Transistor Biasing Circuits

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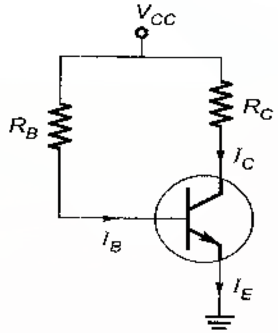
Biasing is about stabilizing I_C and V_{CE} so as to ensure that transistor remains in active region for entire range of input signal.

Fixed Bias

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

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

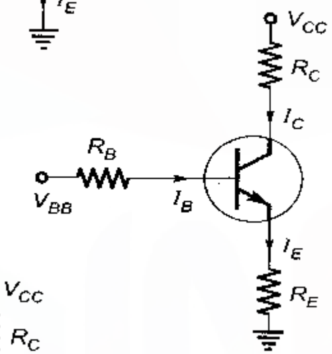


Emitter feedback bias

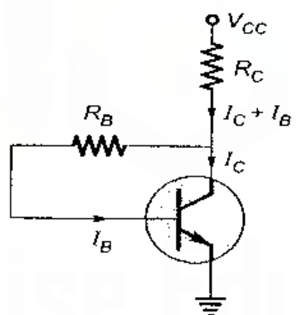
- Collector current I_C

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

(assuming β to be large)



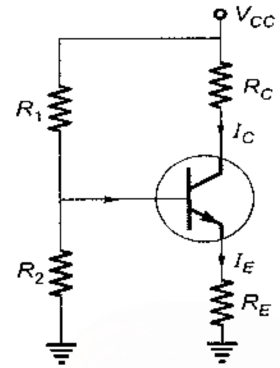
Collector-feedback bias (self bias)



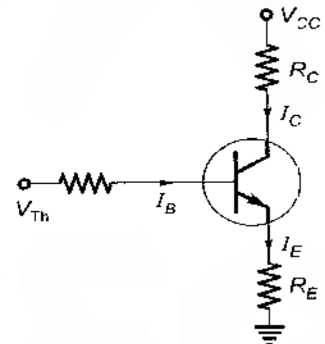
$$I_C \cong \frac{V_{CC} - V_{CE}}{R_C}$$ [Assuming β to be large or $I_B \simeq 0$]

or $$I_C = \left[\frac{V_{CC} - V_{CE}}{R_C}\right] \times \left(\frac{\beta}{\beta + 1}\right)$$ [Exact value]

Voltage Divider Bias (universal bias)



- Widely used in linear circuits and is as
  Equivalent circuit will be → (thevenine equivalent)



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

$R_{Th} = R_1 \parallel R_2$

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

[Assuming β to be large]

$$I_E = \frac{V_{Th} - V_{BE}}{R_E + \left(\frac{R_{Th}}{\beta + 1}\right)}$$

Bias Stabilization

- Stabilization is about making the Q-point independent of changes in temperature and changes in transistor parameters.
- If I_{CO}, V_{BE} and β changes simultaneously then net change in I_C.

$$\Delta I_C = \frac{\partial I_C}{\partial I_{CO}} \Delta I_{CO} + \frac{\partial I_C}{\partial V_{BE}} \times \Delta V_{BE} + \frac{\partial I_C}{\partial \beta} \Delta \beta$$

where, $\frac{\partial I_C}{\partial I_{CO}} = S \rightarrow$ Current stability factor.

$\frac{\partial I_C}{\partial V_{BE}} = S' \rightarrow$ Voltage stability factor

$\frac{\partial I_C}{\partial B} = S_\beta$ or $S'' \rightarrow$ Amplification stability factor.

Note: ....

Out of three stability factor S is most significant reason being, it S is within tolerable limit then other S' and S'' are guaranteed to remain within tolerable limit.

$$S_{\text{ideal}} = 1$$

Practically S should be less than 20.

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For Voltage Divider Bias Circuit

current stability factor,

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

Note: ....

R_E must be large for lesser value of S, but it also decreases the gain.

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- Alternate Evaluation of S

$$\boxed{S = \frac{(\beta + 1)}{1 - \beta \dfrac{\partial I_B}{I_C}}}$$

- Condition for effective stabilization

$$\boxed{S = \frac{(\beta + 1)\ (R_E + R_{Th})}{R_{Th} + (\beta + 1)R_E}} \quad \text{[For voltage divider circuit]}$$

$$\boxed{S = \frac{(\beta + 1)}{1 + \dfrac{\beta}{\left(1 + \dfrac{R_{Th}}{R_E}\right)}}} \ ; \quad \text{if } \frac{R_{th}}{R_E} << 1 \quad \text{then } S \to 1$$

For Collector Feedback Bias Circuit

$$\boxed{S = \frac{(1 + \beta)(R_B + R_C)}{R_B + (1 + \beta)R_C}} \ ; \ \text{if } \frac{R_B}{R_C} << 1 \text{ then } S \to 1$$

For Fixed Bias Circuit

$$\boxed{S = (\beta + 1)} \ \to \text{very large} \to \text{highly unstable.}$$

Condition to Avoid Thermal Run Away

- Thermal resistance (θ)

$$\boxed{\theta = \frac{T_j - T_A}{P_D}} \quad \text{(°C/Watt or °K/Watt)}$$

where, T_j = Junction temperature (collector junction)

T_A = Ambient temperature in Kelvin.

P_D = Power dissipated across collector junction.

- A transistor will be thermally stable if

$$\boxed{\frac{\partial P_C}{\partial T_j} \le \frac{\partial P_D}{\partial T_j} \le \frac{1}{\theta}}$$

$\dfrac{\partial P_C}{\partial T_j} \to$ Rate at which heat is released.

$\dfrac{\partial P_D}{\partial T_j} \to$ Rate at which heat is dissipated.

- For thermal stability $\dfrac{V_{CC}}{2} > V_{CE}$.

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