UNIT I
SEMICONDUCTOR DEVICES

Introduction - Evolution of electronics – Vacuum tubes to nano electronics - Characteristics of PN Junction Diode — Zener Effect — Zener Diode and its Characteristics. Bipolar Junction Transistor — CB, CE, CC Configurations and Characteristics — Elementary Treatment of Small Signal CE Amplifier.

INTRODUCTION:

Electronics engineering, or electronic engineering, is an engineering discipline which utilizes non-linear and active electrical components (such as semiconductor devices, especially transistors, diodes and integrated circuits) to design electronic circuits, devices, Microprocessors /Microcontrollers and systems including VHDL (VHSIC Hardware Description Language) Modelling for Programmable logic devices and FPGAs (Field Programmable Gate Array). The discipline typically also designs passive electrical components, usually based on printed circuit boards.

Electronics Engineering is one of the largest and fastest growing fields of engineering. It covers a wide range of applications which make our life easier and enjoyable such as Television, Radio, computers, telecommunication etc. They help us to see, hear and communicate over vast distances and do things faster.

EVOLUTION OF ELECTRONICS

The history of Electronic Engineering is a long one. Chambers Twentieth Century Dictionary (1972) defines electronics as "The science and technology of the conduction of electricity in a vacuum, a gas, or a semiconductor, and devices based thereon".

Electronic engineering as a profession sprang from technological improvements in the telegraph industry during the late 19th century and in the radio and telephone industries during the early 20th century. People gravitated to radio, attracted by the technical fascination it inspired, first in receiving and then in transmitting. Many who went into broadcasting in the 1920s had become "amateurs" in the period before World War I.

The modern discipline of electronic engineering was to a large extent born out of telephone, radio, and television equipment development and the large amount of electronic-systems development during World War II of radar, sonar, communication systems, and advanced munitions and weapon systems. In the interwar years, the subject was known as radio engineering, The word `electronics' began to be used in the 1940s. In the late 1950s the term 'electronic engineering' started to emerge.

The electronic laboratories (e.g., Bell Labs in the United States) created and subsidized by large corporations in the industries of radio, television, and telephone equipment. began churning out a series of electronic advances. In 1948 came the transistor and in 1960 the integrated circuit. which would revolutionize the electronic industry.

In the U.K., the subject of electronic engineering became distinct from electrical engineering as a university-degree subject around 1960. (Before this time, students of electronics and related subjects like radio and telecommunications had to enroll in the electrical engineering department of the university as no university had departments of electronics. Electrical engineering was the nearest subject with which electronic engineering could be aligned, although the similarities in subjects covered (except mathematics and electromagnetism) lasted only for the first year of three-year courses.)

Electronic engineering (even before it acquired the name) facilitated the development of many technologies including wireless telegraphy, radio, television, radar, computers and microprocessors.

VACUUM TUBES TO NANO ELECTRONICS

Vacuum tubes coexisted with their progeny, the transistor, and even with ICs for a short while. Although solid-state technology overwhelmingly dominates today's world of electronic, vacuum tubes are still holding out in stunt- areas. You might, for example, still have a CRT (cathode ray tube) as your television or computer screen. Tubes also remain in two small but vibrant areas for entirely different reasons. The first involves microwave technology, which still relies on vacuum tubes for their power-hand ling capability at high frequencies. The other-the creation and reproduction of music-is a more complicated story. Tubes distort signals differently than transistors when overdriven, and this distortion is regarded as being more "pleasant" by much of the music community.

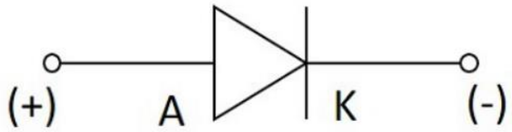
Vacuum Tubes are used in computing, switching, amplification and rectification right up to 60s. Then it died a quick death since most applications solid state device such as semiconductor devices have replaced them. We all know that Semiconductor devices are small in size and cheaper than vacuum tube devices. Silicon transistors are cheaper but they are slower and susceptible to radiation. The performance of Silicon Transistors, far away from Vacuum Tube devices due to their compact size, no heating time, reduced time for electrons to travel. But actually electrons are about 10 times slower in solid material as than in vacuum.

Now NASA combined the advantages of Silicon Transistors and Vacuum Tubes, to form 'Nano Vacuum Tubes'. They have created it by etching tiny cavities in phosphorus doped silicon NASA combined the advantages of Silicon Transistors and Vacuum Tubes, to form 'Nano Vacuum Tubes'. and Source, Drain and Gate are placed around this cavity.

The size of the cavity is very small about 150nm, so there is minimum interaction with electrons and air, avoiding the need for true vacuum thereby reducing the manufacturing difficulties and cost. The term 'Vacuum Tube' is slightly misleading as true Vacuum is not created in these devices.

PN JUNCTION DIODE

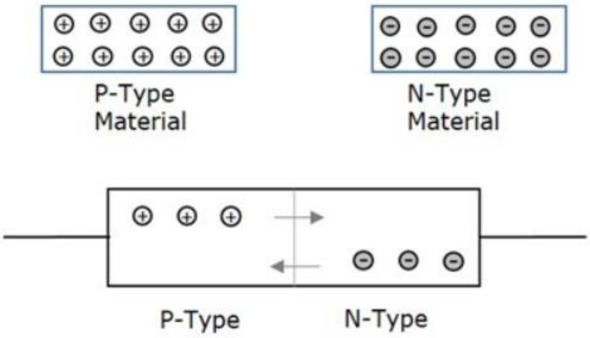
A semiconductor diode is a two terminal electronic component with a PN junction. This is also called as a Rectifier. The symbol of a diode is shown in the fig.



The anode which is the positive terminal of a diode is represented with A and the cathode, which is the negative terminal is represented with K. To know the anode and cathode of a practical diode, a fine line is drawn on the diode which means cathode, while the other end represents anode.

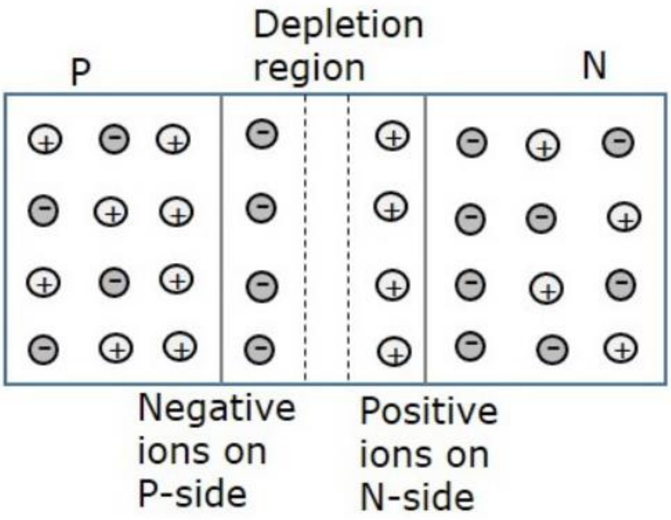
Formation of a Diode:

If a P-type and an N-type material are brought close to each other, both of them join to form a junction, as shown in the figure below.



A P-type material has holes as the majority carriers and an N-type material has electrons as the majority carriers. As opposite charges attract, few holes in P-type tend to go to n-side, whereas few electrons in N-type tend to go to P-side.

As both of them travel towards the junction, holes and electrons recombine with each other to neutralize and forms ions. Now, in this junction, there exists a region where the positive and negative ions are formed, called as PN junction or junction barrier as shown in the figure.



