EC201-ANALOG CIRCUITS : PROBLEM SET 2

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Problem 1

The MOSFET in Fig. 1 has $V_T = 0.7\,V$, and $k = 500\,\mu A/V^2$. The drain current in the device is 1 mA.

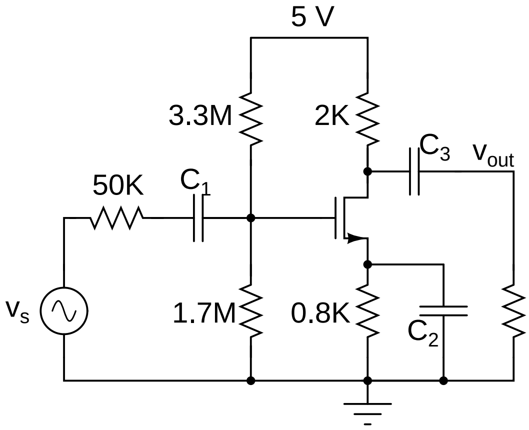


Figure 1: Problem 1

- Determine the small signal gain from v_s to v_{out}.
- Determine the (W/L) of the device and the quiescent V_{GS} and V_{DS}.
- The lowest frequency contained in v_s is 100 rad/s. Determine the minimum values of C_1, C_2 and C_3 required so that the natural frequencies associated with their charging/discharging is atleast 10 times smaller than the smallest input frequency.
- Determine the voltage swing limits at v_{out}. What is the amplitude of the largest sinusoidal input signal that can be applied before the output begins to clip ?
- The supply voltage is changed to 5.5 V. Determine the small signal gain of the amplifier.
- Due to a change in temperature, V_T increases by 100 mV. What is the new small signal gain of the amplifier ?

Problem 2

The MOSFETs in Fig. 2 have $V_T = 0.7\,V$, and $k = 500\,\mu A/V^2$. Like in Problem 1, the drain current in M2 is 1 mA, and has the same (W/L) as in that problem.

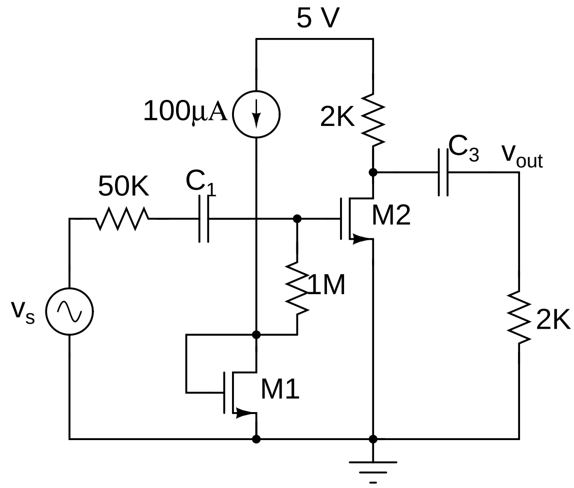


Figure 2: Problem 2

- Determine the small signal gain from v_s to v_{out}.
- Determine the (W/L) of M1 and the quiescent V_{GS} and V_{DS}.
- The lowest frequency contained in v_s is 100 rad/s. Determine the minimum values of C_1 and C_3 required so that the natural frequencies associated with their charging/discharging is atleast 10 times smaller than the smallest input frequency.
- Determine the voltage swing limits at v_{out}. What is the approximate amplitude of the largest sinusoidal input signal that can be applied before the output begins to clip ?
- The supply voltage is changed to 5.5 V. Determine the small signal gain of the amplifier. How does this compare with the results of Problem 1 ? Why ?
- What is the small signal gain of the amplifier if (a) $V_{T,M1} = 0.8\,V$,$V_{T,M2} = 0.7\,V$ (b) $V_{T,M1} = 0.7\,V$,$V_{T,M2} = 0.8\,V$ and (c) $V_{T,M1} = 0.8\,V$,$V_{T,M2} = 0.8\,V$? How does this compare with the results of Problem 1 ? Why ?

Problem 3

The MOSFETs in Fig. 3 have $V_T = 0.7\,V$, and $k = 500\,\mu A/V^2$. Like in Problem 1, the drain current in M2 is 1 mA, and has the same (W/L) as in that problem.

- Determine the small signal gain from v_s to v_{out}.
- Determine the (W/L) of M1 and the quiescent V_{GS} and V_{DS}.
- The lowest frequency contained in v_s is 100 rad/s. Determine the minimum values of C_1 and C_3 required so that the natural frequencies associated with their charging/discharging is atleast 10 times smaller than the smallest input frequency.

