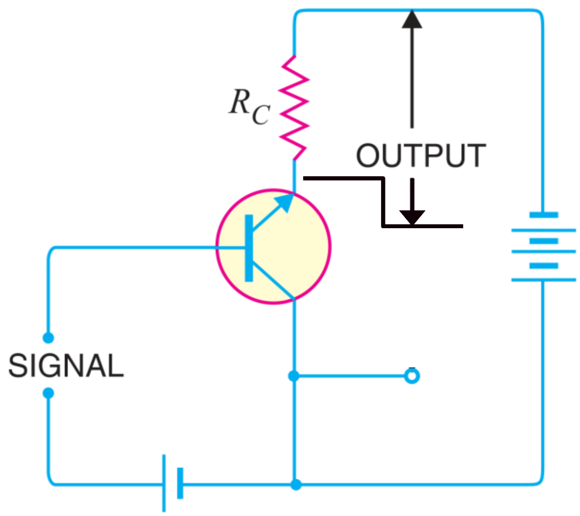
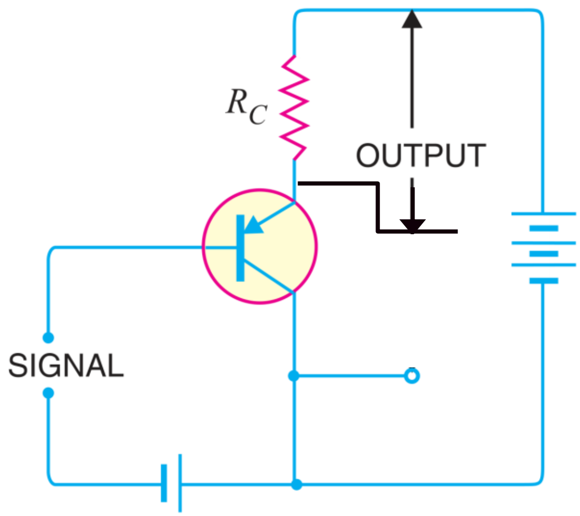
Basic Electronic Circuits
(IEC-103)

Lecture-16

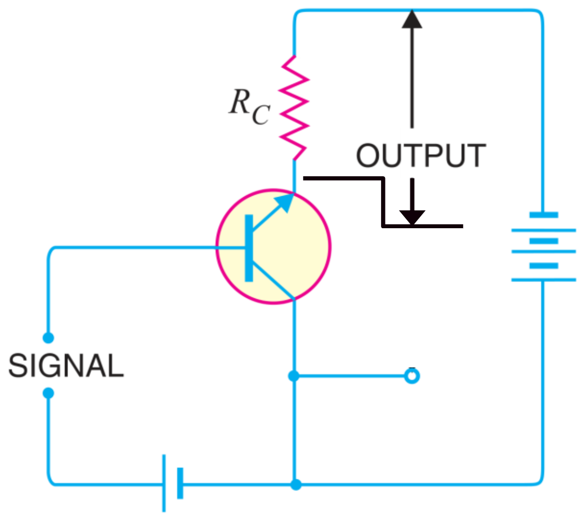
Transistor Connections

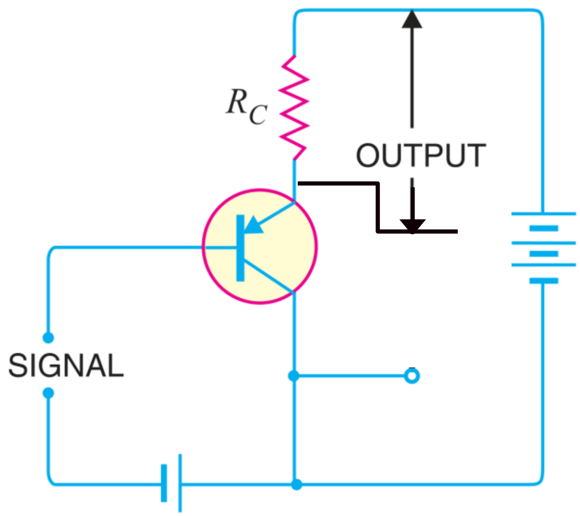
Common Collector Connection





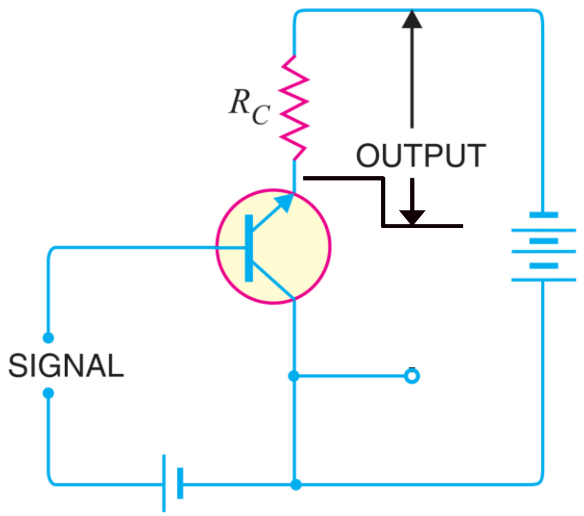
Common Collector Connection





- **Current amplification factor (γ): The ratio of change in emitter current to change in base current at constant collector emitter voltage (V_{CB}).**

Common Collector Connection



- **Current amplification factor (γ): The ratio of change in emitter current to change in base current at constant collector emitter voltage (V_{CB}).**

$$\gamma = \frac{\Delta I_E}{\Delta I_B} \quad \text{at constant } V_{CE}$$

Common Collector Connection

- ❑ **Relation between γ and α**

Common Collector Connection

- Relation between γ and α

$$\boxed{\gamma = \frac{\Delta I_E}{\Delta I_B}}$$

Common Collector Connection

- **Relation between γ and α**

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

Common Collector Connection

$$I_E = I_C + I_B$$

Common Collector Connection

$$\boxed{I_E = I_C + I_B}$$

$$\boxed{\Rightarrow \Delta I_E = \Delta I_C + \Delta I_B}$$

Common Collector Connection

$$I_E = I_C + I_B$$

$$\Rightarrow \Delta I_E = \Delta I_C + \Delta I_B$$

$$\Rightarrow \Delta I_B = \Delta I_E - \Delta I_C$$

Common Collector Connection

$$I_E = I_C + I_B$$

$$\Rightarrow \Delta I_E = \Delta I_C + \Delta I_B$$

$$\Rightarrow \Delta I_B = \Delta I_E - \Delta I_C$$

$$\Rightarrow \frac{\Delta I_E}{\Delta I_B} = \gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C} = \frac{\Delta I_E / \Delta I_E}{\Delta I_E / \Delta I_E - \Delta I_C / \Delta I_E}$$

Common Collector Connection

$$I_E = I_C + I_B$$

$$\Rightarrow \Delta I_E = \Delta I_C + \Delta I_B$$

$$\Rightarrow \Delta I_B = \Delta I_E - \Delta I_C$$

$$\Rightarrow \frac{\Delta I_E}{\Delta I_B} = \gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C} = \frac{\Delta I_E / \Delta I_E}{\Delta I_E / \Delta I_E - \Delta I_C / \Delta I_E}$$

$$\Rightarrow \gamma = \frac{1}{1-\alpha}$$

Common Collector Connection

- **Collector current:**

$$I_E = I_C + I_B$$

Common Collector Connection

- Collector current:

$$I_E = I_C + I_B$$

$$I_C = \alpha I_E + I_{CBO}$$

Common Collector Connection

- **Collector current:**

$$I_E = I_C + I_B$$

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = (\alpha I_E + I_{CBO}) + I_B$$

Common Collector Connection

- **Collector current:**

$$I_E = I_C + I_B$$

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = (\alpha I_E + I_{CBO}) + I_B$$

$$(1-\alpha) I_E = I_B + I_{CBO}$$

Common Collector Connection

- Collector current:

$$I_E = I_C + I_B$$

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = (\alpha I_E + I_{CBO}) + I_B$$

$$(1-\alpha) I_E = I_B + I_{CBO}$$

$$I_E = \frac{1}{(1-\alpha)} I_B + \frac{I_{CBO}}{(1-\alpha)}$$

Common Collector Connection

$$I_E = \frac{1}{(1-\alpha)} I_B + \frac{I_{CBO}}{(1-\alpha)}$$

Common Collector Connection

$$I_E = \frac{1}{(1-\alpha)} I_B + \frac{I_{CBO}}{(1-\alpha)}$$

$$\Rightarrow I_E = (\beta + 1) I_B + (\beta + 1) I_{CBO}$$

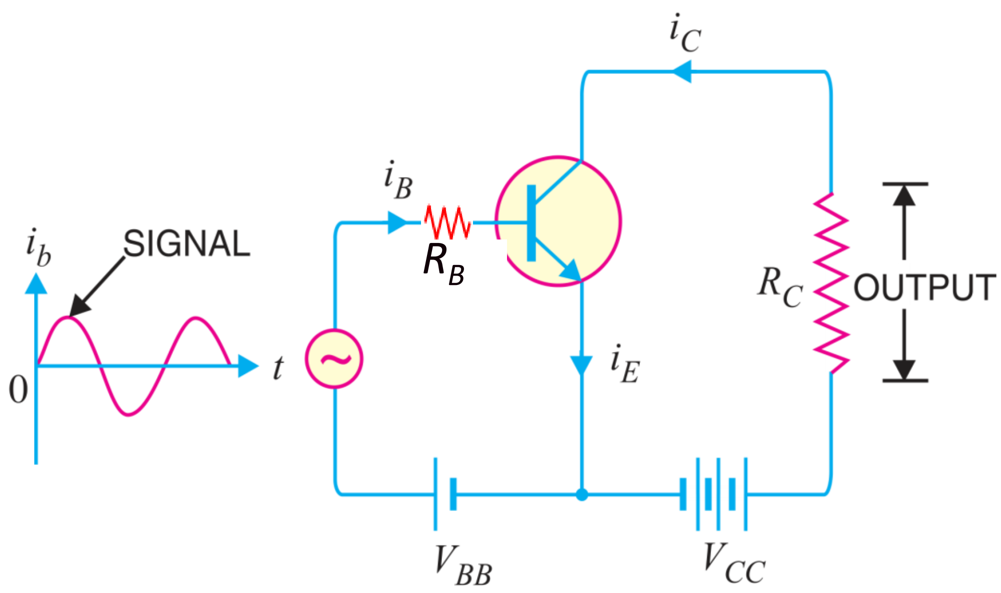
Comparison of Transistor Connections

S. No	Characteristic	Common Base	Common Emitter	Common Collector
1	Input Resistance	Low (about 100 Ω)	Low (about 750 Ω)	Very high (about 750 kΩ)
2	Output Resistance	Very high (about 450 kΩ)	High (about 45 kΩ)	Low (about 50 Ω)
3	Voltage Gain	About 150	About 500	Less than 1
4	Current Gain	Less than 1	High (β)	Appreciable
5	Applications	For high frequency applications	For audio frequency applications	For impedance matching

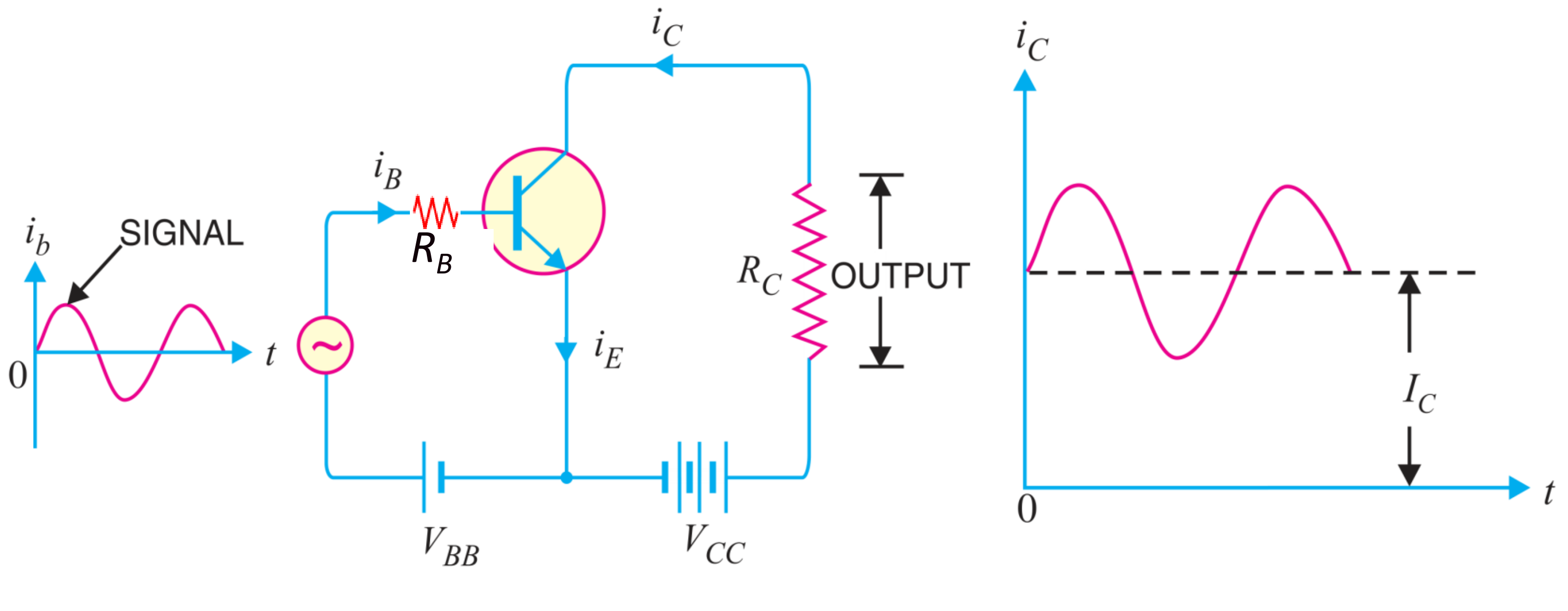
Commonly used Connection

- The most used connection in all transistor applications is CE configuration.
  - High current gain (20 to 500)
  - High voltage gain and power gain
  - Moderate output to input impedance ratio (about 50)

