UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE105 Lab Experiments

Experiment 1: Non-Ideal Op-Amps

Contents

1 Introduction

In this lab, you will characterize a LM741C operational amplifier. In particular, you will be measuring the following non-ideal properties of op-amps: input offset voltage, slew rate, and finite gain and bandwidth. Linked are the datasheet and SPICE model for the LM741C op-amp, which you should find helpful while doing the lab and pre-lab.

Make sure to download and print out the Pre-Lab Worksheet and the Lab Worksheet. Make sure to complete the Pre-Lab Worksheet before coming to lab. Your lab GSI will check that you have completed the Pre-Lab Worksheet at the beginning of your lab section. Fill out the Lab Worksheet while doing the lab and turn it in with supporting traces and plots to your GSI at the beginning of the lab section for Lab 2.

2 Pre-Lab

For the pre-lab, you primarily will be doing SPICE simulations of the measurements that you will be doing in your lab section to help prepare you for the lab. Since you will be using the LM741 circuit model, make sure to download the `LM741.MOD` file into the same directory as your `*.sp` file. Include a `.include LM741.MOD` statement in your `*.sp` file so that the subcircuit definition in `LM741.MOD` can be included in your `*.sp` file. To instantiate the op-amp subcircuit in your `*.sp` file, use the following syntax:

```
x<name> <non-inv input> <inv input> <+ supply> <- supply> <output> LM741/NS
```

2.1 DC Open Loop Transfer Characteristic

Simulate the circuit in Figure 1, sweeping V_{in} from -5 mV to $+5$ mV. Plot V_{out} as a function of V_{in} and determine the open loop gain of the op-amp and input offset voltage.

2.2 Nulling the Offset Voltage

Null the offset voltage by adding a DC component V_{shift} to the input voltage source to cancel the offset. While this works in simulation, in the lab you will use the offset null terminal pins on the op-amp to null the offset voltage. Check the datasheet for the circuit used to null the offset voltage and draw the circuit connected to the pinout diagram for the LM741 on your pre-lab worksheet. Why do we use a potentiometer to null the offset voltage?
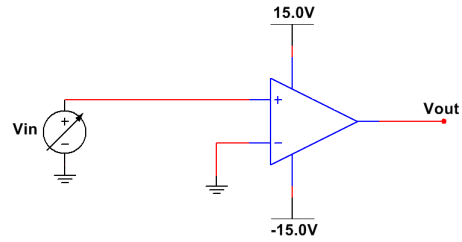
Figure 1: Circuit for Problem 2.1

2.3   Slew Rate Measurement in Unity Gain Configuration

Simulate the circuit in Figure 2 to look at the transient response of V_{out} to the square wave voltage source V_{in}. Set V_{in} to have the following characteristics: an amplitude of ± 10 V, a 1 µs delay, 100 ns rise and fall times, and a pulsewidth and period of 100 µs and 200 µs. In your `.tran` statement, set the timestep to be 100 ns and make sure to simulate one period of the square wave. Plot V_{out} and V_{in} versus time and determine the slew rate (remember: the slew rate has units of $\frac{\text{V}}{\mu\text{s}}$) from the plot. Is the slew rate different for rising and falling voltages?
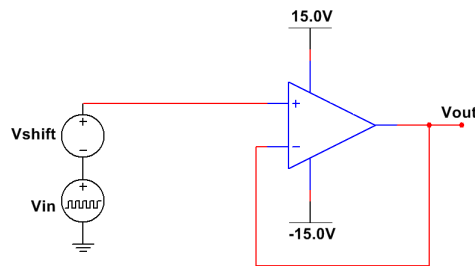

Figure 2: Circuit for Problem 2.3

2.4   Gain and Bandwidth in Unity Gain Configuration

Simulate the circuit in Figure 3, performing an AC analysis from 1 Hz to 1 GHz. Remember to set the magnitude of V_{in} to 1 V to get the proper value of voltage gain and to plot enough points to get a smooth curve. Plot the magnitude response $20 \log \left| \frac{V_{out}}{V_{in}} \right|$, and find the gain and 3 dB bandwidth of the amplifier.
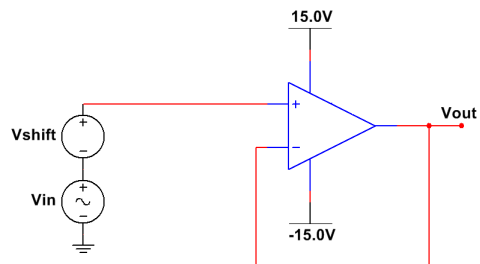

Figure 3: Circuit for Problem 2.4

2.5   Gain and Bandwidth in Non-Inverting Amplifier Configuration

Simulate the circuit in Figure 4 with $R = 100$ kΩ and $R = 10$ kΩ, performing AC analyses from 1 Hz to 1 GHz. Plot the magnitude response of both circuits in dB on the same plot as Problem 2.4, and find the gain and 3 dB bandwidth of both amplifiers. At approximately what frequency and gain do the three curves intersect on the plot? What does this mean? If you are unsure, compute the product of A_0 and f_{3dB} for the three amplifiers.
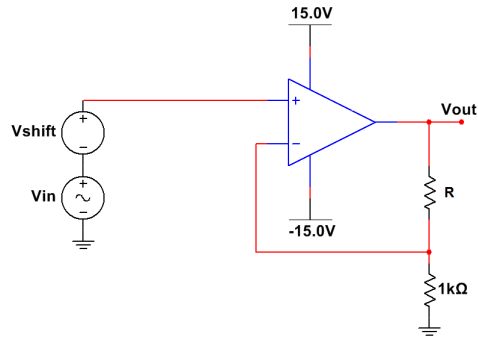

Figure 4: Circuit for Problem 2.5