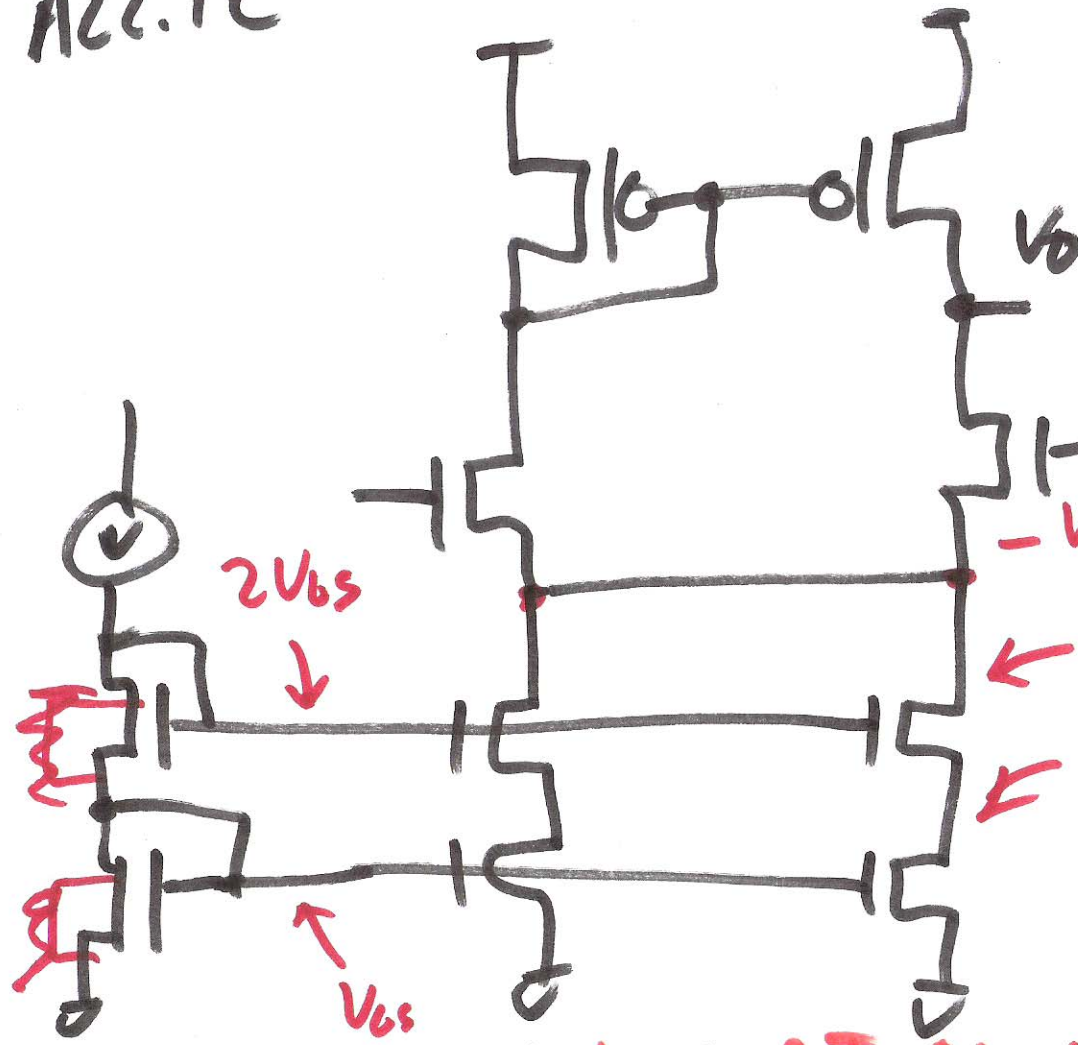
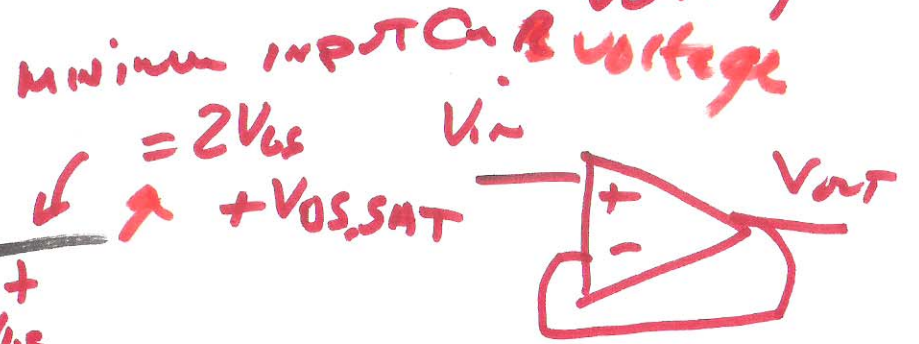


