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DISPLAYS INVADE EMBEDDED-SYSTEM SPACE

Figure 1 Electronic-paper displays from E Ink contain millions of bistable microcapsules that change color with an activating charge.

FULL-COLOR GRAPHICS DISPLAYS IN HIGH-VOLUME CONSUMER PRODUCTS, SUCH AS MOBILE PHONES AND MUSIC PLAYERS, HAVE CAPTURED THE ATTENTION OF THE PUBLIC AND SET NEW STANDARDS FOR EMBEDDED-DEVICE DESIGN.

As prices plummet, embedded-system designers are turning to graphical displays to simplify operation, ease system upgrades, and distinguish their products. Designers of traditional embedded products focused on maximizing performance with less emphasis on the user interface. However, the dazzling full-color graphics in today's PCs, mobile phones, and other portable consumer devices have raised consumer expectations for all electronic products. These rising user-interface expectations, along with ubiquitous networking, have redefined traditional embedded-design rules. Newer embedded products are not necessarily limited in computing and memory resources and may easily require more processing power for communications and a graphical display than for the application.

A graphical-display system allows a designer to create a simple operator interface that sequentially deals with a single command or function at a time. The designer can "hide" most of the complexity and auxiliary features until they are necessary to simplify operation. A graphical-display interface is your product's first impression and provides an obvious way to differentiate your product from your competitors' products. Designers can use graphics to create a unique look and feel for their products and deliver a similar theme across an entire product line. When you couple a graphics display with a touchpanel overlay, the user can simulate almost any front-panel configuration and still be able to add or change features with a firmware modification.

A display system may be able to ease product-development-schedule problems and offer additional or recurring revenues. Prod-

AT A GLANCE

- The recent popularity of consumer devices with full graphics displays puts pressure on embedded-system designers to match the user experience.
- Although internally complex, a graphical display simplifies the user interface by hiding auxiliary functions and features until the user needs them.
- A well-designed embedded device with a graphical user interface may survive product changes and updates without hardware modifications.
- Several vendors offer complete drop-in graphics subsystems that act as stand-alone serial peripherals to embedded processors.
- Embedded-system developers can replace user-interface hardware with a communications link to common external consumer devices.

uct design is always a compromise between first to market and the best set of features. A flexible graphics interface, along with a built-in network connection, offers the option of shipping the product with an initial set of features and then upgrading firmware over the network to meet competitive pressures or to fix problems. Another marketing strategy is to offer a limited-function device at a low price and then offer to sell the user optional, remotely activated features or services. Either approach requires a well-designed, general-purpose hardware platform with an adaptable graphics unit and sufficient system resources to accommodate future software applications.

DISPLAY PROCESSOR

Designing a display-based interface into an embedded product is a major undertaking with significant impact on cost and scheduling. An application that once required an 8-bit processor may need a second CPU or an upgrade to 16 or 32 bits when you take graphics into consideration. A graphics subsystem also consumes substantial memory and power resources. Combining graphics processing with a legacy embedded-system task may also require the addition of a real-time operating system to maintain timing performance for the application. In addition, the display unit requires a new power source and mechanical packaging.

Designers have several alternatives to integrating a graphics display into an embedded device. The most radical approach is to redesign the device with a new processor section that can support both the embedded task and the graphics display. The software team can then develop a custom graphics library for the embedded-system application. Although this method probably requires extensive NRE (nonrecurring-engineering) costs, it should produce the most efficient system with the least expensive production hardware. A less intrusive approach is to treat the graphics section as an external peripheral with a communications channel to the embedded processor. This technique allows developers to choose off-the-shelf graphics and software elements to minimize development costs.

