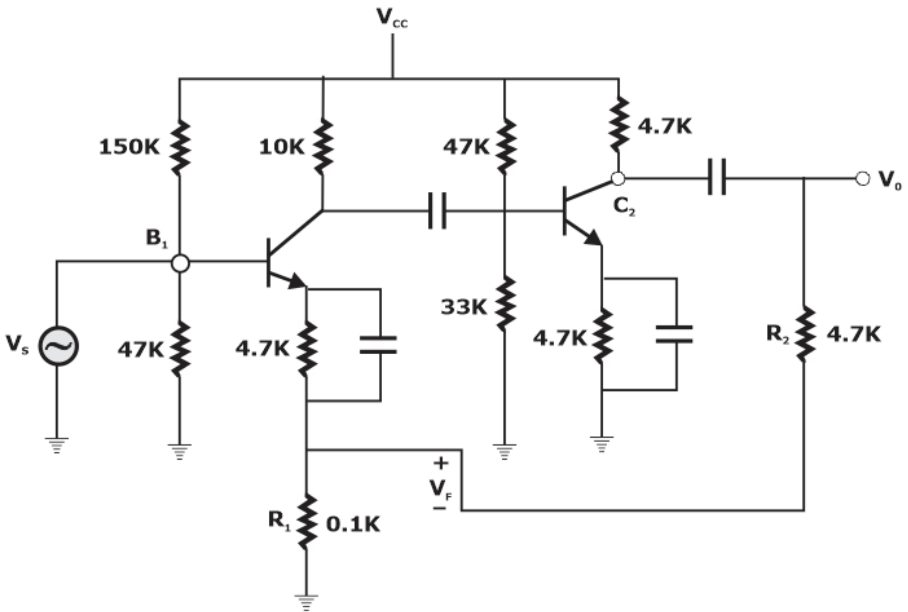
Classroom

ESE Mains
Achiever's Study Plan

Electronics & Communication Engineering

Analog Circuits Part-2

1. A two stage Feedback amplifier is shown below. Transistor parameters are h_{fe} = 50, h_{ie} = 1.1kΩ, h_{re} = h_{oe} = 0. Calculate A_{Vf}, R_{Of}, R_{if}.



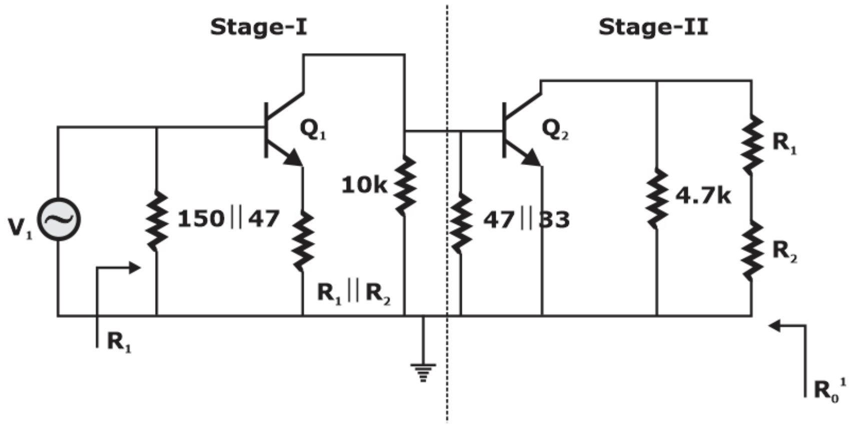
Sol. Step 1: R_1 & R_2 form voltage divider & they constitute Feedback network. This network creates voltages-series Feedback.

$$A = A_V = \frac{V_o}{V_s}$$

Step 2:

If output node G is grounded, then R_1 & R_2 appear in parallel in the input circuit.

If input loop is broken, then R_1 & R_2 appear in series in the output circuit.



Step 3: β = ?

V_o gets divides between R_1 & R_2.

