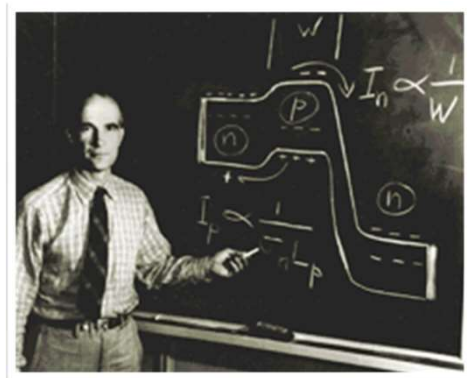# Bipolar Junction Transistor Amplifier

Kithsiri Samarasinghe

Senior Lecturer
Dept. of Electronic & Telecommunication Engineering
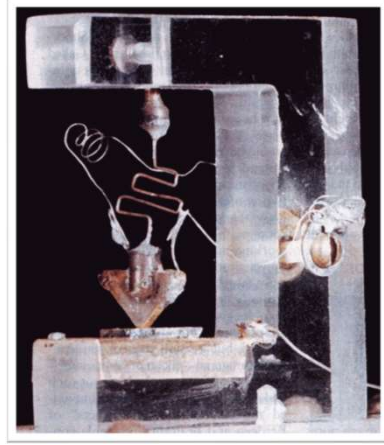

The Great Invention in 1948

William Shokley explaining their invention
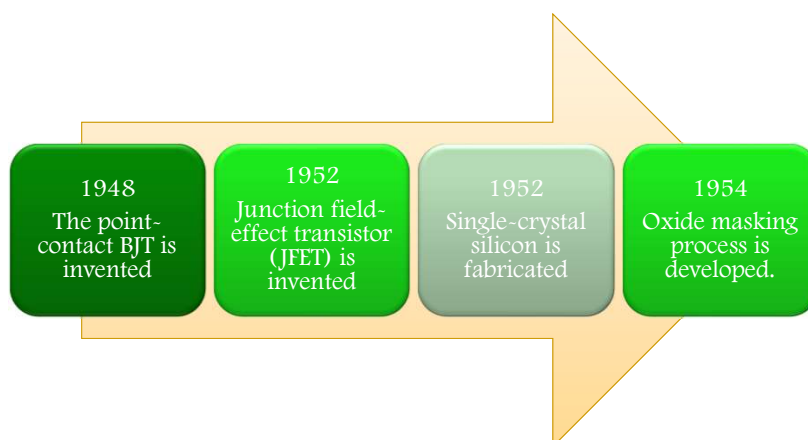
Team : William Shokley, John Bardeen, Walter Brattain
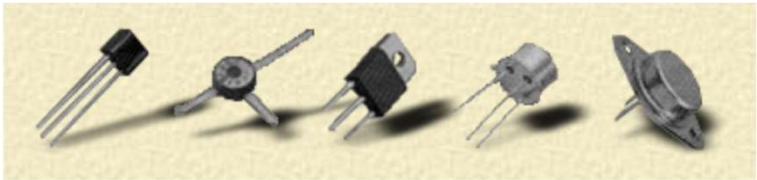
Bell Laboratories, USA

The First-ever Transistor

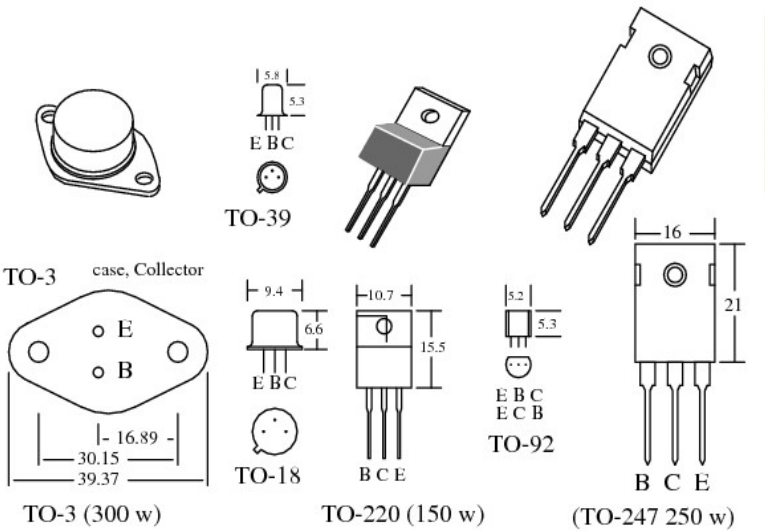World's First Transistor developed by Shokley, Bardeen and Brattain

Early Developments

| 1948 The point-contact BJT is invented | 1952 Junction field-effect transistor (JFET) is invented | 1952 Single-crystal silicon is fabricated | 1954 Oxide masking process is developed. |

Packages for BJT

| TO 18 , TO 39, TO 92, TO 99 |
| TO 5, TO247 |
| TO 3 |

Packaging BJTs for practical use

Miniaturising trend

A Paradigm Shift

TO~92

TO-92 Plastic Package

View from the side.
(Flat face towards you.)

5·2mm

Base

Collector

1·27mm

1·27mm

Emitter

View from below.
(Leads towards you.)

