Advances in Battery Charger IC Design Boost Product Mobility

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Functional integration and shrinking product footprints have had a profound impact on the portable consumer electronics marketplace and the rapid adoption of the convergent digital lifestyle over the past few years. Today mobile handsets that integrate camera and GPS capability now fit into a case less than one-half inch thick. Portable media players that pack thousands of songs or images easily slip inside a shirt pocket. And Bluetooth™ headsets that squeeze together a baseband processor, a microphone and a RF transceiver weigh less than 1 ounce.

Despite these dramatic improvements in integration, reducing product footprint, and with it system cost, remains a primary driver in portable system design. Historically, the integration of digital IC functions has far outpaced similar advances in analog IC design. Recently, however, power management semiconductor manufacturers have achieved major steps forward, particularly in the area of battery charging.

Over the last year manufacturers have introduced a new generation of system power products that integrate multiple power management functions typically used in portable designs into a single die. Some products in this new category support the development of lighter, ultra portable devices, such as Bluetooth headsets, by combining a battery charger, a step-down converter to power the core processor, and an LDO to power RF circuits. Others target higher powered portable devices such as smart phones or portable media players by integrating a battery charger with multiple step-down converters. AnalogicTech's recently announced AAT2550, for example, combines a 1A battery charger with two 600 mA step-down converters in a very small 4 mm x 4 mm QFN package. Designed for single-cell Lithium-ion/polymer batteries, the constant current/constant voltage linear charger integrates a pass device and reverse blocking diodes and offers a user-programmable charge current level. The two 600 mA step-down converters operate at a switching frequency of 1.4 MHz to maximize efficiency, minimize the size of external components and keep switching losses low.

Managing heat

One of the primary challenges IC designers face when they integrate three relatively high-powered blocks such as these into a single package is heat dissipation. When all three blocks operate concurrently, they can generate more heat than the package can dissipate. If thermal conditions exceed limitations, they could impact the operation of the buck converters and potentially cause a processor interrupt or system shutdown.

To address this problem, designers at AnalogicTech have developed a new digital thermal control loop into the battery charger that senses when the device is about to overheat and automatically throttles back the charge current to prevent overheating. This thermal management system continually measures the internal circuit die temperature. Whenever the internal die temperature exceeds a certain threshold (approximately 110º C), the control circuit enters into digital thermal regulation mode (see figure #1). Once the thermal loop becomes active, the device reduces fast charge current by an initial factor of 0.44. The control circuit then re-evaluates the circuit die temperature every 3.3 seconds and adjusts fast charge current up or down in small steps of approximately 35 mA until equilibrium current is reached which will ensure safe operation of the device at the existing ambient temperature.

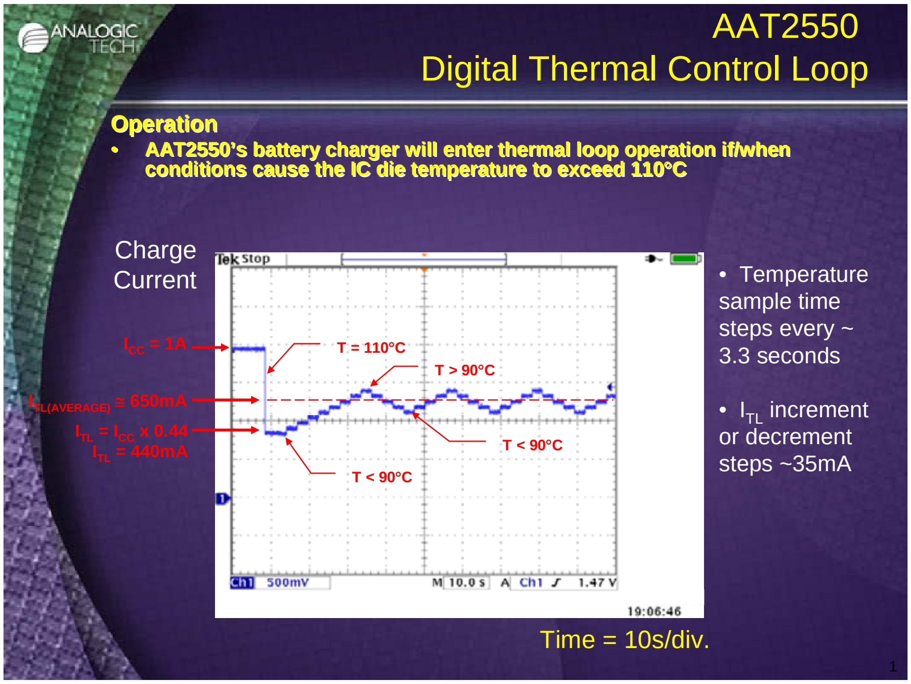


Fig. #1

If ambient temperature drops to less than 85º C, the AAT2550 comes out of thermal regulation mode and automatically resumes charging at the full programmed constant current level (see figure #2). By constantly adjusting charge level to varying die temperature conditions, this intelligent thermal management system allows the battery charger to charge the battery safely over a wide range of conditions. Moreover, by using the maximum possible charge current, it minimizes battery charge time for a given set of operating conditions.

