EEE 51 Assignment 9

2nd Semester SY 2018-2019
Due: 5pm Tuesday, May 7, 2019 (Rm. 220)

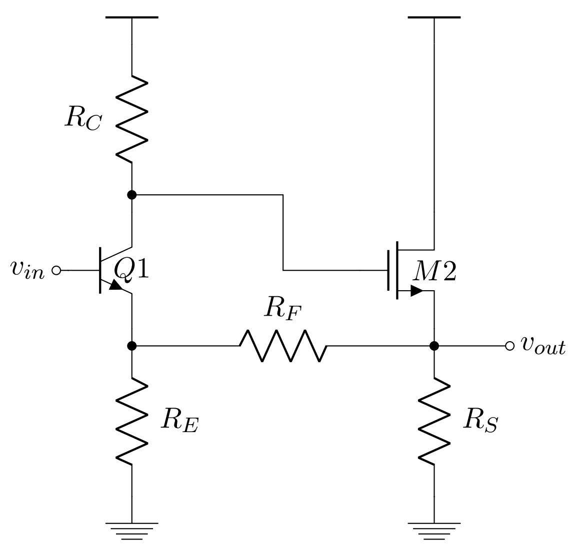
Instructions: Write legibly. Show all solutions and state all assumptions. Write your full name, student number, and section at the upper-right corner of each page. Start each problem on a new sheet of paper. Box or encircle your final answer.

Answer sheets should be color coded according to your lecture section. The color scheme is as follows:

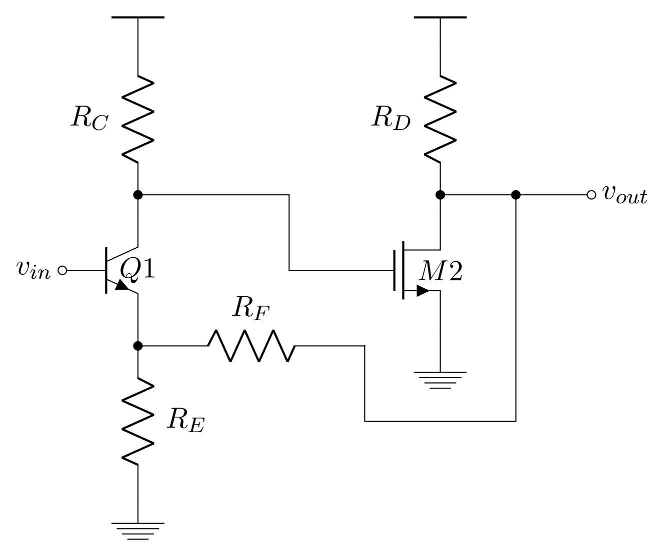
THQ – yellow
THU – white
WFX – pink

1. **Positive-Negative.**

   You are to implement an amplifier with feedback. Given in Figure 1 are two possible designs.



(a) Amplifier A



(b) Amplifier B

Figure 1: Feedback Amplifiers.

   (a) Both of the designs use the same type of feedback. Identify the type of feedback being used. (1 pt)
   (b) Which of the two designs is valid (employs negative feedback and will not blow-up)? Be careful since your answers in the next item will be dependent here. Committing a mistake in this item will automatically void the answers for the next item. (2 pts)
   (c) Using your answer in (b), use the parameters β, g_{mx}, and r_π; and the resistors R_C, R_D, R_E, R_F, and R_S to express your answers. Assume that $r_o \to \infty$ for both transistors. For parallel resistors, just use $(R_1||R_2||...||R_n)$ notation instead. Do not expand the expressions.
      i. Feedback gain $f = \frac{v_{fb}}{v_o}$. (1 pt)
      ii. Open-loop gain (with feedback loading) $a_v = \frac{v_{out}}{v_{in}}$. (1 pt)
      iii. Closed-loop gain $A_V = \frac{v_{out}}{v_{in}}$. (1 pt)
      iv. Closed-loop input resistance $R_{IN} = \frac{v_{in}}{i_{in}}$. (2 pts)
      v. Closed-loop output resistance $R_{OUT} = \frac{v_{out}}{i_{out}}$. (2 pts)

