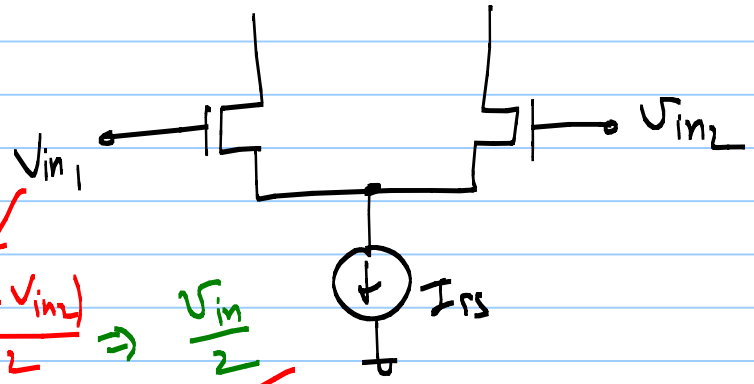
ECE 5411 – Lecture 20

Note Title 4/13/2011



$\frac{(V_{in_1} - V_{in_2})}{2} \Rightarrow \frac{v_{in}}{2}$

$+$

$\left(\frac{v_{in_1} + v_{in_2}}{2}\right)$

v_c

$\frac{(V_{in_2} - V_{in_1})}{2}$ $+$ $\left(\frac{V_{in_1} + v_{in_2}}{2}\right)$

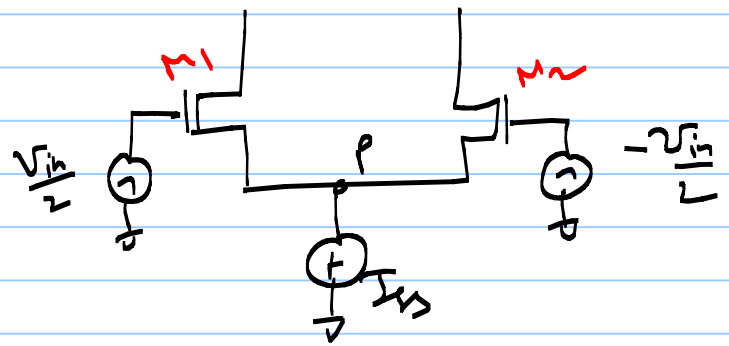
$-\frac{v_{in}}{2}$

v_c

$v_{in} = v_{in_1} - v_{in_2}$

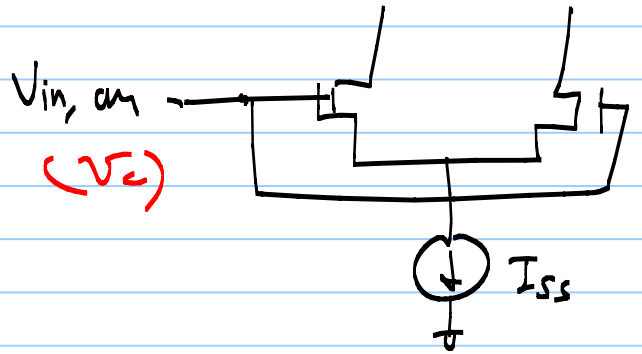
DM

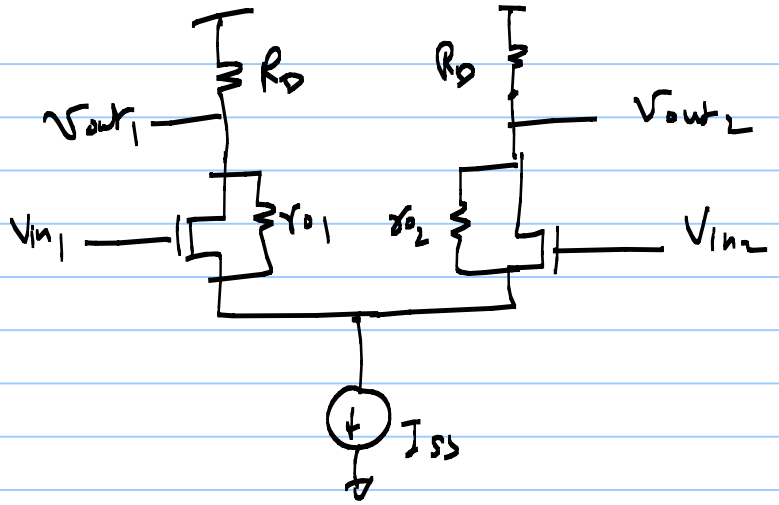
(A)



