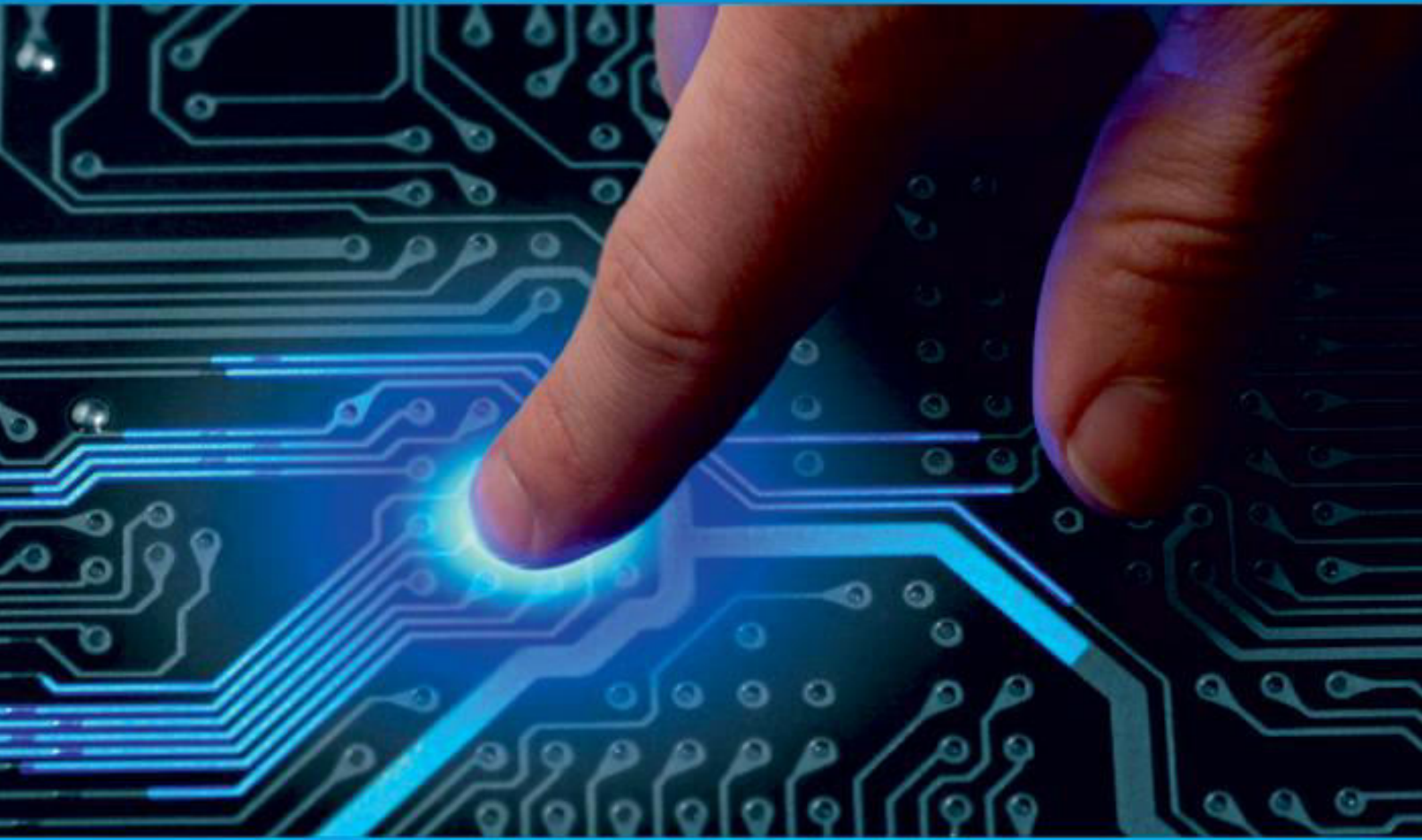




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Design and Implementation of Visible Light Communication System

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ABSTRACT: Visible light from light emitting diodes (LEDs) is used to communicate information in "communication by light," or VLC as it is known in English. The transmission of information is carried out by controlling and manipulating the light that LEDs emit using a computing device and some hardware. The information carried by the modulated light is demodulated on the receiver side by a photo-detector, which is often coupled to a comparable processing device for the information's final recovery. In this article, we discuss a VLC-based application that transmits text/audio from Arduino utilising OOK (On-Off Keying) modulation. Embedded-C was used as the programming language, and many Little Bit modules (LEDs and a sensor light) were also used.

KEYWORDS: VLC, Image transmission, Arduino, Embedded-C,OOK.

I. INTRODUCTION

Visible Light Communication (i.e.VLC)[1,2],can be used to transmit audio, voice and data. It uses laser light or light from emitter diodes (LEDs) and light detectors at the transmit and receive ends respectively (Fig. 1). It works in the 380 nm to 780 nm optical band which is visible light and hence the name VLC[3,4,5].

