CAP-XX

Going Mobile, Going Green

May 19, 2009

How supercapacitors change power design

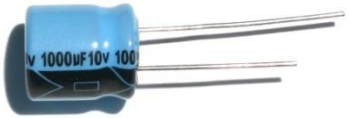
Enabling low power, high energy → infinite energy sources

Power and Energy

- Energy: The total work that can be done
- Power: The rate at which energy is delivered (or how fast you do the work)
- Hi Energy, Low Power: 50Km walk
- Hi Power, Low Energy: 100m sprint

CAP-XX Capacitors & Batteries: Power & Energy

Capacitor



- Low Energy (stores a small amount of energy as static electricity)
- Very High Power (releases it very quickly)

Supercapacitor

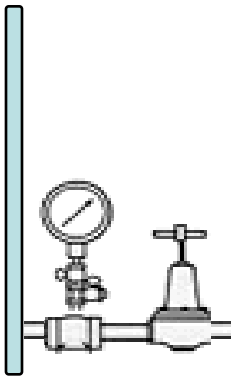
- Moderate Energy (stores a medium amount of energy as static electricity)
- High Power (releases it quickly)

Battery

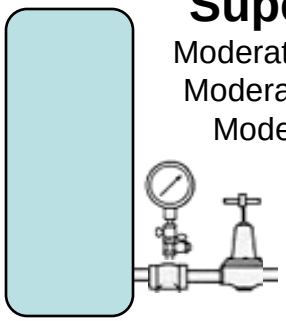
- High Energy (stores a large amount of energy as a chemical reaction)
- Low Power (releases it slowly)

The water tank analogy: How much water = Energy
How fast it flows = Power

Capacitor:
High pressure
Small volume
Large tap



Supercap:
Moderate pressure
Moderate volume
Moderate tap



Battery:
Low pressure
Large volume
Small tap

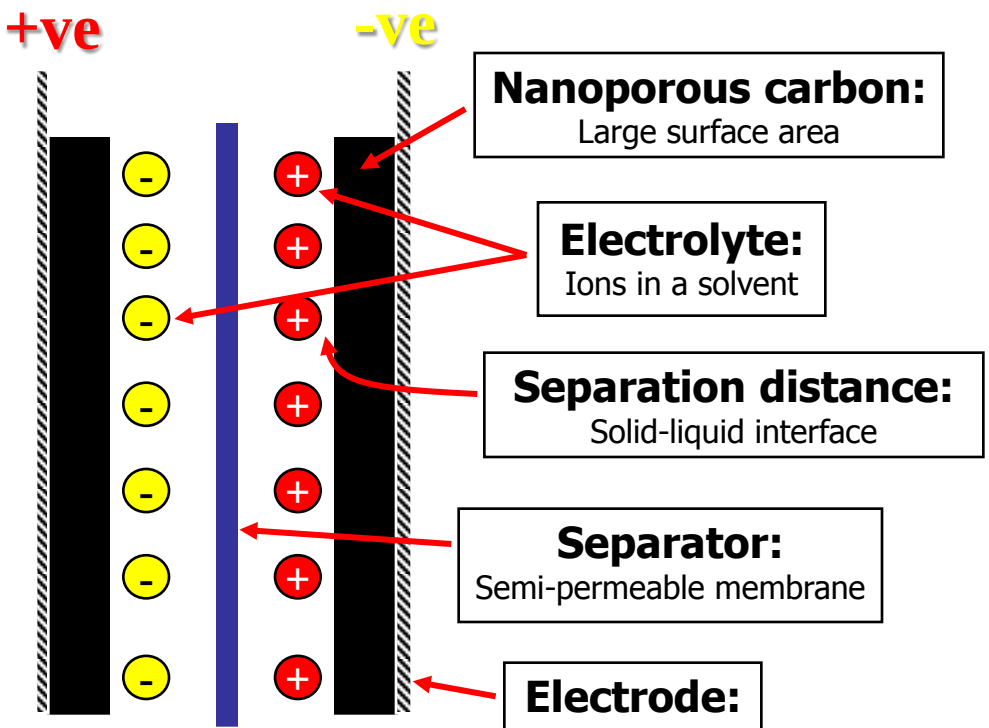
What is a Supercapacitor?

A supercapacitor is an energy storage device which utilizes high surface area carbon to deliver much higher energy density than conventional capacitors

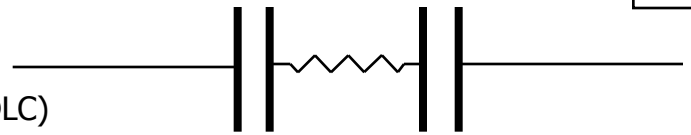
Basic Theory:
Capacitance is proportional to the surface area of the carbon, divided by the charge separation distance (C α A / d)

