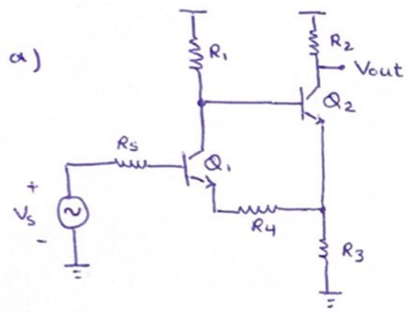
In the name of God

# Assignment 8 :

1. In the following Circuits, specify the feedback network, main Amplifier section and the type of the feed back.

a)




input of main ampl — output of main ampl,

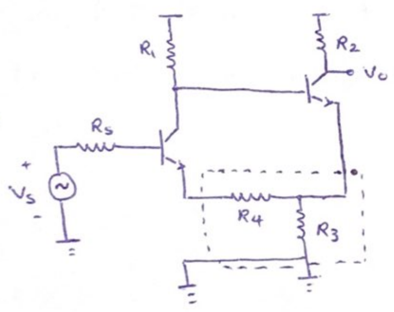
↑ ↑

input - output

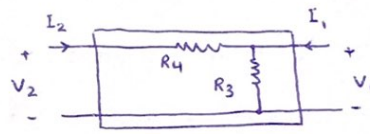
series - series

V - I

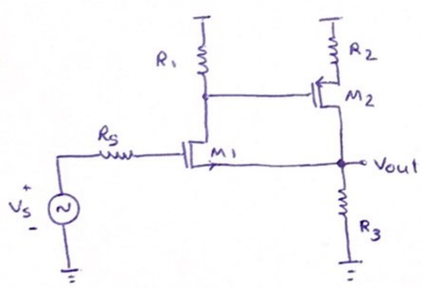
main Ampl :



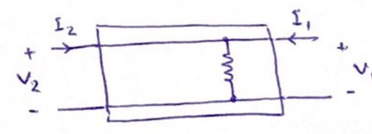

feedback network :




b)




Feedback network :

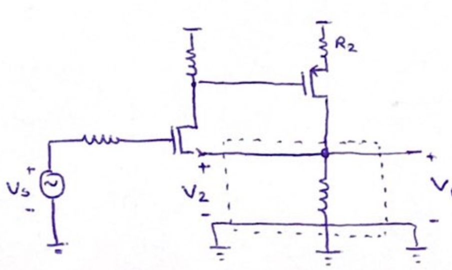



input - output

series - shunt

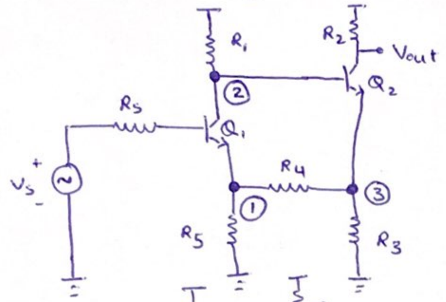
V - V

main Ampl :



2. Determine the sign of the feedback in the following circuits.

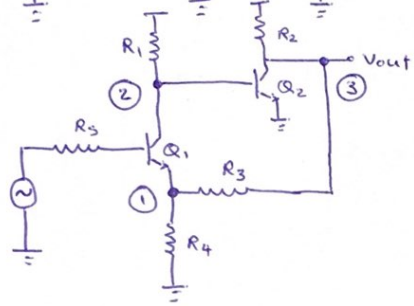
a)




if ① ↑(+) ⟹ ② ↑(+) ⟹ ③ ↑(+)

