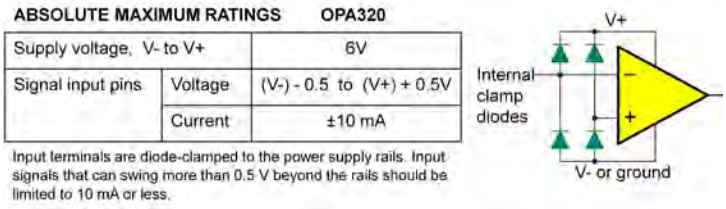
29. Protecting inputs from EOS damage EOS over-voltage

When providing a sensitive amplifier input terminal to the outside world, designers wonder what someone might connect it to or how it might be treated. Will it be treated with care, or could they carelessly plug it into the alternating current (AC) mains? We all would like to make our equipment robust, able to sustain the most brutal treatment, so I will explain how to protect against electrical over-stress (EOS).

The OPA320 is typical of most op amps. The absolute maximum ratings describe the maximum power supply voltage, and the maximum input terminal voltage and current (**Figure 69**). The accompanying note indicates that if you limit input current, you do not need to limit the input voltage. Internal clamp diodes are safe to ±10 mA. However, limiting the current with high-voltage overloads can require a high series input resistance, increasing noise, decreasing bandwidth and possibly creating other errors.



ABSOLUTE MAXIMUM RATINGS **OPA320**

Supply voltage, V- to V+		6V
Signal input pins	Voltage	(V-) - 0.5 to (V+) + 0.5V
	Current	±10 mA

Input terminals are diode-clamped to the power supply rails. Input signals that can swing more than 0.5 V beyond the rails should be limited to 10 mA or less.

Figure 69: Example of an op amp with absolute maximum ratings for power supply voltage and input terminal voltage and current. Internal input clamp diodes shown (right).

The clamp diodes begin conducting when the input voltage exceeds the rails by 0.6 V or so. Many devices can typically tolerate higher current, but the forward voltages increases dramatically – increasing the chance of damage.

You can greatly improve tolerance to higher fault currents and increase the level of protection by adding external diodes. Common signal diodes, such as the ubiquitous 1N4148, typically have a significantly lower forward voltage than the internal clamp diodes.

In bench tests, I found that a variety of 1N4148 diodes in our bin all had forward voltages that are at least 100 mV lower than the internal clamps on our amplifiers. Connected in parallel with the internal ones, the majority of the fault current will flow in the external diode.

Schottky diodes have an even lower forward voltage and may provide improved protection. The disadvantage is that they tend to be very leaky. Reverse leakage current specifications are generally a microamp or more, and that is at room temperature. Leakage rises with temperature.

Beware … you need a solid power supply voltage. Clamp diodes, whether internal or external, rely on a relatively steady power supply voltage to limit the stress. If the offending fault pulse can dump enough current into the power supply rail, raising (or lowering, on V–) the power supply, it can overstress the supply voltage terminal (**Figure 70**). A typical positive linear regulator cannot sink current and cannot be relied upon to hold a steady voltage. Larger supply bypass capacitors can help absorb a large pulse of fault current. Sustained fault current may require a Zener clamp on the power supply. Use a Zener clamp just above the maximum power supply voltage so that it only conducts during a fault. Note that on ± supplies, you would need equivalent protection on the negative side.

These measures still may lead to voltages beyond the rated maximum values, but here is the point: absolute maximum ratings are generally very safe and damage at these voltages or current is extremely unlikely. There is generally a significant margin beyond these ratings where damage is still quite unlikely (but no promises). It is much easier to clamp to a couple volts beyond these ratings, and you are still likely to achieve high survival rate. In many cases, the goal is to dramatically improve the survival rate without great expense or performance compromises.

It is not possible to recommend a one-size-fits-all solution or assure that a particular protection scheme will meet your needs, because application details vary widely. Amplifiers differ in their sensitivity, and the needed level of protection differs dramatically. Sacrifice some amplifiers with some torture testing, if necessary.

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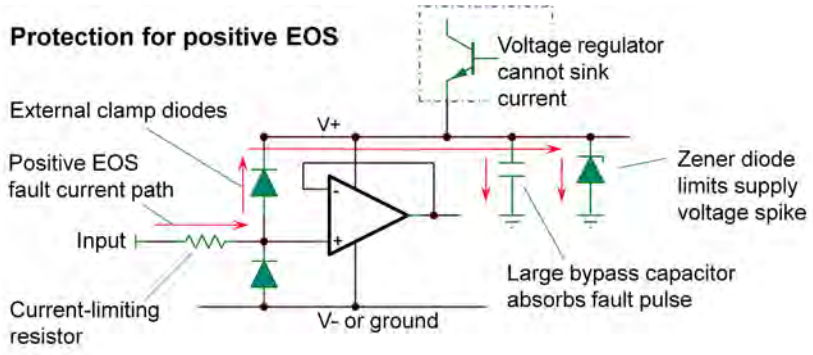

Figure 70: Input over-voltage can create excessive power supply voltage with conduction through the input protection diodes. A Zener diode limits the overstress.