

How to Use the Hysteresis Comparator Circuits

The comparator is a device frequently used in circuit design, which can be simply understood as a circuit that compares an analog signal with a reference voltage. The commonly used single-limit comparator circuit has high sensitivity but poor anti-interference performance. Even slight jitter near the threshold causes frequent level changes at the output voltage, as shown in Figure 1.

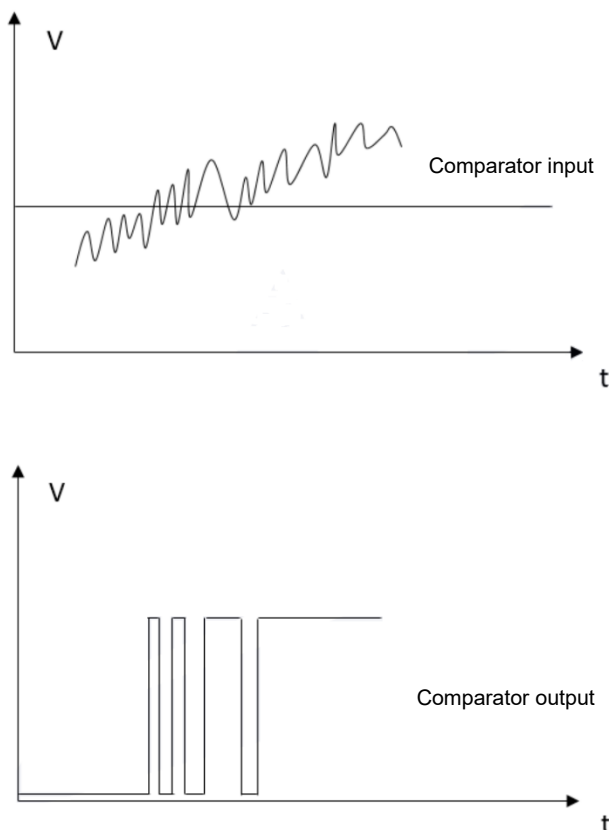


Figure 1: Frequent Level Changes at The Output of a Non-Hysteretic Comparator Due to Input Jitter

This is because the comparator is an

operational amplifier that operates in an open-loop state, so any jitter at the input causes this problem.

The vast majority of comparators are designed with hysteresis circuits, typically with a hysteresis voltage of 5 mV to 10 mV. This internal hysteresis can prevent comparator output oscillation caused by input jitter. However, if the signal jitter is large, the internal hysteresis doesn't effectively prevent this issue. Thus, an external hysteresis circuit is needed to reduce the output jitter caused by the input jitter. Hysteresis is not a threshold point but creates different rising and falling thresholds. This keeps the output in a low or high state.

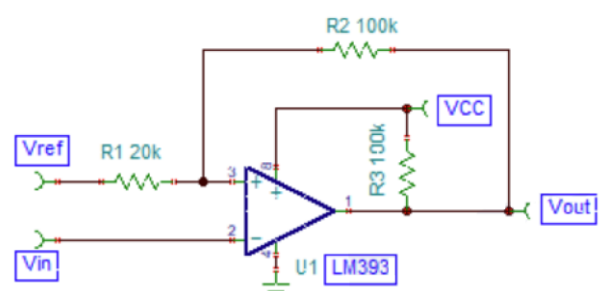


Figure 2-a: Typical Circuit of a Hysteresis Comparator

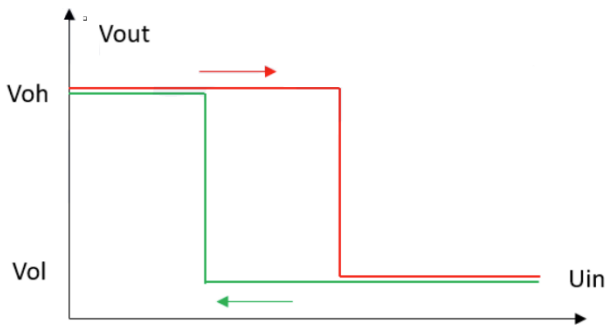


Figure 2-b: Transfer Characteristic Graph

Figure 2 shows a hysteresis comparator circuit, which can be understood as a comparator with positive feedback. From the transfer characteristic graph, it can be seen that after the output state changes, the output voltage is stable as long as the jitter voltage value does not exceed ΔU . However, sensitivity is sacrificed, and voltage values less than ΔU cannot be distinguished.

