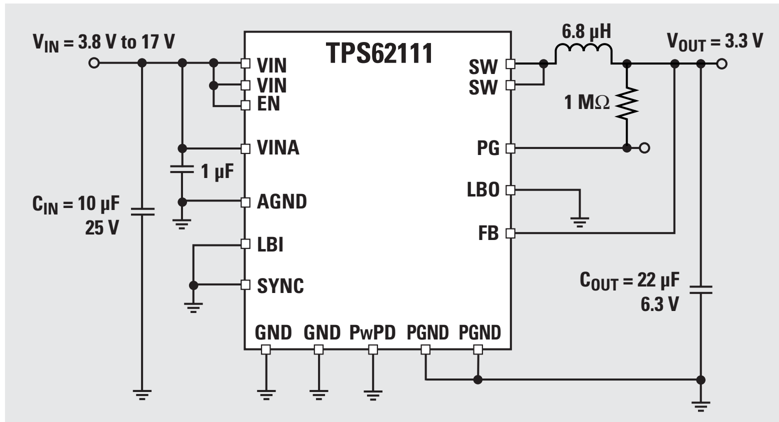
Practical considerations when designing a power supply with the TPS6211x

By Jeff Falin, *Power Management Products/Portable Power dc/dc Applications* (Email: j-falin1@ti.com),
and Bill Johns, *Power Management Products/Portable Power dc/dc Applications* (Email: w-johns2@ti.com)

The TPS6211x dc/dc converter is a synchronous buck converter capable of input voltages up to 17 V, output voltages from 1.2 to 16 V, and output currents up to 1.5 A. The device efficiently steps down 2-cell Li-ion or lead-acid batteries, or 12- to 15-V system rails, to 5 V, 3.3 V, or lower. A typical application circuit is shown in Figure 1.

This article provides an example application and summarizes the key features of designing with the TPS6211x buck converter.

Figure 1. Typical application



External component sizing

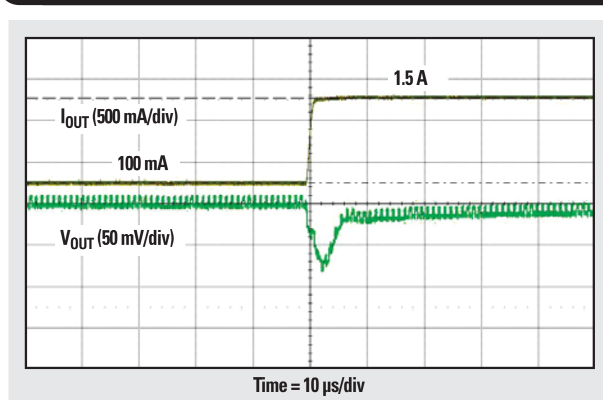
Integrated FETs and internal compensation reduce the required number of external parts to very few. Assuming that the integrated output-voltage and input-voltage supervisory circuits are not used, the fixed-output-voltage (5-V or 3.3-V) versions need only four components: an input capacitor for the power switches, an input filter capacitor for the analog input pin, an output capacitor (C), and a power inductor (L). The device has been internally compensated to work with an L of 6.8 µH and a C of at least 22 µF. Other values of L and C will provide satisfactory operation, and increasing either or both values will reduce output ripple. It is recommended that the LC product remain close to the minimum of 6.8 µH × 22 µF for stability. Two additional feedback resistors and a feed-forward capacitor are required for the adjustable version, which provides output voltages from 1.2 to 16 V. The output voltage supervisory circuit (called power good, or PG, output) provides a logic high when the output is above approximately 98.6% of its nominal voltage. The low-battery indicator is a stand-alone supervisory circuit, active only after EN is pulled high, with a low-battery input (LBI) that is intended to monitor battery input voltage and a low-battery output (LBO) that provides a logic low when the input voltage drops below a certain voltage. LBI requires two external feedback resistors to set the trip point and, if not used, should be pulled low as shown in Figure 1. Both PG and LBO are open-drain outputs providing for maximum user flexibility and therefore require pull-up resistors if used but can be left floating if not used.

Output voltage regulation versus output current

The device's proprietary control architecture ensures that the output voltage maintains ±3% output voltage regulation (excluding feedback resistor tolerances) across input line and output load changes. For 17 V > V_{IN} > 6 V, the IC's high-voltage PMOS FET has plenty of gate drive to provide ±3% regulation from no load to 1.5 A. At lower input voltages, the IC still provides ±3% regulation from no load up to 1.2 A for 6 V > V_{IN} > 4.3 V; 500 mA for 4.3 V > V_{IN} > 3.5 V; and 300 mA for 3.5 V > V_{IN} > 3.1 V. Using a high-side PMOS FET allows 100% duty-cycle operation, during which time the output is tied directly to a nearly depleted battery to maximize battery life.

Assuming that the recommended output-filter product is used, the device is compensated to provide excellent load-transient performance. Therefore, fast changes in output load do not result in significant output-voltage droop before the control loop responds. As shown in Figure 2, the output voltage droops less than 100 mV during a 1-A

Figure 2. The 1-A load transient going from 12 to 3.3 V when L = 6.8 µH and C = 22 µF

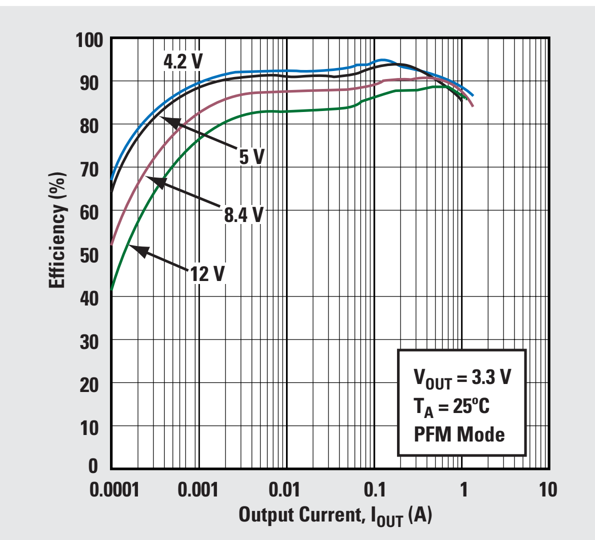


load transient (in forced pulse-width modulation [PWM] mode) with a small 22-µF output capacitor. A larger output capacitor reduces the droop even further.

