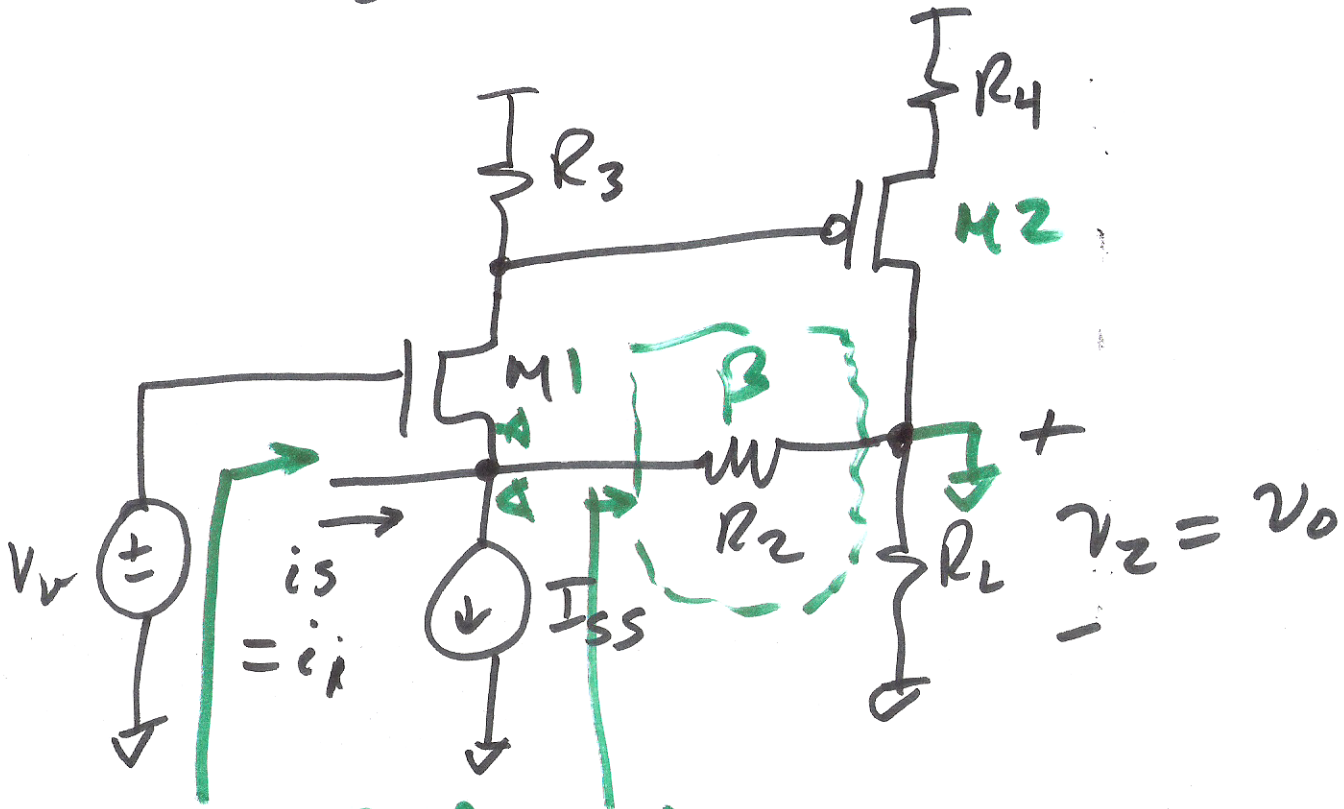
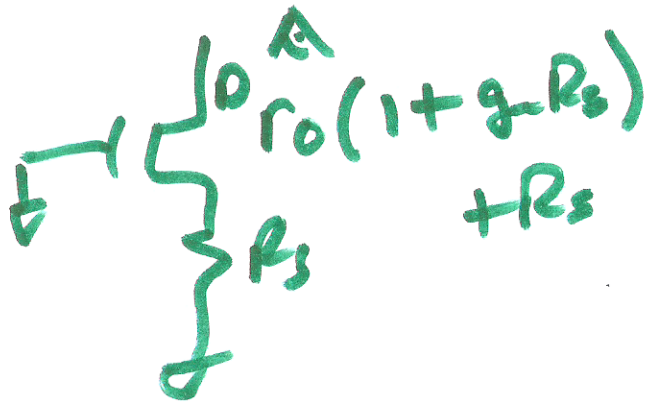
Section 31.5 Shunt-Shunt f.b.

