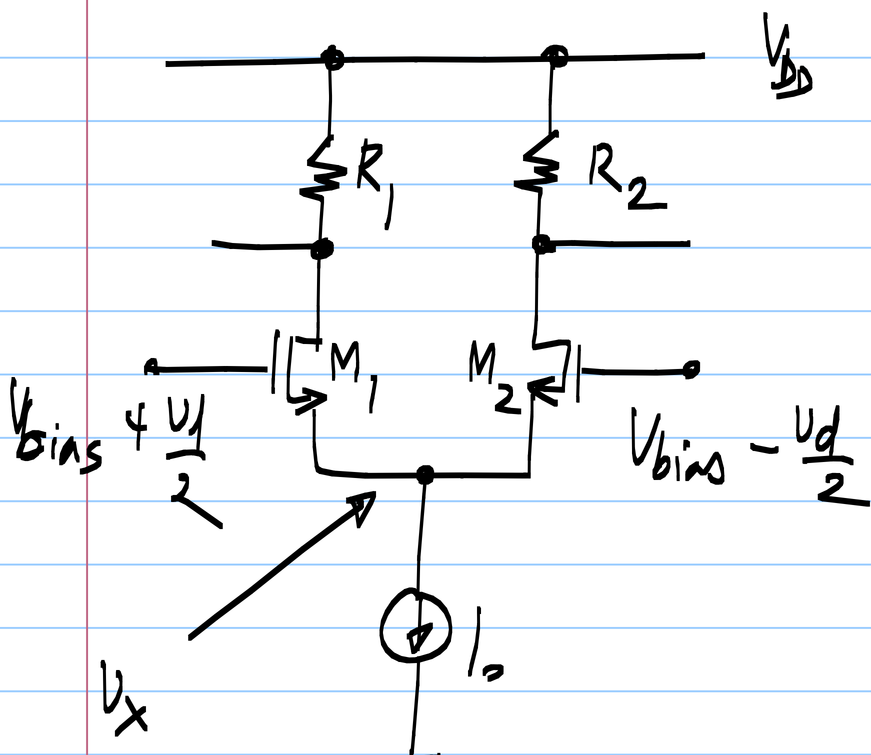
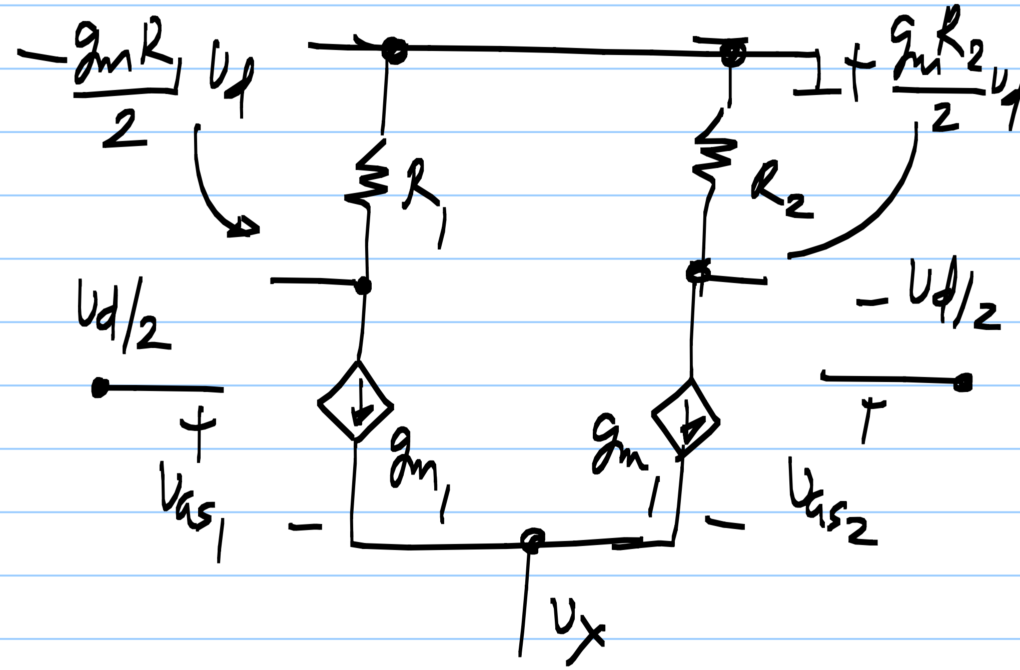
