EEE 51 Assignment 7

2nd Semester SY 2018-2019
Due: 5pm Wednesday, April 10, 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. **Frequency Response Exercise.** For the circuit in Figure 1,

   (a) Solve for the transfer function $\frac{v_{out}(s)}{v_{in}(s)}$. Write it in the form: $K\frac{(1+\frac{s}{\omega_{z1}})(1+\frac{s}{\omega_{z2}})...(1+\frac{s}{\omega_{zn}})}{(1+\frac{s}{\omega_{p1}})(1+\frac{s}{\omega_{p2}})...(1+\frac{s}{\omega_{pn}})}$ (1pt)

   For the succeeding problems, refer to Figure 2.

   (b) Solve for the transfer function $\frac{v_{out}(s)}{v_{in}(s)}$. Write it in the form: $K\frac{(1+\frac{s}{\omega_{z1}})(1+\frac{s}{\omega_{z2}})...(1+\frac{s}{\omega_{zn}})}{(1+\frac{s}{\omega_{p1}})(1+\frac{s}{\omega_{p2}})...(1+\frac{s}{\omega_{pn}})}$ (1pt)

   (c) Plot the pole-zero diagram. Label the axes, and the pole(s)/zero(s). (1pt)

   Suppose $R_A = 159K\Omega$, $R_B = 1.59M\Omega$, $C_A = 1pF$, $C_B = 10pF$, and $v_{IN} = sin(2\pi(100KHz)t)$ V.

   (d) Sketch the magnitude response (in dB) of the circuit on a log-log plot. Label the pole/zero location/s, DC gain, slopes, and the axes. (2pts)

   (e) Sketch the phase response (in degrees) of the circuit on a semi-log plot. Label the pole/zero location/s, phase at 0 Degrees, slopes, the axes, and important frequencies. (2pts)

   (f) Write the expression for v_{OUT}. (1pt)

   (g) The frequency-compensated voltage divider is usually used to increase the bandwidth of a voltage divider with an output parasitic capacitance, like in oscilloscope probes. Given the chance to change C_A, should you? If yes, what C_A would maximize the filter's bandwidth? Else, why? (2pts)

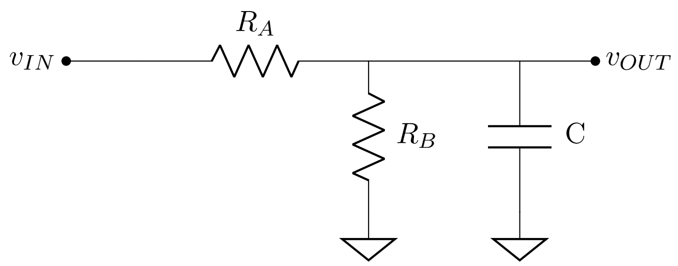

Figure 1: Voltage Divider with Output Capacitance.

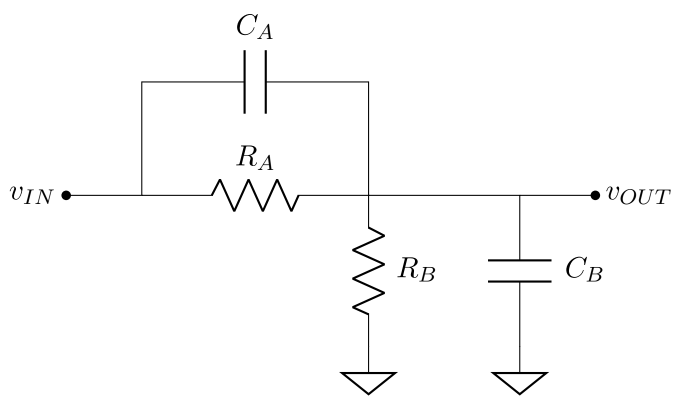

Figure 2: Frequency Compensated Voltage Divider.

2. **Transit Frequency, and Intrinsic Capacitances on Cascode Amplifier**

From the given circuit in Figure 3, assume $T = 300K$, $V_{CC} = 20V$, $I_{source} = 1.5mA$, $R_S = 15.6k\Omega$, $R_L = 8.6k\Omega$, $f_T = 450MHz$, $\beta = 100$, $C_{\pi 1} = C_{\pi 2} = 2pF$, $C_E \longrightarrow \infty$ $V_A \longrightarrow \infty$, $V_{BE} = 0.7V$ and $V_{CE,sat} = 0.2V$ for both transistors $Q1$ and $Q2$.

