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LEARNING THE TYPES OF TFT INTERFACES, THE ELECTRONICS THAT DRIVE AND CONTROL THEM, BASIC CONNECTION SCHEMES, AND SOME OFTEN-MISSED FINE POINTS CAN HELP YOU SELECT A TFT.

Choosing the perfect TFT display: part two

PART ONE OF THIS SERIES covered some of the physical attributes, designer options, and backlight options that exist with TFTs (*EDN*, February 5, pg 59). Part two discusses the types of TFT interfaces and the electronics that drive and control them. It also examines a few basic connection schemes and some often missed fine points when selecting TFTs.

Driving a TFT (thin-film transistor) display presents many options. Some passive panels use a simple controller, and others can just hang off your design's system bus. However, the signals and the data required to drive a TFT necessitate the use of a dedicated TFT controller, along with a system processor or video subsystem capable of providing the bandwidth for driving TFT video. Many chips, chip sets, boards, and SOC (system-on-chip) options, ranging from simple converters to complex video and graphics systems, are available to handle this task. For the connection between these controllers and the TFT itself, TFT manufacturers have adopted two somewhat standard interfaces. The first is a parallel interface usually called TTL (transistor-to-transistor logic) or LVTTL (low-voltage transistor-to-transistor logic), which sends the TFT data and clocking signals via discrete connections (**Figure 1**). The second is a differential serial interface appropriately named LVDS (low-voltage differential signaling), which is available in a few variations, including dual LVDS and TMDS (transition-minimized differential signaling) (**Figure 2**).

Data and clocking signals sent via LVDS are time-domain multiplexed onto several differential serial pairs and then decoded by the TFT. With the LVDS scheme, it's important to note that the LVDS pairs do not correspond with specific data channels or types. There is typically not a red, green, and blue pair. Rather, the scheme spreads multiplexing of the data bits across multiple pairs to achieve efficiency (**figures 3** and **4**).

When looking at interface types, you will also see specifications for the number of bits for the inter-

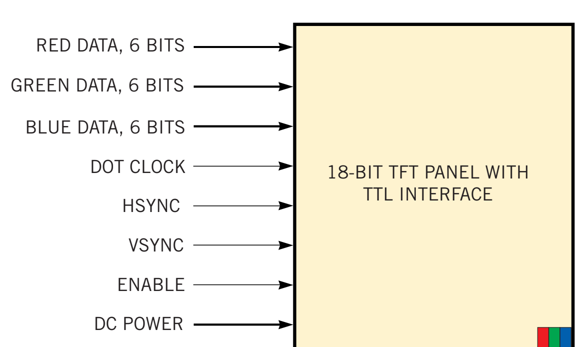

Figure 1

The parallel interface is one of two industry-standard TFT connections.

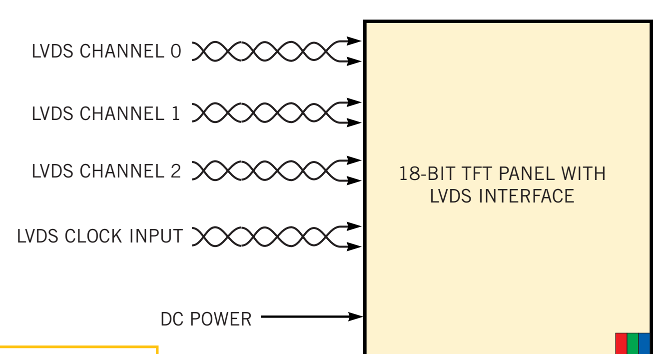

Figure 2

A serial interface, available in several variations, is another standard TFT connection.

face; common examples are 12, 18, 24, 36, and 48 bits. These numbers encompass the entire interface and can be misleading. For example, a TFT uses 4 to 8 data bits per color per pixel. A 24-bit TFT has 8 bits for red, 8 for blue, and 8 for green for each pixel on the display. At 256 variations per color, a 24-bit TFT will offer 16.7 million colors (256×256×256=16.78 million).