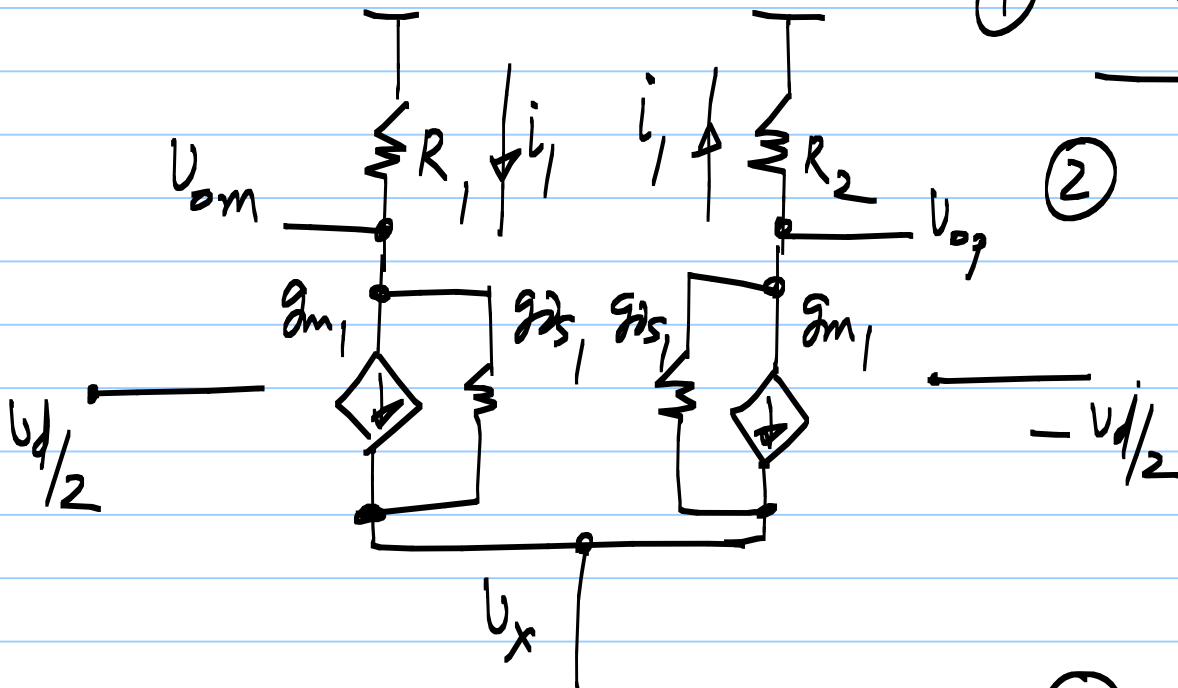
Lecture 30: Differential pair w/ current mirror load.





