5-V to 3.3-V Translation With the SN74CBTD3384

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SCDA003A
August 1996

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Introduction

The emergence of low-voltage technology has required existing 5-V systems to interact with 3.3-V systems. Issues concerning compatibility of the two systems in mixed-mode operation have created the need for 5-V to 3.3-V translation. Buffers and transceivers serve as effective translators. While providing additional drive, these devices also add propagation delay and require directional control. In cases where additional drive is not required, the solution that provides 5-V to 3.3-V translation, in addition to negligible propagation delay, lower power dissipation, and bidirectional bus switching, is the SN74CBTD3384 bus switch. The SN74CBTD3384 uses the inherent voltage drop of its MOSFET switch, coupled with an internal diode from V_{CC} to provide the necessary 5-V to 3.3-V translation. (see Figure 1).

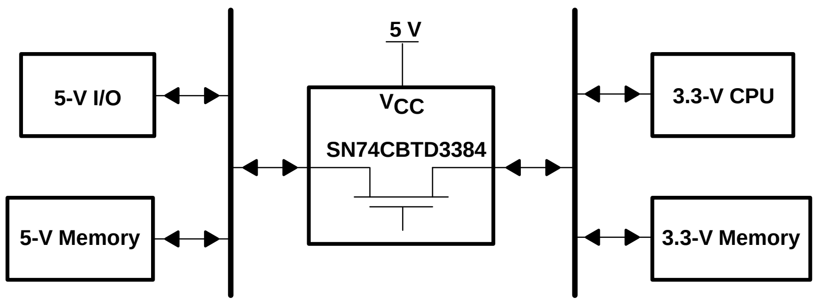

Figure 1. The SN74CBTD3384 Bus Switch Provides 5-V to 3.3-V Translation and Bidirectional Switching

The Need for 5-V to 3.3-V Translation

To realize the need for 5-V to 3.3-V translation, the I/O specifications for mixed-mode operation must be understood. Devices operating in this mode must have TTL-compatible output levels and be able to accept up to 5.5 V at the input. Figure 2 shows various interface levels for 5-V and 3.3-V families. While many 5-V and 3.3-V logic families have been equipped with TTL-compatible interface levels and 5-V input tolerance, some CMOS families lack these features. Certain 5-V CMOS devices drive a bus to 5 V at a logic high, and certain 3.3-V CMOS devices do not tolerate 5 V at the input. It is the inability of the previous two types of devices to interact correctly that creates the need for 5-V to 3.3-V translation.

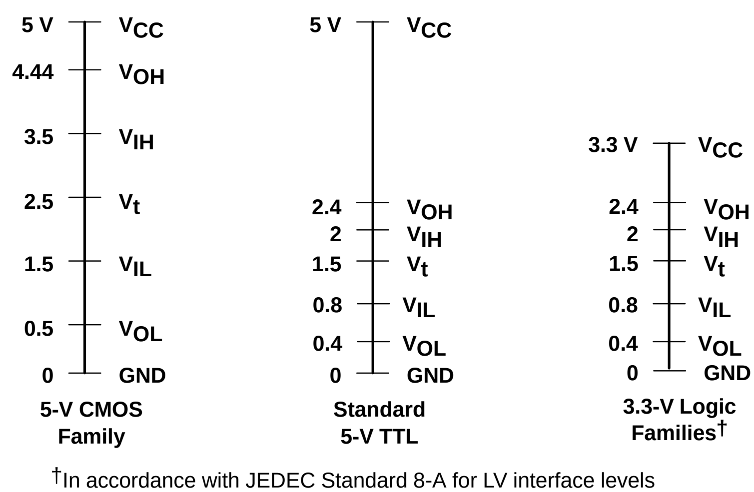

Figure 2. Comparison of 5-V and 3.3-V Interface levels

The Mechanics of 5-V to 3.3-V Translation

Voltage reduction using the SN74CBTD3384 bus switch starts with the physical operation of the switch. CBT bus switches consist of an N-channel MOSFET with its drain driven by the input and the output connected to the source. The switch is disabled when the gate is a logic low. It is enabled when the gate is a logic high, thus providing enough voltage to surpass the 1-V threshold from gate to source. Taking into account a V_{CC} of 5 V connected to the gate and a gate-to-source voltage drop of 1 V, the maximum to which the source voltage can rise is about 4 V. This source voltage limitation, coupled with the transistor's typical on-state resistance of 5 Ω gives the switch both 5-V to 4-V translation and low propagation delay. This physical realization is a major factor in the voltage translation to 3.3 V. If the enabled gate voltage can be reduced to a level lower than V_{CC}, this would limit the source to a voltage even lower than 4 V. As shown in Figure 3, the SN74CBTD3384 has a diode between V_{CC} and the rest of the circuit. This diode induces a 0.7-V voltage drop from V_{CC}, leaving only 4.3 V at the gate. With the additional 1-V drop from gate to source, the typical output of the SN74CBTD3384 is 3.3 V. Additional diodes can be added to limit the output to even lower levels. It is important to note that in some cases, the current (I_{CC}) flowing through the diode may not be enough of a bias current to turn the diode on. A resistor (R) is connected from the cathode of the diode to ground to ensure enough bias current through the diode. The bidirectional nature of the switch is not sacrificed in this translation. A logic high from a 3.3-V device is relayed to the output untranslated. A 5-V receiver with TTL-compatible interface levels reads this signal as a valid high.

