41.1: Reduction of Image Sticking in FLC Devices by 'Kicking'

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When an electric field is applied to a liquid crystal display device, the optical properties of the device change and light modulation is obtained. In a conventional nematic display device, the liquid crystal device turns ON with either positive or negative voltages applied, and turns OFF when the applied voltage is zero, as the liquid crystal molecules respond to the field via dielectric anisotropy. For a ferroelectric liquid crystal (FLC) device, the permanent dipoles of the molecules directly interact with the applied field and the device switches to ON with a positive (or negative) voltage, and to OFF with a negative (positive) voltage.

In addition to dipole and dielectric anisotropy interactions, the ionic impurities of a liquid crystal device also migrate when a field is applied, although often at different time scales. In practical applications of liquid crystal display devices, the migration and accumulation of ions will modify the voltage the liquid crystal layer experiences, and therefore may change the switching characteristics or the performance of the liquid crystal panel. In particular, if the information displayed is such that the applied voltage is not DC balanced, it is believed that there will be accumulation of ions, and the switching characteristics of the liquid crystal device will depend on the ions accumulated or the history of images displayed. In order to avoid this problem of image retention or image sticking, it is widely believed and accepted that overall DC balance of the driving voltage applied to a LCD panel is required [1].

In a nematic device, DC balance can be achieved by driving the device to ON state with an alternating voltage. The case for a FLC panel is quite different, as the positive and negative voltages give two optically different, ON and OFF, states. For a sequence of information displayed on the panel, unless the ON time is exactly the same as the OFF time, there will be a net DC voltage applied to the FLC panel. One way to achieve exact DC balance in FLC panels is to show data and inverse data during alternate fields within a frame, while extinguishing the illumination during the inverse field [2]. However, this driving scheme is not suitable in projection displays where the lamp can not be easily shut off and where the associated light loss can not be tolerated.

In this paper, we present a novel driving scheme where the overall DC balance requirement in driving a FLC liquid crystal device is not required. By applying an alternating signal or 'kicking signal' in a small fraction of time within a frame, we show that the problem of image sticking in FLC devices can be significantly reduced or eliminated.

In a typical 'kicking' experiment, we use a FLC on CMOS spatial light modulator as the test cell and apply a waveform shown in Figure 1 to the common electrode of the spatial light modulator. As is shown in Figure 1, we divide the time slots into two portions within a frame. In the first portion, data voltages are applied to each pixel of the spatial light modulator. During this period, the voltage applied to the common electrode or the 'window' is constant and nominally one half of the CMOS voltage. In the second portion of the time slots, an alternating voltage is applied to the common electrode or the 'window' of the spatial light modulator, and the pixellated CMOS electrode can be a common ground or assumes a voltage that depends on the data within the frame. When the kicking scheme is used in a display application, illumination is turned ON and OFF during the data and kicking portions of the frame, respectively.

We test the efficacy of kicking method using a CMOS FLC spatial light modulator. The experiments consist of two periods: the aging period and the test period. During the aging period, which may last for a few months, the spatial light modulator is driven with a waveform that produces a black and white checkerboard pattern in the data portion of a frame and a kicking waveform in the second portion of the frame. This represents the worst case scenario where the black and white checkers will experience maximum and opposite DC voltage. In the test period, the data portion of a frame produces an all-black image, and the image of the panel is immediately inspected. An ineffective or insufficient kicking scheme will result in stuck images or the checkerboard pattern will show up in the all-black image. From a fundamental point of view, a stuck image in this case will manifest itself in that the extinction orientation in the previously white and black checkers will be different, and this extinction angle difference is a measure of the strength of image sticking.

