AN EXAMINATION OF ACTIVE MATRIX TECHNOLOGIES AND COMPONENTS

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OBJECTIVE

The purpose of this paper is to examine the different active matrix technologies and review the theory behind the different technologies because breakthroughs in the different technologies are happening every day. This paper will review the technologies, discuss some of the problems, and propose some solutions brought about through various research.

INTRODUCTION

Flat panel displays required a technology breakrough, not only to compete with CRTs but more importantly to provide applications that did not and do not exist with CRTs (i.e., color laptop computers, portable T.V.s, and helmet mounted flight simulation devices to name a few). The design criteria was to achieve a display comparable to a CRT, utilizing matrix addressing, while overcoming crosstalk and offering cost effective solutions. The technology that allowed this breakthrough is active matrix technology.

BACKGROUND

Before an examination of the different technologies is possible, an understanding of addressing and crosstalk is required.

Addressing

Direct addressing is the hard wiring of each pixel to driver amplifier. In a 640 x 480 resolution display it would require (640 x 480) 307, 200 driver amplifiers. This method is very expensive because of the number of drivers and physically, the driver circuitry would be very large. Alternative methods of driving the displays had to be found. The method used for driving most flat panel displays is matrix addressing. In matrix addressing each pixel is electronically connected between one row lead and one column lead, therefore the number of driver amplifiers is equal to the number of rows plus the number of columns. In a 640 x 480 resolution display the number of drivers can be reduced from 307, 200 to 1,120 a significant reduction in space and expense. In order to use matrix addressing the display media must posses a strong nonlinear characteristic to prevent partial selection of non-addressed pixels (crosstalk). A nonlinear component can be added; usually a transistor or diode, an active nonlinear device. (1)

Crosstalk

There are several causes of crosstalk; including leakage current, capacitive coupling between address lines, and line delay.

Leakage current

While matrix addressing reduced the number of drivers that are needed it also means that a single driver will drive more than one pixel. A single driver may drive one or more rows or columns. This means that even nonselected pixels will have a voltage on a row or column. This voltage is less than the voltage required to turn the pixel on. However if the active device (transistor or diode) has leakage current, the unaddressed pixel may turn on, causing crosstalk. The leakage current is often expressed as the ratio of Ion/Ioff.

Capacitive coupling

There are two causes of capacitive coupling between address lines. One is the parasitic capacitive coupling between data lines. The second source of capacitive coupling is the high speed of the driving wave form used in matrix addressing. The higher the speed, the greater the probability of capacitive coupling. (2)

Line delay

There are two major causes of line delay. One is the RC line delay between gate terminals of adjacent pixels. The other is the resistance of the LCD cell itself. Figure 1 is a representation of the resistance in the LCD cell.

Rc = represents the resistance across the LCD cell

Rc^1 = represents the resistance through the ITO layer of a LCD cell

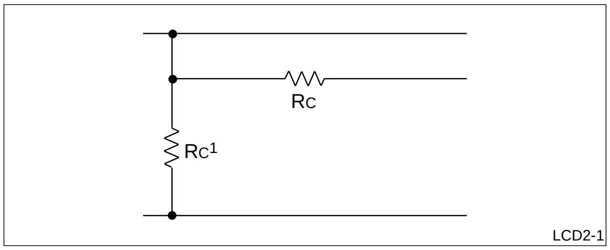


Fig. 1. LCD Cell Resistance

Measurement Method

A method of measuring crosstalk is illustrated below. A brightness measuring device is used to measure the brightness Ya with all the pixels on (white). A pattern (usually a box) is then displayed on the screen and the same spot is measured Yb (Figure 2). The cross modulation ratio can then be measured using the following formula:

$$\text{Cross modulation ratio} = \frac{|Yb/Ya|}{Ya} \times 100$$

Ya = brightness of area without pattern (cd/m)

Yb = brightness of area with pattern (cd/m)

Ya and Yb must be measured at the same spot.

