NTSC of LED-LCD System

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Abstract:

The LED light source has many excellent advantages for the application of LCD backlight module. As we know, the operational temperature can significantly influence the characteristics of LEDs. Heat can decrease LED's output light intensity and make its dominant wavelength (l_d) drift. These two factors make display's color temperature change and induce different NTSC results. Here, we perform an important relation between NTSC and the above two factors of LED-LCD display.

1. Introduction:

LED (Light emitting diode) is a solid state light source featuring the merits of super long life span, power saving, low voltage, high color rendering, low temperature operation, quick responding speed, and conformity to EPA requirements (no Hg content) which are all superior to the current CCFL light source[1, 2, 3]. This LED light source is currently being used for many lighting apparatus and small size cell phone backlight applications. It is obvious that LED will take place of CCFL as the large-scale TFT-LCD backlight source in the near future.

Although LEDs have a lot of advantages, most semiconductor device has a common big problem about heat generation during operation. The operational temperature arises as heat accumulated and high operational temperature will decrease LED's output light intensity and shorten its lifetime. Moreover the behavior of LCD color temperature and colorimetry depend on the relation between Red (R), Green (G), and Blue (B) individual intensity and dominant wavelength changed by floated operational temperature in Fig. 1 and Fig. 2.

As temperature rising, the results can be observed from Fig. 1 and Fig. 2 not only the output intensity of R LED diminishes more dramatically than that of GB LED, but the dominant wavelength drift toward to longer wavelength. The safety operation LED junction temperature is about 85 °C and module temperature is under 70 °C.

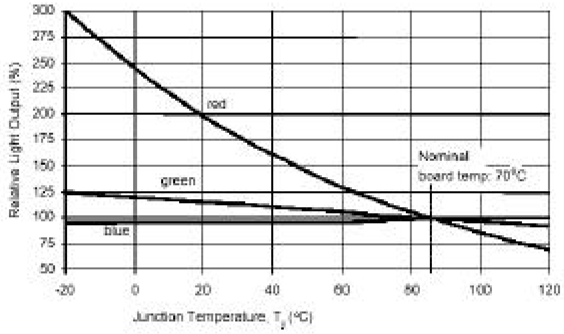

Fig. 1 Relative Luminous light output vs. Junction Temperature for Lumileds Luxeon Emitter. The safety junction temperature is 85 °C and module temperature is under 70 °C.

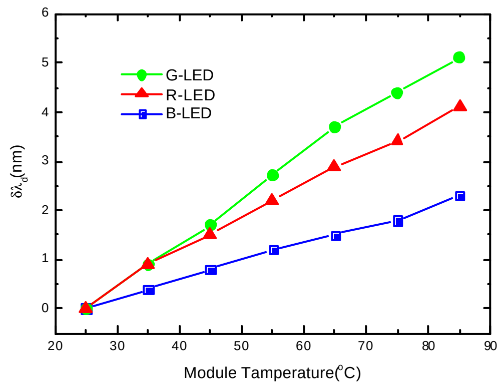

Fig. 2 Dominant wavelength of individual R, G, and B LED drift with rising module temperature from room temperature 25 °C to 85 °C.

2. Theory:

The CIE standard to qualify color by the spectral sensitivity of the three receptors of a human observer $X(l)$, $Y(l)$, and $Z(l)$. The green spectral sensitivity $Y(l)$ is also known as the spectral sensitivity function for photonic vision. Every light source has its associated characteristic spectrum of wavelength $S(l)$. Weighting this spectrum power distribution with the tristimulus curves $X(l)$ (black), $Y(l)$ (gray), and $Z(l)$ (light gray) yields three scalar values X, Y, and Z and tristimulus values:

$$X = \int X(l) S(l) dl$$
$$Y = \int Y(l) S(l) dl \qquad (1)$$
$$Z = \int Z(l) S(l) dl$$

The sum of these values is connected with the perception of brightness, while their ratio determines the perceived color. According to the definition of CIE 1931, color can be represented as a point in a 2D diagram by calculating the color coordination x and y:

$$x = \frac{X}{X+Y+Z} \qquad (2)$$
$$y = \frac{Y}{X+Y+Z}$$

The x y value ranges from 0 and 1. In display field, NTSC value is more important to represent display's vision quality. NTSC is defined by display's RGB color coordination as following:

$$NTSC(\%) = p \begin{pmatrix} x_r y_g + x_g y_b + x_b y_r \\ - y_r x_g - y_g x_b - y_b x_r \end{pmatrix} \times 100 \qquad (3)$$

Moreover, white balance could be restored by changing the three color's (RGB) intensities; however, if you shift the red light source toward to long wavelength, the white light would appear more toward cyan and color temperature become warm.

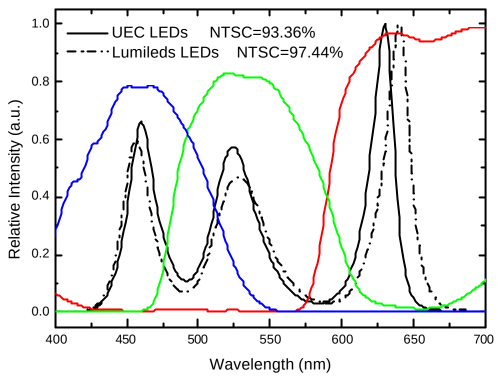

Fig. 3 Color mixing spectrum for UEC and Lumileds RGB-LED at CT 6500 K and spectrum for color filter.

