Lecture 6

BJT BIASING

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Biasing Circuit OF CE BJT Transistors

دارات الانحياز لترانزستورات BJT

The DC voltages applied to a transistor in order to turn it on so that it can amplify the AC signal.

The Three States of Operation:

- Active or Linear Region Operation

Base–Emitter junction is forward biased Base–Collector junction is reverse biased.

- Cutoff Region Operation

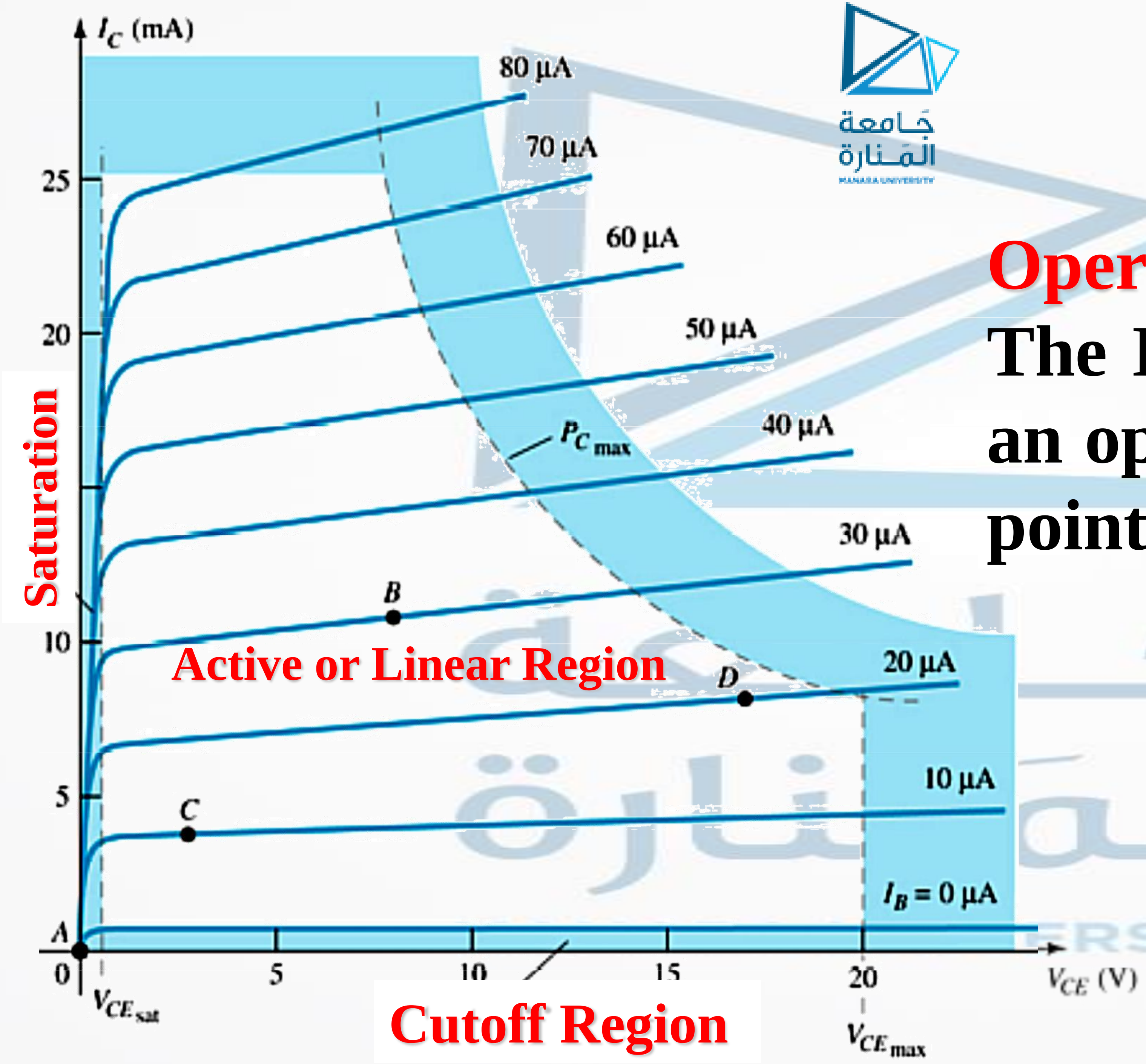
Base–Emitter junction is reverse biased.

- Saturation Region Operation

Base–Emitter junction is forward biased Base–Collector junction is forward biased.

Operating Point

The DC input establishes an operating or quiescent point called the **Q-point**.

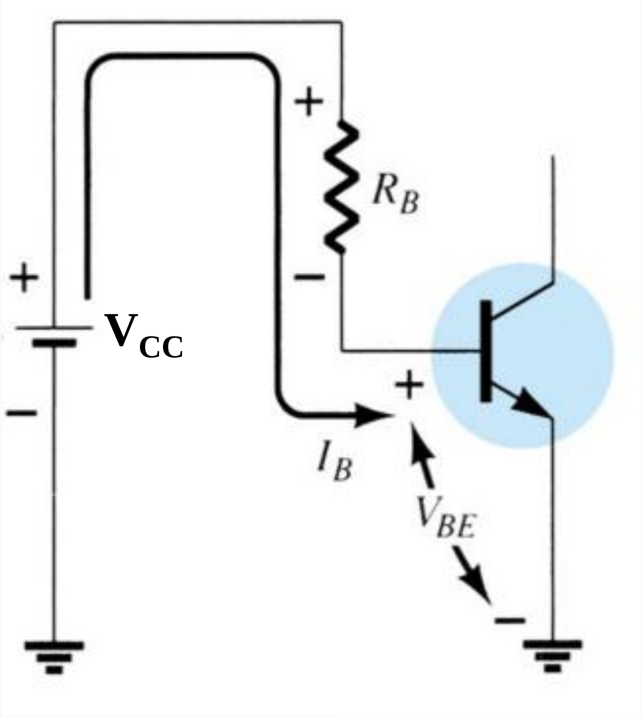


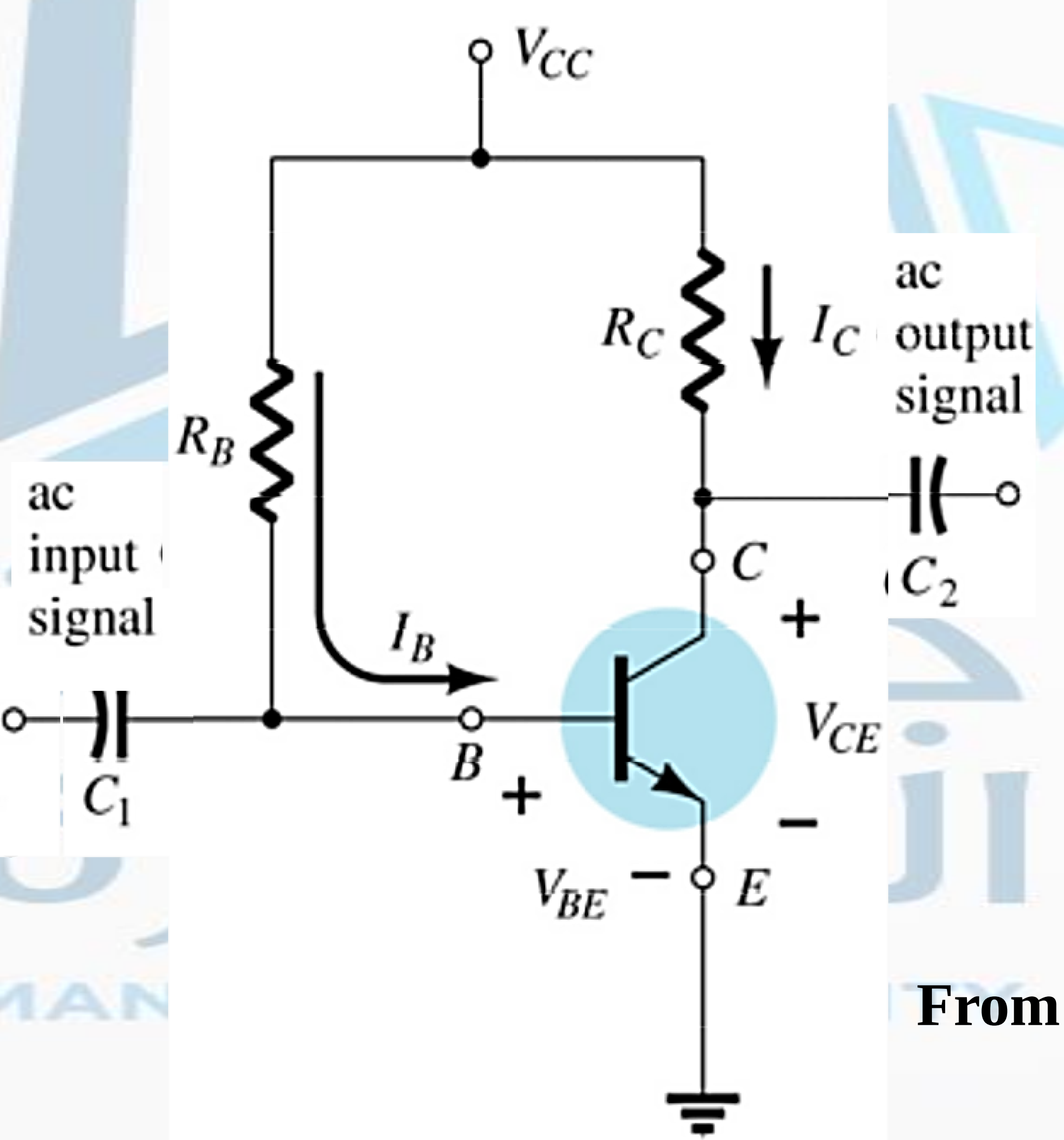
DC Biasing Circuits دارات الانحياز

- **Fixed-bias circuit** دارة الانحياز الثابت
- **Emitter-stabilized bias circuit** دارة انحياز الباعث المستقر
- **Collector-emitter loop** دارة الانحياز لحلقة الباعث المجمع
- **Voltage divider bias circuit** دارة انحياز مجزئ الجهد
- **DC bias with voltage feedback** دارة الانحياز بتغذية عكسية