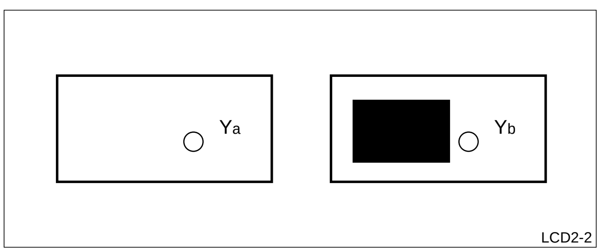


Fig. 2. Method for Measuring Crosstalk

EVALUATION

As we evaluate the different technologies, keep in mind the design criteria: to achieve a display comparable to a CRT, utilizing matrix addressing and good grayscales, while overcoming crosstalk and maintaining cost.

Diode Devices

1. Two Terminal Devices:

A. a-Si Back-to-Back Diodes (Figure 3)

The advantages are:

- Ion/off 10^8 (lower leakage current, improved crosstalk)
- Simple Process (Cost)

The difficulties are:

- The breakdown voltage is neither reproducible or reliable, making large screen uniformity and grayscales very difficult.

B. a-Si Back-to-Back Ring Diodes (Figure 4)

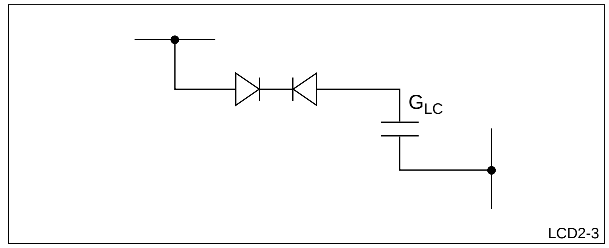


Fig. 3. a-Si Back-to-Back Diodes Equivalent Circuit

The advantages are:

- Same as a-Si Back-to-Back Diodes

The difficulties are:

- One diode, low-voltage threshold voltage
- More diodes, more complex
- Voltage not optimized to liquid crystal threshold

C. Metal Insulator Metal (MIM) (Figure 5)

The advantages are:

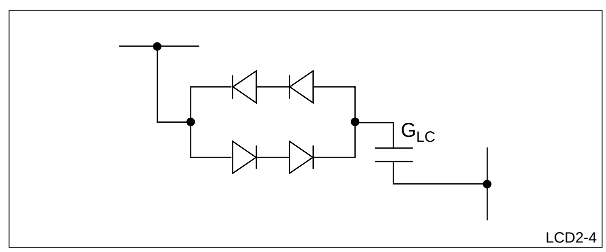


Fig. 4. a-Si Back-to-Back Ring Diodes Equivalent Circuit

- Fewer Masks (2-3) (Cost)
- Light insensitive (TaO MIM)
- High Resolution
- No Crossovers

The difficulties are:

– Crosstalk

– Tight Tolerances: Voltage and temperature (can influence image sticking), insulator thickness (can influence panel uniformity), device area and material issues.

– Complex Cover Plate

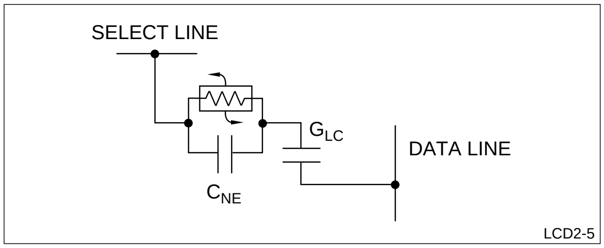


Fig. 5. MIM Equivalent Circuit

MIM LCDs were the first active matrix displays. The MIM is electrically equivalent to a bidirectional zener diode. The bidirectional aspects allows the display to be driven by symmetrical square waves with no DC ie., component.

