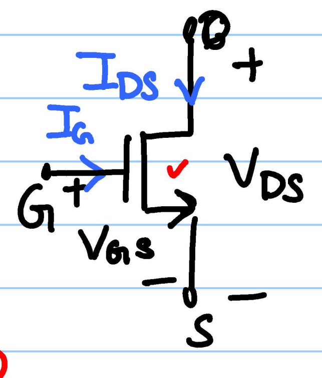
Note Title 17-08-2021

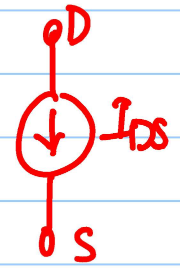
lecture # 7



i) $V_{GS} \leq V_{th}$: $I_{DS} = 0$, $I_G = 0$

ii) $V_{GS} > V_{th}$, $V_{DS} < V_{GS} - V_{th}$:

$$I_G = 0, \quad I_{DS} = \mu_n C_{ox} \frac{W}{L}\left[(V_{GS}-V_{th})V_{DS} - \frac{V_{DS}^2}{2}\right]$$



iii) $V_{GS} > V_{th}$, $V_{DS} \geq V_{GS} - V_{th}$

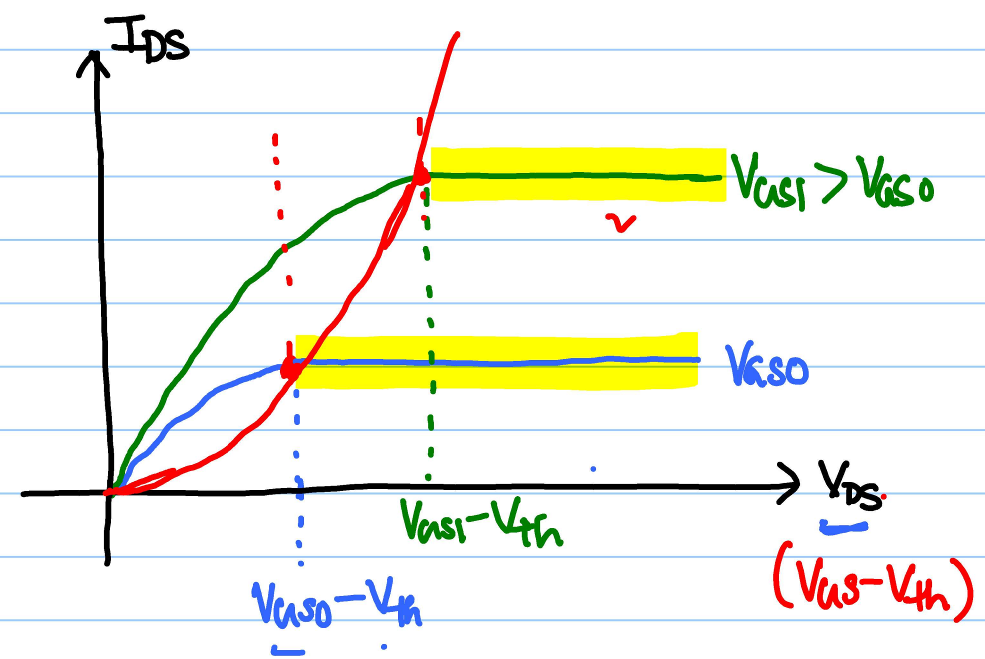
$$I_G = 0, \quad I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS}-V_{th})^2$$

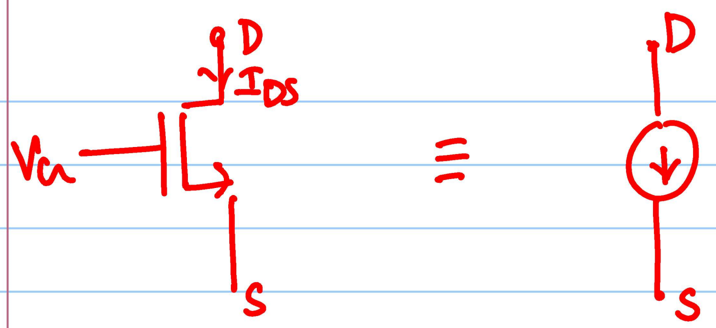
μ_n : mobility of e

C_{ox} : Cap. per unit area.

