ELECTRONIC DEVICES AND CIRCUITS

Set-1: Introduction to Semiconductors

Q-1: What do you understand by semiconductor?

Answer:

Semiconductors (e.g. Germanium, Silicon etc) are those substances whose electrical conductivity lies in between conductors and insulators. In terms of energy band, the valence band is almost filled and conduction band is almost empty.

Q-2: Why do we use semiconductors? Discuss some properties of semiconductors.

Answer:

Semiconductors are materials that have a conductivity between conductors (such as metals) and insulators (such as non-metals), which makes them useful for controlling and manipulating the flow of electrical currents. They are widely used in modern electronic devices such as transistors, diodes, solar cells, and integrated circuits.

Main features/properties of semiconductor:

- The resistivity of a semiconductor is less than an insulator but more than a conductor.
- Semiconductors have negative temperature co-efficient of resistance i.e. the resistance of a semiconductor decreases with the increase in temperature and vice-versa.
- When a suitable metallic impurity (e.g. Arsenic, Gallium etc.) is added to a semiconductor, its current conducting properties change appreciably.

Q-3: What do you understand by Extrinsic and Intrinsic semiconductors?

Answer:

About intrinsic semiconductor.

Intrinsic semiconductors are pure semiconductors that do not have any impurities added to them. They have a very low conductivity, but their conductivity can be increased by adding impurities.

The conductivity of an intrinsic semiconductor is determined by the number of free electrons and holes in the material. Free electrons are electrons that are not bound to any atoms. Holes are vacancies in the electron structure of the material.

Uses:

Intrinsic semiconductors are used in a variety of applications, including light-emitting diodes (LEDs), solar cells, and transistors.

Extrinsic semiconductor: The semiconductor which is produced by adding a small amount of impurity to the intrinsic semiconductor in order to increase its conductivity is known as extrinsic semiconductor. Depending upon the type of impurity added, extrinsic semiconductors are two types. They are: (a) p-type semiconductor (b) n-type semiconductor.

Uses:

Extrinsic semiconductors are used in a wide variety of electronic devices, including transistors, diodes, and integrated circuits.

They can be made to have a wide range of electrical properties: This makes them ideal for use in a variety of electronic devices

Q-4: Describe the construction process of P-type or N-type semiconductor.

Answer:

p-type semiconductor: When a small amount of trivalent impurity is added to a pure semiconductor, it is called p-type semiconductor. The addition of trivalent impurity provides a large number of holes in the semiconductor. Typical examples of trivalent impurities are gallium (atomic no. 31) and indium (atomic no. 49). Such impurities which produce p-type semiconductor are known as acceptor impurities because the holes created can accept the electrons.

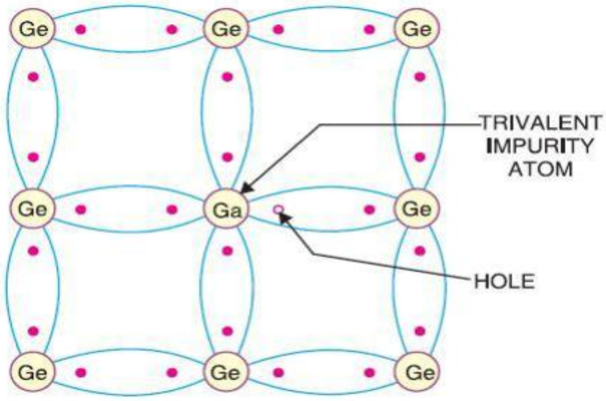


Figure: Structure of p-type semiconductor

n-type semiconductor: When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor. Figure: Structure of p-type semiconductor the addition of pentavalent impurity provides a large number of free electrons in the semiconductor crystal. Typical examples of pentavalent impurities are arsenic (atomic no. 33) and antimony (atomic no. 51). Such impurities which produce n-type semiconductor are known as donor impurities because they donate or provide free electrons to the semiconductor crystal.

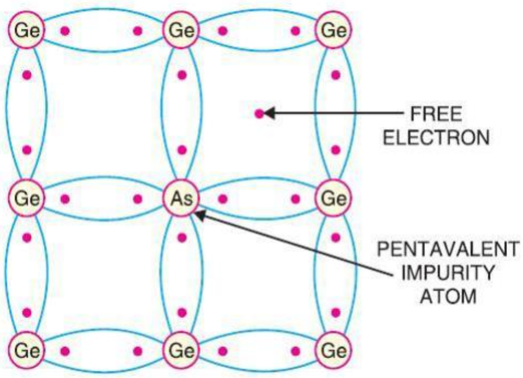


Figure: Structure of n-type semiconductor

Q-5:Discuss the effect of temperature on semiconductors.

Answer:

Effect of temperature on semiconductor: The electrical conductivity of a semiconductor changes appreciably with temperature variation.

(i) At absolute zero: At absolute zero temperature, all the electrons are tightly held by the semiconductor atoms. The inner orbit electrons are bound whereas the valence electrons are engaged in co-valent bonding. At this temperature, the covalent bonds are very strong and there are no free electrons. Therefore, the semiconductor crystal behaves as a perfect insulator.

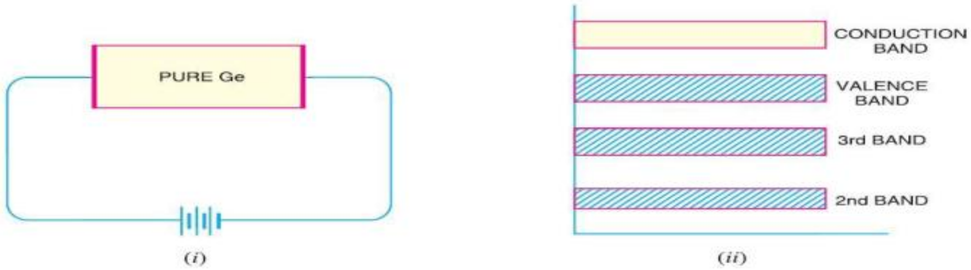


Figure: At absolute zero temperature

In terms of energy band description, the valence band is filled and there is a large energy gap between valence band and conduction band. Due to the non-availability of free electrons, a semiconductor behaves as an insulator.

(ii) Above absolute zero: When the temperature is raised, some of the covalent bonds in the semiconductor break due to the thermal energy supplied. The breaking of bonds sets those electrons free which are engaged in the formation of these bonds. This means that a few free electrons exist in the semiconductor. These free electrons can constitute a very little electric current if potential difference is applied across the semiconductor crystal. This shows that the resistance of a semiconductor decreases with the rise in temperature. At room temperature, current through a semiconductor is too small to be any practical value.

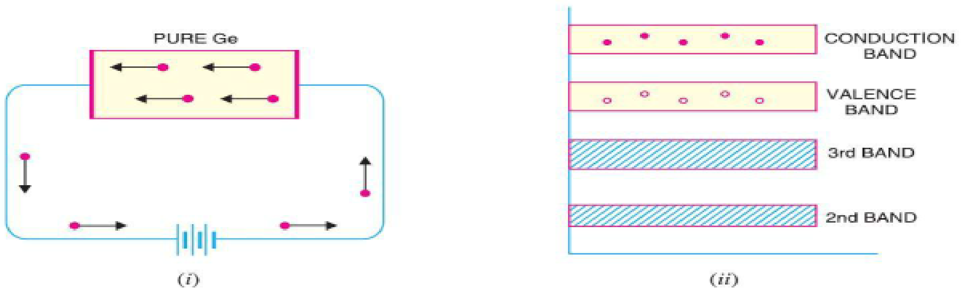


Figure: Above absolute zero temperature

In terms of energy band diagram, as the temperature is raised, some of the valence electrons acquire sufficient energy to enter into the conduction band and this become free electrons. At each time, a valence electron enters into the conduction band, a hole is created in the valence band.

Set-2: Semiconductor Diodes and Special Purpose Diodes

Q-1: What is p-n junction? Explain the formation of the potential barrier in a p-n junction.

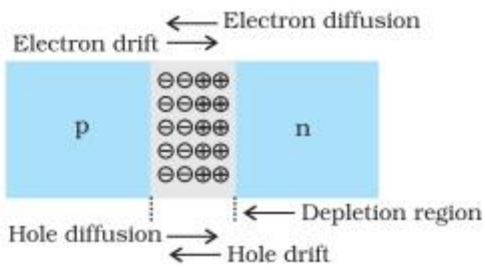
Answer:

A PN junction is a boundary between two semiconductor materials with different electrical properties. One material is p-type, which has an excess of holes, which are positively charged carriers. The other material is n-type, which has an excess of electrons, which are negatively charged carriers.

Formation of a p-n Junction: Two important processes take place during the formation of a p-n Junction-

1) Diffusion
2) Drift

Diffusion: This is the process by which charge carriers (holes and electrons)



p-n junction formation process.

move from a region of high concentration to a region of low concentration. In a p-n junction, the holes in the p-type region diffuse into the n-type region, and the electrons in the n-type region diffuse into the p-type region. This diffusion process creates a depletion region near the junction, where all of the charge carriers have been depleted.

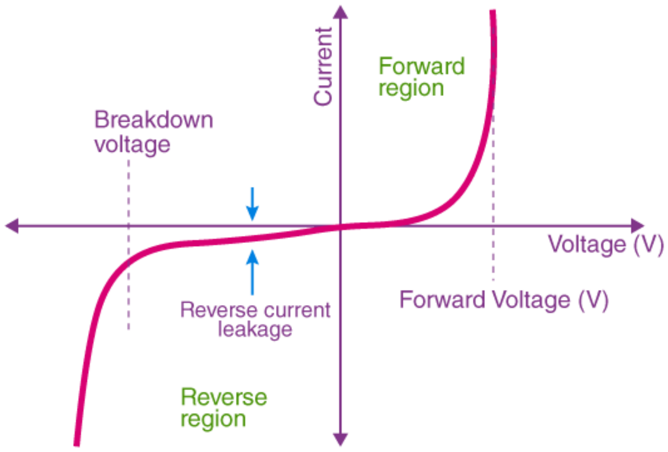
Drift: This is the process by which charge carriers are moved by an electric field. In a p-n junction, the built-in electric field created by the depletion region causes the majority carriers (electrons in the n-type region and holes in the p-type region) to drift towards the junction. This drift current is responsible for the current that flows through a p-n junction in the absence of an external voltage.

These two processes are essential for the operation of p-n junction diodes. The diffusion process creates the depletion region, and the drift process is responsible for the current that flows through the diode.

Q-2:Draw and explain the V-I characteristics curve of a p-n junction.

(Extra)

Answer:

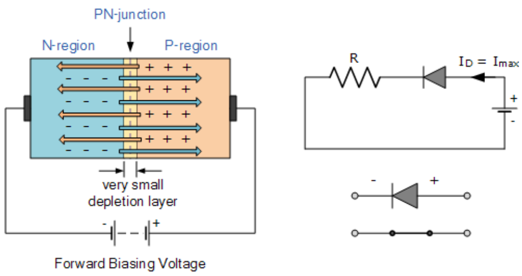


The above graph is the V-I characteristics curve of the P-N junction diode. VI characteristics of P-N junction diodes is a curve between the voltage and current through the circuit.

we can understand that there are three regions in which the diode works, and they are:

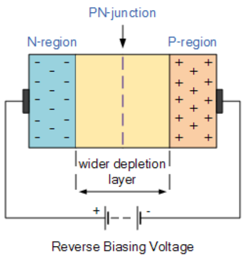
1) **Zero bias:** When the P-N junction diode is in zero bias condition, there is no external voltage applied and this means that the potential barrier at the junction does not allow the flow of current.

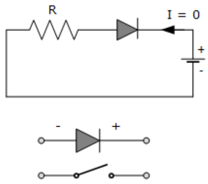
2) **Forward bias:** In forward bias condition, the p-type is connected to the positive terminal while the n-type is connected to the negative terminal of the external voltage. There is a reduction in the potential barrier. For silicone diodes and germanium diodes, when the voltage is 0.7 V and 0.3 V, the potential barriers decrease, and there is a flow of current.



When the diode is in forward bias, the current increases slowly, and the curve obtained is non-linear as the voltage applied to the diode overcomes the potential barrier. Once the diode overcomes the potential barrier, the curve rises as the external voltage increasess, and the curve obtained is linear.

3) **Reverse bias:** In negative bias condition, the p-type is connected to the negative terminal while the n-type is connected to the positive terminal of the external voltage. This results in an increase in the potential barrier. Reverse saturation current flows in the beginning as minority carriers are present in the junction. s





When the applied voltage is increased, the minority charges will have increased kinetic energy which affects the majority charges. This is the stage when the diode breaks down. This may also destroy the diode.

