Basic Electronics

Electronics:-- Electronics is the branch of science or Engineering which deals with flow of electrons through semiconductors.

Electronic devices are capable of performing the following functions.

1. **Rectification**: Conversion of AC to DC is known as rectification.
2. **Amplification**: The process of raising the strength of week signal is know as amplification.
3. **Control**: Electronic devices find wide application in automatic control, controlling the voltage supply to any equipment.
4. **Inverter** : Electronic device can convert DC power to AC power.
5. **Converter** : Electronic device can converter AC to DC power or DC TO DC or AC to AC
6. **Photo electricity**: Electronic devices can convert light energy into electrical energy.

Conductors are those which allow the current to pass through it, insulators are those materials who do not allow the current to pass through it. Semiconductors are those which are having both properties of conductors and insulators. At absolute temperature they behave like perfect insulators but with rise in temperature their conductivity increases. By some special procedure their conducting property controlled by requirement.

In Electronics basically there are two types of components. 1. Active components 2.Passive components.

1. **Active components**: Those components which actively perform the functions like rectification, amplification etc. are known as active components. Examples are **Diodes, transistors** etc.

2. **Passive components:** Passive components are those which support the active components to function them properly but themselves are not capable of amplifying or processing an electrical signal. However these components are as important in an electronic circuit as the active components. Without the aid of these components no active component can work. Eg. **Resistor, Capacitor and Inductor etc.**

Resistors

Resistors: Resistor is a device which opposes the flow of current through it.

Resistors are of two types :

1. **Fixed Resistor**
   I. Wire wound resistor
   II. Carbon composition
   III. Metal film carbon film

2. **Variable resistors**
   I. Potentiometer
   II. Preset

Uses of resistors:

I. It establishes proper values of voltages due to IR drops
II. It is used to provide load.

The Laws of resistance

I. The resistance of conductor is directly proportional to its length i.e. $R \propto L$
II. The resistance of conductor is inversely proportional to its cross-sectional area i.e. $R \propto 1/A$

III. The resistance of a conductor depends upon material.

IV. The resistance of conductor depends upon its temperature.

$$R \alpha L / A$$

$$R = \rho . L / A$$

Where ρ is constant and is known as Specific resistance of the material. If L is equal to 1 cm and A is 1 cm^2 (cross sectional area of the conductor) R =ρ

Specific Resistance: The specific resistance of material is resistance offered by 1cm^3 cube of the material.

The reciprocal of specific resistance is called conductivity. It is denoted by 1/ ρ.

Some resistances used in electronic circuits are having their values directly written. But maximum carbon resistances are color coded. So we must have knowledge about color coding.

Color coding of resistors

Color coding of resistors can be remember by a popular line

B B ROY is a **G**reat **B**atsman and **V**ery **G**ood **W**icket-keeper.

B-------- Black------------0
B--------Brown---------- 1
R--------Red-------------- 2
O-------Orange---------- 3
Y------- Yellow-----------4
G------- Green----------- 5
B--------Blue-------------- 6
V--------Violet------------7
G------- Grey--------------8
W-------White------------9

Gold----- ± 5%
Silver---- ± 10%

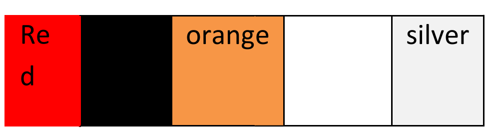
How to calculate the value of a resistor?

A carbon resistor has four colors on it. We should start from the color which is nearest to the terminal.

1. First color is No. 2. Second color is also No. 3. Third color is $10^{\text{no.of color}}$

4. Tolerance color (Gold-----±5%, Silver-------±10%)

Example



1. Fist color RED (2) 2. Second color is BLACK(0) 3.Third color is Orange (3) 4. Fourth color is Silver (tolerance color i.e. ±10%).

The value of resistor is $20 \times 10^3 = 20{,}000\ \Omega = 20\ K\ \Omega$ $(1000\ \Omega = 1K\ \Omega)$

Silver color indicates that practical value of resistor lies in between 19K Ω to 21K Ω

If **third color is gold or silver** then value of resistor is as follows

1. The first color is No. 2. Second color is No. 3. If third color is Gold then multiplied by 10^{-1} and if third color is Silver then multiplied by 10^{-2}.

Example:

If colors on resistor are RED, RED, GOLD then value of resistor is 22×10^{-1} Hence the value is 2.2 Ω and if third color is SILVER then the value of resistor is 22×10^{-2} =0.22 Ω.

Capitalcitors

In any electronic circuit the second most extensively used component after the resistor is capacitor. Capacitors are capable of storing charges. They are used for coupling ac signals from one circuit to another and for frequency selection etc. A capacitor consists of 2 metallic plates separated by a dielectric. Some dielectric materials are mica. Paper, polyester etc. the capacitor gets its name by its insulating materials.

Capacitance:- The property or ability of a capacitor to store electric charge is called capacitance. Unit of capacitance is Farad.

Farad: One farad is defined as the capacitance of a capacitor which required a charge of one coulomb to establish a potential difference of one volt between its plates.

Factors controlling the capacitance of a capacitor

I. Plate area : capacitance of a capacitor is directly proportional to area of plates $C \propto A$
II. Distance between two plates: Capacitance of a capacitor is inversely proportional to distance between the two plates. $C \propto 1/d$
III. Type of Di-electric material : The capacitance of a capacitor depends upon the di-electric constant of the insulating material used

Hence capacitance of capacitor given by

$$C = \epsilon_r \epsilon_0 A/D$$

Where ϵ_r is relative permittivity of free space and

Where ϵ_0 is permittivity of free space which is given by 8.85×10^{-12}

Relative permittivity of some of the material is given below

Material	ϵ_r
Air or vacuum	1
Ceramic	50 to 300
Mica	3 to 6
Paper	3 to 5

Capacitor blocks DC and allows AC to pass through it.

Permittivity:- In electromagnetism, permittivity or absolute permittivity is the measure of resistance that is encountered when forming an electric field in a medium in other words, permittivity is a measure of how an electric field affects, and is affected by , a dielectric medium.

