Op-amp simple comparators

Op-amp in *switching mode* $\Rightarrow$ *comparators* with op-amp.
The **voltage comparator** compares two input voltages and signalizes to the output what input voltage is greater.

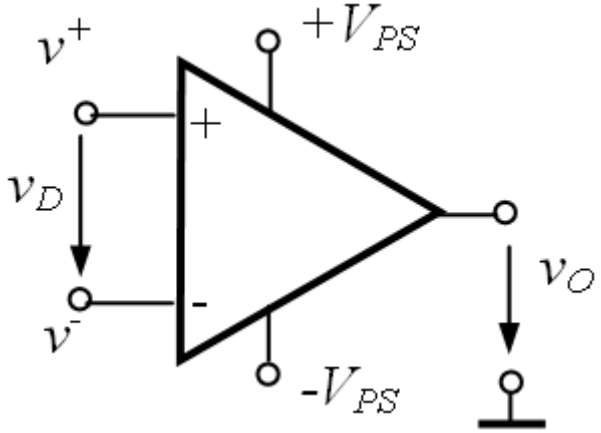
- voltages comparison: by the sign of their difference
- according to the sign of the difference, the comparator outputs one or another of the two possible output voltages
- for op-amp comparators one can consider only one input, namely the difference between v^+ and v^-, meaning v_D

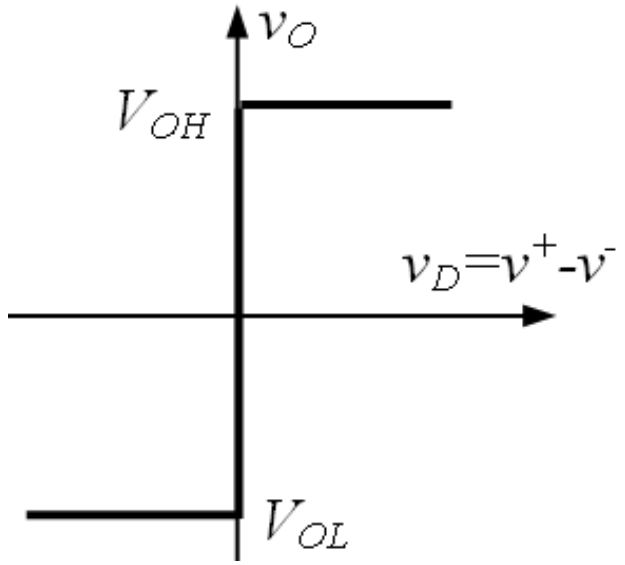
$$V_O \in \{V_{OL}, V_{OH}\}$$

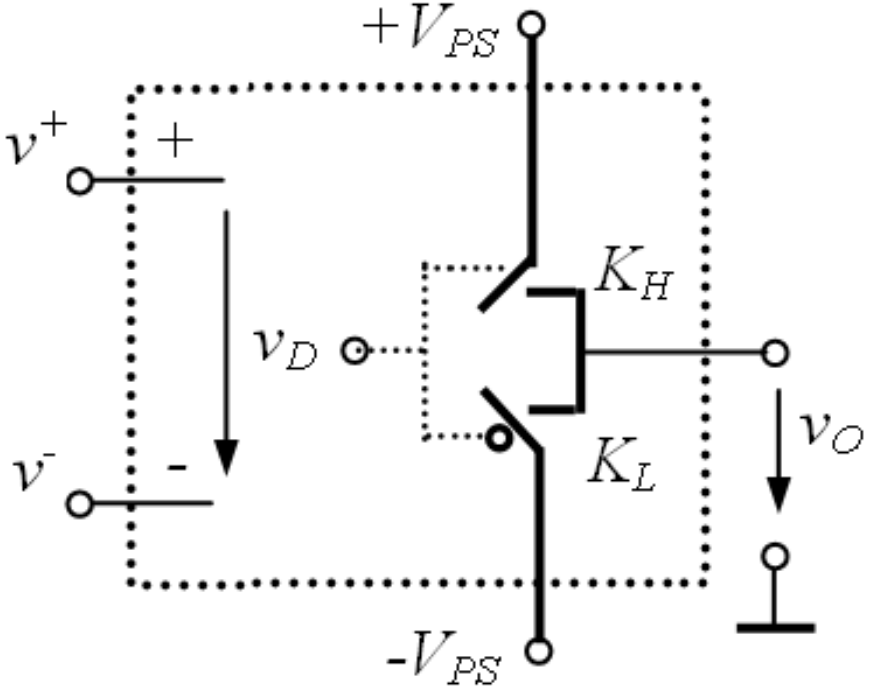
$v_D > 0$, that is $v^+ > v^-$, $v_O = V_{OH}$

$v_D < 0$, that is $v^+ < v^-$, $v_O = V_{OL}$

Op-amp model in switching regime







v_D	K_H	K_L	v_O
>0	*on*	*off*	$V_{OH}=+V_{PS}$
<0	*off*	*on*	$V_{OL}=-V_{PS}$

Appropriate for rail-to-rail op-amp

Two types of voltage comparators:

- **simple comparators**, without any feedback, **one threshold** voltage.

