

**FLAT-PANEL DISPLAYS NOT ONLY PROVIDE THE PRIMARY HUMAN INTERFACE FOR MANY EMBEDDED SYSTEMS BUT ALSO DEFINE THEIR LOOK AND FEEL. MAKE SURE YOUR PRODUCT'S DISPLAY CREATES A POSITIVE FIRST IMPRESSION.**

# Design embedded displays for a lasting impression

**T**HE SPECIFICATION AND DESIGN of a complex piece of equipment generally begins with the needs of end users: what users need to accomplish with the product and the circumstances or environment in which they will use it. However, throughout much of the design cycle for many embedded systems, the human-interface display may be little more than a placeholder in the overall product specification. This placeholder may have some basic specifications, such as mechanical constraints that define the display dimensions, and cosmetic or subjective requirements based on assumed market wants or needs. But all too often, an engineer faces the task of finding a color 6.5-in. VGA flat-panel display for reasons no more specific than “because that’s what the competitor’s product uses.” There is a better way.

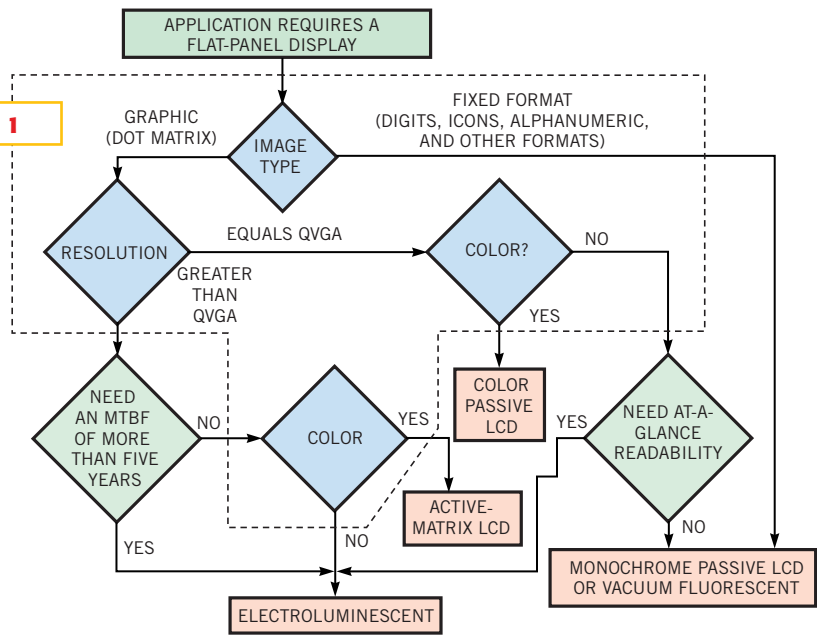
A properly designed embedded-display system is not simply an exercise in integration. It requires careful advance consideration of the entire system, the application, and the user. You might not consider the display the heart of your product, but it is often the first thing your customer sees, and it is usually the primary interface with your product. If the display is inadequate, it may not matter what you have under the hood: Your

customer—and their customers—may need to overcome a negative first impression.

## GETTING STARTED

So what’s a better way to go about the specification and design of your product’s display system? Design teams can begin with a fairly straightforward list of information, based on product *needs* rather than *wants*. **Figure 1** shows a simplified display-technology decision tree. These decisions address issues that impact, for example, total cost of ownership over the life of the product, end users’ satisfaction

**Figure 1**



**A display-technology decision tree will help you base the specification and design of your product’s display on product needs rather than wants.**

with the overall product, and usability and reliability issues related to the environment in which the product will be used.

As you work through these and related decisions, it quickly becomes clear that many of these items are mutually exclusive. For instance, the need for a large-screen, sunlight-viewable display is incompatible with low power requirements. Similarly, an electroluminescent display provides excellent visual and environmental performance, but it lacks color. The challenge, then, becomes not only listing the product's display requirements but also prioritizing them and being prepared to give up one for the other. Note that this chart fails to directly address two key issues: end-user satisfaction and cost. You must subjectively evaluate end-user satisfaction, outside of the constraints of a yes-and-no type of chart. And, although cost may be one of the most important considerations, it is best to evaluate it once you have identified the best display option. At that point, you generate a new set of questions, such as whether the product can afford the most appropriate display technology. And if it can't, where will a compromise have the least negative impact?

Once you've established basic display-system requirements, the display specification develops from consideration of the end-user (human-factors) issues the display must address, the environmental factors under which the display must operate, and the system design into which the display must fit.

### HUMAN FACTORS

If the display is the main interface between users and the embedded system, human-factors issues become prime considerations in engineering decisions. These issues affect how successfully users will interact with the display, and therefore the product, and are particularly vital if the system is mission-critical. For example, the display on a medical device must be quickly and easily readable with a high degree of accuracy, as must the display for an in-vehicle driver-information system that long-distance truck drivers use on the road.

