Mutual Coupling Capacitance and Cross-talk in TFT-LCD

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Abstract

The design of large area thin film transistor liquid crystal displays (TFT-LCDs) requires consideration of cross-talks between the data lines and pixel electrodes. These limits are imposed by the mutual coupling capacitances present in a pixel. The mutual coupling capacitance causes a pixel voltage error. In this study, semi-empirical model, which is adopted from VLSI interconnection capacitance calculations, is used to calculate mutual coupling capacitances. With calculated mutual coupling capacitances and arbitrary given image pattern, the root mean square (RMS) voltage of pixel is calculated to see vertical cross-talk from the first to the last column. The information obtained this study can be utilized to design the larger area and finer image quality panel.

Introduction

The trend toward larger-diagonal active-matrix liquid crystal display (AMLCD) panel sizes and higher spatial and/or gray-scale resolution has been shown to worsen cross-talk. The fundamental root of this worsening cross-talk trend is the relative increase in mutual coupling capacitance. The mutual coupling capacitances between the liquid crystal pixel electrode and the data lines are the source of the data-line-to-pixel (vertical) cross-talk, whereby information in one row of the display can affect the image on other rows. In this study, semi-empirical capacitance model, which is adopted from VLSI multi-level interconnection capacitance calculations, is used to calculate mutual coupling capacitances. It is already proved in many studies that this semi-empirical model is almost same with the numerical model. [1] With calculated mutual coupling capacitances and given image pattern, the RMS voltage of pixel is calculated to see vertical cross-talk from the first to the last column. The relationships between the mutual coupling capacitances and cross-talk obtained from this study can be utilized to design the larger area and higher resolution TFT-LCD.

Simulation

To simulate cross-talk, mutual coupling capacitances between the data lines and the pixel electrode should be calculated in advance. These mutual coupling capacitances can be determined using semi-empirical models. The structure in Figure 1 is used to simulate parallel (in the same layer) placed on the ground plane. One thin strip represents the pixel electrode; the other represents the data line (Figure 2).

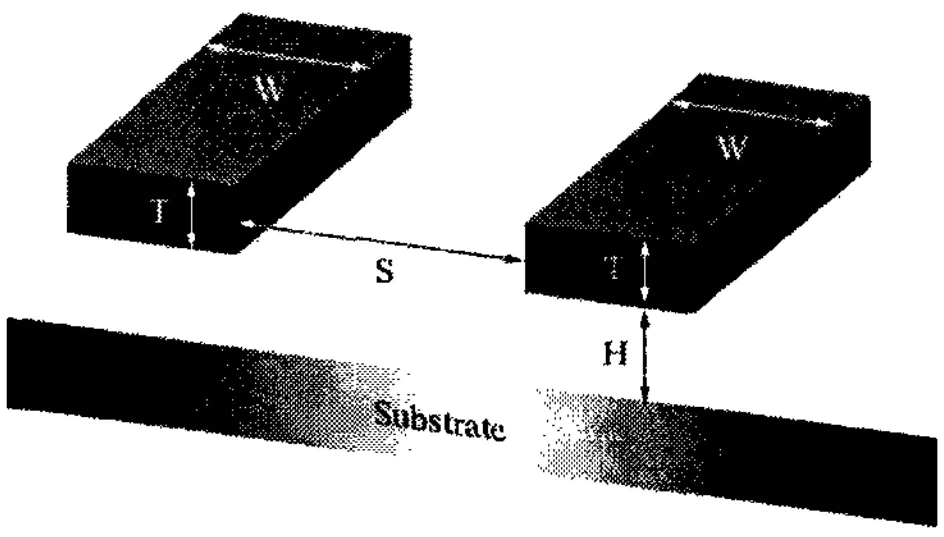

Figure 1. Two parallel lines on ground.

The mutual coupling capacitance is

$$\frac{C}{\varepsilon}=1.064\left(\frac{T}{S}\right)\left(\frac{T+2H}{T+2H+0.5S}\right)^{0.695}+\left(\frac{W}{W+0.8S}\right)^{1.4148}\left(\frac{T+2H}{T+2H+0.5S}\right)^{0.804}+0.831\left(\frac{W}{W+0.8S}\right)^{0.055}\left(\frac{2H}{2H+0.5S}\right)^{3.542}$$

Where W and S represent the width of the data line and the the gap between the data line and the pixel electrode respectively. [2]

