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

• 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 at least 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?

Problem 2
The MOSFETs in Fig. 2 have $V_T = 0.7\,\text{V}$, and $k = 500\,\mu\text{A}/\text{V}^2$. 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 at least 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) $V_{T,M1} = 0.8\,\text{V}, V_{T,M2} = 0.7\,\text{V}$ (b) $V_{T,M1} = 0.7\,\text{V}, V_{T,M2} = 0.8\,\text{V}$ and (c) $V_{T,M1} = 0.8\,\text{V}, V_{T,M2} = 0.8\,\text{V}$? How does this compare with the results of Problem 1? Why?

Problem 3
The MOSFETs in Fig. 3 have $V_T = 0.7\,\text{V}$, and $k = 500\,\mu\text{A}/\text{V}^2$. 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 at least 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. How does this compare with the results of Problem 1 & 2? Why?

- What is the small signal gain of the amplifier if (a) $V_{T,M1} = 0.8\,\text{V}$, $V_{T,M2} = 0.7\,\text{V}$ (b) $V_{T,M1} = 0.7\,\text{V}$, $V_{T,M2} = 0.8\,\text{V}$ and (c) $V_{T,M1} = 0.8\,\text{V}$, $V_{T,M2} = 0.8\,\text{V}$? 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 $V_T = 0.7\,\text{V}$ and $k = 500\,\mu\text{A}/\text{V}^2$. 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 $C_b = 0$.

- 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?

- Based on the observations above, the student adds a huge capacitor $C_b$ 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 $V_T = 0.7\,\text{V}$, and $k = 500\,\mu\text{A}/\text{V}^2$.

- 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 $V_S$. 

![Figure 3: Problem 3](image3.png)

![Figure 4: Problem 4](image4.png)

![Figure 5: Problem 5](image5.png)