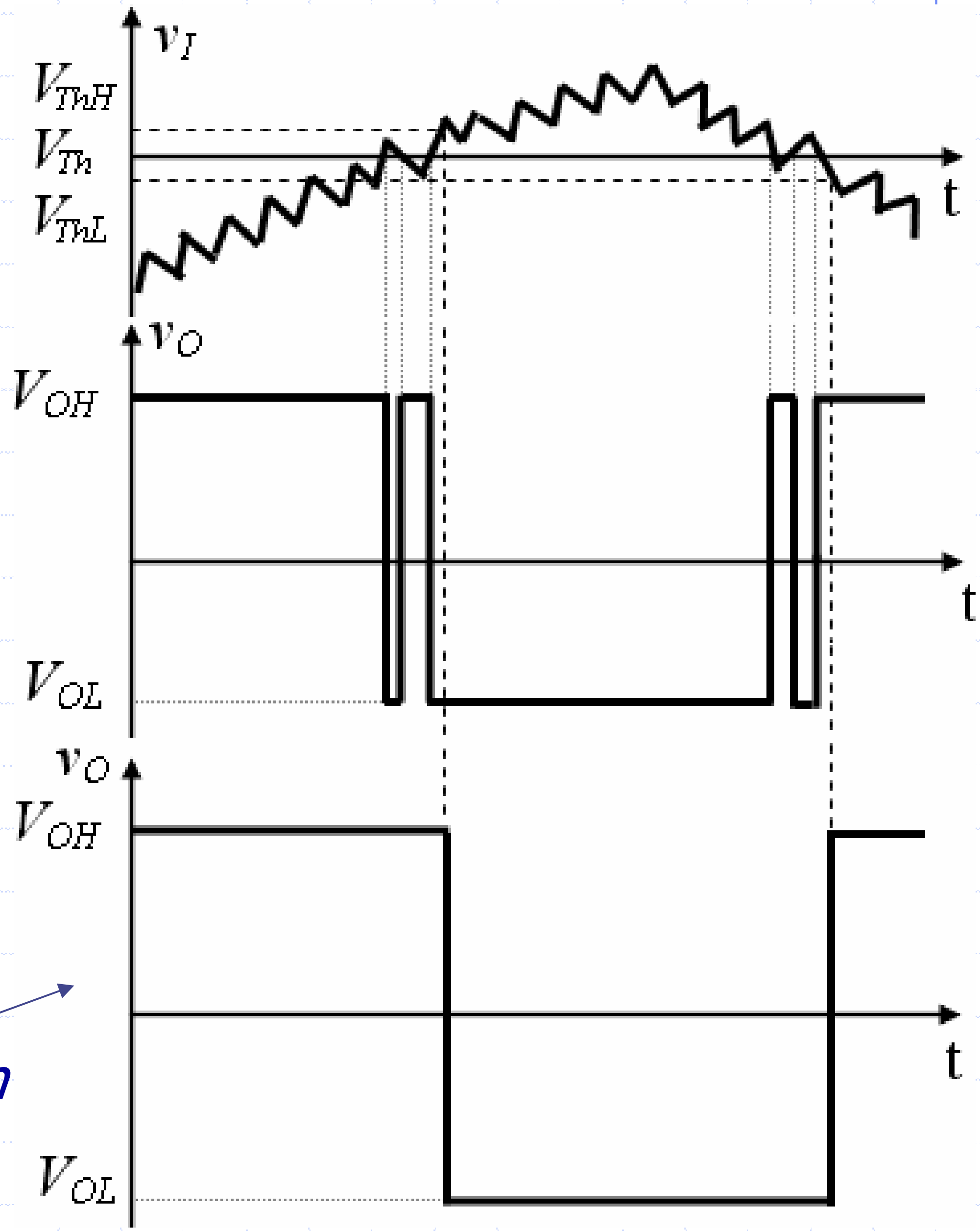
Hysteresis comparators

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)



no more undesirable transition

How can we implement such a VTC ?

