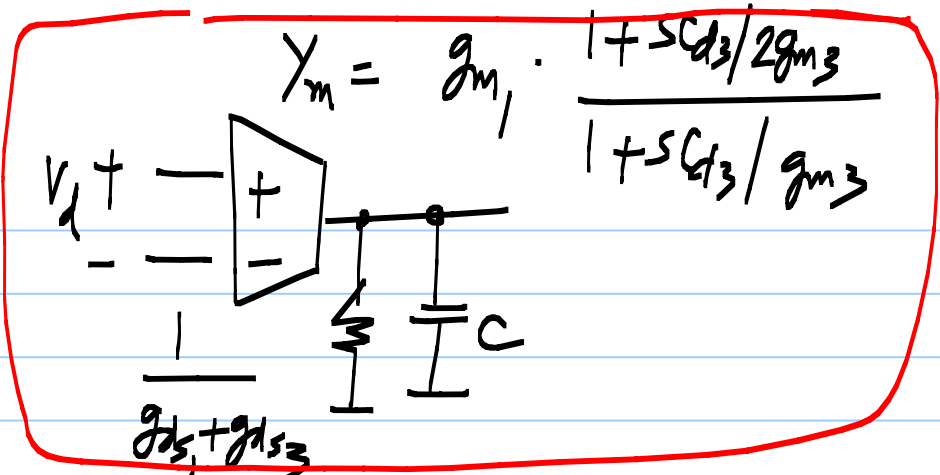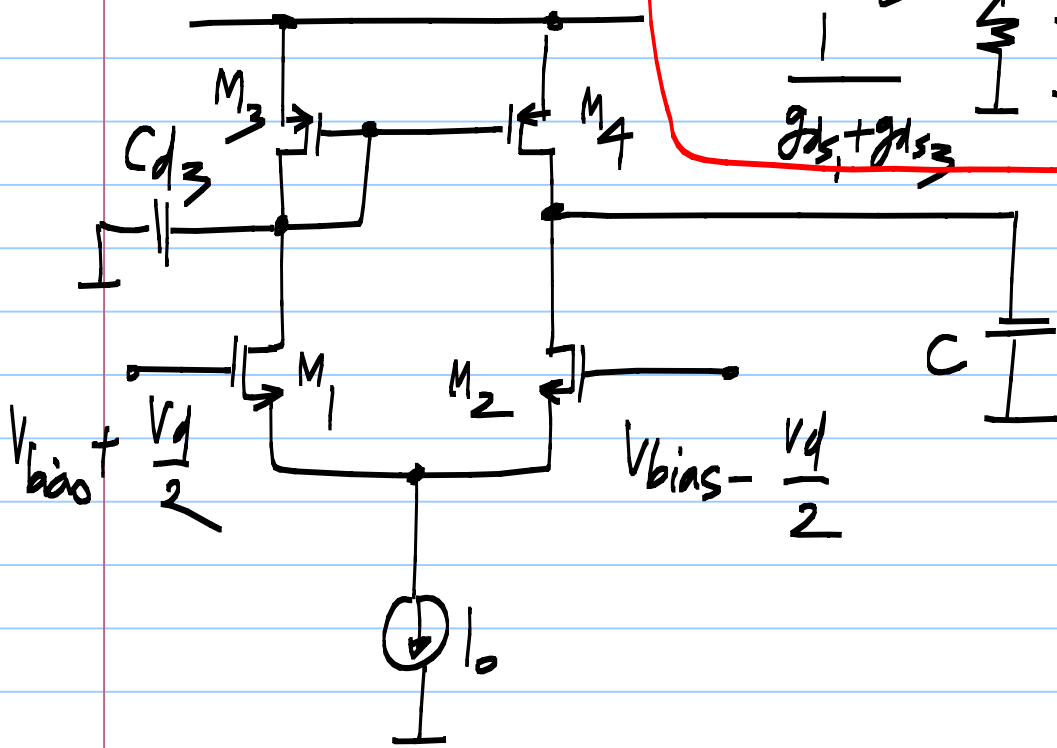