

Excellent Ultra-Fast Gaming Monitor Solution for Response Time 1ms

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Abstract

In this article, we describe the gaming monitor's combination of 1.x ms response time and 2000:1 contrast ratio based on HFS display mode. We use positive liquid crystals and optimize the panel design to improve response speed, while using a special backlight design and high contrast polarizers to improve contrast ratio. Finally, the contrast ratio is increased to 2073:1, and the response time in the form of grey-to-grey time is 1.28 ms, while the color gamut comes to DCI-P3 97.3%.

Author Keywords

Gaming monitor; Contrast ratio; Grey-to-grey (GTG); HFS display technology

1. Introduction

Against the backdrop of the booming development of the electronic sports industry, the demand for e-sports displays has also experienced explosive growth. Data shows that in the past few years, the market share of gaming monitors has doubled, and which has occupied more than 50% of the online market in Chinese mainland. At the same time, gamers' demands for gaming display devices expand from simply performance indicators to improving the overall gaming experience.

High contrast makes black appear purer and the image texture better. Fast response means that the monitor can quickly respond to input signals, reduce ghost and streaking in dynamic graphics, and play a key role in matching high refresh rates and what's more providing a smooth gaming experience. In 2022, LG Display increased the contrast ratio to 2000:1 with a response time of 14ms. Recently, BOE Technology Group has studied the principle of improving CR through liquid crystal materials, process optimization, and dark light unit structure design, and the CR reaches 2225:1 while the grey-to-grey (G-G) response time is 5.27 ms^[1].

In this paper, we have achieved a good balance between response time, white and dark state brightness and color gamut. Based on a 27 inch QHD liquid crystal display and using HFS mode, the G-G response time is 1.28ms with a high response ratio of 2073:1.

2. Results and Discussion

2.1 Low Coefficient and Fast Response LC Material

Among LCD panel materials, LC materials have a particularly significant impact on panel optics, and the successful development of high contrast and fast response liquid crystals is quite conducive to achieving the required optical specifications. As we all know, the contrast ratio of LCD panels can be calculated from the equation (1).

$$CR = \frac{L255}{L0} \quad (1)$$

$$S_{LC} \propto \frac{\Delta n^2 (n_e + n_o)^2 d}{K_{ave}} \quad (2)$$

$$\tau_{on} = \frac{\gamma_1 d^2}{\epsilon_0 \Delta \epsilon (V_{op}^2 - V_{th}^2)} \quad (3)$$

$$\tau_{off} = \frac{\gamma_1 d^2}{K_{ave}} \quad (4)$$

High contrast ration can be achieved by the increase of L255 and the decrease of L0, while both of which are positive correlation with transmittance of panels. From the materials point of view, the increase of L255 needs to improve the material transmittance, and the reduction of L0 means optimizing the L0 gray level light leakage (minimize the value of L0). According to the equation (2), high K value of LC mixtures and suitable Δn value help to improve the contrast ratio.

However, the K value cannot be increased at will. For LC materials, the increase of K value is often accompanied by the higher viscosity γ_1 . The increase of γ_1 will significantly increase τ_{off} and slow down the response speed from the perspective of equation (3) and (4)^[2]. When evaluating the optical performance of liquid crystals on LCD panels, it is necessary to consider both γ_1 and K values, and choose the material solution with as low a γ_1/K as possible to achieve a fast response speed.

In this paper, several high contrast ratio and fast response speed liquid crystals are evaluated, and the following simulation results are obtained through Techwiz 3D simulation.

Table 1. Optical simulation results of several liquid crystals by Techwiz 3D

LC type	TR	GTG	Vop
Ref LC	100%	100%	100%
LC-1	69%	95%	128%
LC-2	93%	97%	125%
LC-3	58%	71%	123%
LC-4	87%	108%	113%
LC-5	91%	102%	117%

LC-3 among them is selected for panel verification on G8.6 generation line. In HFS display mode, the measured optical Contra ratio 2000: 1 and the average of grey-to-grey times (GTG) reached 1.28 ms on 27" QHD 300Hz item. Compared with the gaming monitor currently being sold on the market, the response speed increased over 50%.

