

# Selecting the right charge-management solution

By Masoud Beheshti

Director/Product Line Manager

## Introduction

Today's designers of portable devices have choices of many types of battery chemistries, charger topologies, and charge-management solutions. Selecting the right solution should be simple, but in most cases it is a bit complicated. The designer needs to strike a balance between performance, cost, form factor, and other key requirements. This article provides an overview of several portable-power solutions.

## The three C's of charge management

Charge management is a critical function in any portable design utilizing rechargeable batteries. Sound design techniques ensure that requirements for the following three considerations are met (see Table 1):

1. *Cell safety*—This is not limited to a simple requirement like, for example, meeting the voltage-regulation tolerance of  $\pm 1\%$  during the final phase of charge for a Li-Ion battery. Safety functions also include safety timers, cell-temperature monitoring, and a preconditioning mode to safely handle deeply discharged cells.
2. *Cell capacity*—Any charge-management solution needs to ensure that the batteries are charged to full capacity in every cycle. Early charge termination results in reduced run time and is not desirable in today's power-hungry portable devices.
3. *Cell cycle life*—Adhering to the recommended charge algorithm is an important step towards ensuring that the end user gets the maximum number of charge cycles from each pack. Qualifying each charge with the cell temperature and voltage, preconditioning deeply discharged cells, and avoiding late or improper charge termination are some of the steps necessary for maximizing cycle life.

## Managing battery-chemistry requirements

System designers today have the option to select from a variety of battery chemistries. The selection is typically based on a number of criteria, including energy density; size and form factor; cost; and usage pattern and cycle life. Although there has been a strong trend towards Li-Ion and Li-Pol chemistries in recent years, the NiCd and NiMH chemistries are still viable options for a variety of consumer applications.

Table 1. The three C's of charge management

CHARGE FEATURE	CELL SAFETY	CELL CAPACITY	CELL CYCLE LIFE
Accurate voltage and/or current regulation	✓	✓	
Charge qualification (voltage and temperature)	✓		✓
Temperature monitoring	✓	✓	✓
Preconditioning	✓	✓	✓
End-of-charge termination	✓	✓	✓
Charge timer	✓		
Charge-status reporting	✓	✓	
Detection of battery insertion and removal	✓		
Minimal battery drainage		✓	
Short-circuit current limit	✓		
Automatic recharge		✓	

Regardless of the choice of chemistry, it is critical to adhere to the appropriate charge-management techniques for each chemistry. These techniques ensure that batteries are charged to their maximum capacities in every cycle without compromising safety or cycle life.

### NiCd/NiMH

Before a fast-charge cycle starts, NiCd and NiMH batteries must be qualified and possibly conditioned. Fast charge is prohibited if the battery voltage or temperature is outside the allowed limits. For safety, any charging of a "hot" battery (typically above 45°C) is suspended until the battery cools to the normal operating-temperature range. To condition a "cold" battery (typically below 10°C) or an over-discharged battery (typically below 1 V per cell), a gentle trickle current is applied.

Fast charge begins when the battery temperature and voltage are valid. NiMH batteries are typically charged with a constant current of 1C or less. Certain NiCd batteries can be charged at rates of up to 4C. Proper charge termination is required to prevent harmful overcharge.

For nickel-based rechargeable batteries, fast-charge termination can be based on either voltage or temperature.

As shown in Figure 1, a typical voltage-termination method is peak-voltage detection (PVD), where fast charging is terminated within a range of 0 to  $-4$  mV per cell of the peak cell voltage. The temperature method monitors the rate of battery temperature rise,  $\Delta T/\Delta t$ , to detect full charge. The typical  $\Delta T/\Delta t$  rate is  $1^\circ\text{C}/\text{minute}$ .

### Li-Ion/Li-Pol

Similar to NiCd and NiMH batteries, Li-Ion and Li-Pol batteries must be qualified and possibly conditioned before fast charge. A qualification and conditioning method similar to the one described earlier is used.

As shown in Figure 2, following qualification and preconditioning, a lithium-based battery is first charged with a current of 1C or less until it reaches its charge-voltage limit. This stage of charge typically replenishes up to 70% of the capacity. The battery is then charged with a constant voltage of typically 4.2 V. To maximize safety and the available capacity, the charge voltage must be regulated to at least  $\pm 1\%$ . During this stage of charge, the charging current drawn by the battery tapers down. The charge is typically terminated once the current level falls below 10 to 15% of the initial charging current at a 1C charging rate.

