Internet Access over Visible Light

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Abstract

Visible light communication (VLC) is one of the alternative optical-based wireless communication that can substitute the role of radio frequency (RF) communication because the RF cannot reach a very closed room (eg a basement or underground place). There are various of VLC applications in which one of them is light fidelity (LiFi) for secure/private internet access through the available lighting infrastructure (LED bulb). In this paper, we present the design, implementation, and demonstration of the TCP/IP data-exchanged over visible light within two computers in which the system architecture is efficient and compliance with IEEE 802.15.7. It is built with low-end components. This short paper is brief discussion version from our previous research involving: Data-network selection, System-on-chip (SoC) development, booting the Xillinux OS [9], MAC layer design in Python language [10] and its evaluations. This paper will more highlight the physical part (PHY layer) of the analog front-end transceiver.

Keywords: Internet access, VLC, LiFi

1. Introduction

Along with the increase in consumer's number and their electronic gadgets, the need for data communications wirelessly will also increase from year to year. As a result, the bandwidth usage in the radio frequency spectrum, which has been widely used so far, will be crowded. It can be overcome by exploiting the bandwidth on another spectrum that is safe for human health, that is the visible light spectrum that lies between 380 nm to 780 nm. The application of this visible light communication (VLC) system is in the form of indoor communication instead of Wi-Fi, where the popular term is called as Li-Fi **[1-6]**.

In this paper, we discuss the design and implementation of Li-Fi using off-shelf components in which the overall system is illustrated in Fig. 1 consisting two FPGAs for DSP transceiver, Analog blocks, and two computers (1 acts as host and the second one acts as user client). This paper is a summary of our previous studies related to Li-Fi **[7-8]**, and our system is proved that it can able to be used for real-time streaming video **[9]** as well as digital image transmission. **[10]**. This paper is more highlight of the analog circuit transceiver architecture and the result of internet access demonstration via visible light with white LED as an antenna.

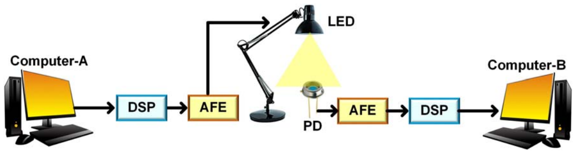

Fig 1. Proposed System for LiFi

2. Design and Implementation

a. Network Design, Selected OS and SoC design

Our work specifies that the number of the employed node is two units of personal computers and used the general topology (*i.e.* point-to-point). The FPGA Xilinx Zynq-7000 EPP development board was chosen as DSP transmitter and receiver. Xillinux OS uses to run MAC Layer software which is implemented in Python script. The processor block implementation is developed under the Vivado 2015.1 software in which this block will run the Xillinux OS. The detailed of this section is discussed in **[7]**.

b. MAC Layer

The MAC layer is in compliance with the IEEE 802.15.7 standard. The design and implementation of our MAC layer is discussed clearly in **[8]**.

c. Analog Front-End Transceiver

The analog front-end (AFE) transceiver consist of transmitter and receiver.

In the transmitter section, there is a switch LED driver circuit **[11]** that serves as an intermediate circuit between the modulated signal from the digital signal processing part and the LED (Fig. 2a). Specifications of LED driver include 9W LED power, digital input signal with 3.3V for high value and 0V for low value, and 12V power supply voltage. Light on the LED will be raised with a certain intensity level.

For the implementation of LED driver circuit, emitter follower configuration with single LED was used. The LED module used is Coochip® Hyrite Lighting production. Co. Based on the datasheet, a Coochip® LED module requires a forward voltage (Vf) of 12V with forward current (If) of 750 mA. However, we used 9V for Vf value. It aims to reduce the power consumed by LEDs.

The transistor used in the circuit is C1972. This transistor is a Radio Frequency NPN transistor manufactured by Mitsubishi Semiconductors. This transistor can control the collector bias current (I_C) to 3.5A and the maximum frequency of 175MHz, so it is considered good enough to be used in LED driver circuit.

While the AFE circuit in the receiver section involves of several parts, namely trans-impedance amplifier (TIA), Non-inverting Amplifier, Comparator, and Transistor switch as shown in Fig. 2(b). The specifications of the AFE receiver circuit include fixed position, an operating frequency of about 100 kHz, a digital output signal with a voltage of 3.3V for high and 0V for low values, a bias current of about 10-2 mA, and a power supply voltage of ± 5 V and 3.3V.

TIA acts to convert the current signal into a voltage signal **[12]**. For the implementation of TIA circuit, the op-amp OPA620KP was used. As for photodiode, we employed BPW34.

