Performance Analysis of LED Driver for Transmitter of Visible Light Communication Using Pulse Width Modulation

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Abstract—Visible Light Communication (VLC) enables high speed internet access especially in indoor environments and works on the principle of modulation of the intensity of existing solid state lighting infrastructure that is often provided by Light-Emitting Diodes (LEDs). In order to analyze the performance, this study examined the effect of using the LT8391 LED driver as a VLC transmitter. By modifying the circuit of the LT8391 LED driver, Vin can be pressed to 5.5 V, while Vout can be enlarged to reach 32.8 V. In addition, the modulation method used is Pulse Width Modulation (PWM). Blinks can be minimized by adjusting the duty cycle of the PWM. Finally, data transmission is realized with no blinking effect, so it will not disturb the room's lighting system.

Keywords—Visible light communication, LED driver, pulse width modulation, blinking effect

I. INTRODUCTION

Recently, wireless communication has been rapidly developed and widely implemented. Normally, Radio Frequency (RF) is the most widely used technology, such as for Wi-Fi [1], Bluetooth [1-3], and Zigbee [4,5]. However, wireless communication using RF technology has limitation of spectrum, efficiency, and security [6]. Due to harmful impact of radiations, another wireless technology is needed for health care application [7].

Visible Light Communication (VLC) is a harmless solution to overcome the limitation of radio spectrum for wireless communication. Visible light band occupies the frequency range from 400 THz to 800 THz, which is much higher than radio waves and micro waves as illustrated in Fig. 1. Therefore, the VLC does not interfere with the use of other the wireless communication technology [6]. Since the VLC is line-of-sight access, the VLC is secure and user cannot easily overhear in another room [8]. The VLC allows information to be transmitted by modulating the intensity of a light source.

Light Emitting Diodes (LEDs) allow the construction of low cost VLC system, especially for indoor applications. Due to unique characteristic of high switching rate, the LEDs become the most suitable light source for the VLC [8,9]. With the latest developments for energy efficient light sources for room lighting, LED light bulbs are rapidly replacing previous light source. It makes the LEDs has much stronger reason to be used for the VLC.

On-Off Keying (OOK) is well known as the simplest modulation type. Data “0” and “1” are represented by light off and on, respectively, or vice versa. Since the modulation can only encode in two states (On/Off), only digital data can be modulated. Hence, it is inefficient in bandwidth utilization. The OOK is widely used, however it has effect on lighting function. Since LED light bulb has the main function for room lighting, flicker or blinking effect must be avoided. Therefore, suitable modulation in the transmitter is needed. In order to avoid flicker, Pulse Width Modulation (PWM) is used. The PWM is a type of modulation which pulse width is varied based on the data. The pulse width or known as duty cycle can be configured in the state of “0” and “1” to avoid blinking [10]. So, in the case of LED light bulb usage, the PWM may minimize the blinking effect caused by the OOK.

In this paper, research on LT8391 LED driver usage as VLC transmitter is reported. The LT8391 LED driver is used to convert input voltage becomes smaller and gain output voltage. The PWM is used based on microcontroller arduino UNO to minimize blinking effect during data transmission. Performance analysis of the PWM usage on the VLC transmitter is also reported.

The paper is organized as follows: Section II describes material and method. It is followed by Section III, which describes results along with the discussions. Finally, conclusion is stated in Section IV. Future work is also presented in the last Section.

II. MATERIAL AND METHOD

A. Material

This research was conducted using several devices, such as DC power supply, LED 34 V/10 W, LT8391 LED driver, Arduino UNO, oscilloscope. The VLC transmitter circuit is shown in Fig. 2. Basically, the circuit is designed to increase switching speed, so blinking effect can be minimized during high speed data transmission. One important thing is the...
circuit is based on DC2345A module with modification of all transistors are replaced by PMOS transistors.

IC LT8391 is a Buck-Boost 4 synchronous switch LED controller that regulates LED current from the initial input voltage to be smaller, equal to or greater at the output voltage. With 4 V to 60 V inputs, 0 V to 60 V outputs, and smooth low noise transitions between operating regions. LT8391 is ideal for LED driver and battery charger applications in automotive, industrial and battery powered systems. LT8391 provides PWM dimming for internal (up to 128: 1) and external LED currents (up to 2000: 1) with P-MOS switches. In addition, LT8391 provides protection in the event of a short circuit on the LED by automatically rebooting the system [11].

