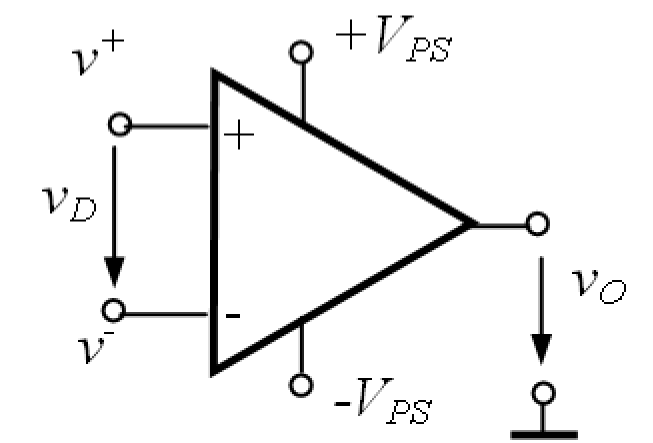
Op-amp simple comparators

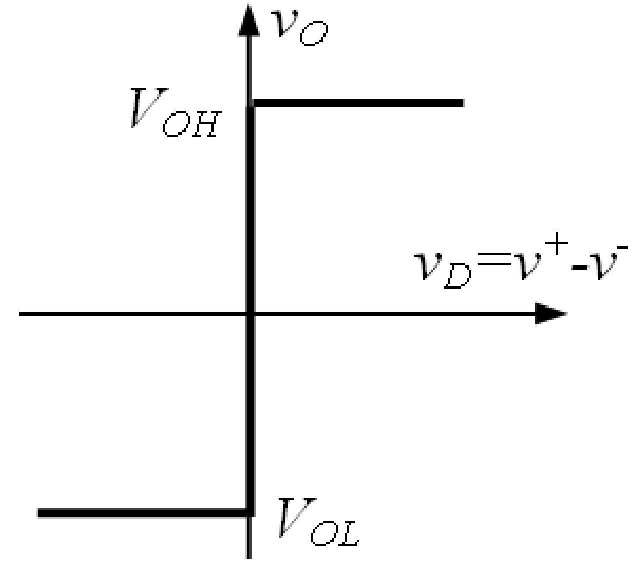
Op-amp in *switching mode* $\Rightarrow$ *comparators* with op-amp*.*
The **voltage comparator** compares two input voltages and signalizes to the output what input voltage is greater.

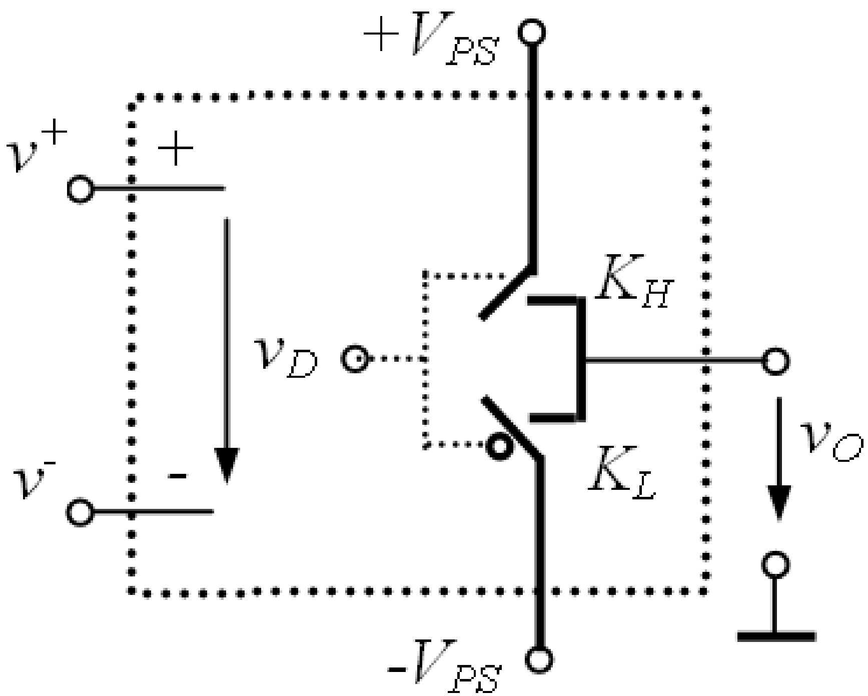
- voltages comparison: by the sign of their difference
- according to the sign of the difference, the comparator outputs one or another of the two possible output voltages
- for op-amp comparators one can consider only one input, namely the difference between v^+ and v^-, meaning v_D

$$V_O \in \{V_{OL}, V_{OH}\} \qquad \begin{array}{ll} \mathbf{v_D > 0}, \ \text{that is } v^+ > v^-, & \mathbf{v_O = V_{OH}} \\ \mathbf{v_D < 0}, \ \text{that is } v^+ < v^-, & \mathbf{v_O = V_{OL}} \end{array}$$

