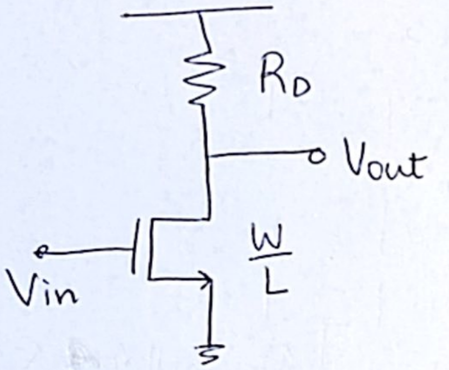
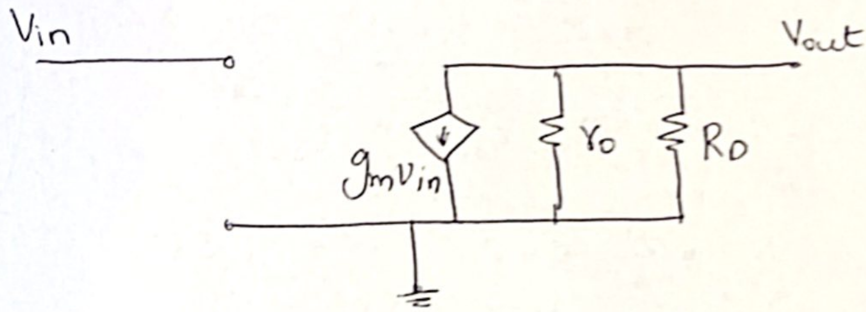
Lec18

Single transistor amplifiers

1) Common Source (review)





$\Rightarrow$ $V_{out} = -g_m V_{in} (r_o \| R_D)$

$\Rightarrow$ $\boxed{A_v = -g_m (r_o \| R_D)}$

Rin

Apply V_{test} & find i_{test}. In this case $\boxed{R_{in} = \infty}$

Rout

$V_x =$ ~~$i_x - g_m V_{in}$ / $r_o \| R_D$~~ $(i_x - g_m V_{in}^{\,0}) r_o \| R_D$

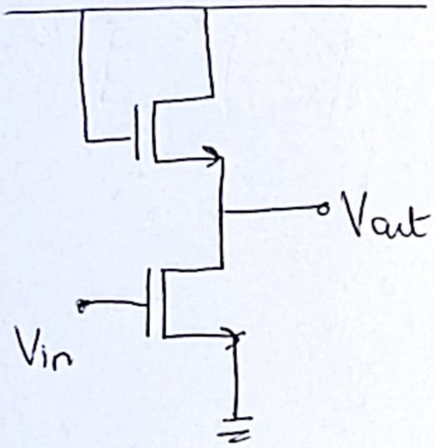
$\Rightarrow$ $\boxed{R_{out} = r_o \| R_D}$

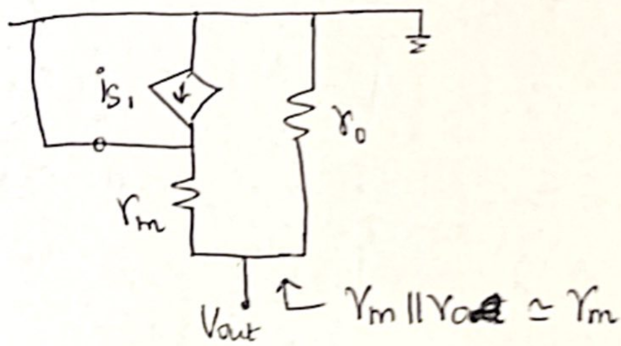
> We discussed source degeneration & also the diode connected load.

Diode connected load

$(r_m \ll r_{mb} \ll r_o)$

100 1k 10k

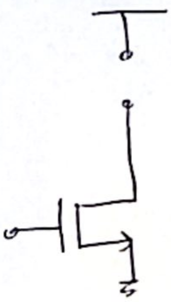




$$\Rightarrow A_v = -g_{m1} r_{m2}$$

$$= -\frac{g_{m1}}{g_{m2}} \simeq -\sqrt{\frac{W_1/L_1}{W_2/L_2}}$$

> Gain is low although it is well defined. What if I want to maximize the gain? We need an infinite resistor.