Transistor as an Amplifier in CE Arrangement



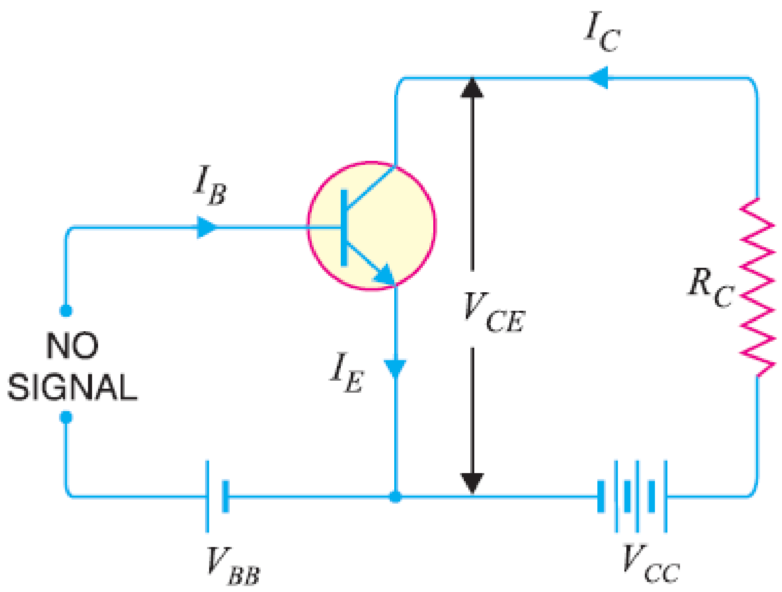
Transistor as an Amplifier in CE Arrangement



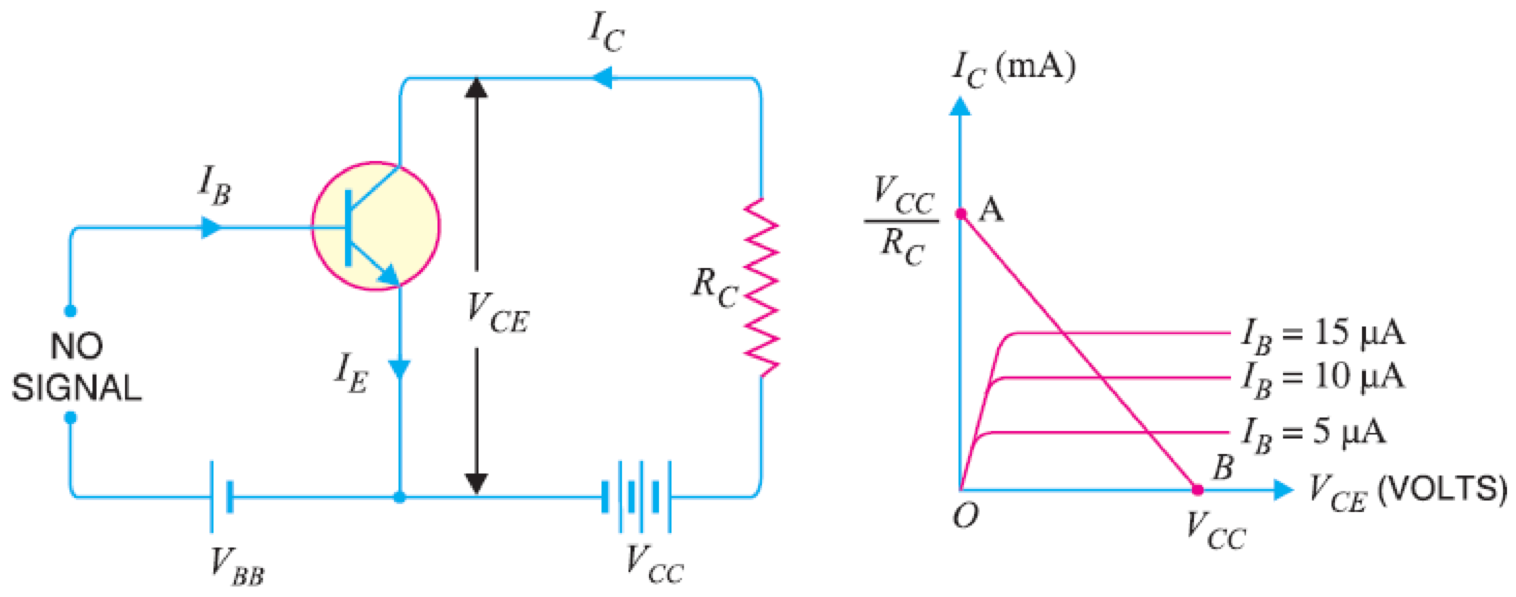
Symbols in Transistor Analysis

S. No	Variable	Instantaneous AC	DC	Total
1	Emitter Current	i_e	I_E	i_E
2	Collector Current	i_c	I_C	i_C
3	Base Current	i_b	I_B	i_B
4	Collector-emitter Voltage	v_{ce}	V_{CE}	v_{CE}
5	Emitter-base Voltage	v_{eb}	V_{EB}	v_{EB}

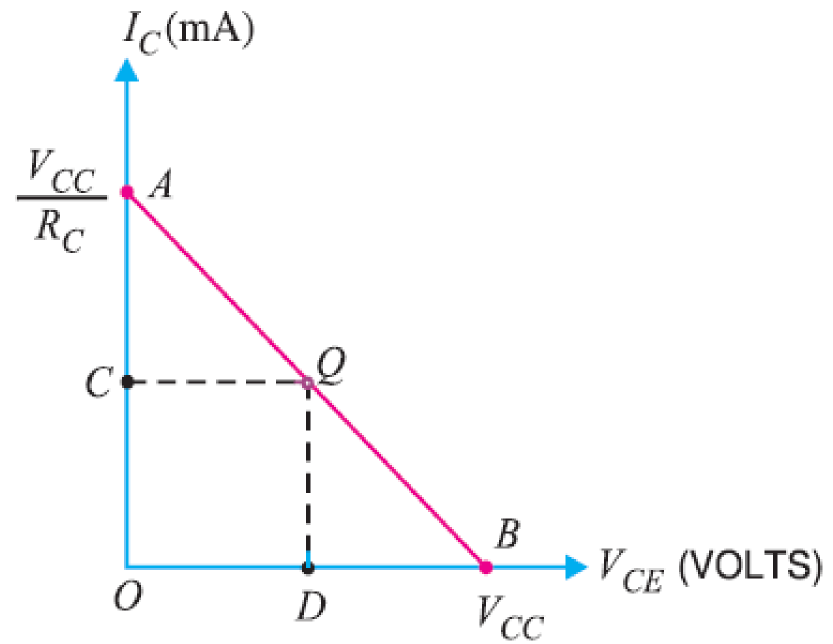
Transistor Load Line Analysis



Transistor Load Line Analysis

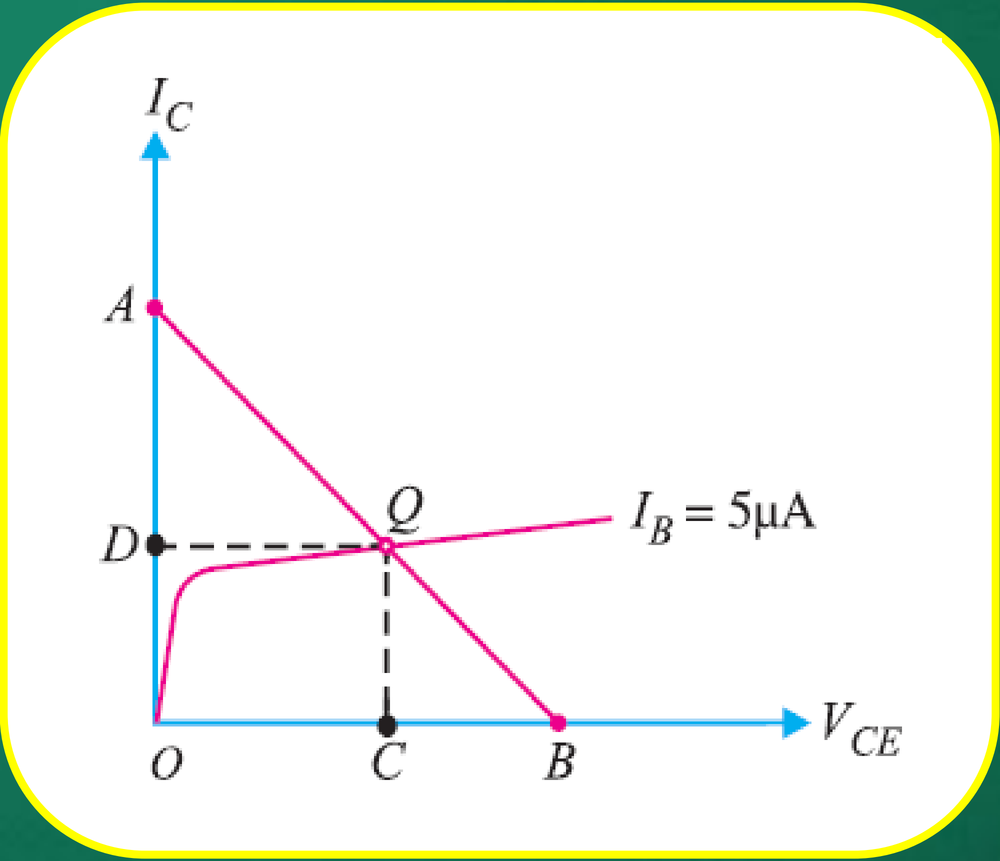


Transistor Load Line Analysis

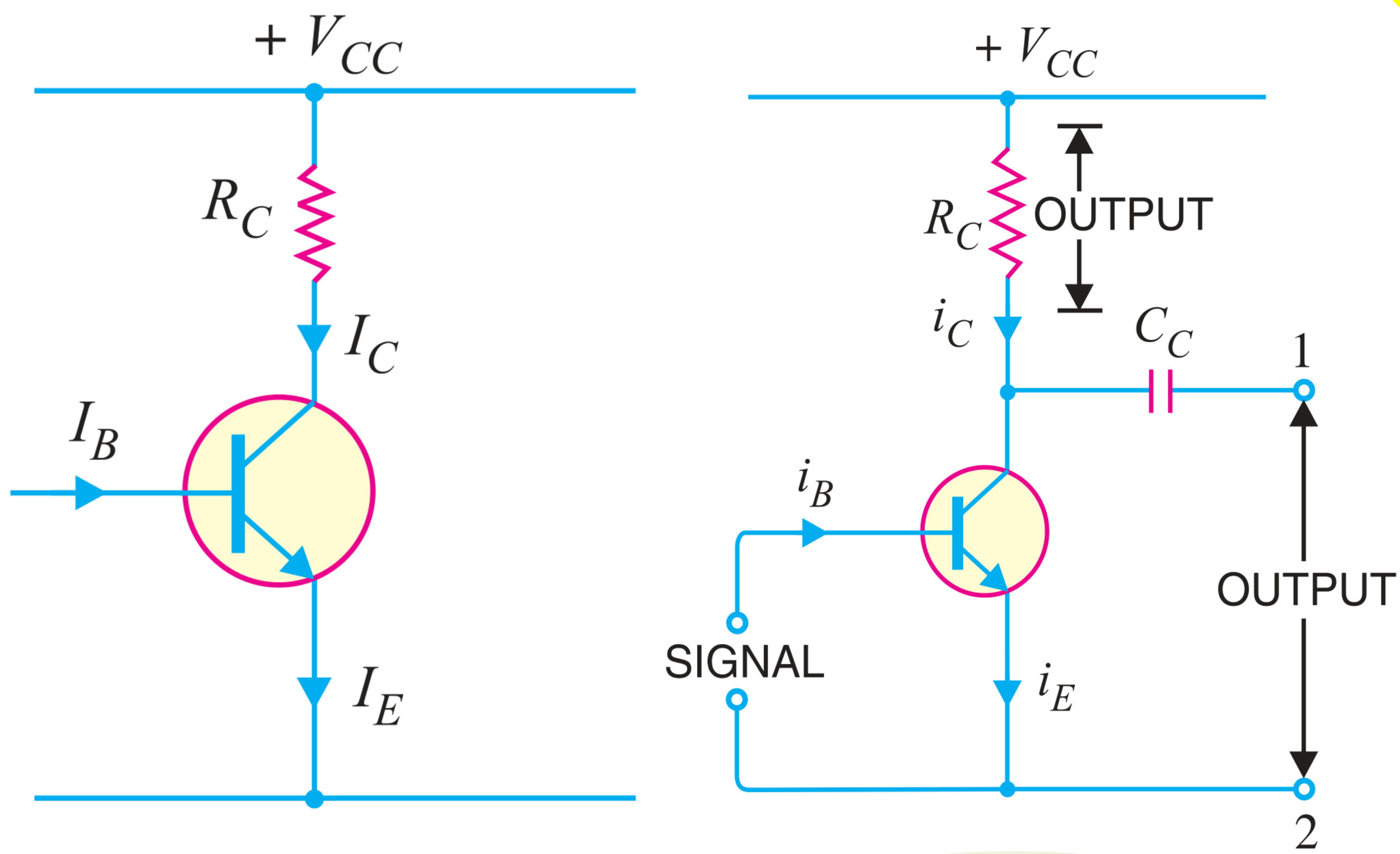


The resistance R_C connected to the device is called load or load resistance and therefore, the line constructed is called load line.

