Backup Power Charge Control and Health Monitoring - A Technology Overview

SNIA NVDIMM SIG Contributor:

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The Storage Networking Industry Association (SNIA) is a not–for–profit global organization, made up of some 400 member companies spanning virtually the entire storage industry. SNIA's mission is to lead the storage industry worldwide in developing and promoting standards, technologies, and educational services to empower organizations in the management of information. To this end, the SNIA is uniquely committed to delivering standards, education, and services that will propel open storage networking solutions into the broader market. For additional information, visit the SNIA web site at http://www.snia.org or http://www.snia.org/international for a list of International Affiliates.

About the SNIA Solid State Storage Initiative

The SNIA Solid State Storage Initiative (SSSI) fosters *the growth and success of the market for solid state storage in both enterprise and client environments*. Members of the SSSI work together to promote the development of technical standards and tools, educate the IT communities about solid state storage, perform market outreach that highlights the virtues of solid state storage, and collaborate with other industry associations on solid state storage technical work. SSSI member companies represent a variety of segments in the IT industry (see http://www.snia.org/forums/sssi/about/members). For more information on SNIA's Solid State Storage activities, visitwww.snia.org/forums/sssi and get involved in the conversation at http://twitter.com/SNIASolidState.

About The Paper Battery Company

The Paper Battery Company designs and manufactures ultrathin ultracapacitors that deliver unprecedented flexibility and benefits in structural integration and distribution of high energy and power densities. The company is a leader in meeting customer needs for reliable backup power solutions for memory cards in various formats and footprints for easy placement within the enterprise servers, including a matched footprint for direct integration onto NVDIMM modules. The company's innovative business model and technology garnered the TIE50 2013 award. More information is available on request at sales@paperbatteryco.com

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Executive Summary

This paper provides an overview of charge control and management technology and the variety of implementations, explains state of health monitoring, and discusses new innovations and technological developments.

Why Is Charge Control and Management Important?

Charge control and management technology is the result of close developmental interaction between the product original equipment manufacturers (OEMs), ultracapacitor/battery OEMs and 3rd party integrated circuit (IC) vendors such as TI, Maxim, and Linear Technology Corporation. Charge control and management functionality may be implemented in OEM products with any combination of discrete components, industry standard ICs, or custom ICs.

A charge control IC, or equivalent charge control circuitry, sits in the power path between the input power source and the ultracapacitor or battery cell which requires charging. Switch mode charge controllers such as the TI BQ24640, which is designed for typical supercapacitor cell chemistry, can accommodate a wide input voltage range and regulate both charge current and charge voltage with built-in monitoring of charge status.

In the cases of NVDIMM and RAID adapter OEMs, the major goals of the charge controller are to ensure adequate energy to backup DRAM cache data into non-volatile Flash memory in the event of power loss over the specified life of the memory module, and to recharge the backup power source as quickly as possible when power returns in the possible event of a follow-on power loss event. Generally speaking, the charging and state-of-health controllers do not function integrally, and thus the target voltage is set at time of installation in historic NVDIMM systems.

Optimization of the local backup energy source through the charge controller requires management of several key parameters in order to achieve these goals safely and reliably. Such parameters include the target charge voltage (also called 100% State of Charge or 100% SOC), high-voltage and low-voltage cutoffs, charging current, charge time, and discharge time. In addition, most charge controllers also offer a separate operating state of health monitoring function to frequently assess the ability of the device to store and deliver adequate energy.

Is Everyone's Charge Controller Implementation Basically the Same? What Can Differ?

There are several classes of charge controller and management systems for each different ultracapacitor/battery and product type. Ultracapacitor and battery chemistry/materials can differ, and this directly impacts charging, equivalent series resistance (ESR), estimation of available energy and other behaviors which the controllers must accommodate and control.

Most lower and middle class charge controllers provide one or more basic common functions. In lower and middle classes of charge controllers, differentiation might occur in charge rate capability (current capability) or integrated features such as DC/DC converters.

