Lab 8: Operational amplifiers (version 1.3)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Summary
An introduction to the operational amplifier and basic signal amplification circuits.

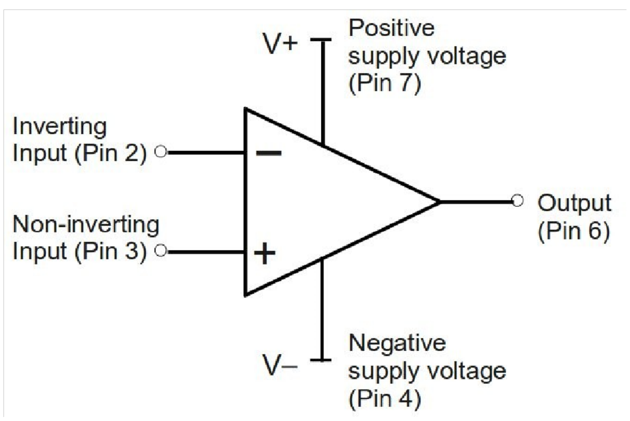
Learning Outcomes

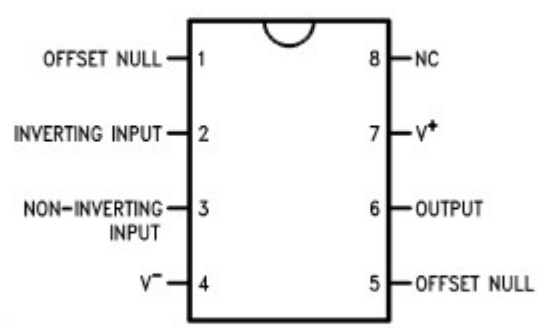
- Understand the basic function of an ideal op amp.
- Build an inverting, non-inverting, and summing amplifier using op amps.
- Build a Differentiating amplifier using op amps.

Lab Goals
Build and test circuits based on Operational Amplifiers and study their performance.

Experiment/Procedure
Operational amplifiers (OpAmps) are generic/versatile integrated circuits that can be used to build complex electronics. In this lab, you will build various electronic devices based on OpAmps. These devices include inverting/noninverting and summing amplifiers and differentiators.

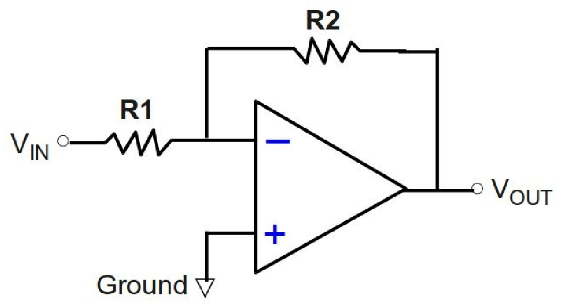
LF411 integrated circuit
The LF411 is a general-purpose operational amplifier. It comes in a variety of packages, including the dual inline pin (DIP) arrangement with two rows of four connectors. The package is oriented with a semi-circle notch located between pins 1 and 8 for orientation. (Pins 1, 5, and 8 are not used.)





Inverting amplifier

Build your inverting amplifier circuit using the LF411 IC chip. Use Supply voltages V+ = +15V and V- = −15V. (Alternatively use V±= ±12V from the breadboard).

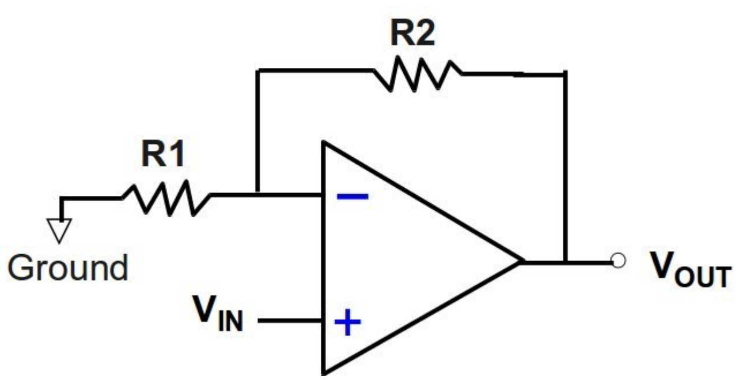


Use resistors within the 10-50 kΩ range. For example, R1 = 10 kΩ and R2 = 5 * R1; neither value is critical, but always measure components before placing them in the circuit. Use a function generator to supply a sine wave in V_{IN} with frequency 1-5 kHz and amplitude < 0.5 Vpp (values not critical). Monitor V_{IN} and V_{OUT} in the oscilloscope in different channels (use BNC T-connector if desired). Measure and record the gain ($V_{OUT}/V_{IN}= - Z_{OUT}/ Z_{IN}$) of the amplifier and the relative phase of V_{OUT} wrt V_{IN}. Replace R2 with a value close to 30 kΩ and repeat the measurement. Do the same for R1=R2.