Operating Point



Output from a Transistor



Performance of an Amplifier (CE)

Performance of an Amplifier (CE)

- Input Resistance

$$R_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

Performance of an Amplifier (CE)

- Input Resistance

$$R_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

- Output Resistance

$$R_o = \frac{\Delta V_{CE}}{\Delta I_C}$$

Performance of an Amplifier (CE)

- Input Resistance

$$R_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

- Output Resistance

$$R_o = \frac{\Delta V_{CE}}{\Delta I_C}$$

- Effective collector load

$$R_{AC} = R_o \parallel R_C = \frac{R_o R_C}{R_o + R_C} \cong R_C$$

Performance of an Amplifier (CE)

- Current Gain

Performance of an Amplifier (CE)

- Current Gain

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

Performance of an Amplifier (CE)

- Current Gain

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

- Voltage Gain

$$A_v = \frac{\Delta V_{CE}}{\Delta V_{BE}} = \frac{\Delta I_C R_{AC}}{\Delta I_B R_i} = \beta \frac{R_{AC}}{R_i}$$

Performance of an Amplifier (CE)

- Current Gain

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

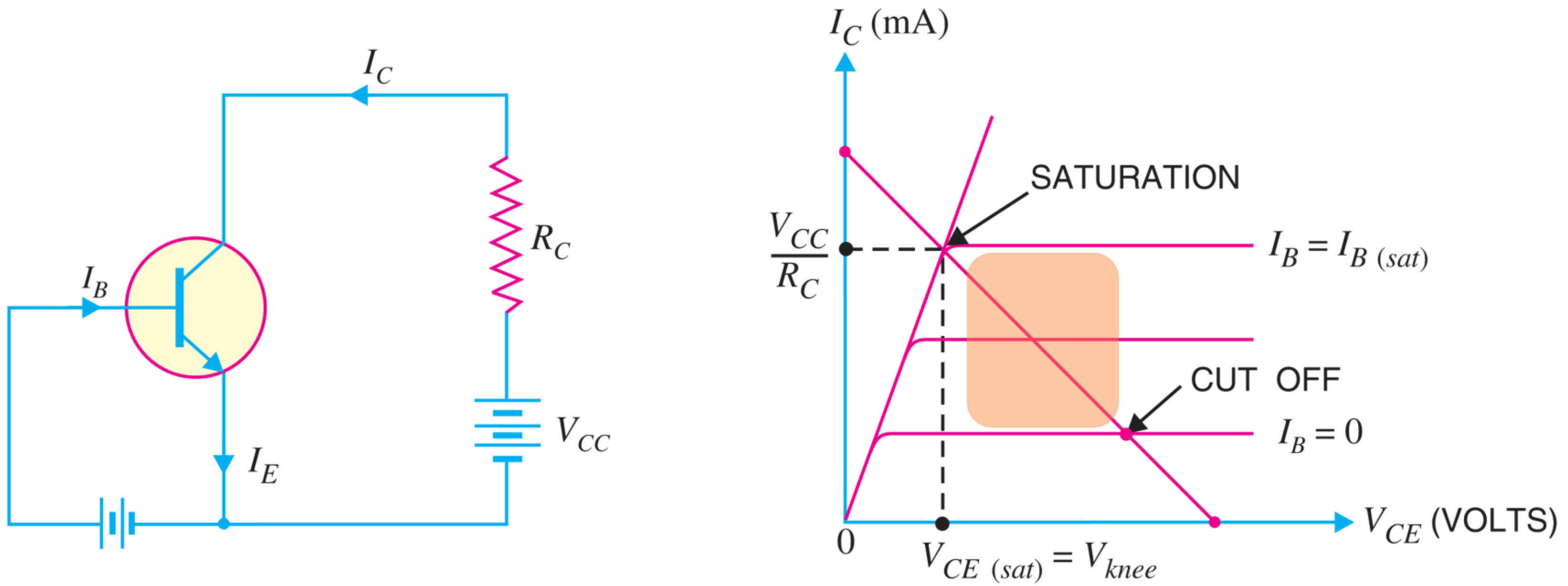
- Voltage Gain

$$A_v = \frac{\Delta V_{CE}}{\Delta V_{BE}} = \frac{\Delta I_C R_{AC}}{\Delta I_B R_i} = \beta \frac{R_{AC}}{R_i}$$

- Power Gain

$$A_p = \beta \times A_v = \beta^2 \frac{R_{AC}}{R_i}$$

Cut off and Saturation Points



Cut off and Saturation Points

- **Cut Off:** The point where load line intersects the $I_B = 0$ curve is known as cutoff. At cutoff, the emitter base is no longer forward biased and normal transistor action is lost. The collector emitter voltage is almost V_{CC}.

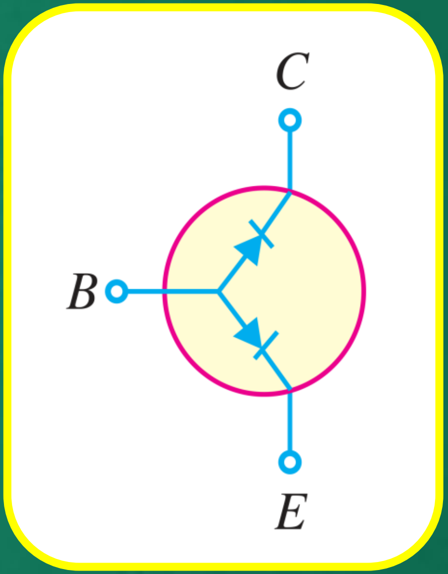
- **Saturation:** The point where load line intersects the $I_B = I_{B(sat)}$ curve is known as saturation. At saturation, collector base junction is no longer reverse biased and transistor action is lost. $I_C = V_{CC}/R_C$.

Active Region

- Active Region: The region between cut off and saturation is known as active region. In the active region, collector base junction is reverse biased and base emitter junction remains forward biased.

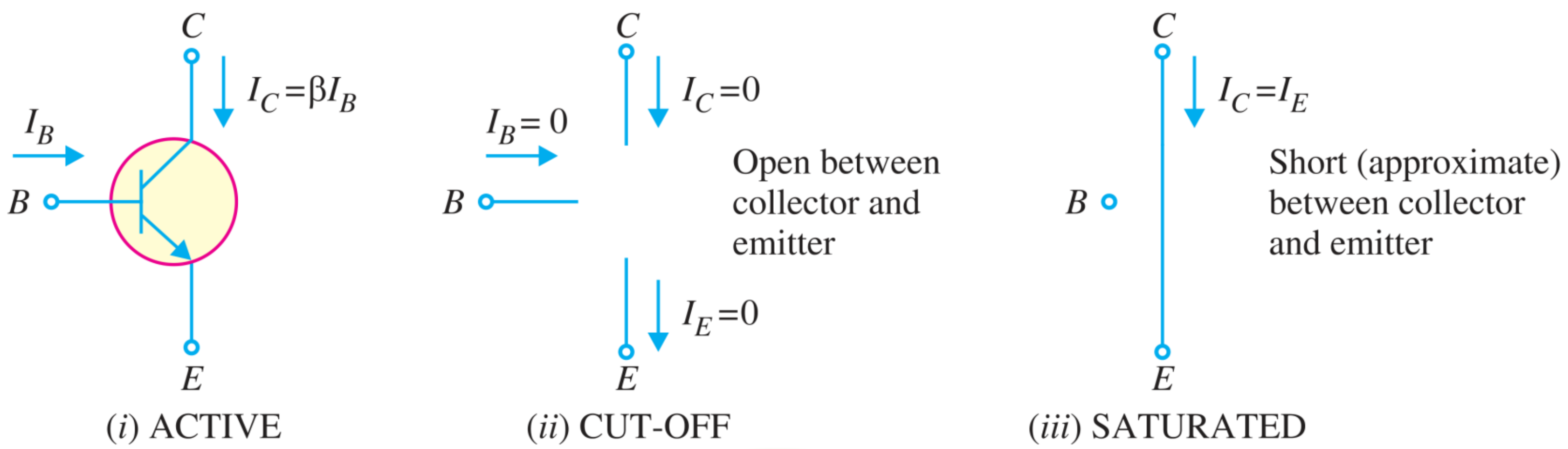
- Note: We provide biasing to the transistor to ensure that it operates in the active.

Cut off, Saturation & Active



- Cut off: Emitter diode and collector diode are off.
- Active: Emitter diode is on and collector diode are off.
- Saturated: Emitter diode and collector diode are on.

Cut off, Saturation & Active



Power Rating of a Transistor

- The maximum power that a transistor can handle without destruction is known as power rating of a transistor.

Power Rating of a Transistor

- The maximum power that a transistor can handle without destruction is known as **power rating** of a transistor.

$$P_{D(\max)} = I_C \times \mathrm{V}_{\mathrm{CB}} + \mathrm{I}_{\mathrm{B}} \times \mathrm{V}_{\mathrm{BE}}$$

Power Rating of a Transistor

- The maximum power that a transistor can handle without destruction is known as power rating of a transistor.

$$P_{D(\max)} = I_C \times \mathrm{V_{CB}} + \mathrm{I_B} \times \mathrm{V_{BE}}$$

- When transistor is in operation, most of the power is dissipated at the reverse biased collector-base junction.

Power Rating of a Transistor

- The maximum power that a transistor can handle without destruction is known as power rating of a transistor.

$$P_{D(\max)} = I_C \times \mathrm{V_{CB}} + \mathrm{I_B} \times \mathrm{V_{BE}}$$

- When transistor is in operation, most of the power is dissipated at the reverse biased collector-base junction.

$$P_{D(\max)} \cong I_C \times \mathrm{V_{CB}}$$

Power Rating of a Transistor

$V_{CE} = V_{CB} + V_{BE}$, since V_{BE} is very small, $V_{CB} \approx V_{CE}$

Power Rating of a Transistor

$V_{CE} = V_{CB} + V_{BE}$, **since** V_{BE} **is very small,** $V_{CB} \approx V_{CE}$

$$\boxed{P_{D(\max)} \cong I_C \times V_{CE}}$$

Power Rating of a Transistor

$V_{CE} = V_{CB} + V_{BE}$, since V_{BE} is very small, $V_{CB} \approx V_{CE}$

$$\boxed{P_{D(\max)} \cong I_C \times V_{CE}}$$

- For power transistors, it is sometimes necessary to draw maximum power dissipation curve on the output characteristics.

Power Rating of a Transistor

$V_{CE} = V_{CB} + V_{BE}$, since V_{BE} is very small, $V_{CB} \approx V_{CE}$

$$\boxed{P_{D(\max)} \cong I_C \times V_{CE}}$$

- ❑ For power transistors, it is sometimes necessary to draw maximum power dissipation curve on the output characteristics.
- ❑ To draw this curve, we should know the power rating of the transistor.