As the LED 34 V/10 W requires an input voltage of 30-34 V, while the LT8391 only has an output of 25 V @ 2 A, it needs to be configured to get the suitable voltage for the LED. The configuration was done by changing the voltage multiplier resistance in Vout. Since pin FB of the LT8391 (see Fig. 3) has regulation voltage about 1 V [11], based on Eq. (1), $R_1$ and $R_4$ are modified to 510 kΩ and 15 kΩ, respectively, to get about 34 V of Vout.

The arduino UNO is used to realize PWM. In this research, the VLC transmitter is tested using “U” character transmission. The “U” character has ASCII code of 0x55 or 0b01010101. Program listing for realizing PWM using arduino UNO is as follows.

```c
char data_buffer[9];
unsigned int PWM_speed, pwm0, pwm1;
unsigned int PWM1_modulated[9];
unsigned char index;
int lamp_pin = 10;

unsigned int fungsi_1PWM(char data_PWM) {  
  if (data_PWM == 0) {  
    return pwm0;  
  } else {  
    return pwm1;  
  }
}

void modulation_1PWM(char data_PWM) {  
  pwm0 = 1500;
  pwm1 = 900;
  space = 800;
  header = 2000;
  hold = 2500;
  data_buffer[1] = data_PWM & 0x01;
  data_buffer[2] = (data_PWM >> 1) & 0x01;
  data_buffer[3] = (data_PWM >> 2) & 0x01;
  data_buffer[4] = (data_PWM >> 3) & 0x01;
  data_buffer[5] = (data_PWM >> 4) & 0x01;
  data_buffer[6] = (data_PWM >> 5) & 0x01;
  data_buffer[7] = (data_PWM >> 6) & 0x01;
  data_buffer[8] = (data_PWM >> 7) & 0x01;
  for (index = 1; index < 9; index++) {  
```

Fig. 2. Schematic circuit of the VLC transmitter

Fig. 3. Voltage multiplier for Vout

$$V_{out} = 1 \times \frac{R_3 + R_4}{R_4}$$ (1)
From the experimental results, it can be concluded that the LED driver circuit can use PWM with a duty cycle of at least 20% and maximum of 100%. If the duty cycle is smaller than 20%, the LED driver does not work properly for switching. Furthermore the PWM and the data transmission cannot be realized. In this case, the output voltage of the circuit is affected by the duty cycle of the PWM.

B. Method

Experiments are focused on the performance of the LED driver after some modifications. The experiments were conducted based on output voltage simulation using LT Spice, output voltage regarding duty cycle of the PWM, and ASCII code transmission. The LT Spice is used because the free software provide simulation for LT8391. The duty cycle effect and ASCII code transmission are confirmed by using oscilloscope.

III. RESULTS AND DISCUSSIONS

Performance of the VLC transmitter is expressed by simulation and experiment results. The results are as follow.

A. LT Spice simulation of output voltage

Before changing resistor value of R3 and R4, the circuit (see Fig.2) was simulated using LT Spice. The simulation result is shown Fig. 4. It illustrates that with 5.5 V input voltage, using the LT8391 can produce 32.8 V output voltage. It indicates that the output voltage is in the input voltage range of LED 34 V/10 W.

B. Output voltage correspond to duty cycle of PWM

Experiment setup is show in Fig. 5. The experiments were confirmed using oscilloscope. The duty cycle is varied from 0 - 100%. Two experiment results are shown in Figs. 6 and 7. The figures show output voltage of the arduino (dark blue) and the LED (light blue) as the result of duty cycle adjustment.
been designed using PWM. The data sent in this experiment is 0b01010101. The experiment result is shown in Fig. 8. The dark blue one is input from arduino to the LT8391. While the light blue one is output from the LT8391 to the LED. The solid and dashed lined boxes indicate the binary data and header, respectively. It seems the PWM happens in the LED with suitable input voltage. It affects to minimize blinking effect. In this case, advanced research and adjustment are necessary to make the PWM result precisely represents the binary data and header.

Fig. 8. Experiment result of “U” transmission

IV. CONCLUSION AND FUTURE WORK

The main goal of this research work was analyzing the performance of the LED driver which is used as VLC transmitter with PWM. The smaller duty cycle percentage may maximize the output voltage until 32.8 V. While maximum duty cycle (100%) produces 30 V output voltage, although not stable. Furthermore, PWM happened successfully with suitable voltage for the LED and supports low blinking effect.