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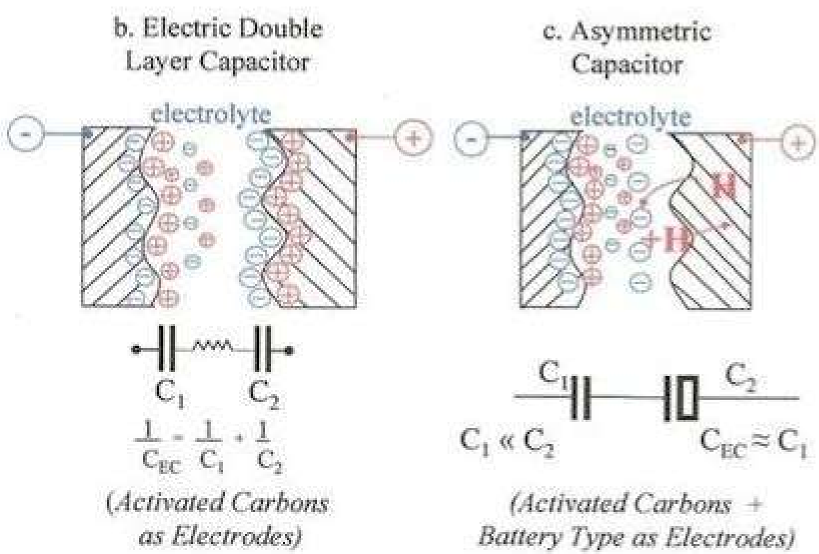
High-functionality charge controllers can be designed to provide significant end product differentiation. One example of this is the inclusion of a battery authentication function, which uses encrypted challenge-response codes to determine if the battery is original OEM, as most reported battery incidents are the result of sub-standard quality, unauthorized copies. Smart charging is another example of a high value-add feature. Smart chargers can be used to charge energy storage devices quicker and extend the useful life of the energy storage device. Smart charging can use, amongst other things, variable rate charging depending on the State of Charge (SOC) and change charging parameters based upon the temperature or aging of the energy storage device. These are usually finely tuned for a specific electrochemistry.

Most charge control hardware implementation use standard ICs wherever possible, though there are some exceptions in high-end chargers. Some new or customized charge controller features are implemented through glue logic and sensors and measuring components. However, the greatest differentiator impacting charge behavior and manageability is still the underlying chemistry/material of the rechargeable energy source itself.

Ultracapacitors that have been commonly used in memory backup applications (from vendors such as Maxwell and Nesscap) are electrochemical double-layer capacitors (EDLCs) with electrodes made from porous, activated carbon material and provide mostly electrostatic capacitance. Advanced hybrid technology ultracapacitors for memory backup, such as those now available from Paper Battery Company, Ioxus, and others, have asymmetric electrodes that provide both electrostatic and electrochemical capacitance. The hybrid ultracapacitors have higher energy density than standard ultracapacitors and a desirable mix of both ultracapacitor and battery benefits such as fast charge time, high-rate capability, longer cycle life (than a battery) and importantly, are much safer than modern batteries, with almost zero risk of internal shorts and runaway thermal flammability concerns.

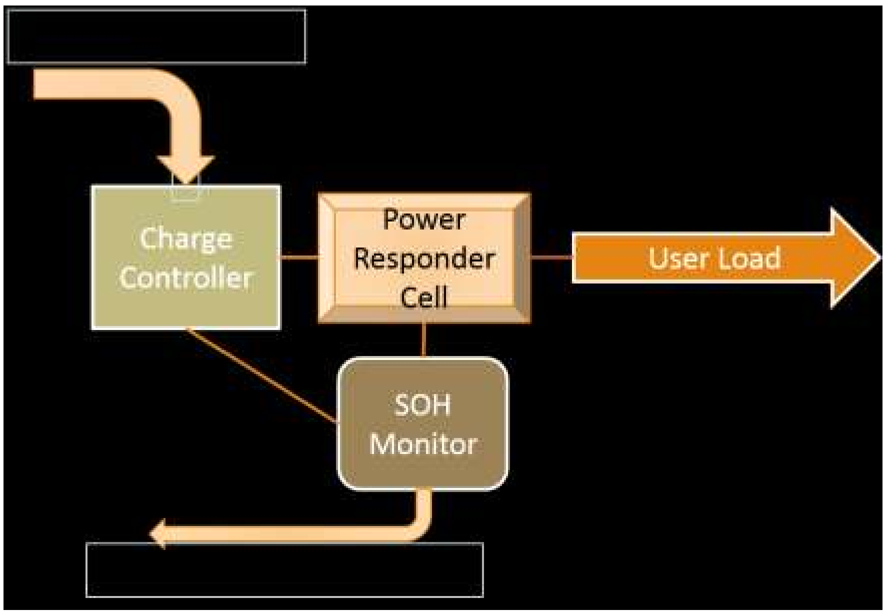


[1]

[1] http://www.energyharvestingjournal.com/articles/nanotecture-develops-asymmetric-electrochemical-supercapacitors-00001328.asp?sessionid=1

What Is State of Health (SOH) Monitoring, and Why Is It Critical?

