

Recent Developments in Liquid Crystal Displays

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ABSTRACT: In a span of about 30 years the technology of Liquid Crystal Displays(LCDs) has developed rapidly and has reached a stage where it can compete with CRTs in many applications. Cost of LCDs is still higher than that of CRTs. Addressing methods used for driving LCDs play an important role in final cost. Some of the important developments in LCDs are discussed here.

Key Words: Liquid Crystal Displays(LCDs), Passive matrix, Active matrix, Addressing

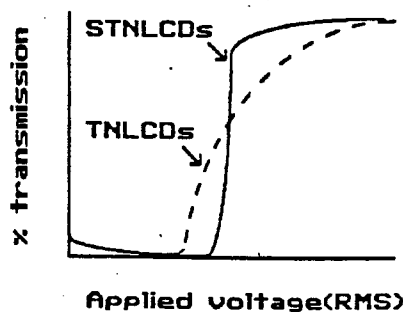
I. INTRODUCTION

Flat panel displays are extensively used in portable products like notebook computers, personal digital assistant(PDA) and portable television etc. Liquid Crystal displays(LCDs) are the most popular among the various flat panel displays available today. Low power consumption, low voltage operation, compatibility with CMOS technology are some of the advantages that has resulted in widespread use of LCDs.

that have been developed using liquid crystals. Typical electro-optic characteristics of TN and STN-LCDs are compared in figure 1.

a) Matrix displays

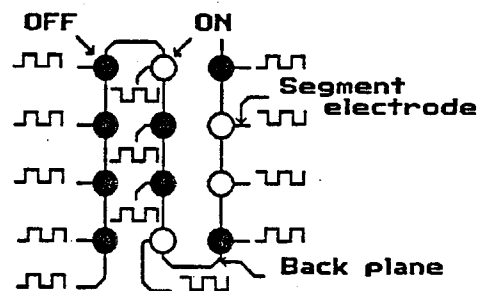
When the number of picture elements(pixels) in a display is small, each pixel can be directly connected to a driver. This type of display is called static driven or non-multiplexed display. Schematic of static driven display is shown in figure 2.



TN & STN LCDs-A Comparison

Figure 1.

Twisted Nematic LCDs(TN-LCDs) and Super Twisted Nematic LCDs(STN-LCDs) are the most popular among the various types of displays



STATIC DRIVE

Figure 2.

When the number of pixels in a display is large then the pixels are interconnected to form a matrix such that each pixel is located at

the intersection of a row address line and a column address line. Number of connections to the display is reduced to (N+M) from (NM+1) in a matrix display with N rows and M columns. Number of connections can be still large (480+(640)3=2400) in a VGA color display. The pitch of the interconnection can be as low as 100 μ m in such displays. Matrix displays are refreshed (line by line) by addressing all the pixels in a row simultaneously, while only one pixel is addressed at a time in CRT.

LCDs are broadly classified as Passive matrix (PM-LCDs) or Active matrix (AM-LCDs) based on the method used for driving them. Some of the recent developments in both passive and active matrix addressing are outlined below.

II. PASSIVE MATRIX LCDs

The passive matrix addressing exploits the nonlinear characteristics of the liquid crystal electro-optic effect. Schematic of a passive matrix LCD is shown in Figure 3. LCDs are slow

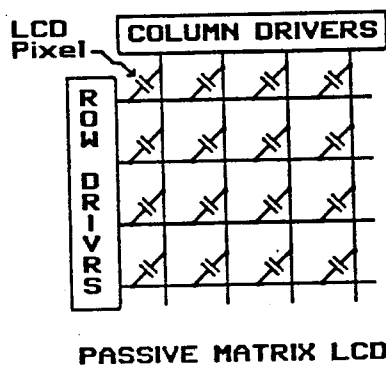


Figure 3.

