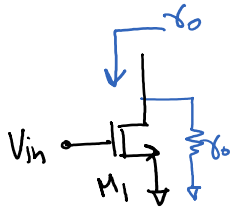
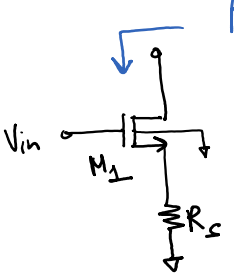
ECE 511 – Lecture 11

Thursday, September 27, 2018 11:06 AM

Razavi Book

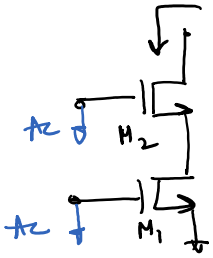




$$R_{out} = \left[1 + (g_{m_1} + g_{mb_1}) R_S\right] r_{o_1}$$

$$\simeq g_{m_1} r_{o_1} R_S$$

M_1 has body-effect

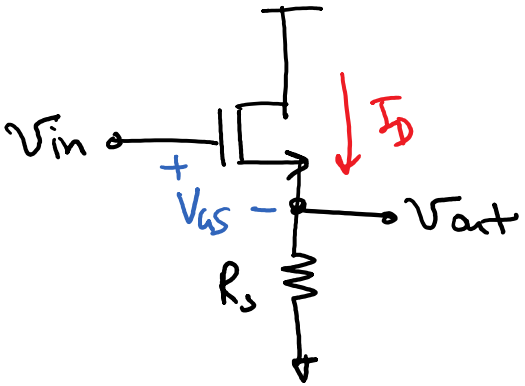


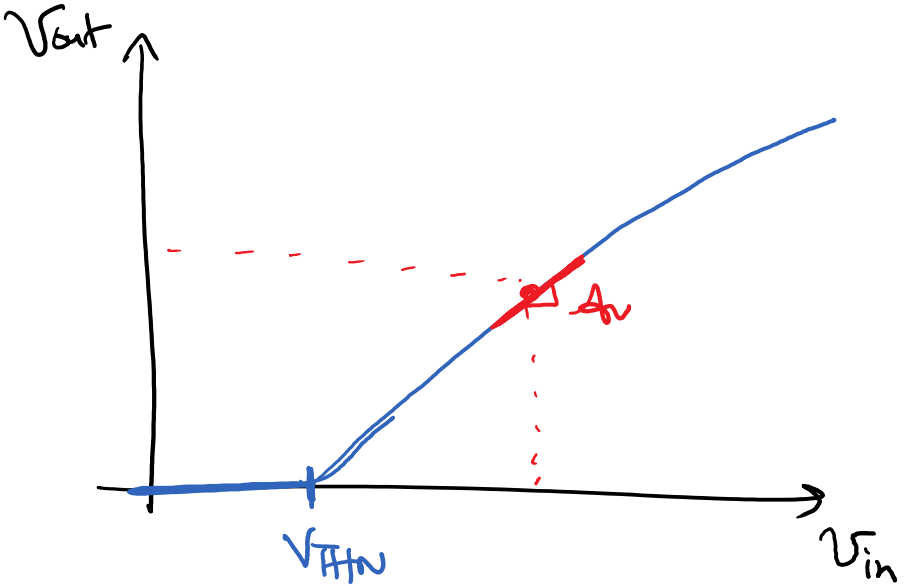
$R_{out} \simeq g_{m_2} r_{o_2} \cdot r_{o_1}$

$R_{out} = r_{o_1} + r_{o_2}$

Source follower (Common Drain amplifier)

