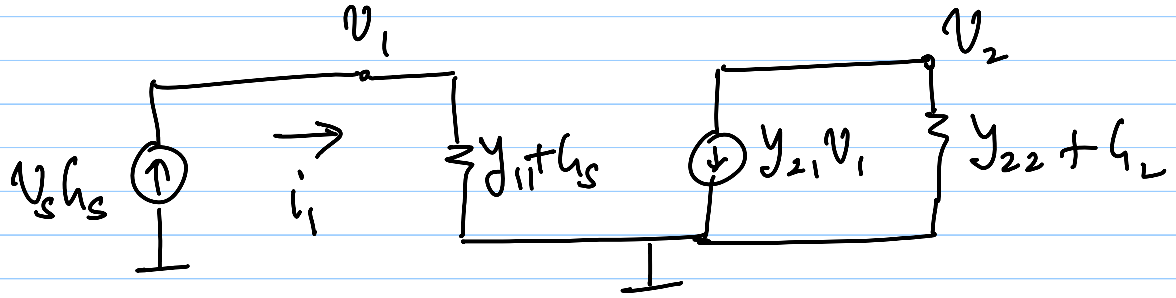
8-8-12

Lec 6

1)



2) Gain independent of G_s

$$\text{Gain} = \frac{-y_{21}}{(y_{22}+G_L)} \cdot \frac{G_s}{y_{11}+G_s}$$

$\Rightarrow$ **set $y_{11}=0$** i.e. make $i_1=0$

$$\frac{v_2}{v_s} = \frac{-y_{21}}{y_{22}+G_L}$$

3) Gain as large as possible

$\Rightarrow$ y_{21} as large as possible

<u>and</u>

$y_{22}+G_L$ as small as possible

* We have no control over G_L

$\rightarrow$ make $y_{22}=0$

$$\Rightarrow \boxed{\frac{v_2}{v_s} = \frac{-y_{21}}{G_L}}$$

still dependent on G_L

* We need a 2-port network with the following incremental y-matrix

$$\begin{bmatrix} 0 & 0 \\ \text{as large as possible} & 0 \end{bmatrix}$$

If $I_1 = f(V_1, V_2)$ & $I_2 = g(V_1, V_2)$

$y_{11} = \partial f / \partial V_1$; $y_{12} = \partial f / \partial V_2$

$y_{21} = \partial g / \partial V_1$; $y_{22} = \partial g / \partial V_2$

$$y_{11} = \frac{\partial f}{\partial V_1} = 0 \quad ; \quad y_{12} = \frac{\partial f}{\partial V_2} = 0$$

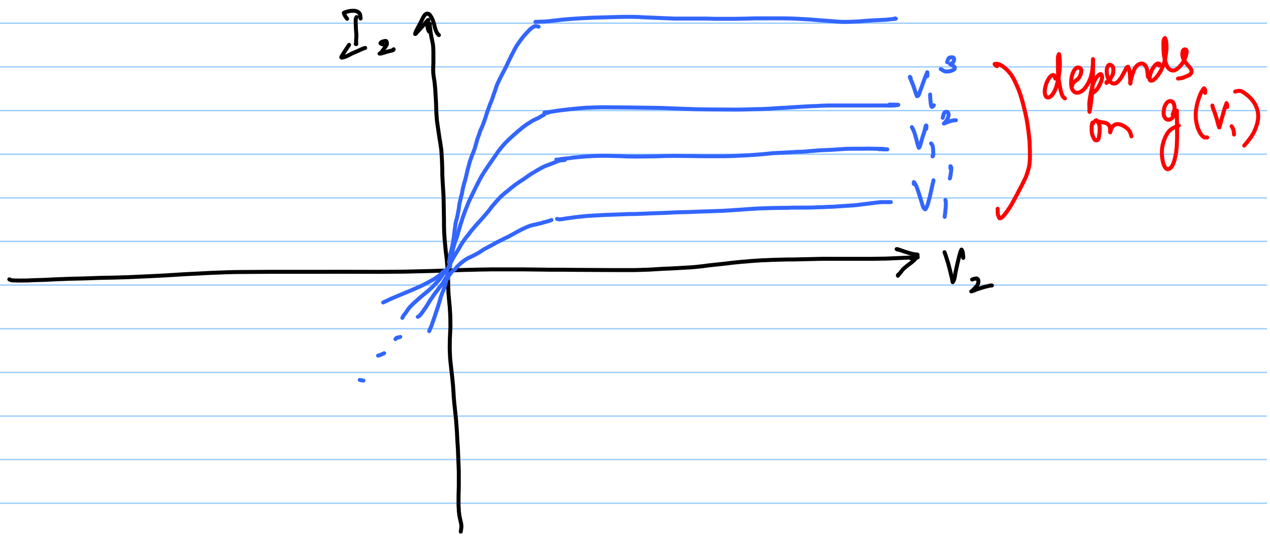
$\Rightarrow I_1 = I_0$ (constant)

$$y_{22} = \frac{\partial g}{\partial V_2} = 0 \quad ; \quad y_{21} = \frac{\partial g}{\partial V_1} = \text{large}$$

