Op-Amp

Introduction

Operational amplifiers (Op-amps) are the quintessential black box. What goes on inside of them is very complex. To use them, we don't need to understand what happens on the inside. We know that the ideal op-amp has an infinite input resistance, zero input current and that $V_n=V_p$ when negative feedback is used. An ideal op-amp also has zero output resistance and can source an infinite amount of current if needed. With this information we can analyze any op-amp circuit.

Op-amp circuits can be built that cause input signals to be amplified. Circuits can be designed to add or subtract two inputs. Commonly the input to an op-amp circuit is some AC signal, maybe your voice in your cell phone. For simplicities sake we are only looking at op-amps with DC inputs. The same analysis and functionality exists if we change the input to an AC signal.

Op-amps sense the voltage/signal on its input and generate the appropriate output. Ideally, the output of the op-amp doesn't depend on the output load. The op-amp is able to draw the needed output current from its DC power supplies. In this way the input to the circuit can be a low current signal while the output is high current. Don't forget to hook up the DC supplies to the op-amp or it won't work.

This lab is divided into two parts. The first part, is designed to measure the input current of an op-amp. The second part involves designing basic op-amp circuits. You will be given a set a specifications to meet. Remember that you must design your circuits using standard, nominal components. Each part has its own prelab. You may wish to do part 1 and then move onto part 2. This is a wise decision if you don't feel comfortable with op-amps.

Objectives

- Experimentally prove the ideal op-amp model is valid
- Review how the passive sign convention determines current or voltage reference directions
- Learn to read basic data sheets
- Increase LTspice comfort
- Use all three supplies in the bench DC power supply
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Part 1 – Input Currents

Procedure

The circuit shown in Schematic 1 will be used in part 1 of this experiment to test the idea that the input currents are actually 0. The op-amp is a standard LM741. You will need to look up the pinout on the data sheet. **Double check your power-supply connections as you can easily blow up your chip.**

Prelab

- Download the data sheet for the LM741 and read through it. Make sure that you understand the pinout of the op amp package you will be using.

- Calculate the expected ideal values of $V_n$, $V_p$, $I_n$ and $I_p$. What is the possible range of values for $V_o$, the output voltage? Notice $I_n$ and $I_p$ are not shown on the schematic. You will need to draw them on your schematic.

- Make all necessary tables in your lab notebook. Consult the **Lab** instructions to find out what you will be measuring and calculating.

Lab

1. Since it is easier to measure voltage than current, we will measure $V_n$ and $V_p$. These measurements will be used to calculate the measures $I_n$ and $I_p$. In order to have accurate $I_n$ and $I_p$ calculations we must know the actual value of $R_1$ and $R_2$. Don't forget to measure and record these values.

2. Measure $V_n$, $V_p$, and $V_o$. Complete the analysis of this part and have it checked by your instructor before you move onto part 2.
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Analysis

• Compare expected Vn, Vp, In, and Ip to measured values. Don't forget about passive sign
  convention when calculating In and Ip.
• Does our ideal model fit for In and Ip? Explain.
• In and Ip are not exactly 0. What direction do In and Ip flow, into or out of the op-amp? Don't
  forget that the op-amp is a black box. Our simple model is just that: a simple model to make
  analysis easier. What is actually going on looks more like the circuit in the data sheet. Even that
  circuit is a simplified model of the actual circuit.

Part 2– Basic Op-Amp Circuits

Procedure

All op-amp circuits will use +-15V DC power-supplies for the op-amps. Don't forget to include these
in your schematics and circuits.

Prelab

• Design, by hand, a simple inverting amplifier. It should use a 15KΩ feedback resistor, a 10KΩ
  load resistor and have a gain of -2. The input signal should be 4V. Once you have your schematic
  create a table showing expected Vn, Vp, and Vo.
• Design, by hand, a non-inverting amplifiers that meets the same specifications as the previous
design except gain = +2. Create a table with expected Vn, Vp, and Vo.
• Simulate your inverting and non-inverting amplifier in LTspice. Record Vn, Vp, and Vo in the
  appropriate data tables. Use the UniversalOpamp2 circuit for your opamp. If you wish for a more
  accurate simulation you may incorporate the model for the LM741 opamp into yours simulation.
  Instructions on how to incorporate this model can be found on the website under the LTSpice
  resources page.
• Decide how you will test your circuit once built to ensure it matches your design. Have this plan
  approved by your instructor.
• What will happen to Vo if the +15V supply is removed from your amplifiers? Think about each
  circuit individually, they may give different results.
• Required data tables: Nominal vs actual resistor values, Nominal vs actual input and output voltage
  levels, Nominal vs actual power supply levels (+15, -15). Data tables for ideal, LTspice, and
  measured data for each design.
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Lab

1. Build and test your two circuits. You have multiple op-amps in your kits, so you should build both circuits at once.

2. For the each circuit remove the +15 supply and record what happens to Vn, Vp, and Vo.

Analysis

• Compare expected results to measured results for both circuits. Does the ideal model work?

• Compare expected results to actual results when the power supply was removed? Any explanation?

• Calculate the output current of the op-amp for each circuit.
  ○ Does this current flow into or out of the op-amp?
  ○ What supplies this current?

• Re-simulate the non-inverting amplifier using the “more realistic model” discussed in Section 5.7. The model in Section 5.7 replaces the op-amp block. You must still connect your designed circuitry around this model. For the LM741 use Ro=75Ω. For Rin and A, consult the data sheet and use typical values.
  ○ Is this model an improvement? (Hint: You may need to take data to more than 3 significant figures)
  ○ This simulation may be done as part of the prelab if you desire.
  ○ This simulation does not replace the simulation using the UniversalOpamp2 or LM741 model done in the prelab.