Analog Circuits (EE3002/EE5310) : Problem Set 2

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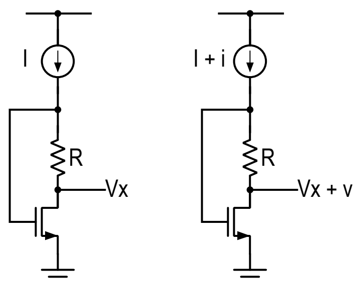
Problem 1



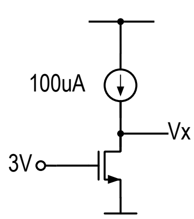
$$\mu_n C_{ox}\left(\frac{W}{L}\right) = 1\,\mathrm{mA/V^2}, V_T = 0.7\,\mathrm{V}$$

Figure 1: Circuit for problem 1.

In Fig. 1(a), determine the largest I that can be used while still maintaining the transistor in saturation.

In part(b) of the figure, i is a small signal, abd I has been chosen so that the transistor is in saturation. Determine the quiescent voltage Vx, and the incremental voltage v. How will you choose R to make v independent of i ?

Problem 2

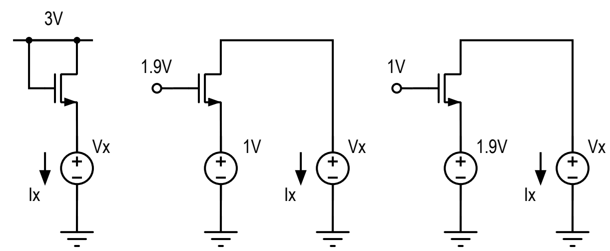


$$\mu_n C_{ox}\left(\frac{W}{L}\right) = 1\,\mathrm{mA/V^2}, V_T = 0.7\,\mathrm{V}$$

Figure 2: Circuit for problem 2.

For the circuit shown above, determine the region of operation of the transistor. Find Vx.

Problem 3



$$\mu_n C_{ox}\left(\frac{W}{L}\right) = 1\,\mathrm{mA/V^2}, V_T = 0.7\,\mathrm{V}$$

Figure 3: Circuits for problem 3.

For each of the circuits shown above, plot I_x as V_x varies from 0-3 V.

Problem 4

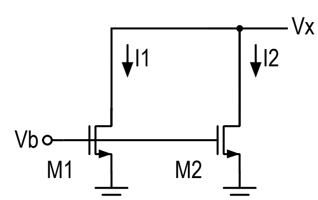


Figure 4: Circuit for problem 4.

Assume that Vx is large enough to keep M1 and M2 in saturation. Both transistors are identical. The threshold voltage of M2 is *slightly* larger than that of M1, by an amount ΔV_T. Determine I_2 in terms of $\mu_n C_{ox}(W/L)$, V_T and V_b.

Problem 5

For the circuits of Fig. 5, sketch I_x as V_x varies in the range 0.5-3 V.

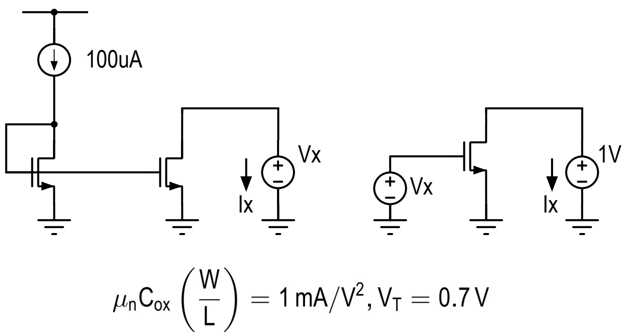


Figure 5: Circuit for problem 5.

Problem 6

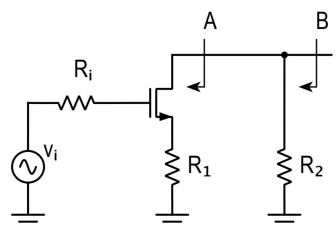


Figure 6: Circuit for problem 6.

The small signal equivalent circuit of an amplifier is shown above. The transistor is assumed to be in saturation, with transconductance g_m and output conductance g_o. Determine the Norton equivalent looking in at A, as well as the Thevenin equivalent looking in at B. What happens to these equivalents when $g_m \to \infty$?

Problem 7

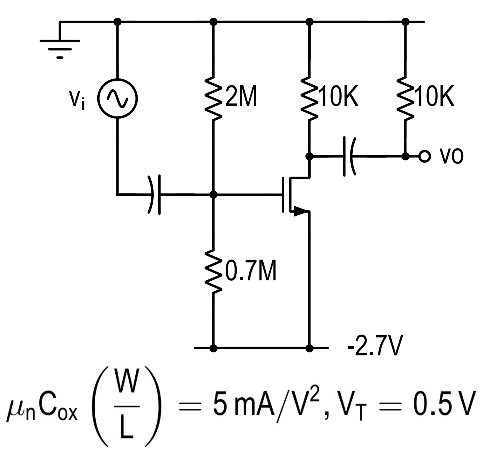


Figure 7: Circuit for problem 7.

