Powering LEDs for various lighting apps

By Tony Armstrong
Product Marketing Manager
Power Products Group
Linear Technology Corp.
E-mail: tarmstrong@linear.com

The incandescent light bulb is about to enter its twilight years. This is largely due to the proliferation of the LED as a solid-state lighting source. LED technology has increased significantly over the past couple of years. Higher brightness levels, higher efficiencies, longer lifetimes and decreasing costs have spun out from the many advances made in terms of heat dissipation, packaging and processing.

Despite these significant advances, however, more can be done in terms of the efficiency of energy conversion, thermal management and production costs. All of these advances have not only fueled the adoption of LEDs as a lighting source in different applications, but have also simultaneously driven the demand for LED driver ICs to power them.

To understand the obstacles to the design and manufacture of these LED driver ICs, it's necessary to understand the white LED's requirements to produce light. A white LED must be driven by a constant current source so that the white point of the light does not shift—i.e. it must be uniform. Furthermore, since the white LED is a diode, its internal forward voltage (V_f) drop has to be overcome. This V_f varies with the current rating of the white LED and will also change with temperature. A typical 20mA white LED has a V_f that varies between 2.5V and 3.9V over the entire operating temperature range. Most applications use more than one white LED and can also have these LEDs configured in parallel, in series or a combination of both (parallel strings of LEDs in series for example). This means that white LED driver ICs must be able to deliver sufficient current and voltage for the specific configuration of LEDs and in a conversion topology that satisfies both the input voltage range, and required output voltage and current requirements.

Thermal management

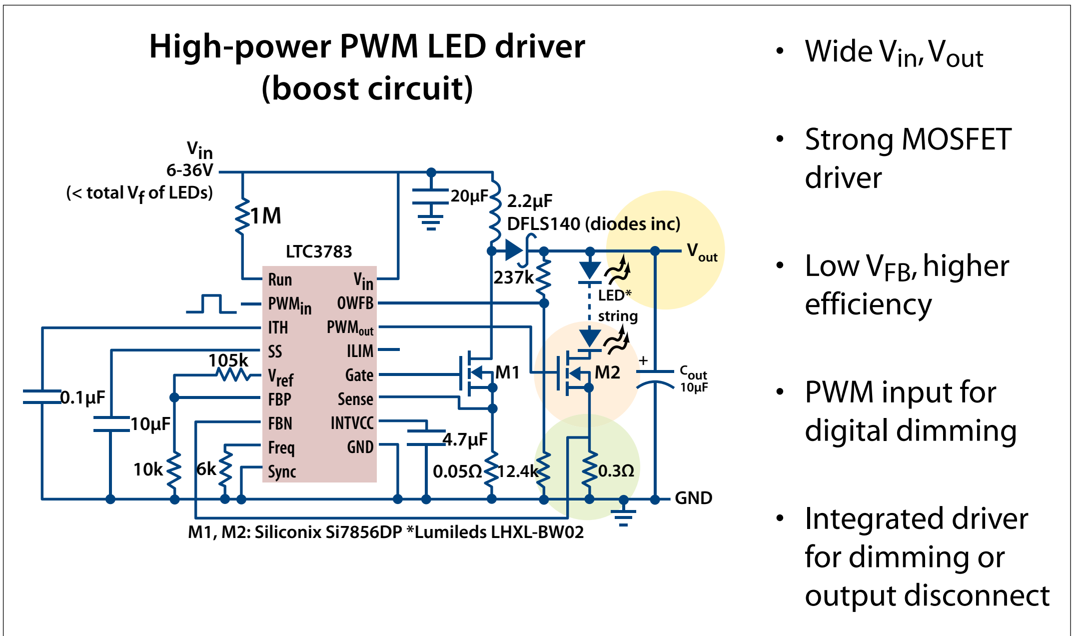
Applications for LEDs are commonly found in displays and indicators for automotive and aircraft dashboards, traffic signals, cellphones, police take-down bars, othoscopes, flat-panel-display (FPD) backlighting, miner's lamps, architectural and outdoor stadium lighting. Nevertheless, the single largest market driver for LED growth now and for the next couple of years is the backlighting of FPDs. These displays come in the form of LCDs used for TVs, navigation systems, portable media players, digital signage and computer monitors.

However, one of the technical hurdles for LED adoption is the concern over thermal management. Although LEDs do not radiate as much heat as other light sources (depending on the output power), they may need appropriate heat sinks so that light output and lifespan do not decrease. For example, a high-brightness LED with 25 lumens output typically consumes more than 1W. This means that the white LED driver IC must have high efficiency conversion so that it is not a major contributor to this thermal issue. Also, as seen by the wide range of applications, in many instances there are space limitations. This means that the LED driver IC must be able to accommodate a compact solution footprint and also be low-profile.

