BATTERY POWER
PRODUCTS & TECHNOLOGY
Solutions for OEM Design Engineers, Integrators & Specifiers of Power Management Products

Key Considerations in Battery Charger Design

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The rapidly expanding feature sets on today's portable electronics products are placing a rising premium on the capabilities of the battery charger function. As designers add new capabilities such as Bluetooth connectivity, higher resolution displays and GPS, the ability of the system power source to deliver as much power as possible for as long as possible and recharge as quickly as possible becomes all the more important to users. Invariably designers must select a charger IC that meets their stringent system requirements for footprint, heat dissipation and cost. But at the same time they must recognize the importance that battery life and recharge time plays in users' perceptions of a product and constantly evaluate the implications of trading off those key selection criteria against better battery performance.

Fortunately designers can select from an increasingly diverse array of battery charger ICs today to meet their specific system needs. Generally, the latest devices offer ever higher levels of power density and a wider array of functions in extremely compact packages. Many of today's charger ICs, for example, integrate a charging device, reverse blocking and current sensing circuits in a single package. To meet the tight space confines of portable and handheld devices, some of these devices occupy less than 10 mm^2 of board space.

Lithium-ion chargers use a three-step process to safely and efficiently charge a lithium-ion cell. The process begins with a limited current pre-charge or trickle charge mode during the period when the battery is heavily discharged. This mode avoids charging the battery at a high rate when the battery resistance is lowest and, in the process, minimizes heat dissipation. Once the battery reaches a pre-defined voltage, the charger switches to a fast charge constant current mode where the charge current increases to the full rated charge current.

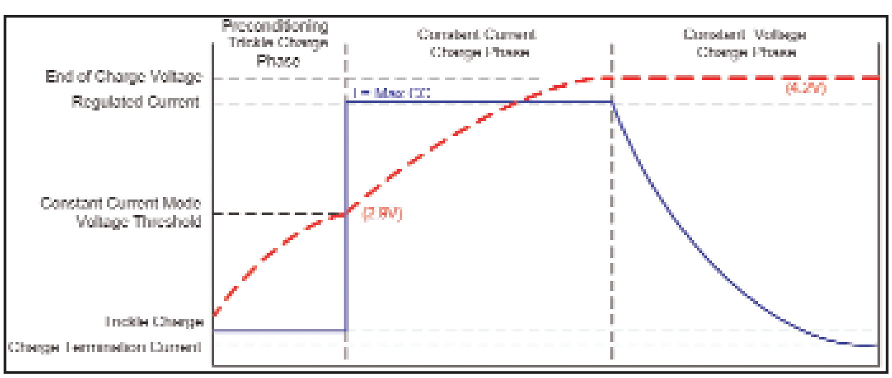

Figure 1. Typical Lithium-Ion Charge Profile

A charge current is selected that will give the maximum discharge capacity over the life of the battery without an excessive charge time. This mode continues until the battery charge level reaches a second voltage threshold near the full charge level. At this point the charger enters into a constant voltage mode in which the battery voltage is kept constant allowing the charge current to gradually level off. This final charge mode is critical for topping off the battery charge. It maximizes the portion of the charging battery voltage that is actually stored charge and not related to the battery ESR multiplied times the fast charge current. It also charges the battery to an accurate voltage level that is optimum for battery longevity. See figure 1 for a typical lithium-ion charge profile.

The battery charger ICs available today offer a wide variety of features to ensure battery safety and system reliability during this charging process. All charger ICs feature some sort of thermal management system to either shut off the charger when heat builds up or intelligently manage the temperature of the die by reducing the charge rate as temperature rises. It is important to note that these functions differ widely. Some of the newer devices on the market now offer intelligent digital thermal loops that automatically track and reduce the charge current as ambient temperature rises. This process automatically continues until the temperature stops rising. If the ambient temperature continues to rise past a pre-defined limit, the charger shuts down. These "intelligent" feedback mechanisms shorten the charge cycle by maintaining charge current at the highest level available short of thermal shutdown.

Many chargers also offer an input under voltage charge suspend function that tracks the input voltage versus the battery voltage and automatically terminates the charger when the charge voltage reaches a point where it can no longer continue charging the battery. Over voltage protection protects the battery by constantly tracking the output voltage and ensuring it does not exceed the maximum charge voltage by a pre-set margin.

