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APPLICATION BULLETIN
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CLAMPING AMPLIFIER TRACKS POWER SUPPLIES

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Clamping amplifiers limit signal magnitude to protect following circuitry from input overload. The clamping amplifier shown here produces limit levels that track the power supply levels selected in any given test configuration. Conventional clamping amplifiers set limit levels referenced to ground, rather than the supply levels, and restrict signal swing to the minimum available under minimum supply conditions. However, the clamping amplifier shown automatically adapts the clamp levels to supply changes, maximizing the allowable signal swing.

Traditional clamping amplifiers produce output voltage limits referenced to common. However, the input overload levels of most circuits depend upon voltage levels referenced to the power supplies. There, the internal bias voltage requirements of a circuit define minimum voltage separations between the signal and the power supply levels. This references the overload levels to the supplies, rather than to ground. Ground-referenced limits adequately accommodate these bias requirements where the power supply levels remain relatively fixed. Then, ground-referenced limits simply subtract fixed amounts from the worst-case, low supply levels.

However, power supply levels vary greatly in test systems where control signals set the supply levels. Then, the worst-case setting of ground-referenced limits often sacrifices operation in otherwise safe signal ranges. The clamping amplifier shown adapts to supply variations by referencing the clamp trip points to the supplies rather than to ground. Higher supply voltages then produce higher clamp levels. This avoids lost signal range by adapting the clamping limits to the varying supply versus input capabilities of the following circuit.

Basically, the circuit shown consists of an inverting amplifier formed with the op amp, R_1 and R_2. The remaining components produce the clamping action, provide breakdown protection, and phase compensate the circuit. The zener diodes, transistors and R_3 establish the basic clamp reference voltages. Diodes D_1 and D_2 protect the transistors from emitter-base breakdown and the capacitor compensates the feedback stability complicated by the clamp. The circuit clamps output e_O by diverting feedback current away from R_2. This occurs when e_O reaches a level sufficient to turn on either Q_1 or Q_2. Then, a transistor collector current absorbs any additional signal current supplied through R_1. No further signal current reaches R_2 and this limits the level of e_O.

Zener diodes D_{Z1} and D_{Z2} primarily determine the power supply and clamp level relationships. These zeners establish voltage levels with fixed separations from the supply voltages. Diode D_{Z1} biases the base of Q_1 at $V_- + V_{Z1}$, and D_{Z2} sets the base of Q_2 at $V_+ - V_{Z2}$. These base biases set the clamp transistors for turn on at specific clamp levels. A negative going e_O turns on transistor Q_1 when e_O reaches a level of $V_{L-} = V_- + V_{Z1} - V_{BE1} - V_{D1}$. Then, Q_1 conducts current through its collector, diverting any additional feedback current away from R_2. Any further increase in e_i magnitude simply supplies more current to Q_1 rather than to R_2. This holds the circuit output voltage at the turn-on level V_{L-}. Similarly, a positive going e_O turns on Q_2 when e_O reaches the positive limit of $V_{L+} = V_+ - V_{Z2} + V_{BE2} + V_{D2}$.

With the components shown, $V_Z = 6.2V$ and V_{BE} and $V_D = 0.6V$ producing 10V output limiting for 15V supplies. Tolerance variations in the component voltages introduce a 400mV worst-case error to the clamp voltages. No significant clamp-level error results from the precision OPA77 shown.

However, the clamp circuit adds gain in the feedback loop, compromising feedback stability. When one of the clamp transistors conducts, it acts as a common-base transistor in the feedback loop. This adds a gain of $(R_1 \parallel R_2)/R_E$ to the open-loop gain of the amplifier. Here, R_E represents the impedance of the transistor's emitter circuit and this impedance is quite low. The emitter circuit impedance includes the dynamic emitter impedance of the transistor and the forward impedance of the diode. Feedback analysis[1] shows that this added gain shifts the net open-loop gain upward, exposing a region of two-pole response roll off. Lower closed-loop gains encounter this stability-compromising region. For those cases, the capacitor shown rolls off the load impedance of the common-base transistors, removing the added gain at high frequencies.

