A Design Method for Improving Line Image Sticking of High-Refresh-rate Gaming Display Screens

Ji Wu, An-Thung Cho, Yong Zhang, Renrui Liao, Fengyun Yang, Tingting Ruan,Youzheng Lu, Lu Mao, Xuefeng Fang, James Hsu, Wade Chen

Chuzhou HKC Optoelectronics technology Co., Ltd., China

Keywords: Line image sticking, DBS voltage, High refresh rate

Abstract

The internal electric field of the product panel with high refresh rate is complex, which easily leads to the accumulation of a large number of ions, resulting in line image sticking. In this paper, we use the method of DBS voltage adjustment to effectively improve the occurrence of line residue.

1. Introduction

With the continuous progress of technology and the persistent increase of material life, people have come up with higher demand for the picture quality of the display. At present, LCDs have made significant progress in terms of resolution, color gamut, and viewing angles [1]. Although LCDs has many advantages, there are still problems such as slow response time. When an electric field is applied or removed, the time required for liquid crystal molecules to start rotating until the free energy density is again maintained at its lowest level is called the response time. Reduce the rotational viscosity of the LC, reduce the resistance of the liquid crystal rotating in the vertical direction, and improve the response speed of the panel [2-5].

In addition, **Fig 1** shows that the gaming display market has been growing in recent years and is expected to grow further. For esports games with rapid screen changes, the refresh rate is too low and the response time is too long, which will cause the screen to drag and lag. OLED is recognized by the display industry because of its fast response time, which can significantly reduce blur of the moving image, as shown in **Fig 1**. However, due to the limitation of production process, OLED's short life and low resolution limit its development. LCD has the advantages of high resolution, high brightness, long life and low cost, but the response time is about 100 times slower than OLED. Therefore, LC with very fast response times is essential to achieve a better gaming experience.

The line image sticking problem is one of the classification of panel residual images, mainly because in the black and white checkerboard test, the movement of ions at the black and white boundary causes ions to gather at the boundary and form an internal electric field. The internal electric field of the product panel with high refresh rate is complex, which easily leads to the accumulation of a large number of ions, resulting in line image sticking.

2. Phenomenon description

The residual image is a bad phenomenon that seriously affects the quality of the picture. The residual image means that the screen displays a fixed picture for a long time, and when the screen is switched, the liquid crystal molecules cannot be deflected normally under the signal voltage, resulting in visibility on the screen the image left over from the last frame.

As shown in **Fig 2**, the evaluation method of line residue level is to evaluate the severity of line residue by 24/48/72 hours of line residue level of a 5×5 black and white checkerboard screen. As shown in **Table 1**, the residual image level of all samples has reached the level of Level4, which is far from meeting the customer's requirements for the picture quality of this product.

In the process of the residual image test, we found the line residual image as shown in **Fig 3**, and the analysis found that the main reason was that the lateral electric field moved at the black and white junction, and there was a brightness difference. After several experiments, we found that the line image appeared in a fixed position, and all of them were from black to white transition. By adjusting the checker board pattern, the position of the line residue changes with the change of the pattern, but the direction is from black to white.

Table 1 Image sticking result

Panel	24h IS	48h IS	72h IS
1#	3	4	4
2#	2	4	4
3#	2	3	4
4#	3	4	4
5#	1	4	4

3. Low rotational viscosity of the LC and analysis

As we have known, response time of VA mode governed by various parameters described as follow where, γ1 , d , K33, E represent rotational viscosity, Cell gap, elastic constant of liquid crystal and applied electric field.

$$\tau_{on} = \frac{\gamma_1}{\varepsilon_0 \Delta\varepsilon V^2 - K_{33}(\pi/d)^2} \quad \tau_{off} = \frac{\gamma_1}{K_{33}(\pi/d)2}$$

γ_1: Rotational viscosity
d: Cell gap
$\Delta\varepsilon$: Dielectric anisotropy
V_{op}: Operating voltage
V_{th}: Threshold voltage
K_{eff}: Effective elastic constant

Low viscosity LC are easier to achieve than changing the electric field intensity. In order to achieve fast response time, our viscosity reduction strategy is to mix the allyl monomer evenly with the existing LC. The new LC is called the fast response LC. We can see the comparison of the parameters of the fast response LC and the original liquid crystal in **Table 2**. The measured GTG avg decreased from 7.8ms to 6.2ms.

