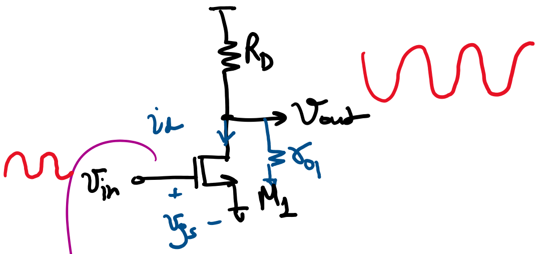
ECE 310 - Lecture 23

Friday, March 9, 2018 10:32 AM

Common Source Amplifiers



Biasing is understood (Bias networks are not shown)

$$i_d = g_m v_{gs} = g_m v_{in}$$

$$v_{out} = -i_d (R_D \| r_{o1})$$

$$= -g_m v_{in} (R_D \| r_{o1})$$

$$\Rightarrow A_v = \frac{v_{out}}{v_{in}} = -g_{m1}(r_{o1} \| R_D)$$

Small signal voltage gain

$$= -g_{m1} R_D \quad \text{if } r_{o1} \gg R_D$$

Output is inverted (180° phase shift)

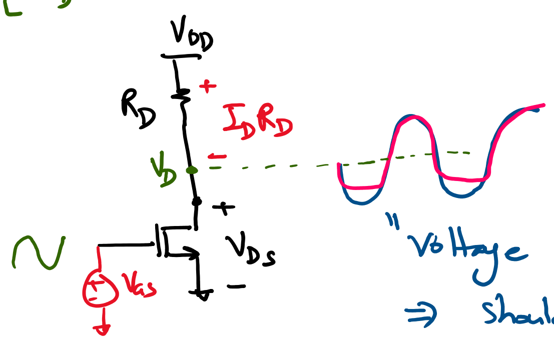
CS ⇒ inverting amplifier

$$A_v = -g_m R_D$$

$$g_m = \sqrt{2 KP_n \frac{W}{L} I_D}$$

$A_v \uparrow \Rightarrow R_D \uparrow$.

$I_D \uparrow$



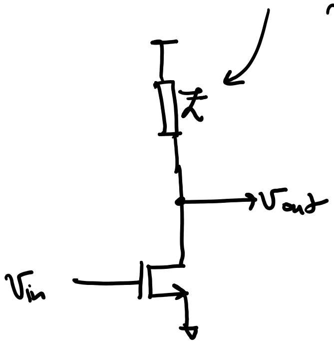
$I_D R_D \uparrow \Rightarrow V_{DS} \downarrow$

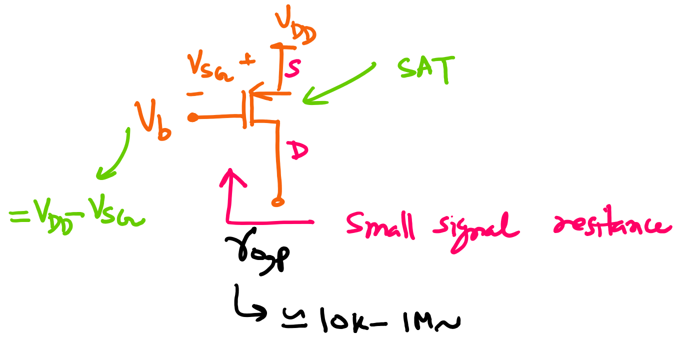
$V_{DS} < V_{DS,sat} \Leftarrow M_1$ will Triode

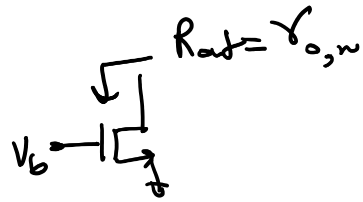
"Voltage headroom"

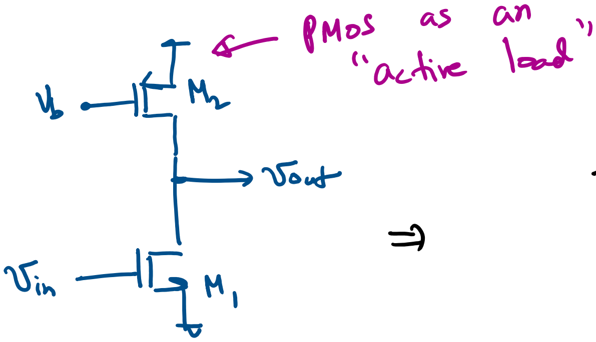
⇒ Should get amplification without Trioding M_1

need high-Z load without dropping much voltage across it.