CM

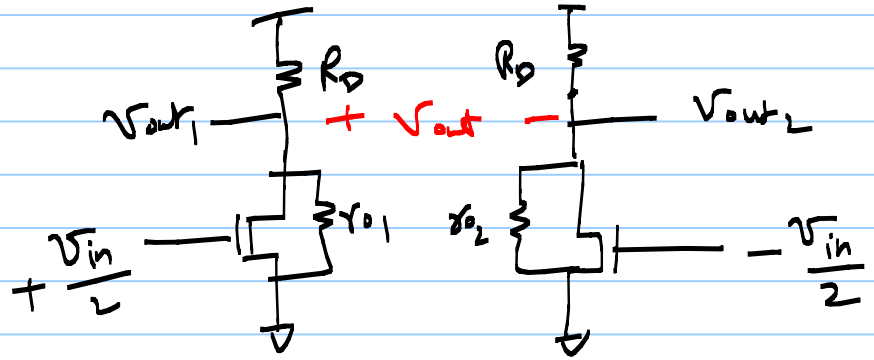
(B)





$$v_{in} = v_{in_1} - v_{in_2}$$

DM

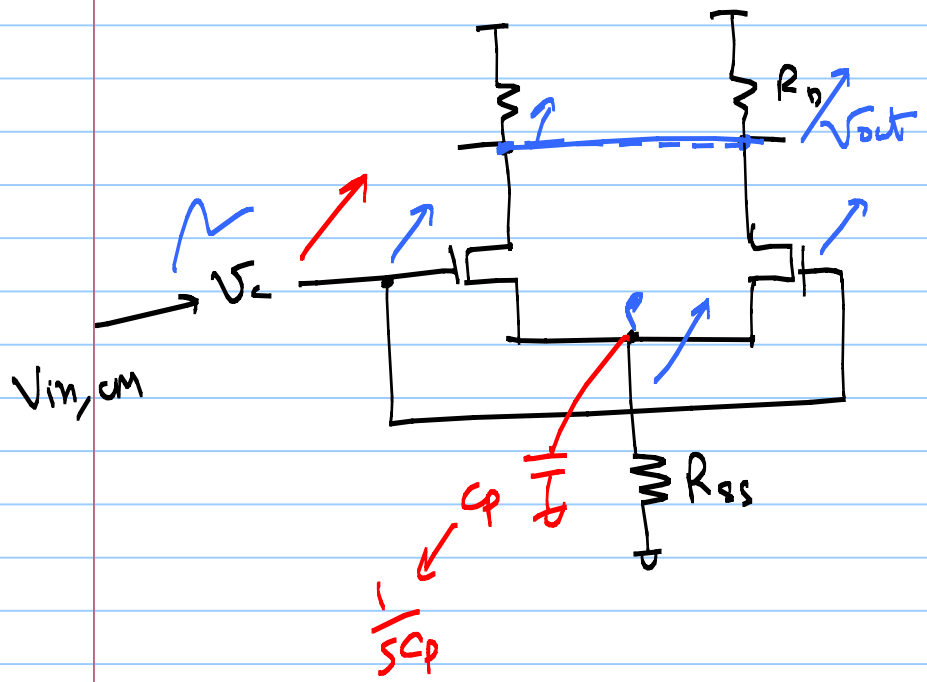


$$v_{out_1} = -g_{m_1} v_{\frac{in}{2}} \cdot (R_D \| r_{o_1})$$

$$v_{out_2} = -g_{m_2} \left(-\frac{v_{in}}{2}\right) \cdot (R_D \| r_{o_2})$$

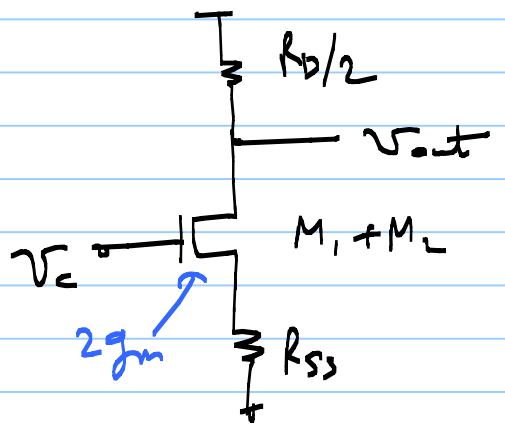
$$v_{out} = v_{out_1} - v_{out_2} = -g_{m_1} v_{in} (r_o \| R_D) = A_{v,DM}$$

