CONSUMER-ELECTRONICS DEVELOPERS FACE A HOST OF CHALLENGES WHEN DESIGNING FOR SMALL, PORTABLE-SYSTEM APPLICATIONS.

DISPLAY OF POWER:

PORTABLE DEVICES GET BIGGER SCREENS WITHOUT BIGGER BATTERIES

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The ready availability of high-resolution color LCDs in high-end cell phones and handheld media players has changed the landscape of consumer electronics by raising user expectations for display quality in portable devices. Meanwhile, the increased use of data and multimedia services requires that displays be active more often—that is, the backlight must be on so that users can see the display—driving the relative power consumption of displays from perhaps a mere 10% of overall power consumption to, in many cases, more than 50% of the available power budget. Additionally, developers need to increase the luminescence of displays to accommodate the wide dynamic range of multimedia content. The technology sufficient for displaying text simply does not produce appealing images.

As a result, LCDs have become second in power consumption only to radio transmitters in cell phones and hard-disk drives in portable media players. In addition, higher quality displays increase BOM (bill-of-materials) costs and require more intense backlighting. Additionally, the number of pixels that a system must process and feed to the display increases interface width and frequency.

Although recent advances in battery technology have increased the overall power available to portable devices, developers cannot depend only on new innovations from this front to accommodate rising power budgets. To remain competitive, engineers must seek increased power efficiencies by taking advantage of the latest LCD technologies and carefully balancing the trade-offs between display cost, power, and size.

BIGGER NOT ALWAYS BETTER

Although consumers demand higher resolution displays, these displays are not always what they need or truly want. Higher resolution displays have lower available brightness than low-resolution displays but are more complex to design and, thus, cost significantly more. Additionally, the higher the resolution, the more power the display consumes and the wider the data interface required to the LCD. Old passive matrices, which must hold each pixel at the appropriate color, begin to consume too much power as resolution increases. Active matrices use a switching matrix to hold the value of pixels. Unfortunately, this matrix comes at the expense of reducing the pixel-to-aperture ratio and requiring a more intense backlight. Deciding which LCD process to use is difficult, especially if you consider OLED (organic-light-emitting-diode) displays and the myriad other display technologies researchers are developing, including LTPS (low-temperature-polysilicon) and PLED (polymer-LED) displays.

High resolution also drives the need for wider interfaces, which introduce physical challenges in implementing hinged designs, such as cell phones and laptops, in which computational resources reside separately from the display. High-resolution displays also require special connectors that can pass the 60 to 80 wires in a cell phone, for example, through the hinge and offer sufficient mechanical reliability.

Depending on the resolution of the display and the frame rate, a significant amount of data can be passing through a hinge at a high enough frequency to result in screen flicker. Additionally, if the interface uses TTL signaling, a significant loss of dynamic current will occur, along with enough EMI to require an EMI filter. For applications in which EMI is a problem, LVDS (low-voltage-differential signaling) can provide a means for reducing the number of wires and eliminating EMI. For example, you can aggregate an LCD interface requiring 16 to 18 wires into a single four-wire LVDS channel. For small displays, LVDS may represent overkill because some small displays' connectors have a fine enough pitch to provide a reliable connection.

AT A GLANCE

- Today's displays may consume more than 50% of the available power budget for portable-system applications; the display's backlight is responsible for most of that power consumption.
- Higher resolution displays have a lower pixel-to-aperture ratio and therefore require a more intense backlight, increasing cost and overall power consumption.
- Emerging display technologies offer innovative ways to increase display brightness and contrast without consuming more power.
- Display selection is truly a system-level decision, balancing trade-offs across all layers of development.

Part of the challenge in selecting a display technology is in determining the typical operating conditions in which the display will find use. Designing for typical use, however, may not be feasible because even a device that will find use primarily indoors and under fluorescent lights will need to provide reasonable quality when you use it outside in bright sunlight or at night. Although you should target the design for the most common case, extremes may dictate final display-technology choices and trade-off balances.

UP-FRONT ON BACKLIGHTING

The backlight consumes the most power within the display subsystem. Backlighting plays a critical role in balancing the brightness and the contrast of the display. A primary challenge that arises with a high-resolution color display is that, the higher the resolution is, the more inefficient the display becomes. The aperture ratio of a display—that is, the proximity of the pixels to each other—determines how much emitted light a user can see from an LCD. The LCD has already experienced losses in visibility due to the gaussian distribution of light over a cone; the wider the viewing angle, the larger the cone, and the less light that hits the eye from any angle (**Figure 1**). As resolution increases, the aperture ratio, along with efficiency, decreases. Additionally, color filters and polarizers that are part of the display also absorb light. To reduce the power drain of the backlight, more light needs to get from the back of the display to the front. You achieve this goal by balancing the brightness and the contrast of the display and by deploying filters and films. For example, as the contrast increases, it becomes more difficult for the human eye to differentiate between contrast and brightness. Engineers can exploit this failing because high contrast lets them use a less bright display, reducing overall power consumption.

Two primary supplemental-backlighting technologies now in widespread use are CCFTs (cold-cathode-fluorescent tubes) and LEDs. The state-of-the-art technology, CCFT, commonly finds use in laptop computers on the top and the bottom of the LCD panel. Light guides shape CCFT-emitted light to maximize its focus and, therefore, brightness across the panel. CCFTs offer consistent brightness across the entire panel. The use of LEDs instead of CCFTs is gaining in popularity. A row of LEDs along the edge of a display

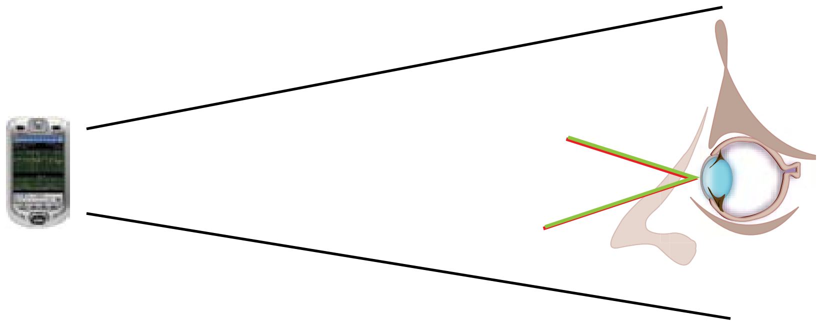

Figure 1 Losses due to the gaussian distribution of light over a cone contribute to the inefficiencies of displays, as do pixel-aperture ratio, color filters, and polarizers.

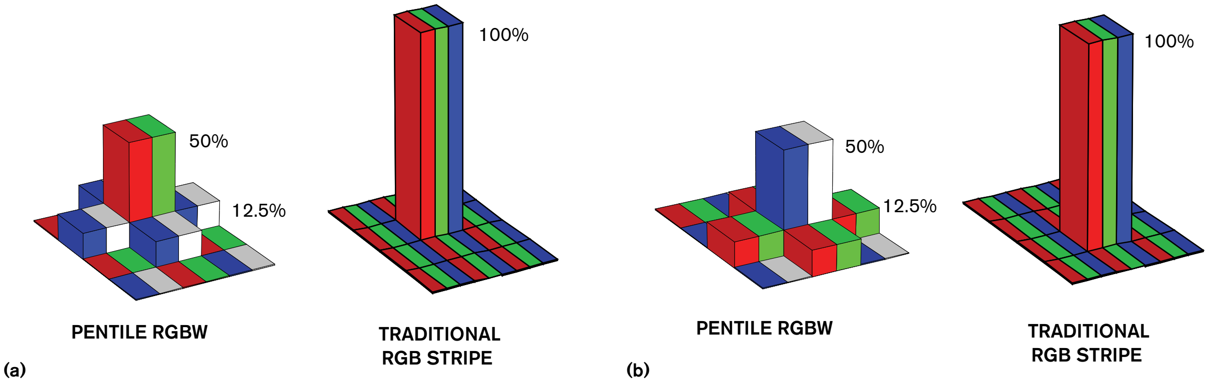

Figure 2 Clairvoyante's PenTile technology uses an RGBW-based approach that pairs pixels rather than use triplets to achieve equivalent resolution to that perceived by the human eye. The use of alternating red/green and blue/white pairs increases the aperture ratio, and the presence of a white subpixel allows more of the available light to pass through. The pixel is located at the second row, second column (a) and at the third row, second column (b). Subpixel rendering uses neighboring subpixels across a 3×3 matrix to eliminate moiré or aliasing artifacts.

