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.

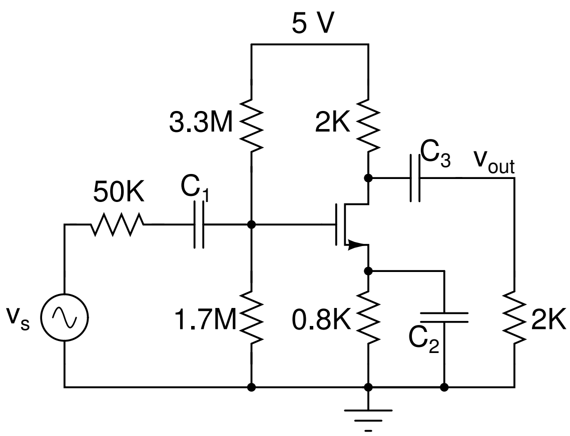

Figure 1: Problem 1

- 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.

- 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}.

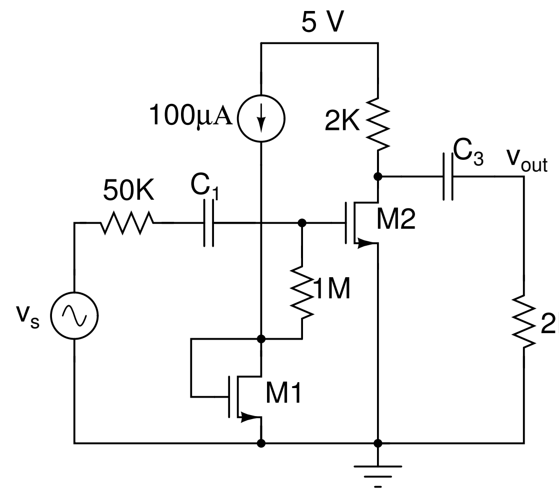

Figure 2: Problem 2

- 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.

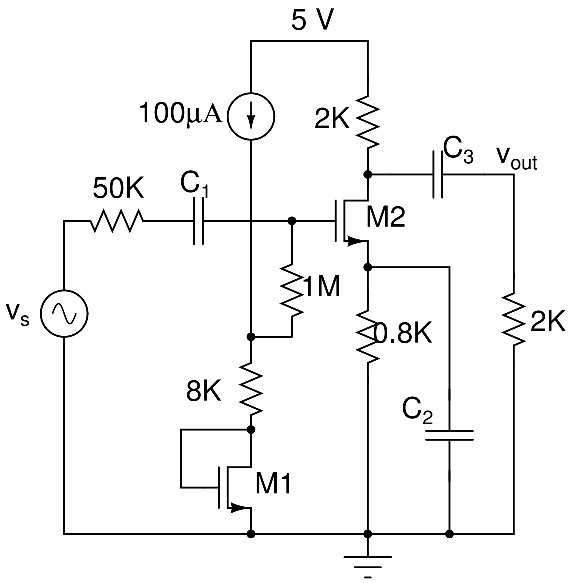

Figure 3: Problem 3

- 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 ?

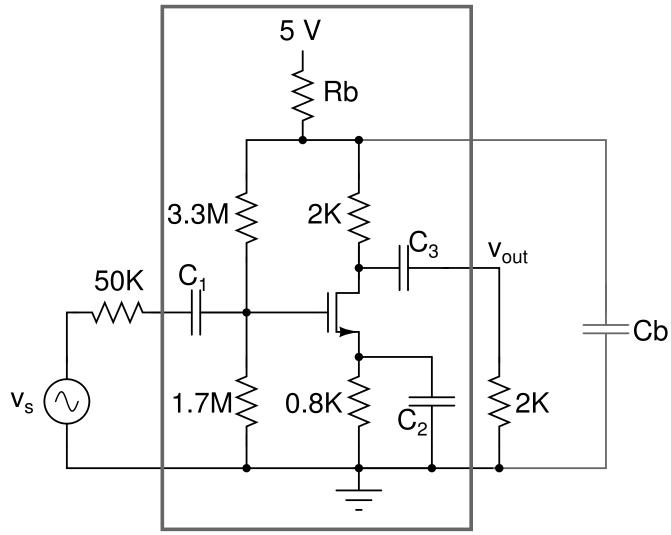

Figure 4: Problem 4

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

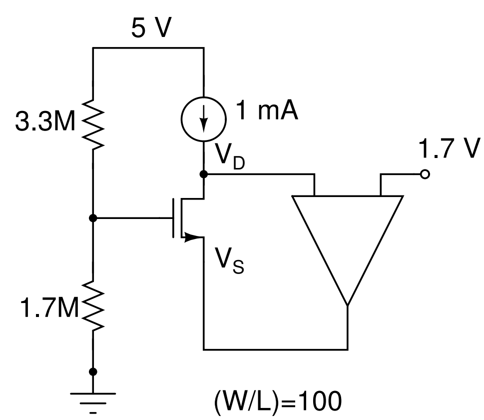

Figure 5: Problem 5

- 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.