EC201-ANALOG CIRCUITS : PROBLEM SET 3

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Problem 1

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

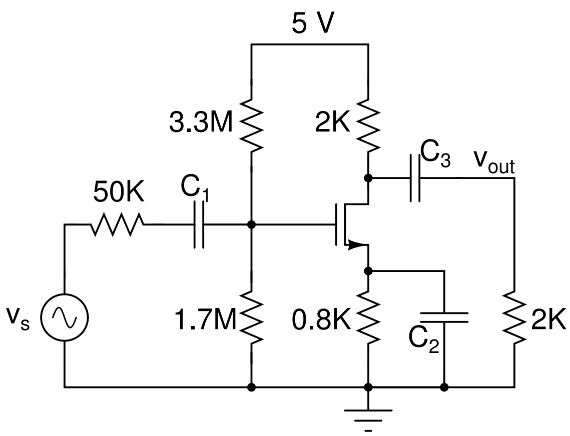


Figure 1: Problem 1

- 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 $\mu_n C_{ox} = 500\,\mu A/V^2$. Like in Problem 1, the drain current in M2 is 1 mA, and has the same (W/L) as in that problem.

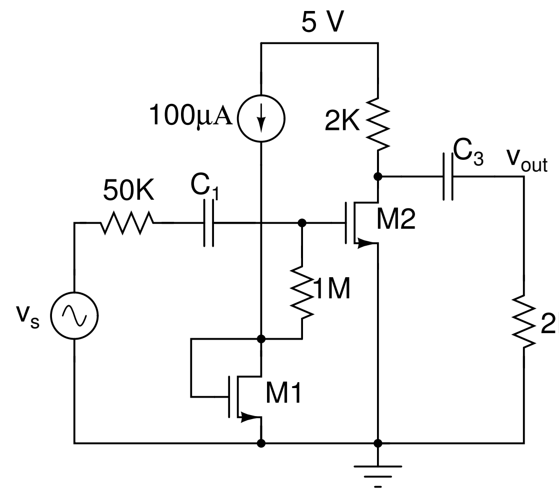


Figure 2: Problem 2

- 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 $\mu_n C_{ox} = 500\,\mu A/V^2$. 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.

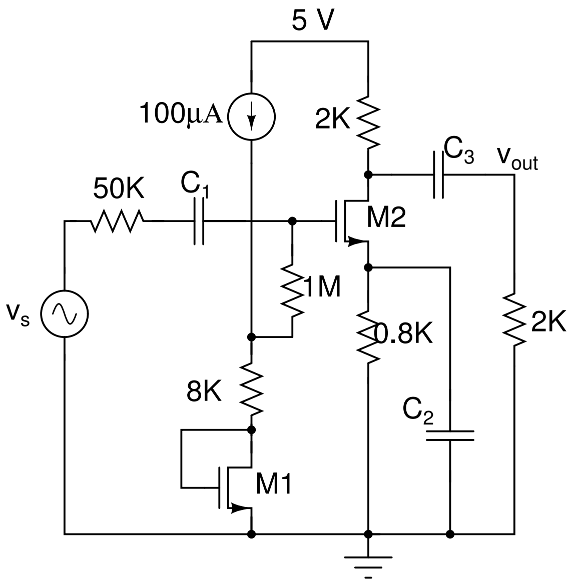


Figure 3: Problem 3

- 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 $\mu_n C_{ox} = 500\,\mu A/V^2$. 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 ?

