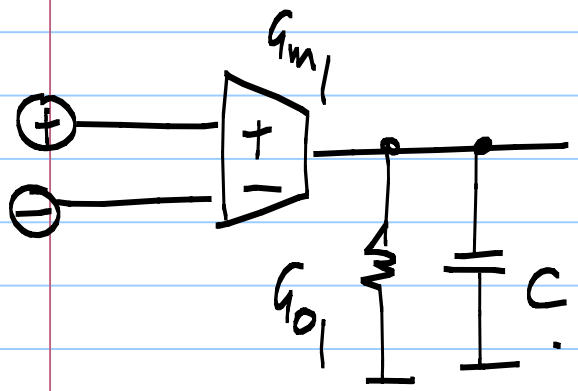
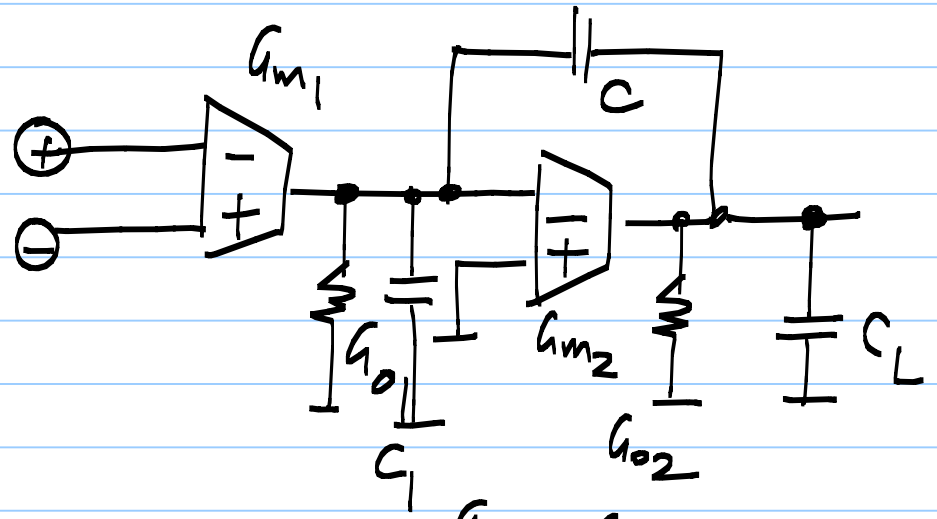
Lecture 36 : Two stage opamp