⟹ ① ↑(+) : Poitive feedback

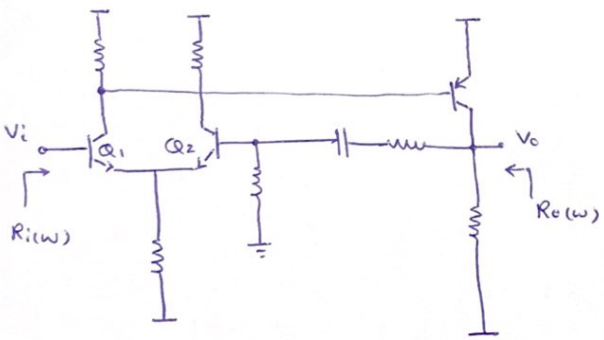
b)



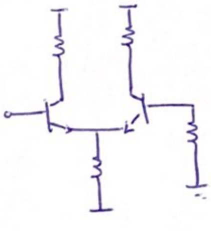

if ① ↑(+) ⟹ ② ↑(+) ⟹ ③ ↓(−)

⟹ ① ↑(+) : negative feedback

3. In the circuit shown below, $R_i(\omega)$ and $R_o(\omega)$ are the input resistance and output resistance in term of $\omega$. How do $R_i(\omega)$ and $R_o(\omega)$ change as the frequency varies from 0 to infinity. (Hint : Capacitor is modeled as an open-circuit in $\omega = 0$ and as the frequency goes to infinity)

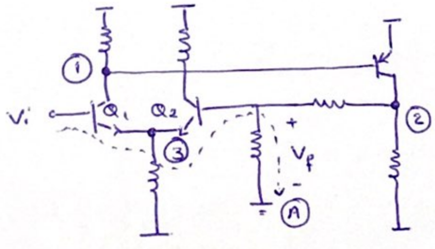



in Low frequency :




there is no feedback

in High frequency :




if ① ↑(+) ⟶ ② ↓(−) ⟶ ③ ↓(−)

⟹ ① ↓(−) : negative feedback

input — output
series — shunt
V — V

KVL @ A : $-V_i + V_{BE1} - V_{BE2} + V_f = 0$

$V_i - V_f = (V_{BE1} - V_{BE2})$ error

$$R_{o\,(CL)} = \frac{R_{o\,(OL)}}{1+af}$$

$$R_{i\,(CL)} = R_{in\,(OL)}\left(1 + af\right)$$

$a$ → open loop gain

$f$ → feedback network gain

پس با افزایش ω، مقاومت ورودی افزایش و مقاومت خروجی کاهش می‌یابد.

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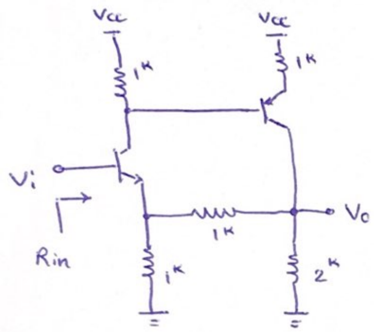
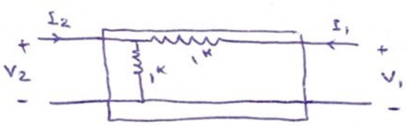
4. Calculate the input resistance of the following circuit.




$$\begin{cases} r_\pi = 1^k \\ \beta = 50 \end{cases}$$

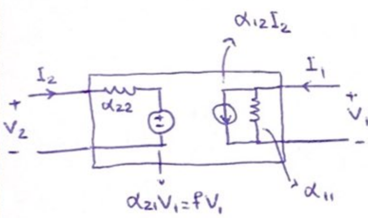
Feedback network :




input — output

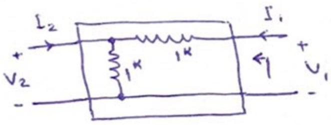
series — shunt

$\bar{V}$ — $\bar{V}$



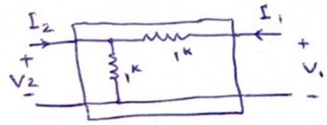

$$\begin{cases} I_1 = \alpha_{11} V_1 + \alpha_{12} I_2 \\ V_2 = \underbrace{\alpha_{21}}_{=f} V_1 + \alpha_{22} I_2 \end{cases}$$