In addition there is lateral MIM technology. Lateral MIM technology uses several lateral MIM devices per pixel. The results are high density per pixel (better resolution), high contrast ratio over a wide temperature range, a redundancy in technology for pixel defects and symmetrical I/V characteristics. (5)

3. Three Terminal Diodes: D^2R (Figure 6)

Advantages:

– Charged storage

– Diodes are small

– Redundancy, series/parallel

– ON/OFF approximately $1O^8$

Disadvantages:

– 2X row interconnect lines (Increase number of drivers are necessary)

– Poor storage capacitors

– Complicated color plate back plane

– Column lines and ITO on top of filters

4. Three Terminal TFTs:

A. a-Si TFT (Figure 7)

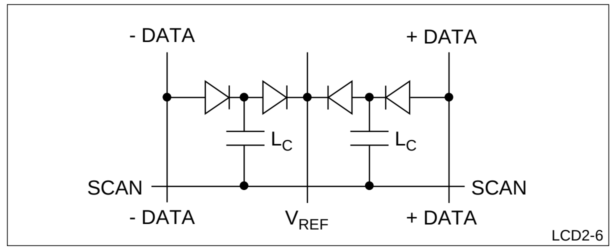


Fig. 6. D^2R Equivalent Circuit

a-Si TFTs are low-temperature polysilicon TFTs. During the manufacturing process the silicon is deposited as an amorphous film then recrystallized it to polysilicon by annealing at temperatures between 300° C and 600° C. This has advantages compared to conventional processing of polysilicon TFT fabrication that requires temperatures as high as 1000° C. The lower temperature process allows the use of low cost glass substrate instead of quartz or high temperature glass. (9)

Advantages:

– Larger temperature process, glass instead of quartz, (cost)

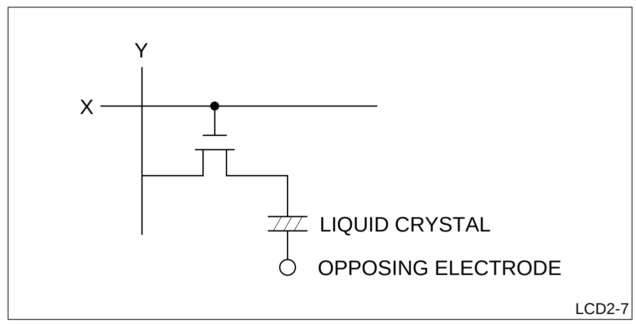


Fig. 7. a-Si TFT Equivalent Circuit

– Lower area capability

– Good uniformity over a large area

Disadvantages:

– Low mobility and high photo conductivity (8), (results is higher leakage current)

– Complex process (Compared with two terminal devices)

Work is being done to improve the leakage current characteristics of polysilicon TFTs at lower temperature process. Including composite fabrication of below 450° C by using laser induced crystallization of PE-CVDed amorphous silicon.

B. poly - Si TFT

Conventional high temperature polysilicon TFTs.

Advantage:

– High mobility (high-drive currents, high-speed circuitry)

Disadvantage:

– Practical applications reduced to devices formed on small area quartz substrates.

– Complex process

– High temperature process

TFT technology is by far the leading technology for active matrix displays because of the high contrast and high picture quality, ability to display good grayscales and superior response time. While MIM technology is attractive because of the cost advantages (fewer masks), the manufacturing of TFT displays has far out numbered the MIM displays because of the superior display performance.

Of the different TFT technologies a-Si TFTs are considered the leading candidates for large area active matrix displays since they can be fabricated at low temperatures on inexpensive glass substrates.

ADVANCES IN COMPONENT TECHNOLOGY

Drivers

1. 3-bit Digital source driver driven by a single 5 V supply for TFT LCD. (6)

   A 3-bit digital source driver has been developed by Sharp Corporation for computer application (CA) displays. The advantages of a digital driver over an analog driver are as follows:

   – Increased sampling speed. The maximum sampling speed of this new driver is 20 MHz, more than three times as fast as the traditional analog sampling driver.

   – Data can be sampled more precisely.

   – Greater computer compatibility because the computer is a digital device

   – +5 V operation eliminates the need for a +12 V supply

2. 16 level grayscale driver for TFT LCD (7)

   A 16 level analog grayscale driver has been developed by Fujitsu which has the following advantages:

   – 16 level grayscale will provide 4096 colors, compared to 512 colors of the standard 8 level grayscale drivers.

   – If frame rate control (FRC) is used it is possible to obtain 64 grayscale levels capable of displaying 262,144 colors. This is useful for multimedia applications.