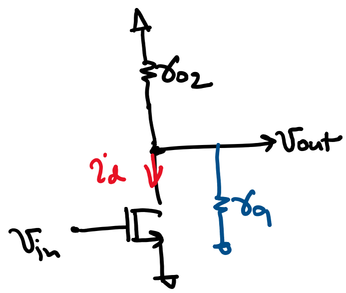






⇒

Ac picture

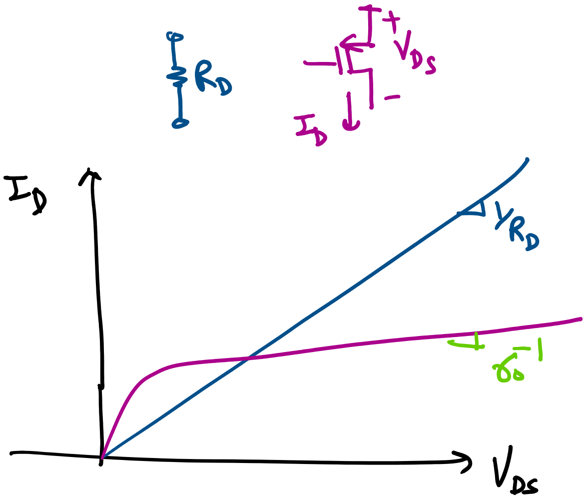


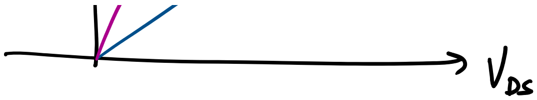
$$v_{out} = -i_d \cdot (r_{o1} \| r_{o2})$$

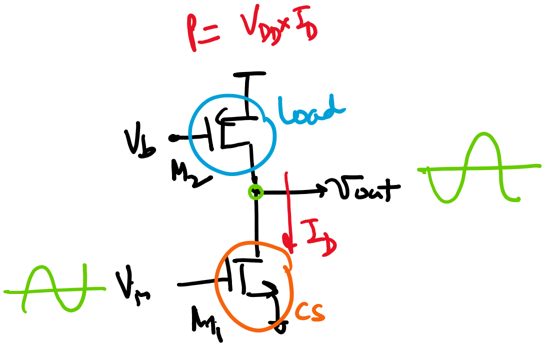
$$= -g_{m1} v_{in} (r_{o1} \| r_{o2})$$

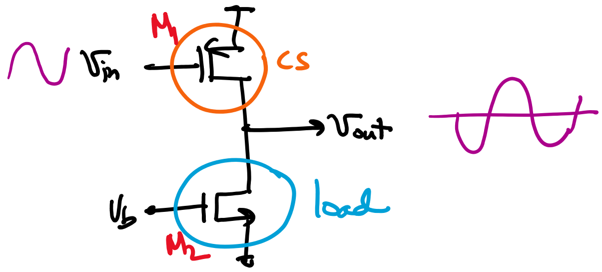
$$\boxed{A_v = -g_{m1} (r_{o1} \| r_{o2})}$$

