Improving the Display Interface: Technological Advances in LCDs for Medical Diagnostic Displays

Dale H. Maunu

New technologies continue to raise the bar on flat-panel display performance in medical diagnostic devices.

Information conveyed by a medical diagnostic device display is critical. It must be clear and legible at all times, and screens are being called upon to display increasingly sophisticated information. In the development of medical devices, the objective is to display more and better data with optimum clarity, accuracy, and reliability. Toward this end, continual improvements in the performance of the human-machine interface have helped reduce the likelihood of user error and patient injury. With increased attention to human factors engineering, medical devices are now easier than ever to interpret and to learn how to use.

To improve medical devices, much focus often centers on the effectiveness of the display. As diagnostic devices become more complex, flat-panel displays are required to provide improved performance.

Can Flat-Panel Display Performance Be Improved?

It is not news that flat-panel displays—particularly thin-film transistor (TFT) LCDs—are increasingly displacing CRT monitors in medical diagnostic devices. In terms of performance, flat-panel displays are easier to integrate, cost less, and provide a higher level of safety, including reducing electromagnetic interference (EMI) and meeting environmental requirements. Compared with a CRT, an LCD is much lighter and has a lower-voltage power-supply requirement.

High-resolution TFT LCDs can handle the high level of content required of medical displays. In an application such as a patient-care monitor, these displays enable the device to have both a small footprint and a large viewable image. They also provide integrated, all-in-one monitoring capabilities. They can show waveforms, color-coded prioritized alarms, and menu functions with on-line help features simultaneously. Moreover, they can show on-screen minitrends for quick historical overviews, 24-hour graphical trends of all parameters, and more. Such capabilities give product engineers much-needed design flexibility.

A major benefit to incorporating a TFT LCD display into a medical device is the display's inherent characteristics—thin, light, and bright. With a 12.1-in.-diagonal screen, these displays tend to weigh just over 1.5 lb (0.680 kg). They have a very small frame, which allows a device designer to create sleek bezels and compelling form factors. And the thickness of a TFT display is typically a half-inch or less, which means a device's overall depth can be substantially reduced.

Because of the advancements in LCD technology, static images now look better on a TFT LCD than on a CRT. An LCD provides higher contrast ratio,
higher luminance, and better color saturation. Traditionally, rapidly moving images had looked somewhat better on CRTs because the CRT's faster response times resulted in less image smearing. Performance improvements are key to a shift toward the use of TFT LCDs. This article discusses those improvements and their effects on the design of medical diagnostic displays.

**The Front of the Screen**

In addition to high resolution, the front-of-screen performance of modern color TFT LCDs is particularly important for medical applications. TFT LCDs already offer contrast ratios of 500:1, luminance of 450 nits, color saturation over 70% of NTSC, and response times of <25 ms. CRTs struggle to achieve a contrast ratio of more than 100:1 and luminance of more than 130 nits. CRTs are also losing ground to TFTs in color saturation and response times, which have traditionally been the primary benefit of using CRTs.

**LCD Performance Enhancements**

The most commonly used flat-panel display in medical diagnostic devices is currently the 0.4-in. VGA (640 x 480 pixels) TFT LCD. Many newer medical workstations are moving toward larger, higher-resolution panels, such as the 12.1-in. SVGA (800 x 600 pixels) and 15-in. XGA (1024 x 768 pixels) (see Figure 1). Recently, the high-resolution XGA format has been to appear in smaller sizes, such as 8.4 and 12.1 in., allowing functionality that was previously available only in the larger sizes. Such performance has enabled TFT LCDs to readily address the requirements of information-intensive, reliability-critical medical diagnostic displays.

**Optimizing Front-of-Screen Performance**

Operating rooms, ambulatory surgical units, emergency rooms, and intensive care units use high-ambient light. In these environments, anything that interferes with readability must be eliminated, including front-of-screen glare. Several advancements in optical technology have been key to eliminating glare in TFT LCDs. Developments include passive optical enhancements such as thick-film coatings and index-matched thin-film coatings on the display surface, as well as active optical-enhancement techniques such as additional backlight power (i.e., adding cold-cathode fluorescent tube [CCFL] lamps).

Traditionally, TFT LCDs have used a front-surface treatment to eliminate glare. This treatment is a thick-film coating applied to the screen’s front polarizing film. It incorporates a hard coating for scratch resistance and a matte finish to disperse ambient light. This treatment works in controlled lighting environments (e.g., an office). However, under bright conditions, such as a sunlit room, this coating tends to appear opaque, making the screen image indiscernible. This effect can be overcome by increasing the backlight power, effectively making the display brighter than the light shining on it.

A more effective front-surface treatment—and a more expensive one—is the use of thin-film antireflective coatings. These coatings are applied using two basic techniques: index matching and multilayer. Index-matched coatings are designed to reduce the index of refraction between the air and the display surface. The smaller the index of refraction, the less reflective the surface becomes, allowing more of the light to pass through the front of the display and, therefore, preventing it from being reflected back toward the observer.

