Application Brief

Enabling Beyond the Supply and Overvoltage Tolerance Using High-Voltage Multiplexers in a Data-Acquisition System

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Multiplexers

Multiplexers in High-Voltage Data Acquisition Systems

Many data acquisition applications use a multiplexer at the front end of the system. Placing signals outside the supply rail on the input can result in damage to the multiplexer, downstream devices, and lead to measurement errors. To address these issues, it can be necessary to add a higher supply rail to the system or use a beyond-supply multiplexer like the TMUX4827. However, designers have the option to utilize lower voltage supply rails by employing a discrete beyond-the-supply and overvoltage tolerance setup, which prevents damage and allows the system to operate effectively.

TI Analog Switches and Multiplexers Internal ESD Current Paths

To implement the beyond-the-supply and overvoltage tolerance design, it is important to first understand how the ESD protection of most TI multiplexers activate when signals outside the supply rails are present on the I/O pins.

While all TI switches and multiplexers incorporate some type of ESD protection, the implementation can differ significantly. Figure 1 shows the typical implementation in the simplified model.

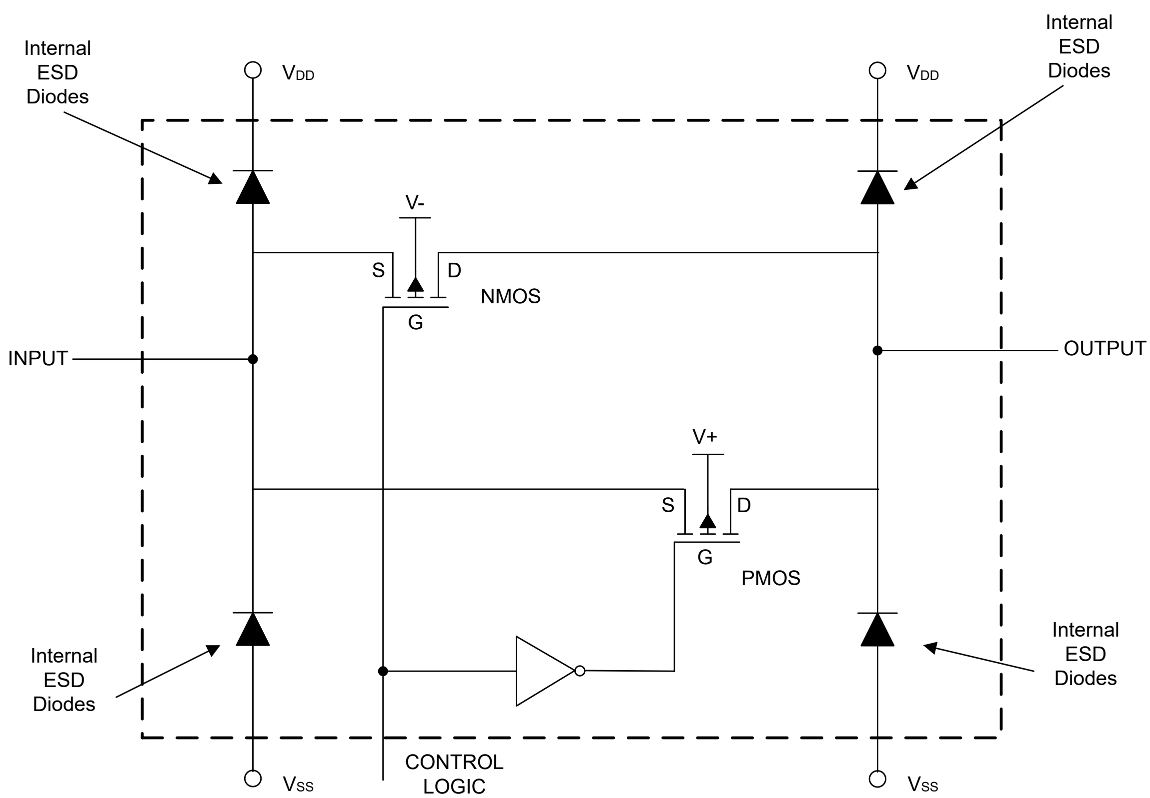

Figure 1. Basic Construction of the CMOS Switch

In this common topology, when an input signal exceeds the multiplexer supply by approximately 0.5–0.7V or is below GND, VSS by about 0.5–0.7V, this triggers an internal ESD diode which conducts and shunts current to supply or to GND (Figure 2).