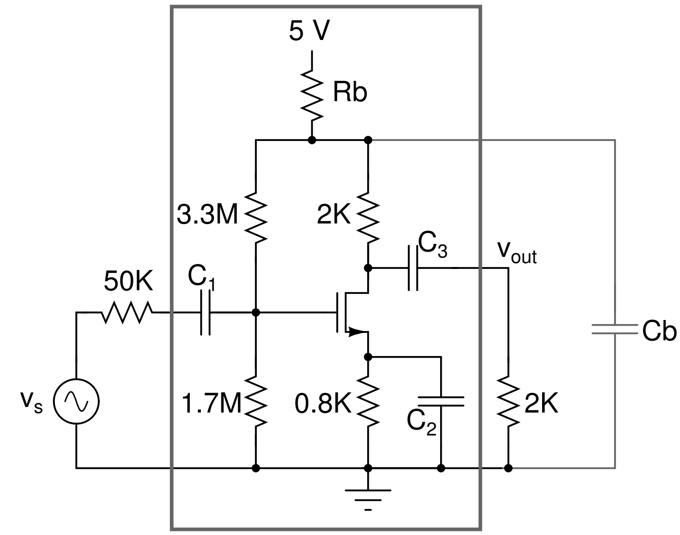


Figure 4: Problem 4

- 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

The MOSFET in Fig. 5 has $V_T = 0.7\,V$, and $\mu_n C_{ox} = 500\,\mu A/V^2$.

