Backlighting the tablet PC

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Introduction

The tablet PC market is expected to grow from just over 50 million units this year to over 200 million units by 2016. There is still no standard architecture for the tablet PCs. For example, some models are powered by single Li-ion batteries while others use dual Li-ion batteries. Regardless of how many batteries are used, all of the tablet PC manufacturers want to maximize battery life. The display's backlight can be one of the most power-consuming systems in the tablet. With display sizes ranging from 7 to 10 inches, the number of backlight LEDs in recently released tablet PCs ranges from 20 to 36. This article gives guidance on how to select the optimal WLED driver and LED-string configuration to meet tablet application requirements without sacrificing efficiency and therefore battery life.

Requirements for tablet backlighting

Similar to a notebook or netbook, a tablet backlight-driver application is based on a DC/DC converter and a resistive path to ground for the LEDs. This type of application typically has the following requirements:

1. Low EMI in the RF range
2. No visible flicker during dimming
3. Minimal audible noise caused by piezoelectric buzzing of the ceramic output capacitor
4. Consistent brightness across the display
5. High dimming ratio
6. Highest efficiency for maximum battery life

Meeting the first requirement, low EMI in the RF range, is relatively easy. Power-supply designers have been achieving this for years with such techniques as setting the switching frequency and subsequent harmonics outside the RF range, using shielded inductors, and designing the PCB with minimal length but with wide traces where appropriate. Some driver ICs have integrated MOSFET gate-drive circuits with tiered rise times to reduce noise emissions in the RF range.

The type of dimming strongly influences the next four requirements. With pulse-width-modulated (PWM) dimming, in which the LED current pulses on and off at its maximum current level to produce an average DC LED current, backlight flicker is not noticeable as long as the PWM dimming frequency is well above 60 Hz. Flicker is not a concern if analog dimming is used, because the LED DC current level is reduced from its maximum for dimming.

The third requirement, minimal audible noise from the ceramic capacitor, is a function of the driver's topology. Figure 1 shows a simple driver with a current-sensing resistor as the ground path for the LED current. The converter regulates the voltage across the current-sensing resistor and therefore controls the LED current.

