ECN Focus on Lighting

Here's a collection of articles on the subject of solid-state lighting.

Addressing management of large display and indicator lighting in mobile phones

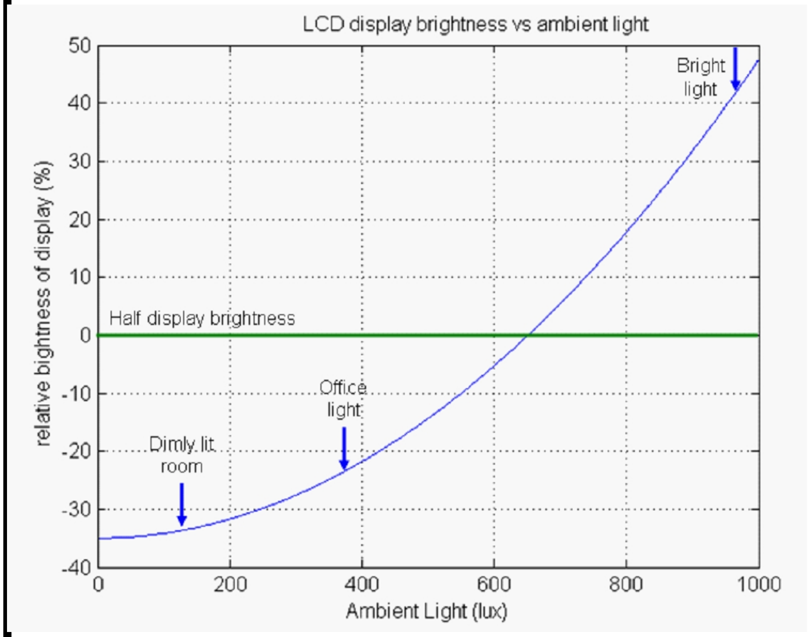
By Crystal Lam, Low voltage power management BU, ON Semiconductor, www.onsemi.com [1]

The use of LEDs is expanding in cellphone design. White LEDs have traditionally been used as a backlight source for LCD panels or keypads. Now, to support the larger display backlights required thanks to the popularity of phones with large touch screen displays, a higher number of white LEDs are needed. In addition, illumination with color LEDs can increase the charm of a phone design and we can already find phones with RGB LED or multiple colored LEDs functioning as indicators to deliver simple messages such as who’s calling or even to indicate the mood of the user. In this article, we will study LED driver examples to discover how new LED drivers with I2C command-base lighting features can help to save software development effort. Finally, an example of an integrated light management IC illustrates how board space can be saved while facilitating multiple light effects without additional processor resources.

Large phone LCD panel Backlight

Primary phone displays are getting larger, with mid- to high-end phone models increasingly featuring displays up to 3.5”. To provide a bright and even backlight on these displays, up to 10 LEDs are needed, and ensuring even luminosity throughout the whole display area typically requires these LEDs to be connected in series. Assuming the maximum forward voltage of a white LED to be 3.5 V, driving 10 units will require at least 35 V from the driver output... The challenge of converting a low lithium ion battery input voltage of 3 V up to 35 V, while switching the DC-DC converter at a high enough frequency to ensure small external inductor size, means that there is only a limited number of devices that can offer an appropriate driver solution.

If we assume the current through the LEDs is 25 mA, the power required to drive the large LCD backlight is 25 mA x 35 V, or 875 mW. Compare this with smaller display backlighting, where only five LEDs may be needed, with a driving power of only 438 mW. To minimize the impact of the increasing LCD backlighting power consumption on battery operating time, ambient light sensing functionality may be required. The ambient light of typical office lighting is 320 – 380 lux and that of a family living room or a building hallway is well below 100 lux. Figure 1 illustrates the relationship between the ambient light and the display luminosity required to ensure readability. The diagram shows that, when the user is in an office or dimmed light environment, the LCD backlight can be dimmed by at least 20-30%. Given that display luminosity is directly proportional to the driving current, ambient light sensing offers a saving in backlight power consumption of more than 20%. This saving can be critical - especially for phones with extra multimedia or data functions...



Human eye response to light

It is interesting to note that the human eye's response to light is a logarithmic, rather than a purely linear relationship. This means that generating a linearly increasing backlight - a light effect sometimes referred to as "fade-in" - requires the driving current to be increased in a logarithmic profile. Using drivers in which this function is integrated eliminates the need for the processor to generate a real time varying frequency signal to pilot the backlight current.

