Top 10 Reasons for using Ultracapacitors in your system designs

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Historically, the use of a single energy device to satisfy the entire power specification of an application required designers to either design for power (at times providing excess energy), or design for energy (at times providing inadequate power).

Ultracapacitors, also known as electrochemical double layer capacitors (EDLC), have unique characteristics when compared to other energy storage devices. By leveraging these unique features, you have more freedom when designing your power system. The high performance characteristics of Maxwell Technologies' ultracapacitors allows you, the system designer, to develop hybrid power system solutions that cost less and perform better than non-hybrid solutions.

The benefits of using ultracapacitor technology in your designs are quite extensive. Here are ten reasons why you should consider using ultracapacitors in your power systems:

1. Very High Efficiency

MAXWELL ultracapacitors are highly efficient components. Their coulombic efficiency (defined as the total charge removed divided by the total charge added to replenish the charge removed) is greater than 99%, even at very high currents, meaning that little charge is lost when charging and discharging the ultracapacitor. Round-trip efficiency is also very high, due to the low equivalent series resistance (ESR). At a 5 second rate*, round-trip efficiency is greater than 70%. At a 10 second rate, RTE is greater than 80%. This results in not only a more efficient use of your energy, but less heating, and therefore potentially less overhead for cooling your energy storage.
*discharging to ½ voltage in 5 seconds, and recharging at the same rate until the ultracapacitor is fully charged

2. High Current Capability

MAXWELL ultracapacitors are designed with a very low equivalent series resistance (ESR), allowing them to deliver and absorb very high current. The low ESR of MAXWELL ultracapacitors allows them to be charged very quickly, making them well suited for regenerative braking applications and other quick-charge scenarios. The inherent characteristics of the ultracapacitor allow it to be charged and discharged at the same rates, something no battery can tolerate.

If you wish to charge your energy storage device quickly (in applications like regenerative braking and quick-charge toys), you can charge the ultracapacitor as quickly as the system will allow, within reasonable limits based only on simple resistive heating. In battery-based systems, you can only charge as fast as the battery will accept the charge. This limits the system to only low to moderate charging rates, and may also limit how frequently one can charge, a significant issue in braking systems. Furthermore, the battery does not self-limit this charging rate, therefore you as the systems designer must manage this charging. In some cases, you may need the extra energy you get with a battery. In these cases, you can combine an ultracapacitor and a battery to get the best of both, optimizing your system design. Examples include consumer electronics such as digital cameras, in which an inexpensive alkaline battery is combined with an ultracapacitor, and automotive applications such as hybrid power trains. In both examples, the high power pulses are provided by the ultracapacitor, while the large energy requirement is provided by the battery.

3. Wide Voltage Range

Because they are capacitors, ultracapacitators are not confined to a narrow voltage window. Designers need only consider the voltage range of the system, which can be much wider than the narrow voltage range required by a battery. The ultracapacitor can operate at any voltage below its maximum continuous operating voltage. To achieve higher voltages, multiple cells are placed in series, and are operated at or below their total series maximum voltage. There is no risk of over-discharging the ultracapacitor, and in fact there is additional safety for service personnel, who can fully discharge an ultracapacitor system before servicing, reducing the electrical hazard. In some systems such as fuel cells, the ability of the ultracapacitor to track with the fuel cell's voltage is a significant benefit over battery/fuel cell systems, where the fuel cell wants to operate over a voltage range that is wider than that tolerated by batteries.

4. Wide Temperature Range

Since ultracapacitors operate without relying on chemical reactions, they can operate over a wide range of temperatures. On the high side, they can operate up to 65°C, and withstand storage up to 85°C, without risk of thermal runaway. On the low side, they can deliver power (with slightly increased resistive losses) as cold as -40°C, well below the cold performance threshold of batteries.

The excellent cold performance of MAXWELL ultracapacitors is an excellent fit for engine-starting applications. When combined with batteries, you can implement a system that meets the energy requirements with a battery (such as powering lights and stereos while the engine is off) and the power requirements with the ultracapacitor (such as turning the engine over when it is cold, or when the battery may be discharged from powering lights and stereos while the engine is off).

