Presentation Topic

Name of the course :- Basic Electronics Engineering

Faculty Name:- Mrs. Rohini Abhijeet Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor Circuits

Mrs. Rohini Abhijeet Chavan

Department of E&TC

VIIT, Pune-411048

Outline

- History
- BJT construction and operation
- Common-base configuration
- Common-emitter configuration
- Common-collector configuration
- Comparison of CE, CB, and CC configurations
- Biasing
- Bias stabilization
- Applications

Objectives of This Session

- History of BJT
- BJT construction and operation

Course Outcome :-

- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

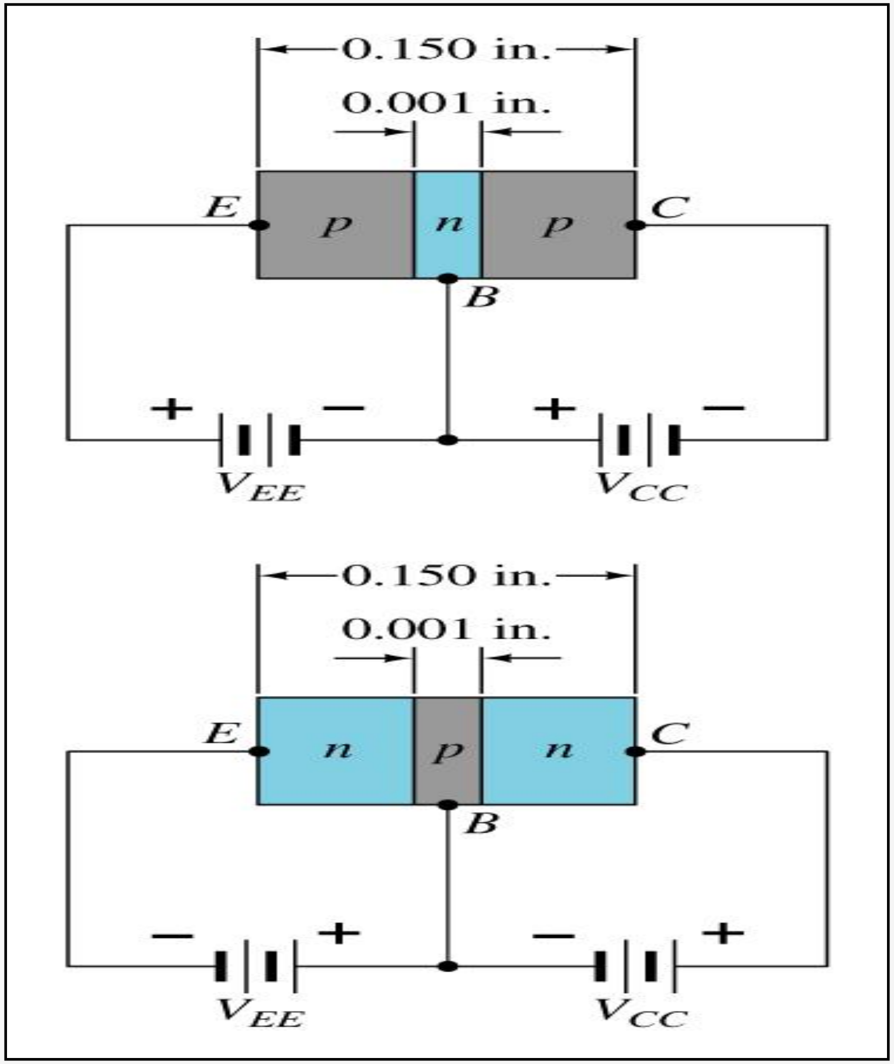
History of BJT

- The first BJT was invented at Bell Labs by the team of scientist namely William Shockley, Walter Brattain, and John Bardeen in 1947
- They had given demonstration of BJT on December 23, 1947.
- All shared the Nobel Prize in 1956 for this contribution.

Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

BJT Construction

- Three layer semiconductor device.
- The emitter layer is heavily doped, with the base lightly and collector moderately doped.
- Bipolar - holes *and* electrons both participate in current conduction process.

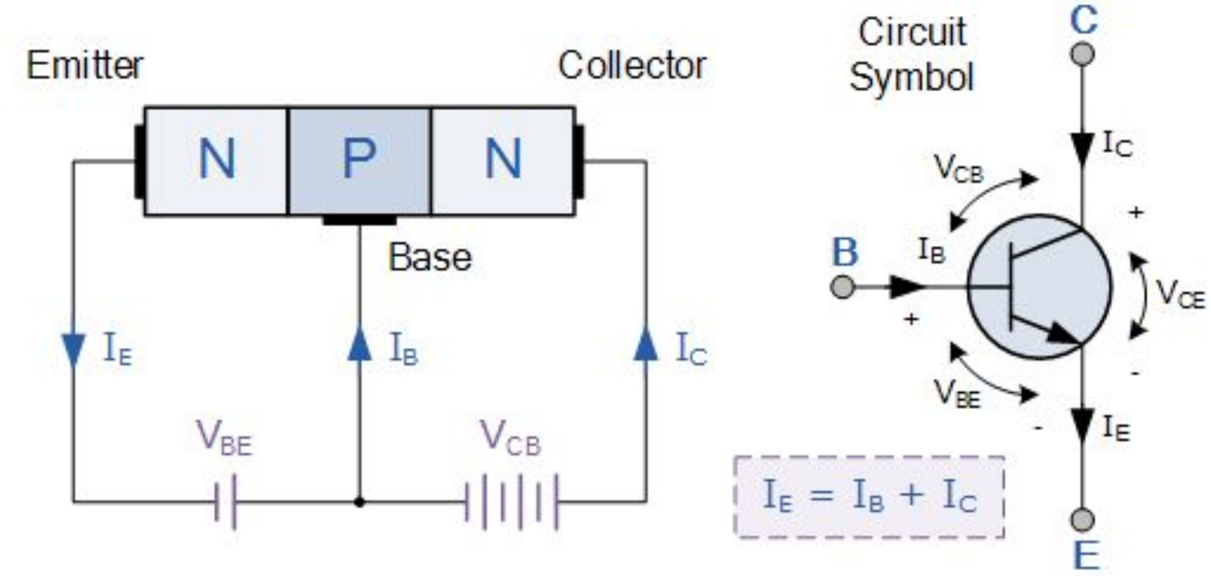


Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Modes of Operation

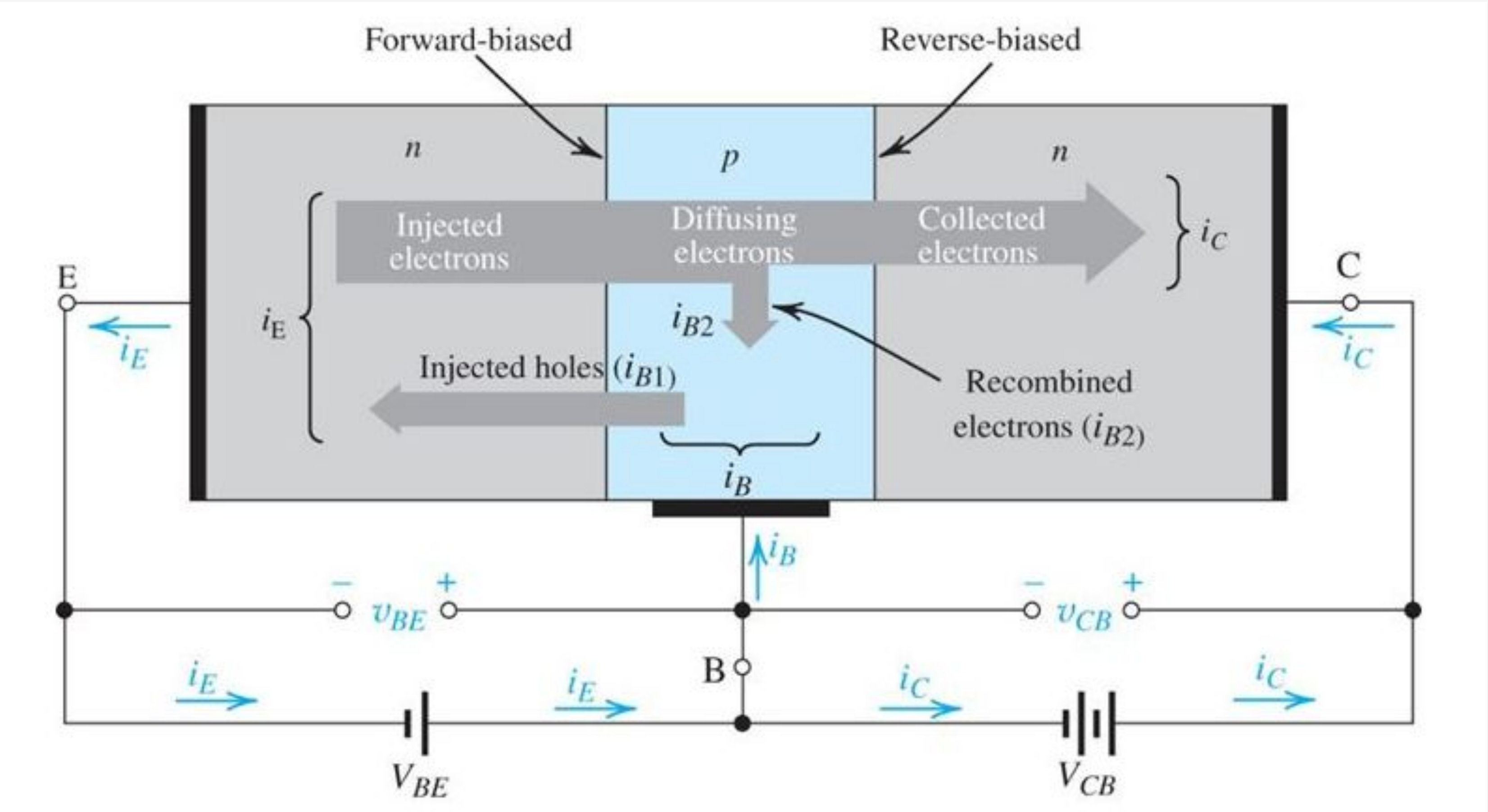
Mode	BE Junction	BC Junction	Applications
Cutoff	Reverse	Reverse	Switching application in digital circuits
Saturation	Forward	Forward	
Active	Forward	Reverse	Amplifier
Reverse Active	Reverse	forward	Degraded performance

NPN Transistor in the Active Mode



(Note: Arrow defines the emitter and conventional current flow, "out" for a Bipolar NPN Transistor.)

Operation of NPN Transistor in the Active Mode



Operation of NPN Transistor in the Active Mode Continues…

- Base-Emitter (BE) junction is forward-biased, whereas the Base-Collector (BC) junction is reverse-biased.
- The emitter current is the sum of the collector and base currents.

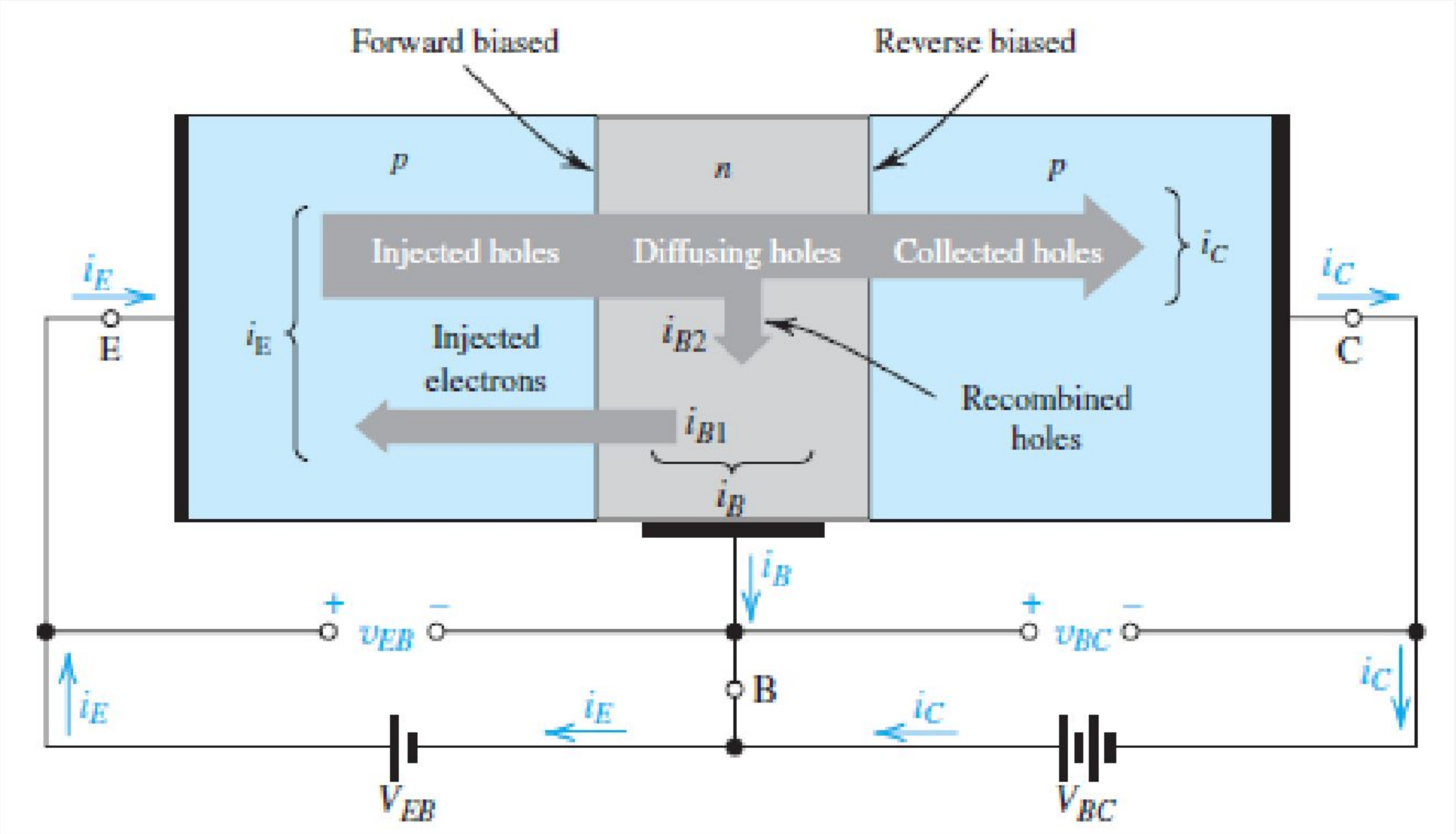
$$I_E = I_C + I_B$$

- The collector current, however, comprises two components—the majority and the minority carriers.

$$I_C = I_{C\,(majority)} + I_{CO\,(minority)}$$

- The minority-current component is called the *leakage current* and is given the symbol I_{CO} (I_C current with emitter terminal open).

Operation of PNP Transistor in the Active Mode



Source: Microelectronic Circuits, Sedra and Smith, 7th Edition

Presentation Topic

Name of the course :- BASIC ELECTRONICS ENGINEERING

Faculty Name:- Mrs. Rohini A. Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor circuits

Mrs. R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Outline

- History
- BJT construction and operation
- Common-base configuration
- Common-emitter configuration
- Common-collector configuration
- Biasing
- Bias stabilization
- Comparison of CE, CB, and CC configurations
- Applications of transistor

Last Session Recap

- History ✔
- BJT construction and operation ✔

Source:- Thomas L. Floyd, “Electronic Devices – Conventional Current Version,” 9th Ed., Pearson Education.

Objectives of This Session

- Common-emitter configuration
- Common-base configuration
- Common-collector configuration

Course Outcome :-

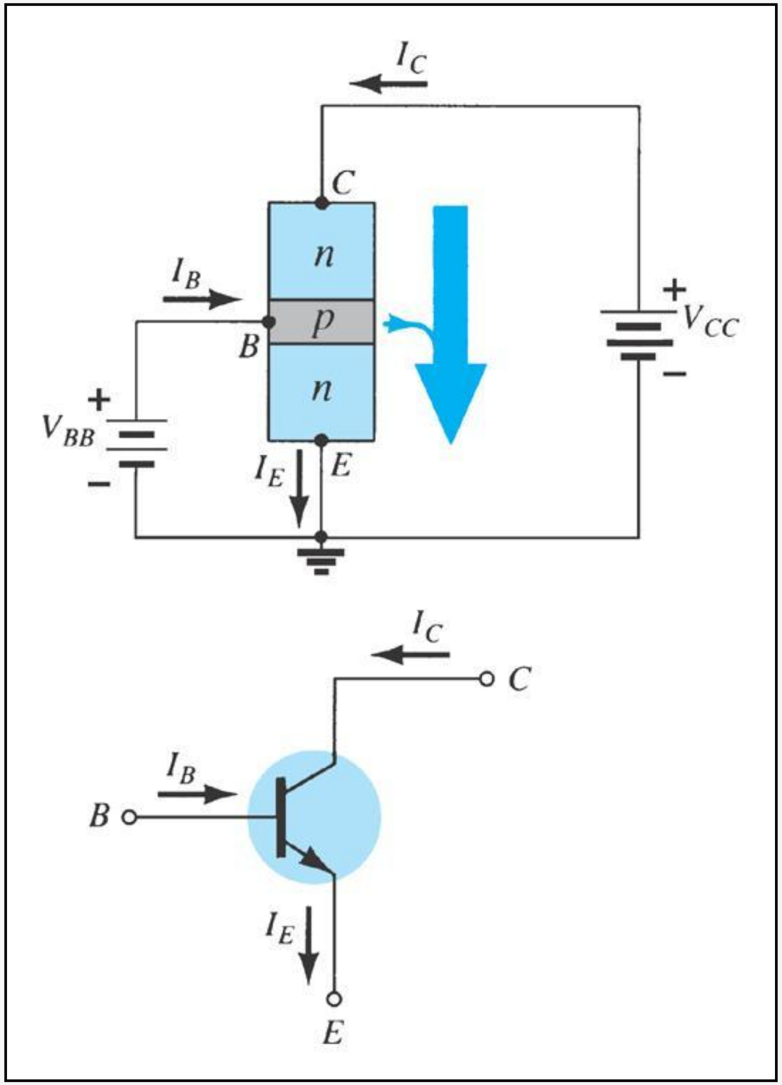
- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

Modes of Operation

<table>
<tr><th>Mode</th><th>BE Junction</th><th>BC Junction</th><th></th></tr>
<tr><td>Cutoff</td><td>Reverse</td><td>Reverse</td><td rowspan="2">Switching application in digital circuits</td></tr>
<tr><td>Saturation</td><td>Forward</td><td>Forward</td></tr>
<tr><td>Active</td><td>Forward</td><td>Reverse</td><td>Amplifier</td></tr>
<tr><td>Reverse Active</td><td>Reverse</td><td>forward</td><td>Degraded performance</td></tr>
</table>

