

31. A two stage circuit is shown in Figure 9. It's BJT parameters are $\beta_1 = \beta_2 = 100$, [10] $V_{BE1} = V_{EB2} = 0.7V$.

- Determine all node voltages and terminal currents under DC analysis
- Determine overall voltage gain of the circuit

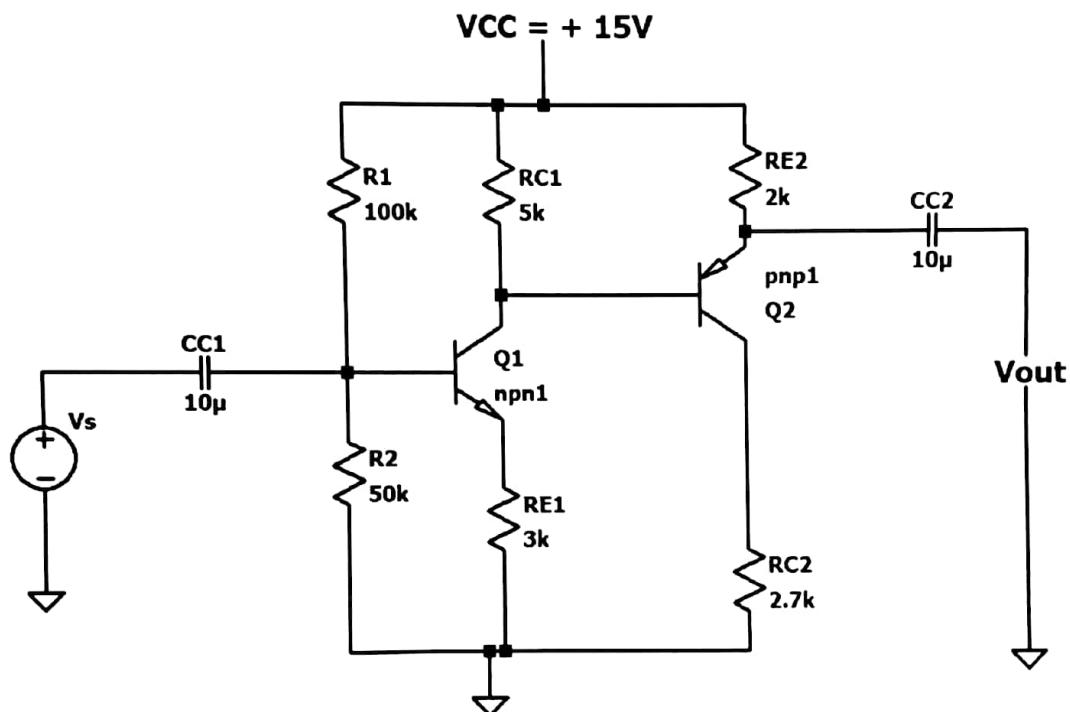


Figure 9: Question 31

Answers:

Node currents: $I_{B1} = 12.785\mu A$ $I_{C1} = 1.2785mA$ $I_{E1} = 1.29mA$ $I_{B2} = 27.47\mu A$

