Comparator Series

Hysteresis Setting for Comparator

Contents:

1. Circuit configuration and operation

Hysteresis comparator

A hysteresis comparator is operated by applying a positive feedback* to the comparator. The potential difference between the High and Low output voltages and the feedback resistor are adjusted to change the voltage that is taken as a comparison reference to the input voltage for the +IN terminal. The width of variation in the reference voltage is the hysteresis width.

In this circuits the signal is input to the - IN terminal ,the output is inverted.

Note: A comparator cannot be operated as a hysteresis comparator when a negative feedback is applied.

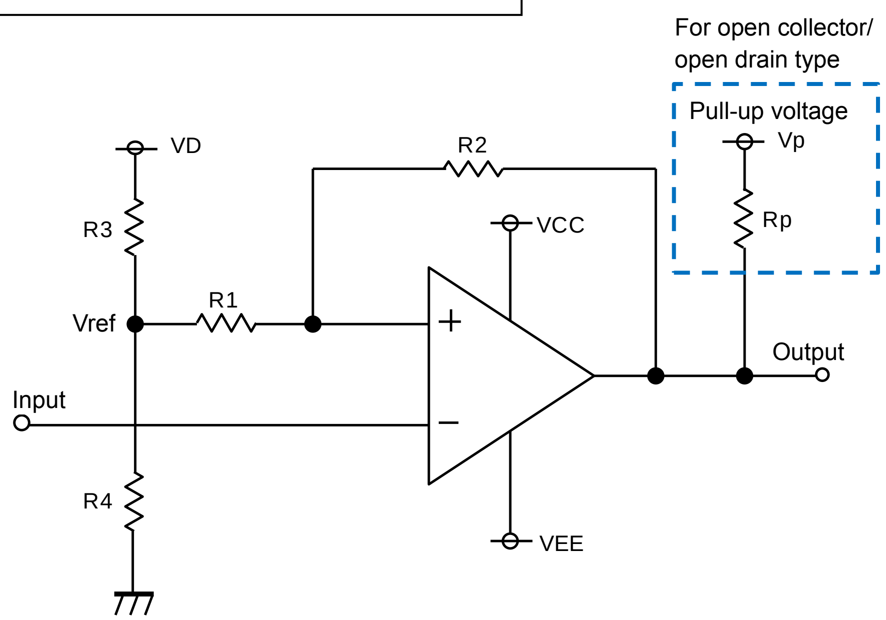

Figure 1. Hysteresis comparator circuit

• Operation without hysteresis

When the input signal and Vref (reference voltage) are nearly equal, exceeding the threshold value due to noise or other causes will destabilize the output. (Chattering occurs)

Figure 2. is Response waveforms of non-hysteresis comparator.

(1) When the input signal (-IN) is applied at a voltage sufficiently higher than Vref(+IN), the output is varied according to Vref as a threshold.

(2) When the input signal (-IN) is applied at a voltage equivalent to Vref(+IN), the input signal may or may not exceed the threshold at Vref due to noise or other causes, resulting in an instability (chattering).

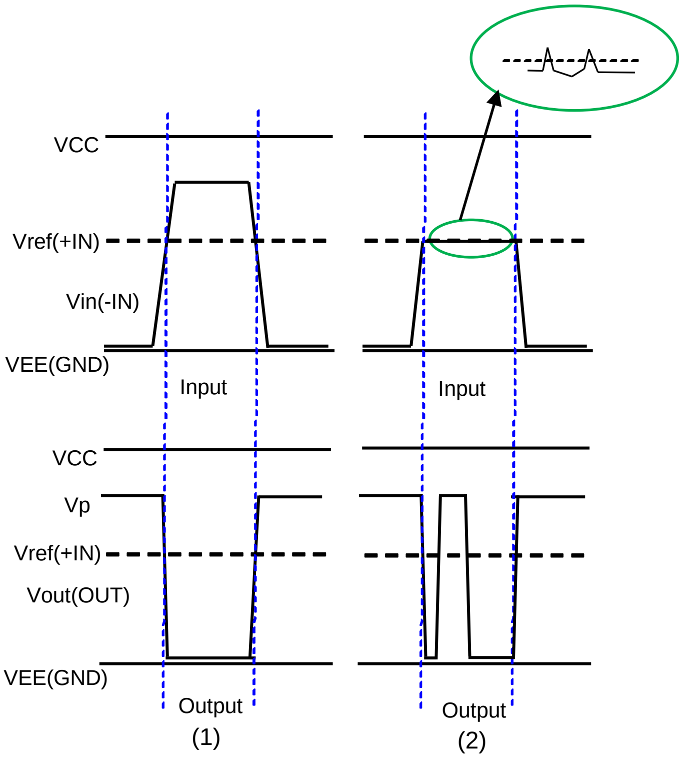

Figure 2. Response waveforms of non-hysteresis comparator

• Operation with hysteresis

Since a margin is provided between the High-to-Low and Low-to-High thresholds, no chattering occurs in the output even when a signal is input at a voltage near the threshold voltages.