Very large gain without incurring a large V_{SD} across M_2







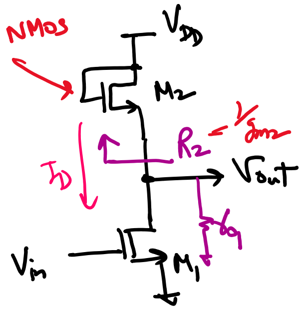


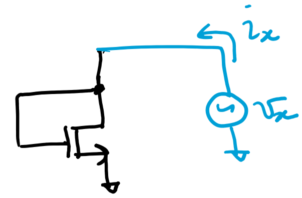
$$A_v = -g_m(r_{o1} \| r_{o2})$$

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

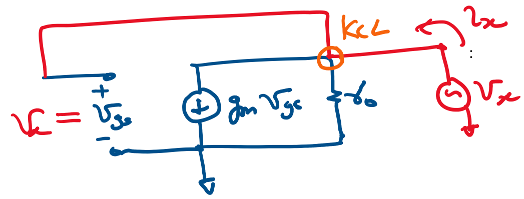
* Do Book Examples

17.14, 15, 16 & 17





$R_{out} = \frac{v_x}{i_x}$



$A_v = -g_{m1}\left(r_{o1} \| \frac{1}{g_{m2}}\right)$

$\simeq -\frac{g_{m1}}{g_{m2}} \Leftarrow$ gain $= (2-5)$

$= -\frac{\sqrt{\cancel{2}\beta_1 \cancel{I_D}}}{\sqrt{\cancel{2}\beta_2 \cancel{I_D}}}$ $\quad \beta_n = KP_n \frac{W}{L}$

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

$= -\sqrt{\frac{W_1}{W_2}}$

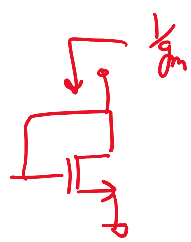
(+) more precise (linear) gain than $g_m r_o$

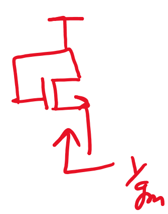
(−) gain is much lower

KCL $\Rightarrow$ $i_x - \frac{v_x}{r_o} - g_m v_{gs} = 0$, $\quad v_{gs} = v_x$

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

$\Rightarrow R_{out} = \frac{v_x}{i_x} = \frac{1}{g_m + 1/r_o} = \frac{r_o}{1 + g_m r_o}$





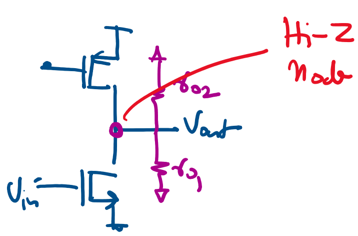
$= \frac{r_o \cdot 1/g_m}{1/g_m + r_o}$

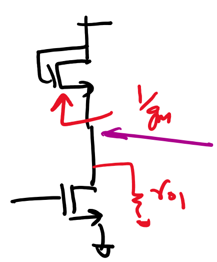
$= \frac{1}{g_m} \| r_o$

If $r_o \gg 1/g_m$

or $g_m r_o \gg 1$

$R_{out} \simeq 1/g_m$

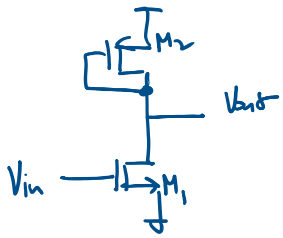




Low-Z node

$\Rightarrow$ gain dropped

for higher gain $\Rightarrow$ High output impedance.



