MAXWELL Ultracapacitors

Push for Power

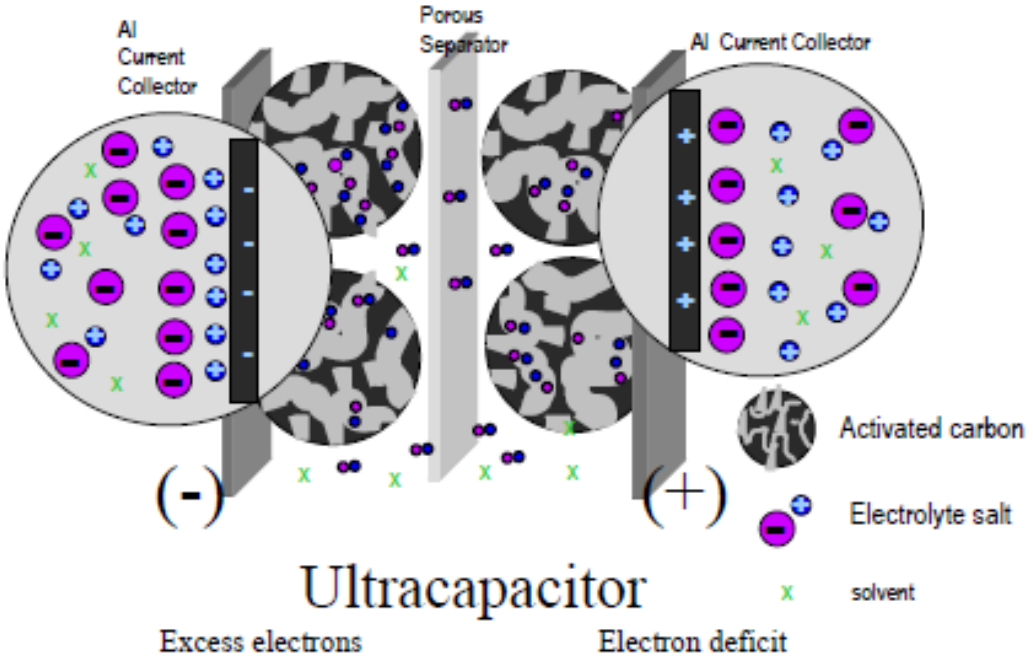
What is an Ultracapacitor?

An ultracapacitor, also known as supercapacitor or double layer capacitor, is an energy storage device which utilizes high surface area carbon to deliver much higher energy density than conventional capacitors

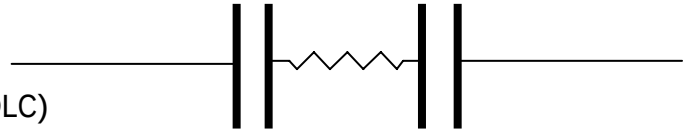
Basic Theory:
Capacitance is proportional to the surface area of the carbon, divided by the charge separation distance (C α A / d)

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

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

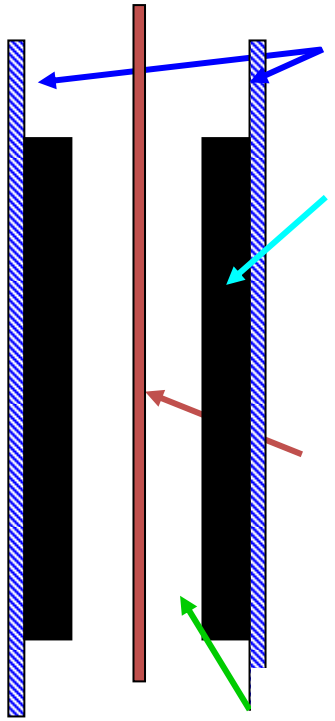


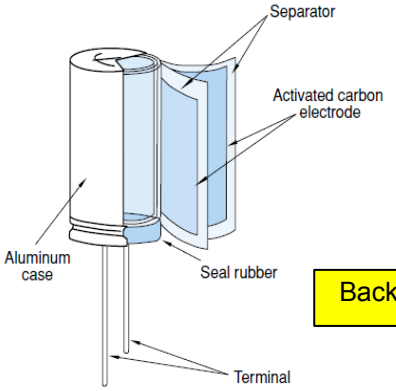
Basic Electrical Model:
Electric Double Layer Capacitor (EDLC)



