Lecture (3)
Feedback Amplifiers (II)

Example (Shunt-series Feedback)

The circuit shown in Figure represents a Shunt-Series Feedback amplifier circuit.

Analyze the circuit and Calculate:

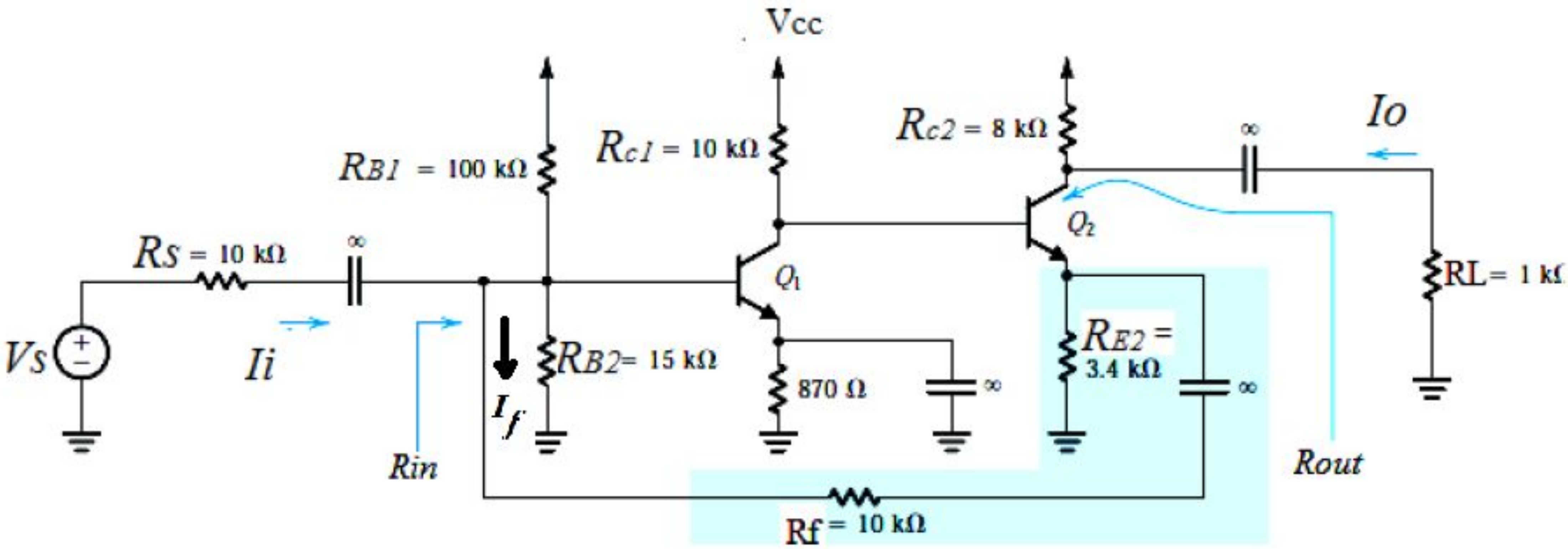
(a) The feedback factor β and the open loop gain A.

(b) The feedback gain A_f.

(c) The feedback input and output resistances (R_{if} and R_{of}).

(d) R_{in} and R_{out}.

Given: $\beta 1 = \beta 2 = 100$, $re1 = 30\Omega$, $re2 = 35\ \Omega$, and $V_A = \infty$.



Solution:

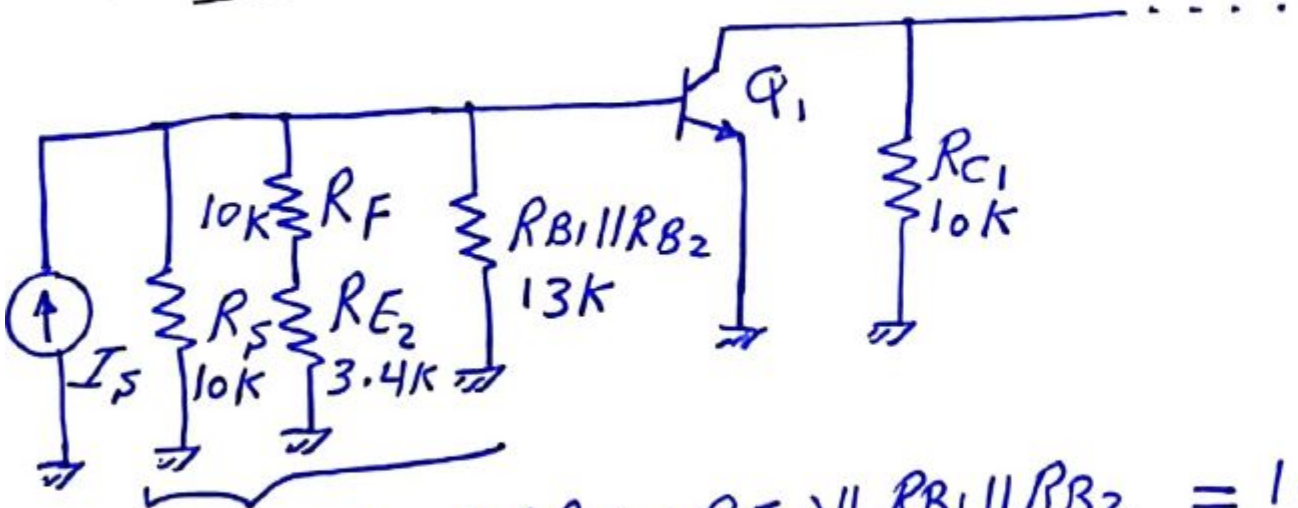
(a) The feedback factor β and the open loop gain A.

shunt – series F.B

i/P = I o/P = I → ∴ current amplifier is used.

