Visual Perception for TCO'03 Angular-Dependence Luminance Uniformity of TFT-LCDs

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Abstract

Due to the stricter requests of the human perception of images, many industrial standards such as TCO'03 have been made to survey the Flat Panel Displays (FPD) nowadays. The angular-dependence luminance uniformity is an important item to evaluate the performance of FPD. In this article, we focus on the above test item base on TCO'03 standard in the case of vertical direction of ±15°. With controlling the driving voltage toward the liquid crystals of TN-type TFT-LCD, there exists a voltage-driving range which can achieve the value of the L_{max}/L_{min} at ±15° ≤1.7 readily. Both experiment and simulation have been well analysis.

1. Objectives and Background

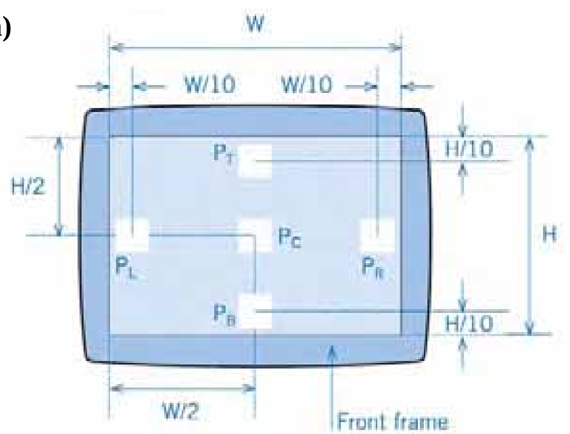
Flat Panel Displays (FPDs) have been developed to replace the traditional CRT displays because of its light weight, small thickness and low power consumption. Therefore, many standards have been established to superintend the image quality of FPDs such as PSWG, ISO 13406-2, TCO and so on. Hence, many studies such as improving panel full-surface luminous uniformity base on TCO'03 standard have been proposed nearly [1]. The Angular-dependence Luminance Uniformity (abbreviated as ALU in the following texts) of vertical ±15° has been stipulated in the standard of TCO'03 [2]. Before the measurement, the central brightness of monitor set should be adjusted to reach 125 to 135 nits by modulating both bottoms of Contrast and Brightness. After above adjustment, the test can be started base on the standard of TCO'03 A.2.3.1. The measure position is shown in Fig. 1(a) and Fig. 1(b).

The ALU of the measured point can be described in the following equation:

$$Uniformity\ (15°\ \ tilted) = \frac{L_{\max}}{L_{\min}} \leq 1.7\ .$$

There exists many unsettled solutions to achieve above request and most of them belong to trial-and-error after the problem emerging, such as modulating lamps-uniformity, lightguide plate or adjusting any variables we can get to obtain small piece of golden samples. In order to find out the main root cause, we undertake the analysis toward the Optics of liquid crystal displays (LCDs). With simulated by 1D finite difference method (FDM), the threshold value of the driving voltage toward the liquid crystals (V_{LC}) can be found to achieve the ALU(±15°) ≤ 1.7.

(a)



(b)

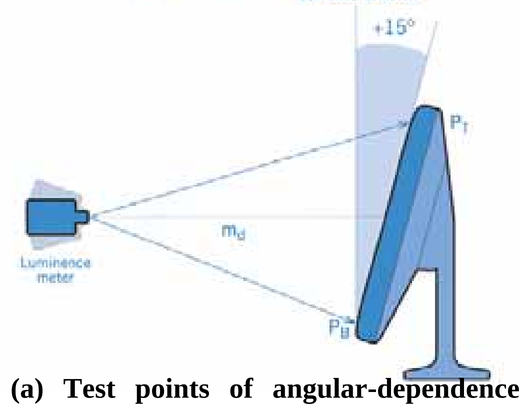


Fig. 1. (a) Test points of angular-dependence luminance uniformity (b) Side view of the test set-up when the screen is tilted 15 degrees backwards

