RC5

ECE3110J Analog Circuits

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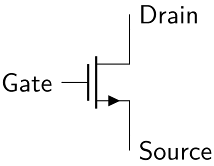
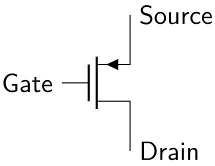
MOSFET Basics

NMOS



PMOS



I-V Characteristics (NMOS)

When $V_{DS} < V_{GS} - V_{TH}$, the NMOS is in triode region.

$$I_D = \mu_n C_{ox} \frac{W}{L_{eff}} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{1}{2} V_{DS}^2 \right] \tag{1}$$

When $V_{DS} \geq V_{GS} - V_{TH}$, the NMOS is in saturation region.

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L'} (V_{GS} - V_{TH})^2 \tag{2}$$

I-V Characteristics (PMOS)

When $V_{SD} < V_{SG} - |V_{TH}|$, the PMOS is in triode region.

$$I_D = \mu_p C_{ox} \frac{W}{L_{eff}} \left[\left(V_{SG} - |V_{TH}| \right) V_{SD} - \frac{1}{2} V_{SD}^2 \right] \tag{3}$$

When $V_{SD} \geq V_{SG} - |V_{TH}|$, the NMOS is in saturation region.

$$I_D = \frac{1}{2} \mu_p C_{ox} \frac{W}{L'} \left(V_{SG} - |V_{TH}| \right)^2 \tag{4}$$

Second Effects

Channel-Length Modulation

$$L' = L_{\text{eff}} - \Delta L \tag{5}$$

$$\begin{aligned} I_D &= \frac{1}{2}\mu_n C_{ox}\frac{W}{L_{\text{eff}}}\left(V_{GS}-V_{TH}\right)^2\left(1+\frac{\Delta L}{L_{\text{eff}}}\right) \\ &= \frac{1}{2}\mu_n C_{ox}\frac{W}{L_{\text{eff}}}\left(V_{GS}-V_{TH}\right)^2(1+\lambda V_{DS}) \end{aligned} \tag{6}$$

Body Effect

$$V_{TH} = V_{TH0} + \gamma\left(\sqrt{|2\Phi_F + V_{SB}|} - \sqrt{|2\Phi_F|}\right) \tag{7}$$

$$g_{mb} = g_m \cdot \eta, \eta = \frac{\gamma}{2\sqrt{2\Phi_F + V_{SB}}} \tag{8}$$

Transconductance

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = \mu_n C_{ox} \frac{W}{L'} (V_{GS} - V_{TH}) = \sqrt{2 \mu_n C_{ox} \frac{W}{L'} I_D} = \frac{2 I_D}{V_{GS} - V_{TH}} \tag{9}$$

With channel-length modulation:

$$\begin{aligned} g_m &= \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH}) (1 + \lambda V_{DS}) \\ &= \sqrt{2 \mu_n C_{ox} (W/L) I_D (1 + \lambda V_{DS})} \end{aligned} \tag{10}$$

Small-Signal Model for NMOS

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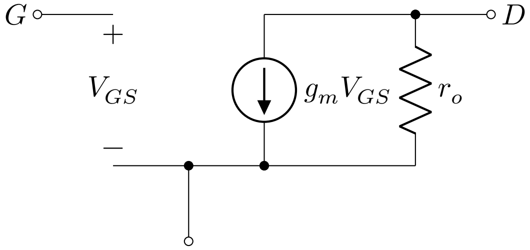
$\lambda \neq 0,\ \gamma = 0$

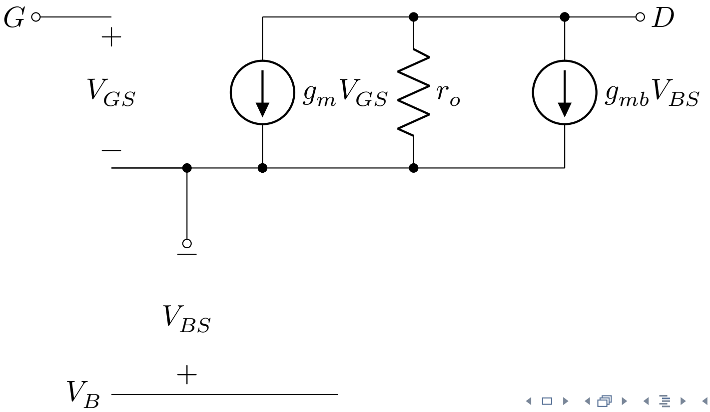


Where,

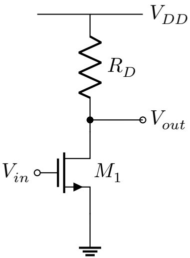
$$r_o = \frac{1}{\partial I_D / \partial V_{DS}} = \frac{1}{\frac{1}{2}\mu_n C_{ox} \frac{W}{L} \left(V_{GS} - V_{TH}\right)^2 \cdot \lambda} \tag{11}$$

Small-Signal Model for NMOS

$\lambda \neq 0$, $\gamma \neq 0$

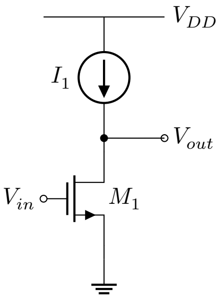


Common-Source with Resistive Load



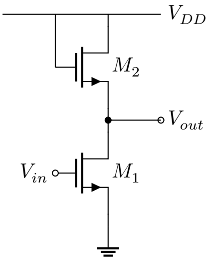
- Draw the curves of V_{out} vs V_{in} and write the corresponding relationship.
- Calculate the voltage gain $A_v = \frac{\partial V_{out}}{\partial V_{in}}$.
- What if $\lambda \neq 0$, $\gamma \neq 0$?

Common-Source with Resistive Load



- Calculate the voltage gain $A_v = \frac{\partial V_{out}}{\partial V_{in}}$ if $\lambda \neq 0$, $\gamma \neq 0$.

Common-Source with Diode-Connected Load



- Draw the curves of V_{out} vs V_{in} and write the corresponding relationship.
- How to compare it to resistive load?
- Calculate the voltage gain $A_v = \frac{\partial V_{out}}{\partial V_{in}}$.
- What if $\lambda \neq 0$, $\gamma \neq 0$?

Something to Talk about Midterm