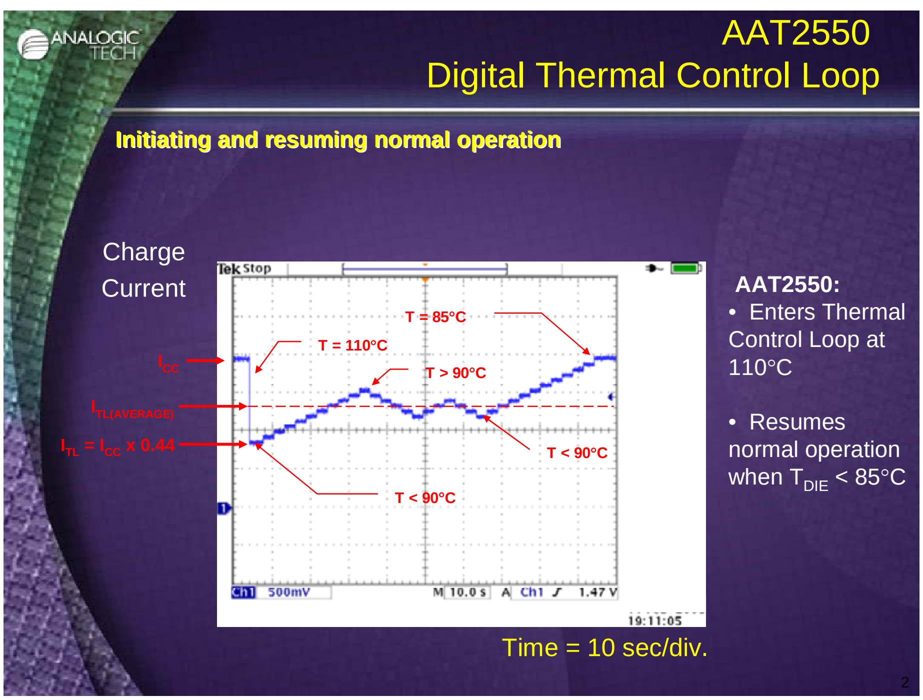


Fig. #2

New power sources

While portable system users have traditionally charged their devices primarily from AC power, the increasing mobility of today's society has increased demand to charge batteries from a wider variety of sources. Today a large number of users prefer to charge their smart phone, portable media player or digital camera from the USB port of a personal computer or computer peripheral. More often than not, convenience is driving this trend. Most personal computers or other computing devices feature USB ports so users can recharge their portable system virtually anywhere. And since a USB port supports bidirectional data transfer, as well as power and ground from the host system, users can recharge their battery and update files or download music or video files at the same time.

The rising use of USB ports as a power source presents new challenges for system designers. First, USB ports come in many variations and may only loosely comply with industry standards. As an example, industry standard USB ports supply a nominal 5 V source with up to 100 mA or 500 mA of current, depending on type. This distinction necessarily will have a dramatic impact on charge time. A 500 mA USB port can be used to charge a 500 mA/hr battery in approximately 1 hour. But a user would have to wait five times as long to charge the same battery from a 100 mA port.

Perhaps more problematic, however, is the highly dynamic nature of the power environment on a USB port. Often the battery charging function must share the available USB port power with its host system, or with other systems. As load demands change, the system must manage the battery charge current charge level to ensure USB port integrity, i.e. not overload, and thus crash the USB port. Typically USB ports feature a current limit protection system. Whenever a USB port is used for a charging function and to power the host system, the system designer must ensure that the battery charging function does not draw more current than the port can deliver or the current limit protection system will shut the port down, stop the battery charge cycle, and potentially crash anything else that is connected to that USB port. Therefore, designers must develop specific mechanisms to address this issue and ensure the USB port will not be overloaded during the charging cycle.

