Development of Vcom Model in TFT-LCD Panels for SPICE Simulation

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Abstract: *The Vcom, common electrode, in thin film transistor-liquid crystal display (TFT-LCD) panels provides the reference DC voltage with TFT-LCD panel and functions as the path of current. The voltage of the distributed capacitive and resistive Vcom fluctuates according to changes of gate and data voltage. These fluctuations of vcom voltage make crosstalk and deteriorate the display image of TFT-LCD [1]. The larger TFT-LCD panels become, the more important it is to consider these fluctuations. This paper describes the Vcom model for 15-inch XGA (1024×768) TFT LCD panels. The parasitic resistance and capacitance between the vcom and each layer is obtained by 3D simulation of a sub pixel. The accuracy of these data is verified by the measured values in an actual panel [2]. The developed vcom model is implemented in the panel simulation platform, the equivalent circuit of 15-inch XGA panel and simulated by HSPICE.*

Keywords: TFT-LCD Panel; Vcom model; .SPICE simulation;

Introduction

Cathode-Ray Tubes (CRT) have been replaced with flat panel display (FPD) devices such as a TFT-LCD panel and a plasma display panel (PDP) in monitor and television markets these days. The thickness of FPDs is not proportional to the screen size of them. This is the great advantage of FPD devices. Among FPDs, a TFT-LCD is emerging as the most leading device in HDTV markets.

However, TFT-LCDs should overcome several barriers to succeed in these markets. These barriers are lower contrast ratio, less bright, slower response time, poorer viewing angle, worse color reproduction than CRT TVs. For example, as the TFT-LCD panels becomes larger and provides higher resolutions, it is more important to consider the propagation delays of row (gate) and column (data) lines and the fluctuations of vcom voltage. To understand and overcome these effects, we need to develop the electrical equivalent model of TFT LCD panels.

Electrical Models of TFT-LCD Panels

LCD panels can be modeled by resistors and capacitors like Figure 1. When row (gate) and column (data) line signals propagate through each line to the other side of panel, they are delayed by resistance and capacitance in each line. Each row and column line should be together with vcom, common electrode. Vcom is made of ITO (Indium Tin Oxide). It is not a perfect conductor and has resistance. Therefore, Vcom model should be made to consider voltage changes of neighboring pixels. Figure 1. is drawn in view of equivalent circuits according to voltage and current. Except for line models and vcom model, the electrical model of TFT LCD panel should have TFT and LC model

Models of these five components, a row line, a column line, TFT model, LC model, and a vcom, are necessary to explain operation of a TFT-LCD panel. All electrical models are verified by comparing the simulated data and measured data in actual 15 inch TFT LCD panels [2].

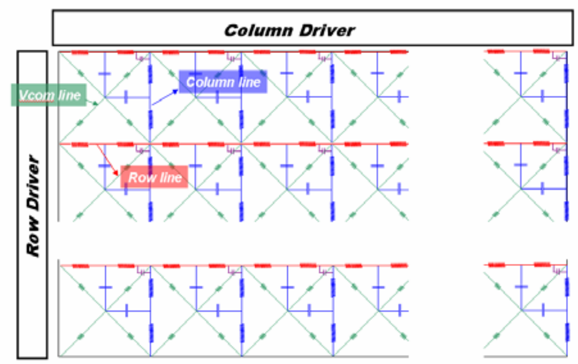
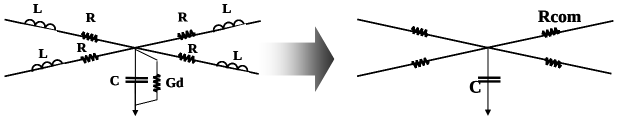


Figure 1. The simplified TFT-LCD panel

Vcom Model

In TN LCD panels, a vcom plane is placed and deposited on a whole color filter part. The voltage of vcom is the reference voltage of the LCD panel. Therefore we can consider this plane as ground plane or power plane. The voltage of vcom fluctuates according to variations of gate and data voltage. It means that current go into or out of vcom. If vcom is made of a superconductor, its voltage won't fluctuate. This fluctuation makes horizontal crosstalks of LCD panels, because vcom connected every pixel. it is important to understand flowing of current and voltage in view of electrical properties in LCD panels.

