R·I·T
Kate Gleason
College of ENGINEERING

# EEEE 281 Experiment 4: Operational Amplifiers

**From:** Andrei Tumbar [Computer Engineering]
**To:** Section 2 TA: LJ Boone
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**Subject:** Lab 4-Operational Amplifiers
**Lab Partner(s):** N/A

| Component | Percentage of Grade | Score | Comment |
|---|---|---|---|
| Report Formatting | 20 % | | |
| Hand Calculation: Inverting Op-Amp | 5 % | | |
| Hand Calculation: Non-Inverting Op-Amp | 5 % | | |
| PSPICE: Setup Conditions | 5 % | | |
| PSPICE: Data and Figures | 10 % | | |
| PSPICE: Discussion of Simulation | 15 % | | |
| Hardware: Experimental Setup | 10 % | | |
| Hardware: Experimental Data and Tables | 10 % | | |
| Hardware: Discussion of Results | 20 % | | |
| **Total Score:** | | | |
| **Graded By:** | | | |

## Abstract

In this laboratory exercise, the setup for a desired op-amp circuit was investigated. There are two circuits in question, an inverting op-amp and a non-inverting op-amp. The amplification, a ratio between the output voltage and the input voltage, was arbitrarily set for both of the circuits. The inverting had a gain of 15 while the non-inverting had a gain of 11. A sinusoidal input voltage was used for simulation to clearly show in the inversion and amplification across a voltage range. The input voltage was defined to be the voltage relative to ground at the oscillating source. The output source was defined on the output of the op-amp.

## 1 Introduction and Theory

The scope of this lab was to provide a working example of setting up an op-amp circuit. An op-amp will take an input voltage and create a proportional gain depending on the resistor between the input and output nodes.

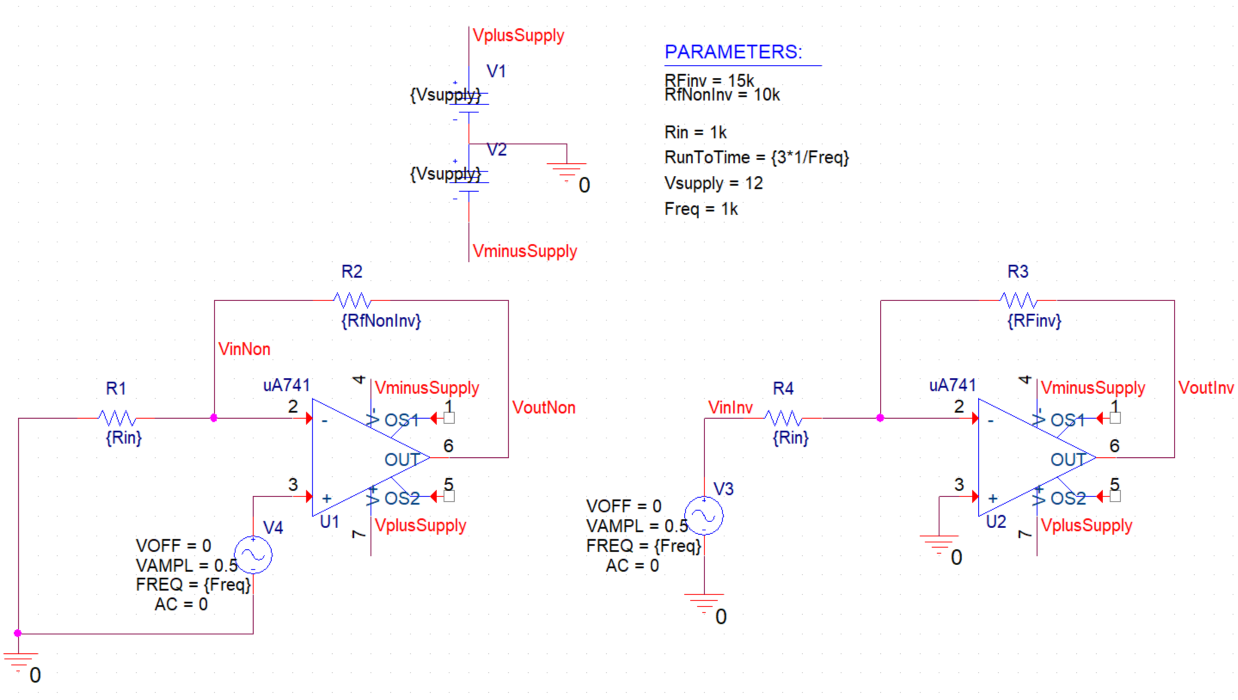


Figure 1.0.1: Schematic diagrams of the inverting (right) and non-inverting (left) OpAmps used in this report. This graphic is the PSPICE schematic capture.

Here two op-amps are shown. The left one is a non-inverting meaning that the gain will be a positive number. This means that the output voltage will non be a negative multiple of the input. Net-alias nodes were used to simplify the wiring of both circuits. Two 12 V supplies were wired in series to then connect to the power nodes on each op-amp.

