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Session 11
Introduction to bipolar junction transistor (BJT)

Electronic Components and Circuits

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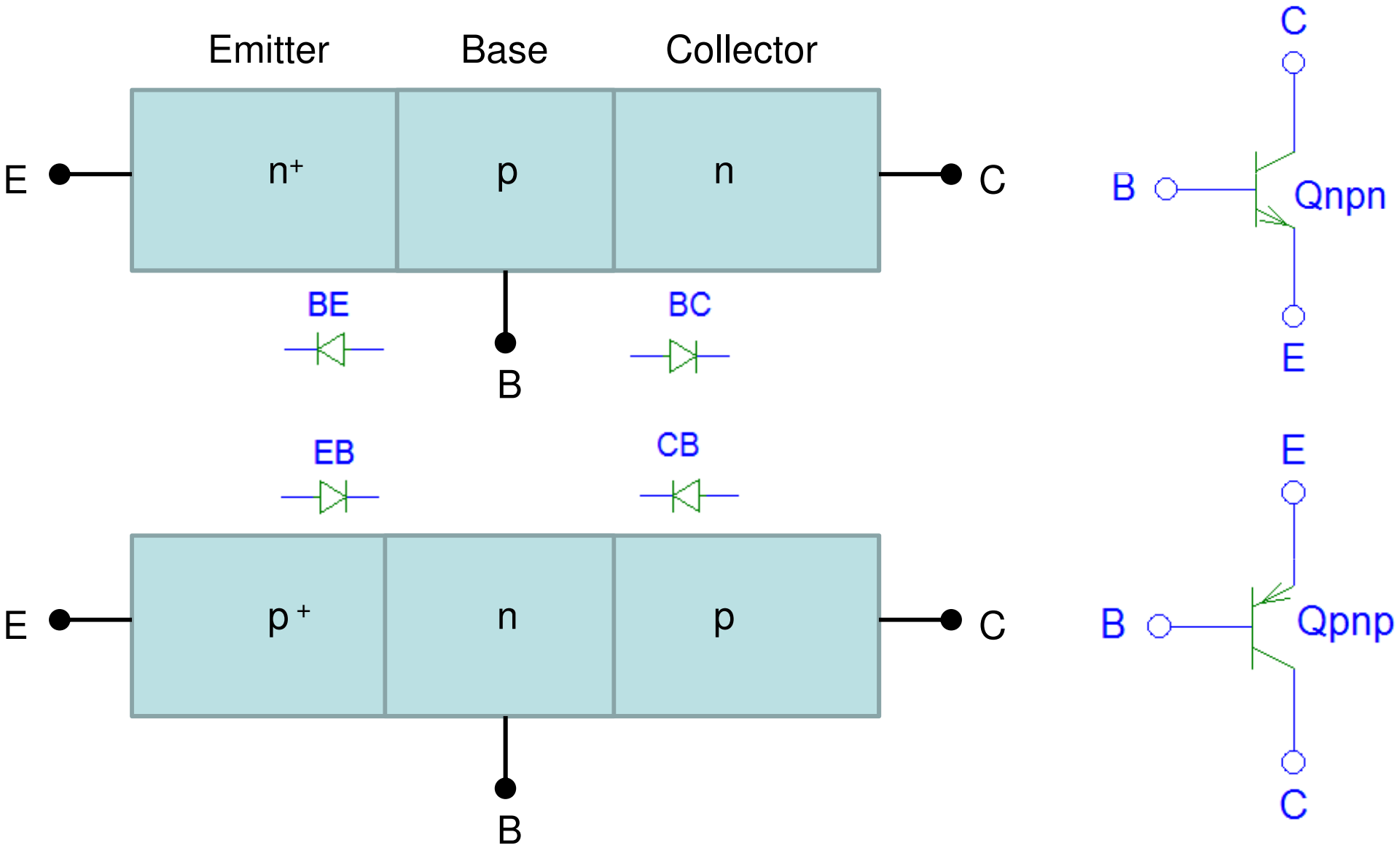
Bipolar Junction Transistor
BJT

