Study on Local Area Transient Response Cause by Flexoelectric Effect of FFS Mode LCD

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ABSTRACT

Flicker is a serious problem in FFS mode LCD, flexoelectric effect is a main reason to affect the flicker phenomenon in FFS LCD panel. In this paper, we analysis the mechanism of Flicker phenomenon in local area. Different driving frequency of FFS LCD panel was discussed.

1 INTRODUCTION

Fringe-field switching (FFS) liquid crystal (LC) mode display has been widely used for mobile phones, pad, and high-end notebook displays due to its high optical efficiency and performance for ultra-high resolution displays [1-3].All companies are trying their best to improve the LCD performance, low power consumptions, viewing angle, response time, etc. Generally, in real panel design, there are different kinds of driving method, frame inversion, column/raw inversion, and dot inversion used in LCD module. Usually, the flicker of panel will be set to minima if the voltage of positive frame and negative frame is balanced, as shows in Figure 1. In real TFT-LCD panel driving, a pure AC voltage cannot be applied for all grey level though ac voltage is applied due to existence of feedthrough voltage $\Delta Vp = Cgs \Delta Vg/(Cgs+Cs+Clc(V))$ where Cgs represents the coupling capacitance of gate electrode and source electrode, Cs and Clc represents a storage capacitance and LC capacitance, respectively and Vg represents the gate voltage. The Clc is voltage-dependent so that ΔVp is not a constant value. In general method, asymmetric gamma voltage setting always set to overcome this problem. However, FFS mode LCD has flexoelectric effect and the transmittance of positive and negative voltage will be affected.

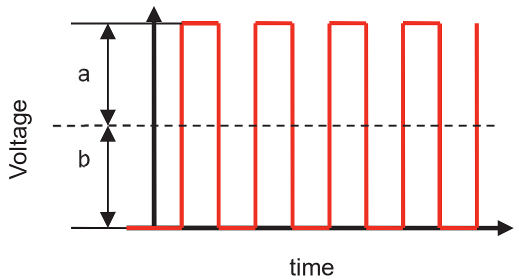


Fig. 1 AC Signal

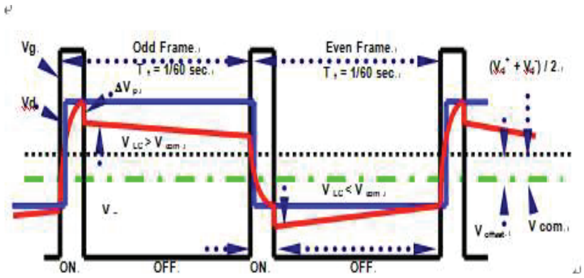


Fig. 2 Feedthrough of signal voltage

The flexoelectric effect in liquid crystals concerns the linear coupling of splay and bend director deformations to an electric polarization. Flexoelectric liquid crystal materials exhibit a polarization P proportional to the orientational deformation of the director field n,

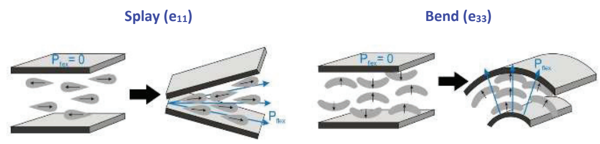


Fig. 3 Spray and band deformation of liquid crystal

$$\vec{P} = e_{11}\vec{n}(\nabla \cdot \vec{n}) + e_{33}(\nabla \times \vec{n}) \times \vec{n}$$

where e11 and e33 denote the flexoelectric coefficients related to splay and bend distortions, respectively. The phenomenon is somewhat similar to the piezoelectric effect in certain solid crystals where a coupling between mechanical stress and polarization is observed, so that the polarization manifests itself due to a positional deformation.

If the voltage of positive frame and negative frame is unequal, the DC residual voltage will occur and resulting in net dc applied to LC layer. As a result, applied DC will attract ions and the accumulated ions at an interface between LC and alignment layer forms residual DC, which affects signal voltage applied to the LC layer.

In this paper, we discuss transient response cause by flexoelectric effect and flicker value variation of FFS mode LC display.

