EE140/240A Problem Set 3

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For all the problems in this problem set, assume $\mu_n C_{ox} = 0.5\text{mA/V}^2$, $V_{Tn} = 0.3\text{V}$, and the channel length modulation parameter $\lambda = 0$, unless specified. Numbers adjacent to the MOS transistors indicate the (W/L) ratio of the transistors. Assume all capacitors and inductors are infinite.

Problem 1. 3+4+2+5+3+4.

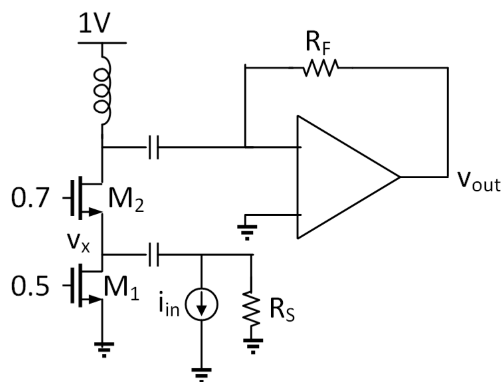

Figure 1: Problem 1

(a) Let the size of M_1 be (W/L) and the size of M_2 be 4(W/L). Compute their sizes for a quiescent current of 2mA to flow through M_1 and M_2. What is the DC voltage of node v_x at this condition?

(b) **Bonus for EE140, mandatory for EE240A** Now, for a quiescent current of 2mA to through M_1 and M_2, and for M_1 and M_2 to remain in saturation, what is the minimum size of transistor M_2?

(c) What must be the signs on the opamp for negative feedback around the loop?

(d) For the (W/L) ratios of M_1, M_2 from part (a), and for $R_S = 500\Omega$, $R_F = 2\text{k}\Omega$, compute v_{out}/i_{in}?

(e) Identify the two controlled sources in this circuit. Based on your knowledge of these controlled sources, make suitable approximations to obtain the answer without any hand calculations. What approximations did you make? How different is your approximate answer to the actual answer?

(f) For this part alone, assume $\lambda = 0.1V^{-1}$, and same transistor sizes as part (a). What is the output impedance looking "down" from the drain of M_2?

Problem 2. 3+3+2+3+4+3+2+3.
Assume $R_A = 750\text{k}\Omega$,$R_B = 500\text{k}\Omega$ for both circuits in Figs 3(a) and 3(b).

(a) Compute the DC operating point of the circuit in Fig. 2a).

(b) For the circuit in Fig 2(a), first assume $R_L = \infty$. Compute the small signal gain v_{out}/v_{in}.

(c) For the circuit in Fig 2(a), now assume $R_L = 250\Omega$. Compute the small signal gain v_{out}/v_{in}.

(d) Compute the DC operating point of the circuit in Fig. 3(b). Assume V_{G2}=0.5V.

(e) For the circuit in Fig 2(b), first assume $R_L = \infty$. Compute the small signal gain v_{out}/v_{in} for the operating point computed in (d).

(f) For the circuit in Fig 2(b), now assume $R_L = 250\Omega$. Compute the small signal gain v_{out}/v_{in} for the operating point computed in (d).

(g) What is your observation from the small-signal gain calculations? What amplifier/controlled source does M2/M3 form?

(h) **Bonus for EE140, compulsory for EE240A** What is the maximum gate voltage V_{G2} for all transistors to remain in saturation?

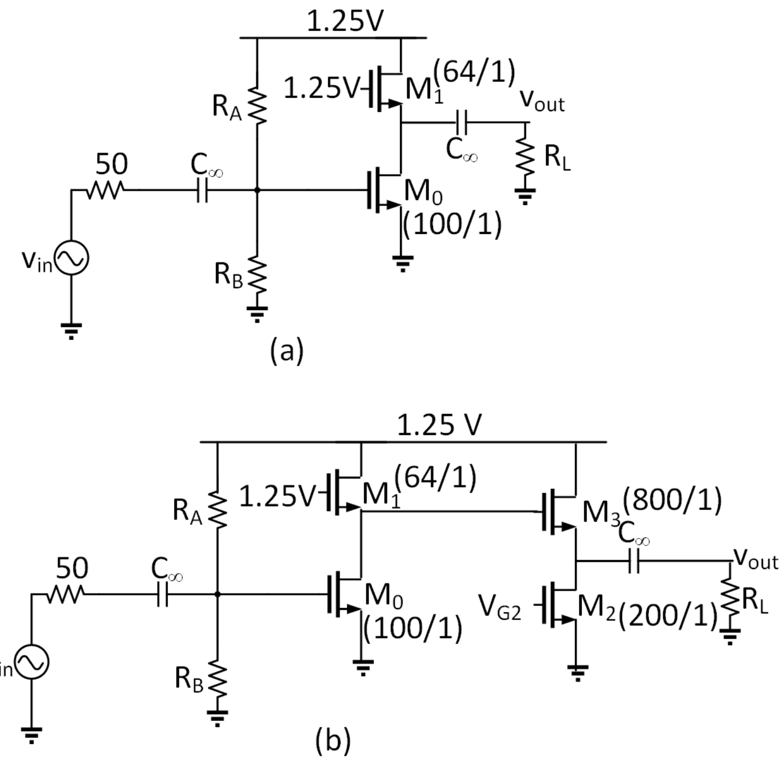

Figure 2: Problem 2

Problem 3. 3+4+4+3.
Refer to the circuit in Fig. 3. Assume $R_C = 300\text{k}\Omega$, $R_D = 200\text{k}\Omega$, and that the size of M_2 is (100/1).