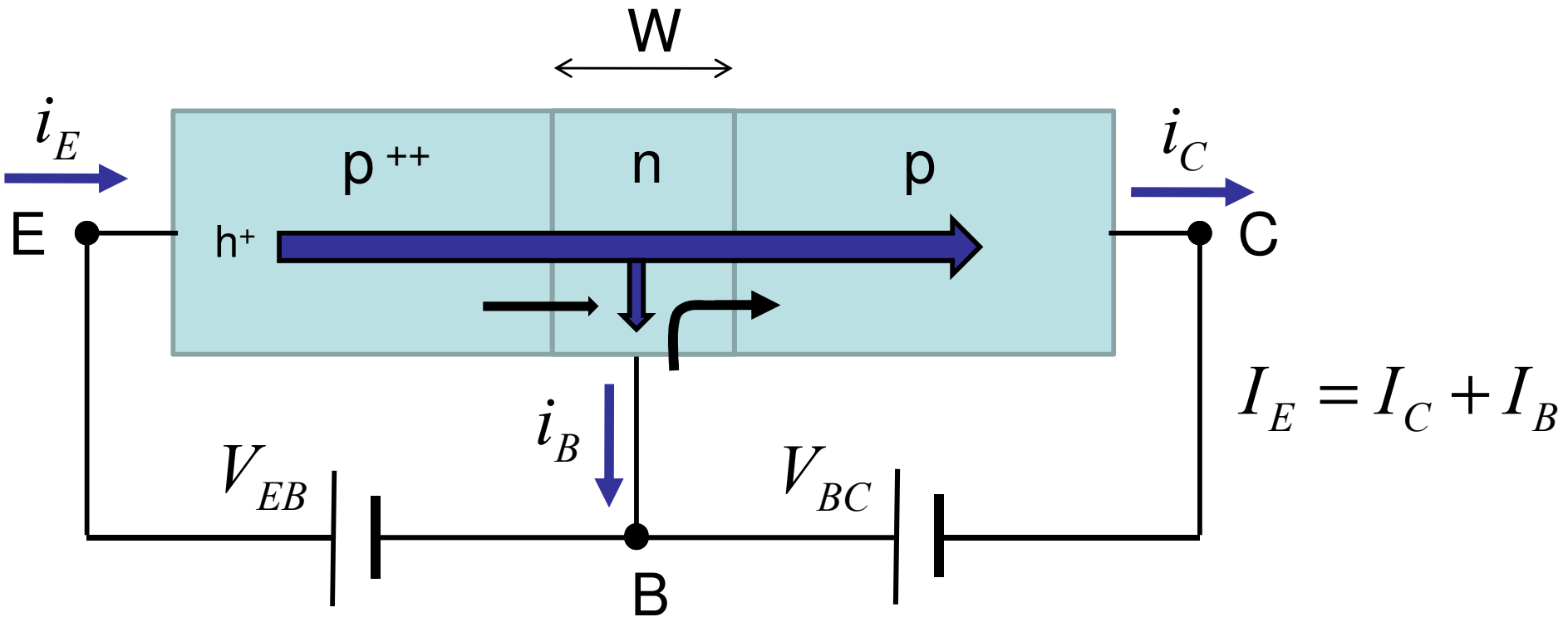
OBJECTIVES

- Knowing the structure of the device and the transistor effect
- Knowing and distinguishing basic parameters related to BJT transistors: α, β, h_{FB}, h_{FE}, I_{CBO}, $V_{BE(on)}$, $V_{CE(sat)}$
- Reading the current-voltage characteristic of the device
- Identifying the operating regions
  Active, Cut-off, Saturation, Inverse Active
- Analyze basic cases in DC of BJT circuits