2. Results

The angular sketch of the measuring system is shown in Fig. 2. When the screen is tilted +15° (denoted as θ_3), the equivalent measuring angle of desired points becomes –24° (denoted as θ_2) and –6° (denoted as θ_1). Therefore, we should measure the test points of 24° and 6° of down and top viewing angle while the screen is tilted backward (+15°) and forward (–15°) respectively. With stimulated by the FDM analysis, the equal luminance contour of normal-white TN LCDs in on-state can be plotted as illustrated in Fig. 3 and where A, B and A', B' is placed in the viewing cone of 6° and 24°. Therefore, we can obtain the ALU value of both top and down viewing angles by simply calculating the luminous ratio of B/B' and A/A' in each V_{LC} (same as gray level). With varying V_{LC} from 0V ~ 5V, the ALU curve has been plotted in Fig. 4 when monitor set is tilted +15° and –15°. It can be noticed that ALU(±15°) ≤ 1.7 is impossible to achieve when driving V_{LC} within the range of 2.0V ~ 3.9V. The luminance polar diagram of either 0V and 3 V are plotted in Fig. 4(b) hence we can see the polar diagram change in vertical viewing angle. Due to the contrast bottom of monitor set will influence panel gamma curve, above results can provide us the reference for optimizing our test conditions.

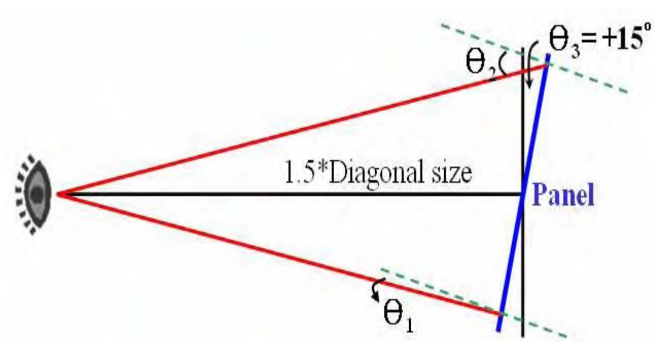


Fig. 2. The equivalent measuring angle of monitor tile +15°, where θ_2 = 24° and θ_1 = 6°

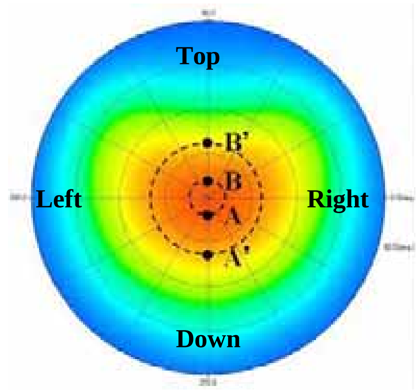
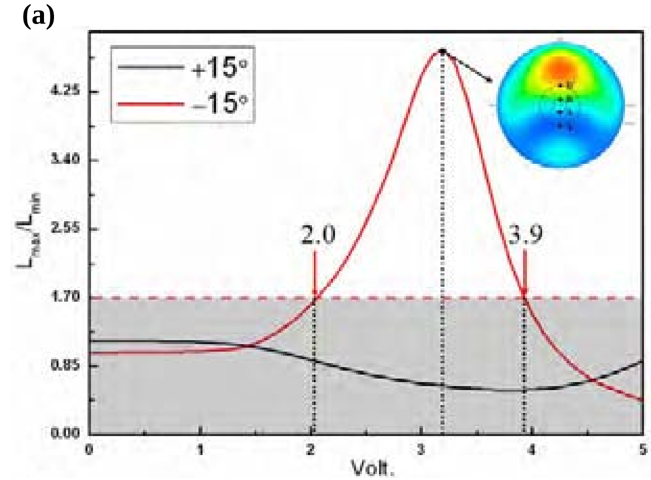


Fig. 3. The equal luminance map of TN LCD. A and A' denotes 6° and 24° in down viewing angle, B and B' denotes 6° and 24° in top viewing angle

(a)



(b)

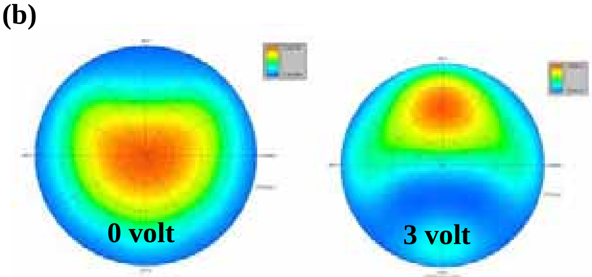


Fig. 4. (a) The simulation result which is calculated by FDM. The gray area indicates the in-spec. region. L_{max}/L_{min} of –15° is failed when V_{LC} is in the range 2.0V to 3.9V (b) The luminance polar diagram while panel driving in 0 volt. and 3 volt..

