Noninverting Amplifiers

Please do the following exercises individually.

Example

A sensor produces a measuring signal between 0 V and 10 mV. The amplified signal must not exceed 1 V. Please choose adequate resistors taken from the E12-series: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820. What is the real output?

Exercise 1

An operational amplifier increases an input voltage of 5 mV to 1 V. Please determine the amplification factor.

Exercise 2

An operational amplifier has a 15 kΩ grounding resistor R_1 and a 120 kΩ series resistor R_2. Please determine the amplification factor.

Exercise 3

The input voltage of an operational amplifier with R_1 = 10 kΩ and R_2 = 100 kΩ is 1.5 V. Please determine the output voltage.

Exercise 4

A non-inverting amplifier has an amplification factor of 250. The grounding resistor R_1 is 8.2 kΩ. Please determine the resistance of the series resistor R_2.

Exercise 5

The output voltage of an op amp must not be above 5 V. Please determine the maximum input voltage if R_1 = 12 kΩ and R_2 = 320 kΩ.

Noninverting Amplifiers

Please do the following exercises individually.

Example

A sensor produces a measuring signal between 0 V and 10 mV. The amplified signal must not exceed 1 V. Please choose adequate resistors taken from the E12-series: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820. What is the real output?

Known Quantities: V_{in} = 10 mV, V_{out} = 1 V
Assumption: R_1 = 10 kΩ

$$A_{CL} = \frac{V_{out}}{V_{in}} = \frac{1\ V}{0.01\ V} = 100$$

$$A_{CL} = 1 + \frac{R_2}{R_1} \rightarrow R_2 = (A_{CL} - 1)R_1 = 99 \cdot R_1 = 990\ k\Omega \overset{E12}{\Longrightarrow} 820\ k\Omega \rightarrow A_{CL_{E12}} = 1 + \frac{R_2}{R_1} = 82$$

$$V_{out} = A_{CL} \cdot V_{in} = 82 \cdot 10\ mV = 820\ mV$$

Exercise 1

An operational amplifier increases an input voltage of 5 mV to 1 V. Please determine the amplification factor.

A_{CL} = 200

Exercise 2

An operational amplifier has a 15 kΩ grounding resistor R_1 and a 120 kΩ series resistor R_2. Please determine the amplification factor.

A_{CL} = 9

Exercise 3

The input voltage of an operational amplifier with R_1 = 10 kΩ and R_2 = 100 kΩ is 1.5 V. Please determine the output voltage.

V_{out} = 16.5 V

Exercise 4

A non-inverting amplifier has an amplification factor of 250. The grounding resistor R_1 is 8.2 kΩ. Please determine the resistance of the series resistor R_2.

R_2 = 2 MΩ

Exercise 5

The output voltage of an op amp must not be above 5 V. Please determine the maximum input voltage if R_1 = 12 kΩ and R_2 = 320 kΩ.

V_{in} must not exceed 180 mV.

Inverting Amplifiers

Please do the following exercises individually.

Example

An operational amplifier has an output range from -12 V to +12 V. You want to measure an alternating current with a voltage of 140 mV. The input resistor R_1 has 4.7 kΩ. Please determine the resistance of the feedback resistor R_2.

Exercise 1

An operational amplifier increases an input voltage of 5 mV to -1 V. Please determine the amplification factor.

Exercise 2

An operational amplifier has a 15 kΩ input resistor R_1 and a 120 kΩ feedback resistor R_2. Please determine the amplification factor.

Exercise 3

The input voltage of an operational amplifier with R_1 = 10 kΩ and R_2 = 100 kΩ is 1.5 V. Please determine the output voltage.

Exercise 4

An inverting amplifier has an amplification factor of 250. The input resistor R_1 is 8.2 kΩ. Please determine the resistance of the feedback resistor R_2.

Exercise 5

The output voltage of an op amp must not be below -5 V. Please determine the maximum input voltage if R_1 = 2.7 kΩ and R_2 = 390 kΩ.

Inverting Amplifiers

Please do the following exercises individually.

Example

An operational amplifier has an output range from -12 V to +12 V. You want to measure an alternating current with a voltage of 140 mV. The input resistor R_1 has 4.7 kΩ. Please determine the resistance of the feedback resistor R_2.