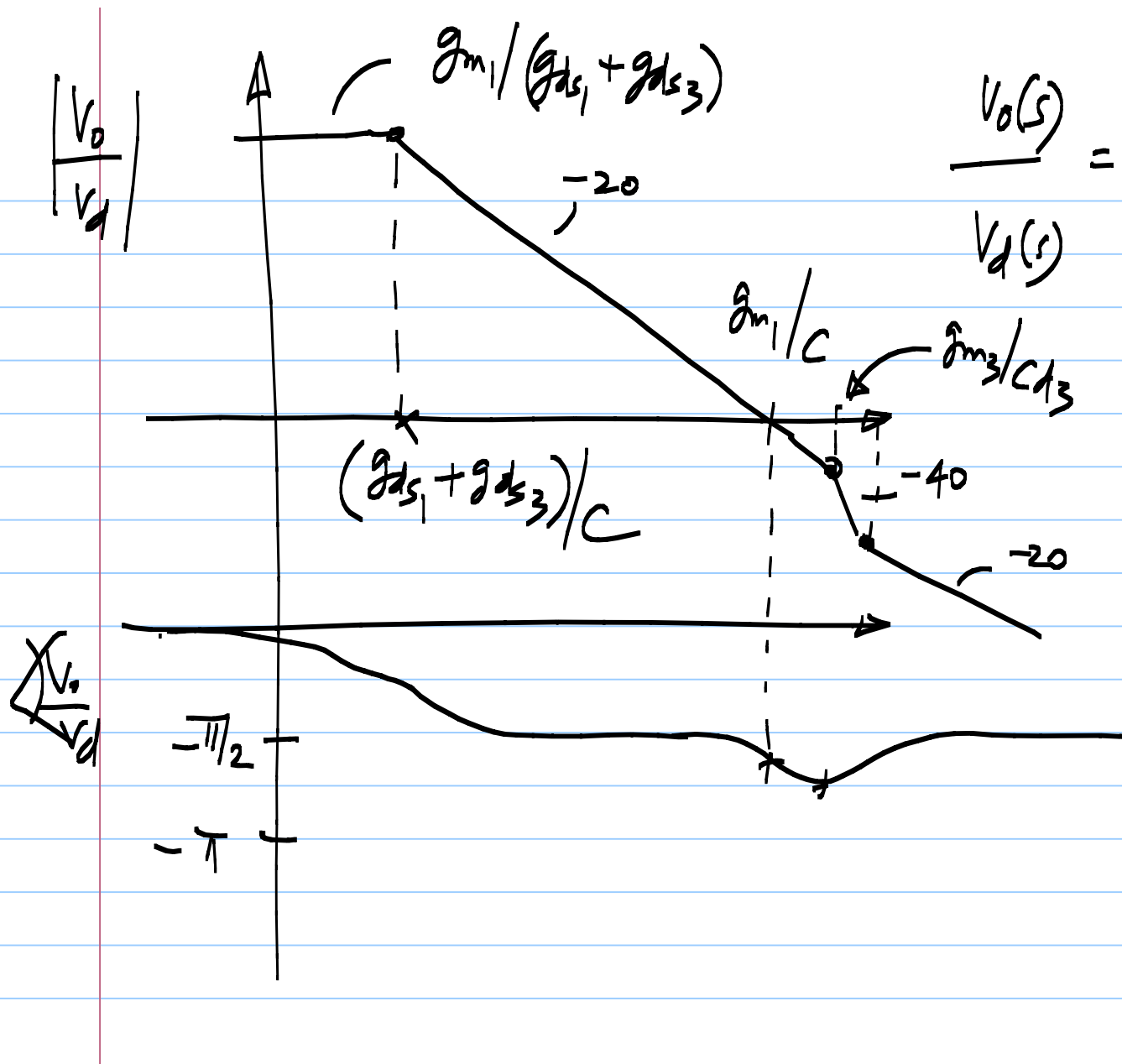# Lecture 31

