Driving a WLED does not always require 4 V

By Will Hadden
Power Management Products, Portable Power DC/DC Applications

The popularity of white-light-emitting diodes (WLEDs) has skyrocketed, primarily because they are used to provide backlight to portable electronics displays. The common belief is that a single WLED requires a 4-V drive voltage. Since a Li-ion battery provides an average voltage of 3.6 V, the general industry consensus is that a step-up converter is required to power WLEDs from a single-cell Li-ion battery. As a result, many ICs are available for driving WLEDs, most requiring an external inductor or flying capacitors to boost the cell voltage high enough. As WLED technology continues to mature, the forward-voltage requirements continue to drop. Currently, there are many LEDs available with typical forward voltages (V_F) in the 3.2- to 3.5-V range with maximum ratings at 3.7 to 4 V. The datasheets usually specify these voltages at LED currents of around 15 to 25 mA. This article discusses lower-current applications and how they affect the forward voltage of the WLED. It also introduces the Texas Instruments (TI) TPS75105, a new LED driver designed to efficiently drive these lower-voltage LEDs with a reduced solution size and cost.
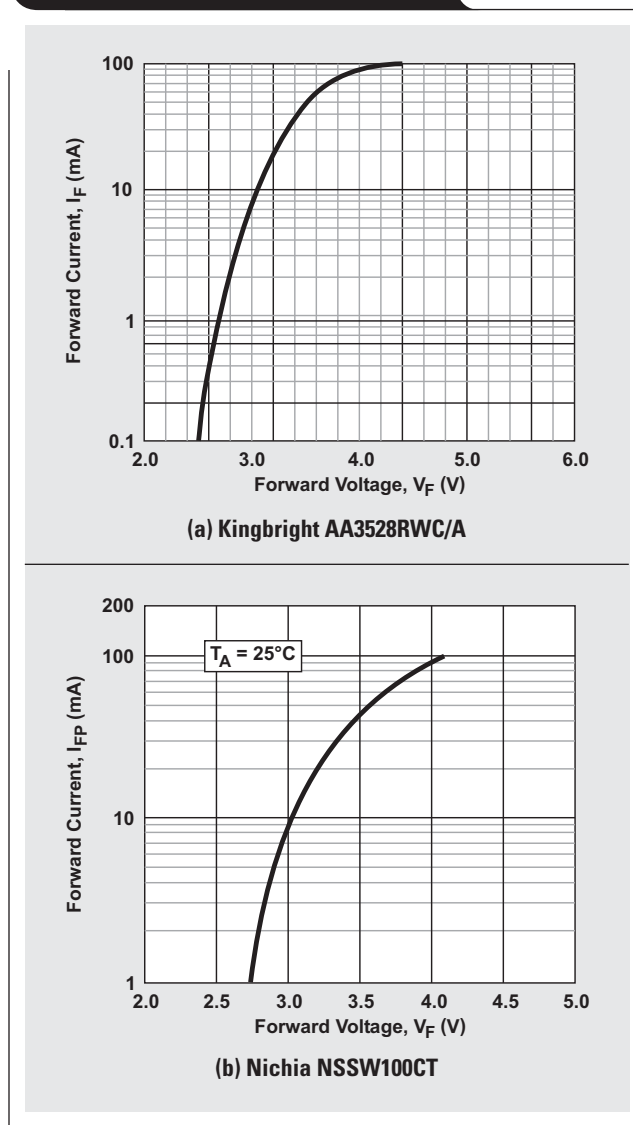
LED forward voltage

The WLED is similar to other standard p-n junction diodes. It does not conduct current until a sufficient forward voltage has been applied. After the threshold is exceeded, the forward current increases with the forward voltage of the WLED. Typical I-V curves for two WLEDs are shown in Figure 1.

Utilizing these graphs is a simple task. As with typical diode I-V curves, the current rises sharply with the voltage after crossing the threshold. The typical forward voltage for the device in Figure 1a is specified to be 3.2 V at 20-mA forward current with a maximum of 3.7 V over process and temperature variations. This leads to the conclusion that the application requires a step-up DC/DC converter to properly drive the WLED from a single Li-ion cell with an output of 3 to 4.2 V. However, this is not necessarily the case. Take, for example, a 5-mA WLED-current application. The curve in Figure 1a shows that the forward voltage required to drive 5 mA is around 2.9 V, which is much less than the typical voltage required to drive 20 mA as specified in the datasheet. A boost converter is not required to drive a 2.9-V output voltage from a 3.6-V Li-ion cell.