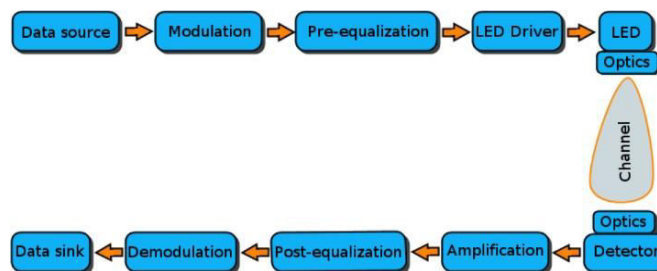


Fig.1.A basic VLC link structure.

To convey information this one has to be coded ,and then the light has to be modulated at the transmitter side and demodulated at the receiver side. There are several methods to do this, some are briefly discussed in the following. Then, the received information has to be decoded and processed to recover it fully. The success of this recovery depends of several factors, among them:1)The number, shape, and wavelength of the LEDs employed; 2) The number and type of light detectors(photo-resistor, photodiode, reverse-biased LED, etc.) used; 3)The encoding method (RZ, NRZ, NRZP, etc.); 4)The Modulation scheme (OOK,WPM,VWPM,PPM,OFDM,etc.), and 5) The synchronization and distance between the LEDs and the light detector. Remember that VLC is a technology that among other things, it requires line-of-sight between emitter and receiver[6].

This paper describes an application based on VLC using OOK (On-Off Keying) modulation, to transmit as-a-proof of concept, color images using a Arduino as the data source and data sink (to simplify the synchronization problem between emitter and receiver),Embedded-C as the programming language,and several modules (LEDs and a sensor light) from Little Bits, to easy the hardware implementation.

The remainder of this paper is organized as follows: Section II presents a summary of works related to the transmission

of digital images using VLC. Section III describes the design of the VLC application. Section IV describe the experiments realized, the results obtained, and their analysis. Finally, the conclusions and future work are presented in Section V.

II. RELATED WORKS

A. How based VLC image systems work

Typical based VLC text/audio systems are implemented using an intensity modulation and direct detection (IM/DD) scheme with a line-of-sight (LOS) configuration [7]. In the transmitter, IM is implemented through the modulation of the transmitted signal into the instantaneous optical power of the LED optics by controlling the radiant intensity with the forward current through the LED (High modulation frequencies are used to avoid flicker). In the receiver, the transmitted signal is recovered using direct detection (DD). In this simple method, a photodiode (or array) is used to convert the incident optical signal power into a proportional current. Figure 2 shows a general flow chart for VLC image transmission [8].

B. VLC Image Transmitter

A typical based VLC image transmitter contains an image generator (a PC with Matlab to convert the image into bits), an interface (usually a USB cable) to send the bits to a microcontroller (for coding and modulation), and take through one of its output ports to the LED driver and the LED optics. See Fig. 2. [9]. The modulated signals are used to switch on-an-off the LEDs at desired frequencies using LED drivers. These drivers rely on trans conductance amplifiers to convert voltage signals into corresponding current signals to excite the LEDs array for communication purposes.

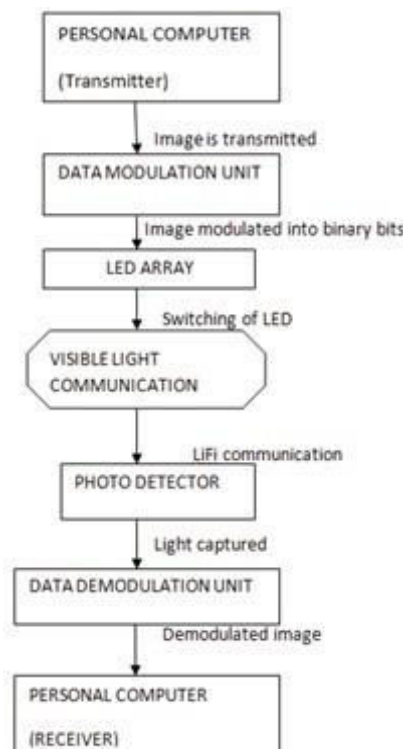


Fig. 2. A flowchart for VLC image transmission and reception.

C. VLC Modulation

Although there are different modulation schemes for VLC ,mainly, on-off keying (OOK),variable pulse-position modulation (VPPM), color shift keying (CSK) and orthogonal frequency division multiplexing (OFDM) [10], OOK is the most popular.OOK is the most commonly used IM/DD modulation scheme in VLC due to its simple implementation. In this method basically the LED intensity is changed between two distinguishable levels corresponding to the data bits (1 or0). See Fig.3.