SOH implementation varies among users, but in general, this function is used to monitor an energy storage device's ability to safely and reliably store and deliver its capacity, using ICs and custom or semi-custom firmware algorithms. A SOH monitoring system reports important parameters back to the user's system often via industry-standard protocols such as an I2C bus. Here is an illustration of an SOH monitoring system attached to Paper Battery Company's PowerResponder™ ultracapacitor.



For ultracapacitors, basic SOH monitoring systems report capacitance (energy), ESR (equivalent series resistance, a measure of its power capabilities), and leakage (a measure of its ability to retain stored charge). As with charge control and management, SOH technology is also the result of close interaction with ultracapacitor/battery OEMs and third party IC vendors, and in the case of SOH there is more room for proprietary technology.

Is Everyone's State of Health Monitoring Implementation Basically the Same? What Can Differ?

No, like charge controllers, there are several possible levels of SOH monitoring, and SOH currently has more opportunities for differentiating, proprietary technology than charge controllers. For instance, the "speed" at which any SOH system can determine if there is or might be an issue may have variable levels of importance depending on the user's application.

Some SOH systems "learn" the energy storage device only by carrying out 100% charge and discharge cycles. Other SOH systems may be able to report potential issues in near-real time. Still others can predict potential issues near-real time and make system adjustments to ensure safe and reliable operation until maintenance service can verify the problem and fix it, as necessary.

Another area for differentiation in SOH systems is the methods by which the SOH system determines whether there is a problem. In SOH systems that "learn" the energy storage device over multiple 100% charge and discharge cycles as an example, these SOH systems often assume the initial measurements taken on the new energy storage device represent "good" responses. The problem here is that not all new energy storage devices are in fact good, and not all are able to meet the variable demands of the users' systems. Thus, monitoring the behavior of a bad or insufficient energy source does not sufficiently enable proper system operation.

High end SOH implementations can determine SOH in near-real time and can quantify or predict upcoming negative trends quickly and accurately in relation to the needs of the user's system. SOH can give warnings to replace well in advance of failure, take part or all of the system offline, or place limits on the acceptable use cases.

IC implementations for SOH are more differentiated than for charge control/monitoring. For example, some use coulomb counters over full charge and discharge cycles for capacity, while others use advanced algorithms based on the specific electrochemistry to predict capacity using incremental changes in SOC, or through specifically chosen charge or discharge increments.

What Are Some of the System Benefits from Doing an Optimal Job with Charge Control and Health Monitoring?

The backup power solutions integrated with NVDIMMs need well-designed charge controllers and SOH monitoring that can allow ultracaps/batteries to be employed at significantly lower costs, be charged much faster, be given longer cycle life, and be taken offline or have their output limited as necessary if SOH is bad or questionable.

In the case of ultracapacitors, for instance, voltage settings and the temperature of the user's system govern the aging of any given electrochemistry and levels of current quality. In most systems, the charge controller and SOH monitor set the ultracapacitor's charging voltage at an initial level, and maintain that voltage to provide sufficiently guard-banded energy at the ultracapacitor's published end of life. By dynamically managing charge voltage, cell voltage can be kept at a minimum for longer life while continuously ensuring sufficient energy is available to provide a backup in the event of the a power loss. Cell placement options within the system are increased when wider temperature ranges are possible without sacrificing cell life. Near real-time monitoring of cell health and adjusting its voltage provides excellent indicators of normal and abnormal cell aging trends. Usually, when a user wishes or needs to place an ultracapacitor in a higher temperature region of the system it either means reducing the ultracapacitor's useful life in the user's system, or buying a bigger, more expensive ultracapacitor.

What Innovations or New Technological Developments Are Happening (or Are Possible) in the Areas of Charge Control and Health Monitoring?

There is ongoing innovation in ultracapacitor chemistry/materials/packaging, and in charging and state of health (SOH) methodologies and algorithms. The benefits from these innovations are likely to include improvements in state of charge (SOC) definition/determination, better service predictability, longer cycle lifetime, improved safety/reliability, tighter ultracapacitor application sizing (lower derating factor), and greater flexibility for ultracap form factors/component placement. These kinds of innovations are expected to occur over the next six months to two years.