Battery and Charge Management: Choices and Tradeoffs

Masoud Beheshti, Director, Product Line Manager, Texas Instruments

Designers of portable electronic devices have a variety of choices on types of chemistries, charger topologies and charge management solutions. Selecting the most suitable solution should be a simple task, but in most cases, it is a more complicated process. The designer needs to reach an optimal balance between performance, cost, form factor and other key requirements. This article tries to provide some guidance and assistance in making these choices easier for the design and system engineers.

Charge Control begins with the three “Cs”
Any system designer utilizing rechargeable batteries needs to be aware of some basic design techniques to ensure that the following three critical requirements are met:

1. Cell Safety: Needless to say, end user safety should be the number one priority in any system design. Most Lithium-Ion (Li-Ion) and Lithium-Polymer (Li-Pol) battery packs contain protection electronics. However, there are other considerations that are critical at the system design level. These include, but are not limited to, ensuring the voltage regulation tolerance of ?1% during the final phase of charge for Li-Ion; preconditioning mode to safely handle deeply discharged cells; safety timers; and cell temperature monitoring.

2. Cell Capacity: Any battery charge solution needs to ensure that batteries are charged to full capacity on each and every cycle. Premature charge termination results in reduced runtime, and is undesirable in today’s power-hungry portable devices.

3. 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 steps necessary for maximizing cycle life.

Choice of Battery Chemistry
System designers today have the option to select from a variety of battery chemistries. The designer typically selects the chemistry based of a number of criteria including:
* Energy density
* Size and form factor
* Cost
* Usage pattern and cycle life

Although there has been a strong trend towards Li-Ion and Li-Pol chemistries in recent years, the Ni-based chemistries are still a viable option for a variety of consumer application.

Regardless of the choice of chemistry, it is critical to adhere to the appropriate change management techniques for each chemistry. These techniques would ensure the batteries are charged to their maximum capacity each and every time without compromising safety or cycle life.

NiCd / NIMH
Prior to start of a charge cycle, Nickel Cadmium (NiCd) and Nickel-Metal Hydride (NiMH) batteries must first be qualified, and possibly conditioned, before the start of the fast charge. 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" (typically below 10°C) or over-discharged battery (typically below 1V 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, where fast charging is terminated within a range of zero to –4mV per cell of the peak cell-voltage. The temperature method looks at the rate of battery temperature rise, °T/°t, to detect full charge. The typical °T/°t rate is 1°C / minute.