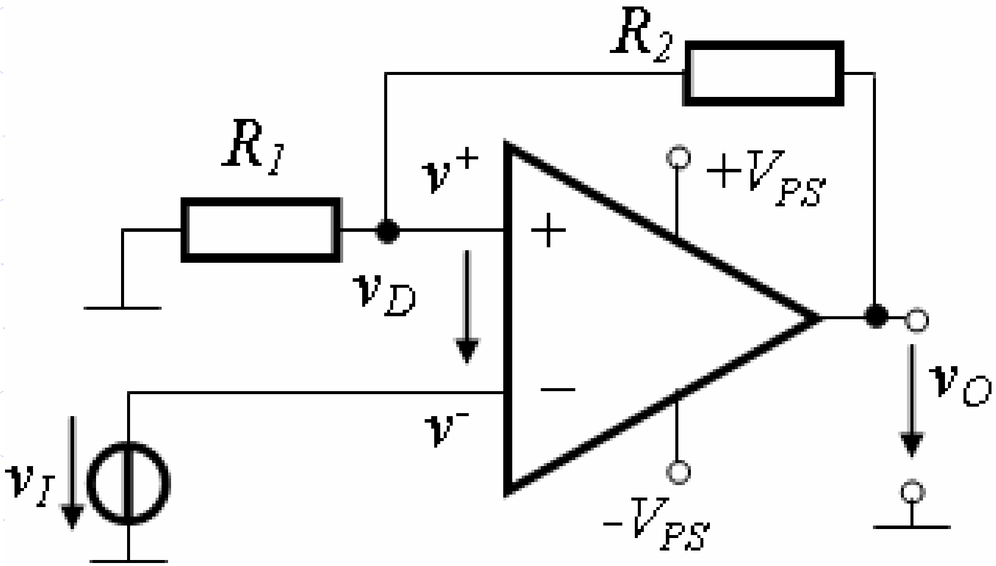
Solution:

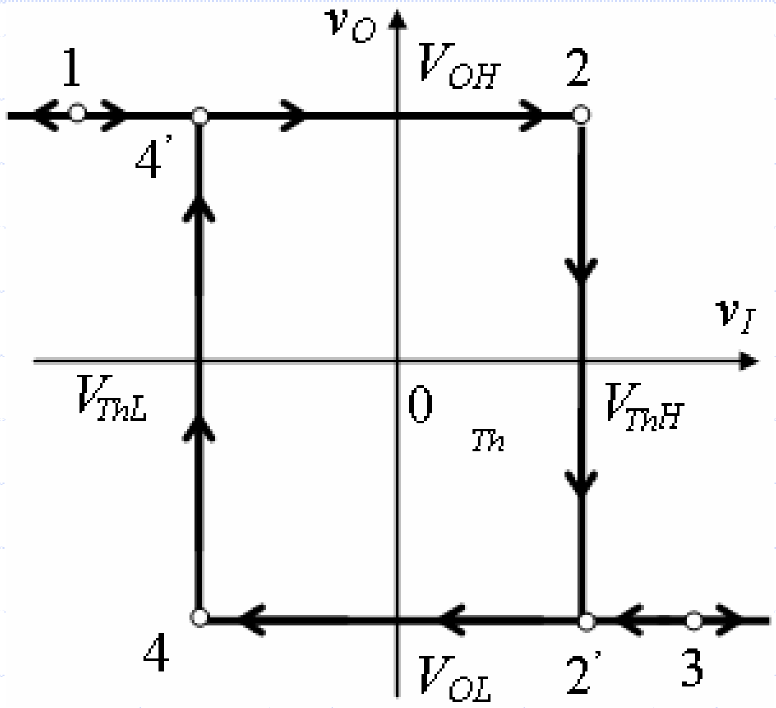
- Two threshold values V_{ThH} and V_{ThL}
- Two distinct output values: V_{OH} and V_{OL}
- the commutation takes place at V_{ThH} only if $v_O=V_{OH}$
- the commutation takes place at V_{ThL} only if $v_O=V_{OL}$

  $\Rightarrow$ 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





$$v^+ = \frac{R_1}{R_1 + R_2} v_O \qquad v^- = v_I$$

$$v_D = \frac{R_1}{R_1 + R_2} v_O - v_I$$

$$v_D = 0 \quad \frac{R_1}{R_1 + R_2} v_O = V_{TH}$$

$$V_{ThH} = \frac{R_1}{R_1 + R_2} V_{OH}$$

$$V_{ThL} = \frac{R_1}{R_1 + R_2} V_{OL}$$

$$\Delta V_{Th} = V_{ThH} - V_{ThL} = \frac{R_1}{R_1 + R_2}\left(V_{OH} - V_{OL}\right)$$

- 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 $v_O = V_{OL}$, $v_I > V_{ThL}$, $v_I \downarrow$, when v_I passes through V_{ThL}

