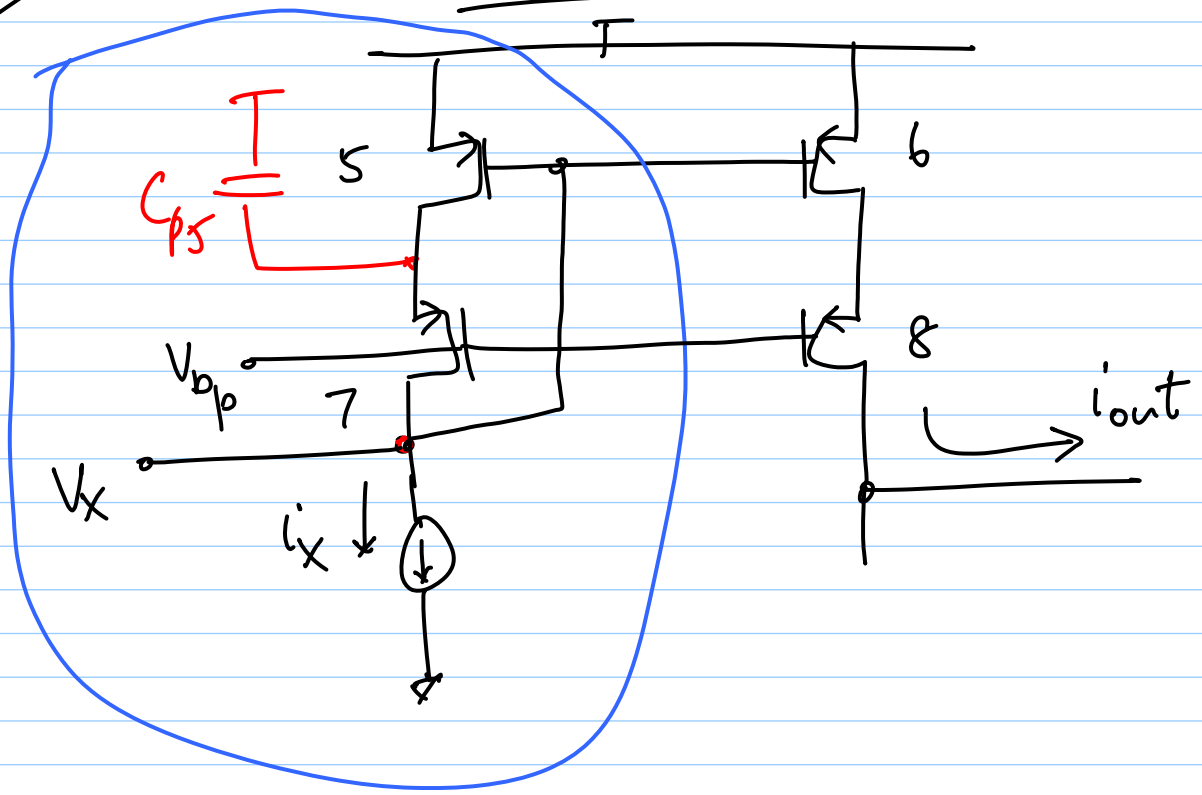
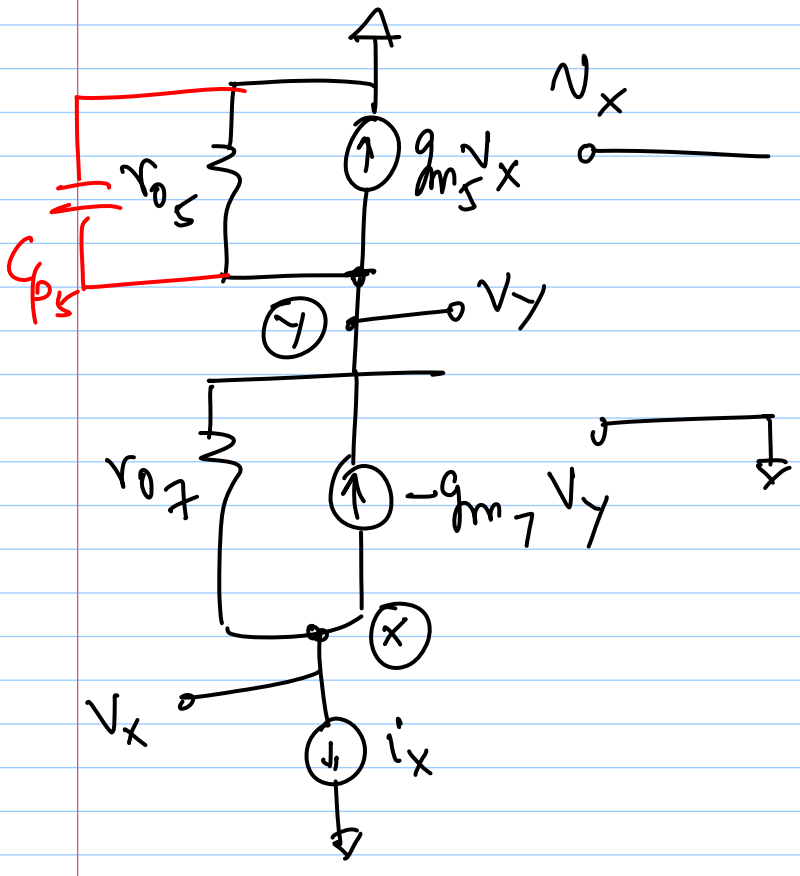
29-2-12

