An Optical Channel Based on Illumination to Link Home Devices

Tang-Jen Liu and Fenq-Lin Jenq
Far East University, Taiwan (R.O.C.)

***Abstract*--Developing visible-light communication (VLC) with easy-to-use circuit modules in order to be integrated with consumer electronics could facilitate VLC technology adopted in more wireless applications for home. The study first implements functions of lighting for reading and data transmitting with a white organic light-emitting diode (OLED) panel. A method to keep the two functions implemented on the same lighting panel from interfering with each other is proposed and investigated. For data transmission, an optical receiver working with the OLED-based data transmitter to organize an optical channel is also proposed with a cost-effective approach based on a mature infrared receiver module. Under the recommended illuminance of 500 lux for reading and office work, home devices can receive codes in 2404 bps with the low-cost and convenient optical channel.**

I. INTRODUCTION

Transferring information with light was developed early. Nowadays, laser is used for high-speed and long-distance data travelling [1], and infrared is common for remote control on some home devices [2]. Visible lights for illumination are considered as necessities in modern lives. For example, people usually work at their places where are illuminated with lamps on the table and the ceiling for partial and global areas. The beams from these lamps can behave as optical channels for data moving. Among artificial lighting, organic light-emitting diodes (OLEDs) can serve comfortable light with high luminous efficacy for home, such as the applications introduced in [3]. The laminated illuminant brings about preferable flat illumination without the need of the lens to diffuse the point light provided with light-emitting diodes (LEDs). In addition, the semiconductor light source had been modulated over the range of kilohertz [4] that offers wider bandwidth for communication than those non-semiconductor illuminants. As a result, the visible light ranging from 450 nm to 750 nm emitted by the OLED panel used in the study is considered not only to serve for illumination but also to exhibit data bits with its beam.

At home, the infrared (IR) receiver module working with a 38K Hz infrared carrier is inexpensive and common for receiving optical data within the space of rooms. It receives bits in low speeds that are less than 2500 bps [5]. However, its stable performance and the compact package help the study to implement a visible-light channel to transmit data from the white OLED lamp to the home devices illuminated by it with the light intensity of 500 lux. Before receiving white-light data with the IR receiver module, a conversion of the wavelength from the visible white light to the invisible infrared used by the IR receiver module has to be applied. In other words, the carrier signal inside the optical channel exhibited with the visible white light has to be rebuilt with the infrared compatible with the input requirements of the IR receiver module.

Besides the optical channel conversion is developed, another effort in the study is to maintain the lighting performance of the white OLED panel constant no matter if it is being used for data transmission or not with the beam. In this paper, the operation of the optical channel conversion is proposed. Its performance is investigated with the results obtained at the receiver end of the channel while the variation of the light intensity is monitored all the time with a luxmeter.

II. MODULE DESIGN

A. *Transmitter Implemented on an OLED Lamp*

Fig. 1 illustrates the scheme of the OLED lamp used as an optical transmitter in the study. The lamp prototype was design for Innovative and Superior Technology Inc. in Taiwan. To transmit data with the beam, to meet the input requirements of the IR receiver module used in the receiver end, and to maintain the light intensity constant for illumination purpose, the rules sketched in Fig. 2 is used to design the firmware of the micro-controller conducting the operation of the OLED panel in Fig. 1. Because only the carrier signal in 38K Hz can be recognized by the IR receiver module, the binary bits are expressed separately with a 38K Hz carrier and a non-38K Hz one in the study, as shown in Fig. 2. However, the duty cycle (DC) of the two carriers are the same for generating the same level of illumination. If there is a need to change the light intensity, both carriers will only be modified to another same DC.

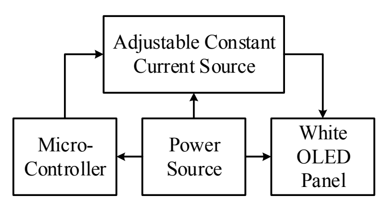

Fig. 1. Scheme of the OLED lamp used as an optical transmitter in the study.

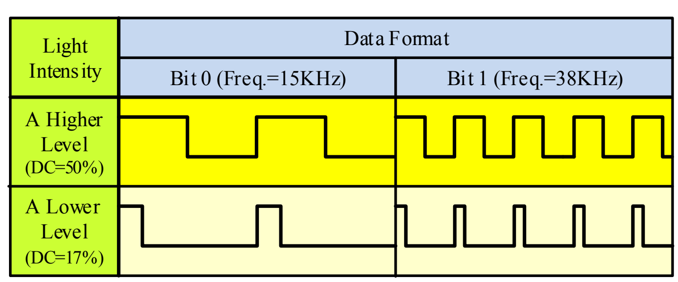

Fig. 2. Rules for carrier signals to implement data transmission and illumination at the same OLED panel.