Intelligent charging

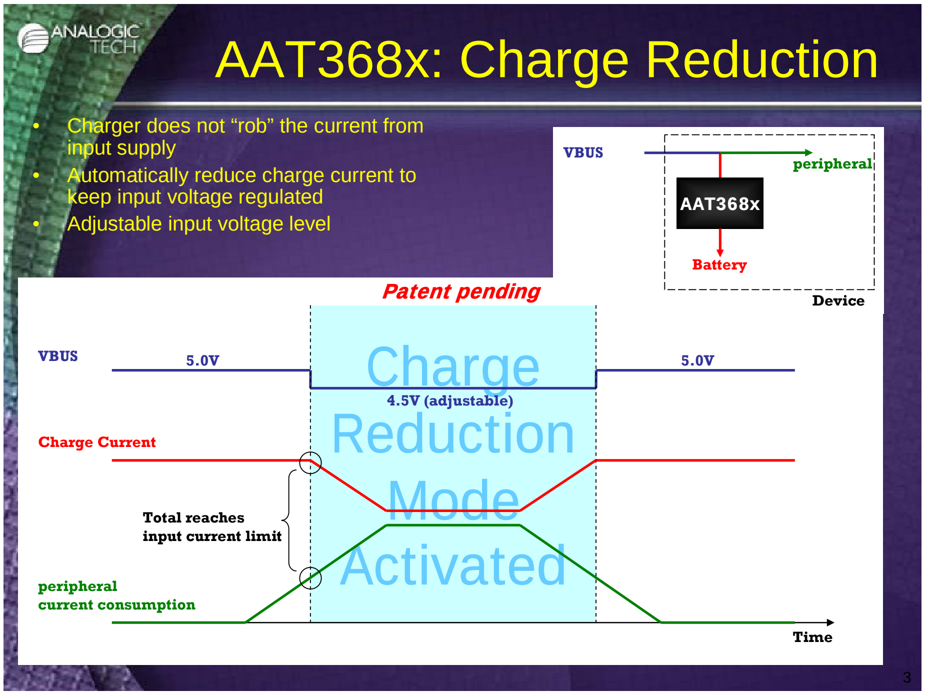
Until recently designers have addressed this problem by either shutting the battery charger off completely when sharing the USB port or by throttling the charge current back to a predetermined low level that necessarily extended the battery charge time to unacceptably long times.

Clearly the industry needed a new, more sophisticated and more intelligent approach to battery charging. Ideally this approach would allow portable system designers to charge the battery at the maximum rate available from a USB port without overloading the port by dynamically adjusting charge current as input conditions change. By automatically adjusting the constant current charge level to maintain a valid USB port voltage level, the charger IC could supply maximum charge to the battery and minimize charging time.

Over the last year or so power management IC manufacturers have begun to address this emerging need. A new generation of intelligent chargers now uses an algorithm-based mechanism to automatically adjust the charge level as the system demands more power. As the input voltage begins to sag, this intelligent control decreases the constant current charge level only to the extent necessary to keep the input voltage regulated and avoid a USB port shutdown.

AnalogicTech's AAT3685 battery charger IC offers an excellent example of this new capability. The device is a highly integrated, single-cell lithium-ion/polymer battery charger IC designed to operate with USB or line adapter inputs. To ensure users can charge the battery with available current from the charge supply while keeping the port voltage regulated, the AAT3685 adds an innovative optional charge reduction loop.

The charge reduction system on the AAT3685 becomes active when the voltage on the input falls below a preset threshold which is typically set at 4.5 V. If the voltage tries to sag below that level, then the system throttles back the fast charge current level only to the extent necessary to maintain the input voltage above the prescribed threshold (see figure #3). The factory preset threshold is 4.5 V. System designers can set a different threshold voltage by adding a simple resistor divider network to the circuit. If desired, the charge reduction loop can also be disabled.



By allowing the charger to continue to deliver to the battery the maximum current available, this charge reduction loop minimizes charge time while maintaining USB port integrity. It also helps simplify system design. The AAT3685 provides a single-wire digital interface which can be used to support high-speed, bi-directional communication between the battery charger IC and the system controller. The interface can be used to update the host controller on the battery charger's state, and thus the battery's condition. From the system designer's perspective, these tasks can now be implemented without the use of complex protocols, high precision timing or the use of multiple pins.

Conclusion
Demand for lighter, smaller, lower cost portable products shows no signs of diminishing. Today users expect their portable devices to offer a wider array of functions than their predecessors without increasing footprint or weight. At the heart of the power system in this new generation of compact portable products lies the reliable Lithium-ion battery. Despite all the functionality they now offer, the success of most portable products still relies largely on the ability of the system designer to deliver longer battery life and shorter recharge times.

Recent advances in battery charger IC design offers portable system designers new opportunities to meet these stringent requirements. By adding a new level of intelligence to the battery charging process, these new devices promise to reduce charge time, autonomously offer closed loop functionality that previously required host system processor involvement, improve safety and lower design complexity while helping shrink product footprint.