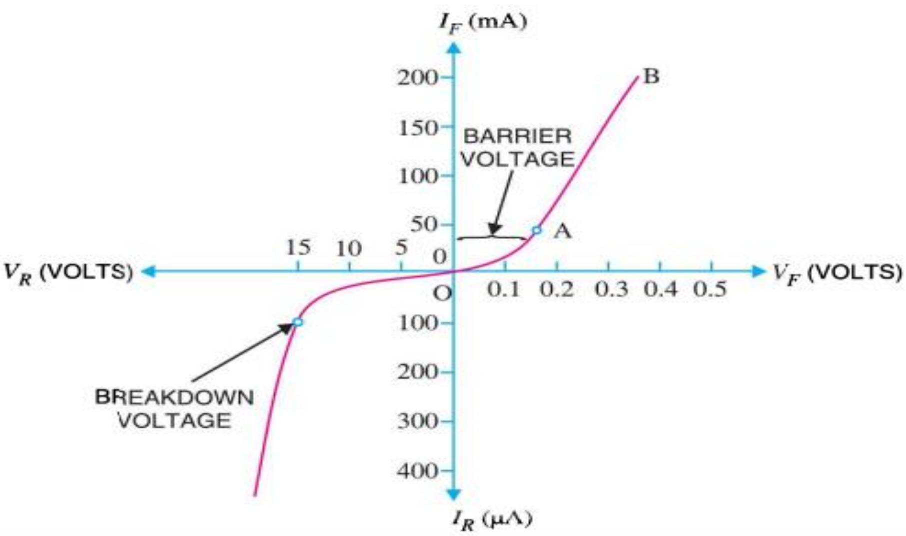
//Difference between p-type and n-type semiconductors.

//Difference between conductor and semiconductor.

///What is doping? Why is it done?

Q-3;Explain the volt-ampere characteristics of a p-n junction with a diagram.

Answer:



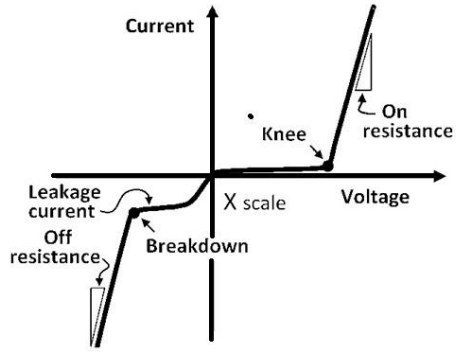
Explanation: Same to q-2.

Q-4: Write short notes on the following: Breakdown Voltage, PIV Voltage, Knee Voltage.

Answer:

Breakdown Voltage: It is the minimum reverse voltage at which pn junction breaks down with sudden rise in reverse current.

Peak Inverse Voltage (PIV): It is the maximum reverse voltage that can applied to the pn junction without damage to the junction. If the reverse voltage across the junction exceeds its PIV, the junction may be destroyed due to excessive beat.

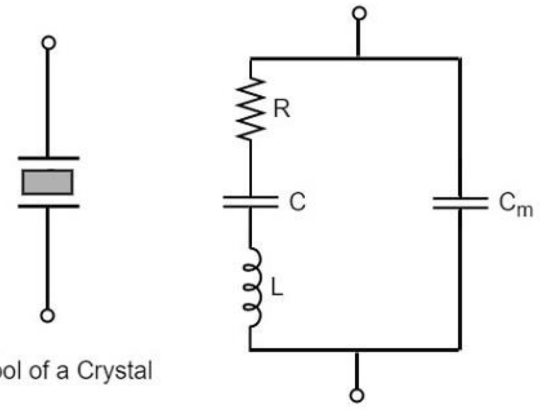


Knee Voltage: It is the forward voltage at which the current through the junction starts to increase rapidly.

//What is a crystal diode? Explain its rectifying action.

Q-5:Draw the equivalent circuit of a crystal diode.

Answer:



Symbol of a Crystal

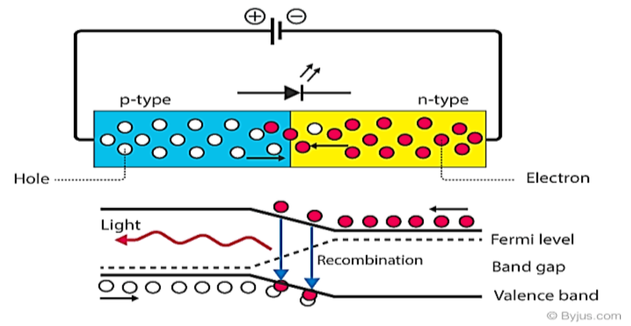
Equivalent circuit of a crystal

Q-6:What is an LED Diode? Explain the working principles of an LED diode.

Answer:

LED: A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons.

When the diode is forward biased, the minority electrons are sent from p → n while the minority holes are sent from n → p. At the junction boundary, the concentration of minority carriers increases. The excess minority carriers at the junction recombine with the majority charges carriers.



The energy is released in the form of photons on recombination. In standard diodes, the energy is released in the form of heat. But in light-emitting diodes, the energy is released in the form of photons. We call this phenomenon electroluminescence. Electroluminescence is an optical phenomenon, and electrical phenomenon where a material emits light in response to an electric current passed through it. As the forward voltage increases, the intensity of the light increases and reaches a maximum.

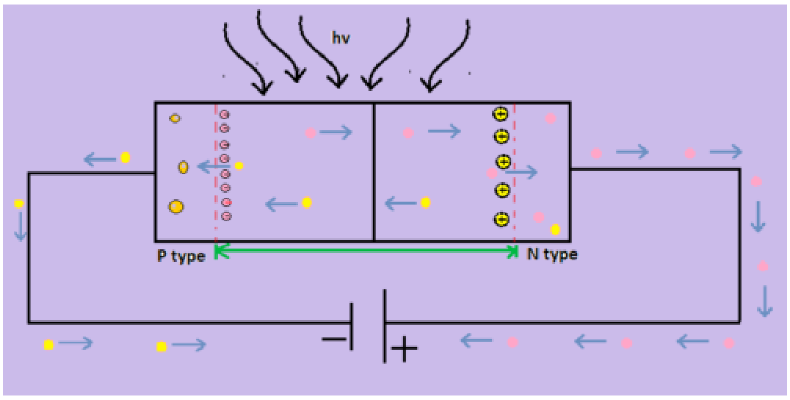
Q-7: What is a Photo Diode? How does a photo diode work?

Answer:

Photo Diode: A photodiode is a PN-junction diode that consumes light energy to produce an electric current. They are also called a photo-detector, a light detector, and a photo-sensor.

Working principle of Photodiode:

It has a P and N junction and is connected in reverse bias that results in a very wide depletion region at the PN Junction. In P-type the majority carriers are holes and n-type majority carriers are electrons. When we connect the photodiode in reverse bias and if there is no illumination or light on photodiode in that condition, we get a very small amount of current in microampere we called that current as dark current.



When a photon having energy greater than the bandgap energy strikes on diode covalent bond breaks and new electrons and hole pairs are generated. This makes a couple of electrons and holes called inner photoelectric effect and the holes move towards the anode and electrons move toward cathode this results in photocurrent. The total current through the diode is the sum of dark current and photocurrent. To maximize the sensitivity of photodiode we need to minimize the dark current

Hv > Eg

Energy of photon > Bandgap energy

Set-3: Diode Application and Filter Circuits

Q-1: What is the ripple factor? What is its value for a Half/Full wave rectifier?

Answer:

Ripple factor: is the ratio of the rms value of the ac component to the dc component, increases with the firing angle.

A lower ripple factor indicates that the output of the rectifier is more pure DC. A higher ripple factor indicates that the output of the rectifier contains more AC ripple.

Ripple Factor Value: Ripple Factor Value talks about how well a rectifier can convert AC voltage to DC voltage.

Equation of Ripple Factor:

$$\textbf{R.F} = \frac{RMS\ value\ of\ AC\ component\ in\ rectifier\ output}{Average\ value\ of\ rectifier\ output} = \frac{I'_{rms}}{I_{dc}} = \frac{V'_{rms}}{V_{dc}}$$

$$\therefore \textbf{R.F} = \frac{\sqrt{(I_{rms})^2-(I_{dc})^2}}{I_{dc}} = \frac{\sqrt{(V_{rms})^2-(V_{dc})^2}}{V_{dc}}$$

The value of Half wave rectifier $= \frac{\sqrt{(V_{rms})^2-(V_{dc})^2}}{V_{dc}}$

$= \mathbf{1.21}$

The value of Half wave rectifier $= \frac{\sqrt{(V_{rms})^2-(V_{dc})^2}}{V_{dc}}$

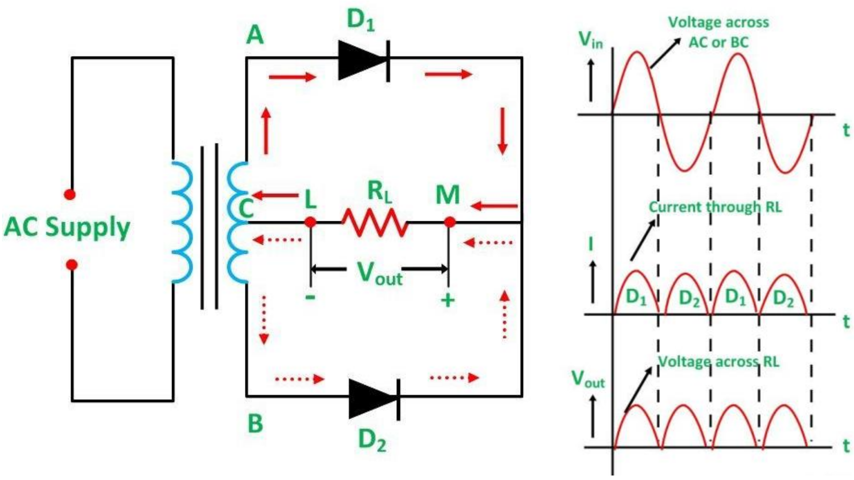
$= \mathbf{0.48}$

Q-2:With a neat sketch, explain the working principle of the center-tap rectifier.

Answer:

Center tap rectifier: A type of rectifier which is designed by using two diodes as well as a center tapped transformer for converting the whole AC signal to DC is called center tapped Full wave rectifier.

When AC supply is switched ON the alternating voltage, $\mathbf{V_{in}}$ appears across the terminals **AB** of the secondary winding of the transformer. During the positive half cycle of the secondary voltage, end **A** becomes positive, and end **B** becomes negative. Thus, the diode $\mathbf{D_1}$ becomes forward biased, and diode $\mathbf{D_2}$ becomes reverse biased.



Therefore, when the diode $\mathbf{D_1}$ conducts, the diode $\mathbf{D_2}$ does not conduct and vice versa.

When the Diode $\mathbf{D_1}$ is conducting, the current (**I**) flows through the diode $\mathbf{D_1}$ load resistor

$\mathbf{R_L}$ (from **M** to **L**) and the upper half of the secondary winding as shown in the circuit diagram marked by the red color arrowheads.

During the negative half-cycle, the end **B** becomes positive, and end **A** becomes negative. This makes the diode $\mathbf{D_2}$ forward biased, and diode $\mathbf{D_1}$ reverse biased. The current (**I**) flows through the diode $\mathbf{D_2}$ load resistor $\mathbf{R_L}$ (from **M** to **L**) and the lower half of the secondary winding as shown by the red dotted arrows.

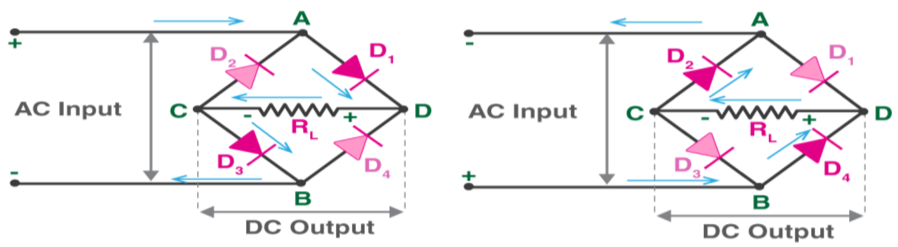
The current flowing through the load resistor RL is in the same direction (i.e., from **M** to **L**) during both the positive as well as the negative half cycle of the input. Hence, the DC output voltage ($\mathbf{V_{out} = I\ R_L}$) is obtained across the load resistor.

Q-3:With a neat sketch, explain the working principle of a full-wave rectifier.

Answer:

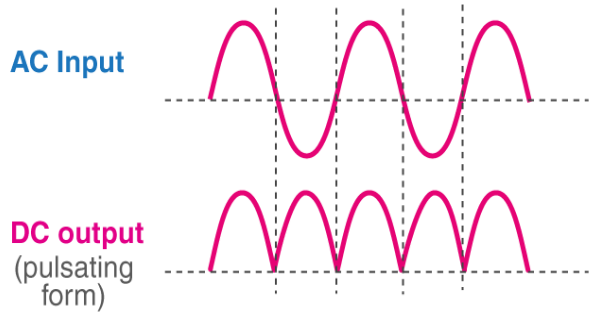
Full Wave Bridge Rectifier: A bridge rectifier is a type of full-wave rectifier that uses four individual rectifying diodes connected together in a closed-loop bridge configuration to efficiently convert the Alternating Current (AC) into Direct Current (DC). It can rectify both half-cycles of an AC input sine wave.

When an **AC** signal is applied across the bridge rectifier, terminal **A** becomes positive during the positive half cycle while terminal **B** becomes negative. This results in diodes **D1** and **D3** becoming forward biased while **D2** and **D4** becoming reverse biased.



