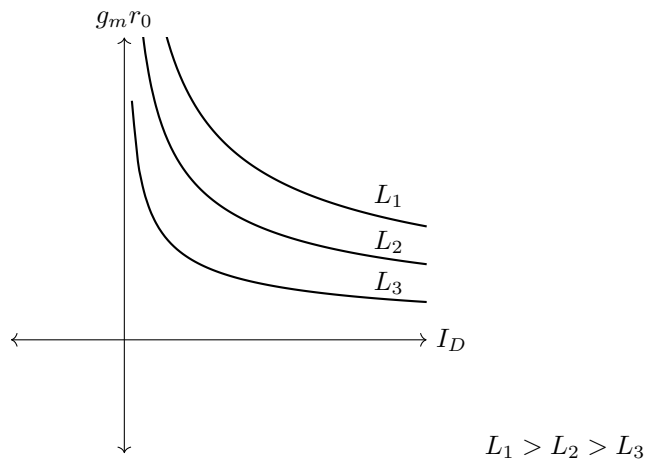


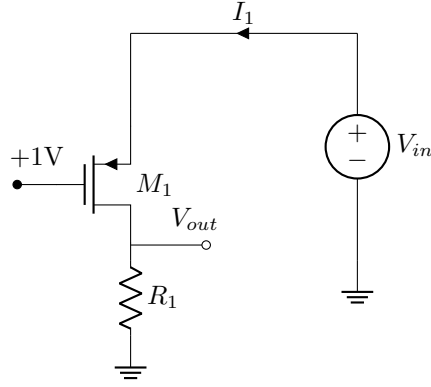
EE-320 – Exercise 3 Solutions - Fall 2024

1

$$\begin{aligned}
 g_m &= \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D} \\
 r_0 &= \frac{1}{\lambda \cdot I_D} \quad \text{and} \quad \lambda \propto \frac{1}{L} \Rightarrow \lambda = \frac{a}{L} \quad a \text{ is a constant} \\
 g_m \times r_0 &= \left(\sqrt{2\mu_n C_{ox} \frac{W}{L} I_D} \right) \left(\frac{L}{a \cdot I_D} \right) \\
 &= \left(\sqrt{\left(\frac{WL}{I_D} \right) (2\mu_n C_{ox} \frac{1}{a^2})} \right) \\
 &= \underbrace{b}_{\text{constant}} \times \sqrt{\frac{W \cdot L}{I_D}}
 \end{aligned}$$



2



$$V_{TH} = -0.8 \quad (\text{PMOS})$$

$$V_{GS} < V_{TH} \Rightarrow \text{device turns on in saturation}$$

$$\text{For } V_{GS} > V_{TH} \Rightarrow \text{device is off, } V_{out} = 0$$

$$V_{GS} = 1 - V_{in} \Rightarrow 1 - V_{in} > -0.8 \Rightarrow V_{in} < 1.8 \quad (\text{off, } V_{out} = 0)$$

$$\begin{cases} V_{in} > 1.8 \Rightarrow \text{in saturation until?} \\ 1 - V_{out} > -0.8 \Rightarrow V_{out} < 1.8 \end{cases}$$

$$\begin{aligned} V_{GD} > V_{TH} &\Rightarrow \text{PMOS in sat.} \\ \text{for } V_{out} > 1.8 &\Rightarrow \text{triode} \end{aligned}$$

$$\text{Transition point: } V_{out} = 1.8$$

$$V_{out} = R_1 \cdot I_1 = 1.8$$

$$(\text{sat}): I_1 = \frac{1}{2} \mu_p C_{ox} \frac{W}{L} (1 - V_{in} - (-0.8))^2 = \frac{1.8}{R_1}$$

$$|1.8 - V_{in}| = \sqrt{\frac{2 \times 1.8}{\mu_p C_{ox} \frac{W}{L} R_1}} \quad \text{since } V_{in} > 1.8 \Rightarrow V_{in} - 1.8 = \underbrace{\sqrt{\frac{2 \times 1.8}{\mu_p C_{ox} \frac{W}{L} R_1}}}_{\text{Transition point}}$$

$$\begin{cases} 1.8 < V_{in} < 1.8 + \sqrt{\frac{3.6}{\mu_p C_{ox} \frac{W}{L} R_1}} \Rightarrow V_{out} = R_1 \times \left(\frac{1}{2} \mu_p C_{ox} \frac{W}{L} (1.8 - V_{in})^2 \right) (\text{sat.}) \\ V_{in} > 1.8 + \sqrt{\frac{3.6}{\mu_p C_{ox} \frac{W}{L} R_1}} \Rightarrow V_{out} = R_1 \times \left[\frac{1}{2} \mu_p C_{ox} \frac{W}{L} (2(1.8 - V_{in})(V_{out} - V_{in}) - (V_{out} - V_{in})^2) \right] (\text{triode}) \end{cases}$$