Chapter 2

Network theorem

1) State and explain Kirchhoff's current law (KCL). [2019, 2021, 2022, 2024]

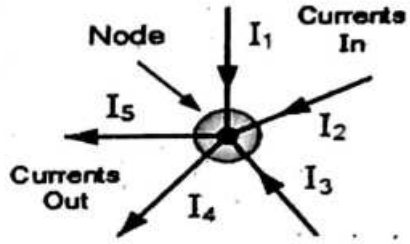
Ans:

State and explain KCL:

Kirchhoff's Current Law or KCL, states that the "*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, $I_{(exiting)} + I_{(entering)} = 0$. This idea by Kirchhoff is commonly known as the Conservation of Charge.

Kirchhoff's Current Law :

Currents Entering the Node
Equals
Currents Leaving the Node



$$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$$

Here, the three currents entering the node, I_1, I_2, I_3 are all positive in value and the two currents leaving the node, I_4 and I_5 are negative in value. Then this means we can also rewrite the equation as;

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

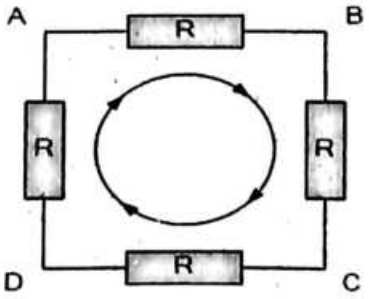
The term Node in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components. Also for current to flow either in or out of a node a closed circuit path must exist. We can use Kirchhoff's current law when analyzing parallel circuits.

2) State and explain Kirchhoff's voltage law (KVL). [2021, 2022, 2024]

Ans:

State and explain KVL:

The sum of all the Voltage Drops around the loop is equal to Zero



$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

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Kirchhoff's Voltage Law:

Starting at any point in the loop continue in the **same direction** noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero. We can use Kirchhoff's voltage law when analysing series circuits.

When analysing either DC circuits or AC circuits using **Kirchhoffs Circuit Laws** a number of definitions and terminologies are used to describe the parts of the circuit being analysed such as: node, paths, branches, loops and meshes. These terms are used frequently in circuit analysis so it is important to understand them.

Common DC Circuit Theory Terms:

- Circuit – a circuit is a closed loop conducting path in which an electrical current flows.
- Path – a single line of connecting elements or sources.
- Node – a node is a junction, connection or terminal within a circuit were two or more circuit elements are connected or joined together giving a connection point between two or more branches. A node is indicated by a dot.
- Branch – a branch is a single or group of components such as resistors or a source which are connected between two nodes.
- Loop – a loop is a simple closed path in a circuit in which no circuit element or node is encountered more than once.
- Mesh – a mesh is a single open loop that does not have a closed path. There are no components inside a mesh.

Note that:

Components are said to be connected together in Series if the same current value flows through all the components.

Components are said to be connected together in Parallel if they have the same voltage applied across them.

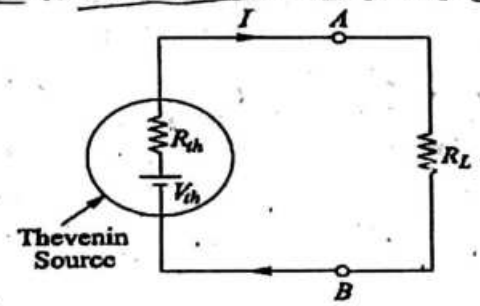
3) Thevenin's theorem. (2023)

Solution

Thevenin's theorem, as applied to d.c. circuits, may be stated as under :

The current flowing through a load resistance RL connected across any two terminals A andB of a linear, active bilateral network is given by Voc || (Ri + RL) where Voc is the open-circuitvoltage (i.e. voltage across the two terminals when RL is removed) and Ri is the internal resistanceof the network as viewed back into the open-circuited network from terminals A and B with allvoltage sources replaced by their internal resistance (if any) and current sources by infiniteresistance.

It provides a mathematical technique for replacing a given network, as viewed from two output terminals, by ***a single voltage source with a series resistance***. It makes the solution of complicated networks (particularly, electronic networks) quite quick and easy.



Suppose, it is required to find current flowing through load resistance RL, as shown in Fig. 2.127 (a). We will proceed as under :

1. Remove RL from the circuit terminals A and B and redraw the circuitas shown in Fig. 2.127 (b). Obviously, the terminals havebecome open-circuited.
2. Calculate the open-circuit voltage Vocwhich appears across terminals A and B when they are open *i.e.* when RL is removed. As seen, Voc= drop across $R2 = IR2$ where I is the circuit current when$A$and$B$ are open.It is also called 'Thevenin voltage' Vth.
3. Now, imagine the battery to be removed from the circuit, leaving its internal resistance $r$behind and redraw the circuit, as shown in Fig. 2.127 (c). When viewed ***inwards*** fromterminals$A$and$B$, the circuit consists of two parallel paths : one containing $R2$ and the othercontaining $(R1 + r)$. The equivalent resistance of the network, as viewed from these terminals is given as

$$R = R_2 \| (R_1 + r) = \frac{R_2(R_1 + r)}{R_2 + (R_1 + r)}$$

This resistance is also called,* Thevenin resistance Rsh(though, it is also sometimes written as Rior$R0$).

4. RL is now connected back across terminals A and B from where it was temporarily removed earlier.Current flowing through RL is given by

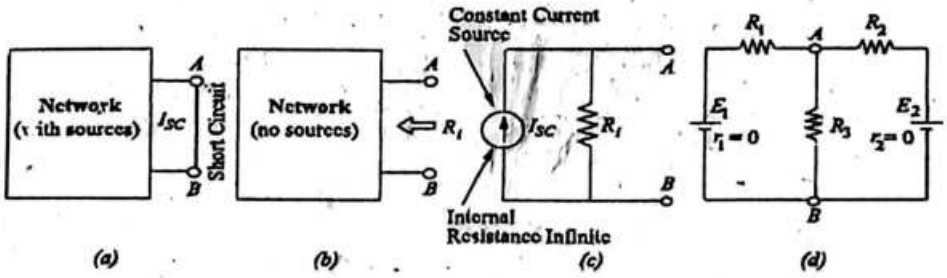
4) *Norton's theorem.* *[2023,2019]*

Solution:

Theorem may be stated as follows :

Any two-terminal active network containing voltage sources and resistance when viewedfrom its output terminals , is equivalent to a constant-current source and a parallel resistance.

The constant current is equal to the current which would flow in a short-circuit placed across theterminals and parallel resistance is the resistance of the network when viewed from these open circuited terminals after all voltage and current sources have been removed and replaced by theirinternal resistances.



Explanation

As seen from Fig. (a), a short is placed across the terminals A and B of the network ***with allits energy sources present.*** The short-circuit current ISC gives the value of constant-current source. For finding Ri, all sources have been removed as shown in Fig. (b). The resistance of the network when looked into from terminals A and B gives Ri.

The Norton's* equivalent circuit is shown in Fig. (c). It consists of an ideal constantcurrentsource of infinite internal resistance having a resistance of Riconnected in parallel with it.

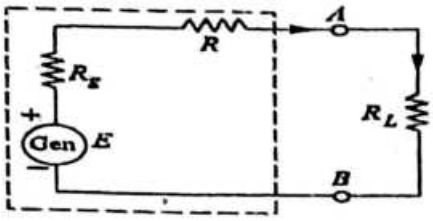
5) *Maximum power transfer theorem.* (2023)

Solution :this theorem may be stated as follows

A resistive load will abstract maximum power from a network when the load resistance is equal to the resistance of the network as viewed from the output terminals, with all energy sources removed leaving behind their internal resistances.

In Fig. 2.230 (*a*), a load resistance of *RL* is connected across the terminals *A* and *B* of a network which consists of a generator of e.m.f. *E* and internal resistance *Rg*and a series resistance *R*which, in fact, represents the lumped resistance of the connecting wires. Let *Ri*= *Rg*+ *R* = internal resistance of the network as viewed from *A* and *B*.

According to this theorem, *RL* will abstract maximum power from the network when *RL* = *Ri*.



the voltage across the load is hold the open-circuit voltage at the terminals *A* and *B*.

$$\text{Max. power is } P_{L\,max.} = \frac{E^2 R_L}{4R_L^2} = \frac{E^2}{4R_L} = \frac{E^2}{4R_i}$$

6) *How to Thevenize a Given Circuit ?* [2010, 2024]

solution :

1. Temporarily remove the resistance (called load resistance RL) whose current is required.
2. Find the open-circuit voltage Vocwhich appears across the two terminals from where Resistance has been removed. It is also called Thevenin voltage Vth.
3. Compute the resistance of the whose network as looked into from these two terminals afterAll voltage sources have been removed leaving behind their internal resistances (if any) andCurrent sources have been replaced by open-circuit i.e. Infinite resistance. It is also calledThevenin resistance RthorTi.
4. Replace the entire network by a single Thevenin source, whose voltage is VthorVocandWhose internal resistance is RthorRi.
5. Connect RL back to its terminals from where it was previously removed.
6. Finally, calculate the current flowing through RL by using the equation,I= Vth/(Rth+ RL) or I = Voc/(Ri+ RL)

7) Find the Power Transfer Efficiency of a resistive network and sketch its wave shape.

[2024].

Solution :

If *PL* is the power supplied to the load and *PT* is the total power supplied by the voltage source,then power transfer efficiency is given by $\eta = PL/PT$.

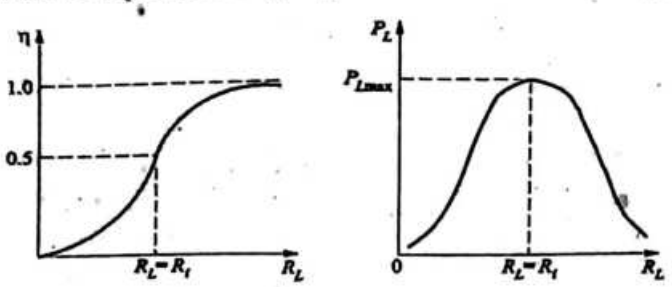
Now, the generator or voltage source *E* supplies power to both the load resistance *RL* and to theinternal resistance *Ri*= (*Rg*+ *R*).

$$P_T = P_L + P_i \quad \text{or} \quad E \times I = I^2 R_L + I^2 R_i$$

$$\eta = \frac{P_L}{P_T} = \frac{I^2 R_L}{I^2 R_L + I^2 R_i} = \frac{R_L}{R_L + R_i} = \frac{1}{1 + (R_i / R_L)}$$

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The variation of η with *RL* is shown in Fig. 2.235 (*a*). The maximum value of η is unity when *RL* = ∞ and has a value of 0.5 when *RL* = *Ri*. It means that under maximum power transfer conditions,the power transfer efficiency is only 50%. As mentioned above, maximum power transfer conditionis important in communication applications but in most power systems applications, a 50% efficiencyis undesirable because of the wasted energy. Often, a compromise has to be made between the loadpower and the power transfer efficiency.

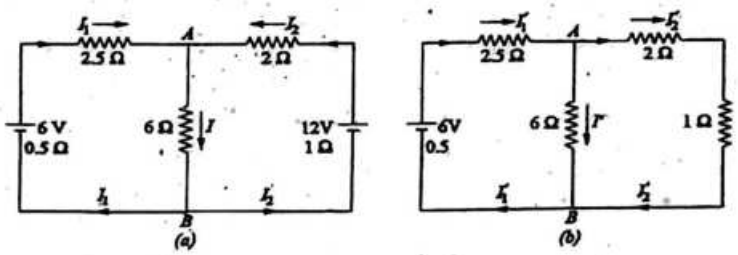


For example, if we make *RL* = 2 *Ri*, then *PL*= 0.222 *E2/Ri*and η = 0.667.
It is seen that the load power is only 11% less than its maximum possible value, whereas the power transfer efficiency has improved from 0.5 to 0.667 *i.e.* by 33%.

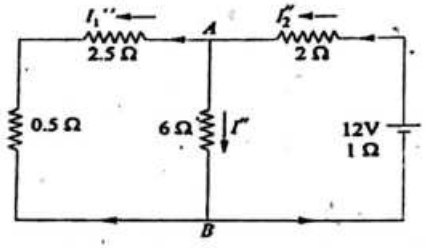
8) State and explain Superposition Theorem. [2022, 2024]

Solution :

Hence, this theorem may be stated as follows:
In a network of linear resistances containing more Than one generator (or source of e.m.f.), the current which flows at any point is the sum of all the Currents which would flow at that point if each Generator where considered separately and all the Other generators replaced for the time being by Resistances equal to their internal resistances.
Explanation



In Fig. (a) I1, I2 and I represent the values ofcurrents which are due to the simultaneous action of the two sources of e.m.f. In the network. In Fig.(b) are shown the current values which would have been obtained if left-hand side battery had Acted alone.



Similarly, Fig. represents conditions obtained when right-hand side battery acts Alone. By combining the current values can Be obtained.
Obviously, I1 = I'1-I_1''
I2 = I2''-I2′,
I = I'+ I''

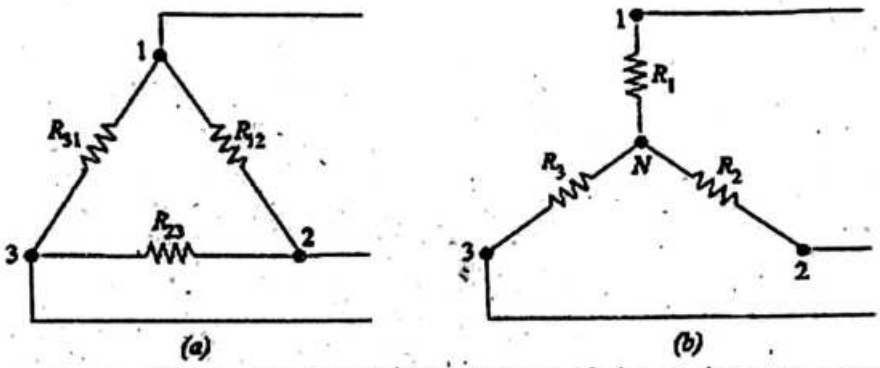
9) Describe Delta/Star* Transformation

Solution :

In solving networks (having considerable number of branches) by the application of Kirchhoff's Laws, one sometimes experiences great difficulty due to a large number of simultaneous equations That have to be solved. However, such complicated network can be simplified by successively replacing Delta meshes by equivalent star system and **vice versa**.

Suppose we are given three resistances R12, R23 and R31 connected in delta fashion between Terminals 1, 2 and 3 as in Fig. (a). So far as the respective terminals are concerned, these three

Given resistances can be replaced by the three resistances R1, R2 and R3 connected in star as shown in
Fig. (b).



These two arrangements will be electrically equivalent if the resistance as measured between anyPair of terminals is the same in both the arrangements. Let us find this condition.
Delta to star :-

$$R_{12} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = R_1 + R_2 + \frac{R_1R_2}{R_3}$$

$$R_{23} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = R_2 + R_3 + \frac{R_2R_3}{R_1}$$

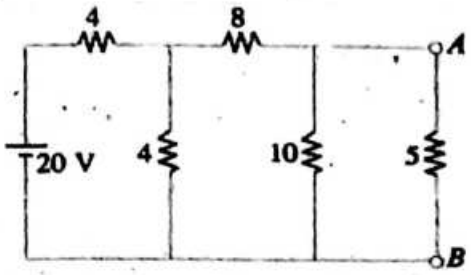
$$R_{31} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} = R_1 + R_3 + \frac{R_3R_1}{R_2}$$

Star to delta:-

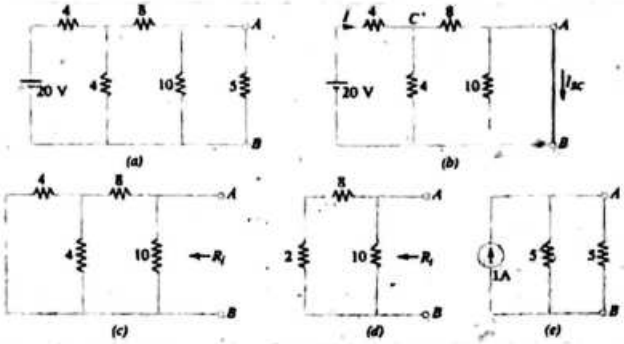
$$R_1 = \frac{R_{12}\,R_{31}}{R_{12} + R_{23} + R_{31}};\ R_2 = \frac{R_{23}\,R_{12}}{R_{12} + R_{23} + R_{31}} \text{ and } R_3 = \frac{R_{31}\,R_{23}}{R_{12} + R_{23} + R_{31}}$$

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10. State Norton's theorem Calculate the current through 5-Ω resistor of the following circuit using Norton's theorem. [2021]



Answer:



(i) Remove 5 – Ω resistor and put a short across terminals A and B as shown in Fig. (b). As seen, 10 – Ω resistor also becomes short-circuited.

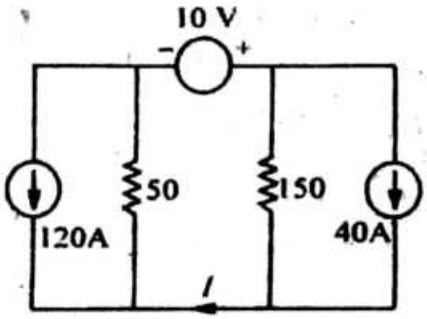
(ii) Let us now find ISC. The battery sees a parallel combination of 4 Ω and 8 Ω in series with a 4 Ω resistance. Total resistance seen by the battery = 4 + 4 || 8 = 20/3 Ω. Hence, I = 20 ÷ 20/3 = 3 A. This current divides at point C of Fig. (b). Current going along path CAB gives ISC. Its value = 3 × 4/12 = 1 A

(iii) In Fig. (c), battery has been removed leaving behind its internal resistance which, in this case, is zero. Resistance of the network looking into the terminals A and B in Fig. (d) is R_i = 10 || 10 = 5 Ω

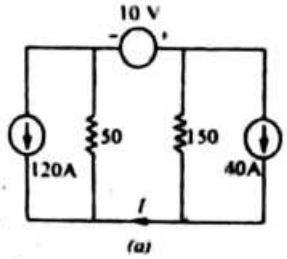
(iv) Hence, Fig. (e), gives the Norton's equivalent circuit.

(v) Now, join the 5 – Ω resistance back across terminals A and B. The current flowing through it, obviously, is I_{AB} = 1 × 5/10 = 0.5 A.

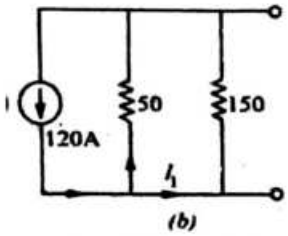
11. Find the current I of the following Circuit using Super position theorem. (2022)



Solution: The given circuit is



Now



In Fig. (b), the voltage source has been replaced by a short and the 40 A current sources by an open. Using the current-divider rule,
we get

$$I. = 120 \times 50/200 = 30\ A.$$

In Fig. (c), only 40 A current source has been considered. Again, using current-divider rule

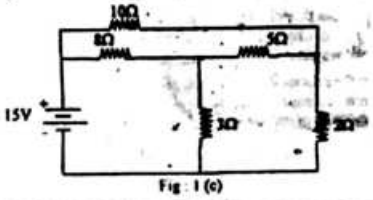
$$I_2 = 40 \times 150/200 = 30\ A$$

In Fig. (d), only voltage source has been considered. Using Ohm's law,

$$I_3 = 10/200 = 0.05\ A.$$

Since I_1 and I_2 cancel out, $I = I_3 = 0.005\ A.$ (ANSWER)

12) Find the current through the 10 Ω resistor of the network in fig 1(b)



[2023]

Answer :

Let I_1 be the current flowing through the 10Ω resistor, I_2 be the current flowing through the 8Ω resistor ,I_3 be the current flowing through the right side, where the 5Ω, 3Ω, and 2Ω resistors are located.

Loop 1: Start from the 15V source, go through the 10Ω and 8Ω resistors, and return to the negative terminal of the battery.

Loop 2: Start from the junction between the 8Ω resistor and the 3Ω resistor, go through the 5Ω, 3Ω, and 2Ω resistors, and return to the junction.

Write a junction equation at the node where the 8Ω, 10Ω, and the 5Ω resistors meet:

$$I_1 = I_2 + I_3$$

Apply Kirchhoff's Voltage Law (KVL)

Loop 1: Starting from the positive terminal of the battery and moving clockwise:

$$15V - 10\Omega.\ I_1 - 8\Omega.I_2 = 0$$

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This simplifies to: $15 = 10\ I_1 + 8\ I_2$ equation (1)

Loop 2:

In the second loop (clockwise), including the 8Ω, 5Ω, 3Ω, and 2Ω resistors:

$$8\Omega.I_2 - 5\Omega.I_3 - 3\Omega.I_3 - 2\Omega.I_3 = 0$$

Simplifying, we get: $8\ I_2 = 10\ I_3 \Rightarrow\ I_2 = \frac{5}{4}\ .\ I_3$ ..... equation(2)

Substitute and Solve the Equations :

Substitute $I_2 = \frac{5}{4}\ I_3$ into equation (1)

$15 = 10\ I_1 + 8\ (\frac{5}{4}\ I_3) \Rightarrow 15 = 10.I_1 + 10.I_3$

Dividing by 10: $1.5 = I_1 + I_3$ ..... equation (3)

Using the junction equation $I_1 = I_2 + I_3$, Substitute $I_2 = \frac{5}{4}\ I_3$

$$I_1 = \frac{5}{4}\ I_3 + I_3 \Rightarrow I_1 = \frac{9}{4}\ I_3 \text{ ..... equation (4)}$$

Substitute Equation 4 into Equation 3:

$$1.5 = \frac{9}{4}\ .\ I_3 + I_3$$

$$\Rightarrow 1.5 = \frac{13}{4}\ .\ I_3$$

Multiply both sides by 4 :

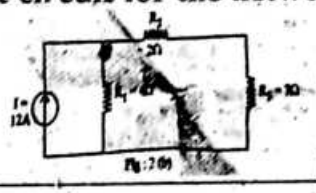
$$6 = 13\ I_3$$

$$\Rightarrow I_3 = \frac{6}{13} \approx 0.462\ A$$

Calculate I_1 :- using $I_1 = \frac{9}{4}\ .\ I_3$, $\Rightarrow I_1 = \frac{9}{4}\ .\ (0.462) \approx 1.039\ A$

The current through the 10Ω resistor I_1, is approximately **1.039 A**.

13) Find the The venin equivalent circuit for the network in fig 2(b)



[2023]

Answer :

Steps 1 and 2: See Fig. 9.33.

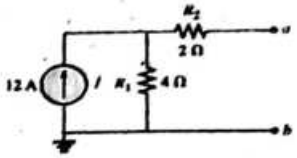


FIG. 9.33
Establishing the terminals of particular interest for the network in Fig. 9.32.

Step 3: See Fig. 9.34.The current source has been replaced with an open-circuit equivalent, and the resistance determined between terminals a and b.

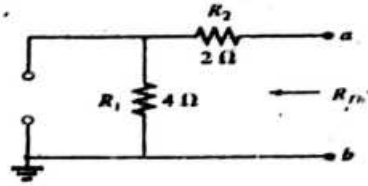


FIG. 9.34
Determining R_{Th} for the network in Fig. 9.33.

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In this case, an ohmmeter connected between terminals a and b sends out a sensing current that flows directly through R1 and R2 (at the same level). The result is that R1 and R2 are in series and the Thévenin re- sistance is the sum of the two.

$R_{th} = R_1 + R_2 = (4+2)\ \Omega = 6\Omega$

Step 4: See Fig. 9.35. In this case, since an open circuit exists between the two marked terminals, the current is zero between these terminals and through the 2 resistor. The voltage drop across R2 is, therefore,

$$V_2 = I_2R_2 = (0).\ R_2 = 0\ v \text{ and } E_{th} = V_1 = I_1R_1 = IR_1 = (12\ A)(4\Omega) = 48\ v$$

Step 5: See Fig. 9.36.

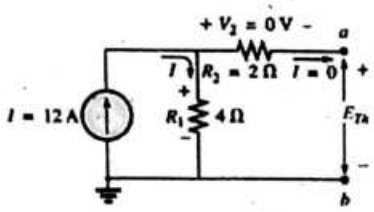


FIG. 9.35
Determining E_{Th} for the network in Fig. 9.33.

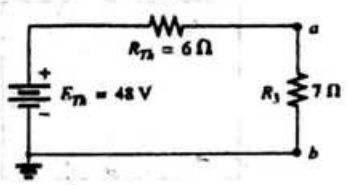


FIG. 9.36
Substituting the Thévenin equivalent circuit in the network external to the resistor R_L in Fig. 9.32.

14)Find the Norton equivalent circuit for the network in fig 3(b):



[2023]

Answer:

Steps 1 and 2: See Fig. 9.62.

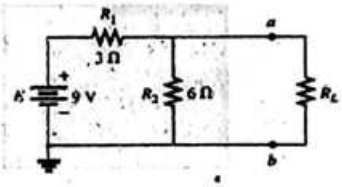


FIG. 9.61
Example 9.11.

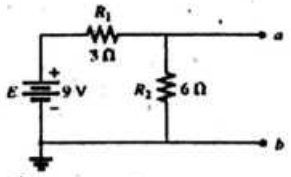


FIG. 9.62
Identifying the terminals of particular interest for the network in Fig. 9.61.

Step 3: See Fig. 9.63, and

where, $R_N = R_1 \| R_2 = \frac{(3.6)}{(3+6)} = 2\Omega$.

Step 4: See Fig. 9.64, which clearly indicates that the short-circuit connection between terminals a and b is in parallel with R2 and eliminates its effect. I_N is therefore the same as through R1, and the full battery voltage appears across R1 since,

$$V_2 = I_2R_2 = 0.(6\Omega) = 0\ v$$

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Therefore,

$$I_N = \frac{E}{R1}$$

$$= \frac{9v}{(3\Omega)} = 3A$$

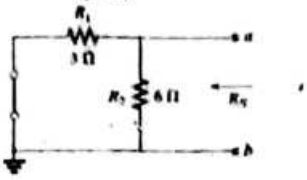


FIG. 9.63
Determining R_N for the network in Fig. 9.62.

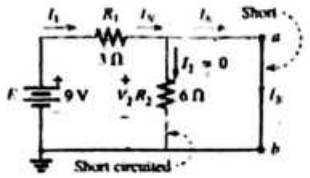


FIG. 9.64
Determining I_N for the network in Fig. 9.62.

step 5: The Norton equivalent circuit for the above figure is shown in fig 9.65

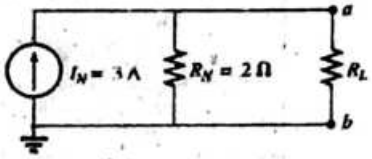
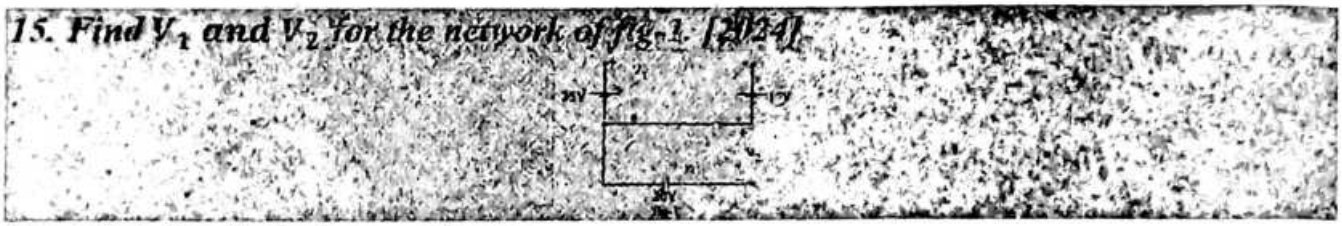


FIG. 9.65
Substituting the Norton equivalent circuit for the network external to the resistor R_L in Fig. 9.61.

15. Find V_1 and V_2 for the network of fig.1. [2024]



From the circuit diagram, we have:

Voltage Source 1: $\mathbf{V_{s1}}$= 25V

Voltage Source 2: $\mathbf{V_{s2}}$ = 15V

Voltage Source 3: $\mathbf{V_{s3}}$ = 20V

1. Finding V_1

- V_{s1} is measured directly in parallel with the 25V source, with matching polarity.
- Formula: $\mathbf{V_1 = V_{s1}}$
- Solution: $\mathbf{V_1}$= 25V

2. Finding V_2

- V_2 is found by applying Kirchhoff's Voltage Law (KVL) to the right-hand closed loop.
- KVL Equation (Clockwise): (Starting from the bottom node)

  $\sum V = 0$

  +20V - 15V - V_2 = 0
- Solution:

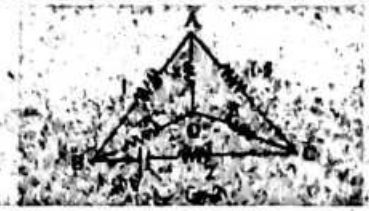
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$5\ V - V_2 = 0$

$V_2 = 5V$

So, the value of V_1 is 25V and the value of V_2 is 5V.

6. Determine the value of R and current through it shown in fig-2, if current through brunch AO is zero. All resistances are in ohm. [2024]



From the circuit diagram (fig-2), we have:

Resistance in branch AB: $R_{AB} = 1\Omega$

Resistance in branch BC: $R_{BC} = 4\Omega$

Resistance in branch AC: $R_{AC} = 1.5\Omega$

Resistance in branch OC: $R_{OC} = R$ (to be determined)

Resistance in branch BO: $R_{BO} = 2\Omega$

Resistance in branch AO: $R_{AO} = \infty$

Voltage Source V= 10V

1. Finding the value of *R*

Condition: Current through branch AO is zero ($I_{AO} = 0$).

Principle: When the current through the galvanometer (here, resistance ∞ in AO branch) is zero, the bridge is balanced. For a balanced Wheatstone bridge, the ratio of resistances in adjacent arms is equal.

$$\frac{R_{AB}}{R_{BC}} = \frac{R_{AC}}{R_{OC}}$$

(Considering the bridge arms as AB, BC, AC, OC)

- Formula: $\frac{1}{4} = \frac{1.5}{R}$
- Solution:

  $1 \times R = 4 \times 1.5$

  $R = 6\Omega$

2. Finding the current through *R*

- **Condition:** Since the bridge is balanced($I_{AO} = 0$), the resistance ∞ (in branch AO) has no effect on the total resistance or the current distribution. The circuit simplifies into two parallel branches: (AB + BO) and (AC + OC).
- **Equivalent Resistance (R_{eq}):**
  - Upper Branch Resistance R_{upper}: $R_{AB} + R_{AC} = 1\Omega + 1.5\Omega = 2.5\Omega$
  - Lower Branch Resistance R_{lower}: $R_{BC} + R_{OC} = 4\Omega + R = 4\Omega + 6\Omega = 10\Omega$
  - Total Equivalent Resistance R_T:
  - $\frac{1}{R_T} = \frac{1}{R_{upper}} + \frac{1}{R_{lower}}$

    $\frac{1}{R_T} = \frac{1}{2.5} + \frac{1}{10} = 0.4 + 0.1 = 0.5$

    $R_T = \frac{1}{0.5} = 2\Omega$
- Total Circuit Current (I_T):
- $I_T = \frac{V}{R_T} = \frac{10V}{2\Omega} = 5A$

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- Current through R (I_R): The resistance R is part of the lower branch (R_{lower}). The current through R is the total current (I_T) divided according to the current divider rule between R_{upper} and R_{lower}.

Formula (Current Divider Rule):

$$I_R = I_T \times \frac{R_{upper}}{R_{upper}+R_{lower}}$$

- Solution:

$$I_R = 5A \times \frac{2.5\Omega}{2.5\Omega+10\Omega} = 5A \times \frac{2.5}{12.5} = 5A \times 0.2$$

$$I_R = 1A$$

So, the value of R is 6 Ω and the current through R(I_R) is 1A.

17. Calculate the current flowing through the 3Ω resistor in the network of fig-3 using Thevenin's Theorem. [2024]



1. The venin Resistance (R_{Th})

Deactivate 24V (short) and 2A (open). R_{Th} is the equivalent resistance across terminals A-B.

- 8 Ω and 4 Ω (below 24V) are in series: $R_{series} = 8 + 4 = 12\,\Omega$.
- R_{series} is in parallel with the 6 Ω resistor,

$$R_{Th} = \frac{6\times12}{6+12} = \frac{72}{18} = 4\,\Omega$$

$$R_{Th} = 4\,\Omega$$

2. The venin Voltage (V_{Th})

$V_{Th} = V_{OC}$ across A-B. Since R_L is removed, no current flows through 6 Ω, so $V_{Th} = V_C$.