$$A = \frac{I_o}{I_i} , \quad \beta = \frac{I_f}{I_o}$$

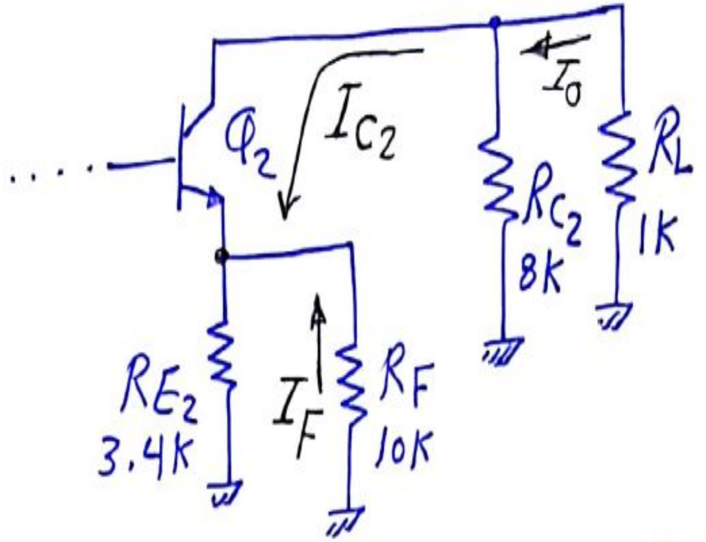
* The input circuit without Feedback (o/P open)



$$\underbrace{R_X = R_S \| (R_F + R_{E_2}) \| R_{B1} \| R_{B2}} = 10 \| 13.4 \| 13$$

$$\boxed{R_X = 3.975\ K\Omega}$$

* output Circuit without Feedback (Input = 0)



$\underbrace{R_Y}_{} = R_{E2} \| R_F = 3.4 \| 10 \cong 2.54\,K\Omega$

* $-I_o = -I_{C2}\dfrac{R_{C2}}{R_{C2}+R_L} \rightarrow I_o = I_{C2}\dfrac{R_{C2}}{R_{C2}+R_L}$

$\therefore\ I_o = \dfrac{8}{9} I_{C2} \rightarrow \boxed{I_{C2} = \dfrac{9}{8} I_o}$

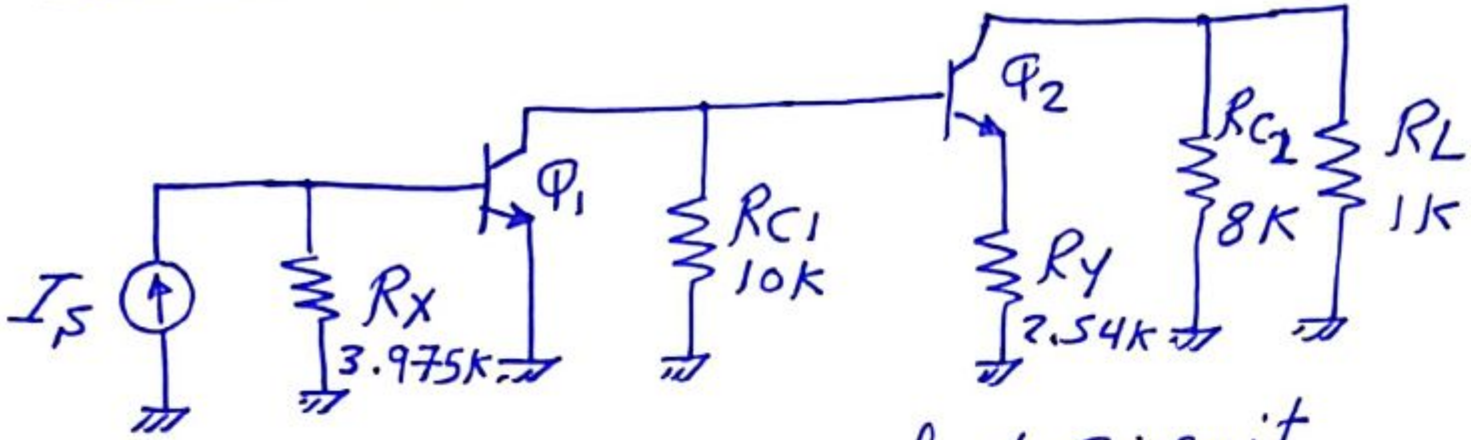
* $-I_F = I_{C2}\dfrac{R_{E2}}{R_{E2}+R_F}$

$\therefore\ I_F = -\left(\dfrac{9}{8} I_o\right)\dfrac{R_{E2}}{R_{E2}+R_F} = -\dfrac{9}{8} I_o \dfrac{3.4}{13.4}$