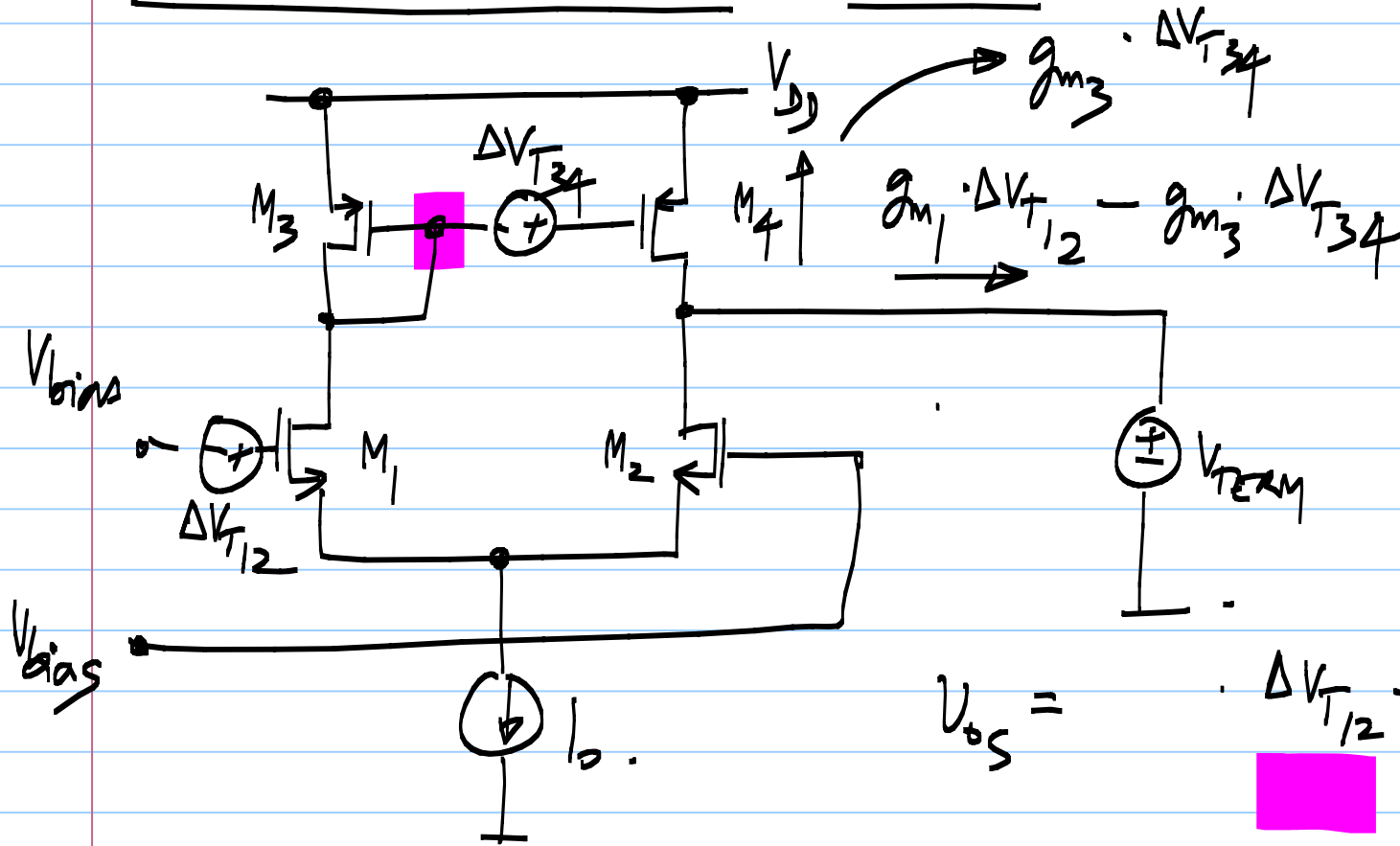$$Y_m = g_{m_1} \cdot \frac{1 + sC_{d_3}/2g_{m_3}}{1 + sC_{d_3}/g_{m_3}}$$