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The formation of negative ions on P-side and positive ions on N-side results in the formation of a narrow-charged region on either side of the PN junction. This region is now free from movable charge carriers. The ions present here have been stationary and maintain a region of space between them without any charge carriers.

As this region acts as a barrier between P and N type materials, this is also called as Barrier junction. This has another name called as Depletion region meaning it depletes both the regions. There occurs a potential difference VD due to the formation of ions, across the junction called as Potential Barrier as it prevents further movement of holes and electrons through the junction.

OPERATION OF P-N JUNCTION DIODE

When a diode or any two-terminal component is connected in a circuit, it has two biased conditions with the given supply. They are Forward biased condition and Reverse biased condition.

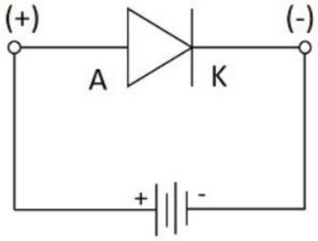
(i)Forward Biased Condition:

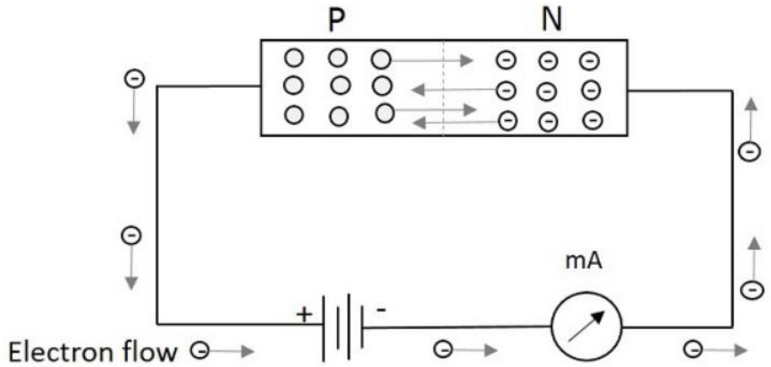
When a diode is connected in a circuit, with its anode to the positive terminal and cathode to the negative terminal of the supply, then such a connection is said to be forward biased condition. This kind of connection makes the circuit more and more forward biased and helps in more conduction. A diode conducts well in forward biased condition.

When an external voltage is applied to a diode such that it cancels the potential barrier and permits the flow of current is called as forward bias. When anode and cathode are connected to positive and negative terminals respectively, the holes in P-type and electrons in N-type tend to move across the junction, breaking the barrier. There exists a free flow of current with this, almost eliminating the barrier.

With the repulsive force provided by positive terminal to holes and by negative terminal to electrons, the recombination takes place in the junction. The supply voltage should be such high that it forces the movement of electrons and holes through the barrier and to cross it to provide forward current.

Forward Current is the current produced by the diode when operating in forward biased condition and it is indicated by I_f.





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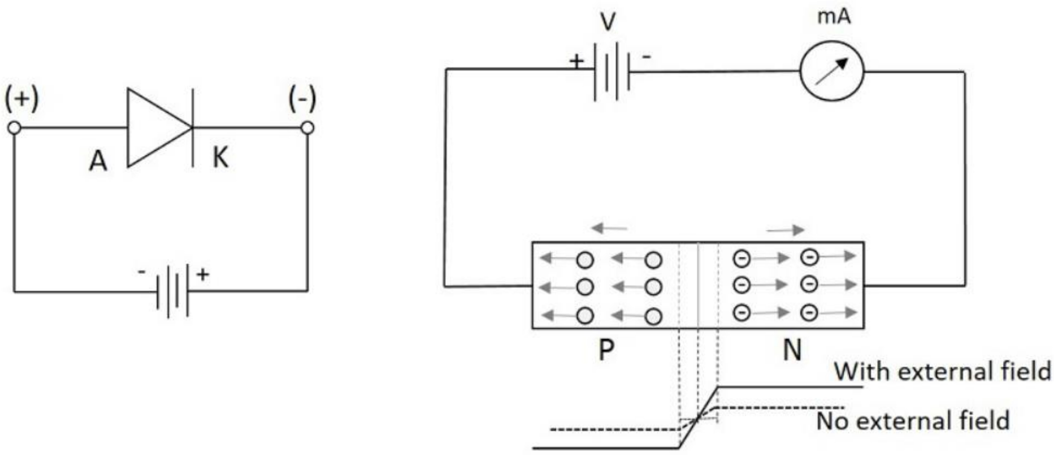
(ii) Reverse Biased Condition:

When a diode is connected in a circuit, with its anode to the negative terminal and cathode to the positive terminal of the supply, then such a connection is said to be Reverse biased condition. This kind of connection makes the circuit more and more reverse biased and helps in minimizing and preventing the conduction. A diode cannot conduct in reverse biased condition.

When an external voltage is applied to a diode such that it increases the potential barrier and restricts the flow of current is called as Reverse bias. When anode and cathode are connected to negative and positive terminals respectively, the electrons are attracted towards the positive terminal and holes are attracted towards the negative terminal. Hence both will be away from the potential barrier increasing the junction resistance and preventing any electron to cross the junction.

The following figure explains this. The graph of conduction when no field is applied and when some external field is applied are also drawn.



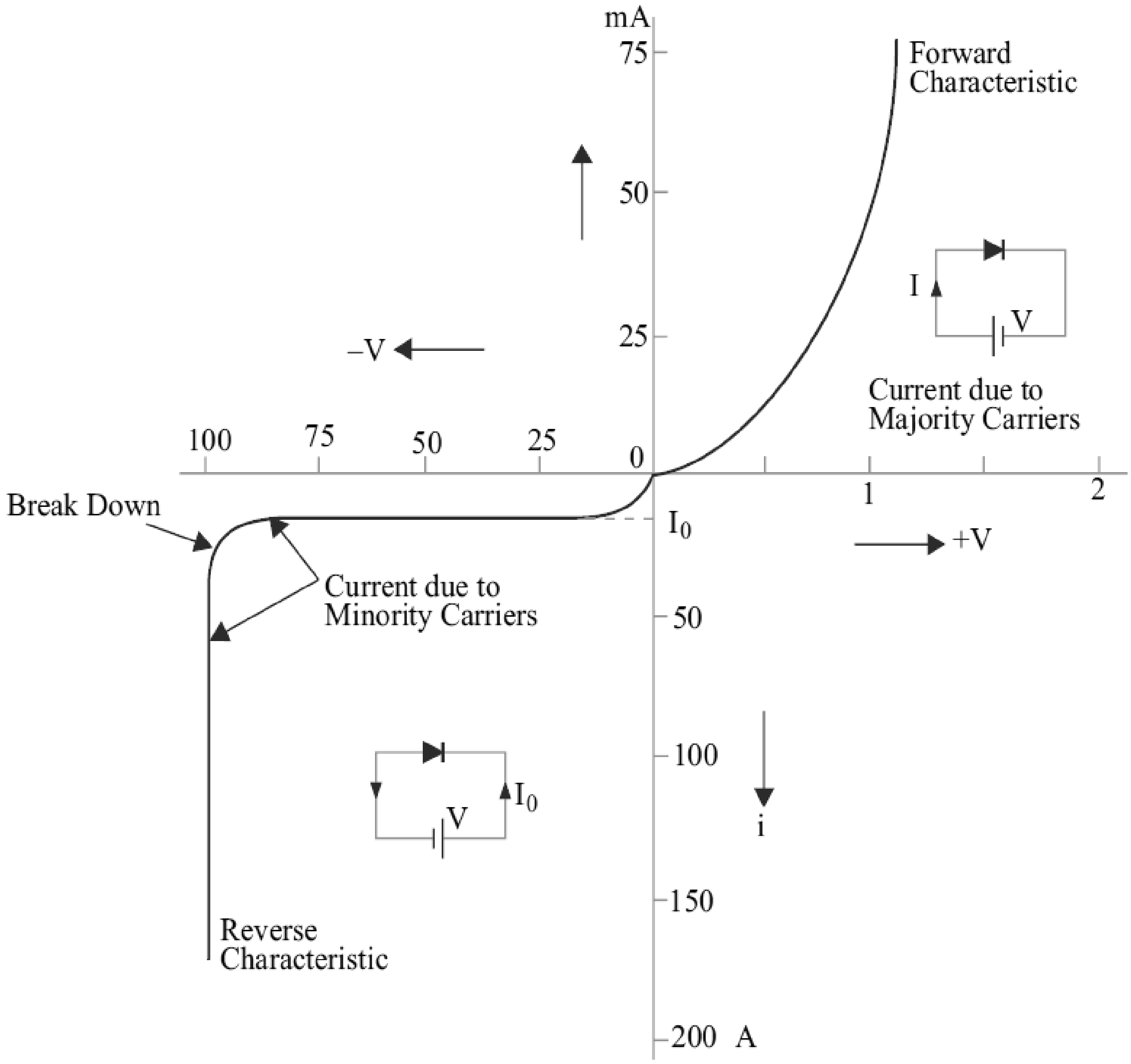
With the increasing reverse bias, the junction has few minority carriers to cross the junction. This current is normally negligible. This reverse current is almost constant when the temperature is constant. But when this reverse voltage increases further, then a point called reverse breakdown occurs, where an avalanche of current flows through the junction. This high reverse current damages the device.

