MATE II, MPLAB PM3 as well as MPLAB ICD 2 can program code into target devices. MPLAB IDE offers full control over programming both code and data, as well as the Configuration bits to set the various operating modes of the target microcontrollers or digital signal controllers.
- iii) In-Circuit Emulators:** MPLAB ICE 2000 and MPLAB ICE 4000 are full-featured emulators for the PICmicro MCU and dsPIC DSC devices. They connect to the PC via I/O ports and allow full control over the operation of microcontroller in the target applications.
- iv) In-Circuit Debugger:** In order to create code that is executable by the target PICmicro MCU, source files need to be put into a project. The code can then be built into executable code using selected language tools (assemblers, compilers, linkers, etc.). In MPLAB IDE, the project manager controls this process.

3.3 Terminate v3.1

Terminate is an easy to use and easy to configure RS232 terminal. It uses an interface similar to that of "messenger" or "chat" programs, with a large window that contains all received data and an edit line for typing in strings to transmit. Highlights of the utility are the ease of installation (possibly with pre-configured settings) using a heuristic search for the appropriate COM port and, as was mentioned, its user-friendliness.

Some of its features are:

- i) Plug-in interface for pre-processing or alternative views of the data, logging received data to a file, adding a toolbar to Terminate, keyboard macros, and other functionality that you may think of.
- ii) A history of commands that you typed, with auto-completion.
- iii) Resizable main window, with a "keep window on top" option, multilingual user interface.
- iv) Ability to run with pre-configured settings from a read-only medium (no installation is necessary).

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

- v) Support for non-standard Baud rates (MIDI, DMX512).
- vi) Different colouring for transmitted and received data (blue=transmitted, green=received).
- vii) Data can be forwarded between two RS232 ports.
- viii) Search dialog for transmitted/received text (right-click pop-up menu).
- ix) Save or print the contents of the transmitted/received text (right-click pop-up menu).