A22.1C



MINIMUM INPUT  
COMMON-MODE  
VOLTAGE



MINIMUM INPUT CM VOLTAGE  
 $= 2V_{bs}$   
 $+ V_{OS,SAT}$

$V_{bs} + V_{OS,SAT}$

$V_{OS} \geq V_{bs} - V_{THN}$

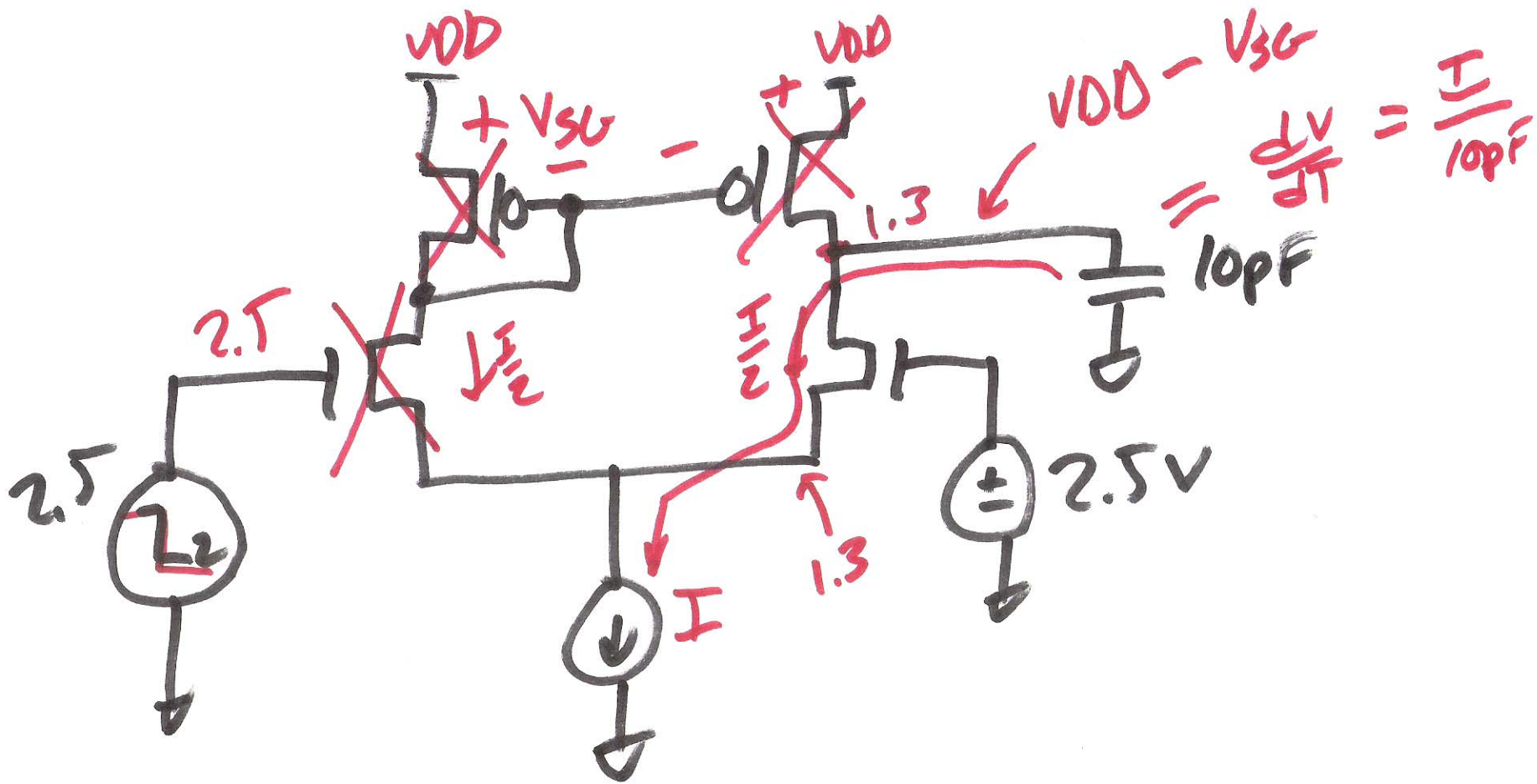
$V_0 - V_s \geq V_0 - V_s - V_{THN}$