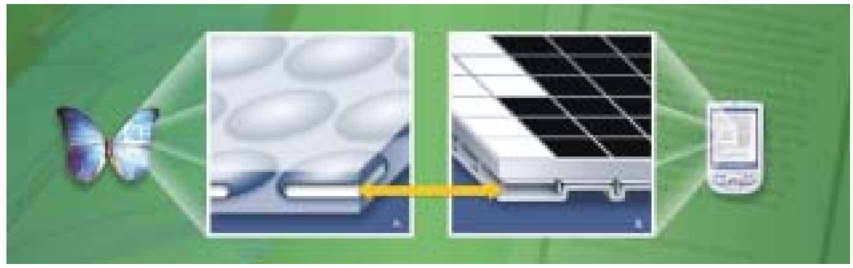

Figure 2 Qualcomm's IMOD technology combines MEMS structures with thin-film optics to duplicate the light interference iridescence in nature.

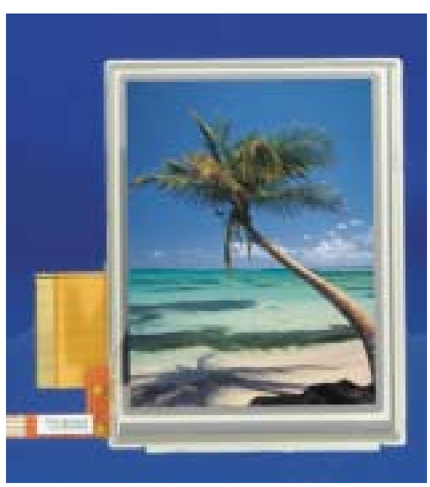

Figure 3 Sharp Microelectronics' 3.5-in., quarter-VGA TFT LCD targets low-power, portable designs requiring high-brightness displays.

Active-matrix-LCD screens are the most popular graphics-output devices for embedded systems because of their low power requirements, low weight, superior image quality, and fast response. LCDs sandwich cells of a light-polarizing liquid between two perpendicularly polarized glass panels that a matrix of TFTs (thin-film transistors) drives. An electric current changes the polarization characteristics of the liquid and blocks light transmission through that cell. Expanding on this basic principle, manufacturers offer a wide array of high-resolution, monochrome and color LCD panels to fit most embedded-system applications. Many designers combine an LCD panel with a resistive touchscreen or several variable-function input switches to form the complete user interface.

OLED (organic-LED)-display technology, which Eastman Kodak developed more than 20 years ago, are gaining popularity in embedded-system applications because the technology offers potentially brighter, higher contrast images with less power and lower manufacturing costs than LCDs. OLEDs sandwich several organic films between a metallic cathode and a transparent anode. The carbon-based films comprise a hole-injection layer, a hole-transport layer, an emissive layer, and an electron-transport layer. The choice of organic materials and the layer structure determine the color, operating lifetime, and power efficiency. When you apply voltage to the OLED, the injected positive and negative charges recombine in the emissive layer and create electroluminescent light. Unlike LCD panels, OLEDs emit light and require no backlighting. OLEDs suffer from reduced yields and limited life span. Further, water can easily damage the matrix.

PAPER DISPLAY

Although the technology has roots in the 1970s, recent advances in manufacturing techniques have renewed interest in electronic-paper displays. These displays possess a paperlike, high-contrast appearance; ultralow power consumption; and a thin, light, sometimes-flexible form (Figure 1). It gives the viewer the experience of reading from paper but adds the power of updatable information. Millions of microcapsules, containing a dark fluid and hundreds of tiny, white chips, cover electronic-paper displays. With an activation grid controlling the charge at each microcapsule, you can specify the color at each pixel by forcing the white chips to rise to the surface or sink to the bottom. An advantage of this electronic-ink approach is that the bistable, nonvolatile microcapsules retain their position when you turn off the power. To demonstrate the concept, E Ink offers a Linux-based electronic-paper-development kit that provides an 800×600-pixel display, electronics, and software to construct a battery-powered, portable book reader.

Qualcomm hopes to define the next generation of display technology by combining MEMS (microelectromechanical-system) structures with thin-film optics. The company used as its model the natural microscopic structures on butterfly wings and peacock feathers to produce the IMOD (interferometric-modulator display), which uses interference to modulate the light and create low-power, reflective displays (Figure 2). IMOD elements typically measure 10 to 100 microns per side and include a tiny film structure that moves just enough to reflect a precise wavelength of light. The reflective film moves a certain distance, and that distance determines the color of the IMOD elements, each of which represents 400 to 1000 dpi. Designers can group several of these elements to form a single pixel. To create a flat-panel display, Qualcomm fabricates and packages a large array of IMOD elements in the desired format. Finally, the company attaches driver chips at the elements' edge to complete the display. Because the reflective IMOD requires no backlight, the unit has low power consumption.

