BASIC ELECTRONIC CIRCUITS

Bipolar Junction Transistor

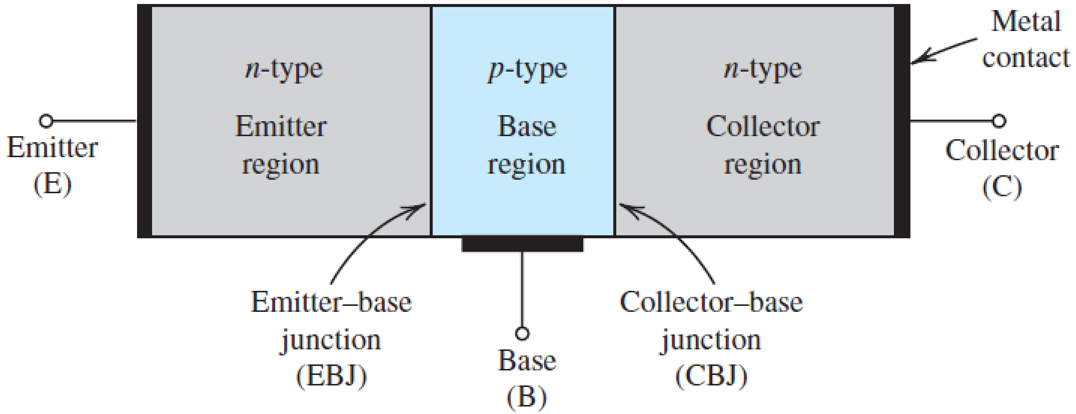
Contents

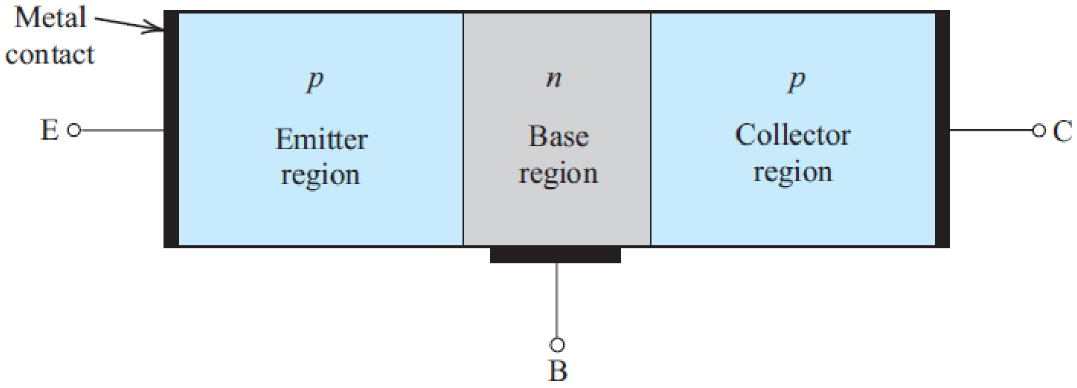
Introduction

- BJT – A three terminal device.
- Applications includes, signal amplification, design of logic circuits and memory circuits
- The basic principle involved is the use of the voltage between two terminals to control the current flowing in the third terminal.
- The control signal can be used to cause the current in the third terminal to change from zero to a large value, thus allowing the device to act as a switch.
- The BJT remains popular in discrete-circuit design, where it is used together with other discrete components such as resistors and capacitors to implement circuits that are assembled on printed-circuit boards (PCBs).

Simplified Structure

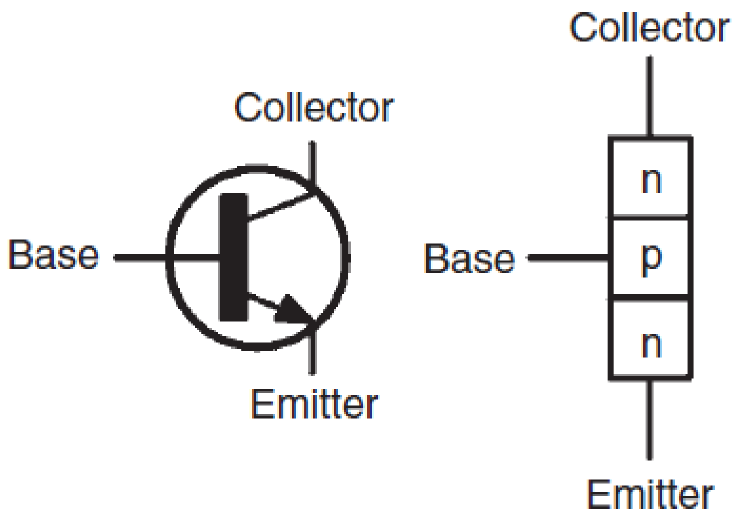
- electrons and holes—participate in the current-conduction process in a bipolar transistor, which is the reason for the name *bipolar*
- The transistor consists of two *pn* junctions, the **emitter–base junction** (EBJ) and the **collector–base junction** (CBJ).