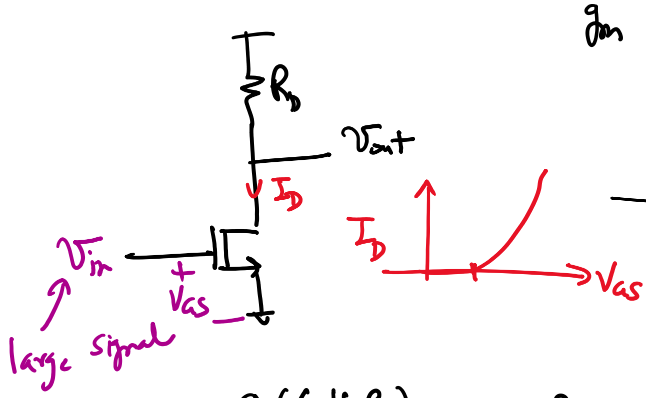
$$A_v \simeq -\frac{g_{m1}}{g_{m2}}$$

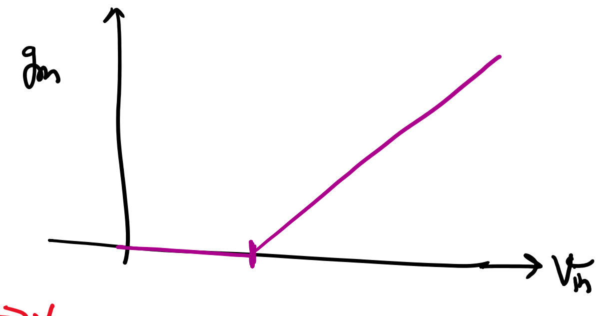
for $r_o \gg 1/g_m$

$$A_v = -g_{m1}\cdot\left(r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2}\right)$$

precise

CS



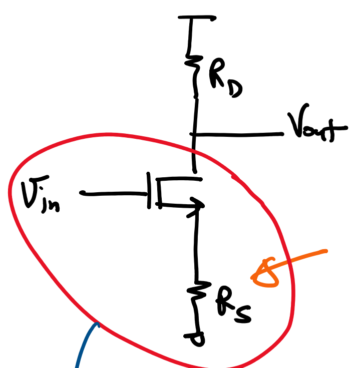


$$-g_m(r_o \,||\, R_D) \simeq -g_m R_D$$

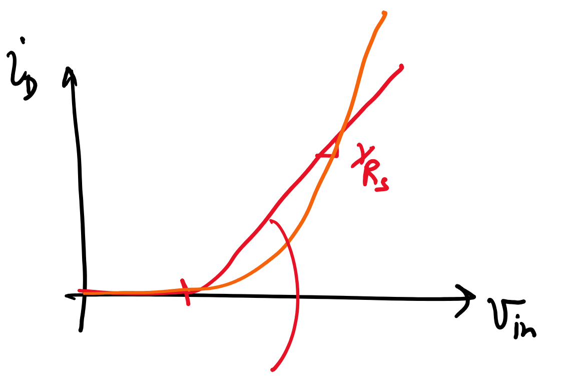
$-g_m R_D \Rightarrow$

non linearity

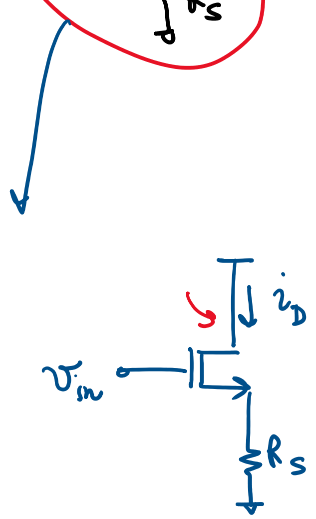
Add R_s to the source



Source degeneration

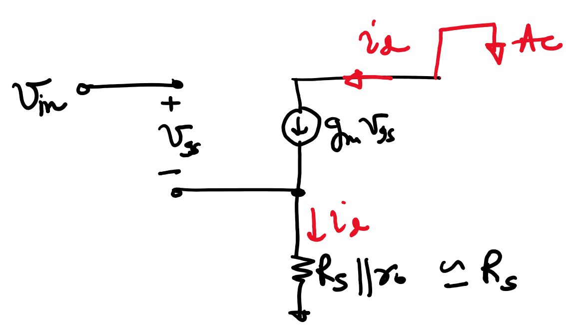


linear gain for large input signals



$\Rightarrow$

Ac Equivalent circuit

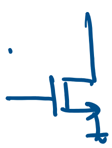


$$v_{in} = v_{gs} + i_d R_s$$

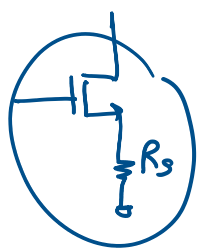
$$= \frac{i_d}{g_m} + i_d R_s$$

$$\Rightarrow \quad i_d\left(\frac{1}{g_m} + R_s\right) = v_{in}$$

$$\Rightarrow \quad i_d = \underbrace{\frac{g_m}{1 + g_m R_s}}_{G_m} v_{in}$$



g_m



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