Single op amp compares bipolar voltage magnitudes

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The operational-amplifier bridge circuit shown in Fig. 1 is a window comparator for bipolar signals. It indicates when the magnitude of the input signal exceeds a preset value. Selection of resistor values sets positive and negative trigger levels independently, so that the trip levels for the two polarities need not be the same.

To analyze the circuit, first ignore the output clamping diode. The input diodes isolate one of the two signal paths, depending on the polarity of e_i. For e_i positive:

$$e_o = -(e_i - e_d)(R_2/R_1) - e_r(R_2/R_3)$$

where e_d is the voltage drop across the diode when it conducts. For e_i negative:

$$e_o = (e_i + e_d)\frac{[1+(R_2/R_3)+(R_2/R_6)]}{[1+(R_4/R_5)]} - e_r(R_2/R_3)$$

The switch-over points are defined by setting $e_o = 0$ in each of these expressions. For e_i positive:

$$(e_i - e_d) = e_r(R_1/R_3) \quad (1)$$

and for e_i negative:

$$(e_i + e_d) = \frac{-e_r[1+(R_4/R_5)]}{[1+(R_3/R_2)+(R_3/R_6)]} \quad (2)$$

If the positive and negative trip levels must have the same magnitude, then the coefficients of e_r in equations (1) and (2) are equal. The equality reduces to:

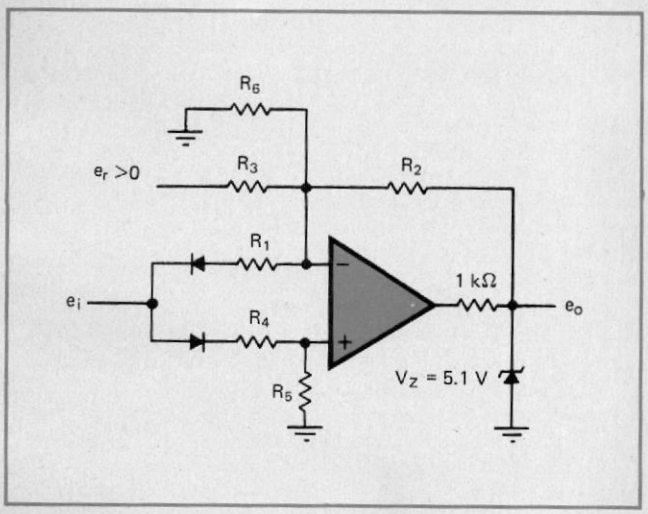
$$[1+(R_3/R_2)+(R_3/R_6)] = [1+(R_4/R_5)](R_3/R_1) \quad (3)$$

If the switching levels are different, equations (1) and (2) must be used to determine the resistor ratios. But regardless of the levels, R_2 is very large and may even be infinite—that is, the circuit may have an open-loop configuration—to provide the maximum gain and thereby produce a sharp transition between the output states at the switch-over points.

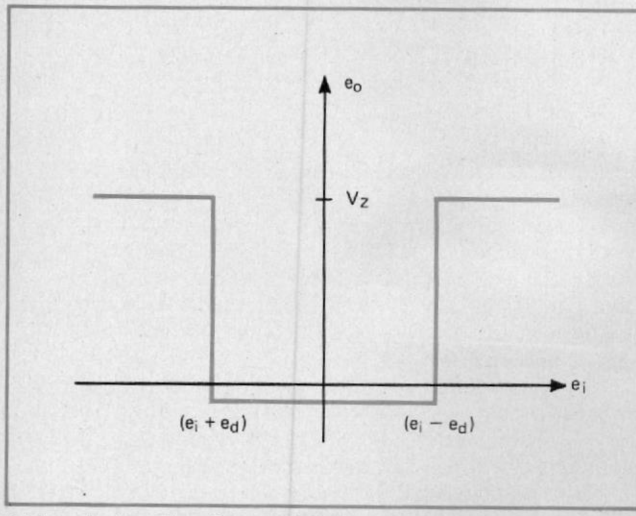
The circuit may be simplified if, for example, the reference voltage is greater than the desired switch-over point. In that case, $R_4 = 0$. If it is less, then R_6 is omitted from the circuit. For symmetrical switching, making $R_4 + R_5$ approximately the same as R_1 equalizes the diode currents, thus more nearly matching the diode forward voltage drops.

If now the output clamp is taken into account, it keeps the lower level of the output from going more than very slightly negative, as shown in Fig. 2. The complement of this transfer function is obtained by changing the polarities of the input diodes and the reference voltage.

As a design example, suppose ±10.0-volt switch-over points are required, and $e_r = 15$ V. Assume $e_d = 0.5$ V, and use 11 kilohms for R_1 and an open circuit for R_2. Equations (1) and (3) show that $R_3 = 17.4$ kilohms, $R_4 = 0$, $R_5 = 11$ kilohms, and $R_6 = 29.9$ kilohms. Building the circuit with these component values results in measured switch-over points of −10.12 and +10.15 V. The actual switching is completed during a change in



1. Comparator. Amplifier output is low when the input is between two levels set by choice of resistances, and high when outside these levels. The two trigger levels are independent.



2. Transfer function. Output clamp keeps low level only a fraction of a volt below ground. The complementary function is obtainable by inverting the two input diodes and the reference voltage.

input of less than a millivolt, because the amplifier gain is high and the open-loop configuration is used.

This simple circuit has some disadvantages. Among these are the forward voltage drops of the input diodes, which are significant. Consequently, the circuit cannot be operated near $e_i = 0$. These voltage drops can be minimized with germanium or hot-carrier diodes.

Another disadvantage is that the switch-over points are temperature-sensitive, because the diode forward drops have a temperature coefficient. Finally, the speed of the circuit depends on the type of operational amplifier and on the clamping scheme. Using a comparator in place of the operational amplifier permits somewhat faster switching. □