Q1

$$r_o = \frac{|V_A|}{I_D} \qquad |V_A| = 10$$

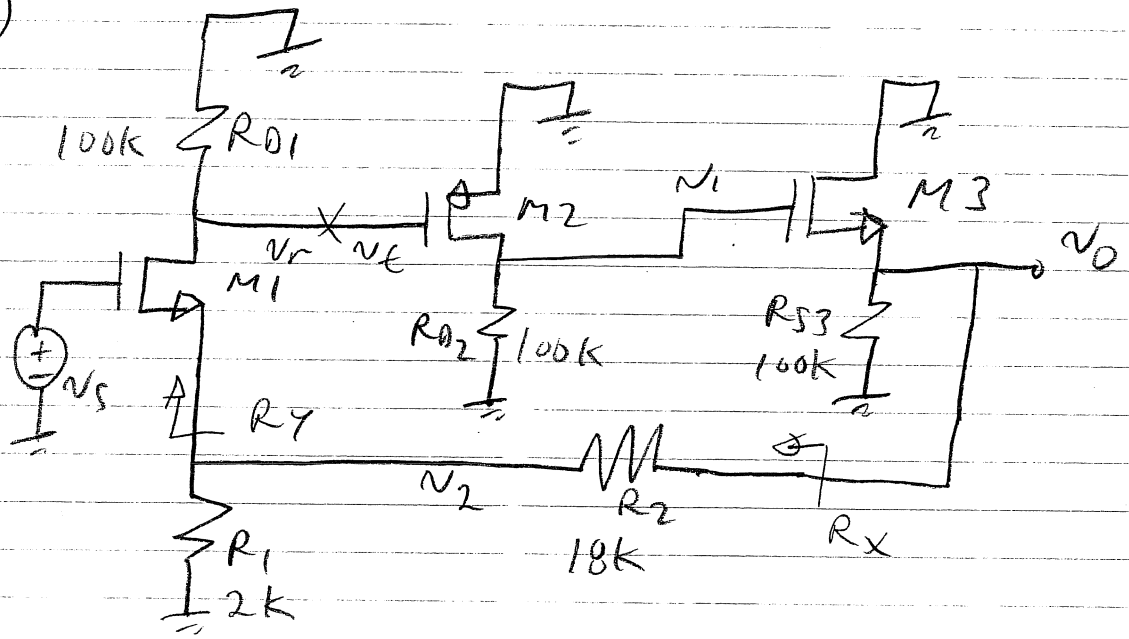
FOR $I_D = 0.1\,mA \Rightarrow r_o = 100k\Omega$

$$g_m = \frac{2I_D}{V_{OV}} \qquad V_{OV} = 0.2V$$

FOR $I_D = 0.1\,mA \Rightarrow g_m = 1\,mA/V \Rightarrow r_s = 1k\Omega$

ASSUME $g_m r_o \gg 1$

a)



$$R_Y = r_{S1} + \frac{R_{D1}}{g_m r_o} = \frac{2}{g_m} = 2k$$

$$R_x = R_2 + (R_1 \| R_Y) = 19k$$

$$\frac{v_1}{v_t} = -\frac{R_{D2} \| r_{o2}}{r_{S2}} = -50$$

Q1 CONT

$$\frac{v_o}{v_1} = \frac{(R_{53} \parallel r_{o3} \parallel R_x)}{(R_{53} \parallel r_{o3} \parallel R_x) + r_{53}} = 0.932$$

$$\frac{v_2}{v_1} = \frac{(R_1 \parallel R_x)}{(R_1 \parallel R_x) + R_2} = 0.0526$$

$$\frac{v_r}{v_2} = g_m (R_{D1} \parallel r_{o1}) = 50$$

$$L \equiv -\frac{v_r}{v_t} = 50 \times 0.932 \times 0.0526 \times 50 = 122.6$$

A_∞

$L \to \infty \Rightarrow v_2 = v_s$ & $i_{D1} = 0$

$$v_s = \frac{R_1}{R_1 + R_2} v_o$$

$$A_\infty \equiv \left.\frac{v_o}{v_s}\right|_{L\to\infty} = \frac{R_1 + R_2}{R_1} = 10$$

