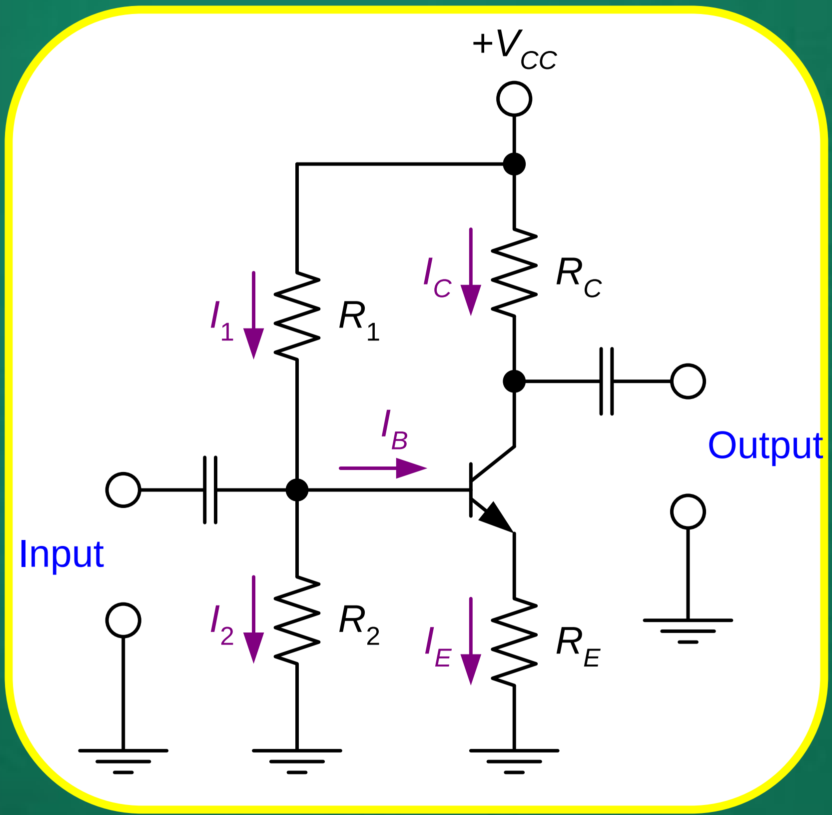
# Basic Electronic Circuits
# (IEC-103)

## Lecture-17

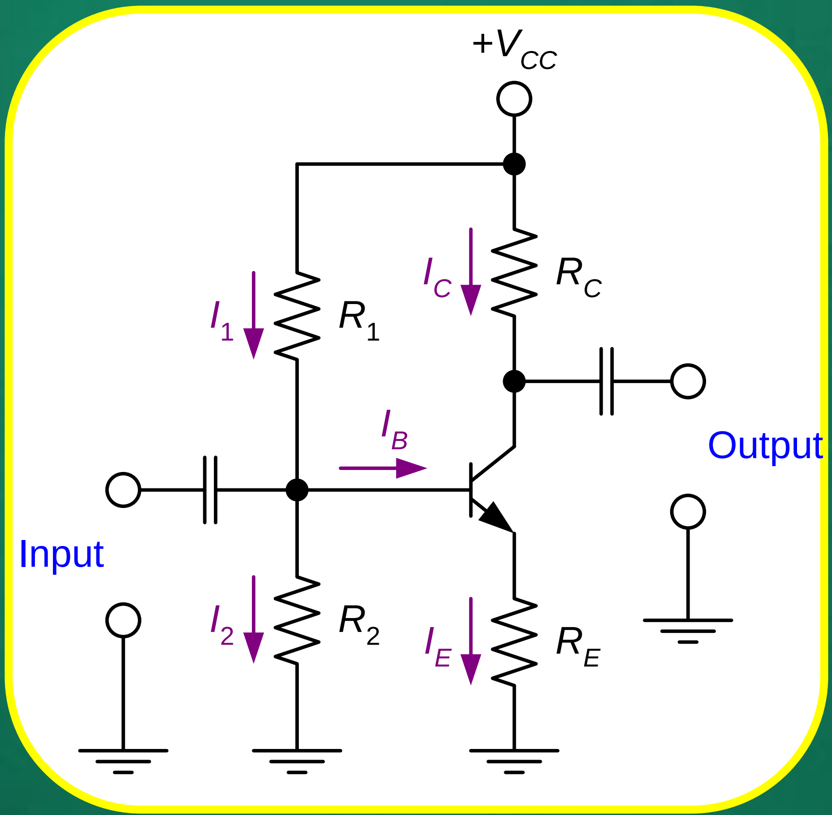
# Transistor Biasing Circuits

# Voltage Divider Bias



# Voltage Divider Bias

**Assume that** $I_2 > 10I_B$.



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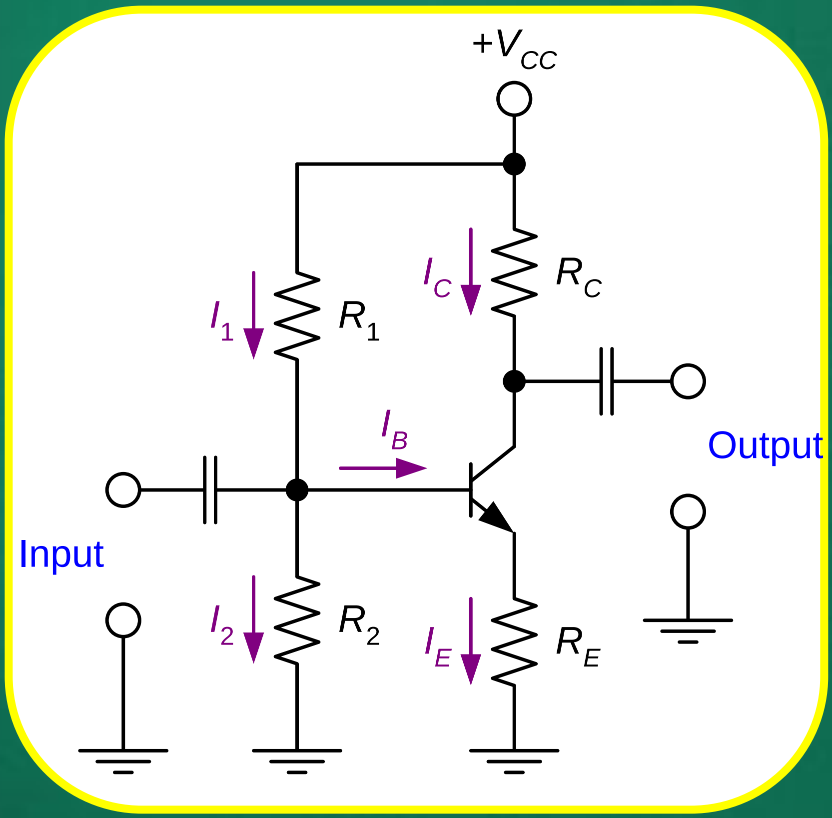

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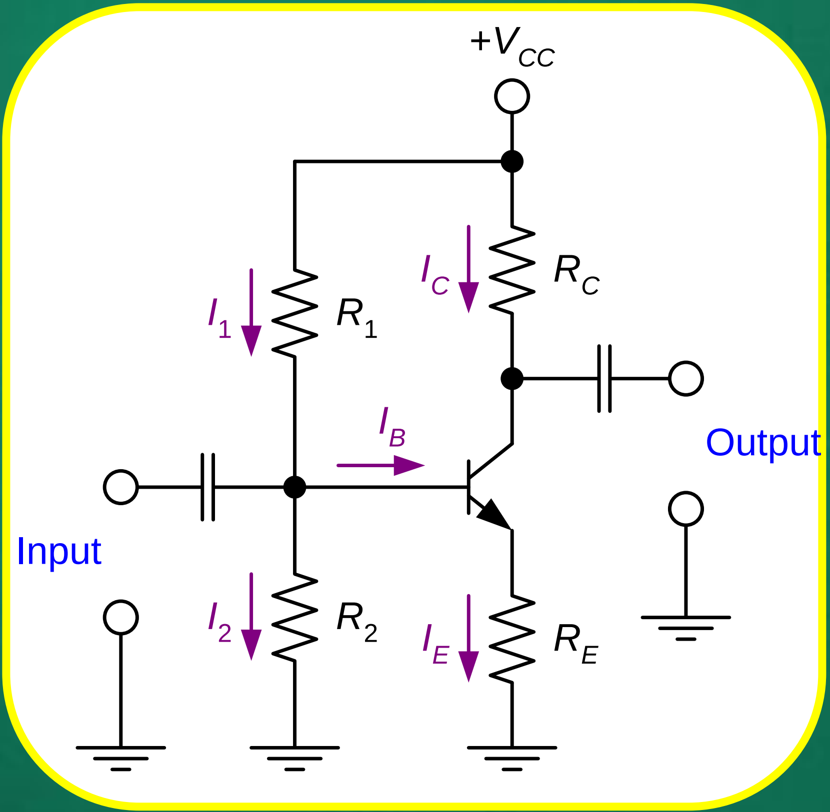


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$$V_E = V_B - 0.7\text{V}$$

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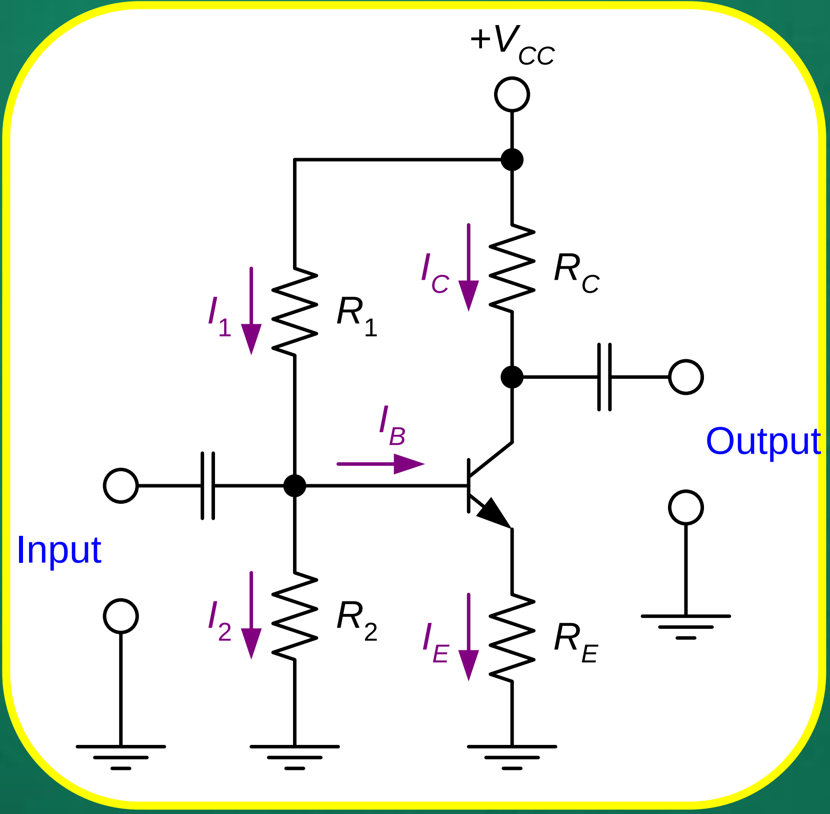


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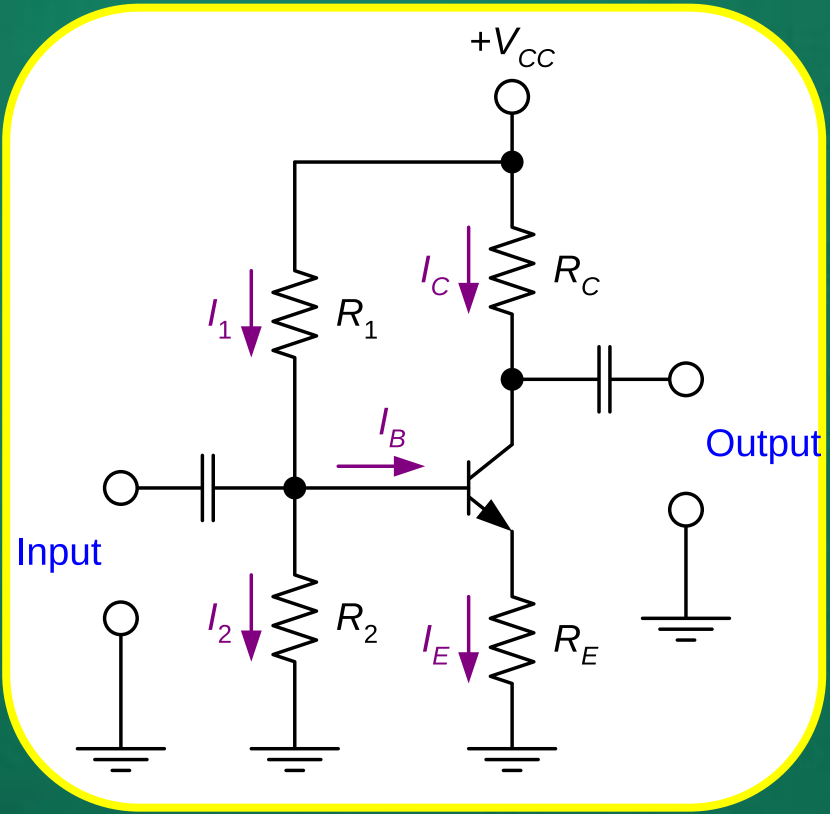


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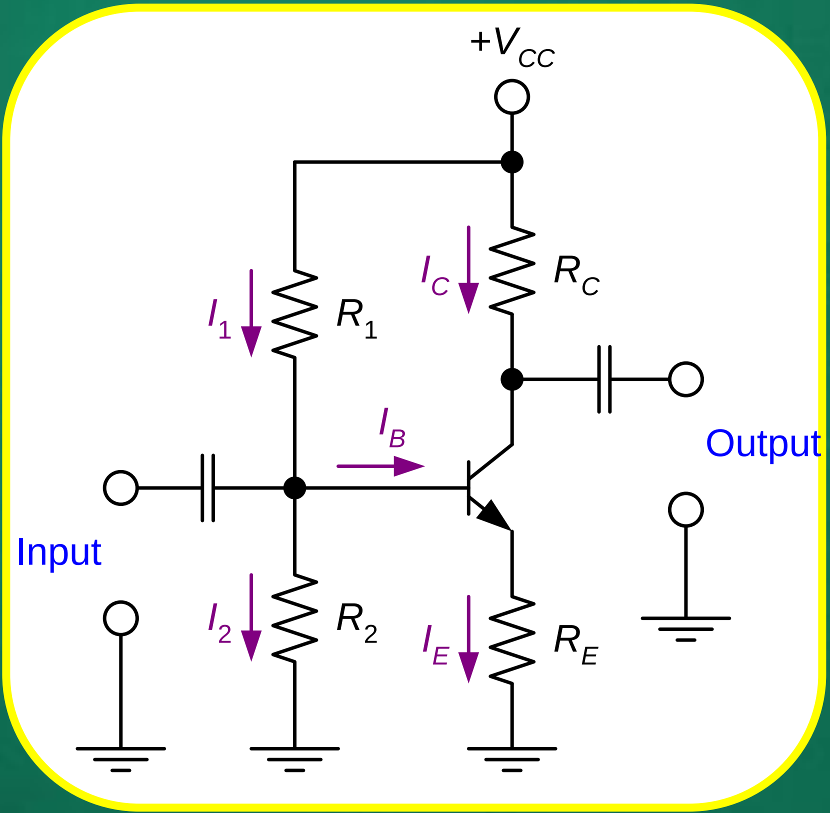


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**Assume that** $I_{CQ} \cong I_E$ **(or** $h_{FE} >> 1$**). Then**

$$V_{CEQ} = V_{CC} - I_{CQ}\left(R_C + R_E\right)$$

# Which value of $h_{FE}$ to use?

**Transistor specification sheet may list any combination of the following $h_{FE}$ : max. $h_{FE}$, min. $h_{FE}$, or typ. $h_{FE}$ . Use typical value if there is one. Otherwise, use**

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$$h_{FE(\text{ave})} = \sqrt{h_{FE(\text{min})} \times h_{FE(\text{max})}}$$

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The Q-point of voltage divider bias circuit is less dependent on $h_{FE}$ than that of the base bias (fixed bias).

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$$\text{At } h_{FE} = 100,\ I_B = \frac{I_E}{h_{FE}+1} = \frac{10\text{mA}}{101} \cong 100\mu\text{A and } I_{CQ} = I_E - I_B \cong 9.90\text{mA}$$

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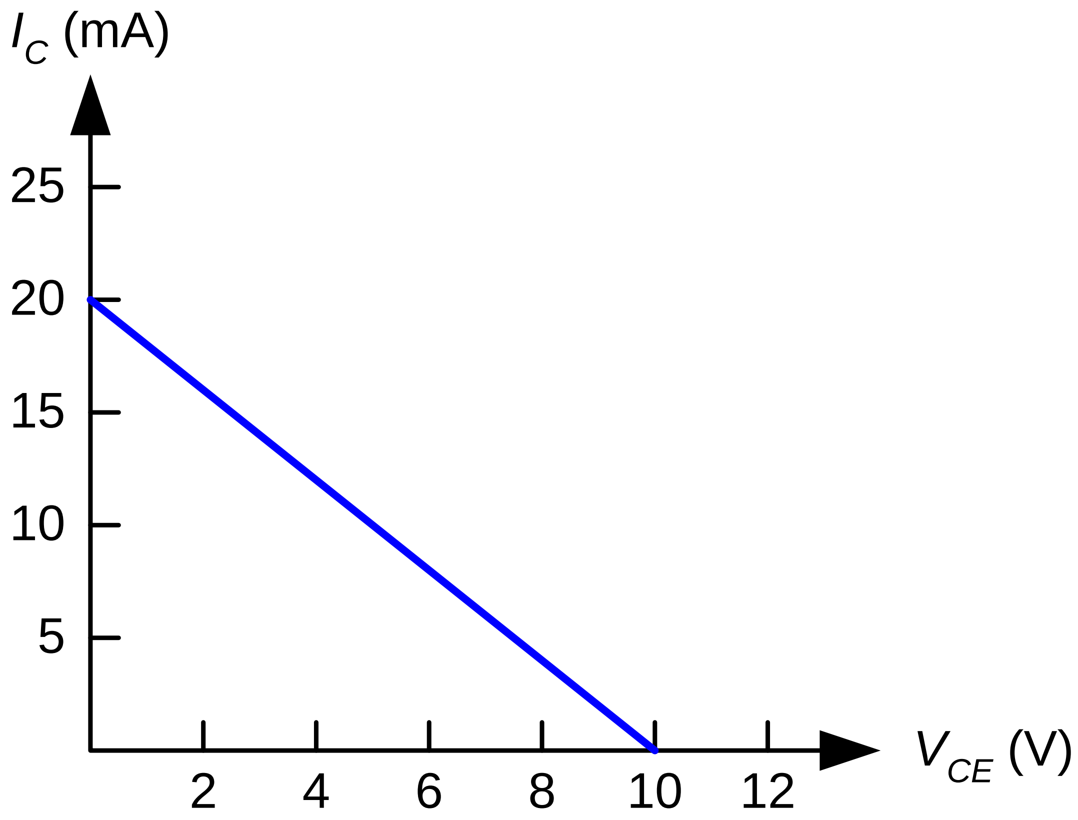
# Load Line for Voltage Divider Bias

Circuit values are from previous example



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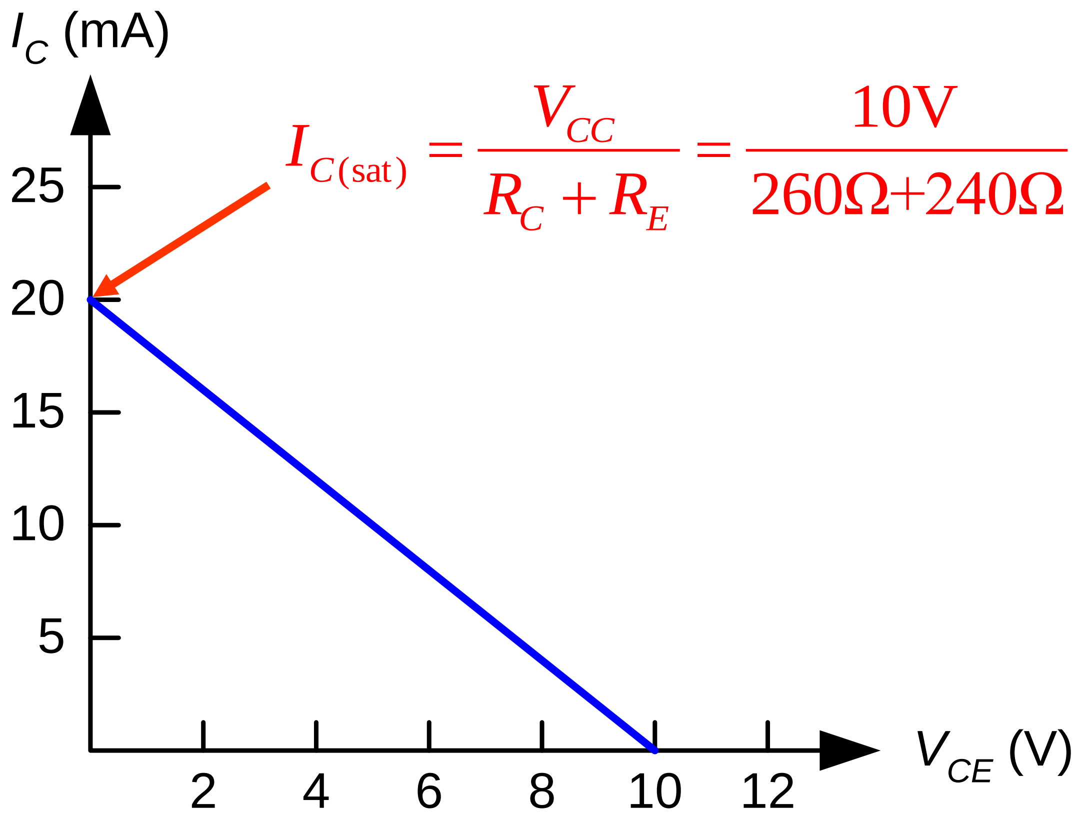