Bipolar Transistor Structure



Operation: Transistor Effect



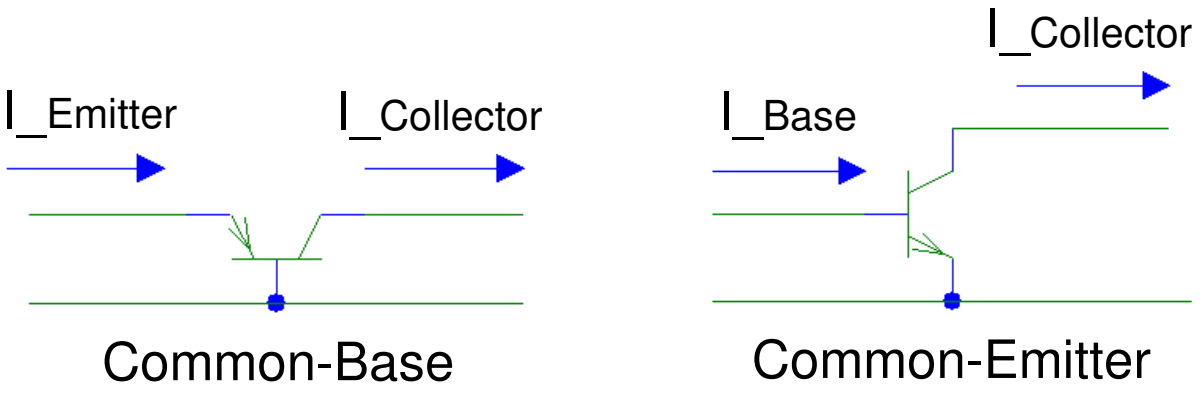
$$I_E = I_C + I_B$$

$$I_C = \alpha \cdot I_E + I_{CBO} \qquad \alpha \approx 1$$

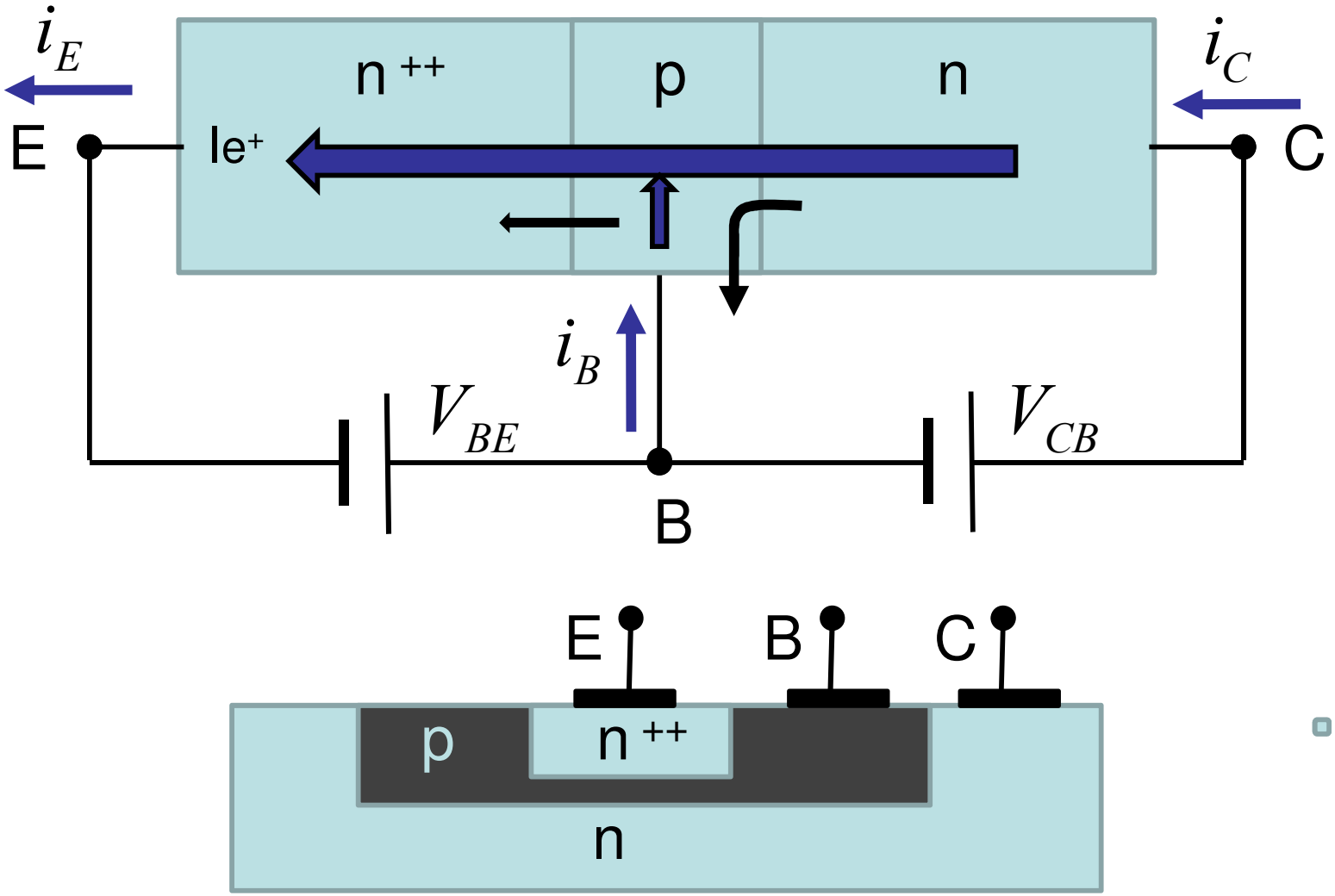
$$I_B = (1-\alpha) \cdot I_E - I_{CBO} \qquad I_C \approx I_E$$