Make a table showing your results for the gain, and phase for the three circuit configurations and show to instructor. Compare your results with the theoretical expectations for this circuit. Discuss your results and comparisons in your lab notebook.

Non-inverting amplifier

Build the following circuit, repeat the above three measurements for the same resistor values, and make a table, show to the instructor. Compare your results with the theoretical expectations for this circuit and discuss your results in the lab notebook.

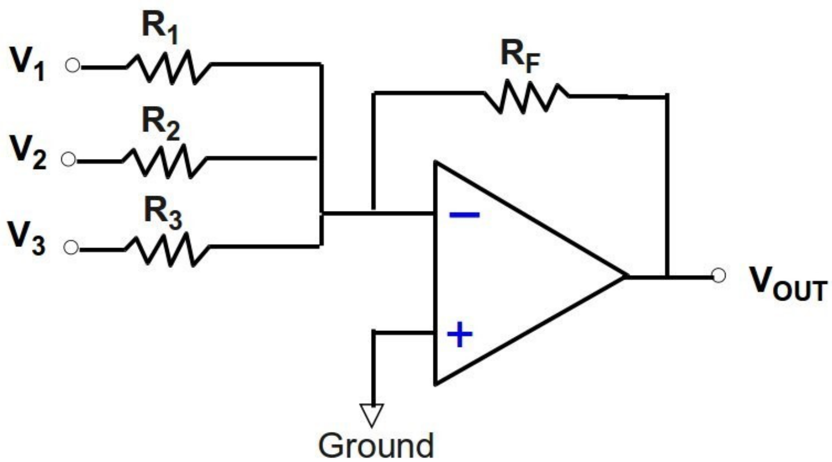


Can you build a noninverting amplifier with gain of 10? Discuss how and show it.

Using the non-inverting amplifier, find the frequency at which the gain drops to 1.

Summing amplifier

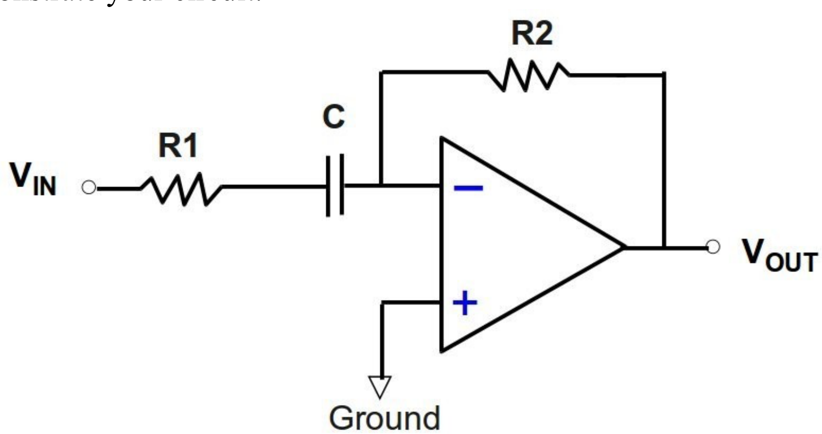
Build a summing amplifier circuit with gain of 1. Connect the function generator with the same output configuration as the inverting amplifier above to V_1 but leave the other inputs open. Record the gain and phase at V_{OUT}. Next connect the second input with a jumper wire between V_1 and V_2, leaving V_3 open. Record the output. Finally connect all 3 inputs to the function generator and record the output. Show the results table to the instructor. Compare your results with the theoretical expectations for this circuit and discuss your results in lab notebook.



As a final test of your summing amplifier, use this amplifier to add a DC offset to an AC signal, record and discuss your results.

Differentiating amplifier

Adding a capacitor to the input of the inverting amplifier converts it to a differentiating amplifier. Construct the following circuit with R1 ~100-200 Ω, R2 = 10-20 kΩ, and C = 10-30 nF. Values are not critical. But it is important calculate the resulting resonance frequency to choose the proper range of frequencies to demonstrate your circuit.



With the same sinusoidal input at frequency 1-5 kHz, the circuit will differentiate V_{IN} at V_{OUT}. i.e., V_{OUT} ~dV_{IN}/dt. Demonstrate its functionality. <u>Derive the expression for the time-dependence of V_{OUT} as a function of V_{IN}</u> to obtain the theoretical model. Compare your results with the theoretical expectations for this circuit and discuss your results.

Note: This circuit can also be thought of as a high pass filter. This is because of the capacitor's frequency dependent impedance $Z_C = 1/j\omega C$. Investigate the high-pass operation by choosing R1 = R2 ~10-20 kΩ and C = 10-20 nF (values not critical). Demonstrate its high pass operation and obtain the cutoff frequency. Show results to instructor.

Analysis

The required elements of the analysis for the different circuits are already discussed in each part of this lab guide. Report on your lab notebook the experimental procedure with diagrams and plots, when necessary, results, analysis, and discussion. (follow the guide for an statement of the required elements).