Reverse current is the current produced by the diode when operating in reverse biased condition and it is indicated by Ir. Hence a diode provides high resistance path in reverse biased condition and doesn't conduct, where it provides a low resistance path in forward biased condition and conducts. Thus, we can conclude that a diode is a one-way device which conducts in forward bias and acts as an insulator in reverse bias. This behaviour makes it work as a rectifier, which converts AC to DC.

A diode is also used as a **Switch**. It helps a faster ON and OFF for the output that should occur in a quick rate.

V-I CHARACTERISTICS OF P-N JUNCTION DIODE

The following Fig. shows the static voltage-current characteristics for a low-power P-N junction diode.



Forward Characteristics:

When the diode is forward-biased and the applied voltage is increased from zero, hardly any current flows through the device in the beginning. It is so because the external voltage is being opposed by the internal barrier voltage V_B whose value is 0.7 V for Si and 0.3 V for Ge. As soon as V_B is neutralized, current through the diode increases rapidly with increasing applied battery voltage. It is found that as little a voltage as 1.0 V produces a forward current of about 50 mA. A burnout is likely to occur if forward voltage is increased beyond a certain safe limit.

Reverse Characteristics:

When the diode is reverse-biased, majority carriers are blocked and only a small current (due to minority carriers) flows through the diode. As the reverse voltage is increased from zero, the reverse current very quickly reaches its maximum or saturation value I0 which is also known as **leakage current**. It is of the order of nanoamperes (nA) for Si and microamperes (μA) for Ge.

The value of I_0 (or Is) is independent of the applied reverse voltage but depends on (a) temperature, (b) degree of doping and (c) physical size of the junction.

As seen from Fig., when reverse voltage exceeds a certain value called break-down voltage V_{BR}, the leakage current suddenly and sharply increases, the curve indicating zero resistance at this point. Any further increase in voltage is likely to produce burnout unless protected by a current-limiting resistor.

These characteristics can be described by the analytical equation called Boltzmann diode equation given below :

$$I_D = I_S\left(e^{\frac{qV_D}{nkT}} - 1\right)$$

where I_S = diode reverse saturation current

V_D = voltage across junction – positive for forward bias and negative for reverse bias.

k = Boltzmann constant = 1.38×10^{-23} J/°K

T = crystal temperature in °K

η = 1 – for germanium

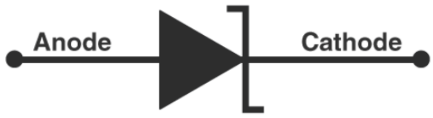
= 2 – for silicon

ZENER DIODE AND ZENER EFFECT

A Zener Diode, also referred to as a breakdown diode, is a specially doped semiconductor device engineered to function in the reverse direction. When the voltage across a Zener diode's terminals is reversed and reaches the Zener Voltage (also known as the knee voltage), the junction experiences a breakdown, allowing current to flow in the opposite direction. This phenomenon, known as the Zener Effect, is a key characteristic of Zener diodes.

A Zener diode is a highly doped semiconductor device specifically designed to function in the reverse direction. It is engineered with a wide range of Zener voltages (Vz), and certain types are even adjustable to achieve variable voltage regulation.

Symbol:



The symbol used to represent a Zener diode in circuit diagrams is similar to that of a regular diode, but with a unique addition. It consists of a triangle or arrowhead pointing towards the cathode side (the side with the band) of the diode. This triangle is accompanied by two perpendicular lines at the cathode end, one extending upwards and the other extending downwards. These lines indicate the specific behaviour of the Zener diode and help distinguish it from other types of diodes in circuit diagrams.

WORKING OF ZENER DIODE:

A Zener diode functions similarly to a regular diode when forward-biased. However, in reverse-biased mode, a small leakage current flows through the diode. As the reverse voltage increases and reaches the predetermined breakdown voltage (Vz), current begins to flow through the diode. This current reaches a maximum level determined by the series resistor, after which it stabilizes and remains constant across a wide range of applied voltages.

There are two types of breakdowns in a Zener Diode: Avalanche Breakdown and Zener Breakdown.

Avalanche Breakdown in Zener Diode:

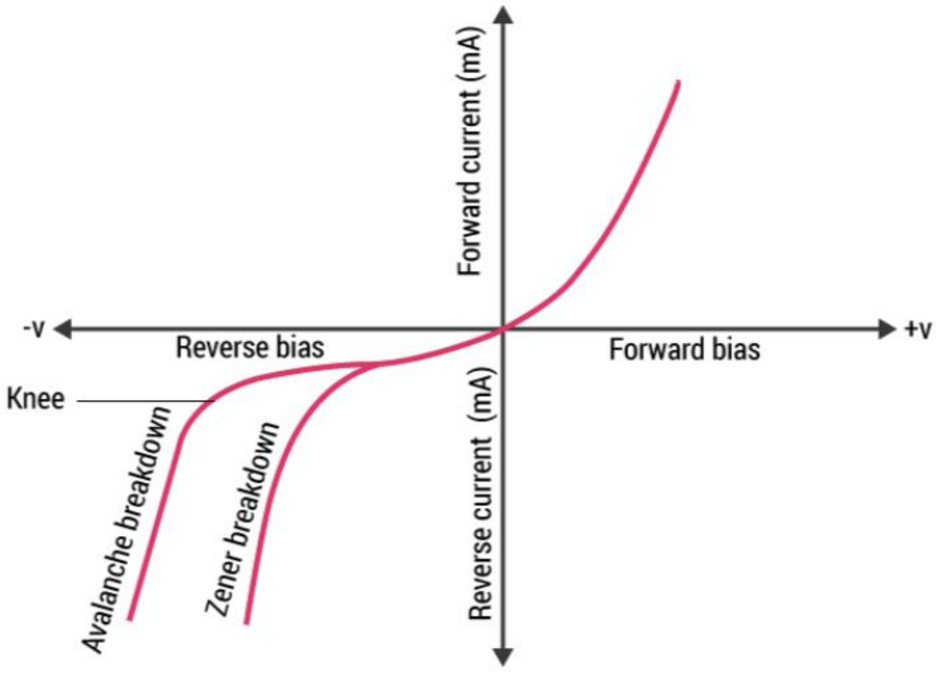
Avalanche breakdown occurs in both normal diodes and Zener diodes when subjected to high reverse voltage. When a significant reverse voltage is applied to the PN junction, the free electrons gain enough energy to accelerate at high velocities. These high-velocity electrons collide with other atoms, causing the ejection of additional electrons. This continuous collision process generates a large number of free electrons, resulting in a rapid increase in electric current through the diode. In the case of a normal diode, this sudden surge in current could permanently damage it. However, a Zener diode is specifically designed to withstand avalanche breakdown and can handle the sudden current spike. Avalanche breakdown typically occurs in Zener diodes with a Zener voltage (Vz) greater than 6V.