Common Mode Response



$\Rightarrow$

CM equivalent circuit



$$\frac{V_{out}}{V_c} = -\frac{R_D/2}{1/2g_m + R_{ss}} = A_{v,cm}$$

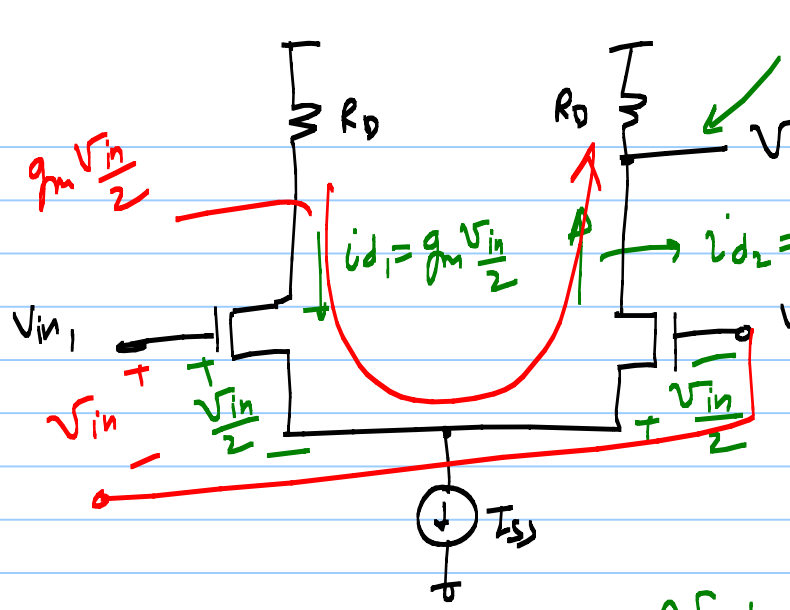
Common Mode Rejection Ratio (CMRR)

$$CMRR = \left| \frac{A_{v,DM}}{A_{v,CM}} \right| \quad \leftarrow dB$$

$A_{v,DM} \to \infty$, $A_{v,CM} \to 0$

$R_D << r_{O1,2}$

$$= \left| \frac{g_{m1,2}(r_{O1,2} \| R_D)}{\dfrac{R_D/2}{\frac{1}{2g_{m1,2}} + R_{SS}}} \right| = \frac{1}{2} + g_{m1,2} R_{SS}$$



$$v_{in} = v_{in1} - v_{in2}$$

$$v_{out} = i_{d2} \cdot (R_D \| r_{o2})$$

$$= g_m \frac{v_{in}}{2} (R_D \| r_{o2})$$

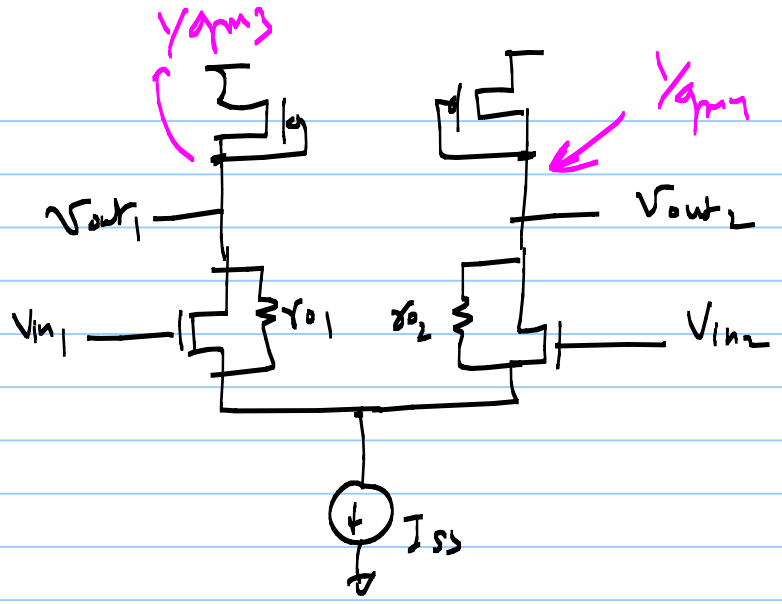
$$A_{v,DM} = \frac{g_m}{2} (R_D \| r_{o1,2})$$