OR Permittivity is ability of a material to store electrical potential energy under the influence of an electric field measured by the ratio of the capacitance of a capacitor with the material as dielectric to its capacitance with vacuum as dielectric- called as dielectric constant.

When capacitor connected to DC voltage.

As the DC voltage is not alters so when DC applied to capacitor plates of capacitor momentarily charged and then discharged and plates become neutral

When capacitor connected to AC voltage.

When AC voltage is applied across the capacitor then during +ve half when alternating value increased from A to B capacitor get charged and plate P1 is positively charged and plate P2 is negatively charged and when value of alternating value decreased from B to C then plates P1 and P2 get discharged and become neutral. During –ve half when alternating value increased in negative side from C to D the charge at plates get reversed i.e. P1 is negatively charged and P2 is positively charged. From D to E of negative side of alternating cycle the plates again get discharged and become neutral. This process will continue and charge across the plates continuously changed. No. of charge and discharge depend upon frequency. As the frequency increases charging and discharging also increases.

Capacitive reactance: The opposition offered by a capacitor to flow of AC current is known as capacitive reactance.

$$X_c = 1/2\pi fc$$

Where X_c is Capacitive reactance in ohms, f is frequency in cycles C is capacitance in farads

When a capacitor is connected across the DC supply then value X_c is infinity as for DC f is zero

$1/2\pi 0c = 1/0 =$ Infinity

When f increases while C is constant the X_c decreases

When f becomes equal to infinity the capacitive reactance become zero.

Voltage rating of a capacitor: The working voltage of a capacitor is given by the maximum potential difference that can be applied across its plates without puncturing its di-electric material.

Capacitor in Series:- Connecting capacitors in series is equivalent to increase the thickness of the di-electric material and distance between the plates increases Hence the combined capacitance will decrease as $C \alpha 1/d$. As d increases C will decrease. Hence

$1/C=1/C1+1/C2+1/C3$……..

Capacitors in parallel:- Connecting capacitors in parallel is equivalent to adding their plate area, and since $C \alpha A$ therefore the value of capacitance increases . Hence net value of capacitance $C=C1+C2+C3+$…………

All capacitors commonly used in electronic circuits are generally divided into two main categories.

1. Fixed Capacitors
   - Electrolytic Capacitors
     - I. Aluminum
     - ii. Tantalum
   - Non Electrolytic Capacitors
     - i. paper
     - ii. polyester
     - iii. Mica
     - iv. Ceramic
2. Variable capacitor
   - i. Trimmer
   - ii. Gang condenser

Aluminum Capacitors: The capacitors are called electrolytic capacitors as they used an electrolyte of Borex, Phosphate or Carbonate between the two aluminum plates. They have a polarity.

Electrolytic capacitors are used in filters circuits in order to remove the AC ripples from the power supply. They are also used for blocking or coupling ac signals

Non Polarized electrolytic capacitors: - This type of capacitor is available for use in electrical ckt. where there is an ac voltage. One application is the starting capacitors for AC motors. It actually contains two capacitors connected internally in series opposite polarity.

Color coding of capacitors

Color coding of capacitors and resistors follow same procedure.

B B ROY of **G**reat **B**riten has **V**ery **G**ood **W**ife

B B R O Y G B V G W

	0	1	2	3	4	5	6	7	8	9
Third Band	10^0	10^1	10^2	10^3	10^4	10^5	10^6	10^7	10^{-1}	10^{-2}

1st band is No. 2nd band is No. third band is $10^{\text{No.}}$

Here tolerance color i.e. 4th band of capacitor whose list is as follows. i. Black------ ±20% ii. Brown-------±1% iii. Red-------±3 iv. Orange--------±3% v. yellow----------±4% vi. Green-----------±5%

In Capacitors there is 5th Band also which indicates about working voltage. List of the color of 5th band as follows

Brown------100V Red---------250 V Yellow----------400 V Black 630 V

Inductance

An inductor is an electrical device which consists of several turns of wire wound on a core. An inductor allows dc and blocks ac depending upon its frequency.

Inductance: The property of coil by virtue of which it opposes any change of current or flux through it by instantaneous production of counter emf is known as inductance of a coil. The self inductance of a coil is measured by Henry and is given by

$$L = \frac{\mu_0 \mu_r AN^2}{L}$$

Where A= Area of cross section of core
L= length of core
N= No. of turns
μ_0=Absolute permeability of vacuum and is given by $4\pi \times 10^{-7}$H/m

i. Permeability of magnetic material is ability of magnetic material to conduct magnetic flux.
ii. The co-efficient of self inductance may be expressed as weber turns per ampere.

L= weber x turns /Ampere
= ϕxN/I

iii. If a change in current is dI/dt and is allowed through coil having inductance L then induces a counter emf e and is given by $e = L \times dI/dt$

$L = e/(di/dt)$

If a change in current is 1 amp/sec and induces an emf of one volt when allowed to coil then the coil is said to possess an inductance of one Henry.

Mutual Inductance:- The phenomenon of production of an emf in one ckt. When current change in other ckt. Is known as mutual inductance. The mutual inductance or co-efficient of mutual inductance measured in terms of Henry and is given by $M = (\mu_0 \mu_r AN_1N_2)/l$

co-efficient of mutual inductance $M = \phi N_2/I$

The flux linkage (Weber turns) per ampere in second coil is co-efficient of mutual inductance.

Co-efficient of coupling:- The two coils are said to be magnetically coupled if part or full of flux produced byu one coil links with other.

The coupling effect is measured in terms of co-efficient of coupling and is given by $K= M/ (L_1L_2)^{1/2}$ Where M= Mutual inductance of two coils L_1=Inductance of first coil L_2= Inductance of second coil.

If 70% of flux produced by one coil links with other then co-efficient of coupling is 70% or .7.

The coils wound on air core gives K equal to almost one.

Combination of Inductors :- When two or more coils are connected in series and there is no mutual inductance M between the coils then resultant inductance in series is L=L1+L2+L3+…………. In Parallel it is $1/L=1/L_1+1/L_2+1/L_3$……….. .

