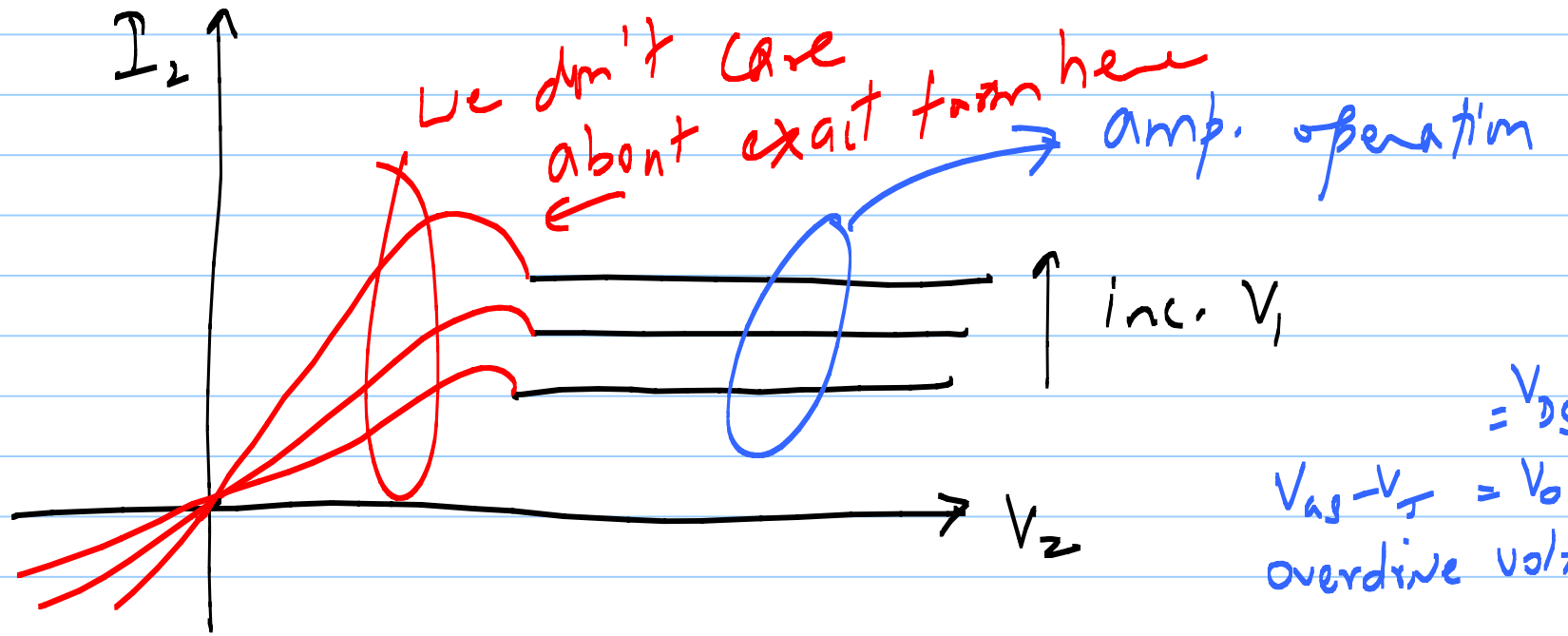
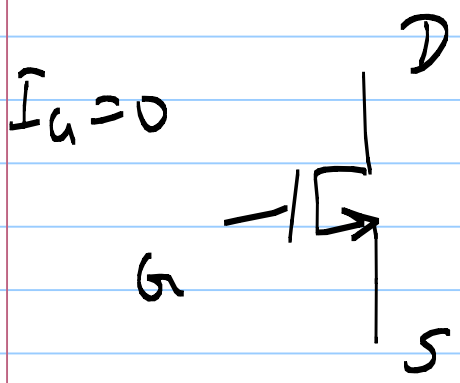
18/8/2020

