By Peter Alfke

The Dangers of Hot Plug-In

Plugging a board or device into a powered-up system is dangerous because the pins make contact in an unpredictable sequence. There may be many milliseconds from making the first contact to the last one, and it's what occurs in between that causes the problem.

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In the best cases, ground and Vcc mate first before any signal pins make contact. There are connectors that enforce such a mating sequence; their ground and Vcc pins are longer, so they always mate first. These kinds of sockets are popular in telecom applications where hot plug-in is standard practice. With such specialized connectors, there are no electrical hazards, and you need only be concerned about the unpredictable sequence of logic connections being made. For example, what happens on a data bus when new drivers are connected, perhaps before the control signals are valid?

Without a specialized connector, permanent electrical damage is possible. Consider the case where ground and a few signal pins make contact first, and one of these signals is driven High by a 5-volt CMOS driver with a 20 ohm output impedance. Until the Vcc pins make contact, this High signal will forward-bias the electrostatic discharge (ESD) protection diode and try to drive the not-as-yet-connected Vcc distribution network to a marginally High level.

The logic signal acts as a surrogate Vcc supply, but none of the signal traces and circuit elements are strong enough for that job. The current value depends on the number and the nature of the devices fed from the unpowered Vcc net. SRAM-based FPGAs may power-up sufficiently close to 3.5 volts to start the configuration process in master mode, still only powered by one or a few logic signals. As a result, the configuration will usually be aborted before it is finished. These uncontrolled activities and uncontrolled electrical overstresses are not desirable.

When Vcc and a few signals make contact before the ground is connected, a similar problem occurs. A Low signal output on the powered-up board acts as the surrogate ground for the plug-in device, with current coming in through the ESD-protection diode from the unpowered device.

The ESD-protection diodes seem to be the main cause of hot plug-in problems, but these diodes are absolutely necessary to protect CMOS inputs against high voltages. Gate oxides are now 50 to 100 Å thick, and 5 volts across a gate oxide of 50 Å means a field strength of 1,000 volts per micron — a megavolt per millimeter. Even the best silicon dioxide reaches its limits under these conditions.

Modern CMOS devices usually have two strong diodes on each input pin, one connected to ground, and one connected to the Vcc, to send excessive input charge into the supply rails. The new Xilinx XC4000XL devices do not have a diode to Vcc, but rather use a positive discharge structure to ground. This eliminates some of the hot-plug-in problems, and makes these devices immune to power-supply sequencing, which is a related but easier problem.

Summary

The normal ramping-up of Vcc in a digital system is complicated enough, with different devices coming "alive" at different voltage levels. A haphazard plug-in procedure is much worse. You should avoid hot plug-in unless the equipment is specially designed. ◆