$$\frac{v_o}{v_s} = A_\infty \left(\frac{L}{1+L}\right) + d\left(\frac{1}{1+L}\right) \qquad d \approx 0 \text{ (GIVEN)}$$

$$\frac{v_o}{v_s} = (10)\left(\frac{122.6}{122.6+1}\right) = 9.92 \ \text{V/V}$$

Q1 CONT

$$R_{OUT} = R_{10}\left(\frac{1+L_S}{1+L_0}\right) \qquad L_S = 0$$

$$L_0 = L = 122.6$$

$$R_{10} = r_{S3} \,||\, R_{S3} \,||\, R_X = 0.94\,k\Omega$$

$$R_{OUT} = 0.94\left(\frac{1}{1+122.6}\right) = \underline{7.6\,\Omega}$$

Q2 DC ANALYSIS

$$V_{ov} = \sqrt{\frac{2I_D}{\mu_N C_{ox}(W/L)}} \qquad V_{ov1} = V_{ov2} = V_{ov3} = 0.2887\ V$$

$$g_{m1} = g_{m2} = g_{m3} = \frac{2I_D}{V_{ov}} = 693\ \mu A/V = \frac{1}{r_{s1}}$$

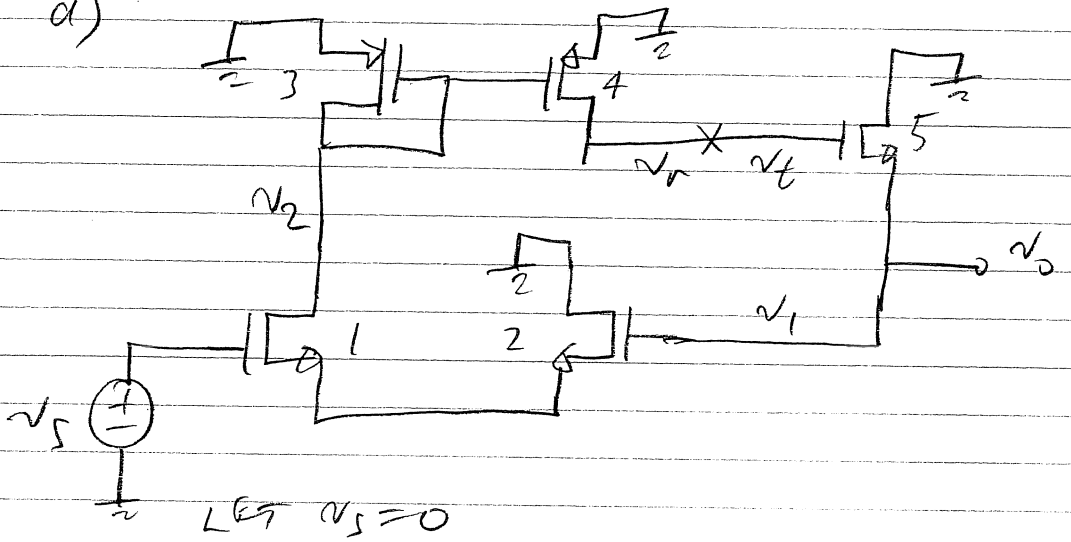
$$g_{m4} = 2.078\ mA/V$$

$$g_{m5} = 1.96\ mA/V \Rightarrow r_{s5} = 511\ \Omega$$

$$r_{o1} = r_{o2} = r_{o3} = \frac{V_A' L}{I_D} = 240\ k$$

$$r_{o4} = 80k \qquad r_{o5} = 30k$$

a)