By raising human-factors issues early in the design cycle, the resulting discussions will lead naturally through a number of visual performance considerations, most of which you will weigh against other considerations, such as cost and system requirements. You should base one of the first decisions on the in-

formation structure (what the system needs to display) and information density (how much information must be displayed at once in what size area). The expected ambient-lighting conditions under normal system usage also dramatically impact display engineering.

If the application requires only an indicator or warning, an indicator light or simple segmented character display may meet your needs. To display simple information, a fixed-format, 20-character, four-line passive "readout" may be all that's necessary. To display a QVGA (quarter-VGA), or about 320×240 pixels in a single screen, a PLCD (passive LCD) is a cost-effective, high-reliability choice. But if the application requires high-resolution color, then you need to consider an AMLCD (active-matrix-LCD) technology. You can generally characterize LCD technologies as reflective, transflective, and transmissive, depending on how the display handles or manipulates light (tables 1 and 2).

If you plan to display full-motion video, scrolling waveforms, or other information requiring high update rates, then you need to concern yourself with the response time of the display technology. An AMLCD with a 40-msec response time may look fine when display-

## DISPLAY-DESIGN CHECKLIST

Adding a human interface to a new product goes beyond the challenges of normal circuit design. Here is a list of system, human, and environmental factors that you should consider when incorporating a flat-panel display into your next embedded product.

### System-design factors

- primary application (user interaction or feedback, entertainment, information only)
- distance from video output source to display (cable length from video source to display panel)
- video-signal format (analog, digital, RGB, NTSC, PAL, composite, component, S-Video, raw logic, LVDS, TMDS, DVI)

- video source (computer-generated, media store and play, real-time camera, or a combination)
- regulatory approvals (UL, FCC, FDA)
- power-supply conditioning (battery, line, ac, dc, filtered, regulated)
- computer-system components (single-board computers, PCMCIA slots, bus cards)
- computer operating-system and drivers (DOS, Windows, Unix, QNX, Linux)
- peripherals (printer, card reader, cash acceptor/dispenser, camera, microphone, speakers)
- color or monochrome display
- networked or wireless (protocol, bandwidth)

- stationary or mobile product
- ridged or flexible display position on product

### Human factors

- human-machine interface (touchscreen, tactile buttons, mouse, keyboard, audio, voice)
- viewing distance from the display to the user
- ambient-lighting extremes (light, dark, office lighting, sunlight, direct, indirect)
- information density (how much in what size area)
- compliance with Americans with Disabilities Act
- space constraints or limits (real-estate limits relative to customer)
- vandal screen or other display protection (optical interference)

- information structure (text, graphics, animation, motion video)
  - number of displays in the system (displays per output source)
  - data security (EMI signature, encryption)
- ### Environmental factors
- shock and vibration (during shipping, at location)
  - environment exposure (indoor, outdoor, moisture)
  - operational temperature extremes at the display (sun loading, ambient temperature)
  - enclosure (ingress of fluids, caustic materials)
  - cleaning requirements (biological contaminants, harsh liquid germicides)

ing full-motion video, but scrolling waveforms may appear fuzzy. Many applications requiring the display of fast, monochromatic data use EL displays, which offer response times of less than 1 msec and are unaffected by temperature. A typical response time of about 30 msec allows AMLCDs—the type of display in most laptop computers—to display full-motion video as well as fast waveform images. PLCDs usually have response times greater than 80 msec, so they are typically inappropriate for displaying motion. Low temperatures also slow response times for AMLCDs and PLCDs, unless you use a heater.

A key human-interface issue relates to how the user will interact with the system. Many embedded systems use touchscreens, which generally interface to a computer system through a standard serial controller, such as an RS-232 or USB. However, you'll need to address a variety of display-system-related issues: Is the display bright enough to be visible behind a touchscreen? Does it need to be responsive to a gloved hand? Can you use a stylus, and if so, which kind? Does it need to be vandal-proof? Does it need to be resistant to false touches from wet or dry surface contaminants? How often will you need to recalibrate it? What is the accuracy or resolution the application requires, and how much drift will it tolerate? How much power is allocated for this device?

Embedded systems are often destined for harsh environments in which temperature extremes, shock and vibration, and moisture, dust, or other contaminants are the norm rather than the exception. Even in indoor environments, such as hospital, retail, or clean industrial applications, users expect the displays on these systems to function for longer periods and under much harsher conditions than any standard desktop or laptop monitor.