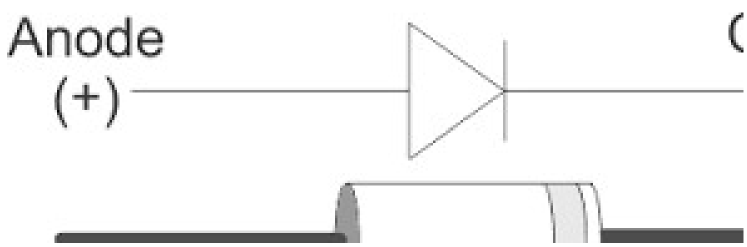
When two coils are connected in series and there is any sign of mutual inductance (H) between the coils then the resultant depends on i. Amount of mutual inductance ii. The series combination is either adding or opposing.

If La= Inductance due to adding effect , L1 and L2 = coils connected in series

Series in adding	La = L1+L2+2M
Series in opposing	Lo= L1+L2-2M
Subtracting equation ii. From i.	La-Lo=4M or M=(La-Lo)/4

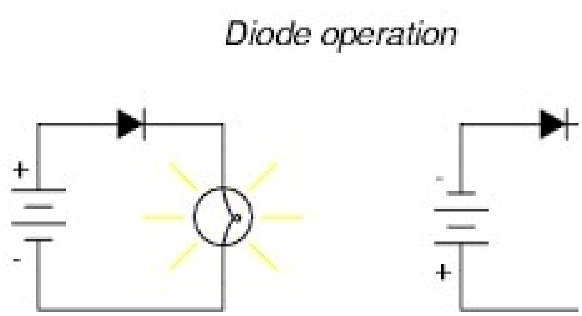
PN junction Diodes

When P and N materials diffuse together then a typical phenomenon can be seen the holes from P material moves towards N material and electrons from N type material move towards P material. The electrons and holes diffuse with each other momentarily at junction. After that a layer of electrons accumulate at the p side and repels the electrons coming from the N side and similar of holes accumulate at N side and repel the diffusion process. Thus a barrier is set up against further movement of charge carriers i.e. Holes and electrons. This is called potential barrier or junction barrier V_o. The barrier voltage in Germanium semiconductor is .3 voltage and in Si it is .7v.

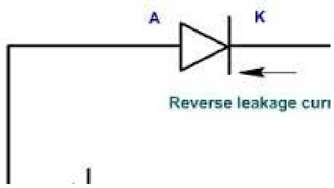


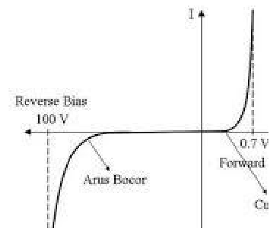
Working of Diode.

1. Forward Bias :- When the forward bias is applied i.e. (P end of diode connected to positive side of battery and N side of diode connected to negative terminal of battery) connected the current starts flowing only when the external voltage crosses the barrier potential .3 for Ge and .7 for Si. This voltage is known as threshold voltage or cut in voltage or knee voltage. Below this threshold voltage the current flow is negligible but as the voltage increases beyond the threshold value the current increases sharply. Now the junction behaves just like a ordinary conductor. If the forward voltage is increased beyond a certain safe value it will produce an extremely large current which may destroy the junction due to overheating.



2. Reverse Bias :- When the reverse bias is applied a very small amount of current of order of micro amps flows in the circuit. This is called the reverse current. Actually when the voltage is increased the minority carriers get accelerated by the increased field and so collide with semiconductor atoms in the barrier region. Upon collision with valence electrons, Covalent bonds are newly generated charges are also accelerated by the electric field resulting in more collision and hence for the production of charge carriers. This leads the avalanche of charges carrier with resistance becomes low. This heavy current damages the PN junction permanently.





Important definitions of diodes

Forward resistance:- The resistance offered by the diode to forward bias is forward resistance.

DC Forward resistance:- It is the opposition offered by the diode to the direct current.

$$\text{DC forward resistance } R_f = \frac{\text{DC voltage across diode}}{\text{DC forward current}}$$

AC Forward resistance: It is the opposition offered by the diode to the changing forward current.

AC forward resistance= change in voltage across diode/corresponding change in current through diode

Forward resistance of diode is very small i.e. 1 ohm to 25 ohm

Reverse Resistance :- The resistance offered by the diode to the reverse bias is known as reverse resistance.

Ideally the reverse resistance of diode is infinite. However in practice the reverse resistance is not infinite because, for any value of reverse bias there does exists a small leakage current.

In Germanium diode the ratio of reverse to forward resistance is 40,000 : 1 while for silicon the ratio is 1000000 : 1

Forward current: It is the current flowing through a forward biased diode. Every diode has a maximum value of forward current which it can safely carry.

Peak inverse voltage: It is maximum reverse voltage that a diode can withstand without destroying the junction.

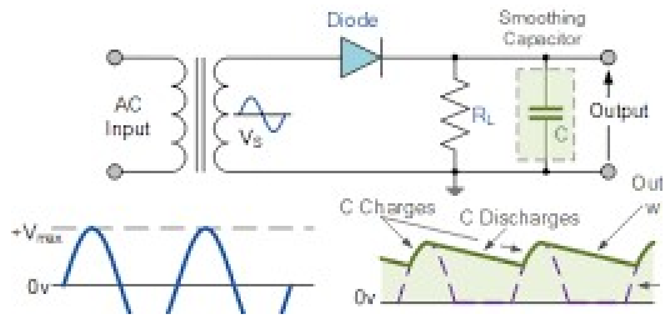
Reverse current or leakage current: It is the current that flows through a reverse biased diode. This current is due to the minority carriers.

Under normal operating voltages the reverse current is quite small. For silicon diodes reverse current is less than 1micro amps but for germanium diodes reverse current is nearly equal to 100 micro amps.

Rectifiers

Half wave rectifier: In half wave rectifier one diode is used as shown in figure. In this type of rectifiers Diode converts ac input voltage to pulsed dc out put voltage. When ever the ac input becomes negative at diodes anode, the diode blocks current flow hence output voltage becomes zero.