$V_0 \geq V_0 - V_{THN}$

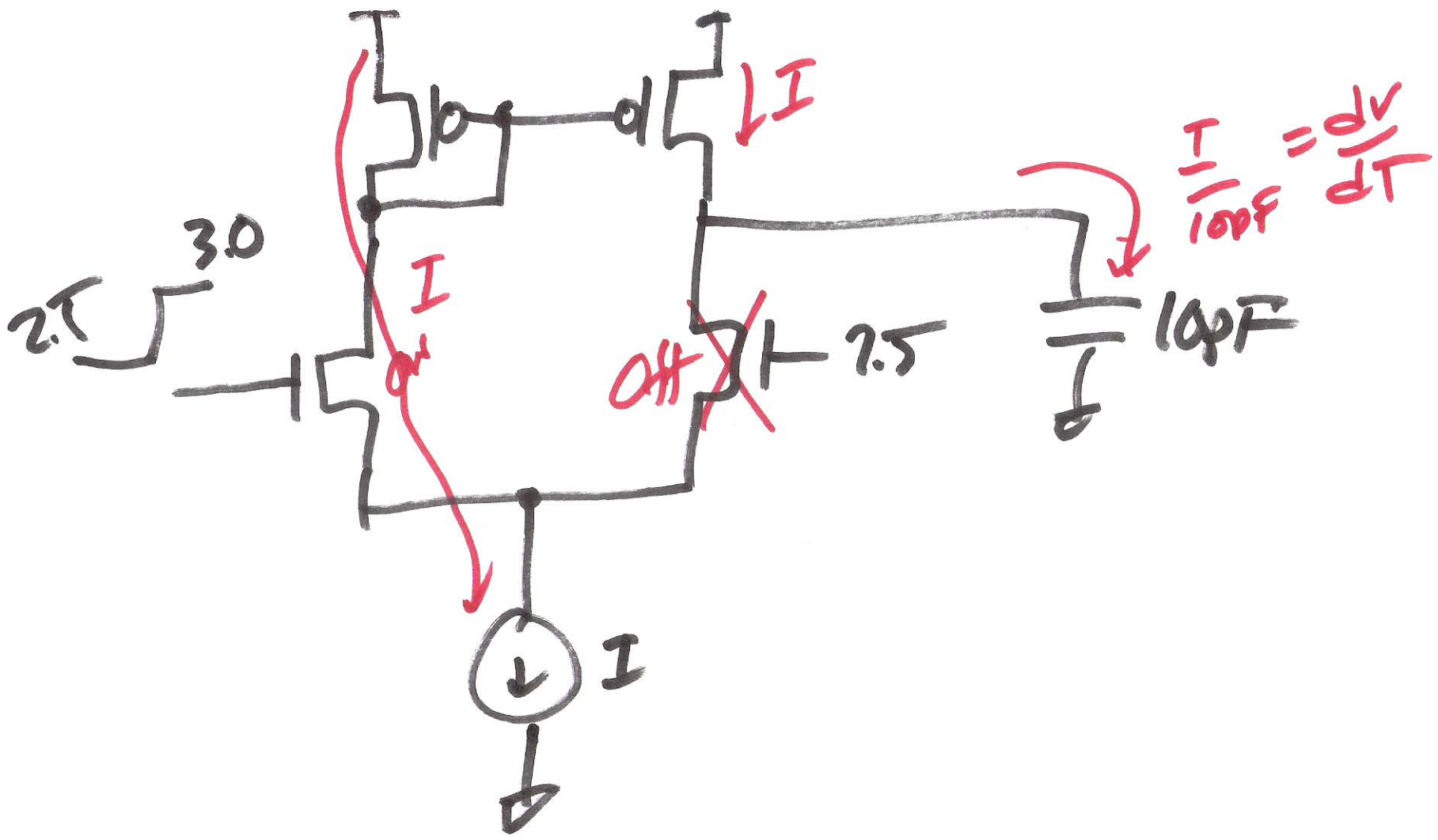
$V_0 \geq V_{OS} - V_{THN}$

MAX INPUT CM VOLTAGE

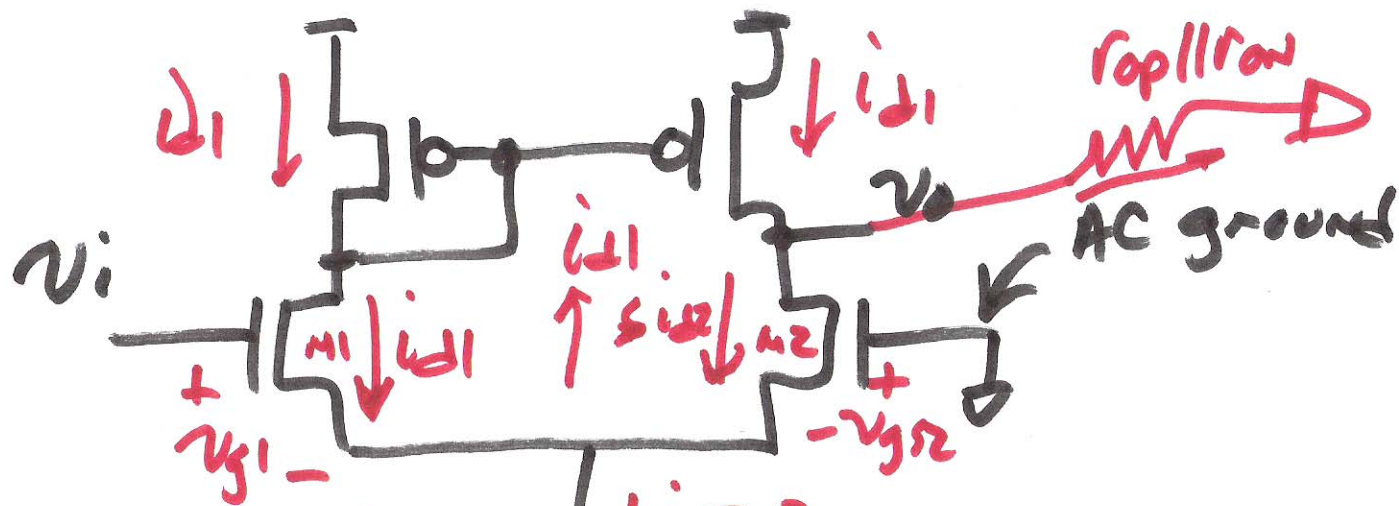
$V_0 \leq V_0 + V_{THN}$



2)



3)



$$g_{m1} v_{gs1} = i_{d1}$$