- **hysteresis comparators**, with positive feedback, **two threshold** voltages

- **threshold voltage** V_{Th}: that particular value of the input voltage v_I for which the output switches, v_D - crosses through zero.

Simple Comparators

- no feedback, only one threshold voltage

Threshold voltage V_{Th}: that particular value of the input voltage v_I for which the output switches from one state in the other state **($v_D = 0$).**

To find V_{Th}:

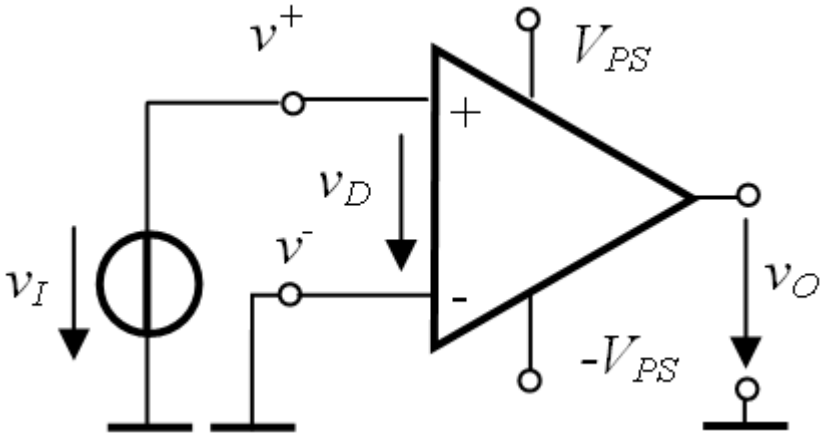
- find the expression of v_D
- use the condition $v_D = 0$ and replace v_I with V_{Th}
- obtain V_{Th}

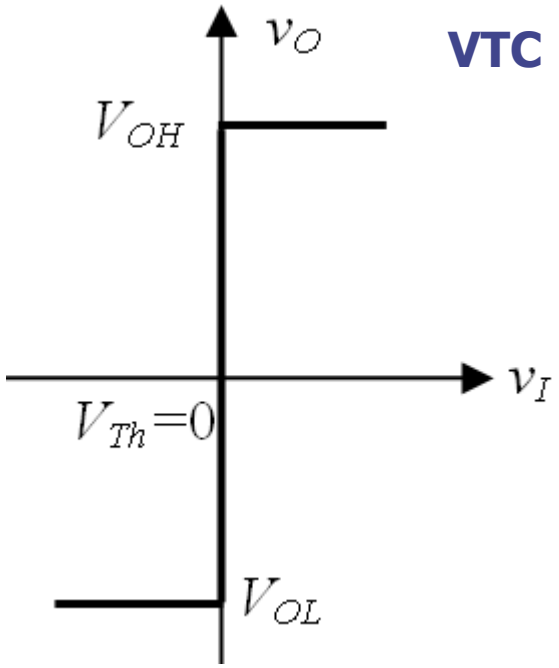
Simple comparators with $V_{Th} = 0$V

- one grounded input
- v_I is applied to the other input

Comparators with $V_{Th} = 0$V

- **noninverting**





$$v_O = \begin{cases} V_{OH} & \text{if } v_D > 0, \text{ this is } v_I > 0 \\ V_{OL} & \text{if } v_D < 0, \text{ this is } v_I < 0 \end{cases}$$

