cap-XX APPLICATION BRIEF No. 1004

Battery Run-Time Extension and Low-Temperature Boost

Version 2, August 2002

Outline

Pulsed loads occur in many battery-powered portable devices. These loads can cause enough voltage-drop to crash the device. At low temperatures (such as < 0°C), the situation can be still worse, as common batteries, like Lithium-ion and NiMH (Nickel-Metal Hydride), exhibit vastly reduced capacity and increased internal resistance. A **cap-XX supercapacitor** used in a parallel hybrid combination with the battery can reduce the voltage excursions under load, permitting a device to operate reliably until most of the battery's energy has been used, or allowing it to function in cold conditions in which it normally fail or shut down after a short time. The supercapacitor also helps to protect the battery from potentially damaging voltage drops and current peaks, which may be of particular benefit to Lithium-ion batteries.

The Problem

- Pulsed loads are common in portable battery-powered devices, such as mobile phones, two-way pagers and GPRS systems. The load pulses may be many times the resting current, causing a large drop in battery voltage, which can cause system shutdown.
- In cold weather, batteries are much less capable of supplying the loads than they are when warm, because of their reduced capacity and increased internal resistance.
- The large voltage drop when load pulses occur may be detrimental to the battery. Conventional capacitors usually cannot support high currents, given the space restrictions in portable electronics.
- Lithium-ion batteries may be damaged by being discharged to low voltages or by load pulses that repeatedly drop the voltage. Automatic cutout circuits may be activated.
- Effective battery run-time is reduced by the need to maintain the voltage above a threshold value at all times. When load pulses drop the voltage below the minimum level, the device must turn off.
- At the time the device shuts down, there may be much useful energy remaining in the battery.

The cap-XX Solution

- Connect a cap-XX supercapacitor with low ESR (equivalent series resistance) in parallel with the battery to obtain a high-performance, low-impedance hybrid with superior characteristics. cap-XX supercapacitors can have ESRs of just a few milliohms, with capacitance from a few millifarads to Farads, and leakage currents of only a few micro-amps.
- The hybrid battery-supercapacitor can be designed to deliver the current demand during transmission pulses or other severe loads without the terminal voltage dropping to unacceptable levels. Low ESR provides cap-XX supercapacitors with an unprecedented ability to deliver high currents.
- During the low-load intervals, the supercapacitor is re-charged by the battery.
- In low temperatures, the supercapacitor delivers the current peaks that the battery cannot.
- cap-XX supercapacitors can be designed to suit the application, in shapes, sizes and packaging to fit the space available, such as thin prismatic forms.

The Benefits

- Reduced voltage drop during load peaks at all temperatures, resulting in extended run-time.
- Reduced source impedance compared with that of the battery alone.
- Designers can use smaller batteries than normal, with higher internal resistance, at reduced cost.
- Pulsed-load systems work in cold conditions; demanding low-temperature industrial requirements can be met.
- Effective battery capacity at low temperatures is increased.
- Low-battery thresholds can be reduced, since voltage ripple is reduced, giving increased voltage margin before shutdown occurs. This allows the battery to deliver more of its energy before shutdown, extending battery run-time.
- The possibility of damage to Lithium-ion batteries from low voltage or from high-current pulses is reduced.
- cap-XX supercapacitors can be designed to fit the space available.

The first graph below shows the battery voltage obtained in actual tests with a 600mAh lithium-ion battery subjected to a continuous load of 100mA and a load pulse representing a 2A GPRS Class 10 (25% duty cycle, 1.154ms pulse-width) load. The battery had an internal resistance of 250mΩ, including its protection circuit. The supercapacitor used was a 0.3F, 40mΩ cap-XX device, type GW208. The dark plot is the battery voltage without a supercapacitor in parallel. The maximum and minimum voltages on the battery are clearly seen as the dark upper and lower lines. The lighter plot in the middle is the battery voltage with the supercapacitor in parallel. (The average values of the two plots are also shown, but may not be clearly visible in print.)

