**Op-amps are versatile elements used to implement various circuits such as amplifiers, comparators, filters, and son on. In this experiment, you become familiar with a typical op-amp and its common applications.**

# MANDATORY EXPERIMENTS

## Experiment 1

**Build the circuit shown in Fig. 1 using an op-amp comparator module. Create a pair of $\pm 18$ V voltages and connect them to the supply connectors of the module.**

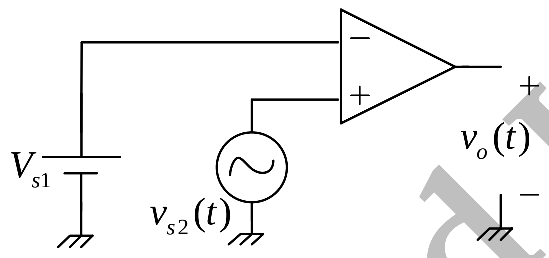


Figure 1: An op-amp as a comparator.

*(a) Set $V_{s1} = 0$ or equivalently, connect the inverting input of the op-amp to the ground. Apply a $1$-V $1$-kHz sine voltage $v_{s2}(t)$ to the non-inverting input. Watch the the output voltage and the non-inverting input voltage of the op-amp simultaneously on the oscilloscope. Interpret the results. Change the sine wave to a triangle wave and observe the results.*

*(b) Set $V_{s1} = \pm 0.5$ V and repeat the previous part.*

*(c) Swap the input voltages to the op-amp and redo the previous parts.*

## Experiment 2

**Build the circuit shown in Fig. 2 using an op-amp comparator module. Create a pair of $\pm 18$ V voltages and connect them to the supply connectors of the module as well as to the fixed legs of the potentiometer.**

*Experiment 2 continued on next page...*

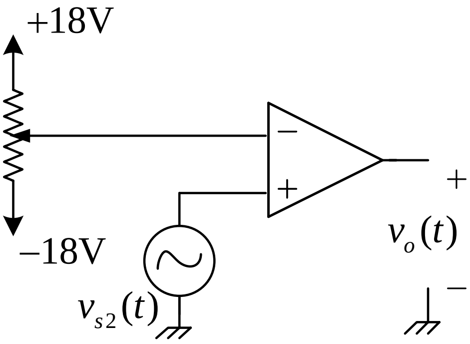


Figure 2: An op-amp as a comparator along with a potentiometer as a voltage divider.

*(a) Apply a* $1$*-V* $1$*-kHz sine voltage* $v_{s2}(t)$ *to the non-inverting input. Watch the the output voltage and the non-inverting input voltage of the op-amp simultaneously on the oscilloscope. Turn the knob of the potentiometer and observe the results.*

*(b) Repeat the previous part for a triangle wave.*

## Experiment 3

**Build the circuit shown in Fig. 3 using an op-amp inverting amplifier module. Create a pair of** $\pm 18$ **V voltages and connect them to the supply connectors of the module.**

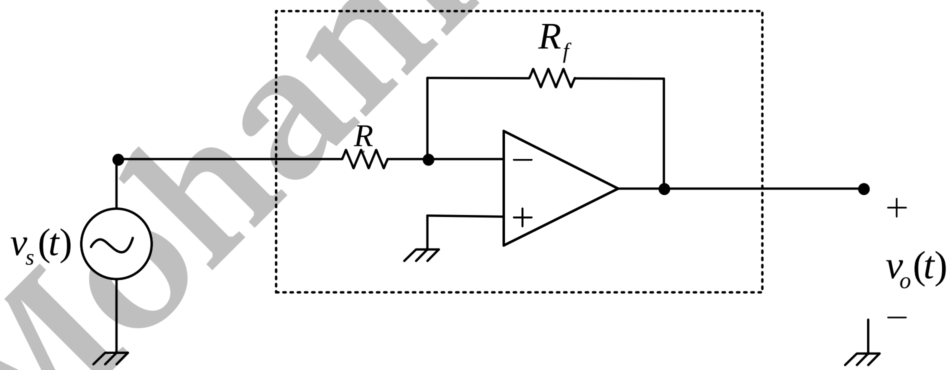


Figure 3: Inverting amplifier.