Power Rating of a Transistor

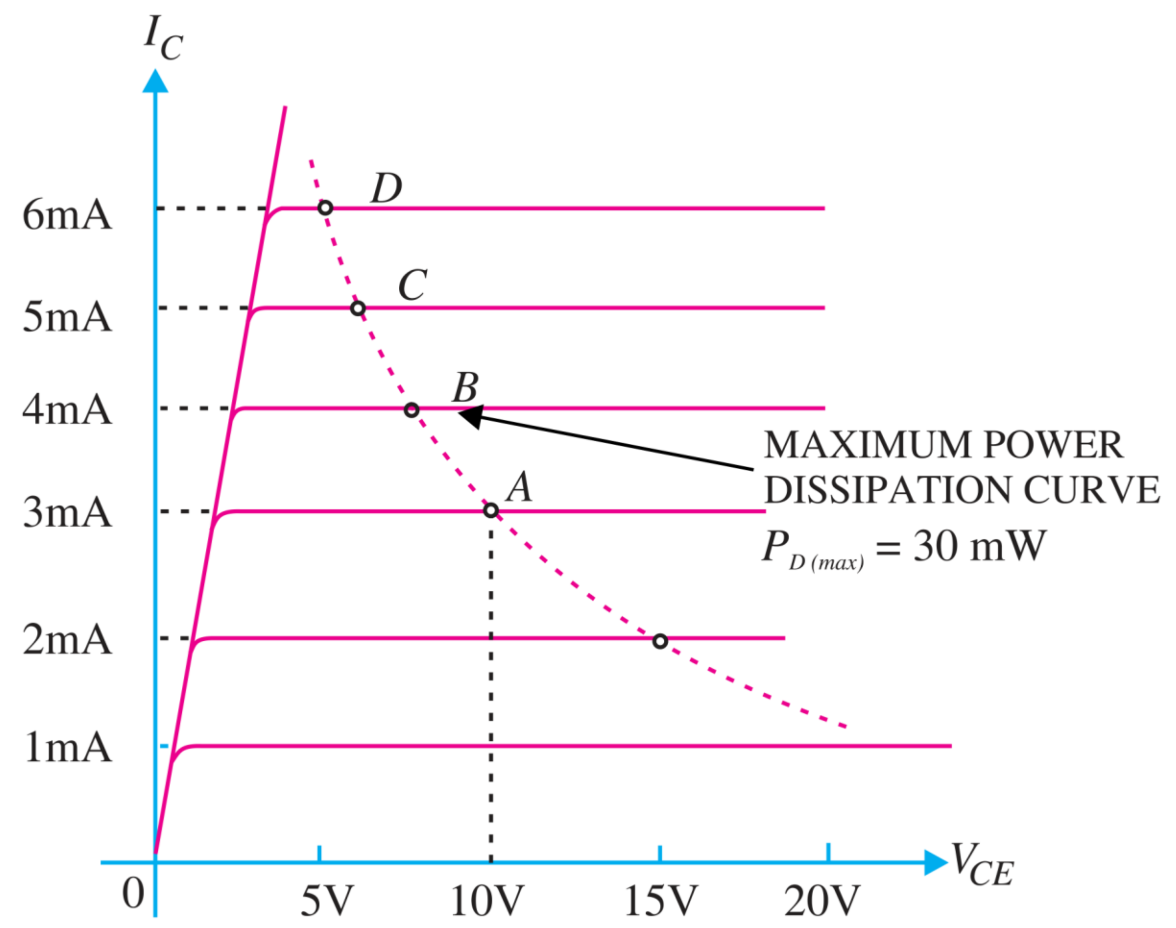
$V_{CE} = V_{CB} + V_{BE}$, since V_{BE} is very small, $V_{CB} \approx V_{CE}$

$$\boxed{P_{D(\max)} \cong I_C \times V_{CE}}$$

- For power transistors, it is sometimes necessary to draw maximum power dissipation curve on the output characteristics.
- To draw this curve, we should know the power rating of the transistor.

$$\boxed{P_{D(\max)} = I_C \times V_{CE}}$$

Max. Power Dissipation Curve

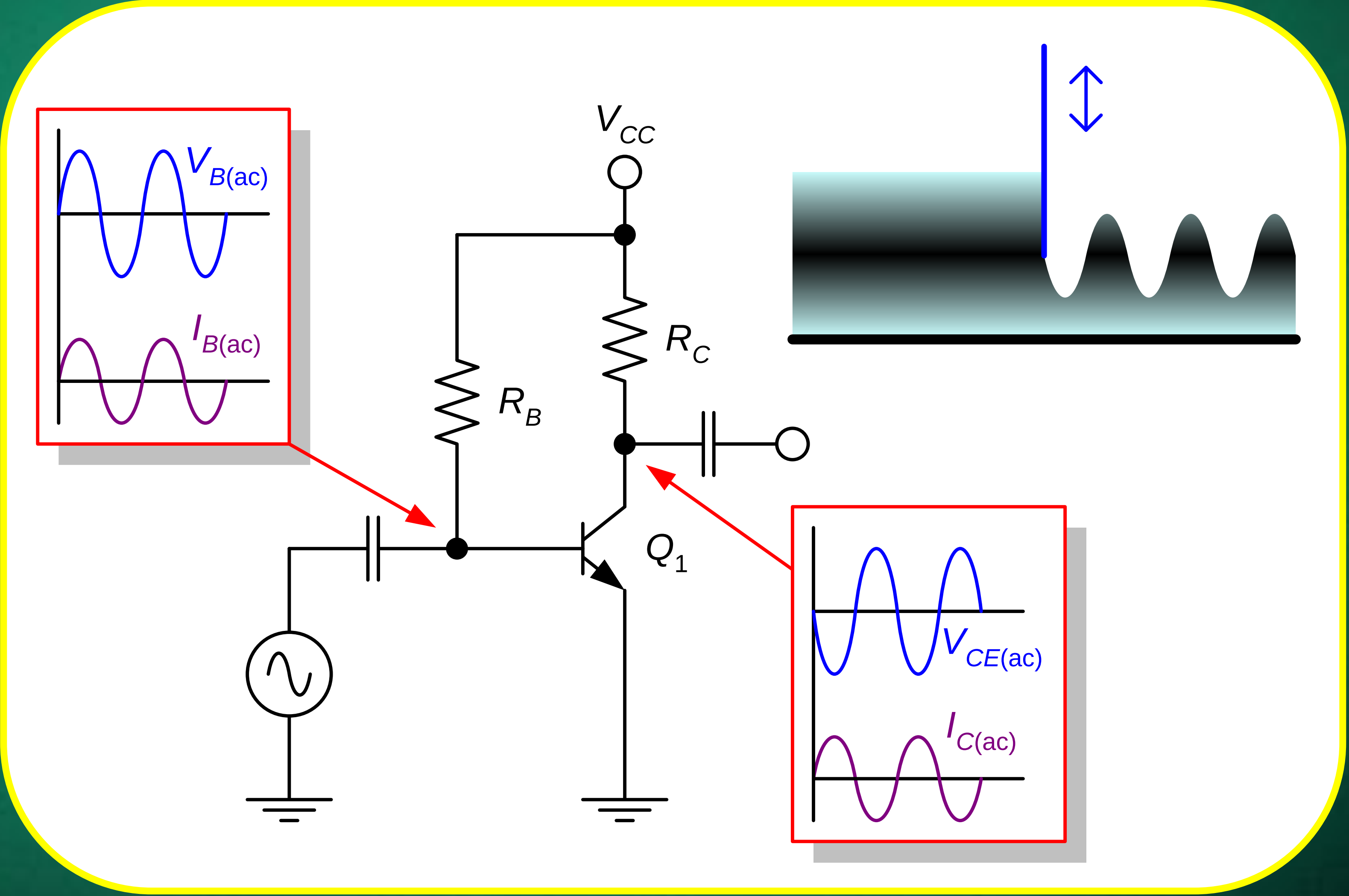


Transistor Biasing Circuits

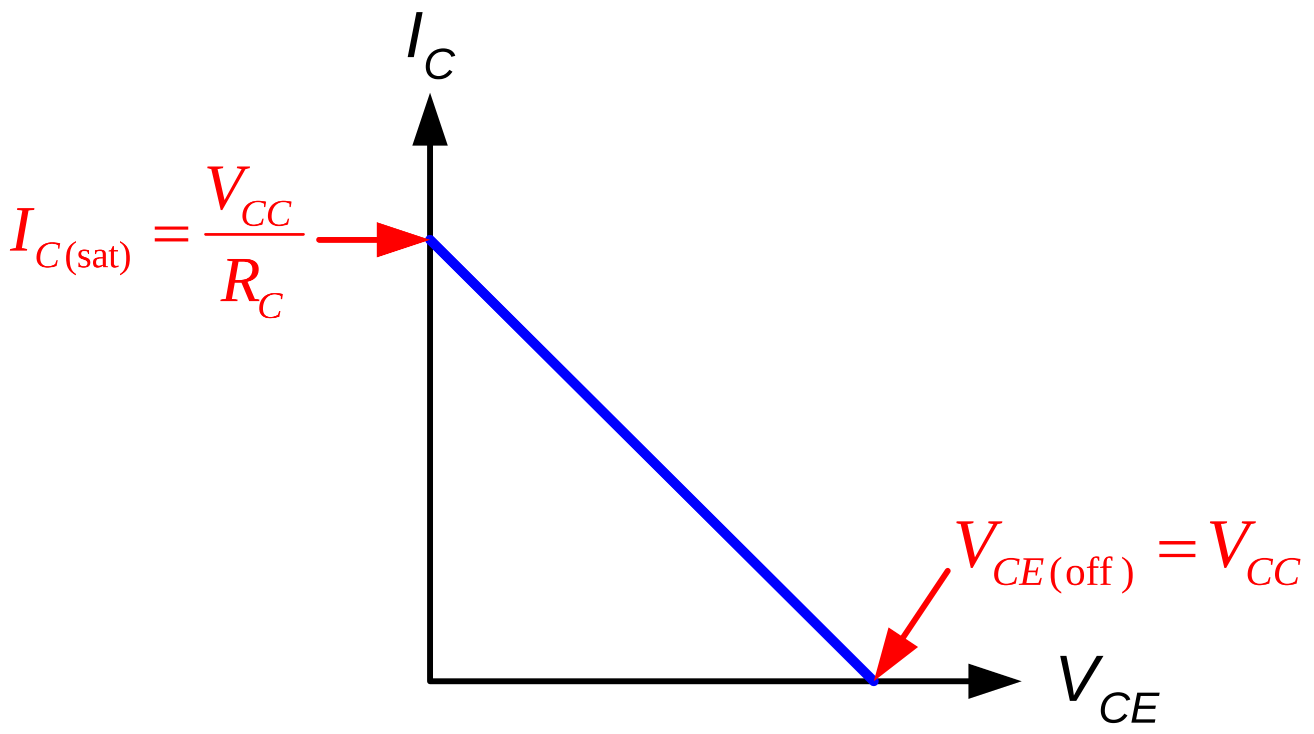
BJT 'Q' Point (Bias Point)

- Q point means Quiescent or Operating point.
- Very important for amplifiers because wrong 'Q' point selection increases amplifier distortion.
- Need to have a stable 'Q' point, meaning the operating point should not be sensitive to variation to temperature or BJT β (h_{FE}), which can vary widely.

