Flat Panel Displays

When talking about computer monitors, the word on the street is that thin is in. For example, at this year’s Comdex Fall ’98, the computer industry’s largest North American tradeshow, every single monitor company was demonstrating the benefits of the new Flat Panel Display (FPD) technology.

These thin Flat Panel Displays offer users many advantages over the bulky, power-hungry cathode ray tube (CRT) monitors that are most common today. FPDs emit less radiation, produce less screen flicker and consume less power. They also take up less space, allowing for a more comfortable work environment. So why isn’t everyone using Flat Panel Displays? One reason is cost. FPDs are between three and four times more expensive than CRT monitors and will most likely be so for the next few years. Another reason is the lack of standards. There are currently a number of ways to send information from the computer to the FPD, and until this issue is resolved, consumers will be reluctant to make the switch.

How does a Flat Panel Display work?
Flat Panel Monitors use a Liquid Crystal Display (LCD) to create the images users see on the screen. LCDs are quite common, and are used in products like digital wristwatches, calculators and laptop computer displays. There are two main types of Liquid Crystal Displays: Passive Matrix and Active Matrix. But before examining the different types of LCDs, it is important to first understand how they work.

An LCD is made up of two very thin glass or quartz panels. On the inner surface of each panel lies a matrix of electrodes, which represent each pixel. The word pixel is short for picture element, and like pieces in a jigsaw puzzle, each pixel contains a piece of information about the picture. Only when they are all put together do they create an entire image. A thin polarizing film is attached to the outer surfaces. The two surfaces are then placed extremely close together and sealed with a gasket. The air is then removed from between the panels and replaced with liquid crystals.

The liquid crystals contain transparent, organic polymers that respond when voltage is applied. They act like shutters on a window to determine how much light passes through the panels. The amount of voltage that is applied by the electrodes on the inside of the panels controls how much light the liquid crystals let through to create the images users see on the screen.

LCDs normally require a source of reflected, or back lighting to pass through the liquid crystals. The source is usually a cold cathode, fluorescent or halogen bulb placed behind the back panel. Since the light must pass through polarizers, glass, liquid crystals, filters and electrodes, the light source must be strong enough to create the desired brightness for the display. Typically, 95 per cent of the back light is absorbed so the viewer only sees about five per cent of the actual light produced. This is one of the biggest reasons why laptops use so much power.

By comparison, CRT monitors rely on phosphors to create the images users see. A “gun” at the back of the monitor fires targeted beams of electrons at the phosphors to “excite” them and generate the light that becomes the image a user sees. The phosphors don’t stay constantly excited and must be refreshed before their flicker becomes noticeable. The phosphor must also be refreshed when the image on the screen is changed, for example when new words are typed into a document or slides are changed during a PowerPoint presentation.

The way users perceive resolution settings also changes with Flat Panel Displays. With CRT monitors users can change resolution anywhere from 640 x 480 to 1600 x 1200 and still maintain full screen display. With a FPD, however, each electrode represents a single pixel, and therefore the only true resolution supported is its maximum. For example, if a user buys a FPD with a resolution of 1024 x 768 it cannot be set to a higher resolution. And if the user selects a 640 x 480 resolution on this FPD, the image will only be displayed on 66 per cent of the screen. The image can, however, be scaled up to a full screen display through a process known as rathiomatic expansion.
**Passive Matrix Liquid Crystal Display**
This type of LCD has been used in watches and calculators since the early 1970s. Passive Matrix LCDs (PMLCDs) have closely spaced, transparent metal electrodes positioned horizontally on one panel, and vertically on the other. A pixel is either turned on or off when the panel’s controller sends an X co-ordinate to the vertical electrode, and a Y co-ordinate to the horizontal one. The pixel is then given a new setting where these co-ordinates meet. This process is done for every single pixel on the display.

