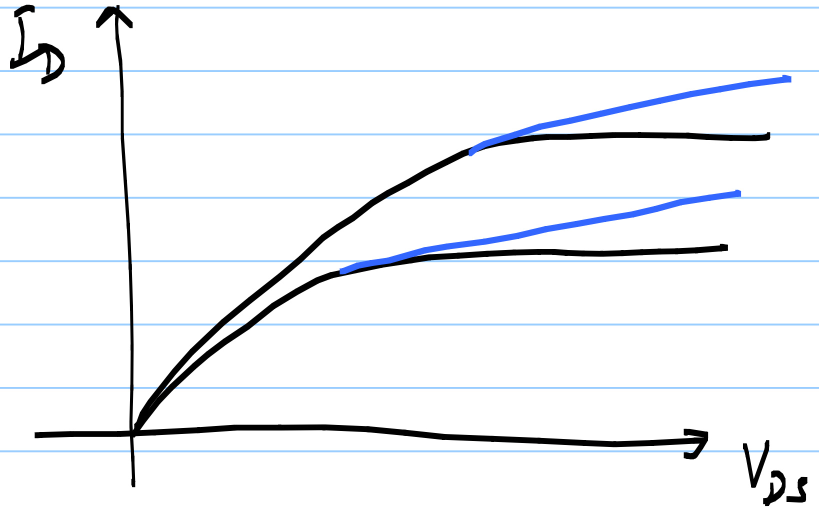
25/8/20

Lecture 12

Real MOSFET Characteristics



We assumed that in sat.,

$I_D = f(V_{GS})$ only

In reality,

$I_D = f(V_{GS}, V_{DS})$

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

for a good MOSFET, $\lambda << 1$

"Channel Length Modulation"

for op. pt. calculations, use: $I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)^2$

2-port parameters:

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

$$y_{21} = g_m = \frac{\partial I_D}{\partial V_{GS}} = \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)(1+\lambda V_{DS})$$

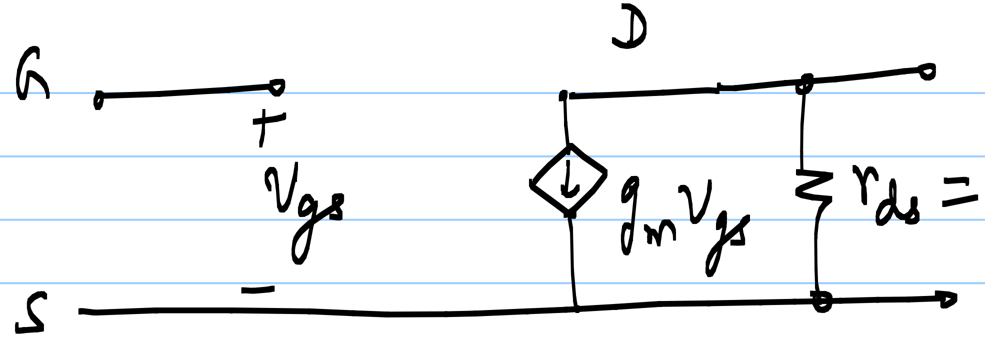
$$\approx \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)$$ {assume same as before}

$$g_{ds} = y_{22} = \frac{\partial I_D}{\partial V_{DS}} = \underbrace{\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T)^2}_{\approx I_D} \cdot \lambda$$

