T: (450) 585-6396
www.sysacom.com

AN200806-01A
Comparing energy density of some capacitors, ultracapacitors and batteries.

By Denis Lachapelle eng.
and
Serge Garcia
June 2008

Introduction

This application note compares energy density of various energy storage components such as capacitors, ultracapacitors and batteries. Energy density by unit of volume and energy density by unit of mass are considered.

The following components are analysed:

- Panasonic lithium ion battery
- A123 Systems lithium ion battery
- Panasonic lead acid battery
- Maxwell Technologies ultracapacitor
- NESSCAP ultracapacitor
- Panasonic electric double layer capacitor
- United Chemicon Aluminium electrolytic capacitor

This application note does not intend to sort out these components in term of quality, the objective is to make clear the different energy density of various devices. Many of these devices are addressed to different applications and need to be properly selected and qualified according to your specific needs.

Panasonic Lithium Ion Battery CGR18650AF

From the datasheet we can compute the energy contained in the fully charged battery. For computing the energy we assume constant current discharge of 1950mA to match the Figure 1 provided in the manufacturer datasheet. Assume we drain the battery down to 1800mAh, the mean voltage during the discharge will be 3.65V, (4.0V + 3.3V)/2. The energy in watt*hour is then 6,57Wh, (1.8Ah*3.65V) and in joule 23700J.

This is a cylindrical battery of 65.2mm length and 18.6mm in diameter; the volume is then 17.7 cm cube. The mass is 42.5g.

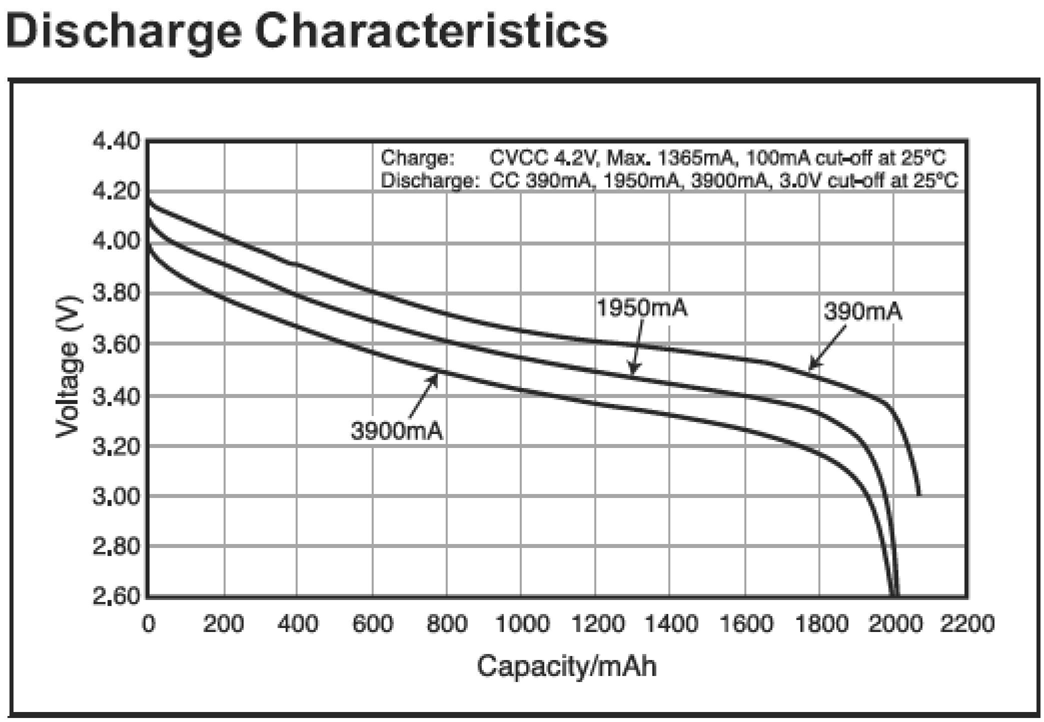

Figure 1 Panasonic Li-ion CGR18650AF

A123 Systems Lithium Ion Battery ANR26650

From the datasheet we can compute the energy contained in the fully charged battery. For computing the energy we assume constant current discharge of 1A to match the Figure 2 provided in the manufacturer datasheet. Assume we drain the battery down to 2Ah, the mean voltage during the discharge will be 3.3V. The energy in watt*hour is then 6.6Wh, (2.0Ah*3.3V) and in joule 23800J.

This is a cylindrical battery of 65.15mm length and 25.85mm in diameter; the volume is then 34.2cm cube. The mass is 70g.