As an example, consider the cellphone. Most of today's cellphones have a built-in digicam that can capture high-resolution still images and video. Gains in camera performance have also created the need for a higher-power white light source for camera use indoors or in dim ambient light. White LEDs have emerged as the primary light source in cellphones equipped with cameras. They possess a desirable combination of features for the modern cellphone designer: small size, high light output, and the ability to provide both "flash" and continuous "video" subject lighting. High-output power LEDs have been developed specifically for use as integrated camera lights.

While making visible light with a high-powered LED is simple, producing a high-performance power supply and current control solution is very difficult without improvements to existing designs. Linear's LTC3454 is a product designed specifically to optimize efficiency, accuracy and control of LED currents in high-current camera light applications.

The LTC3454 is a synchronous buck-boost DC/DC converter optimized for driving a single high-power LED at currents up to 1A from a single-cell Li-ion battery input. The part automatically transitions between synchronous buck, synchronous boost and four-switch buck-boost mode depending on the V_{in} and LED forward voltage. P_{LED}/P_{in} efficiency greater than 90 percent can be achieved over the entire usable range of a Li-ion battery (2.7-4.2V).



The LTC3783 can be used as a boost, buck, buck-boost, SEPIC or flyback converter.

HB, super HB

High-brightness (HB) and super HB LEDs can be found in LCD TFT backlighting in high-end TVs, industrial lighting, automotive navigation displays and projectors. One popular area is for instrument-panel backlighting, interior lighting, and the brake lights of many automobiles and trucks. Luxury automobile manufacturers are increasingly taking advantage of the latest technologies in solid-state LED lighting to enhance the aesthetics of their future model vehicles by relying on these lighter, smaller and more durable devices for interior and exterior illumination. LEDs promise lower long-term cost and longer life, which are among many advantages over incandescent light bulbs for interior lighting.

However, driving LEDs at high current requires the DC/DC converter to accurately regulate the current to ensure uniform light intensity and color integrity, and to protect the LEDs. Furthermore, a significant challenge is to power one or several strings of LEDs from a battery voltage that can be less than, equal to or higher than its load voltage. Yet another concern is to efficiently dim the LEDs over a large dimming ratio while preserving their chromatic characteristics at both low and high brightness levels. And lastly, efficient operation of the DC/DC driver is a crucial requirement, especially in driving HB LEDs, since all the power not emitted as light is dissipated as heat.

Linear's DC/DC LED drivers, LTC3783 and LT3475, address stringent requirements of automotive interior and exterior lighting. The LTC3783 is a current-mode multitopology converter with constant-current pulse-width modulation (PWM) dimming for driving high-power LED strings and clusters. Dimming ratios of 3,000:1 (at 100Hz) can be achieved digitally as True Color PWM dimming guarantees color integrity of white and RGB LEDs. The LTC3783 allows an additional 100:1 dimming ratio using analog control. This is an important criterion since the human eye is extremely sensitive to minor changes in ambient light. This versatile controller can be used as a boost, buck, buck-boost, single-ended primary inductance converter (SEPIC) or flyback converter, and as a constant-current/constant-voltage regulator. No R_{sense} operation uses a MOSFET's on-resistance to eliminate the current-sense resistor and increase efficiency. The figure shows a typical LTC3783 application.

Another product is the LT3475, which is a dual-channel 36V, 2MHz step-down DC/DC converter designed to operate as a constant current LED driver providing up to 1.5A of LED current per channel. An internal sense resistor and dimming control make it ideal for driving high-current LEDs. High output current accuracy is maintained over a wide current range of 50mA to 1.5A while unique True Color PWM circuitry allows a dimming range of 3,000:1.

With its wide input voltage range of 4-36V ($40V_{max}$), the LT3475 regulates a broad array of power sources—from 4-cell alkaline/NiCd/NiMH batteries and 5V logic rails to unregulated wall transformers and automotive power systems. Its switching frequency can be set from 200kHz to 2MHz, enabling the use of tiny inductors and ceramic capacitors while staying out of critical frequency bands such as AM radio.

It is clear that the trend to use white LEDs as a primary lighting source will continue for many decades. Their long life, reliability and efficient energy conversion as compared with the incandescent bulb are too compelling to dismiss. At the same time, their continued adoption will fuel the demand for the LED driver IC required to power them.