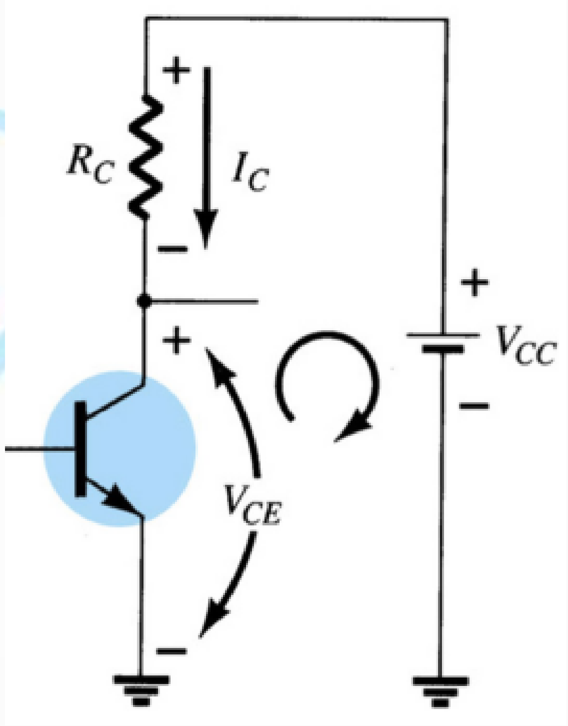
Fixed Bias Circuit

The Base-Emitter Loop





Collector-Emitter Loop



From Kirchhoff's voltage law: $+V_{CC} - I_B R_B - V_{BE} = 0$

Solving for base current:

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

Collector current:

$$I_C = \beta I_B$$

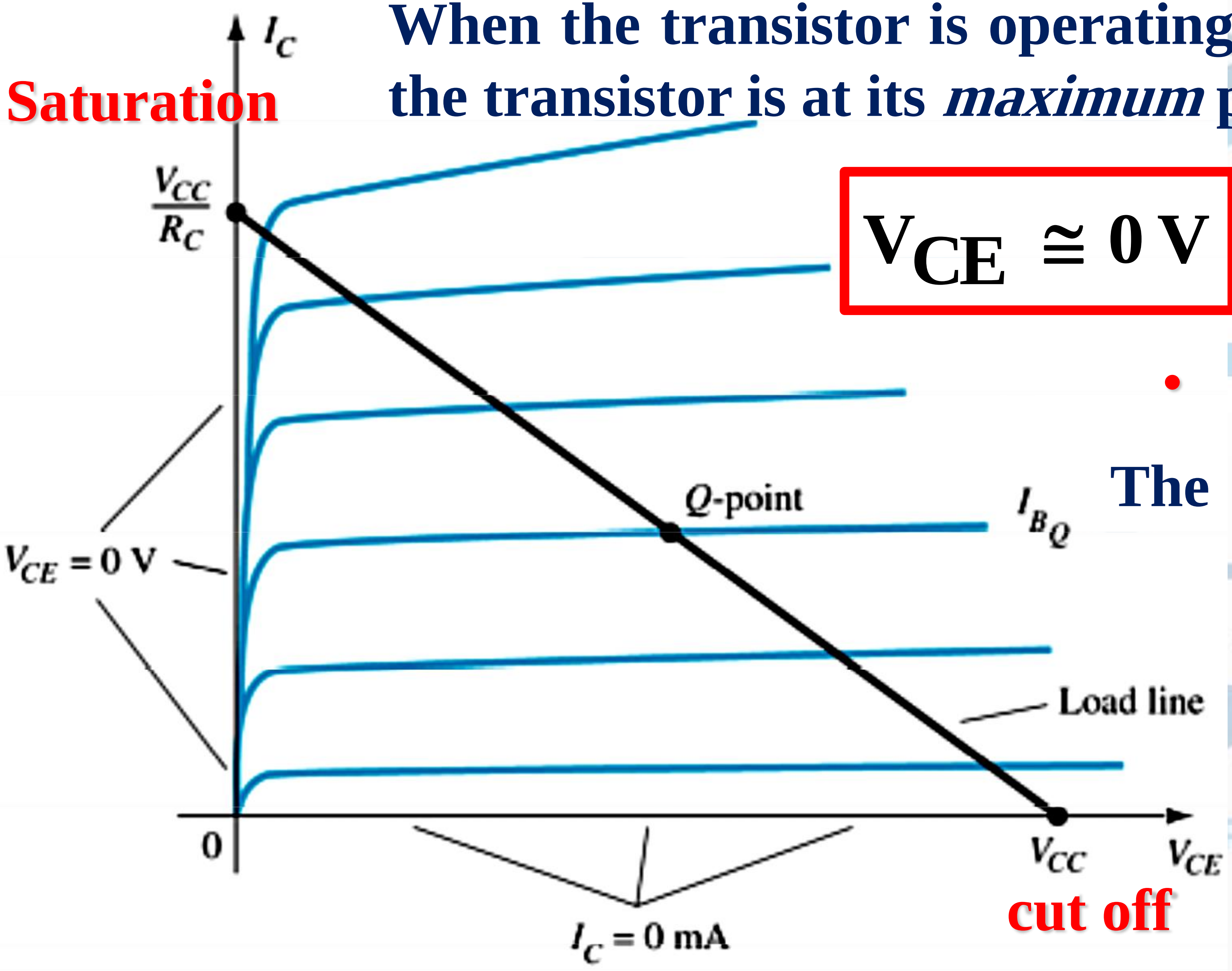
From Kirchhoff's voltage law:

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

Load Line Analysis

- **Saturation**

When the transistor is operating in saturation, current through the transistor is at its *maximum* possible value.



$$\boxed{V_{CE} \cong 0\ \text{V}}$$

$$\boxed{I_{Csat} = \frac{V_{CC}}{R_C}}$$

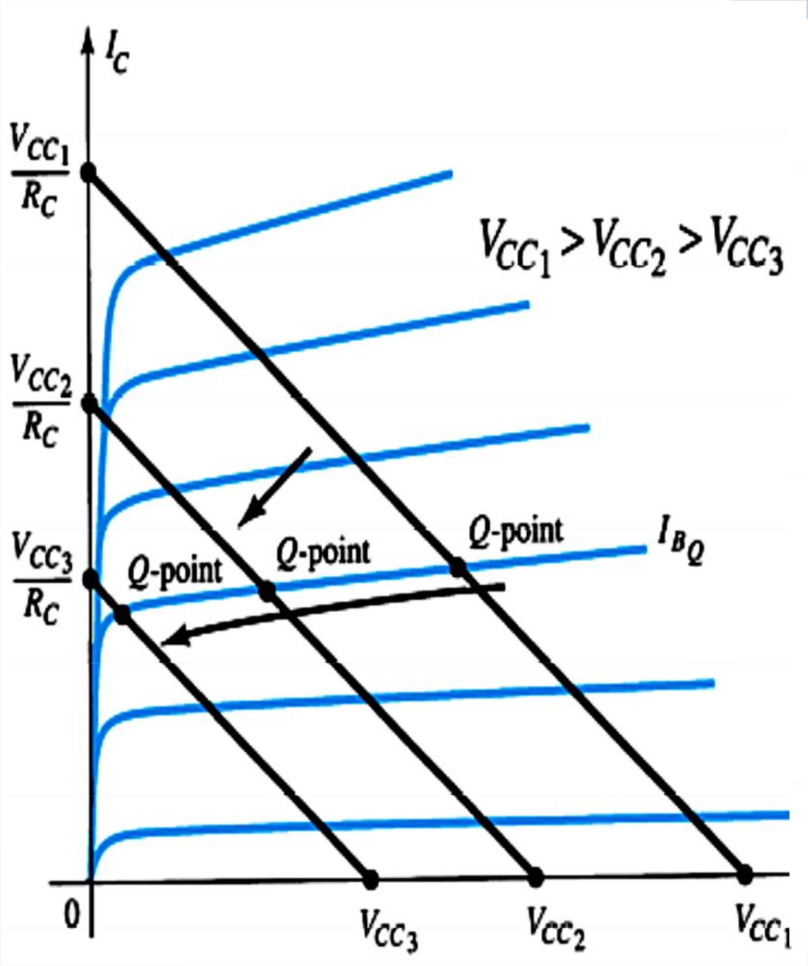
- **Active or Linear Region**

The *Q*-point is the operating point:

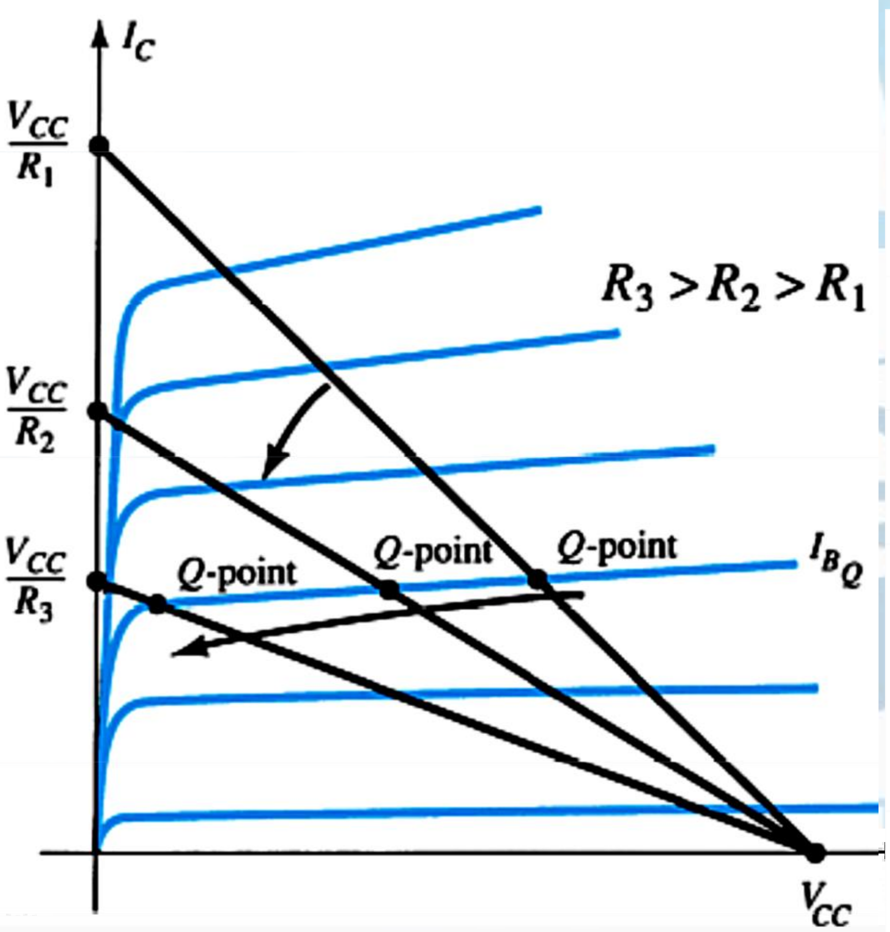
- **where the value of R_B sets the value of I_B**
- **that sets the values of V_{CE} and I_C**

