OP-AMP VOLTAGE COMPARATORS

I. OBJECTIVES

a) Determining the voltage transfer characteristics (VTC) for simple voltage comparators (without feedback) and for hysteresis comparators.
b) Determining the output voltage in accordance with the configuration of the circuits and the input voltage.
c) Determining the effects of modifying the supply and reference voltages on the VTC of comparators.

II. COMPONENTS AND INSTRUMENTATION

You will use the breadboard, one 741 operational amplifier (see Fig. 7.1), a 10KΩ potentiometer and resistors of different values. In order to supply the assembly you will use a dual dc regulated power supply, and as a sinusoidal signal source, you will use a signal generator. In order to visualise the voltages you need a dual channel cathodic oscilloscope and for some dc voltages, you need a dc voltmeter.

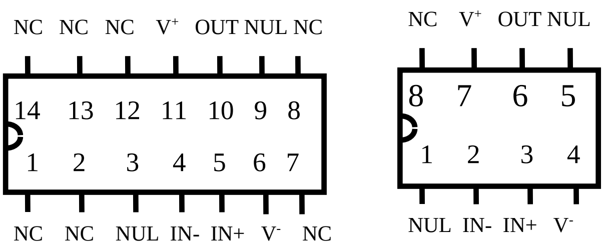

Figure 7.1 741 OP-AMP. Connection diagrams

NC – not connected
NUL – offset compensator
IN^- - inverting input
IN^+ - non-inverting input
V^- - negative voltage supply
V^+ - positive voltage supply
OUT – output

III. PREPARATION

1. P. OP-AMP WITHOUT FEEDBACK

Which is the value of v_O for the circuit schematic of Fig. 7.2 in the following situations:

- inputs not connected (in the air)
- one input not connected and one input connected to the ground
- both inputs connected to the ground.

Note: for OA 741 $a \geq 2 \cdot 10^5$

2. P. COMPARATOR WITHOUT FEEDBACK

2.1. P. INVERTING COMPARATOR

You will use the circuit from Fig. 7.3 supplied with $V^+ = 12V$, $V^- = -12V$.

A. Waveforms

- What does $v_O(t)$ look like, if $v_I(t)$ is a sinusoidal voltage with 8V amplitude and 200Hz frequency, for V_{REF} =0V. But for V_{REF} =4V?
- Which is the value of the threshold voltage V_{Th} (the value of v_I for which the comparator switches)?
- What does $v_O(t)$ look like for a 1V amplitude of v_I?

B. VTC

- What does VTC $v_O(v_I)$ look like for V_{REF} = 0V ?
- What does VTC $v_O(v_I)$ look like for V_{REF} = 4V? But for V_{REF} = -4V?

C. The effects of modifying the supply voltage

- What does the $v_O(t)$ look like for a sinusoidal v_I with a 8V amplitude and 200Hz frequency, V_{REF}=0V, if V^+ = 9V, V^- = -9V? And if V^+= 15V, V^- =-9V?

2.2. P. NON- INVERTING COMPARATOR

- Draw the schematic of a non- inverting voltage comparator with the possibility of adjusting V_{Th} between V^+ and V^-.
- What does VTC for the non- inverting comparator look like with V_{Th}=0V?

3. P. HYSTERESIS COMPARATOR

3.1. P. INVERTING COMPARATOR

You will use the schematic of Fig. 7.4.

- Which are the expression of the threshold voltages $V_{Th,L}$ and $V_{Th,H}$?
- What are the values of $V_{Th,L}$ and $V_{Th,H}$ for V_{REF} = 0V, V^+=12V, V^- = -12V?
- Which is the VTC $v_O(v_I)$? What is the sense of movement on the hysteresis curve?
- What does $v_O(t)$ look like when $v_I = 8\sin 2\pi \cdot 200t$ [V][HZ], for the above data ? What happens if the amplitude of v_I is 1V?
- What are the effects of modifying the supply voltage over VTC?
- What are the effects of modifying V_{REF} over VTC?