To relax the clocking requirements for data sent to a display, higher resolution displays may also use dual interfaces to support odd and even pixels. An example is a 48-bit TFT that actually has two 24-bit interfaces for odd and even pixels (**Figure 5**). Each interface is then broken down further into 8 bits per color per pixel, which provides the TFT with a color depth of 16.7 million colors. Note that more bits don't necessarily make the display better, just different. As always, it's a good idea to discuss your needs both internally and with your perspective TFT vendors. **Table 1** lists several popular combinations and their resultant color depth.

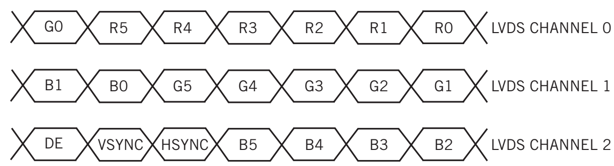

Figure 3 In the LVDS serial interface, color and sync data bits are time-multiplexed for connection efficiency.

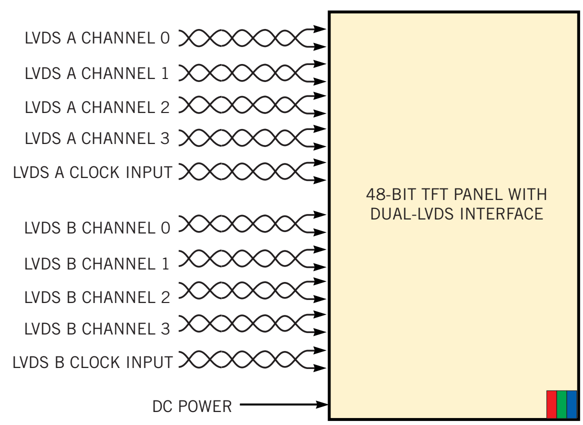

Figure 4 For TFT displays with higher bit counts, the interface connection is divided into subgroups.

Depending on the integration of a TFT, you will also find other interfaces, such as DVI (Digital Visual Interface), analog RGB, and NTSC/PAL video. TFTs with these types of inputs have additional drive and control electronics built into the display module and are designed for specific applications or ease of integration into a design.

THE CONTROLLER-CARD CIRCUS

In some circumstances, it may be undesirable for you to work with a TFT's TTL or LVDS interface; reasons may include available time, budget, need for ease of design, engineering resources, or data that is in another format. In these situations, third-party companies can offer a variety of TFT-controller boards and cards. These cards incorporate electronics to format and convert data from inputs such as DVI, analog RGB, NTSC/PAL video, and others to the TTL or LVDS signals that a TFT requires. In addition, they provide functions such as brightness, contrast, color balance, image shaping, backlight control, dimming, and power management and sequencing for the TFT.

Using third-party controller cards can save you time, but it can also add cost. It's helpful to think about the trade-offs. For instance, consider the reasons that a design might call for an RGB output from a computer-video card, single-board computer, or other video electronics to drive a TFT. Perhaps you need a standard RGB output to drive a CRT or a projection system, or you need an RGB output over a TTL or LVDS interface for ease of implementation or to drive longer cable. Whatever the situation, whenever you fail to use a TTL or LVDS interface, you incur additional costs, because you must use a separate controller, conversion board, or system. Integrated displays, however, are an exception to this rule.

Integrated displays are TFTs designed for specific applications (**Figure 6**). An integrated display incorporates additional electronics in the TFT module to reduce the amount of external components required to operate a TFT. These electronics may include CCFL (cold-cathode-fluorescent-lamp)inverters, dc/dc converters, and a TFT controller to support different input signals. DVI, NTSC, PAL, analog RGB, and digital RGB are just a few of the other inputs you may find. Some integrated panels even support more than one input type, such as analog RGB and NTSC/PAL.

Finally, consider how the display, power, and control go together. **Figures 6**, **7**, **8**, and **9** give some typical applications using TFTs and the associated extras that you need to take into account.