3. 6-bit Digital source driver driven by a single 5 V supply TFT LCD. (10)

   Sharp has developed a 6-bit digital source that can generate 64 gray levels. For audio visual (AV) and computer applications (CA). The driver is driven by a single +5 V source and is packaged by a TAB (tape automatic bonding) process the driverswhen used with the Inter-frame modulation method can produce both AV and CA display, thereby combining CA and AV technology in a single display.

Color Filters

Red, green and blue (RGB) color filters are a very important component of a display. Table 1 summarizes the different color filter application methods.

Color filters are arranged in different formations depending on the design criteria. There are four methods to arrange the color filters in a display (Figure 8).

A. **Vertical Stripe:** Most popular arrangement for CA (computer application) type of displays.

   Good arrangement for good character display capabilities. Requiresthree vertical data line drivers and one horizontal gate line driver for each pixel.

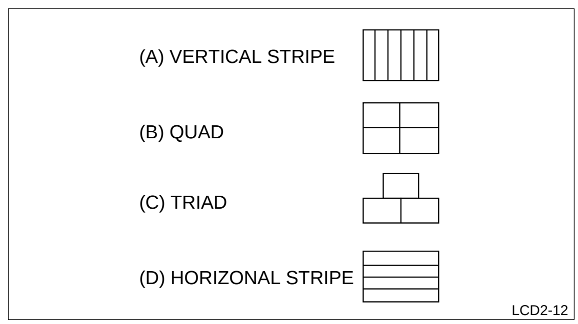


Fig. 8. Methods of Arranging Color Filters in a Display

B. **Quad:** Requires two vertical drivers and two horizontal gateline drivers for each full color pixel.

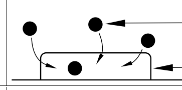
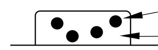
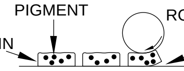
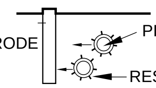
C. **Triad:** Used for AV application because of good appearance, such as TV applications.

D. **Horizontal Stripe:** Requires one vertical data line driver and three horizontal gate line drivers. Because a 640 x 480 panel has more vertical lines than horizontal lines, the horizontal stripe configuration is the most economical. The major disadvantage is that line-buffer memory is required except in applications that have frame memory. (12)

Backlighting Technology

Since LCDs do not emit light, an external light source is needed. The most common light sources

Table 1.
Color Filter Formation Methods

METHOD NAME	DESCRIPTION
Gelatin Dyeing: Patterned resin is dyed.	
Pigment Impregnation: Resin containing pigment is made into a pattern.	
Printing: Color ink containing pigment is printed on.	
Electroplating: A resin coat is electroplated on the pigment surface.	

are: HCFTs (hot cathode fluorescent tubes) or CCFTs (cold cothode fluorescent tubes). The HCFTs are usually brighter, but their life is not as long (10,000 hours). The CCFTs are not as bright, but they have a longer life (20,000 hours).

The tubes can be placed behind the LCD panel for maximum brightness but results in an increased panel thickness; or on the edge of the panel for less brightness but better brightness uniformity and a thinner display.

PUTTING IT ALL TOGETHER

Sharp has put all the technologies together to offer some of the most innovative active matrix displays available in the market. An example of such a display is the LQ9D011 for computer applications. Let's take a look at the LQ9D011 and see how Sharp has combined the various technologies for a state of the art panel. LQ9D011 (640 x 480 x 3 TFT 512 color VGA panel for laptop applications):

1. TFT technology providing high-contrast and high-picture quality, 8 grayscales, and 80 ms typical response time.
2. CCFT Edge Light: Low power (laptop application), thin (12mm), good bri ghtness uniformity and still providing 70 nt typical brightness.
3. 3-bit, 5 V drivers: Providing 512 colors with only 5 V requirement. It is packaged using a Tape Automated Bonding (TAB) process and measures approximately 25 mm x 20 mm with 120 outputs per chip.
4. It utilizes a vertical stripe color filter pattern very good character display.

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NOTES

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