Response Characteristics for Low Voltage Liquid Crystal Display Employing a Constant Charge Model

Mi-Soon Kim*, Su-Jung Huh, Duck-Jong Suh, Yi-Joon Ahn, Kyung-Jin Lee
Seon-Hong Ahn, Kyeong-Hyeon Kim, Sang-Soo Kim
LCD Business SAMSUNG ELECTRONICS CO., LTD
#200, Myeongam-Ri, Tangjeong-Myeon, Asan-City, Chungnam-Do, Korea, 336-841
Phone: +82-41-535-5978, Email: misoony.kim@samsung.com

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Abstract

The response time characteristic of low voltage liquid crystals (LCs) is investigated and a new simulator for low voltage LCs is proposed. In order to enable low voltage operation, it is important to minimize Vth of LCs and variation of pixel voltage caused by dynamic capacitance operation of LC Display. Because dynamic capacitance variation is much larger for low voltage LC operation compared to that of conventional LC material, it is necessary to make a better model for dynamic capacitance operation. A proposed minimizing Vth of LCs and variation of pixel voltage study results through a new constant charge model improve response characteristics for low voltage LCs operation.

1. Introduction

Low voltage liquid crystals (LCs) have been developed for the purpose of reducing power consumption of LCD. In order to achieve low voltage operation, it is important to decrease LC threshold voltage (Vth) and minimize the variation of pixel voltage caused by dynamic capacitance. Effective elastic coefficient (K_{eff}) is a key factor of decreasing the Vth. A lower Keff gives lower Vth. And the variation of a pixel voltage can be minimized by using large storage capacitance.

The pixel capacitance for a LC cell could be described as:

$$C_{pixel} = C_{st} + C_{lc} = C_{st} + \varepsilon \cdot K_{lc} \qquad (1)$$

where C_{st} is storage capacitance, C_{lc} is LC capacitance, ε is dielectric constant of LC, and K_{lc} is a constant related to pixel area and cell gap. For a pixel with electric charge Q_0, its pixel voltage is:

$$V_{pixel} = \frac{Q_0}{C_{pixel}} = \frac{Q_0}{C_{st} + \varepsilon \cdot K_{lc}} \qquad (2)$$

Due to the anisotropic property of LC, the effective ε value changes with LC molecule rotation under electric field. Because the motion of LC is much slower than pixel charge speed, V_{pixel} will decrease with time after the pixel is charged.

Therefore, the properties of LC will affect its electric-optical performance comprehensively. It will have a limitation to lower effective elastic coefficient (K_{eff}). This paper deals with the experiment study of the lowest K_{eff} condition for low voltage LCs.

2. Experimental

For the low voltage LC operating experiments, a new constant charge simulation model is applied. Figure 1 shows response time waveforms of low voltage LC operation, using a new constant charge simulator and figure 2 shows response time of real LCD panel.

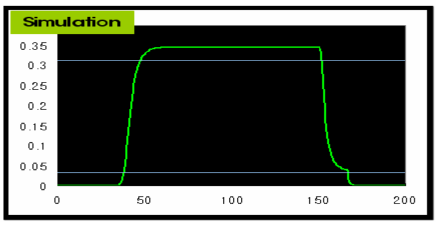

Figure 1. RT of low voltage LC using new simulator

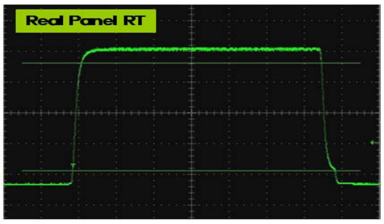

Figure 2. Real LCD Panel's RT of low voltage LC

Like figure 1, and figure 2, new constant charge model can explain dynamic capacitance operation of LC display and its accuracy is over 97%.

Figure 3 shows the simulated waveforms of the pixel voltage and transmittance using the new constant charge model when LC molecules move from a homogeneous state to a homeotropic state. It explains discontinuous transition due to reduce of a pixel voltage by the dynamic capacitance during the frame period, thereby effectively increasing the response time of the LC display. In case of the opposite transition from a homeotropic state to a homogeneous state, a low pixel voltage should be induced. However, as shown in Figure 4, the pixel voltage analogously increases during the frame period due to the reduced dynamic capacitance, likewise increasing the response time.