$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C + R_E} = \frac{10\text{V}}{260\Omega + 240\Omega} = 20\text{mA}$$

# Load Line for Voltage Divider Bias

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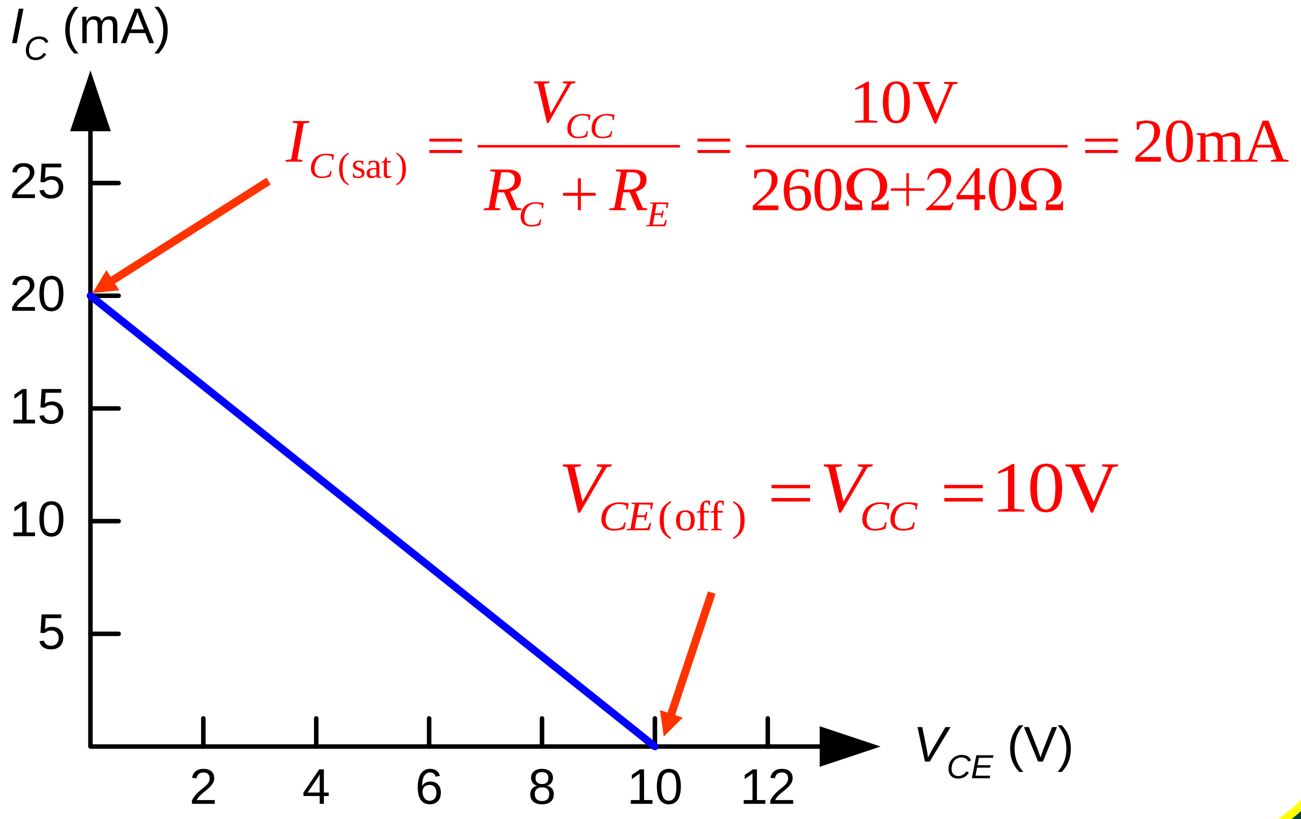
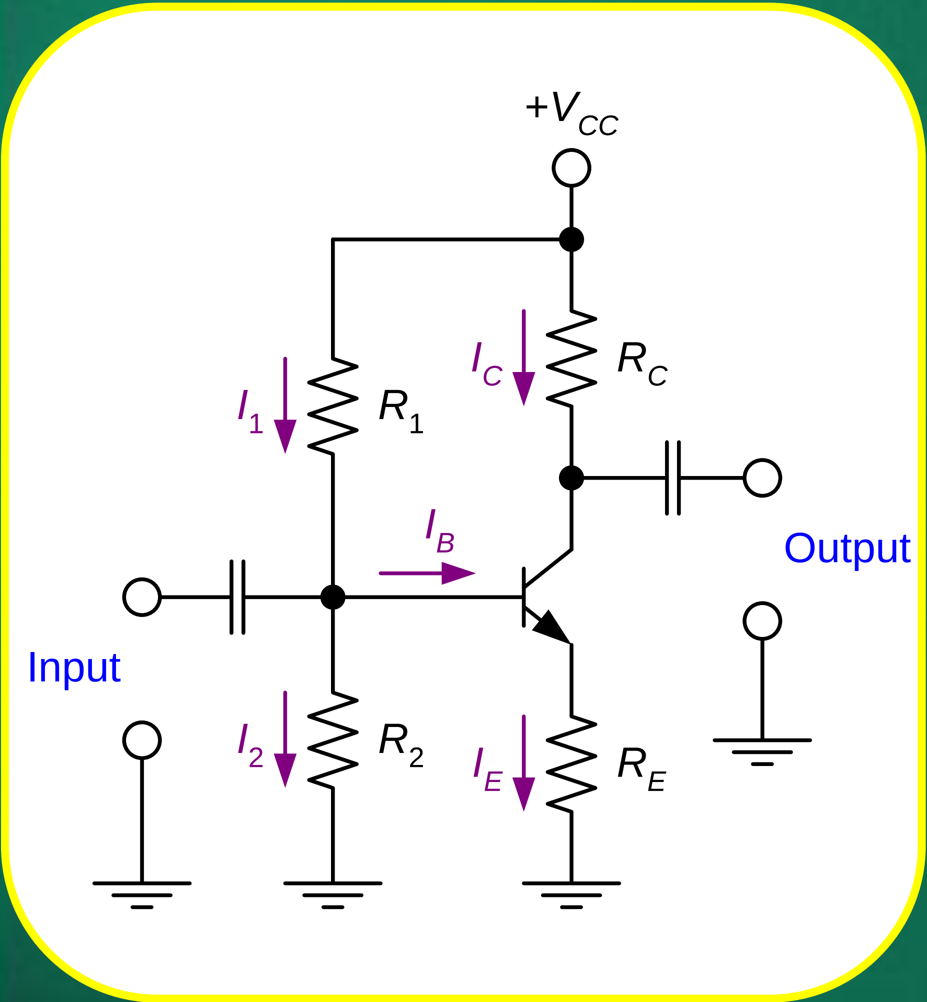


# Voltage Divider Bias Characteristics



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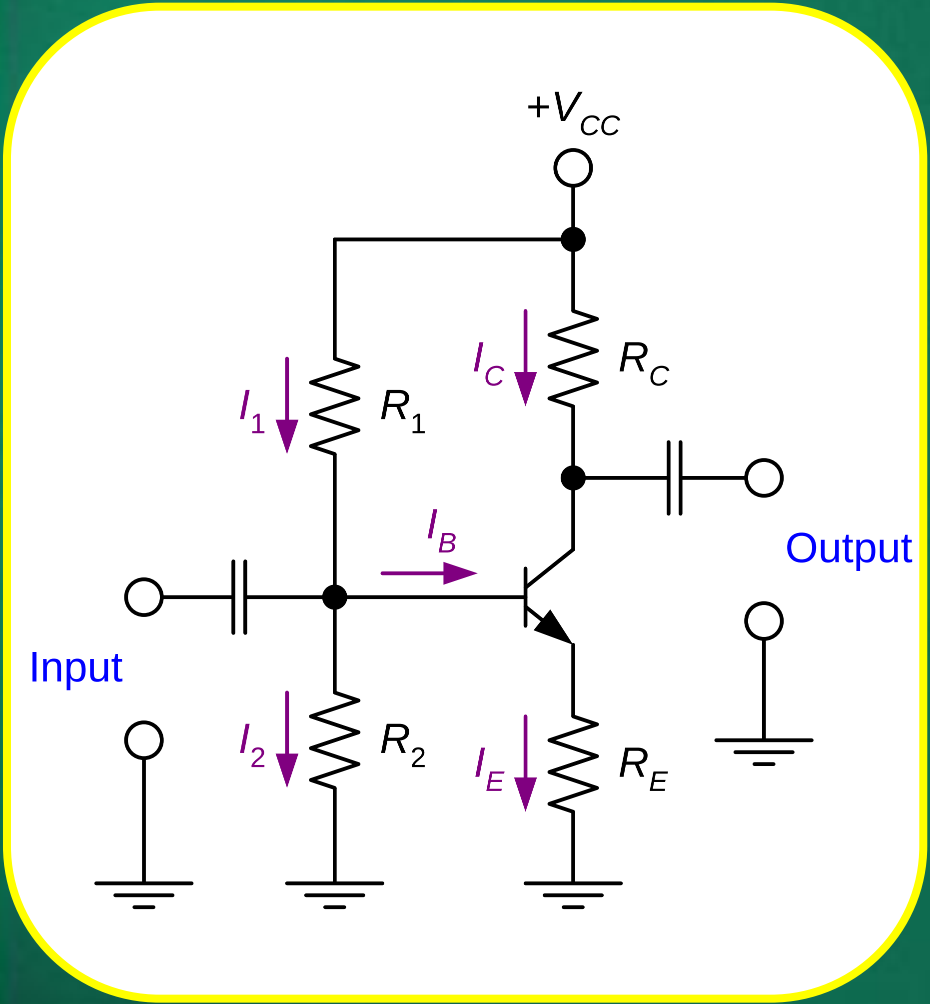


**Circuit recognition:** The voltage divider in the base circuit.

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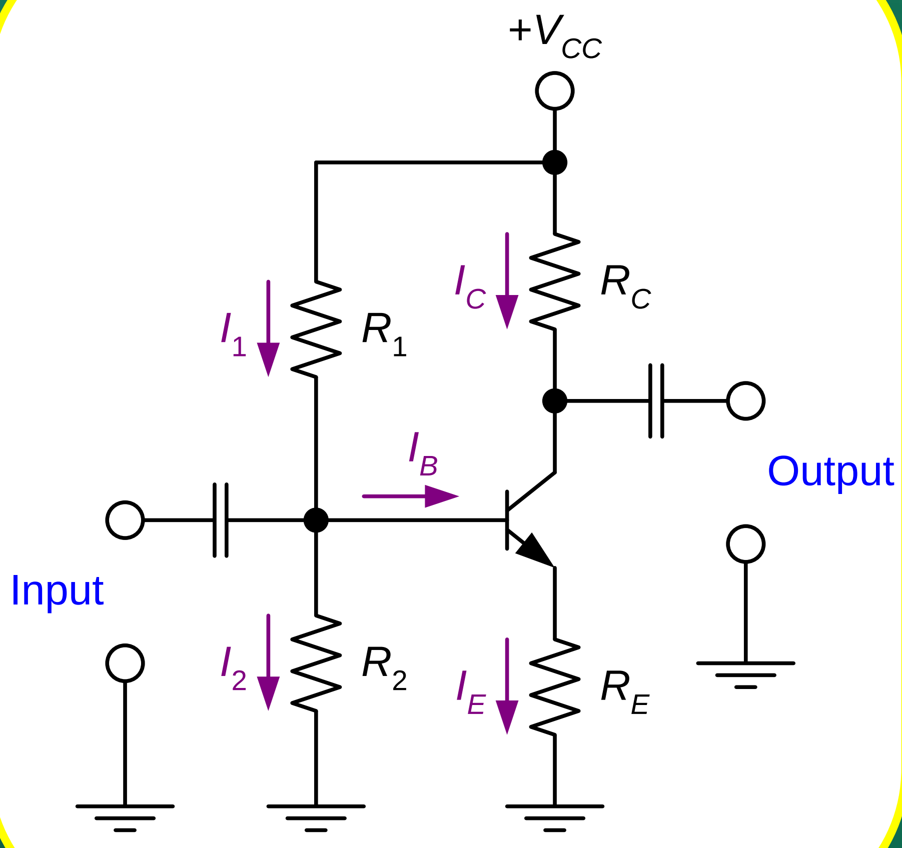


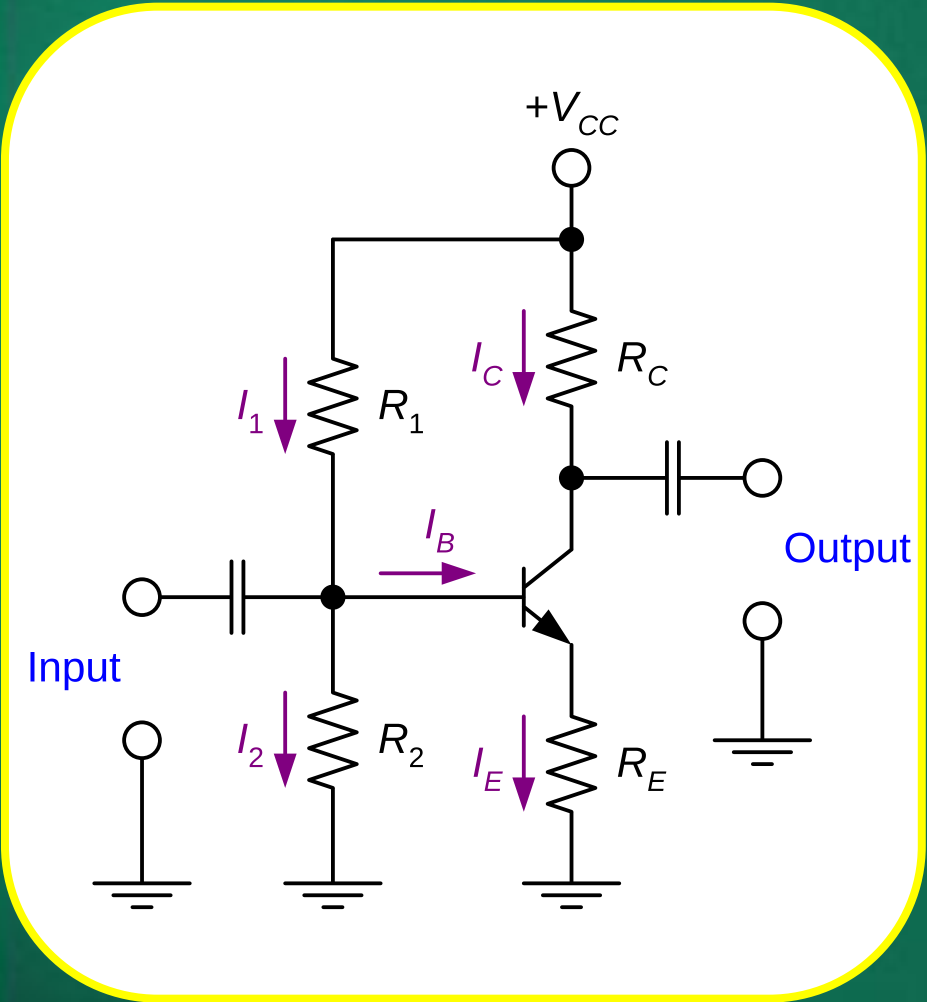

**Circuit recognition:** The voltage divider in the base circuit.

**Advantages:** The circuit Q-point values are stable against changes in $h_{FE}$.

**Disadvantages:** Requires more components than most other biasing circuits.

**Applications:** Used primarily to bias linear amplifier.

# Voltage Divider Bias Characteristics



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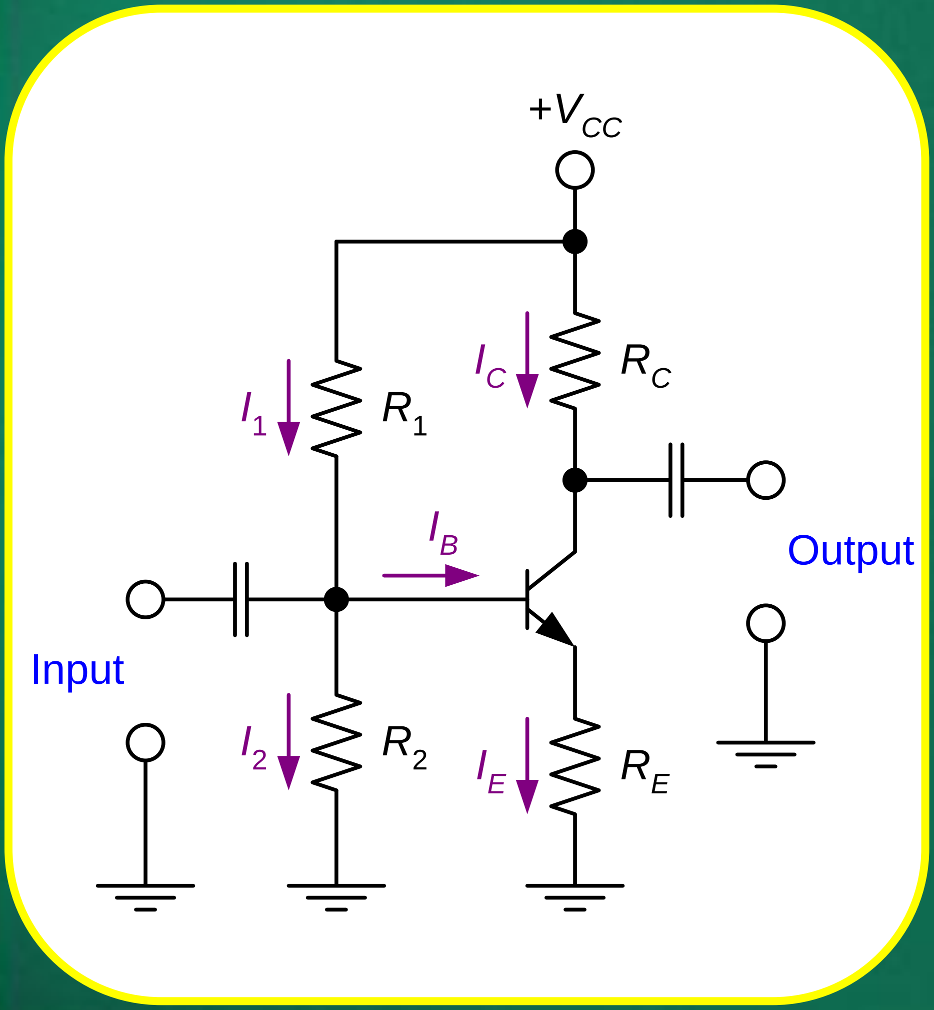