$$\frac{V_0(s)}{V_d(s)} = \frac{g_{m_1}}{g_{ds_1} + g_{ds_3} + sC} \cdot \frac{1 + s\frac{C_{d_3}}{2g_{m_3}}}{1 + s\frac{C_{d_3}}{g_{m_3}}}$$

Labels on plot:

$g_{m_1}/(g_{ds_1} + g_{ds_3})$

-20

g_{m_1}/C

g_{m_3}/C_{d_3}

$(g_{ds_1} + g_{ds_3})/C$

-40

-20

$\frac{V_0}{V_d}$

$\left|\frac{V_0}{V_d}\right|$

$-\pi/2$

$-\pi$

Single stage opamp: offset

$$v_{GS_4} = \Delta V_{T_{34}}$$

$$g_{m_3} \cdot \Delta V_{T_{34}}$$

$$g_{m_1} \cdot \Delta V_{T_{12}} - g_{m_3} \cdot \Delta V_{T_{34}}$$

$$V_{OS} = \quad \cdot \Delta V_{T_{12}} - \frac{g_{m_3}}{g_{m_1}} \cdot \Delta V_{T_{34}}$$
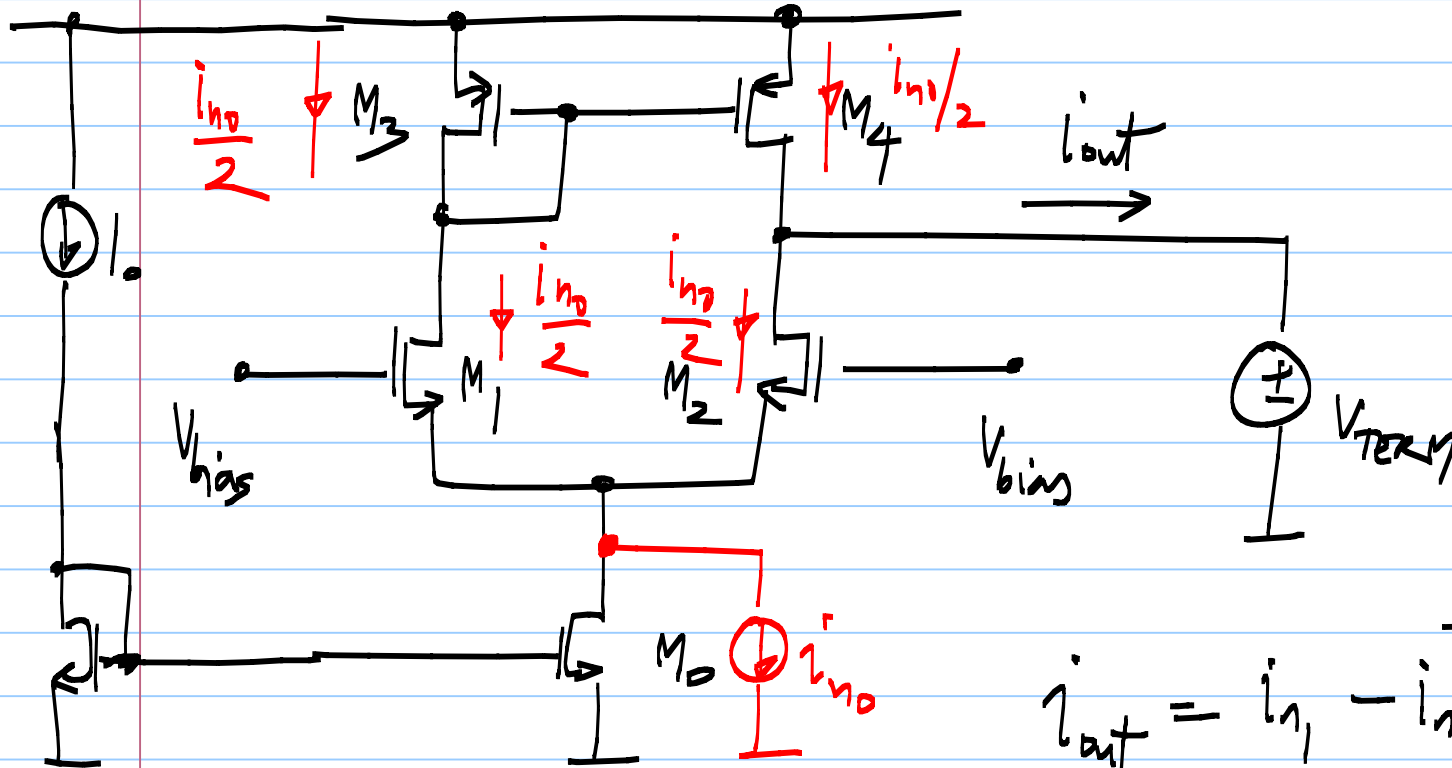
$$\sigma_{V_{OS}}^2 = \sigma_{V_{T_{12}}}^2 + \left(\frac{g_{m_3}}{g_{m_1}}\right)^2 \cdot \sigma_{V_{T_{34}}}^2$$