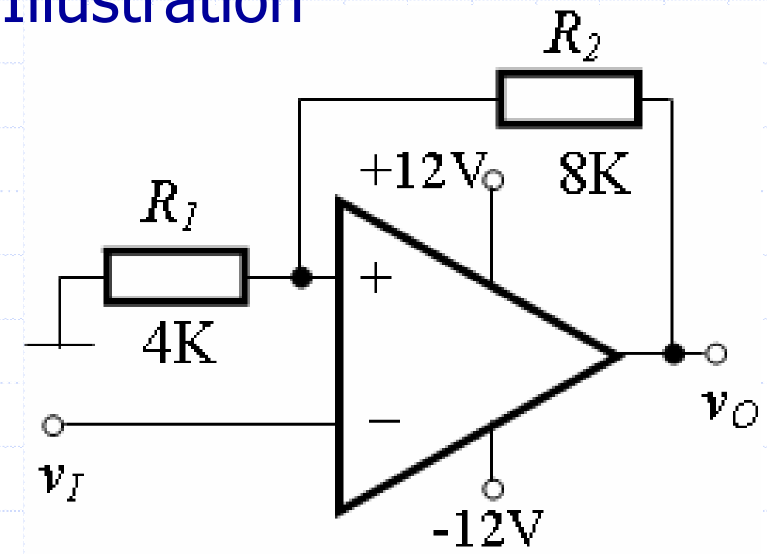
$v_I \downarrow$, $v_D \uparrow$, $\boldsymbol{v_O} \uparrow$, $v^+ \uparrow$, $v_D \uparrow$, $\boldsymbol{v_O} \uparrow$ **PF**

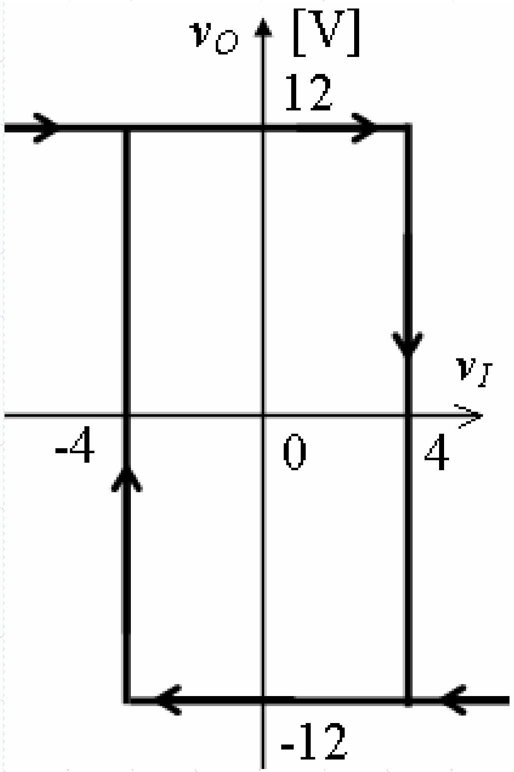
- once the v_O starts to change its value the transition is sustained by the circuit itself due to its PF

