

ELC 3414: Electronic Design

Lab 7: Differential Amplifiers

Objective

The goal of this lab is to design and measure the performance characteristics of an emitter coupled differential amplifier.

Introduction

In the previous lab, we looked at two different current sources (sinks) and compared their performance. We will use these two plus a third (even simpler) source to bias an emitter coupled differential amplifier. This circuit is essentially an operational amplifier (op-amp).

Procedure

We will use an LM3146 (or CA3146) transistor array for our design. The matched transistors in the array will allow us to explore three options for biasing the differential pair. We can use an emitter bias resistor, a current mirror, or a Wilson current source for biasing our differential pair.

Design the three bias circuits so that they will supply approximately 2 ma of bias current to the differential pair. Use transistors Q_1 and Q_2 for the differential amplifier. Operate the amplifier from +/- 15 volts supplies. Let the collector resistors be about 5.1K each.

Note: Remember to pay special attention to the note on the data sheet about the substrate connection on Pin 13!

Model all three designs in PSpice using the Q2N2222 transistor. Measure the differential and common mode gains of the amplifier for the three biasing options. Calculate the common-mode rejection ratio (CMRR) for each. Choose the best one, and assemble it in hardware using the LM3146.

Since these circuits are essentially op-amps, we want to measure some of the critical properties of an op-amp and compare these to known values, like those for the LM741 op-amp. However, we don't have enough time to measure all of the quantities listed on the LM741 data sheet. In particular, we won't be finding the "Absolute Maximum Ratings" (and for good reason!).

Using your already assembled amplifier, design a non-inverting op-amp circuit with a nominal closed-loop voltage gain of $A_{0CL} = 10$ (as in Lab 1 & 2). Measure the following quantities, being sure to record your test conditions (i.e. input/output/supply voltages, resistor values, etc):

- Actual gain, A_{CL} – output should be undistorted
- Maximum input voltage, $V_{s,max}$ – just before the output begins to be distorted
- Output voltage swing, V_o – output rail voltage
- Gain-bandwidth product, f_t – frequency with unity gain

- Slew rate, SR – looking for a linear rise/fall and measuring slope
- Power consumption, P – use the values on the dc power supply (*Hint*: you may want to check both sides of the supply)
- Input resistance, R_i – As in Lab 6, put a 100 Ω resistor in series with the input. Measure the voltage and calculate the current. Take *at least* 3 measurements, and calculate the slope.

Deliverables

Instead of a standard report, you will be creating a set of specifications (i.e. data sheet) for your op-amp and comparing these to the specifications for the LM741. You will have 3 items on your data sheet:

1. A table that contains the values you found when measuring each of the differential amplifiers (3 in PSpice, 1 in hardware). Include in this table:
 - Simulated and actual differential gain (4 values)
 - Simulated and actual common-mode gain (4 values)
 - Common-mode rejection ratio based on both simulated and actual gains (4 values)
2. An “Electrical Characteristics” table, similar to that for the LM741, that contains the values listed below for both your op-amp and the “typical” value of an LM741 op-amp (standard version, not the “A” or “C” version). Include the test conditions and units for each measurement (as is done on the LM741 data sheet). If a particular condition held for all measurements, you need only state it once (e.g. supply voltage). You do NOT need to include temperature information. (*Hint: Be sure the units of the values you are comparing are the same.*)

Include the following items in your table:

- Maximum Input Voltage
 - Output Voltage Swing
 - Large Signal Voltage Gain (i.e. differential gain)
 - Input Resistance
 - Common-Mode Rejection Ratio
 - Slew Rate
 - Power Consumption
3. A comparison (meaning state the values and discuss them) of your non-inverting amplifier’s performance to that of the similar amplifier (using an LM741) you designed in Lab 2, including:
 - Actual gain vs. nominal gain
 - Gain-bandwidth product