$v_x = 0$ when $g_{ds1} = 0$



(1) $$-\frac{v_{om}}{R_1} = \frac{v_{op}}{R_2} = i_1$$

(2) $$\frac{v_{om}}{R_1} + (v_{om} - v_x)\, g_{ds_1} + \left(\frac{v_d}{2} - v_x\right) g_{m_1} = 0$$

(3) $$\frac{v_{op}}{R_2} + (v_{op} - v_x)\, g_{ds_1} + \left(-\frac{v_d}{2} - v_x\right) g_{m_1} = 0$$

$$v_x = \frac{v_d}{2} \cdot \frac{g_{m_1}}{g_{m_1} + g_{ds_1}} \cdot \left[\frac{g_{ds_1}(R_2 - R_1)}{1 + g_{ds_1}(R_2 + R_1)}\right]$$

$$v_x = \frac{v_d}{2} \cdot \frac{g_{m1}}{g_{m1} + g_{ds1}} \cdot \left[\frac{g_{ds1}(R_2 - R_1)}{1 + g_{ds1}(R_2 + R_1)} \right]$$

$$\sim 1$$

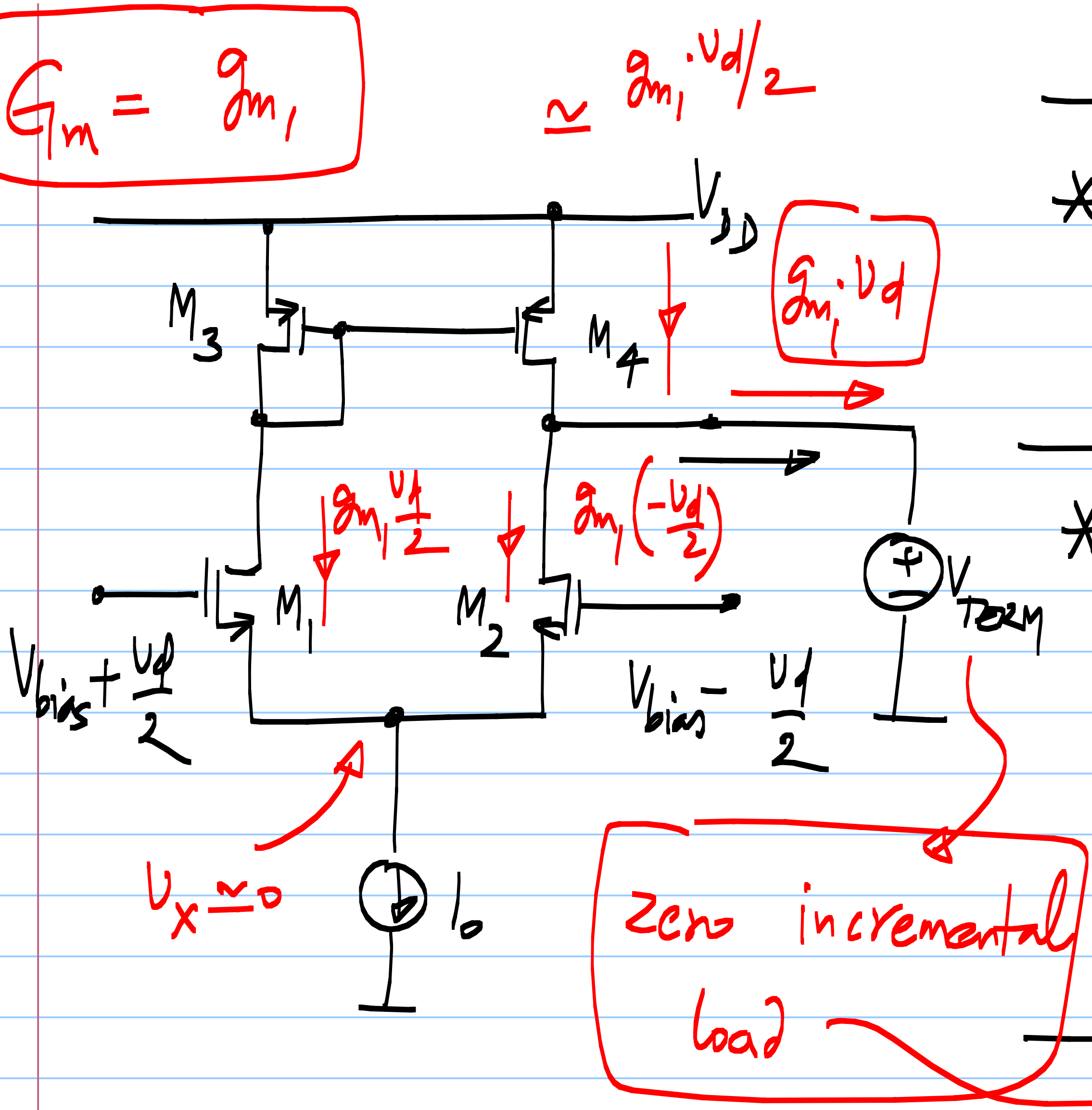
* $v_x = 0$ if $R_2 = R_1$ OR $g_{ds1} = 0$