provides a backlighting source that is brighter and more power-efficient than a CCFT. Developers can either offer significantly greater brightness for the same power as a CCFT or the same brightness with less power. However, they must take care when using LEDs, especially with smaller displays, such as those in cell phones, because LEDs offer a point source of light, and brightness varies depending on the distance and overlap between LEDs. LEDs are also more expensive than CCFTs.

One important disadvantage of CCFTs is that they generate heat multidirectionally in a sphere away from the tube. This fact can make it difficult for the CCFT to dissipate heat as it warms during use; instead, it must passively dissipate heat because the use of a fan is impractical. As a consequence, a CCFT loses as much as 20% of its brightness after one hour of continuous operation. Contrast this situation with that of LEDs, which generate heat primarily in one direction. Through the use of specialized heat-sinking techniques, you can wick away heat from LEDs so that they will lose perhaps only 10% of their brightness after running for 15 hours. LEDs also are rugged because, as solid-state components, they are less susceptible to physical damage.

Heat is an important limitation in the design of an LCD, especially one for industrial and military applications. LCDs use a liquid that may operate improperly at high or low temperatures. Additionally, backlights typically require an inverter. You can reduce thermal issues by placing the inverter and the LCD on separate pc boards and placing the inverter close to the edge of the box.

Achieving the highest power efficiency requires designing a screen that users can frequently view without the use of the backlight or with a dimmer backlight. For devices that find use in a variety of operating environments, a variable backlight can increase overall power efficiency. For example, you can set a variable backlight to 0, 50, or 100% intensity, depending on the available ambient light. In this way, you need not provide an excess of power to the display to accommodate extreme operating conditions when the display is working only in more common, everyday applications. You can set the intensity of the backlight using a light sensor, but this approach might prove too power intensive, costly, and complex to implement in consumer applications. A more practical approach would be to base intensity selection on user profiles. For example, when a user talks into a cell phone, as long as the phone is not in speakerphone mode, the user is not looking at the screen. In this case, you can not only turn off the backlight, but also reduce the number of screen updates that occur. Additionally, LCD drivers can often work in different modes. If the screen is displaying a static image, such as a map or a photo, the screen requires less frequent frame updates.

FILMS, FILTERS, FORM FACTORS

Other ways to improve brightness are to use optical bonding techniques and different filters. CI Lumen, for example, improves the contrast of commercially produced panels through a number of technologies. Alternatively, you can replace CCFTs with LEDs to increase brightness or replace films or filters inside the LCD with higher quality films that increase transitivity. Typically, LCD manufacturers base filter selection not on which filters are the most efficient but on which are the most cost-effective choices across their customer base. For applications in which power efficiency is more important than cost or size, such as in marine, aviation, and military applications, replacing films and filters becomes a viable option.

In addition to adjusting films and filters, you can add an extra antireflective-coating glass, antiglare coating, or both on the front surface of the display glass. You can optically bond this glass to the LCD to eliminate the air gap between the LEDs and the face of the LCD. This approach improves the transitivity of the LEDs and reduces undesirable reflections from the back of the glass. This stage is important because increasing brightness without improving contrast results in a display that appears bright—but also washed out—in sunlight. In reality, users can't see the display in sunlight because of low contrast, not low brightness.

Using optical bonding cannot be a last-minute decision because it adds to the thickness of the display. Optical bonding typically adds approximately 20% to the cost of a display panel, making it an option for applications in which brightness or power consumption is the primary design consideration, such as for mobile tablet computers, PDAs, or industrial sensors.