By measuring the product of 17” TN LCD with unskillful manufacturing process in earlier phases, denoted as Sample-A, we can found that the window (ΔV) to attain ALU spec. is quite narrow and that will lead to the knot when modulating the monitor set for conforming to the TCO standard, as illustrated in Fig. 5. With measuring the sample with improved manufacturing process and panel design, denoted as Sample-B, the ALU curve becomes more similar to the ideal case we simulated above and hence a wider window (ΔV) to attain ALU spec. can be obtained, as illustrated in Fig. 6.

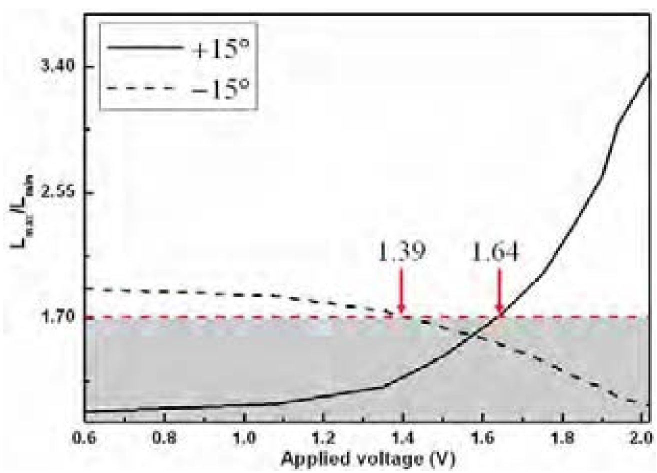


Fig. 5. The L_{max}/L_{min} in each V_{LC} of Sample-A with earlier unskillful process. The in-spec. window is only 0.25V.

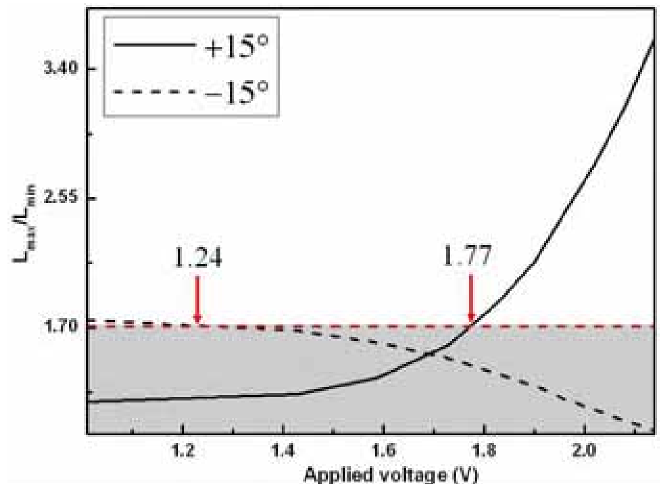


Fig. 6. The L_{max}/L_{min} in each V_{LC} of Sample-B with improved process and design. The in-spec. window becomes twice as wide as Sample-A.

3. Impact

We propose a detailed analysis toward the display performance of angular-dependence luminance uniformity by both simulation and experiment. With calculated by FDM base on the Optics of liquid crystal, the margin of V_{LC} can be found for achieving ALU(±15°) ≤ 1.7 as TCO standard specified. We can control the in-spec. window of V_{LC} by improving the manufacturing process and panel design skill. Two TN-LCD panels with different process have been compared and the ALU in-spec. window improved from 1.39-1.64 volt. to 1.24-1.77 volt. by optimizing the process. A LCD panel with perfect manufacturing process has a wide in-spec. windows between 0 to about 2 volt., such a wide adjustment range will allow end user to adjust the gray level (from 255-gray to about 150-gray) of the displayed white state without bringing on the side effect of noticeable ALU phenomenon. Above analysis result is helpful to avoid negative effect on contrast and the legibility of LCDs.

4. References

[1] Y.-C. Cheng,Y,-J. Hsu and H.-M.Chen, “ A New CCFL Arangement of TFT-LCDs for Fll-surface Luminance Uniformity in Low Lamp Current Driving Situation”, IDW 2005, FMCP-15

[2] *TCO'03 Displays Flat Panel Displays Ver 2.0*, The Swedish Confederation of Professional Employees