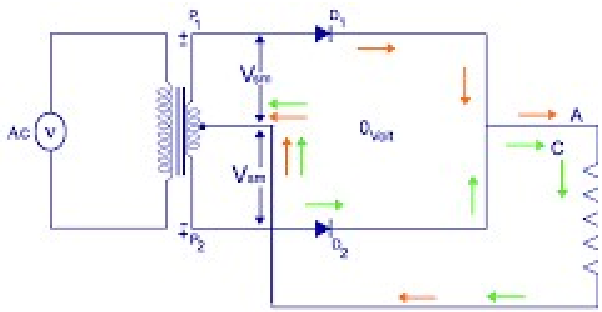
Diode introduces a 0.6v drop so out put peak is 0.6V smaller than the input peak. The out put frequency is same as input frequency.



Efficiency of rectifier (η) = DC power out put/Input AC power

Efficiency of Half wave rectifiers is 40.6%

Full wave rectifier: - A full wave Rectifier rectifies both the halves of ac signal. In full wave rectifier a centre tapped transformer and two diodes are used as shown in figure.

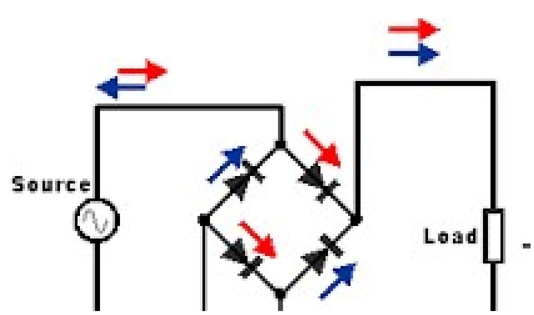


Peak inverse voltage:- Suppose V_m is the maximum voltage across the half secondary winding. Above figure shows the circuit, at the instant the secondary voltage reaches its maximum value in the +ve direction at this instant diode D1 is conducting while diode D2 is non conducting. Therefore whole of the secondary voltage appears across the non conducting diode. Consequently the peak inverse voltage is twice the maximum voltage across the half secondary winding.   PIV= 2Vm

Disadvantages

1. It is difficult to locate the centre tap on the secondary winding.
2. The dc output is small as each diode. Utilizes only half of the transformer secondary voltage.
3. The diodes used must have high peak inverse voltage.

Bridge wave rectifier:- A Bridge wave rectifier also a full wave rectifier which does not block negative swings in the I/p voltage, rather it transforms them into positive swings at the o/p. The Bridge wave rectifier uses four diodes instead of two diodes as in full wave rectifier and avoids use of centre tapped transformer.



From the figure we can clearly understand that during +ve half cycle of ac wave the current flows through D3 – load resistance – D2 and during –ve half of ac cycle the current flows through D4 – R load – D1. Out put voltage peak is 1.2 v below the I /p voltage peak. The out put frequency is twice the i/p frequency.
PIV :- Peak inverse voltage of each diode is equal to the maximum secondary voltage.

Advantages:-

1. the need for centre tapped transformer is eliminated. The output is twice that of the centre-tap circuit for the same secondary voltage.
2. The PIV is one half that of the centre tap circuit.

Disadvantage

1. It requires four diodes.
2. As during each half cycle of ac input two diodes that conduct are in series, therefore voltage drop in the internal resistance of the rectifying unit will twice as great as in the centre tap ckt. This is objectionable when secondary voltage is small.

Maximum efficiency of full wave rectifier is 81.2%

Ripple factor: - The out put of a rectifier consists of a dc. Component and an ac component which is also known as ripples
The ratio of rms. value of ac component to the D.C. component in the rectifier out put is known as ripple factor.

Ripple factor = R.M.S value of ac component/Value of D.C. component.

The smaller the ripple factor, the lesser the effective A.C. component and hence more effective is the rectifier.
Effective (RMS value) of total load current is given by

$$\mathbf{I_{rms} = \quad I_{dc}^2 + I_{ac}^2}$$

$$\mathbf{I_{ac} = \quad I_{rms}^2 - I_{dc}^2}$$

Dividing throughout by I_{dc} we get

$$\mathbf{I_{ac}/I_{dc} = 1/I_{dc}\ (I_{rms}^2 - I_{dc}^2)}$$

We know that $\mathbf{I_{ac} / I_{dc}}$ is ripple factor

Ripple factor = $\mathbf{1/I_{dc} \quad I_{rms}^2 - I_{dc}^2}$

$$= \quad \mathbf{(I_{rms}/ I_{dc})^2 - 1}$$

For half wave rectification Ripple factor = 1.21

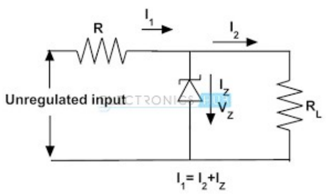
For full waver rectification Ripple factor = 0.48

Zener diode

When a reverse biased voltage on a diode going on increased that at a particular voltage say knee voltage reverse current increases suddenly and this heavy current may puncture the diode. The break down voltage is also known as zener voltage and the current increased suddenly also known as zener current. The breakdown or zener voltage depends upon the amount of doping. If the diode is heavily doped, depletion layer will be thin and thus the reverse voltage is lowered and if diode is lightly doped the depletion layer is thick and higher the breakdown voltage. So when an ordinary diode is properly doped to have a required breakdown voltage it is called a zener diode. A zener diode always connected in reverse bias in circuit.