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2. **Feed me, feed me, feed me back!**
The parameters for all transistors are the following: $V_{be,on} = 0.7\text{V}$, β and V_A approaches infinity. $v_{in,DC} = 0.9\text{V}$, $v_{out,DC} = 2.5\text{V}$, $V_{DD} = 5\text{V}$. All transistors operate in the forward active region at T = 300 K.

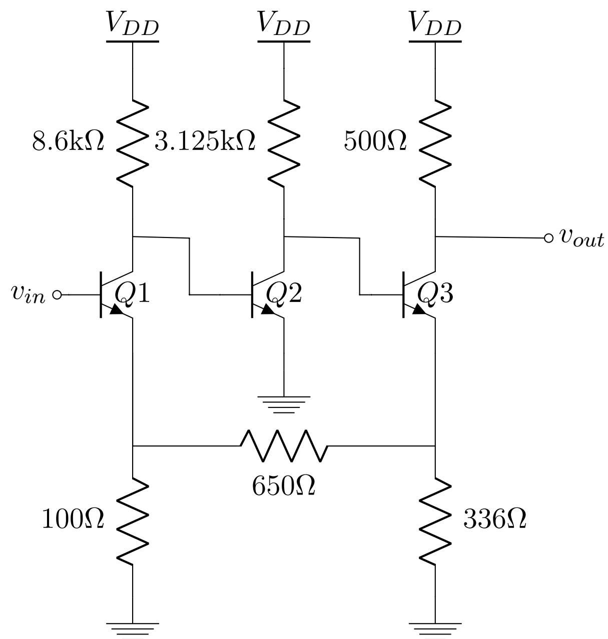


Figure 2: BJT Circuit

(a) Solve for the collector currents, I_{C1}, I_{C2}, I_{C3}, and small signal g_{m1}, g_{m2}, g_{m3} for transistors Q1, Q2, and Q3 (3 pts)

(b) Identify the feedback configuration (1 pt)

(c) Draw the two-port network of the feedback circuit then solve for the feedback parameters $R_{i,fb}$, $R_{o,fb}$, and feedback factor F (4 pts)

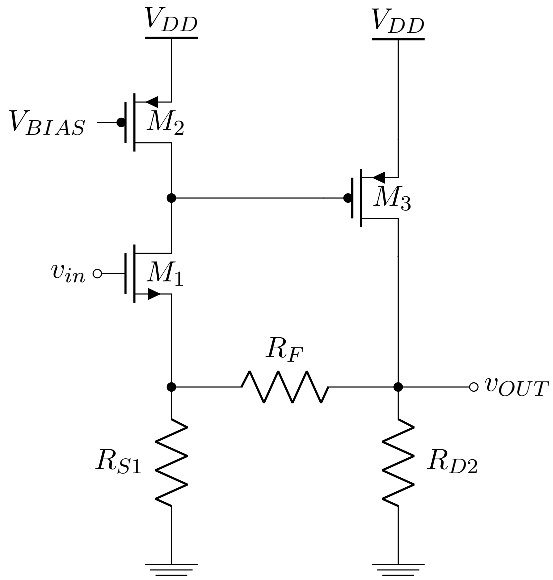
(d) Solve for the loaded open-loop "gain" (depends on your answer in (b)) (2 pts)

(e) Solve for the closed-loop voltage gain, $\frac{v_{out}}{v_{in}}$ of the whole circuit (3 pts)

