The Compensation of Pixel Voltage Error for a-Si TFT LCDs Regarding the Input Gamma Voltage

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Abstract

The liquid crystal(LC) pixel capacitance Clc, which varies as a function of applied pixel voltage, is a main factor of pixel voltage errors on input gamma voltage, and therefore of the electro-optics(E-O) characteristics of LC pixel for a-Si TFT LCDs.

The pixel voltage error(ΔVp) for input gamma voltage was simulated for 14.1 inch diagonal XGA panel. An agreement between the experimental results and simulation was satisfactory for the gamma voltage compensation, ΔVp of the input gamma voltage. The proposed compensation method was successfully introduced to a 14.1 inch diagonal XGA panel, and a remarkable improvement of image sticking was achived.

1. Objectives and Background

As a highly information-oriented society develops, visual communication becomes increasingly important. The a-Si TFT LCDs panels are flat, compact, and portable with light weight. They also have excellent display quality, such as high contrast ratio, full color, high brightness, and high resolution. Therefore, among many kinds of flat panel displays, the a-Si TFT LCDs is the most promising display.

In order to attain high performance of a-Si TFT LCDs, many efforts have been made to tackle several chronic problems for display quality. One of them is the pixel voltage error(ΔVp) inducing deterioration of the display quality such as flickers[4], gray scale error, image sticking[5,6], etc.

Moreover, as the size is getting larger and the resolution is higher, the problem of pixel voltage error is getting more serious.

For last few years, a pixel voltage error minimization - self-alignment process[2], a three step gate voltage driving scheme[3] - had been tried, without much success.

In the proposed paper, the pixel voltage error(ΔVp) for input gamma voltage is simulated[1] for 14.1 inch diagonal XGA panel, we compensated for pixel voltage error of the input gamma voltage by gamma resistance, to have excellent display quality.

2. Results

A twisted nematic liquid crystal display with a inverted staggered TFT structure and previous gate driving method - the storage capacitance is formed between a pixel electrode and the previous gate line - is adopted for 14.1"XGA panel. This paper presents the comparison of the pixel voltage error for constant Clc(normal) and the pixel voltage error of compensation for input gamma voltage, and then the result of reliability for image sticking, for 14.1"XGA panel.

a. Simulation Modeling

Fig.1 shows a driving waveform and the equivalent circuit of pixel for a-Si TFT LCD. The parameters of a-Si TFT LCD array used in the calculation are summarized in Table 1.