Another alternative is to use RGBW (red/green/blue/white)-based technology, such as the technology that Clairvoyante licenses to LCD manufacturers. Clairvoyante breaks pixels into pairs rather than triplets (**Figure 2**) and achieves an equivalent resolution to what the human eye perceives. The use of alternating red/green and blue/white pairs increases the aperture ratio, and the presence of a white subpixel allows more of the available light to pass through. Additionally, innovative subpixel rendering uses neighboring subpixels across a 3×3-pixel matrix, fine-tuned through second- and third-order adjustments, to eliminate any moiré or aliasing artifacts. The overall result is a doubling of LCD transitivity, giving engineers the option of halving backlight intensity to achieve the same white luminescence for the same power.

Developers also have the option of switching to new display form factors, such as microdisplays from companies such as Kopin. These displays have made significant inroads as camcorder viewfinders and in military applications, such as night-vision goggles and weapon sights. Microdisplays have begun to find traction in mobile video applications in which they can offer a perceivably large, 0.97-in.-diagonal display with resolution of 1280×1024 pixels. That is, although the screen is small, it is so close to the eye that it fills the field of vision, providing the equivalent experience of a 48-in. monitor viewed at a distance of 7 feet. It is important to note that long-term viewing of a single microdisplay is taxing to the eye, necessitating the use of two displays. Prices for ¼-VGA-resolution microdisplays start at $10 (low volumes).

SURFACE CONSIDERATIONS

Evaluating trade-offs for selecting a display can be difficult. Consider the details behind implementing an LED-based backlight. After deciding to use LEDs rather than CCFTs, developers have the option of configuring LEDs in parallel or in series, because one driver can drive several LEDs. If you drive them in parallel, you'll need four times more current to light four LEDs than you would need if you drove them in series. Running them in a parallel configuration also requires four wires, which can consume additional conductors in the power ribbon cable. Another disadvantage of a parallel configuration is that the brightness of an LED is relative to the current passing through it. Hence, to achieve a consistent backlighting source, the current through each LED must match that of the other LEDs within a few percentage points.

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Alternatively, running the LEDs in series requires only one wire and provides a single current through all LEDs for better brightness matching, but, in this case, you must boost the voltage. Four white LEDs in series operating at 4V each can require a voltage as high as 18V, in turn requiring an inductive boost of the system voltage. Inductors, however, increase cost and consume board space as well as increase EMI emissions. EMI reduces the sensitivity of radio subsystems, so you must employ a more expensive inductor or another measure in applications such as cell phones.

Because they keep the voltage under 6V, parallel implementations can use switch capacitors to boost a system voltage to 4V from 1.8 or 3V to drive the white LEDs. Switch capacitors are cost-effective and generate no EMI, but they have typical efficiency of only 75%. To improve efficiency, developers can use synchronous boost converters, which replace the internal Schottky diode of asynchronous converters with a PFET. For even higher efficiency, developers can employ a multimode switched capacitor that can boost voltage by a factor of two, one and one-half, or one—that is, without boosting. This approach enables more efficient boosting as battery voltage drops during normal discharging. For example, you can boost a 4.2V lithium-ion battery at full charge times one to provide the necessary 4V. As the battery drops below 4V, the switched capacitor can shift to a one-and-one-half-times boost to provide 5V from 3.6V. Later, as the battery drops to 2.8V, the switched capacitor boosts at two times to provide 5.6V. If the switched capacitor offers only dual-mode operation—that is, one- and two-times boosting—the LEDs will boost to two times as soon as the battery drops below 4V, resulting in higher inefficiencies and losses.

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There is no simple answer for whether to drive LEDs in series or in parallel. Optimizing backlighting power efficiency is like a fairly complex equation that you must solve, with the various variables representing cost, efficiency, size, and complexity. To achieve the highest efficiency, you need to evaluate display trade-offs across all layers of development—from the base silicon to supporting power circuits and from interface lines to actual usage, as the application determines. You cannot isolate the individual layers from each other.

For these reasons, selecting a display comes early in the design process, usually at the same time that you select the primary processor and operating system. Display selection is truly a system-level decision that has significant impact on other design decisions. Fortunately, developers have a multitude of options available to them so that they can achieve an implementation that enables them to improve the user experience through higher resolution without adversely increasing battery size, system cost, or device form factor.**EDN**

AUTHOR'S BIOGRAPHY

Contributing Technical Editor Nicholas Cravotta just celebrated the issuance of his latest patent. He is currently developing an innovative accessory for the video iPod.