WLEDs are specified with a typical value as well as a maximum value to cover lot-to-lot process and manufacturing variations. The I-V curves provided in the datasheet are usually specified with a part that falls at the typical specification. Although the curve shape is valid for every part that is manufactured, the curve shifts to the right or

Figure 1. Typical WLED I-V curves

(a) Kingbright AA3528RWC/A

(b) Nichia NSSW100CT

left depending on the forward voltage at the test conditions for that device. If we use another LED with the same part number as in the previous example, the forward voltage measures 3.7 V (the maximum rating) at the typical test conditions (20-mA forward current). This voltage, which is 0.5 V higher than a typical device, translates to a maximum forward voltage of 3.4 V (2.9 V + 0.5 V) required to drive this WLED at 5 mA. Depending on the cutoff voltage of the application, a boost converter is not needed to drive

this particular WLED at 5 mA. This technique makes it easy to determine the maximum forward voltage for any application.

What about temperature variations?

Some applications require WLEDs to work in harsher conditions with extreme temperatures. Temperature variation affects LED characteristics, but the effect is not as drastic at low current levels as at higher ones. The graph in Figure 2 from a typical WLED datasheet shows forward voltage versus temperature.

This graph shows that the temperature dependence is much stronger with a higher current and forward voltage. Additionally, the forward voltage drops as the temperature increases. The 5-mA curve shows that the forward voltage drops approximately 0.1 V from room temperature (25°C) to the maximum-rated temperature (85°C). This should be taken into account when determining the required forward voltage, but the effect is negligible. If a particular application requires that the LED be driven in a very cold environment, the increased forward voltage may result in lower brightness at low input voltages.

An ultrasmall LED-driver solution

A typical solution for driving multiple WLEDs is to connect them in series and then drive the series string with either an inductive boost converter or a charge pump. This is an excellent method with higher WLED currents that require a higher forward voltage. However, as previously discussed, a boost converter is not required in every WLED driver application. A simpler and lower-cost driver for low-current WLED applications is the ultrasmall TPS75105 LED driver IC. The TPS75105, a linear current source with an ultralow 28-mV dropout voltage, is used for driving four parallel WLEDs in two separate banks. This device provides four 2%-matched current paths in two separately enabled banks. The device is available in the ultrasmall 9-ball, 1.5-mm^2 wafer-chip-scale package (WCSP), requires no external components when using the default current output, and therefore results in an incredibly small 1.5-mm^2 solution size. In addition, the TPS75105 is one of the most inexpensive WLED lighting solutions that TI offers. The application circuit for the TPS75105 is shown in Figure 3.

At first glance, using a low-dropout linear circuit to drive LEDs may seem impractical, given the linear regulator's reputation for low efficiency. However, the efficiency of LDOs is often misunderstood. LDO efficiency is entirely based on the input/output voltage ratio; therefore, the efficiency of driving WLEDs can be quite high. For example, driving a 3-V WLED from a 3.6-V Li-ion battery input