$I_{C2} = 2.743mA$ $I_{E2} = 2.775mA$

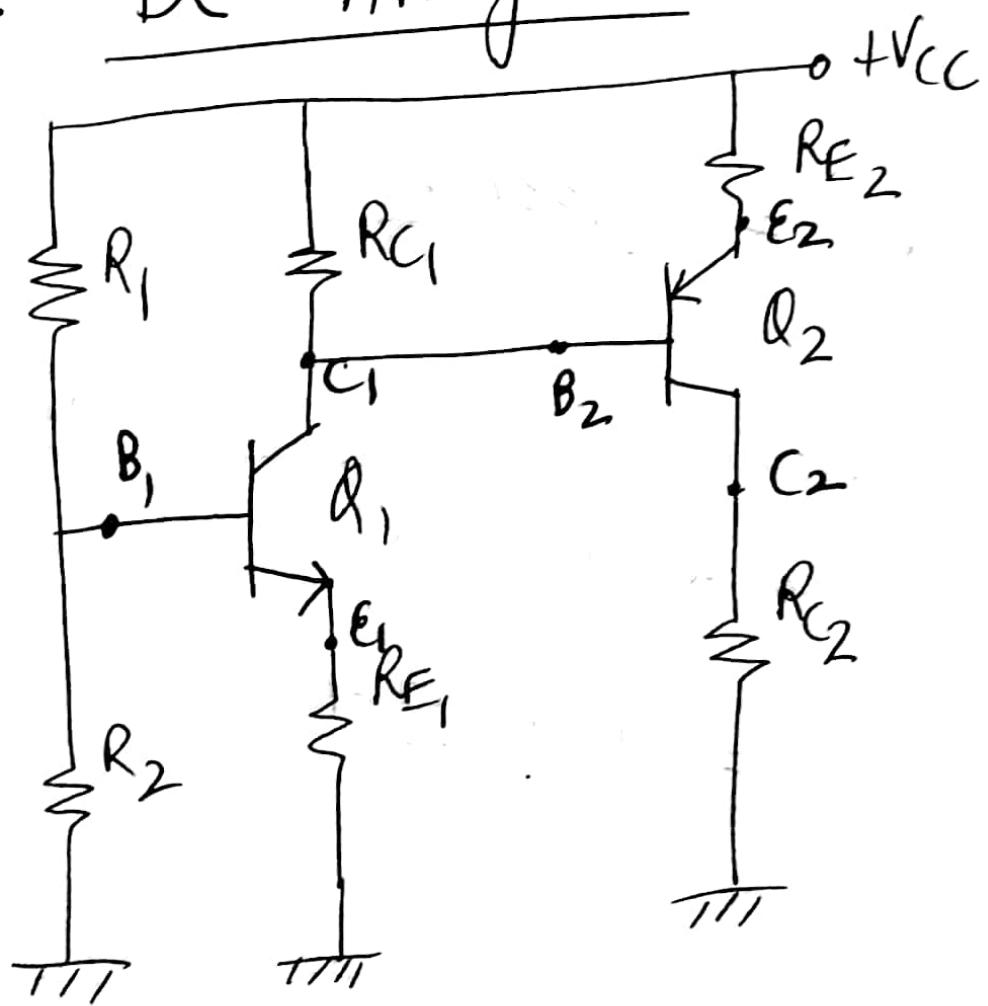
Node voltages: $V_{B1} = 4.573V$ $V_{C1} = V_{B2} = 8.75V$ $V_{E2} = 9.45V$ $V_{C2} = 7.4V$

$V_{E1} = 3.873V$

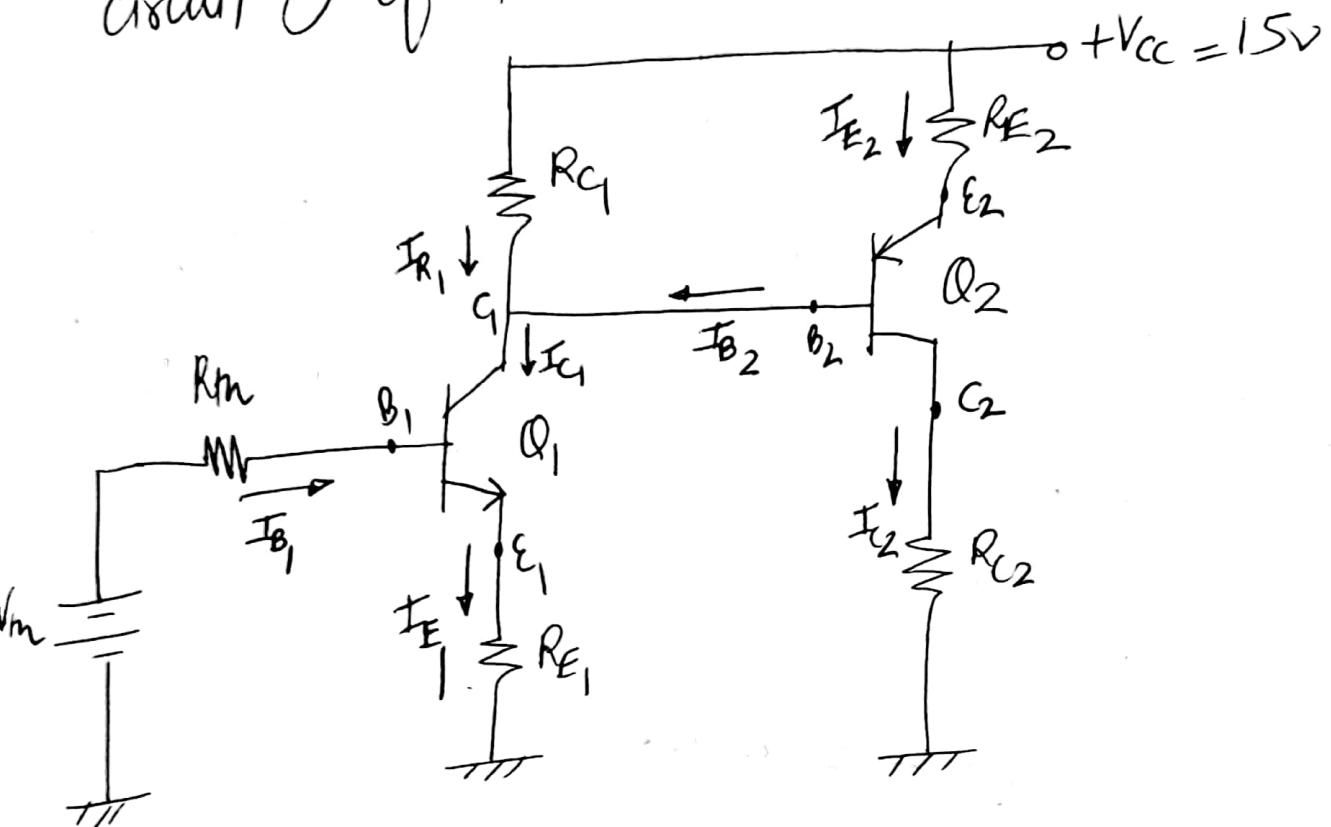
Small signal parameters: $r_{\pi 1} = 2.033k\Omega$ $r_{\pi 2} = 947.867\Omega$

