Optimum TFT-LCD Design Parameter of High Contrast Ratio for Automotive Application OEM5.1

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Keywords: Automotive Application OEM5.1, High Contrast Ratio, Backlight Film Structure,Polarizer,Liquid Crystal

ABSTRACT

We present detailed analysis and in-depth research about how to improve the contrast ratio in the center and at A+/A/B area for automotive application OEM 5.1.

1 INTRODUCTION

Recently, TFT-LCDs has become a general tendency in many application fields because the image quality of TFT-LCDs has been greatly improved owning to extensive research on many new modes. The application of it has been expanded to various devices such as televisions(TVs), personal computers (PCs), smartphones, automotive displays and etc. This expansion is attributed not only to the rapid reduction of the fabrication cost but also the rapid improvement in the display quality. The desired characteristics of a TFT-LCD include high brightness, fast response time, high NTSC, a very high contrast ratio, and a wide viewing angle, etc. Especially, contrast ratio of TFT-LCDs plays an important role on automotive application [1-2].

In the following sections, we have analyzed the effects of backlight film structure(DOE Ⅰ and DOE Ⅱ), the display mode(O-mode and E-mode), polarizer(Pol Ⅰ, Ⅱ and Ⅲ) and liquid crystal(LC Ⅰ and Ⅱ) on contrast ratio. And we finally obtain the best design for high contrast ratio.

2 THE SPEC OF CONTRAST RATIO FOR AUTOMOTIVE APPLICATION OEM5.1

Table 1. The spec of CR at A+/A/B area

Classification	SPEC.(min.)(25℃)	
	OEM5.0	OEM5.1
A+ area: H +/- 10°; V +8/-4°	1200:1	1500:1
A area: H +/- 40° ; V+20/-10°	650:1	750:1
B area: H +/- 50°; V +20/-10°	350:1	500:1

Contrast ratio is one of the most important optical parameters of TFT-LCD. The ratio of the maximum brightness value (all white) divided by the minimum brightness value (all black) is the Contrast Ratio (CR), and the larger the brightness value is, the brighter the color will be. Base on the same white/black brightness of LCD display, the higher the contrast is, the more distinct the image hierarchy is. Display specification for automotive application is becoming increasingly stringent, especially the CR at A+/A/B area whose spec is as following (Table1). What we need to do is to improve the TFT-LCD design to meet the further upgrade CR specification from 1200:1/650:1/350:1 to 1500:1/750:1/500:1.

3 DESIGN TO IMPROVE THE CONTRAST RATIO

There are many factors affecting contrast ratio in the center and at A+/A/B area of TFT-LCD. The key impacting indicators include display mode (O-mode and E-mode), backlight film structure, polarizer and liquid crystal (LC) etc. We will present the detailed analysis including CR in the center and at A+/A/B area, luminance and black color shift in the following article.

3.1 Backlight Film Structure

TFT-LCD requires a backlight to provide light source and LED is side lit. The backlight unit includes LEDs, reflector, light guide plate, diffuser, BEF and DBEF etc. [3-5]. As far as we know, backlight film structure has an effect on the CR in the center and other viewing angle area. In this article, we have developed two types of backlight film structure (Ⅰ and Ⅱ). As can be seen from Fig.1 and Fig.2, backlight film structure Ⅰ can meet the CR spec. at the A+/A/B area while backlight film structure Ⅱ can only meet the CR spec. at the A/B area and cannot meet A+ spec: min.1500. The main factor is one of backlight films is different between backlight film structure Ⅰ and Ⅱ which has a great influence on the luminance of white and black image at viewing angle area. Backlight film structure Ⅱ will decrease the CR by 5% and 3% in the center and at the A+ area compared to backlight film structure Ⅰ.So we will use backlight film structure Ⅰ to improve the contrast ratio for automotive application OEM5.1.