Characteristic parameters

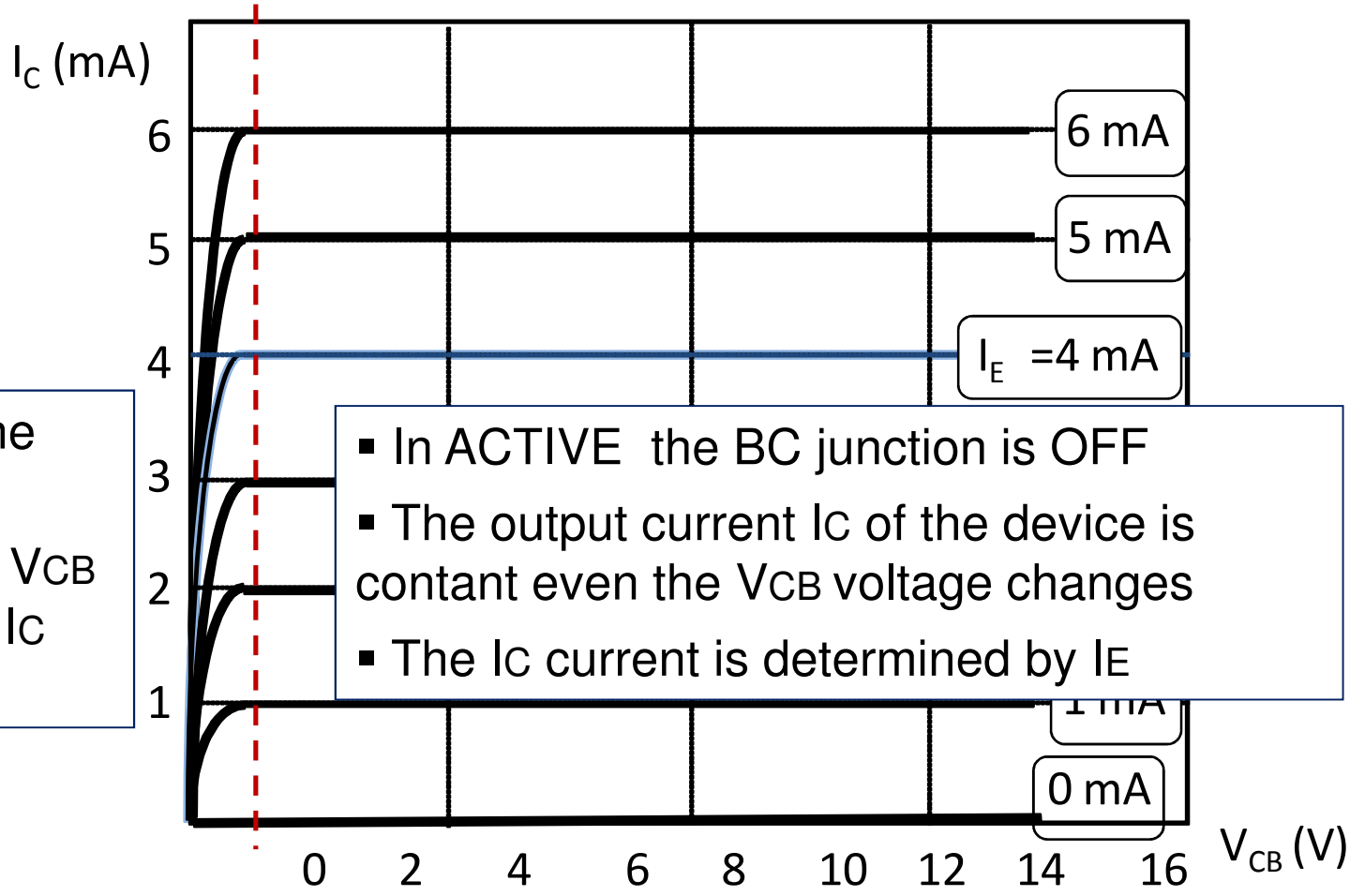
- Physical Parameters
  - α $I_C \approx \alpha \cdot I_E$ $\alpha \approx 1$ $\beta = \frac{\alpha}{1-\alpha}$
  - β $I_C \approx \beta \cdot I_B$ $\beta >> 1$
  - I_{CBO} $I_C = \alpha \cdot I_E + I_{CBO}$ $I_C = \beta \cdot I_B + I_{CBO}$
- Daasheet: Search BC547 in http://www.fairchildsemi.com/
  - h_{FB}
  - h_{FE}
  - I_{CBO}



Dual case: Transistor NPN



Interpretation: current-voltage characteristic



- In SATURATION the BC junction is ON
- The output voltage V_{CB} is constant even the I_C current changes

- In ACTIVE the BC junction is OFF
- The output current I_C of the device is contant even the V_{CB} voltage changes
- The I_C current is determined by I_E

