ON Semiconductor

Is Now

To learn more about onsemi™, please visit our website at
www.onsemi.com

AND8304/D

Interfacing to Analog Switches

Driving the Control Input of an Analog Switch with 1.8 V or Lower − Is it Safe?

ON Semiconductor®

www.onsemi.com

APPLICATION NOTE

Introduction

Analog switches are everywhere today. Due to their small size and low current consumption, they are popular in portable devices where they are effective in a variety of subsystems including audio and data communications, port connections, and even test. They can be used to facilitate signal routing, allow multiple data types to share an interface connector, or permit temporary access to internal processors during manufacturing. Analog switches are often used to give portable system designers a convenient method of increasing their features or accessibility without duplicating any circuitry. Understanding the key specifications and tradeoffs can make the difference between a temporary fix and a truly optimized solution.

The Control Input

One aspect of the analog switch that has come under recent attention is the control input voltage range which defines how low the voltage can be that drives the control input pin. The control input, sometimes called select, determines the state of the switch − open/closed or NO/NC − as illustrated in Figure 1. This input is typically driven by a digital signal that toggles between ground and a set DC voltage and often comes from a much larger, integrated chipset, such as a CODEC or baseband processor. In general, these chipsets are operating off of ever-decreasing supply voltages which in turn sets limits on the voltages they are capable of sourcing. At the same time analog switches are not necessarily seeing the same drop in supply voltages. For example, one popular technique is to power the switch directly off the battery, causing it to not only see a potentially high voltage relative to the control input voltage, but also one that varies constantly over time. This can pose a problem for some system designs that employ switches optimized to accept control input voltages that must toggle strictly between ground and the switch V_{CC}.

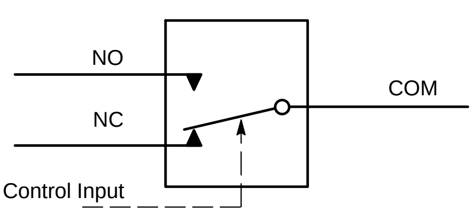

Figure 1. Control Input of Switch

For most analog switches out on the market today, the input buffer that lies directly at the interface of the control input is a standard CMOS or TTL inverter. These structures are modeled as seen in Figure 2. The input signal that drives these inverters, is ideally a digital signal that toggles between ground and the V_{CC} applied to the inverter. For an analog switch, the V_{CC} of the inverter is usually the same as the V_{CC} of the switch. Many systems designers using analog switches today, however, want the flexibility to operate the control input voltage, V_{IN}, at a lower voltage than that applied to the switch V_{CC}.

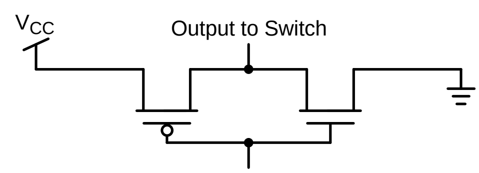

Figure 2. Static CMOS Inverter

The first place a designer might look to see whether he or she can safely lower the high level of V_{IN} is the V_{IH} specification of the analog switch datasheet. V_{IH} and V_{IL} levels define the minimum high voltage and maximum low voltage the input to the inverter must maintain in order to be considered valid, as illustrated in Figure 3.

