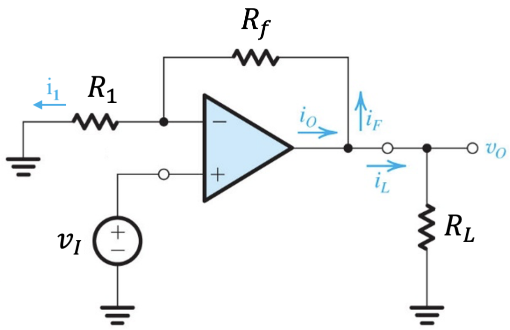
UC San Diego, ECE65

Lab 2: Operational Amplifier circuits

Experiment 1: Op-amp as a voltage amplifier and large-signal limits

One way to use operational amplifiers (op-amps) is as linear voltage amplifiers. A common configuration is the non-inverting amplifier. The op-amp will work as a linear amplifier if the output voltage and the op-amp output current are within the saturation limits. The aim of this experiment is to test the saturation limits and measure the outputs for different input and load conditions. You will use an LM741 op-amp in ECE65 labs. The maximum output current of this Op-amp is about $25mA$, and the saturation voltage is about $\pm 14V$ when $\pm 15V$ DC power supplies are used to power up the op-amp chip. You will use $\pm 15V$ DC power supplies for powering up the op-amp in simulations and lab experiments.



__Prelab:__

Circuit analysis

1. Using $R_1 = 1k\Omega$, find the value of R_f to achieve a voltage gain of $10V/V$.

2. Analyze the circuit and write the equations that relate i_o, i_L, and i_f to v_i.

Simulation

Part 1:

Simulate the circuit with PSpice/LTspice using a sinusoidal signal (v_I) with the peak amplitude $V_p = 1V$ and the frequency $f = 1kHz$. Use the load resistor $R_L = 1k\Omega$.

1. Run Transient (Time domain) Analysis for 5 ms.
2. Plot the input and output waveforms on the same graph. Does the graph match your expectations?
3. Plot the output current of the op-amp (i_o), the load current (i_L), and the currents that flow through R_1 and R_f as labeled on the circuit. Do they match your expectations?
4. What are the peak amplitudes of i_o, i_f, i_1, and i_L?

Part 2:

Simulate the circuit with PSpice/LTspice using a sinusoidal input signal (v_I) with the peak amplitude $V_p = 1.5V$ and the frequency $f = 1kHz$. Use the load resistor $R_L = 1k\Omega$

1. Run Transient (Time domain) Analysis for 5 ms.
2. Plot the input and output waveforms on the same graph.
3. How do you compare the output waveform in this part with the one you found in part 1?
4. Plot the output current of the op-amp (i_o), the load current (i_L), and the currents that flow through R_1 and R_f as labeled on the circuit.
5. What are the peak amplitudes of i_o, i_f, i_1, and i_L?

Part 3:

Using PSpice/LTspice with load resistor $R_L = 1k\Omega$, run a DC SWEEP on the input voltage v_l and plot the output voltage for v_I values between $1V$ and $5V$ ($1V < v_I < 5V$). Use the step size of $10\ mV$.

1. For what value of v_I (approximately) will the output of the op-amp saturate?
2. Plot the output current of the op-amp (i_o). the load current i_L, the current the flows through R_1 and R_f as labeled on the circuit.

Part 4:

Simulate the circuit with PSpice/LTspice using a sinusoidal input signal v_I with the peak amplitude $V_p = 1V$ and the frequency $f = 1kHz$. Use the load resistor $R_L = 200\Omega$.

1. Run Transient (Time domain) Analysis for 5ms.

2. Plot the input and output waveforms on the same graph.

3. What is the peak value of the output voltage waveform?

4. Plot the currents i_o, i_f, i_1, and i_L.

5. Explain your observation.

Part 5:

Simulate the circuit with PSpice using a DC input signal ($v_I = 1V$).

1. Run a parametric SWEEP to generate a plot of v_o as a function of R_L for R_L ranging from $1\ \Omega$ to $10\ k\Omega$ (step size $500\ \Omega$).

