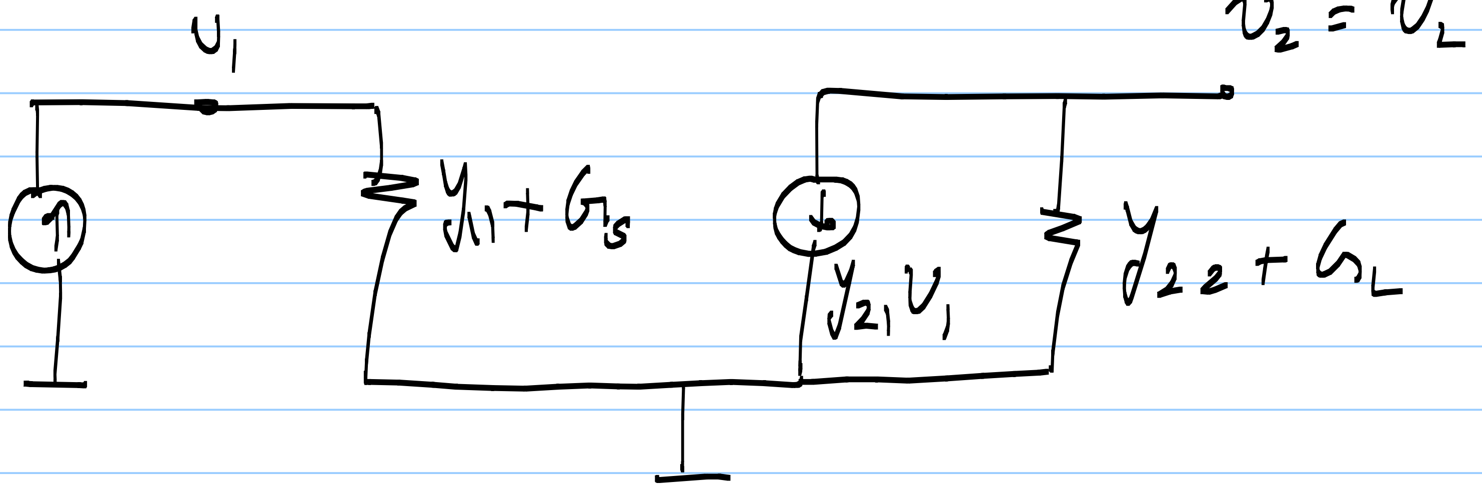
14/8/2020

Lecture 7



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

1) Gain independent of G_s : set $y_{11} = 0$

$\Rightarrow i_1 = 0$

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

2) Gain as large as possible:

y_{21} as large as possible

and

$$\underbrace{y_{22} + G_L \text{ as small as possible}}$$

$\hookrightarrow$ set $y_{22} = 0$

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

gain of amplifier still dep. on G_L

We need a 2-port network with inc $[y]$:

$$[y] = \begin{bmatrix} 0 & 0 \\ \text{as large as possible} & 0 \end{bmatrix} = \begin{bmatrix} \partial f/\partial v_1 & \partial f/\partial v_2 \\ \partial g/\partial v_1 & \partial g/\partial v_2 \end{bmatrix}$$

$$I_1 = f(V_1, V_2) \quad ; \quad I_2 = g(V_1, V_2)$$

$$y_{11}, y_{12} = 0 \Rightarrow \frac{\partial f}{\partial V_1}, \frac{\partial f}{\partial V_2} = 0 \Rightarrow I_1 = I_0$$