Typical Amplifier Operation

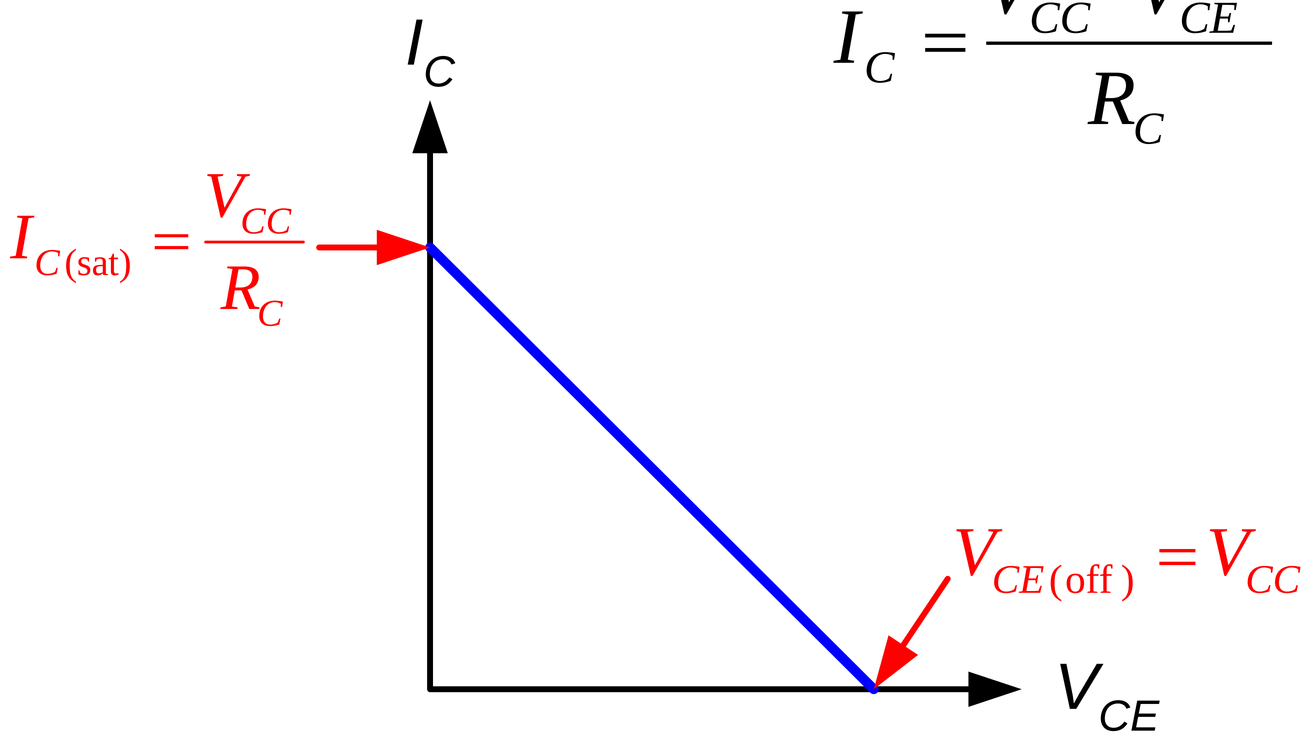


A Generic DC Load Line

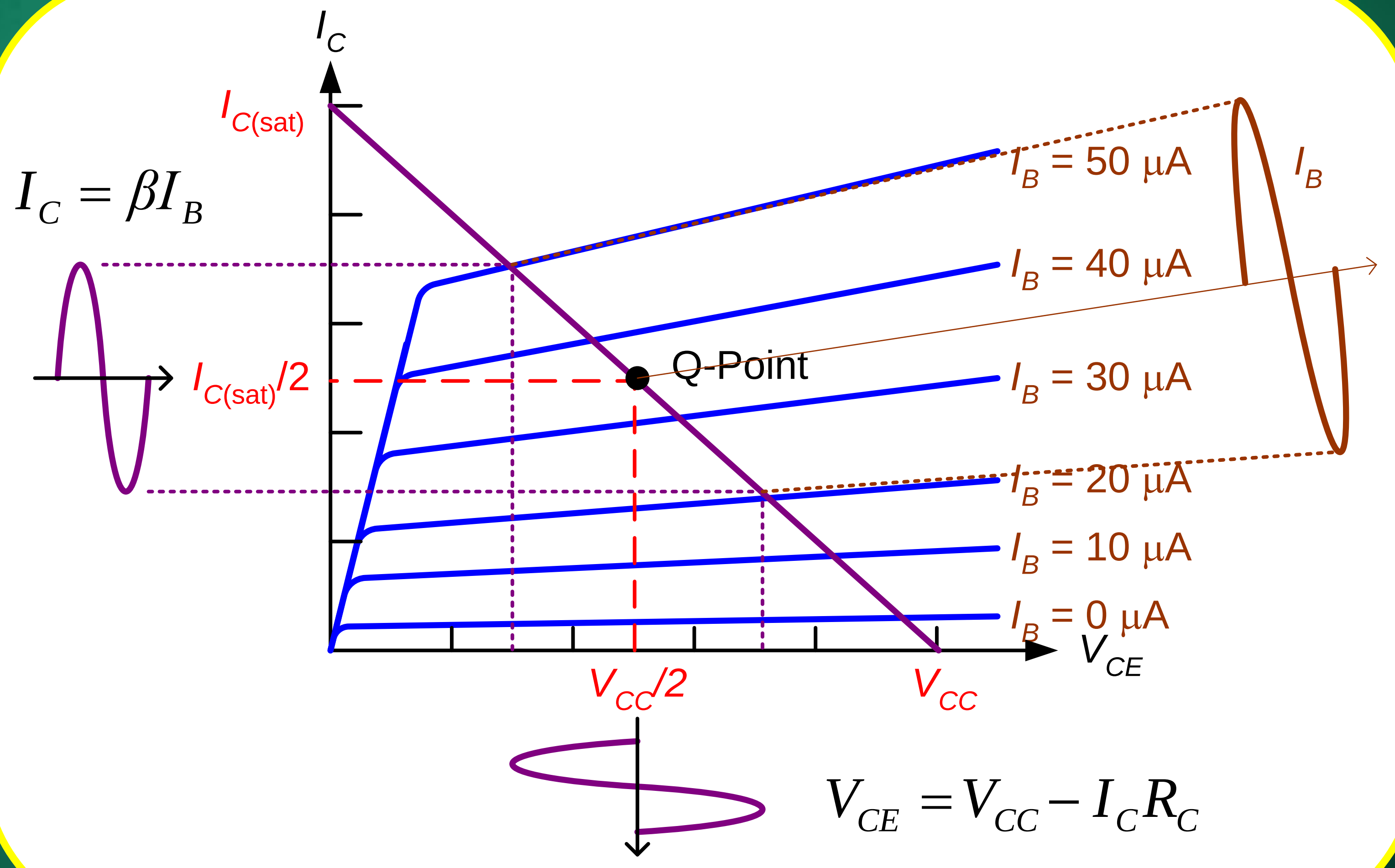


A Generic DC Load Line

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



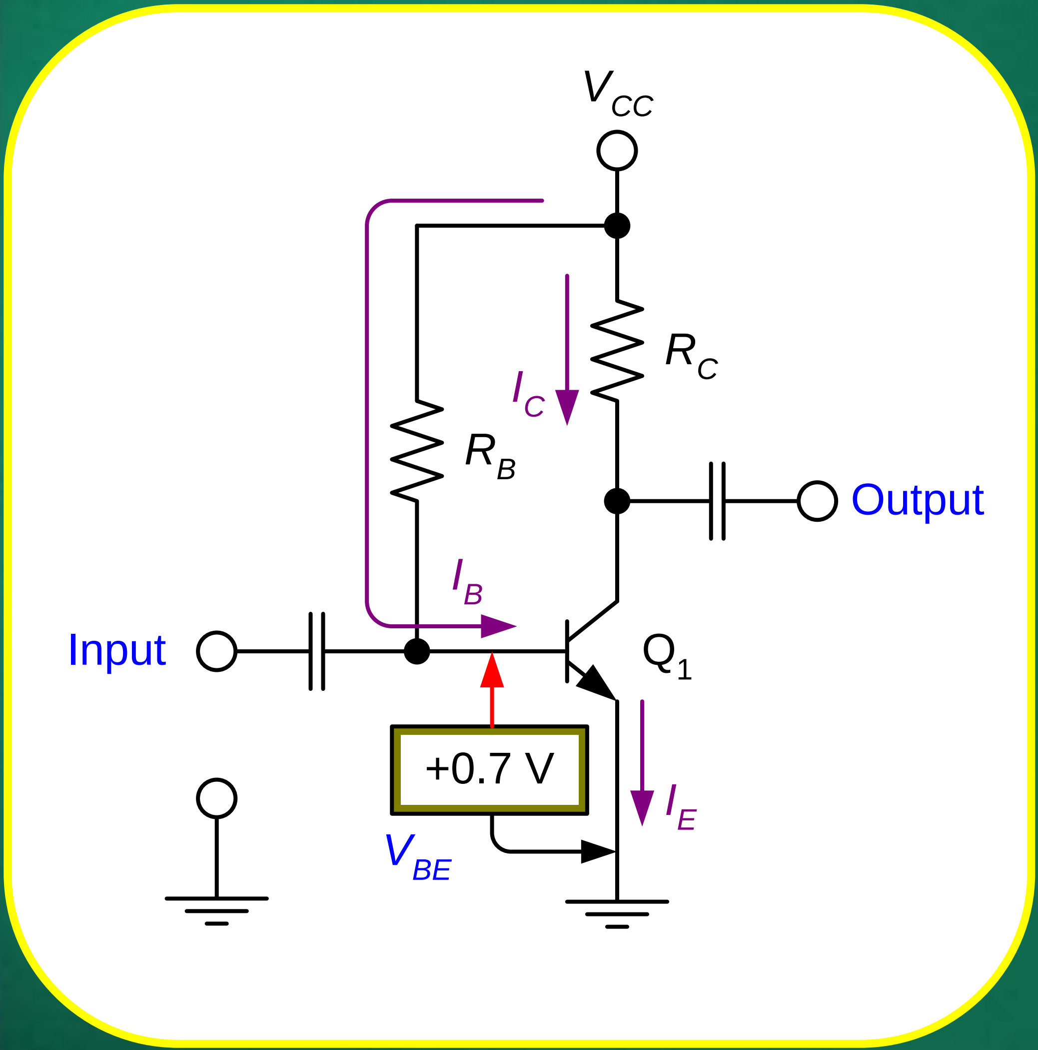
Optimum Q-point



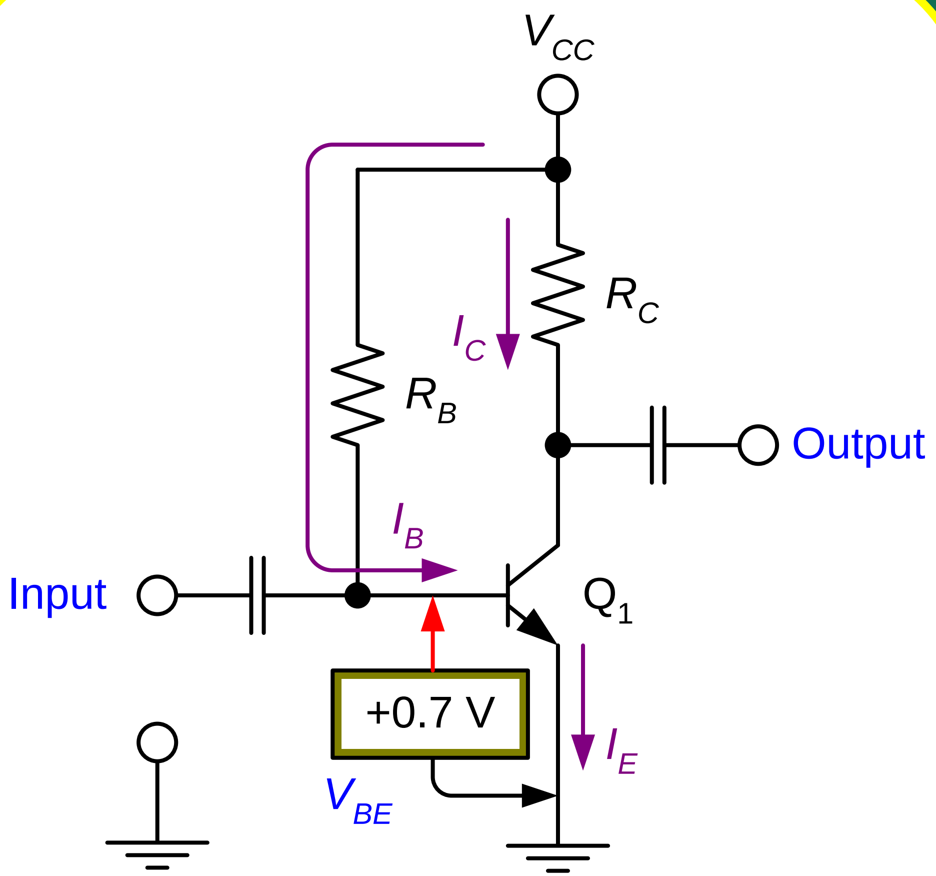
Bias Circuits

- Different types bias circuits
  - Base Bias
  - Voltage Divider Bias
  - Emitter Bias
  - Collector Feedback Bias
  - Emitter Feedback Bias

Base Bias (Fixed Bias)

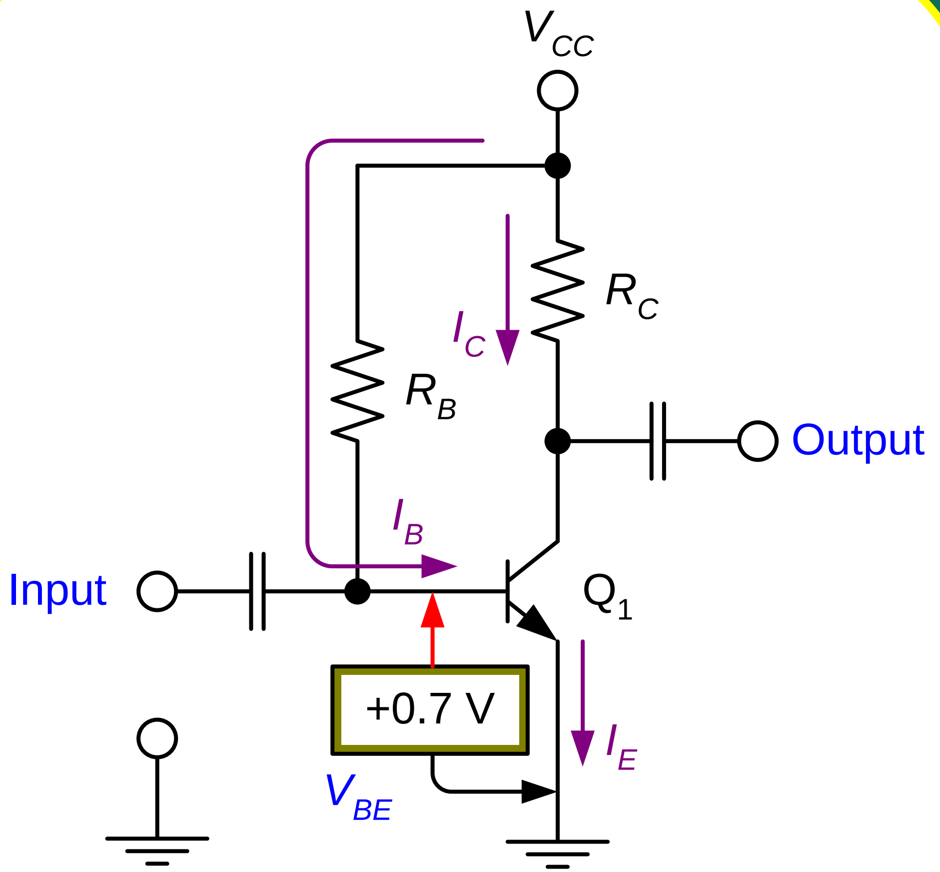


Base Bias (Fixed Bias)



