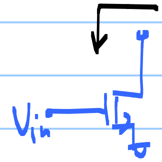
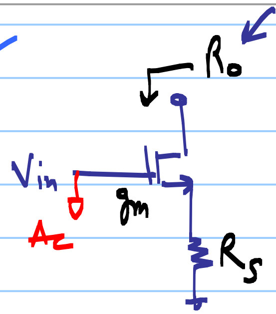
ECE 511 – Lecture 11

Note Title 2/26/2013

$R_o = r_o$

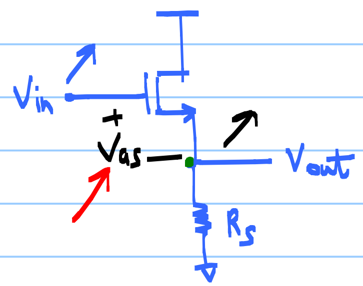


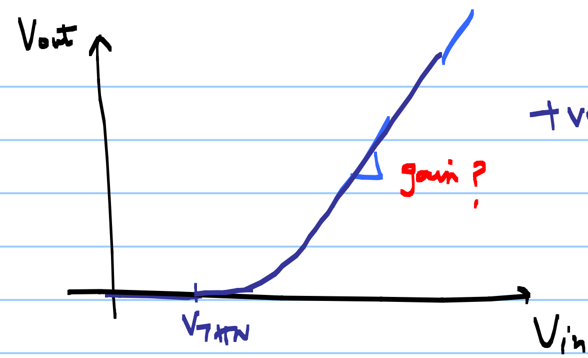


$$R_o = \left(1 + (g_m + g_{mb}) R_s\right) r_o$$

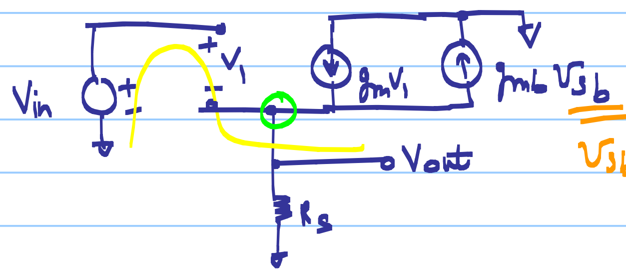
$$\simeq (g_m r_o) R_s \leftarrow \text{moderate} \leftrightarrow \text{high resistance}$$

Source follower (Common Drain Amplifier)





+ve gain



$v_{sb} = v_{out}$

$\boxed{\lambda = 0}$

$V_{in} - V_1 = V_{out} \longrightarrow (1)$

$g_m V_1 - g_{mb} v_{out} = \dfrac{v_{out}}{R_S} \longrightarrow (2)$

(1) & (2) $\quad g_m (V_{in} - V_{out}) - g_{mb} v_{out} = \dfrac{v_{out}}{R_S}$

$$\Rightarrow \quad V_{out}\left(g_m + g_{mb} + \frac{1}{R_S}\right) = g_m V_{in}$$

$$\Rightarrow \quad \boxed{A_v = \frac{V_{out}}{V_{in}} = \frac{g_m R_S}{1 + (g_m + g_{mb}) R_S}}$$

+ve
non-inverting
gain

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

$$= \frac{1}{\eta + 1 + \frac{1}{g_m R_S}}$$

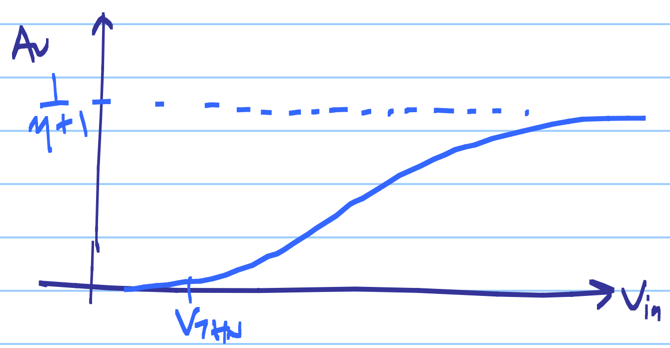
$$\cong \left(\frac{1}{\eta+1}\right) \quad \text{for } g_m R_S >> 1$$

