

Supercaps: ultra-compact Power

Supercaps, also known as supercapacitors, are a special type of energy storage device that combine certain properties of batteries with those of capacitors. In this way, they can store enormous amounts of energy and release it again very quickly, which makes them particularly valuable for many applications.



Supercapacitors come in all shapes and sizes. The thinnest ones measure just 0.4 mm in thickness.

The history of supercapacitors goes back to the 1950s, when scientists discovered the electrochemical properties of activated carbon and recognized its potential for energy storage. After General Electric patented the first supercapacitor in 1957, the technology initially remained immature and limited to laboratory applications. It was not until the 1960s that Standard Oil of Ohio developed a working prototype and patented it in 1966. Commercialization began in the 1970s, driven by NEC, which introduced supercapacitors into electronics. Since the 1990s, advances in materials science and nanotechnology have greatly increased the performance of supercapacitors, particularly in terms of energy density, power density and lifetime.

Difference to Conventional Capacitors and Batteries

Supercapacitors are in a unique position between normal capacitors and batte-

ries. While conventional capacitors store energy by separating electric charges in an electric field and are characterized by their high power density, they have a very low energy density and are therefore not suitable for long-term applications. Batteries, on the other hand, store energy through electrochemical reactions, which gives them a high energy density and therefore the ability to release energy over the long term. However, their power density is low and they are unsuitable for fast charging and discharging cycles. Supercapacitors close this gap by offering a higher energy density than normal capacitors and a higher power density than batteries, making them ideal for applications with short charge and discharge cycles.

Applications: Transportation and Aviation

In the transportation sector, supercapacitors have a special function in electric and hybrid vehicles. They

enable the storage of braking energy (recuperation) and the immediate recovery of this energy when accelerating. This capability increases energy efficiency and reduces both fuel consumption and emissions. In public transportation such as buses and streetcars, supercapacitors absorb energy at stops within seconds and make it available during the journey, which reduces energy consumption and operating costs.

They also help to extend the service life of other energy storage devices such as batteries, as they take over high load peaks and thus reduce the load on the batteries.

Aerospace: Supercapacitors are also used in aerospace applications where fast energy output is required, for example to operate communication systems or maneuvering drives. In aircraft, they are used to support emergency power systems and to provide energy for starting electrical systems.

Renewable Energy

In the area of renewable energies, supercapacitors play an important role in balancing out fluctuations in energy generation. In wind turbines, they stabilize energy output by storing excess energy during strong wind phases and releasing it quickly when there is a lull. This makes it easier to integrate wind energy into the power grid and increases grid reliability. Supercapacitors in solar power plants act as a similar buffer: they store energy during periods of high solar radiation and compensate for sudden fluctuations in yield caused by clouds, for example. This short-term buffer function leads to a more constant energy supply and increases the efficiency of solar systems.

Industrial Applications and Emergency Power Supply

Supercapacitors play a central role in industrial applications and emergency power supplies. They provide energy immediately in the event of power failures so that critical systems can continue to run without interruption or can be shut

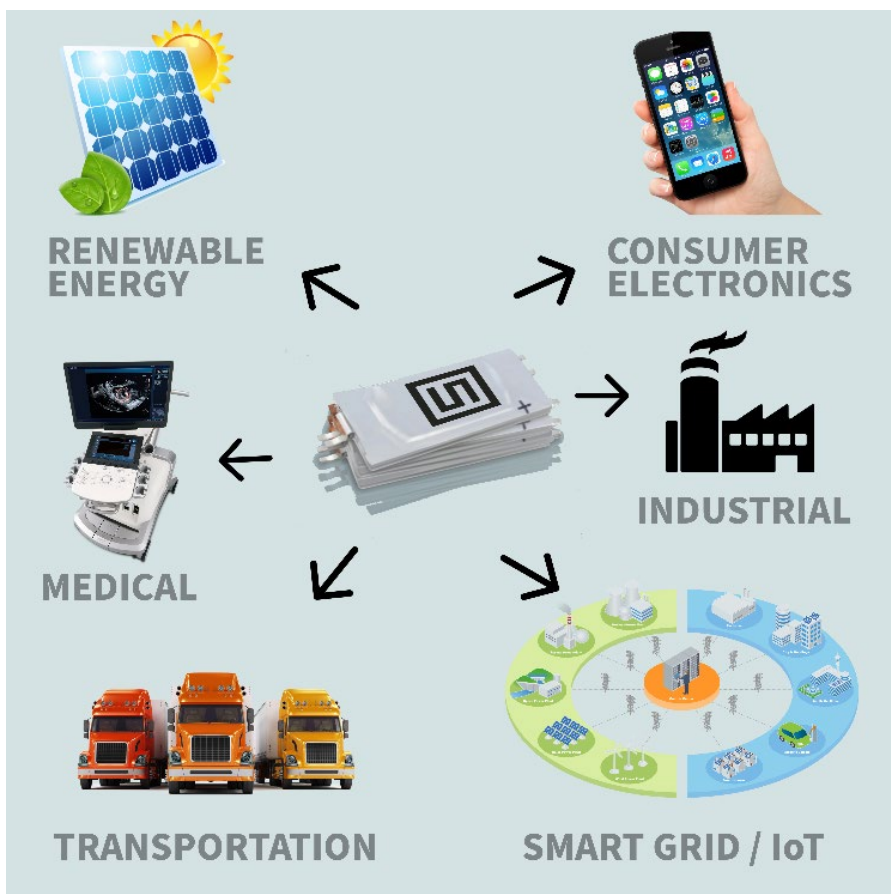
down safely. This reduces downtime and protects against data loss. In emergency power systems, supercapacitors bridge the time until generators are started up and increase operational reliability. They also stabilize the mains voltage by compensating for short-term voltage fluctuations, thus protecting sensitive devices from damage.

Consumer Electronics

Supercapacitors offer significant advantages for consumer electronics as they enable extremely fast charging times. In smartphones, tablets or laptops, they could be used in combination with batteries to cover peak loads and increase overall performance. This reduces charging times and extends the service life of devices. Supercapacitors are also used in portable tools such as cordless drills and electric screwdrivers. They enable immediate readiness for use and increase productivity, as they store enough energy during short charging intervals to enable longer operating times.

Future Areas of Application: Smart Grids, IoT, Medical

The future of supercapacitors offers exciting prospects, particularly in areas such as smart grids, the Internet of Things (IoT) and medical technology. In smart grids, they could support real-time energy management by balancing out rapid fluctuations in energy demand and supply. This improves grid stability and supports the efficient integration of renewable energies. In the field of IoT, supercapacitors are particularly valuable as a reliable and long-lasting energy source. They are suitable for sensors and actuators that require regular energy pulses and help to reduce maintenance costs as no battery replacement is required. Supercapacitors can also increase safety and reliability in medical technology, for example in implants such as pacemakers or wearable devices, as they enable a stable power supply and reduce the need for battery changes. Laser systems in research and medical technology, in which powerful lasers are used, can also use supercapacitors to provide the high current required at short notice for the laser application.



The areas of application for supercapacitors are extremely wide-ranging. There is hardly a branch of industry in which they cannot or should not be used.

Advantages and Challenges

Supercapacitors offer numerous advantages. They charge extremely quickly and can release large amounts of energy in milliseconds, which makes them ideal for applications with short-term high energy requirements. They are characterized by a high power density and an exceptionally long service life. While they can withstand up to one million charge cycles, their capacity remains stable and they are less harmful to the environment than batteries as they contain fewer toxic chemicals and are easier to recycle. They also function reliably in a wide temperature range, often from -40°C to $+70^{\circ}\text{C}$, which qualifies them for demanding applications.

However, there are also challenges. The energy density of supercapacitors is lower than that of batteries, which is why they store less energy per unit volume. They are therefore less suitable for applications that require a continuous energy supply over longer periods of time. In addition, the manufacturing costs are relatively high due to special materials and complex manufacturing processes. Another disadvantage is the higher self-discharge rate, which means that supercapacitors lose energy if they

are not actively used. Their low nominal voltage per cell makes it necessary to connect several cells in series in order to achieve higher voltages, which requires additional balancing circuits.

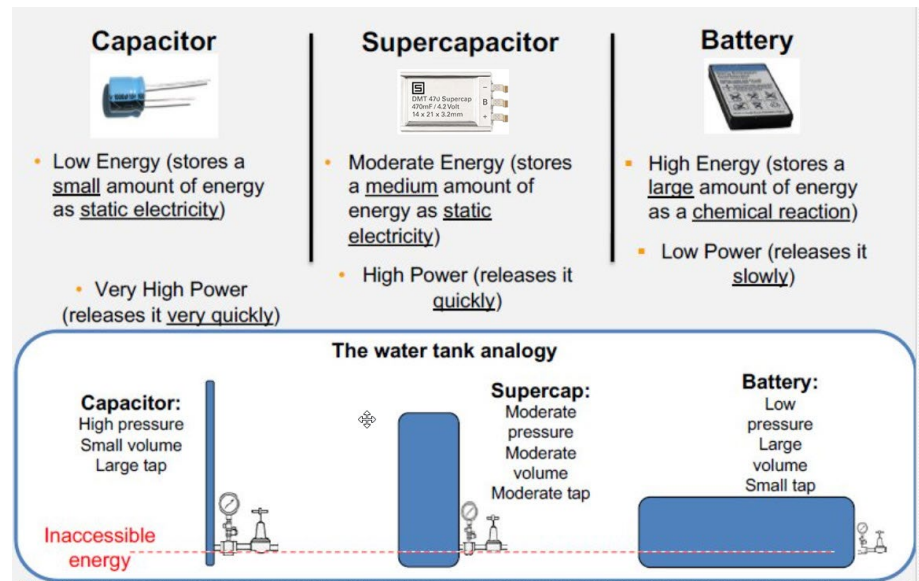
Paving the Way for Future Technologies

Supercapacitors are an extremely promising technology that contributes to increasing efficiency in numerous industries. Their ability to store and release energy quickly predestines them for short-cycle applications and makes them an important component of future energy systems. Especially in combination with renewable energies and in smart grids, they could play a key role in making energy storage and supply more efficient. With further progress in research, the existing challenges could be overcome and the application possibilities significantly expanded, so that supercapacitors could play an even more important role in the energy infrastructure of the future.

About SCHURTER

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Comparison of capacitor vs. supercapacitor vs. accumulator. Supercapacitors are in a special position in terms of their technical properties.

Power Density vs. Energy Density

The **power density** describes how quickly an energy storage device can release or absorb energy. It is measured in watts per kilogram (W/kg) and is crucial for applications that require short-term high energy outputs, such as when starting an engine. Supercapacitors are characterized by a high power density, which is why they can provide energy very quickly.

The **energy density** indicates how much energy a storage device can hold over a longer period of time and is measured in watt hours per kilogram (Wh/kg). A high energy density is essential for applications that require a continuous energy supply, such as in mobile devices. Batteries have a high energy density and are therefore ideal for long-term applications. Supercapacitors, on the other hand, have a lower energy density, which is why they store less energy in comparison, but can release it much faster.