Texas Instruments Crossbar Switches

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SCDA001A
July 1995

TEXAS INSTRUMENTS

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What Are Texas Instruments Crossbar Switches?

Crossbar switches are high-speed bus-connect devices. Each switch consists of an N-channel MOS transistor driven by a CMOS gate. When enabled, the N-channel transistor gate is pulled to V_{CC} and the switch is on. These devices have an on-state resistance of approximately 5 Ω and a propagation delay of 250 ps. They are capable of conducting a current of 64 mA each. The transistor clamps the output at ≈ 1 V less than the gate potential, regardless of the level at the input pin. This is one of the N-channel transistor characteristics (see Figures 1 and 2). Note the ≈ 1-V difference between the gate (V_{CC}) and the source (V_O) at any point on the graph.

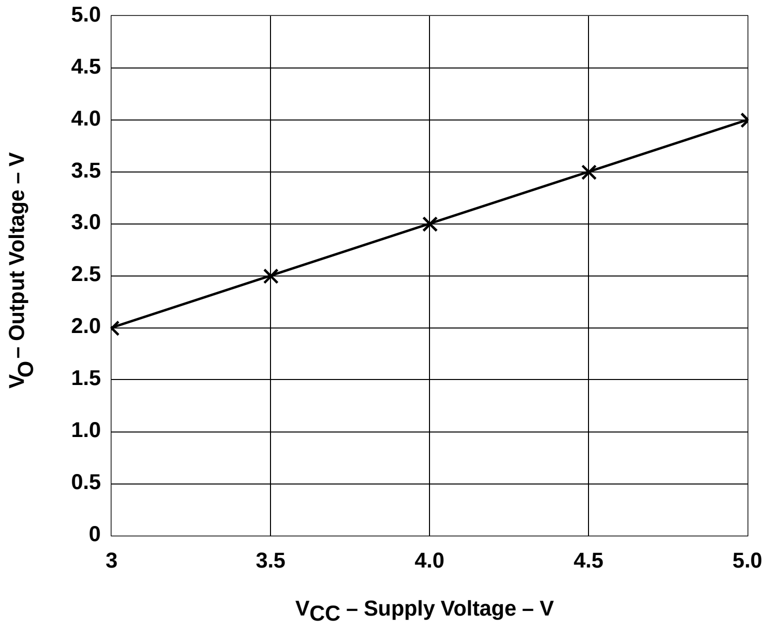


Figure 1. Output Voltage Versus Supply Voltage

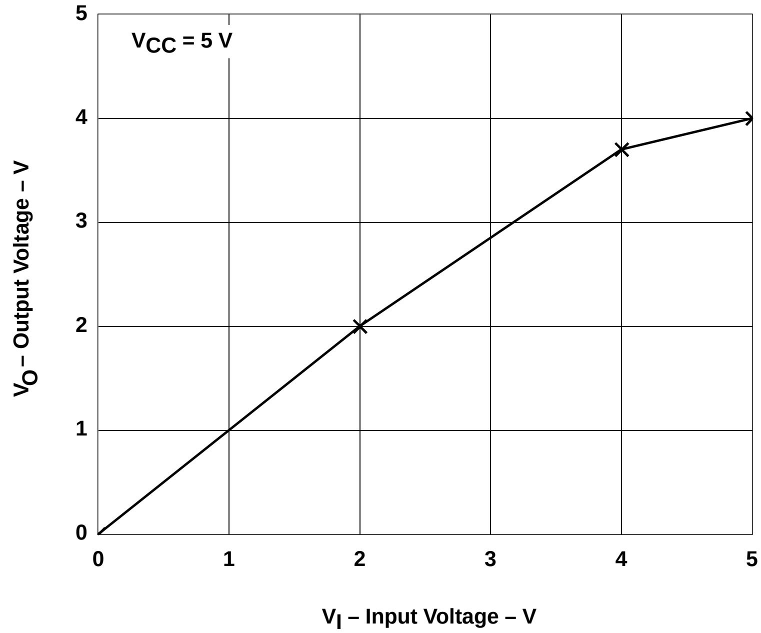


Figure 2. Output Voltage Versus Input Voltage

The on-state resistance (r_{on}) increases gradually with V_I until V_I approaches V_{CC} – 1 V, where r_{on} rapidly increases, clamping V_O at V_{CC} – 1 V (see Figure 3). Also, by the nature of the N-channel transistor design, the input and output terminals are fully isolated when the transistor is off. Leakage and capacitance are to ground and not between input and output, which minimizes feedthrough when the transistor is off.