**Load line equations:**

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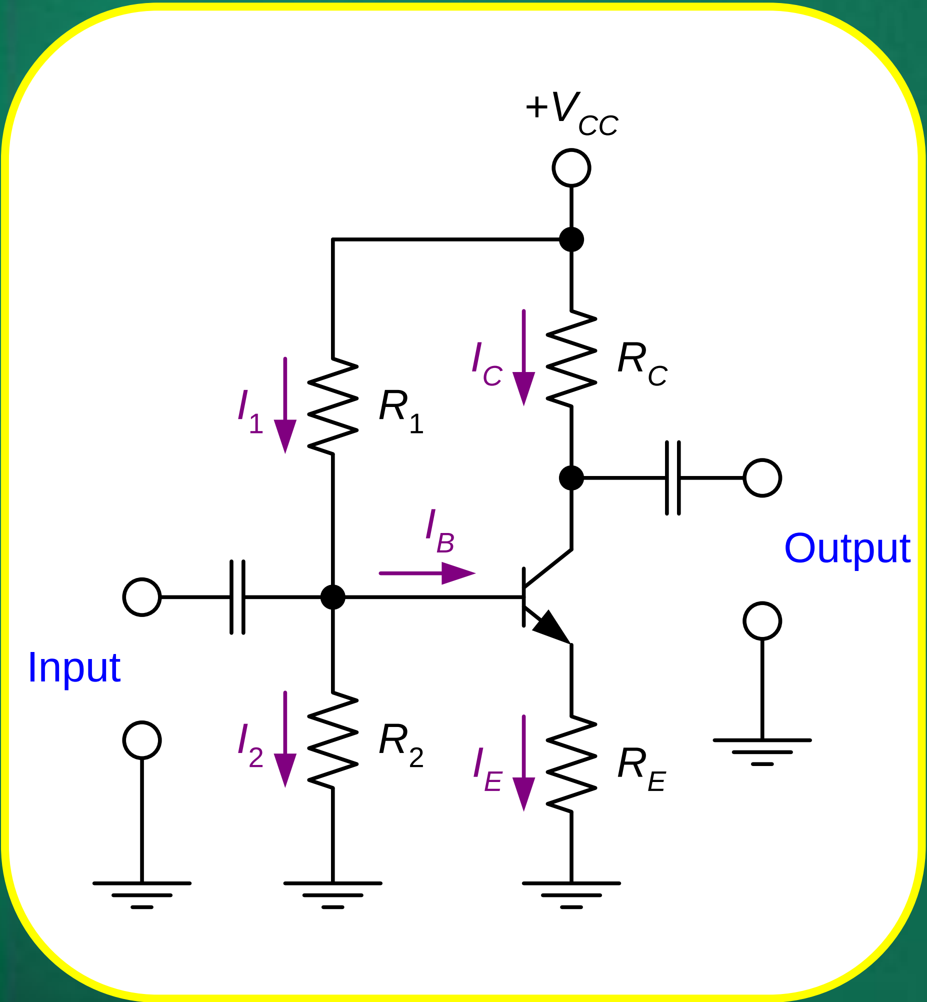


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$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C + R_E}$$

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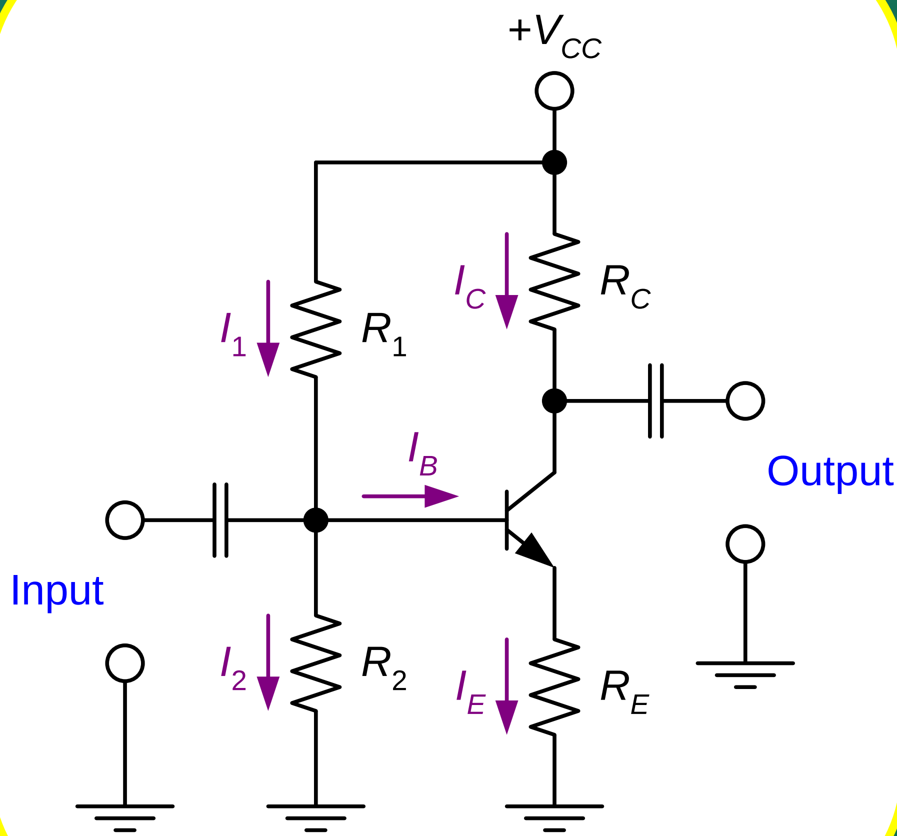


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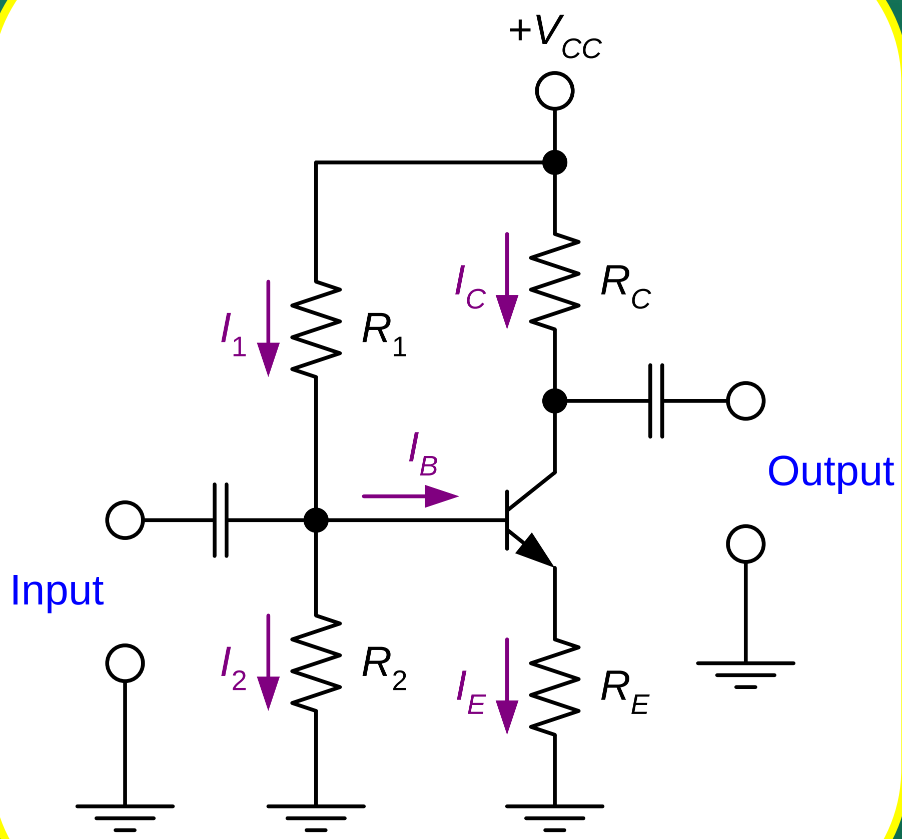


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$$V_B = V_{CC}\frac{R_2}{R_1 + R_2}$$

$$V_E = V_B - 0.7\text{V}$$

$$I_{CQ} \cong I_E = \frac{V_E}{R_E}$$

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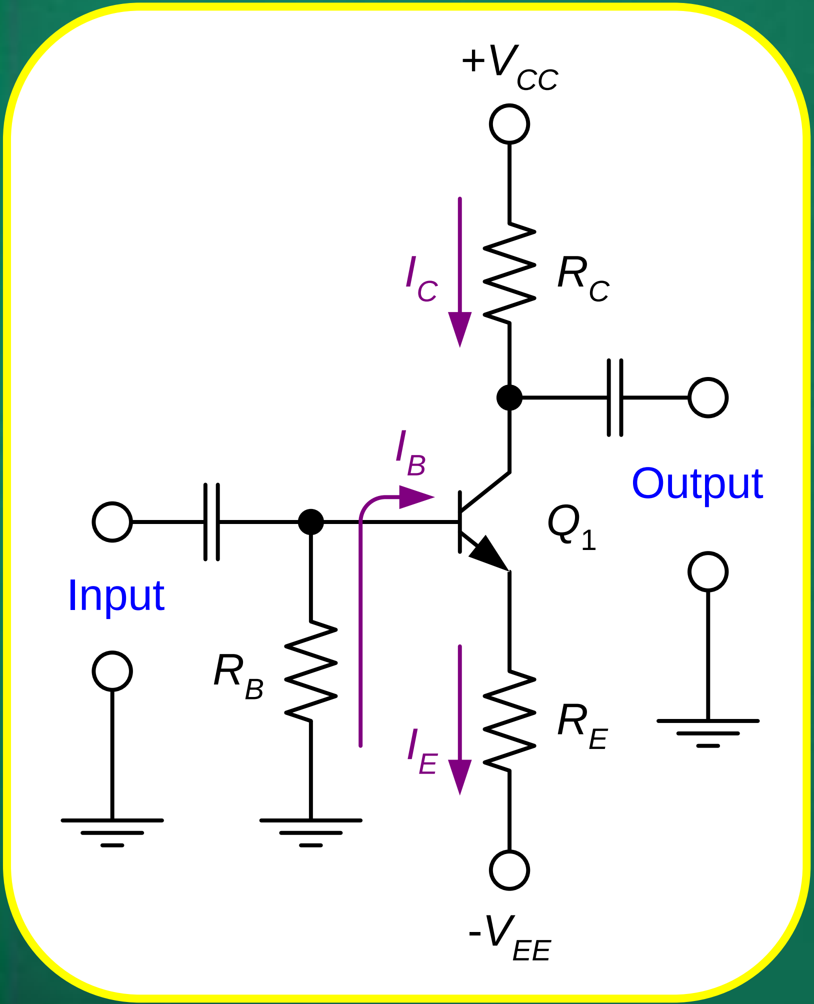
# Other Transistor Biasing Circuits

- Emitter Bias Circuits

- Feedback Bias Circuits
  - Collector Feedback Bias
  - Emitter Feedback Bias

# Emitter Bias



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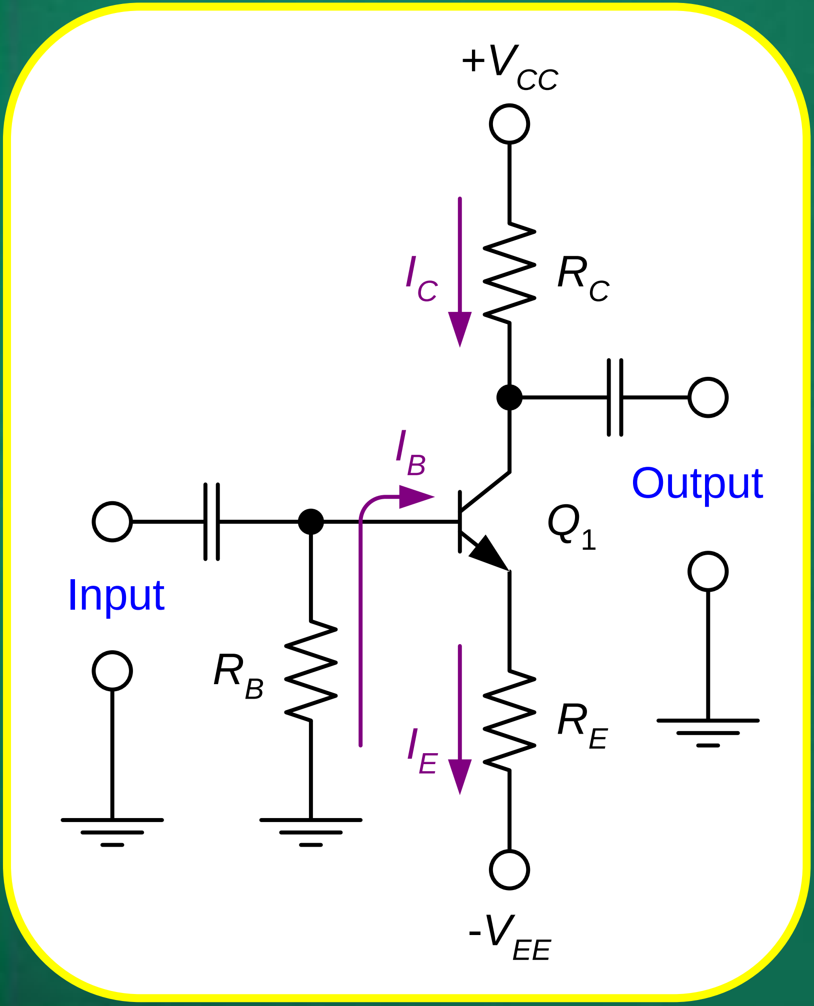


**Assume that the transistor operation is in active region.**

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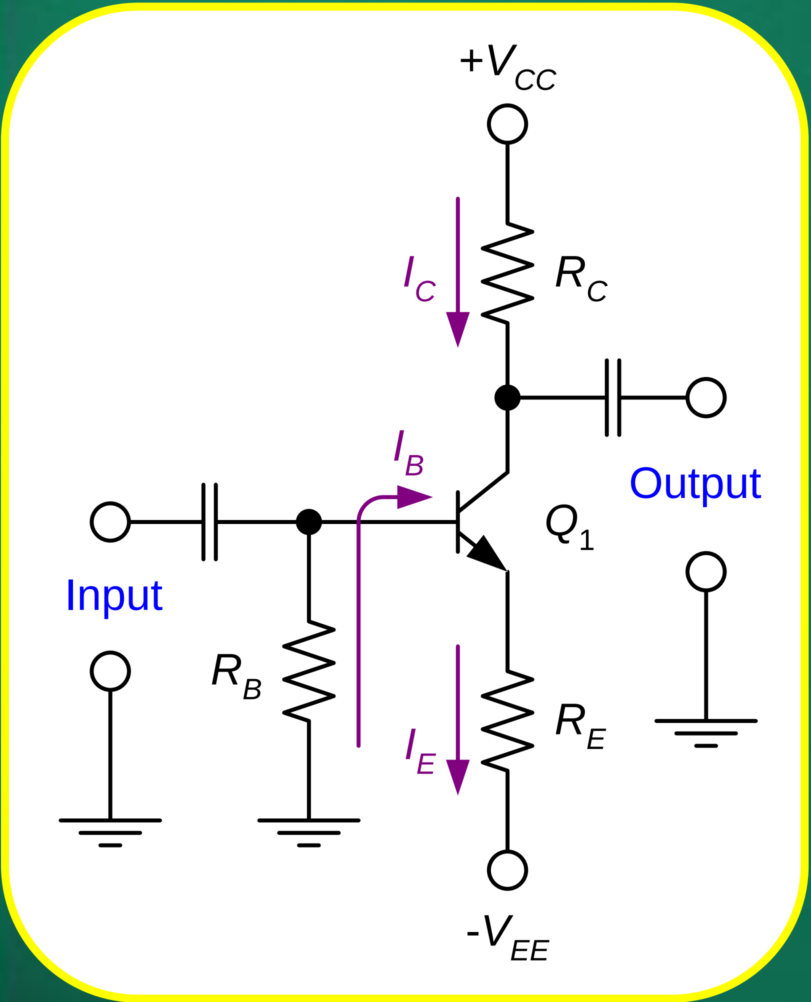


**Assume that the transistor operation is in active region.**

$$I_B = \frac{V_{EE} - 0.7\text{V}}{R_B + (h_{FE} + 1)R_E}$$

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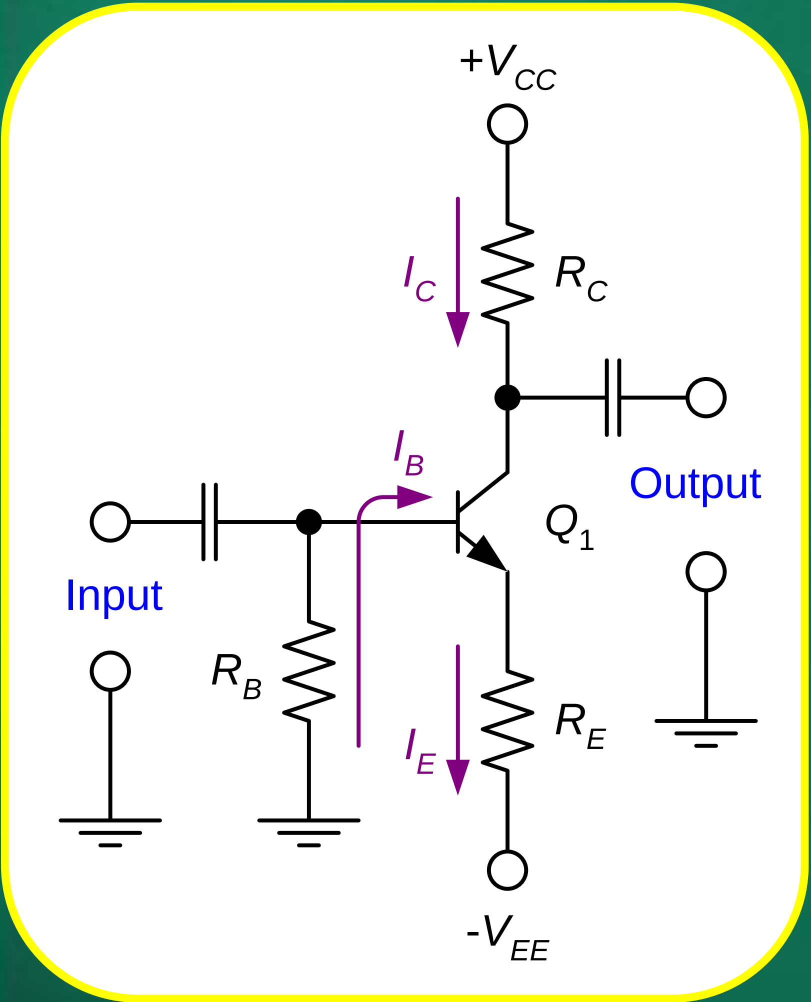


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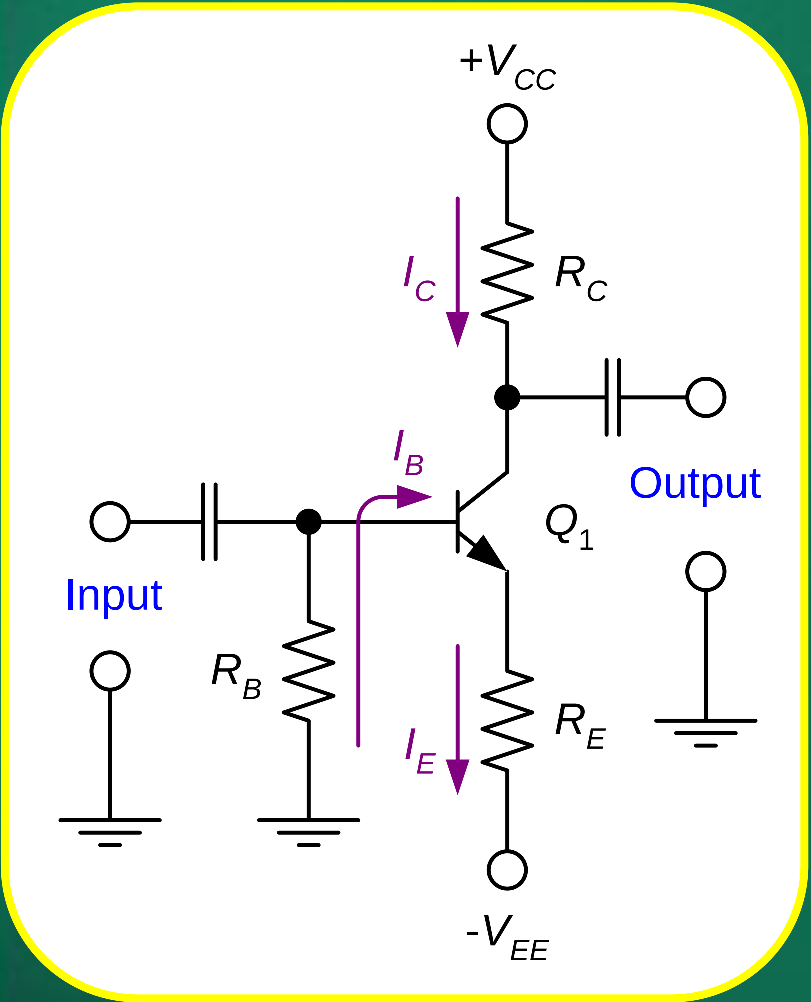


