UNIVERSITY OF CALIFORNIA BERKELEY
Electrical Engineering and Computer Sciences

EE140/240A– MIDTERM #2
Linear/Analog Integrated Circuits

Instructor: Dr. Sashank Krishnamurthy

2024/03/22

Name: ______________________________

SID: ______________________________

This exam contains 21 pages (including this cover page) and 4 questions. Total of points is 48. Please write out the final answers to the questions in the boxes adjacent to the questions. Please show all your work in the space provided to work out the problems. Final answers without any work will not be given any credit. You may reuse results and expressions from lecture, homework and textbooks, as long as you clearly state it.

For all the problems in this exam, assume $\mu_n C_{ox} = 0.5\text{mA/V}^2$, $V_{Tn} = 0.3\text{V}$ for the NMOS transistors. Assume $\mu_p C_{ox} = 0.4\text{mA/V}^2$, $V_{Tp} = 0.4\text{V}$ for the PMOS transistors. Also, assume that the channel length modulation parameter $\lambda = 0$, unless otherwise stated. Numbers adjacent to the MOS transistors indicate the (W/L) ratio of the transistors. Assume all capacitors are infinite, unless otherwise stated.

Distribution of Points

Question	Points	Score
1	9	
2	11	
3	14	
4	14	
Total:	48	

1. In this question, we will analyze inverter-based circuits. Assume $V_{DD} = 0.9V$.

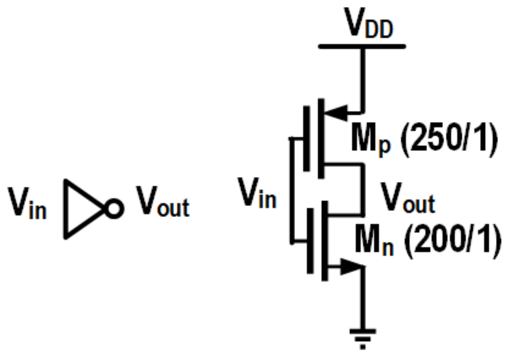


Figure 1: Fig. for Q1(a)

(a) (3 points) Calculate the trip point voltage of the inverter shown in Fig. 1. Trip point voltage is the value of input voltage V_{in} for which both the NMOS and PMOS are in saturation.

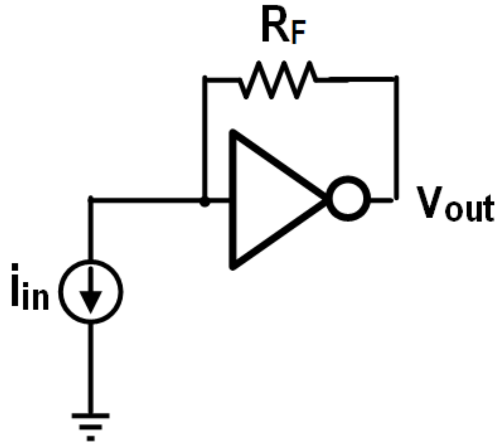
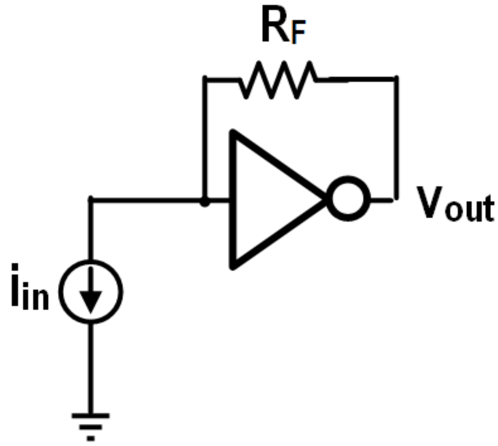


Figure 2: Fig. for Q1(b)-(c)

(b) (4 points) Compute the small-signal gain v_{out}/i_{in} for the circuit shown in Fig. 2. Assume that $R_F = 1.05\text{k}\Omega$ for this part. The inverter of Fig. 1 is used in Fig. 2.



(c) (2 points) For what value of R_F is the small-signal gain $v_{out}/i_{in} = 0$?

Additional space to work out problem 1.