- Find current in the 24V loop (ignoring C-D branch for V_C calculation):

$$I_1 = \frac{24V}{8\,\Omega + 4\,\Omega} = \frac{24}{12} = 2A$$

- Voltage at node C (V_C) relative to B (ground):

V_C = Voltage across 4 Ω resistor = 4 Ω × 2A = 8V

$$V_{Th} = 8V$$

3. Load Current (I_L)

$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

$$I_L = \frac{8V}{4\,\Omega + 3\,\Omega}$$

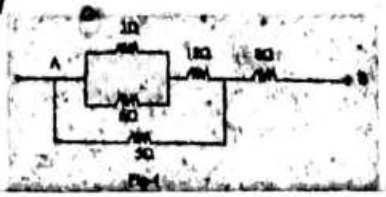
$$I_L = \frac{8}{7}\,A$$

$$I_L = 1.143A$$

So, the load current is 1.143A.

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18. Calculate the equivalent resistance of the following combination of resistances and the voltage drop across each resistance when a potential difference of 60V is applied between points A and B: [2024]



Given Data

- Applied Voltage: $V_{AB} = 60V$
- Resistances: $R_1 = 3\Omega$, $R_2 = 6\Omega$, $R_3 = 5\Omega$, $R_4 = 18\Omega$, $R_5 = 8\Omega$.

1. Calculation of Equivalent Resistance (R_{eq})

Step 1.1: Parallel Combination (R_p)

The resistors R_1 (3Ω), R_2 (6Ω), R_3 (5Ω) are connected in parallel between point A and the subsequent series branch.

$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{6} + \frac{1}{5}$$

$$\frac{1}{R_p} = \frac{10+5+6}{30} = \frac{21}{30} = \frac{7}{10}$$

$$R_p = \frac{7}{10}\Omega = 1.43\Omega$$

Step 1.2: Series Combination (R_{eq})

R_p, R_4 (18Ω), R_5 (8Ω) are connected in series.

$$R_{eq} = R_p + 18\Omega + 8\Omega$$

$$R_{eq} = \frac{10}{7} + 26 = \frac{10+182}{7}\Omega$$

$$R_{eq} = \frac{192}{7}\Omega = 27.43\,\Omega$$

2. Calculation of Total Current (I_T)

The total current flowing through the circuit is calculated using Ohm's Law.

$$I_T = \frac{V_{AB}}{R_{Eq}} = \frac{60V}{192/7\Omega}$$

$$I_T = 60 \times \frac{7}{192} = \frac{420}{192} = \frac{35}{16}A$$

$$I_T = 2.1875A$$

3. Calculation of Voltage Drop across Each Resistor

Step 3.1: Voltage Drop across R_4 (18Ω) and R_5 (8Ω)

These resistors are in series with R_p, so the entire total current(I_T) flows through them.

- $V_{18\Omega} = I_T \times 18\Omega = \frac{35}{16} \times 18 = 39.375V$
- $V_{8\Omega} = I_T \times 8\Omega = \frac{35}{16} \times 8 = 17.5V$

Step 3.2: Voltage Drop across R_1, R_2, R_3 (Parallel Group)

These three resistors share the same voltage (V_p) because they are in parallel. V_p is the voltage drop across the equivalent resistance R_p.

$$V_p = I_T \times R_p = \frac{35}{16}A \times \frac{10}{7}\Omega = \frac{50}{16} = 3.125V$$

$$V_{3\Omega} = V_{6\Omega} = V_{5\Omega} = 3.125V$$

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Chapter 3:
Introduction to Semiconductors

1) What is semiconductor material?[2018] Classify semiconductor materials.[2010]

Ans:

Semiconductor materials are a category of materials that exhibit properties between those of conductors (materials with high electrical conductivity) and insulators (materials with low electrical conductivity). They are essential in modern electronics and are used to create electronic devices like transistors, diodes, and integrated circuits. Semiconductor materials have the following characteristics:

1. **Band Gap:** Semiconductors have a band gap, which is the energy difference between the valence band (the highest energy band of electrons that are not free to move) and the conduction band (the lowest energy band of electrons that are free to move). This band gap is relatively small, allowing electrons to be easily excited from the valence band to the conduction band, but not as easily as in conductors.
2. **Temperature Sensitivity:** The electrical conductivity of semiconductor materials is highly temperature-dependent. As the temperature increases, the number of charge carriers (electrons and holes) increases, making the material more conductive.
3. **Doping:** The electrical properties of semiconductors can be significantly modified by introducing small amounts of specific impurities through a process known as doping. This creates n-type (electron-rich) or p-type (hole-rich) materials, which are crucial for device operation.

Semiconductor materials are classified into several categories based on their elemental composition and properties:

1. **Elemental Semiconductors:** These semiconductors are composed of a single element. The two most common elemental semiconductors are:
    - **Silicon (Si):** Silicon is one of the most widely used semiconductor materials, particularly in integrated circuits and solar cells.
    - **Germanium (Ge):** Germanium was one of the first materials used in early transistors and diodes.
2. **Compound Semiconductors:** Compound semiconductors are made by combining two or more elements from different groups of the periodic table. They often have specific properties suited for particular applications. Examples include:
    - **Gallium Arsenide (GaAs):**GaAs is used in high-frequency applications, such as microwave devices and certain types of LEDs.
    - **Indium Phosphide (InP):**InP is used in optoelectronic and high-speed electronic devices.
3. **Organic Semiconductors:** Organic semiconductors are made from carbon-based compounds, including polymers. They are used in organic electronics and are flexible and lightweight. Organic light-emitting diodes (OLEDs) and organic photovoltaic cells are examples of devices based on organic semiconductors.
4. **Amorphous Semiconductors:** These are non-crystalline semiconductors with a disordered atomic structure. Amorphous silicon (a-Si) is an example used in thin-film transistor (TFT) displays and solar cells.

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Semiconductor materials play a fundamental role in modern technology and have enabled the development of microelectronics, computer chips, solar cells, and various other electronic devices that power our modern world. Their versatile properties make them highly adaptable to a wide range of applications.

2) What is semiconductor? Explain the effect of temperature on emiconductor. [2023,2019]

Solution :

A **semiconductor** is a substance whose resistivity lies between the conductors and insulators. The property of resistivity is not the only one that decides a material as a semiconductor, but it has few properties as follows.

- Semiconductors have the resistivity which is less than insulators and more than conductors.
- Semiconductors have negative temperature co-efficient. The resistance in semiconductors, increases with the decrease in temperature and vice versa.
- The Conducting properties of a Semiconductor changes, when a suitable metallic impurity is added to it, which is a very important property.

The Effect of temperature on semiconductor: When a **semiconductor** is heated, the conductance increases and the resistance decreases. **Semiconductors**, thus, have a negative **temperature** coefficient of resistance. When heat is applied to a **semiconductor** material, the outermost electrons in the atom gain energy.

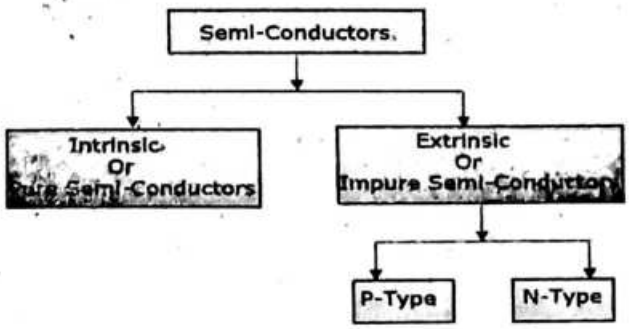
When a semiconductor is heated, the conductance increases and the resistance decreases. Semiconductors, thus, have a negative temperature coefficient of resistance. When heat is applied to a semiconductor material, the outermost electrons in the atom gain energy. These electrons are able to overcome the attraction of the nucleus and leave the atom. Thus they become free electrons which can conduct.

The number of electrons increase exponentially and this results in a large drop in the resistance. Electronic devices will behave erratically above a certain temperatures. Hence, all electronic devices such as laptops will have a safe temperature beyond which they cannot function. The effect of vibration of the atomic lattice on the mobility of the electrons is offset by the large numbers of electrons which enter the conduction band.

3) Describe the classification of semiconductors. [2019,2021]

Solution :

Semiconductor devices are extensively used in the field of electronics. The transistor has replaced the bulky vacuum tubes, from which the size and cost of the devices got decreased and this revolution has kept on increasing its pace leading to the new inventions like integrated electronics. The following illustration shows the classification of semiconductors.



Semiconductors types / classifications

There are two basic groups or classifications that can be used to define the different semiconductor types:

- **Intrinsic material:** An intrinsic type of semiconductor material made to be very pure chemically. As a result it possesses a very low conductivity level having very few number of charge carriers, namely holes and electrons, which it possesses in equal quantities.
- **Extrinsic material:** Extrinisc types of semiconductor are those where a small amount of impurity has been added to the basic intrinsic material. This 'doping' uses an element from a different periodic table group and in this way it will either have more or less electrons in the valence band than the semiconductor itself. This creates either an excess or shortage of electrons. In this way two types of semiconductor are available: Electrons are negatively charged carriers.
  - N-type: An N-type semiconductor material has an excess of electrons. In this way, free electrons are available within the lattices and their overall movement in one direction under the influence of a potential difference results in an electric current flow. This in an N-type semiconductor, the charge carriers are electrons.
  - P-type: In a P-type semiconductor material there is a shortage of electrons, i.e. there are 'holes' in the crystal lattice. Electrons may move from one empty position to another and in this case it can be considered that the holes are moving. This can happen under the influence of a potential difference and the holes can be seen to flow in one direction resulting in an electric current flow. It is actually harder for holes to move than for free electrons to move and therefore the mobility of holes is less than that of free electrons. Holes are positively charged carriers.

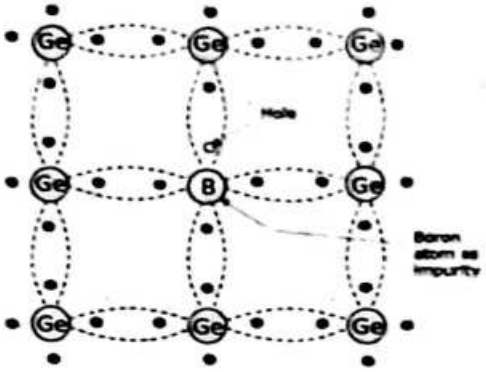
4) Explain how n-type and p-type semiconductors are produced. [2010,2011,2018]
Or, Describe how n-type and p-type materials are formed **[2021,2023]**
Or, ***Explain the doping Process of extrinsic semiconductor.[2022]***

Ans:

p-n junction diodes are made up of two adjacent pieces of p-type and n-type semiconducting materials. p-type and n-type materials are simply semiconductors, such as silicon (Si) or germanium (Ge), with atomic impurities; the type of impurity present determines the type of the semiconductor. The process of purposefully adding impurities to materials is called doping; semiconductors with impurities are referred to as "doped semiconductors".

A small amount of trivalent impurity is added to a pure semiconductor to result in P-type extrinsic semiconductor. The added impurity has 3 valence electrons. For example, if Boron atom is added to the germanium atom, three of the valence electrons get attached with the Ge atoms, to form three covalent bonds. But, one more electron in germanium remains without forming any bond. As there is no electron in boron remaining to form a covalent bond, the space is treated as a hole. This is as shown in the following figure.

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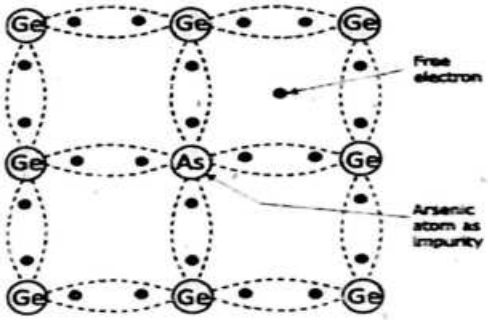
The boron impurity when added in a small amount, provides a number of holes which helps in the conduction. All of these holes constitute hole current.

- In P-type extrinsic semiconductor, as the conduction takes place through holes, the holes are majority carriers while the electrons are minority carriers.
- The impurity added here provides holes which are called as acceptors, because they accept electrons from the germanium atoms.
- As the number of mobile holes remains equal to the number of acceptors, the Ptype semiconductor remains electrically neutral.
- When an electric field is applied to a P-type semiconductor, to which a trivalent impurity is added, the holes travel towards negative electrode, but with a slow pace than electrons. This is called as P-type conductivity.
- In this P-type conductivity, the valence electrons move from one covalent bond to another, unlike N-type.

N-type

A small amount of pentavalent impurity is added to a pure semiconductor to result in Ntype extrinsic semiconductor. The added impurity has 5 valence electrons.

For example, if Arsenic atom is added to the germanium atom, four of the valence electrons get attached with the Ge atoms while one electron remains as a free electron. This is as shown in the following figure.



All of these free electrons constitute electron current. Hence, the impurity when added to pure semiconductor, provides electrons for conduction.

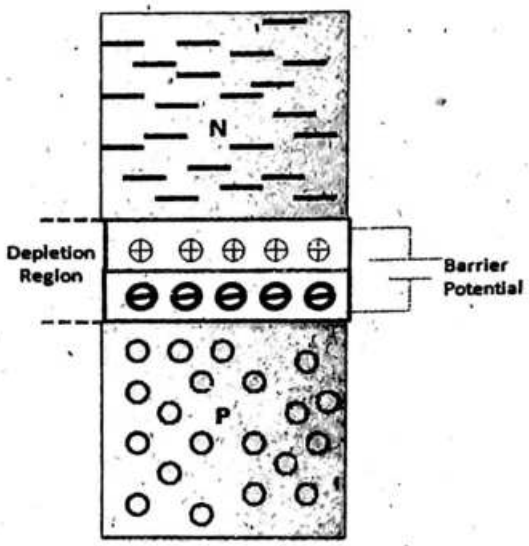
- In N-type extrinsic semiconductor, as the conduction takes place through electrons, the electrons are majority carriers and the holes are minority carriers.
- As there is no addition of positive or negative charges, the electrons are electrically neutral.
- When an electric field is applied to an N-type semiconductor, to which a pentavalent impurity is added, the free electrons travel towards positive electrode. This is called as negative or N-type conductivity.

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5) Explain how depletion layer is developed in a PN junction. [2010]
Or,
Describe what happen when a P-type and N-type material are brought together hence define barrier voltage. [2015]

Answer:
N-type and P-type material are considered as electrically neutral before they are joined together at a common junction. However, after joining diffusion takes place instantaneously, as electrons cross the junction to fill holes causing negative ions to emerge in the P material, this action causes the nearby area of the junction to take on a negative charge. Electrons departing the N material causes it to generate positive ions.

All this process, in turn, causes the N side of the junction to take on a net positive charge. This particular charge creation tends to force the remaining electrons and holes away from the junction. This action makes it somewhat hard for other charge carriers to diffuse across the junction. As a result, the charge is built up or barrier potential emerges across the junction.
As shown in the following figure. The resultant barrier potential has a small battery connected across the P-N junction. In the given figure observe the polarity of this potential barrier, with respect to P and N material. This voltage or potential will exist when the crystal is not connected to an external source of energy.

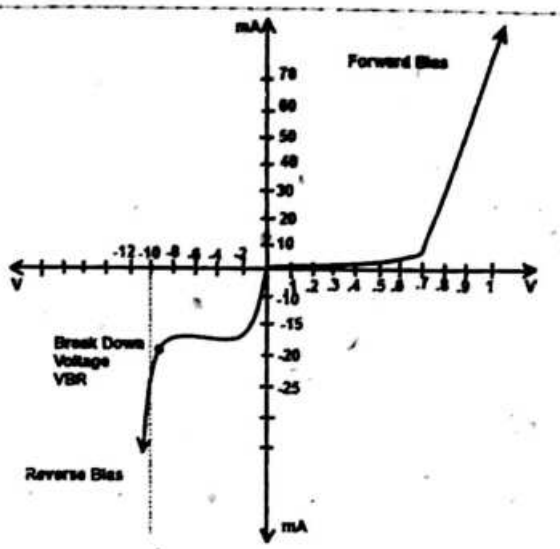


The barrier potential of germanium is approximately 0.3 V, and of silicon is 0.7 V. These values cannot be measured directly and appears across the space charge region of the junction. In order to produce current conduction, the barrier potential of a P-N junction must be overcome by an external voltage source.

6) Describe the operation of a PN junction with characteristic curve. [2010,2013,2014,2018]

Ans:
When the diode is forward biased and the applied voltage is increased from zero hardly any current flows through the diode in beginning, because the external voltage is being oppose by the internal barrier voltage (VB) whose value is 0.7 Volt for silicon and 0.3 Volt for Germanium. It is seen that when the voltage approaches to one volt (1V) a high forward current flows through the diode.

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When the diode is in reverse bias majority carrier are block and only a small current due to minority current flows through the diode. As the reverse voltage is increase from zero the reverse current very quickly reaches its maximum or saturation value I° which is known as leakage. When reverse voltage exceeds a certain value which break down the diode and huge amount of current flow through diode. This voltage is called break down voltage.

f) What is barrier voltage of a diode? Explain how the barrier voltage is developed in it. [2011,2013]

Ans: The n-type and p-type semiconductor materials are electrically neutral before the free electrons and holes had crossed the junction. However, when the free electrons and holes have crossed the junction, the n-type and p-type semiconductors become charged.

Charged atom

If the atom has unequal number of electrons and protons, the atom is said to be charged. This charged atom may be positive or negative. The atom which has more number of electrons than the protons is said to be negatively charged while the atom which has more number of protons than the electrons is said to be positively charged.

Positive and negative barrier voltage at the p-n junction

In positive ion, the total number of electrons orbiting the nucleus of an atom is less compared to the total number of protons present in the nucleus of an atom. Hence, it is positively charged. On the other hand, in negative ion, the total number of electrons orbiting the nucleus of an atom is more compared to the total number of protons present in the nucleus of an atom. Hence, it is negatively charged.

Thus, a net positive charge is built at the n-side of the p-n junction due to the positive ions at the n-side; similarly a net negative charge is built at the p-side of the p-n junction due to the negative ions at the p-side.

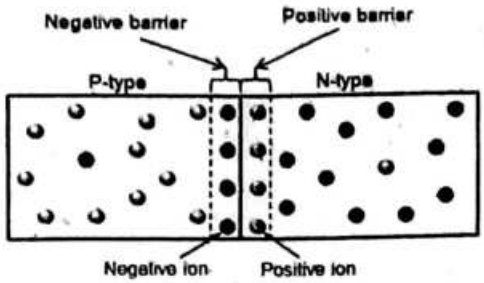
This net negative charge at the p-side of the p-n junction prevents the further flow of free electrons crossing from n-side to p-side because the negative charge present at the p-side of p-n junction repels the free electrons.

Similarly, the net positive charge at n-side of the p-n junction prevents the further flow of holes crossing from p-side to n-side. Hence, positive charge present at n-side and negative charge present at p-side of p-n junction acts as barrier between p-type and n-type semiconductor.



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Thus, a barrier is build near the junction which prevents the further movement of electrons and holes.



The negative charge formed at the p-side of the p-n junction is called negative barrier voltage while the positive charge formed at the n-side of the p-n junction is called positive barrier voltage. The total charge formed at the p-n junction is called barrier voltage, barrier potential or junction barrier.

The size of the barrier voltage at the p-n junction is depends on, the amount of doping, junction temperature and type of material used. The barrier voltage for silicon diode is 0.7 volts and for germanium is 0.3 volts.

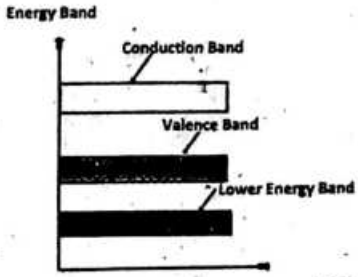
8) What do you understand by intrinsic and extrinsic semi-conductor?

[2011,2013,2014,2016]

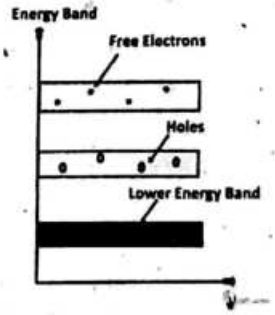
Ans:

Intrinsic Semiconductor

An extremely pure semiconductor is called as Intrinsic Semiconductor. On the basis of the energy band phenomenon, an intrinsic semiconductor at absolute zero temperature is shown below.



Its valence band is completely filled and the conduction band is completely empty. When the temperature is raised and some heat energy is supplied to it, some of the valence electrons are lifted to conduction band leaving behind holes in the valence band as shown below.



The electrons reaching at the conduction band move randomly. The holes created in the crystal also free to move anywhere. This behavior of the semiconductor shows that they have a negative

temperature coefficient of resistance. This means that with the increase in temperature, the resistivity of the material decreases and the conductivity increases.

Extrinsic Semiconductor

A semiconductor to which an impurity at controlled rate is added to make it conductive is known as an extrinsic Semiconductor.

An intrinsic semiconductor is capable to conduct a little current even at room temperature, but it is not useful for the preparation of various electronic devices. Thus, to make it conductive a small amount of suitable impurity is added to the material.

9) What is doping? [2011,2016,2022]

Solution :

The process of adding impurities to the semiconductor materials is termed as doping. The impurities added, are generally pentavalent and trivalent impurities.

Pentavalent Impurities

- The **pentavalent** impurities are the ones which has five valence electrons in the outer most orbit. Example: Bismuth, Antimony, Arsenic, Phosphorus
- The pentavalent atom is called as a **donor atom** because it donates one electron to the conduction band of pure semiconductor atom.

Trivalent Impurities

- The **trivalent** impurities are the ones which has three valence electrons in the outer most orbit. Example: Gallium, Indium, Aluminum, Boron
- The trivalent atom is called as an **acceptor atom** because it accepts one electron from the semiconductor atom.

10) Distinguish between P-type and N-type material. [2015]

Answer:

Comparison between P Type and N Type Semiconductor:

	P Type	N Type
Type of	Extrinsic semiconductor	Extrinsic semiconductor
Description	A type of extrinsic semiconductor that carries a positive charge and has an improved conductivity.	A type of extrinsic semiconductor that carries a negative charge and has an improved conductivity.
Hole concentration	Larger hole concentration	Less hole concentration
Electron concentration	Less electron concentration	Larger electron concentration
Charge	Positive charge of the hole	Negative charge of the electron
Carriers	Holes are the majority carriers and electrons are the minority carriers	Electrons are the majority carriers and holes are the minority carriers
Creation	Created by doping an intrinsic semiconductor with acceptor impurities	Created by doping an intrinsic semiconductor with donor impurities
Dopant	Common p-type dopant for silicon is boron. Others include aluminum or gallium.	Common dopant for n-type silicon is phosphorus. Others include antimony and arsenic.
Effect of doping	Acceptor impurity creates a hole.	Donor impurities contributes free electrons
Contains	Trivalent impurities	Pentavalent impurities
Fermi level	Fermi level is below the intrinsic Fermi level and lies closer to the valence band than the conduction band	Fermi level is greater than that of the intrinsic semiconductor and lies closer to the conduction band than the valence band

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11) Define Semi-conductor, Rectifier, Clipper. [2015]

Ans:

Semi-conductor: Semiconductor, any of a class of crystalline solids intermediate in electrical conductivity between a conductor and an insulator. Semiconductors are employed in the manufacture of various kinds of electronic devices, including diodes, transistors, and integrated circuits. Such devices have found wide application because of their compactness, reliability, power efficiency, and low costs.

Examples of semiconductor materials are germanium, selenium, and silicon

Rectifier: A rectifier is an electrical device composed of one or more diodes that converts alternating current (AC) to direct current (DC). A diode is like a one-way valve that allows an electrical current to flow in only one direction. This process is called rectification.

A rectifier can take the shape of several different physical forms such as solid-state diodes, vacuum tube diodes, mercury arc valves, silicon-controlled rectifiers and various other silicon-based semiconductor switches.

Clipper: A clipper is a device that removes either the positive half (top half) or negative half (bottom half), or both positive and negative halves of the input AC signal. In other words, a clipper is a device that limits the positive amplitude or negative amplitude or both positive and negative amplitudes of the input AC signal. In some cases, a clipper removes a small portion of the positive half cycle or negative half cycle or both positive and negative half cycles.

12) Describe the operation of a P-N junction diode when it is:-

[2013,2014,2015,2016,2020,2022, 2024]

- **No bias;**
- **Forward biased;**
- **Reverse biased.**

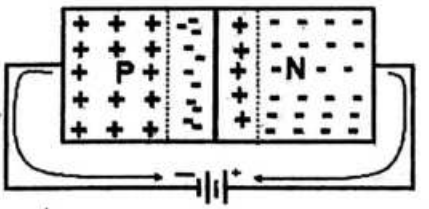
Answer:

A PN Junction Diode *is* one of the simplest semiconductor devices around, and which has the characteristic of passing current in only one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage (I-V) relationship and therefore we can not described its operation by simply using an equation such as Ohm's law.

There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

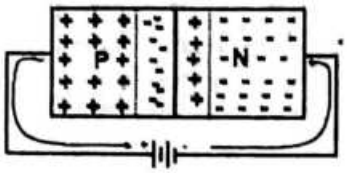
- 1. **Zero Bias:** No external voltage potential is applied to the PN junction diode.

- 2. **Reverse Bias:** The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.

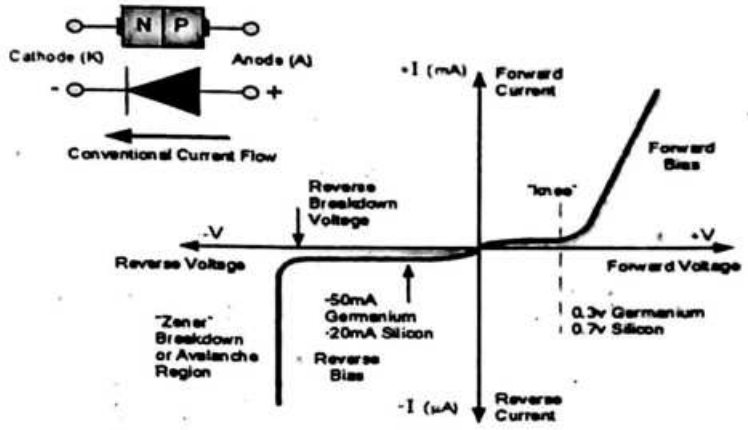


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Forward Bias: The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing the PN** junction diodes width



I-V Characteristics:



But before we can use the PN junction as a practical device or as a rectifying device we need to firstly **bias** the junction, ie connect a voltage potential across it. On the voltage axis above, "Reverse Bias" refers to an external voltage potential which increases the potential barrier. An external voltage which decreases the potential barrier is said to act in the "Forward Bias" direction.

3) Define the terms conductor, semiconductor, insulator in terms of energy band diagram. [2016,2018,2021]
Or, *Explain the classification of meterials according to energy band.[2022]*

Ans:

CONDUCTORS

In the metals like copper, aluminum there is no forbidden gap between valence band and conduction band. The two bands overlap. Hence even at room temperature, a large number of electrons are available for conduction. So without any additional energy, such metals contain a large number of free electrons and hence called good conductors.

INSULATORS

In case of such insulating material, there exists a large forbidden gap in between the conduction band and the valence band. Practically it is impossible for an electron to jump from the valence band to the conduction band. Hence such materials cannot conduct and called insulators. The forbidden gap is very wide, approximately of about 7 eV is present in insulators. For a diamond, which is an insulator, the forbidden gap is about 6 eV. Such materials may conduct only at very high temperatures or if they are subjected to high voltage. Such conduction is rare and is called breakdown of an insulator. The other insulating materials are glass, wood, mica, paper etc.

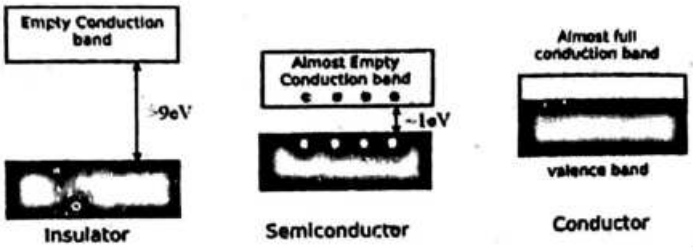
SEMICONDUCTORS

The forbidden gap in such materials is very narrow as shown in Fig. Such materials are called semiconductors. The forbidden gap is about 1 eV. In such materials, the energy provided by the



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heat at room temperature is sufficient to lift the electrons from the valence band to the conduction band

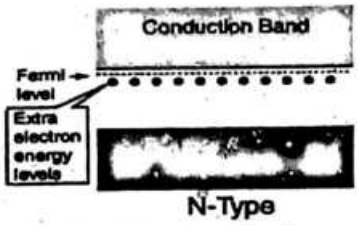


14) Explain the n-type semiconductor with energy band diagram. [2019]

Ans:

N-Type Band Structure

The addition of donor impurities contributes electron energy levels high in the semiconductor band gap so that electrons can be easily excited into the conduction band. This shifts the effective Fermi level to a point about halfway between the donor levels and the conduction band.



Electrons can be elevated to the conduction band with the energy provided by an applied voltage and move through the material. The electrons are said to be the "majority carriers" for current flow in an n-type semiconductor

15) What is biasing? Why biasing is necessary for a transistor circuit. [2019]

Ans:

Biasing: **Biasing** in electronics means establishing predetermined voltages or currents at various points of an electronic circuit for the purpose of establishing proper operating conditions in electronic components. ... The AC signal applied to them is superposed on this DC **bias** current or voltage.

Biasing is necessary for transistor:Transistor works on biasing. A biasing is required to operate the transistor, without biasing it's no more usable and to obtain an output.

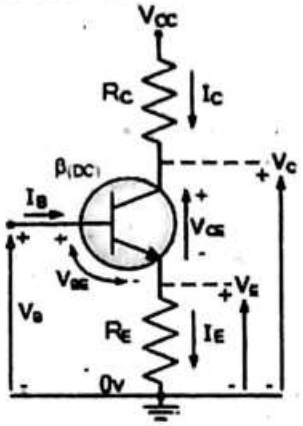
Biasing means to obtain an output i.e. voltage or current from various point and segments in order to establishing a proper operating system through the electronic components.

A biasing is required to activate the transistor and prevents it to either to saturation mode or cut-off mode. A biasing is a phenomenon of getting a proper dc collector current at a certain dc voltage by setting up a proper point.

Transistor biasing is the process of setting a transistors DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor.

A **biasing is required** to activate the **transistor** and prevents it to either to saturation mode or cut-off mode. ... Transistor **biasing** is the process of setting a **transistors** DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the **transistor**.

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(6) Describe the operation of the P-N junction diode with V-I characteristics.[2019,2023]

Answer:

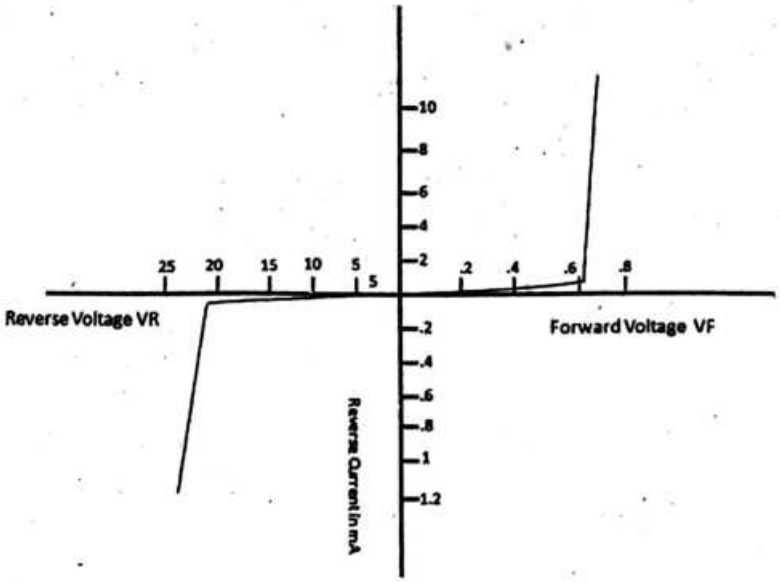
The forward and reverse current voltage (IV) characteristics of a diode are generally compared on a single characteristic curve. The figure depicted under the section Forward Characteristic shows that Forward Voltage and Reverse Voltage are usually plotted on the horizontal line of the graph.

Forward and reverse current values are shown on the vertical axis of the graph. Forward Voltage represented to the right and Reverse Voltage to the left. The point of beginning or zero value is at the center of the graph. Forward Current lengthens above the horizontal axis with Reverse Current extending downward.

The combined Forward Voltage and Forward Current values are located in the upper right part of the graph and Reverse Voltage and Reverse Current in the lower left corner. Different scales are normally used to display forward and reverse values.

Forward Characteristic

When a diode is forward biased it conducts current (IF) in forward direction. The value of IF is directly dependent on the amount of forward voltage. The relationship of forward voltage and forward current is called the ampere-volt, or IV characteristic of a diode. A typical diode forward IV characteristic is shown in the following figure.



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Following are the observations –

- Forward Voltage is measured across the diode and Forward Current is a measure of current through the diode.
- When the forward voltage across the diode equals 0V, forward current (IF) equals 0 mA.
- When the value starts from the starting point (0) of the graph, if VF is progressively increased in 0.1-V steps, IF begins to rise.
- When the value of VF is large enough to overcome the barrier potential of the P-N junction, a considerable increase in IF occurs. The point at which this occurs is often called the knee voltage V_K. For germanium diodes, V_K is approximately 0.3 V, and 0.7 V for silicon.
- If the value of IF increases much beyond V_K, the forward current becomes quite large.