$$g_{m2} v_{gs2} = i_{d2}$$



$$v_i = v_{gs1} - v_{gs2}$$

$$i_{d1} = -i_{d2}$$

$$v_o = 2 i_{d1} \cdot r_{on} \parallel r_{op}$$

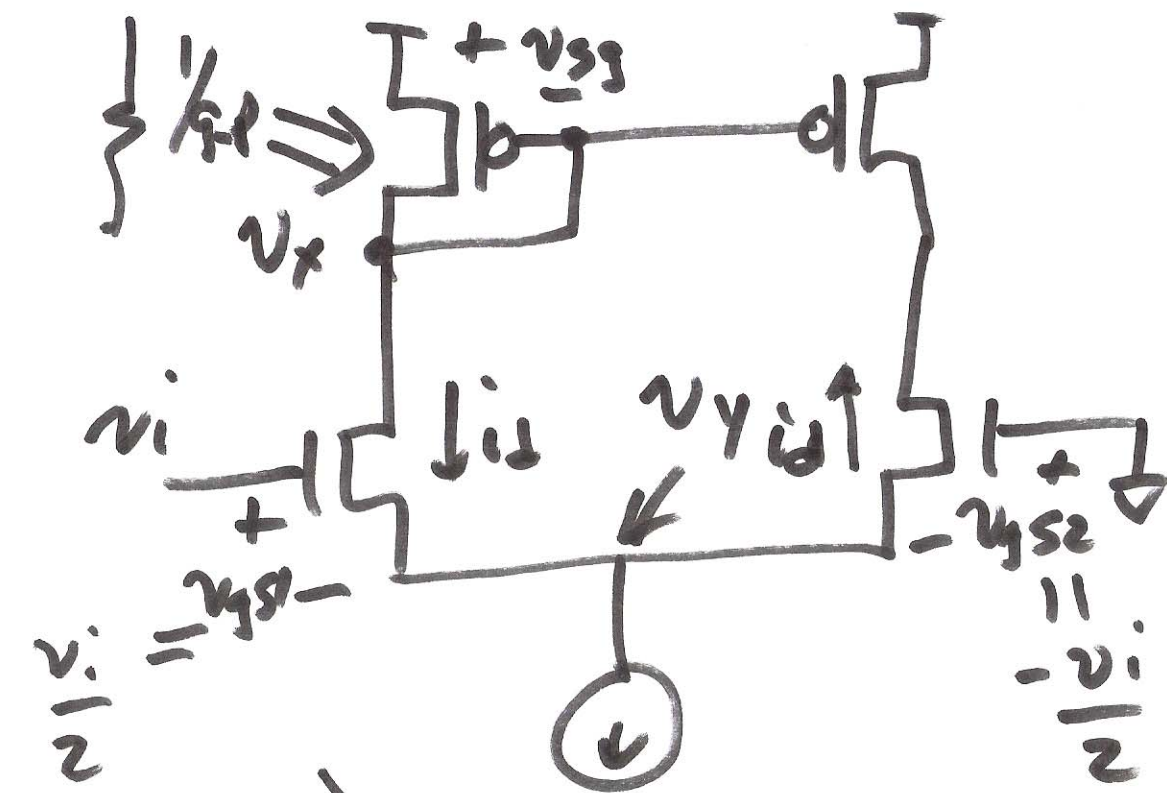
$$\frac{v_o}{v_i} = \frac{2 i_{d1} \cdot r_{on} \parallel r_{op}}{g_{m1} i_{d1}}$$