During the negative half-cycle, terminal **B** becomes positive while terminal **A** becomes negative. This causes diodes **D2** and **D4** to become forward biased and diode **D1** and **D3** to be reverse biased.

From the figures given above, we notice that the current flow across load resistor R_L is the same during the positive and negative half-cycles. The output DC signal polarity may be either completely positive or negative. In our case, it is completely positive. If the diodes' direction is reversed, we get a complete negative DC voltage. Thus, a bridge rectifier allows electric current during both positive and negative half cycles of the input AC signal.

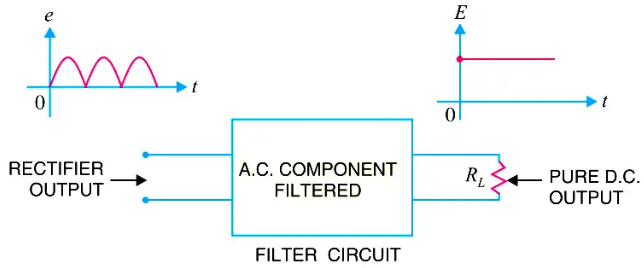


Q-4:What is a filter circuit? Describe some filter circuits.

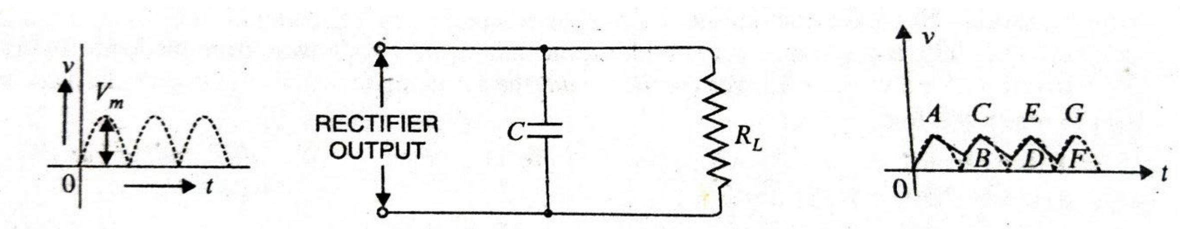
- Capacitor Filter
- Choke Filter
- Capacitor Input Filter or π Filter.

Answer:

Filter Circuit: A filter circuit is a device which removes the AC component of rectifier output but allows the DC component to reach the load.

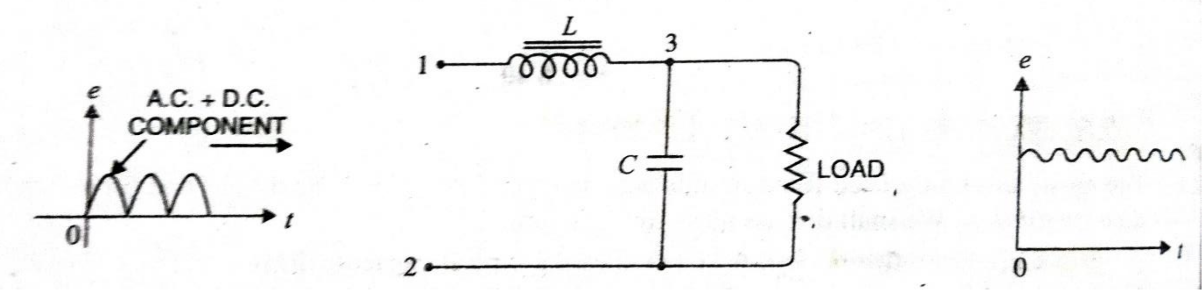


i. **Capacitor Filter:** A capacitor that is used to filter out a certain frequency otherwise series of frequencies from an electronic circuit



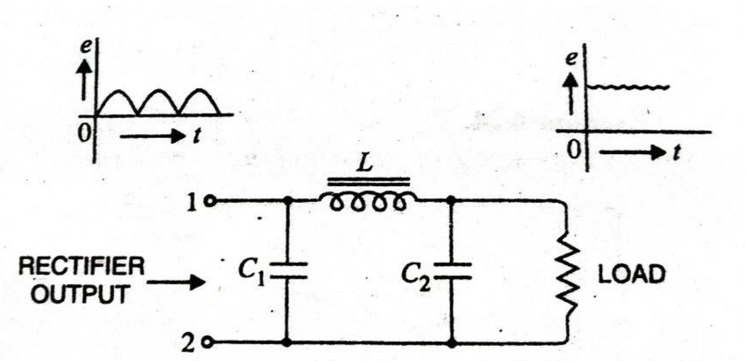
is known as the filter capacitor.

ii. **Choke Input Filter:** Choke filter consists of an inductor connected in series with rectifier output circuit and a capacitor connected in parallel with the load resistor. It is also called L-section filter because the inductor and capacitor are connected in the shape of



inverted L. The output pulsating DC voltage from a rectifier circuit passes through the inductor or choke coil.

iii. **Capacitor Input Filter / π-Filter:** π-filter consists of a shunt capacitor at the input side, and it is followed by an L-section filter. The output from the rectifier is directly given across capacitor. The pulsating DC output voltage is filtered first by the capacitor connected at the input side and then by choke coil and then by another shunt capacitor.



Q-5:What do you mean by Clippers and Clampers Circuit? Mention their classification.

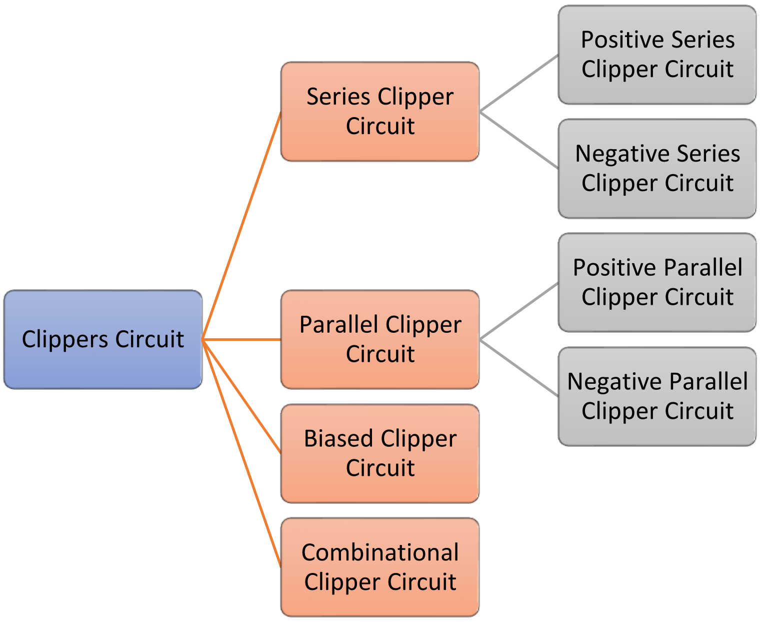
Answer:

Clippers Circuits: Clippers Circuits are the circuits that clip of removes a portion of an input signal with causing any distention to the remaining part of the waveform.

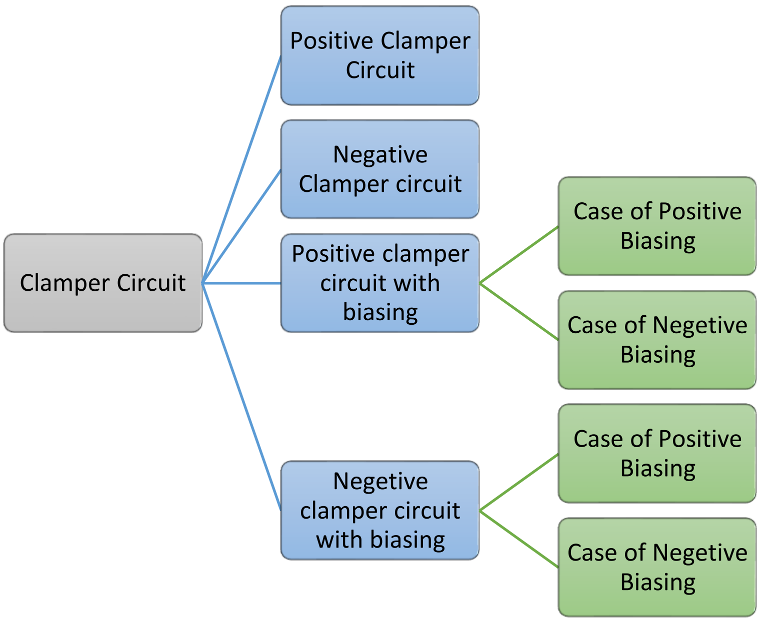
Clipper is basically waving shaping circuits that control the shape of an output wave form.

Clamper Circuits: Clamper circuits are the electronic circuits that shift the dc level of the AC signal. Clampers are also known as DC voltage restorers or level shifter. Clampers are basically classified as positive and negative that includes both biased and unbiased conditions individually.

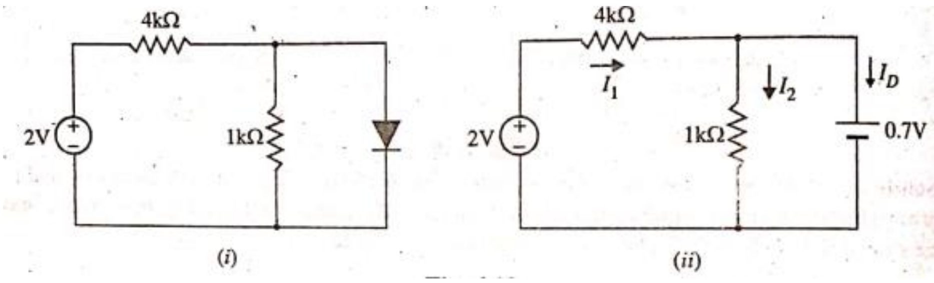
Classification of Clippers Circuit:



Classification of Clamper Circuits:



Q-6:Determine the state of the diode for the circuit shown in Figure (i) (ii) and find the final ID and VD. Assume a simplified model for the diode. (6.11 of V.K Mehta)



Answer:

Solution. Let us assume that the diode is *ON*. Therefore, we can replace the diode with a 0.7V battery as shown in Fig. 6.18 (*ii*). Referring to Fig. 6.18 (*ii*), we have,

$$I_1 = \frac{(2-0.7)\ \text{V}}{4\ \text{k}\Omega} = \frac{1.3\ \text{V}}{4\ \text{k}\Omega} = 0.325\ \text{mA}$$

$$I_2 = \frac{0.7\ \text{V}}{1\ \text{k}\Omega} = 0.7\ \text{mA}$$

Now $$I_D = I_1 - I_2 = 0.325 - 0.7 = -0.375\ \text{mA}$$

Since the diode current is negative, the diode must be **OFF** and the true value of diode current is I_D = **0 mA**. Our initial assumption was wrong. In order to analyse the circuit properly, we should replace the diode in Fig. 6.18 (*i*) with an open circuit as shown in Fig. 6.19. The voltage V_D across the diode is

$$V_D = \frac{2\ \text{V}}{1\ \text{k}\Omega + 4\ \text{k}\Omega} \times 1\ \text{k}\Omega = \mathbf{0.4V}$$

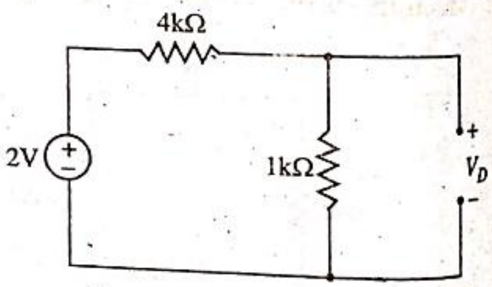
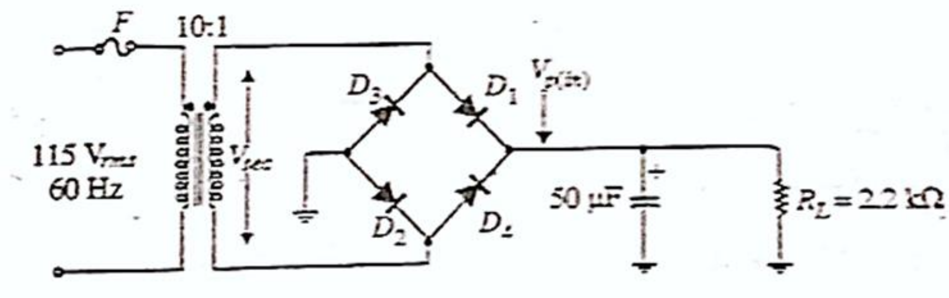


Fig. 6.19

We know that 0.7V is required to turn *ON* the diode. Since V_D is only 0.4V, the answer confirms that the diode is *OFF*.

Q-7:For the circuit shown, find the output d.c. voltage.