* $v_x \simeq 0$ if $|g_{ds1} R_2|, |g_{ds1} R_1| \ll 1$

  $r_{ds1} \gg R_1 \;\&\; R_2$

* $v_x \neq 0$ if R_1 & R_2 are comparable to r_{ds1}

$$G_m = g_{m1}$$



* Load: asymmetrical

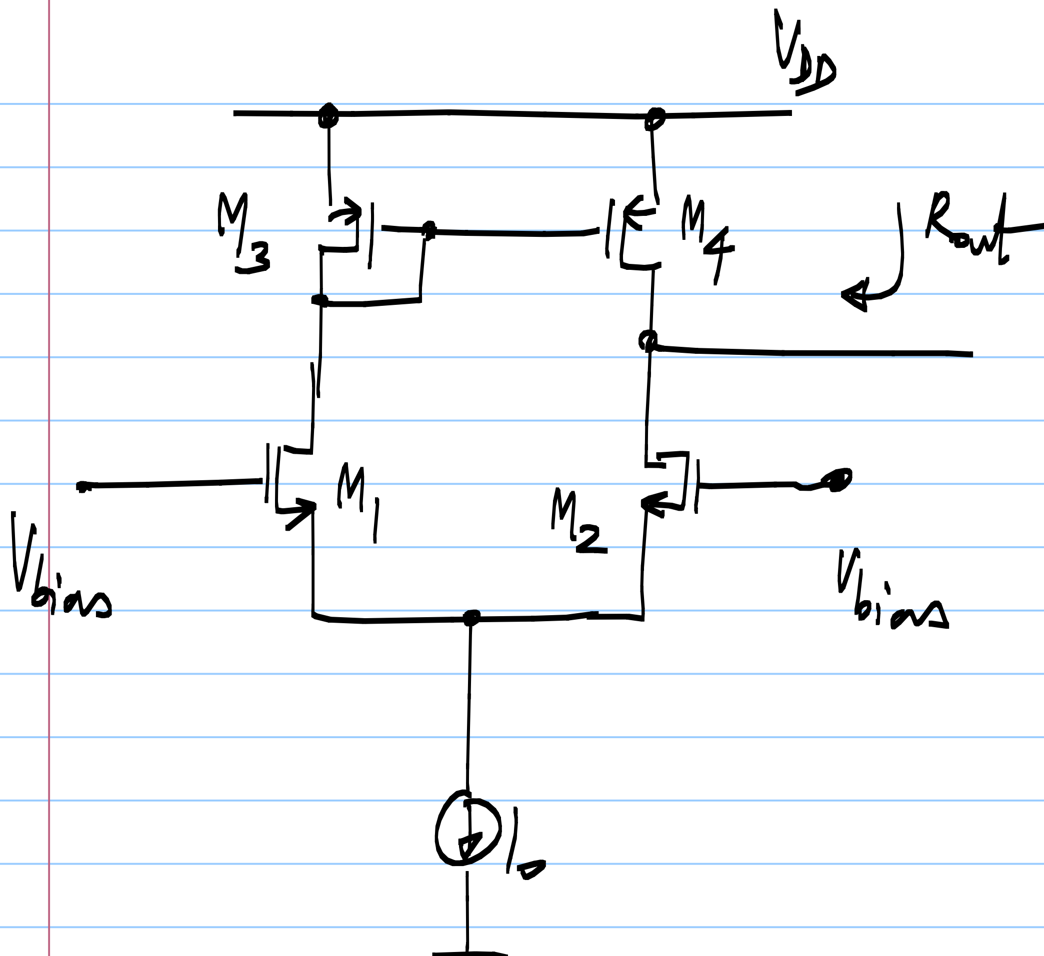
$$\frac{1}{g_{m3}}, \frac{1}{g_{ds3}}$$

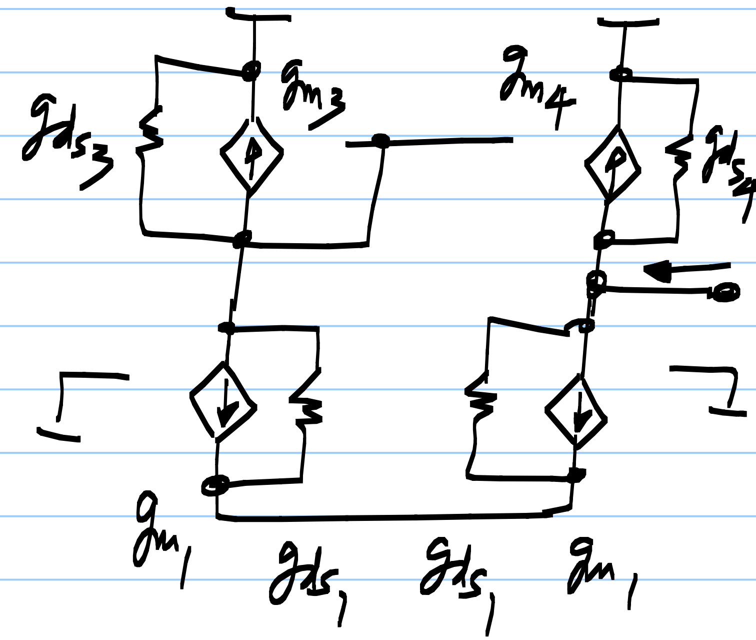
* Not $\ll r_{ds1}$

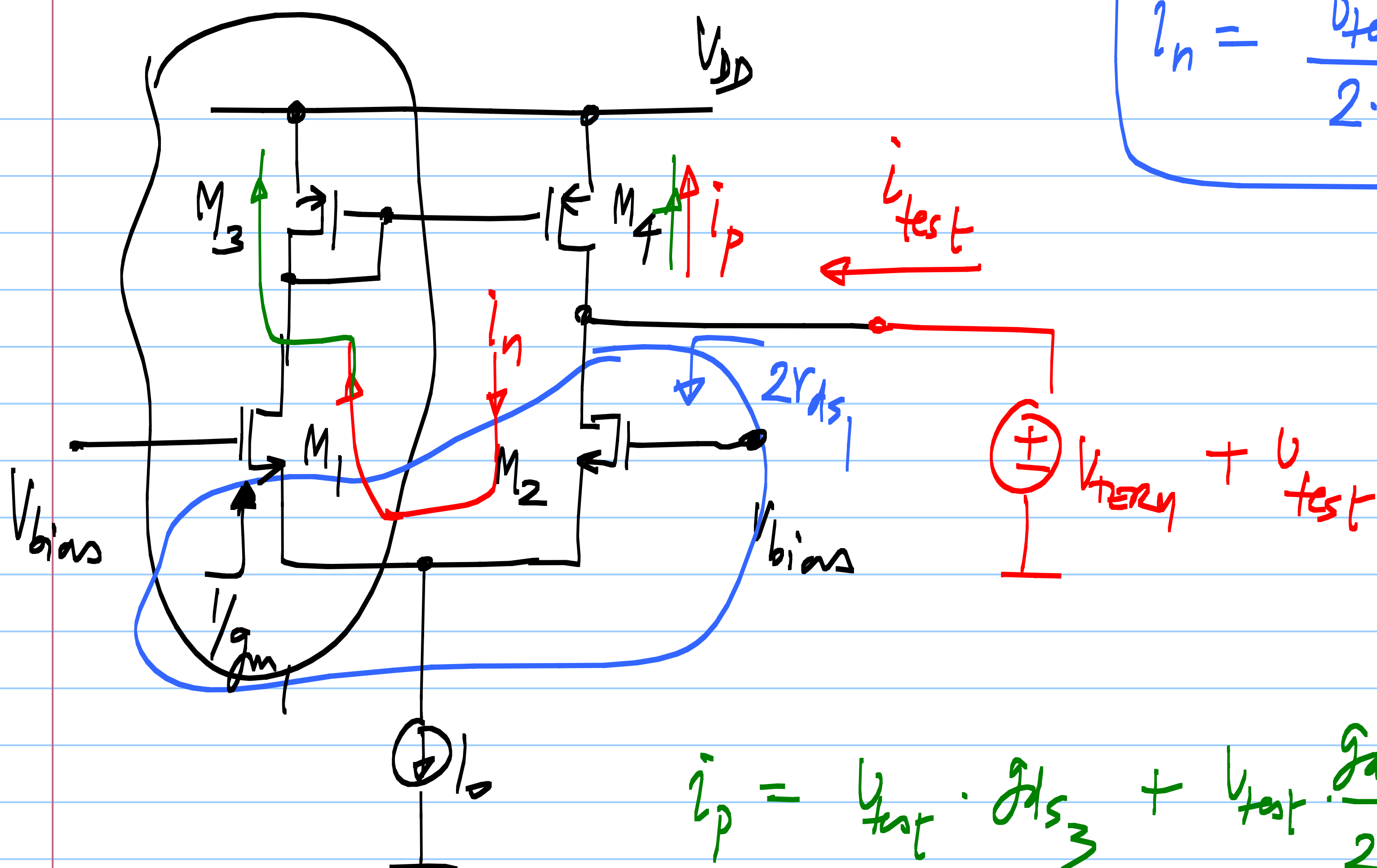