* $g_{m_1} = g_{m_2} + \Delta g_m$

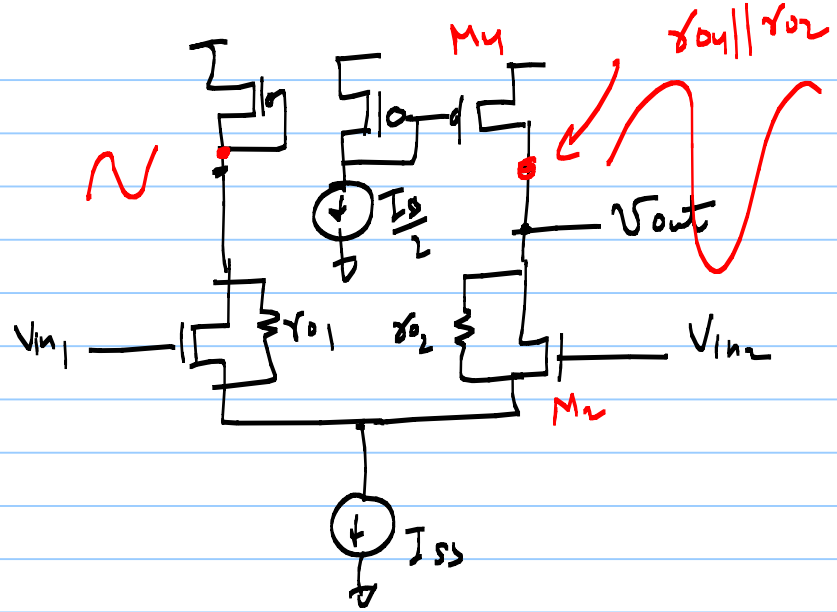
* $R_{D_1} = R_{D_2} + \Delta R_D$

* for g_m mismatch

$$CMRR = \frac{g_m}{\Delta g_m}(1 + 2 g_m R_{SS})$$

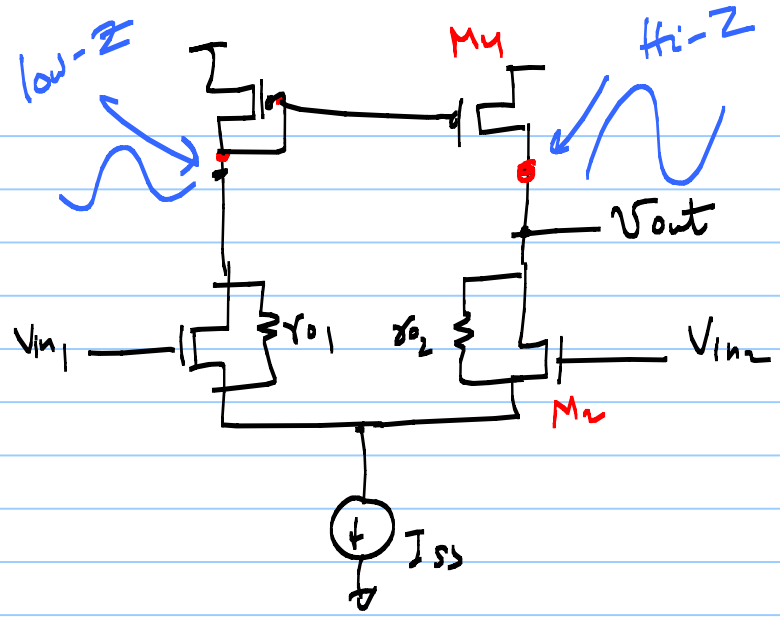


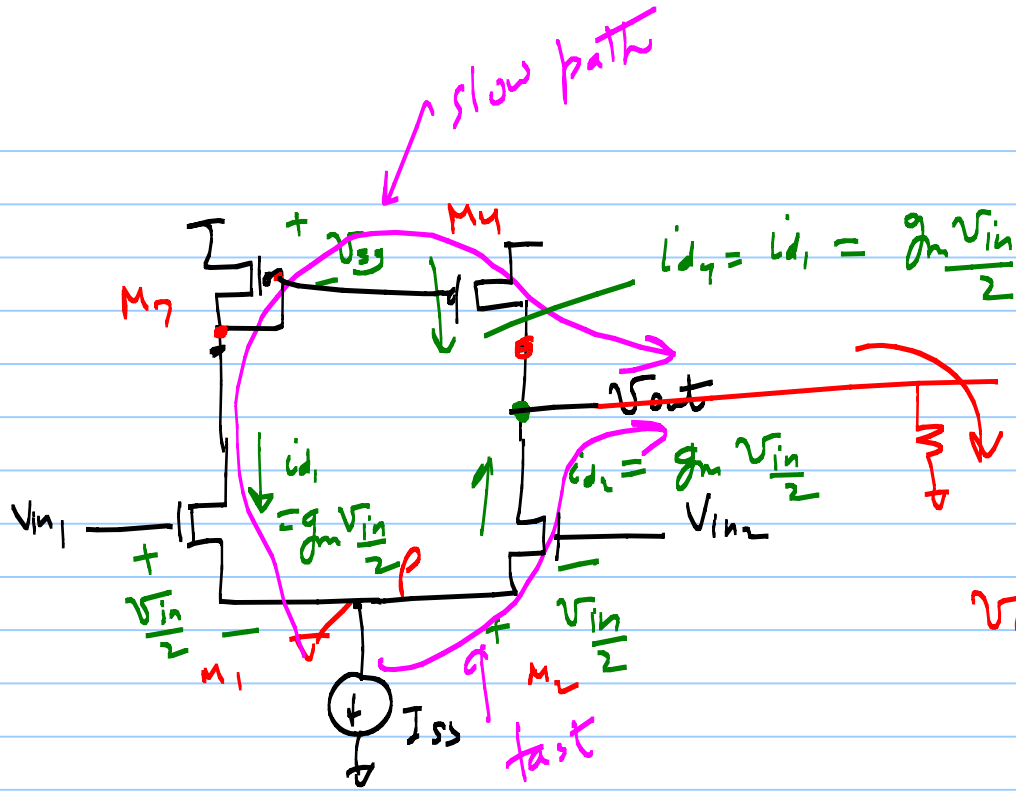
$$g_{m1,2}\left(\frac{1}{g_{m3,4}}\right)$$