Figure 1. Simple LED driver

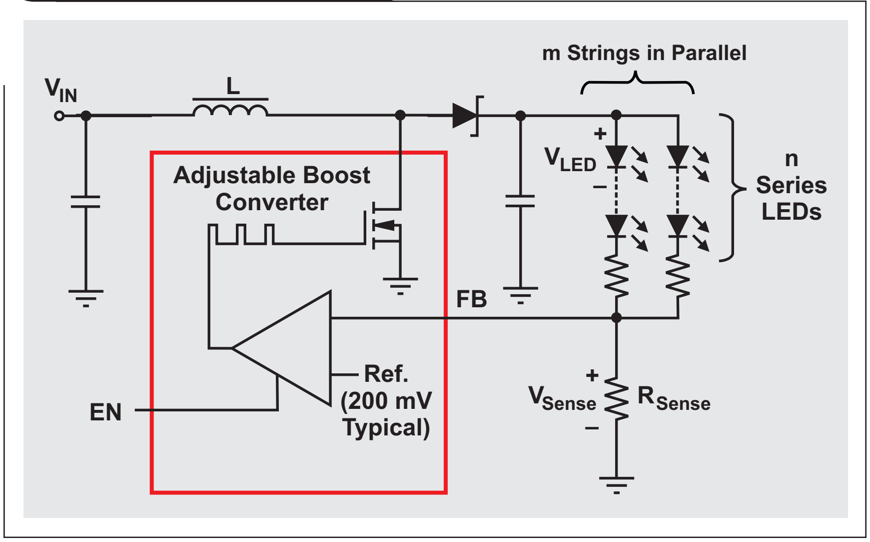


Figure 2. LED driver with integrated current sinks

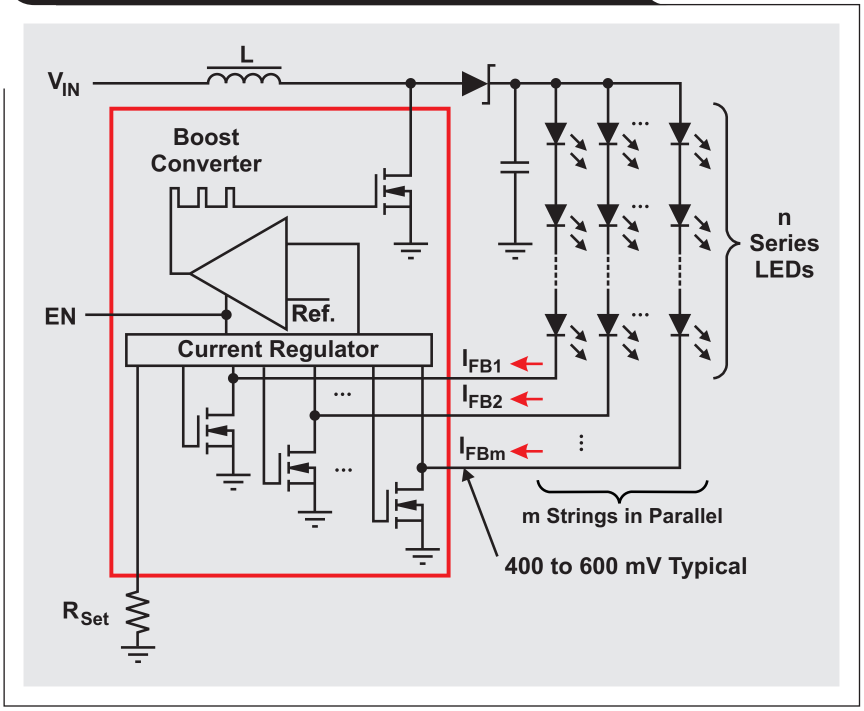


Figure 2 shows a driver with integrated current sinks. The driver samples the voltage at each current sink and ensures that the converter provides just enough power to keep the current sinks operational.

As with flicker, there is no concern when analog dimming is used because the output capacitor's voltage makes only small changes to accommodate the small changes in LED current. However, if PWM dimming is used, the manner in which the driver prevents the output capacitor from discharging becomes important. The simplest driver has a resistor from the driver's feedback (FB) pin to ground, and the output capacitor can become significantly discharged at low dimming duty cycles while the driver's converter effectively turns off. More complex drivers with integrated current sinks (as shown in Figure 2) instead of the current-sensing resistor simply turn off the sink and the DC/DC converter powering the LEDs, thereby removing the output capacitor's discharge and recharge paths. Some drivers even incorporate a sample hold at the output of the converter's error amplifier so that the converter quickly recovers back to its previous state following a PWM pulse and therefore does not significantly change the output capacitor's charge.

The fourth requirement, consistent brightness across the display, is best achieved through accurate matching of the LED current through each string. The key feature of a driver with integrated current sinks is very accurate matching between strings. For drivers without current sinks, ballast resistors placed in series with the LEDs can improve matching between the strings.