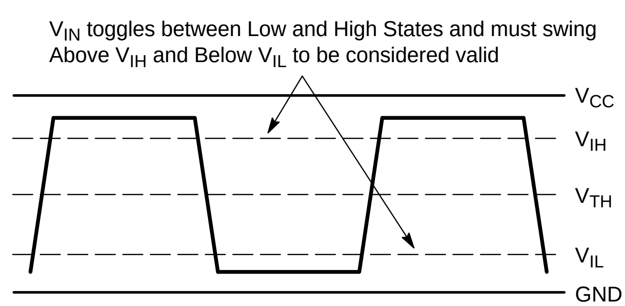

Figure 3. V_{IH} and V_{IL} Levels with Respect to V_{CC} and Ground

Traditionally, V_{IH} was specified fairly simply, often citing standards for either 5 V CMOS, $V_{IH} = 0.7 * V_{CC}$, or 5 V TTL, $V_{IH} = 2.0$ V. These specifications gave ample room for compliance when the driving signal toggled between ground and something relatively high, such as 3 V or 5 V. Even if the V_{CC} were lowered the signals driving the control inputs were still coming from generally the same sources and therefore easily able to meet whatever the switch V_{CC} was at the time. The main difference today is that analog switches are now often simultaneously interfacing with very different circuitry blocks, analog and digital. It is not unusual that the signals that drive V_{CC}, V_{IN}, and the data paths are coming from three distinct sources, such as in the example application of Figure 4. This can create a mishmash of signal swings and voltage requirements for the switch. If the V_{IH} level is specified using just the traditional standards and without elaboration, the system designer may find that the switch does not seem to have the range or flexibility needed for the application.

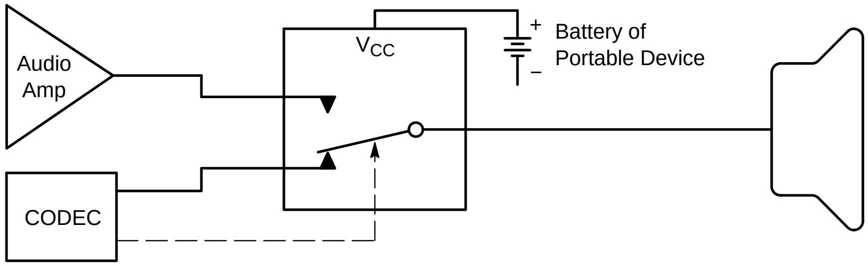

Figure 4. Example of Various Sources for Voltages and Signal Swings Surrounding an Analog Switch

Pushing the Limits

It may be possible to safely operate a switch with a much lower V_{IH} value than V_{CC}, but to understand what the tradeoffs are, it helps to understand the source of the V_{IH} specification. Both the V_{IH} and the V_{IL} specifications are actually *derived* values based on what's known as the threshold voltage, V_{TH}, of the inverter. When ramping up the voltage to the inverter, V_{TH} is defined as the voltage at which the inverter, and subsequently the switch, will toggle. This voltage varies across V_{CC} voltage and temperature and falls in between V_{IH} and V_{IL}. There are two reasons this threshold voltage is not simply specified directly as a minimum voltage switch point. The first is that this threshold is not exact, it varies a little, even for a given V_{CC} and temperature. Figure 5 shows an example of the threshold voltage as it varies across V_{CC}. The voltage falls at slightly different points depending on the direction of approach when ramping V_{IN}: ground to V_{CC} or V_{CC} to ground. When specifying a safe V_{IH} level, the analog switch designer must take into consideration all of these variations and guarantee a value with some safety margin.