Figure 6 shows an integrated TFT with an NTSC video input. A typical use might be a video-entertainment system in a vehicle in which you could route a DVD, VCR, or satellite receiver to the monitor. In such an application, space, cost, and tolerance of wide temperature ranges are important design criteria. A designer for this application may prefer choosing a complete package over worrying about how and where to implement the drive and inverter boards.

Figure 7 shows a similar system to the one in **Figure 6**, but without the integrated TFT. In this case, an off-the-shelf controller board converts a composite video and an analog-RGB video input

TABLE 1—POPULAR INTERFACES AND COLOR DEPTHS

Total number of TFT bits	Dual interface for odd and even pixels	Bits/color	Pixel color depth
9	N	3	512
12	N	4	4000
18	N	6	262,000
24	N	8	16.7 million
36	Y	6	262,000
48	Y	8	16.7 million

into TTL or LVDS signals, which a nonintegrated TFT then uses. A "button board" is attached to the controller card to supply dry contact buttons that adjust the controller's on-screen-display parameters, such as brightness, alignment, contrast, and color balance.

Figure 8 depicts a single-board computer. Many single-board computers support both direct connection to TFTs and the standard RGB computer-video output. This example uses the single-board computer's TFT interface, whether TTL or LVDS, to connect a TFT panel. Some single-board computers have additional inputs; this example contains an optional DVI connection. The CCFL inverter, although a separate module, is also connected to the single-board computer, which provides the inverter with power and analog- or PWM-based signals for dimming the CCFL tubes. The single-board computer powers the entire system from a dual power supply that also powers any IDE drives connected to the single-board computer.

The final example illustrates a completely embedded system (**Figure 9**). In this situation, the TFT controller may be a separate chip or may be incorporated into an SOC, FPGA, or system microcontroller. It may use main memory or separate frame-buffer memory for graphics and text. The controller may either drive the TFT directly or require additional drive-buffer logic. As with the single-board-computer example, the CCFL inverter connects to the embedded system, which allows for power sequencing and CCFL dimming via analog or PWM dimming control, provided that it uses a CCFL inverter that supports dimming.

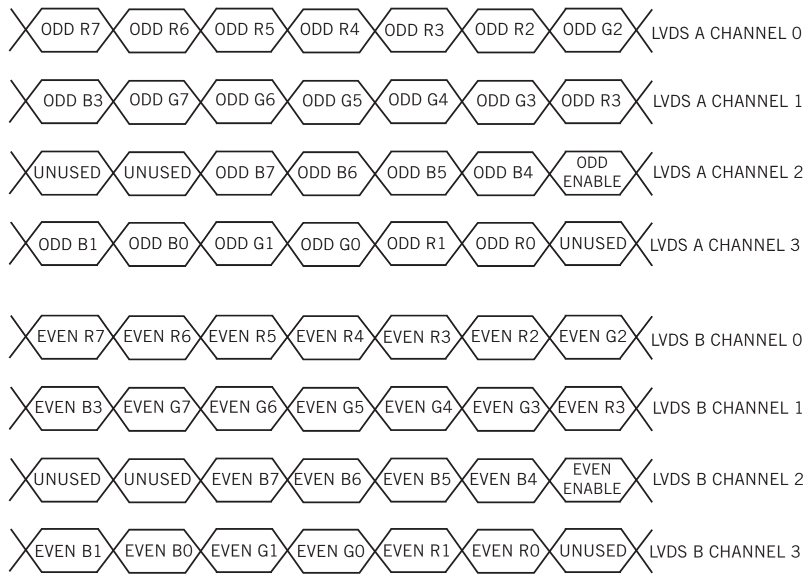

Figure 5 A dual-LVDS interface partitions the bit placement differently than a single interface.

