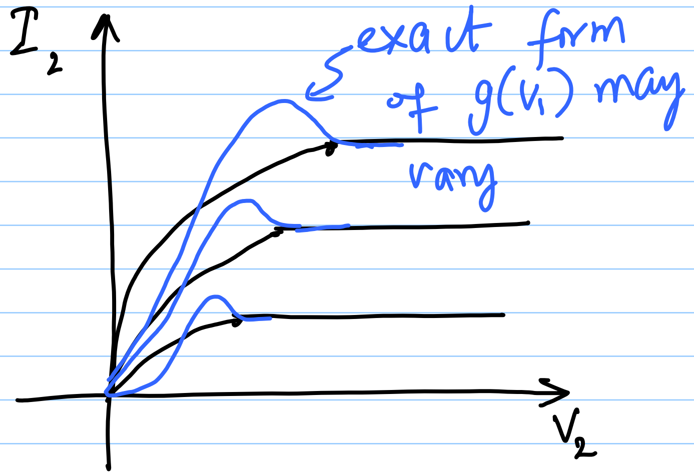
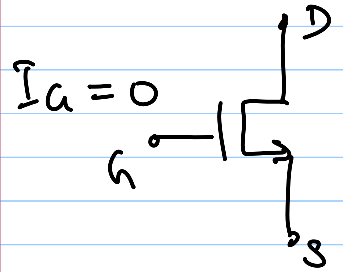
9-8-12