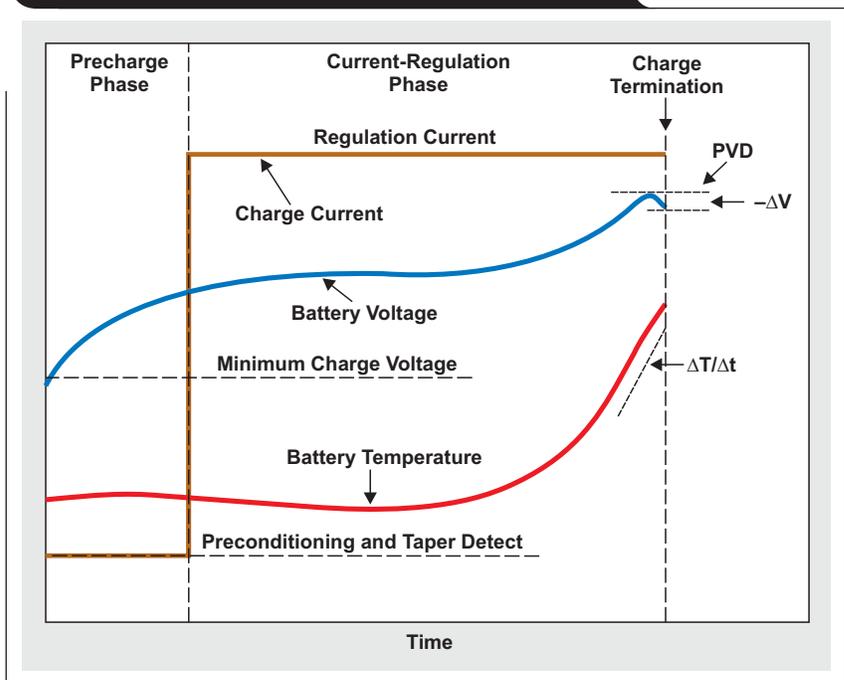
### Linear versus switch-mode charging topology

Linear and switch-mode topologies are commonly used for controlling the charging current and voltage in applications using rechargeable batteries. Each topology provides unique advantages for its intended applications.

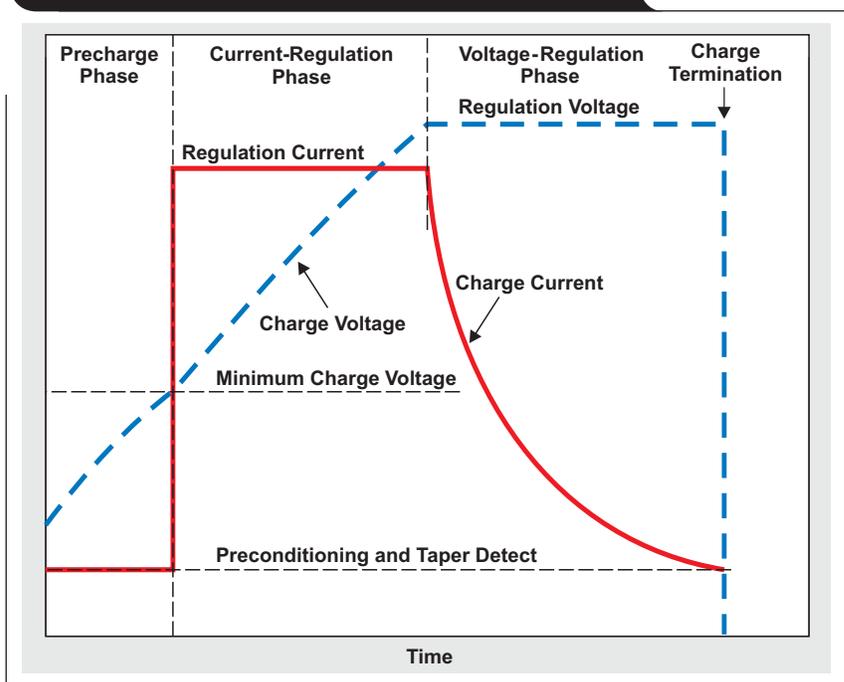
The linear topology is well suited for low cell counts and charging currents. It offers the designer several advantages: low implementation cost, design simplicity, and “quiet” operation due to the absence of high-frequency switching. The linear topology also introduces some power dissipation into the system, in this case mostly during the current-regulation phase of the charge cycle. This is a drawback if the designer has no means to manage the thermal issues in the design.

The switch-mode topology is well suited for higher cell counts and charging currents. Its main advantage is increased efficiency. Unlike linear regulators, the power switch or switches are operated in the saturation region, which substantially reduces the overall losses. The main sources of power loss in a buck converter

**Figure 1. Charge profile for NiCd/NiMH batteries**



**Figure 2. Charge profile for Li-Ion/Li-Pol batteries**



include the switching losses (in the power switches) and the DC losses in the filter inductor. Depending on the design parameters, it is not uncommon to see efficiencies of well over 95% in these applications.

## Inductive charging

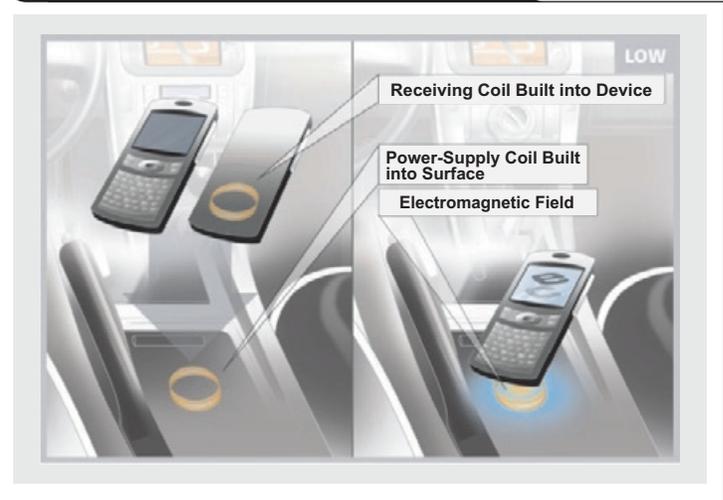
Inductive (wireless) power has been around for a long time and has found applications in many areas. In the industrial area, for instance, induction heating has provided a practical and efficient way to melt large amounts of metals in a manufacturing environment. In the consumer area, inductive power has been used successfully to charge toothbrushes and other small personal-care products. However, when it comes to charging the new generation of portable appliances such as cellular phones, portable media players, and *Bluetooth*® headsets, the use of wireless power is in its infancy.

The wireless chargers commonly used in the consumer market for devices such as toothbrushes are not optimized for efficiency or speed. These chargers “trickle charge” at a low rate, and the form factor is customized to accept only the intended end equipment. However, the demands for portable power are changing; and most consumers now own a multitude of portable devices, each with its own power cable and, in many cases, proprietary connectors. Consumers are beginning to look for the same convenience in charging their portable devices as is offered by wireless data transfer. This concept, although simple, presents a number of barriers for design solution and acceptance:

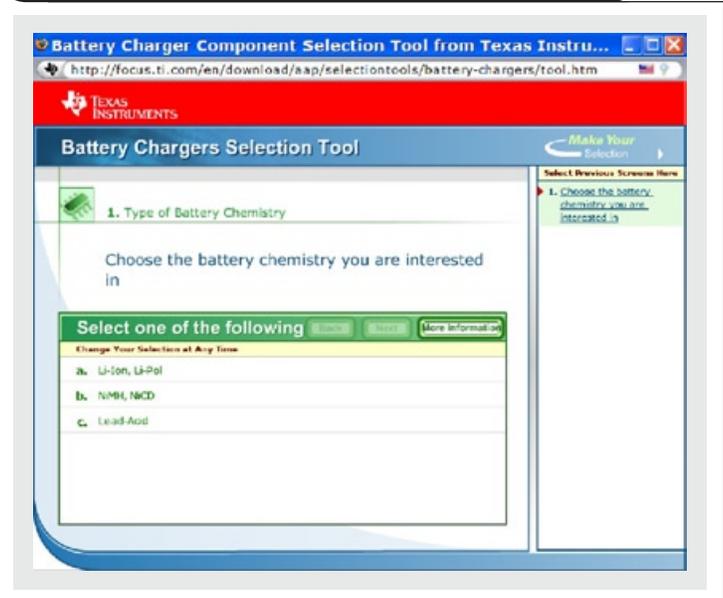
- Unlike the battery for a toothbrush, batteries for the new portable devices need to be charged at a standard fast-charge rate, reaching 70% of capacity in about an hour. The solution must therefore be very power-efficient.
- The battery for each portable device is a different size and has a different charge rate (i.e., power rating), so the concept of “one size fits all” does not apply. The wireless charger needs to have the intelligence to recognize these variations and adjust itself accordingly.
- Consumer safety is very important, so the wireless charger needs not only to differentiate between a coin and a cell phone but also to make certain that no hazardous situations are created under any operating condition.
- Ultimately, what consumers will pay for is convenience, so the wireless charger needs to be substantially easier to use than the easiest corded charger available.