Zener diode as voltage stabilizer

A zener diode can be used as a voltage regulator/stabilizer to provide a constant voltage from a source shoes voltage may vary over a sufficient range. The zener diode of required zener voltage V_Z is reversely connected across the load

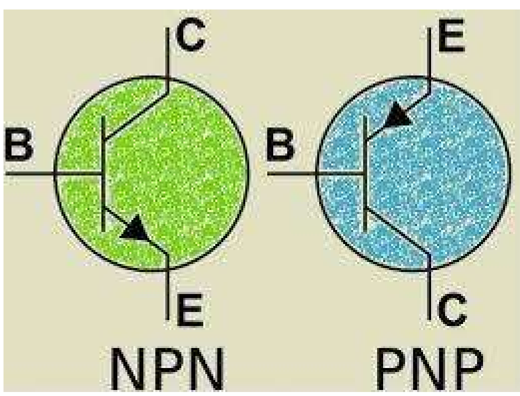


R_L where a constant output voltage is desired. The series resistance R absorbs the output voltage fluctuations so as to maintain constant voltage across the loads. It may be noted that the zener will maintain a constant voltage V_Z (=E_o) across the load so long as the input voltage does not fall below Vz. Suppose the input voltage E_{in} exceeds the zener voltage Vz. This brings the zener diode in the equivalent to a battery Vz. It is clear that out put voltage remains constant at Vz(=Eo). The excess voltage is dropped across the series resistance R. it is because now the zener conducts current flowing through r causes the excess voltage drop across it.

Transistors

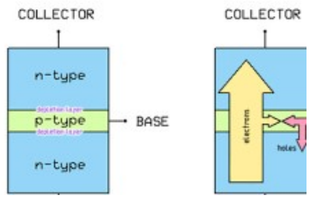
A transistor is a very important active component which consists of two PN junctions formed by sand witching either P type or N type material between a pair of opposite types.

Accordingly there are two types of transistors namely i. NPN transistor ii. PNP transistor



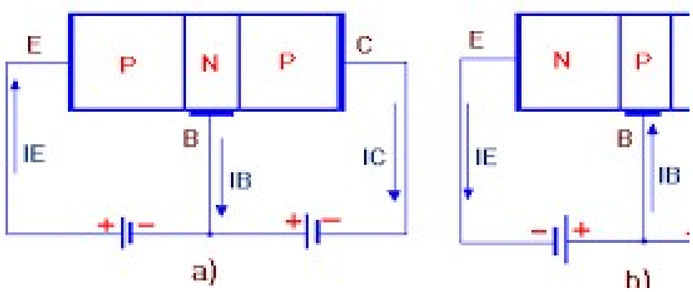
A transistor has two PN junctions. As discussed later, one junction is forward biased and other is reverse biased. The forward biased junction has a low resistance path where as reverse biased junction has a high resistance path. The weak signal is introduced in the low resistance circuit and output is taken from the high resistance circuit. There fore a transistor transfer a signal from a low resistance to high resistance.

A transistor has mainly three sections, Emitter, Bas, Collector.



Emitter is heavily doped region and it emits majority charge carriers from it to collector through base region.

Collector always collects or receives majority charge carriers from emitter through base. It is moderately doped compared emitter but wider in area compared to emitter.
The middle section which forms two PN junction between the emitter and collector is called base. This is very thin and low doped compared to emitter and collector.
The transistor has two PN junction I.e. It is like two diodes. The junction between emitter and base may be called emitter base diodes or simply the emitter diode. The junction between the base and collector may be called collector base diode or simply collector diode.
The emitter diode is always forward biased where as collector diode is always reverse biased. The resistance of emitter diode is very small as compared to collector diode (reverse biased). Therefore forward bias applied to the emitter diode is generally very small where as reverse bias on the collector diode is much higher.



Working of NPN transistor

Here emitter base is forward bias and base collector is reverse bias
and base collector is reverse bias. The forward bias at emitter base junction causes the electrons in emitter (N type) to flow towards base. This constitutes the emitter current I_E. As these electrons flow through the P type base they tend to combine with holes. Since the base is lightly doped and very thin, therefore only a few electrons
(less than 5%) combines with holes to constitute base current I_B. The remainder (more than 95%) crosses over into the collector region to constitute collector current. In this way almost the entire emitter current flows in the collector circuit. It is clear that emitter current is the sum of collector and base currents.

$$I_E = I_B + I_C$$

Working of PNP transistor

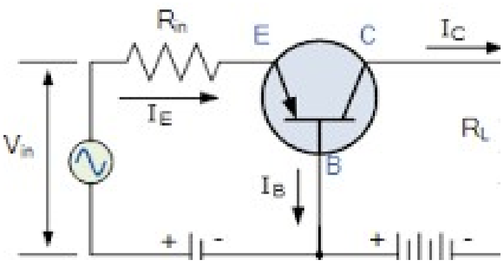
Here emitter base is forward biased. The forward bias causes the holes in the P type emitter to flow towards the base. This constitutes the emitter current I_E. As these holes cross into the N type base they tend to combine with electrons. As the base is lightly doped a few holes (Less than 5%). The remainder (more than 95%) cross into the collector region to constitutes collector current I_C. In this way almost the enter emitter current flows in the collector circuit. It may be noted that current conduction within PNP transistor is by holes. However in the external connecting wires the current is still by electrons.

Transistor Connections

As for any circuit there are two terminals for input and two terminals for out put connection is required but transistor has only three terminals therefore one out of three terminals is made common. By basing common terminal there are three transistor connections.

1. Common base connection 2. Common emitter connection 3. Common collector connection

1. Common Base connection: -- In this circuit arrangement input is applied between emitter and base and output is taken from collector and base.



Current amplification factor (α) – It is ratio of out put current to input current. In a common base connection the input current is I_E and out put current is I_C The ratio of change in collector current to the change in emitter current at constant collector base voltage V_{CB} is know as current amplification factor.

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

Where ΔI_C and ΔI_E are change in collector and emitter current.

From the above it is clear that current amplification factor is less than unity. Maximum value of α can be 1 (unity). But practical value of α in commercial transistors ranges from .9 to .99.

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Collector current:--

We know that $\alpha = \Delta I_C / \Delta I_E$ therefore $\Delta I_C = \alpha \Delta I_E$

As base collector is reverse biased so a small leakage current i.e. $I_{leakage}$ flows in base collector region.

Hence the total collector current $I_C = \alpha \Delta I_E + I_{leakage}$

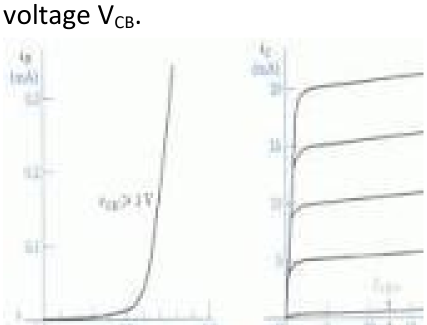
If $I_E = 0$ i.e. emitter circuit is open a small leakage current still flows in the collector circuit. This $I_{leakage}$ is abbreviated as I_{CBO} , means collector base current with emitter open.

$$I_C = \alpha \Delta I_E + I_{CBO}$$

The current I_{CBO} is usually small and may be neglected in transistor circuit calculations. At first sight it might seem that since there is no current gain, therefore no voltage or power amplification could be possible with this arrangement. However it may be recalled that output circuit resistance is much higher than the input circuit resistance. Therefore it does give raise to voltage and power gain.

Characteristics of common base connections.

Input characteristics:- It is the curve between emitter current I_E and emitter base voltage V_{EB} at constant collector base voltage V_{CB}.



1. The emitter current I_E increases rapidly with small increase in V_{EB}. It means input resistance is very low.

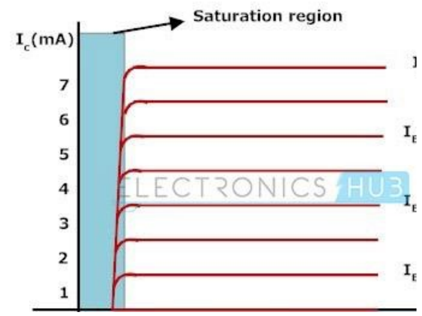
2. The emitter current is almost independent of collector base voltage V_{CB}. This leads to the conclusion that emitter current and hence collector current is almost independent of collector voltage.

$$\text{Input resistance} = \Delta V_{EB} / \Delta I_E \text{ at constant } V_{CB}$$

Input resistance of base emitter is very low in order of few ohms.

Out put characteristics:-

It is curve between collector current I_C and collector base voltage V_{CB} at constant emitter current I_E.



1. The collector current I_C varies with V_{CB} only at very low voltage. The transistor is inoperative in this region. 2. When the value of V_{CB} is raised above 1 – 2 v the collector current becomes constant as indicated by straight horizontal curves. It means that at this stage I_C is independent of V_{CB} and depends upon I_E. The transistor is operative in this region.

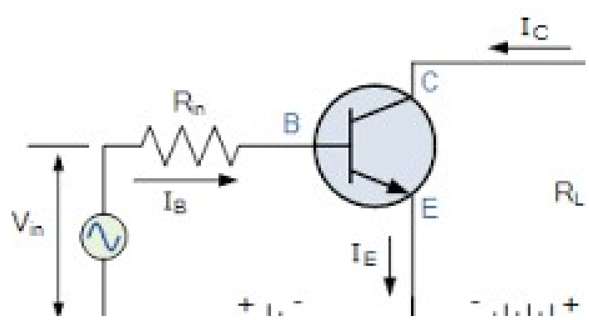
3. A very large change in collector base voltage produces only a tiny change in collector current.

Output resistance :- It is the ratio of change in collector – base voltage i.e. ΔV_{CB} to the change in collector current i.e. ΔI_C at constant emitter current. O/P Resistance = $\Delta V_{CB} / \Delta I_{C.}$ at constant I_E.

The output resistance of CB circuit is very high of the order of several tens of kilo-ohms.

Common emitter connection :-

In this circuit arrangement input is applied between base and emitter, and output is taken from the collector and emitter.



Base current amplification factor (β)

In common emitter connection, input current is I_B and output current is I_C. The ratio of change in collector current ΔI_C to the change in base current ΔI_B is known as base current amplification factor.

$$\beta = \Delta I_C / \Delta I_B$$

In almost any transistor, less than 5% emitter current flows as the base current. There fore the value of β is generally greater than 20 and usually its value ranges from 20 to 500. This type of connection is frequently7 used as it gives appreciable current gain as well as voltage gain.

Relation between β and α

$$\beta = \Delta I_C / \Delta I_B$$

$$\alpha = \Delta I_C / \Delta I_E$$

$$\text{We know that } \Delta I_E = \Delta I_B + \Delta I_C$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$

Substituting the value of ΔI_B in expression for β we get

$$\beta = \Delta I_C / (\Delta I_E - \Delta I_C)$$

Dividing the numerator and denominator of RHS by ΔI_E we get

$$\beta = \Delta I_C / \Delta I_E \,/\, (\Delta I_E / \Delta I_E) - (\Delta I_C / \Delta I_E)$$

$$\beta = \alpha / (1 - \alpha)$$

It is clear that as α approaches unity, β approaches infinity. In other words the current gain in common emitter connection is very high. It is due to this reason that this circuit arrangement used in about 90 to 95% of all transistor applications.

Expression for collector current

In common emitter circuit I_B is input current and I_C is the output current.

$$\text{As we know that } I_E = I_B + I_C \text{ ------------i}$$

$$\text{and } I_C = \alpha I_E + I_{CBO} \text{ ------------------ii.}$$

From the expression ii we get

$$I_C = \alpha I_E + I_{CBO}$$

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

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

$$I_C = \{\alpha / (1 - \alpha)\} I_B + I_{CBO} / (1 - \alpha) \text{ ----------iii.}$$

From expression iii it is apparent that if $I_B = 0$ i.e. base circuit is open the collector current will be the current to the emitter. This is abbreviated as I_{CEO} meaning collector-emitter current with base open. $I_{CEO} = I_{CBO} / (1 - \alpha)$.

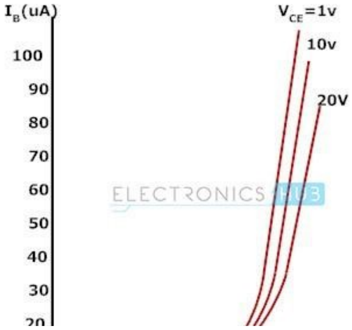
Substituting the value of $I_{CEO} = I_{CBO} / (1 - \alpha)$ in expression iii. We get

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

$$I_C = \beta I_B + I_{CEO} \quad \text{where } \beta = \alpha / (1 - \alpha)$$

Characteristics of common emitter connection

Input characteristics:-- It is the curve between base current I_B and base emitter voltage V_{BE} at constant collector emitter voltage V_{CE}.