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**
  - no feedback,
  - **one threshold** voltage.
- **hysteresis comparators**
  - 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 ($v_D = 0$)

Simple Comparators

- no feedback, one threshold voltage

To find V_{Th}:

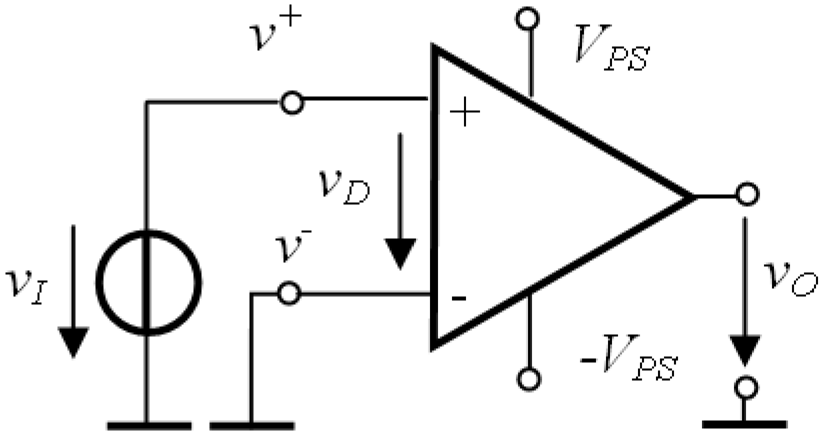
- find the expression of v_D
- use the condition $v_D = 0$ and replace v_I with V_{Th}
- obtain V_{Th}

