Multiple Strategies to Save Energy in High-Resolution Handheld Displays

As higher resolution displays are used in handheld devices, it becomes more difficult to obtain useful battery life. New devices such as the Apple iPhone contains a 320 x 480 and the Toshiba W52T a 400 x 800 pixel display. These large displays cover most of the front surface of the unit and consumers are demanding thinner devices, leaving less room for the battery. The display module (including the backlight) is a major energy drain. In particular, the display must always be running, even during standby mode, so that information such as time of day, call waiting, alarms and so forth may be displayed. Because the display is 'always on', it is an important target for power saving strategies. **Jeffrey A. Small, National Semiconductor, Rochester Product Development Center, USA**

The most obvious strategy is to turn off the backlight when the handheld device is in its standby mode. This requires the use of transflective displays so that information may still be displayed even when the backlight is off. Because the backlight for a colour LCD display typically consumes between 200 to 300mW, turning the backlight off saves large amounts of energy. Another strategy is to sense the ambient light level and to then dim the backlight when the ambient light level is low. Conversely, if the ambient light level is very high, it overpowers the backlight so that the backlight may be completely turned off.

Optimising the backlight

When the backlight is on, using RGB LEDs for the backlight instead of white LEDs may reduce its operating power. This requires three LED drivers, one each for the red, green and blue LED circuits. Devices such as the LP5520 combine three temperature-compensated LED drivers into one package, while using a common inductor for the DC/DC conversion. RGB backlighting has significant advantages, since the peak wavelengths of the RGB LEDs can be picked to coincide with the peak transmissivities of the colour filter array dyes, maximising optical efficiency and increasing the colour gamut. This also improves colour saturation, since there is less crosstalk between the colour channels. If white LEDs are used, they must be driven hard enough so that the weakest colour channel has adequate

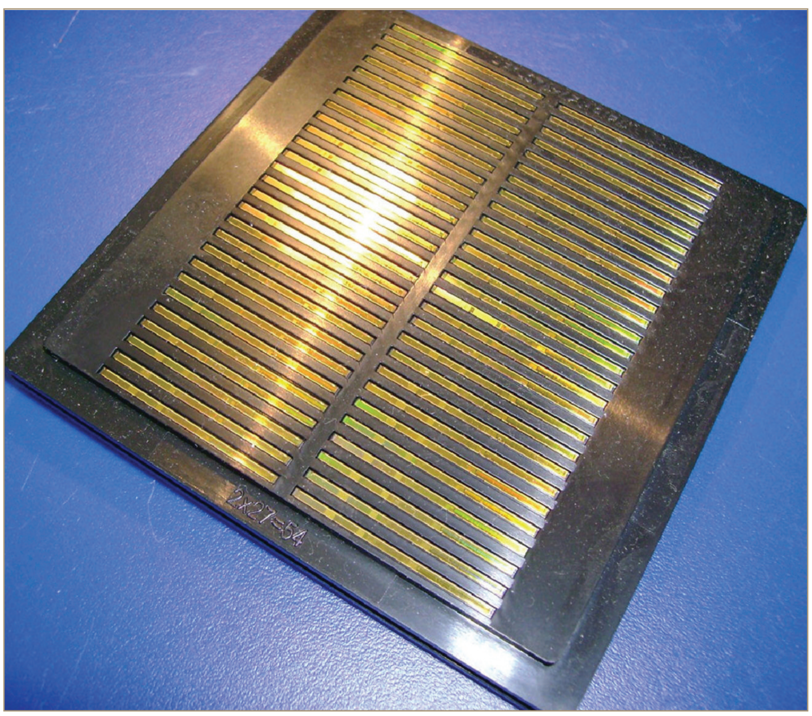

Figure 1: **A tray of FPD95120 display driver chips, each device measures approximately 25mm x 1mm**

