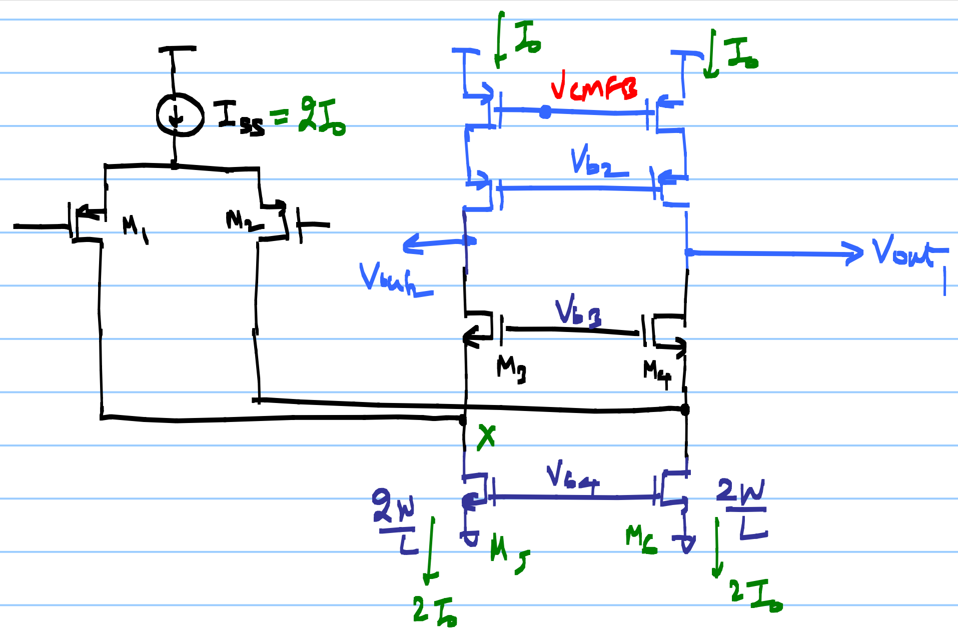
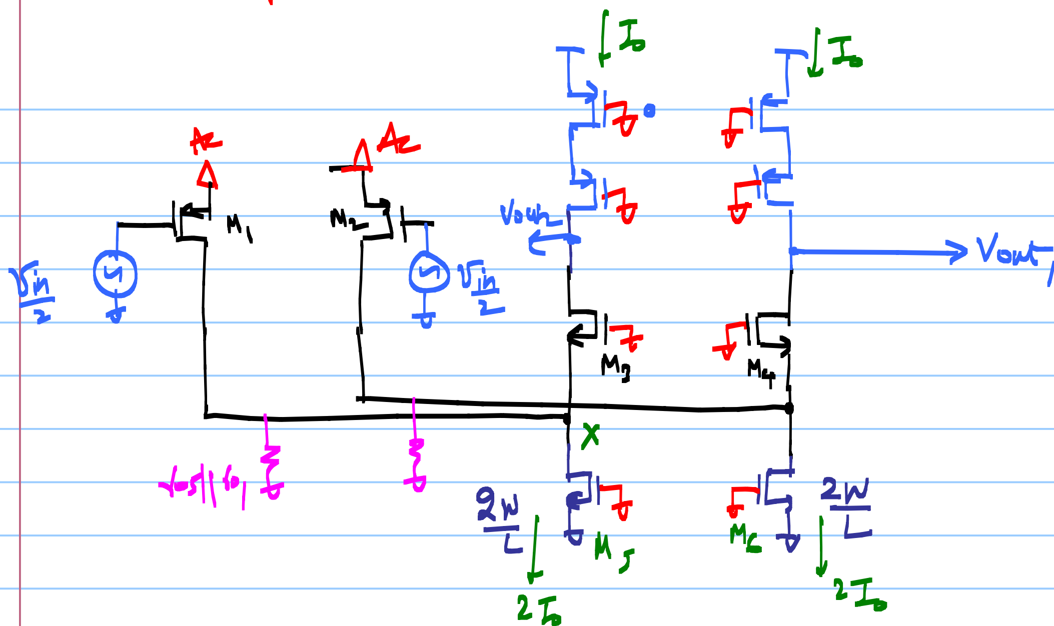
ECE 511 – Lecture 23