Figure 3. is Response waveforms of hysteresis comparator.

(3) When the input signal (-IN) is applied at a voltage sufficiently higher than V_{thH}(+IN) and V_{thL}(+IN), the output is varied according to Vref as a threshold.

(4) When the input signal (-IN) is applied at a voltage equivalent to V_{thH}(+IN) or above, no chattering occurs since the output will not respond unless the input falls below the threshold at V_{thL}(+IN).

V_{thL} is the voltage switching from Low to High.

V_{thH} is the voltage switching from High to Low.

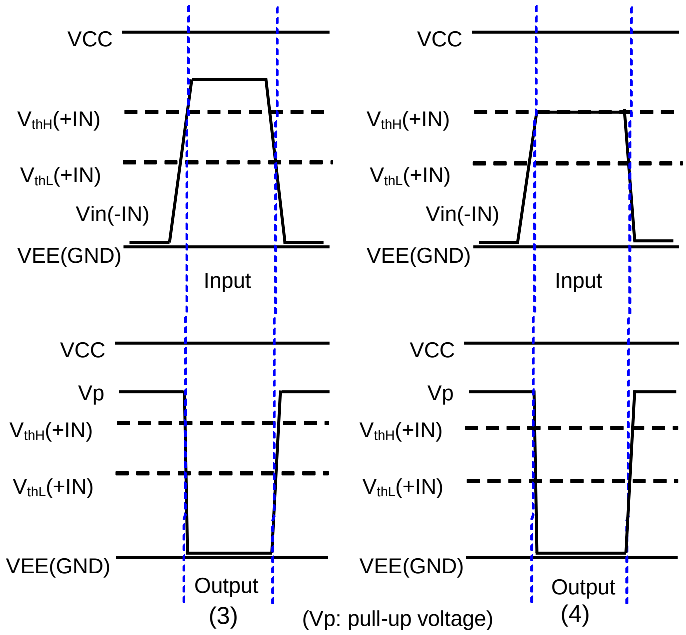

Figure 3. Response waveforms of hysteresis comparator

2. Calculation of threshold voltage (resistance division type)

Derivation of threshold voltage for hysteresis comparator

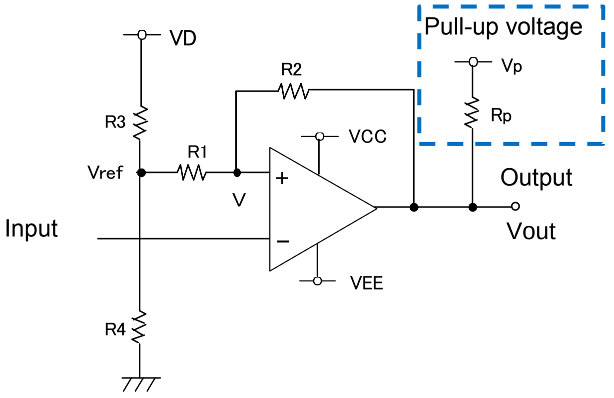

Figure 4. Hysteresis comparator circuit using resistance division

In the circuit configuration shown here, the threshold voltages and the hysteresis width are expressed as follows.

- Threshold voltages

$$V_{thH} = \frac{V_{OH} + \frac{R_2 a}{R_1 R_3} V_D}{\frac{1}{R_1}(R_1 + R_2 - \frac{R_2 a}{R_1})} \qquad V_{thL} = \frac{V_{OL} + \frac{R_2 a}{R_1 R_3} V_D}{\frac{1}{R_1}(R_1 + R_2 - \frac{R_2 a}{R_1})}$$

- Hysteresis width

$$\Delta V_{th} = V_{thH} - V_{thL} \qquad \text{where} \qquad a = \frac{1}{(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4})}$$

Point

- The calculation of the threshold voltages is complicated since it involves many parameters. We suggest inputting the equations in advance with software such as a spreadsheet program to perform the calculation.