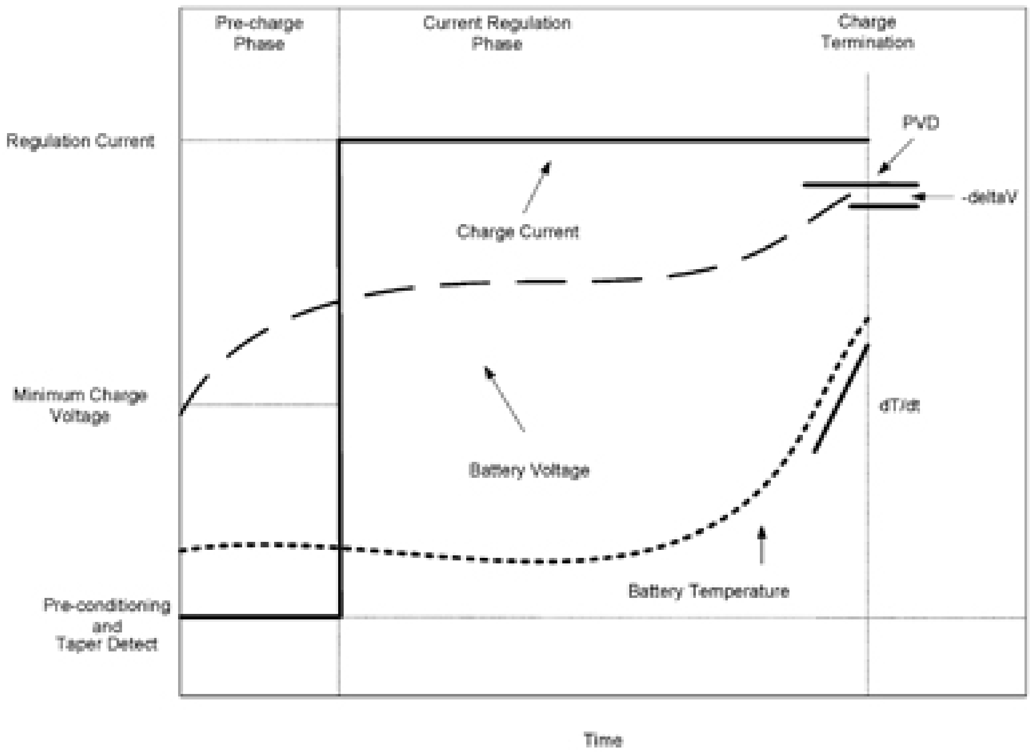

Figure 1: Charge Profile for Nickel Chemistry

Li-Ion / Li-Pol
Similarly to NiCd and NiMH, Li-Ion 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 pre-conditioning, Li-Ion batteries are first charged with a current of 1C or less, until the battery reaches its charge voltage limit. This stage of charge typically replenishes up to 70 percent of the capacity. The battery is then charged with a constant voltage of typically 4.2V. To maximize safety and the available capacity, the charge voltage must be regulated to at least 1 percent. During this stage of charge, the charging current drawn by the battery tapers down. Charge is typically terminated once the current level falls below 10–15 percent of the initial charging current for a 1C-charging rate.

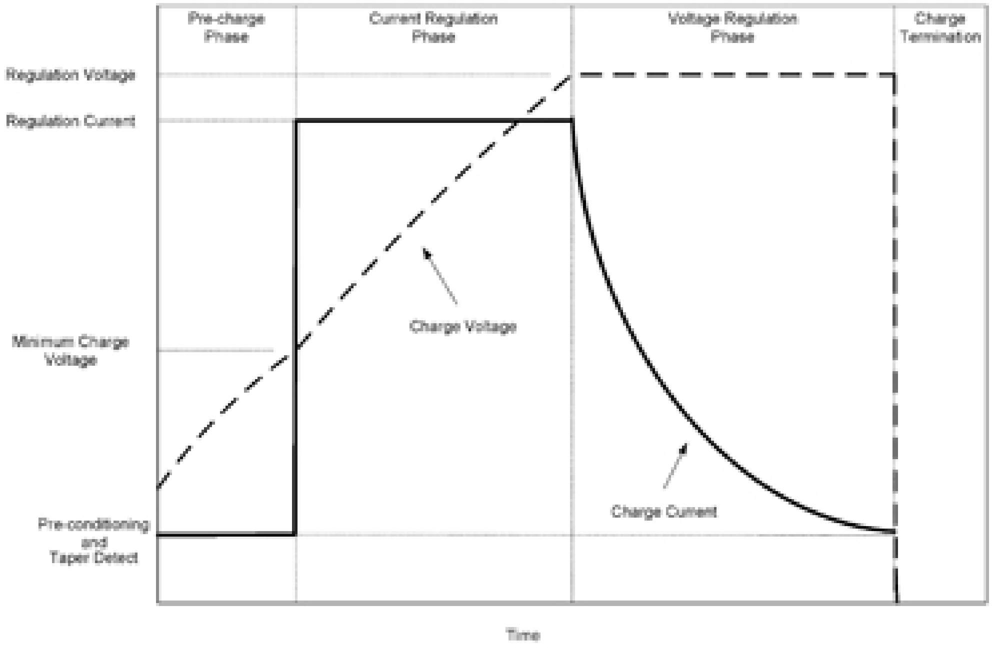

Figure 2: Charge Profile for Lithium Chemistry

Switch-mode versus Linear Charging Topology
Traditionally, handheld devices use a linear charging topology. This method offers the designer several advantages: low implementation cost, design simplicity and “quiet” operation due to the absence of high-frequency switching. The linear topology, however, introduces power dissipation in the system, especially as the charge rates increase due to higher battery cell capacity. This is a major drawback, if the designer has no means to manage the thermal issues in the design.

The other major drawback comes into play when the USB port on a PC is used as the power source. The USB charging option is offered on many portable devices today and can provide charging rates of up to 500mA. With a linear solution, due to its low efficiency, the amount of “power” that can be transferred from the PC’s USB is greatly reduced. This translates into extensive charge time

This is where a switch-mode topology comes to the rescue. The main advantage of a switch-mode topology is increased efficiency. Unlike linear regulators, the power switch (or switches) is operated in the saturation region, which substantially reduces the overall losses. The main sources of power loss in a buck converter include switching losses (in power switches), and the DC losses in the filter inductor. Depending on the design parameters, it is not uncommon to see efficiencies well over 95 percent in these applications.