3.2. P. NON-INVERTING COMPARATOR

For the schematic of Fig. 7.5 the following data is given: V^+=12V, V^- = -12V, V_{REF} = 0V.

- Which is VTC for the non-inverting comparator with positive feedback?
- What does $v_O(t)$ look like for $v_I(t)$ sinusoidal voltage with 3V amplitude and 200Hz frequency ? What happens if the v_I amplitude is 8V?

IV. EXPLORATIONS AND RESULTS

1. OP-AMP WITHOUT FEEDBACK

1.1 WAVEFORMS

Exploration

Consider the experimental circuit of Fig. 7.2.

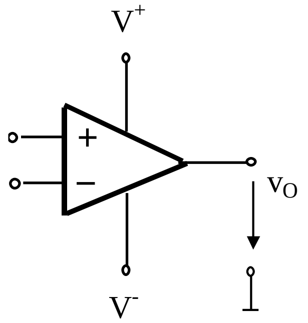

Fig. 7.2 Op-Amp without feedback

The assembly is supplied with a symmetrical differential voltage, V^+= +12V, V^- = -12V from the dual dc regulated power supply.

- Using a dc voltmeter you will measure v_O in the following situations:
  - inputs not connected (in the air)
  - one input not connected and one input connected to the ground
  - both inputs connected to the ground

Results

- v_O in the three above mentioned situations.
- How do you explain that $v_O \neq 0$ in all these situations?

2. COMPARATOR WITHOUT FEEDBACK

2.1. INVERTING COMPARATOR

Consider the experimental circuit of Fig. 7.3

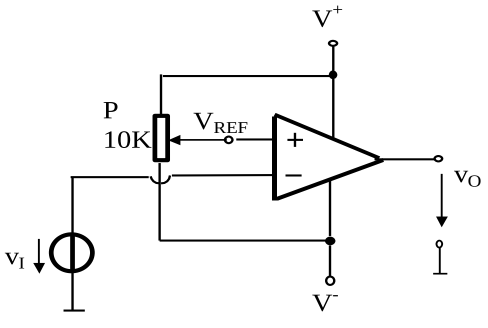

Fig. 7.3 Basic inverting comparator

Exploration

The assembly is supplied with a symmetrical differential voltage, V^+ = +12V, V^- = -12V.

- $v_I = 8\sin 2\pi \cdot 200t$[V][Hz] from the signal generator.
- Using P you will adjust the value of V_{REF}; you will measure this value with a dc voltmeter.

A. Waveforms

- Using the calibrated oscilloscope you will visualize $v_I(t)$ and $v_O(t)$ for V_{REF}=0V and for V_{REF} = 4V.
- Modify the amplitude of v_I to 2V.
- You will visualize $v_O(t)$ and $v_I(t)$ for V_{REF} = - 4V.
- For a v_I amplitude of 8V and for V_{REF} = - 4V you will see $v_O(t)$ and $v_I(t)$ on the oscilloscope.

B. VTC

- Adjust $v_I = 8\sin 2\pi \cdot 200t$ [V][Hz] and V_{REF} = 0V.
- With the help of the calibrated oscilloscope, Y-X mode, you will see VTC $v_O(v_I)$, applying to the two inputs X and Y of the oscilloscope the two voltages $v_I(t)$ and respectively $v_O(t)$.
- You will visualize VTC for V_{REF} = 4V
- You will visualize VTC for V_{REF} = - 4V

C. The effects of modifying the supply voltage

- Supply the assembly with a differential voltage of $V^+ = +9V$, $V^- = -9V$.
- $v_I = 8\sin 2\pi \cdot 200t$[V][Hz] from the signal generator.
- V_{REF} = 0V by adjusting P.
- With the help of the oscilloscope, Y- t mode, you will see $v_I(t)$ and $v_O(t)$.
- Modify the supply voltages: $V^+ = +15V$, $V^- = -9V$.
- You will see $v_I(t)$ and $v_O(t)$ on the oscilloscope.