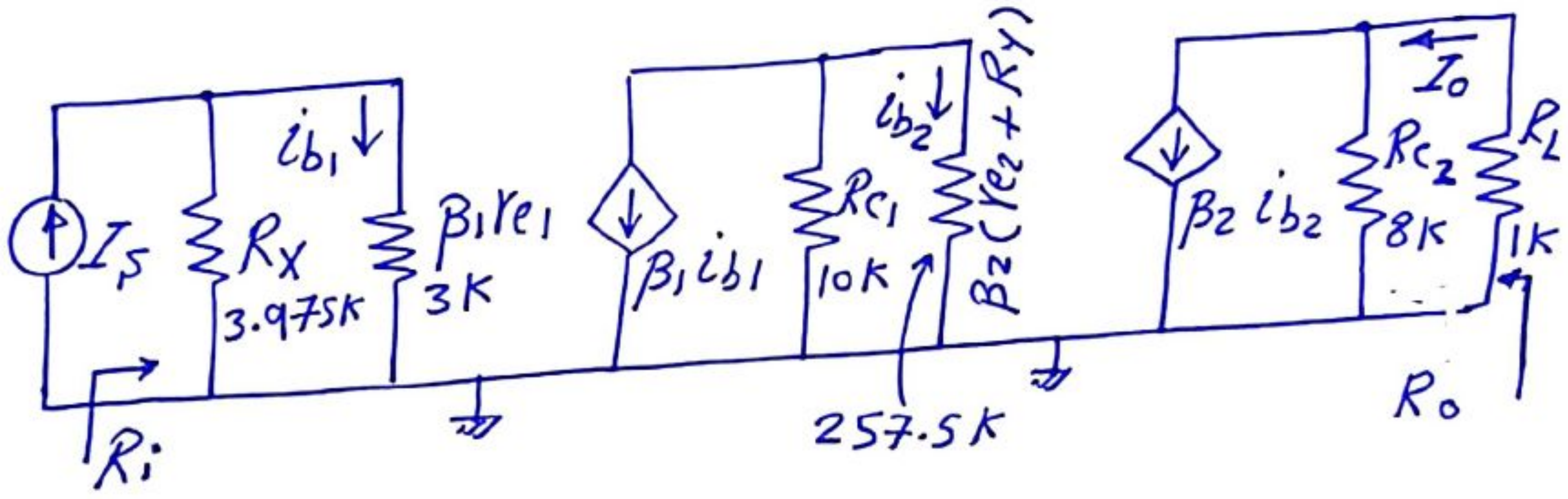
$\therefore\ I_F = -0.28545\, I_o$

$\therefore\ \boxed{\beta = \dfrac{I_F}{I_o} = -0.28545}$ # Feedback Factor

Total Circuit without Feedback



Small-signal A.c equivalent circuit



* open-Loop gain (A)

$$A = \frac{I_o}{I_s} = \frac{I_o}{i_{b2}} \times \frac{i_{b2}}{i_{b1}} \times \frac{i_{b1}}{I_s}$$

* $-I_o = -\beta_2 \, i_{b2} \frac{R_{C2}}{R_{C2}+R_L}$

$$\therefore \frac{I_o}{i_{b2}} = +\beta_2 \frac{R_{C2}}{R_{C2}+R_L} = \frac{100 \times 8}{8+1}$$

$$\boxed{\frac{I_o}{i_{b2}} = \frac{800}{9} = 88.89} \quad \boxed{1}$$

* $i_{b2} = -\beta_1 \, i_{b1} \frac{R_{C1}}{R_{C1}+\beta_2(r_{e2}+R_Y)}$

$$\frac{i_{b2}}{i_{b1}} = \frac{-\beta_1 R_{C1}}{R_{C1}+\beta_2(r_{e2}+R_Y)} = \frac{-100 \times 10}{10+257.5}$$

$$\boxed{\frac{i_{b2}}{i_{b1}} \simeq -3.74} \quad ②$$

* $i_{b1} = I_s \frac{R_X}{R_X + \beta_1 r_{e1}}$

$$\frac{i_{b1}}{I_s} = \frac{R_X}{R_X+\beta_1 r_{e1}} = \frac{3.975}{3.975+3}$$

$$\boxed{\frac{i_{b1}}{I_s} \simeq 0.5699} \simeq 0.57 \quad ③$$

$$\therefore A = (88.89)(-3.74)(0.5699)$$

$$A = -189.46$$ # open-Loop gain

$$\beta = -0.28545$$ # Feedback Factor.

(b) The feedback gain A_f.

$$1 + A\beta = 1 + 189.46 \times 0.28545 = 55.1$$

$$* \; A_f = \frac{A}{1+A\beta} = \frac{-189.46}{55.1} \rightarrow A_f \cong -3.44 \; \#$$

(c) The feedback input and output resistances (R_{if} and R_{of}).

$$* \; R_i = R_X \,//\, \beta_1 r_{e1} = 1.71 \, k\Omega$$

$$* \; R_{if} = \frac{R_i}{1+A\beta} = \frac{1.71}{55.1}$$

$$R_{if} \cong 0.031 \, k\Omega = 31 \, \Omega \; \#$$

$$* \; R_o = R_{C2} \,//\, R_L = \frac{8}{9} k\Omega = 0.8889 \, k\Omega$$

$$* \; R_{of} = R_o(1 + A\beta) = \frac{8}{9} \times 55.1$$

$$R_{of} \cong 48.98 \, k\Omega \; \#$$

(d) R_{in} and R_{out}.

$$* \; R_{in} = \frac{1}{\frac{1}{R_{if}} - \frac{1}{R_S}} = \frac{1}{\frac{1}{0.031} - \frac{1}{10}}$$

$$R_{in} \cong 0.0311 \text{ k}\Omega = 31.1 \, \Omega \; \#$$

$$* \; R_{out} = R_{of} - R_L$$

$$R_{out} = 48.98 - 1$$

$$R_{out} = 47.98 \text{ k}\Omega \; \#$$

Example (Shunt-Shunt Feedback)