W, L : dimensions of MOSFET

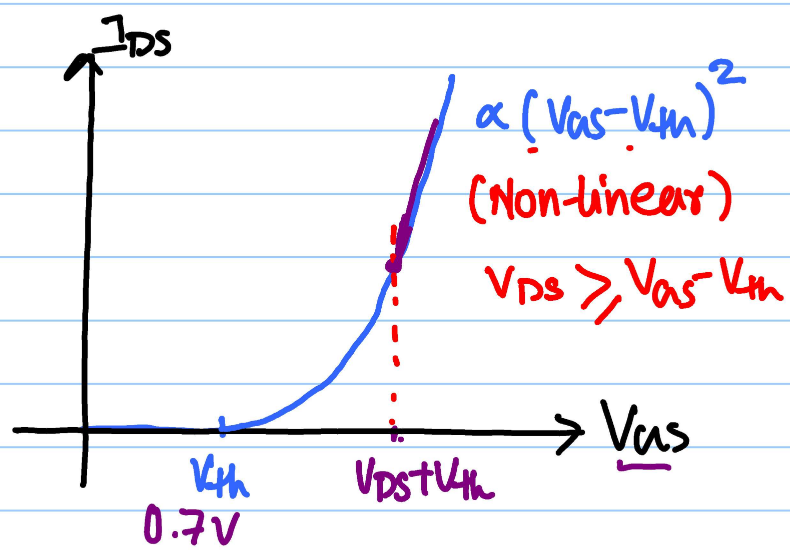
$I_{DS} = f(V_{GS}, V_{DS})$

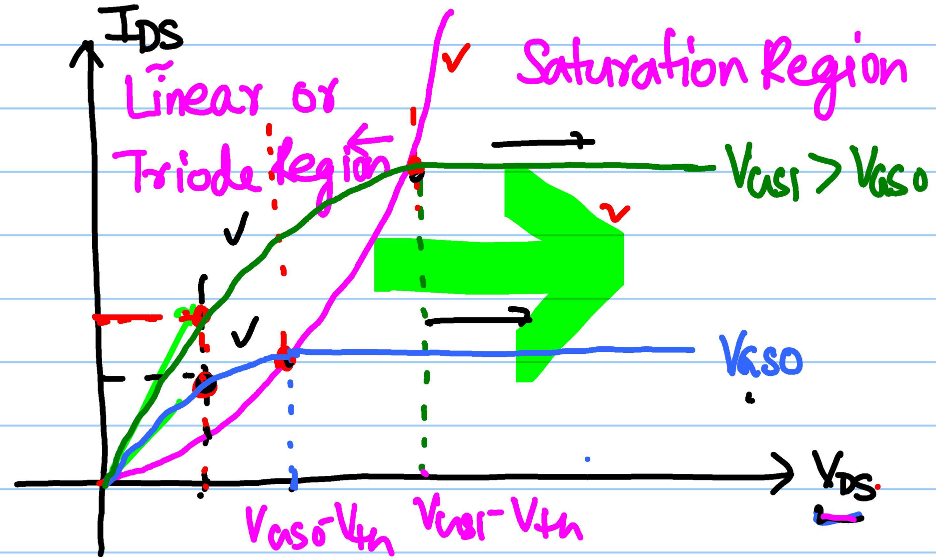




$I_{DS} : \mu_n C_{ox} \frac{W}{2L} (V_{GS} - V_{th})^2$

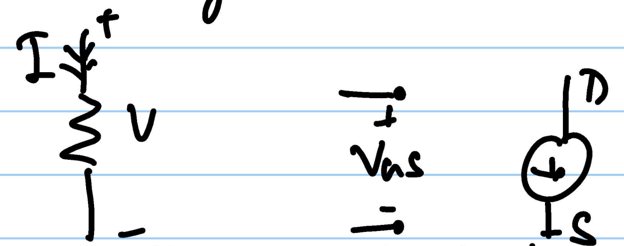
$V_{DS} > V_{GS} - V_{th}$





$I_{DS} = f(V_{GS}, V_{DS})$

- Control voltage to control current.

