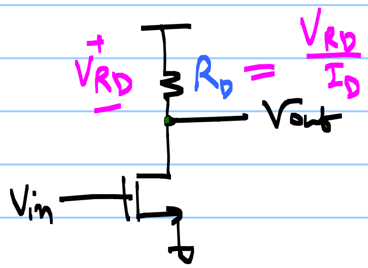
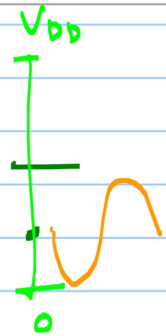
ECE 511 — Lecture 10

Note Title 2/21/2013





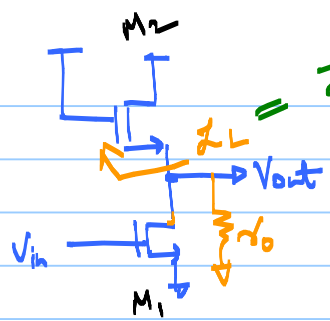
$$A_v = -g_m R_D$$

$$= -\sqrt{2kP_n \frac{W}{L} I_D} \cdot R_D$$

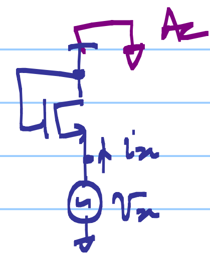
$$= -\sqrt{2kP_n \frac{W}{L} I_D} \cdot \frac{V_{RD}}{I_D}$$

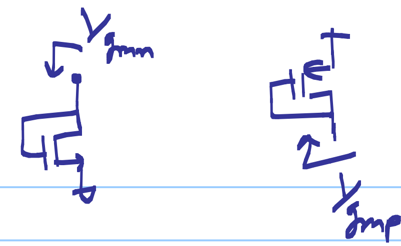
$$= -\sqrt{2kP_n \frac{W}{L}} \cdot \frac{V_{RD}}{\sqrt{I_D}}$$

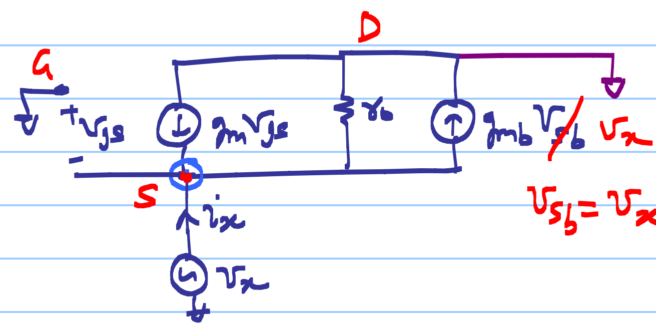
* $\frac{W}{L} \uparrow$ ⇒ large device cap
* $R_D \uparrow$ → $V_{R_D} \uparrow$ ⇒ lower swings
* $I_D \downarrow$ ⇒ $g_m \downarrow$ ⇒ $f_T \downarrow$ ⇒ lower speed



$Z_L = \frac{1}{g_{mp}(\eta+1)}$







$v_{sb} = v_x$

$-g_m v_x$

$$g_m v_{gs} - g_{mb} v_x - \frac{v_x}{r_o} + i_x = 0$$

$v_{gs} = -v_x$

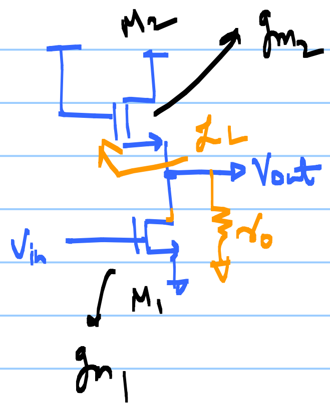
$$i_x = v_x\left(\frac{1}{r_o} + g_m + g_{mb}\right)$$

$$\frac{v_x}{i_x} = \frac{1}{g_m + g_{mb} + r_o^{-1}} \approx \frac{1}{g_m + g_{mb}}$$