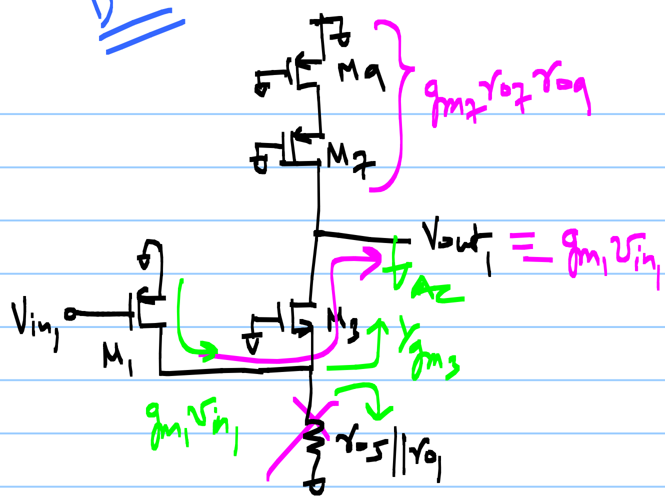
Note Title 4/18/2013



"DM Ac picture"



DM

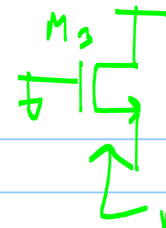


"Lemma"

$$A_v = -G_m \cdot R_{out}$$

$G_m \to g_{m1}$

$R_{out} \to (g_{m7} r_{o7} r_{o9}) \| (g_{m3} r_{o3} (r_{o5} \| r_{o1}))$



$R_{in} = \frac{1}{g_{m3}}$

$$A_{v_{FC,DM}} = -g_{m1} \cdot (g_{m7} r_{o7} r_{o9}) \| (g_{m} r_{o3} (r_{o5} \| r_{o1}))$$

$$\simeq -g_{mp} \cdot \boxed{(g_{mp} r_{op}^2)} \| \boxed{\left(g_{mn} \cdot \frac{r_{on}^2}{2}\right)}$$

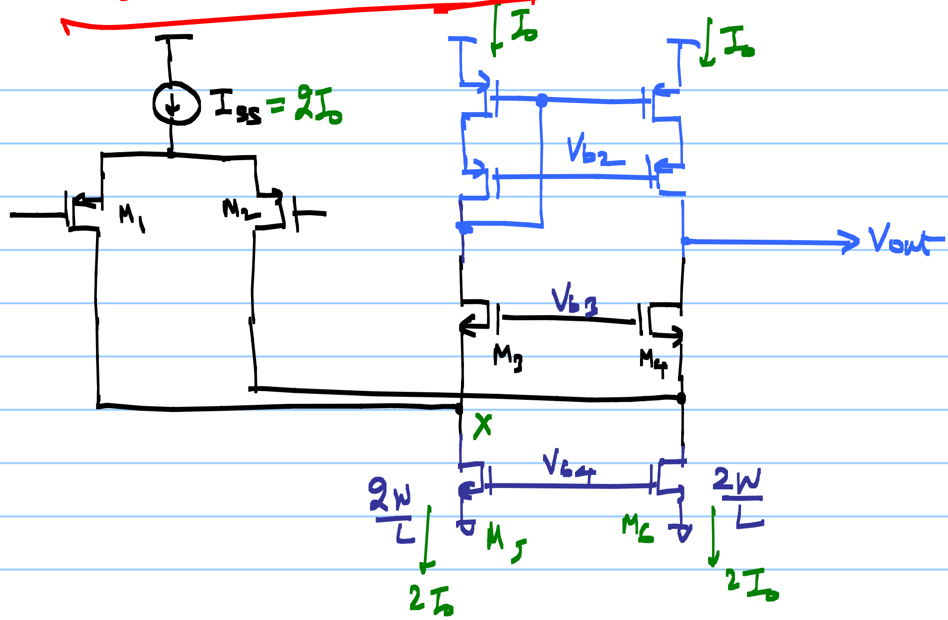
$$= -g_{mp} \cdot (R_{ocasp}) \| \left(\frac{R_{ocasn}}{2}\right) \checkmark$$