Because of the feedback, the threshold voltage of this type of comparator varies with the output voltage. Its sensitivity is lower, but its anti-interference ability is greatly improved. Several hysteresis comparator circuits are introduced below.

1. Using an Operational Amplifier to Form a Hysteresis Comparator

1.1 Input Signal into the Negative Input of the Operational Amplifier

As shown in the Figure 3 we use the LM358, which is a general-purpose operational amplifier, to form a hysteresis comparator

circuit and use a Zener diode as the reference point. The 500- Ω resistor is the Current limit for the Zener diode resistor.

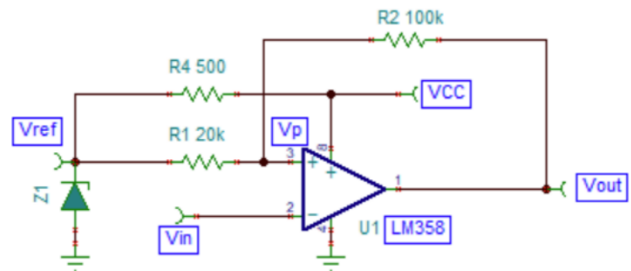


Figure 3: Hysteresis Comparator Circuit A (signal input from the negative input of the operational amplifier)

According to the principle of voltage superposition,

$$V_p = V_{ref} \times \frac{R_2}{(R_1 + R_2)} + V_{out} \times \frac{R_1}{(R_1 + R_2)}$$

The threshold is:

$$U_h = V_{ref} \times \frac{R_2}{(R_1 + R_2)} + V_{oh} \times \frac{R_1}{(R_1 + R_2)}$$

$$U_l = V_{ref} \times \frac{R_2}{(R_1 + R_2)} + V_{ol} \times \frac{R_1}{(R_1 + R_2)}$$

The threshold width is:

$$\Delta U = U_h - U_l = (V_{oh} - V_{ol}) \times \frac{R_1}{(R_1 + R_2)}$$

Where V_{oh} is the potential of VCC, and V_{ol} is the potential of GND.

It should be noted that because LM358 is a non-

rail-to-rail output operational amplifier, the calculation of the threshold voltage needs to consider the situation where the output cannot reach the rail. Therefore, the upper threshold calculation needs to be modified to:

$$U_h = V_{ref} \times \frac{R_2}{(R_1+R_2)} + (V_{CC} - 1.5) \times \frac{R_1}{(R_1+R_2)}$$

The LM358A from 3PEAK can achieve rail-to-rail output, so non-rail-to-rail effects can be ignored when calculating.

In addition, attention should be paid to the V_{ref} error caused by the individual differences of the Zener diode. It can use a resistor divider and a voltage follower circuit to form a reference voltage.

1.2 Input Signal into the Positive Input of the Operational Amplifier

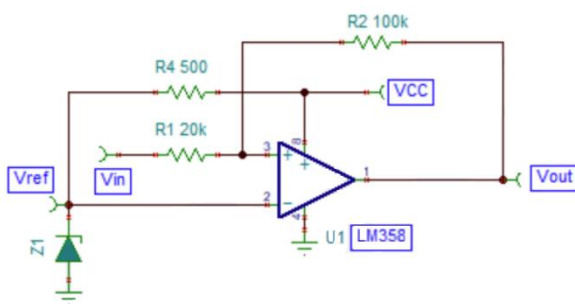


Figure 4: Hysteresis Comparator Circuit B (signal input from the positive input of the operational amplifier)

If the signal is input into the positive input of the operational amplifier, then:

$$V_{ref} = V_{out} \times \frac{20K}{(100K+20K)} + V_{in} \times \frac{100K}{(100K+20K)}$$

Thus, we get

$$U_h = V_{ref} \times \frac{(100K + 20K)}{100K} - V_{oh} \times \frac{20K}{100K}$$

$$U_l = V_{ref} \times \frac{(100K + 20K)}{100K} - V_{ol} \times \frac{20K}{100K}$$

(2)

Note that the output transfer characteristic curve of the two methods is different, and the choice of which method to use depends on the actual output voltage requirements.