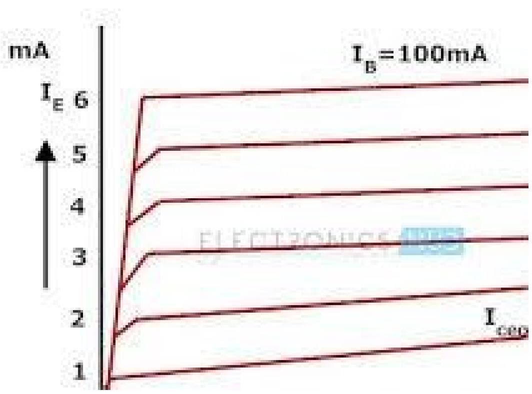
The graph drawn between the various values of V_{BE} (base emitter voltage) to corresponding values of base currents I_B , keeping V_{CE} constant. I_B is along Y axis and V_{BE} is along X axis.
The following points may be noted.

1. The characteristics resemble that of a forward biased diode curve. This is because base-emitter section of transistor is a diode and it is forward biased.
2. As compared to CB arrangement I_B increases less rapidly with V_{BE}. Therefore input resistance of a CE circuit is higher than that of CB circuit.

Input resistance – It is the ratio of change in base – emitter voltage (Δ V_{BE}) to change in base current (Δ I_B) at constant V_{CE} input resistance $R_i = \Delta V_{BE} / \Delta I_B$ at constant V_{CE}

The value of input resistance for a CE circuit is of the order of few hundred ohms.

Out put characteristics:- It is the curve between collector current I_c and collector emitter voltage V_{CE} at constant base current I_B.

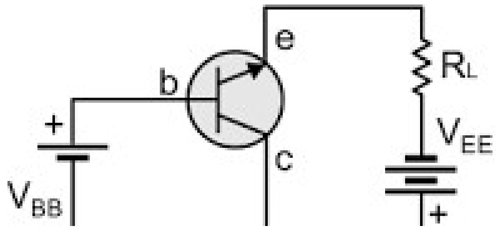


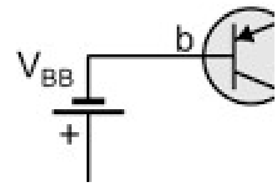
The following points may be noted.

1. The collector current I_C varies with V_{CE} for V_{CE} between 0 to 1v. After this collector current becomes almost constant and independent of V_{CE}. This value of V_{CE} up to which collector current I_C changes is called the knee voltage V_{knee} . The transistor always operated in the region above knee voltage.
2. Above knee voltage I_C is almost constant. However a small increase in I_C with increasing V_{CE} is caused.
3. For any value of V_{CE} above knee voltage the collector current I_C is approximately equal to $\beta \times I_B$.

Out put resistance :- It is the ratio of change in collector emitter voltage Δ V_{CE} to the change in collector current (Δ I_C) at constant I_B. out put resistance = $\Delta V_{CE} / \Delta I_C$
Its value is of the order of 50KΩ.

Common collector connection :- In this circuit arrangement input is applied between base and collector while output is taken from emitter and collector





Current amplification factor:- In common collector circuit input current is base current I_B and output current is emitter current I_E.

The ratio of change in emitter current ΔI_E to the change in base current ΔI_B is know as current amplification factor in common collector arrangement.

$$\acute{Y} = \Delta I_E / \Delta I_B$$

$$\alpha = \Delta I_c / \Delta I_E$$

$$\text{since } I_E = I_B + I_c$$

$$\Delta I_E = \Delta I_B + \Delta I_c$$

$$\Delta I_B = \Delta I_E - \Delta I_c$$

$$\acute{Y} = \Delta I_E / (\Delta I_E - \Delta I_c)$$

Dividing the numerator and denominator by ΔI_E

$$\acute{Y} = \Delta I_E / \Delta I_E \,/\, (\Delta I_E - \Delta I_c)/\Delta I_E$$

$$= 1/ 1-(\Delta I_c / \Delta I_E)$$
$$= 1/ 1- \alpha$$

Expression for collector current

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

Also $I_E = I_B + I_c$

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

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

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

$$\text{Or } I_E = I_B (\beta + 1) + I_{CBO}(\beta + 1)$$

Application :- The common collector circuit has very high input resistance (about 750 kΩ) and very low out put resistance (about 25 kΩ). Due to this reason the voltage gain provided by this circuit arrangement is seldom used for amplification. How ever due to relatively high input resistance and low out put resistance this circuit is primarily used for impedance matching i.e. for driving a low impedance load matching i.e. for driving a low impedance load from a high impedance source.

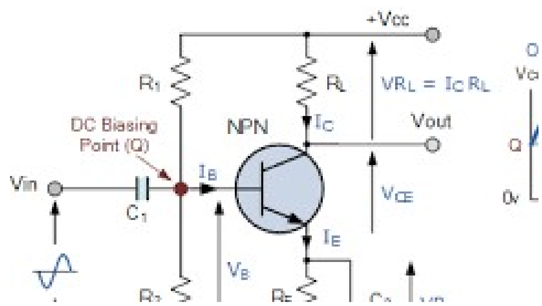
Commonly used transistor connection

Out of the three transistor connect ions the common emitter circuit is most efficient. It is used in about 90% to 95% of all transistor applications. The main reasons for the wide spread use of this circuit arrangement are

1. High current gain :- In a common emitter connection I_c is out put current and I_B is the input current. In this circuit arrangement collector current is given by $I_C = \beta I_B + I_{CEO}$. As the value of β is very large therefore I_C is much more than input put current I_B. Hence the current gain in CE arrangement is very high. It may range from 20 to 500.
2. High voltage gain and power gain :- Due to high current gain the common emitter circuit has the highest voltage and power gain of three transistor connections. This is the major reason for using the transistor in this circuit arrangement.
3. Moderate output to input impedance ratio :- In a common emitter circuit the ratio of output impedance to input impedance is small about 50. This makes this circuit arrangement an ideal one for coupling between various transistor stages. However in other connections the ratio of output impedance to input impedance is very large and hence coupling becomes highly in efficient due to gross mismatching

Transistor as an amplifier in CE arrangement.

Action :- During positive half of AC input signal



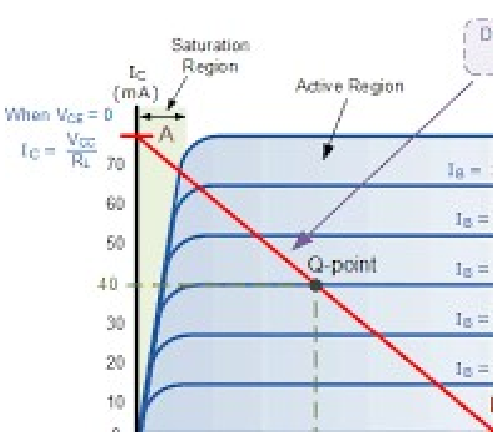
i. The input voltage V_{in} tends to increase as AC signal gets added with fixed base bias.
ii. This increase input voltage causes base current I_B to increase
iii. With increase in I_B the collector current I_C also increase by β times.
iv. The voltage drop $I_C R_L$ also increases.
vii. As result out put voltage V_{CC} has tendency to decrease and produces negative going amplified signal. Similar action can be assumed during –ve half of AC signal but this produces a +ve going amplified signal. Broadly speaking the output signal gets inverted and is at 180^o out of phase.

Current gain = out put current/ In Put current= $I_C/I_B = \beta$

Voltage gain = out put voltage/ In Put voltage = $I_C R_L / I_B R_i$

Power gain = $I_C^2 \times RL / I_B^2 \times R_i$

DC Load line



Let us consider a common NPN transistor circuit where no signal is applied. Therefore DC conditions prevail in circuit. The out put characteristics of this circuit are shown. The value of collector emitter voltage V_{CE} at any point is given by $V_{CE} = V_{CC} - I_C R_L$ As V_{CC} and R_L are fixed values. When collector current $I_C = 0$ then $V_{CE} = V_{CC.}$ This gives first point B (OB = V_{CC}) on the X axis i.e. collector emitter voltage axis. Ii. When collector emitter voltage $V_{CE} = 0$ the collector current is maximum and is equal to V_{CC} / R_C. $I_C = V_{CC} / R_C$.This gives second point A (O = V_{CC} / R_C) on the Y –axis i.e. collector current axis. By joining these two points DC load line AB is constructed.

Operating point

The zero signal values of I_c and V_{CE} are known as operating point. It is called operating point because the variations of I_C and V_{CE} take place about this point when signal is applied. It is called Q point quiescent point or silent point because it is the point on I_c - V_{CE} characteristic. When the transistor is silent i.e. in absence of signal

Field Effect Transistor

A BJT has two principle disadvantages

i. It has low input impedance as emitter junction is forward biased.

ii. It has considerable noise level

Field effect transistor is a three terminal semiconductor device in which current conduction is by one type of carrier i.e. electrons or holes.

In a FET the current conduction is either by electrons or holes and is controlled by means of an electric field between the gate electrode and the conduction channel of devices. The FET has high input impedance and low noise level.

Construction details :- A FET consists of a P type and n type silicon bar containing two PB junctions at the sides as shown in above figure. The bar forms the conduction channel for the charge carriers. If the bar is of n-type it is called n-channel FET. If the bar is P-type it is called a P-channel as shown. The two PN junctions forming diodes are connected internally and a common terminal gate is come out. Other terminals are source and drain taken out from the bar.

FET polarities :- The voltage between gate and source such that gate and source is such that the gate is reverse biased. The drain and source terminals are interchangeable i.e. either end can be used as source and the other end as drain.

Working principle of Field Effect Transistor

When a voltage V_{DS} is applied between drain and source terminal and it gate open then gate voltage zero the two PN junctions at the sides of bar establish depletion layers. The electrons will flow from source to drain through a channel between the depletion layers. The size of these layers determine the width of the channel and hence the current conduction through the bar. When reverse voltage V_{GS} is applied between the gate and source the width of depletion layer is increased. This reduces the width of the conduction channel. There by increasing the resistance of N-type bar. Consequently the current from source to drain is decreased. On the other hand if reverse voltage at gate is decreased the width of depletion layer also decreases. This increased the width of the conduction channel and hence source to drain current.

As the source drain current can be controlled by applying electric field on the gate that why the device is called Field Effect Transistor. The symbol of FET is

Difference between FET and bipolar transistor

1. In a FET there is only one type of carrier, holes in P-type channel and electrons in N-type channel. For this reason it is also called a uni-polar transistor. However in ordinary transistor both electrons and holes play part in conduction.

2. As the input circuit (i.e. gate to source)of a FET is reverse biased therefore the device has high input impedance. However the input circuit of one ordinary transistor is forward biased and hence has low impedance.
3. As the gate is reverse biased and gate circuit carries extremely small current and input voltage controls the o/p current. For this reason FET is essentially a voltage driven device. However ordinary transistor is current operated device i.e. input current controls the o/p current.
4. A bipolar transistor uses a current into base to control a large current between collector and emitter. Where as FET uses voltage on the gate terminal to control the current between drain and source. Thus a bipolar transistor gain is characterized by current gain where as the FET gain is characterized as a trans conductance i.e. the ratio of change in output current (drain current) to the input voltage.
5. In FET there are no junctions as in an ordinary transistor. the conduction is through an n type semiconductor material. For this reason noise level in FET is very small.

Advantages of FET

1. It has a very high input impedance of the order of 100MΩ this permits high degree of isolation between input and out put circuit.
2. The operation of a FET depends upon the bulk material current carriers that do not cross the junction. Therefore the inherent noise of those transistors are not present in a FET,
3. A FET has negative temperature Co-efficient of resistance. This avoids the risk of thermal runaway.
4. A FET has very high power gain. This eliminates the necessity of using driver stages.
5. A FET has a smaller size longer life and high efficiency.