Zener Breakdown in Zener Diode:

When the reverse bias voltage applied to a Zener diode approaches its Zener voltage, the electric field within the depletion region becomes strong enough to attract and remove electrons from their valence band. These valence electrons, energized by the intense electric field, break free from their parent atoms. This phenomenon takes place in the Zener breakdown region, where even a slight increase in voltage leads to a rapid surge in electric current..

CHARACTERISTICS OF ZENER DIODE

The diagram given below shows the V-I characteristics of the Zener diode.



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The V-I characteristics of a Zener diode can be divided into two parts as follows:
(i)Forward Characteristics
(ii) Reverse Characteristics

Forward Characteristics of Zener Diode:

The first quadrant in the graph represents the forward characteristics of a Zener diode. From the graph, we understand that it is almost identical to the forward characteristics of P-N junction diode.

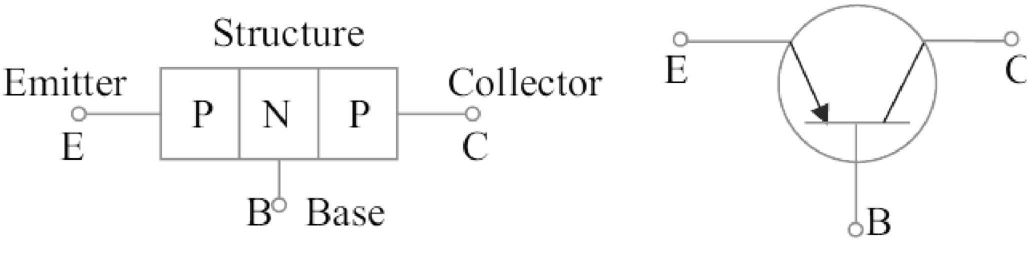
Reverse Characteristics of Zener Diode:

When a reverse voltage is applied to a Zener voltage, a small reverse saturation current Io flows across the diode. This current is due to thermally generated minority carriers. As the reverse voltage increases, at a certain value of reverse voltage, the reverse current increases drastically and sharply. This is an indication that the breakdown has occurred. We call this voltage breakdown voltage or Zener voltage, and Vz denotes it.

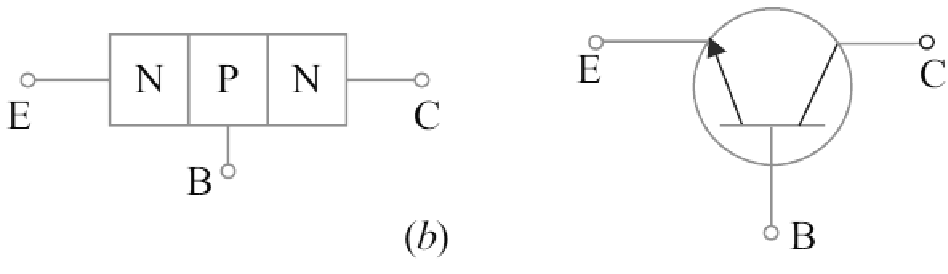
BIPOLAR JUNCTION TRANSISTOR

Basically, the bipolar junction transistor consists of two back-to back P-N junctions manufactured in a single piece of a semiconductor crystal. These two junctions give rise to three regions called emitter, base and collector. As shown in Fig.(a) junction transistor is simply a sandwich of one type of semiconductor material between two layers of the other type. Fig.(a) shows a layer of N-type material sandwiched between two layers of P-type material. It is described as a PNP transistor. Fig.(b) shown an NPN – transistor consisting of a layer of P-type material sandwiched between two layers of N-type material.

The emitter, base and collector are provided with terminals which are labelled as E, B and C. The two junctions are : emitter-base (E/B) junction and collector-base (C/B) junction.



(*a*)



(*b*)

The symbols employed for PNP and NPN transistors are also shown in Fig. The arrowhead is always at the emitter (not at the collector) and in each case, its direction indicates the conventional direction of current flow. For a PNP transistor, arrowhead points from emitter to base meaning that emitter is positive with respect to base (and also with respect to collector)* For NPN transistor, it points from base to emitter meaning that base (and collector as well)* is positive with respect to the emitter.

1. Emitter: It is more heavily doped than any of the other regions because its main function is to supply majority charge carries/ (either electrons or holes) to the base.

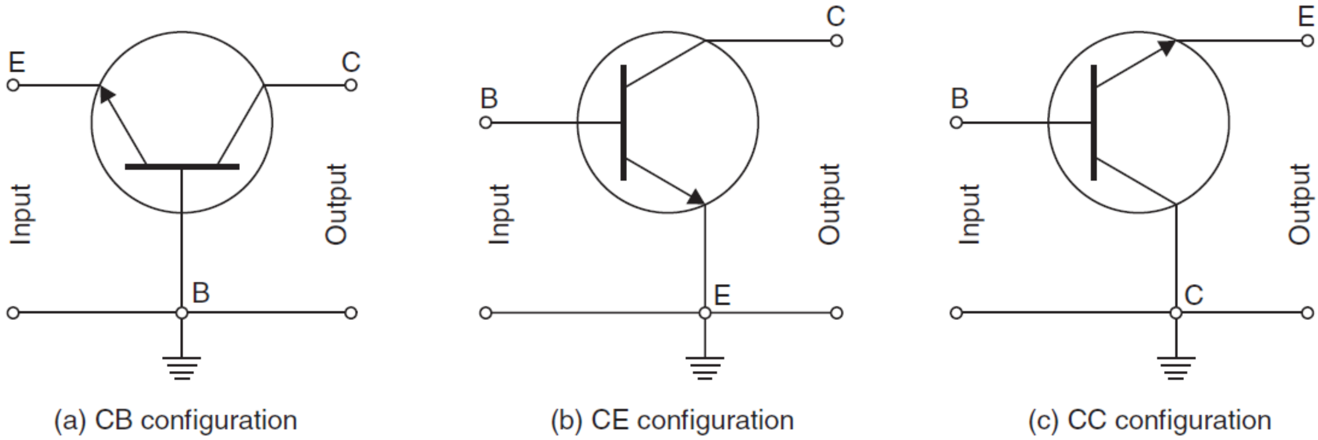
2. Base: It forms the middle section of the transistor. It is very thin (10–6 m) as compared to either the emitter or collector and is very lightly-doped.

3. Collector: Its main function (as indicated by its name) is to collect majority charge carriers coming from the emitter and passing through the base.