This operation causes excessive heat to develop across the junction and can destroy a diode. To avoid this situation, a protective resistor is connected in series with the diode. This resistor limits the forward current to its maximum rated value. Normally, a current limiting resistor is used when diodes are operated in the forward direction.

Reverse Characteristic

When a diode is reverse biased, it conducts Reverse current that is usually quite small. A typical diode reverse IV characteristic is shown in the above figure.

The vertical reverse current line in this graph has current values expressed in microamperes. The amount of minority current carriers that take part in conduction of reverse current is quite small. In general, this means that reverse current remains constant over a large part of reverse voltage. When the reverse voltage of a diode is increased from the start, there is a very slight change in the reverse current. At the breakdown voltage (VBR) point, current increases very rapidly. The voltage across the diode remains reasonably constant at this time.

This constant-voltage characteristic leads to a number of applications of diode under reverse bias condition. The processes which are responsible for current conduction in a reverse-biased diode are called as Avalanche break down and Zener breakdown.

17) Explain how p-type semiconductor are produced with energy band diagram. (2020)

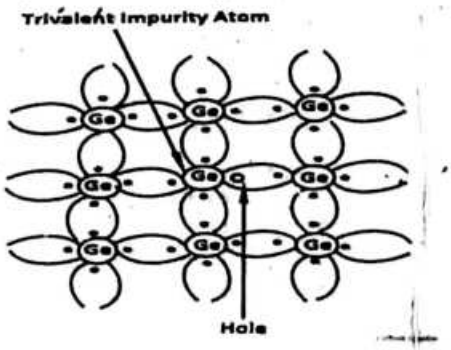
Solution:

p-type semiconductor are known as an **Acceptor Impurities** because each atom of them create one hole which can accept one electron.

Contents:

- Energy Band Diagram of p-Type Semiconductor
- Conduction Through p-Type Semiconductor

A trivalent impurity like gallium, having three valence electrons is added to germanium crystal in a small amount. Each atom of the impurity fits in the germanium crystal in such a way that its three valence electrons form covalent bonds with the three surrounding germanium atoms as shown in the figure below:

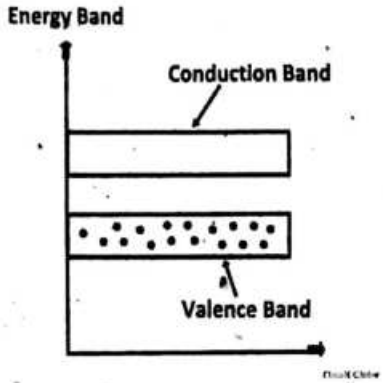


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n the fourth covalent bonds, only the germanium atom contributes one valence electron, while allium atom has no valence bonds.

Hence, the fourth covalent bond is incomplete, having one electron short. This missing electron is nown as a **Hole**. Thus, each gallium atom provides one hole in the germanium crystal.
As an extremely small amount of Gallium impurity has a large number of atoms, therefore, it rovides millions of holes in the semiconductor.

Energy Band Diagram of p-Type Semiconductor
The energy band diagram of a p-type Semiconductor is shown below:



A large number of holes or vacant space in the covalent bond is created in the crystal with the addition of the trivalent impurity. A small or minute quantity of free electrons is also available in the conduction band.

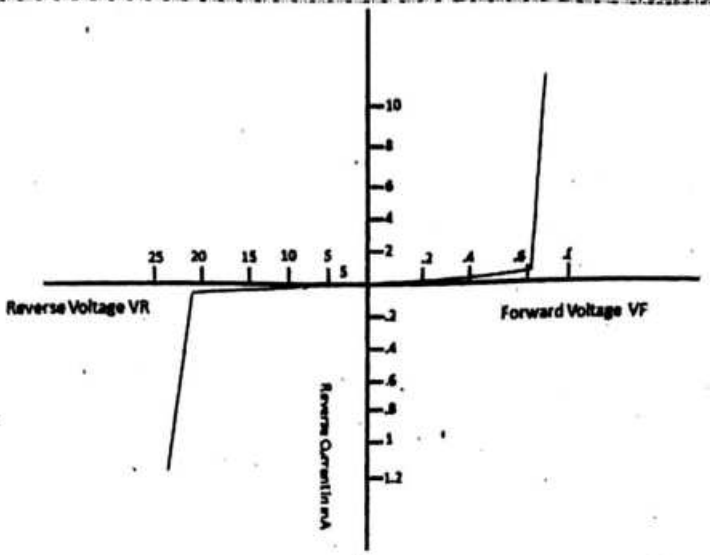
They are produced when thermal energy at room temperature is imparted to the germanium crystal-forming electron-hole pairs. But the holes are more in number as compared to the electrons in the conduction band. It is because of the predominance of holes over electrons that the material is called as a p-type semiconductor.
The word "p" stands for positive material.

(8) What is P-N Junction? Describe I-V characteristics of a forward bised P-N Junction . (2021)

Ans
A PN Junction Diode *is* one of the simplest semiconductor devices around, and which has the characteristic of passing current in only one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage (I-V) relationship and therefore we can not described its operation by simply using an equation such as Ohm's law.

Forward Characteristic
When a diode is forward biased it conducts current (IF) in forward direction. The value of IF is directly dependent on the amount of forward voltage. The relationship of forward voltage and forward current is called the ampere-volt, or IV characteristic of a diode. A typical diode forward IV characteristic is shown in the following figure.

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Following are the observations –

- Forward Voltage is measured across the diode and Forward Current is a measure of current through the diode.
- When the forward voltage across the diode equals 0V, forward current (IF) equals 0 mA.
- When the value starts from the starting point (0) of the graph, if VF is progressively increased in 0.1-V steps, IF begins to rise.
- When the value of VF is large enough to overcome the barrier potential of the P-N junction, a considerable increase in IF occurs. The point at which this occurs is often called the knee voltage V_K. For germanium diodes, V_K is approximately 0.3 V, and 0.7 V for silicon.
- If the value of IF increases much beyond V_K, the forward current becomes quite large.

This operation causes excessive heat to develop across the junction and can destroy a diode. To avoid this situation, a protective resistor is connected in series with the diode. This resistor limits the forward current to its maximum rated value. Normally, a current limiting resistor is used when diodes are operated in the forward direction.

19) Define Clipper and Clamper circuit (2021)

Answer:

Clipper Circuit

A clipper circuit clips off or removes a portion from an AC signal without distorting or changing the remaining part of the waveform. It limits the voltage from rising above or below a certain point. Therefore, it is also used for protection against overvoltage. The clipper circuit can be also known as a clipper, clipping circuit, voltage limiter or slicer, etc.

Clamper Circuit

A clamper circuit is used for shifting the DC level of the AC signal. It either shifts the waveform up or down without changing the shape of the waveform. It increases the amplitude of the signal which is why it is also known as a voltage multiplier circuit.

A clamper circuit is made of a diode, resistor & capacitor where the capacitor is used for storing the necessary charge to amplify the voltage or amplitude of the signal. It does not affect the shape of the waveform.

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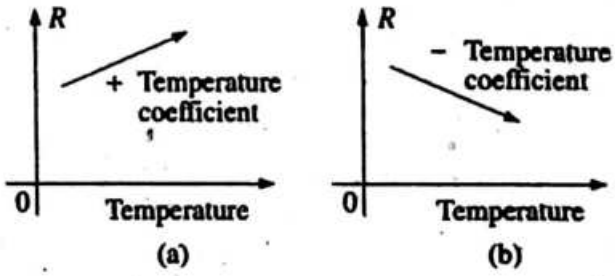
21) Discus the effect of temperature on resistance [2023]

Answer`:

Temperature has a significant effect on the resistance of conductors, semi-conductors, and insulators.

Conductors :

Conductors have a generous number of free electrons, and any introduc- tion of thermal energy will have little impact on the total number of free carriers. In fact, the thermal energy only increases the intensity of the random motion of the particles within the material and makes it increasingly difficult for a general drift of electrons in any one direction to be established. The result is that : for good conductors, an increase in temperature results in an increase in the resistance level. Consequently, conductors have a positive temperature coefficient.



Semiconductor :

In semiconductors, an increase in temperature imparts a measure of ther- mal energy to the system that results in an increase in the number of free carriers in the material for conduction. The result is that for semiconductor materials, an increase in temperature results in a decrease in the resistance level. Consequently, semiconductors have negative temperature coefficients.

Insulators :

As with semiconductors, an increase in temperature results in a decrease in the resistance of an insulator. The result is a negative temperature coefficient.

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Chapter 4

Semiconductor Diodes and Special Purpose Diodes

1. Define

i. **Breakdown Voltage** – It is the minimum reverse bias voltage at which PN junction breaks down with sudden rise in reverse current.

ii. **Knee Voltage** – It is the forward voltage at which the current through the junction starts to increase rapidly.

iii. **Peak Inverse Voltage** – It is the maximum reverse voltage that can be applied to the PN junction, without damaging it.

iv. **Maximum Forward Rating** – It is the highest instantaneous forward current that a PN junction can pass, without damaging it.

v. **Maximum Power Rating** – It is the maximum power that can be dissipated from the junction, without damaging the junction.

2. Define junction diode.

Solution :

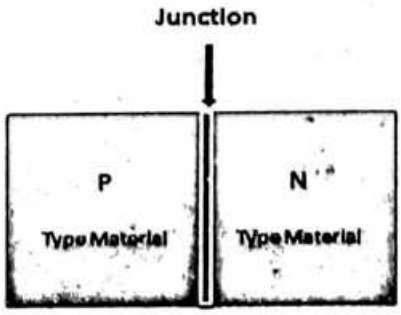
A crystal structure made of P and N materials is generally known as **junction diode**. It is generally regarded as a two-terminal device. As shown in the following diagram one terminal is attached to P-type material and the other to N-type material.

3. Describe the P-N junction diode.

Solution :

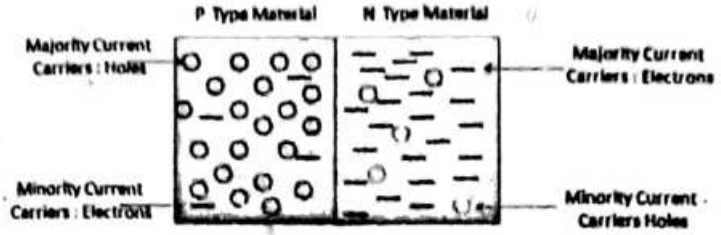
The common bond point where these materials are connected is called a **junction**. A junction diode allows current carriers to flow in one direction and obstruct the flow of current in the reverse direction.

The following figure shows the crystal structure of a junction diode. Take a look at the location of the P type and N type materials with respect to the junction. The structure of crystal is continuous from one end to the other. The junction acts only as a separating point that represents the end of one material and the beginning of the other. Such structure allows electrons to move thoroughly in the entire structure.



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The following diagram shows two portions of semiconductor substance before they are shaped into a P-N junction. As specified, each part of material has **majority** and **minority current carriers**.

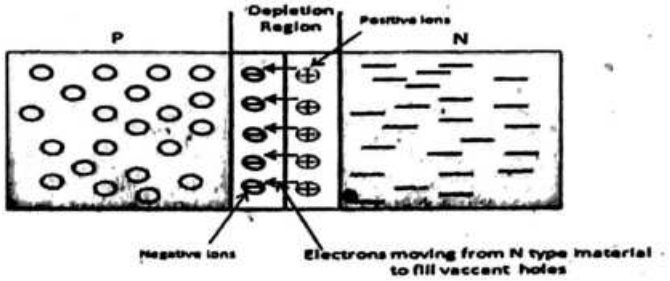


The quantity of carrier symbols shown in each material indicates the minority or majority function. As we know electrons are the majority carriers in the N type material and holes are the minority carriers. In P type material, holes are the majority carriers and electrons are in the minority.

4. Describe Depletion Zone

Solution : Initially, when a junction diode is formed, there is a unique interaction between current carriers. In N type material, the electrons move readily across the junction to fill holes in the P material. This act is commonly called **diffusion**. Diffusion is the result of high accumulation of carriers in one material and a lower gathering in the other.

Generally, the current carriers which are near to the junction only takes part in the process of diffusion. Electrons departing the N material cause positive ions to be generated in their place. While entering the P material to fill holes, negative ions are created by these electrons. As a result, each side of the junction contains a large number of positive and negative ions.



The area where these holes and electrons become depleted is generally known by the term depletion region. It is an area where there is lack of majority current carriers. Normally, a depletion region is developed when P-N junction is formed. The following figure shows the depletion region of a junction diode.

5. Describe the Barrier Potential Semiconductor Devices

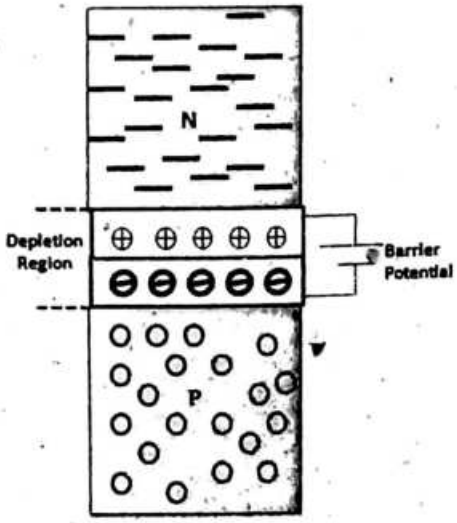
Solution :

N-type and P-type material are considered as electrically neutral before they are joined together at a common junction. However, after joining diffusion takes place instantaneously, as electrons cross the junction to fill holes causing negative ions to emerge in the P material, this action causes the nearby area of the junction to take on a negative charge. Electrons departing the N material causes it to generate positive ions.

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All this process, in turn, causes the N side of the junction to take on a net positive charge. This particular charge creation tends to force the remaining electrons and holes away from the junction. This action makes it somewhat hard for other charge carriers to diffuse across the junction. As a result, the charge is built up or barrier potential emerges across the junction.

As shown in the following figure. The resultant barrier potential has a small battery connected across the P-N junction. In the given figure observe the polarity of this potential barrier with respect to P and N material. This voltage or potential will exist when the crystal is not connected to an external source of energy.

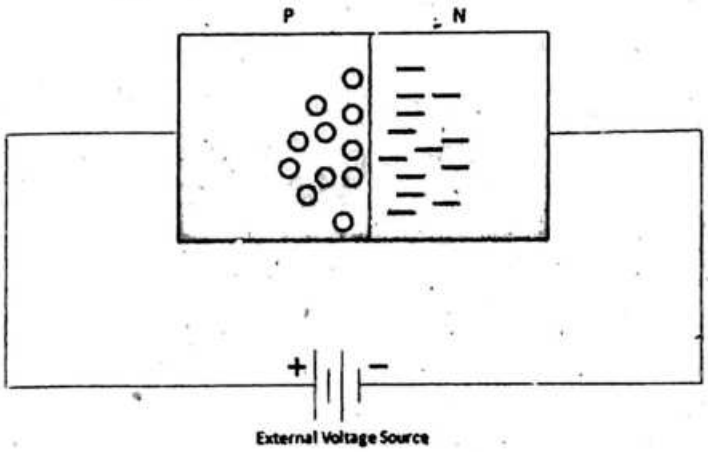


The barrier potential of germanium is approximately 0.3 V, and of silicon is 0.7 V. These values cannot be measured directly and appears across the space charge region of the junction. In order to produce current conduction, the barrier potential of a P-N junction must be overcome by an external voltage source.

6. Describe the Forward Biasing .

Solution :

The following figure shows a forward biased PN junction diode with external voltage applied. You can see that the positive terminal of the battery is connected to the P material and the negative terminal of the battery is connected to the N material.

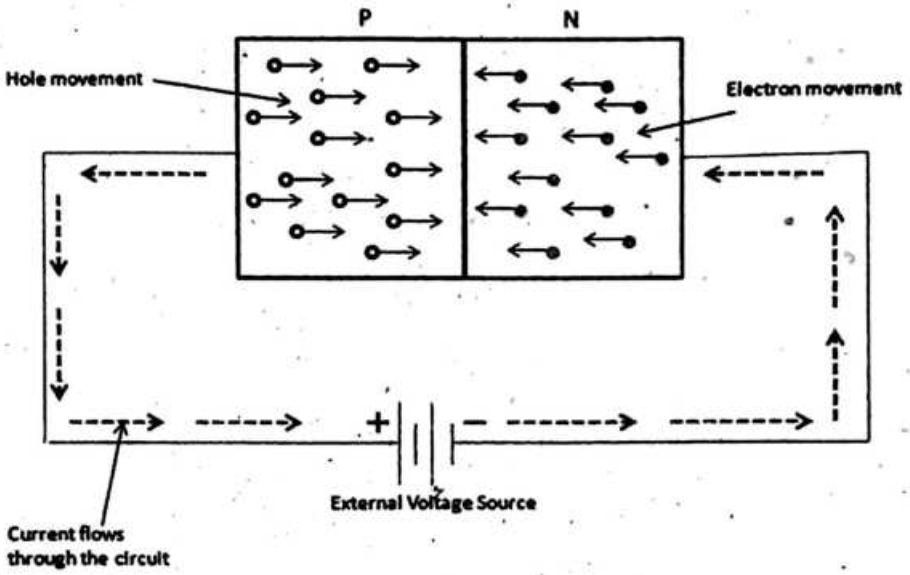


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Following are the observations –

- This bias voltage repels the majority current carriers of each P and N type material. As a result, large number of holes and electrons start appearing at the junction.
- At the N-side of the junction, electrons move in to neutralize the positive ions in the depletion region.
- On the P-side material, electrons are dragged from negative ions, which cause them to become neutral again. This means that forward biasing collapses the depletion region and hence the barrier potential too. It means that when P-N junction is forward biased, it will allow a continuous current flow.

The following figure shows the flow of current carriers of a forward-biased diode. A constant supply of electrons is available due to an external voltage source connected to the diode. The flow and direction of the current is shown by large arrows outside the diode in the diagram. Note that the electron flow and the current flow refers to the same thing.



Following are the observations –

- Suppose electrons flow through a wire from the negative battery terminal to the N material. Upon entering this material, they flow immediately to the junction.
- Similarly, on the other side an equal number of electrons are pulled from P side and are returned to the positive battery terminal. This action creates new holes and causes them to move toward the junction.
- When these holes and electrons reach the junction they join together and effectively disappear. As a result, new holes and electrons emerge at the outer ends of the diode. These majority carriers are created on a continuous basis. This action continues as long as the external voltage source is applied.
- When diode is forward biased it can be noticed that electrons flow through the entire structure of diode. This is common in N type material, whereas in the P material holes are the moving current carriers. Notice that the hole movement in one direction must begin by electron movement in the opposite direction. Therefore, the total current flow is the addition of holes and electrons flow through a diode.

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7. Explain the DIODE IV Characteristics

Solution :

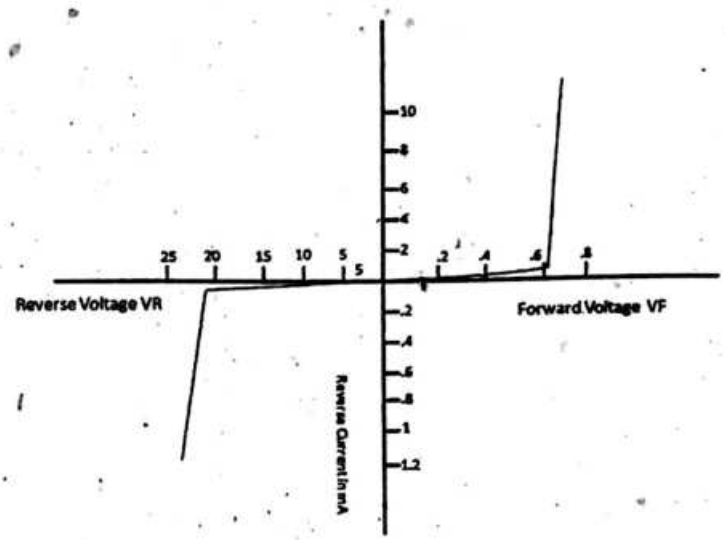
The forward and reverse current voltage (IV) characteristics of a diode are generally compared on a single characteristic curve. The figure depicted under the section Forward Characteristic shows that Forward Voltage and Reverse Voltage are usually plotted on the horizontal line of the graph.

Forward and reverse current values are shown on the vertical axis of the graph. Forward Voltage represented to the right and Reverse Voltage to the left. The point of beginning or zero value is at the center of the graph. Forward Current lengthens above the horizontal axis with Reverse Current extending downward.

The combined Forward Voltage and Forward Current values are located in the upper right part of the graph and Reverse Voltage and Reverse Current in the lower left corner. Different scales are normally used to display forward and reverse values.

Forward Characteristic

When a diode is forward biased it conducts current (IF) in forward direction. The value of IF is directly dependent on the amount of forward voltage. The relationship of forward voltage and forward current is called the ampere-volt, or IV characteristic of a diode. A typical diode forward IV characteristic is shown in the following figure.



Following are the observations –

- Forward Voltage is measured across the diode and Forward Current is a measure of current through the diode.
- When the forward voltage across the diode equals 0V, forward current (IF) equals 0 mA.
- When the value starts from the starting point (0) of the graph, if VF is progressively increased in 0.1-V steps, IF begins to rise.
- When the value of VF is large enough to overcome the barrier potential of the P-N junction, a considerable increase in IF occurs. The point at which this occurs is often called the knee voltage V_K. For germanium diodes, V_K is approximately 0.3 V, and 0.7 V for silicon.
- If the value of IF increases much beyond V_K, the forward current becomes quite large.

This operation causes excessive heat to develop across the junction and can destroy a diode. To avoid this situation, a protective resistor is connected in series with the diode. This resistor limits

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the forward current to its maximum rated value. Normally, a current limiting resistor is used when diodes are operated in the forward direction.

Reverse Characteristic

When a diode is reverse biased, it conducts Reverse current that is usually quite small. A typical diode reverse IV characteristic is shown in the above figure.

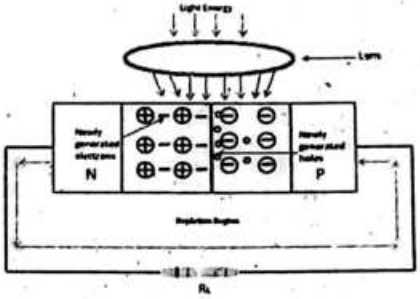
The vertical reverse current line in this graph has current values expressed in microamperes. The amount of minority current carriers that take part in conduction of reverse current is quite small. In general, this means that reverse current remains constant over a large part of reverse voltage. When the reverse voltage of a diode is increased from the start, there is a very slight change in the reverse current. At the breakdown voltage (VBR) point, current increases very rapidly. The voltage across the diode remains reasonably constant at this time.

This constant-voltage characteristic leads to a number of applications of diode under reverse bias condition. The processes which are responsible for current conduction in a reverse-biased diode are called as Avalanche breakdown and Zener breakdown.

8. Describe the Working of a Photovoltaic Cell

Solution :

The construction of a photovoltaic cell is similar to that of a PN junction diode. There is no current flow through the device when no light is applied. In this state, the cell will not be able to generate current.



It is essential to bias the cell properly which requires a fair amount of light. As soon as light is applied, a remarkable state of PN junction diode can be observed. As a result, the electrons acquire sufficient energy and break away from the parent atoms. These newly generated electron-hole pairs in the depletion region crosses the junction.

In this action, the electrons move into the N type material because of its normal positive ion concentration. Likewise holes sweep into the P type material because of its negative ion content. This causes the N type material to instantly take on a negative charge and the P material to take on a positive charge. The P-N junction then delivers a small voltage as a response.

9. Describe the Characteristics of a Photovoltaic Cell

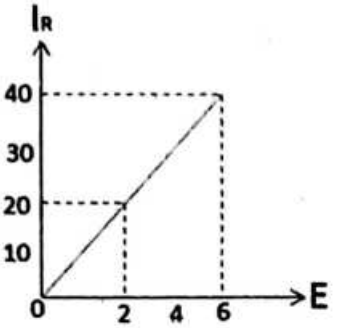
Solution :

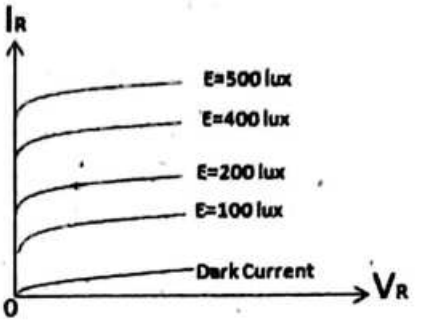
The following figure on the left, shows one of the characteristics, a graph between reverse current (I_R) and illumination (E) of a photo diode. IR is measured on the vertical axis and illumination is measured on the horizontal axis. The graph is a straight line passing through the zero position.

i.e, $I_R = mE$

m = graph straight line slope

The parameter m is the sensitivity of the diode.





The figure on the right, shows another characteristic of the photo diode, a graph between reverse current (I_R) and reverse voltage of a photo diode. It is clear from the graph that for a given reverse voltage, reverse current increases as the illumination increases on the PN junction.

These cells generally supply electrical power to a load device when light is applied. If a larger voltage is required, array of these cells are used to provide the same. For this reason, photovoltaic cells are used in applications where high levels of light energy are available.

10. Define Rectifier, Clipper. (2015)

Answer:

Rectifier : A rectifier is an electrical device composed of one or more diodes that converts alternating current (AC) to direct current (DC). A diode is like a one-way valve that allows an electrical current to flow in only one direction. This process is called rectification.

A rectifier can take the shape of several different physical forms such as solid-state diodes, vacuum tube diodes, mercury arc-valves, silicon-controlled rectifiers and various other silicon-based semiconductor switches.

Clipper: a **clipper** is a device designed to prevent the output of a circuit from exceeding a predetermined voltage level without distorting the remaining part of the applied waveform.

A clipping circuit consists of linear elements like resistors and non-linear elements like junction diodes or transistors, but it does not contain energy-storage elements like capacitors. Clipping circuits are used to select for purposes of transmission, that part of a signal wave form which lies above or below a certain reference voltage level.

11. What is a rectifier? (2015)

Answer: : A rectifier is an electrical device composed of one or more diodes that converts alternating current (AC) to direct current (DC). A diode is like a one-way valve that allows an electrical current to flow in only one direction. This process is called rectification.

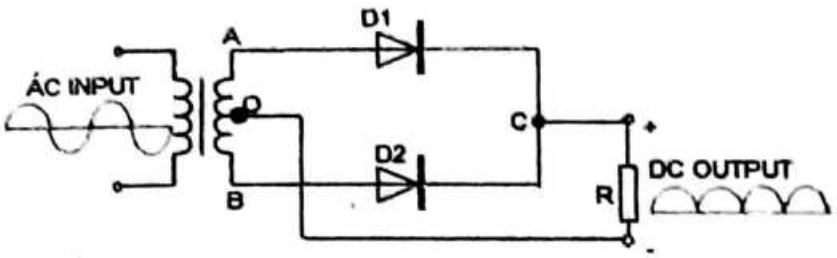
12. Draw the circuit diagram of a half wave and a full wave rectifier and describe their operation. (2017,2011, 2016,2014, 2012,2021,2023, 2024)

Answer:

Full wave rectifier:

In the case of Full wave rectifier of type center tapped, both the halves of input AC voltage produce the current pulses. During the first half cycle, D1 gets forward biased and D2 gets reverse biased. Hence D1 provides current at the output. During the second half cycle, D1 gets reverse biased and D2 gets forward biased and hence D2 here provides current at the output.

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Full Wave rectifier (Centre tap)

Operation:

Positive Half-Cycle:

One pair of diodes becomes forward-biased (conducting).

Current flows from the AC source, through the first forward-biased diode, through the load resistor, through the second forward-biased diode, and back to the AC source.

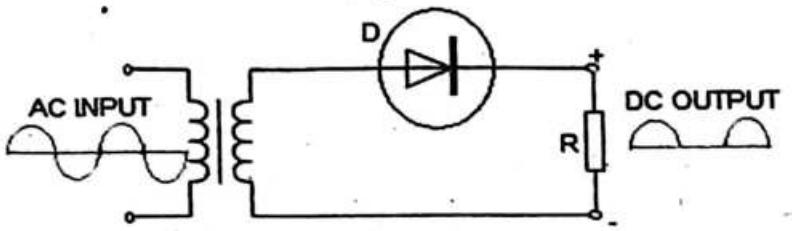
Negative Half-Cycle:

The other pair of diodes becomes forward-biased.

Current flows from the AC source in the opposite direction, but through the same load resistor in the same direction as in the positive half-cycle, and then back to the AC source.

Half wave rectifier

The Half wave rectifier circuit is depicted in the image above For practical representation load R is considered in place of actual electronic equipment.



Half Wave Rectifier

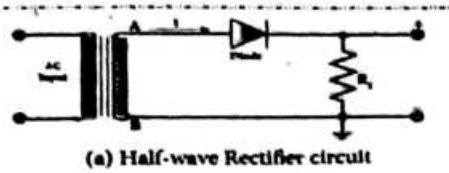
During forward bias condition(i.e. positive half of input cycle), Diode D conducts and will produce pulse of current. This produces voltage across R which will have same value as of inpur voltage provided forward resistance of diode is negligible compare to resistance R.
During reverse bias condition(i.e. negative half of input cycle), diode D is reverse biased. This results into no current in the circuit and voltage across R is Zero.

13. Draw the circuit diagram of a half wave its rectifier and describe operation (2023,2020)

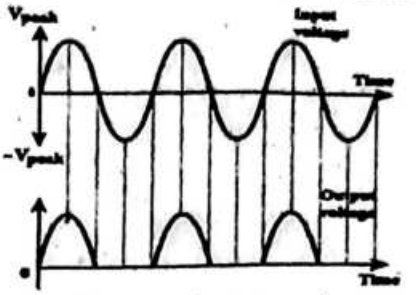
Answer:

The half wave rectifier circuit. The circuit consists of a transformer, a p-n junction diode and a resistor. In a half wave rectifier circuit, either a positive half or the negative half of the AC input is passed through while the other half is blocked. Only one half of the input wave reaches the output. Therefore, it is called half wave rectifier. Here, a p-n junction diode acts as a rectifying diode.

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(a) Half-wave Rectifier circuit



(b) Input and output waveforms

During the positive half cycle:
When the positive half cycle of the ac input signal passes through the circuit, terminal A becomes positive with respect to terminal B. The diode is forward biased and hence it conducts. The current flows through the load resistor RL and the AC voltage developed across RL constitutes the output voltage V and the waveform of the diode current.

During the negative half cycle: When the negative half cycle of the ac input signal passes through the circuit, terminal A is negative with respect to terminal B. Now the diode is reverse biased and does not conduct and hence no current passes through RL . The reverse saturation current in a diode is negligible. Since there is no voltage drop across R , the negative half cycle of ac supply is suppressed at the output. The output of the half wave rectifier is not a steady dc voltage but a pulsating wave. This pulsating voltage is not sufficient for electronic equipments. A constant or a steady voltage is required which can be obtained with the help of filter circuits and voltage regulator circuits. Efficiency (η) is the ratio of the output dc power to the ac input power supplied to the circuit. Its value for half wave rectifier is 40.6 %.

14. What are the characteristics of LED? (2017,2016,2013)

Answer:
There are few characteristics of LED .They are the Polarity, Forward Voltage and Forward Current.

Polarity of LED
Polarity is an indication of symmetricity of an electronic component. A Light Emitting Diode, similar to a PN Junction Diode, is not symmetric i.e. it allows current to flow only in one direction.

Forward Current of LED
Every LED is rated with a maximum forward current that is safe to pass through it without burning off the LED..Allowing current more than the rated current will actually burn the LED.

Forward Voltage of LED
Light Emitting Diodes are also rated for forward voltage i.e. the amount of voltage required for the LED to conduct electricity. For example, all 5mm LEDs have a current rating of 20mA but the forward voltage varies one LED to another.

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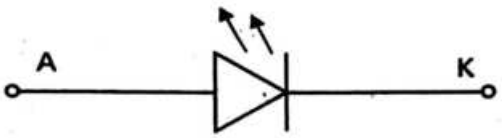
5. Describe the construction and operation of LED. (2020,2017,2015,2012)

Answer:

LED (Light Emitting Diodes)

This one is the most popular diodes used in our daily life. This is also a normal PN junction diode except that instead of silicon and germanium, the materials like gallium arsenide, gallium arsenide phosphide are used in its construction.

The figure below shows the symbol of a Light emitting diode.



Symbol of LED

Like a normal PN junction diode, this is connected in forward bias condition so that the diode conducts. The conduction takes place in a LED when the free electrons in the conduction band combine with the holes in the valence band. This process of recombination emits **light**. This process is called as **Electroluminescence**. The color of the light emitted depends upon the gap between the energy bands.