B. Receiver with an IR Receiver Module Included

The IR receiver module recognizes the input signal according to its frequency and the wavelength of its carrier. Only the frequency of 38K Hz on infrared of 940 nm can be processed by the IR receiver module. To use the IR receiver module to filter, demodulate the received signal and return the data transmitted, the carrier needs to be transferred from the visible white light emitted by the OLED panel to the infrared one acceptable by the IR receiver module first. The conversion of the wavelength is achieved with the circuit shown in Fig. 3. In the figure, the optical signal was detected with a photodiode that responds to the wavelength of 660 nm with the sensitivity of 0.45 A/W. The current output is then transferred to a voltage one by use of resister R_1. The voltage across R_1 is then enlarged by an instrumentation amplifier (IA) and is re-transmitted with the infrared of 940 nm by means of an IR LED. The signal repeated by the IR LED (Fig. 3) is then received by an IR receiver module close to it. Each bit generated at the output of the IR receiver module is then collected by a micro-controller to figure out the code composed of these bits.

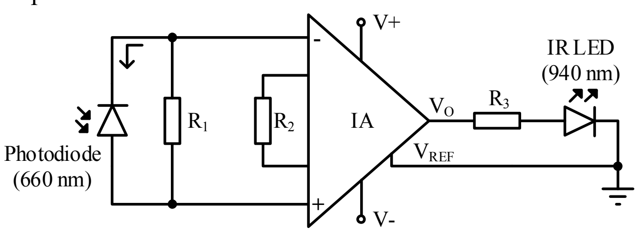

Fig. 3. Circuit for wavelength conversion from 660 nm to 940 nm.

III. RESULTS

According to the optical transmitter and the receiver mentioned above, an OLED lamp prototype (Fig. 1) used for illumination and data transmission is implemented, as shown in Fig. 4. The optical receiver module works with the OLED lamp is carried out as shown in Fig. 5. Before data transmitting, the OLED lamp offers illuminance of 500 lux at the position of the photodiode on the receiver. Then the data transmitted were generated bit by bit at 2404 bps by the micro-controller and presented with the beam emitted from the OLED panel. Then it was obtained that the receiver shown in Fig. 5 figured out the code correctly in time and a luxmeter did not reveal any difference on the light intensity from the lamp before and after the progress of data transmission.

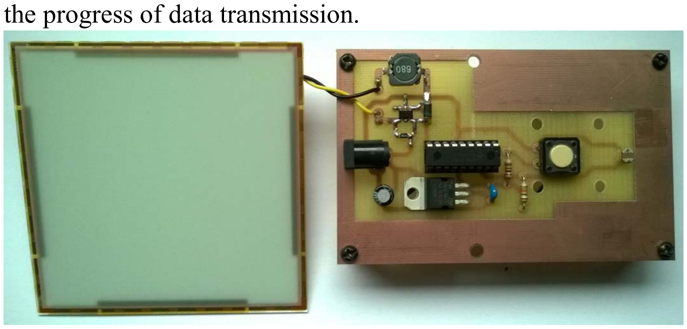

Fig. 4. A white OLED panel and its controller for a lamp prototype. Besides used for illumination, it is also operated as an optical transmitter.

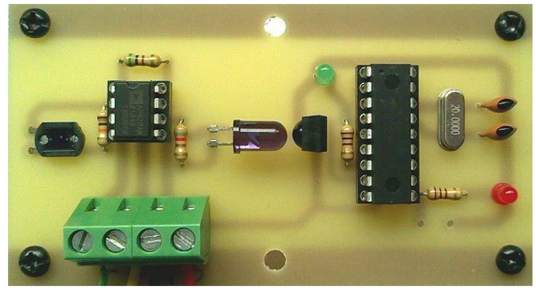

Fig. 5. An optical receiver works with the transmitter (Fig. 4). The conversion of the wavelength shown in Fig. 3 is implemented at the left half part.

IV. DISCUSSIONS

Utilizing the carrier in two different frequencies to present the binary states effectively reduces the load of the signal processing circuit to eliminate the background light noise. In Fig. 3, all the circuit done is to repeat and amplify the signal detected by the photodiode responding mainly to the wavelength of 660 nm into the same one but exhibiting with the infrared of 940 nm. The IR receiver module will filter out the light with its wavelength outside 940 nm and all non-38K Hz signals even the wavelength of the carrier is 940 nm. As a result, the optical receiver is adequately immune and is compact as shown in Fig. 5 that is feasible to be integrated into home devices or consumer electronics.

A limitation on the illuminance of the OLED lamp comes with the use of the IR receiver module and the rules in Fig. 2. To present the periodic signal of 38K Hz, the duty cycle can not be 100%. In other words, the OLED panel can not be activated completely for data transmission. Of course, the OLED panel can optionally light up fully with the function of data transmission temporarily suspended.

The conversion of the wavelength used for the optical link (Fig. 3) proposed here makes it possible to receive data with the mature IR receiver module no matter what wavelength of light is used to transmit data if an optical sensor responding to the semiconductor light source can be found. To transfer the optical signal detected by the sensor to its electrical counterpart, then to enhance the electrical one and use it to drive the IR LED working with the IR receiver module, the wavelength conversion can be achieved to build a low-cost and convenient optical link.

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