Voltage gain: $A_{V1} = -1.639$ $A_{V2} = 0.985$ $A_{VT} = -1.614$

Sol:- DC Analysis:-



Considering the Thévenin's equivalent of base circuit of transistor Q₁.



$$V_{th} = \frac{R_2}{R_1 + R_2} \times V_{cc} = \frac{50K}{50K + 100K} \times 15 = 5V$$

$$R_{th} = R_1 \parallel R_2 = 100K \parallel 50K = 33.33K\Omega$$

$$I_{B1} = \frac{V_m - V_{BE1}}{R_{th} + (1 + \beta_1)R_{E1}} = \frac{5 - 0.7}{33.33K + 101 \times 3K} = 12.785\mu A$$

$$I_C1 = \beta_1 I_{B1} = 100 \times 12.785\mu A = 1.2785mA$$

$$I_{E1} = I_C1 + I_{B1} = 1.2785mA + 12.785\mu A = 1.291mA$$

$$V_{C_1} = V_{CC} - I_{C_1} R_{C_1} \quad \text{(ignoring } I_{B_2} \text{ & } I_{R_C} \approx I_{C_1})^{\text{Q3}}$$

$$V_{C_1} = 15 - 1.2785 \times 10^{-3} \times 5 \text{ k}\Omega = \underline{8.607 \text{ V}}$$

$$\rightarrow V_{C_1} = V_{E_2} = V_{B_2} + V_{EB_2(\text{on})} ; \boxed{V_{C_1} = V_{B_2}}$$

$$V_{E_2} = V_{C_1} + V_{EB_2(\text{on})}$$

$$V_{E_2} = 8.607 + 0.7 = \underline{9.307 \text{ V}}$$

$$\rightarrow I_{E_2} = \frac{V_{CC} - V_{E_2}}{R_{E_2}} = \frac{15 - 9.307}{2k} = \underline{2.8465 \text{ mA}}$$

$$\rightarrow I_{C_2} \approx \frac{\beta_2}{1 + \beta_2} I_{E_2} = \frac{100}{101} \times 2.8465 \text{ mA} = \underline{2.818 \text{ mA}}$$

$$\rightarrow I_{B_2} = \frac{I_{E_2}}{1 + \beta_2} \approx \frac{2.8465 \text{ mA}}{101} = \underline{28.18 \mu\text{A}}$$

Now, rewriting exact expression for eqn ①,

$$V_{C_1} = V_{CC} - I_{R_{C_1}} R_{C_1}$$

$$\rightarrow I_{R_{C_1}} = I_{C_1} - I_{B_2} \\ = 1.2785 \text{ mA} - 28.18 \mu\text{A} = \underline{1.25 \text{ mA}}$$

$$\text{i.e } V_{C_1} = 15 - 1.25 \text{ mA} \times 5 \text{ k}\Omega = \underline{8.75 \text{ V}}$$

$$\rightarrow V_{E_2\text{new}} = V_{C_1\text{new}} + V_{EB_2(0V)}$$

$$V_{E_2\text{new}} = 8.75 + 0.7 = \underline{9.45V}$$

$$\rightarrow I_{E_2\text{new}} = \frac{V_{CC} - V_{E_2\text{new}}}{R_{E_2}} = \frac{15 - 9.45}{2K\Omega} = \underline{2.775mA}$$

$$\rightarrow I_{C_2\text{new}} = \frac{\beta_2}{1+\beta_2} I_{E_2\text{new}} = \frac{100}{101} \times 2.775mA = \underline{2.743mA}$$

$$\rightarrow I_{B_2\text{new}} = \frac{I_{E_2\text{new}}}{1+\beta_2} = \frac{2.775mA}{101} = \underline{27.47\mu A}$$

$$\rightarrow V_{E_1} = I_{E_1} R_{E_1} = 1.291mA \times 3K = \underline{3.873V}$$

$$\rightarrow V_{C_2} = I_{C_2} R_{C_2} = 2.743mA \times 2.7K = \underline{7.406V}$$

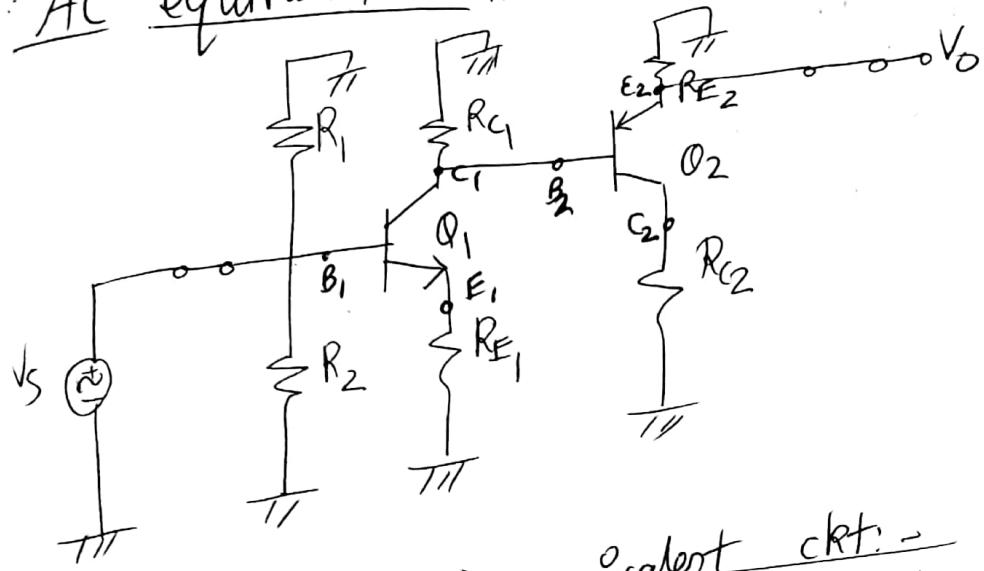
$$\rightarrow V_{B_1} = V_{BE(0V)} + V_{E_1} = \underline{4.573V}$$

Node voltages:- $V_{B_1} = 4.573V$, $V_{C_1} = 8.75V$, $V_{E_1} = 3.873V$
 $V_{C_2} = 7.406V$, $V_{E_2} = 9.45V$, $V_{B_2} = V_{C_1} = 8.75V$

Terminal currents:- $I_{B_1} = 12.785\mu A$; $I_{C_1} = 1.2785mA$; $I_E = 1.291mA$

