

Turbo-boost charger supports CPU turbo mode

By Jinrong Qian, *Product Line Manager*,
and Suheng Chen, *Design Engineer*

Introduction

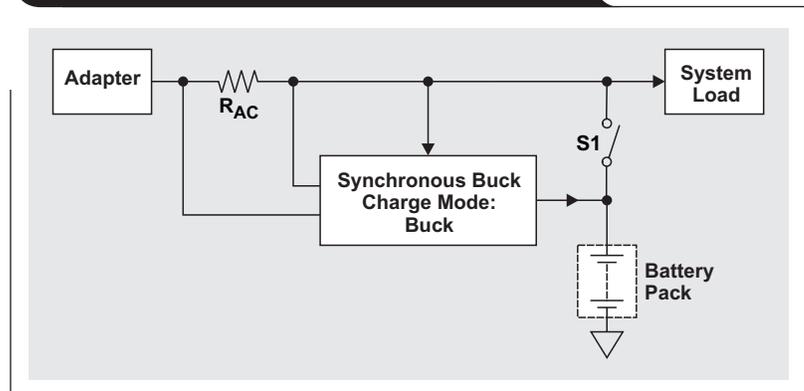
To continuously improve a CPU's dynamic performance for fast processing of multiple complicated tasks in mobile computers, it is essential to increase the CPU frequency with full utilization of the CPU's thermal capability in a short time period. This could cause the total power required by the system to exceed the power delivered from a power source like an AC adapter, which may result in crashing the adapter. One possible solution is to increase the adapter's power rating, but at a higher cost. This article discusses the turbo-boost charger, which allows the adapter and battery to power the system simultaneously to meet instantaneous and excessive power demands from a notebook computer system operating in CPU turbo mode.

In traditional mobile computer systems, an AC adapter provides the power, and any power not needed by the system is used to charge the battery. When an AC adapter is not available, the battery provides power to the system by turning on switch S1 (see Figure 1). The adapter can be used to power the system and charge the battery simultaneously, which may require it to have a high power rating, increasing both its size and its cost without active control. Dynamic power management (DPM) typically is used to accurately monitor the total power drawn from the adapter, which gives high priority to powering the system.

Once the adapter's power limit is reached, the DPM control system regulates the input current (power) by reducing the charge current, providing power directly from the adapter to the system without power conversion for optimum efficiency. With the heaviest system load, all the adapter power is used to power the system without charging the battery at all. Therefore, the main design criterion is to make sure that the adapter's power rating is high enough to support peak CPU power and other system power.

To meet the increasing demand for improved system performance in processing complicated tasks fast with multiple CPU cores and enhanced graphics processor units (GPUs), Intel developed its turbo-boost technology in the Sandy Bridge processors. This technology allows processors to burst their power above the thermal design

Figure 1. Adapter and battery-charger system



power (TDP) for a short time period in the range from a few tens of milliseconds to tens of seconds. However, an AC adapter is designed to provide the power just above the demand from the processors and platform at a TDP level considering the design tolerance. When a charger system detects that the adapter has reached its input power rating after its charge current has been reduced to zero through DPM, the simplest way to avoid crashing the AC adapter is to achieve CPU throttling by reducing the CPU frequency, which compromises system performance. How can the CPU be operated faster at above the TDP level for a short time period without crashing the adapter or increasing its power rating?

