# ALD910030 MOSFETs to Auto-Balance Supercapacitors with Voltage Ratings of 3V or Higher

## The SAB MOSFET provides unprecedented supercap cell balancing and protection by managing the voltage and leakage current, all while consuming near-zero power.

An ultracapacitor, also called a supercapacitor (supercap), is a high-capacity device that stores 10 to 100 times more energy per unit volume or mass than electrolytic capacitors and batteries. It delivers rapid bursts of practically unlimited power cycles. Supercaps are used in applications requiring frequent charge and discharge cycles rather than long-term compact energy storage. The devices are frequently used as backup power sources for data center servers, renewable energy, utility boxes, transportation and power supplies.

The maximum voltage associated with normal supercaps typically ranges between 2.3V to 2.85V, with some reaching 3.0V. Now, next-generation supercaps supporting 3.3V are widely available, and it is anticipated that even higher voltages will be available in the near future.

It is common to connect multiple supercaps in series to reach the desired voltage level. For example, in applications requiring a standard 12V direct current (DC) supply voltage, four 3.3V supercaps can be connected in series. This results in a total of 13.2V, which is enough to satisfy the requirements of a 12V power supply while also providing some headroom for potential fluctuations.

In a perfect world, supercaps would act like ideal elements, such as pure capacitance. In reality, however, they have a small amount of parasitic resistance, which can be modeled as a resistor in parallel with the supercap. In turn, this resistance results in parasitic leakage current.

When multiple supercaps are connected in series, each one will have different parasitic resistance and leakage current value. If these leakage currents are not balanced, the result can be voltage runaway on one or more supercaps. This voltage runaway can be sufficient to catastrophically degrade or destroy the affected supercaps.

Advanced Linear Devices (ALD) has created a family of Supercap Auto-Balancing MOSFET Arrays, or SAB™ MOSFETs. The devices are designed to address the voltage and leakage current balancing requirements of supercaps rated from 1.6V to 3.0V or higher connected in series or parallel. Each part is factory trimmed to meet individual voltage specifications.

## OPERATING ELECTRICAL CHARACTERISTICS*

V+ = +5V, V- = GND, $T_A$ = 25°C, $V_{IN} = V_{GS} = V_{DS}$, $I_{OUT} = I_{DS(ON)}$

| Test Conditions | Parameter | Symbol | Value (typ) | Unit |
|---|---|---|---|---|
| $V_{IN}$ = 2.60V | Drain Source On Resistance | $R_{DS(ON)}$ | 26,000 | MΩ |
| | Output Current | $I_{OUT}$ | 0.0001 | µA |
| $V_{IN}$ = 2.70V | Drain Source On Resistance | $R_{DS(ON)}$ | 2,700 | MΩ |
| | Output Current | $I_{OUT}$ | 0.001 | µA |
| $V_{IN}$ = 2.80V | Drain Source On Resistance | $R_{DS(ON)}$ | 280 | MΩ |
| | Output Current | $I_{OUT}$ | 0.01 | µA |
| $V_{IN}$ = 2.90V | Drain Source On Resistance | $R_{DS(ON)}$ | 29 | MΩ |
| | Output Current | $I_{OUT}$ | 0.1 | µA |
| $V_{IN}$ = 3.00V | Drain Source On Resistance | $R_{DS(ON)}$ | 3 | MΩ |
| | Output Current | $I_{OUT}$ | 1 | µA |
| $V_{IN}$ = 3.10V | Drain Source On Resistance | $R_{DS(ON)}$ | 310 | kΩ |
| | Output Current | $I_{OUT}$ | 10 | µA |
| $V_{IN}$ = 3.22V | Drain Source On Resistance | $R_{DS(ON)}$ | 32 | kΩ |
| | Output Current | $I_{OUT}$ | 100 | µA |
| $V_{IN}$ = 3.30V | Drain Source On Resistance | $R_{DS(ON)}$ | 11 | kΩ |
| | Output Current | $I_{OUT}$ | 300 | µA |
| $V_{IN}$ = 3.44V | Drain Source On Resistance | $R_{DS(ON)}$ | 3.44 | kΩ |
| | Output Current | $I_{OUT}$ | 1 | mA |
| $V_{IN}$ = 3.50V | Drain Source On Resistance | $R_{DS(ON)}$ | 1.17 | kΩ |
| | Output Current | $I_{OUT}$ | 3 | mA |
| $V_{IN}$ = 4.00V | Drain Source On Resistance | $R_{DS(ON)}$ | 400 | Ω |
| | Output Current | $I_{OUT}$ | 10 | mA |