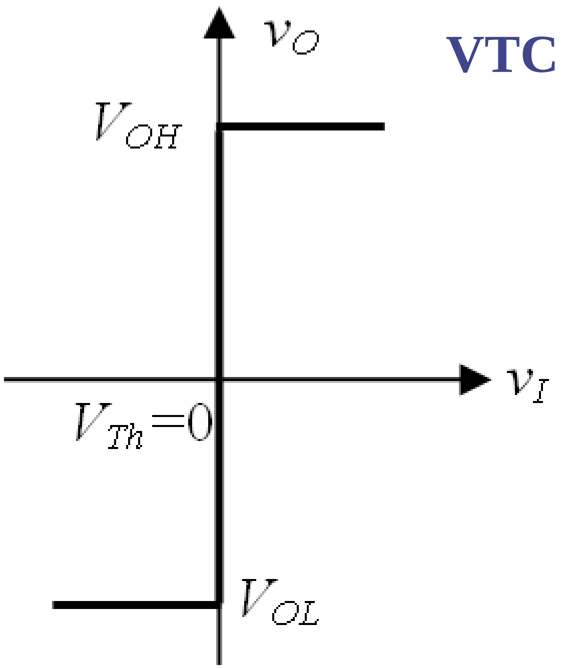
Simple comparators with $V_{Th} = 0V$

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

Comparators with $V_{Th} = 0V$

- **noninverting**





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

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

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

$$v_D = v_I$$

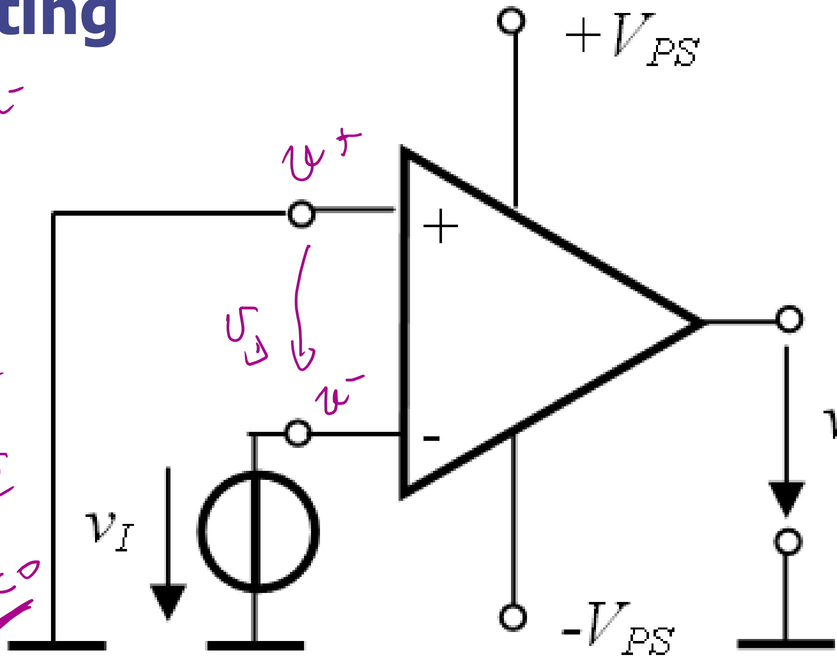
$$v_D = 0; \quad V_{Th} = 0$$

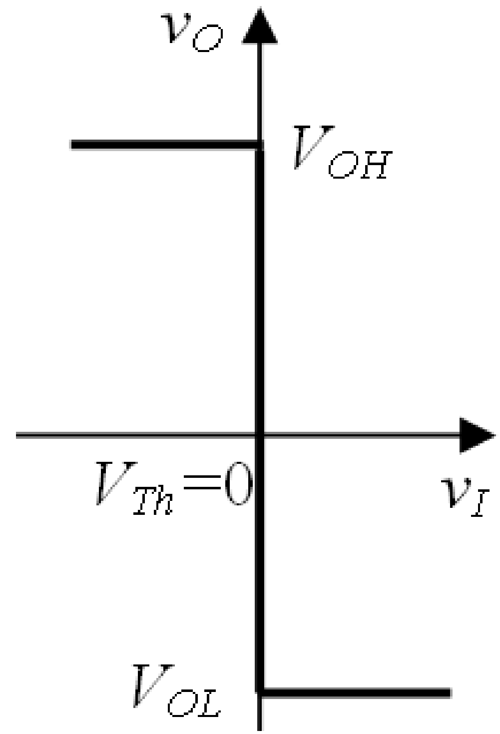
How does the output voltage look like if the input voltage is a sine wave with 3 V amplitude and the supply is $\pm V_{PS} = \pm 12$ V?

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

- **inverting**

$v_d = v^+ - v^-$
$v^+ = 0$
$v^- = v_i$
$v_d = 0 - v_i$
$v_d = -v_i$
$v_d > 0;\ v_i < 0$
$v_o = V_{OH}$