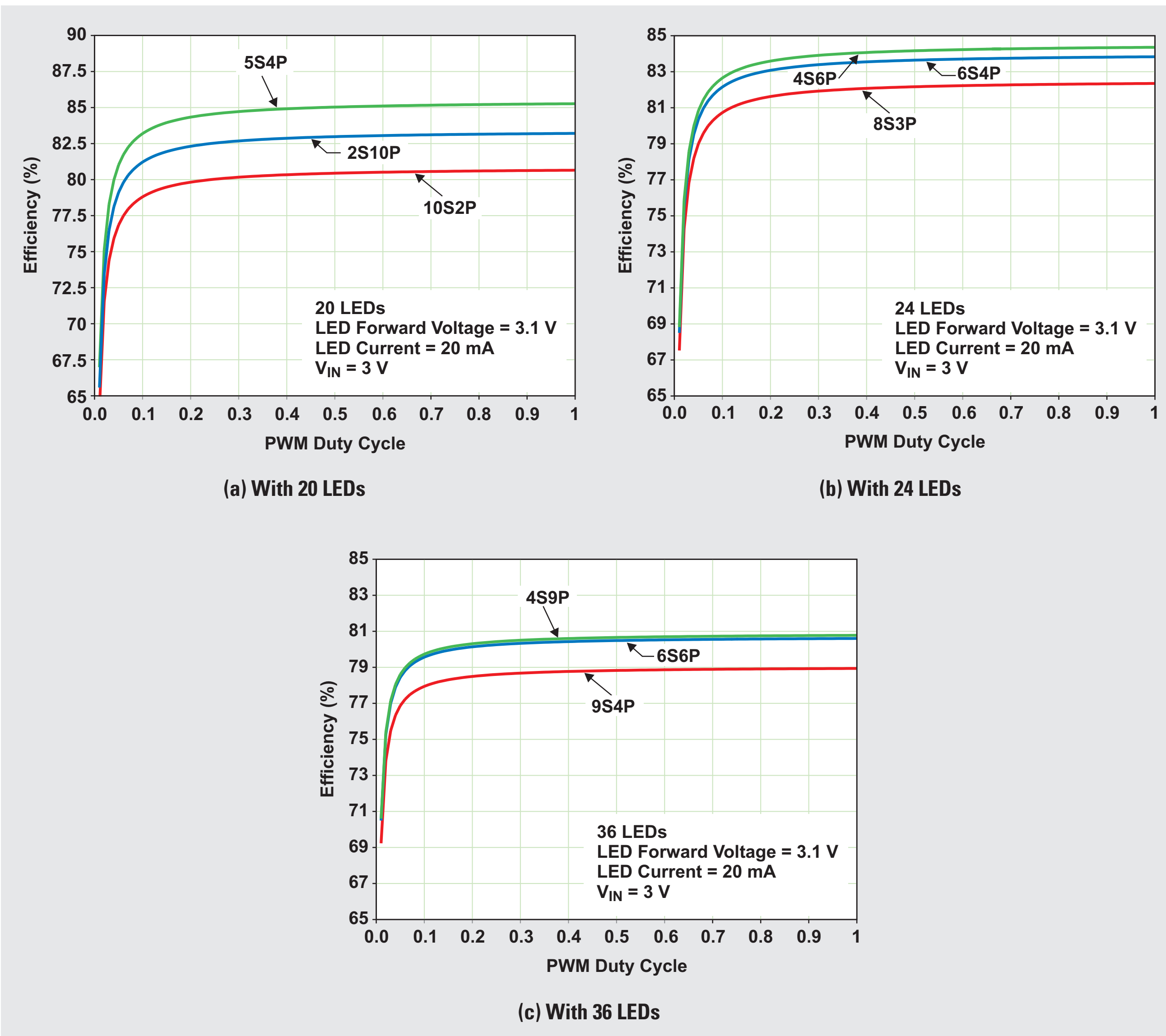
The fifth requirement, a high dimming ratio (e.g., 0.1% or 1000:1), is difficult to achieve with a simple driver, whether analog dimming or PWM dimming is used. With analog dimming at low duty cycles, the analog control voltages become so small that the IC's leakage currents and offset voltages significantly degrade accuracy. PWM dimming with simple drivers is most commonly implemented by turning the converter completely on and off. This type of dimming results in the converter's soft-startup time forcing the PWM dimming frequency to be very low, near the flicker range. The low duty cycle allows the output capacitor to discharge and buzz during recharging. Therefore, high dimming ratios are best achieved with a driver having integrated current sinks, which turn on and off very fast.