Thursday, September 27, 2018 11:12 AM

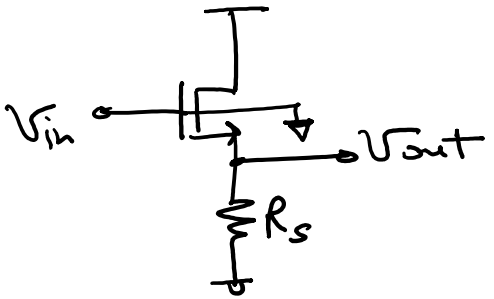


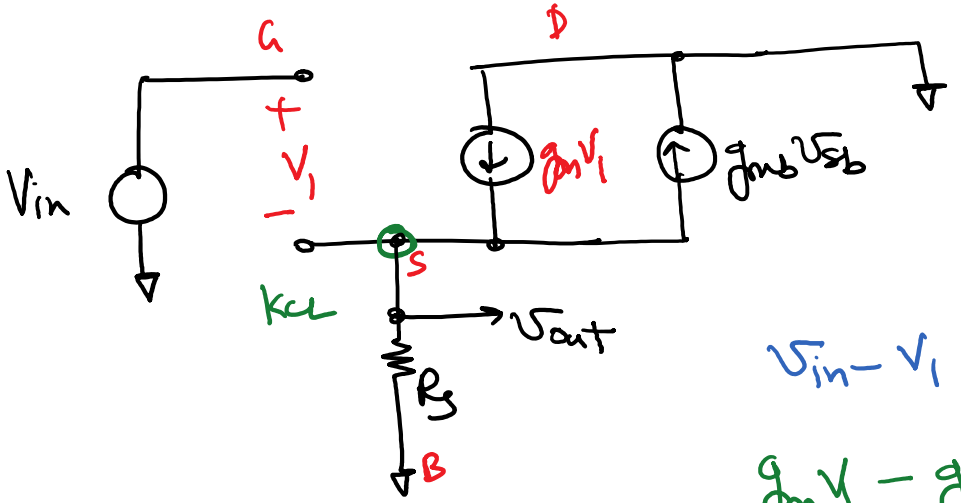


$V_{out} = V_{in} - V_{GS}$

↳ level shift

Small signal gain:





$V_{sb} = V_{out}$

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

$$g_m V_1 - g_{mb} V_{out} = \frac{V_{out}}{R_s} \longrightarrow (2)$$

$$\Rightarrow g_m (V_{in} - V_{out}) - g_{mb} V_{out} = \frac{V_{out}}{R_s}$$

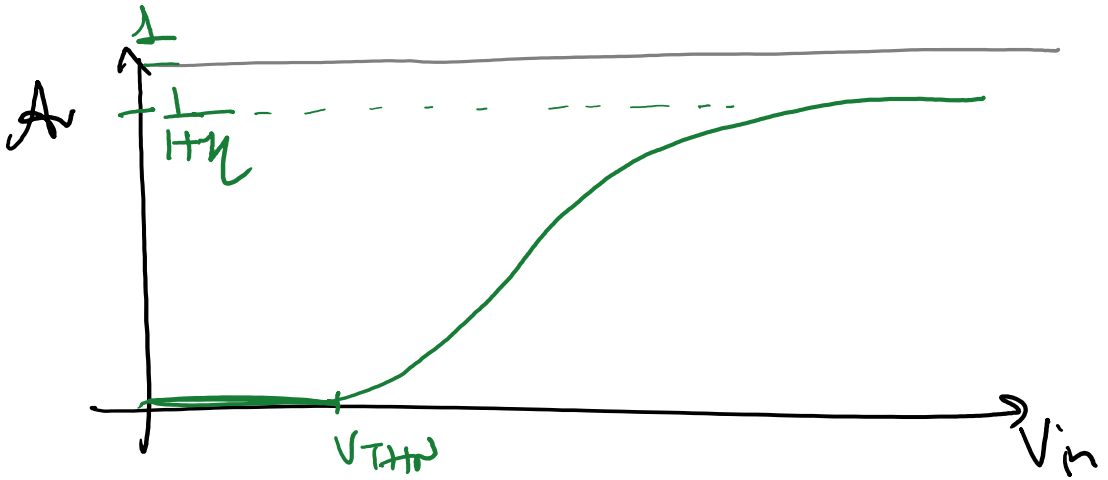
$$\Rightarrow V_{out} \left[(g_m + g_{mb}) + \frac{1}{R_s} \right] = g_m V_{in}$$