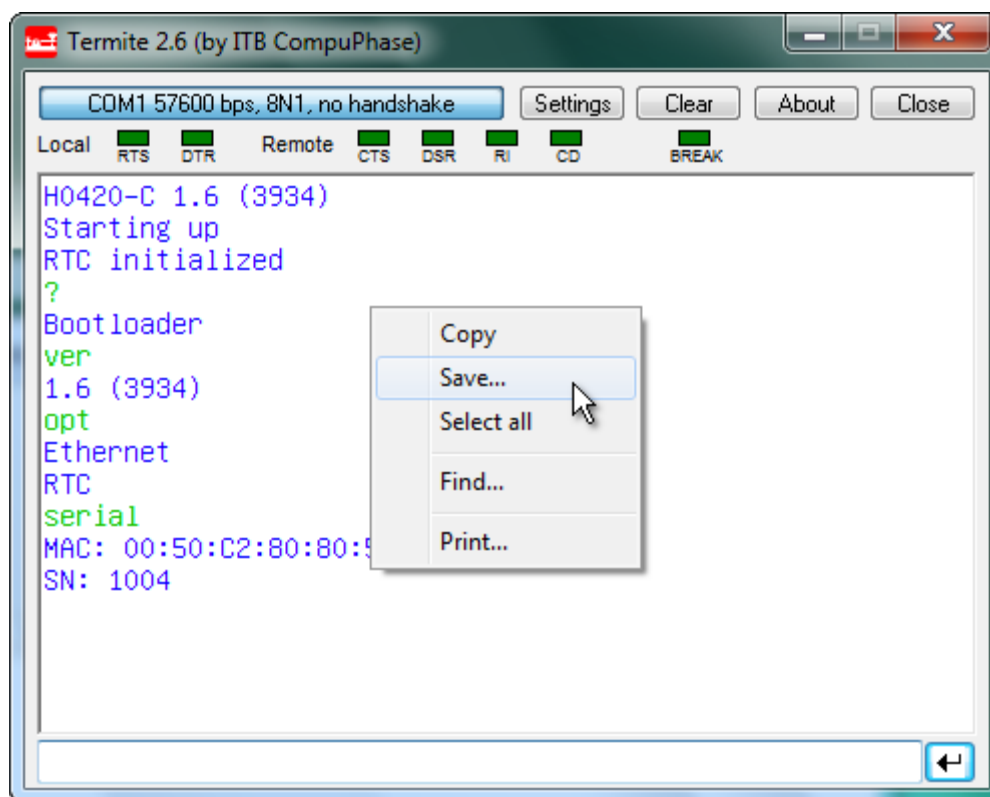


Fig 3.3 User interface of Termitte

Termitte focuses on text data, and specifically text that is sent and received as strings terminated with "new-line" characters. It has no provisions for transferring files or binary data. (That said, with the "hexadecimal view" plug-in, you can send and receive bytes as hexadecimal values, and you may write a "plug-in" filter for file transfer as well). The interface of the Termitte program has one large (initially empty) text area, which is called the "reception view". Above it is a set of buttons in a "button bar" and below it is a "transmit" line into which you can type a line of text. The utility automatically opens the RS232 port for which it was set up. It shows the current configuration at the left in the button bar. If these are not correct, you can use the button Settings to choose a different port or configuration. The Settings dialog also allows you to enable/disable "local echo" and/or to append a line termination to every string that you send.

Received bytes with values below ASCII 32 (the space character) are displayed as either a control character like, or as two hex characters between square brackets. So [08] stands for the "backspace" character and [1B] is the Escape key. There is an exception for the TAB, carriage return and line feed characters (ASCII 9, 13 and 10 respectively); these cause spacing (TAB) or a line break. Whether you see the control character or [08] for the backspace key, depends on whether the "Unifont" font is present and configured in the settings. If you wish to send a non-ANSI/ASCII character, you need the "hexadecimal view" plug-in filter, see "Downloads" above.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

After connecting a serial cable between the PC and the remote device (or remote PC, in which case you must use a null-modem cable) and configuring the port, you can send data by typing text in the transmit line and pressing the "Enter" key. Any data that the remote device sends, will appear in the reception view. Optionally, the text that you transmit is copied to the reception view (the option is called "local echo", you will find in in the dialog under the Settings button). To distinguish the received data from the echoed data, the echoed text is colored blue, whereas the received data is green.

The remaining functionality is straightforward: the Clear button clears the reception view, the About button gives copyright information and the Close button terminates the utility.

One "hidden" feature is the ability to disconnect the RS232 port, without terminating the utility. You can close an RS232 connection with a click in the status field in the upper left corner of the window (left of the button bar). Another click on that line re-opens the connection with the current settings. You can use this to "free" the port temporarily for another application.

3.3.1 Configuration:

Termite stores the configuration in an INI file (see the next section for the location of the INI file). This way, Termite remembers its settings between sessions. When distributing Termite, you may wish to include an INI file with pre-sets. You can run Termite directly off a CD-ROM, but the utility will not be able to store its configuration in the INI file if the INI file resides on a read-only medium. A typical INI file is below.

Most of these settings can be chosen from the "Settings" dialog. This means that to get an appropriate INI file, you can launch Termite, adjust the settings (including activating any plug-in filters that you wish to use), and voilà: you have your pre-configured INI file.