Answer:

It can be proved that output that d.c. voltage is given by:

$$V_{dc} = V_{p(in)}\ (1 - \frac{1}{2f\ \mathrm{R_L}C})$$

Peak primary voltage, $V_{p(prime)} = \sqrt{2} + V_{rms} = \sqrt{2} + 115 = 163V$

Peak secondery voltage, $V_{p(sec)} = V_{p(prime)}$ * Turns Ratio = (1/10) * 163

= 16.3 V

Peak Full-wave rectifier voltage at the filter input is,

$V_{p(in)} = V_{p(sec)}$ -2* 0.7= 16.3 – 1.4 = 14.9V

For Full-wave rectification, f = 2

f_{in} = 2*60 = 120

Now, $(1 - \frac{1}{2f\ \mathrm{R_L}C}) = \frac{1}{2*120*(2.2*10^3)*(50*10^{-6})} = 0.038$

V_{dc} $= V_{p(in)}\ (1 - \frac{1}{2f\ \mathrm{R_L}C})$ = 14.9 (1 – 0.038) = 14.3V

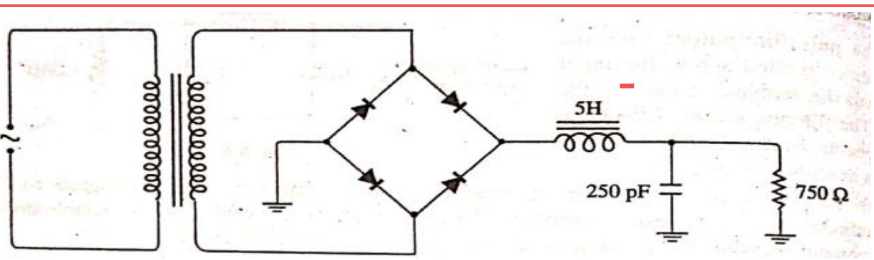
Here,

$V_{p(in)}$ = Peak Rectifier Ful-wave voltage applied to the filter

f = Output frequency

V_{rms} = the root-mean-square (RMS) voltage

Q-8:The choke of Figure has a d.c. resistance of 25Ω. What is the d.c. voltage if the full-wave signal into the choke has a peak value of 25.7V?



Answer:

Solution. The output of a full-wave rectifier has a d.c. component and an a.c. component. Due to the presence of a.c. component, the rectifier output has a pulsating character as shown in Fig. 6.46. The maximum value of the pulsating output is V_m and d.c. component is $V'_{dc} = 2\ V_m/\pi$.

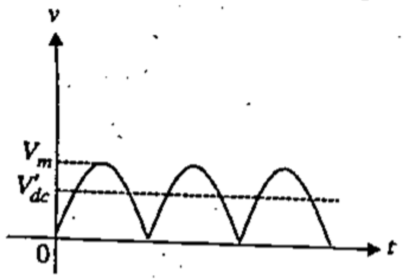


Fig. 6.46

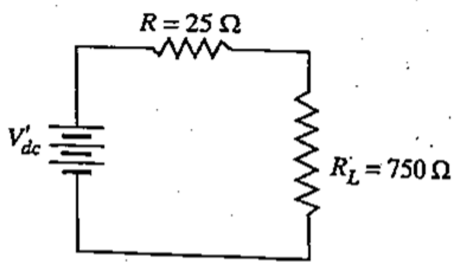


Fig. 6.47

For d.c. component V'_{dc}, the choke resistance is in series with the load as shown in Fig. 6.47.

$$\therefore \quad \text{Voltage across load, } V_{dc} = \frac{V'_{dc}}{R + R_L} \times R_L$$

$$\text{In our example, } V'_{dc} = \frac{2V_m}{\pi} = \frac{2 \times 25.7}{\pi} = 16.4\ \text{V}$$

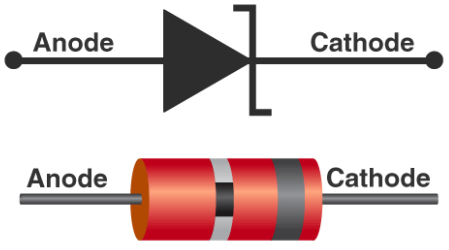
$$\therefore \quad \text{Voltage across load, } V_{dc} = \frac{V'_{dc}}{R + R_L} \times R_L = \frac{16.4}{25 + 750} \times 750 = \mathbf{15.9\ V}$$

The voltage across the load is 15.9 V dc *plus* a small ripple.

<u>Q-9:What is a Zener Diode? Explain how a Zener diode maintains a constant voltage across the load.</u>

Answer:

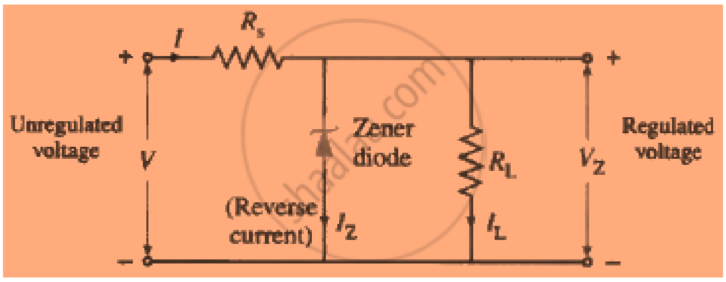
Zener Diode: A Zener diode is a heavily doped semiconductor device that is designed to operate in the reverse direction.



(Zener diode)

A Zener Diode, also known as a **breakdown diode**, is a **heavily doped** semiconductor device that is designed to operate in the **reverse direction**. When the voltage across the terminals of a Zener diode is reversed, and the potential reaches the Zener Voltage (knee voltage), the junction breaks down, and the current flows in the reverse direction. This effect is known as the **Zener Effect**.

Zener diode maintains constant voltage across the load: In the breakdown region of a Zener diode, for widely changing Zener current, the voltage across the Zener diode remains almost constant.



Zener diode as a voltage regulator

Rs - current-limiting resistance,

RL - Load resistance,

Iz - Current through the diode;

***I*L** - Load current

Working: When the input unregulated de voltage *V* across the Zener diode is greater than the Zener voltage ***Vz*** in magnitude, the diode works in the Zener breakdown region. The voltage across the diode and load $\mathbf{R_L}$ is then ***Vz***. The corresponding current in the diode is ***Iz***.

As the load current (*I*) or supply voltage (*V*) changes, the diode current (***Iz***) adjusts itself at constant ***Vz*** The excess voltage *V* — ***Vz*** appears across the series resistance **Rs**, For constant supply voltage, the supply current ***I*** and the voltage drop across **Rs** remain constant. If the diode is within its regulating range, an increase in load current is accompanied by a decrease in ***Iz*** at constant ***Vz***.

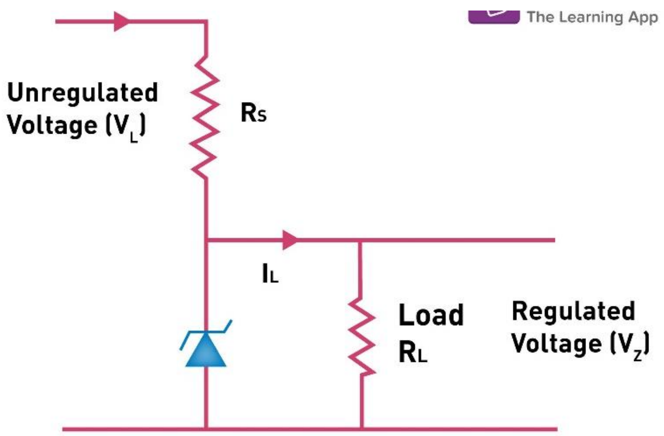
Since the voltage across $\mathbf{R_L}$ remains constant at ***Vz***, the Zener diode acts as a voltage stabilizer or voltage regulator.

Q-10:How does a Zener diode act as a voltage stabilizer?

Answer:

There is a series resistor connected to the circuit in order to limit the current into the diode. It is connected to the positive terminal of the DC. It works in such a way the reverse-biased can also work in breakdown conditions. When the minimum input voltage and the maximum load current is applied, the Zener diode current should always be minimum.

Since the input voltage and the required output voltage is known, it is easier to



choose a Zener diode with a voltage approximately equal to the load voltage, i.e. $V_Z = V_L$.

The value of the series resistor is written as $\mathbf{Rs = (V_L - Vz)I_L}$.

Current through the diode increases when the voltage across the diode tends to increase which results in the voltage drop across the resistor. Similarly, the current through the diode decreases when the voltage across the diode tends to decrease. Here, the voltage drop across the resistor is very less, and the output voltage results normally.

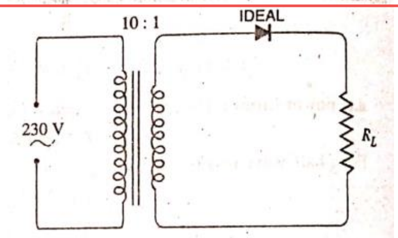
Q-11:Solving Zener diode circuits.

Answer: **[Solve from Article: 6.28 in V.k Mehta]**

Q-12:An AC supply of 230 V is applied to a half-wave rectifier circuit through a transformer of turn ratio 10:1. Find:

1. The output dc voltage?
2. The peak inverse voltage?

Assume the diode to be ideal. (6.11 of V.K Mehta)



Answer:

Solution.

Primary to secondary turns is

$$\frac{N_1}{N_2} = 10$$

R.M.S. primary voltage

$$= 230 \text{ V}$$

$\therefore$ Max. primary voltage is

$$V_{pm} = (\sqrt{2}) \times \text{r.m.s. primary voltage}$$

$$= (\sqrt{2}) \times 230 = 325.3 \text{ V}$$

Max. secondary voltage is

$$V_{sm} = V_{pm} \times \frac{N_2}{N_1} = 325.3 \times \frac{1}{10} = 32.53 \text{ V}$$

(*i*)

$$I_{d.c.} = \frac{I_m}{\pi}$$

$\therefore$

$$V_{dc} = \frac{I_m}{\pi} \times R_L = \frac{V_{sm}}{\pi} = \frac{32.53}{\pi} = 10.36 \text{ V}$$

(*ii*) During the negative half-cycle of a.c. supply, the diode is reverse biased and hence conducts no current. Therefore, the maximum secondary voltage appears across the diode.

$\therefore$ Peak inverse voltage = **32.53 V**

Q-13:A crystal diode having an internal resistance rf = 20Ω is used for half-wave rectification. If the applied voltage v= 50sin(ωt) and load resistance RL = 800Ω, find:

- Im, Idc, Irms
- AC power input and DC power output
- DC output voltage

➢ Efficiency of rectification.

$$v = 50 \sin \omega t$$

$\therefore$ Maximum voltage, $V_m = 50$ V

(i) $$I_m = \frac{V_m}{r_f + R_L} = \frac{50}{20 + 800} = 0.061 \text{ A} = 61 \text{ mA}$$

$$I_{dc} = I_m/\pi = 61/\pi = 19.4 \text{ mA}$$

$$I_{rms} = I_m/2 = 61/2 = 30.5 \text{ mA}$$

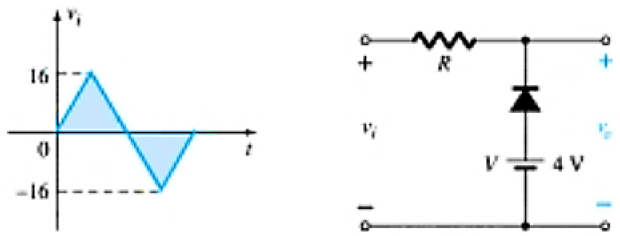
(ii) $$\text{a.c. power input} = (I_{rms})^2 \times (r_f + R_L) = \left(\frac{30.5}{1000}\right)^2 \times (20 + 800) = 0.763 \text{ watt}$$

$$\text{d.c. power output} = I_{dc}^2 \times R_L = \left(\frac{19.4}{1000}\right)^2 \times 800 = 0.301 \text{ watt}$$

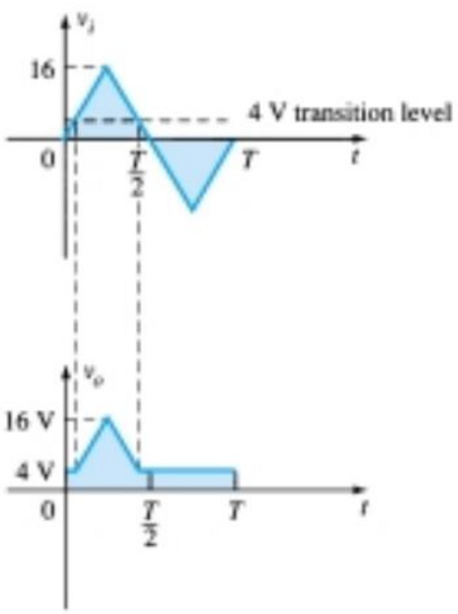
(iii) $$\text{d.c. output voltage} = I_{dc} R_L = 19.4 \text{ mA} \times 800\ \Omega = 15.52 \text{ volts}$$

(iv) $$\text{Efficiency of rectification} = \frac{0.301}{0.763} \times 100 = 39.5\%$$

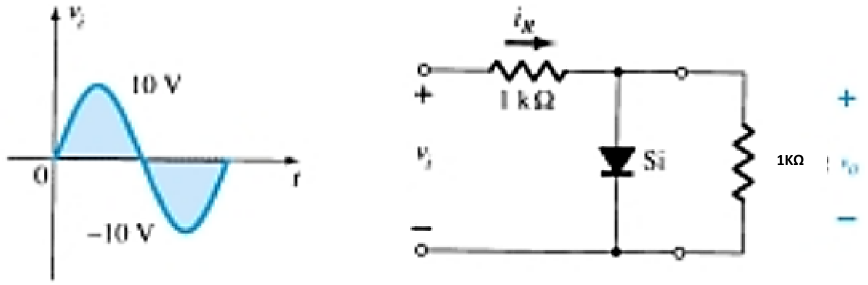
Q-14: Determine Vo for the network of Figure. (Ex: 2.20 Boylsted)



Answer:



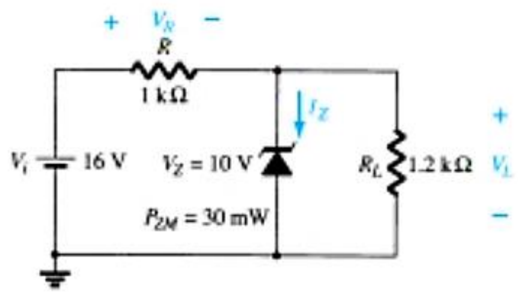
Q-15:For the network of Figure, sketch Vo and IR. (Q:26 Boylsted [page: 124])



Answer: Needed

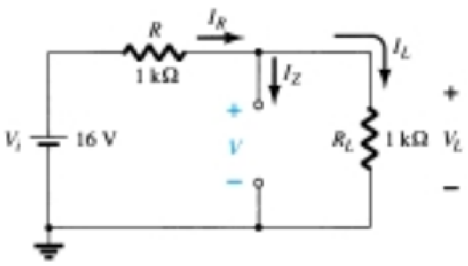
Q-16:For the Zenner diode network of Figure,(Ex: 2.26 Boylsted [page: 94])

- Determine VL, VR, IZ, and PZ
- Repeat part (a) with RL = 3 kΩ



Answer:

(i) Following the suggested procedure the network is redrawn as shown in Fig.