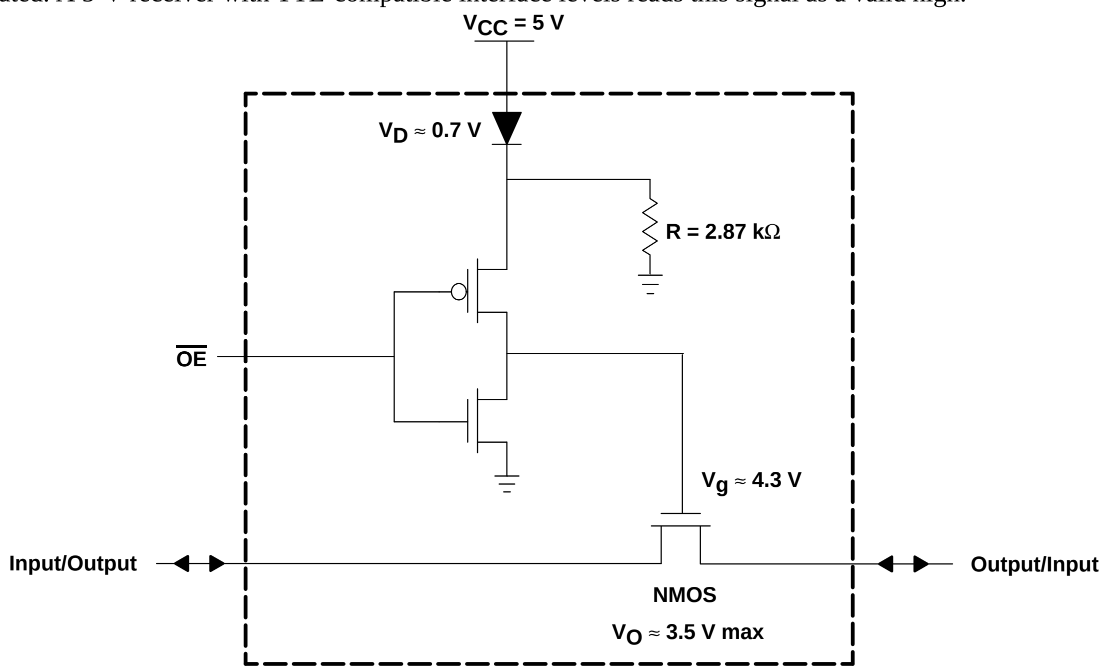

Figure 3. NMOS Switch of SN74CBTD3384 With Maximum V_O of 3.5 V

SN74CBTD3384 Improves Upon Existing Methods for 5-V to 3.3-V Translation

An existing practice for 5-V to 3.3-V translation using a bus switch involves the diode external to the chip. For most purposes, this method provides a quick, effective solution for voltage reduction. But, with increased use of low-voltage technology, the use of smaller, more reliable parts becomes an even more important issue. The SN74CBTD3384 addresses this issue by integrating the diode and resistor internally into the chip. As a result, board space is reduced and the cost of external components is eliminated. The integration of the components into one chip also eliminates extra solder connections and makes testing easier. Noise sensitivity is decreased, as well as the chance of false switching. The modified control input threshold of the SN74CBTD3384 compensates for the diode drop from V_{CC} and retains the normal 5-V TTL input threshold. This further reduces the noise problem. As demonstrated by the preceding factors, the SN74CBTD3384 offers increased reliability.

Figure 4 shows a comparison between the SN74CBT3384A, SN74CBT3384A with a 1N916 external diode for voltage translation, and the SN74CBTD3384. The SN74CBTD3384 output follows the input closely, but reaches a maximum of approximately 3.45 V at a V_{CC} of 5.5 V. Even at an extreme input level of 7 V, the SN74CBTD3384 limits the output to 3.5 V. Figure 5 emphasizes the role of V_{CC} in limiting the output. As V_{CC} changes from 4.5 V to 5.5 V, so does the limit of the output.