$$\alpha_{11} = \left.\frac{I_1}{V_1}\right|_{I_2=0} :$$



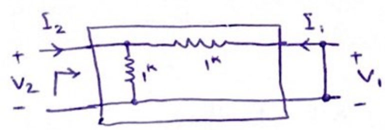

$$: \quad \alpha_{11} = 1 + 1 = \boxed{2^k}$$

$$\alpha_{21} = f = \left.\frac{V_2}{V_1}\right|_{I_2=0} :$$



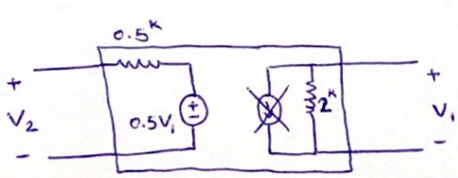

$$: \quad \alpha_{21} = f = \frac{1^k}{1^k + 1^k} = \boxed{0.5}$$

$$\alpha_{22} = \left.\frac{V_2}{I_2}\right|_{V_1=0} :$$

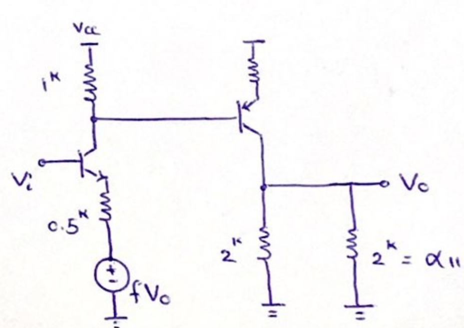



$$: \quad \alpha_{22} = 1^k \,||\, 1^k = \boxed{0.5^k}$$

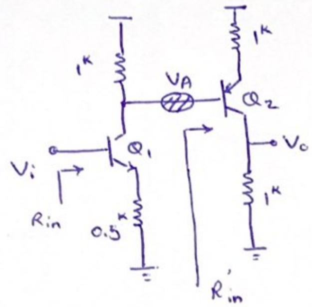
$\Rightarrow$




$\Rightarrow$



$R_{in}\big|_{f=0}$ :




$R'_{in} = r_{\pi_2} + (\beta+1)R_{E_2} = 1^k + 51(1^k) = \boxed{52^k}$

$R_{in}\big|_{f=0} = r_{\pi_1} + (\beta+1)R_{E_1} = 1^k + 51(0.5) = \boxed{26.5}$

open loop input resistance

Calculate open loop gain (a) : $a = \frac{V_o}{V_i}\Big|_{f=0} = \frac{V_o}{V_A} \times \frac{V_A}{V_i} = \frac{-R_{C2}}{R_{E2} + \frac{1}{g_{m2}}} \times \frac{-R_{C1}}{R_{E1} + \frac{1}{g_{m1}}}$

$r_\pi = \frac{\beta}{g_m} \Rightarrow g_m = \frac{\beta}{r_\pi} = \frac{50}{1} = 50^{mmho}$

$$= \left[\frac{-1^k}{1^k + \frac{1}{50}}\right] \times \left[\frac{-1^k \| 52^k}{0.5^k + \frac{1}{50}}\right] = 0.98 \times 1.92 = \boxed{1.88}$$

$$R_{in} = R_i\big|_{f=0} \cdot (1+af) = 26.5\,(1 + 1.88 \times 0.5) \simeq \boxed{52^k}$$

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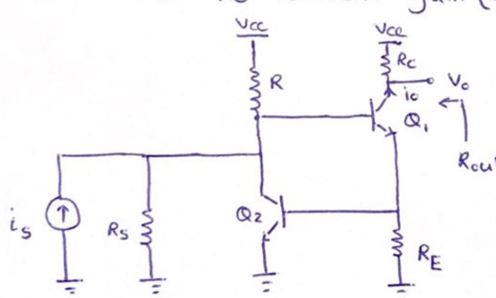
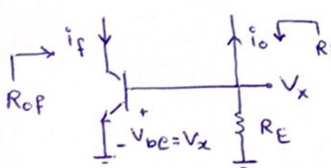
5. In the following circuit, specify the type of the feedback configuration. In addition calculate the current gain ($\frac{i_o}{i_s}$) and the output resistance.