responding devices and hence their response depends on Root Mean Square (RMS) of the applied voltage. In the conventional technique [1] the N rows in a matrix are sequentially scanned one row at a time. Data voltages that are applied in

parallel to the columns are in phase with row select voltage for OFF pixels and are out of phase with row select voltage for ON pixels. Polarity of the row select voltage is reversed in a periodic manner to eliminate any dc voltage across the pixels. Typical waveforms of the conventional line by line addressing are shown below in Figure 4. Selection ratio,

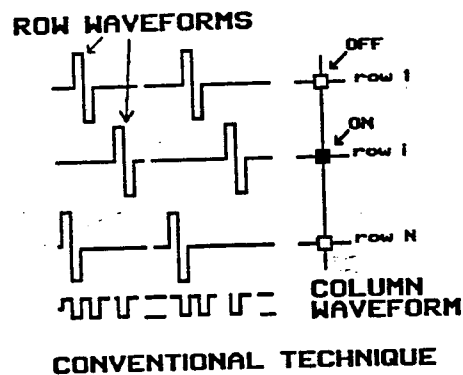


Figure 4.

defined as the ratio of RMS voltage across ON pixels to that across OFF is a measure of discrimination between ON and OFF pixels. The selection ratio is given in the following equation:

$$\text{Selection Ratio} = \sqrt{\frac{\sqrt{N} + 1}{\sqrt{N} - 1}}$$

Selection ratio decreases rapidly as shown in Figure 5. While TN-LCDs can be multiplexed when N is less than 100 lines, STN-LCDs with steeper electro-optic characteristics is better suited for displays with large matrix size.

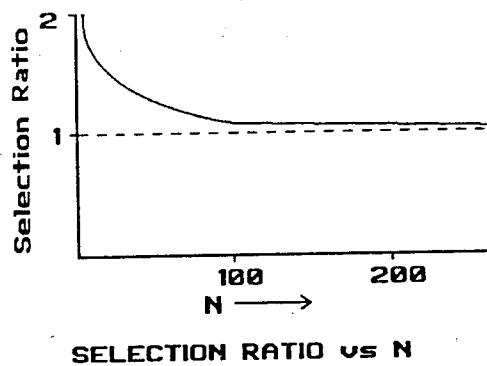


Figure 5.

III. ADVANCES IN PM - LCDS

VGA format passive matrix LCDs based on STN technology are commercially available today in monochrome as well as color. The 640x480 matrix is split horizontally in to two 640x240 matrices for addressing the display. Here, the number of lines multiplexed (N) is 240. Reducing N by half is necessary to achieve sufficient contrast in the display. This is referred to as "Dual scan".

The typical response times of the STN LCDs are in the range of 100 to 200 ms. It is difficult to follow the mouse movements on the screen with such slow displays. Response times of the STN LCDs have been reduced to about 50 ms by reducing the cell thickness to $4\mu\text{m}$ and using liquid crystals with low viscosity. They are referred to as fast responding STN LCDs. Contrast in these displays is poor when conventional addressing technique is used to drive them. Transmission through the OFF pixels increases due to large amplitude of the row select pulses, resulting in low contrast. This is referred to as Frame response[2] phenomenon and is illustrated in Figure 6.

Increasing the refresh rate of the display can suppress frame response. However, the distortion in the addressing waveforms due to RC

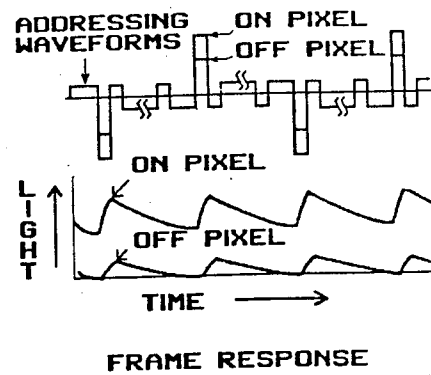


Figure 6.

time constant becomes significant as the row select time is reduced resulting in poor brightness uniformity of pixels. Several new addressing techniques based on selecting more than one line at a time have been proposed [3,4,5]. These techniques suppress the frame response in fast STN-LCDs, since the amplitude of the row select pulses decreases when L (number of rows that are selected simultaneously) is increased.

