WHITE PAPER

DISTRIBUTED ULTRACAPACITOR MODULES TO ADDRESS POWER AND REDUNDANCY NEEDS OF VEHICLES

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Increasing comfort and safety demands, as well as reduced environmental impact, are today's main market drivers for passenger vehicles. To fulfill these requirements, more and more electrical systems with increased package density will be implemented in vehicles in the near future. Along with these new vehicle functions, the electrical distribution system has to fulfill all the increasing power and reliability demands. Ultracapacitors meet these requirements perfectly: they offer pulse power and power cycling capability far in excess of traditional energy storage technologies and can be designed for the life of the application.

Ultracapacitors have already found application in the propulsion system of conventional gasoline and diesel hybrid as well as fuel cell hybrid vehicles. BMW's hybrid X5 and Volkswagen's fuel cell powered Bora are example prototype vehicles, while Honda's IMA, and Toyota's ES are production vehicles that incorporate ultracapacitors as high power energy storage devices in the hybrid electric power trains. The reason for the acceptance of ultracapacitors in vehicle propulsion systems is their high pulse power capability, fast transient response, and high efficiency during discharge and re-charging plus full charge cycling in excess of 500k cycles. The ultracapacitor is now proven to be an ideal augmentation to hybrid power trains as an electrical peaking unit.

Due to the increasing power demand, as well as the need for redundancy that new vehicle functionalities require, automotive engineers need to develop new electrical distribution system architectures. Examples of such functions include safety critical subsystems, power train subsystems, as well as body electrical systems and customer amenities that increase the comfort of passenger vehicles. Safety critical subsystems include steer, brake and drive by wire and electrified engine functions such as electro-mechanical engine valve actuation. Power train subsystems include engine cooling fans, water and oil pumps, transmission oil pumps, catalyst pre-heating systems, and motor-generators (ISG) for hybrid functions. Body electrical systems include door, seat, window, trunk and many other electrically actuated subsystems. Customer amenities such as electrically driven air-conditioning, quick heat for seats, steering wheel and passenger cabin are typical applications that require electrical power.

Safety critical loads are typically short duration, high power loads. Power train functions such as boosting and energy recuperation as well as body electrical systems are medium term loads. While batteries are ideally suited to deliver the energy for long term events such as cabin air conditioning during idle-stop mode of an ISG, they are not designed to satisfy the most important requirements of short and medium term loads: to provide bursts of power in the seconds time frame over many hundreds of thousands of cycles.

Ultracapacitor Technology

Compact in size, ultracapacitors can deliver much higher peak power compared to batteries and store an incomparably higher amount of energy than conventional capacitors. Indeed, ultracapacitors from Maxwell offered under the trademark BOOSTCAP® are currently available on the market from small prismatic cells offering 5 and 10 Farad capacitance up to larger cylindrical cells which deliver 2700 Farads. Maxwell recently developed a new, high power ultracapacitor that features a revolutionary case design. The BCAP0350 “D cell” BOOSTCAP is the first in a series of new ultracapacitors to be standardized on battery-sizing to drive down the costs and allow easier integration of the technology.

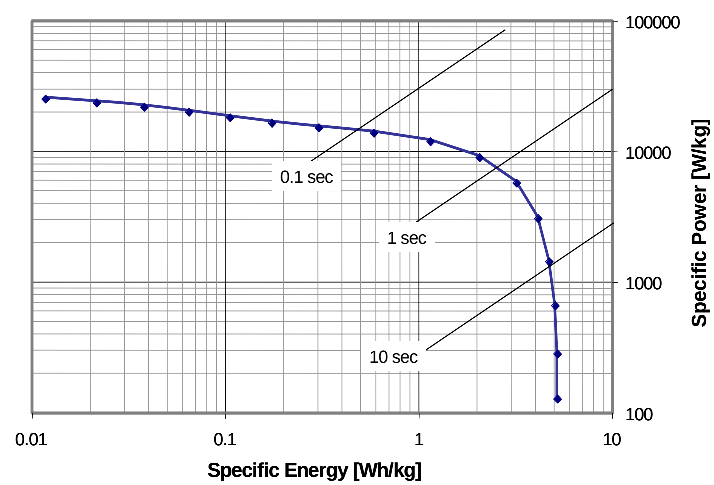

Figure 1: New, high power BCAP0350 “D cell” BOOSTCAP® and its Ragone plot showing the specific power density against the specific energy density

This 350 Farad ultracapacitor, rated at 2.5 V, is designed for maximum power throughput. Weighing less than 60 g, it features a power density of up to 25 kW/kg and energy density of 5.1 Wh/kg and the operating temperature range extends from -40 to +70°C. Thanks to the outstanding performance, as well as the low cost design, this cell is ideally suited for distributed module architecture of vehicles. They can repeatedly provide very high power pulses, recharging as fast as they are discharged, all with little affect on the life of the product. Because they are capable of cycling over 500k times, they are virtually maintenance-free over the life of any product in which they are used. To facilitate adoption of ultracapacitors for energy storage and power delivery demands of large systems, Maxwell provides fully integrated power packs.

Safety critical x-by-wire applications of distributed power modules

An electrical system architecture with modular and distributed power modules is one method of addressing the need for power and redundancy required by the safety critical and security systems in automotive applications. Distributed ultracapacitor modules alleviate electrical distribution system voltage sag and transients by supplying high peak power locally, while requiring only the average power from the vehicle's primary power supply. This essentially decouples the high transient power load from the vehicle's power supply system.

A further requirement of safety critical applications is the necessity of redundant power supply in the event of loss of the main electrical distribution system branch circuit for x-by-wire functions. Distributed power modules located at critical loads such as near the electric power assist steering system, or near electro-hydraulic brake modules offers the vehicle designer additional redundancy for such safety critical applications.

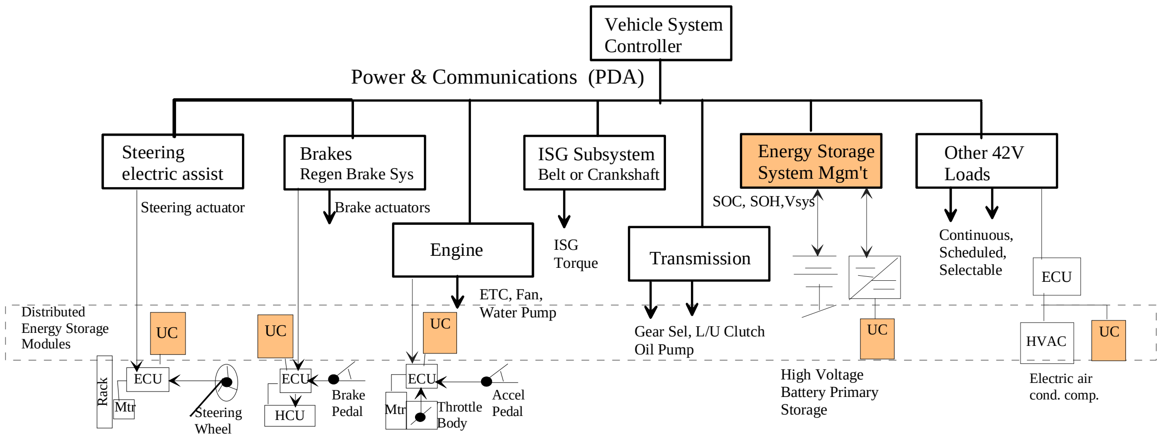

Figure 2: Distributed module architecture for vehicle safety critical and hybrid functionality

Properly sized ultracapacitor modules, at the point of load in electric assist steering, insure that adequate power is delivered to the electric steering motor without incurring excessive electrical distribution system line voltage drop and its consequent impact on steering system dynamics and represents a redundant source of power in close proximity to the actuators. Unlike hydraulic power assist, which is generally over sized for the function, electric systems rely on fast transient response to deliver the desired function. The situation with brakes is similar, high pulse power from distributed modules, which could be packaged in the brake systems hydraulic electronic control unit, provide not only point-of-load power but also function as a redundant energy supply as well. 20 Farad, 42-volt ultracapacitor power modules, consisting of a string of 18 BCAP0350 D Cells in series, would meet all the load requirements of electric assist steering and braking system applications. Such modules are capable of greater than 500,000 full charge/discharge cycles without exceeding 20% loss in performance.

The distributed module concept can also be extended to the case of mild hybridization, by the introduction of new drive train functions like start-stop and regenerative braking, e.g. by a ISG subsystem. Such hybrid functions can be made more durable with a modest amount of distributed energy while decoupling the vehicle energy storage system from high cycling loads.

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