Circuit Values Affect the Q-Point

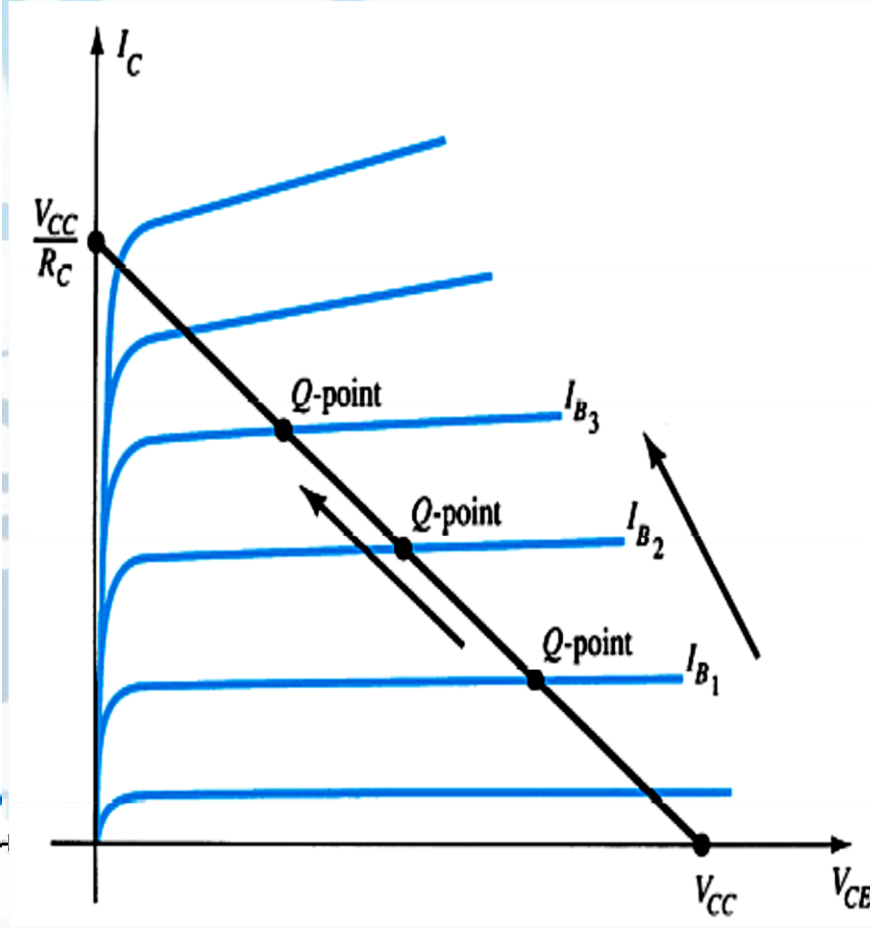
V_{CC} Variable



R_C Variable

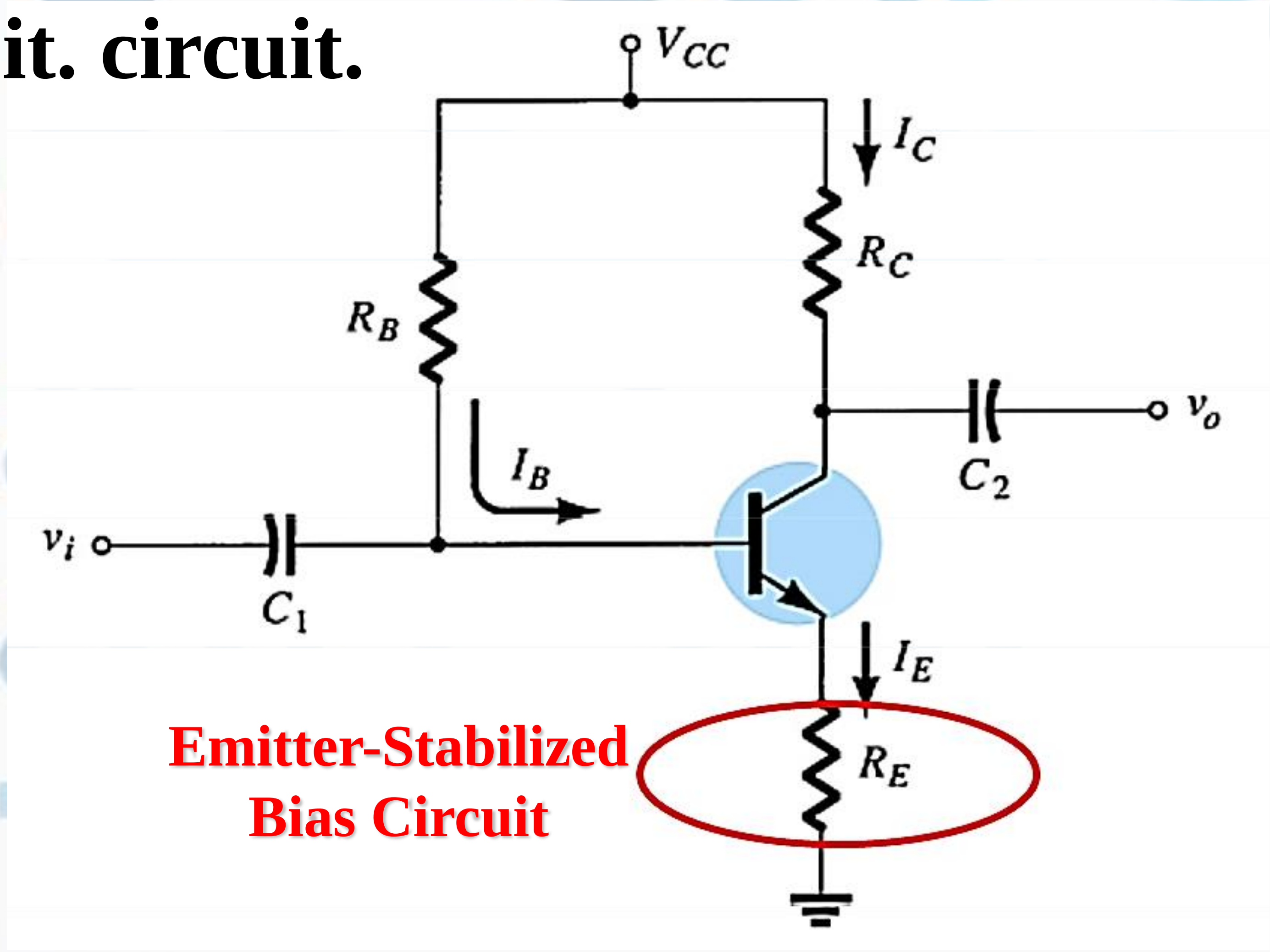


I_B Variable



Emitter-Stabilized Bias Circuit

Adding a resistor (R_E) to the emitter circuit stabilizes the bias circuit. circuit.



Emitter-Stabilized Bias Circuit

Emitter-Stabilized Bias Circuit

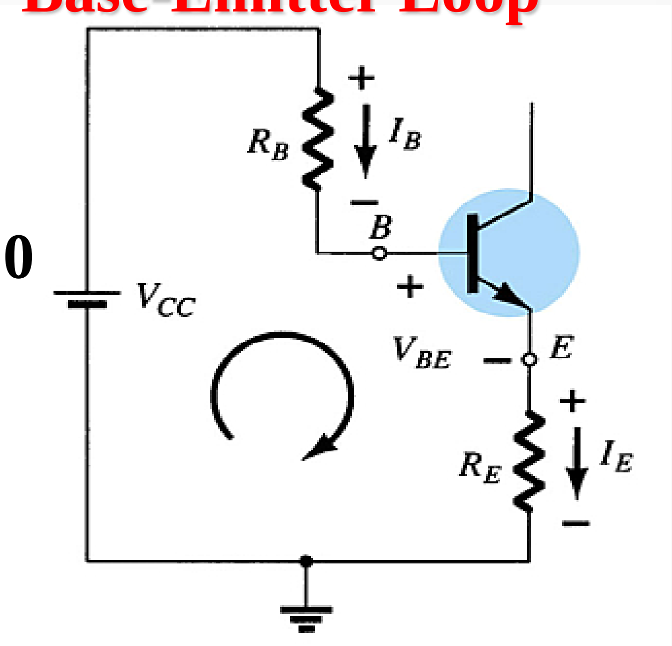
Base-Emitter Loop

From Kirchhoff's voltage law: $+V_{CC} - I_E R_E - V_{BE} - I_E R_E = 0$

Since $I_E = (\beta + 1)I_B$: $V_{CC} - I_B R_B - (\beta + 1) I_B R_E = 0$

Solving for IB: $$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1) R_E}$$

Base-Emitter Loop



Collector-Emitter Loop

From Kirchhoff's voltage law: $I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$

Since IE ≅ IC: $V_{CE} = V_{CC} - I_C (R_C + R_E)$

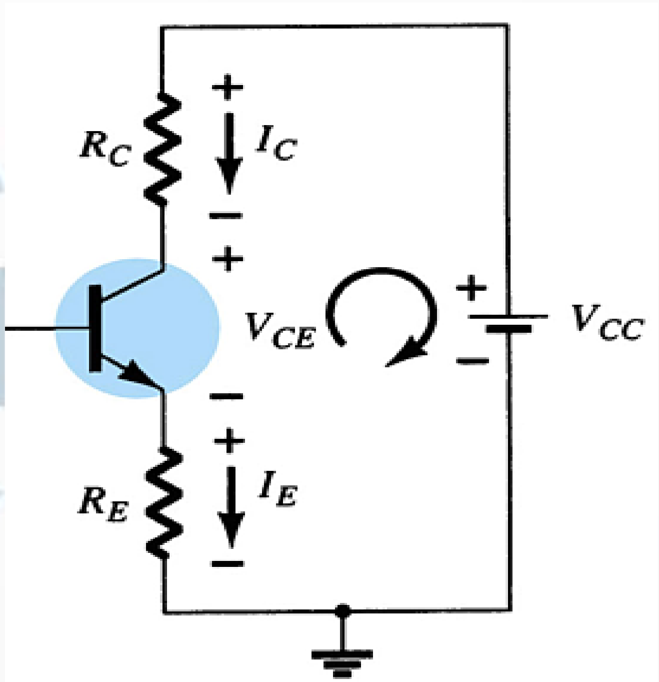
Also:

$$V_E = I_E R_E$$

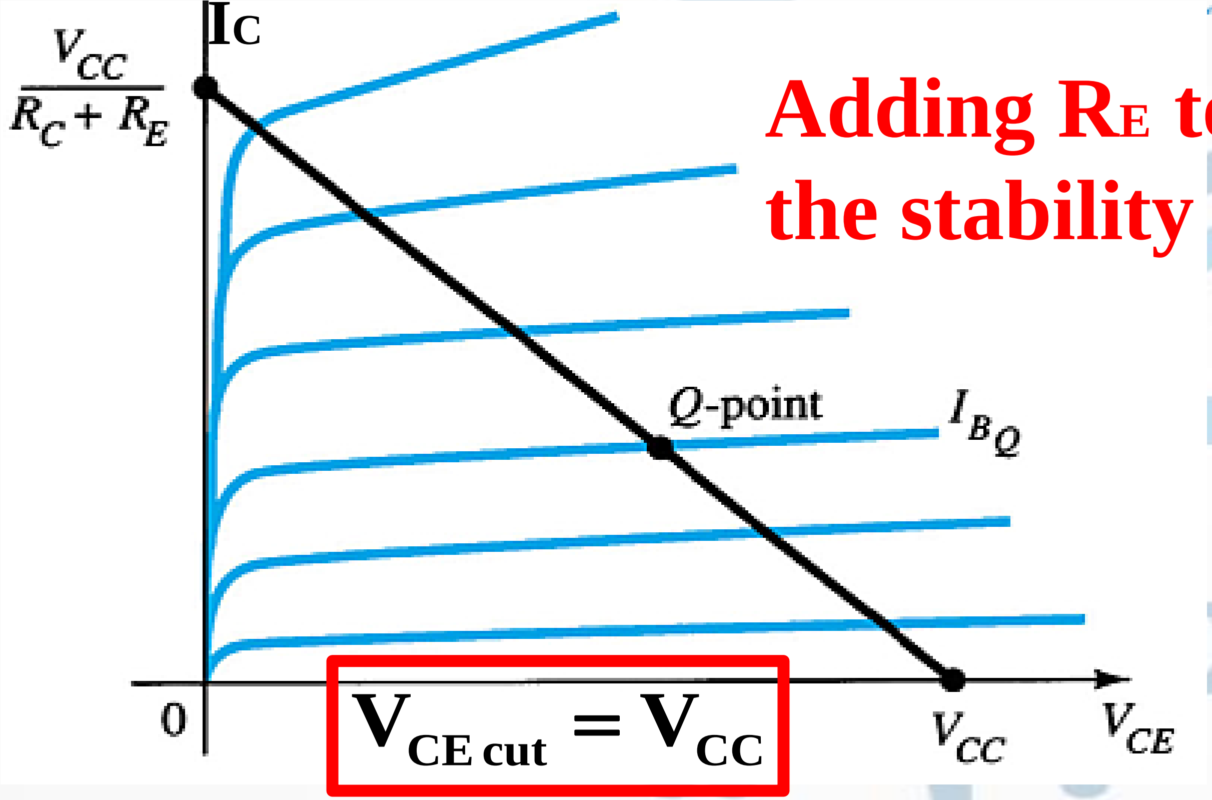
$$V_C = V_{CE} + V_E = V_{CC} - I_C R_C$$

$$V_B = V_{CC} - I_R R_B = V_{BE} + V_E$$

Collector-Emitter Loop



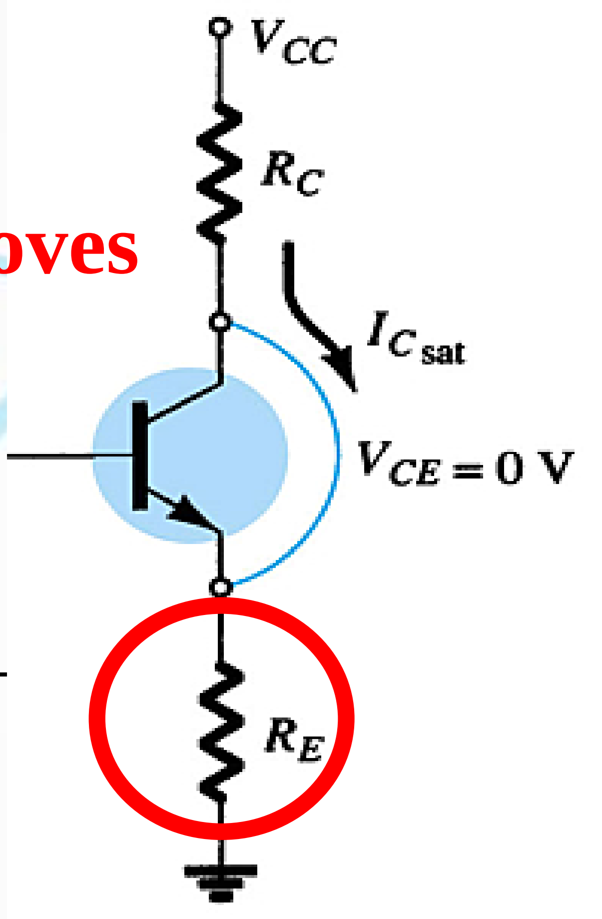
Improved Biased Stability



$$V_{CE\ cut} = V_{CC}$$

Adding R_E to the emitter improves the stability of a transistor.