Lec 7



$I_1 = 0$ and passive 2-port

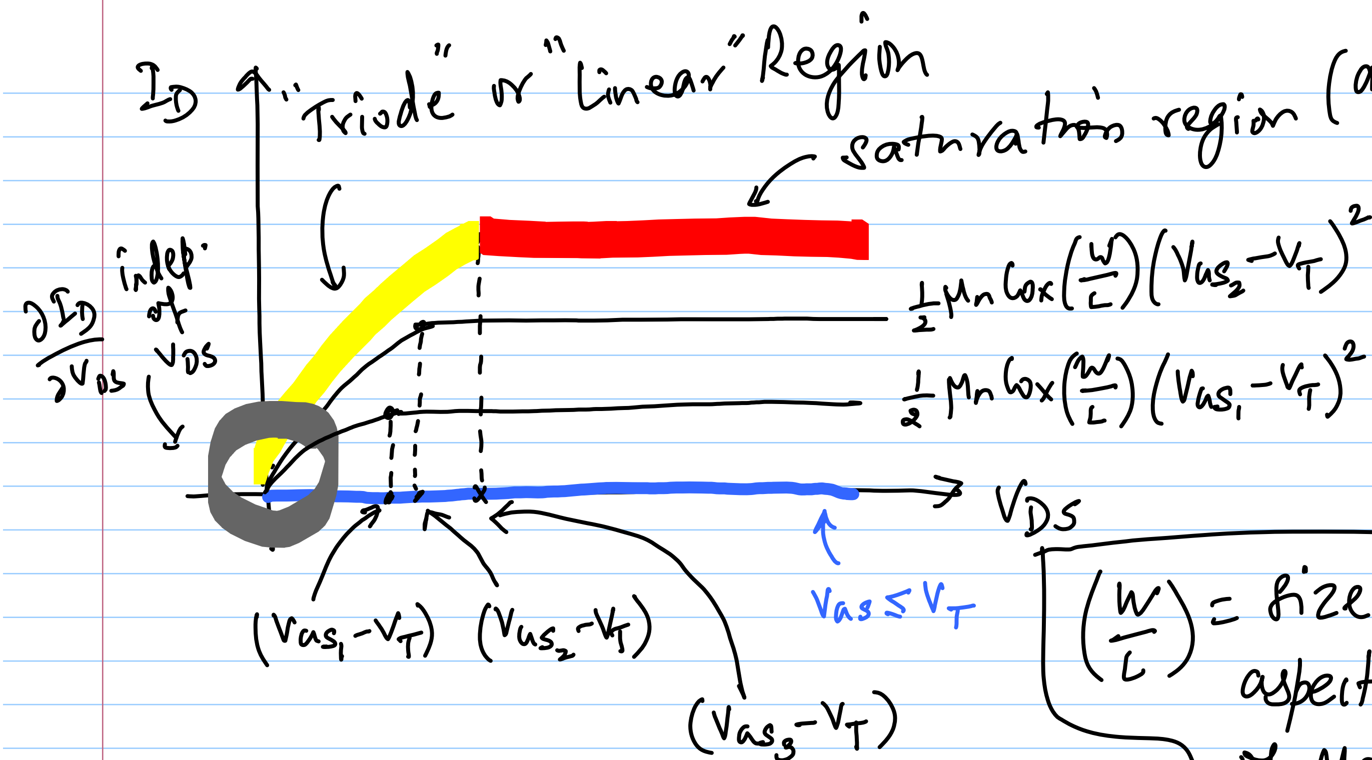
$\Rightarrow$ 1st & 3rd - Q only



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

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

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



$\left(\frac{W}{L}\right)$ = size or aspect ratio of MOSFET

$V_{DS} < V_{GS} - V_T \Rightarrow$ Linear region

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

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

$$\simeq \mu_n C_{ox}\left(\frac{W}{L}\right)\left(\text{[illegible]} - V_T\right)$$

if $V_{DS} << V_{GS} - V_T$

$\Rightarrow$ Voltage-controlled resistor

$$r_{ds} = f(V_{GS} - V_T)$$

$$(V_{GS} - V_T) = V_{DSat}$$

If $V_{DS} < V_{DSat}$, $y_{22} \neq 0$

sometimes also $) = V_{OV}$ or <u>Gate overdrive</u> <u>voltage</u>

$V_{DS} = V_{GS} - V_T$ = limit of sat. region

$$V_D - \cancel{V_S} = V_G - \cancel{V_S} - V_T$$

$\Rightarrow V_D = V_G - V_T$ (decoupled from Source voltage)

In saturation:

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

$$y_{11} = 0, \quad y_{12} = 0, \quad y_{22} = 0$$

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

$y_{21} \Rightarrow$ units of conductance, but i/p and o/p ports are involved

"transconductance" $g_m = \dfrac{\partial I_D}{\partial V_{GS}}$

$$= \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

<u>Different expressions</u>:

1) $g_m = \mu_n C_{ox} \left(\frac{W}{L}\right)(V_{GS} - V_T)$

2) $g_m = 2 \times \dfrac{\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)^2}{(V_{GS}-V_T)} = \dfrac{2 I_D}{V_{GS} - V_T}$

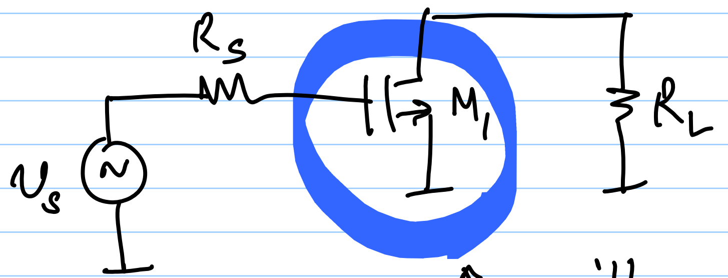
3) $g_m^2 = \frac{2}{2}\mu_n^2 C_{ox}^2 \left(\frac{W}{L}\right)^2 (V_{GS} - V_T)^2$

$$= 2\mu_n C_{ox}\left(\frac{W}{L}\right) I_D$$

$$\Rightarrow g_m = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right) I_D}$$