= 2-3 × lower than the Telescopic

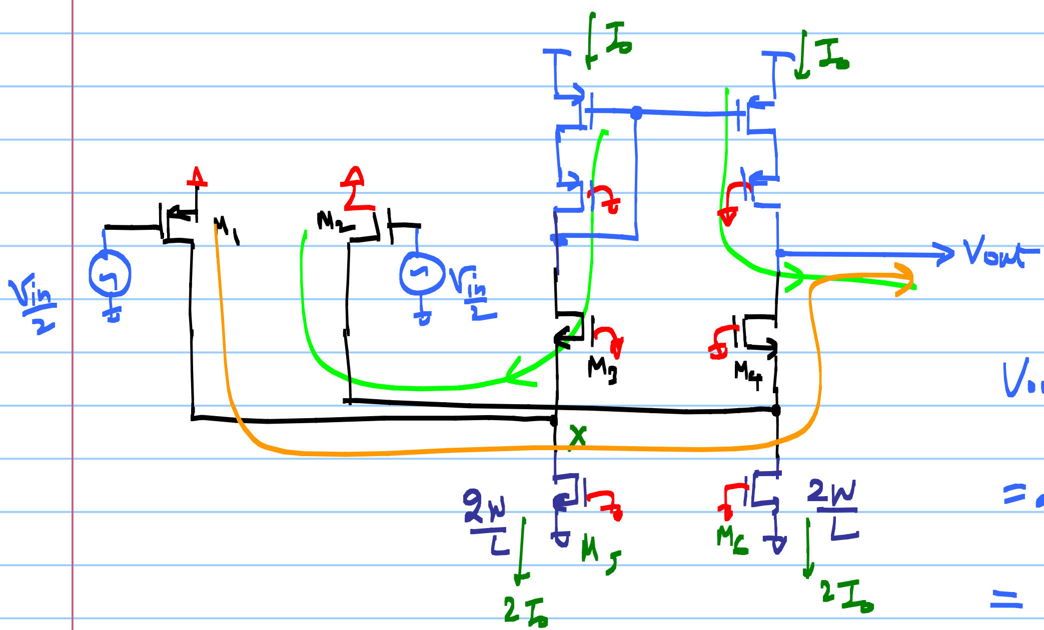
Telescopic gain

$$A_{v_T} = -g_{mn} \cdot (R_{ocasp} \| R_{ocasn})$$

Single-ended fc opamp



AC picture



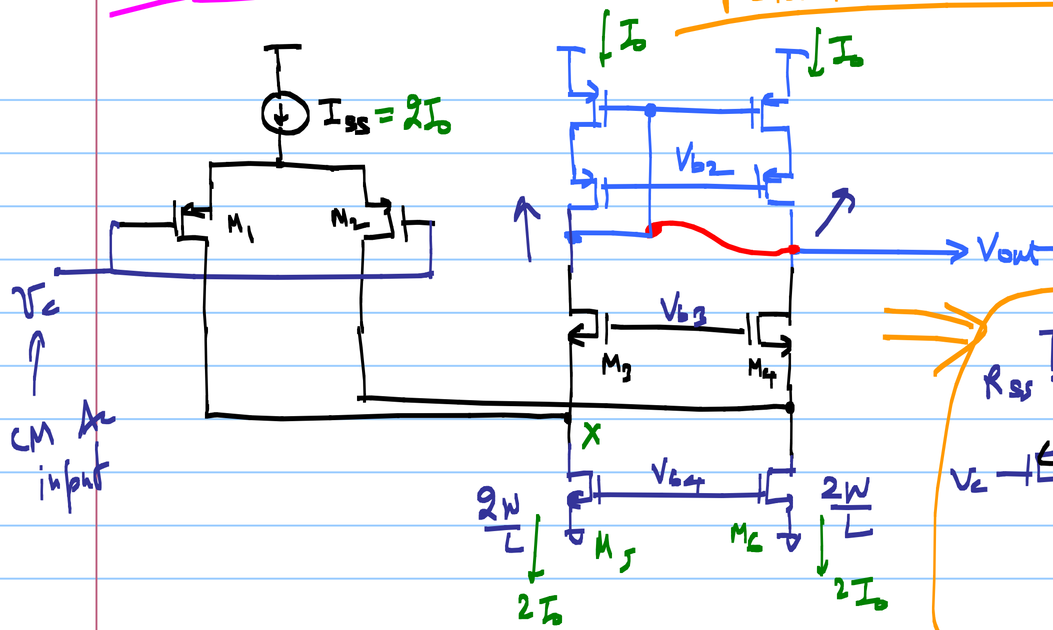
$V_{out} = 2\, i_{d_1} \cdot R_{out}$

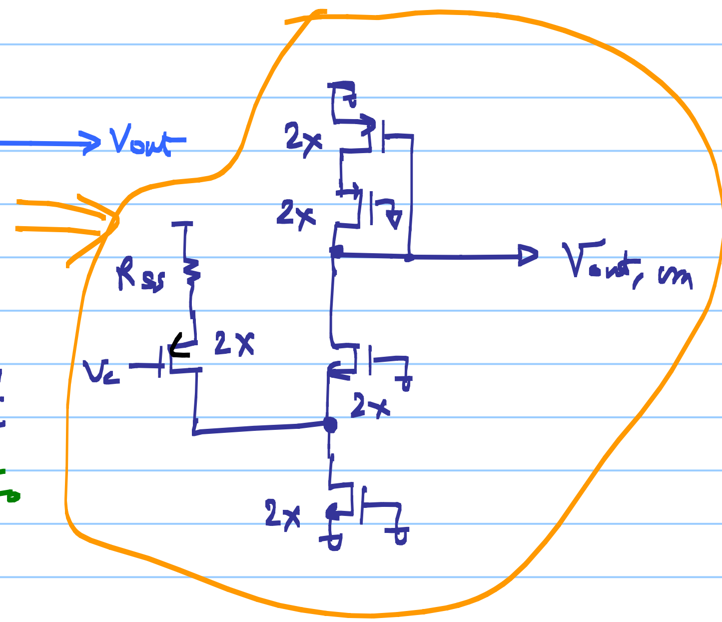