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

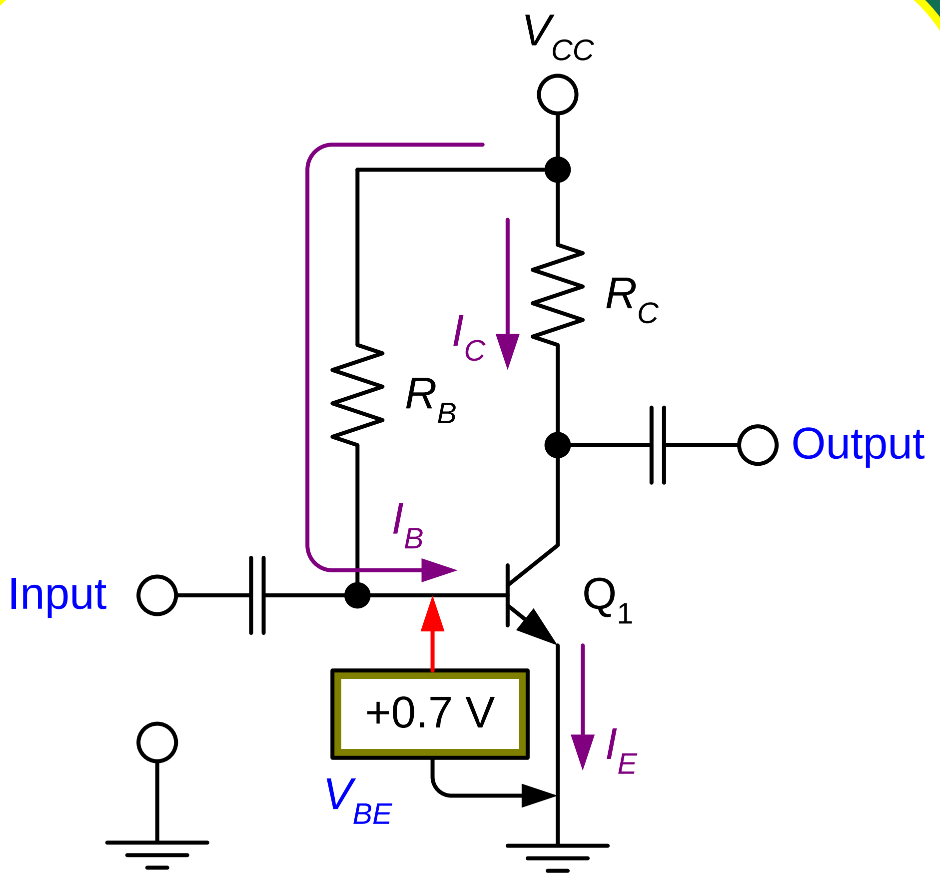
Base Bias (Fixed Bias)



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

$$I_C = \beta I_B$$

Base Bias (Fixed Bias)

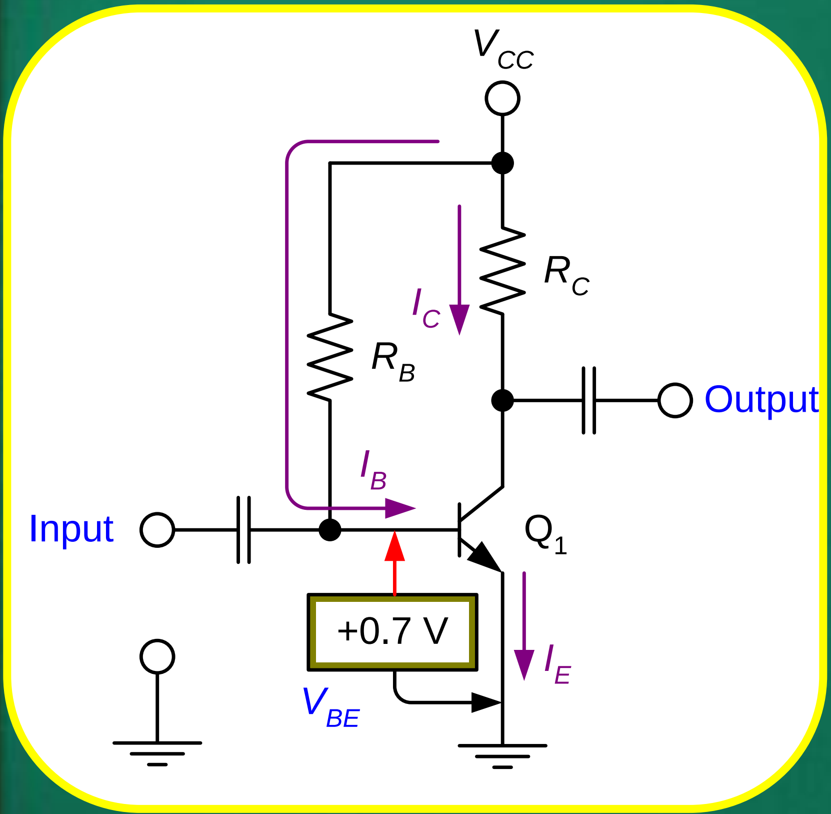


$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

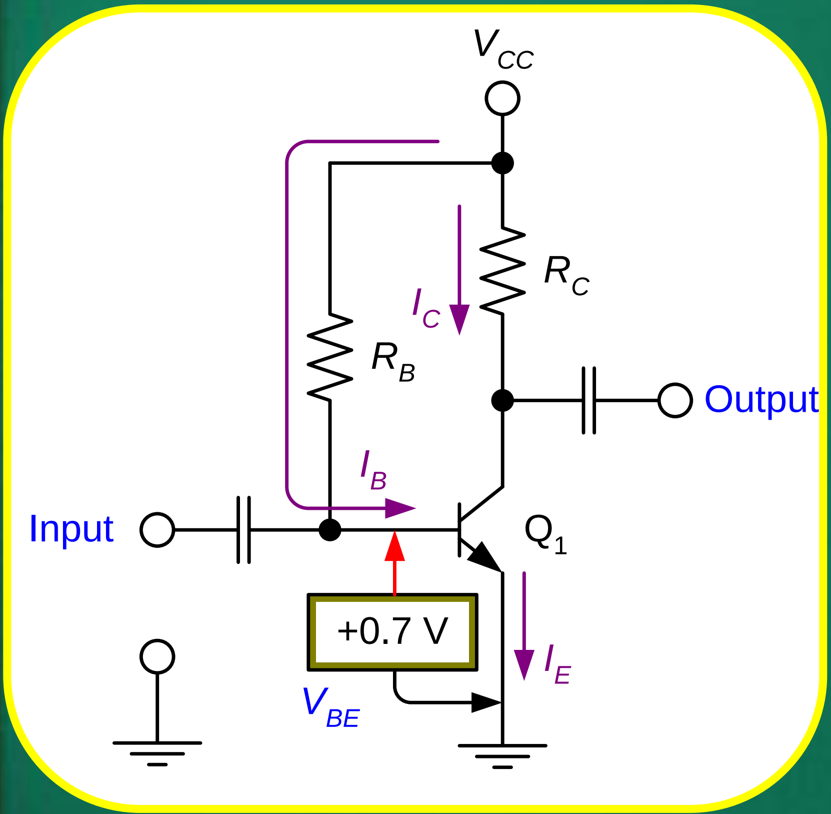
$$I_C = \beta I_B$$

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

Base Bias Characteristics

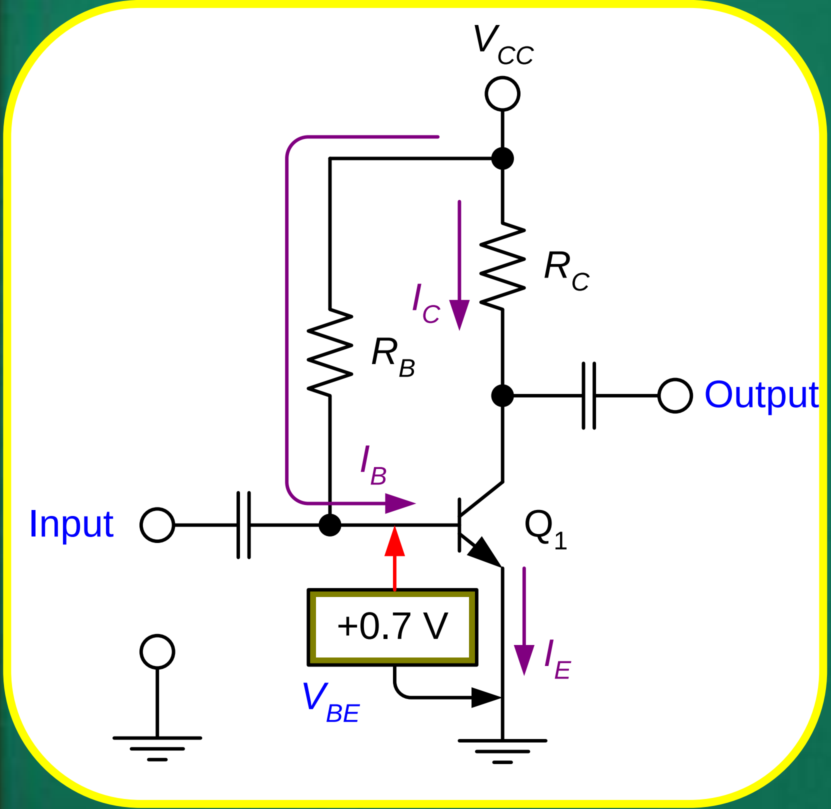


Base Bias Characteristics



Circuit recognition: A single resistor (R_B) between the base terminal and V_{CC}. No emitter resistor.

Base Bias Characteristics



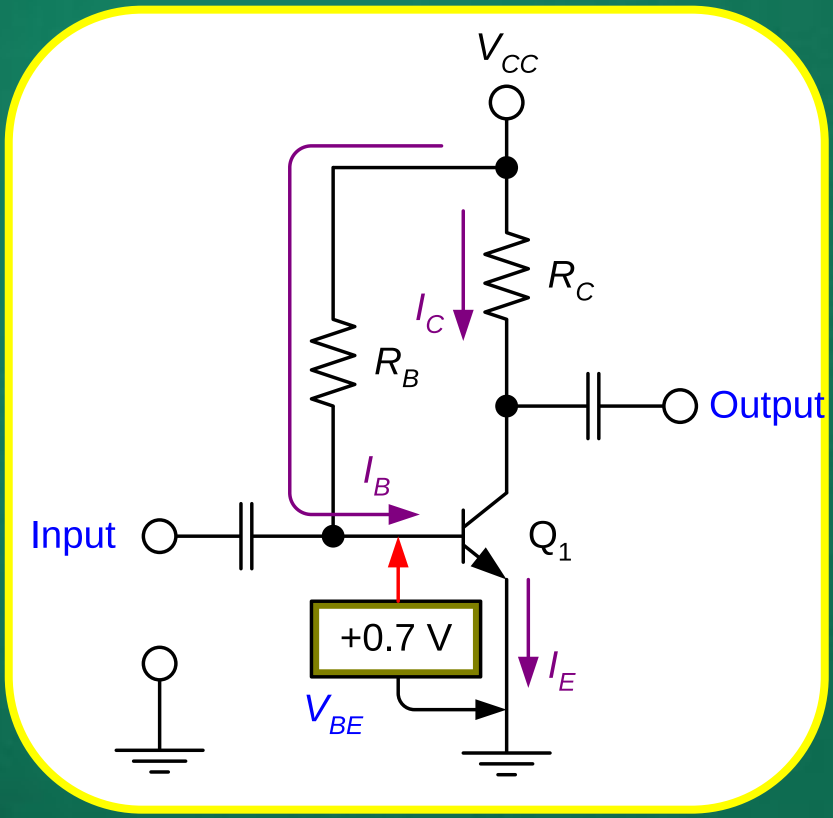
Circuit recognition: A single resistor (R_B) between the base terminal and V_{CC}. No emitter resistor.