Known quantities: V_{rms} = 140 mV, V_{out} = ±12V, R_1 = 4.7 kΩ

$$V_{in} = \hat{V} = \sqrt{2} \cdot V_{rms} = 198\,mV \approx 0.2\,V$$

$$A_{CL} = \frac{V_{out}}{V_{in}} = \frac{12\,V}{0.2\,V} = 60$$

$$A_{CL} = \frac{R_2}{R_1} \rightarrow R_2 = A_{CL} \cdot R_1 = 60 \cdot 4.7\,\text{k}\Omega = 282\,\text{k}\Omega$$

Exercise 1

An operational amplifier increases an input voltage of 5 mV to -1 V. Please determine the amplification factor.

A_{CL} = 200

Exercise 2

An operational amplifier has a 15 kΩ input resistor R_1 and a 120 kΩ feedback resistor R_2. Please determine the amplification factor.

A_{CL} = 8

Exercise 3

The input voltage of an operational amplifier with R_1 = 10 kΩ and R_2 = 100 kΩ is 1.5 V. Please determine the output voltage.

V_{out} = -15 V

Exercise 4

An inverting amplifier has an amplification factor of 250. The input resistor R_1 is 8.2 kΩ. Please determine the resistance of the feedback resistor R_2.

R_2 = 2 MΩ

Exercise 5

The output voltage of an op amp must not be below -5 V. Please determine the maximum input voltage if R_1 = 2.7 kΩ and R_2 = 390 kΩ.

V_{in} = 35 mV

Differential Amplifiers

Please do the following exercises individually.

Example

The are 5 mV on the non-inverting input of a differential amplifier and 1.8 mV on the inverting one. The input resistor has 10 kΩ. You need an output of about 4 V. Please determine the resistance of the other resistor. Choose a value from the E12-series: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820. What is the actual output voltage?

Exercise 1

A differential amplifier has an input resistor of 47 kΩ and a feedback resistor of 560 kΩ. What is the close loop amplification of the circuit?

Exercise 2

You need an amplification of 350. Which resistors will you use?

Exercise 3

The input voltages of a differential amplifier with R1 = 470 kΩ and R2 = 82 kΩ are 1.2 V and 3.0 V. Please determine the two possible output voltages.

Exercise 4

The output voltage of a differential amplifier with an amplifications factor of 100 is 7.5 V. The voltage at the inverting input is 50 mV. What is the voltage at the non-inverting input?

Exercise 5

The amplification factor of a differential amplifier is 50. The input resistor has 15 kΩ. What is the resistance of the other resistor?

Differential Amplifiers

Please do the following exercises individually.

Example

The are 5 mV on the non-inverting input of a differential amplifier and 1.8 mV on the inverting one. The input resistor has 10 kΩ. You need an output of about 4 V. Please determine the resistance of the other resistor. Choose a value from the E12-series: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820. What is the actual output voltage?

Known quantities: V_{in+} = 5 mV, V_{in-} = 1.8 mV, R_1 = 1 kΩ, V_{out} = 4 V

$$V_{out} = A_{CL}(V_{in_+} - V_{in_-}) \rightarrow A_{CL} = \frac{V_{out}}{V_{in_+} - V_{in_-}} = \frac{4\ V}{0.005\ V - 0.0018\ V} = 1250$$

$$A_{CL} = \frac{R_2}{R_1} \rightarrow R_2 = A_{CL} \cdot R_1 = 1250 \cdot 1\ k\Omega = 1250\ k\Omega = 1.25\ \text{M}\Omega \xrightarrow{E12} 1.2\ M\Omega \rightarrow A_{CL} = \frac{R_2}{R_1} = 1200$$

$$V_{out} = A_{CL}(V_{in_+} - V_{in_-}) = 1200 \cdot (0.005\ V - 0.0018\ V) = 3.84\ V$$

Exercise 1

A differential amplifier has an input resistor of 47 kΩ and a feedback resistor of 560 kΩ. What is the close loop amplification of the circuit?

A_{CL} = 12

Exercise 2

You need an amplification of 350. Which resistors will you use?

R_2 = 350 kΩ

Exercise 3

The input voltages of a differential amplifier with R1 = 470 kΩ and R2 = 82 kΩ are 1.2 V and 3.0 V. Please determine the two possible output voltages.