$$v_i = i_{d1} \left( \frac{1}{g_{m1}} - \left( \frac{-1}{g_{m1}} \right) \right)$$

$$= g_{m1} \cdot r_{on} \parallel r_{op} \quad v_i = i_{d1} \cdot \frac{2}{g_{m1}}$$

$$g_{m1} = g_{m2} = g$$

4)



$$v_y = \frac{v_i}{2}$$

$$v_x = -i_d \cdot \frac{1}{g_m}$$

$$v_i = v_{gs1} - v_{gs2}$$

$$i_{d1} = -i_{d2}$$

$$v_{gs1} = -v_{gs2}$$

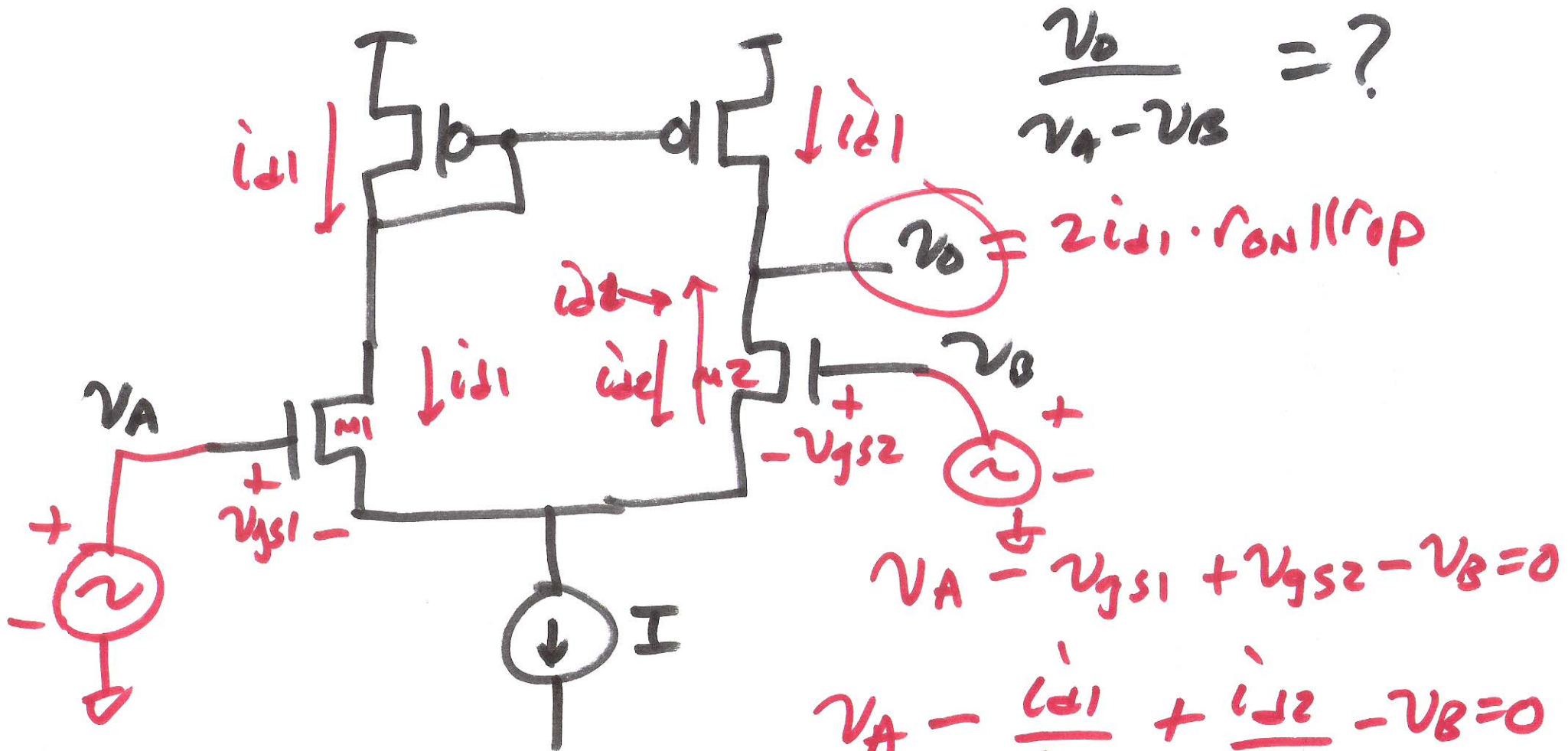
$$v_i = 2v_{gs1}$$