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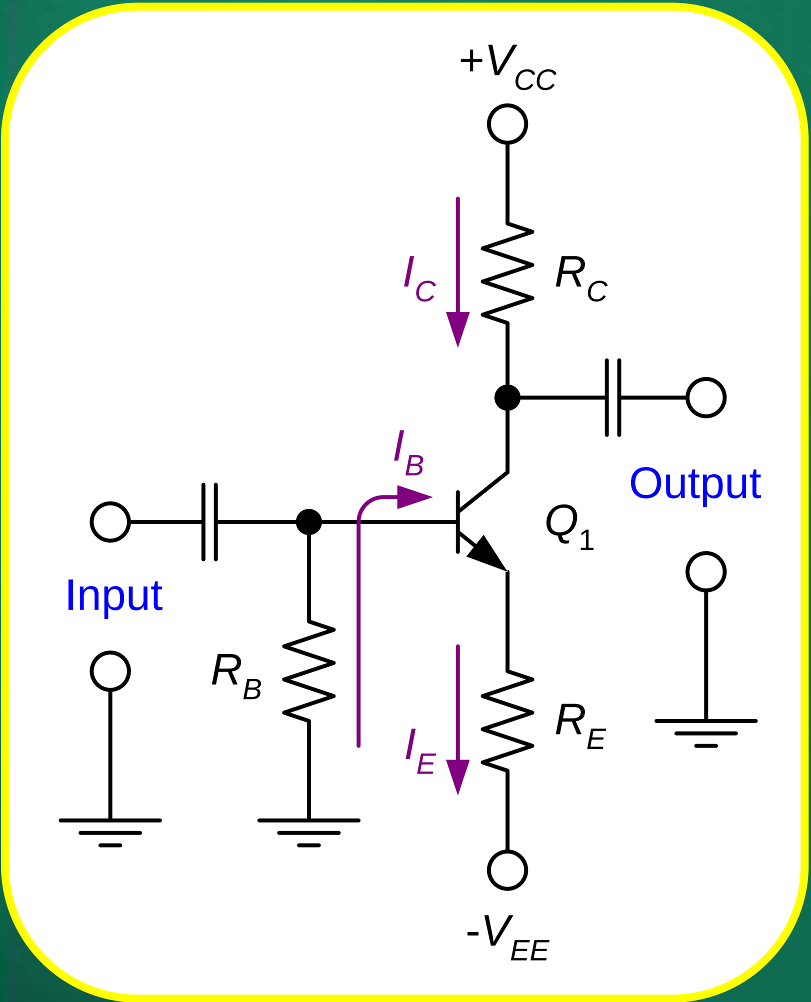


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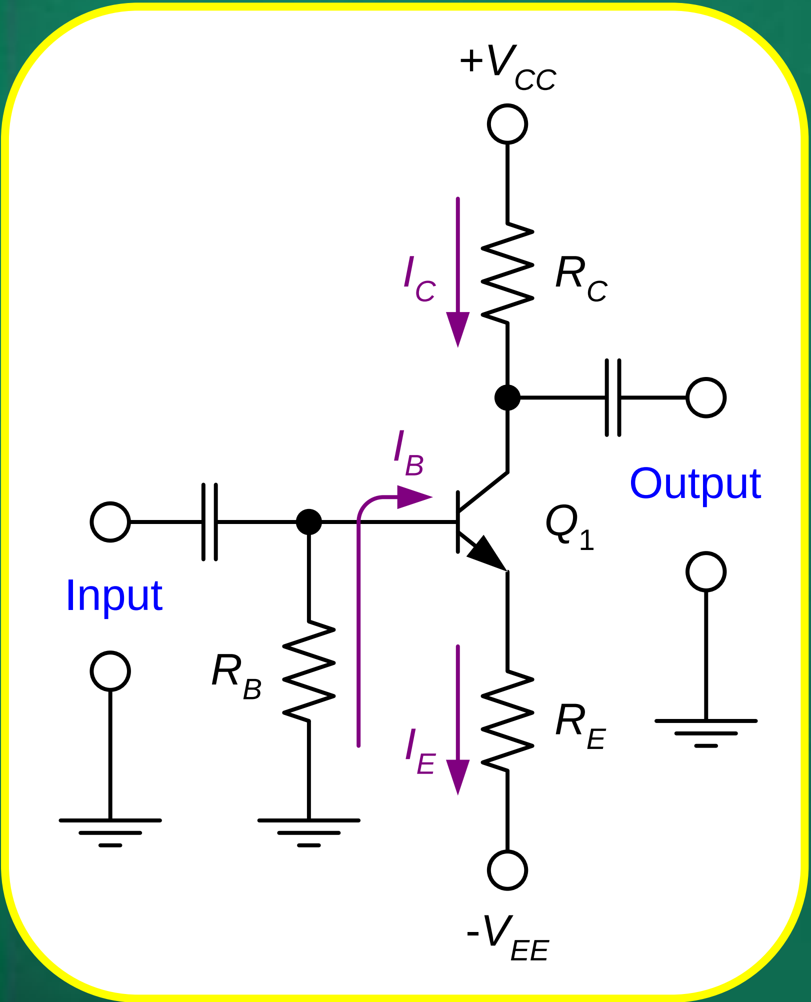


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**Assume that** $h_{FE} >> 1$**.**

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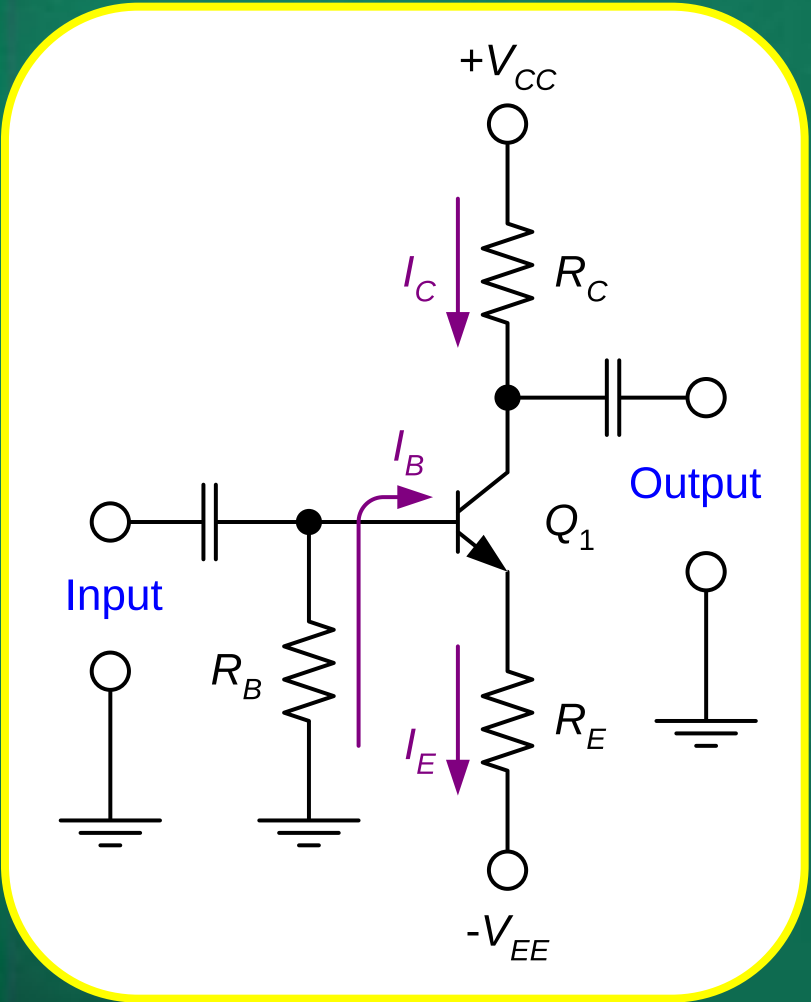


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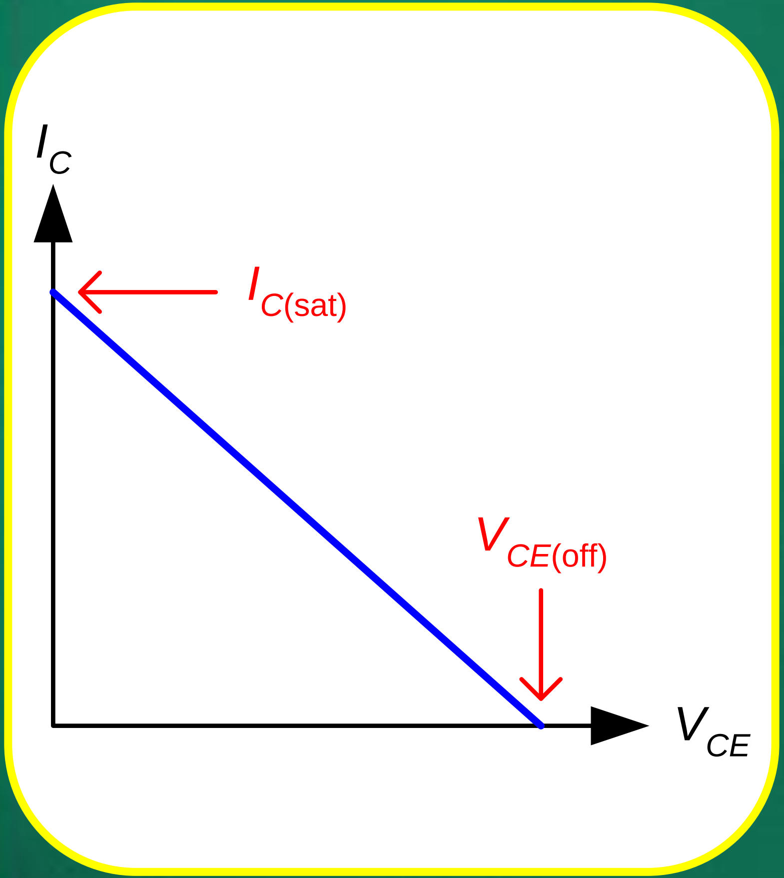
$$V_{CE} \cong V_{CC} - I_C (R_C + R_E) + V_{EE}$$

# Load Line for Emitter Bias Circuit



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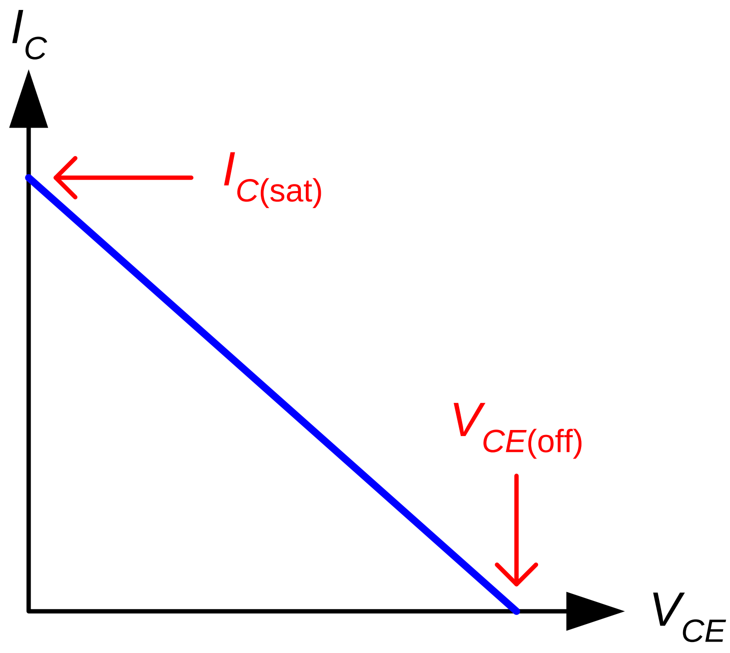


$$I_{C(\mathrm{sat})} = \frac{V_{CC} - (-V_{EE})}{R_C + R_E} = \frac{V_{CC} + V_{EE}}{R_C + R_E}$$

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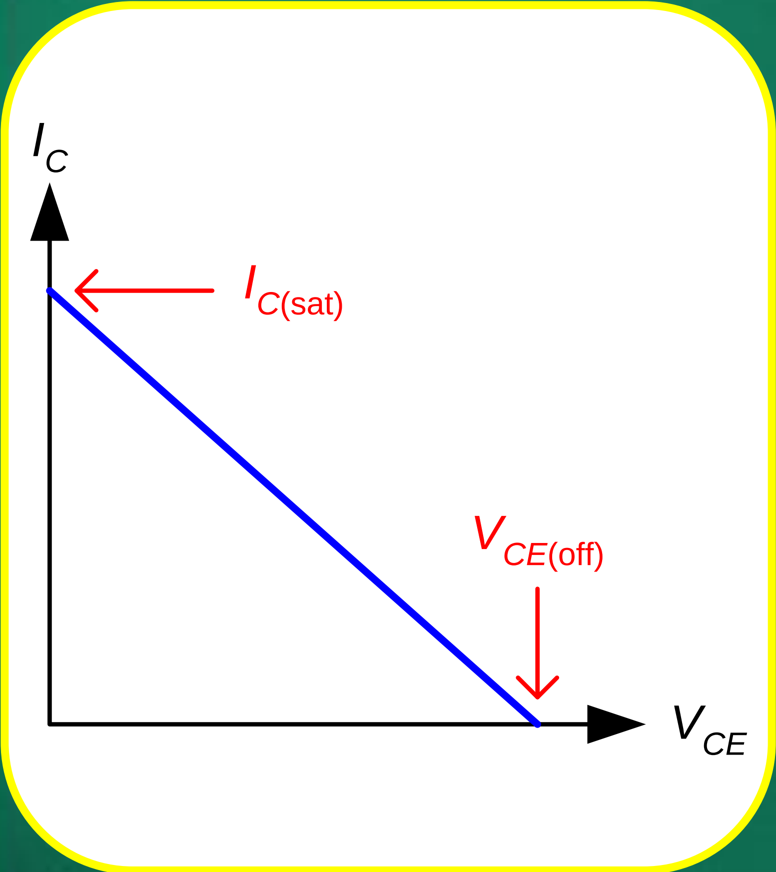


$$I_{C(sat)} = \frac{V_{CC} - (-V_{EE})}{R_C + R_E} = \frac{V_{CC} + V_{EE}}{R_C + R_E}$$

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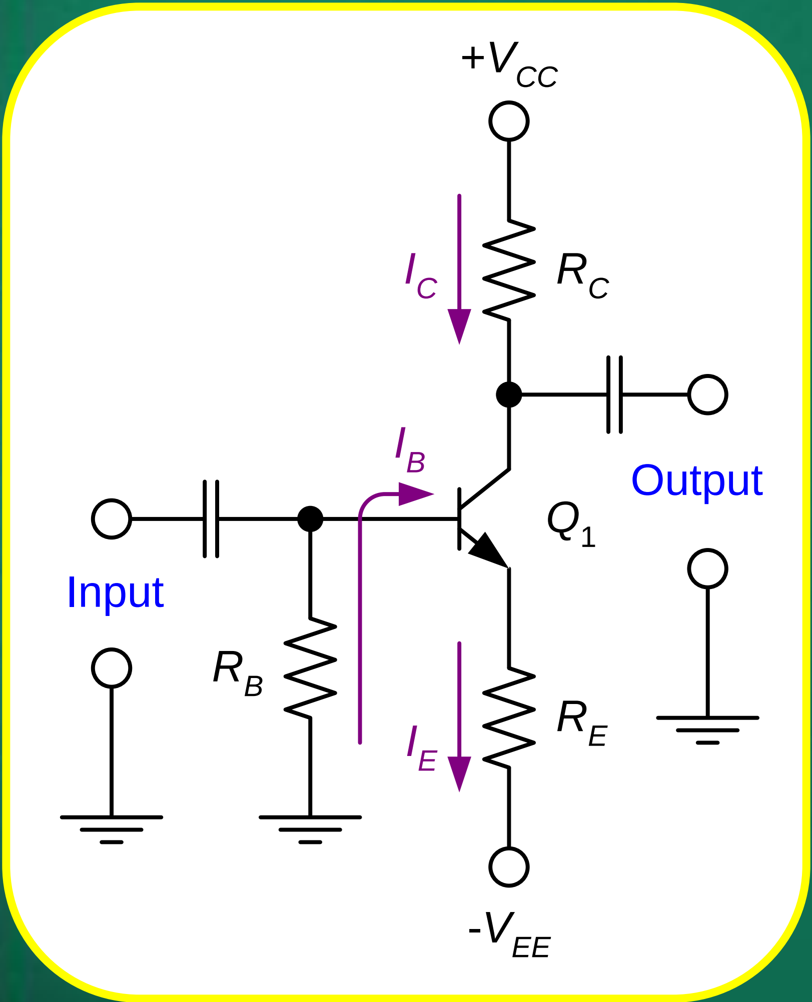
# Emitter Bias Characteristics



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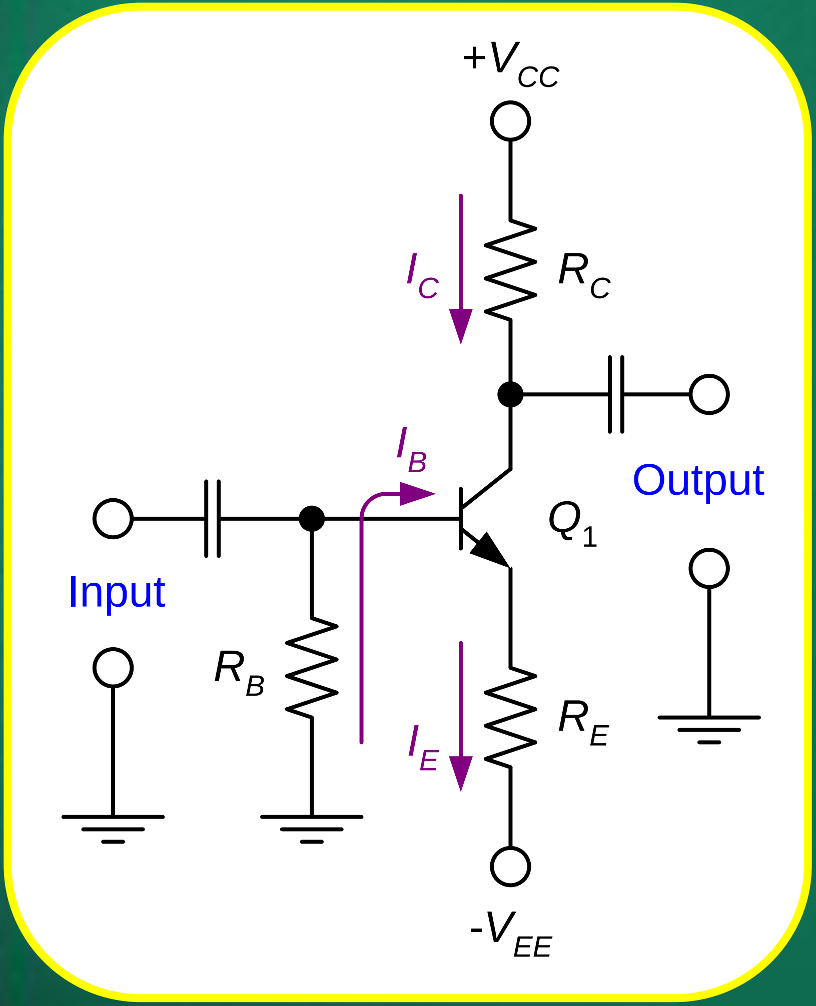


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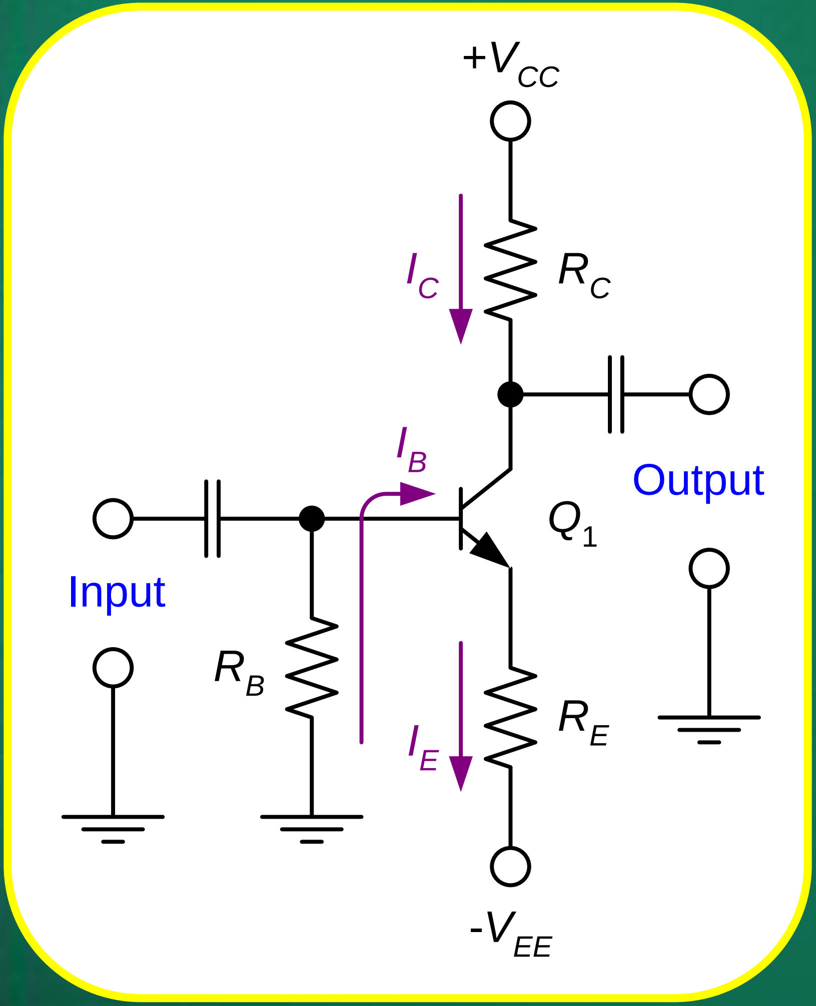