Input — output
shunt — series
I — I




$\beta = \frac{i_f}{i_o}$

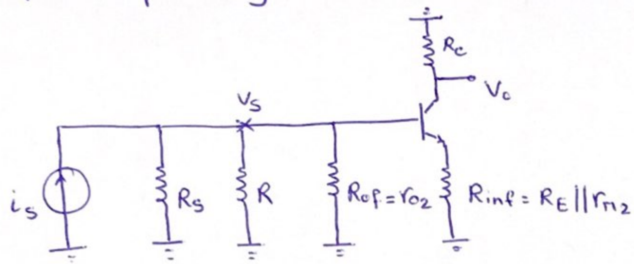
$V_x = \frac{1}{g_{m2}} i_f$

KCL @ $V_x$ : $\frac{V_x}{R_E} + \frac{i_f}{\beta_2} = -i_o$

$\Rightarrow \frac{1}{R_E g_{m2}} i_f + \frac{i_f}{\beta_2} = -i_o$

$\Rightarrow \frac{i_f}{i_o} = \frac{-\beta_2 R_E g_{m2}}{\beta_2 + R_E g_{m2}} = \beta$ $\longrightarrow$ $\begin{cases} R_{if} = R_E \| r_{\pi 2} \\ R_{of} = r_{o2} \end{cases}$

## Open Loop Analysis :




$$A_{OL} = a = \frac{i_o}{i_s} = \frac{i_o}{V_o} \times \frac{V_o}{V_s} \times \frac{V_s}{i_s}$$

$$= \left[ \frac{1}{R_c} \right] \times \left[ \frac{-R_c}{R_E \| r_{\pi 2} + \frac{1}{g_{m1}}} \right] \times \left[ R_s \| R \| r_{o2} \| \left( r_{\pi 1} + (\beta+1)\left[ R_E \| r_{\pi 2} \right] \right) \right] \approx \frac{-R \| R_s}{R_E \| r_{\pi 2} + \frac{1}{g_{m1}}}$$

$$\simeq \boxed{\frac{-R \| R_s}{R_E \| r_{\pi 2}}}$$

$$R_{out\,(OL)} = r_{o1} \cdot \left[ 1 + g_{m1} \left( R_E \| r_{\pi 2} \| r_{\pi 1} \right) \right] \quad , \quad T = af = a\beta = \frac{(R \| R_s)(\beta_2 R_E g_{m2})}{(R_E \| r_{\pi 2})(\beta_2 + R_E g_{m2})}$$

$$A_i = \left[ \frac{i_o}{i_s} \right]_{CL} = \frac{A_{OL}}{1+T} = \frac{a}{1+af} = \frac{a}{1+a\beta}$$

$$R_{out\,(CL)} = R_{o,OL}\,(1+af) \quad , \quad R_{out} = R_c \| R_{out\,(CL)} \simeq R_c$$

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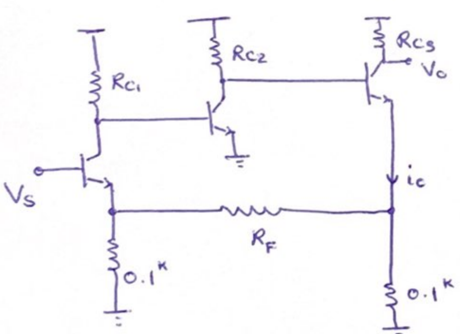
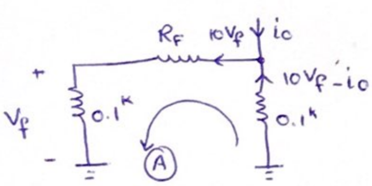
6. In the following circuit, specify $R_f$ so that $\frac{i_o}{V_s} = 0.1$. the gain of the main Amplifier is assumed be very large.