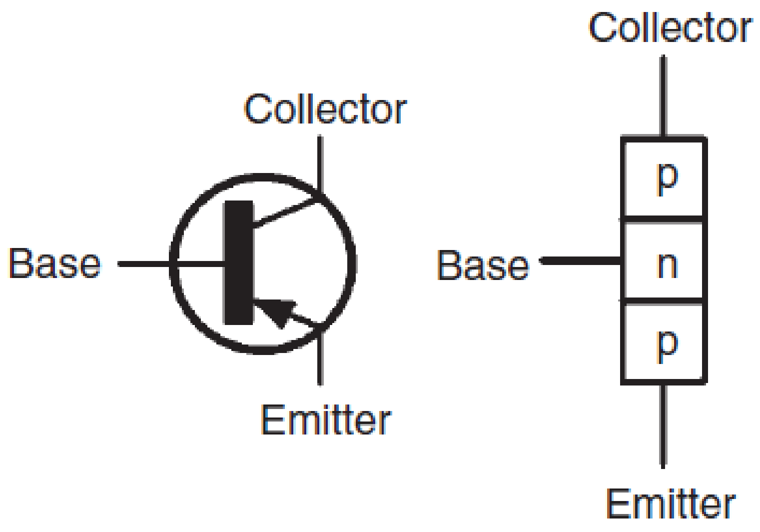




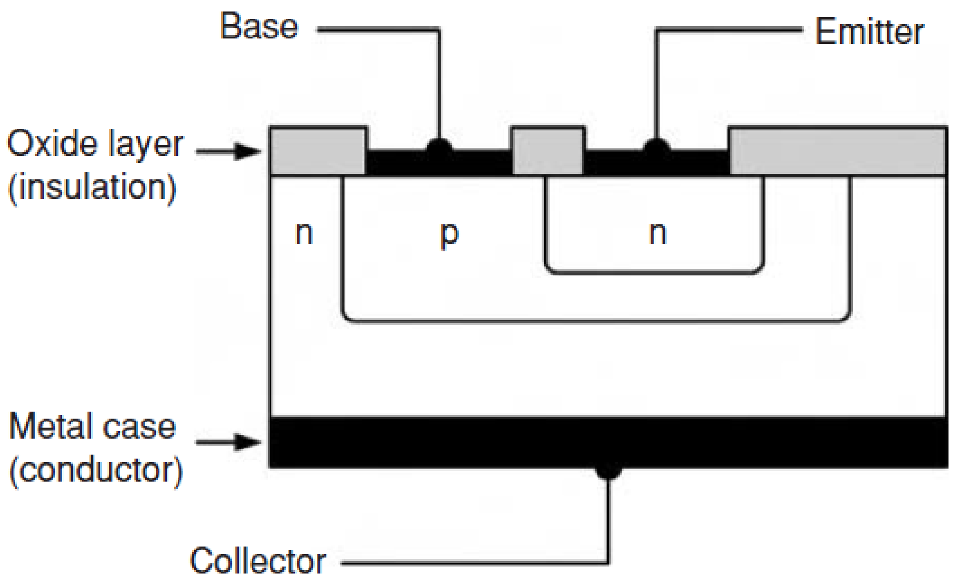
BJT: Symbols and junction models

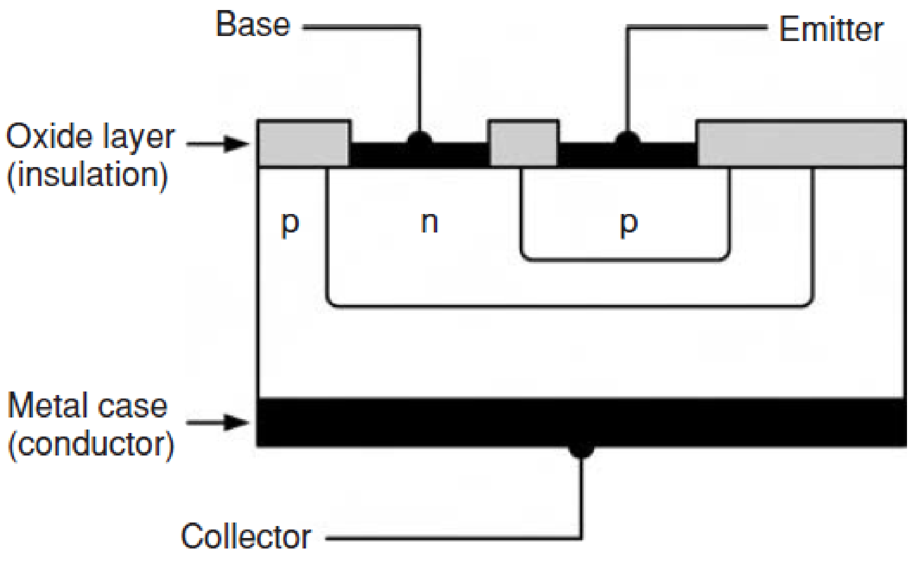
- Emitter – Medium sized and heavily doped, to inject majority carriers to collector through Base.
- Collector – Thick and lightly doped, designed to collect the majority carriers from emitter.
- Base – Thin and medium doped, control the flow of current between Emitter and Collector.



