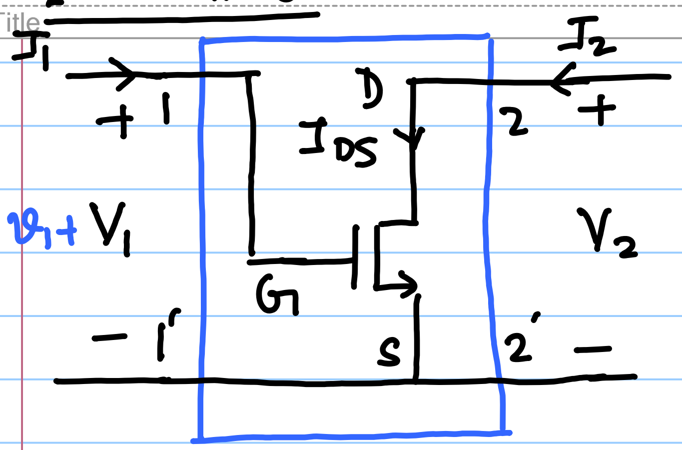
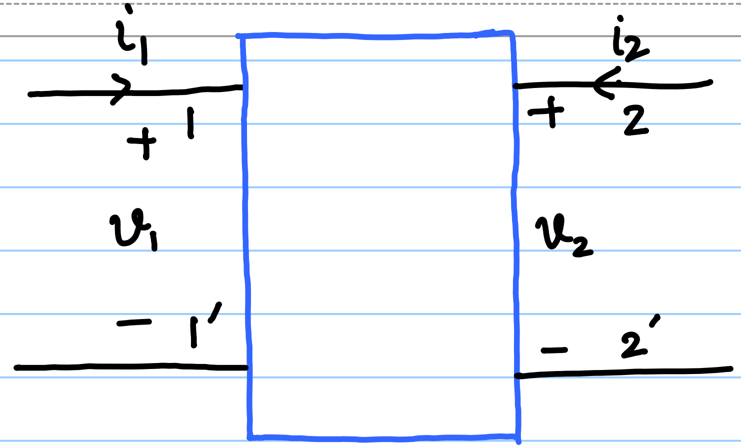
Lecture # 08





MOSFET is in saturation region.

$$I_2 = I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{tn})^2 \checkmark$$

"Square-law"

$$I_G = I_1 = 0$$

Since, $I_G = 0$ always, $\Rightarrow i_1 = 0$

$$I_2 + i_2 = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} + v_1 - V_{tn})^2$$

$$= \frac{\mu_n C_{ox}}{2} \frac{W}{L} \left((V_{GS} - V_{tn})^2 + v_1^2 + 2 v_1 (V_{GS} - V_{tn}) \right)$$

$$\checkmark \quad = I_2 + \frac{\mu_n C_{ox}}{2} \frac{W}{L} \left\{ +2 (V_{GS} - V_{tn}) v_1 + v_1^2 \right\}$$

e^x, $\sin(x)$, $\cos(x)$
$\tan(x)$, $\ln(1+x)$

$\sin(x) = x - \frac{x^3}{3!}$

$X + x \longrightarrow Y + y$

y is linearly dependent on x.

NO

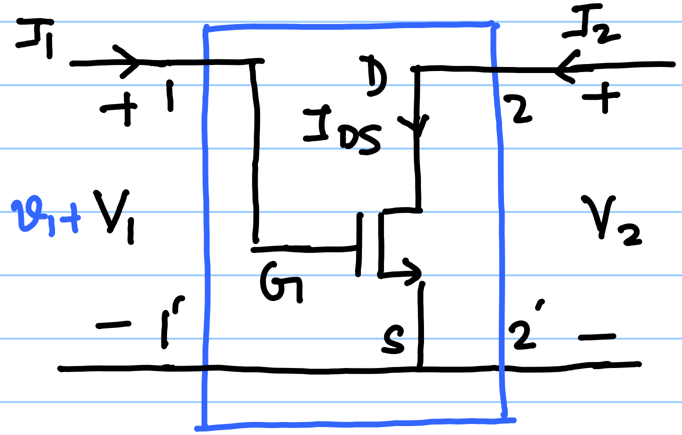
$$i_2 = \frac{\mu_n C_{ox}}{2}\frac{W}{L}\left\{+2(V_{GS}-V_{tn})v_1 + v_1^2\right\} \quad ; \quad v_1^2 \ll 2v_1(V_{GS}-V_{tn})$$

$$i_2 \approx \underbrace{+\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{tn})}_{y_{21}}\, v_1$$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ y_{21} & 0 \end{bmatrix}\begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$g_m = y_{21} = \mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{tn})$$

Transconductance "g_m"