$$A_v = \frac{V_{out}}{V_{in}} = \frac{g_m R_s}{1 + R_s (g_m + g_{mb})}$$

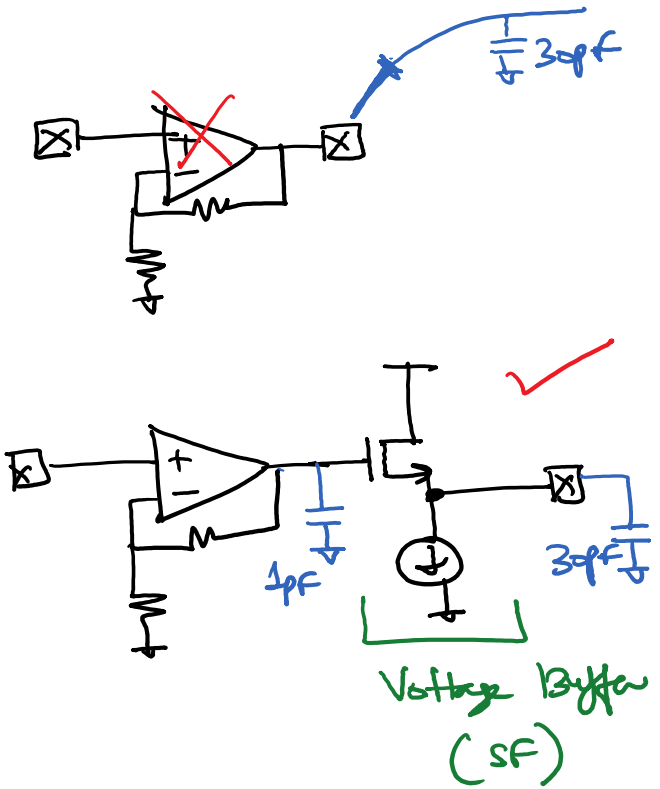
$$A_v = \frac{v_{out}}{v_{in}} = \frac{v_{out}}{1 + (g_m + g_{mb}) R_s}$$

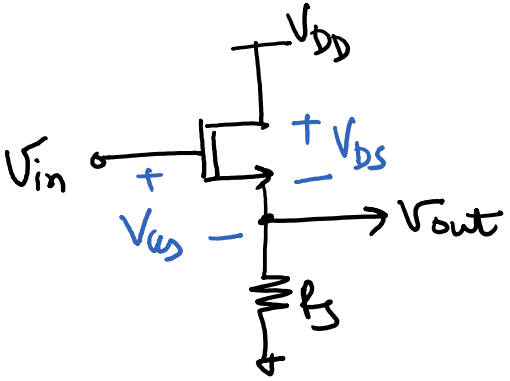
$$A_v = \frac{g_m R_S}{1+(\eta+1) g_m R_S} = \frac{1}{(\eta+1)+\frac{1}{g_m R_S}} \simeq \frac{1}{\eta+1} \quad \text{if } g_m R_S \gg 1$$

