

How to interface a 5V Transceiver to a 3V Controller

Many low-voltage RS-485 bus node designs utilizing 3V micro controller units (MCU) favor 5V over 3V transceivers (XCVR) due to higher drive capability, which ensures higher noise immunity and allows for longer transmission distance (Figure1). Because the output voltage levels of 3V MCUs are sufficiently high to properly drive the TTL input levels of 5V transceivers, controller outputs can be directly connected to transceiver inputs.

In the opposite direction however, the transceiver output level exceeds the MCU maximum input rating and level shifting (LS) is required.

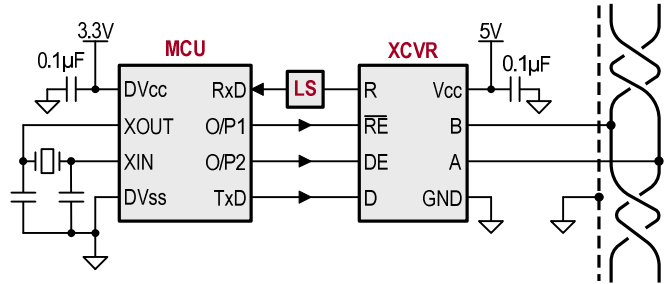


Figure 1. Typical interface challenge between 3V MCU and 5V transceiver

As a first level-shifting solution the common resistive voltage divider comes to mind followed by a Zener diode approach (Figure 2).

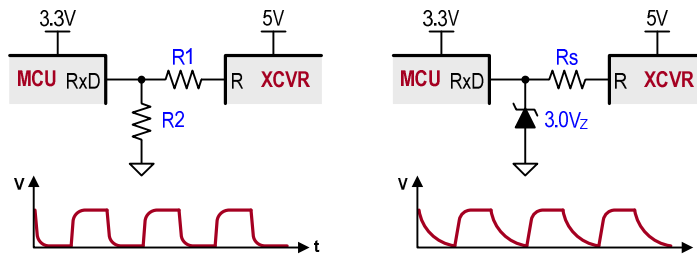


Figure 2. Level-shifting via voltage divider (left) and Zener diode (right)

The problem with both solutions is that during a bus-idling, the receiver commonly outputs a high which causes current to flow through the level-shifter, thus occurring at times when current isn't actually needed but rather wasted. Of course, it is possible to increase the resistor values in order to reduce the current consumption, but higher impedance in combination with the input capacitance of MCU I/O can lead to signal distortion at higher data rates. For the Zener diode approach, distortion can occur earlier due to the high diode capacitance of 400 to 500 pF.

A better solution preventing current flow during bus-idle and only causing a small current to flow when the receiver output goes low, is the implementation of a reverse-biased Schottky diode in combination with a pull-up resistor (Figure 3).

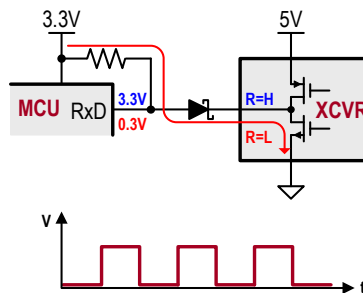


Figure 3. Level-shifting with Schottky diode and pull-up resistor

When the receiver output is high the diode is reverse biased, a 3.3V potential lies the MCU receive data input, RxD. When the receiver output goes low, the diode is forward biased and current flows from the 3.3V supply

through the pull-up resistor and the lower transistor of the receiver push-pull output stage towards ground. The voltage at the MCU input is now reduced to the diode forward voltage.

Figure 4 shows a generic and a specific design solution. The left circuit represents a generic MCU with an external pull-up resistor and separate enable lines for driver and receiver. The right circuit focuses on a specific MCU with programmable internal pull-up resistors. Here the interface is simplified by avoiding an external resistor and using only a single direction-control line (DIR) to configure the transceiver for drive and receive mode.