In the new addressing techniques L rows are selected simultaneously with waveforms corresponding to a set of orthogonal functions. The non-selected rows are grounded. Column waveform corresponds to orthogonal transform of the data to be displayed in the selected rows. Amplitudes of the row and column waveforms are optimized to obtain maximum selection ratio. Typical waveforms of Improved Hybrid Addressing Technique (IHAT), a new addressing technique is shown below in figure 7. Here, two rows are selected simultaneously for illustrating IHAT.

Typical contrast ratio (CR) of STN-LCDs using conventional addressing technique is 20. A CR of 40 and 64 gray shades has been

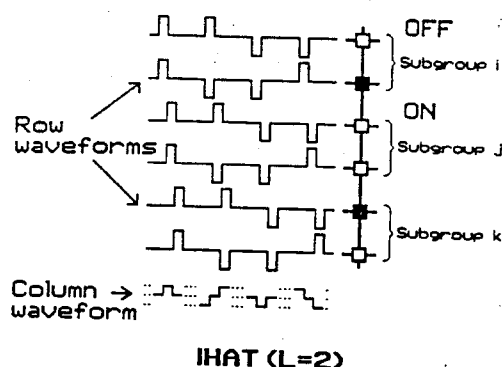
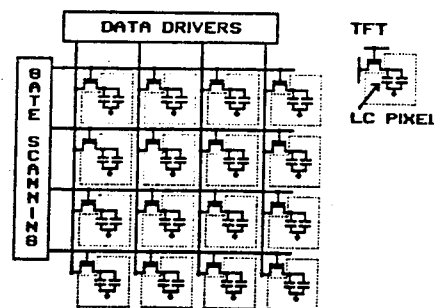


Figure 7.

achieved in fast responding STN-LCDs by using the new addressing techniques[6]. While this is lower than CR of 100 in active matrix LCDs, these new techniques have the potential to reach this performance soon. Two thirds of the large format(matrix size of 640x400 and larger) LCDs are STN-LCDs. This is mainly due to simple structure of the passive matrix LCDs and low cost as compared to active matrix LCDs..

IV. ACTIVE MATRIX LCDs

Steepness of electro-optic characteristics of TN-LCDs is not adequate for large format LCDs. A non-linear element like diode or transistor is incorporated in the display for each pixel. The non-linear element is used as a switch to charge the capacitor of each pixel. Schematic of an active matrix LCD is shown in Figure 8. This charge is held during the frame period. Hence the contrast ratio of these displays is high and is comparable to static driven displays. The manufacturing process is complex as compared to passive matrix LCDs. Large substrate size of AMLCDs is a great challenge for yields. The fault densities for a VGA display should be 20 times lower than that for production of 1Mbit DRAM with 50% yield.



SCHEMATIC OF AM-LCD

Figure 8.

V. ADVANCES IN AM-LCDs

Active matrix LCD up to a size of 21" diagonal has been demonstrated. Displays up to 11.5" diagonal VGA and S-VGA formats are being mass produced. Most of the AMLCDs manufactured today use amorphous-silicon thin film transistors(a-Si TFT). Mobility of a-Si TFTs are not adequate for integrating row and column drivers on to the substrate. Clock frequency of 15 to 30 MHz or more is necessary depending on the size of the display and the data format in the display drivers. Outputs of CMOS LSI drivers (in TAB package) are connected to display substrate using heat seal connectors. Cost of the drive circuit and inter-connections is significant and it is preferable to fabricate the drivers along with the TFTs in the AM-LCDs. This will reduce the cost and increase the reliability . Polysilicon thin-film transistors (poly-si TFTs) have carrier mobilities that are 2-3 orders of magnitudes higher as compared to a-Si TFTs. Higher mobilities enable integration of drivers on the display substrate. Light transmission through the cell is also increased as the TFT size is reduced with high carrier mobility. AM-LCDs with poly-Si TFTs are being manufactured for small size displays in head-

mounted, camcorder and projection applications. Efforts are being directed to develop large size(ex:10.5") displays using poly-Si TFTs. Viewing angle of conventional LCDs is limited. This problem has been over come by several methods and about 120° viewing angle has been achieved using domain divided TN-LCDs[7].