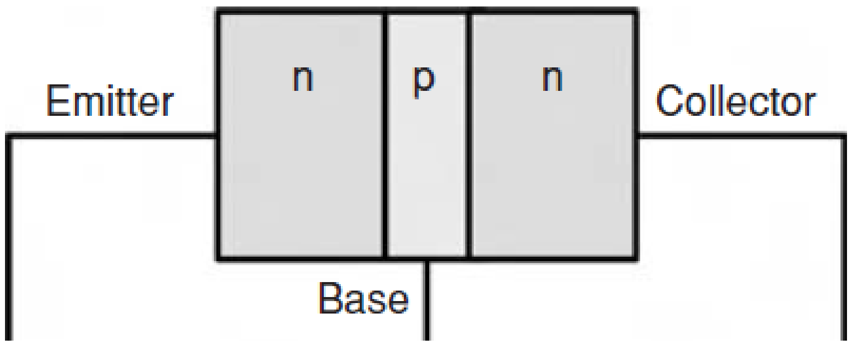


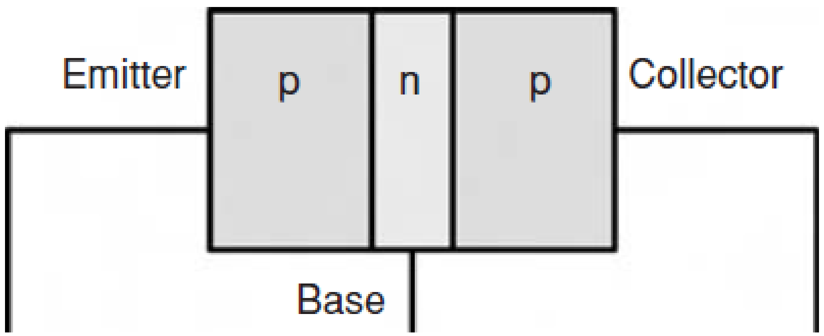
BJT: Physical Construction



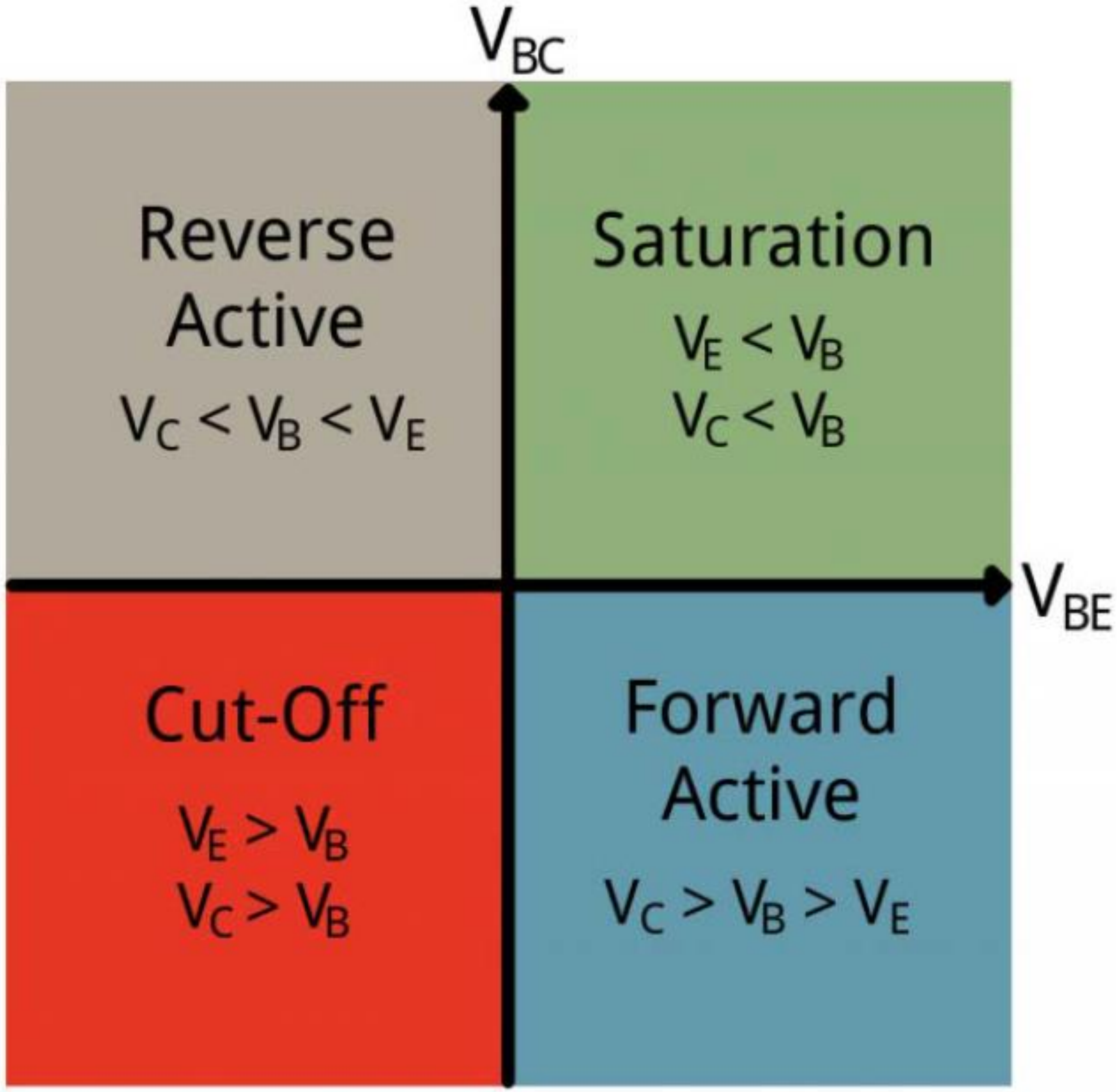


BJT: Modes of Operation

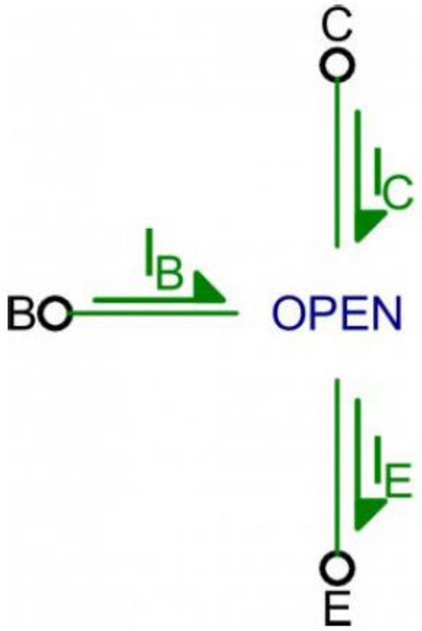




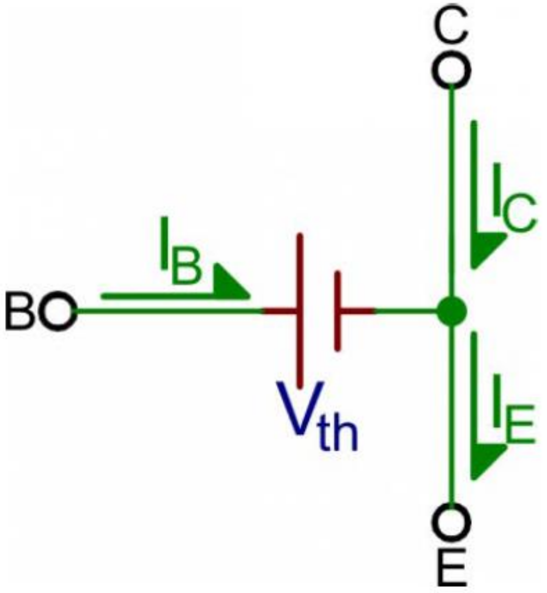
S. No.	Mode	Emitter-Base Junction	Collector Base Junction	Action	Application
1	Cut-off	Reverse	Reverse	Open	Switch
2	Saturation	forward	forward	Short	
3	Active	Forward	Reverse		Amplifier
4	Reverse active	Reverse	Forward		


V_{BC}
Reverse Active
$V_C < V_B < V_E$
Saturation
$V_E < V_B$
$V_C < V_B$
V_{BE}
Cut-Off
$V_E > V_B$
$V_C > V_B$
Forward Active
$V_C > V_B > V_E$

- Cut-off Mode:
- No collector current and no emitter current.
- Very much like a open circuit



- Saturation mode: on state
- Acts like a short circuit between the collector and emitter.
- Both the junctions are forward biased, V_B must be at higher potential than V_C and V_E.
- V_C must be slightly greater than V_E.
- $V_{CE} = 0.2$ V.