TYPES OF TRANSISTOR CONFIGURATIONS

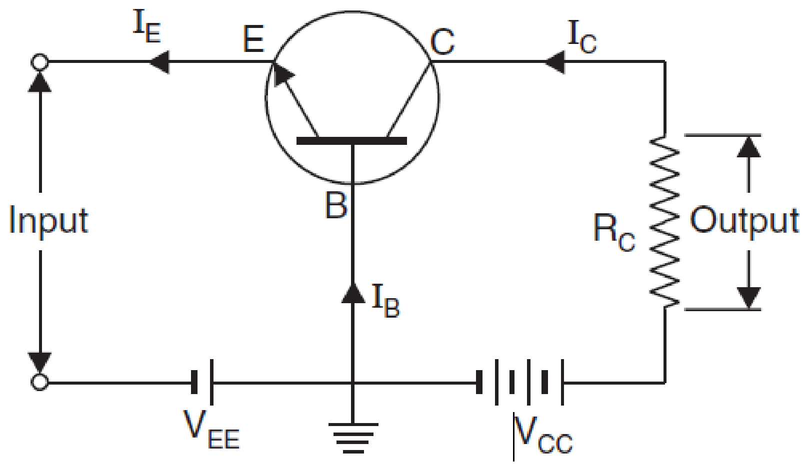
Transistors (BJTs) are operated in three configuration namely,

1. Common Base Configuration (C.B)
2. Common Emitter Configuration (C.E)
3. Common Collector Configuration (C.C)



COMMON BASE CONFIGURATION (C.B)

In this circuit configuration, input is applied between emitter and base and output is taken from collector and base. Here, base of the transistor is common to both input and output circuits and hence the name common base configuration. A common-base configuration for N-P-N transistor is shown in Fig.



Current amplification factor (α). *It is the ratio of output current to input current.* In CB configuration, the input current is the emitter current I_E and output current is the collector current I_C.

The ratio of change in collector current to the change in emitter current at constant collector-base voltage V_{CB} *is known as* ***current amplification factor*** i.e.,

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

If *only D.C. values are considered,* then $\alpha = \frac{I_C}{I_E}$

α is *less than unity*. This value can be increased (not more than unity) by decreasing the base current. This is accomplished by *making the base thin and doping it lightly.*

In commercial transistors, practical value of α varies from 0.9 to 0.99.

Collector current (I_C) :

Total collector current, $I_C = \alpha I_E + I_{leakage}$

(αI_E is the part of emitter current that reaches the collector terminal)

where, I_E = Emitter current, and

$I_{leakage}$ = Leakage current (This current is due to movement of minority carriers across base-collector junction on account of it being reversed ; it is *much smaller* than αI_E)

When emitter is open, $I_E = 0$, but a small leakage current still flows in the collector circuit. This $I_{leakage}$ is abbreviated as I_{CBO}, meaning collector-base current with emitter open.

$$I_C = \alpha I_E + I_{CBO}$$
$$I_C = \alpha(I_C + I_B) + I_{CBO}$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \frac{I_{CBO}}{(1-\alpha)}$$

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— In view of improved construction techniques, the magnitude of I_{CBO} for general-purpose and low-powered transistors (especially silicon transistors) is usually very small and may be neglected in calculations.

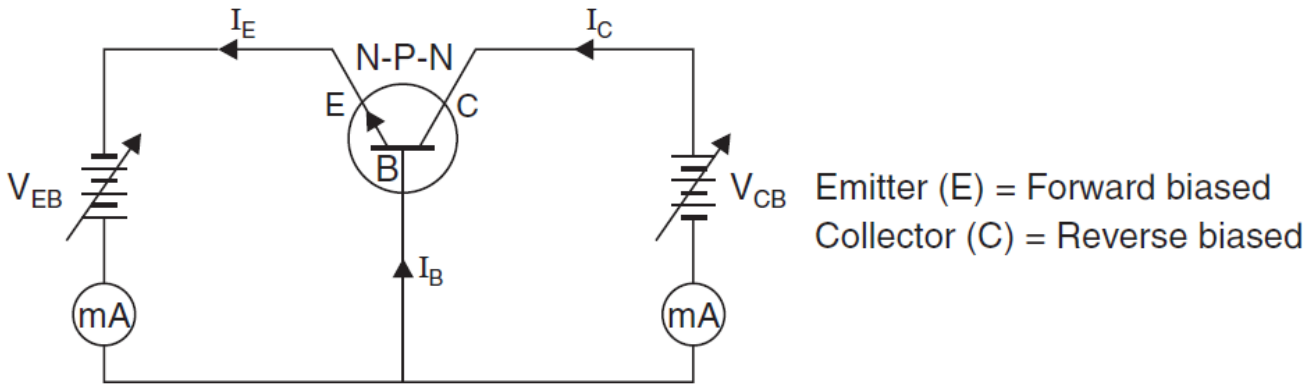
— For high power calculations, I_{CBO} appears in μA range.

— I_{CBO} is temperature dependent, therefore, at high temperature it must be considered in calculations.

CHARACTERISTICS OF CB CONFIGURATION

Curves representing the variation of current with voltage in a transistor triode circuit are called **transistor characteristic curves.** There are the following two types of characteristic curves :

1. **Input characteristic curves** of I_E *versus emitter-base voltage* (V_{EB}).
2. **Output characteristic curves** of *collector current* (I_C) *versus collector-base voltage* (V_{CB}).

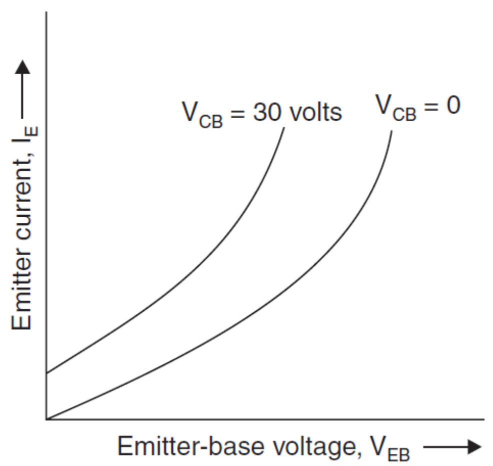


1. **Input characteristic curves :**

— To plot these curves the collector voltage is first put at zero potential (say), *i.e.*, $V_{CB} = 0$.

— The emitter-base voltage (V_{EB}) is now increased from zero onwards and emitter current (I_E) is recorded.

— A graph is plotted between I_E and V_{EB} as shown in Fig.



— Another similar graph is plotted for V_{CB} = 30 volts (say).

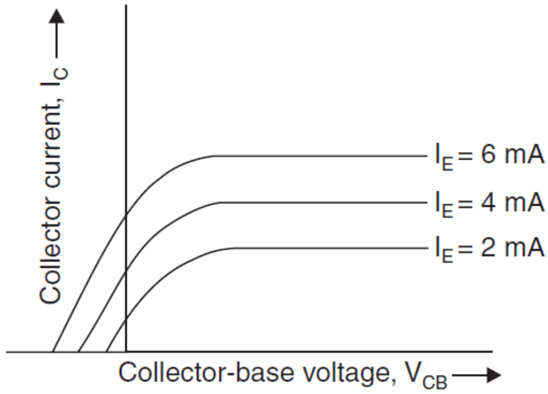
From the graph we observe that :

(*i*) For a given collector voltage, the emitter current rises rapidly even with a very small increase in emitter potential. It means that *the input resistance* $R_i \left(= \frac{\Delta V_{EB}}{\Delta I_E} \text{ at constant } V_{CB} \right)$ *of the emitter-base circuit is very low.*

(*ii*) The emitter current is nearly *independent* of collector-base voltage.