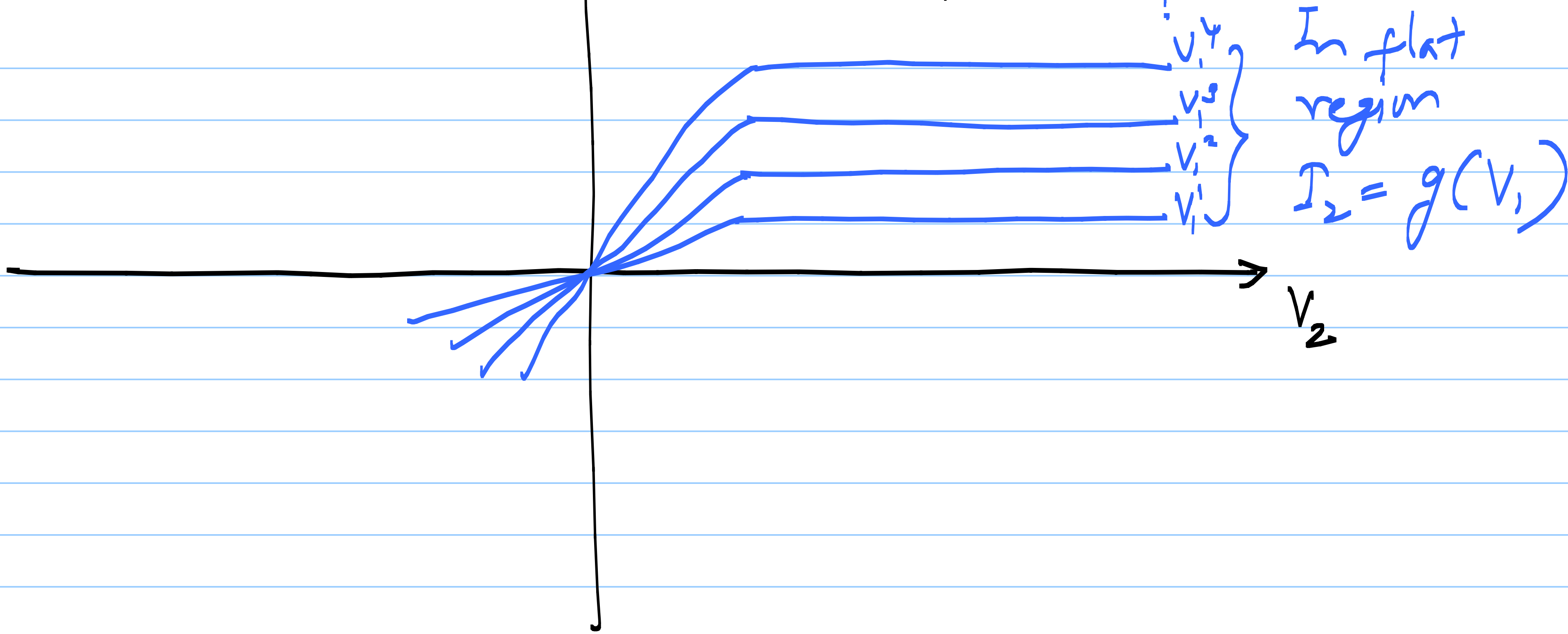
constant current

$$y_{22} = 0, \quad y_{21} = \text{large} \Rightarrow I_2 = g(V_1) \text{ only}$$

$$I_1 = I_0$$

$$I_2 = g(V_1)$$

Output characteristics



special case : $I_1 = 0 \Rightarrow$ passivity : $V_1 I_1 + V_2 I_2 \geq 0$

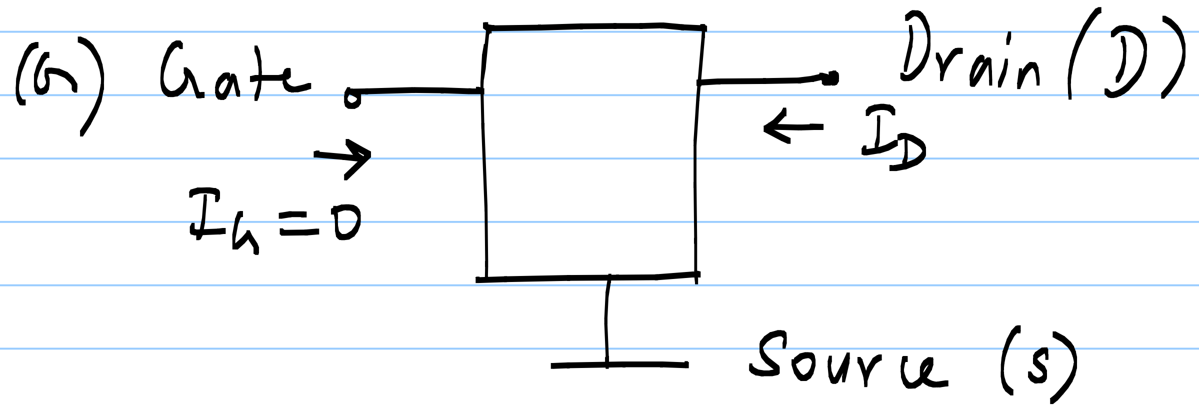
$\Rightarrow V_2 I_2 \geq 0$

All devices that exhibit "good" amplifier behaviour (high gain etc.) have such characteristics
(inc.)