2 EXPERIMENT

A FFS panel is filled with positive LC and driving by function generator with square wave. Gate signal is setting DC voltage to turn on TFT all the time and reduce ΔVp effect. The structure is showed as Figure4. We use photo diode and oscilloscope to find the minimum peak to peak voltage difference to get the balance voltage of positive frame and negative frame. In TN type LC panel, we can get minima peak to peak value when the voltage of positive and negative frame is balanced. In FFS mode, the minima peak to peak value is not occur when the voltage of positive and negative frame is equal. Minima peak to peak difference voltage value will be got if we set a bias voltage to LC cell.

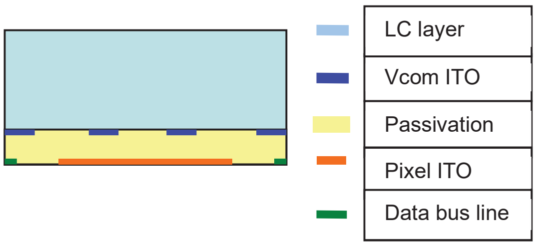
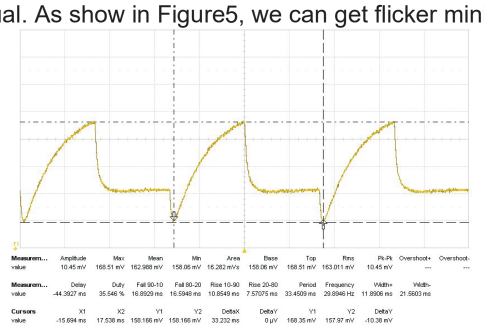
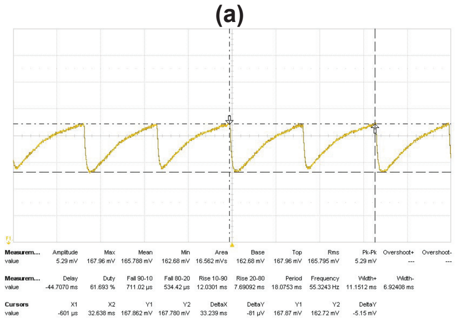


Fig. 4 The cross section of FFS mode LCD Pixel

The p-to-p voltage with different driving voltage. Different Vop will get different Vpp. It is cause by different LC deformation and the transmittance of positive and negative voltage is different. In panel design, gamma tuning is always set the Vcom value while the flicker value is minimal. We use 30Hz driving and set a bias voltage to get Vpp minimum, it is the same as flicker minimum. For FFS mode LC display, tune the minima flicker value of Vcom voltage will cause negative and positive frame unequal. As show in Figure5, we can get flicker minima.



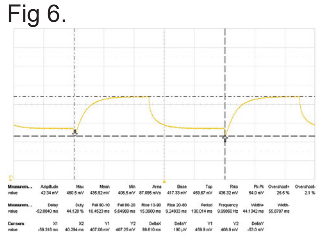
(a)



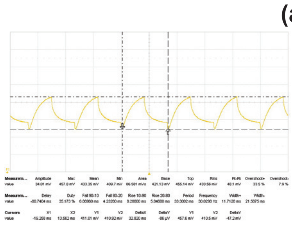
(b)

Fig. 5 Waveform of (a) pure AC signal, and(b)minimize Vpp value

We change the driving frequency in 10Hz,30Hz and 60 Hz to compare Transmittance waveform. The measured data show in Fig 6.



(a)



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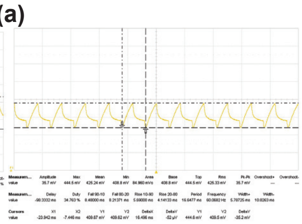


(c)

Fig. 6 Waveform of (a) 10Hz, (b)30Hz, and(c)60Hz Vpp value

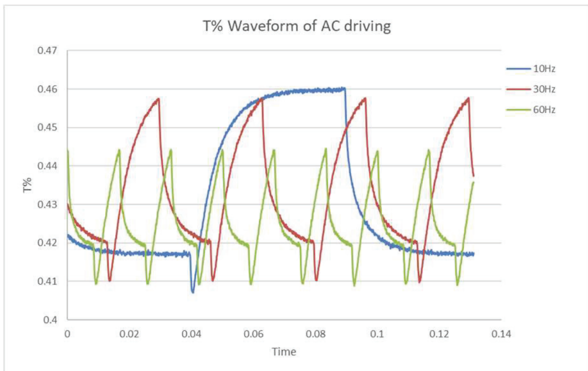


Fig. 7 Transmittance waveform with different driving frequency

In Figure7, it is obviously when the driving voltage change from negative to positive, transmittance will drop very fast and then rising. When we change the driving frequency, the transmittance drop level of is the same in different frequency. However, the rising transmittance will be different.

