감성조명 시스템을 위한 색온도 조정 가능한 LED 조명

Jia Liu, 김훈, 김희준
한양대학교 전자전기제어계측공학과

An LED Lighting with Varying Color Temperature for Emotional Lighting Systems

Jia Liu, Hoon Kim, Hee-Jun Kim
Department of Electronics, Electrical, Control, and Instrumentation Engineering, Hanyang University

Abstract - This paper presents an LED lighting which can control its color temperature. It consists of a power factor correction (PFC) circuit, an LED driver, and an LED color control circuit. The proposed system can adjusts the light intensity to obtain a desired color with independently changeable illuminance. The power factor of the PFC circuit is 98%. The LED driver has 90% efficiency at 300mA output current. The output power of the experimented LED lighting is 150 W. The achieved color temperature range was from 3000K to 7500K, and the illumination one was from 500 lux to 1500 lux.

1. Introduction

Light emitting diode (LED) lightings have a great potential recently due to its long lifetime and small size [1]. Especially, an LED lighting composed of the red, green, and blue (RGB) LEDs can change its light color by adjusting the light intensity of each LEDs. There are several approaches to obtain multicolor LED lightings. The crucial point is the control of the contribution for each color LEDs.

Pulse Width Modulation (PWM) is widely used in controlling the LED lights. An LED color control system reported in [2] obtain the linear relationship between tristimulus values and PWM dimming duty cycles. There were a number of measured data which may cause inaccuracy to this linear relationship. Since there is no direct relation between tristimulus values and illuminance, the LED light intensity may be changed by varying the color temperature.

This paper proposed an emotional LED lighting system with a color temperature change algorithm. The system can directly control the LED color with independently changeable illuminance.

2. Proposed LED Lighting System

2.1 Proposed Control System

Red, green, blue, and white (RGBW) LEDs can generate various colors. The proposed system adjusts the light intensity of each LEDs to achieve a required color. Fig. 1 shows the configuration of the proposed color control system. An LED module and a driver module cooperate to implement the color change control of LED lights.

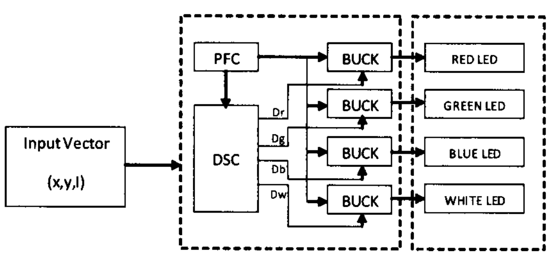


Fig. 1 Block diagram of LED lighting system

In the LED driver module, the power factor correction (PFC) circuit provides DC powers to the LED driver circuits and the digital LED color controller. The LED driver supplies constant driving current to the LED module. The digital controller controls the driving current with the color temperature algorithm.

The same color LED are connected in series, while every four color LEDs forms a group and they are placed closely to create a well mixed light.

The color control system converts an input vector to the required PWM duty cycles for each LEDs using the color control algorithm which is implemented by the digital controller. The PWM signal adjusts LED driving currents to achieve a desired color.

2.2 Ballast for LED Module

The LED ballast provides the constant driving currents and the proper forward voltages for the LED module. The PFC circuit converts a AC voltage of an ordinary source to a DC voltage at a constant frequency for the LED driver. The power factor value should be big enough to achieve a high power efficiency. A dc-dc buck converter was used as the LED driver.

The LED driver offers a constant driving current for LED module. The power efficiency of the dc-dc converter achieves 90% at a operating current which is shown in Fig. 2. The output current of this ballast can be controlled by a PWM dimming signal. The frequency of the PWM dimming signal is appropriate to avoid the flicker of the LED lights.

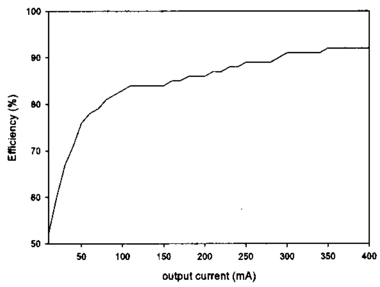


Fig. 2 Power efficiency of dc-dc converter

2.3 PWM Digital Control Module

This LED lighting system was proposed to achieve a desired color. According to the color mixing theory [3], the contribution of the red, green, and blue lights determines a mixed light color. Based on the LED ballast, the LED color controller was introduced to provide the adequate PWM dimming signals for the dc-dc converters.

The LED color control circuit uses the CIE 1931 color space [4] to input the requested color. A particular color in CIE 1931 color space can be expressed as a vector (x,y,I) [5]. This input vector includes three values. The x and y values are the color coordinate of a desired color. The desired color should be inside the color triangle area [4] made by a red, green, and blue LED lights. The third value of the input vector is the illuminance of the requested color. The x and y values are dimensionless while the I value have unites of *lux*. This input vector can completely describe the light with color and illuminance. Each LED lights has a particular (x,y,I) vector at a specific temperature and a driving current. The LED color controller receives the input vector and converts it to the PWM dimming signals for each LEDs.