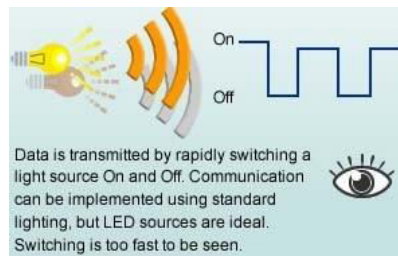


Fig. 3. On-Off Keying.

A. VLC Image Receiver

A typical optical text/audio receiver consists of a photo detector followed by an amplifier. The photo detector can be a phototransistor, a reverse-biased LED, or a Light Detect Resistor (LDR). The light captured by the photo detector which acts as sensor, passes the output to the data demodulation output.

a sensor, passes the output to the Data Demodulation Unit, and the original image is recovered using Matlab software in the PC. See Figure 2 [8,9].

I. TRANSMISSION&RECEPTIONWITHVLC

In the following we develop a VLC application to transmit and receive in real-time, an image using two LEDs in the transmitter, and a photo detector in the receiver.

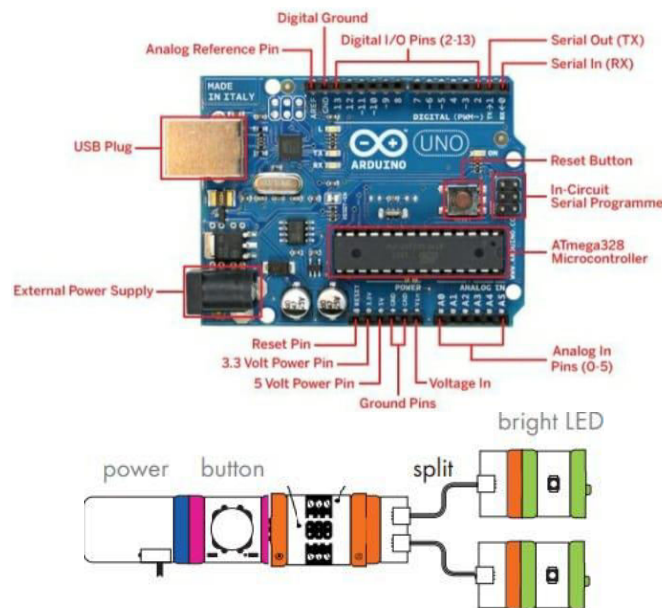


Fig.4. Arduino, power, button, proto, split and two LEDs.

While in the receiver we will use three Little Bits components: power, light sensor, and another proto bit. See Fig. 5. The light sensor captures the light emitted by the two LEDs and converts it into a digital signal which is fed to the proto module. The proto module in turn sends this signal toward the SPI MISO (Master Input Slave Output) input Interface (Pin21 in Fig.4) of the Arduino.



Fig 5. Receiver components: Light sensor and proto bits

A. Transmitting an text/audio via VLC

To transmit an text/audio via VLC, the Arduino with a script written in Embedded-C, opens a file (“lenna.jpeg”) and it reads it into a byte array “b”. Then with a “for” loop reads byte by byte of the picture and it send them to the SPI MOSI output port 19, using the *spi.xfer ()* directive. This MOSI output is fed using two wire connectors (signal and ground), into the input of the “proto” module (lower middle connector in Fig. 5). The proto module outputs and split the OOK signals to drive the two LEDs. The Embedded-C code to execute the above mentioned is shown in Fig.6.

B. Transmitting an Image via VLC

To transmit an text/audio via VLC, the Arduino with a script written in Embedded-C, opens a picture file (“lenna.jpeg”) and it reads it into a byte array “b”. Then with a “for” loop reads byte by byte of the picture and it send them to the SPI MOSI output port 19, using the *spi.xfer ()* directive. This MOSI output is fed using two wire connectors (signal and ground), into the input of the “proto” module (lower middle connector in Fig. 5). The proto module outputs and split the OOK signals to drive the two LEDs. The Embedded-C code to execute the above mentioned is shown in Fig.6.

These LEDs are simple yellow LEDs with a wavelength of 550-to-600 nm, luminous flux of 4-to-5 lm, and consume around 16-to-20 mA each, with an aperture angle of about 120degrees. See Fig.7.



Fig.7.Little Bits bright LED.

C. Receiving an text/audio via VLC

As it was mentioned, the picture was sent via VLC as LED light. This light is received through a light sensor module which then sent it back through out another proto module, to the MISO port 21 of the Arduino. This light sensor not only receives the OOK light signals but also has a trans impedance amplifier for high speed operation. The light sensor has 2 modes, Fig. 5. In LIGHT mode, as the light shining on the sensor gets brighter, more signal passes through it. In DARK mode, the signal increases as it gets darker. Furthermore, the light sensor has a sensitivity dialer slide dimmer to adjust how much light it takes to change the signal, and has a spectral sensitivity range from 500-to-600nm similar the LEDs wavelength. The recovered picture from the SPI MISO input is stored into a buffer, saved and displayed, as can be seen from the last 9 Python code lines of Fig.6.