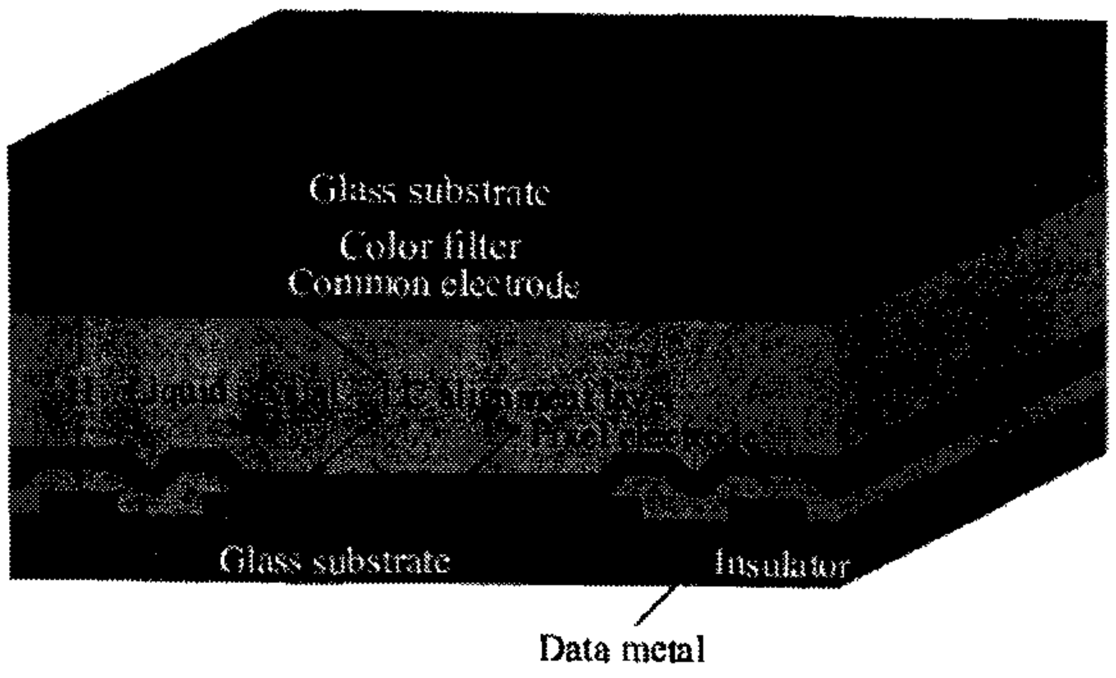

Figure 2. Pixel cross-sectional view.

