Comparator circuit makes versatile Schmitt trigger

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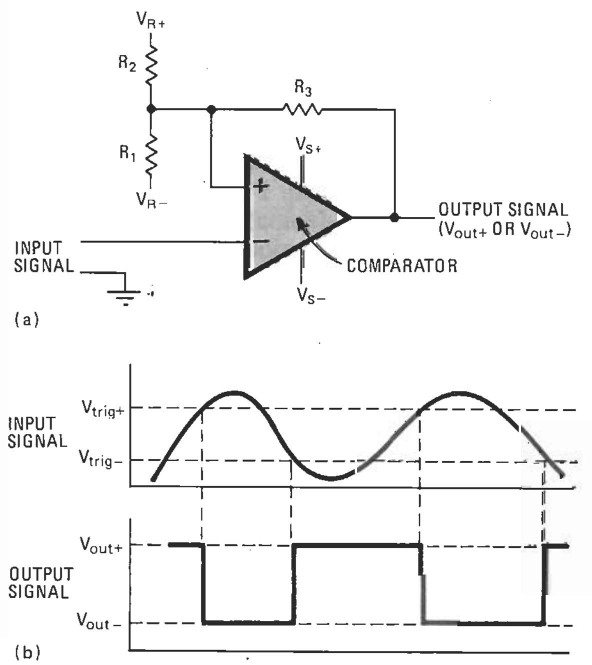
Just three resistors added to a monolithic comparator or operational amplifier are enough to build an inverting Schmitt trigger. What's more, the trigger voltages for switching the output state may easily be set at any values desired if the resistor values are chosen according to the formulas in Fig. 1.

The operation of the circuit is straightforward. When the input signal falls below the voltage at the comparator's noninverting input, the comparator switches on into the output-high state. The high output voltage is fed back through resistor R_3 to the voltage divider circuit R_1R_2, which is connected to the noninverting input. This positive feedback causes the trigger-voltage level to swing to a higher value (V_{trig+}). When the input signal rises to a level above this voltage, the output of the comparator goes to its low value (V_{out-}), pulling the trigger voltage to a lower value (V_{trig-}).

The relative values of resistors R_1, R_2, and R_3 set the trigger points; circuit operation is unaffected if all three are multiplied by a constant. Consequently the formulas yield values for R_2 and R_3 that are ratios of these resistances to the value of R_1, taken to be 1 ohm. Then all three values may be multiplied by a constant to scale them to reasonable resistances. Anything in the range of 1,000 to 50,000 ohms is usually acceptable. In general, each of the resistance values should be less than 1/10 the input resistance of the comparator.

The output voltages of the comparator (V_{out+} and V_{out-}) typically swing within 1 or 2 V of the comparator supply voltages (V_{s+} and V_{s-}). Thus, the desired output-voltage levels determine the supply voltages and hence the choice of comparator.

Figure 2 is an example. The Schmitt trigger in this

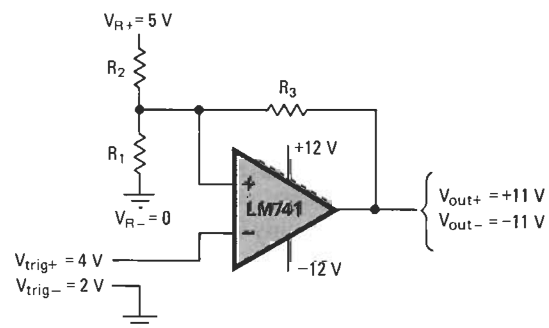


LET $R_1 = 1\,\Omega$

$$R_2 = \frac{(V_{trig-} - V_{R+})(V_{out+} - V_{trig+}) - (V_{trig+} - V_{R+})(V_{out-} - V_{trig-})}{(V_{trig+} - V_{R-})(V_{out+} - V_{trig-}) - (V_{trig-} - V_{R-})(V_{out+} - V_{trig+})}$$

$$R_3 = \frac{R_2 (V_{out+} - V_{trig+})}{R_2 (V_{trig+} - V_{R-}) + V_{trig+} - V_{R+}}$$

1. Design equations. Inverting Schmitt-trigger circuit (a) has triggering voltages and output levels as shown in (b). The circuit diagram and the waveforms illustrate the terms used in the design equations for resistors R_1, R_2, and R_3. The resistance values found from these equations are then scaled up to match the comparator.



LET $R_1 = 1\,\Omega$

$$R_2 = \frac{(2-5)(11-4) - (4-5)(-11-2)}{(4-0)(-11-2) - (2-0)(11-4)} = 0.515\,\Omega$$

$$R_3 = \frac{(0.515)(11-4)}{(0.515)(4-0) + 4 - 5} = 3.40\,\Omega$$

SCALING BY 10,000 GIVES CIRCUIT VALUES

$R_1 = 10{,}000\,\Omega$
$R_2 = 5{,}150\,\Omega$
$R_3 = 34{,}000\,\Omega$

2. Example. Here is an inverting Schmitt circuit intended for trigger voltages of 2 and 4 V, output levels of ±11 V, and a 5-V bias supply. The design equations yield resistance values that are then scaled up by 10,000 to match the National LM741 op amp, chosen because its ±12-V supply voltages bracket the desired output levels.

design requires positive- and negative-going trigger voltages of 4 V and 2 V, respectively, bias voltages of +5 V and ground, and output levels of +11 V and −11 V. The formulas then supply values for R_1, R_2, and R_3 as shown. The supply voltages selected are +12 V and −12 V, making a National LM741 op amp appropriate. Resistor values are then scaled up by a factor of 10,000 to complete the design. □