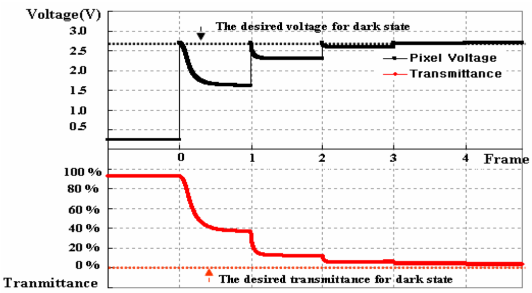

Figure 3. Simulated response curves, light to dark state

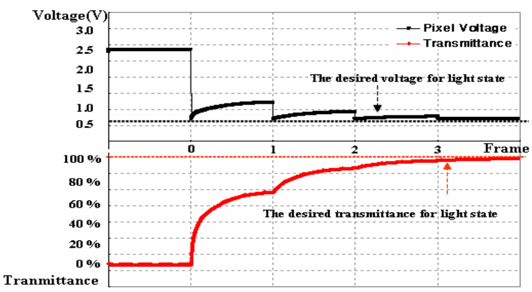

Figure 4. Simulated response curves, dark to light state

This phenomenon is caused by dynamic capacitance operation of LCD panel, which is much larger influence for low voltage LCs operation.

3. Results

Figure 5 shows decrease variation of the pixel voltage waveforms according to large storage capacitance application.

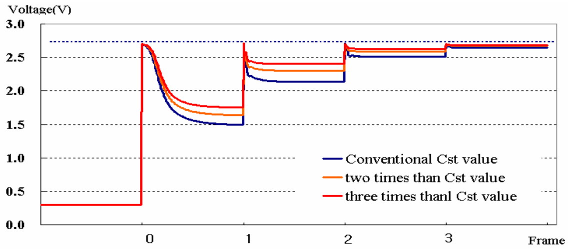

Figure 5. Simulated voltage waveforms, according to increasing Cst value

If the variation of pixel voltage decreases, response time characteristics of low voltage LCs are improved. Figure 6 shows decrease the response time characteristics according to increase storage capacitance application and figure 7 shows response time decrease ratio.

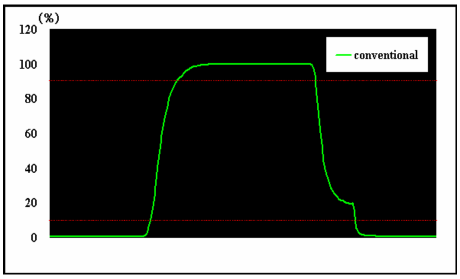

Figure 6(a) Conventional Cst

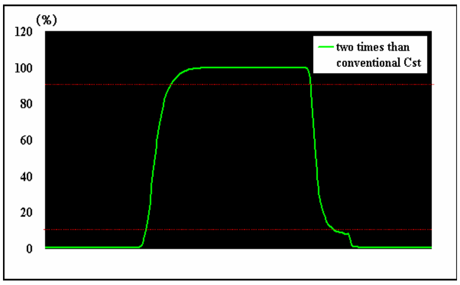

Figure 6(b) Two Times than Conventional Cst

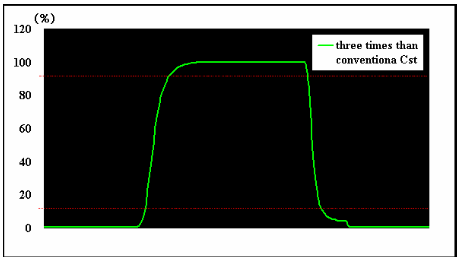

Figure 6(c) Three Times than Conventional Cst

Figure 6. Response time characteristics according to increasing storage capacitance

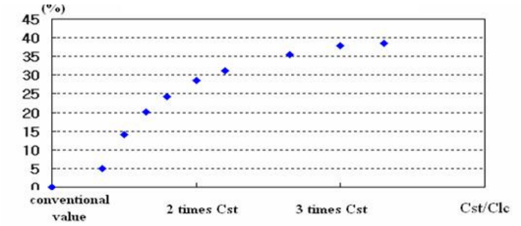

Figure 7. Simulated response time decrease ratio

As shown in Figure 6, response time characteristics of low voltage LCs operation is delayed and cusp of the waveforms means that LC has the two step motions due to large variation of pixel voltage.

However, according to large storage capacitance application, cusp of the transmittance waveforms are lower than 10% below that nearly don' t have influence on LCs response time characteristics.

4. Summary

This paper proposes that minimize the variation of pixel voltage caused by dynamic capacitance operation throughout an optimized constant charge model for low voltage LC. According to this study, the response time of low voltage LC is improved in order to achieve a fine-tuned portable LCD panel.

5. References

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