3. Discussion:

LED backlight system is chosen to match a LCD module with a specific color filter (CF) to get high NTSC performance. Operational module temperature is fixed at 50 ^{o}C by applying heat sink [4]. Adjusting the intensities of RGB LED individually can achieve different color temperature and the color coordination of white balance we want. Here five different color temperatures (5000 K, 5500 K, 6500 K, 7500 K and 9300 K) are chosen to evaluate their NTSC performance in our measurement.

Fig. 3 is a color mixing example: there are two types of LED-backlight (BL) system from Lumileds, USA and United Epitaxy Company (UEC), Taiwan at color temperature 6500 K. The RGB spectrum of Lumileds LED-BL is more separate each other than that of UEC LED-BL. Lumileds LED-BL gets the pure hue $S(l)$ after pass through specific CF at the same color temperature. The NTSC value 97.44 of Lumileds LED-BL system can be calculated from equations (1)(2)(3) higher than that of UEC LED-BL system. The color mixing spectrums of two types LEDs as backlight source of LCD module can be measured by CAS-1000 in front of LCD module at five different color temperature conditions. Results of their color coordination x and y are listed in table I. x and y are changed with different color temperature and NTSC value is also increased with rising color temperature as shown in Fig. 4. The blue intensity increases more dramatically at high color temperature, which changes the value of color coordination x_b y_b x_g, and y_g. Besides, the factor about heat accumulation must also be considered to explain variation of x and y. Although module temperature can be controlled, junction temperature depends on current injection which obeys operational intensities of RGB LEDs. According to Fig. 2, junction temperature was known as a reason for the spectrum of B and G separate widely, referred to alteration of x y value of LED-LCD module and NTSC increasing.

Table I: xy value of LED-LCD module.

Color Temp.(K)	x_r	y_r	x_g	y_g	x_b	y_b
UEC						
5000	0.6873	0.3076	0.2109	0.6868	0.1297	0.1470
5500	0.6867	0.3075	0.2088	0.6854	0.1307	0.1378
6500	0.6856	0.3072	0.2052	0.6836	0.1321	0.1260
7500	0.6846	0.3070	0.2035	0.6807	0.1333	0.1160
9300	0.6833	0.3065	0.2003	0.6784	0.1345	0.1076
Lumileds						
5000	0.6975	0.2972	0.2254	0.6936	0.1355	0.1321
5500	0.6966	0.2973	0.2252	0.6926	0.1367	0.1214
6500	0.6948	0.2976	0.2222	0.6922	0.1381	0.1101
7500	0.6935	0.2973	0.2207	0.6904	0.1388	0.1024
9300	0.6914	0.2975	0.2180	0.6897	0.1400	0.0937

From above discussion, junction temperature and heat accumulation are important factors that contribute the changes of LED emission spectrum, *x y* and NTSC. Moreover, from Fig. 1, the red light intensity diminishes more rapidly than blue and green light when junction temperature is rising, which induces color temperature increas ing. The dominant wavelength also rises with increasing module temperature. Additionally, the green and red spectrums are more sensitive about 4-5nm drift from room temperature to 85°C as shown in Fig. 2. Wavelength drift at high module temperature make the interval between B spectrum and G spectrum broaden obviously and increase NTSC value, which

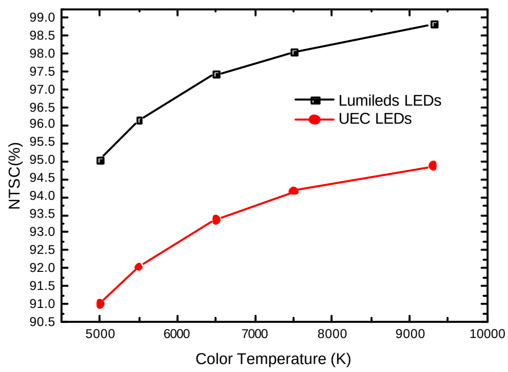

Fig. 4 The NTSC value grows with increasing color temperature for two types of (RGB) LED, Lumileds and UEC.

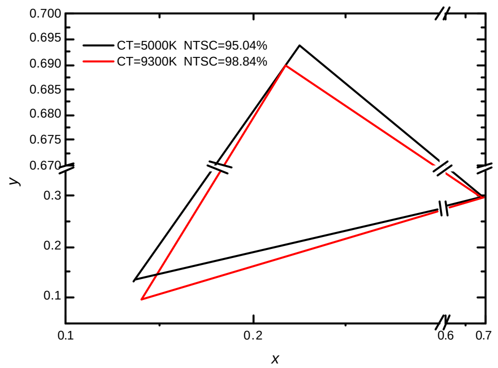

Fig. 5 NTSC diagrams of two different color temperature situations 5000 K and 9300 K for LED-LCD module with Lumileds LEDs backlight source.

can be understood by using equations (1)(2)(3). The NTSC diagrams show their area 95.04@5000 K and 98.84@ 9300 K in Fig. 5, which mean rising color temperature shifts color coordination x_r ,y_r, x_g, *and* y_g significantly.

4. Conclusion:

We successfully demonstrate the important relation between color temperature and NTSC value. The increasing color temperature can get higher NTSC value including heat factor. Adjusting display's color temperature to get higher NTSC value can be achieved. In this paper, the high NTSC 98.84 is performed successfully at 9300 K. Although heat has a lot of disadvantage for LED chip, its advantage is found finally to enlarge NTSC value resulted from heat accumulation which decays R-LED intensity to get high color temperature and drifts R and G-LED spectrum to separate widely.

Reference:

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