Design & Simulate 13

ECE2204 CRN:82929

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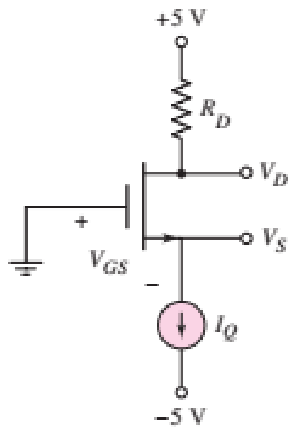
Problem 15.3-8.a.1:

Design

Modify the circuit below to replace the current source with a resistor R_S and preserve the quiescent point. Design W/L and R_D to bias $I_d = 250\mu A$ and $V_S = -2.25V$. Let k'_n vary by $\pm 5\%$. Compare the stabilities of the Q-points of the two bias schemes (current source vs. resistive) by comparing the % variations of I_{dQ}, V_{dsQ}, and V_{gsQ}. Assume $V_T = 0.8V$, $k'_n = 80\mu A/V^2$, $V_G = 0$



$$
\begin{aligned}
V_{GS} &= V_G - V_S = 0V + 2.25V = 2.25V \\
I_D &= \frac{k'_n}{2} \times \frac{W}{L}(V_{GS} - V_{TN})^2 \\
\frac{W}{L} &= \frac{2I_D}{k'_n(V_{GS} - V_{TN})^2} = \frac{2(250\mu A)}{(80\mu A/V^2)(2.25V - 0.8V)^2} = 2.97 \\
V_{R_D} &= \frac{V_{DD} - V_S}{2} = \frac{5 + 2.25V}{2} = 3.625V \\
R_D &= \frac{V_{R_D}}{I_D} = \frac{3.625V}{250\mu A} = 14.5k\Omega \\
V_{R_S} &= V_S - V_{SS} = -2.25V + 5V = 2.75V \\
R_S &= \frac{V_{R_S}}{I_D} = \frac{2.75V}{250\mu A} = 11k\Omega
\end{aligned}
$$

Evaluating Modes

$$
\begin{aligned}
k_n' &= [76, 80, 84]\mu A/V^2 \\
V_{DG} &= V_T = 0.8V \\
V_D &= V_G + V_{DG} = 0 + 0.8V = 0.8V \\
I_D &= \frac{5V - 0.8V}{14.5k\Omega} = 289.7\mu A \\
V_{R_S} &= R_S I_D = (11k\Omega)(289.7\mu A) = 3.1867V \\
V_S &= V_{SS} + V_{R_S} = -5V + 3.1867V = -1.813V \\
V_{GS} &= V_G - V_S = 0 + 1.813V = 1.813V \\
V_{GS}' &= \sqrt{\frac{2I_D}{K_n'}\frac{W}{L}} + |V_T| = \sqrt{\frac{2(289.7\mu A)}{[76, 80, 84]\mu A/V^2(2.97)}} + |0.8V| = [2.402, 2.362, 2.324]V
\end{aligned}
$$

As all $V_{GS}' > V_{GS}$, the transistor is in saturation mode.

$$
\begin{aligned}
V_{DS} &= V_{DD} - V_{SS} - I_D(R_D + R_S) = 5V + 5V - I_D(14.5k\Omega + 11k\Omega) = 10V - I_D(25.5k\Omega) \\
V_{GS} &= V_G - I_D R_S = -I_D(11k\Omega) \\
I_D &= \frac{K_n' W}{2L}(V_{GS} - V_T) \\
&= \frac{K_n'}{2}(2.97)(-I_D(11k\Omega) - 0.8V)(10V - I_D(25.5k\Omega))^2 \\
I_D(76\mu A/V^2) &= 402\mu A \\
I_D(80\mu A/V^2) &= 412\mu A \\
I_D(84\mu A/V^2) &= 420\mu A \\
V_{DS}(402\mu A) &= 10V - (402\mu A)(25.5k\Omega)
\end{aligned}
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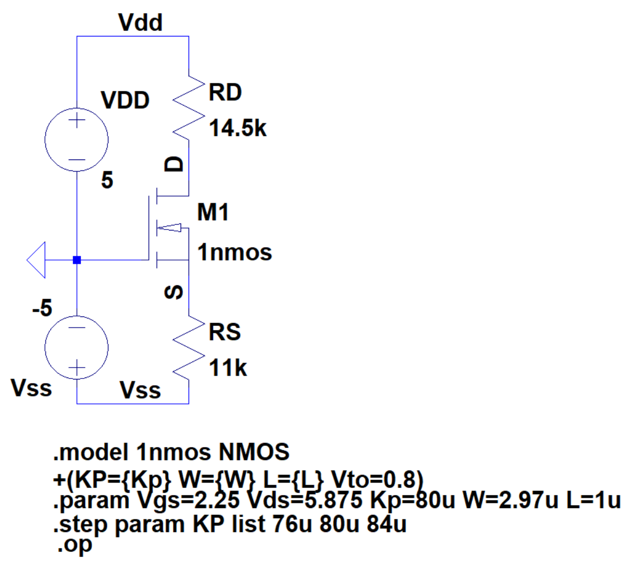
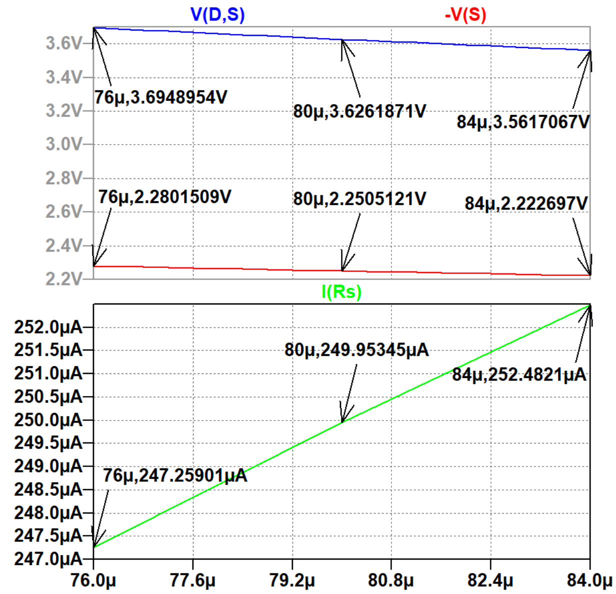
Validation

LTSpice Implementation (values within < 1%)





I messed something up with this and have been fighting with it for days to no avail. I apologise for submitting this largely incomplete assignment so late.

This assignment should demonstrate a basic understanding of DC analysis of basic MOSFET circuits.

I have neither given nor received unauthorized assistance on this assignment.