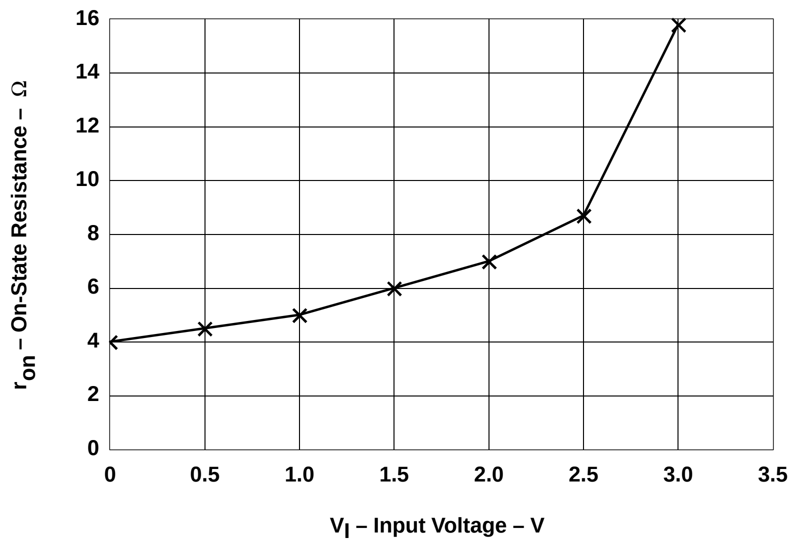


Figure 3. On-State Resistance Versus Input Voltage

Bus Switches Provide 5-V to 3-V Translation When 3-V Supply Line Is Not Provided

These devices also can provide bidirectional 5-V to 3-V translation with minimal propagation delay or direction control, using only a 5-V supply line and a diode. Figure 4 illustrates this application. A 4.3-V V_{CC} can be created by placing a diode between V_{CC} and the switch. This causes gate voltage of 4.3 V due to the diode drop of approximately 0.7 V. This drop, coupled with the gate-to-source drop of 1 V, brings V_O to a maximum 3.3-V level that can be used to drive a signal in a 3-V environment.

These devices consume very little current (I_{CC} = 3 µA). This current is not satisfactory for the diode to operate. Using a resistor from the cathode of the diode to GND allows more current from the supply voltage, causing the diode to operate and to clamp at the specified 4.3 V (see Figure 4). The recommended value of the resistor is 1 KΩ or less.

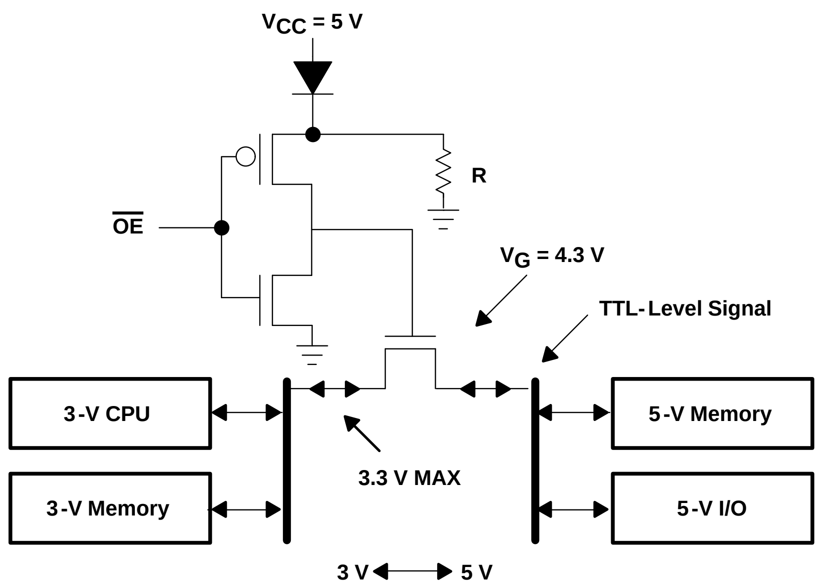


Figure 4. 5-V TTL to 3-V TTL Translator System

Bus Switches Can Be Used to Replace Drivers and Transceivers in Bus Applications

Bus switches introduce near-zero propagation delay. They can replace drivers and transceivers in systems in which signal buffering is not required. They can be used in a multiprocessor system as a fast bus connect, or they can be used as a bus-exchange switch for crossbar systems, ping-pong memory connect, or bus-byte swap. These devices also can replace relays that are used in automated test equipment (ATE) to connect or disconnect load resistors in negligible time with the same low on-state resistance and without relay-reliability problems.

Bus Switches Convert TTL Logic to Hot-Card Insertion Capability

This application is used mostly in systems that require hot-card insertion or removal of cards without disturbing or loading down the bus. These systems are designed to run continuously and cannot be shut down for any reason, such as telephone switches, manufacturing controls, real-time transaction systems, and airline-reservation networks. These systems/cards use some logic families like ACL, HCMOS, etc., which do not provide isolation from the bus when power is partially removed, causing system error. Also, connectors are designed so that the ground pins are connected first, followed by the signal pins, then V_{CC} last. In this condition, the existing logic must ensure that the I/O signals do not disturb or load down the bus. This assurance cannot be achieved using CMOS logic since it contains P-channel transistors that provide an inherent diode between the I/O pins and V_{CC}. The diode is forward biased when driven above V_{CC} (see Figure 5). In a situation where V_{CC} is disconnected, these diodes are capable of pulling the system bus to approximately one diode drop above ground, leaving the bus disturbed.