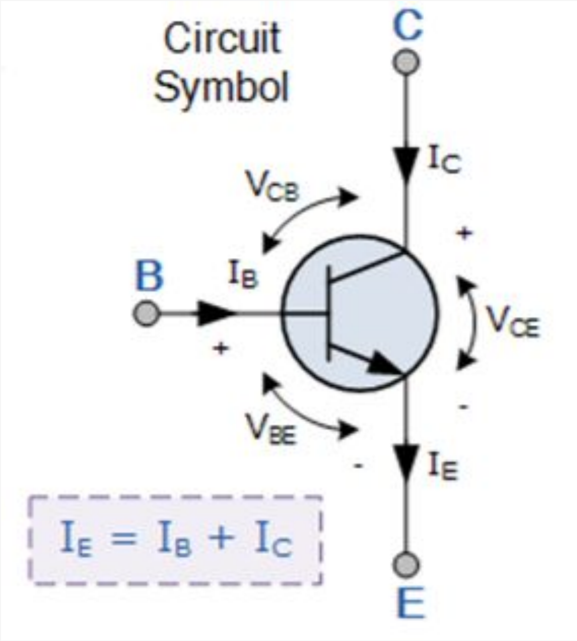
Common-Emitter Configuration

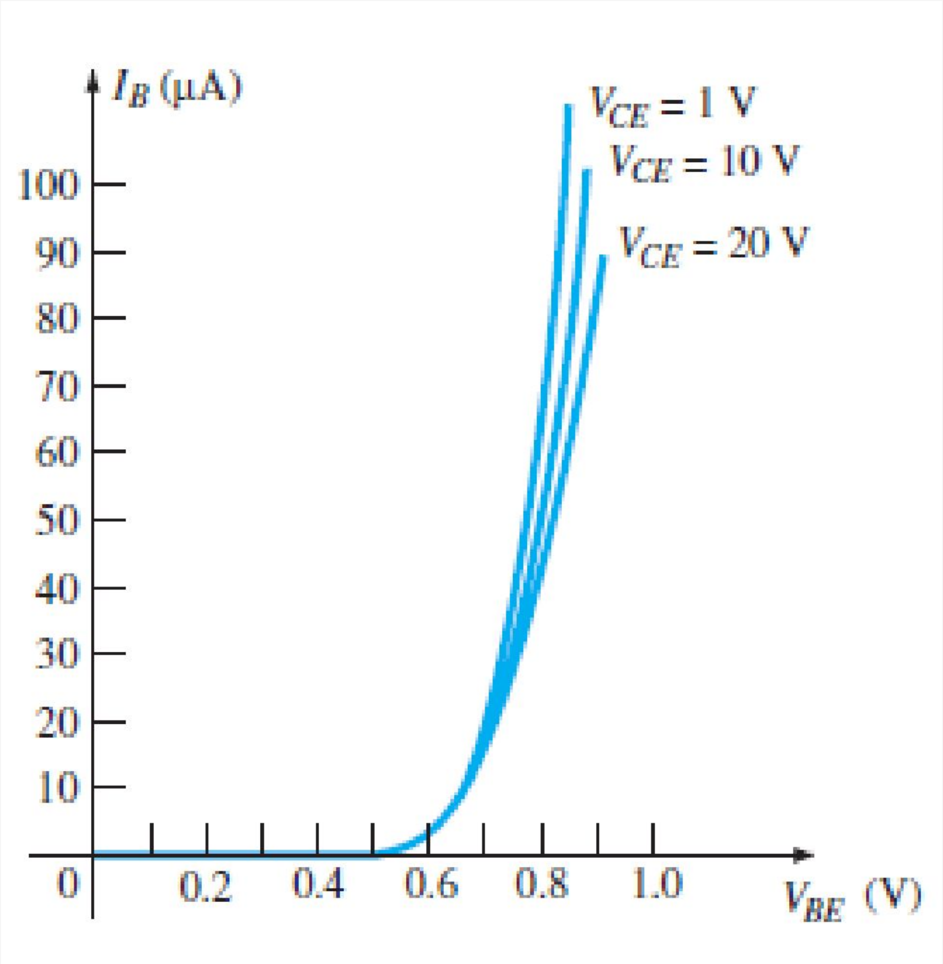
- In a Common Emitter configuration of a Junction Transistor, the emitter is the common terminal.
- Input is between the base and emitter.
- The output is between the collector and emitter.
- $I_E = I_C + I_B$



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Input Characteristics





Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

$$V_{CE} = V_{CB} + V_{BE}$$

$$V_{CE} = V_{CB} + 0.7$$

$$V_{CE} \square = V_{CB} \square +0.7$$

Input Characteristics

- V_{CE} □ = V_{CB} □ +0.7

- If the output voltage V_{CE} applied to the collector-base junction is further increased, the depletion region width further increases.
- The base region is lightly doped as compared to the collector region.
- So the depletion region penetrates more into the base region and less into the collector region.
- As a result, the width of the base region decreases which in turn reduces the input current (I_B) produced in the base region.

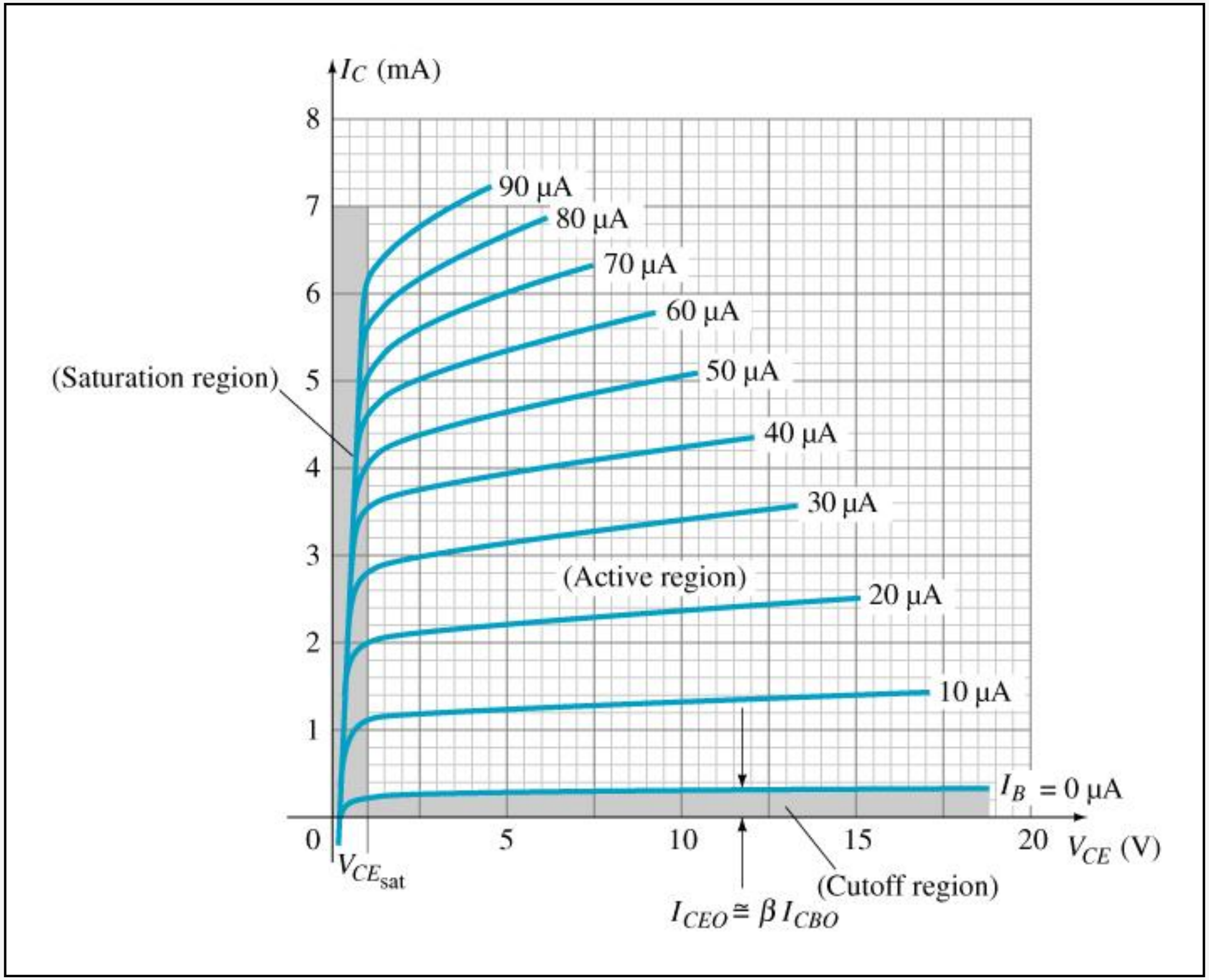
Output Characteristics

$V_{CE} = V_{CB} + V_{BE}$

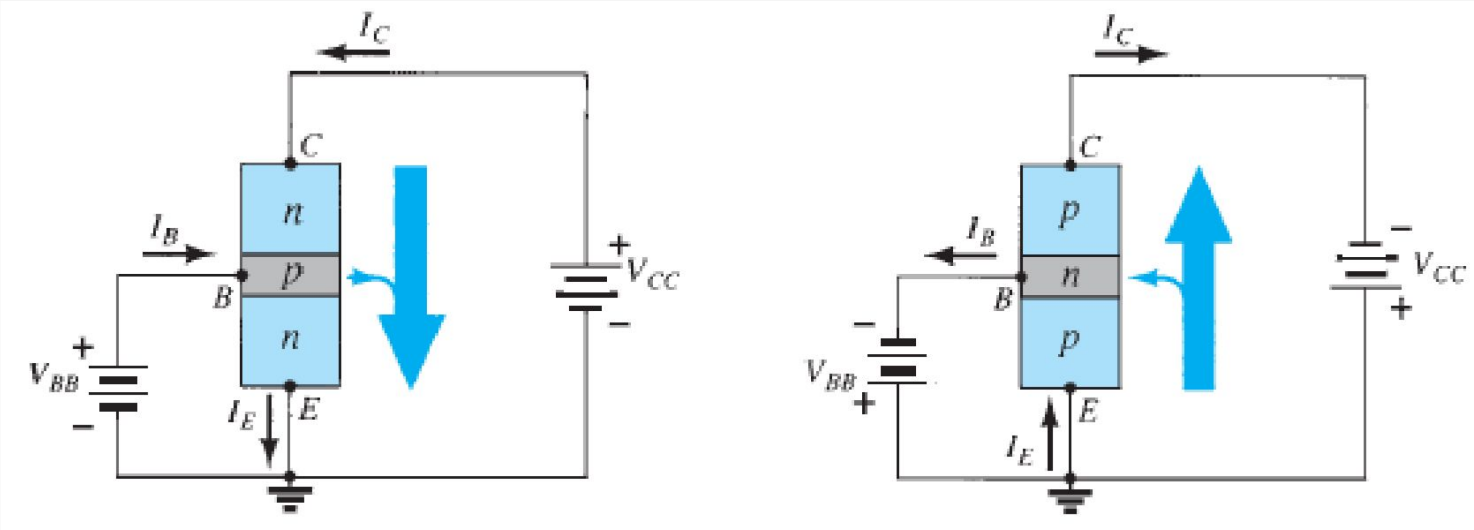
$I_E = I_C + I_B$

$I_C = \alpha I_E$

Source:



Common-Emitter Current Gain, β

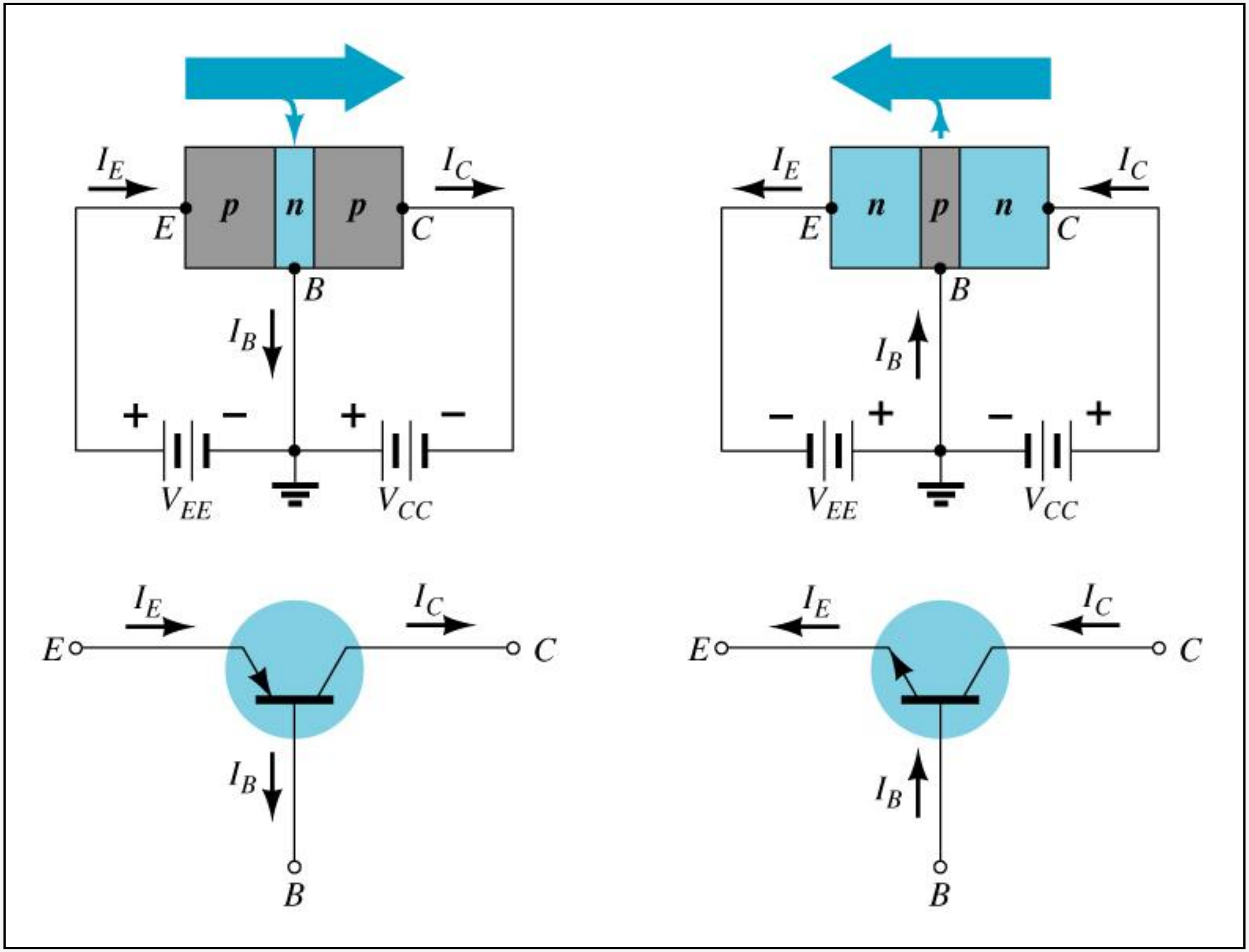


$$\beta_{DC} = h_{FE} = \frac{I_C}{I_B} \qquad \beta_{AC} = h_{fe} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE} = \text{constant}}$$

Typical values of β_{DC} range from less than 20 to 200 or higher. β_{DC} is usually designated as an equivalent hybrid (*h*) parameter, h_{FE}.

Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

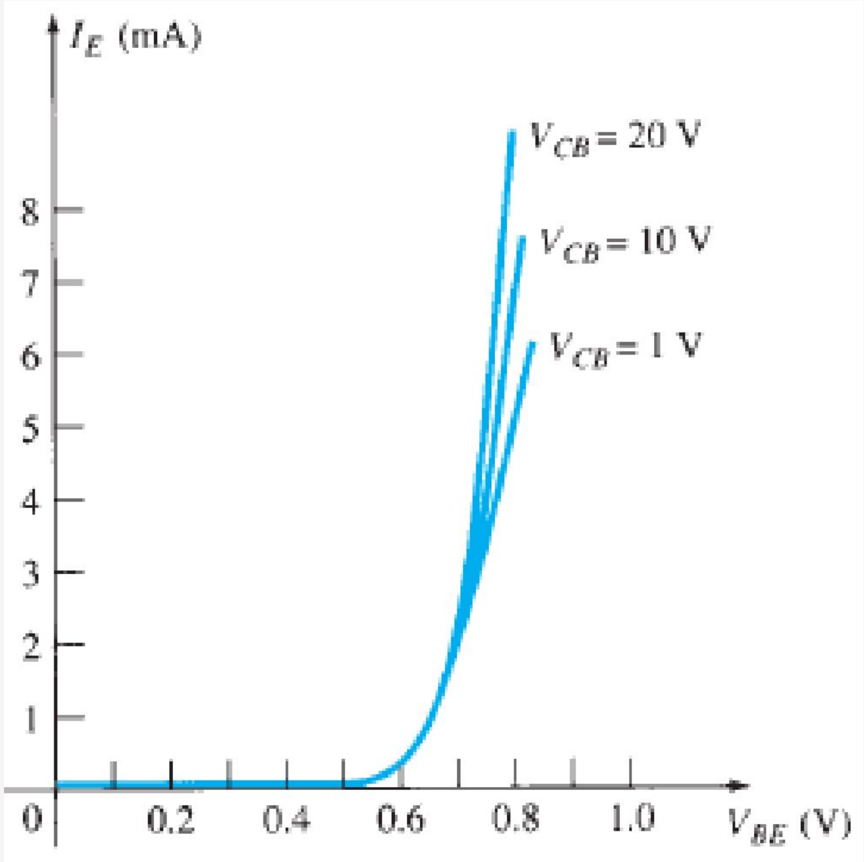
Common-Base Configuration



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

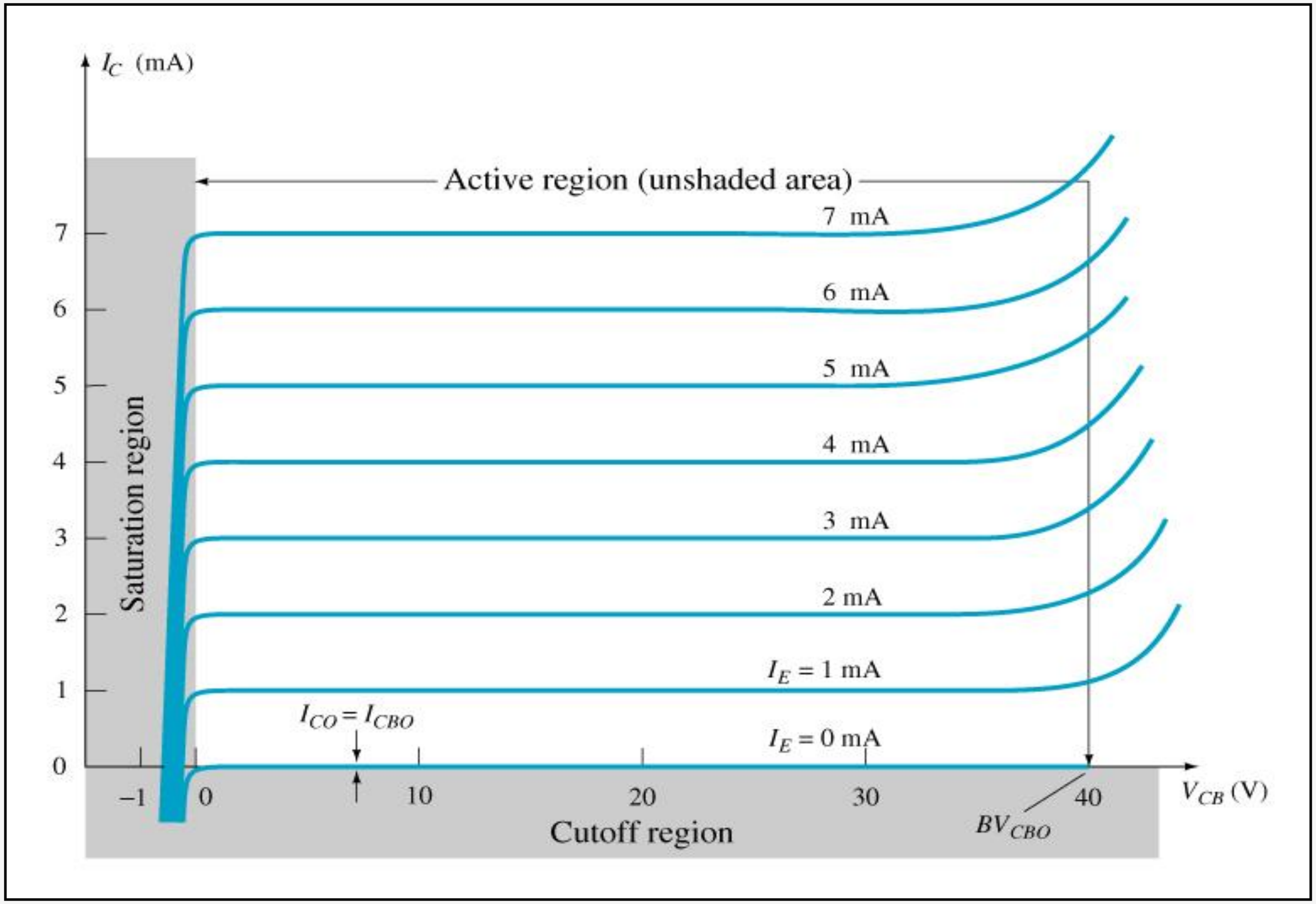
Input I-V Characteristic

- This curve shows the relationship between of input current (I_E) to input voltage (V_{BE}) for three output voltage (V_{CB}) levels



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Output I-V Characteristic



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Common-Base Current Gain, α

$$\alpha_{DC} = \frac{I_C}{I_E} \qquad \alpha_{AC} = \frac{\Delta I_C}{\Delta I_E}$$

- Typically, values of α_{DC} range from 0.95 to 0.99, α_{DC} is always less than 1.

- The reason is that I_C is always slightly less than I_E by the amount of I_B.

Presentation Topic

Name of the course :- Basic Electronics Engineering

Faculty Name:- Mrs. Rohini Abhijeet Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor

Mrs. R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Outline

- History
- BJT construction and operation
- Common-base configuration
- Common-emitter configuration
- Common-collector configuration
- Comparison of CE, CB, and CC configurations
- Biasing
- Bias stabilization
- Applications

Last Session Recap

- Common-emitter configuration ✔
- Common-base configuration ✔

Source:- Thomas L. Floyd, “Electronic Devices – Conventional Current Version,” 9th Ed., Pearson Education.

Objectives of This Session

- Common-collector configuration
- Comparison among three configurations
- BJT DC analysis
- Numericals

Course Outcome :-

Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

Relation between α_{DC} and β_{DC}

$$I_E = I_C + I_B$$

$$I_C = \beta I_B$$

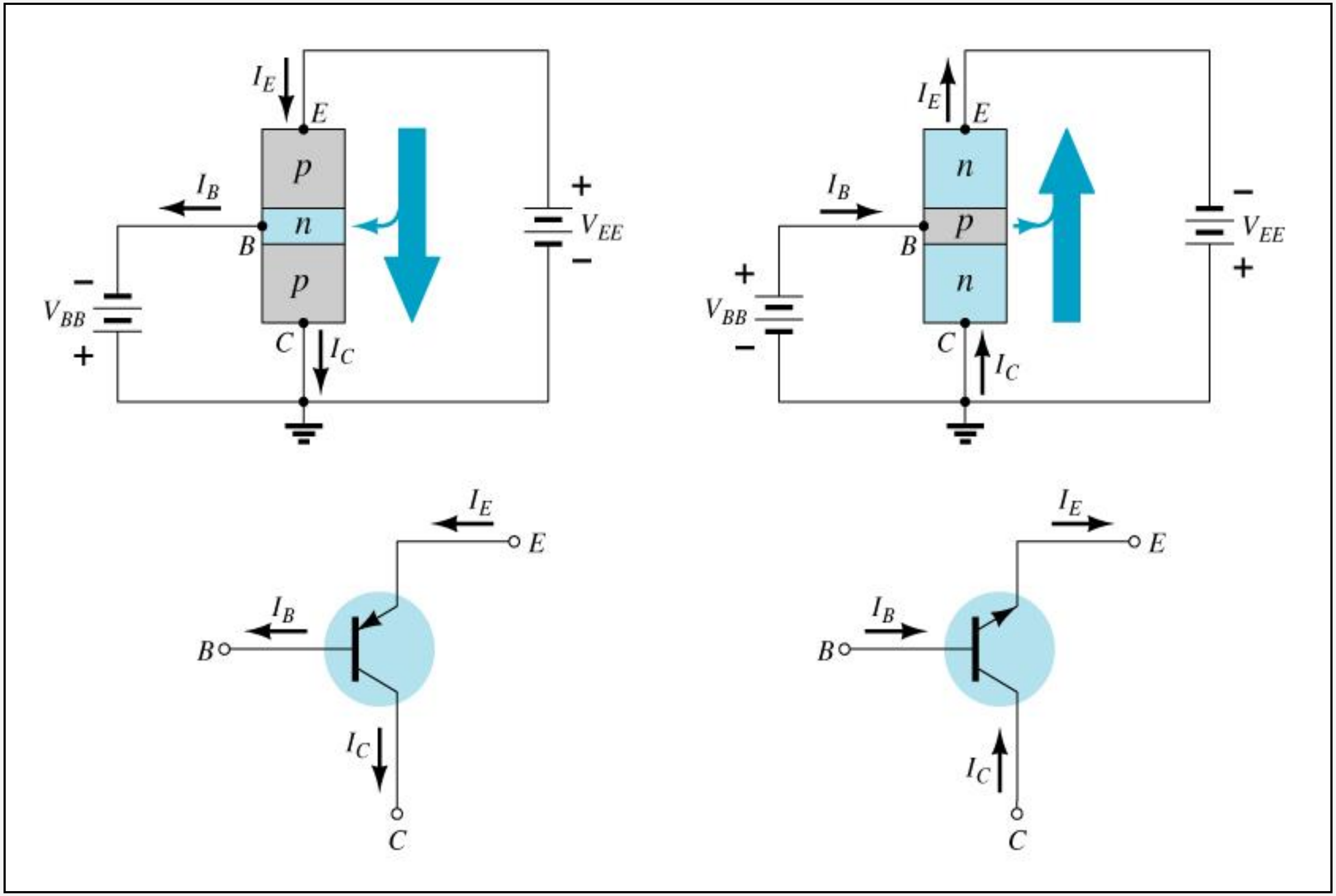
$$I_E = (1+\beta) I_B$$

$$I_C = \left(\frac{\beta}{1+\beta} \right) I_E$$

$$As\ I_C = \alpha I_E$$

$$\alpha = \frac{\beta}{1+\beta} \text{ and } \beta = \frac{\alpha}{1-\alpha}$$

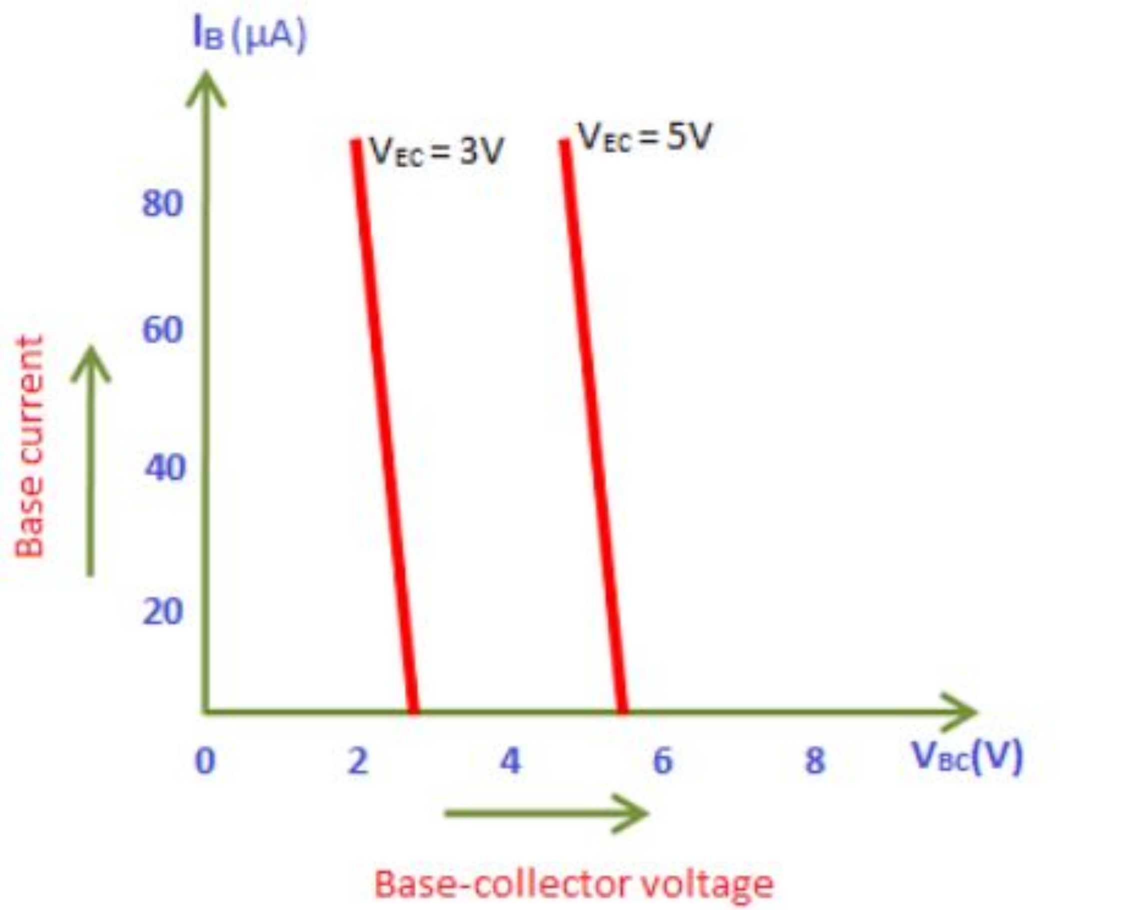
Common-Collector Configuration



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

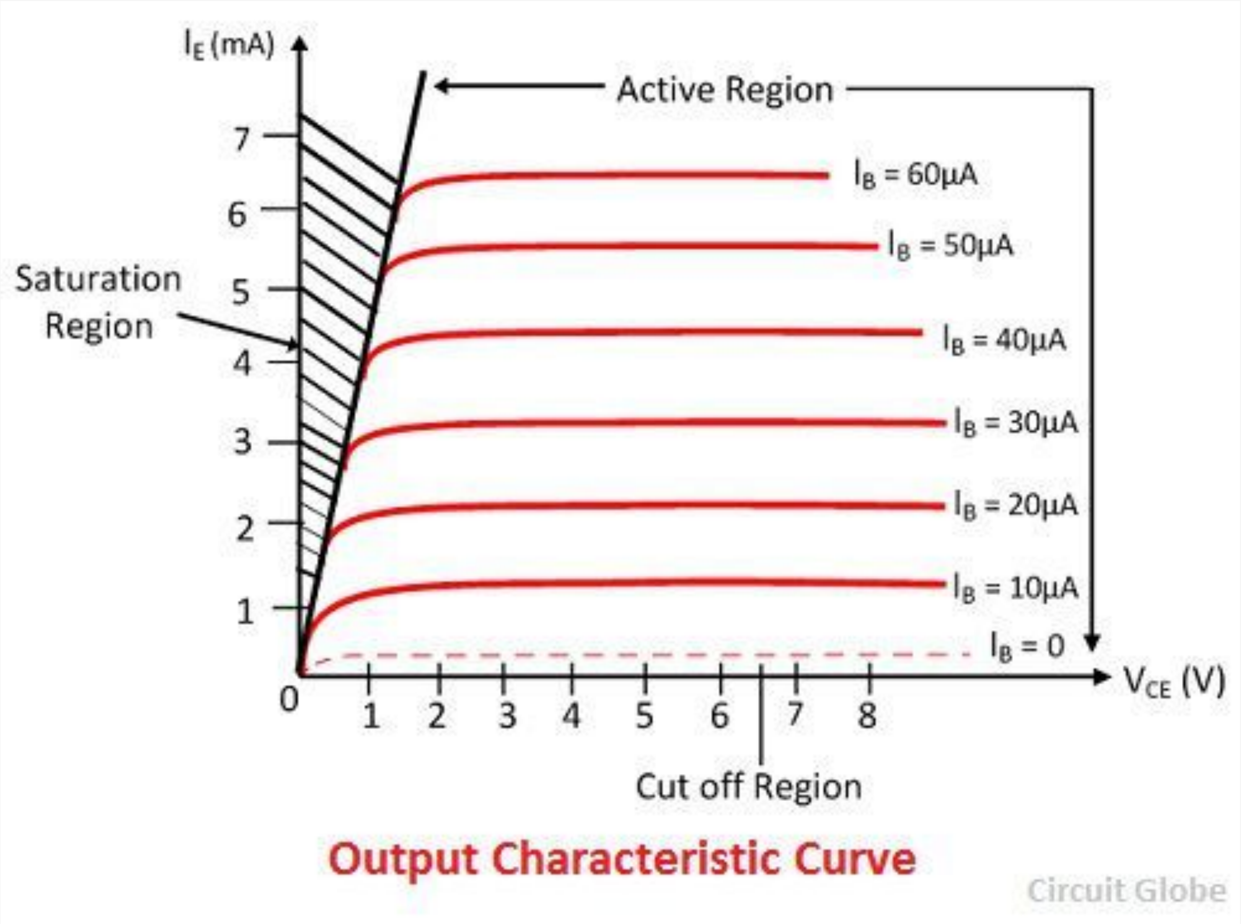
Input Characteristic of CC Configuration

For fixed value of V_{CE}, if we increase V_{BC}, then I_B reduces.



Input characteristics

Output I-V Characteristic of CC Configuration



Common-Collector Configuration

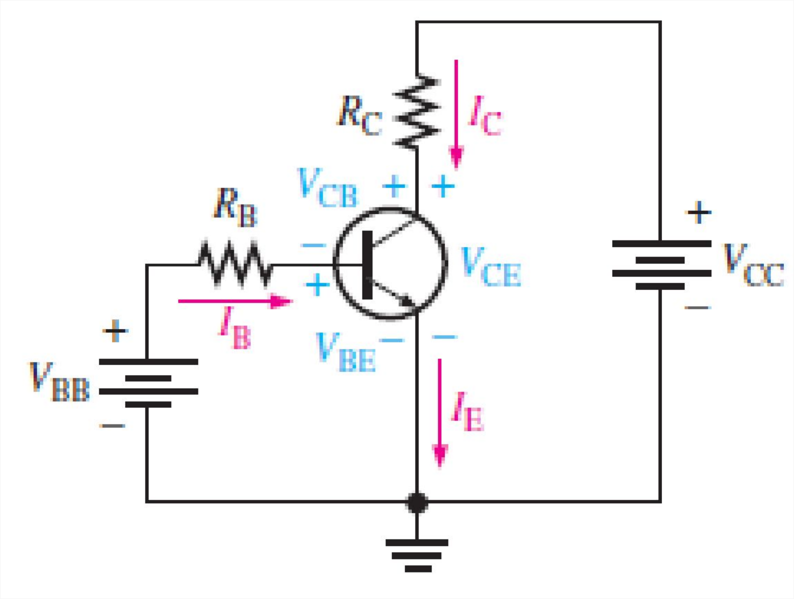
- The common-collector configuration is used primarily for impedance-matching purposes since it has a high input impedance and low output impedance.
- Voltage gain is almost equal to one and no phase shift in input and output. Hence known as emitter follower.

$$\gamma = \frac{I_E}{I_B} = \frac{I_C + I_B}{I_B} = \beta + 1 = \frac{\alpha}{1-\alpha} + 1 = \frac{1}{1-\alpha}$$

Comparison among three configurations

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.	Applications	For high frequency applications	For audio frequency applications	For impedance matching
5.	Current gain	No (less than 1)	High (β)	Appreciable

BJT DC Circuit Analysis



$$V_{BE} \cong 0.7V$$

$$V_{R_B} = V_{BB} - V_{BE}$$

$$V_{R_B} = I_B R_B$$

$$I_B R_B = V_{BB} - V_{BE}$$

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

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

$$V_{R_C} = I_C R_C$$

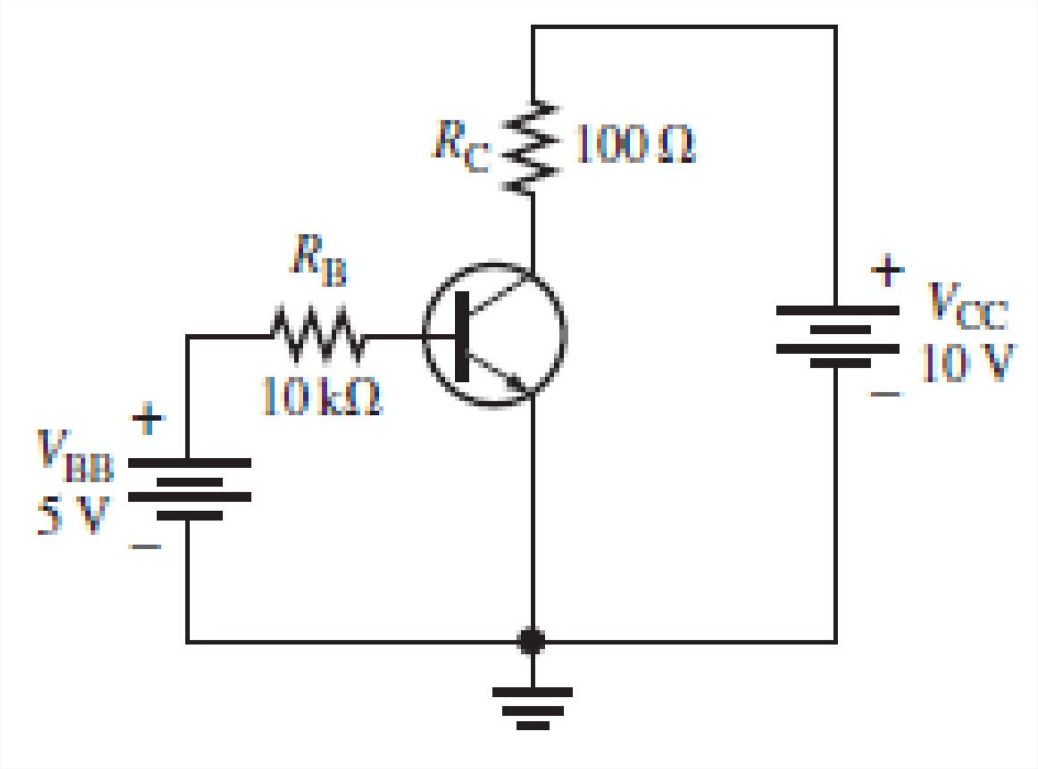
$$V_{CE} = V_{CC} - I_C R_C$$

$$V_{CB} = V_{CE} - V_{BE}$$

 Source: Electronic Devices, Floyd, 9th Edition

Example 1

- Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit of given figure. The transistor has a $\beta_{DC} = 150$.