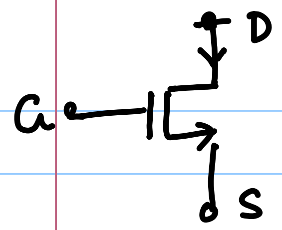


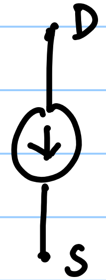
$V_{DS} < V_{GS} - V_{th}$

$V_{DS} = 2.5V$

$V_{GS} - V_{th} = 2.5$

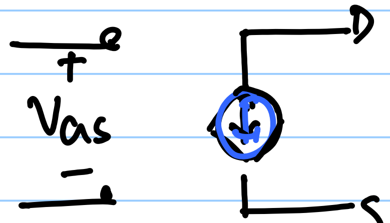
w.r.t V_{GS}. Voltage Controlled Current Source



a) 

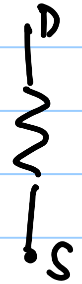
current source

Saturation

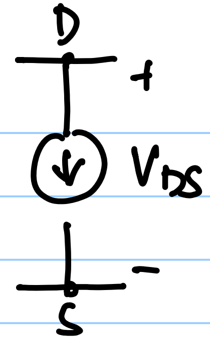
b) 

voltage controlled current source

c) resistor : voltage controlled resistor



linear



w.r.t V_{DS}, current source when $V_{DS} \geq V_{GS} - V_{th}$.

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

$V_{GS} - V_{th} > V_{DS}$

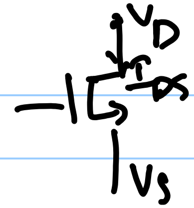
$V_{DS} \ll V_{GS} - V_{th}$

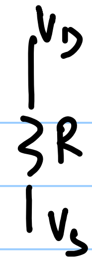
$$I_{DS} \approx \mu_n C_{ox} \frac{W}{L} \left[V_{GS} - V_{th} \right] V_{DS}$$

$$R = \frac{V_{DS}}{I_{DS}} = \frac{1}{\mu_n C_{ox} \frac{W}{L} \left[V_{GS} - V_{th} \right]}$$

MOSFET behaves like a resistor w.r.t V_{DS}.

