Supercapacitors investigations
Part I: Charge/discharge cycling

I-Introduction

Among all the system dedicated to energy storage, supercapacitors are one of the most promising especially for powering electronic devices. This application requires indeed an energy storage device able to provide many charge/discharge and short term pulses (A typical shape of current pulses is displayed in Fig. 1). These requirements are in agreement with the intrinsic characteristics of the supercapacitor.

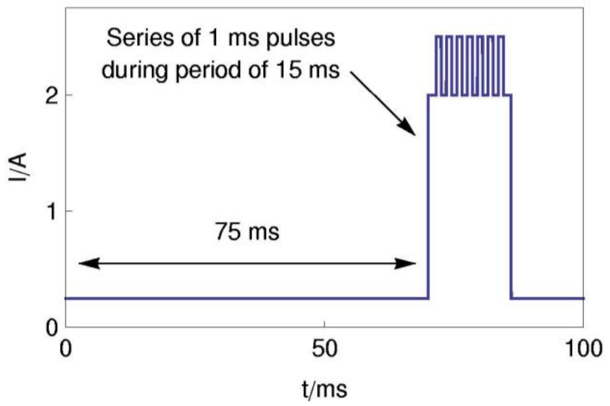


Fig. 1: Typical pulse output requirement for a digital communication device from ref [1].

The capacitor is made of one anode and one cathode separated by a dielectric membrane (Fig. 2).

Capacitor is called supercapacitor when the capacitance is higher than 1 F.

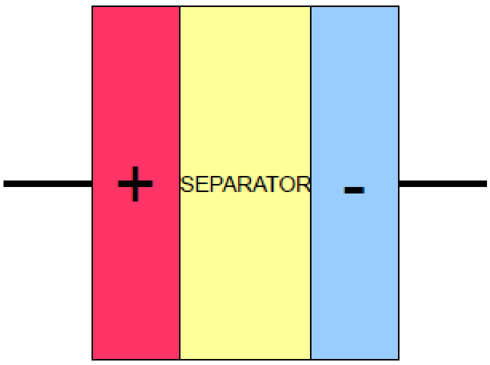


Fig. 2: Sketch of supercapacitor.

In this note, charge/discharge behavior of supercapacitor is investigated. Firstly, successive charges/discharges are done with a potential scan. Then, the second part of this note is dealing with discharge at constant power.

N.B.: All settings and raw data files presented hereafter are available in the Data Sample folder of EC-Lab® Software with the following name: technique_supercap.mpr.

II-Set-up description

Investigations are performed with a VMP3 equipped with a standard board.

Characteristics of supercapacitor are the following:

- capacitance: 22 F
- maximum operating voltage: 2.3 V
- mass of active material: ~10g

Supercapacitor is connected to VMP3 *via* a standard 2-electrode connection.

III-Charge/discharge cycling

As stated above, one of the most important characteristic of an energy storage device is the ability of the device to be charged and discharged many times without any performance loss.

In this paragraph, charge/discharge characterizations are carried out by potentiodynamic sweep at slow scan rate. Cycling of the supercapacitor are performed with 41 cycles of Cyclic Voltammetry (CV). at 3 mV/s between 0 and 2.3 V (Fig. 3).

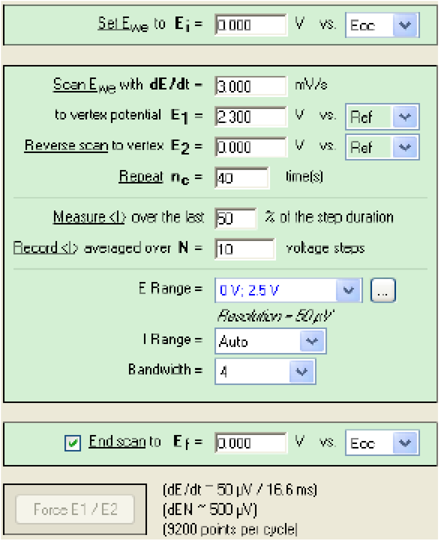


Fig. 3: CV settings window.

I vs E and *C vs E* curves are plotted in Fig. 4. These curves show that current and capacitance are stable over 41 cycles. The cycling doesn't affect the performance of the supercapacitor.

