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Smart- battery technology: power management's missing link

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You no longer need to view a battery as a power-generating element whose characteristics are beyond your knowledge and control. The technology now exists to provide batteries with varying degrees of smarts, forming a critical link between the battery and host equipment.

A smart-battery-management philosophy and a surge of battery-management products now provide you with powerful means to optimize battery performance. Smart-battery technology produces accurate information about the state of a battery and enables optimum charge control. One implementation of this technology is a standardized smart battery that includes all the necessary electronics to monitor itself and communicate to its host (see **box** on pg 50, "What's a smart battery?"). However, you can also team up many available ICs and batteries to tailor the battery's level of intelligence to your particular system.

The need for smart-battery technology stems from the introduction of new battery types, each with its own stringent requirements for charging. In many cases, battery manufacturers won't supply these batteries-nickel-metal hydride (NiMH) and lithium-ion (Li-ion) batteries in particular-without mandating the use of an approved charge-control scheme.

NiMH batteries are more sensitive to overcharge than their NiCd relations. High heat resulting from a high-rate overcharge is most damaging to an NiMH battery's capacity and cycle life. Thus, fast charging an NiMH battery requires tight control of charging characteristics and accurate feedback about the state of the battery.

Although not widely available, Li-ion batteries mandate tight battery management for safety purposes alone. Li-ion batteries are simply dangerous if not charged properly. As one manufacturer said, "without battery management, Li-ion batteries wouldn't exist in the marketplace."

PICTURE 1

One goal of an intelligent battery and battery-management system, which this example GUI illustrates, is to provide reliable data-charge condition and charge state-to the end user. Another important goal is to control charging to enhance battery life. (Courtesy of SystemSoft Corp)

The concept and underlying technology of a smart battery is not new. In 1989, without much fanfare, Sanyo Energy USA introduced the SI101, a fast-charge control module for NiCd and NiMH batteries ($6.89 for 10,000 of the modules, $2.93 for just the IC). The company has integrated the module into battery packs for a wide variety of OEM customers. Many top-tier computer manufacturers are on this list, and others have developed their own battery-management schemes and ICs.

However, recent industry developments have put the spotlight on smart batteries and battery management. In an effort to standardize smart batteries and the way they communicate, Duracell and Intel introduced the System- Management Bus and Smart-Battery Data Specification last year. They hope their efforts, which included widespread industry input, will lead to a standard power-management bus for portable equipment and a standard smart-battery hardware configuration and data set (see **box**, "Smart-Battery and System-Management Bus Specifications"). The standards push is not without controversy (see **box**, "The debate over smart-battery standards," pg 59).

This year, Duracell will introduce its smart-rechargeable batteries as the first products to comply with these specs. However, many companies have designed intelligent-battery schemes of their own and perfected the underlying technology necessary to bestow battery intelligence, such as gas-gauge and charge-control techniques (see **box**, "For free information..." pg 63). Since 1991, Benchmarq Microelectronics has designed six gas-gauge ICs. In addition to Sanyo's module, Energizer Power Systems and National Semiconductor have teamed to develop an intelligent-battery chip set. And Rayovac and Benchmarq Microelectronics have cooperated on the design of an IC to control charging of Rayovac's Renewal line of reusable alkaline batteries. Rayovac plans to offer a full rechargeable system comprising four AA cells, the bq2901 IC, and a wall-cube adaptor for an OEM price of less than $6.

Finally, software vendors are getting involved. SystemSoft and Phoenix Technologies offer software that makes some of the battery data that an intelligent battery supplies available to a computer end user. The goal of such products is to let the user make changes in power-management software. The software would indicate what affect these changes would have on battery capacity.

Smart-Battery and System-Management Bus Specifications
The Smart-Battery Specification jointly developed by Intel and Duracell-with input and feedback from major computer OEMs and component suppliers-attempts to address the three major problems that batteries pose to equipment designers and end users. Batteries are unpredictable and, in their simplest form, have no knowledge of remaining operating time. Battery-powered equipment has difficulty determining if the battery can supply power for an additional load. And, you must tailor current

Smart-Battery and System-Management Bus Specifications

battery chargers to a specific battery chemistry.
The ultimate smart battery would provide complete information on its state of charge; answer questions of remaining capacity, based on a certain discharge rate; control its own charge regime that may vary with battery chemistry; and provide information on its history, such as maximum temperature extremes and numbers of cycles.

The Duracell/Intel specification attempts to provide this information according to each company's interests in the battery and portable-equipment marketplace. Duracell's interest in developing this specification is to standardize all types of rechargeable batteries. Intel's interest is to further the acceptance of its power-management bus, which they hope would further the use of portable computers. Although the companies tightly aimed the specification at the portable-computer industry, it is applicable to other portable products. Remember that the well-thought-out scheme they present is only one way to implement an intelligent battery system.

The specification itself comprises two essential parts: one defines a two-wire power-management bus that can communicate with various components, including but not limited to batteries. Intel's Architecture Labs created this System-Management Bus, or SMBus. The second is the actual smart-battery data and charger specification that details the batteries' data set and charge-control schemes.

The bidirectional SMBus lets you send any type of command with two wires that link all components. The bus's goal is to improve mobile systems by enabling better power-management software and hardware and providing more control over power-managed components. The SMBus uses the I2C-bus as its backbone and adds a software protocol (a definition of bus transfers, commands, etc) on top of I2C's physical electrical layer. The SMBus specifies certain voltages, such as logic-0 and -1 threshold voltages, more tightly.