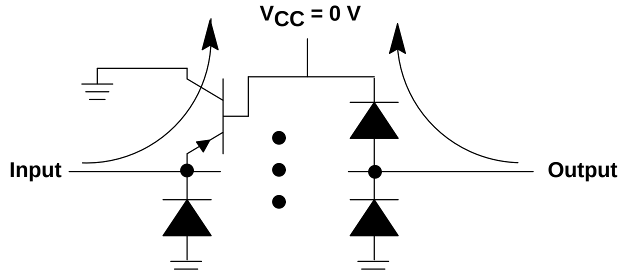


Figure 5. ACL Direction of Current Flow When V_{CC} = 0 V

Another issue to consider is that, when V_{CC} is ramping but still below the device-operating voltage, the logic should ensure that the outputs are in the high-impedance state and that the bus is totally isolated until the card is ready for operation. Finally, the capacitance of the card must be seen by the system bus as low as possible so that when the card is inserted and the capacitance is charged up, disturbance or bus error does not occur.

There are two solutions to this problem; one is to use Texas Instruments BiCMOS technology (BCT) or advanced BiCMOS technology (ABT) families, since both ensure the input and output to be off when V_{CC} is removed due to the absence of the clamping diodes to V_{CC} (see Figure 6). They also provide an active circuit that ensures the output to be in the high-impedance state during part of the V_{CC} power up or power down.

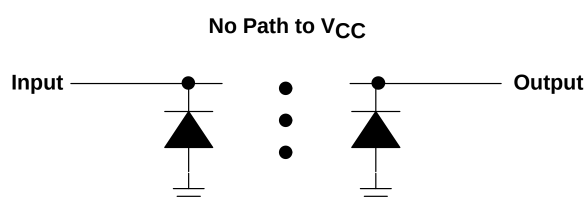


Figure 6. No ABT Current Flow When V_{CC} = 0 V

The second solution is to use the Texas Instruments CBT family. This can be done by placing the switch between the card logic and the connector to serve as an isolator when power is removed. The switch uses an n channel that prevents the current from flowing into the switch when powered down (see Figure 7). One device in particular, the SN74CBT6800, is designed specifically for hot-card insertion. It has a built-in channel pullup tied to a bias voltage (BIASV) that is provided to ensure power up with the buses not connected. Other devices can be used in the same manner, however, to ensure the high-impedance state during power up or power down. The enable pins of the switch should be tied to V_{CC} through a pullup resistor. The minimum value of the resistor is determined by the current-sinking capability of the driver (see Figure 8).

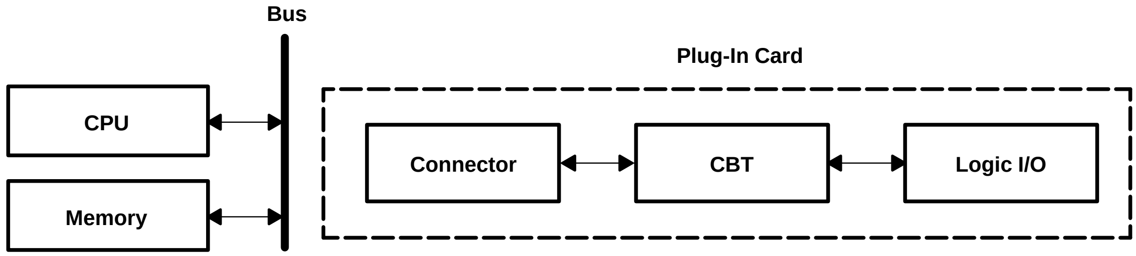
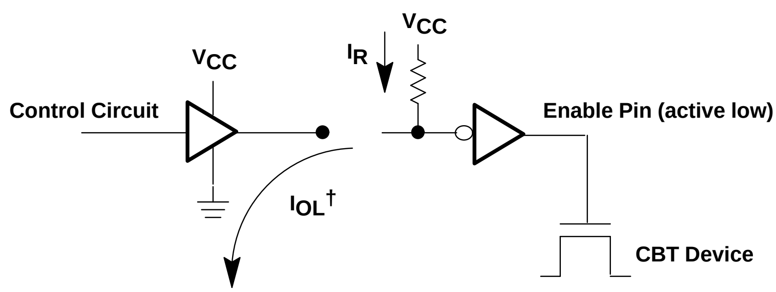


Figure 7. Hot-Card Insertion Application



† $I_{OL} > I_R$, so the control signal can override the pullup resistor.

Figure 8. Power-Up High-Impedance State With CBT

Conclusion

Texas Instruments crossbar switches can be used in several applications. Although they are simple N-channel transistors, they are capable of providing several important bus functions, such as hot-card insertion, near-zero-delay communication, 5-V to 3-V translation, and memory management in multiprocessor environments.