Hence, $V_F = \frac{V_o R_1}{R_1 + R_2}$

$$\frac{V_F}{V_o} = \beta = \frac{R_1}{R_1 + R_2} = \frac{0.1}{0.1 + 4.7} = \frac{1}{48}$$

Step 4: If required then replace Transistor with appropriate small signal model.

Step 5: Calculate gain without Feedback, input & output impendences without feedback.

Q_2 CE amplifier with Bypass C

$$A_{V_2} = \frac{-h_{fe}R_L^1}{h_{ie}}$$

$$R_L^1 = 4.7 || 4.7 = 2.37K$$

$$= \frac{-50 \times 2.37}{1.1}$$

= - 107.7

$$R_{i2}^1 = 47 || 33 || h_{ie} = 47 || 33 || 1.1$$

= 1.05 K Ω

$$R_{L1}^1 = 10 || Ri_2^1 = 10 || 1.05$$

= 0.95 K Ω

Q_1: CE amplifier with un-bypassed resistance

$(R_1 || R_2) = R_E = 0.098K\ \Omega$

$$A_{V_1} = \frac{-h_{fe} / R_L^1}{h_{ie} + (1 + h_{fe})R_E}$$

$$= \frac{-50 \times 0.95}{1.1 + 51 \times 0.098}$$

= -7.78

$$\frac{V_o}{V_s} = A_V = A_{V_1} \times A_{V_2} = -7.78 \times (-107.7) = 838$$

$R_i = 150 || 47 || [h_{ie} + (1 + h_{fe}) R_E)$

= 150 || 47 || 6.09

= 5.21 K Ω

$Ro^1 = 4.7 || 4.8$

= 2.37 K Ω

Step 6: D = 1 + βA = ?

$$D = 1 + \beta A_v = 1 + \frac{1}{48} \times 838 = 18.46$$

Step 7:

$$D = 1 + \beta A_v = 1 + \frac{1}{48} \times 838 = 18.46$$

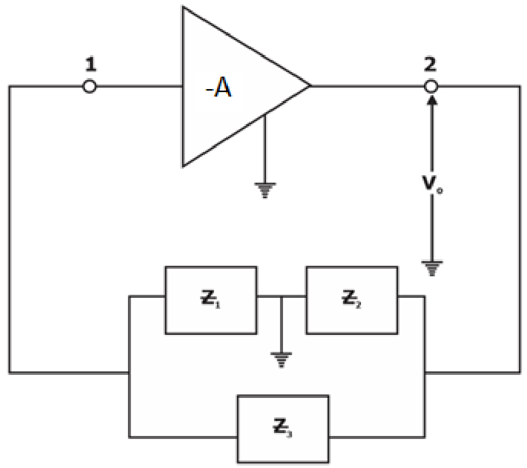
$$A_{VF} = \frac{A_v}{1 + \beta A_v} = \frac{838}{18.46} = 45.4$$

$R_{iF} = R_i \times D = 5.21 \times 18.46 = 96.17\ k\ \Omega$

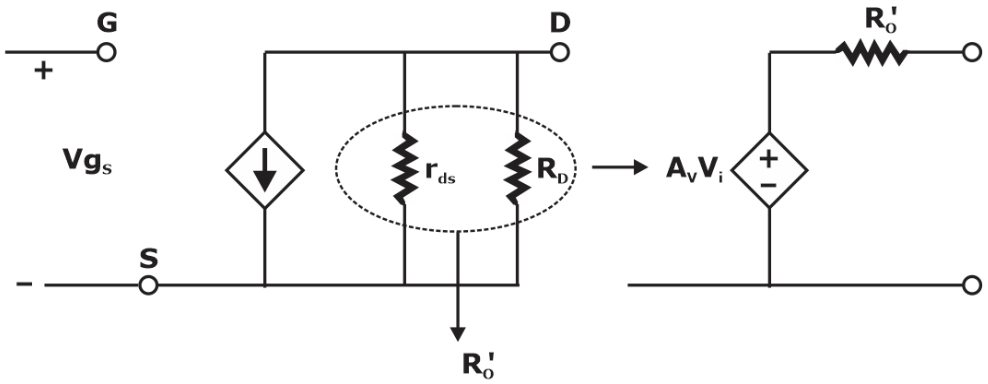
$$Ro^1F = \frac{Ro^1}{D} = \frac{2.37}{18.46} = 0.128 K\Omega$$