Lecture 8



$= V_{DSat}$

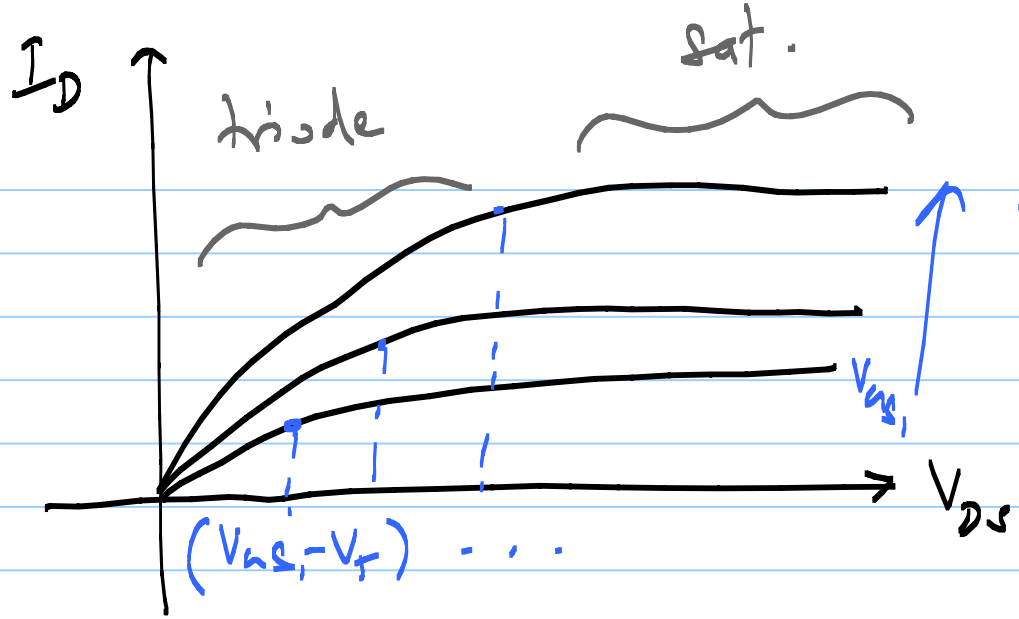
$V_{GS} - V_T = V_{ov}$ overdrive voltage



$I_D = 0$ if $V_{GS} < V_T$ (off)

$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$ if $V_{GS} \geq V_T$ and $V_{DS} \geq V_{GS} - V_T$ (sat.)

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



V_T = threshold voltage

V_t = thermal voltage $= \frac{kT}{q}$

Amplifier: Use sat. region

$$I_G = 0 \; ; \quad I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$$

use this to define op. pt.

$$y_{11} = \frac{\partial I_G}{\partial V_{GS}} = 0 \; ; \quad y_{12} = \frac{\partial I_G}{\partial V_{DS}} = 0 \; ;$$

$$y_{22} = \frac{\partial I_D}{\partial V_{DS}} = 0 \; ; \quad y_{21} = \frac{\partial I_D}{\partial V_{GS}}$$

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

transconductance of MOSFET

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

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

$$= \frac{2 I_D}{V_{GS} - V_T}$$

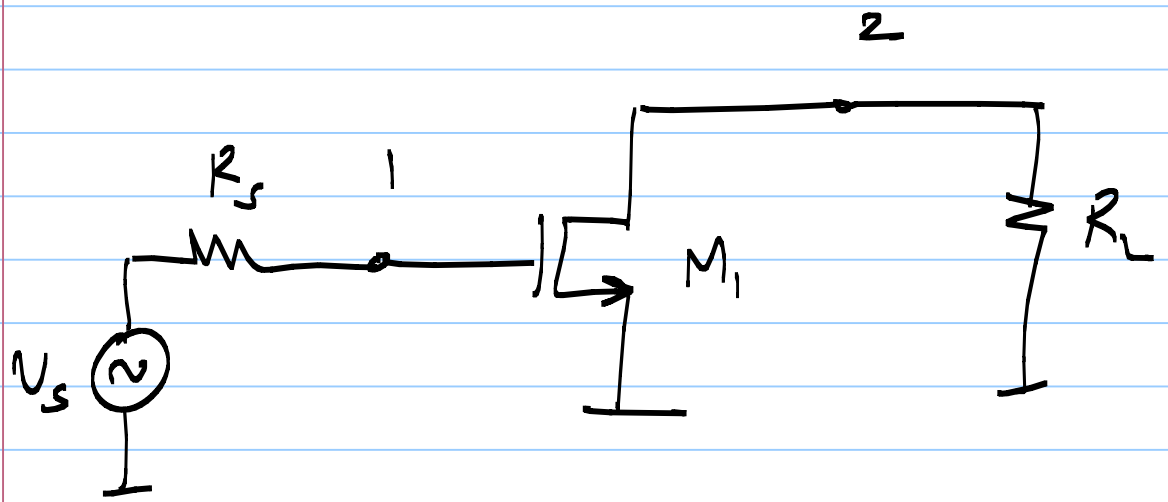
3) $$g_m^2 = 2 \times \frac{1}{2} \mu_n^2 C_{ox}^2 \left(\frac{W}{L}\right)^2 (V_{GS} - V_T)^2$$

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

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

$$[y] = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix}$$

MOSFET Amplifier



Small-signal picture

(op. pt. should be such that M_1 is biased in sat.)