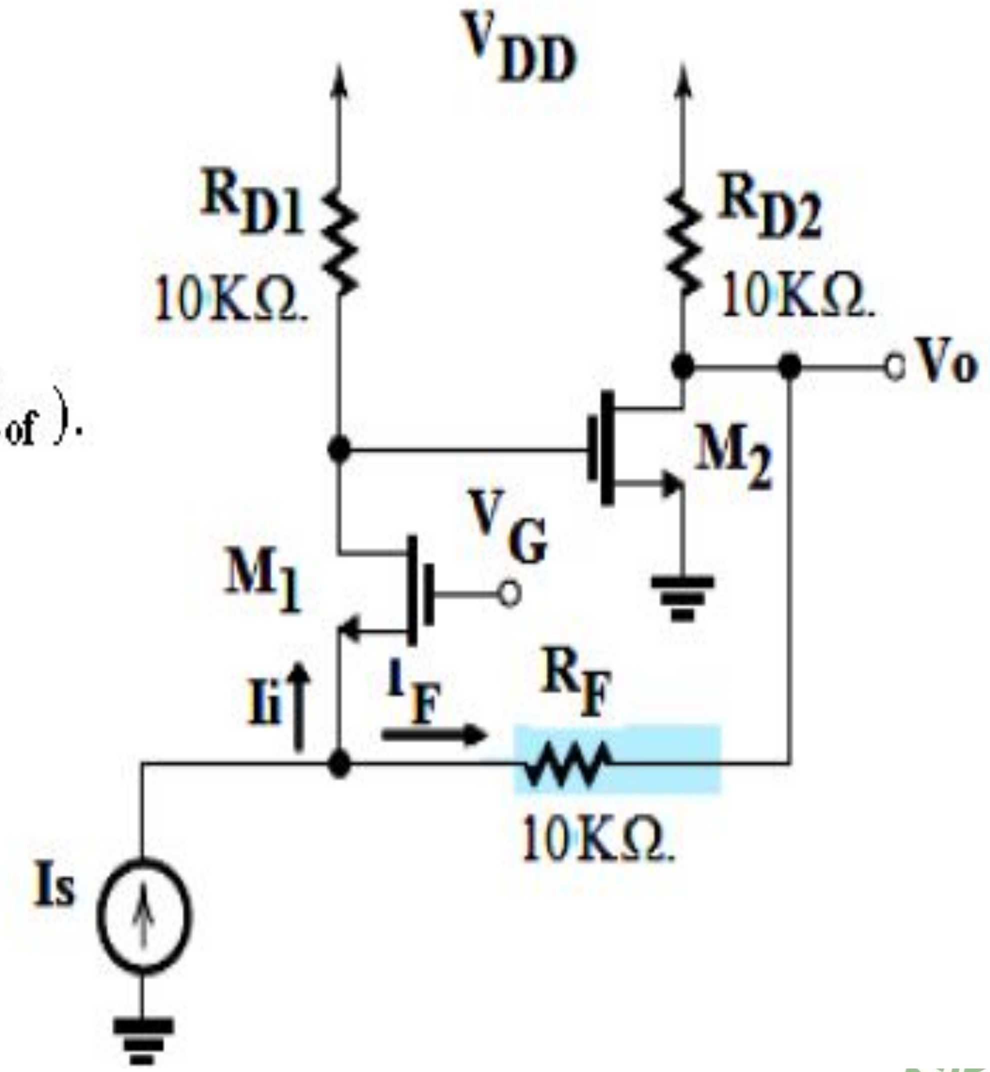
The circuit shown in Figure represents a **Shunt- Shunt** Feedback amplifier circuit. Analyze the circuit and Calculate:

(a) The feedback factor (β) and the open loop gain (**A**).

(b) The feedback gain $\mathbf{A_f}$.

(c) The feedback input and output resistances ($\mathbf{R_{if}}$ **and** $\mathbf{R_{of}}$).

Given: $g_{m1} = g_{m2} = 2$ mA/V and $V_A = \infty$.

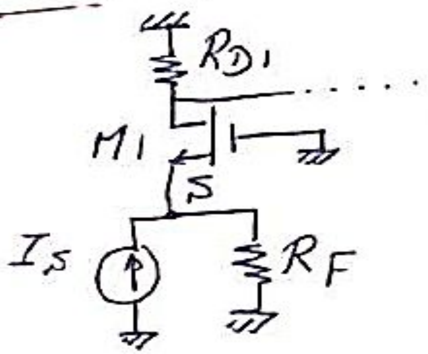


Solution:

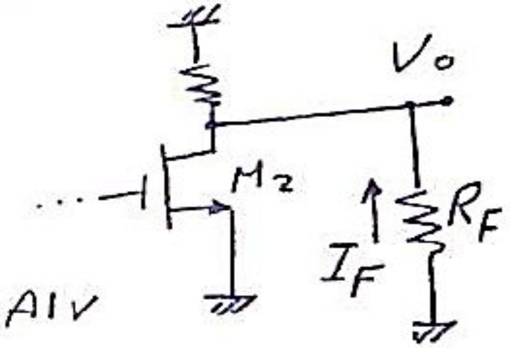
* Topology: shunt-shunt
  I/P: I, O/P: V

$\therefore A = \frac{V_o}{I_i}$, $\beta = \frac{I_F}{V_o}$

* The input circuit without F.B ($V_o = 0$)



* The output circuit without F.B ($S = 0$)