$$A_o = \frac{G_{m1}}{G_{o1}}$$

$$\omega_u = \frac{G_{m1}}{C}$$

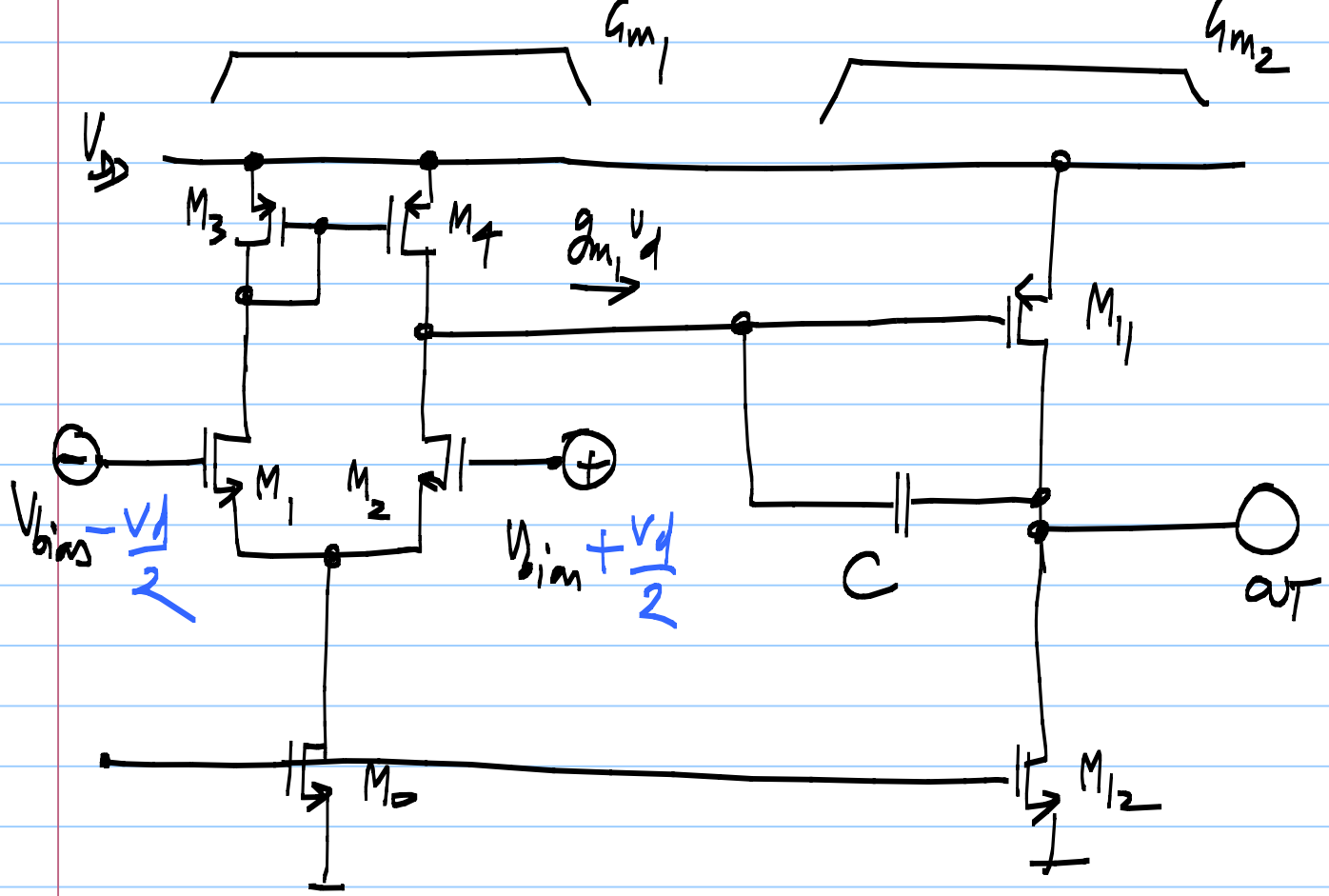
CC VS



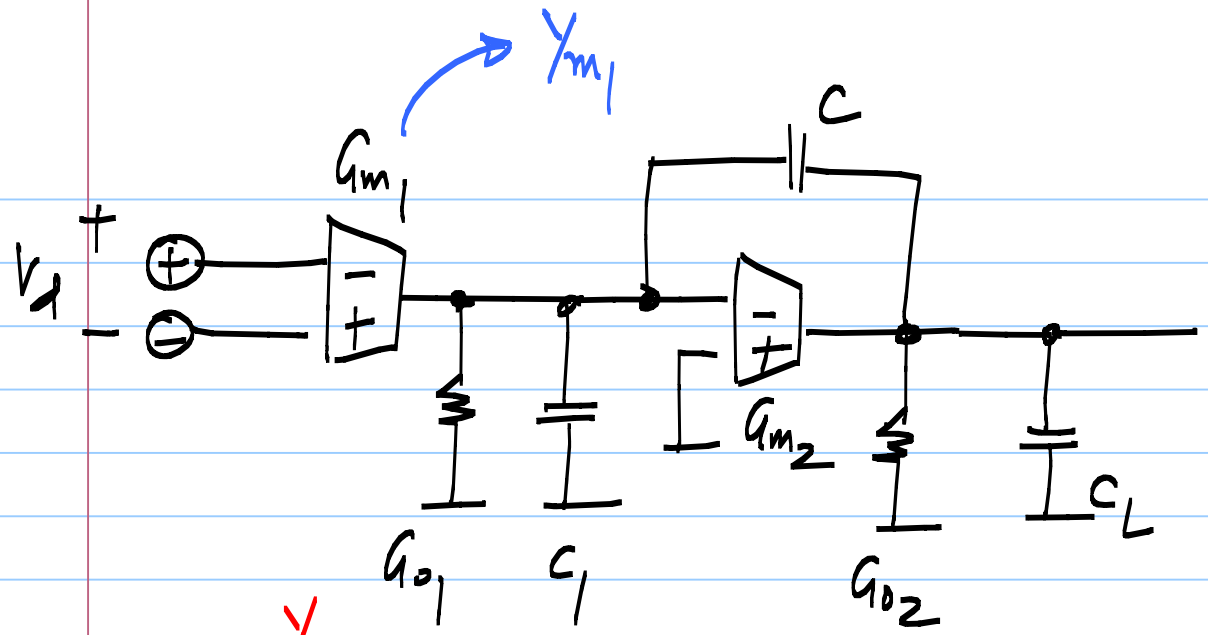
$$A_o = \frac{G_{m1}}{G_{o1}} \cdot \frac{G_{m2}}{G_{o2}}$$

$$\omega_u = \frac{G_{m1}}{C}, \quad p_2 = -\frac{G_{m2}}{C_L + C_1}$$

First stage: G_{m_1} : Differential pair transconductor



Two stage miller-compensated opamp.

