Undershoot Protection When Using Bus Switches

by Jimmy Ma

Introduction

Pericom Semiconductor Corp. has introduced a family of Switches to target the PCI Hot Swap applications in servers, PCs and notebooks computers. The PI5C3XXXC series offer undershoot protection of up to –2V with 25-nanoseconds duration. In this application note, we will describe in more details how it works and what is the benefits of an undershoot protection.

What is Undershoot?

Bus switches are basically NMOS (PMOS) transistors that allow signals to pass through when they are ON. Figure 1 illustrates a simple bus switch. A switch is ON when a positive signal is applied at the gate voltage (V_G) and is OFF when a low signal is applied at the gate voltage (V_G). The threshold voltage (V_T) for an NMOS transistor is approximately 1.1V. When the differences between the gate voltage and the source voltage ($V_{GS} = V_G - V_S$) is greater than V_T, the switch is ON. When the switch is at an ON stage, undershoot is not a concern. Undershoot is only a concern when the switch is OFF. Undershoot is a negative voltage respect to ground that occurs at the falling edge of the input signal that may inadvertently turn the switch ON. When the switch is at an OFF stage, a negative voltage at V_S will create a relative positive V_{GS}, that is, when greater than V_T will turn the switch ON (see example below).

NMOS Operational Conditions:

- $V_{GS} < V_T$ ——OFF
- $V_{GS} \geq V_T$ ——ON

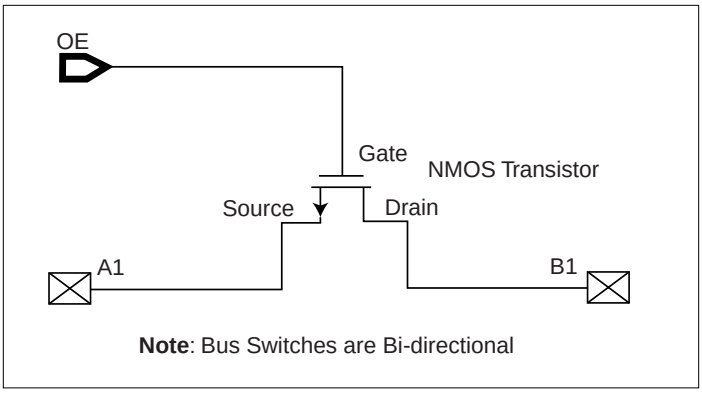

Figure 1. Basic NMOS-Transistor Bus Switch

Undershoot Example

In a typical case when 0V is applied at the gate, the switch is OFF.

$V_G = 0V \rightarrow$ switch OFF
$V_T \sim 1.1V$

If a –1.5V undershoot occurs at the source (or drain) then,

$V_{GS} = V_G - V_S$
$= 0V - (-1.5V) = +1.5V$
$= 1.5V > 1.1V \rightarrow V_{GS} > V_T \rightarrow$ ON

In this case, an undershoot of –1.5V will inadvertently turn ON the switch. Figure 2 illustrates a comparison between a non-undershoot signal and an undershoot signal.

