# Problem Set 06: Operational Amplifier Circuits

## BME253L - Fall 2025

2025-11-07

Please complete the following problems and tasks, and upload your solutions to Gradescope, using the formatting guidelines below.

## 1. Design an Amplifier

You have an input signal described by the equation:

$$v_{in}(t) = 0.1\sin(2000\pi t) \text{ V}$$

Design an operational amplifier circuit that is powered by $\pm$ 12 V that meets the following specifications:

- Gain: The output signal should have a peak voltage of 5 V.

- Phase Shift: The output signal should be inverted (180-degree phase shift).

a. Sketch your circuit, labeling all relevant components and their values.

b. Derive the expression for the output voltage $v_{out}(t)$.

c. Plot both the input and output signals over 5 periods of the input signal. Be sure to label your axes, including units.

## 2. Input Impedance

a. Describe why we typically want the input impedance of an op-amp circuit to be very high.

b. What is the input impedance of your circuit from Problem 1?

c. If the input impedance of your circuit from Problem 1 isn't "ideal" given the considerations you described in part (a), suggest a modification to your circuit that would improve the input impedance.

## 3. Op-Amp Saturation

You have an input signal described by the equation:

$$v_{in}(t) = 0.2\cos(1000\pi t) \text{ V}$$

What is the maximum gain that you can achieve with a single op-amp stage powered by $\pm$ 12 V without clipping the output signal?

## 4. DC Offset

You have an input signal described by the equation:

$$v_{in}(t) = 0.05\sin(500\pi t) + 0.5 \text{ V}$$

Design an operational amplifier circuit powered by $\pm$ 12 V that creates an output signal described by the equation:

$$v_{out}(t) = 2\sin(500\pi t) \text{ V}$$

> **i** Note
>
> Note the phase of the output signal relative to the input signal. You can use more than one op-amp stage if necessary.

a. Sketch your circuit, labeling all relevant components and their values.

b. For your design, how much power does your $v_{in}(t)$ signal source deliver if your overall circuit is driving a load of 100 kΩ?

## 5. Differential Amplifier

For the differential amplifier circuit that was presented in lecture, we make an assumption that $R_1 = R_2$ and $R_3 = R_4$.
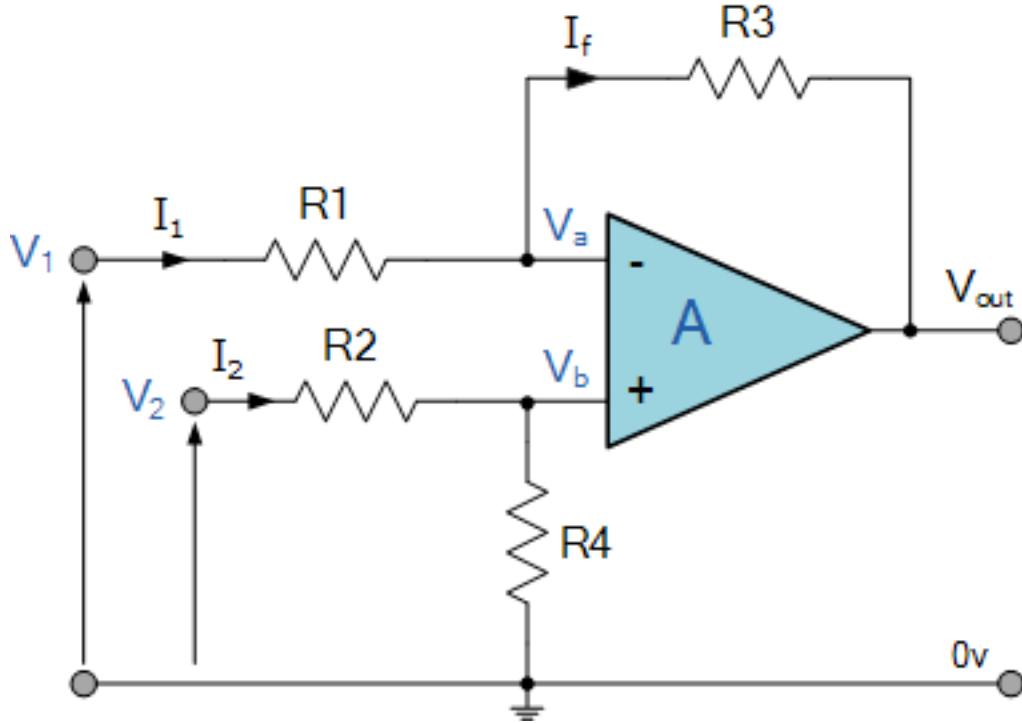


Figure 1: Differential Amplifier Circuit

If $R_2 = (1 \pm 0.1)R_1$ and $R_4 = (1 \pm 0.1)R_3$, meaning that the resistors can vary by as much as 10% from their nominal values, what is the maximum possible error in the output voltage $V_{out}$ when the input voltages are $V_1 = 2$ V and $V_2 = 1$ V? Assume that $R_1 = R_3 = 10$ k$\Omega$.