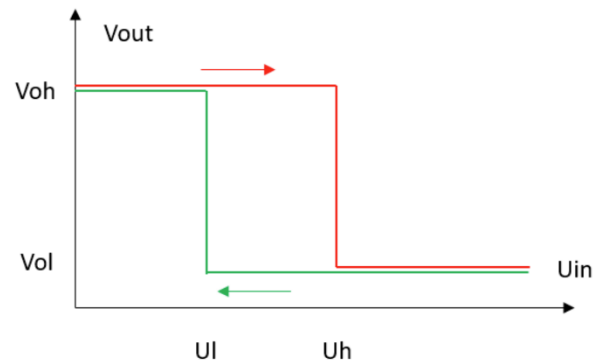


Figure 5: Output Transfer Characteristic Curve of Hysteresis Comparator Circuit A

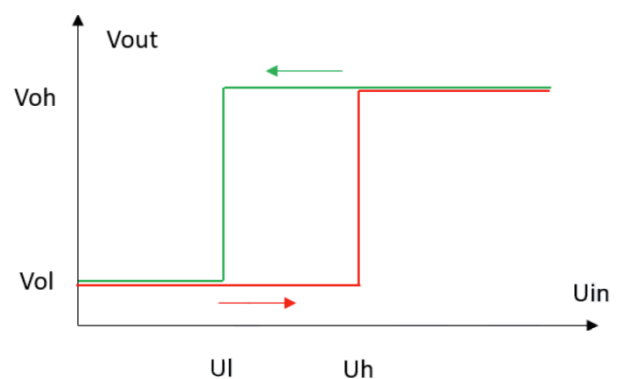


Figure 6: Output Transfer Characteristic Curve of Hysteresis Comparator Circuit B

2. Using a General Comparator to Form a

Hysteresis Comparator

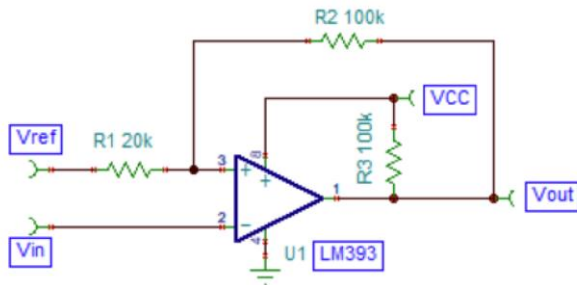


Figure 7: Hysteresis Comparator Composed of General Comparator

As shown in Figure 7, the general comparator LM393 is used. Because the output of the LM393 is an OC or OD structure, a pull-up resistor of about 100 k is added to the output. The increase in this resistor causes a certain change in the threshold voltage, which needs to be considered when calculating:

$$U_h = V_{ref} \times \frac{(R_2 + R_3)}{(R_1 + R_2 + R_3)} + V_{CC} \times \frac{R_1}{(R_1 + R_2 + R_3)}$$

$$U_l = V_{ref} \times \frac{R_2}{(R_1 + R_2)} + V_{ol} \times \frac{R_1}{(R_1 + R_2)}$$

Where V_{ol} is GND. Therefore,

$$U_l = V_{ref} \times \frac{R_2}{(R_1 + R_2)}$$

It can be seen that the output pull-up resistor and the pull-up voltage affect the threshold,

which increases the complexity of the calculation. If a comparator with push-pull output is used, the output pull-up resistor can be eliminated.

The TP201x/TP194x/TP196x/TP198x from 3PEAK are all comparators with push-pull output. The difference among them lies mainly in the transmission delay and power consumption.

3. Adding a Diode in Feedback Can Simplify the Calculation Formula

By adding a diode in the positive feedback circuit, the calculation formula of the threshold voltage can be simplified as follows:

(2)

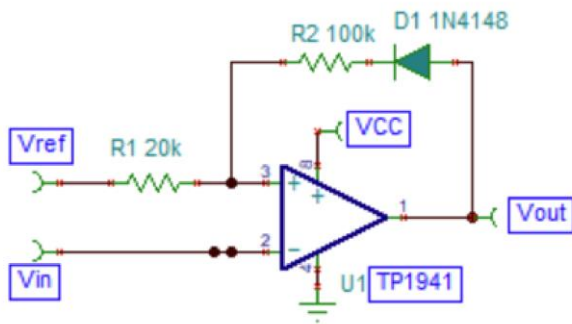
$$U_h = (V_{oh} - V_{diodes}) \times \frac{R_1}{(R_1 + R_2)} + V_{ref}$$

$$U_l = (V_{ol} - V_{diodes}) \times \frac{R_1}{(R_1 + R_2)} + V_{ref}$$

Since V_{ol} is 0, no current flows through D1, so

$$U_l = V_{ref}$$

Where V_{oh} is VCC, and V_{ol} is GND.



We hope that this article can help readers in designing hysteresis comparator circuits.