There is a curve for each input value IE

Operating Regions

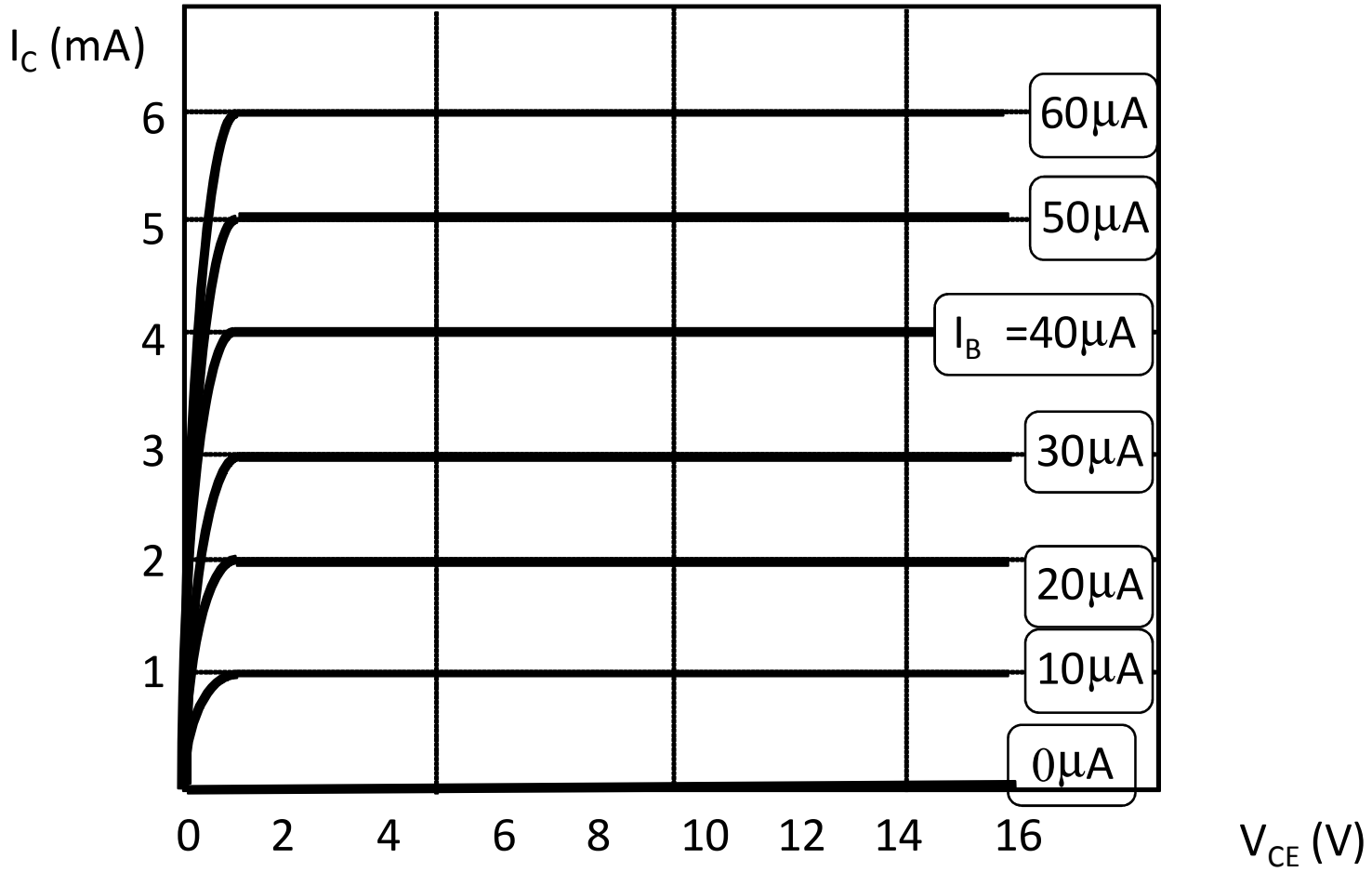
Region	Base-Emitter Junction	Base-Collector Junction
Cut-off	**Reverse(OFF)**	Reverse
Active	**Forward (ON)**	**Reverse (Transistor Effect)**
Saturation	**Forward (ON)**	**Forward (Saturated)**
Active Reverse	Reverse	Forward

Region	Conditions NPN	Operation NPN
Cut-off	$V_{BE} < V_{BE\text{-}ON}$ o $I_B = 0$	$I_B=0$, $I_C=I_E=0$
Active	$V_{BE\text{-}ON}$ y $V_{CE} > V_{CE\text{-}SAT}$	$I_C \approx h_{FE} \cdot I_B$ $[V_{BE}=V_{BE\text{-}ON}]$
Saturation	$V_{BE\text{-}ON}$ y $V_{CE\text{-}SAT}$	$V_{CE} = V_{CE\text{-}SAT}$ $[V_{BE}=V_{BE\text{-}SAT}]$