$$A_v = + \frac{g_{m1/2}}{2} (R_D \| r_{o1/2})$$

Diffamp with CM load

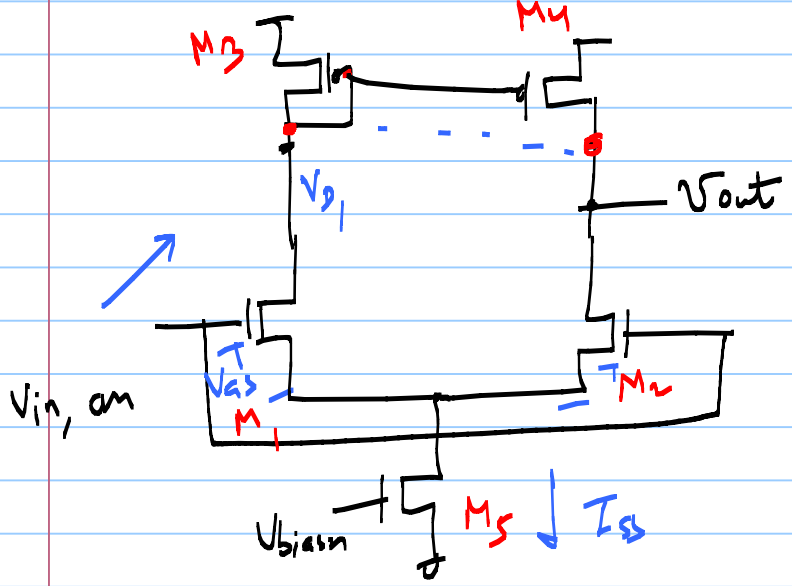


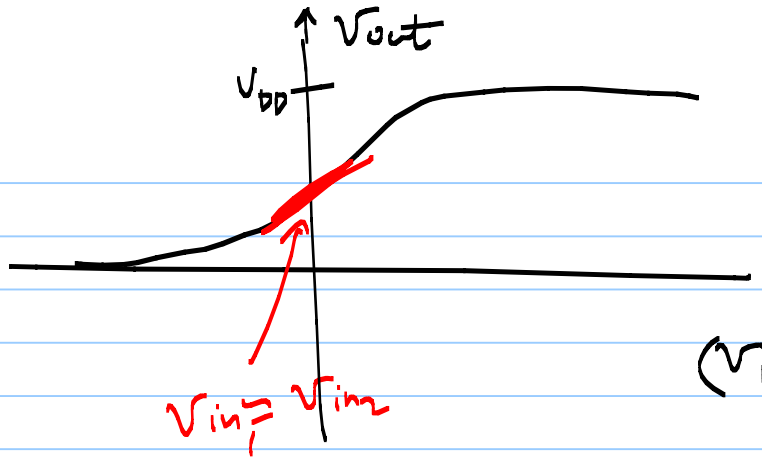


$$v_{out} = (i_{d_2} + i_{d_4})(r_{o_2} \| r_{o_4})$$

$$= g_m v_{in} (r_{o_2} \| r_{o_4})$$

$$A_{v,DM} = +g_{m_{1,2}} (r_{o_2} \| r_{o_4})$$



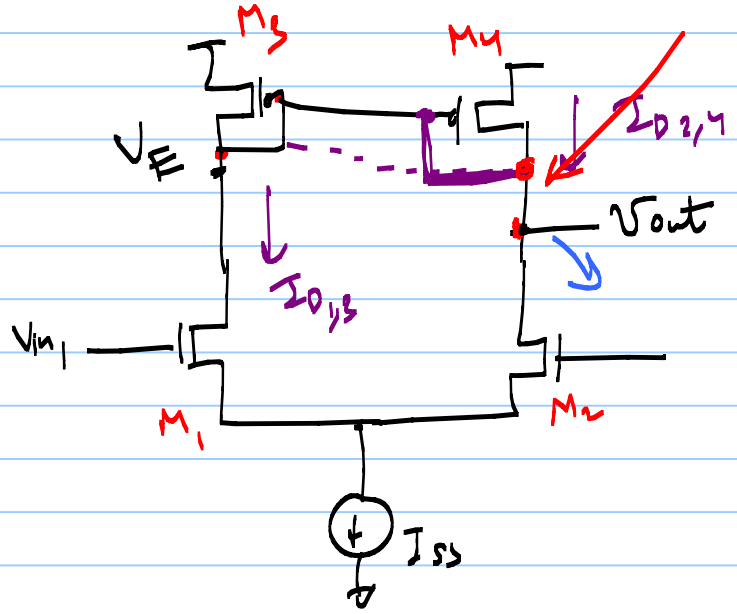


All devices are in SAT.

$$V_{in,cm} \geq V_{GS_{1,2}} + V_{DS,sat_5}$$

$$V_{in,cm} \leq V_{THN} + V_{D_1} = V_{DD} - V_{SG_3} + V_{THN}$$

$(\lambda \neq 0)$



Lets assume $V_{out} < V_E$

$I_{D_1} > \frac{I_{SS}}{2}$ ←

