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

EE105 Lab Experiments

Report 10: Differential Amplifiers

Solutions

3.2.2 Measure I_{C1}, I_{C2}, I_{C3}, and $V_{OUT,DC}$. How do they compare with hand calculations?

$$I_{C1} = \boxed{1.741 \text{ mA}}$$
$$I_{C2} = \boxed{2.076 \text{ mA}}$$
$$I_{C3} = \boxed{1.035 \text{ mA}}$$
$$V_{OUT,DC} = \boxed{3.860 \text{ V}}$$

I_{C1} matches very well with hand calculations (0.6 % error). I_{C2} is much larger than what we'd expect assuming $V_A = \infty$, meaning V_{CE2} must be quite high (which makes sense given the biasing). I_{C3}, correspondingly, is larger than expected, making $V_{out,DC}$ smaller than expected.

3.2.3 Sketch the waveforms at v_{in+} and v_{out+}.

3.2.4 Measure the peak-to-peak voltages of v_{in+} and v_{out+}

$$v_{in+,p-p} = \boxed{56.25 \text{ mV}}$$
$$v_{out+,p-p} = \boxed{4.875 \text{ V}}$$

3.2.5 Qualitatively describe how v_{out+} and v_{out-} are related. Is this what you'd expect?

They're inverses of each other. Given that this is a differential amplifier, this is expected.

3.2.6 Measure the peak-to-peak voltage of $v_{out+} - v_{out-}$ and calculate the differential gain of the circuit. Does this match the gain you calculated in the prelab?

$$v_{out,p-p} = \boxed{9.688 \text{ V}}$$
$$A_{DM} = \boxed{172.2}$$

This exceeds the gain computed in the prelab by about 9.5 %. This is a result of I_{C3}, and therefore g_{m3}, being larger than expected.

3.2.7 What do you see at the output? Why?

There should be no output signal. This is because the common-mode gain is extremely small.

3.2.8 Measure the gain. Does it match your prelab calculations? Does it match your result from 3.2.6?

$$A_{DM} = \boxed{160.0}$$

It is a bit more than the gain in the prelab and a bit less than the gain from 3.2.6. It's within 10 % of both.

3.3.2 Sketch the output waveform. Why isn't it sinusoidal?

The gain is too large. The output is swinging to the rail, creating a square-like wave.

3.3.4 Calculate the differential gain of the amplifier with the added load.

$$R_{out} = 5\text{ k} \parallel r_{o4} \parallel r_{o6} = 3.876\text{ k}\Omega$$
$$A_{DM} = \boxed{129.1}$$

3.3.5 Sketch v_{out}. What is the measured differential gain of the circuit? How does it compare to your hand calculations? Does it match the gain you observed in step 3.2.6? Should it?

$$A_{DM} = \boxed{158.1}$$

The gain is about 22.5 % higher than expected. This means that the output resistance didn't drop as much as expected, which means that r_{o4} and r_{o6} aren't as low as calculated by hand. It's within 10 % of the gain measured in 3.2.6. They should be roughly the same, assuming that the 5 kΩ load dominates R_{out}.

3.4.1 Attach your netlist on a separate sheet.

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* EE105 Lab 10 - Differential Amplifiers with Active Load

.inc ‘2N3904.mod’
.inc ‘2N3906.mod’

* +/- 9V supply
vcc vcc gnd 9V
vee gnd vee 9V
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* Current mirror
r1  vcc vb1 10k
q1  vb1 vb1 vee QN3904

* Tail transistor
q2  vc2 vb1 vee QN3904

* Input transistors
q3  vop  vip vc2 QN3904
q4  von  vin vc2 QN3904

* Load resistors
r2  vop  vcc 5k
r3  von  vcc 5k

* Differential input
vdiff vdiff gnd SIN(0 30mV 1k 0s 0 0)
eip vip gnd vdiff gnd 0.5
ein vin gnd vdiff gnd -0.5

.op
.tran 0.001ms 5ms
.option post=2 nomod
.end
```

3.4.2 Use SPICE to find I_{C1}, I_{C2}, I_{C3}, and $V_{out,DC}$. Compare these values with your calculations from the prelab and measurements in lab.

$$I_{C1} = \boxed{1.7083\ \text{mA}}$$
$$I_{C2} = \boxed{1.8852\ \text{mA}}$$
$$I_{C3} = \boxed{935.9\ \mu\text{A}}$$
$$V_{OUT,DC} = \boxed{4.321\ \text{V}}$$

These values are comparable to both the hand calculated values and the values measured in lab. They match more closely to the hand-calculated values than the measured values.

3.4.3 Attach your plot on a separate sheet. What is the gain as measured from the plot? Does it match your hand calculations? Does it match your measurements?

$$\boxed{A_{DM} = 155}$$

This gain is comparable to both the hand-calculated gain and the measured gain of this circuit. It lies within 10 % of both values.