

# Solution Manual for CMOS Digital Integrated Circuits Analysis and Design 4th Edition Kang Leblebici Kim ISBN 0073380628 9780073380629

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## Exercise Problems

3.1 Consider a MOS system with the following parameters:

$$\begin{aligned} t_{ox} &= 1.6 \text{ nm} \\ \phi_c &= 1.04 \text{ V} \\ N_A &= 2.8 \times 10^{18} \text{ cm}^{-3} \\ Q_{ox} &= q \cdot 4 \times 10^{10} \text{ C/cm}^2 \end{aligned}$$

a. Determine the threshold voltage  $V_{T0}$  under zero bias at room temperature ( $T = 300 \text{ K}$ ).

Note that  $\epsilon_{ox} = 3.97 \epsilon_0$  and  $\epsilon_{si} = 11.7 \epsilon_0$ .

**SOLUTION:**

First, calculate the Fermi potentials for the p-type substrate and for the n-type polysilicon gate:

$$\phi_F(\text{substrate}) = \frac{kT}{q} \ln \frac{N_i}{N_A} = \frac{0.026 \text{ V}}{1} \ln \frac{1.5 \times 10^{10}}{2.8 \times 10^{18}} = -0.49 \text{ V}$$

The depletion region charge density at  $V_{SG} = 0$  is found as follows:

$$Q_{D0} = \sqrt{2 q N_A \epsilon_{si} |2 \phi_F(\text{substrate})|} = \sqrt{2 \cdot 1.6 \times 10^{-19} \cdot (2.8 \times 10^{18}) \cdot 11.7 \cdot 8.85 \times 10^{-14} \cdot 2 \cdot 0.49} = 9.53 \times 10^{-7} \text{ C/cm}^2$$

The oxide-interface charge is:

$$Q_{ox} = q N_{ox} = 1.6 \times 10^{-19} \text{ C} \cdot 4 \times 10^{10} \text{ cm}^{-2} = 6.4 \times 10^{-9} \text{ C/cm}^2$$

The gate oxide capacitance per unit area is calculated using the dielectric constant of silicon dioxide and the oxide thickness  $t_{ox}$ :

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.97 \cdot 8.85 \times 10^{-14} \text{ F/cm}}{1.6 \times 10^{-7} \text{ cm}} = 2.2 \times 10^{-6} \text{ F/cm}^2$$

Now, we can combine all components and calculate the threshold voltage.

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**Ting-Yuan Wang**



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