TADIRAN BATTERIES

TECHNICAL NOTICE

CAPACITOR SUPPORT

Electrolytic capacitors and supercapacitors can often be used to support low rate batteries during high current pulses of short duration. The combination of a battery and a high capacitance capacitor, is an “old trick” to optimize performance of low rate lithium batteries.

The main benefits would be as follows:

1. Low and medium rate lithium batteries can be used, rather than high rate batteries.

   Thus, **higher safety** levels and higher energy densities can be obtained.
2. A higher percentage of the nominal capacity of the battery becomes available (rather than only 50-80 percent, or even less).
3. The maximal voltage drop during the pulse is stable and can easily be predicted in worse case conditions.
4. Smaller batteries can be used at a lower cost and with smaller PCB footprint.

By connecting a capacitor permanently across the battery, short current pulses can be easily supported with a known voltage drop, which can be calculated as shown below:

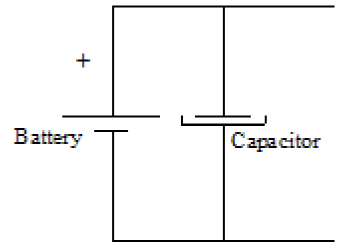
$$dV^* = I / C \times dt$$

where:

I= the current in Amps

C= the capacitance in Farads

dt= pulse duration in sec.



The capacitance required to fully support the battery is therefore:

$$C=I \times dt/dV^*$$

* Assuming that the ESR (Equivalent Serial Resistance) of the capacitor is negligible.

The rated leakage current from the data sheets of electrolytic capacitors is often misleading and confusing when it comes to calculate the capacity losses. The manufacturer usually measures the rated leakage current, when the capacitor is charged for few minutes only. The real leakage current of the capacitor is the steady-state leakage current, which can be measured quite accurately, after 24 hours.

The table below compares the real leakage current as measured on EDLC 5V/5F supercapacitor Vs Tadiran's HLC1550

Type	Leakage @+25°C AFTER 24 HOURS
EDLC 5V/5F	10-15µA
HLC 1550	<3µA

The temperature also affects the leakage current, however data is not always available from the capacitor vendor.

The ESR, which represents the internal impedance of the capacitors, must be taken in consideration when the current pulses are higher than 50 mA or at low temperatures.

Whenever the ESR is significant, the voltage drop is calculated as follows:

$$dV^* = I/C \times dt - ESR \times I$$

Below is an example showing how to determine a required capacitance:

pulse current: 100mA

pulse duration: 10msec

operating voltage: 3.45V

cut off voltage: 2.8V

ESR: 2.3ohm

C=100*10msec/(3.45-2.8)=1.54mF

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The calculated pure capacitance C doesn't take the capacitor resistance- ESR into account.

However, as already stated, this factor strongly impacts the required capacitance and therefore

Must not be neglected.

The actual required capacitance will then be referred to as C':

C'= 100*10/ (3.45-2.8-0.23) = 2.38mF

The capacitance is obviously the most important factor when trying to determine which capacitor is required for a specific application. By knowing the accurate capacitance, we can easily calculate the expected voltage drop at any applied current, and thus make sure it will not fall below cut-off.

In this aspect as well, the HLC's, being **Lithium Ion technology based**, rather than being pure capacitors, exhibits a much greater capacitance in comparison to pure capacitors/supercapacitors.

In fact, the HLC's capacitance can reach 100's of Farads, whereas supercapacitors having the same physical dimensions can barely reach a few Farads at best.

The HLC family capacitance is shown below:

HLC size	Capacitance (F)
1020	50
1520	150
1550	600

Another important factor which should be taken into account is the sealing mechanism of the capacitor. Whereas most electrolytic capacitors use a crimped gasket (usually rubber), Tadiran's HLC is sealed by GMS (glass to metal) hermetic sealing which provides greater durability and many decades of operation without any electrolyte leakage, even at the harshest environmental conditions.

<u>The main conclusions are as follows:</u>

High ESR and leakage currents are the main drawbacks of double layer capacitors. Despite the large dimensions, regular electrolytic capacitors are more suitable to support short and high current pulse load applications.

Compared to commercial capacitors and suprecapacitors, Tadiran's Hybrid Layer Capacitors (HLC) will provide superior performance and longer life due to their many technical advantages.

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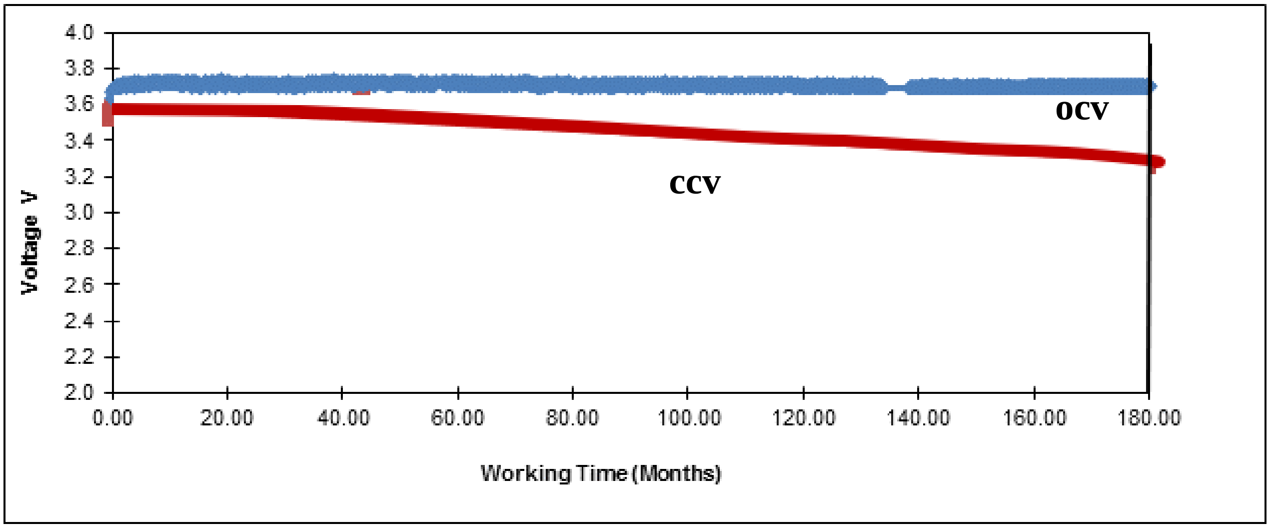
The remarkable superiority of HLC vs other commercial capacitors can be recognised by the accelerated storage curves below. As clearly shown, the HLC keeps providing a high operating voltage, even after 15 years at 72°C! as a matter of fact, this test is still running and the HLC is expected to keep operating at high voltage for many more years.

As this test has been performed at 72°C as an acceleration test method, we can conclude that the HLC can keep providing high- power performance for decades at more moderate temperatures.

Accelerated storage tests at 72°C

1/2AA Li/SOCl2+HLC1520: 0.5A 1sec/week



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