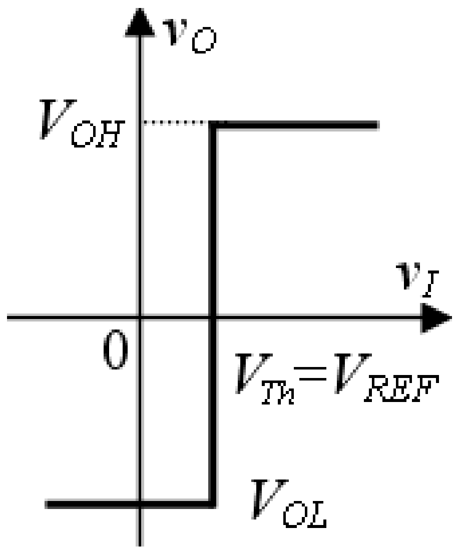


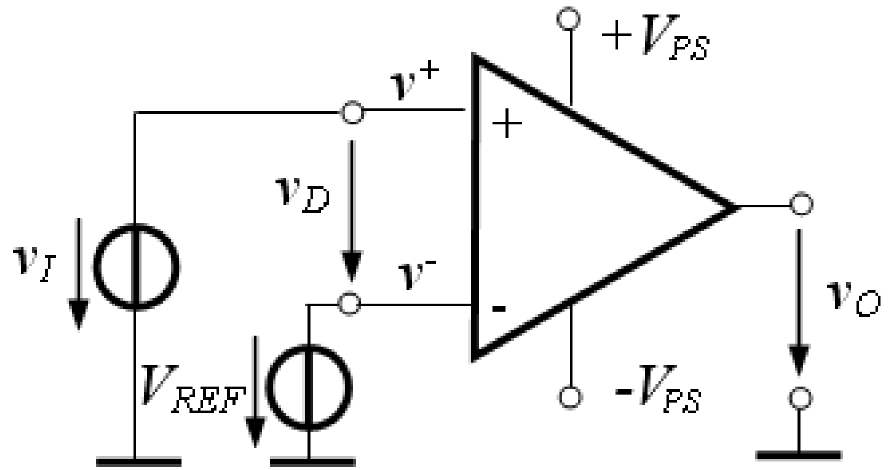


How does the output voltage look like if the input voltage is a sine wave with 3V amplitude and the supply is $\pm V_{PS} = \pm 12\text{V}$?

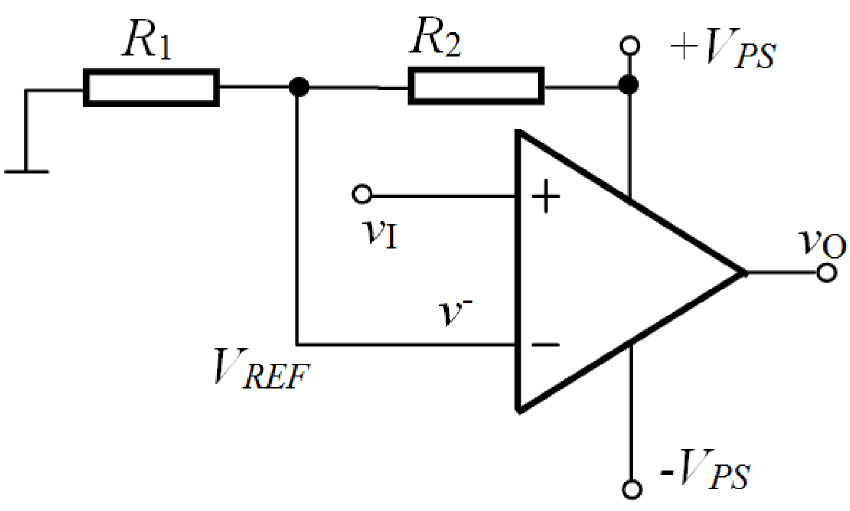
Comparators with $V_{Th} \neq 0$

noninverting



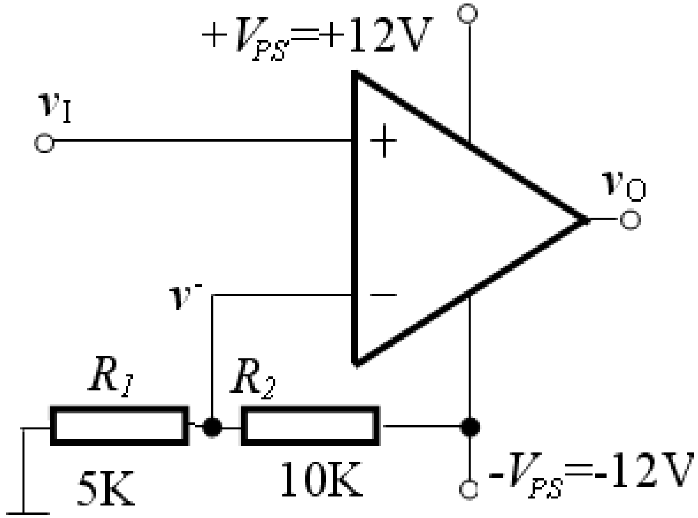


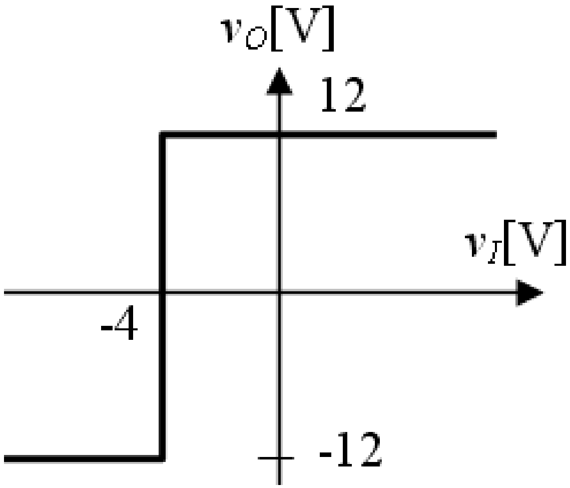
How can V_{REF} be obtained from the available dc sources?