2. **The output characteristic curves :**

These curves are obtained by plotting the variation of collector current (I_C) with collector-base voltage (V_{CB}) at different constant values of emitter current (I_E).



— These *curves* shown in Fig. indicate that some collector current is present even when the collector voltage is zero. To make the collector current zero, we have to give a certain amount of *negative potential* to the collector.

— The *curves* also indicate that the collector current attains a high value even at a very low collector voltage and further increase in collector voltage does not produce any appreciable increase in collector current. It means that the *output resistance*

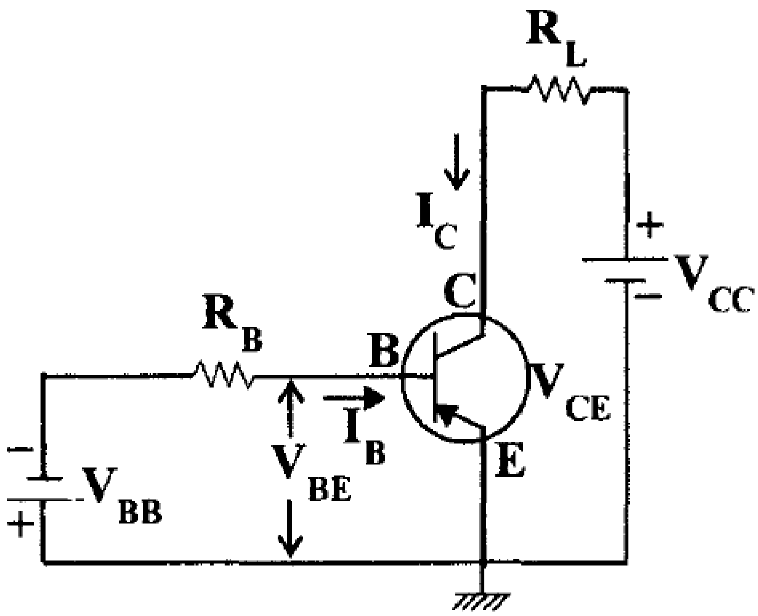
$\left(R_o = \frac{\Delta V_{CB}}{\Delta I_C} \text{ at constant } I_E \right)$ *of the collector-base circuit is very large.*

The *collector current is always a little less than the emitter current* because of the neutralisation of a few holes and electrons within the base due to recombination.

COMMON EMITTER CONFIGURATION (C.E)

In this circuit as shown in the Fig, emitter is common to both base and collector. So this is known as CE configuration or grounded emitter configuration. The input voltage V_{BE} and output current Ic are taken as the dependent variables. These depend upon the output voltage V_{CE} and input current I_B.

$$V_{BE} = f_1 (V_{CE}, I_B)$$
$$I_C = f_2(V_{CE}, I_B)$$



Relation between β and α. The relation between β and α is derived as follows

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

Now, $$I_E = I_B + I_C$$

$$\Delta I_E = \Delta I_B + \Delta I_C \quad \text{or} \quad \Delta I_B = \Delta I_E - \Delta I_C$$

Inserting the value of ΔI_B in (*i*), we get

$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

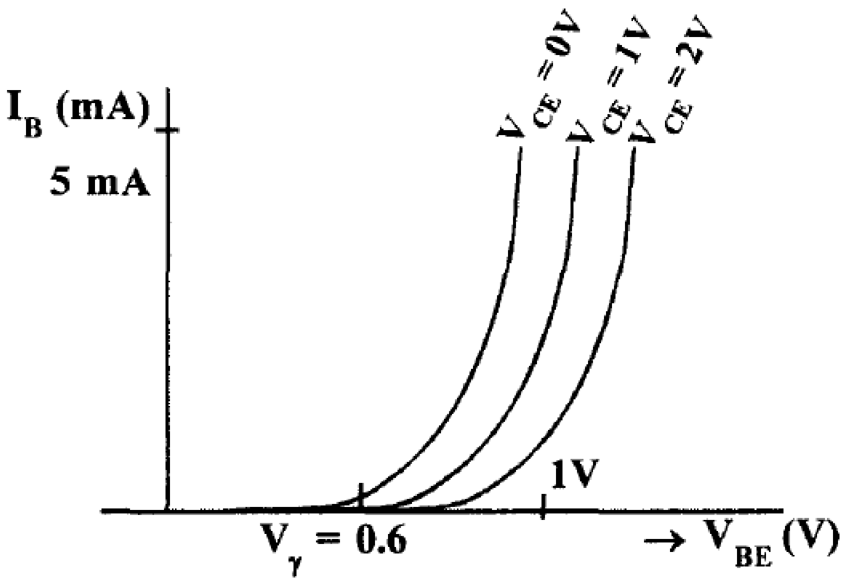
Dividing the numerator and denominator of R.H.S. by ΔI_E, we get

$$\beta = \frac{\Delta I_C/\Delta I_E}{(\Delta I_E/\Delta I_E) - (\Delta I_C/\Delta I_E)} = \frac{\alpha}{1-\alpha}$$

∴ $$\beta = \frac{\alpha}{1-\alpha}$$

INPUT CHARACTERISTICS:

If the collector is shorted to the emitter, the transistor is similar to a Forward Biased Diode. So I_B increases as V_{BE} increases. The input characteristics are as shown in fig. I_B increases with V_{BE} exponentially, beyond cut-in voltage $V\gamma$. The variation is similar to that of Forward Biased Diode. If $V_{BE} = 0$, $I_B = 0$, since emitter and collector junctions are shorted. If V_{CE} increases, base width decreases (Early effect), and results in decreased recombination. As V_{CE} is increased, from -1 to -3 I_B decreases. $V\gamma$ is the cut in voltage.



$$I_E + I_B + I_C = 0$$
$$I_E = -(I_B + I_C)$$

As V_{CE} increases, I_C increases, therefore I_B decreases. Therefore, base recombination will be less. The input characteristics are similar to a forward biased p-n junction diode.

$$I_B = I_o\left(e^{\frac{V_{BE}}{nV_T}} - 1\right)$$

The input characteristics I_B vs V_{BE} follow the equation,

$$I_B = I_o\left(e^{\frac{V_{BE}}{nV_T}} - 1\right)$$

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OUTPUT CHARACTERISTICS:

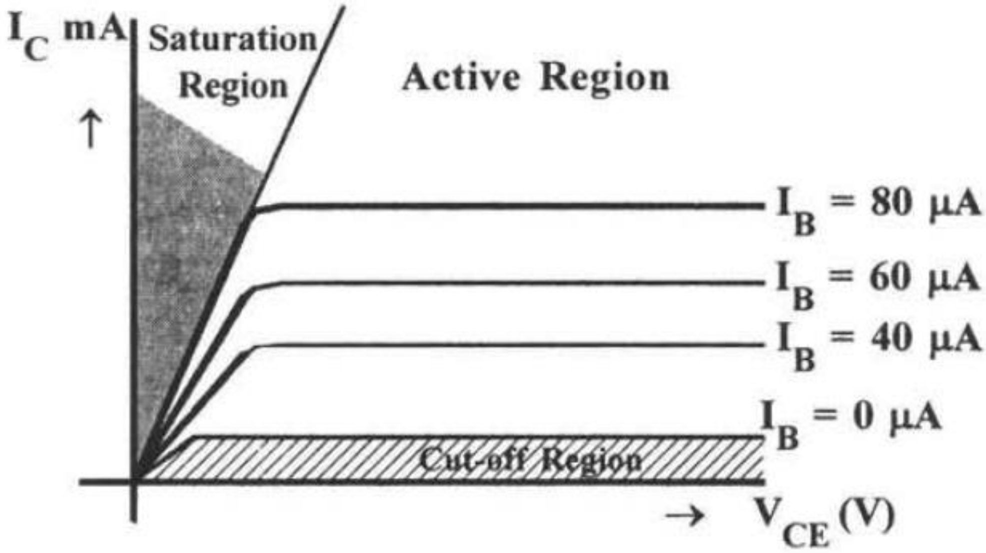
The transistor is similar to a Collector Junction Reverse Biased Diode. The output characteristics is divided into three regions namely,

1. Active Region. 2. Saturation Region 3. Cut-Off Region.

These are shown in Fig. If I_B increases, there is more injection into the collector. So I_C increases. Hence characteristics are as shown.

