TFT-LCD modules improve video quality

By Michael Jennings
Director of Marketing
Intersil Corp.

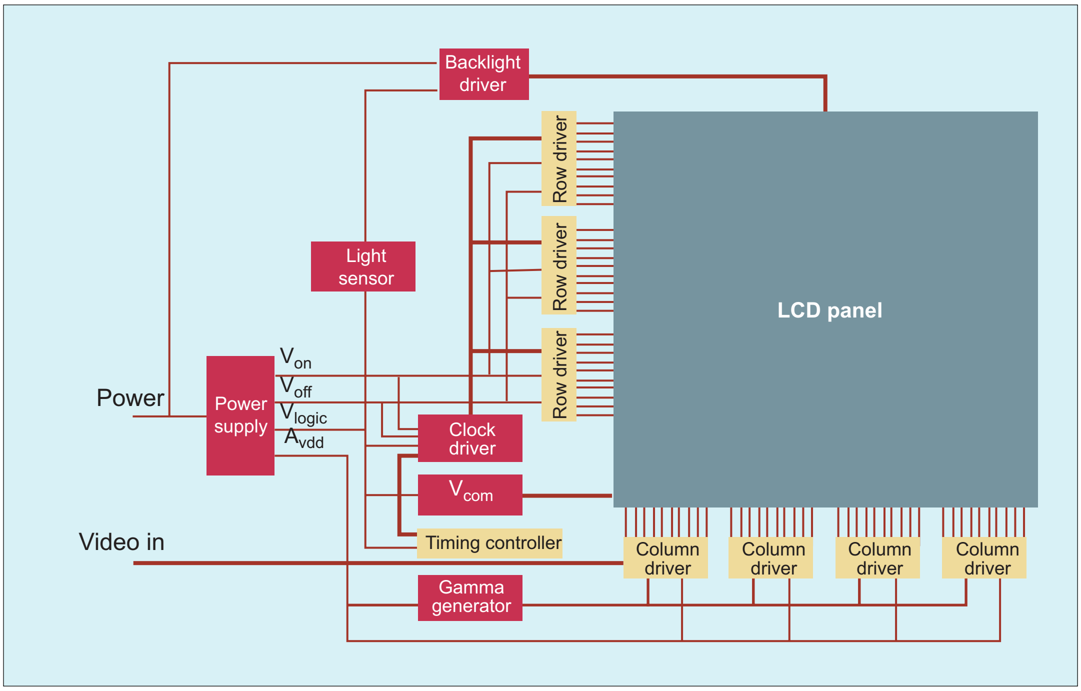

Figure 1: The LCD system depends on row and column drivers, gamma correction and multiple supply voltages.

The popularity of LCDs has grown rapidly over the past five years. The technology that enabled the growth of the notebook market has now taken over the CRT in many desktop applications, where it offers sharp text reproduction and large format displays in a smaller form factor. With the merging of the PC and the multimedia experience, video reproduction is becoming a key requirement for LCDs. Some historical disadvantages of this technology have been weak color representation, the smearing of moving images and the inability to reproduce detail, especially in the very bright or very dark picture regions.

In addition to technological issues, a major drawback of the LCD has been cost. If space is not a concern, the incumbent CRT provides a cost-effective solution. Panel prices have been dropping rapidly because supply has outstripped demand, although some manufacturers have also cut back on production to bring the supply/demand curve back in line.

Module components

Figure 1 shows the typical circuitry of an LCD module. The timing controller is a digital IC that sits at the heart of the panel. It controls the timing of the scanning mechanism used to handle the writing of data into the LCD. This device resets the row and column drivers to start writing data in at the top of the display and scan one row at a time to the bottom of the display. The row drivers are power drivers used to select which row will have its data written at a given time. The column driver converts the digital video data input to the display into an analog voltage to be stored across each individual pixel cell.

The panel carries four primary voltage supplies. The main supply (A_{vdd}) provides a high voltage that powers many of the analog ICs within the LCD, including the column drivers that drive image content into the display itself. Although many people think of TFT-LCDs as a digital display, the brightness of each pixel is determined by an analog voltage level stored across that pixel. RGB filters in front of the pixels enable color reproduction. Because of the analog nature of the display, the A_{vdd} supply rail has to offer good load regulation and supply enough current to charge and discharge all pixels within the display very quickly.