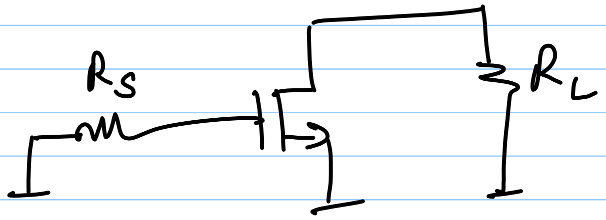
All 3 forms of g_m show dependence on <u>operating point</u>

<u>MOSFET Amplifier</u>



<u>small-signal picture</u>

will work as amplifier if M_1 is in saturation region i.e. operating point should be in saturation region



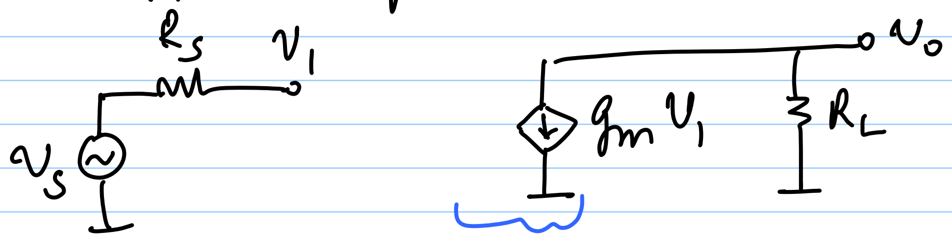
$\leftarrow$ $I_G = 0$

$I_D = 0$

$V_{GS} = 0$

$V_{DS} = 0$

incremental eq. circuit:



$$\boxed{\frac{v_o}{v_s} = -g_m R_L}$$

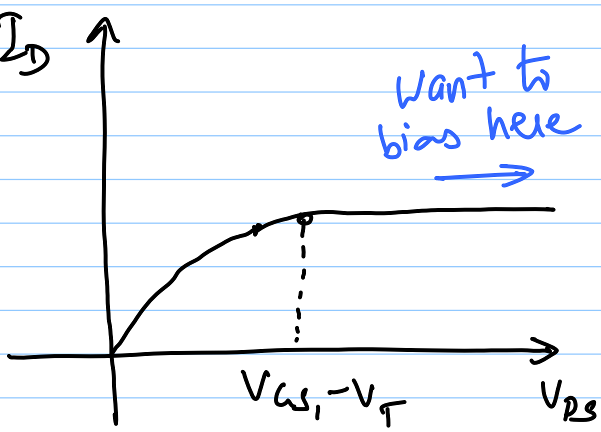
y_{21} = incremental VCCS

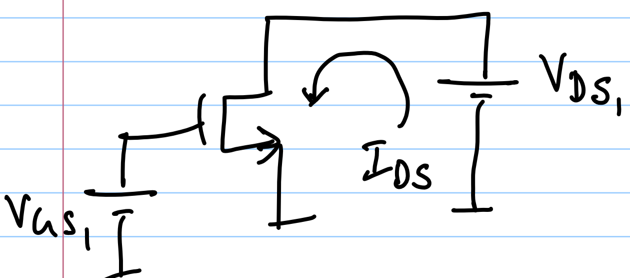
Incremental gain depends on op. pt. through $\underline{g_m}$