$$v_D = v^+ - v^-$$

$$v^+ = v_I; \quad v^- = 0$$

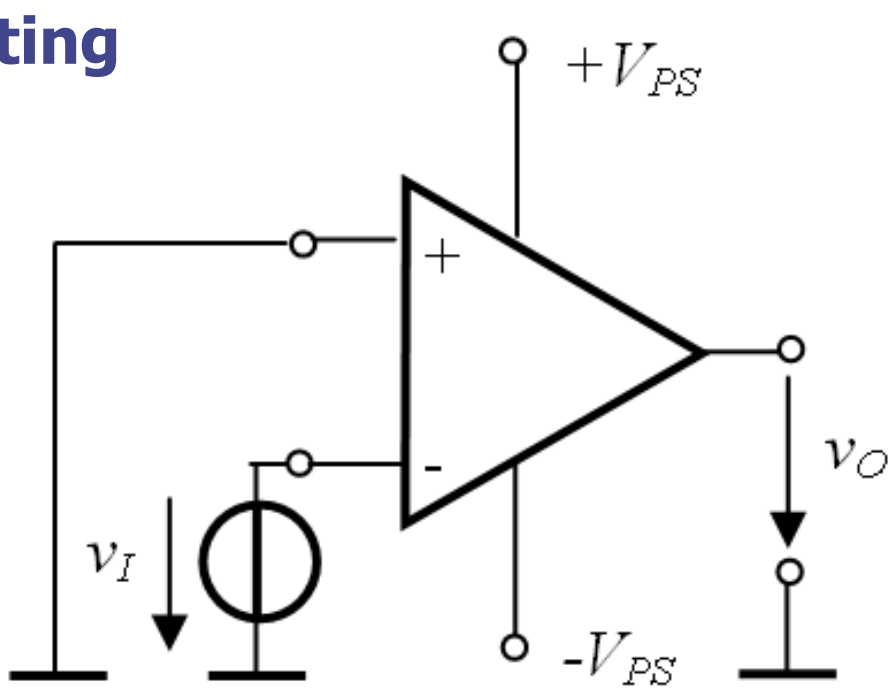
$$v_D = v_I$$

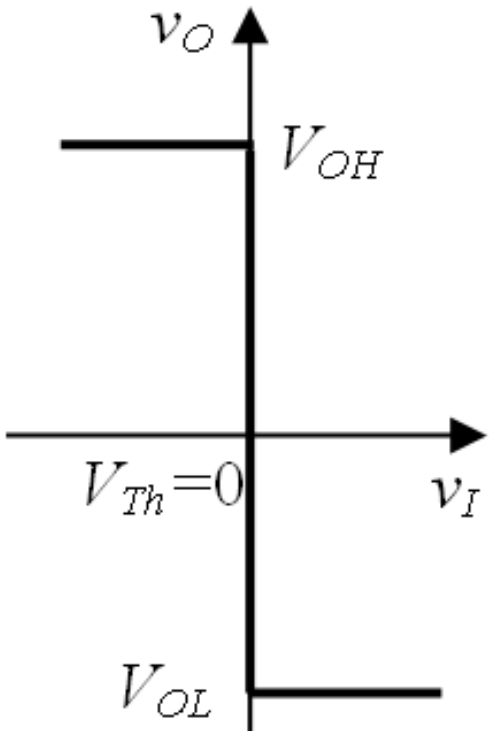
$$v_D = 0; \quad V_{Th} = 0$$

How does the output voltage look like if the input voltage is a sine wave with 3 V amplitude and the supply is $\pm V_{PS} = \pm 12$ V?