Source: Electronic Devices, Floyd, 9th Edition

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega} = \mathbf{430\ \mu A}$$

$$I_C = \beta_{DC} I_B = (150)(430\ \mu\text{A}) = \mathbf{64.5\ mA}$$

$$I_E = I_C + I_B = 64.5\text{ mA} + 430\ \mu\text{A} = \mathbf{64.9\ mA}$$

Solve for V_{CE} and V_{CB}.

$$V_{CE} = V_{CC} - I_C R_C = 10\text{ V} - (64.5\text{ mA})(100\ \Omega) = 10\text{ V} - 6.45\text{ V} = \mathbf{3.55\ V}$$

$$V_{CB} = V_{CE} - V_{BE} = 3.55\text{ V} - 0.7\text{ V} = \mathbf{2.85\ V}$$

Since the collector is at a higher voltage than the base, the collector-base junction is reverse-biased.

Home work
Example 2

- Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit of given figure. The transistor has a β_{DC} = 100.
- (Refer the circuit diagram of previous problem)
- Consider V_{BB}=6V, R_B= 8K ohm, R_C=500 ohm and V_{CC}= 12V

Presentation Topic

Name of the course :- Basic Electronics Engineering

Faculty Name:-Mrs. Rohini Abhijeet Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor

Mrs. R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Last Session Recap

- Common-collector configuration ✔
- Comparison of CE,CB and CC configuration ✔
- BJT DC circuit analysis ✔

Source:- Thomas L. Floyd, “Electronic Devices – Conventional Current Version,” 9th Ed., Pearson Education.

Objectives of This Session

- Transistor Biasing
- State the purpose of dc biasing circuits.
- Describe the Q-point of an amplifier.
- Describe and analyze the operations of various bias circuits:

Course Outcome :-

- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

The Three Operating Regions and Biasing

- **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

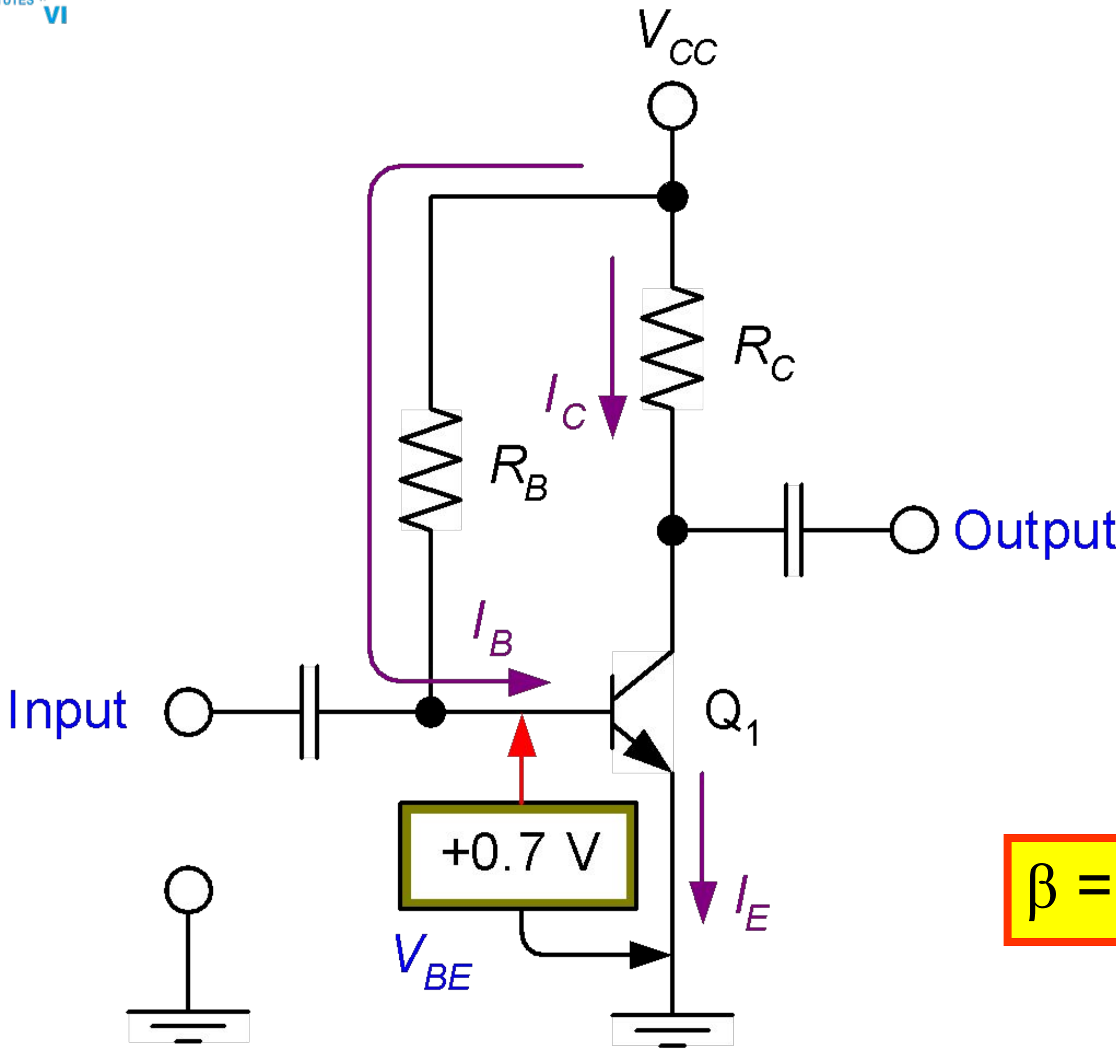
Biasing

Applying dc voltages to a transistor to establish a fixed level of DC current and DC voltage to turn it ON so that it can amplify AC signals.

Types of Biasing Circuits

- Fixed-bias circuits
- emitter-bias circuits
- voltage-divider bias circuits

Fixed Bias



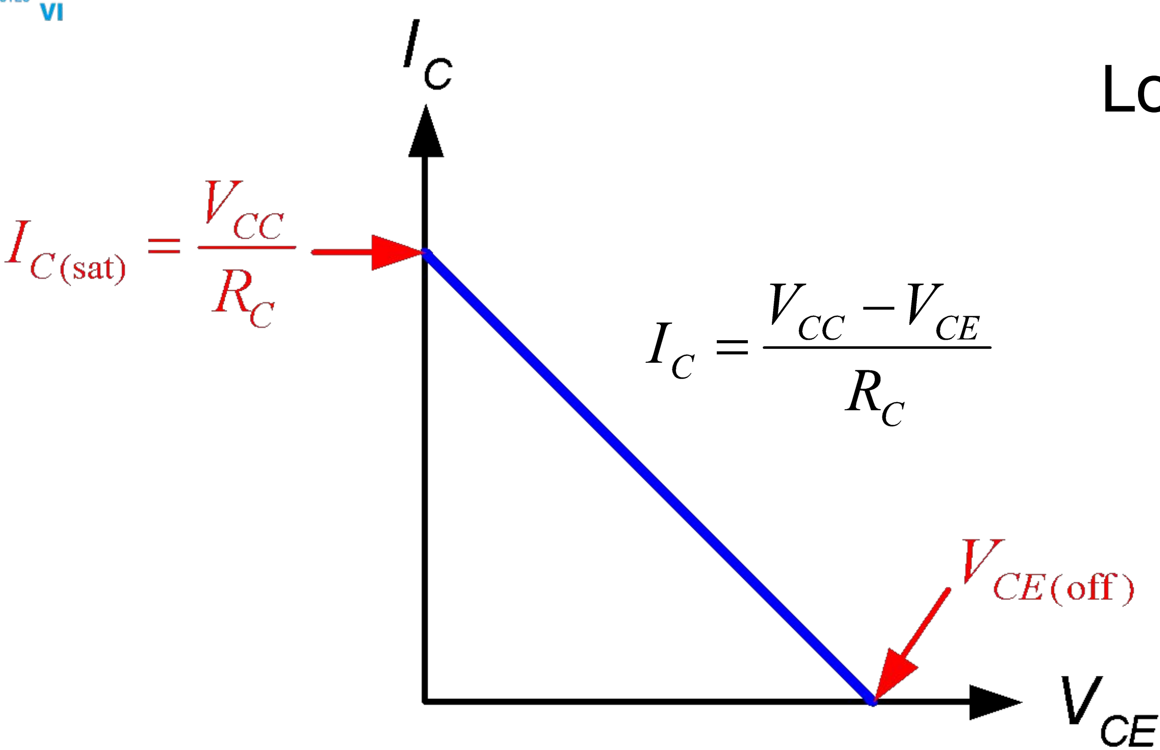
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

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

β = dc current gain = h_{FE}

A Generic Dc Load Line.



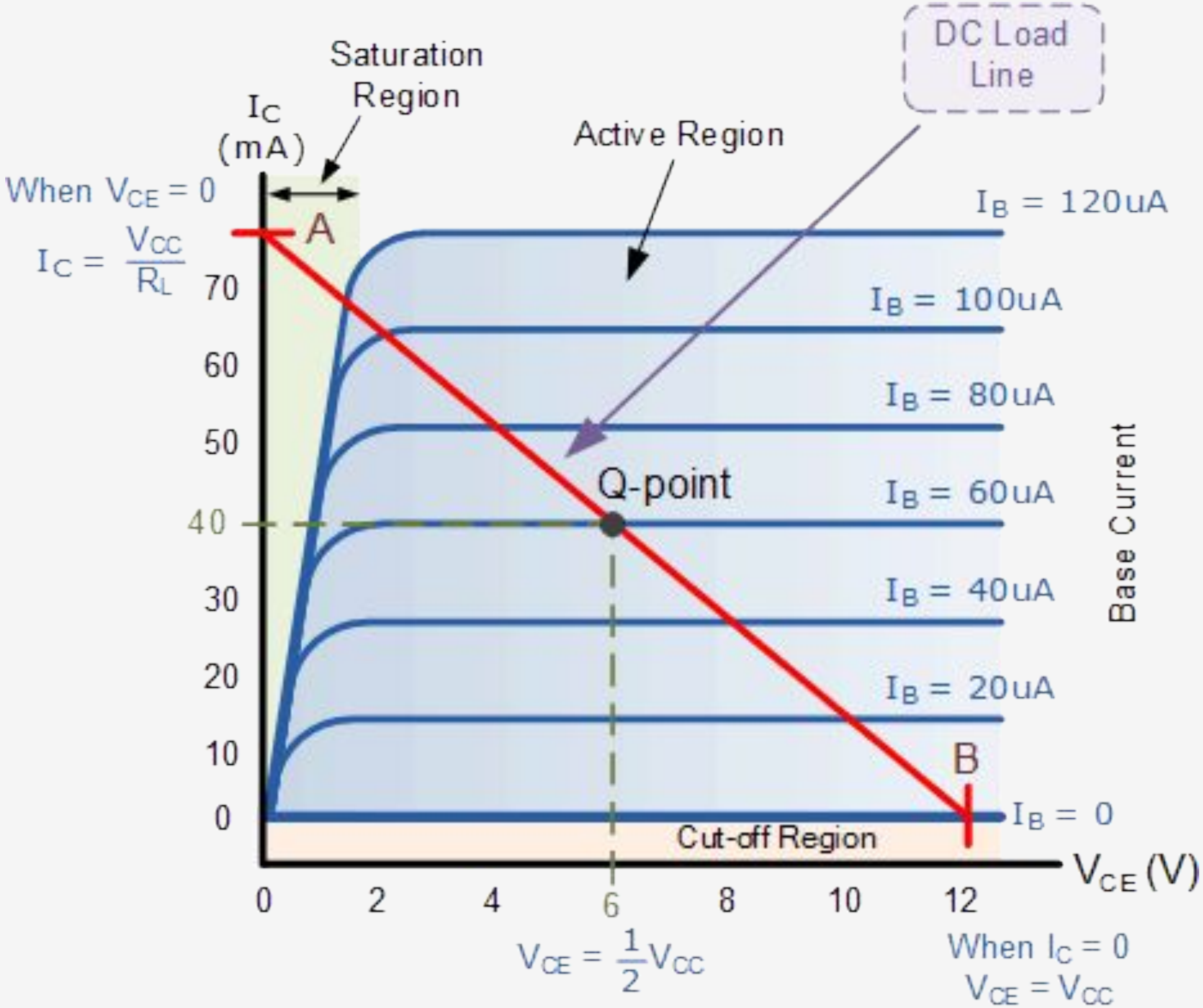
Load line equations:

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

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

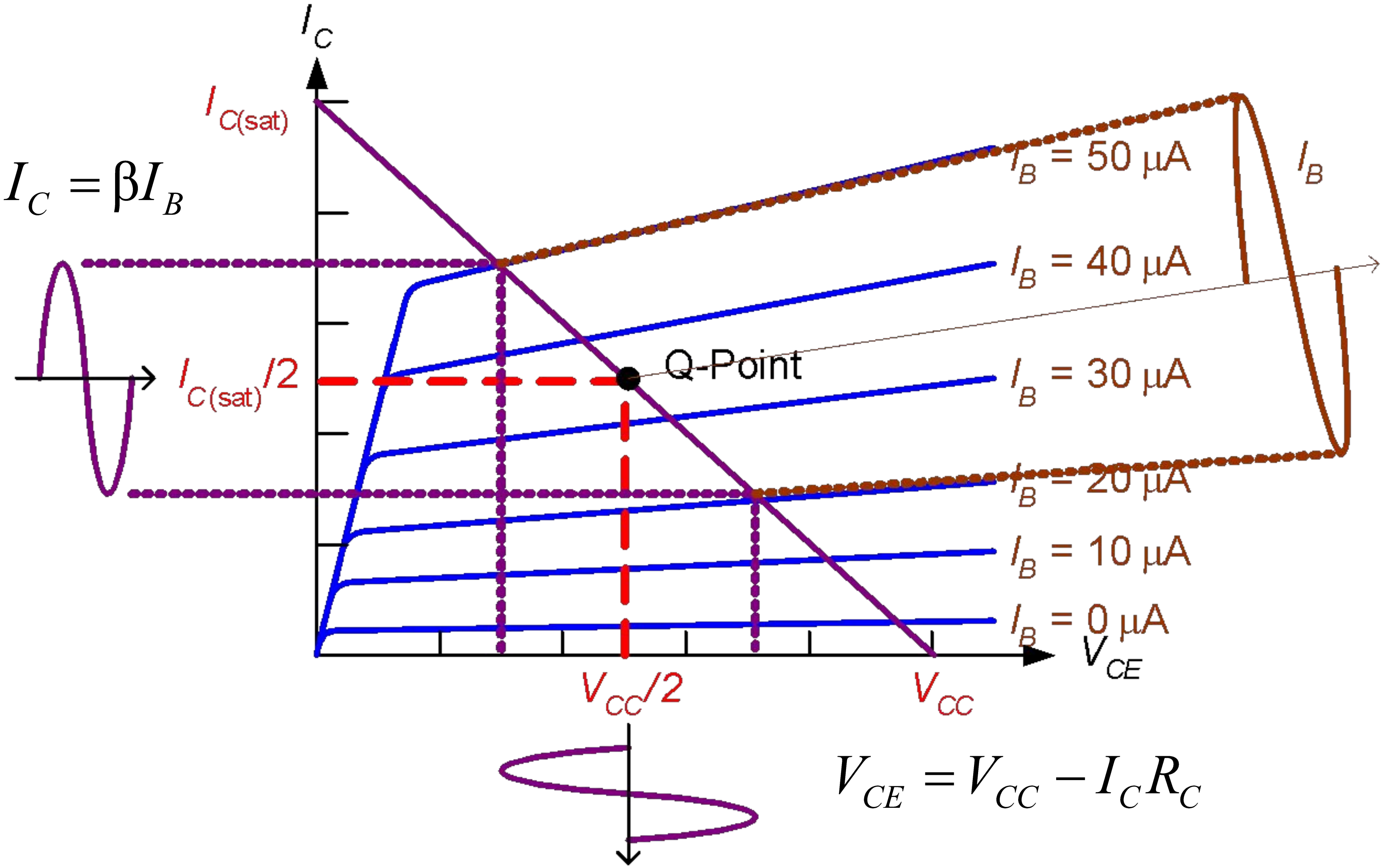
- For transistor amplifiers the resulting dc current and voltage establish an *operating point* on the characteristics that define the operating region of transistor.
- Because the operating point is a fixed point on the characteristics, it is also called the *quiescent point* (abbreviated Q -point).

