Factory Data: MOSFET Controls Supercapacitor Power Dissipation

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Recently revealed independent testing data shows that SAB MOSFET arrays designed into supercapacitor applications of two or more cells can reduce leakage current. By reducing leakage current, the MOSFETs automatically balance the voltage in each supercapacitor cell and ensure its long life and reliability. Additionally, reducing leakage current is an effective way to control power dissipation in supercapacitor cells, which is important for applications like energy harvesting and long-life primary battery based circuits that require the utmost efficiency.

Supercapacitor voltage needs to be controlled to less than its rated voltage; without control over-voltage will cause damage to the supercapacitor cells which will subsequently result in failure. Without control, the failure may happen quickly or may take several weeks or even months but it will happen. When MOSFETs are used to reduce leakage, the supercapacitor voltage can be balanced automatically. Using MOSFETs when stacking supercapacitor cells used in series, as this applies to as few as two or over 100 cells, there are also additional benefits. A MOSFET balancing circuit lowers component count, reducing cost, saves board space and power dissipation compared to both resistor-and op amp-based voltage balancing circuits.

A supercapacitor manufacturer CapXX recently conducted testing to evaluate the SAB MOSFET functionality. The figure below demonstrates the use of Advanced Linear Devices ALD910023 array in a series stack that results in voltage balance.

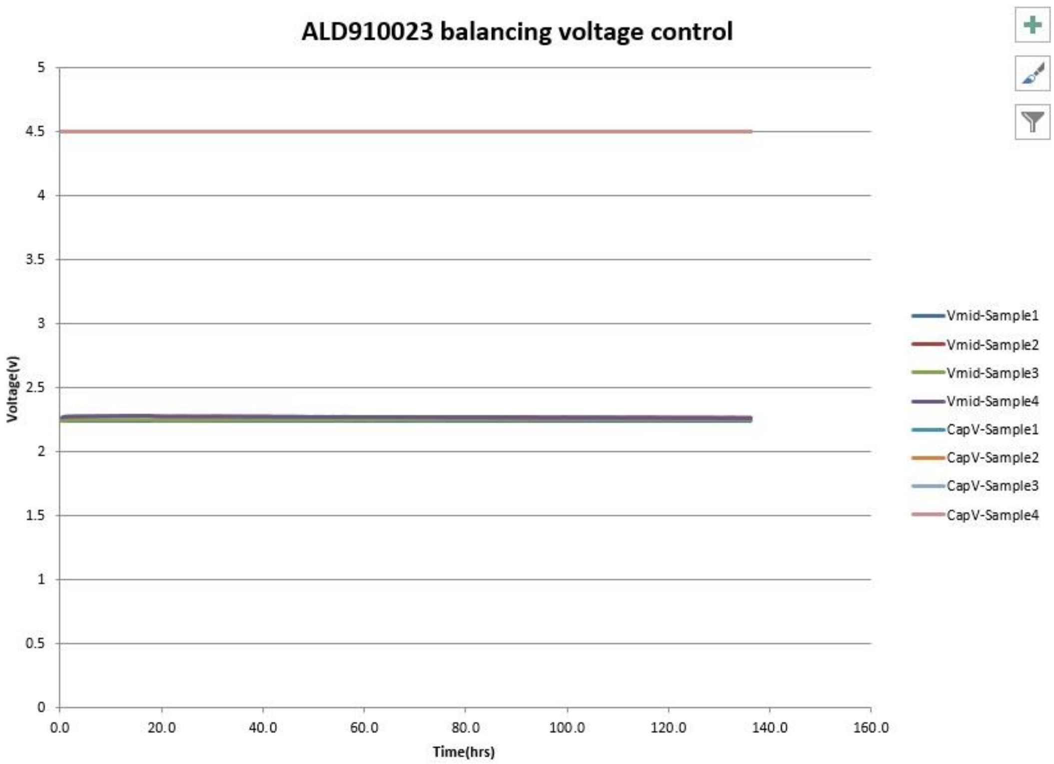

Figure 1: Courtesy CapXX

In Figure 1, the graph shows that overvoltage has been mitigated; it is simultaneously balancing the supercapacitor and controlling that voltage for four different sets of samples.

