THE HANSEN REPORT
ON AUTOMOTIVE ELECTRONICS

Vol. 27, No. 7 ◆ hansenreport.com ◆ September 2014

Ultracapacitors Still Showing Promise

More Applications Coming

Ultracapacitors can do things that batteries can't: They can provide an instantaneous power boost, and they can be charged and discharged millions of times, making them a perfect complement to batteries. Batteries provide significantly greater energy density and are best at providing power over a longer period, but over time the charge and discharge process degrades their ability to store energy.

Ultracapacitors are well suited to powering start-stop applications, especially when fast restarts (in 300 milliseconds or less) are required, and for maintaining the vehicle's supply voltage, as frequent restarts can drain the battery. Electric turbochargers, which require frequent power bursts, are another promising application, as is brake recuperation, because ultracapacitors can quickly take big gulps of power.

In 2010, **Maxwell Technologies** began shipping its ultracapacitors to **Continental** on behalf of a voltage-stabilization system that supports start-stop functionality in **PSA Peugeot-Citroën** vehicles. When the voltage from the lead acid battery falls too low, two ultracapacitors, connected in series, temporarily add five volts to the negative side of the battery to power engine starts and maintain sufficient bus voltage. As of May 2014, Continental had produced one million voltage-stabilization systems.

Since 2010, only one other ultracapacitor application has come to light. In August 2012, production began in Japan and Europe for the Mazda6 (non-hybrid) wagon, which featured **Mazda's** i-ELOOP (intelligent energy loop) regenerative braking system. The system includes a 12-25 volt, variable-voltage alternator connected to an electric double-layer capacitor (ultracapacitor) module. A DC to DC converter steps the alternator's output from 25 volts to 12 volts for distribution to the vehicle electrical system. i-ELOOP converts the vehicle's kinetic energy into electricity as the vehicle decelerates.

The Mazda6 with i-ELOOP, available in the U.S. since May 2013, is rated for 40 mpg on the highway. i-ELOOP is also available on the Mazda3. The double-layer capacitors are made by the Japanese company **Nippon Chemi-Con**.

High Costs

Historically, high costs have limited ultracapacitors' use in automotive applications, but costs are headed downward. According to Maxwell senior product manager Jens Keiser, carmakers have targeted a cost of a half-cent per farad. "We are starting to get there in high volume with our cells," he said. Maxwell offers 2.7-volt cells in 3,000-farad, 1,500-farad and 1,200-farad versions. At 2.7 volts per cell, a module with six cells is needed for operation at 14 volts. At a half-cent per cell, six 3,000-farad cells would cost $90, not including the module's housing, wiring and assembly.

Some carmakers have considered using ultracapacitors in 48-volt applications, but that would require 18 cells at a cost of $270 for the capacitor cells alone. Even at the target half-cent per farad price, most of the early ultracapacitor applications will be for 12 volts.

More Ultracapacitors Coming

Despite the fact that only two ultracapacitor automotive applications have thus far reached production, suppliers of them are confident that significantly more business is coming their way. Maxwell Technologies hasn't yet booked any orders beyond the PSA Peugeot-Citroën application but has lately been talking to a lot of carmakers and sees momentum building.

In correspondence with *The Hansen Report*, Nippon Chemi-Con describes the market for its double-layer capacitors as "very promising [given] the growing concern for the environment, worldwide." The company writes that it has already landed additional business beyond Mazda's i-ELOOP application.

Bosch hasn't yet sold a system with an ultracapacitor but has proposed systems that use them. "We see a lot of promise for ultracapacitors in multiple applications, not only in the automotive world but in subway and bus systems and in green energy applications," said Scott Averitt, a technical expert with Robert Bosch LLC. "As those volumes increase, ultracapacitor prices will come down, and that will drive more automotive applications."

Continental wrote: "We see high potential for double-layer capacitors, especially in 12-volt networks. ... We see more potential for DLCs in vehicles with start-stop systems equipped with pinion starters, where the customer expects fast restarts and support for cold starts." ◆

With an extremely high surface area of activated carbon, ultracapacitors have orders of magnitude more capacitance (up to 3,000 farads per 2.7-volt cell) and orders of magnitude more energy density than conventional capacitors. Ultracapacitors, which store energy electrostatically, have very low internal resistance ranging from 8 milliohms to as low as 0.3 milliohms for the 3,000-farad ultracapacitor offered by Nippon Chemi-Con.

Benefits

High power density: While their energy density is only a fraction of what a battery can provide, the power density of ultracapacitors is many times greater.
Temperature range: With an operating range of minus 40C to plus 65C, says Maxwell Technologies, ultracapacitors are better suited to the engine compartment than lithium-ion batteries and better for cold engine starting than batteries.
High cycling: Ultracaps can withstand more than one million charge-discharge cycles.
Fast charge and discharge: As little as a fraction of a second for charging or discharging.
High charge-discharge efficiency: More than 95%, with a power density of 1kW/kg, according to Nippon Chemi-Con. Uncompromised by the depth of discharge.
Environmentally friendly: Unlike batteries, ultracapacitors have no heavy metals.
Long lifespan: Ultracaps provide 15 years or more of maintenance-free operation in automotive applications.
Volumetric density: higher than batteries