Operating Points



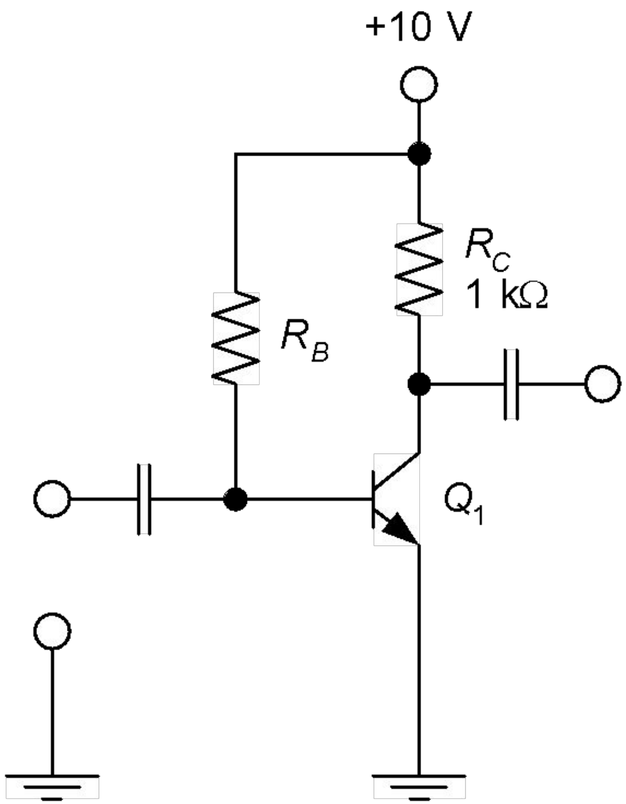
Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

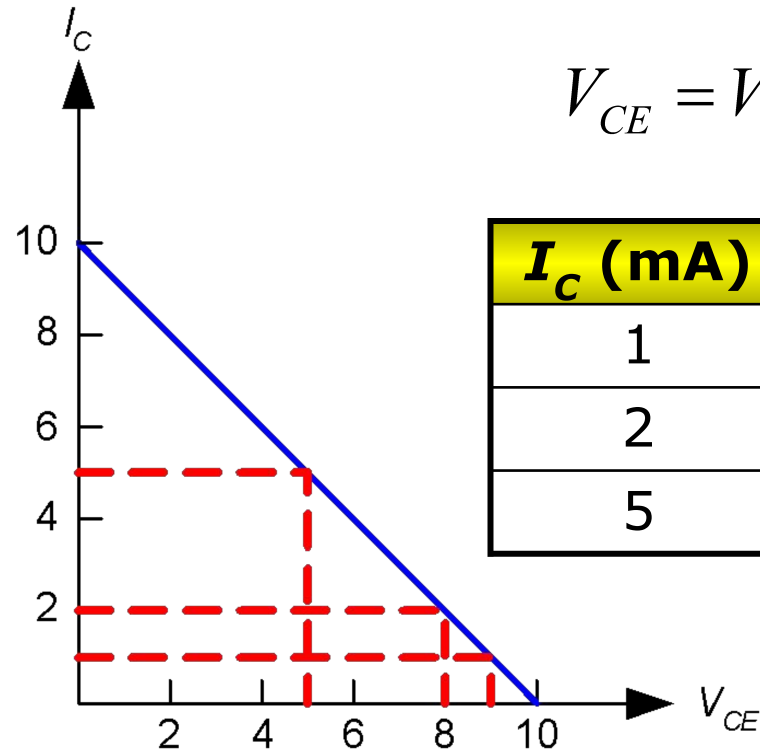
Optimum Q-point with amplifier operation.



Example 3

Plot the dc load line for the circuit shown in Fig. Then, find the values of V_{CE} for I_C = 1, 2, 5 mA respectively.



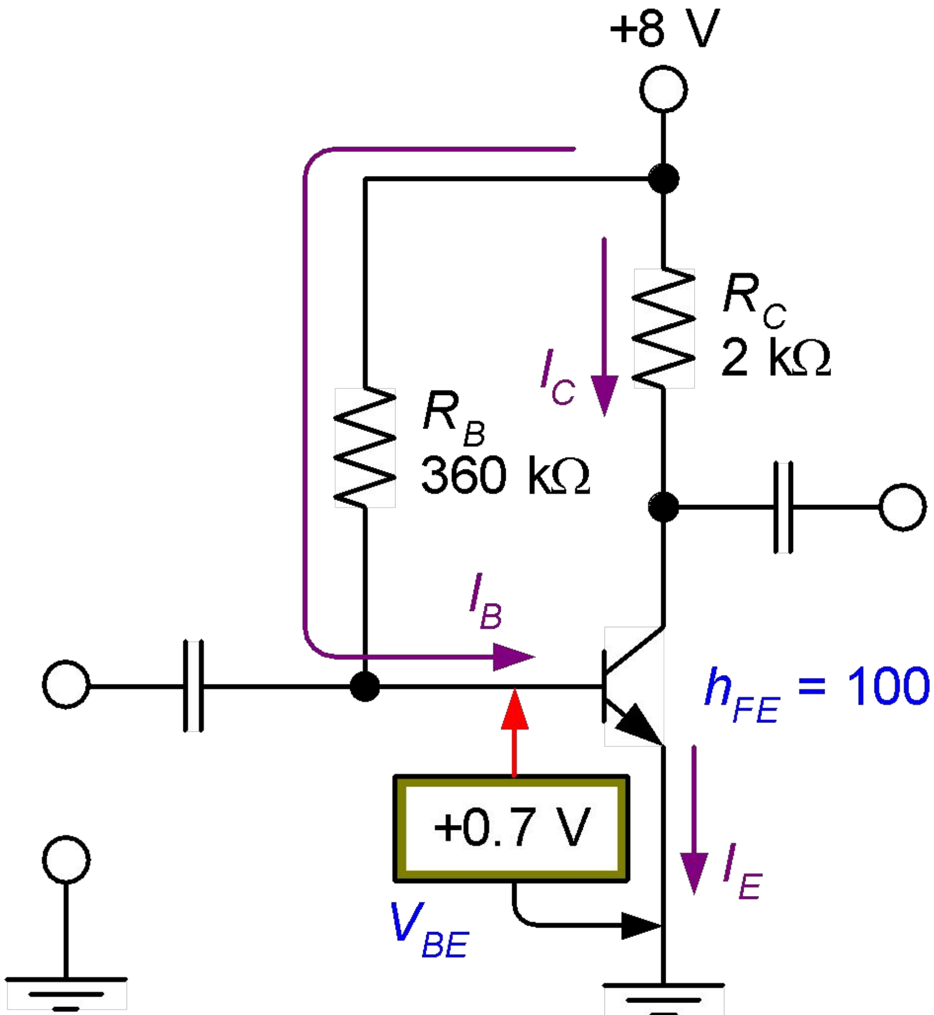


$$V_{CE} = V_{CC} - I_C R_C$$

I_C (mA)	V_{CE} (V)
1	9
2	8
5	5

Example 2

Construct the dc load line for the circuit shown below and plot the Q-point from the values obtained. Determine whether the circuit is midpoint biased.



$$I_B = \frac{V_{CC} - 0.7\text{V}}{R_B} = \frac{8\text{V} - 0.7\text{V}}{360\text{k}\Omega}$$

$$= 20.28\ \mu\text{A}$$

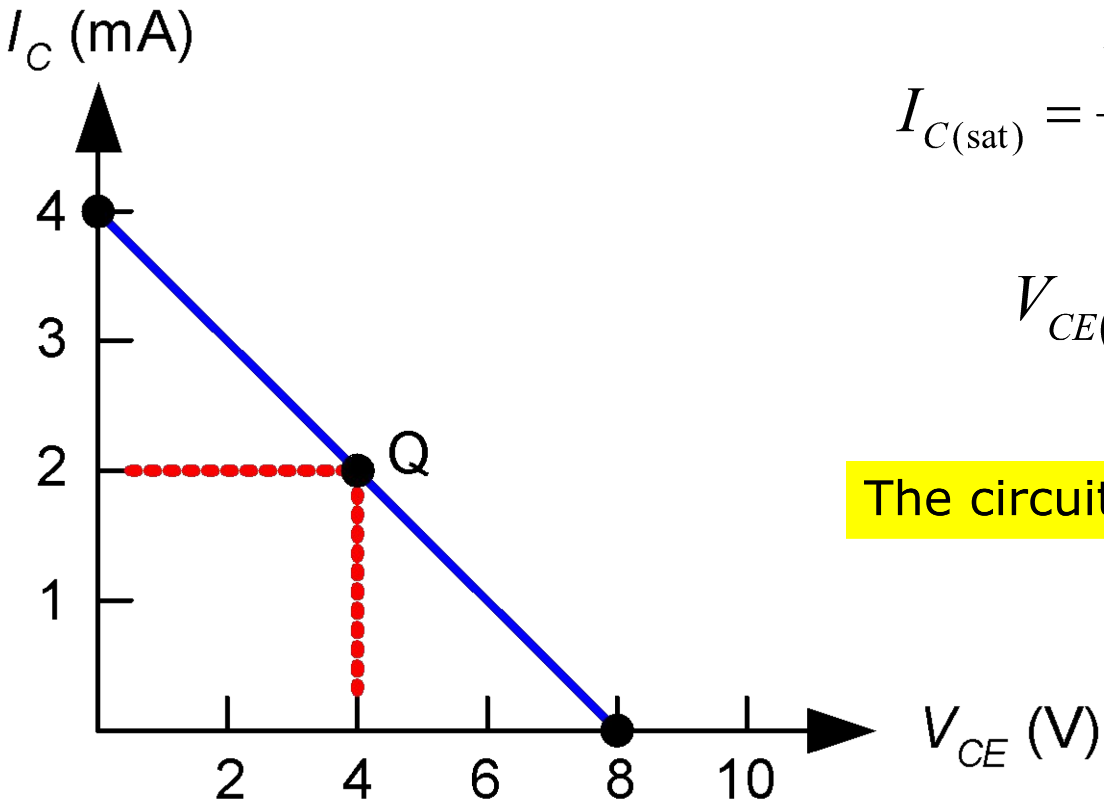
$$I_C = h_{FE} I_B = (100)(20.28\ \mu\text{A})$$

$$= 2.028\text{mA}$$

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

$$= 8\text{V} - (2.028\text{mA})(2\text{k}\Omega)$$

$$= 3.94\text{V}$$



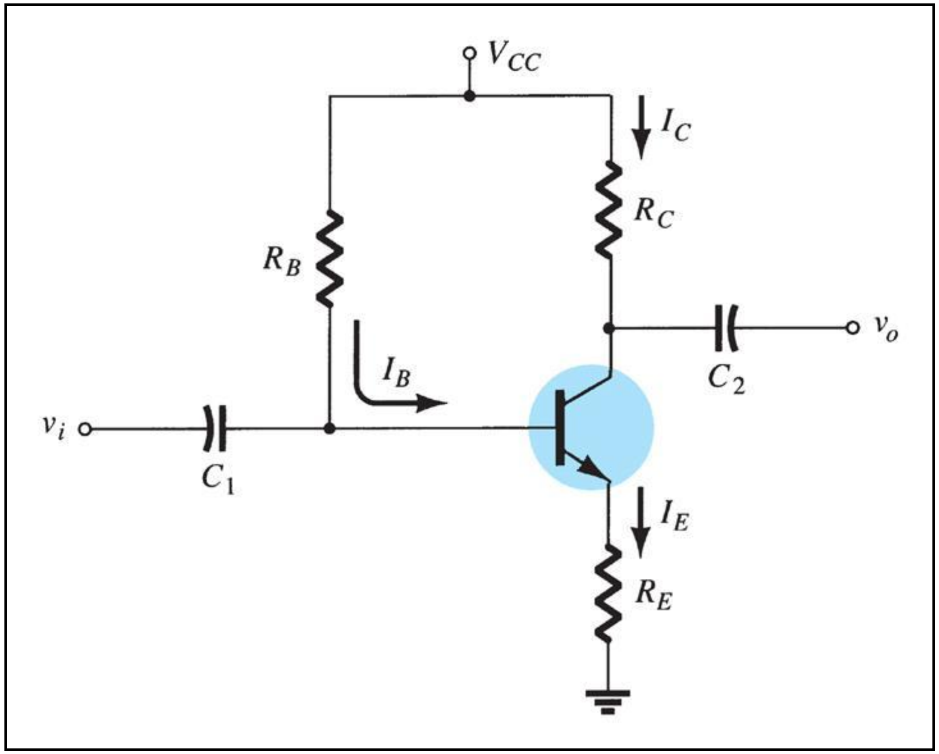
$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C} = \frac{8\text{V}}{2\text{k}\Omega} = 4\text{mA}$$

$$V_{CE(\text{off})} = V_{CC} = 8\text{V}$$

The circuit is midpoint biased.

Emitter-Bias Configuration

- Contains an emitter resistor to improve the stability level over that of the fixed-bias configuration.



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

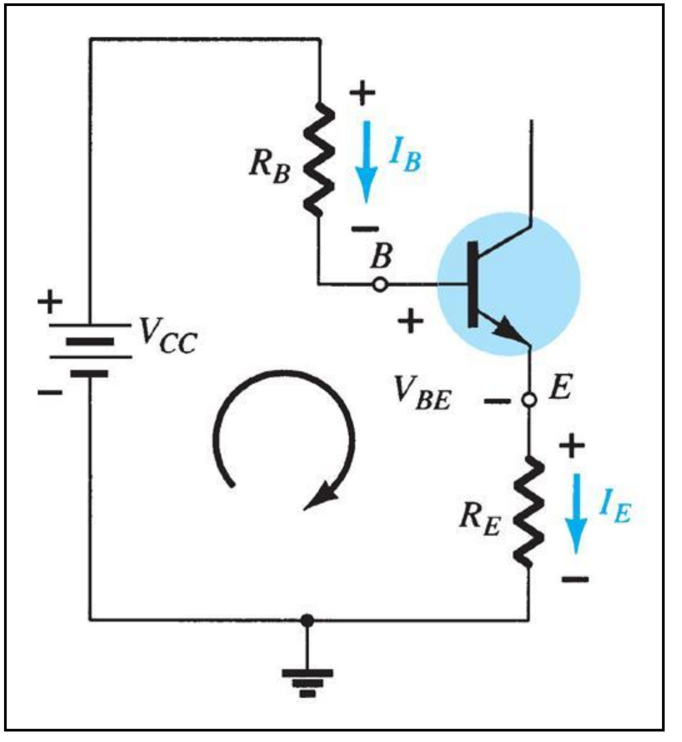
Base-Emitter Loop

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$$

Since $I_E = (\beta + 1)I_B$

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

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



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Collector-Emitter Loop

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

$$I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

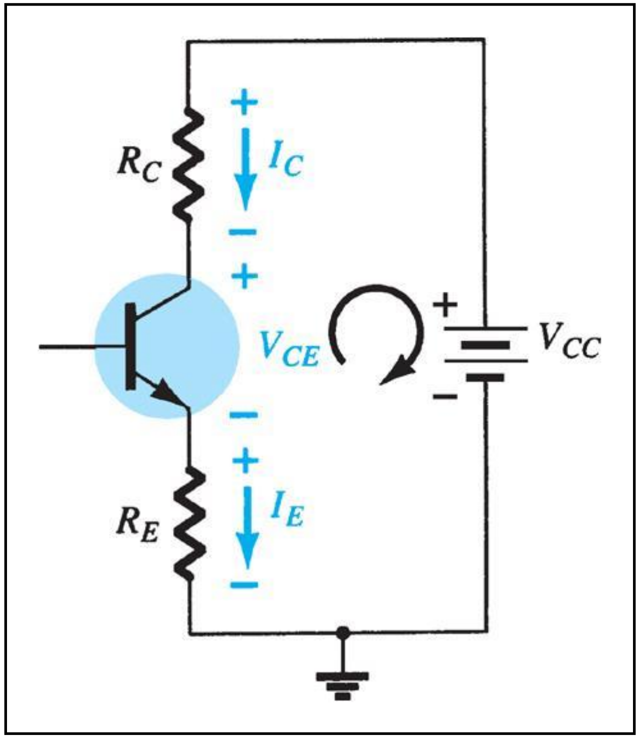
Since $I_E \cong I_C$:

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

$$V_E = I_E R_E$$

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

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

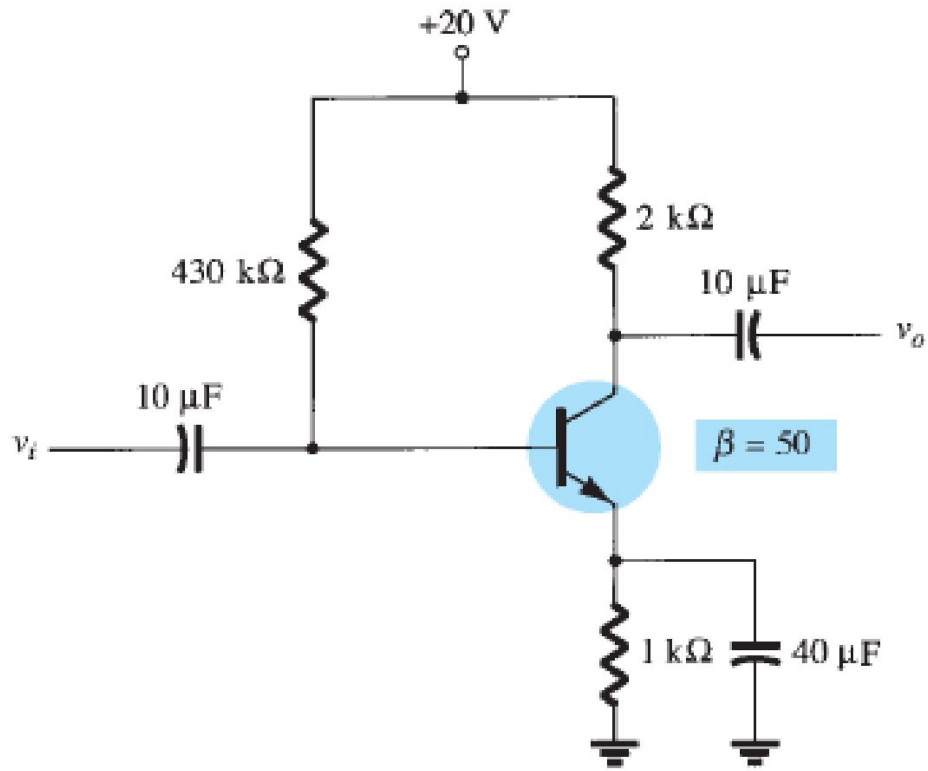


Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Example 4

- Determine:

  a. I_B.
  b. I_C.
  c. V_{CE}.
  d. V_C.
  e. V_E.
  f. V_B.
  g. V_{BC}.