$$\Rightarrow A_v < 1$$



Thursday, September 27, 2018 11:25 AM





$$V_{DS} = V_{DD} - V_{out}$$

$$= V_{DD} - (V_{in} - V_{GS})$$

$$= V_{DD} - V_{in} + V_{GS} \longrightarrow (1)$$

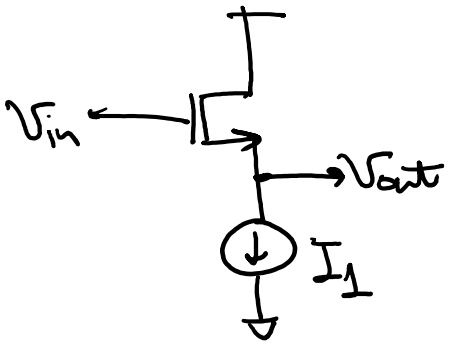
for SAT: $V_{DS} > V_{DS,sat}$

$$V_{DD} - V_{in} + V_{GS} > V_{GS} - V_{THN}$$

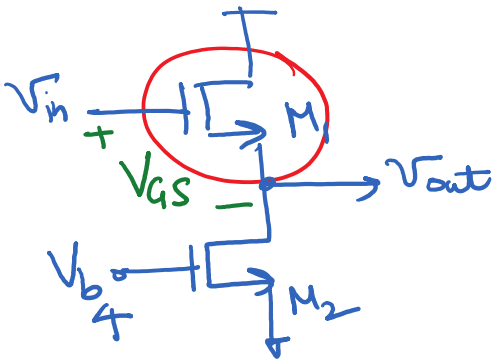
$$V_{DD} - V_{in} > -V_{THN}$$

$$\Rightarrow \quad V_{in} < V_{DD} + V_{THN}$$

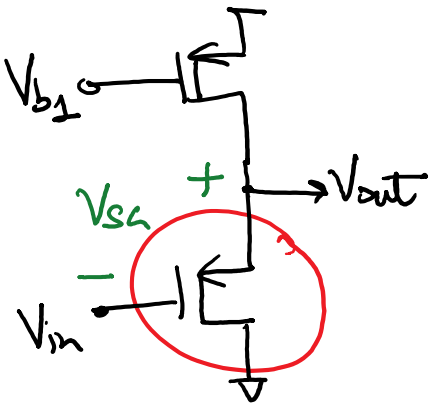
M_1 never triodes!