4·2mm

Base

5·2mm

Collector

Emitter

All dimensions apart from the lead spacing are approximate. Note that although defined in mm, all the dimensions are multiples of a 20th of an inch!
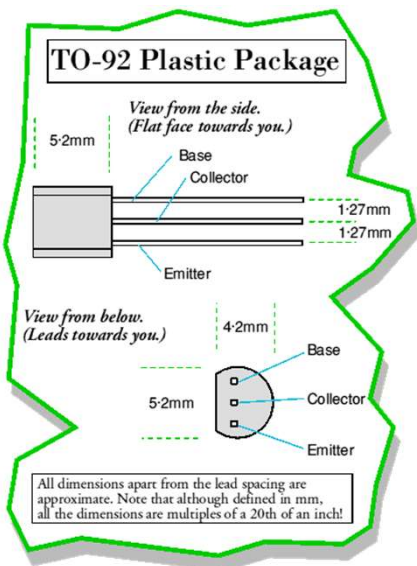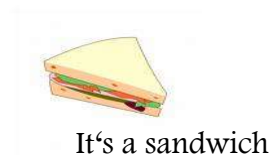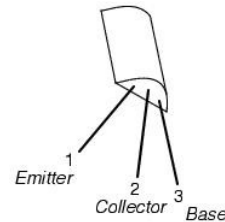
