WHITE PAPER

FROM COMPONENTS TO SOLUTIONS: DESIGNING ULTRACAPACITORS INTO REAL-WORLD APPLICATIONS

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While batteries have improved steadily, new alternative or complementary technologies are also developing fast to provide energy storage across a wide range of applications. As they reach the mainstream, these new components must make the jump from being just stand-alone parts, to being solutions and modules that are fully designed for the reality of harsh environments and high-reliability applications.

One example is the ultracapacitor, an energy storage device that is well-suited for delivering high power over short periods. Compared to batteries, ultracapacitors are more reliable with a longer lifetime, can operate better at extreme temperatures, and can be physically smaller for a given power requirement. This makes them the perfect companion to batteries in some applications.

The activated carbon electrode of an ultracapacitor has a charge separation of 10 Angstrom or less with a specific surface area of 2000m^2/g, which means the device has a very high capacitance and thus power density. The energy storage mechanism is highly reversible, leading to a cycle life of over 1 million cycles with minimal degradation. Wide operating temperatures between –40ºC and +65ºC, or even higher for short durations, are possible due to their high conductivity and low freezing point electrolyte.

Today, ultracapacitor products range from small, flat form factors integrated into industrial wireless devices, through to larger modules for harsh environments, such as wind turbines or city buses. While their construction is application-centric, the common goal of ultracapacitor products remains reliable power delivery over a long operating lifetime in order to minimize maintenance and service costs.

While reliability is key, industrial customers also want to be removed from the detailed design of the energy storage system. Off-the-shelf components rarely meet these requirements, and application-specific solutions are needed.

Real-world applications

Let's consider four examples, which show how ultracapacitors can be adapted for different demands. The packaging and connectors provided are vital to ensure effective integration, and this is where most advances have been made over the last year or so.

Firstly, ultracapacitors are used in automatic meter reading (AMR), where reliability and long life are crucial, since the cost of a maintenance event may well outweigh the cost of the meter itself. In one application, wireless meters were using batteries which provided

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a three to five year operating life. By switching to ultracapacitors as an energy storage device, the operating life was extended to over ten years.
Ultracapacitors for this application were supplied with a glass seal that guarantees effective isolation from temperature, humidity and mechanical stress, and were designed and tested for low leakage current. They are able to provide predictable operations in a wide range of temperatures with limited cooling, and due to their flat form factor are straightforward to integrate in the meter to lower manufacturing costs.
Likewise, reliability and long lifetime are vital in uninterruptible power supplies (UPS) applications for telecom power backup, and in particular for cell phone base stations. To ensure a predictable lifetime over many years, Maxwell has packaged its 350F ultracapacitors for UPS applications in a hermetically sealed, impurity-free can design. This also provides mechanical and dimensional stability over the operating life of the component, while wide, tin plated tabs ensure ease of board assembly and reliable support for high current spikes. “Ultracapacitors have much longer operational life, require little or no maintenance and are far more reliable, especially in harsh environments where backup power often is needed most. The use of ultracapacitors also reduces the overall system weight and volume due to the stable capacity in farads that enables us to scale the bridge power to the exact system requirements,” stated Per Albaek, Dantherm Power’s President and Chief Executive Officer.
Another growing demand for reliable energy storage is in wind turbines, which are often located in remote and even offshore places. A power backup system is needed so if there is an interruption to the energy grid supply the pitch of the turbine blades can be safely controlled, even in high wind conditions. Maintenance must be kept as low as possible, even in harsh climates ranging from hot deserts with wide temperature swings, to high humidity areas.

Maxwell has designed its 75V modules into this application by putting special emphasis on the construction and testing for high isolation voltage, and by integrating monitoring and balancing. The modules must also be designed for harsh conditions of vibration, temperature and humidity, by careful component placement and selection of appropriate grade mechanical parts.

Finally, ultracapacitors are finding increasing usage in vehicle applications, storing the energy available on braking and then releasing it for acceleration. Large capacity ultracapacitors are used in busses and public transport, as well as in industrial cranes. Again, the requirements are for high reliability in extreme environments: a city bus in central Europe can experience frigid temperatures in winter and 40ºC in summer, and must perform reliably throughout.

For transportation applications, compromising on passenger and personal safety is just not an option. Thus, the construction of ultracapacitor modules requires consideration of the appropriate creepage and clearance specifications to achieve the most reliable electrical isolation, even at operations over 800V. The modules must also be designed so that no modifications to existing vehicles are needed, for example by allowing them to installed on the bus roof, thus minimising costs and cutting time to market.

They must be designed and tested to meet the most stringent vibration standards and IP65 humidity resistance, with special attention paid to the mechanical sturdiness of the interface between ultracapacitor cells within the module.

In summary, the main technical reason why ultracapacitors are being considered in many applications is their high power density. However, long lifetime and robustness are equally important to industrial customers, simply because cost of ownership is much higher than the initial cost of purchase. Hence, the need for an ultracapacitor energy storage that is optimized for the specific reliability and environmental requirements of a particular end user's market.

Pictures:
Maxwell's 75V and HTM125 ultracapacitor modules

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