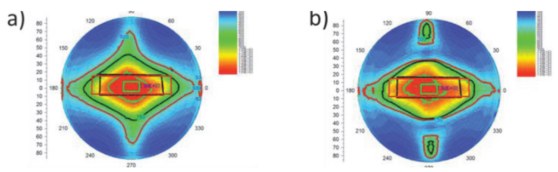


Fig.1 Iso-Contrast Contours (The same scale)
a) Backlight Film Structure Ⅰ
b) Backlight Film Structure Ⅱ

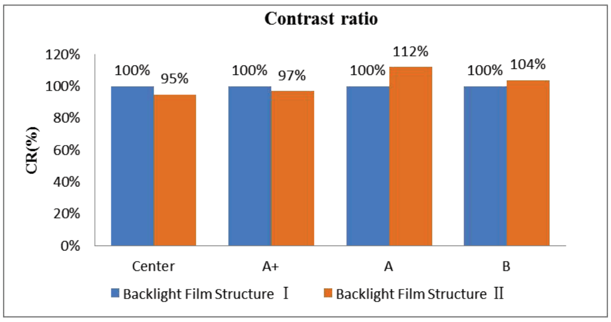


Fig.2 The CR difference between backlight film structure Ⅰ and Ⅱ

3.2 Polarizer

The polarizer, one of the important parts of a liquid crystal display, impacts the quality of display directly [6]. In other words, for TFT-LCD (in the FFS mode), there is no polarizer, there is no normal display. Linear polarizer can change natural light into linear polarized light. In the TFT-LCD, we use two polarizers: top polarizer and bottom polarizer whose absorption axes are perpendicular to each other. Polarizer plays an important role on improving CR at the viewing angle. In this article, we will describe the effects of three types of polarizers on optics, especially the display mode (O-mode and E-mode), black luminance and black color shift of liquid crystal module (LCM).

3.2.1 O-mode and E-mode

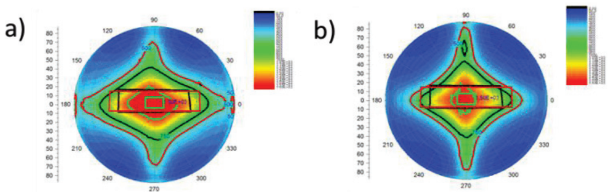


Fig.3. Iso-Contrast Contours (The same scale)
a) O-mode; b) E-mode

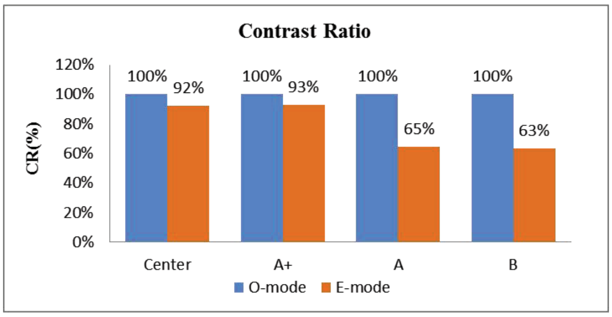


Fig.4 The CR difference between O-mode and E-mode

To achieve a high contrast ratio (CR) in the FFS (TFT-LCD) mode, we have analyzed and validated O-mode and E-mode. According to the measured results for CR with EZ-Contrast in all directions, the cell with O-mode shows higher CR with varying viewing direction than the cell with E-mode. Especially, as can be seen from Fig.3, at the A+/A/B area, the CR of O-mode can meet the spec.min.1500:1/750:1/500:1 while the CR of E-mode is out of the spec. O-mode has an advantage in terms of the CR. Fig.4 tells us that E-mode shows smaller CR in the center and at A+/A/B area compared to the O-mode which decreased by 8%, 75%, 35% and 37% respectively.