Note C vs. E curve is plotted thank to the graphic customization ability of EC-Lab®, $C = i\,\frac{dt}{dE}$.

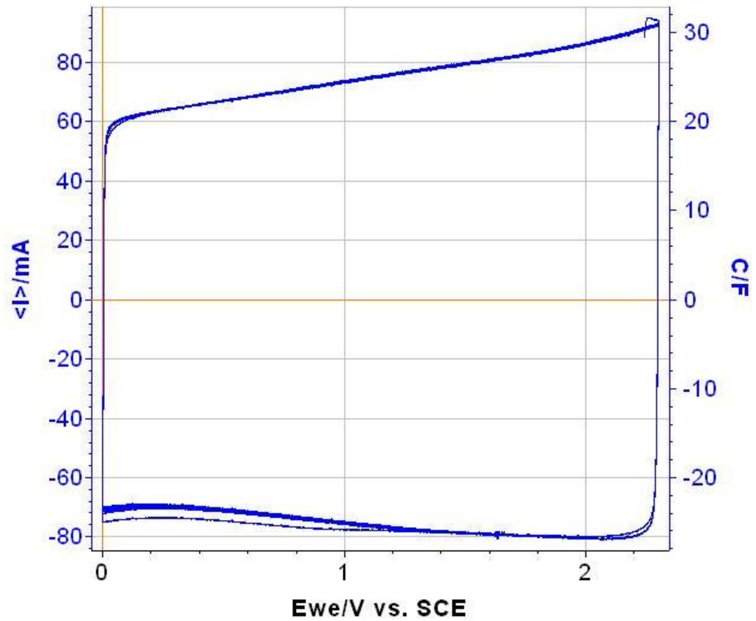


Fig. 4: Charge/discharge cycling.

IV-Constant power discharge

Energy storage devices are commonly represented by Ragone plot *i.e. E vs. P*. This diagram can be plotted from Constant Power Discharge (CPW) data after mathematical treatment.

Setting of the CPW technique applied to the supercapacitor is described in Fig. 5. The following constant power steps are successively applied to the system: 200, 100, 50, 20, 10, 5 and 1 mW.

Plot of Power *vs.* Energy is shown in Fig. 6.

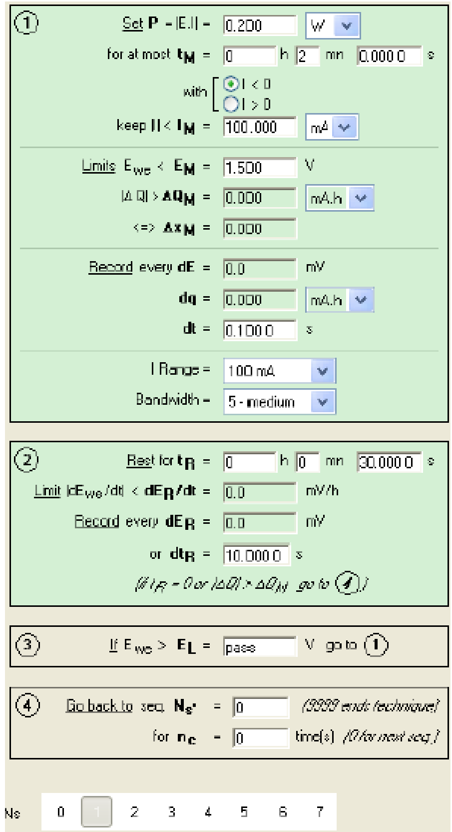


Fig. 5: CPW settings window.