The SMBus has much in common with the Access.bus protocol because both are based on I2C. The manufacturer intended the SMBus to act as an internal bus for connecting nonremovable components (the battery is the only exception). The Access.bus is an external bus for Plug-and-Play capability for external peripheral devices. However, the Access.bus spec can accommodate SMBus devices. Thus, a single controller can handle both.

The Smart-Battery Data Set

The Smart-Battery Specification defines a smart battery as "a battery equipped with specialized hardware that provides present state, calculated, and predicted information to its SMBus host under software control." The Smart-Battery Data (SBD) specification defines the data that flows across the SMBus between a smart battery, SMBus host, smart-battery charger, and other devices. The SBD specification includes software definition, error-detection, and signaling; the smart-

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battery data protocols; and the smart-battery data set of all messages between the host, smart battery, and smart-battery charger.

The data set defines 34 values of battery information. These values include temperature, voltage, and current. The data set also includes computed and stored values, such as AtRateTimeToEmpty (the predicted remaining operating time if the battery is discharged at the AtRate), RunTimeToEmpty (the predicted remaining battery life at the present rate of discharge), AverageTimeToEmpty (a one-minute rolling average of the predicted remaining battery life), AverageTimeToFull (a one-minute rolling average of predicted time until the battery reaches full charge), RemainingCapacity (in units of either current or power), RelativeStateOfCharge (predicted remaining capacity as percent of full-charge capacity), FullChargeCapacity (predicted pack capacity when fully charged), and CycleCount (number of charge/discharge cycles of the battery).

FIGURE A**As envisioned by Duracell and Intel in their Smart-Battery Specification, a typical single smart-battery system consists of a power supply, host, smart battery, and smart-battery charger. The last three communicate via the two-wire serial SMBus.**

Fig A shows a possible smart-battery implementation that consists of a single battery (the spec also allows extensions for multiple batteries), battery charger, and a host. As envisioned in the specification, the smart charger is independent of the battery, but under the battery's control. Also, to be compatible with multiple battery chemistries, the battery must have some control of the charge regime. Chargers that closely cooperate with the battery have two distinct advantages. First, they provide the battery with all the power it can handle without overcharging, and second, they can recognize and correctly charge batteries with different chemistries and voltages.

Smart-battery chargers

The smarts in a battery are basically for self-monitoring and communication. For controlled charging, the battery needs a smart charger listening to it. The battery knows how it must be charged, but the actual power generation is the job of the external charger. According to the specification, a smart-battery charger is "a battery charger that periodically communicates with a smart battery and alters its charging characteristics in response to information provided by the smart battery."

At the very least, a smart battery has a charge-control algorithm, but a smart charger can also have algorithms. You can implement a simple system, one in which the battery simply communicates whether it wants to be turned on or off. Or, you can implement a more sophisticated system, one in which a charger is smart enough to control a specialized battery.

To accommodate these possible schemes, the Smart-Battery Charger Specification defines three levels of chargers. Level-1 chargers can only interpret the battery's critical warning messages that indicate the system should no longer charge a battery. A level-1 charger can't adjust its output in response to requests from the battery or

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host, thus, it is not chemistry independent. In addition to supporting level-1 commands, a level-2 charger is an SMBus slave device that responds to charging voltage and current messages sent from the smart battery and can dynamically adjust its output characteristics. Using the charging algorithm in the battery, the level 2-charger may simply set a charge condition once or may adjust its output periodically to meet the needs of the changing battery. Thus, a level-2 charger is chemistry independent. A level-3 charger is an SMBus master device. This charger can poll the battery to determine the battery's desired charging voltage and current and can dynamically adjust its output to meet the battery's charging requirements. In addition to all capabilities of a level-2 charger, a level-3 charger can also implement an alternative specialized charging algorithm and can interrogate the battery for any relevant data, such as time remaining to full charge, battery temperature, or other data used to control proper charging and discharging. To order a copy of the Smart-Battery and SMBus specification, call (503) 797-4216 or (800) 253-3696, or e-mail ial_product@ccm.hf.intel.com and specify product code SBS5220.

The advantages of a high IQ

The advantages of an intelligent battery or intelligent battery-management system are clear: longer run times, longer lifetimes, and more end-user confidence in the battery information. Batteries that can deliver accurate information about their state of charge let you use all of that available charge more fully. Shorter charge times, which must be commensurate with controlled charging, result in longer run times. And, proper handling of the battery results in the longest possible life for that battery.

Depending on the specific implementation, other advantages include a management scheme that can recognize and handle batteries of different chemistries. The Duracell/Intel spec and many of the battery-management products can currently deal with numerous battery chemistries, including NiCd, NiMH, Li-ion, and lead acid. In addition, many ICs tailored specifically for Li-ion batteries will appear this year.

One of the greatest advantages of smart batteries or systems is the power-management possibilities they offer to a system engineer. These batteries provide a wealth of information that you can use to develop a proprietary power-management scheme, regardless of whether you use a standard battery or communication protocol. Dave Heacock of Benchmarq Microelectronics suggests adaptive charge control as one such technique. Using information from an intelligent battery, you could design a system that caters its sensitivity to the reported battery state. If you know a battery is empty, you could design the system to apply the full charge current. Once the battery fills up, the system could increase the sensitivity to identify the end-of-charge point very closely.

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