Single-Rail Noninverting Schmitt Trigger Has Symmetrical Thresholds

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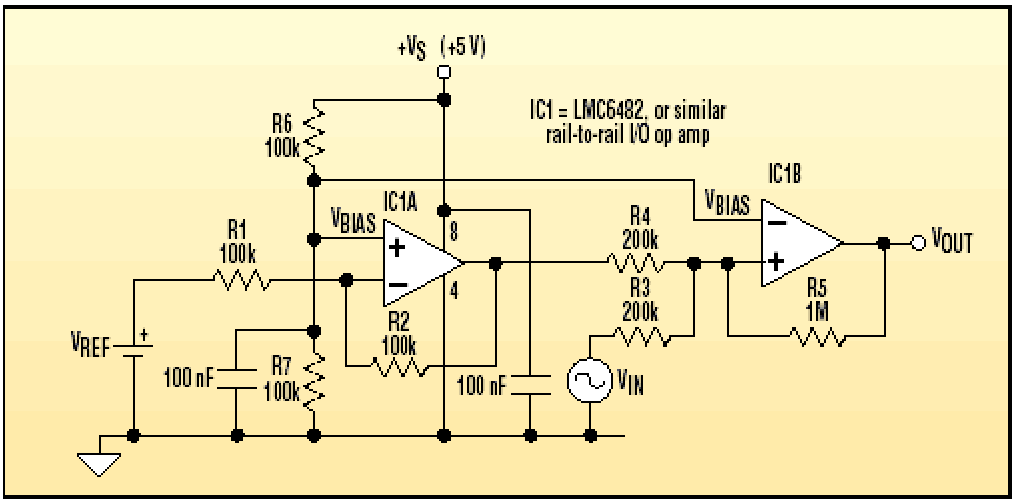
A single-supply, inverting Schmitt trigger was detailed in a previous Idea For Design ("Comparator Features Symmetrical Thresholds," by Samuel Kerem, Electronic Design, March 6, p. 124). The thresholds of this device remained symmetrical about a reference voltage as the reference was varied over a wide range.

For applications requiring a single-rail, noninverting Schmitt trigger, this circuit provides a simpler solution (Fig. 1). Opamp IC1A effectively subtracts the reference voltage (V_{REF}) from a bias voltage (V_{BIAS}) that's generated by R6 and R7. Therefore, the output of IC1A is a dc potential that lies above or below V_{REF}, depending on the magnitude of V_{REF}.



1. This single-supply, noninverting Schmitt trigger has symmetrical thresholds around the reference voltage, V_{REF}. The bias voltage is also dependent only on the values of R6 and R7.

The same bias voltage is used to bias the comparator formed by IC1B. Here, positive feedback via R5 provides the required hysteresis. In a fairly complex manner, the comparator's thresholds rely on V_{REF} and V_{REF}, R1 to R5, and IC1B's output saturation levels. But if we make R1 = R2 and R3 = R4, the relationships are simplified considerably. The equations reduce to:

Upper threshold voltage,

$$V_{TU} = V_{REF} + \frac{R3(V_{BIAS} - V_{SAT-})}{R5}$$

Lower threshold voltage,

$$V_{TL} = V_{REF} + \frac{R3(V_{BIAS} - V_{SAT+})}{R5}$$

where V_{SAT}– and V_{SAT}+ represent IC1B's negative and positive output saturation voltages, respectively. By subtracting V_{TL} from V_{TU}, the hysteresis voltage (V_H) is obtained:

$$V_H = \frac{R3(V_{SAT+} - V_{SAT-})}{R5}$$

Note that V_H is completely independent of V_{REF}. The midpoint of the hysteresis band is simply V_{TL} + $V_H/2$.

$$V_{MIDPT} = (V_{TL} + V_H / 2)$$
$$= V_{REF} + \frac{R3}{R5}\left[V_{BIAS} - \frac{(V_{SAT+} + V_{SAT-})}{2}\right]$$

and by setting

$$V_{BIAS} = \frac{(V_{SAT+} + V_{SAT-})}{2},$$

it can be seen that (V_{TL} + $V_H/2$) = V_{REF}.

In other words, the bias voltage can be set to equal half of the sum of the saturation levels. Doing this will force the midpoint of the hysteresis band to equal the reference voltage, V_{REF}.

The circuit in Figure 1 has several advantages over the previously published idea. It requires only two op amps rather than three, and it uses three fewer resistors. Also, the bias voltage set by R6 and R7 is independent of other resistance values.