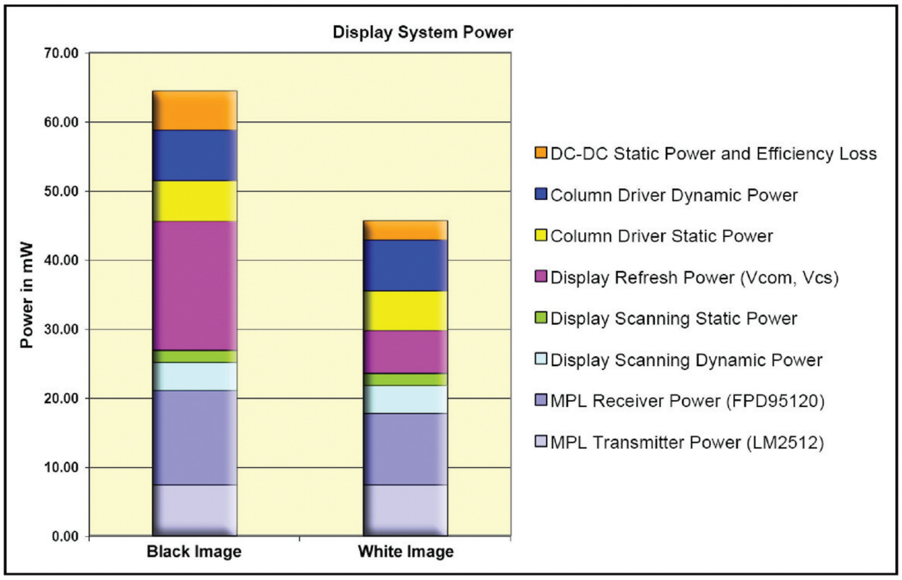

Figure 2: Power consumption of a 320 x 480 3.62in (92mm) display (actual data from a display module operating in 18bit colour mode at 60 fps)

illumination. This results in excess power in the stronger colour channels, which is then wasted. On the other hand, if RGB LEDs are used, each colour may be driven with the exact amount of required power so that no power is needlessly wasted.

Minimising the supply voltages

Lithium-ion cells are the most common power source for handheld devices. These supply approximately 3V, which must be converted to various regulated voltages to operate the subsystems. For example, an LTPS colour LCD typically requires voltages of –5V and +10V, while a graphics processor requires voltages ranging from 1 to 2V. Unlike switched-capacitor DC/DC converters, inductive DC/DC converters maintain high efficiencies over a large range of input and output voltages and allow the required voltages to be generated even as the battery voltage drops at the end of each battery discharge cycle. This allows more of the energy stored in the battery to be used.

Also, inductive DC/DC converters may be used to generate voltages that are close to the final required voltages, followed by low-dropout regulators (LDOs) to tightly regulate the required voltages with little insertion loss.

Typically, the RF power output of a mobile phone is dynamically adjusted by the host system so that only the minimum required RF power is generated. Devices such as the LM3207 may be used to dynamically minimise the RF power amplifier supply voltage according to this required RF power. The LM3207 has an efficiency of 90 to 95% under typical operating conditions.

The dynamic power consumed by the system processor and/or the graphics processor is proportional to the square of the digital supply voltage. These processors consume significant power, especially when performing computationally intensive tasks such as decoding and processing a video stream. For processors that are compliant with PowerWise Adaptive Voltage Scaling technology (AVS), devices such as the LP5550 family of PowerWise AVS energy management units provide autonomous closed-loop minimisation of the supply voltages to the processors. Optimisation of the supply voltage takes into account process and temperature variation of the processor while transparently supporting processor frequency scaling. PowerWise AVS technology can reduce processor energy consumption by up to 70%.

Standby Mode

To minimise power consumption during standby mode and to minimise display driver chip size, the image data may be stored using a reduced number of bits per pixel. The FPD95120 display driver chip (Figure 1) supports 1 and 3 bits/pixel in standby mode, allowing trade-offs between power, displayed image size and image quality. Using 1 or 3 bits per pixel allows the display to be driven in frame inversion mode with no visible flicker. This consumes less power than line inversion mode, because the column driver voltages are toggled once per frame rather than once per line.