Turbo-boost battery charger

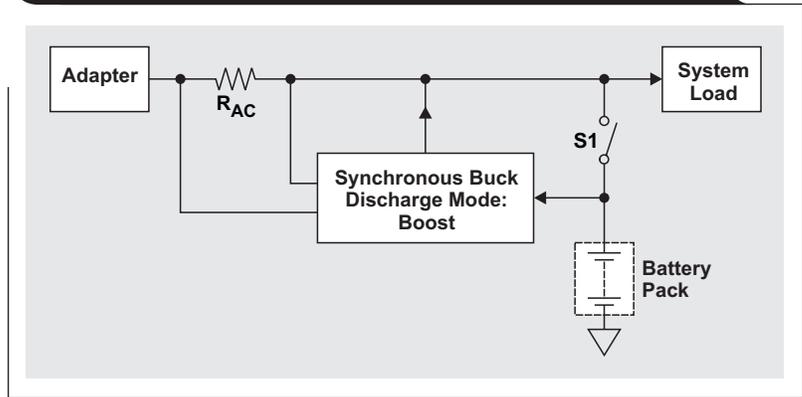
When the total power required by the system load and battery charger reaches the adapter's power limit, DPM starts to reduce the battery's charge current. The battery charger stops charging, and its charge current is reduced to zero when the system load alone reaches the AC adapter's power limit. As the system continues to increase its load during the CPU turbo mode, the battery charger, which is usually a synchronous buck converter, is idle, as no remaining power is available to charge the battery. The synchronous buck converter is actually a bidirectional DC/DC converter that can operate in either buck or boost mode, depending on the operating conditions. If the battery has enough capacity, the battery charger can operate in boost mode to provide power to the system in addition

to the power from the AC adapter. Figure 2 shows a block diagram of a turbo-boost battery charger.

When and how does the battery charger start to transition from buck charge mode to boost discharge mode? The system can enter CPU turbo mode at any time, and it is usually too late to inform the charger to initiate this transition through an SMBus. The charger should automatically detect which operating mode is needed. It is also critical that the system be designed to achieve a fast transition from buck to boost mode and vice versa. A DC/DC converter needs a soft-start time of a few hundred microseconds to a few milliseconds to minimize the inrush current. The adapter should have a strong overloading capability to support the whole system's peak power before the charger transitions into boost discharge mode. Most of the AC adapters currently available can hold their output voltage over a few milliseconds.

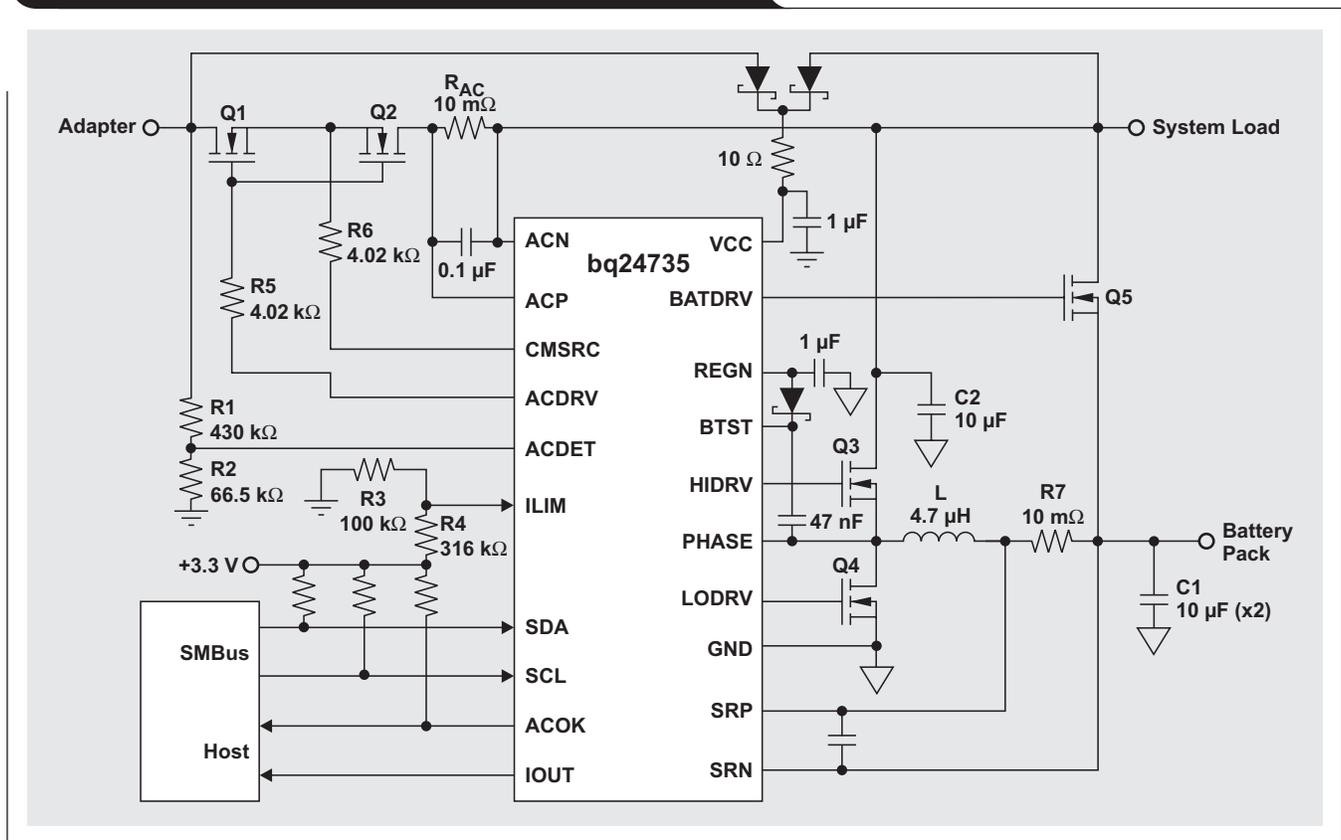
Figure 3 shows an application circuit for a turbo-boost battery charger supporting CPU turbo mode. The R_{AC} current-sense resistor is used to detect the AC adapter current for the DPM function and to determine whether the battery charger is operating in buck charge mode or boost discharge mode. Current-sense resistor R7 is used