Determine the quiescent operating point and small signal gain of the amplifier of Fig. 7. What is the maximum permissible amplitude of the sinewave input so that clipping of the output is avoided?

Problem 8

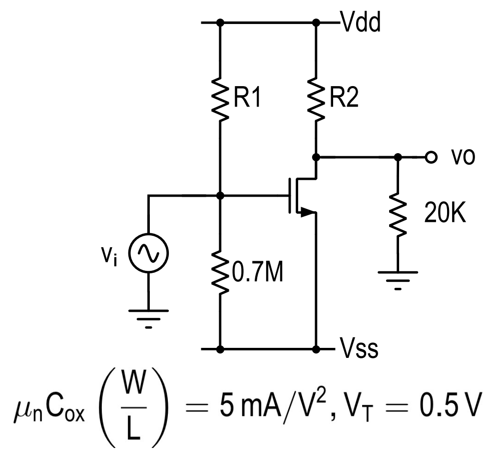


Figure 8: Circuit for problem 8.

The input to the amplifier shown below is a sinusoid of amplitude A. Determine $R1$, $R2$, A, Vdd and Vss in the circuit to achieve the following:

- There must be no quiescent current flowing through the 20K load, and input source.
- The incremental gain must be -4.
- The output sinewave must begin to just begin to clip at both extremes.

Problem 9

The MOSFET in Fig. 9 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.

- Determine the small signal gain from v_i to vo.
- Determine the (W/L) of the device and the quiescent V_{GS} and V_{DS} .
- The lowest frequency contained in vs is 100 rad/s. Determine the minimum values of $C1$, $C2$ and $C3$ required so that the natural frequencies associated with their charging/discharging is atleast 10 times smaller than the smallest input frequency.

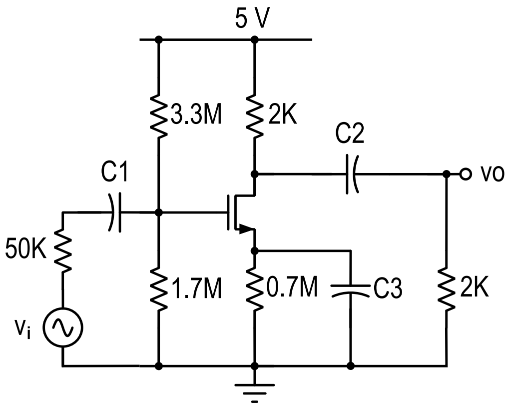


Figure 9: Circuit for problem 9.

- Determine the voltage swing limits at vo. 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 10

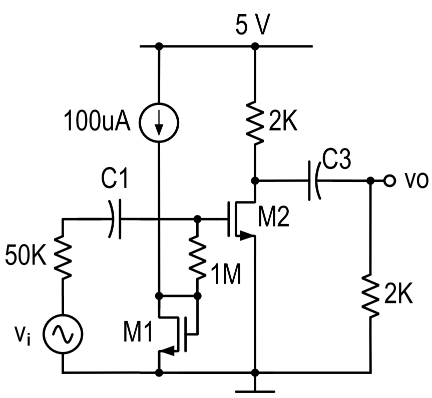


Figure 10: Circuit for problem 10.

The MOSFETs in Fig. 10 have $V_T = 0.7\,V$, and $\mu_n C_{ox} = 500\,\mu A/V^2$. Like in Problem 9, 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_i to vo.
- Determine the (W/L) of M1 and the quiescent V_{GS} and V_{DS}.
- The lowest frequency contained in v_i 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 vo. 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 9 ? 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 9 ? Why ?

Problem 11

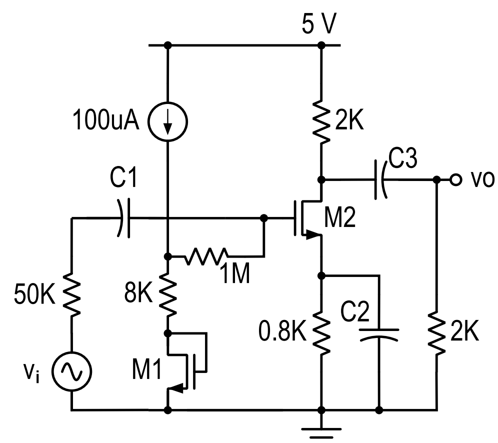


Figure 11: Circuit for problem 11.

The MOSFETs in Fig. 11 have $V_T = 0.7\,V$, and $\mu_n C_{ox} = 500\,\mu A/V^2$. Like in Problem 10, 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_i to vo.
- Determine the (W/L) of M1 and the quiescent V_{GS} and V_{DS}.
- The lowest frequency contained in v_i 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 vo. 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 9 ? 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 9 ? Why ?