كلية مدينة العلم الجامعة
قسم هندسة الحاسوب

محاضرات المرحلة الاولى لمادة الهندسة الالكترونية

اعداد

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The Transistor

المحاضرة الاولى

References

Text Books :

1-ELECTRONIC DEVICES AND CIRCUIT THEORY

Eleventh Edition By

Robert L. Boylestad and Louis Nashelsky

2-ELECTRONIC DEVICES

Ninth Edition By

Thomas L. Floyd

Transistor

A ***transistor*** *consists of two pn junctions formed by *sandwiching either p-type or n-type semiconductor between a pair of opposite types.* Accordingly ; there are two types of transistors, namely;

(*i*) *n-p-n* transistor

(*ii*) *p-n-p* transistor

An *npn* transistor is composed of two *n*-type semiconductors separated by a thin section of *p*-type where, a *pnp* transistor is formed by two *p*-sections separated by a thin section of *n*-type

Naming the Transistor Terminals

A transistor (*pnp* or *npn*) has three sections of doped semiconductors. The section on one side is the ***emitter*** and the section on the opposite side is the ***collector***. The middle section is called the ***base*** and forms two junctions between the emitter and collector.

(***i***) **Emitter.** The section on one side that supplies charge carriers (electrons or holes) is called the ***emitter. The emitter is always forward biased w.r.t. base*** so that it can supply a large number of *majority carriers. the emitter (*p*-type) of *pnp* transistor is forward biased and supplies hole charges to its junction with the base. Similarly, the emitter (*n*-type) of *npn* transistor has a forward bias and supplies free electrons to its junction with the base.

- (***ii***) **Collector.** The section on the other side that collects the charges is called the ***collector***. ***The collector is always reverse biased***. Its function is to remove charges from its junction with the base.
- (***iii***) **Base.** The middle section which forms two *pn*-junctions between the emitter and collector is called the ***base***. ***The base-emitter junction is forward biased***, allowing low resistance for the emitter circuit. ***The base-collector junction is reversing biased*** and provides high resistance in the collector circuit.
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Transistor Symbols

The symbols used for *npn* is shown in Fig.

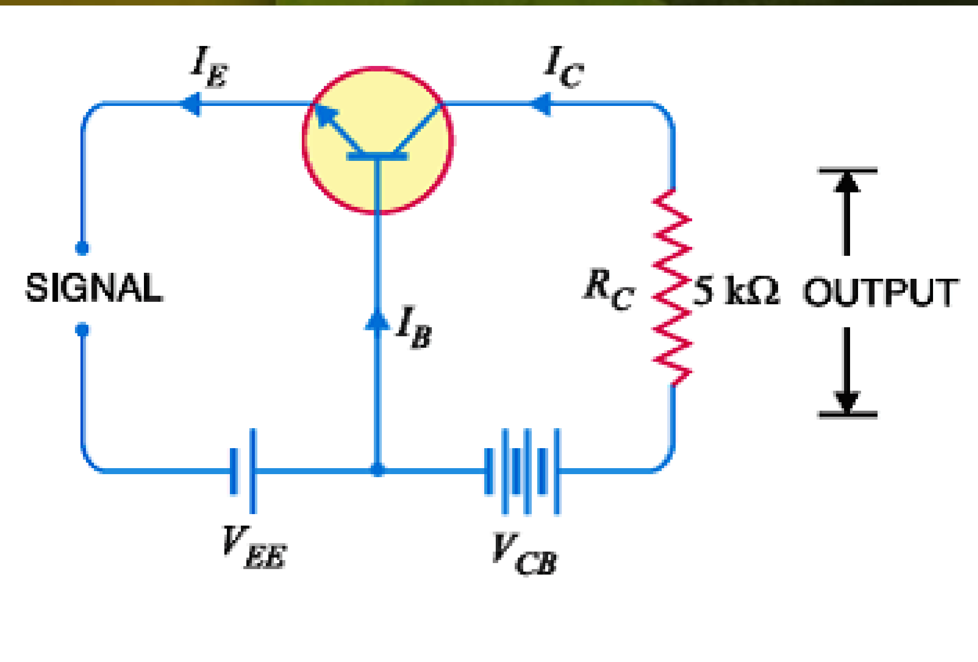
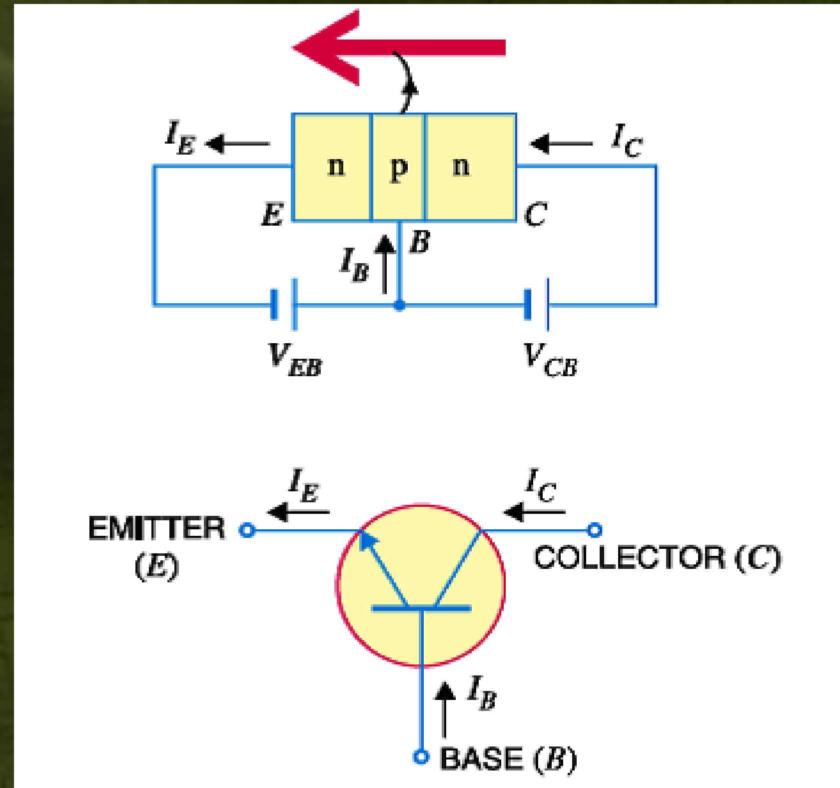