Through experimental verification, we found that different liquid crystals will have different results. The VHR and ion content of different liquid crystals were tested, and the results showed that the VHR performance of fast LC was weaker and the ion content was higher than that of normal LC as shown in **Table 2**.

Table 2 Physical and chemical properties of fast LC and regular LC

LC	Normal LC	Fast LC
Δn	0.109	0.109
ε//	3.5	3.5
ε⊥	6.7	6.7
Δε	-3.2	-3.2
γ 1/K33	5.18	5.18
GTG（ms）	7.8	6.2
VHR/%	59.46	49.35
ION/nC	3.991	5.774

Fig 4 shows that through the simulation analysis of the positive and negative electric fields in the black and white area, when the product sets the electric field, the fixed voltage from the white area to DBS direction is 1.5V, and the fixed voltage from the black area to DBS direction is 0.5. There is a transverse electric field between the black region and the white region, and the ions will move sideways.

As shown in **Table 3**, the DBS ITO is shifted to one side due to differences in the precision of the process pairs.

Table 3 DBS Overlap Data

DBS CD	Measure	DBS Overlap Data		
		Left	Right	Δ
10	10.2	2.2	2.75	0.55

4. Experiment

From the point of view of mechanism, the main reason for the linear residual image is the change of the state of the electric field, which leads to the arrangement of liquid crystal molecules. The position is different, because after the ion balance is broken, there is a single direction of movement, which will form a fixed electric field, which affects the deflection of the liquid crystal.

Through simulation analysis, it is confirmed that when the screen is a black and white checkerboard, there is a fixed direction electric field in the black and white region. Under the action of an electric field, the ions move horizontally, and the DBS moves in the same direction between pixels and matches the position where the line residues appear. Switching the position of the black and white checkerboard shows that the position of the line shadow has also changed, but the position is still in the transition between black and white. Therefore, introducing the method of adjusting DBS voltage to improve the line residual image can effectively prevent the horizontal movement of ions.

5. Results and discussion

As shown in **Fig 5**, line residue was effectively improved by adjusting the voltage of the DBS. In order to compare the results, 5 samples from the previous batch of samples were selected and compared. The results of the residual image are shown in **Table 4**, and the horizontal level of the linear residual image has improved greatly. From the mechanism point of view, since the horizontal electric field always exists, the adjustment of DBS voltage causes a vertical electric field to form between DBS and CF COM. The horizontal ions do not pass through the vertical electric field, which can effectively prevent the movement of ions and maintain the balance of the electric field, thus improving the line residue as shown in **Fig 6**.

Table 4 Image sticking result after DBS voltage adjustment

Panel	24h IS	48h IS	72h IS
1#	0	0	0
2#	0	0	1
3#	0	0	0
4#	0	1	1
5#	0	0	1

6. Conclusions

In this paper, we use the method of DBS voltage adjustment to effectively improve the occurrence of line residue.From the mechanism point of view, since the horizontal electric field always exists, the adjustment of DBS voltage causes a vertical electric field to form between DBS and CF COM. The horizontal ions do not pass through the vertical electric field, which can effectively prevent the movement of ions and maintain the balance of the electric field, thus improving the line residue.

References

[1] G. W. Gray. The mesomorphic behaviour of the fatty esters of cholesterol. Journal of the Chemical Society, 1956: 3733-3739.

[2] H. J. Coles, M. N. Pivnenko. Liquid crystal 'blue phases' with a wide temperature range. Nature, 2005, 436(7053): 997-1000.

[3] H. X. Fan, Q. H. Wang. High transmittance blue-phase liquid crystal displays with improved protrusion electrode. Liquid Crystal, 2015, 42(4): 481-485.

[4] C. Gu, P. E. Yeh. Extended Jones matrix method II, Journal of the Optical Society of America, 1993, 10(5): 966-973.

[5] T. B. Jung, Y. B. Kim, S. H. Lee, et al. A hybrid aligned nematic reflective liquid crystal display driven by a fringe-field. Liquid Crystals, 2004, 31(10): 1393-1397.