There are a variety of solutions being developed to address these concerns. A great example is eCoupled™ technology developed by Fulton Innovation. This technology includes an inductively coupled power-supply circuit that dynamically seeks resonance, adapting its operation to match the needs of each device it supplies (see Figure 3). By communicating with each device individually in real time, eCoupled technology not only determines power needs but also takes into account the age of a battery or device and its charging life cycles. This supplies the optimal

**Figure 3. Concept of inductively coupled power supply**



**Figure 4. TI Battery Chargers Quick Search tool**



amount of power to the device and keeps it operating at peak efficiency.

### Selecting the charger

Texas Instruments offers a variety of tools to make the process of selecting the right charger easier for designers. Figure 4 shows the “Battery Chargers Quick Search” tool available at [power.ti.com](http://power.ti.com) (Scroll down to “Analog eLab™ Design Support” to view links under “Design, Simulation, and Selection Tools.”)

### Related Web site

[power.ti.com](http://power.ti.com)

## 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 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:

<b>Products</b>		<b>Applications</b>	
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>	Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>	Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>	Broadband	<a href="http://www.ti.com/broadband">www.ti.com/broadband</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>	Digital Control	<a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>	Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>	Military	<a href="http://www.ti.com/military">www.ti.com/military</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>	Optical Networking	<a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>	Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>	Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>	Video & Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>
RF/IF and ZigBee® Solutions	<a href="http://www.ti.com/lprf">www.ti.com/lprf</a>	Wireless	<a href="http://www.ti.com/wireless">www.ti.com/wireless</a>

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

# TI Worldwide Technical Support

---

## Internet

### TI Semiconductor Product Information Center Home Page

[support.ti.com](http://support.ti.com)

### TI Semiconductor KnowledgeBase Home Page

[support.ti.com/sc/knowledgebase](http://support.ti.com/sc/knowledgebase)

## Product Information Centers

<b>Americas</b>	Phone	+1(972) 644-5580
<b>Brazil</b>	Phone	0800-891-2616
<b>Mexico</b>	Phone	0800-670-7544
	Fax	+1(972) 927-6377
	Internet/Email	<a href="http://support.ti.com/sc/pic/americas.htm">support.ti.com/sc/pic/americas.htm</a>

## 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	<a href="http://support.ti.com/sc/pic/euro.htm">support.ti.com/sc/pic/euro.htm</a>

## Japan

Fax	International	+81-3-3344-5317
	Domestic	0120-81-0036
Internet/Email	International	<a href="http://support.ti.com/sc/pic/japan.htm">support.ti.com/sc/pic/japan.htm</a>
	Domestic	<a href="http://www.tij.co.jp/pic">www.tij.co.jp/pic</a>

## Asia

Phone	
International	+91-80-41381665
Domestic	<u>Toll-Free Number</u>
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	<a href="mailto:tiasia@ti.com">tiasia@ti.com</a> or <a href="mailto:ti-china@ti.com">ti-china@ti.com</a>
Internet	<a href="http://support.ti.com/sc/pic/asia.htm">support.ti.com/sc/pic/asia.htm</a>

**Safe Harbor Statement:** This publication may contain forward-looking statements that involve a number of risks and uncertainties. These "forward-looking statements" are intended to qualify for the safe harbor from liability established by the Private Securities Litigation Reform Act of 1995. These forward-looking statements generally can be identified by phrases such as TI or its management "believes," "expects," "anticipates," "foresees," "forecasts," "estimates" or other words or phrases of similar import. Similarly, such statements herein that describe the company's products, business strategy, outlook, objectives, plans, intentions or goals also are forward-looking statements. All such forward-looking statements are subject to certain risks and uncertainties that could cause actual results to differ materially from those in forward-looking statements. Please refer to TI's most recent Form 10-K for more information on the risks and uncertainties that could materially affect future results of operations. We disclaim any intention or obligation to update any forward-looking statements as a result of developments occurring after the date of this publication.

**E093008**

Analog eLab is a trademark of Texas Instruments. The Bluetooth word mark and logos are owned by the Bluetooth SIG, Inc., and any use of such marks by Texas Instruments is under license. All other trademarks are the property of their respective owners.