$r_o \gg \frac{1}{g_m + g_{mb}}$

$$= \frac{1}{g_m(\eta+1)}$$

$\boxed{g_{mb} = \eta\, g_m}$



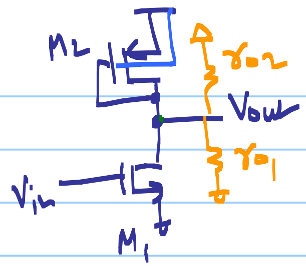
$$A_v = -g_{m_1} \frac{1}{g_{m_2}(\eta+1)}$$

$$= -\frac{g_{m_1}}{g_{m_2}} \cdot \frac{1}{\eta+1}$$

$g_{m_2} \ll g_{m_1}$

$\Rightarrow (W/L)_2 \ll (W/L)_1$

DC Biasing is implied



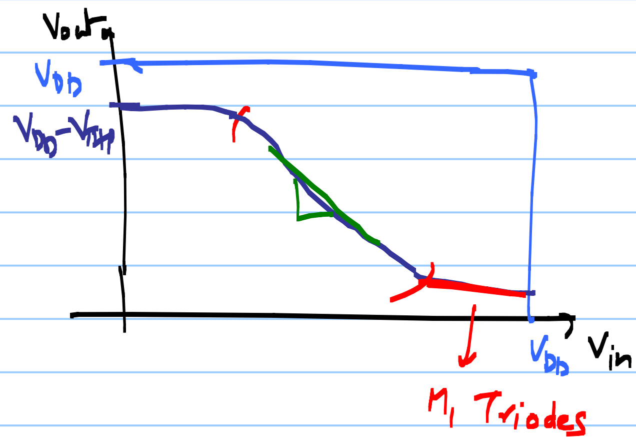
$$A_v = -g_{m_1} \cdot r_{o_1} \| r_{o_2} \| \frac{1}{g_{m_2}}$$

"low gain"

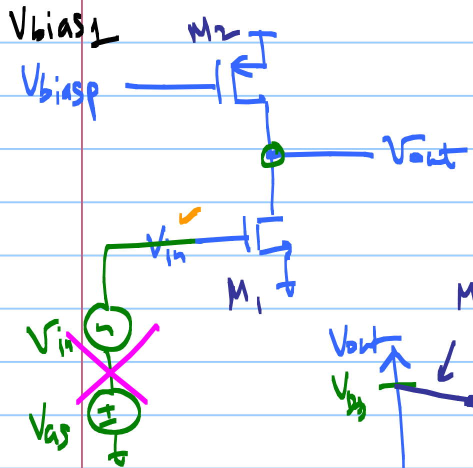
$$\approx -\frac{g_{m1}}{g_{m2}} = -\frac{\sqrt{2\beta_1 I_D}}{\sqrt{2\beta_2 I_D}}$$

$$= -\frac{\sqrt{(W/L)_1}}{\sqrt{(W/L)_2}}$$

"linear"