MOSFET $\Rightarrow I_1 = 0$; $\left.\begin{array}{l}\text{BJT}\\ \text{JFET}\end{array}\right\} \Rightarrow I_1$ very small

MOSFET

NMOSFET



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

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

"saturation"

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

"triode", "linear"

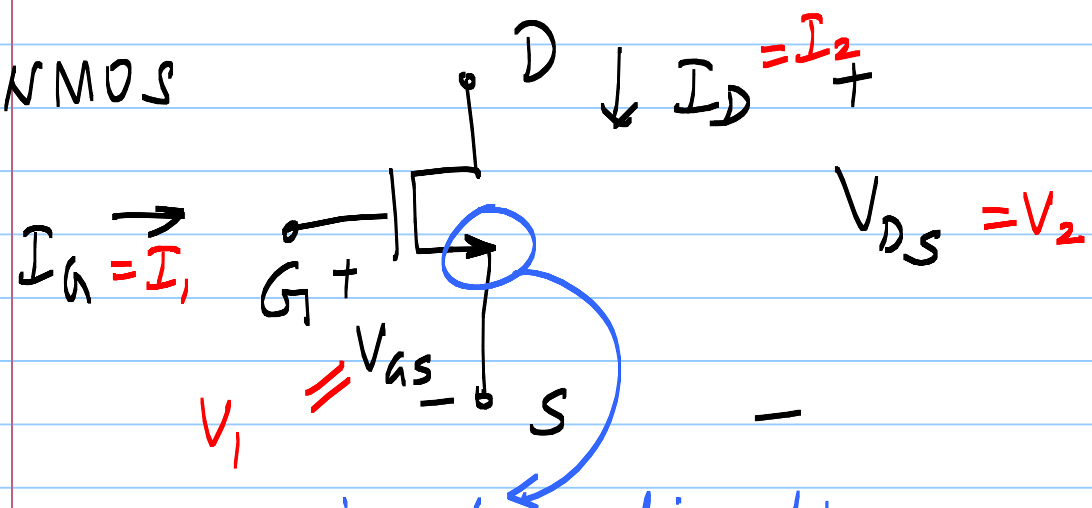
V_T = Threshold voltage

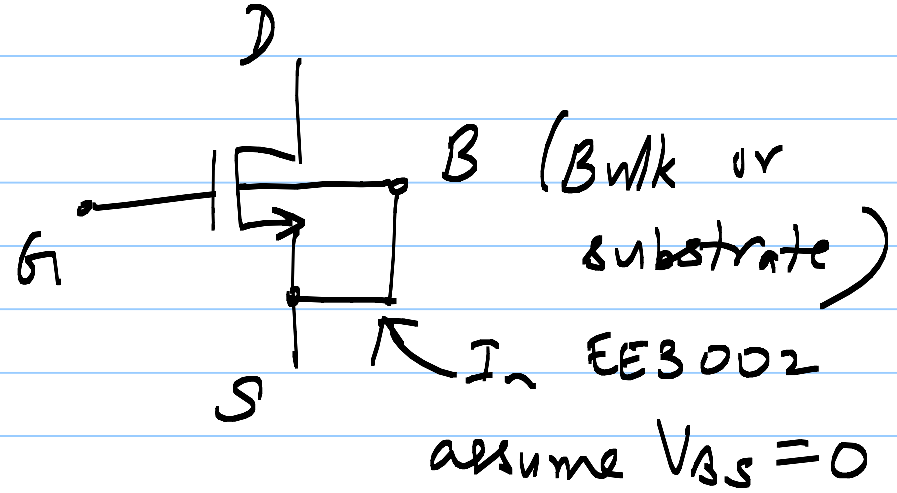
μ_n = mobility of electrons

C_{ox} = oxide cap. per unit area

W, L = geometric parameters of MOSFET

NMOS





current flow direction

$I_G = 0 \Rightarrow y_{11} = y_{12} = 0$

In sat., I_D is independent of V_{DS}

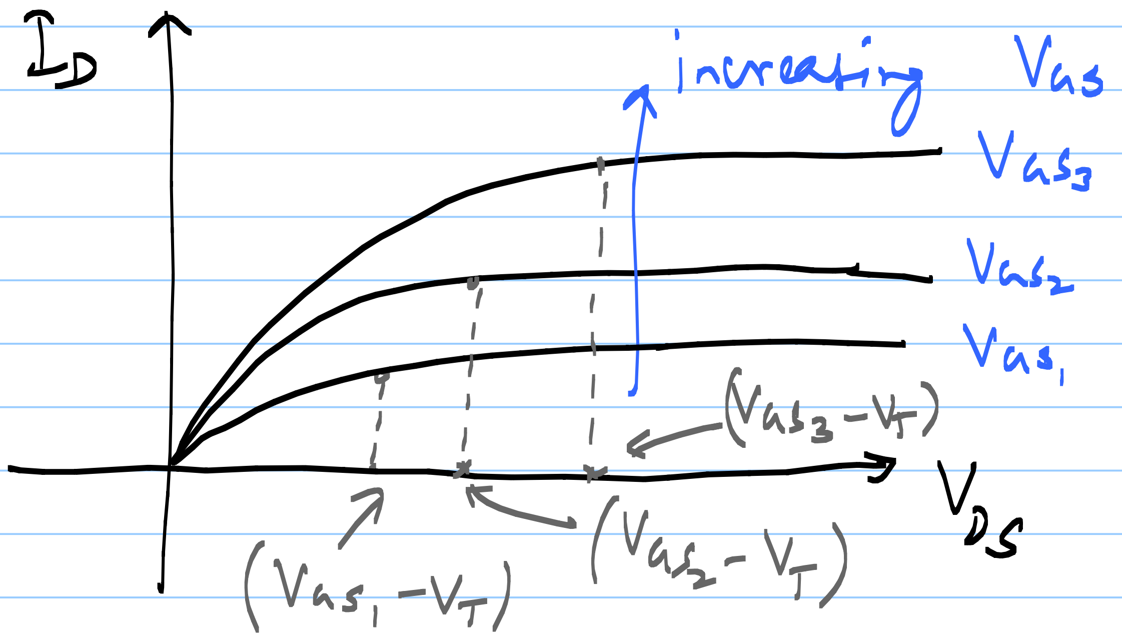
Operate MOSFET in sat. for building a good amplifier