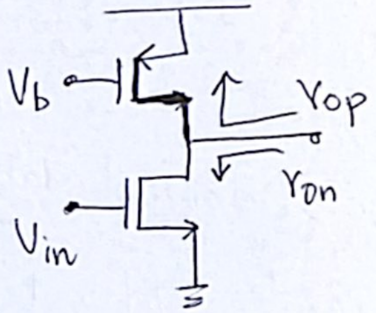


→ We need only an open in "small signal".

$$\frac{\partial I}{\partial V} = 0$$

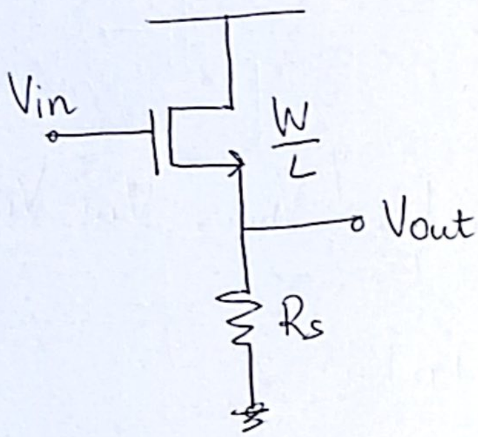
$A_v = -g_m r_o$

- In practice we use a PMOS load.



$$\Rightarrow \boxed{A_v = -g_m (r_{on} \| r_{op})}$$

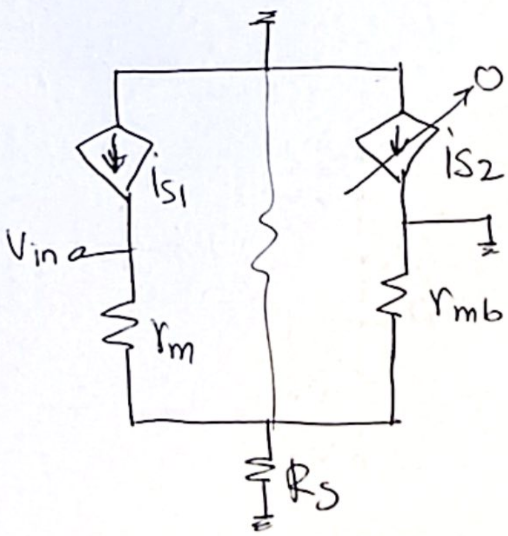
Common Drain (Source Follower)



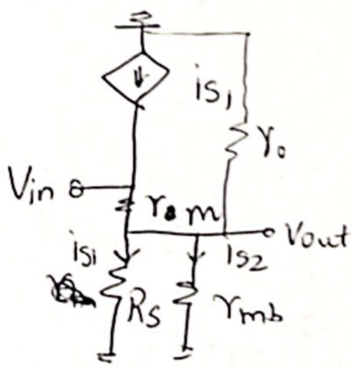
$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{in} - V_{out} - V_T)^2$$

$$V_{out} = R_S \left[\frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{in} - V_{out} - V_T)^2 \right]$$

Small Signal Model



$\rightarrow$



$$\Rightarrow A_v = \frac{R_S \| r_{mb}}{R_S \| r_{mb} + r_m}$$

$$= \frac{R_S}{r_m + R_S(1+\chi)}$$

$$\chi = \frac{g_{mb}}{g_m}$$

Note: $A_v < 1$

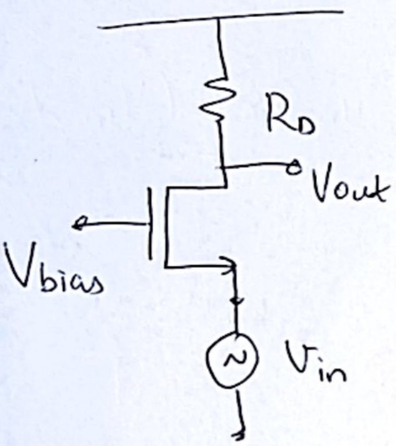
Source Follower since V_{out} closely follows V_{in} - Why is it useful?

$R_{in} = \infty$

$R_{out} = R_S \| r_m \| r_{mb} < r_m$ → good driver stage.