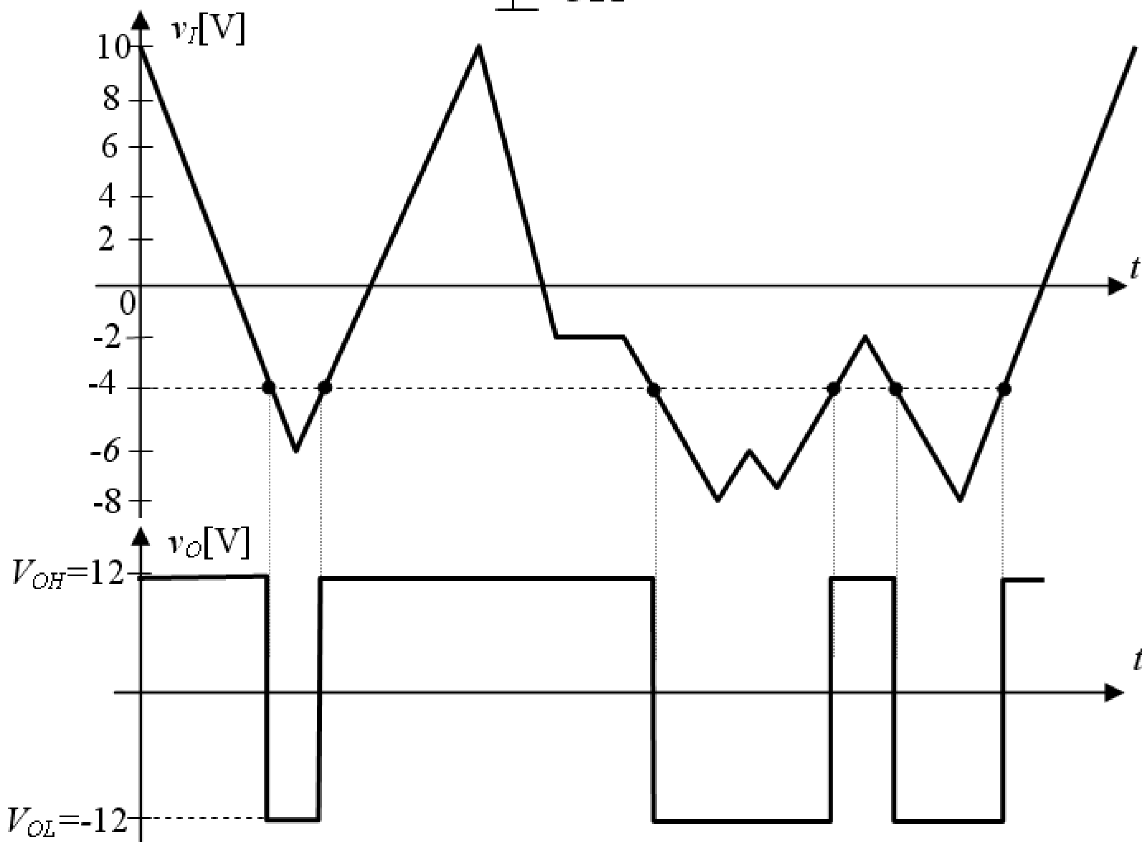


$$V_{REF} = \frac{R_1}{R_1 + R_2} V_{PS}$$

Example







Redesign:

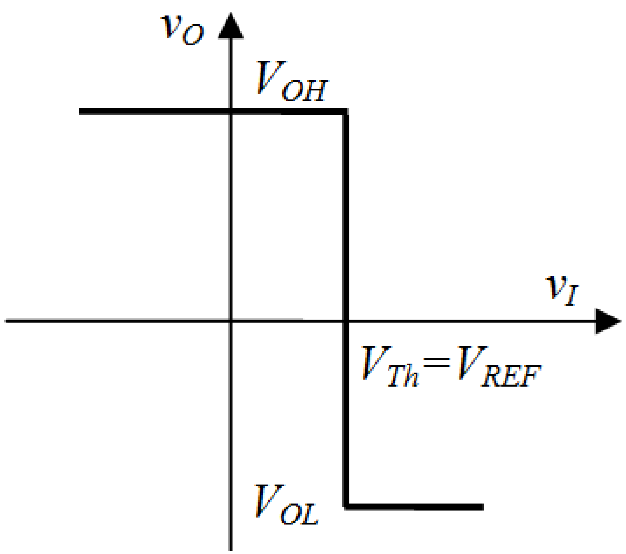
✓ inverting

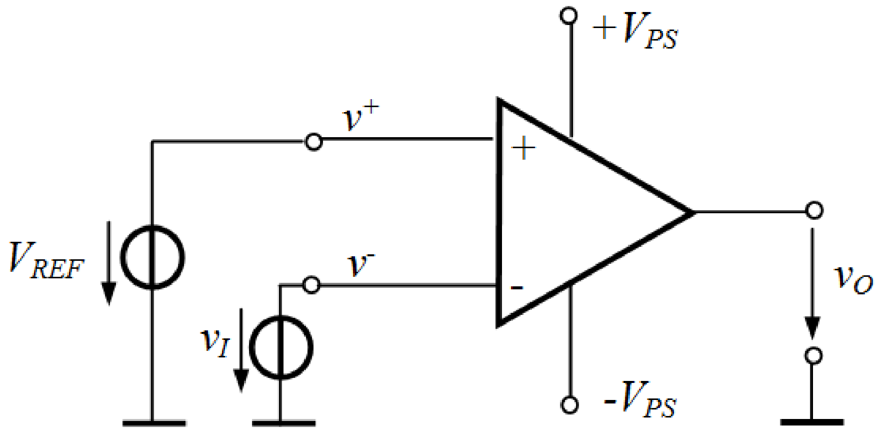
✓ V_{Th}= +6V

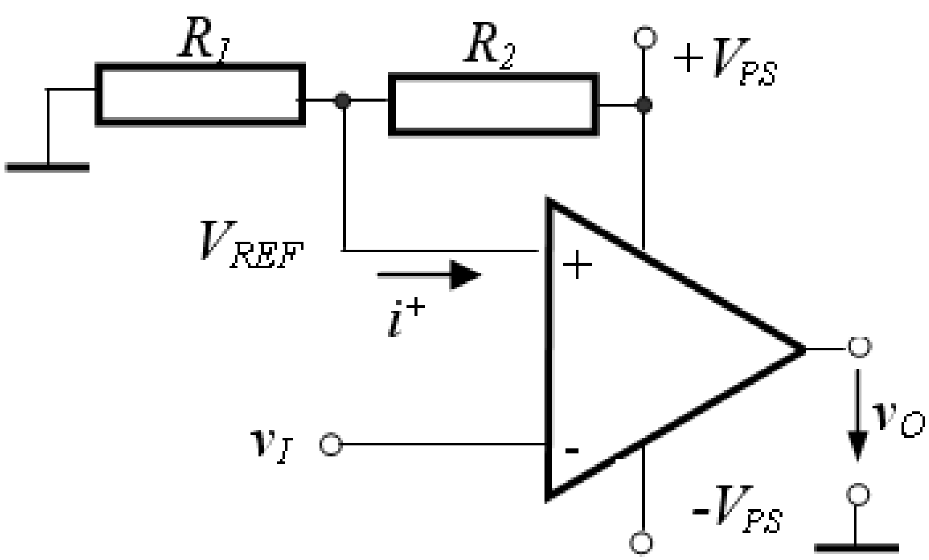
? VTC

? $v_O(t)$

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

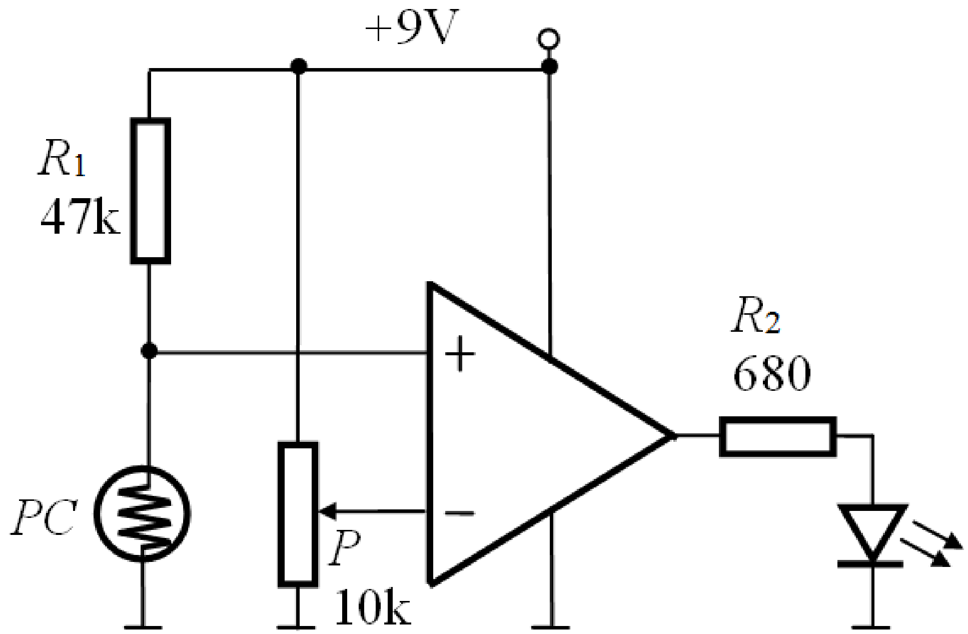