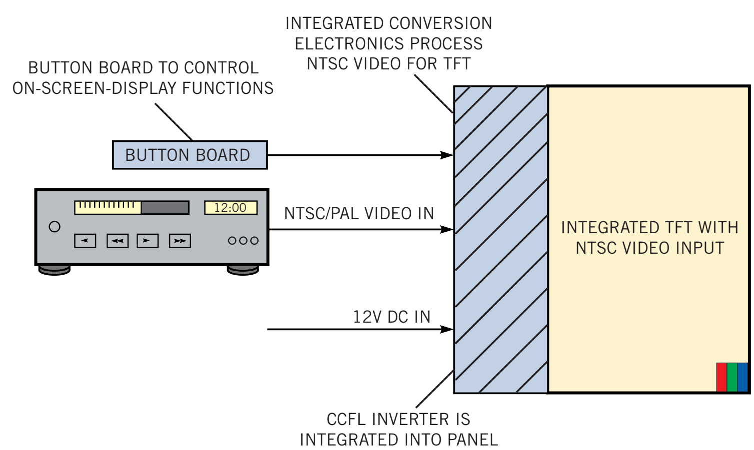

Figure 6 You can choose a TFT with fully integrated composite NTSC or equivalent video input for greatest ease of interface.

CONSIDER THE MINUTIAE

Although this article has covered the major points in choosing and using TFTs, there are a handful of smaller details worth mentioning that may be important to your application and TFT-selection process. To start with, contrast ratio is the ratio between the blackest black and the whitest white a TFT can display. The higher the ratio, the less light and dark colors blend, which results in a sharper, more vibrant image. However, higher contrast ratios can add cost.

A second detail is bad pixels. A perfectly good TFT may have bad or missing pixels. Although the concept may sound odd, it's up to each TFT manufacturer to define its own quality-control process. With thousands of pixels in a display, individual manufacturers determine what they consider an acceptable amount of failed pixels, beginning at zero failed pixels. This number is often smaller than the overall number of pixels in the display and the display's physical size. For example, a 10.4-in. SVGA (800×600-pixel) display has 480,000 pixels and a maximum allowance of perhaps 9 bad pixels, which works out to less than 0.002%. Further, manufacturers may specify that none of these pixels be within the vicinity of one another to prevent visible "holes." For demanding design requirements, TFT vendors may "bin sort" (grade or sort displays for minimum defects) for a premium, so don't count a certain vendor out until you've asked.

Viewing angle is a possible issue, especially in oddly shaped or small TFTs. Viewing angle tells the designer the point from which the display was designed to be viewed (**Figure 10**). The common viewpoints are 12, 3, 6, and 9 o'clock. Imagine a centerline perpendicular to the display face, such as the center of a clock. The viewing angle specifies that optimum viewing is slightly above, below, left, or right of this center point. It does not mean that you cannot see the display from any other viewpoint, only that it is the optimum viewing point for which the TFT was designed. Think of a person sitting in front of a laptop. The person usually sits slightly above the device, looking down on the screen. For this reason, laptops have a viewing angle of 12 o'clock. A PDA might have a 12 or 6 o'clock viewing angle, because you can hold and view it from above or below. On the other hand, a display for a rack-mounted device, a vehicle GPS system, or perhaps a medical device that a doctor must view but does not sit in front of may require a 3 or 9 o'clock viewing angle for best performance.

If you are working with applications for portable systems or power-constrained designs, you may need to consider power. TFTs consume more power than passive LCDs and may require power sequencing. A TFT's power consumption is also dynamic in that it draws more or less power depending on the image displayed. Most TFT data sheets specify either maximum power consumption or power consumption based on various tests, usually with mosaic patterns, to provide an average power rating. This information is not intended to deter designers of portable systems from using TFTs. (Millions of PDAs and other handheld devices contain TFTs.) Rather, it is just another point to consider during the selection process.

Some displays, usually small TFTs, require additional chips, such as timing ICs, gray-scale generators, and dc/dc-converter circuits. In space-constrained applications, such as PDAs and other handheld devices, it makes sense to save on space by removing additional ICs from the TFT's module and combining them with other circuits or moving them into ASICs or FPGAs. Doing so allows for a smaller, more compact TFT panel. Keep this fact in mind when evaluating small TFTs. You may need to ask the display vendor whether the TFT includes everything or you'll need additional ICs beyond the usual TFT-interface requirements.