2. Derive the condition for LC oscillations in basic feedback amplifier.

Sol. Consider the basic amplifier having gain A and with the feedback network as shown below:

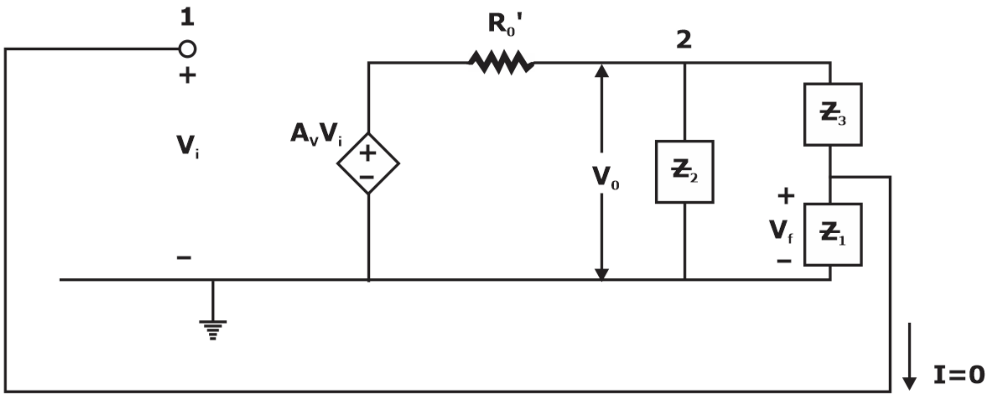


Consider it to be FET amplifier and has a small signal model as shown:



 # Analysis:-

LC oscillator can be redrawn by replacing the amp block with it's equivalent circuit.



If the effect of feedback network is considered, then net load for amplifier will be $Z_L \Rightarrow$

$$Z_L = Z_2 \,||\, (Z_1 + Z_3)$$

$$Z_L = \frac{Z_2 (Z_1 + Z_3)}{Z_1 + Z_2 + Z_3}$$

$A_v V_i$ gets divided into R_o^1 & Z_L

$$V_o = \frac{A_V . V_i Z_L}{R_o^1 + Z_L}$$

$$\frac{V_o}{V_i} = A = \frac{A_V . Z_L}{R_o^1 s + Z_L}$$

$$A = A_V . \frac{\dfrac{Z_2 (Z_1 + Z_3)}{Z_1 + Z_2 + Z_3}}{R_o^1 + \dfrac{Z_2 (Z_1 + Z_3)}{Z_1 + Z_2 + Z_3}}$$

$$A = \frac{A_V . Z_2 (Z_1 + Z_3)}{Z_2 (Z_1 + Z_3) + R_o^1 (Z_1 + Z_2 + Z_3)}$$

V_o gets divided between Z_3 & Z_1

$$V_F = \frac{V_o Z_1}{Z_1 + Z_3}$$

$$\frac{V_F}{V_o} = \beta = \frac{Z_1}{Z_1 + Z_3} \quad ....(2)$$

Loop gain = A × β

$$= \frac{A_V Z_1 Z_2}{R_o^1 (Z_1 + Z_2 + Z_3) + Z_2 (Z_1 + Z_3)}$$

Put $Z_1 = jX_1, Z_2 = jX_{2,} Z_3 = jX_3$

Consider only purely reactive components

$$\text{Loop gain} = \frac{-A_V X_1 X_2}{jRo_0^1 (X_L + X_2 + X_3) - X_2 (X_1 + X_3)} \quad ......(3)$$

At ω_o, phase of loop gain should be 360°

Hence, $R_o^1 (X_1 + X_2 + X_3) = 0$

$X_1 + X_2 + X_3 = 0$ at $\omega = \omega_0$

Condition for oscillation to occur

At $\omega = \omega_0$,

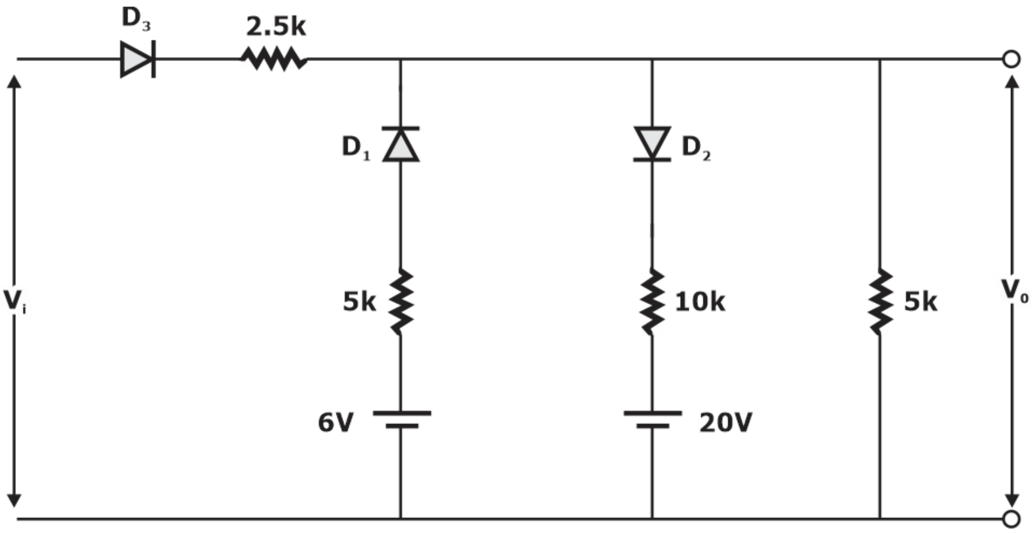
$$\text{Loop gain} = \frac{-A_V X_1 X_2}{jo - X_2 (X_1 + X_3)} = \frac{A_V X_1}{X_2}$$

