

Backlight for Large-area LCD-TVs using Light Emitting Diodes

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Abstract

A backlight for large-area LCD (Liquid Crystal Display)-TVs has been developed using Light Emitting Diodes (LEDs). Performances of the backlight and the methods driving the LEDs are introduced in this research. A spectral relationship between the LEDs and the color filters of a panel were investigated as well. In order to realize a CRT-like dynamic effect, the area-focused luminance control (AFLC) technology was adopted in developing the backlight. Thus, a possibility of applying the LEDs to the backlight for large-area LCD-TVs was systematically proved.

1. Introduction

LCDs have been typically at the head of flat panel displays. Based on an optical design and analysis, each of the LCDs has a characteristic backlight, which plays a role of generating static and dynamic images on the screen, followed by a corresponding light source. Until now, several types of light sources have been developed for the LCD backlights: i.e., Fluorescent Lamps, LED [1][2], and CNT (Carbon Nano Tube) [3][4]. Fluorescent Lamps are reclassified into CCFL (Cathode Fluorescent Lamp), EEFL [5][6], and Flat Lamp [7][8]; CCFL is most conventional.

Demands for a higher backlight performance are currently increased in the LCD display market. Especially, a wider color gamut and a faster response time are newly requested to realize ultimate characteristics of the LCD-TV, i.e., a large size, high brightness, and long life. As for the color gamut and response time, no light source can compete with LEDs. In addition, LEDs are free from laws and regulations on environmental pollution. It makes experts to predict that LEDs would replace conventional light sources in the near future.

In this paper, the two primary issues for achievement of a higher performance are discussed in detail: the first is an optimal method driving the LEDs and the

second is a spectral relationship between the LEDs and the color filters.

2. Spectral Relationship between LEDs and Color Filters

In order to get a wider color gamut, spectrums of R/G/B LEDs should be basically pure: the Full Width Half Maximum (FWHM) of those spectrums is to be narrow with no background noise.

For the lights coming through the LCD panel, it should be considered how the LED lights convert as they penetrate the liquid-crystal layer and color filters. One has an unusual sensibility for the brightness depending on the wavelength of the light, and so should be more considerate for the deep blue LED to achieve a wider color gamut and higher color temperature. It is based on the fact that a blue-light wave significantly affects power consumption: on the contrary, it has less effect on light luminance.

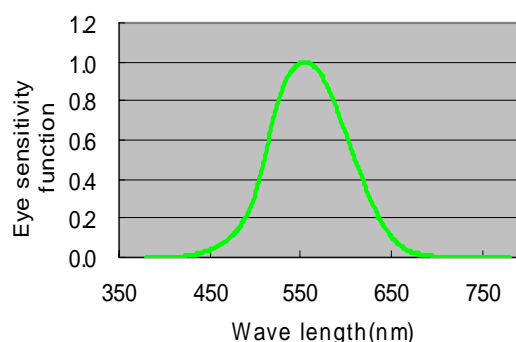


Figure 1. Plot of Eye sensitivity function

As shown in Fig. 1, one's sensitivity for the brightness has the peak value at a wavelength of 555 nm: the closer the wavelength to 555 nm, the brighter one feels at a same intensity of a light. Accordingly, only for the brightness, it is advantageous to select a specific wavelength of the LED as closer to 555nm as possible.

The brightness, however, should be sacrificed to get a wide color gamut because the wide color gamut can be achieved as the wavelength of the LED goes deeper and deeper; a blue-light wave goes shorter and a red-light wave goes longer. Moreover, efficiency of the LED backlight significantly depends on how to match the peak wavelength of the LEDs and color filters. To get more increased backlight efficiency, it is recommended that the peak wavelength of the LED should correspond to that of the color filters as shown in Fig. 2.

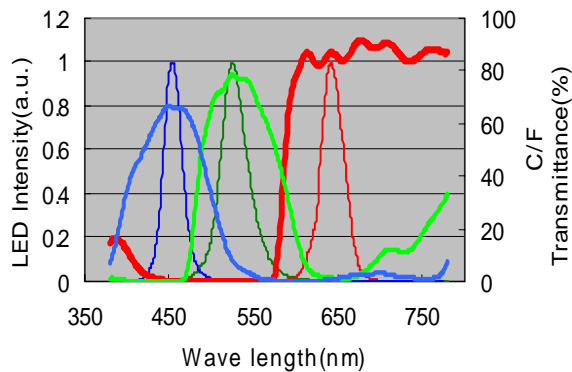


Figure 2. Plot of a spectral relationship between LEDs and color filters.

