

40.5L: Late-News Paper: 18.1-inch XGA TFT-LCD with Wide Color Reproduction using High Power LED-Backlighting

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Abstract

We develop 18.1-inch XGA TFT-LCD using high power Light Emitting Diodes (LEDs) as light sources for backlighting. By matching the transmissive spectra of color-filter to LEDs radiation, the higher brightness and the wider color reproduction of 95%-NTSC are achieved on the front-of-screen.

1. Introduction

Many products using TFT-LCDs have been developed to replace CRT displays with going up the performance of TFT-LCDs. However the images on LCDs are still inferior to those of CRTs in especially the performance for motion video. This is related to the response time of liquid crystal [1], algorithm of scaling [2], afterimage on a retina [3], color-shift by viewing angle, brightness and color reproduction. The color performance of CRT is better than LCD now, but even the color reproduction on CRT is not enough to achieve the accurate images in specific business regions, e.g., publishing and photograph. The color reproduction of LCD depends on the emissive spectra of the backlighting and the transmissive spectra of the color-filter. The emitted light from sources is going through the color-filter that consists of individual sub-pixels having R, G and B. In order to make the color reproduction wider, there is an important condition that we need to discuss; lights from each color pixel of LCD does consist of only one narrowing ingredient spectrum around the dominant wavelength.

The emissive spectra of backlighting using a Cold Cathode Fluorescent Lamp (CCFL) contain various unnecessary wave-length of lights outside these peak spectra of Red, Green

and Blue. When we apply the CCFL for LCD, these unnecessary components should be cut off by the color-filter effectively. Since a backlighting using LEDs can be designed to have three ingredients spectra around the dominant wavelength of Red, Green and Blue, it is better to realize the wider color reproduction than using CCFLs [4] [5]. The color-filter has to cut off the all of spectra except the ingredient components around its each own peak wavelength. In order to overcome the tradeoff relationship between the brightness and the color reproduction, each peak wavelength of LEDs needs to be coherent to the corresponding peak wavelength of color-filter.

In this paper, a newly developed 18.1-inch XGA TFT-LCD applied by backlighting using high power LEDs (LED-BL) and a well-tuned color filter is shown and its optical characteristics are discussed.

2. 18.1 inch XGA TFT-LCD module

Figure 1 shows a block diagram of a newly developed 18.1-inch XGA TFT-LCD module using LED-Backlighting unit. A side-edge type backlight is applied and two LED strips are located on the top and bottom edges of light-pipe. Each LED strip arranges multiple Red, Green and Blue LEDs. These lights from Red, Green and Blue LEDs are mixed and injected to the light pipe. The brightness of Red, Green and Blue LEDs can be dimmed independently by a control circuit. The color-filter of this LCD panel is well-tuned to get the higher color saturation described below in detail.

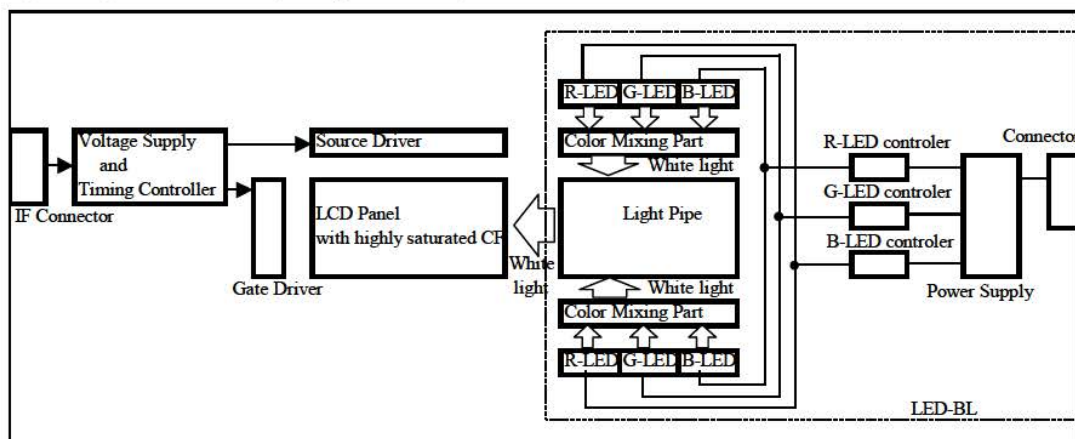


Figure 1. Block Diagram of 18.1-inch XGA TFT-LCD with LED-BL

3 Optical Characteristics

In this section, we describe the optimized optical system to achieve the wider color reproduction and its performance.

3.1 Optimization of Spectroscopic Characteristics

The color reproduction of LCD on the front-of-screen is defined by the chromaticity of Red, Green and Blue on a CIE color chart. The nearer the chromaticity of each Red, Green and Blue located to the spectrum locus, the wider color reproduction is obtained. Also ideally, the spectrum profiles of Red, Green and Blue should be single and narrow without any unnecessary components.