Three Terminals of a BJT

- **E** ~ Emitter

- **B** ~ Base

- **C** ~ Collector

Emitter
Collector
Base

It's a sandwich

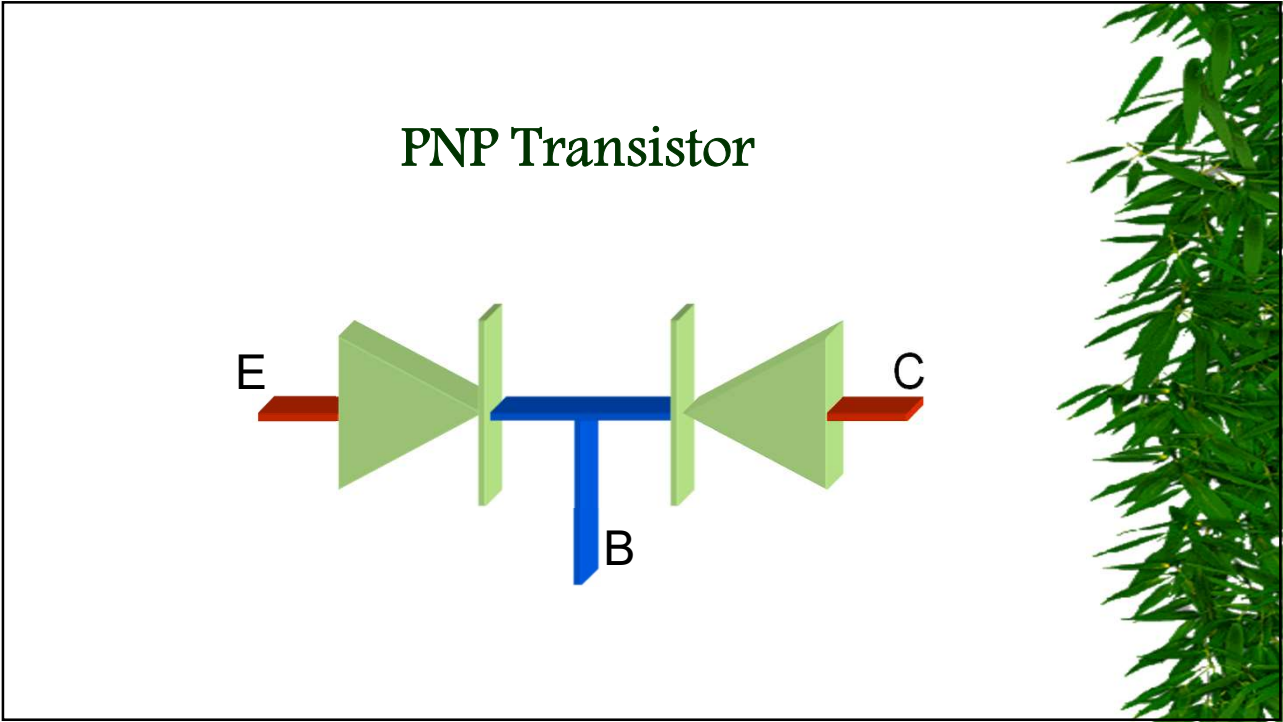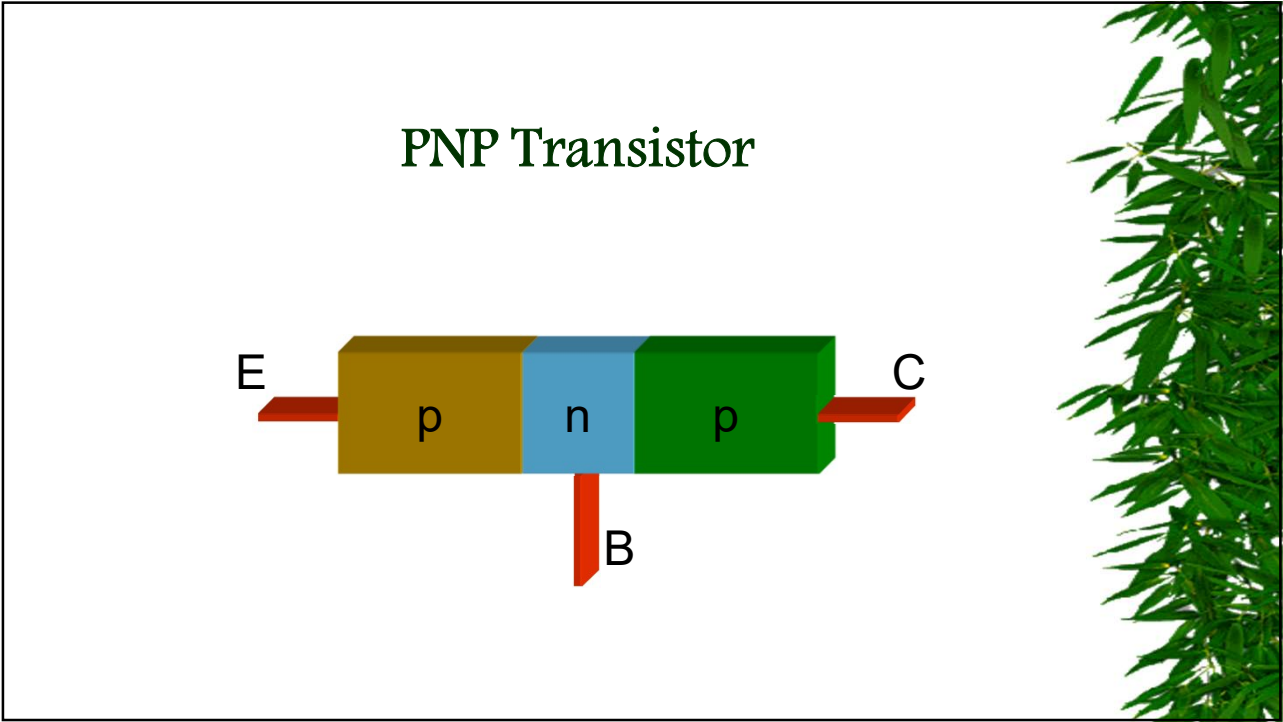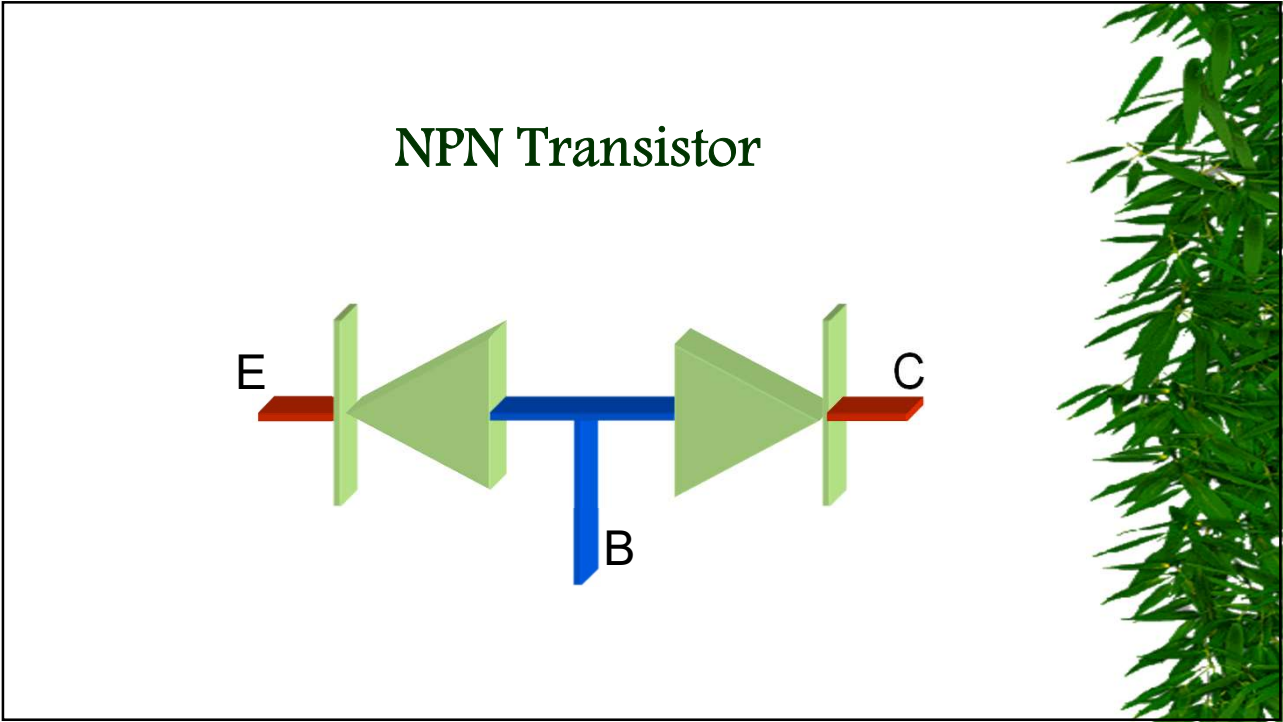# Internal Structure

