

Performing supercapacitor calculations and predicting solutions for applications can be tedious, therefore PowerStor® has developed an Aerogel Supercapacitor Calculator in Microsoft Excel®. This program is available online at <http://www.cooperbusmann.com>. An example of this program is shown on the following page.

To determine the aerogel supercapacitor requirements for an application, four key parameters are required:

- Working voltage, V_w , in Volts
- Minimum voltage, V_{min} in Volts
- Average discharge current, I , in Amps
 - If necessary convert power, P , in Watts to current, where $I = P / V_{avg}$
- Discharge time, t , in seconds

Simply enter these four parameters into the calculator in step 1 and the program will calculate:

- Energy requirement, W , in Joules
- Minimum capacitance requirement, C , in Farads
- Maximum resistance, R , in Ohms

In step 2, select the operating parameters specific to the application including whether the discharge is more similar to a DC pulse or AC pulse at a 1kHz frequency. Next select the operating temperature and use the "deviation from nominal capacitance" factor to build in a safety margin, if necessary. The program will then use these correction factors for both capacitance and resistance throughout the remainder of the calculations.

The pull-down menu in step 3 has a list of PowerStor supercapacitor products. Select the appropriate supercapacitor that

meets both the capacitance and resistance requirements from step 1. In this step there is an option to configure supercapacitors in parallel and/or to force the number of supercapacitors in series to a specific number. For example, the calculator would recommend six 2.5V supercapacitors for an automobile voltage of 14.4V ($14.4V / 2.5V$ per supercapacitor = 5.76 supercapacitors, which round up to 6). In practice, increasing the number of supercapacitors to eight in automobile applications lowers the voltage to 1.8V per supercapacitor, providing an increased reliability margin for high temperature exposure, with a direct result of longer life. The number of supercapacitors in series (actual) can be overwritten from the calculated value.

Confirmation of the predicted aerogel supercapacitor solution is done in step 4. First the total capacitance and resistance values calculated are compared to the required values. Next the energy and hold-up time requirements are confirmed. If the energy and hold-up time are insufficient, chose a larger supercapacitor or increase the number of supercapacitors in parallel. Finally, the voltage drop is confirmed. The calculated components of resistive and capacitive discharge are summed and compared to the maximum value allowed. If the maximum voltage drop value is exceeded, simply chose a supercapacitor solution with lower ESR or increase the number of supercapacitors in parallel.

Our goal for this calculator was to assist you in finding a solution for your design challenges. Note: this program is only intended to predict aerogel supercapacitor solutions. All calculated solutions should be tested in the final application. Contact Cooper Busmann directly for further assistance and application support.

PowerStor Aerogel Supercapacitor Calculations for:

Enter Company or Project Name

09/04/02

Four Simple Steps for Determining Supercapacitor Requirements

1. Enter values for Working Voltage, Minimum Voltage, Current and Time

Enter Known Value	
Working Voltage (Vw)	2.5 Volts
Minimum Voltage (Vmin)	1 Volts
Current (I)	1 Amps
Time (t)	1 seconds

Energy needed during hold-up period (Minimum) $W = (Vw + Vmin) \cdot 2 \cdot I \cdot t = 1.75$ Joules

Desired Capacitance (Minimum) $C = 2 \cdot Vw \cdot I \cdot t / (Vw^2 - Vmin^2) = 0.6667$ Farads

Desired Impedance (Maximum) $R = (Vw - Vmin) / I = 1.500$ Ohms

Legend
Input Values in Yellow
Required Values in Gray
Calculated Values in Light Blue
Comments in Green

2. Select Operating Parameters and Correction Factors from pull-down menu

Use pull-down menu for Correction Factors to Capacitance and ESR	Discharge Pulse Frequency	Temperature	Deviation from Specified Capacitance (-20% to +80%)
DC	-20°C	Nominal Capacitance	
Capacitance Correction Factors :	1	0.8	1
ESR Correction Factors :	1.5	2.25	

3. Choose Supercapacitor from pull-down menu to meet Desired Capacitance and Desired Impedance

Note 1: Total Capacitance equals 1/2x for two in series, 1/3x for three in series, etc.
 Note 2: Total Capacitance equals 2x for two in parallel, 3x for three in parallel, etc.
 Note 3: Total Resistance equals 2x for two in series, 3x for three in series, etc.
 Note 4: Total Resistance equals 1/2x for two in parallel, 1/3x for three in parallel, etc.

Use pull-down menu to choose a specific model Supercapacitor	Part Number	Capacitance	ESR (AC @ 1 kHz)
	B0620-2R5225	2.2 F	0.225 Ohms

	Standard Values	Corrected Values
Single Device Capacitance	C = 2.2 Farads	1.76 Farads
Single Device Resistance	R = 0.225 Ohms	0.759375 Ohms
Single Device Max Voltage	Vmax = 2.5 Volts	2.500 Volts
# supercapacitor(s) in parallel	1	
# supercapacitor(s) in series (min. calculated)	1	
# supercapacitor(s) in series (actual)	1	

Note 5: Formula for # supercapacitor(s) in series (actual) can be manually overwritten if lower or higher Vw per supercapacitor desired. View Corrected Value for actual Single Device Max Voltage.

4. Confirm Time requirement is met for hold-up applications and/or Voltage Drop is acceptable for pulse applications.

Final Supercapacitor Configuration	Calculated Values	Required Values	Comments
Total Capacitance	C = 1.76 Farads	0.6667 Farads	Capacitance Value Met
Total Resistance	R = 0.759375 Ohms	1.500 Ohms	Resistance Value Met
Check Energy and Time Requirements	Calculated Values	Required Values	Comments
Energy available in supercapacitor(s)	W = 4.62 Joules	1.75 Joules	Energy Value Met
Max. Hold-up Time with chosen supercapacitor(s)	t = 1.30 seconds	1 seconds	Time Requirement Met
If Energy is insufficient, choose a Single Device with higher Capacitance or increase # supercapacitors in parallel. Check to ensure that Energy available in supercapacitors is greater than Energy needed during hold-up period, or Maximum Hold-up Time is sufficient.			
Check Voltage Drop	Calculated Values	Required Values	Comments
Total Voltage Drop of supercapacitor(s) = Vdrop (resistive) + Vdrop (capacitive) =	1.328 Volts	1.500 Volts	Voltage Drop Acceptable
Voltage drop (resistive)	0.759 Volts		
Voltage drop (capacitive)	0.568 Volts		
If Total Voltage Drop is greater than Maximum Allowed, determine whether resistance or capacitance is the main factor. Choose supercapacitors with either more capacitance or less resistance, or increase # capacitors in parallel. If Total Voltage Drop is less than Maximum Voltage Drop Allowed, STOP.			

This program is intended to provide product design solutions that will help the user with design applications.
 Once a product design solution has been determined, it should be tested by the user in all possible applications.

© Cooper Electronic Technologies 2002