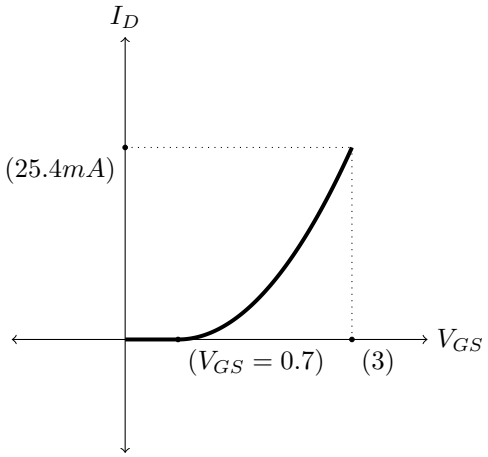
EE-320 – Exercise 2 Solutions - Fall 2024

1

$$\begin{cases} For\ \ V_{GS} < V_{TH} = 0.7 \Rightarrow\ \textbf{The device is off,}\ I_D = 0 \\ For\ \ V_{GS} > V_{TH} = 0.7 \Rightarrow I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - 0.7)^2(1 + \lambda \times 3) \qquad (V_{DS} = 3) \end{cases}$$

$$\begin{aligned} L_{eff} &= L_{drawn} - 2L_D = 0.5\mu m - 0.16\mu m = 0.34\mu m \\ \Rightarrow I_D &= \frac{1}{2} \times 50\frac{\mu A}{V^2} \times \frac{50}{0.34} \times (V_{GS} - 0.7)^2 \times (1.3) \\ &= 4.8\frac{mA}{V^2} \cdot (V_{GS} - 0.7)^2 \\ V_{GS} &= 3 \cdot V \Rightarrow I_D = 25.4mA \end{aligned}$$



2

$$
\begin{aligned}
V_{GS} &= V_{DD} - V_X = 3 - V_X \\
V_{DS} &= V_{DD} - V_X = 3 - V_X \\
V_{SB} &= V_X - 0 = V_X \\
V_{TH} &= V_{THO} + \gamma \times (\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}) \\
&= 0.7 + 0.45(\sqrt{0.9 + V_X} - \sqrt{0.9})
\end{aligned}
$$

$$
\begin{cases}
0 < V_X < 1 \Rightarrow \underbrace{V_{GS}}_{3-V_X} > V_{TH}? \\
V_X = 0 \Rightarrow 3 - 0 > \underbrace{V_{TH}}_{0.7} \qquad\qquad V_X = 1 \Rightarrow 3 - 1 > 0.7 + 0.45(\sqrt{1.9} - \sqrt{0.9})
\end{cases}
$$

$V_{GD} = 0 < \underbrace{V_{TH}}_{Positive} \quad \Rightarrow \quad$ The device is in saturation

$$
\begin{aligned}
I_X &= \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(3 - V_X - 0.7 - 0.45(\sqrt{0.9 + V_X} - \sqrt{0.9}))^2(1 + \lambda \underbrace{V_{DS}}_{3-V_X}) \\
I_X &= \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(2.72 - V_X - 0.45\sqrt{0.9 + V_X})^2(1.3 - 0.1V_X) \\
g_m &= \sqrt{2\mu_n C_{ox}\frac{W}{L} I_X (1.3 - 0.1V_X)}
\end{aligned}
$$

(or $g_m = \dfrac{2 \cdot I_X}{V_{GS} - V_{TH}}$

$g_m = \mu_n C_{ox}\dfrac{W}{L}(V_{GS} - V_{TH})(1 + \lambda V_{DS})$ all three equations for g_m are valid)