Backlighting the tablet PC

By Jeff Falin, Senior Applications Engineer, and Xianghao Meng, Systems Engineer

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 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](image-url)
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.
**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**

[www.ti.com/sc/device/TPS61181A](http://www.ti.com/sc/device/TPS61181A)
**TI Worldwide Technical Support**

**Internet**

**TI Semiconductor Product Information Center**

**Home Page**

support.ti.com

**TI E2E™ Community Home Page**

e2e.ti.com

## Product Information Centers

### Americas

**Phone** +1(972) 644-5580

**Brazil**

**Phone** 0800-891-2616

**Mexico**

**Phone** 0800-670-7544

**Fax** +1(972) 927-6377

**Internet/Email** support.ti.com/sc/pic/americas.htm

### Brazil

**Phone** 0800-891-2616

### Mexico

**Phone** 0800-670-7544

**Fax** +1(972) 927-6377

**Internet/Email** support.ti.com/sc/pic/americas.htm

### Europe, Middle East, and Africa

**Phone**

**European Free Call** 00800-ASK-TEXAS
(00800 275 83927)

**International** +49 (0) 8161 80 2121

**Russian Support** +7 (4) 95 98 10 701

**Fax** +(49) (0) 8161 80 2045

**Internet** support.ti.com/sc/pic/euro.htm

**Direct Email** asktexas@ti.com

### Asia

**Phone**

**International** +91-80-41381665

**Domestic** Toll-Free Number

**Note:** Toll-free numbers do not support mobile and IP phones.

**Australia** 1-800-999-084

**China** 800-820-8682

**Hong Kong** 800-96-5941

**India** 1-800-425-7888

**Indonesia** 001-803-8861-1006

**Korea** 080-551-2804

**Malaysia** 1-800-80-3973

**New Zealand** 0800-446-934

**Philippines** 1-800-765-7404

**Singapore** 800-886-1028

**Taiwan** 0800-006800

**Thailand** 001-800-886-0010

**Fax** +8621-23073686

**Email** tiasia@ti.com or ti-china@ti.com

**Internet** support.ti.com/sc/pic/asia.htm

### Japan

**Phone**

**Domestic** 0120-92-3326

**Fax**

**International** +81-3-3344-5317

**Domestic** 0120-81-0036

**Internet/Email**

**International** support.ti.com/sc/pic/japan.htm

**Domestic** www.tij.co.jp

### Important Notice:
The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

© 2011 Texas Instruments Incorporated

SLYT414
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications. TI is not responsible or liable for any such statements. TI products are neither designed nor intended for use in automotive applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>Communications and Telecom</td>
</tr>
<tr>
<td>Amplifiers</td>
<td>Computers and Peripherals</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Consumer Electronics</td>
</tr>
<tr>
<td>DLP® Products</td>
<td>Energy and Lighting</td>
</tr>
<tr>
<td>DSP</td>
<td>Industrial</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Medical</td>
</tr>
<tr>
<td>Interface</td>
<td>Security</td>
</tr>
<tr>
<td>Logic</td>
<td>Space, Avionics and Defense</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Transportation and Automotive</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Video and Imaging</td>
</tr>
<tr>
<td>RFID</td>
<td>Wireless</td>
</tr>
<tr>
<td>RF/IF and ZigBee® Solutions</td>
<td></td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated