Application Note 41

Protecting Current-Output D/A Converters from Latchup

Device latchup is a well-understood phenomenon in the integrated circuit industry. Products built in CMOS technology are particularly susceptible, but techniques have been developed to raise the latchup threshold to acceptable levels in most applications.

Current-output D/As intended for video applications, however, have two factors working against them with respect to latchup sensitivity: the ability to drive low-impedance loads (as low as 37Ω) precludes the use of standard protection circuits, and the video signal is often driven outside of the equipment enclosure, exposing the D/A output to electrical abuse that is beyond the control of the equipment manufacturer.

While it is always possible to buffer the D/A output through a protective video amplifier, this increases the power dissipation and cost of the application circuit, and often degrades performance as well.

A single Schottky diode is sufficient to protect Raytheon D/A converters from latchup in normal operation.

Latchup

A Silicon Controlled Rectifier (SCR) is a four-layer semiconductor structure that has a unique characteristic in that it does not conduct until it is turned on, but once turned on it "latches," remaining on until the power is removed from the device. This is very useful in constructing ac voltage regulators, dimmers, etc. It is an unfortunate side-effect in modern IC design, when the combination of active semiconductor layers, in combination with an isolating junction, form just such a four-layer device.

When it is critical to avoid latchup, special IC processes can be employed (like Silicon On Insulator, or SOI) that do not have isolation junctions, hence only three-layer devices, but these are substantially more expensive than standard bulk and epitaxial processes, which leaves the rest of us with a problem.

ICs will operate normally until something occurs (typically a voltage/current spike) that triggers latchup. We then have a direct power-to-ground short circuit.

What happens next depends on the IC and the power supply. If the supply is current limited to just above the normal operating current of the device, the power supply voltage will be dragged close to ground. The chip will, of course, quit operating, along with all the other chips on the same power supply. As long as the current supplied to the chip is within the absolute maximum of the device rating, there will usually be no damage to the chip. When the power supply is turned off, the internal parasitic SCRs reset themselves and, when the power is restored, the chip operates normally. These problems are rather difficult to diagnose, and may be the cause of instances when a piece of equipment simply stops working, but comes back to life when power cycled. If this happens, check the supply voltages (and look for dimmed panel lights).

More often, however, the power supply has current to spare, and the latched-up chip takes all it can get. One of two failure modes will then occur if the power is not quickly removed. If the power supply is very large, conductors will melt or vaporize. These could be metallization on the IC, bond wires inside the IC package, or even traces on the printed circuit board. If the power supply is more moderate, the part will draw large amounts of current, get very hot, and eventually burn itself up. ICs tend not to catch fire, but they will discolor, crack, char, and may shatter.

D/A Converters and Latchup

Generally speaking, D/A converters are no better or worse with respect to latchup than other circuits. Current output D/As, however, are expected to drive very low impedances (a doubly-terminated video load is 37.5Ω). The normal latchup protection circuits employ series resistance to limit the current that can trigger the SCR action: in a current output D/A, this is not allowed.

Empirical testing has shown that Raytheon D/A converters can be made to latch up with a positive current forced into the output of an operating device at levels between 100mA and 300mA. They will typically sustain a negative current (drawn out of the device) of more than one Ampere without damage: the eventual failure mode with negative currents is fusing of the output bond wires due to overcurrent stress, and latchup does not occur.

A current of more than 100 mA sounds like a lot, considering that a D/A output is normally connected to a video input. Even if it is accidentally tied to another video output, a 75W source will only provide 14 mA at one volt, and that has to be one volt *above one diode drop above the V_{DD} supply* (which is normally 5V or 3.3V). If the sourcing D/A is powered off, that 1.7V is measured to ground, but the power is off, so no latchup is possible. However, if the power to the D/A is turned on while a latchup-inducing current is being provided, it will indeed latch. This is the condition under which the circuit exhibits the greatest sensitivity.

So how do we get >100mA and latch up a D/A? There are two principal ways.

The first is ESD. Zapping an output while the chip is powered up creates all sorts of amazing currents within the device. Just as we are unable to provide tradition latchup protection on D/A outputs, we are similarly unable to apply standard ESD protection circuits. ESD itself in not a problem, though, because the D/A output devices are quite large and able to absorb ESD transients. But an ESD pulse can be enough to turn on one of the parasitic SCRs at the output.

We have also seen problems with the type of equipment to which the D/A output is connected. Some video monitors employ nonstandard grounding techniques which allow their chassis to float at 50V or so. The capacitance of a 27 inch color monitor is substantial, and can readily supply a current pulse sufficient to latch the D/A. Just to help out, the traditional RCA video jacks have been carefully designed to make contact with the center conductor before the shield is connected, ensuring that the D/A output carries the full burden of discharging the TV set.

Latchup Protection

The solution to the latchup problem is simple. We need to keep a large positive current from flowing through the D/A output to the POSITIVE power supply pins. This current doesn't start to flow until the output is one diode-drop ABOVE V_{DD}. An inexpensive Schottky diode (like a 1N5818) from the output to V_{DD} does the trick. This diode tracks the V_{DD} supply to the chip, so protection is provided during power-up as well.

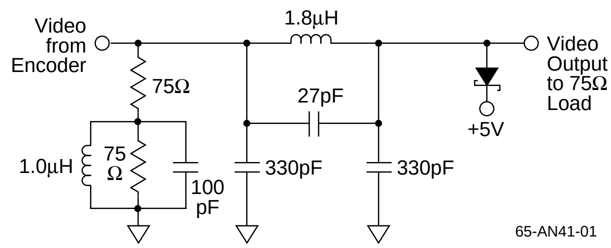

Figure 1. Video Output Filter with Latchup Protection Diode

Figure 1 illustrates a 75Ω doubly-terminated video reconstruction filter (with sinX/X correction) and a latchup protection diode. The +5V connected to the diode should be the same supply that is provided to the D/A, and the connection should be made reasonably close to the D/A power connection.

Recommendation

A Schottky diode from the output to V_{DD} is recommended in all applications where a current-output D/A is connected directly to the outside of a piece of equipment. It represents low-cost protection against electrical abuses that are out of the control of the equipment manufacturer.

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