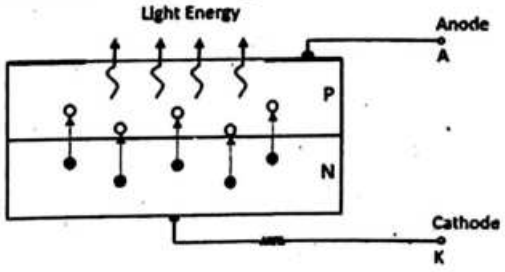
The materials used also effect the colors like, gallium arsenide phosphide emits either red or yellow, gallium phosphide emits either red or green and gallium nitrate emits blue light. Whereas gallium arsenide emits infrared light. The LEDs for non-visible Infrared light are used mostly in remote controls.

The following figure shows a how the practical LEDs of different colors looks like.



LED in the above figure has a flat side and curved side, the lead at the flat side is made shorter than the other one, so as to indicate that the shorter one is **Cathode** or negative terminal and the other one is **Anode** or the Positive terminal.

The basic structure of LED is as shown in the figure below.



Basic Structure of LED



As shown in the above figure, as the electrons jump into the holes, the energy is dissipated spontaneously in the form of light. LED is a current dependent device. The output light intensity depends upon the current through the diode.

16. Differentiate between LED and Zener diode. (2016,2013,2020)

Answer:

Basis for Comparison	LED	Diode
Definition	The type of diode which when placed in an electric field emits light.	It is a semiconductor diode which conducts only in one direction.
Symbol		
Material	GaAs (Gallium Arsenide) and GaP (Gallium Phosphide)	Silicon and Germanium
Principle	Converts energy into light.	Converts energy into heat.
Reverse Breakdown Voltage value	Low	High
On-state voltage range	1.2v – 2.0v	0.7v for silicon and 0.3v for germanium.
Application	Rectification i.e., converts the ac to dc.	Emits light
Uses	Indicators in seven segment displays, use as light source.	Rectifiers, voltage multipliers, clamping, etc.

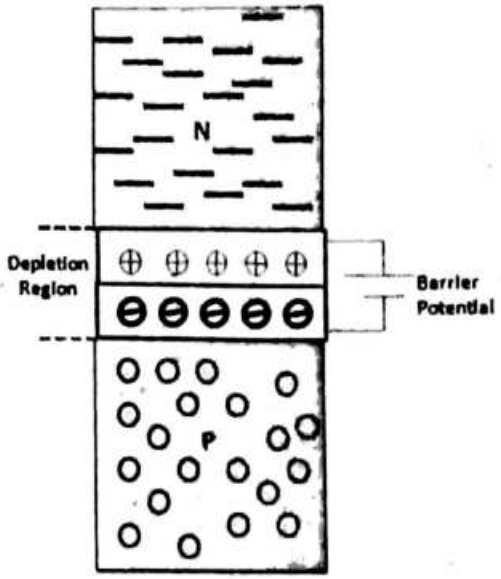
17. What is barrier voltage of a diode? Explain how the harrier voltage is developed in it. (2013,2011)

Answer: N-type and P-type material are considered as electrically neutral before they are joined together at a common junction. However, after joining diffusion takes place instantaneously, as electrons cross the junction to fill holes causing negative ions to emerge in the P material, this action causes the nearby area of the junction to take on a negative charge. Electrons departing the N material causes it to generate positive ions.

All this process, in turn, causes the N side of the junction to take on a net positive charge. This particular charge creation tends to force the remaining electrons and holes away from the junction. This action makes it somewhat hard for other charge carriers to diffuse across the junction. As a result, the charge is built up or barrier potential emerges across the junction.

As shown in the following figure. The resultant barrier potential has a small battery connected across the P-N junction. In the given figure observe the polarity of this potential barrier with respect to P and N material. This voltage or potential will exist when the crystal is not connected to an external source of energy.

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The barrier potential of germanium is approximately 0.3 V, and of silicon is 0.7 V. These values cannot be measured directly and appears across the space charge region of the junction. In order to produce current conduction, the barrier potential of a P-N junction must be overcome by an external voltage source.

18. What is ideal diode? (2013)

Answer:

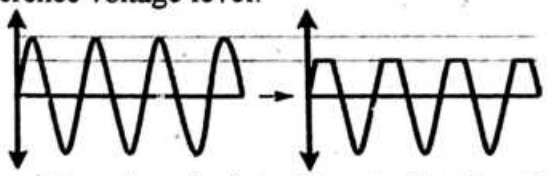
Ideal diode is a perfect conductor or acts as a short circuit in the forward bias and acts as an open circuit in the reverse bias. In forward bias, voltage drop across the diode is zero and in reverse bias, voltage drop across the diode is infinity.

19. Define clipper, clamper circuit and cut in voltage. (2016,2012)

Answer:

Clipper: a **clipper** is a device designed to prevent the output of a circuit from exceeding a predetermined voltage level without distorting the remaining part of the applied waveform.

A clipping circuit consists of linear elements like resistors and non-linear elements like junction diodes or transistors, but it does not contain energy-storage elements like capacitors. Clipping circuits are used to select for purposes of transmission, that part of a signal wave form which lies above or below a certain reference voltage level.



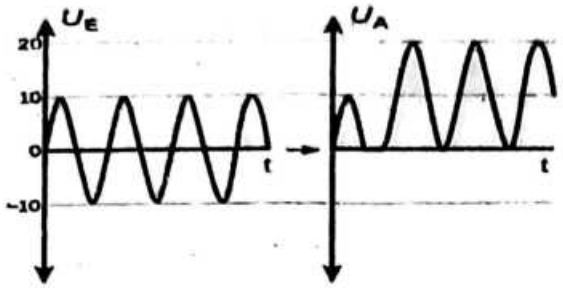
Voltage clipping limits the voltage to a device without affecting the rest of the waveform

Clamper :

A clamper is an electronic circuit that fixes either the positive or the negative peak excursions of a signal to a defined value by shifting its DC value. The clamper does not restrict the peak-to-peak excursion of the signal, it moves the whole signal up or down so as to place the peaks at the

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reference level. A **diode clamp** (a simple, common type) consists of a diode, which conducts electric current in only one direction and prevents the signal exceeding the reference value; and a capacitor, which provides a DC offset from the stored charge.



Positive unbiased voltage clamping vertically translates the input waveform so that all parts of it are approximately greater than 0 V. Note that the negative swing of the output will not dip below about −0.6 V, assuming a silicon pn diode.

Cut-off voltage :

The **cut-off voltage** is the voltage at which a battery is considered fully discharged, beyond which further discharge could cause harm. Some electronic devices, such as cell phones, will automatically shut down when the cut-off voltage has been reached.

20. What are the purposes of a clamper? With neat diagrams explain the operation of negative clamper.(2015)

Answer:

The purposes of a clamper

A clamper is an electronic circuit that changes the DC level of a signal to the desired level without changing the shape of the applied signal. In other words, the clamper circuit moves the whole signal up or down to set either the positive peak or negative peak of the signal at the desired level.

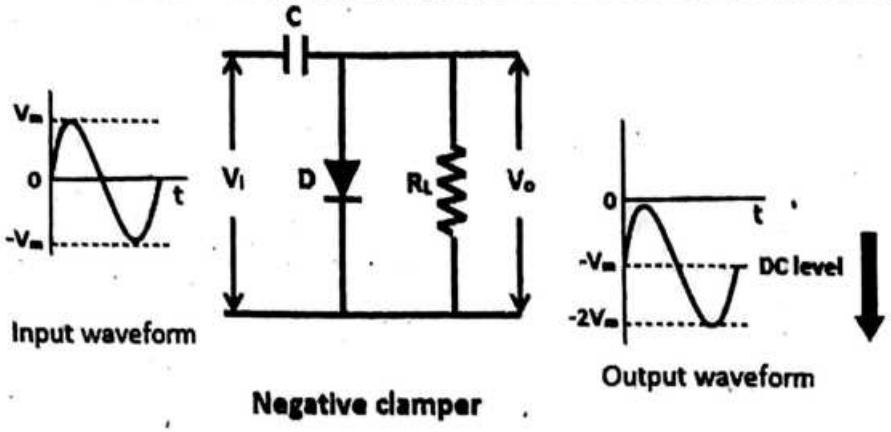
The dc component is simply added to the input signal or subtracted from the input signal. A clamper circuit adds the positive dc component to the input signal to push it to the positive side. Similarly, a clamper circuit adds the negative dc component to the input signal to push it to the negative side.

Negative clamper

During positive half cycle:

During the positive half cycle of the input AC signal, the diode is forward biased and hence no signal appears at the output. In forward biased condition, the diode allows electric current through it. This current will flows to the capacitor and charges it to the peak value of input voltage in inverse polarity $-V_m$. As input current or voltage decreases after attaining its maximum value V_m, the capacitor holds the charge until the diode remains forward biased.

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Negative clamper

Physics and Radio-Electronics

During negative half cycle:

During the negative half cycle of the input AC signal, the diode is reverse biased and hence the signal appears at the output. In reverse biased condition, the diode does not allow electric current through it. So the input current directly flows towards the output.

When the negative half cycle begins, the diode is in the non-conducting state and the charge stored in the capacitor is discharged (released). Therefore, the voltage appeared at the output is equal to the sum of the voltage stored in the capacitor ($-V_m$) and the input voltage ($-V_m$) {I.e. $V_o = -V_m - V_m = -2V_m$} which have the same polarity with each other. As a result, the signal shifted downwards.

21. What you understand by cut-in voltage of a diode? (2014)

Answer:

The forward voltage at which the current through the junction starts increasing rapidly, is called the knee voltage or cut-in voltage.

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Chapter 5

Regulated Power Supply

1.What is a rectifier? **[2011]**

Ans:

A rectifier is a circuit that is used for converting AC supply into unidirectional DC supply. This process of converting alternating current (AC) to direct current (DC) is also called as rectification. These bridge rectifiers are available in different packages as modules ranging from few amperes to several hundred amperes. Mostly in bridge rectifier circuits, semiconductor diode is used for converting AC since it allows the current flow in one direction only (Unidirectional device).



3.What are the advantages of a full wave rectifier over a half wave rectifier? **[2023,2011,2019]**

Ans:

Advantages of Half wave rectifier:

- A half wave rectifier is rarely used in practice. It is never preferred as the power supply of an audio circuit because of the very high ripple factor. High ripple factor will result in noises in input audio signal, which in turn will affect audio quality.
- Advantage of a half wave rectifier is only that it's cheap, simple and easy to construct. It is cheap because of the low number of components involved. Simple because of the straight forwardness in circuit design. Apart from this, a half wave rectifier has more number of disadvantages than advantages.

Advantages of full wave rectifier:

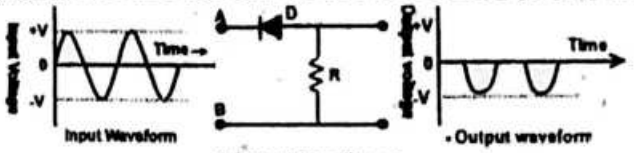
- The rectification efficiency is double than half wave rectifier.
- Ripple factor is less and ripple frequency is double hence easy to filter out.
- DC output voltage and current is higher hence output power is higher.
- Better transformer utilization factor
- There is no DC saturation of core in transformer because the DCcurrents in two halves of secondary flow in opposite directions

4.What is a clipper circuit? **[2010,2016,2018]**

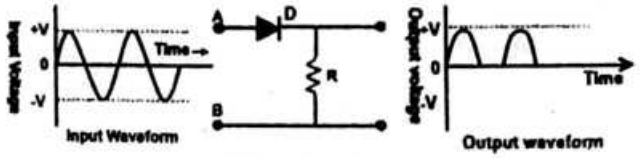
Ans:

A **clipper** is a device designed to prevent the output of a circuit from exceeding a predetermined voltage level without distorting the remaining part of the applied waveform.

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(a) Positive clipper

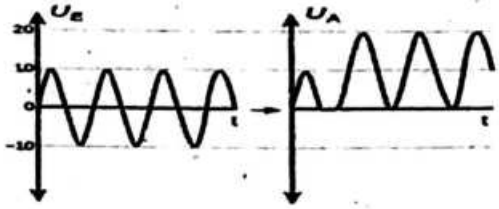


(b) Negative clipper

5.Define clamper circuit and cut in voltage. **[2016]**

Ans:

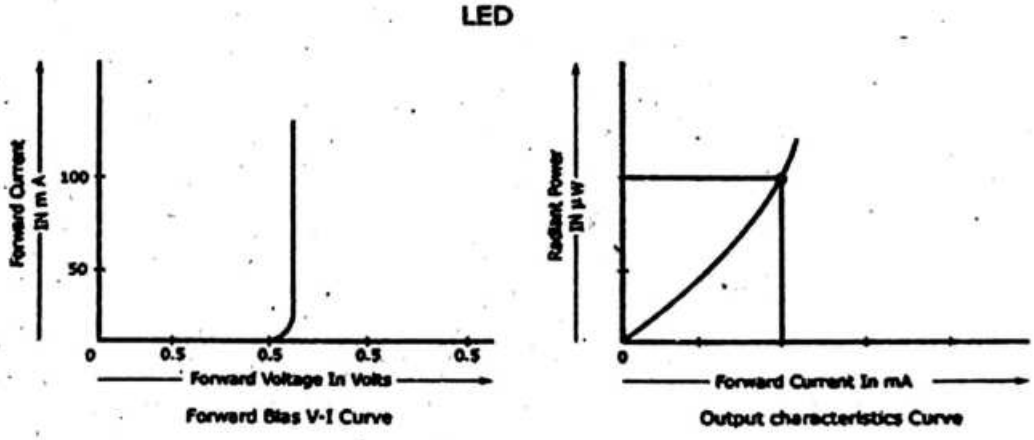
Clamper circuit: A **clamper** is an electronic **circuit** that fixes either the positive or the negative peak excursions of a signal to a **defined** value by shifting its DC value. The **clamper** does not restrict the peak-to-peak excursion of the signal, it moves the whole signal up or down so as to place the peaks at the reference level.



6.What are the characteristics of LED? **[2013,2016]**

Ans:

LED Characteristics



LED Characteristics

The forward bias Voltage-Current (V-I) curve and the output characteristics curve is shown in the figure above. The V-I curve is practically applicable in **burglar alarms**. Forward bias of approximately 1 volt is needed to give significant forward current. The second figure is used to represent a radiant power-forward current curve. The output power produced is very small and thus the efficiency in electrical-to-radiant energy conversion is very less.

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The figure below shows a series resistor R_{series} connected to the LED. Once the forward bias of the device exceeds, the current will increase at a greater rate in accordance to a small increase in voltage. This shows that the forward resistance of the device is very low. This shows the importance of using an external series current limiting resistor. Series resistance is determined by the following equation.

$R_{series} = (V_{supply} - V)/I$

V_{supply} – Supply Voltage

V – LED forward bias voltage

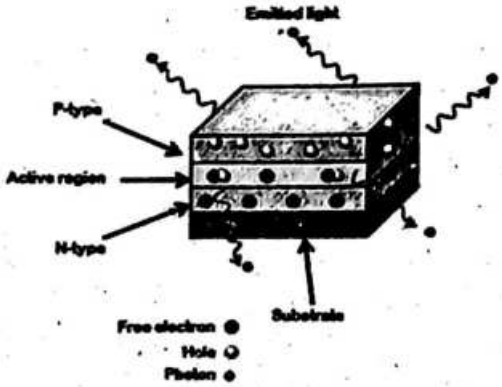
I – Current

7.Describe the construction and operation of a LED. **[2010,2015]**

Ans:

LED construction

One of the methods used to construct LED is to deposit three semiconductor layers on the substrate. The three semiconductor layers deposited on the substrate are n-type semiconductor, p-type semiconductor and active region. Active region is present in between the n-type and p-type semiconductor layers.



Construction of LED

When LED is forward biased, free electrons from n-type semiconductor and holes from p-type semiconductor are pushed towards the active region.

When free electrons from n-side and holes from p-side recombine with the opposite charge carriers (free electrons with holes or holes with free electrons) in active region, an invisible or visible light is emitted.

In LED, most of the charge carriers recombine at active region. Therefore, most of the light is emitted by the active region. The active region is also called as depletion region.

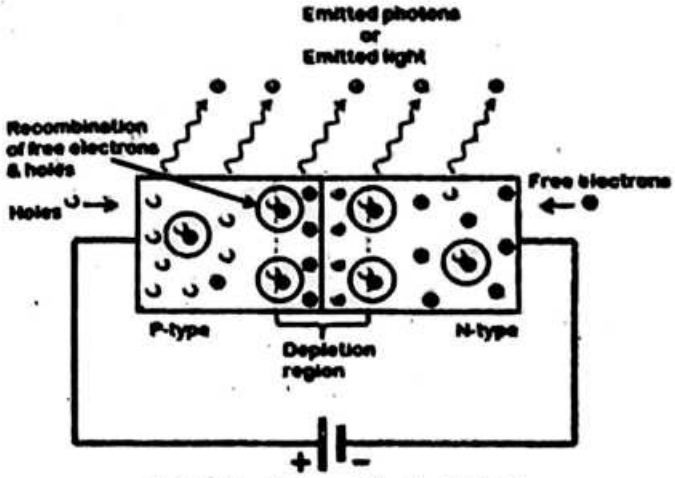
Operation of a LED:

Light Emitting Diode (LED) works only in forward bias condition. When Light Emitting Diode (LED) is forward biased, the free electrons from n-side and the holes from p-side are pushed towards the junction.

When free electrons reach the junction or depletion region, some of the free electrons recombine with the holes in the positive ions. We know that positive ions have less number of electrons than protons. Therefore, they are ready to accept electrons. Thus, free electrons recombine with holes

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in the depletion region. In the similar way, holes from p-side recombine with electrons in the depletion region.

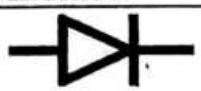


Light Emitting Diode (LED)

Because of the recombination of free electrons and holes in the depletion region, the width of depletion region decreases. As a result, more charge carriers will cross the p-n junction.

Some of the charge carriers from p-side and n-side will cross the p-n junction before they recombine in the depletion region. For example, some free electrons from n-type semiconductor cross the p-n junction and recombines with holes in p-type semiconductor. In the similar way, holes from p-type semiconductor cross the p-n junction and recombines with free electrons in the n-type semiconductor.

8.Differentiate between LED and Zener diode. **[2013,2016,2018]**

Basis for Comparsion	LED	Diode
Definition	The type of diode which when placed in an electric field emits light.	It is a semiconductor diode which conducts only in one direction.
Symbol		
Material	GaAs (Gallium Arsenide) and GaP (Gallium Phosphide)	Silicon and Germanium
Principle	Converts energy into light.	Converts energy into heat.
Reverse Breakdown Voltage value	Low	High
On-state voltage range	1.2v – 2.0v	0.7v for silicon and 0.3v for germanium.
Application	Rectification i.e., converts the ac to dc.	Emits light
Uses	Indicators in seven segment displays, use as light source.	Rectifiers, voltage multipliers, clamping, etc.

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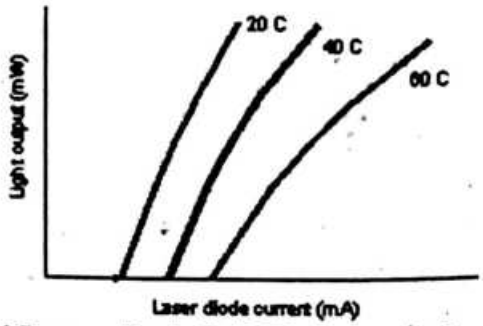
9.Mention some characteristics of LASER diode. [2014]

Ans:

Laser diode L/I characteristic

One of the most commonly used and important laser diode specifications or characteristics is the L/I curve. It plots the drive current supplied against the light output.

This laser diode specification is used to determine the current required to obtain a particular level of light output at a given current. It can also be seen that the light output is also very dependent upon the temperature.



Laser diode L/I Characteristic

From this characteristic, it can be seen that there is a threshold current below which the laser action does not take place. The laser diode should be operated clear of this point to ensure reliable operation over the full operating temperature range as the threshold current rises with increasing temperature. It is typically found that the laser threshold current rises exponentially with temperature.

Laser diode efficiency characteristic

It is possible to deduce the laser diode efficiency parameter from the L/I curve. However it is easier to visualise when plotted separately. In view of the importance of the laser diode efficiency this is often usefully plotted.

The plot of the laser diode efficiency characteristic will show that the efficiency falls with increasing temperature. A typical laser diode specification for efficiency will be around 0.3 mW per mA at around 25°C and will fall by about 0.01 for each 10°C increase.

Laser diode tracking ratio characteristic

Many laser diode packages include a second photo diode to monitor the output of the laser. In this way the output power of the laser can be controlled and stabilised - the output from the monitor diode is fed back into the laser diode control and drive circuitry. Normally the unwanted light exiting from the back face of the laser diode is used for the measurement as this light cannot be used elsewhere.

In order for the laser output to be accurately controlled it is necessary for the monitor diode to accurately track the laser diode output. The monitor photodiode current is directly proportional to the light output from the laser and therefore a figure known as the tracing ratio is used. Measured in mA/mW it is the ratio of the photodiode current in milliamps compared to the laser diode light output in milliwatts.

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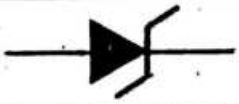
10.LED. [2011]

Ans:

A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current passes through it. The light is not particularly bright, but in most LEDs it is monochromatic, occurring at a single wavelength. The output from an LED can range from red (at a wavelength of approximately 700 nanometers) to blue-violet (about 400 nanometers). Some LEDs emit infrared (IR) energy (830 nanometers or longer); such a device is known as an infrared-emitting diode (IRED).

11.Write the differences between ordinary diode and zener diode. [2011]

Ans:

Parameters	Diode	Zener Diode
Definition	Diode is a semiconductor device which conducts only in forward biased.	Zener diode is semiconductor device which can conduct in forward as well as reversed biased.
Operation in Reverse Biased	It gets damaged in reverse biased.	It can operate without getting damaged.
Circuit Symbol		
Doping Intensity	In normal diodes doping intensity is low.	In Zener diode doping intensity is high to achieve sharp breakdown.
Application	Diode is used in rectifiers, clippers, clampers etc.	Zener diode is mostly used in voltage regulator.

12.Breakdown voltage [2011]

Ans:

The breakdown voltage of an insulator is the minimum voltage that causes a portion of an insulator to become electrically conductive. For diodes, the breakdown voltage is the minimum reverse voltage that makes the diode conduct appreciably in reverse

13.What is ideal diode. [2013]

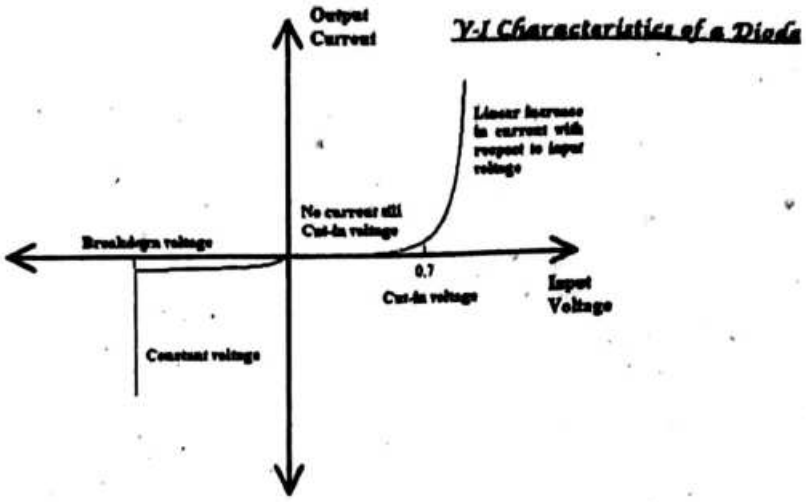
Ans:

An ideal diode is a diode that acts like a perfect conductor when voltage is applied forward biased and like a perfect insulator when voltage is applied reverse biased. So when positive voltage is applied across the anode to the cathode, the diode conducts forward current instantly

What do you understand by 'cut-in' voltage of a diode? (2014)

Ans: The forward voltage at which the current through the junction starts increasing rapidly, is called the knee voltage or cut-in voltage.

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For a bias less than the Peak Inverse Voltage, the reverse current is very small. Therefore there will be a definite forward voltage at which the diode starts to conduct significantly. Here cut-in voltage comes in the picture.

A **Silicon** diode has higher forward voltage potential (0.7V) than **Germanium**diode (0.3V).

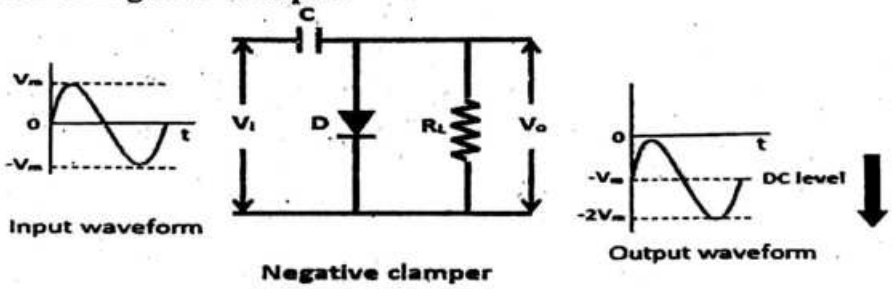
14.What are the purposes of a clamper? With neat diagrams explain the operation of negative clamper. **[2015]**

Ans:

The purposes of a clamper:

A **clamper** is an electronic circuit that fixes either the positive or the negative peak excursions of a signal to a defined value by shifting its DC value. The clamper does not restrict the peak-to-peak excursion of the signal, it moves the whole signal up or down so as to place the peaks at the reference level. A **diode clamp** (a simple, common type) consists of a diode, which conducts electric current in only one direction and prevents the signal exceeding the reference value; and a capacitor, which provides a DC offset from the stored charge.

Explain the operation of negative clamper:



Negative clamper

Physics and Radio-Electronics

During positive half cycle:

During the positive half cycle of the input AC signal, the diode is forward biased and hence no signal appears at the output. In forward biased condition, the diode allows electric current through it. This current will flows to the capacitor and charges it to the peak value of input voltage in inverse polarity $-V_m$. As input current or voltage decreases after attaining its maximum value V_m. the capacitor holds the charge until the diode remains forward biased.

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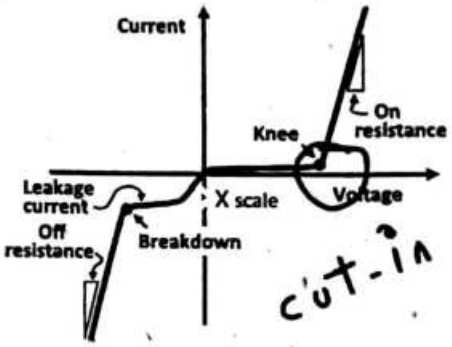
During negative half cycle:

During the negative half cycle of the input AC signal, the diode is reverse biased and hence the signal appears at the output. In reverse biased condition, the diode does not allow electric current through it. So the input current directly flows towards the output.

When the negative half cycle begins, the diode is in the non-conducting state and the charge stored in the capacitor is discharged (released). Therefore, the voltage appeared at the output is equal to the sum of the voltage stored in the capacitor ($-V_m$) and the input voltage ($-V_m$) {I.e. $V_o = -V_m - V_m = -2V_m$} which have the same polarity with each other. As a result, the signal shifted downwards

19.What you understand by cut-in voltage of a diode?[2014]

The forward voltage at which the current through the junction starts increasing rapidly, is called the knee voltage or cut-in voltage.



For a bias less than the Peak Inverse Voltage, the reverse current is very small. Therefore there will be a definite forward voltage at which the diode starts to conduct significantly. Here cut-in voltage comes in the picture.

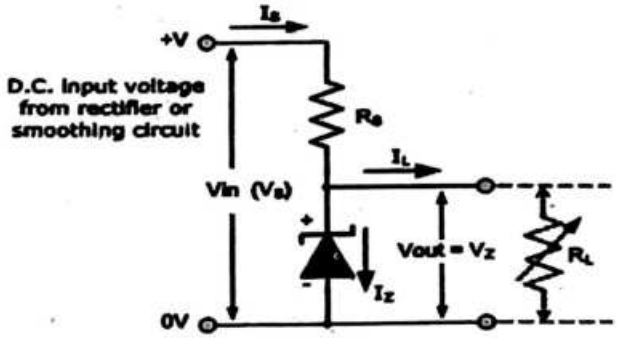
A **Silicon** diode has higher forward voltage potential (0.7V) than **Germanium** diode (0.3V).

20.Explaine the operation of zener diode as a voltage regulator. [2019,2017,2014]

Or, Briefly explain the circuit operation and discuss the effects of load current for a zener diode voltage regulator. (2020)

Ans:

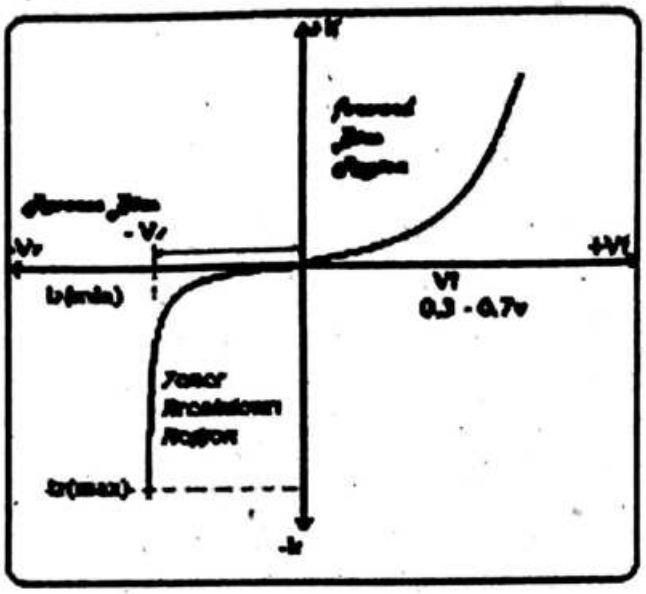
Zener diodes are widely used as **voltage** references and as shunt **regulators** to regulate the **voltage** across small circuits. When connected in parallel with a variable **voltage** source so that it is reverse biased, a **Zener diode** conducts when the **voltage** reaches the **diode's** reverse breakdown **voltage**.



Zener diode is somewhat similar to the ordinary p-n junction diode but with an outstanding property of **sharp breakdown voltage.**

This property enables to use it as a voltage regulator.

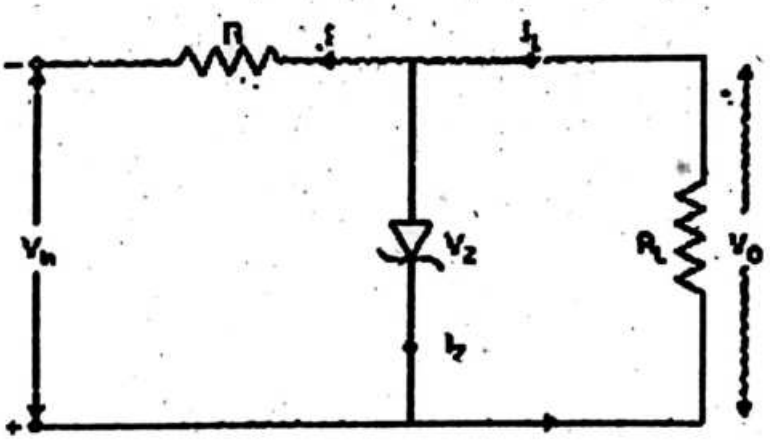
When we connect zener diode in forword biased condition, it works similar to the ordinary diode. But in reverse biased condition once the breakdown voltage is reached, it conducts the current heavily. So in reverse region zener diode acts as a **constant voltage source (Battery).**



The diagram shows that zener diode is connected in reverse biased condition across the load across which constant voltage is desired.

Despite of any change in input voltage or load resistance, the output voltage always remains equal to zener's breakdown voltage (**Vo = Vz**).

P.S. - Zener diode is used as a voltage regulator only when input voltage is more than zener's breakdown voltage.



21.Bandwidth,Photodiode,Light-emiting diode. [2019]

Ans:

Bandwidth: Bandwidth describes the maximum data transfer rate of a network or Internet connection. It measures how much data can be sent over a specific connection in a given amount of time. For example, a gigabit Ethernet connection has a bandwidth of 1,000 Mbps, (125 megabytes per second). An Internet connection via cable modem may provide 25 Mbps of bandwidth.

While bandwidth is used to describe network speeds, it does not measure how fast bits of data move from one location to another. Since data packets travel over electronic or fiber optic cables, the speed of each bit transferred is negligible. Instead, bandwidth measures how much data can flow through a specific connection at one time.