LET $v_s = 0$

$$\frac{v_1}{v_t} = \frac{r_{o5}}{r_{o5} + r_{s5}} = 0.98$$

$$\frac{v_2}{v_1} \cong \frac{\frac{1}{g_{m3}}}{r_{s1} + r_{s2}} = 0.5$$

$$\frac{v_r}{v_2} = -g_{m4} r_{o4} = -166.2$$

$$L = 0.98 \times 0.5 \times 166.2 = \underline{81.4}$$

a) INSERT GAIN A_N AT "X"

AS $A_N \to \infty$ $\Rightarrow$ $v_r \to 0$

$v_r \to 0 \Rightarrow v_2 \to 0 \Rightarrow i_{o1} \to 0$

$\Rightarrow v_1 \to v_s$

$A_\infty = 1$

d) $d = 0$

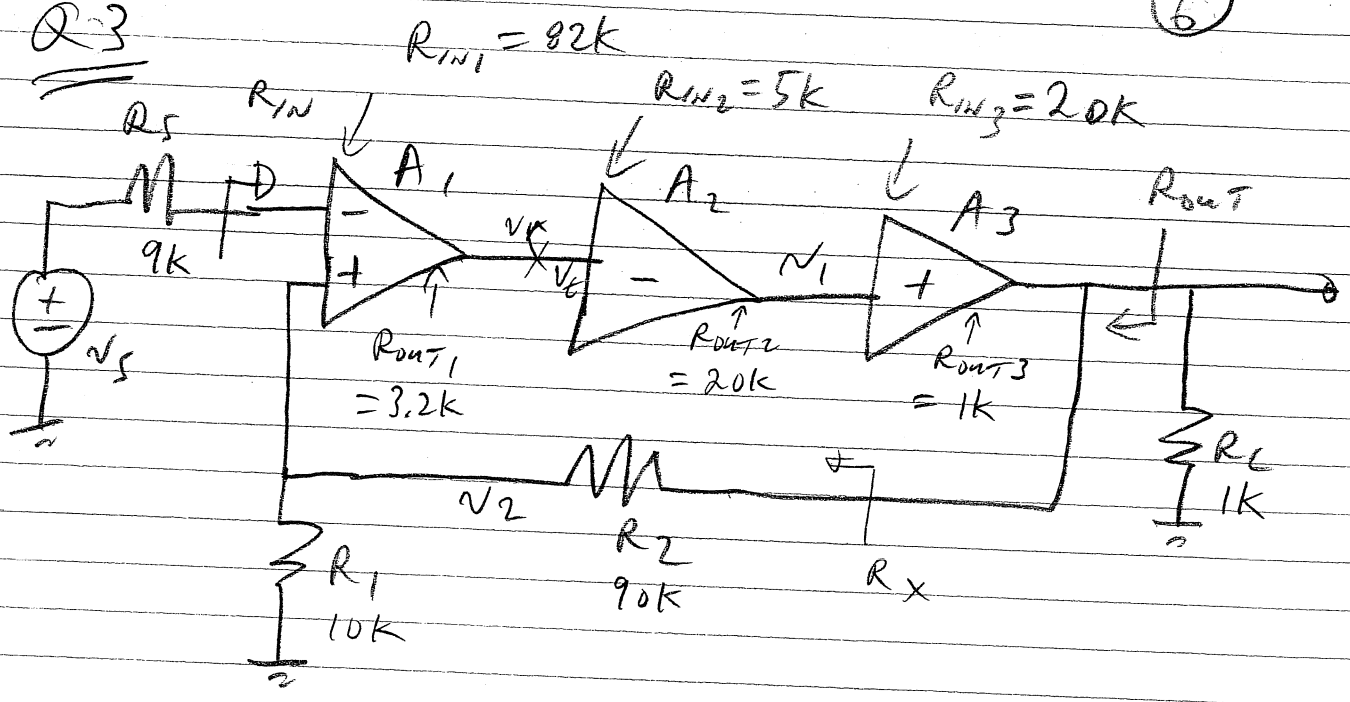
$$\frac{v_o}{v_s} = A_\infty \left(\frac{L}{1+L}\right) + d\left(\frac{1}{1+L}\right) = \frac{L}{1+L} = 0.988 \ \frac{V}{V}$$

b) $R_{OUT} = R_{po}\left(\frac{1+L_s}{1+L_o}\right)$ $\quad L_s = 0$, $L_o = 81.4$