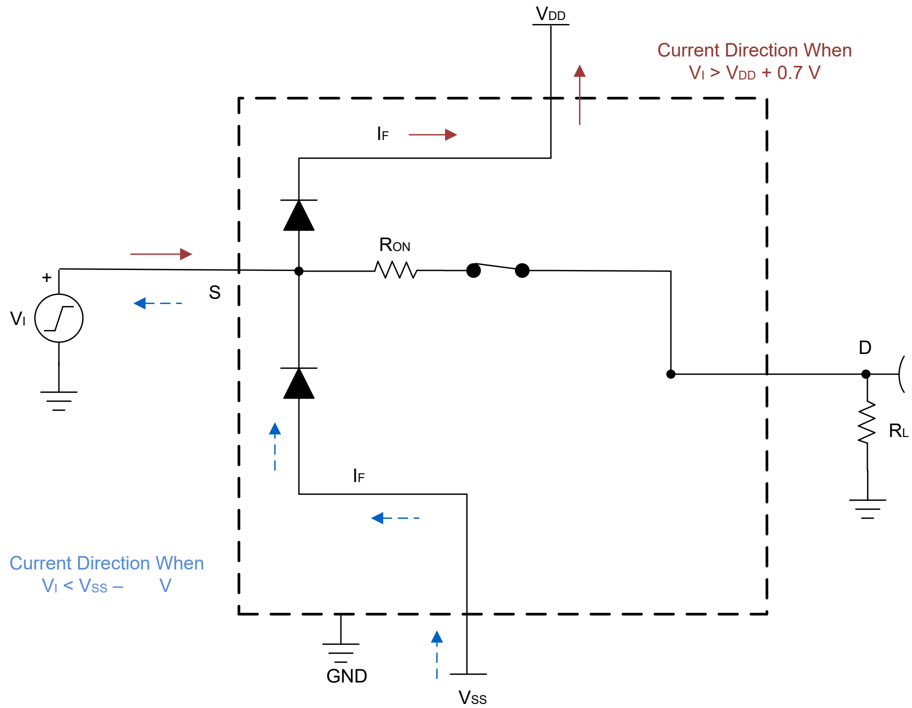

Figure 2. Multiplexer Internal Model During Overvoltage or Undervoltage Event

If the current is not properly controlled and kept below the rated diode current, often found in the data sheet as I_K, I_{OK}, or I_{IK}, the current can damage the device. Figure 3 shows that when the internal ESD diode is forward-biased, the voltage on the I/O pin can backpower the multiplexer and damage downstream components.

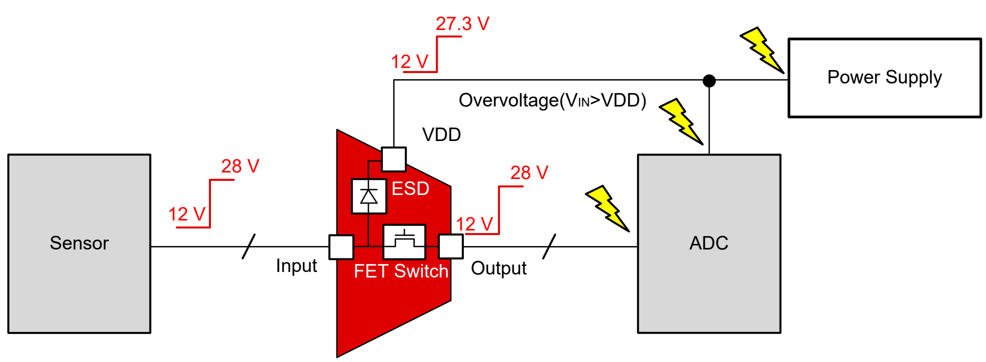

Figure 3. System-Level Perspective During Overvoltage Event

Discrete Beyond-the-Supply and Overvoltage Tolerance Operation with Experimental Results