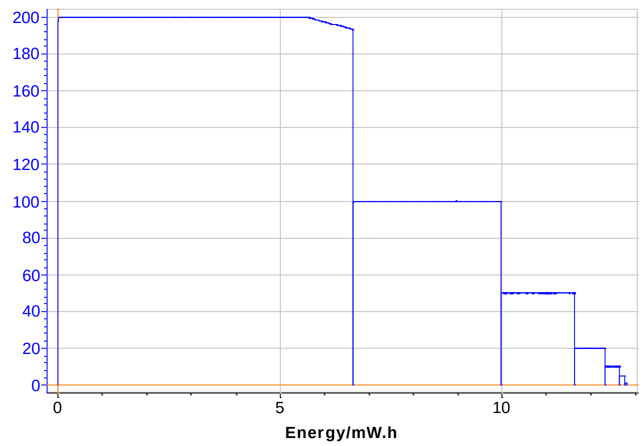
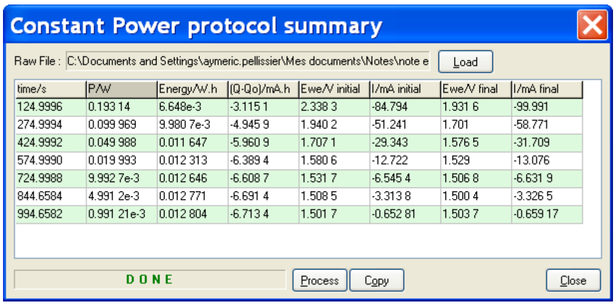


Fig. 6: CPW settings window.

The analysis tool « Constant Power protocol summary » (Fig. 7) allows user to calculate the energy and potentials and currents at the beginning and at the end at each power step. For this supercapacitor , this energy is around 10 mW/h.


Constant Power protocol summary

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time/s	P/W	Energy/W.h	(Q-Qo)/mA.h	Ewe/V initial	I/mA initial	Ewe/V final	I/mA final
124.9996	0.193 14	6.648e-3	-3.115 1	2.338 3	-84.794	1.931 6	-99.991
274.9994	0.099 969	9.980 7e-3	-4.945 9	1.940 2	-51.241	1.701	-58.771
424.9992	0.049 988	0.011 647	-5.960 9	1.707 1	-29.343	1.576 5	-31.709
574.9990	0.019 993	0.012 313	-6.389 4	1.580 6	-12.722	1.529	-13.076
724.9988	9.992 7e-3	0.012 646	-6.608 7	1.531 7	-6.545 4	1.506 8	-6.631 9
844.6584	4.991 2e-3	0.012 771	-6.691 4	1.508 5	-3.313 8	1.500 4	-3.326 5
994.6582	0.991 21e-3	0.012 804	-6.713 4	1.501 7	-0.652 81	1.503 7	-0.659 17

DONE Process Copy Close Load

Fig. 7: CPW protocol result.

Finally from these calculated values Ragone diagram can be plotted (Fig. 8).

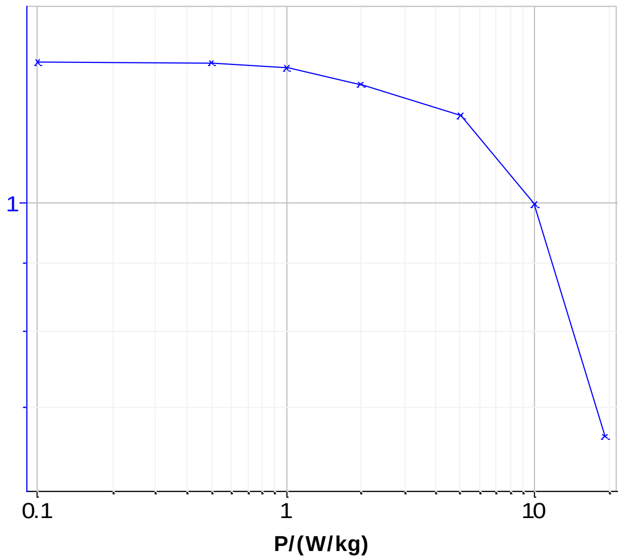

Fig. 8: Ragone plot.

V-Conclusion

Thank to these potentiodynamic and constant power discharge, the cycling performance of the supercapacitor is characterized. These characterizations allow user to determine if the studied supercapacitor fits the need (according to its corresponding pulse output) of the electronic device to powered.

The determination of the time constant is shown and discussed in the following application note [2].

References

[1] Supercapacitors and electrochemical pulse source. R. A. Huggins, Solid State Ionics, 2000, 13, 179-195.

[2] Supercapacitors investigations. Part II: time constant determination, Application note 34, http://www.bio-logic.info/potentiostat/notes.html