$R_{po} = r_{55} \| r_{05} = 0.502\,k$

$R_{OUT} = 0.502\left(\frac{1}{1+L}\right) = 6.1\,\Omega$

Q3



$A_1 = 20\ V/V \qquad A_2 = 20\ mA/V \qquad A_3 = 1\ V/V$

$$R_X \equiv R_2 + [R_1 \| (R_{IN1} + R_S)] = 99k$$

$$\frac{V_1}{V_t} = -A_2 \times (R_{OUT2} \| R_{IN3}) = (-20\,mA/V)(10k)$$

$$= -200\ V/V$$

$$\frac{V_o}{V_1} = A_3 \frac{(R_L \| R_X)}{(R_L \| R_X) + R_{OUT3}} = 0.5\ V/V$$

$$\frac{V_2}{V_o} = \frac{R_1 \| (R_{IN1} + R_S)}{[R_1 \| (R_{OUT1} + R_S)] + R_2} \approx \frac{9}{9+90} = 0.091\ V/V$$

Q3 CONT

$$\frac{V_r}{V_2} = \left(\frac{R_{IN1}}{R_{IN1} + R_S}\right) A_1 \left(\frac{R_{IN2}}{R_{IN2} + R_{OUT1}}\right)$$

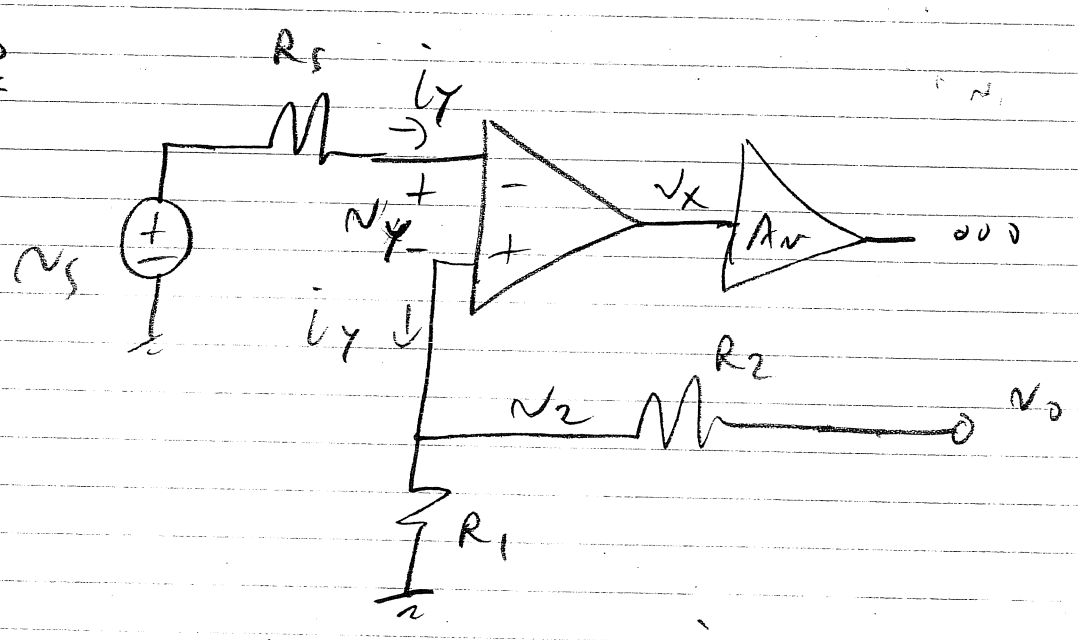
$$= \left(\frac{82}{82 + 9}\right)(20)\left(\frac{5}{5 + 3.2}\right)$$

$$= 11 \ V/V$$

$$L = -\frac{V_r}{V_t} = 200 \times 0.5 \times 0.091 \times 11$$

$$L = 100 \ V/V$$ dão GIVEN

A_∞



$A_V \to \infty \Rightarrow V_Y \to 0$ e $i_Y \to 0$

$v_y \to 0$ & $i_y \to 0 \Rightarrow v_2 = v_s$

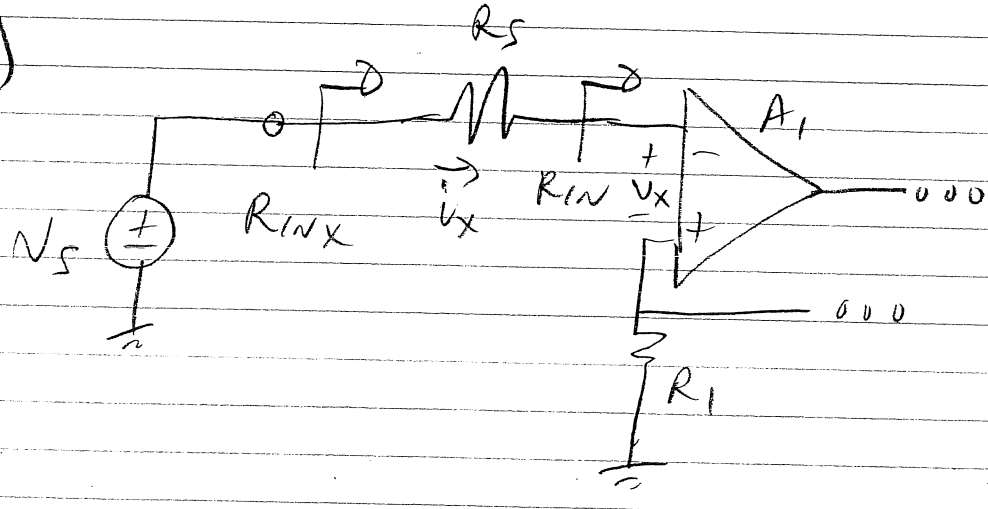
$$v_s = \frac{R_1}{R_1 + R_2} v_o$$

$$A_\infty \equiv \left.\frac{v_o}{v_s}\right|_{L\to\infty} = \frac{R_1 + R_2}{R_1} = 10$$

$$\frac{v_o}{v_s} = A_\infty \left(\frac{L}{1+L}\right) + d\left(\frac{1}{1+L}\right)$$

$$= (10)\left(\frac{100}{1+100}\right) = \underline{\underline{9.9}}$$

b)



EASIER TO FIND R_{INX} THAN R_{IN}

$\downarrow$ $R_{INX} = R_{IN} + R_S$

Q3 CONT

$$R_{INX} = R_{10}\left(\frac{1+L_S}{1+L_0}\right) \qquad L_S = L = 100, \quad L_0 = 0$$

($L_0 = 0$ SINCE $i_x = 0 \Rightarrow v_x = 0$)

$$R_{10} = R_S + R_{IN_1} + \left[R_1 \| \left(R_2 + (R_L \| R_{OUT3})\right)\right]$$

$$= 100\,K$$

$$R_{INX} = (100k)(1+100) = 10.1\,M\Omega$$

$$R_{INX} = R_{IN} + R_S \Rightarrow R_{IN} = R_{INX} - R_S$$

$$R_{IN} = 10.1\,M\,\Omega$$

R_{OUT}

$$R_{OUT} = R_{10}\left(\frac{1+L_S}{1+L_0}\right) \qquad L_S = 0, \quad L_0 = L = 100$$

$$R_{10} = R_{OUT3} \| R_L \| \left[R_2 + (R_1 \| (R_{IN_1} + R_S))\right]$$

$$R_{10} = 500\ \Omega$$

$$R_{OUT} = \frac{500}{1+100} \cong 5\,\Omega$$