Figure 2 shows each spectrum when White, Red, Green and Blue are displayed on the front-of-screen of LCD applied by the conventional color-filter and backlighting using a Cold Cathode Fluorescent Lamp (CCFL-BL). Table 1 shows the chromaticity of this case. The peak wavelength in the spectrum profile of Red is 615 nm and the other ingredients are existing around mainly 590 nm and 545 nm. The peak wavelength of Green is 545 nm and the other ingredients around mainly 490 nm and 590 nm. The peak wavelength of Blue is 435 nm and other

ingredients are also existing. The color reproduction is limited to 45%-NTSC because the spectra contain the various unnecessary components.

Figure 3 shows each spectrum of LCD using the conventional color-filter and LED-BL. Each peak emissive wavelength of LED is coherent to the corresponding transmissive wavelength of the color-filter, and closer to target points on the spectrum locus. Table 2 shows the chromaticity in this case. The each profile of peak wavelength is simplified and isolated to the others well compared with LCD using CCFL-BL. The color reproduction is enlarged to 58%-NTSC even the color-filter is just same to the one applied in Figure 2 and Table 1.

Figure 4 shows each spectrum of LCD using the highly saturated color-filter and CCFL-BL. This color-filter can cut off the unnecessary component more effectively. The thickness and the materials of color inks are in the current conditions for the actual productions. Table 3 shows the chromaticity in this case. The ingredients except the peak wavelength of Red, Green and Blue are reduced compared with the case in Figure 2 and Table 1. The color reproduction is enlarged to 72%-NTSC.

Figure 5 shows each spectrum of LCD using the highly

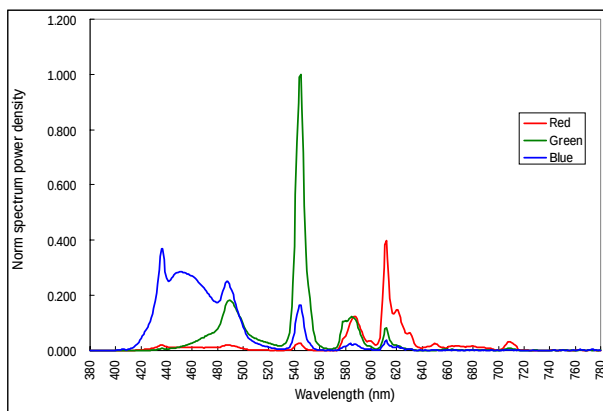


Figure 2. Emissive Spectra of conventional 18.1-inch XGA TFT-LCD (Light source of BL is CCFL and color-filters are conventional one)

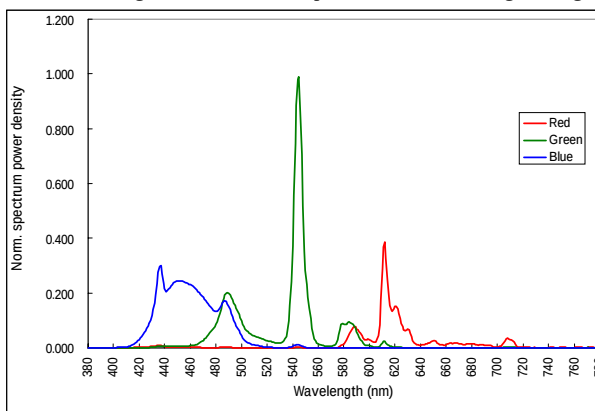


Figure 4. Emissive Spectra of 18.1-inch XGA TFT-LCD (Light source of BL is CCFL and color-filters are highly saturated one)

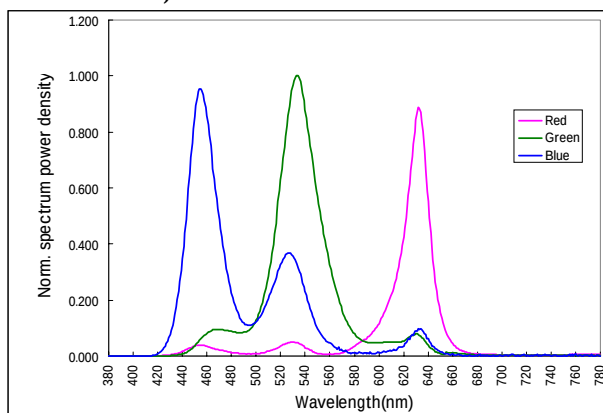


Figure 3. Emissive Spectra of 18.1-inch XGA TFT LCD with LED-BL (color-filters are conventional one)