<u>Transistor "biasing"</u>

<u>Op. point:</u>

* $V_{DS} \geq V_{GS} - V_T$

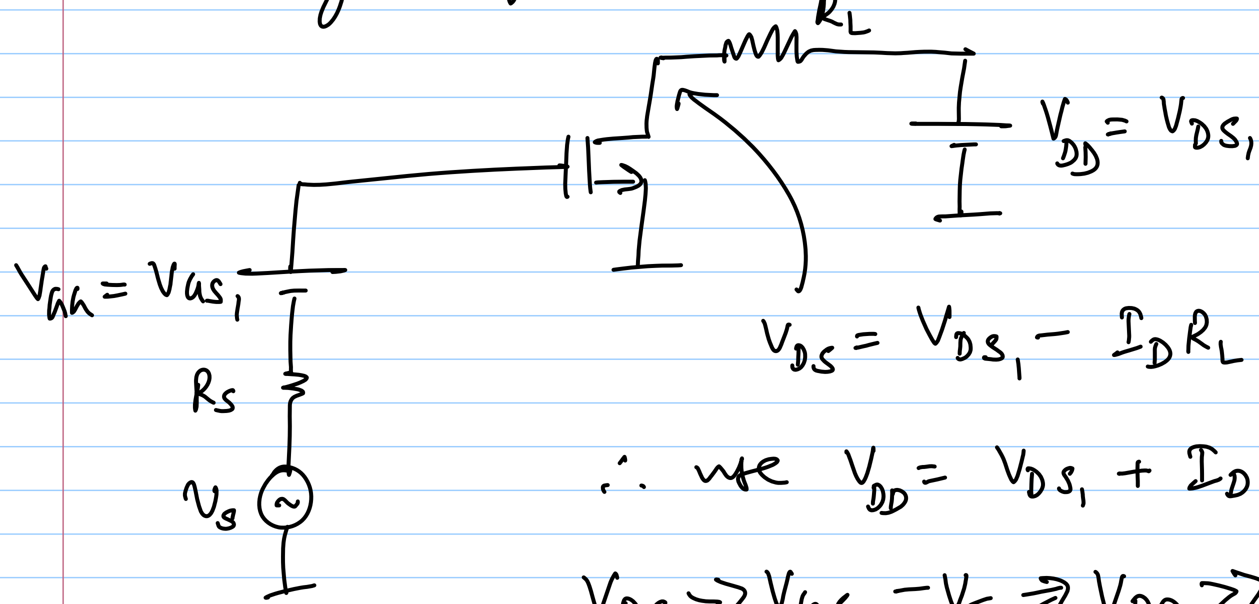




$$I_D = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right) (V_{GS_1} - V_T)^2$$

* $V_{DS_1} >> V_{GS_1} - V_T$ is desirable

adding signal source:

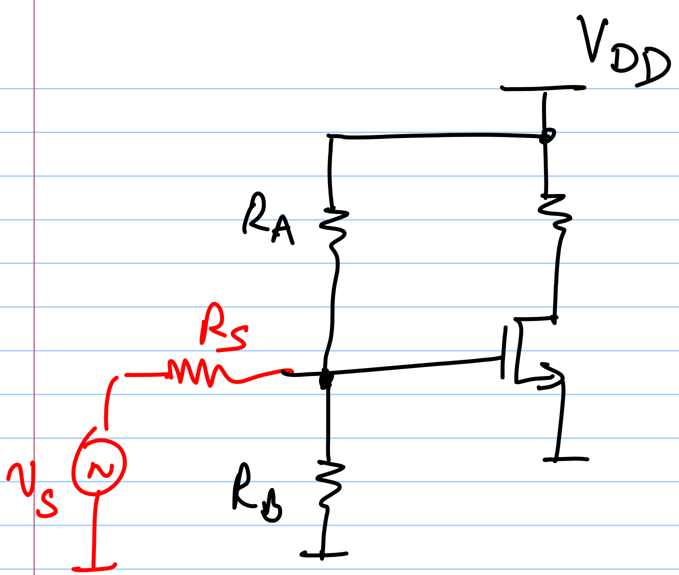


$$V_{DS} = V_{DS_1} - I_D R_L$$

$\therefore$ use $V_{DD} = V_{DS_1} + I_D R_L$

$$V_{DS_1} \gg V_{GS_1} - V_T \Rightarrow V_{DD} \gg V_{GS_1}$$

* We don't want to use multiple batteries
  → generate V_{GS_1} from V_{DD}



$$V_{DD} \cdot \frac{R_B}{R_A + R_B} = V_{GS_1}$$

increment cannot be added directly
⇒ OP will change due to R_s

e.g. if $R_s = 0 \Rightarrow V_{GS_1} = 0$