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UNDERSTANDING TFT TRADE-OFFS LETS YOU BETTER MATCH THE DISPLAY AND INTERFACE TO YOUR APPLICATION.

Choosing the perfect TFT display: part one

As the cost of TFT (thin-film-transistor) displays drops and the desire for more user-friendly and graphical interfaces increases, more companies are asking engineers to design these products into their own. Although many engineers have designed with monochrome, passive, graphic-LCD modules, the task of selecting and working with a TFT, or active-matrix, display may seem somewhat confusing and daunting.

The first thing to consider is whether you need a TFT. Management, marketing requirements, or design specifications often answer this question. Remember: Color adds cost. You can save lots of money by designing with monochrome graphic-LCD modules. They are inexpensive, relatively easy to interface and control, and readily available. Monochrome displays require less overhead in hardware and less complex software. It's easier to manage one color per pixel than three (red, green, and blue) per pixel. Also, "monochrome" doesn't necessarily refer to just black and white. Depending on the backlight and LCD material, so-called monochrome LCDs come in a variety of colors, including black and white, yellow, green, blue, and a host of variations in between.

Color passive-LCD modules also exist. Depending on the design criteria, a color passive panel may have benefits over TFT panels, such as outdoor brightness or overall color brilliance. When deciding between a TFT and a color passive panel, keep in mind update speed and viewing angle. A TFT can provide viewing angles of nearly 180° degrees, whereas passive color modules, although constantly improving, usually provide only 70 to 80°.

LCD panels comprise a layer of LCD material and one or more polarizing layers made of plastic, glass, or some other material (**Figure 1**). When you align two polarizing materials with each other, light passes through. However, when one polarizing agent is at a 90° angle to the other, light is blocked. LCD fluid acts as a dynamic polarizing agent. When you place a voltage across an LCD cell, the cell twists by 90°, which, depending on the orientation of the polarizing agent under the LCD layer, either blocks or passes light (see **sidebar** "Reflecting on reflectivity").

In passive-LCD technology, the cells act as capac-

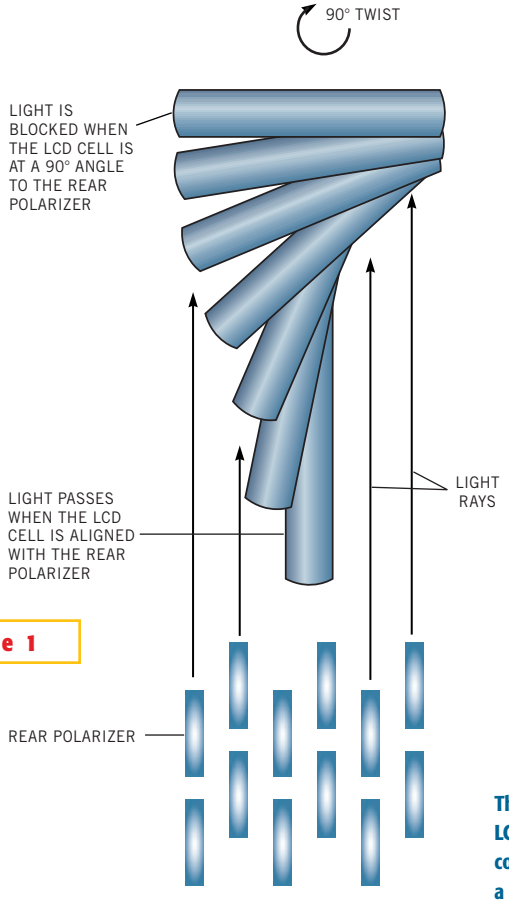


Figure 1

The basic operation of an LCD involves electrically controlled polarization of a fluid.

itors. Once charged, they bleed off their voltage and slowly twist back to their original position. Because of this, passive panels cannot quickly change the state of their cells and are unsuitable for fast-moving graphics. To overcome this weakness, TFT LCDs use transistors to drive the LCD cells. Although this approach is more complex and expensive, it allows for faster control of the LCD cell. A TFT can therefore display full-motion video and graphics, whereas a passive-LCD module starts to blur with images moving faster than eight to 15 frames/sec, depending on the manufacturer.