In the future, photo diode based VLC receiver needs to be designed for realizing point to point data transmission. The VLC system need to be developed based on IEEE 802.3 standard. Then, research on FPGA (Field Programmable Gate Array) implementation for digital signal processing module will have more benefits in the future of VLC systems.

ACKNOWLEDGMENT

The experiment was done at Agency for the Assessment and Application of Technology, Indonesia. Authors would like to thank Dr. Sasono Rahardjo and Mr. Dena Karunianto Wibowo for valuable discussion and assistance. This work is also supported by Lembag Penelitian dan Pengabdian Masyarakat Universitas Brawijaya (LPPM - UB) through Doktor Mengabdi (Award No. 438.28/UN10.C10/P.M/2020).

REFERENCES


C. ASCII code transmission

As explained in the previous section, data transmission is tested using character “U”. The following are the results of sending data to the transmitter using the LED driver that has

TABLE I. EXPERIMENT RESULTS OF DUTY CYCLE VARIATION

<table>
<thead>
<tr>
<th>No</th>
<th>DC</th>
<th>Vin (V)</th>
<th>In (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>DC(Out)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20%</td>
<td>5.3</td>
<td>0.6</td>
<td>32.8</td>
<td>0.070</td>
<td>19.29%</td>
</tr>
<tr>
<td>2</td>
<td>25%</td>
<td>5.3</td>
<td>0.8</td>
<td>32.8</td>
<td>0.087</td>
<td>24.49%</td>
</tr>
<tr>
<td>3</td>
<td>30%</td>
<td>5.2</td>
<td>0.9</td>
<td>32.8</td>
<td>0.102</td>
<td>29.04%</td>
</tr>
<tr>
<td>4</td>
<td>35%</td>
<td>5.1</td>
<td>1.0</td>
<td>32.4</td>
<td>0.114</td>
<td>33.82%</td>
</tr>
<tr>
<td>5</td>
<td>40%</td>
<td>5.1</td>
<td>1.1</td>
<td>32.4</td>
<td>0.127</td>
<td>37.77%</td>
</tr>
<tr>
<td>6</td>
<td>45%</td>
<td>5.0</td>
<td>1.2</td>
<td>32.0</td>
<td>0.140</td>
<td>43.21%</td>
</tr>
<tr>
<td>7</td>
<td>50%</td>
<td>4.9</td>
<td>1.3</td>
<td>32.3</td>
<td>0.151</td>
<td>48.19%</td>
</tr>
<tr>
<td>8</td>
<td>55%</td>
<td>4.9</td>
<td>1.4</td>
<td>32.4</td>
<td>0.161</td>
<td>54.19%</td>
</tr>
<tr>
<td>9</td>
<td>60%</td>
<td>4.8</td>
<td>1.5</td>
<td>32.8</td>
<td>0.171</td>
<td>58.73%</td>
</tr>
<tr>
<td>10</td>
<td>65%</td>
<td>4.8</td>
<td>1.6</td>
<td>32.4</td>
<td>0.181</td>
<td>64.54%</td>
</tr>
<tr>
<td>11</td>
<td>70%</td>
<td>4.7</td>
<td>1.7</td>
<td>31.6</td>
<td>0.190</td>
<td>68.79%</td>
</tr>
<tr>
<td>12</td>
<td>75%</td>
<td>4.7</td>
<td>1.8</td>
<td>32.4</td>
<td>0.197</td>
<td>72.50%</td>
</tr>
<tr>
<td>13</td>
<td>80%</td>
<td>4.6</td>
<td>1.8</td>
<td>32.0</td>
<td>0.196</td>
<td>78.60%</td>
</tr>
<tr>
<td>14</td>
<td>85%</td>
<td>4.5</td>
<td>1.8</td>
<td>31.2</td>
<td>0.196</td>
<td>84.54%</td>
</tr>
<tr>
<td>15</td>
<td>90%</td>
<td>4.5</td>
<td>1.8</td>
<td>31.2</td>
<td>0.196</td>
<td>88.58%</td>
</tr>
<tr>
<td>16</td>
<td>95%</td>
<td>4.4</td>
<td>1.8</td>
<td>30.4</td>
<td>0.195</td>
<td>93.73%</td>
</tr>
<tr>
<td>17</td>
<td>100%</td>
<td>4.3</td>
<td>1.8</td>
<td>30.0</td>
<td>0.194</td>
<td>99.16%</td>
</tr>
</tbody>
</table>

*DC: Duty cycle  *Frequency: 490 Hz
IEEE International Conference on Computational Approach in Smart Systems Design and Applications, pp. 1-6, August 2018.