3.2.2 Black luminance

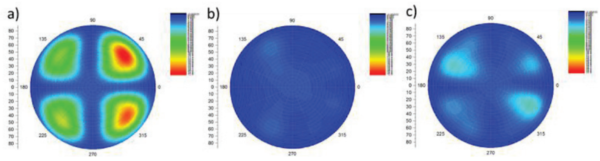


Fig.5 Iso-Black Luminance Contours (The same scale)
a) Pol Ⅰ; b) Pol Ⅱ; b) Pol Ⅲ

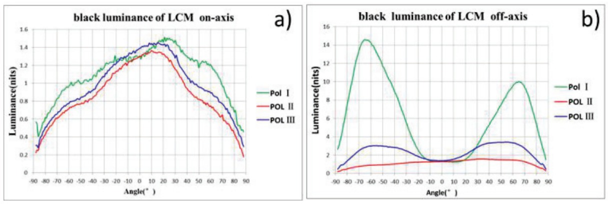
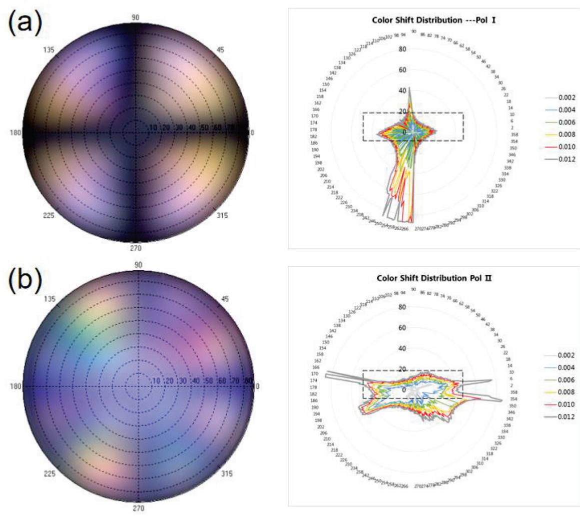


Fig.6 The black luminance difference between Pol Ⅰ/Ⅱ/Ⅲ

a) 90°/270°on-axis angle;
b) 135°/315°off-axis oblique angle

From Fig.5 and Fig.6, we can come to the conclusion that there is little difference on black luminance on-axis between Pol Ⅰ, Ⅱ and Ⅲ with the same mode (O-mode) which shows that the polarizer almost does not affect black luminance on-axis (a) viewing angle area. However, Pol Ⅱ and Ⅲ can largely improve the black luminance off-axis (b) viewing angle area, compared to Pol Ⅰ. In terms of improvement effect on black luminance at wide viewing angle area, Pol Ⅱ is better than Pol Ⅲ. But Pol Ⅱ is easy to bend during RA test. Therefore, we use Pol Ⅲ to improve the black luminance for automotive application OEM5.1.

