The modulation of LEDs driving current and duration ratio in application of Color-Sequential Pico-Projector

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Abstract --- *In this paper, the modulation of LEDs driving current and duration ratio for white balance in pico-projector display were proposed. We designed two different conditions and two modes with driving current and duration ratio modulation to achieve white region presented by CIE. In considering of the pico-projector brightness, the RGB LEDs duration ratio operated with 0.4/0.29/0.25 offered flux outputs up to 96.8 lm. While consideration of power consumption, the RGB LEDs supplied 72 lm with duration ratio 0.33/0.35/0.3 and obtained the white point on Cx/Cy=0.302/0.303 under the LEDs driving power 1.35 watts.*

Keywords: white balance, CIE 1931, power consumption, lumens, pico-projector

INTRODUCTION

Nowadays, consuming electronic products, such as digital camera, mobile phone, mp3 player, etc, deeply affect our daily life. These popular products have common properties that are compact volume, reasonable power consumption, and friendly human computer interface. Therefore, a compact device that is able to integrate various functions intensively draws our interests. Mobile phone is a general platform already combining digital camera, music player, GPS, etc. However, the display size of mobile phone is limited and difficult to be extended within a reasonable phone volume accepted by consumers. Hence, a small-size projector imbedded in phone is a competitive solution for this issue. Color filter proposed by Politecnico di Milano, is a general method to control the specific colors reflected by panel pixels.[5] Phosphor-based white LED is commonly used to be the illumination engine for this type of projector. However, the luminous output is considerably wasted, because the reflectivity of color filter LcoS panel (Himex) is as low as 20%. Moreover, color rendering of phosphor-based white LED is difficult to be improved. LcoS panel with higher reflectivity and RGB LEDs source with CRI as high as 80 are exploited for color-sequential type projection[9]. Its driving mode also enables lower power consumption because the specific light color is turned on only when used. Furthermore, desired white balance is adjustable for relative durations of red, green, and blue fields are respectively controlled by pulse drive current and duration ratio.

In this paper, we propose a numerical LED drive mode analysis to achieve white light region according to CIE color space. Furthermore, three different purposes in consideration of LED life time, projection brightness and power consumption respectively are designed. The RGB LED source applied in the study is OSRAM SMT with a 2x2 RGGB LED array and the effective emission region is 4 mm^2 [3].

DESIGN METHOD AND EXPERIMETAL RESULTS

White balance performed by RGB LED array has been studied in LEDMAN's paper[2]. The relative flux output of red, green, and blue fields are designed as 30%/60%/10% to perform a white point (CIE 1931 Cx/Cy=0.3127/0.3291) on color temperature of 6500K. In this paper, drive current and duration ratio of RGB fields are both modulated to give a desired proportion of RGB light output, which is calculated as the following equation. [6]

$$I_{avg} = I_p \times T_{on\ time} * 1000 / P_{pr}$$

Where I_{avg} is the average light output; Ip is light output generated from a unit current pulse; $T_{on\ time}$ is turn-on time of LED light within a time frame; P_{pr} is pulse repetition rate. Our estimates of light flux available for projector illumination can be understood from an example portrayed in Table 1, based on the Osram SMT 40mil LEDs. For frame rate of 60 Hz, a complete RGB color cycle lasts 16.66 ms. Relative durations of red, green, and blue fields are modulated to achieve a desired white balance at the allowed pulse currents. In addition, two widely-used sequential drive mode, RRGGBB and RRGGBBGG as shown in figure 1, are both considered for design purposes.

Figure 2 shows our experimental scheme containing an LED drive board (HXP307SH2)[7], an integrating sphere (ISM-180, integrating sphere size of 12inch) and Osram OSTAR-SMT LED (LE ATB S2W)[3]. The drive board controlling the drive current of RGB LEDs and RGB-field durations is commanded by a computer.

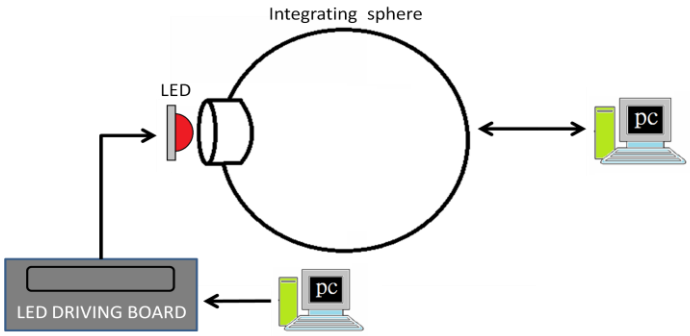

Figure 2. The experimental scheme consists of an LED drive board (HXP307SH2), an integrating sphere (ISM-180, integrating sphere size 12inch) and Osram OSTAR-SMT LED (LE ATB S2W)

PARAMETER	UNIT	RED	GREEN	BLUE	TOTALLY
pulse current	**mA**	1100	680	860	
pulse forward voltage	**V**	3.3	3.5	3.75	
frame rate	**Hz**				60
R:G:B ratio		0.29	0.22	0.18	
RGB field duration	**ms**	4.83	3.67	3.00	
LED blanking	**ms**	0.21	0.21	0.21	
LCOS response time	**ms**	0.2	0.2	0.2	
LED on time	**ms**	4.62	3.46	2.79	
average LED light output	**lm**	18.86	21.36 *2	6.65	68.23
average power consumption	**W**	1.01	0.49	0.54	2.04

Table 1. LED light output for Osram SMT 40 mil.