## 1.1 Hand Calculations: Inverting Op-Amp

The inverting op-amp has a desired gain of 15. The value of $V_{in}$ is an arbitrary test value that will be used to produce a ratio, this value is set 1 V.

$$V_{in} = 1\,\mathrm{V} \tag{1.1.1}$$
$$\frac{V_{out}}{V_{in}} = -15.0 \tag{1.1.2}$$
$$V_{out} = -15\,\mathrm{V} \tag{1.1.3}$$
$$i_{in} = \frac{0\,\mathrm{V} - V_{in}}{1\,k\Omega} = -1\,m\mathrm{A} \tag{1.1.4}$$
$$V_{out} - i_{in} \cdot R_f = 0\,\mathrm{V} \tag{1.1.5}$$
$$-15\,\mathrm{V} - (-1\,m\mathrm{A}) \cdot R_f = 0\,\mathrm{V} \tag{1.1.6}$$
$$R_f = 15\,k\Omega \tag{1.1.7}$$

Because this op-amp is inverting, the $\frac{V_{out}}{V_{in}}$ ratio must be $-15$ as shown in Equation 1.1.2. $i_{in}$ is the current from the test source to the negative node of the op-amp. This same current will travel through the $R_f$ resistor. The desired resistance can be calculated because the required voltage drop is known. $R_f$ is determined to be $15\,k\Omega$.

Table 1.1.1: $R_1$ and $R_f$ selection for the Inverting Op Amp

| $R_{in}$ ($\Omega$) | $R_f$ ($\Omega$) |
|---|---|
| 1k | 15k |

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## 1.2 Hand Calculations: Non-Inverting Op-Amp

Looking at the non-inverting op-amp in Figure 1.0.1, the voltage on the negative terminal is equal to the one on the positive. If the input source voltage is set to the arbitrary value of 1 V, the $V_{in}$ node is also 1 V.

$$V_{in} = 1\,\mathrm{V} \tag{1.2.1}$$
$$\frac{V_{out}}{V_{in}} = 11.0 \tag{1.2.2}$$
$$V_{out} = 11\,\mathrm{V} \tag{1.2.3}$$
$$i_{out} = \frac{V_{in} - 0\mathrm{V}}{1\,k\Omega} = 1\,m\mathrm{A} \tag{1.2.4}$$
$$V_{out} - i_{out} \cdot R_f = V_{in} \tag{1.2.5}$$
$$11\,\mathrm{V} - (1\,m\mathrm{A}) \cdot R_f = 1\,\mathrm{V} \tag{1.2.6}$$
$$R_f = 10\,k\Omega \tag{1.2.7}$$

We begin with the set value $V_{in}$ being 1 V and the gain of the target circuit to be 11. To find the $R_f$ value the current through this resistor must be determined. The current $i_{out}$ defines the current from the $V_{in}$ to the ground node as depicted in Figure 1.0.1. The current will be the same as the current going through the $R_f$ resistor. The resistance of $R_f$ is determined to be $10\,k\Omega$.

Table 1.2.1: $R_1$ and $R_f$ selection for the Non-Inverting Op Amp

| $R_{in}$ ($\Omega$) | $R_f$ ($\Omega$) |
|---|---|
| 1k | 10k |

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## 1.3 Theory: PSPICE Simulation Summary

The PSPICE simulation began with a design of the circuit. The PSPICE setup used the libraries imported from the Circuits 1 library from the lab computer. The libraries were called **analog.olb**, **opamp.olb**, **source.olb**, and **special.olb**. The components used were "R/ANALOG" from the **analog.olb** for the resistors, "VDC/SOURCE" and "VSIN/SOURCE" from the **source.olb** for the voltage source, "O/CAPSYM" and "PARAMETER/SPECIAL" from the **special.olb** for ground and "ua741/OPAMP" from **opamp.olb** for the op-amp.

The Vsin supply is a power source that provides a sinusoidal voltage supply. The DC offset is the phase shift of the start of the sinusoid. VAMPL is the amplitude of the sinusoid with is set to 0.5 so that the range of the input sinusoid is 1 V. Finally the FREQ is the frequency with is parameterized so ease of change. The parameter RunToTime is useful to in the transient simulation to set how long the simulation should run for. In this case $\frac{3}{\{freq\}}$ will run the simulation for 3 oscillation periods.