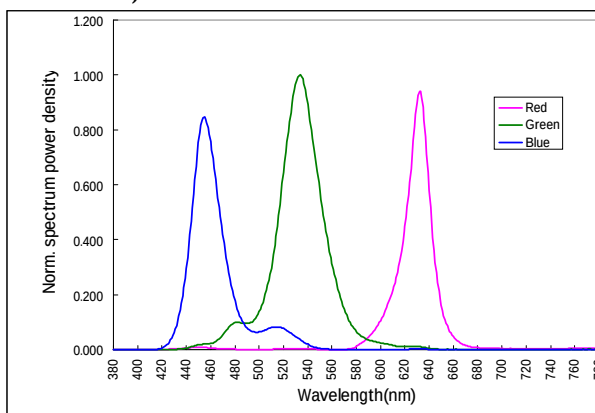


Figure 5. Emissive Spectra of 18.1-inch XGA TFT-LCD with LED-BL (color-filters are highly saturated one)

saturated color-filter and LED-BL. Table 4 shows the chromaticity in this case. Each profile of peak wavelength is simplified and isolated to others and the ingredients except the peak wavelength are reduced. The color reproduction is enlarged to 95%-NTSC. We adopt this optimized color-filter and LED-BL to 18.1-inch XGA TFT-LCD.

Table 1. The chromaticity TFT-LCD treated in Figure 2

	x	y
Red	0.552	0.333
Green	0.288	0.551
Blue	0.164	0.116
Color reproduction	45%	

Table 2. The chromaticity TFT-LCD treated in Figure 3

	x	y
Red	0.604	0.321
Green	0.253	0.634
Blue	0.169	0.187
Color reproduction	58%	

Table 3. The chromaticity TFT-LCD treated in Figure 4

	x	y
Red	0.630	0.331
Green	0.266	0.589
Blue	0.143	0.055
Color reproduction	72%	

Table 4. The chromaticity TFT-LCD treated in Figure 5

	x	y
Red	0.673	0.307
Green	0.233	0.676
Blue	0.144	0.068
Color reproduction	95%	

3.2 Front-of-Screen Performance

We develop 18.1-inch XGA TFT-LCD module product using the high power LED-Backlighting and the highly saturated color-filter. Table 5 summarizes these specifications. Figure 6 shows the color reproduction on the CIE chart. The wider color reproduction of 95%-NTSC and more than 400 cd/m² of brightness are achieved. The accuracy of color reproduction on this TFT-LCD is reaching almost same grade as the actual photographs and printings. Each LED can be dimmed independently. The white color chromaticity and the brightness of the module can be controlled in the color reproduction area optionally without any reduction in the range of gray scale levels.

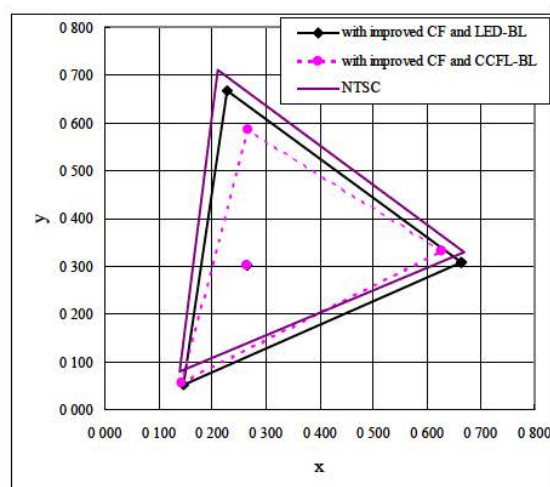


Figure 6. Color chromaticity of 18.1-inch XGA TFT-LCD

Table 5. Specifications of 18.1-inch XGA module with LED-BL

ITEM	SPECIFICATION
Display Area (mm)	367.2 (H) x 275.4 (V) (18.1-inch Diagonal)
Number of Dots	1024 (H) x 3 x 768 (V)
Number of Color	16.7M (8 bit/Color)
Response Time (ms)	$t_r + t_f = 25$
Color Gamut (%)	95%-NTSC (in CIE xy space)
Contrast Ratio	400
Viewing Angle (degree)	H: -75 ~ 75, V: -60 ~ 65 (CR>=10)
Brightness (cd/m ²)	400
White Color Temperature (K)	4,000 ~ 10,000 (variable)
Interface	CMOS (3 ~ 5 V, 2 Pixel/CLK)
Lifetime (h)	50,000

4. Discussion

Figure 7 shows the dependence of brightness on chromaticity compared with 18.1-inch XGA TFT-LCD with LED-BL and with CCFL-BL. These are calculated based on their spectra. In Figure 7 x-axis and y-axis mean each axis of CIE x-y coordinate and L-axis means the relative brightness. The LED-BL is controlled so White chromaticity of both modules are the same. Figure 8 shows the vertical section A-A' in Figure 7. The relative brightness of LCD with LED-BL is always higher at any chromaticity. This is because LED-BL realizes the wide color reproduction. Human eyes perceive color more vividly when its brightness is high. Therefore the LCD with LED-BL can display the natural image more vividly at any chromaticity.