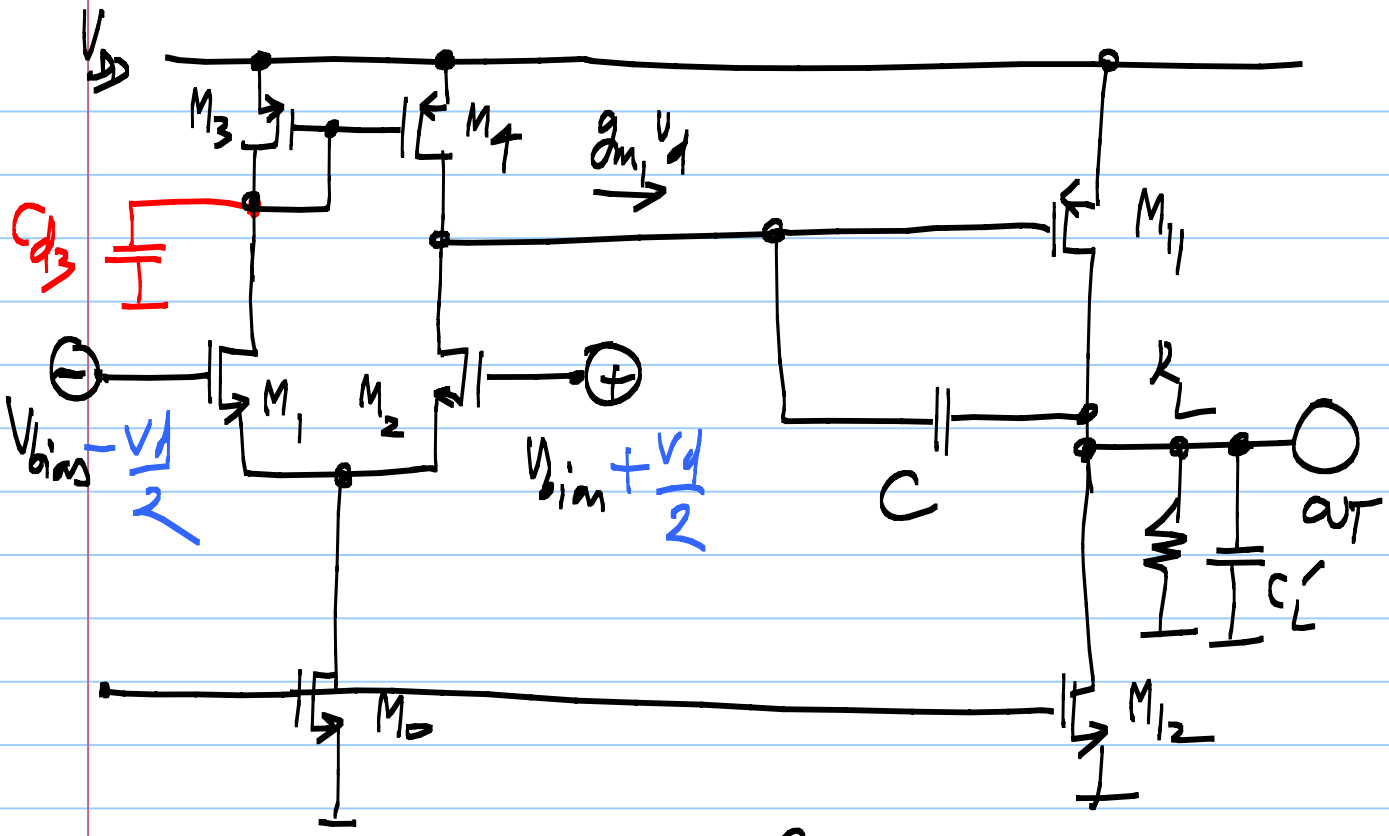


$$Z_1 = G_{m_2}/C$$

$$p_1 \simeq \frac{G_{o_1}}{C_1 + C\left(\frac{G_{m_2}}{G_{o_2}} + 1\right)}$$

$$p_2 \simeq \frac{G_{m_2}\cdot\frac{C}{C+C_1} + G_{o_2}}{C_L + \frac{CC_1}{C+C_1}}$$

$$\frac{V_o}{V_d} = \frac{\cancel{Y_{in_1}}\; G_{m_1} G_{m_2}}{G_{o_1}\cdot G_{o_2}} \cdot \frac{\left(1 - s/z_1\right)}{\left(1 + \frac{s}{p_1}\right)\left(1 + \frac{s}{p_2}\right)}$$