Comparators with $V_{Th} = 0\text{V}$ – *cont.*

- **inverting**

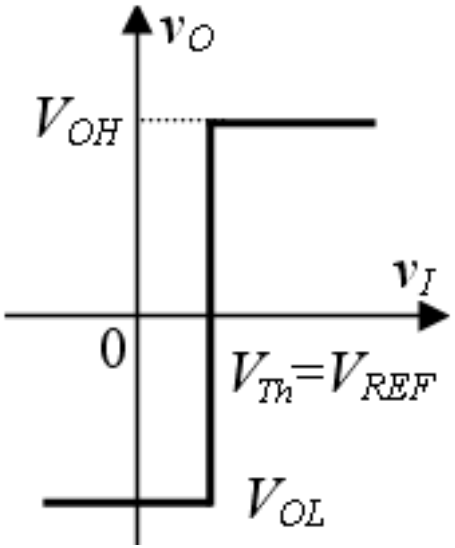


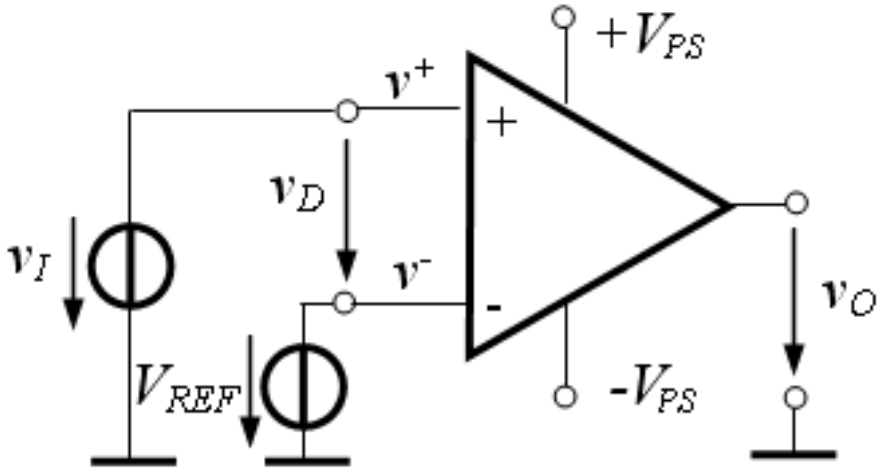


How does the output voltage look like if the input voltage is a sine wave with 3V amplitude and the supply is $\pm V_{PS} = \pm 12\,\text{V}$?

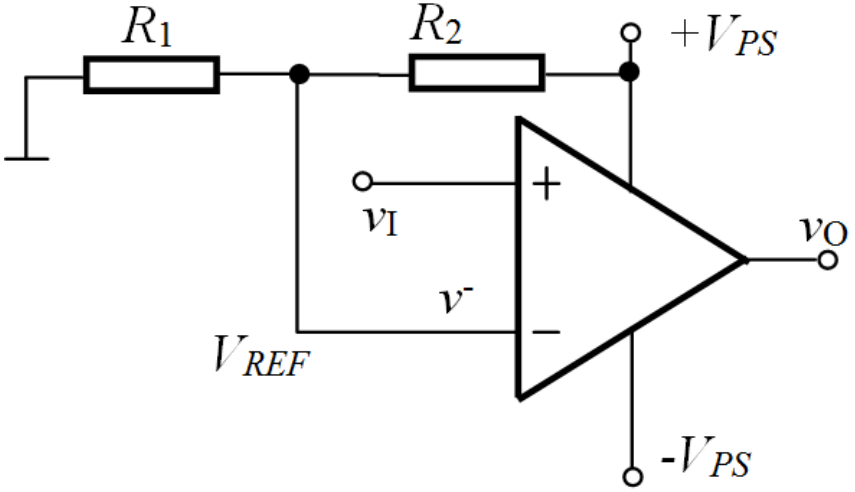
Comparators with $V_{Th} \neq 0$

noninverting



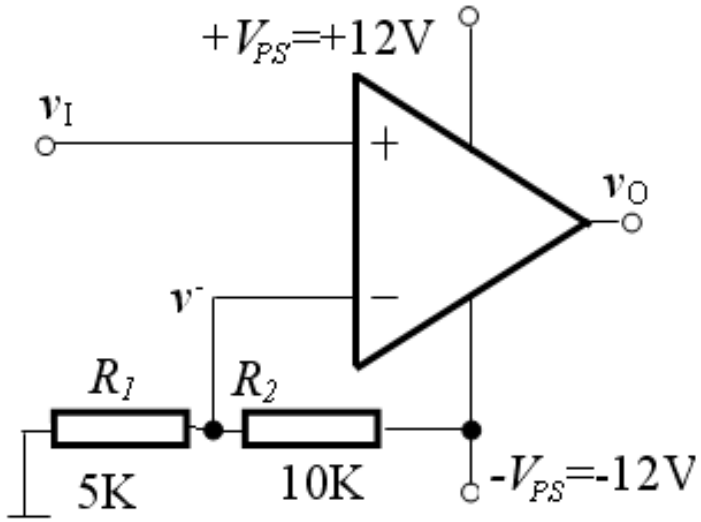


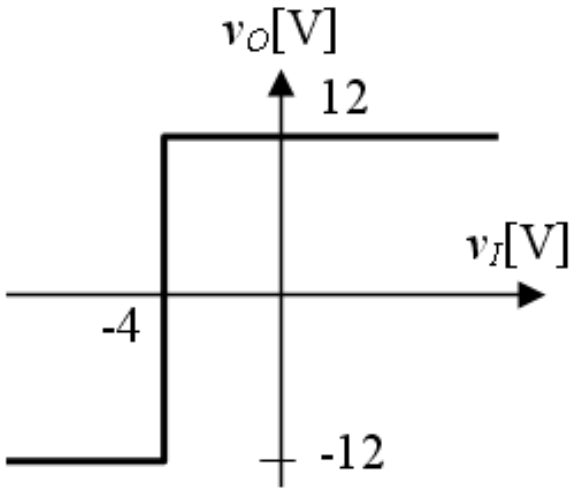
How can V_{REF} be obtained from the available dc sources?