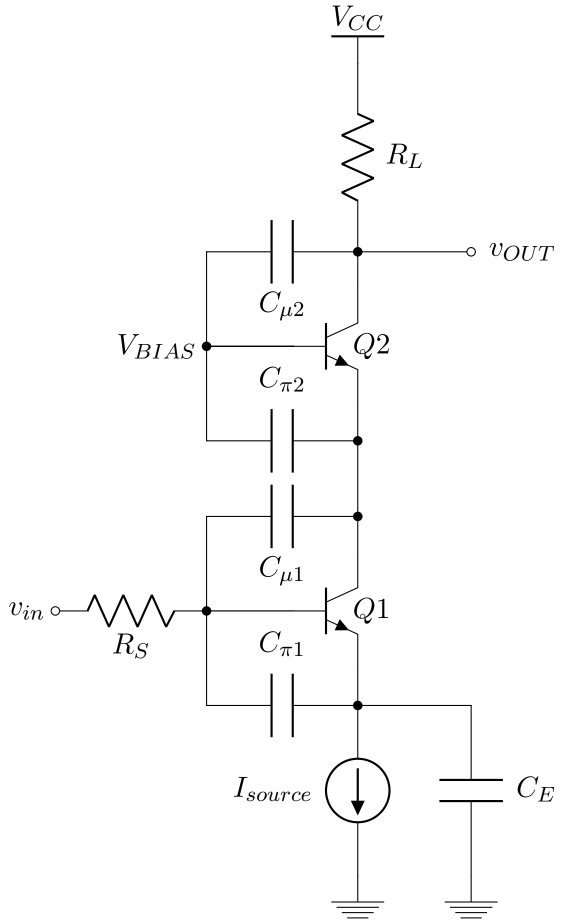

Figure 3: BJT Cascode Amplifier with Input and Miller Capacitance

(a) Solve for the minimum V_{BIAS} for $Q1$ and $Q2$ to remain in forward active region. (0.5pt)

(b) Solve for $C_{\mu 1}$ and $C_{\mu 2}$. (Limit only to two decimal places). (0.5pt)

(c) Draw the complete and simplified small-signal model of the cascode amplifier. Label all necessary small signal parameters, all terminals, and proper ground connections. (0.5pt)

(d) Only for this Question C_E will not be assumed infinite. What is the effect of C_E under DC operation? Also what is its effect under any certain frequency operation with the assumption that typical values of capacitors are used ranging from ($1\mu F$ to $10\mu F$)? (1pt)

(e) Derive the Transfer Function of the Cascode Amplifier. Do not use the miller approximation method. The complete transfer function will **exactly** have the form of:

$$\frac{v_{out}}{v_{in}}(s) = a_o \frac{\left(1 + \frac{s}{\omega_{z1}}\right)}{\left(1 + \frac{s}{\omega_{p1}}\right)\left(1 + \frac{s}{\omega_{p2}}\right)\left(1 + \frac{s}{\omega_{p3}}\right) + a_1\left(1 + \frac{s}{\omega_{p1}}\right)\left(1 + \frac{s}{\omega_{z1}}\right)(s\tau_1)}$$

but for easier analysis on plotting the magnitude and phase response, ignore the term: $a_1\left(1 + \frac{s}{\omega_{p1}}\right)\left(1 + \frac{s}{\omega_{z1}}\right)(s\tau_1)$ as we want to see for now the response between poles and zeroes with no offsets contributed by this term. So the simplified form for plotting analysis is shown below. (3pts)

$$\frac{v_{out}}{v_{in}}(s) = a_o \frac{\left(1 + \frac{s}{\omega_{z1}}\right)}{\left(1 + \frac{s}{\omega_{p1}}\right)\left(1 + \frac{s}{\omega_{p2}}\right)\left(1 + \frac{s}{\omega_{p3}}\right)}$$

(f) Get the expression and solve for the values for the DC gain (a_o), the zero (f_{z1}) and all the poles (f_{p1}, f_{p2}, f_{p3}). (Note the difference in units for ω and f). (1pt)

(g) Sketch the magnitude response (in dB) on a log-log plot and phase response on a semi-log plot. Label all necessary important frequencies (poles f_p & zeroes f_z), slopes, degrees including phase at 0 deg. (2.5pts)

