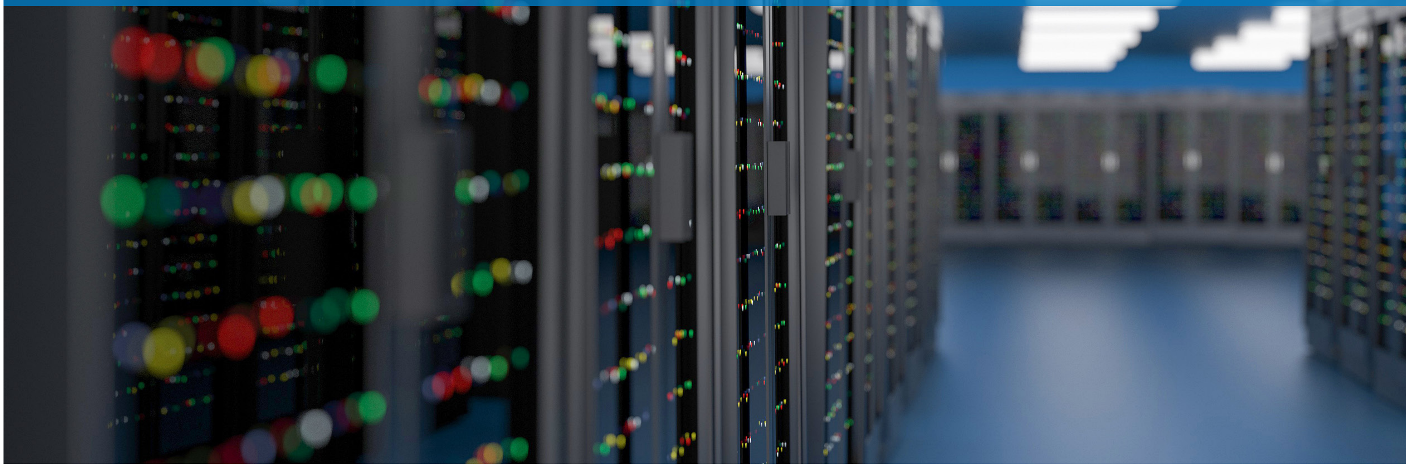
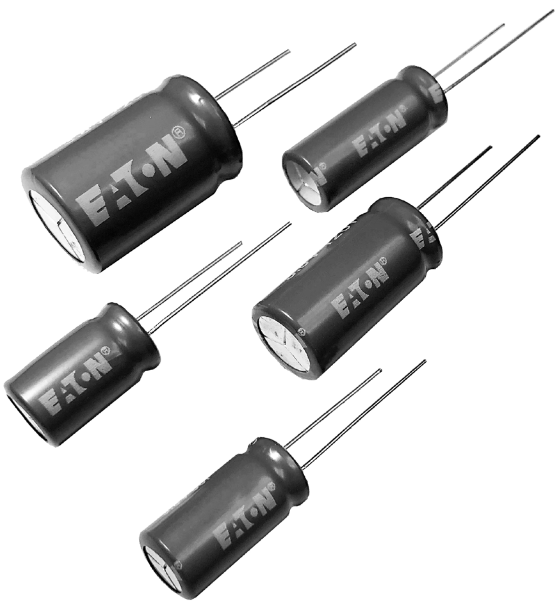
Hybrid supercapacitors white paper



Eaton's hybrid supercapacitors combine proprietary materials to achieve greater energy density and cycle lifetimes



Executive summary

With the ever-increasing need for reliable power in industrial, energy, and computing applications, the use of portable energy storage has become more commonplace than ever. Lithium batteries, a once-ubiquitous energy storage solution, are rapidly giving way to the more reliable, efficient, and long-lasting supercapacitors (aka "ultracapacitors").

Key drivers of this market are the fast charging capabilities, temperature stability, flexibility, and longevity of supercapacitors. Supercaps deliver hundreds of thousands of charge/discharge cycles, compared to only hundreds (or a few thousand) in lithium-ion batteries. Moreover, supercapacitors pose zero thermal runaway risk over a wide range of temperatures, making them inherently safer than batteries.

Hybrid supercapacitors are variants of standard supercapacitors that combine lithium-ion technology and electric double-layer capacitor (EDLC) construction for improved performance. As promising solutions for reliable energy storage, there has been a strong demand for these devices in recent years. This white paper will discuss the hybrid capabilities of the Eaton's HS, HSL, and HSH families of supercapacitors, their benefits over conventional EDLC types, and their suitability for industrial, energy, and computing applications.

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Hybrid supercapacitors: The best of both worlds

Hybrid supercapacitors are energy storage devices that combine the benefits of electric double-layer capacitors (EDLCs) and lithium-ion technology, achieving over 100% greater energy densities with very long cycle lifetimes. Inside a hybrid supercapacitor, one of the carbon-based electrodes is replaced with a lithium-doped carbon electrode similar to a battery.

Key terms

The following are some essential terms associated with Eaton's hybrid supercapacitors:

• **Capacitance**: The maximum amount of charge stored by a capacitor, measured in farads, F.

• **Cycle life**: The maximum number of charge / discharge cycles a supercapacitor can achieve. Eaton's HS, HSL and HSH hybrid supercapacitors can deliver 250,000 to 500,000 charge / discharge cycles.

• **Energy density**: The amount of charge a supercapacitor can store per unit volume, measured in watt-hours per liter (Wh/L). Many applications are also looking at specific energy, watt-hours per kilogram (Wh/kg).