Consider a backlighting scheme based around the NCP5021 1.3 MHz inductive boost LED driver, which can drive up to 10 LEDs in series with very high efficiencies of up to 90%. Compared to charge pump type drivers, the inductive boost structure offers advantages of perfect LED current matching and high efficiency. An integrated logarithmic current profile with 31 current levels compensates the eye's response to light. The integrated gradual dimming function is called up via I2C commands to automatically generate either a fade-in or fade-out effect without using host processor resources, leaving it free to concentrate on other tasks. Finally, a built-in ambient light sensing capability can optimize power consumption. Based on the input from an analog ambient light sensor, the driver can adjust the backlight current automatically to match display luminosity to the ambient lighting conditions.

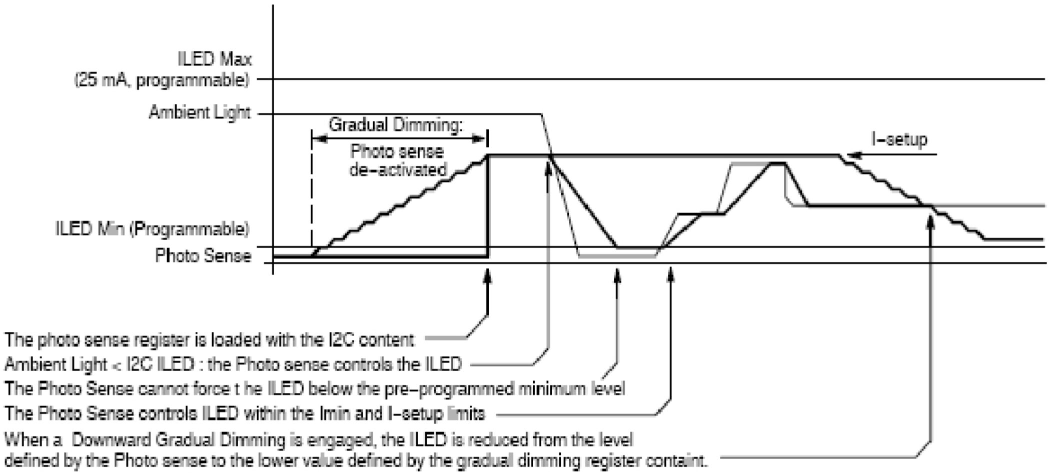


Figure 2 depicts the operation of both gradual dimming and ambient light sensing. At start up, the display can be lit up with a smooth fade-in effect to the preset maximum level (as defined by the user). As soon as the ambient light drops below the corresponding current ambient light level, backlight current will start to decrease to adapt to the new light conditions. If the ambient light is significantly below a preset minimum, the backlight should settle at the minimum LED current. When the ambient light increases again, the backlight current will increase in line with the corresponding ambient light level. The rate of change of the backlight current is specified by the phone designer and can be changed by the end user. Because the complete operation is automatic it requires no intervention from the main processor.

Thanks to the adjustable gain control through the I2C interface, the driver can operate with any type of photo sensor. When implementing ambient light functionality it is recommended that the RC filter is tuned to remove all short light pulses (e.g. street lighting) that may interfere with the ambient light detection.

RGB indicator light

Now let’s address the need to use LEDs as indicators. Generating color with Red, Green, Blue (RGB) LEDs demands an LED driver with three individually controlled outputs. These outputs dictate the contribution of each colour to generate the precise color needed. Due to the low power involved and the need to individually control LEDs connected in parallel, this type of driver usually employs a charge pump structure to step-up the battery voltage. At the same time, control via an I2C interface ensures precise timing control. Historically, adding an RGB LED scheme to a system that already has an LCD backlight driver requires an extra driver. Now, however, integrated devices that offer both backlight and RGB driving capability are becoming available.