$\Rightarrow$ we want $I_2 = g(V_1)$ only

$$\left.\begin{aligned} I_1 &= I_0 \\ I_2 &= g(V_1) \end{aligned}\right\} \text{graphical representation}$$

<u>Output</u> <u>Characteristics</u>



* Special case of $I_1 = 0$

passivity $\Rightarrow$ $\underbrace{V_1 I_1}_{0} + V_2 I_2 \geq 0$

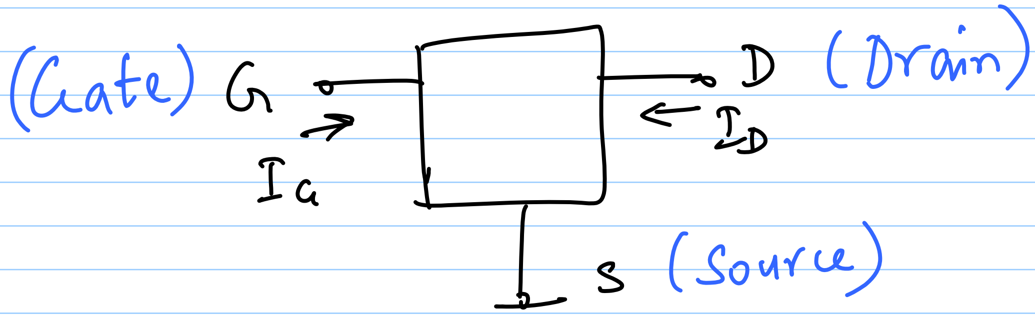
$\Rightarrow$ $V_2 I_2 \geq 0$ { 1st & 3rd Q only }

* All devices that exhibit high incremental gain have characteristics similar to these!

* MOSFET $\Rightarrow$ $I_1 = 0$

JFET, BJT $\Rightarrow$ I_1 very small

MOSFET



$I_G = 0$

If $V_{GS} > V_T$:

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)^2 \quad \text{for } V_{DS} \geq (V_{GS}-V_T)$$

saturation region

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

$I_D = 0$ if $V_{GS} < V_T$

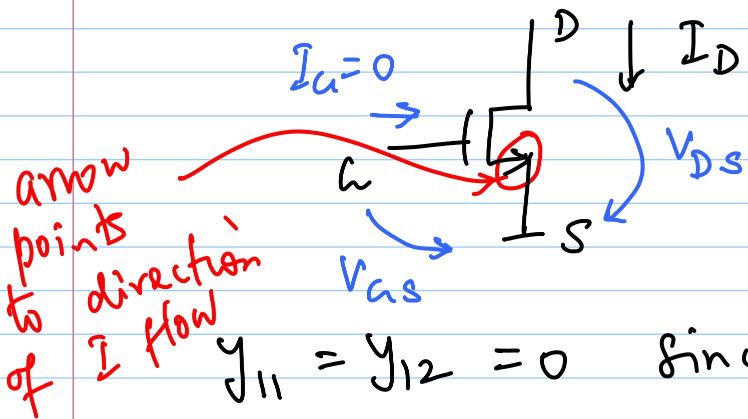
μ_n = mobility of electrons

C_{ox} = oxide capacitance

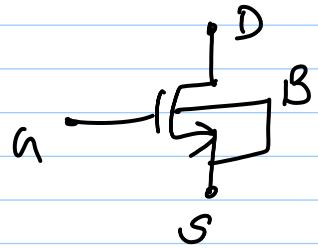
W, L = Geometric parameters

V_T = Threshold voltage

learn more in devices course



In this course:



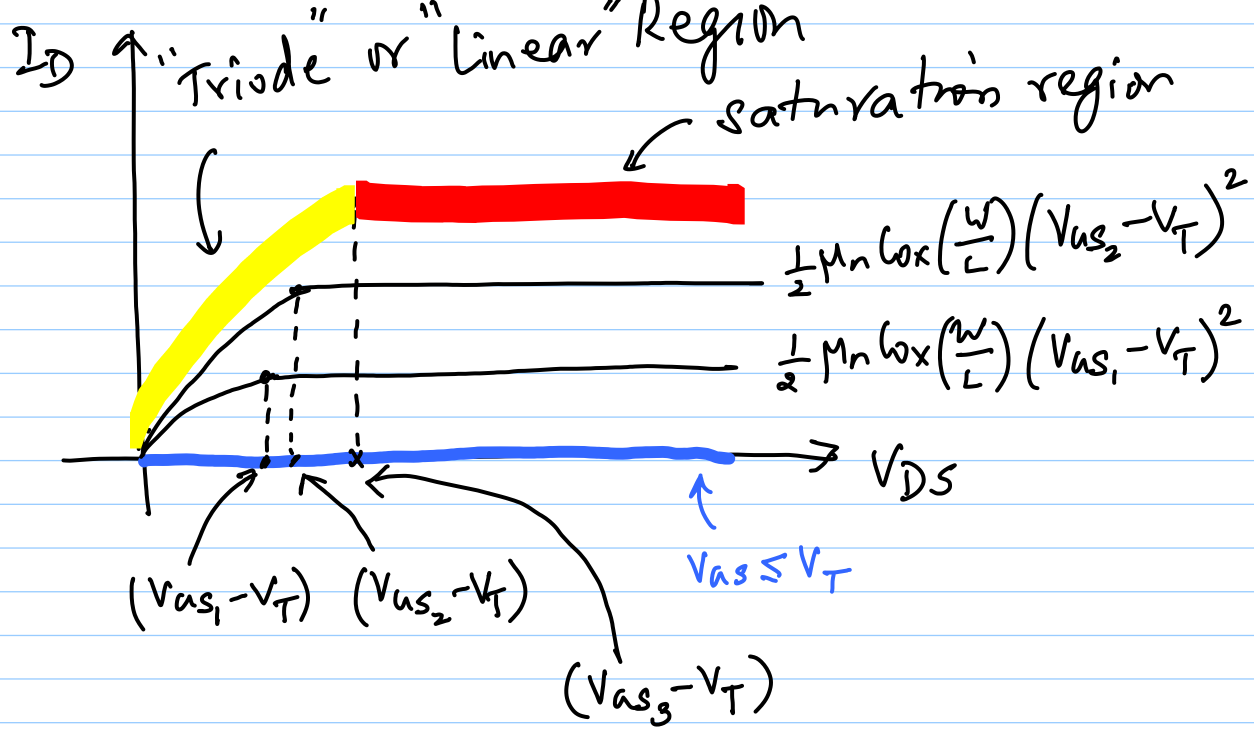
$y_{11} = y_{12} = 0$ since $I_G = 0$

$$y_{21} = \partial I_D / \partial V_{GS} = \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)$$

for $V_{GS} > V_T$ & $V_{DS} \geq V_{GS} - V_T$

* In saturation : I_D is independent of V_{DS}

{ I_2 indep. of V_2 }



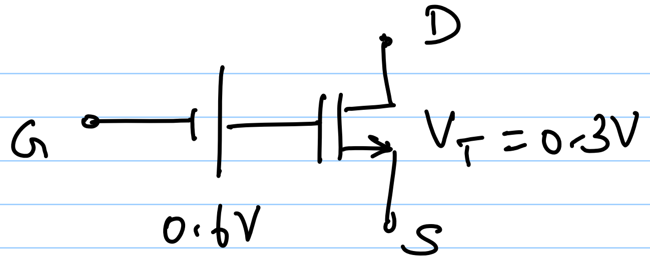
* "Enhancement mode" MOSFET
  or "normally OFF" device :

  $V_T > 0 \Rightarrow$ @ $V_{GS} = 0$
  $I_D = 0$

  e.g. If $V_T = 0.3V$, $I_D = 0$ for $V_{GS} \leq 0.3V$
  $I_D > 0$ for $V_{GS} > 0.3V$

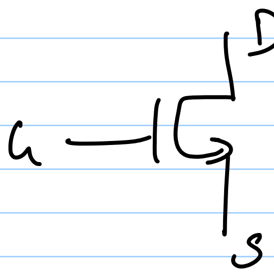
* "Depletion mode" MOSFET
  or "normally ON" device

  $V_T < 0 \Rightarrow$ @ $V_{GS} = 0$, $I_D > 0$



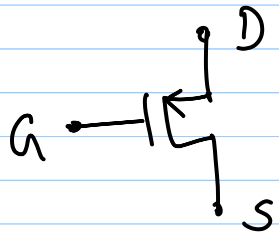
} effective $V_T = -0.3V$

→ everything else is the same



⇒ nMOS transistor

→ e^- carriers



⇒ pMOS transistor { later in the course }

→ hole carriers

enhancement mode nMOS transistor equations:

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2 \quad \begin{cases} V_{GS} \geq V_T \\ V_{DS} \geq V_{GS} - V_T \end{cases}$$

$$= \mu_n C_{ox}\left(\frac{W}{L}\right)\left[(V_{GS} - V_T)V_{DS} - \frac{1}{2}V_{DS}^2\right] \quad \begin{cases} V_{GS} \geq V_T \\ V_{DS} < V_{GS} - V_T \end{cases}$$