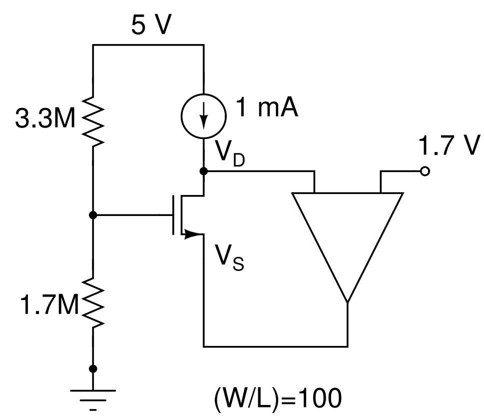


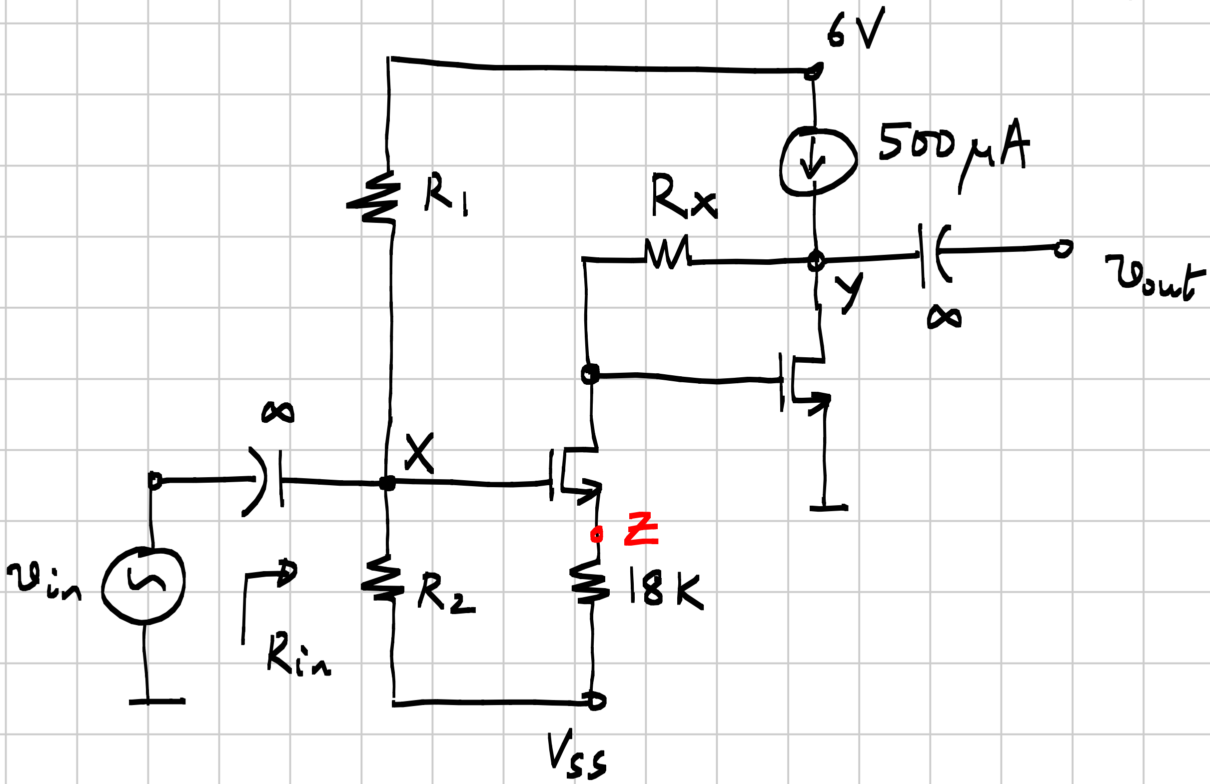
Figure 5: Problem 5

- 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.

Note Title

Problem 6

* For this problem, both transistors are identical, with $V_T = 0.5\,V$, $\lambda = 0$, $\mu_n C_{ox} \frac{W}{L} = 500\,\mu A/V^2$.



The quiescent currents through both transistors are equal. Determine R_x, V_{SS}, R_1 & R_2 so that

(a) v_{in} can be coupled without using C_1

(b) $R_{in} = 1\,M\Omega$

(c) $\frac{v_{out}}{v_{in}} = 2$, after accounting for finite g_m of the transistors

After determining the values above, find the quiescent voltage at node Y and the maximum sinusoidal amplitude one can use at the input so that the output is not distorted.

Now, an infinite capacitor is connected from node Z to ground. What is $\frac{v_{out}}{v_{in}}$ now?

Problem 7

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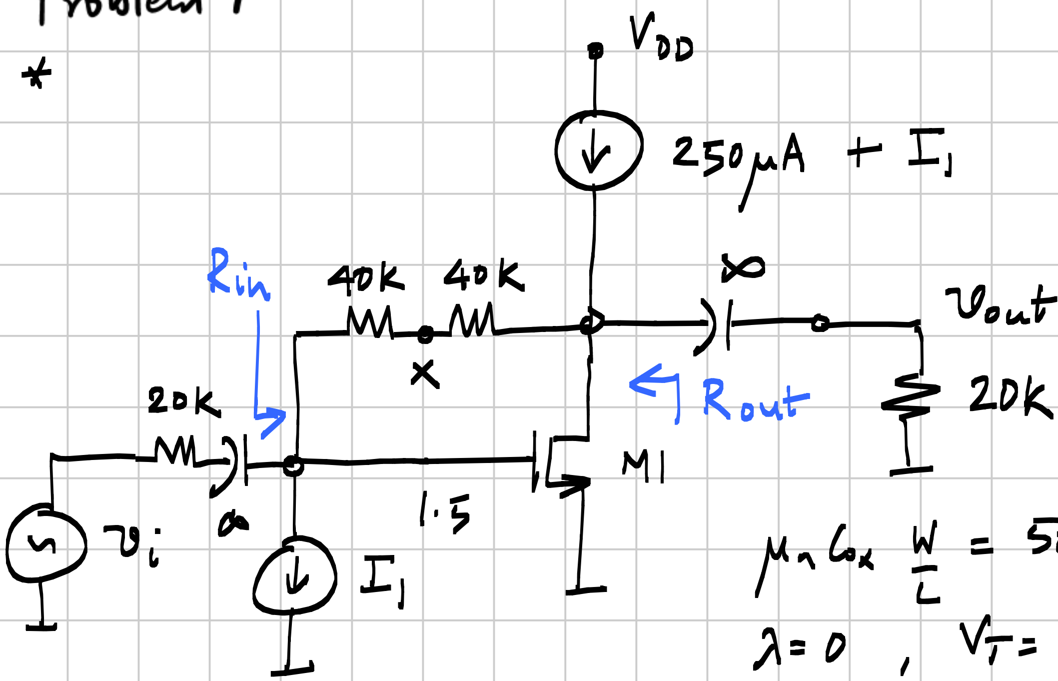

$\mu_n C_{ox} \frac{W}{L} = 500 \mu A/V^2$

$\lambda = 0$, $V_T = 0.5V$

(a) Determine the quiescent current of M1.