Figure 2. Turbo-boost battery charger in CPU turbo mode



to sense the battery charge current programmed from the host through the SMBus based on the battery conditions. The total power drawn by both the charger and the system can be monitored through the I_{OUT} output, which is 20 times the voltage drop across sense resistor R_{AC} for achieving CPU throttling, if needed. Through SMBus control registers, the battery's boost discharge mode can be enabled or disabled based on the battery's state of charge and temperature conditions. In boost discharge mode, the circuit provides additional cycle-by-cycle current-limit protection by monitoring the voltage drop across the

Figure 3. Application circuit for turbo-boost battery charger



low-side MOSFET, Q4. To achieve a small form factor for a notebook computer like Intel's Ultrabook™, the switching frequency can be programmed at 615, 750, or 885 kHz. This minimizes the inductor size and the number of output capacitors. To further reduce the number of external components, the charger's controller chip fully integrates the loop compensators for the charge current, the charge voltage, and the input-current regulation loops. The power-source selector MOSFET controller is also integrated in the charger. Furthermore, the charger system uses all n-channel MOSFETs for cost reduction instead of the p-channel power MOSFETs used in traditional charge solutions. Another benefit of this turbo-boost charger system is that it can be used for either function without changing the bill of materials. System designers can do a quick system-performance evaluation without additional hardware-design effort.

Figure 4 shows the switching waveforms that occur during the transition from buck charge mode to boost discharge mode. When the input current reaches the adapter's maximum power limit due to a system-load increase, the battery charger stops charging and the battery transitions into boost mode to provide additional power to the system.

Figure 5 shows the efficiency of the turbo-boost charger. It can be seen that over 94% efficiency is achieved for charging and discharging a 3-cell or 4-cell battery pack. If the battery is removed or the battery's remaining capacity is not high enough, it is necessary to throttle the CPU to avoid the adapter crash.

Now the battery can be discharged even when the adapter is connected. However, one possible concern is the battery cycle life. Since the boost discharge mode lasts from only tens of milliseconds to tens of seconds, the impact on battery cycle life will be minimal. Battery degradation is proportional to the battery-cell voltage; so the higher this voltage is, the faster the battery will degrade and the shorter its cycle life will be. Discharging the battery in the boost discharge mode results in a lower battery-cell voltage, reducing the degradation of the battery and lengthening its cycle life.