$V = \frac{R_L V_i}{R + R_L} = \frac{1.2 * 16}{1 + 1.2} = 8.73$ V

Since V = 8.73 V is less than V_Z = 10 V, the diode is in the “off” state

$V_L = V = 8.73$ V

$V_R = V_i - V_L = 16$ V - 8.73 V = 7.27 V

$I_Z = 0$ A

$P_Z = V_Z I_Z = V_Z$ (0 A) = 0 W

(ii)

$V = \frac{R_L V_i}{R + R_L} = \frac{3 * 16}{1 + 3} = 12V$

Since V = 12 V is greater than V_Z = 10 V, the diode is in the “on” state

$V_L = V_Z = 10$ V

and $V_R = V_i - V_L = 16$ V - 10 V = 6 V

with $I_L = \frac{V_L}{R_L} = \frac{10}{3} = 3.33$ mA

and $I_R = \frac{V_R}{R} = \frac{6}{1} = 6$ mA

so that $I_Z = I_R = I_L = 6$ mA - 3.33 mA = 2.67 mA

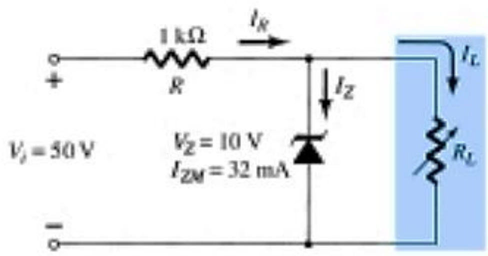
The power dissipated,

$P_Z = V_Z I_Z = (10\text{ V})*(2.67\text{ mA}) = 26.7$ mW

which is less than the specified P_{ZM} = 30 mW

Q-17:For the network of Fig. (Ex: 2.27 Boylsted [page: 96])

- Determine the range of RL and IL that will result in V_(R_L) being maintained at 10 V
- Determine the maximum wattage rating of the diode



Answer:

(i) To determine the value of RL that will turn the Zener diode on,

$$R_{L_{min}} = \frac{RV_Z}{V_i - V_Z} = \frac{1k\Omega * 10V}{50V - 10V} = \frac{10\ k\Omega}{40} = 250\ \Omega$$

The voltage across the resistor R is then determined by

$$V_R = V_i - V_Z = 50\text{ V} - 10\text{ V} = 40\text{ V}$$

the magnitude of I_R,

$$I_R = \frac{V_R}{R} = \frac{40\ V}{1\ k\Omega} = 40\text{ mA}$$

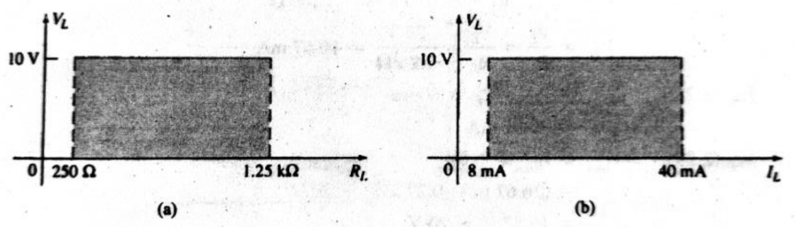
The minimum level of IL is then determined by

$$I_{L_{min}} = I_R - I_{ZM} = 40\text{ mA} - 32\text{ mA} = 8\text{ mA}$$

The maximum value of R_L,

$$R_{L_{max}} = \frac{V_Z}{I_{L_{min}}} = \frac{10\ V}{8\ mA} = 1.25\text{ k}\Omega$$

A plot of V_L versus R_L appears in Fig.**a** and for V_L versus I_L in Fig. **b**



(ii) $P_{max} = V_Z\, I_{ZM} = 10\text{ V} * 32\text{ mA} = 320\text{ mW}$

Set-4: Bipolar Junction Transistors

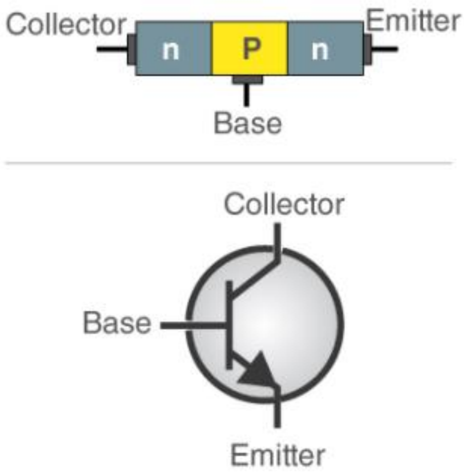
Q-1: Define Transistor? Explain types of transistors.

Answer:

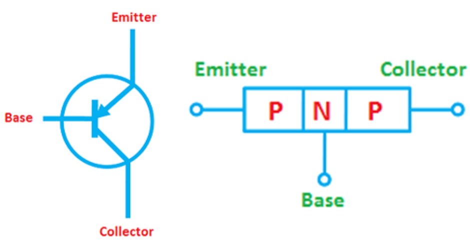
Transistor: A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.

There are two types of transistors, namely

1. **n-p-n transistor:** An n-p-n transistor is composed of two n-type semiconductors separated by a thin section of p-type. Here, electrons are the majority charge carriers, while holes are the minority charge carriers.



2. **p-n-p transistor:** A p-n-p transistor is formed by two p-sections separated by a thin section of n-type. Here, Holes are the majority charge carriers, while electrons are the minority charge carriers.



Q-2:How does a Transistor circuit work as a switch?

Answer:

Transistor acts as a switch.

Answer: The switching action of a transistor can be explained by the output characteristics of a CE circuit. The load line is drawn for the load R_C and collector supply V_{CC}. It can be explained by off region, on region and by active region.

1. **Off region:** When the input voltage is zero or negative then the transistor is said to be in the off condition. In this condition I_B=0 and collector current is equal to the collector leakage current I_{CEO}.

   ∴ Power loss = Output current × Output voltage

   = $V_{CC} \times I_{CEO}$

   Since I_{CEO} is very small and it is negligible, the power loss is very low i.e. the transistor has a high efficiency as a switch in the off condition.

2. **On region:** In on condition, the input voltage is positive. In this condition the saturation collector current is

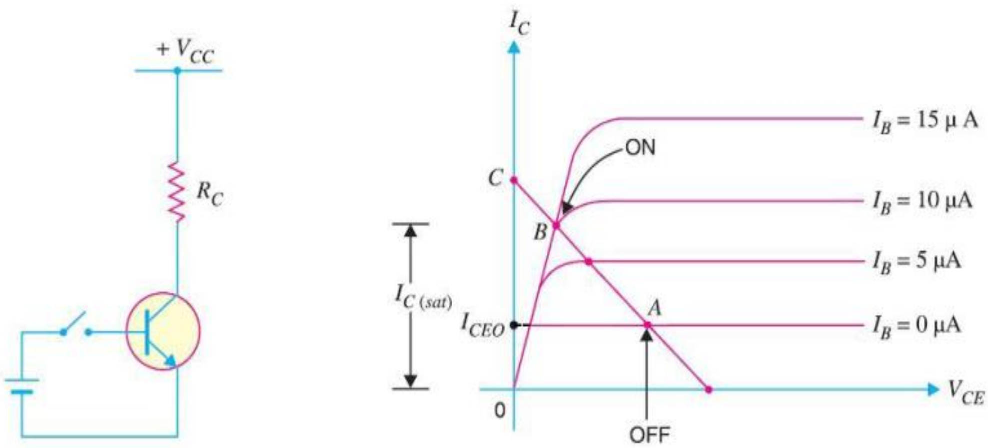
   $I_{C(sat)} = (V_{CC}-V_{knee})/R_C$

   Power loss = Output voltage × Output current

   Output voltage is equal to knee voltage.

   ∴ Power loss = $V_{knee} \times I_{C(sat)}$

   Again the efficiency as a switch in on condition is high.

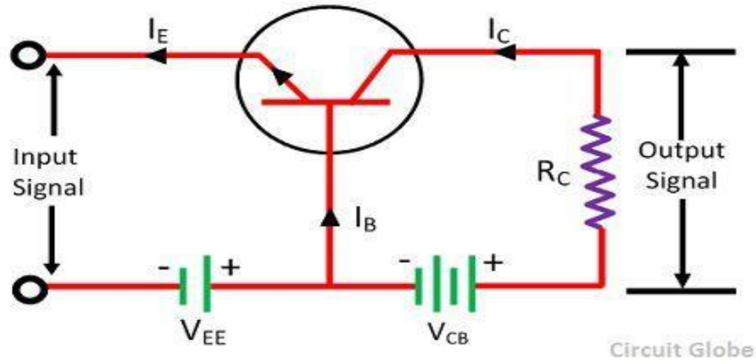


3. **By active region:** It is the region that lies between off and on condition. In this region the transistor operates as a linear amplifier where small changes in input current causes relatively large changes in output current.

Q-3:How does a Transistor circuit work as an Amplifier?

Answer:

The transistor raises the strength of a weak signal and hence acts an amplifier. The transistor amplifier circuit is shown in the figure below. The transistor has three terminals namely emitter, base and collector. The emitter and base of the transistor are connected in forward biased and the collector base region is in reverse bias. The forward bias means the P-region of the transistor is connected to the positive terminal of the supply and the negative region is connected to the N-terminal and in reverse bias just opposite of it has occurred.



The input signal or weak signal is applied across the emitter base and the output is obtained to the load resistor RC which is connected in the collector circuit. The DC voltage VEE is applied to the input circuit along with the input signal to achieve the amplification. The DC voltage VEE keeps the emitter-base junction under the forward biased condition regardless of the polarity of the input signal and is known as a bias voltage.

Q-4:Relation between α and β.

Relation between β and α:

We know,

$$I_E = I_C + I_B$$

or, $$I_B = I_E - I_C$$

From the definition of amplification factor of common emitter,

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

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

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

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

$$= \frac{\alpha}{1-\alpha} \qquad [\because \alpha = \frac{\Delta I_C}{\Delta I_E}]$$

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

This is the relation between β and α.

Relation between α and β:

We know,

$$I_E = I_C + I_B$$

From the definition of amplification factor of common base,

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

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

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

$$= \frac{\frac{\Delta I_C}{\Delta I_B}}{\frac{\Delta I_C}{\Delta I_B} + 1}$$

$$= \frac{\beta}{\beta+1} \qquad [\because \beta = \frac{\Delta I_C}{\Delta I_B}]$$

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

This is the relation between α and β.

Q-5:Define Operating Point.

Answer:

Operating Point: The zero signal values of I_C and V_{CE} are known as the Operating Point.

An operating point (also known as a **quiescent point** or **Q-point**) is the point in the transfer characteristics of an electronic circuit where it is operating under steady-state conditions. The operating point is typically determined by the DC biasing of the circuit.

Q-6:What is Cut off, Saturation point, and Active Region?

Answer:

The three main regions of operation of a transistor are cutoff, saturation, and active.

- **Cutoff region:** In this region, the transistor is turned off. There is no current flowing through the collector and emitter, and the voltage between the collector and emitter is equal to the supply voltage.
- **Saturation region:** In this region, the transistor is turned on fully. The collector and emitter are essentially short-circuited, and the voltage between the collector and emitter is very small.
- **Active region:** In this region, the transistor is amplified. The collector current is proportional to the base current, and the voltage between the collector and emitter is between the cutoff voltage and the saturation voltage.

