31. Op amps used as comparators: is it okay?

Many of you (and I, too) occasionally use an operational amplifier (op amp) as a comparator. Often, this is when you only need one simple comparator and you have a "spare" op amp in a quad op amp package. The phase compensation required for a stable op amp operation means that it will be very slow as a comparator; however, if speed requirements are modest, the op amp may suffice. We get sporadic questions about this use of an op amp. While some op amps work okay, some don't operate as expected. Why?

Many op amps have voltage clamps between the input terminals, most often implemented with back-to-back diodes (sometimes with two or more diodes in series). These diodes protect the input transistors from reverse breakdown of their base-emitter junctions. With many IC processes, breakdown would occur at approximately 6-V differential input and could significantly alter or damage the transistor. With the negative-positive-negative (NPN) input stage shown in **Figure 74**, D1 and D2 provide the protection.

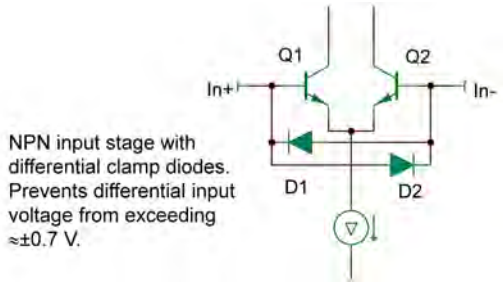

Figure 74: Internal differential clamp diodes in this op amp input stage prevent transistor damage but may create undesirable behavior when used as a comparator.

In most common op amp applications, you have near zero volts across the inputs and never turn on these diodes. But clearly, this protection can be a problem for comparator operation. You have a limited differential voltage range (0.7 V or so) before one input will tug on the other, pulling its voltage in an unexpected manner. This may not rule out its use as a comparator, but it would require some careful consideration. In some circuits, it may be totally unacceptable.

The problem is that TI and other op amp manufacturers have been inconsistent in communicating the presence of these clamps. Even when we do, we may not explain or interpret the message. Maybe we should say, "Be careful if used as a comparator!" The authors of datasheets often just assume that you are going to use an op amp as an op amp. We held a meeting with our team and resolved that we would communicate this more clearly in the future. But what about all the op amps already out there? Following are some guidelines that may help.

In general, op amps with bipolar NPN transistors have input clamps. Examples would be the OP07, OPA227, OPA277, and many others. An exception is the old µA741, which has NPN input transistors, but additional lateral positive-negative-positive (PNP) transistors in series that provided inherent protection for the NPNs (**Figure 75**).

General-purpose op amps with lateral PNP input transistors generally do not have input clamps. Examples include the LM324, LM358, OPA234, OPA2251 and the OPA244. These op amps are

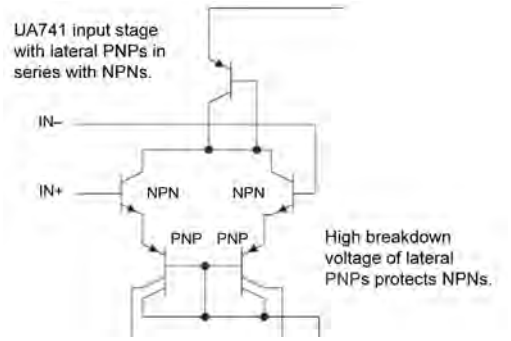

Figure 75: Some op amp input stage types use high breakdown voltage lateral PNPs that protect NPNs. These op amp types are better-suited to comparator operation.

generally "single-supply" types, meaning that they have a common-mode range that extends to the negative supply terminal or slightly below. They often can be identified because the input bias current is listed as a negative number, indicating that input bias current flows out of the input pins. Note, however, that high-speed op amps using PNP inputs generally have input clamps as these are vertical PNPs with lower breakdown voltage.

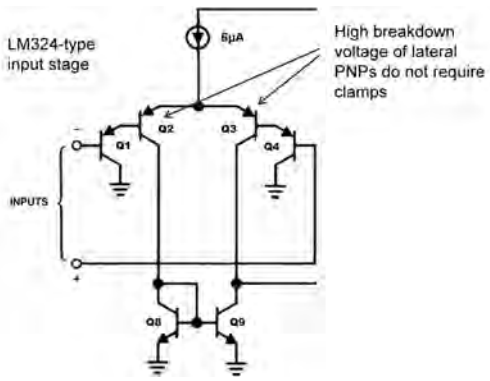

Figure 76: The LM324-type input stage uses high breakdown voltage lateral PNPs and does not require clamps. This op amp type is better-suited to comparator operation.

JFET and CMOS amplifiers that operate on higher voltage (greater than 20 V or so) may or may not have clamps. It is an iffy proposition that requires more checking. The characteristics of the process and the particular transistors used determine whether clamps are present internally.

Most low-voltage CMOS op amps do not have clamps. There is a special exception for auto-zero or chopper types that may have behaviors that look like clamps.

The bottom line ... if you consider using an op amp as a comparator, use caution. Glean what you can from the data sheet, including comments in the applications section. Validate its behavior in a breadboard or prototype, checking for influence of one input voltage on the other. Do not rely on a simulation program with integrated circuit emphasis (SPICE) macromodel. Some macromodels may not include extra components to model the clamps. Furthermore, other behaviors that can arise when you bang an op amp from rail to rail may not be accurately modeled.To see this original post with comments, click here.