Figure 4 A new, 4-in., color, touch-display module from Reach Technology allows designers to integrate graphics as an intelligent serial device.

Regardless of the technology you select, graphics-software libraries and drivers are essential to any display system. You can obtain control routines from the display manufacturer, third-party vendors, or in-house. Alternatively, the operating system may integrate these routines. Simple drawing libraries include subroutines to render lines, circles, boxes, and a limited selection of text type styles. The next step up is an object-oriented graphics library that includes pushbuttons, sliders, gauges, graphs, and drop-down menus. If you change one or more objects on the screen, library routines automatically redraw the affected objects. The third level of software is the graphics manager, such as Microsoft Windows or X Windows, in which applications can independently control their portions of the display screen. The complexity and software footprint grow depending on the library model you select.

For designers wanting to start with a bare-bones display and develop their own interfaces and custom software, Sharp Microelectronics recently introduced a 3.5-in. transflective TFT-LCD display with 100 cd/m^2 of brightness (Figure 3). The quarter-VGA LQ035Q7DH01 module targets portable devices requiring low power consumption and operation in a wide range of lighting conditions. Such applications include GPS (global-posi-

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tioning-system) units, PDAs (personal digital assistants), bar-code scanners, and test equipment. The display features 262,144 colors, power consumption of less than 365 mW, a contrast ratio in transmissive mode of 100-to-1, and an operating temperature of −10 to +70°C. Including the LED-backlight system, the display module measures only 4 mm thick and weighs approximately 45g. The LQ-035Q7DH01 sells for $145 (50).

DROP-IN DISPLAYS

Several vendors offer evaluation platforms that combine the LCD screen, display controller, graphics library, and touchscreen to minimize the development effort. This off-the-shelf approach eliminates the user-interface-hardware development and software integration and allows the designer to add graphics to a device with a simple serial interface. For example, Reach Technology recently announced a 4-in., color, TFT touch-display module for medical, industrial, and gaming applications (**Figure 4**). The company based the 42-0086 display-module kit on the Reach SLCD controller card and a 320×240-pixel LG Philips LCD panel. The unit requires no special operating system or library on the host processor and allows users to access the LCD as an intelligent serial device. The system writes text and graphics images to the display by issuing one of more than 50 high-level commands. Standard features include a variety of built-in fonts, buttons, charts, and meters, along with high-level macro capability. A built-in touch interface allows you to define graphics buttons on-screen; when you push these buttons, they return a serial string. The SLCD microprocessor code includes a graphics library, text fonts, predefined bit maps, and a command interpreter. The 42-0086 module is available as an evaluation kit with a power supply and serial cable for $345 (one).

A display system would be cost-prohibitive for deeply embedded devices; however, you can still create a graphical user interface for such devices. For example, a short-range wireless connection to a general-purpose device, such as a PDA, laptop computer, or mobile phone, can give users a full-graphics display of device operation. Bluetooth, 802.11, infrared, and even a hard-wired connection enable graphical interaction with a much lower development effort and minimal hardware cost. Embedded devices lacking network connections may need no hardware user interface at all. An Internet connection can turn any connected PC with a standard browser into a remote front panel. Plenty of free or low-cost Web-development tools are available to help create a user-friendly interface. With an Internet connection, you can also use the same communications link for remote software updates and product data collection.

As graphics become commonplace in computer and consumer electronics, embedded-system designers must offer similar multimedia features to live up to user expectations and stay competitive. A graphical user interface can often transform a complex embedded device into a simpler, streamlined product with easy-to-update features. With a broad range of off-the-shelf hardware and software products available, designers now have the tools to incorporate a sophisticated graphics interface into ever smaller embedded devices. EDN

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