# Ultracapacitor's in Automotive: Where and When Ever Power Needed

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**Abstract**
*As ultracapacitors are being used for many years in applications in the fields of transportation, regenerative energy and industry recently they become more and more an important component for automotive engineers. Global pressure on car manufacturers to build low or zero emission vehicles forces designers to review energy storage systems. Therefore an ultracapacitor is used because of significant advantages compared to traditional storage systems as batteries. Besides enabling to size the primary energy system only for average power needs ultracapacitors fascinate by their robustness under challenging thermal, mechanical and electrical conditions. With these characteristics they can form a highly efficient system in combination with other energy storage systems. Maxwell Technologies offers a wide range of components which match to many applications in automotive and other engineering sectors.*

**Keywords**
*ultracapacitor, power storage, battery, electrical energy*

## 1. INTRODUCTION

Global pressure on improving the environment and the subsequent search for significantly cleaner and more efficient vehicles is driving the development of hybrid and electrical vehicles. The success of these new vehicle architectures depends on the development of advanced energy storage technologies, including batteries and Ultracapacitors (UC). A challenge is the combination of different components, supporting the needs also fitting into the price targets of the manufacturers and fulfil both all their requirements.

## 2. ULTRACAPACITORS AS POWER STORAGE

The majority of vehicle systems in development today rely on battery technology, due to high energy density, its relative maturity, and its familiarity to designers. Already today the continuous increase of power demand, due to comfort and security improvements and the trend to fuel reduction drive the automotive industries towards new solutions and use of new components meeting such kind of requirements.

While progress has been made in control, engine and motor design, they have not been successful with regards to the electric power storage systems. Automotive engineers generally address peak power needs by designing the primary energy source, such as an engine or a battery system, to the size needed to satisfy peak demands, even if those demands occur for only a few seconds. Sizing an entire system for peak power needs, rather than for the average power requirement, is costly and inefficient. Such systems can be significantly improved by storing electrical energy generated from the primary energy source such as an engine, a battery or a fuel cell and then delivering that energy in controlled high power bursts only when high power is required. Such high power delivery provides automotive electrical systems with dynamic power range to meet peak power demands for periods of time ranging from fractions of a second to several minutes.

Although batteries currently are the most widely used component for both primary energy sourcing and energy storage/peak power delivery, UC increasingly are being used for energy storage and peak power delivery. The deficiencies of battery storage systems are multiple and they create many design challenges for engineers. [KiloFarad International, 2008]

Batteries have a poor low temperature performance, a very limited lifetime under extreme conditions, which results in repeated replacement throughout the life of the vehicle, and they are not designed to satisfy the most important requirements of automotive power sources: to provide bursts of power over many hundreds of thousands of cycles. With no moving parts, UC's provide a simple, solid state, highly reliable solution to buffer short term mismatches between power available and power required. When appropriately designed with a systems approach, they offer excellent performance, wide temperature range, long life, flexible management, reduced system size and cost as well as high reliability.

The UC products are already in operation in various applications outside of automotive for more than 8 years. While the UC's are performing and used in a variety of ways, like the large-cell UC used in the design of power trains for engine starting and in regenerative braking systems and the smaller UC used for interior lighting, back up systems, lock, and power door/window applications the products got accepted. [Deshpande et al., 2008]

Meanwhile the automotive industry recognizes the advantages and availability of ultracapacitors at reasonable cost level too. Any application that requires the storage of electrical energy and the discharge of highly variable amounts of power is a potential market for UC's. They are becoming a standard energy storage option, but nevertheless the significant differences between batteries and UC requires new system design approaches.

### 3. THE TOP 10 REASONS FOR USING UCS IN SYSTEM DESIGNS

1. Very high efficiency
2. High current capability
3. Wide voltage range
4. Wide temperature range
5. Life extension for other energy sources
6. Condition monitoring (SOC & SOH)
7. Long cycle life
8. Long operational life
9. Ease of maintance
10. Very safe and reliable in operation


**Fig. 1** Maxwell's MC cell series

### 4. ULTRACAPACITOR USE IN AUTOMOTIVE APPLICATIONS

In combination with other energy storage solutions such as lead-acid batteries, fuel engines, and fuel cells, the complete system can meet performance and cost goals unachievable with a single energy storage technology.

Any application that requires the storage of electrical energy and the discharge of highly variable amounts of power is a potential market for UC. Since UC's and batteries have significantly different characteristics, few current designs can immediately replace the battery with an UC. The unique characteristics of the UC allow additional dimensions in design to be explored, and open up opportunities for the development of new power train- and subsystem-architectures which can improve on the goals of performance, efficiency, and cleanliness.

### 5. BOARDNET STABILIZATION

With today's 14 V systems, designers have responded with stopgap measures to avoid the voltage drops and the corresponding failures of embedded circuits. For example, some vehicles now have a second battery to support the boardnet. However, this adds weight, cost and complexity and still can't eliminate all incidents.

This has led designers to explore ultracapacitor solutions. The short-term power demands that cause voltage dipping can be buffered with a 14 V ultracapacitor module with enough energy storage to supplement peak power demands. [Miller, 2008] The ultracapacitor recharges itself from the main power bus when it is not under load, and stores sufficient power locally to meet a local peak. It also ensures that the voltage to a logic board does not drop below the cut-off level, even if the voltage on the main power system dips briefly.

The ultracapacitor replaces the need for a second battery, takes less weight and space, requires no maintenance, lasts the life of the car, and performs reliably at – 40 C. The acquisition cost, in high volume, is about the same as a second battery and associated cabling, and the life cycle cost to the consumer is lower.

### 6. DISTRIBUTED POWER MODULES

As well as boardnet stabilization, ultracapacitors are also being used to provide distributed power systems elsewhere. Ultracapacitors' long life and high cycle life make them ideal for sub-systems such as steering, braking, heating, hi-fi stereo, and power seats that demand highly variable power loading. Localized load levelling of pulse loads such as electric brakes, electric steering racks, electric heaters, door actuators, and electronically actuated parking pawls also will reduce the need to run high-current wires long distances within the vehicle.

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. [Deshpande, 2008] This essentially decouples the high transient power load from the vehicle's power supply system. A further requirement of safety critical applications is the need for a 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, offer the vehicle designer additional redundancy for such safety critical applications.

**ABOUT MAXWELL TECHNOLOGIES**

Maxwell Technologies applies industry-leading capabilities in power and computing to develop and commercialize electronic components and power and computing systems for customers in multiple industries, including transportation, telecommunications, consumer and industrial electronics and automation, medical imaging, and aerospace. [Maxwell Technologies, 2008].

Our high-reliability components and systems business consists of the following product lines:

- Ultracapacitors for energy storage and delivery of rapid bursts of power for applications ranging from consumer electronics to hybrid diesel/electric buses
- Microelectronics for space and military applications requiring high reliability in radiation-intense environments
- High voltage capacitors for switchgear, CVT and laboratory applications

These products address rapidly growing, high-value markets, and are protected by strong intellectual property positions.

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