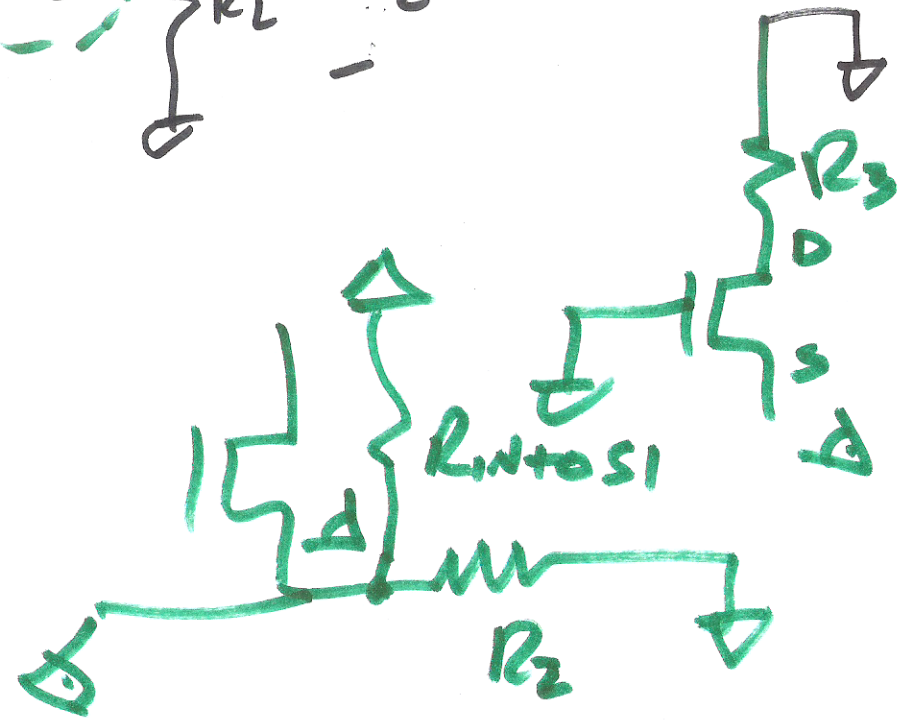


$R_i = R_2 \| R_{in\,to\,M1} \| R_{Bi}$

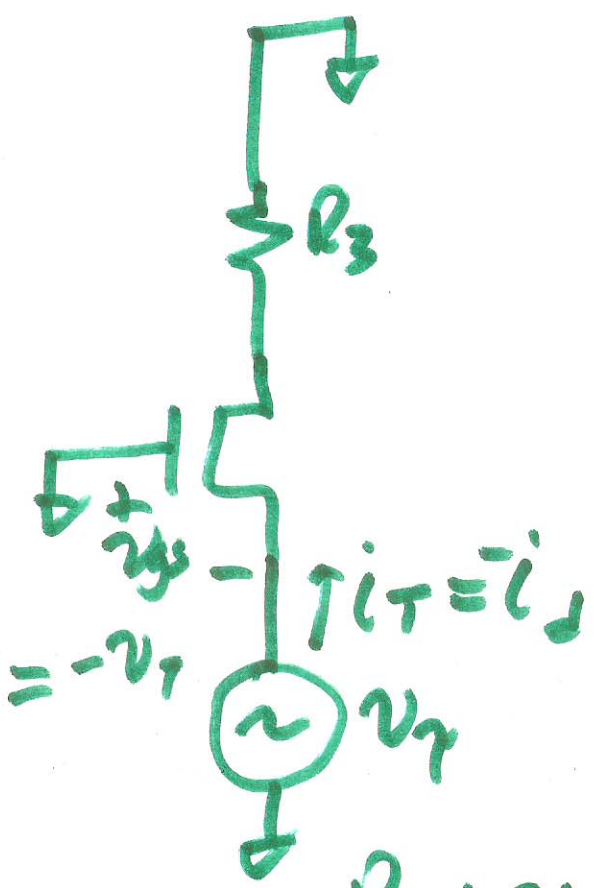
$R_{Bi} = R_2$

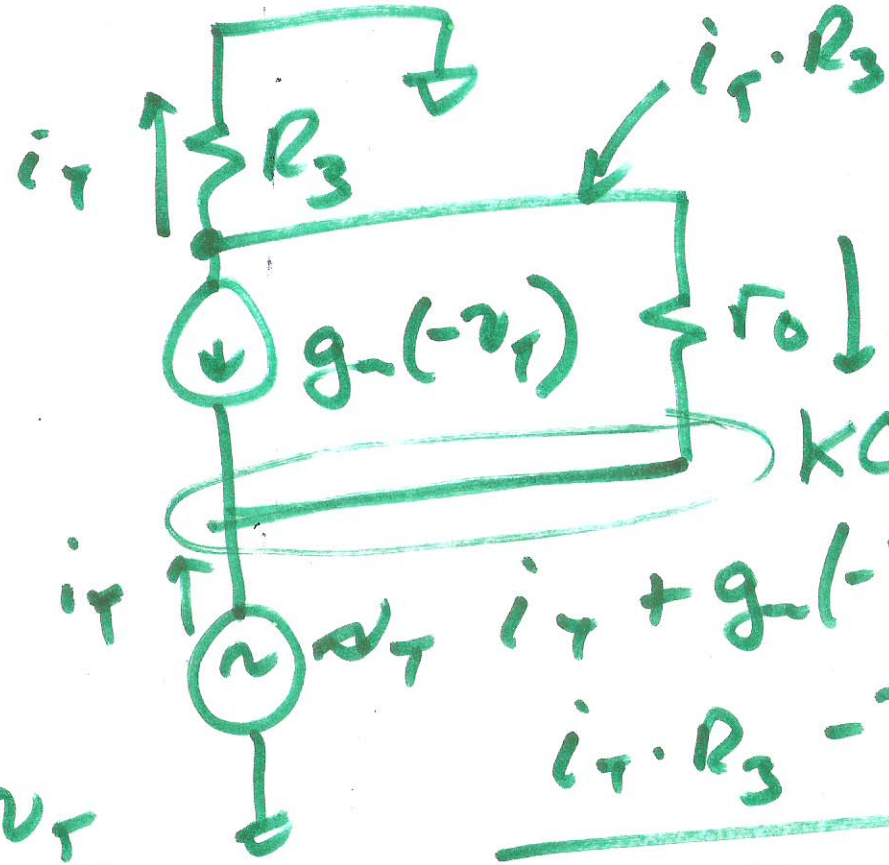
NO f.b.





$R_{in\,to\,S1} \| R_2$





$$i_T + g_m(-v_T) + \frac{i_T \cdot R_3 - v_T}{r_o} = 0$$

$$R_{out\,SI} = \frac{v_T}{i_T}$$

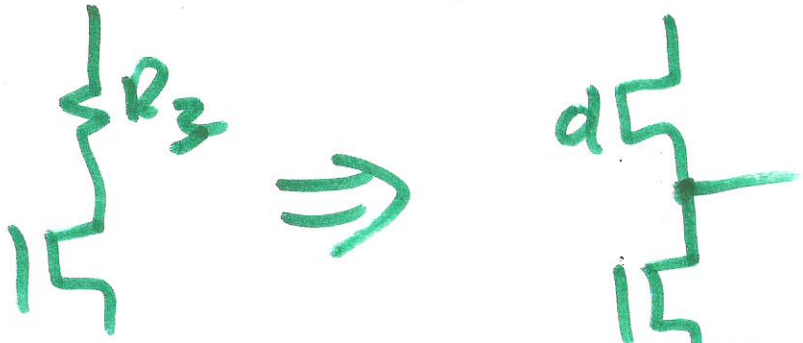
$$i_T\left(1 + \frac{R_3}{r_o}\right) = v_T\left(g_m + \frac{1}{r_o}\right)$$

$$\frac{v_T}{i_T} = \frac{\left(1 + \frac{R_3}{r_o}\right)}{g_m + \frac{1}{r_o}} = r_o \| \frac{1}{g_m} \cdot \left(1 + \frac{R_3}{r_o}\right)$$

$$\frac{\frac{1}{g_m} \cdot r_o}{\frac{1}{g_m} + r_o} = r_o \| \frac{1}{g_m} = \frac{1}{g_m + \frac{1}{r_o}}$$