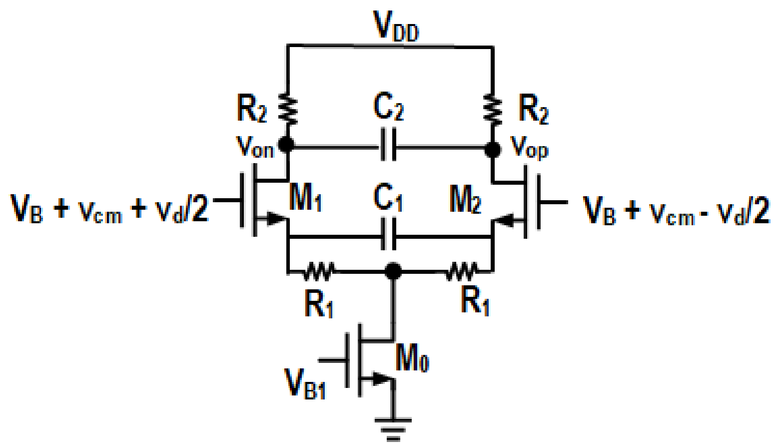
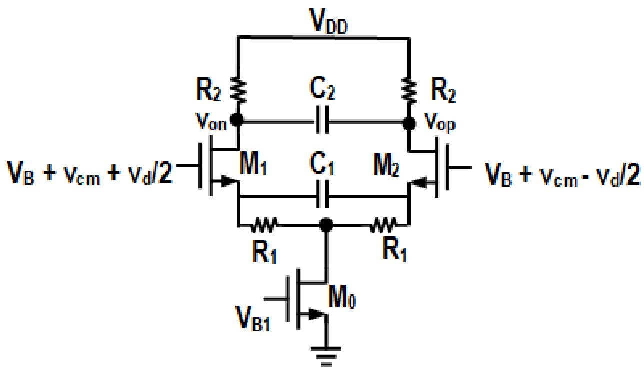


Figure 3: Fig. for Q2

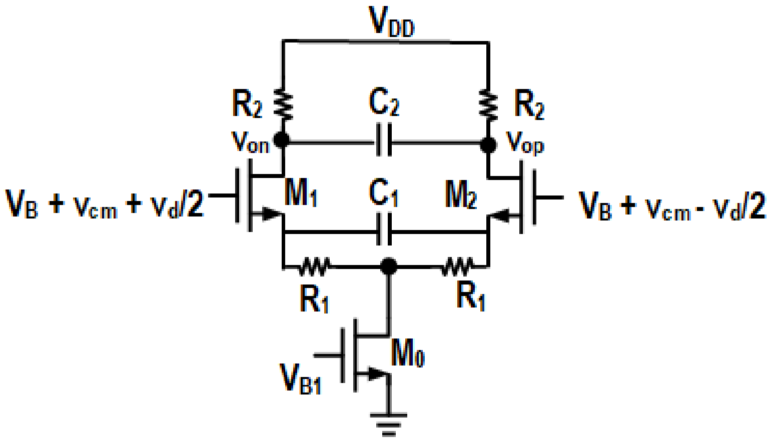
2. In this question, we will take a look at a differential continuous time linear equalizer circuit. Assume that the transistors M_1 and M_2 are identical and in saturation. Assume $g_{m1} = g_{m2} =$ 5mS, $R_1 = 800\Omega$, $R_2 = 500\Omega$, $C_1 = \frac{0.5}{2\pi}$pF, $C_2 = \frac{20}{2\pi}$fF. Neglect channel length modulation for M_1 and M_2. Assume that the small-signal output resistance of M_0 is r_{o0}.

   (a) (3 points) What is the DC small-signal differential gain $\frac{v_{op}-v_{on}}{v_d}$? Assume $v_{cm} = 0$ for this part.



$g_{m1} = g_{m2} = 5\text{mS}$, $R_1 = 800\Omega$, $R_2 = 500\Omega$, $C_1 = \frac{0.5}{2\pi}\text{pF}$, $C_2 = \frac{20}{2\pi}\text{fF}$. Neglect channel length modulation for M_1 and M_2. Assume that the small-signal output resistance of M_0 is r_{o0}.

(b) (5 points) How many poles and zeroes are there in the differential transfer function $\frac{v_{op}-v_{on}}{v_d}(s)$? What are their frequencies? Assume $v_{cm} = 0$ for this part. Consider only the capacitors C_1 and C_2 for this part and ignore all parasitic capacitors of the transistors.



(c) (3 points) What is DC small-signal common-mode gain $\frac{v_{op}}{v_{cm}}$, which is also equal to $\frac{v_{on}}{v_{cm}}$? Answer this symbolically in terms of R_1, R_2, $g_{m1,2}$ and r_{o0}. Assume $v_d = 0$ for this part.

Additional space to work out problem 2.