- Datasheet $V_{BE(on)}$ $V_{CE(sat)}$ h_{FE} $V_{BE(sat)}$

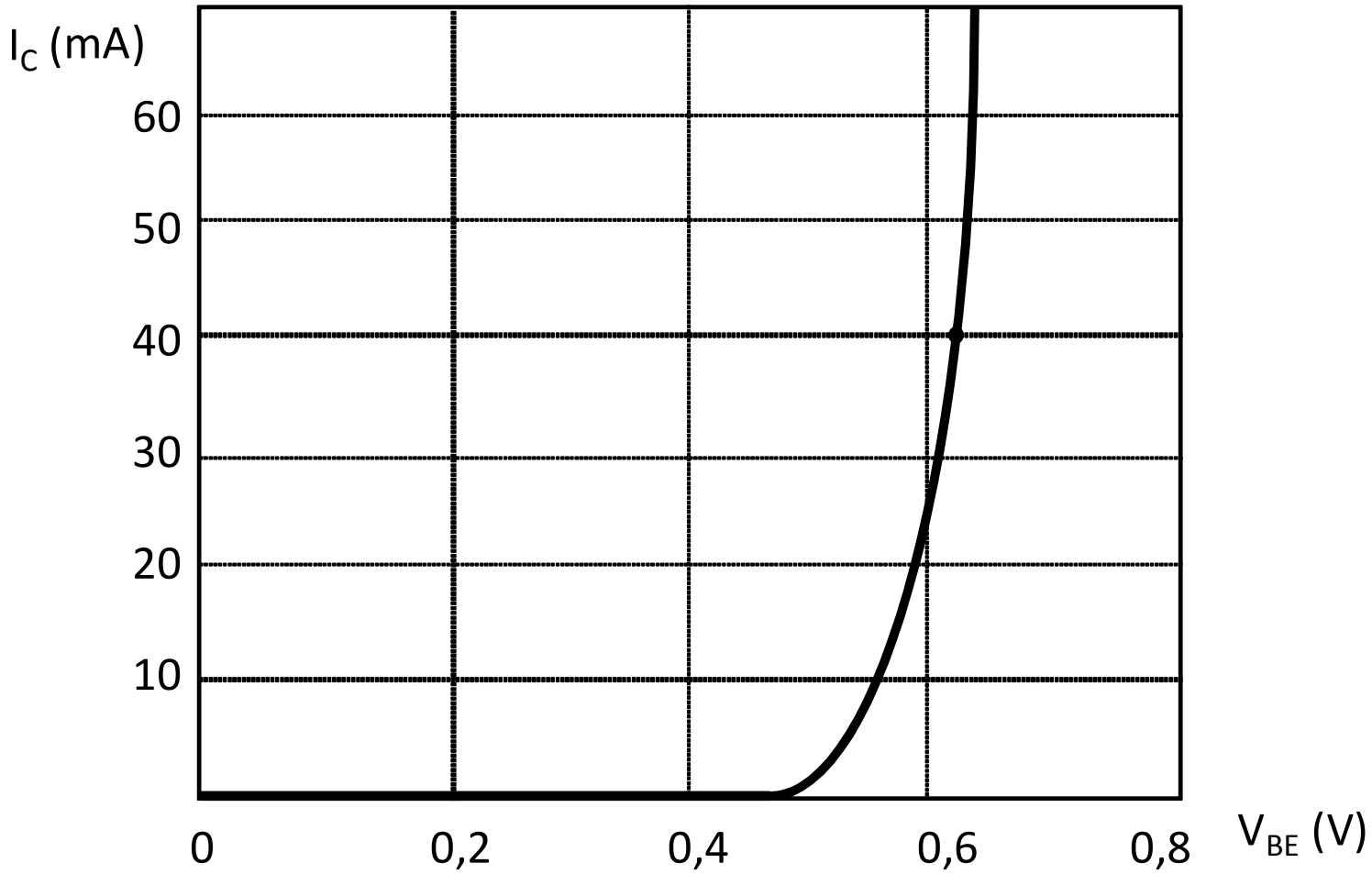
  Search BC547 in http://www.fairchildsemi.com/

Output Characteristics (Common - Emitter)



What input characteristic represent?

Transfer Charateristic

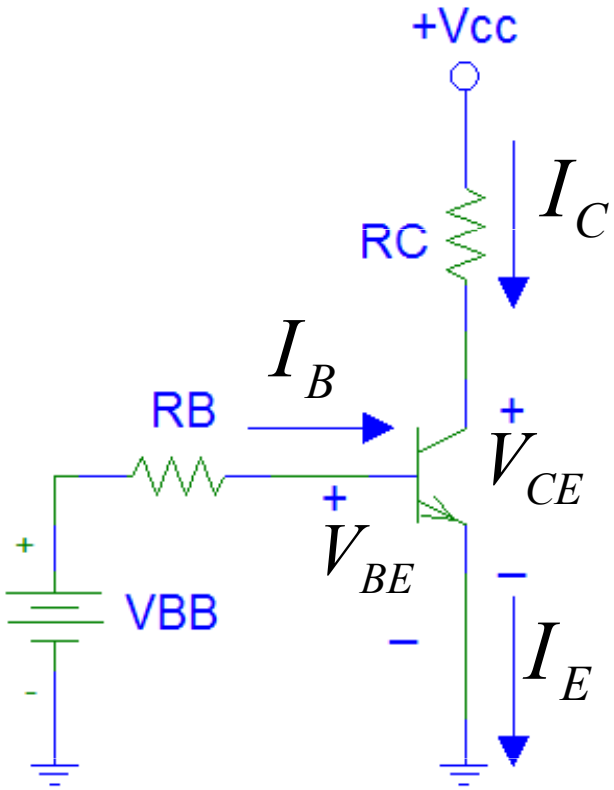


What operating regions can be identified?

