TECHNICAL PAPER

Bestcap®: A New Dimension in Fast Supercapacitors

Scot Tripp
KYOCERA AVX Components Corporation
Fleet, UK

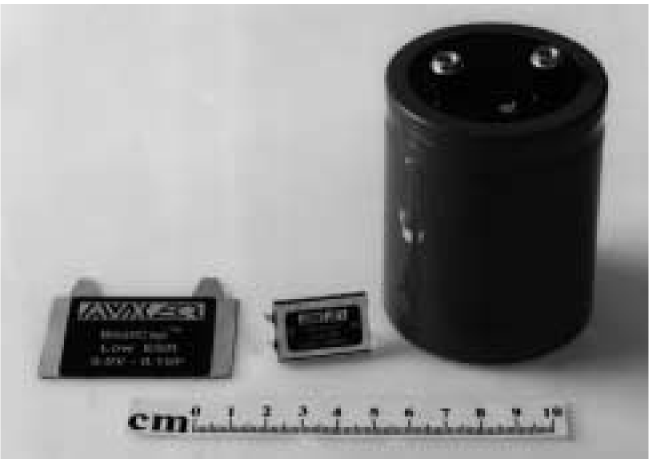
Dr. Arieh Meitav
Rehovot, Israel

BESTCAP
A NEW DIMENSION IN "FAST" SUPERCAPACITORS

Scot Tripp
Tel: +44(0) 1252 770043 Email: tripps@flt.avxeur.com

Dr. Arieh Meitav
Tel: +972 8 940 7920 Email: arieh@ecr.co.il

Supercapacitors or electrochemical caps are rapidly recognized as an excellent compromise between electronic capacitors such as ceramic, tantalum and aluminum electrolytic devices and batteries (Figure 1).



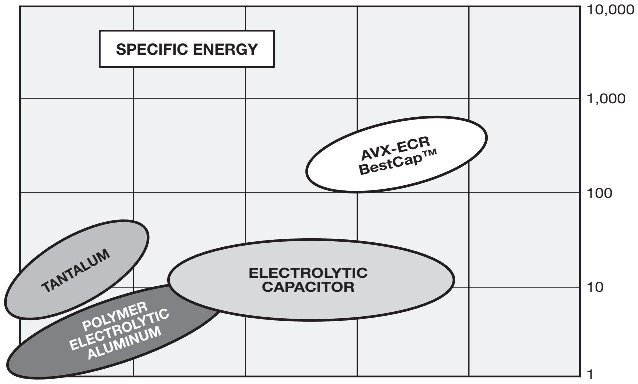


Figure 1. BestCap™ Electrochemical Cap vs. Conventional

Generally, supercapacitors have energy densities several orders of magnitude higher than electronic capacitors (Table 1) and power densities significantly superior to batteries.

There are, however, two negative characteristics associated with existing electrochemical capacitors, Viz: high ESR and capacitance loss when called upon to supply very short duration pulses at high current. This paper will demonstrate how the BestCap successfully addresses both of these issues.

CAPACITOR TYPE	CAP (mF)	VOLTAGE (V)	DIMENSIONS (mm)	ESR (mΩ)	CV/c.c. (mFV /c.c.)
Tantalum	0.47	6.3	6.0 x 7.0 x 3.5	100	20
	1.0	4.0	6.0 x 7.0 x 3.6	30	26
Electrolytic Aluminum solid capacitor organic semi-conductive electrolyte	1.5	4.0	ø10 x L20	15	3.2
	2.2	4.0	ø12.5 x L22	10	3.3
	2.2	6.3	ø16 x L25	15	2.8
Electrolytic Capacitor	4.7	6.3	ø16 x L26	100	6
	15	6.3	ø16 x L35.5	30	13
	22	6.3	ø18 x L41	20	13
	15	10	ø18 x L35.5	30	17
	330	10	ø76 x L114	10	6
BestCap™	250	8.0	52 x 50 x 4.0	50	200
	250	5.5	48 x 30 x 3.0	60	300
	500	5.5	48 x 30 x 5.0	30	400
	600	4.5	48 x 30 x 4.8	25	400
	700	3.5	48 x 30 x 4.2	20	400
	60	5.5	28 x 17 x 3.0	200	250
	120	5.5	28 x 17 x 5.0	100	300

Table 1. Performance of BestCap™
vs. Conventional Capacitor Technologies

EDLCs

To understand the benefits offered by the BestCap, it is necessary to examine how an electrochemical capacitor works. The most significant difference between an electronic capacitor and an electrochemical capacitor is that the charge transfer is carried out by the electrons in the former and by electrons and ions in the latter. The anions and cations involved in double layer supercapacitors are contained in the electrolyte which maybe liquid, (normally an aqueous or organic solution) or solid. The solid electrolyte is almost universally a conductive polymer.