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Solution:

a. Eq. (4.17): $$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{20\text{ V} - 0.7\text{ V}}{430\text{ k}\Omega + (51)(1\text{ k}\Omega)}$$

$$= \frac{19.3\text{ V}}{481\text{ k}\Omega} = \mathbf{40.1\ \mu A}$$

b. $$I_C = \beta I_B$$

$$= (50)(40.1\ \mu\text{A})$$

$$\cong \mathbf{2.01\ mA}$$

c. Eq. (4.19): $V_{CE} = V_{CC} - I_C(R_C + R_E)$

$$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega + 1\text{ k}\Omega) = 20\text{ V} - 6.03\text{ V}$$
$$= \mathbf{13.97\text{ V}}$$

d. $V_C = V_{CC} - I_C R_C$

$$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega) = 20\text{ V} - 4.02\text{ V}$$
$$= \mathbf{15.98\text{ V}}$$

e. $V_E = V_C - V_{CE}$

$$= 15.98\text{ V} - 13.97\text{ V}$$
$$= \mathbf{2.01\text{ V}}$$

or $V_E = I_E R_E \cong I_C R_E$

$$= (2.01\text{ mA})(1\text{ k}\Omega)$$
$$= \mathbf{2.01\text{ V}}$$

f. $V_B = V_{BE} + V_E$

$$= 0.7\text{ V} + 2.01\text{ V}$$
$$= \mathbf{2.71\text{ V}}$$

g. $V_{BC} = V_B - V_C$

$$= 2.71\text{ V} - 15.98\text{ V}$$

$= \mathbf{-13.27\text{ V}}$ (reverse-biased as required)

Presentation Topic

Name of the course :- BASIC ELECTRONICS ENGINEERING

Faculty Name:- Mrs. Rohini Abhijeet Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor Circuits

Mrs R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Last Session Recap

- Transistor Biasing ✔
- Fixed bias ✔
- Emitter bias ✔
- Numerical ✔

Source:- Thomas L. Floyd, “Electronic Devices – Conventional Current Version,” 9th Ed., Pearson Education.

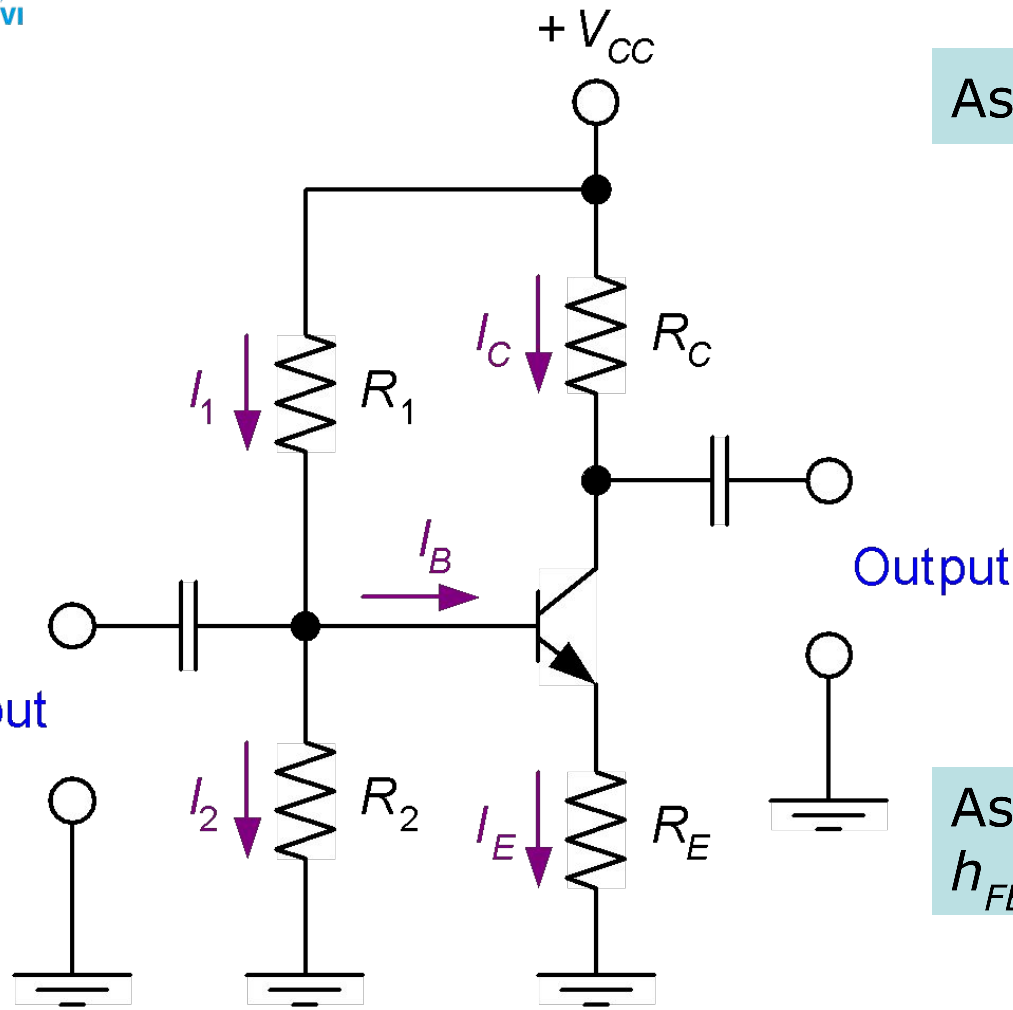
Objectives of This Session

- Voltage Divider Biasing
- Numerical on biasing

Course Outcome :-

- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

Voltage divider bias.



Assume that $I_2 > 10 I_B$.

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

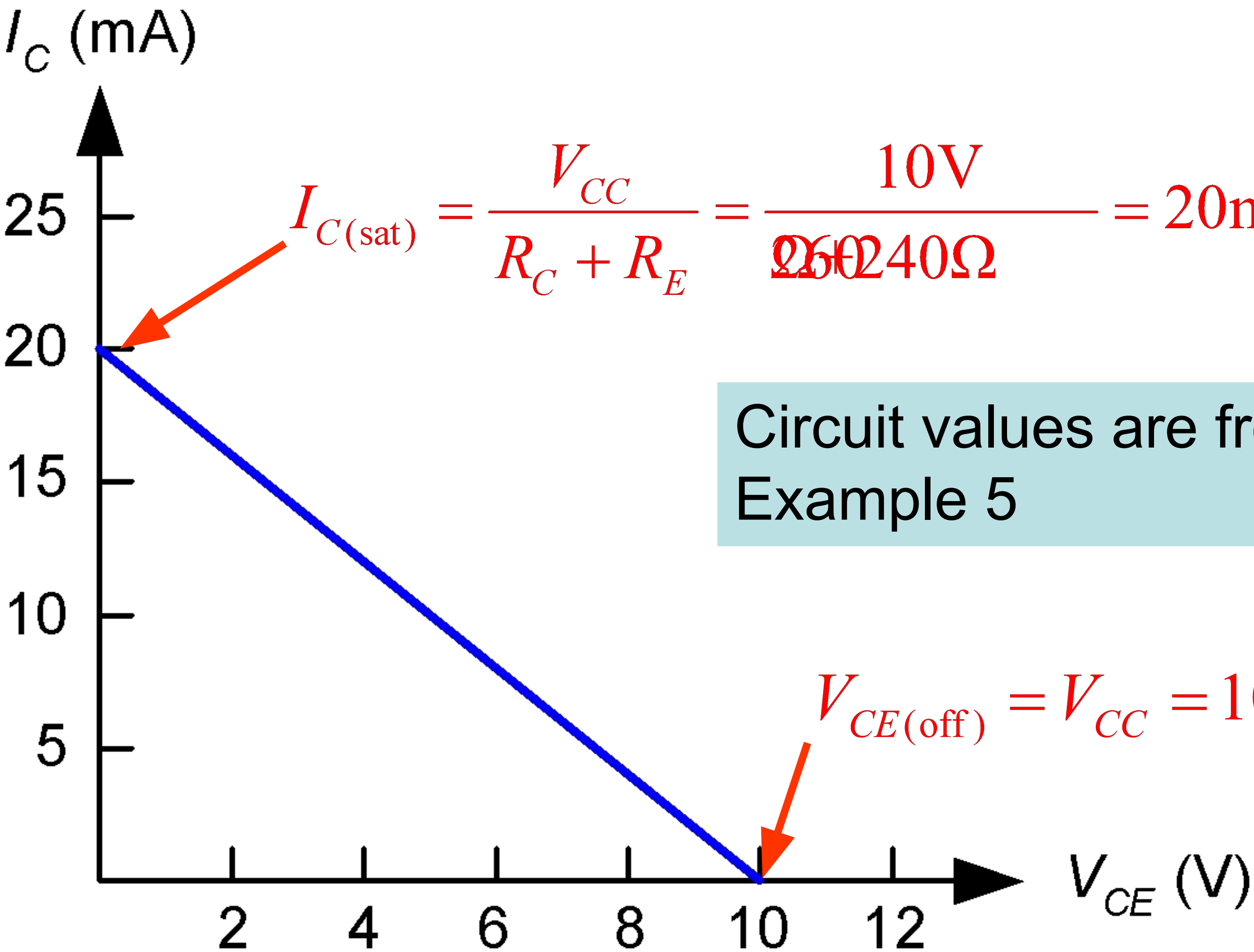
$$V_E = V_B - 0.7\text{V}$$

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

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

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

Load line for voltage divider bias circuit.

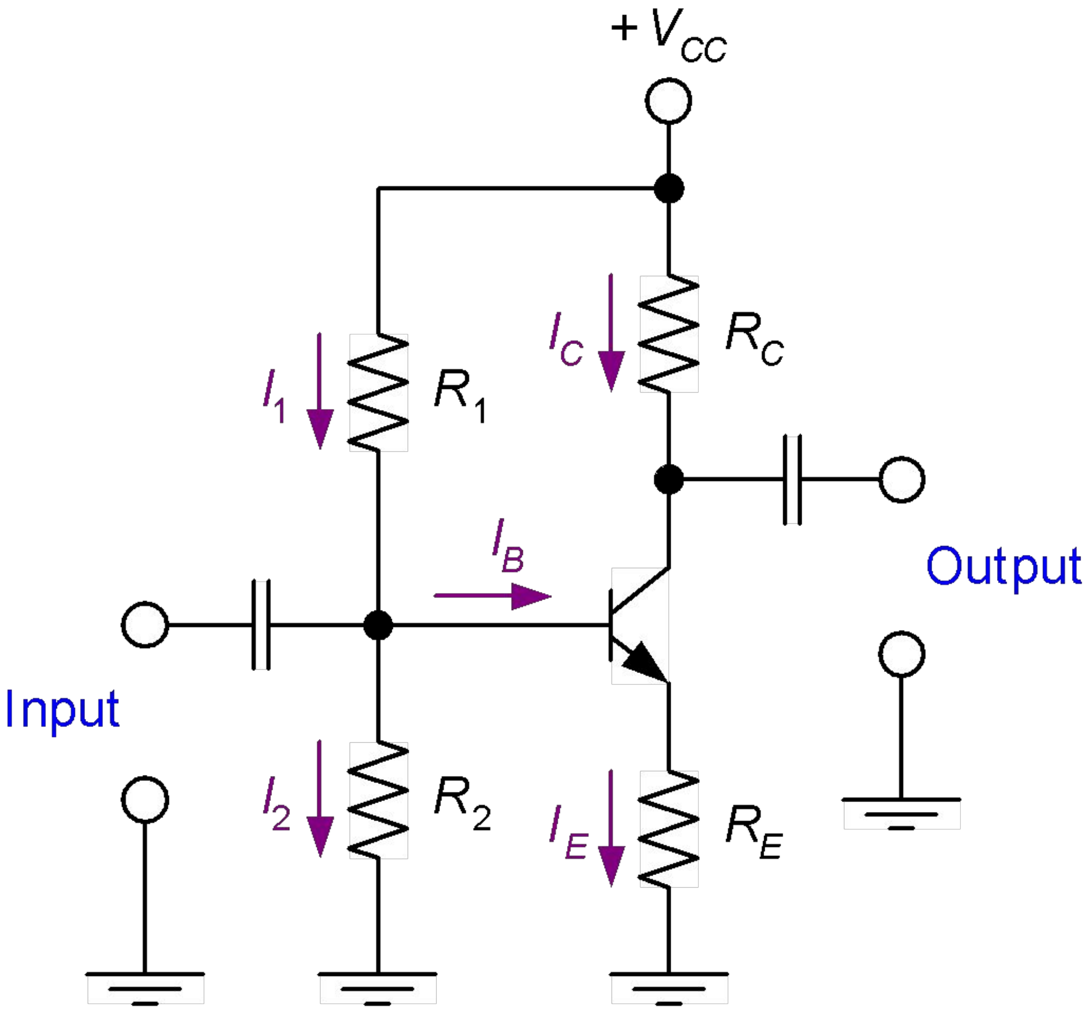


$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C + R_E} = \frac{10\text{V}}{260\Omega + 240\Omega} = 20\text{mA}$$

Circuit values are from Example 5

$$V_{CE(\text{off})} = V_{CC} = 10\text{V}$$

Voltage-divider bias characteristics



Load line equations:

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

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

Q-point equations (assume that $h_{FE}R_E > 10R_2$):

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

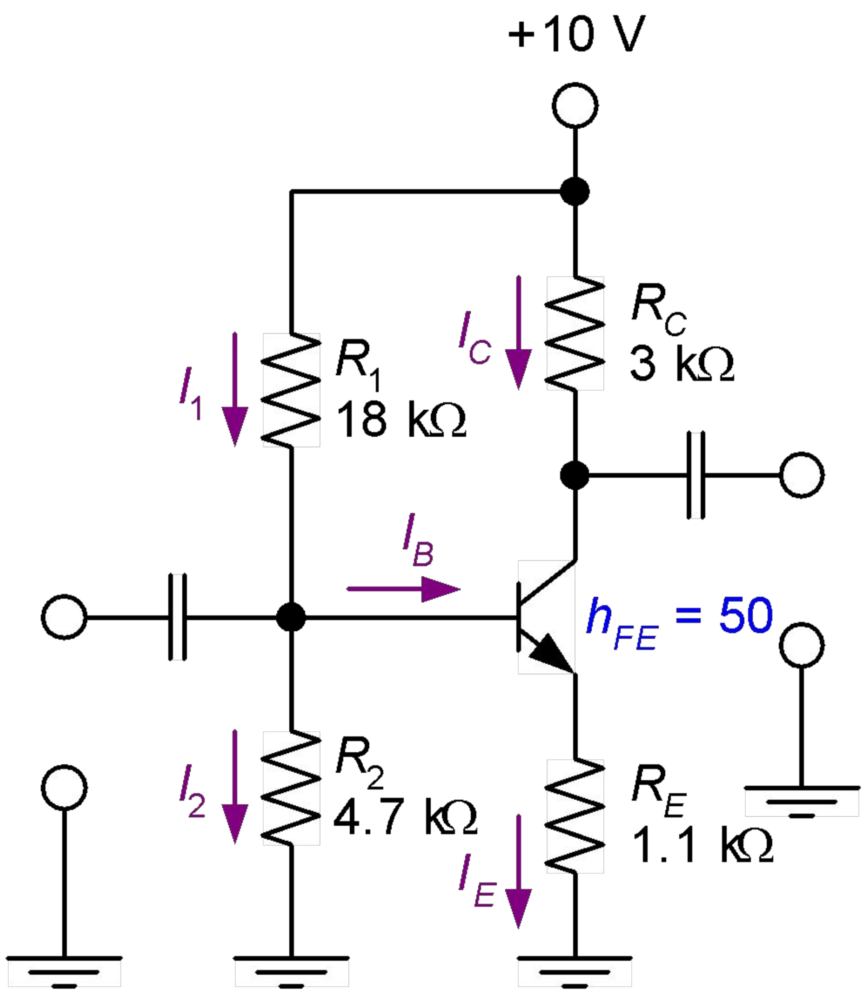
$$V_E = V_B - 0.7\text{V}$$

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

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

Example 5

Determine the values of I_{CQ} and V_{CEQ} for the circuit shown in Fig.



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

$$= (10\text{V})\frac{4.7\text{k}\Omega}{22.7\text{k}\Omega} = 2.07\text{V}$$

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

$$= 2.07\text{V} - 0.7\text{V} = 1.37\text{V}$$

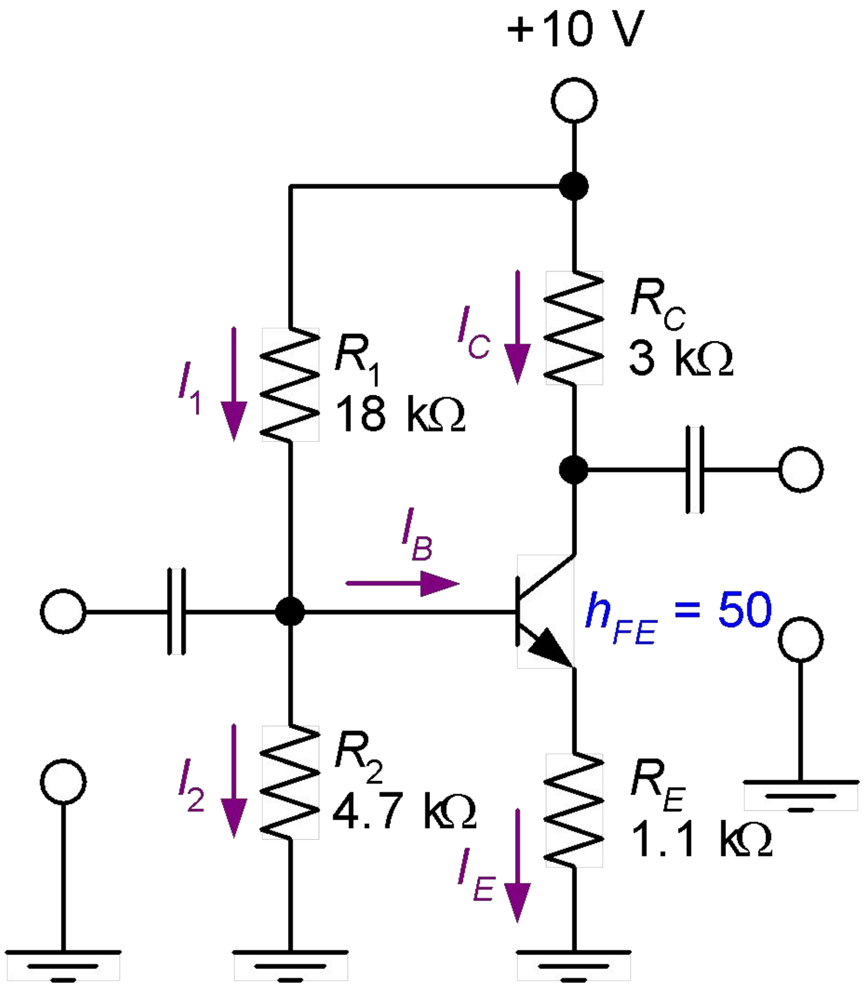
Because $I_{CQ} \cong I_E$ (or h_{FE} >> 1),

$$I_{CQ} \cong \frac{V_E}{R_E} = \frac{1.37\text{V}}{1.1\text{k}\Omega} = 1.25\text{mA}$$

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

$$= 10\text{V} - (1.25\text{mA})(4.1\text{k}\Omega) = 4.87\text{V}$$

Example 5 Continues



Verify that $I_2 > 10\ I_B$.

$$I_2 = \frac{V_B}{R_2} = \frac{2.07\text{V}}{4.7\text{k}\Omega} = 440.4\ \mu\text{A}$$

$$I_B = \frac{I_E}{h_{FE}+1} = \frac{1.25\text{mA}}{50+1}$$

$$= 24.51\ \mu\text{A}$$

$$\therefore I_2 > 10 I_B$$

Example 5

A voltage-divider bias circuit has the following values: R_1 = 1.5 kΩ, R_2 = 680 Ω, R_C = 260 Ω, R_E = 240 Ω and V_{CC} = 10 V. Assuming the transistor is a 2N3904, determine the value of I_B for the circuit.

$$V_B = V_{CC}\frac{R_2}{R_1 + R_2} = (10\text{V})\frac{680\ \Omega}{2180\ \Omega} = 3.12\text{V}$$

$$V_E = V_B - 0.7\text{V} = 3.12\text{V} - 0.7\text{V} = 2.42\text{V}$$

$$I_{CQ} \cong I_E = \frac{V_E}{R_E} = \frac{2.42\text{V}}{240\ \Omega} = 10\text{mA}$$

$$h_{FE(ave)} = \sqrt{h_{FE(\min)} \times h_{FE(\max)}} = \sqrt{100 \times 300} = 173$$

$$I_B = \frac{I_E}{h_{FE(\text{ave})} + 1} = \frac{10\text{mA}}{174} = 57.5\ \mu\text{A}$$

Presentation Topic

Name of the course :- BASIC ELECTRONICS ENGINEERING

Faculty Name:- Mrs. Rohini Abhijeet Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor Circuits

Mrs. R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Last Session Recap

- Voltage divider Biasing ✔
- Numerical Based on voltage divider Biasing ✔

- Source:- Boylstad, Nashlesky, "Electronic Devices and Circuits Theory", 9th Edition, PHI, 2006.