$$A_{OL} = \frac{i_o}{V_s} \gg 1 \longrightarrow A_{CL} = \frac{i_o}{V_s} = \frac{a}{1+af} \simeq \frac{1}{f}$$

$$f = \frac{V_f}{i_o}$$

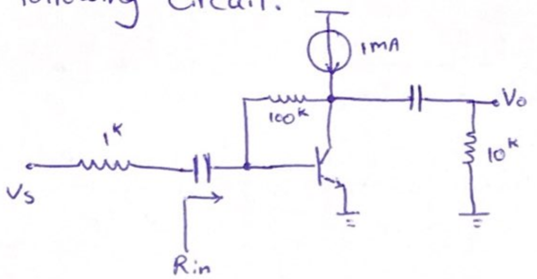
$$\frac{1}{f} = \frac{1}{10} \Rightarrow f = 10$$




$$KVL\,@\,A : V_f - 0.1\,i_o + 10V_f R_f + V_f = 0 \Rightarrow (2 + 10R_f)\,V_f = 0.1\,i_o$$

$$\Rightarrow \frac{V_f}{i_o} = \frac{1}{10(2+10R_f)} = 10 \Rightarrow \boxed{R_f = 0.8^K}$$

7. Calculate the Voltage gain ($\frac{V_o}{V_s}$) and the input resistance ($R_{in}$) of the following circuit.



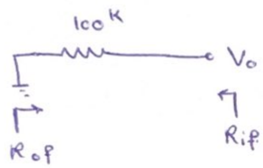

$\begin{cases} V_T = 25^{mV} \\ \beta = 100 \end{cases}$

input — output
shunt — shunt
(V) — (V)

$i_c = 1^{mA} \longrightarrow g_m = 40^{mmho}$

$r_\pi = 2.5^k$

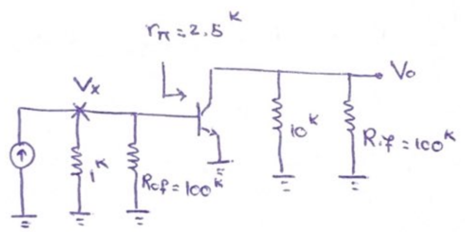
Feedback network :




$R_{of} = R_{if} = 100^k$

$f = \frac{i_f}{V_o} = \frac{-1}{100}$

open loop Analysis :




$A_{OL} = a = \frac{V_o}{i_s} = \frac{V_o}{V_x} \times \frac{V_x}{i_s} = -g_m R_c \cdot \left[1^k \| 100^k \| 2.5^k\right] = -400\left(0.7^k\right) = \boxed{-280}$

$R_{in(OL)} = 0.7^k$

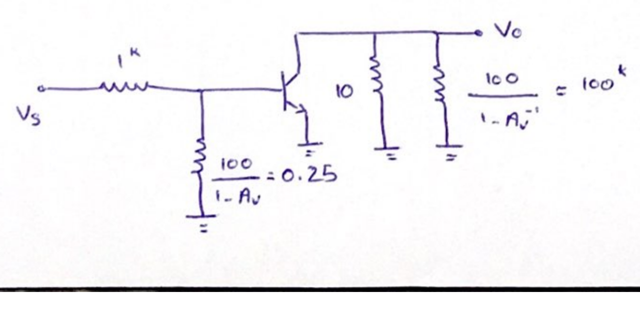
$A_{CL} = \frac{V_o}{i_s} = \frac{a}{1+af} = \frac{-280}{1+2.8} = -73.68$