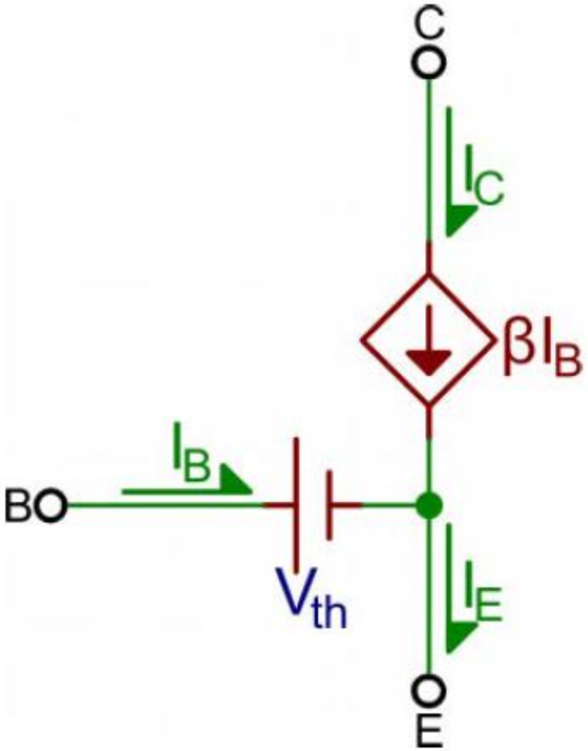
- Active Mode:
- V_{BE} must be positive and V_{CB} must be negative. $V_C > V_B > V_E$.
- Gain (amplification factor) – β
- Common base current gain - α