Take, for example, the NCP5890 integrated driver based on a 1.3 MHz inductive boost design. This device can drive between two and five LEDs for LCD backlighting, plus three other LEDs with independent control to generate white or color light patterns for backlighting or indication. Just like the NCP5021, the NCP5890 has ambient light sensing capability and can automatically generate fade-in and fade-out effects. Figure 5 shows a design based around the device. All of the LEDs are connected in series; with three PWM switches (PWM1-PWM3) connected across three LEDs (D4-D6). Generating a different current over any of the D4-D6 LEDs requires turn on and turn off of the corresponding PWM switch with the duty cycle used to determine the current level to be delivered to the particular LED. Such functionality is possible due to a unique structure that combines both inductive boost and PWM switches to offer high efficiency operation for both backlight and RGB lighting. The result is an LED driver that can save board space while using I2C control to simplify the control of the overall lighting effect.

Summary

The requirement for LEDs for LCD backlighting in cellphone designs is growing, thanks to the popularity of larger displays. To support this requirement while optimizing the backlight power consumption to maintain battery budget for other functions means that ambient light sensing functionality is becoming critical. This functionality, which adapts the backlight current level in accordance with ambient light conditions, can achieve 20% or more reduction in backlight power due to the fact that end users are likely to spend many hours indoors, when the level of backlight current can be reduced. In addition to backlight driving, LED drivers should be capable of automatically generating some common lighting effects, such as the fade-in or fade-out effect that is required at the start-up and shut-down of the operating system. Furthermore, there is a growing requirement to support indicator functions using several white or RGB LEDs to generate different color or light patterns. In the past this has necessitated separate charge pump LED drivers with individually controlled outputs. New developments, however, mean that designers now have access to integrated lighting devices that can offer board space savings by combining LCD backlight and RGB LED driver outputs in the same package.

Who’s Got the Frame Buffer?

Smart Displays and RAM-Less Displays in MIDs

By Allen Tung, California Micro Devices, www.cmd.com [2]

Like everything else in a mobile Internet device (MID), the display electronics must operate on low standby power and low operating voltage. Intel, which has supplied a majority of the processors used in these handheld devices, has announced that its goal for the next-generation Moorestown MID processor platform is to reduce the idle power consumption by ten times over that of first-generation MIDs based on its Menlow platform. At the same time, Moorestown will support a range of power-hungry digital entertainment applications for mobile social networking, including wireless communication capabilities such as 3G, WiMAX, WiFi, GPS, Bluetooth, and mobile TV.

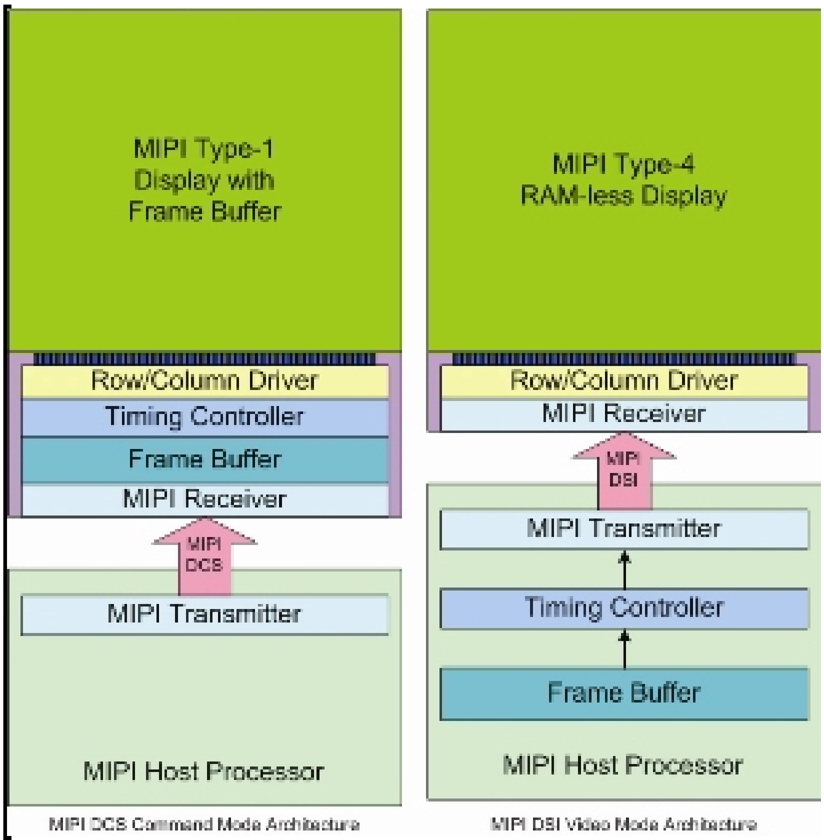
MIDs can include the functions of smart phones and ultra-mobile PCs (UMPCs). MID displays are expected to be somewhat larger than those on cell phones, up to 8 inches in size, according to iSuppli. Along with their larger size, MID displays will also feature higher resolutions than current cell phone displays. Two major display architectures differ primarily in the location of the frame buffer that stores display data: integrated into the display itself, or on the host baseband processor.