Below is a graph showing leakage current for two CAP-XX GS208 supercapacitors used in a module and the resulting reduction in leakage current when an ALD 910023 MOSFET is integrated into the circuit. (Green line).

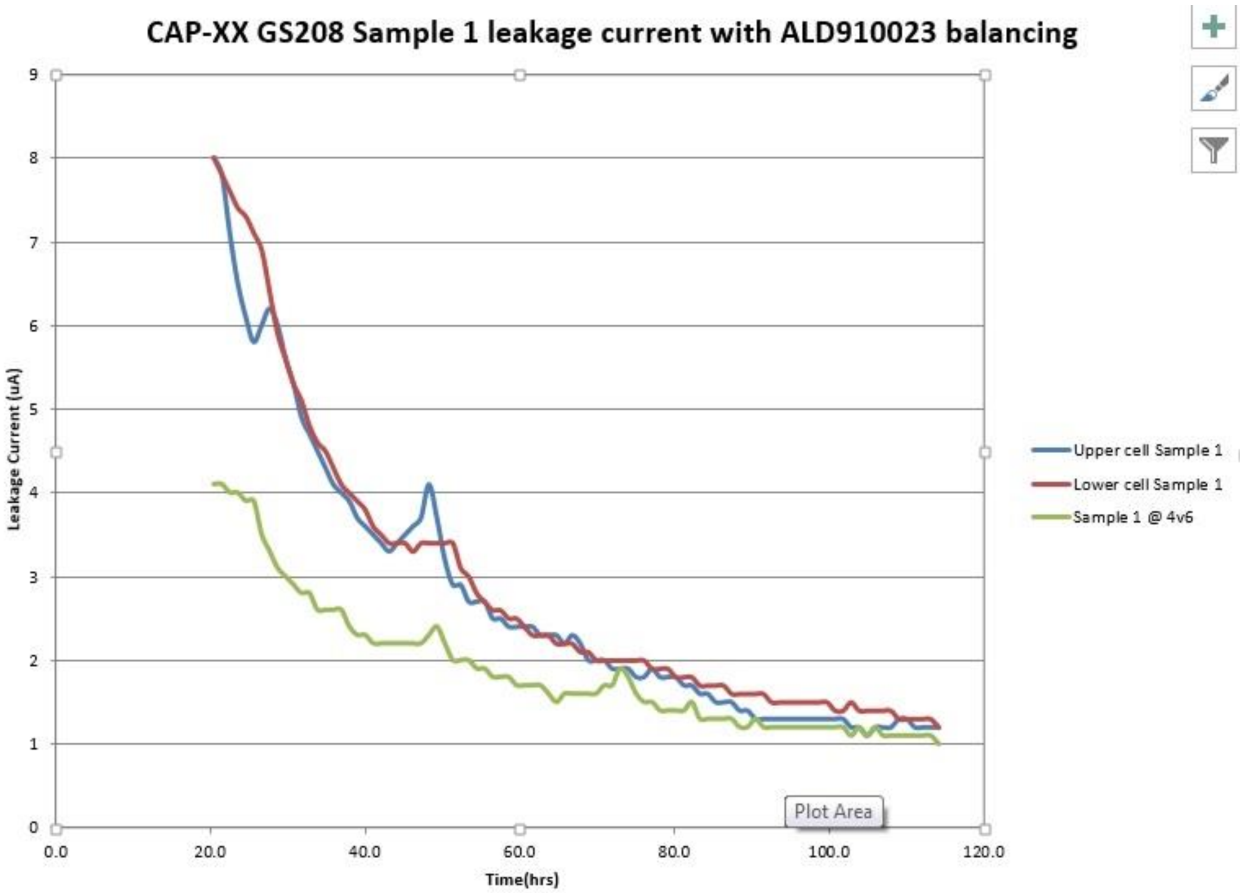

Figure 2: Courtesy CapXX

Figure 2, shows that the leakage current when controlled by the SAB MOSFET's is actually reduced and in some cases to less than zero. For energy harvesting applications this is an important development. The MOSFET is actually saving leakage current rather than dissipating power.