The Non-inverting Amplifier circuit serves to increase the output voltage of the TIA circuit to match the input specifications of the comparator circuit. The op-amp used is TL072.

The function of comparator circuit is for conditioning its output signal circuit into a fully digital signal. It will have a high and low value in accordance with the specified threshold. In our system, the digital condition has a high value of 5V and a low of 0V.

The last stage is switch circuit that has function to change the output voltage of the comparator output to match the standard voltage level of 3.3V. This circuit will continue the high value of 3.3V if the input is given a high voltage, and will break the current if the low voltage, so that the voltage at the output will be equal to ground.

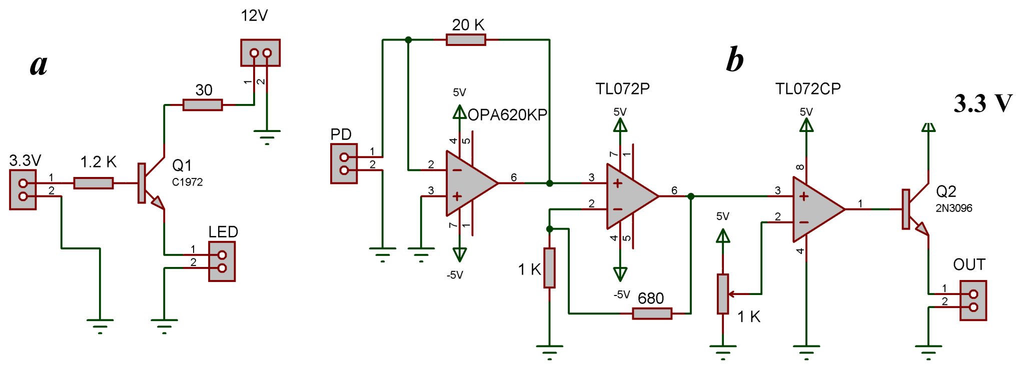

Fig 2. AFE Transceiver Circuit

d. System Demonstration

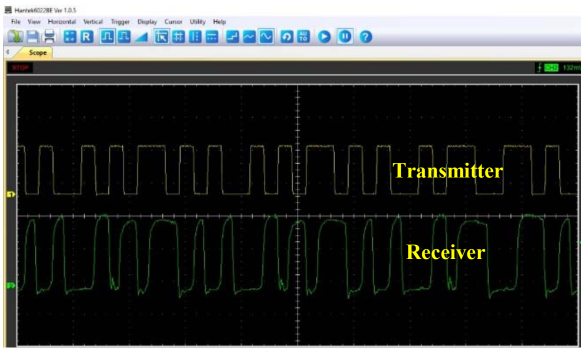

Fig 3. AFE test

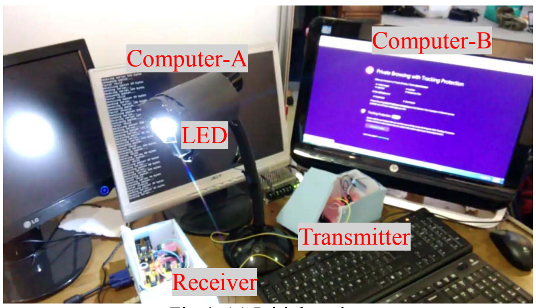

Fig 4. (a) Initial setting

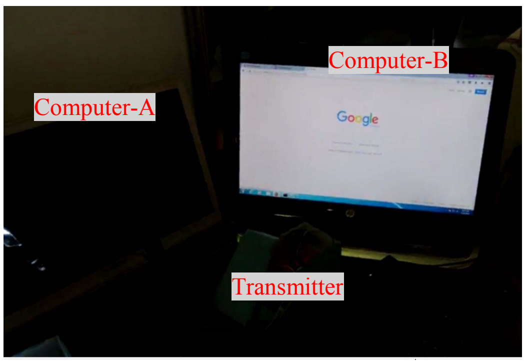

Fig 5. (b) Success the LiFi demo

To demonstrate our LiFi system, several procedures must be conducted as presented with detail in the previous papers **[7-10]**. Fig. 3 shows the AFE transceiver test, it can be seen that the received signal is similar with transmitted signal. The effective bandwidth is about 100 kHz.

In brief summary, the internet browsing is successfully demonstrated as well. The demo is visualized in Fig. 4(a) and Fig. 4(b). We obtained 33 mm of average latency and 11 kilo Bit per second of transfer speed.

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e. Conclusion

We develop LiFi system that consist of analog front-end transceiver and FPGA as DSP. The real-time internet access via visible light is successfully demonstrated. The detailed of each block is elaborated in separated paper **[7-10]**. The demo video can be seen in the following link: https://www.youtube.com/watch?v=9H6J-H8PdrY.

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