This document provides basic guidelines for application development using aerogel capacitors, also known as supercapacitors. If questions arise during your development process and are not answered in this document, contact Cooper Electronic Technologies.

Lifetime

PowerStor supercapacitors have a longer lifetime than secondary batteries, but their lifetime is not infinite. The basic end-of-life failure mode for a supercapacitor is an increase in equivalent series resistance (ESR) and/or a decrease in capacitance. The actual end-of-life criteria are dependent on the application requirements. Prolonged exposure to elevated temperatures, high applied voltage and excessive current will lead to increased ESR and decreased capacitance. Reducing these parameters will lengthen the lifetime of a supercapacitor. In general, cylindrical supercapacitors have a similar construction to electrolytic capacitors, having a liquid electrolyte inside an aluminum can sealed with a rubber bung. Over many years, the supercapacitor will dry out, similar to an electrolytic capacitor, causing high ESR and eventually end-of-life.

Voltage

Supercapacitors are rated with a nominal recommended working or applied voltage. The values provided are set for long life at their maximum rated temperature. If the applied voltage exceeds this recommended voltage, the result will be reduced lifetime. If the voltage is excessive for a prolonged time period, gas generation will occur inside the supercapacitor and may result in leakage or rupture of the safety vent. Short-term overvoltage can usually be tolerated by the supercapacitor.

Polarity

PowerStor supercapacitors are designed with symmetrical electrodes, meaning they are similar in composition. When a supercapacitor is first assembled, either electrode can be designated positive or negative. Once the supercapacitor is charged for the first time during the 100% QA testing operation, the electrodes become polarized. Every supercapacitor either has a negative stripe or sign denoting polarity. Although they can be shorted to zero volts, the electrodes maintain a very small amount of charge. Reverse polarity is not recommended, however previously charged supercapacitors have been discharged to -2.5V with no measurable difference in capacitance or ESR. Note: the longer they are held charged in one direction, the more polarized they become. If reversed charged after prolonged charging in one direction, the life of the supercapacitor may be shortened.

Ambient Temperature

The standard temperature rating for PowerStor supercapacitors is –25°C to 70°C. Temperature in combination with voltage can affect the lifetime of a supercapacitor. In general, raising the ambient temperature by 10°C will decrease the lifetime of a supercapacitor by a factor of two. As a result, it is recommended to use the supercapacitor at the lowest temperature possible to decrease internal degradation and ESR increase. If this is not possible, decreasing the applied voltage to the supercapacitor will assist in offsetting the negative effect of the high temperature. For instance, 85°C ambient temperature can be reached if the applied voltage is reduced to 1.8V per supercapacitor.

At temperatures lower than normal room temperature, it is possible to apply voltages slightly higher than the recommended working voltage without significant increase in degradation and reduction in lifetime. Raising the applied voltage at low temperatures can be useful to offset the increased ESR seen at low temperatures.

Increased ESR at higher temperatures is a result of permanent degradation / electrolyte decomposition inside the supercapacitor. At low temperatures, however, increased ESR is only a temporary phenomenon due to the increased viscosity of the electrolyte and slower movement of the ions.

Discharge Characteristics

Supercapacitors discharge with a sloping voltage curve. When determining the capacitance and ESR requirements for an application, it is important to consider both the resistive and capacitive discharge components. In high current pulse applications, the resistive component is the most critical. In low current, long duration applications, the capacitive discharge component is the most critical. The formula for the voltage drop, V_{drop}, during a discharge at *I* current for *t* seconds is:

$$V_{drop} = I(R + \frac{t}{C})$$

To minimize voltage drop in a pulse application, use a supercapacitor with low ESR (R value). To minimize voltage drop in a low current application, use a supercapacitor with large capacitance (C value).

An Aerogel Capacitor Calculator program is available at http://www.cooperet.com/products_supercapacitors.asp for predicting electrical requirements and matching these requirements to various supercapacitor configurations / alternatives.

Charge Methods

Supercapacitors can be charged using various methods including constant current, constant power, constant voltage or by paralleling to an energy source, i.e. battery, fuel cell, DC converter, etc. If a supercapacitor is configured in parallel with a battery, adding a low value resistor in series will reduce the charge current to the supercapacitor and will increase the life of the battery. If a series resistor is used, ensure that the voltage outputs of the supercapacitor are connected directly to the application and not through the resistor, otherwise the low impedance of the supercapacitor will be nullified. Many battery systems exhibit decreased lifetime when exposed to high current discharge pulses.

The maximum recommended charge current, *I*, for a supercapacitor where V_w is the charge voltage and *R* is the supercapacitor impedance is calculated as follows:

$$I = \frac{V_w}{5R}$$

Overheating of the supercapacitor can occur from continuous overcurrent or overvoltage charging. Overheating can lead to increased ESR, gas generation, decreased lifetime, leakage, venting or rupture. Contact the factory if you plan to use a higher charge current or higher voltage than specified.

Series Configurations of Supercapacitors

Individual supercapacitors are limited to 2.5V (P Series reaches 5V using two supercapacitors in series). As many applications require higher voltages, supercapacitors can be configured in series to increase the working voltage. It is important to ensure that the individual voltages of any single supercapacitor do not exceed its maximum recommended working voltage as this could result in electrolyte decomposition, gas generation, ESR increase and reduced lifetime.