**Circuit recognition:** A split (dual-polairty) power supply and the base resistor is connected to ground.

**Advantage:** The circuit Q-point values are stable against changes in $h_{FE}$.

**Disadvantage:** Requires the use of dual-polarity power supply.

**Applications:** Used primarily to bias linear amplifiers.

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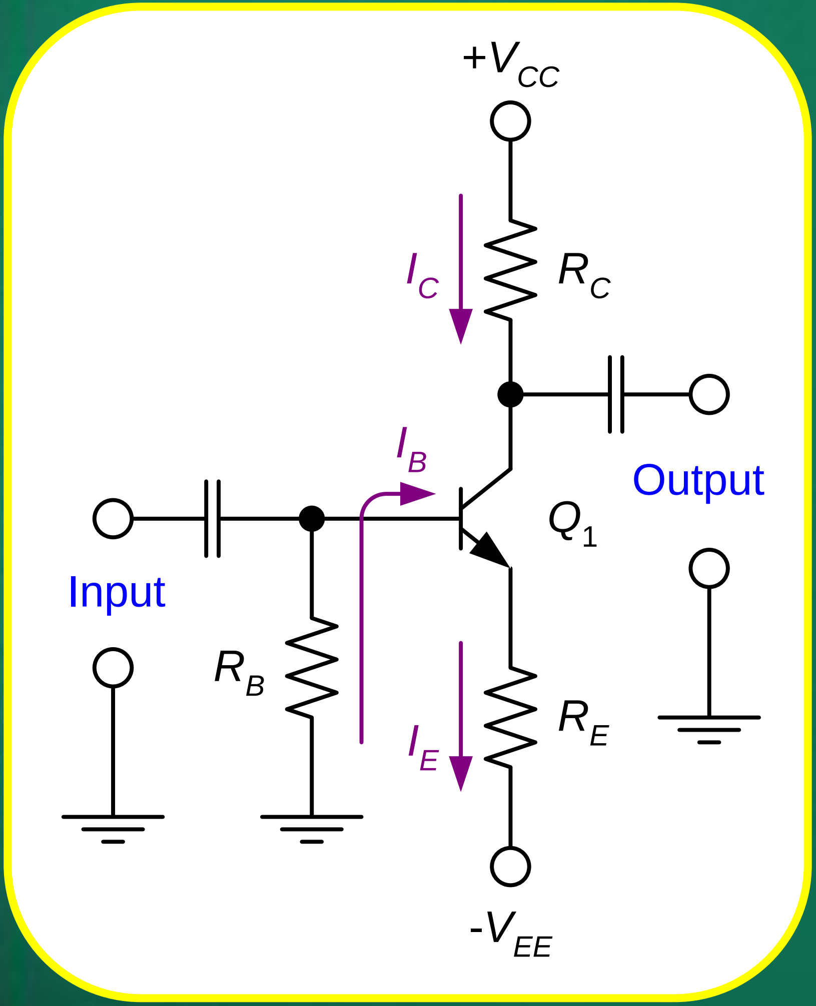

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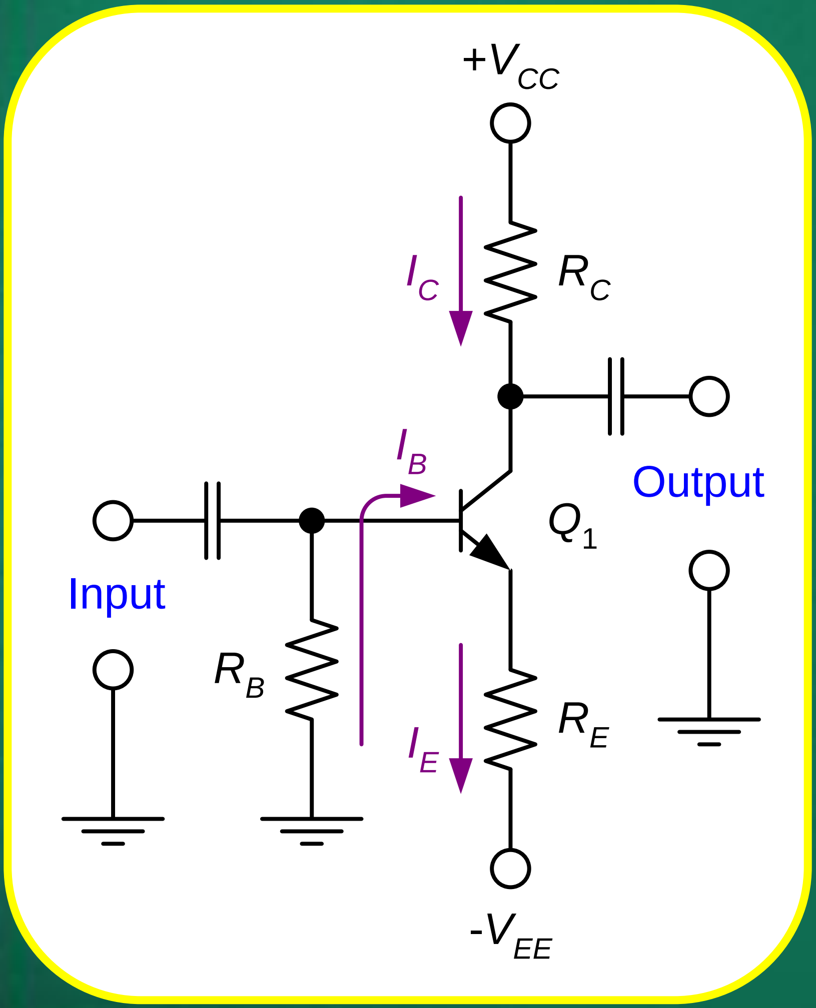


**Load line equations:**

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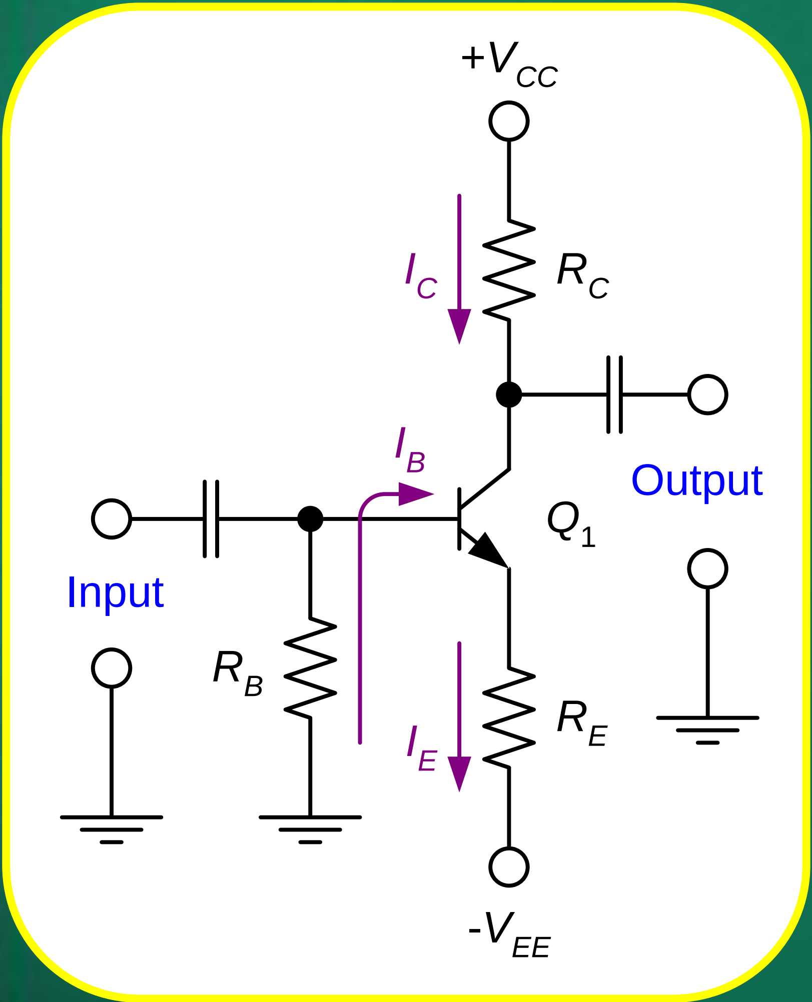


**Load line equations:**

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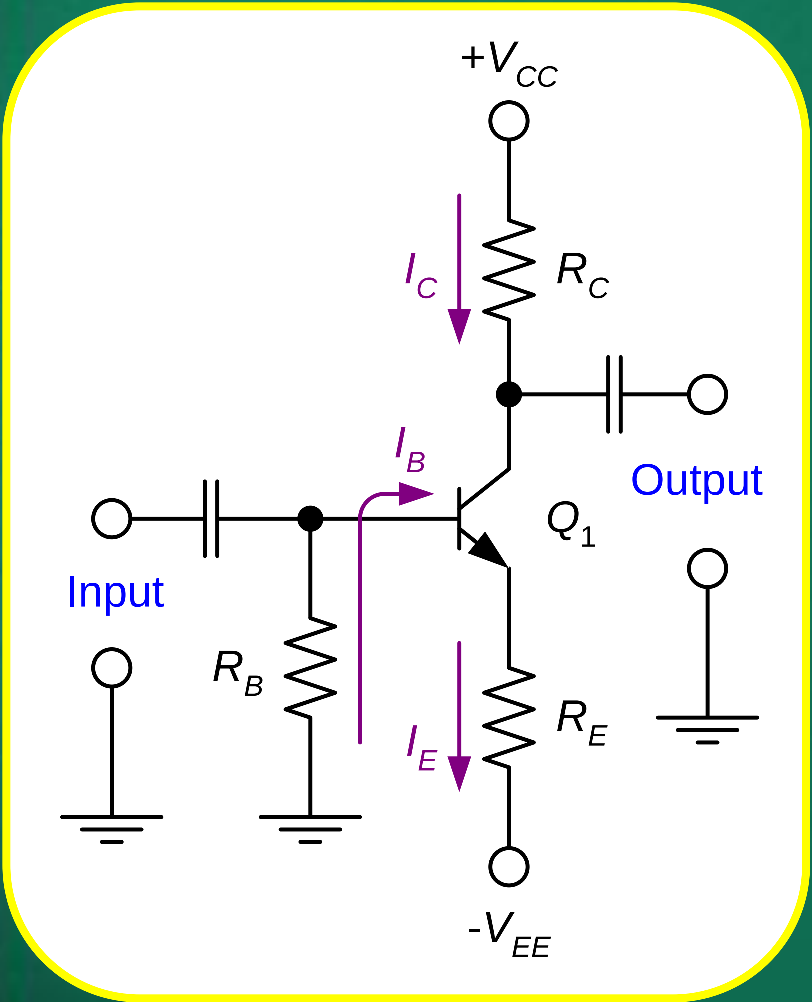


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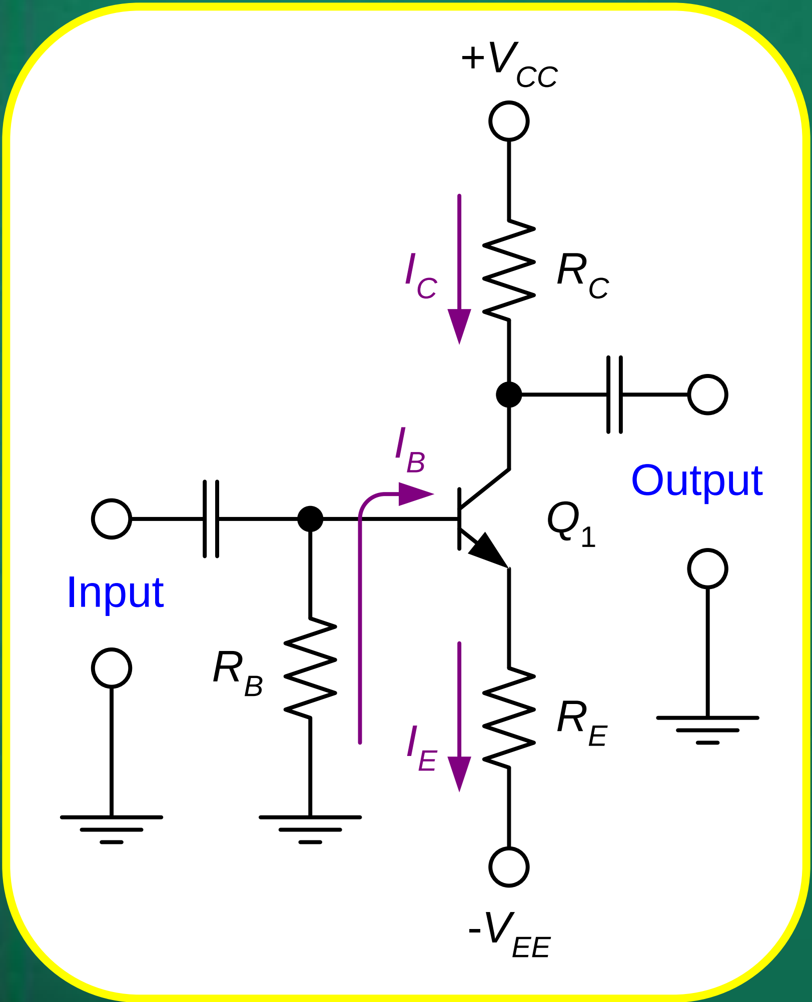


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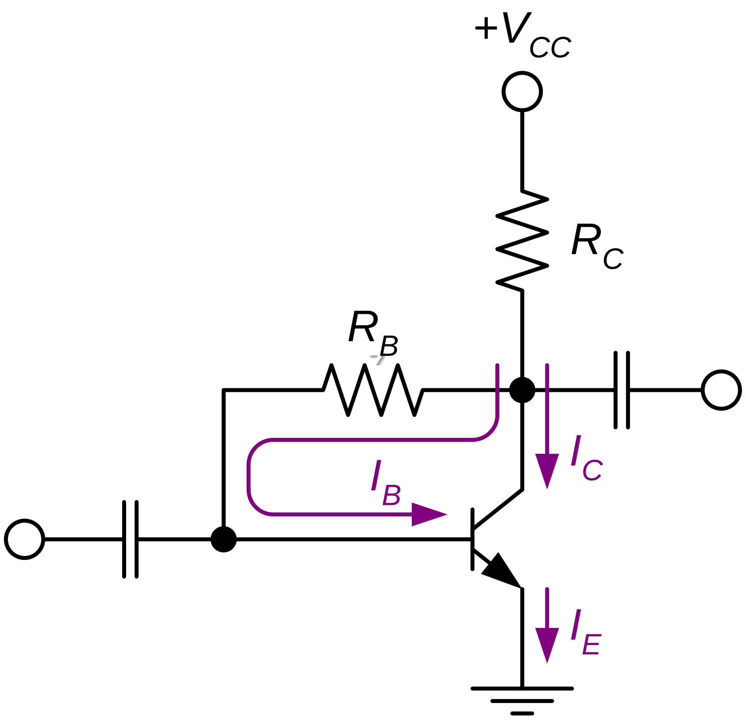
## Q-point equations:

$$I_{CQ} = (h_{FE}) \frac{-V_{BE} + V_{EE}}{R_B + (h_{FE} + 1) R_E}$$

$$V_{CEQ} \cong V_{CC} - I_{CQ}(R_C + R_E) + V_{EE}$$

# Collector Feedback Bias



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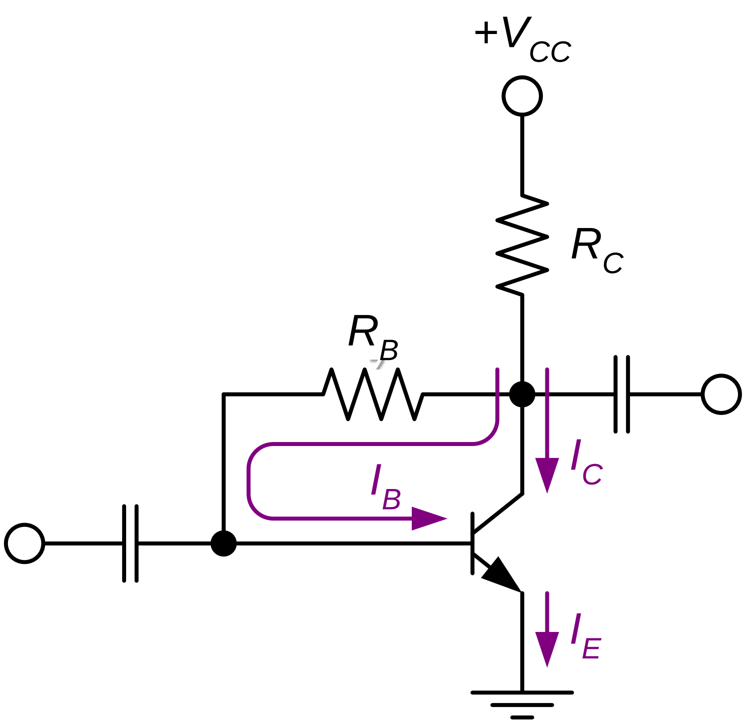


$$V_{CC} = \left(I_C + I_B\right) R_C + I_B R_B + V_{BE}$$

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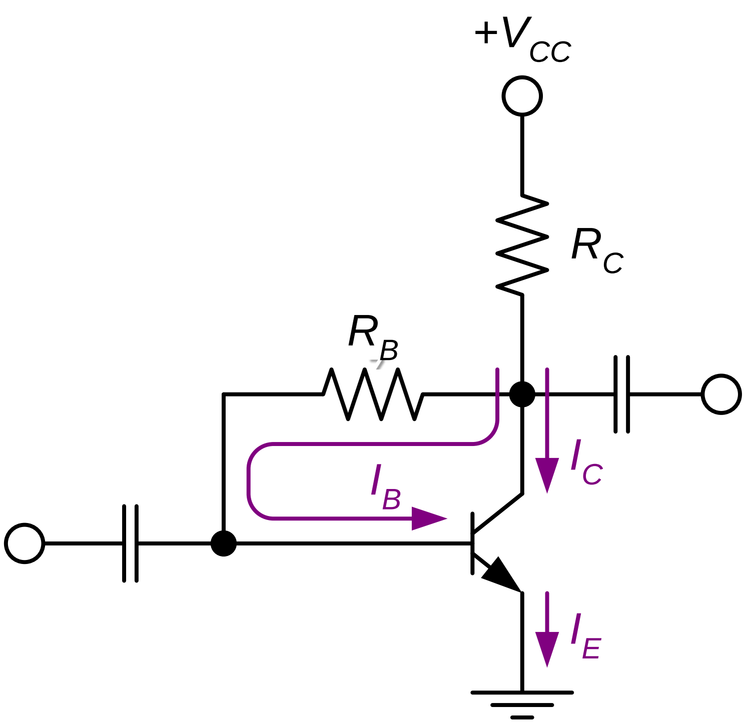


$$V_{CC} = \left(I_C + I_B\right) R_C + I_B R_B + V_{BE}$$

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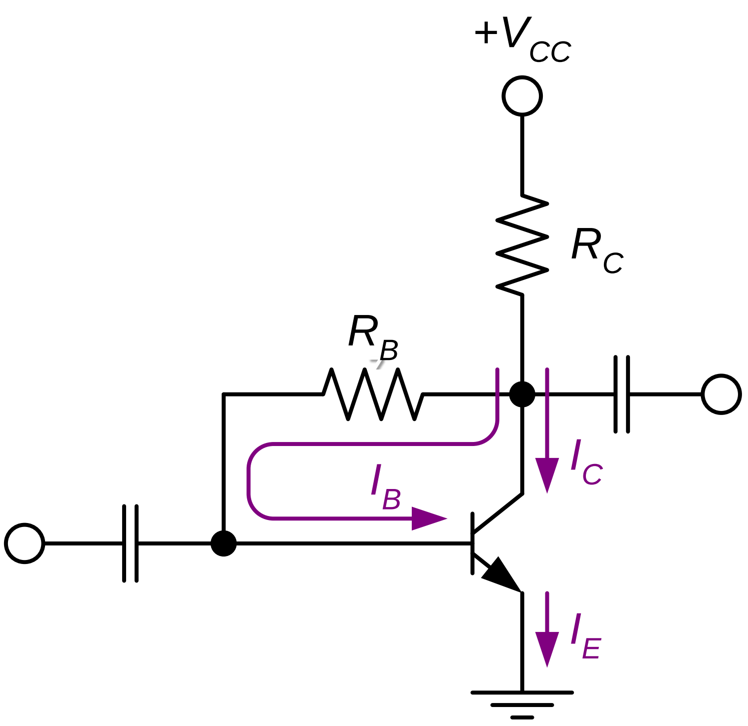


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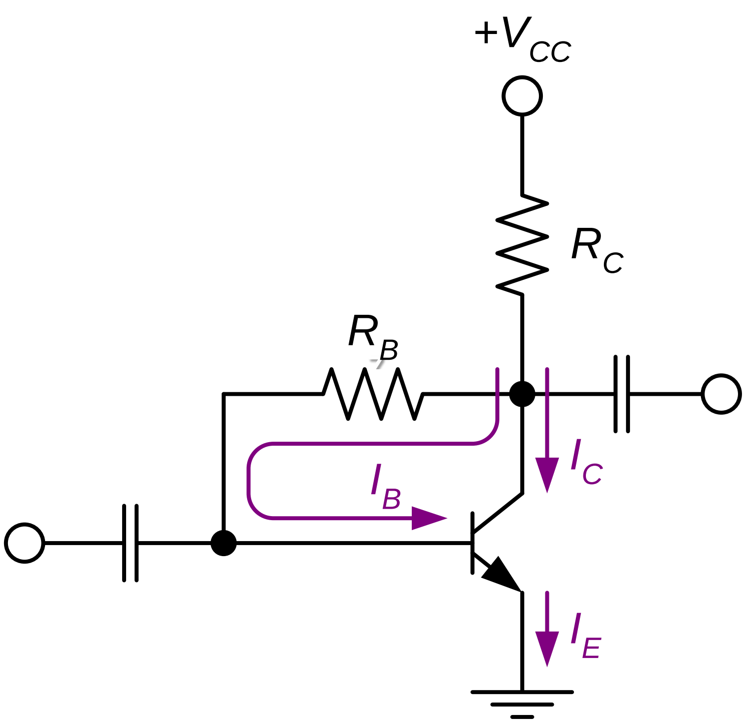


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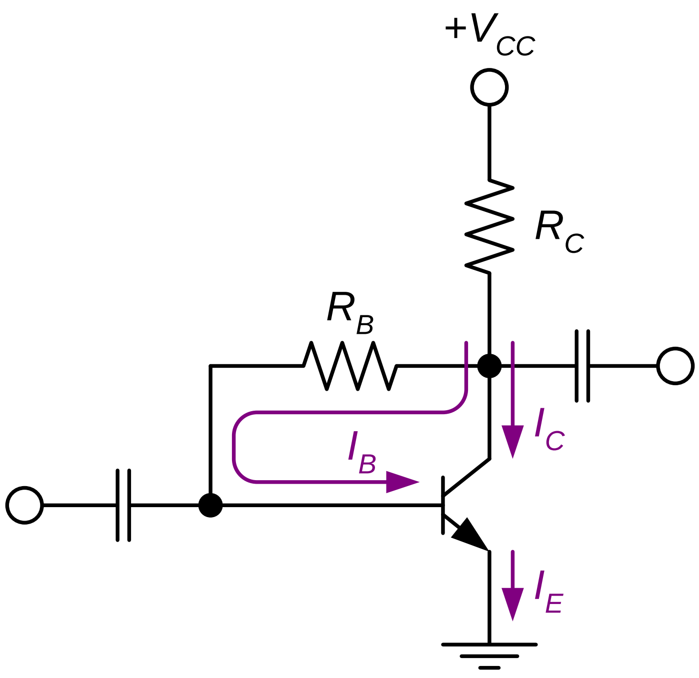
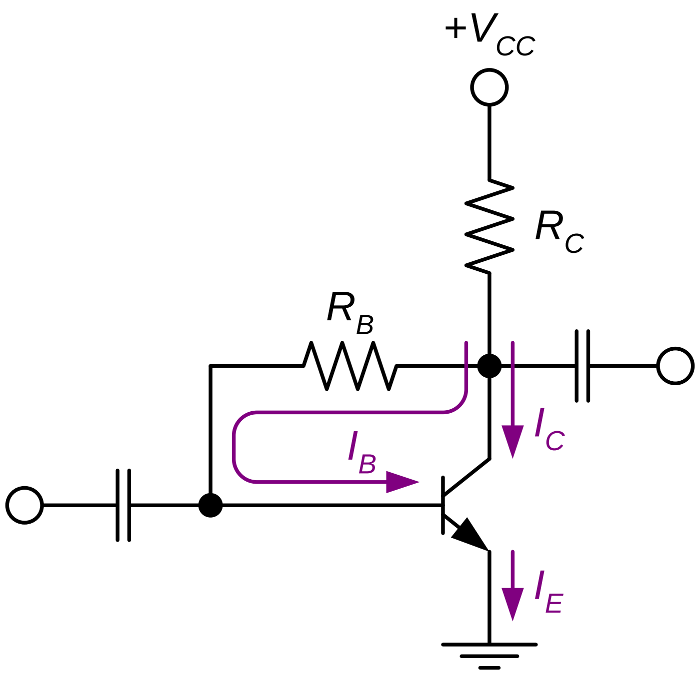
$$\begin{aligned} V_{CEQ} &= V_{CC} - \left(h_{FE} + 1\right) I_B R_C \\ &\cong V_{CC} - I_{CQ} R_C \end{aligned}$$

# Circuit Stability



# Circuit Stability




$h_{FE}$ increases

↓

$I_C$ increases (if $I_B$ is the same)

↓

$V_{CE}$ decreases

↓

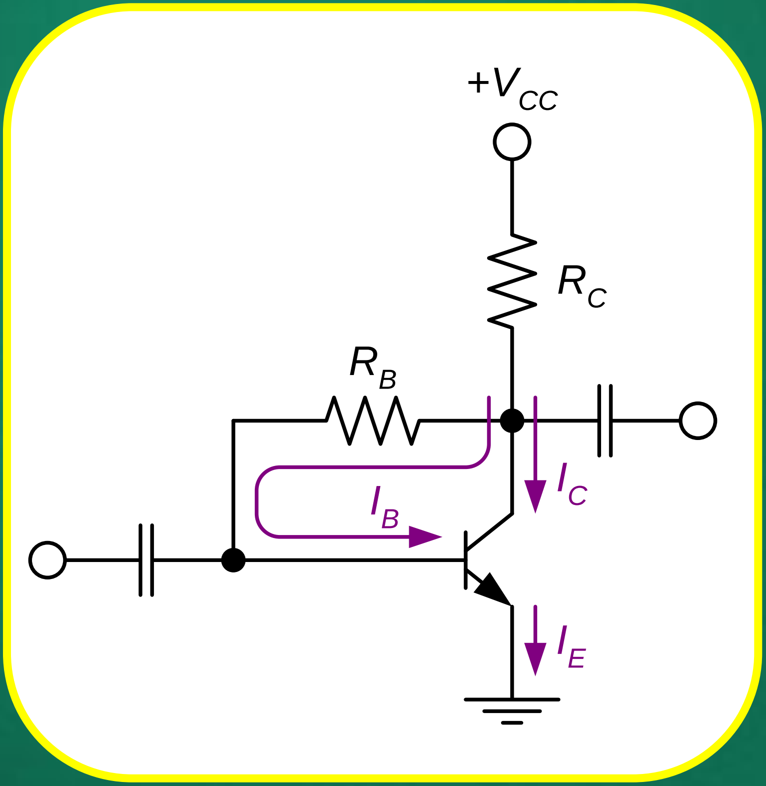
$I_B$ decreases

↓

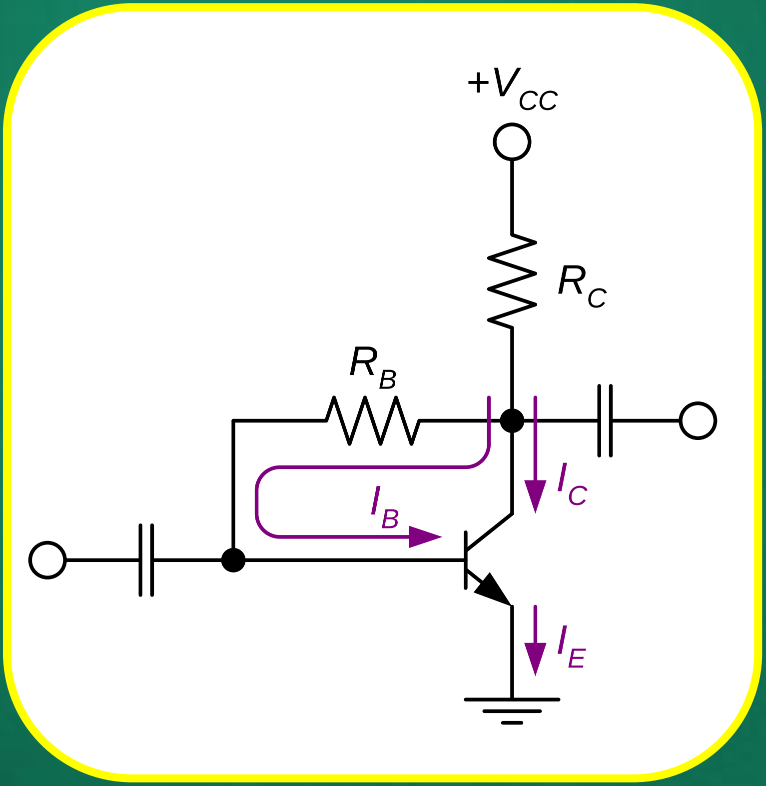
$I_C$ does not increase that much.

Good Stability. Less dependent on $h_{FE}$ and temperature.

# Collector Feedback Characteristics

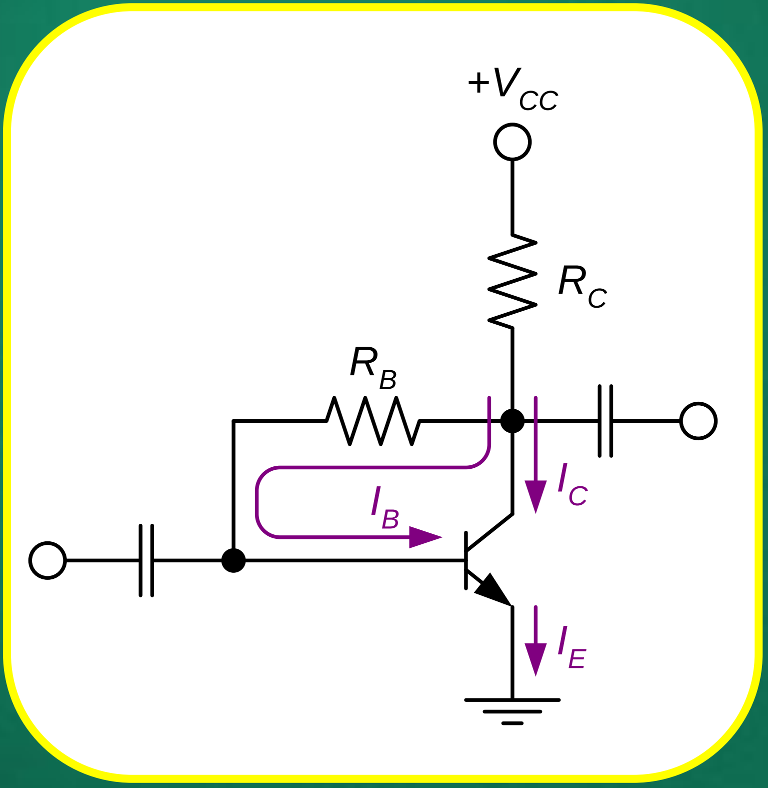


# Collector Feedback Characteristics




**Circuit recognition:** The base resistor is connected between the base and the collector terminals of the transistor.

# Collector Feedback Characteristics



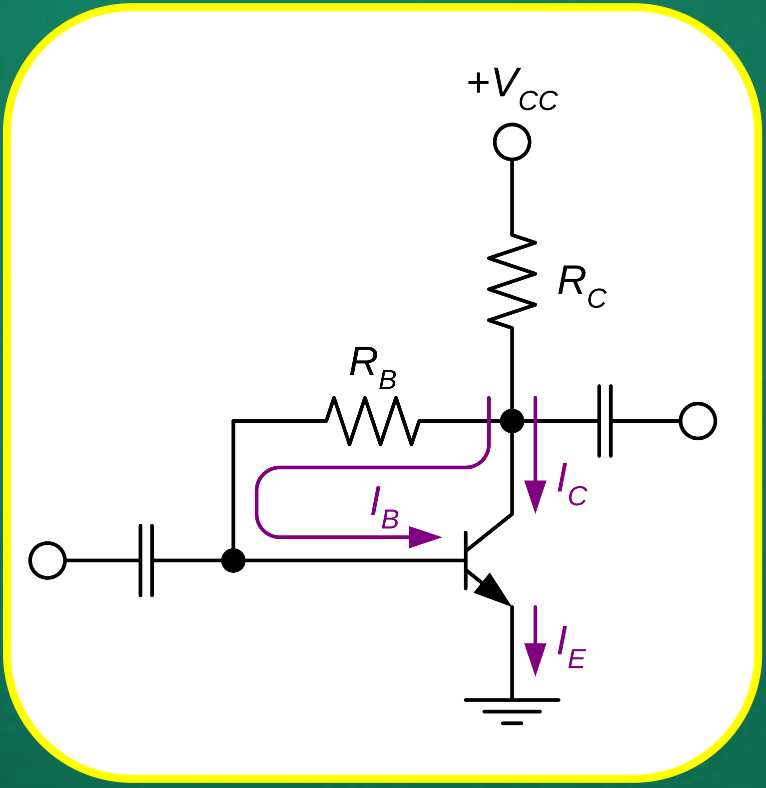

**Circuit recognition:** The base resistor is connected between the base and the collector terminals of the transistor.

**Advantage:** A simple circuit with relatively stable Q-point.

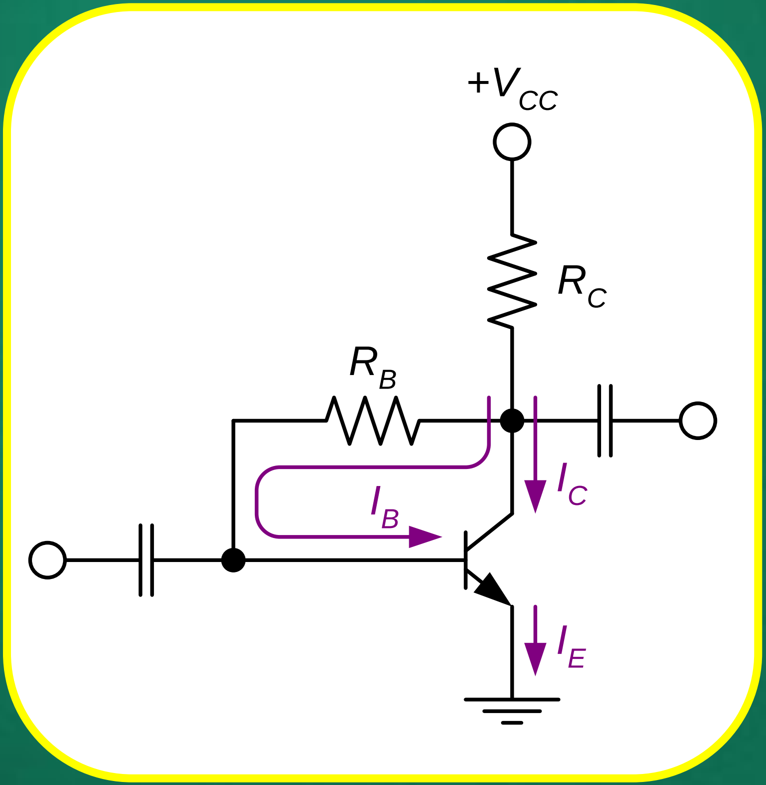
**Disadvantage:** Relatively poor ac characteristics.

**Applications:** Used primarily to bias linear amplifiers.

# Collector Feedback Characteristics

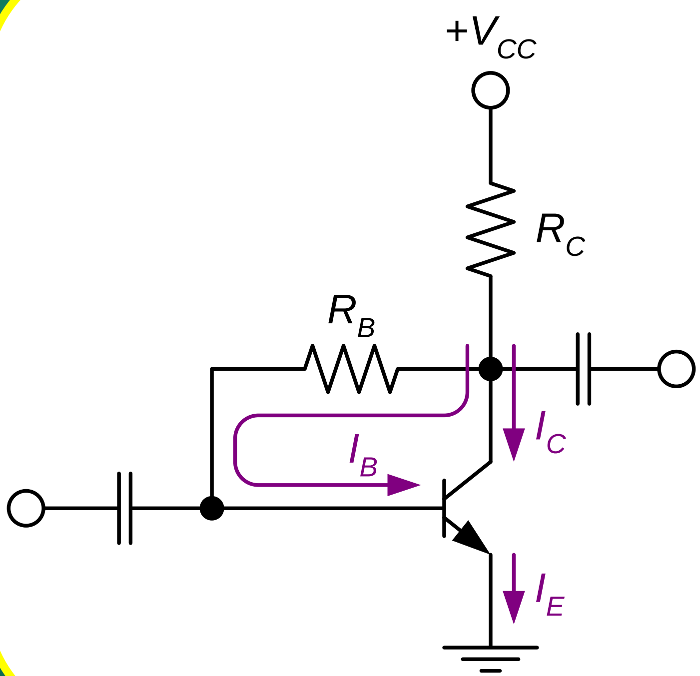


# Collector Feedback Characteristics




**Q-point relationships:**

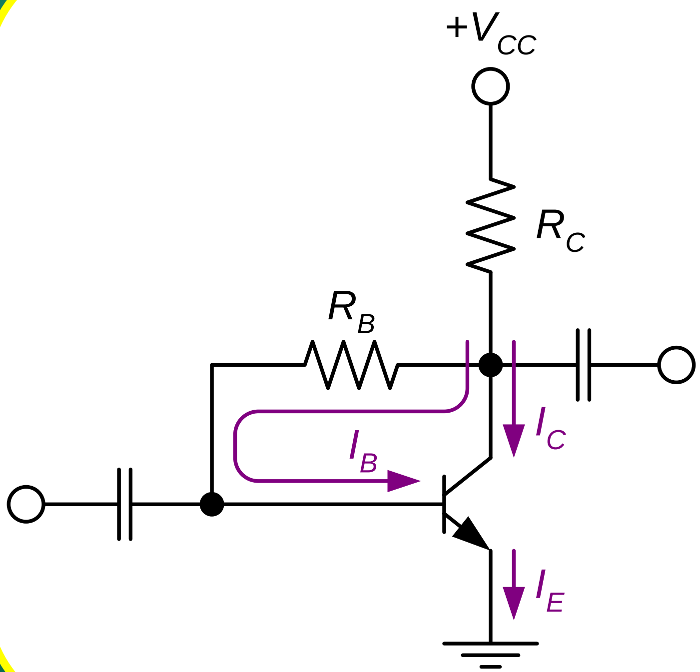
# Collector Feedback Characteristics




**Q-point relationships:**

$$I_B = \frac{V_{CC} - V_{BE}}{(h_{FE}+1)R_C + R_B}$$

# Collector Feedback Characteristics

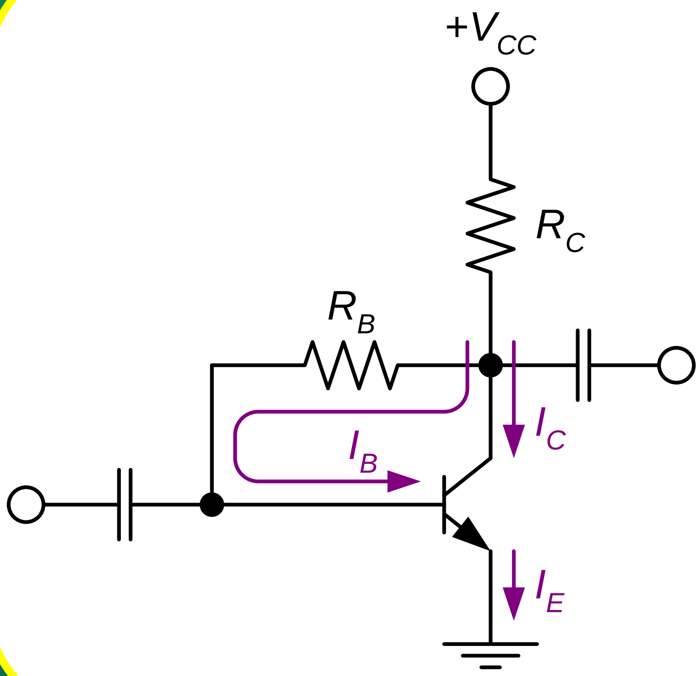



**Q-point relationships:**

$$I_B = \frac{V_{CC} - V_{BE}}{(h_{FE} + 1)R_C + R_B}$$

$$I_{CQ} = h_{FE} I_B$$

# Collector Feedback Characteristics



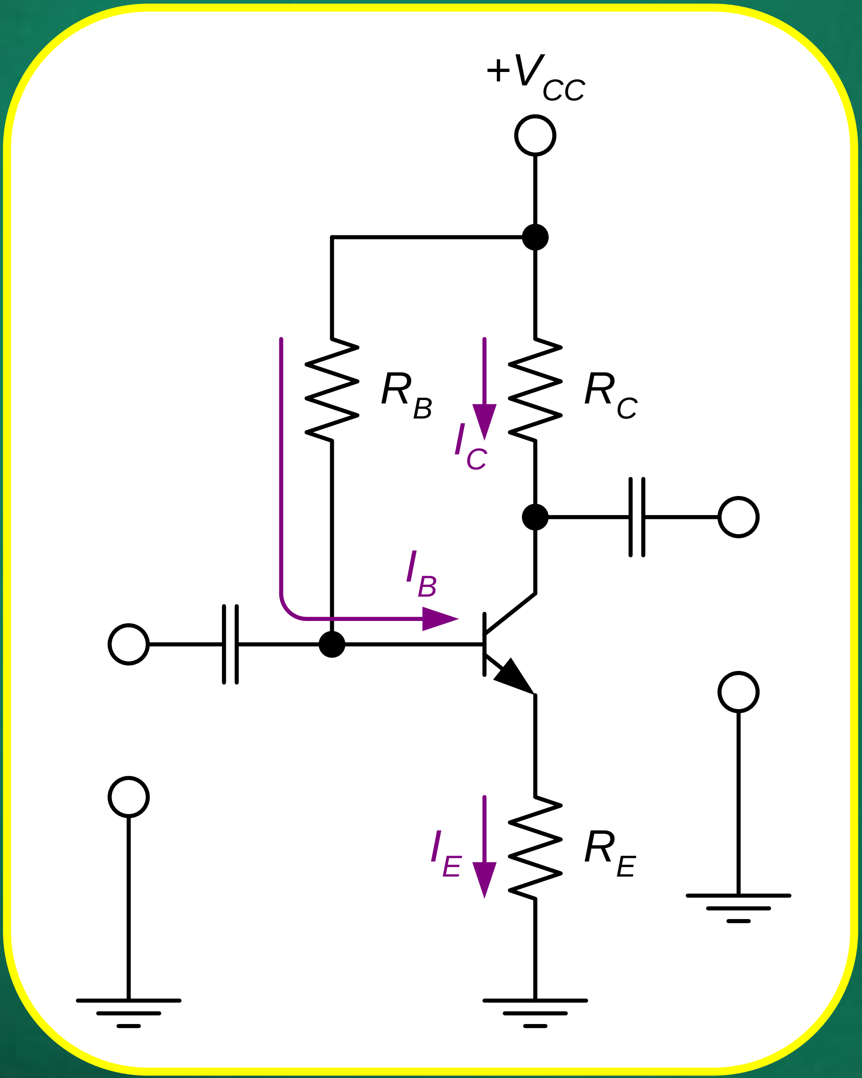

**Q-point relationships:**

$$I_B = \frac{V_{CC} - V_{BE}}{(h_{FE}+1)R_C + R_B}$$

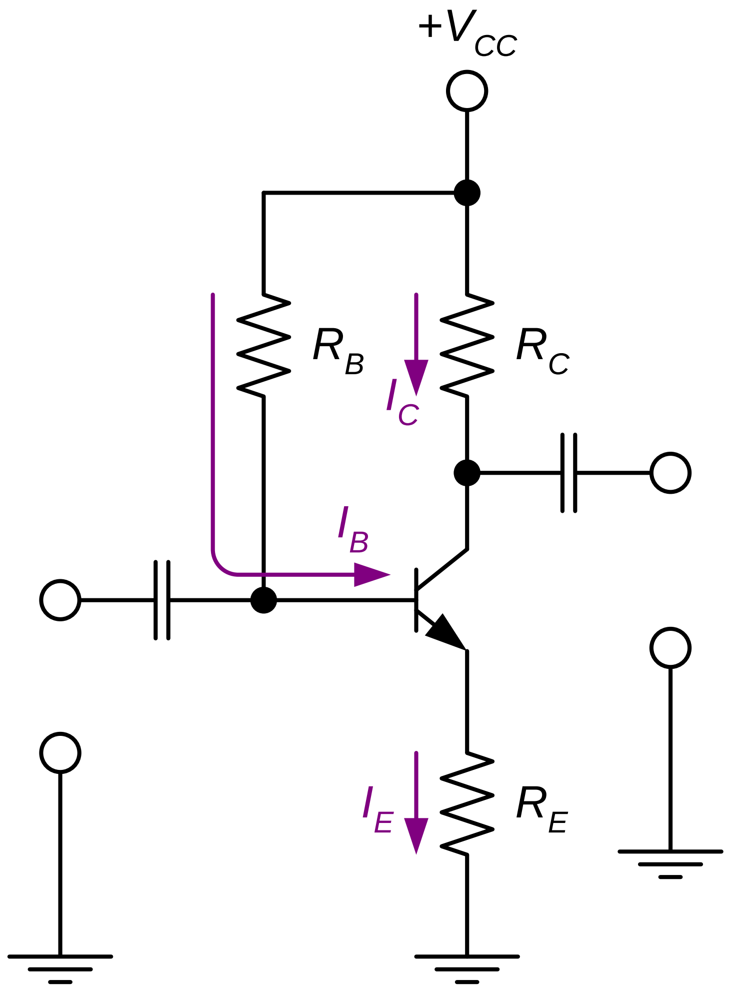
$$I_{CQ} = h_{FE} I_B$$

$$V_{CEQ} \cong V_{CC} - I_{CQ} R_C$$

# Emitter Feedback Bias

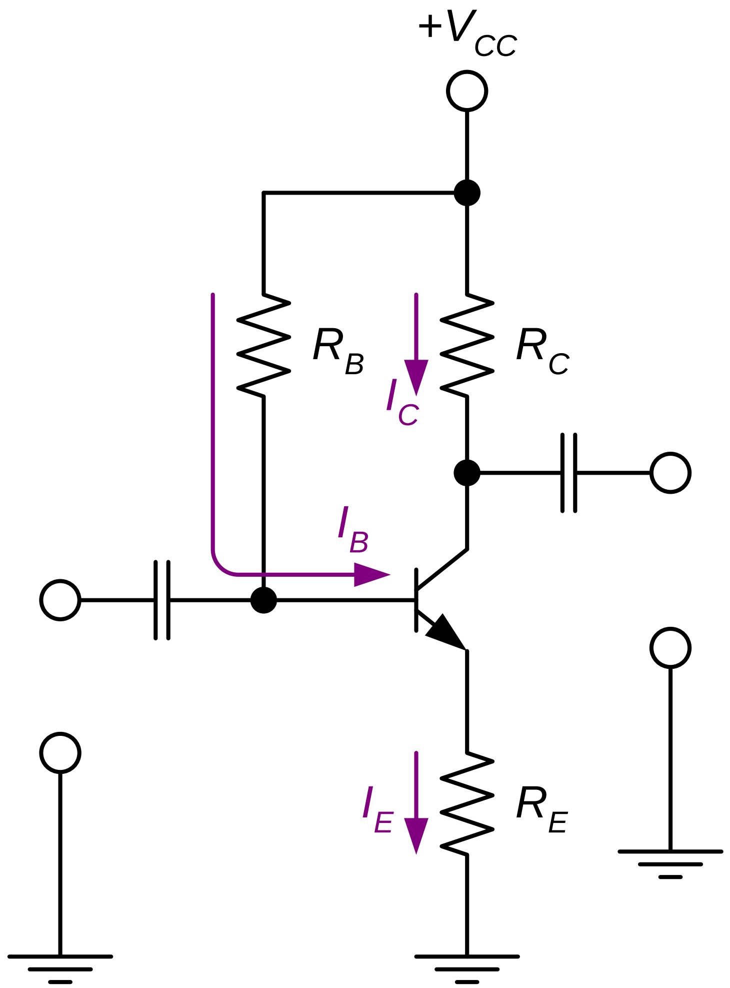


# Emitter Feedback Bias




$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \left(h_{FE} + 1\right) R_E}$$

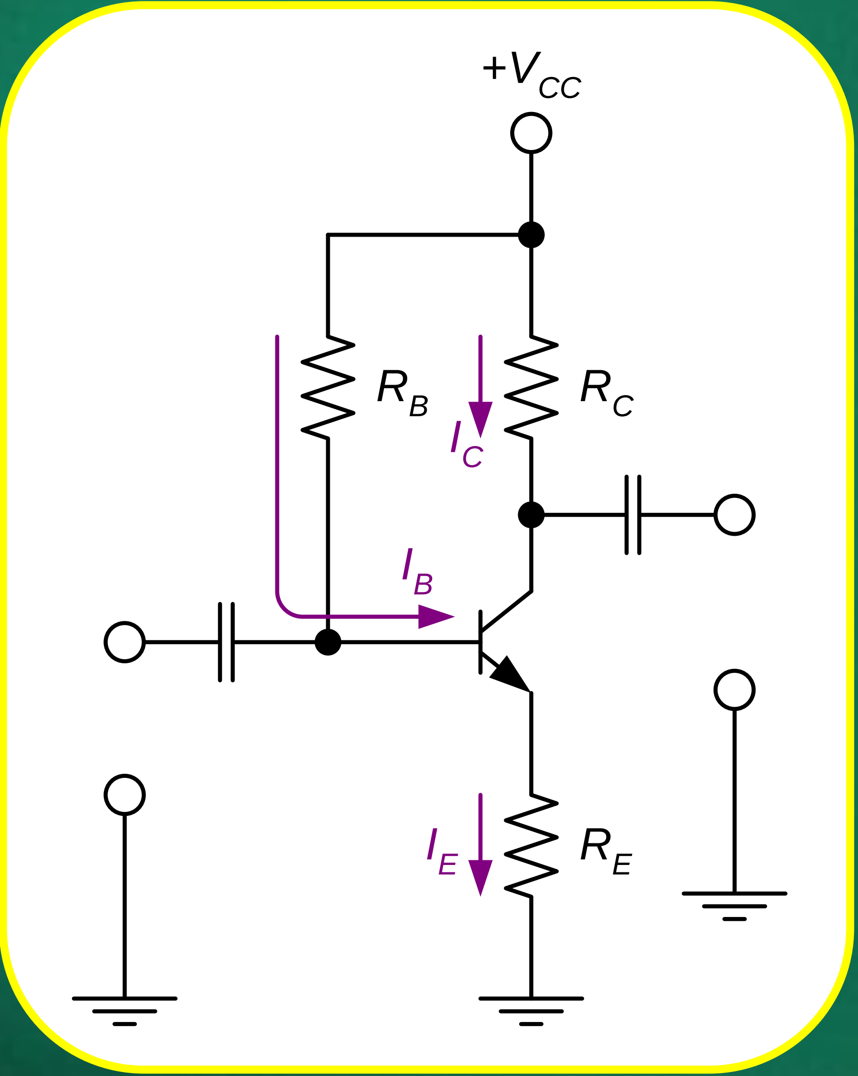
# Emitter Feedback Bias




$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1) R_E}$$

$$I_{CQ} = h_{FE} I_B$$

# Emitter Feedback Bias

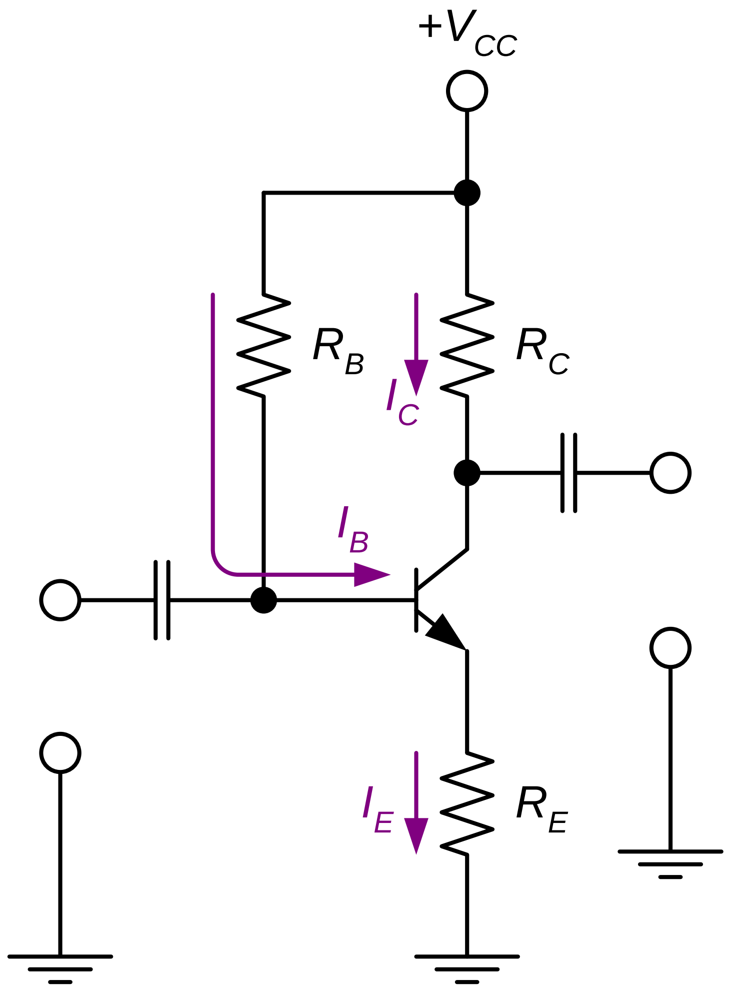



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \left(h_{FE} + 1\right) R_E}$$

$$I_{CQ} = h_{FE} I_B$$

$$I_E = \left(h_{FE} + 1\right) I_B$$

# Emitter Feedback Bias



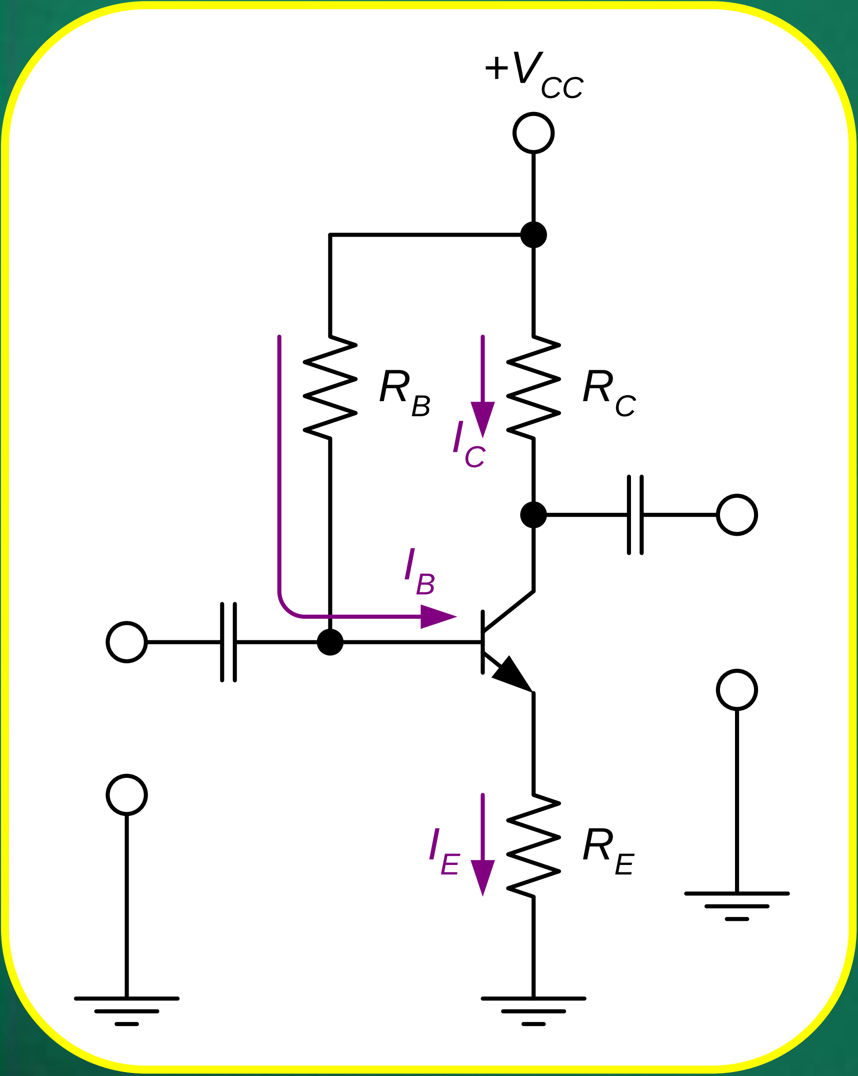

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1) R_E}$$

$$I_{CQ} = h_{FE} I_B$$

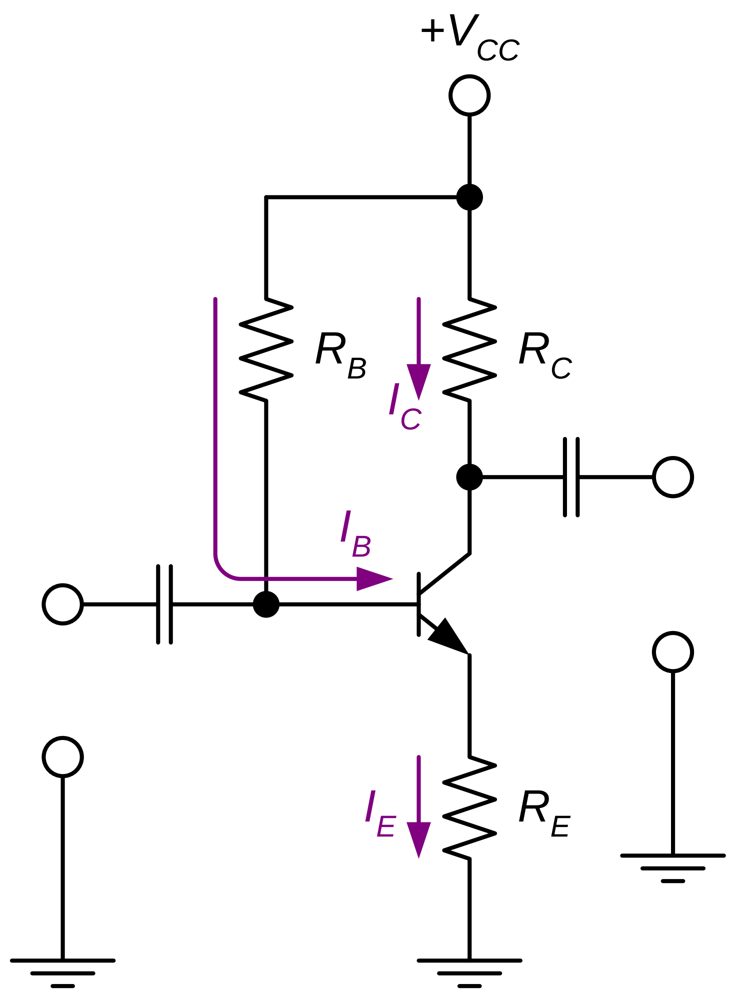
$$I_E = (h_{FE} + 1) I_B$$

$$\begin{aligned} V_{CEQ} &= V_{CC} - I_C R_C - I_E R_E \\ &\cong V_{CC} - I_{CQ} (R_C + R_E) \end{aligned}$$

# Circuit Stability



# Circuit Stability




$h_{FE}$ increases

↓

$I_C$ increases (if $I_B$ is the same)