**Active Matrix Liquid Crystal Display**
This type of LCD is often used in laptop displays. Active Matrix LCDs (AMLCDs) use Thin Film Transistors (TFTs) at each pixel to control its on-off state. To make an AMLCD, the front transparent electrode is simply placed over the entire glass surface to serve as the ground electrode. The rear glass is then placed with a matrix of transistors and metal interconnect lines. At least one transistor per pixel is required for monochrome displays, while at least three are required for color displays - one each for red, green and blue.

**Other FPD Technology**
The largest available Flat Panel Displays are called Plasma Display Panels (PDPs). They consist of front and back panels with phosphors placed on the inside of the front panels. While a LCD uses liquid crystals between the panels to control the amount of light that passes through, PDPs use an inert gas between the glass panels of each cell in order to excite phosphor to generate light. The red, green and blue phosphors determine the color of each pixel just like a CRT monitor. Other FPD technology also exists, including Electroluminescent Displays (ELDs), Field Emission Displays (FEDs), Light Emitting Diodes (LEDs), Vacuum Fluorescent Displays (VFDs) and more.

Within the Flat Panel Display category, there are differences between the various technologies. The two types of LCDs and PDPs offer certain advantages and disadvantages to users. Table 1 identifies the respective advantages of PMLCDs, AMLCDs and PDPs while Table 2 examines each of their disadvantages.

**Table 1. Advantage Comparison of FPD Technology**

<table>
<thead>
<tr>
<th></th>
<th>PMLCD</th>
<th>AMLCD</th>
<th>PDP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PMLCD</strong></td>
<td>Lower cost of production than AMLCD</td>
<td>Faster than PMLCD</td>
<td>Much lower cost than LCDs</td>
</tr>
<tr>
<td><strong>AMLCD</strong></td>
<td>Prolific use in laptops enables good economy of scale</td>
<td>Generates much higher resolutions</td>
<td>Built on proven technology</td>
</tr>
<tr>
<td><strong>PDP</strong></td>
<td>Easier to produce than AMLCD</td>
<td>Better viewing angles than PMLCD</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Disadvantage Comparison of FPD Technology**

<table>
<thead>
<tr>
<th></th>
<th>PMLCD</th>
<th>AMLCD</th>
<th>PDP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PMLCD</strong></td>
<td>Slower than AMLCD, especially at higher resolutions</td>
<td>More expensive than PCLCDs</td>
<td>High power consumption</td>
</tr>
<tr>
<td><strong>AMLCD</strong></td>
<td>Lower contrast ratio than AMLCD</td>
<td>Quality control problem with transistors used for display</td>
<td>High operating voltage</td>
</tr>
<tr>
<td><strong>PDP</strong></td>
<td>Limited viewing angle compared to AMLCD &amp; PDP</td>
<td></td>
<td>Low color brightness</td>
</tr>
</tbody>
</table>
Comparing FPDs and CRTs

FPDs have five significant benefits over CRTs:
1. Flat panels take up much less desk space and can be hung on cubicle walls. In cities where office space is extremely expensive, businesses can reduce the square footage for each employee, while still providing the same amount of actual work space.
2. Flat panels do not emit radiation and they ease the worries of prolonged exposure to a CRT monitor.
3. Flat panels consume less power, which can save businesses money.
4. Flat panels do not flicker like CRTs and they eliminate the eyestrain and headaches that can result from flicker.
5. Flat panels are nicer to look at than CRTs.

CRTs have two significant benefits over FPDs:
1. CRTs are three to four times cheaper than FPDs, which can save businesses a substantial amount of money in capital investment.
2. CRTs are currently the industry standard and all equipment is designed to work with them.

FPDs and CRTs with the same approximate screen size have different viewing space and maximum resolution. Since FPDs are completely flat they offer a greater viewing area than the slightly curved CRT screen. FPDs are not only thinner than CRTs, the actual screen size can be smaller to fit the same resolution. [see Table 3].