For sustained oscillation; |loop gain| ≥ 1

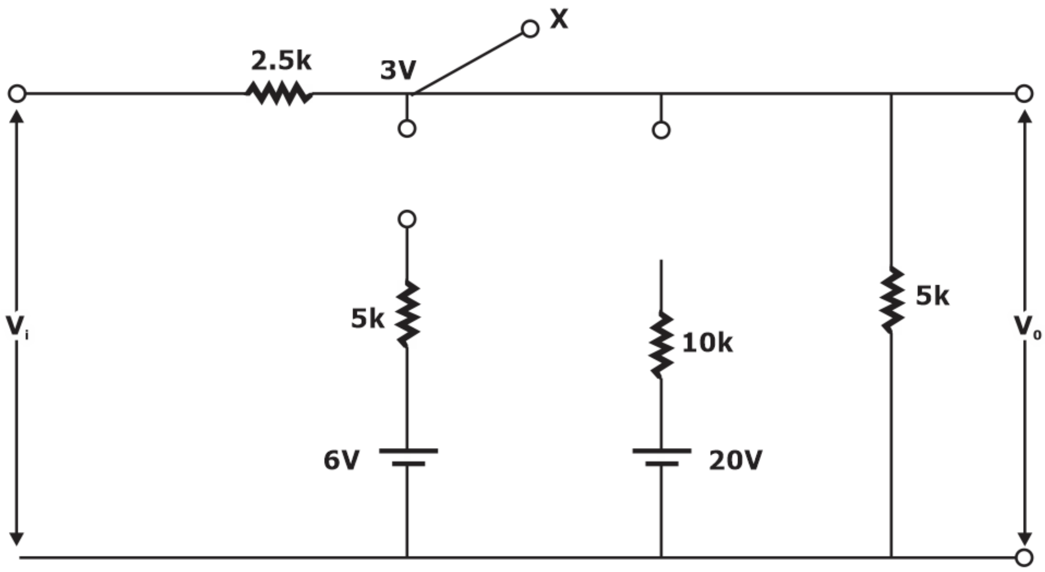
$$|A_V| \frac{X_1}{X_2} \geq 1$$

$$|A_V| \geq \frac{X_2}{X_1}$$

3. In the circuit shown below diodes are ideal, input is varied from 0 to 50V. Plot transfer characteristics.



Sol.



Let D_1, D_2 & D_3 be off

→ $V_x = 0$ initially but as D_1 is ON

Then $V_x = \frac{5}{5+5} \times 6 = 3V$

(a) $V_i < 3V$: $D_3 \to$ OFF, $D_2 \to$ OFF

& $D_1 \to$ ON

$V_o = V_x = 3V$

(b) If $V_i > 3V$: $D_3 \to$ ON

KCL at X:

$$\frac{V_i - V_x}{2.5} + \frac{6 - V_x}{5} = \frac{V_x - 0}{5}$$

$2V_i - 2V_x + 6 - V_x = V_x$

$$V_x = \frac{2Vi+6}{4} = \frac{V_i+3}{2}$$

D_1 remains On, if

$V_x < 6$

$$\frac{V_i+3}{2} < 6$$

$V_i < 9V$

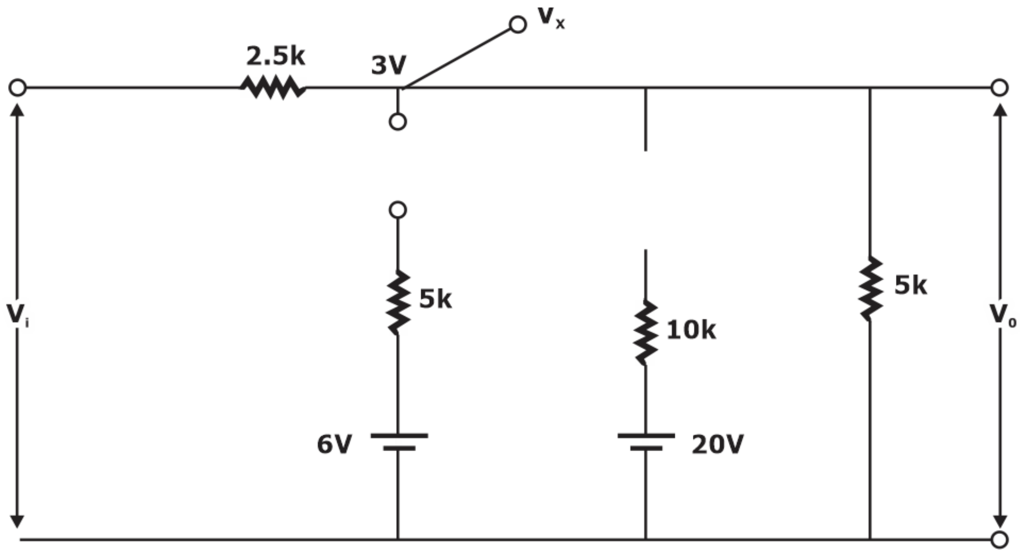
(c) $3 < V_i < 9$: D_1 & D_3 are ON

D_2 = OFF

$$V_o = V_x = \frac{V_i+3}{2}$$

(d) $V_i > 9$: D1 →OFF

Let D_2 be OFF



$$V_x = \frac{5}{2.5+5} \times V_i$$

$$V_x = \frac{2}{3} V_i$$

D_2 remains off $V_x < 20$

$$\frac{2V_i}{3} < 20$$

$V_i = 30V$

(i) If $9 < V_i < 30$: - D_1 & D_2 → OFF

D_3 is ON & $V_o = V_x = \frac{2}{3} V_i$

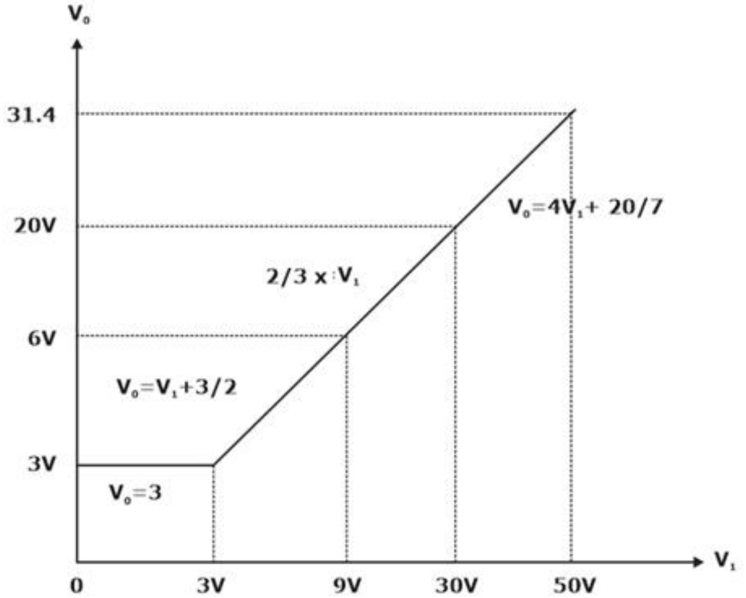
(ii) If $V_i > 30$: D_2 becomes ON

D_3 is ON

D_1 is OFF

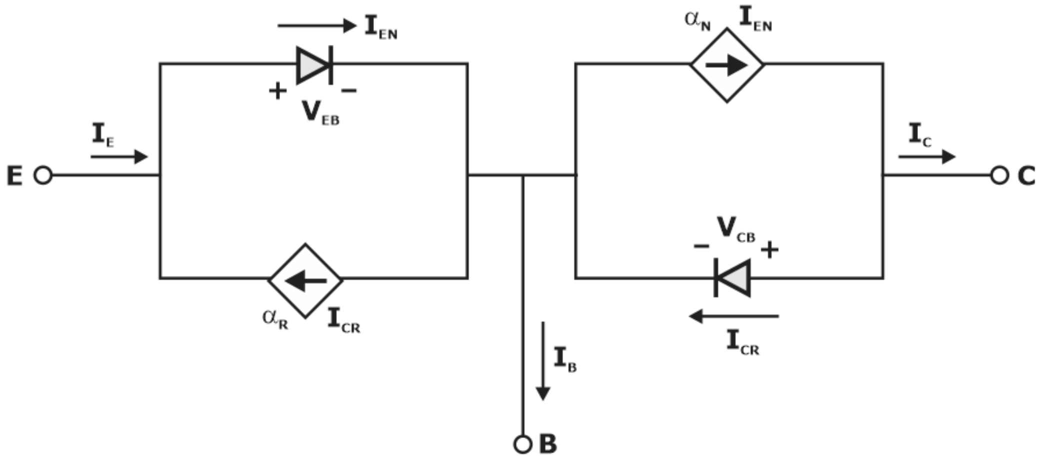
$$\text{KCL at } X: \frac{V_i - V_x}{2.5} = \frac{V_x - 20}{10} + \frac{V_x}{5}$$

$$V_x = \frac{4V_i + 20}{7}$$



4. Explain the BJT model using Eber-molls model.

Sol. Ebers- moll model of BJT: consider Coupled diode model for PNP transistor



→ The two diodes represent J_E & J_C.

→ I_{EN} is the current through emitter June in normal active mode.

$I_{EN} = I_{ES}\,(e^{V_{EB}/V_T} - 1)$

→ I_{CR} → current thorough collector June in reverse active mode.

