Window comparator needs only one op amp

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Diode gating can considerably simplify the circuitry for a window comparator, reducing it to just one operational amplifier, a single voltage reference element, and a diode bridge. A window comparator indicates whether or not a signal is within a given voltage range for applications such as go/no-go testing. Normally, it requires two op amps and two voltage references, as well as an AND gate.

A signal within the comparator's defined range produces a low output state, while a signal above or below that range produces a high output state. In the conventional window comparator, one op amp detects signals above the acceptable range, and the other op amp detects signals below the range,[1] by comparing the signal against separate voltage references. To provide a single comparator output, the signals from the op amps are combined by an AND gate.

For applications where moderate accuracy, say 1%, is acceptable, the circuit shown here can be used. Since only one op amp is required, there is no longer any need for a gate to combine the outputs from two op amps. Also, the same reference element, a zener diode, now serves to define both the upper and lower voltage limits. Because of this common reference element, the upper and lower limits will be well-matched about zero. For limits not centered about zero, the center of the range can be shifted by connecting bias resistors from the power-supply voltages to the appropriate amplifier input.

Through diode gating, the input signal is directed to the proper amplifier input. Input signals above the positive limit forward-bias diode D_1, pulling the zener voltage upward so that diode D_2 is also forward-biased. A positive voltage is now applied to the noninverting input of the amplifier, causing this device's output to swing to its positive state. The upper range limit, therefore, is the zener voltage plus two forward diode drops ($V_Z + 2V_F$).

A positive output swing is also produced by negative input signals that exceed $-V_Z - 2V_F$. These negative signals will forward-bias diodes D_3 and D_4 so that a negative signal appears at the amplifier's inverting input. Signals within the range defined by the positive and negative voltage limits are not passed by the diode bridge to the amplifier, and the amplifier's output is negative because of the bias voltage from resistor R_1.

The accuracy of this comparator is controlled by the diode voltages at low input frequencies and by the amplifier's gain-bandwidth limit at high input frequencies. Since both the zener and diode voltages are subject to tolerance and temperature variations, the range limits can be in error by several percent. To reduce the temperature sensitivity of the range limits, resistors R_2 and R_3 bias the zener so that its thermal voltage variation approximately cancels those of two junction diodes. (The dc voltage shift introduced by resistor R_1 adds to the amplifier's offset voltage error, making this offset error comparatively small.)

At high input frequencies, the comparator error is dominated by the gain-bandwidth-limited output swing of the amplifier from its positive state to its negative state. This transition occurs when the input signal is disconnected from the amplifier by the diode bridge, leaving only the small voltage developed by resistor R_1 at the amplifier's noninverting input. The limited input drive voltage to the amplifier results in a slow output fall time.

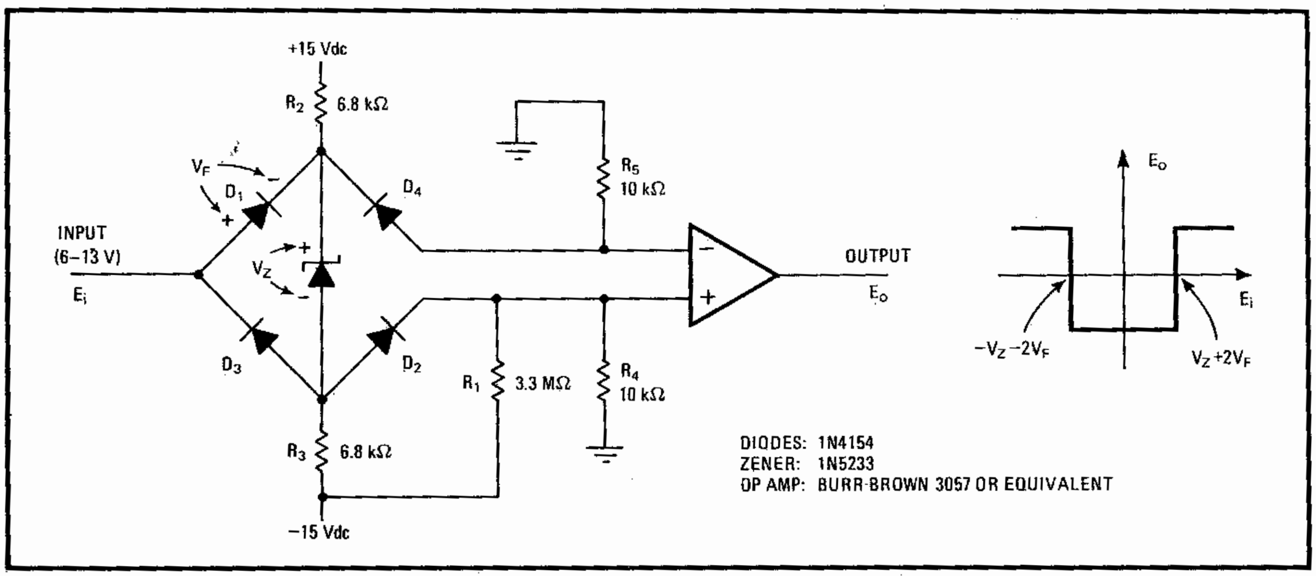
If a compensated op amp is being used in the circuit, its gain-bandwidth product can be improved by removing the device's phase compensation. Or, an uncompensated op amp can be used instead, as is done here. With the uncompensated op amp shown, the window comparator will have a bandwidth of 2 kilohertz and an ac error of only 1%.

There are a couple of other response limitations that should be considered. They are the amplifier's overload recovery delay and the discharging time of the diode capacitances. In order to switch, the amplifier must first recover from its saturated condition—this introduces a time delay. Fortunately, removing the phase compensation from most op amps shortens their overload recovery time.

Another switching delay can be produced by the capacitance discharging time of diodes D_2 and D_4 through resistors R_4 and R_5, respectively. This factor, along with the input resistance, is determined by one of these resistors shunted by either resistor R_2 or R_3. □

REFERENCE

1. "Applications of Operational Amplifiers—Third-Generation Techniques," J. Graeme, McGraw-Hill Inc., 1973.



Saving an op amp. Window comparator for moderate-accuracy applications can be built with only one op amp. The zener diode and the diode bridge determine the circuit's voltage limits, directing positive and negative signals to the appropriate amplifier input. The circuit's output is low for signals within the defined range. D_1 and D_2 conduct for positive signals, while D_3 and D_4 conduct for negative signals.