Here is a table summarizing the three regions of operation:

Region	**Collector current**	**Collector- emitter Voltage**	**Base current**
Cutoff	0	VCC	0
Saturation	I_C (Saturation)	V_{CE} (Saturation)	I_B (Saturation)
Active	$I_C = \beta I_B$	V_{CE} (Active)	I_B

where:

I_C is the collector current

V_{CE} is the collector-emitter voltage

V_B is the base current

β is the transistor's gain

Q-7: What is Faithful Amplification? Discuss the basic condition of Faithful Amplification.

Answer:

Faithfull Amplification: the process of raising the strength of a weak signal without any change in it general shape is known as Faithful Amplification.

There are three basic conditions that must be met in order to achieve faithful amplification:

1. **Proper zero signal collector current:** The value of zero signal collector current should be at least equal to the maximum collector current due to signal alone. This ensures that the transistor is always in the active region, even when there is no input signal.
2. **Proper base-emitter voltage at any instant:** The base-emitter voltage must be greater than 0.5 V for germanium transistor and 0.7 V for silicon transistor at any instant. If the voltage decreases beyond this potential barrier voltage, it will result in unfaithful amplification.
3. **Proper collector-emitter voltage at any instant:** The collector-emitter voltage should not fall below 0.5 V for germanium and 1 V for silicon transistors. This is called knee voltage. If the collector-emitter voltage falls below this value, the transistor will not be able to amplify the signal properly.

Q-8:What is the Stability Factor? Write down the Formula of the Stability Factor.

Answer:

Stability Factor: Stability factor is a measure of how well an operational amplifier (op-amp) can maintain its output voltage in the presence of changes in its input voltage. It is defined as the ratio of the change in output voltage to the change in input voltage, with all other parameters held constant.

Formula of Stability Factor:

The rate of change of collector current I_C with respect to the collector leakage current *I_{CO} at constant and I_B is called stability factor i.e.

Stability Factor, S= $\frac{dI_C}{dI_{CO}}$ at constant I_B and β

Q-9:What is Transistor Biasing? Draw Transistor Biasing method diagrams. (Article: 9.2, 9.7 V.K Mehta)

Or, Draw the four methods of transistor biasing circuit.

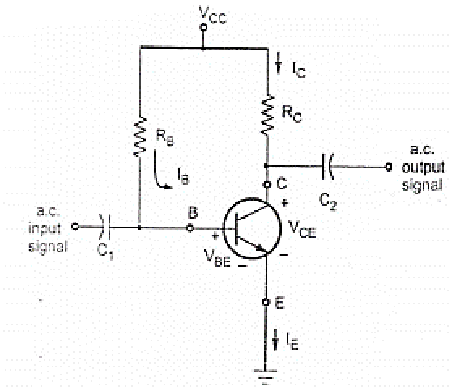
Answer:

Transistor Biasing: Transistor biasing is the process of setting the DC operating conditions of a transistor so that it can amplify or switch signals effectively.

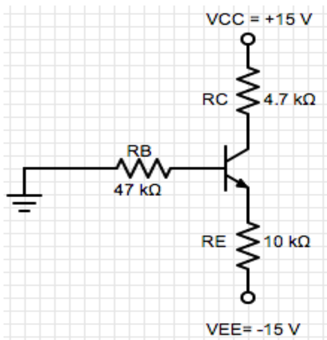
The biasing circuit must provide the correct amount of base current, IB, and collector current, IC, to the transistor so that it operates in its desired region.

Transistor Biasing methods: The commonly used methods of transistor biasing are

1. **Base Bias/ Fixed Bias**



2. **Emitter Bias / Self Bias**



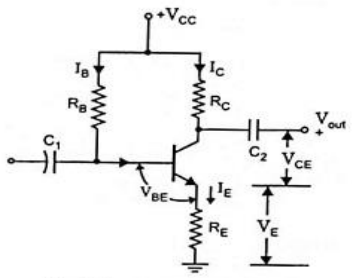
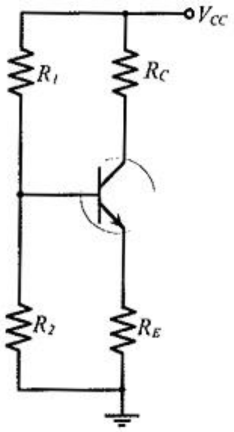
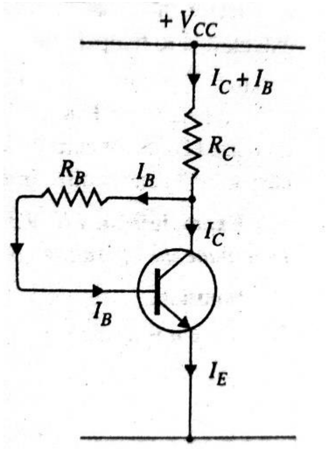


Fig. 12.9 *Emitter Bias Circuit*

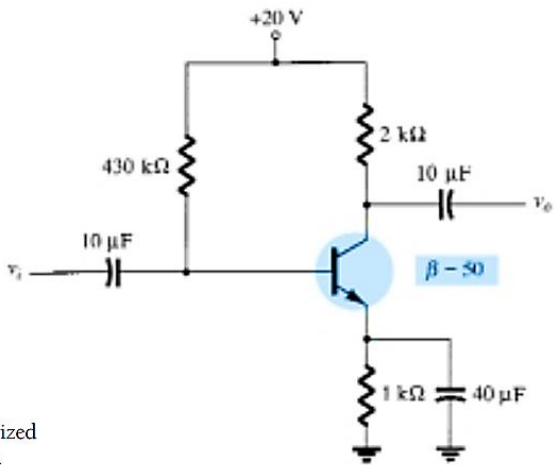
3. Voltage Divider Bias



4. Collector Feedback Bias



Q-10: For the emitter-bias network, determine:



ilized
4.

- IB, IC, VCE, VC, VE, VB, VBC.

Answer:

(a) Eq. (4.17): $$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{20\text{ V} - 0.7\text{ V}}{430\text{ k}\Omega + (51)(1\text{ k}\Omega)}$$
$$= \frac{19.3\text{ V}}{481\text{ k}\Omega} = \mathbf{40.1\ \mu A}$$

(b) $I_C = \beta I_B$
$= (50)(40.1\ \mu\text{A})$
$\cong \mathbf{2.01\ mA}$

(c) Eq. (4.19): $V_{CE} = V_{CC} - I_C(R_C + R_E)$
$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega + 1\text{ k}\Omega) = 20\text{ V} - 6.03\text{ V}$
$= \mathbf{13.97\ V}$

(d) $V_C = V_{CC} - I_C R_C$
$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega) = 20\text{ V} - 4.02\text{ V}$
$= \mathbf{15.98\ V}$

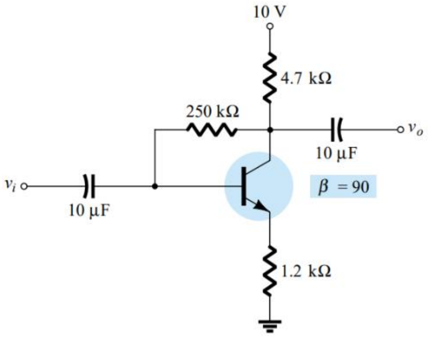
(e) $V_E = V_C - V_{CE}$
$= 15.98\text{ V} - 13.97\text{ V}$
$= \mathbf{2.01\ V}$

or $V_E = I_E R_E \cong I_C R_E$
$= (2.01\text{ mA})(1\text{ k}\Omega)$
$= \mathbf{2.01\ V}$

(f) $V_B = V_{BE} + V_E$
$= 0.7\text{ V} + 2.01\text{ V}$
$= \mathbf{2.71\ V}$

(g) $V_{BC} = V_B - V_C$
$= 2.71\text{ V} - 15.98\text{ V}$
$= \mathbf{-13.27\ V}$ (reverse-biased as required)

Q-11:Determine the quiescent levels of I_{CQ} and V_{CEQ} for the network shown.



Answer:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$

$$= \frac{10\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)}$$

$$= \frac{9.3\text{ V}}{250\text{ k}\Omega + 531\text{ k}\Omega} = \frac{9.3\text{ V}}{781\text{ k}\Omega}$$

$$= 11.91\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B = (90)(11.91\ \mu\text{A})$$

$$= \mathbf{1.07\ mA}$$

$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$

$$= 10\text{ V} - (1.07\text{ mA})(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)$$

$$= 10\text{ V} - 6.31\text{ V}$$

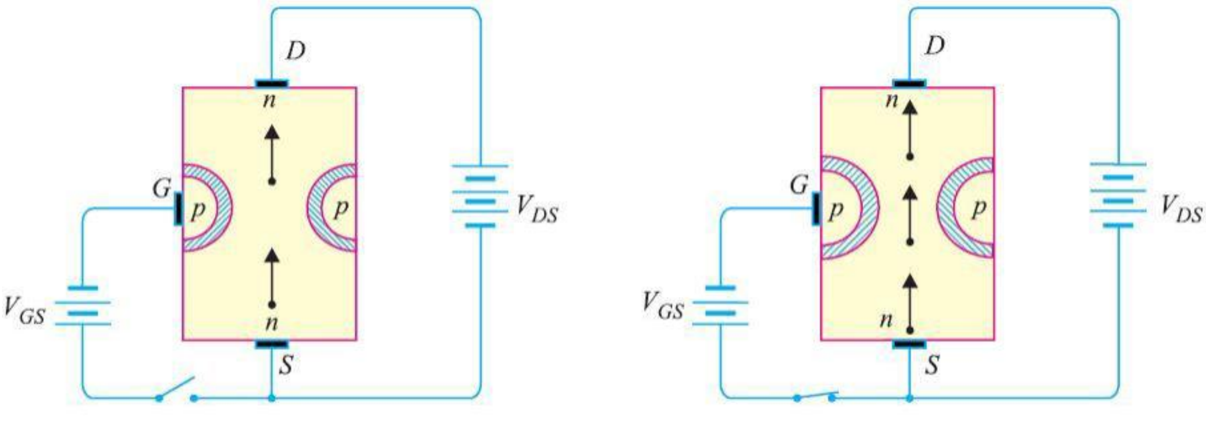
$$= \mathbf{3.69\ V}$$

Set-5: Field Effect Transistor (FET)

Q-1: Working Principle of JFET. and Uses. Extra:MOSFEET

Answer:

The working of JFET can be explained as follows:



(i) (ii)

Case-1: When a voltage $\mathbf{V_{DS}}$ is applied **drain** and **source** terminals and voltage on the **gate** is 0. The two PN junction at the sides of the bar establish deflation layers. The electrons will flow from **source** to **drain** through a channel between the deflation layers. The size of these layers determines the width of the channel and here the current conduction through the bar.

Case-2: When a reverse voltage $\mathbf{V_{GS}}$ is applied between the **gate** and **source**, the width of the depletion layers is increased. This reduces the width of conducting channel, thereby increasing the resistance of n-type bar competency the current from **source** to **drain** is decreased. On the other hand, if the reverse voltage on the **gate** is decreased, the width of the depletion layers also decreases. This increases the width of the conducting channel and hence **source** to **drain** current.

Q-2:Salient Features of JFET. Discuss the working principle of JFET with necessary diagram.

Answer:Here are some of the **salient features of JFET** (Junction Field Effect Transistor):

- A JFET is a three-terminal voltage-controlled semiconductor device i.e . input voltage controls the output characteristics of JFET.
- The JFET is always operated with gate-source pn junction *reverse biased.
- In a JFET, the gate current is zero i.e. $I_G = 0$ A.
- Since there is no gate current, $I_D = I_S$.
- The JFET must be operated between $V_{GS} = 0$ V and $V_{GS(off)}$. For this range of gate-to-source voltages, I_D will vary from a maximum of I_{DSS} to a minimum of almost zero.
- Because the two gates are at the same potential, both depletion layers widen or narrow down by an equal amount.
- The JFET is not subjected to thermal runaway when the temperature of the device increase.
- The drain current I_D is controlled by changing the channel width.

The working principle

- JFET involves the control of current flow through the channel between the source and the drain by varying the voltage applied to the gate terminal. The gate of a JFET is formed by a p-n junction, which creates a depletion region in the channel when it is reverse biased. When no voltage is applied to the gate, the channel is open and current flows freely between the source and drain. However, when a negative voltage is applied to the gate, the depletion region widens and reduces the cross-sectional area of the channel, thus reducing the current flow.
- There are two types of JFETs: n-channel and p-channel. In an n-channel JFET, the channel is made up of n-type semiconductor material and the gate is made up of p-type semiconductor material. In a p-channel JFET, the channel is made up of p-type semiconductor material and the gate is made up of n-type semiconductor material.
- JFETs have high input impedance and low noise, making them suitable for use in amplifiers, switches, and other electronic applications where low power consumption and high performance are important.