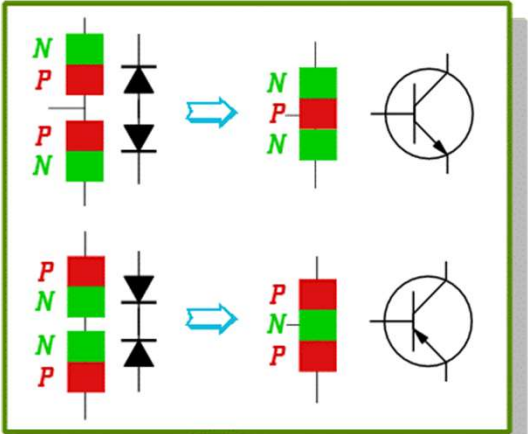Three Layers of Extrinsic Semiconductors

Middle Layer is the BASE

Base is thin

E

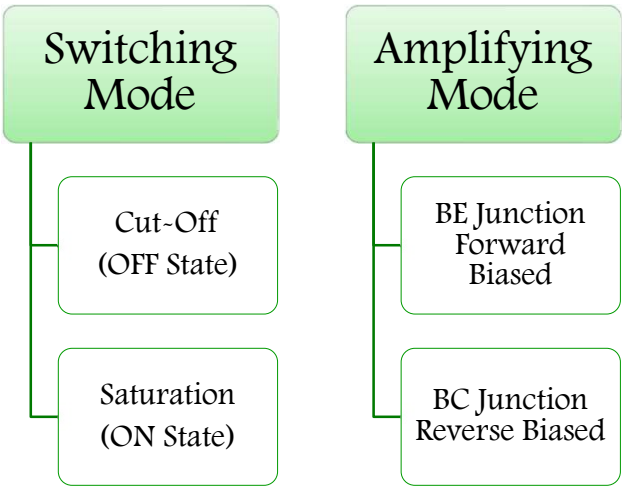Emitter | Base | Collector

C

B

PNP Transistor

E p n p C

B

PNP Transistor

E B C

NPN Transistor
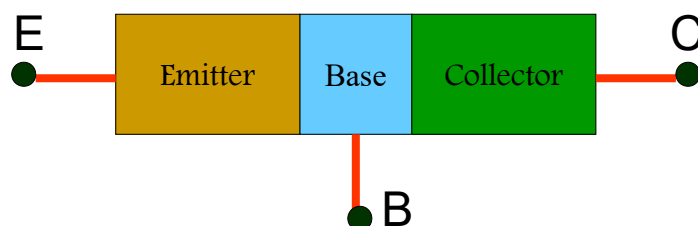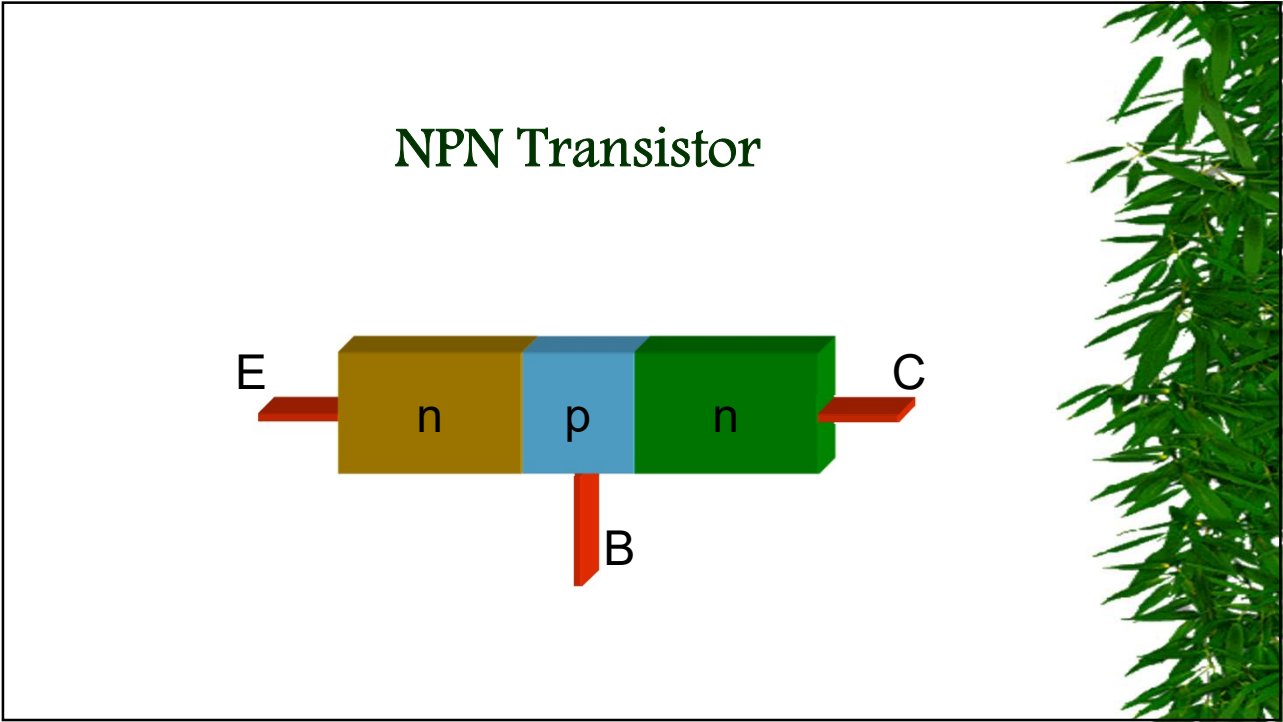
NPN Transistor

Summary

DC Bias & Operating Modes

Switching Mode	Amplifying Mode
Cut-Off (OFF State)	BE Junction Forward Biased
Saturation (ON State)	BC Junction Reverse Biased

Summary of Modes

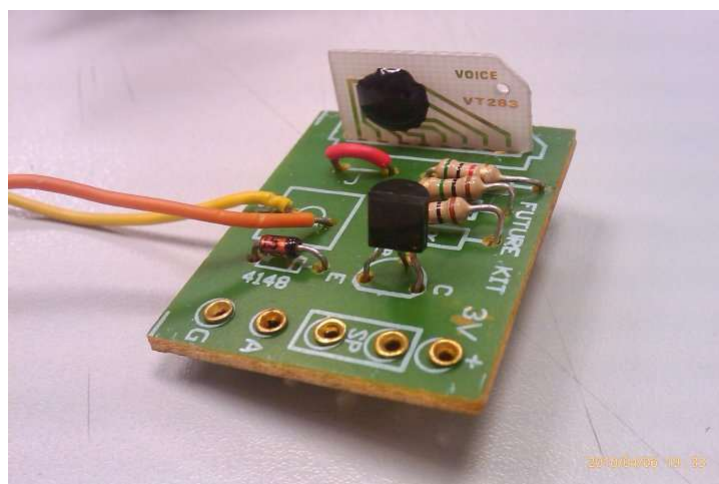| Mode & State		BIAS	
		BE	BC
Switching	Cut-Off	Rev	Rev
	Saturation	Fwd	Fwd
Amplifying	Active	Fwd	Rev