To date, many cell phone manufacturers have preferred to use smart displays that integrate a frame buffer. In this architecture, the display can refresh itself directly from the frame buffer without the need for communication with the host processor. But as display resolution increases, so does the size of the frame buffer required. In the high-resolution displays demanded by most consumer computing systems, such as those for MIDs, integrating a full frame buffer on a display client module is especially costly. The smart display architecture also increases the die size of the display interface controller chip, and results in most of the chip’s area being consumed by the frame buffer. An additional problem is the fact that display manufacturers may need each display interface controller implemented with a specific amount of frame buffer memory for each separate resolution.

An alternative architecture shifts the frame buffer from the display client to the host. In this RAM-less architecture, the host must continually refresh the display, similar to the traditional RGB interface, so it may consume slightly more power over long periods of time. With this architecture, MID manufacturers don’t need more expensive displays with integrated frame buffers. Instead, with a display bridge controller chip, they can use less expensive, widely available, higher-resolution RGB displays, without being required to use the traditional, cumbersome RGB parallel bus.

Display Architectures and MIPI Display Modes

Over the last few years, LCD display interfaces on mobile handsets have been gradually shifting from slower, cumbersome, parallel RGB or CPU interfaces to high-speed serial display interfaces. One of these high-speed serial interfaces, Mobile Industry Processor Interface (MIPI), has been widely adopted by CPU manufacturers such as Intel and Marvell, because it combines high speed with signaling power even lower than LVDS: 0.1 to 0.3 volts for MIPI compared to 1.0 to 1.4 volts for LVDS and 1.8 to 3.3 volts for RGB. Because of its scalable data lanes configuration, the MIPI interface transmits data at up to 3 Gbits/s. In addition, MIPI’s low differential swing voltage means it has very low EMI. ECC and CRC checksum embedded in MIPI packets let the display client perform error correction and recovery, thus decreasing the overall error rate during data transmission.



MIPI supports two different display architectures: Display Command Set (DCS) command mode and Display Serial Interface (DSI) video mode. The DCS command mode architecture is targeted for displays with a built-in frame buffer, such as smart displays, and DSI video mode is targeted for RAM-less displays (see Figure 1). In DCS command mode, the MIPI host sends a pixel data stream to the display using display command set packets. The display requires a frame buffer to store all of the pixel data. The timing controller on the display module fetches the data from the frame buffer and sends it to the display autonomously, without intervention by the MIPI host. In this mode, the host is not required to continually refresh the display.

In contrast, DSI video mode operation is similar to a traditional RGB display interface: the host must continually refresh the display client. The display therefore does not need a frame buffer to store pixel data. Digital signals and RGB data are represented in video packet format and transmitted over the MIPI bus. Instead of sending a high-speed blanking packet during blanking periods, the DSI bus may be put into the low power state whenever possible to reduce power consumption. Without an integrated frame buffer, silicon size can be greatly reduced, thus the cost for the display sub-system can be lower.

Display controllers based on either DCS command mode or DSI video mode display architectures require a certain amount of programming. In both, the display controller’s register settings must be programmed to accommodate different display resolutions, aspect ratios, and operating modes. Since MIPI does not define a standard protocol to access these internal registers, display manufacturers have each developed their own manufacturer-specific commands to access internal register read/write operation. To avoid the hassle of developing several different sets of manufacturer-specific code, one for each different manufacturer’s display, some interface controller vendors prefer the display to be capable of self-initializing to a working state without requiring the MIPI host to configure the display. To do so, these displays include a one-time-programmable (OTP) EEPROM with proven working parameters and initialization sequences that are programmed during manufacturing. After power-on reset, the parameters are retrieved by microcontroller logic, which then sets internal registers. Although this is a convenient feature, the OTP EEPROM occupies a significant amount of die space.