Other supplies in the display include the logic supply for the digital IC products, as well as a high V_{on} voltage and a negative V_{off} voltage, which are used to power the row drivers within the display. For high-performance video displays, it is important to use a high-performance TFT-LCD regulator to reduce image distortion and

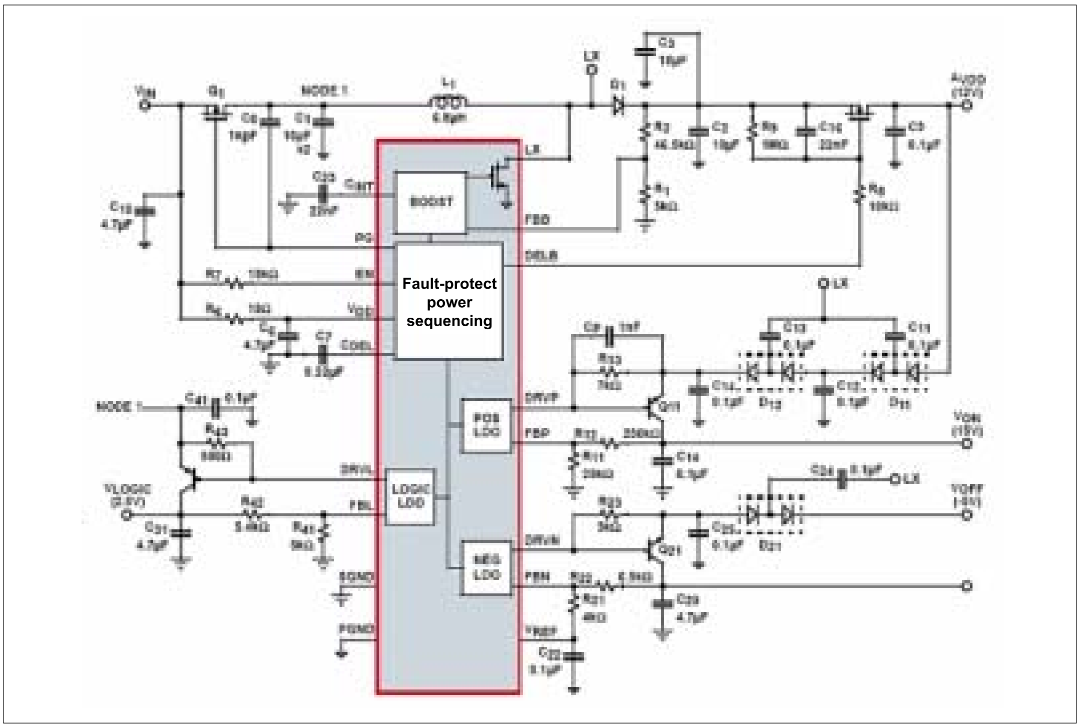

Figure 2: EL7585 generates four LCD power-supply voltages.

smearing. Devices like the EL7585 (**Figure 2**) include all four of these supplies in a single IC and incorporate supply sequencing, which is important to prevent damage to the LCD.

The V_{com} amplifier supplies a stable reference voltage for all pixels in the display. This supply is typically about half the value of A_{vdd} and the brightness at every pixel is determined by the difference between the voltage driven by the column drivers and this V_{com} voltage.

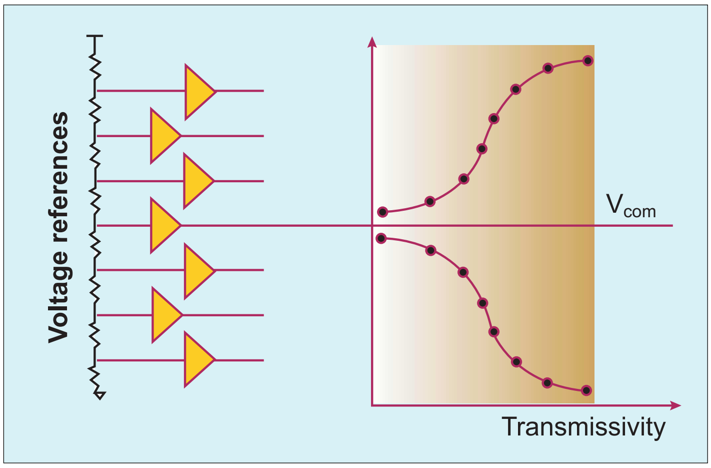

Figure 3: The S-shaped "gamma curve" shows a nonlinear relationship between the light emitted from a pixel and the voltage applied to it.