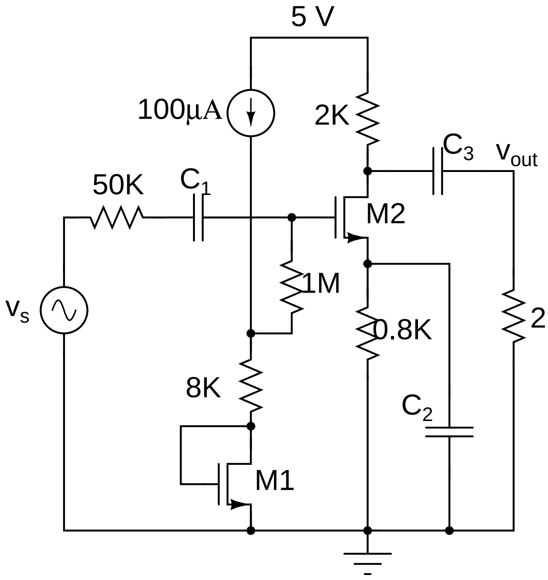


Figure 3: Problem 3

- Determine the voltage swing limits at v_{out}. What is the amplitude of the largest sinusoidal input signal that can be applied before the output begins to clip ?
- The supply voltage is changed to 5.5 V. Determine the small signal gain of the amplifier. How does this compare with the results of Problem 1 & 2 ? Why ?
- What is the small signal gain of the amplifier if (a) $V_{T,M1} = 0.8\,V$,$V_{T,M2} = 0.7\,V$ (b) $V_{T,M1} = 0.7\,V$,$V_{T,M2} = 0.8\,V$ and (c) $V_{T,M1} = 0.8\,V$,$V_{T,M2} = 0.8\,V$? How does this compare with the results of Problem 1 & 2 ? Why ?

Problem 4

This problem illustrates the effects of battery internal resistance on the small signal performance of an amplifier. The MOSFETs in Fig. 4 have $V_T = 0.7\,V$, and $k = 500\,\mu A/V^2$. Like in Problem 1, the drain current in M2 is to be 1 mA. R_b represents the internal resistance of the battery. To determine the operating point, neglect the drop across R_b due to the current flowing through the gate-bias resistors. For the first three parts, set $Cb = 0$.

- For $R_b = 0$, determine the (W/L) of the FET and the quiescent V_{GS} and V_{DS}. Determine the small signal y-parameters of the two port enclosed in the box. What do you observe about y_{12} ? Why ? Is there *any* AC negative feedback around M2 ?
- Repeat the above exercise for $R_b = 500\,\Omega$. Comment on the results.
- To avoid degradation in performance due to the DC drop across R_b, a student deliberately increases the battery voltage to 5.5 V, so that the device operating point is identical to that in the first part of this problem. Determine the small signal y-parameters of the two port enclosed in the box. What do you observe about y_{12} ? Why ? Is there *any* AC negative feedback around M2 ?

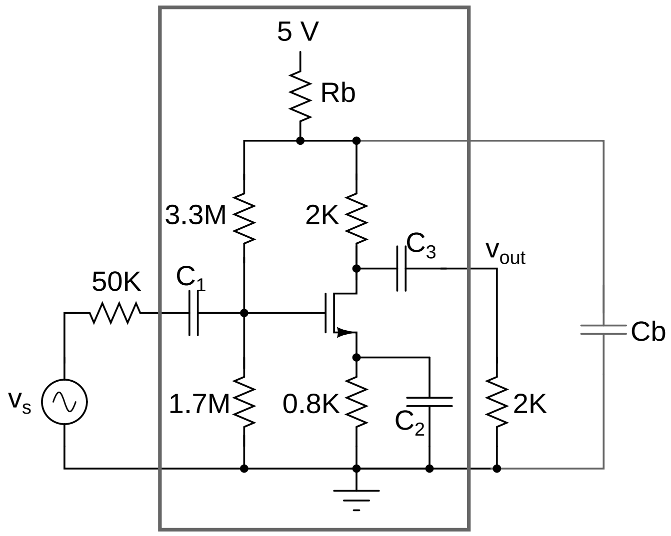


Figure 4: Problem 4

- Based on the observations above, the student adds a **huge** capacitor Cb between the battery output and ground. Does this solve the problem(s) faced in part 3 above? Why ?

Problem 5

In class, we saw that the bias current in a MOSFET could be set accurately using negative feedback. In that discussion, we saw that the device current could be measured in either the drain or the source, with correction being applied at either gate or source, leading to four different possibilities. We investigated only two of those in class. In this problem, we look at the third possibility. It uses an ideal opamp. The idea is to compare the drain current to a reference current (1 mA in this case) , and apply corrective feedback to the *source*. The MOSFET in Fig. 5 has $V_T = 0.7\,V$, and $k = 500\,\mu A/V^2$.