$$Y_m(s) = g_{m_1} \cdot \frac{1 + s \cdot \frac{C_{d_3}}{2g_{m_3}}}{1 + s \cdot C_{d_3}/g_{m_3}}$$

$$C_1 = C_{db_4} + C_{db_2} + C_{gs_{11}}$$

$$C_L = C_L' + C_{db_{11}} + C_{db_{12}}$$

$$G_{o_1} = g_{ds_1} + g_{ds_3}$$

$$G_{o_2} = g_{ds_{11}} + g_{ds_{12}} + G_L$$

$$G_{m_2} = g_{m_{11}}$$

$$A_0 = \frac{g_{m_1}}{g_{ds_1} + g_{ds_3}} \cdot \frac{g_{m_{11}}}{g_{ds_{11}} + g_{ds_{12}}}$$

$$\omega_u = \frac{g_{m_1}}{C}$$

$$p_2 = -\frac{g_{m_{11}} \cdot \frac{C}{C + C_1} + g_{o_2}}{\frac{C \cdot C_1}{C + C_1} + C_L} \; ; \quad p_3 = -\frac{g_{m_3}}{C_{d_3}}$$

$$z_1 = +\frac{g_{m_{11}}}{C} \; ; \quad z_2 = -\frac{2 \cdot g_{m_3}}{C_{d_3}}$$

$A_0 = 1000$

$R_L = 1k\Omega$

$G_L = 1mS$

$G_{m_1} = 1000mS$

$= 1S$

(Single stage opamp)