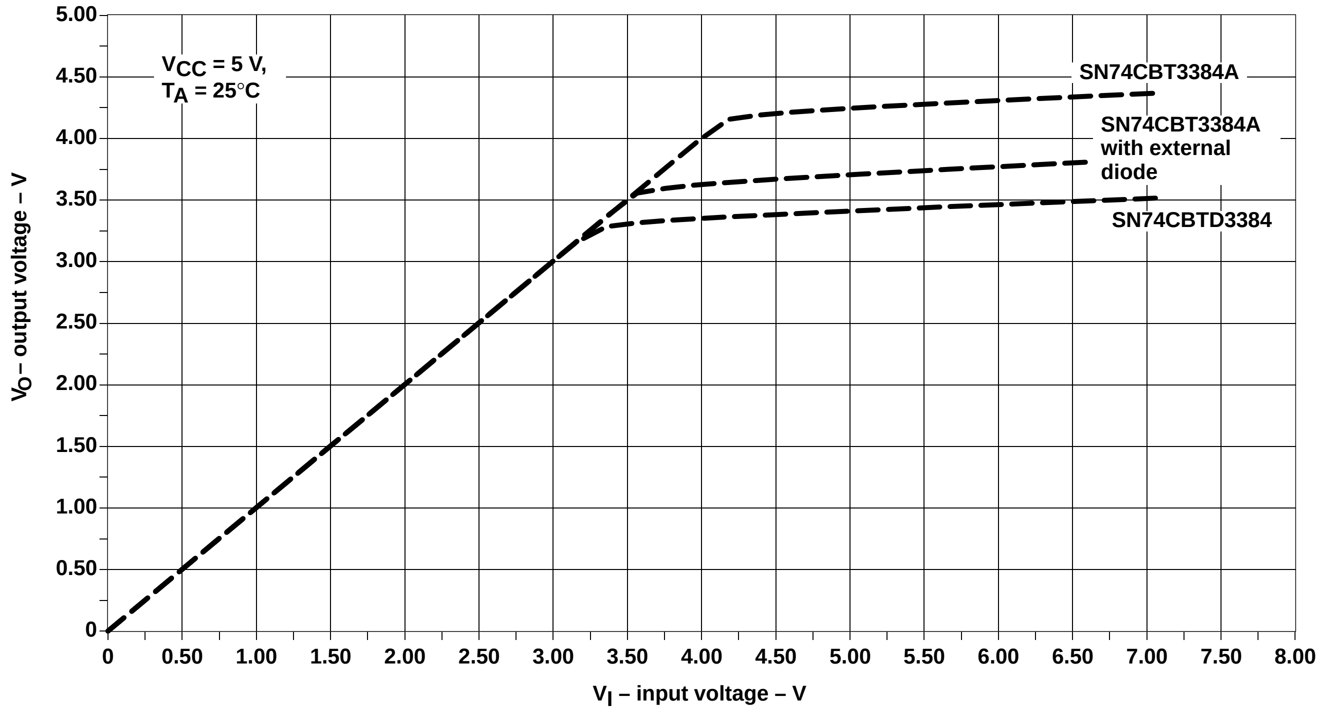

Figure 4. V_O Versus V_I of SN74CBT3384A, SN74CBT3384A With 1N916 External Diode, and SN74CBTD3384

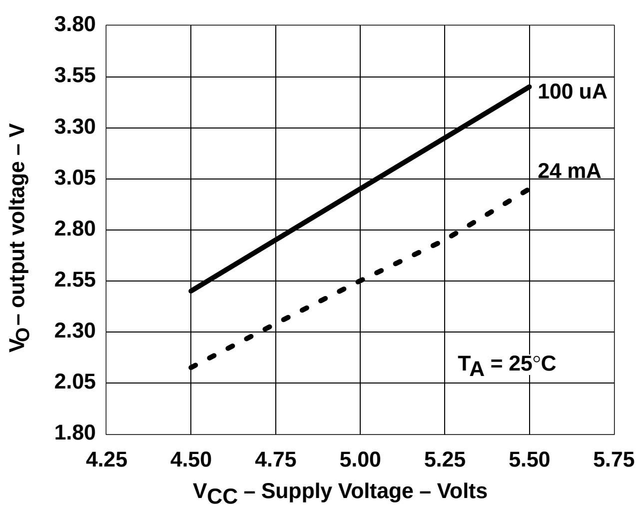

Figure 5. V_O Versus V_{CC} of the SN74CBTD3384

Conclusion

Lack of compatibility between certain 5-V and 3.3-V devices has driven the need for 5-V to 3.3-V translation. The standard method of using a bus switch to address this need has required the use of an external diode. The SN74CBTD3384 bus switch is an improvement to this method because it provides reliable, internal 5-V to 3.3-V translation and maintains its bidirectional capability, negligible propagation delay, and low power dissipation.