EECE 142
Fall 2002

EECE 142 - Laboratory #6
Differential Amplifier Basics

Purpose: Investigate the properties of the differential amplifier, including

1. DC characteristics and operation.
2. Small signal differential gains for single ended loads ($A_{v,SEL}$) and differentially connected loads ($A_{v, DCL}$).
3. Small signal common mode gains for single ended loads ($A_{cm,SEL}$) and differentially connected loads ($A_{cm, DCL}$).
4. Common Mode Rejection Ratio (CMRR).
5. Effect of current sources.

Preparation:

1. Review the following sections in Sedra & Smit
   a. 6.2 Small Signal Operation of the BJT Differentail Amplifier. Equation 6.32 will be useful in calculating the differential gain ($A_{D,SEL}$) of the amplifier designed for this lab. It can also be shown that the common mode gain

$$A_{cm,\,SEL} \approx \frac{Total\ Collector\ R}{Total\ Emitter\ R} = \frac{R_c}{r_e + \mathrm{R}_e + 2R_t}$$

   b. 6.4 Biasing in BJT Integrated Circuits. Note that in applying equation 6.65, the circuit will operate as a constant-current source as long as Q_2 remains in the active region.
2. Review the data sheet for a CA3086 transistor array and record pertinent information. These transistors will be used when building your differential amplifiers since they are "matched" significantly better than would be the discrete transistors in your component packs.
3. What must be connected to pin 13 of the CA3086 IC?
4. Determine the DC operating point of Q1 and Q2 in Figure 1. What is the current flowing through R_t? What is the DC Quiescent value of V_{out}?
5. What is the purpose of the 10k resistors?
6. How do you connect a FG to the differential amplifier in Figure 1 to provide a single ended differential input? (By single ended we mean that one of the inputs is connected to ground.)
7. How do you determine the maximum magnitude for the differential input[1]?
8. How do you connect a FG to the differential amplifier in Figure 1 to provide a common mode input?
9. How do you determine the maximum magnitude for the common mode input?
10. What is the *differential gain* for the circuit in Figure 1?
11. What is the *common mode gain* for the circuit in Figure 1?

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[1]That is, without distortion in the output.

12. What is the *common mode rejection ratio (CMRR)* for the circuit in Figure 1?
13. What is the input impedance for a single ended input?
14. What are the effects of mismatches in R_{C1} and R_{C2}?
15. What are the effects of mismatches in Q1 and Q2?
16. If the 100 Ω emitter resistors were omitted, what effects on circuit performance would you see? Specifically, what would happen to the output quiescent point, the gains, and maximum value of the differential input?
17. Design a differential amplifier (similar to Figure 1) with the following specifications:
    a. Power supplies less than ± 20 Volts
    b. $I_{C1} = I_{C2} = 0.5$ mA
    c. $A_D = 25$
    d. $A_{CM} \leq 1$
18. Design a 1mA current source (using a *Current Mirror* circuit) that can be used in the lab to replace R_t. Use the same value negative, DC power supply.
19. Replace R_t with a 1mA current source. How does this change the CMRR for your differential amplifier. Explain why this change occurs.
20. Let $R_{e1} = R_{e2} = 10$ ohms and determine the changes in the performance of the differential amplifier.
21. Devise a laboratory procedure that will illustrate the effect of reducing the size of R_{e1} and R_{e2} .

Experiments:

1. Build the differential amplifier designed in step 17 of the Preparation.
2. Take DC measurements so that the operating points of Q1 and Q2 can be found and so that β and α for Q1 and Q2 can be calculated.
3. Connect the Function Generator to the differential amplifier and obtain data so that plots of $A_{d,SEL}$ and $A_{d,DCL}$ vs frequency can be made. (Provide a single ended differential input.)
4. Connect the Function Generator to the differential amplifier and obtain data so that plots of $A_{cm,SEL}$ and $A_{cm,DCL}$ vs frequency can be made.
5. Remove resistor R_t from the differential amplifier and replace with the appropriate current source. Repeat steps 2, 3, and 4.
6. Perform the procedure developed in the Preparation for illustrating the effect of varying R_{e1} and R_{e2}.

Post-Lab Questions:

1. Tabulate and compare all simulated and measured DC values including I_C, V_{CE}, V_{BE}, β, and α.
2. Calculate CMRR for both SEL and DCL loads.
3. Plot $|A_{d,DCL}|_{dB}$ and $|A_{cm,DCL}|_{dB}$ vs frequency.
4. Using results of step 3, plot $|CMRR|_{dB}$ vs frequency.
5. Discuss the effects of the current source vs R_t. Refer to your experimental results.
6. What effect does R_e have on the gain of the differential amplifier? Refer to your experimental results.
7. Consider a single 10k load that can be connected either SEL or DCL. Which connection would provide the highest gain? Which connection will provide the largest CMRR? Once again, refer to your experimental results to justify your answer.
8. Re-simulate the circuit of Figure 1 with Rc2 removed. Why are the bias currents essentially unchanged? (Hint: consider the base-emitter voltages.) Under what condition must Rc2 be included? (Hint: think SEL and DCL.)

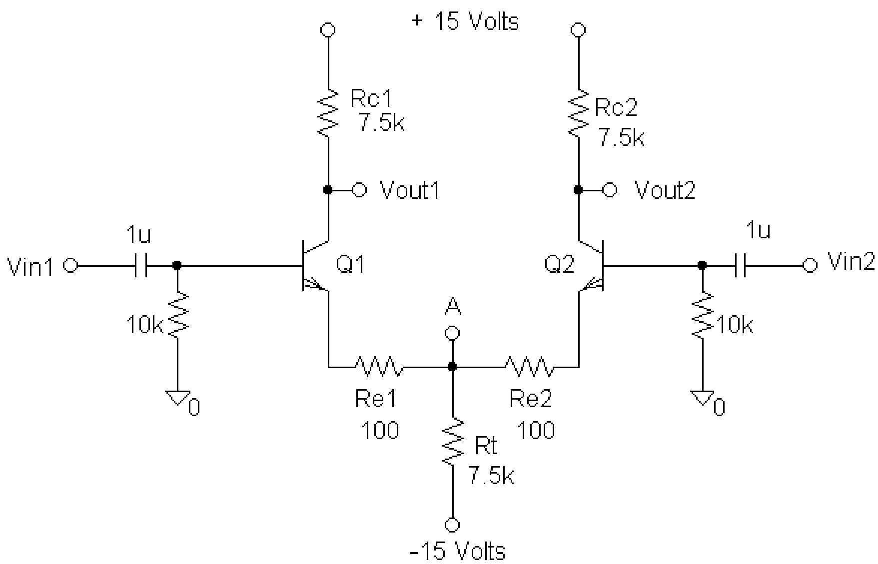

Figure 1