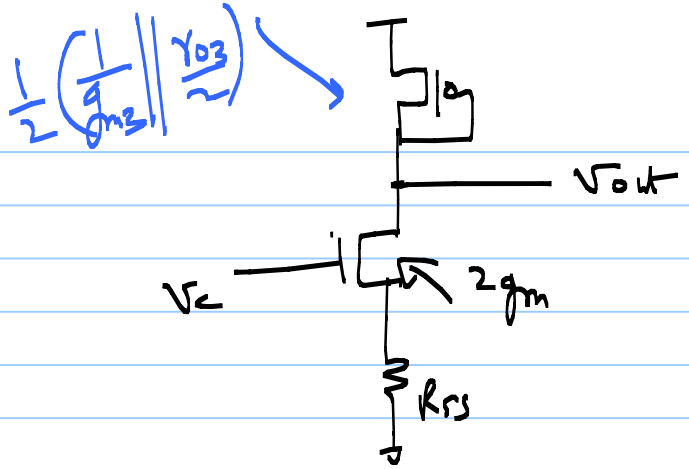
$I_{D_2} < \frac{I_{SS}}{2}$ ← Contradiction

$I_{D_3} > \frac{I_{SS}}{2}$

$I_{D_4} > \frac{I_{SS}}{2} \Rightarrow I_{D_2} > \frac{I_{SS}}{2}$

$V_{out} = V_E$

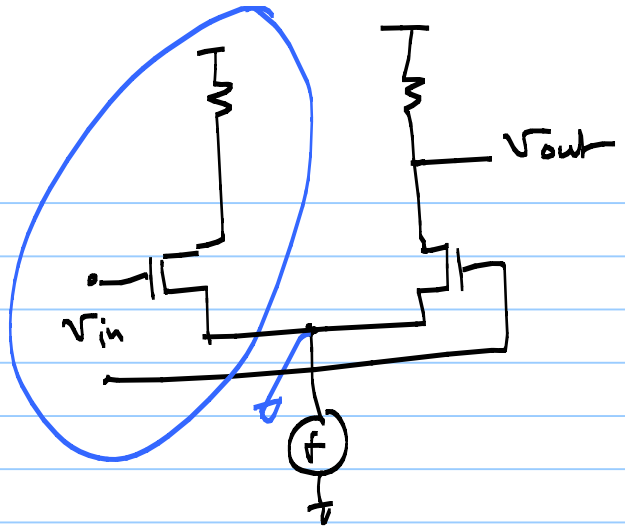
cm equivalent circuit



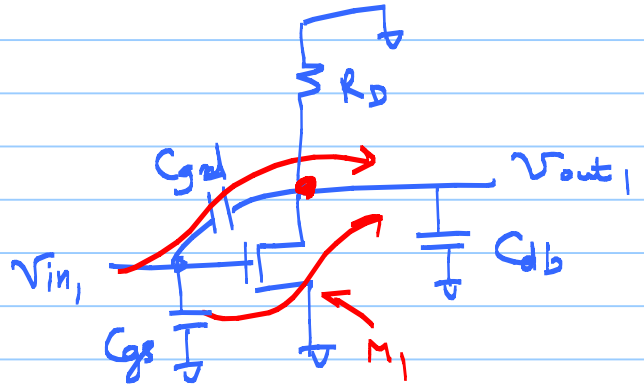
$$A_{v,cm} = \frac{-\frac{1}{2g_{m3,4}} \| \frac{r_{O3,4}}{2}}{\frac{1}{2g_{m1,2}} + R_{SS}}$$

$$\approx -\frac{1}{2g_{m3,4}R_{SS}}$$

$$CMRR = \left|\frac{A_{v,dm}}{A_{v,cm}}\right| = g_{m1,2}\left(r_{O1,2} \| r_{O3,4}\right) \cdot 2g_{m3,4}R_{SS}$$