$$I_C = \beta I_B$$

$$I_C = \alpha I_E$$

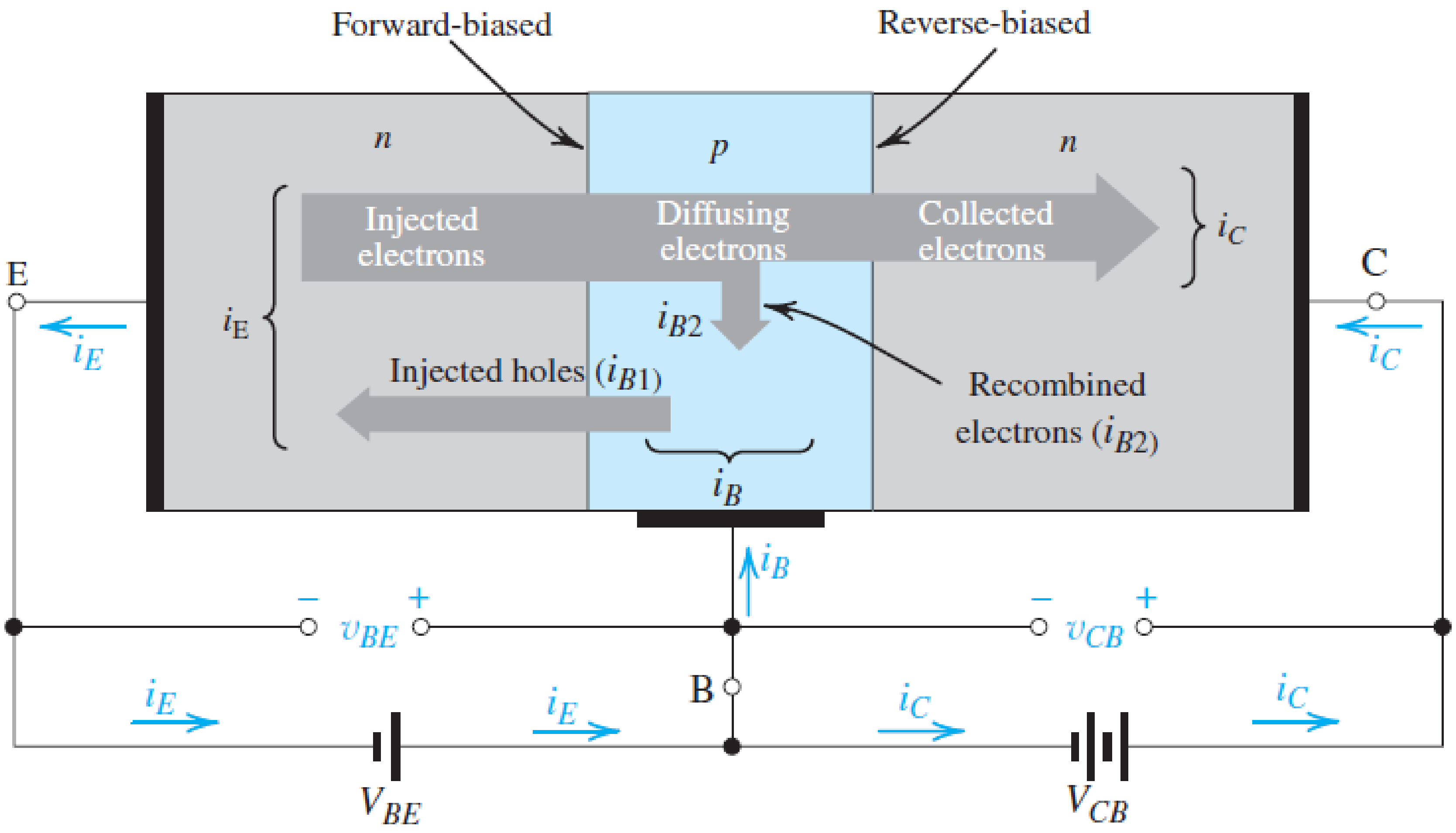
$$\beta = \frac{\alpha}{(1-\alpha)}$$

$$\alpha = \frac{\beta}{\beta+1}$$



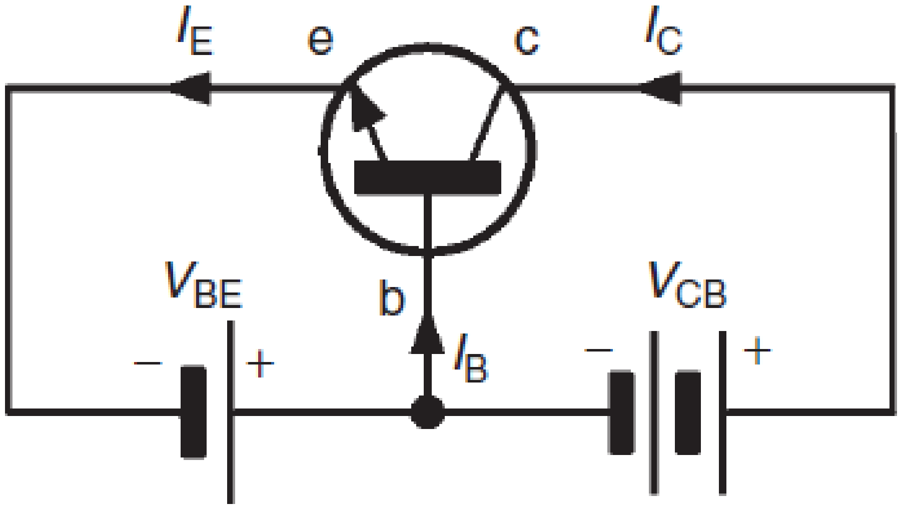
Transistor Action: Active mode

- Emitter-Base junction is Forward Biased, Collector-Base junction is Reverse Biased

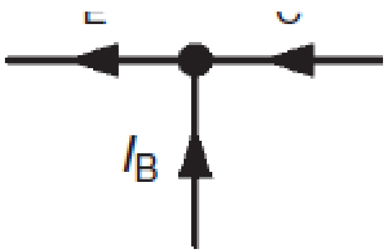


BJT: Bias and Current Flow

- For linear amplification, BE junction is forward bias and CE junction is reverse biased.
- Base region is made very small such that the carriers are swept across it from emitter to collector.



$$I_E = I_B + I_C$$



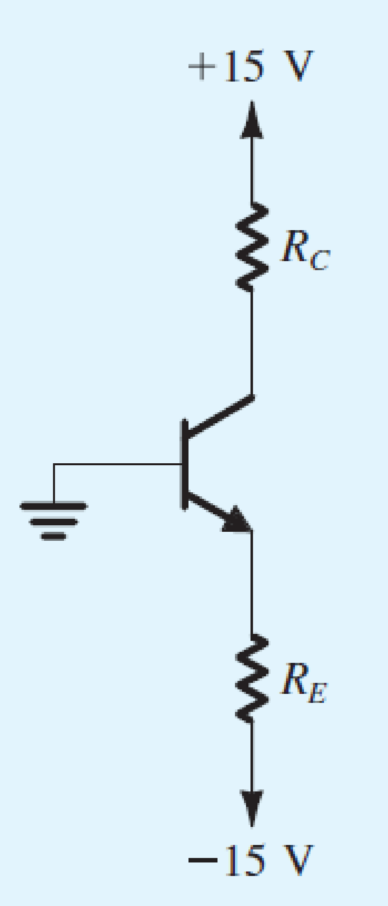
$$\beta = \frac{\alpha}{(1-\alpha)}$$

$$\alpha = \frac{\beta}{\beta+1}$$

$$I_C = \beta I_B \qquad I_C = \alpha I_E$$

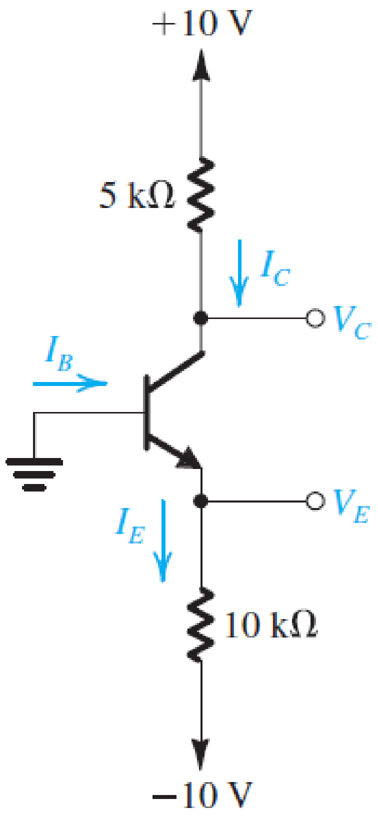
The transistor in the circuit of Figure has **β** =100 and exhibits a v_{BE} of 0.7 V at i_C = 1 mA. Design the circuit so that Collector current is 2 mA and a voltage of +5 V appears at the collector.

- V_{BE} = 0.717 V, R_c = 5 KΩ, R_E = 7.07KΩ



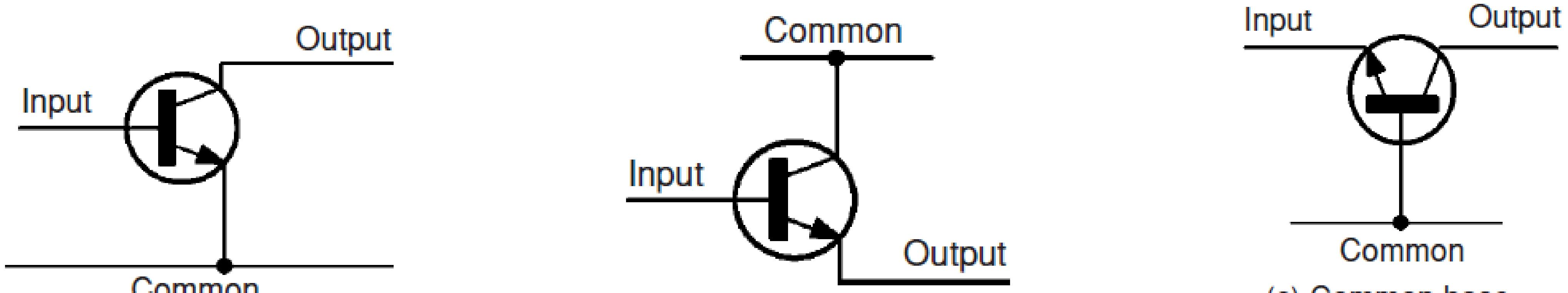
For a transistor circuit, the base terminal is grounded, and Collector is connected to a supply voltage of 10 V via R_C = 5 K ohms and emitter is connected to a supply voltage of -10 V via R_E = 10 K ohms, the voltage at the emitter was measured and found to be -0.7 V. if β = 50, find I_E, I_B, I_C, and V_C.

