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Key Power Management Considerations When Charging Lithium-Ion Batteries from USB Ports

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Over the last few years, the number of portable devices operating from lithium-ion batteries has expanded and the number of features contained in these products has exploded. So, too, has the demand for faster, more convenient and more mobile battery charging systems. Users on-the-go don't always have access to AC power. As they use their portable systems more often, they need charging solutions that better conform to their mobile lifestyle. Indicative of this trend is users' growing preference to charge their portable platforms from the USB port on a notebook or desktop computer, or computer peripheral.

Charging a portable device via a USB port offers a number of very attractive advantages. USB ports are widely available, so users can recharge their device virtually anywhere. Since a USB port provides bidirectional data transfer, as well as power and ground from the host system, users can charge the battery on their portable device while downloading or updating files at the same time.

Portable system designers planning to offer battery recharge capability from a USB port face a number of challenges; not all USB ports are created equal. Some do not comply exactly with the USB 2.0 standard. A compliant USB host source is specified to supply no more than 500 mA, but passive and non-powered ports built into hubs and other computer peripherals are limited to as little as 100 mA. Typically, USB ports feature a current limit protection function that can be set as high as 5.0 A and as low as 500 mA (in the case of a host or self-powered hub) or 100 mA (in the case of a low-power hub or bus). Anyone using a USB port to charge a battery and power a product must ensure that it does not draw more current than the USB port can deliver or the current limit protection circuit will shut the port down and stop the battery charge cycle. Accordingly, designers must add specific mechanisms to their peripheral product to ensure the USB port will not be overloaded during the charging cycle and undermine system reliability.

Additional complications arise if the portable system is designed to operate at the same time as the battery is charging. In these circumstances, the charging function must share the available port power with the operating system. As port supply capabilities or peripheral load demands change, the system must manage the constant current charge level to the battery in order to ensure valid USB port operation.

Typically, designers have solved these problems by developing complex hardware and firmware solutions. In most cases, this approach allows the designer to manually set two different constant current charge levels, one high and one low, via two external set resistors, and provide an input control to toggle from one level to the other (see Figure 1). In portable systems that transfer data via a USB port, the internal USB controller reads the system ID and the system micro-controller adjusts the battery charge current level based on the type of port it is connected to. Alternately, these levels are preset at the factory.

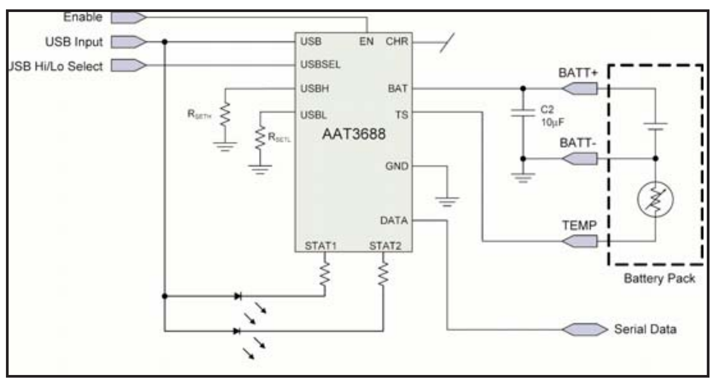

Figure 1. Battery Charger IC Typical Application Diagram

While this "high-low" methodology offers a reliable solution, it is far from ideal. First, some portable systems cannot read a host USB port ID. But more importantly, even if the system does offer that capability, it's limited to two discrete charge levels. The high level, typically set to 500 mA, will charge the battery in the shortest possible time. The lower level, usually set to 100 mA to protect the port, will require an extended charge cycle time. Therefore, if a portable device has a fully capable 500 mA USB port, but uses any amount of current to operate while the battery is charging, the charge control will be driven to the lower level and the charge cycle will be unnecessarily extended. The difference in the charge cycle time can be dramatic. For example, at the lower level, a 500 mA/hr battery could take five hours or more to charge.

New Techniques

Ideally, a USB charge system should charge at the maximum rate available, no matter what type of power source it is using and no matter how much power the operating system requires. A charger should be able to charge at the maximum rate possible regardless of variables such as source supply capacity, operating temperature or IC power dissipation. To accomplish this task most efficiently, the system would have to adjust charging current dynamically as input conditions change. By automatically reducing the constant current charge level to maintain a valid USB port voltage level, the charger IC could supply the maximum available current to the battery under charge and ensure the fastest possible charging time.

