A Wide Color Gamut LCD Module using RGB BLU

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Abstract

We have developed 2.4" QVGA wide color gamut LCD module using RGB-LED backlight. The color gamut is achieved 100% of NTSC compared to 70% of NTSC when used with White-LED backlight. But RGB LED backlight is difficult to maintain its color balance since RGB LED is gradually degraded by the change of ambient temperature and a long term aging characteristic, etc. This paper describes a feasibility study of our optical feedback system developed for preventing such a color shift.

1. Introduction

White LEDs are extensively used in small size LCD backlight system to car-navigation, PMP, MP3P and mobile phones. Recently better color performance is required as the mobile application products adopt DMB system. However, color reproducibility of current backlight system using white LED is usually limited to be 60% of NTSC. The consumers want to the same video color reproduction level as of the current FPD TV's 80% of NTSC which normally use CCFLs, LEDs or both combined. In order to cope with this customers' requirement, numbers of LCD manufacturers have been putting their effort to find solutions to get better color performance over the 80% of NTSC. As one of the best solutions to attain higher color gamut, the RGB LED backlight system has recently been spot-lit due to its excellent color reproducing capability to reach to over 100% of NTSC with proper LCD Panels.

In case of using RGB LED light source for the small size LCD, the main technical challenges are color stability and wavelength matching between color filter and RGB LEDs.[1] But LED in itself has thermal and time-based dependencies. Color and white luminance levels of LED are not stable over a wide range of temperature due to its inherent long term aging characteristics.[2] In order to maintain color balance and brightness level, we have used the method of optical feedback system, a core technology in the backlight system using RGB LED. In this paper, we'll explain the mechanism of color control in our RGB LED backlight system and describe its experimental result in detail.

2. Wide color gamut

It is generally known that the property of color gamut in LCD tends to be influenced by the characteristics of both color filter and backlight system. The color gamut supported by the white LED is usually ranged around 50% of NTSC.[1] On the contrary, the color gamut of our prototype LCD module was improved up to as high as 100% of NTSC through our efforts of wavelength matching between color filter and RGB backlight. Another effect of wavelength matching between color filter and RGB backlight leads to increase of luminance. Generally speaking, luminance characteristic of white LED is known to be superior to that of RGB LED at the point of power consumption. Under the same level of power consumption, the luminance of backlight system using white LEDs is brighter than that of using RGB LEDs. However, the luminance of our prototype LCD module with RGB LEDs shows much better performance, almost equal to that of using white LEDs at the same electric power.

Fig.1 shows the color gamut mapping of our prototype LCD module using improved color filter. As you can see in the figure, our LCD module using RGB-LED backlight shows almost the same color gamut range as NTSC coordinate, comparing 70% of NTSC in case of using White-LED backlight

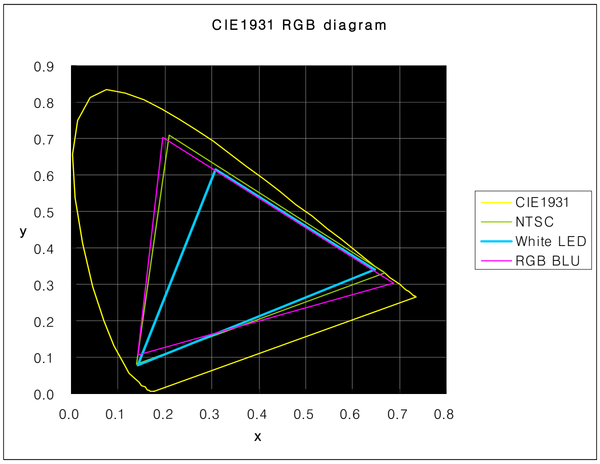


Fig. 1 A Color gamut of RGB LED BLU LCD model compared with White LED BLU LCD model

3. Color Control

Table.1 shows degree of wavelength characteristics change of RGB LED after 1000-hour aging. We obtained satisfied degree of wavelength shift that gives little impact to wider color gamut RGB LED backlight system, even though long term aging apply.

Table.1 Wavelength characteristic change after 1000-hour aging

LED		Initial value		1000H After value	
		λp	λd	λp	λd
B	Max	454.0	459.1	455.0	460.3
	Avg	453.3	458.5	453.8	459.0
	Min	453.0	458.3	453.0	457.9
G	Max	522.0	528.5	523.0	529.0
	Avg	520.7	527.0	521.8	527.6
	Min	519.0	525.5	521.0	526.1
R	Max	631.0	620.4	631.0	620.3
	Avg	630.7	620.2	630.6	620.0
	Min	630.0	619.9	630.0	619.

But RGB LED intensity characteristic change is serious.

Table.2 shows each RGB LED's intensity degradation results after 1000-hour aging at normal temperature. The RGB LED is a 3-in-1 package. These results show that it will bring about significant color shift in open loop system, as time goes by.

Table.2 Intensity Degradation of RGB LED (Temp. 25℃, If = 20mA)

Item	Max	Avg	Min
Iv R	-12.5%	-4.5%	-0.1%
Iv G	-14.3%	-6.3%	-0.3%
Iv B	-49.7%	-37.5%	-0.8%

We measured white color coordinate difference at the initial value and 1000-hour aging value in LCD module with open loop RGB LED backlight. The result is shown in Table.3.