Table 3. Screen Sizes Required to Achieve the same resolution

<table>
<thead>
<tr>
<th>FPD Size</th>
<th>CRT Size</th>
<th>Maximum Resolution</th>
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</thead>
<tbody>
<tr>
<td>13.5&quot;</td>
<td>15&quot;</td>
<td>800 x 600</td>
</tr>
<tr>
<td>14.5 - 15”</td>
<td>17”</td>
<td>1024 x 768</td>
</tr>
<tr>
<td>17”</td>
<td>21”</td>
<td>1280 x 1024 or 1600 x 1200</td>
</tr>
</tbody>
</table>
Examining the differences between a 13.5” PMLCD and AMLCD compared to that of a 15” CRT can also help to demonstrate some of the technical differences between FPDs and CRTs. See Table 4 here. Contrast ratio is a measure of how much brighter a pure white output is compared to a pure black output. The higher the contrast, the sharper the image and the more pure the white will be. When compared with LCDs, CRTs offer by far the greatest contrast ratio.

Response time is measured in milliseconds and refers to the time it takes each pixel to respond to the command it receives from the panel controller. Response time is used exclusively when discussing FPDs, because of the way they send their signal. An AMLCD has a much better response time than a PMLCD. Conversely, response time doesn’t apply to CRTs because of the way they handle the display of information (an electron beam exciting phosphors).

There are many different ways to measure brightness. The higher the level of brightness (represented in Table 4 as a larger number), the brighter the white displays. When it comes to the life span of a FPD, the figure is referenced as the mean time between failures for the flat panel. This means that if it is runs continuously it will have an average life of 60,000 hours before the light burns out. This would be equal to about 6.8 years.

<table>
<thead>
<tr>
<th>Display Type</th>
<th>Viewing Angle</th>
<th>Contrast Ratio</th>
<th>Response Speed</th>
<th>Brightness (NIT)</th>
<th>Power Consumption</th>
<th>Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMLCD</td>
<td>49-100 degrees</td>
<td>40:1</td>
<td>300ms</td>
<td>70-90</td>
<td>45 watts</td>
<td>60K hours</td>
</tr>
<tr>
<td>AMLCD</td>
<td>more than 140 degrees</td>
<td>140:1</td>
<td>25ms</td>
<td>70-90</td>
<td>50 watts</td>
<td>60K hours</td>
</tr>
<tr>
<td>CRT</td>
<td>more than 170 degrees</td>
<td>300:1</td>
<td>n/a</td>
<td>220-270</td>
<td>180 watts</td>
<td>less than LCD</td>
</tr>
</tbody>
</table>
Where each type of FPDs are used
PMLCDs are used primarily in laptops since they are smaller in size and less expensive than AMLCDs. While AMLCDs constitute the majority of stand-alone FPDs used in the computer desktop market, they are also penetrating the high-end laptop market due to superior performance.

To date, AMLCDs have been used for stand-alone displays by early adopters of this new technology. Financial markets use AMLCDs because of the number of benefits they offer. They include:

1. Players in the financial markets tend to have very expensive floor space and many employees. Using FPDs allows more financial traders to work in less space because of each panel’s small “footprint.”
2. FPDs consume less power and since most financial traders use up to three or four monitors, they can save up to 30 per cent on power consumption.
3. FPDs generate less heat, and therefore reduce the office cooling costs incurred by businesses.
4. Less emissions from the monitors makes for a safer environment in the notoriously crowded financial trading offices.

Flat Panel Display technology benefits more than just financial traders. In fact, Liquid Crystal Display FPDs are ideal solutions for public safety control stations, hospitals, factory automation, hospitality and retail promotions, video editing and video wall displays, as well as industrial and CAD displays. PDPs are found primarily in very large FPDs, of 30-40”, used for large promotional campaigns and presentations. In the future, PDPs may even enter the home entertainment market as large televisions that can be hung on the wall.