1000 mS

$A_0 = 100 \times 10$

$G_L = 1mS$

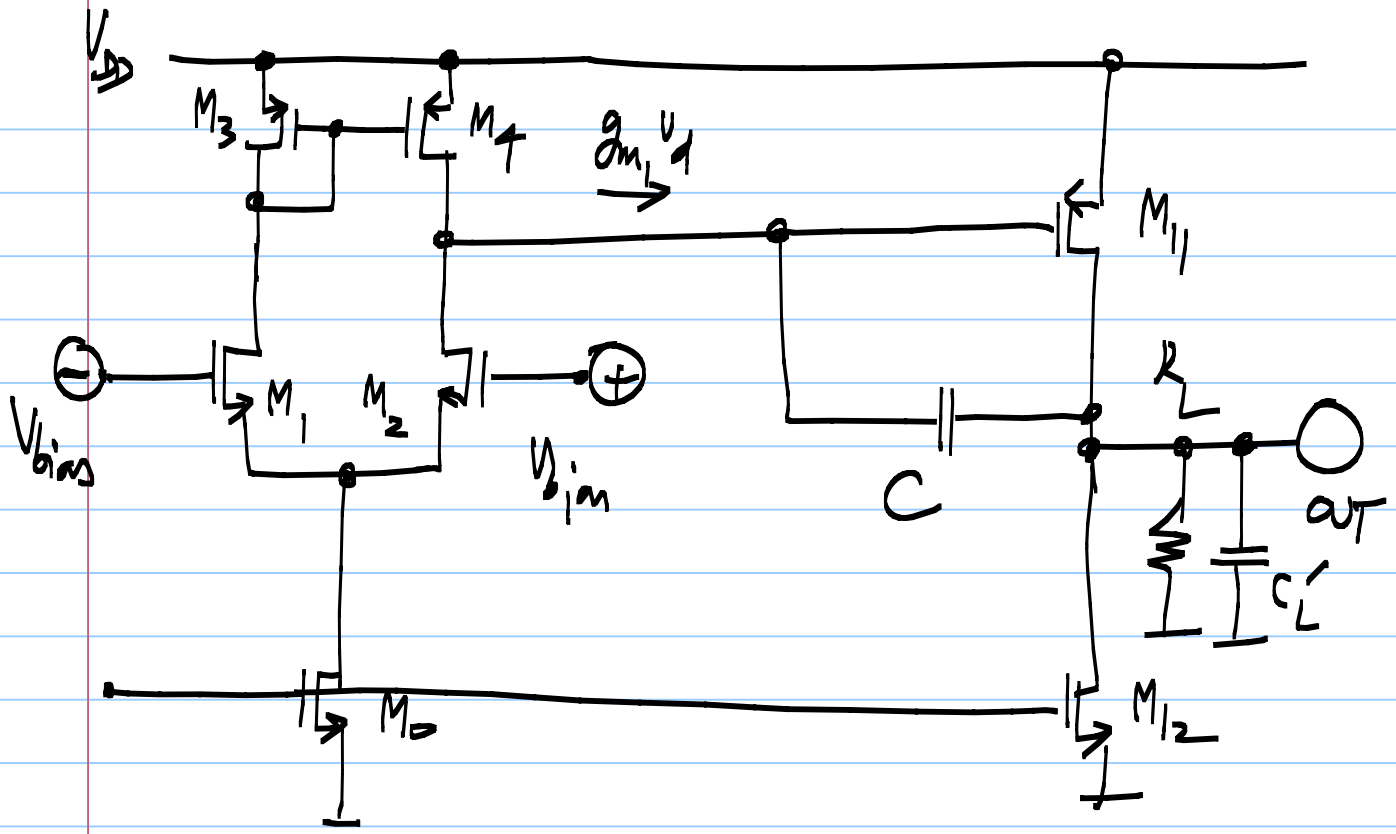
$G_{m_2} = 10mS$

$\left\{ \frac{G_{m_1}}{G_{o_1}} = 100 \right\}$ $G_{m_1} = 2mS$

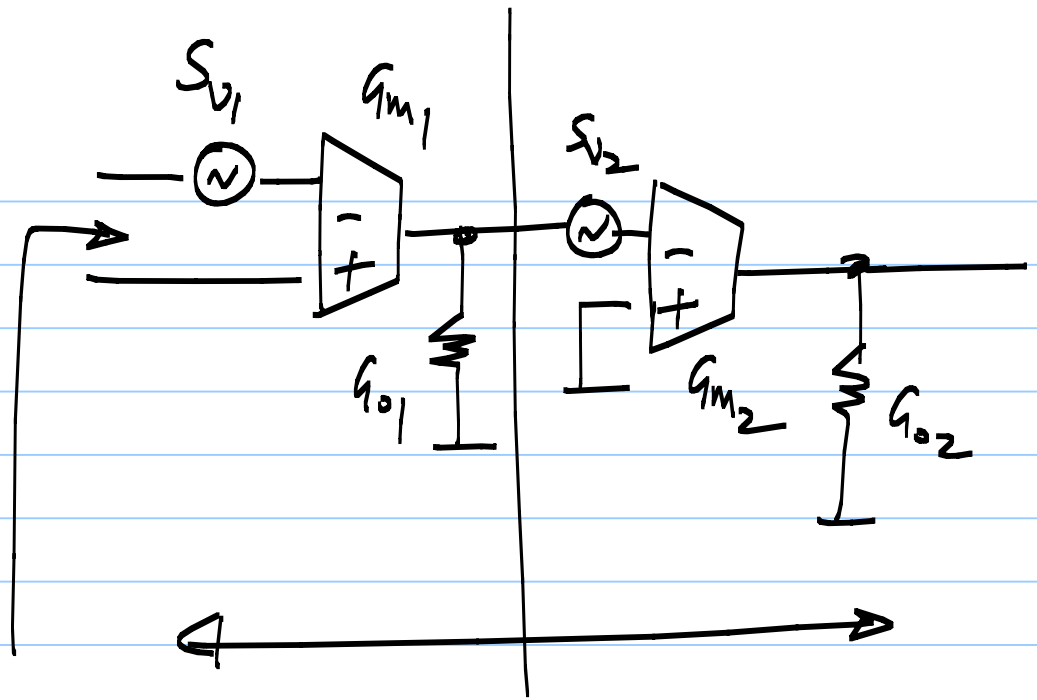
12mS

Noise:

Offset:



$$\frac{16}{3} \cdot \frac{kT}{g_{m_1}} \left(1 + \frac{g_{m_3}}{g_{m_1}}\right)$$