Lec 23





$$\frac{V_x}{i_x} \quad (\Omega)$$

@ (x)

$$(V_x - V_y) g_{o_7} - g_{m_7} V_y = -i_x$$

$$V_y = \frac{g_{o_7} V_x + i_x}{(g_{m_7} + g_{o_7})}$$

@ (Y),

$$V_Y\left(sC_{p5} + g_{o5}\right) + g_{m5}V_X = -i_X$$

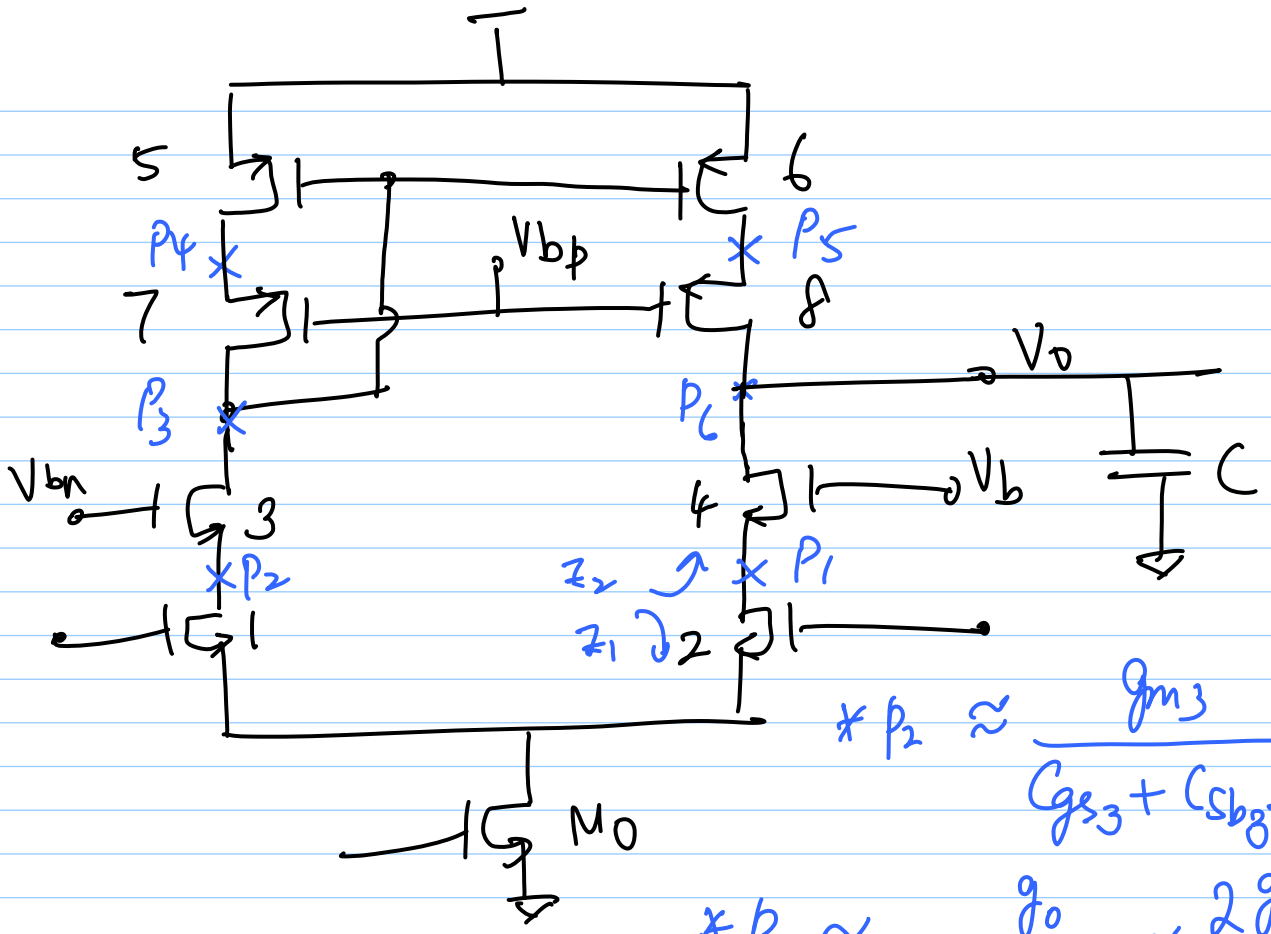
$$\frac{\left(g_{o7}V_X + i_X\right)}{g_{m7}}\left(sC_{p5} + g_{o5}\right) + g_{m5}V_X = -i_X$$