Analog & Digital

Analog Electronics

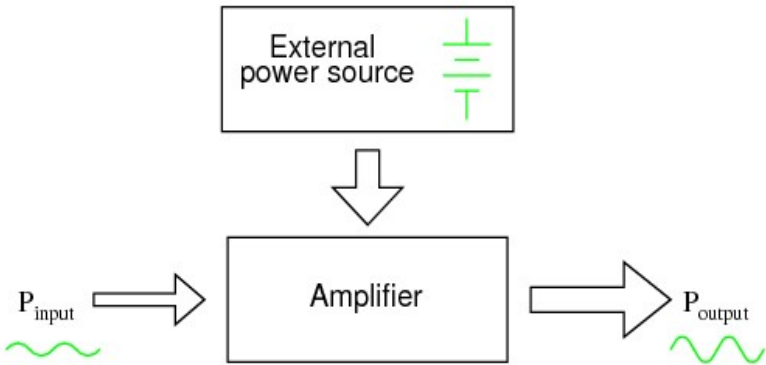we study how transistors are used as amplifiers

Digital Electronics

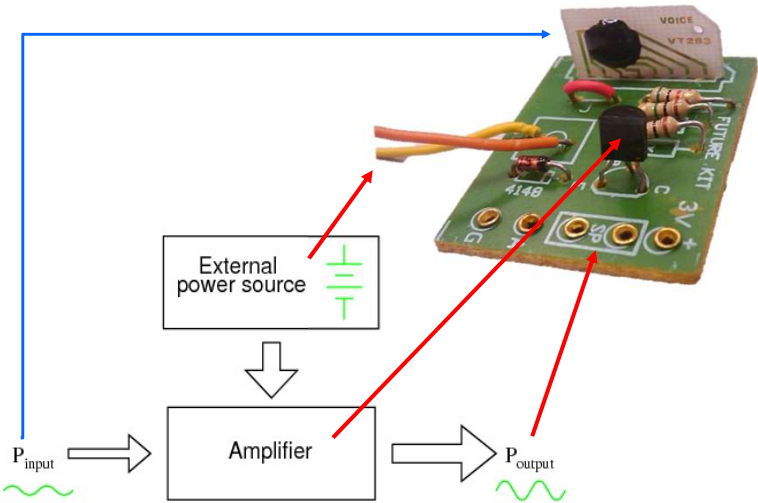we study how they are used as switching devices