Table.3 Δx, Δy in backlight using 1000-hour aging RGB LED

	Max	Avg	Min
Δx	0.0814	0.0637	0.0484
Δy	0.1503	0.0832	0.0745

In order to minimize color coordinate shift and brightness difference due to degradation of LED, we used optical feedback system depicted in Fig.2.

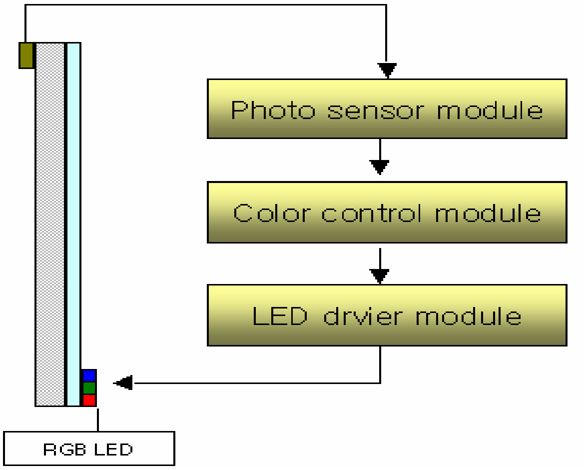


Fig. 2 Optical feedback system with RGB LED backlight

Optical feedback system is made up of photo sensor module, color control module, LED driver module and RGB LED.

The technical core is color control module that incorporates a set of algorithms that analyze color information from the tricolor photo sensor and compute the PWM drive signal to achieve the target color point. The color control module samples the photo sensor at about 100times per second to ensure that periodic adjustment to the PWM signals is not perceptible to the human eye. [3] The color control module also contains an algorithm that prevents changing the chromaticity of the RGB light output from LED degradation. Fig.3 shows block diagram of color control module in optical feedback system.

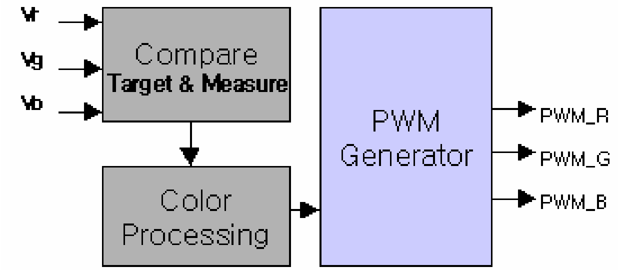


Fig. 3 Color control module

4. Experimental results

Fig. 4 and Table 4 are an experimental result illustrating the variation of white color coordinate under the operation of our optical feedback system and intensity level of LED degradation respectively.

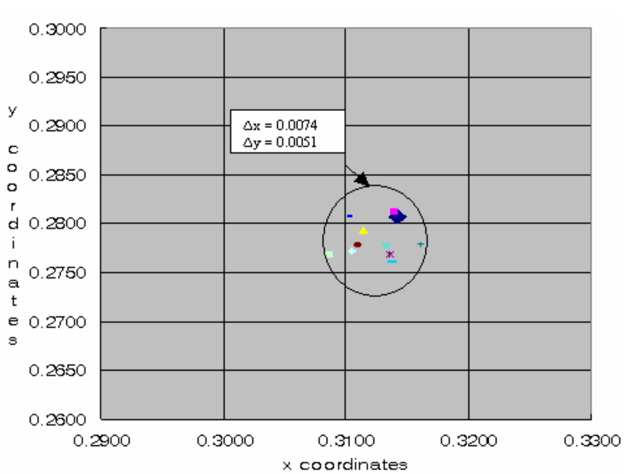
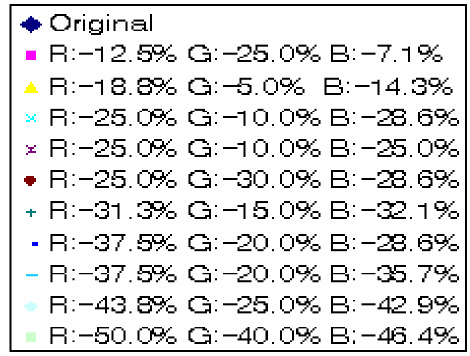


Fig. 4 Color stability with various LED degradation

Table. 4 Various LED intensity degradation values in Fig.4



These results show the performance of our optical feedback control system how well it works. A good rule-of-thumb to judge performance is to use color coordinate shift Δx, Δy = 0.02 as the minimum change in chromaticity that the human eye can detect a change. In our Optical feedback system, the color sensor detects the luminance of each RGB LED and provides an electrical signal to the controller for comparison between initial set values and the measured values. If there is a difference between the set and measured values, the color control module compensates the PWM signal to the LED driver module to achieve target color.

The experiment was conducted at 7,000K, a target white color temperature, (0.28, 0.31) in CIE1931 coordinates system. Although intensity of LED was decreased significantly, the color shift change Δx and Δy were kept below 0.01 by the optical feedback system. From this result we are sure to say that our optical feedback system works as well as expected.

5. Conclusion

We have developed a wide color gamut LCD module used RGB LED backlighting system, achieving 100% of NTSC, quite suitable for mobile application. And the problem that variability of LED characteristics causes the RGB light to deviate from the intended color, can be solved with adoption of our optical feedback control system. Our optical feedback system improved the color instability to less than 0.01 of Δx and Δy.

6. References

[1] J. Kim, et. al. Proc. IDW/AD ’05, pp. 1425 (2005)

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[3] K. Kakinuma, et. al Proc.CVCE’05 pp. 45(2005)

[4] Avago Technologies Website, http://www.avagotech.com