3.2.3 Black color shift



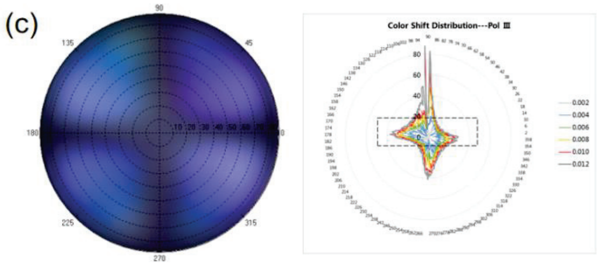


Fig.7 Iso-Black Color Shift Contours

a) Pol Ⅰ; b) Pol Ⅱ; c) Pol Ⅲ

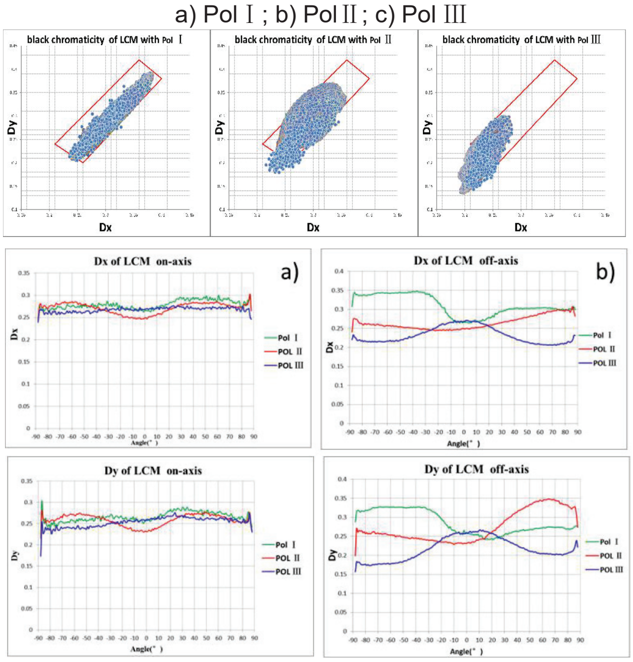


Fig.8 The black color chromaticity difference between Pol Ⅰ/Ⅱ/Ⅲ

a) 90°/270°on-axis angle;

b) 135°/315°off-axis oblique angle

From Fig.7 and Fig.8, we can know there is a very obvious difference on black color shift between Pol Ⅰ, Ⅱ and Ⅲ, especially off-axis at oblique viewing angle area (b). Meanwhile, The black image exhibit bluish purple with Pol Ⅲ which is preferred by a great many automotive clients. As we all know, the polarizer (Pol) is one of the most important materials of TFT-LCD which plays a vital role in the display. We will further study in the future.

3.3 Liquid Crystal

The working principle of liquid crystal display is: under the action of electric field (TFT), the light transmittance of backlight is changed (modulated) by changing the arrangement direction of liquid crystal molecules to complete the electro-optical conversion, and then the color redisplay in time domain and space domain is completed by using different excitation of Red, Green, Blue trichromatic signal through red, green and blue primary color filter. The liquid crystal acts as a light valve which determines the display effect and affects the transmittance of panel, black luminance, contrast ratio and response time etc. In this article, we have studied the effects on optics of LC Ⅰ and Ⅱ.

3.3.1 White luminance

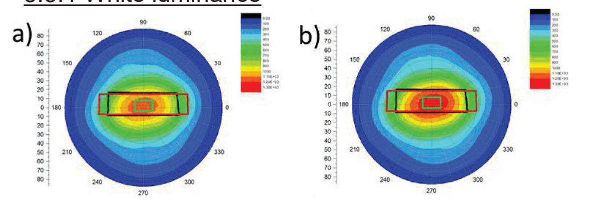


Fig.9 Iso-White Luminance Contours (The same scale)

a) LC Ⅰ; b) LC Ⅱ

As shown by Fig.9, that uses the same scale, we can get that LC Ⅱ has an excellent performance in the white luminance which is better than LC on-axis(a) and off-axis(b) (as shown by Fig.10). However, CR is determined by white luminance and black luminance. We will further study the black luminance difference between LC Ⅰ and Ⅱ in the next parts.

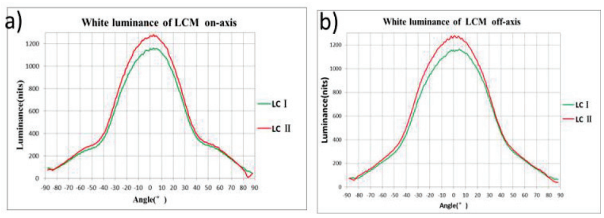


Fig.10 The white luminance difference between LC Ⅰ and Ⅱ

a) 90°/270°on-axis angle;

b) 135°/315°off-axis oblique angle

3.3.2 Black luminance

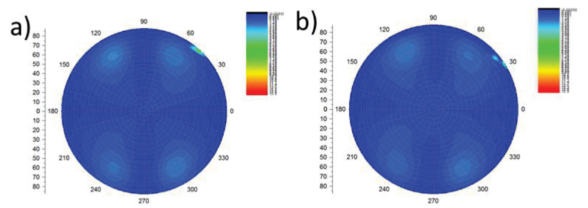


Fig.11 Iso-Black Luminance Contours (The same scale)