Calculation process

Form a current equation for Vref and VD in Figure 4.

$$\frac{V_D - V_{ref}}{R_3} + \frac{V - V_{ref}}{R_1} = \frac{V_{ref}}{R_4} \qquad \text{...(1)}$$

$$\frac{V - V_{ref}}{R_1} = \frac{V_{out} - V}{R_2} \qquad \text{...(2)}$$

Solve equation (2) for Vout.

$$\frac{R_2}{R_1} V - \frac{R_2}{R_1} V_{ref} = V_{out} - V$$

$$V_{out} = (\frac{R_2}{R_1} + 1) V - \frac{R_2}{R_1} V_{ref} \qquad \text{...(3)}$$

Solve equation (1) for Vref.

$$\frac{V_D}{R_3} - \frac{V_{ref}}{R_3} + \frac{V}{R_1} - \frac{V_{ref}}{R_1} = \frac{V_{ref}}{R_4}$$

$$(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}) V_{ref} = \frac{V_D}{R_3} + \frac{V}{R_1}$$

$$V_{ref} = \frac{1}{(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4})} \cdot \frac{V_D}{R_3} + \frac{1}{(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4})} \cdot \frac{V}{R_1}$$

$$V_{ref} = \frac{a}{R_3} V_D + \frac{a}{R_1} V \qquad \text{...(4)} \qquad \text{where} \qquad a = \frac{1}{(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4})}$$

Solving equations (3) and (4) for V allows equation (5) to be obtained.

$$V = \frac{V_{out} + \frac{R_2 a}{R_1 R_3} V_D}{\frac{1}{R_1}(R_1 + R_2 - \frac{R_2 a}{R_1})} \quad ...(5)$$

V provides two threshold voltages for the hysteresis comparator: V_{thL} is the voltage switching from Low to High and V_{thH} is the voltage switching from High to Low.

Vout is the output voltage of the comparator providing two values: VOH is the High output voltage and VOL is the Low output voltage.

3. Calculation of threshold voltage (reference voltage type)

Calculation of threshold voltages for a hysteresis comparator when a reference voltage is provided from a power source or other supplies.

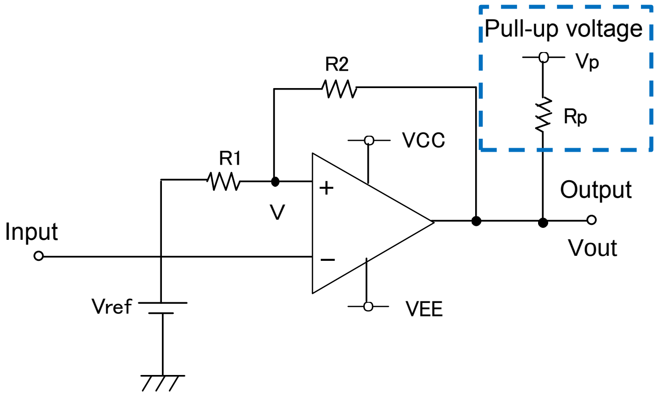

Figure 5. Hysteresis comparator circuit using Vref reference power source

- Threshold voltages

$$V_{thH} = a\frac{R_2}{R_1}V_{ref} + aV_{OH} \qquad a = \frac{1}{1+\frac{R_2}{R_1}}$$

$$V_{thL} = a\frac{R_2}{R_1}V_{ref} + aV_{OL}$$

- Hysteresis width

$$\Delta V_{th} = V_{thH} - V_{thL}$$

Point

- Since there are fewer variables involved in determining the threshold compared with the calculation for the resistance division type, the design flexibility is reduced for the voltage setting.

Form a current equation for Vref and V.

$$\frac{V_{ref} - V}{R_1} = \frac{V - V_{out}}{R_2} \quad ...(1)$$

$$\frac{R_2}{R_1}V_{ref} - \frac{R_2}{R_1}V = V - V_{out}$$

$$\frac{R_2}{R_1}V_{ref} + V_{out} = (1 + \frac{R_2}{R_1})V \quad ...(2)$$

Substitute the coefficient of V with 1/a and solve equation (2) for V

$$a = \frac{1}{1+\frac{R_2}{R_1}} \qquad V = a\frac{R_2}{R_1}V_{ref} + aV_{out} \quad ...(3)$$

Since Vout takes two values, the high level output voltage VOH and the low level output voltage VOL, the threshold voltages V_{thL} and V_{thH} can be expressed as in equation (3).