What is an Ultracapacitor

- The aluminum foil is used to get charge into and out of the carbon charge storage
- The carbon is highly porous giving a massive charge storage area (1000s of m^2 /gram)
- Charge transport is by movement of ions in the electrolyte which can pass through the separator
- There is no dielectric, ions in the electrolyte are next to ions at the carbon surface, so charge separation distance is in the order of Å
- Massive charge storage area/minute charge separation distance → supercapacitance
- Multiple layers are stacked and connected in parallel for low ESR
- The more layers the lower the ESR and higher the C
- Thicker carbon can be used for more capacitance
- No chemical reactions take place during charge/discharge unlike a battery





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Cycling capabilities Ultracap's vs. Batteries

Lead acid

3'000 load cycles (20% DOD)

Nickel Cadmium

10'000 load cycles (40% DOD)

Lithium Ion

20'000 load cycles (40% DOD)

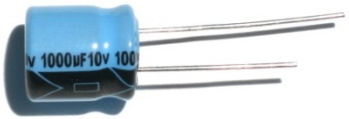
Ultracapacitors

More than

1'000'000 load cycles (75% DOD)

Ultracapacitors vs Capacitors & Batteries

Capacitor



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

Ultracapacitor

- 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)

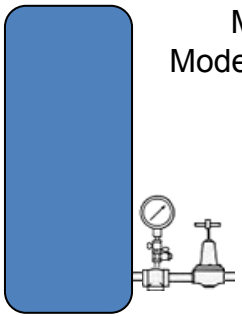
The water tank analogy

Capacitor:

High pressure
Small volume
Large tap

Ultracapacitors:

Moderate pressure
Moderate volume Moderate tap

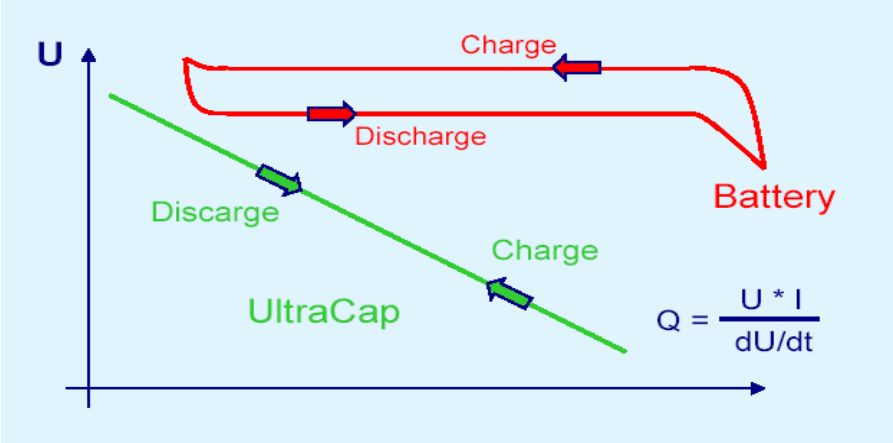


Battery:

Low pressure
Large volume
Small tap

Ultracapacitors vs Capacitors & Batteries

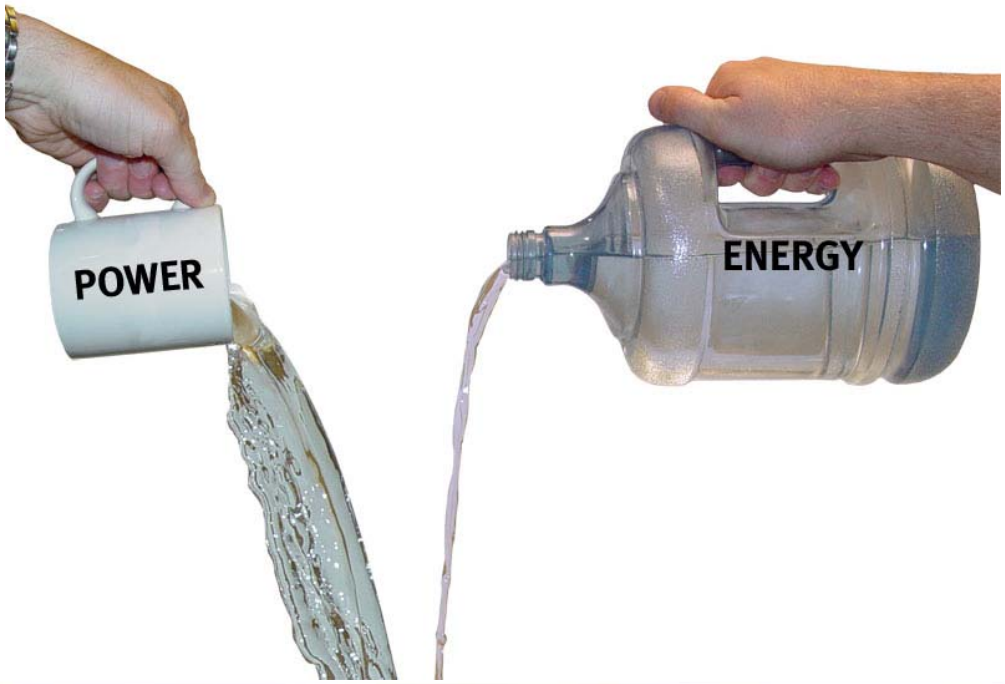
Available Performance	Lead Acid Battery	Ultracapacitor	Conventional Capacitor
Charge Time	1 to 5 hrs	0.3 to 30 s	10^{-3} to 10^{-6} s
Discharge Time	0.3 to 3 hrs	0.3 to 30 s	10^{-3} to 10^{-6} s
Energy (Wh/kg)	10 to 100	1 to 10	< 0.1
Cycle Life	1,000	>500,000	>500,000
Specific Power (W/kg)	<1000	<10,000	<100,000
Charge/discharge efficiency	0.7 to 0.85	0.85 to 0.98	>0.95
Operating Temperature	-20 to 100 C	-40 to 65 C	-20 to 65 C



