# Level Shifters: Why We Can't Shift Away

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## Introduction

The current trend in today's high tech industry is to move to lower voltages. Nowadays, 3.3V is standard but is rapidly moving to 2.5V and 1.8V. The migration or communication between these mixed voltages is necessary in many system designs. With such an abundant of mixed voltages systems on the market, the demand for voltage translation devices is very high and Pericom Semiconductor offers a total solution including bi-directional voltage translators.

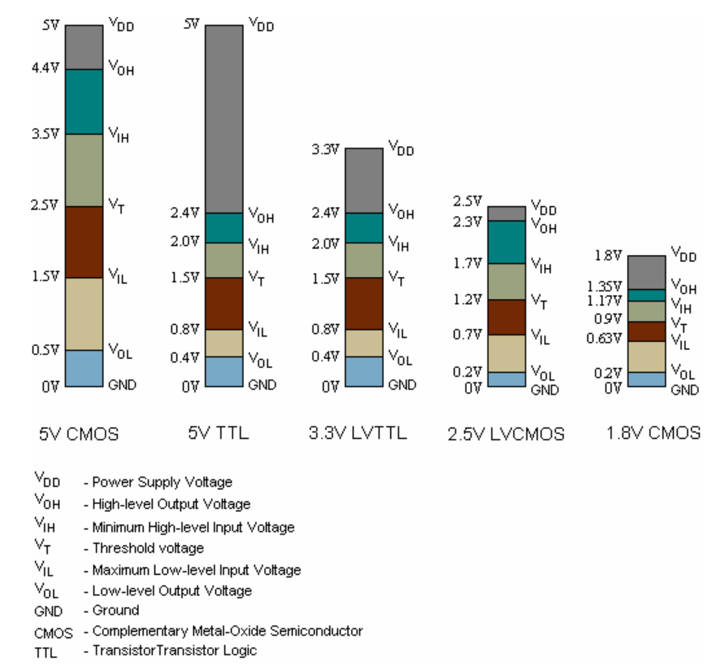
## Going Down

Some designers might use a bus switch such as the PI5Cxxxx or the PI3Cxxxx as a voltage translator. The benefit of using a bus switch as a voltage translator is that it offers a near-zero propagation delay. However, bus switches can only translate in a downward direction, or from a higher voltage to a lower voltage. In some systems, a higher voltage device can often drive a lower voltage device without any special translation circuit needed as long as the receiving device input can tolerate the higher voltage.

## Going Up

In applications where the voltage translation is needed bi-directionally (higher voltage to a lower voltage and vice versa), the lower voltage signal alone will not be able to meet the higher voltage receiver's $V_{IH}$ requirements (i.e. a 2.5V CMOS driving a 5V CMOS).

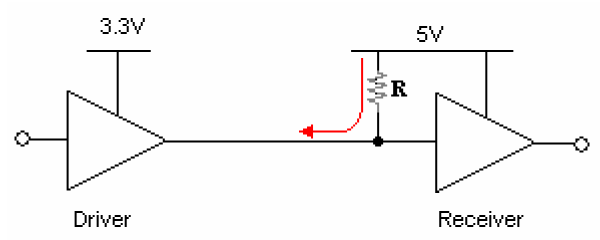
The following chart shows the voltage requirements for some common receivers.




Note: 1. 5V and 2.5V CMOS levels: $V_{IL}$ = 0.3 * Vcc and $V_{IH}$ = 0.7 *$V_{DD}$
Note: 2. 1.8V CMOS level: $V_{IL}$ = 0.35* Vcc and $V_{IH}$ = 0.65 *$V_{DD}$

**Input and Output Characteristic of CMOS and TTL signals**

Some designers use special circuitry to raise the voltage. A commonly used technique is to use an external pull-up resistor with a typical resistor value of 1K-ohm to 10K-ohm connected to a higher secondary power source, similar to the circuit shown below.




The technique works, but there are few drawbacks to take into consideration. The first drawback occurs when the driver is driving low. When this occurs, there will be a constant current flow across the resistor due to the potential differences between the resistor. As a result, there will be an increase in the system power dissipation.

For example, if a system is driving high 50% of the time and driving low 50% of the time with a 1K-ohm pull-up resistor at the receiver's end, the power consumption would be as follows when the device is driving low:

$I_{CC} = \Delta V/R$

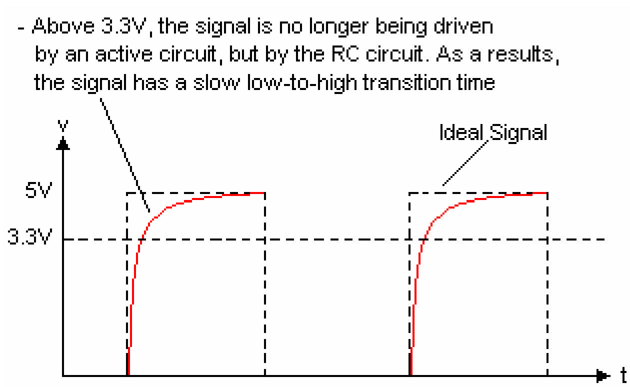
$I_{CC} = 5V\text{-}0V/1K\Omega = 5mA$

$5mA/2 = 2.5mA$

As a result, each output using a pull-up resistor would consume an additional 2.5mA each time the device is driving low. For a switch to drive a 64-bits signal, it will consume an additional 160mA!

