EEE 51 Assignment 10

2nd Semester SY 2018-2019
Due: 5pm Tuesday, May 14, 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. **Last Push**
Figure 1 shows an equivalent circuit of some amplifier with compensation capacitor C_x. Its loop gain, T_o is 2 x 10^5. The components have values $C_i = 50$ pF, $R_i = 31.83$ kΩ, $g_m = 100$ mA/V, $R_o = 15.92$ kΩ, and $C_o = 10$p. The amplifier also has unknown break frequencies, f_i and f_o, and a known break frequency $f_a = 10$ MHz.

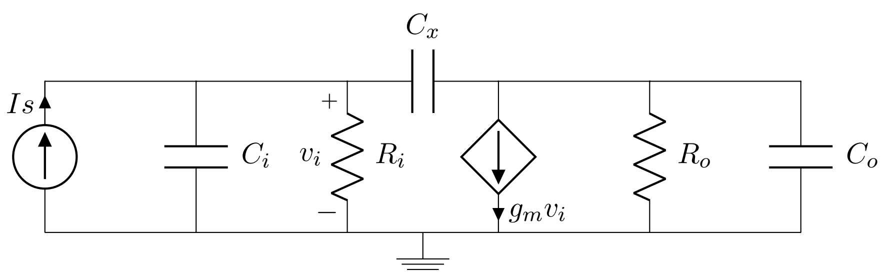

Figure 1: Oscillator

   (a) Solve for break frequencies f_i (input side) and f_o (output side) without the compensating capacitance. (2 pts)
   (b) Upon inserting the compensating capacitance C_x, compute the new break frequency f_o' (output side). (Assume that $C_x >> C_o$). (3 pts)
   (c) Solve for the new break frequency f_i' for a PM of 45° and unity feedback factor (f=1) at f_a. (2 pts)
   (d) Solve for the value of the compensating capacitance C_x. (Assume that $C_x >> C_i$). (3 pts)

2. **Last 51HW problem for real.**
Consider the circuit shown in Fig. 2 below. Assume that $M1$ and $M2$ are identical with $\lambda = 0$. Also, assume that $R_1 > R_2$ and that all intrinsic capacitances can be ignored and consider only the capacitors that are shown in the figure.

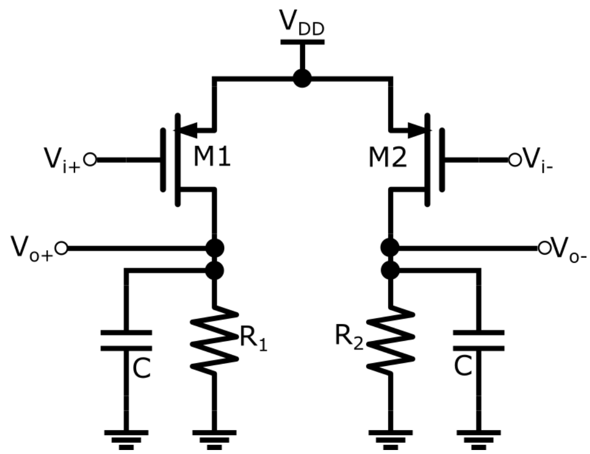

Figure 2: Simple pseudo-differential amplifier circuit

(a) Find the expression for the transfer functions $H_1(s) = \frac{v_{o+}}{v_{i+}}$ (1 pt) and $H_2(s) = \frac{v_{o-}}{v_{i-}}$ (1 pt) in terms of R_1, R_2, C and g_m.

(b) Roughly sketch the magnitudes of H_1 and H_2 against frequency in the same plot. Label important/relevant plot points. (1 pt)

(c) Determine the time-domain response of V_{o+} and V_{o-} to a voltage step in V_{i+} and V_{i-} respectively (1 pt) and sketch both responses on the same plot (1 pt). Label important/relevant plot points.

(d) Find the transfer function for the differential gain and express it in the form $H(s) = A\frac{\left(1+\frac{s}{w_z}\right)}{\left(1+\frac{s}{w_{p1}}\right)\left(1+\frac{s}{w_{p2}}\right)}$ (1 pt) and sketch the magnitude of the transfer function vs frequency (2 pts). Label completely.

From your plot in (d), you might have noticed the appearance of a zero. This is due to the mismatch between the left and right side of the circuit ($R_1 \neq R_2$). This phenomenon is what is usually called a "pole-zero doublet". This issue also arises when cancelling a pole by introducing a zero in a two-stage amplifier for example wherein the pole and the zero do not coincide. Suppose the open-loop TF of an 2-stage amplifier is expressed as:

$$H_{open}(s) = \frac{A_0\left(1+\frac{s}{w_z}\right)}{\left(1+\frac{s}{w_{p1}}\right)\left(1+\frac{s}{w_{p2}}\right)}$$

Ideally if $w_z = w_{p2}$, the system seems like a "first-order" system. For this system,

(e) Determine the transfer function of the amplifier in a unity-gain feedback loop. (1 pt)

(f) Determine the two poles of the closed transfer function assuming they are widely spaced in terms of w_{p1}, w_{p2} , w_z and A_0. (1 pt)

(g) **BONUS** Assuming $w_z \approx w_{p2}$ and $w_{p2} << (1 + A_0)w_{p1}$, determine the time-domain step-response of the closed-loop amplifier. What can we infer from this result? (5 pts)

TOTAL: 25/20 points.