$$v_i = 2 \cdot \frac{i_d}{g_m}$$

$$v_i/2 = v_{gs1}$$

$$\frac{v_i}{2} - \left( -\frac{v_i}{2} \right) = v_i$$

$$\frac{v_x}{v_i} = \frac{-i_d \cdot \frac{1}{g_m}}{i_d \cdot \frac{2}{g_m}}$$



$$\frac{v_0}{v_A - v_B} = ?$$

$$v_0 = 2i_{D1} \cdot r_{on1} \parallel r_{op}$$

$$v_A - v_{gs1} + v_{gs2} - v_B = 0$$

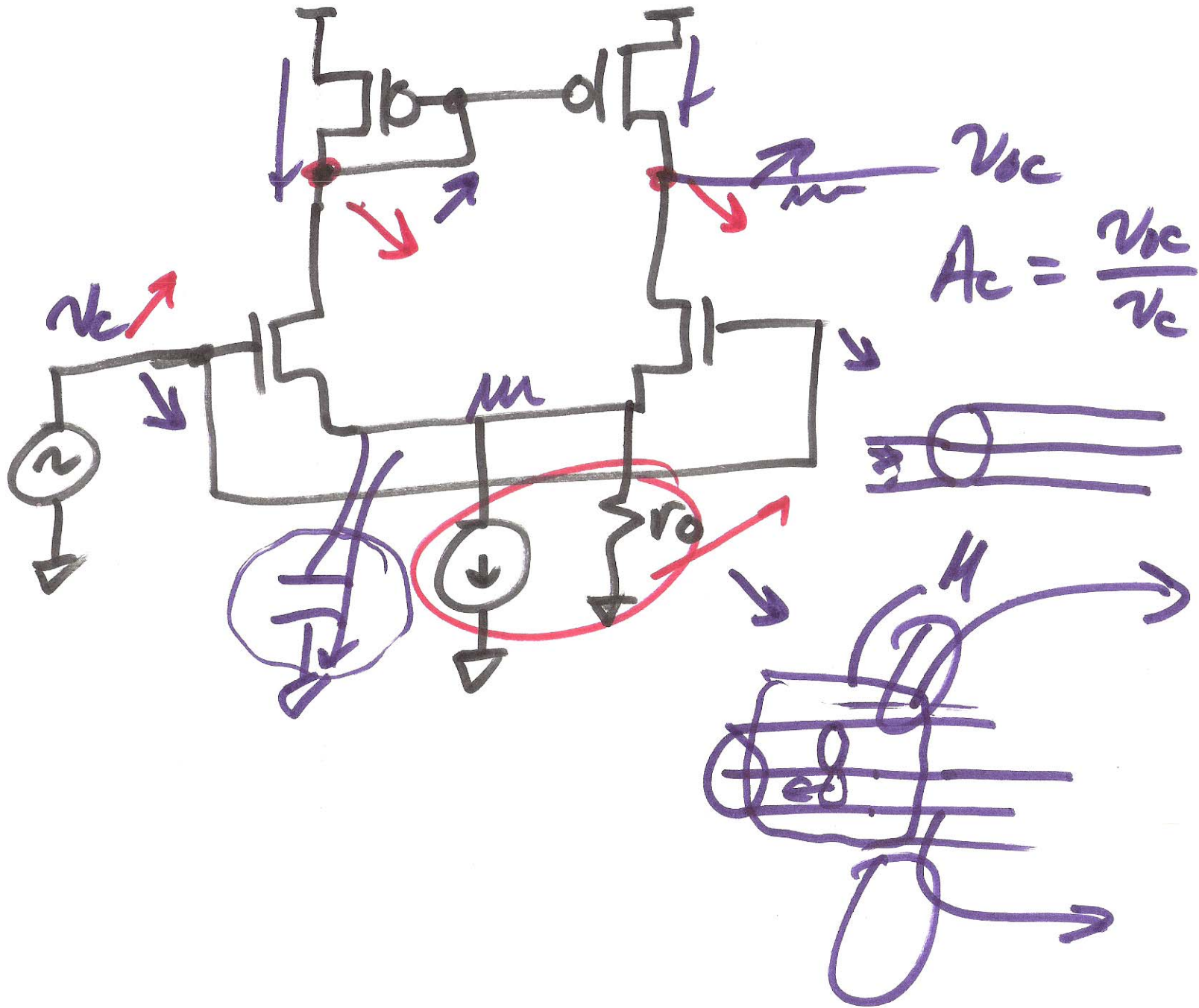
$$v_A - \frac{i_{D1}}{g_m} + \frac{i_{D2}}{g_m} - v_B = 0$$