I_2 is indep. of V_2 $\Rightarrow$ $y_{22} = 0$

$$y_{21} = \frac{\partial I_2}{\partial V_1} = \frac{\partial I_D}{\partial V_{GS}} = \mu_n C_{ox} \left(\frac{W}{L}\right) (V_{GS} - V_T)$$

for $V_{GS} > V_T$ and

$V_{DS} \geq (V_{GS} - V_T)$



$\vdots$

$$I_{D_1} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right) (V_{GS_1} - V_T)^2$$

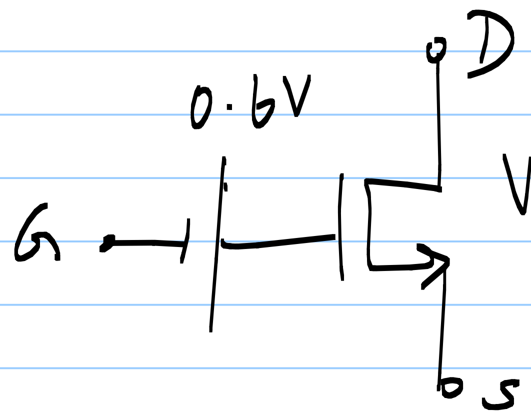
In this course, assume $V_T > 0$

1) "Enhancement mode" MOSFET (Normally OFF)

i.e. $V_T > 0$; @ $V_{GS} = 0$, $I_D = 0$

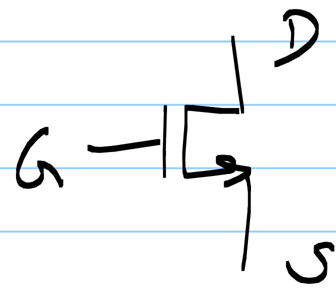
2) "Depletion mode" MOSFET (normally ON)

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



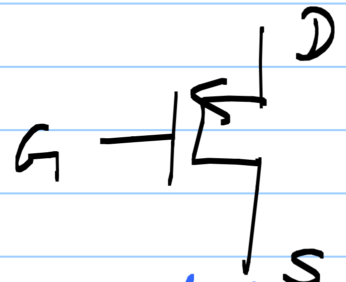
$V_T = 0.3V$ Effective $V_T = -0.3V$

3)



NMOSFET

carriers $= e^-$



PMOSFET

carriers $= p^+$

later in the course