Fig. 8.7



the input circuit should always remain forward biased. To do so, a d.c. voltage V_{EE} is applied in the input circuit in addition to the signal as shown. This d.c. voltage is known as <u>bias voltage</u> and its magnitude is such that it always keeps the input circuit forward biased regardless of the polarity of the signal.

Transistor Connections

There are three leads in a transistor *viz.*, emitter, base and collector terminals. However, when a transistor is to be connected in a circuit, we require four terminals; two for the input and two for the output. This difficulty is overcome by making one terminal of the transistor common to both input and output terminals. The input is fed between this common terminal and one of the other two terminals. The output is obtained between the common terminal and the remaining terminal. Accordingly; a transistor can be connected in a circuit in the following three ways:

- ***common base connection***
- ***common emitter connection***
- ***(iii) common collector connection***

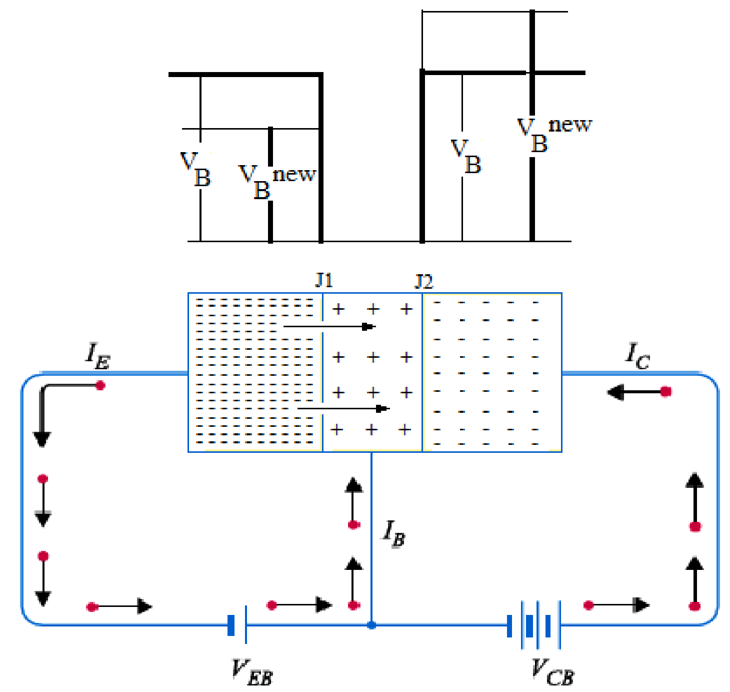
Transistor Circuit

As the input circuit has low resistance, therefore, a small change in signal voltage causes an appreciable change in emitter current. This causes almost the same change in collector current due to transistor action. The collector current flowing through a high load resistance R_C produces a large voltage across it. Thus, a weak signal applied in the input circuit appears in the amplified form in the collector circuit. It is in this way that a transistor acts as an amplifier.