a) LC Ⅰ; b) LC Ⅱ

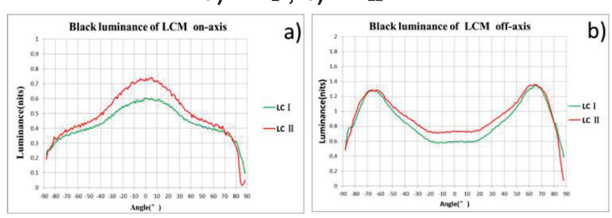


Fig.12 The black luminance difference between LC Ⅰ and Ⅱ

a) 90°/270°on-axis angle;

b) 135°/315°off-axis oblique angle

From the experimental data of Fig.11 and Fig.12, LC Ⅰ has an excellent performance in the black luminance which is darker than LC Ⅱ on-axis(a) and off-axis(b). The Δn of LC Ⅰ and Ⅱ are different from each other which determine the black luminance of LCM varies to each other over wide viewing angle area.

3.3.3 Contrast Ratio

Fig.13 and Fig.14 show us LC Ⅰ has an excellent performance in the contrast ratio which is higher than LC Ⅱ on-axis(a) and off-axis(b). And LC Ⅰ can meet the spec of contrast ratio in the center and at the A+/A/B area. Therefore, we use LC Ⅰ to improve the contrast ratio for automotive application OEM5.1.

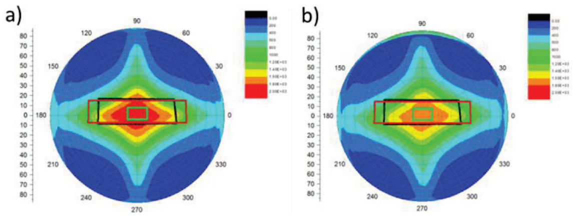


Fig.13 Iso-Contrast Contours (The same scale)

a) LC Ⅰ ; b) LC Ⅱ

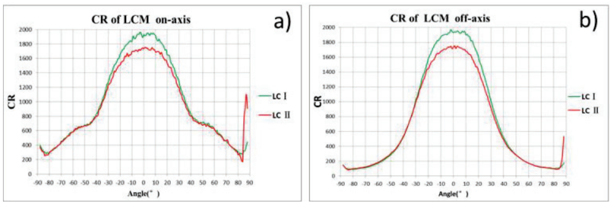


Fig.14 The CR difference between LC Ⅰ and Ⅱ

a) 90°/270°on-axis angle;

b) 135°/315°off-axis oblique angle

3.3.4 Conclusion

The transmittance is the ratio of the brightness of the light passing through the cell panel to the brightness of the backlight. The higher the transmittance is, the higher the brightness of the light passing through the cell panel based on the same backlight brightness. In other words, high transmittance means high brightness. The panel transmittance of the cell panel with LC Ⅱ is 5% higher than LC Ⅰ .However, the effect of black brightness on contrast ratio is greater than that of white brightness. As can be seen from fig.15, The contrast ratio of the cell panel with LC Ⅰ is 11% higher than LC Ⅱ .Liquid crystal is very significant when we evaluate and design the TFT-LCD cell.

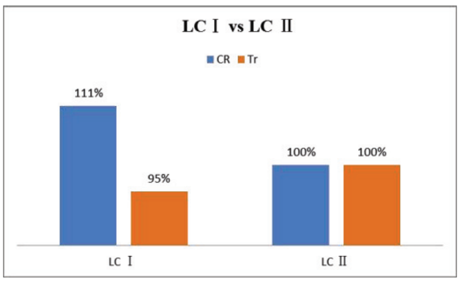


Fig.15 The CR and Tr difference between LC Ⅰ and Ⅱ

4 Conclusion

Contrast ratio is one of the most important parameters of TFT-LCD (FFS). More than ever, viewing angle is fairly significant for automotive application. In order to improve CR in the center and at the A+/A/B area, we have analyzed four factors which play a crucial role on the CR. As follows, backlight film structure, display mode (O-mode and E-mode), polarizer and liquid crystal etc. We have come to the conclusion that the cell with backlight structure Ⅰ, O-mode, polarizer Ⅲ and LC Ⅰ shows the best CR performance and can meet the CR spec of A+/A/B min.1500:1/ 750:1/ 500:1.

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