In this study, a simulation tool for the LED backlight has been developed to calculate LCM performances from the very first step of the selection of the LEDs. The optimum wavelengths of the LEDs and driving conditions to achieve a desirable LCM performance could be obtained by modeling and analysis.

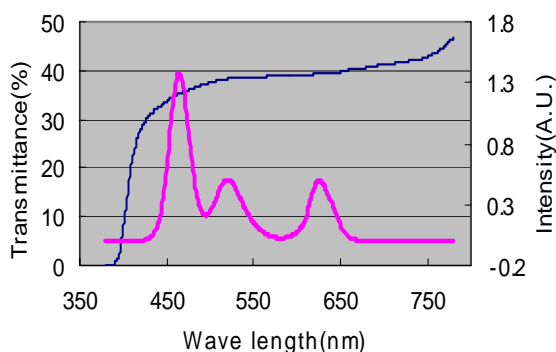


Figure 3. Plot of the transmittance of the polarizer and spectrum of the LED backlight.

Once the wavelength of the LEDs is determined, the separate R/G/B spectrums are to be merged to make a

backlight spectrum, and then optical properties of the LCD panel should be considered. Therefore, the transmittance of a polarizer, a liquid crystal layer, and color filters are to be applied to the simulation as shown in Figs. 3, 4 and 5.

Considering all the optical factors for the multi-layered LCD panel, the performance of the LCD TV can be calculated. The desirable color temperature and white balance could be also obtained by the fine tune of the driving duty ratio.

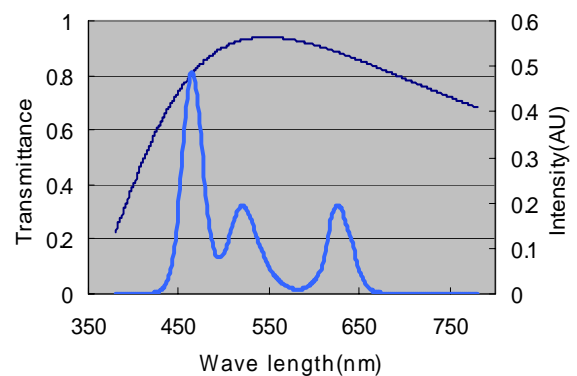


Figure 4. Plot of the transmittance of liquid crystal layer and the spectrum of LED backlight after passing through the polarizer.

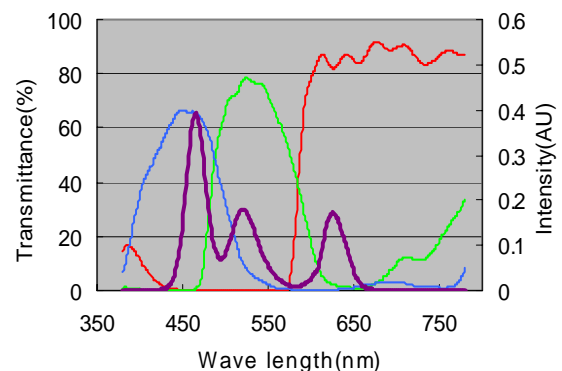


Figure 5. Plot of the transmittance of color filters and the spectrum of LED backlight after passing through the polarizer and liquid crystal layer.

Just after getting the final spectrum on the LCD panel, the color gamut and correlated color temperature (CCT) can be predicted by integrating the spectrum for calculation of the tristimulus values defined in CIE 1931. The tristimulus values obtained on the basis of

the color matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ can be calculated by the following formulas.

$$X = k \int S(\lambda) \bar{x}(\lambda) R(\lambda) d\lambda \quad (2.1)$$

$$Y = k \int S(\lambda) \bar{y}(\lambda) R(\lambda) d\lambda \quad (2.2)$$

$$Z = k \int S(\lambda) \bar{z}(\lambda) R(\lambda) d\lambda \quad (2.3)$$

, in which $S(\lambda)$ is a relative spectral power distribution of the LEDs and $R(\lambda)$ is a spectral reflectance of the specimen which was neglected because only a direct light from LCD itself has been concerned in this study.

Next, the xyz chromaticity coordinates can be calculated from the XYZ tristimulus values according to the following formulae.

$$x = \frac{X}{X + Y + Z} \quad (2.4)$$

$$y = \frac{Y}{X + Y + Z} \quad (2.5)$$

$$z = \frac{Z}{X + Y + Z} = 1 - x - y \quad (2.6)$$

The figure 6 shows a x-y-chromaticity diagram, in which R, G, and B chromaticity coordinates plotted are calculated by using the above formulae.