Don't let these factors turn you away from passive color panels. When searching for that perfect display, it's always best to explore all options. For instance, your application may need an outdoor, handheld system requiring good sunlight readability. You may find that a small TFT display and a color passive LCD both work well in the application, but perhaps the TFT display has a better viewing angle, whereas the passive panel's color looks better. Often, display se-

REFLECTING ON REFLECTIVITY

Once you select a size and a resolution for your TFT (thin-film-transistor) LCD, you need to choose how your display uses light. If you remember your LCD basics, an LCD screen generates none of its own light. It merely blocks light or allows it to pass through the LCD medium. The same situation holds true with TFT LCDs. Although the details of how LCDs and TFT displays accomplish these tasks differ, the basic principle is the same. An LCD or a TFT display can use light only after you adhere a polarizing filter to the back of the LCD or TFT material. The type of polarizing technology– transmissive, transflective, or reflective– determines how the TFT panel uses light.

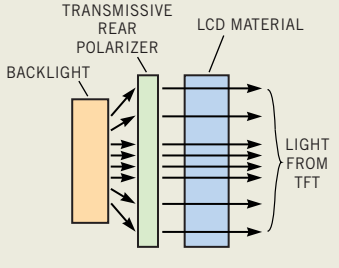
A transmissive TFT uses a backlight, usually comprising one or more CCFL tubes or LEDs, to shine light through the TFT panel's rear polarizing medium and glass (**Figure A**). Because a transmissive polarizing medium is clear, any light shining on the display from the front competes with the backlight and, if strong enough, washes out the display image so a user can't see it. Thus, transmissive displays are a poor choice for outdoor or bright-ambient-light applications unless a third-party display-enhancement company or electronics distributor adds significant backlighting and, hence, cost to the TFT panel. Therefore, a transflective or reflective TFT display is usually more suitable for applications with high ambient light.

A transflective display has a partially reflective, mirrorlike rear polarizing medium (**Figure B**). This transflective layer allows light from a backlight to pass through it, while reflecting light coming from the front of the display back through the TFT panel and adding to the backlight's light. This area is one of constant competition as TFT companies try to find better ways to make transflective layers that reflect as much light as possible, making them readable even in sunlight, yet that allow enough light to pass through from the backlight to be useful indoors or in cloudy weather.

A reflective TFT has no backlight (**Figure C**). The rear polarizing agent is simply a mirror layer behind the TFT panel that reflects incoming light from the front of the display. This feature makes these displays useful for applications in which users need to read the display in sunlight or in well-lit rooms. Often, TFT-display manufacturers add sidelights or front lights to these displays. Sidelights and front lights are virtually the same as backlights, except that front lights sit on the side or slightly in front of the TFT layers. The light they produce shines through the TFT panel and bounces off the reflective polarizing agent back through the display just as ambient light does. In some cases, TFT producers may incorporate light guides to help evenly distribute the light throughout the display. Reflective TFT panels are other areas of competition and constant improvement among display manufacturers. In a reflective TFT panel, the sidelight or front light adds only to the overall light for the display.

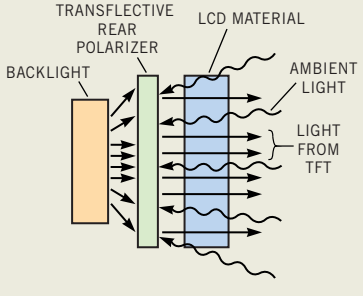
The method of reflectivity your TFT panel employs depends on your application and its requirements for visibility in sunlight, indoor light, or other ambient-light conditions. As with every step of selecting a TFT panel, work closely with your prospective display vendors to select the best display type for your needs.