3 SIMULATION AND DISCUSSION

We use LCDMaster software developed by Shintech to simulate the flexoelectric properties of FFS mode LC display. In Figure 8, the 30Hz driving transmittance of FFS LCD is showed. Transmittance waveform is almost the same as measured data in Figure 5. It is very clearly that when the pure AC signal apply to the panel, the flicker value is not minimum. In Figure 10 the Voltage to Transmittance with and without flexoelectric effect is show. Normally, the transmittance difference in positive and negative driving voltage is discussed in low frequency driving. It is easy to be detected by human eyes.

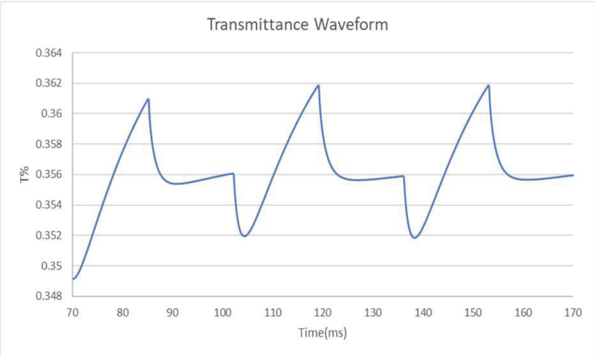
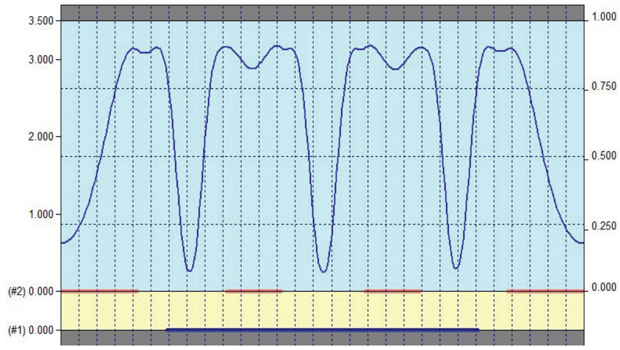
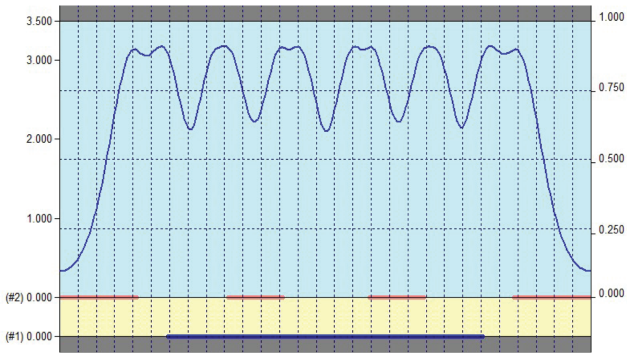


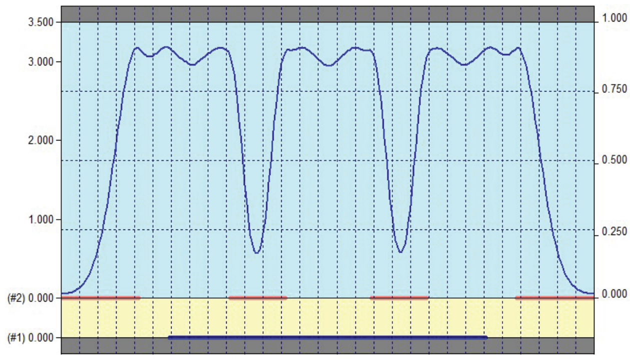
Fig. 8 Simulation of Transmittance waveform



(a)



(b)



(c)

Fig. 9 Transmittance profile of (a)positive frame, (b)transient state, and(c)negative frame with flexoelectric effect