$= 2 \times$ (gain of the half circuit)

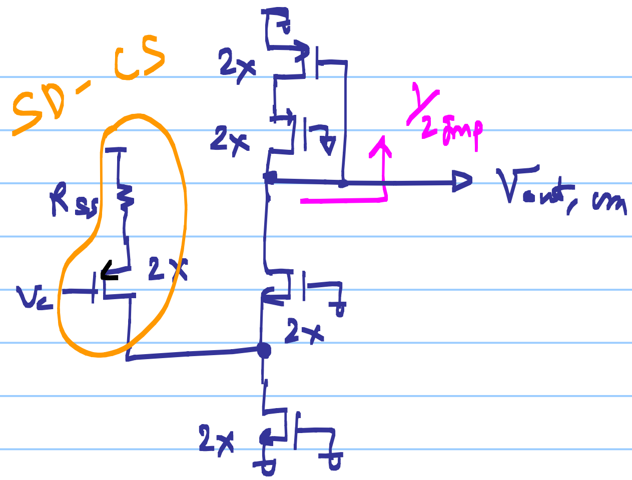
$= -g_{m_p} \cdot (R_{ocasp}) \| \left(\frac{R_{ocasn}}{2}\right)$

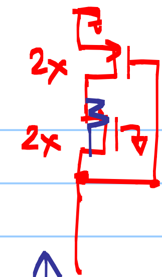
AC CM Picture

"Fold the circuit"









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

"Lemma"

