Application Report
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Basics of Voltage-Level Translation

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ABSTRACT

Circuit designers are faced with the challenge of developing systems with increasing functionality and complexity while under demanding power and time-to-market constraints. Such systems often require voltage level translation devices to allow interfacing between integrated circuit devices built from different process technologies. The choice of the proper voltage level translation device depends on many factors and will affect the performance and efficiency of the circuit application. Texas Instruments offers a variety of solutions to meet customer requirements.

Contents

1 Introduction 2
2 Potential Problems Without Voltage-Level Translation 2
3 Methods of Voltage-Level Translation 3
4 Conclusion 5
5 References 5

List of Figures

1 Flexible Voltage-Translation Application 2
2 Typical Situation in Which a Level Translator is Needed 2
3 Examples of Level Translation Using AVC Devices 3
4 Open-Drain Outputs 4
5 Down-Translation Using a Logic Device With Over-Voltage-Tolerant Inputs 4
6 Level Translation With FET Switches 5

1 Introduction

Advances in manufacturing processes in the fabrication of semiconductors have allowed for smaller geometries in circuit design and lower supply voltage levels. These advances in technology support many of the low-power, high-performance applications currently being designed. To use these new designs with existing technology, there must be a means to match the output voltage level of one device with the input voltage level of another device in the circuit such as shown in Figure 1. Several different options exist to accomplish this requirement.

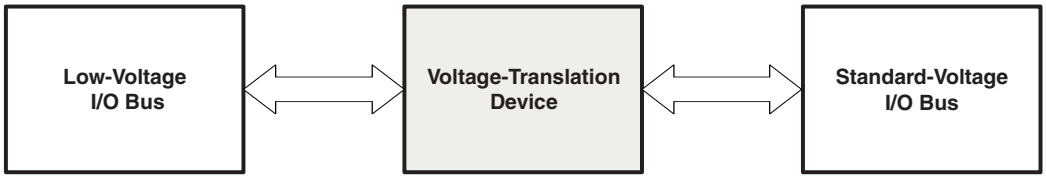

Figure 1. Flexible Voltage-Translation Application

The different technologies available in circuit design determine the input voltage threshold and output voltage level achievable in different devices. To interface two devices of differing technologies successfully, voltage level translation may be required. These requirements include (1):

1. The high-level output voltage (V_{OH}) of the driver device must be greater than the high-level input voltage (V_{IH}) of the receiver device.
2. The low-level output voltage (V_{OL}) of the driver device must be less than the low-level input voltage (V_{IL}) of the receiver.
3. The output voltage from the driver must not exceed the I/O voltage tolerance of the receiver.

(1) *Selecting the Right Level-Translation Solution*, TI literature number SCEA035A, June 2004.

2 Potential Problems Without Voltage-Level Translation

Voltage-level translation is needed when two device have differing supply voltage nodes. Two possible conditions exist:

1. A higher-voltage device may be needed to drive a low-voltage device.
2. A lower-voltage device may be needed to drive a high-voltage device.

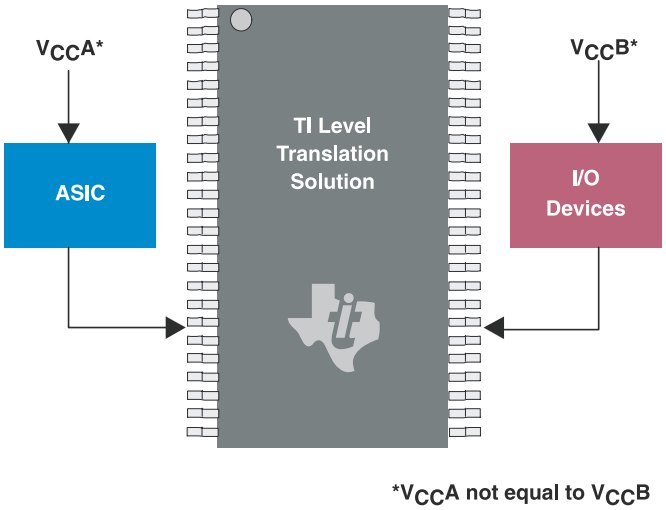

Figure 2. Typical Situation in Which a Level Translator is Needed

If the high voltage device is the driver, the circuit can often operate reliably if the following conditions are met.