As area (A) ↑, and
charge distance (d) ↓
capacitance (C) ↑↑↑↑

C = I * dt / dV
ESR = dV / I
Charge stored: Q = CV

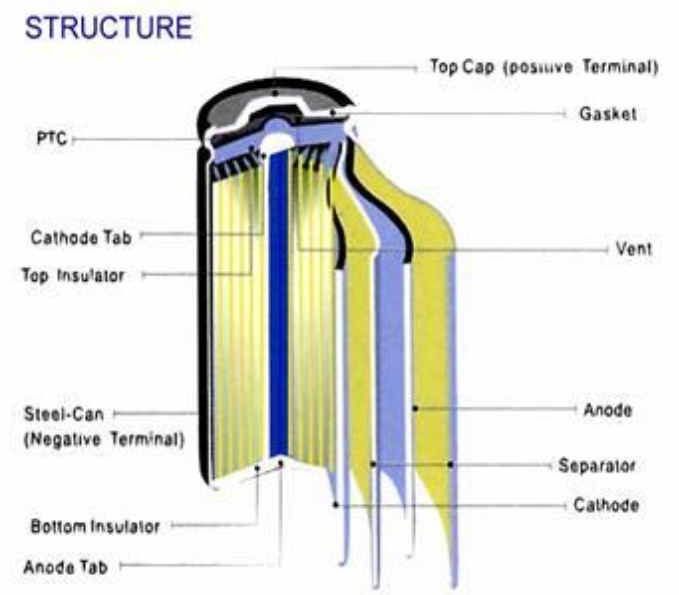


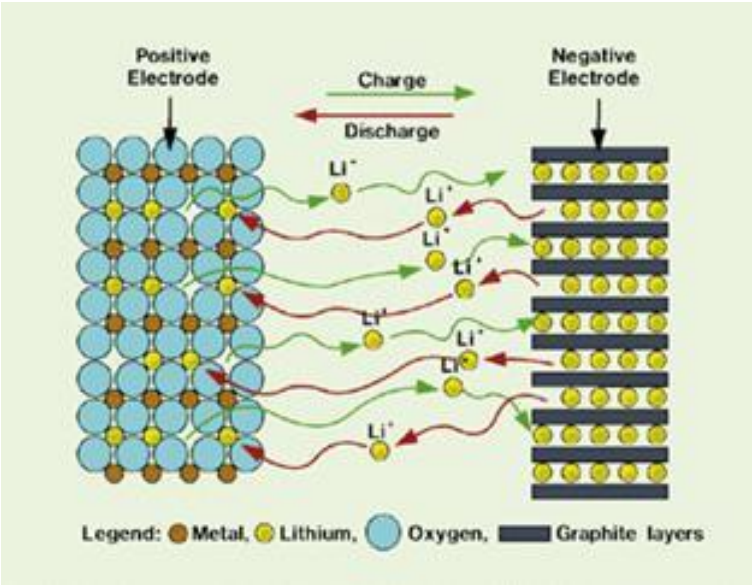
Basic Electrical Model:
Electric Double Layer Capacitor (EDLC)



Battery design

- Chemical reaction converts chemical energy to electrical energy
- Reversing the reaction (charging the battery): electrical energy to chemical energy
- Some damage to the material structure as this occurs, limiting battery life



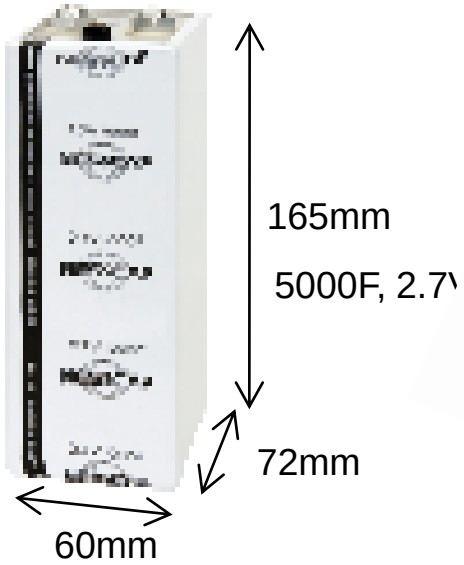


Battery design is a compromise between energy and power:

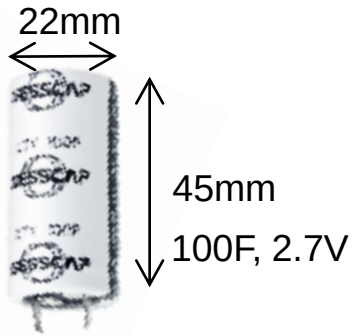
- Which chemistry?
- Thickness of electrodes (more volume → higher energy)
- Area of electrodes (more area → higher power)

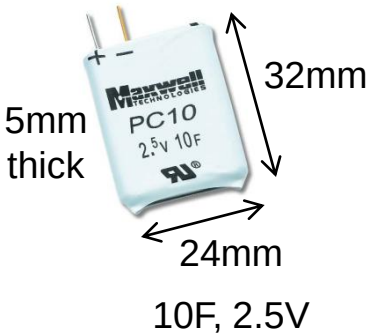
CAP-XX Different supercapacitors for different jobs