- I_E = 0.93 mA
- I_B = 18.2 μA
- I_C = 0.91 mA
- V_C = 5.45 V



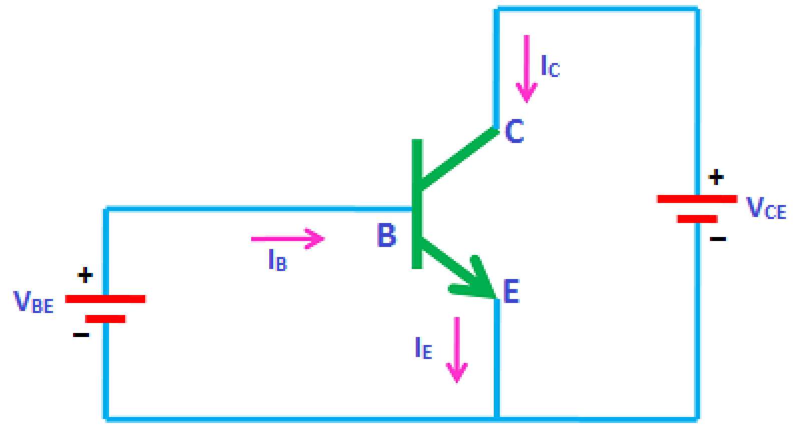
BJT: operating Configurations

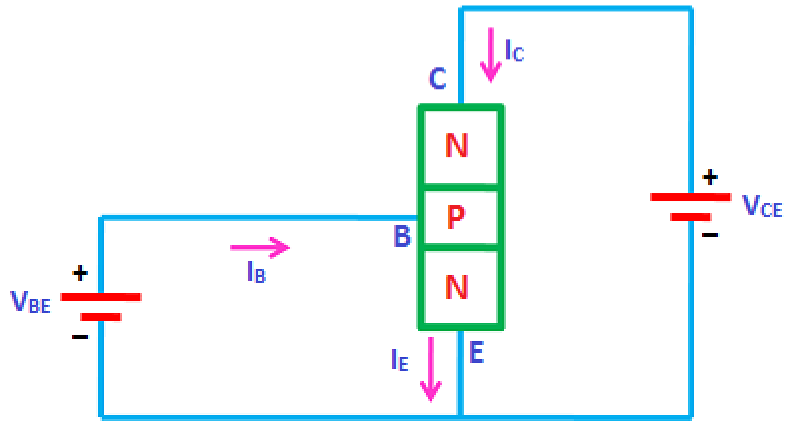
- Symbols and simplified junction models



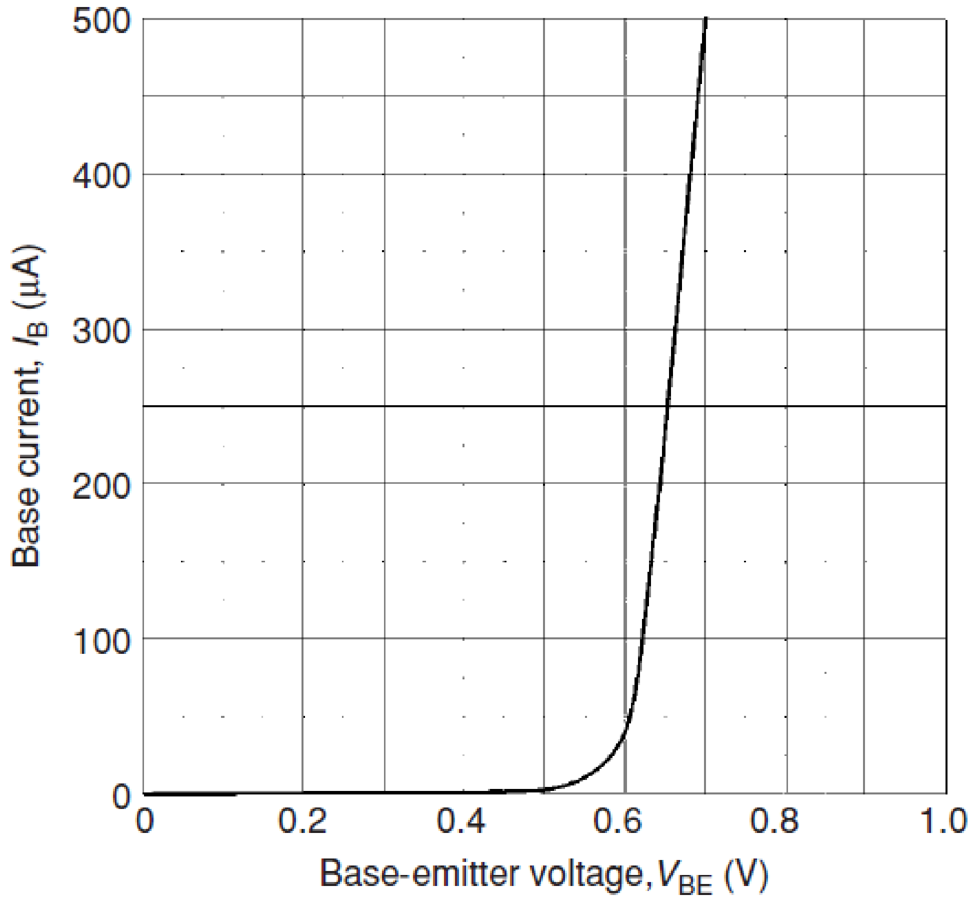
(a) Common emitter (b) Common collector (c) Common base

