Introduction

Purpose

- To provide an overview of the main considerations when selecting a PowerStor supercapacitor.

Objectives

- Enable engineers to make a basic product selection using only four circuit parameters
- Review the effects of temperature and aging on supercapacitor performance
- Look at the required precautions when connecting supercapacitors in series
- Explain inflow current, self leakage and leakage current

Supercapacitor Applications

- **Pulse**
  - High current for short duration
- **Bridge or Hold-up Power**
  - High current for short duration, followed by ultra-low current, sleep mode for longer duration
- **Main**
  - Lower current or short duration
- **Memory Backup**
  - Ultra-low current, sleep mode for long duration

www.alcom.eu

Alcom Belgium - Singel 3 - 2550 Kontich
Tel.: ++32 (0)3 458.30.33 - Fax: ++32 (0)3 458.31.26 - info@alcom.be

Alcom Netherlands - Rivium 1e straat 52 - 2909 LE Capelle a/d IJssel
Tel.: ++31 (0)10 288.25.00 - Fax: ++31 (0)10 288.25.25 - info@alcom.nl

Parameters Required for Supercapacitor Selection

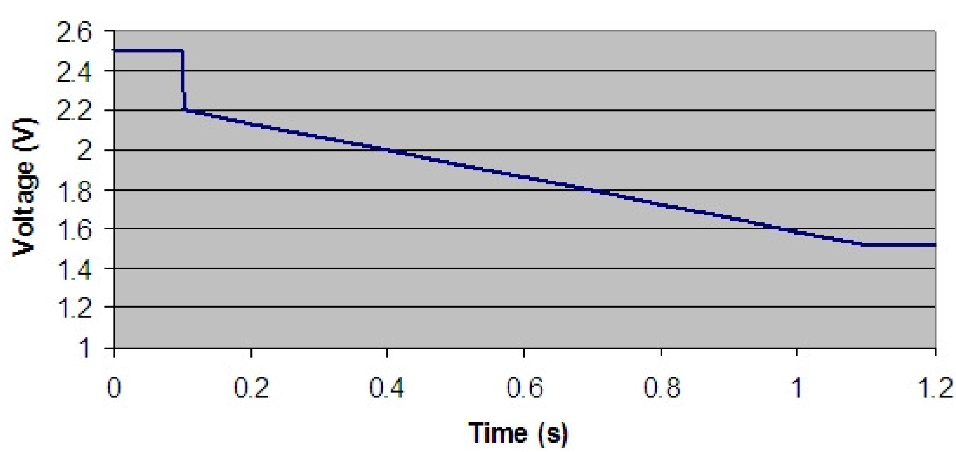
Four Basic Selection Parameters:

- Nominal Operating Voltage
- Minimum Allowable Voltage (circuit drop-out voltage)
- Average Capacitor Discharge Current
- Duration of Required Hold-up or Current Pulse

Additional Selection Criteria:

- Operating Temperature Range
- Required Operating Life

Capacitor Discharge Voltage



Calculating Minimum Capacitance

Minimum capacitance can be calculated using the equation:

$i = C \, . \, dv / dt$

Where, i is the discharge current, C is the capacitance, dv is the change in voltage and dt is the duration of the discharge. From this we get:

$C = (i \, . \, dt) / dv$

For example, a system has a nominal voltage of 2.5V and a drop out voltage of 2.0V. The system must continue to operate for 5 seconds after a mains fail and has an average current demand of 0.5A. In this case:

C = (0.5A x 5s) / (2.5V – 2.0V) = 5 Farad

Calculating Maximum ESR

Maximum ESR can be calculated using the equation:

$V = I \, . \, R$

Where, I is the discharge current, R is the ESR and V is the voltage drop. From this we get:

$R = V / I$

Using the same example of nominal voltage of 2.5V, drop out voltage of 2.0V, 5 seconds hold up time and average current demand of 0.5A:

R = (2.5V – 2.0V) / 0.5A = 1 Ohm

Capacitor Selection

So we are looking for a capacitor with capacitance >5F and ESR < 1 Ohm. Looking at the PowerStor supercapacitor data sheets we find that the B1030-2R5685-R gives 6.8F with 0.1 Ohm ESR @ 1kHz.

For a DC discharge the specified ESR must be multiplied by 1.5.