Necessary diagram:

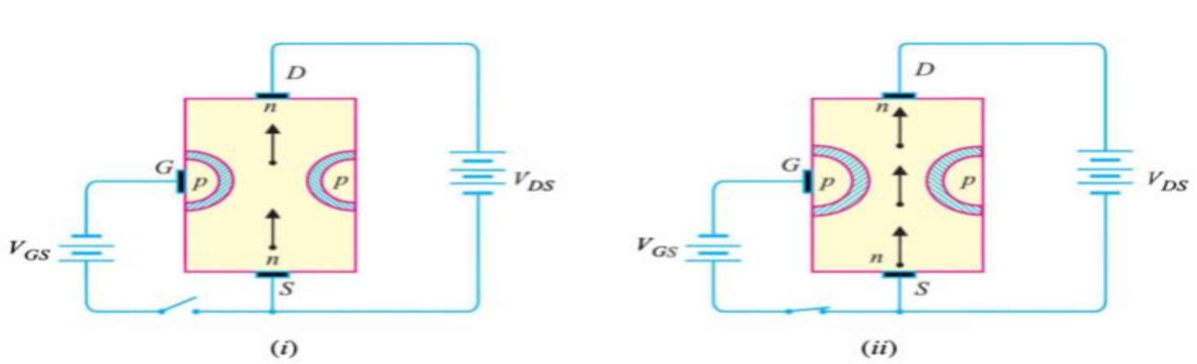


Fig. 19.3

Q-3:Write down the differences between BJT and FET.

Answer:

BJT	JFET
1. Both hole and electron take part to current conduction.	1. Either hole or electron takes part to current conduction.
2. It is called bipolar transistor.	2. It is called unipolar transistor.
3. Input circuit is always forward biased.	3. Input circuit is reverse biased.
4. Input impedance is low.	4. Input impedance is high.
5. In BJT base controls the current flow.	5. In JFET gate controls the current flow.
6. There are two junctions in BJT.	6. No junction is applied in JFET.
7. The base current might be μA.	7. The gate current is zero.
8. Noise level is high from JFET.	8. Boise level is very low or small.
9. Symbol	9. Symbol

Q-4:What is transistor biasing? Why biasing is necessary for BJT transistor?

Answer:

Transistor biasing is the process of setting up the correct operating conditions for a transistor circuit or device. It involves applying the appropriate voltage or current to the transistor's terminals to establish a desired DC operating point.

Biasing is necessary for Bipolar Junction Transistors (BJTs) for several reasons:

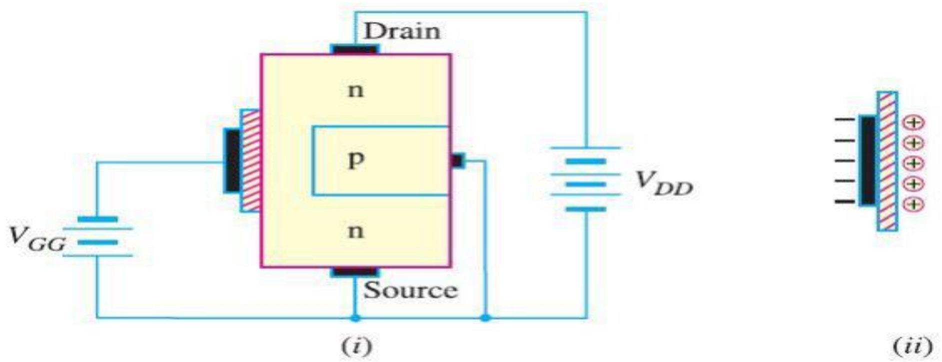
1. Stability: Proper biasing ensures that the transistor operates in a stable region and remains in a desired operating point, preventing any unwanted fluctuations.
2. Amplification: A BJT operates as an amplifier only when it is biased properly. Biased in the active region, a BJT exhibits a linear relationship between input and output, enabling efficient signal amplification.
3. Linearity: Biasing helps achieve linearity in the amplification process. A properly biased BJT ensures a linear response to small signal variations without distortion.
4. Thermal Stability: Transistors generate heat during operation, and biasing helps maintain thermal stability by setting a proper quiescent (no input signal) current that compensates for variations due to temperature changes.
5. Operating Point: Biasing establishes the required operating point or quiescent point, which determines the voltage and current levels at which the transistor operates. This point is crucial for achieving the desired transistor behavior.

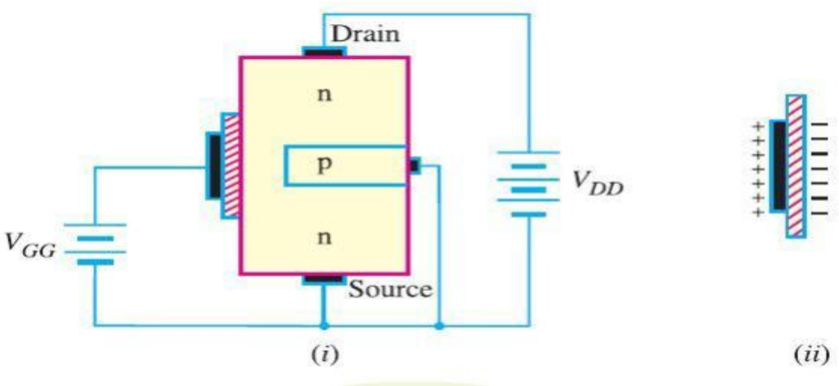
Q-5:Explain the circuit operation of DE-MOSFET with characteristics curve.

Answer:

A depletion-mode MOSFET (D-MOSFET) is a type of MOSFET that is turned on by default. This means that there is a small current flowing between the source and drain terminals even when the gate terminal is at 0 volts. The drain current can be increased by applying a positive voltage to the gate terminal.

The circuit operation of a D-MOSFET can be explained with the help of the following diagram:





Q-:For the JFET amplifier circuit shown in the figure, calculate the voltage gain with

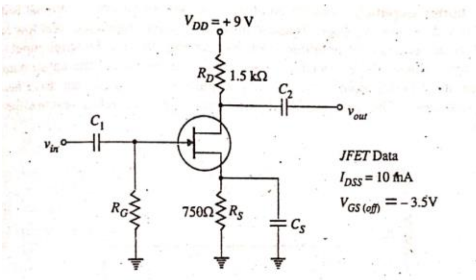


Fig. 19.40

- RS bypassed by a capacitor and
- RS unbypassed.

Answer:

Solution. From the d.c. bias analysis, we get, $^*I_D = 2.3$ mA and $V_{GS} = -1.8$V.

The value of g_m is given by;

$$g_m = \frac{2\,I_{DSS}}{|V_{GS\,(off)}|}\left(1 - \frac{V_{GS}}{V_{GS\,(off)}}\right)$$

$$= \frac{2\times 10}{3.5}\left(1 - \frac{-1.8}{-3.5}\right) = (5.7 \text{ mS})\,(0.486) = 2.77 \text{ mS}$$

(i) The voltage gain with R_S bypassed is

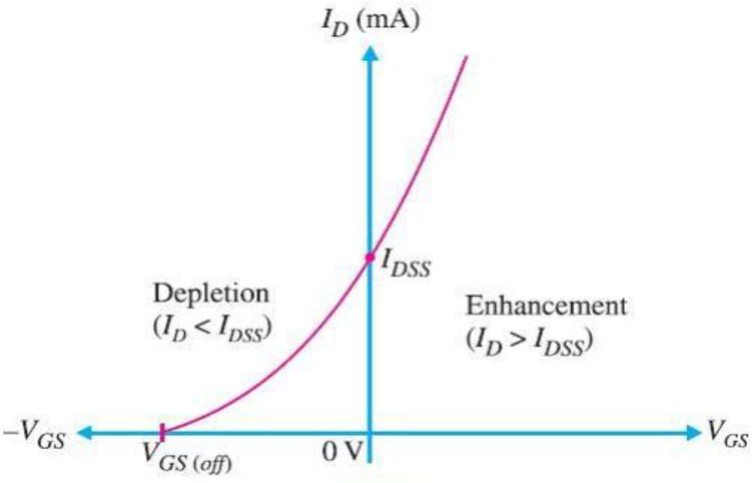
$$A_v = g_m R_D = (2.77 \text{ mS})\,(1.5 \text{ k}\Omega) = 4.155$$

(ii) The voltage gain with R_S unbypassed is

$$A_v = \frac{g_m R_D}{1 + g_m R_S} = \frac{4.155}{1 + (2.77 \text{ mS})\,(0.75 \text{ k}\Omega)} = 1.35$$

Q-4:D-MOSFET transfer characteristics.

Answer:



The transfer characteristic curve (ortransconductance curve) for n-channel D-MOSFET is shown in the figure below. The behavior of this device can be

beautifully explained with the help of this curve as under:

(i) The point on the curve where VGS=0, ID=IDDS. It is expected because IDDS is the value of ID when gate and source terminals are shorted i.e. VGS=0.

(ii) As VGS goes negative, ID decreases below the value of IDDS till ID reaches zero when VGS=VGS(off) just as with JFET.

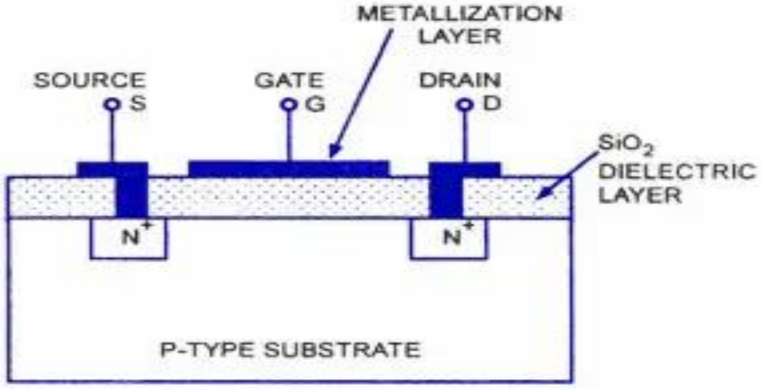
(iii) When VGS is positive, ID increases above the value of IDDS. The maximum allowable value of ID is given on the data sheet of D-MOSFET.

Q-5:What is E-MOSFET? Describe the operational diagram of E-MOSFET and the Equation of Transconductance Curve of E-MOSFET.

Answer:

E-MOSFET: Enhancement MOSFET or **E-MOSFET** is a type of MOSFET where there is no channel constructed during its fabrication but it is induced in the substrate using the gate voltage. The E-MOSFET does not conduct when there is no gate voltage i.e. VGS= 0v. Therefore, E-MOSFET is also known as normally OFF transistor.

Operational Diagram of E-MOSFET: The diagram shows the three terminals of an E-MOSFET: the source (S), the drain (D), and the gate (G). The source and drain are connected to the semiconductor substrate, and the gate is separated from the substrate by an insulating layer.

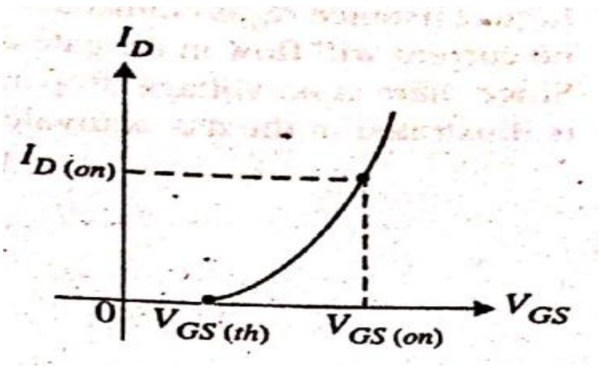


When the gate voltage is zero, there is no channel between the source and drain, and the transistor is OFF. When a positive voltage is applied to the gate, it creates an inversion layer of carriers in the substrate, which forms a channel between the source and drain. The current flows between the source and drain when the gate voltage is greater than the threshold voltage.

The operational diagram of an E-MOSFET can be divided into three regions:

1. **Cutoff region:** In this region, the drain current is zero. This is because the gate voltage is below the threshold voltage, which is the voltage required to turn on the transistor.
2. **Linear region:** In this region, the drain current increases linearly with the gate-source voltage. This is because the channel is already formed and the gate-source voltage is simply increasing the number of carriers in the channel.
3. **Saturation region:** In this region, the drain current reaches a maximum value and does not increase further with the gate-source voltage. This is because the channel is fully saturated and the gate-source voltage cannot increase the number of carriers in the channel any further.

Transconductance Equation of EMOSFET:



$$I_D = K(V_{GS} - V_{GS\,(th)})^2$$

Q-7: Applications and Characteristics of JFET and MOSFET.

Answer:

Some applications of JFET are listed below:

- JFET is used as a switch
- JFET is used as a chopper
- JFET is used as a buffer
- JFETs are used in oscillatory circuits
- JFETs are used in cascade amplifiers

Some important applications of MOSFET are given below:

- MOSFET is used for some switching applications and in electronics device.
- It is used in some amplifying circuits.
- It is used in chopper circuits
- MOSFET can be used as a high-frequency amplifier.
- It can be used in voltage regulator circuits.
- It is used as an inverter in some of the electronics circuits.
- It can be used as a passive element e.g. resistor, inductor used in a circuit.