(b) Assuming large g_m, what gain do you expect from v_{in} to v_{out}? What is the actual gain?

(c) Determine the input & output impedances Rin & Rout.

(d) Determine I_1 so that the output sinusoid just clips at both extremes for an input amplitude of 1 V. For this part, assume g_m is very large.

(e) An infinite capacitor is now connected between the node marked X and ground. Determine the incremental gain from v_i to v_{out}.

Problem 8

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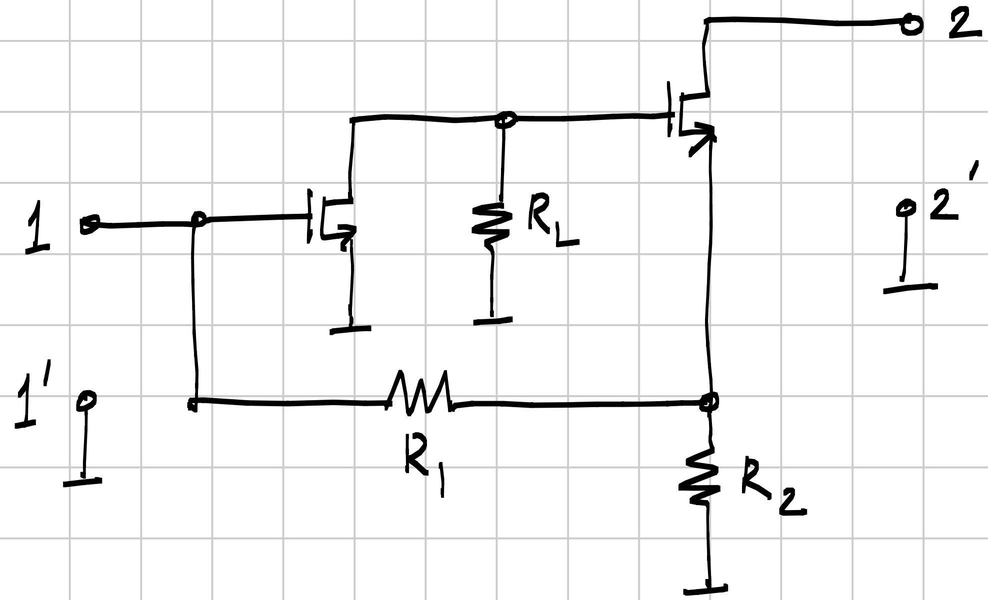


The circuit above is the incremental equivalent of an amplifier. The transistors have transconductances denoted by g_m.

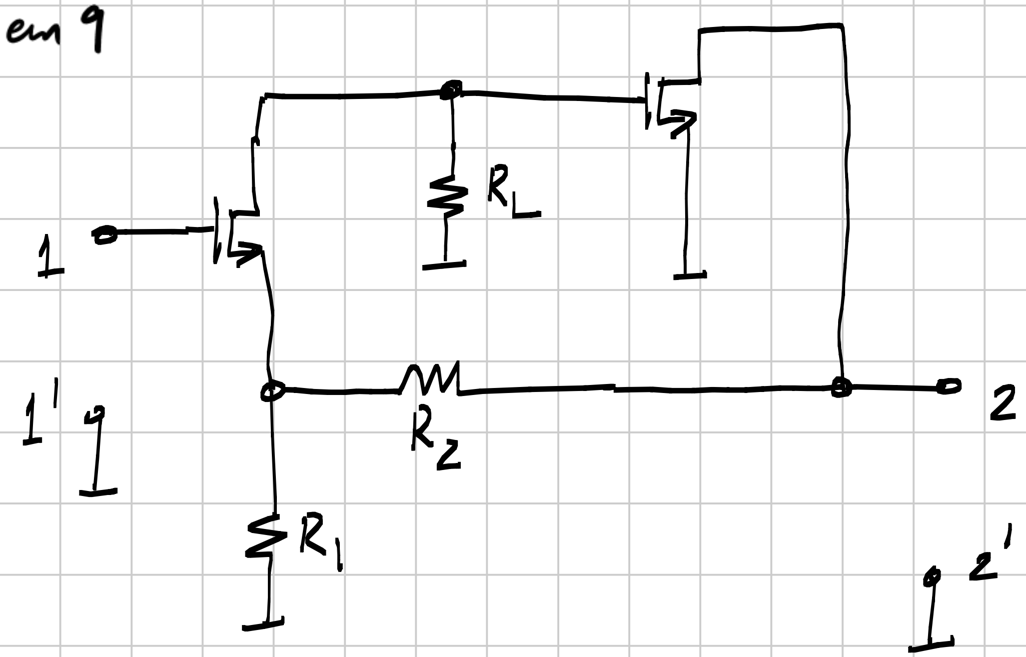
(a) Determine the input impedance @ port 1 when port 2 is shorted.