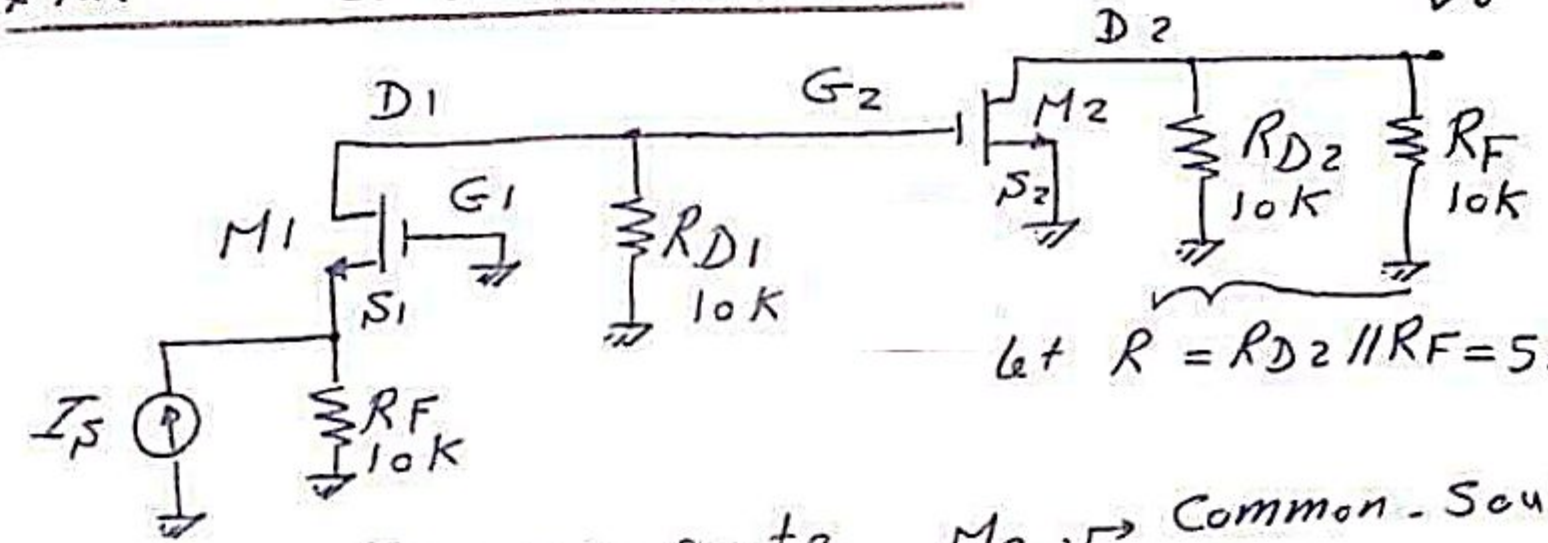


$I_F = \frac{0 - V_o}{R_F} \rightarrow V_o = -I_F R_F$

$\therefore \boxed{\beta = \frac{I_F}{V_o} = -\frac{1}{R_F} = -0.1}$ mA/V

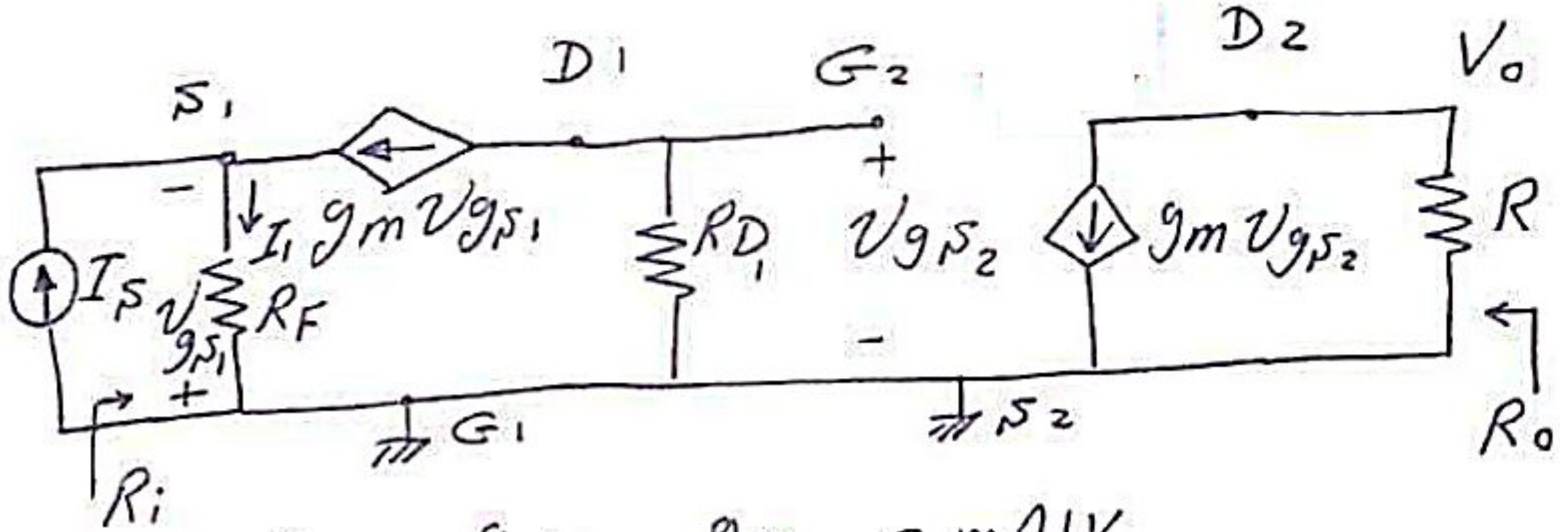
↳ Feedback Factor

* The total circuit without F.B



let $R = R_{D2} // R_F = 5k\Omega$

M1 ✓→ Common - gate , M2 ✓→ Common - Source



$$g_{m1} = g_{m2} = g_m = 2\,mA/V$$

* open-Loop gain (A)

$$A = \frac{V_o}{I_s} = \frac{V_o}{v_{gs2}} \times \frac{v_{gs2}}{v_{gs1}} \times \frac{v_{gs1}}{I_s} \rightarrow \boxed{1}$$

* $V_o = -g_m v_{gs2} . R$

$$\therefore \boxed{\frac{V_o}{v_{gs2}} = -g_m R = -2 \times 5 = -10} \quad (2)$$

* $v_{gs2} = -g_m v_{gs1} . R_{D1}$

$$\therefore \boxed{\frac{v_{gs2}}{v_{gs1}} = -g_m R_{D1} = -2 \times 10 = -20} \quad (3)$$

* **K.C.L** $\quad I_S + g_m V_{gs1} = I_1$

$$I_S + g_m V_{gs1} = -\frac{V_{gs1}}{R_F}$$

$$I_S = -V_{gs1}\left[g_m + \frac{1}{R_F}\right] \qquad (4)$$

$$\therefore \boxed{\frac{V_{gs1}}{I_S} = \frac{-1}{g_m + \frac{1}{R_F}} = \frac{-1}{2+0.1} = -\frac{10}{21}}$$

$$= -0.4762$$

sub. from (2), (3) and (4) into [1]

$$\therefore A = (-g_m R)(-g_m R_{D1})\left(\frac{-1}{g_m + \frac{1}{R_F}}\right)$$

$$A = (-10)(-20)\left(-\frac{10}{21}\right)$$

$$\boxed{A = -95.2381}$$ open-Loop gain

(b) The feedback gain $\mathbf{A_f}$.

$$A_F = \frac{A}{1+A\beta} = \frac{-95.2381}{1+(-95.2381)(-0.1)}$$

$$\boxed{A_F \cong -9.05}$$

(c) The feedback input and output resistances ($\mathbf{R_{if}}$ and $\mathbf{R_{of}}$).