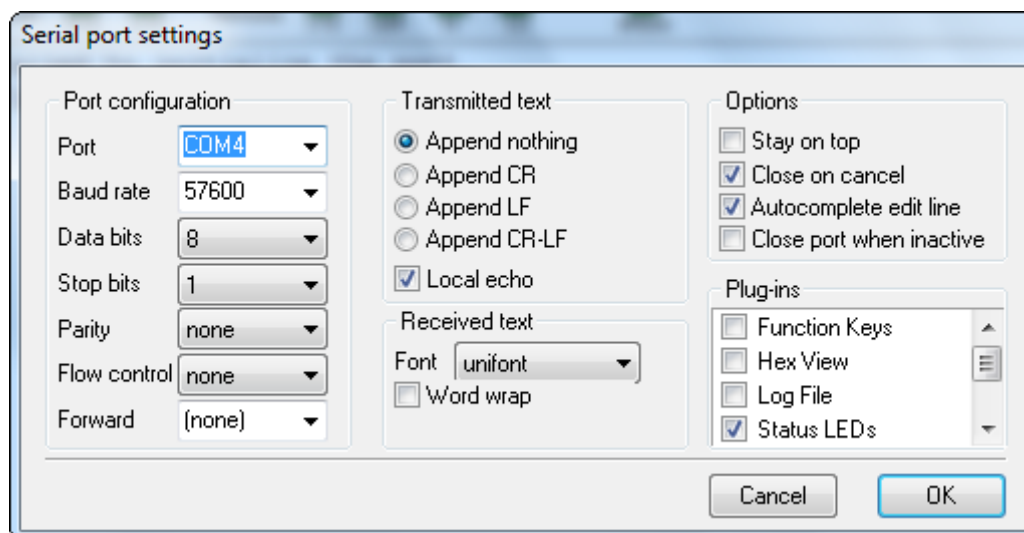


Fig 4.5 Serial Port Settings in Termite

A few more configurations can be done by editing the INI file directly (using a text editor like Notepad). These are the keywords Caption, TxColour and RxColour in the [Options] topic. The Caption item allows you to change the title bar of the main Termite window. Add the item Caption (below topic [Options]) and set it to the string that you wish to have displayed—for example, the model name of the product for which you are distributing a pre-configured Termite. The items TxColour and RxColour allow you to change the colours for transmitted and received text (from the default blue and green respectively). The syntax for the colours must be #rrggbb, where rr, gg and bb are two hexadecimal digits. So for example, #FF0000 is bright red and #808000 is dark yellow.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

3.3.2 RS232 port scan

Most RS232 settings for a device can be chosen by the developer (the Baud rate and the number of data and stop bits are usually determined by the other device). One setting that the developer *cannot* foresee, however, is what COM port the user will attach it to. For this reason, Termite contains a "port lookup" function plus a simple "port scanning" protocol.

The "port lookup" function only works with virtual COM ports, such as USB-to-serial cables. Since Microsoft Windows has drivers pre-installed for USB devices simulating a serial port, it is a popular design. To use the *port lookup* function, put the complete device name of the virtual COM port at the "Port=" setting.

IV. PROPOSED SYSTEM

The proposed project explains usage of Light Circuit connected to serial communication of a microcontroller and the same can be transmitted to another circuit which is kept a feet away and is able to receive the data into the microcontroller and display the same on the LCD or on a laptop.