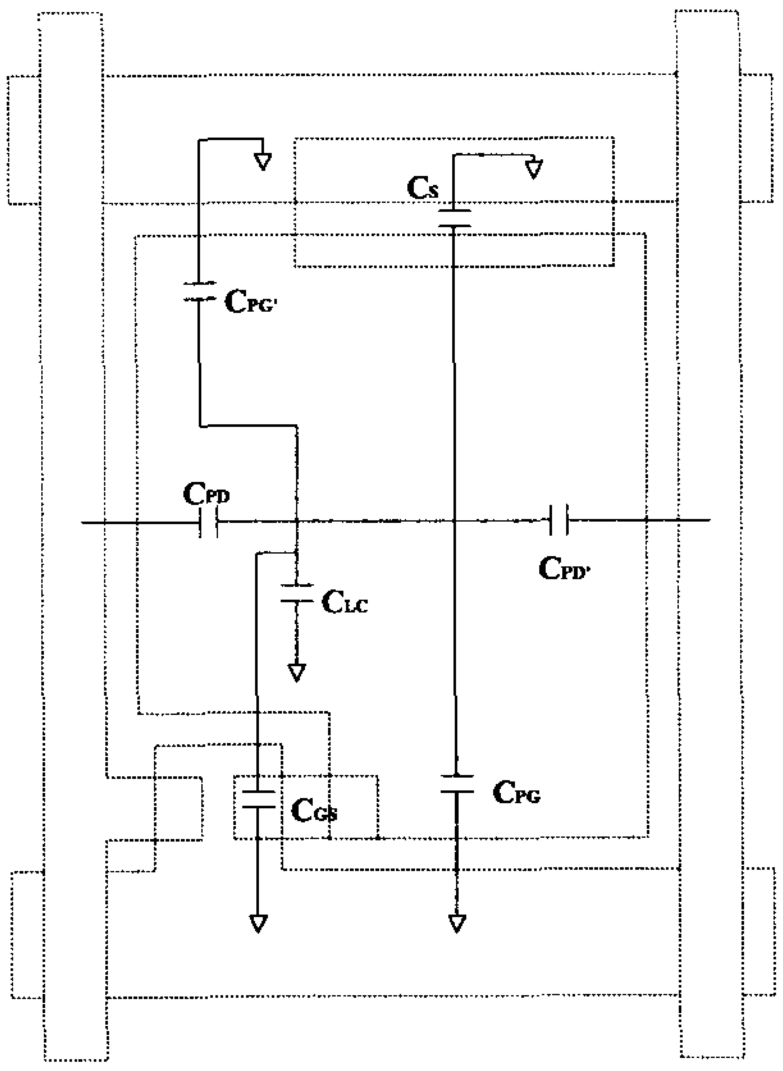

Figure 3. Equivalent circuit for capacitive coupled transmission-line analysis of pixel layout designs for cross-talk evaluation.

The displacement currents caused by mutual coupling capacitances are an increasingly troublesome by-product of scaling to smaller lithographic dimensions and tighter ground rules. From the cross-talk capacitance equivalent circuit of Figure 3, the ratio of parasitic capacitive coupling between the pixel-to-data line (α) and pixel-to-adjacent-data line (β) can be expressed as

$$\alpha = \frac{C_{PD}}{C_{LC} + C_S + C_{PG} + C_{PG'} + C_{GS} + C_{PD} + C_{PD'}}$$

$$\beta = \frac{C_{PD'}}{C_{LC} + C_S + C_{PG} + C_{PG'} + C_{GS} + C_{PD} + C_{PD'}}$$

Where C_{PD} and $C_{PD'}$ are the data-line- and adjacent-data-line-to-pixel-electrode coupling capacitances, respectively; C_{PG} and $C_{PG'}$ are the gate-line- and adjacent-gate-line-to-pixel electrode coupling capacitances, respectively; C_{LC} is the liquid crystal capacitance between the common electrode and the pixel electrode; C_S is the storage capacitance between the adjacent gate line and the pixel electrode; and C_{GS} is the TFT gate-to-source parasitic overlap capacitance.

The value of the instantaneous voltage V_{pi} across the liquid crystal capacitor in the *i*th row position for the standard configuration is given by

$$V_{pi}(t) = V_i + \alpha[V_j(t) - V_i] + \beta[V_{j'}(t) - V_{i'}]$$

V_i and $V_{i'}$ are the data voltages initially written onto the pixel and adjacent pixel through pixel selection, respectively, through their corresponding TFTs. $V_j(t)$ and $V_{j'}(t)$ are the data-line and adjacent-data-line voltages with parasitic coupling factor to the pixel, α and β, respectively.

For frame inversion method, where each signal line has the same data polarity and the data polarity is inverted once per frame time, the RMS voltage at the *i*th row position at the LC can be expressed as [3]

$$[V_{pi}(RMS)]^2 = \frac{1}{N}\left\{\begin{array}{l} V_i^{\,2} + \sum\limits_{j>i}^{N}\left[V_i - \alpha(V_i - V_j) - \beta(V_{i'} - V_{j'})\right] \\ + \sum\limits_{j=1}^{i-1}\left[V_i - \alpha(V_i + V_j) - \beta(V_{i'} + V_{j'})\right] \end{array}\right\}$$

Results and Discussion

Figure 4 shows image-pattern used to simulate cross-talk.

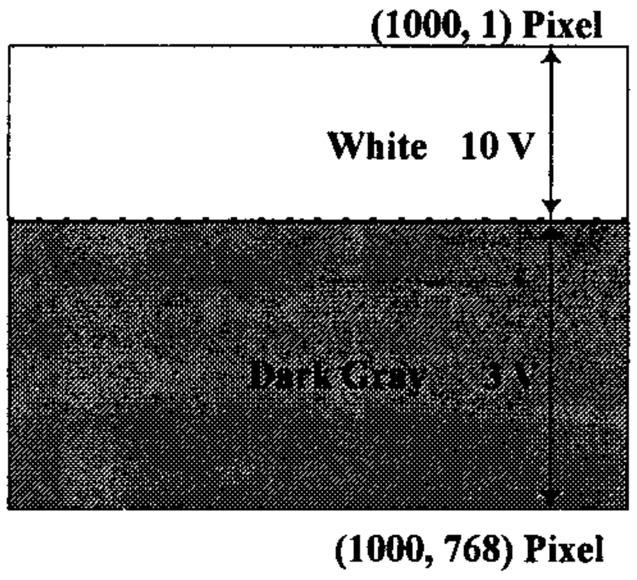

Figure 4. Image pattern for simulation of cross-talk

Figure 5 shows the mutual coupling capacitance as a function of the gap between the data line and the pixel electrode. From this data, scaling toward higher-density and higher resolution displays will significantly increase the mutual coupling capacitance.