Results

A. Waveforms

- $v_I(t)$ and $v_O(t)$ for a v_I amplitude of 5V, for V_{REF} = 0V and for V_{REF} = 4V.
- What are the values of the threshold voltage V_{Th} of the comparator in the two situations above? You will find V_{Th} from the waveforms of v_I and v_O in the following way: you will find the instantaneous values of v_I when the comparator is switching.
- What is the relation between V_{Th} and V_{REF}?
- $v_O(t)$ for a v_I amplitude of 1V and V_{REF} = 4V.
- Why isn't $v_O(t)$ a rectangular voltage anymore ?
- V_{Th} =?

B.VTC

- VTC for V_{REF}=0V, 4V, -4V.
- How is VTC modified on the coordinate system v_I-v_O for a modified V_{REF}? Why?

C. The effects of modifying the supply voltage

- $v_I(t)$ and $v_O(t)$ for $V^+= +9V$, $V^- = -9V$ and for $V^+= +15V$, $V^- = -9V$.
- What is the effect of modifying the supply voltage on the V_{Th}?
- Which are the maximum and minimum values of the output voltage of the comparator, V_{OH} and V_{OL}, if modifying the values of the supply voltage? Compare the values of V_{OH} and V_{OL} with the ones you have obtained at A and B.

2.2 NON- INVERTING COMPARATOR

Exploration

Build the experimental circuit drawn at 2.2. P.

- $v_I = 8\sin 2\pi \cdot 200t$[V][Hz] from the signal generator.
- Using P, adjust V_{REF}, which is measured with a dc voltmeter.
- We will visualize $v_I(t)$ and $v_O(t)$ for V_{REF}=0V.
- We will visualize VTC $v_O(v_I)$ for V_{REF}=0V.

Continue the experiment in a similar manner with paragraph 2.1 for waveforms and VTC.

Results

- $v_I(t)$ and $v_O(t)$
- VTC
- What is the difference of the VTC compared with the one obtained at 2.1
- The results will be presented in a similar manner with the ones in paragraph 2.1.

3. HYSTERESIS COMPARATOR

3.1. INVERTING COMPARATOR

Exploration

You will use the experimental schematic from Fig. 7.4.

- V^+ = +12V, V^- = -12V from the dual dc regulated power supply.
- You will measure V_{REF} with a dc voltmeter and you will adjust V_{REF} = 0V, with P.
- $v_I = 8\sin 2\pi \cdot 200t$[V][Hz] from the signal generator.
- Using the oscilloscope, Y-t mode, visualize $v_I(t)$ and $v_O(t)$.
- Using the oscilloscope, Y-X mode visualize VTC $v_O(v_I)$.
- Modify the amplitude of v_I to 1V.
- Using the oscilloscope, Y-t mode, visualize $v_I(t)$ and $v_O(t)$.

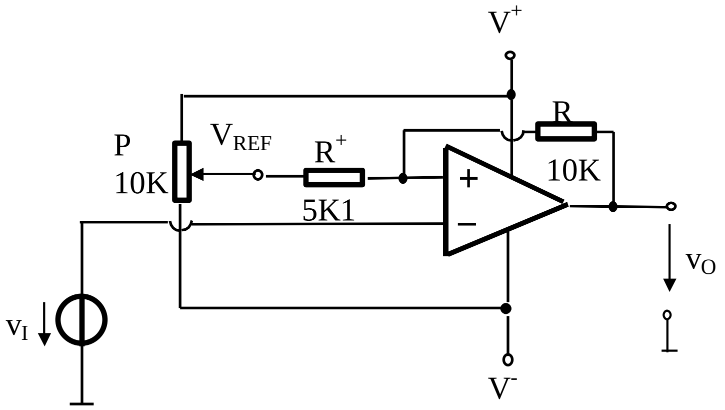

Fig. 7.4 Inverting comparator with positive feedback

A. The effects of modifying the voltage supply

- You will modify the supply voltages V^+= +9V, V^- = -9V.
- Using the oscilloscope visualize $v_I(t)$, $v_O(t)$, then VTC $v_O(v_I)$ for V_{REF}= 0V and v_I amplitude of 8V.
- You will modify the supply voltages to V^+= +15V, V^- = -9V.
- Visualize $v_I(t)$, $v_O(t)$ and VTC.

B. The effects of modifying V_{REF}

- Supply the assembly with V^+=+12V, V^-= -12V.
- Adjust P until V_{REF} =3V.
- Using the oscilloscope, visualize $v_I(t)$, $v_O(t)$ and $v_O(v_I)$.
- Set V_{REF} = -3V. Using the oscilloscope visualize $v_I(t)$, $v_O(t)$ and $v_O(v_I)$.

Results

- $v_I(t)$ and $v_O(t)$ for a v_I amplitude of 8V and 1V.
- VTC $v_O(v_I)$ when the amplitude of v_I is 8V.
- What are the values of the threshold voltages $V_{Th,H}$ and $V_{Th,L}$?
- What is the width of the hysteresis curve $\Delta V_{Th}=V_{Th,H}-V_{Th,L}$?

A. The effects of modifying the voltage supply

- $v_I(t)$, $v_O(t)$,$v_O(v_I)$ for V^+= +9V, V^- = -9V, and for V^+= +15V, V^- = -9V.
- What are the effects of modifying the supply voltages on the threshold voltages?
- Is the width of the hysteresys curve affected by the modification of the supply voltage? Why?

B. The effects of modifying V_{REF}

- $v_I(t)$, $v_O(t)$, $v_O(v_I)$ for V_{REF} = 4V and for V_{REF} = -4V and for V^+= +15V, V^-= -9V.
- What are the values of the threshold voltages $V_{Th,H}$ and $V_{Th,L}$? Are they related to V_{REF}?
- Is the width of the hysteresis curve modified for V_{REF} = 0V?
- Modifying V_{REF}, the hysteresis curve will move along one of the axis. Which one?

3.2. NON-INVERTING COMPARATOR

You will use the circuit shown in Fig. 7.5

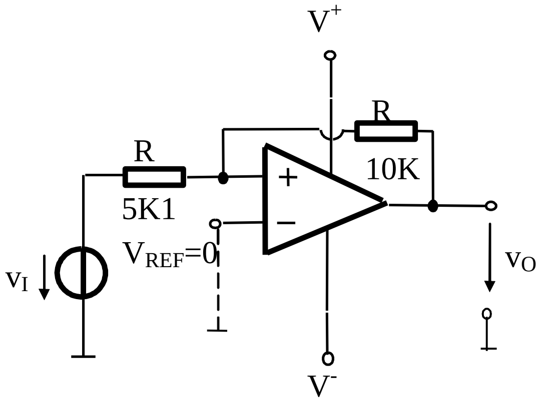

Fig 7.5 Non-inverting comparator with positive feedback

Exploration

- Supply the assembly with the differential voltage: V^+=12V, V^- = -12V.
- V_{REF}=0, by connecting the inverting input to the ground.
- v_I is a sinusoidal voltage with 8V amplitude and 200Hz frequency from the signal generator.
- Using the calibrated oscilloscope, you will see v_I(t), v_O(t) and VTC $v_O(v_I)$.

Results

- v_I(t), v_O(t).
- VTC
- Compare the VTC with the one obtained for the inverting comparator with positive feedback, for the same values of the supply and reference voltages, from the point of view of the output voltage values, the threshold voltages, and the sense of movement on the hysteresis curve.
- Why is this comparator called" non-inverting"?