< 1

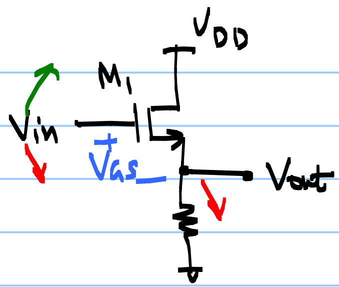
0.7–0.8

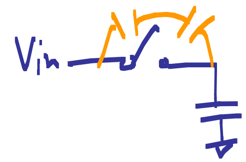
$\because g_{mb} = \eta g_m$

$\eta < 1$



* Will M_1 ever triode?





$$
\begin{aligned}
V_{DS} &= V_{DD} - V_{out} \\
&= V_{DD} - (V_{in} - V_{GS}) \\
&= V_{DD} - V_{in} + V_{GS} \\
&= V_{GS} - (V_{in} - V_{DD})
\end{aligned}
$$

$V_{DS} \geq V_{DS,sat}$

$= V_{GS} - V_{THN}$

M_1 Triodes for: $V_{DS} < V_{GS} - V_{THN}$

$\cancel{V_{GS}} - V_{in} + V_{DD} < \cancel{V_{GS}} - V_{THN}$

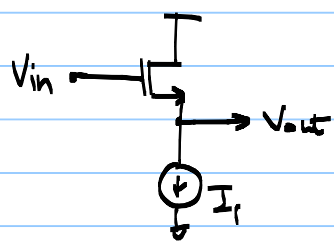
$\Rightarrow$ $V_{in} > V_{DD} + V_{THN}$

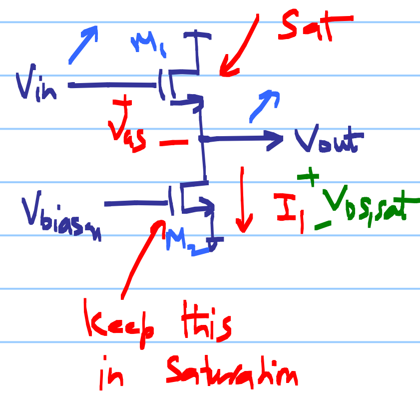
Never happens!