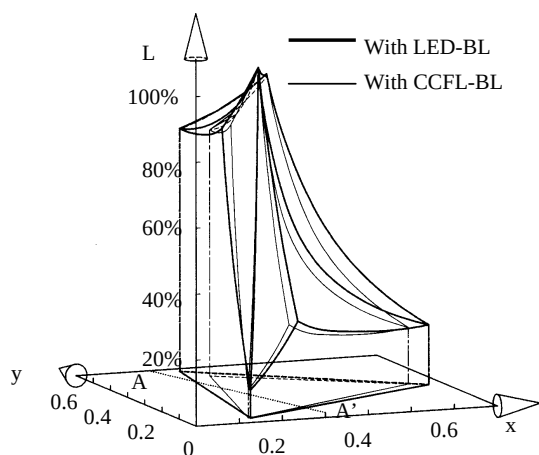


Figure 7. The relative brightness at each the chromaticity of 18.1-inch XGA TFT-LCD with LED-BL and CCLF-BL (color-filters are improved)

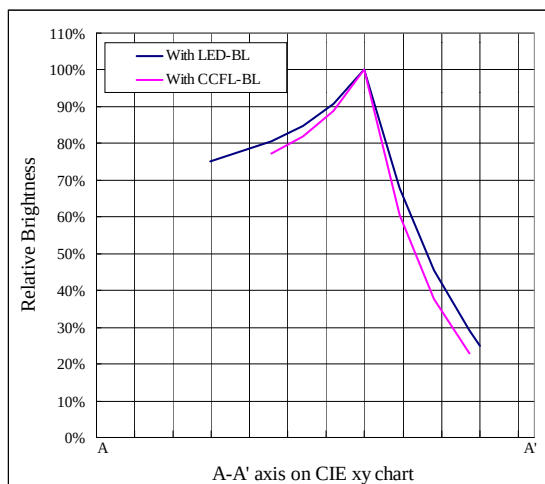


Figure 8. The Vertical section of Figure 7 on A-A'

5. The Other Details

The lifetime of LCD with LED-BL is defined by a decay curve of emissive flux from LED as shown in Figure 9. Long lifetime is achieved.

The LED lighting system gives us the solution on the environmental protection because the LED doesn't contain mercury. Recently mercury in CCFL is seriously paid attention.

The power consumption is about 60W with 400 cd/m². The power consumption will be reduced by the improvement of efficiency of LEDs.

6. Conclusion

We have developed the 18.1-inch XGA TFT-LCD module using the high power LED-Backlighting and the highly saturated color-filter. The accuracy of color reproduction on this TFT-LCD is reaching almost same grade as the actual photographs and printings. This wider color reproduction can display low saturated color more vividly. The color-filter have no issue from the standpoint of cost, productivity and reliability. The controllable white color point, long lifetime and mercury free are beneficial points of LED-BL. We suggest that the wide color reproduction does improve the human perception of motion video on TFT-LCD.

7. Acknowledgements

The authors thank to Dr. Wiep Folkerts of Lumileds and Dr. Eishi Gofuku of Mitsubishi Electric corp. and Dr. Ikuo Ogo of Advanced Display inc..

8. References

- [1] K. Nakanishi et al., SID 29.3 (2001)
- [2] J. Someya, et al., SID 15.4L (2001)
- [3] H. Oura et al., IDW VHF1-7 (2001)
- [4] G. Harbers et al., SID, LP-2 (2001)
- [5] G. Harbers IDMC, 13.2 (2002)

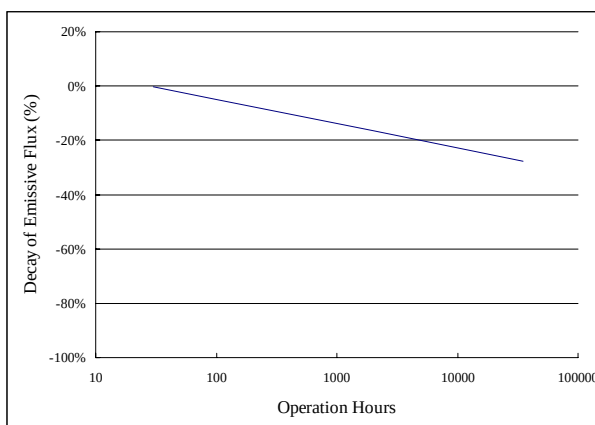


Figure 9. Decay Curve of Emissive flux from LED