$I_{CR} = I_{CS}\,(e^{V_{CB}/V_T} - 1)$

→ Dependent source $\alpha_N.I_{EN}$ represents current through collector Junction in normal active mode.

→ Dependent source $\alpha_R.I_{CR}$ represents current through J_E in reverse active mode.

α_N = large signal current gain of normal active mode

α_R = large signal current gain of Reverse Active mode.

→ $\alpha_N \gg \alpha_R$ ($\alpha_N \cong 1$ & α_R signally greater than zero (Because BJT is unsymmetrical $N_E \neq N_C$)

KCL at Emitter:

$I_E + \alpha_R I_{CR} = I_{EN}$

$I_E = I_{EN} - \alpha_R I_{CR}$.........(1)

$I_E = I_{ES}(e^{V_{EB}/V_T}-1) - \alpha_R I_{CS}(e^{V_{CB}/V_{T1}})$.............(2)

KCL at collector:-

$I_C + I_{CR} = \alpha_N I_{EN}$

$I_C = \alpha_N I_{EN} - I_{CR}$ ....(3)

$I_C = \alpha_N I_{ES}(e^{V_{EB}/V_T}-1) - I_{CS}(e^{V_{CB}/V_T}-1)$ ....(4)

$I_B = I_E - I_C$ by equation (2)-(4)

$I_B = (1-\alpha_N) I_{ES}(e^{V_{EB}/V_T}-1) + (1-\alpha_R) I_{CS}(e^{V_{CB}/V_T}-1)$ ....(5)

Eqn. (2), (4) & (5) are known as equation they can be used to calculate I_E, I_C & I_B for all modes of operation.

Combine eqn. (1) & (3)➔

$I_E = I_{EN} - \alpha_R(\alpha_N I_{EN} - I_{CR})$

$I_E = (1-\alpha_R . \alpha_N) I_{EN} + \alpha_R I_{CR}$

$I_E = (1-\alpha_R . \alpha_N) I_{ES}[e^{V_{EB}/V_T}-1] + \alpha_R I_{CR}$

$I_E = I_{Eo}[e^{V_{EB}/V_T}-1] + \alpha_R I_C$...........(6)

When $I_{EO} = (1-\alpha_R\alpha_N) I_{ES}$.

I_{EO} – called Reverse sat n current of emitter June. When collector terminal is open circuited.

Form eqn. (3):

$I_C = \alpha_N I_{EN} - I_{CR}$

$I_C = \alpha_N[I_E + \alpha_R I_{CR}] - I_{CR}$ ....(from (1)

$I_C = \alpha_N I_E - (1-\alpha_N \alpha_R) I_{CR}$

$I_C = \alpha_N I_E - (1-\alpha_N\alpha_R) I_{CS}(e^{V_{CB}/V_T}-1)$

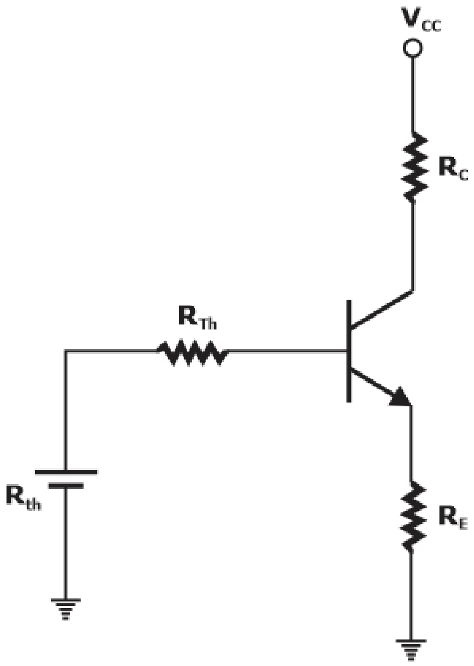
$I_C = \alpha_N I_E - I_{Co}(e^{V_{CB}/V_T}-1)$ ....(7)

I_{CO} → Reverse saturation current of [where $I_{CO} = (1-\alpha_N\alpha_B)I_{CS}$]

Collection June when emitter is open Circuit.