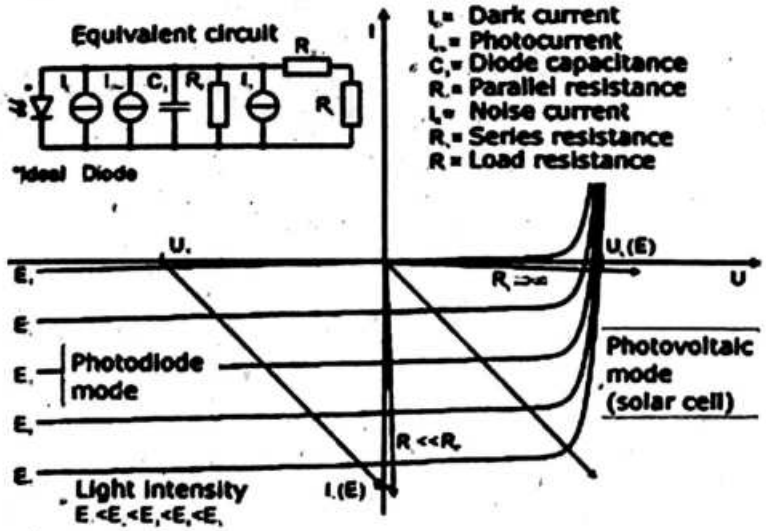
When visualizing bandwidth, it may help to think of a network connection as a tube and each bit of data as a grain of sand. If you pour a large amount of sand into a skinny tube, it will take a long time for the sand to flow through it. If you pour the same amount of sand through a wide tube, the sand will finish flowing through the tube much faster. Similarly, a download will finish much faster when you have a high-bandwidth connection rather than a low-bandwidth connection.

Data often flows over multiple network connections, which means the connection with the smallest bandwidth acts as a bottleneck. Generally, the Internet backbone and connections between servers have the most bandwidth, so they rarely serve as bottlenecks. Instead, the most common Internet bottleneck is your connection to your ISP.

NOTE: Bandwidth also refers to a range of frequencies used to transmit a signal. This type of bandwidth is measured in hertz and is often referenced in signal processing applications.

Photo-doide: A **photodiode** is a semiconductor device that converts light into an electrical current. The current is generated when photons are absorbed in the **photodiode**. **Photodiodes** may contain optical filters, built-in lenses, and may have large or small surface areas.

Working principle: Converts light into current
Pin configuration: anode and cathode
Type: Passive



Light-emitting diode A **light-emitting diode (LED)** is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor.[5] White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.[6]

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared light.[7] Infrared LEDs are used in remote-control circuits, such as those used with a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with high light output.



22. Explain the characteristics of Zener diode. [2024]

Zener Diode: A Zener diode is a specialized semiconductor diode designed to operate in the reverse breakdown region. Unlike a normal diode, it allows current to flow in the reverse direction when the voltage exceeds a specific, stable threshold called the Zener voltage. This stable breakdown voltage makes Zener diodes ideal for use as a voltage regulator, overvoltage protector, and in clipping circuits.

Characteristics: Its key characteristics include:

1. **Heavily Doped Junction**
   – The diode contains a highly doped p–n junction, creating a very thin depletion layer and enabling a sharp breakdown at a precise voltage.
2. **Well-Defined Breakdown Voltage**
   – It has a specific reverse breakdown voltage known as the Zener voltage, which remains almost constant during operation.
3. **Excellent Voltage Regulation**
   – It maintains a stable and constant output voltage even when the input voltage or load current changes, making it suitable for regulation.
4. **Low Dynamic Resistance in Breakdown Region**
   – In the breakdown region, the resistance stays very low, leading to minimal voltage variation with changes in current.
5. **Dual Breakdown Mechanism**
   – The diode exhibits both Zener breakdown (at low voltages) and avalanche breakdown (at higher voltages), ensuring controlled reverse conduction across different voltage ranges.
6. **Specified Power Rating**
   – Every Zener diode includes a maximum power dissipation rating to prevent overheating and device damage.

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Chapter 6

Bipolar Junction Transistors

1) What is transistor? Discuss the working principle of npn transistors. *(2016)*

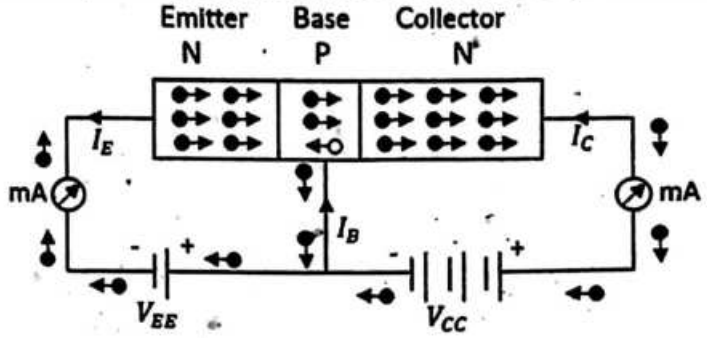
Answer:

A **Transistor** is a three terminal semiconductor device that regulates current or voltage flow and acts as a switch or gate for signals.

two PN junctions which make a new component called **Transistor**.

NPN Transistor

The operation of an NPN transistor can be explained by having a look at the following figure, in which emitter-base junction is forward biased and collector-base junction is reverse biased.



Operation of a NPN transistor

The voltage V_{EE} provides a negative potential at the emitter which repels the electrons in the N-type material and these electrons cross the emitter-base junction, to reach the base region. There a very low percent of electrons recombine with free holes of P-region. This provides very low current which constitutes the base current I_B. The remaining holes cross the collector-base junction, to constitute the collector current I_C.

As an electron reaches out of the collector terminal, and enters the positive terminal of the battery, an electron from the negative terminal of the battery V_{EE} enters the emitter region. This flow slowly increases and the electron current flows through the transistor.

Hence we can understand that –

- The conduction in a NPN transistor takes place through electrons.
- The collector current is higher than the emitter current.
- The increase or decrease in the emitter current affects the collector current.

2) What is BJT? *[2010,2011,2016]*

Ans:

Bipolar Junction Transistor (BJT) is a Semiconductor device constructed with three doped Semiconductor Regions (Base, Collector and Emitter) separated by two p-n Junctions, Figure 1. The p-n Junction between the Base and the Emitter has a Barrier Voltage (V_0) of about 0.6 V, which is an important parameter of a BJT.

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3) Explain input characteristics of a common emitter configuration of BJT. [2013,2018]

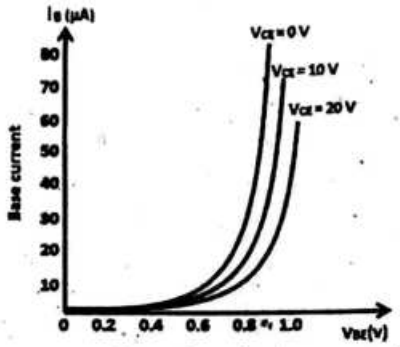
Ans:

Input characteristics

The input characteristics describe the relationship between input current or base current (I_B) and input voltage or base-emitter voltage (V_{BE}).

First, draw a vertical line and a horizontal line. The vertical line represents y-axis and horizontal line represents x-axis. The input current or base current (I_B) is taken along y-axis (vertical line) and the input voltage (V_{BE}) is taken along x-axis (horizontal line).

To determine the input characteristics, the output voltage V_{CE} is kept constant at zero volts and the input voltage V_{BE} is increased from zero volts to different voltage levels. For each voltage level of input voltage (V_{BE}), the corresponding input current (I_B) is recorded.



I/P characteristics CE configuration

4) Draw the output characteristic of a transistor in Common Emitter configuration and describe three regions. [2010,2011,2016,2018]

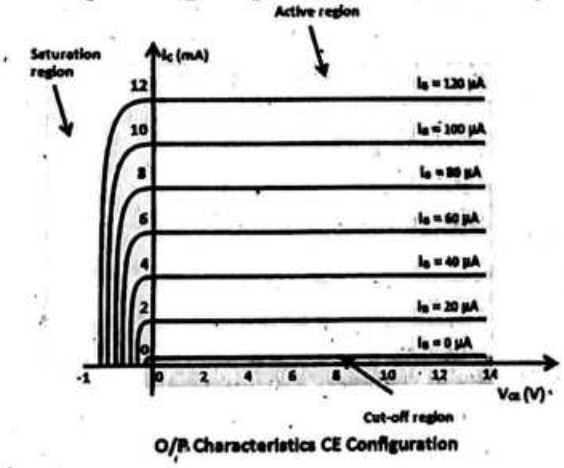
Answer:

Output characteristics

The output characteristics describe the relationship between output current (I_C) and output voltage (V_{CE}).

First, draw a vertical line and a horizontal line. The vertical line represents y-axis and horizontal line represents x-axis. The output current or collector current (I_C) is taken along y-axis (vertical line) and the output voltage (V_{CE}) is taken along x-axis (horizontal line).

To determine the output characteristics, the input current or base current I_B is kept constant at 0 μA and the output voltage V_{CE} is increased from zero volts to different voltage levels. For each level of output voltage, the corresponding output current (I_C) is recorded.



O/P Characteristics CE Configuration

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A curve is then drawn between output current I_C and output voltage V_{CE} at constant input current I_B (0 μA).

When the base current or input current $I_B = 0$ μA, the transistor operates in the cut-off region. In this region, both junctions are reverse biased.

Next, the input current (I_B) is increased from 0 μA to 20 μA by adjusting the input voltage (V_{BE}). The input current (I_B) is kept constant at 20 μA.

While increasing the input current (I_B), the output voltage (V_{CE}) is kept constant at 0 volts.

After we kept the input current (I_B) constant at 20 μA, the output voltage (V_{CE}) is increased from zero volts to different voltage levels. For each voltage level of output voltage (V_{CE}), the corresponding output current (I_C) is recorded.

A curve is then drawn between output current I_C and output voltage V_{CE} at constant input current I_B (20 μA). This region is known as the active region of a transistor. In this region, emitter-base junction is forward biased and the collector-base junction is reverse biased.

This steps are repeated for higher fixed values of input current I_B (I.e. 40 μA, 60μA, 80 μA and so on).

When output voltage V_{CE} is reduced to a small value (0.2 V), the collector-base junction becomes forward biased. This is because the output voltage V_{CE} has less effect on collector-base junction than input voltage V_{BE}.

As we know that the emitter-base junction is already forward biased. Therefore, when both the junctions are forward biased, the transistor operates in the saturation region. In this region, a small increase in output voltage V_{CE} will rapidly increases the output current I_C.

Dynamic output resistance (r_o)

Dynamic output resistance is defined as the ratio of change in output voltage or collector voltage (V_{CE}) to the corresponding change in output current or collector current (I_C), with the input current or base current (I_B) kept at constant.

$$r_o = \frac{\Delta V_{CE}}{\Delta I_C}, \qquad I_B = \text{constant}$$

In CE configuration, the output resistance is high.

Current gain (α)

The current gain of a transistor in CE configuration is defined as the ratio of output current or collector current (I_C) to the input current or base current (I_B).

$$\alpha \frac{I_C}{I_B}$$

The current gain of a transistor in CE configuration is high. Therefore, the transistor in CE configuration is used for amplifying the current.

5) *Define α and β and find the relation between them.*

[2011,2013,2015,2016,2018,2021,2023]

Ans:

Relation Between Current Amplification Factor (α) & Base Amplification Factor (β)

The relation between B and α can be derived as

We Known,

$$\beta = \frac{-\Delta I_C}{\Delta I_B} \ldots\ldots\ldots (1)$$

$$\alpha = \frac{-\Delta I_C}{\Delta I_B} \ldots\ldots\ldots (2)$$

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Now,

$$I_E = I_C + I_B$$

$$\Delta I_E = \Delta I_C + \Delta I_B$$

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

Substituting the value of ΔI_E in equation (1), we get,

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

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

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

The above equation shows that the when the α reaches to unity, then the β reaches to infinity. In other words; the current gain in a common emitter configuration is very high, and because of this reason, the common emitter arrangement circuit is used in all the transistor applications.

6) Why DC biasing is necessary for transistor operation? [2013]

Ans:

The proper flow of zero signal collector current and the maintenance of proper collectoremitter voltage during the passage of signal is known as Transistor Biasing. The circuit which provides transistor biasing is called as Biasing Circuit.

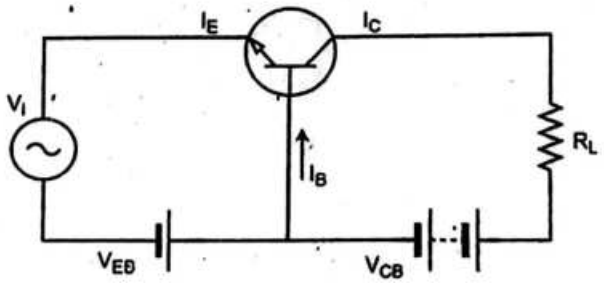
Need for DC biasing

If a signal of very small voltage is given to the input of BJT, it cannot be amplified. Because, for a BJT, to amplify a signal, two conditions have to be met.

The input voltage should exceed cut-in voltage for the transistor to be ON.
The BJT should be in the active region, to be operated as an amplifier.

If appropriate DC voltages and currents are given through BJT by external sources, so that BJT operates in active region and superimpose the AC signals to be amplified, then this problem can be avoided. The given DC voltage and currents are so chosen that the transistor remains in active region for entire input AC cycle. Hence DC biasing is needed.

The below figure shows a transistor amplifier that is provided with DC biasing on both input and output circuits.



For a transistor to be operated as a faithful amplifier, the operating point should be stabilized. Let us have a look at the factors that affect the stabilization of operating point.

Factors affecting the operating point

The main factor that affect the operating point is the temperature. The operating point shifts due to change in temperature.

As temperature increases, the values of I_{CE}, β, V_{BE} gets affected.

I_{CBO} gets doubled (for every 10° rise)

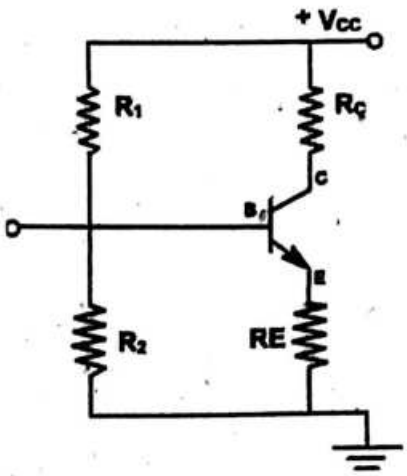
V_{BE} decreases by 2.5mv (for every 1° rise)

So the main problem which affects the operating point is temperature. Hence operating point should be made independent of the temperature so as to achieve stability. To achieve this, biasing circuits are introduced.

7) Draw a voltage divider bias circuit and explain its operation. [2011,2013]

Ans:

Voltage divider bias circuit:



Voltage divider bias

Circuit operation: Voltage divider bias also known as emitter current bias, is the most stable of the three basic transistor biasing circuits. A voltage divider bias circuit is shown in fig. below, and the current and voltage conditions throughout the It is seen that there is an emitter resistor R_E connected in series with emitter, so that the total dc load in series with the transistor is (R_C+ R_E) and this resistance must be used when drawing the dc load line for the circuit. Resistor R1 and R2 constitute a voltage divider that divides the supply voltage to produce the base bias voltage IB. Voltage divider bias circuits are normally designed to have the voltage divider current (I2) very much larger than the transistor base current (IB). In this circumstance, VBE is largely affected by IB so VBE can be assumed to remain constant. Referring to above figure 8, with VB constant, the voltage across the emitter resistor is also a constant quantity; this means that the emitter current is constant. The collector current is approximately equal to the emitter current, so Ic is held at constant level. Again referring to the figure, the transistor collector to emitter voltage is,

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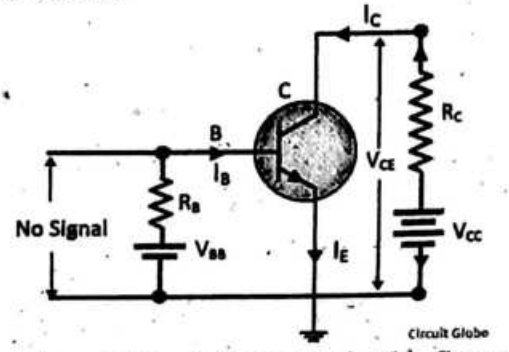
$V_{CE} = V_{cc} - (I_C + I_B) R_C$ Clearly, with Ic and IE constant, the transistor collector- emitter voltage remains at a constant level. It should be noted that the transistor β value is not involved in any of the above equations. The effect of max and min. β in voltage divider bias circuit The following example will demonstrate the variation of β with transistor replacements. The variations of β on the operating point Q is much less than the C-B bias. Hence this biasing technique is more reliable and stable. This makes it the most popular and preferred biasing technique used in circuits

8) What is DC load line? How to draw a DC load line? Explain with diagram. [2024]

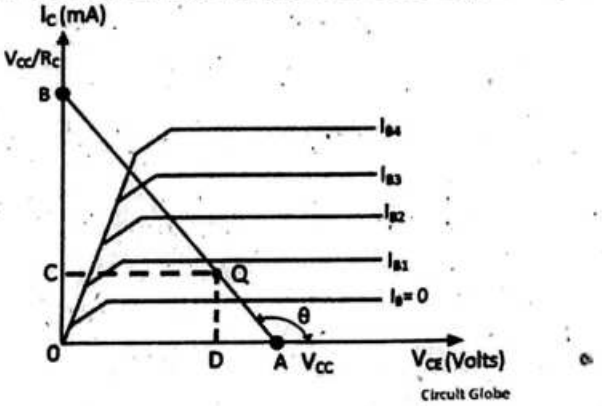
DC Load Line

The DC load represents the desirable combinations of the collector current and the collector-emitter voltage. It is drawn when no signal is given to the input, and the transistor becomes bias.

Consider a CE NPN transistor circuit shown in the figure below where no signal is applied to the input side. For this circuit, DC condition will obtain, and the output characteristic of such a circuit is shown in the figure below.



The DC load line curve of the above circuit is shown in the figure below.



By applying Kirchhoff's voltage law to the collector circuit, we get,

$$V_{CC} = V_{CE} + I_C R_C$$

$$V_{CE} = V_{CC} - I_C R_C \ldots . equ(1)$$

The above equation shows that the V_{CC} and R_C are the constant value, and it is the first-degree equation which is represented by the straight line on the output characteristic. This load line is known as a DC load line. The input characteristic is used to determine the locus of V_{CE} and I_C point for the given value of R_C. The end point of the line are located as

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1. The collector-emitter voltage V_{CE} is maximum when the collector current $I_C = 0$ then from the equation (1) we get,

$$V_{CE} = V_{CC} - 0 \times R_C$$

$$V_{CE} = V_{CC}$$

The first point A (OA = V_{CC}) on the collector-emitter voltage axis shown in the figure above.

2. The collector current I_C becomes maximum when the collector-emitter voltage $V_{CE} = 0$ then from the equation (1) we get.

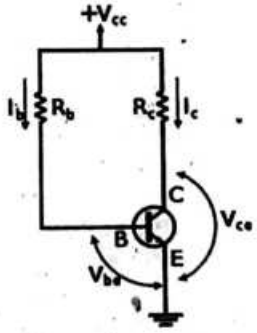
$$0 = V_{CC} - I_C R_C$$

$$I_C = \frac{V_{CC}}{R_C}$$

This gives the second point on the collector current axis as shown in the figure above.
By adding the points A and B, the DC load line is drawn. With the help of load line, any value of collector current can be determined.

9) *What is fixed based circuit?* [2013]

Ans:
This form of biasing is also called base bias or fixed resistance biasing. In the example image on the right, the single power source (for example, a battery) is used for both collector and base of a transistor, although separate batteries can also be used.



In the given circuit,
$V_{cc} = I_b R_b + V_{be}$
Therefore,
$I_b = (V_{cc} - V_{be})/R_b$
For a given transistor, V_{be} does not vary significantly during use. As V_{cc} is of fixed value, on selection of R_b, the base current I_b is fixed. Therefore, this type is called *fixed bias* type of circuit.

10) *Draw the circuits of the various transistor configurations.* [2014,2015]

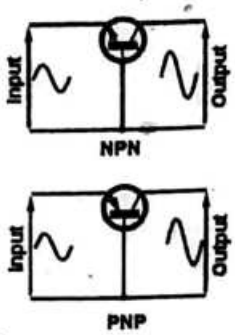
Answer:
Transistor configuration basics
The terminology used for denoting the three basic transistor configurations indicates the transistor terminal that is common to both input and output circuits. This gives rise to the three terms: common base, common collector and common emitter.

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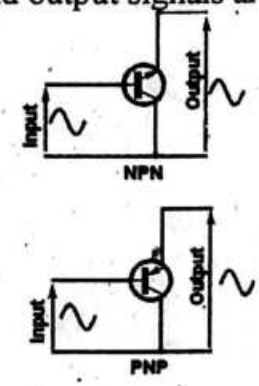
The term grounded, i.e. grounded base, grounded collector and grounded emitter may also be used on occasions because the common element signal is normally grounded.

The three different transistor configurations are:

- ***Common base:***
  This transistor configuration provides a low input impedance while offering a high output impedance. Although the voltage is high, the current gain is low and the overall power gain is also low when compared to the other transistor configurations available. The other salient feature of this configuration is that the input and output are in phase.

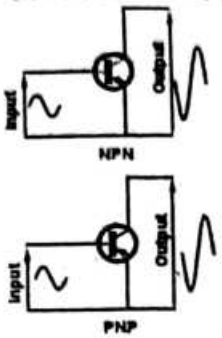


- **Common base transistor configuration**
  As can be seen from the diagram, in this transistor configuration, the base electrode is common to both input and output circuits.
- ***Common collector:*** This transistor configuration is also known as the emitter follower because the emitter voltage follows that of the base. Offering a high input impedance and a low output impedance it is widely used as a buffer. The voltage gain is unity, although current gain is high. The input and output signals are in phase.



- **Common collector transistor configuration**
  As can be seen from the diagram, in this transistor configuration, the collector electrode is common to both input and output circuits.
- ***Common emitter:*** This transistor configuration is probably the most widely used. The circuit provides a medium input and output impedance levels. Both current and voltage gain can be described as medium, but the output is the inverse of the input, i.e. 180° phase change. This provides a good overall performance and as such it is often thought of as the most widely used configuration.

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- **Common emitter transistor configuration**
  As can be seen from the diagram, in this transistor configuration, the emitter electrode is common to both input and output circuits.

11) Comparison of Transistor Configuration (2023)

Solution :

The following table shows the comparison of transistor configuration.

Characteristics	Common Emitter	Common Base	Common Collector
Current Gain	High	No	Considerable
Applications	Audio frequency	High frequency	Impedance matching
Input Resistance	Low	Low	Very high
Output Resistance	High	Very high	Low
Voltage Gain	Approx. 500	Approx. 150	Less than 1

12) List out the Advantages and Disadvantages of Transistors

Solution :

The lists the advantages and disadvantages of transistors.

Advantages

a. Low source voltage
b. High voltage gain
c. Smaller in size

Disadvantages

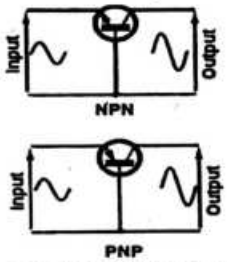
a. Temperature dependency
b. Lower power dissipation
c. Low input impedance

13) Why common emitter configuration is mostly used? Give its typical uses.[2014]

Ans:

The three different transistor configurations are:

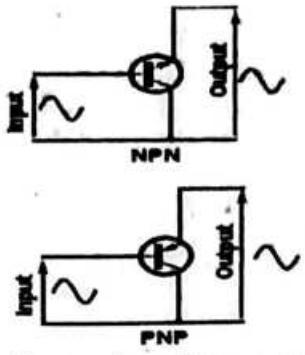
Common base:



Common base transistor configuration

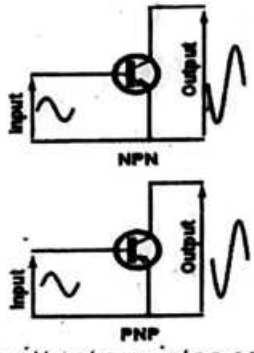
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Common collector:



Common collector transistor configuration

Common emitter:



Common emitter transistor configuration

The common emitter (CE) configuration is the most widely used transistor configuration.
The common emitter (CE) amplifiers are used when large current gain is needed.

The input signal is applied between the base and emitter terminals while the output signal is taken between the collector and emitter terminals. Thus, the emitter terminal of a transistor is common for both input and output and hence it is named as common emitter configuration.

14) What is transistor biasing? What are the basic conditions which are to be necessarily fulfilled for achieving faithful amplification of input signal in transistor amplifiers?

[2014]

Ans:

Transistor Biasing is the process of setting a transistors DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor.

The process of raising the strength of a weak signal without changing its shape is known as faithful amplification . For faithful amplification, a transistor must satisfy the following conditions :

Proper zero signal collector current.
Minimum proper base-emitter voltage (VBE) at any instant.
Minimum proper collector-emitter voltage (VCE) at any instant.

15) Describe the basic construction of BJT. *[2015]*

Ans:

Basic construction of BJT :

A Bipolar Junction Transistor (BJT) is a transistor whose operation depends on the contact made by two semiconductors. It can act as a switch, amplifier or oscillator. It is known as a bipolar transistor since its operation requires two types of charge carriers (holes and electrons). Holes

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constitute the dominant charge carriers in P-type semiconductors while electrons are the main charge bearers in N-type semiconductors.

Symbols of a BJT

There are two Types of BJT: npn and pnp. The npn Type consists of two n-Regions separated by a p-Region. The pnp Type consists of two p-Regions separated by an n-Region. Figures 2 and Figure 3 are their schematic symbols respectively. The following explanation focuses on the npn BJT.

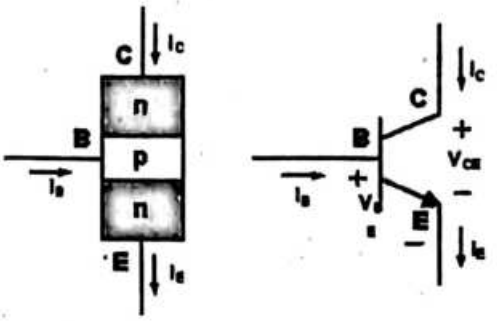
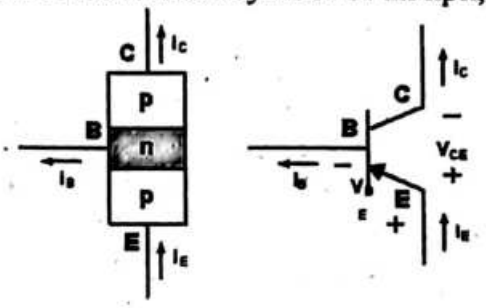


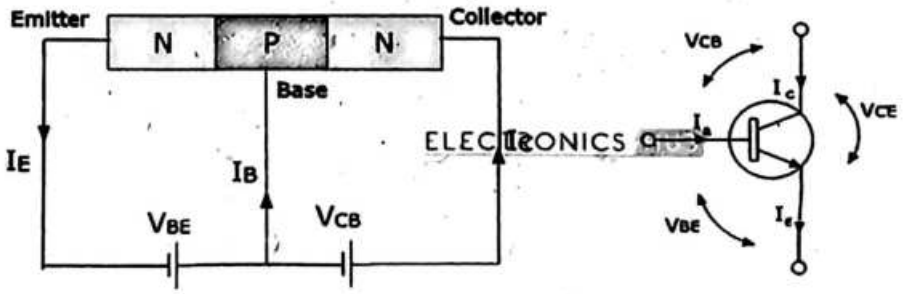
Figure 2: Schematic symbol of an npn, BJT



16) Discuss the working principle of n-p-n transistors. ***[2016]***

Ans:

NPN transistor is one of the Bipolar Junction Transistor (BJT) types. The NPN transistor consists of two n-type semiconductor materials and they are separated by a thin layer of p-type semiconductor. Here the majority charge carriers are the electrons. The flowing of these electrons from emitter to collector forms the current flow in the transistor. Generally the NPN transistor is the most used type of bipolar transistors because the mobility of electrons is higher than the mobility of holes. The NPN transistor has three terminals – emitter, base and collector. The NPN transistor is mostly used for amplifying and switching the signals.

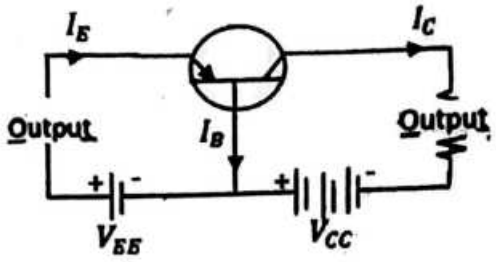


The above figure shows the symbol and structure of NPN transistor. In this structure we can observe the three terminals of transistor, circuit currents and voltage value representations. Now let us see the operation of the NPN transistor with explanation.

17) Explain the operation of a transistor as an amplifier. [2016, 2018, 2020, 2022, 2024]

Ans:

We can use a transistor as an amplifier by raising the strength of the weak signal. With the help of suitable diagram, we explain you how transistor circuit acts as an amplifier. The Figure given below shows the basic circuit of a transistor amplifier.



Transistor amplifier circuit

As shown in the figure above, we apply input signal or the weak signal between the emitter-base junctions and take the output across the load R_c connected in the collector circuit. For faithful amplification, always ensure that the input circuit is forward-biased and the output circuit is reverse-biased. For this purpose, we apply d.c voltage i.e. V_{EE} in the input circuit in addition to the signal as shown in the figure above. This d.c voltage is known as a bias voltage and its magnitude is such that it always keeps the input circuit forward biased despite the polarity of the signal.

As we know the input circuit has **low resistance**, consequently, a small change in the signal voltage occurs at the input circuit lead to an appreciable change in the emitter current. Due to transistor action, change in emitter current causes a similar change in the collector circuit. Now, the collector current flowing through a high load resistance R_c produces a large voltage across it. Thus,

the weak signal applied in the input circuit appears in the amplified form in the collector circuit. In this way, transistor acts an amplifier.

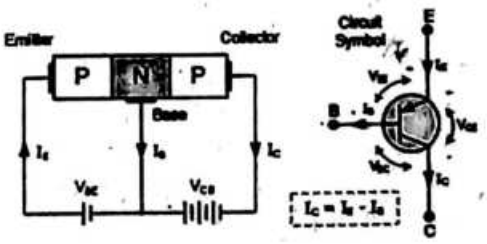
18) What is operation point?

The operating point of a device, also known as bias point, quiescent point, or Q-point, is the steady-state (DC) voltage or current at a specified terminal of an active device (a transistor or vacuum tube) with no input signal applied.

19) The working of p-n-p transistor.

Ans:

The main **working principle** of a **PNP transistor** is, when the current exists at the base of the **PNP transistor**, and then the **transistor** turns OFF. When there is no flow of current at the base of the **transistor**, then the **transistor** switches ON.



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20) Define load-line and Operating Point. [2022,2023]

load-line A load line is a line drawn on the characteristic curve, a graph of the current vs the voltage in a nonlinear device like a diode or transistor. It represents the constraint put on the voltage and current in the nonlinear device by the external circuit. The load line, usually a straight line, represents the response of the linear part of the circuit, connected to the nonlinear device in question. The points where the characteristic curve and the load line intersect are the possible operating point(s) (Q points) of the circuit; at these points the current and voltage parameters of both parts of the circuit match.

Operating Point An operating point, also known as a quiescent point or bias point, refers to the steady-state condition of a device or circuit under specific operating conditions. It represents the values of key parameters (such as voltage, current, or power) at which the device or circuit is intended to operate. The operating point is a crucial concept in electronics and is used to ensure that electronic components and circuits function within desired specifications.

21) What is Amplifying and switching actions of transistor?

Ans:

By turning a small input current into a large output current, the transistor acts like an amplifier. But it also acts like a switch at the same time. When there is no current to the base, little or no current flows between the collector and the emitter. Turn on the base current and a big current flows.

22) Define manufacturing techniques used in the construction of a transistor

Answer:

Following are some manufacturing techniques used in the construction of a transistor –

Diffusion Type

In this method, the wafer of semiconductor is subjected to some gaseous diffusion of both N type and P type impurities to form emitter and collector junctions. First, base-collector junction is determined and photo-etched just prior to base diffusion. Later, the emitter is diffused on the base. Transistors manufactured by this technique have better noise figure and improvement in current gain is also seen.

Grown Type

It is formed by drawing a single crystal from melted silicon or germanium. The required concentration of impurity is added during crystal drawing operation.

Epitaxial Type

A very high purity and thin single-crystal layer of silicon or germanium is grown on a heavily doped substrate of the same type. This improved version of the crystal forms the collector on which the emitter and base junctions are formed.

Alloy Type

In this method, the base section is made of a thin slice of N type material. At the opposite sides of the slice, two small dots of Indium are attached and the complete formation is kept to a high temperature for a shorter time. The temperature would be above melting temperature of Indium and below Germanium. This technique is also known as fused construction.

Electrochemically Etched Type

In this method, on the opposite sides of a semiconductor wafer, depression is etched in order to reduce the width of the base region. Then a suitable metal is electroplated into the depressions area to form emitter and collector junctions.

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23) Define Current Amplification Factor (α)

Solution :

The ratio of change in the collector current to the change in the emitter current at constant collector to base voltage V_{CB} is known as current amplification factor 'α'. It can be expressed as

$$\alpha = \Delta I_c / \Delta I_B$$

at Constant V_{CB}

It is clear that current amplification factor is less than unity and it is inversely proportional to the base current considered that the base is lightly doped and thin.