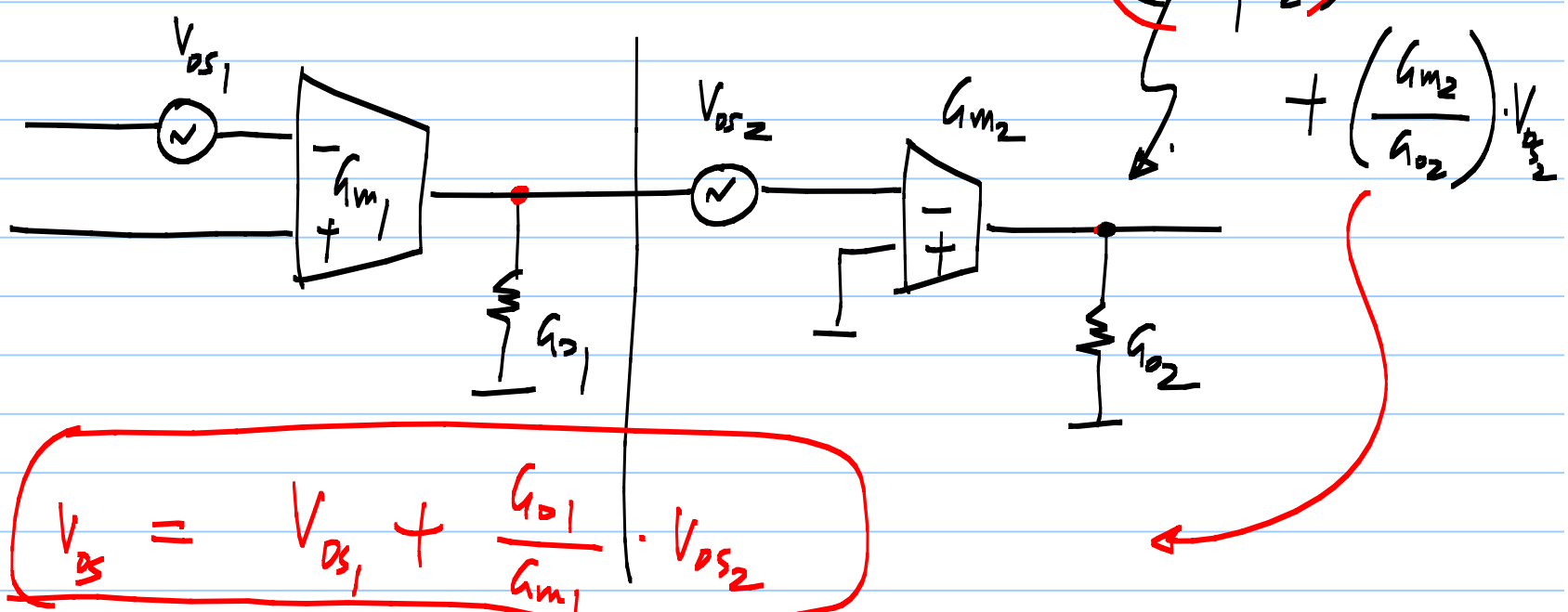
$$S_{v_1}\left(\frac{G_{m_1}}{G_{o_1}}\cdot\frac{G_{m_2}}{G_{o_2}}\right)^2 + S_{v_2}\left(\frac{G_{m_2}}{G_{o_2}}\right)^2$$

$$\left(\frac{G_{m_1}}{G_{o_1}}\cdot\frac{G_{m_2}}{G_{o_2}}\right)^2$$

$$S_{v_{in}} = S_{v_1} + S_{v_2}\cdot\left(\frac{G_{m_1}}{G_{m_1}}\right)^2$$

$$S_{V_{in}} \approx \frac{16}{3} \cdot \frac{kT}{g_{m_1}} \left(1 + \frac{g_{m_3}}{g_{m_1}}\right)$$