BJT as an Amplifier
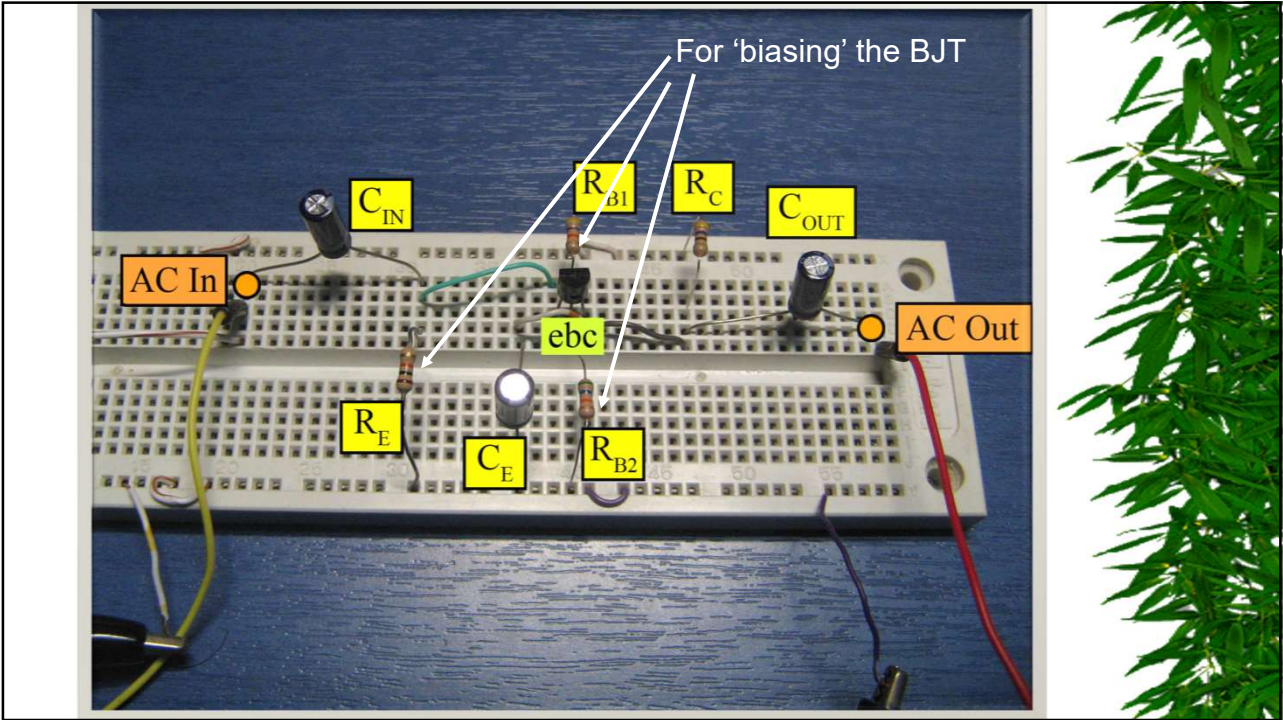
Amplification

Amplification

For 'biasing' the BJT

C_{IN} R_{B1} R_C C_{OUT}

AC In

ebc

AC Out

R_E C_E R_{B2}

Biasing an NPN BJT for Amplifying Mode

V_{CE}

Emitter
Base
Collector
V_{BE}
V_{CB}
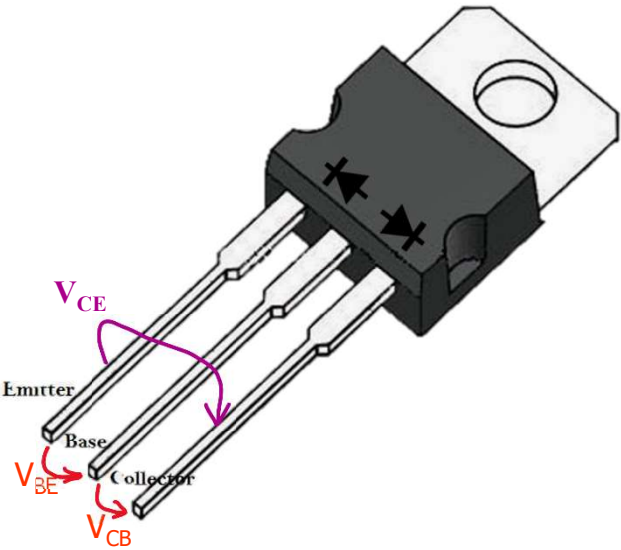
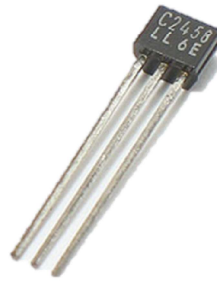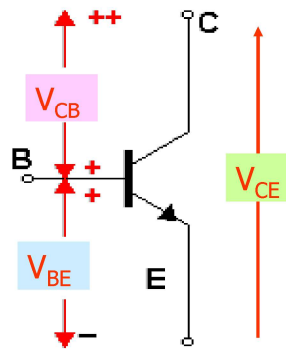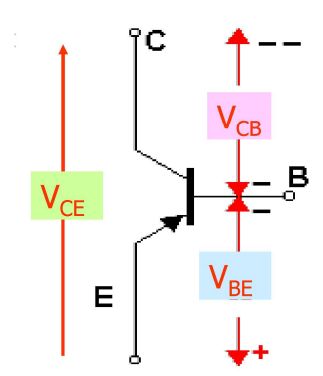# Biasing an NPN BJT for Amplifying Mode

NPN BJT Biasing

- The Base must be more positive than the Emitter

- The Collector must be even more positive than the Base

Biasing the PNP BJT

Activity

If a PNP transistor is selected, The base terminal must be more .... than the emitter terminal in order to forward bias the B-E junction.

The collector terminal must be even.........…..... than the base terminal in order to reverse bias the B-C junction.

Solution

If a PNP transistor is selected, The base terminal must be more <u>NEGATIVE</u> than the emitter terminal in order to forward bias the B-E junction.

The collector terminal must be even <u>MORE NEGATIVE</u> than the base terminal in order to reverse bias the B-C junction.
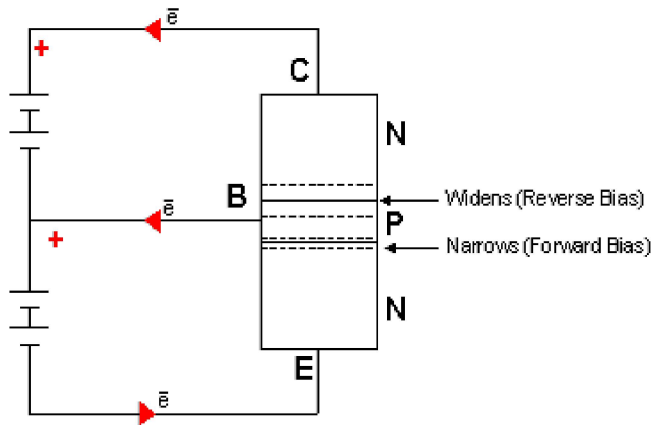
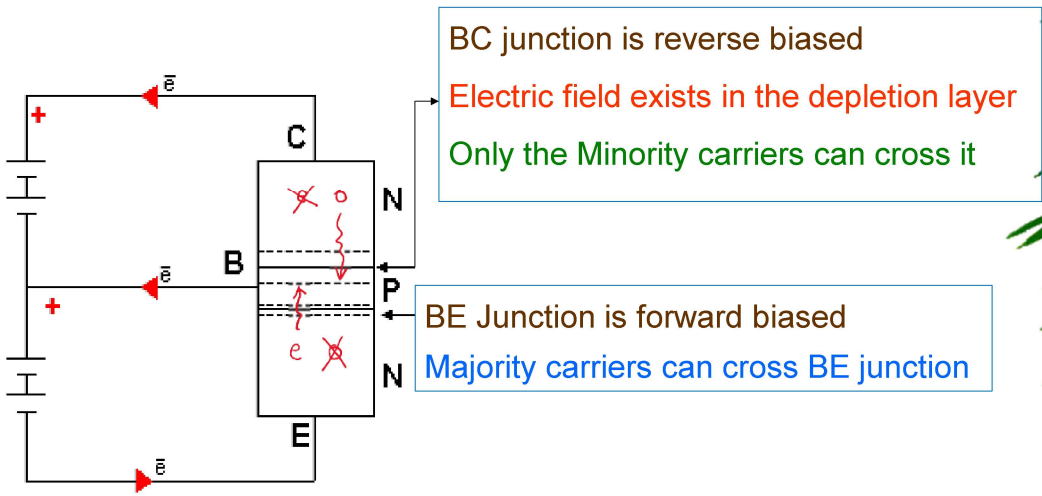# External Voltages and Currents
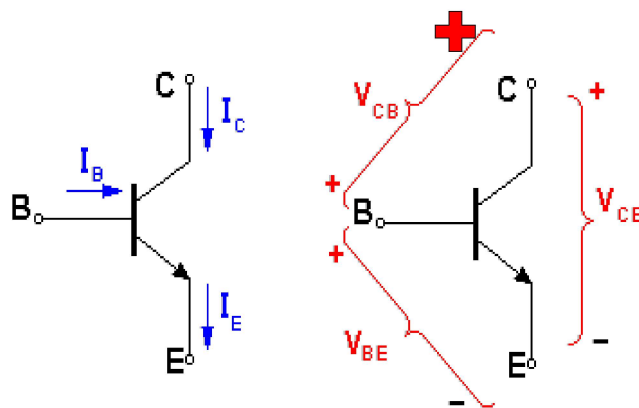
Kirchoff's Current Law

$$I_E = I_B + I_C$$

Internal Operation of BJT

Junctions Biased by External DC sources

	Widens (Reverse Bias)
	Narrows (Forward Bias)