Some sort of resume charging function is also common. This feature allows the user to disengage the portable device from the charger before the charge cycle is complete and then later reattach the charger and automatically resume charging at the appropriate level. It is important to note that lower cost chargers that don't offer this capability instead offer a simple enable pin that can be used to manually recycle the part to start the battery recharge cycle.

Most charger ICs also feature status monitor outputs capable of driving external LEDs to indicate charge status. Some also offer a battery charge timer that helps protect the battery and system by terminating charge if a user-programmable charge time is exceeded.

System Power Functions

As handset and other portable product designers squeeze what often seems like an endless array of new functions into their platforms, board space has become increasingly scarce. Power management IC developers are attempting to address this problem by folding a growing number of system power functions into the same IC responsible for the battery charger function. As a result, a growing number of battery charger ICs on the market today now offer integrated DC/DC converters to drive the system microcontroller, memory, a hard disk drive or other I/O and one or more low dropout voltage regulators (LDOs) to power noise sensitive RF circuits.

Typically the DC/DC converters on these integrated power management devices are designed to step-down the average 3.6 V output available from a lithium-ion battery to the lower 1.8 V or 2.5 V voltages required for most microcontrollers. Efficiency is an especially important consideration in these power functions. An inefficient DC/DC converter can have a major impact on the runtime of the battery. Many converters offer excellent efficiency at high loads, but their efficiency drops dramatically under 100 mA. Given the large amount of time portable devices run in standby mode, it is important to carefully consider the converters efficiency across all load ranges. Some DC/DC converters in this class of devices do a better job of maximizing load efficiency across the entire load range by operating in both fixed switching frequency and variable switching frequency modes. Switching frequency is important for size considerations as well. Converters that operate at higher switching frequencies require smaller and lower profile external components. That, in turn, can help the system designer build smaller, thinner portable products.

RF and audio circuits require a high degree of isolation and a low noise power source to prevent the propagation of noise. LDOs offer far lower efficiency than a DC/DC converter, but their low noise characteristics make them well suited for applications such as the microphone pickup circuit in a Bluetooth headset. Look for LDOs that offer fast transient response, support fast startup and are compatible with lower cost, low-ESR ceramic capacitors.

Multiple Power Sources

One of the more difficult challenges charger IC designers face is the desire by users to charge their battery from a growing variety of power sources. Users are no longer satisfied charging their portable device from an AC source. They want to charge their cell phone, MP3 player or PDA while traveling in the car, on a plane or on a train. Oftentimes the most accessible power source available is the USB port of some other electronics device. Widely available on most laptops and computer peripherals, USB ports support bidirectional data transfer as well as power and ground and allow users to simultaneously recharge a battery and update data, audio and video files. As a result many vendors now offer dual path charger ICs that support charging from both AC and USB sources.

But adding this capability to a charger IC significantly complicates its design. USB ports are not universal in design. Passive USB ports often found on network and computer peripherals only supply 100 mA of current. USB ports on most notebook computers, on the other hand, typically supply a 5 V source with up to 500 mA. The difference can have a dramatic impact on charge time. Moreover, the level of power available from a USB port can change dynamically as the host system draws power for other functions. Attempts to charge at more than 500 mA can cause the port voltage to sag and drive the USB host to shut down the USB port and terminate charging.

Many charger ICs provide protection from port shutdown with a binary "all-or-nothing" scheme. Typically the charger will blindly attempt to charge at the highest current rate possible and, once a fault condition occurs, shut down immediately. This approach is particularly problematic in hot climates where overheating of the charger IC is most likely to occur at the maximum charging rate. Attempts to restart the charging process after overtemperature shutdown can damage the battery cell through incomplete electrochemical reactions that can occur when repeatedly initiating and terminating the charging process. It also extends the charging cycle. In addition, most of these devices only indicate their charging status through indicator lights. They don't provide direct communication with the baseband or applications processor that would allow the introduction of more intelligent charge control mechanisms.

To avoid overloading the USB port and continue the charging process, one ideally wants a charger that automatically reduces charge current when the system is drawing power for other functions. Some chargers address this problem by offering two constant current charge levels, one high and one low, either preset at the factory or user-programmable via two external set resistors. In this case, the charger IC will charge at the maximum or "high" current level of 500 mA when the USB pot can support it, and then switch to the second "low" setting, usually 100 mA, when power draws on the system limit the availability of power via the USB port. This ensures USB port integrity under most conditions and maintains the battery charge cycle at either of the two levels.