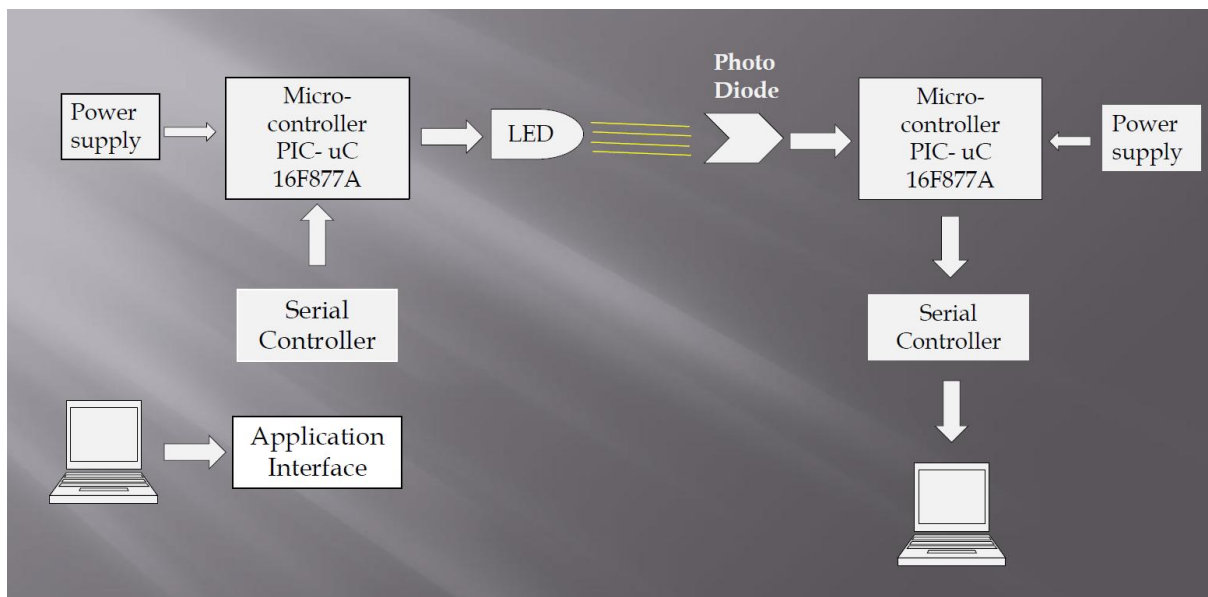


Fig 3.1 VLC system

VLC system is typically implemented using white LED light bulbs at the downlink transmitter. These devices are normally used for illumination only by applying a constant current.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2015

BLOCK DIAGRAM

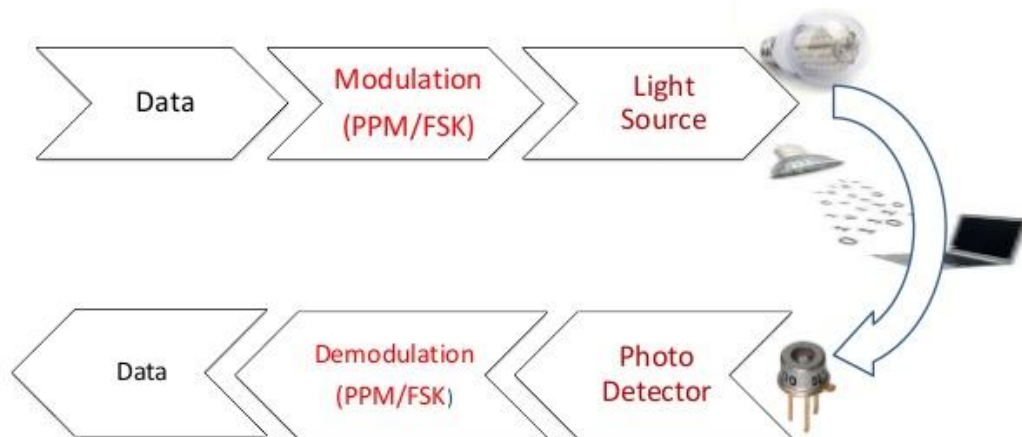


Fig 3.2 Steps in Light Data Transmission

The VLC system consists of mainly two parts, the transmitter and the receiver. The transmitter part modulates the input signal with the required time period and transmits the data in the form of 1's and 0's using a LED bulb. These 1's and 0's are nothing but the flashes of the bulb. The receiver part catches these flashes using a photodiode and amplifies the signal and presents the output.

The transmit section consists of the data input which is then fed into a switching control system. Based on the data, the switching control generates a stream of 1s and 0s thereby encoding the data in binary. The output of this control is given to the array of LEDs which turn OFF and ON at extremely high speeds. This ON-OFF modulation of the LED light transmits the data. The receive section consists of a photodiode, e.g. silicon photo detector or an Infrared germanium cylindrical detector. The photo detector demodulates the incoming received signal based on the sequence of 1s and 0s. The demodulated signal is then sent to a filter to remove unwanted noise.