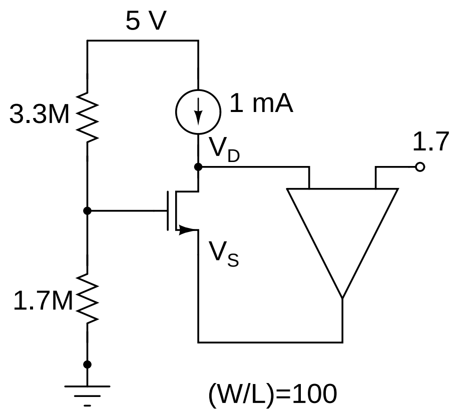


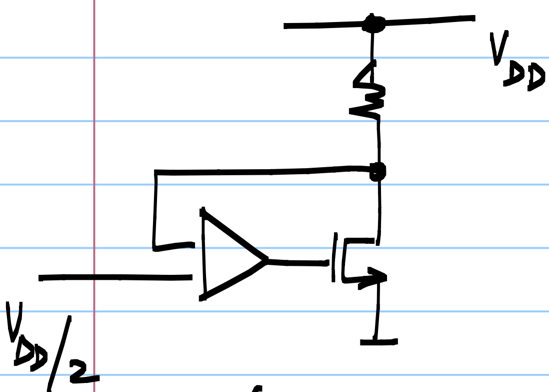
Figure 5: Problem 5

- Reason through the circuit of Fig. 5 and figure out *why* this makes sense.
- Determine the signs on the opamp for negative feedback operation.
- Determine the potentials at nodes V_D and V_S.

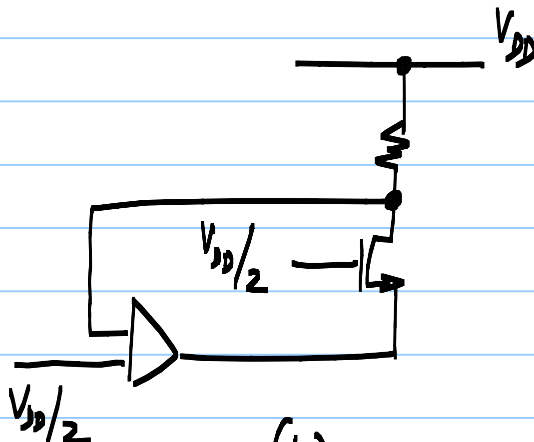
Problem 6 :

Note Title 9/17/2010

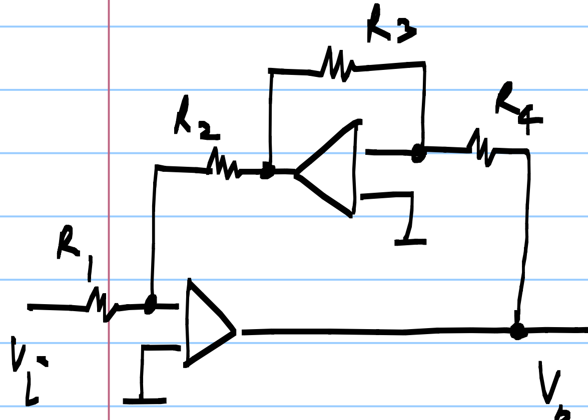
Find the correct signs of the OPAMP for negative feedback



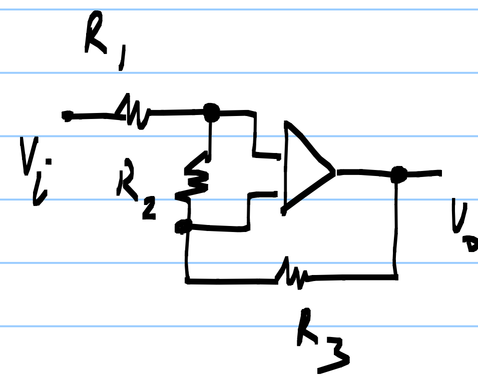
(a)



(b)



(c)