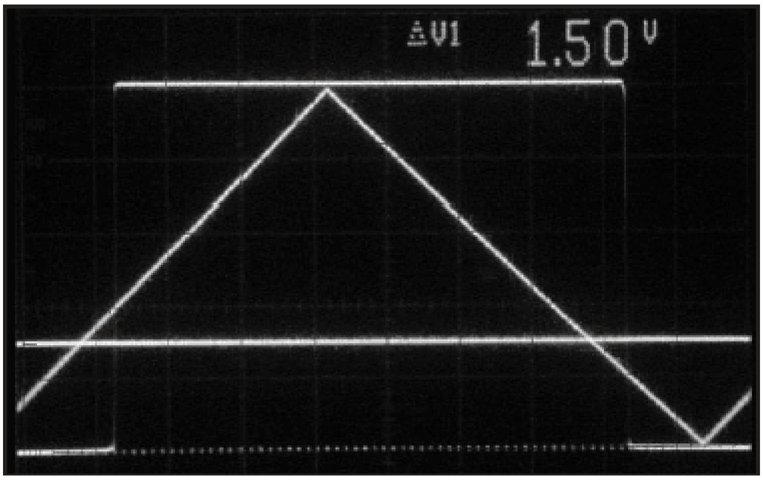
V_{IN}, the input voltage, sees a primarily resistive input impedance that varies between positive and negative as IC1B's output changes state. Therefore, for sources with high output resistance, R3, R4, and R5 should be maximized.

This circuit is particularly well suited for use with rail-to-rail operational amplifiers like the dual LMC6482. When lightly loaded, the LMC6482's output will typically swing within 20 mV of either supply rail. Under these conditions, we can assume V_{SAT}+ = +V_S and V_{SAT}– = 0 such that V_{REF} = +$V_S/2$, requiring that R6 = R7.

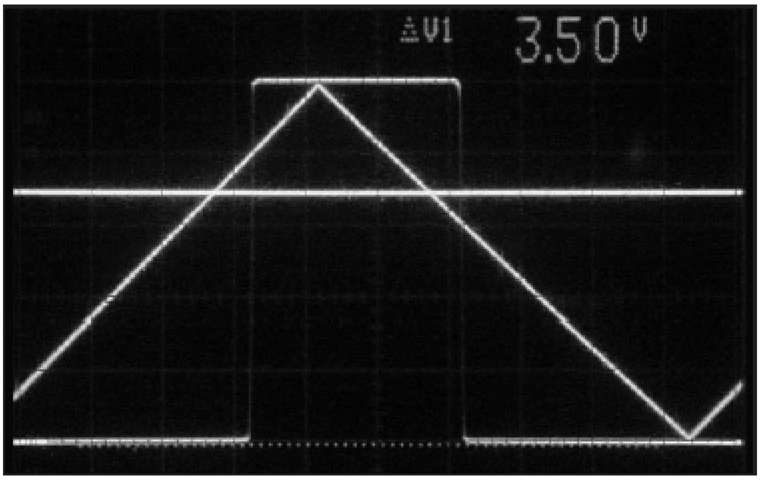
Another benefit of the LMC6482 is its extremely low-input bias current (a maximum of just 4 pA over the full temperature range). This permits the use of large resistance values, which minimizes the loading on V_{IN}. It also helps to keep power consumption low.

Figure 2 achieves its low-frequency performance by using the values shown in Figure 1 and with V_{REF} = 1.5 V (IC1 = LMC6482). For these conditions, the nominal thresholds are V_{TU} = 2 V and V_{TL} = 1 V. As shown, the input triangle wave cuts the rectangular output at 2 V and 1 V (the vertical scale is 1 V/div., while 0 V is indicated by the dotted line). The thresholds are symmetrical about V_{REF}, as represented by the continuous horizontal line.

Increasing V_{REF} to 3.5 V results in thresholds of V_{TU} = 4 V and V_{TL} = 3 V (Fig. 3). Again, the thresholds are symmetrical about V_{REF}.



2. This scope photo illustrates the circuit's symmetric thresholds and excellent low-frequency performance with V_{REF} = 1.5 V.



3. The thresholds remain symmetrical about V_{REF} (V_{TU} = 4 V and V_{TL} = 3 V) even when V_{REF} has been increased to 3.5 V.

Offering a modest slew rate of 1 V/µs, the LMC6482 permits operation only up to a few kilohertz. Beyond this frequency, the apparent threshold values will begin to shift due to the effects of op-amp response time.

For operation at higher frequencies, consider a faster rail-to-rail op amp like the dual LM6142. But be aware that its input bias current is much higher (typically 250 nA). Canceling the effects of higher bias currents demands smaller resistance values. This also applies to the need for minimizing the effects of node capacitances that have a pronounced effect when operating at high frequencies.