Transistor Action

Working of npn transistor.

The *npn* transistor with forward bias to emitter base junction and reverse bias to collector-base junction. The forward bias causes the electrons in the *n*-type emitter to flow towards the base. This constitutes the emitter current I_E. As these electrons flow through the *p*-type base, they tend to combine with holes. As the base is lightly doped and very thin.



Basic connection of *npn* transistor

$I_E = I_B + I_C$
$I_C = \alpha\ I_E$
$\alpha = I_C / I_E$

Transistor Action

- Suppose that number N of electrons in the emitter terminal and αN are pass the base region (more than 95%) cross over into the collector region to constitute collector current I_C only a few$(1-\alpha)$N electrons (less than 5%) combine with holes to constitute base current I_B. It is clear that emitter current is the sum of collector and base currents *i.e.*

	(N)	no.of electron exist in emitter region	N	
and	(αN)	no.of electron pass to collector region	(αN)	$= I_C$
	$(1-\alpha)$N	no.of electron are recombine in base region	$(1-\alpha)$N	$= I_B$

Or

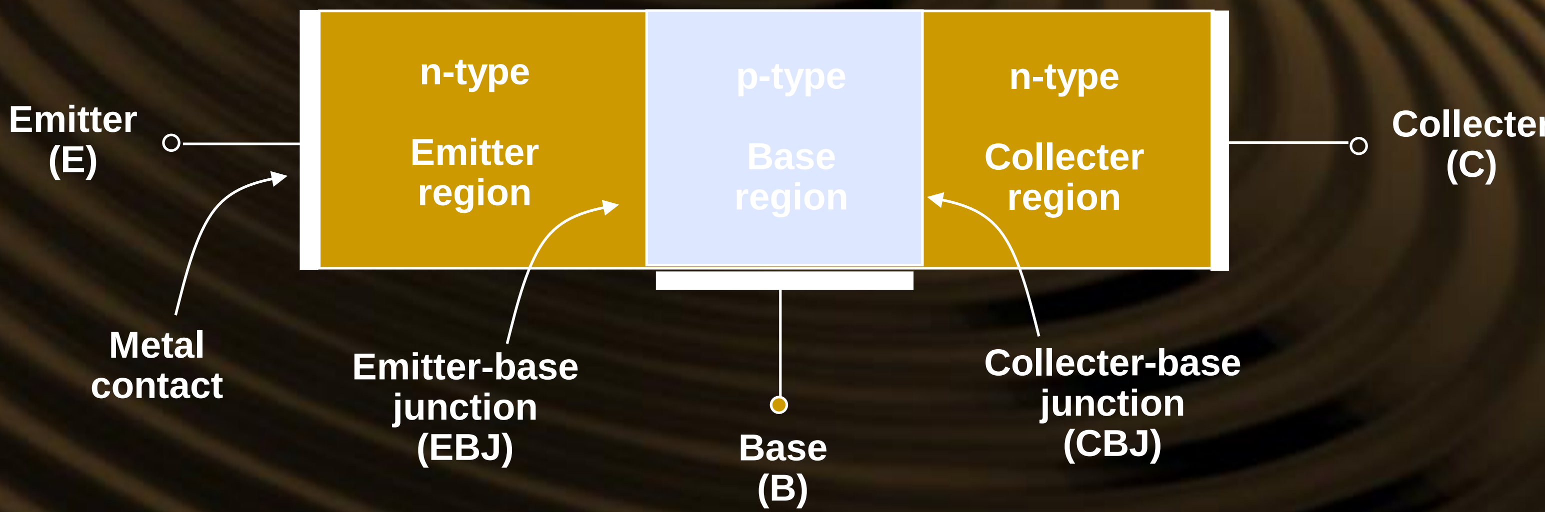
$$N = (1-\alpha)N + \alpha N$$

$$I_E = I_B + I_C$$

$$I_C = \alpha\ I_E$$

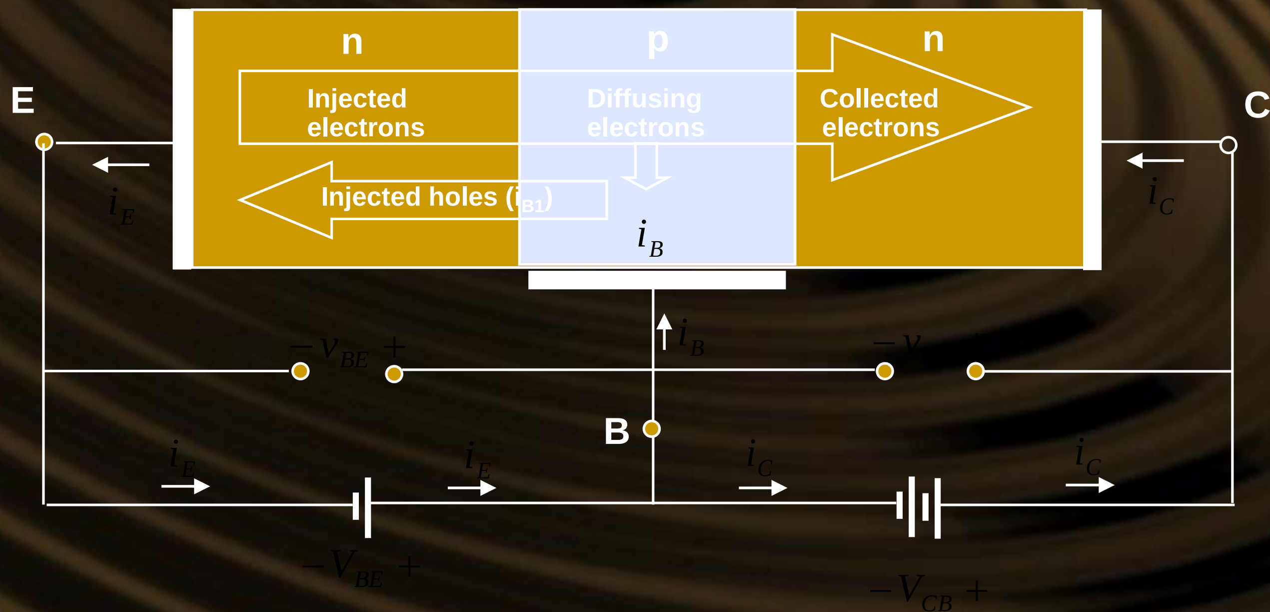
$$\alpha = I_C / I_E$$

Physical Structure and Modes of Operation



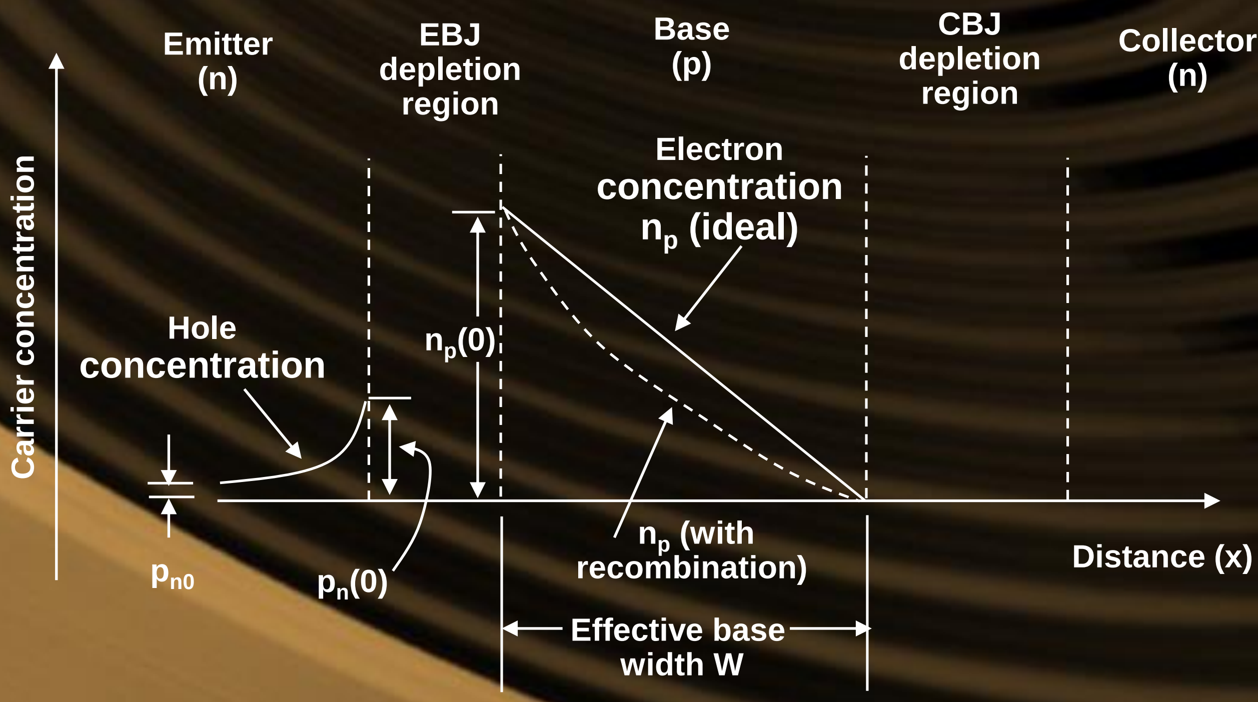
Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