special case $R_3 = r_o$

$$\frac{v_T}{i_T} = 2\,\frac{1}{g_m}$$



$$\frac{1 + \frac{r_{op}}{r_{on}}}{g_m + \frac{1}{r_{on}}}$$

Open-ckt gain $= g_m \cdot r_o$

$= \dfrac{r_o}{1/g_m}$

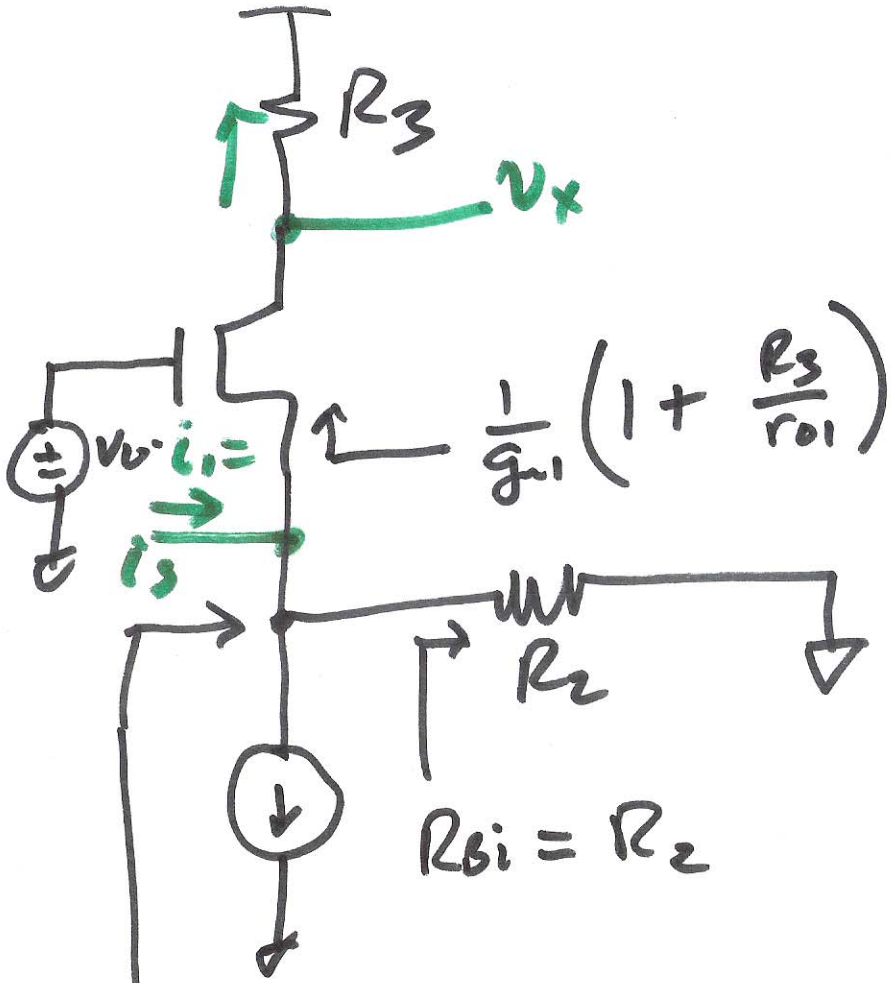
We want for good transistors is $\dfrac{1}{g_m} \ll r_o$

$r_o \gg \dfrac{1}{g_m}$

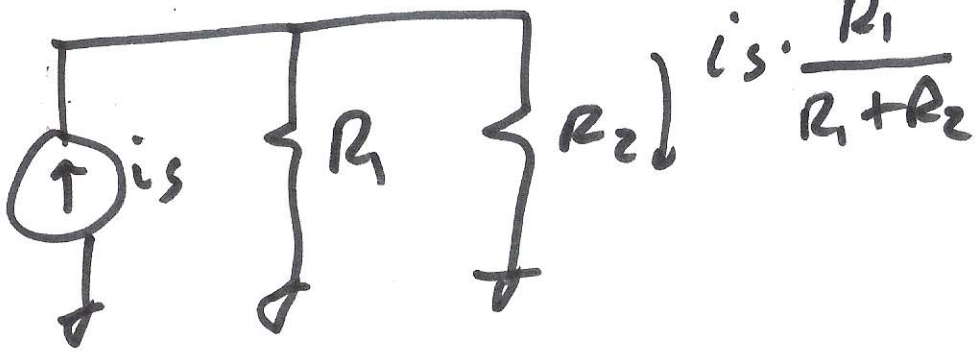
$g_m \ll \dfrac{1}{r_o}$

$$\frac{v_T}{i_T} \simeq \frac{1}{g_m}\left(1 + \frac{R_3}{r_o}\right)$$

$$\simeq \frac{1}{g_{mN}}\left(1 + \frac{r_{op}}{r_{on}}\right)$$



$$R_i = \frac{1}{g_{m1}}\left(1+\frac{R_3}{r_{o1}}\right) \| R_2$$

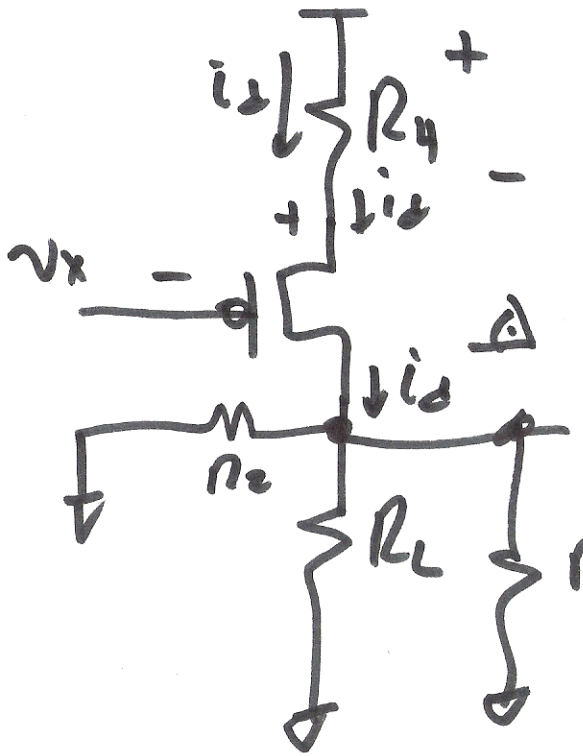


$$v_x = R_3\left(i_s \cdot \frac{R_2}{R_2+\frac{1}{g_{m1}}\left(1+\frac{R_3}{r_{o1}}\right)}\right)$$

$$\frac{v_x}{i_s} = \frac{R_2 \cdot R_3}{R_2+\left(\frac{1}{g_{m1}}\left(1+\frac{R_3}{r_{o1}}\right)\right)}$$