Applications of simple comparators

- **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

Photocell *PC*

e.g.: PDV-P8001



Dark resistance (big): R_D >200 kΩ

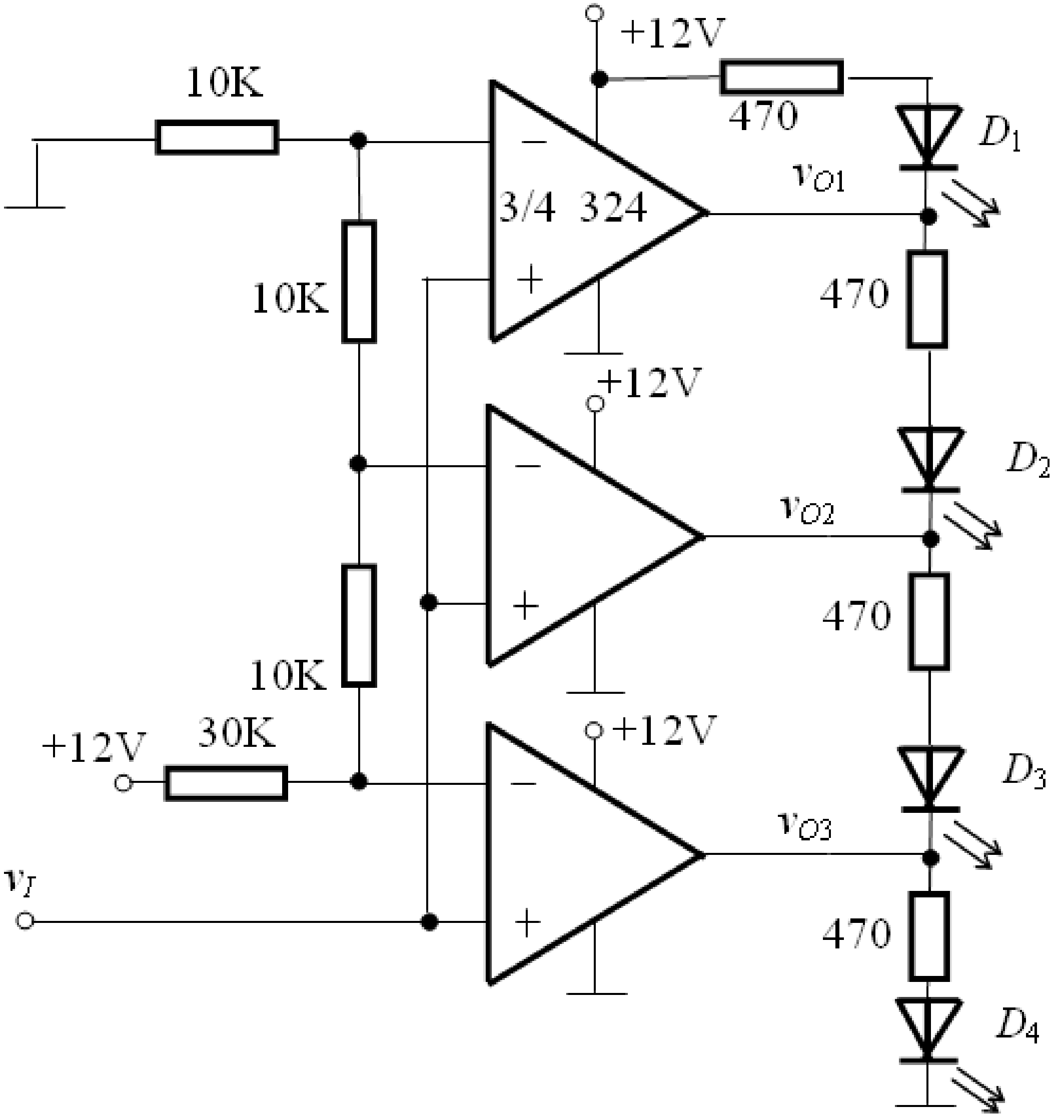
Illuminated resistance (small): $R_I \in (3; 11)$ kΩ