Junctions Biased by External DC sources

BC junction is reverse biased

Electric field exists in the depletion layer

Only the Minority carriers can cross it

BE Junction is forward biased

Majority carriers can cross BE junction
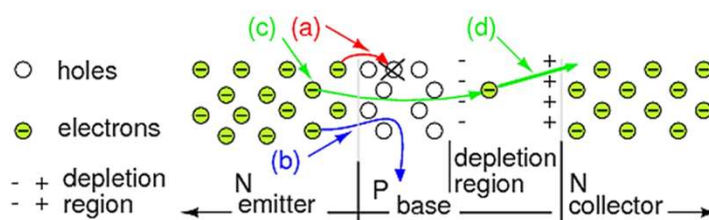
Behaviour of Current Carriers
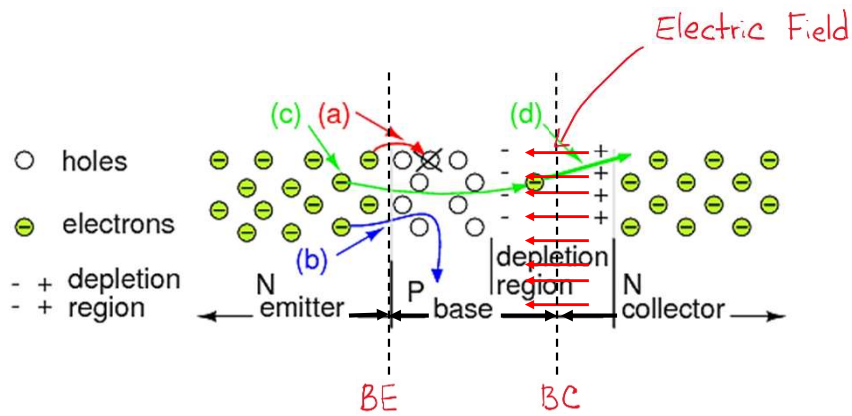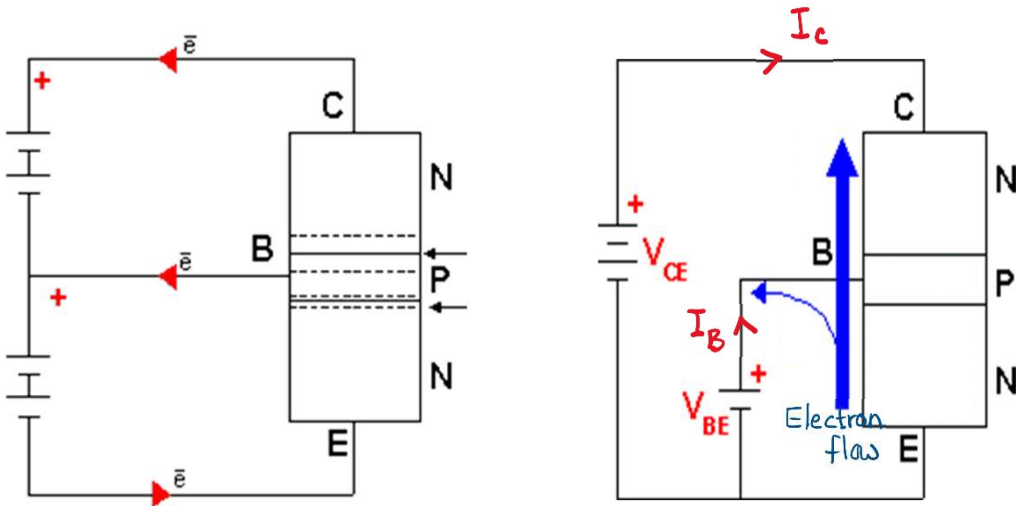

Transistor Action

Majority carriers from emitter gets injected to the base at high velocity
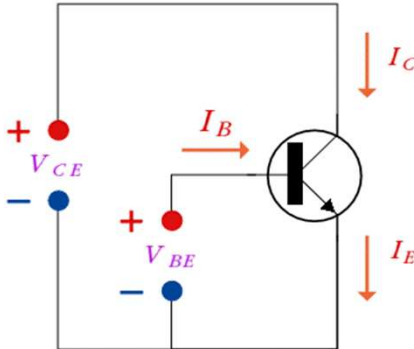
But the Base is thin

Therefore most of them get caught in the electric field of BC junction
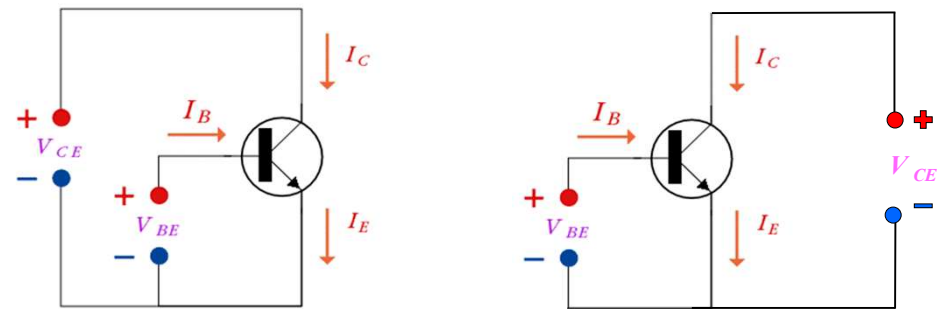
They are swept to the Collector
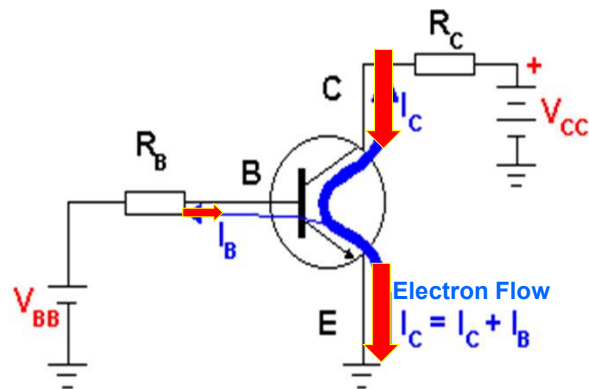
Rearranging the Bias Supplies