Additionally, there are significantly fewer problems in the supercapacitor module because the energy is not trickling out. Any energy that is not saved will hurt the ability to capture, store and discharge power when it is required. In many cases, energy harvesting applications are capturing very small amounts of energy over time. If this energy is spent in balancing the voltage of supercapacitors, there would be very little left to discharge from the supercapacitor.

Previously, when balancing supercapacitors, resistor or op-amp based circuits will always burn extra power. For applications requiring energy efficiency, the goal is to reduce this added power to as low as possible. Designers who have been balancing supercapacitor before with op amps and resistors, experience added power burn to achieve the desired results. These added power dissipation could, for certain applications, significantly affect the effectiveness of the supercapacitor circuit or its use. The SAB MOSFET, in contrast, does not burn any additional power.

That's important in energy harvesting because the whole intent of capturing the energy is to hold it in place until it needs to be delivered in some way. If a backup power system relies on an energy harvesting scheme, than it is important that the supercapacitors dissipate as little power as possible, so that it can hold a charge for as long as needed and maximize the energy capture function.

The two Figures above, together show that SAB MOSFETs balance supercapacitors, protecting them from over voltage and also reduce power dissipation at the same time, this is a key benefit of using a SAB MOSFET.

Currents are always passing through any supercapacitor. It is often called leakage current because it is internal to the supercapacitor and is often not controlled. However, leakage current is actually a form of power dissipation.

As an example, charge current can be measured in amperes, whereas, leakage current is only micro amperes. It is 100 times or 1,000 times less current. Nevertheless, it operates on a different scale. This charged current can discharge in a second whereas leakage current may be small but it can dissipate over thousands or even millions of seconds between charging and discharging events. Regardless, the magnitude of the leakage current integrated over a long period of time can be just as high as discharge current in a short burst.

If there are multiple supercapacitors designed in a series, each one will have different leakage or power dissipation rates that will cause a voltage imbalance. The leakage current is what causes the supercapacitors voltage imbalance.

When an application requires more voltage than a single 2.7 volt cell can provide, several supercapacitors are stacked in series to meet the required voltage. An essential part of ensuring long operational life for these stacks is to balance each cell to prevent leakage current from causing damage to other cells through over-voltage. MOSFETS offer the smallest, simplest solution because they enable supercapacitors to be stackable and scalable.

Applications for supercapacitor stacks are rapidly growing, but the problem of leakage current and over-voltage is not well known. Designers need a clear path forward to address this potential problem.

The use of supercapacitors are gaining momentum as replacements for rechargeable batteries and one-time use batteries in backup power systems because of the unlimited amount of charge and discharge cycles in comparison to batteries with a limited life cycle.

An example of backup power systems highlights the designers' need for higher reliability and demonstrates why supercapacitors offer such great promise. Backup power supply for a mission-critical computer terminal is where power availability is essential. If the power goes out, a backup power system must provide enough juice to store vital information in memory before all the power is gone.

Batteries used in backup power systems have a limited lifespan because they die after a few hundred or few thousand charge/discharge cycles. If a battery fails after two or three years, then the backup power supply won't retain information during power loss.

Supercapacitors offer a clear advantage with hundreds of thousands of charge/discharge cycles. They are ideal for either buffering or replacing batteries because they can reliably supply backup power for the entire service life of a system. SAB MOSFETs, by way of comparison, would outlast even the supercapcitors it balances by an order of magnitude.

For more information on how and why SAB MOSFETs protect supercapacitors from over-voltage, refer to this article “New method uses MOSFETs to balance Supercaps in a series stack”, in *Electronic Products* published December 18,2014:

http://www.electronicproducts.com/Discrete_Semiconductors/Transistors_Diodes/New_method_uses_MOSFETs_to_balance_Supercaps_in_a_series_stack.aspx?terms=ALD%20SAB%20MOSFET

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