$$V_X\left[g_{m5} + \frac{g_{o7}}{g_{m7}}\left(sC_{p5} + g_{o5}\right)\right] = -i_X\left[1 + \frac{sC_{p5} + g_{o5}}{g_{m7}}\right]$$

$$\frac{V_X}{i_X} = -\frac{g_{m7} + g_{o5} + sC_{p5}}{g_{m5}g_{m7} + g_{o7}\left(sC_{p5} + g_{o5}\right)}$$

$$= -\frac{g_{m7} + sC_{p5}}{g_{m5}g_{m7} + g_{o7}sC_{p5}}$$

$$= \frac{-1}{g_{m5}} \cdot \frac{1 + sC_{p5}/g_{m7}}{1 + \frac{sC_{p5}\cdot g_{o7}}{g_{m5}g_{m7}}}$$



$$* p_2 \simeq \frac{g_{m3}}{C_{gs3} + C_{sb8} + C_{db1}}$$

$$* p_1 \sim \frac{g_o}{C} \sim \frac{2 g_{ds}}{(g_m r_{ds}) \cdot C}$$

$$z_1 \simeq r_{ds2}$$

$$z_2 = \frac{1}{g_{m4}} \left[1 + \frac{g_{m8} r_{ds8} \cdot r_{ds6}}{r_{ds4}} \right]$$