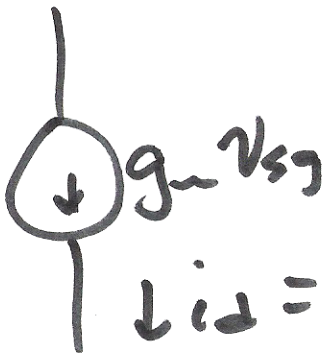
$$A_{OL} = \frac{v_o}{i_s}$$

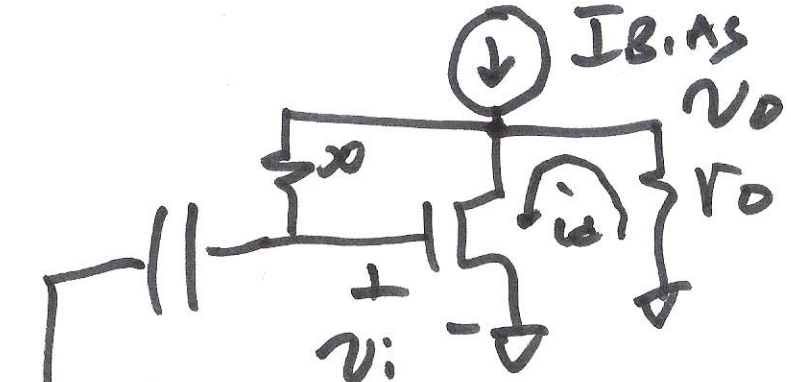
$$i_d \cdot R_4 + v_{sg} + v_x = 0$$



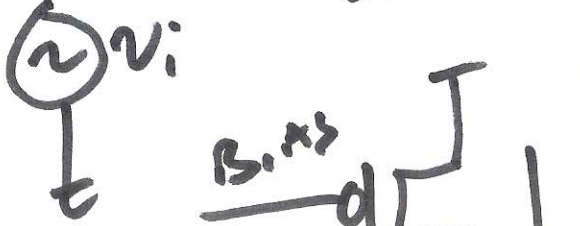
$$v_o = i_d \cdot R_2 \| R_L \| \left(r_{op}(1 + g_{mp} \cdot R_4) + R_4 \right)$$

