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A Holistic Approach To Reducing Backlight Power Consumption

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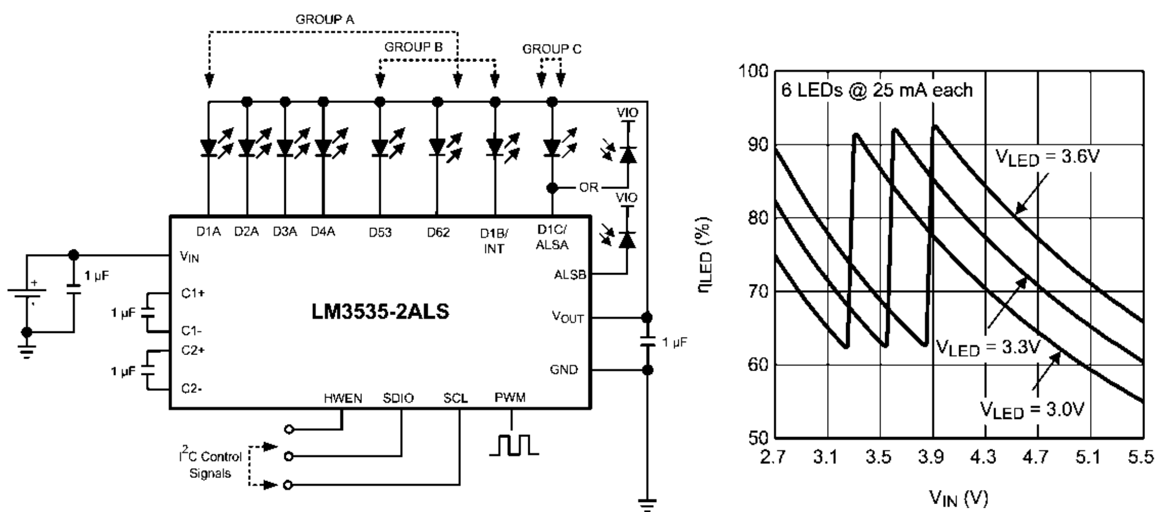
Long battery life is a key metric in the portable electronics market. The LED backlight driver for LCD displays accounts for 25% to 40% of the total active system power. In the past, the tools a designer had to minimize backlight display power consumption were limited to decreasing the LED driver current and increasing the converter efficiency. Today, power savings of up to 50% are possible by utilizing LED drivers with an optimized converter, ambient light sensors, and content adjusted backlight control (CABC) methods. These techniques can enhance driver efficiency without severely degrading the visual quality of the information found on the display (web, video, pictures, etc.)

Traditional Power Optimization

The primary power-saving technique surrounding the backlight driver traditionally has concerned the selection of a boost architecture. Two main types of boost topologies dominate the backlight driver architecture—the inductive boost and the switched-capacitor boost. The inductive boost is typically used in applications requiring series-LED drive whereas the switched-capacitor boost is typically used in parallel-LED drive architectures.

A switched-capacitor boost relies on the charging and discharging of capacitors to create a boosted output voltage. The number of gains offered by a switched-capacitor boost is determined by the number of flying capacitors and internal MOSFET switches. By selectively charging the capacitors in series/parallel combinations between the input and ground in one phase, and then reconfiguring the capacitors in parallel/series connections between the input and the output in a second phase, the converter is able to provide an output that has a higher voltage than the input.

A switched-capacitor boost converter is often limited to a fixed number of voltage gains (1x, 3/2x and sometimes 2x) to help increase the solution efficiency, while keeping the number of external components to a minimum. Additionally, the sizing of the switches used to configure the flying capacitors is key to maximizing efficiency. Minimizing the output impedance of the gains allows the charge pump to remain in the lowest gain for a long period of time, helping to boost the solution efficiency. Fig. 1 provides an example of a switched-capacitor boost converter based on the LM3535 multi-display LED driver and the associated LED drive efficiency as a function of input voltage and LED voltage.



(a) *(b)*

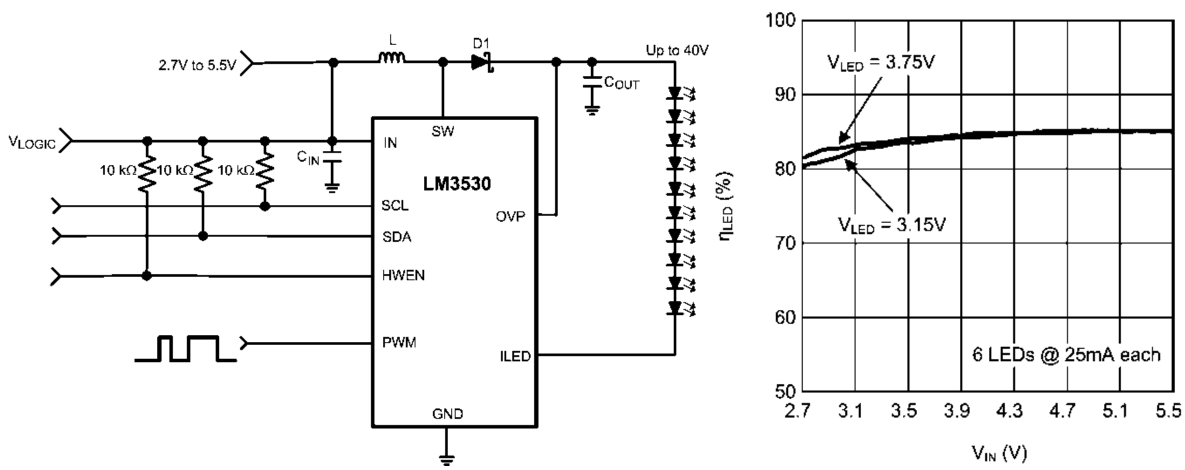
Fig. 1. An LM3535-based switched-capacitor boost converter drives multiple LEDs in a typical display application (a). LED drive efficiency is graphed as a function of boost-converter input voltage and the LEDs' forward voltage.

Where a switched-capacitor has a finite number of gains, an inductive boost converter has an infinite number of gains. By regulating the switching duty cycle of the inductive boost, the exact boost gain needed to support the load (LED string) can be achieved. This optimization helps to prevent "over-boosting" that can occur in a switched-capacitor boost right after a fixed-gain transition occurs.

To optimize an inductive boost converter, the on-resistance ($R_{DS(ON)}$) of the NMOS power switch and the series resistance of the inductor should be minimized. Unfortunately, decreasing these two parameters typically results in an increase in physical size because a smaller inductor will typically have a higher resistance compared to a larger one with the same inductance value.

Increasing the boost switching frequency can help shrink the inductor's physical size by allowing the use of an inductor with lower inductance value, but increasing the switching frequency results in higher switching losses. Selecting a schottky diode with a low forward turn-on voltage will aid in boosting the conversion efficiency. But again, schottky diodes with lower forward voltages are typically larger than those with higher voltages. Additionally, the high duty cycles associated with series backlight drivers (80%+) minimize the impact of a low V_F diode as the device is only conducting for a small percentage of the switching cycle.

The series-LED drive implementation helps minimize the power loss associated with the current-control element (typically a current sink). In a series converter, a single current sink is required to control the current through the LED string, whereas the parallel converter requires one current sink for every LED used in the system. To further boost efficiency, the current-source regulation voltage should be set to a level that is slightly higher than the headroom (or dropout) voltage of the current source to prevent current variations in the LED string due to dips in the input voltage and/or the output voltage ripple caused by the charge/discharge cycle of the output capacitor. An example of a series-LED drive implementation of a boost converter based on the LM3530 appears in Fig. 2.



(a) *(b)*

Fig. 2. An LM3530-based inductive boost converter drives a series string of LEDs (a). LED drive efficiency is graphed as a function of boost-converter input voltage and the LEDs' forward voltage (b).

Ambient Light Sensing

Besides power converter optimization, there are additional power saving features that can be implemented to create an efficient backlight system. Many modern handsets employ a power-saving mechanism utilizing an ambient light sensor (ALS) to monitor environmental lighting conditions and adjust the backlight intensity accordingly. (More ambient light means the backlight must be driven at a higher current, while at low light conditions the backlight current can be reduced.) In a bright, outdoor environment, a very high level of display backlight is needed in order for the display to remain visible. The opposite is true for a very dark environment where the backlight can be dimmed, while still providing a sufficient amount of light to maintain display readability.

Sensing of the ambient light requires a photosensor or photodiode be used in combination with a detection circuit. Most photosensors are current-based devices that provide an output current proportional to the amount of light entering the sensor. This ambient information can be used to determine the ambient condition (outside, office, movie theater, etc.) and then used to scale the backlight to predetermined brightness levels.

By adjusting the backlight to the appropriate level, the power drawn from the battery can be reduced significantly. Fig. 3 shows a use case, highlighting the power savings that are possible using a system with five brightness zones: sunlight, cloudy outdoors, bright office, dim room, and night/movie. The brightness values are set to 100%, 85%, 70%, 60% and 50%, which correspond to LED drive currents of 25 mA, 21.3 mA, 17.5 mA, 15 mA and 12.5 mA, respectively.

As the ALS voltage rises (or ambient light received by the sensor increases), the driver IC samples the ALS voltage for a predetermined period of time before the driver forces an LED current change. This sampling of the ALS voltage over a specified period (or averaging) helps prevent the LEDs from flickering in the presence of rapidly changing lighting conditions.

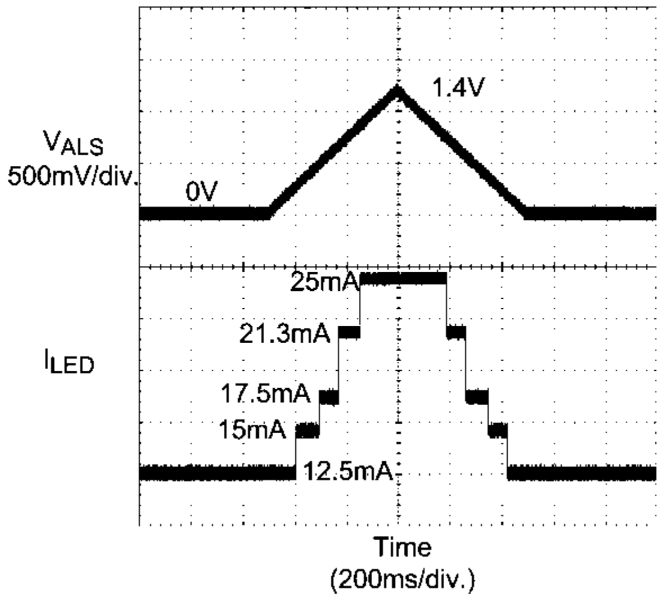


Fig. 3. The output of the LM3535 LED driver (a switched-capacitor boost converter) varies as a function of the ambient light sensor output. Here, the LM3535 boost drives six LEDs at 25 mA.

Dynamic Backlight Control Or Content Adjusted Backlight Control

Traditional mobile handsets provide the user the ability to manually adjust the system display brightness to their liking. Some users leave the brightness set to the maximum all of the time, while others adjust the brightness to lower levels that provide better battery life. This manual adjustment scheme forces the user to compromise. Recent advancements in LCD display drivers have provided the system designer with a mechanism to adjust the backlight based upon the information being displayed on the screen. This concept is referred to as dynamic or content adjusted backlight control (DBC or CABC). By analyzing the display information, the display driver can communicate the required backlight level to the backlight driver directly.

For example, if we utilize an inductive-boost LED driver (National's LM3530 from Texas Instruments in this case) with a string of six LEDs at 19 mA to backlight a 3.5-inch LCD screen while watching a television show (around 20 minutes), the driver will constantly draw 137 mA from the battery assuming a $V_{BATTERY}$ of 3.6 V (Fig. 4.) Utilizing DBC on the same backlight driver, with possible brightness levels set to 100%, 75%, 50% and 33% of full-scale, the average current draw drops to 78 mA. With DBC, the backlight driver will draw 45% less input current on average than without DBC.