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

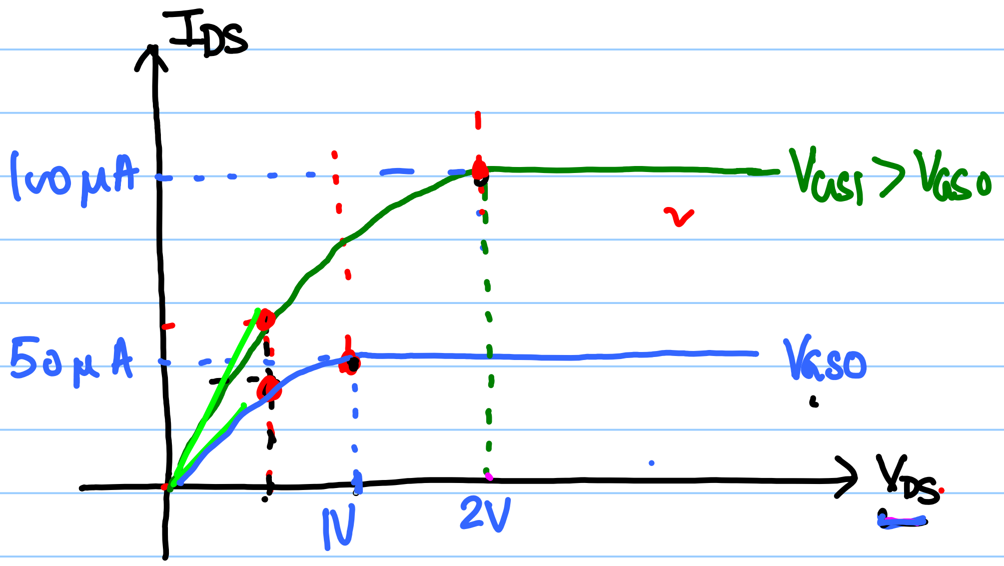




$$R = \frac{V_{DS}}{I_{DS}} = \frac{1}{\mu_n C_{ox} \frac{W}{L} \left[V_{GS} - V_{tn} - \frac{V_{DS}}{\cancel{2}} \right]}$$

$$R = f(V_{GS}, V_{DS})$$

$$= R_0 + \underbrace{\alpha V_{DS} + \beta \frac{V_{DS}^2}{2}}$$ ✓



Ex: $V_{th} = 1V$, $\frac{W}{L} = \frac{1\mu m}{1\mu m}$

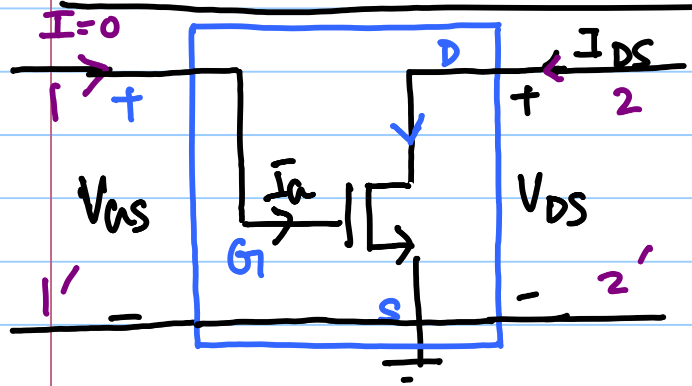
$\mu_n C_{ox} = 100\ \mu A/V^2$

a) $V_{GS} = 2V$, $V_{DS} = 2V > 2-1 = 1V$

$I_{DS} = \frac{100\times10^{-6}}{2}\ \frac{1}{1}\ (2-1)^2 = 50\mu A$

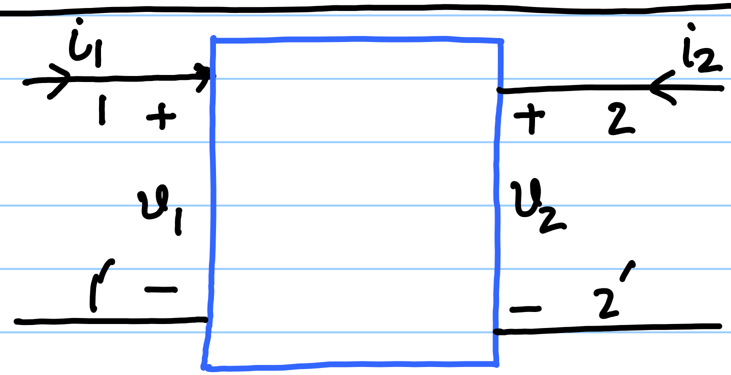
b) $V_{GS} = 3V$

$I_{DS} = \frac{100\times10^{-6}}{2} \times \frac{1}{1} \times (3-1)^2 = 200\mu A$

