Li-ion battery-charger solutions for JEITA compliance

By Jinrong Qian

Sector Manager, Battery Charge Management – Advanced Portable

Introduction

Lithium-ion (Li-ion) batteries tend to become dangerous when they are overcharged at high temperatures. Safely charging these batteries has become one of the most important design specifications in battery-powered portable equipment. Progress has been made in establishing industry standards such as the Japan Electronics and Information Technology Industries Association (JEITA) guidelines for improving battery-charging safety. This article addresses safety requirements and battery-charger solutions that meet these requirements in both notebook and single-cell handheld applications.

Battery-charger safety and the JEITA guidelines

Widely used in consumer electronics from cell phones to laptops, Li-ion batteries have the highest volumetric and gravimetric energy densities among the rechargeable batteries, with no memory effect. They also have a self-discharge rate that is 10 times lower than that of NiMH batteries, and they can provide the instant power required by the system; but are they safe?

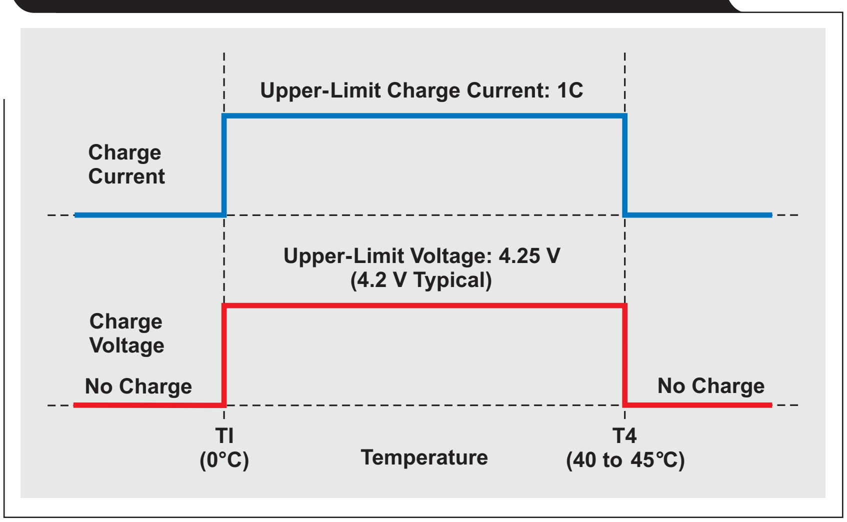
Everyone in the industry has seen pictures of exploding laptops and heard about the massive and unprecedented recalls of Li-ion batteries due to cell safety concerns. Such battery explosions or fires originated within the manufacturing process. Batteries contain several metal parts that can sometimes result in undesirable metal impurities within the cell. These impurities are typically sharp metal shards from the battery casing or from electrode materials. If these shards get between the battery's electrode and separator, battery cycling in the negative electrode can eventually cause the shards to puncture the separator. This results in a microshort between the positive and negative electrodes, producing high heat that may ultimately result in fire and/or an explosion.

High temperatures, fire, and explosions are all results of thermal runaway—a condition whereby a battery enters into an uncontrollable reaction. Thermal runaway is a process in which the internal temperature of a battery with $LiCoO_2$ as the cathode material and graphite as the anode material reaches approximately 175°C. This is an irreversible and highly exothermic reaction that can cause a fire, usually when the battery is charging.

Figure 1 shows the charge current and charge voltage over temperature commonly used in the older Li-ion-battery-charging systems that are prone to thermal runaway. Both the battery charge current and charge voltage are constant over the cell temperature from 0 to 45°C. High cell temperatures not only speed up battery aging but also increase the risk of battery failure.

To improve the safety of charging Li-ion batteries, JEITA and the Battery Association of Japan released new safety guidelines on April 20, 2007. Their guidelines emphasized the importance of avoiding a high charge current and high charge voltage at certain low and high temperature ranges. According to JEITA, problems in the Li-ion batteries occur at high charge voltages and high cell

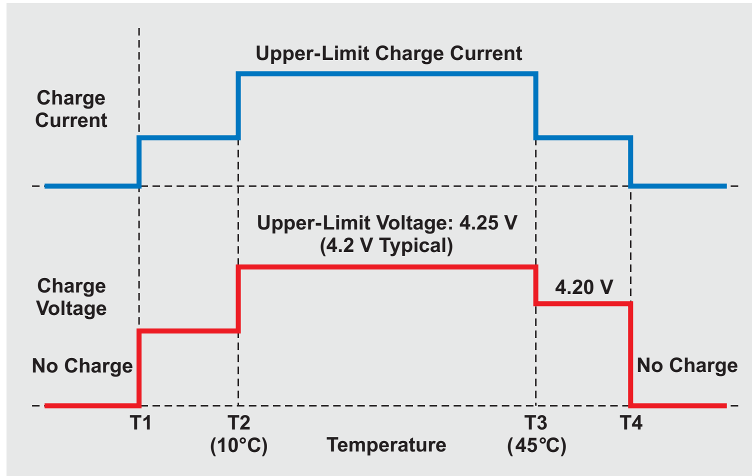
Figure 1. Upper-limit charge current and charge voltage in older Li-ion-battery-charging systems



temperatures. Figure 2 shows the JEITA guidelines for the charge current and charge voltage over cell temperature for batteries used in notebook applications. These batteries have $LiCoO_2$ as the cathode active material and graphite as the anode active material.

In the standard charging temperature range from T2 to T3, a Li-ion cell can be charged in the optimal conditions of the upper-limited charge voltage and the upper-limited charge current recommended by the cell's manufacturer for safety.

Figure 2. JEITA guidelines for charging Li-ion batteries in notebook applications



Charging at low temperatures

If the cell's surface temperature becomes lower than T2 during charging, the lithium ions could each gain one electron and become metallic lithium. This metallic lithium is likely to deposit on the anode, because at low temperatures the transfer rate decreases and the penetration of lithium ions into the negative electrode carbon slows down. Such metallic lithium could easily react with electrolyte, causing permanent loss of the lithium ions, which degrades the battery faster. In addition, the chemical reaction between metallic lithium and the electrolyte generates a lot of heat, which could lead to thermal runaway. Therefore, the charge current and charge voltage are reduced at low cell temperatures. If the temperature is further reduced to T1 (0°C as an example), the system should not allow charging.

Charging at high temperatures

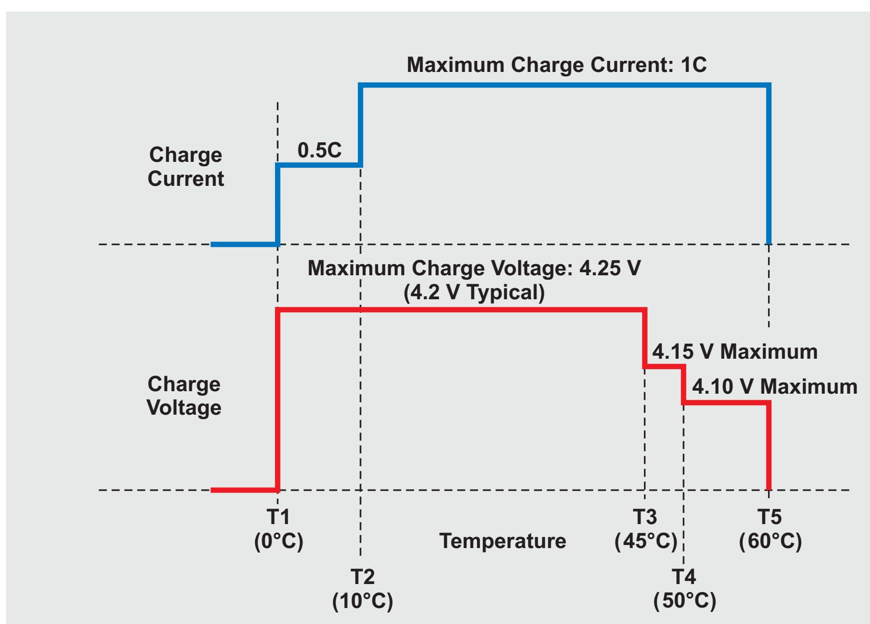
If the cell's surface temperature rises above T3 (45°C as an example) during charging, the cathode material, $LiCoO_2$, starts to become more active and can chemically react with the electrolyte when the cell voltage is high. If the cell temperature is further increased to T4, the system should prohibit charging. If the cell temperature reaches 175°C with a cell voltage of 4.3 V, thermal runaway may occur and the battery may explode.

Similarly, Figure 3 shows the JEITA guidelines for charging Li-ion batteries in single-cell handheld applications, where the charge current and charge voltage are also functions of the cell temperature. The maximum charge voltage of 4.25 V includes the battery charger's full tolerance. The battery can be charged at up to 60°C with a reduced charge voltage for safety.

Battery-charger solutions for meeting JEITA guidelines

The smart battery pack, which includes a fuel gauge, analog front end, and second-level protector, is commonly used in notebook applications. The fuel gauge provides the battery's cell voltage, charge and discharge current, cell temperature, remaining capacity, and run time to the system through SMBus for optimizing the system performance. The bq20z45 and bq20z40 fuel gauges with Impedance Track™ technology, recently developed by

Figure 3. JEITA guidelines for charging Li-ion batteries in single-cell handheld applications

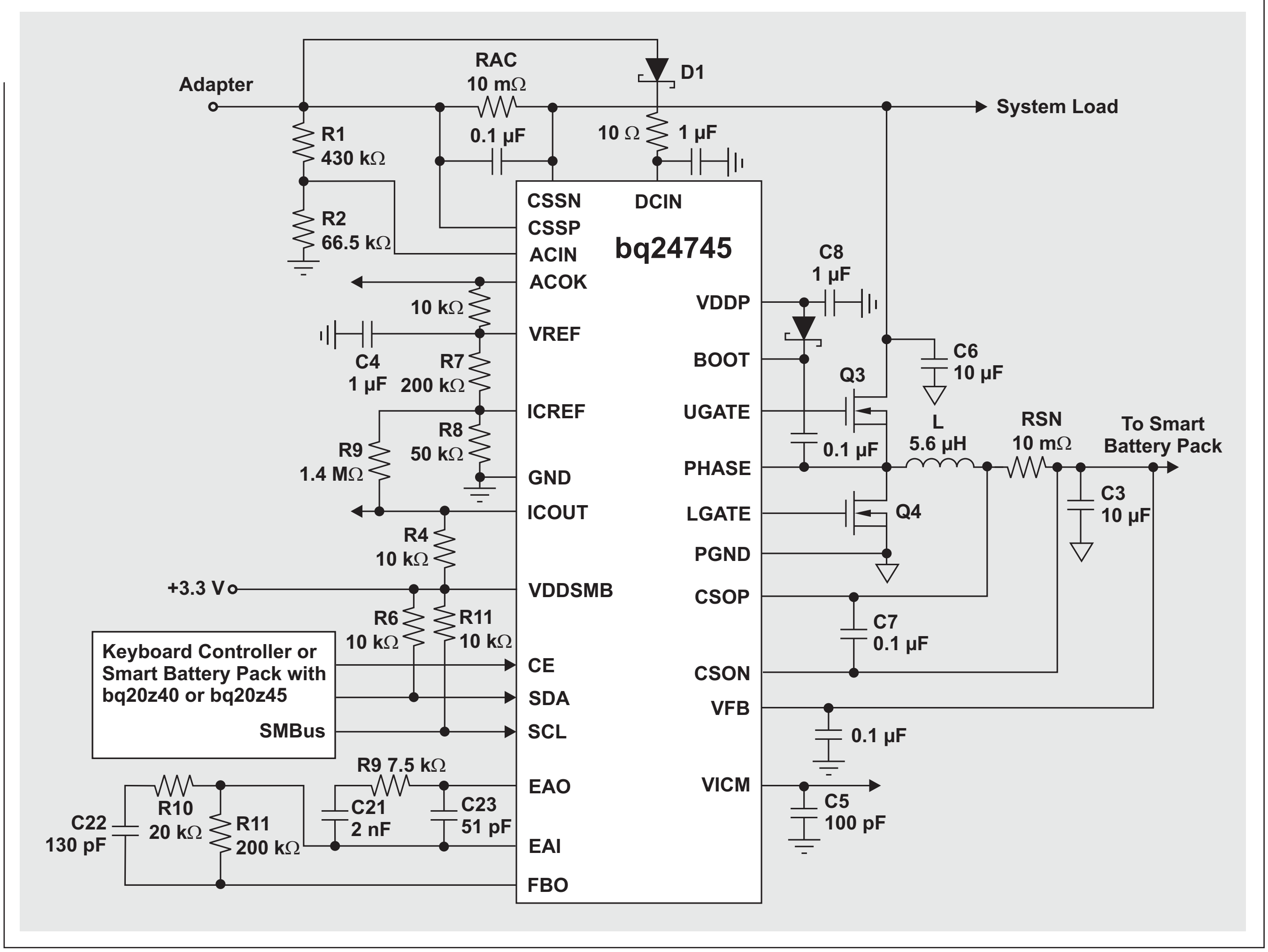


Texas Instruments (TI), include a series of flash-memory constants for flexibly programming the battery's charge current and charge voltage based on the JEITA guidelines. The temperature thresholds are user-programmable and provide flexibility for meeting different specifications with different applications. The fuel gauge usually broadcasts the charge current and voltage information to the smart battery charger or keyboard controller for periodically setting the proper charge current and voltage. An SMBus-controlled battery charger, such as the TI bq24745, can be used as a slave device to get the charge voltage and current information from a smart battery pack with either the bq20z40 or the bq20z45 fuel gauge.

Figure 4 shows a schematic of a smart battery charger with a smart battery pack that complies with the JEITA guidelines for notebook applications. This SMBus-controlled battery charger with a synchronous switching buck converter can support Li-ion batteries with one to four cells and a charge current of up to 8 A. The dynamic power-management function allows charging the battery and powering the system simultaneously without increasing the adapter's power rating.

The battery pack in single-cell portable devices usually has the cell and a safety protector but uses the charger instead of a fuel gauge to monitor the cell temperature and adjust the charge voltage and current. TI's bq24050 single-cell linear battery charger was designed to meet the JEITA specifications for handheld devices. It reduces the charge current by half when the cell temperature is between 0°C and 10°C, and reduces the charge voltage to

Figure 4. Smart battery charger bq24745 with fuel gauge bq20z40 or bq20z45



4.06 V when the cell temperature is between 45°C and 60°C. Figure 5 shows a typical application circuit with the bq24050 linear charger. The charger monitors the battery's cell temperature via the thermistor (TS) pin and adjusts the charge current and voltage when the monitored temperature reaches the threshold.

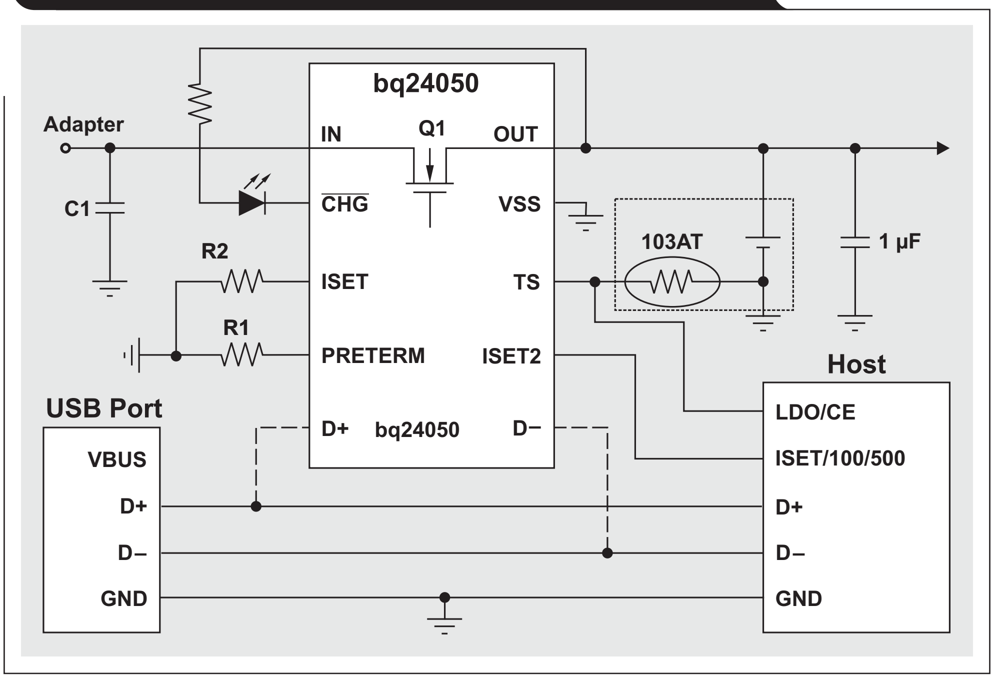
Conclusion

Charging Li-ion batteries safely is critical and has become one of the key specifications for charger design. Reducing the charge current and voltage at lower and higher temperature ranges as JEITA recommends can significantly improve the safety of charging these batteries. Both switch-mode and linear battery-charger solutions that comply with JEITA guidelines have been presented.

Related Web sites

power.ti.com
www.ti.com/sc/device/*partnumber*
Replace *partnumber* with bq24050, bq24745, or bq24747

Figure 5. Typical single-cell application circuit with JEITA-compliant linear battery charger



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	support.ti.com/sc/pic/euro.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/pic

Asia

Phone

International	+91-80-41381665
Domestic	Toll-Free Number
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	+886-2-2378-6808
Email	tiasia@ti.com or ti-china@ti.com
Internet	support.ti.com/sc/pic/asia.htm

IMPORTANT NOTICE

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

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DLP® Products	www.dlp.com	Communications and Telecom	www.ti.com/communications
DSP	dsp.ti.com	Computers and Peripherals	www.ti.com/computers
Clocks and Timers	www.ti.com/clocks	Consumer Electronics	www.ti.com/consumer-apps
Interface	interface.ti.com	Energy	www.ti.com/energy
Logic	logic.ti.com	Industrial	www.ti.com/industrial
Power Mgmt	power.ti.com	Medical	www.ti.com/medical
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Space, Avionics & Defense	www.ti.com/space-avionics-defense
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video and Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless-apps

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