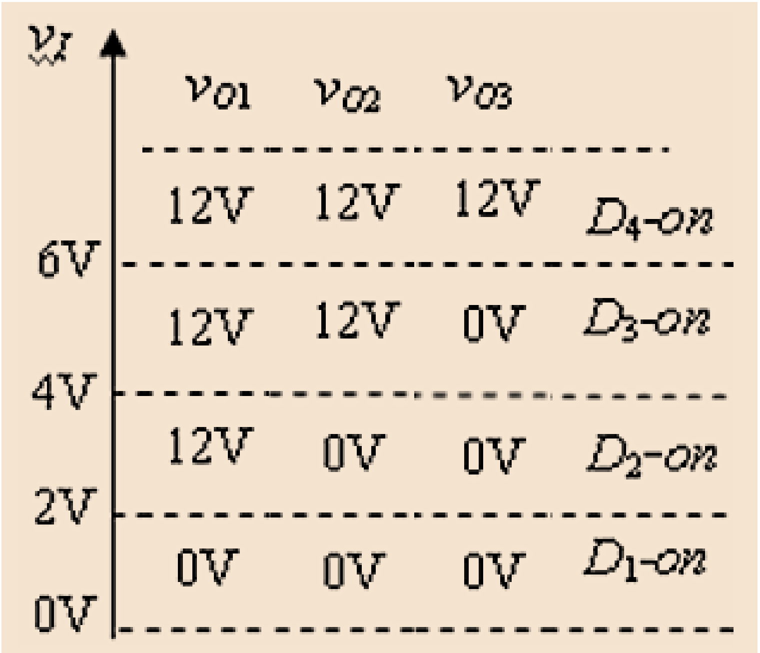
A photocell (*PC*) is a resistor that changes resistance depending on the amount of light incident on it (*LDR* – light dependent resistor).

A photocell operates on semiconductor photoconductivity: the energy of photons hitting the semiconductor frees electrons to flow, decreasing the resistance.

When the amount of light increases => the resistance decreases

Optical Indicator for Voltage Level





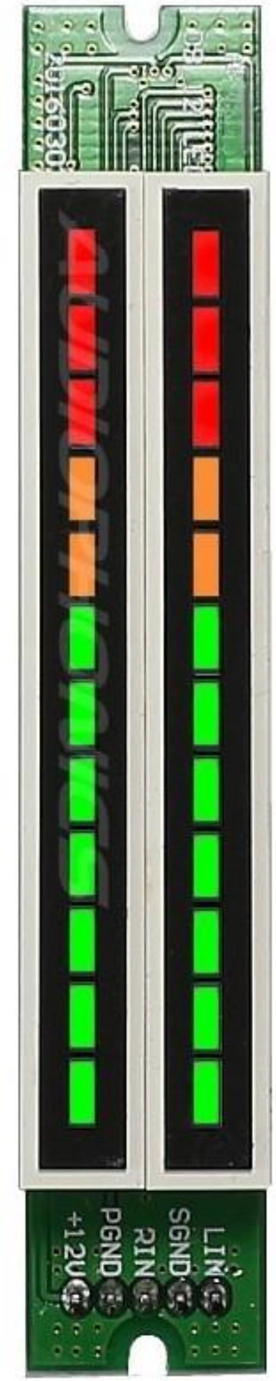
Design a bar graph optical indicator for the voltage level using 5 LEDs

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 knob on the rear panel.



Analog to Logic Circuits Interfacing

High speed voltage comparator