• **Maximum working voltage**: The maximum voltage that the supercapacitor can withstand without damage.

• **Self-discharge**: The rate of discharge (volts per day, week, month) of a supercapacitor when not in use or during storage. An associated parameter is leakage current. Leakage current is the current (amps) required to keep the capacitor at a fixed voltage.

The inner workings of standard EDLC solutions

EDLCs comprise two carbon-based electrodes and a porous separator separating them. When a voltage is applied across the electrodes, positive and negative ions in the material migrate to electrodes of the opposite potentials. Charges are stored in the electric double-layer formed between the two electrodes. Both hybrid and EDLC-type supercapacitors provide high-density, short-duration power in electronic applications. Although standard supercapacitors exhibit minimal leakage current, hybrid supercapacitors significantly surpass this benchmark.

EDLC supercapacitors utilize standard electric double-layer capacitor construction to provide ultra-high power and high capacitance in wide ranges of operating temperatures, low ESR, and more. However, this technology has its limitations - end-users often require higher energy densities than EDLCs can provide, as well as higher voltage levels, with less self-discharge.

Eaton's HS, HSL, and HSH hybrid supercapacitors: Pushing the limits of energy storage

Today, Eaton is building hybrid-type supercapacitors, with significantly improved performance over standard supercapacitors. Eaton's HS, HSL, and HSH hybrid supercapacitors utilize proprietary new materials, offering up to 10 times the energy density of standard supercapacitors in the same footprint. Their unique construction gives end-users a robust, reliable, and cost-effective energy storage solution.

One of the electrodes is composed of lithium-doped graphite, while the other is a typical EDLC electrode. The result is a cycle life close to that of EDLCs, but with lower self-discharge.

These hybrid supercapacitors can provide reliable ride-through or backup power in applications such as data storage systems, servers, utility meters, and controllers for automated systems.

When a voltage is applied across the electrodes, the hybrid supercapacitor stores charge electrostatically as a thin film that builds upon the surface of the electrodes.

Although Eaton's hybrid supercapacitors contain lithium, they are free of the metal oxides that cause thermal runaway, which can lead to catastrophic breakdown or explosions. The doped electrode also has a lower potential, which increases its maximum working voltage to a level similar to that of a lithium-ion battery.

The HS and HSL series hybrid cylindrical cells offer capacitance values between 10 F and 220 F, while the new HSH series extends the range with even higher capacitance from 3 F to 1400 F. Both series have a maximum working voltage of 3.8 V, an operating temperature range of –15° C to +70° C/85° C (3.5V) for HS and -25° C to +70°C for HSL and HSH, and ultra-low ESR. Individual cells can be in series or parallel and used as standalone energy storage or to augment battery storage. Used this way, HS, HSL and HSH hybrid supercapacitors can optimize the lifetime, runtime, and cost of existing energy systems.

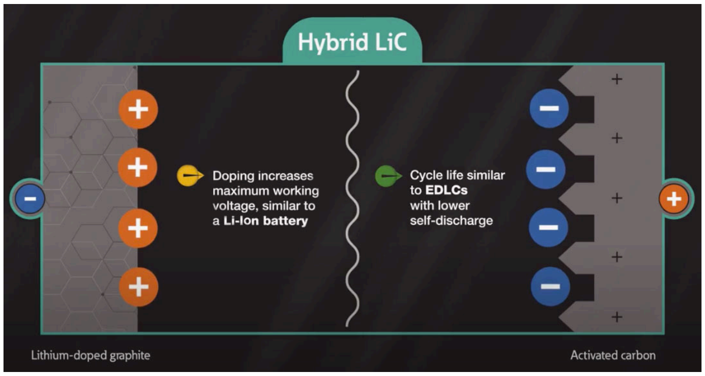

Figure 1: Eaton's HS, HSL, and HSH hybrid supercapacitors combine the benefits of EDLCs and lithium-ion technologies into one package.

Energy, industrial, and computing applications

Eaton's HS, HSL and HSH hybrid supercapacitors are useful in energy, industrial, and computing applications.

For energy users, Eaton's hybrid supercapacitors provide pulse power to utility meters, such as gas / water meters. The long cycle life and low self-discharge make them ideal to provide power for communications radios in meters either alone (if a main power source is available to recharge) or in parallel with a battery.

Eaton's HS, HSL, and HSH hybrid supercapacitors can also serve as backup energy storage to provide ride-through power to industrial process controllers for a brief duration during a brownout or power outage. Even a short, partial power drop in power to machine controllers can lead to costly downtime that can quickly run into several thousands of dollars. Hybrid supercapacitors are cost-effective ride-through power to prevent latency failures in machinery.

At data centers, Eaton's hybrid supercapacitors can provide backup power to storage servers, RAID storage systems, and more to prevent loss of volatile cache memory during brownouts or power outages. With their small footprints, design engineers can meet higher voltage requirements with fewer cell counts and smaller volume compared to using standard supercapacitors and meet temperature and lifetime requirements more efficiently than batteries. The high capacitance of the HSH series, as much as 1400 F, enables even longer runtimes in these applications.

Conclusion

Due to their higher energy densities, long cycle lifetimes, and higher working voltages, Eaton's HS, HSL, and HSH hybrid supercapacitors are preferable over lithium-ion batteries and some EDLC supercapacitors applications. They are especially valuable in energy, industrial, and computing applications, with customers increasingly looking to provide more power within their electronics while meeting performance, size, and safety constraints.

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