VE320 Homework 9

Due Dec. 4, 11:40am

In the following problems, assume the semiconductor and oxide in the MOS system are silicon and silicon dioxide, respectively, and assume the temperature is T=300 K unless otherwise stated.

1.

A p-channel MOSFET has the following parameters: $k_p' = 0.10$ mA/V^2, $W/L = 15$, and $V_T = -0.4$ V. Calculate the drain current I_D for (*a*) $V_{SG} = 0.8$ V, $V_{SD} = 0.25$ V; (*b*) $V_{SG} = 0.8$ V, $V_{SD} = 1.0$ V; (*c*) $V_{SG} = 1.2$ V, $V_{SD} = 1.0$ V; and (*d*) $V_{SG} = 1.2$ V, $V_{SD} = 2.0$ V.

2.

Consider a p-channel MOSFET with the following parameters: $k_p' = 0.12$ mA/V^2 and $W/L = 20$. The drain current is 100 μA with applied voltages of $V_{SG} = 0$, $V_{BS} = 0$, and $V_{SD} = 1.0$ V. (*a*) Determine the V_T value. (*b*) Determine the drain current I_D for $V_{SG} = 0.4$ V, $V_{SB} = 0$, and $V_{SD} = 1.5$ V. (*c*) What is the value of I_D for $V_{SG} = 0.6$ V, $V_{SB} = 0$, and $V_{SD} = 0.15$ V?

3.

An NMOS device has the following parameters: n$^+$ poly gate, $t_{ox} = 400$ Å, $N_a = 10^{15}$ cm^{-3}, and $Q_{ss}' = 5 \times 10^{10}$ cm^{-2}. (*a*) Determine V_T. (*b*) Is it possible to apply a V_{SB} voltage such that $V_T = 0$? If so, what is the value of V_{SB}?

4.

Consider an ideal n-channel MOSFET with a width-to-length ratio of $(W/L) = 10$, an electron mobility of $\mu_n = 400$ cm^2/V-s, an oxide thickness of $t_{ox} = 475$ Å, and a threshold voltage of $V_T = +0.65$ V. (*a*) Determine the maximum value of source resistance so that the saturation transconductance g_{ms} is reduced by no more than 20 percent from its ideal value when $V_{GS} = 5$ V. (*b*) Using the value of r_s calculated in part (*a*), how much is g_{ms} reduced from its ideal value when $V_{GS} = 3$ V?

5.

Assume that the subthreshold current of a MOSFET is given by

$$I_D = 10^{-15} \exp\left(\frac{V_{GS}}{(2.1)V_t}\right)$$

over the range $0 \le V_{GS} \le 1$ volt and where the factor 2.1 takes into account the effect of interface states. Assume that 10^6 identical transistors on a chip are all biased at the same V_{GS} and at $V_{DD} = 5$ V. (*a*) Calculate the total current that must be supplied to the chip at $V_{GS} = 0.5$, 0.7, and 0.9 V. (*b*) Calculate the total power dissipated in the chip for the same V_{GS} values.

6.

A silicon MOSFET has parameters $N_a = 4 \times 10^{16}$ cm^{-3}, $t_{ox} = 12$ nm $= 120$ Å, $Q'_{ss} = 4 \times 10^{10}$ cm^{-2}, and $\phi_{ms} = -0.5$ V. The transistor is biased at $V_{GS} = 1.25$ V and $V_{SB} = 0$. (*a*) Calculate ΔL for (*i*) $\Delta V_{DS} = 1$ V, (*ii*) $\Delta V_{DS} = 2$ V, and (*iii*) $\Delta V_{DS} = 4$ V. (*b*) Determine the minimum channel length L such that $\Delta L/L = 0.12$ for $V_{GS} = 1.25$ V and $\Delta V_{DS} = 4$ V.

7.

Consider an n-channel silicon MOSFET. The parameters are $k'_n = 75\ \mu$A/V^2, $W/L = 10$, and $V_T = 0.35$ V. The applied drain-to-source voltage is $V_{DS} = 1.5$ V. (*a*) For $V_{GS} = 0.8$ V, find (*i*) the ideal drain current, (*ii*) the drain current if $\lambda = 0.02$ V^{-1}, and (*iii*) the output resistance for $\lambda = 0.02$ V^{-1}. (*b*) Repeat part (*a*) for $V_{GS} = 1.25$ V.

8.

The initial parameters of an n-channel MOSFET are $k'_n = 0.15$ mA/V^2, $L = 1.2\ \mu$m, $W = 6.0\ \mu$m, and $V_T = 0.45$ V. The device operates over a voltage range of 0 to 3 V. Assume a constant-field scaling factor of $k = 0.65$, but assume the threshold voltage is constant. (*a*) Determine the maximum drain current in the (*i*) original device and (*ii*) scaled device. (*b*) Determine the maximum power dissipation in the (*i*) original device and (*ii*) scaled device.

9.

The parameters of an n-channel MOSFET are $N_a = 2 \times 10^{16}$ cm^{-3}, $L = 0.70\ \mu$m, and $t_{ox} = 8$ nm $= 80$ Å. The diffused junction radius is $r_j = 0.30\ \mu$m. The designed threshold voltage is to be $V_T = 0.35$ V taking into account the shift due to short-channel effects. What is the equivalent long-channel threshold voltage?

10.

An n-channel MOSFET has parameters of $N_a = 3 \times 10^{16}$ cm^{-3}, $W = 2.2\ \mu$m, and $t_{ox} = 8$ nm $= 80$ Å. Neglecting short-channel effects, calculate the shift in threshold voltage due to narrow-channel effects. Assume the fitting parameter is $\xi = \pi/2$.