Example: Operating Regions

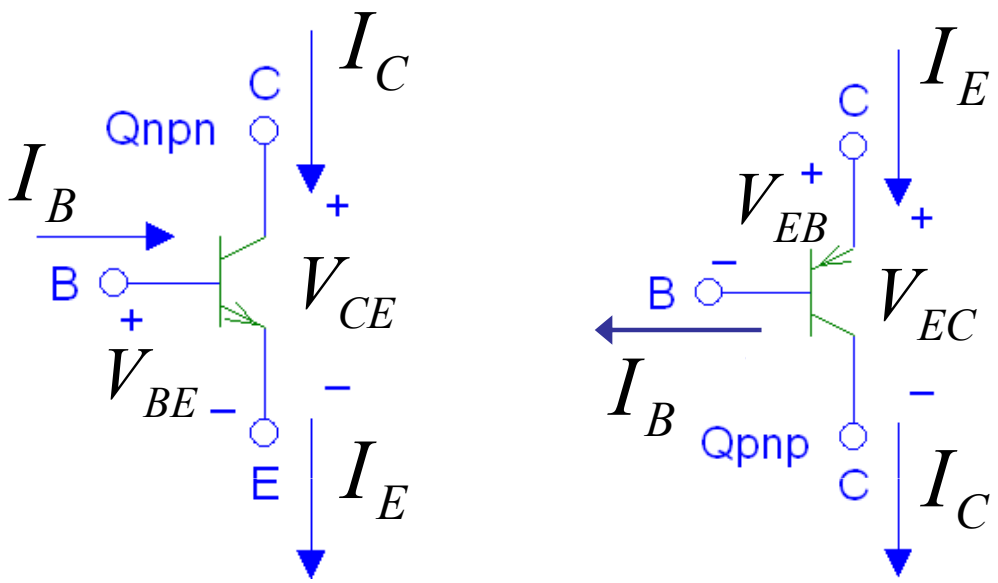
EXAMPLE

- RC = 100 Ω
- RB = …
- VCC = 10 V
- VBB = …
- VBE(on) = 0,7 V
- VCE(sat) = 0,2 V
- hFE = 100



Case 1	Case 2	Case 3	Case 4
VBB = 0 V	$I_B = 0$	VBB = 10 V	VBB = 10 V
RB = 10 kΩ	RB = 10 kΩ	RB = 10 kΩ	RB = 1 kΩ

Currents and Voltages of NPN and PNP



Operating Regions
Case of PNP transistor

- Datasheet $V_{EB(on)}$ $V_{EC(sat)}$ h_{FE} $V_{EB(sat)}$

  Search BC557 in http://www.fairchildsemi.com/

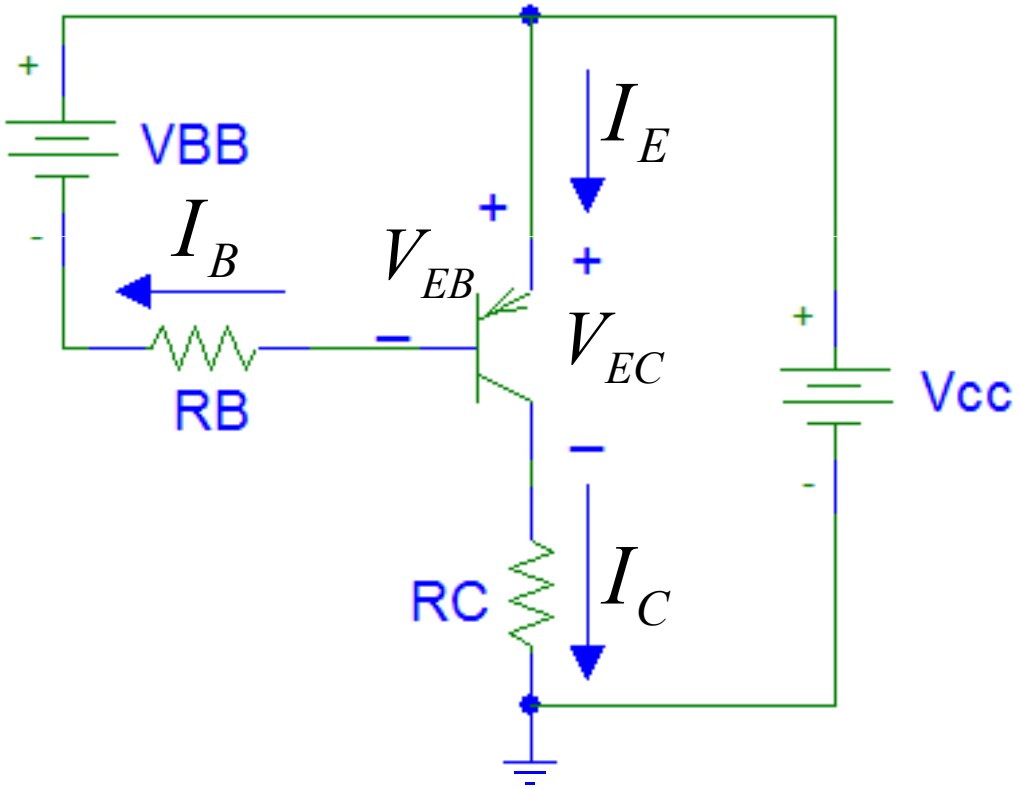
Region	Emitter-Base Junction	Collector-Base Junction
Cut-off	Reverse(OFF)	Reverse
Active	Forward (ON)	Reverse (Transistor Effect)
Saturation	Forward (ON)	Forward (Saturated)