(h) Does f_T corresponds to the pole/zero location? Why or Why not? (1pt)

3. **The Danger in Miller approximation.** Assume T=300K when necessary. Also assume that the external capacitances are much much greater than the parasitic capacitances. For the CE amplifier in fig. 4,, $V_{BE,on} = 0.7V$, $V_{CE,sat} = 0.2V$, $\beta = 200$, $V_A \to \infty$, $R_B = 95K\Omega$, $R_C = 204\Omega$, and $R_L = 794\Omega$:

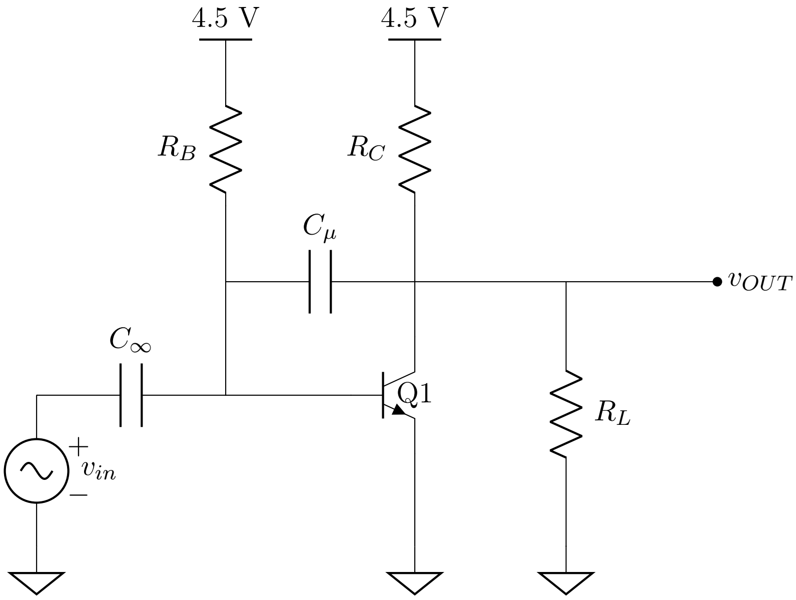

Figure 4: Common Emitter with capacitances

(a) Draw the small-signal model without using the Miller approximation for C_μ. Label the values of all components, v_{in}, and v_{out}. (1pt)

(b) Solve for the transfer function $\frac{v_{out}(s)}{v_{in}(s)}$. Write it in the form: $K\frac{(1+\frac{s}{\omega_{z1}})(1+\frac{s}{\omega_{z2}})...(1+\frac{s}{\omega_{zn}})}{(1+\frac{s}{\omega_{p1}})(1+\frac{s}{\omega_{p2}})...(1+\frac{s}{\omega_{pn}})}$ (1pt)

(c) If there are finite pole(s)/zero(s) in the transfer function, write their location/s. (0.5pt)

(d) Draw the small-signal model, using the Miller approximation for C_μ. Label the values of all components, v_{in}, and v_{out}. (1pt)

(e) Solve for the transfer function $\frac{v_{out}(s)}{v_{in}(s)}$. Write it in the form: $K\frac{(1+\frac{s}{\omega_{z1}})(1+\frac{s}{\omega_{z2}})...(1+\frac{s}{\omega_{zn}})}{(1+\frac{s}{\omega_{p1}})(1+\frac{s}{\omega_{p2}})...(1+\frac{s}{\omega_{pn}})}$ (1pt)

(f) If there are finite pole(s)/zero(s) in the transfer function, write their location/s. (0.5pt)

(g) Is there a difference/s between the transfer functions in parts (b) and (e)? If yes, enumerate it/them. (1pt)

For the remainder of the problem, refer to the transfer function in part (b).

(h) Plot the pole-zero diagram. Label the axes, and the pole(s)/zero(s). (1pt)

(i) Sketch the magnitude response (in dB) of the circuit on a log-log plot. Label the pole/zero location/s, DC gain, slopes, and the axes. (1pt)

(j) Sketch the phase response (in degrees) of the circuit on a semi-log plot. Label the pole/zero location/s, phase at 0 Degrees, slopes, the axes, and important frequencies. (1pt)

(k) What is the unity-gain frequency (in rad/s), ω_u? (1pt)

TOTAL: 30 points.