In triode region :

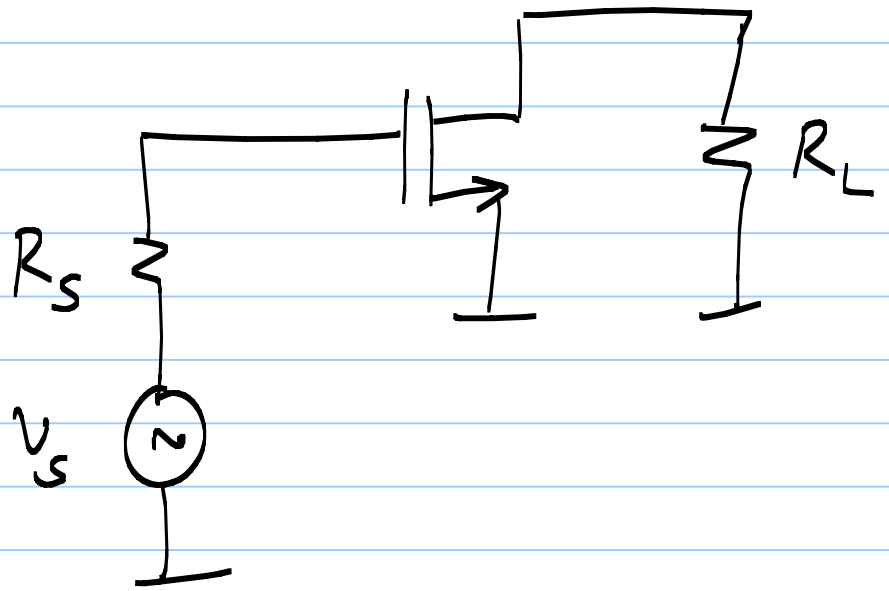
$$y_{11} = y_{12} = 0$$

$$y_{22} = \frac{\partial I_D}{\partial V_{DS}} = \frac{\partial}{\partial V_{DS}} \left[\mu_n C_{ox} \left(\frac{W}{L} \right) \left\{ (V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2} \right\} \right]$$

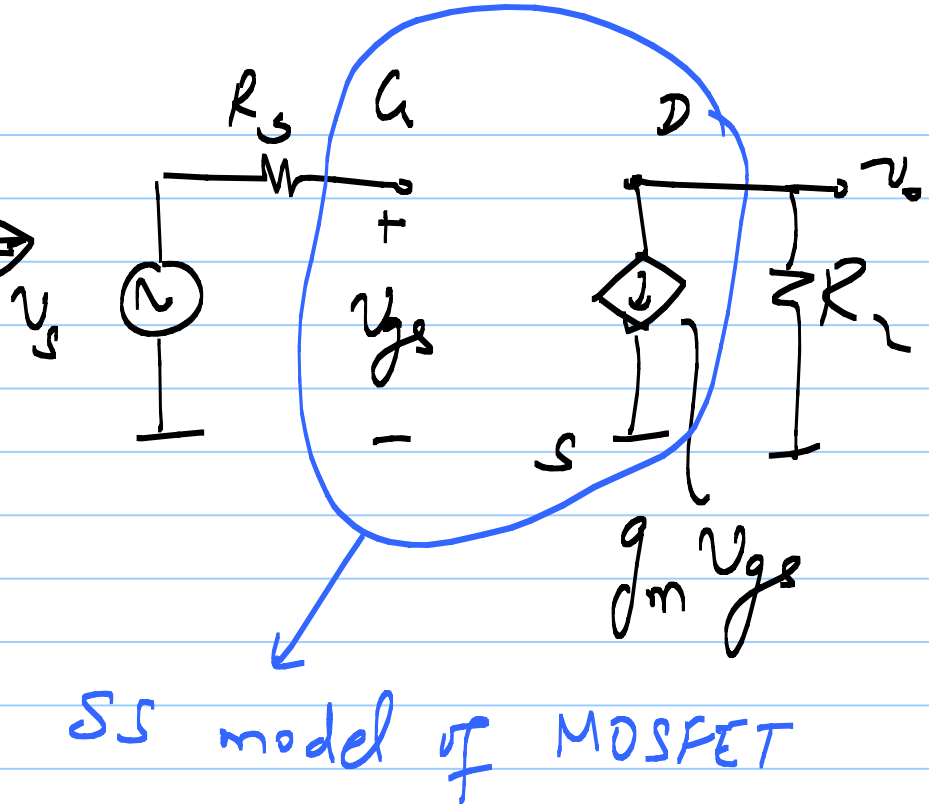
$$= \mu_n C_{ox} \left(\frac{W}{L} \right) \left(V_{GS} - V_T - V_{DS} \right) \neq 0$$

$$y_{21} = \partial I_D / \partial V_{GS}$$

$$= \mu_n C_{ox} \left(\frac{W}{L} \right) \cdot V_{DS} \quad \left\{ V_{DS} < (V_{GS} - V_T) \right\}$$