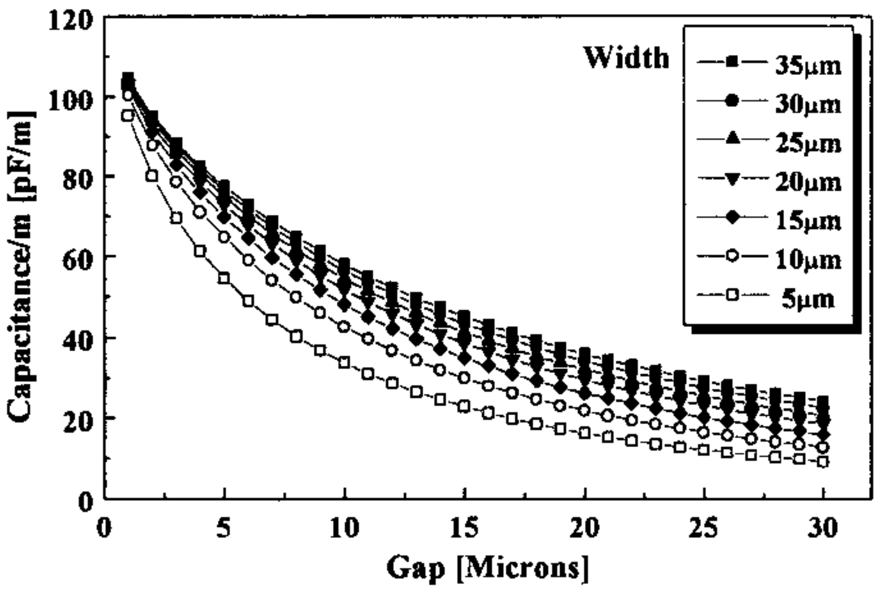

Figure 5. Variation of mutual coupling capacitance with varying gap of two metal lines

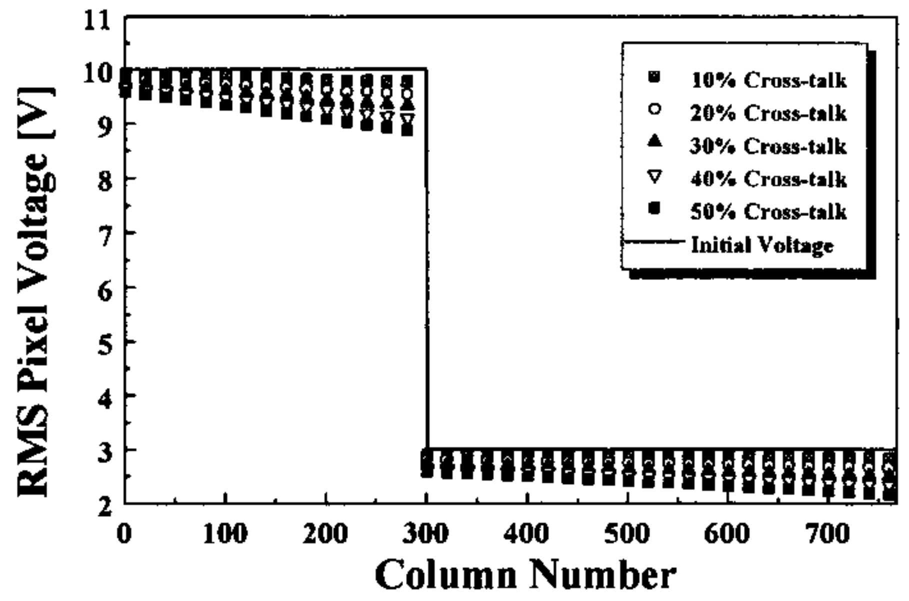

Figure 6. RMS pixel voltage with varying α, β

Figure 6 shows RMS pixel voltage from the first row to the last row with varying α, β. As expected, mutual coupling capacitance increase is directly proportional to a vertical cross-talk increase.

Conclusion

To simulate cross-talk, we calculate mutual coupling capacitance using semi-empirical model. With calculated mutual coupling capacitances and given image pattern, the RMS voltage of pixel is calculated to see vertical cross-talk from the first to the last column. Scaling toward higher-density and higher resolution displays will significantly increase the mutual coupling capacitance. Mutual coupling capacitance increase is directly proportional to a vertical cross-talk increase.

Acknowledgements

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References

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