$I_{B_2} = 27.47\mu A$, $I_{C_2} = 2.743mA$, $I_{E_2} = 2.775mA$

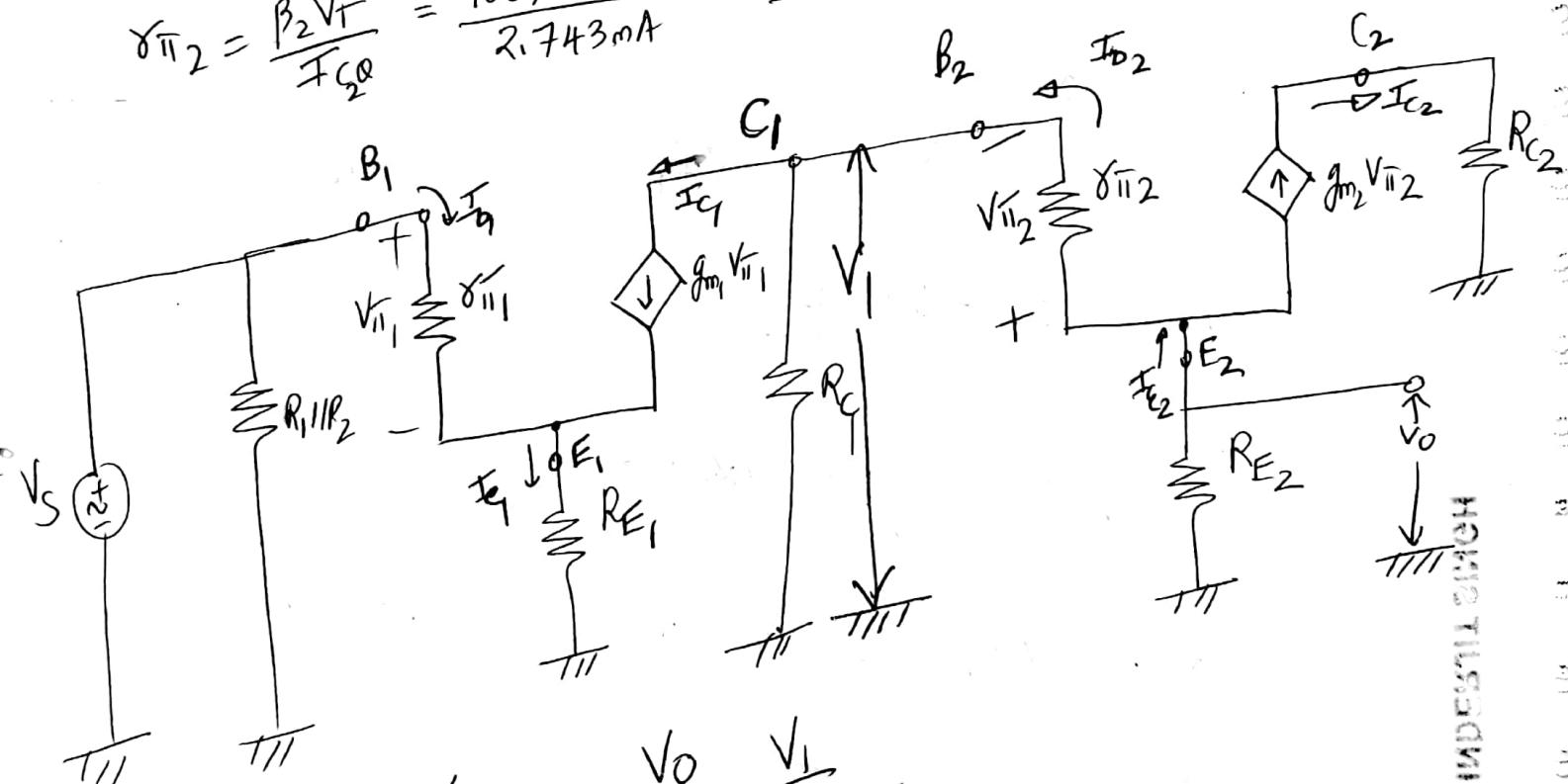
AC equivalent ckt:-



AC (mid-frequency) equivalent ckt:-

$$\text{Small-sig parameters: } \gamma_{II1} = \frac{B_1 V_T}{I_C Q_1} = \frac{100 \times 26 \text{mV}}{1.2785 \text{mA}} = 2.033 \text{K}\Omega$$

$$\gamma_{II2} = \frac{B_2 V_T}{I_C Q_2} = \frac{100 \times 26 \text{mV}}{2.743 \text{mA}} = 947.867 \text{K}\Omega$$



$$A_{VT} = \frac{V_O}{V_S} = \frac{V_O}{V_I} \cdot \frac{V_I}{V_S}$$

$$A_{V2} \quad A_V$$

$$A_{V_2} = \frac{V_0}{V_1} = \frac{(g_m 2 V_{II2}) R_{E2}}{\beta_b [r_{II2} + (1+\beta_2) R_{E2}]} = \frac{(\beta_2 R_{E2}) R_{E2}}{\beta_b [r_{II2} + (1+\beta_2) R_{E2}]} \quad 06-2$$

$$= \frac{\beta_2 R_{E2}}{r_{II2} + (1+\beta_2) R_{E2}} = \frac{100 \times 2K}{947.867 + 101 \times 2K}$$

$$A_{V_2} \approx \underline{0.985}$$

$$\rightarrow A_{V_1} = \frac{V_1}{V_S} = \frac{-(g_m 1 V_{II1}) R_{C1}}{\beta_b [r_{II1} + (1+\beta_1) R_{E1}]} = \frac{-(\beta_1 R_{C1}) R_{C1}}{\beta_b [r_{II1} + (1+\beta_1) R_{E1}]} \quad 06-3$$

$$\approx \frac{-\beta_1 \times R_{C1}}{r_{II1} + (1+\beta_1) R_{E1}} \approx \frac{-100 \times 5K}{(2.033K + 101 \times 3K)}$$

$$A_{V_2} \approx -1.639$$

\rightarrow Overall voltage gain A_T :-

$$A_T = A_{V_1} A_{V_2} = 0.985 \times (-1.639)$$

$$A_T \approx -1.614$$