5. Condition Monitoring (SOC & SOH)

Determining battery state of charge (SOC) and state of health (SOH) is a significant factor in designing robust battery systems, requiring sophisticated data acquisition, complex algorithms, and long-term data integration. In comparison, it is very simple to determine the SOC and SOH of ultracapacitors.

Since the energy stored in a capacitor is a function only of capacitance and voltage, and the capacitance is constant (relatively speaking), a simple open-circuit voltage measureament defines state of charge. Since capacitance is relatively stable, voltage alone effectively determines SOC. Because of the relatively slow change in capacitance and equivalent series resistance over time, occasional calculations of capacitance and ESR can be used to determine SOH. A short (2-10 sec) discharge at any constant current can provide sufficient data to calculate capacitance and ESR. Since these values change slowly, this SOH data point, when combined with an open- circuit voltage measurement for SOC, yields all the information required to determine the condition of the ultracapacitor.

6. Long Cycle Life

The energy storage mechanism of an ultracapacitor is a highly reversible process. The process moves charge and ions only. It does not make or break chemical bonds. It therefore is capable of hundreds of thousands of complete cycles with minimal change in performance. Cycle depth is also not an issue, so ultracapacitors can be micro-cycled (cycled less than 5% of their total energy) or full cycled (cycled greater than 80% of their total energy) with the same long life. They can be cycled infrequently, such as in an uninterruptible power supply system where they may only be discharged a few times a year, or they may be cycled very frequently, as in a hybrid vehicle.

7. Long Operational Life

Since there are no chemical reactions, the energy storage mechanism of an ultracapacitor is a highly stable process. It is therefore capable of many years of continuous duty with minimal change in performance. Long-term storage is not an issue, since the ultracapacitor can (and should) be stored completely discharged. The long cycle life and long operational life make the ultracapacitor a lifetime component for most applications. Battery replacement is considered normal routine maintenance, costing time and money. In most cases, ultracapacitors are installed for the life of the system.

8. Life Extension for Other Energy Sources

Energy sources such as batteries, specialty engines, and fuel cells don't perform well in transient conditions. For some components, transients can significantly shorten life. Coupling an ultracapacitor with these energy sources off-loads many of these transients from the main energy source. The benefits are a smaller main energy source, and one that has potentially much longer life. The life cycle cost of the battery associated with an ultracapacitor-battery system may be much lower than that of a battery-only system.

9. Ease of Maintenance

Ultracapacitors require basically no maintenance. They have no memory effects, cannot be over-discharged, and can be held at any voltage at or below their rating. If kept within their wide operating ranges of voltage and temperature, there is no recommended maintenance.

10. Straightforward Integration

The inherent nature of ultracapacitors makes system integration relatively easy, much easier than with batteries. Systems integration with respect to the ultracapacitor is primarily focused on keeping the ultracapacitor within its wide operating limits of voltage and temperature. Ultracapacitors can be placed in series or in parallel. When installed in parallel, no extra management is necessary. When placed in series, a voltage management circuit is often used to keep the voltage of each cell within operating limits. Voltage management circuitry is often used in battery systems as well, however, an ultracapacitor management system need only prevent cells from exceeding their rated voltage. This is typically done with a simple voltage-sensitive current-bypass circuit. No control is necessary to keep cells above a minimum voltage, since ultracapacitors have no lower voltage limit. For installations that are conservative with respect to individual cell voltage, no management system may be needed. Recent technology improvements have significantly decreased variations in performance from cell to cell, reducing the need for management systems, with the potential to eliminate them completely.

Ten Reasons = Design Flexibility

These ten reasons give you additional flexibility when designing your system. Ultracapacitors can be used as the only energy storage in a system, or can be used to augment other energy sources in a hybrid system. They can be charged and discharged quickly, allowing them to be used in a variety of system architectures. Though the high power density of the ultracapacitor is offset by its low energy density, appropriate systems design with ultracapacitors accounts for the high power/low energy density by using the ultracapacitor as an intermittent power cache rather than a continuous power source. Where one previously traded system performance against the size of a single component, one can now strive to meet the optimum system performance by balancing two components; an energy cache, and a power cache.