V. DEVELOPMENT

The construction of the VLC system can be divided into two parts:

- a. Transmitter
- b. Receiver

These modules were first designed and simulated in Proteus 8. As shown the Fig 5.1 below, the circuit for PIC micro-controller and the LCD display panel, the micro-controller is able to successfully hold and display the data stored in its memory.

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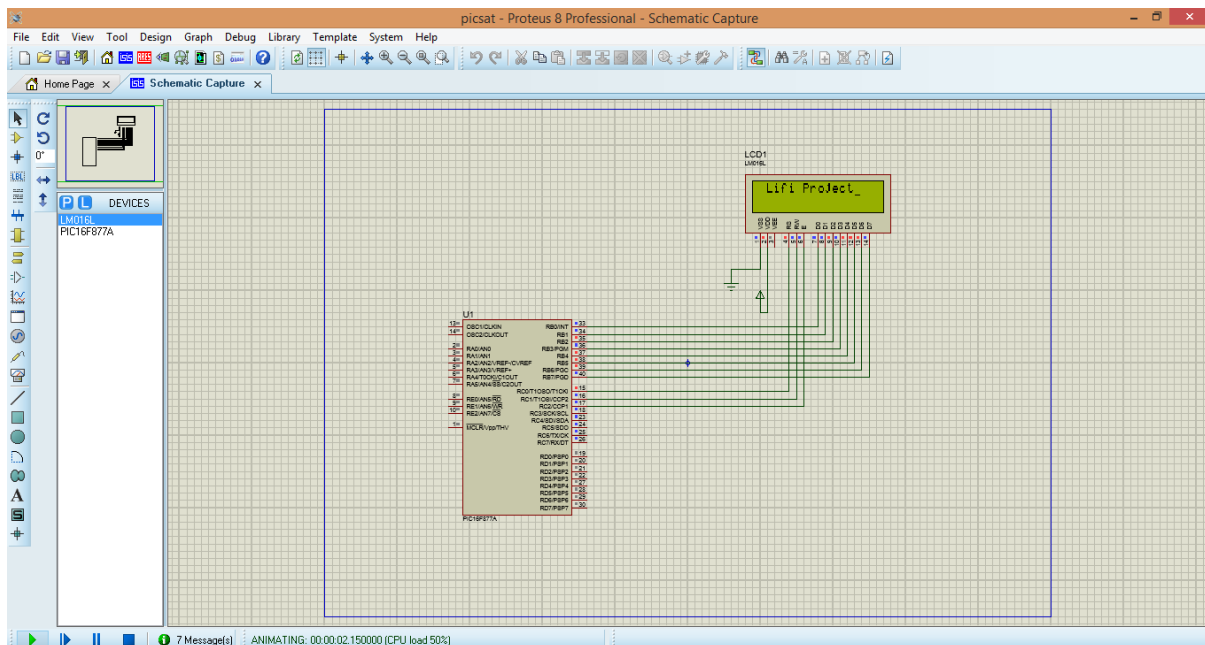


Fig 5.1 Simulation Result1 displayed on LCD

The Transmitter and Receiver modules were then developed as follows.

5.1 Transmitter Module

This module consists of the following components:

- i) Server System
- ii) USB to UART module
- iii) Micro-controller PIC16F 877a
- iv) Information Sender Circuit

The server in the module sends the data using the Termite terminal. This data which is transmitted at word lengths by the system is converted to a single stream of databits and sent to the micro-controller using USB to UART module. The purpose of a micro-controller in this setup is to make it more efficient to demonstrate the transfer of data. The micro-controller is programmed to repeatedly transmit the contents of the file to the receiver. The micro-controller then controls the flow of current to the transistor based on the digital data stream, which regulates the state of LED. The micro-controller also displays the contents of file stored in its memory on LCD panel to affirm the user that the data is being transmitted.