Conclusion

A turbo-boost charger is a simple and cost-effective way for a battery to supplement AC adapter power for short periods when an AC adapter and battery simultaneously power the system. This topology supports CPU turbo mode while ensuring the lowest system cost without the need

Figure 4. Waveforms between buck charge mode and boost discharge mode

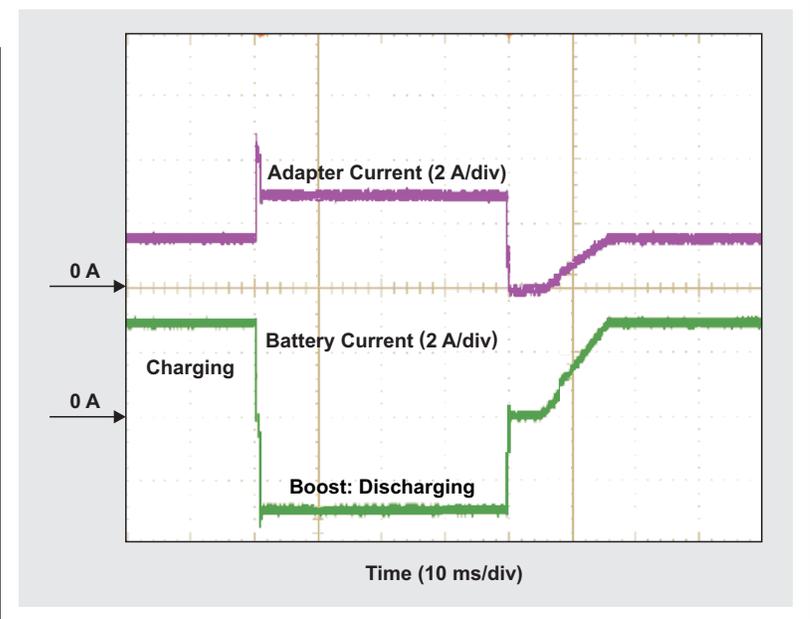
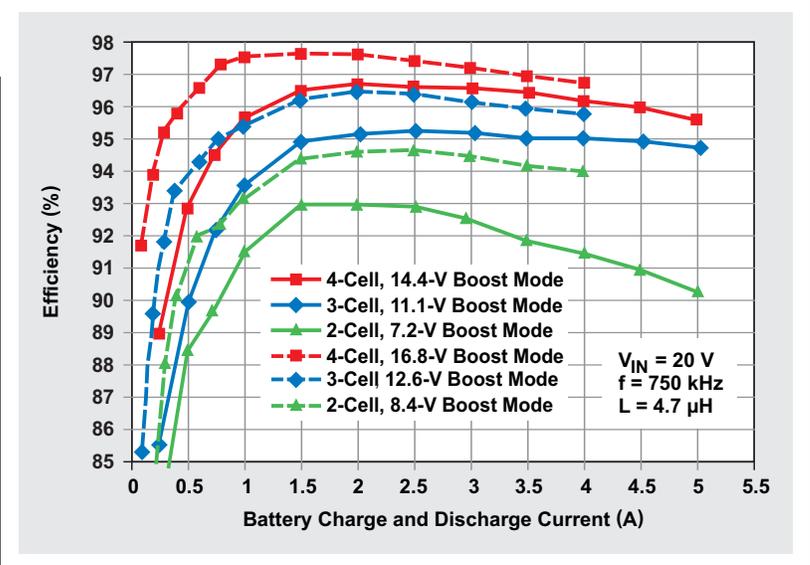


Figure 5. Efficiency of turbo-boost charger



for upgrading to an AC adapter rated for peak system power. The test results show that the turbo-boost charger is a practical solution in real mobile-computer designs.

Related Web sites

power.ti.com
www.ti.com/product/bq24735

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

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	www.ti.com/asktexas
Direct Email	asktexas@ti.com

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/pic

Asia

Phone	
International	+91-80-41381665
Domestic	<u>Toll-Free Number</u>
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

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.

A011012

E2E is a trademark of Texas Instruments. Ultrabook is a trademark of Intel Corporation. All other trademarks are the property of their respective owners.

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 any 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, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

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:

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2012, Texas Instruments Incorporated