ECE3040 Assignment 4

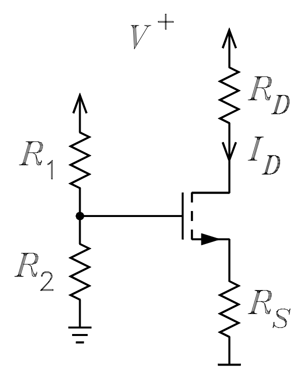
1. (a) Calculate the drain current in an NMOS transistor if $K = 125\,\mu\text{A/V}^2$, $V_{TO} = -2\,\text{V}$, $\lambda = 0$, $V_{GS} = 0\,\text{V}$, and $V_{DS} = 6\,\text{V}$. [0.5 mA] (b) Repeat assuming $\lambda = 0.025\,\text{V}^{-1}$. [0.575 mA]

2. An n-channel MOSFET has $K = 125\,\mu\text{A/V}^2$, $V_{TO} = 1\,\text{V}$, and $\lambda = 0.02\,\text{V}^{-1}$. At what drain current will the MOSFET no longer be able to provide any voltage gain when connected as a common-source amplifier? Note, the maximum gain is denoted by μ_F and it is given by $\mu_F = g_m r_0$. The object here is to determine the maximum I_D such that $\mu_F \leq 1$. This will require you to select V_{DS} that minimizes μ_F before solving for I_D. [1.25 A]

3. An n-channel MOSFET has a resistor $R_D = 60\,\text{k}\Omega$ connected between its drain and a power supply voltage $V^+ = 18\,\text{V}$. At what Q-point will $r_0 \| R_D = 50\,\text{k}\Omega$ if the transistor has $\lambda = 0.02\,\text{V}^{-1}$? Use the relations $r_0 = \left(\lambda^{-1} + V_{DS}\right)/I_D$, and $V_{DS} = 18 - I_D R_D$. [0.189 mA, 6.67 V]

4. The drain current in an n-channel JFET can be written $i_D = I_{DSS}\left(1 - v_{GS}/V_P\right)^2$, where $I_{DSS} = I_{DSS0}\left(1 + \lambda v_{DS}\right)$. Show that the expression for the JFET can be represented in exactly the same form as that of the MOSFET using the substitution $V_{TO} = V_P$ and $K = I_{DSS}/V_P^2$.

5. For $K = 1.78\,\text{mA/V}^2$, $V_{TO} = 1.5\,\text{V}$, $V^+ = 18\,\text{V}$, $R_1 = 110\,\text{k}\Omega$, $R_2 = 68\,\text{k}\Omega$, $R_D = 0$, and $R_S = 1\,\text{k}\Omega$, solve for I_D and verify that the MOSFET is biased in the saturation region, i.e. its active mode. [$I_D = 3.897\,\text{mA}$, $V_{DS} = 14.10\,\text{V}$, $V_{GS} - V_{TO} = 1.480\,\text{V}$]



6. Add a resistor $R_3 = 20\,\text{k}\Omega$ from gate to source for the circuit in problem 5. Solve for I_D and verify that the MOSFET is biased in the saturation region. [$I_D = 0.492\,\text{mA}$, $V_{DS} = 17.41\,\text{V}$, $V_{GS} - V_{TO} = 0.526\,\text{V}$]

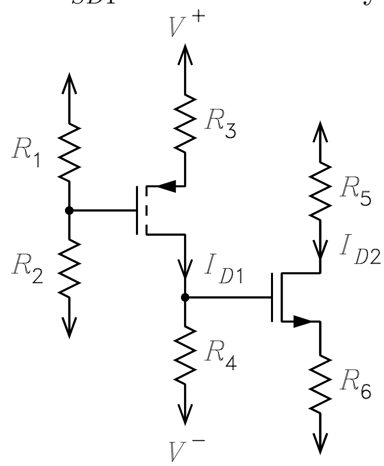
7. Problem 4.26 in Jaeger. Assume $K' = 25 \times 10^{-6}\,\text{A/V}^2$.

8. Problem 4.34 in Jaeger. Note, $K = K_n/2 = 250 \times 10^{-6}\,\text{A/V}^2$.

9. Problem 4.35 in Jaeger. Assume $K' = 25 \times 10^{-6}\,\text{A/V}^2$. [(a) $I_D = 103\,\mu\text{A}$, (b) $I_D = 104\,\mu\text{A}$, (c) $I_D = 107\,\mu\text{A}$]

10. Problem 4.41 parts (a) and (b) in Jaeger. Assume $K' = 25 \times 10^{-6}\,\mathrm{A/V^2}$. Hint: Show first that the device is operated in the triode region.

11. It is given that $K = 0.001\,\mathrm{A/V^2}$, $V_{TH1} = 1.25\,\mathrm{V}$, $V_{TH2} = -1.25\,\mathrm{V}$, $V^+ = +24\,\mathrm{V}$, $V^- = -24\,\mathrm{V}$, $R_1 = 100\,\mathrm{k\Omega}$, $R_3 = 1\,\mathrm{k\Omega}$, and $R_6 = 200\,\Omega$. We desire $I_{D1} = 1.5\,\mathrm{mA}$, $I_{D2} = 5\,\mathrm{mA}$, and $V_{DS2} = 12\,\mathrm{V}$. Show that $R_2 = 1.108\,\mathrm{M\Omega}$, $R_4 = 1.324\,\mathrm{k\Omega}$, $R_5 = 7\,\mathrm{k\Omega}$, and $V_{SD1} = 44.514\,\mathrm{V}$. Verify that both MOSFETs are in the saturation region.



12. Assume that you are given the values for V^+, V^-, and all the resistor values in the circuit for problem 11. Solve for I_{D1}, I_{D2}, and verify that both MOSFETs are in the saturation region.

13. Problem 13.76 in Jaeger. $[I_D = 1.25\,\mathrm{mA},\ W/L = 250]$

14. Problem 13.81 in Jaeger. Assume that a resistor R_D connects from the MOSFET drain to V^+, the MOSFET source is grounded, and $V_{DS} = V^+/2$. Solve for I_D such that $R_{out} = r_0 \| R_D = 50\,\mathrm{k\Omega}$.