### 1.3.1 PSPICE Simulation: Inverting OpAmp

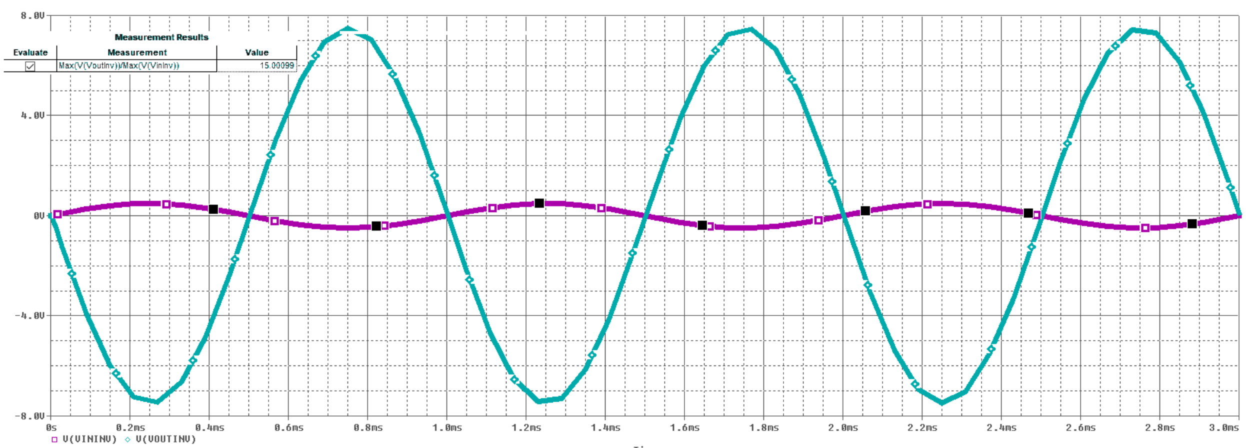


Figure 1.3.1: Transient simulation of the inverting OpAmp. The input wave had a peak-to-peak voltage of 1 V, the output wave had a peak-to-peak voltage of 15 V, and the gain was 15.

The inverting op-amp circuit was simulated by placing a probe on the input node and the output node. This generated two sinusoids as shown in 1.3.1. The gain was an measurement evaluation of the maximum peak of the output wave over the maximum on the input wave. This yieled a measured gain of just over 15. This indicates that the calculated $RF_{inv}$ resistor was correct. The amplitude of the waves are inverted in sign which is expected from the inverting op-amp.

### 1.3.2 PSPICE Simulation: Non-Inverting OpAmp

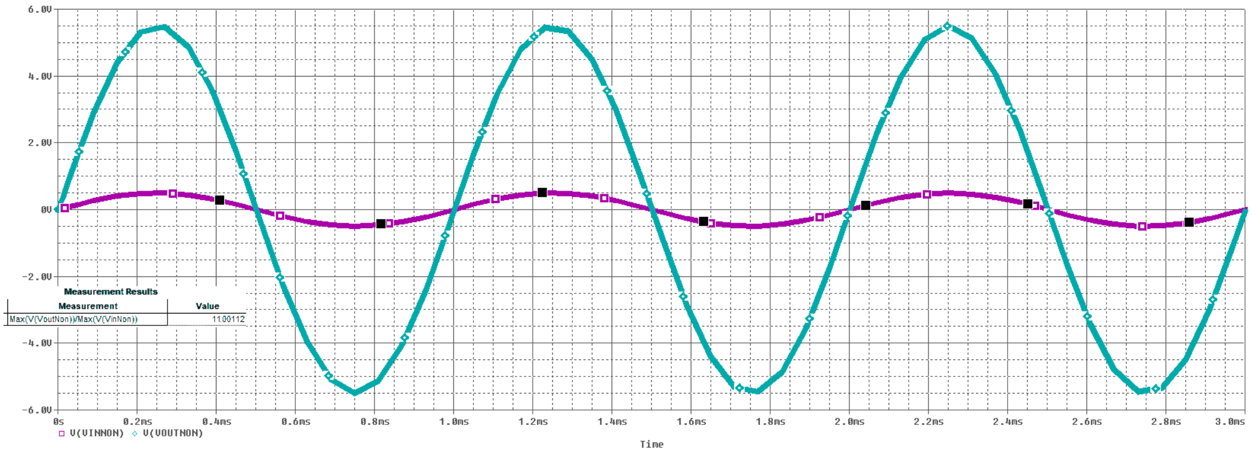


Figure 1.3.2: Transient simulation of the non-inverting OpAmp. The input wave had a peak-to-peak voltage of 1 V, the output wave had a peak-to-peak voltage of 11 V, and the gain was 11.

The non-inverting op-amp circuit was simulated similarly to the inverting op-amp. The evaluated gain was measured to be 11 which matches the hand calculations. The sinusoids do not have a phase shift like the inverting op-amp. The sign of the output is the same as the input as is expected in a non-inverting op-amp.

## 2 Conclusion

This laboratory experiment set up two op-amps with different gains. The PSPICE simulation showed the graph of the output and input curves generated by a sinusoidal input voltage source. The simulated circuit did not have exact gains from the calculated circuits. This is because the ideal op-amp model was used to calculate the resistor values. The slight different between the ideal and simulated op-amp accounts for this difference. In this configuration no clipping occures because the peak output voltage never reaches a value above the voltage powering the op-amp. If the output gain were to bring the output voltage above this value, the output sinusoid would reach a ceiling at this value. If the power supply voltage was adjusted to 15 V, the both of the op-amps would peak at 15 V if the input voltage were to bring it that high.

## 3 Acknowledgments

- wikibooks.org helped with the LaTeX code.
- tex.stackexchange.com helped with the circuit diagram in LaTeX.
- Petre Tumbar and Walter Sigel were present for the prelab and experiment.

## References

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