III. RESULTS

For the experiments we use as was mentioned a Arduino with several Little Bits components. The whole setup is shown in Fig.8.

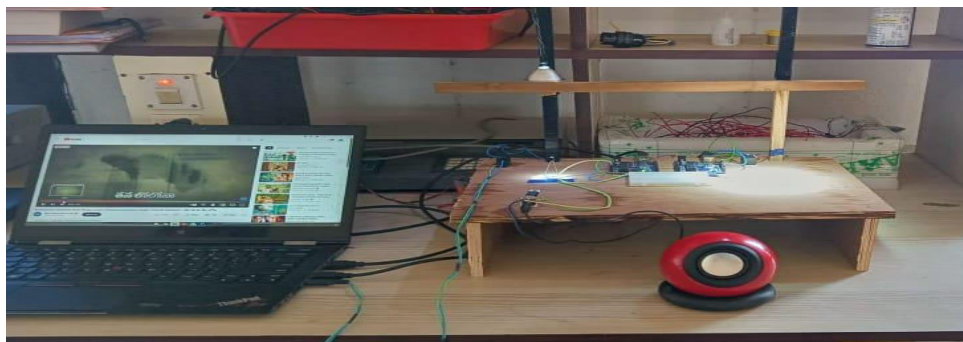


Fig.8.Setup for the transmission and reception of images using VLC

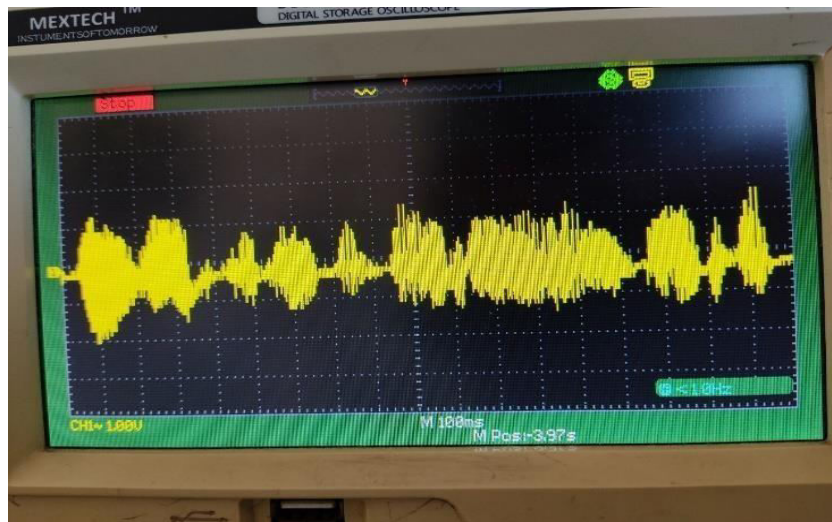


Fig.9.a Wave form of transmitter block

Fig.8 shows the Arduino Board connected through out bus connections to a HP display. The figure also shows the recovered picture after the execution of the line command “*sudopythonlena_spi.py*”. Fig.9a.



Fig;9b waveform of receiver block

Fig. 9b also shows that the recovered picture was no perfect. That was due to the presence of noise, mainly: Fluorescent light from ceiling lamps, misalignment and distance between LEDs and light sensor, and low sensitivity from the sensor.

A. Discussion of Results

After several adjustments to the setup and a few intents, the picture was finally well recovered. The whole transmission and recovering of a audio/image weighting 8Kbytes, took less than a second. See Fig. 10. Naturally, the noise cannot completely eliminated and increases when the misalignment and the distance between the LEDs and the light sensor is larger. Also the brightness of the LEDs influence the performance. That was the main reason for using two LEDs in parallel to increase the amount of light sent to the light sensor.

This work differs with respect to similar works a sin[8],[9] and [11], in the following. In [8] only a design model is proposed without any proof of implementation. In[9], a hardware setup is showed, but again, there is not any proof of sending and receiving any picture the serial transmission and reception of two 24 x 25 color pictures, but without using visible light communication.

IV. CONCLUSIONS

An image transmission and reception application using VLC was developed using a Arduino, two bright LEDs and a light sensor from Little Bits ,OOK modulation. The text/audio, was recovered acceptably well although with a small

presence of noise. It should be noted that this noise is due to environment light, and the distance between the LEDs and the light sensor. Additionally, the alignment between the LEDs and the light sensor influences the reception, and consequently the quality of the text/audio reproduction. This application could be improved by: 1) Increasing the number and/or power of the LEDs to increase the reception distance; and 2) Implement a synchronization mechanism for LEDs-to-light sensor.

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