$$r_{op}(1 + g_{mp} \cdot R_4) + R_4$$



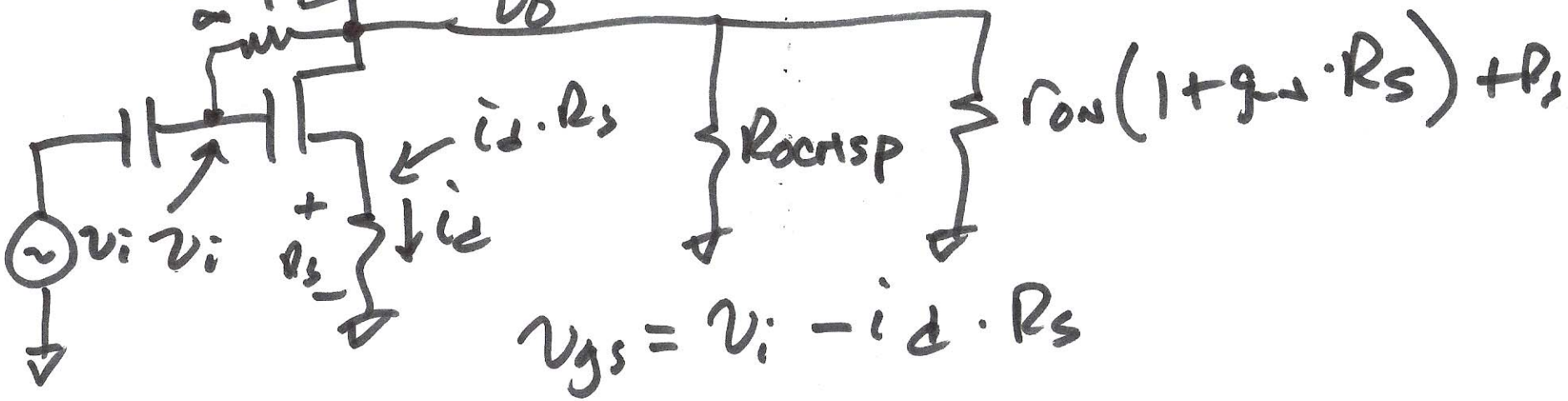


$$\Rightarrow v_o = -i_d \cdot r_o$$
$$= -g v_i \cdot r_o$$

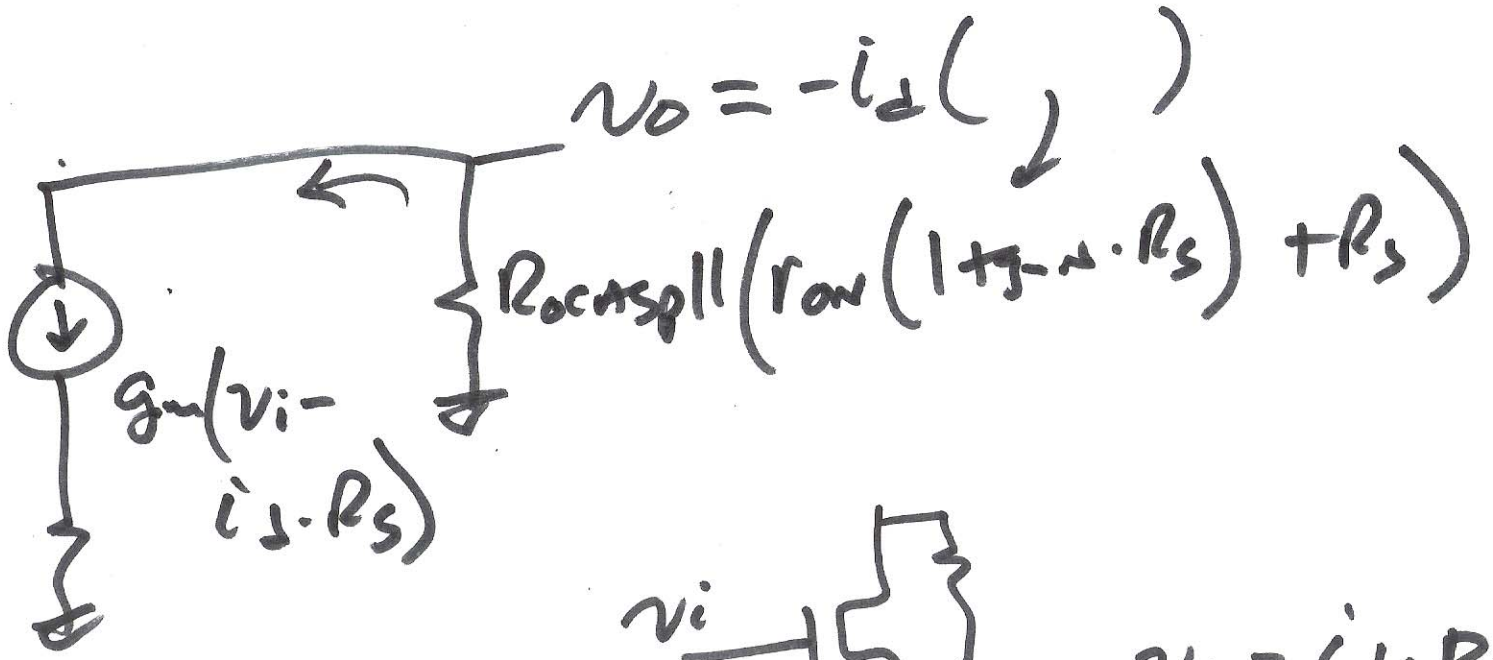


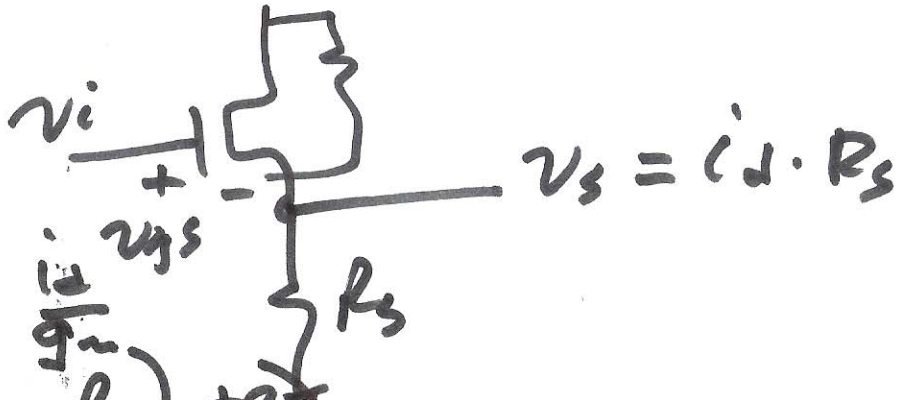
$$i_d = g_m v_{gs} = g_m v_i$$

$$\frac{v_o}{v_i} = -g_m r_o$$



$$v_{gs} = v_i - i_d \cdot R_s$$



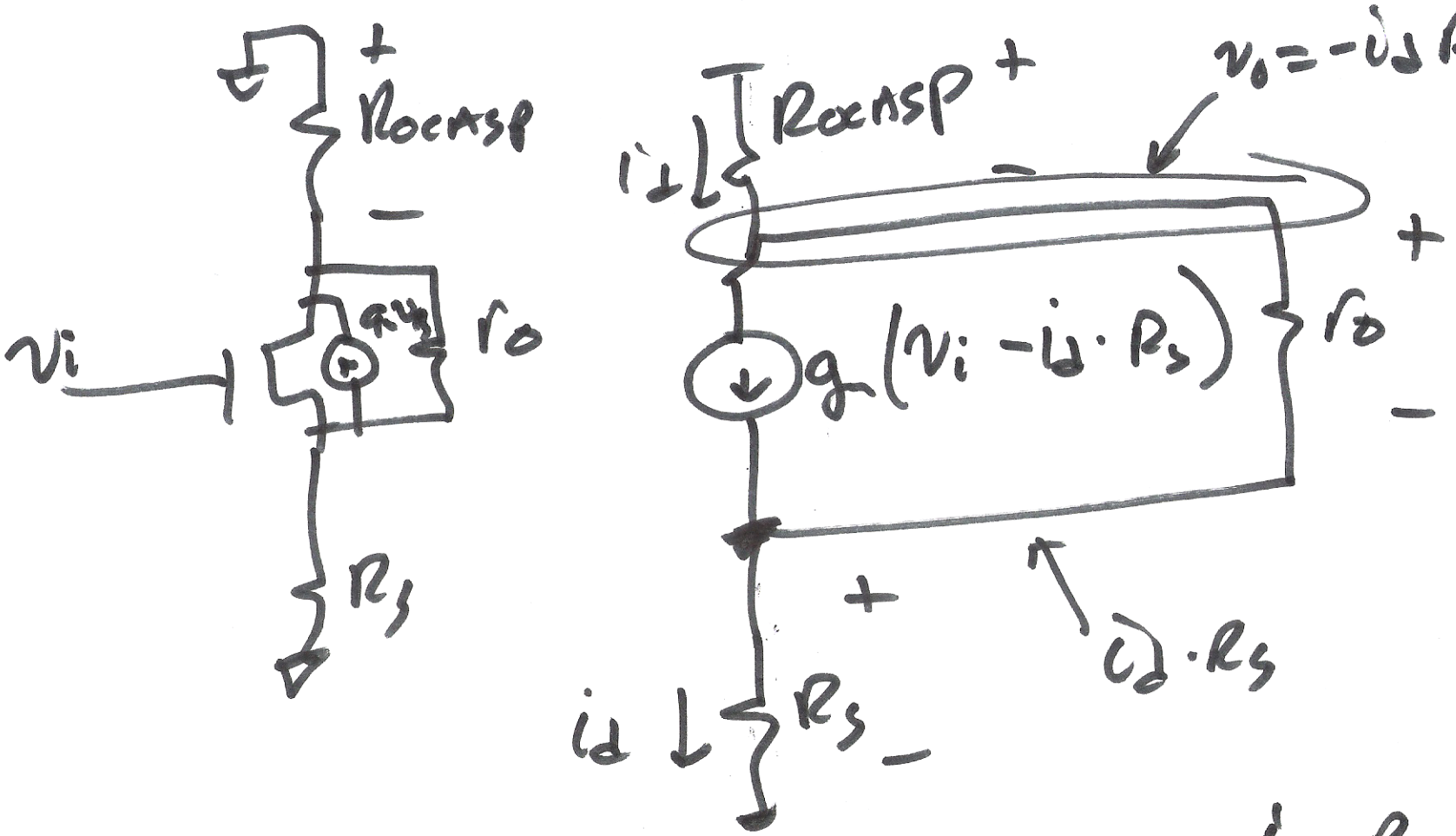


$$v_o = -R_{ocnsp} \| \left(r_{on}\left(1+g_m \cdot R_s\right) + R_s\right)$$

$$\frac{v_o}{v_i} = \frac{-R_{ocnsp} \| \left(r_{on}\left(1+g_m \cdot R_s\right) + R_s\right)}{\frac{1}{g_m} + R_s}$$

$$v_i = v_{gs} + i_d \cdot R_s$$

$$v_i = i_d\left(\frac{1}{g_m} + R_s\right)$$



$$i_d = g_m(v_i -$$

$$v_o = -i_d \cdot R_{ocntsp}$$

$$i_d \cdot R_{ocntsp} + r_o\left(i_d - g_m(v_i - i_d R_s)\right) + i_d \cdot R_s$$

