Innovation For Tomorrow's Designs®

Supercapacitors vs. Batteries

Abracon

APRIL 2024

Table of Contents

Supercapacitors vs. Batteries

Supercapacitor Benefits in Durability

Cycle Life

Operating Temperature

Summary

Supercapacitors vs. Batteries

A good analogy to compare supercapacitors to batteries is to compare an athlete running a 100m sprint to someone running a 26-mile marathon. Both are races, but the athletes who participate are conditioned totally different. They manage their energy differently and how they apply it -fast/short bursts for the sprint or long/endurable for the marathon.

The management of energy also applies to supercapacitors and batteries and their application of energy over a given span of time. Supercapacitors are the sprinters, while batteries are the marathoners. Continuing with the same analogy, supercapacitors are conditioned for large bursts of energy for a short duration. In most cases, batteries provide consistent energy over longer spans of time, but fail to respond quickly to fast, large increases in transient power.

Batteries typically measure energy capacity using Wh (Watt-Hour) or Ah (ampere-hour). If the battery voltage is known, it is simple to switch between units of measure.

$$Wh = Voltage * Capacity, \quad \text{where Capacity is Ah.}$$

Batteries maintain their voltage until much of their charge has depleted, so specifying the battery using either of these units works fine. Furthermore, batteries typically deplete their charge over a long period of time and are not capable of sourcing short bursts of high current due to their design and relatively high internal resistance, sometimes referred to as "ohmic resistance".
Supercapacitors are not typically rated by energy capacity, but only by maximum operating voltage and typical capacitance. Given these two parameters allows the calculation of total charge and therefore maximum stored energy.

Unlike the battery, the voltage of the supercapacitor drops linearly as the amount of charge in the capacitor depletes. As a result, the easiest method to analyze capacitor's viability for an application is to use the following formulas which are a function of the capacitors decreasing voltage:

Charge: $Q = C * V$ (coulombs)
Work: $W = \frac{1}{2} Q * V = \frac{1}{2} C * V * V$ (joules)
Stored Energy: $E = \frac{1}{2}C * V^2$ (joules)

Supercapacitors have very low Equivalent Series Resistance (ESR), which can be thought of as its internal resistance. The supercapacitor's ESR does not fluctuate as the current changes as much as it does with battery technology. Consequently, supercapacitors are much more efficient delivering power due to their high current capability ($P = I^2 * R$) and low internal resistance.

The illustration in Fig. 1 shows the relationship between Power and Energy of different sources. Notice batteries are far superior when a marathoner is needed. Energy is consumed over a period of time, hence the 'h' in Wh/kg.

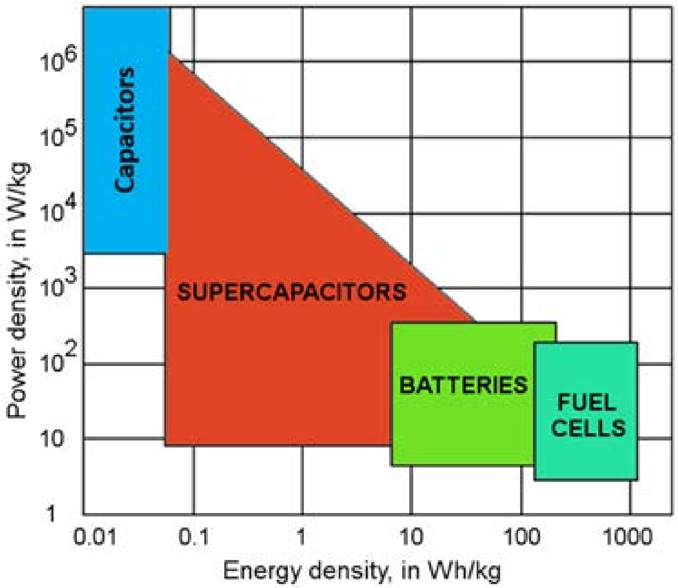

Fig. 1 Graph illustrating the relationship of Power and Energy between several sources of energy.

In some applications, supercapacitors can also consume power over an extended period. However, they are much more efficient in delivering instantaneous power. This can be seen clearly in the Fig. 1 illustration. Supercapacitors bridge the energy and power gaps between standard capacitors and batteries.

Supercapacitor Benefits in Durability

The advantages of supercapacitors exceed the benefits of just delivering power. In many applications, the supercapacitor reigns superior in durability. Granted, many factors affect the durability in an application, such as cycle life (charge/discharge cycles), power density, energy density, temperature sensitivity, etc.

Cycle Life

Cycle life is the number of charge/discharge cycles the supercapacitor can endure before the component begins to degrade. Cycle life of a supercapacitor, for example, will usually be greater than 100K charge/discharge cycles. Compare this to a typical Li+ battery, which will last several hundred charge/discharge cycles -perhaps a thousand if you are lucky.

The underlying reason for such a big contrast in cycle life is the differences in their charging structures and chemistry. The most prominent reason is that batteries use an electro-chemical reaction, while supercapacitors use an electro-static charge mechanism, hence the 'E' in EDLC or Electro-Static Double Layer Capacitor. The batteries' electro-chemical mechanism is much more damaging than the electro-static method, and as a result, over time, batteries lose their ability to maintain their charge, yielding shorter lifetimes compared to supercapacitors.

Operating Temperature

Temperature sensitivity is an advantage of supercapacitors in many applications. Both batteries and supercapacitors are sensitive to temperatures, specifically high temperatures. However, batteries tend to be more sensitive to high temperatures due to their chemical reactions being accelerated by the high temperatures. The batteries' working voltage can be derated such that operating in higher temperatures is possible. However, thermal management and dynamically adjusting the load may be required. This process can get very complex and, in some cases, very expensive.

Supercapacitors can also be derated by reducing the working voltage or the maximum charge voltage. Derating the supercapacitor to operate at elevated temperatures or considerably extending its lifetime is as simple as reducing the operating voltage. Since supercapacitors charges and discharges are relatively short-lived compared to batteries, there is very little to no internal heating, eliminating any need for thermal management.

Summary

Supercapacitors and batteries are expected to co-exist. Each component has its strengths and weaknesses. However, supercapacitors are far superior when it comes to high, instantaneous power delivery and component durability. Designers who want to reduce the maintenance cost of their products at the customer may want to consider supercapacitors as the primary backup source of power due to their durability.

Furthermore, supercapacitors can be used to increase the perceived performance of batteries by “assisting” the battery with power delivery, which, in turn, will reduce internally generated heat and stress on the battery, extending its life. Refer to the following app note for more information about using supercapacitors: [Supercapacitors and the Potential to Revolutionize Energy Storage and Power Delivery.]