The additional power dissipation can be easily reduced when a high resistor value is used. But on the contrary, using a higher value resistor will compromise the low-to-high transition time. When using a pull-up to pull a lower voltage to a higher voltage, the transition to go the additional voltage will be driven by the RC time constant of the resistor and the load as shown in Figure

Another drawback to consider is due to the slow transition time, the technique is not suitable for high frequency above 10 MHz.




A higher resistor value will reduce the system power dissipation, but a low resistor value is desired to have minimal low to high transition time. This dilemma has shifted the industries to move towards logic devices rather than switches for bi-directional voltage translation.

## Up, Down and Back

With the voltage trend heading to lower voltages, the voltage gap between new emerging technologies and legacy technologies becomes even bigger. Many times, systems will not only require translating a higher voltage to a lower voltage, but vice versa and at very high frequency. The methodologies of using a bus switch or external passive components are not capable of completing the job without sacrificing some kind of system performances. This requires logic devices to complete the job. Pericom Semiconductor offers a wide range of voltage translation devices from 5V, 3.3V down to 1.8V translation.

The current most commonly used level shifting is between 5V ↔ 3.3V or 3.3V ↔ 1.8V. But the industries are continuing to move on a downward trend.

The table below the current line of Pericom's voltage translators.

## Pericom Voltage Translators

| Part Number | Translation | Advantages | # Bits |
|---|---|---|---|
| PI3Cxxx or PI5Cxxx | 5 V → 3.3V | Near-zero propagation delay | 2- 40-bits |
| PI74LVC 3245A | 3.3V ↔ 5V | Allows 3.3V to 5V and vice versa. | 8-bit |
| PI74LVCC 3245A | 3.3V ↔ 5V<br>3.3V ↔ 3.3V | Allows 3.3V to 5V and vice versa. Also allows 3.3V to 3.3V. | 8-bit |
| PI74LVC 4245A | 3.3V ↔ 5V | Allows 3.3V to 5V and vice versa. | 8-bit |
| PI74LVCC 4245A | 3.3V ↔ 5V<br>5V ↔ 5V | Allows 3.3V to 5V and vice versa. Also allows 5V to 5V. | 8-bit |
| PI74AVC 164245 | 3.3V ↔ 2.5V<br>3.3V ↔ 1.8V<br>3.3V ↔ 1.5V | Individual banks allow high to low in one bank and low to high in another bank | 16-bits |
| PI74HSTL 1212 | 3.3V ↔ 1.8V | Allows LVTTL or LVCMOS to HSTL | 24-bits |

## Translators in Action

The below figure shows the PI74AVC164245 in an actual 10 Gigatbit Router application. The PI74AVC164245 is used to translate bi-directionally between a 3.3V memory bus and a 1.8V ASIC. If a switch, along with a 1KΩ pull-up resistor was used is this case, it would generate an additional 160mA. Figure 4 shows the PI74AVC164245 translating from 1.8V to 3.3V and vice versa simultaneously.

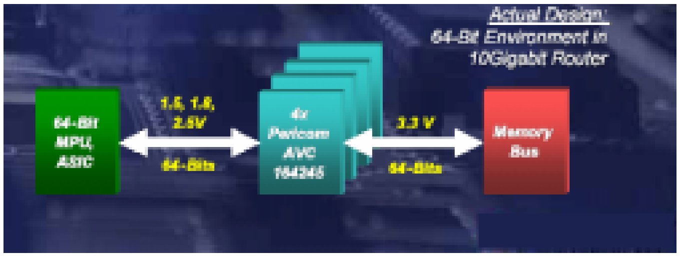



**Figure 3. 10 Gigabit Router using four PI74AVC164245's**

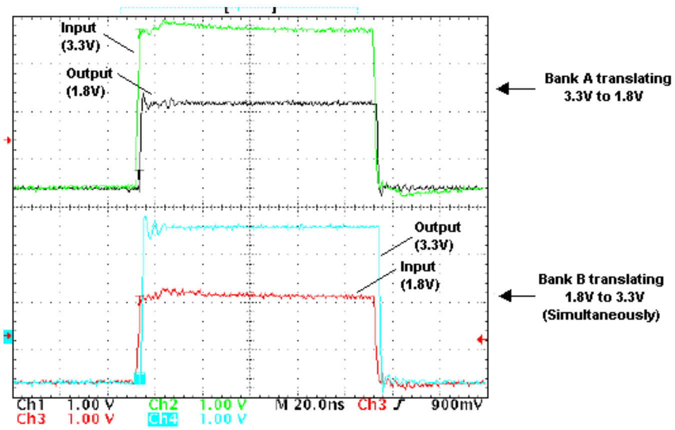



**Figure 4. PI74AVC164245 translating voltage from 3.3V→1.8V and 1.80V → 3.3V simultaneously**

## Advantages of Logic Translators

- Suitable for long trace application
- Ability to drive heavy loads
- Higher operating frequency
- Wide range of voltage translators
- Isolation for input capacitance of the device
- Individual banks allows high-to-low and low-to-high simultaneously

## Typical Applications

- Routers/switches
- PCI applications
- Servers
- PCMCIA Cards
- Handheld System

## Conclusion

As the industry moves to lower voltages while increasing speed, the gaps between new technology and older legacy technology becomes greater, it is increasingly important to bring these mixed voltage technology together. Pericom Semiconductor offers a wide range of voltage translator logic devices that has helped industry leaders to close the gap between legacy technologies and new emerging technologies.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