$$* \; R_i = \frac{V_{in}}{I_{in}} = \frac{-V_{gs}}{I_s} \rightarrow \text{from (4)}$$

$$\boxed{R_i = -\frac{V_{gs}}{I_s} = \frac{1}{g_m + \frac{1}{R_F}} = \frac{1}{g_m} \parallel R_F = \frac{10}{21}\, k\Omega}$$

$$* \; R_{iF} = \frac{R_i}{1+A\beta} = \frac{10/21}{10.52381}$$

$$\boxed{R_{iF} = 0.04525\, k\Omega = 45.25\,\Omega}$$

$$* \; R_o = \frac{V_x}{I_x}\Big|_{I_s=0} \rightarrow \text{As } I_s = 0 \rightarrow V_{gs_1} = 0$$

$$\therefore g_m V_{gs_1} = 0 \rightarrow V_{gs_2} = 0 \;\therefore g_m V_{gs_2} = 0$$

$$\boxed{R_o = R = 5\, k\Omega}$$

$$* \; R_{oF} = \frac{R_o}{1+A\beta} = \frac{5}{10.52381}$$

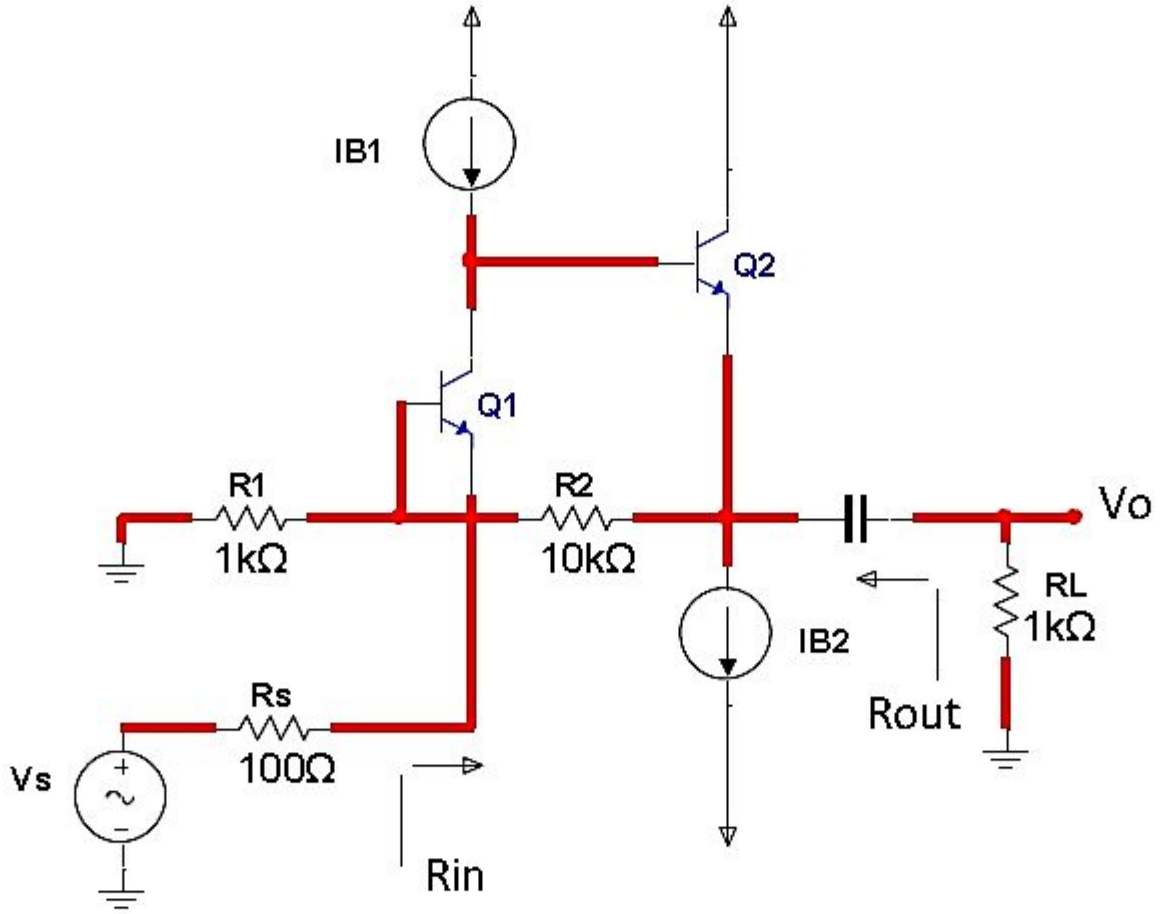
$$\boxed{\begin{aligned} R_{oF} &= 0.475\, k\Omega \\ &= 475\,\Omega \end{aligned}} \; \#$$

Example (Series-Shunt Feedback)

Analyze the Series-Shunt feedback amplifier circuit shown in Figure.