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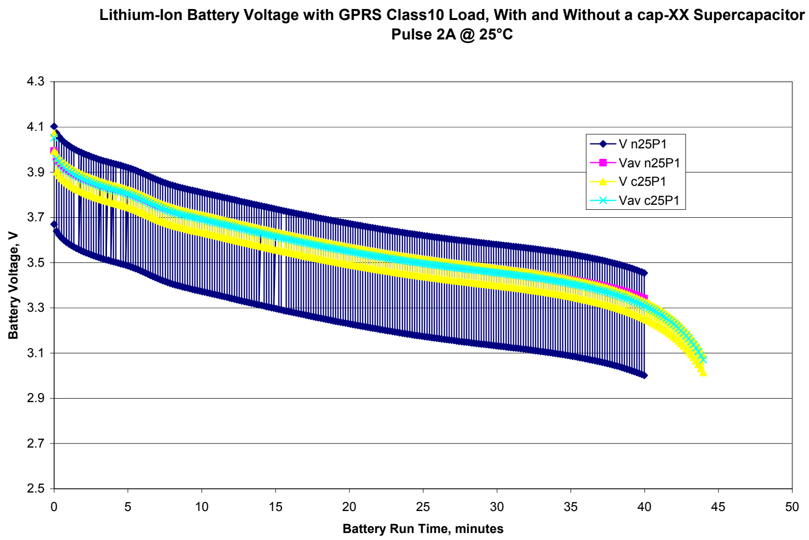
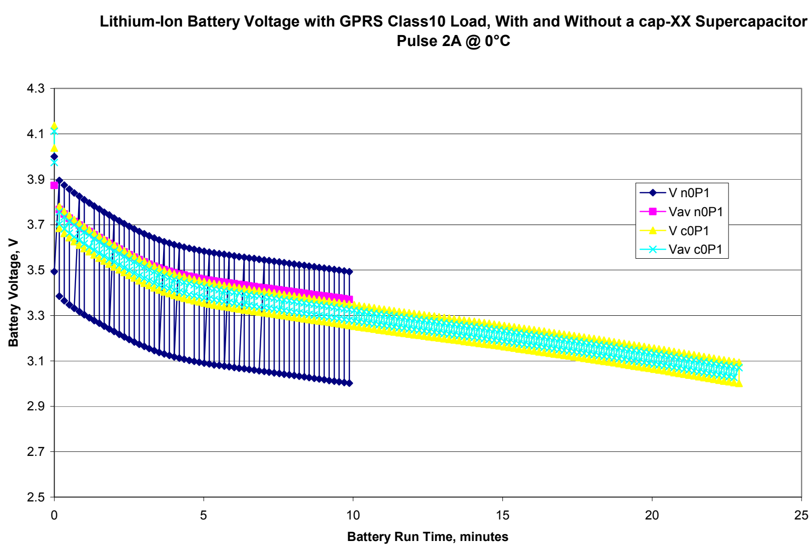


The supercapacitor had a dramatic effect in reducing the voltage ripple. If the device required a minimum of 3.3V to function correctly, which is the case with some GPRS modules, then it would have shut down after 14.9 minutes without a supercapacitor. With the supercapacitor in parallel, the voltage did not drop below this threshold until 38.1 minutes into the test, 2.56 times the original run-time. This represents an effective extension in run-time of 156%. If repeating this test, the result will vary with battery type and quality.

The second graph shows the battery voltage during a test performed at 0°C, using the same test load, battery and supercapacitor as in the test above. The low temperature reduced the battery's terminal voltage, resulting in reduced headroom for the load. Again, the dark plot was the battery voltage without the supercapacitor in parallel with the battery. In cold conditions, the battery was much less able to deliver load current than it was at room temperature. Its internal resistance was increased, which increased the voltage drop at the leading edge of each pulse; its ability to maintain a steady voltage during load pulses was decreased, which resulted in increased voltage droop during load pulses. The lighter plot in the middle was the battery voltage with the supercapacitor in parallel. The total voltage ripple was reduced to a level comparable to that at room temperature. If we select the same 3.3V minimum voltage threshold for operation of the load, then it would have functioned for 1.2 minutes without the supercapacitor and 7.7 minutes with the supercapacitor, 6.42 times as long, or an increase of 542%. This result will also vary greatly with battery type and quality. However, it shows that a cap-XX supercapacitor can make a substantial difference to a product's run-time in pulsed-load conditions and its ability to function at low temperatures.



Further Information:

cap-XX will be pleased to supply you with detailed data and design information. Please use the contact information listed at the foot of this page.

cap-XX Application Briefs are produced as a means of providing product designers with useful information about cap-XX supercapacitors and their applications. They are revised periodically to include new information. For detailed specifications of cap-XX products, the reader is referred to the data sheet of the relevant product, which is available on request.

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