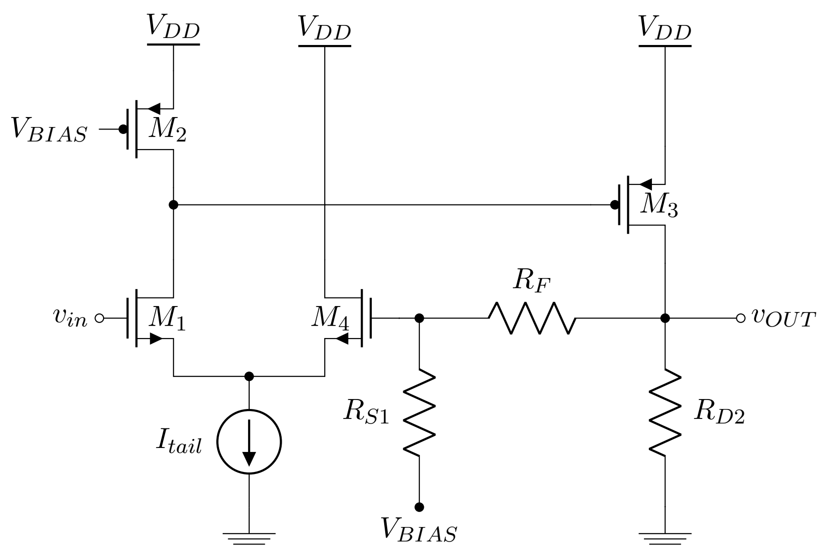
(f) Suppose the open-loop "gain" increased by 10%, by how much is the approximate increase, in percentage, of the closed-loop voltage gain? (2 pts)

3. **Give Me Some More Feedback**

For the amplifier feedback circuits in Figure 3, assume $k_n = 13.42mA/V^2$, $k_p = 3.83mA/V^2$, $\lambda_{n1} = \lambda_{p3} = 0$, $\lambda_{p2} = 0.2V^{-1}$, $\lambda_{n4} = 0.1V^{-1}$, $I_{D1} = I_{D2} = I_{D3} = I_{D4} = 0.5mA$, $R_F = R_{S1} = R_{D2} = 3k\Omega$ and I_{tail} is an ideal current source.



(a) Resistive Feedback



(b) Resistive with Transistor (M_4) in Feedback

Figure 3: Two-Stage Amplifier with Feedback

For Figure 3a, refer to the following: (**Note:** For parallel resistors, just use $(R_1||R_2||...||R_n)$ notation instead. Do not expand the expressions for all the items below)

(a) Identify the feedback configuration and justify why. (1pt)

(b) Draw the feedback circuit, find the expression for input, output resistance and the feedback factor ($R_{I,fb}$,$R_{O,fb}$,F). Using these expressions, transform the feedback circuit to a unilateral two-port equivalent model. (2.5pts)

(c) Draw the whole small-signal equivalent model circuit (Amplifier+Feedback) (Only include small signal parameters that are finite). Use the obtained feedback unilateral two-port model in (b). Label the forward path and the **ideal** feedback path. (Hint: Ideal feedback path is where no resistances are in the path. Think this through: How to remove the resistances in the feedback path to make it ideal?) (2pts)

(d) Derive the expression and solve for the open-loop gain/forward gain $A_{v,ol}$ using the small signal model in (c). (1.5pts)

(e) Find the expression and solve for the loop gain T. (0.5pt)

(f) Find the expression and solve for the closed-loop gain $A_{v,cl}$. (0.5pt)

(g) Find the expression and solve for the output resistance of the feedback amplifier $R_{O,cl}$. (1pt)

For Figure 3b, M_4 is inserted in the feedback loop. Refer to the following:

(h) Is the feedback configuration changed? Why or Why not? (1pt)

(i) Repeat (b) to (g) for the second circuit. Transform M_4 to its equivalent small-signal model when drawing the feedback circuit. (8pts)

(j) Compare the obtained closed-loop gain and output resistance of the two feedback circuits and explain the differences if there is any. What is the use of adding M_4 in the feedback loop? (2pts)

TOTAL: 45 points.