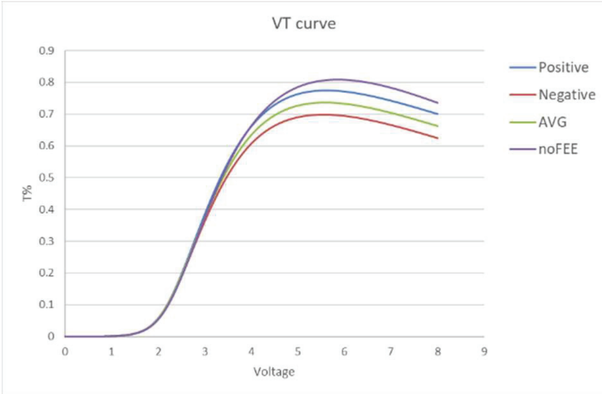


Fig. 10 VT with positive and negative driving

As shows in Figure 9, different area shows different transmittance value due to not only spatial electric distribution difference but also the bend and spray behavior of liquid crystal is different in different electric distribution. In dynamic analysis, the spray and bend behavior transits in space and electrode area and cause different transmittance ripple. The response from spray to bend is faster than bend to spray. So, in measuring average transmittance of pixel, we will get some small peak signal, that is due to the transmittance is different in local area when the polarity of driving voltage is transfer. Different driving frequency cause different transmittance value, the reason may cause from the flexoelectric effect of liquid crystal.

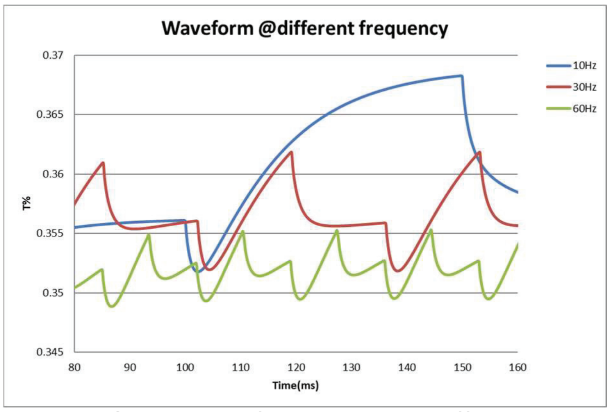


Fig. 11 Simulation of transmittance difference at different position of pixel cross section

In Figure 11, it shows the transmittance waveform with flexoelectric effect in different driving frequency. It is the same with the measured data. Compare with different driving frequency, the transmittance drop when the polarity from negative to positive is similar in different frequency. The falling time is faster than rising time.

As show in Figure 12, consider the transient response, the flicker value will be different. The flicker value of different frequency will not the same because when the driving voltage change, the transient response will affect the transmittance in different local area. Consider the pixel design, we can turn the electrode and space to balance the transmittance difference of voltage changing.

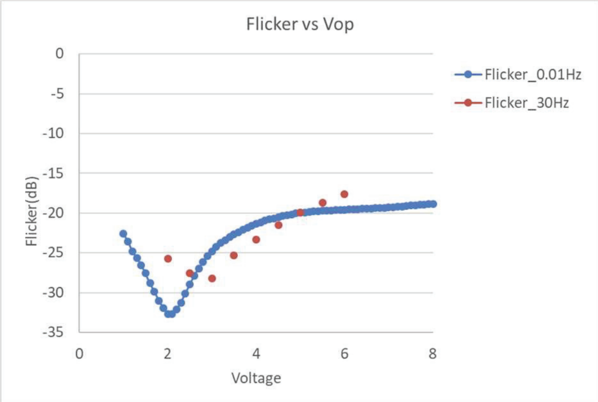


Fig. 12 Flicker value with different driving voltage

4 CONCLUSIONS

In FFS mode LCD, the flicker shift phenomenon is cause by ion accumulation. The reason is we use flicker minimum to set the optimum Vcom and DC bias voltage was apply to the cell. The transient state of spry and bend will cause transmittance difference to become serious and flicker phenomenon will get worse. The influence of flexoelectric effect in flicker shift play an important role because the optimum Vcom setting process was affected due to the flicker minimum is not the best Vcom voltage. Change spatial distribution of pixel can balance the transmittance difference cause by positive and negative polarity. However, the transient response cause by flexoelectric effect still affect the flicker value in different driving frequency and voltage.

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