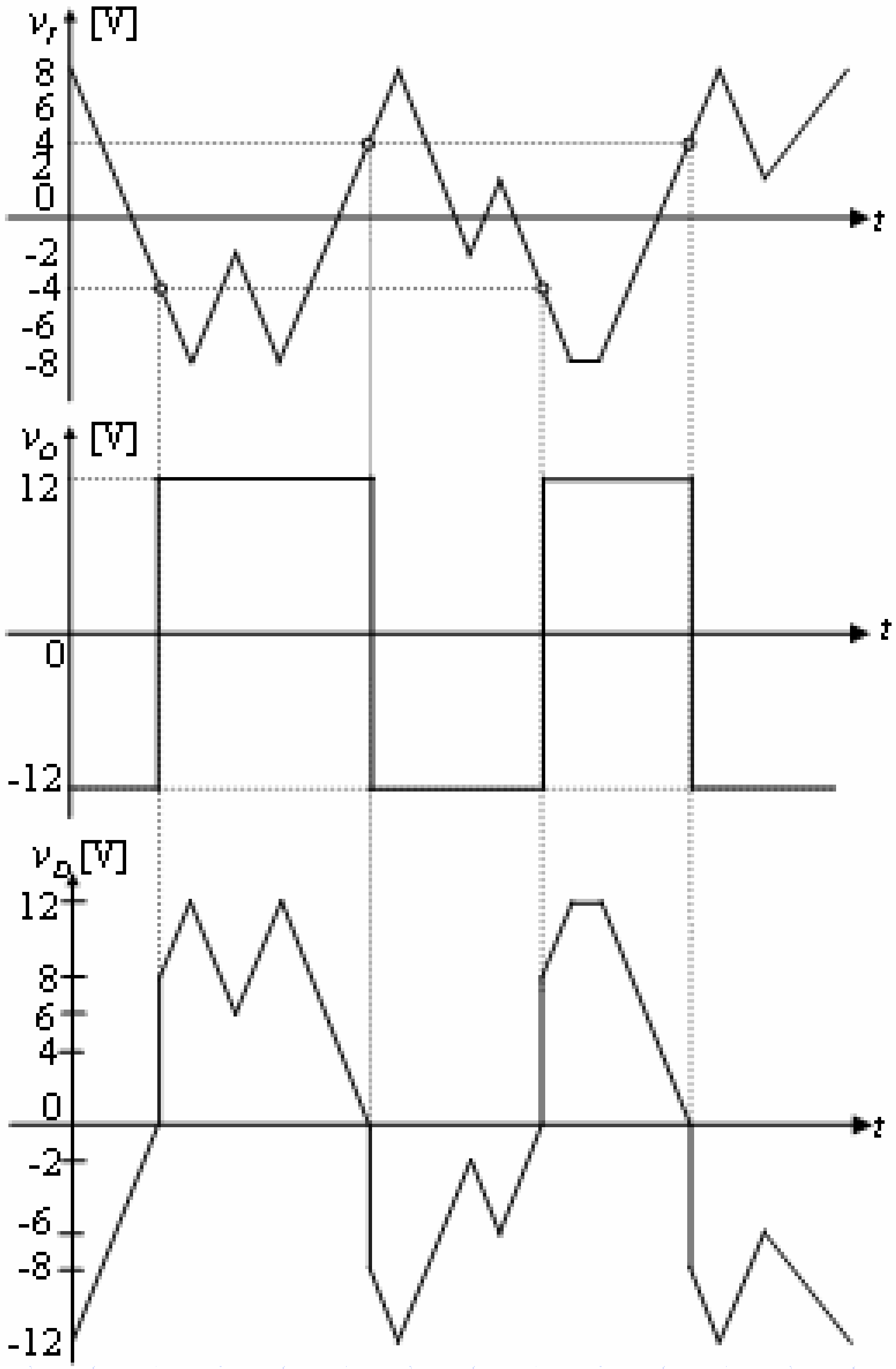
$\Rightarrow$ fast (accelerated) switching