*(a) Apply a* $0.5$*-V* $1$*-kHz sine voltage* $v_s(t)$ *to the input of the amplifier. Watch the the output and input voltages of the amplifier simultaneously on the oscilloscope. Calculate the gain of the amplifier.*

*Experiment 3 continued on next page...*

*(b) Devise an experiment to measure the input and output resistance of the amplifier module.*

*(c) Increase the amplitude of the input $1$-kHz sine wave and record your observations. Interpret and discuss the results.*

*(d) Increase the frequency of the input $0.5$-V sine wave and record your observations. Interpret and discuss the results.*

## Experiment 4

**Build the circuit shown in Fig. 4 using an op-amp non-inverting amplifier module. Create a pair of $\pm 18$ V voltages and connect them to the supply connectors of the module.**

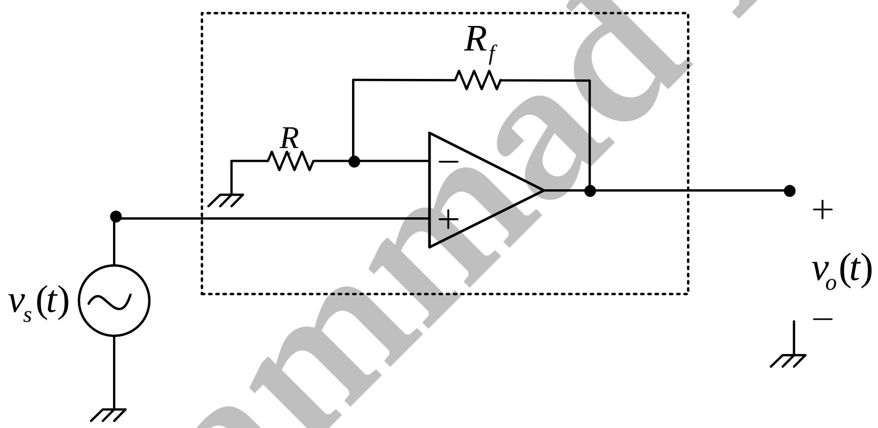


Figure 4: Non-inverting amplifier.

*(a) Apply a $0.5$-V $1$-kHz sine voltage $v_s(t)$ to the input of the amplifier. Watch the the output and input voltages of the amplifier simultaneously on the oscilloscope. Calculate the gain of the amplifier.*

*(b) Measure the input and output resistance of the amplifier module experimentally.*

*(c) Increase the amplitude of the input $1$-kHz sine wave and record your observations. Interpret and discuss the results.*

*Experiment 4 continued on next page...* 

*(d) Increase the frequency of the input $0.5$-V sine wave and record your observations. Interpret and discuss the results.*

## Experiment 5

**Cascade an inverting amplifier and a non-inverting amplifier as shown in Fig. 5 .**

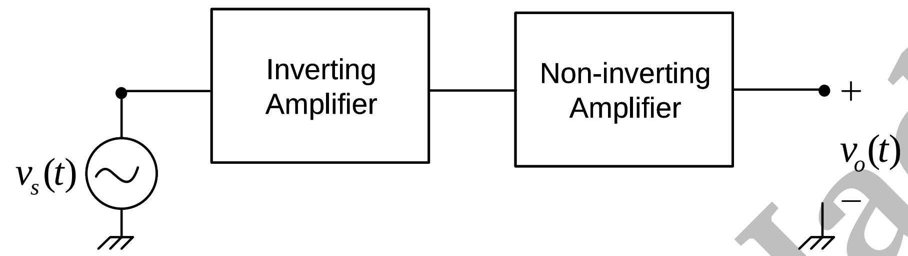


Figure 5: Cascade of two amplifiers.

*(a) Apply a $100$-mV $1$-kHz sine voltage $v_s(t)$ to the input of the cascaded amplifiers. Watch the the output and input voltages of the cascaded amplifiers simultaneously on the oscilloscope. Calculate the overall gain of the cascaded amplifiers.*

*(b) Swap the order of the amplifiers and repeat the previous part. Is there any difference between the measured gains in the two experiments? Explain.*

BONUS EXPERIMENTS

## Experiment 6

**In a circuit design, we need to cascade an inverting and a non-inverting amplifier to get the overall gain of $G_{tot} = G_{inv}G_{nnv}$.**

*(a) From analytical point of view, is there any difference to change the order of the cascaded amplifiers?*



*Experiment 6 continued on next page. . .* 

*(b) From practical point of view, is there any difference to change the order of the cascaded amplifiers? Justify your answer using PSpice simulation.*

## Experiment 7

**Op-amps usually need a pair of positive and negative DC supply voltages $\pm V_s$.**

*(a) What happens if the absolute values of the supply voltages differ?*

*(b) Is it possible to use an op-amp with the supply voltages $0$ and $+V_s$? Explain.*

## Experiment 8

**Return your work report by filling the LaTeXtemplate of the manual. Include useful and high-quality images to make the report more readable and understandable.**