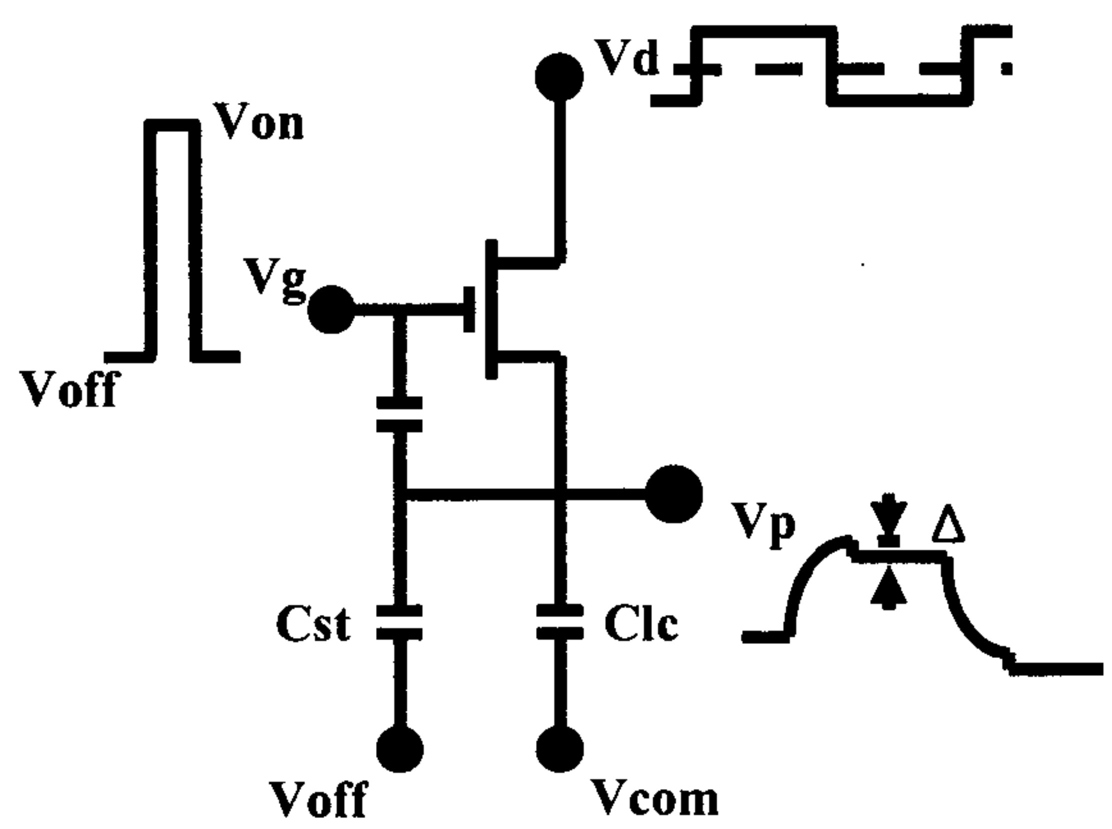


Fig 1. Driving waveform and the equivalent Circuit of pixel for a-Si TFT LCD

By the law of conservation of electric charge, from Fig.1, we have

$$(Vp - Vcom)Clc\text{-}on + (Vp - Voff)Cst + (Vp - Von)Cgs\text{-}on = (Vp' - Vcom)Clc\text{-}off + (Vp' - Voff)Cst + (Vp' - Voff)Cgs\text{-}off$$

where

Clc-on,Clc-off LC pixel capacitance referring ON and OFF state of a-Si TFT respectively;

Vcom voltage of common electrode;

Vp data voltage, i.e., the LC pixel voltage referring ON state of TFT;
Vp' LC pixel voltage referring OFF state of TFT;
Cgd crossover capacitance between gate and source
Cg channel capacitance;
Cgs-on = Cgd + Cg/2 ON state
Cgs-off = Cgd OFF state

therefore, from above

$$\Delta Vp = Vp - Vp'$$
$$= [(Vcom - Vp)(Clc\text{-}on - Clc\text{-}off) + \Delta VgCgd + (Von - Vp)Cg/2] \div [Cgd + Clc\text{-}off + Cst] \quad \text{- Eq.1}$$

Parameter	value
Cgs	* pF
Cst	* pF
Thickness of gate oxide(nm)	450
Dielectric constant of gate oxide	6.9
LC cell gap(um)	4.5
On state gate voltage(V)	20
Off state gate voltage(V)	-6.0
Common electrode voltage(V)	3.0

Table 1. Parameter of a-Si TFT LCD used in the Simulation

b. LC capacitance and pixel voltage error for applied pixel voltage(Vp)

The LC dielectric constant under various applied pixel voltage(Vp) is shown in Fig 2, which changes with the director of liquid crystal molecules as a function of applied pixel voltage. The pixel voltage error for applied pixel voltage is simulated[1] by Eq.1 and the agreement between the experimental results and simulation was satisfactory, is shown in Fig. 3.

Fig.3 shows that a large ΔVp is obtained at Vp = 0 V - at the normally white mode, 63 gray(white)- since Clc is minimized, we can see that from Fig.2.