$$\sigma_{V_{OS}} = \sqrt{\sigma_{V_{T_{12}}}^2 + \left(\frac{g_{m_3}}{g_{m_1}}\right)^2 \cdot \sigma_{V_{T_{34}}}^2}$$
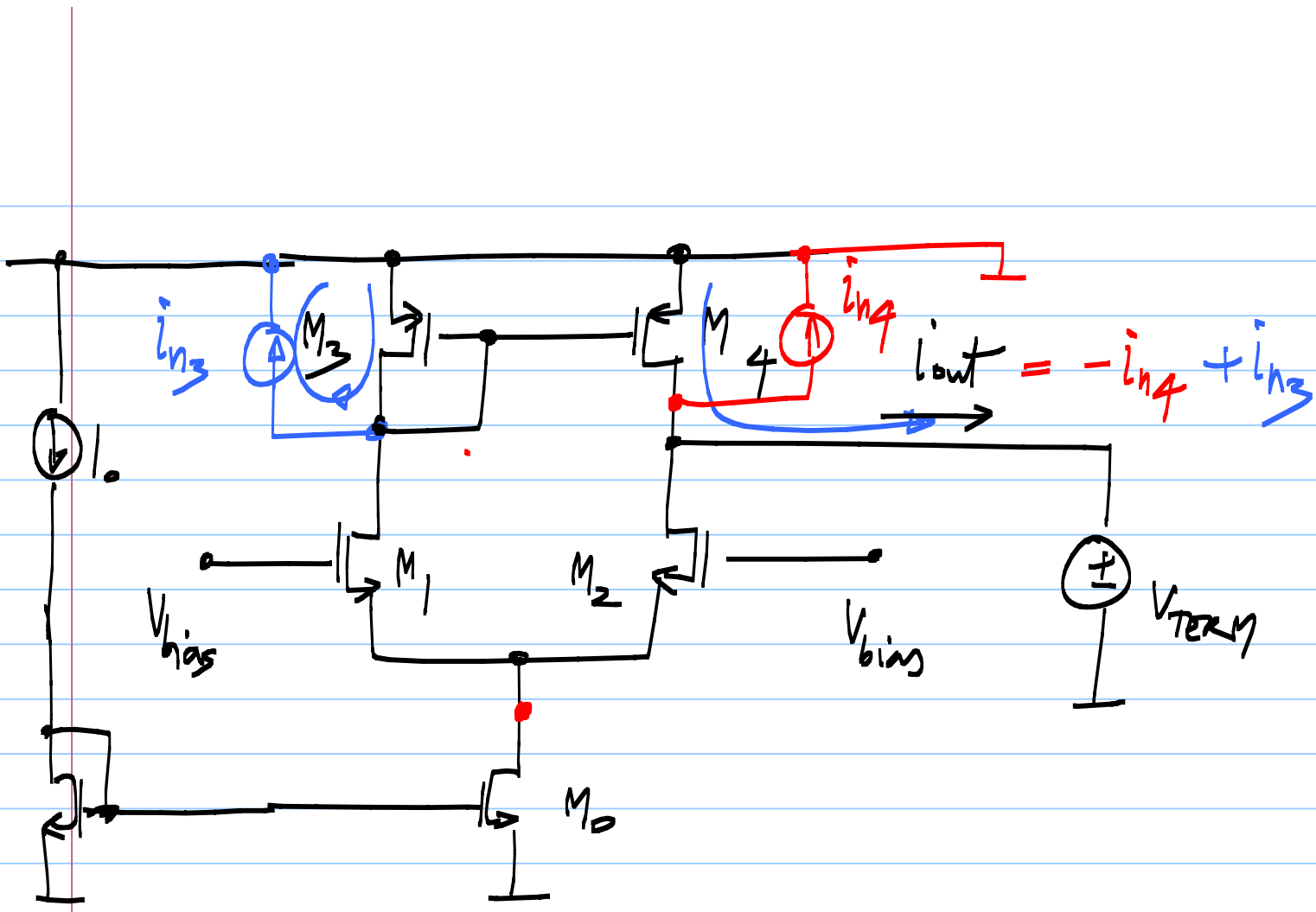
$$\sigma_{V_{OS}}^2 = \frac{A_{V_{Tn}}^2}{W_1 L_1} + \left(\frac{g_{m_3}}{g_{m_1}}\right)^2 \cdot \frac{A_{V_{Tp}}^2}{W_3 L_3}$$