So, for the given example, the voltage drop using the B1030-2R685-R will be:

$$= i \cdot (R + t/C) = 0.5\text{A} \times (0.15\,\Omega + 5\text{ s} / 6.8\text{ F})$$

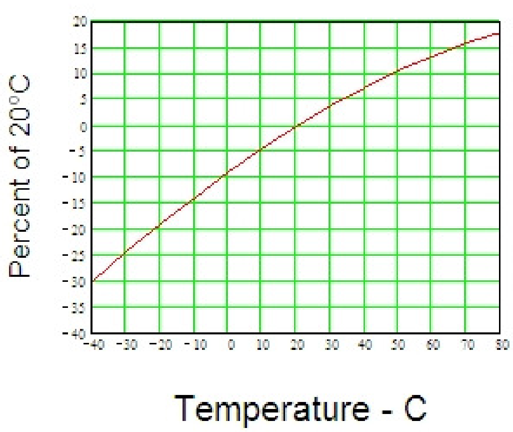
$$= 0.443\text{V}$$

This meets the basic requirements of the application for a voltage drop of < 0.5V.

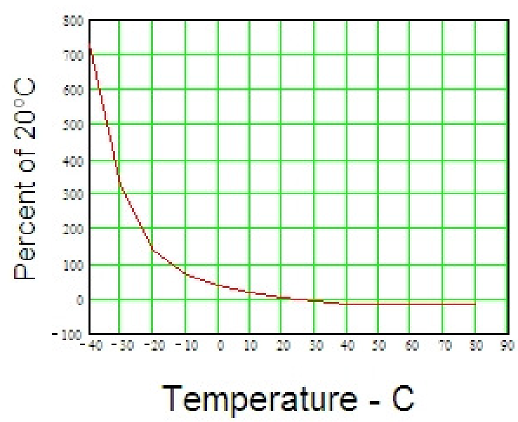
Additional Selection Criteria

Operating Temperature Range:

Percent Capacitance Change Over Temperature Range

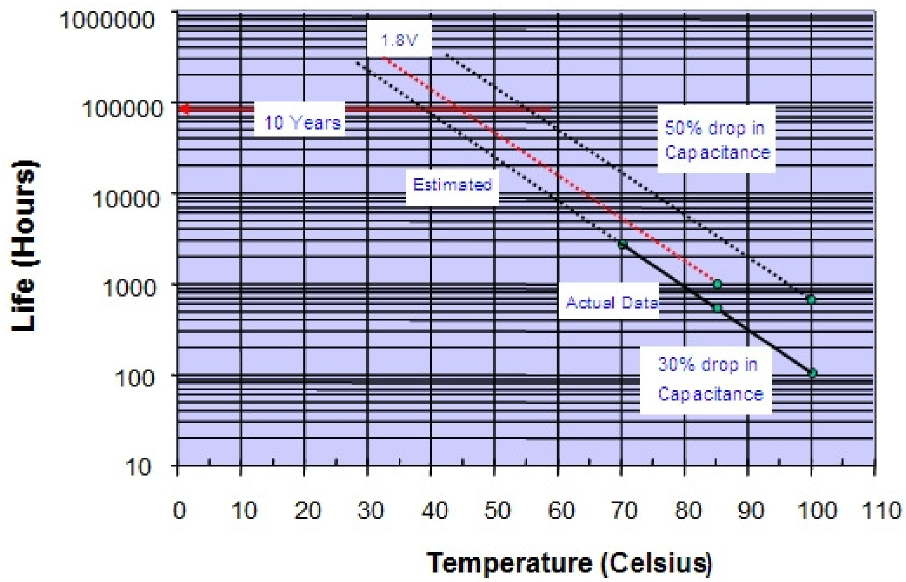


Percent ESR Change Over Temperature Range



Additional Selection Criteria

Operating Life:



Additional Selection Criteria

Operating Life:

Average temperature < 40 °C, maximum temperature < 70 °C :

Capacitance Change = -30%

ESR Change = +100% (ESR will be 200% of initial value)