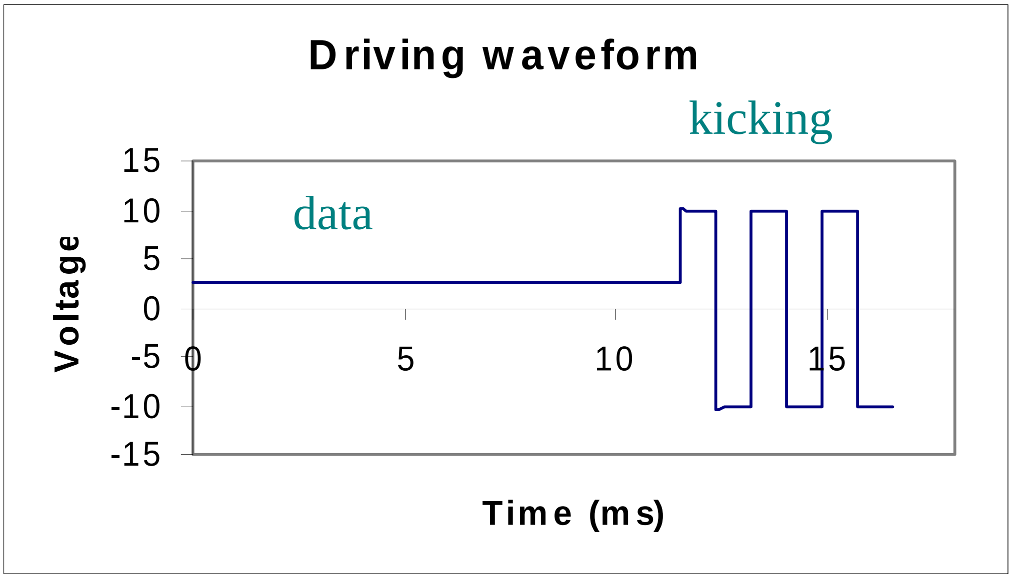

Figure 1. The window voltage in a kicking scheme

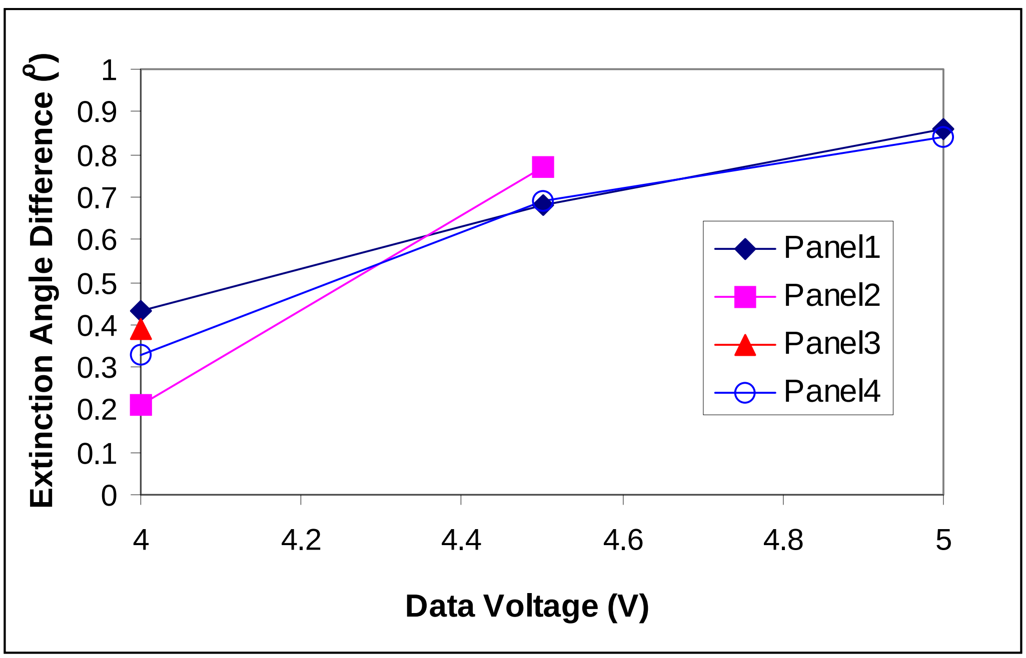

Figure 2. Extinction angle difference measured in a typical FLC microdisplay panel as a function of drive voltage during the data period. Drive voltage during the kicking period was 6V as were the peak to peak window kicking pulses.

In Figure 2, we plot the extinction angle differences measured in 4 different FLC on CMOS panels for drive waveforms with 60Hz frame rate, 20% kicking duty cycle, 6V inverse-data amplitude, 6 V window kicking amplitude, and data voltage ranging from 4 to 5 volts. The measurements were made after 3 hours of continuous DC unbalanced checkerboard test pattern drive. As is readily seen, the measured extinction angle differences are less than 1^o and decreases as the data voltage is reduced, indicating an imperceptible image sticking under this worst-case condition of black and white test checkerboard followed by uniform black images. Although not shown in the figure, a FLC panel under same driving condition but without kicking easily produce an extinction angle difference that is greater than 2^o.