Single stage opamp: Noise

$$i_{out}$$

$$M_0: \quad 0$$

$$M_1: \quad i_{n_1}$$

$$M_2: \quad -i_{n_2}$$

$$M_3: \quad i_{n_3}$$

$$M_4: \quad -i_{n_4}$$

$$i_{out} = i_{n_1} - i_{n_2} + i_{n_3} - i_{n_4}$$

$i_{out} = -i_{n4} + i_{n3}$

M_3

M_4

i_{n3}

i_{n4}

M_1

M_2

V_{bias}

V_{bias}

V_{TERM}

M_0

I_0

$i_{n_1}/2$

i_{n_1} M_3 M_4 i_{n_1}

$i_{out} = i_{n_1}$

$\dfrac{i_{n_1}}{2}$

i_{n_1}

$\dfrac{i_{n_1}}{2}$

I_0

M_1 M_2

i_{n_1}

V_{bias} $\dfrac{i_{n_1}}{2}$ i_{n_1} $\dfrac{i_{n_1}}{2}$ V_{bias}

V_{TERM}

M_0

D

i_x i_x

A i_x B

i_x
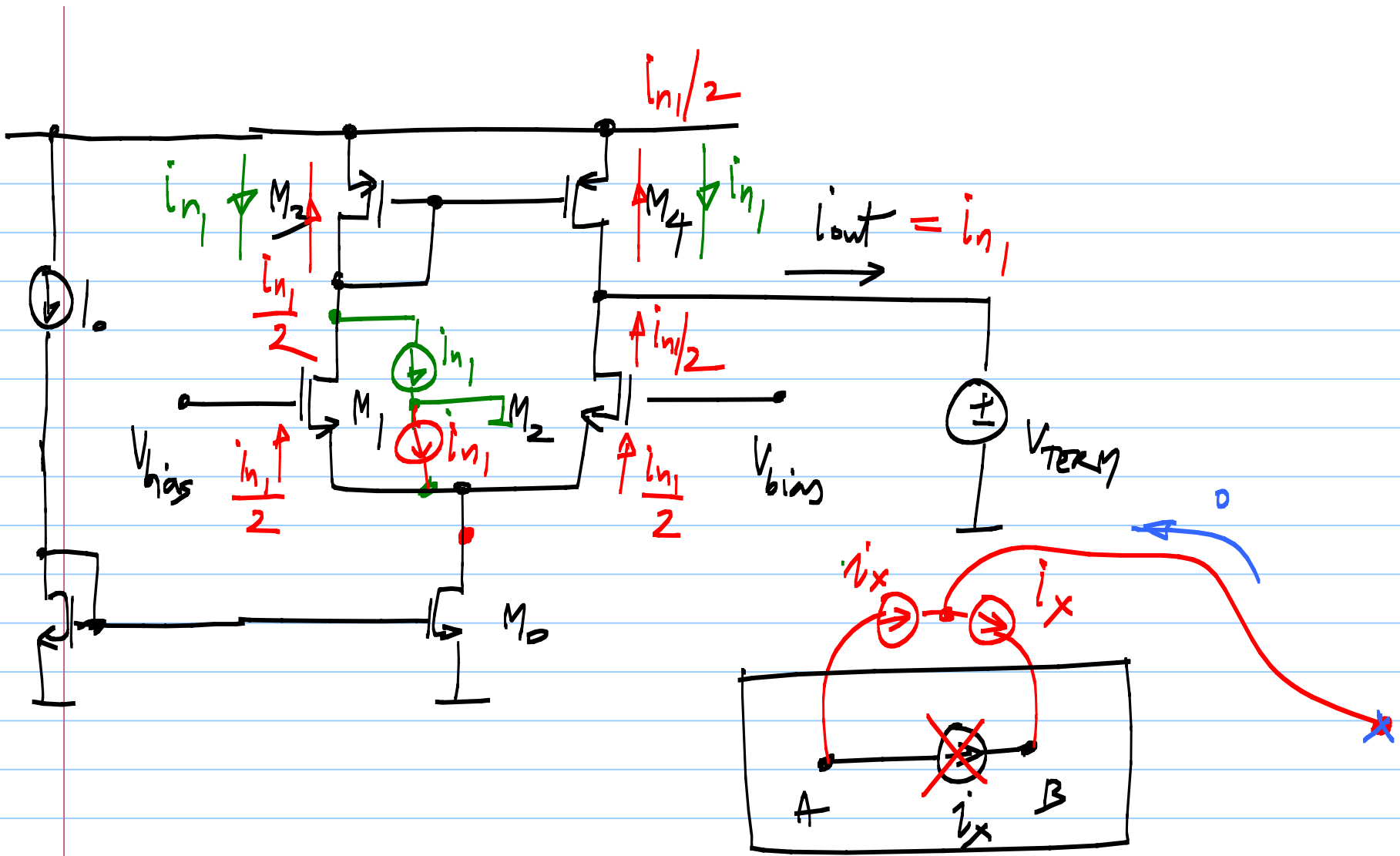
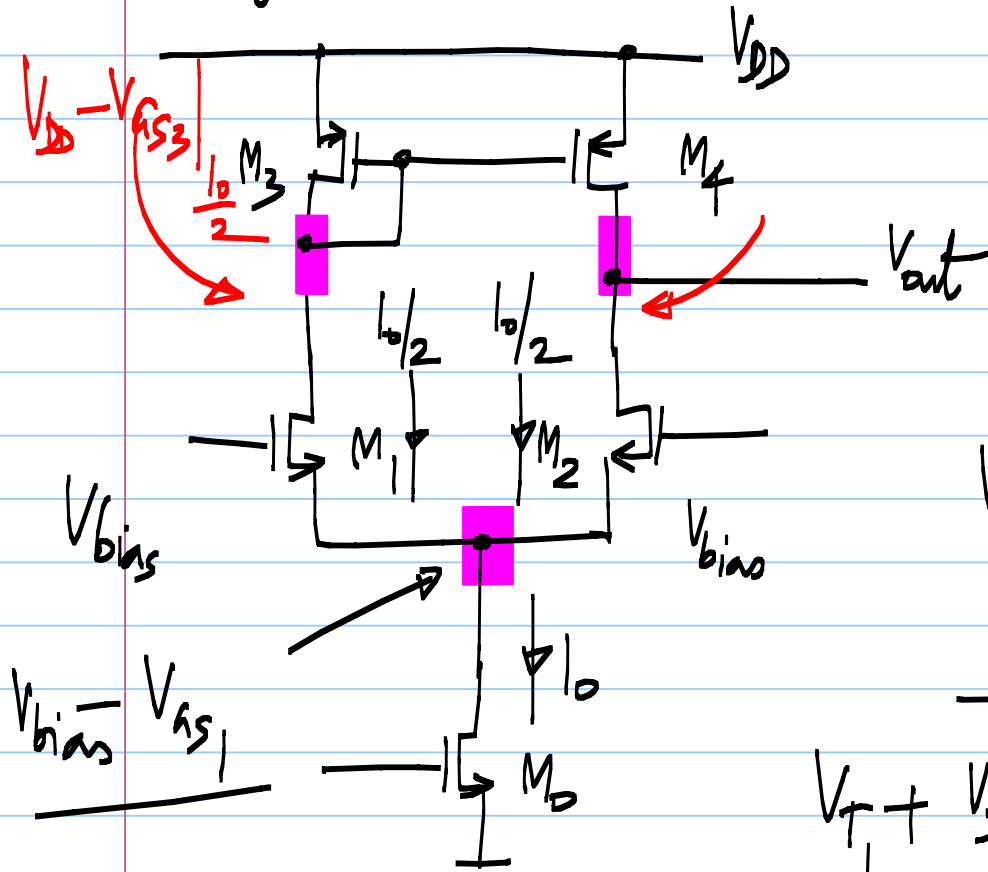$$i_{out} = i_{n_1} - i_{n_2} + i_{n_3} - i_{n_4}$$