4. Calculation of threshold voltage (simple type)

Calculation formula for the hysteresis of the simple type hysteresis comparator

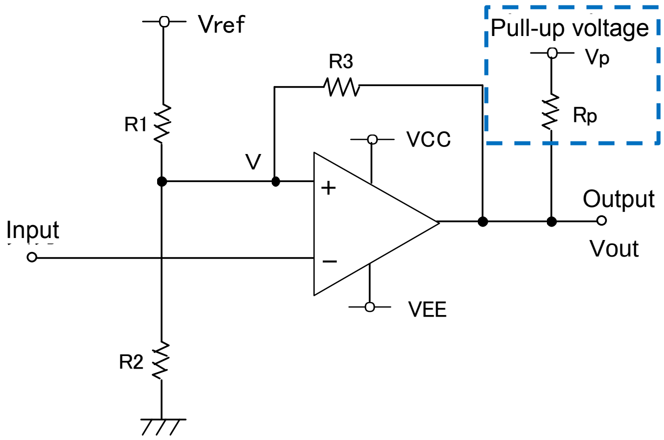

Figure 6. Simple type hysteresis comparator

- Threshold voltages

$$V_{thH} = \frac{a}{R_1}V_{ref} + \frac{a}{R_3}V_{OH} \qquad a = \frac{1}{(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3})}$$

$$V_{thL} = \frac{a}{R_1}V_{ref} + \frac{a}{R_3}V_{OL}$$

- Hysteresis width

$$\Delta V_{th} = V_{thH} - V_{thL}$$

Point

- As there is no input resistance, the design flexibility is reduced for the setting width of the threshold.

Form a current equation for V.

$$\frac{V_{ref}-V}{R_1} - \frac{V}{R_2} - \frac{V_O - V}{R_3} = 0 \quad \text{...(1)}$$

$$\frac{1}{R_1}V_{ref} - \frac{1}{R_1}V - \frac{1}{R_2}V + \frac{1}{R_3}Vo - \frac{1}{R_3}V = 0$$

$$(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3})V = \frac{1}{R_1}V_{ref} + \frac{1}{R_3}Vo$$

$$V = \frac{1}{(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3})}(\frac{1}{R_1}V_{ref} + \frac{1}{R_3}Vo)$$

Substitute the coefficient of V with 1/a and solve equation (2) for V.

$$a = \frac{1}{(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3})} \qquad V = \frac{a}{R_1}V_{ref} + \frac{a}{R_3}V_O \quad \text{...(2)}$$

5. Comparator output voltage (common)

For the output voltages, the same calculation can be used for the resistance division and reference voltage types and simple type.

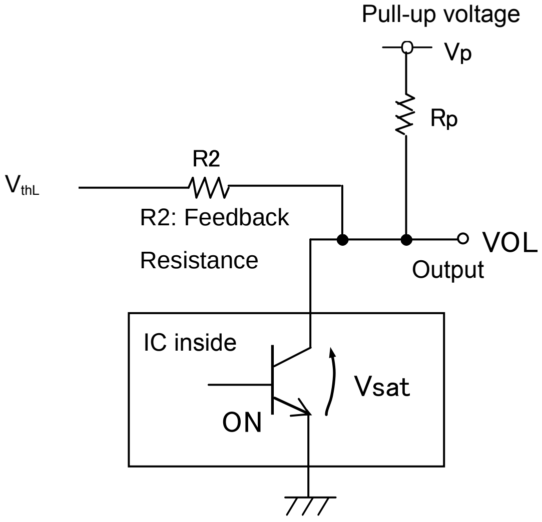

Figure 7. Low voltage output

VOL depends on the current supplied to the IC.
It is estimated from the measurement data.

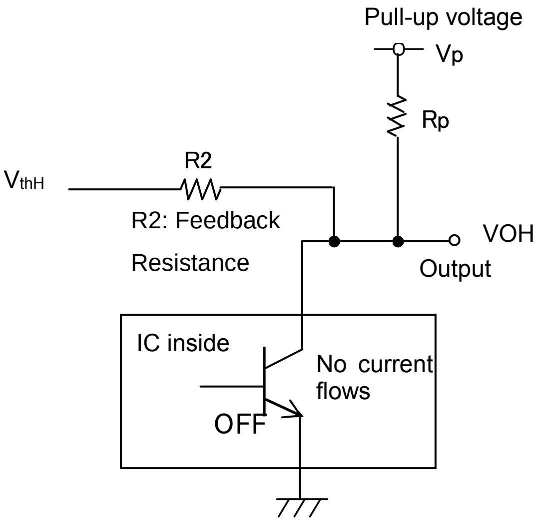

Figure 8. High voltage output

VOH can be calculated since it is determined by the external resistors and the threshold voltage.

$$\frac{V_p - V_{OH}}{R_p} = \frac{V_{OH} - V_{thH}}{R_2}$$

$$\left(\frac{1}{R_2} + \frac{1}{R_p}\right)V_{OH} = \frac{V_p}{R_p} + \frac{V_{thH}}{R_2}$$

$$V_{OH} = \frac{a}{R_p}V_p + \frac{a}{R_2}V_{thH} \qquad a = \frac{1}{\frac{1}{R_2} + \frac{1}{R_p}}$$

Point
- When a circuit is configured with an approximate value of the hysteresis voltage, VOH can be calculated and VOL can be directly measured.

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