No Undershoot vs. Undershoot

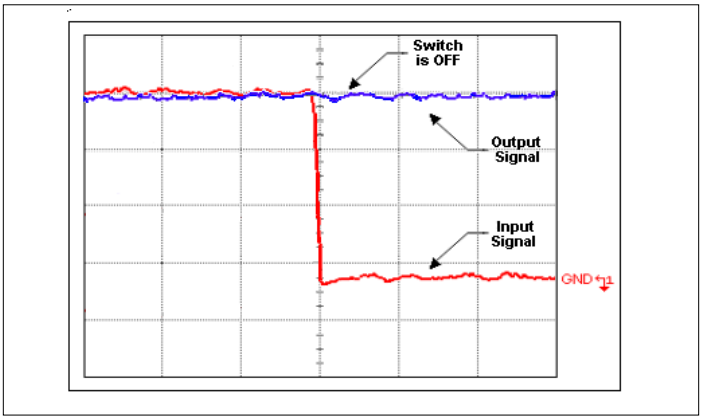

Figure 2a. No Undershoot

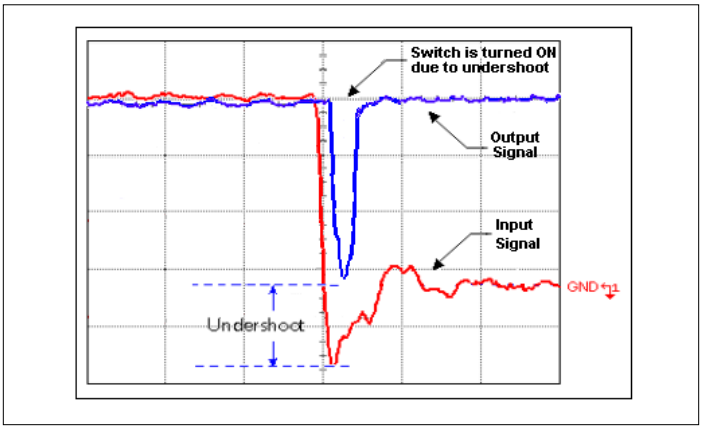

Figure 2b. Undershoot Signal

How Does Undershoot Occur?

In obtaining good signal integrity, termination is one of the most significance criteria. Undershoot occurs when a bus is not terminated or is poorly terminated. Poor termination such as mismatching of output impedance with trace impedance may cause undershoot. Normally, undershoot is not higher than –1.5V when the bus is well terminated. With some designs such as PCI Bus, it is necessary for it not to be terminated to achieve high speed at low power. With such designs, reflection can also cause severe undershoot conditions that may inadvertently turned the switch ON.

Solution for Undershoot

The problem with undershoot can be resolved using Pericom PI5C3XXXC. Currently Pericom is offering 10 devices with undershoot protection. The PI5C3XXXC series uses Pericom patented technology with active-sense circuitry to protect against undershoots of up to –2V with a 25-nanosecond duration. During an event of an undershoot, the charge-pump maintains a negative voltage respect to ground at the substrate voltage and the gate voltage of the transistor, thereby maintaining the switch at an OFF stage. With active-sense circuitry, the charge-pump is only active for a short period of time, just long enough to detect and provide protection from a –2V undershoot for a duration of 25 nanosecond. With this kind of implementation, the PI5C3XXXC series maintain low power consumption by being active only when necessary. Figure 3 shows a block diagram of Pericom undershoots protection switch technology.

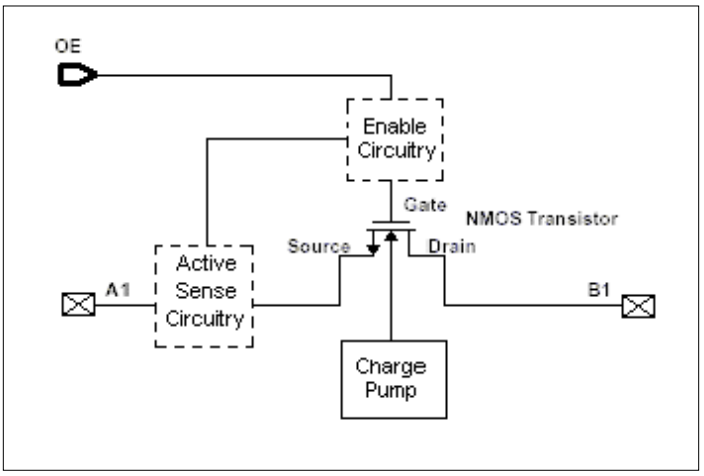

Figure 3. Bus Switch with for Undershoot Protection

Advantages of Charge-Pump Technology

- Excellent undershoot protection
- Low input/output capacitance
- Low power consumption
- Low I_{off}

Laboratory Testing

Laboratory testing demonstrated excellent undershoot capability for Pericom patented undershoot protection technology. Figure 4 shows the test configuration. The product used during actual testing was the PI5C3306CD. The switch was at an OFF stage and tests were done with one output switching.