$$i_{D1} = -i_{D2}$$

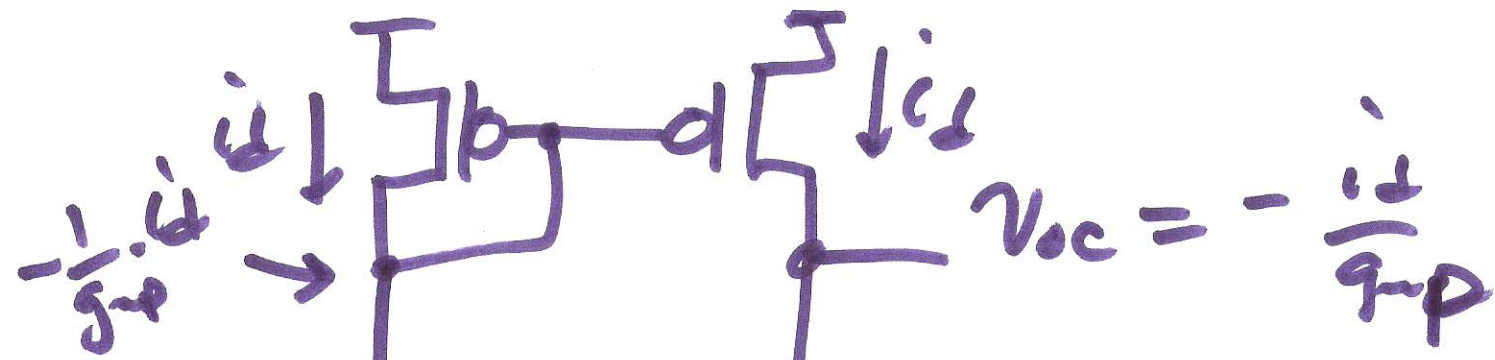
$$v_A - v_B = i_{D1} \cdot \frac{2}{g_m}$$

$$\frac{v_0}{v_A - v_B} = g_m \cdot r_{on1} \parallel r_{op}$$

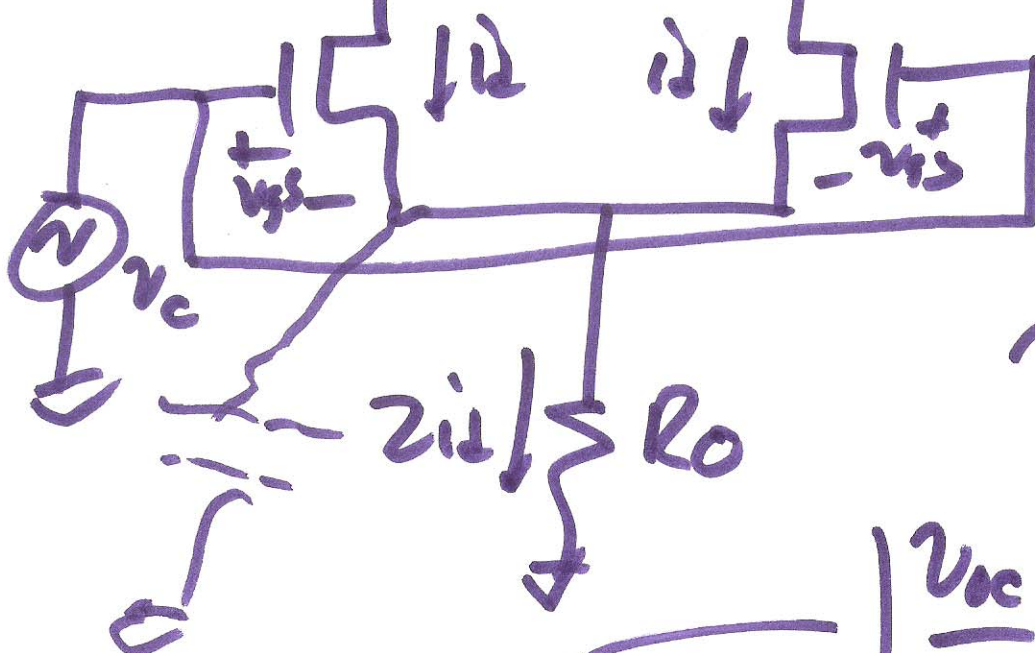
6)



7)



$$v_{oc} = -\frac{i_d}{g_{mP}}$$



$$v_c = v_{gs} + 2i_d \cdot R_o$$

$$\sqrt{\approx} \left| \frac{v_{oc}}{v_c} \right| = A_c = \frac{\frac{1}{g_{mP}}}{\frac{1}{g_{mP}} + 2R_o}$$

