EEE 51 Assignment 2

2nd Semester SY 2018-2019
Due: 5pm Tuesday, February 12, 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. **Common Collector/Emitter Follower Sziklai Pair.**
Figure 1 shows a Sziklai pair used as an emitter follower. The capacitor C_C is just an AC coupling capacitor (open circuit at DC and shorted at AC, the value is irrelevant as of now). For both of the transistors Q_1 and Q_2, $|V_{be,on}| = 0.65\,\text{V}$, $|V_{ce,sat}| = 0.2\,\text{V}$, and $|V_A| \to \infty$. Moreover, $\beta_1 = 50$ for Q_1 and $\beta_2 = 100$ for Q_2. The transistors are biased such that the voltage at node B is $V_B = 1.85\,\text{V}$. Answer the following questions. **DO NOT ASSUME THAT $\mathbf{I_C = I_E}$.** Round all of your answers to one (1) decimal place only and use the appropriate unit of measure.

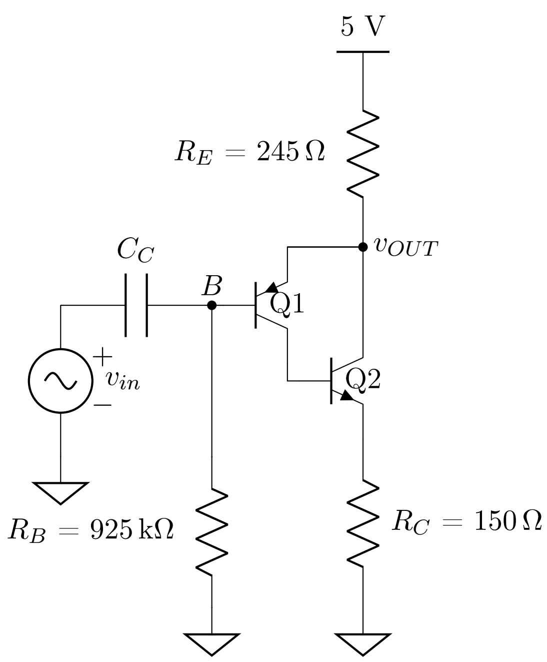

Figure 1: Emitter Follower Sziklai Pair

(a) Calculate the value of the base current of Q_1 I_{B1} and the emitter current of Q_2 I_{E2}. If I_{E2} is treated as the collector current of the transistor pair, what is the overall current gain β_{SZ}? (3 pts)

(b) Determine the value of the DC voltage at the output node. (1 pt)

(c) Draw the small-signal model of the circuit. Label the transistor terminals, small-signal parameters, external resistors, and their values. (2 pts)

(d) Find the values of the overall input resistance R_{IN}, transconductance G_M, gain A_V, and output resistance R_O of the whole emitter follower. You may draw additional schematics/diagrams to aid in your solutions. (4 pts)

2. **Common Emitter Amplifier with Load.**

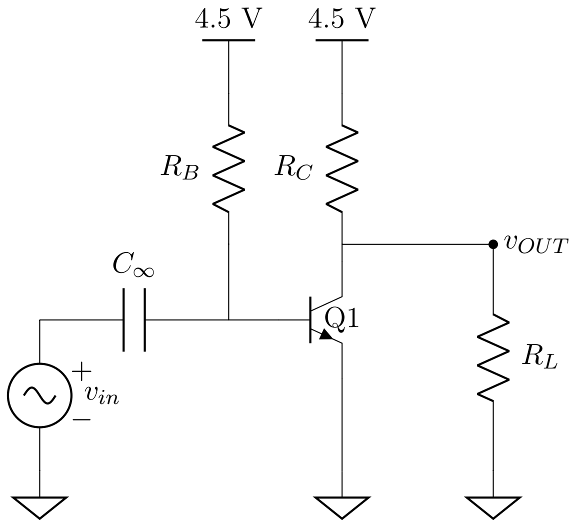

Figure 2: Common Emitter with biasing

Assume T=300K when necessary. For the CE amplifier in fig. 2 with $V_{BE,on} = 0.7V$, $V_{CE,sat} = 0.7V$, $\beta = 200$, $V_A = 100V$, $R_B = 95K\Omega$, $R_C = 204\Omega$, and $R_L = 794\Omega$:

(a) Calculate the DC biasing parameters:

   i. base current (I_B) (0.5 pt)

   ii. collector current (I_C) (0.5 pt)

   iii. output voltage (V_{OUT}) (1 pt)

(b) Draw the small-signal model of the circuit. You may omit R_B. Label the values of each small-signal parameter, and component. (3 pts)

(c) Compare (a) R_{O1} = parallel combination of r_o, R_C and R_L, with (b) R_{O2} = parallel combination of R_C and R_L. Would r_o significantly affect the effective resistance? How much error relative to R_{O1} would you get, if you simply used R_{O2} rather than R_{O1} to simplify your calculations? Express this number as a percentage. (1.5 pts)

(d) Calculate the small-signal gain (v_{out}/v_{in}) (1 pt)

(e) Sketch v_{out} from 0 ms to 2 ms for $v_{in} = 10sin(2\pi ft)$ mV with $f = 1KHz$. Label the peak voltages, axes, and units. (1.5 pts)

(f) Should you expect the amplifier to work linearly, with the same gain for $v_{in} = 52sin(2\pi ft)$ mV, with $f = 1KHz$? Why or why not? Prove mathematically. [Hint: You may revisit the Taylor series expansion of i_C.] (1 pts)

3. **MOS Common Source and Common Gate Cascode.**

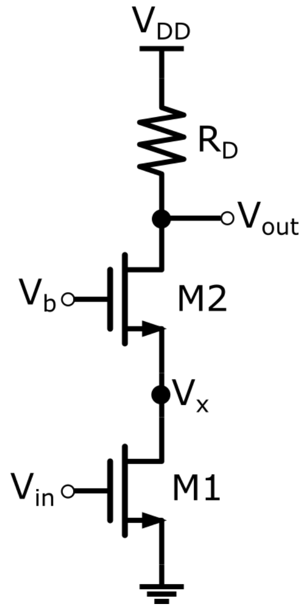

Figure 3: CS-CG Cascode

Consider the circuit shown above. For this problem, use $V_{DD} = 3V$, $I_{D1} = I_{D2} = 1mA$, $k_{M1} = 6.7m\frac{A}{V^2}$, $k_{M2} = 1.4m\frac{A}{V^2}$, $V_{TH1} = V_{TH2} = 0.7V$, $\lambda_{M1} = \lambda_{M2} = 0.1V^{-1}$ and $R_D = 1.5k\Omega$. Express your answers to four (4) decimal places and use the appropriate unit of measure.

(a) Determine the minimum voltage, V_x, needed to keep M1 in saturation. (1 pt)

(b) Choose the bias voltage, V_b such that M1 is $50mV$ away from the linear region of operation. (1 pt)

(c) Draw the small-signal equivalent model of the circuit. Label the transistor terminals, the transistor small-signal parameters and their values. (2 pts)

(d) Calculate for the overall transconductance, G_m, and output impedance, R_{out}. (5 pts)

(e) Calculate the small-signal voltage gain. (1 pt)

TOTAL: 30 points.