Op-amp simple comparators

Op-amp in *switching mode* ⇒ *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 \( v_D \)

\[
V_O \in \{V_{OL}, V_{OH}\} \quad v_D > 0, \quad \text{that is} \quad v^+ > v^- , \quad v_O = V_{OH} \\
\quad v_D < 0, \quad \text{that is} \quad v^+ < v^- , \quad v_O = V_{OL}
\]
Op-amp model in switching regime

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 $V_{Th} = 0V$

➢ one grounded input
➢ $v_I$ is applied to the other input
Comparators with $V_{Th} = 0V$

- noninverting

![Comparator Circuit Diagram]

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

How does the output voltage look like if the input voltage is a sine wave with 3 V amplitude and the supply is $\pm V_{PS} = \pm 12 \text{ V}$?
Comparators with $V_{Th} = 0V$ – cont.

- inverting

How does the output voltage look like if the input voltage is a sine wave with 3V amplitude and the supply is $\pm V_{PS} = \pm 12V$?
Comparators with $V_{Th} \neq 0$

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

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

### Inverting Comparator

\[ V_{OH} - V_{OL} = V_{Th} - V_{REF} \]

\[ i^+ \ll \text{current through} \ R_1, R_2 \text{ divider (} i^+ \approx 0 \) \]
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): $R_D > 200 \, \text{k}\Omega$
Illuminated resistance (small): $R_I \in (3; 11) \, \text{k}\Omega$

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.
High speed voltage comparator

LM 311, 393, etc.

\[ V_o = \begin{cases} 0V; & V_I < 0; \text{ } K \text{ - (on)} \\ 5V; & V_I > 0; \text{ } K \text{ - (off)} \end{cases} \]