Common Emitter: Input Characteristics





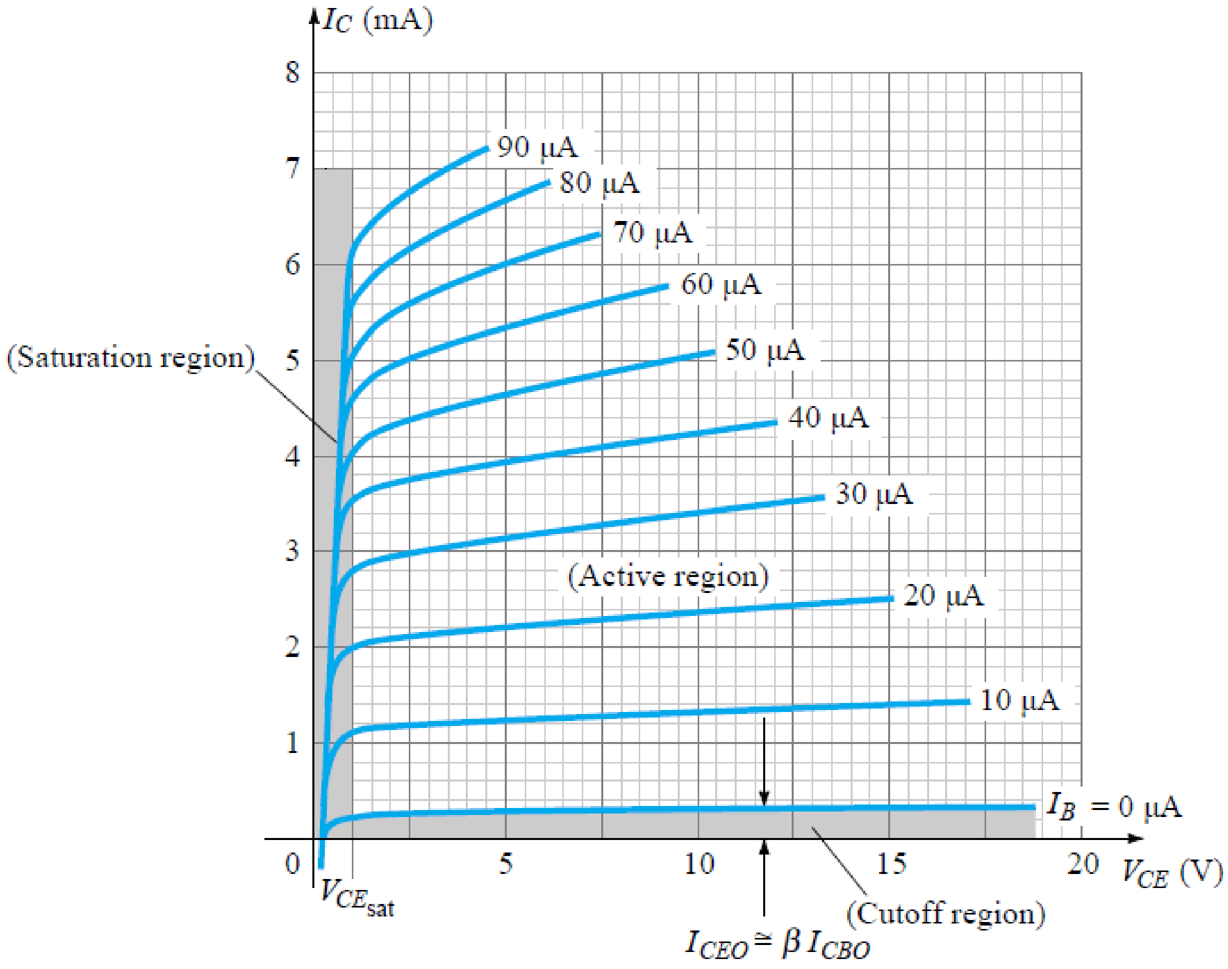
Common emitter configuration



- V_{BE} Vs I_B
- Small current flows until V_{BE} exceeds 0.6 V, shows the Si diode forward char.

Common Emitter: Output Characteristics

- V_{CE} Vs I_C
- There modes of operation are shown
- I_B = 0 cut-off
- V_{CE} < V_{CEsat} saturation



BJT: Parameters

- Input resistance:

$$\text{Static (or d.c.) input resistance} = \frac{V_{BE}}{I_B}$$

$$\text{Dynamic (or a.c.) input resistance} = \frac{\Delta V_{BE}}{\Delta I_B}$$

- Output resistance:

$$\text{Static (or d.c.) output resistance} = \frac{V_{CE}}{I_C}$$

$$\text{Dynamic (or a.c.) output resistance} = \frac{\Delta V_{CE}}{\Delta I_C}$$

- Current Gain:

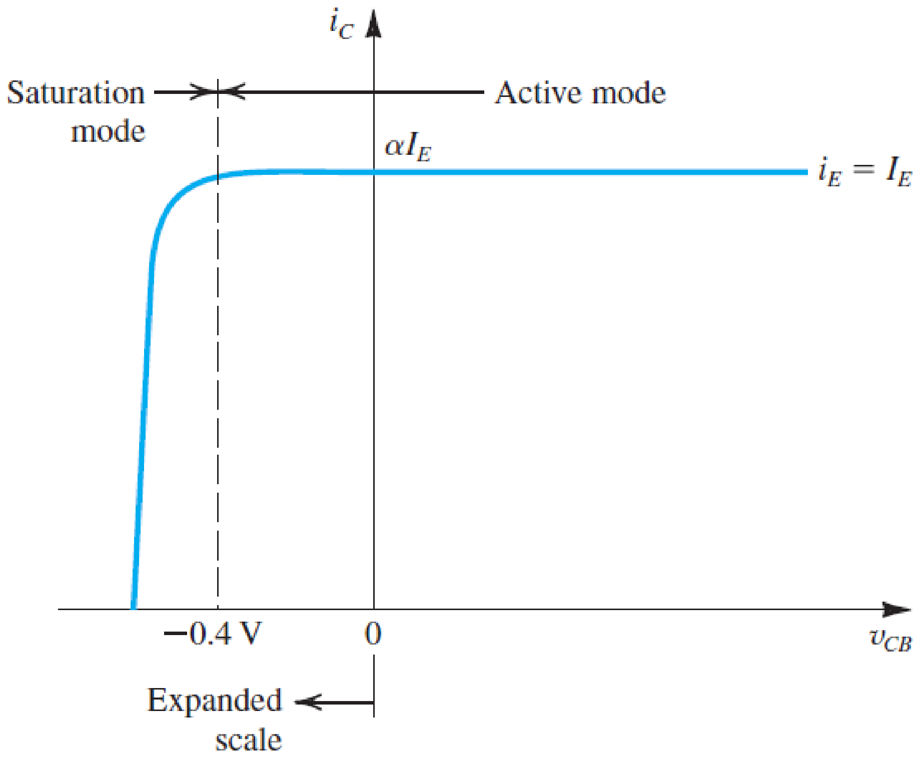
$$\text{Static (or d.c.) current gain} = \frac{I_C}{I_B}$$