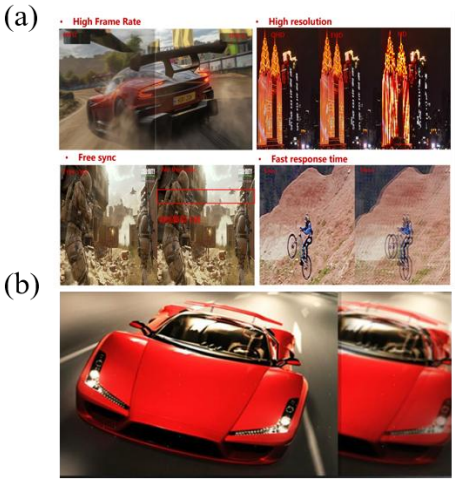

Figure 1 (a) User demand for gaming monitor (b) OLED and LCD moving image comparison

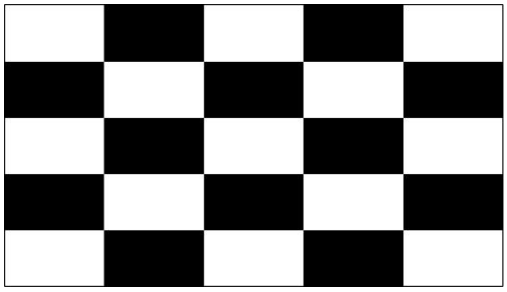

Figure 2 A 5x5 black and white checkerboard is used to evaluate line image sticking

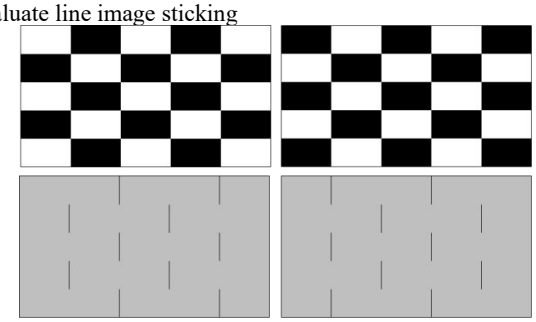

Figure 3 The position of the line image sticking

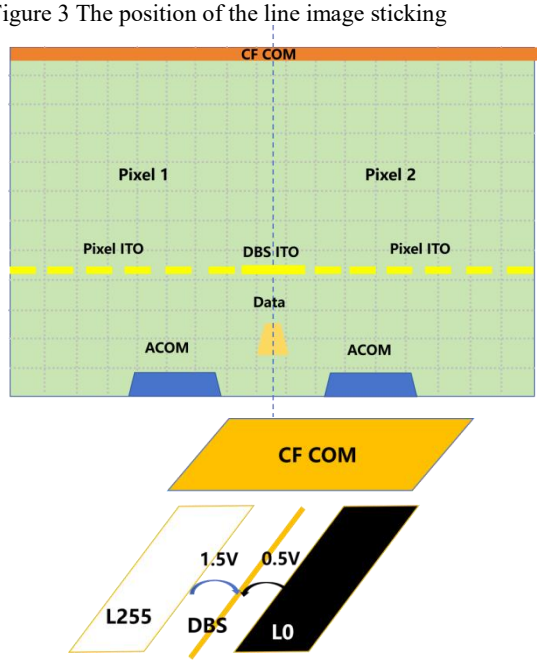

Figure 4 Simulation and analysis of the electric field state

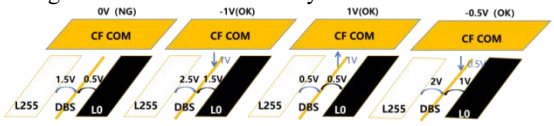

Figure 5 Different DBS voltage improvement results

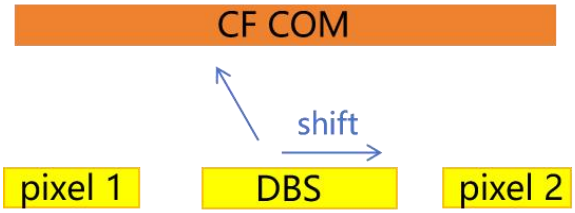

Figure 6 Different response times the important parameters of VA mode