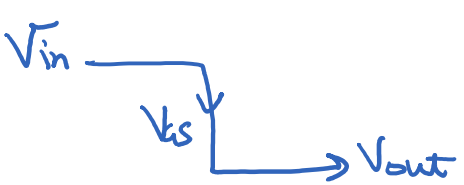


NMOS SF

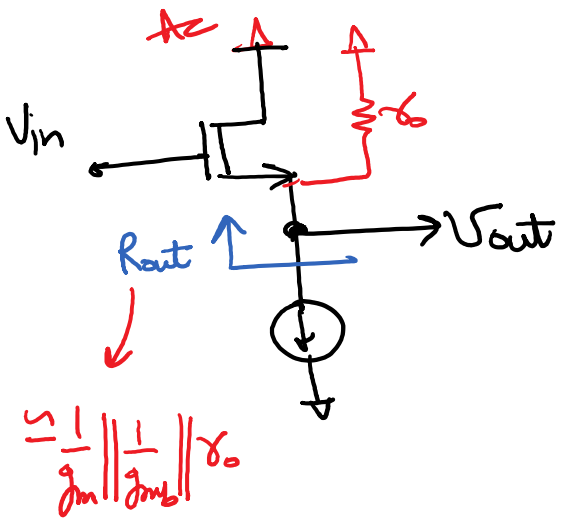


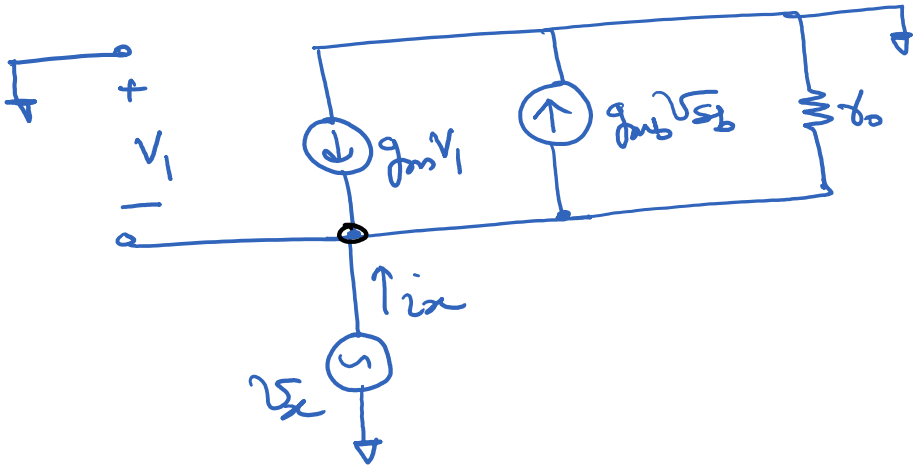
PMOS SF





Level shifter





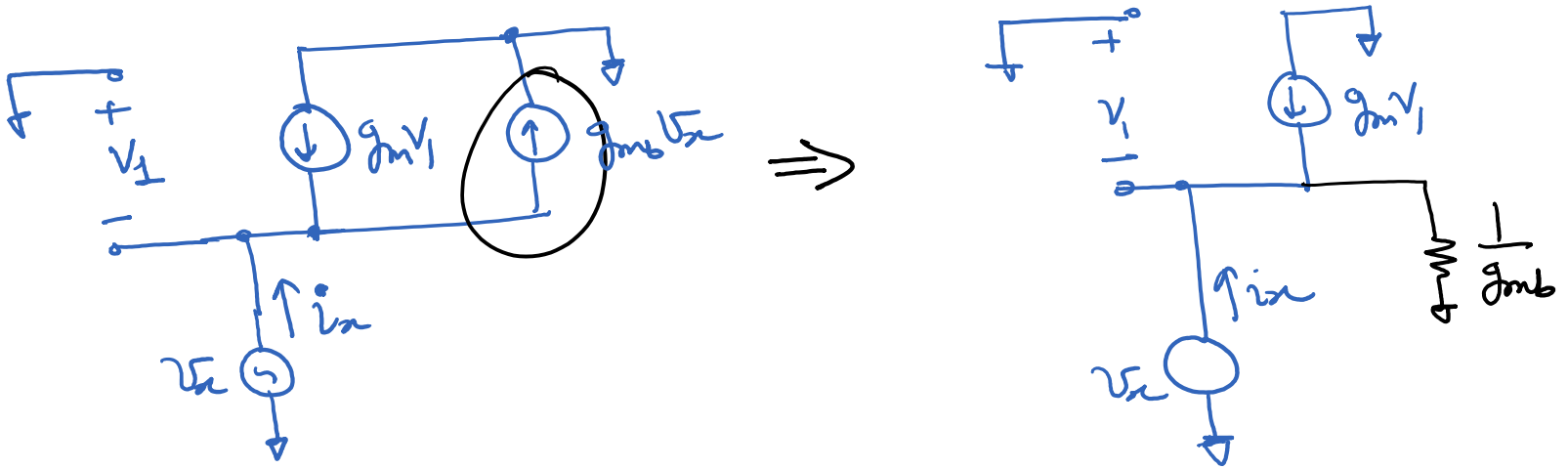
KCL:

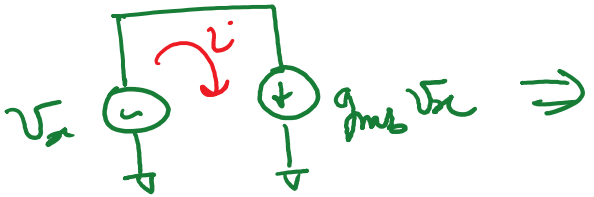
$$i_x - g_m V_x - g_{mb} V_x + \frac{V_x}{r_o} = 0$$

$$R_{out} = \frac{1}{g_m + g_{mb} + r_o^{-1}} = \frac{1}{g_m} \| \frac{1}{g_{mb}} \| r_o \simeq \frac{1}{g_m}$$