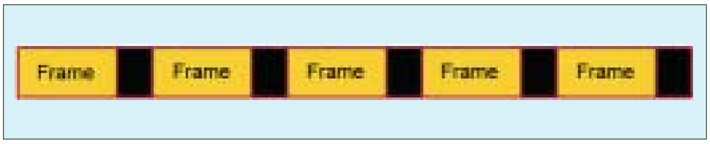

Figure 4: Black insertion puts a black frame between each of the image frames. This creates a fast pulsing effect similar to a CRT.

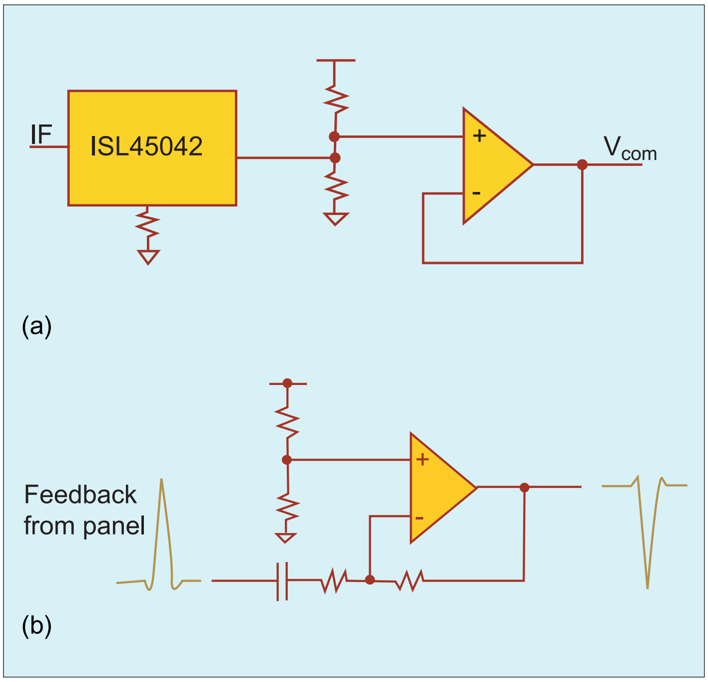

Figure 5: (a) The Intersil ISL45041 can drive an EL5111 high-power V_{com} amplifier; (b) Newer panels use the actual V_{com} value inside the panel to close a control loop.

The relationship between the light emitted from a pixel and the voltage applied to it is nonlinear. This so-called "gamma curve" (**Figure 3**) is an S-curve in nature and can either be positive or negative referenced to V_{com}. In fact, most panels switch alternating pixels between one polarity and the other. This gives an average DC voltage of 0V across the display, avoiding the burn-in effect associated with such offsets. As each panel has a different gamma-curve response, the column drivers need a reference curve so that they can drive the right voltage to each pixel to get the required brightness. These curves are typically supplied using gamma buffers and a string of resistors that can be used to mimic the curve.

The final device in the LCD block diagram example is the backlight driver. Nearly all LCD panels today use a cold cathode fluorescent lamp (CCFL) backlight. These are required as the LCD panel itself does not emit light, but actually gates on or off the light from the source behind it. These CCFL devices require a high-voltage AC waveform to drive them. Typical notebooks and monitors can use just one CCFL controller per panel. However, large-panel, TV-type displays require much brighter backlights and more CCFLs and, therefore, more drivers. The light from each of these CCFLS also has to be matched; otherwise, the image brightness will vary across the screen.

Reducing motion blur

One of the biggest issues in viewing video on LCDs is motion blur. This effect comes from the very slow response of the liquid crystal within the display, leading to the appearance of a smear behind any moving image. Today's liquid crystal technologies have yield response times in the 12-16ms range. Although much faster than the 20-30ms of a few years ago, this is still not fast enough to remove the artifact altogether. Of course, this has been a major area of focus for LCD development and there are now technologies that can be used to eliminate the problem.

