Hysteresis comparators

Simple comparators have two drawbacks:

- For a very slowly varying input output switching can be rather slow.
- For a noisy input signal the output may make several undesirable transitions (commutations) as the input passes through the threshold voltage value (trigger point).

How can we implement such a VTC?
Solution:

- Two threshold values $V_{ThH}$ and $V_{ThL}$
- Two distinct output values: $V_{OH}$ and $V_{OL}$
- The commutation takes place at $V_{ThH}$ only if $v_o = V_{OH}$
- The commutation takes place at $V_{ThL}$ only if $v_o = V_{OL}$

$\Rightarrow$ The threshold values should depend on the output value $\rightarrow$ The output voltage should be fed back to the input to contribute to the threshold values:

*positive feedback* (PF) (to strengthen the effect)

- Feeding back one fraction of the output voltage to the non-inverting input by means of a resistive divider
Inverting hysteresis comparator

\[
\begin{align*}
  v^+ &= \frac{R_1}{R_1 + R_2} v_O, \quad v^- = v_I \\
  v_D &= \frac{R_1}{R_1 + R_2} v_O - v_I \\
  v_O &= \frac{R_1}{R_1 + R_2} v_O = V_{TH} \\
  V_{ThH} &= \frac{R_1}{R_1 + R_2} V_{OH} \\
  V_{ThL} &= \frac{R_1}{R_1 + R_2} V_{OL}
\end{align*}
\]
\[ \Delta V_{Th} = V_{ThH} - V_{ThL} = \frac{R_1}{R_1 + R_2} (V_{OH} - V_{OL}) \]

- moving direction on the hysteresis
- at a certain moment only one threshold is “active”
- hysteresis comparators are bistable circuits
- the input signal triggers the switching of the output, the switching process being sustained by the PF
- suppose \( v_O = V_{OL}, \ \nu_I > V_{ThL}, \ \nu_I \downarrow \), when \( \nu_I \) passes through \( V_{ThL} \)

\[ \nu_I \downarrow, \ \nu_D \uparrow, \ \nu_O \uparrow, \ \nu^+\uparrow, \ \nu_D\uparrow, \ \nu_O \uparrow \] \( \text{PF} \)
- once the \( \nu_O \) starts to change its value the transition is sustained by the circuit itself due to its PF
  \( \Rightarrow \) fast (accelerated) switching
- Bistable multivibrator circuit or Schmitt triggers
Illustration

[Diagram of an electronic circuit with resistors and an operational amplifier.]

- $R_I$: 4K ohms
- $R_2$: 8K ohms
- $v_I$: Input voltage
- $v_O$: Output voltage
- $+12V$: Positive supply voltage
- $-12V$: Negative supply voltage
Inverting comparator with asymmetric thresholds

\[ v^+ = \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} V_{REF} \]

\[ v_D = v^+ - v^- = \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} V_{REF} - v_I \]

\[ V_{ThL} = \frac{R_1}{R_1 + R_2} V_{OL} + \frac{R_2}{R_1 + R_2} V_{REF} \]

\[ V_{ThH} = \frac{R_1}{R_1 + R_2} V_{OH} + \frac{R_2}{R_1 + R_2} V_{REF} \]
Non-inverting hysteresis comparators

\[ v_D = v^+ - v^- = \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} v_I - 0 \]

\[ \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} V_P = 0 \]

\[ V_{Th} = -\frac{R_1}{R_2} v_O \]

\[ V_{ThL} = -\frac{R_1}{R_2} V_{OH} \]

\[ V_{ThH} = -\frac{R_1}{R_2} V_{OL} \]
\[ v_D = v^+ - v^- = \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} v_I - V_{REF} \]

\[ V_{THH} = -\frac{R_1}{R_2} v_{OL} + \left(1 + \frac{R_1}{R_2}\right) V_{REF} = -\frac{1}{5}(-10) + \left(1 + \frac{1}{5}\right)(-5) = -4 \text{ V} \]

\[ V_{THL} = -\frac{R_1}{R_2} v_{OH} + \left(1 + \frac{R_1}{R_2}\right) V_{REF} = -\frac{1}{5}(10) + \left(1 + \frac{1}{5}\right)(-5) = -8 \text{ V} \]