Designers can take advantage of the common multiplexer ESD architecture to implement the discrete design. This involves restricting the current through the switch with a resistor to meet the specifications listed in the data sheet (I_K, I_{OK}, or I_{IK}), and placing a diode in series with the external power supply. This setup enables the multiplexer to be backpowered, allowing the multiplexer to pass signals beyond the supply voltage. Additionally, the diode connected to the supply prevents current from causing damage to the power supply. By adopting this approach, the system can handle and endure voltages that exceed the supply using a high-voltage (HV) capable switch or multiplexer (Figure 4).

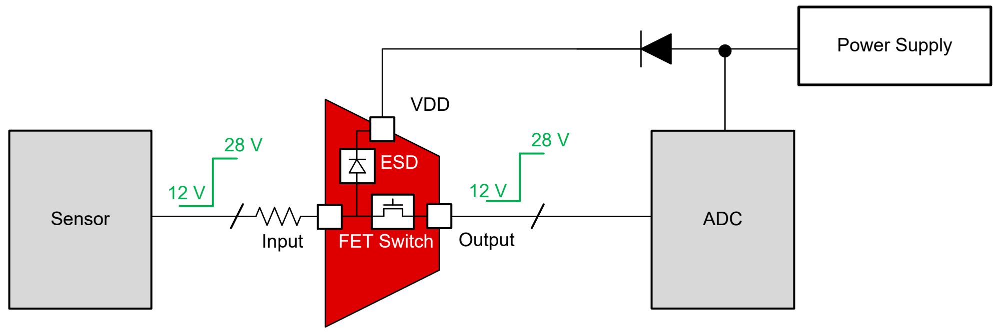

Figure 4. System Level Perspective With Discrete Beyond-the-Supply and Overvoltage Tolerance Setup

The functionality of data acquisition systems can be expanded by enabling high-voltage (HV) multiplexers to pass signals that are beyond the supply. However, a drawback that system designers need to be aware of is the error in the output signal of the multiplexer. This error is caused by two factors: the extraction of current from the input signal to backpower the multiplexer and the internal architecture of the multiplexer. An analysis of the test results from multiplexers with an identical external-resistors-and-diodes setup is completed to understand this signal error (Figure 5).