V_{out} = ±0.31 V

Exercise 4

The output voltage of a differential amplifier with an amplifications factor of 100 is 7.5 V. The voltage at the inverting input is 50 mV. What is the voltage at the non-inverting input?

V_{out} = 125 mV

Exercise 5

The amplification factor of a differential amplifier is 50. The input resistor has 15 kΩ. What is the resistance of the other resistor?

R_2 = 750 kΩ

Schmitt Trigger

Please do the following exercises individually.

Example

The threshold voltage of a Schmitt Trigger is 0 V. The supply voltages are $\pm V_S$. Where are the switching levels of the circuit?

Exercise 1

The input resistor of a Schmitt trigger has 10 kΩ and the feedback resistor 82 kΩ. The threshold voltage is 0 V and the supply voltages are ±5 V. At which input voltages flips the output?

Exercise 2

The input resistor of a Schmitt trigger has 8.2 kΩ and the feedback resistor 15 kΩ. The threshold voltage is 2.5 V and the supply voltages are 5 V and 0.V. Where are the switching points of the circuit?

Exercise 3

A voltage comparator has a supply voltage of 12 V. The reference input is connected with 5 V. What is the physical and logical output of the comparator if the voltages 0 V, 3 V, 4,9 V und 5,1 V are probed?

Schmitt Trigger

Please do the following exercises individually.

Example

The threshold voltage of a Schmitt Trigger is 0 V. The supply voltages are ±V_S. Where are the switching levels of the circuit?

Known quantities: V_{thr} = 0 V, V_{S+} = +V_S, V_{S-} = -V_S

$$V_{HT} = V_{thr} + \frac{R_1}{R_1 + R_2}\left(V_{S_+} - V_{thr}\right) = \frac{R_1}{R_1 + R_2} \cdot V_S$$

$$V_{LT} = V_{thr} + \frac{R_1}{R_1 + R_2}\left(V_{S_-} - V_{thr}\right) = \frac{R_1}{R_1 + R_2} \cdot -V_S = -\frac{R_1}{R_1 + R_2} \cdot V_S$$

Exercise 1

The input resistor of a Schmitt trigger has 10 kΩ and the feedback resistor 82 kΩ. The threshold voltage is 0 V and the supply voltages are ±5 V. At which input voltages flips the output?

V_{HT} = 0.54 V, V_{LT} = -0.54 V

Exercise 2

The input resistor of a Schmitt trigger has 8.2 kΩ and the feedback resistor 15 kΩ. The threshold voltage is 2.5 V and the supply voltages are 5 V and 0.V. Where are the switching points of the circuit?

V_{HT} = 2.88 V, V_{LT} = 1.62 V

Exercise 3

A voltage comparator has a supply voltage of 12 V. The reference input is connected with 5 V. What is the physical and logical output of the comparator if the voltages 0 V, 3 V, 4,9 V und 5,1 V are probed?

V_{in}	0 V	3 V	4.9 V	5.1 V
V_{out}	0 V	0 V	0 V	12 V
	0	0	0	1

Integrator

Please do the following exercises individually.

Example

The output voltage increases by 2 V per ms when an input voltage of -1 V is provided. Please determine the time constant of the circuit. Select an adequate resistor and capacitor from the E12-series: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820. What is the actual time constant then?

Exercise 1

An integrator has a resistor with 56 kΩ and a capacitor with 12 nF. It is connected with a constant 1 V power source. What is the change in output voltage after 3 ms?

Exercise 2

An integrator which is constructed by means of an op amp has an input resistor of 27 kΩ. At the input, there is a constant voltage of 3 V. The output voltage drops 1.2 V per ms. Determine the capacity of the feedback capacitor.

Exercise 3

At the beginning input and output voltage of an integrator are 1V. 2 milliseconds later the output voltage has doubled. What is the time constant of the device?

Integrator

Please do the following exercises individually.

Example

The output voltage increases by 2 V per ms when an input voltage of -1 V is provided. Please determine the time constant of the circuit. Select an adequate resistor and capacitor from the E12-series: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820. What is the actual time constant then?