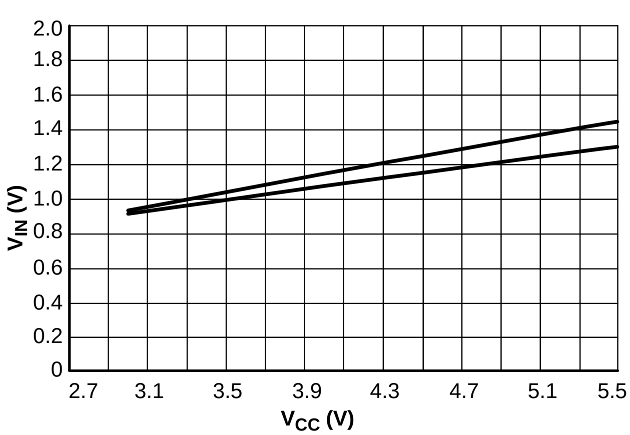

Figure 5. V_{CC} vs. V_{TH}

The second reason V_{TH} is not used directly as a V_{IH} or V_{IL} value is that if the system designer were to drive the control input exactly at the threshold voltage the switch would pull a lot of current from the V_{CC} line causing the device to be very leaky − sometimes in the mA range. The farther away from the threshold voltage the high and low values of V_{IN} are set, the less leaky the switch will be. This is demonstrated in Figure 6, which shows the leakage current at different V_{IN} values for a handful of different V_{CC}'s. It is evident from this graph that if V_{IN} switches rail-to-rail, then the static leakage current will be very low, regardless of the V_{CC}. But, as the high state voltage of V_{IN} is lowered, the leakage creeps up. For example, for a V_{CC} of 3.3 V, if the high state voltage of V_{IN} is 2.5 V the leakage current will easily be less than 5 μA. But if you lower it down to 1.8 V, the leakage current jumps up to 100 μA. This problem is exacerbated when the application attempts to pair a fixed V_{IN} of, say, 1.8 V with a variable V_{CC} voltage of 2.7 V to 4.2 V, as in the case when a switch is operating directly off a portable battery. Here, the leakage current would vary between < 1 μA and 450 μA depending on the V_{CC} at the moment.

Many system designers may think that 450 μA of leakage is too much for any amount of time. But it must be understood that even when swinging rail-to-rail, this leakage current is seen for at least a brief amount of time as the control input voltage is ramped up or down. Most control input signals are digital-type signals, but they are not perfect and there is some amount of rise and fall time associated with each transition. When swinging from ground to V_{CC}, the input signal still has to pass through each V_{IN} level, momentarily exhibiting the I_{CC} leakage associated with each level. When the high state of V_{IN} is lowered with respect to V_{CC}, the leakage will remain at its associated value for as long as V_{IN} is in its high state. This is true for all CMOS input structures.

ON Semiconductor's Solutions

ON Semiconductor has developed a new control input buffer designed specifically to interface with low voltage chipsets. The new structure achieves two important goals − it lowers the minimum allowable V_{IH} value that guarantees switching and maintains low leakage for the new expanded range of V_{IN} values. Figure 7 shows leakage curves from ON Semiconductor's NLAS5223BL. The graph shows the typical leakage current across V_{IN} for three different switch V_{CC} voltages − 2.7 V, 3.3 V, 4.2 V. It is clear that with the new structure the leakage current is significantly reduced for a wider range of V_{IH} values. For example comparing the graphs in Figures 6 and 7, the leakage current for a V_{CC} of 4.2 V and a V_{IH} of 1.8 V is 450 μA for the original structure and 100 μA for the new structure, yielding a significant improvement.