The sixth and last requirement, high efficiency, is a function of not only the driver but also the LED configuration. The power MOSFET of the driver's DC/DC converter; the inductor; and the rectifying diode determine the converter's efficiency. The simple driver's ground path is the current-sensing resistor. The lower the converter's FB voltage, the more efficient the overall driver will be. Similarly, for a driver with integrated current sinks, the lower the minimum operating voltage across those sinks, the higher the driver's efficiency will be. A simple driver will almost always be more efficient than a driver with sinks, assuming they both have exactly the same external components, because the current sinks typically require a higher bias voltage than does the current-sensing resistor. However, in order to meet the other performance requirements of a tablet PC, a driver with integrated sinks is usually the best choice.

Optimal LED configuration

Choosing the optimal number of strings and LEDs per string to minimize power consumption and therefore maximize battery life can be challenging. Using fewer strings requires more LEDs per string and results in higher output voltages for the boost converter. The larger the difference between the boost converter's input and output voltages, the lower its efficiency will be. In addition, more strings result in higher total output current and more losses through the inductor and boost rectifier diode. Figure 3 shows the simulated boost power-stage efficiency for three different LED configurations with various series (S) and parallel (P) combinations. Using more strings allows for fewer LEDs per string and provides a lower output voltage, but it requires more current sinks that have to dissipate power and that therefore lower the driver's overall efficiency.