Most people picture large ICs, big PowerFETs and super-sized inductors when they hear the term switch-mode! Although that may, in fact, be a realistic picture for applications handling tens of amperes of current, it is certainly not true for the new generation of solutions for handheld devices. The new generations of single-cell, Li-Ion switch-mode chargers provide the highest level of silicon integration, using frequencies above 1MHz to minimize the size of the inductor. Figure 1 illustrates such a solution available today. The silicon size, which has both the high and lowside PowerFETs integrated, is less than 4 mm2 in area. With a 3MHz switching frequency, this solution requires a small 1uH inductor, measuring only is 2mm x 2.5mm x 1.2mm (WxLxH) in dimensions.

Selecting the Charger

A variety of tools are available in order to make the process of selecting the right charger easier for designers. Figure 3 is an example of one of the tools available on TI’s web site.

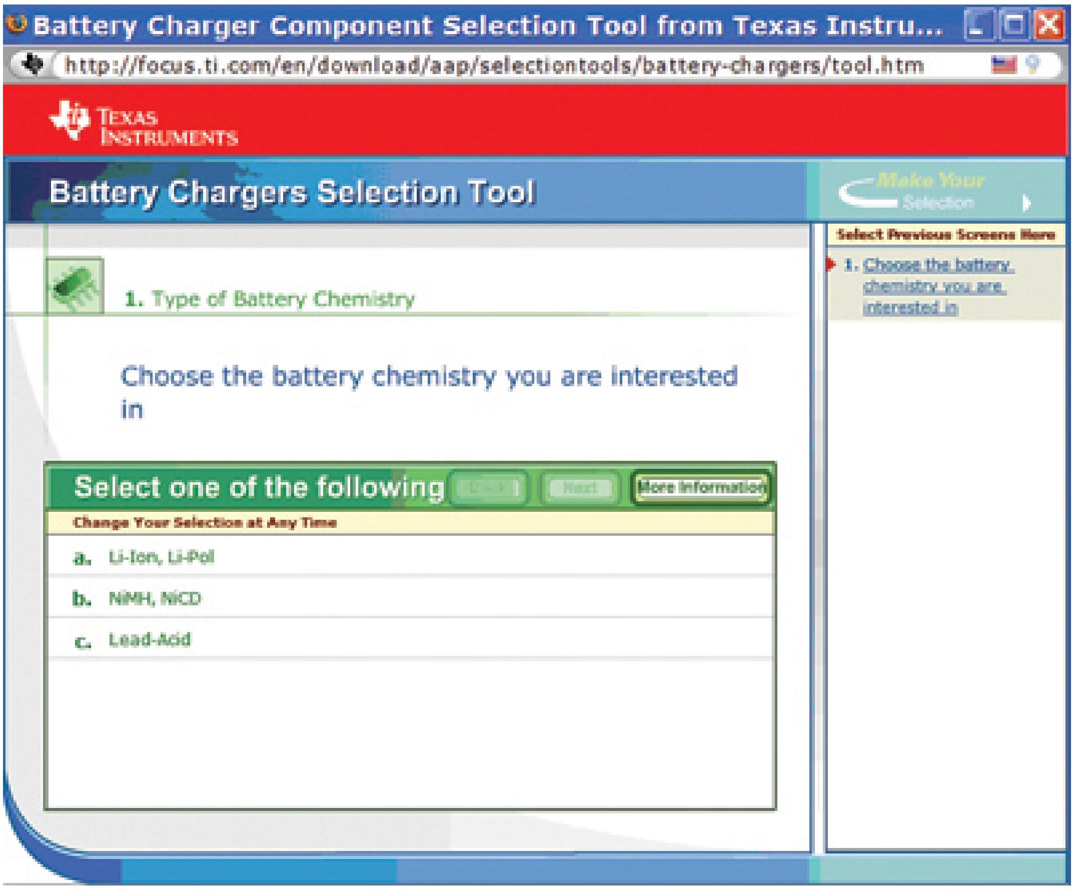

Figure 3. Battery Charger Selection Tool

References
* Battery Charger Selection Tool: www.ti.com/batterychargerselector-ca [1].
* To learn more about this and other power solutions from Texas Instruments, visit: www.ti.com/power-ca [2],

About the Author
Masoud Beheshti is the Director of Battery Charge Management at Texas Instruments. He has more than 19 years experience in design, product definition, strategic marketing and business management in the power and battery management areas. Masoud holds a BSEE from Ryerson University, Toronto, Canada, and an MBA in finance and marketing from Southern Methodist University, Dallas, Texas. Masoud can be reached at: ti_masoud_beheshti@list.ti.com [3].

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