Balancing Multiple Supercapacitors; Control voltage, saves power, board space and cost with SAB MOSFETs

As it often happens, when new technology is introduced to replace the traditional circuit design methodologies, designers have questions. This was the case when Advanced Linear Devices recently announced its Supercapacitor Auto-balancing MOSFET arrays.

These devices are positioned to balance the voltage for supercapacitors used in a series to prevent each cell from over voltage while offering a significant cost saving when compared to traditional options. Overcharging can lead to the degradation of supercapacitor cells in the series which dramatically reduces the lifespan and can result in catastrophic product failure.

To prevent supercapacitor overvoltage, designers traditionally turn to op amp-based solutions. These solutions often require several components which cannot precisely control the over voltage additionally op/amps burn considerable amounts of power and take up board space. SAB MOSFETS were introduced as a less expensive, more energy efficient solution and prevents over-voltage when compared to op amps.

Upon announcing the SAB MOSFET, ALD technical support received a few salient questions from a leading OEM product designer about how to use a small-signal MOSFET to balance a supercapacitor.

What follows here are the original questions received by ALD’s technical support and the answers to the question. This exchange can be insightful to any designer who wants to utilize the intrinsic qualities of low-power, precision MOSFET arrays as the market for supercapacitor applications promises substantial growth over the next five years.

Tech Support Question: We generally use resistors or an active balance circuit for balancing. I am trying to see what advantages your new devices offer. We design products that require a large number of ultracap modules and these devices maybe useful in future designs. Can you let me know if the info below is correct about the new ALD8100 and ALD9100 devices?

If you use them as a shunt regulator across 1 cell to prevent over voltage with an energy harvester, then they are good devices. If you used one as a shunt regulator to protect a single cell against over voltage with an energy harvester, would performance depend on the V-I characteristics of the energy harvester for the environmental energy available?

ALD Reply: The ALD8100 and ALD9100 family of devices does require some design work to be used to advantage for cell balancing. Please refer to Table 1 in the datasheet to check the characteristics of each MOSFET.

If you use the MOSFETs as an over-voltage regulator, then it works as you have indicated. Note that the MOSFET only dissipates power if you are at or over the targeted regulation voltage. As each cell has its own over-voltage limiter, cells connected in series self balance and their performance are not affected much by the input characteristics of the energy harvester. At less than 0.3V below the target voltage, the power dissipation by the MOSFET is essentially zero. Hence, the device is great for energy harvesting applications.

Tech Support Question: If you used them as a cell balancer, then they protect against over voltage (again, how well depends on the V-I characteristic), but can they balance to the midpoint? If you have a 2-cell ultracap with 2.6V FETs across each cell, and the device was charged to 4V, you might have one cell at 2.65V and the other at 1.35V, which would lead to premature aging of the supercap compared to having 2 cells at 2V each.

ALD Reply: As a 2-cell balancer, the MOSFET nominal threshold voltage works best if an operating target supercap voltage is selected. For example, if the 2 cells are charged to 4.6V, each with an ALD810023 device, then you may find that one cell is charged to say, 2.35V and the other is charged to 2.25V, when the difference in leakage between on supercap cell is 10 times that of the other. If the relative leakages of the two supercap cells are closer to each other, then the cell voltage would perhaps settle to 2.32V for one cell and 2.28V for the other cell. The MOSFETs would get you very close to balanced cell voltages. The active MOSFET shunts only excess leakage current of one cell over another, whichever is greater.

For charge voltages in this example to be 4.0V instead of 4.6V, one of the MOSFETs can act more like an over-voltage clamp, thereby limiting the two cell voltages to 2.20V and 1.80V (or 2.15V and 1.85V, etc.) with actual voltages depending on the relative and absolute leakages of each supercap. This will still protect the supercap that is most vulnerable to overvoltage. The other MOSFET in the package is completely turned “OFF” resulting in zero additional leakage and zero additional power.

A more appropriate device for a charge voltage of 4.0V would be using ALD810021 (for max. supercap leakage of 1uA) or the ALD810020 (for max. supercap leakage current of 10uA). Consider the case when each of the MOSFET is rated at 2.1V and the overall charge voltage is 4.0V. Depending upon the actual relative leakages of each of the two supercaps, the resulting voltages are likely to be one of three cases: 2.10V and 1.90V, 2.05V and 1.95V, or 2.00V and 2.00V. In the case of 2.10V and 1.90V, then the 2.10V supercap has a leakage current that is 100 times less than that of the 1.90V supercap. The MOSFETs connected across each supercap having 1.00uA and 0.01uA drain currents respectively.

In the case when the supercap voltages are 2.05V and 1.95V, then the leakage current between the two supercaps is about 0.3uA and 0.03uA, a ten to one ratio.

If the supercap voltages are 2.00V and 2.00V, then the two supercaps has very nearly equal leakage currents and each MOSFET would conduct about 0.1uA.

Tech Support Question: I have an industrial application where the temperature range needs to be from +85C to -40C.

ALD Reply: That would be no problem. All that is necessary is to specify SAB MOSFETs with industrial temperature range, which would be rated for -40C to +85C. The part number would feature an “I” suffix. For example, ALD810026SCL would be ALD810026SCLI for industrial temperature range. The MOSFETs are rugged throughout wide temperature ranges and could even be operated in military temperature ranges of -55C to +125C. In this case the testing and screening of the MOSFETs would cost more time and resources.

Tech Support Question: If my max. supercap leakage current is 100uA instead of 1uA, which SAB MOSFET should be specified for the 4.0V two supercapacitor stack?

ALD Reply: In general you would select a SAB MOSFET with a lower threshold voltage. Look down the selection TABLE1 under the column IDS(ON) of 100uA. The ALD910019 device would specify 2.12V at 100uA. At 2.0V the MOSFET would conduct 10uA. For typical pair of supercapacitors, in this case, the typical voltages are likely to be 2.03V and 1.97V. This also bring up another interesting point, which is the fact that for very large supercapacitors that have very high leakage currents, the SAB MOSFET can be parallel connected for a specific target maximum leakage current. A supercapacitor array with 400uA maximum leakage can be balanced with up to four ALD910019 pairs connected in parallel.