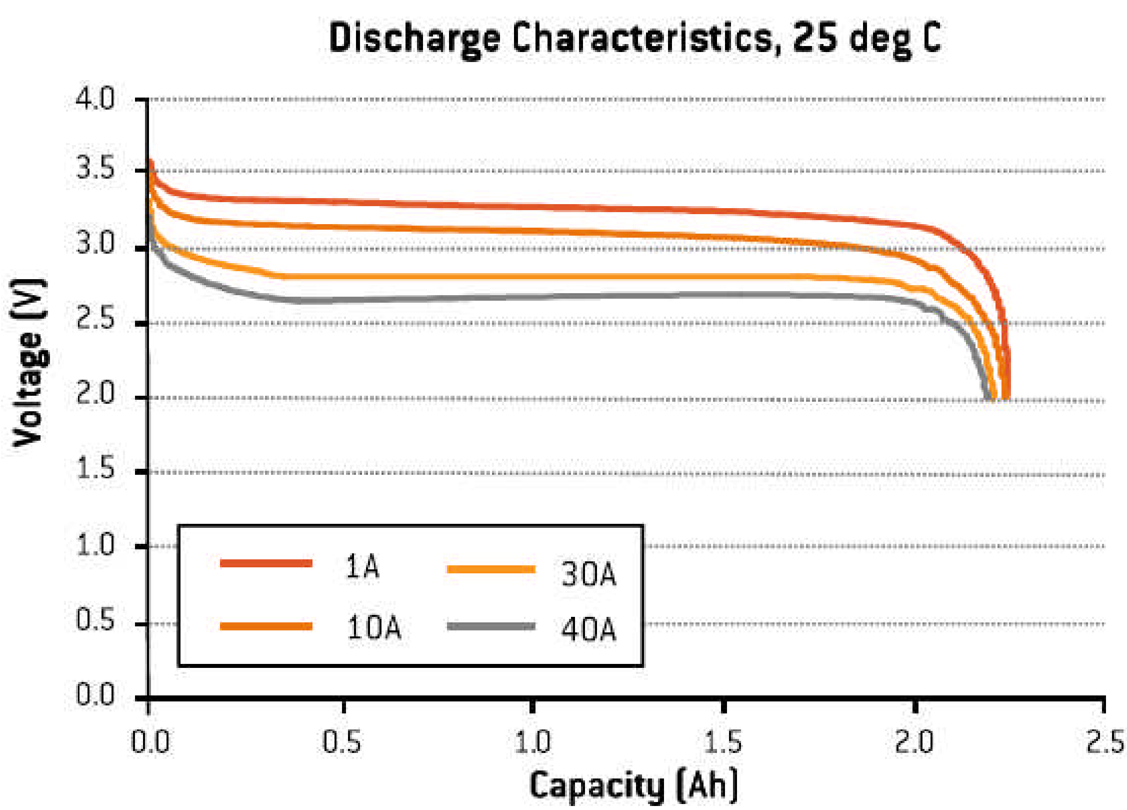

Figure 2

Panasonic Lead Acid Battery LC-R121R3P

From the datasheet we can compute the energy contained in the fully charged battery. For computing the energy we assume constant current discharge of 65mA to match the Figure 3 provided in the manufacturer datasheet. Assume we drain the battery 20 hours; the mean voltage during the discharge will be 11.7V. The energy in watt*hour is then 15.2Wh, (20h*11.7V*0.065A) and in joule 54800J.

The battery volume is 230cm^3. The mass is 590g.