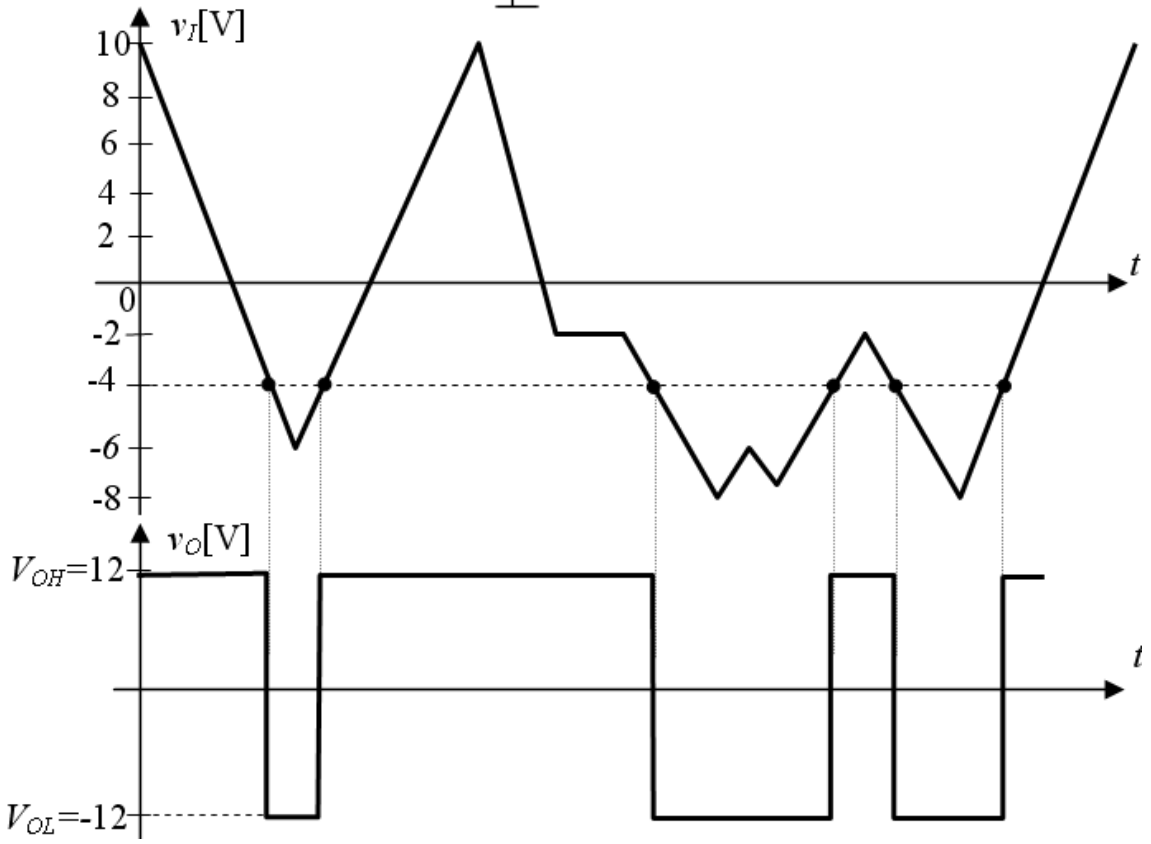


$$V_{REF} = \frac{R_1}{R_1 + R_2} V_{PS}$$

- **Example**



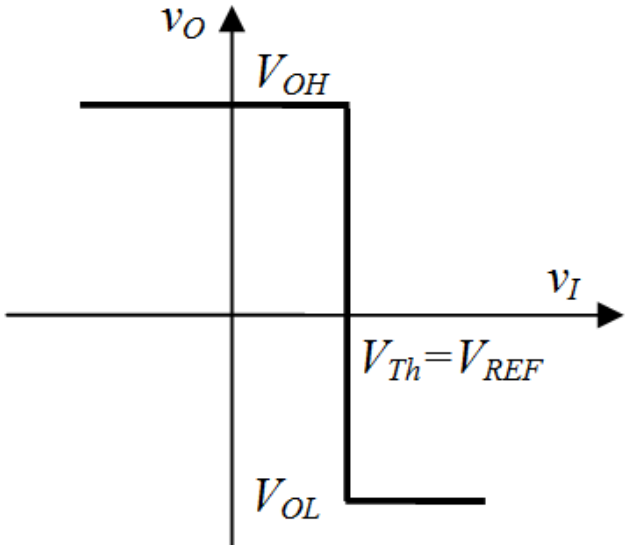


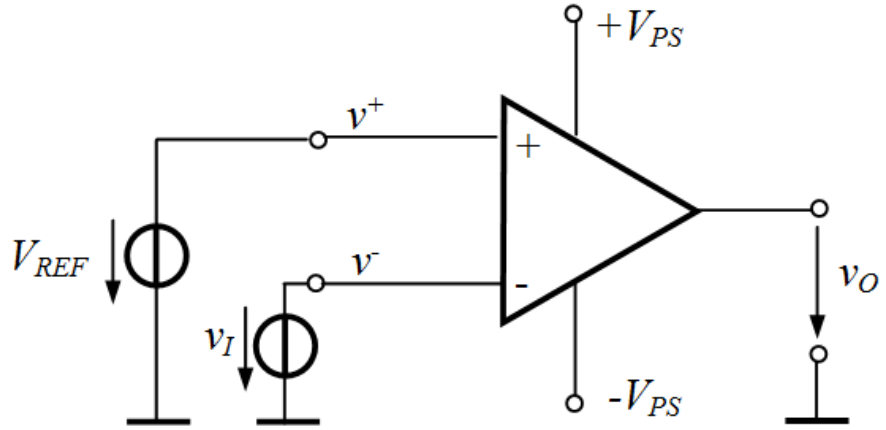