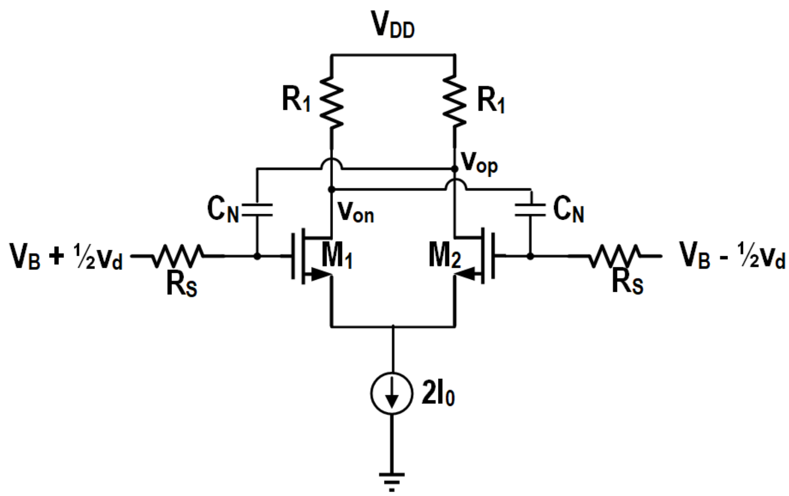
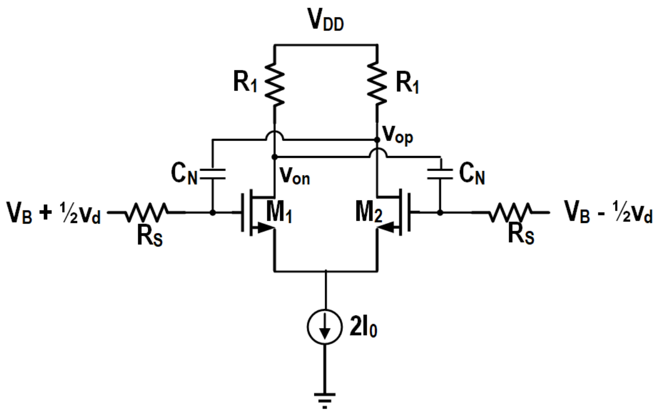


Figure 4: Fig. for Q3

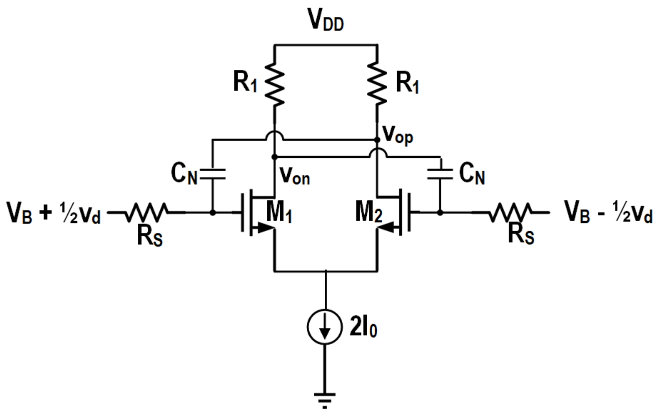
3. In this question, we will look at frequency response and Miller effect. Assume that M_1 and M_2 are identical and in saturation. Assume $g_{m1} = g_{m2} = 45\text{mS}$, $R_1 = 200\Omega$, $R_S = 2\text{k}\Omega$, $C_{gd} = C_{db} = \frac{200}{2\pi}\text{fF}$, $C_{gs} = \frac{400}{2\pi}\text{fF}$. Neglect channel length modulation for M_1 and M_2.

   (a) (4 points) Assume $C_N = 0$ in this part. Estimate the 3-dB bandwidth of the differential transfer function $\frac{v_{op}-v_{on}}{v_d}(s)$? State any approximations you make.



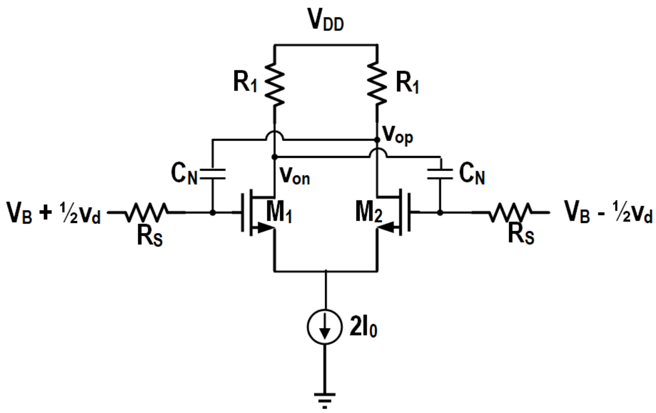
Assume $g_{m1} = g_{m2} = 45\text{mS}$, $R_1 = 200\Omega$, $R_S = 2\text{k}\Omega$, $C_{gd} = C_{db} = \frac{200}{2\pi}\text{fF}$, $C_{gs} = \frac{400}{2\pi}\text{fF}$. Neglect channel length modulation for M_1 and M_2.