24) Define Base Current Amplification Factor (β)

Solution :

It is the ratio of change in collector current to the change in base current. A small variation in base current results in a very large change in collector current. Therefore, the transistor is able to attain current gain. It can be expressed as

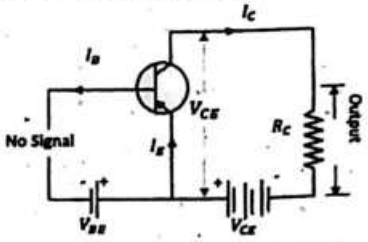
$$\beta = \frac{\Delta IC}{\Delta IB}$$

25) Define dc load line and q point of a transistor circuit[2021]

Solution :

DC Load Line

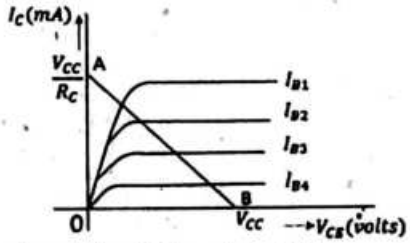
When the transistor is given the bias and no signal is applied at its input, the load line drawn under such conditions, can be understood as **DC** condition. Here there will be no amplification as the **signal is absent**. The circuit will be as shown below.



The value of collector emitter voltage at any given time will be

$$VCE=VCC-ICRCVCE=VCC-ICRC$$

As V_{CC} and R_C are fixed values, the above one is a first degree equation and hence will be a straight line on the output characteristics. This line is called as **D.C. Load line**. The figure below shows the DC load line.



To obtain the load line, the two end points of the straight line are to be determined.

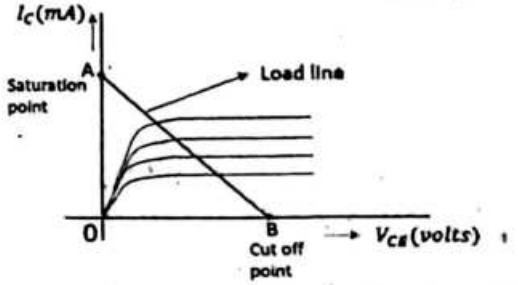
Q-point.

When a value for the maximum possible collector current is considered, that point will be present on the Y-axis, which is nothing but the **Saturation point**. As well, when a value for the maximum possible collector emitter voltage is considered, that point will be present on the X-axis, which is the **Cutoff point**.

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When a line is drawn joining these two points, such a line can be called as **Load line** This is called so as it symbolizes the output at the load. This line, when drawn over the output characteristic curve, makes contact at a point called as **Operating point** or **quiescent point** or simply **Q-point**.

The concept of load line can be understood from the following graph.



The load line is drawn by joining the saturation and cut off points. The region that lies between these two is the **linear region**. A transistor acts as a good amplifier in this linear region.

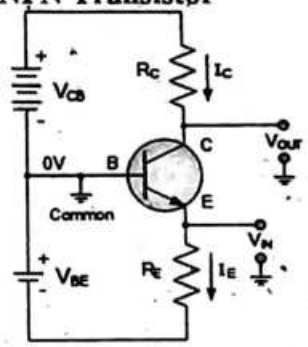
26) Draw a Common-base (CB) Transistor circuit and explain its operation. [2021]

The **Common Base Amplifier** is another type of bipolar junction transistor, (BJT) configuration where the base terminal of the transistor is a common terminal to both the input and output signals, hence its name *common base* (CB). The common base configuration is less common as an amplifier than compared to the more popular *common emitter*, (CE) or *common collector*, (CC) configurations but is still used due to its unique input/output characteristics.

For the common base configuration to operate as an amplifier, the input signal is applied to the emitter terminal and the output is taken from the collector terminal. Thus the emitter current is also the input current, and the collector current is also the output current, but as the transistor is a three layer, two pn-junction device, it must be correctly biased for it to work as a *common base amplifier*. That is the base-emitter junction is forward-biased.

Consider the basic common base amplifier configuration below.

Common Base Amplifier using an NPN Transistor



Then we can see from the basic common base configuration that the input variables relate to the emitter current I_E and the base-emitter voltage, V_{BE}, while the output variables relate to the collector current I_C and the collector-base voltage, V_{CB}.

Since the emitter current, I_E is also the input current, any changes to the input current will create a corresponding change in the collector current, I_C. For a common base amplifier configuration, current gain, A_i is given as i_{OUT}/i_{IN} which itself is determined by the formula I_C/I_E. The current gain for a CB configuration is called Alpha, (α).

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In a BJT amplifier the emitter current is always greater than the collector current as $I_E = I_B + I_C$, the current gain (α) of the amplifier must therefore be less than one (unity) as I_C is always less than I_E by the value of I_B. Thus the CB amplifier attenuates the current, with typical values of alpha ranging from between 0.980 to 0.995.

The electrical relationship between the three transistor currents can be shown to give the expressions for alpha, α and Beta, β as shown.

$$I_E = I_B + I_C$$

$$\text{Alpha}(\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta}(\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha \times I_E = \beta \times I_B$$

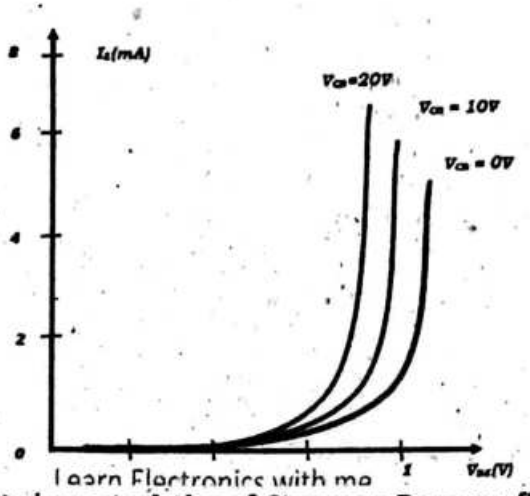
$$\text{thus: } \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

30)Draw and explain input and output characteristics of common base configure of BJT [2022]

Solution:

In common base configuration, the input impedance is low and the output impedance is high and the overall power gain is low when compared with other configuration.

Input characteristics:



Input characteristics of Common Base configuration

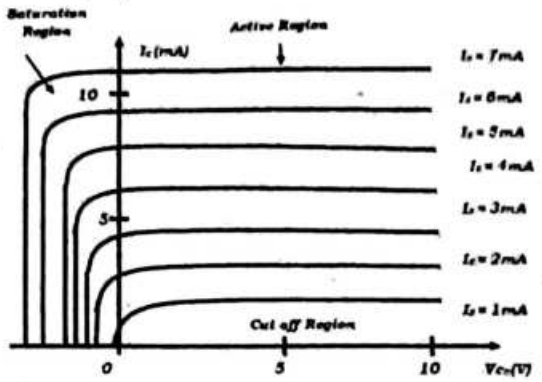
Input characteristics are the relationship between the input current and input voltage with constant output voltage. In common base configuration input current is emitter current IE and the input voltage is base emitter voltage VBE. The curve is plotted between IE and VBE keeping VCB as constant.

The VBE is increased keeping VCB constant, initially at zero and the input current IE is noted, similarly the VCB value is increased and kept constant and VBE is increased and the input current IE is noted.

Input side is forward biased so the input resistance is small so for a small increase in VBE there is rapid increase in the emitter current IE. As the output voltage VCB is increased the width of the depletion layer between emitter base decreases and the cut in voltage is reduced so the curve drifts to the left side.

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Output characteristics:



Output characteristics of common base configuration

Output characteristics are the relationship between output current IC and output voltage VCB keeping input current IE constant. When the input current IE is zero it is in cut off region. In saturation region both emitter base junction and collector base junction are forward biased.

In active region IE is gradually increased and kept constant and output voltage VCB is increased further and the output current IC almost remains constant. So in active region curve is almost flat. Output voltage causes only a very little change in output current.

Q1) Explain how transistor can be used as switch . [2023]

Answer :

Transistor as a switch: A **transistor** can be used as a **solid state switch**. If the transistor is operated in the **saturation** region then it acts as closed **switch** and when it is operated in the **cut off region** then it behaves as an open switch.

The transistor operates as a **Single Pole Single Throw (SPST)** solid state switch, When a zero input signal applied to the base of the transistor, it acts as an open switch. If a positive signal applied at the input terminal then it acts like a closed switch.

When the transistor operating as switch, in the cut off region the current through the transistor is zero and voltage across it is maximum, and in the saturation region the transistor current is maximum and voltage across is zero. Therefore, both the on – state and off – state power loss is zero in the transistor switch.

Circuit diagram of a transistor as a switch :

Cut off state (open switch): When transistor operates in the cut off region shows the following characteristics –

- The input is grounded i.e. at zero potential.
- The V_{BE} is less that cut – in voltage 0.7 V.
- Both emitter – base junction and collector – base junction are reverse biased.
- The transistor is fully – off acting as open switch.
- The collector current $I_C = 0A$ and output voltage $V_{out} = V_{CC}$.

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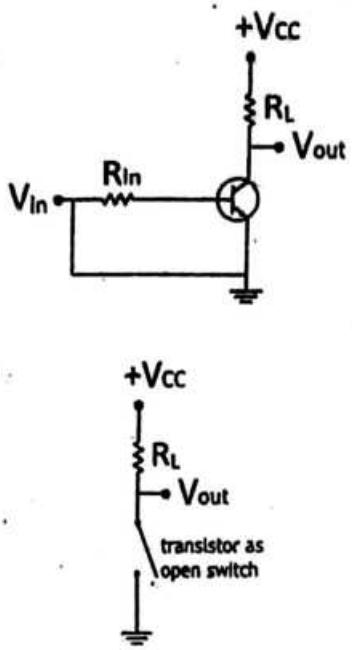


fig : transistor as open switch

Saturation State (Closed Switch): The transistor operating in the saturation region exhibits following characteristics –

- The input is connected to V_{CC}.
- Base – Emitter voltage is greater than cut – in voltage (0.7 V).
- Both the base – emitter junction and base – collector junction are forward biased.
- The transistor is fully – ON and operates as closed switch.
- The collector current is maximum
  $I_c = \frac{Vcc}{Rl}$ and $V_{out} = 0$ v .

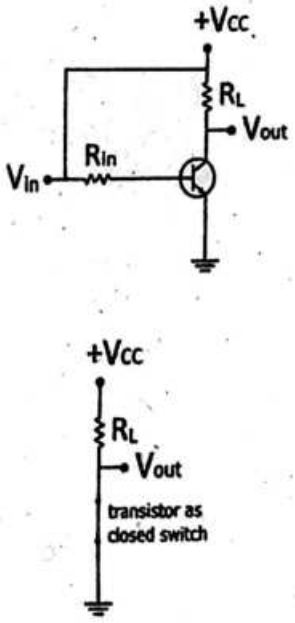


fig: Transistor as closed switch

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Chapter 7

Field Effect Transistors

1. *What is FET? [2018,2019,2020] Compare FET with BJT. [2010,2015,2020,2022]*

Solution :

A Field Effect Transistor (FET) is a three-terminal semiconductor device. Its operation is based on a controlled input voltage. By appearance JFET and bipolar transistors are very similar. However, BJT is a current controlled device and JFET is controlled by input voltage. Most commonly two types of FETs are available.

- Junction Field Effect Transistor (JFET)
- Metal Oxide Semiconductor FET (IGFET)

Different between FET and BJT:

FET	BJT
1. FET is an unipolar semiconductor device because its operation depends upon the flow of majority carriers *i.e.*, either holes or electrons as the case may be.	1. BJT is a bipolar semiconductor device because the current constituting elements are both majority carriers as well as minority carriers in this case.
2. The input impedance of FET is much more larger (ranging in Megaohms) than BJT. The reason behind this is that the input terminal *i.e.*, gate to source of FET is reverse biased and reverse bias offers ideally infinite resistance.	2. The input impedance of BJT is very less in comparison to FET.
3. FET is a voltage controlled device.	3. BJT is a current controlled device.
4. FET is less noisy. Because there are no junctions.	4. Much noisy than FET.
5. Higher frequency response.	5. Frequency variation affects the performance.
6. Good thermal stability because of absence of minority carriers.	6. Temperature dependent, thermal runaway may cause.
7. Costlier than BJT.	7. Relatively cheaper.
8. Small sized.	8. Comparatively bigger.
9. In FET, relationship between input and output quantities is nonlinear due to square term in shockley's equations $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$	9. The BJT is an almost linear device or we can say that BJT works linearly in active region as an amplifier.
10. No offset voltage; so it works better as a switch or chopper.	10. There is always an offset voltage before switching.
11. Small gain bandwith product.	11. Greater than FET.

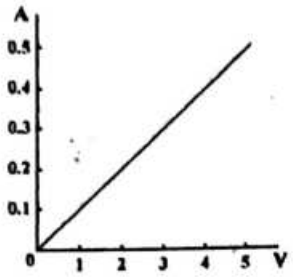
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2. *Draw the transfer characteristic curve of a BJT and explain. [2010]*

Ans:

a BJT characteristic is a graph that shows us how the current in a transistor changes when we change the voltage.

So, a general characteristic would look something like this:

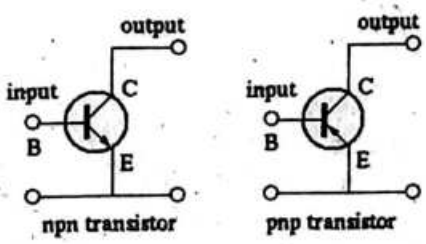


Here, we see how the current in a device changes when we change the voltage across the device. At 0 volts, the current is 0 amp. At 1 volt, the current is 0.1 amp, and so on.

The next term we need to talk about is "transfer."

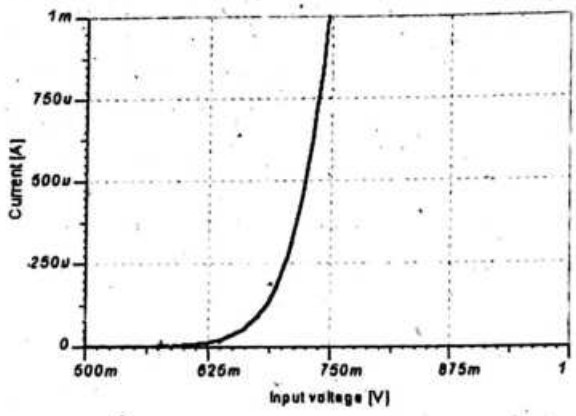
For basic devices such as resistors, inductors, and capacitors, they have only two terminals. So, there is only one voltage-current relationship. We apply voltage across the two terminals of the device, and we observe the current through the device.

Out BJT is a three terminal device. So we can have two voltage-current pairs as follows:



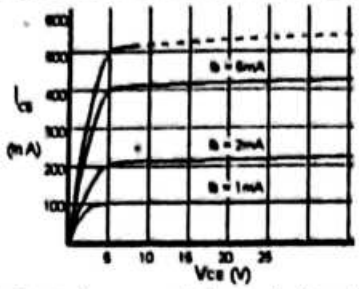
On the left we the input terminals, so we can have an input voltage and an input current. Similarly on the right we have output terminals, so we have an output voltage and an output current.

If we draw a graph that shows us the relationship between the input voltage and the input current, we call this the "input characteristic," like the one you see below.



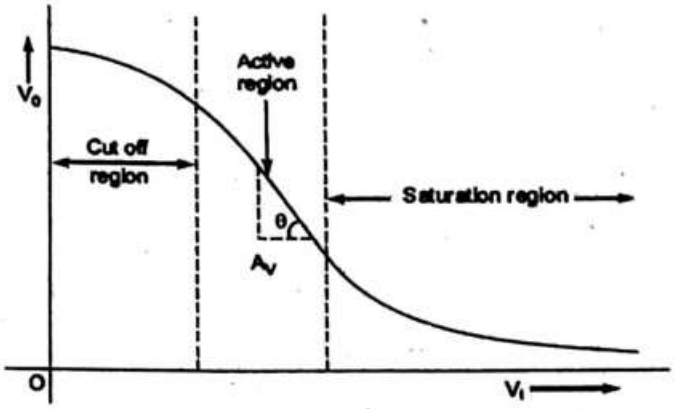
If we draw a graph of the output current against the output voltage, this would become the "output characteristic," like the graph below.

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A transfer characteristic is a graph that shows us the relationship between two quantities, one on the input side, and one on the output side. For example, one transfer characteristic would be output current versus input voltage. Or, we could also plot the output voltage as a function of the input voltage.

So, a BJT transfer characteristic would look like this:



So, in summary, a characteristic is a plot showing us how one electrical quantity changes with respect to another. And, a transfer characteristic is a plot that shows us how an output quantity changes with respect to an input quantity.

3. ***What are the differences between the depletion and enhancement MOSFET?*** ***[2010,2015,2020,2022]***

Ans:

D-MOSFET	E-MOSFET
It is called as Depletion MOSFET, because of depletion of channel.	It works only in Enhancement mode, hence called as EnhancementMOSFET
n-type semiconductor exists between source and drain in construction itself	n-channel doesn't exist between sources and drain
When Vgs = 0V, Ids flows due to Vds	When Vgs = 0V, Ids = 0 though Vds is applied
It can be used as E-MOSFET	It can not be used as a D-MOSFET.
Does not occur	At Vgs = Vt, MOSFET becomes ON.

4. ***Draw and explain JFET characteristic curve with external bias. [2011,2015]***

Ans:

Drain Characteristics With External Bias

The circuit diagram for determining the drain characteristics with different values of external bias is shown in Fig.2(i). and a family of drain characteristics for different values of gate-source voltage V_{GS} is shown in Fig.2(ii).

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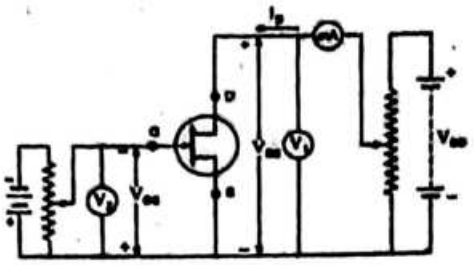


Fig.2 (i)

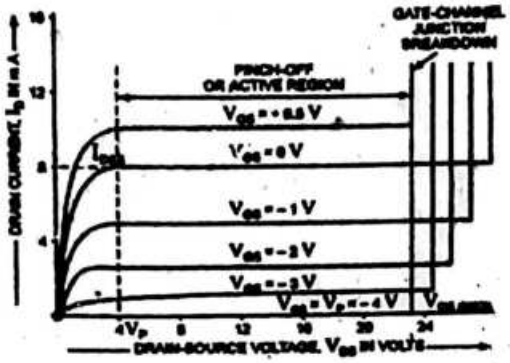


Fig.2 (ii)

It is observed that as the negative gate bias voltage V_{GS} is increased;

(1) The maximum saturation drain current becomes smaller because the conducting channel now becomes narrower.

(2) Pinch-off voltage is reached at a lower value of drain current I_D than when $V_{GS} = 0$.

When an external bias of, say – 1 V is applied between the gate and the source, the gate-channel junctions are reverse-biased even when drain current, I_D is zero. Hence the depletion regions are already penetrating the channel to a certain extent when drain-source voltage, V_{DS} is zero.

Due to this reason, a smaller voltage drop along the channel (i.e. smaller than that for $V_{GS} = 0$) will increase the depletion regions to the point where they pinch-off the current. Consequently, the pinch-off voltage V_P is reached at a lower drain current, I_D.

(3) Value of drain-source voltage V_{DS} for the avalanche breakdown of the gate junction is reduced.

It is simply due to the fact that gate-source voltage, V_{GS} keeps adding to the reverse bias at the junction produced by current flow.

5. *Describe how DEMOSFET can work in both enhancement and depletion mode. [2011]*

Ans:

De-Mosfet amplifier

DE-MOSFETcan be operated either with positive or negative gate, so its operating or quiescent point can be set at VGS= 0, as illustrated in figure. In figure the gate G is at ground potential for dc since ac signal source appears to be short-circuited for dc and sets Q-point at VGS= 0. The ac input signal causes the gate-source voltage V to vary above and below zero developing drain current Idand drain voltage Vout. The biasing circuit given in figure, has V = 0, Id= IDDSand dc drain voltage VDS= VDD– IDSSRD

The zero bias of figure is unique with depletion-mode MOSFETs. Although any of the JFET biasing method will work with a depletion-modeMOSFET, the zero-bias method shown in figure is preferred as it does the job simply and adequately.

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After biasing the depletion-mode MOSFET to a Q-point, it can amplify small signals. The JFET formulas for voltage gain can be applied directly to a MOSFET amplifier. But like the JFET, the depletion-mode MOSFET has a relatively low voltage gain. MOSFETs have excellent low-noise properties, a definite advantage for any stage near the front end of a system where the signal is weak, such as a TV receiver. As with a JFET, the transconductancegmin case of MOSFET can be controlled by varying the gate-source voltage.

N-CHANNEL DE-MOSFET

Figure shows the construction of an N- Channel Depletion MOSFET. It consists of a highly doped P-type substrate into which two blocks of heavily doped N-type material are diffused forming the Source and Drain. An N-channel is formed by diffusion between the source and Drain.

The type of impurity for the channel is same as for the source and drain. Now a thin layer of SiO2 dielectric is grown over the entire surface and holes are cut through the SiO2 layer to make contact with the N-type blocks. metal is deposited through the holes to provide drain and source terminals, and on the surface area between drain and source, a metal plate is deposited.

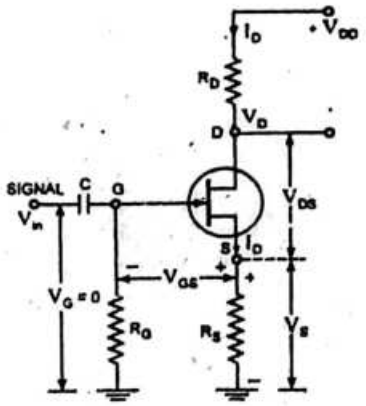
This layer constitutes the Gate. SiO2 layer results an high Impedence about 10^10 to 10^15 ohms.

A P-channel DE-MOSFET is constructed just like an N-CHANNEL, starting with an N-type substrate and diffusing P-type drain and source blocks and connecting them internally by a P-dopped channel region.

6. *Sketch the FET Self bias and Fixed bids circuit.* ***[2011]***

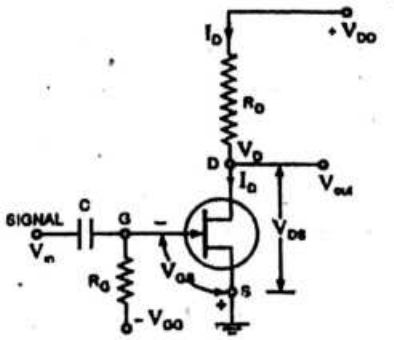
Ans:

FET Self bias:



Self-Bias Circuit For N-Channel JFET

Fixed bias circuit:



Fixed Biasing Circuit For JFET

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7. *Write the advantage of FET. [2011,2014]*

Ans:

The advantage of FET over BJT:

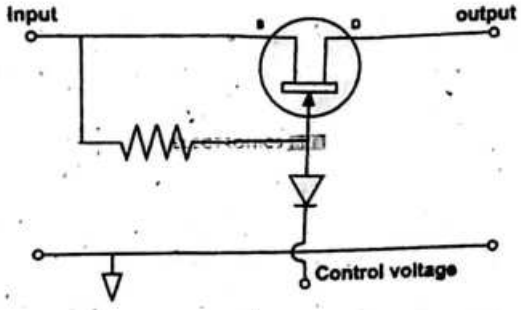
1. FET gas high input impedance of several mega ohms.
2. The noise produced by a FET is less than that produced by a BJT.
3. FETs are less effect by radiation compared to BJT.
4. FET has no offset voltage at zero drain current and hence it forms an excellent signal chopper.
5. FETs are voltage controlled devices.
6. FETs have better thermal stability.
7. In the integrated circuit form FET is simpler to fabricate and it occupies less – space.

8. *Show how FET can be used as a switch with appropriate diagram.[2011,2015,2019]*

Ans:

FET Used as a Series Switch:

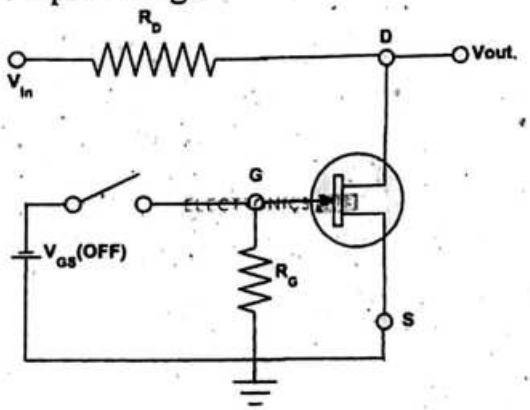
Below figure shows another configuration of FET switch circuit. In this circuit FET acts as a series switch. It acts as a closed switch if the control voltage is zero and open switch if control voltage is negative. When the FET is ON, the input signal will appear at the output and when it is OFF the output is zero.



FET Used as a Shunt Switch

Let us look at the below figure where FET is connected in parallel with the load and it acts like an analog switch.

- When the VGS applied is zero the FET is turned ON by operating in saturation region and its resistance is very small nearly 100 ohms. The output voltage across the across the FET is $V_{OUT} = V_{in} * \{R_{DS} / (R_D + R_{DS\,(ON)})\}$. Since the resistance R_D is very large, the output voltage is approximately considered as zero.
- When we apply the negative voltage which is equal to the pinch off voltage at the gate, FET operates in the cutoff region and acts as a high resistance device and the output voltage is equal to the input voltage.



9. *Why the input impedance in FET is very high in comparison with BJT? [2014]*

Ans:

JFET is exclusively voltage-controlled in that they do no need biasing current. It is three terminal semiconductor device which is used as electronically controlled switch. Electric charge flows through a semiconducting channel between *source* and *drain* terminals. By applying a reverse bias voltage to a gate terminal, the channel is "pinched", so that the electric current is impeded or switched off completely. A JFET is usually on when there is no potential difference between its gate and source terminals. If a potential difference of the proper polarity is applied between its gate and source terminals, the JFET will be more resistive to current flow, which means less current would flow in the channel between the source and drain terminals. Therefore, JFETs are sometimes referred to as depletion-mode devices.

JFETs can have an n-type or p-type channel. In the n-type, if the voltage applied to the gate is less than that applied to the source, the current will be reduced (similarly in the p-type, if the voltage applied to the gate is *greater* than that applied to the source).

"A JFET has a large input impedance (sometimes on the order of 1010 ohms), which means that it has a negligible effect on external components or circuits connected to its gate."

10. *Explain pinch of voltage and Idss of JFET with diagram. [2014,2020]*

Ans:

Pinch of Voltage: Pinch off voltage is the drain to source voltage after which the drain to source current becomes almost constant and JFET enters into saturation region and is defined only when gate to source voltage is zero.

IDSS of JFET: IDSS (referred to as the drain current for zero bias) is the maximum current that flows through a FET transistor, which is when the gate voltage, VG, supplied to the FET is 0V.When the gate voltage decreases for N-Channel FETs, or increases for P-Channel FETs, the drain current ID

becomes smaller and smaller, until after a certain threshold, the transistor shuts off.

The current, IDSS is important because it's the maximum current that a FET can reach without entering the restricted breakdown region. It is the maximum current in the tolerance range of drain-source voltages, VDS, that can be achieved.

IDSS is referred to as the drain current for zero bias, because the gate-source voltage requires no bias voltage to operate. The gate-source voltage is just zero. No voltage needs to be applied to it.

11. Describe the basic construction and operation of JFET with appropriate diagram.

[2023,2015,2020,2022]

Ans:

Junction Field Effect Transistor (JEFT)

A field effect transistor is a voltage controlled device i.e. the output characteristics of the device are controlled by input voltage. There are two basic types of field effect transistors:

1. Junction field effect transistor (JFET)
2. Metal oxide semiconductor field effect transistor (MOSFET)

Junction Field Effect Transistor (JFET)

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

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The current conduction is controlled by means of an electric field between the gate and the conducting channel of the device.
The JFET has high input impedance and low noise level.

Construction Details:

A JFET consists of a p-type or n-type silicon bar containing two pn junctions at the sides as shown in fig.1.

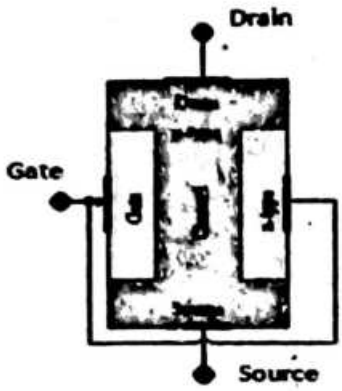


Fig.1(i)

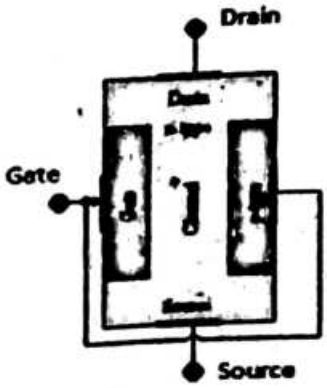


Fig.1 (ii)

The bar forms the conducting channel for the charge carriers.
If the bar is of p-type, it is called p-channel JFET as shown in fig.1(i) and if the bar is of n-type, it is called n-channel JFET as shown in fig.1(ii).
The two pn junctions forming diodes are connected internally and a common terminal called gate is taken out.
Other terminals are source and drain taken out from the bar as shown in fig.1.
Thus a JFET has three terminals such as , gate (G), source (S) and drain (D).

Operation of JEFT

The working of JFET can be explained as follows:

Case-i:

When a voltage V_{DS} is applied between drain and source terminals and voltage on the gate is zero as shown in fig.3(i), the two pn junctions at the sides of the bar establish depletion layers.

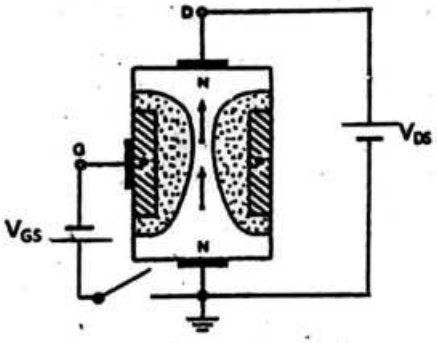


Fig.3 (i)

The electrons will flow from source to drain through a channel between the depletion layers.
The size of the depletion layers determines the width of the channel and hence current conduction through the bar.

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Case-ii:

When a reverse voltage V_{GS} is applied between gate and source terminals, as shown in fig 3(ii). the width of depletion layer is increased.

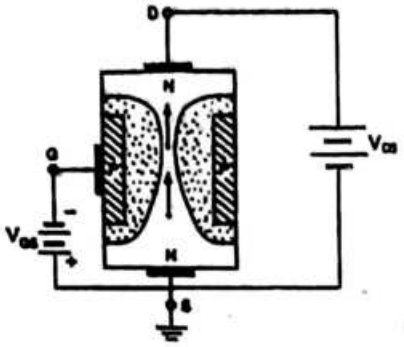


Fig.3 (ii)

This reduces the width of conducting channel, thereby increasing the resistance of n-type bar. Consequently, the current from source to drain is decreased.

On the other hand, when the reverse bias on the gate is decreased, the width of the depletion layer also decreases.

This increases the width of the conducting channel and hence source to drain current.

A p-channel JFET operates in the same manner as an n-channel JFET except that channel current carriers will be the holes instead of electrons and polarities of V_{GS} and V_{DS} are reversed.

12. *What is pinch off voltage? [2023]*

Answer:

Pinch off Voltage

As we continue to increase the reverse bias of gate terminal the depletion layer widens and a point is reached where entire channel is filled with depletion layer and drain current will be reduced to zero except for small reverse saturation currents order of nano amperes. The gate to source voltage at which at which the entire channel will be depleted of charge carrier is called **pinch-off voltage.**

13. *Classification of FET.*

Ans:

FETs can be classified into;

1. JFET (Junction Field Effect Transistor) and
2. MOSFET (Metal Oxide Semiconductor FET).

JFET is subdivided into N-Channel (Made up of N-Type Material) and P-Channel (Made up of P-Type Material). MOSFET is subdivided into Depletion Type MOSFET and Enhancement Type MOSFET.

14. *What is JEFT?[2021]*

Ans:

A JFET, or junction field-effect transistor, or JUGFET, is a FET in which the gate is created by reverse-biased junction (as opposed to the MOSFET which creates a junction via a field generated by conductive gate, separated from the gate region by a thin insulator).

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15. *What is MOSFET?[2019,2020]*

Solution :

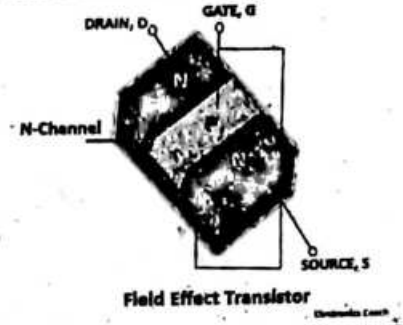
Metal-oxide semiconductor field-effect transistors, also known as MOSFETs, have greater importance and are a new addition to the FET family.

It has a lightly doped P type substrate into which two highly doped N type zones are diffused. A unique feature of this device is its gate construction. Here, the gate is completely insulated from the channel. When voltage is applied to the gate, it will develop an electrostatic charge.