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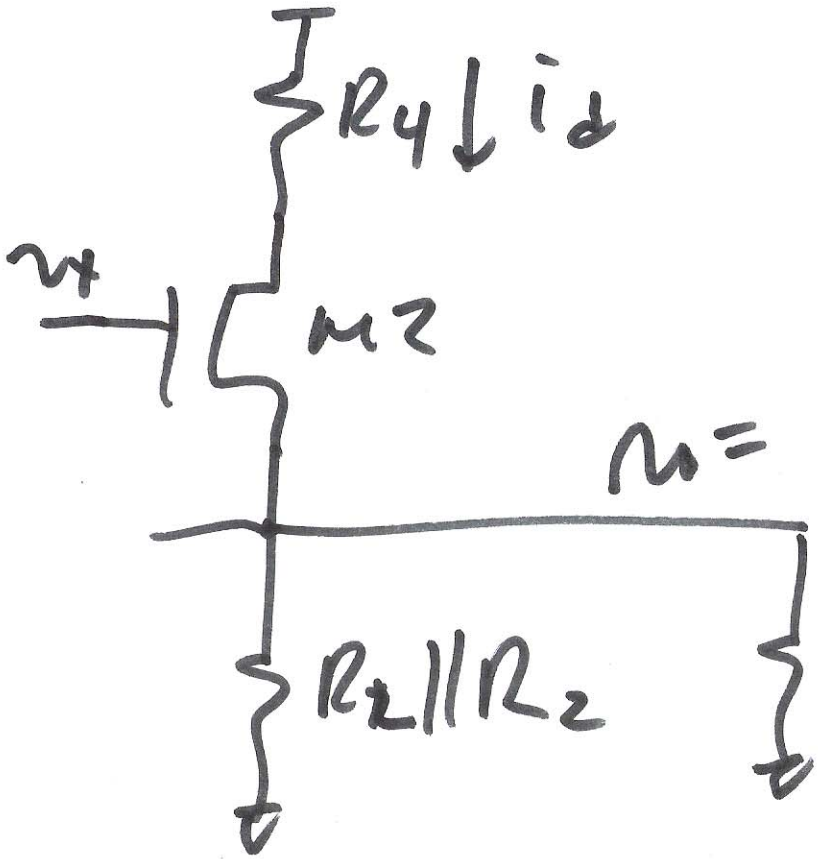
$$-v_o + r_o\left(\frac{-v_o}{R_{ocns}} - g_m v_i - g_{mb}\frac{v_o R_s}{R_{ocns}}\right)$$

$$- \frac{v_o \cdot R_s}{R_{ocns}} = 0$$

$$v_o\left(\frac{R_s}{R_{ocns}} + g_m \frac{R_s}{R_{ocns}} \cdot r_o + \frac{r_o}{R_{ocns}} + 1\right) =$$

$$\frac{v_o}{v_i} = \frac{-g_m}{\frac{R_s}{R_{ocns}} + g_m \frac{R_s}{R_{ocns}} r_o + \frac{r_o}{R_{ocns}} + 1}$$

$-g_m v_i$



$$R_4 \cdot i_d + \underbrace{v_{sg}}_{i_d \cdot \frac{1}{g_{m1}}} + v_x = 0$$

$$v_x = -i_d \left(R_4 + \frac{1}{g_{mp}} \right)$$

$$R_o =$$

$$r_{op}\left(1 + \frac{R_4}{r_{op}}\right) + R_4$$

$$v_o = \frac{-R_2 \| R_2 \| \left(r_{op}\left(1 + \frac{R_4}{r_{op}}\right) + R_4 \right)}{R_4 + \frac{1}{g_{mp}}}$$

$$A_{02} = \frac{v_x}{i_s} \cdot \frac{v_o}{v_x} = \frac{-R_2 \| R_3 \| \left(r_{op}\left(1+\frac{R_4}{r_{op}}\right)+R_4\right)}{R_4 + \frac{1}{sC_4}} \cdot \frac{R_2 R_3}{R_2 + \left(\frac{1}{sC_{gs1}}\left(1+\frac{R_3}{r_{o1}}\right)\right)}$$

$$= \frac{10K \cdot 10K \cdot 150K}{\frac{6.5K}{4} \cdot \left[10K + 2 \cdot 6.5K\right)}$$

$$= \frac{100 \cdot 150K}{\frac{6.5}{4} \cdot 23} = \frac{100}{143} \cdot 150K$$

$$\simeq \underline{\underline{100K}}$$

$M = 4$

12)