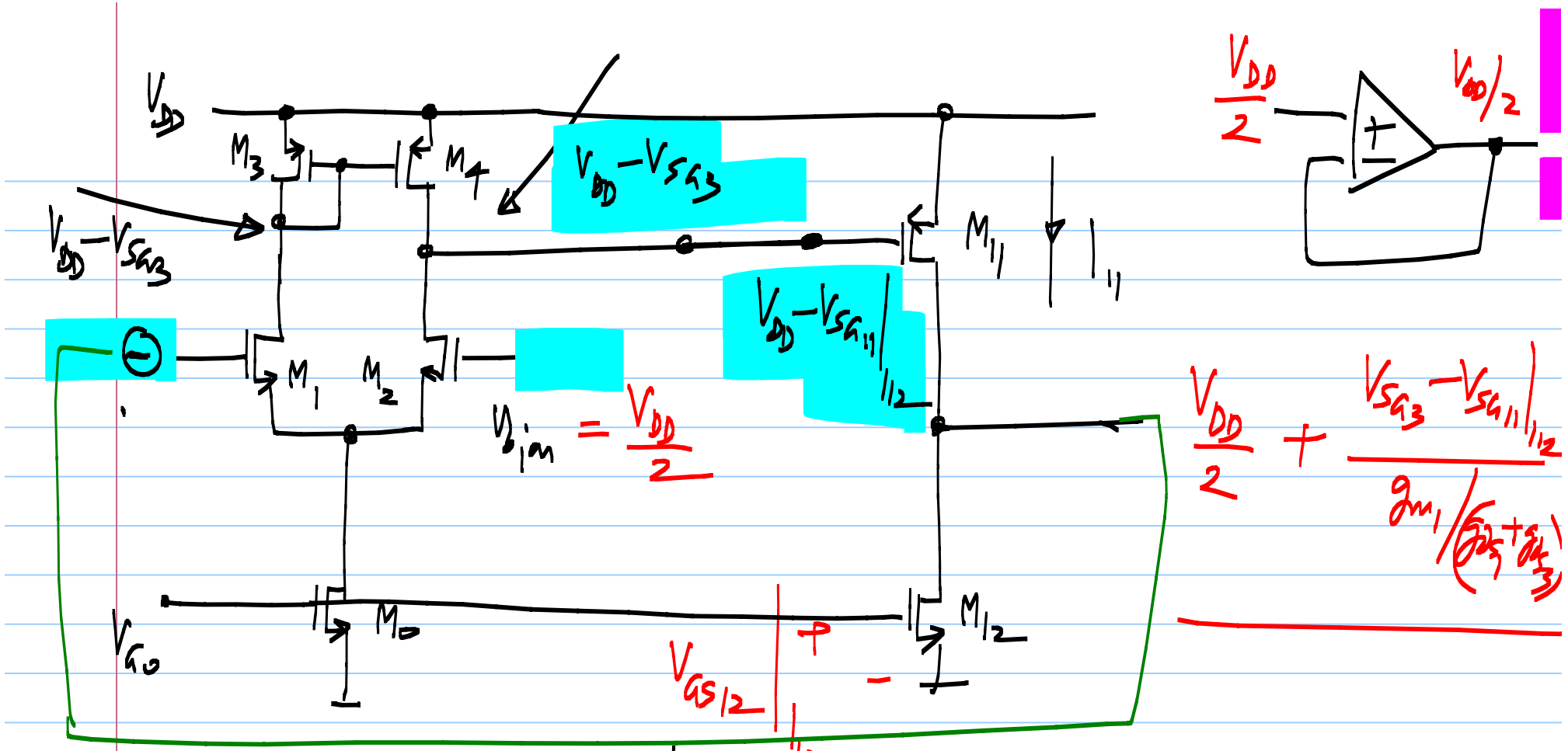
(2 stage opamp)



$$\left(\frac{G_{m_1} G_{m_2}}{G_{D_1} G_{D_2}}\right) \cdot V_{os_1} + \left(\frac{G_{m_2}}{G_{D_2}}\right) \cdot V_{os_2}$$

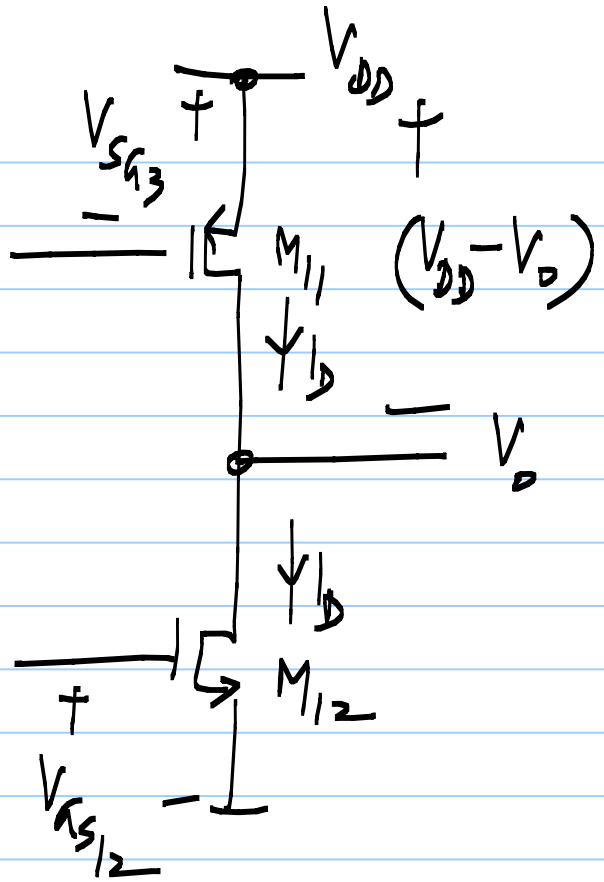
$$V_{os} = V_{os_1} + \frac{G_{D_1}}{G_{m_1}} \cdot V_{os_2}$$