At this point of time, no current is allowed to flow in the gate region of the device. Also, the gate is an area of the device, which is coated with metal. Generally, silicon dioxide is used as an insulating material between the gate and the channel. Due to this reason, it is also known as **insulated gate FET**. There are two MOSFETS widely used i) Depletion MOSFET ii) Enhancement MOSFET.

16. *Define construction of FET.*

The semiconductor is the basis of all FETs. Depending on the channel we are using, i.e. N-channel or P-channel, the semiconductor specimen will be used. If we are designing N-channel JFETs, then the channel will be of an N-type semiconductor. And in the middle of the opposite phases of the specimen will be diffused with the P-type semiconductor.



Field Effect Transistor

The P-type semiconductor bar will act as a gate terminal. The opposite ends of the P-type semiconductor will be connected together to form a common gate terminal. Thus, there will be two P-N junctions on either side of the gate, and that will be termed as source and drain terminal.

Components of FETs

1. **Channel:** This is the area in which majority charge carriers flow. When the majority charge carriers are entered in FET, then with the help of this channel only they flow from source to drain.
2. **Source:** Source is the terminal through which the majority charge carriers are introduced in the FET.
3. **Drain:** Drain is the collecting terminal in which the majority charge carriers enter and thus contribute in the conduction procedure.
4. **Gate:** Gate terminal is formed by diffusion of a type of semiconductor with another type of semiconductor. It basically creates high impurity region which controls the flow of carrier from source to drain.

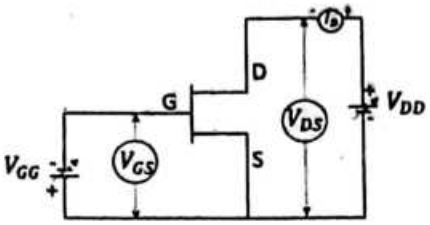
17. *Write down the characteristics of JEFT and its operation.*

Answer:

Drain Characteristics of JFET

Let us try to summarize the function of FET through which we can obtain the characteristic curve for drain of FET. The circuit of FET to obtain these characteristics is given below.

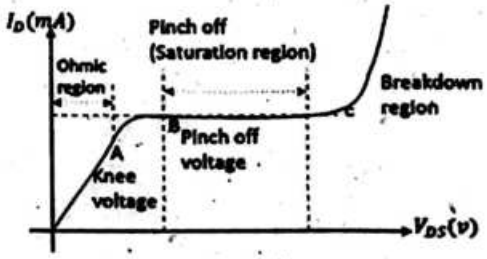
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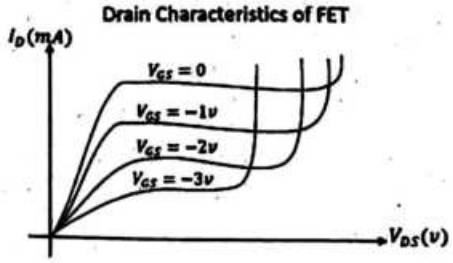
When the voltage between gate and source V_{GS} is zero, or they are shorted, the current I_D from source to drain is also nil as there is no V_{DS} applied. As the voltage between drain and source V_{DS} is increased, the current flow $I_D$from source to drain increases. This increase in current is linear up to a certain point A, known as **Knee Voltage**.

The gate terminals will be under reverse biased condition and as I_D increases, the depletion regions tend to constrict. This constriction is unequal in length making these regions come closer at drain and farther at drain, which leads to **pinch off** voltage. The pinch off voltage is defined as the minimum drain to source voltage where the drain current approaches a constant value (saturation value). The point at which this pinch off voltage occurs is called as **Pinch off point**, denoted as **B**.

As V_{DS} is further increased, the channel resistance also increases in such a way that I_D practically remains constant. The region **BC** is known as **saturation region** or amplifier region. All these along with the points A, B and C are plotted in the graph below.



The drain characteristics are plotted for drain current I_D against drain source voltage V_{DS} for different values of gate source voltage VGS. The overall drain characteristics for such various input voltages is as given under.



As the negative gate voltage controls the drain current, FET is called as a Voltage controlled device. The drain characteristics indicate the performance of a FET. The drain characteristics plotted above are used to obtain the values of Drain resistance, Tran conductance and Amplification Factor.

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18. *Write down the characteristics of MOSFET and its operation.*

Ans:

In general, any MOSFET is seen to exhibit three operating regions viz.,

1. Cut-Off Region
   Cut-off region is a region in which the MOSFET will be OFF as there will be no current flow through it. In this region, MOSFET behaves like an open switch and is thus used when they are required to function as electronic switches.
2. Ohmic or Linear Region
   Ohmic or linear region is a region where in the current I_{DS} increases with an increase in the value of V_{DS}. When MOSFETs are made to operate in this region, they can be used as amplifiers.
3. Saturation Region
   In saturation region, the MOSFETs have their I_{DS} constant inspite of an increase in V_{DS} and occurs once V_{DS} exceeds the value of pinch-off voltage V_P. Under this condition, the device will act like a closed switch through which a saturated value of I_{DS} flows. As a result, this operating region is chosen whenever MOSFETs are required to perform switching operations.

19. *Advantage of FET. How can be used it as a switch?*

Ans:

Advantages of FET

- High input resistance
- Low noise figure
- High efficiency as compare to BJT.
- Operating frequency ranger is higher compare to conventional BJT transistor.

It is an analog switch. The **FET** has high gate-to-main current resistance, on the order of 100 MΩ or more, providing a high degree of isolation between control and flow.



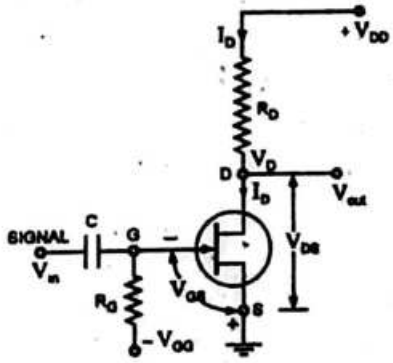
FET Symbols

20. *Sketch the FET self-bias and fixed bias circuit.*

Ans:

Various FET biasing circuits in given below:

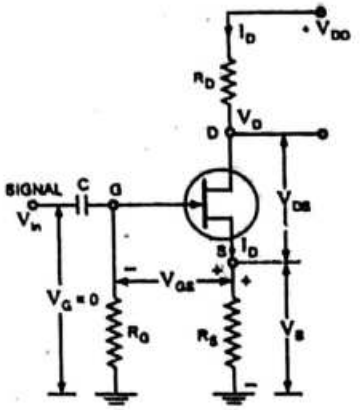
The **FET** has high input impedance and there are no gate current flows. The dc voltage of gate is set by **voltage divider** is not affected by **FET**. The **fixed bias** is given by using a battery. This battery ensures the gate is negative with respect to source



Fixed Biasing Circuit For JFET

Self-biasing circuits: **Self-bias circuit** for N-channel **JFET** is shown in figure. So voltage drop across resistance R_s provides the **biasing** voltage V_{Gs} and no external source is required

for **biasing** and this is the reason that it is called **self-biasing**. Thus dc conditions of **JFET** amplifier are fully specified.

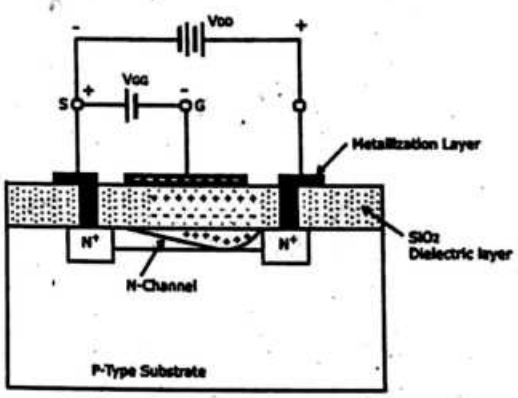


Self-Bias Circuit For N-Channel JFET

21. *Describe how DEMOSFET can work in both enhancement and depletion mode.(2017)*

Answer:

Operation of DEMOSFET.



Depletion Mode Operation

DEMOSFET-Operation

DE-MOSFET can be operated with either a positive or a negative gate. When gate is positive with respect to the source it operates in the enhancement—or E-mode and when the gate is negative with respect to the source, as illustrated in figure, it operates in depletion-mode.

When the drain is made positive with respect to source, a drain current will flow, even with zero gate potential and the MOSFET is said to be operating in E-mode. In this mode of operation gate attracts the negative charge carriers from the P-substrate to the N-channel and thus reduces the channel resistance and increases the drain-current. The more positive the gate is made, the more drain current flows.

On the other hand when the gate is made negative with respect to the substrate, the gate repels some of the negative charge carriers out of the N-channel. This creates a depletion region in the channel, as illustrated in figure, and, therefore, increases the channel resistance and reduces the drain current. The more negative the gate, the less the drain current. In this mode of operation the device is referred to as a *depletion-mode MOSFET*. Here too much negative gate voltage can pinch-off the channel. Thus operation is similar to that of JFET.

CSE Exam Notes

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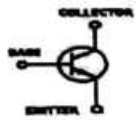
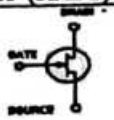
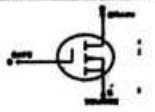
22. Distinguish between BJT and JFET. (2015)

Answer:

JFET	BJT
It is an unipolar device	It is a bipolar device
Voltage driven device	Current driven device
High input impedance	Low input impedance
Low noise level	High noise level
Better thermal stability	Less thermal stability
Gain is characterized by transconductance	Gain is characterized by voltage gain

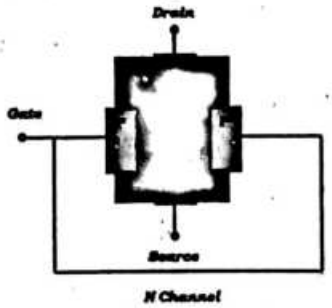
23. Compare BJT , FET and MOSFET (2014)

Answer:

Parameters	Bipolar Junction Transistor (BJT)	Junction Field Effect Transistor (JFET)	Metal Oxide Semiconductor Field Effect Transistor (MOSFET)
Symbol			
Definition	BJT is known as Biploar Junction Device because it uses both electrons and holes for conduction.	JFET is known as unipolar device because current is due to one charge carriers i.e. electrons or holes.	MOSFET is known as unipolar device because current is due to one charge carriers depending on type of MOS.
Input Resistance	BJT offers low input resistance.	JFET offers large input resistance order of 1MΩ1MΩ to 5MΩ5MΩ.	MOSFET offers very large input resistance.
Biasing used	Fixed bias, Collector base bias, Voltage divider biasing.	Self bias& Voltage divider biasing.	In DMOSFET we use self bias and voltage divider biasing, in EMOSFET we use feedback bias and voltage divider biasing.
Operating Region	Active, Saturation & Cut off region.	Ohmic& Pinch off region	Linear & Saturation region
Thermal Runaway	Thermal runaway occurs at high temperature.	No thermal runaway.	No thermal runaway.
Type of device	Current controlled device.	Voltage controlled device.	Voltage controlled device
Terminals	Base, Emitter & Collector.	Gate, Drain & Source.	Gate, Drain, Source .
Input current	Input current is order of mA (milli ampere).	Gate current is order of nA (nano ampere).	Gate current is order of pA (pico ampere).
Applications	Low Current application.	Low voltage application.	Since power consumption is less used in CMOS circuits

[redacted]

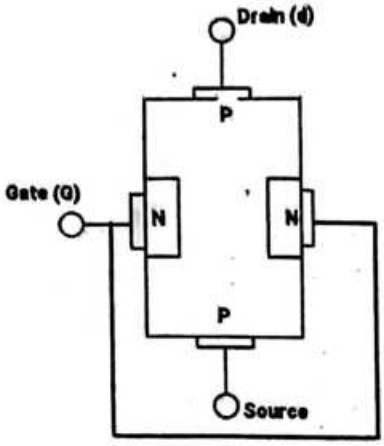
Answer:



Construction of N channel

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In N Channel JFET in the N type substrate drain and source terminals are taken by creating ohmic contacts and P type material is used at the either side of the channel and the gate terminals are taken from the P type materials.
The drain and source terminal is taken from the both the sides of the channel. A small voltage at the Gate terminal controls the current flow between source and drain.



P channel JFET

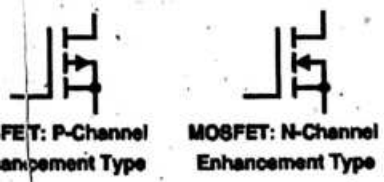
P-Channel Junction Field Effect Transistor

The p-channel junction field effect transistor is a semiconductor device that has three terminals: gate, source, and drain. It is made up of a semiconductor p-type thin bar material, the majority of carriers are holes in the p type. This forms a channel between source and drain.

When a positive voltage is applied to the gate terminal, it creates an electric field across the insulating material between the gate and the channel. Whenever a positive voltage in the gate increases, the electric field also increases, narrowing the channel and decreasing the current flow between the source and drain. In applications such as amplifiers, switches, and signal processing, the high input of this p channel impedance JFET can be used to control the flow of holes.

Describe the basic construction and operation of enhancement MOSFET.

Answer: MOSFETs are usually classified into two types. They are Enhancement and the Depletion MOSFETs. The MOSFET that is basically in OFF condition which requires a certain amount of voltage at the terminal gate to turn ON is referred to as Enhancement MOSFET.
Due to the application of gate voltage the channel among the terminal of drain and source gets less resistive. If the applied voltage at the gate increases then the current flow from the terminals drain to the source increases until and unless it reaches its maximum point. The behavior of this type of MOSFET resembles the behavior of bipolar junction transistor (BJT).
The Schematic symbol of Enhancement MOSFETs of both p-channel and n-channel MOSFETs are:



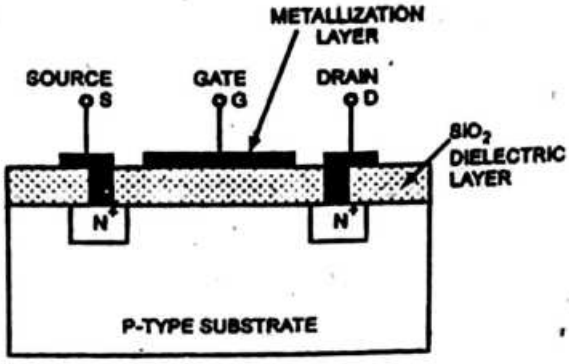
Enhancement MOSFET Symbol

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Construction

The steps involved in the **construction of Enhancement MOSFET** are:

- Two N regions separated by a distance of 25 micrometers with heavy doping concentration are diffused on a lightly doped substrate of p-type. Those N-regions are enacted as the terminals drain and source.
- Over the surface, a thin layer of insulation called silicon dioxide is developed. The holes made on this layer establishes aluminum contacts for the terminal's source and the drain.
- This layer of conduction acts as the terminal gate. It is laid over the silicon dioxide and on the entire area of the channel.
- But it doesn't have any physical channel for conduction.
- The p-type substrate extended over the entire silicon dioxide layer in this type of enhancement MOSFET.



Enhancement MOSFET Diagram

Operation of an Enhancement MOSFET

The operation of the Enhancement MOSFET are

- To induce the channel positive polarity of the Gate to Source voltage is required. A large amount of voltage must be applied at the terminal gate for this operation.
- If the voltage applied at the terminals gate to the source is zero, Enhancement MOSFET doesn't conduct. This can be the reason it is initially in the OFF condition.
- When the applied amount voltage at the terminal gate exceeds the limit of the threshold the current at the drain tends to flow through the circuit.

Let us consider a situation when the positive amount of the voltage applied at the Drain- Source by keeping the gate voltage as zero.

- In this situation, the p-type of the substrate and the two N-regions behave like the two junctions of PN.
- This makes both the junctions reverse bias and the leakage current tends to flow through the circuit.
- Now if the voltage applied at the gate is made positive. The minority carriers present in the substrate of p-type (that is electrons) get attracted to the positive potential of the terminal gate.
- These negative charge carriers get accommodated below the terminal of the gate. Further increment in the VGS will deposit more amount of carriers called electrons.
- The use of dielectric prevents the movement of these electrons across the layer of silicon dioxide.
- This accumulation results in the formation of the n-channel amid Drain-Source.

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- This leads to the generated drain current flow through the channel.
- This drain current is proportional to the resistance of the channel which is further dependent upon the carriers attracted towards the positive terminal of the gate.

Hence from the above points, it can be concluded that the channel conduction is enhanced based on the positive potential of the gate terminal.

Q7) Explain the working principle of enhancement type MOSFET (N-channel) (2024)

Answer:

Working principle of N-channel enhancement mode MOSFET

(1) The control effect of vGS on ID and channel

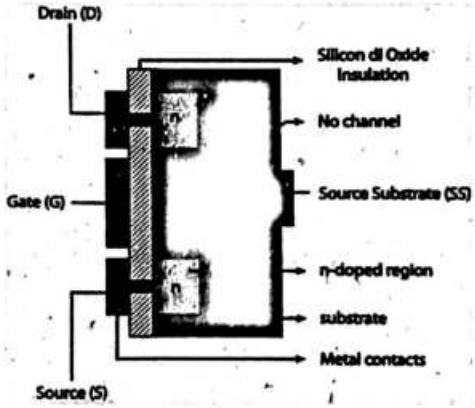
① Case of vGS=0

It can be seen that there are two back-to-back PN junctions between the drain d and source s of the enhancement-mode MOSFET.

When the gate-source voltage vGS=0, even if the drain-source voltage vDS is added, and regardless of the polarity of vDS, there is always a PN junction in the reverse biased state. There is no conductive channel between the drain and the source, so the drain current ID≈0 at this time.

② The case of vGS>0

If vGS>0, an electric field is generated in the SiO2 insulating layer between the gate and the substrate. The direction of the electric field is perpendicular to the electric field directed from the gate to the substrate on the semiconductor surface. This electric field repels holes and attracts electrons. Repelling holes: The holes in the P-type substrate near the gate are repelled, leaving immovable acceptor ions (negative ions) to form a depletion layer. Attract electrons: The electrons (minority carriers) in the P-type substrate are attracted to the substrate surface.

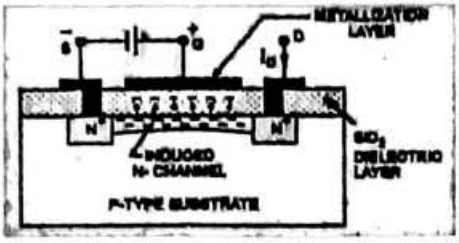


(2) Formation of conductive channel:

When the vGS value is small and the ability to attract electrons is not strong, there is still no conductive channel between the drain and the source. As vGS increases, more electrons are attracted to the surface layer of the P substrate. When vGS reaches a certain value, these electrons form an N-type thin layer on the surface of the P substrate near the gate and are connected to the two N+ regions, forming an N-type conductive channel between the drain and source. Its conductivity type is opposite to that of the P substrate, so it is also called an inversion layer. The larger vGS is, the stronger the electric field acting on the semiconductor surface is, the more electrons are attracted to the surface of the P substrate, the thicker the conductive channel is, and

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the smaller the channel resistance is. The gate-source voltage when the channel begins to form is called the turn-on voltage, represented by VT.



The N-channel MOSFET discussed above cannot form a conductive channel when vGS< VT, and the tube is in a cut-off state. Only when vGS≥VT can a channel be formed. This kind of MOSFET that must form a conductive channel when vGS≥VT is called an enhancement-mode MOSFET. After the channel is formed, a drain current is generated when a forward voltage vDS is applied between the drain and source. The influence of vDS on ID, when vGS>VT and is a certain value, the influence of drain-source voltage vDS on the conductive channel and current ID is similar to that of junction field effect transistor. The voltage drop generated by the drain current ID along the channel makes the voltages between each point in the channel and the gate no longer equal. The voltage at the end close to the sourc is the largest, where the channel is thickest. The voltage at the drain end is the smallest, and its value is VGD=vGS-vDS, so the channel is the thinnest here. But when vDS is small (vDS<vGS-VT), it has little effect on the channel. At this time, as long as vGS is constant, the channel resistance is almost constant, so ID changes approximately linearly with vDS. As vDS increases, the channel near the drain becomes thinner and thinner. When vDS increases to VGD=vGS-vDS=VT (or vDS=vGS-VT), the channel appears pre-pinched at the drain end. . As vDS continues to increase, the pinch-off point will move toward the source. Since the increase in vDS almost all falls in the pinch-off zone, the ID almost does not increase with the increase in vDS. The tube enters the saturation zone, and the ID is almost only determined by vGS.

28) Explain the working principle of depletion type MOSFET (N-channel). [2024]

An N-channel depletion-type MOSFET's working principle is that it is "normally on" because a conductive channel of electrons already exists between the source and drain. Applying a negative gate-source voltage (V_{GS}) repels electrons, shrinking the channel and reducing current (depletion mode), while a positive V_{GS} attracts more electrons, widening the channel and increasing current (enhancement mode).

Working principle

At zero gate-source voltage ($V_{GS} = 0$): A conductive N-type channel exists between the source and drain terminals. When a positive voltage is applied between the drain and source (V_{DS}), electrons flow from the source to the drain, creating a current (I_D). This is its default, "ON" state.

With a negative gate-source voltage ($V_{GS} < 0$): This is the "depletion mode".

- The negative voltage at the gate repels the free electrons in the N-channel.
- These electrons move away from the gate, combining with holes in the P-type substrate, which creates a depletion region.
- As the negative voltage increases, more electrons are depleted, narrowing the channel and reducing the drain current.

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- A sufficiently negative V_{GS} can pinch off the channel completely, stopping the current flow.

With a positive gate-source voltage ($V_{GS} < 0$): This is the "enhancement mode".

- The positive voltage at the gate attracts minority carriers from the P-type substrate into the N-channel.
- This increases the number of free electrons in the channel.
- The channel becomes wider and its conductivity increases, leading to a greater drain current (I_D).

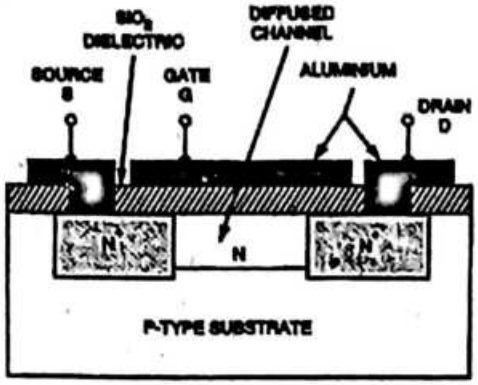
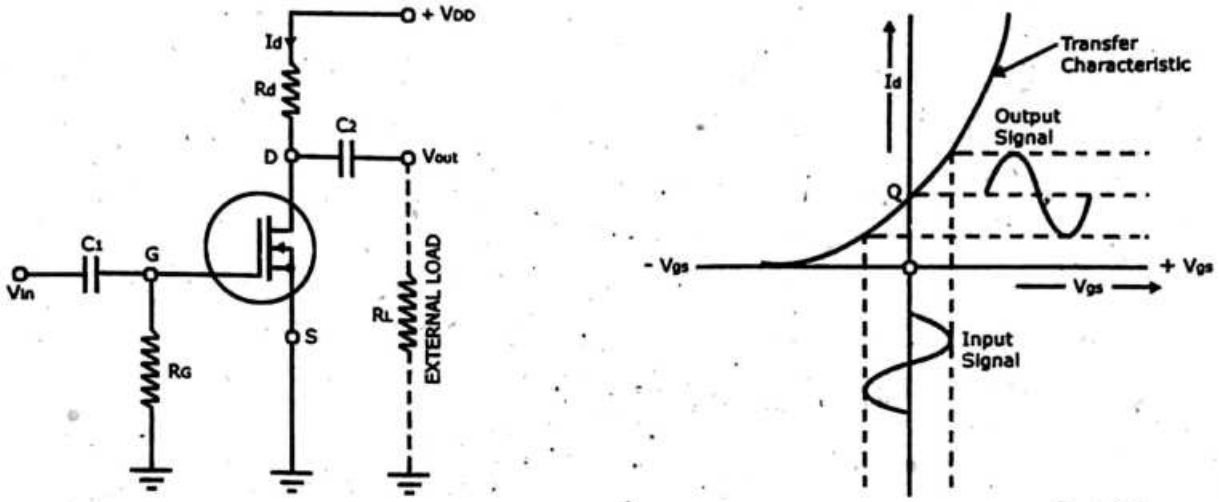


Fig. 13.67 *N-Channel DE-MOSFET Structure*

29) *Discuss with diagram how De-MOSFET work as an amplifier. [2024]*



A Depletion-type MOSFET (DE-MOSFET) can amplify signals because a small change in gate voltage (V_{GS}) produces a large change in drain current (I_D). This varying drain current creates a large AC voltage across the drain resistor R_D; resulting in amplification.

Step-by-step Working

1. Biasing the DE-MOSFET

- The MOSFET is biased with $V_{GS} = 0$ or a slightly negative voltage.
- This sets a stable operating point (Q-point) in the depletion region, where the device shows linear behavior.

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2. Input Signal Control

- The input AC signal is applied to the gate.
- Since the gate draws almost no current, the input impedance is very high.

3. Small V_{GS} Change → Large I_D Change

- When the input signal increases, the channel widens V_{GS}→ I_D increases.
- When the input reduces V_{GS}, the channel narrows → I_D decreases.

4. I_D Change Creates Output Voltage Variation

The output is taken across the drain resistor R_D.

$$V_{out} = V_{DD} - I_D R_D$$

So

- If I_D increases, V_{out} decreases
- If I_D decreases, V_{out} increases

This produces an inverted and amplified version of the input signal.

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Chapter 8

Feedback Techniques and Op-amps

1. *What is feedback?[2011,2021,2022]*

Ans:

Feedback: Feedback is a technique use to influence the behavior and properties of a system by the output quantity of the system the effect produced by a certain cause influences the consequent action of that cause feed back to the input a fraction of the output quantity

2. *Define positive and negative feedback. List the five characteristics of an amplifier which are modified by negative feedback.[2014]*

Ans:

Positive feedback : The feedback in which the feedback energy i.e., either voltage or current is in phase with the input signal and thus aids it is called as Positive feedback.

Both the input signal and feedback signal introduces a phase shift of 180° thus making a 360° resultant phase shift around the loop, to be finally in phase with the input signal.

negative feedback

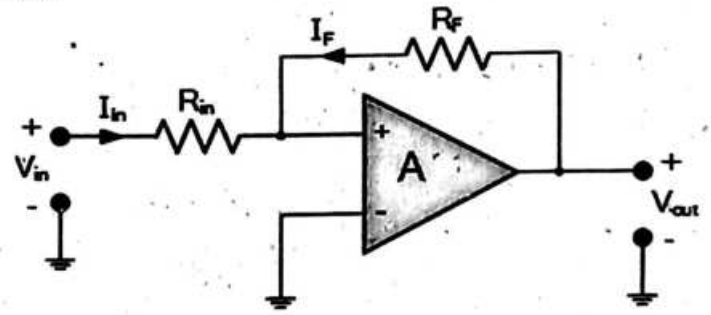
The feedback in which the feedback energy i.e., either voltage or current is out of phase with the input and thus opposes it, is called as negative feedback.

In negative feedback, the amplifier introduces a phase shift of 180° into the circuit while the feedback network is so designed that it produces no phase shift or zero phase shift. Thus the resultant feedback voltage V_f is 180° out of phase with the input signal V_{in}.

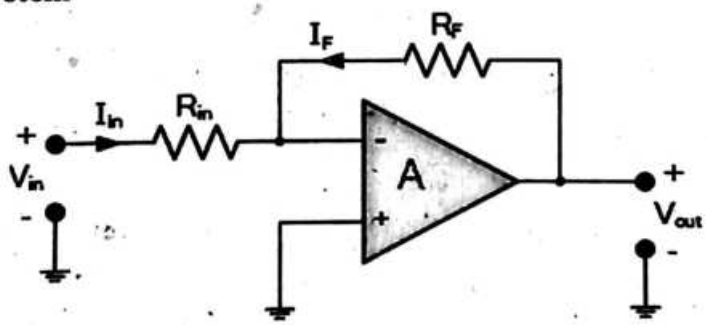
3. *Draw the circuit diagram of different types of feedback .[2010,2013]*

Ans:

Positive Feedback System



Negative Feedback System



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4. What are the differences between positive and negative feedback. [2010]

Ans:

Parameter	Positive Feedback	Negative Feedback
Overall phase shift	0 or 360 degrees	180 degrees
Input and output voltage, noise	increases due to feedback	Decreases due to feedback Feedback
Feedback signal and input signal	In phase	Out of phase
Gain	increases	Decreases
Stability	Poor	Better
applications	oscillators	Amplifiers

5. What are the advantages and disadvantages of negative feedback?

[2010,2013,2016,2018,2021]

Ans:

Following are the advantages of negative feedback over positive feedback.

- Negative feedback stabilizes gain of amplifier.
- Input resistance increases for certain configurations.
- Output resistance decreases for certain configurations.
- Operating point is stabilized.
- The negative feedback is employed in various applications such as electronic amplifiers, regulated power suplies, wideband amplifiers etc.

Following are the disadvantages of negative feedback over positive feedback.

- Reduction in gain
- Reduction in input resistance in case of current shunt and voltage shunt type amplifiers.
- Increase in output resistance in case of current series and current shunt feedback amplifiers.

6. How negative feedback reduces noise and non-linear distortion? [2019,2022]

Ans:

Feedback reduces the overall gain of a system with the degree of **reduction** being related to the systems open-loop gain. **Negative feedback** also has effects of **reducing** distortion, **noise**, sensitivity to external changes as well as improving system bandwidth and input and output impedances.

An ideal amplifier provides consistent gain for any input signal. We have already seen that real-life amplifiers eventually lose gain as the frequency of the input *increases*. ... So adding *negative feedback* to an amplifier actually *reduces* the amount of *nonlinear distortion* in the output signal.

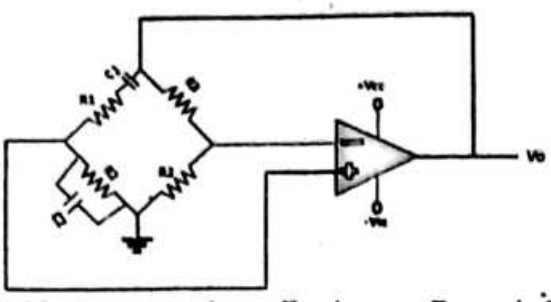
7. Draw the Wien bridge oscillator and write the expression for frequency of oscillation.

[2010]

Ans:

A practical oscillator circuit uses an op-amp and RC bridge circuit, with the oscillator frequency set by the **R** and **C** components. The following figure shows a basic version of a Wien bridge oscillator circuit.

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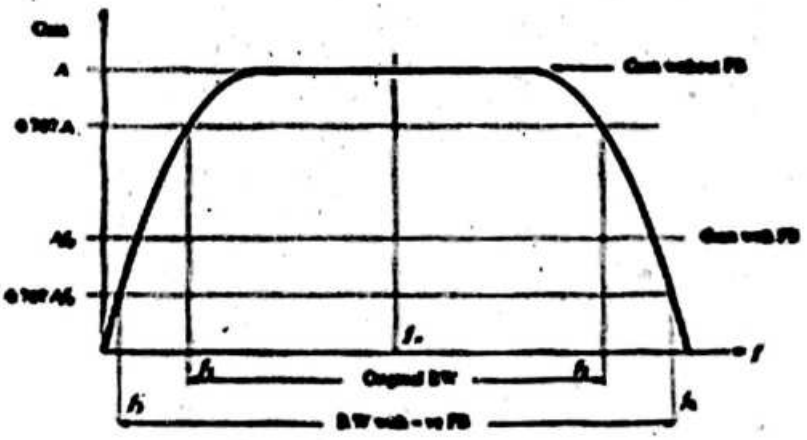
Note the basic bridge connection. Resistors R_1 and R_2 and capacitors C_1 and C_2 form the frequency-adjustment elements, while resistors R_3 and R_4 form part of the feedback path.
In this application, the input voltage (V_i) to the bridge is the amplifier output voltage, and the output voltage (V_o) of the bridge is feedback to the amplifier input. Neglecting the loading effects of the op-amp input and output impedances, the analysis of the bridge circuit results in

8. *Write the conditions for oscillation of an amplifier.* ***[2010]***

Ans:
These two conditions are
1. The loop gain must be unity or greater
2. The feedback signal feeding back at the input must be phase shifted by 360 degrees (which is same as zero degrees). In most of the circuits, an inverting amplifier is used to produce 180 degrees phase shift and additional 180 degrees phase shift is provided by the feedback network.

9. *Prove that negative feedback increases bandwidth and decreases distortion of an amplifier.* ***[2011]***

ANs:
Increase in the bandwidth: When the gain decreases by a factor (1 + m_vA_v) by providing negative feedback. It is seen that the lower cut off frequency is also lowered by this factor (1 + m_vA_v) and upper cut off frequency is raised by the same factor. As a result the difference between the frequencies means bandwidth is increased.