PWM versus power-save mode

Efficiency varies inversely with the input to output voltage differential for all converters. In addition, efficiency drops dramatically at light loads for fixed-frequency PWM converters due to the IC's quiescent current and switching losses dominating the output power being provided. To improve efficiency at light load, the TPS6211x has a pulse-frequency modulation (PFM), or power-save, mode that is enabled by tying the SYNC pin low. Efficiency curves for V_{OUT} = 3.3 V and for various input voltages with power-save mode enabled are shown in Figure 3.

Figure 3. Efficiency of 3.3-V fixed-output version of TPS62111 with power-save mode enabled



In power-save mode, the TPS6211x's quiescent current is reduced, and the switches turn on only long enough to keep the output voltage in regulation for a given load current. This type of operation causes the output-voltage ripple to be slightly higher (up to 1% of the output voltage) and to vary in frequency until being transitioned back to fixed-frequency PWM mode at currents above approximately 280 mA for V_{IN} > 7 V. In power-save mode there is no minimum duty cycle. Low $r_{DS(ON)}$ FETs with copper overlay reduce I^2R losses and keep efficiency high at heavy load as well.

The TPS6211x can be forced into fixed-frequency PWM mode, resulting in extremely low-amplitude, fixed-frequency output ripple (typically < 10 mV_{PP}) across the entire load range, either by pulling SYNC high to V_{IN} or by tying it to an external oscillator. Pulling SYNC high results in the 1-MHz, fixed-frequency operation. The device can be synchronized through the SYNC pin to an external oscillator with a frequency between 800 kHz and 1.4 MHz. In addition, since the synchronous FET allows current to flow back to the input, there is always current flowing though the inductor, keeping it in continuous conduction mode over the entire load range. This eliminates the ringing that occurs at the switch node after other converters enter discontinuous mode. Therefore, at the expense of slightly lower efficiency at light load, forcing the TPS6211x into PWM mode provides extremely low-noise operation.

Output power

The TPS6211x's 4-mm × 4-mm QFN package with PowerPAD™ has a junction-to-pad thermal resistance ($R_{\Theta JP}$) of 8°C/W and a junction-to-ambient thermal resistance ($R_{\Theta JA}$) of approximately 40°C/W for a high-K board with no air flow. With power dissipation computed as $P_{Dmax} = (T_{Jmax}–T_A)/R_{\Theta JA}$, maximum output power is computed as $P_{OUTmax} = P_{Dmax}/(1/\eta – 1)$, where T_{Jmax} = 125°C and η is the expected efficiency. For example, with typical efficiencies of 85% and 89% at I_{OUT} = 1.5 A, the 3.3- and 5-V fixed-output versions can easily provide 4.95 and 7.5 W, respectively, from a 12-V input rail at 85°C ambient temperature.

Typical applications

The TPS6211x family of buck converters is ideally suited for a wide range of applications. For example, in the computing world, the converter's fast transient response is useful for stepping down 12-V input rails to the 5- or 3.3-V (or lower) rails that power fast-switching digital ICs in a server/workstation or in a personal printer. Consumer applications such as set-top boxes, which typically have 12-V ac/dc power supplies, and portable DVD players, with either 9-V/12-V wall adapters or dual Li-ion (8.4-V nominal) input power, have traditionally needed their input rails stepped down to a 5- and/or 3.3-V midrange bus voltage for I/O power. Further down-conversion of these bus voltages by additional dc/dc switchers and/or linear regulators to power the lower-voltage ICs in the box is also required. However, with its high-efficiency, low-noise operation and low minimum duty cycle, the TPS6211x can power the lower-voltage (e.g., 2.5-V, 1.x-V) processors and peripherals directly, thereby eliminating the midrange bus and improving efficiency and battery life, if applicable. Since 12- and 15-V rails are common in industrial applications, this converter, with its low-noise mode and synchronization feature, could be useful as a point-of-load regulator powering a data acquisition system. Lastly, 2-cell Li-ion and lead-acid battery-powered systems such as battery-backup or alarm systems use the LBI/LBO feature, high efficiency, and 100% duty cycle mode to provide maximum operation time by extending battery life.

Related Web sites

power.ti.com
www.ti.com/sc/device/TPS62111

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

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			
Belgium (English)	+32 (0) 27 45 54 32	Netherlands (English)	+31 (0) 546 87 95 45
Finland (English)	+358 (0) 9 25173948	Russia	+7 (0) 95 363 4824
France	+33 (0) 1 30 70 11 64	Spain	+34 902 35 40 28
Germany	+49 (0) 8161 80 33 11	Sweden (English)	+46 (0) 8587 555 22
Israel (English)	180 949 0107	United Kingdom	+44 (0) 1604 66 33 99
Italy	800 79 11 37		
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	+91-80-51381665 (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

C120905

Mailing Address: Texas Instruments
Post Office Box 655303
Dallas, Texas 75265