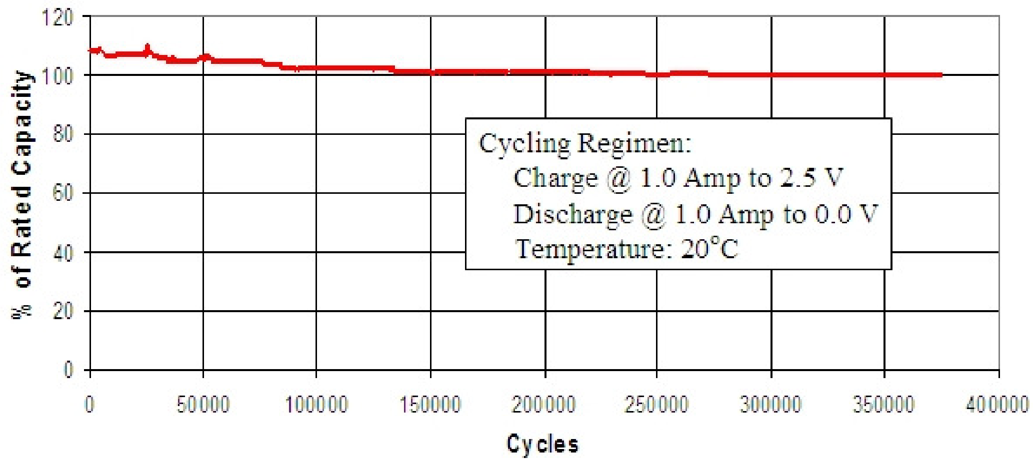
Average temperature > 40 °C, long term exposure to high temperatures, > 10 year operating life:

Capacitance Change = -50%

ESR Change = +200% (ESR will be 300% of initial value)

Additional Selection Criteria

Operating Life:



Final Product Selection

Adding a requirement for –10 °C to +65 °C operation and > 5 years operating life to our example and the required capacitance and ESR is as follows:

For –10 °C operation:

Required Capacitance = 5F / 0.85 = 5.88F (drops by 15% @ –10 °C)

ESR Change = 1 Ohm / 1.60 = 0.625 Ohm (increases by 60% @ –10 °C)

Allowing for > 5 year life:

Required Capacitance = 5.88F / 0.7 = 8.4F (drops by 30% @ EOL)

ESR Change = 0.625 Ohms / 2 = 0.312 Ohms (increases by 100% @ EOL)

So we need a part with a specification of >8.4F and <0.312 Ohms.

COOPER

Alcom electronics

Final Product Selection

Selecting a 10F, 0.06 Ohm part, adjusting this for –10 °C operation, end of life and DC discharge gives us:

Capacitance = 10F x 0.85 x 0.7 = 5.95F

ESR = 0.06 Ohms x 1.5 x 1.6 x 2 = 0.288 Ohms

Checking the voltage drop for these values:

= i . (R + t/C) = 0.5A x (0.288Ω + 5 s / 5.95 F) = 0.56V

Voltage drop is to high.

Using two 6.8F, 0.1 Ohm parts connected in parallel:

Capacitance = 13.6F x 0.85 x 0.7 = 8.09F

ESR = 0.05 Ohms x 1.5 x 1.6 x 2 = 0.24 Ohms

Voltage Drop = i . (R + t/C) = 0.5A x (0.24Ω + 5 s / 8.09 F) = 0.43V

Series Connection of Supercapacitors

For circuits that are required to operation at greater than 2.5V supercapacitors can be connected in series.

Series connection:

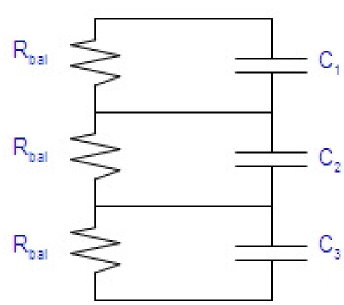
$C = 1/(1/C_1 + 1/C_2 + 1/C_3)$

$ESR = ESR_1 + ESR_2 + ESR_3$

Parallel connection:

$C = C_1 + C_2 + C_3$

$ESR = 1/(1/ESR_1 + 1/ESR_2 + 1/ESR_3)$



Alcom electronics
www.alcom.eu
Alcom Belgium - Singel 3 - 2550 Kontich
Tel.: ++32 (0)3 458.30.33 - Fax: ++32 (0)3 458.31.26 - info@alcom.be
Alcom Netherlands - Rivium 1e straat 52 - 2909 LE Capelle a/d IJssel
Tel.: ++31 (0)10 288.25.00 - Fax: ++31 (0)10 288.25.25 - info@alcom.nl

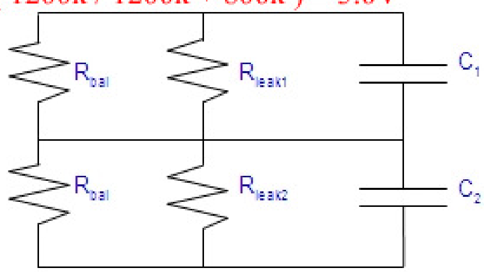
Voltage Balancing

Passive:

$$V_{C1} = V_{supply} \times R_{leak1} / (R_{leak1} + R_{leak2})$$

Assuming a 5V supply, R_{leak1} equivalent to 1.2 MΩ and R_{leak2} to 800 kΩ then without the addition of balancing resistors, R_{bal}, the voltage on capacitor C_1 would be:

$$V_{C1} = 5V \times (1200k / 1200k + 800k) = 3.0V$$



Voltage Balancing

Passive:

Adding 100 kΩ balancing resistors across each capacitor and the effective leakage resistance values become:

$$R_{leak1}(\text{effective}) = R_{leak1} \times R_{bal} / R_{leak1} + R_{bal}$$

$$= 1200k \times 100k / 1200k + 100k = 92.31\ k\Omega$$

$$R_{leak2}(\text{effective}) = R_{leak2} \times R_{bal} / R_{leak2} + R_{bal}$$

$$= 800k \times 100k / 800k + 100k = 88.89\ k\Omega$$

As a result:

$$V_{C1} = 5V \times (92.31k / 92.31k + 88.89k) = 2.55V$$

Voltage Balancing

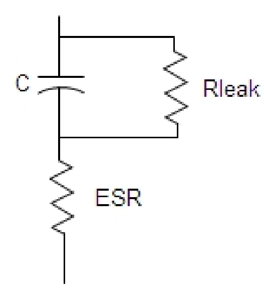
Active:

Advantages of active voltage balancing,

- Effective against imbalance caused by either capacitance or leakage current mismatch
- Rapid voltage balancing can be achieved
- Voltage balancing is very accurate
- Adds only a small amount of additional leakage current

Inflow Current

Inflow current is a combination of charge current and leakage current. Leakage current is a parasitic element that occurs due to supercapacitor construction, this is modelled as a parallel connected resistor.

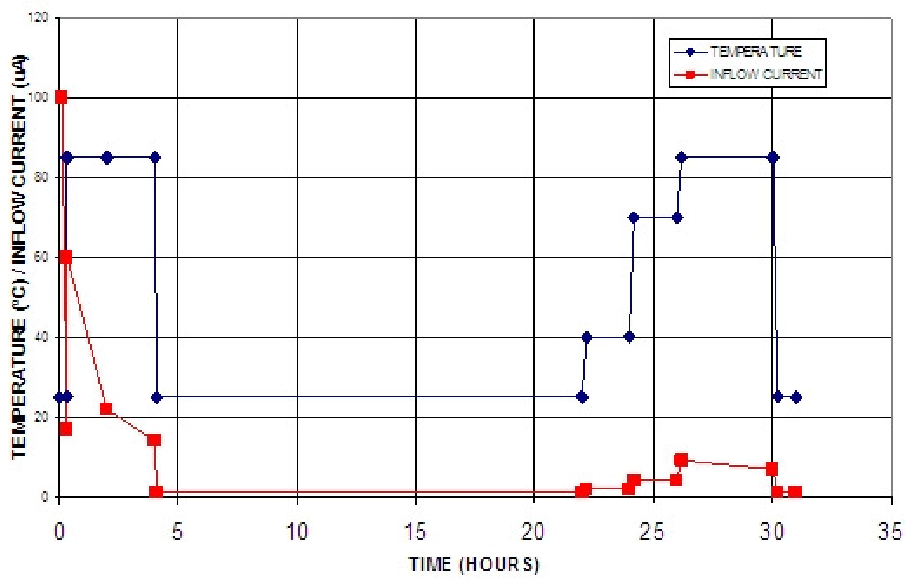


Inflow Current

Inflow current expressed in micro Amps/Farad

	100 Hours Charge		1000 Hours Charge	
Capacitance (F)	25 °C	70 °C	25 °C	70 °C
0.22 – 1.0	3.0 – 6.0	15 – 25	0.5 – 1.5	5 – 10
2.2 – 10	1.5 – 3.0	8 – 15	0.2 – 0.75	3 – 5
22 - 100	1.0 – 2.0	5 - 10	0.1 – 0.5	2 - 4

Inflow Current vs. Temperature



Summary

- Only four basic parameters are required for basic supercapacitor selection
- Allowance needs to be made for changes in capacitance, ESR and leakage current over the operating temperature range
- Apply "rule of thumb" to obtain end of life requirements
- Don't forget the potential effect of leakage current on battery life and capacitor discharge time.
- If in doubt use the PowerStor calculator spreadsheet or contact Cooper Bussmann