Figure A



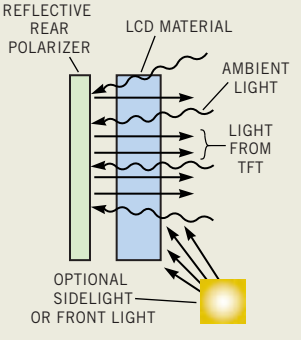
A transmissive display allows light to pass from a backlight to the front and viewer.

Figure B



The transreflective display uses light from the rear and the front of the display.

Figure C



The reflective display operates without any backlight; it uses light only from the display's front side.

lection can be as much a function of marketing requirements as it is a function of engineering specs. Displays can directly affect the look and feel of a product, and you will find that they are often subjective. When selecting a display, whether passive or active, make sure you work with a supplier or a distributor that will show you—and, if necessary, the marketing and management decisionmakers in your company—the display in operation. Most display vendors today have demo systems that allow you to observe the display showing canned pictures or video, or perhaps with inputs for a VCR or a DVD player.

CONGRATULATIONS! IT'S A TFT

The first thing to consider in selecting a TFT display is size. Unlike most passive-LCD modules, which you measure by the length and the width of the display, you measure TFT panels as you would CRTs: diagonally. Thus, a monochrome module measuring 122×92 mm might closely equate to a 5.7-in. TFT. When designing a product's mechanics, consider whether you plan to later update a monochrome product to a color display. Like picture tubes, TFT panels come in a handful of somewhat standard sizes or size ranges, including 1.5 to 2.5 in., which find use in cell phones; 3.5 to 3.9 in. for PDA and handheld systems; 5.7, 8.4, 10.4, 15, 17, 19, 21 in.; and other sizes. Other less common sizes are 4.5, 5, 6, and 7 in.

Size depends on application and annual requirements. For instance, the cell-phone market is highly volatile. If your application needs only a few hundred or few thousand displays per year, you need to make sure that the display vendor doesn't plan to declare end-of-life status for the TFT display you've chosen when a new cell-phone design makes that display obsolete. This situation could occur when you are only halfway through your design cycle. Similarly, the volatile PDA-system market usually requires 3.5- to 3.9-in. displays.

This sizing situation can have positive benefits as well. A 10.4-in. display, which once targeted only laptop computers, is now a sweet spot for price versus size in displays. This situation is a result of the fact that a large volume of applications exists for this size LCD. Also, vendors get a large yield from this size glass when they cut it, and this size LCD has a user legacy. A system that includes a 10.4-in. display may be less expensive than one using an 8.4-in. display and, depending on the TFT display's design, may be about the same overall size as one incorporating an 8.4-in. display. No matter which way you go, ask for feedback from your prospective display vendor.

Along with selecting your TFT display's size, you need to select its resolution. As the viewing area of a display decreases, so does a user's ability to distinguish individual pixels. It is therefore rare to see a VGA or higher resolution display smaller than 6 in.; most smaller displays offer QVGA or lower resolution. Similarly, 15-in. panels usually offer at least XGA resolution.

You will also find specialty panels with odd resolutions, such as 480×234 or 320×96 pixels. These panels target use in video, automotive, and rack-space applications. If your project displays video, for example, you may find such a panel more useful than a TFT display with QVGA or VGA resolution. Also note that aspect ratio comes into play with size and resolution. Most TFT panels have a 3-to-4 aspect ratio; however, you can also find 16-to-9 aspect ratios, as well as "almost" 3-to-4 or 16-to-9 ratios in specialty TFT panels.

Now, consider the backlights, sidelights, and front lights that TFT panels use. This article uses "backlight" to represent all three, because, although you mount them differently, their basic purpose is the same. It's useful to understand the measure of brightness (see **sidebar** "Don't be a nitwit").

The most common TFT-display backlight is the CCFL (cold-cathode fluorescent lamp). CCFLs are similar to fluorescent light tubes that you commonly find in offices and homes. They are small, relatively easy to use, good sources of white light for TFT displays, and usually field-replaceable. Both color and monochrome passive-LCD panels also often use CCFLs.