- The input pins of the receiving device must be specified as tolerant of the higher voltage device.
- The logic swing must pass through V_{IL} and V_{IH} voltage levels specified for the receiving device.

If the low voltage device is the driver, the circuit typically cannot function properly without the use of a translation device. One problem can be too great a voltage difference. If this condition exists, the low voltage signal cannot provide enough voltage to turn on the receiving device, making the system non-functional. Secondly, if the voltage level is enough to turn on the receiving device, the V_{IH} level may not be high enough, for example, to completely turn off the PMOS device in the input buffer.

3 Methods of Voltage-Level Translation

Several methods can be used to effectively accomplish voltage level translation. Device selection and utilization in a circuit is determined by the circuit design, the allowable (or desired) power consumption, the voltage translation levels required, and the current sourcing capability of the device.

One option for voltage level translation is dual supply level translator devices. These devices allow for bidirectional voltage level translation. They can be used to translate from a lower input voltage to a higher output voltage, or to translate from a higher input voltage to a lower output voltage. These devices offer low power consumption and can be found in the ALVC, AVC and LVC device families.

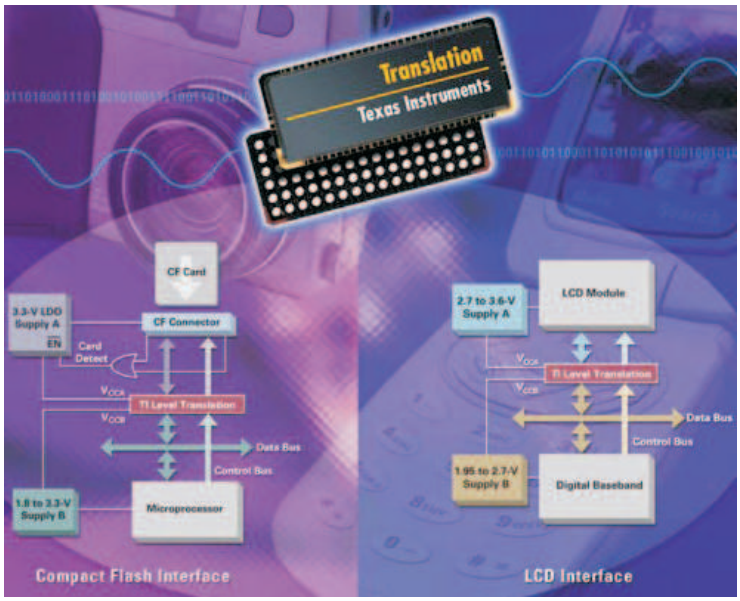

Figure 3. Examples of Level Translation Using AVC Devices

A second method for voltage level translation is the use of open drain devices. An open drain device can be used for voltage level translation to and from a variety of voltage nodes. The output voltage is determined by V_{CCB}. V_{CCB} can be higher than the input high-level voltage (up translation) or lower than the input high-level voltage (down translation). However, depending on the configuration in the circuit, open drain devices can contribute to higher power consumption in a system. Figure 4 shows a translation circuit with open drain outputs.

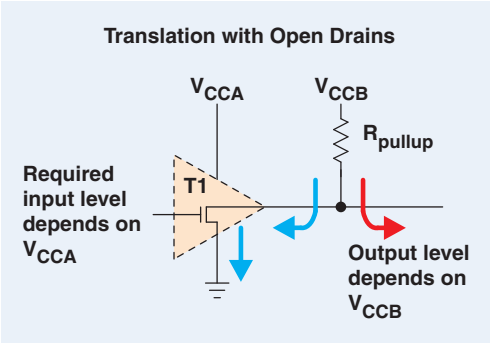

Figure 4. Open-Drain Outputs

Other devices can translate in only one direction. One example of unidirectional translation is devices with overvoltage tolerant inputs. These devices can handle input voltages that are higher than the supply voltage of the device to be interfaced and are suitable for downward voltage level translation. Power consumption for these devices is good, and only one supply voltage is needed. Device families with over voltage tolerant inputs include AHC, AUC, AVC, LV-A, and LVC. When using overvoltage tolerant devices for level translation, slow edges on the input signal could affect the duty cycle of the output signal. Further, the switching level of a circuit is limited by V_{CC}. Therefore, overvoltage tolerant devices might not be the best solution in an application where duty cycle is critical.