Power vs Energy

What is the difference between Power and Energy?

Power * Time = Energy
Power is the rate of using energy.



Applications: Access and Security

Function

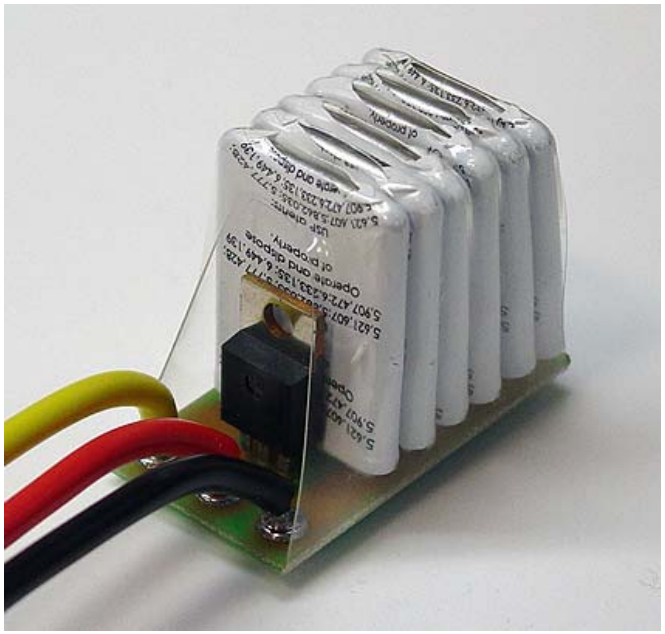
- Supply power to motors and actuators during power disruption
- Supply power to alarm

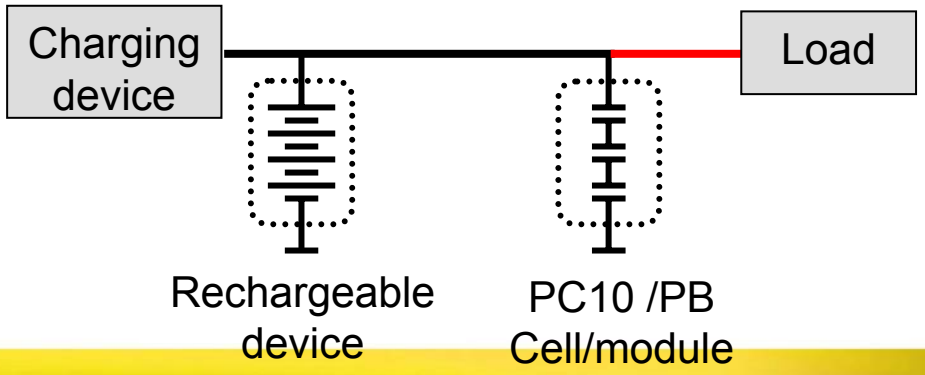
Advantages

- Redundant local power
- Reduction in cabling
- Weight reduction
- Built in active or passive balancing

Product

- TPL, custom PB/PBLL Modules





Why Ultracaps

- Lowest Total Cost of Ownership
- Long lifetime – 8-14 years
- Maintenance free
- Predictable wearout
- No toxic materials
- Fast recharge, fast system recovery
  - No C rate limitations on lifetime
  - Immediate use upon installation, no battery forming
  - Less downtime
- High power density
  - 5.5KW per kg
  - 7.5 KW per 1U/rack unit