* I_D depends upon V_{in} → DC level

⇒ $I_D = f(V_{in})$

$g_m = f(V_{in})$ → non-linear

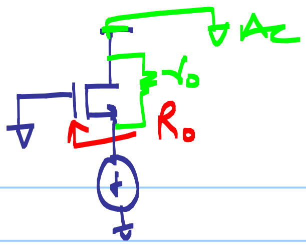


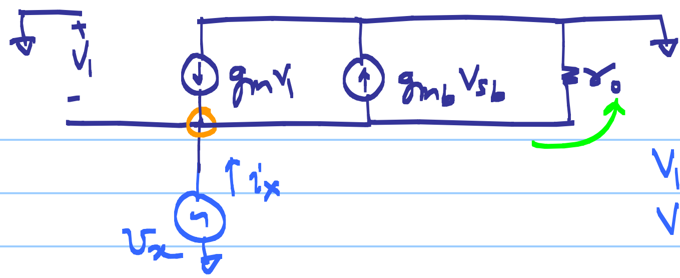


I_1 biases M_1

$V_{in} \geq V_{GS_1} + V_{DS,sat_2}$

↑ input headroom issue





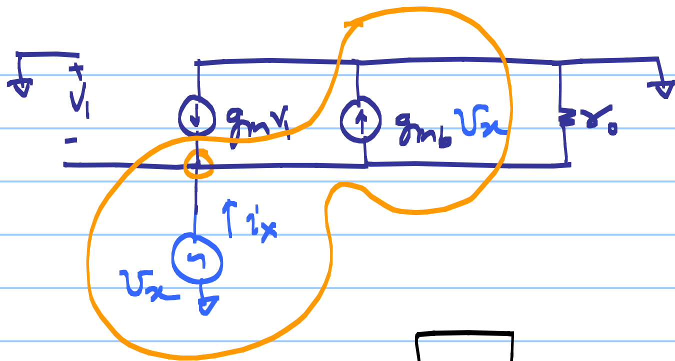
$V_1 = -V_x$

$V_{sb} = v_x$

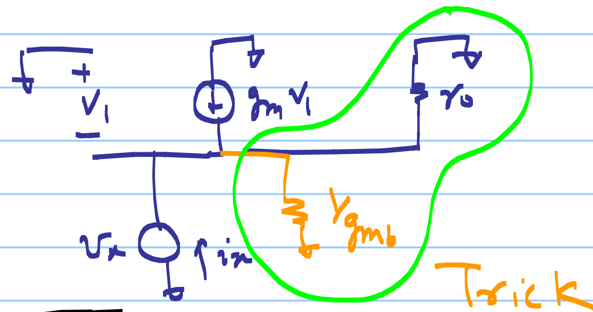
$$i_x - g_m v_x - g_{mb} v_x - \frac{v_x}{r_o} = 0$$

$$\Rightarrow \quad R_o = \frac{v_x}{i_x} = \frac{1}{g_m + g_{mb} + 1/r_o} = 1/g_m \,\|\, \frac{1}{g_{mb}} \,\|\, r_o$$

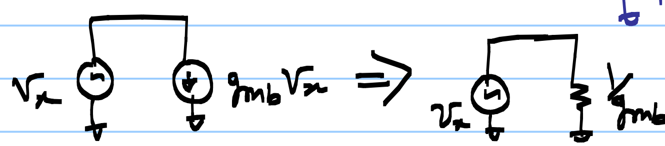
$$\simeq \frac{1}{g_m} \quad \leftarrow \text{Rout is small}$$



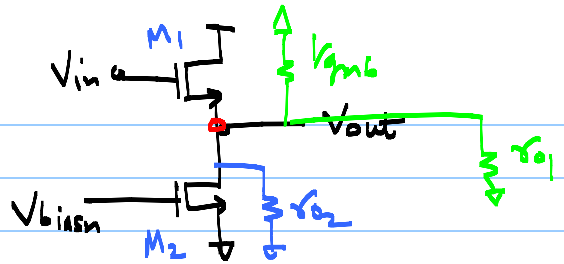
+
V_1
-
$g_m V_1$
$g_{mb} v_x$
r_o
i_x
v_x



+
V_1
-
$g_m V_1$
r_o
$1/g_{mb}$
v_x
i_x
Trick

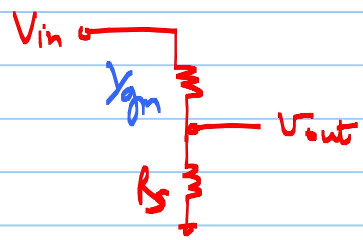


v_x
$g_{mb} v_x$
$\Rightarrow$
v_x
$1/g_{mb}$



$R_S = \frac{1}{g_{mb}} \| r_{o1} \| r_{o2}$

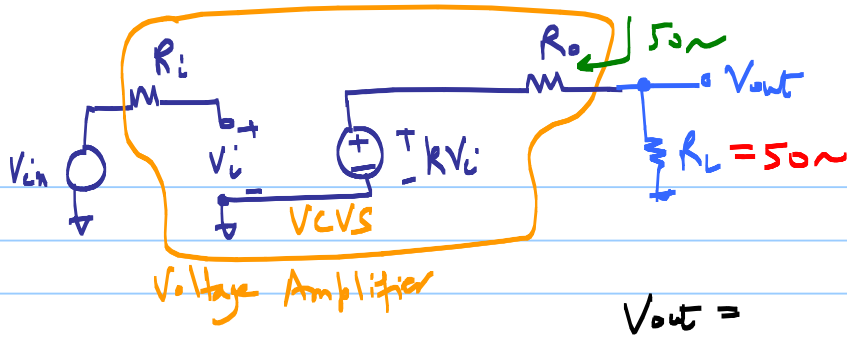
resistance connected to source



"Voltage Divider Analogy"