AM-LCDs have been fabricated up to 21". However it is difficult to fabricate very large panel of size 40". (Plasma displays of 40" size have been demonstrated.) Plasma addressed liquid crystal (PALC) technology is a likely solution for large size LCDs. The principle of PALC is given below.

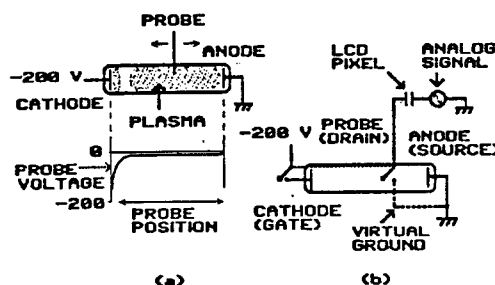
VI. PLASMA ADDRESSING

Plasma addressing [8] is based on difference in conductivity of gas in ionized and de-ionized state. The gas is conducting in ionized state and the conductivity depends on the mobility and the number of charge carriers. Conductivity in the de-ionized states is lower by 10 orders of magnitude. Figure 9 (a) shows a glass tube containing a gas like helium or neon. When the voltage between anode and cathode is sufficiently

nearly equal to the anode potential except near the cathode. When the plasma is off, the probe is floating and is electrically isolated from the anode or cathode. Figure 9 (b) illustrates the plasma switch. When the cathode is switched on the probe is at the same potential as the anode and is virtually connected to the ground. The capacitor (a pixel in the LCD) can be charged to the required voltage. When the cathode potential is removed or reduced below sustaining voltage of the plasma, the probe is floating and hence the charge is retained across the capacitor. In a plasma addressed LCD(PA-LCD) all the TFTs in a row of an AM-LCD are replaced by a single channel of plasma. Pixels in a row are charged to the desired voltage through the column electrodes. The rows are sequentially selected for refreshing the display. Rows can be scanned at the rate of 5μs/row (includes striking a plasma and its decay) when helium at 40 millibars is used in the channels. Hence a matrix with few thousand rows can easily be driven.

PA-LCD panel structure has been simplified[9] recently by forming the plasma channels using screen printing techniques. Schematic of a plasma addressed panel with simple structure is shown in figure 10. Panel can be produced in low-grade clean rooms and semiconductor production facility is not required. 20" panels have been demonstrated and the process can be easily scaled up to 50" size.

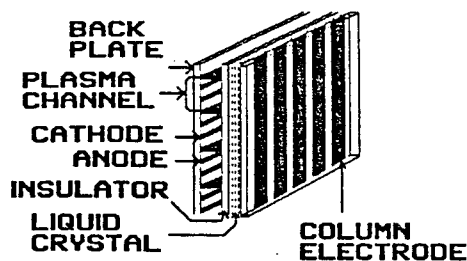
PA-LCDs are simpler to produce as compared to AM-LCDs with TFTs or diodes. The yeild can be higher than that of AM-LCDs. Hence the plasma addressing has the potential to be future technology for large area displays in applications like wall hanging HDTV.



PLASMA ADDRESSING - PRINCIPLE

Figure 9.

large, the gas in the tube is ionized and glows. The probe voltage measured along the discharge path is



SCHEMATIC OF PA-LCD

Figure 10.

VII. CONCLUSION

LCDs are mainly used in portable applications today. Most of the large format LCDs (VGA and S-VGA displays of size 8.5" to 11.5" diagonal) are used in Laptop or notebook computers. About 187,000 m² of LCDs with varying size and format are being produced every month. Approximately 4000 panels of STN monochrome, STN color and AM-LCDs are being produced (each type) every month[10]. The demand for these displays is estimated to increase at the rate of 30%. The demand could increase further with advances in LCD technology, reduction in cost and its use in large consumer electronic application like television in the near future.

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