With applications designed for outdoors, avionics, or extreme environments, temperature and pressure are topics of concern. TFTs, as well as CCFL tubes, can fail, partially fail, or

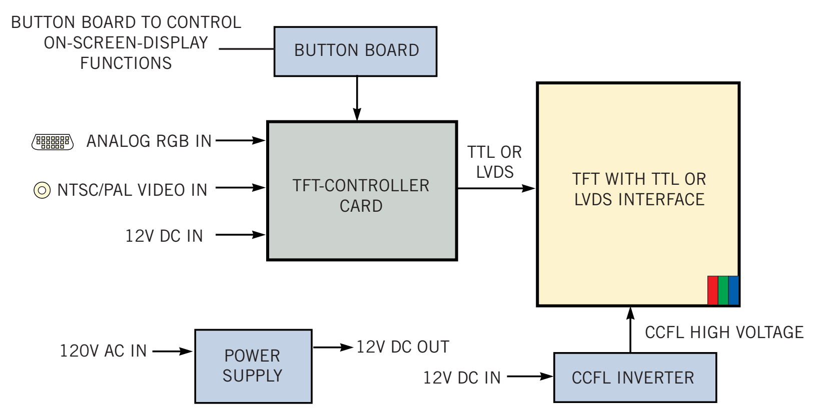

Figure 7 A TFT with an external controller card can accept other signals, such as NTSC or analog RGB.

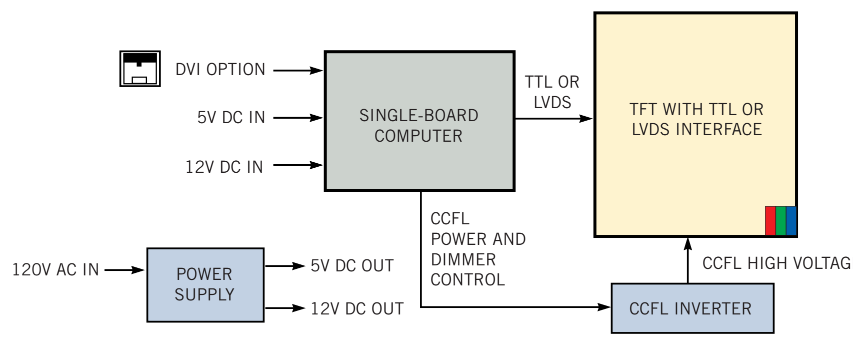

Figure 8 Some single-board computers can directly drive TFT displays, minimizing your interface issues.

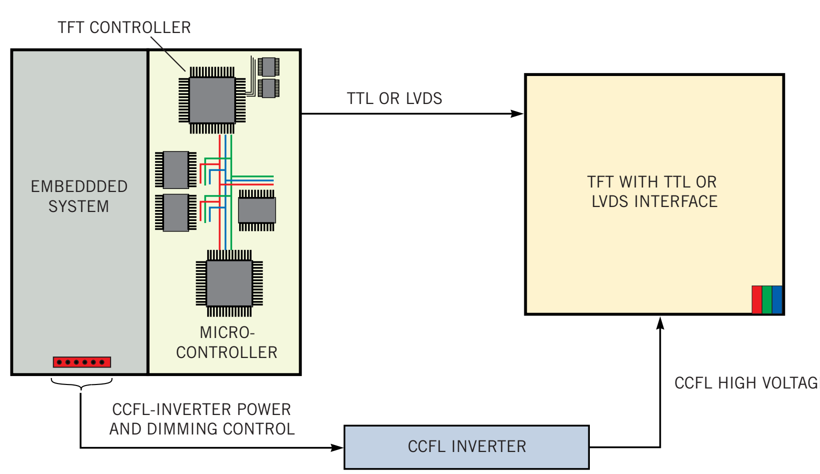

Figure 9 In a completely embedded system, the TFT controller can be a separate IC or part of a system-level controller or processor.