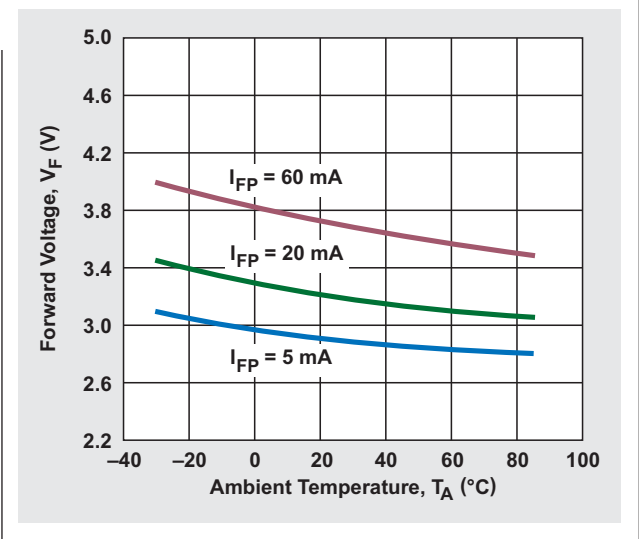Figure 2. Forward voltage vs. temperature (Nichia NSSW100CT)
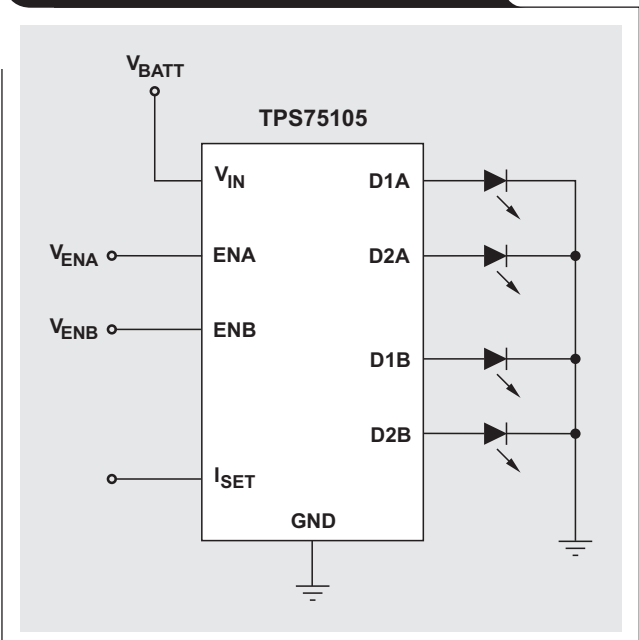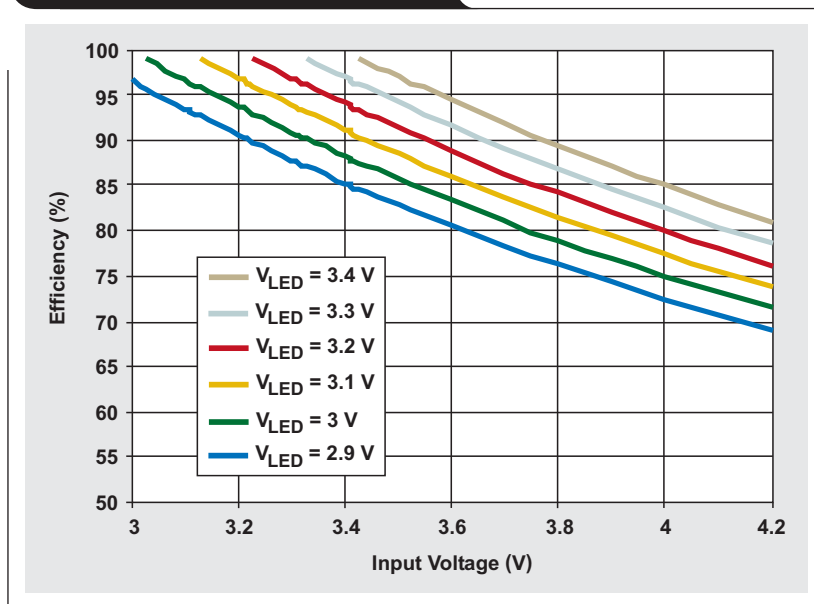