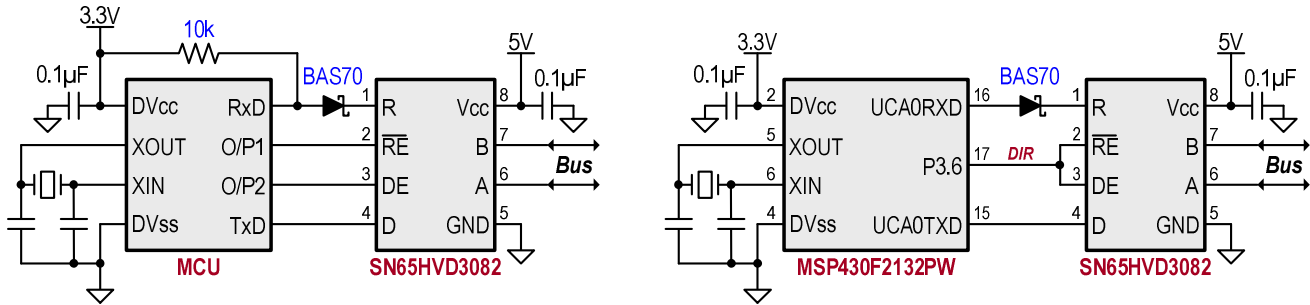


Figure 4. Final interface solutions using a Schottky diode and an external or internal pull-up resistor

The transceiver chosen provides a maximum data rate of 250 kbps, typically used in long-haul and e-metering applications. For low an input capacitance of about 5 pF, the combination of BAS70 diode and 10kΩ resistor provides crisp level-shifting up to approximately 1 Mbps.

Beware of those cheap current limiting tricks that try to save you a second resistor versus the voltage-divider solution but instead compromise the long term reliability of your controller (Figure 5). Like most logic circuits, the inputs of micro controllers possess low-voltage triggered silicon-controlled rectifiers (LVTSCR) that protect the inner circuitry from over-voltages. Thus if an over-voltage were applied to the RxD-pin, the SCR would conduct and divert excessive current straight to ground.

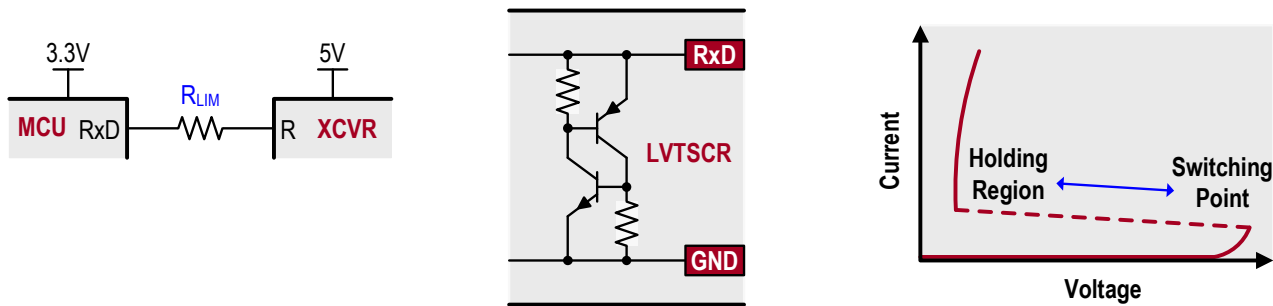


Figure 5. Using a single current-limiting resistor will cause damage to the input circuitry

However when applied in conjunction with a current limiting resistor, the 5V from the transceiver output will trigger the SCR in the MCU input but the current limiting resistor, R_{LIM} , won't allow the SCR to reach its holding region. Because of that, the SCR will drop back into high-impedance thus allowing the over-voltage to reach the inner input circuitry. This oscillating between switching point and holding region continues until the over-voltage is removed (i.e. the receiver output goes low). However during bus-idling the high output of the receiver will cause an over-voltage at the MCU input, just with frequent interruptions towards ground. This behavior clearly presents a long term reliability issue and should be avoided.

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