$$\simeq \frac{g_{m8} r_{ds8} r_{ds6}}{g_{m4} r_{ds4}} \sim r_{ds}$$

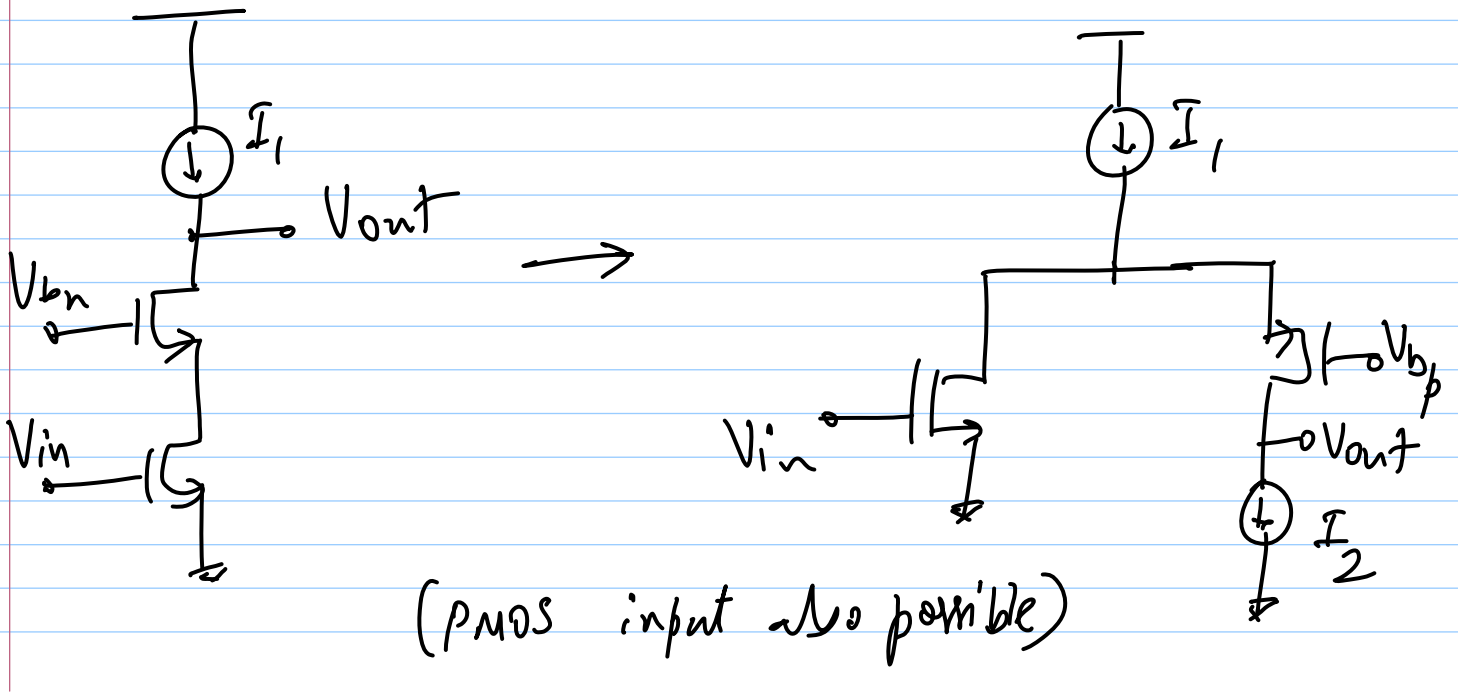
$$\Rightarrow \quad Z = z_1 \| z_2 \sim r_{ds}/2 \; \| \left(\frac{1}{2 g_{ds}} \right)$$

$$\Rightarrow p_1 \sim \frac{2 g_{ds}}{C_{gs4} + C_{sb4} + C_{db2}} \Rightarrow p_1 \ll p_2$$