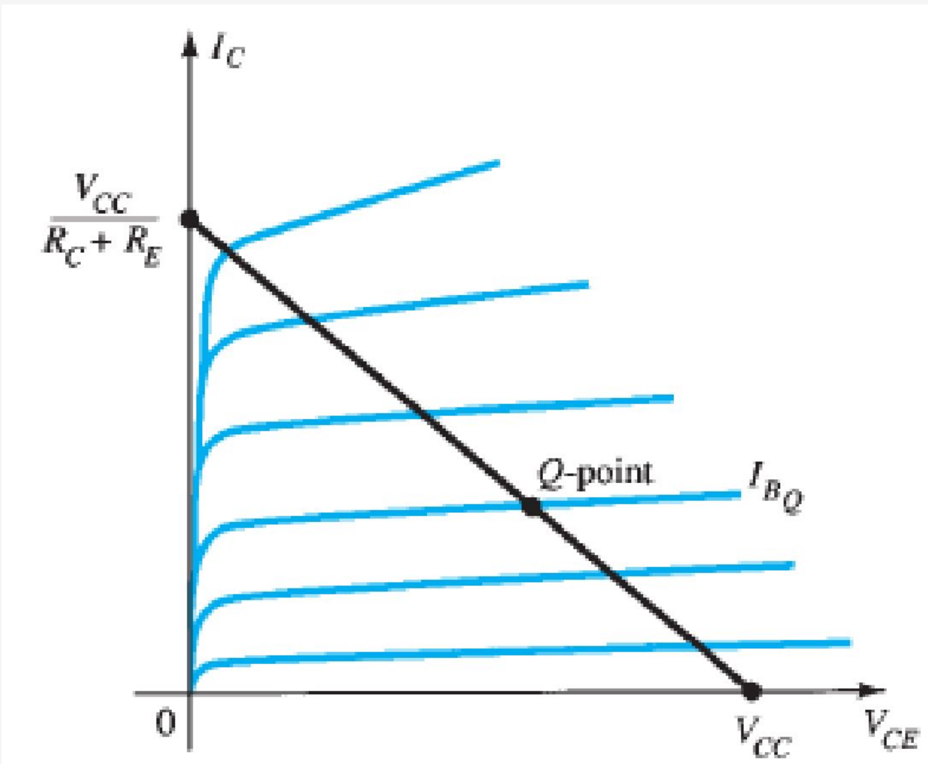
Objectives of This Session

- Bias stabilization

Course Outcome :-

- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

Load Line Analysis for Voltage Divider Biasing



$$I_C = \left. \frac{V_{CC}}{(R_C + R_E)} \right|_{V_{CE} = 0\text{ V}}$$

$$V_{CE} = V_{CC} \Big|_{I_C = 0\text{ mA}}$$

Source: Electronic Devices and Circuit Theory, Boylestad and Nashelsky, 11th Edition

Bias Stabilization

- The stability of a system is a measure of the sensitivity of a network to variations in its parameters.
- The collector current I_C is sensitive to each of the following parameters:
  - β : *increases with increase in temperature*
  - V_{BE} : *decreases about 2.5 mV per degree Celsius (°C) increase in temperature*
  - I_{CO} *(reverse saturation current): doubles in value for every 10° C increase in temperature*

Bias Stabilization (cont'd)

- Any or all of these factors can cause the bias point to drift from the designed point of operation.

Variation of Silicon Transistor Parameters with Temperature

T (°C)	I_{CO} (nA)	β	V_{BE} (V)
−65	0.2×10^{-3}	20	0.85
25	0.1	50	0.65
100	20	80	0.48
175	3.3×10^{3}	120	0.3

Source: Electronic Devices and Circuit Theory, Bylestad and Nashelsky, 11th Edition

Stability Factors $S(I_{CO})$, $S(V_{BE})$, and $S(\beta)$

- A stability factor *S* is defined for each of the parameters affecting bias stability as follows:

$$S(I_{CO}) = \frac{\Delta I_C}{\Delta I_{CO}}$$

$$S(V_{BE}) = \frac{\Delta I_C}{\Delta V_{BE}}$$

$$S(\beta) = \frac{\Delta I_C}{\Delta \beta}$$

Derivation of Stability Factor S(ICO) or S

$$S = \frac{\Delta I_C}{\Delta I_{CO}}$$

$$I_C = \beta I_B + (1+\beta)I_{CO}$$

Differentiate w.r.t. I_C and consider β constant

$$1 = \beta \frac{dI_B}{dI_C} + (1+\beta)\frac{\partial I_{CO}}{\partial I_C} = \beta \frac{dI_B}{dI_C} + \frac{(1+\beta)}{S}$$

$$S = \frac{1+\beta}{1-\beta(dI_B / dI_c)}$$

Refer Electronic Devices and Circuits by Millman and Halkias

Presentation Topic

Name of the course :- BASIC ELECTRONICS ENGINEERING

Faculty Name:- Mrs. Rohini Abhijeet Chavan

Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in

Department of E&TC Engineering

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)

(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor

Mrs. R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Last Session Recap

- Bias stabilization ✔
- Derivation for stability factor✔

- Source:- Boylstad, Nashlesky, “Electronic Devices and Circuits Theory”, 9th Edition, PHI, 2006.
-

Objectives of This Session

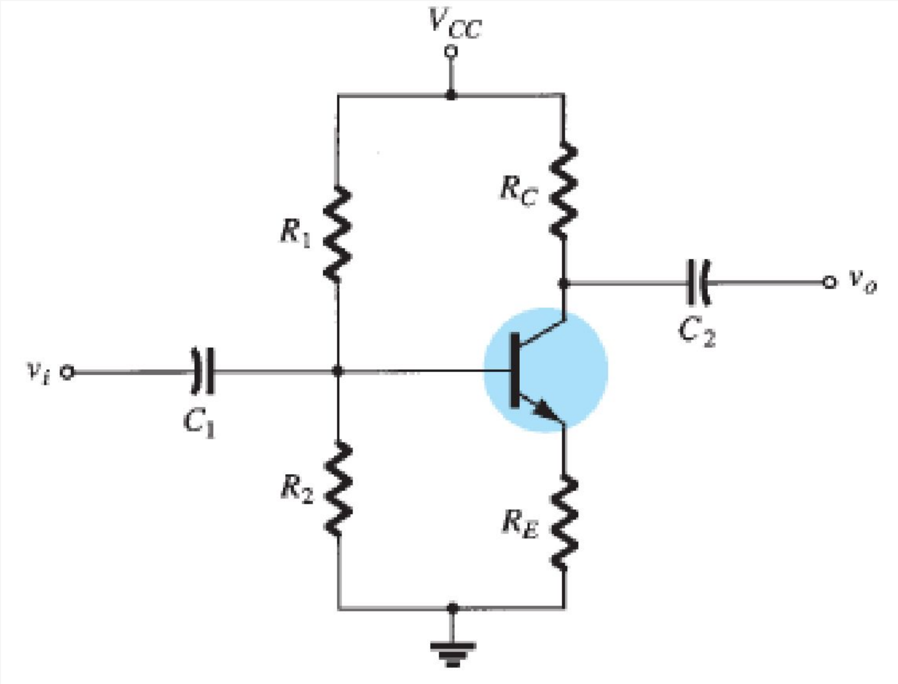
- Derivation of S for voltage divider biasing
- Transistor as a switch
- Common Emitter Amplifier

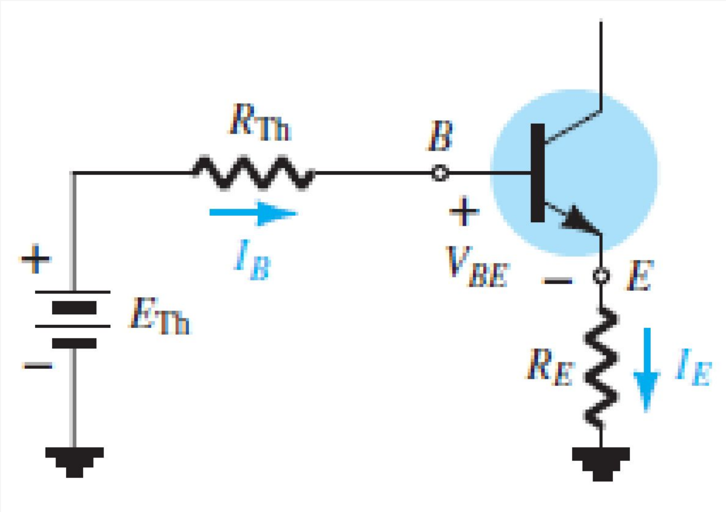
Course Outcome :-

- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

Stability Factors S(ICO) for voltage divider bias

- For voltage-divider bias configuration





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

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2}$$

Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Stability Factors S(ICO) or S

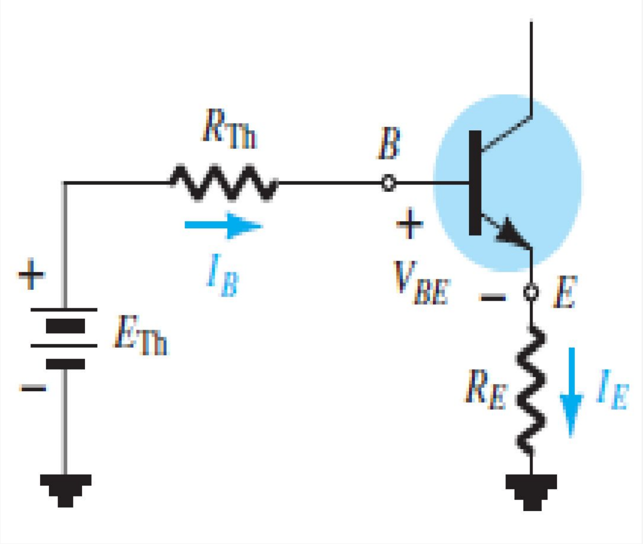
- Applying KVL around base circuit, we have

$$S = \frac{1+\beta}{1-\beta(dI_B / dI_c)}$$

For voltage divider biasing

$$\frac{dI_B}{dI_c} = -\frac{R_E}{R_E + R_{Th}}$$

$$\therefore S = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_E + R_{Th}}\right)}$$



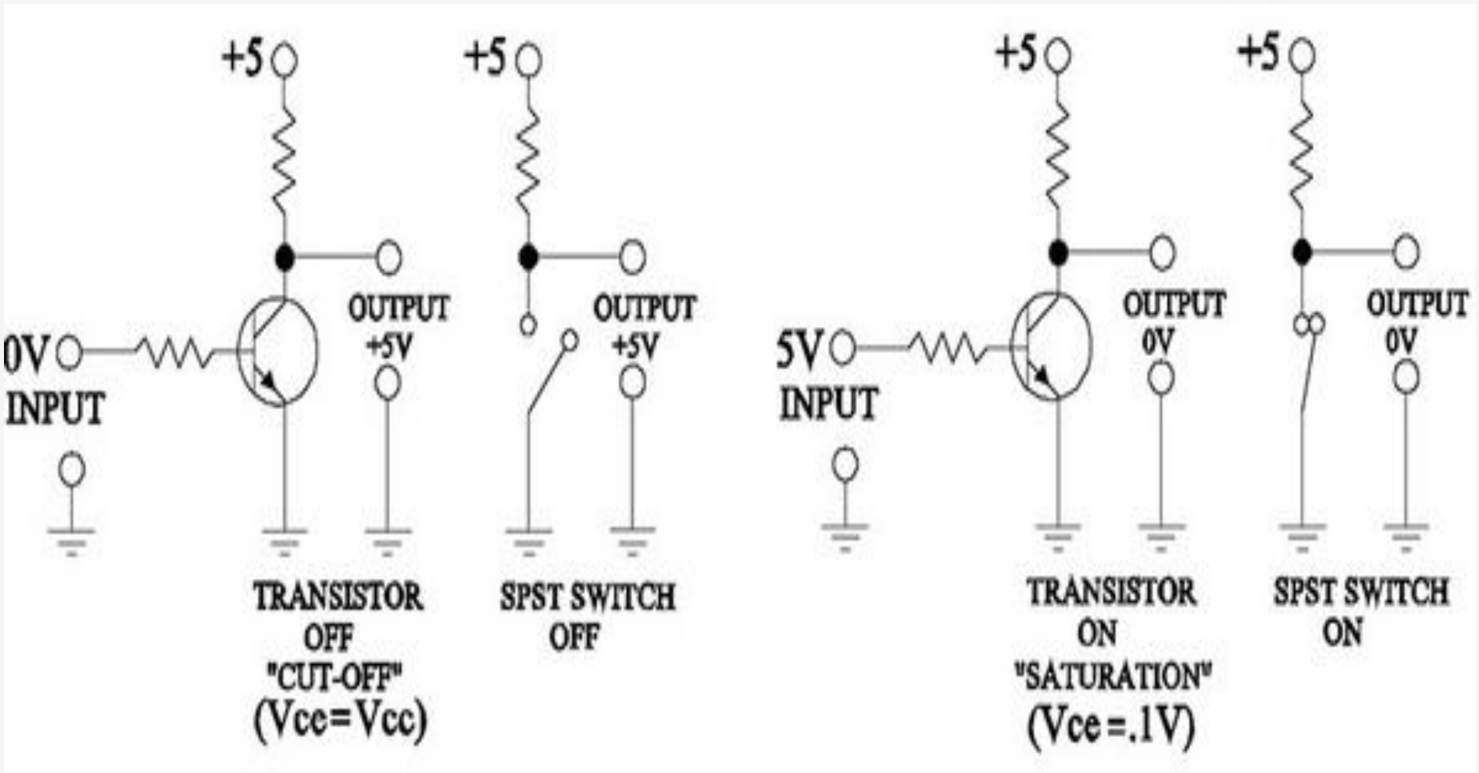
Refer Electronic Devices and Circuits by Millman and Halkias

Transistor as a switch

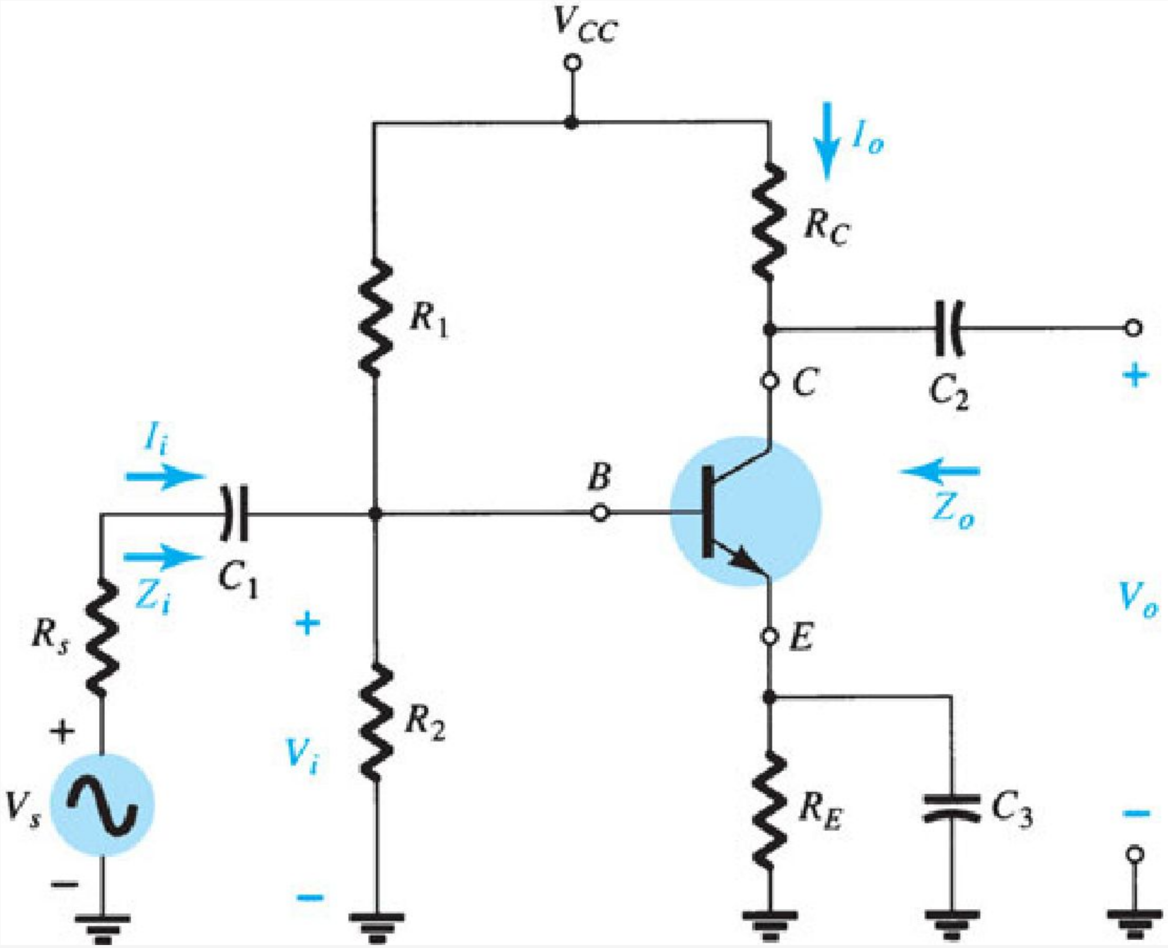
- When used as an electronic switch, a transistor is operated alternately in cutoff and saturation
- A transistor is in cutoff when the emitter-base junction is reverse biased and Collector-base is also reverse biased.