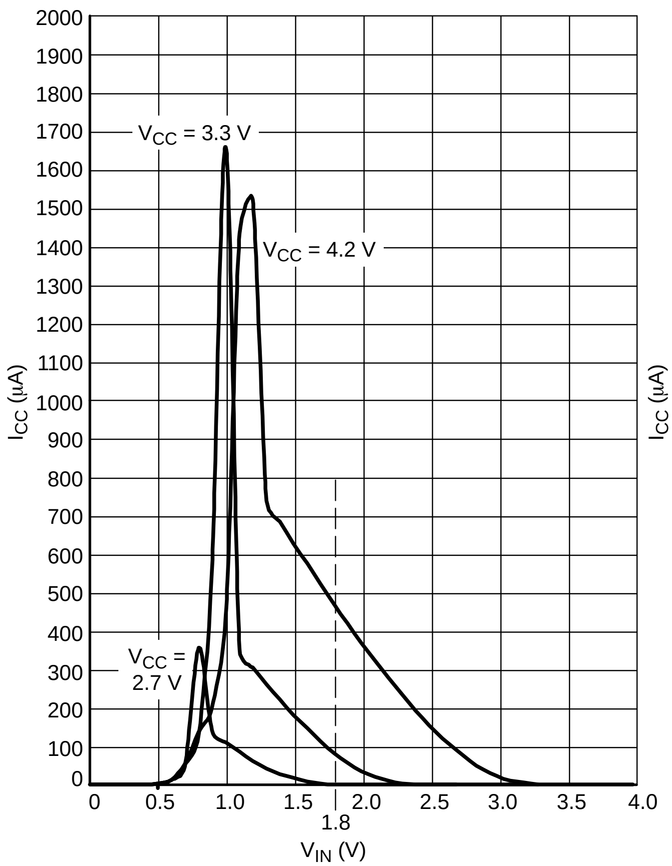

Figure 6. V_{IN} vs. I_{CC}, Standard Control Input

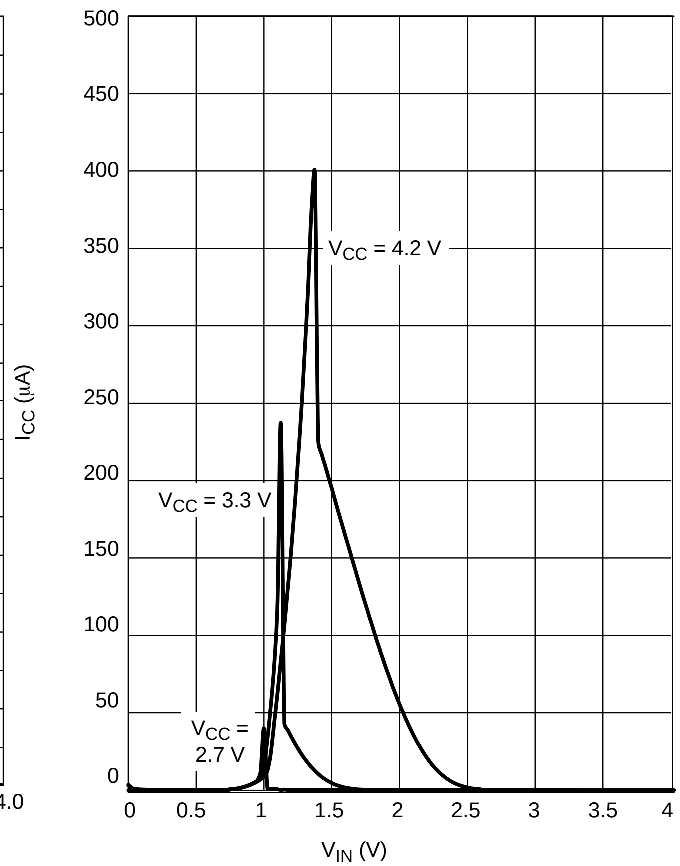

Figure 7. V_{IN} vs. I_{CC} of ON Semiconductor's NLAS5223BL with Optimized Control Input

It is important to remember that even with the lower leakage values, there is still a limit to how low the V_{IH} can safely operate. This goes back to the arguments made previously that the threshold voltage which defines the switch point varies with a number or parameters and a safety margin must be maintained in order to guarantee an effective switch. The V_{IH} values specified in the datasheet take both factors into account. ON Semiconductor's NLAS5223BL is designed to safely operate with V_{IH} levels down to 1.6 V for V_{CC} levels up to 4.3 V. In this scenario, a battery voltage that varies between 2.7 V and 4.2 V will never induce a leakage above 200 μA, typically much lower, when operated by a control input that toggles between ground and 1.6 V.

ON Semiconductor's portfolio of data and audio switches includes new devices designed to allow low baseband voltages, such as 1.8 V or lower, to drive the control input. The datasheet for each newly released device will include I_{CC} leakage graphs for varying levels of V_{IN}− giving the system designer a more complete picture of the tradeoffs and options available for interfacing to the switch. With this additional information, the designer is one step closer to an analog switch solution that is truly optimized for the application.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative