

**Intermediate Vocational Course, 1st Year
ELECTRONIC DEVICES AND CIRCUITS
(For the Course of Electronics Engineering Technician)**

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1. Solid State Devices

1.0 Introduction to Solid State Devices (Semiconductor Devices)

The advent of transistor completely revolutionized the electronic industry and by the end of 1950's, the semiconductor devices almost fully replaced the electron tubes except for very high voltage or very high power applications due to the following merits of semiconductor devices; small size and weight, low cost, long life, very small power supply voltage, small power requirement, no filament heating power etc. Along with semiconductor diodes and transistor come other semiconductor devices such as special purpose diodes (zener diodes, tunnel diodes, photo diodes, varactor diodes, light emitting diodes etc), Field effect transistors (FET's), thyristors etc.

Use of transistors resulted in reduction in size and weight of electronic equipments. Further miniaturization of electronic equipments become possible in early 60's with the advent of integrated circuits (IC's). This IC Technology consists in simultaneous fabrication of all components, devices and inter connecting wires of an electronic circuit on a very small semiconductor wafer or chip. Further a large number of such IC chips are produced simultaneously. This results in reduction of the cost of IC chip. Rapid development in the IC technology resulted in increasing the density of packing is placing more and more components on the same small chip. This progressively gave rise to Small Scale Integration (SSI), Medium Scale Integration (MSI), Large Scale Integration (LSI), Very Large Scale Integration (VLSI) and Very Large Scale Integration (VVLSI). Currently IC's are popularly used in all electronic instruments and gadgets in preference to circuits using discrete semiconductor devices and components.

More recent advances in the field of electronics include the digital circuits, microprocessors, digital computers, optoelectronics, laser technology etc.

Applications of Electronics

Today electronics have invaded every walk of life and its applications are increasing at a very fast rate. Broadly, the various applications of electronics may be put into the following categories.

- | | |
|------------------------------|------------------------------------|
| 1. Communications | 5. Medical Electronics |
| 2. Entertainment Electronics | 6. Instrumentation |
| 3. Industrial Electronics | 7. Navigation and Aircraft Landing |
| 4. Defence Electronics | 8. Telemetry |

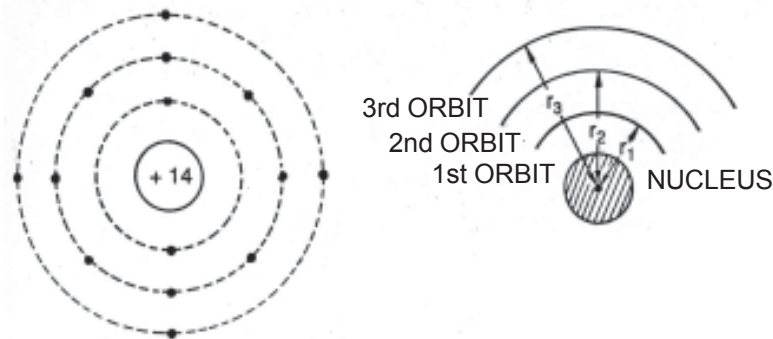
1.1 Atomic Structure K,L,M,N Energy levels, Valence Electrons

Bohr's Atomic Model:

In 1913, Neils Bohr, Danish Physicist gave clear explanation of atomic structure.

According to Bohr:

- (i) an atom consists of a positively charged nucleus around which negatively charged electrons revolve in different circular orbits.
- (ii) The electrons can revolve in different circular orbits outside Nucleus.
- (iii) The electrons in each permitted orbit have a certain fixed amount of energy. The larger the orbit (ie larger radius), the greater is the energy of electrons.
- (iv) If an electron is gain additional energy (e.g. heat, light etc), it is lifted to the higher orbit. The atom is said to be in a state of excitation. This atom is said to be in a state of excitation. This state does not last long, because the electron soon falls back to the original lower orbit. As it falls, it gives back the acquired energy in the form of heat, light.



The figure shows the structure of silicon atom. It has 14 electrons. Two electrons revolve in the first orbit, 8 in the second orbit and 4 in the third orbit. The first second third orbits etc. are also known as K,L,M,N orbits respectively.

Energy Bands:

In case of a single isolated atom, the electron in any orbit possess definite energy. However, an atom in a solid is greatly influenced by the closely-packed neighboring atoms. The result is that the electron in any orbit of such an atom can have a range of energies rather than a single energy. This is known as energy band.

The range of energies possessed by an electron in a solid is known as energy band.

Important Energy bands in Solids:

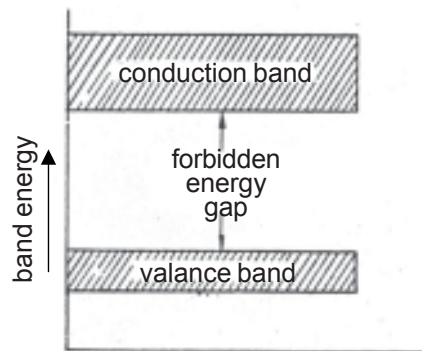


Fig 1.2

The individual K,L,M,N etc. energy levels of an isolated atom are converted into corresponding bands when the atom is in a solid. The following energy bands are important in a solid.

Valence band:

The range of energies possessed by valence electrons in outer most orbit is known as valence band. The electrons in the outer most orbit of an atom are known as valence electrons.

Conduction band:

The range of energies possessed by conduction band electrons is known as conduction band. All electrons in the conduction band are free electrons.

Forbidden Energy Gap:

The gap between conduction band and valence band on the energy levels diagram is known as forbidden energy gap.

1.2 Inter Atomic Bonds:**(i) Germanium :**

Germanium has become the model substance among the semiconductor the main reason being that it can be purified relatively well advanced crystallised form easily.

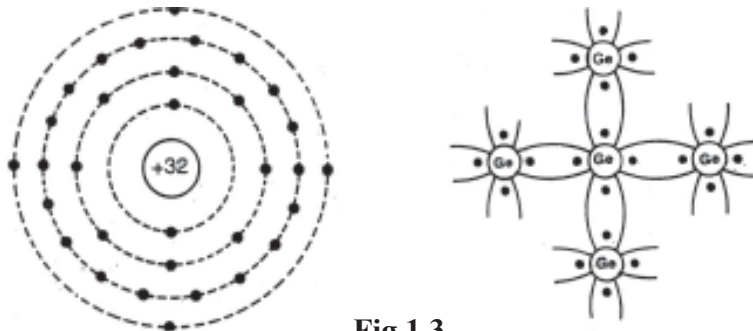
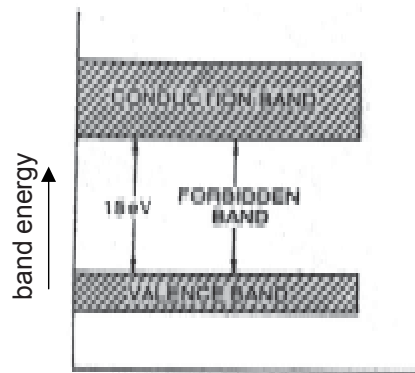


Fig 1.3

The atomic number of Germanium is 32. Therefore it has 32 protons and 32 electrons. Two electrons in the first orbit, eight electrons in the second, eighteen electrons in the third and four electrons in the outer or valence orbit. It is clear that Germanium atom has four valence electrons ie it is a tetravalent element. The above fig shows how the two Germanium atoms are formed covalent bonds.

(ii) Silicon :

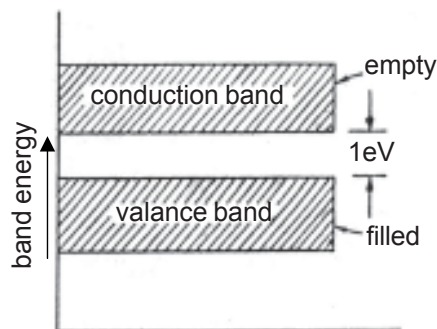
Silicon is an element in most of the common rocks

(ii) Insulators:**Fig 1.0**

Insulators (e.g. wood, glass) are those substances which do not allow the passage of electric current through them. The valence band is full, while the conduction band is empty. The energy gap between valence and conduction bands is very large ($=15\text{ eV}$) as shown in the fig. Therefore a very high electric field is required to push the valence electrons to the conduction band. For this reason the conductivity of such materials is extremely small and offers very high resistivity and behaves as an insulator.

(iii) Semiconductors:

Semi conductors germanium, silicon are those substances whose electrical conductivity lies in between conductors and insulators. The valence band is almost filled and conduction band is almost empty.

**Fig 1.7**

The energy gap between valence and conduction bands is very small as shown in the fig. Therefore, comparatively smaller electric field is required to push the electrons from the valence band to the conduction

band. The electrical conductivity of a semiconductor increases with the rise in temperature i.e. a semiconductor has negative temperature coefficient of resistance.

1.4 Electrical properties of semiconductor materials:

- (i) The resistivity of a semiconductor is less than an insulator but more than a conductor.
- (ii) Semiconductors have negative temperature coefficient of resistance i.e. the resistance of a semiconductor decreases with the increase in temperature and vice-versa.
- (iii) When a suitable metallic impure arsenic, gallium is added to a semiconductor, its current conducting properties change appreciably.

1.5 Intrinsic and Extrinsic Semiconductors:

Intrinsic Semiconductor:

A semiconductor in its pure form is known as an Intrinsic semiconductor. There are two types of intrinsic semiconductors. They are

- i) P-type intrinsic semiconductor
- ii) N-type intrinsic semiconductor

P-type Intrinsic Semiconductor

In this semiconductor the majority carriers are holes and there is no electrons.

N-type Intrinsic Semiconductor

In this semiconductor the majority carriers are electrons and there is no holes.

Doping:

The process of adding impurities to a pure form of semiconductor is known as doping. Generally, for 10^6 to 10^8 atoms of semiconductor, one impurity atom is added.

Extrinsic Semiconductor:

The impure form of semiconductor is known as extrinsic semiconductor.

1.6 Formation of P-type and N-type materials:

P-type semiconductor:

When a small amount of trivalent impurity is added to a pure form of semiconductor. P-type semiconductor is formed. In this the majority carriers are holes and the minority carriers are electrons. The trivalent impurities are Gallium, Indium.

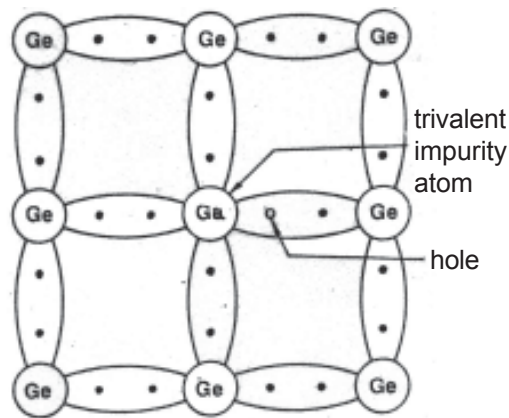


Fig 1.8

N-type semiconductor:

When a small amount of pentavalent, tetravalent impurity is added to a pure semiconductor, an N-type semiconductor is formed. In this the majority carriers are electrons and minority carriers are holes. The pentavalent impurities are antimony, arsenic.

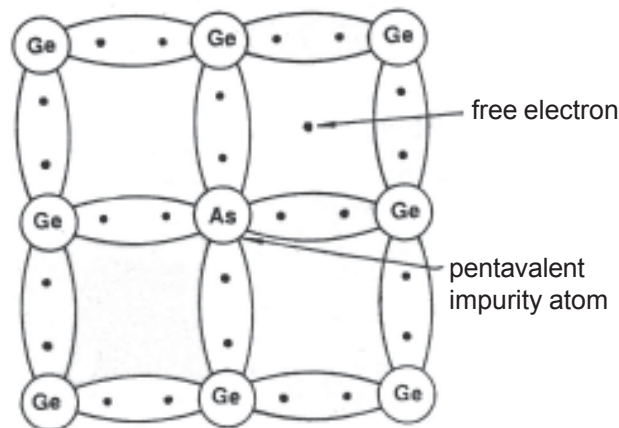


Fig 1.9

button serves as a suitable base for soldering on leads.

Working of PN Junction diode:

1. Forward biasing :

At room temperature the majority carriers in each semiconductor cross the PN-Junction.

When external voltage applied positive terminal of the battery to anode or P-type semiconductor and negative terminal is connected to the N-type semiconductor then the diode is said to be connected in forward bias mode.

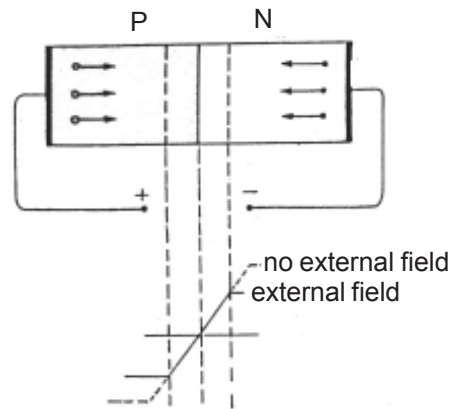


Fig 1.11

Potential barrier :

The majority carrier which were crossed across the junction. The majority carriers sharing opposite charge carriers present at the junction is called potential barrier.

Therefore the PN junction required minimum amount of voltage the minimum cut of voltage to conduct a diode is 0.2V, 0.3V for germanium diodes in the case of silicon diode the minimum cut of voltage is 0.6V, 0.7V. In this forward bias condition the junction offers low resistance due to sharing of majority charge carrier.

2. Reverse Biasing:

When P-type semiconductor is connected to negative terminal of the supply and N-type semiconductor is connected to positive terminal of the supply then the connection is the said to be the diode is connected in

reverse bias mode. In this condition the majority carriers gap increases due to directly attracting the holes in P-type semiconductor to the electrons of the cathode / negative terminal of supply, the N-type semiconductor and the electrons are attracted towards holes in the anode supply resulting the gap between P&N-type semiconductor increases resulting it offers very high resistance in reverse bias mode.

With increase in temperature the kinetic energy of minority charge carriers increases due to negative temperature coefficient of the semiconductor. Due to this phenomena the minority carrier comes into the picture the small of current flows across the PN junction. This is order of micro ampere. This results few hundreds of kilo ohm resistance of in reverse bias mode.

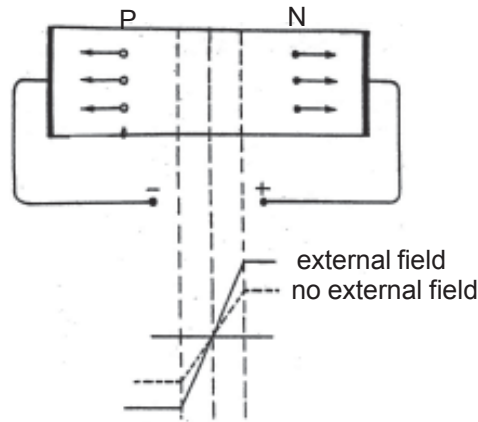


Fig 1.12

Volt-Ampere Characteristics of PN Junction:

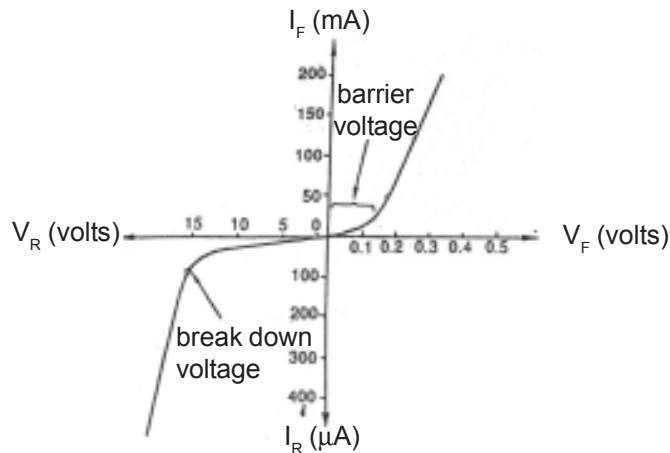


Fig 1.13

(i) Zero external Voltage :

When the external voltage is Zero, the potential across the junction and there is no current flow, as indicated by point 0 in fig.

(ii) Forward bias :

With forward bias to the PN Junction, the potential barrier is reduced. At some forward voltage (0.7V for Si and 0.3V for Ge), the potential barrier is altogether eliminated and current starts flowing in the circuit. From now onwards, the current increases with the increase in forward voltage. Thus a rising curve 0B is obtained with forward bias as shown in fig.

(iii) Reverse bias:

With reverse bias to the PN Junction, potential barrier at the junction is increased. Therefore the junction resistance becomes very high and practically no current flows through the circuit. However, in practice, a very small current (of the order of mA) flows in the circuit with reverse bias as shown in fig. This is called reverse saturation current (I_s) and is due to the minority carriers.

Zener Diode :

It is a P-N Junction Silicon diode. Its safe inverse voltage or breakdown voltage is kept lower than that of any ordinary diode and each diode is designed to have a specific breakdown voltage. The amount of leakage current increases suddenly by increasing the reverse bias. The current flowing through the zener diode on breakdown voltage is called avalanche current or zener current. A zener diode is used in voltage regulator circuit as shown in the fig (A voltage regulator circuit controls the voltage variations).

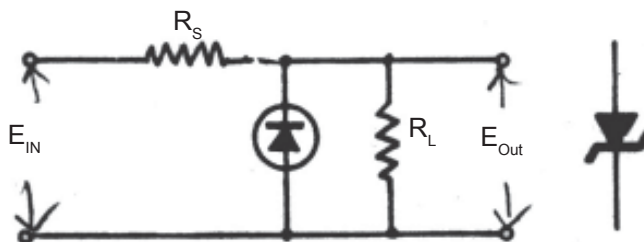


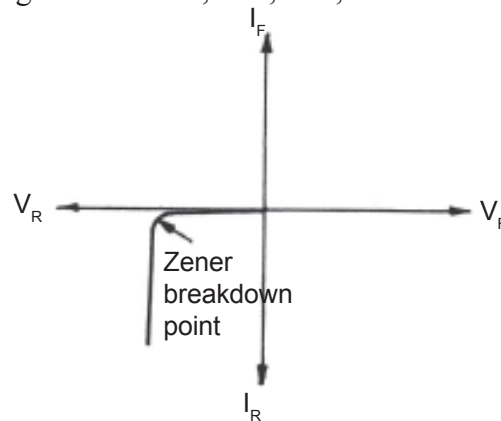
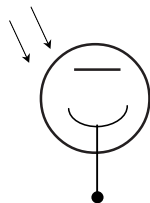
Fig 1.14

Working :

A zener diode is connected across the voltage to be regulated with a series resistor in opposite polarity. The load resistor is connected in parallel to the zener diode.

When the input voltage rises beyond the breakdown voltage of the zener diode, the conduction of current is started through the series resistor R_s . The magnitude of current flowing through R_s is equal to the sum of the currents i.e. zener, load current. The magnitude of current through R_s will increase further for increase in the input voltage. But due to the decreased zener resistance, only the magnitude of zener current will increase and not the magnitude of load current. Now, there will be more voltage drop across R_s . and the output voltage will remain unchanged. In this way, the circuit can effectively work for small changes of input voltage of even less than one volt.

When the diode is connected in reverse bias mode with increase in anode to cathode voltage, due to leakage currents the zener offers breakdown voltage. Generally the zener referred as keeping in view of the breakdown voltage. for Ex. 9V, 12V, 24V, etc.

**Fig 1.15****Photo Diode:****Fig 1.16**

In the photo diode cadmium sulphide or cadmium sulphide-selamide is deposited on a ceramic base and then the device is enclosed in a glass envelope. Cadmium sulphide is a semiconductor and its resistance decreases with the incidence of light rays on it. If the resistance of a photo diode in dense darkness is 10 mega ohms then its resistance will remain only 300 ohms in the presence of 92 foot - candle light. It is used in automatic flash system in phot cameras where the photo diode does not allow the shutter of the camera to get open in dim light.

L.E.D (Light Emitting Diode):

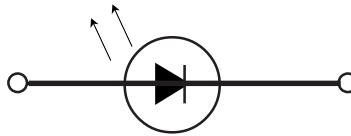


Fig 1.17

It is a special type of diode which is different from a conventional semiconductor diode. It employs a Gallium-Arsenide (Ga As) or Gallium phosphide (Ga P) PN Junction instead of a Germanium or silicon PN-Junction. The device is then used as a light indicator in electronic equipments for various visual display purposes. In LED, the rate of recombination of holes and free electrons is much higher due to which energy packets (photons) are released by the PN Junction in the form of light rays of visible and infrared spectrum.

Common type of LED's are operated at a forward bias of IV to 3V and they emit light at a current of 10 to 15 mA. They are made in 4 different colours - green, red, yellow and blue.

Varactor Diode:

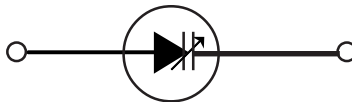


Fig 1.18

It is a PN Junction diode designed to work at high frequencies. Its internal capacitance depends on the voltage applied across it, whereas in an ordinary diode the same is limited to a minimum possible value. Since the internal capacitance of a varactor diode varies in accordance with the signal applied, hence it is used for amplification, frequency multiplication and switching purposes. The effective capacitance of a varactor diode depends on the reverse bias voltage applied to varactor diode.

Applications :

The device can be used in RF tuning circuit tuner in TV receivers in different channels. This type of circuit can be used in remote controlled tuning circuit of receivers.

1.8 Introduction to Transistors:

The transistor was developed shortly after the invention of a P-N Junction diode. A transistor is used for amplification.

Primarily, transistors are of two types- NPN and PNP. A PNP transistor consists of two P-regions and a very thin N-region between them. Similarly, a N-P-N transistor consists of two N-Regions and a very thin P-region between them.

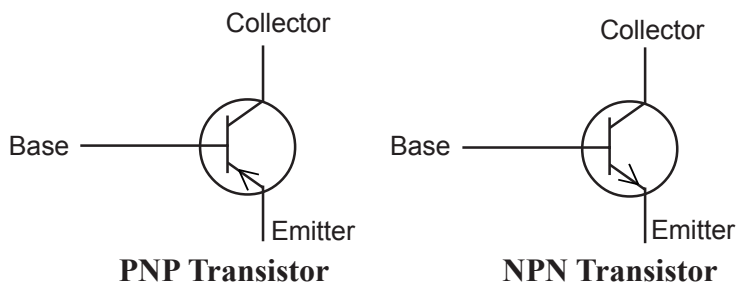


Fig 1.19

Bipolar and unipolar transistors:

The conduction of current in both types of transistors (NPN and PNP) takes place by the movement of 'free electrons' and 'holes'. Such transistors are called bipolar transistors. In this both voltage current amplification is done in the case of in unipolar transistors, the conduction of current takes place either voltage mode of operation or current mode of operation.

1.9 Formation, working and properties of PNP and NPN transistor:

Working of a P-N-P Transistor:

In a transistor emitter is heavily doped, collector is moderately doped and base thinly doped. A P-N-P transistor in forward bias state is shown in the fig. Its emitter is connected to the positive and collector to the negative terminal of the battery. A small amount of negative voltage is applied to the base also.

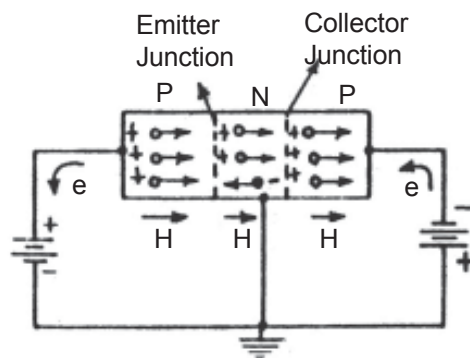


Fig 1.20 PNP Transistor Circuit

The positive potential of the emitter repels the holes towards the 'emitter-junction'. N-type material of the base has a natural attraction for the holes repelled by the emitter some of the holes combine with free electrons in the base region but most of them are attracted by the strong negative potential of the collector. In this way, holes drift from emitter region to 'emitter-junction', through base region to the 'collector junction' and finally reach the collector region. In a transistor base to emitter junction is forward biased and collector to base junction is reversed bias.

In this way in a PNP transistor, the holes drift from emitter to collector, consequently the equal number of free electrons move from collector to emitter. The free electrons complete their circuit by moving from emitter to collector through battery etc. in the external circuit. The number of holes drifting from emitter region to collector region is controlled by the base bias and due to this very property, a transistor is used for amplification etc.

Working of a N-P-N transistor:

A N-P-N transistor in forward bias state is as shown in fig. Its emitter is connected to the negative and the collector to the positive terminal of the battery. A small amount of the positive voltage is applied to the base to emitter.

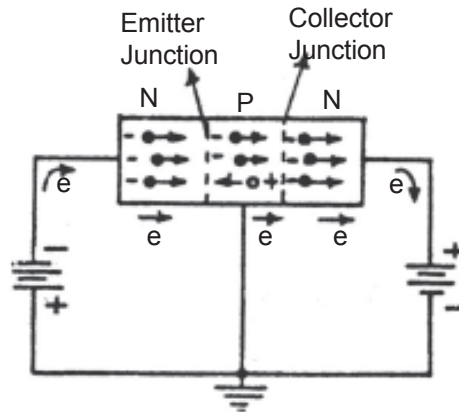


Fig 1.21 NPN Transistor Circuit

The negative potential of the emitter repels the free electrons towards the 'emitter junction'. P-type material of the base has a natural attraction for the free electrons repelled by the emitter. Some of the free electrons combine with holes in the base region but most of them are attracted by the strong positive potential of the collector. In this way, free electrons move from emitter region to 'emitter-junction', through the base region to the 'collector-junction' and finally reach the collector region.

The free electrons are the media for the conduction of current in a N-P-N transistor and in its external circuit. The number of free electrons reaching the collector is controlled by the base bias and due to this very property, a transistor is used for amplification etc. The base-emitter junction offers low resistance and collector-base junction offers very high resistance.

1.10 Transistor Configurations, Input and Output Characteristics. Define alpha, beta, I_{co} , Relation between alpha and beta.

A transistor can be connected in three configurations in a circuit which are called three basic configurations. Input signal can be applied

between any two electrodes of a transistor and the output can be taken from the third electrode and the electrode kept common. The three basic connections are:

- 1) Common Base Circuit (CB)
- 2) Common Emitter Circuit (CE)
- 3) Common Collector Circuit (CC)

1. Common Base Circuit :

A common base circuit is shown in the fig. Here the input is applied between the base and the emitter and the output is taken from the base and the collector. In this way the base remains common in this circuit. The circuit has a low input impedance (50 to 500 Ω) and a high output impedance (1 to 10M Ω). The current gain is less than unity.

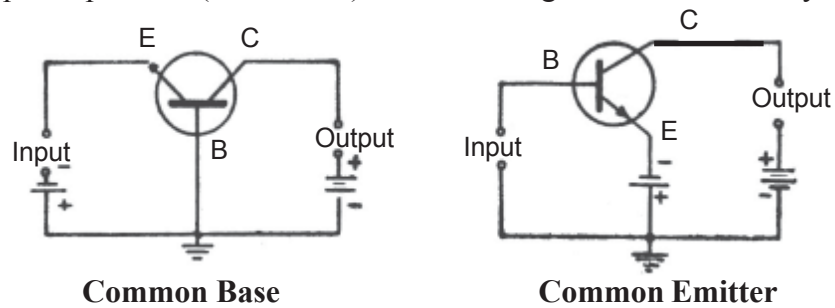


Fig 1.22

Input Characteristics:

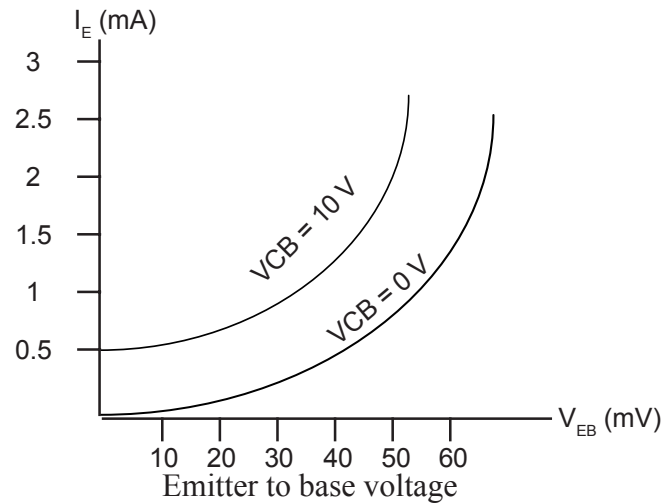


Fig 1.23

It is the curve between emitter current I_E and emitter-base voltage V_{EB} at constant collector base voltage V_{CB} . The emitter-current is generally taken along Y-axis and emitter-base voltage along X-axis. The following points may be noted from these characteristics.

- (i) The emitter current I_E increases rapidly with small increase in emitter-base voltage V_{EB} . It means that increase in input resistance is very small.
- (ii) The I_E is almost independent of V_{CB} . This means that I_E (and hence I_C) is almost independent of collector voltage.

Output Characteristics:

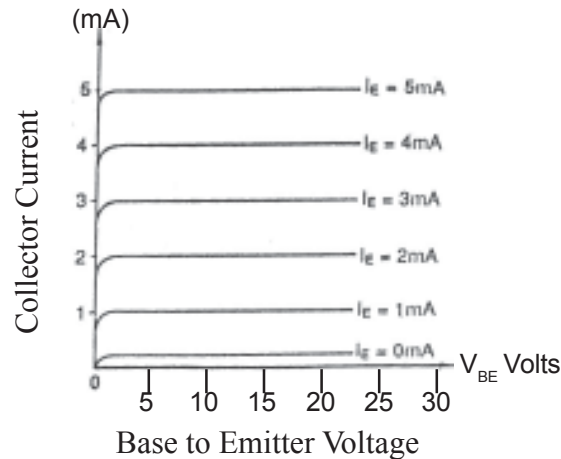


Fig 1.24

It is the curve between collector current I_C taken along Y-axis and collector-base voltage V_{CB} taken along X-axis at constant emitter current I_E .

The following points may be noted down from the characteristics.

- (i) The collector current I_C varies with V_{CB} only at very low voltages ($<1\text{V}$). The transistor is never operated in this region.
- (ii) When the V_{CB} is raised above $1\text{-}2\text{V}$, the collector current becomes constant as indicated by straight horizontal curves. It means that now I_C is independent of V_{CB} and depends upon I_E only. This shows that I_E flows almost entirely to the collector terminal. The transistor is always operated in this region.
- (iii) A very large change in V_{CB} produces only a tiny change in I_C . This means that output resistance is very high.

Current Amplification factor (α) :

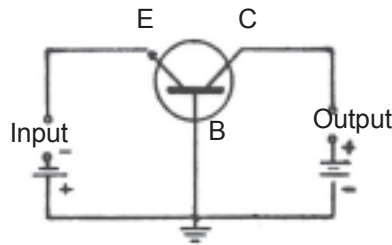
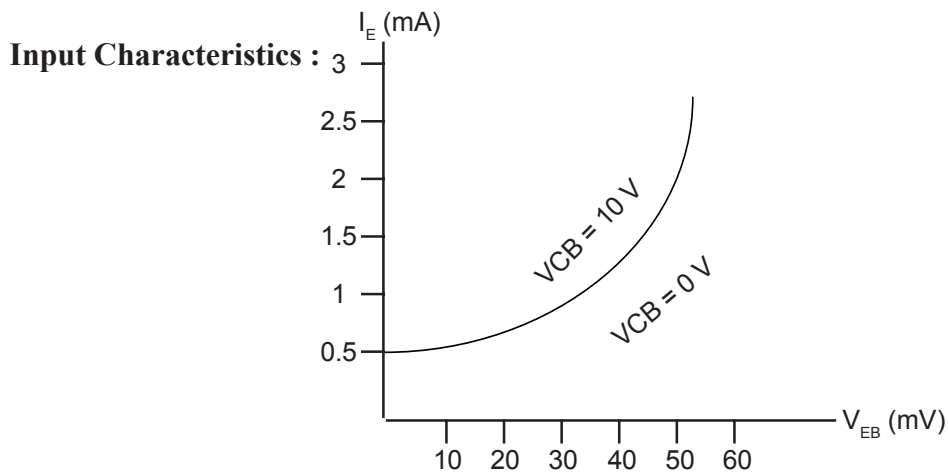
It is the ratio of change in collector current to the change in emitter current at constant collector-base voltage V_{CB} is known as current amplification factor. i.e.

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

It is clear that α is less than unity. Practical values of α in commercial transistors range from 0.9 to 0.99

Common Emitter Connection :

A common emitter circuit is shown in the fig. Here the input is applied between the emitter and base and the output is taken from the emitter and collector. In this way, the emitter remains common to both input and output. The circuit has a input impedance is $1K\Omega$ to $2K\Omega$. The output impedance is above $100K\Omega$. The current gain β of this circuit 20-200.

**Common Base****Fig 1.25****Fig 1.26**

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

The following points may be noted from the curve

- (i) The input characteristic resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode which is forward biased.
- (ii) 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.

Output Characteristics :

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

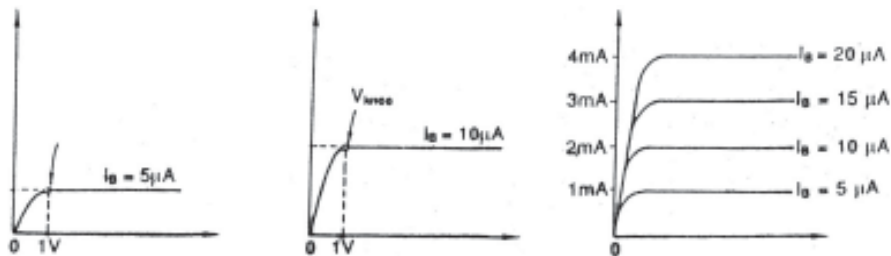


Fig 1.26

The following points may be noted from the characteristics :-

- (i) The collector current I_C varies with V_{CE} for V_{CE} between 0 to V_{knee} only. After this I_C becomes almost constant and independent of V_{CE} . This value of V_{CE} upto which I_C changes with V_{CE} is called the knee voltage V_{knee} . The transistors are always operated in the region above V_{knee} voltage.
- (ii) Above the V_{knee} voltage, I_C is almost constant.
- (iii) For any value of V_{CE} above V_{knee} voltage, the collector current I_C is approximately equal to I_B .

Base current Amplification Factor (β):

The ratio of change in collector current (I_C) to the change in base current (I_B) is known as base current amplification factor.

$$\text{ie } \beta = \frac{I_C}{I_B}$$

I_{CEO} : In CE configuration, a small collector current flows when the base current is zero. This is collector cutoff current i.e. these are called reverse saturation currents the collector current that flows when base is open and is denoted by I_{CEO} (collector to emitter reverse saturation current). The value of I_{CEO} is much larger than I_{CBO} (collector to base reverse saturation current).

Relation between α and β :

$$\text{Now, } \beta = \frac{I_C}{I_B} \quad (\text{i})$$

$$\alpha = \frac{I_C}{I_E} \quad (\text{ii})$$

$$\text{Now, } I_E = I_B + I_C$$

Substituting the value of I_B in exp (i), we get

$$\beta = \frac{I_C}{I_E - I_C} \quad (\text{iii})$$

Dividing the numerator and denominator of R.H.S of exp (iii) by I_E , we get

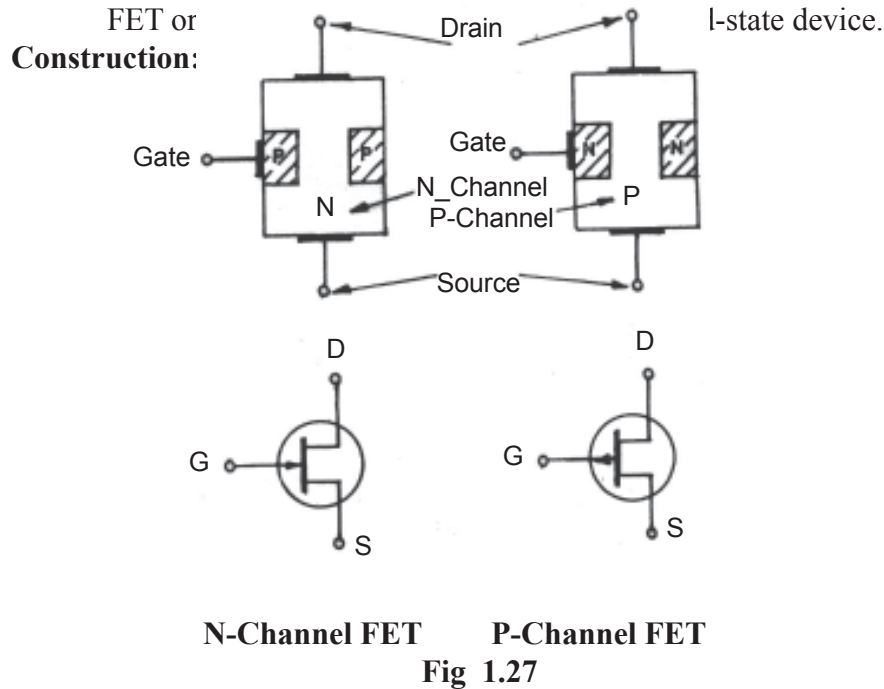
$$\beta = \frac{I_C / I_E}{\frac{I_E}{I_E} - \frac{I_C}{I_E}} = \frac{\alpha}{1 - \alpha}$$

$$\beta = \frac{\alpha}{1 - \alpha} \quad (\text{iv})$$

It is clear that α approaches unity, β approaches infinity. Due to this reason, this circuit arrangement is used in about 90 to 95 percent of all transistor applications.

1.11 Working of FET & MOSFET, Characteristics & applications :-

FET (Field Effect-Transistor):



An FET can be fabricated with either N-channel or P-channel; N channel is preferred. For fabricating N-channel FET, a narrow bar of N-type semiconductor is taken and two P-type junctions are diffused on opposite sides of its middle part as shown in fig. These two junctions form two P-N diodes or Gates and the area remained between the two gates is called the CHANNEL. The two gates are connected internally and a single connecting lead is brought out of the device which is called the gate terminal. Two leads are joined to the bar, one on each side and they are called the Source and Drain.

Working V-I Characteristics :

In an N-Channel FET, the source terminal is connected to the negative and the drain terminal to the positive of the battery. The gate is always

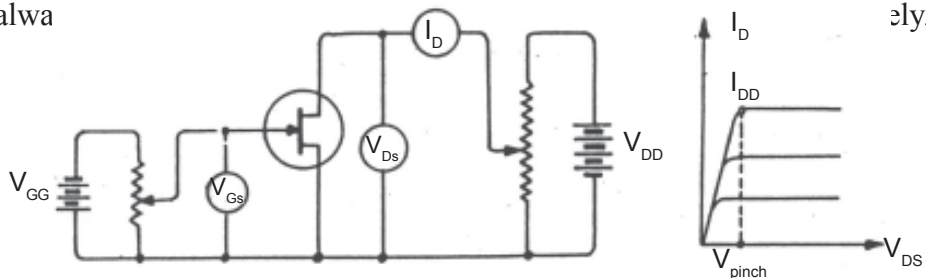


Fig 1.28

The following points may be noted from the characteristics

- (i) At first, the drain current I_D rises rapidly with drain-source voltage V_{DS} but then becomes constant. The V_{DS} above which I_D becomes constant is known as pinch-off voltage. V_{DS} is the pinch off voltage.
- (ii) Increase in I_D is very small with V_{DS} above pinch off voltage. Consequently I_D remains constant.
- (iii) The characteristic resemble that of a pentode valve.

Advantages of FET :

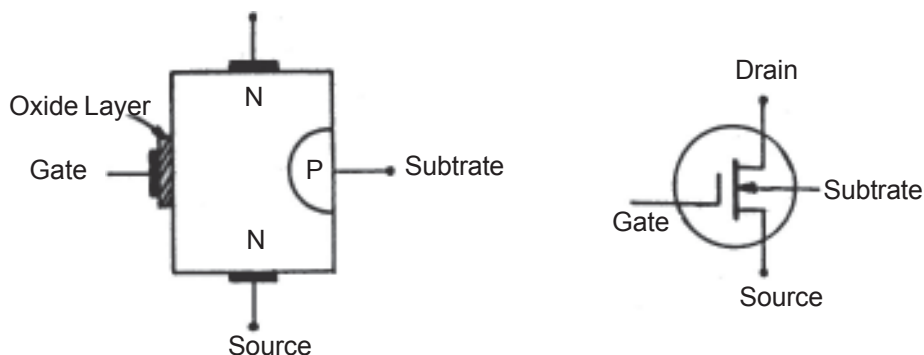
- 1) High input impedance
- 2) Small size, rugged and long life
- 3) Low noise, good high frequency response
- 4) Better thermal stability
- 5) High power gain
- 6) It is a unipolar device

Applications:

- 1) As input stage in amplifiers in oscilloscopes and other electronic testing instruments
- 2) In logic circuits
- 3) As 'mixer' stage in FM radio and TV receivers
- 4) In computers for large scale integration (LSI) in memory circuits.

MOSFET (Metal Oxide Semiconductor FET) :

The input impedance of a MOSFET is much more than that of a JFET because of very small gate leakage current. The MOSFET can be used in any of the circuits covered for the JFET.



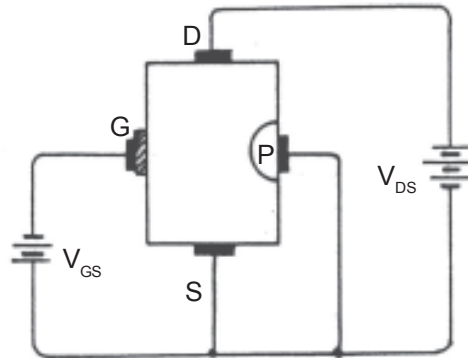


Fig 1.30

The above fig shows the circuit of MOSFET instead of gate diode as in JFET, here gate is formed as a small capacitor. The following points may be noted:

- (i) In a MOSFET, the source to drain current is controlled by the electric field of capacitor formed at the gate.
- (ii) Unlike the JFET, a MOSFET has no gate diode. This makes it possible to operate the device with positive or negative gate voltage.
- (iii) As the gate forms a capacitor, therefore, negligible gate current flows whether positive or negative voltage is applied to the gate. Consequently, the input impedance of MOSFET is very high, ranging from $1,000\text{M}\Omega$ to $10,000,00\text{M}\Omega$.

Applications of MOSFET : used as

- 1) Input amplifiers in oscilloscopes and electronic voltmeters
- 2) In logic gate circuits
- 3) For 'Mixer' operation of FM radio and TV receivers
- 4) As voltage variable resistors in computer memories.

1.12 Special devices SCR, UJT, Triac, Diac, their characteristics and their applications:

SCR : (Silicon Controlled Rectifier)

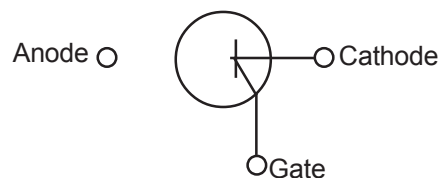


Fig 1.31

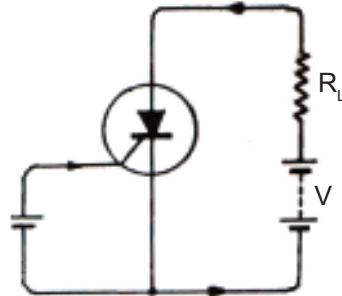


Fig 1.32

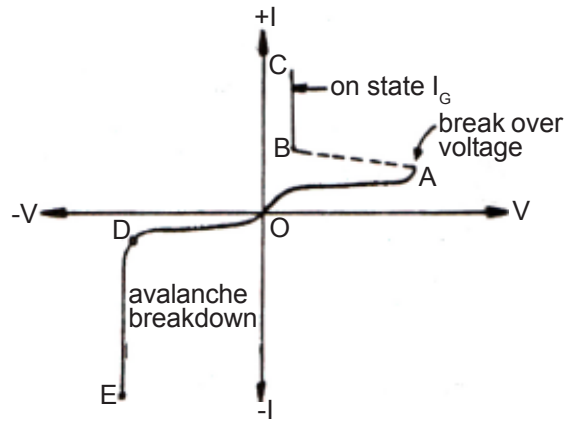


Fig 1.33

A SCR is a solid state equivalent device of a thyatron. It consists of a P-N alloy junction and a diffused P-N-P silicon transistor joined together. Its main part is the P-N rectifier. The N-P-N transistor is diffused as a dot in the N-Region of the rectifier. These two sections together form a PNP silicon device. The rectifier has an anode and cathode and the P-N-P dot is called gate. In this way, a SCR has three terminals named anode, cathode and gate.

The SCR acts in such a way that no current conducts through it till a definite positive voltage is not applied at the gate even if the normal positive and negative voltages are being present on the anode and the cathode respectively.

With increasing supply voltage anode to cathode voltage increases in small amount and increases small amount of anode current. As soon as SCR reaches break over voltage immediately SCR fires and reaches

saturation region with high saturation current. I_{AS} and anode to cathode voltage falls to near to origin. Further reducing supply voltage gradually anode to cathode voltage at a particular point starts increasing at the same time saturation current starts to reduce at a particular point is called holding point. The corresponding voltages current starts at to the said to be holding current voltages I_H , V_H . Further reducing supply voltage I_H further reduces and anode to cathode voltage increases.

If a SCR starts to function on 18 volts and the voltage present across is 17 volts (ie one volt less than the required value) the SCR will not conduct. When a signal of 1.5V, 30mA is applied to the gate, the SCR will start to conduct and it will continue to conduct till it is not 'switched off' completely at least for 20 micro seconds. Once the conduction of current is started the function of the gate is finished and the magnitude of current is then controlled by varying the load resistor or the supply voltage. A SCR can conduct 30 to 100 amperes of current.

Applications : It is used in

- 1) Switching circuits
- 2) Regulated Power Supplies
- 3) Radar Modulator
- 4) Servo System
- 5) Electronic Ignition System etc.
- 6) Speed control motor and short circuit protection in electronic systems

TRIAC :

A TRIAC is a three terminal semiconductor switching device which can control alternating current in a load.

A TRIAC is equivalent to two SCR's joined together in parallel. It has two main terminals and one gate as shown in fig.

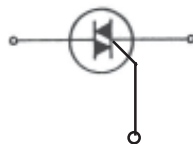


Fig 1.34

It has the characteristic that by keeping its main terminal no.2 on positive or negative potential and then by applying a positive or negative pulse to the main terminal no.1, a conduction of current can start. Once it starts to conduct, the gate will no longer will have a control over the conduction of current like a SCR. The conduction of current continues till the value of voltage on the main terminal does not fall below the operating voltage or the polarity of the main terminal's voltage does not change.

Applications :

- 1) used in digital circuits
- 2) used as electronic on/off switch controlled by a low-current mechanical switch.
- 3) As a high power lamp switch
- 4) As electronic change over of transformer taps.

DIAC :

A DIAC is a two terminal, three layer bidirectional device which can be switched from its OFF state to ON state for either polarity of applied voltage.



DIAC Symbol

Fig 1.35

The DIAC can be constructed in either NPN or PNP form. The fig shows the basic structure of a DIAC in PNP form. The two leads are connected to P-regions of silicon separated by an N-region. The structure of a DIAC is very much similar to that of a transistor.

When the positive or negative applied voltage is equal to or greater than the break down voltage, DIAC begins to conduct and the voltage drop across it becomes a few volts. Conduction then continues until the device current drops below its holding current.

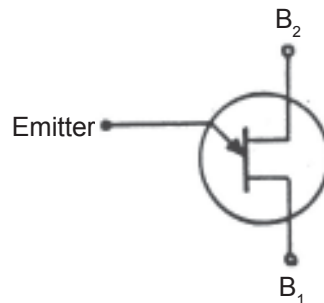
Applications :

- 1) DIACS are primarily used for triggering of TRIACS in adjustable phase control of a.c. mains power
- 2) Light dimming

- 3) heat control
- 4) universal motor speed control

UJT (Uni Junction Transistor) :

A UJT is a three terminal semiconductor switching device. It consists of an N-type silicon bar with an electrical connection on each end. The leads to these connections are called base leads base-one B1 and base two B2. Partway along the bar between the two bases, nearer to B2 than B1, a PN Junction is formed between a P-type emitter and the bar. The lead to this junction is called the emitter lead. The following fig. shows the symbol of UJT.

**Fig 1.36**

In a common type circuit, B1 is grounded and the positive signal is applied to base-2. The N-region acts as a voltage divider so long as the magnitude of emitter current in the emitter region is zero. Hence a positive potential is maintained on the junction. If the magnitude of emitter voltage is lesser than the voltage present on the base, the transistor will remain in reverse bias state. When the emitter voltage exceeds the voltage present on the base, the transistor will be changed into forward bias state and the holes will start to reach the base-1 region by crossing the emitter junction. In this way, the conduction of emitter current will start and the effective resistance of the junction will be reduced. It will produce a rise in emitter voltage. Hence, the transistor will show a negative resistance characteristic.

Applications :

- 1) used as relaxation oscillator
- 2) as over voltage detector
- 3) in timer circuit
- 4) in pulse and voltage sensing circuits.

Summary :**Atomic Structure :**

Energy Levels K,L,M,N are the first, second, third, fourth orbits. The number of electrons present in each orbit is given by $2n^2$.

Inter Atomic Bonds :

Ionic bond, covalent bond, coordinate covalent bond.

Energy band diagrams of conductors, semi conductors and insulators. based on conduction band electrons, forbidden gap and valence electrons.

Semi conductors :

The conductivity lies in between conductors and insulators. These consisting of negative temperature of resistance. With increase in temperature the conductivity of semi conductors raises exponentially and behaves as good conductors.

Intrinsic Semi conductor :

The pure form of semi conductors is known as intrinsic semi conductors. These are two types P-type intrinsic semi conductor and N-type intrinsic semi conductor.

Extrinsic Semi conductor :

The impure form of semi conductors is known as extrinsic semi conductor. These are two types 1) P-type extrinsic semi conductor 2) N-type extrinsic semi conductor

Doping :

The processes of adding impurities to the pure form of semi conductor is known as dope.

PN Junction Diode :

A piece of P-type material, a piece of N-type material bring together to form PN Junction. The PN Junction diodes used as a rectifier.

Zener Diode :

With compare to PN Junction diode 10% more doping is used in zener diode. Due to this in reverse bias characteristics in a particular voltage junction brakes. The corresponding voltage, current is said to be zener breakdown voltage, current respectively.

Zener diode used as voltage regulators.

Photo Diode :

In this cathode heated by light energy so that it conduction starts these are used in remote sensing applications.

LED :

Light Emitting Diodes These are used as indicators in all electronic systems.

Varactor Diode :

These are used in RF frequency tuning in RF amplifier as well as TV tuners.

Transistor :

These are two types N-P-N Transistor, P-N-P Transistor. The terminals are called base, collector and emitter. Emitter is heavily doped, collector is moderately doped and base is thinly doped. The N-P-N Transistors as got current gain from 20-200 where as a P-N-P Transistor as got current gain from 2-20.

Transistors input impedance is low, output admittance is high current gain is 40-50. And the transistors used as an amplifiers in various electronic circuits in CB, CC, CE configurations.

α : It is the ratio of collector current to emitter current in the CB transistor configuration.

β : It is the ratio of collector current to base current.

Transistors are bipolar devices and hence these are called bipolar junction transistors. Referred as BJT.

FET : Field Effect Transistor

These are possess very high input impedance compare to transistors. These are unipolar devices.

MOSFET : Metal Oxide Semi Conductor Field Effect Transistor

These possess very high impedance $10\text{ M}\Omega$ to $10,000\text{ M}\Omega$ and hence these are used as memory devices.

SCR : Silicon Control Rectifier These are used high current rectifier where it requires more than 5 amperes and also used as switches.

UJT : Uni Junction Transistor These are used as in relaxation oscillators. Which consists of negative temperature coefficient of resistance.

TRIAC :

This is used in motors to control speed and high voltage controlling network as a switch.

DIAC :

This is also used as switch used to control speed of the motor.

Short Questions :

- 1) How many electrons present in K,L,M,N levels.
- 2) How many types of inter atomic bonds.
- 3) Define ionic bond.
- 4) Define coordinate covalent bond.
- 5) Define covalent bond.
- 6) Draw the energy band diagram of conductors.
- 7) Draw the energy band diagram of insulator.
- 8) Draw the energy band diagram of semiconductor.
- 9) Define intrinsic semiconductor.
- 10) Define doping.
- 11) Define extrinsic semiconductor
- 12) What are the application of PN Junction diode.
- 13) Define potential barrier.
- 14) Define work function.
- 15) What is the application of zener diode.
- 16) What are the applications of photo diode, LED.

- 17) What is application of varactor diode.
- 18) Define current gain in common base amplifier.
- 19) What are the applications of transistor.
- 20) Define large signal current gain in CE amplifier.
- 21) Write the relation between α and β .
- 22) Write any two comparisons between BJT and FET.
- 23) Write any two comparisons between FET and MOSFET.
- 24) What are the applications of SCR.
- 25) Write applications of UJT, TRIAC and DIAC.

ESSAY QUESTIONS

- 1) Draw the atomic structure of Germanium, silicon atoms explain atomic bond in each one.
- 2) Explain briefly ionic, covalent and coordinate covalent bond.
- 3) Classify the materials based on energy band diagram.
- 4) Explain briefly intrinsic, extrinsic semiconductors.
- 5) Explain the formation of PN Junction diode. Discuss volt-ampier characteristic in both forward and reverse bias.
- 6) Explain the working of zener diode, photo diode.
- 7) Explain the working of LED and varactor diode.
- 8) Draw the CE amplifier neatly explain input and output characteristics.
- 9) Draw the CB amplifier neatly explain input and output characteristics.
- 10) Derive the relation between α and β .
- 11) Compare the characteristics of CE, CB and CC.
- 12) Draw the characteristics of FET explain working.
- 13) Explain the VI characteristics of SCR.
- 14) Explain VI characteristics of the UJT.
- 15) Explain the VI characteristics of TRIAC.
- 16) Explain the VI characteristics of DIAC.

2: Power Supplies

2.0 Introduction - 2.0

Now a days A.C is employed as a source of electricity all over world because its easy and economical production and distribution. Though AC is suitable for the most of the electric applications but there are some applications where DC is essential.

- Eg:**
1. Electro plating
 2. Electro typing
 3. Electro metal refining
 4. Arc lamp
 5. Battery charging
 6. Electromagnetic
 7. Valve or transistorised electronic equipments

Hence, it becomes necessary to convert A.C to D.C for the above explained purposes A.C supply areas. The conversion of A.C into D.C to called 'Rectification'. The diode employed for rectification is called 'Rectifier'. A power supply unit is essential for all A.C operated electronic equipments for the conversion of A.C into D.C. The unit mainly consists of a rectifier and a filter circuit.

2.1 Types of Rectifier circuits

The rectifier circuits may be classified into following 3 main classes.

1. Half wave rectifier
2. Full wave rectifier
3. Bridge rectifier

All the above 3 types of circuits can be made by using diode, solid state rectifiers. Electronic equipments like radio receiver, television etc. do not require a direct current of more than one ampere and hence solid state rectifiers are used.

2.2 Half wave rectifier

A rectifier circuit designed with a single diode which provides an output only for half cycle of A.C. only for +ve half cycle is called a half-wave rectifier.

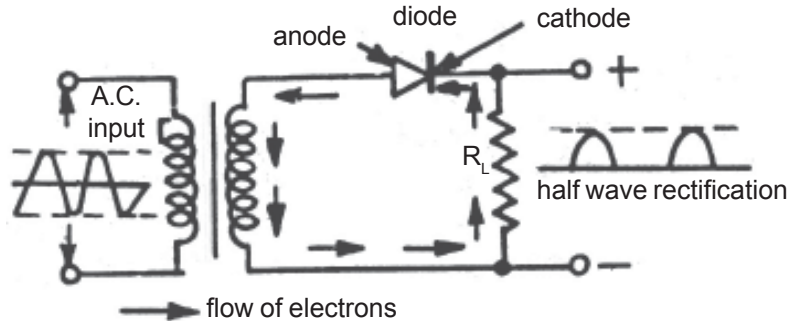


Fig 2.1

A.C voltage is applied to the primary of the step down transformer. From the secondary of the transformer positive half cycle is given to the diode conducts current only for positive half cycle time of each input cycle. The anode current will flow only in the state when anode is positive w.r.t cathode. When the anode is negative w.r.t. cathode, there will be no conduction of current because no attraction will take place between the electrons and the negative anode.

In this way. A.C is converted into a unidirectional positive cycles current. The cathode becomes +ve due to emission of a number of electrons by it and hence the cathode acts as +ve terminal for the output D.C. The electrons flow completes its circuit from anode to cathode through the transformer, load resistor and filtering capacitor and it becomes a D.C. supply.

As shows in the figure, the magnitude of output current varies, from zero to maximum and from maximum to zero, only in one direction. This variation of current is called 'Ripple'. The 'Ripple frequency' is equal to the supply frequency (50Hz). The variation in the magnitude of anode current are called 'pulsations' and the D.C. So obtained is called 'pulsating D.C.' Filter circuits are introduced for the conversion of pulsating D.C into smooth D.C.

The efficiency of a half wave rectifier is poor and a multistage filter circuit is required for the conversion of pulsating D.C. into smooth D.C. because the value of ripple and supply frequency is the same.

Full wave Rectifier

Two diodes are employed in this type of circuit. The anodes of both the diodes are connected to the secondary winding of a transformer having a centre tap. The flow of load current is maintained by the operation of any one of the 2 diodes for each half cycle. Since, the complete wave of A.C. is used in this circuit hence, it is called a full wave rectifier.

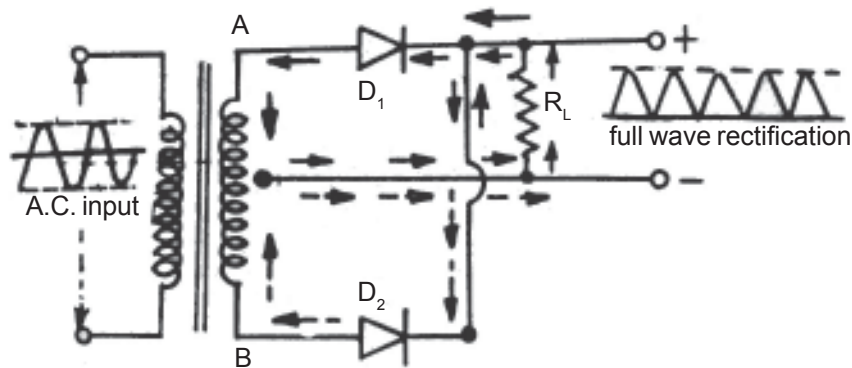


Fig 2.2

A full wave rectifier circuit is shown in the figure. In this circuit, both the diodes are connected to the secondary winding and the load resistor in such a way each diodes circuits is completed through half secondary winding and the common load resistor.

During first +ve half cycle, the anode of the diode D_1 becomes +ve and the flow of electrons takes place through the diode D_1 (cathode to anode) secondary winding's upper section and the load resistor R_L . The diode D_2 remains inactive during this period.

During negative half cycle the diode D_1 remains inactive but the flow of electrons takes place through the diode D_2 . Due to +ve potential of the lower terminals of the secondary winding. Remember that the direction of flow of current is always opposite to that of the electrons flow.

In this way, output is obtained for each half cycle because of alternate functions of the two diodes. The flow of current continues in the output circuit. The ripple frequency of the circuit is double of the supply frequency (Normally 100Hz). The output current flows continuously due to the double ripple frequency. The circuit has a higher efficiency and due to flow of current in opposite direction through the 2 sections of the secondary winding, the D.C. magnetic saturation of the core will also have a lower value.

Comparison of Half - wave and full - wave rectifiers.

Half-wave Rectifiers	Full-wave Rectifiers
It has a low efficiency.	It has a high efficiency which is nearly double of that of the half-wave type.
Since the ripple frequency is 50Hz hence a multi-section filter circuit is required. circuit assembly easy.	Since the ripple frequency is 100Hz, hence an ordinary filter circuit is sufficient.
It employes only one diode.	Two diodes are used.
It is a cheap circuit	It is compositively costly circuit
A step down transformer is used.	A voltage step down and centre tapped secondary type is necessary

Bridge Rectifier:

A transformer with centre-tab tapped secondary is necessary for an ordinary type full-wave rectifier, a bridge rectifier does not require such transformer. Since 4 diodes are connected like wheat stone bridge circuit, hence, the circuit is known as bridge rectifier. The circuit performed full-wave rectification.

As shown in the figure, four diodes are connected in such a way that two of them work when the terminal 'A' is +ve and the rest to work when the terminal 'B' is +ve. Let the terminal A be +ve the flow of electrons will take place through diodes D1 and D3. When terminal B is

+ve, the flow of electrons take place through the diodes D2 and D4. The direction of flow of current through the load resistor R_L will remain the same in both cases. Hence, D.C. voltage will be available across the load resistor. The repel frequency of this circuit is double of the supply frequency. Like an ordinary full wave rectifier.

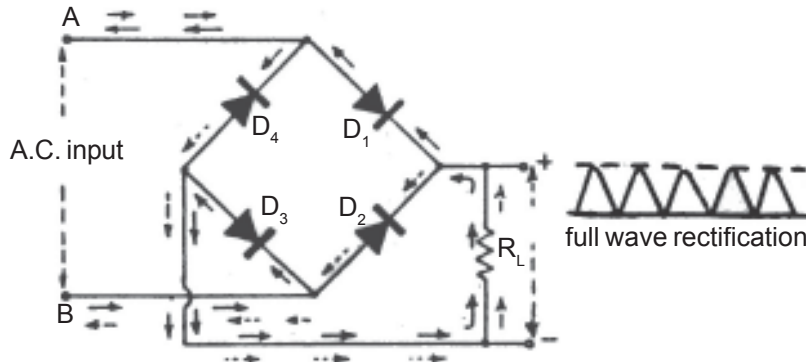


Fig 2.3

Merits:

Its output is double that of an ordinary full wave rectifier because of the absence of transformer with centre tapped secondary.

Demerits:

Since four diodes are employed in this circuit, hence it becomes rather costly. If the circuit is of valve type then its power consumption will be high enough because four filaments will consume more power.

2.3 Define RMS, DC value, Ripple factor and efficiency of above circuits.

RMS value (Root Mean Square Value) :

It is the value of an alternating current is measured in terms of the direct current, which when flowing through a given circuit for given time to produce the heat as produced by the alternating current when flowing the same circuit for the same time.

$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \dots + i_n^2}{n}} = \frac{I_m}{\sqrt{2}} = \text{sinsoidal a.c.}$$

DC value:

It is the value of an alternating current is expressed by that steady current, which transfers across any circuit the same charge as is transferred by that alternating quantity.

$$I_{av} = \frac{i_1 + i_2 + \dots + i_n}{n} = \frac{2 I_{max}}{\pi} \quad \text{for sinusoidal a.c}$$

Ripple Factor :

In the output the a.c. content in d.c. output is known as ripple. The ripple always expressed in percentage (%) and hence it is called ripple factor.

The output of a Rectifier consists of a d.c. component and an a.c. component (also known as ripple). The a.c. component is undesirable and accounts for the pulsations in the rectifier output. The smaller the magnitude of a.c. component in the output, the more effective is the rectifier.

The ratio of r.m.s. value of a.c. component to the d.c. component in the rectifier output is known as ripple factor i.e.

$$\text{Ripple factor} = \frac{\text{r.m.s. value of a.c. component}}{\text{value of d.c. component}} \times 100 = \frac{I_{ac}}{I_{dc}} \times 100$$

Rectifier Efficiency:

The ratio of d.c. power output to the applied input ac power is known as rectifier efficiency i.e.

$$\text{Rectifier Efficiency, } \eta = \frac{\text{d.c. power output}}{\text{input a.c. power}} \times 100$$

The efficiency of a half-wave rectifier is 40.6%, the efficiency of centre-tap full-wave rectifier is 81.2% and that of a Bridge type rectifier is 81.2%.

2.4 Filter circuits

Necessity:

The output of a rectifier contains a.c. rippler too in addition to the d.c. in order to obtain pure d.c., a.c. rippler should necessarily be removed. Similarly a complex circuit may have (i) D.C (ii) 50 Hz A.C (iii) A.F. current (iv) R.F current. Hence, it becomes necessary to have a device which can select the desire type of current out of above stated types of currents at any specific point of a circuit. Such a device is called a filter.

In this way a filter circuit is a device which can select a desired type of current out of various types of currents.

Types of filter circuits :

There are 3 types of filter circuits. They are

Choke input filter circuit :

In this circuit the pulsating input is applied to a choke. The choke opposes pulsations and gives rise to D.C. Hence, the amplitude of pulsations is reduced to a great extent. If a capacitor is also connected in parallel to the input after the choke, the amplitude of pulsations will be reduced further. A 10H choke in a 8 μ F capacitor reduces a pulsations upto a value to 1% only.

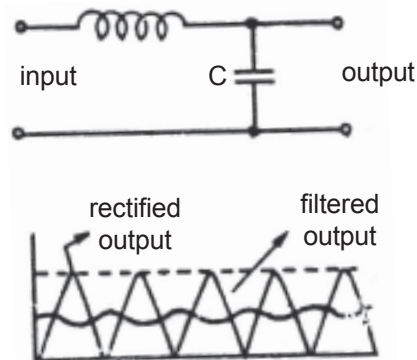
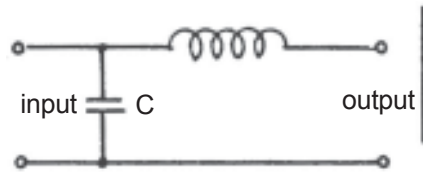


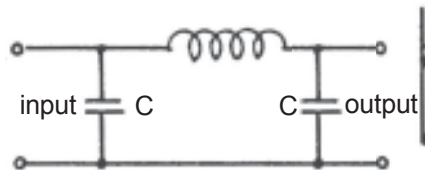
Fig 2.4

Capacitor input filter circuit :

In this circuit, the pulsating input is applied to a capacitor. The capacitor charges upto peak value of first pulse and it discharges during gap between the first in the second pulse. Capacitor's discharging rate is usually very low in comparison to its charging rate; hence it tries to maintain the charge accumulated during first cycle. In this way the amplitude of pulsations is reduced to a great extent. If a choke is connected in series after the capacitor, the amplitude of pulsation will be reduced further. The voltage regulation of this type of circuit is lesser than that of a choke input filter circuit in the magnitude of output voltage begins to fall with a rise in load current.

**Fig 2.5** **π filter circuit :**

In this circuit, two capacitors are used to filter the pulsating a.c. to d.c. supply.

**Fig 2.5****2.5 Voltage regulation.**

It is the ratio the difference between no load voltage to load voltage to no load voltage multiplied by 100 gives the voltage regulation.

$$\text{voltage regulation} = \frac{E_N - E_L}{E_L} \times 100$$

The percent of output voltage variations due to output current variations for a rectifier, is called voltage regulation.

where E_N = No-load voltage
 E_L = load voltage

The voltage regulation of a capacitor input filter circuit is poor because the output voltage is unable to remain stable due to load current variations.

The voltage regulation of a choke input filter circuit is much better because the choke controls the load current variations. On the other hand, the voltage available in the output of a choke input filter owing to voltage drop caused by choke.

Line Regulation:

The process of voltage stabilization in which the line voltage is kept stable is known as line regulation. Load regulation the process of voltage stabilization in which the line current is kept stable is known as load regulation.

Zener diode voltage Regulator :

A zener diode can be used as a voltage regulator to provide a constant voltage from a source whose voltage may vary over sufficient range. The circuit arrangement is shown in the fig.

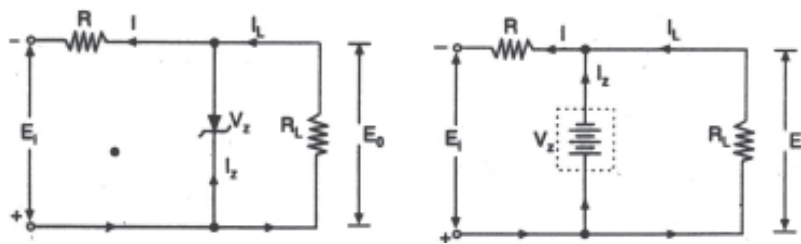


Fig 2.6

The zener diode of zener voltage V_Z is reverse connected across the load R_L across which constant output is desired. The series resistance R absorbs the output voltage fluctuations so as to maintain constant voltage across the load. It may be noted that the load. So long as the input voltage does not fall below V_Z .

When the circuit is properly designed, the load voltage E_0 remains essentially constant (equal to V_z) even though the input voltage E_1 and the load resistance R_L may vary over a wide range.

(i) suppose the input voltage increases. Since the zener is in the break-down region, the zener diode is equivalent to a battery V_z as shown in fig. It is clear that output voltage remains constant at $V_z = E_0$. The excess voltage is dropped across the series resistance R . This will cause an increase in the value of total current I . The zener will conduct the increase of current in I while the load current remains constant. Hence, output voltage E_0 remains constant irrespective of the changes in the input voltage E_1 .

(ii) Now suppose that input voltage is constant but the load resistance R_L decreases. This will cause an increase in load current. The extra current cannot come from the source because drop in R (and hence source current I) will not change as the zener is within its regulating range. The additional load current will come from a decrease in zener current I_z . Consequently, the output voltage stays at constant value.

Voltage drop across $R = E_1 - E_0$

Current through $R, I = I_z + I_L$

Applying ohm's Law, we have

$$R = \frac{E_1 - E_0}{I_z + I_L}$$

2.6 List the IC Regulations.

(i) **IC fixed 5-volt Regulator:** The IC voltage regulator is a device that is used to hold the output voltage from a dc power supply constant as the input voltage or load current changes. For example, LM 309 (fixed positive) provides a +5v d.c output. This regulator is frequently used in digital circuits.

(ii) **IC Adjustable voltage Regulator:** Sometimes we want a voltage regulator whose voltage we can vary. An example of such a voltage regulator is LM 317. By varying the value of adjustable resistance, the output voltage of the regulator can be adjusted.

Summary :

Power Supply : It is the electronic circuit which converts a.c. supply into d.c. supply.

Rectifiers : Rectifiers are three types 1) half wave rectifier 2) full wave rectifier 3) bridge rectifier.

RMS value : It is the value is taken some of the square root of squares of the voltages or currents divided number of parts average value is RMS value.

D.C. value : It is average value of a d.c. quantity for half wave rectifier average value = maximum value / π .

Ripple factor : It is a ratio of a.c. content presenting d.c. output to d.c. output multiplied by 100 is known as Ripple factor.

Efficiency : It is the ratio of output power to input power. For half wave, full wave rectifiers the efficiencies are 40.6%, 81.2% respectively.

Filter : By using an electrolytic capacitor the pulsating half waves are converted into d.c. voltage.

Voltage Regulator : It is the ratio of difference of no load voltage to load voltage to no load voltage multiplied by 100. Generally for small power applications zener diode used as voltage regulator.

Short Questions :

- 1) How many diodes are used in half, full and bridge rectifiers.
- 2) Define voltage regulation.
- 3) Define RMS value.
- 4) Define Average value.
- 5) Define ripple factor.
- 6) Define efficiency of rectifier.

Essay Questions :

- 1) Draw the block diagram of power supply. Explain working of each block.
- 2) Draw the half wave rectifier with filter circuit explain working.
- 3) Draw the full wave rectifier with filter circuit explain working.
- 4) Draw the bridge rectifier circuit explaining working.

3. Small Signal Amplifiers

3.0 Introduction:

A properly biased transistor raises the strength of a weak signal to strengthen signal and thus acts as an amplifier. Almost all electronic equipments must include means for amplification of electrical signals. For instance radio receivers amplify very weak signals sometimes a few millionth of a volt at antenna until they are strong enough to fill a room with sound. The transducers are used in the medical and scientific investigations generate signals in the microvolt (μV) and milli volt (mV) range. These signals must be amplified thousands and millions times before they will be strong enough to operate indicating instruments. Therefore electronic amplifiers are a constant and important ingredient of electronic systems.

Basic concept of amplifier circuits by CB, CE, CC Amplifiers using transistors, compare their features:

CB, CE configurations as discussed later.

CC configuration (common collector configuration)

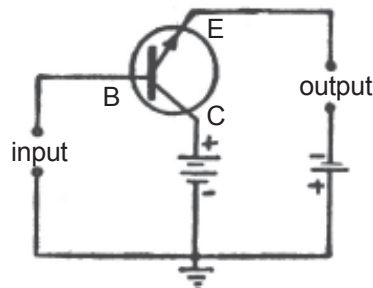


Fig 3.0

A common collector circuit is shown in fig. Here, input is applied between the collector and the base and the output is taken from the collector and the emitter. In this way, the collector remains common in this circuit. The circuit has a high input impedance (150 to 600 $\text{K}\Omega$) and a low output impedance (100 to 1000 Ω). The value of its current gain beta is upto 99 but the values of its voltage and power gains are less than unity. A common collector circuit is also known as emitter follower.

Comparison between CB, CE and CC circuits:

S.No.	Characteristic	Common Base	Common Emitter	Common Collector
1	Voltage gain	100-200	300-600	<1
2	Current gain	<1	20-100	20-100
3	Power gain	Medium	high	low
4	Input impedance	Very low	low	Very high
5	Output impedance	Very high	medium	Very low
6	Phase inversion	00	1800	00
7	Applications	For H F applications	For A F applications	For impedance matching

3.2 Biasing and stabilisation of BJT Amplifiers:

For the faithful amplification, a transistor amplifier must satisfy three basic conditions namely

- (i) Proper zero signal collector current
- (ii) Proper base-emitter voltage and
- (iii) Proper collector-emitter voltage

When a transistor fulfils of above conditions are requirement for transistor biasing.

The basic purpose of transistor biasing is to keep the base-emitter junction properly forward biased and collector -base junction properly reverse biased during the application of signal. This can be achieved with a bias battery or associating a circuit with a transistor. The latter method is more efficient and is frequently employed. The circuit which provides transistor biasing is known as biasing circuit. It may be noted that transistor biasing is very essential for the proper operation of transistor in any circuit.

Methods of Transistor Biasing:

The following are the most commonly used methods of obtaining transistor biasing from one source of supply ie V_{CC}

- (i) Base resistor method
- (ii) Biasing with feed back resistor
- (iii) Voltage - divider bias.

Stabilisation :

The collector current in a transistor changes rapidly when

- (i) the temperature changes
- (ii) the transistor is replaced by another of the same type. This is due to the inherent variations of transistor parameters.

When the temperature changes or the transistor is replaced, the operating point I_C and V_{CE} also changes. However, for faithful amplification, it is essential that operating point remains fixed.

The process of making operating point independent of temperature changes or variations in transistor parameters is known as stabilisation. A good biasing circuit always ensures the stabilisation of operating point.

3.3 Classification of amplifiers according to frequency, mode of operation, type and methods of coupling, R.C.coupled, Transformer coupled and Directly coupled.**Classification of Amplifiers:**

Various types of amplifier Circuits can be classified on the following four bases.

1. On the base of frequency:

- (i) A.F. Amplifier
- (ii) R.F. Amplifier
- (iii) I.F. Amplifier
- (iv) Video Amplifier

2. On the base of ability (mode of operation):

- (i) Class 'A' Amplifier
- (ii) Class 'B' Amplifier
- (iii) Class 'AB' Amplifier
- (iv) Class 'C' Amplifier

3. On the base of Coupling:

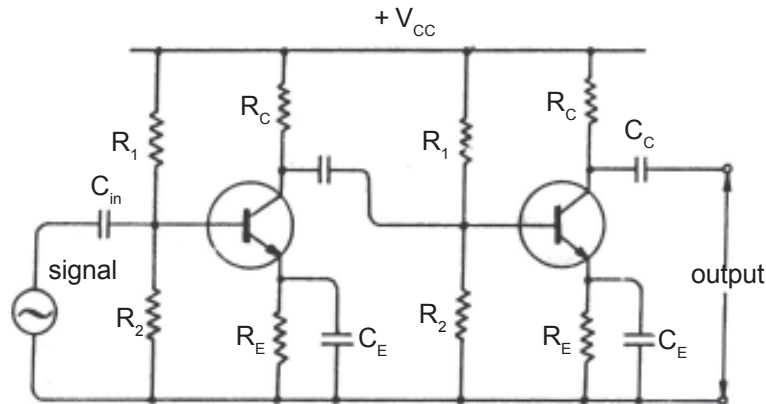
- (i) RC Coupled Amplifier
- (ii) LC Coupled Amplifier
- (iii) Transformer Coupled Amplifier
- (iv) Direct Coupled Amplifier

4 On the base of Power:

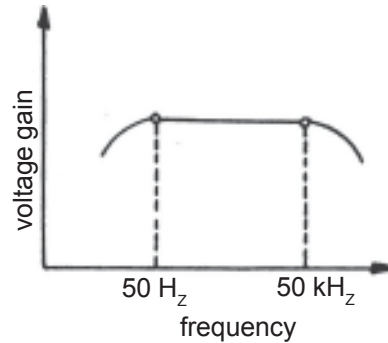
- (i) Voltage Amplifier
- (ii) Power Amplifier

3.4 Know the frequency response, gain of the above amplifier:

When a single amplifier stage cannot produce sufficient amplification, two or more stages are coupled together for this purpose. The method of applying the output signal of the first amplifier stage to the input circuit of second stage is called coupling.

1. R.C. Coupled Amplifier:**Fig 3.1**

In the R-C coupling of signal is performed by employing two resistors and a capacitor that is why it is called R-C coupling. This method is most economical and amplifies a wide frequency. The resistor R_C is the load resistor which acts as collector load resistor for the first transistor. The ac component of first transistor reaches to the base of second transistor through coupling capacitor C_C . The capacitive reactance of the coupling capacitor should be lesser than the load resistance, otherwise, the ac component of the signal will also pass through the load resistor. The coupling capacitor also prevents the d.c. voltage to reach the base of the second transistor and does not allow the later to become over loaded. Hence, it is also known as blocking capacitor. an R-C coupled Amplifier is shown in the above fig.

Frequency response:**Fig 3.3**

The fig shows the frequency response of a typical R-C coupled Amplifier. It is clear that the voltage drops at low ($< 50\text{Hz}$) and high ($> 20\text{KHz}$) frequencies whereas it is uniform over mid-frequency range (50Hz to 20KHz).

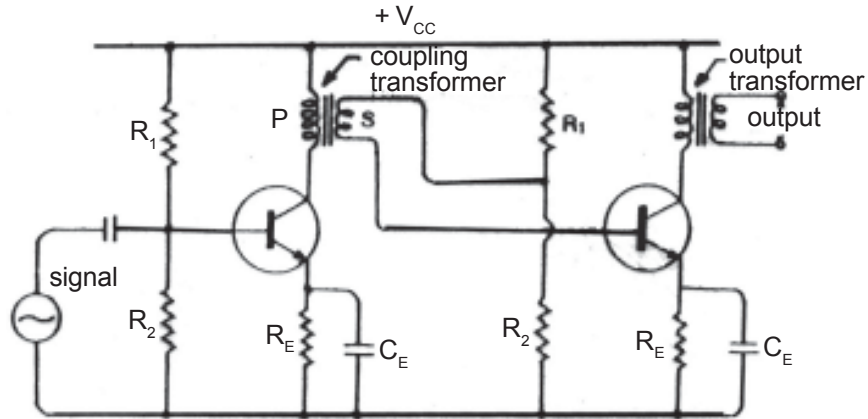
At low frequencies ($< 50\text{Hz}$), the reactance of coupling capacitor C_c is quite high and hence very small part of signal will pass from one stage to the next stage.

At high frequencies ($> 20\text{KHz}$), the reactance of C_c is very small and it behaves as a short circuit. This increases the loading effect of next stage and serves to reduce the voltage gain.

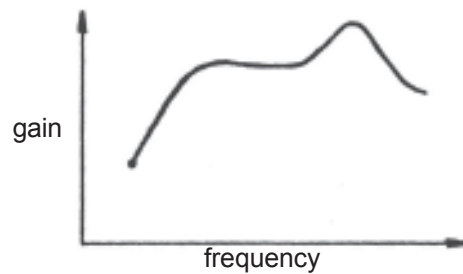
At mid frequencies (50Hz to 20KHz), the voltage gain of the amplifier is constant. The effect of coupling capacitor in this frequency range is such so as to maintain a uniform voltage gain.

Applications :

They are widely used as voltage amplifiers i.e. in the initial stages of public address system. It is cheap and provides excellent audio fidelity over a wide range of frequency.

Transformer - Coupled Amplifier:**Fig 3.4**

In the transformer coupling method an interstage or a driver transformer is employed for coupling. The primary winding of the transformer acts as an inductive load for the first transistor and the secondary winding acts as the signal source for the second transistor.

Frequency response:**Fig 3.5**

The frequency response of a transformer coupled amplifier is shown in the above fig. It is clear that frequency response is rather poor i.e. gain is constant only over a small range of frequency.

The output voltage is equal to the collector current multiplied by reactance of primary. At low frequencies, the reactance of primary begins to fall, resulting in decreased gain. At high frequencies, the capacitance between turns of windings acts as a bypass condenser to reduce the output

voltage and hence gain. Therefore there will be disproportionate amplification of frequencies in a complete signal such as music, speech etc. Hence, transformer - coupled amplifier introduces frequency distortion.

Applications:

Transformer coupling is mostly employed for impedance matching. In general, the last stage of a multistage amplifier is the power stage. Here, a concentrated effort is made to transfer maximum power to the output device e.g. a loud speaker. For maximum power transfer, the impedance of power source should be equal to that of load. Transformer coupled amplifier is used for power amplification.

3. Direct Coupled Amplifier:

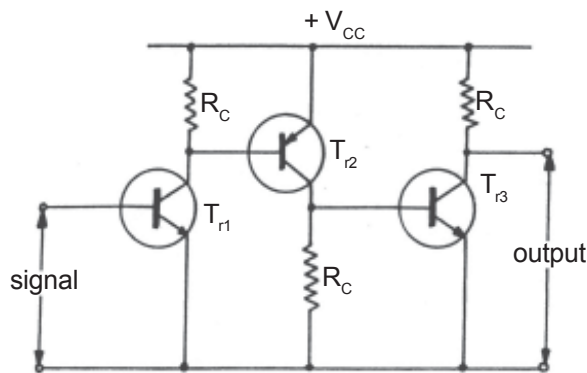


Fig 3.6

The latest method of coupling is direct coupling. Its circuit is very simple as shown in the fig. In this method, the collector of the first transistor is directly connected to the base of the second transistor. Hence, D.C. will be present on the base too.

The advantages of direct coupling are - no distortion and uniform response over a wide frequency range. These circuits are used for very low frequency amplification purposes.

Applications :

The transformer coupled amplifiers are used for amplifying extremely low frequencies (as low as a fraction of a Hertz).

3.4 Frequency response of the amplifier:

Fig shows the frequency response of a typical R-C coupled amplifier. It is clear that voltage gain drops off at low ($< 50\text{Hz}$) and high ($> 20\text{KHz}$) frequencies whereas it is uniform over mid-frequency range ($50\text{ Hz to } 20\text{ KHz}$). This behaviour of the amplifier is briefly explained below:

(i) At low frequencies ($< 50\text{ Hz}$), the reactance of coupling capacitor C_C is quite high and hence very small part of signal will pass from one stage to the next stage. Moreover, C_E cannot shunt the emitter resistance R_E effectively because of its large reactance at low frequencies. These two factors cause a falling off voltage gain at low frequencies.

(ii) At high frequencies ($> 20\text{ KHz}$), the reactance of C_C is very small and it behaves as a short circuit. This increases the loading effect of next stage and serve to reduce the voltage gain. Moreover, at high frequency, capacitive reactance of base-emitter junction is low which increase the base current. This reduces the current amplification factor β . Due to these two reasons, the voltage gain drops off at high frequency.

(iii) At mid-frequencies ($50\text{ Hz to } 20\text{ KHz}$), the voltage gain of the amplifier is constant. The effect of coupling capacitor in this frequency range is such so as to maintain a uniform voltage gain. Thus, as the frequency increases in this range, reactance of C_C decreases which tends to increase the gain. However, at the same time, lower reactance means higher loading of first stage and hence lower gain. These two factors almost cancel each other, resulting in a uniform gain at mid frequency.

Advantages :

(i) It has excellent frequency response. The gain is constant over the audio frequency range which is the region of most importance for speech, music etc.

(ii) It has lower cost since it employs resistors and capacitors which are cheap.

(iii) The circuit is very compact as the modern resistors and capacitors are small and extremely light.

Disadvantages :

(i) The R-C coupled amplifiers have low voltage and power gain. It is because the low resistance presented by the input of each stage to the preceding stage decreases the effective load resistance (R_{AC}) and hence the gain.

(ii) They have the tendency to become noisy with age, particularly in moisture climates.

(iii) Impedance matching is poor. It is because the output impedance of R-C coupled amplifier is several hundred ohms whereas that of a speaker is only a few ohms. Hence, little power will be transferred to the speaker.

Applications :

The R-C coupled amplifiers have excellent audio fidelity over a wide range of frequency. Therefore, they are widely used as voltage amplifiers e.g. in the initial stages of public address system. If other type of coupling (e.g. transformer coupling) is employed in the initial stages, this results in frequency distortion which may be amplified in next stages. However, because of poor impedance matching, R-C coupling is rarely used in the final stages.

Summary:

Amplifiers : There are three transistor configurations. They are common base amplifier, common collector amplifier, common emitter amplifier.

Biasing : The process of giving supply to the transistor is known as biasing. They are three types biasing 1) Base resistor biasing 2) Collector feedback resistor biasing 3) Voltage divider biasing.

In a transistor biasing a transistor should fulfill following requirement to acts as an amplifier.

- 1) Zero signal collector current
- 2) Minimum collector to emitter voltage
- 3) Minimum V_{BE} in the case of silicon transistor 0.7 volts, germanium transistor 0.3 volts.

Stabilization : The proper operating point, reverse saturation currents and large signal current gain plays important role in stabilization.

The Coupling Networks : In the transistor the coupling components used as RC, LC, RL, Transformer and Direct Coupling.

Short Questions :

- 1) What are the applications of CB amplifier.
- 2) What are the applications of CE amplifier.
- 3) What are the applications of CC amplifier.
- 4) What is stabilization.
- 5) Define stabilization.
- 6) Name the different types of coupling networks.

Essay Questions :

- 1) Compare the characteristics of CB, CE, CC amplifiers.
- 2) Explaining biasing and stabilization of transistors.
- 3) Draw the two stage RC coupled amplifier explain working.
- 4) Draw the transformer couple amplifier explain working.
- 5) Draw the direct couple amplifier explaining working.
- 6) Draw the frequency response curve of an amplifier and explain AF and RF frequency response.

4. Power Amplifiers

4.0 Introduction to AF and RF power Amplifiers

A practical amplifier always consists of a number of stages that amplify a weak signal until sufficient power is available to operate a loudspeaker or other output device. The first few stages in this multistage amplifier have the function of only voltage amplification. However, the last stage is designed to provide maximum power. The final stage is known as power amplifier.

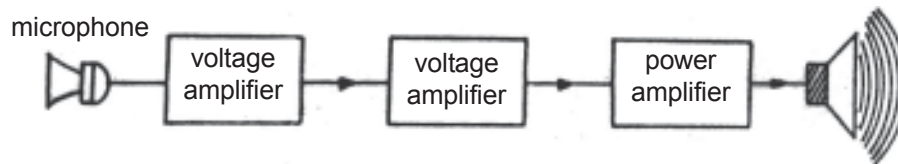


Fig 4.0

The audio frequency range from 20Hz to 20KHz. Therefore, audio amplifier amplify electrical signals that have a frequency range corresponding to the range of human hearing i.e. 20 Hz to 20 KHz. The above fig. shows the block diagram of an audio amplifier. The early stages build up the voltage level of the signal while the last stage builds up power to a level sufficient to operate the loudspeaker.

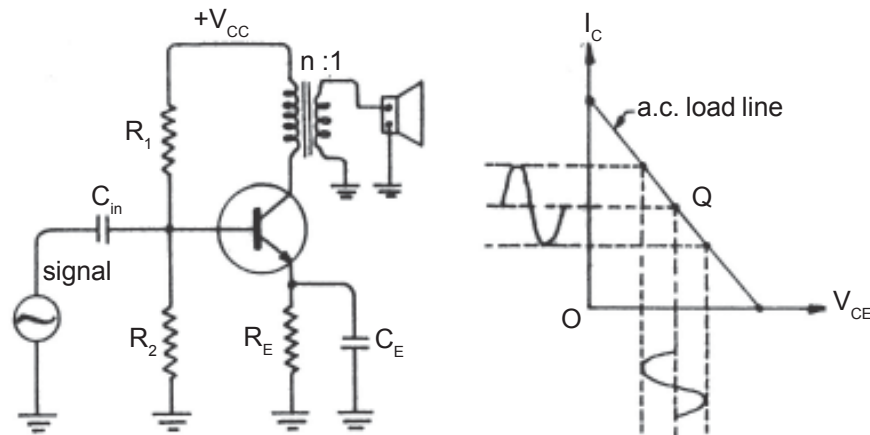
The amplifier which amplifier in the frequency range of 20KHz to 30MHz is called RF amplifier. A RF transistor is used in this circuit and the values of capacitors and inductors are kept such that they do not have high impedance for RF range. These amplifiers are used in receivers, transmitters, signal generators etc. for RF amplification.

4.1 Distinguish between voltage and power amplifier:

A voltage amplifier is designed to achieve maximum voltage amplification. It is not important to raise the power level. On the other hand, a power amplifier is designed to obtain maximum output power (ie product of voltage and current).

Comparison between voltage and power amplifier:

S.No.	Particular	Voltage Amplifier	Power Amplifier
1.	β	High > 100	low 20 to 50
2.	Input Impedance	High 4-10K Ω	low 5 to 20 Ω
3.	Coupling	usually R-C coupling	Invariably transformer coupling
4.	Input voltage	low a few mV	High 2-4V
5.	Collector Current	low 1mA	High > 100mA
6.	Power output	low	high
7.	Output Impedance	High 12K Ω	low 200 Ω

4.2 Explain working of single ended class A power amplifier:**Fig 4.1****Class a power Amplifier :**

If the collector current flows at all times during the full cycle of the signal, the power amplifier is known as class A power Amplifier.

Obviously, for this to happen, the power amplifier must be biased in such a way that no part of the signal is cut off. The collector has a transformer as the load which is most common for all classes of power amplifiers. The use of transformer permits impedance matching, resulting in the transference of maximum power to the load e.g. loudspeaker.

The above fig shows the class A operation in terms of a.c. load lines. The operating point Q is so selected that collector current flows at all times through out the full cycle of the applied signal. As the output waveshape is exactly similar to the input wave shape, therefore, such amplifiers have least distortion. However, they have the disadvantage of low power output and low collector efficiency (about 35%).

4.3 Explain the working of class B push-pull Amplifier:

The push-pull amplifier is a power amplifier and is frequently employed in the output stages of electronic circuits. It is used whenever high output power a high efficiency is required. As shown in the circuit diagram, two transistors Tr1 & Tr2 placed back to back are employed. Both transistors are operated in class B operation i.e. collector current is nearly zero in the absence of the signal. The centre - tapped secondary of driver transformer T1 supplies equal and opposite voltages to the base circuits of two transistors.

The output transformer T2 has the centre tapped primary winding. The supply voltage V_{CC} connected between the bases and this centre tap. The loudspeaker is connected across the secondary of this transformer.

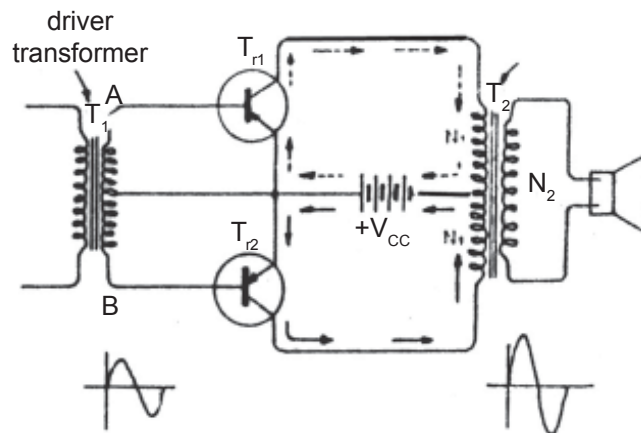


Fig 4.2

Circuit operation:

The input signal appears across the secondary AB of driver transformer. Suppose during the first half cycle of the signal, end A becomes positive and end B negative. This will make the base-emitter

junction of Tr1 reverse biased and that of Tr2 forward biased. The circuit will conduct current due to Tr2 only and is shown by solid arrows. Therefore this half cycle of the signal is amplified by Tr2 and appears in the lower half of the primary of output transformer. In the next half cycle of the signal, Tr1, is forward biased whereas Tr2 is reverse biased. Therefore Tr1 conducts and is shown by dotted arrows. Consequently, this half-cycle of the signal is amplified by Tr1 and appears in the upper half of the output transformer primary. The centre - tapped primary of the output transformer combines two collector currents to form a sine wave output in the secondary.

Advantages:

- (i) The efficiency of the circuit is quite high (75%) due to class B operation.
- (ii) A high a.c. output power is obtained

Disadvantages:

- (i) Two transistors have to be used. If their parameters are not the same, there will be unequal amplification of the two halves of the signal.
- (ii) The circuit give more distortion.
- (iii) Transformers used as bulky and expensive.

4.4 Explain the working of complementary - symmetry push - pull Amplifier:

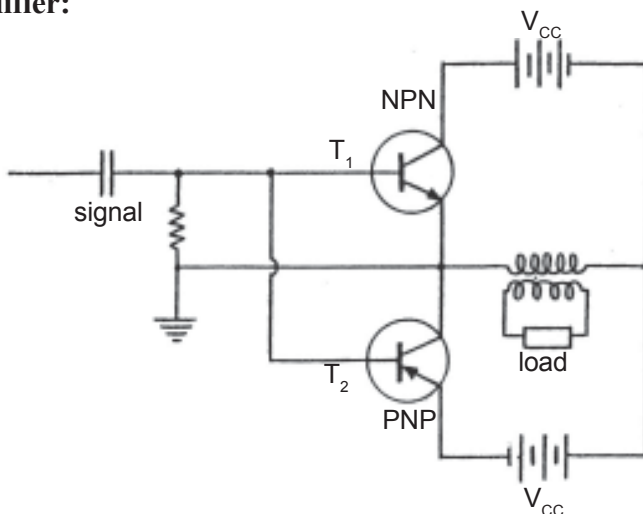


Fig 4.3

By complementary symmetry is meant a principle of assembling push - pull class B amplifier without requiring centre - tapped transformers at the input and output stage. It employs one NPN and one PNP transistor and requires no centre - tapped transformers.

Circuit Operation:

During the positive half cycle of the input signal, transistor T1 (the NPN transistor) conducts current while T2 (the PNP transistor) is cut off. During the negative half cycle of the signal, T2 conducts while T1 is cut off. In this way, NPN transistor amplifies the positive half - cycle of the signal while the PNP transistor amplifies the negative half cycle of the signal. We generally use an output transformer (not centre tapped) for impedance matching.

Advantages:

- (i) This circuit does not require transformer. This saves on weight and cost.
- (ii) Equal and opposite input signal voltages are not required.

Disadvantages:

- (i) It is difficult to get a pair of transistors (NPN and PNP) that have similar characteristics.
- (ii) We require both positive and negative supply voltages.

4.5 List the applications of power amplifiers:

The power amplifier stage becomes necessary in

- (i) Public address Amplifier
- (ii) Receivers
- (iii) Transmitters etc.

In case the power of the amplified signal is insufficient to operate a loudspeaker, a picture tube or to perform any useful work in spite of employing many voltage amplifier stages.

Summary:

AF amplifier : these are used in audio frequency (20Hz to 20KHz) range.

RF amplifier : these are used in RF frequency (20KHz to 30MHz) range.

Voltage amplifier : it is an amplifier which gives only voltage amplification.

Power amplifier : It is an amplifier which gives power amplification.

Power Amplifier :

- 1) Class A power amplifier
- 2) Class B power amplifier
- 3) Class B push-pull power amplifier
- 4) Class C power amplifier

Power amplifier are used voltage and power amplification purpose in communication networks.

Short Questions :

- 1) What are the applications of AF amplifier.
- 2) What are the applications of RF amplifier.
- 3) Which amplifier is used audio output power
- 4) What are the advantages of complementary symmetry in push-pull amplifier.
- 5) What are the applications of power amplifiers.

Essay Questions:

- 1) Distinguish between voltage and power amplifiers?
- 2) Explain working of single ended class A power amplifier?
- 3) Explain working of Class B push-pull amplifier?
- 4) Explain working of complementary symmetry push-pull amplifier?

5. Feedback Amplifiers

5.0 Introduction of Feedback Amplifiers:

The phenomenon of feeding a portion of the output energy back to the input circuit is known as feedback. The effect results in a dependence between the output and the input and an effective control can be obtained in the working of the circuit. Feedback is of two types.

1. Positive Feedback
2. Negative Feedback

Positive or regenerative feedback:

When the feedback voltage or current is in phase with the input signal, it is called positive or regenerative feedback. The positive feedback increases the amount of amplification.

Negative or Degenerative feedback:

When the feedback voltage or current is out of phase to the input signal; it is called negative or degenerative feedback. Negative feedback decreases the magnitude of amplification. Its main advantage is the reduction in the distortion of the amplifier.

5.1 Principle of negative feedback amplifiers and their advantages:

A feedback amplifier has two parts viz an amplifier and a feedback circuit. The feedback circuit usually consists of resistors and return a fraction of output energy back to the input. The following fig shows the principles of negative voltage feedback in an amplifier. Typical values have been assumed to make the treatment more illustrative. The output of the amplifier is 10V. The fraction mv of this output i.e. 100mv is feedback to the input where it is applied in series with the input signal of 101mv. As the feedback is negative, therefore, only 1mv appears at the input terminals of the amplifier.

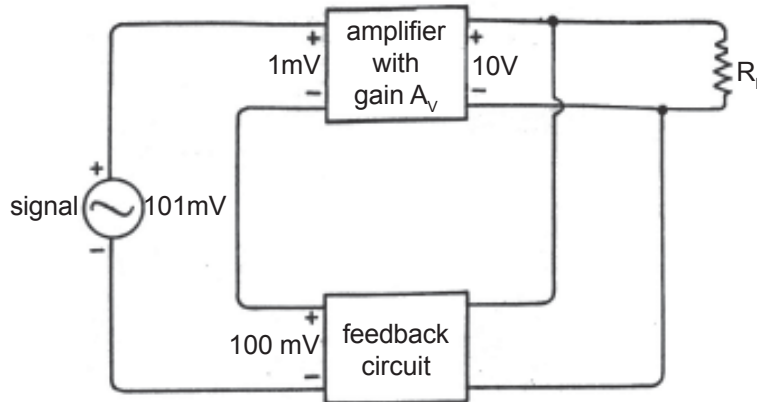


Fig 5.1

Referring to the above fig

Gain of the amplifier without feedback

$$A_v = \frac{10_v}{1\text{mV}} = 10,000$$

Fraction of the output voltage feedback

$$A_v = \frac{100\text{mV}}{10_v} = 0.01$$

Gain of the amplifier with feedback

$$A_{vf} = \frac{10_v}{101\text{mV}} = 100$$

The following points are worth noting:

- 1) When the negative voltage feedback is applied, the gain of the amplifier is reduced.
- 2) When the negative voltage feedback is employed, the voltage actually applied to the amplifier is extremely small.
- 3) In a negative voltage feedback circuit, the feedback fraction of mV is always between 0 and 1.
- 4) The gain with feedback is sometimes called closed - loop gain while the gain without feedback is called open - loop gain.

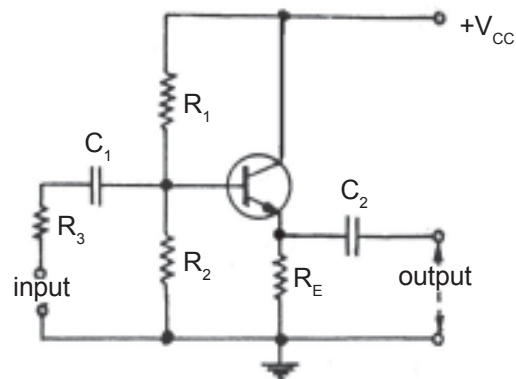
Advantages of negative voltage feedback:

- 1) Gain stability
- 2) Reduces nonlinear distortion
- 3) Improves frequency response
- 4) Increase circuit stability
- 5) Increases input impedance and decreases output impedance.

5.2 Different types of negative feedback:

There are two principal types of negative feedback amplifier circuits.

1. Voltage feedback Amplifier
2. Current feedback Amplifier

1. Voltage feedback Amplifier:**Fig 5.2**

The circuit of a voltage feedback amplifier is shown in the fig. The feedback voltage is derived through the resistor R_E . There is no collector load resistor in this circuit and the output is taken across R_E through C_2 . The circuit is similar to an Emitter follower circuit.

2. Current feedback Amplifier:

In the current feedback amplifier circuit, a voltage which is proportional to the output current is feedback in series with the input signal. The resistor R_E is the feedback resistor. Here the output is taken from the collector across R_C .

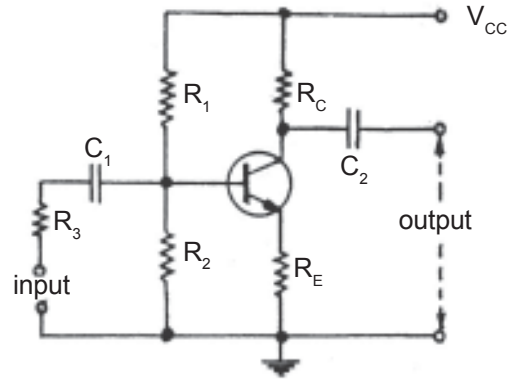


Fig 5.3

The current feedback amplifier is commonly used in practical amplifier circuits such as record players, tape recorders, stereo systems etc.

5.3 Explain the working of Emitter Follower circuit and mention its Advantages.

Emitter Follower:

It is a negative current feedback circuit. The Emitter Follower is a current amplifier that has no voltage gain. Its most important characteristic is that it has high input impedance and low output impedance. This makes it an ideal circuit for impedance matching.

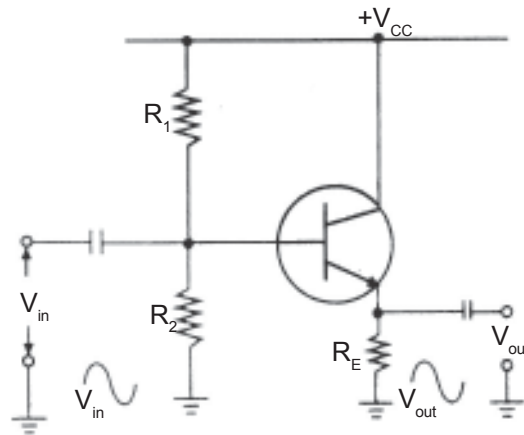


Fig 5.4

Working:

The input voltage is applied between base and emitter and the resulting a.c. emitter current produces an output voltage $i_e R_E$ across the emitter resistance. This voltage opposes the input voltage, thus providing negative feedback. Clearly, it is a negative current feedback circuit since the voltage feedback is proportional to the emitter current i.e. output current. It is called emitter follower since the output voltage follows the input voltage.

Advantages:

- 1) No voltage gain. Infact, the voltage gain of an emitter follower is close to 1.
- 2) Relatively high current gain and power gain.
- 3) High input impedance and low output impedance.
- 4) Input and output ac voltages are in phase.

5.4 Explain the working of basic differential amplifiers:**Differential Amplifier:**

The circuit is employed mainly in digital equipments. It has two input terminals A and B.

Two NPN transistors have been employed in this circuit (a circuit can be designed with two PNP transistors too). A single battery is employed to supply bias to the two transistors, C and D are the output terminals. When the input signal voltages at A and B are equal to each other, the output will be zero. Conversely, if there is a voltage or phase difference between the two input signals then the difference voltage will be amplified by the circuit and an output will be available. The circuit is known as differential amplifier or common mode rejection circuit on account of its above stated property.

The output voltage of a differential amplifier $E_0 = \text{Gain} (E_1 - E_2)$

Where E_0 = output voltage

E_1 = Input voltage to one transistor

E_2 = Input voltage to the second transistor

In digital circuits if the two inputs are 1 then the output will be 0 and if one input is 1 and the other is zero then output will be 1. This circuit can also be utilised for noise rejection in radio receivers.

5.5 Block diagram of operational Amplifier:

A high gain I.C. based direct coupled amplifier is known as 'operational amplifier'. The amplifier is capable to amplify AC and DC both types of input signals.

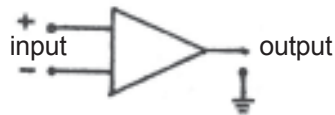


Fig 5.5

This circuit has two input terminals marked as (+) and (-). If the input signal is applied to (+) terminal, the output will be in phase with the input. Conversely, if the input signal is applied to the (-) terminal, the output will be out of phase to the input, This amplifier circuit is a combination of different types of direct coupled circuits. It has a high input impedance.

Typically an IC Op-Amp consists of the following stages in cascade as shown in fig.

- 1) A differential amplifier with double ended output
- 2) A differential amplifier with single ended output
- 3) An emitter follower
- 4) A dc level transistor and output driver.

The OP-Amp uses monolithic IC technology to get all the benefits of this technology. Such a circuit has the merits of low voltage and current, small size, high reliability and excellent temperature tracking.

Differential Amplifier forms the most important unit of an Op-Amp.

5.6 Advantages of OP-Amp:

- 1) It may be used for performing various linear operations and some nonlinear operations
- 2) A novel feature of Op-Amp is that by simply changing the feedback impedance, its operation may be altered.
- 3) Present day Op-Amp uses IC technology.
- 4) IC Op-Amp are widely used as versatile predictable, accurate and economic system building block
- 5) It possesses all the merits of monolithic IC's namely small size, high reliability, low cost, temperature tracking and low offset voltage and current.

5.7 Applications of Op-Amp:

An OP-Amp may be used to perform numerous linear operations and some nonlinear operations.

Linear Analog Systems using IC Op-Amps

- 1) Analog computer
- 2) Voltage to current converters
- 3) Current to voltage converters
- 4) Amplifier for numerous specific uses such as dc instrumentation, tuned amplifier, video amplifier etc.
- 5) voltage follower
- 6) Active filter
- 7) Delay equalizers.

Nonlinear Analog systems using IC OP-Amps.

IC OP-Amps may also be used in nonlinear analog systems. Typical such systems are:

- i) Amplitude modulators
- ii) Logarithmic Amplifiers and Analog multipliers
- iii) Sample and hold circuits
- iv) Comparators
- v) Square wave generators
- vi) Triangular wave generators

Summary :**Feedback :**

A part of output energy taken through a network to give input is known as Feedback. There are two types of feedback

- 1) Positive feedback
- 2) Negative feedback

Advantages of Negative Feedback:

1) It gives voltage, current, power gains more distortion and frequency response is over wide band.

Different types Feedback

- 1) Voltage Feedback
- 2) Current Feedback

Emitter follower circuit is used for impedance matching in between two stages in RF amplification.

Differential amplifier :

This circuit works two modes one is common mode and the other is difference mode.

Advantages of operational amplifier :

Zero input impedance, infinity output admittance, high current gain used as integrator, differentiator and half adder full adder circuit etc.,

Short Questions :

- 1) Define Feedback
- 2) What are the advantages of negative feedback
- 3) Name the different types of feedback networks
- 4) What are the applications of the emitter follower
- 5) What are the advantages of Op-Amp.
- 6) What are the applications of Op-Amp.

Essay Questions:

- 1) Explain Principle of negative feedback used in amplifier and their advantages?
- 2) Explain the working of emitter follower. Mention the advantages?
- 3) Explain working of differential amplifier?
- 4) Draw the block diagram of Op-Amp, Explain working?

6. Oscillators

6.0 Understand working of electronic oscillators:

Many electronic devices require a source of energy at a specific frequency which may range from a few Hz to several MHz. This is achieved by an electronic device called an oscillator. Oscillators are extensively used in electronic equipment. Oscillators are also widely used in Radio and TV receivers, Radar, electronic computers and other electronic devices. Oscillators can produce sinusoidal or non-sinusoidal (e.g. square waves)

6.1 List the requirements of an Oscillator:

The following three items are essential for an oscillator

1. Transistor amplifier circuit
2. Feedback circuit
3. Tank circuit

1. Amplifier :

An amplifier circuit with positive feedback works as an oscillator

2. Feedback circuit :

An oscillator requires positive feedback. A portion of the output energy is received by the input circuit by means of feedback. If the amount of feedback is not enough to compensate the losses of the amplifier circuit then the circuit will not oscillate at all.

3. Tank Circuit :

A resonant circuit consisting of an inductor and a capacitor or a crystal is known as tank circuit. This circuit produces oscillations and decides their frequency.

Tank circuit working :

A circuit which produces electrical oscillators of any desired frequency is known as an oscillatory circuit or tank circuit.

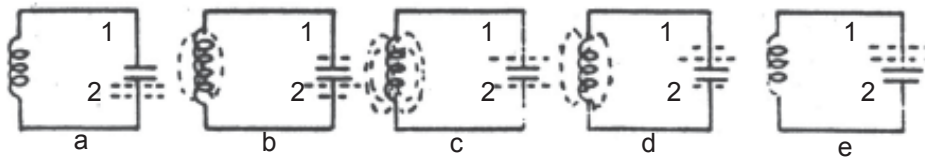


Fig 6.1

If a capacitor is charged and then connected across an inductor, it will start to discharge. fig (a). The electrons will start to move from plate 2 to plate 1 through the coil. An alternating magnetic field will be produced around the coil due to the flow of electrons. A back emf will be induced in the coil due to alternating nature of the magnetic field which will oppose the flow of current and thus will reduce the current fig (b).

When the number of electrons on the two plates becomes equal i.e. the capacitor is fully discharged, the current will be reduced further and the magnetic field will begin to conduct. The flow of current will continue due to contracting magnetic field and the back emf will now oppose its contraction fig (d). The process will continue till the charge of the plate is not lost completely. In this way, the capacitor will be charged in opposite direction fig (e).

Now the former action will repeat. Hence, the electrostatic field of the capacitor will continue to transfer energy to the electromagnetic field of the coil and vice-versa. As a result, an alternating current will start to flow in the circuit. If there Occurs no loss in the transfer of energy, the oscillations will continue indefinitely, but an energy loss always exists in the circuit due to ohmic resistance of the coil and the capacitor. Consequently, the amplitude of oscillations goes on reducing continuously. Oscillations whose amplitude goes on reducing continuously are called damped oscillations. The following formula is used for the calculation of oscillatory frequency of the tank circuit.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where f = frequency, Hz

L = inductance, H

C = capacitance, F

2π = constant 2×3.142

If the loss of energy in each cycle of a damped wave is compensated regularly, the oscillations will continue.

Barkhausen Criterion :

The condition for sustained oscillations in a single wave excited oscillator worked out by the German scientist Barkhausen is that the voltage multiplication of the amplifier must exactly counter balance the voltage dividing ratio of the feedback circuit.

$$B = \frac{1}{A} \quad \text{Where } B = \text{feedback factor, } A = \text{Voltage gain}$$

6.2 Explain the working of Hartley, Colpitts, Crystal, Tuned Collector Oscillators:

Tuned Collector Oscillator :

The tuned collector oscillator contains tuned circuit $L_1 - C_1$ in the collector and hence the name. The frequency of oscillations depends upon the values of L_1 and C_1 and is given by

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

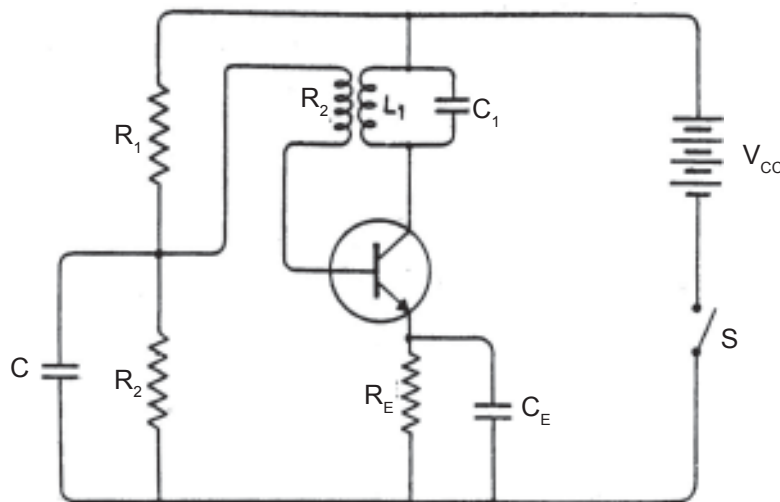


Fig 6.2

The feedback coil L_2 in the base circuit is magnetically coupled to the tank circuit L_1 . In practice, L_1 and L_2 form the primary and secondary of the transformer. The biasing is provided by potential divider arrangement. The capacitor C connected in the base circuit provides low reactance path to the oscillations.

Circuit Operation:

When switch S is closed. Collector current starts increasing and charges the capacitor C_1 . When this capacitor is fully charged, it discharges

through Coil L_1 , setting up oscillations of frequency. $f = \frac{1}{2\pi\sqrt{L_1 C_1}}$

These oscillations induce some voltage in coil L_2 by mutual induction. The frequency of voltage in coil L_2 is the same as that of tank circuit but its magnitude depends upon the number of turns of L_2 and coupling between L_1 and L_2 . The voltage across L_2 is applied between base and emitter and appears in the amplified form in the collector circuit, thus overcoming the losses occurring in the tank circuit. The number of turns of L_2 and coupling between L_1 and L_2 are so adjusted that oscillations across L_2 are amplified to a level just sufficient to supply losses to the tank circuit.

It may be noted that the phase of feedback is correct i.e., energy supplied to the tank circuit is in phase with the generated oscillations. A phase shift of 180° is created between the voltages of L_1 and L_2 due to transformer action. A further phase shift of 180° takes place between base-emitter and collector circuit due to transistor properties. As a result the energy feedback to the tank circuit is in phase with the generated oscillations.

Colpitt's Oscillator :

The fig shows a colpitt's oscillation. It uses two capacitors C_1 and C_2 placed across a common inductor L and the centre of the two capacitors is tapped. The tank circuit is made up of C_1 , C_2 and L . The frequency of oscillations is determined by the values of C_1 , C_2 and L and is given by

$$f = \frac{1}{2\pi\sqrt{LC_T}} \quad \text{where } C_T = \frac{C_1 C_2}{C_1 + C_2}$$

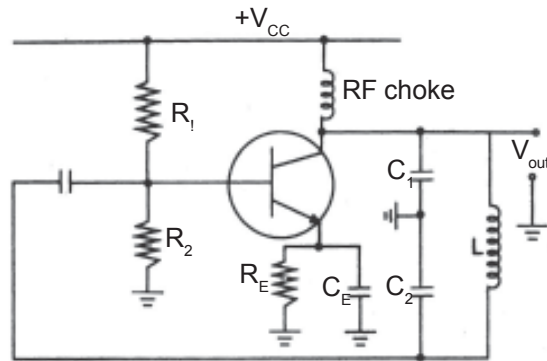


Fig 6.3

Circuit Operation :

when the circuit is turned on, the capacitors C_1 and C_2 are charged. The capacitors discharge through L , setting up oscillations of frequency of

frequency. $f = \frac{1}{2\pi\sqrt{C_T L}}$ The output voltage of the amplifier appears across

C_1 and feedback voltage is developed across C_2 .

The voltage across C_2 is 180° out of phase with the voltage developed across C_1 (V_{out}). It is easy to see that voltage feedback (Voltage across C_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by C_1 - C_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillation.

Hartley Oscillator:

The hartley oscillator is similar to colpitt's oscillator with minor modifications. Instead of using tapped capacitors, two inductors L_1 and L_2 are placed across a common capacitor C and the centre of inductors is tapped as showing fig. The tank circuit is made up of L_1 , L_2 and C . The frequency of oscillations is determined by the values of L_1 , L_2 and C and is given by

$$f = \frac{1}{2\pi\sqrt{L_T C}} \quad \text{where } L_T = L_1 + L_2 + 2M$$

Here M = mutual inductance between L_1 and L_2

Note that $L_1 - L_2 - C$ is also the feedback network that produces a phase shift of 180°

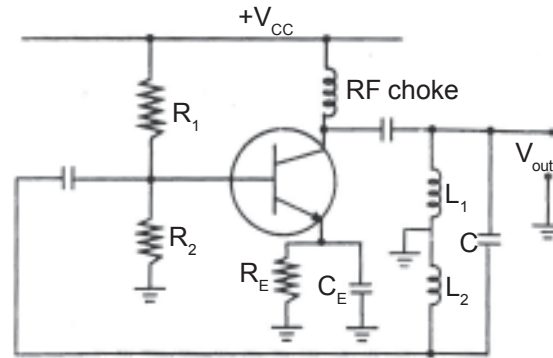


Fig 6.4

Circuit Operation :

When the circuit is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils L_1 and L_2 setting up

oscillations of frequency determined. $f = \frac{1}{2\pi\sqrt{CL_T}}$

The output voltage of the amplifier appears across L_1 and the feedback voltage across L_2 . The voltage across L_2 is 180° out of phase with the voltage developed across L_1 (V_{out}). It is easy to see that voltage feedback (ie voltage across L_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by L_1, L_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

Crystal Oscillator:

Piezo electric effect :

Certain crystalline materials, namely : Rochelle salt, quartz and tourmaline exhibit the piezo electric effect i.e. when we apply a d.c. voltage across them, they vibrate at the frequency of the applied voltage. Conversely, when they are compressed or placed under mechanical strain to vibrate, they produce an a.c. voltage.

Working of Quartz crystal :

In order to use crystal in an electronic circuit, it is placed between two metal plates. The arrangement then forms a capacitor with crystal as the dielectric. If an a.c. voltage is applied across the plates, the crystal will start vibrating at the frequency of applied voltage. However, if the frequency of the applied voltage is made equal to the natural frequency of the crystal, resonance takes place and crystal vibrations reach a maximum value. This natural frequency is almost constant. Effects of temperature can be eliminated by mounting the crystal in a temperature controlled oven as in radio and television transmitters.

Transistor crystal oscillator :

The fig shows the transistor crystal oscillator. It is the Colpitt's oscillator modified to act as a crystal oscillator. The only change is the addition of the crystal (Y) in the feedback network. The crystal will act as a parallel tuned circuit.

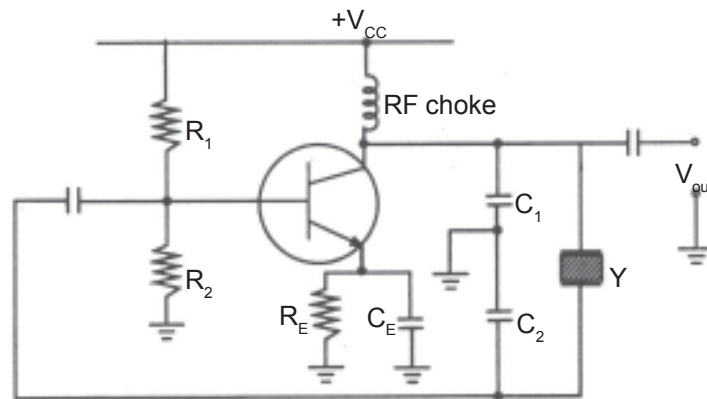


Fig 6.5

In this circuit it is seen that instead of resonance caused by L and $(C_1 + C_2)$, we have the parallel resonance of the crystal. At parallel resonance, the impedance of the crystal is maximum. This means that there is a maximum voltage drop across C_1 . This in turn will allow the maximum energy transfer through feedback network at f_p .

Note that the feedback is positive. A phase shift of 180° is produced by the transistor. A further phase shift of 180° is produced by the capacitor voltage divider. This oscillator will oscillate only at f_p . Even

the smallest deviation from f_p will cause the oscillator to act as an effective short. Consequently, we have an extremely stable oscillator.

Advantages :

- (i) They have a high order of frequency
- (ii) The Q-factor of the crystal is very high. The Q factor of the crystal may be as high as 10,000 compared to about 100 of L - C tank.

6.3 RC phase shift oscillator :

The RC phase shift oscillator consists of a conventional transistor amplifier and a RC. Phase shift network. The phase shift network consists of three sections R_1, C_1, R_2, C_2 and R_3, C_3 . At some particular frequency f_0 , the phase shift in each RC section is 60° so that the total phase shift produced by the RC network is 180° . The frequency of oscillations is given by

$$f_0 = \frac{1}{2\pi RC\sqrt{6}}$$

$$\begin{aligned} \text{Where } R_1 = R_2 = R_3 = R \\ C_1 = C_2 = C_3 = C \end{aligned}$$

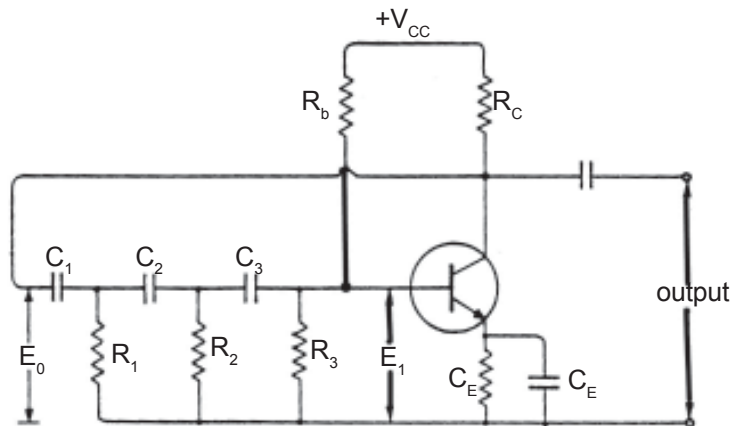


Fig 6.6

Circuit operation :

When the circuit is switched ON it produces oscillations of frequency determined by $f_0 = \frac{I}{2\pi RC\sqrt{6}}$. The output E_0 of the amplifier is

feedback to RC feedback network. This network produces a phase shift of 180° and a voltage E_i appears at its output which is applied to the transistor amplifier.

The feedback fraction $m = \frac{E_i}{E_0}$. The feedback phase is correct. A

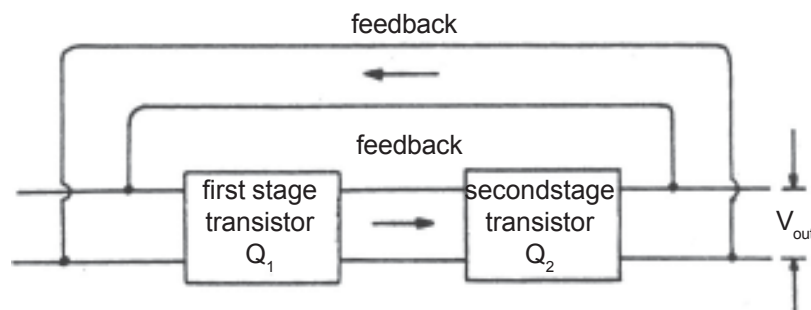
phase shift of 180° is produced by the transistor amplifier. A further phase shift 180° is produced by the RC network. As a result, the phase shift around the entire loop is 360°

Advantages :

- (i) It does not require transformers or inductor
- (ii) It can be used to produce very low frequencies.
- (iii) The circuit provides good frequency stability.

6.4 List the different types of multivibrators.**Multivibrator :**

An electronic circuit that generates square waves (or other non-sinusoidals such as rectangular, saw tooth waves) is known as a multivibrator.

**Fig 6.7**

A multivibrator is a switching circuit which depends for operation on positive feedback. It is basically a two stage amplifier with output of one feedback to the input of the other as shown in the fig.

Types of Multivibrators :

A multivibrator is basically a two - stage amplifier with output of one feedback to the input of the other. At any particular instant one transistor is ON and the other is OFF. After a certain time depending upon the circuit components, the stages reverse their conditions the conducting stage suddenly cuts off and the non-conducting stage suddenly starts to conduct. The two possible states of a multivibrator are:

	ON	OFF
First State	Q1	Q2
Second State	Q2	Q1

Depending upon the manner in which the two stages interchange their states, the multivibrators are classified as:

- (i) Astable or free running multivibrator
- (ii) Monostable or one - shot multivibrator
- (iii) Bistable or flip - flop multivibrator

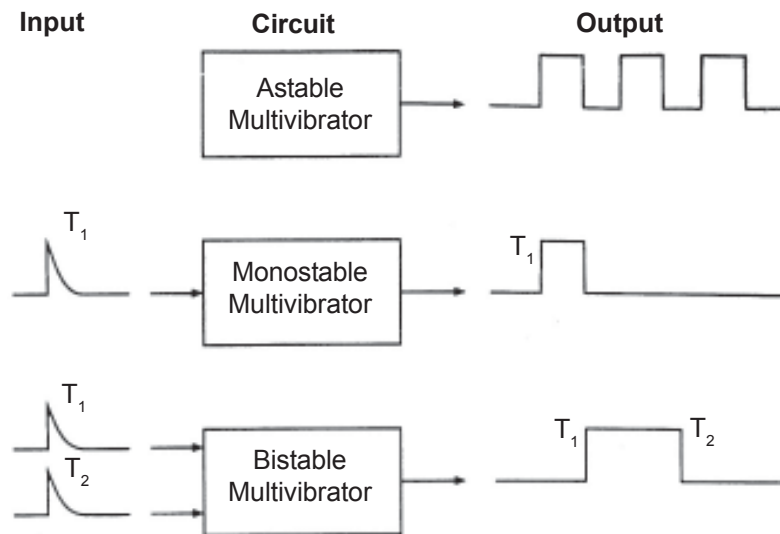


Fig 6.8

6.5 Explain with circuit diagram, astable multivibrator.

Astable or free running multivibrator :

It has no stable working state and that is why it is called a free - running or astable multivibrator.

It employs two transistors Q_1 and Q_2 . Let Q_2 to conduct first then Q_1 remains non - conducting. The collector voltage of Q_1 charges capacitor C_1 and makes the base of Q_2 to be positive. The base - emitter junction of Q_2 completes the changing path of capacitor C_1 . Now the capacitor starts to discharge through the resistors R_2 and R_5 . The voltage drop developed across R_5 depends on the current flowing through the transistor R_2 and R_5 . The base bias will now be available for resistor Q_1 and it will start to conduct and the same time Q_2 will become non - conducting because the collector voltage will have become zero by that time. The capacitor C_1 will discharge through the resistors R_2 and R_3 .

In this way, the conducting states of transistors Q_1 and Q_2 will change continuously and the circuit will continue to oscillate till the power supply is present.

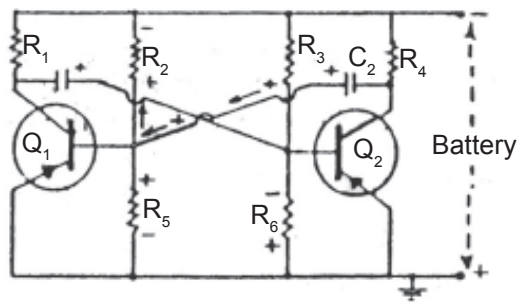


Fig 6.9

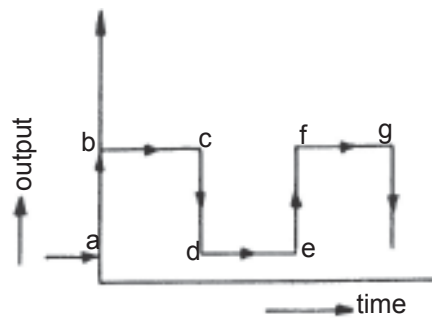


Fig 6.10

6.6 Explain the principle of Bistable and Monostable Multivibrators:

Monostable Multivibrator :

A multivibrator in which one transistor is always conducting (i.e in the ON state) and the other is non-conducting (i.e. in the OFF state) is called a monostable multivibrator.

A Monostable multivibrator has only one stable state. In other words, if one transistor is conducting and the other is non-conducting, the circuit will remain in this position. It is only with the application of external pulse that the circuit will interchange the states. However, after a certain time, the circuit will automatically switch back to the original stable state and remains there until another pulse is applied. Thus a monostable multivibrator cannot generate square waves of its own like an astable multivibrator. Only external pulse will cause it to generate the square wave.

Bistable Multivibrator :

A multivibrator which has both the states stable is called a bistable multivibrator.

The bistable multivibrator has both the states stable. It will remain in whichever state it happens to be until a trigger pulse causes it to switch to the other state. For instance, suppose at any particular instant, transistor Q_1 , is conducting and transistor Q_2 is at cut off. If left to itself, the bistable multivibrator will stay in this position forever. However, if an external pulse is applied to the circuit in such a way that Q_1 is cut off and Q_2 is turned on, the circuit will stay in the new position. Another trigger pulse is then required to switch the circuit back to its original state.

Summary :

There are two types of feedback

- 1) Positive feedback
- 2) Negative feedback

Conditions to get oscillations**1. Barkhausen Criterion :**

Closed phase shift 360° and loop gain unity

Oscillators:

Hartley, Colpitts, tuned collector, phase shift and crystal oscillators

Multivibrators :

Mono stable multivibrator : It is used as a timer circuit,

Bistable multivibrator :

It has got two stable states used a flip-flop

Astable multivibrator :

It generates square wave and used as a clock.

Short Questions :

- 1) Define positive feedback?
- 2) Name the conditions to get oscillations?
- 3) What are the advantages of crystal oscillators?
- 4) What are the applications tuned collector oscillator?
- 5) How do you get 180° phase shift in RC phase shift oscillator?
- 6) What are the applications of multivibrator?

Essay Questions :

- 1) What is feedback explain conditions to get oscillations any oscillator?
- 2) Draw the Hartly oscillator explain working?
- 3) Draw the Colpitts oscillator explain working?
- 4) Draw the tuned collector oscillator explain working?
- 5) Explain the working of RC phase shift oscillator?
- 6) Explain with circuit diagram astable multivibrator?
- 7) Explain biastable multivibrator?
- 8) Explain the monostable multivibrator?

7. Pulse Shaping Circuits

7.1 Distinguish between linear wave shapping and nonlinear wave shapping circuits.

Linear wave shapping network :

It is the network which produces the wave form amplitude is symmetrical in time axis. Ex. Sine wave, Square wave, Rectangular wave, Triangular wave etc.,

Nonlinear wave shapping network :

It is the network in which produces the wave form is asymmetrical amplitude to time axis. Ex. Distorted wave and Exponensive waves.

7.2 Integrating and differentiating circuits :

Differentiating circuit : A circuit in which output voltage is directly proportional to the derivative of the input is known as a differentiating circuit.

$$\text{Output} \propto \frac{I_C}{I_B} (\text{Input})$$

A differentiating circuit is a simple RC series circuit with output taken across the resistor R. The circuit is suitably designed so that output is proportional to the derivative of the input. Thus if a d.c. or constant input is applied to such a circuit, the output will be zero. It is because the derivative of a constant is zero.

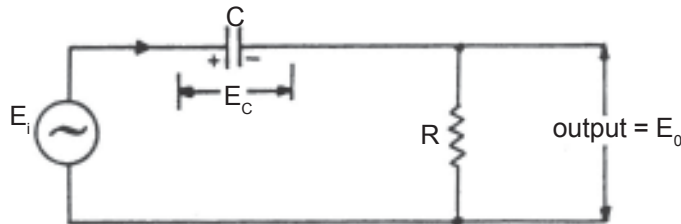


Fig 7.1

The fig shows a typical differentiating circuit. The output across R will be the derivative of the input. It is also necessary to set the proper circuit values. In order to achieve good differentiation, the following two conditions should be satisfied.

- (i) The time constant RC of the circuit should be much smaller than the time period of the input wave
- (ii) The value of X_c should be 10 or more times larger than R at the operating frequency.

Fulfilled these conditions, the output across R will be the derivative of the input.

Let e_i be the input alternating voltage and let i be the resulting alternating current. The charge q on the capacitor at any instant is

$$q = Ce_c$$

$$\text{Now } i = \frac{dq}{dt} = \frac{d}{dt} (q) = \frac{d}{dt} (Ce_c)$$

$$\text{or } i = C \frac{d}{dt} (e_c)$$

Since the capacitive reactance is very much larger than R , the input voltage can be considered equal to the capacitor voltage with negligible error

Output voltage :

Output waveforms :

The output waveform from a differentiating circuit depends upon the time constant and shape of the input wave

- (i) When input is a square wave : When the input fed to a differentiating circuit is a square wave, output will consist of sharp narrow pulses as shown in fig. E_i

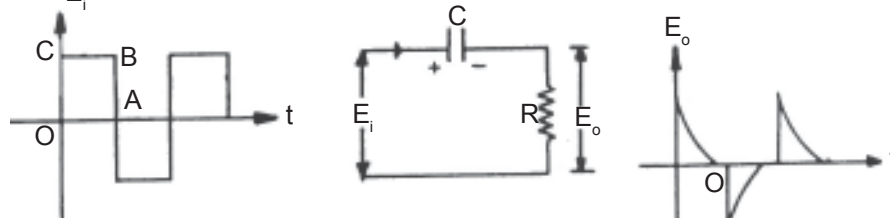


Fig 7.2

(ii) When input is a saw tooth wave : When the input fed to a differentiating circuit is a saw - tooth wave, the output will be a rectangular wave as shown in fig.

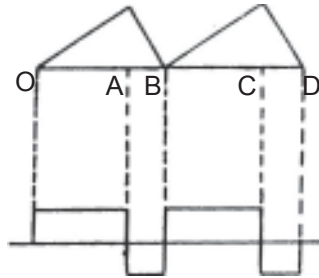


Fig 7.3

(iii) When input is a sine wave : A sine wave input becomes a cosine wave and a cosine wave input becomes an inverted sine wave at the output.

Integrating Circuit :

A circuit in which output voltage is directly proportional to the integral of the input is known as an integrating circuit. i.e. Output is an integral of Input

An integrating circuit is a simple RC series circuit with output taken across the capacitor C as shown in fig. It may be seen that R and C of the differentiating circuit have changed places. In order that the circuit renders good integration, the following conditions should be fulfilled.

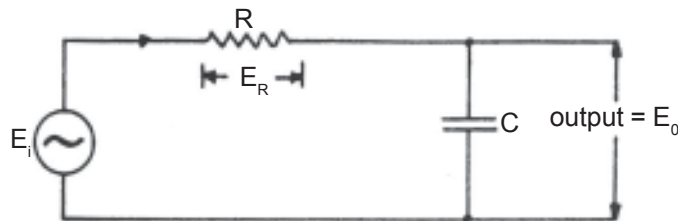


Fig 7.4

(i) The time constant RC of the circuit should be very large as compared to the time period of the input wave.

(ii) The value of R should be 10 or more times larger than X_c .

Let e_i be the input alternating voltage and let i be the resulting alternating current. Since R is very large as compared to capacitive reactance X_c of the capacitor, it is reasonable to assume that voltage across R (ie e_R) is equal to the input voltage is.

$$e_i = e_R$$

$$\text{Now } i = \frac{e_R}{R} = \frac{e_i}{R}$$

The charge q on the capacitor at any instant is

$$\begin{aligned} q &= \int i \, dt \\ \text{output voltage, } e_o &= \frac{q}{C} = \frac{\int i \, dt}{C} = \frac{\int i \, dt}{C} \left[\because i = \frac{e_i}{R} \right] \\ &= \frac{1}{RC} \int e_i \, dt \end{aligned}$$

$$\begin{aligned} &\propto \int e_i \, dt \quad (\because RC \text{ is constant}) \\ \therefore \text{output voltage} &\propto \int \text{input} \end{aligned}$$

Output wave forms. The output wave form from an integrating circuit depends upon time constant and shape of the input wave.

(i) When input is a square wave : When the input fed to an integrating circuit is a square wave, the output will be a triangular wave as shown in fig.

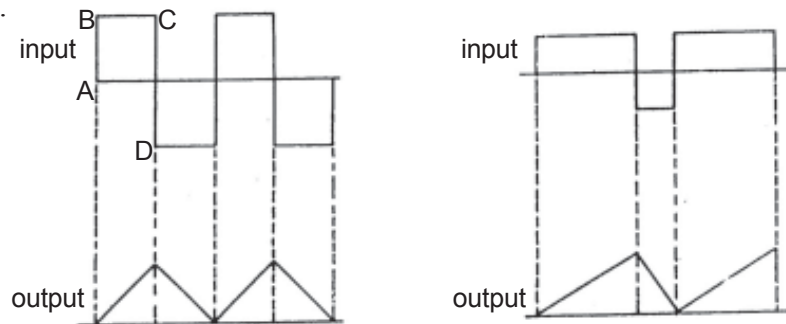


Fig 7.5

(ii) When the input is rectangular wave : When the input fed to an integrating circuit is a rectangular wave, the output will be a saw tooth wave as showing fig.

7.3 Clipping and clamping circuits :

A clipper (or limiter) is used to clip off or remove a portion of an a.c. signal. The half-wave rectifier is basically a clipper that eliminates one of the alternations of an a.c. signal.

Clipping circuits :

The circuit with which the wave form is shaped by removing (or clipping) a portion of the applied wave is known as a clipping circuit.