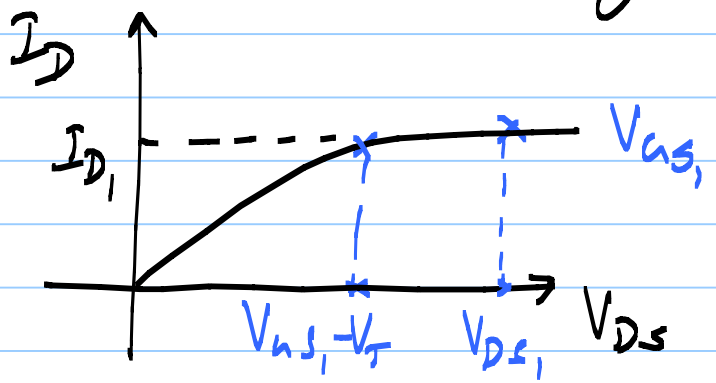
$\Rightarrow$

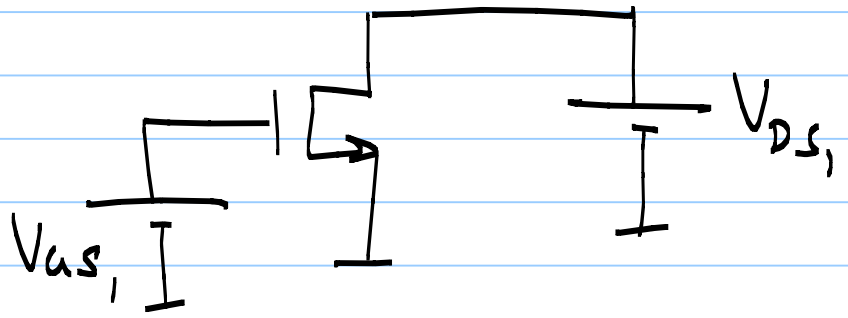


SS model of MOSFET

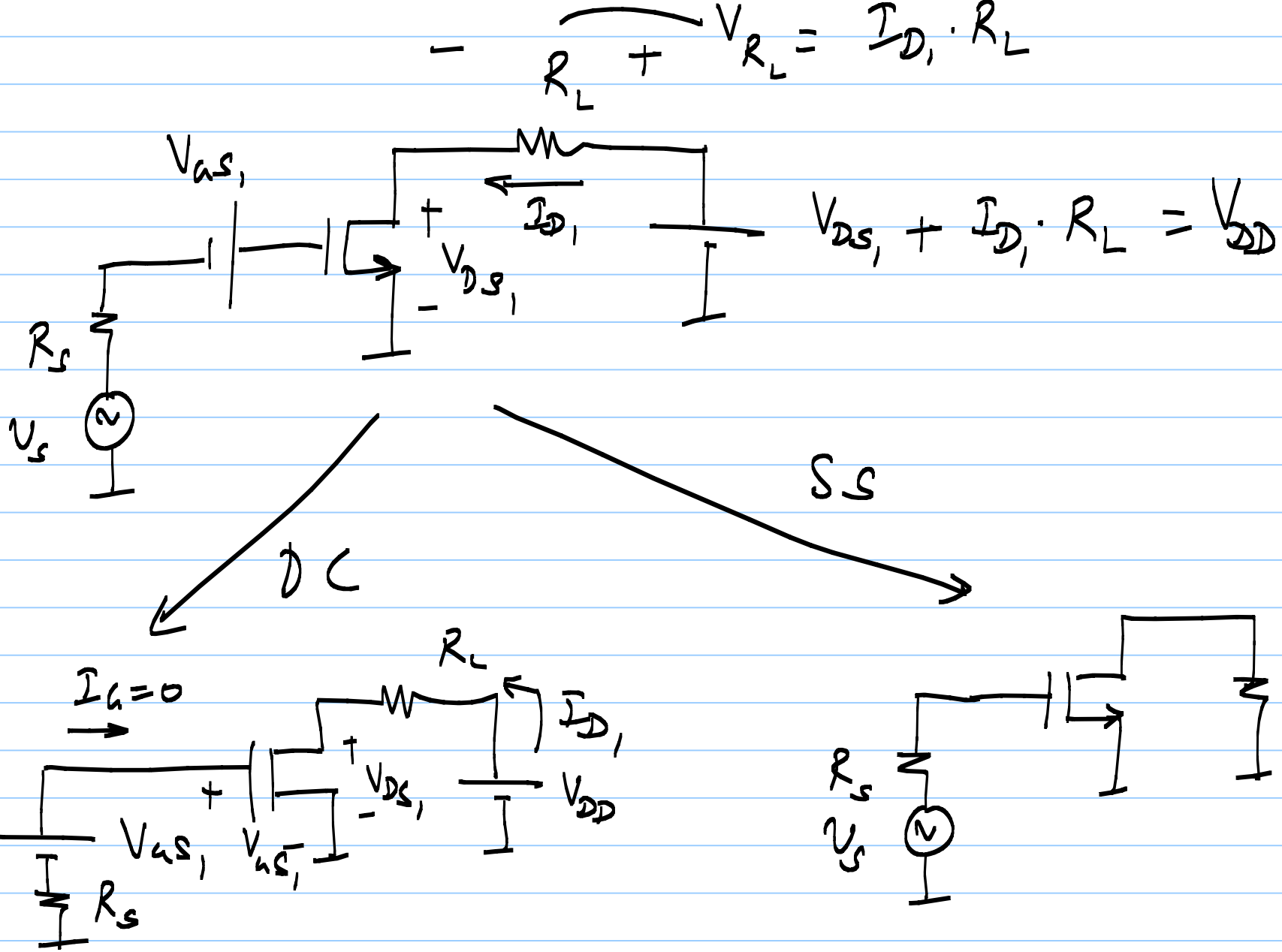
$$\text{gain} = \frac{v_o}{v_s} = -g_m R_L$$