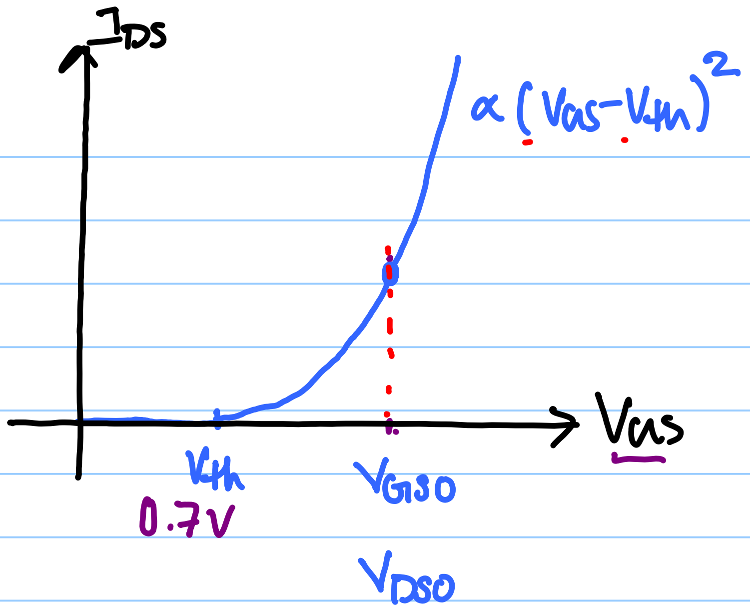


MOSFET: a non-linear

≡



linear . system.



$I_{DS} = f(V_{GS}, V_{DS})$ ✓

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} & \\ & \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

i_1, i_2: small changes in i/p & o/p current

v_1, v_2: 〃 i/p & o/p voltage. ✓

$$\begin{bmatrix} i_{GS} \\ i_{DS} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ y_{21} & 0 \end{bmatrix} \begin{bmatrix} v_{GS} \\ v_{DS} \end{bmatrix}$$

y_{11}, y_{22}: 0

y_{12}: 0

Saturating region

$I_{DS} = \mu_n C_{ox} \frac{W}{2L} (V_{GS}-V_{th})^2$ ✓

$+i_{DS}$ $\quad +v_{gs}$

$= f(V_{GS}, V_{DS})$

$i_{DS} = \frac{\partial f}{\partial V_{GS}} \cdot v_{GS} + \frac{\partial f}{V_{DS}} \cdot v_{DS}$ ✓

$y_{21} = \frac{\partial f}{\partial V_{GS}} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{th})$

$\frac{\partial f}{\partial V_{DS}} = 0$

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

$$\frac{\partial f}{\partial V_{GS}} = \mu_n C_{ox} \frac{W}{L} V_{DS}$$

$$\frac{\partial f}{\partial V_{DS}} = \mu_n C_{ox} \frac{W}{L} \left[V_{GS} - V_{th} - V_{DS} \right]$$

$$\begin{bmatrix} i_{GS} \\ i_{DS} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ \frac{\partial f}{\partial V_{GS}} & \frac{\partial f}{\partial V_{DS}} \end{bmatrix} \begin{bmatrix} v_{GS} \\ v_{DS} \end{bmatrix}$$

$y_{11}, y_{12} : 0$

y_{22} : non-zeros

y_{21} : non-zero

$$I_{DS} = \mu_n C_{ox} \frac{W}{2L} (V_{GS} - V_{tn})^2 = f(V_{GS})$$

$$\cancel{I_{DS0}} + i_{DS} = \cancel{f(V_{GS})} + f'(V_{GS}) v_{gs} + f''(V_{GS}) \frac{v_{gs}^2}{2!} + \ldots$$

$$i_{DS} = f'(V_{GS}) \cdot v_{gs}$$

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

$$I_{DS} + i_{DS} = f(V_{GS0}, V_{DS0}) + \left[\frac{\partial f}{\partial V_{GS}} \cdot v_{gs} + \frac{\partial f}{\partial V_{DS}} v_{ds} \right] + \partial^2$$

$$I_{DS} + i_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} + v_{gs} - V_{tn})(V_{DS} + v_{ds}) - \frac{(V_{DS} + v_{ds})^2}{2} \right]$$

$$v_{gs}^2, \; v_{ds}^2, \; v_{gs} \cdot v_{ds} \; \ldots$$