Electrons are relatively fast moving and therefore transfer charge “‘instantly”. However, ions have to move relatively slowly from anode to cathode, and hence a finite time is needed to establish the full nominal capacitance of the device. This nominal capacitance is normally measured at 1 second.

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We may summarize the differences between EDLC (Electrochemical Double Layer Capacitors) and electronic capacitors as shown in Table 2 below:

• A capacitor basically consists of two conductive plates (electrodes), separated by a layer of dielectric material.
• These dielectric materials may be ceramic, plastic film, paper, aluminum oxide, etc.
• EDLCs do not use a discrete dielectric interphase separating the electrodes.
• EDLCs utilize the charge separation, which is formed across the electrode - electrolyte interface.
• The EDLC constitutes two types of charge carriers: IONIC species on the ELECTROLYTE side and ELECTRONIC species on the ELECTRODE side.

Table 2.

Because highly activated carbon is used as the electrode material, each carbon particle functions as a double layer capacitor having a capacitance value of Cn (Figure 2).

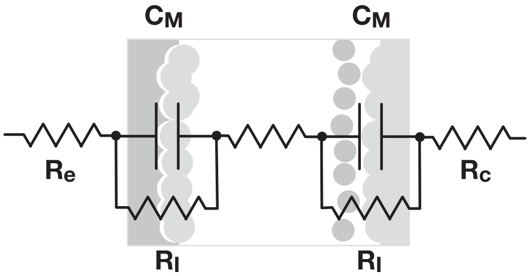

Figure 2. Simplified Equivalent Circuit of Electrochemical Capacitor

Upon charging the capacitor, the charge has to be transferred through two resistances electronic (Re) at the carbon electrode and at the carbon - current collector interface (Rc), and ionic (Ri) passing through the electrolyte. Therefore, the equivalent circuit of the EDLC is given by the above R-C combination, where R_1, R_2 and Rn are the internal resistances of the activated carbons.

Since the EDL capacitor is comprised of capacitors having various resistances, the charge/discharge voltage and charge/discharge time will define the apparent available capacity. Charging or discharging at a high rate may result in an apparently smaller capacitance than when done at a lower rate. This is due to the small capacitors that have large internal resistance not being fully charged or discharged which results in a large voltage drop at the start of measurement.

BestCap Pulse Performance

BestCap technology is based on a patented, highly conductive polymeric, proton conductive electrolyte. The innovation of BestCap is that this polymer electrolyte possesses very high ionic conductivity, thereby providing low ESR in the range of 20-200 milliohms and maintaining high apparent capacitance for very short pulses.

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These two factors are critical in determining the total voltage drop in short pulse operations, such as in GSM and other pulsed-mode digital mobile phones. Figure 3 shows the voltage time relationship for a capacitor. First there is the instantaneous voltage drop $\Delta V(TR)$ caused by the ESR, followed by $\Delta V(Q)$, which is a function of the available capacitance.

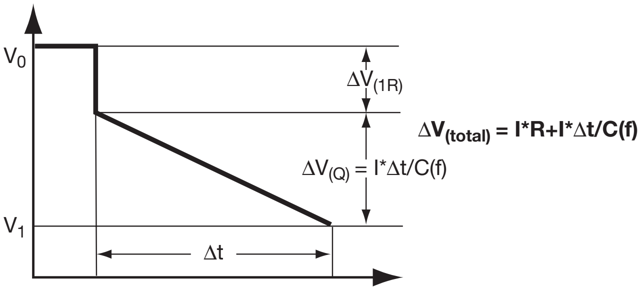


Figure 3. Voltage-Time Relation of Cap Unit

$C = I\Delta t(Vo-Vt-IR) \rightarrow I = C*(Vo-Vt)/(R*C+t)$

Spec. Power = $I*(Vo-I*R+Vt)/2$ per unit Volume

Spec. Energy = $I*\Delta t*(Vo-I*R+Vt)2$ per unit Volume

$R=ESR$

Now consider the available capacitance for very short pulse widths and for various EDLCs from a number of manufacturers, as shown in Figure 4. It can be clearly seen that virtually all EDLCs with the exception of BestCap lose >>90% of their nominal capacitance when used in the millisecond range.