The clippers can remove signal voltages above or below a specified level. The important diode clippers are (i) positive clipper (ii) biased clipper (iii) combination clipper

(i) Positive Clipper :

A positive clipper is that which removes the positive half - cycles of the input voltage. Fig shows the typical circuit of a positive clipper using a diode. As shown, the output voltage has all the positive half cycles removed or clipped off.

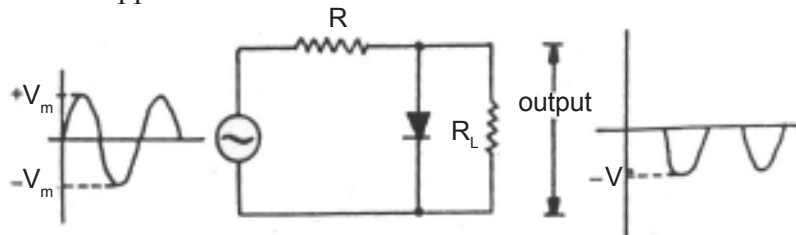


Fig 7.6

The circuit action is as follows. During the positive half cycle of the input voltage, the diode is forward biased and conducts heavily. Therefore, the voltage across the diode (which behaves as a short) and hence across the load R_L is zero. Hence output voltage during positive half cycles is zero.

During the negative half cycles of the input voltage, the diode is reverse biased and behaves as an open. In this condition, the circuit behaves as a voltage divider with an output of

$$\text{output voltage} = \frac{R_L}{R+R_L} V_m$$

Generally, R_L is much greater than R .
 \therefore output voltage = $-V_m$

It may be noted that if it is desired to remove the negative half cycle of the input, the only thing to be done is to reverse the polarities of the diode in the circuit as shown in fig. Such a clipper is then called a negative clipper.

(ii) Biased clipper :

Some times it is desired to remove a small portion of positive or negative half cycle of the input signal voltage. For this purpose biased clipper is used. Fig shows the circuit of a biased clipper using a diode with a battery of V volts. With the polarities of battery shown, a portion of each positive half cycle will be clipped. However, the negative half cycles will appear as such across the load. Such a clipper is called biased positive clipper.

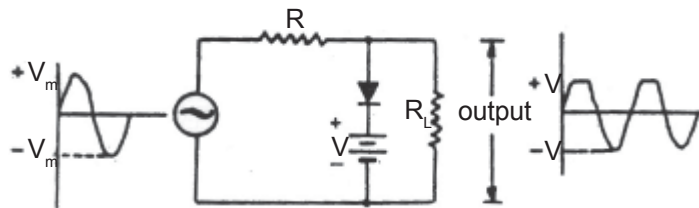


Fig 7.7

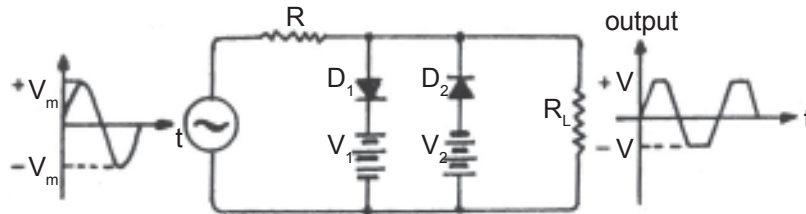
The circuit action is as follows. The diode will conduct heavily as long as input voltage is greater than $+V$. When the input voltage is greater than $+V$, the diode behaves a short and the output equals $+V$. The output will stay at $+V$ so long as the input voltage is greater than $+V$. During the period the input voltage is less than $+V$, the diode is reverse biased and behaves as an open. Therefore, most of the input voltage appears across the output. In this way the biased positive clipper removes input voltage above $+V$.

During the negative half - cycle of the input voltage, the diode remains reverse biased. Therefore almost entire negative half cycle appears across the load.

If it is desired to clip a portion of negative half cycles of input voltage, the only thing to be done is to reverse the polarities of diode or battery. Such a circuit is then called a biased negative clipper.

(iii) Combination Clipper :

It is a combination of biased positive and negative clipper. With a combination clipper, a portion of positive and negative half cycles of input voltage can be removed or clipped as shown in fig.

**Fig 7.8**

The circuit action is as follows. When positive input voltage is greater than $+V_1$, diode D_1 conducts heavily while diode D_2 remains reverse biased. Therefore a voltage $+V_1$ appears across the load. This output stays at $+V_1$, so long as the input voltage exceeds $+V_1$. On the other hand, during the negative half-cycle, the diode D_2 will conduct heavily and the output stays at $-V_2$ so long as the input voltage is greater diode is on.

Between $+V_1$ and $-V_2$ neither diode is on. Therefore, in this condition, most of the input voltage appears across the load. The clipping circuit can give square wave output if V_m is much greater than the clipping levels.

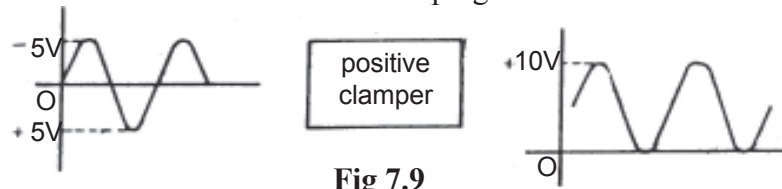
Applications of Clippers:

In general, clippers are used to perform one of the following two functions.

- (i) Changing the shape of waveform
- (ii) Circuit Transient protection

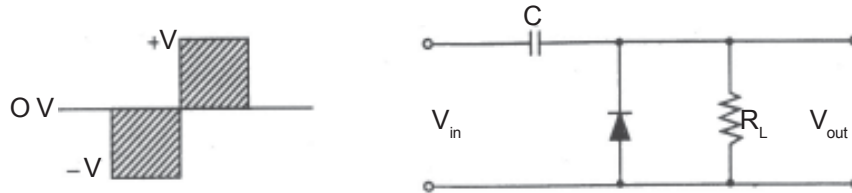
Clamping Circuits :

A circuit that places either the positive or negative peak of a signal at a desired d.c. level is known as a clamping circuit.

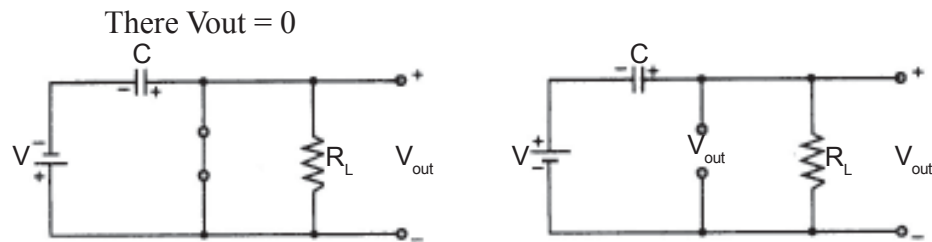
**Fig 7.9**

Positive Clamper :

The fig shows the circuit of a positive clamper. The input signal is assumed to be a square wave with time period T . The clamped output is obtained across R_L .

**Fig 7.10****Operation :**

(i) During the negative half cycle of the input signal, the diode is forward biased. Therefore the diode behaves as a short as shown in fig. The charging time constant ($= CR_f$ where R_f = forward resistance of the diode) is very small so that the capacitor will charge to V volts very quickly. It is easy to see that during this interval, the output voltage is directly across the short circuit.

**Fig 7.11**

(ii) When the input switches to $+V$ state (ie positive half cycle), the diode is reverse biased and behaves as an open as shown in fig. Since the discharging time constant ($= CR_L$) is much greater than the time period of the input signal, the capacitor remains almost fully charged to V volts during the off time of the diode. Referring to Fig and applying kirchoff's voltage law to the input. loop, we have,

$$V + V - V_{out} = 0 \text{ (or) } V_{out} = 2V$$

The resulting waveform is shown in fig. It is clear that it is positively clamped output. That is to say the input signal has been pushed upward by V volts so that negative peaks fall on the zero level.

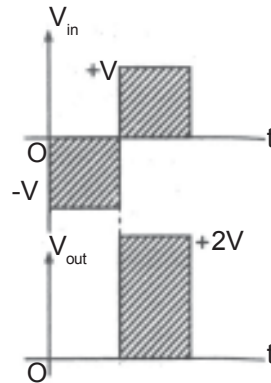


Fig 7.12

Negative Clamper:

The fig shows the circuit of a negative clamper. The clamped output is taken across R_L . Note that only charge from the positive clamper is that the connections of diode are reversed.

(i) During the positive half - cycle of the input signal, the diode is forward biased. Therefore, the diode behaves as a short as shown in fig. The charging time constant ($= CR_p$) is very small so that the capacitor will charge to V volts very quickly. It is easy to see that during this interval, the output voltage is directly across the short circuit. Therefore $V_{out} = 0$

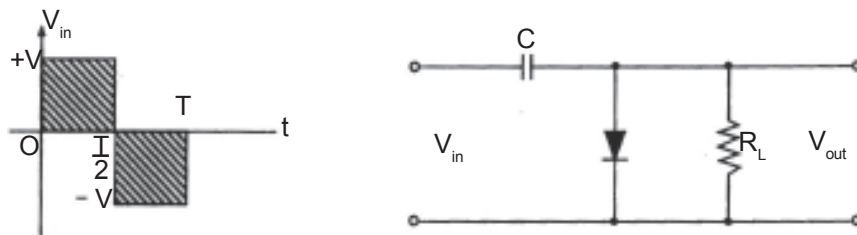


Fig 7.13

(ii) When the input switches to $-V$ state (i.e. negative half - cycle), the diode is reverse biased as shown in fig.

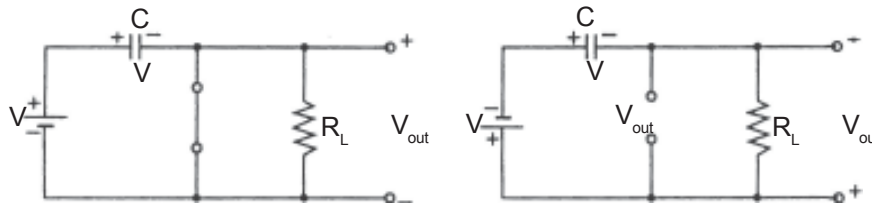


Fig 7.14

Since the discharging time constant ($+ CR_L$) is much greater than the time period of the input signal, the capacitor almost remains fully charged to V volts during the off - time of the diode. Referring to the above fig. and applying kirchoff's voltage law to the input loop, we have

$$-V - V - V_{out} = 0$$

$$(or) V_{out} = -2V$$

The resulting waveform is shown in fig. Note that total swing of the output signal is equal to the total swing of the input signal.

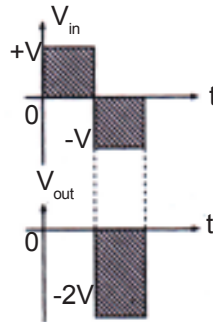


Fig 7.15

Applications :

A clamper (or dc restorer) is used to restore or change dc reference of an ac signal.

Summary :

The symmetrical wave form is one amplitude is symmetric with respect to time both in positive and negative amplitude axis

The asymmetrical wave form is one which is asymmetric with respect to time axis both in positive and negative amplitude axis.

Wave shaping networks are four types. They are

- 1) RC Integrator circuits
- 2) RC Differentiator circuits
- 3) Clipping circuit
- 4) Clamping circuit

Short Questions :

- 1) Define linear wave shaping?
- 2) Define symmetric wave shaping network?
- 3) Define asymmetries wave shaping network?
- 4) Draw negative clipping circuit?
- 5) Draw positive clipping circuit?
- 6) What is clamping?
- 7) What are the applications of clipping and clamping circuits?
- 8) Define time constant of the circuit?

Essay Questions :

- 1) Distinguish between linear and non linear network with suitable examples?
- 2) To RC differentiator circuit square wave input is given explain the output with wave forms?
- 3) Draw the clipping circuit explain positive and negative clippings?
- 4) Draw the clamping circuit explain how the reference line is shifted above positive real axis?

8. Integrated Circuits

8.1 Introduction to Microelectronics :

The circuits discussed so far in the text consisted of separately manufactured components. (Eg. resistors, capacitors, diodes, transistors etc.) joined by wires or plated conductors on printed circuit boards. Such circuits are known as discrete circuits because each component added to the circuit is discrete (i.e. distinct or separate) from others. Discrete circuits have 2 main disadvantages. Firstly, in a large circuit (eg. TV circuit, computer circuit) there may be hundreds of components and consequently discrete assembly would occupy a large space. Secondly, there will be hundreds of soldered points posing a considerable problem of reliability. To meet these problems of space conservation and reliability, engineers started a drive for miniaturized circuits. This led to the development of Microelectronics in the late 1950's.

Micro electronics is the branch of electronics engineering which deals with micro circuits. A micro circuit is simply a miniature assembly of electronic components. One type of such a circuit is the integrated circuit, generally abbreviated as IC. An IC has various components such as resistors, capacitors, diodes, transistors etc. fabricated on a small semiconductor chip.

Integrated Circuit:

An integrated circuit is one in which circuit components such as transistors, diodes, resistors, capacitors etc. are automatically part of a small semi conductor chip.

8.2 Advantages of IC's : An integrated circuits possess the following advantages over discrete circuits :

- (i) Increased reliability due to lesser number of connections
- (ii) Extremely small size due to the fabrication of various circuit elements in a single chip of a semiconductor material

- (iii) Lesser weight and space requirement due to miniaturized circuit.
- (iv) Low power requirements
- (v) Greater ability to operate at extreme values of temperature.
- (vi) Low cost because of simultaneous production of hundreds of alike circuits on a small semi-conductor wafer.
- (vii) The circuit layout is greatly simplified because integrated circuits are constrained to use minimum number of external connections.

8.3 Various IC Packages :

In order to protect IC's from external environment and to provide mechanical protection, various forms of encapsulation are used for integrated circuits. Just as with semi - conductor devices, IC Packages are of two types.

- (i) hermetic (metal or ceramic with glass)
- (ii) non-hermetic (plastics)

Plastics are cheaper than hermetic but are still not regarded as satisfactory in extremes of temperature and humidity. The three most popular types of IC Packages are shown in Fig.

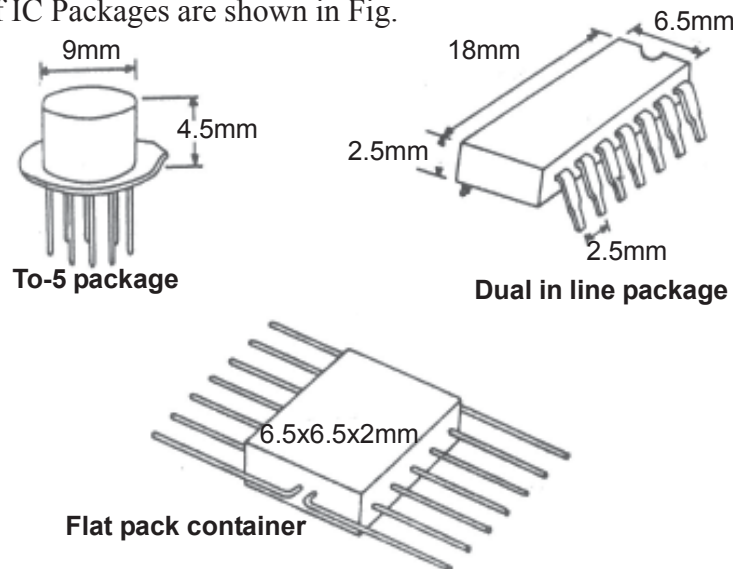


Fig 8.1

(i) Fig (i) shows to-5 package which resembles a small signal transistor in both appearance and size but differs in that it has either 8,10 or 12 pigtail - type leads. The close leads spacing and the difficulty of removal from a printed circuit board has diminished the popularity of this package with the users.

(ii) fig (ii) shows a flat pack container with 14 leads, seven on each side

(iii) Fig (iii) shows the dual - in - line (DIL) pack in 14 lead version. The 14 pin DIL is the most popular form and has seven connecting pairs per side. The pairs of pins of this pack are in line with one another, the pins being 2.5mm apart, to allow IC to be fitted directly into the standard printed circuit boards.

8.4 IC Pin Identification:

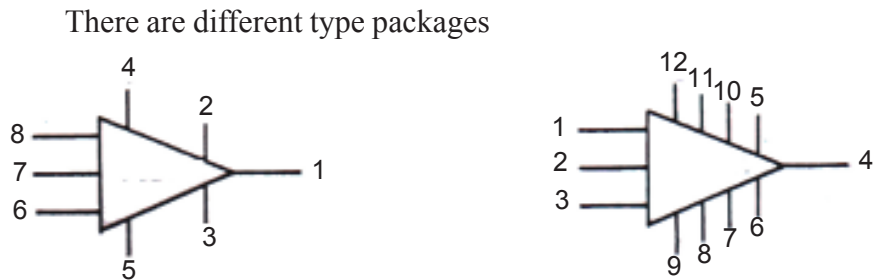


Fig 8.2

Flat Package :

- 1) In flat packages count starts with pin where dot is located.
- 2) Count begins from left hand side to right hand side and right hand side to left hand side continuous on other side.

To package :

- 1) Count starts with in the pin left of the tab
- 2) Count proceeds in anti clock wise direction

Dual in line packages (DIP) :

- 1) Count starts with pin which is left half of notch
- 2) Count begins from left hand side to right hand side and right hand to left side continuously on other side.

To - 220 package : This IC's are used in voltage regulators

To - 5 package : It has a circular base and 8-10 connecting pins.

Plastic Package :**a) Single in line package (SIP) :**

In this type of IC connecting pins are only on one side of the IC as shown in fig. (a)

b) Dual in line package (DIP) :

In this type of IC the connecting pins are provided on both sides as shown in fig (b). The pin numbers start from L.H.S. to R.H.S. from the identification mark. On the other side from R.H.S. to L.H.S. in continuous.

c) Quad in line package (QIP) :

In this type of IC the connecting pins are more. Therefore there are arranged in two lines on each side as shown in fig. (c).

d) MOS- LSI Package :

Its full name is metal oxide semiconductor large scale integration. It has up to 40 connecting pins as shown in fig. (d)

e) Mini dual in line package (MDIP) : In this type of IC there are only 8 pins 4 pins on each side as shown fig. (e).

8.5 Scale of Integration SSI, MSI, LSI, VLSI :

An IC chip may contain as large as 100,000 semiconductor devices or other components. The relative number of these components within the chip is given by referring to its scale of integration. The following terminology is commonly used.

Scale of Integration	Abbreviation	Number of Components
Small Scale Integration	(SSI)	1 to 20
Medium Scale Integration	MSI	20 to 100
Large Scale Integration	LSI	100 to 1000
Very Large Scale Integration	VLSI	1000 to 10,000
Super Large	SLSI	10,000 to 100,000

8.6 Mention the precautions to be taken while handling IC's. :

- 1) IC's are kept in separate plastic envelop and fixed on a thermocol.
- 2) IC's pins should not be bent.
- 3) While soldering/mounting on PCB proper grounding should be provided.
- 4) After soldering it is clean neatly with the patrol or methyl alcohol
- 5) A 10W, 25W soldering iron is used for soldering.
- 6) Should not use high power wattage soldering iron,
- 7) Excessive heat should not be apply
- 8) While applying excessive heat IC's should not function in the circuit.

Summary :

Advantages of IC's :

Small in size, cost less, more operations, active and passive components can be mounted on single wafer.

IC Packages :

Single in line package (SIP), Dual in line package (DIP), Quad in line package (QIP), Circular and Flat packages.

Scale of Integration :

Small scale integration, Medium scale integration, Large scale Integration, Very large scale integration.

Short Questions :

- 1) What is an IC?
- 2) How do you count pin numbers in SIP, DIP?
- 3) How do you count pin numbers in QIP, circular flat packages?
- 4) Classify IC's on scale of integration?

Essays Questions :

- 1) Write pin identification processor in IC packages?
- 2) Write short notes on each one of the following?
SSI, MSI, LSI and VLSI
- 3) Mention the precautions to be taken while handling IC's?