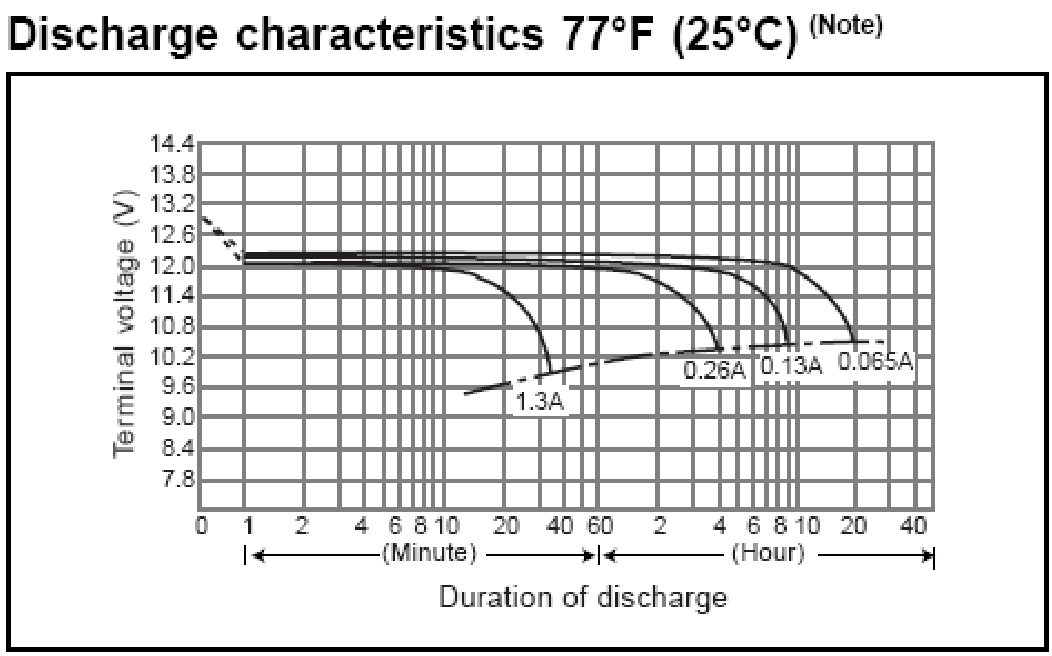

Figure 3 Panasonic Lead Acid LC-R121R3P

Maxwell Technologies PC-10 Ultracapacitor

This ultracapacitor is 10F and can be charged at 2.5V. Assuming we can extract all the energy from the capacitor, we have storage for 31.3J, (1/2 * 10F * 2.5V^2).

The volume is 3.35cm cube. The mass is 6.3g.

NessCap Ultracapacitor ESLSR-0010C0-002R3

This ultracapacitor is 10F and can be charged at 2.3V. Assuming we can extract all the energy from the capacitor, we have storage for 26.5J, (1/2 * 10F * 2.3V^2).

The volume is 2.4cm cube. The mass is 3.6g.

Panasonic Electric double layer capacitor series HW, EECHW0D105

This capacitor is 1F and can be charged to 2.3V. Assuming we can extract all the energy from the capacitor, we have storage of 2.65J, (1/2 * 1F * 2.3V^2).

The volume is 1.11cm cube. Mass is not shown in the datasheet.

United Chemicon Aluminium Electrolytic Capacitor, EKMH160VSN393MR50T

This capacitor is 39000uF and can be charged to 16V. Assuming we can extract all the energy from the capacitor, we have storage of 5.0J, (1/2 * 0.039F * 16V^2).

The volume is 35.3cm cube. Mass is not shown in the datasheet.

Results

The following table and figures present the results. Energy density values are computed within the table using embedded formulae. The results are graphically represented in Figure 4 for energy density by unit of mass and Figure 5 for energy density by unit of volume.

We regroup using circles the devices having similar energy densities, in Figure 4 there is a group for battery with energy density in the hundreds to near thousand joule per gram and a second group for the ultracapacitor with energy density near 10 joule per gram.

In Figure 5 there are three groups; one for battery, one for the ultracapacitor or supercapacitor and one for the electrolytic capacitor.

It is now clear where battery, ultracapacitor and electrolytic capacitor stand in term of energy density.

Table 1

Devices	Energy (J)	Volume (cm^3)	Mass (g)	Energy Density by Volume	Energy Density by mass
Panasonic Lithium Ion battery	23700	17.7	42.5	1339.0	557.6
A123 Systems Lithium-ion Battery	23800	34.2	70	695.9	340.0
Panasonic Lead Acid battery	54800	230	590	238.3	92.9
Maxwell Technologies PC-10 Ultracapacitor	31.3	3.35	6.3	9.3	5.0
NESSCAP CO. LTD. Ultracapacitor	26.5	2.4	3.6	11.0	7.4
Panasonic Electric double layer capacitor series HW	2.65	1.11		2.4	
United Chemicon Aluminium Electrolytic Capacitor	5	35.5		0.1	