Figure 5a shows the switch output signal *with* undershoot protection. As demonstrated, the switch remains OFF even if an undershoot occurs. Figure 5b shows a switch *without* undershoot protection. The switch is inadvertently turned ON.

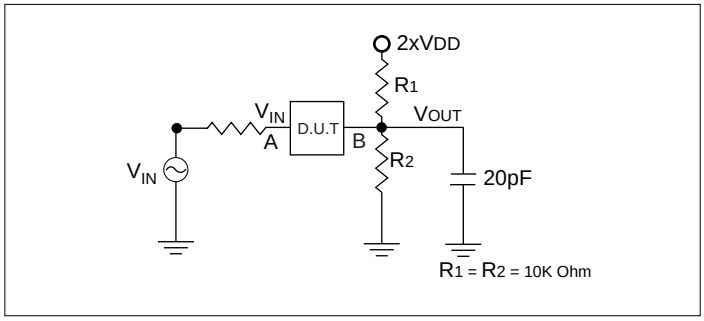

Figure 4. Undershoot Test Circuit

Signal Comparison

Undershoot protection vs. Without Undershoot Protection

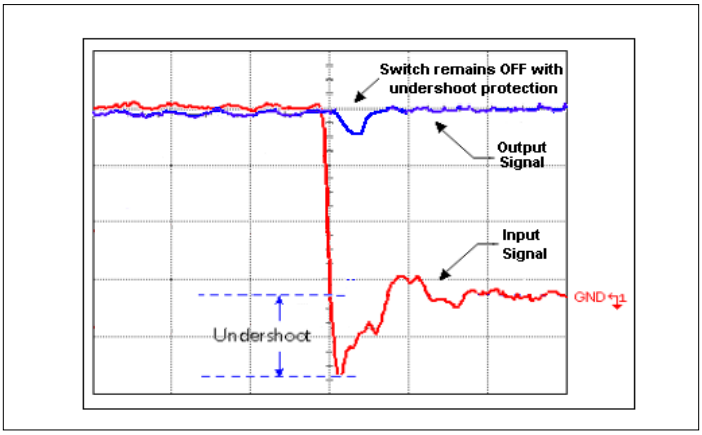

Figure 5a. Signal *With* Undershoot Protection

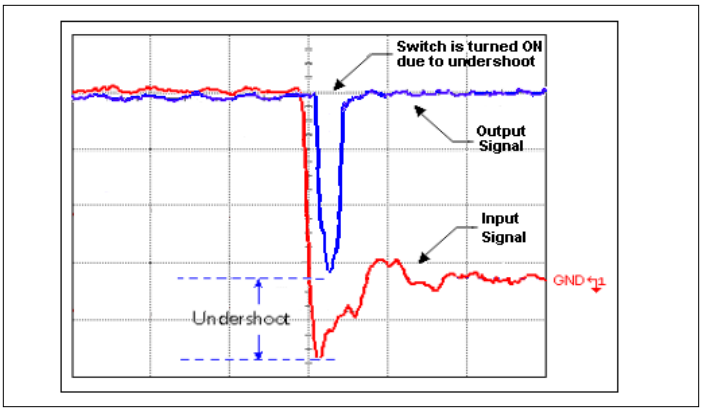

Figure 5b. Signal *Without* Undershoot Protection

Conclusion

As technology advances, devices will require lower voltage and higher speed that will require bus switches that can prevent undershoot from occurring. Pericom PI5C3XXXC series is the solution. The PI5C3XXXC series has low power consumption and low input/output capacitance. It offers undershoot protection over other competitors with protection of up to –2V with 25-nanosecond duration.