The multilayer approach uses layers of film with a thickness of 1/4 wavelength of the frequency of light. The idea is that the light will be partially reflected off the front surface of the film and partially reflected off the back surface of the film. The net effect is that the two reflections are 1/4 wavelength out of phase and, therefore, cancel out any reflections that might otherwise be seen by an observer. Because this approach is wavelength-dependent, it tends to cancel more of the reddish light (long wavelength) than the bluish light (short wavelength). The overall effect is a significant reduction in unwanted reflection.

The most common method to ensure that a display can be used in high ambient light is to make it brighter. Increasing the luminance of a TFT LCD typically involves three options: using brightness-enhancement films, increasing the
Table 1. A comparison of the performance characteristics of TN, VA, and IPS, and their variations.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Twisted Nematic (TN)</th>
<th>Vertical Alignment (VA)</th>
<th>In-Plane Switching (IPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TN</td>
<td>Optical Compensation</td>
<td>Multidomain Vertical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Film</td>
<td>Alignment</td>
</tr>
<tr>
<td>Viewing Cone (CR&gt;10) (H/V)</td>
<td>90/50</td>
<td>140/110</td>
<td>170/150</td>
</tr>
<tr>
<td>Transmittance</td>
<td>7-8%</td>
<td>7-8%</td>
<td>60-80%</td>
</tr>
<tr>
<td>Aperture Ratio</td>
<td>60-80%</td>
<td>60-80%</td>
<td>80%</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>Asymmetrical</td>
<td>Good</td>
<td>Asymmetrical</td>
</tr>
<tr>
<td>Color Shift</td>
<td>Some</td>
<td>Some</td>
<td>Some</td>
</tr>
<tr>
<td>Response Time (ms)</td>
<td>~25</td>
<td>~25</td>
<td>~25</td>
</tr>
</tbody>
</table>

Backlight power, or using a combination of these two options. The brightness-enhancement films are placed between the rear display glass and the light guide. These films include reflective polarizers and collimators. Backlight power can be improved by adding lamps or by increasing the current to the existing lamps. However, both techniques increase the heat generated by the backlight, so special attention must be paid to the product design to prevent premature aging of the backlight system.

It is impractical to define a required display luminance for high-ambient-light environments. Depending on the techniques used, as little as 300 nits or as much as 2200 nits might be necessary to ensure effective luminance. Displays need to be used at night as well as in the daytime, which requires a wide dimming range. In general, displays from different manufacturers can look different but still have similar performance specifications. It is essential that designers evaluate as many displays as possible to determine which is best suited to the particular application.

**Getting the Color Right**

The advent of color-correction techniques is another area in which TFT LCD front-of-screen performance has evolved. Color correction has enabled displays to reproduce color much more accurately. LCD components such as CCFL backlights and optical films can cause color shifts, so these effects must be compensated for in the design of the display. Traditional color-correction technologies process three basic color coordinates (red, green, and blue) relative to each other, so correcting one color influences the others. A new technology called *natural color matrix* (NCM) enables six basic colors (red, yellow, green, cyan, blue, and magenta) to be controlled independently along with brightness, with no influence to other colors (see Figure 2).

Using this technology, a display vividly reproduces even the most subtle colors. A special circuit automatically adjusts the color tones of the entire image for immediate reproduction of an image with optimum color balance.

NCM is a hardware-based, real-time color-space conversion technology that enables an LCD to present a color image conforming to the sRGB (IEC 61966-2-1) specification. The reproduction has no deviation from the original image and is not affected by color shifts caused by any of the display components.

**Expanded Viewing Angle**

Medical device LCDs must be readable from all directions, and LCD manufacturers have been developing technologies to improve the traditionally narrow viewing angle inherent in TFT LCDs. Three basic liquid-crystal modes are currently in large-scale production, and each mode has variants that improve viewing-angle performance. The three basic modes are twisted nematic (TN, vertically aligned (VA), and in-plane switching (IPS). Table 1 compares the performance of each. The images in Figure 3 illustrate and compare the three basic modes.

The liquid-crystal molecule has the unique property of being able to twist and bend light in a controllable way so that, with the application of an electric field, the molecules can act as a light valve. By arranging electrodes in a precise pattern, aligning the liquid crystals between two sheets of glass, and applying an electric field, the display is created. Shining polarized light through the display results in visible white, black, or shades of gray. By placing colored filters in the optical path, a color display is created from this fundamentally black and white structure. This is the basic concept of an LCD.

TN is the oldest and most common liquid crystal. It is used in both active- and passive-matrix displays. The cigar-shaped molecules naturally stack up widthwise with one another, while twisting at the same time (off = white). Applying an electric field causes the molecules to tilt up on end (on = black). The shades of gray result from transition from off to on.