- Bistable multivibrator circuit or Schmitt triggers

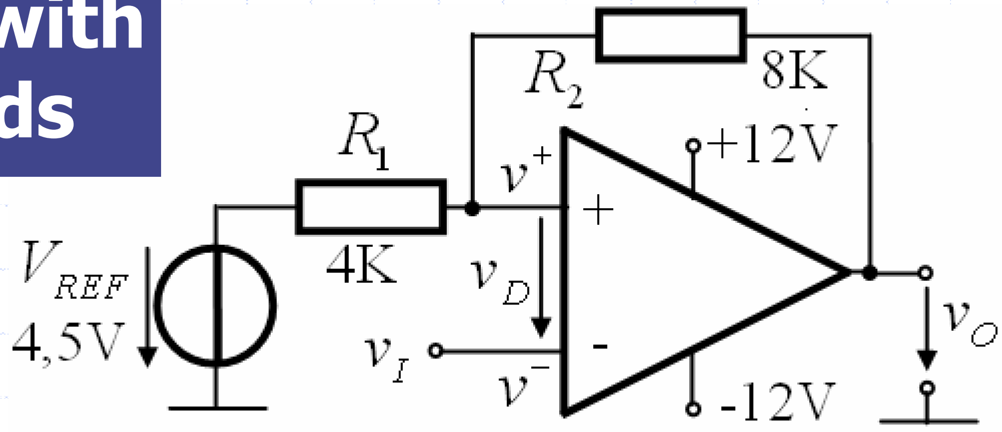
Illustration

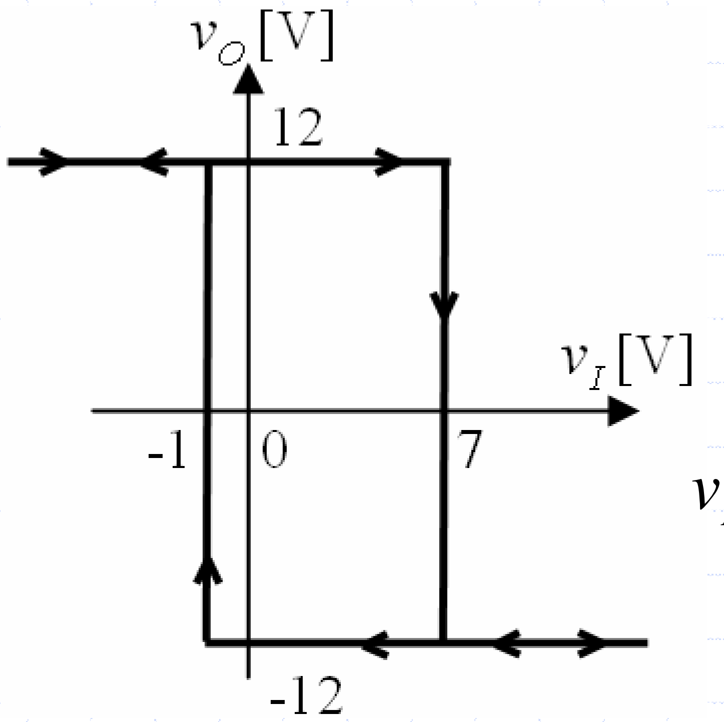






Inverting comparator with asymmetric thresholds





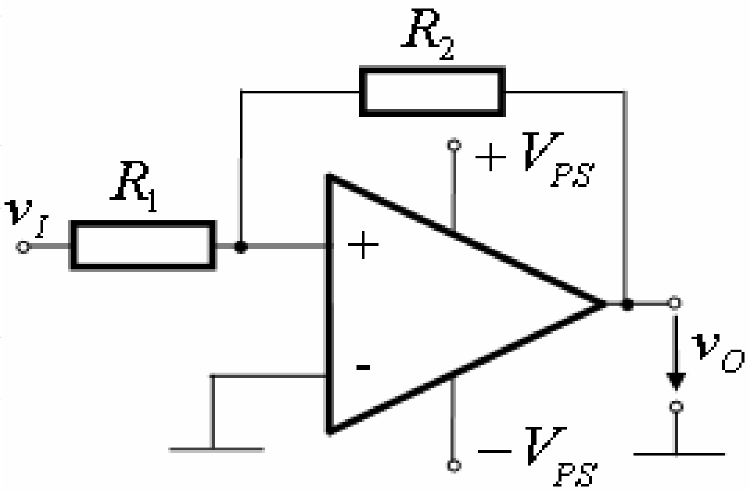
$$v^{+} = \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} V_{REF}$$

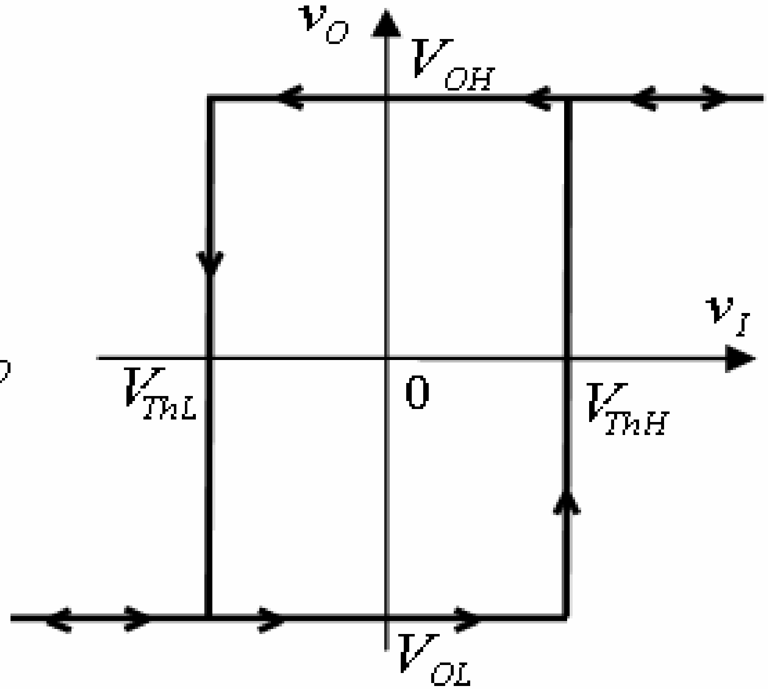
$$v_D = v^{+} - v^{-} = \frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} V_{REF} - v_I$$