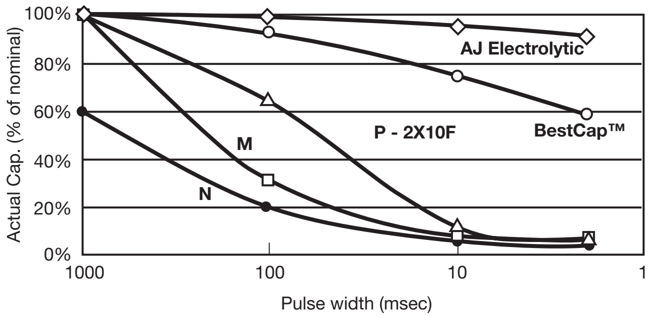
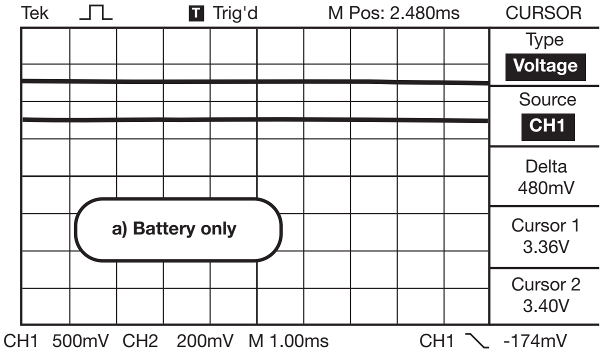


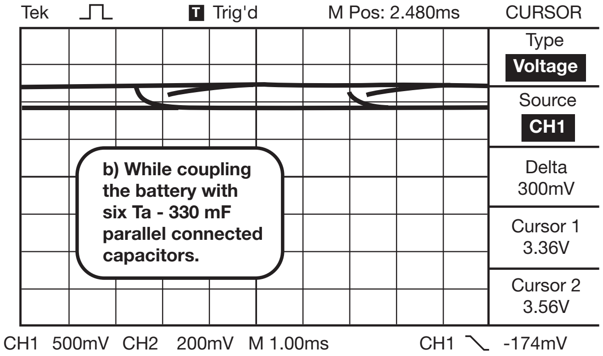
Figure 4. Actual Capacitance vs. Pulse Width

This combined with their higher ESF, means that they will exhibit very high significant voltage drop under short pulse conditions, whereas the voltage drop for BestCap is very small.

Battery



Hybrid: Battery coupled to six parallel Ta capacitors – 330µF each.



Hybrid: Battery coupled to ECR P-SC

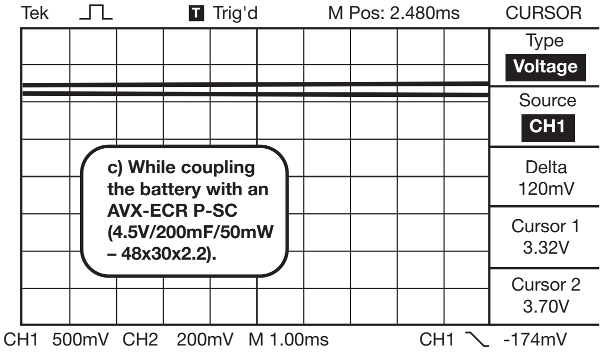


Figure 5. Discharge of a 500 mAh Li-ion Battery
(48 x 30 x 6.3) at a GSM "talk" Simulation Mode

When used in a mobile phone, for example, and placed between the battery and the power amplifier, BestCap reduces the pulsed current drain on the battery thereby significantly increasing "Talk Time" from the battery.

Other BestCap Characteristics

The material systems used in the BestCap structure features the following characteristics:

- Totally solid state, no liquids or gels used.
- Completely non-toxic.
- Capable of very thin formats with thickness down to < 0. 7mm.
- Shock resistance to > 30000G's.
- Easy to produce in various voltage ratings.
- Non-Polar.
- Low leakage current - < 0.05µA/mF.
- Capacitance values 40-500mF.

Summary

The high conductivity proton polymer electrolyte utilized in BestCap allows high current, short duration pulses to be delivered with minimal voltage drop. The product uses only "green" material and is physically very robust.

NORTH AMERICA
Tel: +1 864-967-2150

ASIA
Tel: +65 6286-7555

CENTRAL AMERICA
Tel: +55 11-46881960

EUROPE
Tel: +44 1276-697000

JAPAN
Tel: +81 740-321250

WWW.KYOCERA-AVX.COM