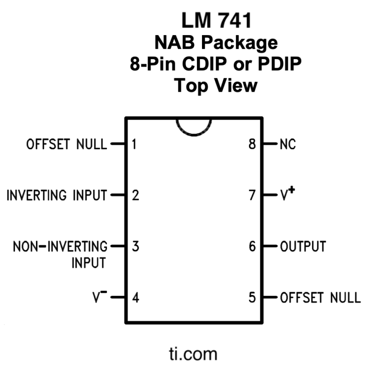
2. What is the maximum amplitude of v_o?

3. Does the result match your expectations?

Lab Exercise:

Build the circuit on the breadboard using an LM 741 chip. The supply terminals, pin 4 and pin 7 must be connected to $\pm 15V$. The balance terminals and pin 8 can be left "floating," i.e., not connected. Connect the resistors in the appropriate fashion to form the non-inverting amplifier.

LM741 pinout:



Part 1:

Set the function generator to generate a sinusoidal waveform with a peak amplitude of $V_P = 1\ V$

and the frequency of 1 kHz and use this waveform as the input voltage signal (v_I). Use $R_L = 1k\Omega$ in your circuit.

1. Measure the input and output waveform using the Oscilloscope.
2. Is the gain of the circuit as expected by the equations?
3. Include the graphs of the waveforms in your lab report.
4. Include a photo of your circuit setup in your lab report.

Part 2:

Repeat Part 1 for a sinusoidal waveform with the peak amplitude of $V_P = 1.5V$ and the frequency of $1kHz$, and $R_L = 1k\Omega$

1. Measure the input and output waveform using the Oscilloscope.
2. Is the output waveform any different from the previous one? Explain your observation.
3. Measure the total output current.
4. What is the limiting factor of the amplitude of the input signal?

Part 3:

Keeping $R_L = 1k\Omega$ and using a sinusoidal input voltage, find the peak amplitude of the input voltage at which the output of the op-amp saturates.

1. What is the peak amplitude of the output current for this value of V_P?

Part 4:

Set the function generator to generate a sinusoidal waveform with the peak amplitude of $Vp = 1V$ and the frequency of $1kHz$ and use this waveform as the input voltage signal (v_I). Use a $10k\Omega$ potentiometer as the load. Set the value of the potentiometer to its maximum $10k\Omega$ and gradually decrease R_L.

1. How does the output voltage waveform change when you reduce the value of R_L?
2. For what R_L value will the output of the op-amp saturate?

3. What is the maximum peak amplitude of the op-amp output current?

Experiment 2: Op-amp weighted summer

In this part of the experiment, we will design a summing amplifier in the inverting configuration. This circuit can be used to design and test standard mathematical linear equations and see the different results in terms of the output signals.

The following diagram represents a summing amplifier.

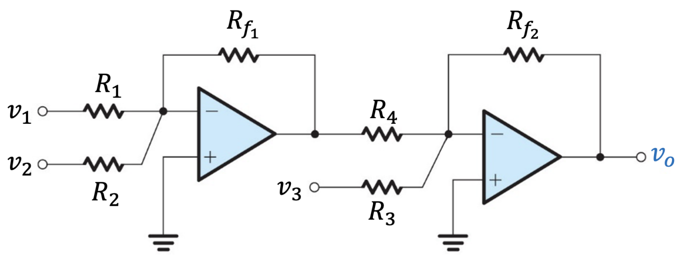
Prelab:

Circuit analysis

1. Using the commercially available resistors, design the following circuit to implement the function of

$$v_o = 2v_1 + v_2 - 4v_3$$

Use resistor values between 500 Ω and 100 $k\Omega$ in your design.



Simulation

1. Simulate the circuit with PSpice/LTspice using two DC voltage sources as v_1 and v_3 and a sinusoidal with $f = 1\ kHz$ as v_2. Choose the amplitudes of the voltage sources such that the op-amps function as linear amplifiers.

2. Run Transient (Time domain) Analysis for $5ms$.

3. Plot v_1, v_2, v_3, and v_o waveforms on the same graph.

Lab exercise:

Build the circuit on the breadboard using two LM741 op-amps.

1. Use two DC voltage sources as v_1 and v_3 and a sinusoidal signal with $f = 1\ kHz$ from the function generator as source voltages. Use the voltage source amplitudes that you calculated in your prelab.
2. Measure the voltage waveforms at the output of each op-amp using the oscilloscope and include a photo of these waveforms in your report.
3. Do the results match your expectation?
4. Include a photo of your circuit setup in your lab report.