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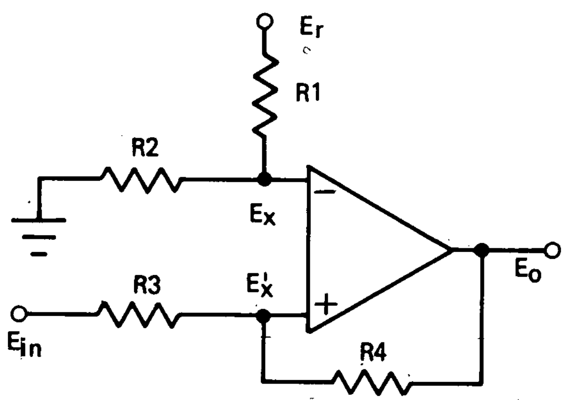
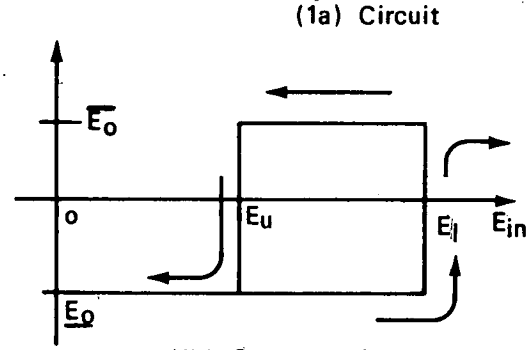
Ames Research Center

Design of Hysteresis Circuits Using Differential Amplifiers

Operational amplifiers, now readily available at relatively low cost, can be used for designing hysteresis circuits with specified characteristics. For example, any differential input amplifier can be converted



(1a) Circuit



(1b) Output vs. Input

Operational Amplifier Schmitt Trigger

to a hysteresis circuit (Schmitt trigger). The circuit to be considered is shown in Figure 1a, and the output vs input in Figure 1b.

The following assumptions simplify the derivation of the design equations: (1) The amplifier input impedance is much larger than the source impedance; (2) the amplifier output impedance is much less than the load impedance; and (3) the amplifier switches state when the differential input voltage is approximately zero. In order to maintain low offset effect, the dc source impedance of both amplifier inputs should be equal. The design equations are derived as follows:

At the switching point:

$$E_x = \frac{R2}{R1 + R2} E_r = E'_x = \frac{R4}{R3 + R4} E_{in} + \frac{R3}{R3 + R4} E_o$$

$$\text{or } E_{in} = \frac{R2\,(R3 + R4)}{R4\,(R1 + R2)} E_r - \frac{R3}{R4} E_o \qquad (1)$$

For low offset:

$$\frac{R1\,R2}{R1 + R2} = \frac{R3\,R4}{R3 + R4} \qquad (2)$$

The following parameters are assumed to be known from specifications:

$E_{in} = E_u$ = input voltage required to switch from high to low output.

$E_{in} = E_l$ = input voltage required to switch from low to high output.

E_r = reference supply voltage.

$\overline{E_o}$ = output voltage in the high state.

$\underline{E_o}$ = output voltage in the low state.

The above knowns can be applied to Eq. (1) for each switching, to yield:

$$E_u = \frac{R2\,(R3 + R4)}{R4\,(R1 + R2)} E_r - \frac{R3}{R4} \overline{E_o} \qquad (3)$$

$$E_l = \frac{R2\,(R3 + R4)}{R4\,(R1 + R2)} E_r - \frac{R3}{R4} \underline{E_o} \qquad (4)$$

(continued overleaf)

These equations relate the desired switching points to the unknown resistors and the given parameters. The equations in this form are useful for error analysis.

Equations (2), (3), and (4) have four unknowns; i.e., R1, R2, R3, and R4. One of the resistors can be selected arbitrarily. Assuming R3 is selected (since it controls the minimum-circuit input impedance), the design equations are:

$$R4 = \frac{R3(\overline{E_o} - \underline{E_o})}{E_l - E_u} \quad (5)$$

$$R1 = \frac{(\overline{E_o} - \underline{E_o})R3\,E_r}{\overline{E_o}\,E_l = \underline{E_o}E_u} \quad (6)$$

$$R2 = \frac{1}{\frac{1}{R4} + \frac{1}{R3} - \frac{1}{R1}} \quad (7)$$

Notes:

1. The technique is useful for designing hysteresis circuits to any given specifications. Examples are: pulse-width, pulse-frequency modulators, and level detectors.
2. An error analysis on the performance of practical hysteresis circuits has been developed.
3. Requests for further information may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
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Patent status:

No patent action is contemplated by NASA.

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