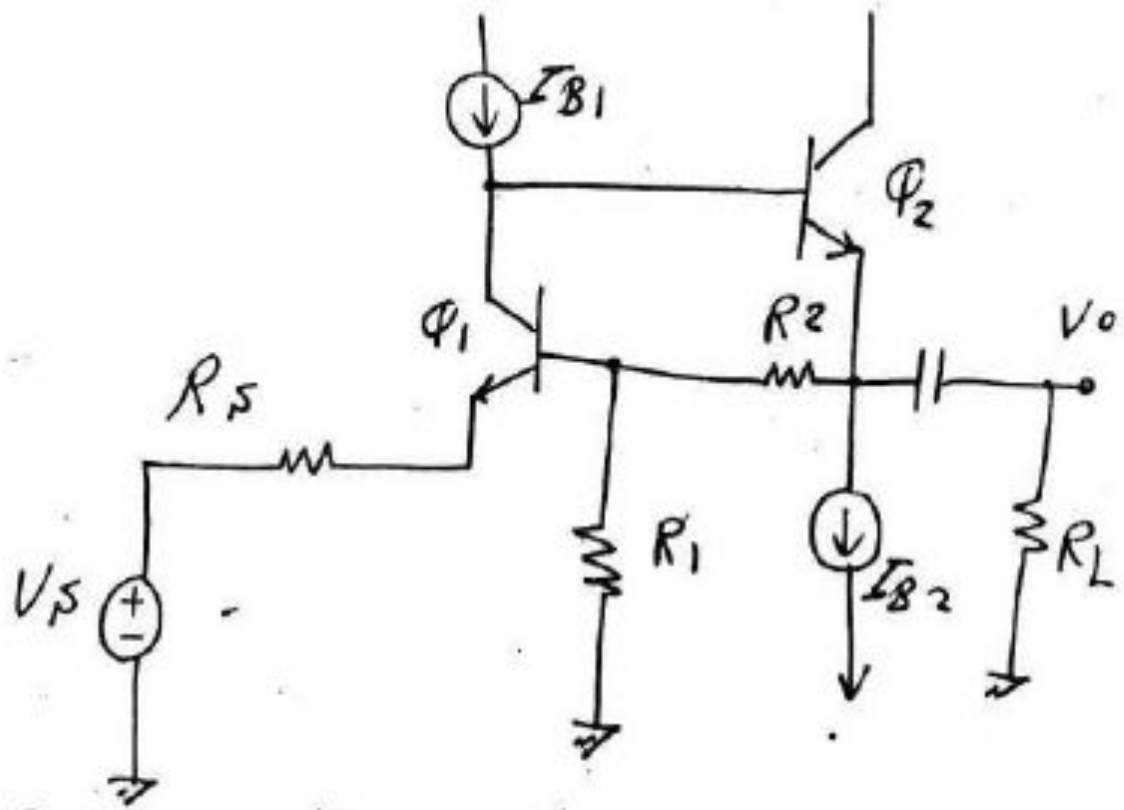
Assuming $\beta_1 = \beta_2 = 100$, $r_{e1} = 260\ \Omega$, $r_{e2} = 26\ \Omega$ and r_o is neglected.

1. Calculate the open loop gain A, the feedback factor β and the feedback gain A_f.
2. Calculate R_{if}, R_{in}, R_{of} and R_{out}.



Solution:

we can Redraw the Circuit as follow

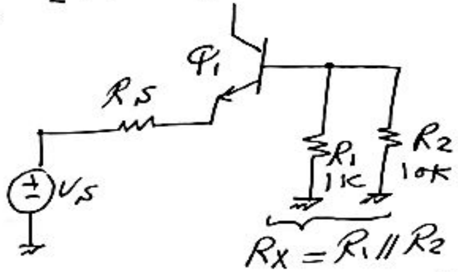


I/P — O/P

series — shunt $\rightarrow A = \frac{V_o}{V_{in}}, \beta = \frac{V_f}{V_o}$

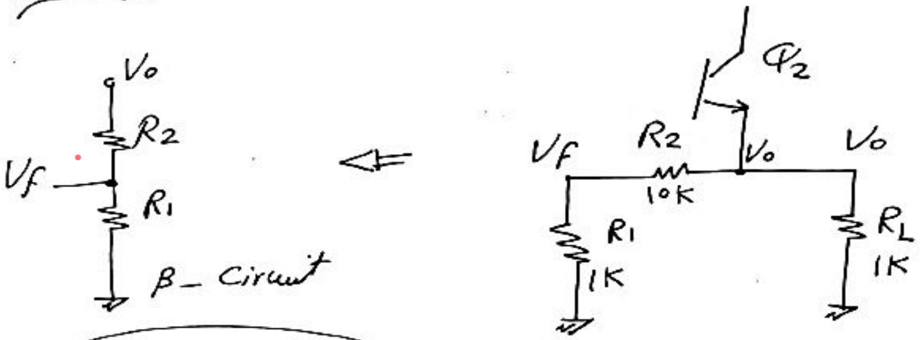
V — V

I/P Circuit without F.b [$V_o = 0$]



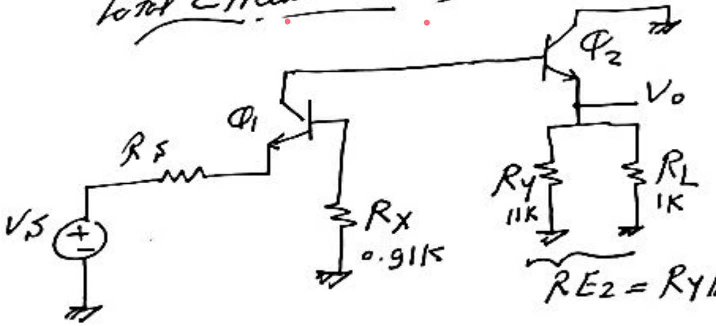
$R_X = R_1 // R_2 = 0.909 K\Omega$

O/P Circuit without F.B [I/P open]



$$\beta = \frac{V_f}{V_o} = \frac{R_1}{R_1 + R_2} \Rightarrow \beta = \frac{1}{11} = 0.0909$$