Figure 3. Boost power-stage efficiency



(a) With 20 LEDs

(b) With 24 LEDs

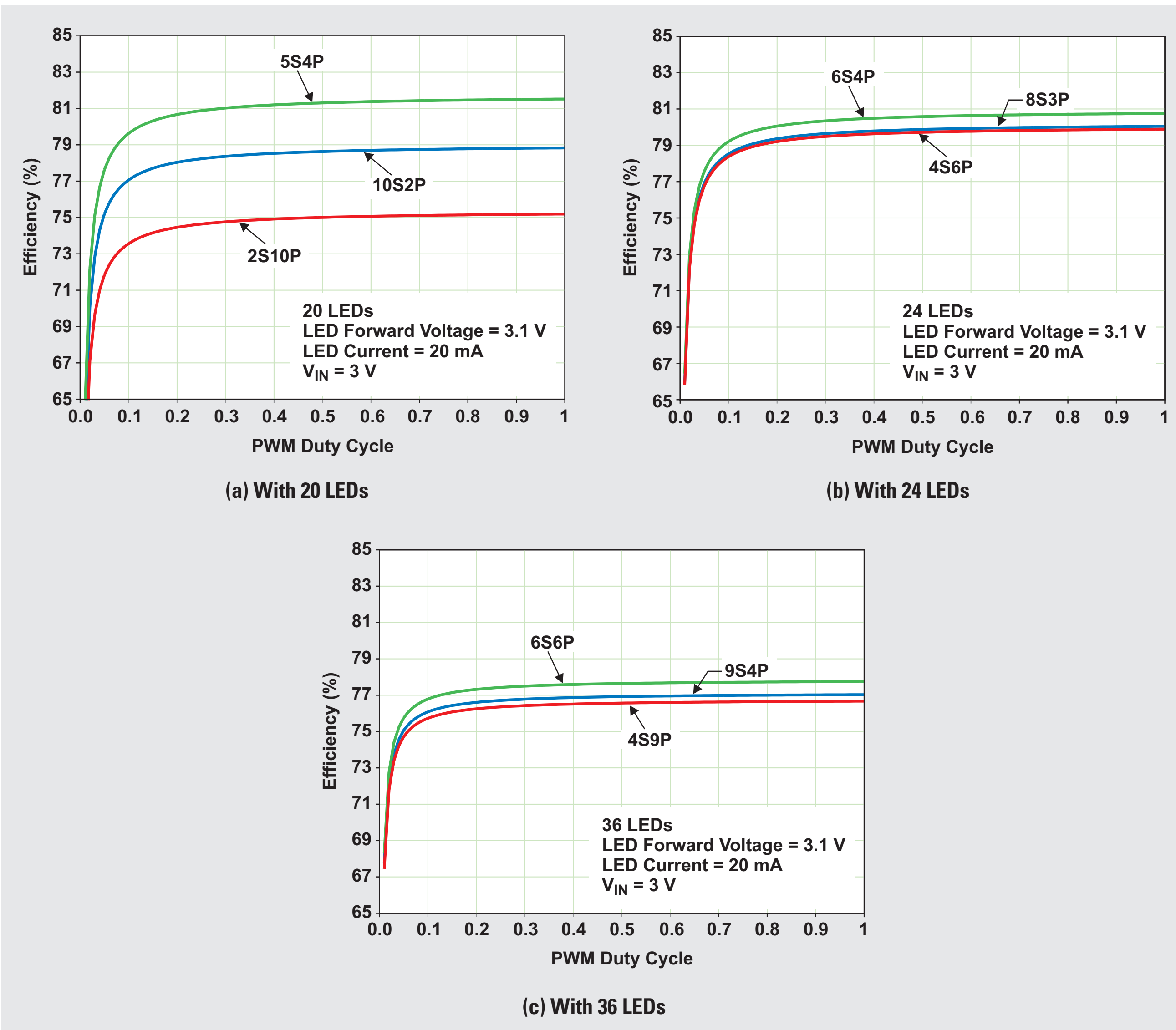
(c) With 36 LEDs

Figure 4 shows the total driver efficiency, which includes both the power-stage and current-sink efficiencies, for the same LED configurations as in Figure 3. From the curves, it is easy to see that the best simulated efficiency occurs with 5 series LEDs in 4 parallel strings (5S4P) for 20 LEDs, 6S4P for 24 LEDs, and 6S6P for 36 LEDs. Based on these results, a general rule of thumb for maximizing a tablet's backlight-driver efficiency is to choose numbers for S and P that are equivalent or as close to each other as possible, but to choose the smaller number for P when given two alternatives.

Example backlighting configuration

Based on the preceding analysis, a backlight driver with integrated sinks, like the Texas Instruments TPS61181A notebook backlight driver, can be optimized for backlighting tablet PCs (see Figure 5). For tablets with two Li-ion batteries, both the driver and the boost power stage can be powered directly from the battery. For a tablet powered by a single Li-ion battery, the driver bias rail can be provided by the panel's AVDD rail or another supply in the system that is 4.5 V or greater. Because the TPS61181A is capable of providing slightly higher power than is required by most tablet PCs (i.e., the power FET is slightly oversized and therefore has very low $R_{DS(on)}$), the converter's power losses are lower than for one designed specifically for that output power, further maximizing efficiency. Figure 6 shows measured efficiency results with the TPS61181A in a 6S6P configuration.

Figure 4. Total driver efficiency



Conclusion

Choosing the optimal backlight driver for tablet PCs requires consideration of all of the application's requirements. A driver with integrated current sinks is best at meeting all of the requirements with the possible exception of efficiency. However, careful selection of a driver with a slightly oversized converter, external components with the lowest power drop, and an optimal LED-string configuration yields a tablet backlight that meets all of the design requirements while maximizing battery life.