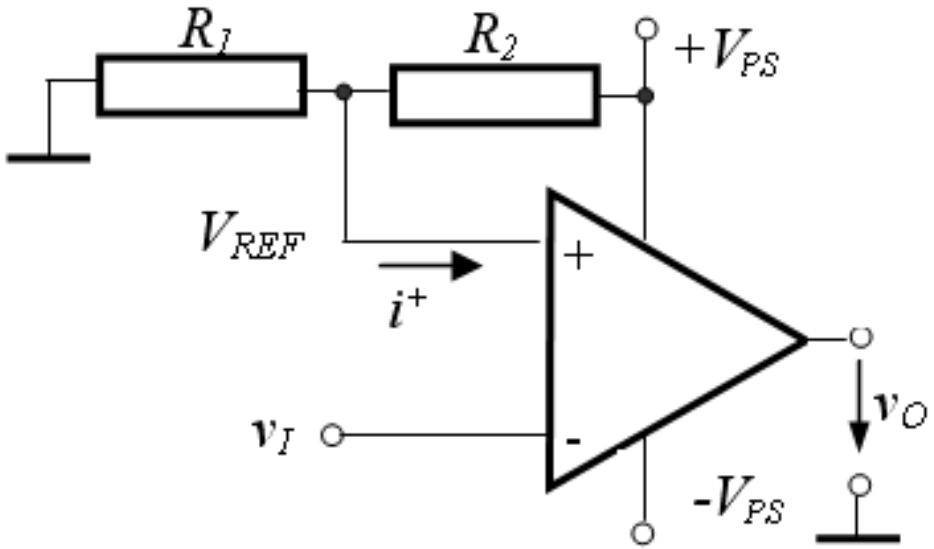
***Redesign*:**

- ✓ inverting
- ✓ V_{Th}= +6V
- ? VTC
- ? $v_O(t)$

Comparators with $V_{Th} \neq 0$ inverting







i^+ << current through R_1, R_2 divider ($i^+ \cong 0$)