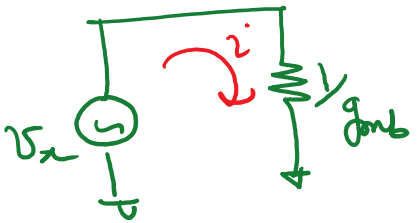
resistance looking into the source

$\times$ low-impedance output

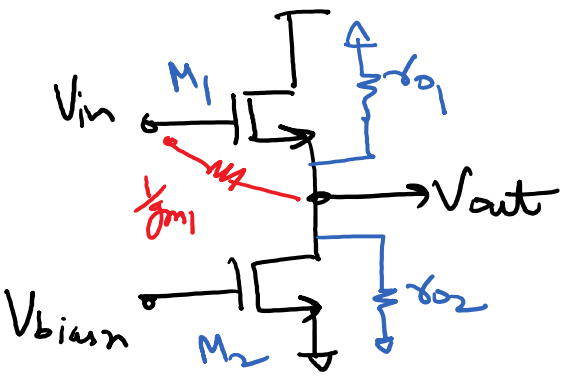


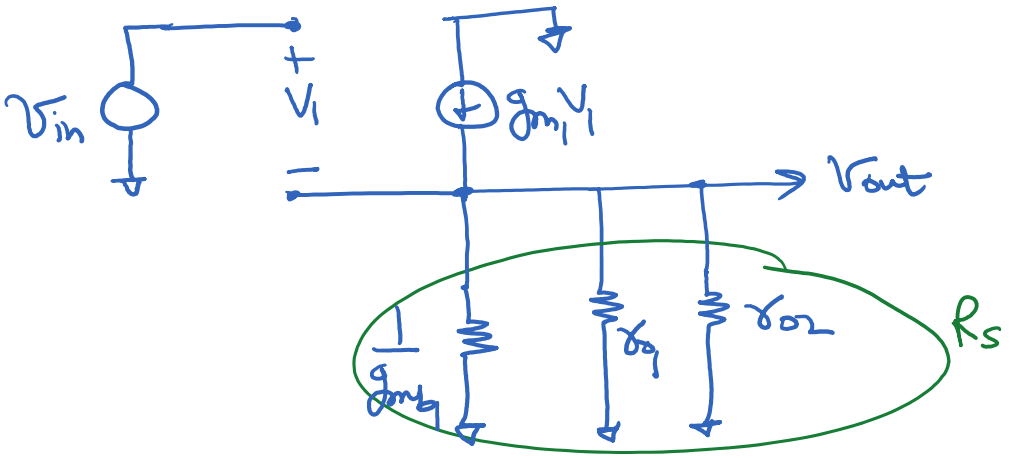


$i = g_{mb} v_x$

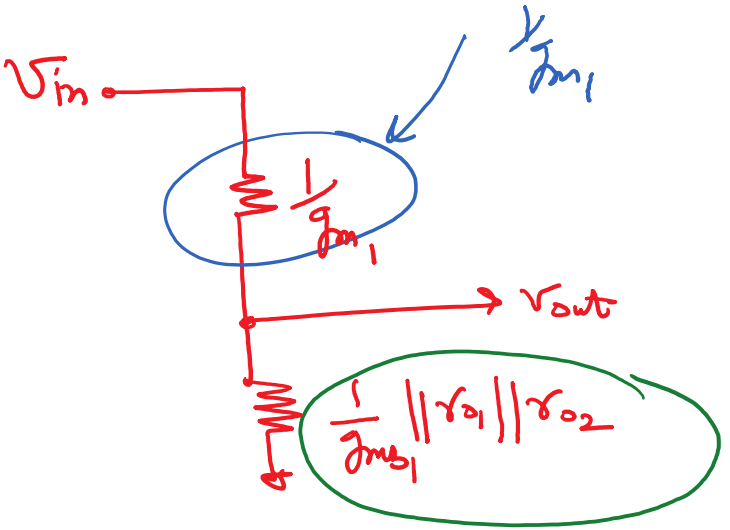


$i_x = v_x g_{mb}$

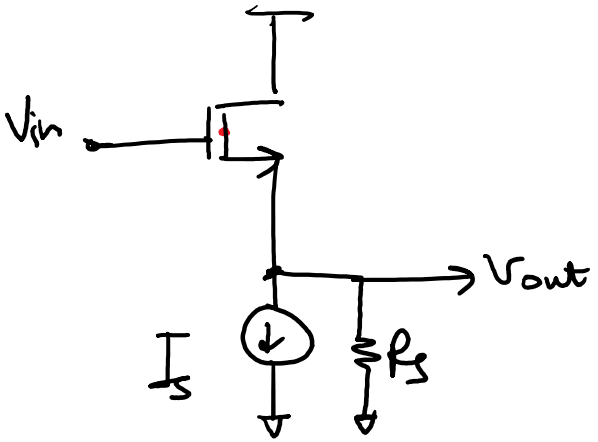