Decreased distortion: Let the harmonic distortion voltage generated within in the amplifier change from D to D', when negative feedback is applied to the amplifier.
Suppose $D' = xD$
The fraction of the output distortion voltage which is feedback to the input is $m_vD' = m_vxD$

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After amplification, it becomes $m_v x DA_v$ and is antiphase(due to negative feedback) with orginal distortion voltage D.

Hence the new distortion voltage D/ which appears in the output is-

$D' = D - m_v x DA_v$

Or, $xD = D - m_v x DA_v$

Or, $x = 1 - x m_v A_v$

Or, $x (1 + m_v A_v) = 1$

Or, $x = 1/ (1 + m_v A_v)$

Or, $xD = D/(1 + m_v A_v)$

Or, $D' = D/(1 + m_v A_v)$

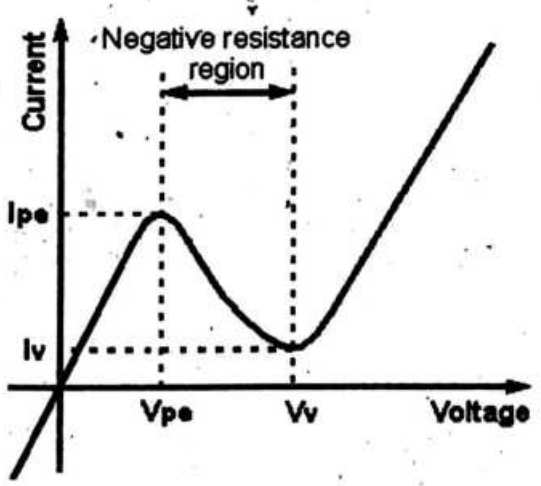
Therefore, the negative feedback reduces the distortion.

10. Draw the characteristic curve of a tunnel diode and explain.[2011]

Ans:

The key to understanding tunnel diode theory is the characteristic curve in which there is a negative slope – this indicates an area of negative resistance. An area of negative resistance means that if the voltage is increased, the current actually falls – the opposite to Ohms Law.

It is also interesting to note that current also flows in the reverse direction - the reverse breakdown voltage is actually zero and the diode conducts in the reverse direction. The characteristics near the origin of the graph are virtually symmetrical.



Tunnel diode IV characteristic

The characteristic curve for the tunnel diode is made up from several different elements:.

- **Normal diode current:** This is the normal or expected current that would flow through a PN junction diode.
- **Tunnelling current:** This is the current that arises as a result of the tunnelling effect.
- **Excess current:** This is a third element of current that contributes to the overall current within the diode. It results from what may be termed excess current that results from tunnelling though bulk states in the energy gap, and means that the valley current does not fall to zero.

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11. Explain how negative feedback decreases gain. *[2013]*

Ans:

The gain of the amplifier without feedback is A_v. Negative feedback is then applied by feeding a fraction m_v of the output voltage e_o back to amplifier circuit.

Therefore,

the actual input to amplifier = $e_g - m_v e_o$

The output e_o must be equal to the input voltage multiplied by gain A_v of the amplifier.

$$(e_g - m_v e_o) A_v = e_o$$

$$\text{Or, } e_g A_v - m_v A_v e_o = e_o$$

$$\text{Or, } e_o (1 + m_v A_v) = e_g A_v$$

$$\text{Or, } e_o / e_g = A_v / (1 + m_v A_v)$$

But e_o / e_g is the gain of the amplifier with feedback. Therefore-

$A_{vf} = A_v / (1 + m_v A_v)$

So due to negative voltage feedback, the gain is reduced by a factor $(1 + m_v A_v)$

For effective design $m_v A_v >> 1$

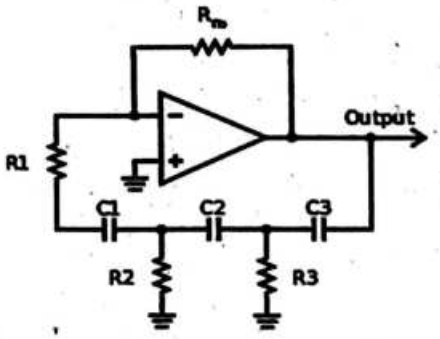
then $A_{vf} = A_v / m_v A_v = 1/m_v$

As the gain of the negative feedback depends on only feedback ratio or feedback circuit which is actually a resistive network that is why the negative feedback gain is unaffected from the variations of transistor parameters, temperature, frequency. Therefore it will be extremely stable.

12. Draw the circuit diagram of phase – shift oscillator and find out the expression for the frequency of oscillation. *[2011,2013,2016,2018]*

Ans:

A **phase-shift oscillator** is a linear electronic **oscillator circuit** that produces a sine wave output. It consists of an inverting amplifier element such as a transistor or op amp with its output fed back to its input through a **phase-shift**network consisting of resistors and capacitors in a ladder network.



Objects can oscillate in all sorts of ways but a really important form of oscillation is SHM or Simple Harmonic Motion.

An object is undergoing simple harmonic motion (SHM) if;

1. the **acceleration of the object is directly proportional to its displacement**from its equilibrium position.
2. the **acceleration is always directed towards the equilibrium position**.

The frequency (f) of an oscillation is measure in hertz (Hz) it is the number of oscillations per second. The time for one oscillation is called the period (T) it is measured in seconds.

$$f = \frac{1}{T}$$

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13. How integrated circuits are classified and state the advantages and limitations of IC. *[2010,2016]*

Ans:
ICs can be classified on the basis of their chip size as given below:
Small scale integration (SSI)—3 to 30 gates/chip.
Medium scale integration (MSI)—30 to 300 gates/chip.
Large scale integration (LSI)—300 to 3,000 gates/chip.
Very large scale integration (VLSI)—more than 3,000 gates/chip.
The advantages and limitations of IC:
Advantages of IC:

1. Extremely small size – Thousands times smaller than discrete circuits. It is because of fabrication of various circuit elements in a single chip of semiconductor material.
2. Very small weight owing to miniaturised circuit.
3. Very low cost because of simultaneous production of hundreds of similar circuits on a small semiconductor wafer. Owing to mass production of an IC costs as much as an individual transistor.
4. More reliable because of elimination of soldered joints and need for fewer interconnections.
5. Lower power consumption because of their smaller size.
6. Easy replacement as it is more economical to replace them than to repair them.

Limitations of IC:

1. Limited power rating as it is not possible to manufacture high power (say greater than 10 W) ICs.
2. Need of connecting inductors and transformers exterior to the semiconductor chip as it is not possible to fabricate inductor and transformers on the semiconductor chip surface.
3. Operation at low voltage as ICs function at fairly low voltage.
4. Quite delicate in handling as these cannot withstand rough handling or excessive heat.

14. Distinguish between series and shunt feedback. *[2014]*

Ans: In series feedback, the feedback signal is connected in series with the input voltage signal. In shunt feedback, the feedback signal is connected in parallel with an input current source

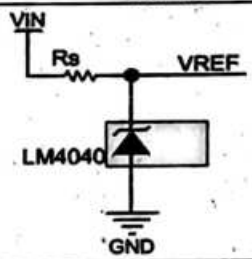
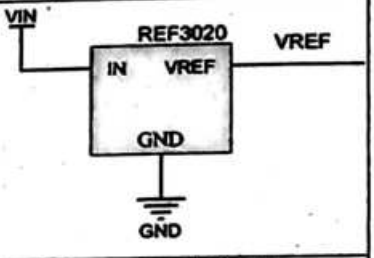
	Shunt	Series
Basic schematic		
Strengths	• No maximum VIN • Accommodates large VIN ranges with proper Rs • Can be used as a negative reference • Can be used as floating reference (cathode not grounded)	• Lower power dissipation • No need for external resistor • Low Dropout • Can have extra pins with additional features
Use cases	• Wide VIN • VIN transients • Floating/negative references	• Load current variation • Low-power consumption requirements

Table 1: Typical comparison table of shunt versus series voltage references

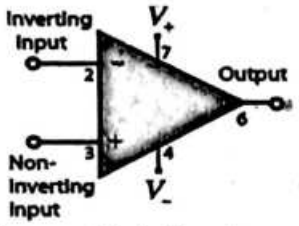
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15. What is operational amplifier? Give the characteristics of an ideal operational amplifier. [2010,2011,2013,2015,2016,2018,2019,2020,2021,2022]

Ans:

Operational amplifier:

An operational amplifier, or op amp, is a high-gain electronic voltage amplifier which is DC coupled and contains a differential input and, usually, a single-ended output.



An op amp produces an output voltage which is often several times larger than the voltage difference between its input terminals. The differential inputs of an operational amplifier consist of a V− input and a V+ input. Op amps amplify the voltage difference in between the two, i.e. the differential input voltage.

The characteristics of an ideal operational amplifier :

1. Open Loop gain

Open loop gain is the gain of the Op Amp without a positive or negative feedback. An ideal OP Amp should have an infinite open loop gain but typically it range between 20,000 and 2, 00000.

2. Input impedance

It is the ratio of the input voltage to input current. It should be infinite without any leakage of current from the supply to the inputs. But there will be a few Pico ampere current leakages in most Op Amps.

3. Output impedance

The ideal Op Amp should have-zero output impedance without any internal resistance. So that it can supply full current to the load connected to the output.

4. Band width

The ideal Op Amp should have an infinite frequency response so that it can amplify any frequency from DC signals to the highest AC frequencies. But most Op Amps have limited bandwidth.

5. Offset

The output of the Op Amp should be zero when the voltage difference between the inputs is zero. But in most Op Amps, the output will not be zero when off but there will be a minute voltage from it.

16. CMRR [2010,2011,2013,2016,2020,2022]

Ans:

Common Mode Rejection Ratio is defined in several essentially equivalent ways by the various manufacturers. Generally, it can be defined as the ratio of the differential gain A_D to the common mode gain A_{CM} that is,

$$CMRR = \frac{A_D}{A_{CM}}$$

For 741C, CMRR is typically 90dB. CMRR is usually expressed under the test condition that the input source resistance RSRS≤ 10kΩ. Higher the value of CMRR, better is the matching between two input terminals and smaller the output common-mode voltage

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17. Slew rate. [2010,20011,2013,2016,2020,2022]

Ans:

The slew rate of an op amp or any amplifier circuit is the rate of change in the output voltage caused by a step change on the input.

It is measured as a voltage change in a given time - typically V / μs or V / ms.



Op amp slew rate illustration

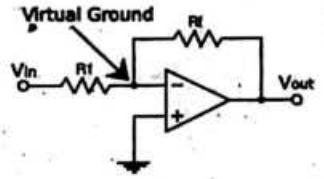
A typical general purpose device may have a slew rate of 10 V / microsecond. This means that when a large step change is placed on the input, the device would be able to provide an output 10 volt change in one microsecond.

The figures for slew rate change are dependent upon the type of operational amplifier being used. Low power op-amps may only have figures of a volt per microsecond, whereas there are fast operational amplifiers capable to providing rates of 1000 V / microsecond.

18. Virtual –ground .[2010,2011,2020,2023]

Ans:

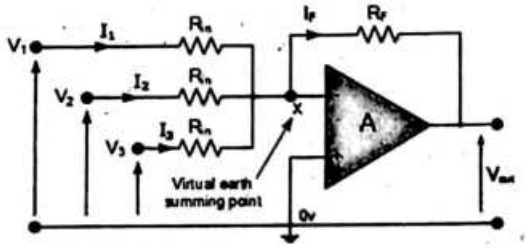
An active virtual ground circuit is sometimes called a rail splitter. Such a circuit uses an op-amp or some other circuit element that has gain. Since an operational amplifier has very high open-loop gain, the potential difference between its inputs tend to zero when a feedback network is implemented



19. Summing Amplifier.[2019]

Ans:

The Summing Amplifier is another type of operational amplifier circuit configuration that is used to combine the voltages present on two or more inputs into a single output voltage.

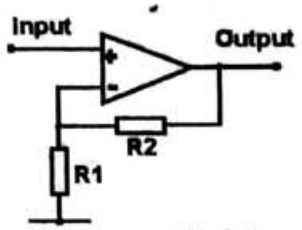


20. Draw the non-inverting amplifier using operational amplifier and find out the expression for the voltage gain . [2010]

Ans:

The basic non-inverting amplifier circuit using an op-amp is shown below. In this circuit the signal is applied to the non-inverting input of the amplifier. However the feedback is taken from

the output via a resistor to the inverting input of the operational amplifier where another resistor is taken to ground. It is the value of these two resistors that govern the gain of the operational amplifier circuit.



Basic non-inverting operational amplifier circuit

The gain of the non-inverting amplifier circuit for the operational amplifier is easy to determine. The calculation hinges around the fact that the voltage at both inputs is the same. This arises from the fact that the gain of the amplifier is exceedingly high. If the output of the circuit remains within the supply rails of the amplifier, then the output voltage divided by the gain means that there is virtually no difference between the two inputs.

As the input to the op-amp draws no current this means that the current flowing in the resistors R1 and R2 is the same. The voltage at the inverting input is formed from a potential divider consisting of R1 and R2, and as the voltage at both inputs is the same, the voltage at the inverting input must be the same as that at the non-inverting input. This means that Vin = Vout x R1 / (R1 + R2). Hence the voltage gain of the circuit Av can be taken as:

$$\frac{V_{out}}{V_{in}} = A_V = 1 + \frac{R_2}{R_1}$$

As an example, an amplifier requiring a gain of eleven could be built by making R2 47 k ohms and R1 4.7 k ohms.

21. Describe common mode operation of optional amplifier. ***[2013]***

Ans:

Like the input signal, the output signal is also balanced and since the collector voltages either swing in opposite directions (anti-phase) or in the same direction (in-phase) the output voltage signal, taken from between the two collectors is, assuming a perfectly balanced circuit the zero difference between the two collector voltages.

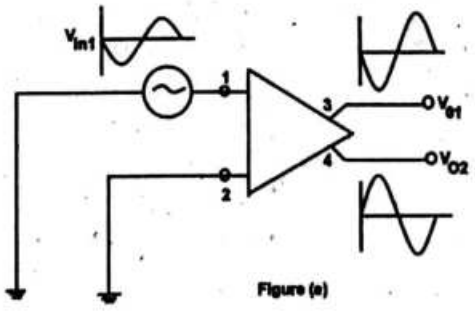


Figure (a)

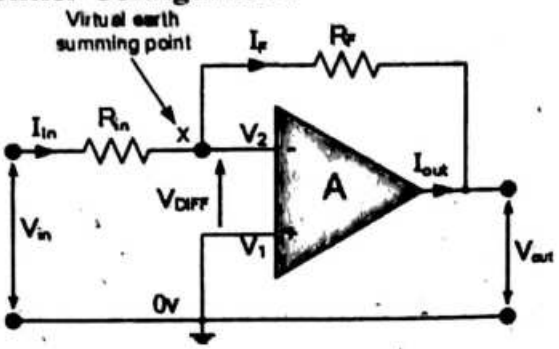
This is known as the Common Mode of Operation with the **common mode gain** of the amplifier being the output gain when the input is zero.

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22. *Draw the circuit diagram of an inverting amplifier using op-amp and find out the expression for the voltage gain.* ***[2013,2020]***

Ans:

Inverting Operational Amplifier Configuration



In this **Inverting Amplifier** circuit the operational amplifier is connected with feedback to produce a closed loop operation. When dealing with operational amplifiers there are two very important rules to remember about inverting amplifiers, these are: "No current flows into the input terminal" and that "V1 always equals V2". However, in real world op-amp circuits both of these rules are slightly broken.

This is because the junction of the input and feedback signal (X) is at the same potential as the positive (+) input which is at zero volts or ground then, the junction is a **"Virtual Earth"**. Because of this virtual earth node the input resistance of the amplifier is equal to the value of the input resistor, Rin and the closed loop gain of the inverting amplifier can be set by the ratio of the two external resistors.

We said above that there are two very important rules to remember about **Inverting Amplifiers** or any operational amplifier for that matter and these are.

- No Current Flows into the Input Terminals
- The Differential Input Voltage is Zero as V1 = V2 = 0

23. *Classify the amplifiers based on frequency response.* ***[2013]***

Ans:

On contrary to power amplifiers, frequency response amplifier amplifies a band or range of frequencies of the current. The frequency in an amplifier keeps on changing and it is very important that this frequency is controlled. Moreover, the capacitors and inductors also change their reactance as frequency changes and thus it is important to control the frequency. The frequency response amplifiers can be divided into three main categories – audio, radio frequency and Video Amplifier.

All the frequency response amplifiers are divided on the basis of the range of frequency that they amplify. For e.g. an audio amplifier amplifies frequencies in the range of 15 Hz - 20 KHz. Also, all the amplifiers that amplify frequency in between this range are by default known as audio amplifier. In the same way, the Radio Frequency amplifier or RF amplifier, amplifies frequencies in between kHz to 100,000 MHz. High level amplification is not a one stage process but requires a number of stages to reach the right frequency.

A Video amplifier amplifies frequencies in the range of 10 Hz to 6 MHz. These long range video amplifiers are often termed as wide band amplifiers. However, all these amplifiers require many additional components to enable such wide band of frequency amplification.

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24. Explain how op-amp can be used as a: [2013]

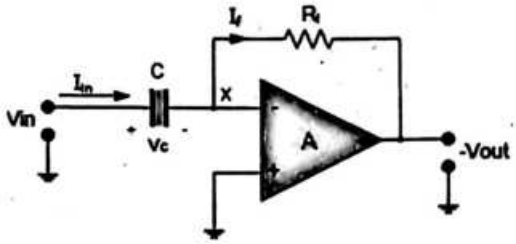
- *Differentiator[2018,2022]*
- *Integrator [2019,2023]*
- *Inverting amplifier[2019]*
- *Non-Inverting*
- *Voltage follower[2019]*

(i) Differentiator; 2018

Ans:

the position of the capacitor and resistor have been reversed and now the reactance, X_C is connected to the input terminal of the inverting amplifier while the resistor, R*f* forms the negative feedback element across the operational amplifier as normal.

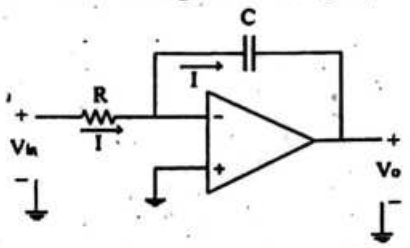
This operational amplifier circuit performs the mathematical operation of **Differentiation**, that is it "produces a voltage output which is directly proportional to the input voltage's rate-of-change with respect to time".



(ii) Integrator [2019,2023]

A circuit in which output voltage waveform is the time integral of the input voltage waveform is called integrator or integrating amplifier.

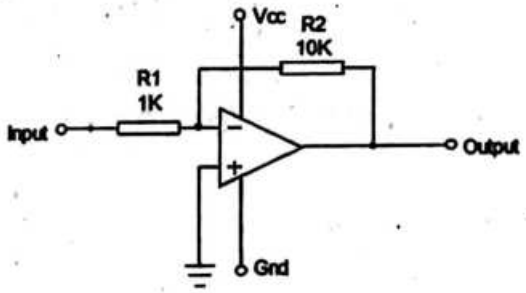
The following circuit shows a basic/ideal integrator using op-amp,



The non-inverting input terminal is at ground potential and hence, the inverting terminal is appearing to be at ground potential

(iii) Inverting amplifier 2019

Ans: **Inverting Amplifier:**



The circuit shown above is an inverting amplifier with the Non inverting input connected to the ground. Two resistors R1 and R2 are connected in the circuit in such a fashion that R1 feeds the input signal while R2 returns the output to the Inverting input, Here when the input signal is

positive the output will be negative and vice versa. The voltage change at the output relative to the input depends on the ratio of the resistors R1 and R2. R1 is selected as 1K and R2 as 10K. If the input receives 1 volt, then there will be 1 mA current through R1 and the output will have to become – 10 volts in order to supply 1 mA current through R2 and to maintain zero voltage at the Inverting input. Therefore the voltage gain is R2/R1. That is 10K/1K = 10

(iv) Non-Inverting

Non-inverting amplifier is "the operational amplifier in which the output is in phase with input signal". In non-inverting amplifier, the input signal has applied to positive terminal of Op–Amp. Figure 1 is the Non-inverting amplifier.

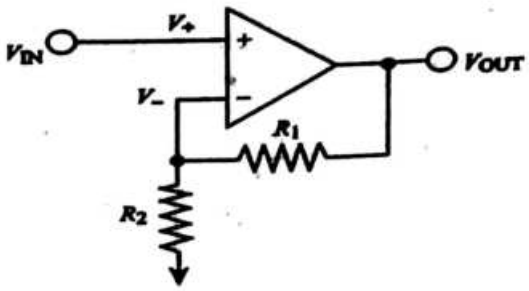
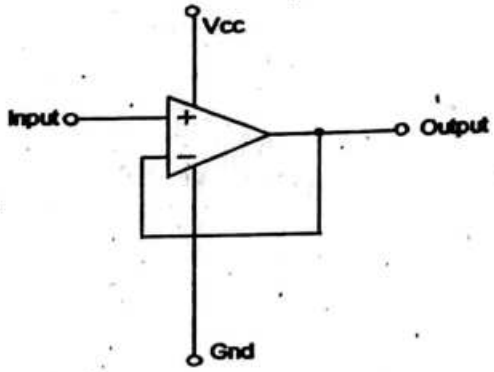


Figure 1

(iv) Voltage follower 2019

Ans:

Voltage Follower



The circuit above is a voltage follower. Here it provides high input impedance, low output impedance .When the input voltage changes, the output and the inverting input will change equally.

25. What do you mean by active filter? Describe low pass. high pass and band pass filters.

[2015,2016]

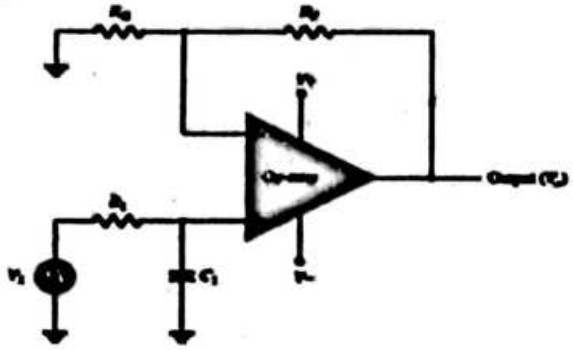
Ans:

An active filter is a type of analog circuit implementing an electronic filter using active components, typically an amplifier. Amplifiers included in a filter design canbe used to improve the cost, performance and predictability of a filter.

Low pass filter

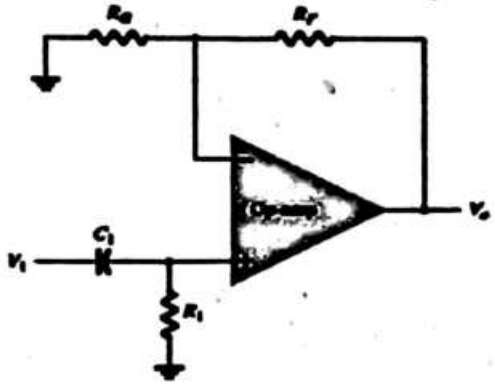
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A low pass filter is used in circuits that only allow low frequencies to pass through. It is often used to block high frequencies and AC current in a circuit. Given below is a sample low pass filter circuit using op-amp.



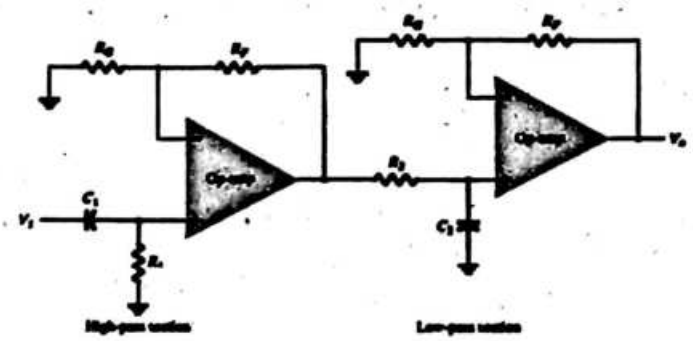
High pass filter

A high pass filter is used in circuits that only require high frequencies to operate. It blocks most low frequencies & DC component. Given below is a sample high pass filter circuit using op-amp.



Band pass filter

A band pass filter is a combination of a high pass and a low pass filter. It allows only a select range of frequencies to pass through. It is designed such a way that the cut off frequency of the low pass filter is higher than the cut off frequency of the high pass filter, hence allowing only a select range of the frequencies to pass through. Presented here is a sample band pass filter circuit using op-amp



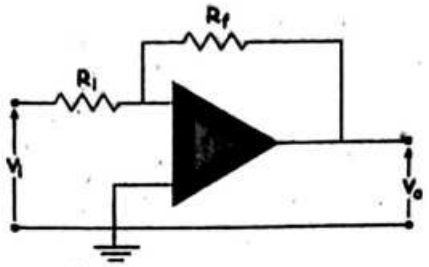
26. Explain how op-amp can be used as a Summing Amplifier *[2021,2022]*

Ans: An op amp is an amplifier. But an op amp can also perform summing operation. We can design an op amp circuit to combine number of input signals and to produce single output as a weighted sum of input signals.

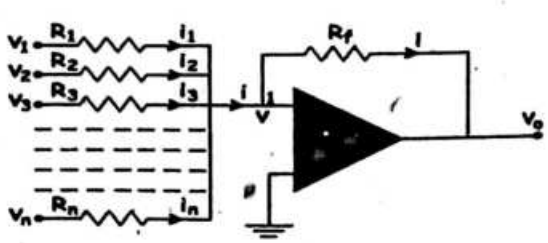
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Summing amplifier is basically an op amp circuit that can combine numbers of input signal to a single output that is the weighted sum of the applied inputs.

The **summing Amplifier** is one variation of inverting amplifier. In inverting amplifier there is only one voltage signal applied to the inverting input as shown below,



This simple inverting amplifier can easily be modified to **summing amplifier**, if we connect several input terminals in parallel to the existing input terminals as shown below.



Here, n numbers of input terminal are connected in parallel. Here, in the circuit, the non-inverting terminal of the op amp is grounded, hence potential at that terminal is zero. As the op amp is considered as ideal op amp, the potential of the inverting terminal is also zero. So, the electric potential at node 1, is also zero. From the circuit, it is also clear that the current i is the sum of currents of input terminals.

Therefore,

$$i = i_1 + i_2 + i_3 + \cdots\cdots + i_n$$

$$\Rightarrow i = \frac{v_1 - 0}{R_1} + \frac{v_2 - 0}{R_2} + \frac{v_3 - 0}{R_3} + \cdots\cdots + \frac{v_n - 0}{R_n}$$

$$\Rightarrow i = \frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} + \cdots\cdots + \frac{v_n}{R_n} \cdots\cdots (i)$$

Now, in the case of ideal op amp the current at the inverting and non-inverting terminal are zero. So, as per Kirchhoff Current Law, the entire input current passes through the feedback path of resistance R_f. That means,

$$i = \frac{0 - v_0}{R_f} = -\frac{v_0}{R_f} \cdots\cdots (ii)$$

From, equation (i) and (ii), we get,

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} + \cdots\cdots + \frac{v_n}{R_n} = -\frac{v_0}{R_f}$$

$$\Rightarrow v_0 = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3 + \cdots\cdots + \frac{R_f}{R_n}v_n\right)$$

This indicates that output voltage v_0 is weighted sum of numbers of input voltages.

Example of summing Amplifier

Let us calculate the output voltage of 3 inputs summer or **summing amplifier**, circuit as shown below,

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Here, as per equation of summing amplifier,

$$v_0 = -\left(\frac{2k\Omega}{2k\Omega} \times 2V + \frac{2k\Omega}{2k\Omega} \times 2V + \frac{2k\Omega}{2k\Omega} \times 2V\right)$$
$$\Rightarrow v_0 = -(2V + 2V + 2V)$$
$$\Rightarrow v_0 = -6V$$

27. What are the silent features of op-Amp. [2022]

Solution:

Operational amplifiers, often referred to as op-amps, are essential components in electronics due to their versatility and numerous desirable features. Here are some of the key characteristics and features of operational amplifiers:

1. **High Input Impedance:** Op-amps have very high input impedance, which means they draw very little current from the input signal source. This feature minimizes the loading effect on the source and allows for easy interfacing with various sensors and signal sources.
2. **Low Output Impedance:** Op-amps have low output impedance, which enables them to drive loads and other circuits effectively.
3. **High Gain:** Op-amps have a very high voltage gain, often in the range of 100,000 or more. This high gain makes them suitable for amplifying weak signals and performing a wide range of signal processing functions.
4. **Differential Inputs:** Op-amps have two input terminals, an inverting (-) and a non-inverting (+) input. They can process the difference between these two inputs, making them ideal for applications like differential amplifiers.
5. **Linear Operation:** Op-amps are designed to operate linearly within a specified input voltage range. This linearity allows for precise signal processing.
6. **Versatility:** Op-amps can be used in various configurations, including inverting amplifiers, non-inverting amplifiers, voltage followers, integrators, differentiators, and more. They are highly adaptable and versatile.
7. **Low Offset Voltage and Drift:** Modern op-amps have low input offset voltage and drift, which means the difference between the inverting and non-inverting input voltages required for the output to be zero is minimized and remains stable over temperature changes.
8. **Common-Mode Rejection Ratio (CMRR):** Op-amps have good CMRR, meaning they can reject common-mode signals (signals that are present on both inputs) and focus on amplifying the differential signal.
9. **High Slew Rate:** Op-amps have a high slew rate, allowing them to respond to rapid changes in input signals and output voltage.
10. **Wide Operating Voltage Range:** Op-amps can operate over a wide range of power supply voltages, making them suitable for various applications.
11. **Negative Feedback:** Op-amp circuits often utilize negative feedback, which stabilizes the gain, reduces distortion, and enhances the overall performance of the amplifier.
12. **Low Noise:** Op-amps have low input-referred noise, making them suitable for applications where low noise is critical, such as in audio equipment and sensor interfaces.
13. **High Input Common-Mode Voltage Range:** Op-amps can handle a wide range of common-mode input voltages, which is important in many practical applications.
14. **Low Power Consumption:** Many modern op-amps are designed for low power consumption, making them suitable for battery-powered devices.
15. **High Open-Loop Gain:** Op-amps have an extremely high open-loop gain, which is useful in applications where a precise gain is required.

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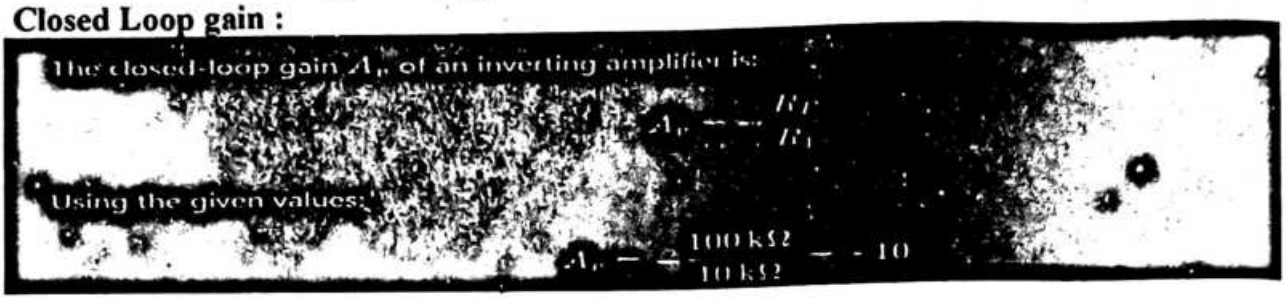
These features make operational amplifiers an indispensable component in electronics and enable their use in a wide range of applications, including amplification, signal conditioning, filtering, oscillators, and more.

30)In an invering amplifier let , R_f = 100 KΩ and R_1 = 1KΩ and V = 1v calculate –

1. ***Input Current***
2. ***Output Voltage***
3. ***Closed loop gain*** ***[2023]***

Sloution

1. **Input Current :** $I_{in} = \frac{V1}{R1} = \frac{1v}{10K\Omega} = 0.1mA$
2. **Output Voltage,** $V_{out} = -\left(\frac{Rf}{R1}\right).V1 = -\frac{100k\Omega}{1\Omega}.1v = -10v$
3. **Closed Loop gain :**



31) Find out the gain stability of a feedback amplifier. [2024]

The gain stability of a feedback amplifier refers to how the overall gain remains constant even if the amplifier's internal parameters (transistor gain, temperature, biasing, or component variations) change.

Negative feedback improves gain stability by reducing the dependence of gain on the amplifier's internal characteristics.

Derivation of Gain Stability

Let:

- A = open-loop gain
- β = feedback factor
- A_f = closed-loop gain (with feedback)

The closed-loop gain is:

$$A_f = \frac{A}{1+A\beta}$$

Now, to measure stability, we compare change in closed-loop gain with change in open-loop gain.

$$\frac{\Delta A_f}{A_f} = \frac{1}{1+A\beta} \cdot \frac{\Delta A}{A}$$

Interpretation

- $\frac{1}{1+A\beta}$ is the desensitivity factor.
- When Aβ is large, $\frac{1}{1+A\beta} \approx 0$

So, $A_f < \Delta A$

This means that even if the internal gain A changes significantly, the gain with feedback A_f changes only slightly, and therefore the overall gain becomes very stable.

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