Table 2. Physical properties of LC-3 and normal LC

Item	Normal LC	LC-3
Δn [@589 nm]	0.131	0.108
$\Delta \epsilon$ [@1 kHz]	3.1	3.4
γ_1 [mPas]	45	76
K_{11}/K_{33} [pN]	13.5/12.9	22.7/22.1
d [μm]	2.3	2.0
S	0.0348	0.0118
γ_1/K_{11}	3.3	3.4

2.2 Unique Panel Design for Fast Response

For response speed improvement, panel design plays a particularly important role in addition to material optimization. Based on CSOT's extensive panel design experience, we creatively designed ITO's slit to be 15 degrees, which increases the alignment Angle compared to normal gaming monitor design, greatly speeding up the response speed of the LCD. Meanwhile, the channel material of the TFT device uses Indium Gallium Zinc Oxide (IGZO, a semiconductor material), which possesses higher electron mobility compared with the traditional α -Si material, and makes the designed TFT device a higher charging rate so that can drive the liquid crystal's rotation efficiently and quickly.



Figure 1. The difference between ITO 7° (a) and 15° (b).

In addition, thanks to the excellent process capability of the Guangzhou CSOT Panel Factory production line, we reduced the cell gap to about 2 μm and further optimized the response time (according to equation (3) and (4)).

2.3 Backlight Structure Design for High CR

The backlight design has a significant improvement in contrast, and the impact of different backlight structures on contrast is even more than 20%. For HFS display mode, the liquid crystal molecules are arranged horizontally in the panel. When the light emits from the backlight, it will form an angle with the LC molecules' ne direction. Different backlight structural designs have significant differences in this angle, and the larger the angle, the lower the brightness of its dark state. In combination with the new LC solution and optimized technological process, we selected backlight structures containing prisms or reverse prisms to converge the angle of the emitting backlight and minimize the dark state brightness, thereby improving contrast ratio.

Table 3. Comparison of optical specifications

Item	Conventional Gaming	High CR Gaming
Color Gamut	DCI-P3 97% @CIE1976	DCI-P3 97% @CIE1976
CR	1105	2073
L255	485 nit	419 nit
L0	0.439 nit	0.202 nit
GTG	4.67 ms	1.28 ms

It is worth noting that for the gaming monitor, due to the low cell gap, the phase delay is also on the low side, which usually leads to the blue problem of the white dots on the display white pattern. We adjust the backlight spectrum so that the LCD panel white spot can meet the product specifications in reaching the target response time and contrast ratio. What's more, the measured color gamut reached DCI-P3 97%.

2.4 Polarizer for High CR Display

LCD panel controls the brightness and darkness of the display screen through the optical rotation characteristics of liquid crystal

and the polarization characteristics of the polarizer (POL). Selecting the appropriate POL types can effectively reduce the brightness of the dark state.

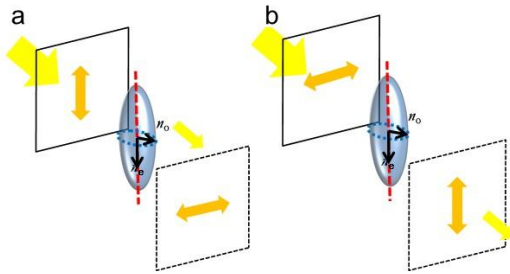


Figure 2. The principle by which a polarizer controls light transmission.

This paper uses a high-precision and high-contrast polarizer, which can effectively separate and block un-polarized light, so that the display can better absorb ambient light when displaying black images, thereby improving contrast ratio.



Figure 3. The principle by which a polarizer controls light transmission.

3. Conclusion and Prospect

In order to develop a high contrast esports display, we focused on the evaluation and selection of liquid crystal materials, panel design, backlight design and polarizer type, and finally achieved a combination of contrast ratio 2000:1 and response time 1.x ms, which demonstrated excellent optical results. In the specification reached at the same time, we should still pay attention to the technical solution of cell gap $2\mu\text{m}$ has high requirements for the process capacity of the factory, which brings certain challenges to the mass production of the product. We will continue to try more new solutions to reduce the difficulty of mass production, response time 1.x ms and contrast 2000:1 gaming monitor display is expected to become a high-end product in the future gaming display market.

4. Acknowledgements

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5. References

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