$\Rightarrow \frac{V_o}{V_s} = \frac{V_o}{i_s} \times \frac{i_s}{V_s} = \boxed{-73.68}$

$R_{in(CL)} = \frac{R_{in(OL)}}{1+af} = 0.2^k$ , $R_{in(CL)} = R_{in} \| 1^k \Longrightarrow R_{in} = 1^k \| -R_{in(CL)}$

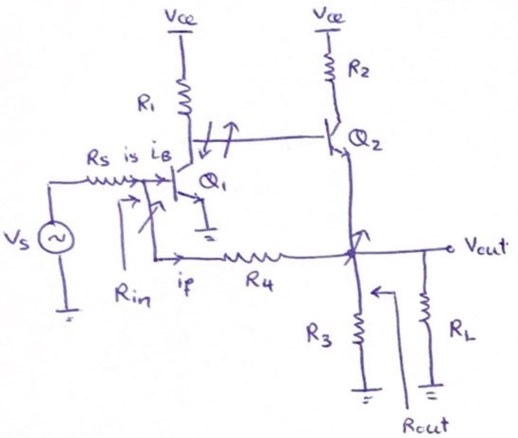
$R_{in} = -1^k \| 0.2^k = \boxed{0.25^k}$

این مسئله با قضیه میلر نیز حل می شود :



8. In the following circuit, Prove that the feedback sign is negative. in addition specify the type of the feedback configuration.

b) Calculate the Voltage gain, input resistance and output resistance of the circuit.

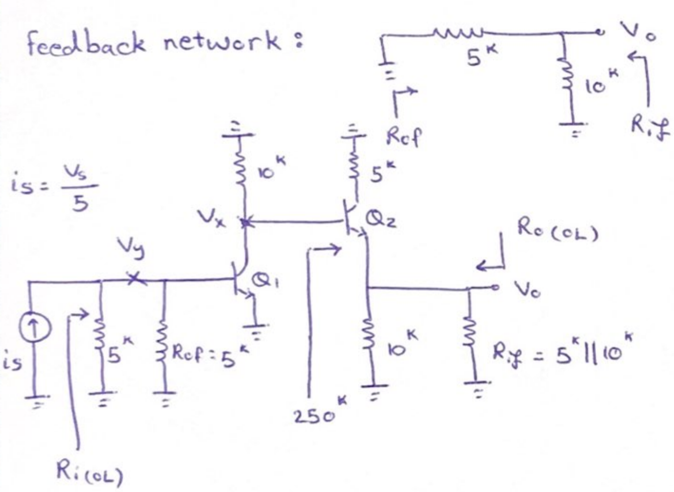



( $R_1 = R_3 = R_L = 10^k$, $R_2 = R_S = R_4 = 5^k$, $\beta = 100$, $g_m = 40^{mmho}$

$V_A = \infty$, $V_{CC} = 10^V$ )

input — output
shunt — shunt
$\textcircled{V}$ — $\textcircled{V}$

feedback network :




$f = \frac{i_f}{V_o} = \frac{-1}{5^k}$

$R_{if} = 5^k \| 10^k = 3.33^k$

$R_{of} = 5^k$

$A_{OL} = a = \frac{V_o}{i_s} = \frac{V_o}{V_x} \times \frac{V_x}{V_y} \times \frac{V_y}{i_s} = \left[\frac{2.5}{2.5 + \frac{1}{40}}\right] \times \left[-40\,(10)\right] \times \left[5^k \| 5^k \| 2.5^k\right] \simeq -500$

$R_{O(OL)} = 25 \| \left(\frac{1}{40} + \frac{10}{100}\right) = 119^{\Omega}$

$R_{i\,(OL)} = 1.25^k$

$A_{CL} = \frac{A_{OL}}{1 + af} = \frac{-500}{1 + 100} = -4.95^k = \frac{V_o}{i_s}$

$\frac{V_o}{V_s} = \frac{V_o}{i_s} \times \frac{i_s}{V_s} = -4.95\left(\frac{1}{5}\right) = \boxed{-0.99}$