$$\frac{1}{g_{m3}} \ll r_{ds1}$$

$$\frac{1}{g_{ds3}} = r_{ds3} \checkmark\ r_{ds1}$$

$v_x \simeq 0$

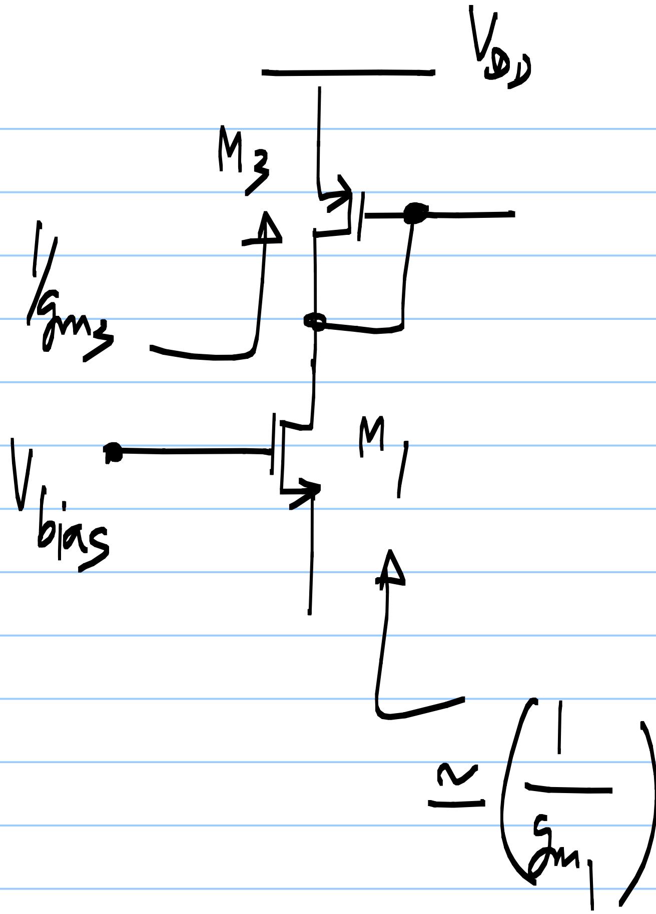

VDD
M3
M4
Rout
M1
M2
Vbias
Vbias
I0


gds3
gm3
gm4
gds4
gm1
gds1
gds1
gm1



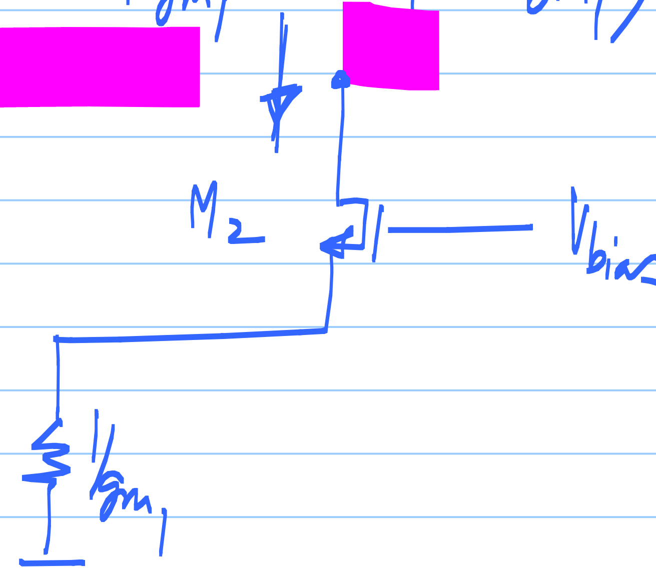
$$i_n = \frac{v_{test}}{2 \cdot r_{ds_1}} = \frac{v_{test} g_{ds_1}}{2}$$

$$i_p = v_{test} \cdot g_{ds_3} + v_{test} \cdot \frac{g_{ds_1}}{2}$$