To offload the host CPU, many display controllers are already capable of performing functions such as rotation, mirroring, and scaling to manipulate display output. However, in some cases this is over-designing them. Host CPUs on MIDs, such as Intel's Atom processors, are already equipped with high-end graphics capability, and can perform these functions better and more accurately than most display controllers.

The platform based on Intel's Moorestown processor for mobile Internet devices (MIDs), expected in the market by 2010, will include two high-speed serial display interfaces. For larger displays with higher resolutions, such as WXGA (1280 x 800), adopted by many netbook manufacturers, the platform will include a Low-Voltage Differential Signaling (LVDS) interface. For lower-resolution WVGA displays (800 x 480), which are being designed into many MIDs, the platform will include both of the MIPI interface's operating modes: DSI video mode and DCS command mode.

California Micro Devices will provide a high-speed serial interface display bridge controller that will be used in next-generation MIDs based on the Intel Moorestown platform. This controller operates in DSI video mode and can connect to TFT LCDs of any resolution, up to WXGA. Its innovative architecture will enable the design of low-cost MIPI-based display modules that feature a reduced number of interface signals for better signal integrity due to differential signaling, lower power consumption, and reduced electromagnetic interference (EMI) compared to legacy display interface solutions.

RGB LED Chromaticity Control

By Joe Smith, Texas Advanced Optoelectronic Solutions (TAOS), www.taosinc.com [3]

How to Generate White Light

There are two primary methods for producing white light with LEDs. The first is to coat blue (or ultraviolet) LEDs with phosphor that emits broadband light. A second method involves blending the light from multiple monochromatic LEDs to form a white light. The most typical configuration of this second method involves combining red, green and blue (RGB) LEDs.

Although it is currently more expensive and complex to implement an RGB LED system, this method for producing white light has one key advantage over the phosphorescent white LED method. The chromaticity and intensity of an RGB LED system can be controlled, whereas only the intensity of a white LED can be controlled. As RGB LED systems are implemented into more general lighting and display lighting applications, cost and design complexity will be reduced.

The Need for Chromaticity Control

Chromaticity control is important for two reasons. The first reason is that the target chromaticity of the light source can be changed. Thus, a single light source could offer light in varying hues or color temperatures.

The second reason is that the target chromaticity can be regulated once it is determined. LEDs experience spectral and intensity variation over time, temperature, production batch and forward current. This variation is not consistent for different diode materials. Thus a red (AlInGaP) LED will vary in a manner different from a green (InGaN) LED. Figure 1 shows how the output of typical red, green and blue LEDs vary over temperature. If the red LEDs in an RGB LED system lose intensity faster than the green LEDs, the chromaticity of the blended light will drift away from the target point, unless a feedback chromaticity control system is in place to compensate and ensure stability and consistency.

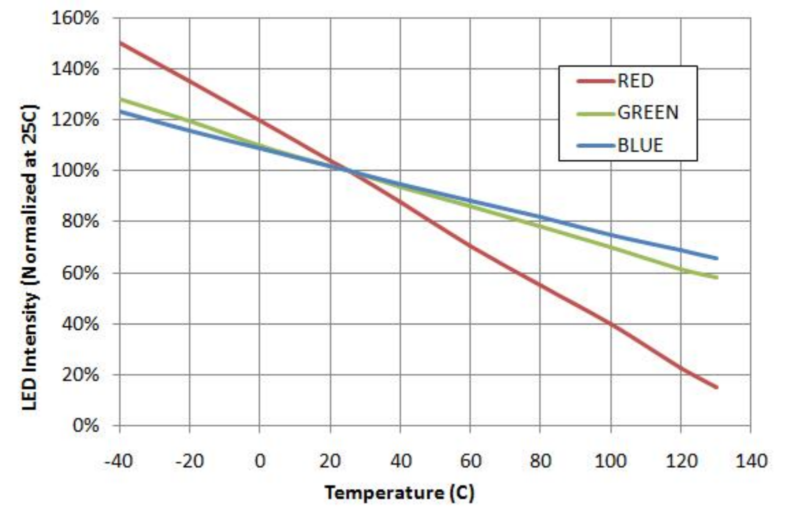


Figure 1 – Intensity of typical RGB LEDs over temperature.