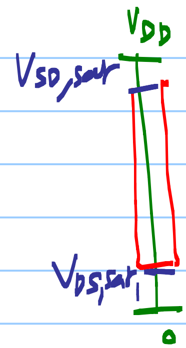
* Swing is limited on the output



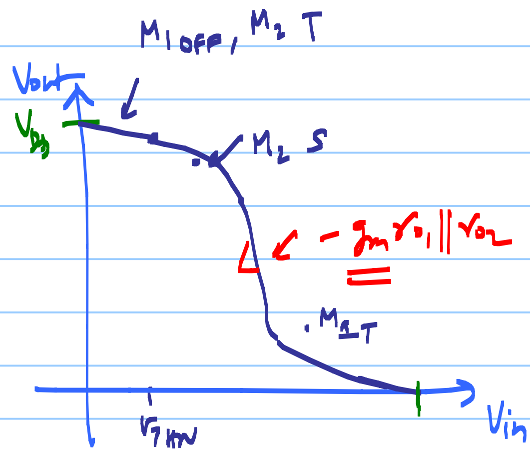
$A_v = -g_{m_1}\cdot(r_{o1}\|r_{o2})$

larger gain

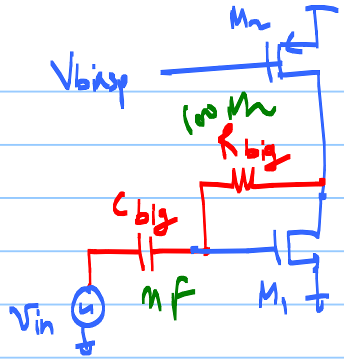
$\sim g_m r_o \propto \frac{L}{V_{ov}}$



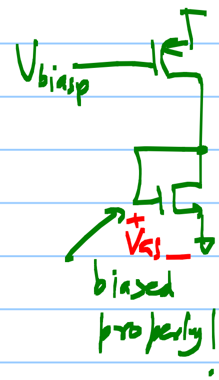
Large Swing



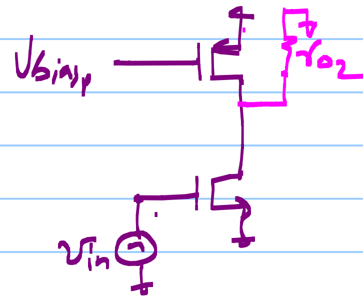
"Large signal"