$$A_v = \frac{\frac{1}{g_{mb}} \| r_{o1} \| r_{o2}}{\frac{1}{g_m} + \frac{1}{g_{mb}} \| r_{o1} \| r_{o2}}$$

for a very large g_m, $A_v \rightarrow 1$



$$V_{out} = kV_{in} \cdot \left(\frac{R_L}{R_o + R_L}\right)$$

$$= \frac{kV_{in}}{\left(\frac{R_o}{R_L}\right) + 1}$$

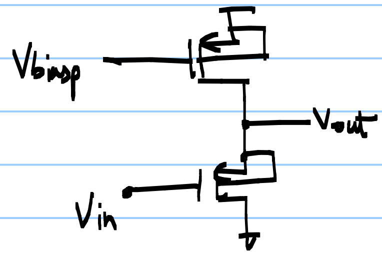
$$\simeq kV_{in} \quad \text{for} \quad R_o \ll R_L$$

Issues as a Voltage Buffer

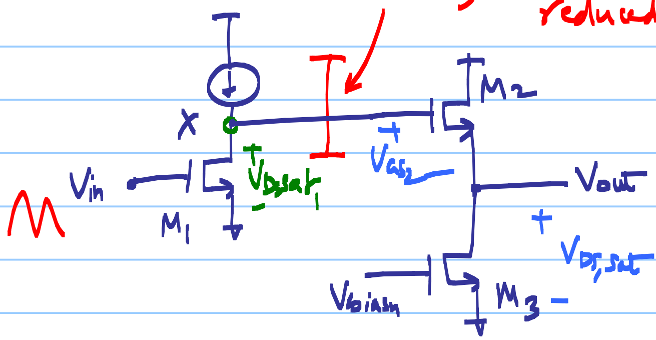
1. Body effect, $V_{THN} = f(V_{in}) \rightarrow$ non-linearity
2. DC shift $\rightarrow$ headroom issues
3. A_v drops significantly for low R_L.

Body-effect

PMOS SF

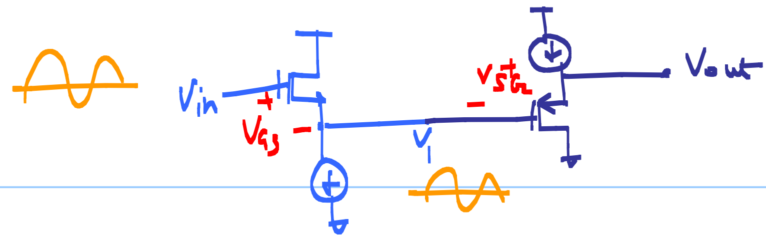


Voltage headroom reduced by V_{GS_2}



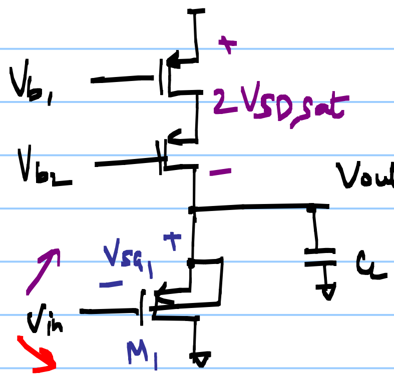
$V_x > V_{GS_2} + V_{DS,sat}$

"DC level shift"



NMOS

"DC level manipulations"



$$V_{out} = V_{in} + V_{SG_1}$$

* find allowed range of V_{in}

$$-V_{THp} \le V_{in} \le V_{DD} - \underbrace{2V_{SD,sat} - V_{SG_1}}_{\text{headroom loss}}$$

↑ Triode condition