How to Control RGB LEDs

Chromaticity points in RGB LED systems are controlled by varying the ratio of the red, green and blue intensities to each other. The system intensity can be controlled by varying the LED intensities while keeping the RGB ratio constant.

There are two methods for controlling LED intensity: varying the forward current or the duty cycle. Increasing the forward current results in an increase in LED intensity, however it also produces a spectral shift of the LED output. For this reason, variation of the duty cycle is preferred in an RGB system.

The duty cycle of the LED is the percentage of the period that the LED is on and the process for controlling the duty cycle is pulse width modulation (PWM). This is possible because the human eye can only detect the pulse flicker up to about 70 hertz. As long as the pulse frequency is greater than 70 hertz any change in duty cycle will result in a perceived intensity change. Thus as the duty cycle is increased, the perceived brightness of the LED increases.

In order to control the chromaticity or the luminance of the RGB LED system, it is necessary to first know the current chromaticity and luminance. This is where it is important to have a color sensor that can detect the intensity of the red, green and blue LEDs independently as well as detect the overall system brightness.

Using a color sensor such as the TAOS TCS3414CS, the systems red, green, blue and clear (measuring all light) values can be detected.

These values must be correlated to a standard set of RGB values. Such a standard has been created by the Commission Internationale de l'Eclairage (CIE). The CIE is the main international organization concerned with color and color measurement. In 1931, the CIE created the 1931 CIE color matching functions. When the RGB values are normalized to the color matching functions the CIE tristimulus values (XYZ) are obtained.

The CIE Chromaticity Diagram

The tristimulus values can be plotted two-dimensionally on the CIE chromaticity chart, shown in figure 2. Chromaticity values on the curved boundary of the diagram represent pure spectral (monochromatic) colors and vary from the short wavelengths (blue) on the left to long wavelengths (red) on the right.

The curved line that runs from the lower right corner through the middle of the diagram is the Planckian locus and represents the color temperature, increasing from left to right. Color temperature, measured in degrees Kelvin (K), refers to the temperature to which one would have to heat a blackbody (or planckian) radiator to produce light of a particular color.

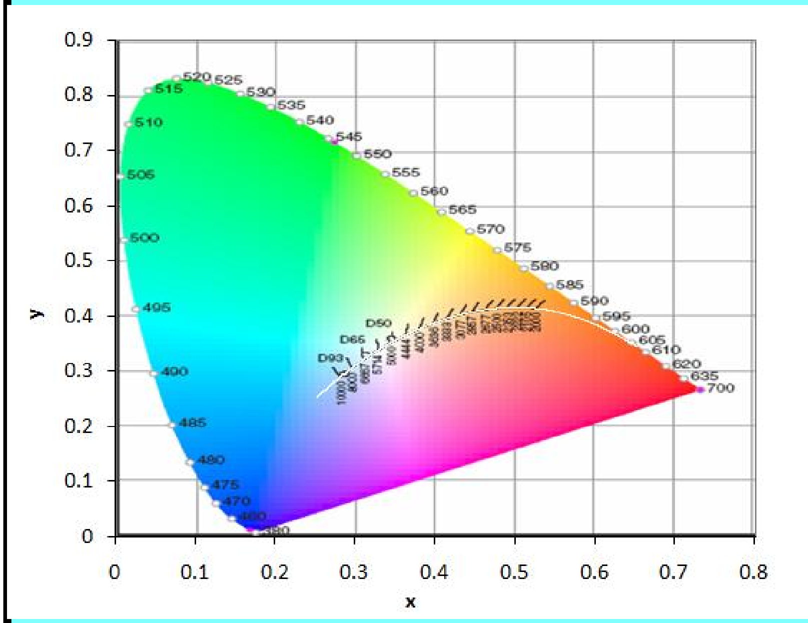


Figure 2 – CIE chromaticity diagram

An incandescent bulb can be modeled by a blackbody radiator. As the tungsten filament is heated up it will glow red, then orange and finally yellow. If you could continue to heat the filament without damaging it, the light would eventually change from yellow to white to bluish-white.

Correlated color temperature (CCT), is a convenient way to describe the color of a near-white non-planckian light source, such as a fluorescent bulb or an RGB LED system. The CCT is the temperature that a Planckian source would need to be, to emit the same color. Common CCT values range from 3000K to 6500K, and make convenient white-point chromaticity targets.