Every display technology has its own inherent strengths and weakness. Sometimes you can overcome these weaknesses through engineering modifications. But often you can do so only by sacrificing one or more inherent strengths. For example, designers often consider transmissive AMLCDs for embedded applications because of their inherent low power, rugged compact packaging, and relatively low cost. However, these displays perform poorly in the high-ambient-lighting or extreme-temperature environments that exist in many embedded applications, such as outdoor kiosks or ATMs. The use of bright backlights often improves viewability in high ambient lighting. But this approach increases power consumption, the size of the packaging, and the cost. It may also compromise the ruggedness and thermal dynamics of the display. To extend the temperature range, you might employ heaters and other thermal-management

techniques, but doing so again increases power consumption and costs. A thorough understanding of the trade-offs and display-engineering principles involved is necessary to achieve an economical balance among these characteristic improvements.

“Sun loading” is an example of an environmental issue that you must explore early in the design process to avoid an unexpected display failure in the field. Sun loading occurs when prolonged exposure to the sun raises the temperature of the display. It is a concern mostly with LCD-based displays; the increased temperature may render the display unreadable unless the display is designed to operate at these extended temperatures.

Another potential stumbling block that can occur late in the design process relates to product certification. As components, flat-panel displays are designed to meet emissions requirements, but they cannot be certified alone. Rather, you must certify the complete system. The system designer is, therefore, left with the sometimes-daunting final task of getting an assembled system of many components from several manufacturers to meet emissions requirements. During testing, the display often appears to be a source of offending radiated emissions. But, in many cases, the display is not the real source but is acting as an antenna for internal radiation that

**TABLE 1—LCD GRAPHIC-DISPLAY MODES**

LCD mode	How it works	Pros	Cons
Reflective	Light from environment shines onto display, though LCD, and reflects off a mirror to create image	Works in bright sunlight (the brighter the ambient light, the brighter and higher contrast the display)	Requires ambient light, so inappropriate for nighttime use unless you use a front light
Transmissive	Uses a backlight to shine through LCD and create image	Good contrast in dim or no ambient lighting	Requires bright, high-power backlight for sunlight readability
Transreflective	Combines reflective and transmissive elements	Provides reasonable readability in a range of lighting conditions	Less contrast than reflective in bright light; less contrast than transmissive in low light

**TABLE 2—EMISSIVE GRAPHIC-DISPLAY TECHNOLOGIES**

Technology	How it works	Pros	Cons
Electroluminescent	Thin-film electroluminescent material excited by a high electric field	Rugged, high contrast	Monochrome, limited colors
VFD (vacuum fluorescent display)	Phosphor excited by electron emission	Custom character displays available	Low pixel count, monochrome, limited colors, low contrast
PDP (plasma display panel)	Phosphor excited by a plasma discharge	Full color, large formats	Limited pixel size, low contrast
OLED (organic LED)	Polymer film excited by an electric current	Low power, full color	In early development, burn-in images from aging pixels

the display conducts to the outside world. You must take steps to ensure that the display is shielded internally and that all cables attached to the display incorporate EMI suppression.

#### SYSTEM DESIGN

Once you've considered the external factors, such as human-interface and environmental issues, you need to consider the system design into which the embedded display will fit. There are as many issues to consider here as there are embedded applications, so one article could not touch on them all (see sidebar "Display-design checklist"). However, a few key considerations can cause considerable heartache if you don't address them early in the project.

For example, low-voltage processors and single-board computers are very popular in embedded systems and help to reduce power and EMI levels. These single-board computers employ low-voltage CMOS components and require low power-supply voltages. Therefore, they result in display-interface signals with low-voltage CMOS levels. Not all displays are compatible with these low signal levels, so they may require the addition of voltage-level translation circuitry. The translation circuits and the display's logic supply require higher power-supply voltages from the system's power source than those that the single-board computer requires. Also, the display often requires additional power-supply inputs of 12V or more. By defining and addressing these issues early in the design cycle, you can avoid these potential pitfalls and their consequences: delayed project completion, additional costs, or end-user dissatisfaction.

Other types of embedded systems put the display several feet away from the single-board computer or display controller. If it is a matrix display greater than QVGA, consider using an LVDS or TMDS interface between the two to minimize EMI and signal crosstalk in the cabling.

Other system-level issues include how the user will interact with the display. A touchscreen or other peripheral may require a driver for your operating system. If the peripheral vendor doesn't support

your OS, you may need to develop a driver—a software project that could add several months to your project.

Another issue high in consideration for almost all embedded systems is product life cycle. It makes configuration control—continued availability of the same components and subsystems throughout the life of the product—a key design issue. Demand within certain market segments, such as laptop PCs, drives the availability of some displays, particularly AMLCDs. If you design one of these displays into your product, you may find yourself in two years unable to obtain that component or paying significantly more for it because it is no longer within the sweet spot of the manufacturer's volume-related output.

With careful advance consideration of the entire system, the application, and the user, a properly designed embedded-display system can have a dramatic impact on the success—or failure—of your embedded system. □

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