(a) For what (W/L) of M_1 will there be a drain current of 1mA through M1, M2 assuming M1, M2 are in saturation? Use this computed (W/L) for subsequent parts.

(b) Asssume $R_A = 400\text{k}\Omega$. For what range of values of R_B will both M1 and M2 be in saturation.

(c) Assume $R_B = 1.2\text{M}\Omega$, $R_S = 1\text{k}\Omega$ and $R_F = 6\text{k}\Omega$ for this part and the subsequent parts. Compute the small-signal gain v_{out}/v_{in}.

(d) **Bonus for EE140, compulsory for EE240A** Identify the two controlled sources in this circuit. Based on your knowledge of these con-

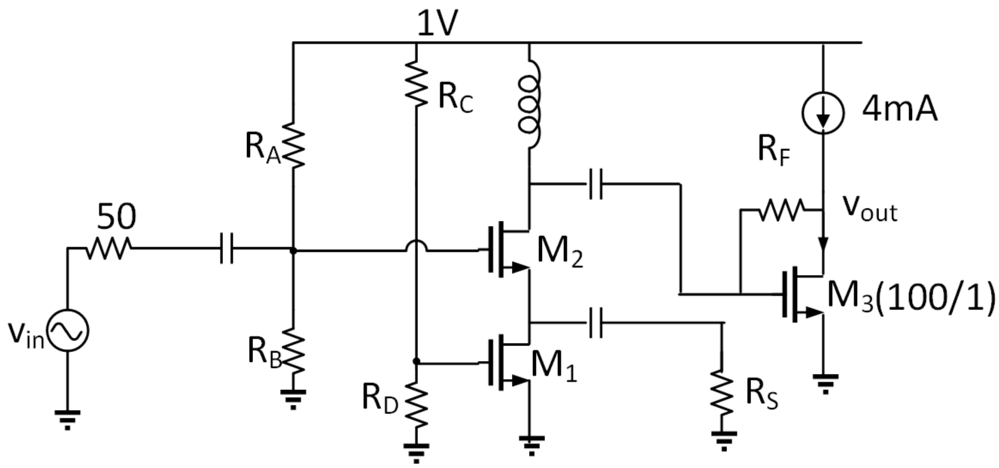

Figure 3: Problem 3

trolled sources, make suitable approximations to obtain the answer without any hand calculations. What approximations did you make? How different is your approximate answer to the actual answer?

Problem 4. 2+4+3+3+3. In lecture, we had seen that the circuit in Fig.

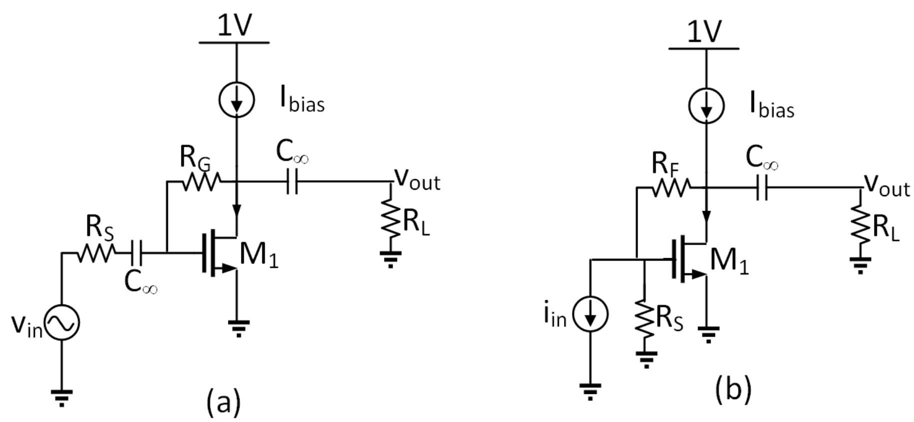

Figure 4: Problem 4

4(a) is a common source amplifier with drain feedback biasing, and the circuit in Fig. 4(b) was a trans-resistance amplifier (or a current controlled voltage source). The two circuits are identical, and the inputs are just Thevenin-Norton transformations of one another. In this problem, we will see the conditions under which these operate as a CS amplifier and a trans-resistance amplifier/CCVS. You will solve this problem symbolically. Assume that the transconductance of M_1 is g_m. Neglect channel length modulation.

(a) What is the gain of the the circuit from v_{in} to v_{out} in Fig. 4(a) if $R_G \to \infty$? Obtain this answer by just inspection.

(b) What is the gain from v_{in} to v_{out} for finite R_G? In this expression, let $R_G \to \infty$ and verify if the gain is the same as part (a). How large should R_G so that we can safely neglect the other terms in an approximation and get the same gain as a common source amplifier?

(c) What is the gain from i_{in} to v_{out} for the circuit in Fig. 4(b)? You may obtain it quite easily by applying appropriate transformations from the answer in part (b).

(d) Now, assume the CCVS is driven by an ideal current source, that is, $R_S \to \infty$. What does the previous expression simplify to?

(e) Now, further assume that $R_L \to \infty$. Show that this expression is the same as what we had obtained in lecture.