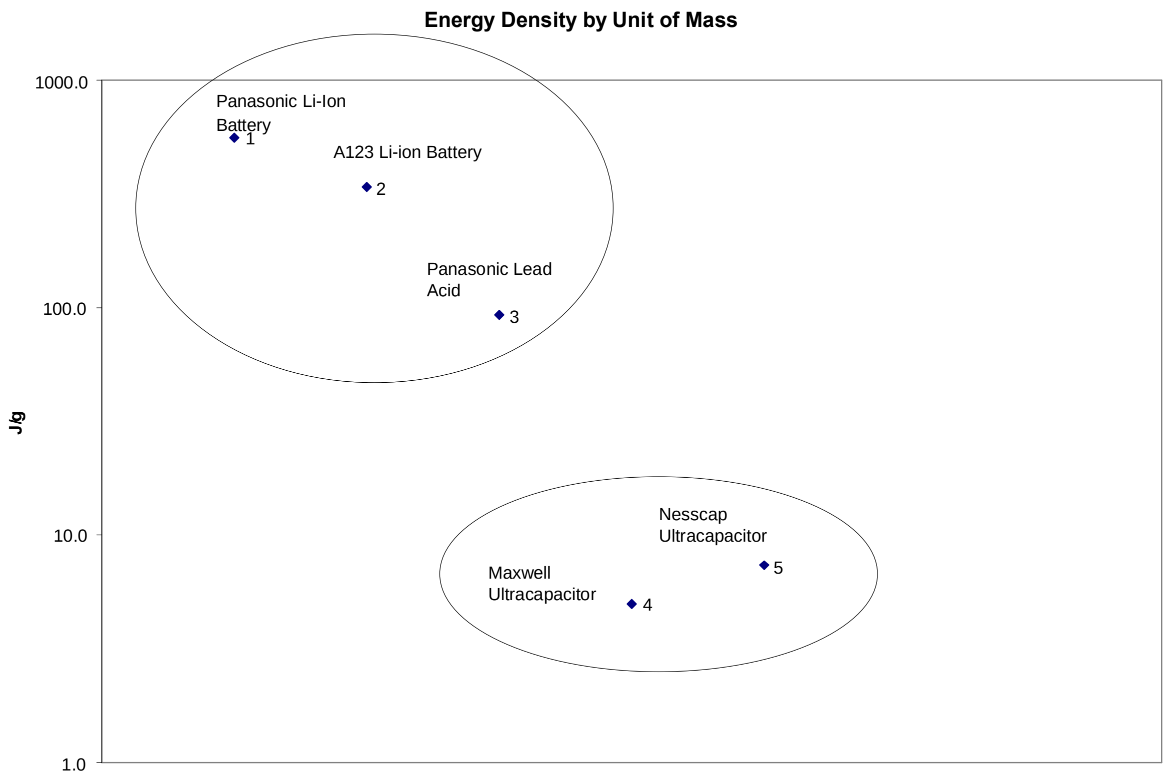

Figure 4, Energy Density by unit of mass

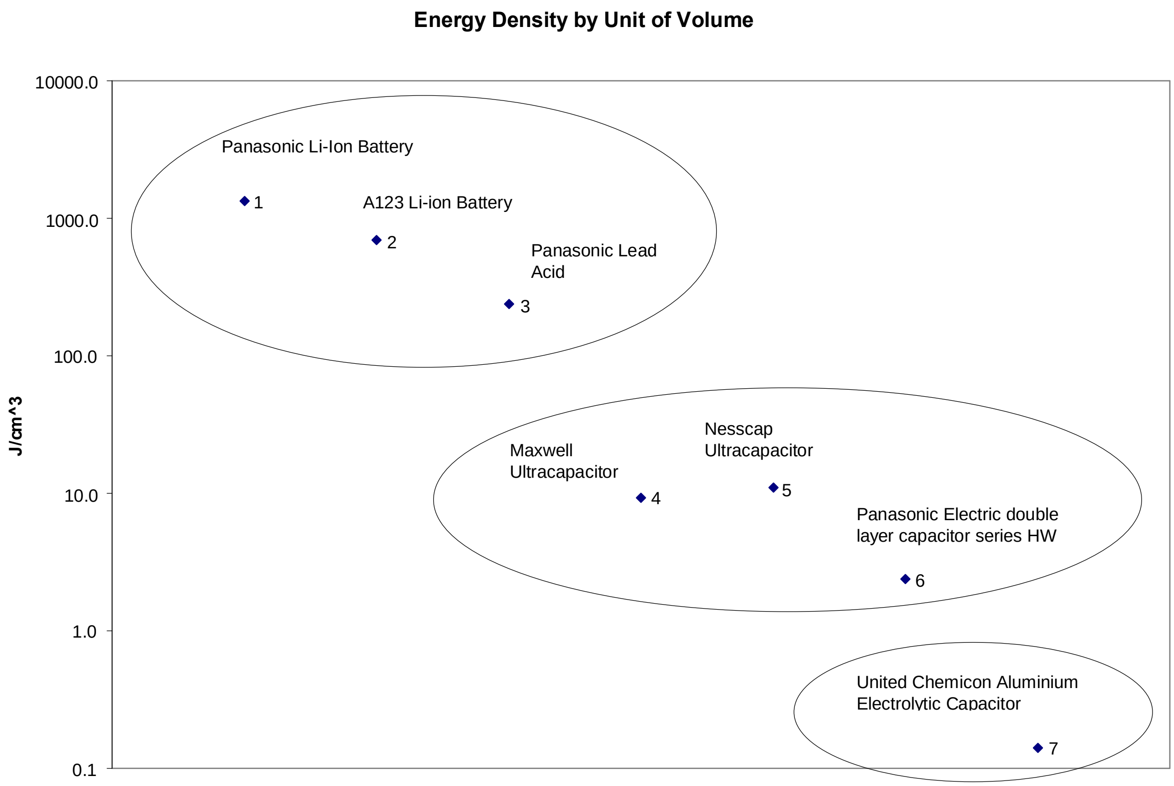

Figure 5, Energy Density by unit of volume