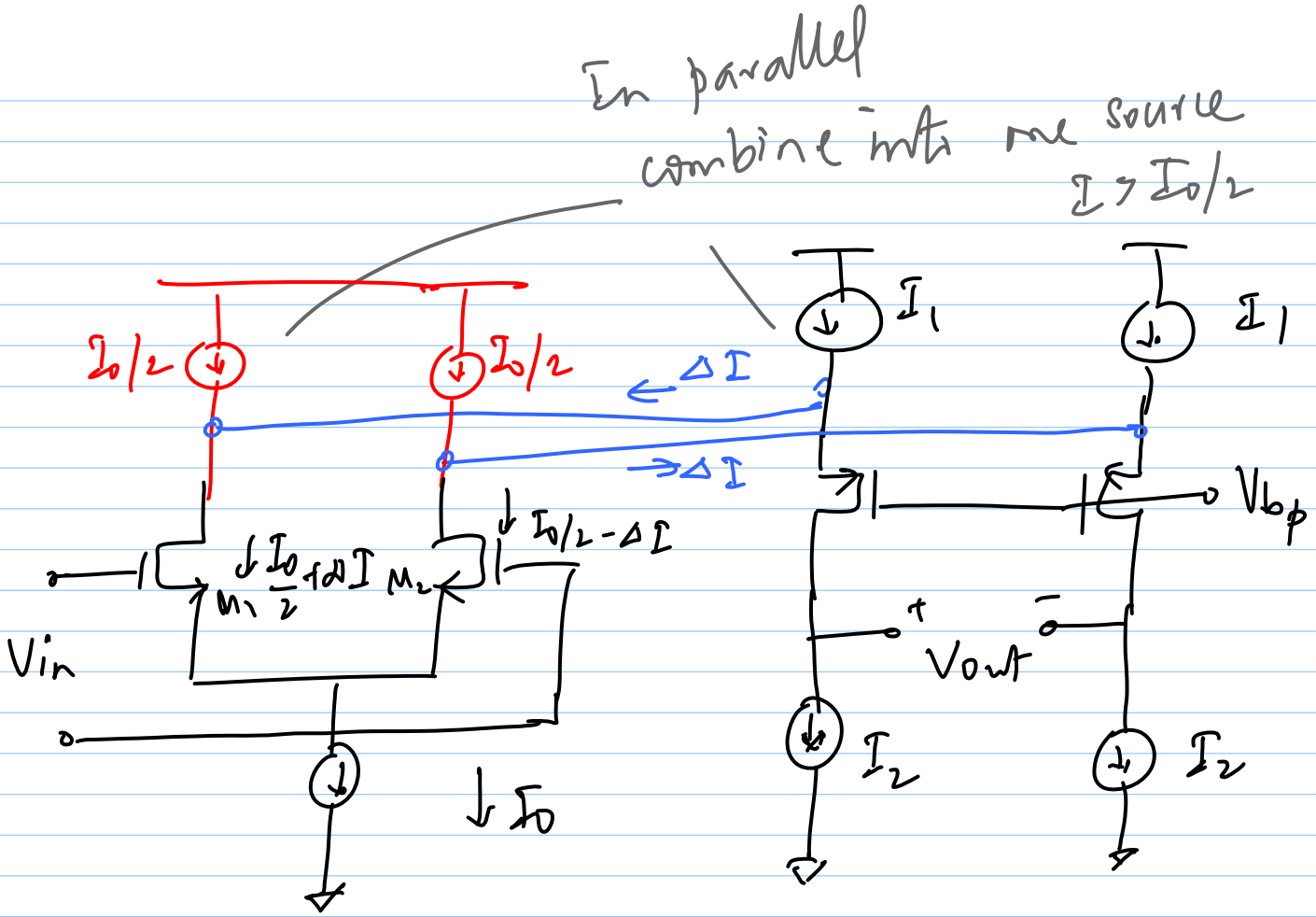
but

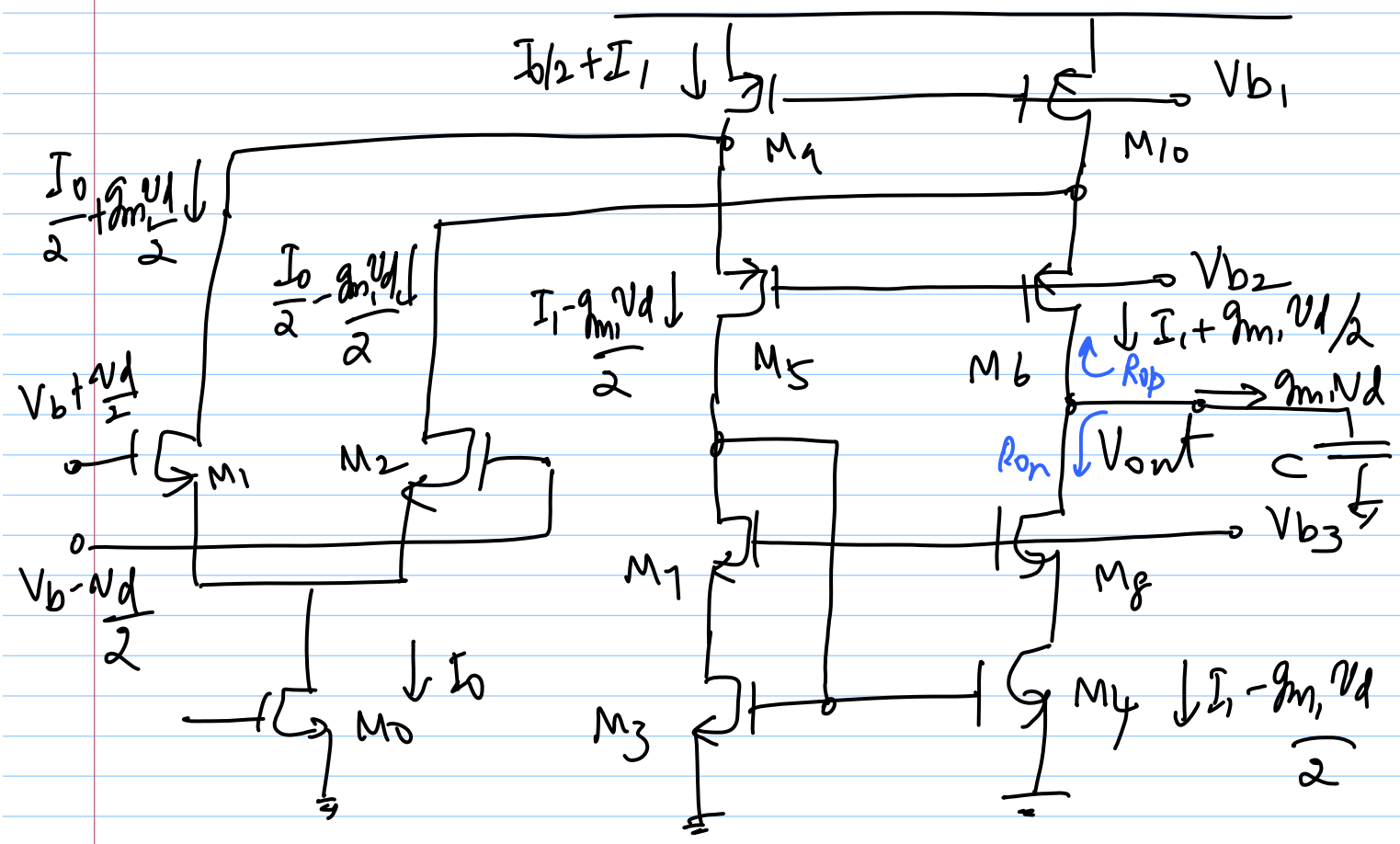
Folded Cascode opamp

→ pmos cascode for nmos diff pair



(PMOS input also possible)





$$G_m \simeq g_{m1}$$

$$R_{out} = R_{op} \,||\, R_{on}$$

$$= \left(g_{m6} r_{o6} \left(r_{o,10} \,||\, r_{o2} \right) \right) \,||\, g_{m8} r_{o8} r_{o4}$$

$$a_v = g_{m1} \cdot \Big[\left\{ g_{m6} r_{o6} \left(r_{o10} \,||\, r_{o2} \right) \right\} \,||\, g_{m8} r_{o8} r_{o4} \Big]$$

DC gain is slightly lower (extra term in cascode R_{out} term)

Advantage: swing limits are better

* V_o limits are not dependent on $V_{CM,in}$
* M_1 & M_2 can be biased independently