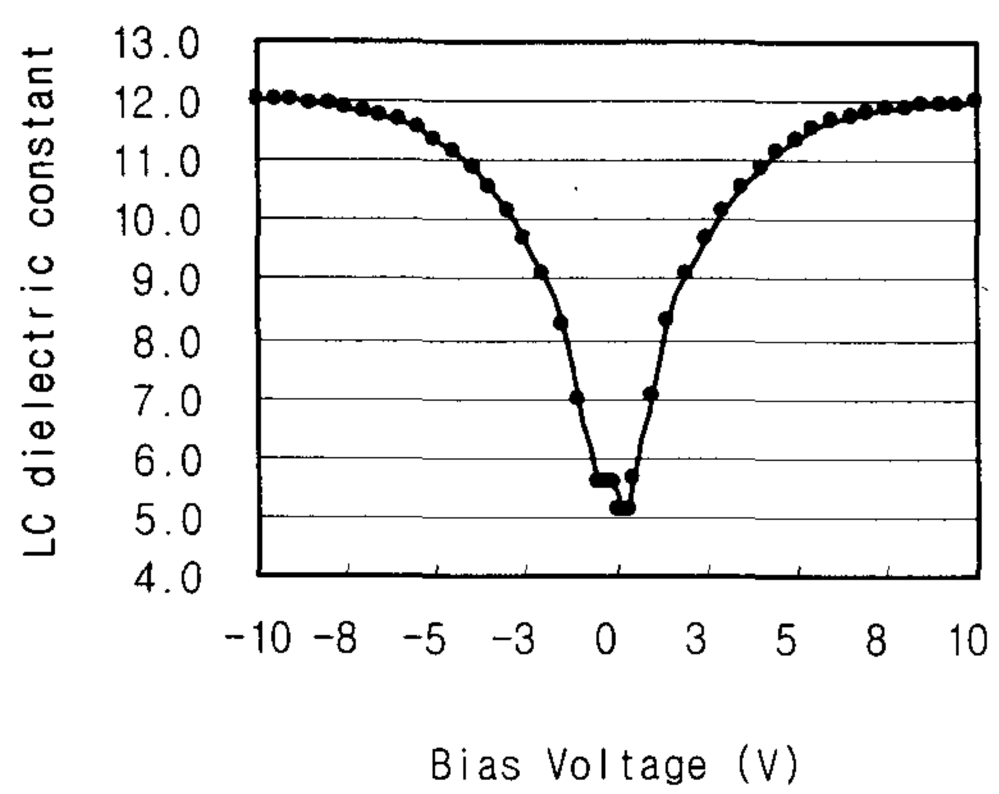


Fig 2. LC dielectric constant as a function of Vp

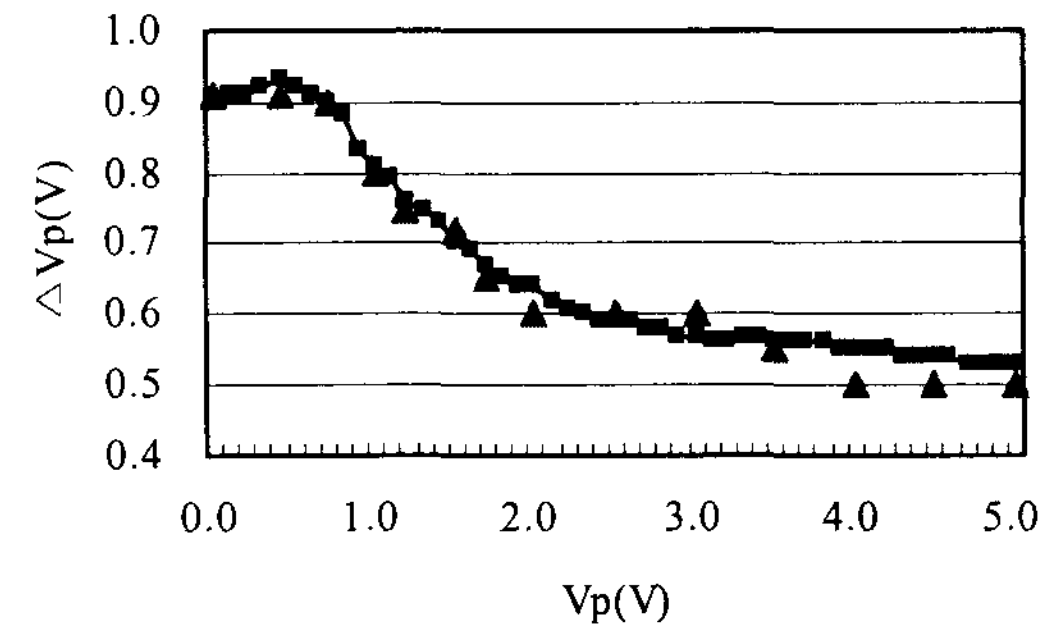


Fig 3. Pixel voltage error as a function of Vp for 14.1"XGA
Simulation ■ / Experiment ▲

c. Gamma voltage compensation

Generally, the constant Clc of center gray(non-compensated) is applied for pixel voltage error of the whole gray, and the input gamma voltage is determined by constant pixel voltage error due to constant Clc, too. From Fig.3, the pixel voltage error of the input gamma voltage is obtained by pixel voltage error simulation, and then the input gamma voltage is compensated for pixel voltage error.