$$g_m r_{ds} \cdot R_s + r_{ds} + R_s$$

$$\left(g_{m1} \cdot r_{ds1} \frac{1}{g_{m1}} + r_{ds1} + \frac{1}{g_{m1}}\right)$$



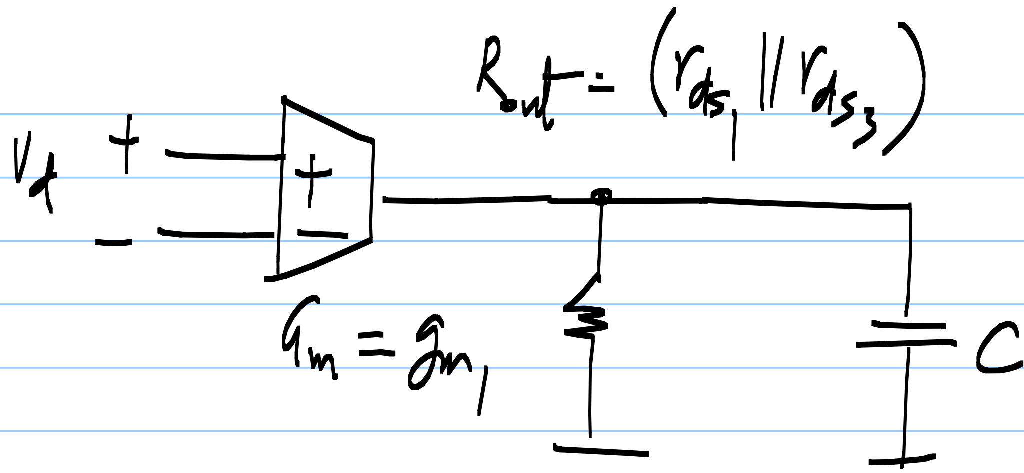
$$\left[2 \cdot r_{ds1} + \frac{1}{g_{m1}}\right]$$

$$i_{test} = i_p + i_n$$

$$= v_{test}\left\{\left[g_{ds_3} + \frac{g_{ds_1}}{2}\right] + \frac{g_{ds_1}}{2}\right\}$$