The most obvious solution from the LCD panel front is to speed up the response of the liquid crystal material. The response of current materials can be increased by overdriving each pixel. However, this still does not produce the required quick response. Some companies are now demonstrating new materials with response times of 5ms (gray to gray), and with gray-to-black times of around 1ms. The fast gray-to-black time also enables the very effective use of black insertion (**Figure 4**). This technique inserts a black frame between each of the image frames. This creates a fast pulsing effect similar to a CRT. The human brain filters out this flickering and automatically creates the intermediate images. Demonstrations of this technique at recent exhibitions have proved effective.

If fast liquid crystal is not available, this effect can also be simulated by pulsing the backlight. This technique has also been demonstrated effectively. By scanning the backlight from top to bottom, further motion artifacts can be removed, resulting in very sharp moving images.

Reducing flicker

Due to offset in the LCD panel, the required V_{com} voltage can differ slightly from the ideal of one-half A_{vdd}. This, in turn, can cause the appearance of flicker in the display. To eliminate this effect, the V_{com} is usually adjusted on a panel-by-panel basis until the appearance of flicker is removed. This mechanical pot is now being replaced by digital potentiometers that enable automatic adjustment of these offsets, eliminating the possibility of offsets through human error. **Figure 5a** shows the ISL45041 driving an EL5111 high-power V_{com} amplifier in such an application.

As each line is latched onto the LCD panel, charge injection into the V_{com} plane can also

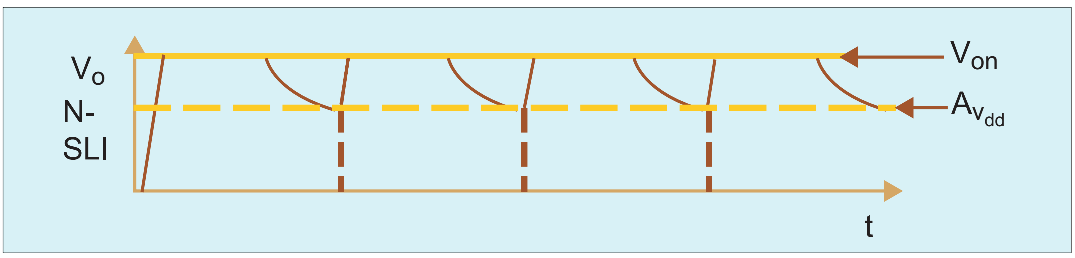

Figure 6: To eliminate flicker, the V_{com} can also be discharged by reducing switching currents at the end of each line.

cause offsets that are seen as flicker. To eliminate this issue, newer panels now use a technique where the actual V_{com} value inside the panel is used to close a control loop that minimizes these offsets. This, in turn, reduces flickering artifacts. **Figure 5b** shows such a circuit.

A third approach is to try to reduce the switching currents at the end of each line. A V_{on}-slice circuit is used to discharge the V_{on} voltage at the end of each line, reducing the switching charge injection into the V_{com} line **Figure 6**.

Removing gamma mismatch

Due to variations in manufacturing and process parameters, each LCD that comes from a production line exhibits slightly different gamma responses. Typically, a single gamma curve is used for all panels, which means that when we place multiple panels next to each other, each will have a slightly different color response. For many applications, this is undesirable. To overcome this issue, the gamma curves ideally need to be set on a part-by-part basis as components of a closed loop system. Programmable gamma generators such as the EL5325 (**Figure 7**) from Intersil enable the gamma curve to be controlled via a microprocessor and reprogrammed as part of the manufacturing process.

LCDs are not very good at distinguishing different contrast levels when producing very bright or very dark images. The use of dynamic gamma can overcome this problem. This is where the gamma curve is adjusted on a frame-by-frame basis, depending on the image content. This can be done in the digital domain as part of the scaling process, but limitation in bit depths of these devices leads to a number of undesirable artifacts. To overcome these artifacts, new systems will adjust the gamma reference curve using programmable gamma generators such as the EL5325.

Improving color reproduction

Using CCFL technology as a backlight source impacts the color spectrum in an LCD. The typical CCFL backlight will enable an LCD to reproduce less than 50 percent of the colors that can be transmitted using an NTSC signal. New high-power LED technologies are now available as a backlight source to improve this coverage to more than 100 percent of the color spectrum of NTSC. In addition, these new LED backlights eliminate the mercury found in CCFL backlights, making them suitable for green applications.

