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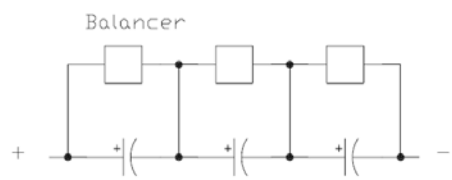
Cell Balancing

For most applications a single cell at low voltage is not very useful and multiple cells are required to be placed in series. Since there is a tolerance difference between manufactured cells in capacitance, resistance and leakage current there will be an imbalance in the cell voltages of a series stack. It is important to ensure that the individual voltages of any single cell do not exceed its maximum recommended working voltage as this could result in electrolyte decomposition, gas generation, ESR increase and ultimately reduced life.

This imbalance is initially dominated by the capacitance difference between the cells (i.e. a cell with a lower capacitance will charge to a higher voltage in a series string). For example, if two cells of 10F each are connected in series with one at +20% of nominal capacitance and the other at -10%, then the worst case voltage across the capacitors can be calculated by:

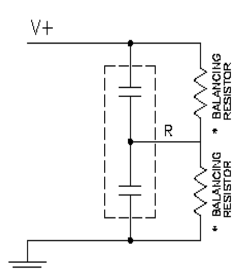
Vcap1=Vsupply x (Ccap1/(Ccap1 + Ccap2)
Assuming Vsupply=5.4V
Vcap1=5.4 x (12/(12+9)) = 3.08V

As can be seen, a proper cell balancing scheme needs to be placed within series connected cells to ensure no cell sees higher than rated voltage.



Also, when the cells are on charge for a period of time the leakage current will dominate this difference (i.e. a cell with a higher leakage current will go to a lower voltage distributing the voltage amongst other cells resulting in an over-voltage). Proper cell balancing can eliminate this imbalance. There are two balancing schemes to tackle this problem, and ensure a properly balanced module. They are:

Passive Balancing: One technique to compensate for variations in parallel resistance is to place a same valued bypass resistor in parallel with each cell, sized to dominate the total cell leakage current. This effectively reduces the variation of equivalent parallel resistance between the cells which is responsible for the leakage current. For example, if the cells have an average leakage current of 10uA +/- 3uA, a 1% resistor which will bypass 100uA may be a good choice. By using this resistor in parallel to each cell the average leakage current is now 110uA +/- 4uA. Introduction of this resistor has now decreased the variation in leakage current from 30% to 3.6%.



By having the same value resistor in parallel with all cells, the cells with higher voltages will discharge through the parallel resistor at a higher rate than the cells with lower voltages. This will help to distribute the total stack voltage evenly across the entire series of capacitors.

Passive voltage balancing is only recommended for applications that don't regularly charge and discharge the ultracapacitors and that can tolerate the additional load current of the balancing resistors. It is suggested that the balancing resistors be selected to give additional current flow of at least 10 times the worst-case cell leakage current. Higher ratio can be used to balance the cells faster. A typical tradeoff is based on time to balance vs. leakage current. Once the system is balanced response time to balance is less of an issue unless a system it being severely cycled.

Active Balancing: For applications with a limited energy source or high level of cycling an active voltage balancing circuit is preferred since it typically draws much lower current in steady state and only requires larger currents when the cell voltage is out of balance. The active circuit forces the voltage at the nodes of series connected cells to stay below a fixed reference voltage.

In addition to ensuring accurate voltage balancing, active circuits typically draw much lower levels of current in steady state, and only require larger currents when the capacitor voltage goes out of balance. These characteristics make active voltage balancing circuits ideal for applications that charge and discharge the cells frequently as well as those with a finite energy source.