Schmitt Trigger or Regenerative Comparator Circuit

A Schmitt trigger circuit is also called a regenerative comparator circuit. The circuit is designed with a positive feedback and hence will have a regenerative action which will make the output switch levels. Also, the use of positive voltage feedback instead of a negative feedback, aids the feedback voltage to the input voltage, instead of opposing it. The use of a regenerative circuit is to remove the difficulties in a zero-crossing detector circuit due to low frequency signals and input noise voltages. Shown below is the circuit diagram of a Schmitt trigger. It is basically an inverting comparator circuit with a positive feedback. The purpose of the Schmitt trigger is to convert any regular or irregular shaped input waveform into a square wave output voltage or pulse. Thus, it can also be called a squaring circuit.

As shown in the circuit diagram, a voltage divider with resistors Rdiv1 and Rdiv2 is set in the positive feedback of the 741 IC op-amp. The same values of Rdiv1 and Rdiv2 are used to get the resistance value Rpar = Rdiv1||Rdiv2 which is connected in series with the input voltage. Rpar is used to minimize the offset problems. The voltage across R1 is feedback to the non-inverting input.
The input voltage \( V_i \) triggers or changes the state of output \( V_{out} \) every time it exceeds its voltage levels above a certain threshold value called Upper Threshold Voltage (\( V_{upt} \)) and Lower Threshold Voltage (\( V_{lpt} \)).

Let us assume that the inverting input voltage has a slight positive value. This will cause a negative value in the output. This negative voltage is fed back to the non-inverting terminal (+) of the op-amp through the voltage divider. Thus, the value of the negative voltage that is fed back to the positive terminal becomes higher. The value of the negative voltage becomes again higher until the circuit is driven into negative saturation (\( -V_{sat} \)). Now, let us assume that the inverting input voltage has a slight negative value. This will cause a positive value in the output. This positive voltage is fed back to the non-inverting terminal (+) of the op-amp through the voltage divider. Thus, the value of the positive voltage that is fed back to the positive terminal becomes higher. The value of the positive voltage becomes again higher until the circuit is driven into positive saturation (\( +V_{sat} \)). This is why the circuit is also named a regenerative comparator circuit.

![Schmitt Trigger Input and Output Waveform](www.CircuitsToday.com)

Schmitt Trigger Input and Output Waveform
When \( V_{\text{out}} = +V_{\text{sat}} \), the voltage across \( R_{\text{div1}} \) is called Upper Threshold Voltage (\( V_{\text{upt}} \)). The input voltage, \( V_{\text{in}} \) must be slightly more positive than \( V_{\text{upt}} \) inorder to cause the output \( V_{\text{out}} \) to switch from \(+V_{\text{sat}}\) to \(-V_{\text{sat}}\). When the input voltage is less than \( V_{\text{upt}} \), the output voltage \( V_{\text{out}} \) is at \(+V_{\text{sat}}\).

**Upper Threshold Voltage, \( V_{\text{upt}} = +V_{\text{sat}} \left( \frac{R_{\text{div1}}}{R_{\text{div1}} + R_{\text{div2}}} \right) \)**

When \( V_{\text{out}} = -V_{\text{sat}} \), the voltage across \( R_{\text{div1}} \) is called Lower Threshold Voltage (\( V_{\text{lpt}} \)). The input voltage, \( V_{\text{in}} \) must be slightly more negative than \( V_{\text{lpt}} \) inorder to cause the output \( V_{\text{out}} \) to switch from \(-V_{\text{sat}}\) to \(+V_{\text{sat}}\). When the input voltage is less than \( V_{\text{lpt}} \), the output voltage \( V_{\text{out}} \) is at \(-V_{\text{sat}}\).

**Lower Threshold Voltage, \( V_{\text{lpt}} = -V_{\text{sat}} \left( \frac{R_{\text{div1}}}{R_{\text{div1}} + R_{\text{div2}}} \right) \)**

If the value of \( V_{\text{upt}} \) and \( V_{\text{lpt}} \) are higher than the input noise voltage, the positive feedback will eliminate the false output transitions. With the help of positive feedback and its regenerative behaviour, the output voltage will switch fast between the positive and negative saturation voltages.

**Hysteresis Characteristics**

Since a comparator circuit with a positive feedback is used, a dead band condition hysteresis can occur in the output. When the input of the comparator has a value higher than \( V_{\text{upt}} \), its output switches from \(+V_{\text{sat}}\) to \(-V_{\text{sat}}\) and reverts back to its original state, \(+V_{\text{sat}}\), when the input value goes below \( V_{\text{lpt}} \). This is shown in the figure below. The hysteresis voltage can be calculated as the difference between the upper and lower threshold voltages.

\[
V_{\text{hysteresis}} = V_{\text{upt}} - V_{\text{lpt}}
\]

Substituting the values of \( V_{\text{upt}} \) and \( V_{\text{lpt}} \) from the above equations:

\[
V_{\text{hysteresis}} = +V_{\text{sat}} \left( \frac{R_{\text{div1}}}{R_{\text{div1}} + R_{\text{div2}}} \right) - \{-V_{\text{sat}} \left( \frac{R_{\text{div1}}}{R_{\text{div1}} + R_{\text{div2}}} \right)\}
\]

\[
V_{\text{hysteresis}} = \left( \frac{R_{\text{div1}}}{R_{\text{div1}} + R_{\text{div2}}} \right) \{+V_{\text{sat}} - (-V_{\text{sat}})\}
\]
Applications of Schmitt Trigger

Schmitt trigger is mostly used to convert a very slowly varying input voltage into an output having abruptly varying waveform occurring precisely at certain predetermined value of input voltage. Schmitt trigger may be used for all applications for which a general comparator is used. Any type of input voltage can be converted into its corresponding square signal wave. The only condition is that the input signal must have large enough excursion to carry the input voltage beyond the limits of the hysteresis range. The amplitude of the square wave is independent of the peak-to-peak value of the input waveform.

Source: http://www.circuitstoday.com/schmitt-trigger-using-op-amp