- When the emitter-base junction is forward-biased and Collector-base is also forward biased. There is enough base current to produce a maximum collector current and the transistor is saturated.

Transistor as a switch



CE amplifier



Source: Electronic Devices and Circuit Theory, Byolestad and Nashelsky, 11th Edition

Presentation Topic

Name of the course :- BASIC ELECTRONICS ENGINEERING

Faculty Name:- Mrs. Rohini Abhijeet Chavan
Faculty official (VIIT) mail Id:- rohini.chavan@viit.ac.in
Department of E&TC Engineering

VISHWAKARMA INSTITUTES
VI

BRACT'S, Vishwakarma Institute of Information Technology, Pune-48

(An Autonomous Institute affiliated to Savitribai Phule Pune University)
(NBA and NAAC accredited, ISO 9001:2015 certified)

Unit – 02: Bipolar Junction Transistor Circuits

Mrs. R. A. Chavan

Department of E&TC

VIIT, Pune-411048

Last Session Recap

- Bias stabilization ✔
- Transistor as a switch✔
- CE amplifier ✔

- Source:- Boylstad, Nashlesky, “Electronic Devices and Circuits Theory”, 9th Edition, PHI, 2006.

-

Objectives of This Session

- Oscillator
- Types of oscillator
- Working of oscillator

Course Outcome :-

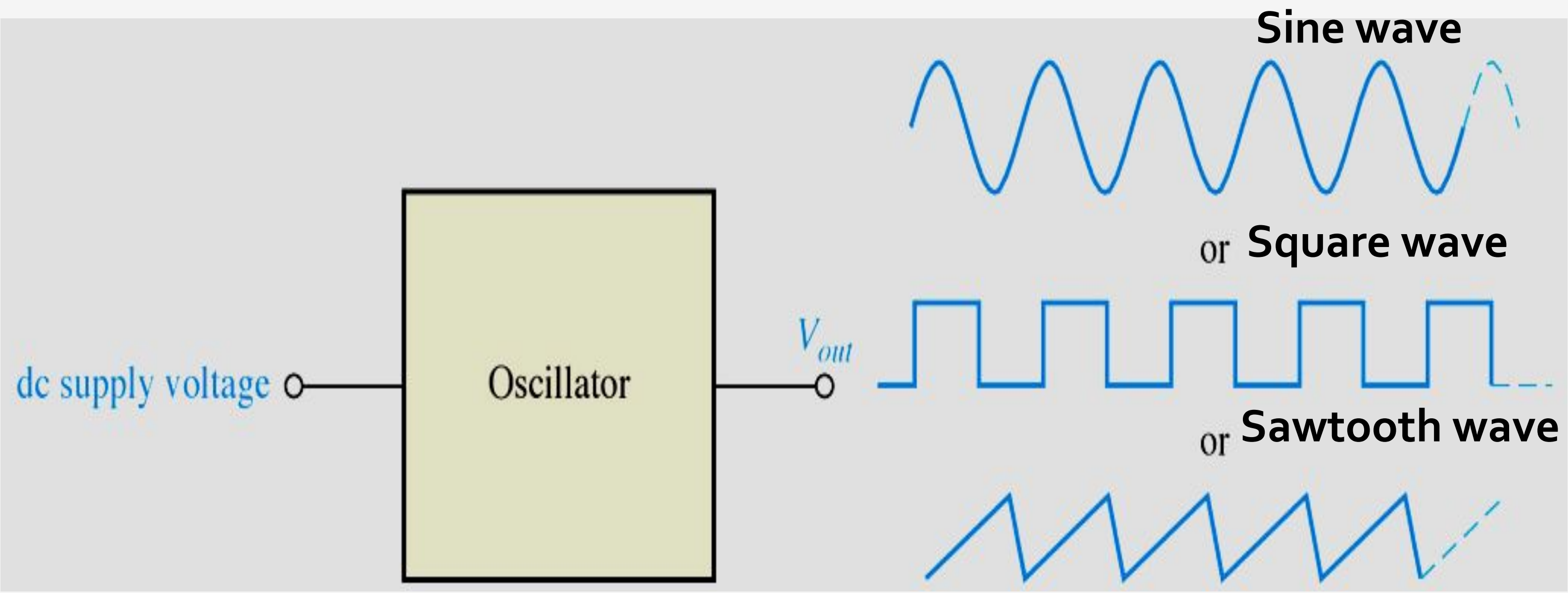
- Explain the construction, working and characteristics of BJT to construct amplifier and switch circuits.

Oscillator

- Oscillator is an electronic circuit that generates a periodic waveform on its output without an external signal source. It converts dc signal into ac signal.
- Oscillator is a circuit which produce a continuous signal of some type without need of an input signal.
- These types of signals are used in various applications.
- For example, Communications systems, digital systems (including computers), and test equipments make use of oscillators

Oscillator

- An oscillator is a circuit that produces a repetitive signal from a dc voltage.
- The feedback oscillator relies on a positive feedback of the output to maintain the oscillations.



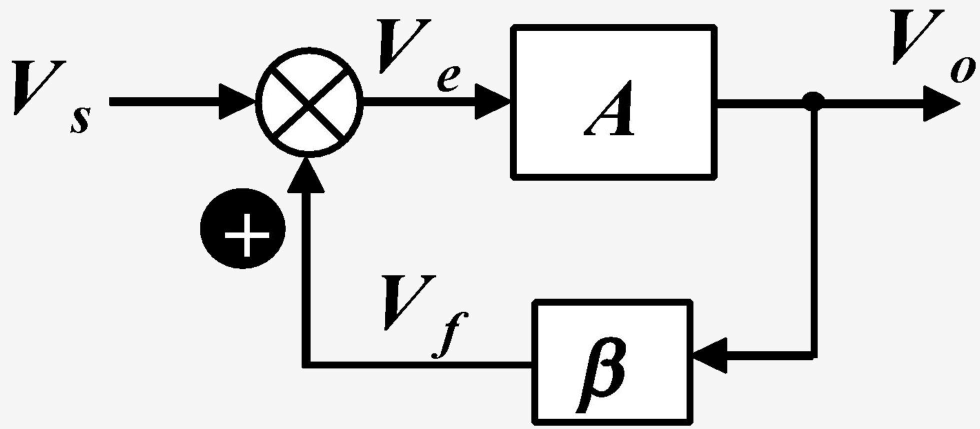
Types of oscillators

1. **RC oscillators**
   - Wien Bridge
   - RC Phase-Shift

2. **LC oscillators**
   - Hartley
   - Colpitt
   - Crystal

Basic principles for oscillation

- An oscillator is an amplifier with positive feedback



$$V_e = V_s + V_f \quad (1)$$

$$V_f = \beta V_o \quad (2)$$

$$V_o = A V_e = A\left(V_s + V_f\right) = A\left(V_s + \beta V_o\right) \quad (3)$$

Basic principles for oscillation

$$V_o = AV_s + A\beta V_o$$

$$(1 - A\beta)V_o = AV_s$$

The closed loop gain is:

$$A_f \equiv \frac{V_o}{V_s} = \frac{A}{(1 - A\beta)}$$

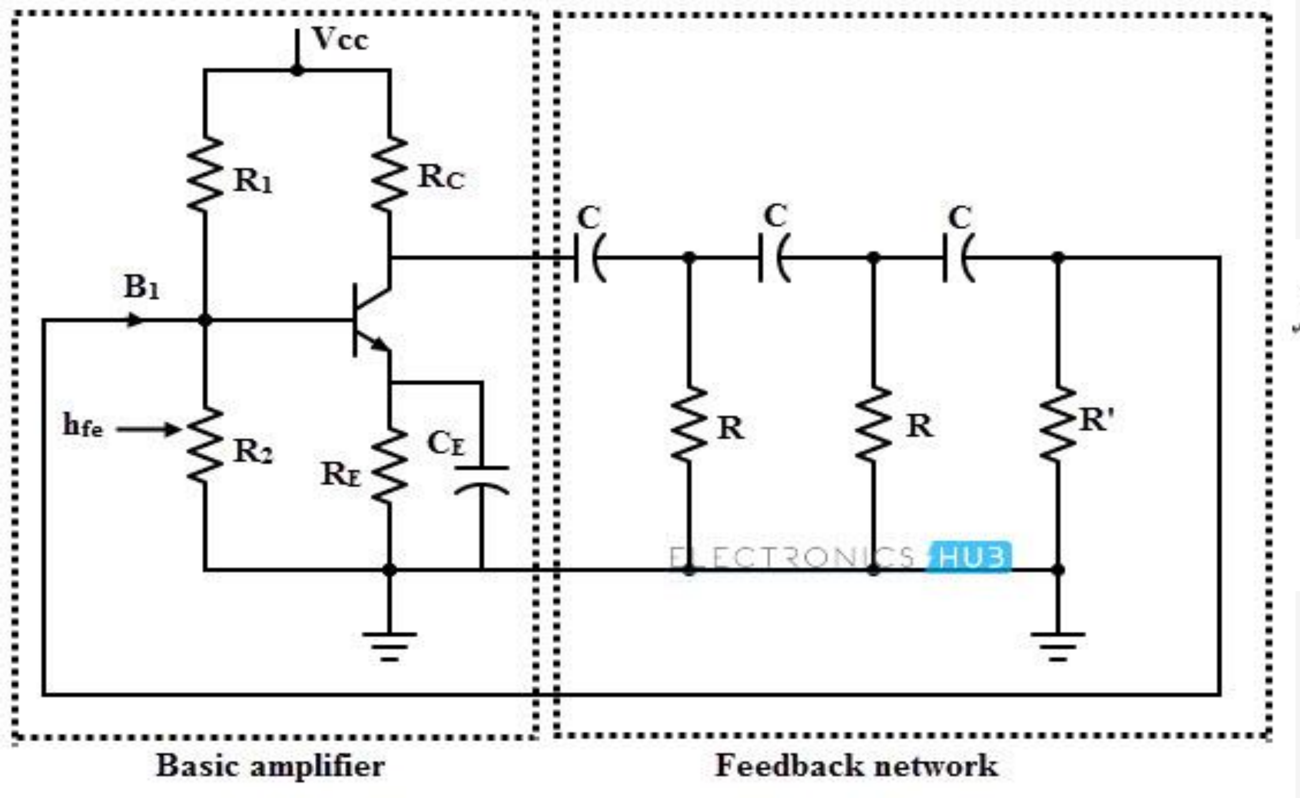
Barkhausen Criterion

1. The loop gain magnitude is slightly higher than unity at the desired frequency of oscillation

2. Over all Phase shift 360 degree or 0 degree.

3. Feed back must be Positive.

RC Phase shift oscillator circuit



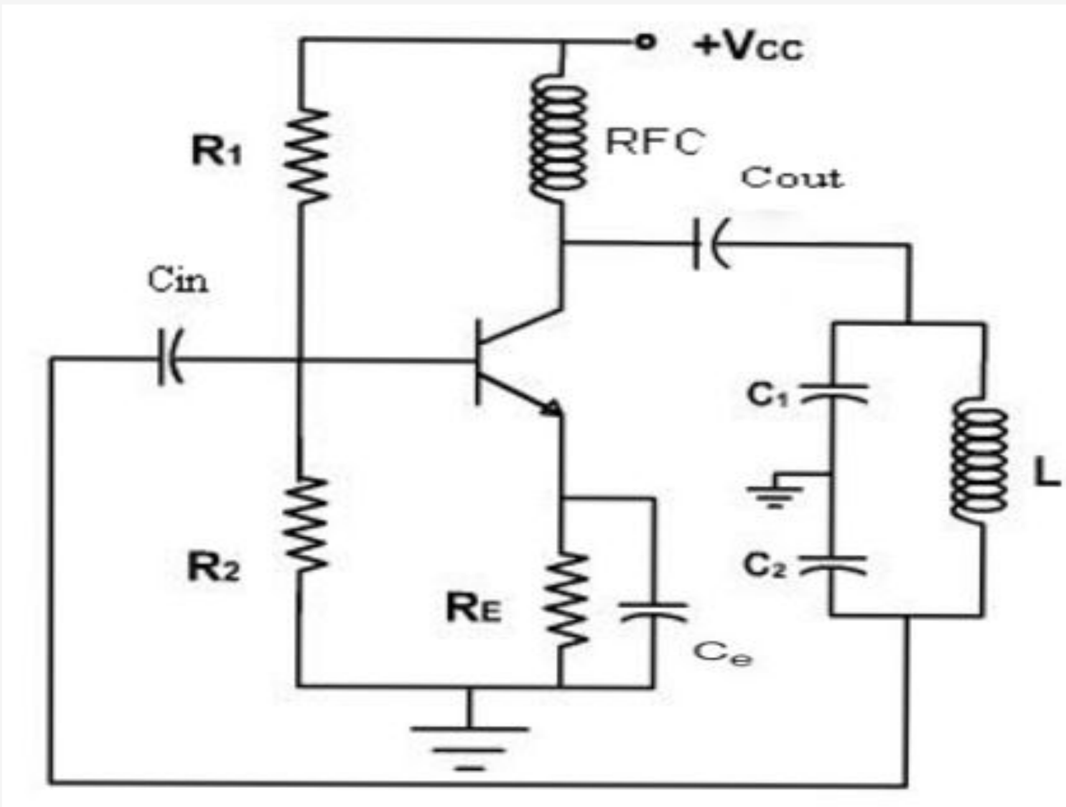
$$f_o = \frac{1}{2\pi(\sqrt{6})CR}$$

$$= \frac{1}{2\pi \times 2.449 \times 10\exp^{-9} \times 10\exp^{3}}$$

$$= 650\text{Hz}$$

LC oscillator

Colpitt oscillator



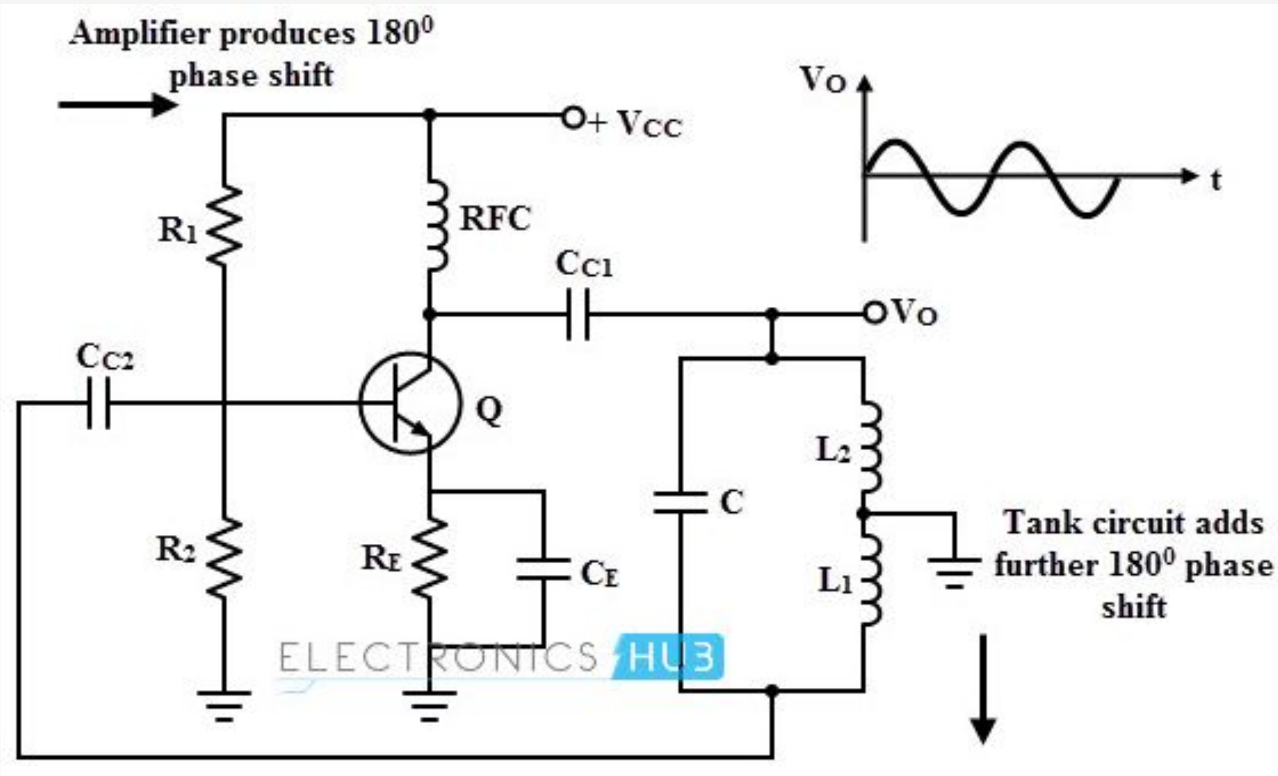
$$\text{Frequency} = \frac{1}{2\pi\sqrt{LC_T}}$$

where

$$C_T = \frac{(C_1)(C_2)}{C_1 + C_2}$$

LC Oscillator

Hartley Oscillator



$$\text{Frequency} = \frac{1}{2\pi\sqrt{L_T C}}$$

where $L_T = L_1 + L_2$

References

1. Boylestad and Nashelsky, “Electronic Devices and Circuits Theory,” 11th Edition, Pearson.

2. Millman and Halkias, “Electronic Devices and Circuits,” TMH. (For stability factor derivation and hybrid model numerical)

3. Thomas L. Floyd, “Electronic Devices – Conventional Current Version,” 9th Ed., Pearson Education.