Based on size and nit rating, a TFT display uses one or more CCFL tubes, but these tubes also have drawbacks. For example, depending on its size, a CCFL tube needs 300 to 750V ac at 2 to 7 mA of current to operate. This requirement means that, if you want to use CCFLs, you must add your own or an off-the-shelf CCFL-inverter module to your design. Such modules provide varied functions, ranging from simple power conversion to soft start, dimming, and temperature compensation; they range in volume price from a few dollars to approximately $25.

Because CCFLs are fluorescent tubes, they also have limitations in temperature. Low temperatures make CCFLs flicker and produce less light, whereas high temperatures shorten tube life. Temperature extremes often make it difficult to design TFT displays into outdoor and automotive applications. TFT displays have a narrower temperature range than do semiconductors and other electronic parts, so designers sometimes use heaters or cooling fans as precautions to help overcome temperature-related design barriers.

DON'T BE A NITWIT

You use nits to measure the brightness of a TFT display. A "nit" is a unit of illuminative brightness equal to one candela per square meter, measured perpendicular to the rays of the source. When speaking of nits, you might ask: "How bright is that?" Unfortunately, you cannot answer this question unless you have previously worked with TFT displays.

Although a nit is a quantitative, mathematical function, it is still somewhat subjective. One person might see a dimly lit display, and another might see beautiful color. As a guideline, most laptop TFT displays have brightness ranging from 300 to 400 nits. You can find displays ranging from only a few to several hundred nits, depending on type and size. Note that many reflective displays have low nit ratings, or they specify nits with only the sidelight or the front light on, because you cannot specify a nit rating when you use ambient light. Some third-party companies specialize in TFT enhancements and can add light sources to most displays to push the nits rating to well beyond 1000 nits, but they do so at a cost.

Also, although CCFLs have a life span of several thousand hours, they can burn out or grow dim with age. They produce some heat, which you must take into account, and, because they are glass, you can break them by jarring or dropping them. Increasingly, manufacturers are making TFT displays with replaceable CCFLs; you may want to consider this type depending on how long you expect your product to last and whether you want to later replace an entire TFT display rather than just the CCFL. It may be just as cost-effective to replace the entire TFT display if you designed your product to last only a few years before users upgrade it, if it becomes obsolete, if the cost of carrying extra CCFL tubes is exorbitant, or the if associated cost of manpower for replacing them is too high.

LED backlighting is an option for 5.7-in. and smaller TFT displays. Although monochrome LCDs have used TFT panels for years, LED technology has only recently achieved the white light necessary to illuminate these panels. LEDs offer several advantages over CCFLs, such as stability over temperature ranges, mechanical durability, and simple power requirements. However, like CCFLs, LEDs generate heat, and they can also be difficult to arrange to light a TFT without hot spots, because of the LED's small surface area. White LEDs can also have a life rating. Over time, some white LEDs can burn out the doping material manufacturers use to make them appear white. Although this defect does not cause the LED to fail, it does result in a color shift for the LED's output and, consequently, for the TFT panel.

Based on the application, this color shift may or may not be an issue in the overall design but is something a design engineer should consider and discuss with the TFT-panel supplier. White LEDs are also a newer technology and are currently expensive. Due to these limiting factors, it is uncommon to see TFT panels with LED backlights larger than the 5.7-in. standard.

Some designers who have worked with monochrome LCDs may be familiar with EL (electroluminescent) panels. Although inexpensive, an electroluminescent panel generates a soft green to yellow to blue light, depending on the EL material and the applied voltage and frequency. Because EL panels produce light having limited color range, they are unsuitable for TFT displays. EL technology has several other disadvantages. EL panels have shorter lives than do LEDs or CCFLs, and their light intensity diminishes with age. They also require high frequency and high voltage, similar to those of the CCFLs that drive them.

Part two of this article will cover a few basic connection schemes as well as some points that designers often overlook when selecting TFT displays.□

AUTHOR'S BIOGRAPHY

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