$$= v_{test}\left[g_{ds_3} + g_{ds_1}\right]$$

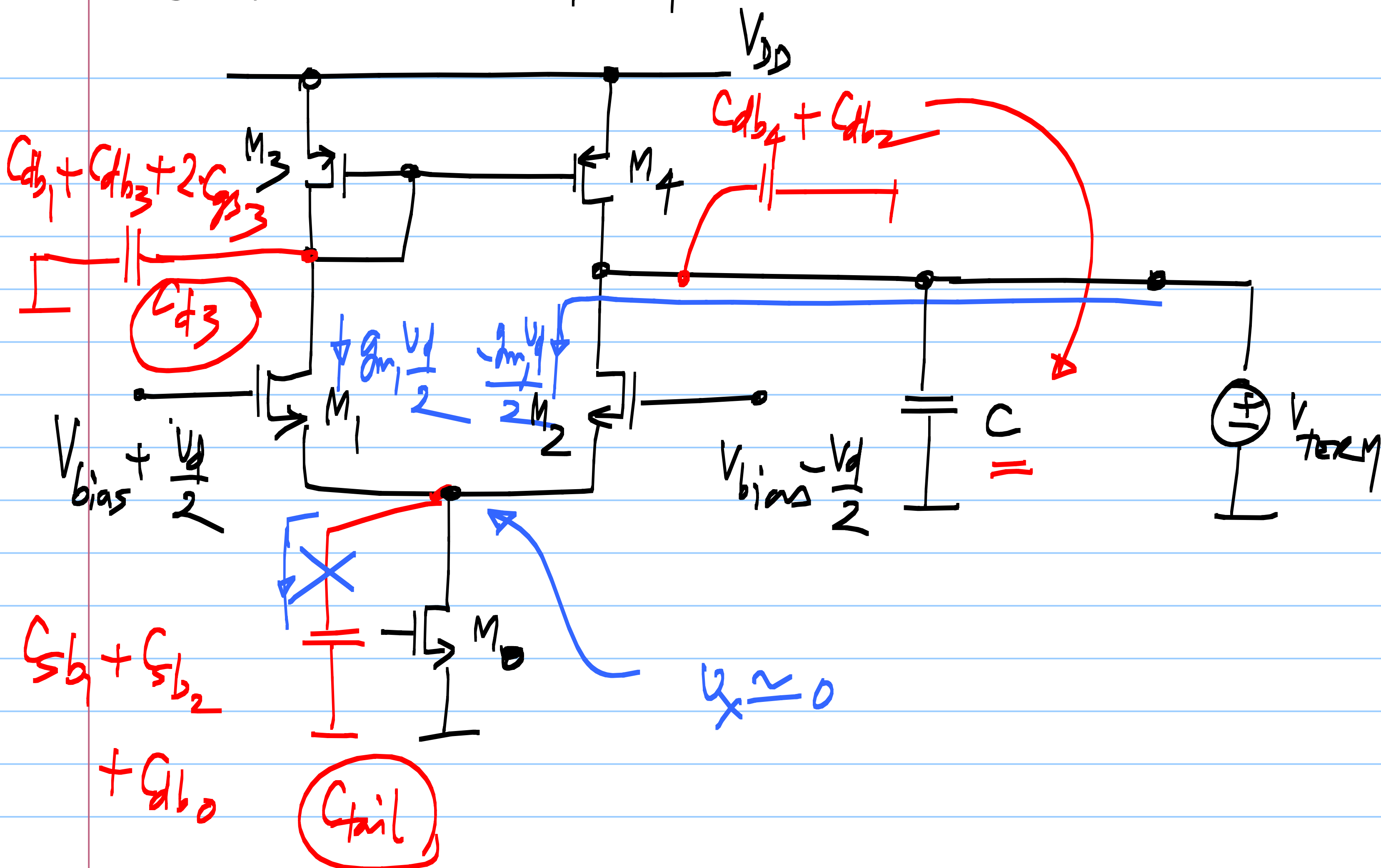
$$R_{out} = \frac{1}{g_{ds_1} + g_{ds_3}} = \left(r_{ds_1} \| r_{ds_3}\right)$$