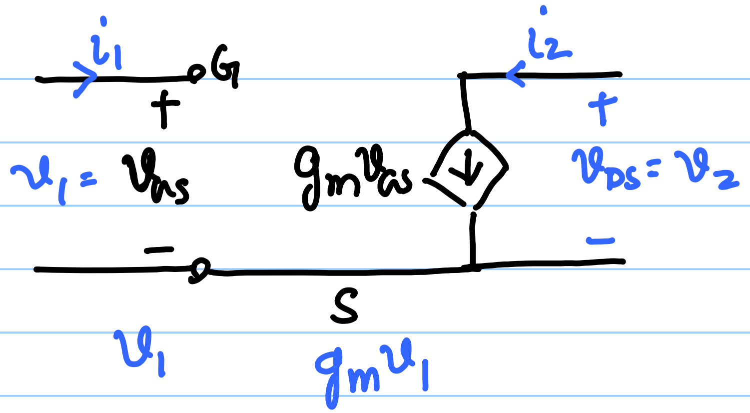


$$I_1 = f_1(V_1, V_2) = 0$$

$$I_2 = f_2(V_1, V_2) = \frac{\mu_n C_{ox}}{2}\frac{W}{L}(V_{GS}-V_{tn})^2 \checkmark \quad (V_1)$$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} \frac{\partial f_1}{\partial V_1} & \frac{\partial f_1}{\partial V_2} \\ \frac{\partial f_2}{\partial V_1} & \frac{\partial f_2}{\partial V_2} \end{bmatrix}\begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$\frac{\partial f_1}{\partial V_1} = 0, \quad \frac{\partial f_1}{\partial V_2} = 0, \quad \frac{\partial f_2}{\partial V_1} = \frac{\mu_n C_{ox}}{2}\frac{W}{L} \times 2(V_{GS}-V_{tn}), \quad \frac{\partial f_2}{\partial V_2} = 0$$



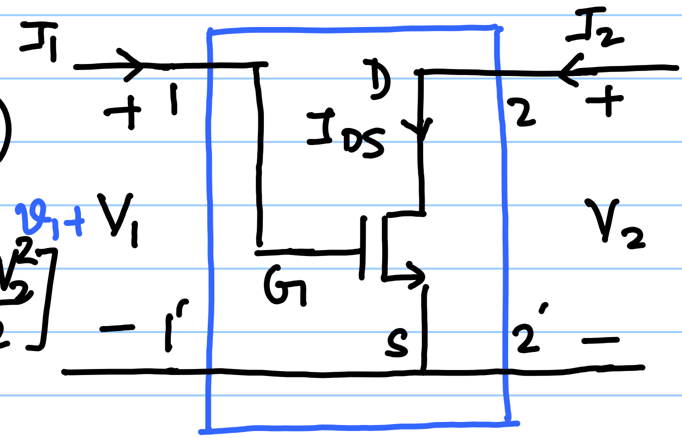
Small-signal model in saturation region.

In triode region.

$$I_2 = \mu_n C_{ox} \frac{W}{L}\left[(V_{GS}-V_{tn})V_{DS} - \frac{V_{DS}^2}{2}\right] = f_2(V_1, V_2)$$

$$I_1 = 0 = f_1(V_1, V_2)$$

$$I_2 = \mu_n C_{ox}\frac{W}{L}\left[(V_1 - V_{tn})V_2 - \frac{V_2^2}{2}\right]$$



$V_1 = V_{GS}$, $V_2 = V_{DS}$.

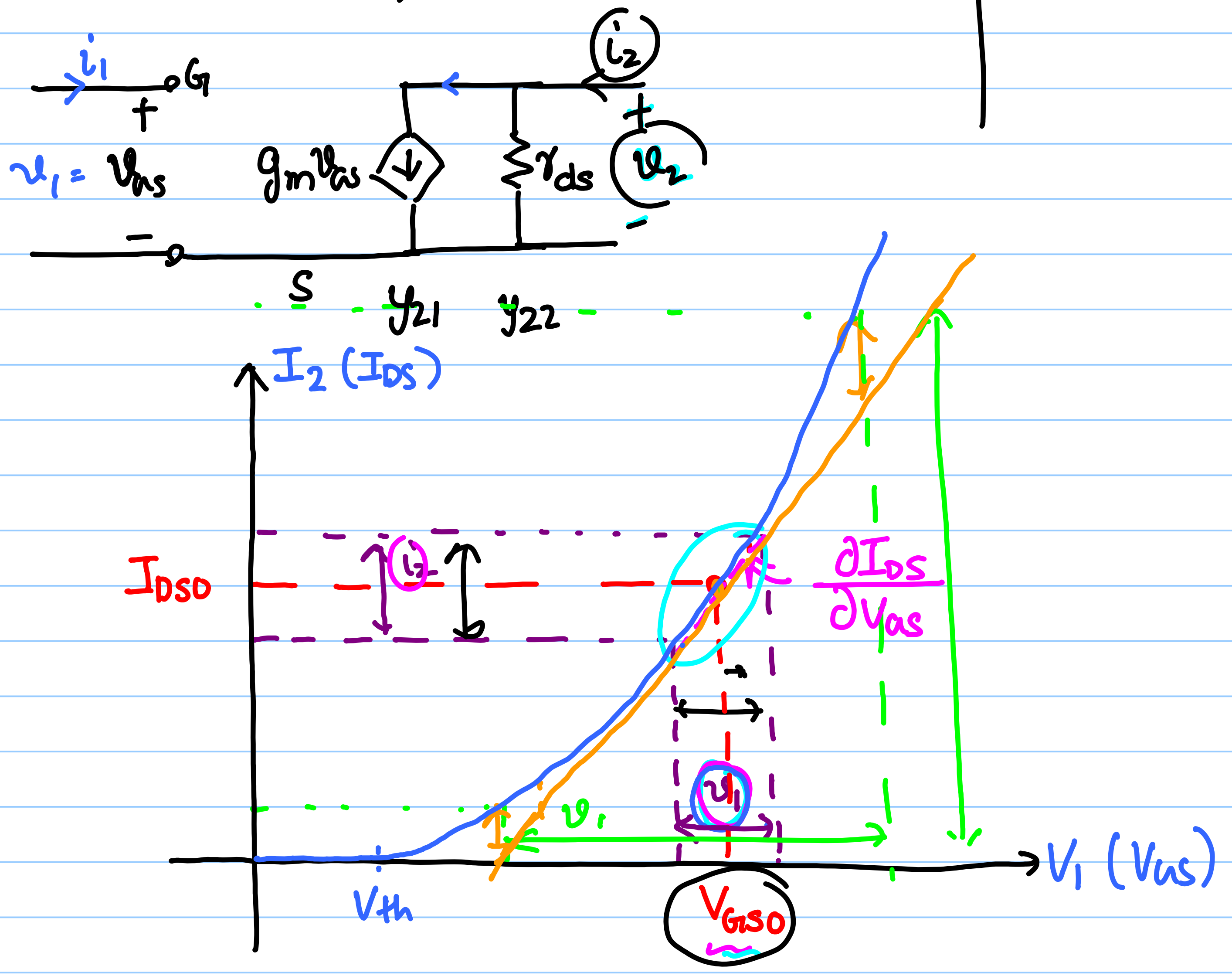
$$\frac{\partial f_1}{\partial V_1} = 0, \quad \frac{\partial f_1}{\partial V_2} = 0$$

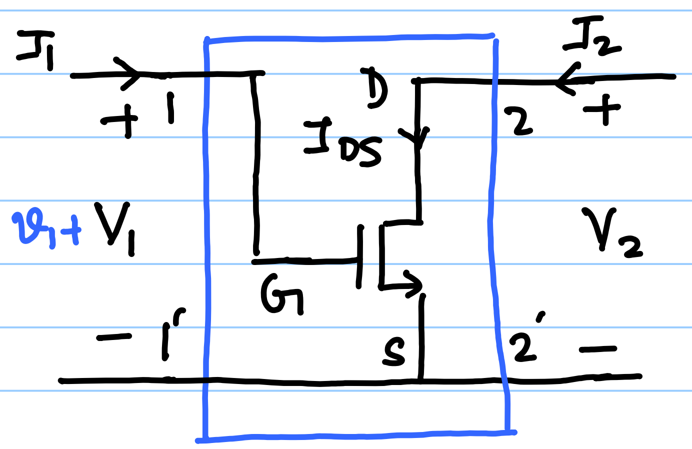
$$\frac{\partial f_2}{\partial V_1} = \mu_n C_{ox}\frac{W}{L}(V_{DS}) = y_{21}$$

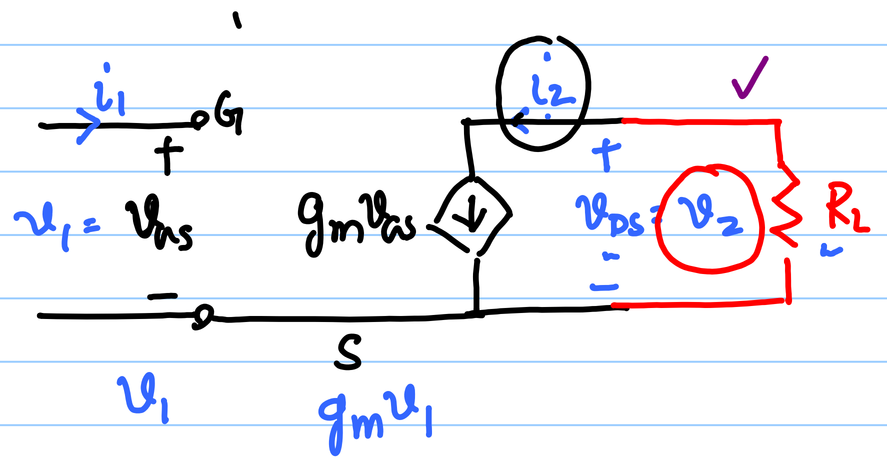
$$\frac{\partial f_2}{\partial V_2} = \mu_n C_{ox}\frac{W}{L}\left[(V_{GS}-V_{tn}) - V_{DS}\right] = y_{22}$$

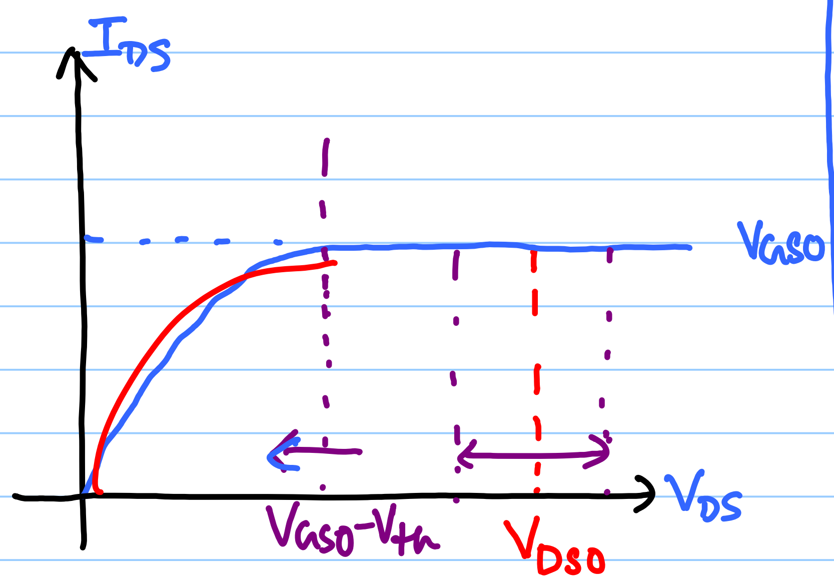
$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$r_{ds} = \frac{1}{y_{22}}$$









$\left| \frac{v_2}{v_1} \right|$ large value

$$v_2 = -i_2 R_L = -g_m v_1 \cdot R_L$$

$$= -g_m R_L \cdot v_1$$

$$\frac{v_2}{v_1} = -g_m R_L \ ; \ \left| \frac{v_2}{v_1} \right| = g_m R_L$$

$$V_{DS} = V_{DSO} + v_2$$

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS0} - V_{th}) \uparrow$$

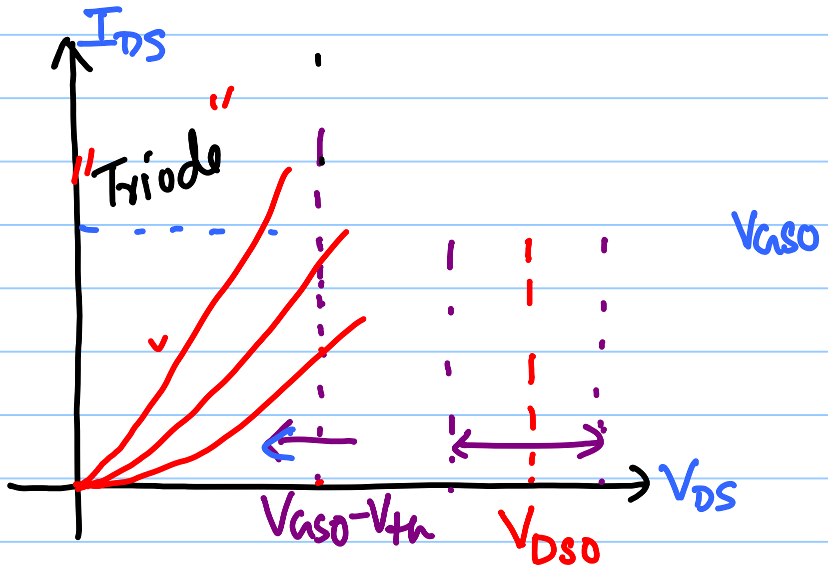
$$= \frac{2 I_{DS0}}{V_{GS0} - V_{th}}$$

$$= \sqrt{2 I_{DS0} \mu_n C_{ox} \frac{W}{L}}$$

Gate-overdrive $= V_{GS} - V_{th}$

I_{DS0}, $V_{GS0} - V_{th}$, $\frac{W}{L}$

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



"1910"

Vaccum-Tube : 3 electrodes.

Cathode	Grid	Anode
S	G	D