Operation of the npn Transistor in the Active Mode



Current Flow

- Only diffusion-current components are considered
- Profiles of minority-carrier concentrations in the base and in the emitter of an npn transistor operating in the active mode; $v_{BE} > 0$ and $v_{CB} \geq 0$.



$$n_p(0) = n_{p0} e^{v_{BE}/V_T}$$

$$I_n = A_E q D_n \frac{dn_p(x)}{dx} = A_E q D_n \left(-\frac{n_p(0)}{W}\right)$$

The Collector Current

- Most of the diffusing electrons will reach the boundary of the collector-base depletion region
- These successful electrons will be swept across the CBJ depletion region into the collector
- By convention, the direction of i_C is opposite to that of electron flow

$$i_C = I_n \quad \text{and } n_p(0) = n_{p0} e^{v_{BE}/V_T}$$

$$i_C = I_S e^{v_{BE}/V_T}$$

saturation current $$I_S = \frac{A_E q D_n n_i^2}{N_A W}$$

$$n_{p0} = n_i^2 / N_A$$

$$I_S = A_E q D_n n_{p0} / W$$

The Base Current

Two components of base current, i_{B1} and i_{B2}.

$$i_{B1} = \frac{A_E q D_p n_i^2}{N_D L_p} e^{v_{BE}/V_T}$$

D_p: **Hole diffusivity in the emitter**

L_p: **Hole diffusion length in the emitter**

N_D: **Doping concentration of the emitter**

$$i_{B2} = \frac{Q_n}{\tau_b}$$

τ_b: **minority-carrier lifetime**

$$Q_n = A_E q \times \frac{1}{2} n_p(0) W$$

$$Q_n = \frac{A_E q W n_i^2}{2 N_A} e^{v_{BE}/V_T}$$

$$i_{B2} = \frac{1}{2} \frac{A_E q W n_i^2}{\tau_b N_A} e^{v_{BE}/V_T}$$

$$i_B = I_S \left(\frac{D_p}{D_n} \frac{N_A}{N_D} \frac{W}{L_p} + \frac{1}{2} \frac{W^2}{D_n \tau_b} \right) e^{v_{BE}/V_T}$$

$$i_B = \frac{i_C}{\beta}$$

$$i_B = \left(\frac{I_S}{\beta} \right) e^{v_{BE}/V_T}$$

$$\beta = 1 \Big/ \left(\frac{D_p}{D_n} \frac{N_A}{N_D} \frac{W}{L_p} + \frac{1}{2} \frac{W^2}{D_n \tau_b} \right)$$

common-emitter current gain

The Emitter Current

$$i_E = i_C + i_B$$

$$i_E = \frac{\beta + 1}{\beta} i_C$$

$$i_E = \frac{\beta + 1}{\beta} I_S{}^{v_{BE}/V_T}$$

$$i_C = \alpha i_E$$

common-base current gain

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

$$i_E = \left(I_S / \alpha\right) e^{v_{BE}/V_T}$$

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