This two-tier approach brings with it two liabilities, however. First, it requires the addition of a fairly complex and time-consuming hardware and software feedback mechanism between the charger and the system microcontroller to track and control charge level relative to the changing status of the USB port.

Perhaps more importantly, however, it does not maximize efficiency of the battery charge cycle. By resorting to an arbitrary 100 mA low charge level when power availability is limited, this strategy fails in some conditions to use all of the power available from the USB port. As an example, if the USB port can supply 200 mA but the charger IC switches to its lower charge level of 100 mA to protect the port, it will take twice as long to charge a 500 mA-hour battery than it would if it had accessed the full 200 mA current available.

To address this limitation, some charger IC developers have begun exploring the use of more sophisticated feedback mechanisms to more efficiently manage charge current from a USB port. The goal is to be able to charge the battery at the maximum rate possible without overloading the power source by dynamically adjusting the charge current as input conditions change. Ideally, this control scheme will allow the user to charge at the maximum rate possible without overheating the charger IC by adjusting the charging current as ambient temperature conditions change.

These new "intelligent" schemes typically feature a mechanism that allows the charger IC to communicate the charging and thermal conditions of the battery to the host processor. They also allow the host processor to dynamically alter the charge current level as the battery's electrical and environmental conditions change. For example, when the IC becomes too hot or the input voltage begins to sag, which indicates the power source is becoming overloaded, this control mechanism immediately reduces the charge current by a preset amount to avoid a fault condition. Ideally, this control loop can then step up or back down the charge current in discrete steps until an equilibrium level is reached. These algorithm-based functions allow users to charge the battery at the maximum charge current available while keeping the USB port regulated. Most importantly, by constantly tracking conditions and adjusting charge current, they maximize charge efficiency and shorten the battery charging cycle (see figure 2).

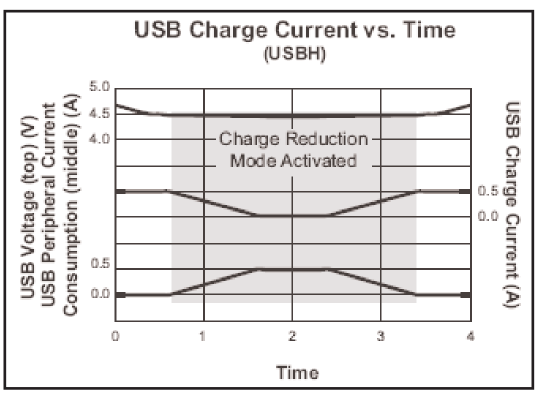

Figure 2. USB Charge Current Reduction for AAT3670

Higher Powered Applications

With portable system designers continually expanding the functionality of their systems, many are moving from single- to dual lithium-ion battery cells connected in series to support the increased power requirements of these feature sets. An increasing number of high-end handsets, portable media players, single-lens-reflex (SLR) cameras and other devices now require two battery cells to support their high levels of performance. While traditional single-cell portable devices require 4.2 V to charge a single cell, these dual-cell powered devices require between 8.4 V and 8.8 V input to charge.

In the past designers have typically used discrete charger ICs to address this higher-end segment of the market. But recently power management IC manufacturers have introduced new battery charger ICs specifically targeted for this application segment. By supporting input voltages between 4 V and 8.8 V, these charger ICs can be used with both single and dual-cell powered systems. Some support voltages significantly higher to give designers the freedom to use lower-cost unregulated adapters.

Thermal management is particularly crucial at these higher power levels. Accordingly, it is important that designers look for charger ICs in this class of devices that feature an intelligent thermal feedback mechanism that maintains battery charging current by constantly measuring die temperature and modifying the fast charge current to compensate for thermal conditions.

Conclusion

Battery life remains a key differentiator in portable system design. Users demand portable products that can deliver longer battery life and shorter recharge times. By carefully considering the various functions and features in today's battery charger ICs and identifying the best fit for their application, designers can reduce charge time, maximize battery discharge capacity, number of recharge cycles, and ensure system reliability and customer safety.

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