Hysteresis Setting for Comparator

Contents:
1. Circuit configuration and operation
2. Calculation of threshold voltage (resistance division type)
3. Calculation of threshold voltage (reference voltage type)
4. Calculation of threshold voltage (simple type)
5. Comparator output voltage (common)

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 circuit 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
Hysteresis Setting for Comparator

• 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).

• 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 VpHu(+IN) and VpLl(+IN), the output is varied according to Vref as a threshold.

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

VpHu is the voltage switching from Low to High. VpLl is the voltage switching from High to Low.

Figure 3. is Response waveforms of hysteresis comparator.
2. Calculation of threshold voltage (resistance division type)

Derivation of threshold voltage for hysteresis comparator

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

- Threshold voltages
  \[ V_{thH} = V_{ref} + \frac{R_2a}{R_1R_3}V_D \]
  \[ V_{thL} = V_{ref} - \frac{R_2a}{R_1R_3}V_D \]

- Hysteresis width
  \[ \Delta V_{th} = V_{thH} - V_{thL} \]

where \( a = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}\right)} \)

Calculation process

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

\[ \frac{V_D - V_{ref}}{R_3} + \frac{V - V_{ref}}{R_1} = \frac{V_{ref}}{R_4} \] \( \text{(1)} \)

\[ \frac{V - V_{ref}}{R_1} = \frac{V_{out} - V}{R_2} \] \( \text{(2)} \)

Solve equation (2) for Vout.

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

\[ V_{out} = \left(\frac{R_2}{R_1} + 1\right)V - \frac{R_2}{R_1}V_{ref} \] \( \text{(3)} \)

Solve equation (1) for Vref.

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

\[ \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}\right)V_{ref} = \frac{V_D}{R_3} + \frac{V}{R_4} \]

\[ V_{ref} = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}\right)} \cdot V_D + \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}\right)} \cdot \frac{V}{R_4} \]

\[ V_{ref} = aV_D + aV \] \( \text{(4)} \)

where \( a = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}\right)} \)

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

\[ V = \frac{V_{in} + \frac{R_2}{R_1} a V_D}{\frac{1}{R_1} (R_2 - \frac{R_2}{R_1})} \]  

...(5)

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

Form a current equation for \( V_{\text{ref}} \) and V.

\[ \frac{V_{\text{ref}} - V}{R_1} = \frac{V - V_{\text{out}}}{R_2} \]  

...(1)

\[ \frac{R_2}{R_1} V_{\text{ref}} - \frac{R_2}{R_1} V = V - V_{\text{out}} \]

\[ \frac{R_2}{R_1} V_{\text{ref}} + V_{\text{out}} = (1 + \frac{R_2}{R_1})V \]  

...(2)

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

\[ a = \frac{1}{\frac{R_2}{R_1}} V = a \frac{R_2}{R_1} V_{\text{ref}} + a V_{\text{out}} \]  

...(3)

Since Vout takes two values, the high level output voltage VOH and the low level output voltage VOL, the threshold voltages \( V_{\text{thL}} \) and \( V_{\text{thH}} \) 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

- **Threshold voltages**
  
  \[ V_{thH} = \frac{a}{R_1} V_{ref} + \frac{a}{R_3} V_{ref} \]
  \[ V_{thL} = \frac{a}{R_1} V_{ref} + \frac{a}{R_3} V_{ref} \]

- **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 \( V \).

\[
\frac{V_{ref} - V}{R_1} - \frac{V}{R_2} - \frac{V_o - V}{R_3} = 0 \quad \text{...(1)}
\]

\[
\frac{1}{R_1} V_{ref} - \frac{1}{R_1} V + \frac{1}{R_2} V + \frac{1}{R_3} V_o - \frac{1}{R_3} V = 0
\]

\[
(\frac{1}{R_1} \frac{1}{R_2} \frac{1}{R_3}) V = \frac{1}{R_1} V_{ref} + \frac{1}{R_3} V_o
\]

\[
V = \frac{1}{(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3})} (\frac{1}{R_1} V_{ref} + \frac{1}{R_3} V_o)
\]

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

\[
a = \frac{1}{(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3})} \quad V = \frac{a}{R_1} V_{ref} + \frac{a}{R_3} V_o \quad \text{...(2)}
\]
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.

\[
V_{\text{VOL}} = \frac{V_p - V_{\text{OH}}}{R_p} = \frac{V_{\text{OH}} - V_{\text{thH}}}{R_2}
\]

\[
(\frac{1}{R_2} + \frac{1}{R_p})V_{\text{OH}} = \frac{V_p}{R_p} + \frac{V_{\text{thH}}}{R_2}
\]

\[
V_{\text{OH}} = \frac{a}{R_p} V_p + \frac{a}{R_2} V_{\text{thH}} \quad a = \frac{1}{R_2 + \frac{1}{R_p}}
\]

Figure 7. Low voltage output

Figure 8. High voltage output

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

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications:

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors. Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Products beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products are intended for use in general electronic equipment (i.e. AV/OA devices, communication, consumer systems, gaming/entertainment sets) as well as the applications indicated in this document.

7) The Products specified in this document are not designed to be radiation tolerant.

8) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative: transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

9) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

10) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

11) ROHM has used reasonable care to ensure the accuracy of the information contained in this document. However, ROHM does not warrants that such information is error-free, and ROHM shall have no responsibility for any damages arising from any inaccuracy or misprint of such information.

12) Please use the Products in accordance with any applicable environmental laws and regulations, such as the RoHS Directive. For more details, including RoHS compatibility, please contact a ROHM sales office. ROHM shall have no responsibility for any damages or losses resulting non-compliance with any applicable laws or regulations.

13) When providing our Products and technologies contained in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Foreign Exchange and Foreign Trade Act.

14) This document, in part or in whole, may not be reprinted or reproduced without prior consent of ROHM.

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

ROHM Customer Support System

http://www.rohm.com/contact/