Known quantities: ΔV_{out} = 2 V, V_{in} = -1 V
Assumption: R = 1 kΩ

$$\Delta V_{out} = -\frac{1}{\tau} \cdot V_{in} \cdot \Delta t \rightarrow \tau = -\frac{V_{in} \cdot \Delta t}{\Delta V_{out}} = \frac{1\,V \cdot 0.001\,s}{2\,V} = 0.0005\,s = 0.5\,ms$$

$$\tau = R \cdot C \rightarrow C = \frac{\tau}{R} = \frac{0.0005\,s}{1000\,\Omega} = 0.5 \cdot 10^{-6}\,F = 0.5\,\mu F \xrightarrow{E12} 0.47\mu F \text{ or } 0.56\,\mu F$$

$$\tau = R \cdot C = 1 \cdot 10^{3}\,\Omega \cdot 0.47 \cdot 10^{-6}\,F = 0.47 \cdot 10^{-3}\,s = 0.47\,ms \text{ or } 0.56\,\mu F \rightarrow 0.56\,ms$$

Exercise 1

An integrator has a resistor with 56 kΩ and a capacitor with 12 nF. It is connected with a constant 1 V power source. What is the change in output voltage after 3 ms?

ΔV_{out} = 44.64 V

Exercise 2

An integrator which is constructed by means of an op amp has an input resistor of 27 kΩ. At the input, there is a constant voltage of 3 V. The output voltage drops 1.2 V per ms. Determine the capacity of the feedback capacitor.

C = 92.6 nF

Exercise 3

At the beginning input and output voltage of an integrator are 1V. 2 milliseconds later the output voltage has doubled. What is the time constant of the device?

T = 0.2 ms

Differentiator

Please do the following exercises individually.

Example

The input voltage of a differentiator is constant 1.2 V for 5 ms. Then it drops to 0.5 V within 0.5 ms. Afterwards it remains constant again. The resistor of the differentiator has 12 kΩ, the capacitor 100 nF. Please determine the output voltage as a function of time.

Exercise 1

A differentiator has a resistor with 2.2 kΩ and a capacitor with 56 nF. What is the time constant of the differentiator?

Exercise 2

A differentiator has a 10 µF capacitor. Its time constant is 2 ms. What is the resistance of the resistor?

Exercise 3

The input voltage of a differentiator is recorded. In the time range from 3 ms til 6 ms the voltage drops from 5 V to 1V. The differentiator is constructed with a 27 kΩ resistor and a 47 nF capacitor. Please determine the output voltage during this period.

Exercise 4

While the input voltage of a differentiator with R = 220 kΩ and 8.2 µF drops from +6V to -1V, the has constantly 4 V. Please calculate the duration of the voltage drop.

Differentiator

Please do the following exercises individually.

Example

The input voltage of a differentiator is constant 1.2 V for 5 ms. Then it drops to 0.5 V within 0.5 ms. Afterwards it remains constant again. The resistor of the differentiator has 12 kΩ, the capacitor 100 nF. Please determine the output voltage as a function of time.

Facts: V_{in} = 1.2 V const for 5 ms, ΔV_{in} = -0.7 for 0.5 ms, V_{in} = 0.5 V const then
Known quantities: ΔV_{in} = -0.7, Δt = 0.5 ms, R = 12 kΩ, C = 100 nF

$$V_{out} = -R \cdot C \cdot \frac{\Delta V_{in}}{\Delta t} = -12 \cdot 10^3\ \Omega \cdot 100 \cdot 10^{-9}\ F \cdot \frac{0.7\ V}{0.5 \cdot 10^{-3}\ s} = 1.68\ V$$

$$V_{out}(t) = \begin{cases} 0\ V, & t < 5ms \\ 1.68\ V, & 5ms \leq t \leq 5.5\ ms \\ 0\ V, & t > 5.5\ ms \end{cases}$$

Exercise 1

A differentiator has a resistor with 2.2 kΩ and a capacitor with 56 nF. What is the time constant of the differentiator?

τ = 123 µs

Exercise 2

A differentiator has a 10 µF capacitor. Its time constant is 2 ms. What is the resistance of the resistor?

R = 200 Ω

Exercise 3

The input voltage of a differentiator is recorded. In the time range from 3 ms til 6 ms the voltage drops from 5 V to 1V. The differentiator is constructed with a 27 kΩ resistor and a 47 nF capacitor. Please determine the output voltage during this period.

V_{out} = 1.69 V

Exercise 4

While the input voltage of a differentiator with R = 220 kΩ and 8.2 µF drops from +6V to -1V, the has constantly 4 V. Please calculate the duration of the voltage drop.

Δt = 3.16 ms