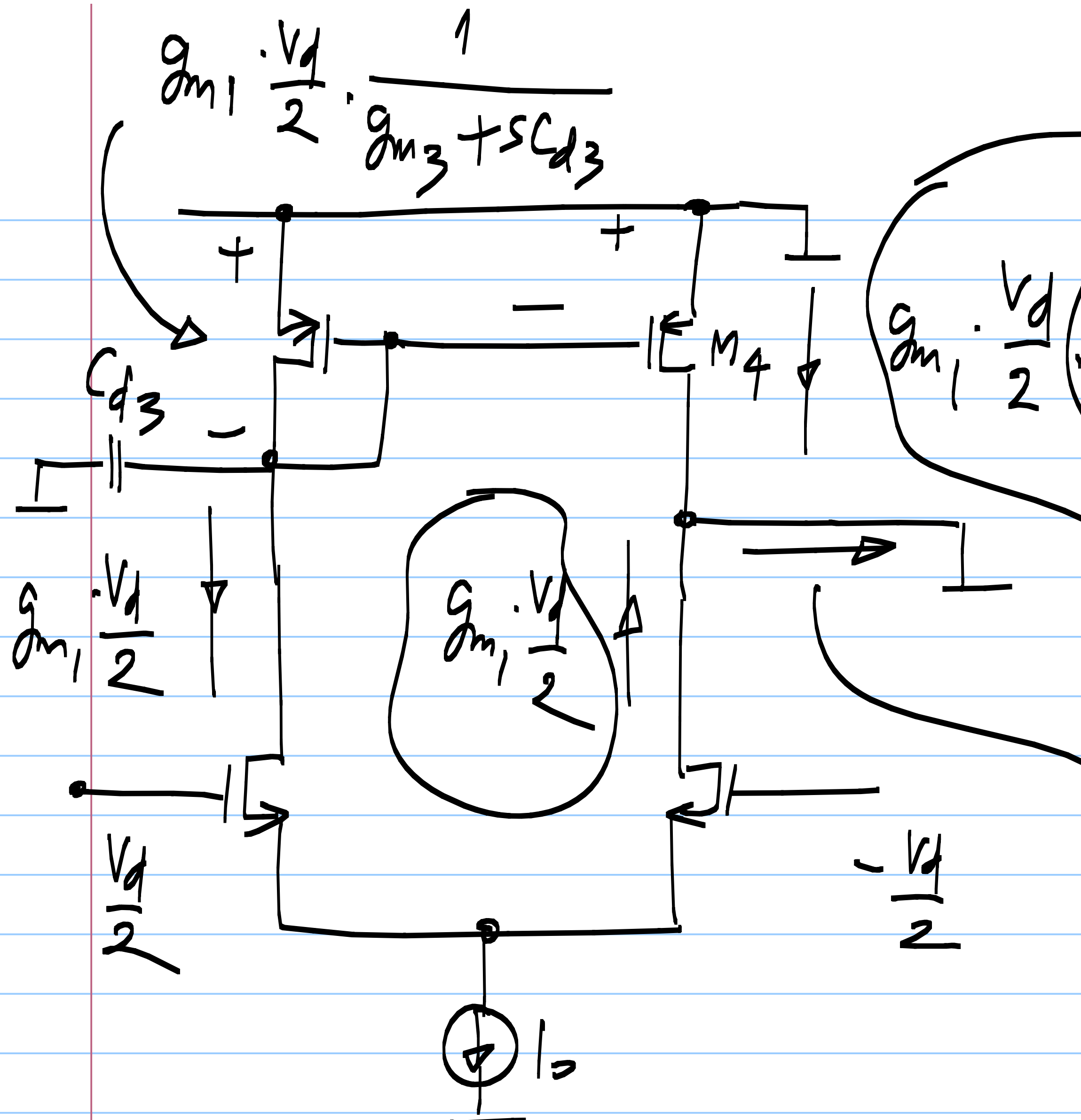


$$\omega_u = \frac{g_{m_1}}{C} \; ; \quad A_0 = g_{m_1}(r_{ds_1} \| r_{ds_3})$$

Single stage opamp

$\omega_u = g_{m1}/C$; $A_0 = g_{m1}/(g_{ds1} + g_{ds3})$

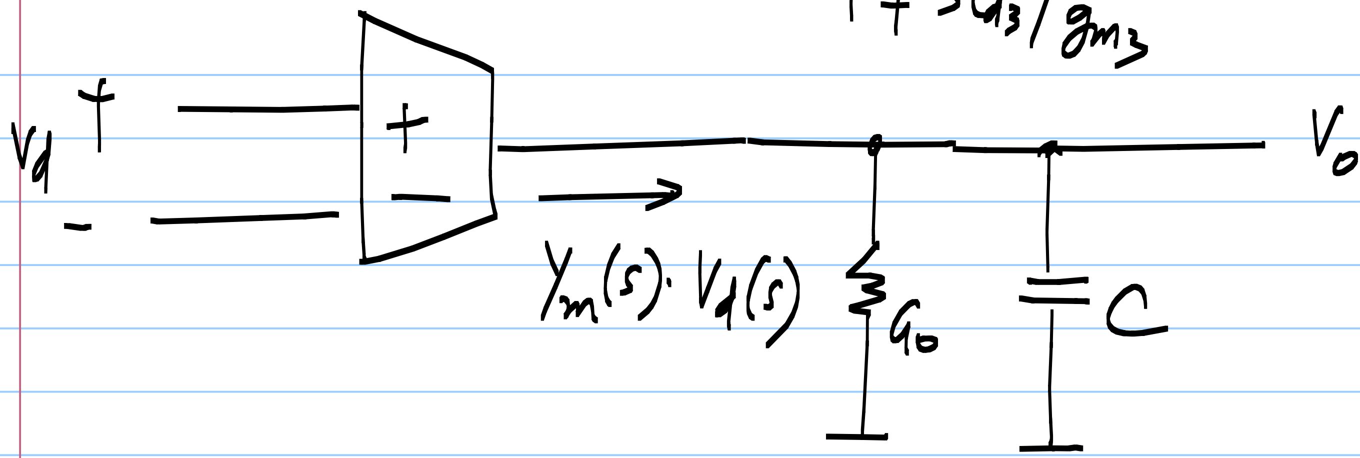




$$g_{m1}\cdot\frac{v_d}{2}\left(\cdot\frac{g_{m3}}{g_{m3}+sC_{d3}}\right)$$

$$g_{m1}\cdot v_d\left[\cdot\frac{1+s\cdot C_{d3}/2g_{m3}}{1+s\cdot C_{d3}/g_{m3}}\right]$$

$$Y_m(s) = g_m \cdot \frac{1 + sC_{d3}/2g_{m3}}{1 + sC_{d3}/g_{m3}}$$



$$= (g_{ds3} + g_{ds1})$$

$$\frac{V_o}{V_d} = \frac{Y_m(s)}{(g_{ds3} + g_{ds1} + sC)}$$