The success of reducing or eliminating image sticking by the kicking method in many ways is unexpected and is against conventional thinking. It has shown for the first time that a liquid crystal panel may be driven with DC unbalanced signals without visible image degradation.

To explore the mechanism of kicking method, we measure the current flow in a FLC panel when driven with a simple kicking waveform. Figure 3 shows one typical ionic current measurement. As we can readily see, other than the capacitance charge current (and the polarization reversal current), the net ionic current flow, the integration of the current, is close to zero, although the voltage the FLC device experiences is highly unbalanced.

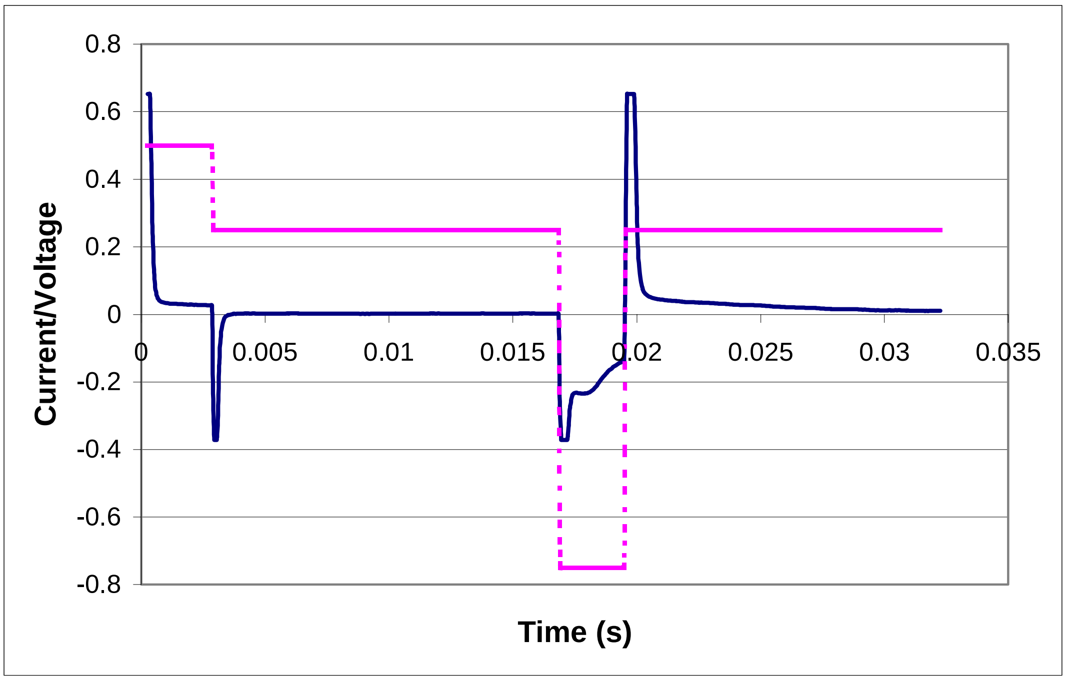

Figure 3. Measurement of current flow in a FLC microdisplay panel using a non-DC balanced (kicking) drive scheme. The dashed (pink) line is the driving waveform, and the voltage is reduced by a facto of 10 in order to be plotted on the same plot. The solid curve is measured current.

The measurement of ionic current flow show in Figure 3 can then offer the following plausible mechanism for kicking methods. To avoid image sticking, there should be no accumulation of ionic impurities near the substrates. DC balanced drive provides one sufficient condition. However, due to the nonlinear nature of the ionic response to the applied electric field, there may exist other driving (kicking) waveforms where although the voltage is not averaged to zero, the ionic current flow is balanced, resulting in no net accumulation of ionic impurities.

To conclude, we demonstrated a DC unbalanced driving scheme for FLC devices where minimal image sticking is observed.

References

[1]: C. Colpaert, et al, Euro Display `96 p325 (1996).

[2]: D. Banas, et al, Journal of the SID **5/1**, 27(1997)