THE LEADING MANUFACTURER OF ULTRACAPACITORS AND LITHIUM-ION CAPACITORS

LICAP Technologies Application Note

Do We Need Module Cell Balancing?

With the lower operating voltage range of ultracapacitor cells, it is common that some number of them are connected in series to reach the desired working voltage for most applications. Ultracapacitors inherently have a high impedance internal current path (a subset of ESR) between anode and cathode requiring a small current flow to maintain constant voltage across the cell. This is known as leakage current and when this current flow is turned off, the related phenomenon known as self-discharge occurs with current flow in reverse through the same current path. Capacitance values also vary from cell to cell and combined with leakage current variations, the cells act as a voltage divider resulting in cell to cell voltage imbalances. A key module design goal is for individual cell voltages to never exceed the specified cell voltage rating as this can shorten cell life through capacitance loss, increasing equivalent series resistance (ESR), and heat generation.

Historically, ultracapacitor module assemblers have attempted to mitigate the unwanted cell to cell voltage imbalances with both passive and active balancing schemes. Passive balancing places a resistor in parallel with each cell and given all resistor values are equal, cells at a higher voltage will discharge at a faster rate than those with lower voltage effectively equalizing cell to cell voltages. Due to the lower energy storage density of ultracapacitors, passive balancing is typically used in stationary applications where the module is under constant charge with no dependence on low self-discharge rate to meet energy requirements over time. Where there is need for longer periods without charging, maximizing stored energy is accomplished with active balancing. Active balancing switches the balancing load off the cells until needed thus minimizing the balancing discharge time.

Advantage LICAP

LICAP Technologies has been conducting module tests with series connected ultracapacitors and no passive or active balancing. The results of these tests are shown in Figure 1 below. Our test results show that in the beginning there is variance in cell to cell voltages, which is

expected. During the first 500 hours the standard deviation of cell voltages increased, showing that the cell voltages were drifting apart, but no single cell exceeded the rated cell voltage of 2.7V. After 500 hours the standard deviation started to decrease and continued to decrease though 1676 hours to a point where it was 50% less than the standard deviation at the beginning of the tests. The rated voltage of the cells in the module under test were 2.7V x 6 cells = 16.2V rated module voltage. Modules with no balancing should be operated slightly below rated voltage to ensure no single cell exceeds rated voltage. Our test measurements in the table below were done at ~15.4V. The self-balancing capability of LICAP's ultracapacitors is related to our proprietary activated dry electrode technology and advanced production line processes. Additional tests are on-going at LICAP and we will update this document with new data as it becomes available.

Figure 1 displays the results of extended high temperature testing

6 Series 350F Cell Voltages After Weekly Tests - Under Duress At Continuous 65°C										
Hours	Cell 1 (V)	Cell 2 (V)	Cell 3 (V)	Cell 4 (V)	Cell 5 (V)	Cell 6 (V)	Module (V)	Std Deviation	Mean	Median
368	2.592	2.593	2.585	2.583	2.575	2.580	15.508	0.0069	2.5847	2.5840
500	2.573	2.549	2.550	2.538	2.529	2.548	15.287	0.0148	2.5478	2.5485
1004	2.601	2.593	2.582	2.578	2.570	2.574	15.498	0.0118	2.5830	2.5800
1172	2.531	2.534	2.533	2.528	2.526	2.524	15.176	0.0040	2.5293	2.5295
1676	2.580	2.579	2.574	2.572	2.573	2.573	15.451	0.0034	2.5752	2.5735

Figure 1. 350F cell test data illustrating tight standard deviation of cell voltages.

Our Story

LICAP Technologies. Inc. (LICAP) is a world-class manufacturer of supercapacitor and lithium-ion capacitor products with market leading performance. We also conduct research and development to identify innovative new materials and processes to improve energy storage device performance and reduce overall costs. This includes supercapacitors, lithium ion capacitors and lithium ion batteries. Our primary research center and USA Headquarters is located in Sacramento, CA USA.

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