$$\frac{v_{out}}{v_{in}} = \frac{\frac{1}{g_{mb_1}} \| r_{o_1} \| r_{o_2}}{\frac{1}{g_{m_1}} + \frac{1}{g_{mb_1}} \| r_{o_1} \| r_{o_2}}$$



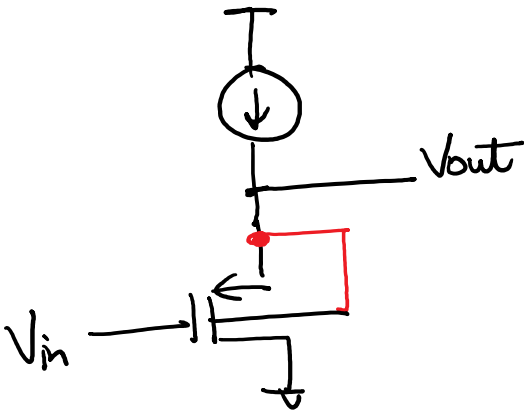
Resistance connected to the source

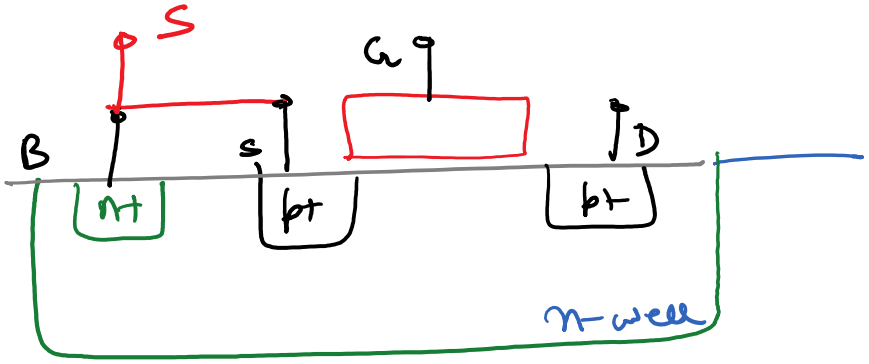


$$A_v = \frac{R_s \| \frac{1}{g_{mb}} \| r_{o1}}{\frac{1}{g_{m1}} + R_s \| \frac{1}{g_{mb}} \| r_{o1}}$$