(b) Determine the output impedance @ port 2 when port 1 is shorted.

(c) What kind of controlled source is this?

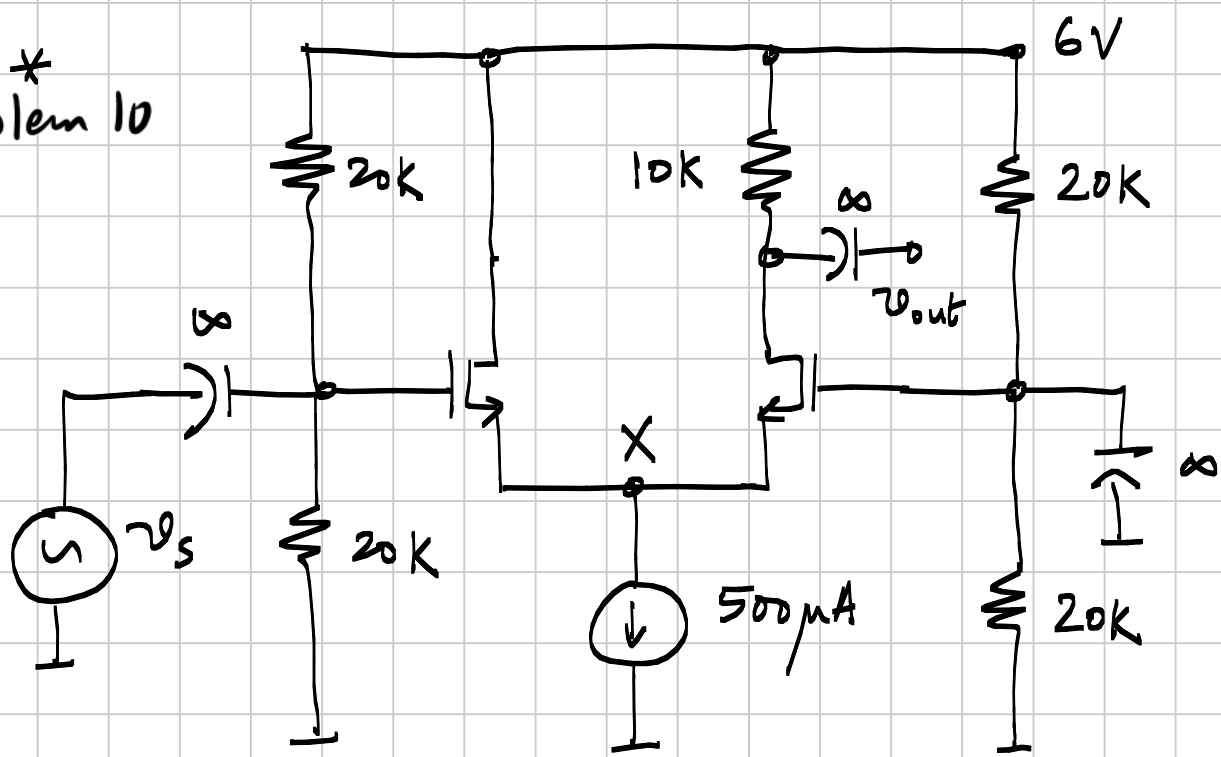
(d) If $g_m \to \infty$, determine the transfer function of the above controlled source.