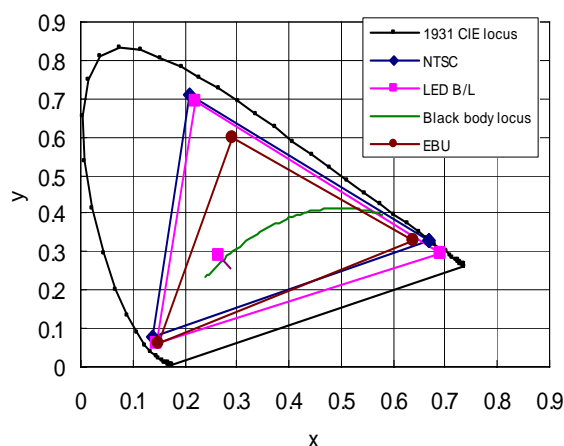


Figure 6. xy chromaticity diagram (CIE 1931)

As shown in the Fig. 6, the color gamut of a LCM using the LED backlight is over 100% as compared to the area defined by National Television System Committee (NTSC), and the color temperature is about 12,000 K

The spectral relationship between the LEDs and the color filters has been studied as well. As based on the analytical results, appropriate selection of LEDs having specific dominant wavelengths is most important to get a desired color gamut, in which the wavelengths should be properly matched with the spectrum of the color filters under the corresponding duty ratio. In addition, the color gamut of more than 100 % and the color temperature of approximate around 12,000 K were achieved, which allow the viewers to see more vivid and colorful pictures as shown in Fig. 7.



Figure 7. Example of a large-area (47'' model) LCD-TV using a LED backlight.

3. Driving Method of LED Backlight

In order to improve the contrast ratio (CR) and to decrease the power consumption of a LCD TV using a LED backlight, the AFLC technology has been adopted in this research. The figure 8 shows a basic concept on the AFLC technology consisting of two primary parts; one is for the AFLC backlight with LEDs and the other is for the AFLC algorithm. As shown in Fig. 8, input images are transferred from the system to the data analysis block. Two types of signals such as data stretching and dimming control are created in the data analysis block. One is for displaying a picture display and the other is for dimming control of the backlight.

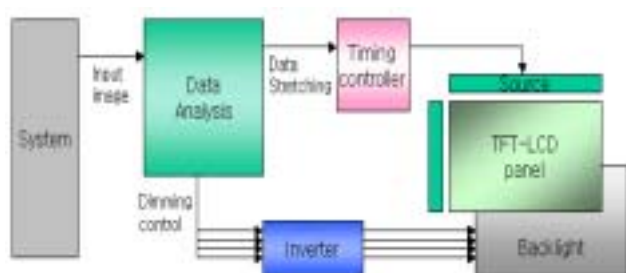


Figure 8. Illustration of the AFLC backlight technology block diagram.

The AFLC technology has been improved for the LED backlighting system. Since the LED clusters are periodically arranged all over the backlight unit, the freedom of changing a number and shape of a unit area divided in a backlight can be dramatically increased. Through this AFLC technology improved, we could design the dividing area, emitting lights respectively, into as many as we want up to the total number of LED clusters.

The picture in Fig. 9 shows one moment of a firework: the center of the exploding area is dazzling bright but the background is dark of night. In this case, the AFLC with the LED backlight shows its outstanding advantage because it can make the center of the exploding area brighter and the background darker by controlling the backlight area by area.



Figure 9. Example of dynamic effect realized by AFLC technology.

Being different from a conventional CCFL with a limit of dimming the driving current to about 40%, the LED applied has almost no limit in a dimming range. Therefore, the contrast ratio could be maximized over 10,000 to 1 even in a still picture.

It is a matter of grant that a LED backlight consumes more power than conventional backlights, because the luminous efficiency of LEDs has not reach to that of conventional light sources such as CCFLs and EEFLs. However, the advantage of dimming range of LED and the improved AFLC technology have made it possible to reduce the average power consumption of 47" LCD TV using LED backlight under 300W for a normal broadcasting condition.

4. Conclusion

The 47-inch Liquid Crystal Module (LCM) with the LED backlight has been synthesized. The luminance of the LCM is over 500 cd/m², the color gamut obtained is wider than 100% as compared to NTSC, the corresponding color temperature is about 12,000 K, and the luminous uniformity (max./min.) is less than 1.3 which satisfies the specifications for the 47-in. LCD-TVs.

A large-size backlight for LCD TVs using LEDs has been realized much faster than conventional ones. Although they already had been applied to small size displays and common lighting sources preceding LEDs were adopted as backlight sources of large size LCDs, they would widely spread much faster than ever before triggered by the success of large size LED backlights and supported by environmental demands as well.

5. References

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