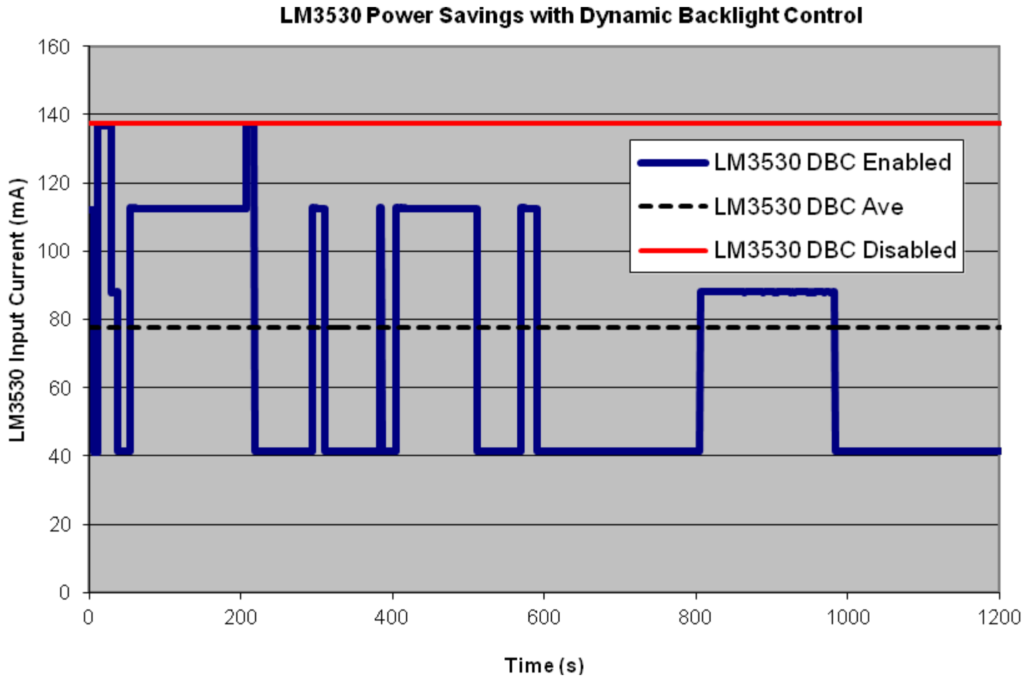


Fig. 4. Power savings for an LM3530 inductive-boost LED driver with dynamic backlight control.

Additionally, with DBC active, it is possible to achieve higher contrast levels on the LCD display due to a lower level of light leakage through the pixel due to the varying backlight brightness. While the power savings employing DBC is drastic, there is a slight side-effect to the picture quality. When the DBC level is operating at the lower brightness levels, the white screen content will not look as bright and can sometimes appear to have a slight grey tint. However, with proper selection of brightness level, the designer can optimize power consumption and maintain picture quality.

Summary

While traditional efficiency improvements can be obtained through the selection of the backlight driver boost architecture, many newer additional features are available that further decrease battery drain. By utilizing ambient light sensors, the modern backlight driver can provide the correct amount of backlight given the display's ambient light environment. Additionally, through the use of dynamic backlight control, the display driver can adaptively adjust the backlight intensity based upon the image content.

While these two newer backlight-dimming technologies do not necessarily improve the LED driver's efficiency, they do ultimately decrease the input power consumption and increase the usable battery life of the handset. These methods can all be applied without significantly lowering the visual quality displayed on the screen.

About The Author

Greg Lubarsky is a senior applications engineer with Texas Instrument's Grass Valley design center and works in the Mobile Devices Power group. He received his Bachelor of Science degree in Electrical Engineering from the University of California, Davis in 2002. Lubarsky has over nine years of experience as an applications engineer working with white LED backlight drivers, LED flash drivers and other power management electronics.

For more on the design of LED driver circuits, see the How2Power Design Guide, search by Design Guide Category, and select "Lamp ballasts and LED drivers" in the Power Supply Function category.