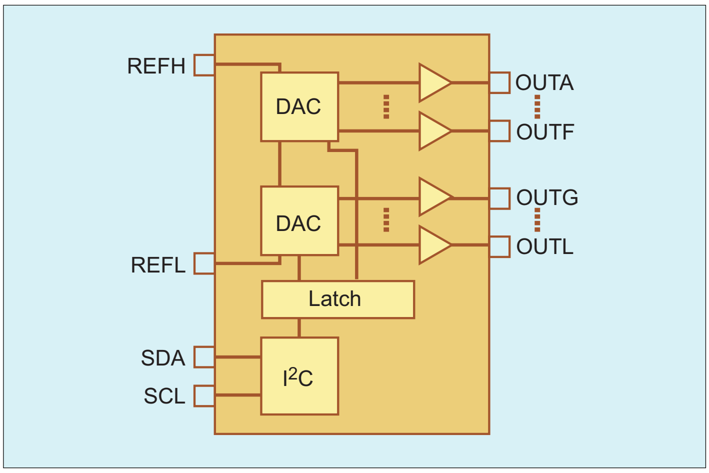

Figure 7: Programmable gamma generators such as the EL5325 enable the gamma curve to be controlled via a microprocessor.

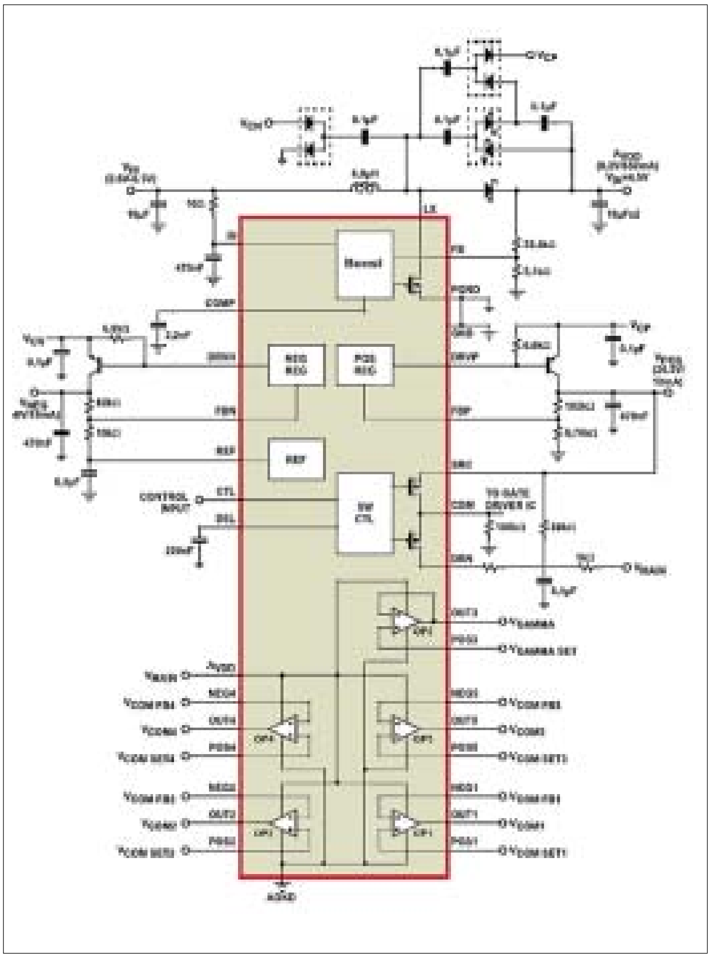

Figure 8: The EL7642 includes DC/DC, V_{com}, gamma and V_{on}-slicing functions in a single package.

The LED backlight has other advantages. For larger panels, separate red, green and blue LEDs are used. This enables the color temperature to easily be adjusted in a display. The fast response of these devices also makes them suitable for strobing backlight applications.

Although many manufacturers are working with these new technologies to improve image performance in their displays, they are also under intense pressure to reduce the cost of these devices to win market share. Without cost reduction, the growth of the market will be limited. This has led to many manufacturers removing functionality from the displays instead of improving the performance. It is common in mainstream monitors not to use gamma buffers. The curve is typically generated using a simple string of resistors and the performance degradation is accepted.

As the fiercely competitive desktop-monitor market continues to grow, we will see limited adoption of these new technologies for better video performance introduced into these displays. Many of these desktop monitors are used in corporate environments where the emphasis is on text and graphics usage. But for the rapidly growing LCD-TV market, and for home PC multimedia stations, image quality is becoming an important factor. □