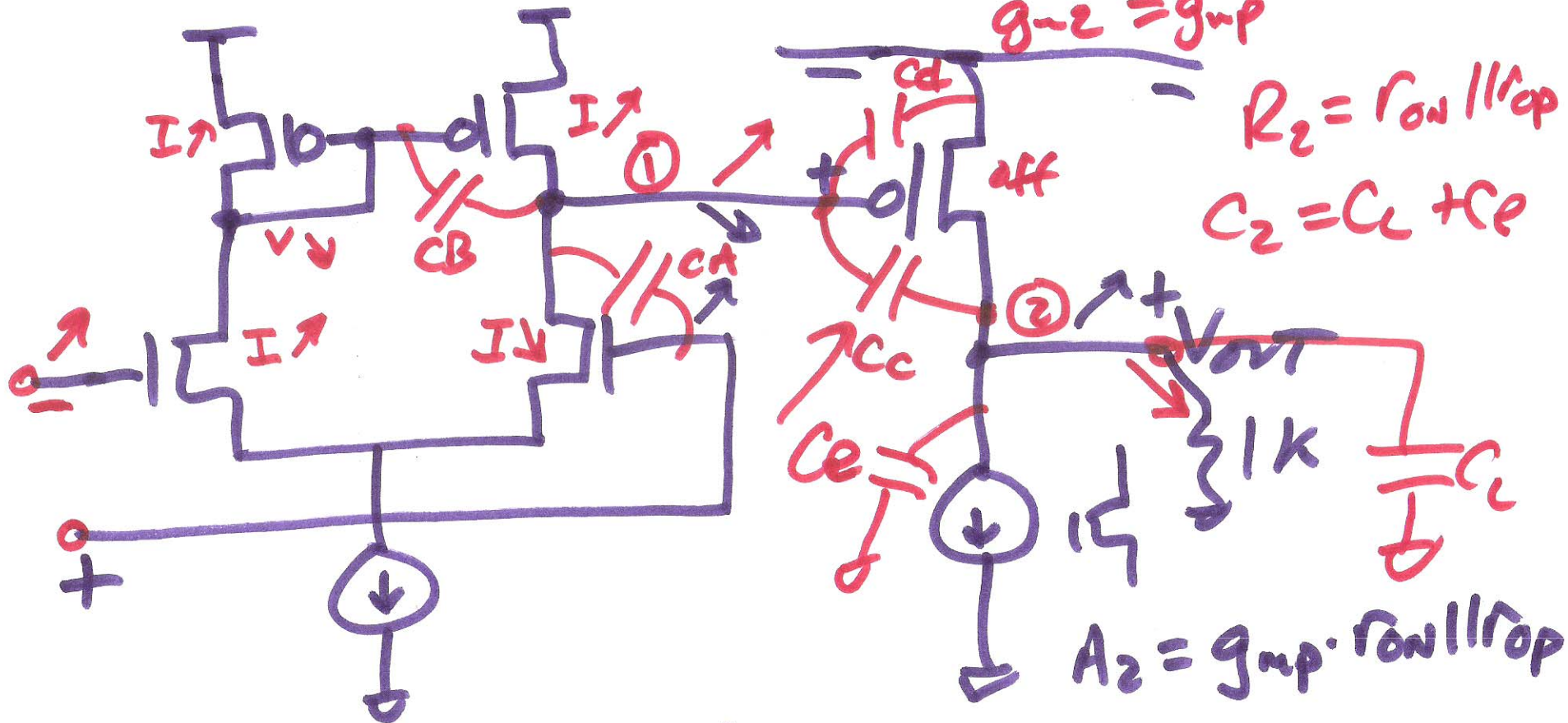
$$A_c \approx \frac{1}{2g_{mP} \cdot R_o} \quad A_c \rightarrow 0, R_o \rightarrow \infty$$

8)



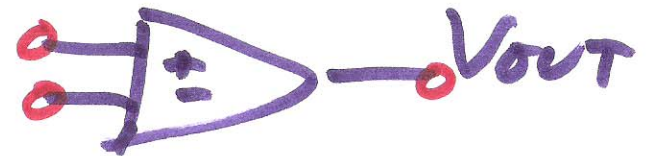
# 2-Stage Op-Amp

$C_1 = C_x + C_b + C_d$      $g_{m1} = g_{mn}$      $R_1 = r_{on} || r_{op}$



$A_1 = g_{mn} \cdot r_{on} || r_{op}$

$A_{o2} = g_{mn} \cdot r_{on} || r_{op} \cdot g_{mp} \cdot r_{on} || r_{op}$



9)