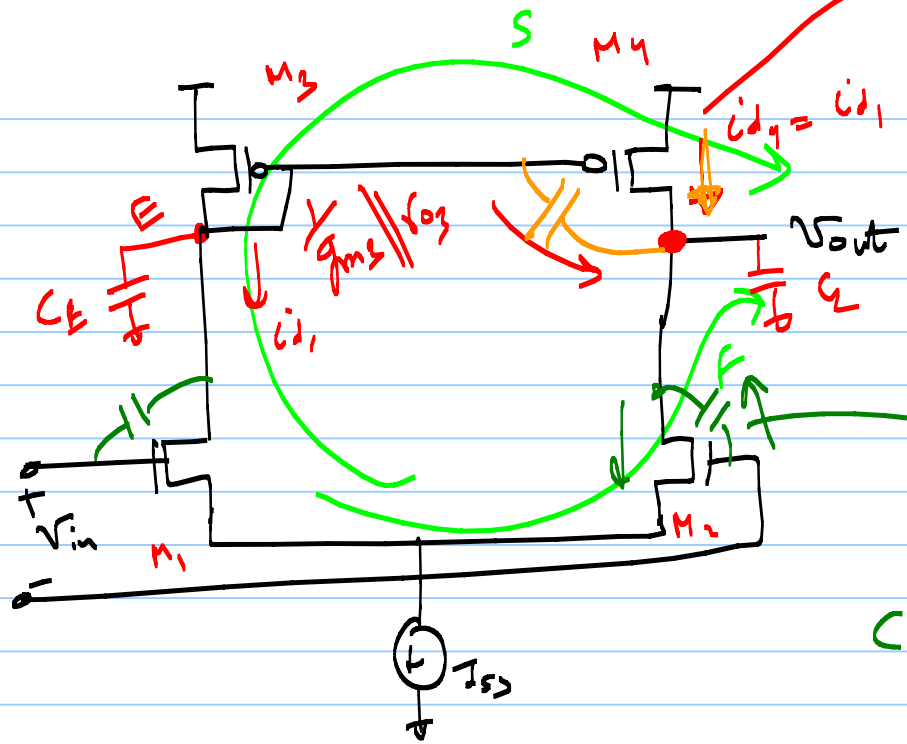


CS $R_s = 0$



$$\omega_{p_1} = \frac{1}{(r_o \| R_D) C_L} \qquad C_{gd_1} + C_{db}$$

$$\omega_{z_1} = + \frac{g_{m_1}}{C_{gd_1}} \qquad (RHP)$$



LHP zero (slow path)

pole at node E

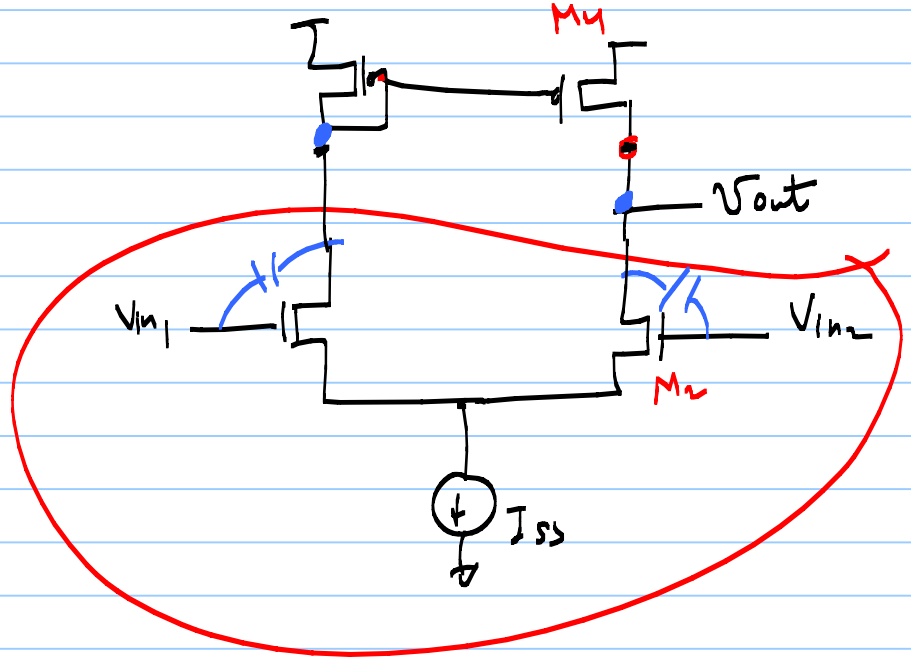
↳ $\frac{g_{m3}}{C_E}$ (Mirror pole)