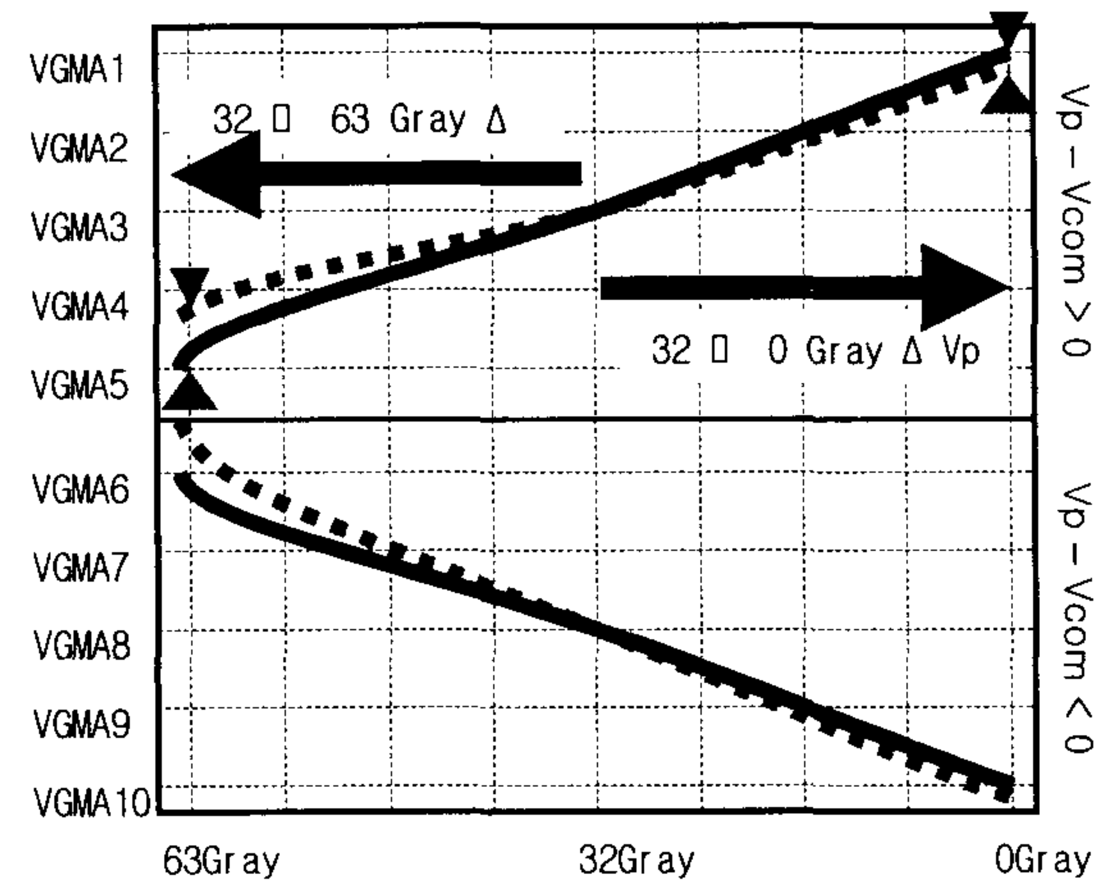