Figure 3. TPS75105 application circuit

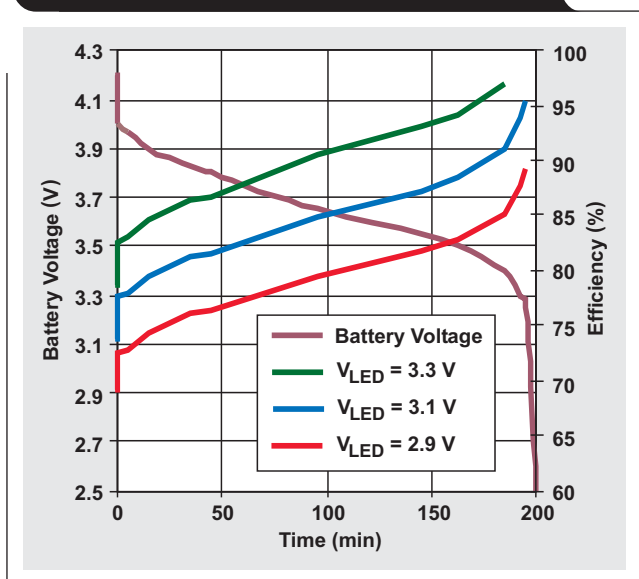**Figure 4. TPS75105 LED efficiency**

translates into an LED efficiency of 83%. Figure 4 shows the TPS75105 efficiency data for several different WLED forward voltages over the Li-ion battery range. The LED efficiency for the TPS75105 is comparable to or better than that of other WLED-driver solutions.

Figure 5 demonstrates the LED efficiency of the TPS7510x over the Li-ion discharge curve. The average efficiency for the entire discharge range is over 80% for all three curves, and up to 90% when V_{LED} = 3.3 V.

While this article concentrates on low-current applications, the TPS7510x can drive up to 25 mA per LED if the input voltage allows. These applications benefit from the very small size.

Figure 5. TPS7510x LED efficiency over the Li-ion discharge curve

Conclusion

When an LED-driver application is evaluated, special consideration should be given to how much current the application requires. If it is well below the current at which the application's WLED V_F is specified, the WLED datasheet I-V curves should be reviewed to determine the actual V_F in the application. The application may be able to use a low-dropout linear current source such as the TPS75105 to achieve an ultralow solution size and low cost without sacrificing the efficiency of a switching step-up converter.

References

For more information related to this article, you can download an Acrobat Reader file at www-s.ti.com/sc/techlit/ *litnumber* and replace *"litnumber"* with the **TI Lit. #** for the materials listed below.

Document Title	TI Lit. #
1. Kingbright Corporation, City of Industry, CA, AA3528RWC/A Datasheet, Spec. No. DSAG3655.	—
2. "Specifications for Nichia Chip Type White LED," Nichia Corporation, NSSW100CT Datasheet, No. STSE-CC6014B.	—
3. "Low Dropout, Two-Bank LED Driver with PWM Brightness Control," TPS7510x Datasheet	.sbvs080
4. TPS75105EVM User's Guide	.slvu182

Related Web sites

power.ti.com
www.ti.com/sc/device/TPS75105

Products	
Amplifiers	**amplifier.ti.com**
Data Converters	**dataconverter.ti.com**
DSP	**dsp.ti.com**
Interface	**interface.ti.com**
Logic	**logic.ti.com**
Power Management	**power.ti.com**
Microcontrollers	**microcontroller.ti.com**

Applications	
Audio	**www.ti.com/audio**
Automotive	**www.ti.com/automotive**
Broadband	**www.ti.com/broadband**
Digital control	**www.ti.com/digitalcontrol**
Military	**www.ti.com/military**
Optical Networking	**www.ti.com/opticalnetwork**
Security	**www.ti.com/security**
Telephony	**www.ti.com/telephony**
Video & Imaging	**www.ti.com/video**
Wireless	**www.ti.com/wireless**

TI Worldwide Technical Support

Internet

TI Semiconductor Product Information Center Home Page
support.ti.com

TI Semiconductor KnowledgeBase Home Page
support.ti.com/sc/knowledgebase

Product Information Centers

Americas

Phone	+1(972) 644-5580	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

Note: The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

Fax	+(49) (0) 8161 80 2045
Internet	support.ti.com/sc/pic/euro.htm

Japan

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/pic		

Asia

Phone			
International	+886-2-23786800		
Domestic	Toll-Free Number		Toll-Free Number
Australia	1-800-999-084	Malaysia	1-800-80-3973
China	800-820-8682	New Zealand	0800-446-934
Hong Kong	800-96-5941	Philippines	1-800-765-7404
India	+91-80-41381665 (Toll)	Singapore	800-886-1028
Indonesia	001-803-8861-1006	Taiwan	0800-006800
Korea	080-551-2804	Thailand	001-800-886-0010
Fax	+886-2-2378-6808	Email	tiasia@ti.com
Internet	support.ti.com/sc/pic/asia.htm		ti-china@ti.com

C062907

SLYT284