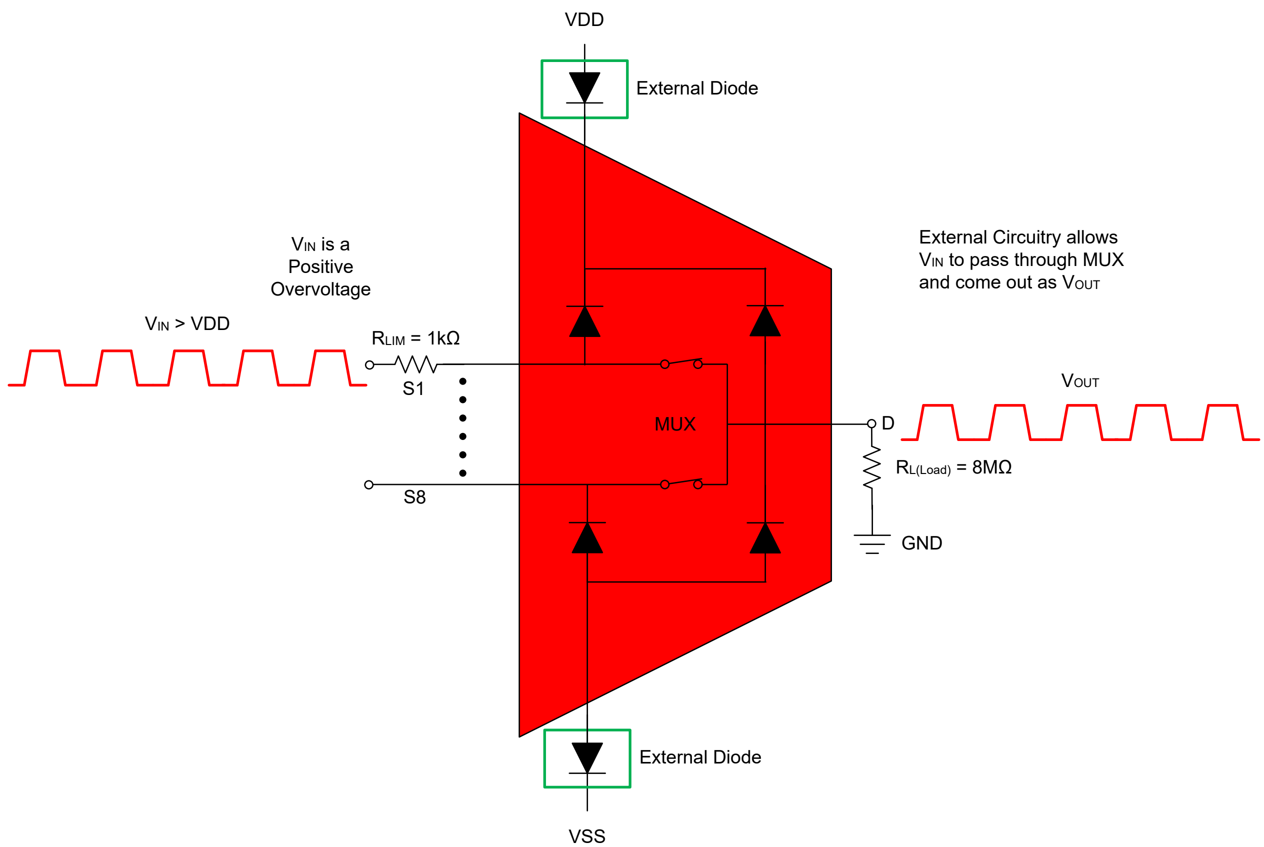

Figure 5. Discrete Beyond-the-Supply and Overvoltage Tolerance Multiplexer Test Setup

Table 1. Test Results for Discrete Beyond-the-Supply and Overvoltage Tolerance

Device Name	VDD	Current Extracted from Input Signal	Reverse Leakage of Diode	V_{IN}	V_{OUT}
TMUX4051	10V	28.5µA	–7.2µA	20V	19.96V
TMUX8108	10V	257µA	–7µA	20V	17.88V

When looking at the testing results, a clear distinction can be made between the performance of the TMUX4051 and TMUX8108. The TMUX4051 is good for applications that need the discrete beyond-the-supply support because the device requires a low amount of current to backpower and has transmission-gate internal architecture. The transmission-gate topology of the TMUX4051 allows the device to have flat R_{on} (on resistance) even as the input voltage reaches and exceeds the supply voltage of the multiplexer. The flat R_{on} of the transmission gate minimizes the effects of the multiplexer on the output voltage (V_{OUT}). For this device, the extracted current from the input signal to backpower the multiplexer is the main cause of the error on V_{OUT}.

The TMUX8108 is an excellent choice for applications requiring overvoltage tolerance with up to 100V or ±50V input signals. While the back-powering of this device contributes to the error, the V_{OUT} error of this device mainly comes from the NFET internal architecture. For instance, in an overvoltage scenario where V_{IN} on an NFET becomes greater than $V_{DD} – V_{TH}$ (threshold voltage), the NFET enters the saturation region. This causes the NFET to function like a current source, outputting constant current instead of a resistor with a linear IV curve. When the NFET operates in the saturation region, the NFET is unable to pass signals beyond the supply rails and instead, displays a clamped signal on the output. It is important to remember that NFET switches can only pass signals up to $V_{DD} – V_{TH}$.

References

- Texas Instrument, *How to Handle High Voltage Common Mode Applications using Multiplexers Application Note*
- Texas Instrument, *System-Level Protection for High-Voltage Analog Multiplexers Application Note*
- Texas Instrument, *What are common switch architectures?* Precision Lab Video Series

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