We can consider that modeling vcom is the same as modeling power and ground plane in high speed digital system except for operating frequency [3]. Vcom is divided into square unit cells with lumped element models in Figure 2. The number of square unit cell in TFT-LCD panels is determined by the number of block in the distributed row and column lines. In this 15-inch XGA panel, there are 16-block distributed row lines and 12-block distributed column lines in Figure 3. The unit cell of Vcom represents 64(=768/12) × 192(1024×3/16) sub pixels. The results of calculation are as follows:



R = Rdc + Rac = 34.54 + 5.88E-4 = 34.54 Ω
L = 5.82E-12(H) → can be ignored
C = value from 3D simulation
Gd = 9E-6 → can be ignored
(∵ Maximum frequency = 46kHz)

Figure 2. The process of modeling Vcom

ρ= resistivity of ITO (Indium Tin Oxide),

t = thickness of ITO

δ_s = skin depth of ITO at 46kHz,

μ_o= permeability constant,

d = Cell gap of LCD panel,

w = the length of unit cell in row and column,

C= the total capacitance between ITO and other layers,

tan(δ)= loss tangent of dielectric,

(This value is usually below 0.01 except for water.)

$$R = R(dc) + R(ac)$$

$$R(dc) = \frac{\rho}{t} \times \frac{w}{w} = \frac{190 \times 10^{-8} \Omega \bullet m}{550 \times 10^{-10} m} = 34.54\Omega$$

$$R(ac) = \frac{\rho}{\delta_s} = \frac{190 \times 10^{-8} \Omega \bullet m}{3.23 \times 10^{-3} m} = 5.88 \times 10^{-4} \Omega$$

$$L = \mu_0 \times d = (4\pi \times 10^{-7} H/m) \times (4.6um) = 5.8 \times 10^{-12} H$$

$$Gd = \omega C \tan(\delta) = (46 \times 10^3) \times (19563 pF) \times (0.01) = 9 \times 10^{-6} \Omega^{-1}$$

C(Capacitance) uses the value that got from the 3D parasitic parameter extraction tool. It means that row, column lines, TFT, LC behavioral model are connected to the cross point, vcom. As we know the calculated results of each component, we can ignore R(ac), Inductance(L), Conductance(Gd). The final model vcom is shown in the right side of Figure 2. Rcom is 34.54 ohms, because the resistance values should be the same as each values every direction of unit cell block.

Results

Figure 3. Illustrates the panel simulation platform, the equivalent circuit of TFT-LCD panels in Cadence Environment. Gate and column voltage drive into it and gate deselect voltage and Vcom voltage (4V) also is applied to it. Each unit cell block consists of row and column lines model, a Vcom, a TFT, and a LC model. To observe different fluctuations of Vcom, two kinds of HSPICE simulations are done. One (a) is the Vcom voltage is applied to panel simulation platform in every side of it. The other (b) is the Vcom voltage is applied to it in only left side. As we expected, the result of (a) is much smaller than that of (b). We can observe changes of vcom every part of panel through it easily.

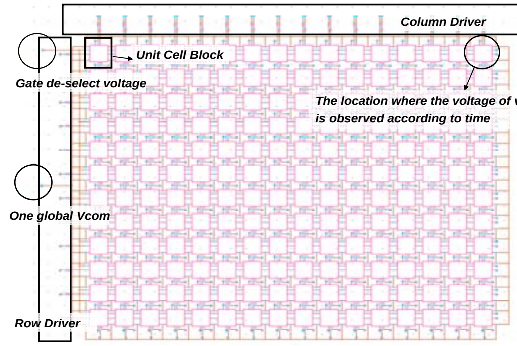


Figure 3. The panel simulation platform of 15-inch XGA panel

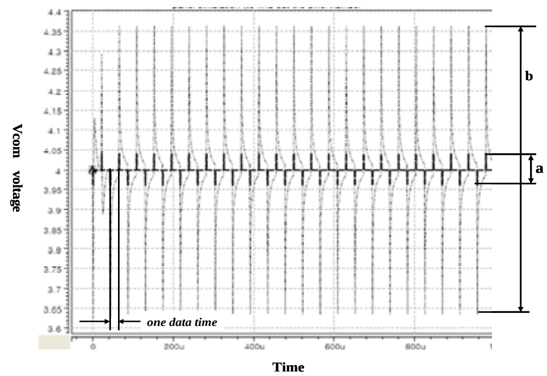


Figure 4. Variation of Vcom voltage according to time

Conclusion

We developed the Vcom model and observed the fluctuations of Vcom through HSPICE simulation based on the data of 15-inch XGA Panel. To improve the image quality of a TFT LCD panel, it is important to understand its electrical property. The developed Vcom model will contribute to improve the performance of large size LCD TV panels by expecting the fluctuations of Vcom voltage according to each pixel's position and time.

Acknowledgement

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