5.1.1 Server System

It is the independent system which contains the data to be sent. In this case a laptop with the UART driver installed was used, with textual data to be sent. The Termite 3.1 software terminal was installed and configured to the following parameters:

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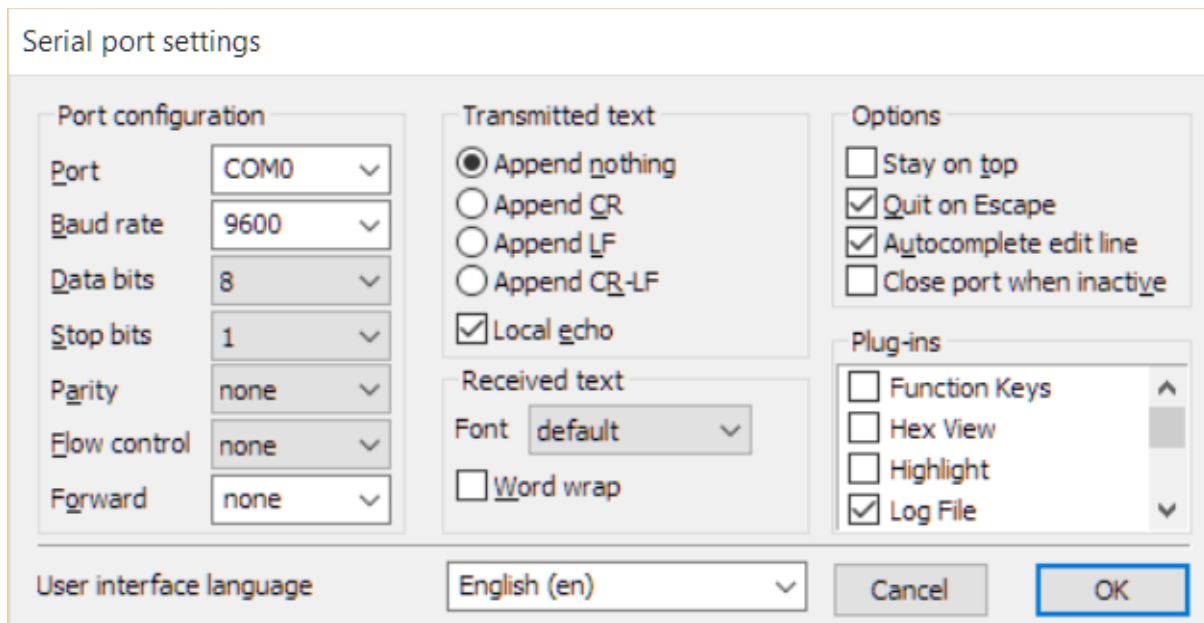


Fig 5.2 Termit Serial Port Settings

5.1.2 USB to UART

USB to UART Converter is a very useful tool for Embedded Systems. It provides bridging between a USB port and an enhanced UART serial port. The TUSB3410 contains all the necessary logic to communicate with the host computer using the USB bus. It contains an 8052 microcontroller unit (MCU) with 16K bytes of RAM that can be loaded from the host or from the external on-board memory via an I2C bus. It also contains 10K bytes of ROM that allow the MCU to configure the USB port at boot time. The ROM code also contains an I2C boot loader. All device functions, such as the USB command decoding, UART setup, and error reporting, are managed by the internal MCU firmware under the auspices of the PC host. The SAT0045 can be used to build an interface between a legacy serial peripheral device and a PC with USB ports, such as a legacy-free PC. Once configured, data flows from the host to the TUSB3410 via USB OUT commands and then out from the TUSB3410 on the SOUT line. Conversely, data flows into the TUSB3410 on the SIN line and then into the host via USB IN commands.