TN-mode displays suffer from poor off-axis viewing due to the assymmetric...
nature of the optical path. Applying a compensation film to the top and bottom surfaces improves the viewing angle. Newer ultra-wide-viewing films have greatly improved on this concept.

IPS-mode displays were created to improve the viewing-angle characteristics of LCDs. In IPS mode, the liquid-crystal molecules, while still cigar shaped, no longer twist. Rather, they actually line up widthwise between the two sheets of glass. The electrodes are placed on each side of the cell instead of at the top and bottom. When the electric field is applied, the molecules turn on their axes to align with the field. By eliminating the twisting and tilting, the optical path for the light is more consistent and can be seen easily off axis. Historically, the downside to this technology has been a slower response time (due to the weaker electric field of the side-by-side electrodes) as well as a shift in the image color when viewed from an angle. New liquid-crystal materials have significantly improved the response time, and a TA technology called Super-IPS creates a zigzag cell structure, which addresses the color-shift problem.

The most recent advancement in liquid-crystal technology has been the introduction of VA mode. In its basic form, the liquid-crystal molecules naturally align themselves vertically when off and turn horizontal when an electric field is applied. Although the basic mode resulted in a fast-response display, more work was needed to improve the viewing angle. Three approaches have been developed to improve VA mode. The first is multidomain VA (MVA), in which each subpixel is divided into four domains, and the liquid crystal is forced to align in different directions in each domain. The second is patterned VA (PVA), in which the top and bottom electrodes are offset, forcing the liquid-crystal molecules to align differently within each subpixel. The third is axial symmetric view (ASV), in which the upper electrode is made very small, and when the electric field is applied, the molecules create an umbrella-shaped alignment in each subpixel.

In general, the IPS- and VA-based approaches have better front-of-screen performance than TN-mode displays; however, IPS and VA tend to be harder to produce and more expensive. The recent advances in compensation films make traditional, low-cost, easy-to-produce TN-mode displays a viable option for even the most image-critical medical devices.

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**The Clarity of Moving Images**

Another performance drawback traditionally associated with TFT LCDs has been their slow intragrayscale response time, which has posed a problem for applications that require crystal clarity of fast-changing images, such as moving pictures or scrolling text. A technology called Feed Forward Driving (FFD) has been developed to resolve this issue. Incorporated in an application-specific integrated circuit (ASIC) that can be added to any TFT LCD module, FFD uses a predictive...
algorithm to calculate and apply the necessary voltage overshoot, eliminating the need for expensive frame memory.

This technology substantially reduces cell response time at a fraction of the cost required to develop new liquid-crystal material or structures. FFD uses familiar TN technology to maintain a high contrast ratio and an eight-bit grayscale resolution. The intragyscale response time is improved from the traditional average of 84 milliseconds or more to less than 20 milliseconds.

Reducing EMI in TTL Devices

Most TFT LCDs currently being used in the medical device market have traditional transistor-transistor logic (TTL) interfaces. EMI can be a problem in these TTL devices, and, due to increased video bandwidth requirements, addressing EMI becomes more challenging as the display resolution increases.

To alleviate this problem, the trend for newer designs is to use low-voltage differential signaling (LVDS) for data transmission. Because LVDS is differential, it is an inherently low-noise interface. It has an added advantage over TTL. Longer, simpler interface cables can be constructed while still ensuring minimal EMI.

A more recent advancement has been the implementation of reduced-swing differential signaling (RSDS) as the interface inside a TFT module. The RSDS interface is placed between the timing controller and the column drivers. With the combination of LVDS to the display and RSDS inside the display, it is easier than ever before to achieve electromagnetic compatibility compliance with the latest generation of TFT LCDs.

Environmental Compliance: Green LCDs

The European Union has issued the Reduction of Hazardous Substances (RoHS) Directive (2002/95/EC), restricting the use of certain hazardous substances in electrical and electronic equipment. It prohibits the use of substances such as lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers. There are some exemptions to this directive, but generally, all manufacturers selling products in Europe must comply with the directive by July 2006.

Currently, displays have an exemption for a small amount of mercury in the backlight, but many display companies are developing strategies to eliminate all mercury as well as the other banned materials from their products in time to meet the deadline. Elimination of hazardous substances will certainly gain urgency as the deadline to comply with the directive approaches.

Conclusion

Medical diagnostic displays now must be able to convey more information, with more sophistication, than ever. With each generation of devices, manufacturers are asked to pack more and more features into a smaller footprint. Such demands require that TFT LCDs provide excellent performance characteristics that include antireflection, color correction, wide viewing angle, fast response time, and low-EMI data transmission. Materials that are used in displays must meet environmental requirements.

Ultimately, enhanced front-of-screen performance plays a big role in the overall improvement of a medical device. It can be the key to ensuring accurate display of data and reducing user error and patient injury.

References


Bibliography


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