$$V_{REF} = \frac{R_1}{R_1 + R_2} V_{PS}$$

Op-amps specially intended for comparators

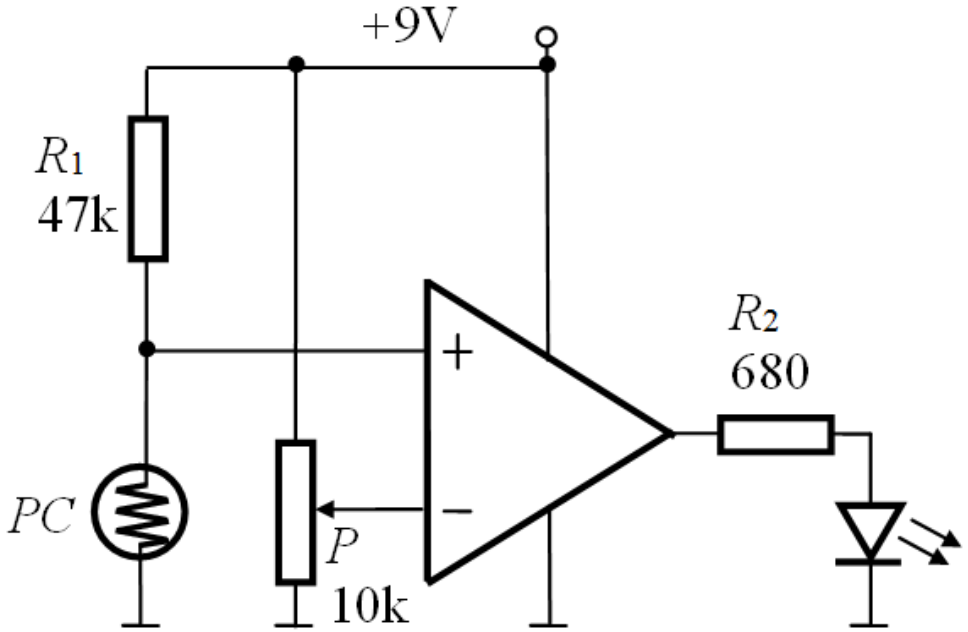
- general-purpose op-amp comparators
- **special class** of op-amp intended for comparators like: *LM306, LM 311 ,LM 399, LM 393, LM 339* :
  - ***high*** differential ***voltages***
  - ***very fast*** response (very high slew rate)
  - usual comparators has ***open collector*** output (they necessitate an external resistor connected from the output towards a positive potential)
  - can have an extra ***ground terminal*** beside the usual supply terminals

Applications of simple comparators

- Light sensor
- Interface between analog and logic circuits
- Obtaining rectangular signal from sinusoidal (triangular) signal
- Optical indicator for voltage level
- Pulse width modulation
- Signalizing and control circuit
- Analog to digital converter
- .....