$$\text{Dynamic (or a.c.) current gain} = \frac{\Delta I_C}{\Delta I_B}$$

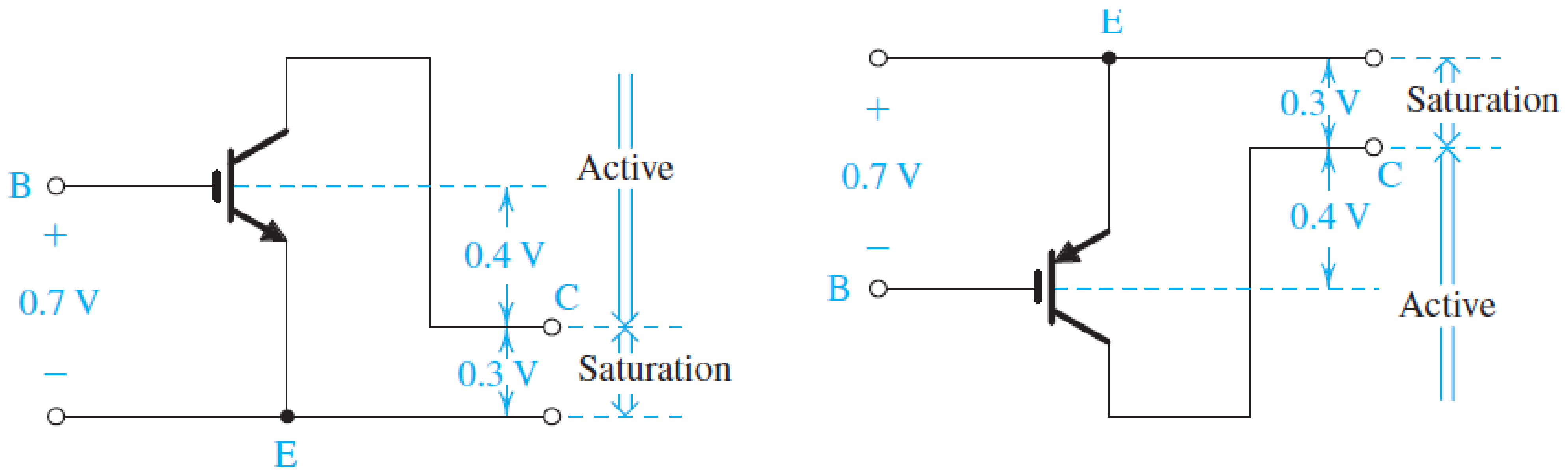
In Saturation Mode

- Two things need to be verified?
- 1. is the CBJ is forward biased by more than 0.4 V?
- 2. is the ratio if $i_C/i_B < \beta$

$$\beta_{\text{forced}} = \left.\frac{i_C}{i_B}\right|_{\text{saturation}} \leq \beta$$



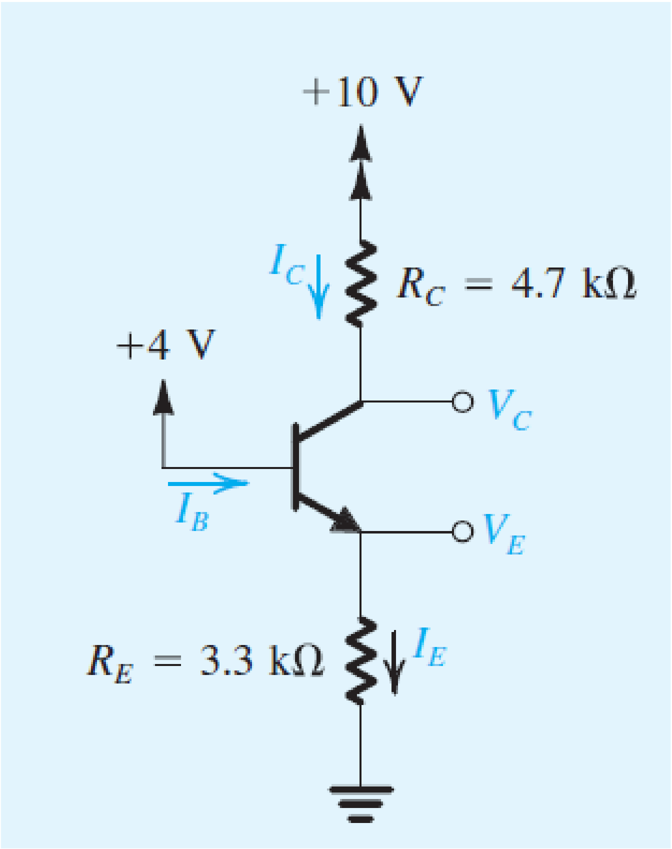
Condition for operating BJT in active mode and in saturation mode



(a) *npn* (b) *pnp*

Consider the circuit shown in Figure, We wish to analyze this circuit to determine all node voltages and branch currents. We will assume that β is specified to be 100.

- $I_E = 1\ mA$
- $I_B = 10\ \mu A$
- $I_C = 0.99\ mA$
- $V_C = 5.35\ V$
- $V_B = 4\ V$
- $V_E = 3.3\ V$



We wish to analyze the circuit of Fig. 6.24(a) to determine the voltages at all nodes and the currents through all branches, We will assume that β is specified to be 50.

- I_E = 1.6 mA
- I_B = 10 μA
- I_C = 0.99 mA
- V_B = 6 V; V_E = 5.3 V;V_C = 2.63 V not in active region
- Then VC = VE +0.2 V= 5.5 V, Ic = 0.96 mA
- βforce = ic/ib = 0.96/0.64=1.5.