Replacing BJT with its Symbol…

Separating Input and Output Terminals…

Limiting Currents with External Resistors

BJT Current Relationships

Static Current Gain Concept

* Ratio between static output current and static input current.

* Also given as h_{FE}

$$\beta \;=\; h_{FE} \;=\; \frac{I_C}{I_B}$$

$$\alpha = h_{FB} = \frac{I_C}{I_E}$$

$$I_E = I_C + I_C$$

$$\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C}$$

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

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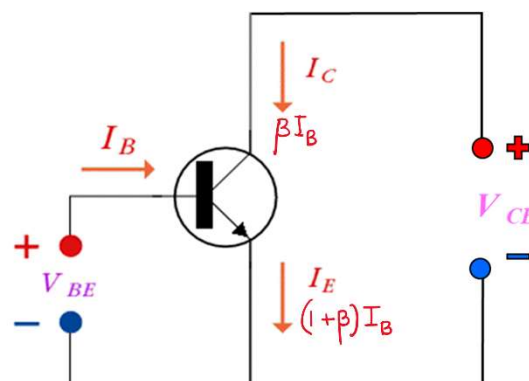
$$\beta = \frac{\alpha}{1 - \alpha}$$

Current Relations

$I_C = \beta I_B$

$I_E = I_B + I_C$
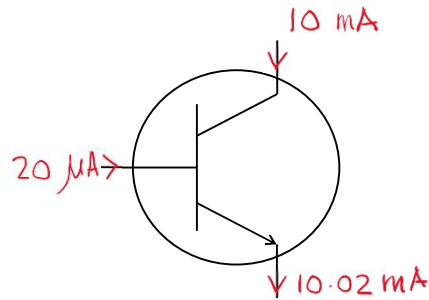
$I_E = I_B + \beta I_B$

$I_E = (1 + \beta) I_B$

Example

* BC 109C BJT

* β = 500 (Typ.)

* Find currents in the three terminals when the Base current is 20 μA ?

10 mA

20 μA →

↓ 10.02 mA

Generating a Higher Force…

Current Control Concept

* Using a small current to control a larger current

* Collector current is determined by the base current.

* BJT is a current-controlled device.

* Controlling + Controlled =Emitter current

* Current means; electron and hole movement

BJT Amplifier Configurations

An Amplifier

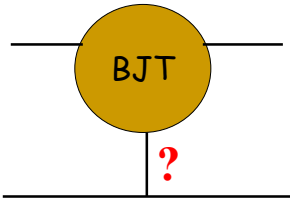* An amplifier should have an input port and an output port (Four wires).

Input port   **Amplifier**   Output port

Two Ports from Three Terminals ?

Input port   **Amplifier**   Output port

* BJT is a three terminal device !
* Solution : Take one of it's terminals as a common terminal for both ports.
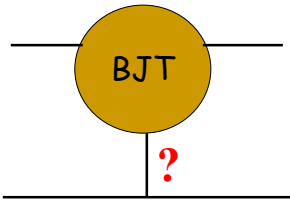
Three Amplifier Configurations

BJT

?

| Common Base Configuration (CB) | Common Emitter Configuration (CE) | Common Collector Configuration (CC) |

Three Amplifier Configurations

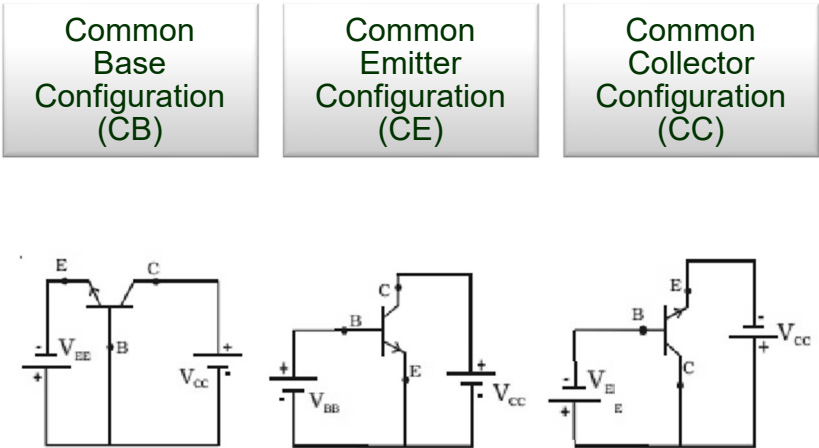| Common Base Configuration (CB) | Common Emitter Configuration (CE) | Common Collector Configuration (CC) |

Configuration	CE	CC	CB
Voltage Gain	High	<1	HIgh
Current Gain	High	High	<1
Power Gain	High	Moderate	Moderate
Phase Inversion	Yes	No	No
Input Impedance	Moderate ($\approx$1K)	High ($\approx$300K)	Low ($\approx$50 Ohm)
Output Impedance	Moderate ($\approx$50K)	Low ($\approx$300 Ohm)	High ($\approx$1M)