HEV, Utilities, Large UPS

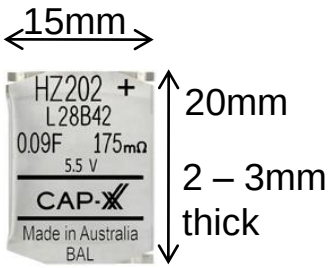


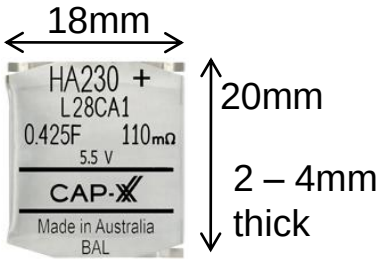
General Purpose, Small UPS

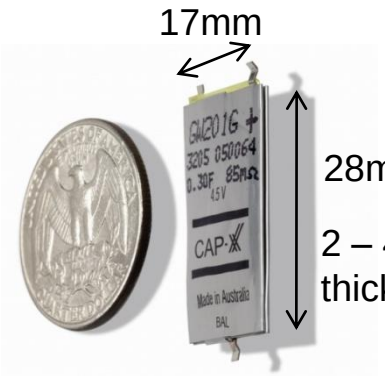




4.5V, 70°C; 5.5V, 85°C
0.12F < C < 1.2F
30mΩ < ESR < 180mΩ







Portable Power: Cell Phones, PDA's, Modems, DSC
M2M: Wireless sensors, Modems, Location tracking

Power design before supercapacitors

Battery must be able to deliver peak current

DC:DC converter must be sized for **peak** load power

Load. Hi power peaks

Battery pack + protection circuit + contact impedance = 150mΩ. Load is constant power. When battery = 3.4V (unloaded), solve

$$i_b^2 \bullet R_b - V_{b(unloaded)} + P = 0$$

i_b = 2.85A, $V_{b(loaded)}$ = 2.97V

e.g. 85% efficient. i/p power = 7.2W/85% = 8.5W

If ripple = 30%, then peak inductor current = 3.3A → large inductor

Report position 1/hr with GPRS class 8: 2A @ 3.6V peak power for transmission

$i_b.R_b$ drop may cause under voltage lockout when there is still plenty of energy left in the battery

Power design with supercapacitors

Battery or energy harvesting source must be able to deliver **average** current

Supercapacitor with high C (energy) and low ESR (power) buffers the source from the load. Source sees average power. Load sees low impedance source.

DC:DC converter can be sized for **average** load power

Load.
Hi power peaks

Battery + contact impedance = 650mΩ.
Load is constant power.
When battery = 3.4V (unloaded), solve

$$i_b^2 \bullet R_b - V_{b(unloaded)} + P = 0$$

e.g. 60% efficient. i/p power = 0.75mW/60% = 0.00125W

Use a charge pump, **peak current = 425µA**

Report position 1/hr with GPRS class 8; 3 sec SMS: 2A @ 3.6V/8 x 3/3600 = **0.75mW average power, with 7.2W peak power**

i_b = 370µA, $V_{b(loaded)}$ = 3.40V ← $i_b.R_b$ drop negligible, extract all the energy from the battery

Going green with a supercapacitor

- Supercapacitors enable the use of high energy, low power batteries:
  - $LiSOCl_2$
  - Li Primary
  - Zn Air
  - Alkaline
- Supercapacitors enable the use of low power, high energy sources from the environment:
  - Solar (or other light)
  - Vibration (or other movement)
  - RF
  - Thermoelectric, piezoelectric, etc.

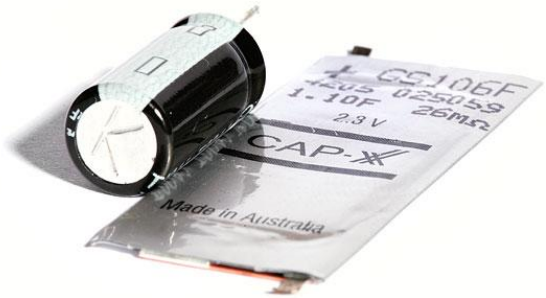
No batteries, green energy, perpetual free power

Green power examples

- **Cymbet**
  - Fluorescent light in washrooms powers a solar cell, which
  - Trickle charges a supercapacitor, which
  - Turns taps on/off in response to motion sensor
- **Perpetuum**
  - Electro-magnetic vibration transducer trickle charges a supercapacitor, which
  - Provides power to collect & transmit data on rotating machinery for condition monitoring
- **Powercast**
  - RF transmitter powers receivers throughout a building, which
  - Trickle charge a supercapacitor, which
  - Powers sensors to report data: security, fire, temperature, etc.

About CAP-XX

- Export-driven supercapacitor manufacturer founded in 1997
- Listed on the London Stock Exchange (AIM) in 2006
- World leader in the design & development of thin, prismatic, high power supercapacitors (ultracapacitors)
- Provide a high power energy storage solution in portable & other space-constrained electronic devices
- Unique technology & powerful IP, built on in-house R&D
- Millions of devices sold to global, brand name customers
- Applications in many high growth markets



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