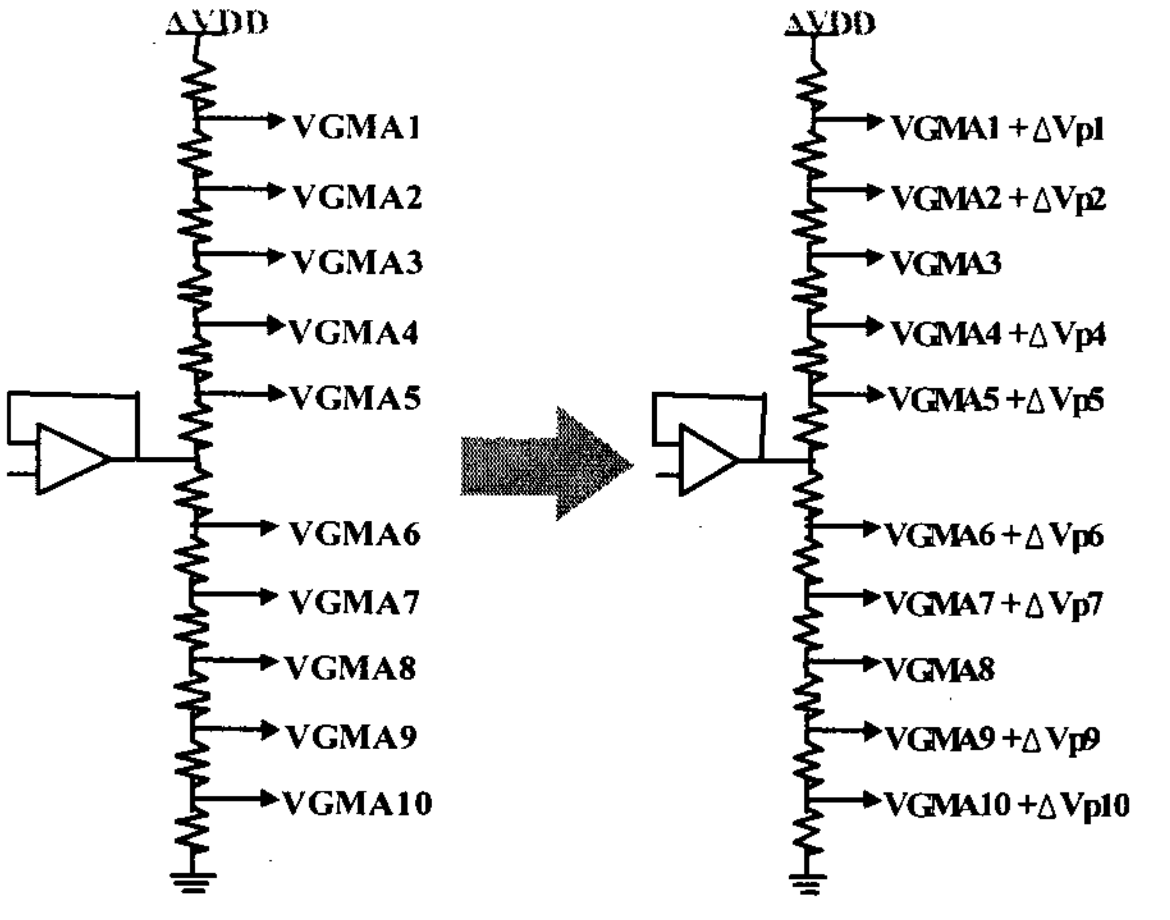


