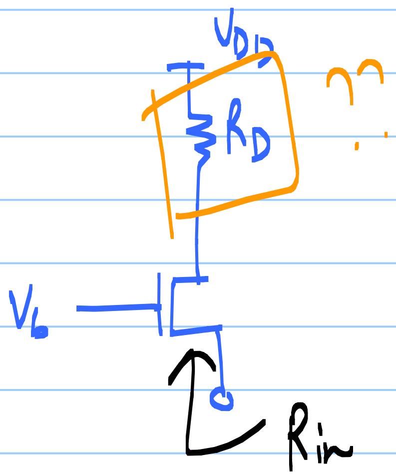
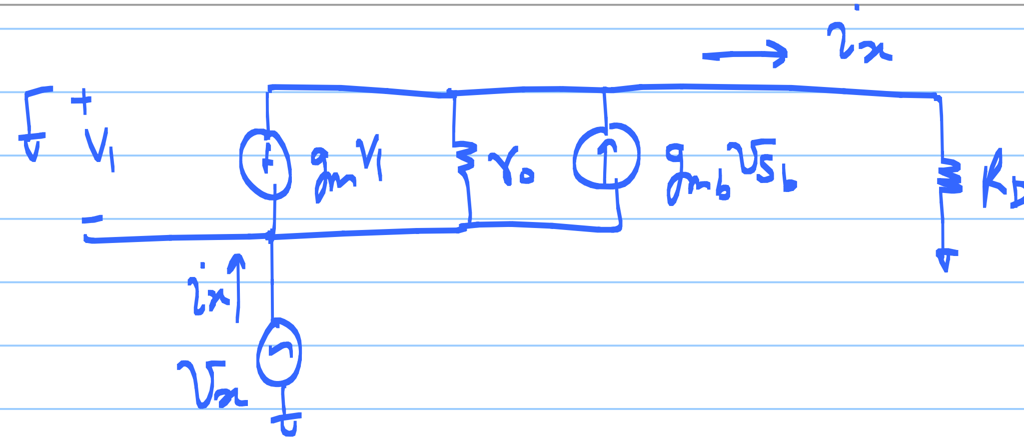
ECE 511 — Lecture 20

Note Title 4/11/2012





$$R_{in} = \frac{v_x}{i_x} = \frac{R_D + r_o}{1 + (g_m + g_{mb}) r_o}$$

$$\simeq \frac{R_D}{(g_m + g_{mb}) r_o} + \frac{1}{g_m + g_{mb}}$$

(1) $R_D \simeq r_o$

$$R_{in} = \frac{1 + \cancel{r_o}}{(g_m + g_{mb})\cancel{r_o}} + \frac{1}{(g_m + g_{mb})} \simeq \frac{1}{g_m}$$

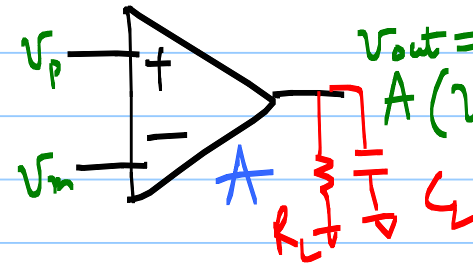
(2) $R_D \simeq g_m r_o^2$

$$R_{in} = \frac{g_m r_o^2}{g_m r_o} + \frac{1}{g_m} \simeq r_o$$

opamps

Opamp (operational amplifier)

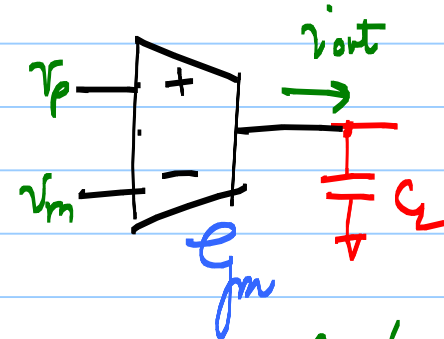
VCVS



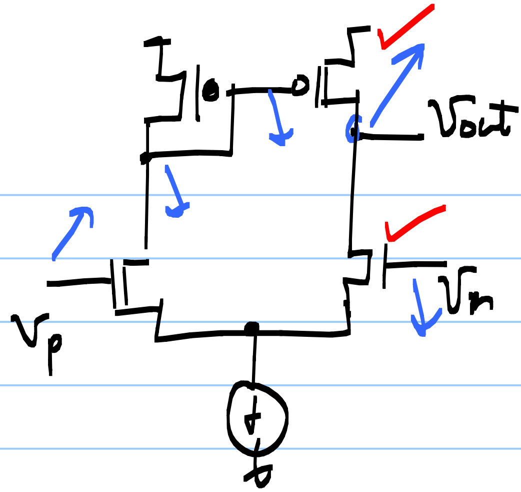
$v_{out} = A(v_p - v_m)$

OTA (Operational transconductance amplifier)

VCCS



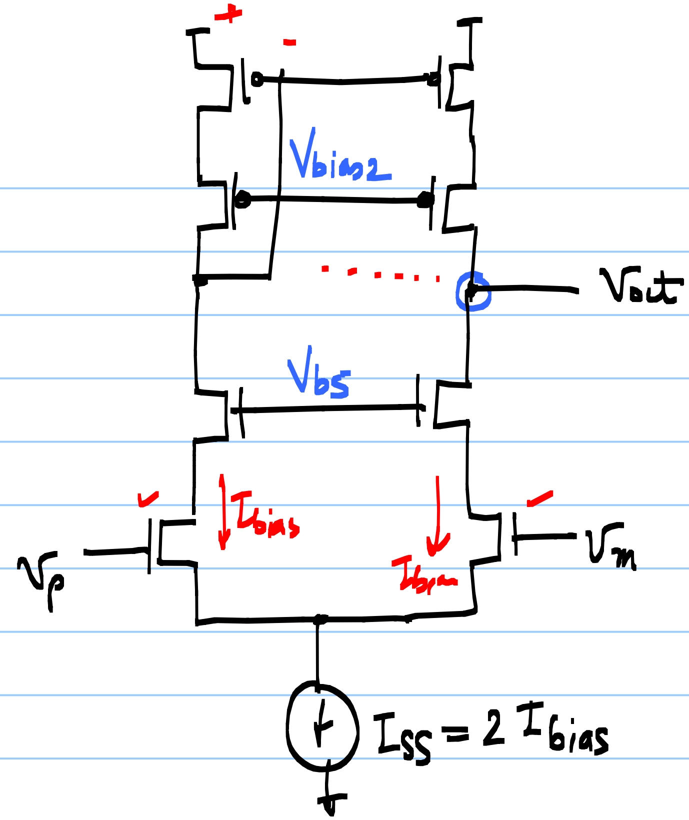
$i_{out} = g_m(v_p - v_m)$

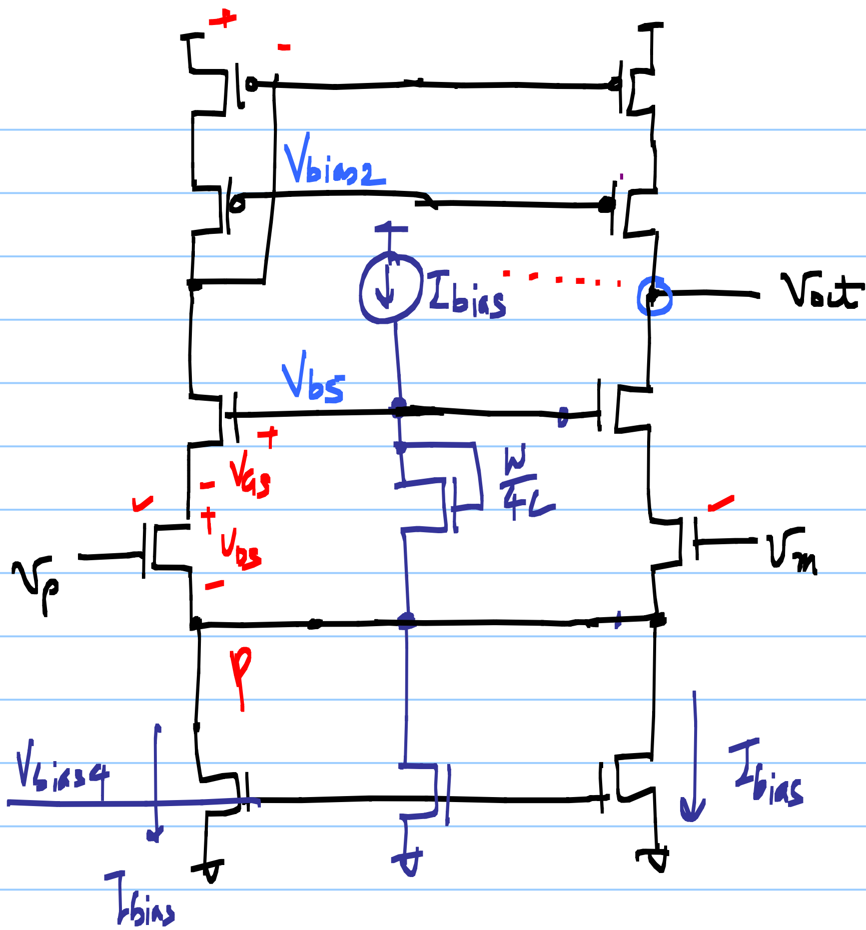


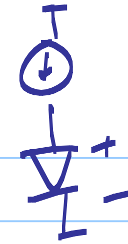
$+ g_m (r_{op} \| r_{in}) \approx g_m r_o$

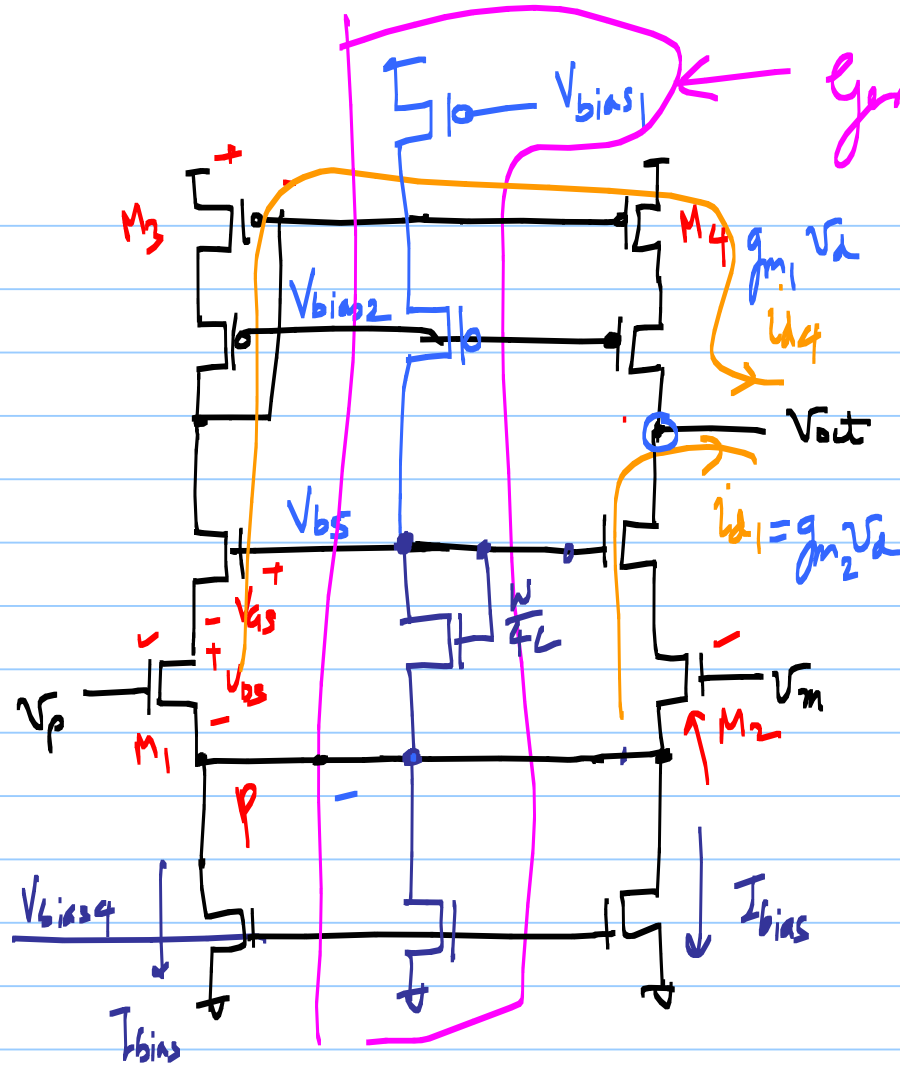
more gain → Cascode

Telescopic Amplifier




Vbias2
Ibias
Vout
Vb5
W/4L
VGS
VDS
Vp
Vm
P
Vbias4
Ibias
Ibias



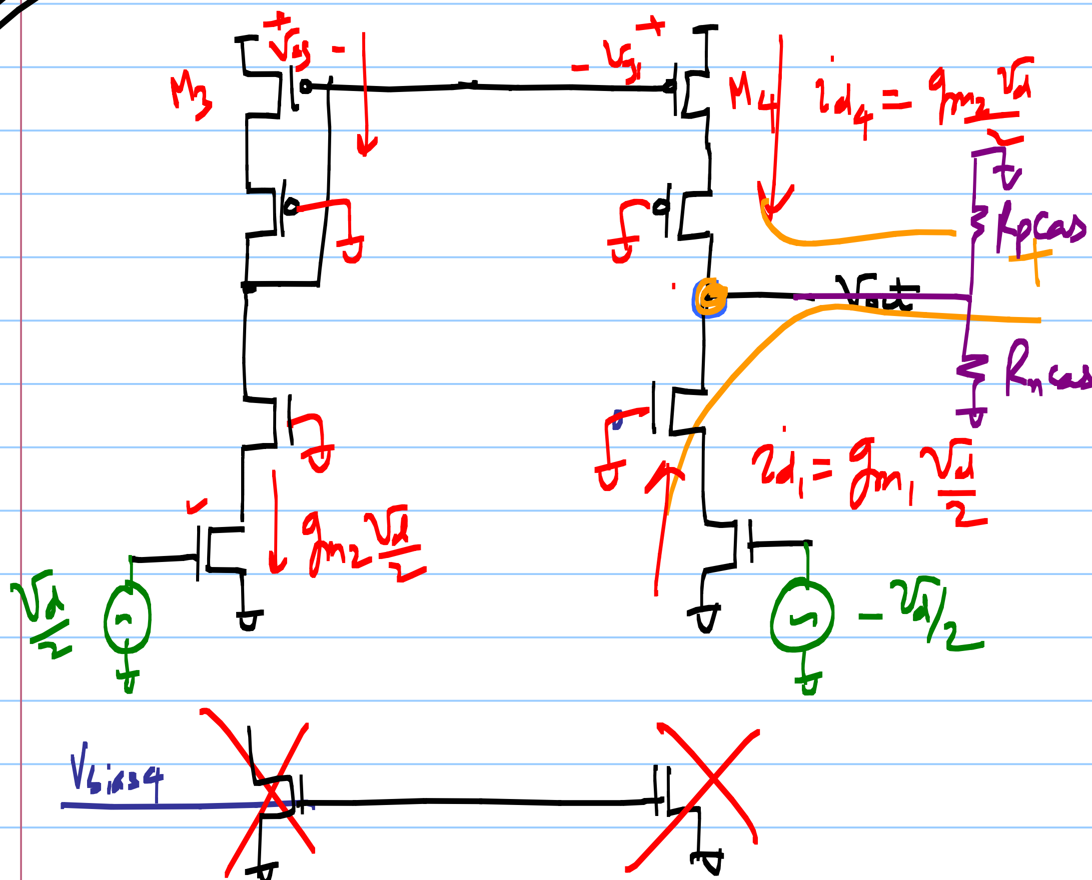


Generate Bias voltage V_{b5}

$$A_{v,DM} = g_{m1,2} \cdot \left(\overbrace{g_{m_n} r_{o_n}^2}^{R_{ncas}} \right) \| \left(\underbrace{g_{m_p} r_{o_p}^2}_{R_{pcas}} \right)$$

Ac → Differential Mode

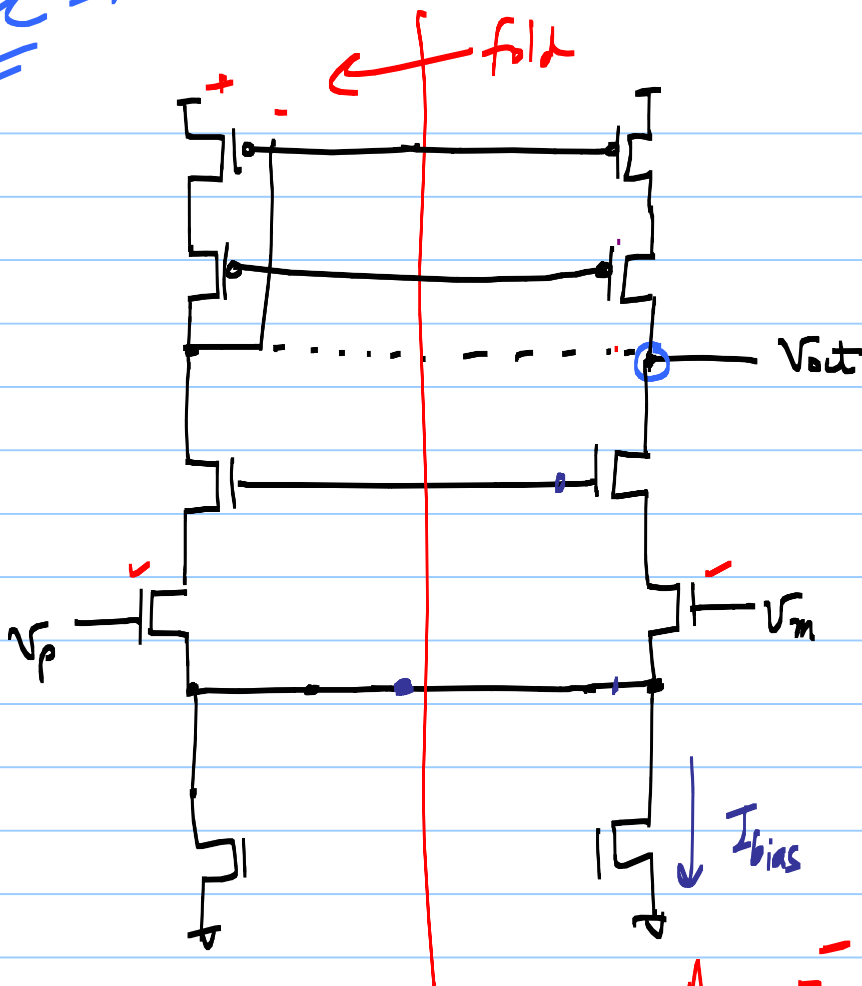
$$v_d = v_p - v_m$$

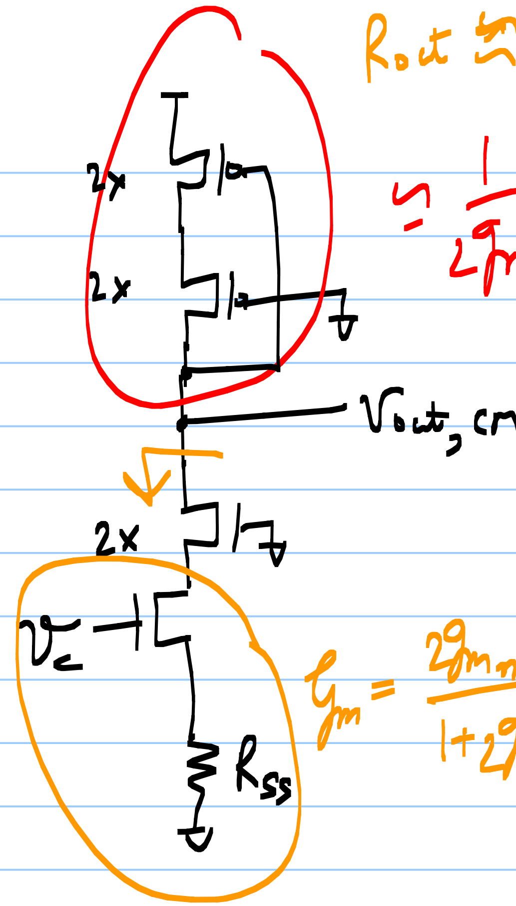


$g_m v_d$

$$v_{out} = g_m v_d \left(R_{pcas} \| R_{ncas}\right)$$

$\underline{\underline{A_C}}$ → Common-mode





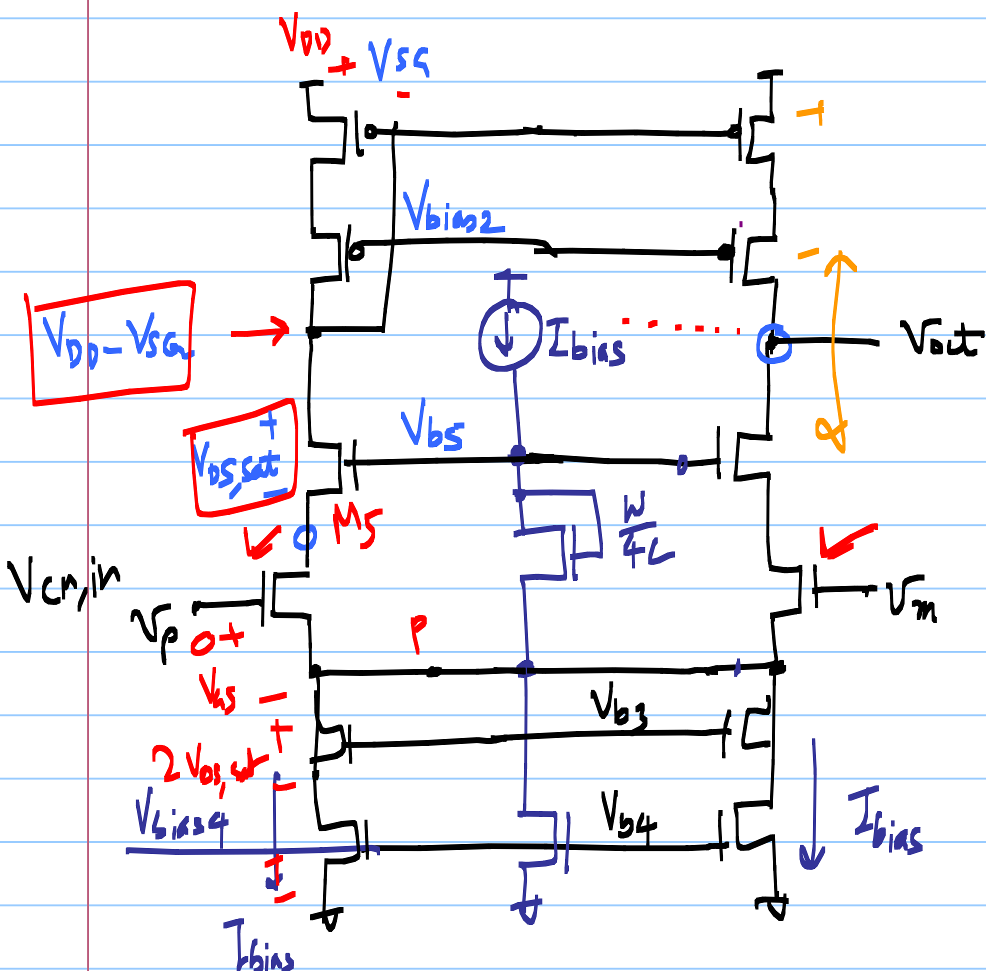
$$R_{out} \cong \frac{1}{2g_{mp}}$$

$$\approx \frac{1}{2g_{mn}}$$

$$G_m = \frac{2g_{mn}}{1+2g_{mn}R_{SS}}$$

$$A_{v,cm} = -G_m \cdot R_{out} = -\frac{2g_{mn}}{1+2g_{mn}R_{SS}} \cdot \frac{1}{2g_{mp}}$$

$$CMRR = 20 \log_{10} \left| \frac{A_{v,DM}}{A_{v,CM}} \right|$$



Input CMR ??

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

$$V_{cm,in} < \underbrace{V_{DD} - V_{SG} - V_{DS,sat}}_{V_{D5}}$$

$$V_{DS5} > V_{GS5} - V_{THN}$$

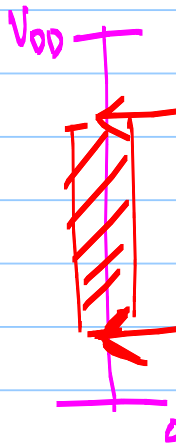
$$V_{D5} > V_{G5} - V_{THN}$$

$$V_{GS} < V_{D5} + V_{THN}$$

$$V_{CM,in} < V_{DS} + V_{THN}$$

$$= (V_{DD} - V_{SG}) - (V_{DS,sat}) + V_{THN}$$

$$ICMR \in [V_{GS} + \underbrace{2V_{DS,sat}}, \ V_{DD} - \overbrace{V_{SG} - V_{DS,sat}} + V_{THN}]$$



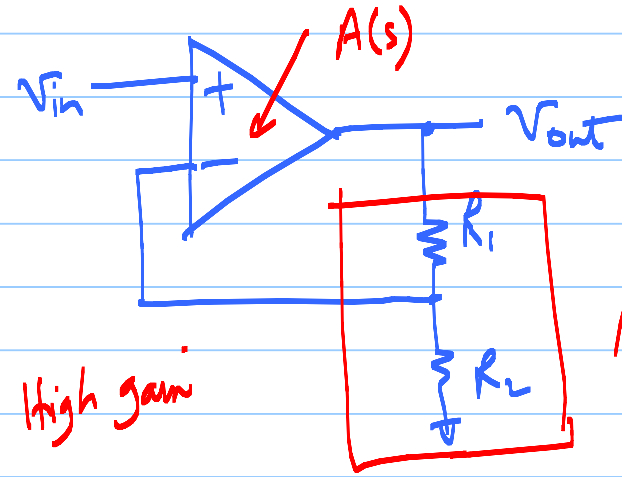
lower ICMR & output swing

Output Swing

$$(V_{in,cm} - V_{THN} + V_{DS,sat}) \leq V_{out} \leq (V_{DD} - 2V_{SD,sat})$$

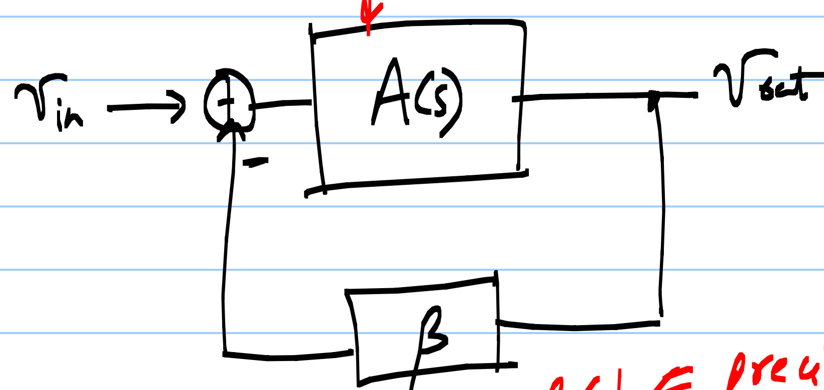
Performance Parameters:

① Gain:



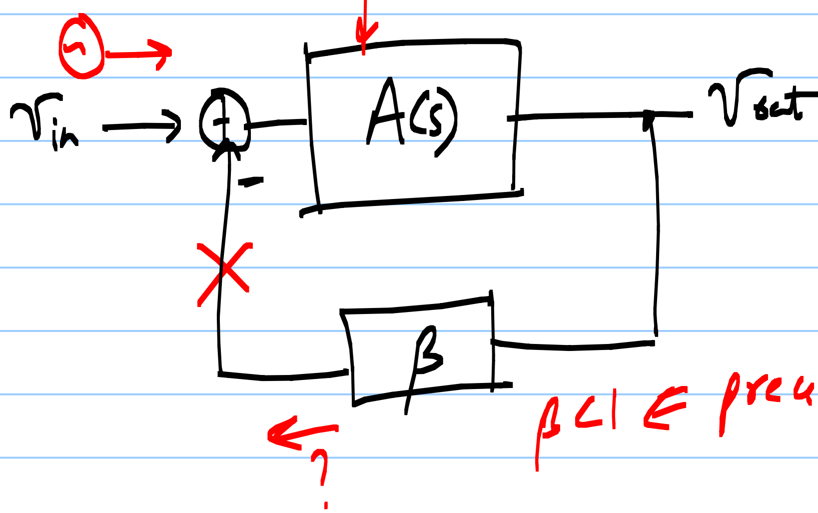
$$\beta = \frac{R_2}{R_1 + R_2} < 1$$

High gain

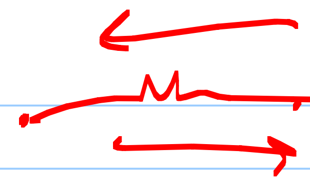


$\beta < 1$ & precise

High gain



$\beta < 1 \Leftarrow$ precise



$A\beta \Leftarrow$ open-loop response $\Rightarrow$ loop-response

$$(V_{in} - \beta V_{out})A(s) = V_{out}$$

$$\frac{V_{out}}{V_{in}}(s) = \frac{A(s)}{1 + A(s)\beta} = \frac{A}{1+A\beta} \leftarrow A_{CL}(s)$$

closed-loop response

Assume $A(s) = A$

$|x| \ll 1$

$\frac{1}{1+x} \simeq 1 - x$

$$A_{CL} = \frac{V_{out}}{V_{in}} = \frac{A}{1+A\beta} = \frac{1}{\beta} \cdot \frac{1}{\left(1 + \frac{1}{A\beta}\right)}$$

$$A_{CL} = \frac{1}{\beta}\left[1 - \frac{1}{A\beta}\right] \simeq \frac{1}{\beta} \leftarrow$$

if $\boxed{A\beta \gg 1} \leftarrow$ loop gain is ∞

$$A_{CL} = \underbrace{\frac{1}{\beta}}_{\text{ideal } A_{CL}} \left[1 - \overbrace{\underbrace{\frac{1}{A\beta}}_{\text{relative gain error}}}^{\epsilon} \right] = A_{CL,\,ideal}\,(1 - \underbrace{\epsilon}_{\text{gain error}})$$

$$\epsilon \downarrow \ \Rightarrow\ A\beta \uparrow \ \Rightarrow\ A \uparrow$$

for $\epsilon < 1\%$

$$\Rightarrow\ A > 1000 = 60\,dB$$

② $A(s) = \dfrac{A}{\left(1+\frac{s}{\omega_0}\right)}$ ← Dominant pole model