$$V_{DD} - V_{DSAT_{10}} - V_{DSAT_6} \geq V_o \geq V_{DSAT_4} + V_{DSAT_8}$$

1) DC gain

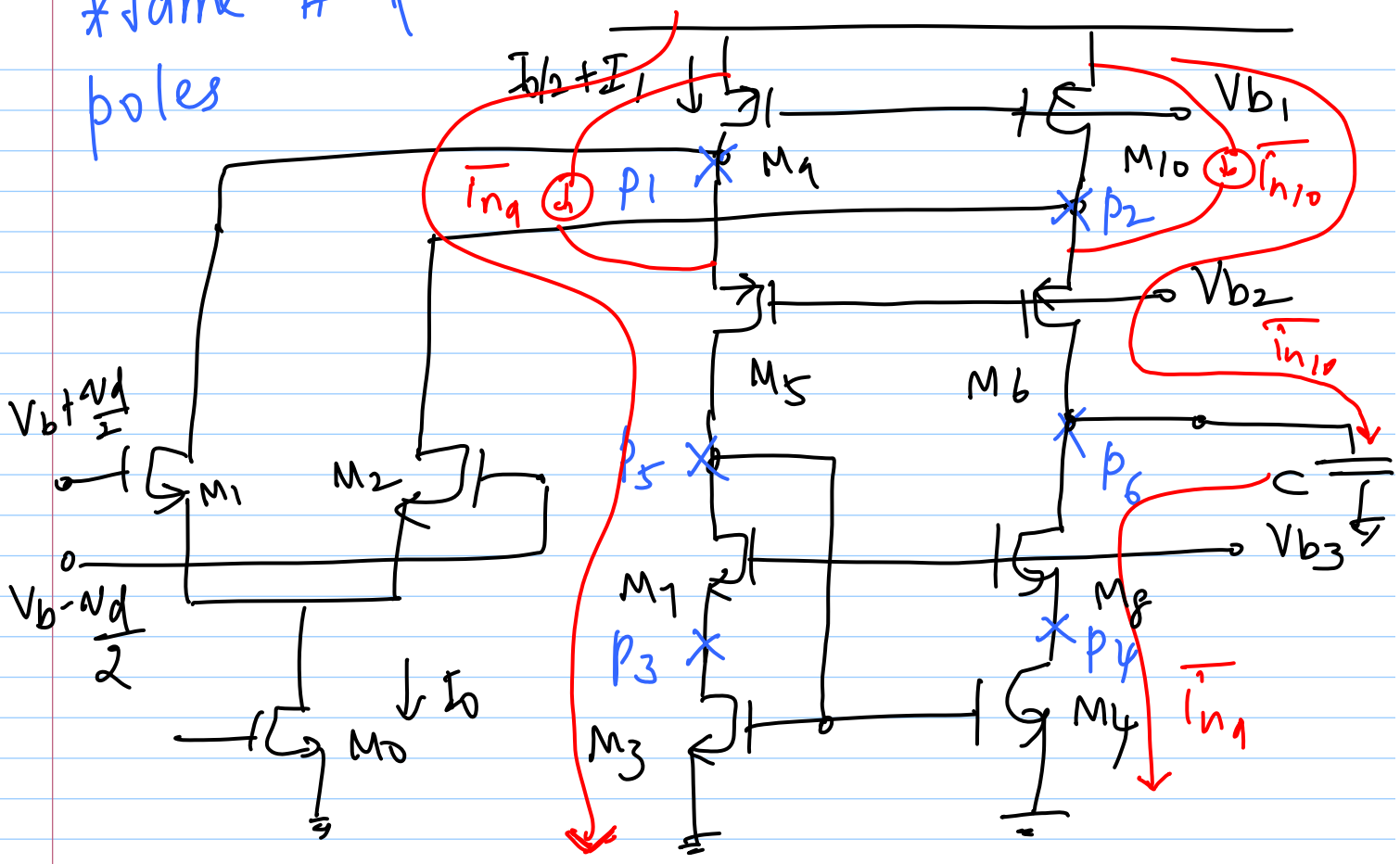
$$= g_{m_1} \left[\left\{ g_{m_6} r_{o_6} \left(r_{o_{10}} \| r_{o_2} \right) \right\} \| \, g_{m_8} r_{o_8} r_{o_4} \right]$$

2) $UGF = \dfrac{g_{m1}}{C}$ (same as before)

3) N.D. poles

M_9 & M_{10} are probably larger (more current) $\Rightarrow$ more cap @ p_1 & p_2

*same # of poles



4) Noise

No noise from: M_5, M_6, M_7, M_8 (cascodes)

noise from: $M_1, M_2, M_3, M_4, M_9, M_{10}$

$\Rightarrow$ larger than telescopic opamp

$$S_{iout} = \frac{16kT}{3}\left(g_{m1} + g_{m3} + g_{m9}\right)$$

$g_{m1} + g_{m3}$: telescopic

g_{m9}: larger I. $\Rightarrow$ larger noise

$$S_{i,in} = \frac{16kT}{3g_{m1}}\left(1 + \frac{g_{m3}}{g_{m1}} + \frac{g_{m4}}{g_{m1}}\right)$$

5) $$\overline{V_{OS}}^2 = \overline{V_{T1,2}}^2 + \overline{V_{T3,4}}^2 \cdot \left(\frac{g_{m3}}{g_{m1}}\right)^2 + \overline{V_{T4,10}}^2 \cdot \left(\frac{g_{m4}}{g_{m1}}\right)^2$$

6) Output swing

$$V_{DD} - 2V_{OSAT} > V_o > V_{OSAT}$$