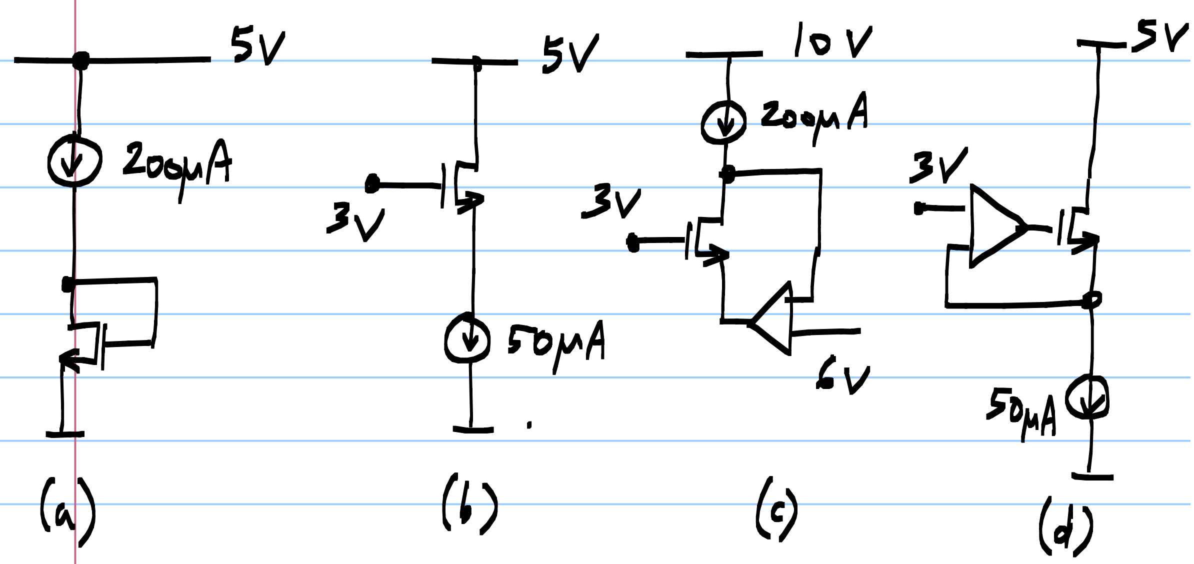
(d)

Problem 7

(i) Find the drain, gate, and source voltages of M_1 in the circuits below

(ii) Find the value of the resistance that can replace the current source in each case

$\mu_n C_{ox} = 100\mu A/V^2$, $V_T = 0.5V$, $W/L = 1$

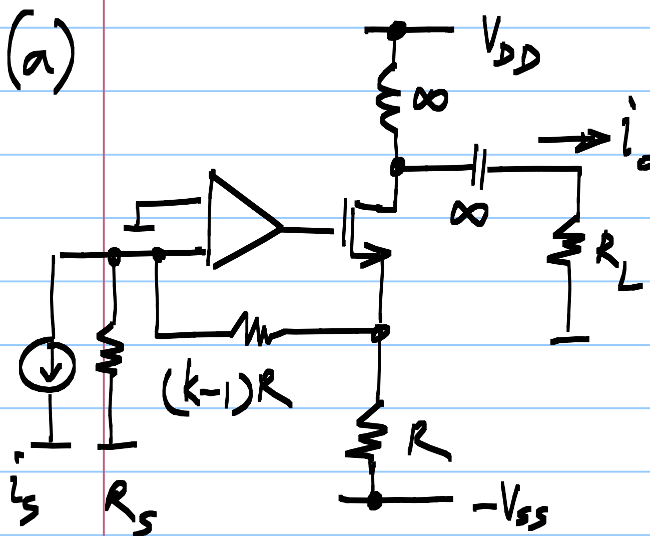


[In all cases, assign OPAMP signs for negative feedback operation]

Problem 8

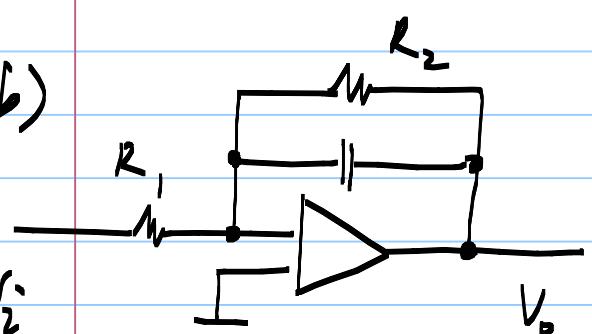
Assuming ideal opamps, derive the quantities asked for

(a)



$$\frac{i_o}{i_s} = ?$$

(b)