output conductance of MOSFET

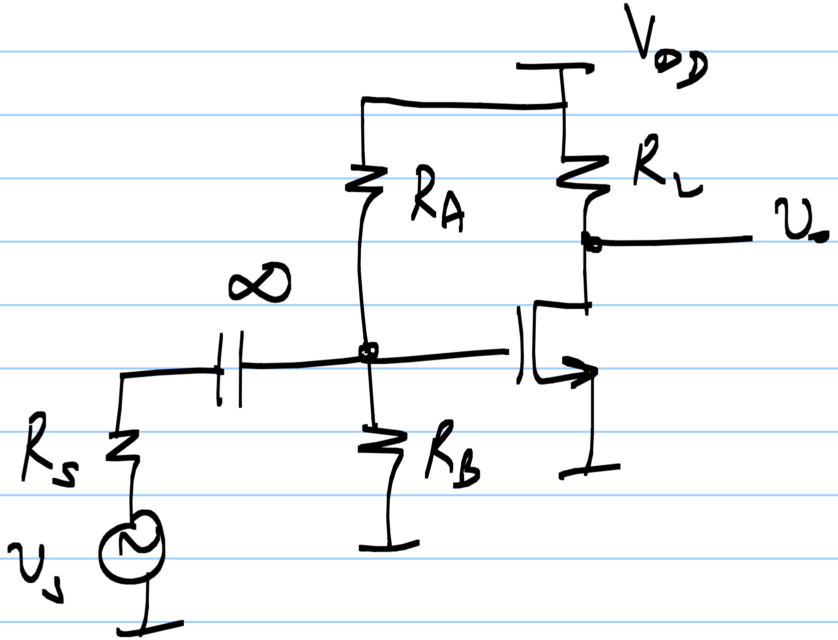
$$g_{ds} \approx \lambda \cdot I_D$$

$$r_{ds} = \frac{1}{g_{ds}} = \frac{1}{\lambda I_D}$$



$$r_{ds} = \frac{1}{\lambda I_D}$$

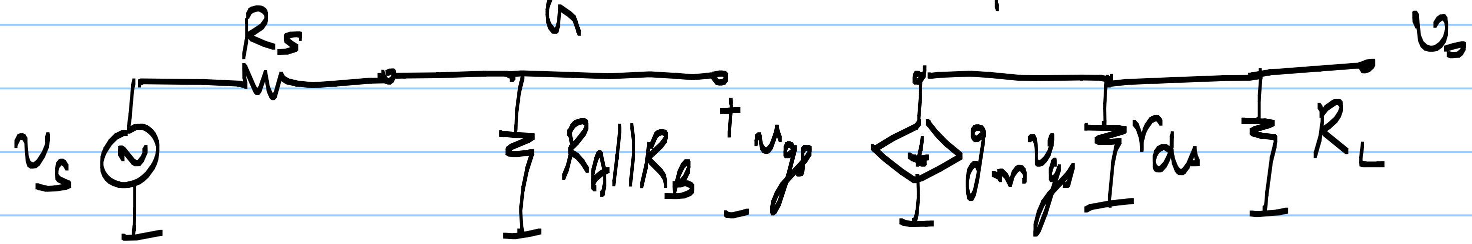
Common-Source amp.