5.1.3 Micro-controller PIC16F877a

The micro controller memory is used to store the incoming data and broadcast it to the receiver using the LED. The PIC micro controller is programmed to relay the stored data in a continuous loop. The stored data is also displayed on the LCD panel as a reference to the sender. The MPLAB IDE is the platform used to program the micro-controller to perform the desired functions. The embedded C language is used to write the firmware, the software that will control the hardware aspects of the embedded application. Compile, assemble and link the software using the assembler and/or compiler and linker to convert your code into ones and zeroes machine code for the PIC micro MCUs. This machine code will eventually become the firmware. Here, the firmware contains code to display the message in the LCD panel, which is stored in the MC memory and also continuously transmit the data to the LED circuit.

5.1.4 Information Sender Circuit

The schematic for the transmitter was a simple n channel enhancement mode mosfet driving a CREE xlamp LED “warm white” element. Vcc was 4.7V from laptop’s USB, and the entire circuit including the LED at 100% duty cycle used 110 mA. IE: To make lamp very bright upgrade to a higher current (but as low-as-possible voltage) LED for brighter PWM, thus higher gain at high switching speeds. Essentially, data was transmitted via TTL RS-232, at 8 data bits, no parity, and 1 stop bit, from a vanilla freesoc UART module.

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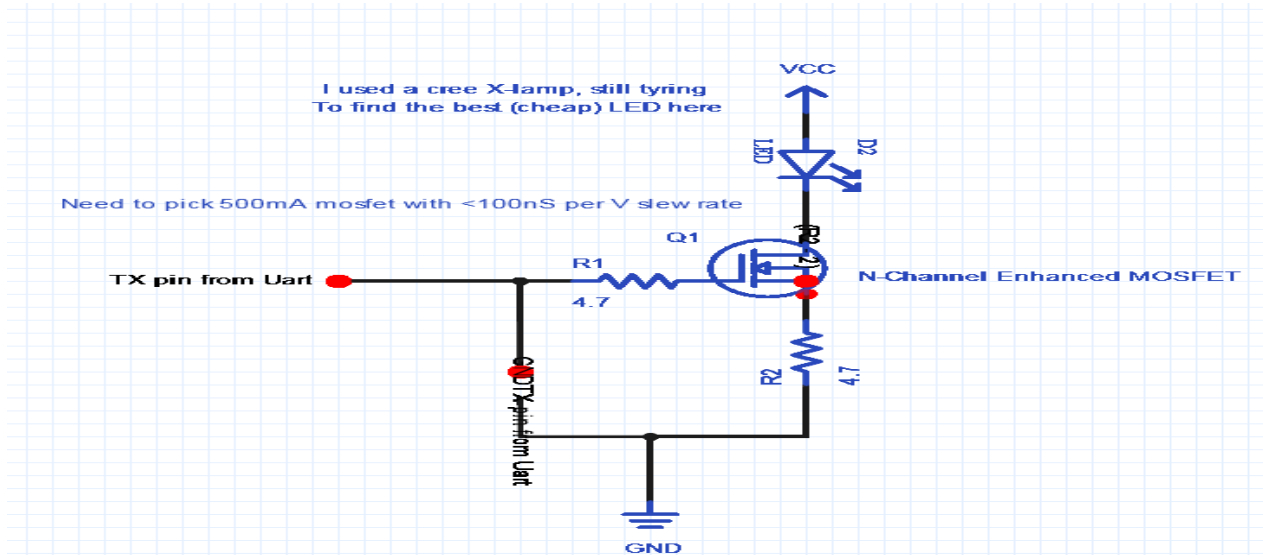


Fig 5.3 Information Sender Circuit

5.2 Receiver Module

This module consists of the following components:

- i) Information Receiver Circuit
- ii) USB to UART module
- iii) Client System

The receiver module detects the changes in the intensity of light from the LED. These changes generate a corresponding pulses of current which is thentransmitted to the client system and the data is received and display using the Termite terminal.