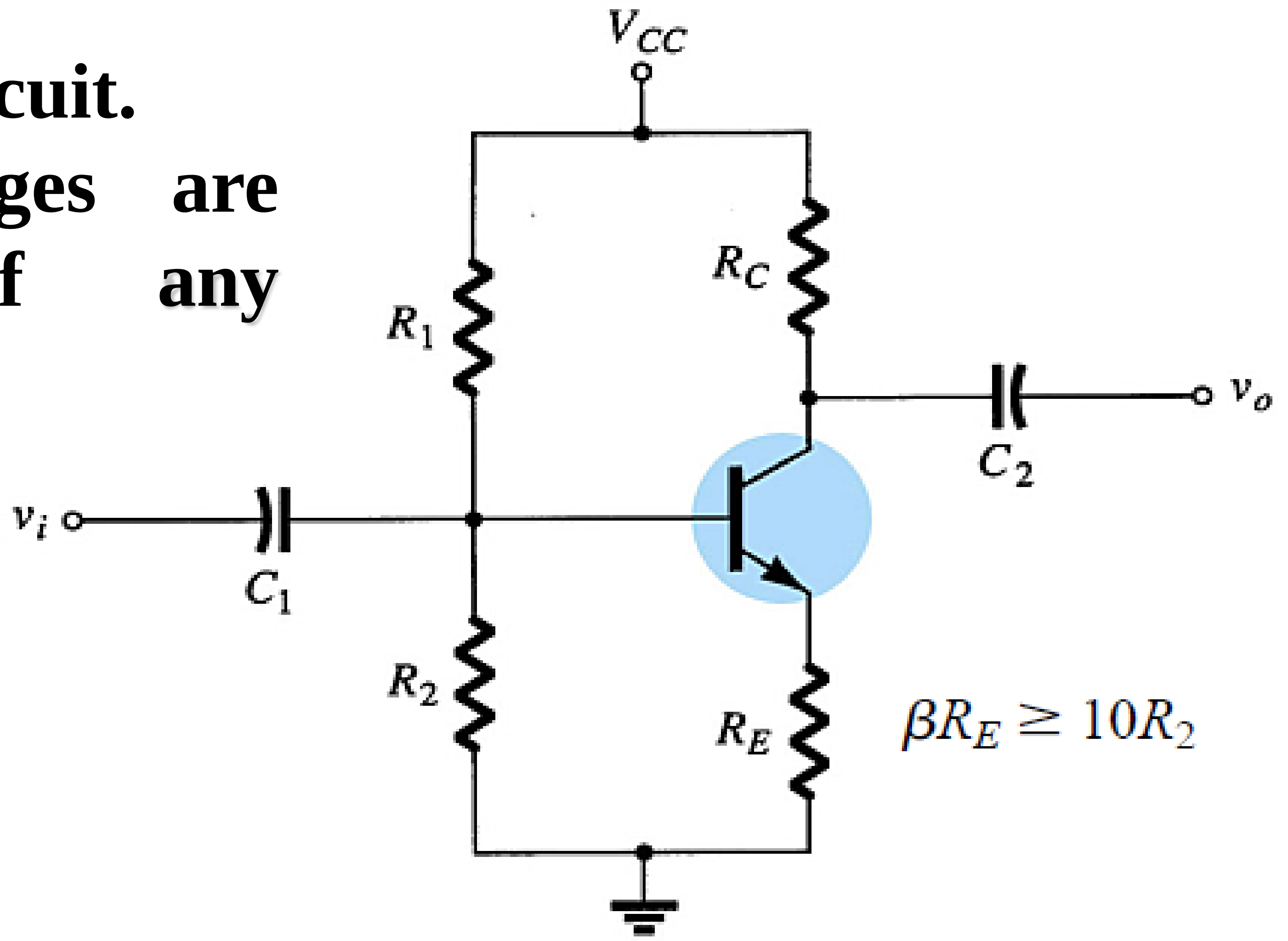
$$I_{C\,sat} = \frac{V_{CC}}{R_C + R_E}$$



Stability refers to a circuit condition in which the currents and voltages will remain fairly constant over a wide range of temperatures and transistor Beta (β) values.

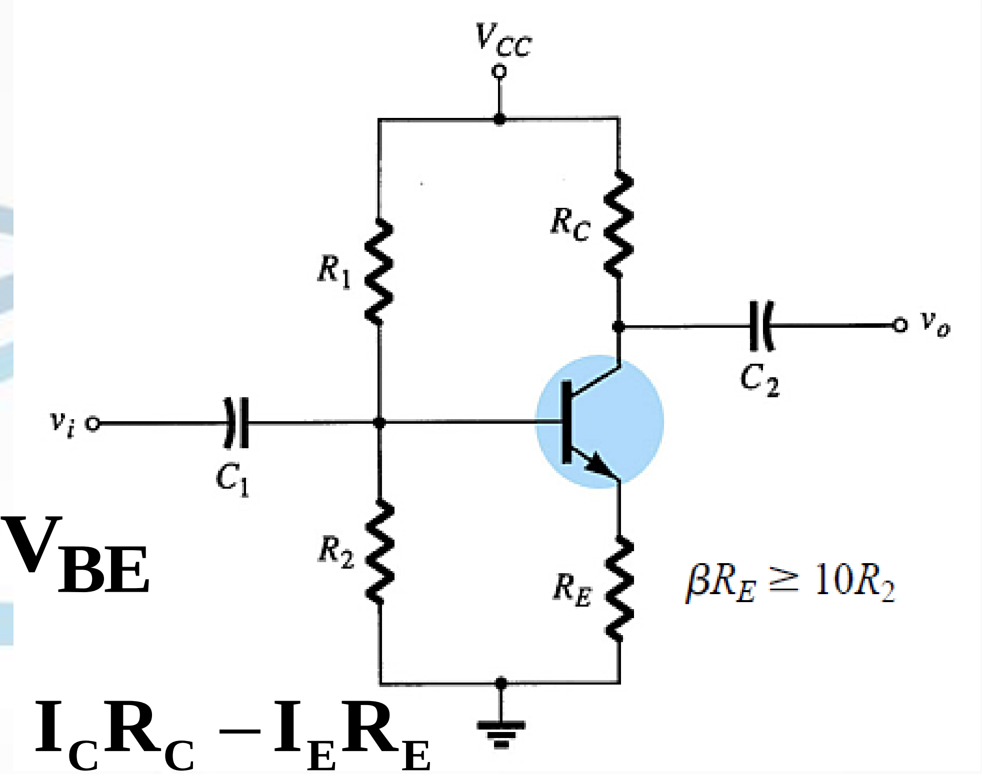
Voltage Divider Bias

This is a very stable bias circuit. The currents and voltages are nearly independent of any variations in β.



$$\beta R_E \geq 10R_2$$

Voltage Divider Bias



Approximate Analysis

Where $I_B << I_1$ and $I_1 \cong I_2$:

$$V_B = \frac{R_2 V_{CC}}{R_1 + R_2}$$

Where $\beta R_E > 10R_2$:

$$I_E = \frac{V_E}{R_E} \qquad V_E = V_B - V_{BE}$$

From Kirchhoff's voltage law:

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

Transistor Saturation Level

$$I_{Csat} = I_{Cmax} = \frac{V_{CC}}{R_C + R_E}$$

Load Line Analysis

$$I_E \cong I_C \qquad V_{CE} = V_{CC} - I_C (R_C + R_E)$$

Cutoff:

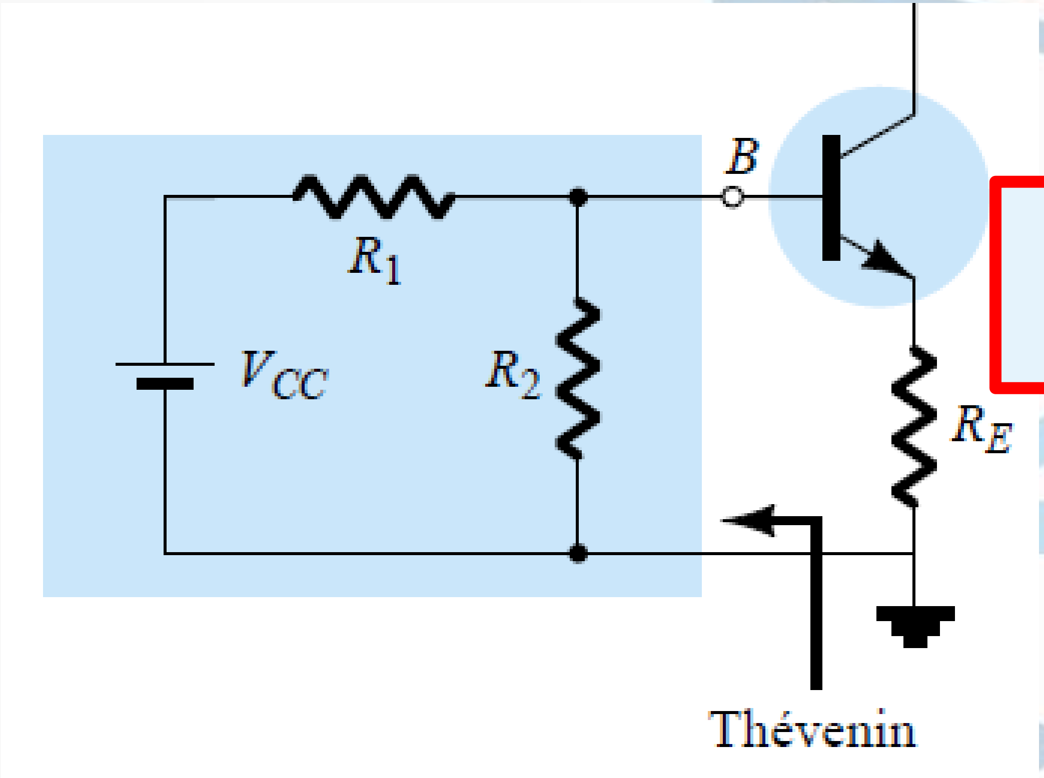
$$V_{CE} = V_{CC}$$

$$I_C = 0mA$$

Saturation:

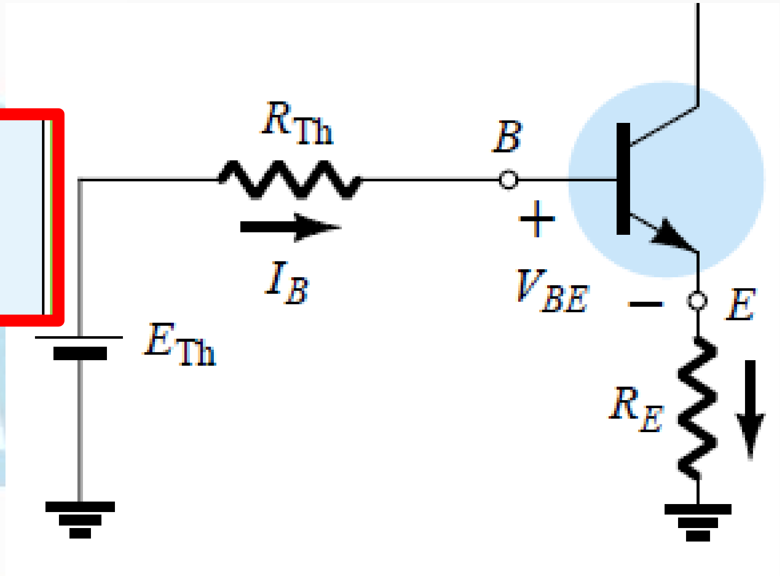
$$I_C = \frac{V_{CC}}{R_C + R_E}$$

$$V_{CE} = 0V$$



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

$$R_{\mathrm{Th}} = R_1 \| R_2$$

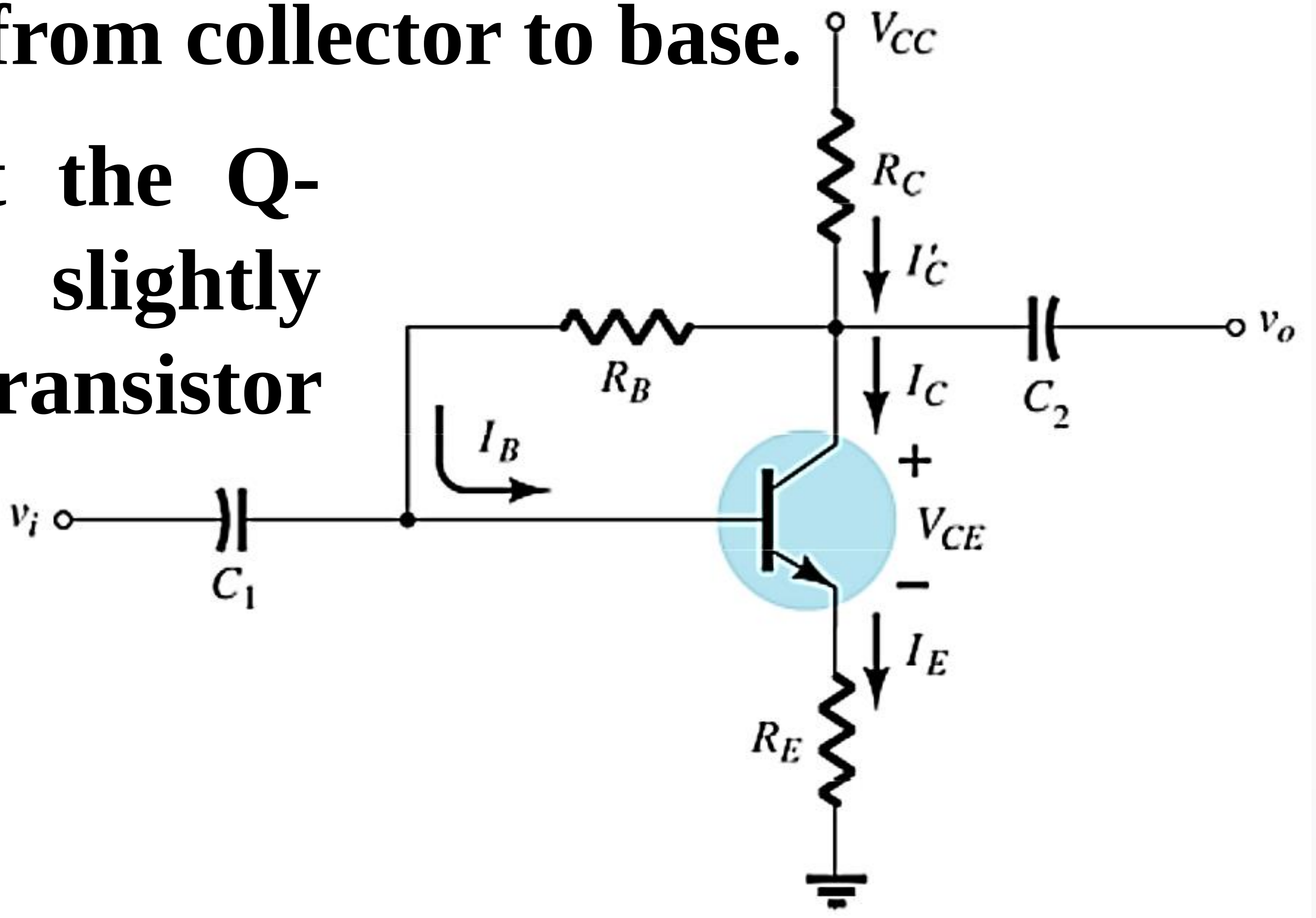


$$I_B = \frac{E_{\mathrm{Th}} - V_{BE}}{R_{\mathrm{Th}} + (\beta + 1)R_E}$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

DC Bias with Voltage Feedback

- Another way to improve the stability of a bias circuit is to add a feedback path from collector to base.



- In this bias circuit the Q-point is only slightly dependent on the transistor beta, β.