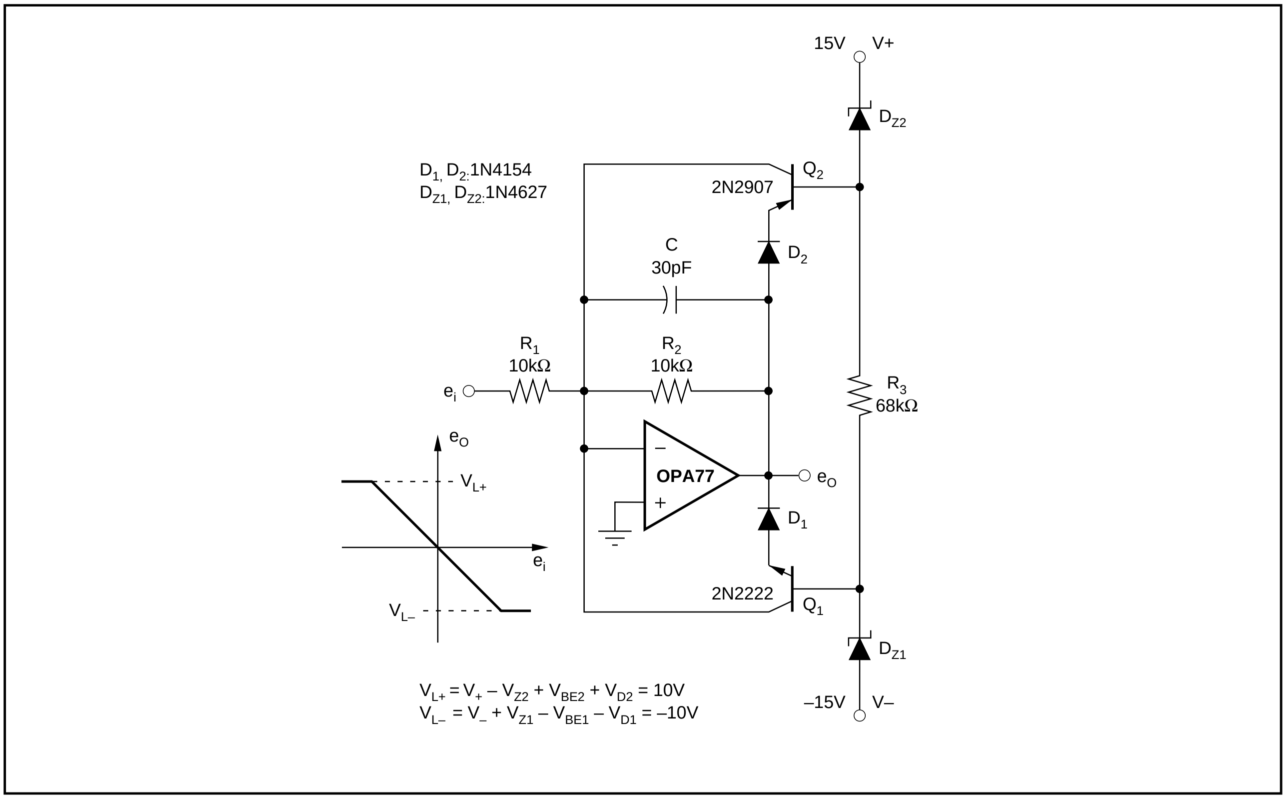

FIGURE 1. The limit levels of a clamping amplifier track the power supply levels when zener diodes establish fixed voltage differences between the two levels.

REFERENCE

1. Graeme, J. G., *Feedback Plots Define Op Amp AC Performance*, Burr-Brown Application Bulletin AB-028, 1991.