$$\frac{v_o}{v_s} = \frac{v_o}{v_{gs}} \cdot \frac{v_{gs}}{v_s}$$

$$= -g_m (r_{ds} \| R_L) \cdot \frac{R_A \| R_B}{R_s + R_A \| R_B}$$

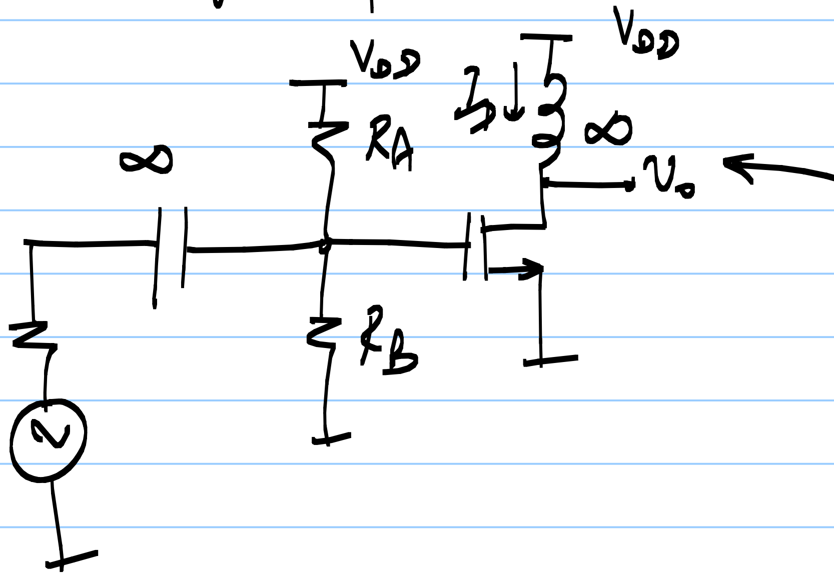
≈ 1

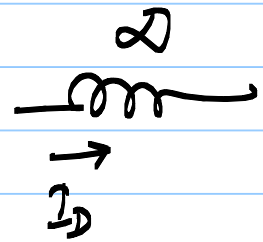


$$\frac{v_o}{v_s} \approx -g_m (r_{ds} \| R_L)$$ gain is smaller

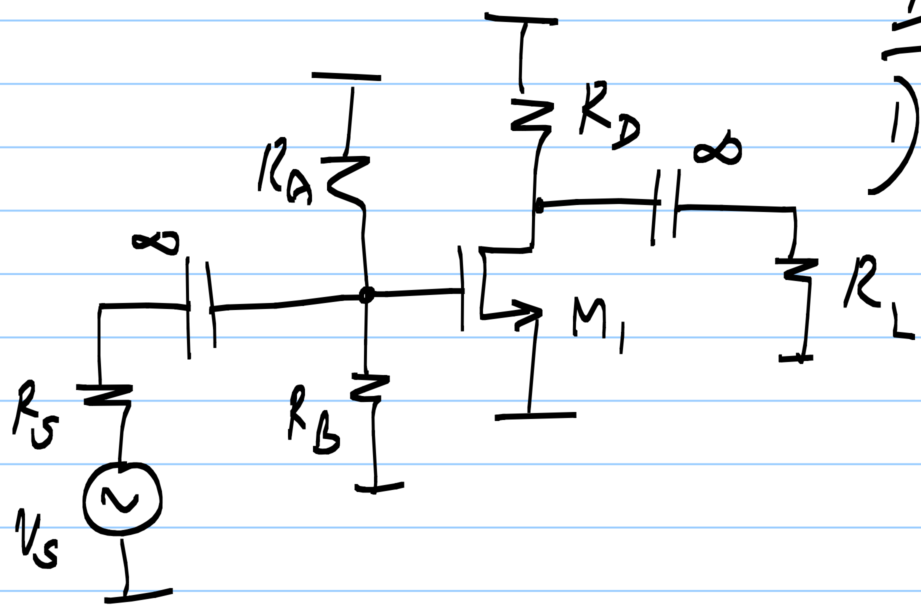
Max possible gain : $R_L = \infty$

$|\text{max. gain}| = g_m r_{ds} \equiv$ "intrinsic gain" of MOSFET





: DC short
AC open



Issues:

1) M_1 parameters vary with
   a) ambient temp.
   b) time
   c) device to device

   i.e. random variations in device properties

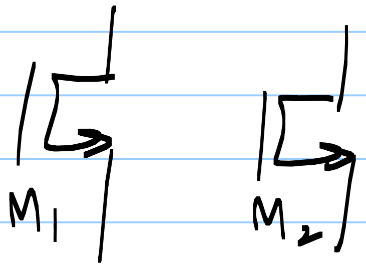
e.g. if V_T changes, $\longrightarrow$ I_D changes $\rightarrow$ changes in g_m, r_{ds}, V_{DS}, V_{ov} etc.

$\Rightarrow$ Undesirable

2) Tolerance in R_A, R_B etc

On an IC:

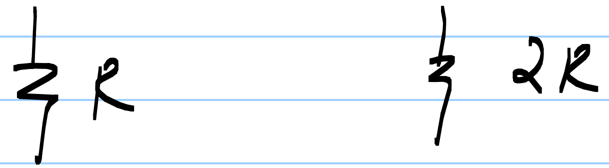
1) Multiple copies of the same device (R, C, MOSFET etc.) nominally have same properties, (On the same IC)



V_{T_1}, V_{T_2}, μ_{n_1}, μ_{n_2} etc. } vary together

2) Properties may vary across multiple ICs

3) Ratios of like components vary similarly



$$\frac{R_B}{R_A + R_B}$$ — used to generate V_{GS} from V_{DD}

Issues still exist:

1) V_{GS} is constant ($\propto V_{DD}$), but V_T etc. can vary $\Rightarrow$ I_D varies $\Rightarrow$ gain, swing limits vary.

$\Rightarrow$ Make V_{GS} vary with V_T to get desired I_D

Use "negative feedback" to generate V_{GS}

* Desired Value (desired Drain bias current $= I_0$)
* Measure actual value (I_D)
* Compare actual with desired ($I_D \leftrightarrow I_0$)

* Use error to move actual value towards desired value (make $I_D \rightarrow I_0$, using V_{GS})