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

$$V_{ThH} = \frac{R_1}{R_1 + R_2} V_{OH} + \frac{R_2}{R_1 + R_2} V_{REF}$$

Non-inverting hysteresis comparators





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

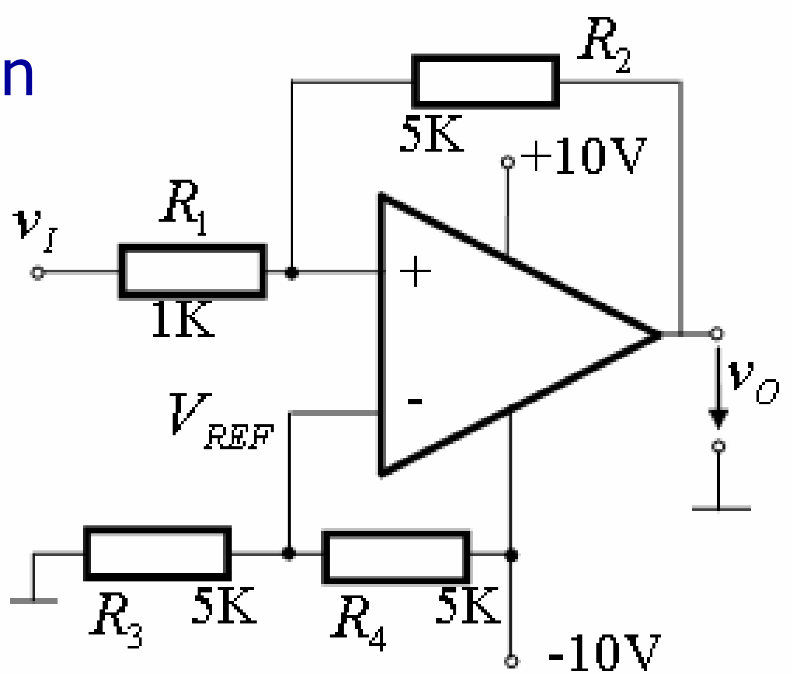
$$\frac{R_1}{R_1 + R_2} v_O + \frac{R_2}{R_1 + R_2} V_P = 0$$

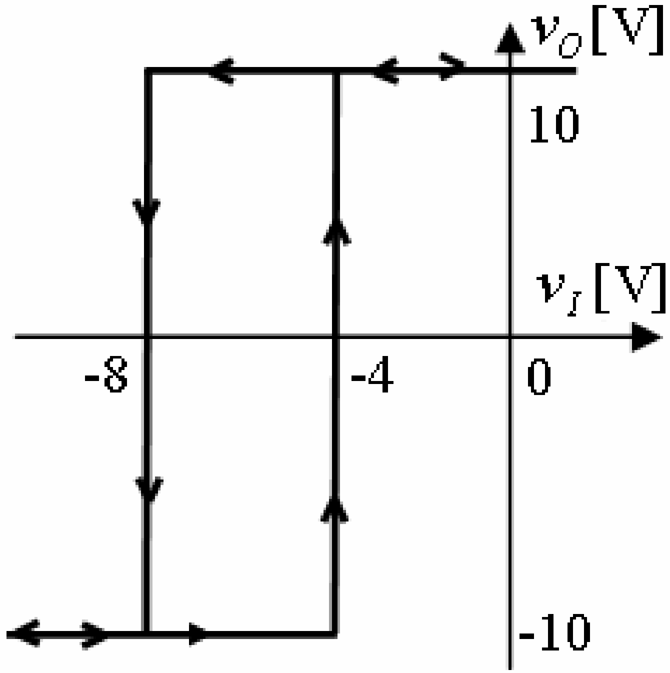
$$V_{Th} = -\frac{R_1}{R_2} v_O$$

$$V_{ThL} = -\frac{R_1}{R_2} V_{OH}$$

$$V_{ThH} = -\frac{R_1}{R_2} V_{OL}$$

Illustration





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

$$V_{ThH} = -\frac{R_1}{R_2} V_{OL} + \left(1 + \frac{R_1}{R_2}\right) V_{REF} = -\frac{1}{5}(-10) + \left(1 + \frac{1}{5}\right)(-5) = -4\ \text{V}$$

$$V_{ThL} = -\frac{R_1}{R_2} V_{OH} + \left(1 + \frac{R_1}{R_2}\right) V_{REF} = -\frac{1}{5}(10) + \left(1 + \frac{1}{5}\right)(-5) = -8\ \text{V}$$