

$$I_{C1} = I_{C2}$$

$$I_{C1}$$

$$V_{nm} = R$$

$$R_2 I_{C2} + \cancel{I_{C1}} = R_1 I_{C1} + \cancel{I_{C2}}$$

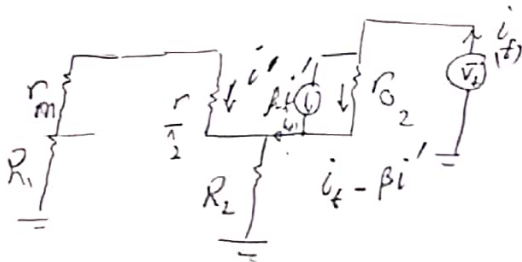
$$I_{ref} = I_{B1} + I_{B2} + I_{C1}$$

$$\rightarrow \frac{I_{C1}}{I_{C2}} = \frac{R_2}{R_1}$$

$$\rightarrow I_{ref} = I_{C1} \left(1 + \frac{1}{\beta} \right) + \frac{I_{C2}}{\beta} = I_{C1} \left(1 + \frac{1}{\beta} + \frac{1}{\beta} \times \left(\frac{R_1}{R_2} \right) \right)$$

$$I_0 = I_{C2} \times \frac{R_1}{R_2} \times \frac{I_{ref}}{1 + \frac{1}{\beta} \left(1 + \frac{R_1}{R_2} \right)}$$

$$V_{nm} = R_2 I_0 \times 2 \rightarrow V_{nm} \approx 2 + \frac{R_1 I_{ref}}{H \frac{1}{\beta} \left(1 + \frac{R_1}{R_2} \right)}$$



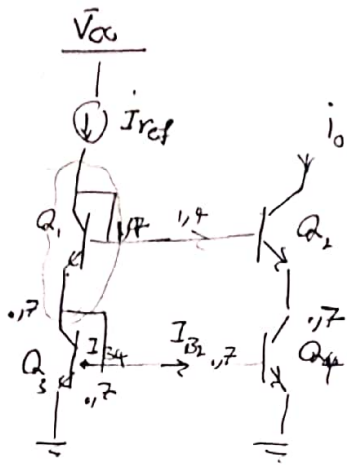
$$\begin{cases} -i'(R_1 + r_m + r_{\pi 2}) - R_2(i' + i_{t+}) = 0 \\ v_{t+} = r_{o2}(i_t - \beta i') - R_1(i' + i_{t+}) = 0 \end{cases}$$

$$i'(R_1 + R_2 + r_m + r_{\pi 2}) = -R_2 i_{t+}$$

$$v_{t+} = r_{o2} i_{t+} - R_2 i_{t+} - (r_{o2} \beta + R_2) i' = 0$$

$$v_{t+} = i_{t+} (r_{o2} + R_2) - \frac{R_2 (\widehat{r_{o2} \beta} + R_2)}{R_1 + R_2 + r_m + r_{\pi 2}}$$

$$R_{out} = \frac{v_{t+}}{i_{t+}} = r_{o2} \left(1 + \frac{\beta R_2}{r_{\pi 2} + R_2 + R_1 + \frac{r_m}{\beta}} \right)$$



$$I_{ref} = I_E + I_{B_2} + I_{B_3}$$

$$i_{out} = \frac{\beta I_C}{\beta + 1}$$

$$I_{C_3} = I_{C_4}$$

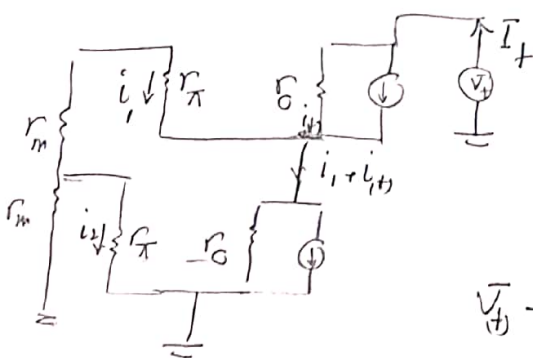
$$I_{ref} = I_{B_2} + I_{C_3} + I_{B_4} + I_{B_5}$$

$$I_{ref} = I_{B_2} + \frac{2 I_{C_4}}{\beta} + I_{C_4}$$

$$I_{ref} = \frac{I_0}{\beta} + \frac{2}{\beta} \left(\frac{1+\beta}{\beta} \right) I_0 + \frac{\beta+1}{\beta} I_0 = \frac{I_0}{\beta^2} (4\beta + \beta^2 + 2)$$

$$\rightarrow I_0 = \frac{I_{ref}}{1 + \frac{4}{\beta} + \frac{2}{\beta^2}}$$

$$\bar{V}_{min} - \bar{V}_{Beon} = 0.2 \rightarrow \bar{V}_{min} = \bar{V}_{CE_{sat}} + \bar{V}_{Be_{on}}$$



$$-r_m(i_1 + i_2) - r_{\pi} i_2 = 0 \rightarrow i_1 = -\frac{r_m + r_{\pi}}{r_m} i_2$$

$$+ r_m(i_1 + i_2) + (r_m + r_{\pi}) i_1 + (r_o(-i_1 + i_{th}) - \beta i_2) = 0$$

$$\bar{V}_{th} - r_o(i_{th} - \beta i_1) - r_o(i_1 + i_{th} - \beta i_2) = 0$$

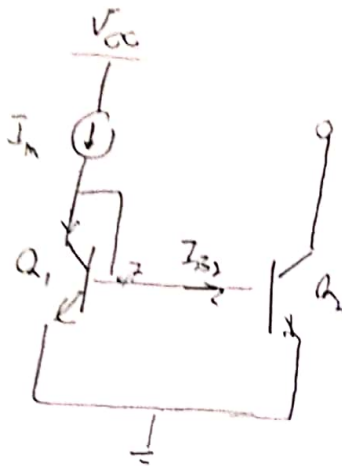
$$\bar{V}_{th} - r_o(i_{th}) + r_o \beta i_1 + r_m(i_1 + i_2) + (r_m + r_{\pi}) i_1$$

$$r_m \left(-\frac{r_{\pi}}{r_m} \right) i_2 + \left(\frac{r_m + r_{\pi}}{r_m} \right) i_1 + \left(\frac{\beta}{2} + 1 \right) r_o i_{th}$$

$$\rightarrow \frac{\bar{V}_t}{i_{th}} = \left(\frac{\beta}{2} + 1 \right) r_o \approx \frac{\beta r_o}{2} \left| R_{out} \right|$$

$$\bar{I}_C = \bar{I}_S \left(e^{\frac{\bar{V}_{BE}}{\bar{V}_T}} + 1 \right) \left(1 + \frac{\bar{V}_{CE}}{\bar{V}_A} \right)$$

مسئله ۱۲



$$I_n = I_{C1} + I_{B1} + I_{B2}$$

$$I_{C1} = \bar{I}_S \left(e^{\frac{\bar{V}_{BE}}{\bar{V}_T}} + 1 \right)$$

$$\frac{I_{C1}}{1 + \frac{\bar{V}_{CE1}}{\bar{V}_A}} = \frac{I_{C2}}{1 + \frac{\bar{V}_{CE2}}{\bar{V}_A}}$$

$$\left\{ \begin{array}{l} \bar{V}_A \rightarrow \infty \\ \bar{I}_n = \bar{I}_0 + \frac{\bar{I}_0}{\beta} \\ \rightarrow \bar{I}_0 = \frac{\bar{I}_n}{1 + \frac{1}{\beta}} \end{array} \right.$$

$$\bar{I}_0 = \frac{I_{C1}}{1 + \frac{\bar{V}_{BEon}}{\bar{V}_0}} \left(1 + \frac{\bar{V}_{CE2}}{\bar{V}_A} \right) \approx I_{C1} \left(1 - \frac{\bar{V}_{BEon}}{\bar{V}_A} \right) \left(1 + \frac{\bar{V}_{CE2}}{\bar{V}_A} \right)$$

$$I_{C1} = \bar{I}_0 \left(1 + \frac{\bar{V}_{BEon}}{\bar{V}_0} \right) \left(1 - \frac{\bar{V}_{CE2}}{\bar{V}_A} \right)$$

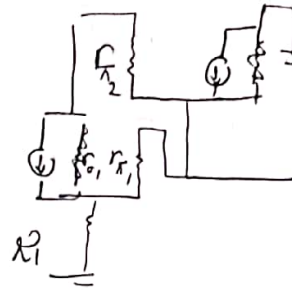
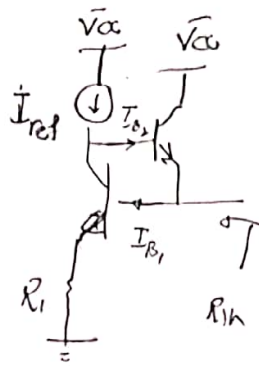
$$\rightarrow I_n = I_{C1} + \frac{I_{C1}}{\beta} + \frac{I_0}{\beta} = \bar{I}_0 \left[\left(1 + \frac{\bar{V}_{BEon}}{\bar{V}_A} \right) \left(1 - \frac{\bar{V}_{CE2}}{\bar{V}_A} \right) + \frac{1}{\beta} \left(1 + \frac{\bar{V}_{BEon}}{\bar{V}_A} \right) \left(1 - \frac{\bar{V}_{CE2}}{\bar{V}_A} \right) + \frac{1}{\beta} \right]$$

$$\rightarrow \bar{I}_0 = \frac{I_n}{1 + \frac{\bar{V}_{BEon} - \bar{V}_{CE2}}{\bar{V}_A} + \frac{1}{\beta} \left(2 + \frac{\bar{V}_{BEon} - \bar{V}_{CE2}}{\bar{V}_A} \right)}$$

$$\frac{I_n}{1 + \frac{2}{\beta} + \frac{\bar{V}_{BEon} - \bar{V}_{CE2}}{\bar{V}_A} + \frac{1}{\beta} \times \frac{\bar{V}_{BEon} - \bar{V}_{CE2}}{\bar{V}_A}}$$

$$\frac{I_n}{1 + \frac{2}{\beta} + \frac{\bar{V}_{BEon} - \bar{V}_{CE2}}{\bar{V}_A}}$$

11)



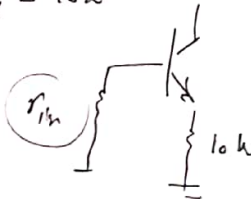
→ $- \beta i'$

$i_i + (\beta + 1)i' = i'$

$i_{i(t)} = i' (\beta(\beta + 1) + 1)$ $v_{i(t)} = r_{\pi} i' - (\beta + 1)i' R_E = 0$

→ $r_{in} = \frac{r_{\pi} + (\beta + 1)R_E}{\beta(\beta + 1) + 1}$

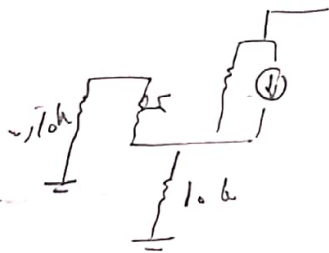
$\begin{cases} r_{\pi} = 25k\Omega \\ R_E = 10k\Omega \end{cases}$ $22 + \frac{\beta}{\beta + 1}$



$r_{in} = \frac{25 + 101 \times 10}{100(101) + 1} = 0.1025k$

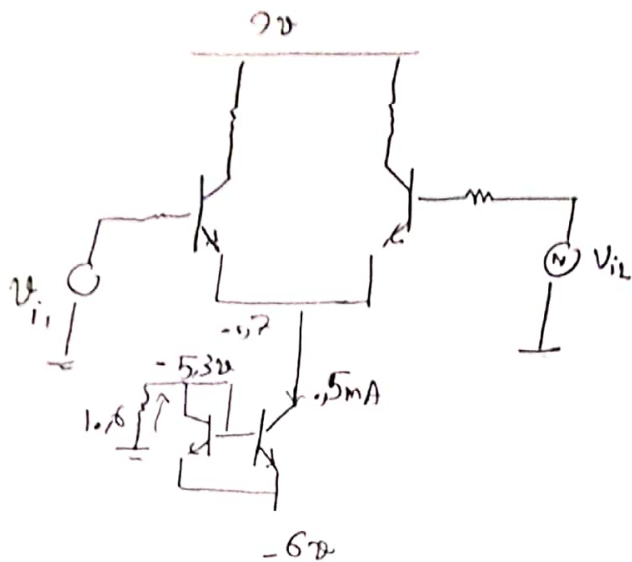
$\frac{50}{0.1} = 500$

$r_o (1 + \frac{\beta}{\beta + 1} \times (25 + 101 \times 10k)) = 14.8M\Omega$



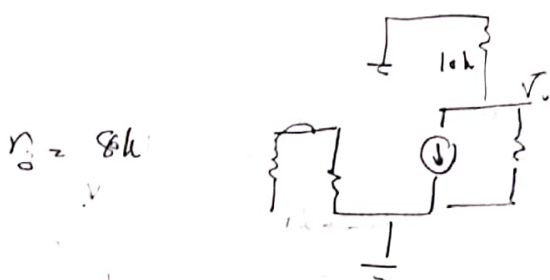
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(أ)



$$Q_1, Q_2 \begin{cases} I_C = 0.25 \text{ mA} \\ \bar{V}_{CE} = 9 - 10 \times 0.25 - 0.7 = 7.2 \text{ V} \end{cases}$$

$$Q_3, Q_4 \begin{cases} I_C = 0.5 \text{ mA} \\ \bar{V}_{CE3} = 0.7 \text{ V} \\ \bar{V}_{CE4} = 5.3 \text{ V} \end{cases}$$



$$r_o = 8 \text{ k}\Omega$$

$$A = \frac{1}{2} \times \frac{\frac{9}{10.118 \text{ mS}}}{\frac{21}{200}} = 42.33$$

$$R_{in} = 2(20 + 1) = 42 \text{ k}\Omega$$

$$R_1 = 40 \text{ k}\Omega \quad (2)$$

$$A = \frac{1}{2} \times \frac{10}{40 \text{ k}\Omega + \frac{21}{200}} = 0.124$$

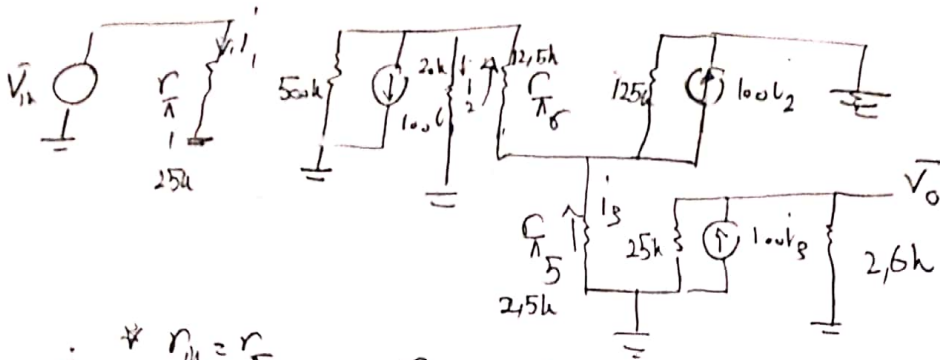
$$50 = \frac{2}{20 \times 10^{-3}} + 0.7 =$$

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$$Q_1, Q_2 \begin{cases} I_C = 0.1 \text{ mA} \quad r_o = 25 \text{ k}\Omega \\ \bar{V}_{CE} = 3.7 \text{ V} \quad r_o = 500 \text{ k}\Omega \end{cases}$$

$$Q_3, Q_4 \begin{cases} I_C = 0.2 \text{ mA} \quad r_o = 125 \text{ k}\Omega \\ \bar{V}_{CE} = -8.7 \text{ V} \quad r_o = 125 \text{ k}\Omega \end{cases} \quad Q_5, Q_6 \begin{cases} I_C = 1 \text{ mA} \quad r_o = 25 \text{ k}\Omega \\ \bar{V}_{CE} = 6.8 \text{ V} \quad r_o = 25 \text{ k}\Omega \end{cases}$$

(ب)



$$* r_{th} = r_{\pi_1} \rightarrow r_{th} = 2 r_{\pi_1} = \frac{50k\Omega}{2} = 25k\Omega$$

$$i_1 = \frac{V_{th}}{25k}$$

$$i_3 = i_2 + 100i_2 + \frac{2,5}{125} i_3$$

$$i_3 \approx -99 i_2$$

$$(i_2 = 100i_1) \times (120 \parallel 500) = -2,5(99i_2) - 12,5i_2$$

$$279,23 i_2 = 83$$

$$\rightarrow i_2 = 6,887 \mu A$$

$$i_3 = -99 i_2 = -682,7 \mu A$$

$$A_V = \frac{6,887 \mu A}{25k} \times (25 \parallel 2,6) \times 99 \times 100 = 6422,9$$

$$\bar{V}_{C_5} = -2,4 V$$

$$\bar{V} = -(2,6k \parallel 25) \times 1mA = -2,36 V$$

$$-6,87 V < \bar{V} < -2,36 V$$

$$\rightarrow \bar{V}_{R_P} = -2,36 \times 4 = 9,4 V$$

$$-1,7 V$$

$$-V_{C_n} + 3,7 V$$

$$\bar{V} = -1,7 V = -5,1 V$$

$$\bar{V} = 4 V$$

$$\rightarrow -4 V < \bar{V}_{C_n} < 3,5 V$$

$$-2 - 0,7 \quad (-8 + I_{re}) + 0,6 + 0,6 - 8 = -I_{ref}(24,6)$$

$$\rightarrow I_{ref} \approx 0,5 \text{ mA}$$

$$\frac{2,5 \text{ V}}{25} = 0,1$$

	1	2	3	4	5	6	7	8	9	10
$J_{E^{(n)}}$	0,2	0,2	0,1	0,1	0,5	0,1	0,2	0,2	0,1	0,5
$V_{CE^{(n)}}$	5,2	5,2	8,6	8,6	1,2	4,9	4,3	4,3	4,9	12,9

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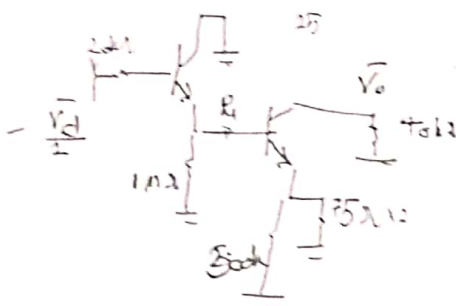
$$8 - (-0,6 + V) > 0,2$$

$$8,4 > V$$

$$-4,7 < V_{in} < 8,4 \text{ cmR}$$

(1)

(2)



$$r_{o1} = \frac{100}{0,1} = 1 \text{ M}\Omega$$

$$r_{o2} = 500 \text{ k}\Omega$$

$$R = 125 \text{ k}\Omega + 101 \left(\frac{500 \text{ k}\Omega \parallel 750 \text{ k}\Omega}{100} \right) \approx 20 \text{ k}\Omega$$

$$CC = \frac{+ \frac{19,6 \text{ k}\Omega \parallel 100 \text{ k}\Omega}{100}}{19,6 \text{ k}\Omega \parallel 100 \text{ k}\Omega + \frac{20 \text{ k}\Omega + 25 \text{ k}\Omega}{100}} = 0,978$$

$$CE = - \frac{40 \text{ k}\Omega}{75 \text{ k}\Omega + \frac{12,5}{100}} = -200$$

$$\rightarrow \frac{V_o}{V_{in}} = +195,6 \rightarrow A_V = 97,8$$

$$\rightarrow R_1 = 27,7 \text{ k}\Omega$$

$$CMRR = 20 \log \left(\frac{97,8}{2,1 \times 10^{-3}} \right) \approx 93$$

$$\frac{26,9}{26,9 + \frac{45}{1,1}} \times - \frac{40 \text{ k}\Omega}{500 \text{ k}\Omega + \frac{12,5}{100}} = -2,1 \times 10^{-3}$$

(د) Q_1 ید ساخار β h_{fe} سکه در انفری اکر می کند حقت بن تأثیر می اندازد

(ه) I_{C3} و I_{C4} بسیار کمی شوند بهر به کور کلمی نمی اند