Total Circuit without F.B

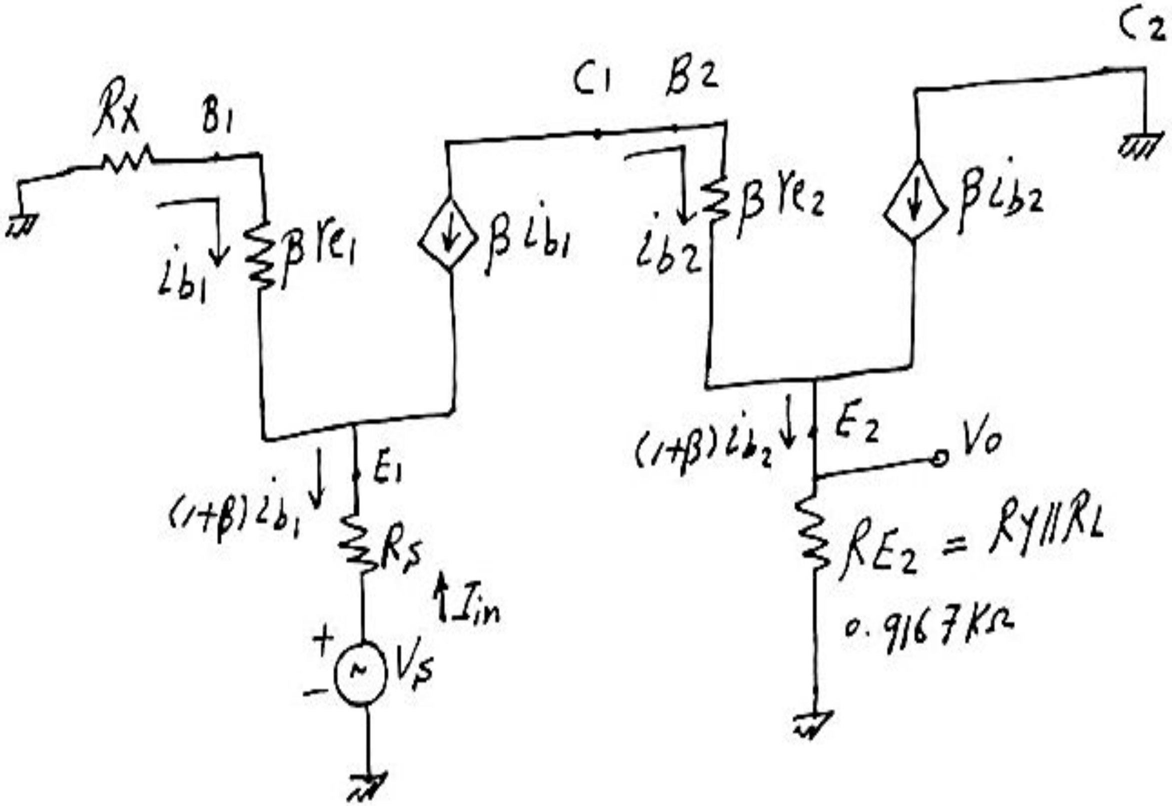


$R_{E2} = R_Y // R_L = 0.9167 K\Omega$

$R_Y = R_1 + R_2 = 11 k\Omega$

$$* \ r_{e1} \cong \frac{0.026}{I_{C1}} = \frac{0.026V}{0.1 mA} = 0.26 K\Omega = 260\Omega$$

$$* \ r_{e2} \cong \frac{0.026}{I_{C2}} = \frac{0.026V}{1 mA} = 0.026 K\Omega = 26\Omega$$



$$* \ \boxed{\beta = \frac{V_f}{V_o} = \frac{1}{11} = 0.0909}$$

$$* \; A = \frac{V_o}{V_s} = \frac{V_o}{i_{b2}} \times \frac{i_{b2}}{i_{b1}} \times \frac{i_{b1}}{V_s}$$

$$* \; V_o = (1+\beta)\, i_{b2} \cdot R_{E2}$$

$$\therefore \boxed{\frac{V_o}{i_{b2}} = (1+\beta) R_{E2}} = 101 \times 0.9167 = 92.583 \text{ K}$$

$$* \; i_{b2} = -\beta\, i_{b1}$$

$$\therefore \boxed{\frac{i_{b2}}{i_{b1}} = -\beta = -100}$$

K.V.L at input Loop :-

$$0 = i_{b1}(R_X + \beta r_{e1}) + (1+\beta) i_{b1} R_S + V_S$$

$$\therefore V_S = -i_{b1}[R_X + \beta r_{e1} + (1+\beta) R_S]$$

$$\therefore \boxed{\frac{i_{b1}}{V_S} = \frac{-1}{R_X + \beta r_{e1} + (1+\beta) R_S}} \quad \text{I}$$

$$\frac{i_{b1}}{V_S} = \frac{-1}{0.909 + 100 \times 0.26 + 101 \times 0.1} = -0.02702$$

$$\therefore A = \frac{V_o}{V_S} = 92.583 \times -100 \times -0.02702$$

$$A = \frac{V_o}{V_S} = 250.16 \quad , \quad \beta = 0.0909$$

$$* \; A_f = \frac{A}{1+A\beta} = \frac{250.16}{1 + 250.16 \times 0.0909} = 10.5377$$

$$* \; R_i = \frac{V_S}{I_{in}} = \frac{V_S}{-(1+\beta) i_{b1}} = -\frac{1}{1+\beta}\left(\frac{V_S}{i_{b1}}\right)$$

From I $\quad V_S = -i_{b1}[R_X + \beta r_{e1} + (1+\beta) R_S]$

$$\frac{V_S}{i_{b1}} = -[R_X + \beta r_{e1} + (1+\beta) R_S]$$

$$\therefore \boxed{R_i = \frac{R_X + \beta r_{e1} + (1+\beta) R_S}{1+\beta}}$$

$$R_i = \frac{0.909 + 100 \times 0.26 + 101 \times 0.1}{101}$$

$$\boxed{R_i = 0.36643\,K\Omega} = 366.43\,\Omega$$

$$* \; R_{if} = R_i(1 + A\beta) = 366.43\,\Omega\,(1 + 250.16 \times 0.0909)$$

$$R_{if} = 8.699\,K\Omega \cong 8.7\,K\Omega$$

$$* \; R_{in} = R_{if} - R_S = 8.599\,K\Omega$$

Series

$* \; R_o = \frac{V_X}{I_x}\Big|_{V_S=0}$, As $V_S=0 \rightarrow i_{b1}=0 \rightarrow i_{b2}=0$

$$\boxed{R_o = R_{E2} = R_Y \parallel R_L = 0.9167\,K\Omega}$$

$$* \; R_{of} = \frac{R_o}{1+A\beta} = \frac{0.9167}{1+250.16 \times 0.0909} = 0.0386\,K\Omega$$

$$\boxed{R_{of} = 38.6\,\Omega}$$

$$* \; R_{out} = \frac{1}{\frac{1}{R_{of}} - \frac{1}{R_L}} = \frac{1}{\frac{1}{38.6} - \frac{1}{100}}$$

$$\boxed{R_{out} = 62.866\,\Omega}$$