Selecting the right charge-management solution

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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 ±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, ΔT/Δt, to detect full charge. The typical ΔT/Δt rate is 1°C/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 ±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.

Figure 1. Charge profile for NiCd/NiMH batteries

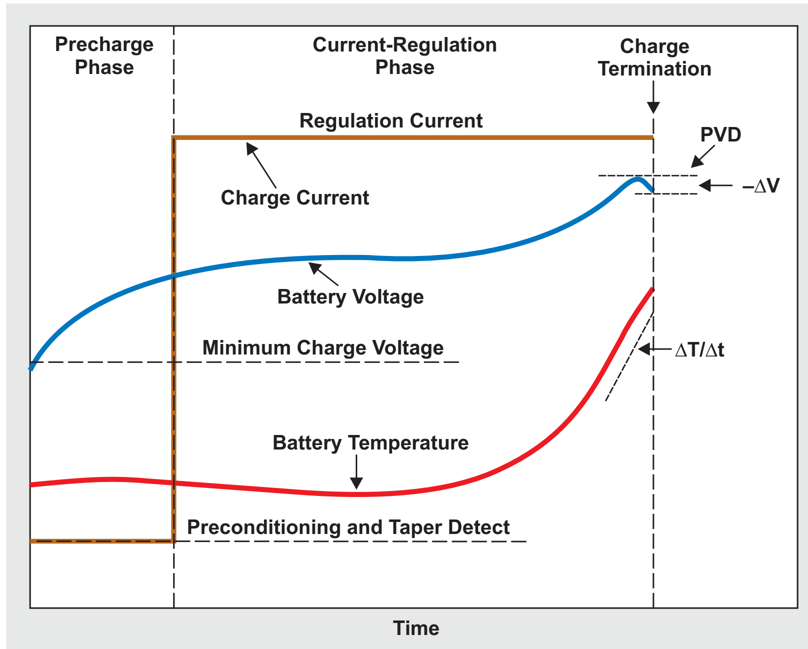
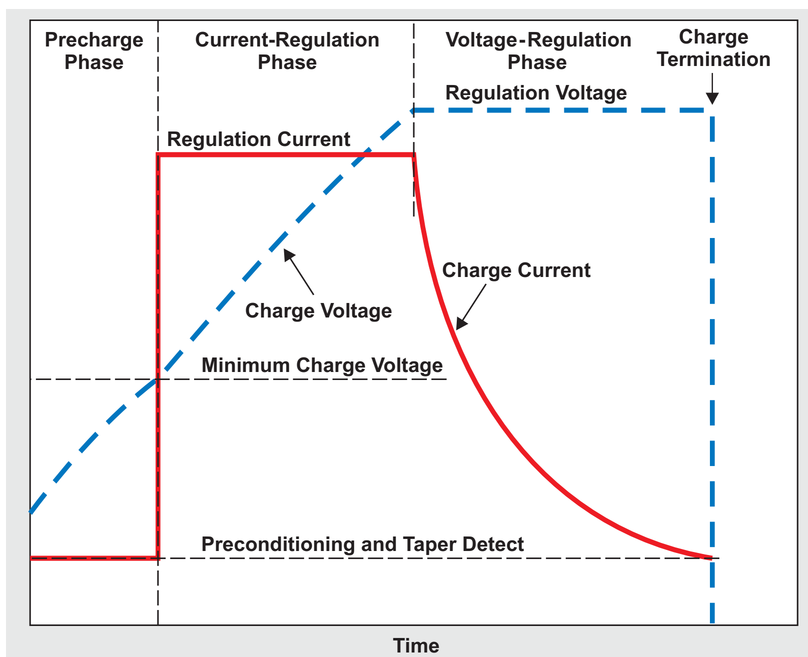


Figure 2. Charge profile for Li-Ion/Li-Pol batteries



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

Figure 3. Concept of inductively coupled power supply

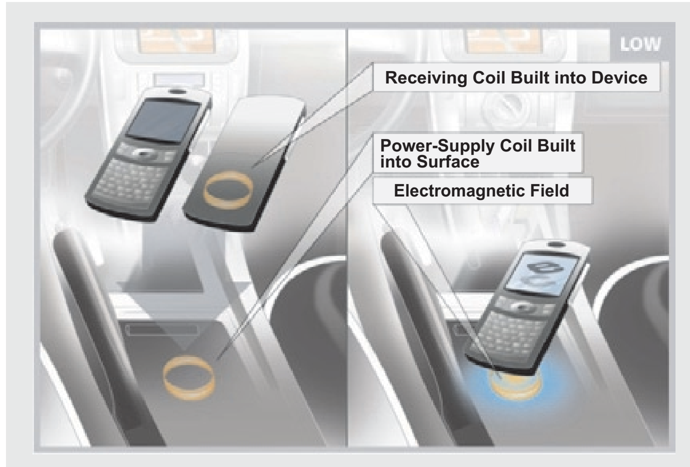
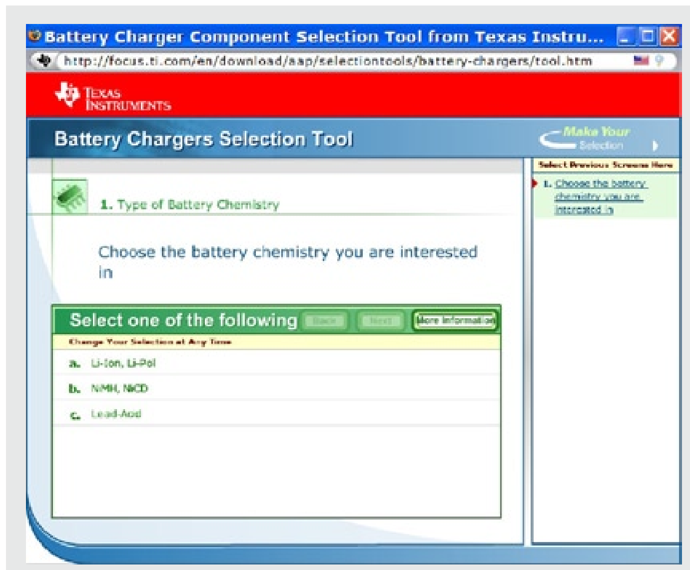


Figure 4. TI Battery Chargers Quick Search tool



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 (Scroll down to "Analog eLab™ Design Support" to view links under "Design, Simulation, and Selection Tools.")

Related Web site

power.ti.com

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

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

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.

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