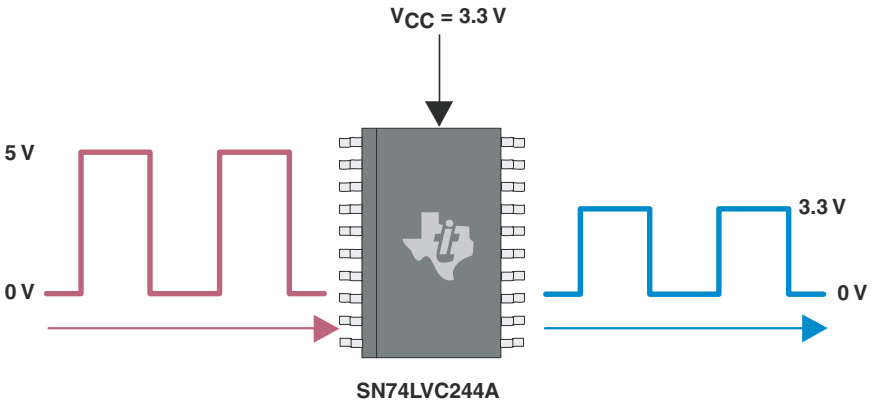

Figure 5. Down-Translation Using a Logic Device With Over-Voltage-Tolerant Inputs

Another family of devices performs auto-direction voltage level translation. These devices improve connectivity between next generation processors and peripheral devices. These devices, like the TXB0104 and TXS0104E, eliminate the requirement for direction control signals used by traditional voltage level translation devices. They offer low power consumption, V_{CC} isolation, and partial power-down-mode operation.

Finally, FET switches also can be used for level translation. One advantage they offer is fast signal propagation. Some FET switch devices translate only in the downward direction, while others can be configured to translate bi-directionally. Devices from the CBT, CBTD, and TVC families can offer level-translation solutions. For example, the TVC (translation-voltage clamp) family has been designed specifically for protecting sensitive I/Os. Each TVC-family device offers specific I/O protection application that can be used by design engineers to utilize the device to fit their particular need.

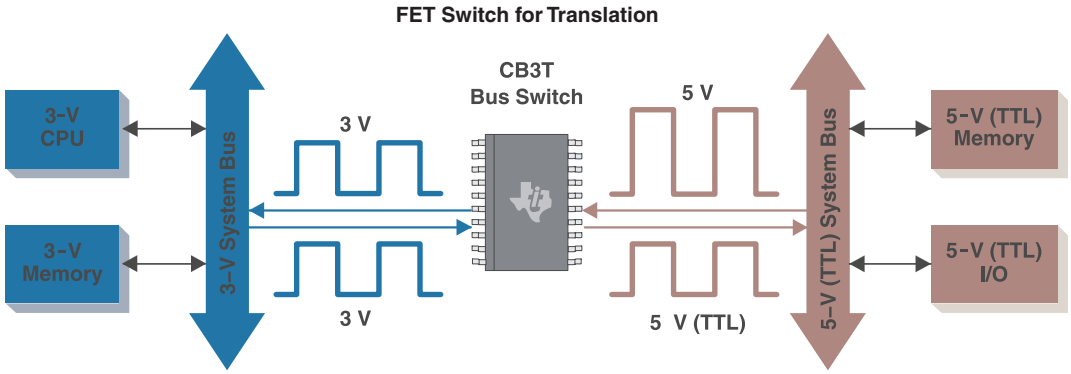

Figure 6. Level Translation With FET Switches

4 Conclusion

Texas Instruments offers a wide range of options depending on the system application, power consumption, voltage translation level, and current sourcing requirements. Whether there is a low output voltage to be translated up, or a higher output voltage level to be translated down to match the input voltage of a subsequent device, there is a device that meets the need. In many cases, the dual supply level translator offered by Texas Instruments may be the best solution to accomplish voltage translation. A TI field sales representative can help make a selection for specific application requirements.

5 References

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