American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-9, pp-278-283
www.ajer.org
Research Paper Open Access

Flexible Color Controller In Visible Light Communication System

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ABSTRACT :*The research proposes the visible light communication (VLC) technique for flexible color control. The system creates the desired color from three primary colors of Red, Green and Blue in both lighting and communication. The proposed system uses 3 switches to select 7 color states independently and immediately according to surrounding environment such as mood, music, food, and so on. Instead, the fixed color is embedded in the convenient VLC system. By doing so, the VLC system can generate the clearly mixed color even in low data speed. The blocks of modulation and demodulation are loaded on chip FPGA at 50 MHz clock by merging VPPM and PPM techniques. The experiment also measures the distance capacity in various supply currents in which the system still receives correct data.*

KEYWORDS *Visible light communication, color-independent VLC, RGB LED, FPGA, VLC modulation*

Date of Submission:13-09-2018 Date of acceptance: 28-09-2018

I. INTRODUCTION

Light-emitting diode (LED) has been considered as the most promising lighting device for the future lighting technology. LEDs can be used for wireless optical communication due to characteristics of high modulation rate and short response time. Visible light communication (VLC) is a wireless communication method which uses visible light wave as carrier of information [1-2]. In VLC system, LED can be used for illumination and communication at the same time. The VLC system has many attractive features such as occupying no RF spectrum, unlicensed bandwidth, immunity to electromagnetic interference and low energy cost [3-4].

In the Fig. 1, the LEDs are used for both illumination and wireless data transmission. Here, data is transmitted to LED which plays a role as a hub for transferring data to computer. In orderto control the brightness of the visible light communication systems, the IEEE 802.15.7 standard proposed by the Institute of Electrical and Electronics Engineers (IEEE) introduced Variable Pulse Position Modulation (VPPM) technique. The VPPM technique changes the working cycle of each transferred bit to control the brightness [5]. It is necessary to control the pulse width of each bit cycle. To implement the VPPM scheme, if the data is logic '0', the signal will be modulated from the right. If the data is logic '1', the signal will be modulated from the left. [7-8].

In order to control color, there primary colors of red, green, blue (RGB) LED is combined to create the various colors. The input current of LED can be changed to control the LED color that was implemented by dimming method. The dimming solutions can change both LED colors and brightness for various applications [6] [8]. Usually, most of applications use white LED in VLC system [9]. However, data diversity is very useful for emotional applications. Emotional lighting can be changed according to surrounding environments such as mood, music, food, temperature, and energy saving. Illumination scheme builds VLC system not only supplying the light for user but also varying the different colors for emotional purposes. Pulse Width Modulation (PWM) scheme is used to generate any colors by sequencing the time slot for displaying RGB colors [9-10]. A fixed slot time is reserved for each color.

The color VLC scheme can also be designed by using pulse width modulation to control color or combining both VPPM technique and PWM technique to allow control both brightness and color [10].However, displaying RGB color in way that is shown in time sequence causing the flickerphenomenon.

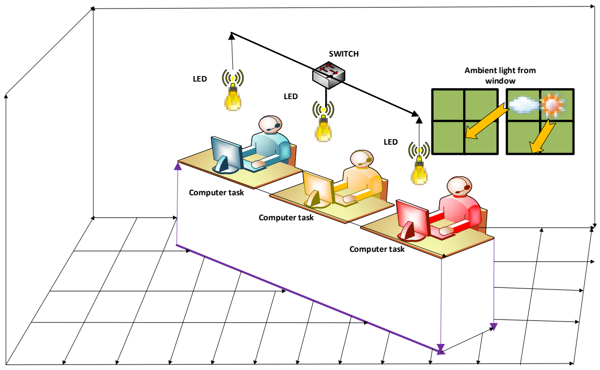

Fig.1 VLC system using white LEDs which are used for both illumination and wireless data transmission.

It is because "1" level width is so short that human eye can detect switching from "1" level to "0" level. The color combination is created by "1" levels of Red, Green, Blue colors in turn. If speed of these colors is slow, the color combination may be shown only single color. In other consideration, a color-independent VLC modulation scheme was published that generated all colors in visible range. However, it is only in simulation without any modulation hardware suggestion [11].

In this paper, the color combination is created by three primary colors in parallel. By doing so, the three-LED light density is tripled compared to single LED light density. It means that a lower power generator can be used to save cost and each color is created distinctly. The proposed modulation scheme that is the parallel color combination together with merging both VPPM and VPM techniques, proves lower cost, power loss and flexible color control.

Moreover, the conventional technique controls the color and brightness in the sequential light method. Thus, the bit output rate has to be defined in advance to determine the type of color combination. Then, this rate has to be programmed fixedly in chip for each application. The color combination is fixed according to each color. It is detrimental to emotional applications. The proposed flexible color controller allows users easily control the switches or rotate knob to adjust the illumination intensity.

II. PRINCIPLES OF THE FLEXIBLE COLOR CONTROL SYSTEM

The visible light communication not only transmits data but also uses color light to make more emotional applications by RGB LEDs. By combining three primary colors of Red, Green and Blue to create the desired color in the media, we will use up all of the visible light spectrums.

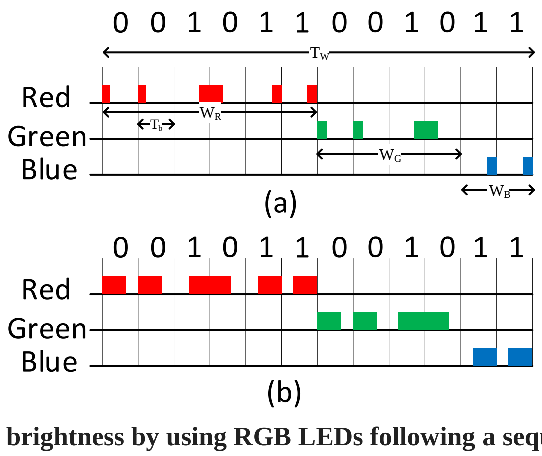

Fig. 2: Controlling color and brightness by using RGB LEDs following a sequential light method (a)30% brightness (b)70% brightness .

Figure 2 shows the waveform of combining VPPM technique and PWM technique for controlling both color and brightness. For color control, three basic LEDs with Red, Green, and Blue can create any colors by changing the ratio of the 3 RGB LED output bits. For example, with a 3-LED ratio of RGB 1: 1: 1, we achieve white light, or a ratio of 1: 1: 0, we get yellow. To control brightness, we change the pulse width of each bit cycle according to IEEE 802.15.7 standard. Figure 2 (a) shows color and brightness control with a pulse width of 30% bit cycle. Figure 2 (b) shows the color and brightness control with pulse width of 70% bit cycle. In this conventional technique, it is only possible to transmit one bit per LED at one time. Thus, a larger size of LED arrays is required to gain high power transmission and increase the illumination intensity. Thus, the system should be designed to control color and brightness using parallel light LEDs. The conventional control method can set any colors if data speed is enough fast to merging there primary colors. This is because data is transmitted in sequential way in each color as shown in figure 2.

The conventional technique controls color and brightness of RGB LED sequentially. Here, the light can be set any colors but the color generation needs to be intervened by the software of the system. Because the RGB ratio has to be updated according to the desired color by reprograming FPGA chips, the conventional system will not facilitate the simple reality applications in selecting light color. Sometimes, users want to change the desired color immediately but the conventional technique takes certain amount of time to reprogram controlling the color and brightness. For this reason, the research proposes technique to control RGB LED lights synchronously by three switches.

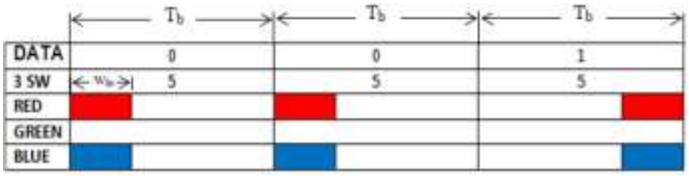

Fig. 3. Combining PWM and VPPM is proposed for controlling color and brightness, W_{Br} = 30% T_b, 3 switches are selected at 101.

The fig. 3 shows the timing waveform of combining modulation technique of PWM and VPPM for controlling color and brightness. Here, the three switches are selected at '101', so combination output generates pink color, with brightness bit width of W_{Br}= 30% T_b. Here, only red and blue color is activated to brightness with $W_R=W_B=W_{Br}=30\%T_b$ while the green color is off.

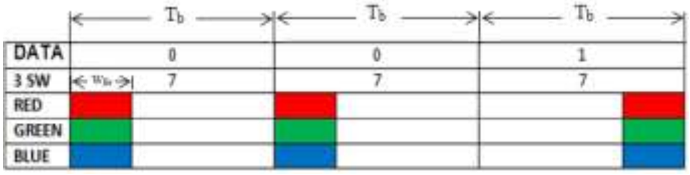

Fig. 4. Combining PWM and VPPM is proposed for controlling color and brightness, W_{Br} = 30% T_b, 3 switches are selected at 111.

The Fig. 4 shows the 3 switches are selected at 111, so the output shows white color, $W_R = W_G = W_B = W_{Br}$=30% T_b. The advantage of this proposed method is that data is transmitted in parallel way, increasing transmission power. It is noted that the system can be changed in the brightness and color depending on the application and environment by varying W_{Br}.

The fig. 5 shows block diagram of VLC modulation. VLC modulation uses same VPPM and PWM technique for the both sequential color light transmission and parallel color light transmission. The fig. 5 (a) shows block diagram of VLC modulation according to the sequential color light transmission method. Here, the color is created by rate of RGB in sequential order. It means that only one of red, green or blue color is generated and transmitted at one time which is representative for one data bit. The transmission time reserved for one color may be more than one bit as shown in fig. 2. Here, red color is transmitted in 6 bits, green color is transmitted in 4 bits, and blue color is transmitted in 2 bits. Because the transmission data speed is often quite fast, human eye can recognize the desired color as result of the combination rate of RGB color. If bit speed is slightly slow or period of single color is quite long, human eye just detect combination color as result of single colors. In addition, the desired color is programmed on chip for only a specific application and it takes some times for reprogramming. In this convenient technique, we cannot change the interested color according to surrounding environment unless we reprogram a different rate of RGB LED to find out the suitable color in VLC system.

Figure 5 (b) shows the block diagram of VLC modulation based on parallel light color transmission technique. Similarly, the inputs of system also include clk50M, data and RST. Three switches that play a role as 3-bit select signal, SW [2:0], is used as selective inputs. Because three primary colors are transmitted simultaneously, the color combination is mixed by there switches, named as SW [2:0] signal. Thus, even the bit

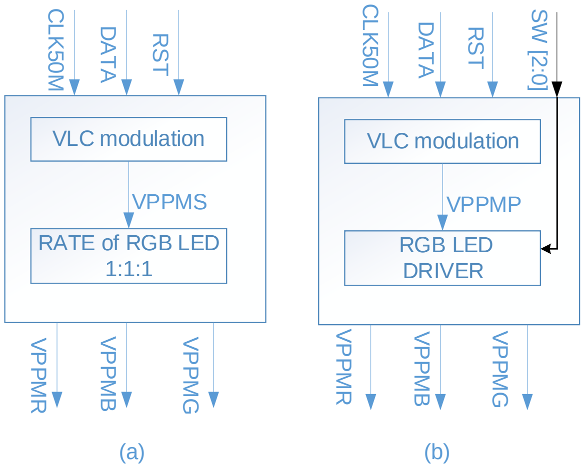

Fig. 5 Block diagram of VLC modulation (a). sequential color light transmission technique. (b) parallel color light transmission technique.

speed is quite slow, the desired color displays more clearly as a result of mixing three primary colors. The light density on three LEDs also increase three times compared to single LED.

III. SIMULATION AND EXPERIMENT RESULTS

In figure 6 and figure 7, we combine techniques of PWM and VPPM with 3 switches to control color and brightness of the RGB LED. The simulation data is 10 bits of "0001101100". The selective signal of SW [2:0] is 101 and 111 each test case. Each bit cycle is 200ns.

The source clock pulse is taken from FPGA chip at operation frequency of 50 MHz, named ck50mhz. The transmitted data is “0001101100”. The three control switches, SW [2: 0], is “101” in Fig. 3 and “111” in Fig. 4. The Vppmr signal is LED output with red color. The Vppmg output is LED output with green color. The Vppmb signal is LED output with blue color. When rst signal is "0" and the bit data is '0', the ck50Mhz signal starts counting 10 cycles. Here, the first 3-cycle output is set to '1', the last 7-cycle output is set to '0'. It means that the level ‘1’ is set to 30% bit cycle. Conversely, when rst = '0' and the data bit is '1', the ck50Mhz signal starts counting 10 cycles. Here, the first 7-cycle output is set to "0", the last 3-cycle output is set to '1'. It means that the level-1 is also set to 30% bit cycle in both bit ‘1’ and bit ‘0’.

Fig. 6 shows simulation results with 10-bit data and 3 switches at “101”. So, the mixed color is combination result of red and blue. Here, bit ‘0’ is encoded to symbol “10” and bit ‘1’ is encoded to symbol ‘01’. The duration of symbol ‘1’ is 30% bit cycle inencoded data “10” or “01” as explained in figure 3.

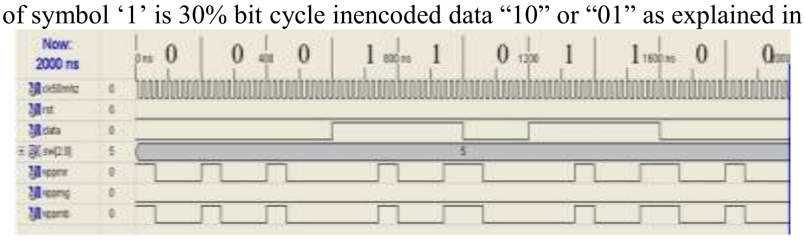

Fig. 6 Simulation result with 10-bit data “0001101100” and 3 switches are set at “101”.

Fig. 8 shows the demodulation waveform results in VLC receiver. The input of demodulation block is modulated Vppm signal which is modulated at the transmitter. The clock source is 50 MHz. The result shows the receiving data is demodulated to 10-bit data “0001101100” which is the same as the transmitted data.

Fig. 9 illustrates the whole VLC system consisting of receiver and transmitter. In this experiment, the computer is used to transmit data to FPGA through serial port. The FPGA implements VLC modulation by merging both PWM and VPPM techniques. The LED driver is used to synchronize the three different colors and makes sure that they display three colors at the same time. As a result, the color combination is got in effect. The LED array is a group of three RGB LEDs which are red LED, green LED and red LED. At the receiverside, a photodiode receives the light from these RGB LEDs. The photodiode sensitivity is very important to decide the bit speed of VLC system. The higher photodiode sensitivity, the more cost and higherspeed.

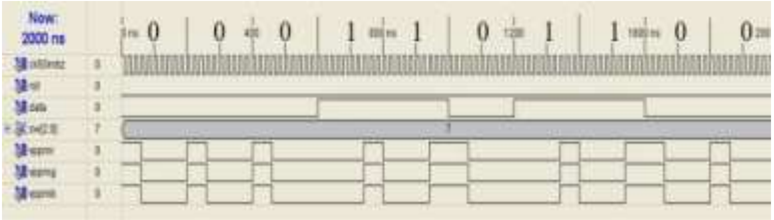

Fig. 8. Demodulation simulation results with 10-bit data "0001101100".

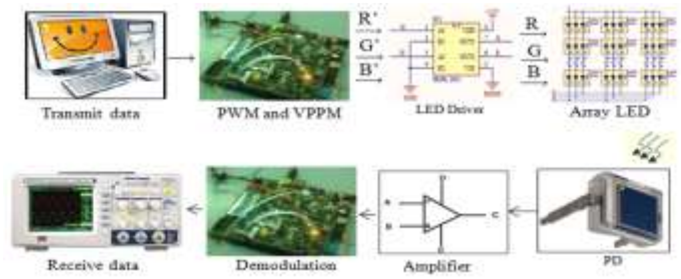

Fig. 9. Block diagram of transmitter and receiver of VLC system

Fig. 10. Diagram block of testing VLC communication system.

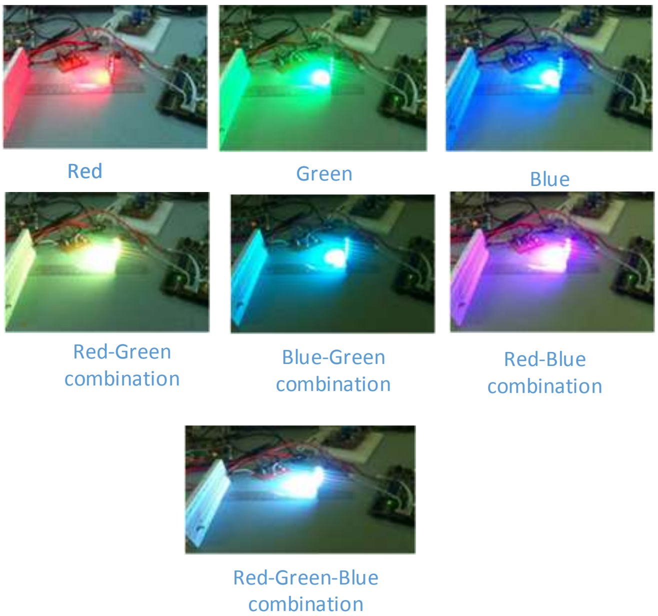

Fig. 11. Results in color combination to select 7 different colors.

