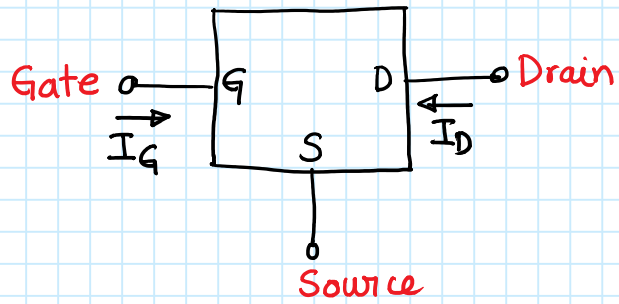
Lecture 7 (MOS transistor)

"Ideal" MOSFET: (will discuss non-idealities later)

- 3 terminal device



N-MOSFET I-V characteristics:

$I_G = 0$ (always)

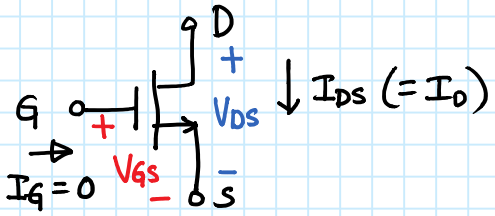
$$I_D \begin{cases} = 0 & \text{if } V_{GS} < V_T \\ = \mu_n C_{ox} \cdot \left(\frac{W}{L}\right)\left[(V_{GS}-V_T)V_{DS} - \frac{V_{DS}^2}{2}\right] & \text{if } V_{GS} > V_T \ \& \ V_{DS} < V_{GS}-V_T \\ = \frac{\mu_n C_{ox}}{2} \cdot \left(\frac{W}{L}\right)(V_{GS}-V_T)^2 & \text{if } V_{GS} > V_T \ \& \ V_{DS} > V_{GS}-V_T \end{cases}$$

μ_n	:	mobility of electrons
C_{ox}	:	oxide capacitance
V_T	:	Threshold voltage

$\Rightarrow$ set by device technolgy

W, L : Device dimensions $\Rightarrow$ Designer can choose

N-MOSFET Symbol:

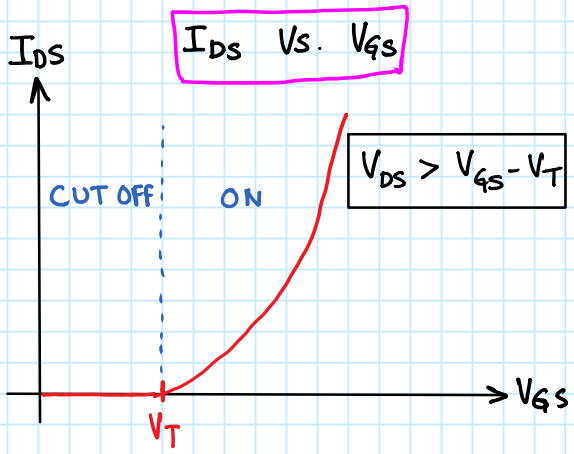


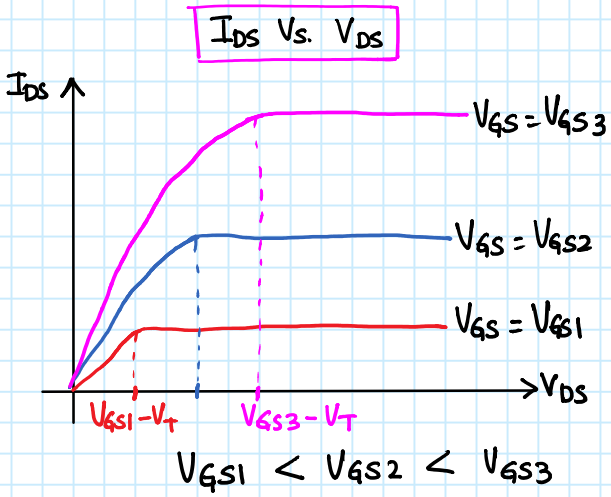
MOSFET is a symmetric device

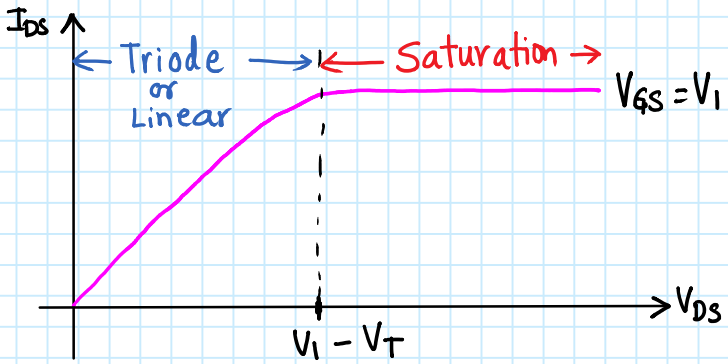
$\Rightarrow$ Drain & source are identical

We denote the terminal connected to lower voltage as source and the other as drain.

I-V characteristics : Graphical view





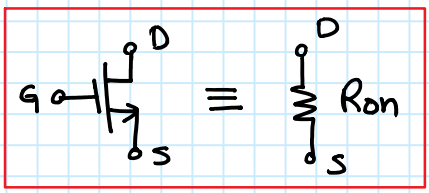


Triode or Linear region : $V_{GS} > V_T$ & $V_{DS} < V_{GS} - V_T$

$$I_{DS} = \mu_n C_{ox}\left(\frac{W}{L}\right)\left[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}\right]$$

$$\frac{\partial I_{DS}}{\partial V_{DS}} = \mu_n C_{ox}\left(\frac{W}{L}\right)\left[(V_{GS} - V_T) - V_{DS}\right]$$

$$R_{on} = \left(\frac{\partial I_{DS}}{\partial V_{DS}}\right)^{-1} = \frac{1}{\mu_n C_{ox}\left(\frac{W}{L}\right)\left[(V_{GS} - V_T) - V_{DS}\right]}$$

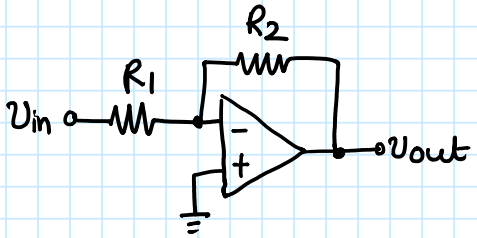


$$R_{on} \approx \frac{1}{\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)} \quad \text{if } V_{GS} - V_T \gg V_{DS}$$

Note : R_{on} can be changed by varying V_{GS} ⇒ Voltage Controlled Resistor (VCR)

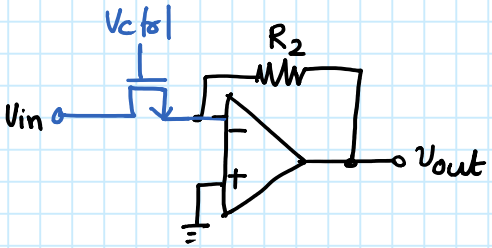
Application of NMOS biased in triode region

Fixed gain amplifier



$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$$

Variable gain amplifier



$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_{on}} \; ; \; R_{on} = f(V_{ctrl})$$