MOSFET Biasing :





Add signal source & load to DC biased MOSFET:

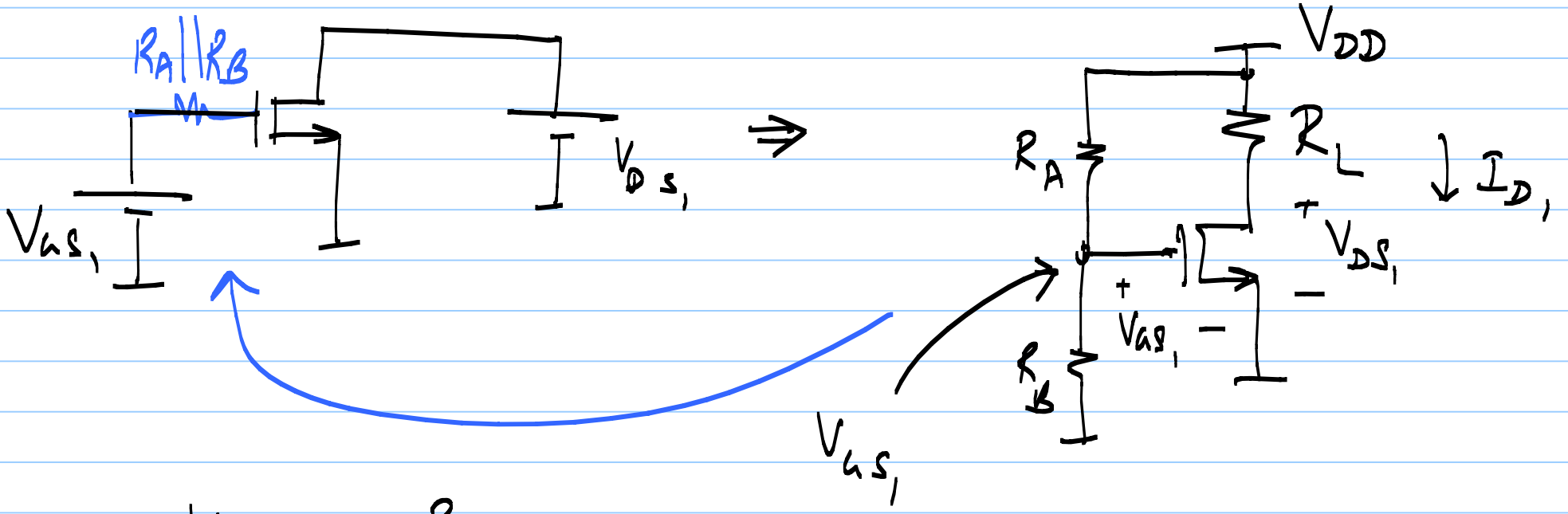


* Avoid use of 2 batteries:

⇒ generate V_{GS_1} from V_{DD} → largest voltage in the circuit

($V_{DD} > V_{GS_1}$)

DC:



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