The output characteristics are similar to a reverse biased p-n junction. (Collector Base junction is reverse biased). They follow the equation.

$$I_C = I_o\left(e^{\frac{V_{CE}}{nV_T}} - 1\right)$$



$$I_B + I_C + I_E = 0$$

$\therefore$ $$I_E = -(I_B + I_C)$$

$$-I_C = +I_{CO} - \alpha \cdot I_E$$

But $$I_E = -(I_B + I_C)$$

$\therefore$ $$I_C = -I_{CO} + \alpha \cdot I_B + \alpha \cdot I_C$$

$$I_C(1-\alpha) = -I_{CO} + \alpha \cdot I_B$$

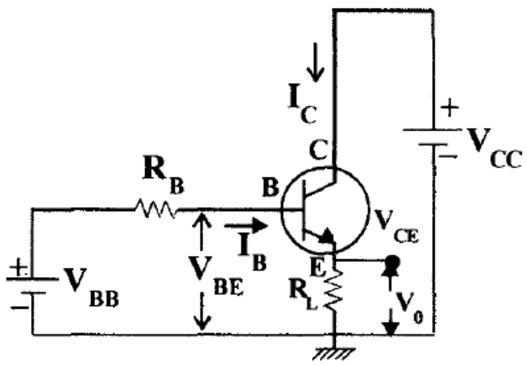
If the transistor were to be at cut off, I_B must be equal to zero.

COMMON COLLECTOR CONFIGURATION (C.C)

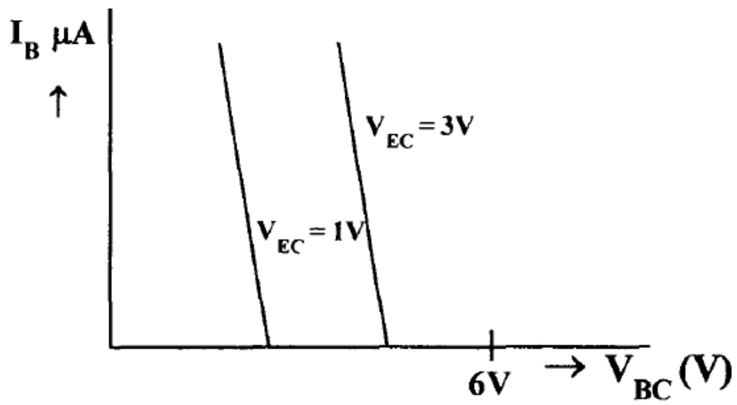
Here the load resistor R_L is connected in the emitter circuit and not in the collector circuit. Input is given between base and ground. The drop across R_L itself acts as the bias for emitter base junction. The operation of the circuit similar to that of Common Emitter Configuration. When the base current is I_{C0}, emitter current will be zero. So no current flows through the load. Base current I_B should be increased so that emitter current is some finite value and the transistor comes out of cut-off region.

Input characteristics I_B vs V_{BC} and Output characteristics I_C vs V_{EC}

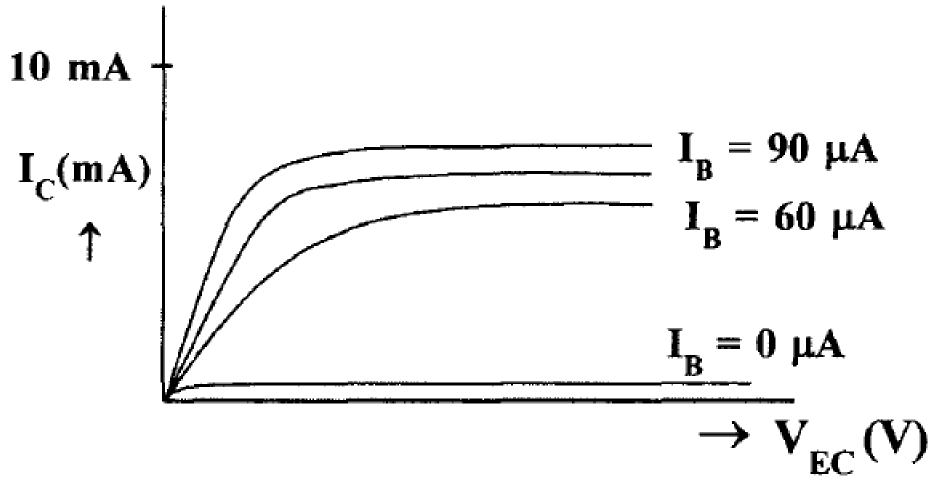
The circuit diagram is shown in Fig.(a) and the characteristics are shown in Fig.(b) and (c).



. (a)



(b)



(c)

The input characteristic of the common collector configuration is drawn between collector base voltage V_{CE} and base current I_B at constant emitter current voltage V_{CE}. The value of the output voltage V_{CE} changes with respect to the input voltage V_{BC} and I_B with the help of these values, input characteristic curve is drawn. The input characteristic curve is shown below.

The output characteristic of the common emitter circuit is drawn between the emitter-collector voltage V_{EC} and output current I_E at constant input current IB. If the input current I_B is zero, then the collector current also becomes zero, and no current flows through the transistor.

The transistor operates in active region when the base current increases and reaches to saturation region. The graph is plotted by keeping the base current I_B constant and varying the emitter-collector voltage V_{CE}, the values of output current I_E are noticed with respect to V_{CE}. By using the V_{CE} and I_E at constant I_B the output characteristic curve is drawn.

Relation between γ and α.

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

Now, $$I_E = I_B + I_C$$

$$\Delta I_E = \Delta I_B + \Delta I_C \qquad \text{or} \qquad \Delta I_B = \Delta I_E - \Delta I_C$$

Inserting the value of ΔI_B in (i), we get

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

Dividing the numerator and denominator of R.H.S. by ΔI_E, we get

$$\gamma = \frac{\Delta I_E/\Delta I_E}{(\Delta I_E/\Delta I_E) - (\Delta I_C/\Delta I_E)} = \frac{1}{1-\alpha}$$

$$\therefore \qquad \gamma = \frac{1}{1-\alpha}$$

Collector current :