**Note that this is only a subset of the full table from the [ALD910030 data sheet](ALD910030 data sheet).*

*Figure 1. Table illustrates the wide ranges of output current for small changes in* $V_{IN}$.

SAB MOSFETs have unique electrical characteristics for superior, active, continuous leakage current regulation and self-balancing of stacked series-connected supercaps. While dissipating near-zero leakage currents, the devices practically eliminate extra power consumption. As a result, the automatic charge balancing of SAB MOSFETs offers a simple, economical and highly effective method to balance and regulate supercap voltages.

With these chips, each supercap in a series-connected stack is continuously monitored and automatically controlled for precise, effective balancing of its voltage and leakage current. Refer to the table in Figure 1 above. The device regulates the voltage across a supercap cell by increasing its drain current exponentially when its voltage increases and decreasing its drain current exponentially when its voltage decreases.

The most recent addition to the SAB MOSFET family, the ALD910030, is a dual MOSFET presented in an 8-pin SOIC-8 package. The small size makes it economical. Additionally, it has double the balancing power of other ALD products.

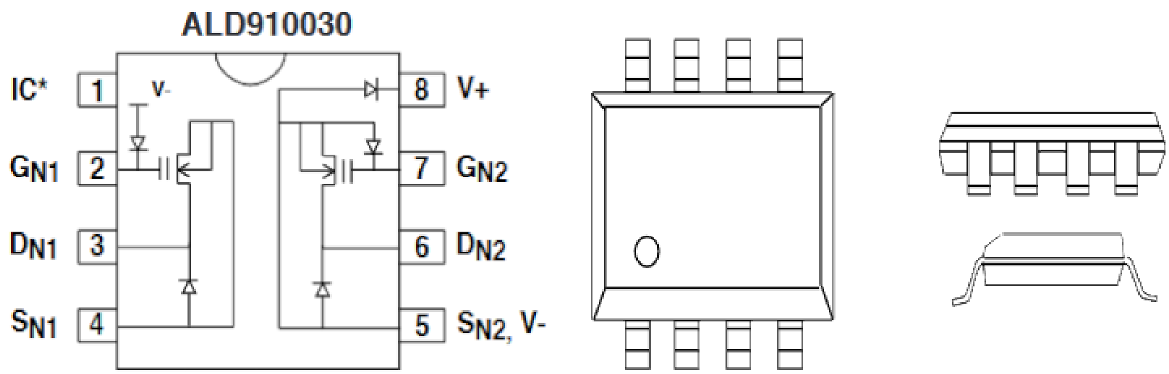
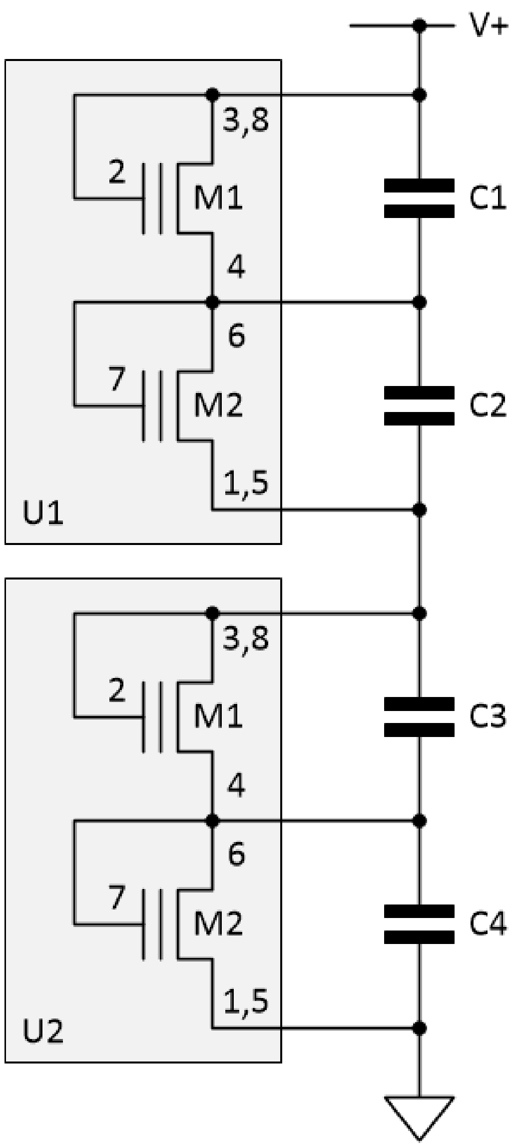