Region	Conditions PNP	Operation PNP	
Cut-off	$V_{EB} < V_{EB\text{-}ON}$ o $I_B = 0$	$I_B=0$, $I_C=I_E=0$	
Active	$V_{EB\text{-}ON}$ y $V_{EC} > V_{EC\text{-}SAT}$	$I_C \approx h_{FE} \cdot I_B$	$[V_{EB}=V_{EB\text{-}ON}]$
Saturation	$V_{EB\text{-}ON}$ y $V_{EC\text{-}SAT}$	$V_{EC} = V_{EC\text{-}SAT}$	$[V_{EB}=V_{EB\text{-}SAT}]$

Exercise: Operating Regions

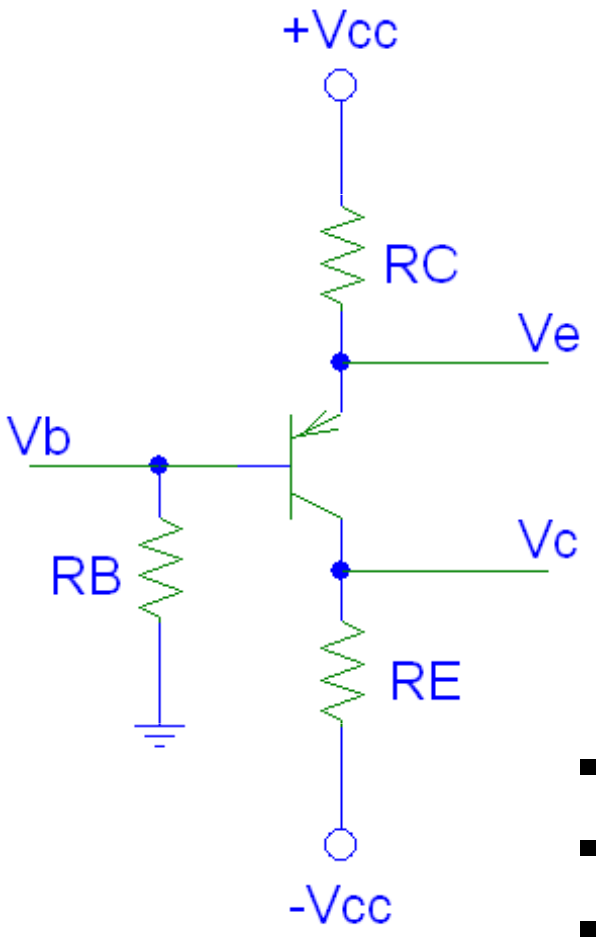
DATA

- RC = 100 Ω
- RB = …
- VCC = 10 V
- VBB = …
- VEB(on) = 0,7 V
- VEC(sat) = 0,2 V
- hFE = 100

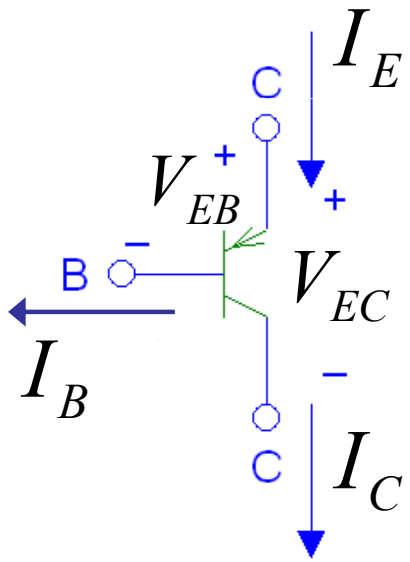


Case 1	Case 2	Case 3	Case 4
VBB = 0 V	I_B = 0	VBB = 10 V	VBB = 10 V
RB = 10 kΩ	RB = 10 kΩ	RB = 10 kΩ	RB = 1 kΩ

Proposed exercise



Voltages and currents



- Indicate what type of transistor is
- Reasoning the operating region
- Relate V_B and V_E, V_B and I_B, V_E and I_E, I_E and I_B.
- Relate V_C and I_C