Light Sensor Circuit

PC: CdS
Photoconductive
Photocells
PDV-P8001



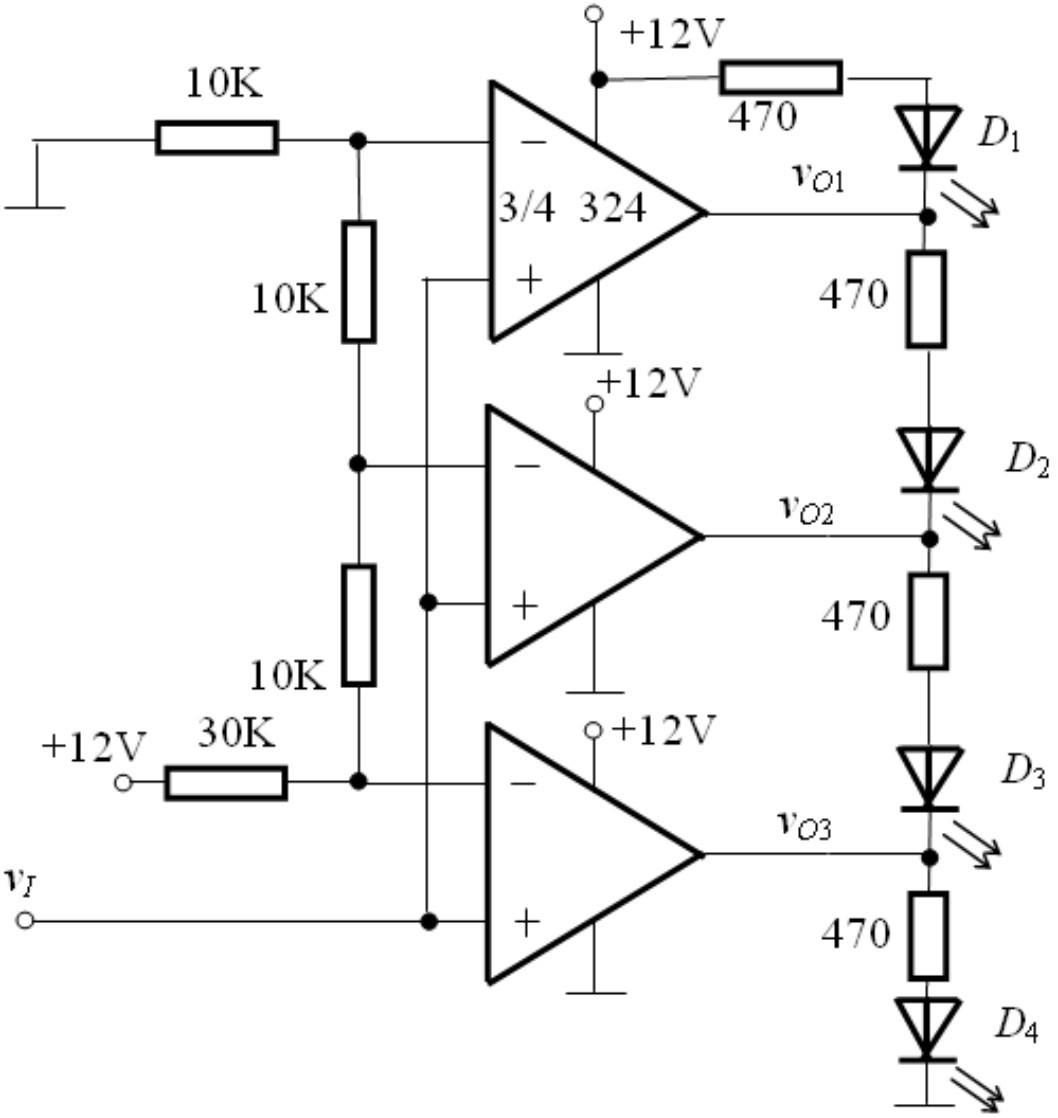
LDR - Light Dependent Resistor

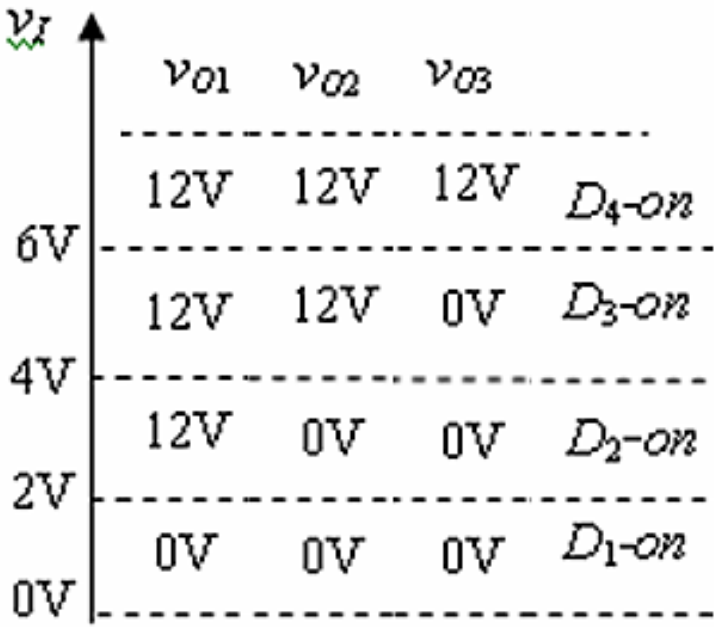
Dark resistance (big): R_D >200 kΩ

Illuminated resistance (small): $R_I \in$(3; 11) kΩ

When the light falling on the photocell (PC) is blocked, its resistance will increase and the voltage across PC will rise. When the voltage rises above 1/2 of the supply voltage the output of the comparator will turn ON and the LED will be lit.

Optical Indicator for Voltage Level





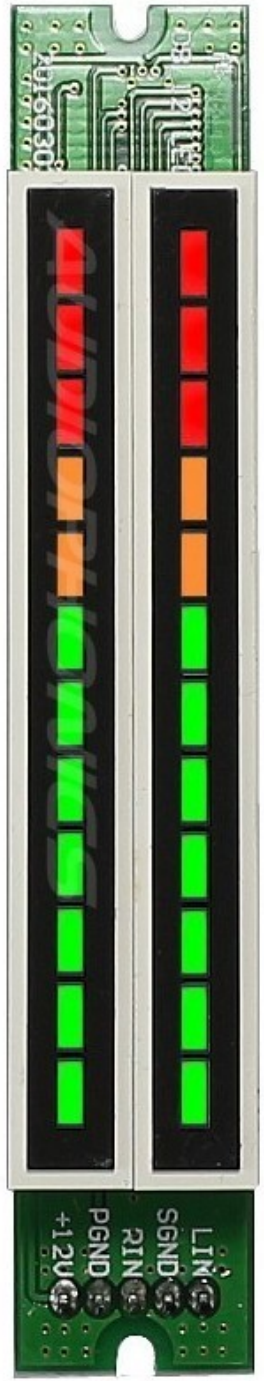
Design a bar graph optical indicator for the voltage level using 5 LEDs

LED Bar Graph Dual Column Vu-meter display
Decibel level 2x12

Bar graph LED indicating the audio level under 2X12 levels (stereo)

It contains 12 LEDs per side (7 green, 2 orange, 3 red).

The display speed and peak level can be adjusted individually by the button on the rear panel.



Analog to Logic Circuits Interfacing

High speed voltage comparator