Related Web sites

power.ti.com
www.ti.com/sc/device/TPS61181A

Figure 5. TPS61181A powering tablet backlight

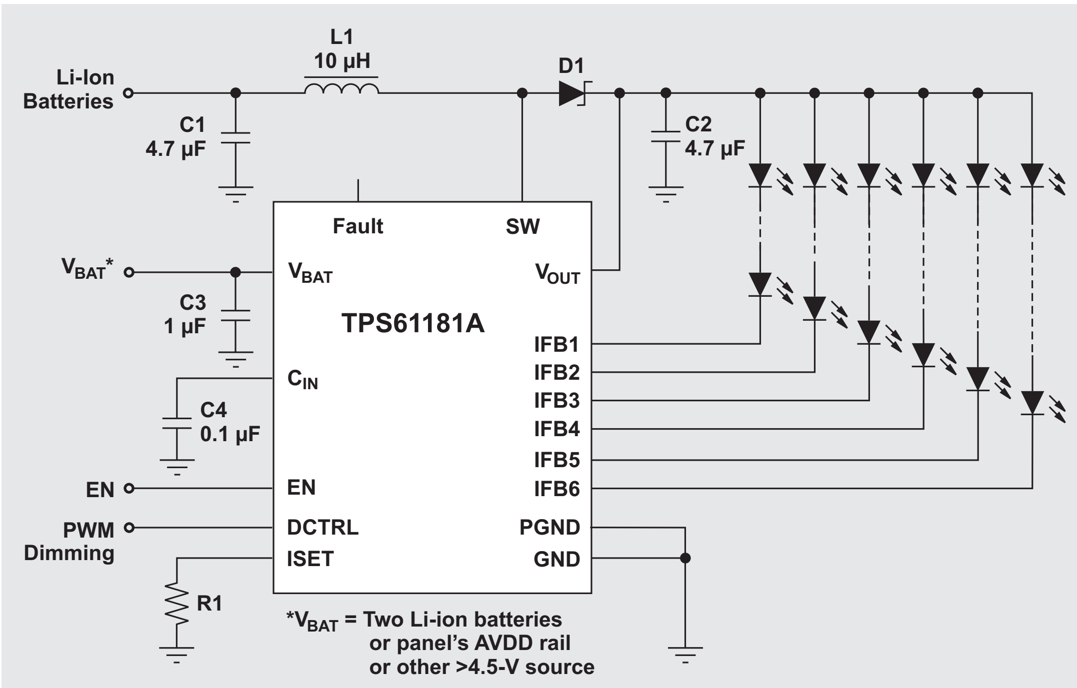
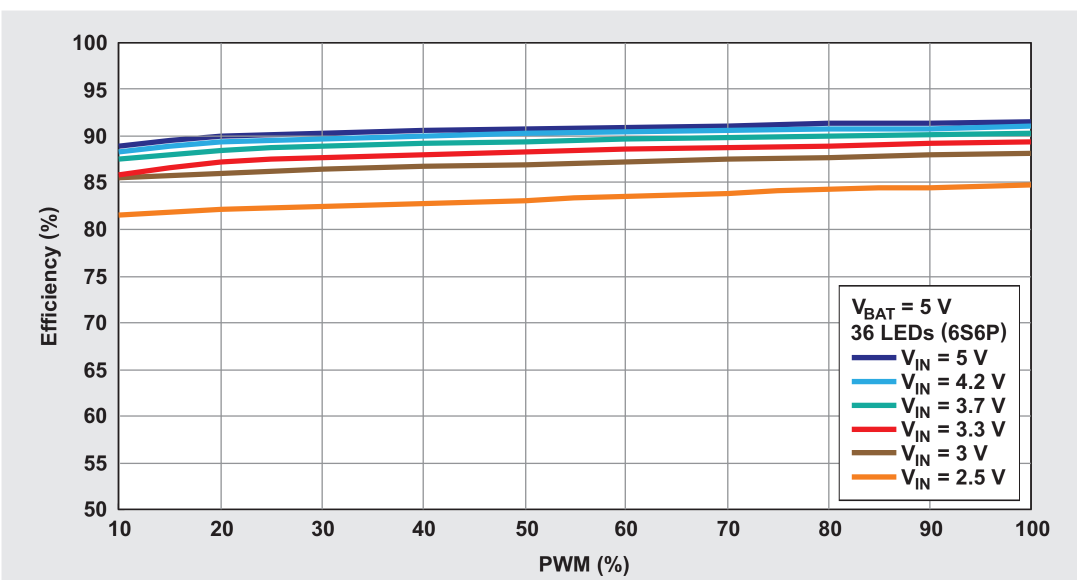


Figure 6. TPS61181A efficiency when powered with single Li-ion battery



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