In this measurement experiment, we use the commercial photodiodes for low cost applications. Thus, allowance speed is quite low to allow increasing higher bit accuracy. The signal from the photodiode is amplified in amplitude and is put to the VLC demodulation FPGA block. The modulated data is presented to oscilloscope display or computer.

An experiment test is implemented in laboratory. Here, we use two FPGA kits for VLC modulation at transmitter side and VLC demodulation at receiver side as shown in Figure 10.

Fig.11 shows seven different colors from group combinations of three primary colors of red, green, and blue which create differently mixed colors of red, green, blue, red-green, blue-green, red-blue and blue-green. By choosing the flexible colors from switches, the preferred color is used for both illumination and data transmission.

Table 1 shows the maximum distance which receiver can implement demodulation and achieve right data correctly. The various currents are supplied to RGB LEDs to increase the light density and test the capacity of data transmission distance while the proposed system still guarantees the received data correctly. The maximum distance is measured in consideration of the accurately received data.

Table 1 Testing The Distance Of Receiving Accuracy Data By Applying Various Currents At 5 Khz Clock

Current (mA)	Distance (cm)
43	18
50	20
65	24
75	26
85	30
95	30

IV. CONCLUSION

The research proposes the combination technique of PWM and VPPM to modulate/demodulate the VLC system and uses 3 switches to control flexibly mixed colors and brightness from three primary colors. The external switches select immediately the desired color according to surrounding environment based emotional purposes. The three primary colors are transmitted simultaneously in parallel way, thus the mixed color is very clear even in low data speed compared to the fixed color and high speed requirement in the conventional technique. The commercial RGB LEDs and photodiodes are used in low cost for this experiment.

REFERENCES

[1]. Parth .H. Pathak, et al, “Visible light communication, networking and sensing: a survey, potential and challenges”,IEEE Communication Surveys & Tutorials, vol 17, 2015 pp. 2047-2077.

[2]. Christian Pohlmann, “Visible Light Communication, Seminar Kommunikationsstandards”, In der Medizintechnik, 29. June 2010.

[3]. Eun Tae Won, Dongjae Shin, D.K. Jung, Y.J. Oh, Taehan Bae, Hyuk-Choon Kwon, Chihong Cho, Jaeseung Son, Dominic O’Brien, Tae-Gyu Kang, Tom Matsumura, “Visible Light Communication_ Tutorial”,University of Oxford, 9 March 2008.

[4]. Khald Werfli, et al, “Experimental Demonstration of High-Speed 4 × 4 Imaging Multi-CAP MIMO Visible Light Communications”, Journal of Lightwave Technology, Vol. 36, No. 10, 2018.

[5]. Huan-Minh Vo, “File transfer system with computer using visible light communication technology on FPGA”, 2016 International Conference on System Science and Engineering (ICSSE), pp. 1-3, 2016.

[6]. FAHAD ZAFAR, et al, “ Dimming schemes for visible light communication: the state of research”, IEEE Wireless Communication, April 2015.

[7]. H. Sugiyama, S. Haruyama, and M. Nagagawa, “Experimental Investigation of Modulation Method for Visible-Light Communications,” IEICE Trans. Commun., vol. E89-B, no. 12, Dec. 2006, pp. 3393-3400.

[8]. Xiang Liu; Aiying Yang; Yankun Li; Lihui Feng, “Separate dimming controlling and data transmission for an indoor visiblelight communication system”, China Communications, Vol. 12, No. 3, pp. 71 – 76, 2015.

[9]. K. Choi et al., “Visible Light Communications with Color and Dimming Control by Employing VPPM Coding,” Proc. ICUFN, July 2012, pp. 10-12.

[10]. Kyungmook Choi, Yunseon Jang, MinChul Ju, and Youngil Park, “Visible Light Communication with Color and Brightness Control of RGB LEDs”,ETRI Journal, Volume 35, Number 5, October 2013, pp 927-4.

[11]. P. Das et al., “Color-Independent VLC Based on a Color Space without Sending Target Color Information,” Optics Communication, vol. 286, Jan. 2012, pp. 69-73.

Minh-Huan Vo "Flexible Color Controller In Visible Light Communication System "American Journal of Engineering Research (AJER), vol. 7, no. 09, 2018, pp. 278-283