When the RGB LEDs are individually plotted on this diagram they will be near the boundary at their peak wavelength. If lines are drawn connecting the RGB chromaticity points, the resulting triangle will encompass the color gamut for the RGB LED system. In other words, by controlling the PWM of the RGB LEDs any target chromaticity point in the gamut can be reached and regulated.

For more information please visit www.taosinc.com [3]

“Green” LEDs Produce White Light

By Tony Armstrong, Linear Technology, www.linear.com [4]

The last calendar year was pivotal for the adoption of LEDs into what is quickly becoming a mainstream business for many analog IC suppliers. During the course of the last twelve months, some key metrics were met by the LEDs themselves, which will translate into a significant increase in the demand for the LED driver ICs necessary to power them in a wide variety of end applications.

By examining a few of the catalysts that will precipitate the escalation of demand for LED driver ICs from their current early growth stage and into an accelerated growth stage, it is clear that LEDs will quickly be a mainstream lighting source. Four of the main market driving forces behind this demand are automotive lighting systems, the increased LED light output capability, a LED continuing cost-effectiveness and a LEDs potential use as a replacement for incandescent light bulbs.

Audi was the first automotive manufacturer to use LED headlights in its vehicles. Their assembly contains two low-beam headlamps, as the main function, consisting of two LED arrays with four active elements each. Three additional LED arrays with two LED chips each are located behind the optical lens; their task is controlling the bright/dark boundary and the range of the headlights. For the high-beam headlight, a four-LED array is located adjacent to the low-beam arrays. Near the lower edge of the assembly, a row of 24 LEDs forms the daytime running light. At a current of 1A, each LED array achieves a luminous flux of six hundred 600 lumens. This assembly was first offered as an option in the 2008 model year R8 luxury sports car. Nevertheless, other carmakers, such as VW, Lexus and Cadillac soon followed with their own LED headlamps in their current model year cars.

A high-power, and high brightness, LED’s light output has already passed the critical milestone of 100 lumens/W in the lab, with some manufactures claiming 120 lumens/W peak output capability. This means that the LED has now surpassed the CCFL, at 80 lumens/W output, in terms of energy efficiency. It is further projected that by 2012, the LED will attain150 lumens/W output. Furthermore, with all the current focus on having “Green” energy-efficient products, an LED lighting system qualifies since it does not contain any hazardous materials like a CCFL -which has toxic mercury vapor inside its tube.

This is also significant because the U.S. Department of Energy (DOE) has stated that lighting consumes 22% of all the electricity produced in the United States on an annual basis. Therefore, the widespread adoption of LED lighting alternatives could cut this electric consumption in half, resulting in far fewer greenhouse gases. To expand on this further, consider that the total electrical consumption of the United States is approximately 4 trillion kW annually [Source: World Book of Facts]. It comes as no surprise that the largest production source for electricity generation is fossil fuels.

Since fossil fuel consumption has a significant impact on the total production of greenhouse gases, the more we can do to reduce the need for them, the better off the world will be. Whether it is coal, gas or oil, it does not matter - the effect is the same. To put this into perspective, by 2027, LED lighting could cut the annual energy use by the equivalent of 500 million barrels of oil, with the attendant reduction in emissions of carbon dioxide

The cost of LED lighting sources has been dropping very quickly each year. Polybrite (a leading manufacturer of lighting products that incorporates LED technology) has stated that the cost of individual white-light diodes, several of which go into an LED bulb and make up much of the cost, have come down in price from upwards of $7 to around $1.50 during the course of the last year alone. They further project that by during 2009 LED bulb replacements for the incandescent light bulb will be priced at a level that will be acceptable for the consumer.

Furthermore, Cree (a North American manufacturer of the die used inside many different medium- to high-power LEDs) has claimed that it has designed a light-emitting chip that could power a LED bulb producing light comparable to the 75-Watt incandescent bulbs so commonly used in American homes.

Green LED Lighting Solutions

It is clear that any products targeted toward energy conservation or energy harvesting will see growth opportunities and be insulated from the current market conditions. LED drivers ICs will enable a new generation of low power lighting for a range of applications, from cars and medical instruments to laptops and office lighting.

Linear Technology has a wide variety of products to address the design needs of LED driving. Some examples of our most recent innovative product in this area are the LT3595(A), LT3513 and LT3755.