(b) (3 points) Assume $C_N = 0$ in this part. Does the differential transfer function $\frac{v_{op}-v_{on}}{v_d}(s)$ have a zero? If yes, estimate its frequency. If no, explain why.



Assume $g_{m1} = g_{m2} = 45\text{mS}$, $R_1 = 200\Omega$, $R_S = 2\text{k}\Omega$, $C_{gd} = C_{db} = \frac{200}{2\pi}\text{fF}$, $C_{gs} = \frac{400}{2\pi}\text{fF}$. Neglect channel length modulation for M_1 and M_2.

(c) (3 points) Assume $C_N = C_{gd} = \frac{200}{2\pi}\text{fF}$ in this part. Does the differential transfer function $\frac{v_{op}-v_{on}}{v_d}(s)$ have a zero? If yes, estimate its frequency. If no, explain why.



Assume $g_{m1} = g_{m2} = 45\text{mS}$, $R_1 = 200\Omega$, $R_S = 2\text{k}\Omega$, $C_{gd} = C_{db} = \frac{200}{2\pi}\text{fF}$, $C_{gs} = \frac{400}{2\pi}\text{fF}$. Neglect channel length modulation for M_1 and M_2.

(d) (4 points) Assume $C_N = C_{gd} = \frac{200}{2\pi}\text{fF}$ in this part. Estimate the 3-dB bandwidth of the differential transfer function $\frac{v_{op}-v_{on}}{v_d}(s)$? State any approximations you make.

Additional space to work out problem 3.

4. The circuit in Fig. 5 is connected in unity gain feedback. A, B, X, Y and Z are used to identify the various nodes in the circuit in Fig. 5. For the circuit in Fig. 5 connected in unity gain feedback, assume $V_{DD} = 2V$, $V_B = 1V$, $V_{B1} = 0.5V$. Assume $\lambda = 0$ for the first three parts.

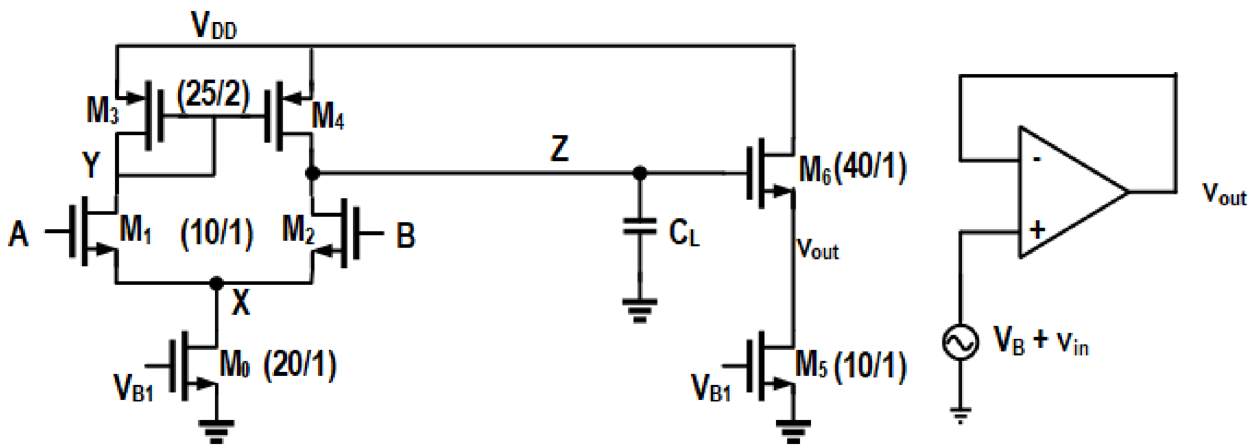
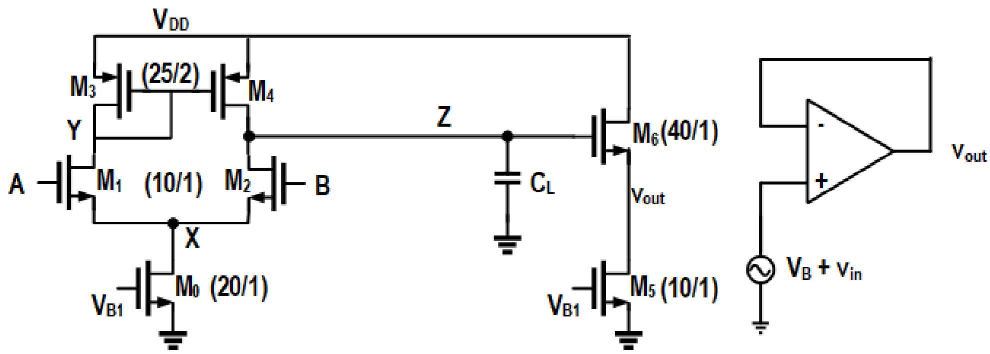