Commonly used as a buffer stage.

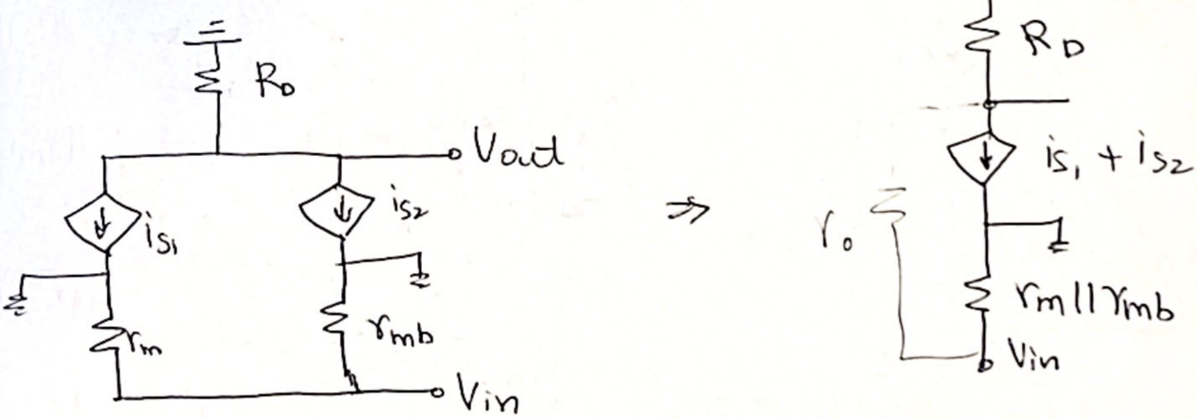
Common Gate

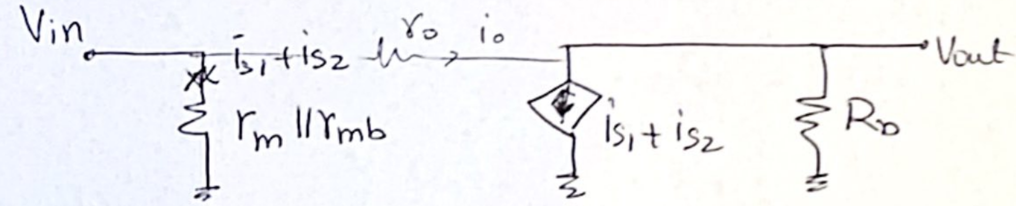


$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(V_{bias}-V_{in}-V_T\right)^2$$

$$V_{out} = V_{DD} - I_D R_D$$

Small Signal Model



$\Rightarrow$ 

$$V_{out} = -(i_{s_1} + i_{s_2}) R_D = \left(V_{in} / (r_m \parallel r_{mb}) \right) R_D$$

$$\Rightarrow A_v = \frac{R_D}{r_m \parallel r_{mb}} = (g_m + g_{mb}) R_D$$

$$\Rightarrow \boxed{A_v = (g_m + g_{mb}) R_D}$$ $\rightarrow$ Non inverting.

Note: Here Body Effect increases the gain!

$R_{in} = r_m \parallel r_{mb}$
$R_{out} = R_D$
} Ignoring r_o

<u>Including r_o</u>

$V_{in} =$ ~~$i_s(r_m \parallel r_m$~~ $+ i_s (r_m)$

$$\frac{V_{in} - V_{out}}{r_o} = i_o \qquad V_{out} = (i_o + i_s) R_D$$

$$V_{out} = \left[\left(\frac{V_{in}-V_{out}}{r_o}\right) + \frac{V_{in}}{r_m}\right] R_D$$

$$V_{out}\left(\frac{1}{R_D} + \frac{1}{r_o}\right) = V_{in}\left(\frac{1}{r_o} + \frac{1}{r_m}\right)$$

$$\Rightarrow A_v = (R_D \| r_o) / (r_o \| r_m)$$

$$\boxed{A_v = \frac{R_D \| r_o}{r_o \| r_m \| r_{mb}}}$$

Rout

$$R_{out} = R_D \| r_o$$

$$R_{in} = r_m \| r_{mb} \| r_o$$