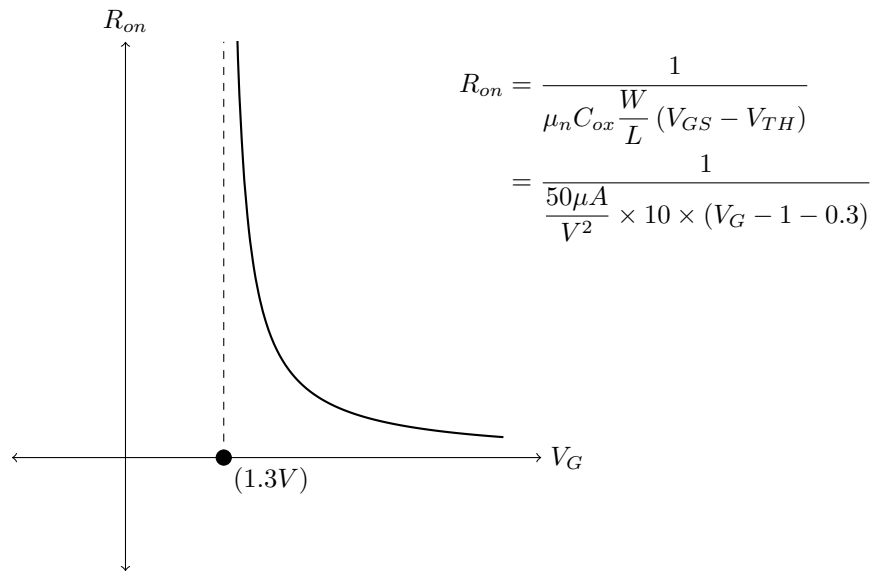


EE-320 – Exercise 1 Solutions - Fall 2024

1

The drain is open $\Rightarrow I_D = 0$ & $V_{DS} = 0$ So if M_1 is on, it is in deep triode region

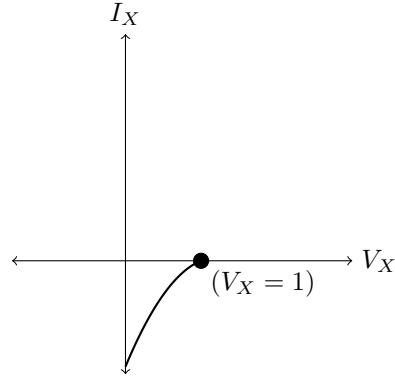
$$\begin{cases} V_{GS} < V_{TH} \Rightarrow V_G - 1 < 0.3 \Rightarrow V_G < 1.3 \Rightarrow M_1 \text{ is off} \\ V_{GS} > V_{TH} \Rightarrow V_G > 1.3 \Rightarrow M_1 \text{ is on in deep triode} \Rightarrow R_{on} = \infty \end{cases}$$



2

For $V_x < 1V \Rightarrow$ Source and drain exchange roles: (since $V_D < V_S$)

$$\left\{ \begin{array}{l} V_{GS} = 1.9 - V_x \quad V_{DS} = 1 - V_x \\ V_{GD} = 1.9 - 1 = 0.9 > V_{TH} \Rightarrow \text{device is in triode} \\ I_X = -\frac{1}{2}\mu_n C_{ox} \frac{W}{L} [2(V_{GS} - V_{TH})V_{DS} - V_{DS}^2] \quad (I_D \text{ is in opposite direction, so we add a negative sign}) \\ \quad = -\frac{1}{2}\mu_n C_{ox} \frac{W}{L} [2(1.9 - V_x - 0.7)(1 - V_x) - (1 - V_x)^2] \\ \quad = -\frac{1}{2}\mu_n C_{ox} \frac{W}{L} (1 - V_x)(1.4 - V_x) \end{array} \right.$$



3

$$\left\{ \begin{array}{l} 0 < V_X < 1 \Rightarrow V_{GD} = (2 - V_X) > V_{TH} \Rightarrow \text{triode region} \\ I_{R1} = I_1 - I_X \quad V_{Source} = V_X - R_1 \cdot I_{R1} \Rightarrow \begin{array}{l} V_{GS} = 2 - (V_X - R_1(I_1 - I_x)) \\ \quad = 2 - V_X + R_1(I_1 - I_X) \end{array} \end{array} \right.$$

$$\left\{ \begin{array}{l} I_X = I_{D,triode} = \frac{1}{2}\mu_n C_{ox} \frac{W}{L} \times [2(V_{GS} - V_{TH})V_{DS} - V_{DS}^2] \\ \quad = \frac{1}{2}\mu_n C_{ox} \frac{W}{L} [2(2 - V_X + R_1(I_1 - I_x) - 0.7) - V_{DS}]V_{DS} \quad V_{DS} = R_1(I_1 - I_X) \\ \quad = \frac{1}{2}\mu_n C_{ox} \frac{W}{L} [2(1.3 - V_X) + R_1(I_1 - I_X)]R_1(I_1 - I_x) \end{array} \right.$$