Advantage: Circuit simplicity.

Disadvantage: Q-point shift with temp.

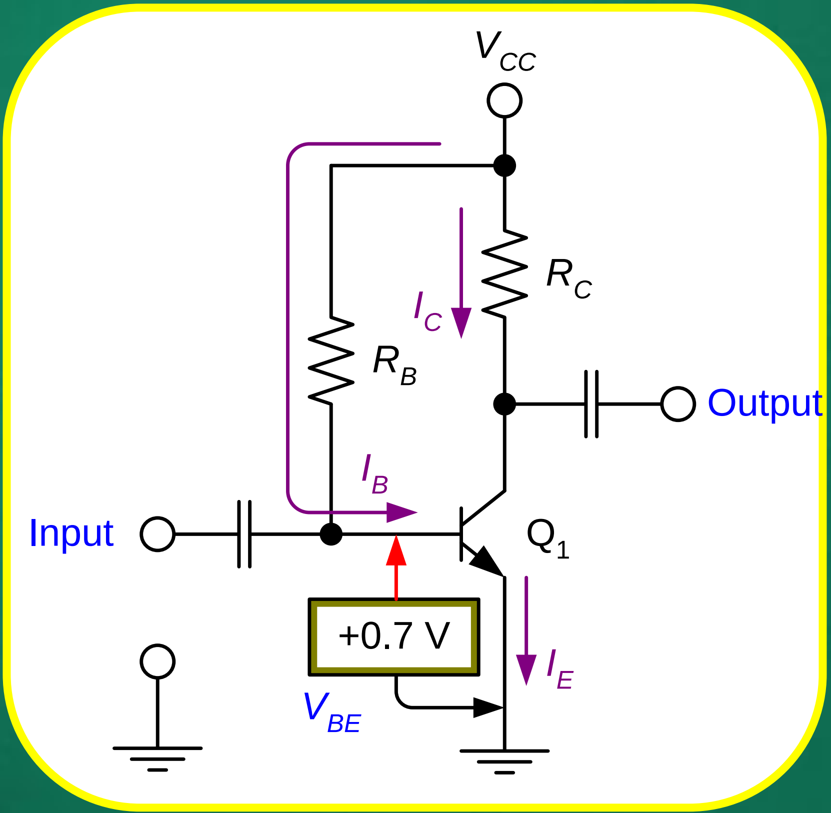
Applications: Switching circuits only.

Base Bias Characteristics

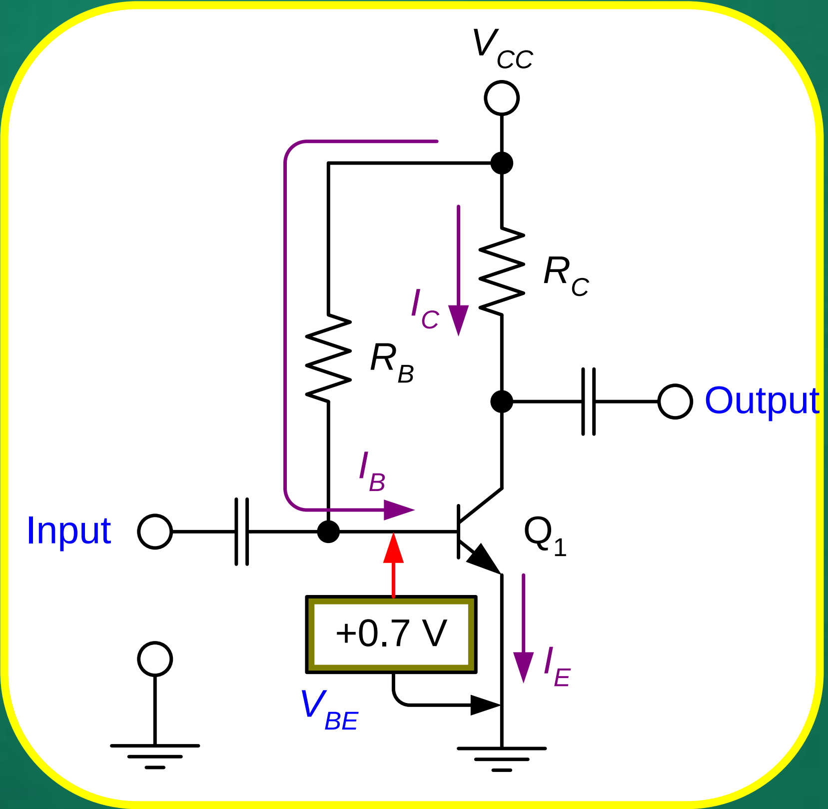


Base Bias Characteristics

Load line equations:



Base Bias Characteristics

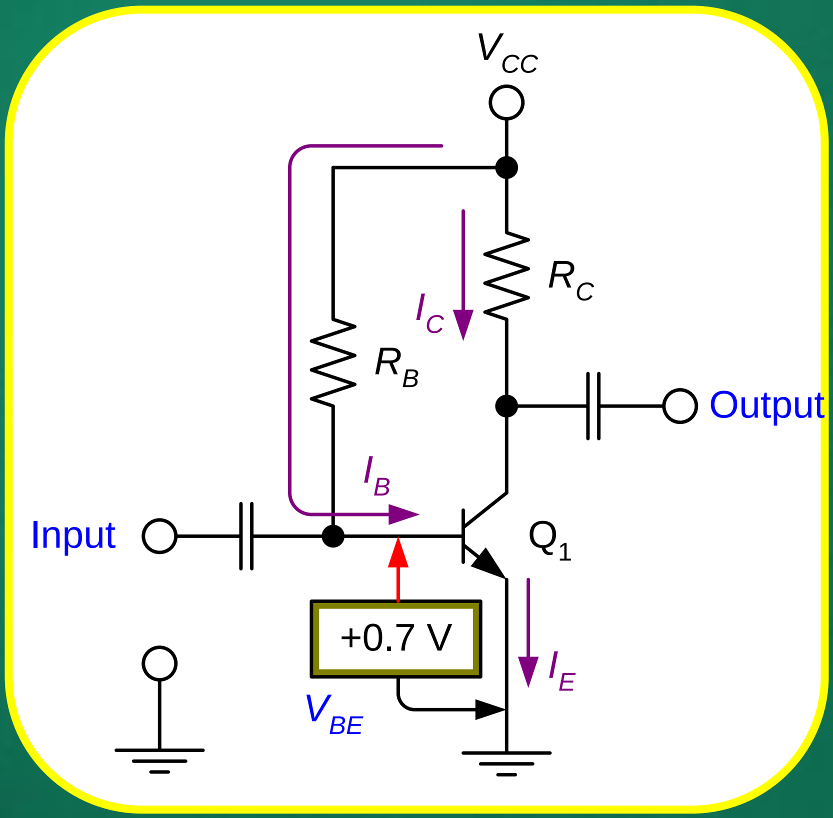


Load line equations:

$$I_{C(\text{sat})} \cong \frac{V_{CC}}{R_C}$$

$$V_{CE(\text{off})} = V_{CC}$$

Base Bias Characteristics



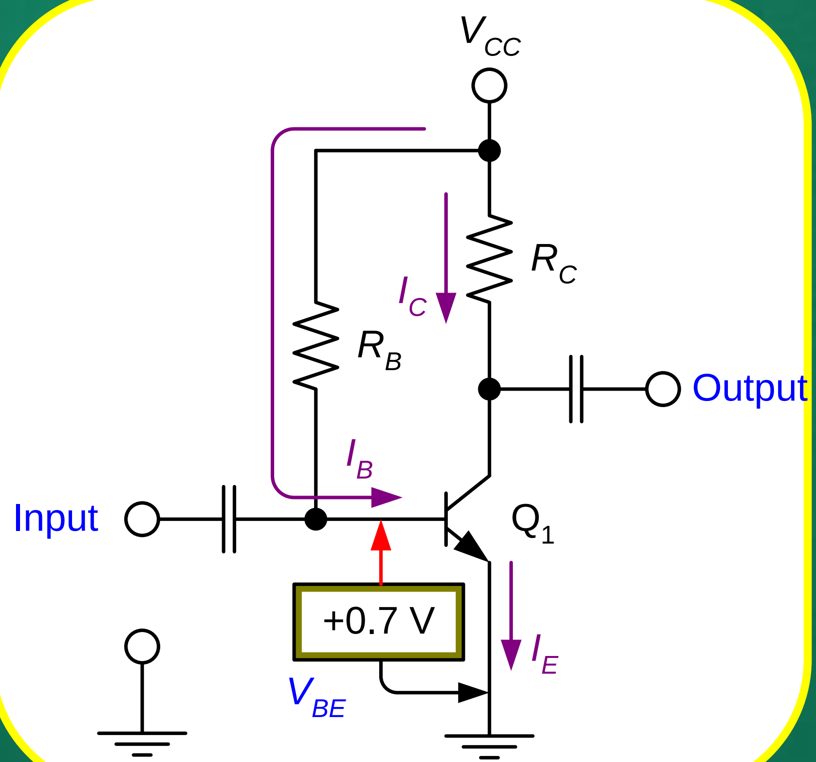
Load line equations:

$$I_{C(\text{sat})} \cong \frac{V_{CC}}{R_C}$$

$$V_{CE(\text{off})} = V_{CC}$$

Q-point equations:

Base Bias Characteristics



Load line equations:

$$I_{C(\text{sat})} \cong \frac{V_{CC}}{R_C}$$

$$V_{CE(\text{off})} = V_{CC}$$

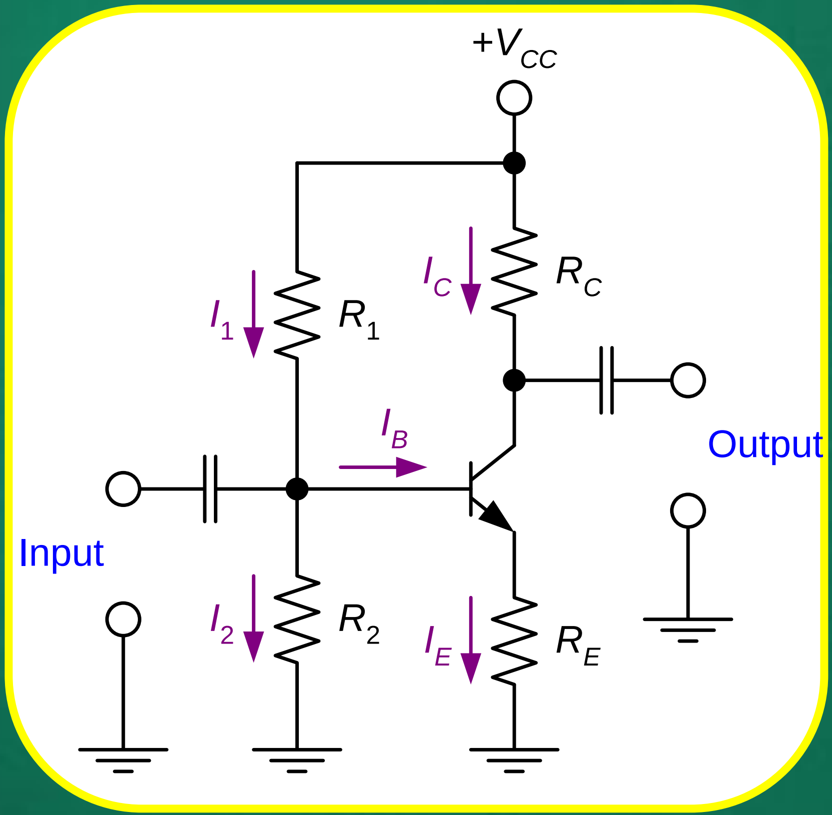
Q-point equations:

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

$$I_C = h_{FE} I_B$$

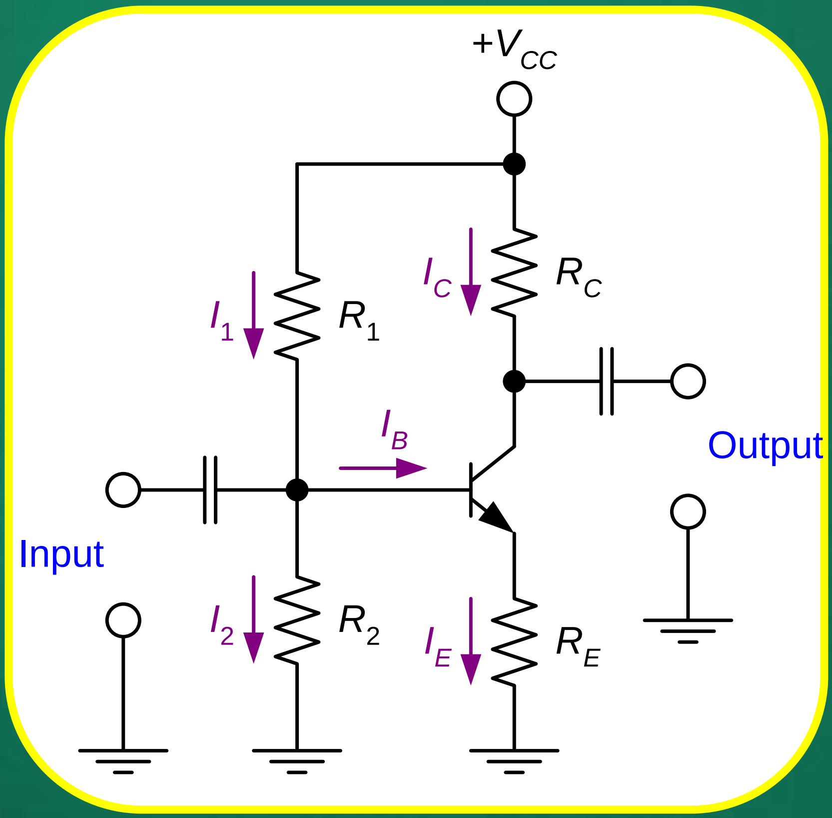
$$V_{CE} = V_{CC} - I_C R_C$$

Voltage Divider Bias



Voltage Divider Bias

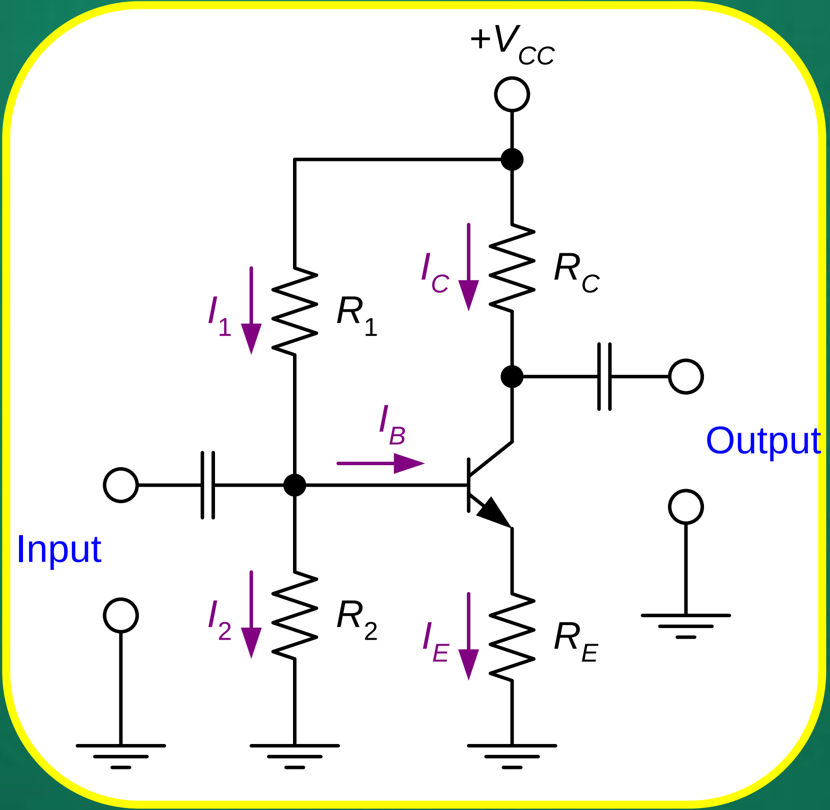
Assume that $I_2 > 10I_B$.



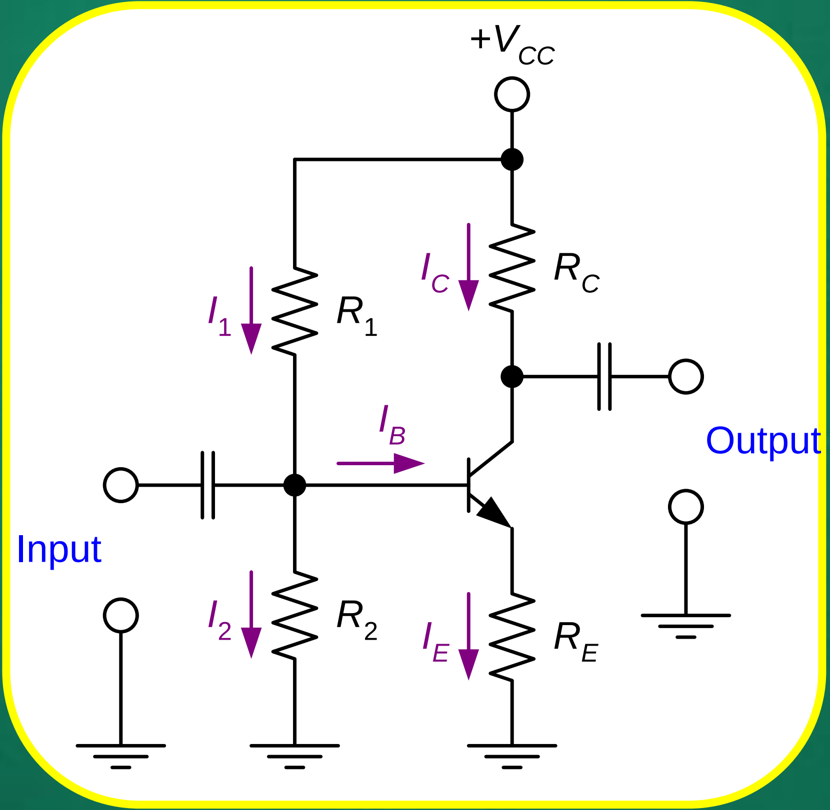
Voltage Divider Bias

Assume that $I_2 > 10I_B$.

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



Voltage Divider Bias



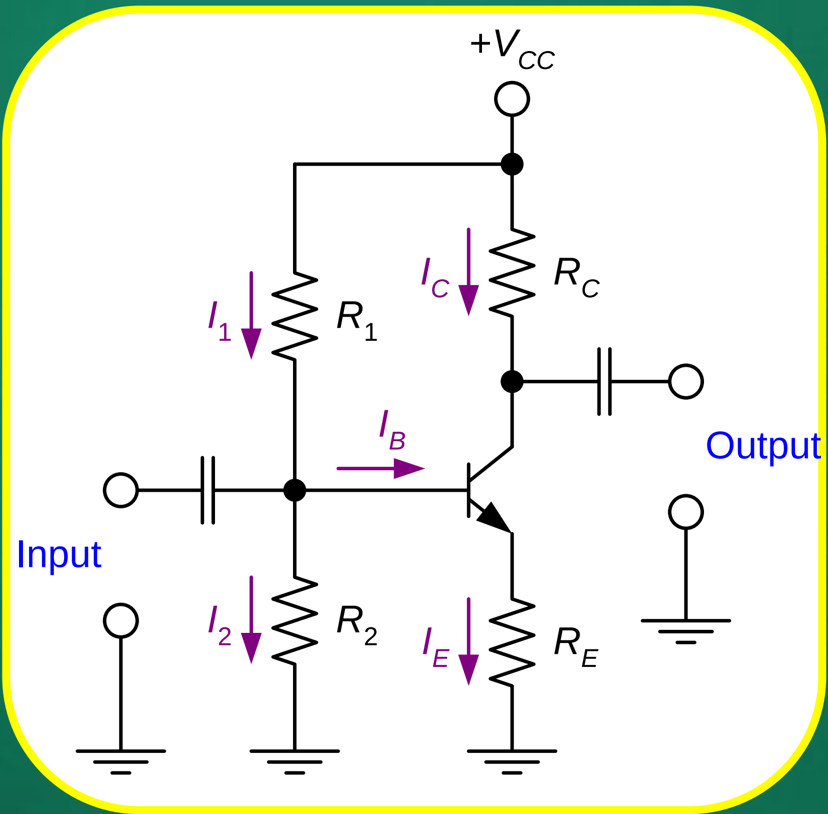
Assume that $I_2 > 10I_B$.

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

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

Voltage Divider Bias

Assume that $I_2 > 10I_B$.

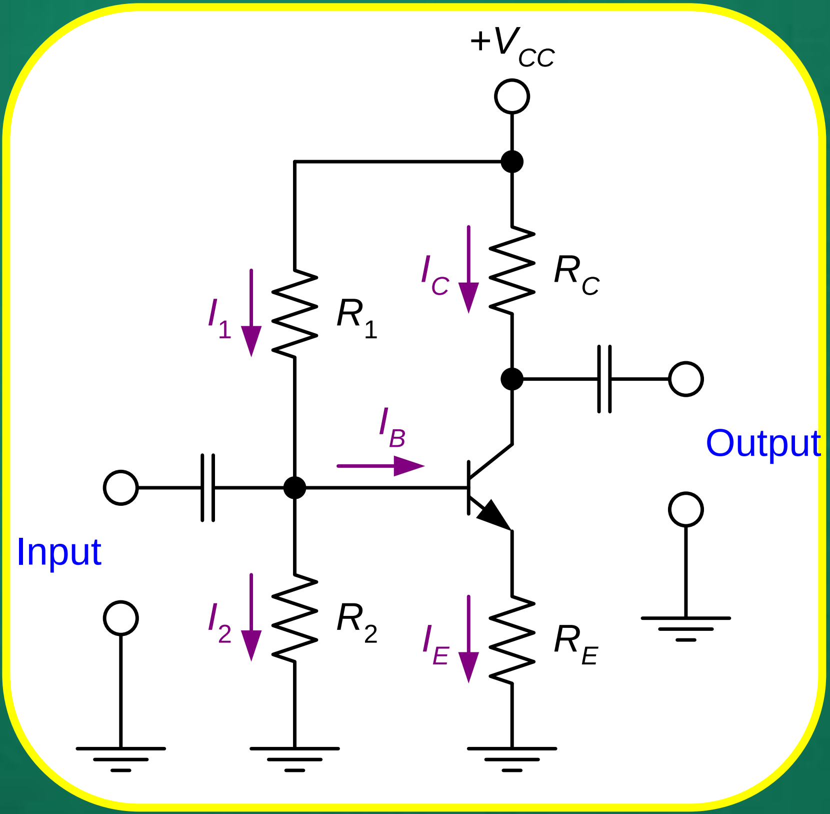


$$V_B = \frac{R_2}{R_1 + R_2} V_{CC}$$

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

$$I_E = \frac{V_E}{R_E}$$

Voltage Divider Bias



Assume that $I_2 > 10I_B$.

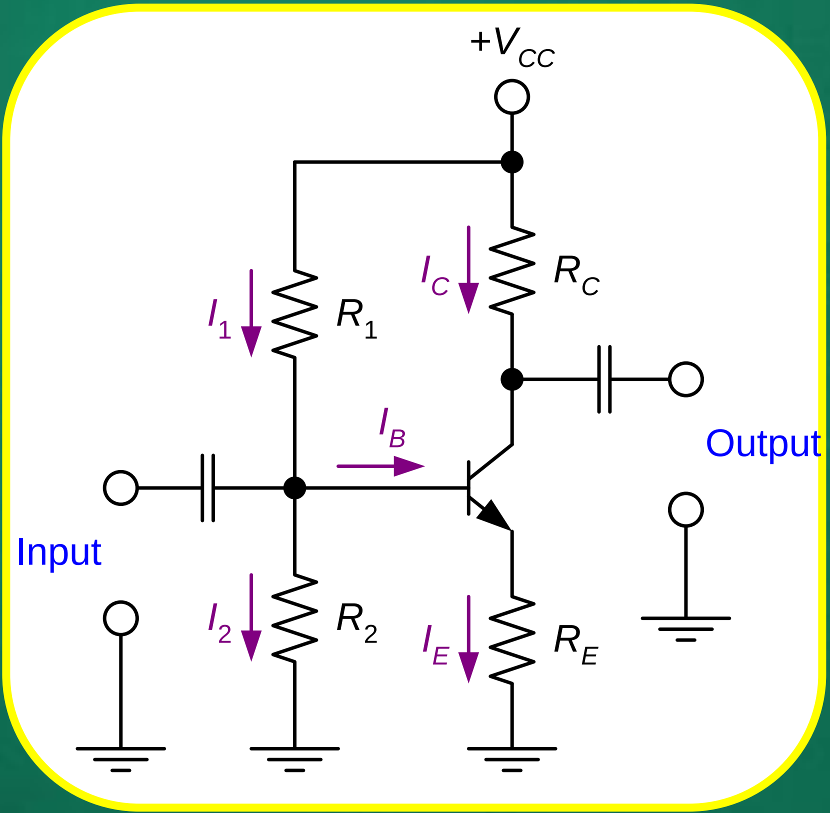
$$V_B = \frac{R_2}{R_1 + R_2} V_{CC}$$

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

$$I_E = \frac{V_E}{R_E}$$

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

Voltage Divider Bias



Assume that $I_2 > 10 I_B$.

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

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

$$I_E = \frac{V_E}{R_E}$$

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

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