$A_{v,cm} = -g_m \cdot R_{out}$

$g_m \to \frac{2g_{m1}}{1+2g_{m1}R_{SS}}$

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

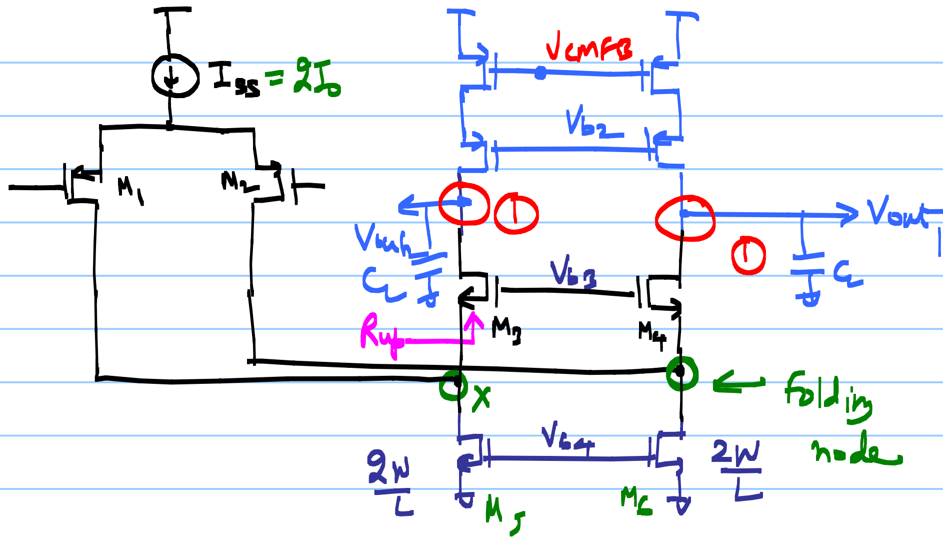
$$\boxed{CMRR = \frac{A_{v,DM}}{A_{v,cm}}}$$

For single-ended FZ

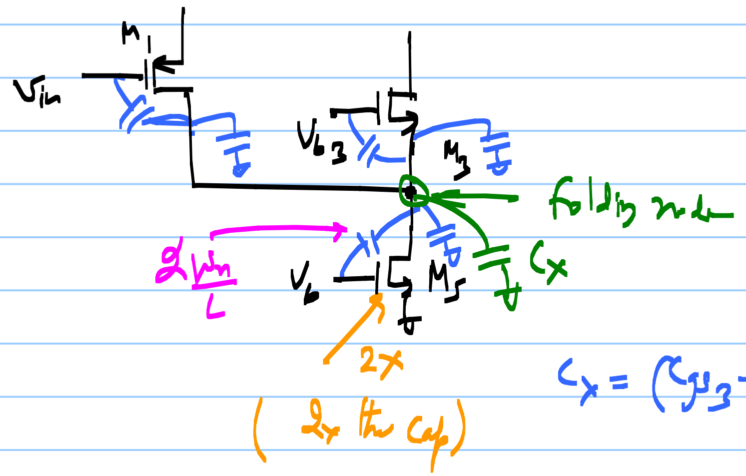
$$A_{v,DM} = g_{mp} \cdot (R_{ocasp}) \| \left(\frac{R_{ocasn}}{2}\right)$$

$$A_{v,cm} = \frac{\cancel{2g_{m1}}}{1 + 2g_{m1} R_{S1}} \cdot \frac{1}{\cancel{2g_{m1}}} \simeq \frac{1}{1 + 2g_{mp} R_{SS}}$$

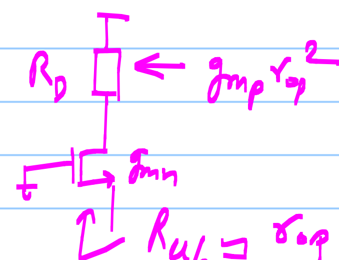
$$CMRR = \frac{A_{v,DM}}{A_{v,cm}} = (1 + 2g_{mp} R_{SS}) \cdot g_{mp} \cdot \left[(g_{mp} r_{op}^2) \| \left(\frac{g_{mn} r_{on}^2}{2}\right) \right]$$



$$\omega_{p1} = \frac{1}{R_{out} C_L}$$



$$C_x = (C_{gs_3} + C_{sb_3}) + (C_{db_1} + C_{gd_1}) + (C_{gd_5} + C_{db_5})$$



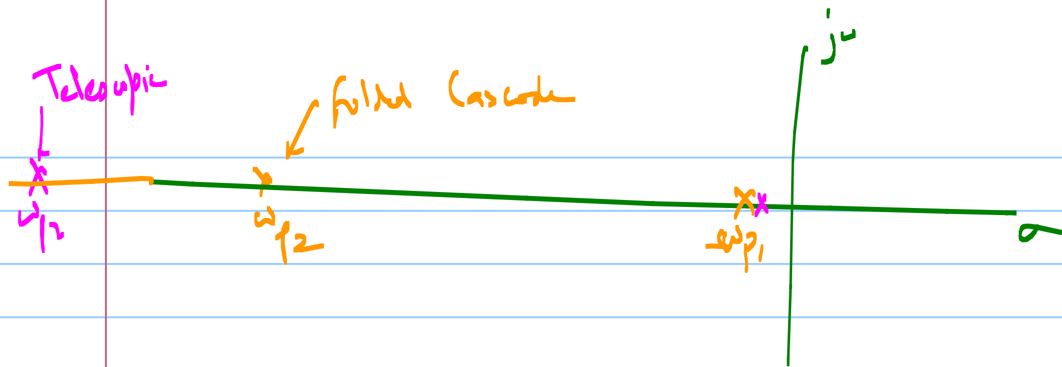
$R_{up} \simeq r_{op}$

$= \frac{1}{g_m}$ only iff $R_D \leq r_o$

$$R_x = r_{o_1} \| r_{o_5} \| R_{up}$$

$$\simeq \frac{r_o}{3}$$

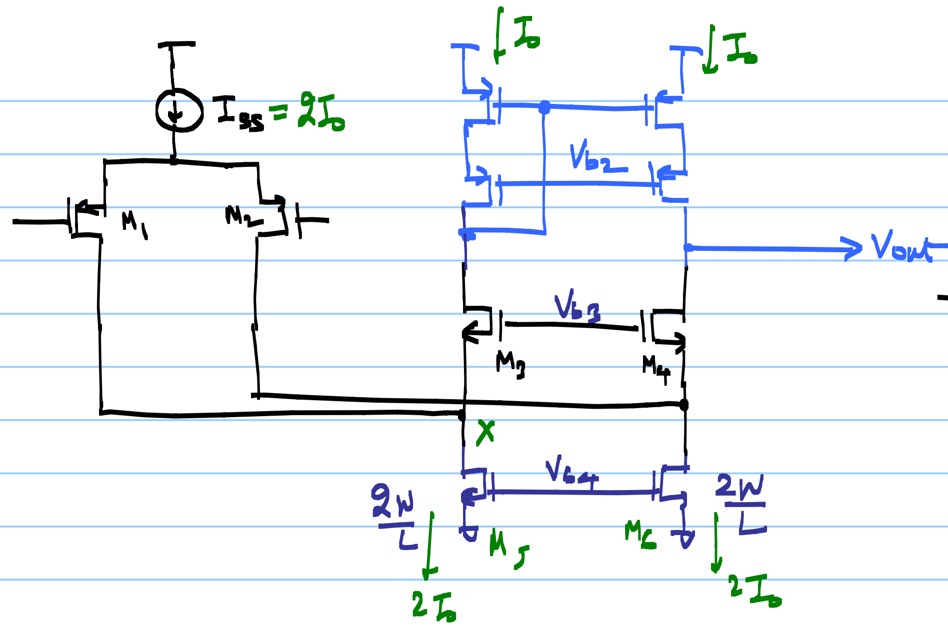
$$\omega_{p_2} \simeq \frac{1}{R_x C_x}$$