* Problem 9



Repeat the previous problem for the incremental circuit shown above.

* Problem 10



$V_T = 0.5\,V$ $\quad \mu_n C_{ox} \frac{W}{L} = 500\,\mu A/V^2$

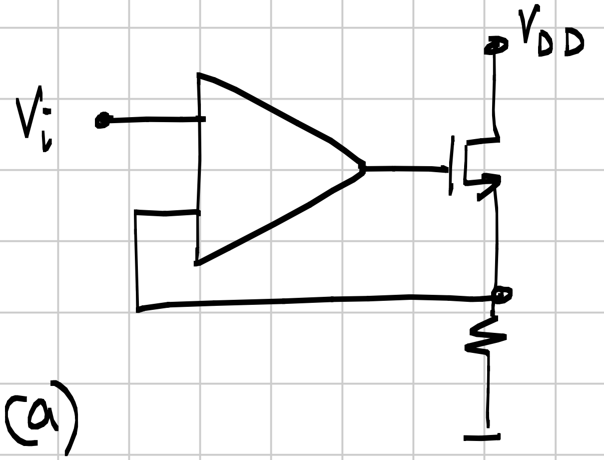
$\lambda = 0$

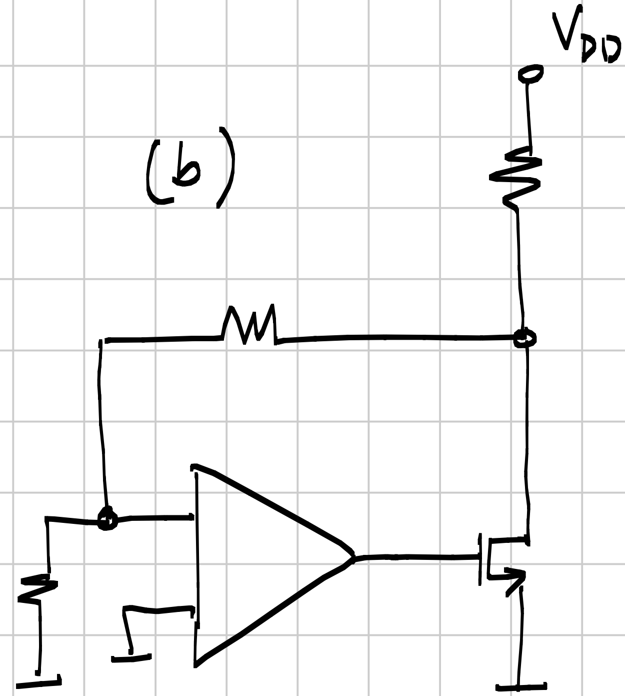
In the circuit above

(a) find the operating point.

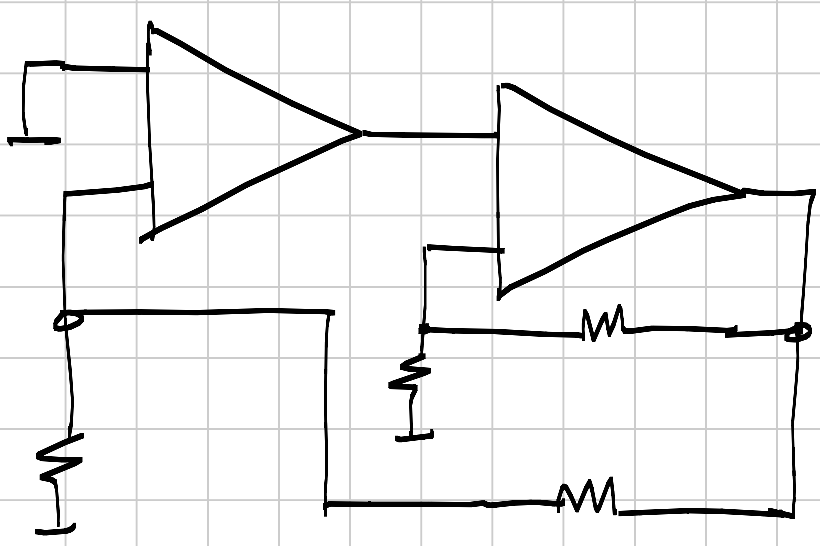
(b) The incremental gain v_{out}/v_s.

