Eliminate power sequencing with powered-off protection signal switches

Introduction

System isolation is critical for power sequencing, managing bus contentions, and turning off sub-circuits to save power. Signal switches are one way to provide isolation in both analog and digital signaling applications such as I2C, LAN, MIPI, SPI, UART, JTAG, etc. Signal switches can ensure that a high impedance (Hi-Z) path is maintained between the input and output (I/O) signal paths and system power rails. However, there are cases where power sequencing, hot plug / hot insertion, and fault / over-voltage events can cause the switch isolation to fail.

During these events, voltages on the switch I/O path can exceed the supply voltage rail (VDD) which forward-biases the internal electrostatic discharge (ESD) protection diode that exists between the I/O pins and VDD. When the internal ESD diode is forward-biased, the voltage on the I/O path can back-power the switch supply pin and damage components on the power rail. Additionally, the forward biased diode can provide a path to back-power the signal switch itself, unintentionally turning on the I/O path. Designers must know the voltage limits of the signal switch I/O pins relative to the switch power supply (VDD) especially when the switch is powered off (VDD = 0V). Devices with powered-off protection features protect their systems in cases where the signal switch is powered-off and a voltage is present on the I/O path and eliminate the need for power sequencing.

Definition of powered-off protection features: back-power protection and powered-off isolation

Back-power protection: prevents a device from providing power to a circuit other than through the designated power supply circuitry.

Powered-off isolation: ensures a devices maintains a high impedance (Hi-Z) state when an IC is powered down (VDD = 0V).

Figure 1 shows a signal switch used to isolate a WiFi module that is always transmitting and waiting to wake up the rest of the powered-off circuitry. In this case, the switch is powered-off (VDD = 0V), but continuously receives 3.3-V signal from the WiFi module to its input. Since the input voltage is greater than the switch power supply voltage VDD, the voltage on the input forward-biases the internal ESD protection diode. For devices without powered-off protection, the supply rail can be back-powered and compromise the Hi-Z isolation from the WiFi module to the processor.

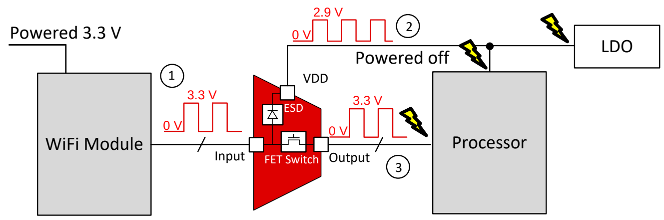

Figure 1. Subsystem A back-powering the switch

1. WiFi module transmits 3.3-V data or clock signals to the switch input
2. The 3.3-V data/clock signals from the WiFi module forward-biases the internal ESD diode, creating a low impedance path that unintentionally back-powers the switch power rail.
3. The signal switch is back-powered through the ESD diode and turns on the FET that isolates the I/O path, causing the data/clock signals to unintentionally transmit to the powered-off processor.

Ensuring system isolation with powered-off protected switches

Powered-off protected switches ensure the device maintains its high impedance (Hi-Z) performance even without power to the IC. Switches with powered-off protection include proprietary IP which prevents back-power conditions when the voltage on the I/O signal paths are greater than the supply rail (VDD). This feature eliminates the need for power sequencing because the I/O paths remain Hi-Z even when VDD = 0 V.

To determine if a signal switch has powered-off protection, check the datasheet for the powered-off leakage specifications with the test conditions including VDD = 0V.

6.5 Electrical Characteristics

T_A = –40°C to +85°C, Typical values are at V_{CC} = 3.3 V, T_A = 25°C, (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I_{OFF}	Power-off leakage current	V_{CC} = 0 V	Switch ON or OFF, V_B = 1.65 V to 3.45 V, V_{COM} = NC	–10		10	µA

Figure 2. TMUX136 Power-off leakage current specification

Figure 2 shows the leakage current specification of the TMUX136 device. It states no more than 10 µA leaks through the I/O signal path with V_{CC} = 0 V and $V_{I/O}$ = 3.45 V.

Example using signal switches with and without powered-off protection features

Figure 3 is an example using two different signal switches to isolate a DC 1.8-V input signal (top) or 3.3-V AC clock input signal (bottom). The TS3A44159 device (left) does not have powered-off protection and the SN74CBTLV3125 device (right) has powered-off protection. In both examples, the VDD supply rail is powered-off and the voltage on VDD drops to 0 V. In both cases, the device without powered-off protection back-powers the signal switch and a voltage that is one diode drop (~0.4 V) below the input voltage can be seen on VDD. When the switch is back-powered, the switch unintentionally turns and passes the signals though the switch. The device with powered-off protection; however, maintains the signal path isolation when the VDD = 0V.

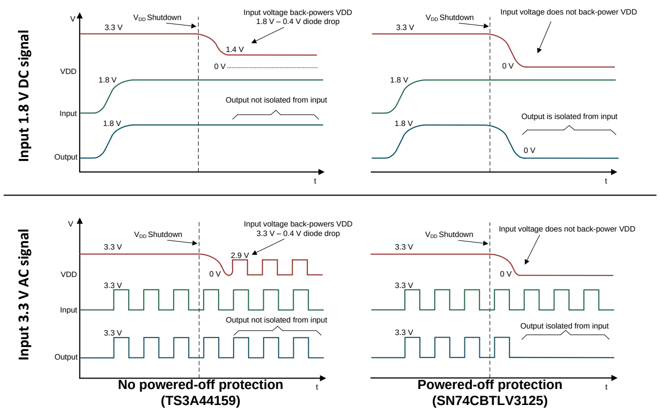

Figure 3. Signal switch with and without powered-off protection

Conclusion

During power sequencing, hot plug / hot insertion, and fault / over-voltage events, voltages on the switch I/O signal path exceeding the supply voltage rail make the switch isolation ineffective. Using signal switches with powered-off protection can assure Hi-Z isolation performance when VDD = 0V, eliminating the need for power sequencing and protecting system components.

Table 1. Alternative Device Recommendations

Device	Configuration	Key Features
TMUX1574	4-channel 2:1	Powered-off protection, Low Con (7.5pF), Low Ron (2Ω), Wide bandwidth (2GHz), 1.8V Logic Compatible
TMUX1511	4-channel 1:1	Powered-off protection, Low Con (3.3pF), Low Ron (2Ω), Wide bandwidth (3GHz), 1.8V Logic Compatible
TMUX136	2-channel 2:1	Powered-off protection, Low Con (1.6pF), Wide bandwidth (6GHz), 1.8V Logic Compatible
TMUX1072	2-channel 2:1	Powered-off protection, Overvoltage Protection (up to 20V) Wide bandwidth (1.2GHz), 1.8V Logic Compatible
SN74CB3Q3257	4-channel 2:1	Powered-off protection, Low Ron (4Ω), Wide bandwidth (500MHz), Supports signals beyond Vdd (up to 5.5V),

1 Trademarks

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from A Revision (September 2018) to B Revision	Page
• Changed devices listed in Table 1	2

Revision History

Changes from Original (July 2018) to A Revision	Page
• Changed the document title From: Eliminate Power Sequencing Using Signal Switches with Powered-off Protection To: Eliminate Power Sequencing with Powered-off Protection Signal Switches	1

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