↓

$V_E$ increases

↓

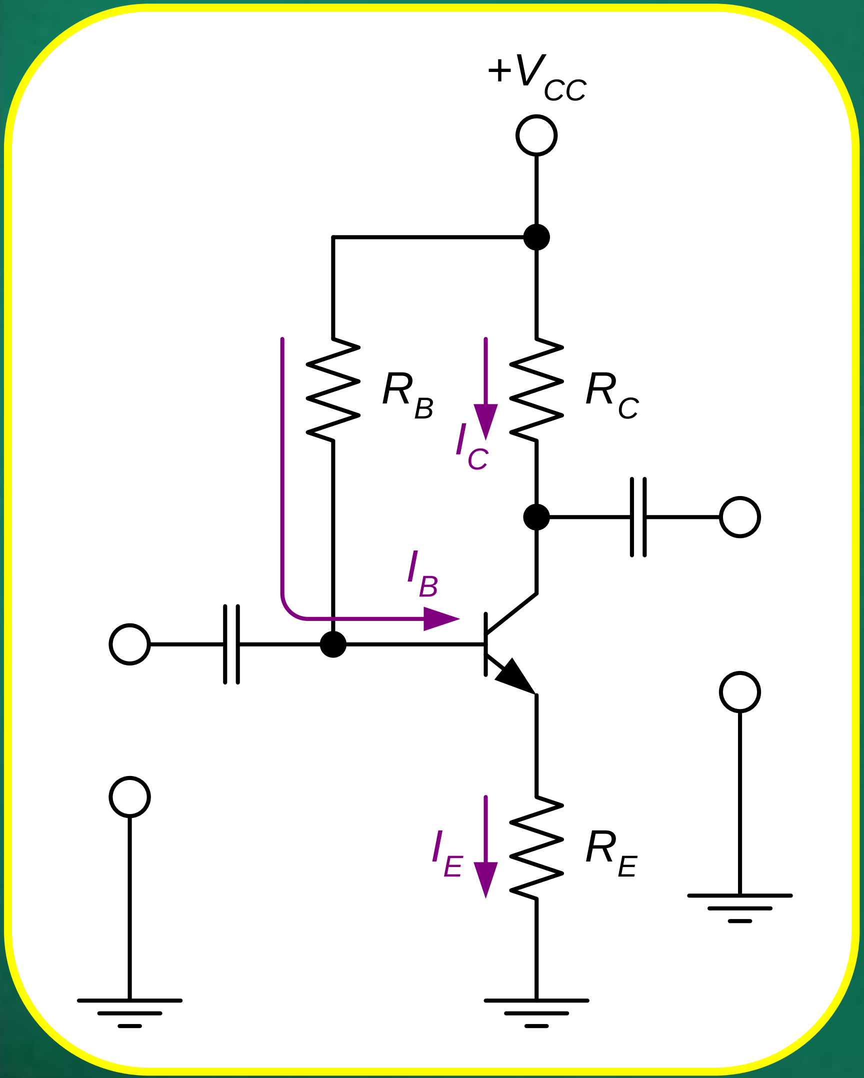
$I_B$ decreases

↓

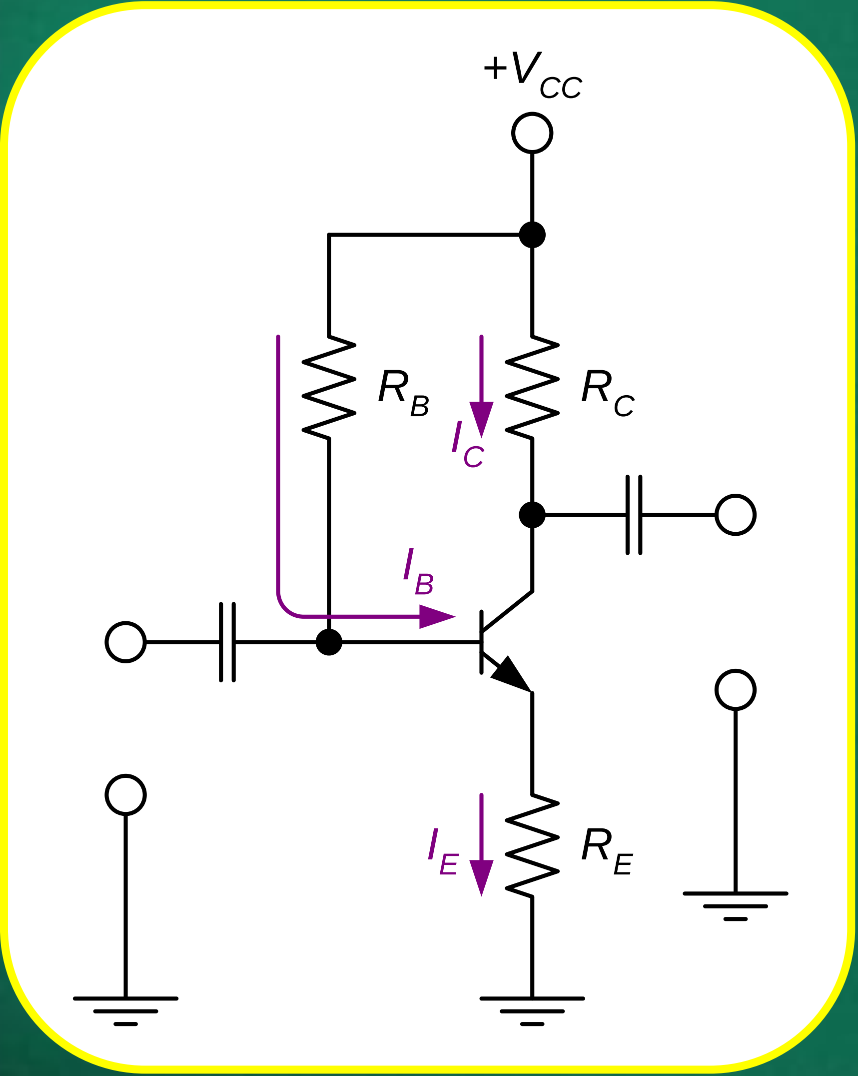
$I_C$ does not increase that much.

$I_C$ is less dependent on $h_{FE}$ and temperature.

# Emitter Feedback Characteristics

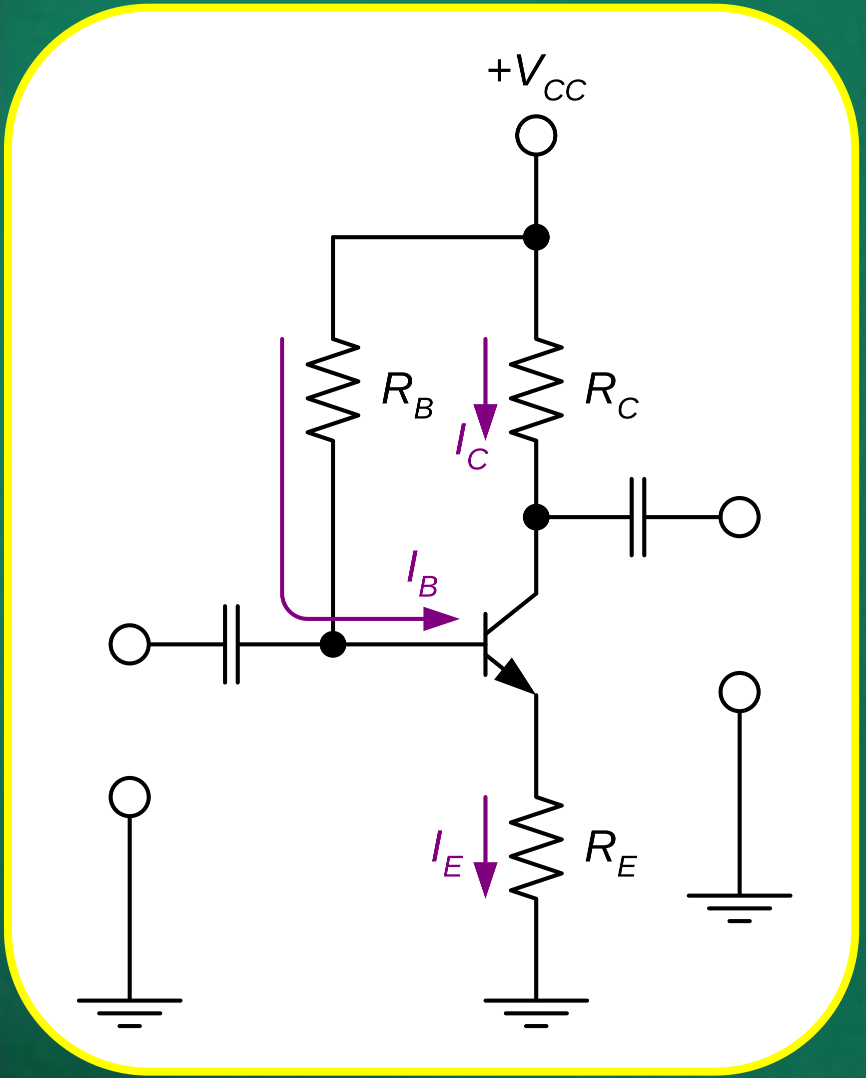


# Emitter Feedback Characteristics




**Circuit recognition:** Similar to voltage divider bias with $R_2$ missing (or base bias with $R_E$ added).

# Emitter Feedback Characteristics



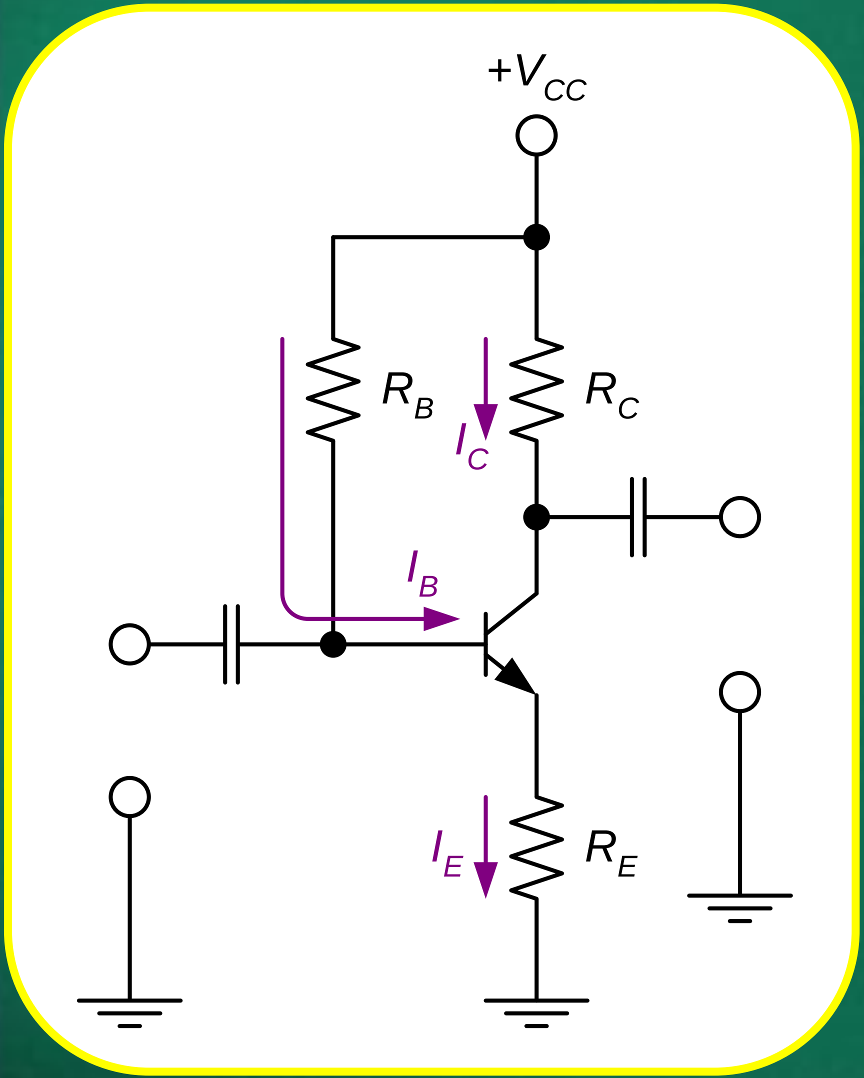

**Circuit recognition:** Similar to voltage divider bias with $R_2$ missing (or base bias with $R_E$ added).

**Advantage:** A simple circuit with relatively stable Q-point.

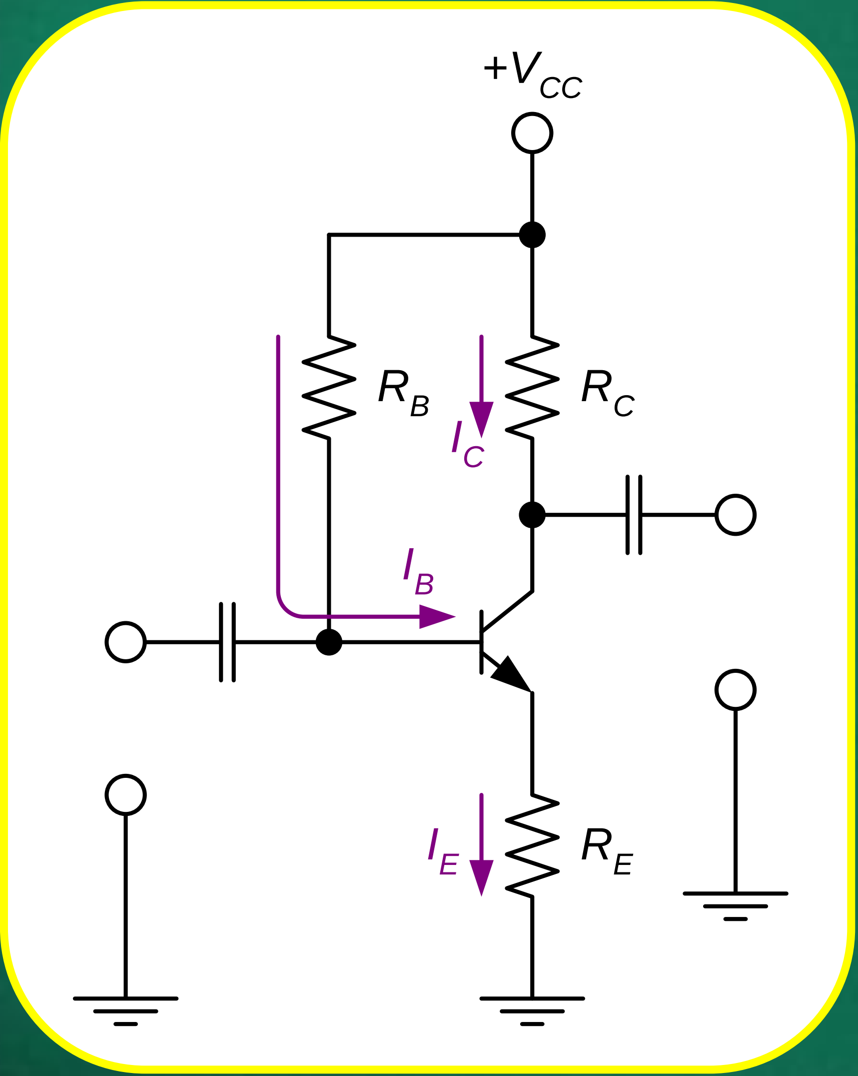
**Disadvantage:** Requires more components than collector-feedback bias.

**Applications:** Used primarily to bias linear amplifiers.

# Emitter Feedback Characteristics

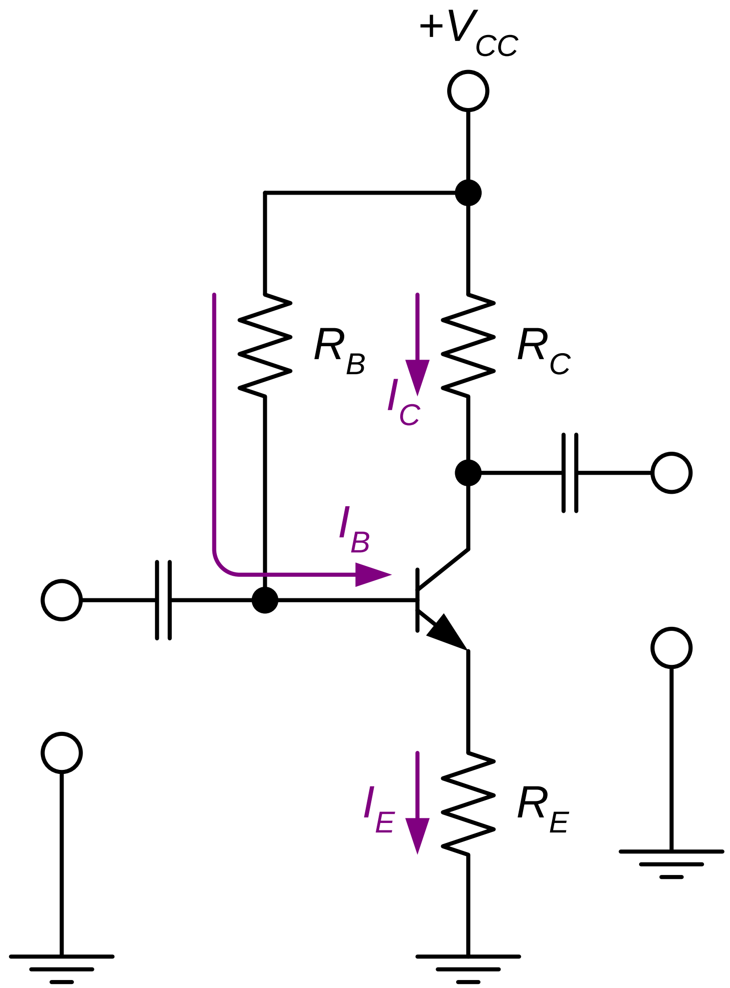


# Emitter Feedback Characteristics




**Q-point relationships:**

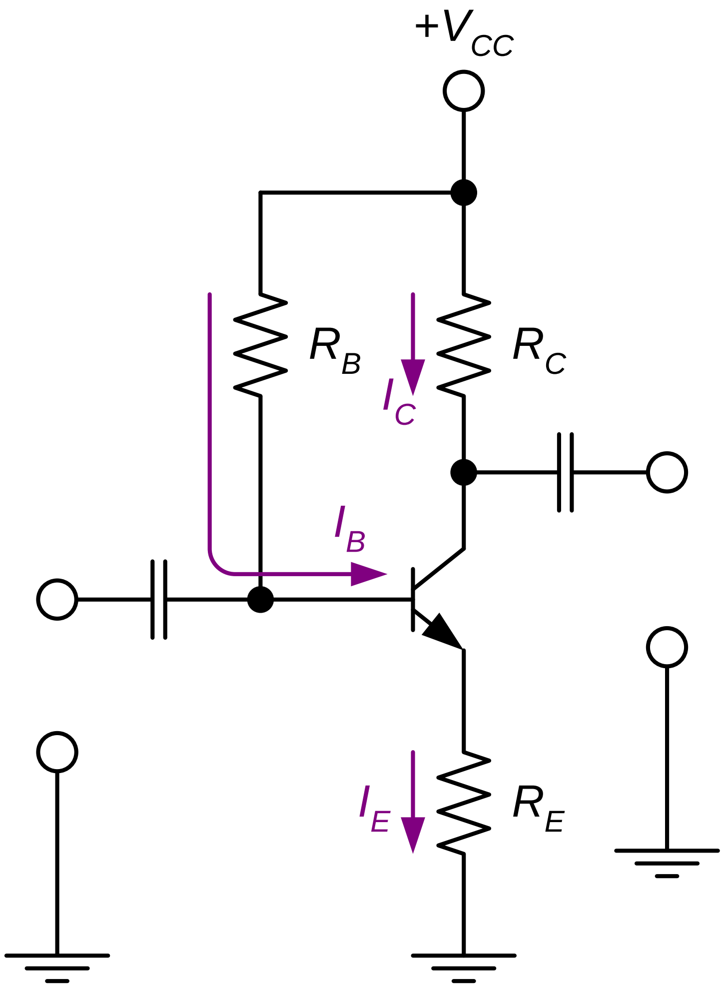
# Emitter Feedback Characteristics




**Q-point relationships:**

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1)R_E}$$

# Emitter Feedback Characteristics

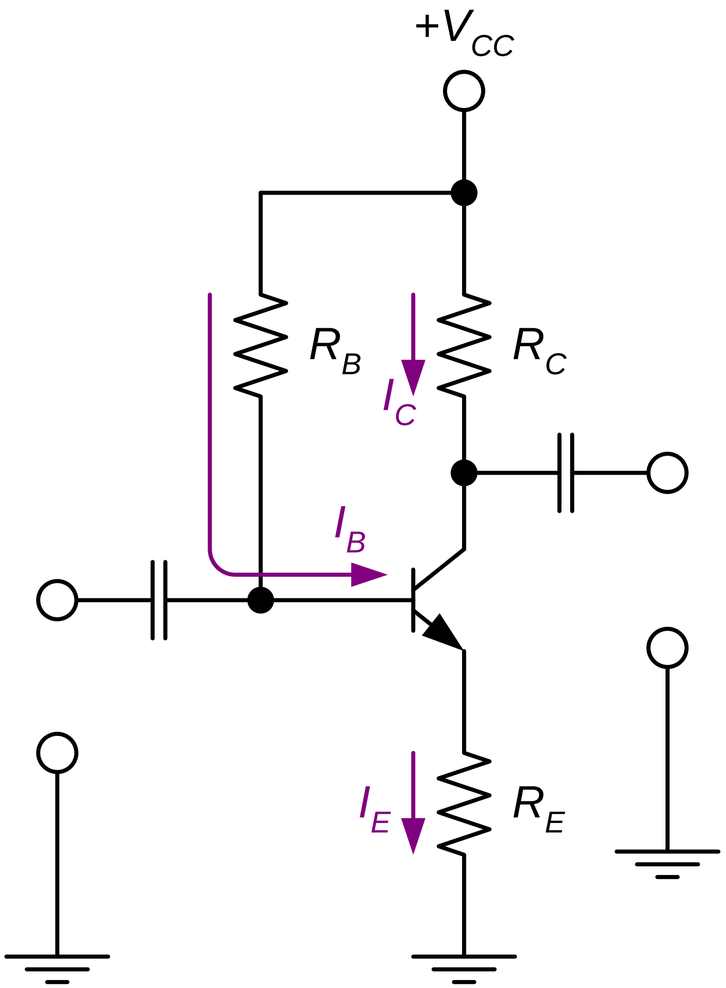



**Q-point relationships:**

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1)R_E}$$

$$I_{CQ} = h_{FE} I_B$$

# Emitter Feedback Characteristics




**Q-point relationships:**

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1)R_E}$$

$$I_{CQ} = h_{FE} I_B$$

$$V_{CEQ} \cong V_{CC} - I_{CQ}\left(R_C + R_E\right)$$