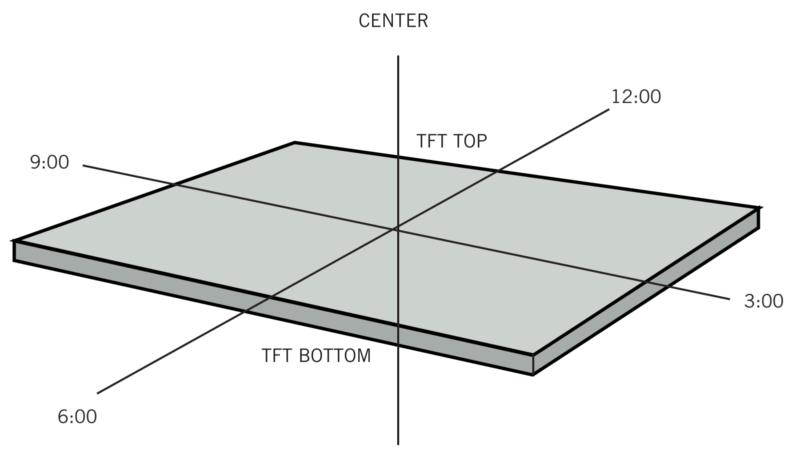

Figure 10 To judge the suitability of a TFT, consider the likely angle at which the viewer will be looking at the display.

perform poorly in heat, in cold, or with above- or below-normal pressure. In applications involving extreme environments, it is important to consult the TFT manufacturer. Although some panels are designed for wide temperature ranges, such as those in automotive or handheld applications, few data sheets reveal information on pressure extremes, such as suitability for unpressurized avionics use. However, if you find the perfect display, and it does not match these needs, you can overcome temperature and pressure problems through the use of heaters, coolers, and pressurized casings.

Many TFT manufacturers place relevant quality-control information, as well as handling and packaging data, into their data sheets. This information can be extremely helpful, because it exposes the vendor's process and acceptance procedures for determining what makes a good display.

Cables are an often-overlooked part of TFTs. Although TFT manufacturers attempt to standardize on connectors, until recently, no formal agreement or specification had emerged. Some TFT cables and connectors have high minimum-order levels, are difficult to build, or require costly equipment for stuffing the small, multipin connectors. A third-party cable house, a display-enhancement company, or even an electronics distributor can help.

A noteworthy source on standardization is the SPWG (Standard Panels Working Group), www.spwg.org), a collaboration of various companies to introduce formal mechanical and electrical standards for TFTs. The SPWG does not specify optical or performance characteristics, leaving them to the individual TFT manufacturers, but rather supports efforts to lower costs and keep portability in design across TFT manufacturers.

Most electronics distributors will work closely with third-party-enhancement companies to provide and coordinate add-ons, cable kits, and enhancements for the TFTs they sell. Many distributors also have entire groups or business units dedicated to working with their customers, TFT manufacturers, and third-party houses to provide the best service possible when selecting and working with TFTs.

Why should you pay for a TFT when you can spend less for a complete LCD monitor and rip out the parts you need? First, LCD-monitor makers either make TFTs themselves or buy them in huge volumes, driving down their cost. As LCD-monitor suppliers continually redesign their products to reduce costs and add features, there is no guarantee that the LCD monitor you are using today will have the same parts in it tomorrow. Also, consider the time and manpower involved in removing and reusing a TFT from a monitor without damage. Last, if you do have an issue or a problem, there is little or no course of action for quality control or RMA (return-material authorization) of defective panels or changes in materials.

Although TFTs are not the ultimates in display technology, they are popular, readily available, cost-effective, and easy to select and design with, although at first they can seem daunting.□

Author's biography

Rob Dautel is a field applications engineer at All American Semiconductor (Salt Lake City), where he provides engineering support for All American's product lines. His spare-time pursuits include music and spending time with his wife and three dogs.