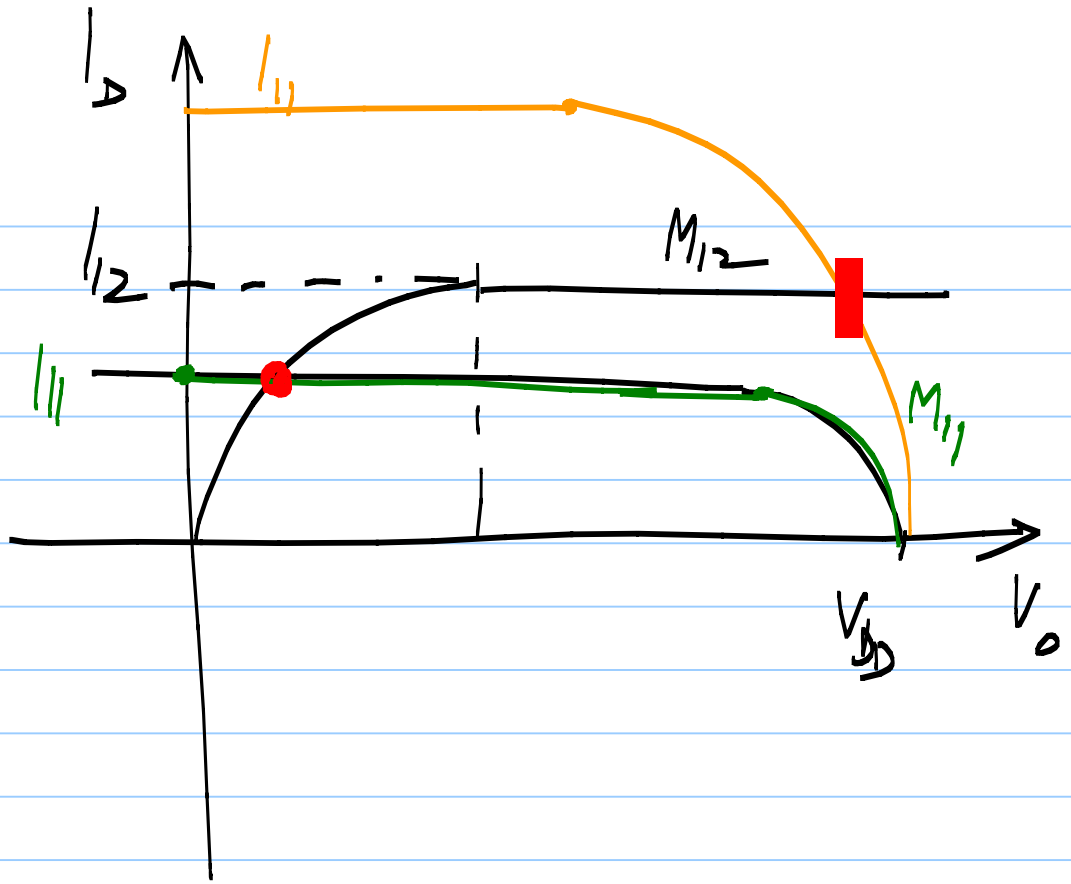
$$\sigma_{V_{OS}}^2 = \sigma_{V_{T12}}^2 + \left(\frac{g_{m1}}{g_{m3}}\right)^2 \cdot \sigma_{V_{T34}}^2$$



$I_{11} > I_{12}$: M_{11} in triode, $I_D(M_{11}) = I_{12}$

$I_{11} < I_{12}$: M_{12} in triode, $I_D(M_{12}) = I_{11}$


V_{DD}
V_{SG_3}
M_{11}
$(V_{DD}-V_o)$
I_D
V_o
I_D
M_{12}
$V_{GS_{12}}$


I_D
I_{11}
I_{12}
M_{12}
I_{11}
M_{11}
V_{DD}
V_o

Systematic offset if $V_{SG_3}\Big|_{\frac{I_D}{2}} \neq V_{SG_{11}}\Big|_{I_2}$

$\left\{ \begin{array}{l} \text{o/p of } 1^{st} \text{ stage} = V_{DD} - V_{SG_3}\Big|_{I_D/2} \\ \text{i/p req. for } 2^{nd} \text{ stage} = V_{DD} - V_{SG_{11}}\Big|_{I_2} \end{array} \right.$

To avoid this : $\boxed{V_{SG_{11}}\Big|_{I_2} = V_{SG_3}\Big|_{I_D/2}}$

$$V_{Tp} + \sqrt{\frac{2 \cdot I_D/2}{\mu_p C_{ox} W_3/L_3}} = V_{Tp} + \sqrt{\frac{2 \cdot I_{12}}{\mu_p C_{ox} W_{11}/L_{11}}}$$

$$\left[\frac{I_D/2}{W_3/L_3} = \frac{I_{12}}{W_{11}/L_{11}} \right]$$