5.2.1 Information Receiver Circuit

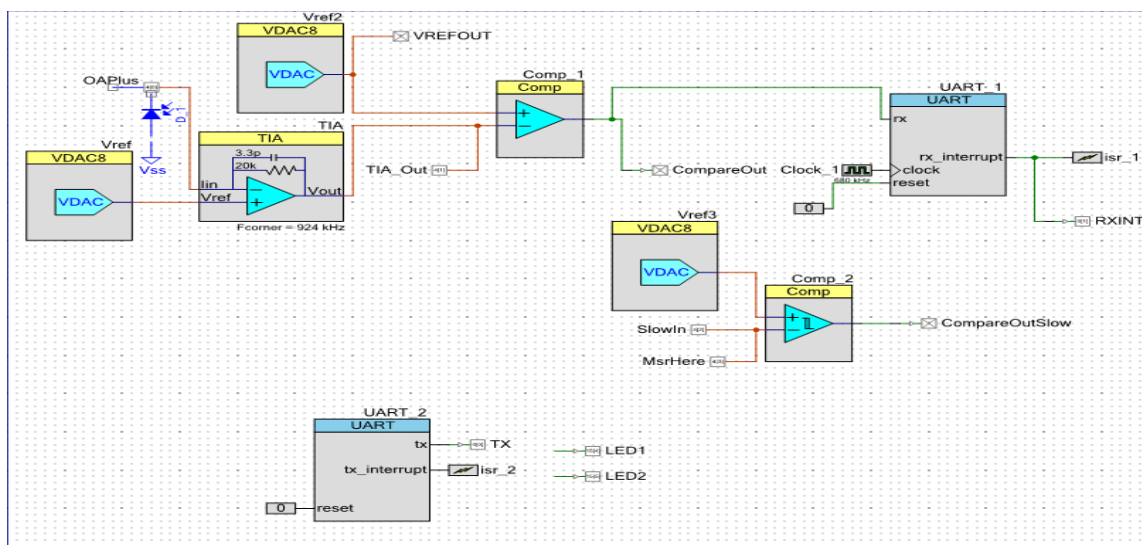


Fig 6.2 Information Receiver Circuit



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Vol. 3, Issue 11, November 2015

The receiver section consists of photodiode to receive the incoming light signals. These light signals are then demodulated and filtered. The filtered signal is amplified and passed to the USB to UART module.

5.2.2 Client System

The independent system which requires the data that is present in the server system. The drivers for USB to UART module are also installed in the Client system. The terminal Termite 3.1 is installed and configured identical to the server system.

VI. CONCLUSION

With the development of the technology, and its application for the industrial use, it can be put into practical use, every bulb can be used something like a Wi-Fi hotspot to transmit wireless data and we will proceed toward the cleaner, greener, safer and brighter future. The concept of VLC system is currently attracting a great deal of interest, not least because it may offer a genuine and very efficient alternative to radio-based wireless. As a growing number of people and their many devices access wireless internet, on one way, it can transmit the data at higher rate and on the other it is very cheap as compared with Wi-Fi. The airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. This may solve issues such as the shortage of radio-frequency bandwidth and also allows internet where traditional radio based wireless isn't allowed such as aircraft or hospitals.

VII. FUTURE ENHANCEMENTS

- i) VLC system has great potential in the field of wireless data transmission. It is a promising alternative to conventional methods of wireless communications that use radio waves as data carrier.
- ii) Many enhancements can be made to the existing technology. For example, encoding and decoding can be implemented directly in the transmitter and receiver part of the circuit. This would reduce error in transmission.
- iii) Also, by using fast-switching LEDs, data transmission rates can be further enhanced. The driving speed of the circuit can be improved by using fast switching transistors.
- iv) Here it can be concluded that data rate can be increased by decreasing the size of LED bulb, for example the LED can be reduced from 1mm to 1 μ m for high data rate. The data rate can also be increased by increasing the number and ON-OFF switching of LEDs.
- v) The data rate is in the range of 150 Mbps to 10 Gbps and can further be increased with some new up gradation and parameters.
- vi) If this technology is put into full-fledged practical use, every LED can be used like a Wi-Fi hotspot to transmit wireless data. This can lead us to a safer and greener future.

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