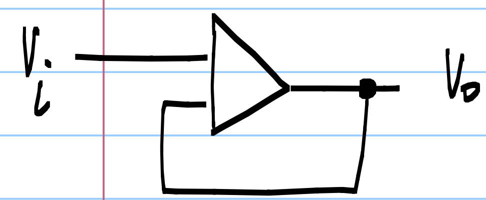


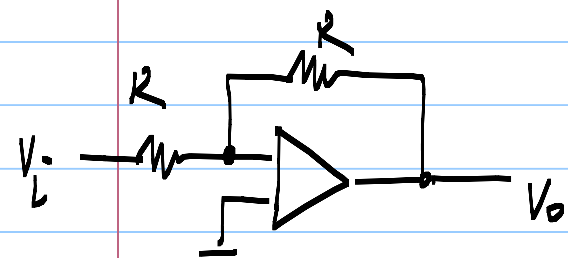
$$\frac{V_o}{V_i} = ?$$

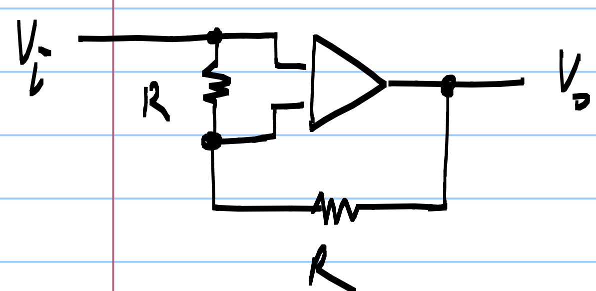
[In all cases, assign OPAMP signs for negative feedback operation]

Problem 9

Assuming an opamp with gain A_0, derive V_o/V_i in the following circuits





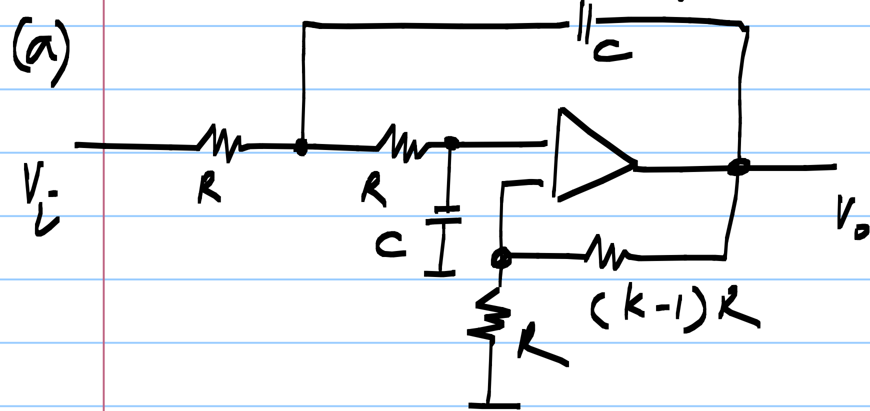


[In all cases, assign OPAMP signs for negative feedback operation]

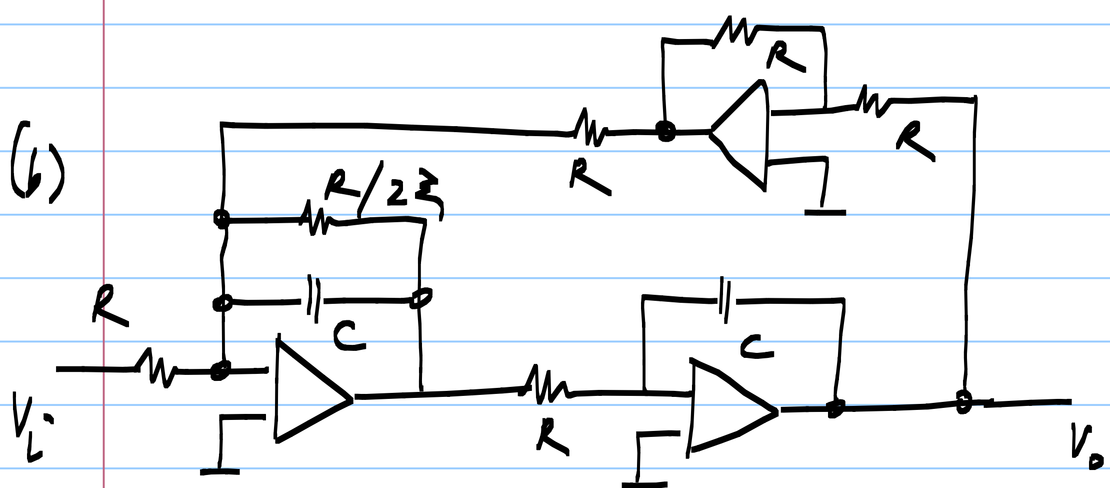
Extra problems:

Derive V_o/V_i assuming ideal opAMPs

(a)



(b)



[In all cases, assign OPAMP signs for negative feedback operation]