The LT3595(A) is a LED driver IC that is a buck mode LED driver which has 16 individual channels—each can drive a string of up to ten 50mA of LEDs from inputs up to 45V. Each channel can be used to drive a cluster of 10 LEDs to provide local dimming. Thus, each LT3595(A) can drive up to 160 50mA white LEDs. A 46” LCD

TV would require approximately 10 LT3595(A)s per HDTV. Each of its 16 channels can be independently controlled and has a separate PWM input that is capable of up to a 5000:1 PWM dimming ratio

Each channel requires only a tiny chip inductor and an even tinier ceramic output capacitor. The only other required components are a single input capacitor and current setting resistor (Figure 1). All 16 channels of catch diodes, power switches, and control logic with compensation is squeezed inside the LT3595's relatively small 56-pin, 5mm × 9mm QFN package.

Most battery-powered portable products have one or more screen in which to relay graphical information to the user. However, the powering of TFT-LCD display panels, or even OLED panels, requires special care an attention from the systems designer. For the correct powering of a TFT-LCD panel, a DC/DC converter needs to be able to provide the three independent output voltages: AVDD, VON and VOFF with the correct power-up and power-down sequencing. Linear Technology recognizes this and has developed dedicated monolithic DC/DC converters specifically for this purpose. The most recent introduction is our LT3513. This converter has five independently controlled regulators to address all the necessary power rails within a TFT-LCD panel.

Its buck regulator can deliver up to 1.2A of continuous output current for logic rails. A lower voltage secondary logic supply may be generated via the LDO controller and an external NPN MOSFET. A high power step-up converter (ISW=1.5A), a lower power step-up converter (ISW=250mA) and an inverting converter (ISW=250mA) provide the three independent output voltages: AVDD, VON and VOFF usually required by LCD panels. An integrated high side PNP provides a delayed turn on of the VON signal while Panel Protect circuitry disables VON if any of the four outputs are more than 10% below their programmed output voltage protecting the TFT-LCD panel. Other features include integrated Schottky diodes, PGOOD pin for AVDD, output disconnect and inductor current sense for the buck regulator.

The LT3755/-1 is a 60V, high-side current sense DC/DC controller designed to drive high current LEDs from an input voltage range of 4.5V to 40V. The LT3756/-1 uses the same design, but delivers outputs to 100V from 6V to 100V inputs. The -1 versions of both parts offer external synchronization capability, whereas the standard units replace the functionality of this pin with an Open LED status indicator. Both parts are ideal for a wide variety of applications, including automotive, industrial and architectural lighting. For applications which require input voltages higher than 40V, such as 48V rails, the LT3756/-1 will be the preferred solution. Both devices use an external N-channel MOSFET and can drive up to 14 x 1A white LEDs from a nominal 12V input, delivering in excess of 50 watts. They incorporate a high-side current sense, enabling it to be used in boost, buck, buck-boost or SEPIC and Flyback topologies. The LT3755/-1 and the LT3756/-1 can deliver efficiencies of over 94% in boost mode, eliminating any need for external heat sinking. A frequency adjust pin permits the user to program the frequency between 100kHz and 1MHz, optimizing efficiency while minimizing external component size and cost. Combined with either a 3mm x 3mm QFN or thermally enhanced MSOP-16E package, the LT3755/-1 and LT3756/-1 offer a very compact high power LED driver solutions.

Both the LT3755/-1 and LT3756/-1 use True Color PWM™ dimming, which offers constant LED color with dimming ranges of up to 3,000:1. For less demanding dimming requirements, the CTRL pin can be used to offer a 10:1 analog dimming range. Its fixed frequency, current mode architecture offers stable operation over a wide range of supply and output voltages. A ground-referenced voltage FB pin serves as the input for several LED protection features, making it possible for the converter to operate as a constant-voltage source.

Conclusion

It is clear that LED lighting sources have become the mainstream choice for the latest generation of green lighting requirements in a broad spectrum of applications. However, the system designer still needs to have a LED driver IC that satisfies his performance envelope for his specific design. As a result, LED driver ICs must be capable of delivering sufficient current and voltage for many different types of LED configurations with a conversion topology that satisfies both the input voltage range and required output voltage and current requirements while simultaneously meeting Green environmental standards.

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