$A_v \downarrow$ 2-3x

Stability is impaired due to ω_{p2}

(+) Headroom

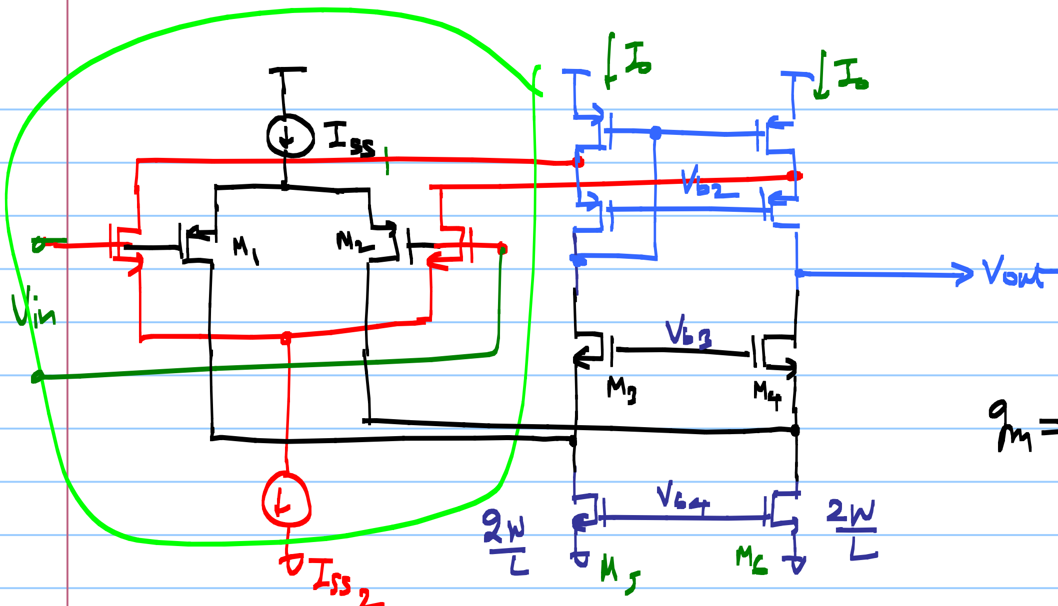


Input CMR

PMOS input ⇒ g_m ↓

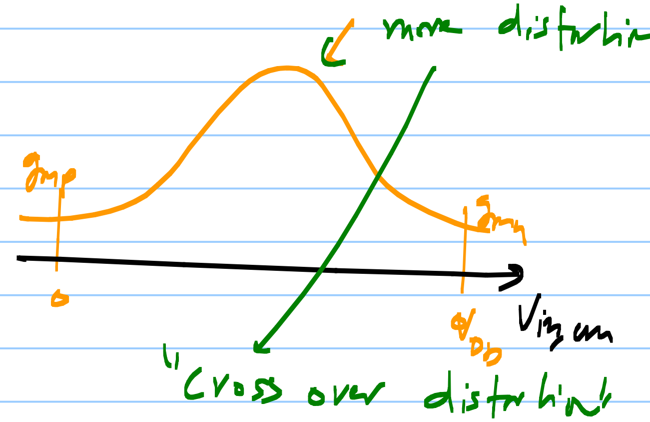
NMOS input ⇒ V_{DD}

"Combine for rail-rail Input CMR"



I_{SS_1}
M_1
M_2
V_{in}
I_{SS_2}
I_b
I_b
V_{b2}
V_{out}
V_{b3}
M_3
M_4
V_{b4}
$\frac{2W}{L}$
M_5
M_6
$\frac{2W}{L}$

$$g_m = g_{mn} + g_{mp}$$



more distortion
g_{mp}
g_{mn}
0
V_{DD}
$V_{in,cm}$
"cross over distortion"