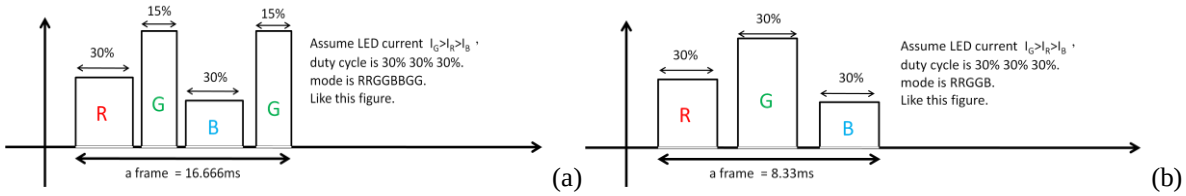

Figure 1. Different sequential type (a)RRGGBBGG type(b)RRGGBB type

In consideration of brightness need of pico-projector, we require that light source supplies at least 70 lm. To increase output flux of LED, pulse current and durations are raised. For the LED drive board limits maximum pulse current supply to 1100mA for safety reason, we prolong RGB-field durations to achieve the brightness request. As table 2a shows, in RRGGBB drive mode, pulse current of each light is fixed at maximum that the LED drive board can supply, and duration Ratio of red field, green field, and blue field is design at 0.29:0.22:0.18. This design experimentally performs flux output of 73.5 lm with color temperatures of 6331 K. Furthermore, to lengthen LED life time, LEDs only work in 69% of a unit time frame.

We extend our research on two design purposes in respect of power consumption and of brightness. Flux output versus power consumption is considerable for imbedded pico-projector imbedded. For efficient purpose, we suppress pulse currents to make LEDs work in linear working area. RGB-field durations are respectively prolonged to compensate average flux output for the loss caused by reduction of pulse current. As shown in table 2b, we are successful to reduce power consumption down to 1.39 W and further obtain at least flux output of 70 lm from the same LED array working in RRGGBB drive mode. The pulse current and duration of each light field is modulated to experimentally achieve average flux output of 78.76 lm with white balance of 6470K. This design enables continously 1-hour projection driven by a cellpone battery with 960mAh. With comparison of table 2a,

To achieve the maximum light flux output, LED lifetime and power consumption are sacrificed. Since red LEDs requires higher pulse current and longer duration to supply sufficient flux output that is proportional to available blue and green flux output, pulse current of red LED is set at the highest value that the drive board can supply. According to the fixed pulse current, drive mode of blue and red fields is optimized. As shown in Table

2c, light flux output of 92.9 lm with white balance of 6207K under power consumption of 2.83 We are obtained in RRGGBB drive mode.

MEASUREMENT METHOD AND RESULTS

Design 1 information.	Each LED current(mA)	Duration Ratio (R,G,B)	Output flux Measurement	power consumption	Measurement CIE value	Color temperature
RRGGBB	(1100,680,860)	0.29,0.22,0.18	73.5 lm	2.04 W	0.319,0.325	6179 K
RRGGBBGG	(1100,680,860)	0.29,0.24,0.18	74 lm	2.06 W	0.314,0.345	6331 K

Design 2. Information	Each LED current(mA)	Duration Ratio (R,G,B)	Output flux Measurement	power consumption	Measurement CIE value	Color temperature
RRGGBB	700,380,400	0.37,0.3,0.32	78.76 lm	1.39 W	0.312,0.33	6470 K
RRGGBBGG	700,380,400	0.33,0.35,0.3	72.5 lm	1.35 W	0.302,0.303	7453 K

Design 3. Information	Each LED current(mA)	Duration Ratio (R,G,B)	Output flux Measurement	power consumption	Measurement CIE value	Color temperature
RRGGBB	1100,680,860	0.4,0.29,0.25	96.8 lm	2.83 W	0.319,0.317	6207 K
RRGGBBGG	1100,530,720	0.38,0.33,0.27	94.3 lm	2.55 W	0.314,0.318	6515 K

Table 2a 2b 2c The measurement data of different condition.

CONCLUSION:

In this paper, we successfully proposed LED drive mode modulations for white light souce of pico-projector. Pulse current of each LED and light field durations are modulated to achieve purposed flux output, power consumption, and color temperature in white region according to CIE color space. Three purposes are presented for different projeciton conditions. For realibity consideration, we decrease light field durations to prolong LED lifetime. Flux ouputs of over 70 lm within the white light region (defined by CIE) are obtained in both RRGGBB and RRGGBBGG drive modes. For reduction of power consumption, pulse current and light field durations are both reduced. The light source offers over 70 lm but only consumes below 1.4 W. For highest brightness, 96.8 lm is obtained in RRGGBB drive mode. In the future, we will extend our research in consideration of thermal effect. For the Osram OSTAR-SMT LED only offers 96.8 lm at best, we are surveying brighter light source for drive mode research.

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