We know that, $$I_C = \alpha I_E + I_{CBO}$$

Also, $$I_E = I_B + I_C = I_B + (\alpha I_E + I_{CBO})$$

$$I_E(1-\alpha) = I_B + I_{CBO}$$

$$I_E = \frac{I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha}$$

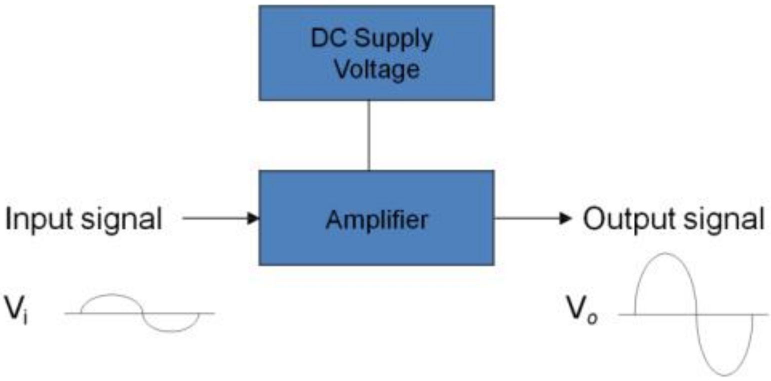
$$I_C, I_E = (\beta + 1)I_B + (\beta + 1)I_{CBO}$$

$$\left[\beta = \frac{\alpha}{1-\alpha} \quad \therefore \quad \beta + 1 = \frac{\alpha}{1-\alpha} + 1 = \frac{1}{1-\alpha}\right]$$

AVRK

ELEMENTARY TREATMENT OF SMALL SIGNAL CE AMPLIFIER

- Amplifier is a system that can amplify weak electrical signal into strong one by increasing the power level of the weak input signal.
- Amplifier can amplify current, voltage, and/or power.

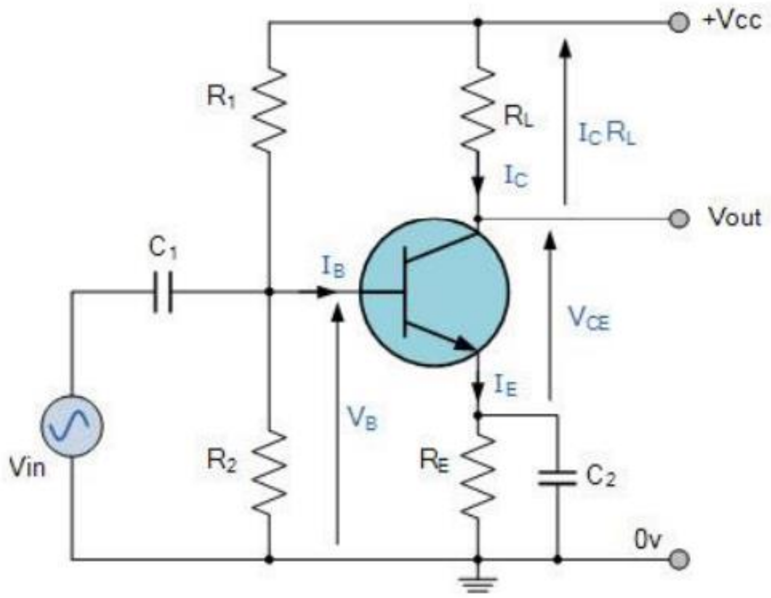


Amplifier has 3 basic quantities (gain, A; input impedance, Z_i, & output impedance, Z_o).

Gain

- Voltage gain : $A_V = \frac{V_O}{V_i}$
- Current gain : $A_i = \frac{I_O}{I_i}$
- Power gain : $A_P = \frac{P_O}{P_i} = A_V A_i$

- Small Signal Amplifiers are also known as **Voltage Amplifiers**.
- Voltage Amplifiers have 3 main properties, **Input Resistance**, **Output Resistance** and **Gain**.
- The Gain of a small signal amplifier is the amount by which the amplifier "Amplifies" the input signal.
- Gain is a ratio of output divided by input, therefore it has no units but is given the symbol (A) with the most common types of transistor gain being, **Voltage Gain (Av), Current Gain (Ai)** and **Power Gain (Ap)**
- The power Gain of the amplifier can also be expressed in **Decibels** or simply **dB**.
- The **Common Emitter Amplifier** configuration is the most common form of all the general purpose voltage amplifier circuit using a Bipolar Junction Transistor.



common emitter amplifier circuit and it consists of voltage divider biasing, used to supply the base bias voltage as per the necessity. The voltage divider biasing has a potential divider with two resistors are connected in a way that the midpoint is used for supplying base bias voltage.

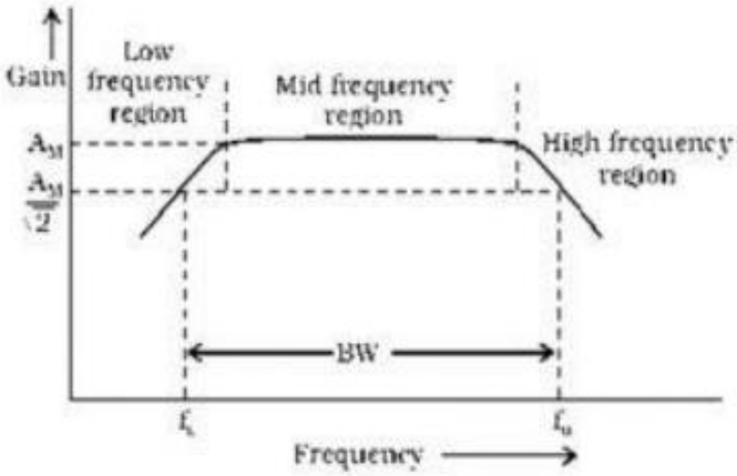
There are different types of electronic components in the common emitter amplifier which are R1 resistor is used for the forward bias, the R2 resistor is used for the development of bias, the RL resistor is used at the output it is called the load resistance. The RE resistor is used for thermal stability. The C1 capacitor is used to separate the AC signals from the DC biasing voltage and the capacitor is known as the coupling capacitor.

When a signal is applied across the emitter-base junction, the forward bias across this junction increases during the upper half cycle. This leads to an increase in the flow of electrons from the emitter to a collector through the base, hence increases the collector current. The increasing collector current makes more voltage drops across the collector load resistor RC.

The negative half cycle decreases the forward bias voltage across the emitter-base junction. The decreasing collector-base voltage decreases the collector current in the whole collector resistor Rc. Thus, the amplified load resistor appears across the collector resistor.

CE Amplifier Frequency Response

The voltage gain of a CE amplifier varies with signal frequency. It is because the reactance of the capacitors in the circuit changes with signal frequency and hence affects the output voltage. The curve drawn between voltage gain and the signal frequency of an amplifier is known as frequency response. The below figure shows the frequency response of a typical CE amplifier.



At Low Frequencies (< FL) The reactance of coupling capacitor C2 is relatively high and hence very small part of the signal will pass from the amplifier stage to the load.

Moreover, CE cannot shunt the RE effectively because of its large reactance at low frequencies. These two factors cause a drops off of voltage gain at low frequencies.

At High Frequencies (> FH) The reactance of coupling capacitor C2 is very small and it behaves as a short circuit. This increases the loading effect of the amplifier stage and serves to reduce the voltage gain.

Moreover, at high frequencies, the capacitive reactance of base-emitters junction is low which increases the base current. This frequency reduces the current amplification factor β. Due to these two reasons, the voltage gain drops off at a high frequency.

At Mid Frequencies (FL to FH) The voltage gain of the amplifier is constant. The effect of the coupling capacitor C2 in this frequency range is such as to maintain a constant voltage gain. Thus, as the frequency increases in this range, the reactance of CC decreases, which tends to increase the gain.

Frequency points like fL & fH are related to the lower corner & the upper corner of the amplifier which are the gain falls of the circuits at high as well as low frequencies. These frequency points are also known as decibel points. So the BW can be defined as

BW = fH – fL