In order to prevent voltage imbalance, passive or active voltage balancing is recommended. Passive voltage balancing uses voltage-dividing resistors in parallel with each supercapacitor to allow current to flow around higher voltage supercapacitors into lower voltage devices, thus balancing the voltage. It is important to choose balancing resistor values that provide for higher current flow than the anticipated leakage current of the supercapacitors, while ensuring they do not significantly reduce the life of the energy source (i.e., battery) to which they may be connected. When low leakage current is required, use 470 kΩ to 1.2 MΩ resistors, which will leak from 2 to 5 µA at 2.5V per supercapacitor. When continuous power sources, i.e. AC, solar, or fuel cell are available, smaller value balancing resistors can be chosen, resulting in faster and tighter supercapacitor voltage balancing. Resistor values from 4.7 kΩ to 10 kΩ would provide excellent voltage balancing as long as the application can lose 0.25 mA to 0.5 mA continuously at 2.5V per supercapacitor.

Soldering Information

Excessive heat may cause deterioration of the electrical characteristics of the aerogel supercapacitor, electrolyte leakage or an increase in internal pressure.

Follow the specific instructions listed below.
In addition:

- Do not dip aerogel supercapacitor body into melted solder.
- Only flux the leads of the aerogel supercapacitor.
- Ensure that there is no direct contact between the sleeve of the aerogel supercapacitor and the PC board or any other component. Excessive solder temperature may cause sleeve to shrink or crack.
- Avoid exposed circuit board runs under the aerogel supercapacitor to prevent electrical shorts.

Manual Soldering

Do not touch the aerogel supercapacitor's external sleeve with the soldering rod or the sleeve will melt or crack. The recommended temperature of the soldering rod tip is less than 260°C (maximum: 350°C) and the soldering duration should be less than 5 seconds. Minimize the time that the soldering iron is in direct contact with the terminals of the aerogel supercapacitor as excessive heating of the leads may lead to higher equivalent series resistance (ESR).

Wave Soldering

Use a maximum preheating time of 60 seconds for PC boards 0.8 mm or thicker. Preheating temperature should be limited to less than 100°C.

Use the following table for wave soldering on leads only:

Solder Bath	Solder Exposure Time (seconds)	
Temperature (°C)	Recommended	Maximum
220	7	9
240	7	9
250	5	7
260	3	5

Reflow Soldering

Do not use reflow soldering on PowerStor supercapacitors using infrared or convection oven heating methods unless the supercapacitor is specifically rated to withstand reflow soldering temperatures.

Ripple Current

Although PowerStor aerogel supercapacitors have very low resistance in comparison to other supercapacitors, they do have higher resistance than aluminum electrolytic capacitors and are more susceptible to internal heat generation when exposed to ripple current. Heat generation leads to electrolyte decomposition, gas generation, increased ESR and reduced lifetime. In order to ensure long lifetime, the maximum ripple current recommended should not increase the surface temperature of the supercapacitor by more than 3°C.

Circuit Board Design

Do not design exposed circuit board runs under the supercapacitor. An electrical short could occur if the supercapacitor electrolyte leaked onto the circuit board.

Circuit Board Cleaning

Avoid cleaning of circuit boards, however if the circuit board must be cleaned use static or ultrasonic immersion in a standard circuit board cleaning fluid for no more than 5 minutes and a maximum temperature of 60°C. Afterwards thoroughly rinse and dry the circuit boards. In general, treat supercapacitors in the same manner you would an aluminum electrolytic capacitor.

Long Term Storage

Do not store supercapacitors in any of the following environments:
- High temperature and/or high humidity
- Direct contact with water, salt water, oil or other chemicals
- Direct contact with corrosive materials, acids, alkalis, or toxic gases
- Direct exposure to sunlight
- Dusty environment
- Environment subject to excessive shock and/or vibration

Transportation Information

PowerStor supercapacitors are non-regulated by the US DOT (Department of Transport) and IATA. The correct international shipping description is "Electronic Parts – Capacitors".

Emergency Procedures

If a supercapacitor is found to be overheating or if you smell a sweet odor, immediately disconnect any power or load to the supercapacitor. Allow the supercapacitor to cool down, then dispose of properly. Do not expose your face or hands to an overheating supercapacitor. Contact the factory for a Material Safety Data Sheet if a supercapacitor leaks or vents. If exposed to electrolyte:

- Skin Contact: Wash exposed area thoroughly with soap and water.
- Eye Contact: Rinse eyes with water for 15 minutes and seek medical attention.
- Ingestion: Drink milk/water and induce vomiting; seek medical attention.

Note: In general the electrolyte, using the NFPA/HMIS (0 to 4) rating system, has slight (1 out of 4) health and fire hazard and minimal (0 out of 4) reactivity hazard.

Regulatory Information

PowerStor supercapacitors are rated non-hazardous under the OSHA hazard communication standard (29 CFR 1910.1200)

General Safety Considerations

- Supercapacitors may vent or rupture if overcharged, reverse charged, incinerated or heated above 150°C.
- Do not crush, mutilate, nail penetrate or disassemble.
- High case temperature (burn hazard) may result from abuse of supercapacitor.

Disposal Procedures

PowerStor supercapacitors are non-regulated under RCRA Waste Code. Supercapacitors may however be disposed of by a specialized industrial waste processor or by incineration. Use caution when incinerating as the supercapacitor can explode unless it is crushed or punctured prior to incineration. Wear protective gear, such as face shields or goggles, coats/aprons and gloves. Use high temperature to incinerate the supercapacitors as the plastic (poly vinyl chloride) sleeving can produce chlorine gas at lower incineration temperatures.

PS-5006 7/05

Visit us on the Web at www.cooperET.com
3601 Quantum Boulevard Boynton Beach, Florida 33426-8638
Tel: +1-561-752-5000 Toll Free: +1-888-414-2645 Fax: +1-561-742-1178