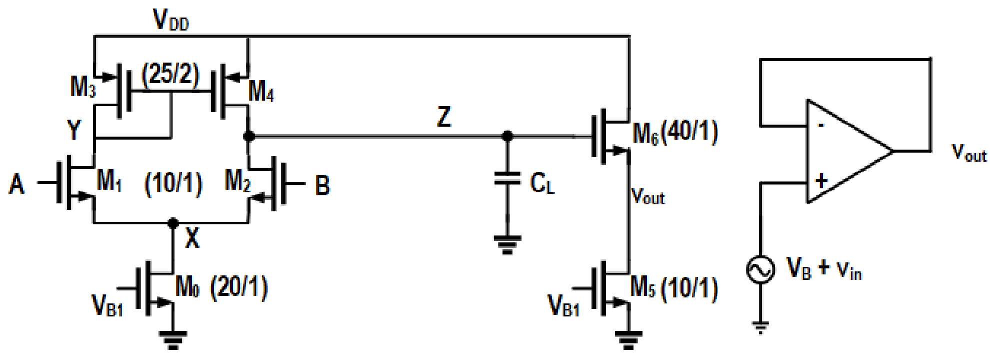
Figure 5: Fig. for Q4

(a) (2 points) To which input terminal of the opamp should the output node v_{out} be connected for unity gain negative feedback? A or B?



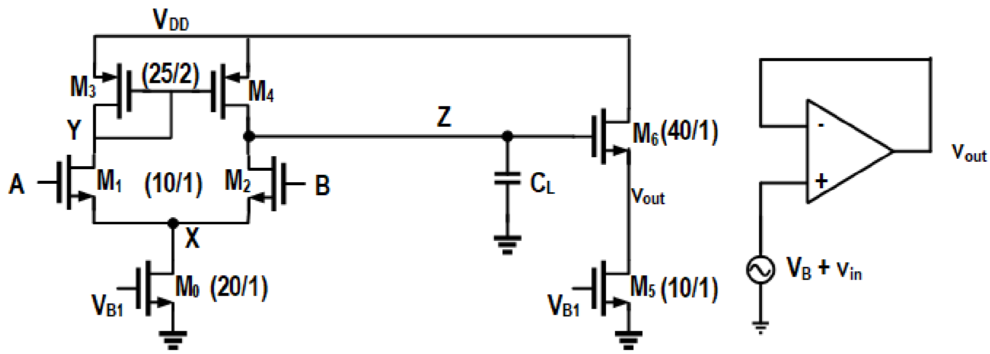
Assume $V_{DD} = 2V$, $V_B = 1V$, $V_{B1} = 0.5V$. Assume $\lambda = 0$ for part (b).

(b) (3 points) When the circuit in Fig. 5 is connected in unity gain feedback, what are the DC voltages established at nodes A, B, X, Y and Z?



Assume $V_{DD} = 2V$, $V_B = 1V$, $V_{B1} = 0.5V$. Assume $\lambda = 0$ for part (c).

(c) (5 points) Assuming v_{in} is a sinusoid of the form $v_{in} = A\sin\omega_0 t$, what is the maximum amplitude A for which all the transistors in the circuit of Fig. 5, connected in unity gain feedback, remain in saturation? Which transistor causes the limitation?



Assume $V_{DD} = 2V$, $V_B = 1V$, $V_{B1} = 0.5V$.

(d) (4 points) Now, assume $\lambda = 0.2V^{-1}$ for the transistors M_1 to M_4. Ignore channel length modulation for the other transistors. Assume $C_L = \frac{1}{2\pi}$pF. What is the 3-dB bandwidth of the closed loop transfer function $\frac{v_{out}}{v_{in}}(s)$, when the opamp is in unity gain feedback? Consider only the capacitor C_L and ignore all parasitic capacitors of the transistors.

Additional space to work out problem 4.

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