Prob 11* Determine the signs on the opamps for negative feedback operation.





(c)



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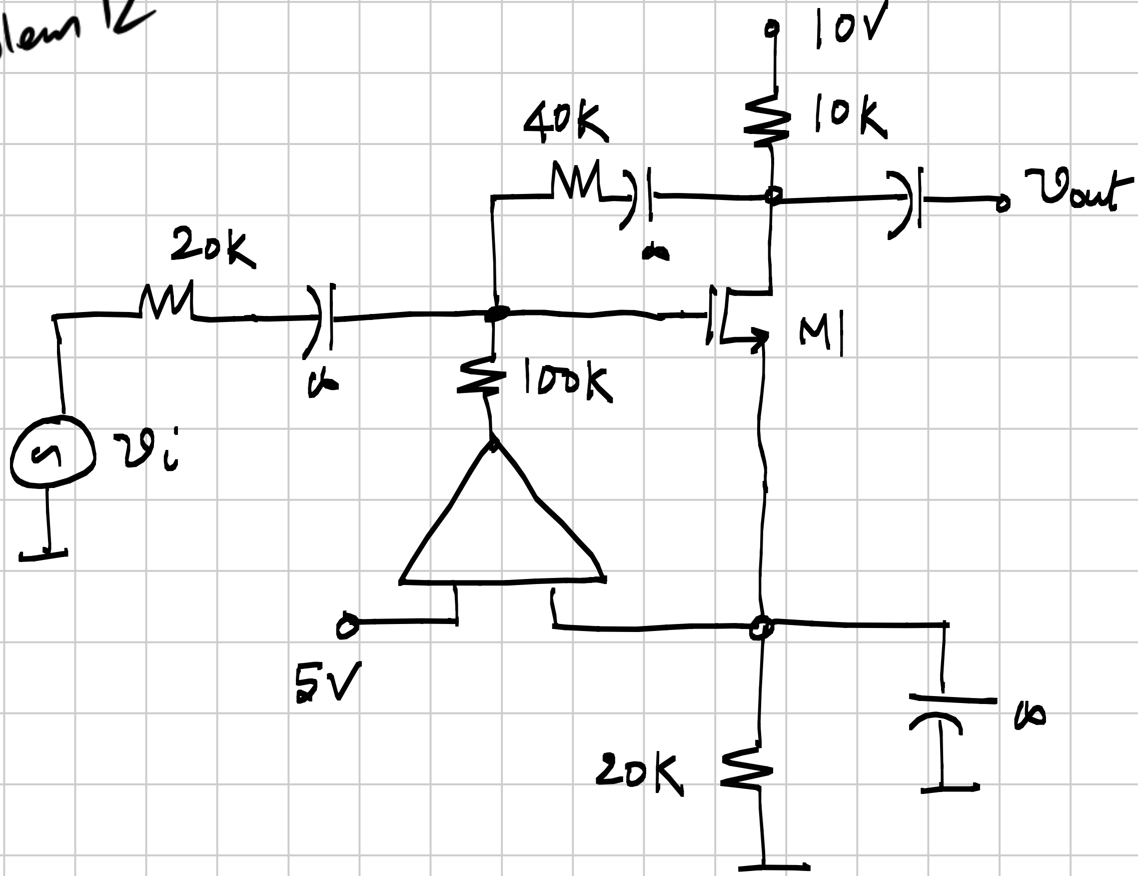
Problem 12



(a) Determine the signs on the opamp for negative feedback operation

(b) Determine the quiescent potential @ the gate of M1.

(c) What is the incremental gain $\frac{v_{out}}{v_i}$?