What is PanelLink and how does it work?
Matrox Flat Panel links to the flat panel monitor and replaces the analog interface with the new PanelLink digital version, to provide the most vivid, photo-realistic displays. PanelLink is the brand name of the standard that is owned by a company called Silicon Image. PanelLink consists of two ASICs. One is a transmitter and the other is a receiver. The transmitter is located on or near the graphics controller of a system. The receiver is located on the panel. The transmitter takes the digital information of the computer and encodes it into a scheme called transition minimized differential signaling (TMDS), which is also part of the Plug and Display standard from VESA. The transmitter encodes the data, clock, and control signals from the graphics controller and then sends it out to the panel. The receiver in the panel then decodes the information and sends it to the panel’s controller.

The current solution is scaleable and can support resolutions from 640 x 480 to 1280 x 1024. There will be another chip that will support 1600 x 1200 in the near future. The clock speeds required to encode and decode this data are:

<table>
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<tr>
<th>Resolution</th>
<th>Clock Speed</th>
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<tbody>
<tr>
<td>SVGA 800 x 600</td>
<td>40 Mhz</td>
</tr>
<tr>
<td>XGA 1024 x 768</td>
<td>65 Mhz</td>
</tr>
<tr>
<td>SXGA 1280 x 1204</td>
<td>108 Mhz</td>
</tr>
<tr>
<td>UXGA 1600 x 1200</td>
<td>162 Mhz</td>
</tr>
</tbody>
</table>
Silicon Image currently has two different sets of ASICs. One runs at 85Mhz and the other at 110Mhz.

The physical connection consists of 3 differential data pairs and one clock pair, keeping the cable width small and the same regardless of the resolution demanded. Another advantage is that data can be transmitted over several meters using copper TP cable or several hundred meters using fiber optics.

This standard will finally allow a less expensive, more powerful performant, and will standardize digital solutions for the FPDs. Since it is the VESA standard, all of the panel makers will be making PanelLink compliant displays similar to the DDC compliant CRTs.

Matrox’s PanelLink module has the SII 150 PanelLink transmitter on board and is attached to the MAFC connector, where it gets the data before going to the DAC. Matrox supports the P&D connector from Molex and the MDR 20 from the DFP standard with two separate modules. The actual bracket on the main graphics board will have to be removed and be replaced by another bracket with a space for the digital connector. The same Matrox module will work with both NLX and ATX versions of graphics boards.

Flat Panel Displays will still be a niche market for most of 1999, with only the least price sensitive consumers buying them for very specific reasons (i.e. hospitals for low radiation, traders for space and power). Beyond the question of the adoption rate of FPDs, there is the question of the adoption rate of PanelLink in those FPDs. Panel makers will only be releasing some of their models with the PanelLink interface. The majority sold will still have the VGA connector. Graphics card companies want to make sure that there are enough panels out there to support it.

The Market, Pricing and Production
Stanford Research has forecasted that by the year 2000, nearly six per cent of the 100 million display products produced will be FPDs of 14” or more. Interestingly, this number does not include FPD that come with laptops. The laptop market has also been expanding. There were approximately 12 million laptops sold in the United States in 1998 and that number should rise to approximately 15 million in 1999.
Glossary of Acronyms

AMLCD
Active Matrix Liquid Crystal Display; one of the two main categories of Liquid Crystal Displays used; most commonly used as stand-alone Flat Panel Displays on business desktops; relies on liquid crystals stimulated by electrodes to let light pass through and display the image on screen.

CRT
Cathode Ray Tube; the most commonly used type of monitor currently used; relies on phosphors excited by beams of electrons to generate light and create the display on screen.

LCD
Liquid Crystal Display; one of the technologies used in Flat Panel Displays; two main categories exist - Active Matrix and Passive Matrix; uses transparent, organic polymers stimulated by electrodes to let light pass through and create the display.

PDP
Plasma Display Panel; a type of Flat Panel Display which uses an inert gas to excite phosphors and create the display on screen.

PMLCD
Passive Matrix Liquid Crystal Display; one of the two main categories of Liquid Crystal Displays used; most commonly associated with digital wristwatches and calculators; relies on liquid crystals stimulated by electrodes to let light pass through and display the image on screen.

TFT
Thin Film Transistors; control the on-off state of a pixel used to create the display of Active Matrix Liquid Crystal Displays.