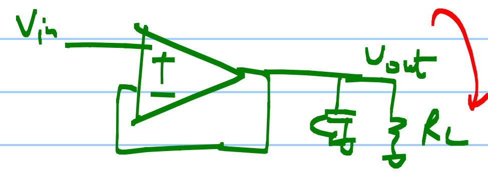
Two-stage opamps

* Issues with single-ended opamp

(−) ↳ gain is limited by $g_m \cdot R_{out}$

heavy load → Big C

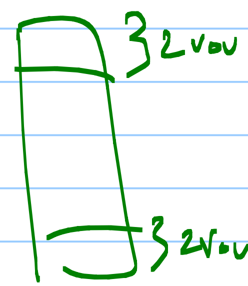
Small R



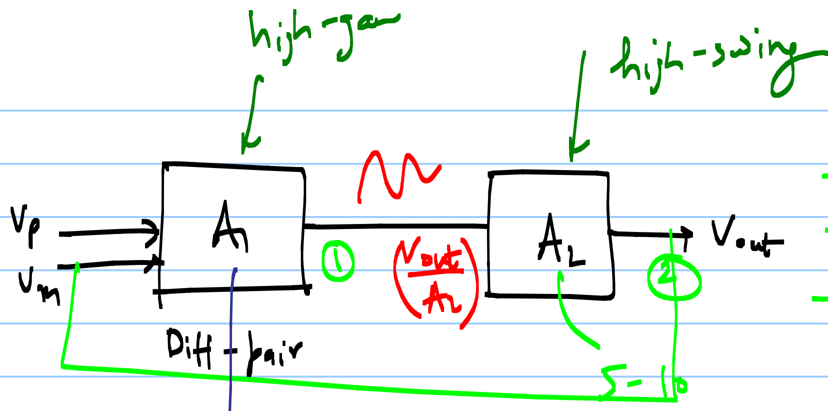
$i_c = C \frac{d V_{out}}{dt}$

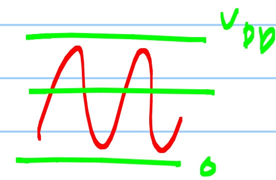
$i_c = \frac{V_{out}}{R_L}$

(−) ↳ output swing is limited by cascode output



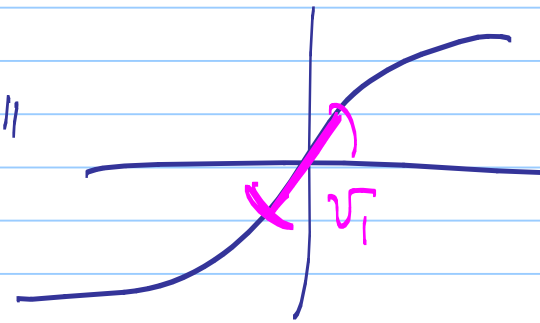
(+) Large gain if unloaded ← Cascoding (Tel, F2)



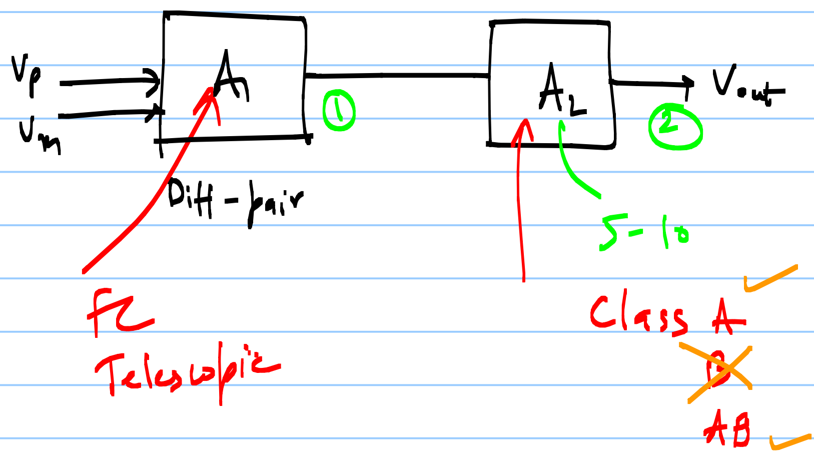


output excursions are small

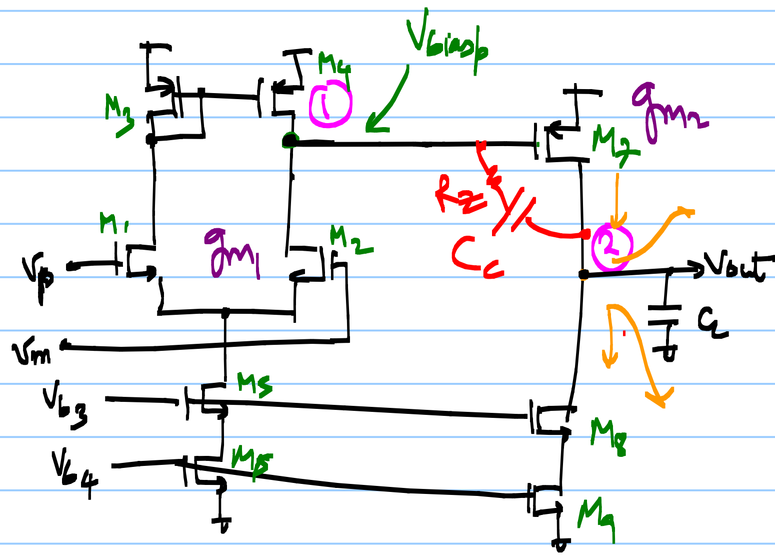
↳ low-distortion



→ Two-stage opamps provide much higher linearity. → Second stage could be slightly non-linear



Vp
Vm
A1
A2
Vout
1
2
Diff-pair
5-10
FC
Telescopic
Class A
~~B~~
AB



$$\omega_{p_1} = \frac{1}{g_{m_2} R_2 R_1 C_c}$$

$$\omega_{p_2} \simeq \frac{g_{m_2}}{C_L}$$

$$\omega_{un} \simeq \frac{g_{m_1}}{C_c}$$