A number of recently introduced charger ICs offer a more intelligence-based approach to USB charging that addresses this new need. These devices add a unique USB charge reduction control feature which automatically adjusts the constant current charge level in a linear fashion as the system demands more power. Whenever the input voltage from a USB port begins to sag due to the applied load, this control circuit reduces the charging current to a level which will avoid a port fault condition. This automatic mechanism continuously senses the USB port supply voltage and adjusts the battery charge current as the input voltage changes due to the total system load. By allowing the charger IC to continually deliver the maximum possible current to the battery under charge, this charge reduction function minimizes charge time and still maintains USB port integrity and protects the host system.

These charger ICs still allow the user to set two programmable fast charge levels: one high, one low. The charge reduction system becomes active when the voltage on the input falls below a preset threshold which is typically set at 4.5 V. No matter which constant current charge level is selected (high or low), the charge reduction function is controlled by the voltage measured on the charger input pin which reduces the current charge level in a linear fashion until the voltage sensed on the input recovers to a point above the charge reduction activation threshold. Charger ICs that utilize the charge reduction feature usually provide for an external user set threshold by employing a simple a resistor divider network.

A single-wire digital interface on the charger IC is used to deliver high-speed bi-directional communication between the IC and host microcontroller. With this interface, the system processor can be continually updated on the battery charge cycle. More importantly, all of these tasks can be accomplished without the need for complex protocols, high precision timing or multiple pins.

Shorter Charge Time

The key advantage to the automatic charge reduction feature is its ability to maximize the efficiency of the charge cycle and reduce charge time by ensuring the battery will be charged at the maximum rate possible at all times throughout the cycle. As an example, consider a portable device connected to a 500 mA USB host supply and drawing 200 mA to operate other system functions. In this scenario, 300 mA is potentially available to charge the battery. A conventional charger IC with typical preset high and low charging thresholds of 500 mA and 100 mA, respectively, would reduce the charge level to the battery to the lower 100 mA value. The remaining 200 mA would go unused. With an automatic charge reduction capability, the charge control IC can sense the voltage level supplied by the USB port. Since the port's current sourcing capability is exceeded by the system's attempt to draw 200 mA in addition to the charger's attempt to draw the maximum 500 mA, the port under load will enter a current limit fault condition, resulting in a drop in port voltage. Once the port voltage reaches the 4.5 V charge reduction threshold, the charge reduction function is activated. The constant current fast charge level set by the charger IC will be reduced, leaving the battery to be charged with the 300 mA available, rather than dropping all the way down to 100 mA. Once the system current demand terminates, the charge reduction control circuit will turn off and allow the constant current charge to resume at the maximum level (see Figure 2).

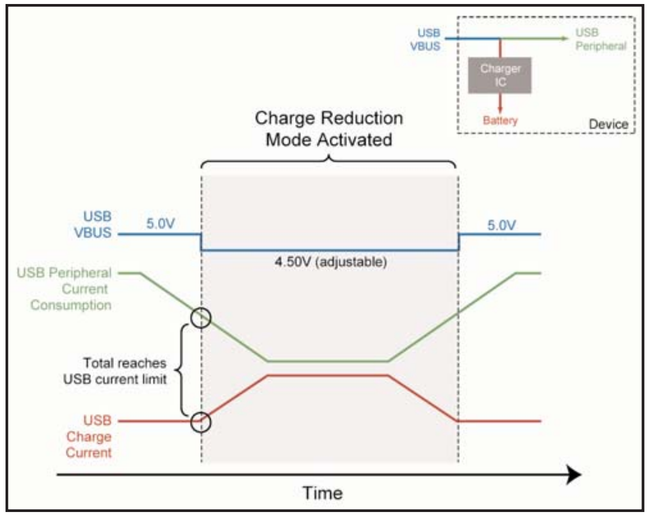

Figure 2. USB Charge Reduction Operation

One potential concern with a USB charge reduction system of this kind is reaction time to an over-current situation at the USB port. A long lag time could expose the port to a potential power surge. Charger ICs that feature a USB charge reduction system avoid this problem by activating the charge reduction system and settling in less than 10 µs. This response is faster than the ability of most host USB port over-current protection circuitry to detect an event. Therefore, there is little need to add additional capacitance to the input of the charger IC to dampen a potential power surge.

Conclusion

The ongoing migration of mobile lifestyles and the increasing capabilities of portable systems will continue to drive demand for more flexible and portable battery charging systems. Given these trends, the demand for USB charging capabilities is likely to grow. By carefully reviewing the abilities of today's battery charger ICs, portable system designers can meet this demand and, in the process, develop the most efficient USB port-supplied charging system for their application.

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