University of Michigan
EECS 311: Electronic Circuits
Fall 2008

LAB 6 – DIFFERENTIAL AMPLIFIER

Issued 11/24/2008
Completed in Lab 12/3/2008

Introduction

In this lab you will build a 6-transistor operational amplifier (differential-input, single-ended-output), similar to the LM741, and then characterize its performance. You will build a current mirror and use it to bias two stages, build a differential pair, and an output buffer. The goal of this lab is to get a functional opamp built so that you can characterize it similarly to how the LM741 was characterized in Lab 1. Because the opamp is built using discrete devices, its performance will not come close to that of the LM741. If you are interested in learning more about how to design high-performance integrated opamps, take EECS 413 next Fall!

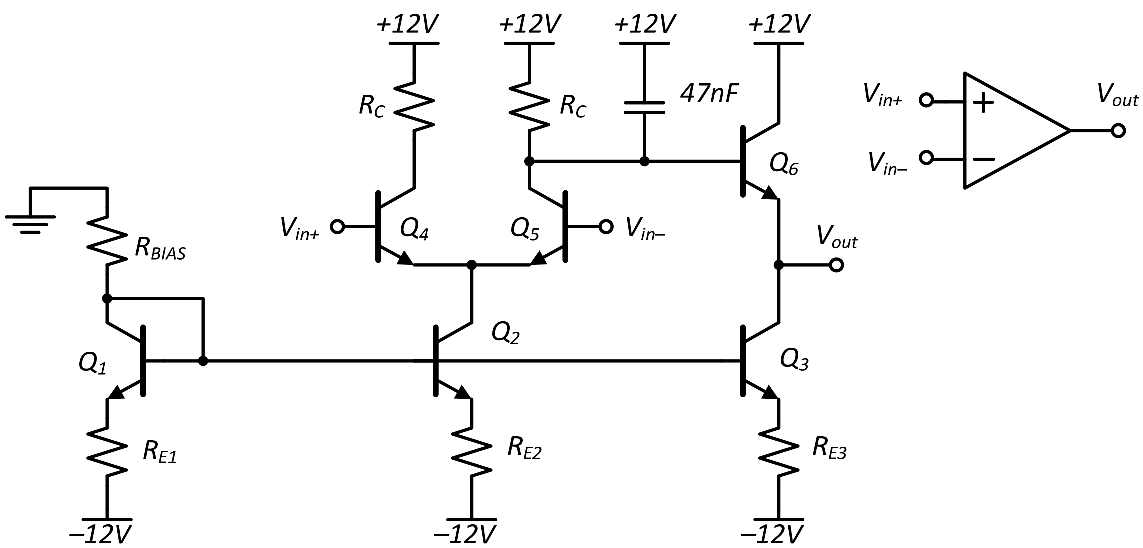

Figure 1. Operational Amplifier Schematic. $Q_{1\text{-}3}$ form a current mirror for biasing, $Q_{4\text{-}5}$ form a differential pair, and Q_6 is an emitter follower. Transistors $Q_{1\text{-}5}$ are from a single CA3083, transistor Q_6 is a 2N3904.

Prelab Component

Refer to the schematic in Figure 1.

P6.1 You will use the resistors R_{BIAS} and R_{E1-3} to set the bias currents in the two stages. For good bias stability, use a voltage drop across all R_{Ex} resistors of 5V. The reference bias current I_{C1} in Q_1 should be 500µA, current I_{C2} in Q_2 should be 2mA (4x the reference current), and current I_{C3} in Q_3 should be 1mA (2x the reference current). Choose values for the resistors R_{E1}, R_{E2}, and R_{E3} based on these assumptions for bias currents and desired voltage drop. Now choose a value for R_{BIAS} that sets the reference current in Q_1. Use only resistors from the table of available values online. Choose values closest to calculated values to meet the bias specifications; do not combine multiple resistors to create more precise values.

In-Lab Component

L6.1 Build the opamp shown in Figure 1. Use $R_C = 5.6k\Omega$, and the values for other components found in P6.1. Use the CA3083 for the 5 transistors Q_{1-5}. This chip, found in your lab kit, contains 5 NPN transistors that have similar device parameters (β, I_S, etc.). A datasheet with pinout can be found at the website below. Transistor Q_6 should be implemented using a 2N3904. Do not forget to add decoupling capacitors on both your +12 and -12 power supplies (watch polarity of caps on -12V supply). Also, do not forget the capacitor at the output of the differential pair. This is used to stabilize the opamp, for more information read section J&B 17.12.

http://www.eecs.umich.edu/courses/eecs311/f08/labs/ca3083.pdf

L6.2 Configure the circuit in unity-gain feedback as shown in Figure 1 by wiring the output of your circuit to the inverting terminal, and the input from the signal generator to the non-inverting terminal. Initially connect the non-inverting input terminal to ground and measure the DC output voltage using the multimeter. This is the offset voltage of the amplifier, record this on your check-off sheet.

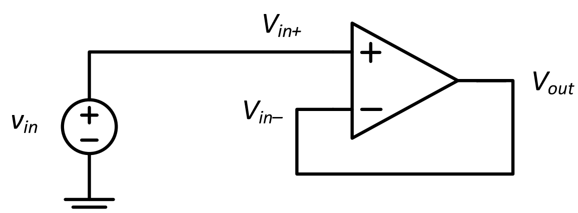

Figure 2. Opamp in unity-gain feedback.

L6.3 With the opamp still in unity-gain feedback, apply a 50mVppk sine wave and measure the 3dB cutoff frequency of the amplifier and record this in you check-off sheet.

L6.4 With the opamp still in unity-gain feedback, apply a 1kHz square wave with an amplitude of 1Vppk. Measure the slew rate of the amplifier on the falling edge of Vout.

L6.5 *OPTIONAL*: Measure the gain in your amplifier using the same technique used in Lab 1 with the HP4155. Refer to Exercise L1.1 in Lab 1 for instructions on setting up the HP4155.

http://www.eecs.umich.edu/courses/eecs311/f08/labs/lab1.pdf

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LAB 6 – CHECK-OFF SHEET

NAMES: ________________________________ ___________________________________

Have the GSI check you off once your circuit is complete and characterized. Be prepared to answer questions about your circuit or the results.

Results Summary

Parameter	**LM741 Datasheet**	**Measured**	**Units**
Input Offset Voltage	$2\ mV$		mV
Unity-Gain Bandwidth	$1.2\ MHz$		MHz
Slew Rate	$0.5\ V/\mu s$		V/µs
Gain (optional)	$200\ kV/V$		V/V

Table 1. Results summary table.

Exercise .... Date Completed

Demonstrated working amplifier.._______________