$R_{in\,(CL)} = \frac{R_{in\,(OL)}}{1 + af} = \frac{1.25}{101} = 12.5^{\Omega}$

$R_{in(CL)} = 5^k \| R_{in} \Rightarrow R_{in} = 12.5$

$R_{o(CL)} = \frac{R_{o(OL)}}{1 + af} = 1.19^{\Omega} \Rightarrow R_{o\,(CL)} = R_L \| R_o \Rightarrow \boxed{R_o = 1.19}$

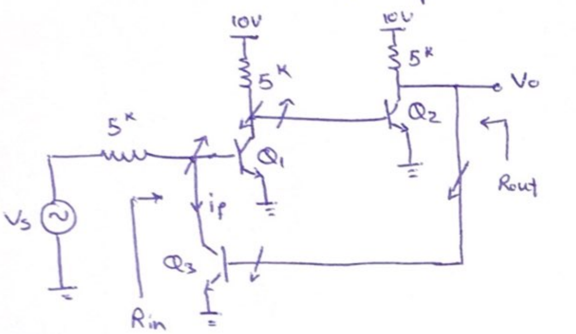
9. In the following Circuit, suppose that $I_C = 1^{mA}$ and $\beta = 100$ for all of the transistor.

a) Specify the feedback loop of the Circuit and show that the feedback sign is negative.

b) specify the type of the feedback configuration.

c) Calculate the Voltage gain.

d) Calculate the input and output resistance ($R_{in}$ and $R_{out}$)




$I_C = 1^{mA}$

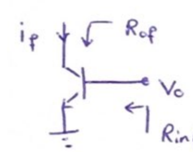
$\beta = 100$

$g_m = 40^{mmho}$

$r_\pi = 2.5^K$

a) negative feedback

b) input — output
shunt — shunt
V — V



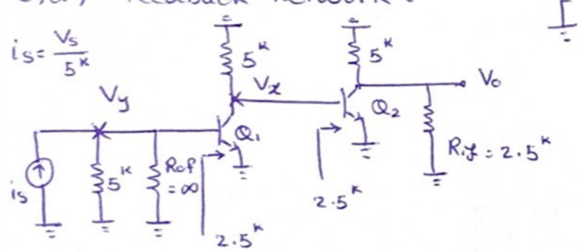

$f = \frac{i_f}{V_o} = g_m = 40$

$R_{if} = r_\pi = 2.5^k$

$R_{of} = r_o = \infty$

c, d) Feedback network :

$i_s = \frac{V_s}{5^K}$




$$\frac{V_o}{i_s} = (A_v)_{oL} = a = \frac{V_o}{V_x} \times \frac{V_x}{V_y} \times \frac{V_y}{i_s} = \left[-40(1.66)\right] \times \left[-1.66 \times 40\right] \times \left[1.66^K\right] = 7319^K$$

$R_{in(oL)} = 1.66^k$ , $R_{o(oL)} = 1.66^k$

$$A_{CL} = \frac{V_o}{i_s} = \frac{A_{OL}}{1+af} \xrightarrow{af \gg 1} A_{CL} = \frac{1}{f} = \frac{1}{40} = 25^{\Omega} = \frac{V_o}{i_s}$$

$$\frac{V_o}{V_s} = \frac{V_o}{i_s} \times \frac{i_s}{V_s} = 25 \times \frac{1}{500} = 5 \times 10^{-3} = \frac{1}{200} = \frac{V_o}{V_s}$$

$$R_{in(CL)} = \frac{1.66^k}{1+af} = 5.67^{m\Omega} \Rightarrow 5.67^M = R_{in} \| 5^k \Rightarrow \boxed{R_{in} = 5.67^M}$$

$$R_{o(CL)} = R_o = \frac{1.66^k}{1+af} = 5.67^M = R_o$$