$$S_{i_{out}} = S_{i_{n_1}} + S_{i_{n_2}} + S_{i_{n_3}} + S_{i_{n_4}}$$

$$= \frac{8}{3} kT \left(g_{m_1} + g_{m_1} + g_{m_3} + g_{m_3} \right)$$

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

$$S_{v_{in}} = \frac{S_{i_{out}}}{g_{m_1}^2} = \frac{16}{3} \frac{kT}{g_m} \left(1 + \frac{g_{m_3}}{g_{m_1}} \right)$$

Large signal limits:

$V_{DD} - V_{GS3}\Big|_{\frac{I_0}{2}}$

M_3

M_4

V_{DD}

V_{out}

$I_0/2$ $I_0/2$

M_1 M_2

V_{bias} V_{bias}

$V_{bias} - V_{GS1}$

M_0

I_0

Find the limits on V_{out} &

V_{bias}

Assume $v_d \simeq 0$

$$V_{bias} - V_{T_1} < V_{out} < V_{DD} - V_{DSAT4}\Big|_{\frac{I_0}{2}}$$

$$V_{T_1} + V_{DSAT_1} + V_{DSAT_0} < V_{bias} < V_{DD} - V_{T_3} - V_{DSAT_3} + V_{T_1}$$

Output range:

$$V_{bias} - V_{T_1} < V_{out} < V_{DD} - V_{DSAT_3}\Big|_{I_0/2}$$

Input common mode range:

$$V_{T_1} + V_{DSAT_1}\Big|_{\frac{I_0}{2}} + V_{DSAT_6}\Big|_{I_0} < V_{bias} < V_{DD} - V_{T_3} - V_{DSAT_3}\Big|_{\frac{I_0}{2}} + V_{T_1}$$

$$V_{DD}$$

$$V_{DD} - V_{DSAT_3}$$

$$V_{out}$$

$$V_{bias} - V_{T_1}$$

$$0$$

$$V_{DD} - V_{T_3} + V_{T_1} - V_{DSAT_3}$$

$$V_{bias}$$

$$V_{T_1} + V_{DSAT_1} + V_{DSAT_3}$$