Fig 4. Gamma curve(gray vs gamma voltage) of normal(a solid-line) and compensation(a dotted-line) for pixel voltage error

Fig 4 shows the compensated gamma curve for pixel voltage error, compared with constant pixel voltage error of center gray. For positive pixel signal(Vp - Vcom > 0), at 0 ~ 32 gray, ΔVp is larger than constant pixel voltage error at center gray, therefore compensated gamma curve for gray pixel voltage error is lower than the gamma curve of constant pixel voltage error at center gray. At 32 ~ 63, ΔVp is smaller than constant pixel voltage error at center gray, therefore compensated gamma curve for gray pixel voltage error is upper than at center gray. Similarly, for negative pixel signal(Vp - Vcom < 0), at 0 ~ 32 gray, compensated gamma curve for gray pixel voltage error is lower than constant pixel voltage error, at 32 ~ 63 gray is upper than constant pixel voltage error.



(a) normal (b) compensation

Fig 5. Gamma voltage generation by resistor ladders

The compensation method of gamma voltage is shown in Fig. 5, a gamma resistance is controlled to obtain VGMA + ΔVp for each input gamma voltage. Because a VGMA3, VGMA8 is gamma voltage of center gray for positive and negative pixel signal, the compensation of pixel voltage error is not necessary.

d. Results

The main deterioration of display quality due to pixel voltage error is flicker[4] and image sticking[5,6]. There is no difference of flicker, between normal and compensation panel. But, the remarkable improvement of image sticking is obtained by the compensation of gamma resistance for pixel voltage error of input gamma voltage. This result is shown in Fig. 6. For normal panel, weak, strong and fail image sticking is observed after 12hr, 18hr and 21hr respectively. When the compensation method of pixel voltage error is applied, very weak and weak image sticking is observed after 18hr, 23hr respectively, reliability fail of image sticking is not observed up to 24hr. – generally, reliability test condition is 25 / 10hr @ lattice pattern –

The appearance time of image sticking has increased 50%(12 => 18hr), 28%(18 => 23hr) for weak and strong image sticking respectively.

However, when the process variation related with pixel voltage error(Cgs, Cst, Clc, harge holding capability of aligning layer material[5], etc.) is occurred, the gamma resistance must be varied with pixel voltage error, too. Otherwise, the image sticking may become more serious. Therefore, to obtain the optimized image sticking, the pixel voltage error due to process variation is checked periodically, and then the magnitude of compensation resistance is controlled with the process variation.

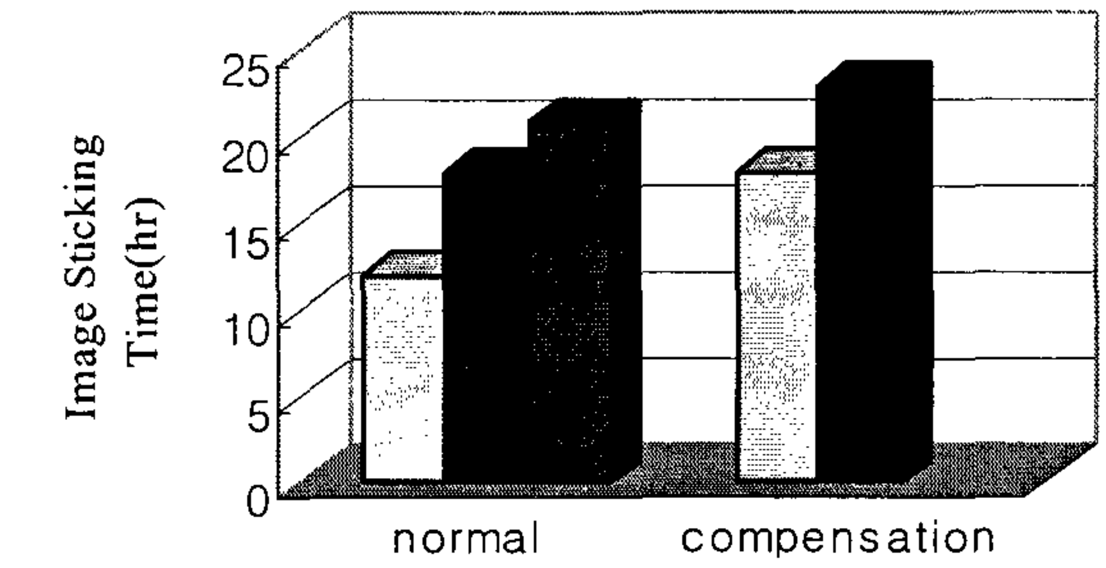


Fig 6. Image sticking time - normal /compensation at lattice pattern, 25℃ Pass(weak □, strong ■) / Fail ■

3. Impact

The pixel voltage error of input gamma voltage was simulated, and then was compensated by control of gamma resistance, for 14.1 inch diagonal XGA panel. This compensation method was successfully introduced to a 14.1 inch diagonal XGA panel, and a remarkable improvement of image sticking was confirmed, compared with non-compensated panel, other display qualities including the flicker was the same.

5. References

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[3]Y.Kaneko,"A New Address Scheme to Improve the Display Quality of a-Si TFT/LCD Panels" in IEEE 1989., p.2949

[4]Tatsuo Katagishi,"A New Driving Technique for Flicker-Free Full-Resolution LC-TV" in SID 86 DIGEST., p.285

[5]Yutaka Nanno,"Characterization of Sticking Effects of TFT-LCD" in SID 90 DIGEST.,p.404

[6]Y.Kanemori,"10.4-in.-Diagonal Color TFT-LCDs without Residual Images" in SID 90 DIGEST.,p.408