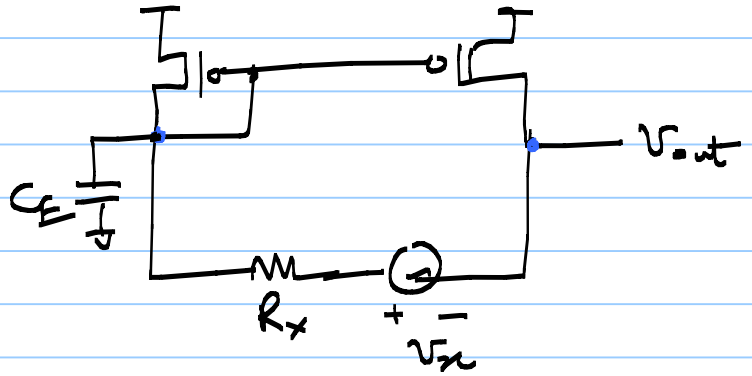
RHP zero (fast path)

$C_E = C_{gs_3} + C_{gs_4} + C_{db_3} + C_{db_1}$

+ Miller contribution from

C_{gd_1} & C_{gd_4}


M4
Vout
Vin1
Vin2
M2
Iss


Vout
Rx
+
Vx
−

$$\frac{V_{out}}{V_{in}}(s) = \frac{g_{mN} r_{on} \left(2g_{mp} + sC_E \right)}{2 r_{op} r_{on} C_E C_L s^2 + \left[(2r_{on} + r_{op}) C_E + r_{op}(1 + 2g_{mp} r_{on}) C_L \right] s + 2g_{mp}(r_{on} + r_{op})}$$

LHP zero @ $\omega_{z_1} = -\frac{2g_{mp}}{C_E}$

ω_{p_1} , ω_{p_2}

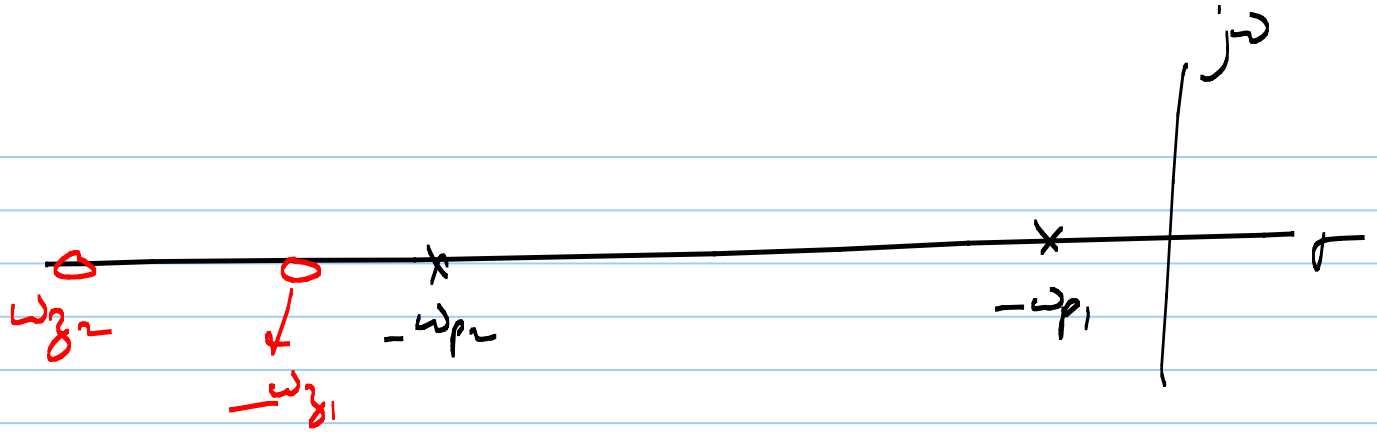
$$\omega_{p_1} = \frac{1}{(r_{on} \| r_{op}) C_L}$$

$$\omega_{p_2} = \frac{g_{mp}}{C_E}$$

LHP

$$\omega_{z_1} = -\frac{2g_{mp}}{C_E} = 2\omega_{p_2}$$

$$\omega_{z_2} = \frac{g_{mn}}{C_{gdn}}$$ RHP


jω
σ
ω_{z_2}
$-\omega_{z_1}$
$-\omega_{p_2}$
$-\omega_{p_1}$