DC picture



AC

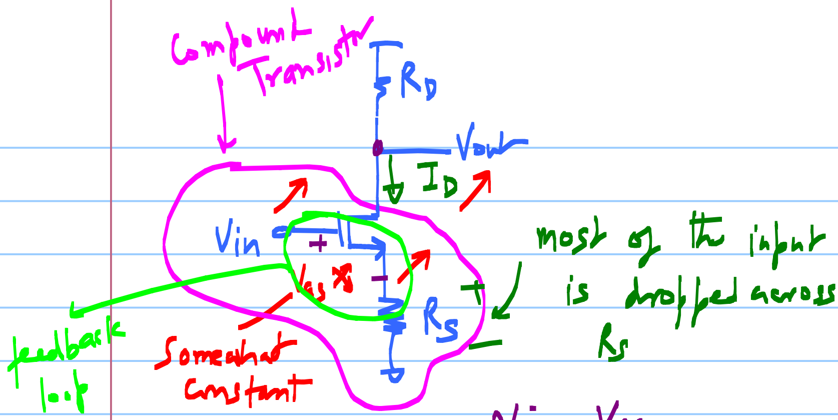


$$A_v = -g_m \, r_{o1} \| r_{o2}$$

↳ non-linearity

$$V_{in} \uparrow \Rightarrow V_{ov} \uparrow \Rightarrow g_m \uparrow$$

$$g_m = f(V_{in})$$



$$i_D = \frac{V_{in} - V_{GS}}{R_S}$$

Large Signal drain current

$\Rightarrow V_{out}$ is more linear

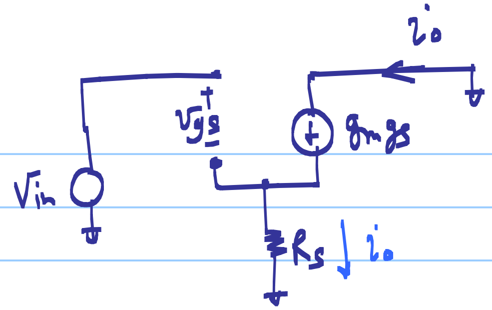
Source - Degeneration

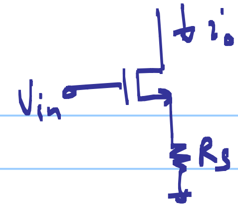
* When all the dropped across R_S

$$i_d \approx \frac{v_{in}}{R_S}$$

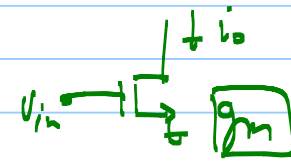
$$v_{out} \approx -\, i_d \cdot R_D =$$

$$\Rightarrow A_v \approx -\frac{R_D}{R_S}$$





$$\boxed{\begin{aligned}\gamma &= 0\\ \lambda &= 0\end{aligned}}$$



$$v_{gs} = V_{in} - i_o R_S \longrightarrow (1)$$

$$i_o = g_m v_{gs} \longrightarrow (2)$$

$$i_o(1 + g_m R_S) = g_m V_{in}$$

$$\boxed{\frac{i_o}{V_{in}} = \frac{g_m}{1 + g_m R_S} = G_m}$$

transconductance of the compound device

$$A_v = -G_m R_D$$

$$= -\frac{g_m R_D}{(1 + \underbrace{g_m R_S}_{\text{open loop gain}})}$$

g_m

$$G_m = \frac{g_m}{1+g_m R_s}$$

$$\cong \underbrace{1/R_s}_{\text{linear}}$$

large W device

$\frac{1}{g_m} \ll R_s$

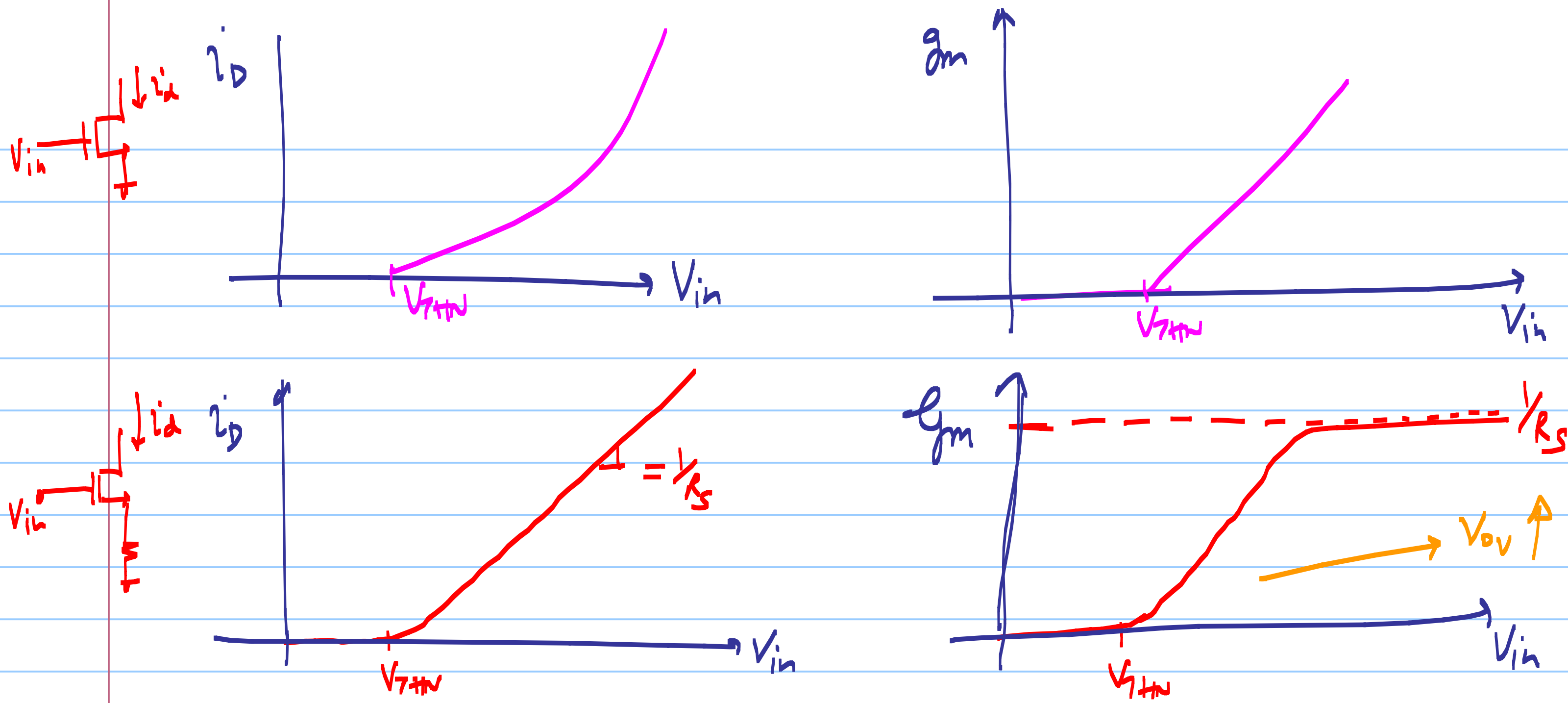
(+) higher linearity

(−) lower gain

(−) higher noise

with λ & $\gamma > 0$

$$G_m = \frac{g_m r_o}{R_s + [1+(g_m+g_{mb})R_s]r_o} \longleftarrow$$ HW Exercise



$$i_D = \frac{V_{in} - V_{GS}}{R_S}$$