DC Bias with Voltage Feedback

Base-Emitter Loop

From Kirchhoff’s voltage law:

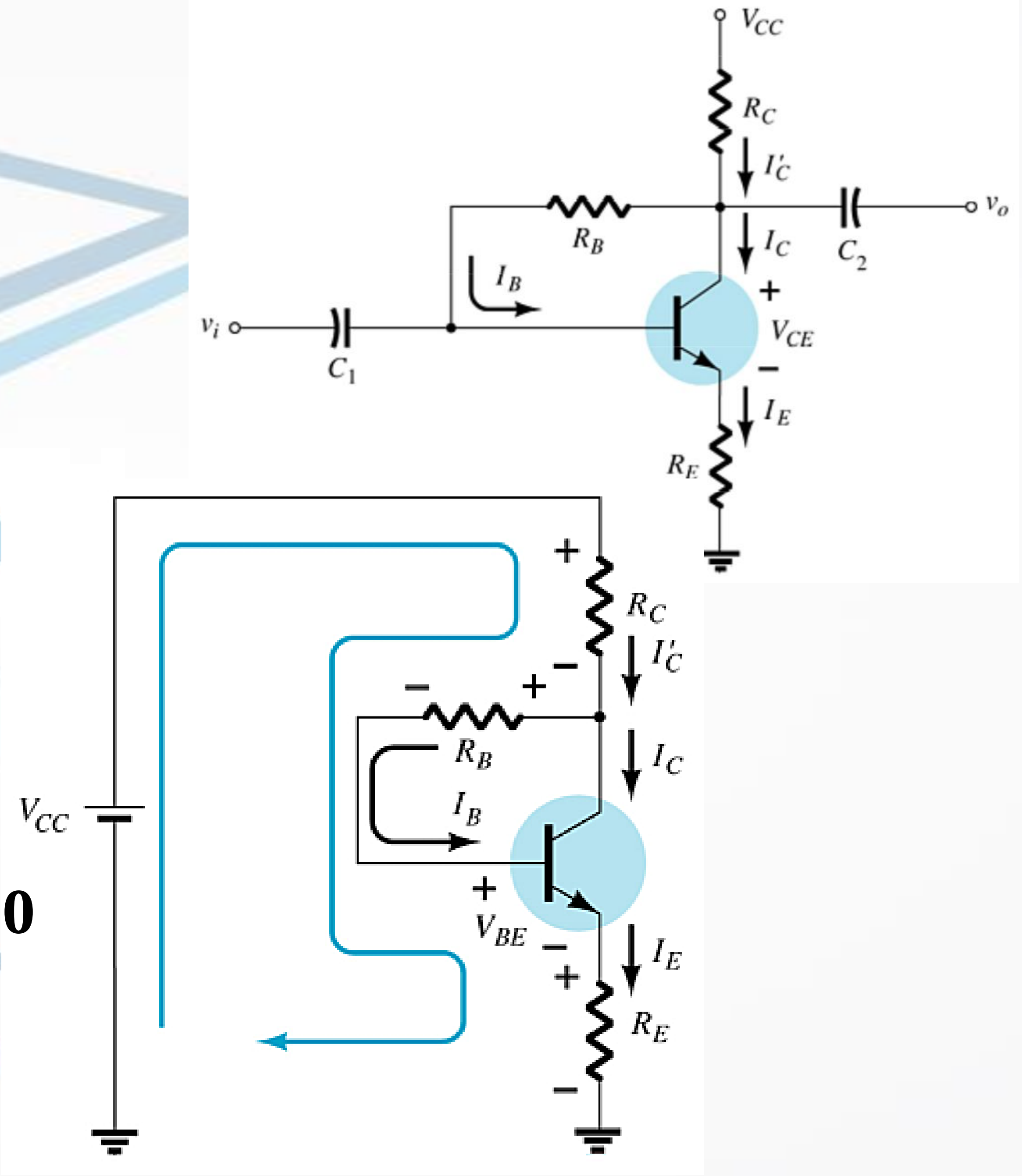
$$V_{CC} - I'_C R_C - I_B R_B - V_{BE} - I_E R_E = 0$$

Where $I_B << I_C$: $$I'_C = I_C + I_B \cong I_C$$

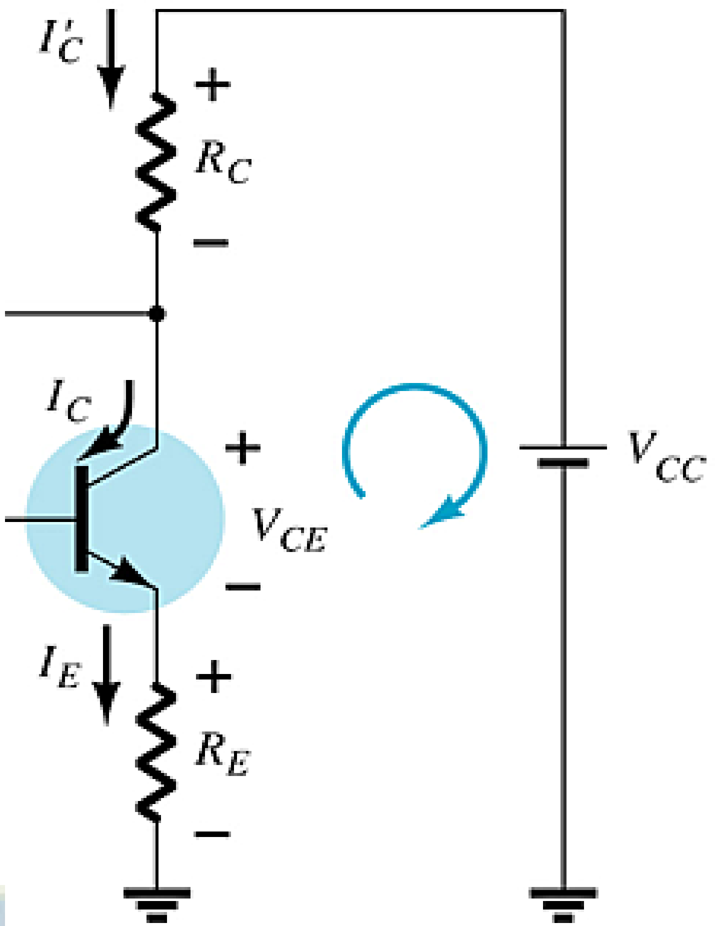
Knowing $I_C = \beta I_B$ and $I_E \cong I_C$, the loop equation becomes:

$$V_{CC} - \beta I_B R_C - I_B R_B - V_{BE} - \beta I_B R_E = 0$$

Solving for I_B: $$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$



Collector-Emitter Loop



Applying Kirchoff's voltage law: $I_E + V_{CE} + I'_C R_C - V_{CC} = 0$

Since $I'_C \cong I_C$ and $I_C = \beta I_B$: $I_C(R_C + R_E) + V_{CE} - V_{CC} = 0$

Solving for V_{CE}: $V_{CE} = V_{CC} - I_C(R_C + R_E)$

Transistor Saturation Level

$$I_{Csat} = I_{Cmax} = \frac{V_{CC}}{R_C + R_E}$$

Load Line Analysis

Cutoff:

$$V_{CE} = V_{CC}$$

$$I_C = 0\ \text{mA}$$

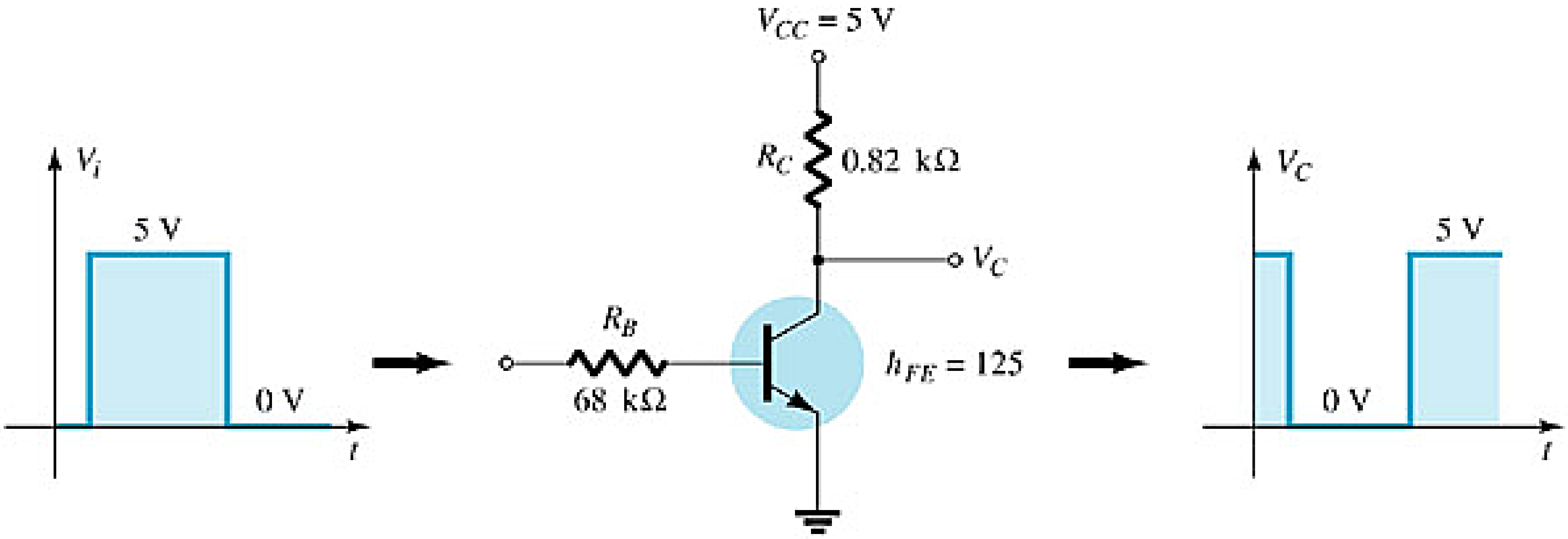
Saturation:

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

$$V_{CE} = 0\ \text{V}$$

Transistor Switching Networks

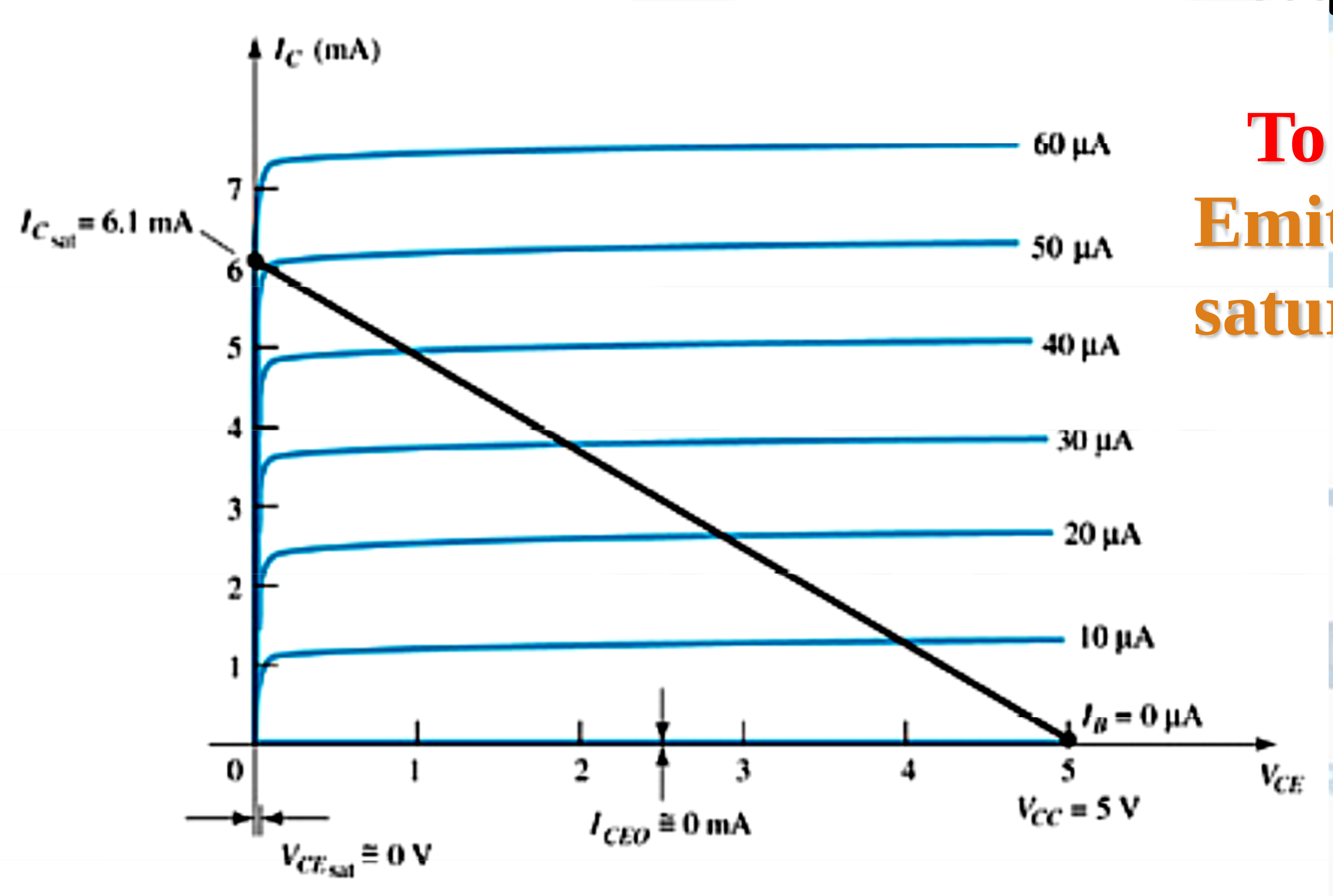
Transistors with only the DC source applied can be used as electronic switches.



Switching Circuit Calculations

Saturation current:

$$I_{Csat} = \frac{V_{CC}}{R_C} \qquad I_B > \frac{I_{Csat}}{\beta_{dc}}$$



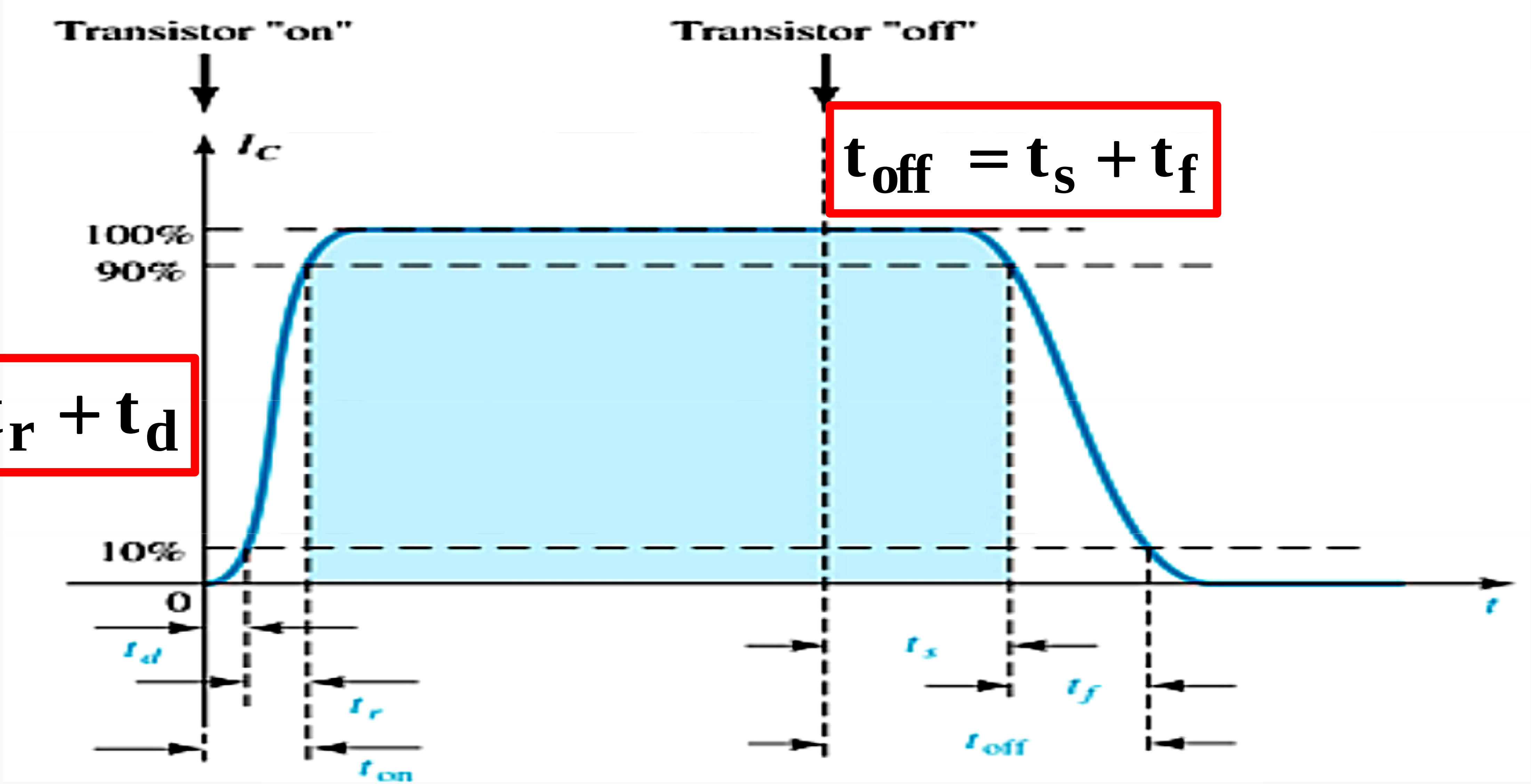
To ensure saturation:

Emitter-collector resistance at saturation and cutoff:

$$R_{sat} = \frac{V_{CEsat}}{I_{Csat}}$$

$$R_{cutoff} = \frac{V_{CC}}{I_{CEO}}$$

Transistor switching times:



$$t_{off} = t_s + t_f$$

$$t_{on} = t_r + t_d$$

PNP Transistors

The analysis for *pnp* transistor biasing circuits is the same as that for *npn* transistor circuits. The only difference is that the currents are flowing in the opposite direction.