The color change algorithm converts the input vector to the illuminance of a desired color. The PWM duty cycles can be obtained using a linear relationship between the illuminance and duty cycle [5]. The proposed LED lighting is based on four kinds of colors, red, green, blue, and white. The color temperature change algorithm is achieved by the following equation.

$$\begin{bmatrix} x_m \\ y_m \\ I_m \end{bmatrix} = \begin{bmatrix} \frac{x_r - x_m}{y_r} & \frac{x_g - x_m}{y_g} & \frac{x_b - x_m}{y_b} & \frac{x_w - x_m}{y_w} \\ \frac{y_r - y_m}{y_r} & \frac{y_r - y_m}{y_g} & \frac{y_r - y_m}{y_b} & \frac{y_r - y_m}{y_w} \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} I_R \\ I_G \\ I_B \\ I_W \end{bmatrix} \quad (1)$$

The (x_m,y_m,I_m) is the input value which represents a desired color. The (I_R,I_G,I_B,I_W) means the required illuminance for each LEDs. The x and y values represents the color coordinates of each LED lights with the subscript describing the LED color.

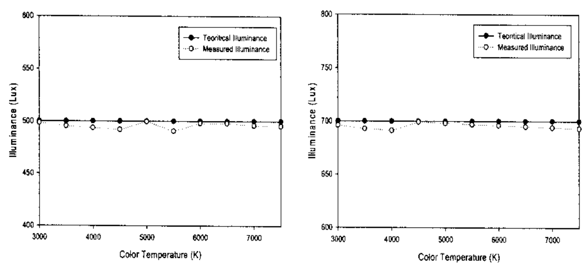
The PWM dimming duty cycles of LEDs can be achieved using the linear relation function of the illuminance and duty cycle. The linear function is determined by LED characteristics which vary form the different manufacture. The proper combination of the illuminance of each LED lights produces the desired color. The illuminance and color of the LED lights can be changed independently.

3. Experiment Results

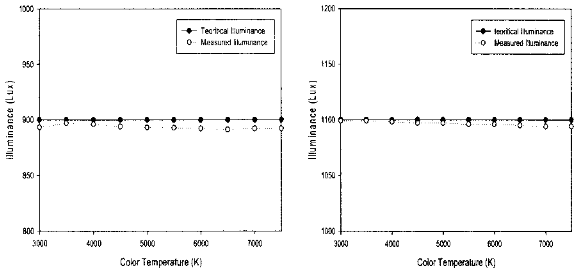
In the experimental system, we use LUXEON LEDs of Lumileds company which providing the LED color coordinate on the data sheet. The LED module is constructed by ten red LEDs, ten green LEDs, ten blue LEDs, and ten white LEDs. The LEDs are mounted on a heat sink. The HV3402 chip is used as the constant current driver for the LED module. The color change algorithm is implemented in the digital controller supplying the PWM signal for the LED drivers. There is a 4x4 keyboard in the LED color controller to set the desired color. This digital controller can communicate with a computer through RS232.

The LED color change system was first calibrated at a fixed temperature by adjusting four driving currents for red, green, blue, and white LEDs. The KONICA MINOLTA CL-200 colorimeter was used to test the color coordinates and illuminance of the achieved color.

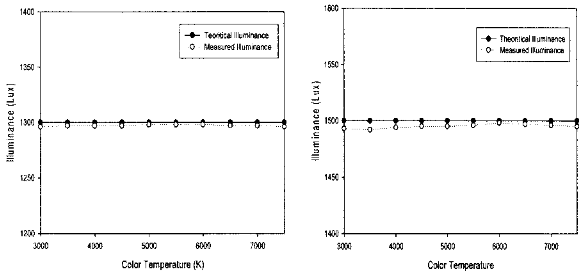
Fig.3 illustrates the results of changing LED color temperature while maintaining the illuminance. The change of the illuminance was less than 2% under the color temperature from 3000 K to 7500K. The color deviation was $\Delta T \leq$ 100K with the illuminance level of 70%.



(a) Illuminance =500 lux (b) Illuminance =700 lux



(c) Illuminance =900 lux (d) Illuminance =1100 lux



(e) Illuminance =1300 lux (f) Illuminance =1500 lux

Fig. 3 Results of changing color temperature while maintaining illuminance

4. Conclusion

An emotional LED lighting with color change algorithm has been proposed in this paper. This system can change the LEDs color and illuminance separately. The results show the illuminance stability over varying color temperature. This multicolor LED lighting control system can be applied to outdoor building or commercial space illumination.

[Reference]

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