5. BJT has β = 100 & V_{BE} = 0.7 Volt, Design self-bias circuit to operate BJT at V_{CE} = 6V, I_C = 1.5 mA. Assume stability factor S = 8

Sol. Step 1: Draw simplified self-bias circuit



$$V_{Th} = \frac{V_{CC} \times R_2}{R_1 + R_2}$$

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2}$$

Where V_{CC} is the voltage supply of the self bias circuit and R_1 and R_2 form self bias resistors.

Step 2: Calculate R_C & R_E by using KVL in collector loop

$$+V_{CC} - R_C I_C - V_{CE} - R_E \underset{\cong I_C}{\underset{\downarrow}{I_E}} = 0$$

$$R_C + R_E = \frac{V_{CC} - V_{CE}}{I_C}$$

$$= \frac{12 - 6}{1.5} = 4k\Omega$$

$$\left\{ V_{CE} = \frac{V_{CC}}{2} (OR)\, V_{CC} = 2V_{CE} \right\}$$

Select $R_C > 2R_E$

Let R_C = 2.8 k Ω

R_E = 1.2 k Ω

Step 3: calculate R_{th} by using stability factor value.

$$S = \frac{1+\beta}{1+\frac{\beta R_E}{R_{Th}+R_E}}$$

$$S = \frac{101}{1+\frac{100\times 1.2}{R_{Th}+1.2}} = 8$$

R_{Th} = 9.12 k Ω = R_B

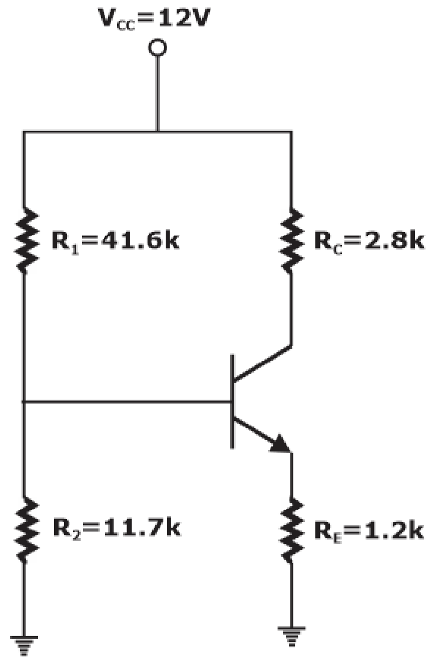
Step 4: Calculate V_{th} by using KVC in base loop

$V_{Th} = R_B \,.\, I_B + V_{BE} + I_E + I_E R_E$

$$= \frac{1.5}{100}\times 9.12 + 0.7 + 1.5\times 1.2$$

V_{Th} = 2.63 volt

Step 5: Calculate R_1 & R_2



$$\frac{R_{Th}}{V_{Th}} = \frac{\frac{R_1.R_2}{(R_1+R_2)}}{\frac{V_{CC}.R_2}{(R_1+R_2)}} = \frac{R_1}{V_{CC}}$$

$$R_1 = \frac{V_{CC}}{V_{Th}}\times R_{Th}$$

$$= \frac{12}{2.63}\times 9.12$$

R_1 = 41.61 k Ω

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} \Rightarrow R_2 \frac{R_{Th}.R_1}{R_1 - R_{Th}}$$

R_2 = 11.7 k Ω

Note: If stability factor value is not provided then R_{Th} is calculated by using the condition $(1 + \beta) R_E >> R_{Th}$

Take $(1 + \beta) R_E = 10R_{Th}$

$$R_{Th} = \frac{(1+\beta)}{10} R_E$$

Thus R_1 = 41.61 k Ω, R_2 = 11.7 k Ω, V_{CC} = 12V, R_C = 2.8 k Ω, R_E = 1.2 k Ω

****