*Figure 2. Pin configuration for the ALD910030 SAB MOSFET*




| | |
|---|---|
| U1-U2 | Denotes ALD910030 devices |
| M1-M2 | Denotes SAB™ MOSFETs |
| C1-C4 | Denotes supercapacitors |
| 1-8 | Denotes package pin numbers |

- Connect in series to achieve higher voltages.
- Connect in parallel to achieve higher currents.

*Figure 3. An example deployment involving two ALD910030 SAB MOSFETs balancing four supercaps.*

Although ALD910030 devices are of particular interest when working with supercaps whose voltages are 3V and higher, they are also of interest in the case of lower-voltage supercaps. Consider $V_{IN}$ (voltage in) and $I_{OUT}$ (current out) as detailed in the ALD910030 data sheet. When $V_{IN}$ = 3.00V is applied to an ALD910030, its $I_{OUT}$ is 1µA. For a 100mV increase in $V_{IN}$ to 3.10V, $I_{OUT}$ increases tenfold to 10µA. Conversely, for a 100mV decrease in $V_{IN}$ to 2.90V, $I_{OUT}$ decreases to 0.1µA, which is one-tenth of its 3.00V value. Another 100mV decrease in input voltage would reduce $I_{OUT}$ to 0.01µA. Hence, when an ALD910030 SAB MOSFET is connected across a supercap that charges to less than 2.80V, it dissipates essentially no power.

**ABSOLUTE MAXIMUM RATINGS**

| | |
|---|---|
| V+ to V- voltage | 15V |
| Drain-Source voltage, $V_{DS}$ | 10.6V |
| Gate-Source voltage, $V_{DS}$ | 10.6V |
| Operating current | 80mA |
| Power dissipation | 500mW |
| Operating temperature range SAL | 0°C to +70°C |
| Operating temperature range SALI | –40°C to +85°C |
| Storage temperature range | –65°C to +150°C |
| Lead temperature (10 seconds) | +260°C |

**CAUTION: ESD Sensitive Device**
Use electrostatic control procedures in an ESD-controlled environment.

*Figure 4. The chart displays the absolute maximum ratings for the ALD910030.*

The ALD910030 SAB MOSFET provides a groundbreaking solution for auto-balancing and managing supercap voltages connected in series to protect against catastrophic failure. Its unique electrical characteristics, precise voltage regulation and near-zero power consumption make it a game-changer in the market. With the ability to handle supercaps with voltage ratings of 3V and higher, the chip offers efficient power management across various applications. By connecting multiple MOSFETs, it is now possible to meet the requirements of a standard 12V power supply. As the demand for energy storage and power delivery solutions continues to grow, the ALD910030 from Advanced Linear Devices provides a simple, economical and highly effective product to optimize supercap performance and enhance system reliability.