ignoring g_{mb} we would have gotten

$$A_v = \frac{R_s \| r_{o1}}{\frac{1}{g_{m1}} + R_s \| r_{o1}}$$ X



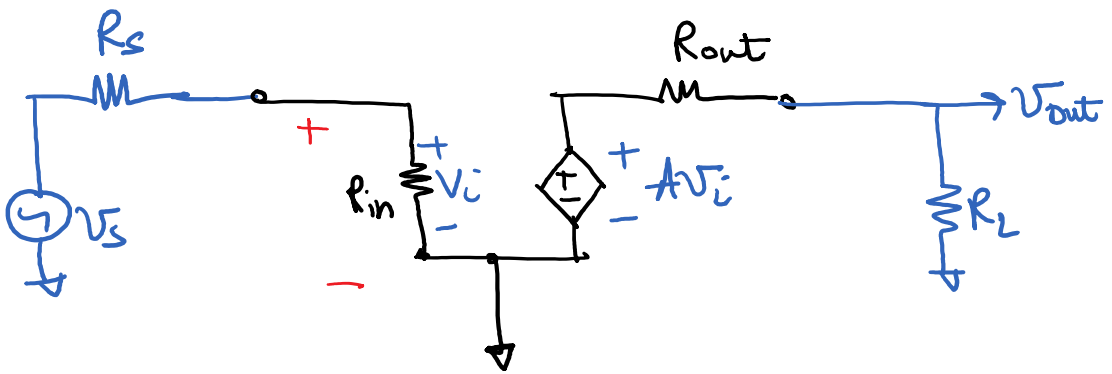


p-Si

PMOS SF offers flexibility of eliminating body effect

Voltage amplifier

Thursday, September 27, 2018 11:56 AM



$v_{out} \simeq A v_i$

$R_{in} \to \infty$

$R_{out} \to 0$

$V_i = v_s$

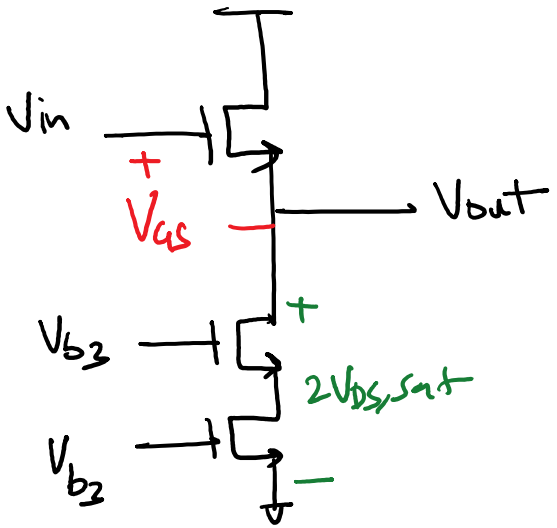
SF $\to$ $R_{out} \simeq \frac{1}{g_m} \Rightarrow$ low-Z output

most of the voltage is transfered to the load

Issue with SF as a buffer

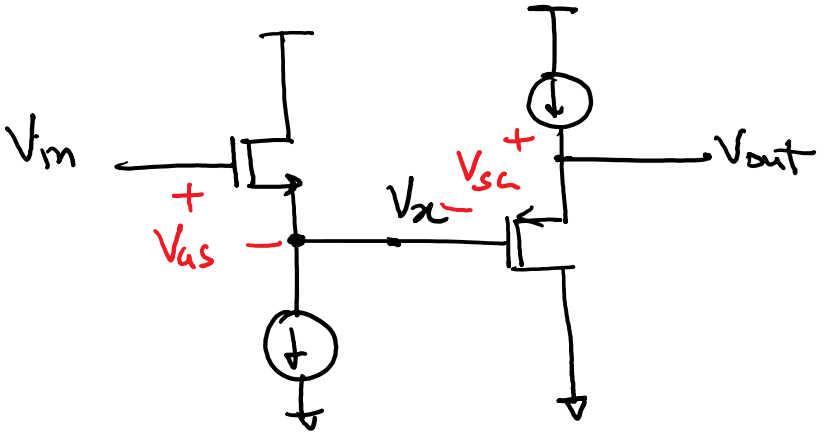
DC level shift

⇒ limited input swing



$V_{in} > V_{GS} + 2V_{DS,sat}$

& reduced VO Hoge headroom


Vin
+
Vgs
−
Vx
Vsd
+
Vout