The display driver chip must be able to refresh the display in a self-contained manner during standby mode, providing all required DC voltages, clocks and signals for the display module. The FPD95120 display driver chip contains all required DC/DC converters, an internal oscillator and internal memory to hold the data that is being displayed. The host system can update this data as desired via a serial interface. Once data has been loaded into the device, the host system need only provide battery voltage for the data to be displayed. In standby mode, the total power consumption of the display is typically between 5 ~ 10mW from the battery.

Full operating mode

During full operation of the display, power is consumed by the digital link supplying data to the display. The LM2512A, in concert with the FPD95120 display driver chip, uses a high-speed low-power serial link (Mobile Pixel Link or MPL-1) to transmit video data from the host system to the display module. The MPL-1 link requires one clock line and two serial data lines for HVGA applications. EMI is reduced because MPL-1 uses current-mode signalling with a typical voltage swing of just >100 mV and because it does not create large ground spikes. The power consumed by an MPL-1 link (transmitter operating power plus receiver operating power) is comparable to the power that would be consumed by an equivalent LVCMOS connection. A significant advantage of MPL-1 is the reduction from 26 wires (clock, data enable and 24bit RGB) to just three. If the system's graphics processor (GPU) has MPL-1 built-in (MPL-1 is an open standard), the LM2512A is not required; the GPU can connect directly to the FPD95120 driver.

The LM2512A also contains a dithering block, which converts 24bit RGB video into 18bit RGB video with little noticeable loss of image quality. This uses a proprietary psuedo-random spatio-temporal algorithm that provides near 24bit quality on an 18bit display. This reduces the link power, since only 18bits/pixel need to be transmitted rather than 24bits/pixel (25% less data). Furthermore, a driver chip designed for 18bits will consume less power than one designed for 24bits, because the D/A converters in the driver chip will be smaller.

The DC/DC converter for the LCD panel voltages must be contained in the display driver chip, so that it is available during standby mode when the host's DC/DC converters might be shut down. It should be directly connected to the battery to eliminate losses associated with pre-regulation. For high conversion efficiency, it is especially important to minimise the impedance of the path from the inductor to the display driver chip on the glass and from the ground pads of the display driver chip on the glass back to the negative side of the battery supply.

In addition, using multiple clock domains can reduce the dynamic power in the display driver. This allows large portions of the driver's logic to run at slow clock speeds or to be shut off when they are idle.

Charge recycling

During full operation, a significant amount of power is required to charge and discharge the column lines and pixel storage capacitances on the LCD glass. For normally-white LC material, this power is greatest for black pixels and smallest for white pixels, as shown by the 'Display Refresh Power' in Figure 2. A portion of this power may be saved by the use of charge-recycling techniques in the driver chip. The FPD95120 includes a patented charge-recycling technique.

The display system power consists of several components as shown in Figure 2. The largest component is the power required to charge and discharge gate lines, column lines, pixels and the common electrode of the LCD glass (display power + column driver power). The next largest component is the power required to operate the video interface between the video source and the display driver. This power includes the actual signalling power (current sources for MPL-1 or $fCV^2/2$ for LVCMOS), as well as the power used by the interface circuits on each end of the video link. Some power is lost in the DC/DC converter, primarily due to resistive losses in the inductor charge and discharge paths. For an HVGA display refreshed at 60 fps, the total battery power consumption for an FPD95120-based display is typically between 45 ~ 65mW.

Conclusion

Because the display is 'always on' in handheld devices such as mobile phones and PDAs, the key to maximising battery life is to minimise the average power consumption of the LCD module and its backlight. The use of RGB LED backlighting minimises the backlight power, and the use of efficient display drivers that run directly from the battery minimises the LCD module power. The use of transflective LCD modules and self-refreshing display drivers allows the backlight and system processor to be shut down during standby mode, even though the display is still active. Display power during standby mode is minimised by using 1 or 3bit colour modes, primarily because these modes allow the display to be driven in frame inversion mode with no flicker. Battery life may be further improved by using closed-loop minimisation of the supply voltages to the system processors (PowerWise Adaptive Voltage Scaling technology), by open-loop minimisation of the supply voltage to the RF power amplifier, and by the use of efficient peripherals such as the LM49100 audio subsystem.