Here are some of the characteristics of JFETs:

- **High input impedance:** The input impedance of a JFET is very high, typically in the range of 100 MΩ to 1 GΩ. This means that the JFET is not very susceptible to noise from other parts of the circuit.
- **Low output impedance:** The output impedance of a JFET is typically in the range of 10 Ω to 100 Ω. This means that the JFET can be used to drive a relatively large load.
- **Linear operation:** JFETs can be operated in a linear region, where the output current is proportional to the input voltage. This makes JFETs suitable for use as amplifiers.

- **Low noise:** JFETs are relatively low-noise devices. This makes them suitable for use in applications where noise is a concern, such as audio amplifiers.

Here are some of the characteristics of MOSFETs:

- **High input impedance:** The input impedance of a MOSFET is very high, typically in the range of 100 GΩ to 1 TΩ. This means that the MOSFET is not very susceptible to noise from other parts of the circuit.
- **Low output impedance:** The output impedance of a MOSFET is typically in the range of 10 Ω to 100 Ω. This means that the MOSFET can be used to drive a relatively large load.
- **Linear operation:** MOSFETs can be operated in a linear region, where the output current is proportional to the input voltage. This makes MOSFETs suitable for use as amplifiers.
- **Fast switching speed:** MOSFETs have a fast-switching speed, typically in the range of nanoseconds. This makes MOSFETs suitable for applications where fast switching is required.

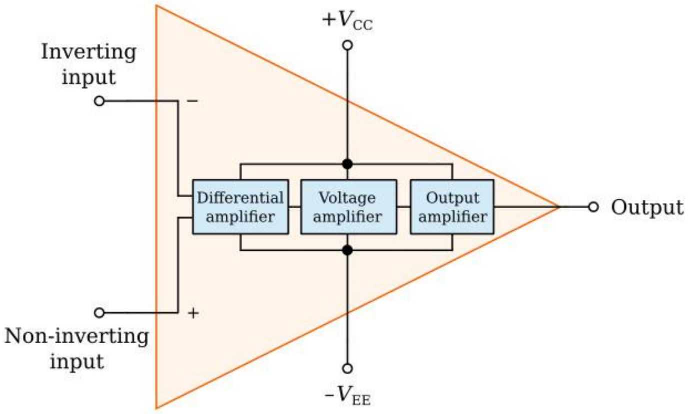
Low power consumption: MOSFETs consume less power than other types of transistors, such as bipolar junction transistors (BJTs). This makes MOSFETs suitable for applications where power consumption is a concern

Set-6: Feedback Techniques and Operational Amplifiers (Op-amps)

Q-1:What is an Operational Amplifier (OP-amp)? Describe the block diagram of an OP-amp.

Answer:

Operational Amplifier: An operational amplifier (op amp) is an analog circuit block that takes a differential voltage input and produces a single-ended voltage



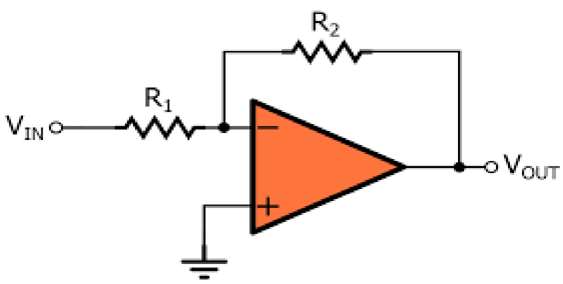
output.

The op-amp begins with a differential amplifier stage, which operates in the differential mode. Thus the inputs noted with '+' & '- ' . The positive sign is for the non-inverting input and negative is for the inverting input. The non-inverting input is the ac signal (or dc) applied to the differential amplifier which produces the same polarity of the signal at the output of op-amp. The inverting signal input is the ac signal (or dc) applied to the differential amplifier. This produces a 180 degrees out of phase signal at the output.

Q-2:What is Inverting Operational Amplifier and Non-Inverting Operational Amplifier? (Article: 25.4 & Article: 25.26 V.K Mehta)

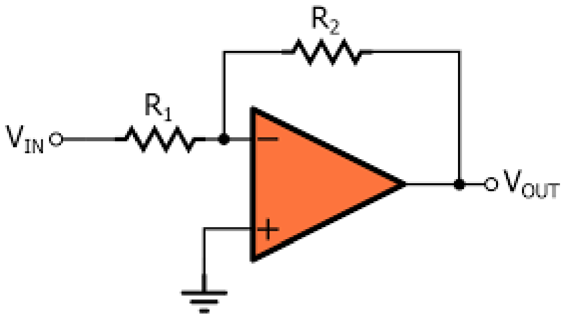
Answer:

Inverting Operational Amplifier: An inverting op amp is an operational amplifier circuit with an output voltage that changes in the opposite direction as the input voltage. In other words, it is out of phase by 180̊.



Non-Inverting Operational Amplifier: A non-inverting op amp is an operational amplifier circuit with an output voltage that is in phase with the input voltage. Its complement is the inverting op amp, which produces an output signal that is 180° out of phase.

This means that if the input pulse is positive, then the output pulse will be negative and vice versa.



Q-3:Find the output voltage for the circuit shown in the figure.

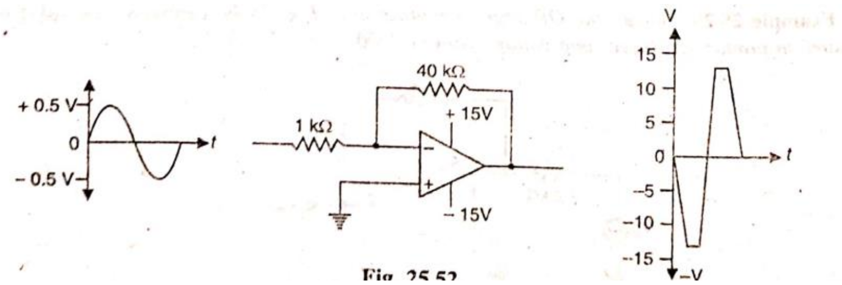


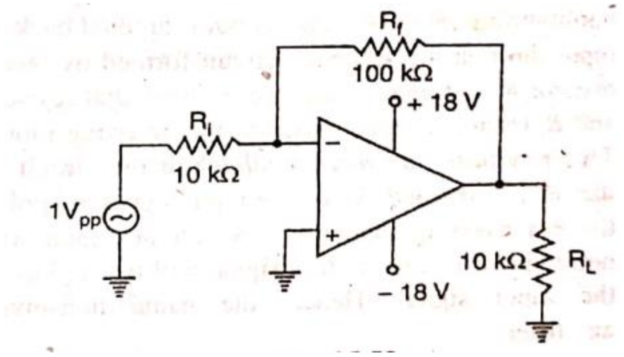
Fig. 25.52

Answer:

$$\text{Voltage gain, } A_{CL} = -\frac{R_f}{R_i} = -\frac{40\text{ k}\Omega}{1\text{ k}\Omega} = -40$$

Note that the input signal is the same as in example 25.27 but now the voltage gain is −40 instead of −1. Since the supply voltages are ± 15 V, the *saturation occurs at ± 13 V. Since the output voltage far exceeds the saturation level, the *OP*-amp will be driven to deep saturation and it will behave as a non-linear amplifier. This means that the output will not have the same shape as input but will clip at the saturation voltage. Note that 180° phase inversion does occur.

Q-4:For the circuit shown in the figure,



- find the closed-loop voltage gain,
- input impedance, and the maximum operating frequency.
- The slew rate is 0.5V/µs.

Answer:

(i) Closed-loop voltage gain, $A_{CL} \;=\; -\dfrac{R_f}{R_i} = -\dfrac{100\text{ k}\Omega}{10\text{ k}\Omega} = -10$

(ii) The input impedance Z_i of the circuit is

$$Z_i \simeq R_i = 10\text{ k}\Omega$$

(iii) To calculate the maximum operating frequency (f_{max}) for this inverting amplifier, we need to determine its peak output voltage. With values of $V_{in} = 1\ V_{pp}$ and $A_{CL} = 10$, the peak-to-peak output voltage is

$$V_{out} = (1V_{pp})\,(A_{CL})$$
$$= (1V_{pp}) \times 10 = 10\ V_{pp}$$

Therefore, the peak output voltage is

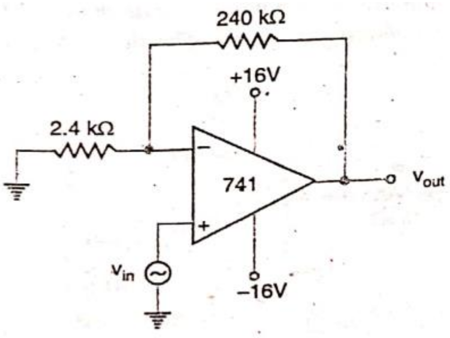
$$V_{pk} = 10/2 = 5\text{ V}$$

$$\therefore \quad f_{max} = \frac{\text{Slew rate}}{2\pi V_{pk}} = \frac{0.5\text{ V}/\mu\text{s}}{2\pi \times 5}$$

$$= \frac{500\text{ kHz}}{2\pi \times 5} = 15.9\text{ kHz}$$

$(\because\ 0.5\text{ V}/\mu\text{s} = 500\text{ kHz})$

Q-5:Calculate the output voltage from the non-inverting amplifier circuit shown in the figure, for an input of 120 µV.



Answer:

Solution. Voltage gain, $A_{CL} = 1 + \dfrac{R_f}{R_i} = 1 + \dfrac{240\ \text{k}\Omega}{2.4\ \text{k}\Omega} = 1 + 100 = 101$

Output voltage, $v_{out} = A_{CL} \times v_{in} = (101) \times (120\ \mu\text{V}) = \mathbf{12.12\ mV}$

Q-6:What is the need for negative feedback in an OP-amp?

Answer:

Negative feedback is used in op-amps for a number of reasons, including:

- **To reduce the gain of the amplifier**. The open-loop gain of an op-amp is very high, which can lead to instability. Negative feedback can be used to reduce the gain of the amplifier, making it more stable.
- **To improve the bandwidth of the amplifier**. The bandwidth of an amplifier is the range of frequencies that it can amplify without distortion. Negative feedback can be used to improve the bandwidth of the amplifier by reducing the gain at high frequencies.
- **To reduce the distortion of the amplifier**. Distortion is the introduction of unwanted signals into the output of an amplifier. Negative feedback can be used to reduce the distortion of the amplifier by averaging out the output signal.
- **To make the amplifier more linear**. The linearity of an amplifier is the degree to which it amplifies the input signal without changing its shape. Negative feedback can be used to make the amplifier more linear by reducing the gain at high frequencies.
- **To stabilize the amplifier**. The stability of an amplifier is its ability to maintain its output voltage even when the input signal changes. Negative feedback can be used to stabilize the amplifier by reducing the gain at high frequencies.

Q-7: What is a voltage follower?

Answer:

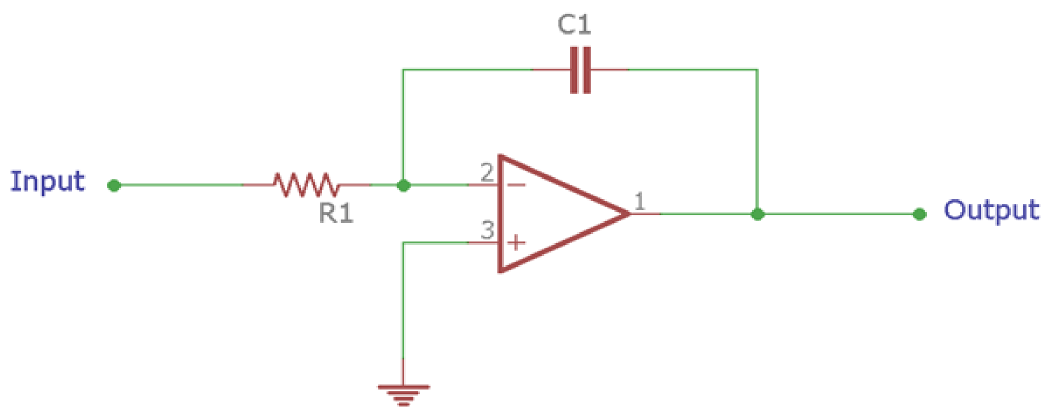
Voltage Follower: A voltage follower (also known as a buffer amplifier, unity-gain amplifier, or isolation amplifier) is an op-amp circuit whose output voltage is equal to the input voltage (it "follows" the input voltage).

Q-8: Discuss the operation of an OP-amp integrator.

Answer:

OP-amp Indicator: An op-amp integrator is an electronic circuit that performs the mathematical operation of integration with respect to time. That is, its output voltage is proportional to the integral of the input voltage over time.

Construction and Working of Op-amp Integrator Circuit: Op-amp is very widely used component in Electronics and is used to build many useful amplifier circuits.



The construction of simple Integrator circuit using op-amp requires two passive components and one active component. The two passive components are resistor and capacitor. The Resistor and the Capacitor form a first-order low pass filter across the active component Op-Amp. Integrator circuit is exactly opposite of Op-amp differentiator circuit.

A simple Op-amp configuration consists of two resistors, which creates a feedback path. In the case of Integrator amplifier, the feedback resistor is changed with a capacitor.

In the above image, a basic integrator circuit is shown with three simple components. The resistor R1 and capacitor C1 is connected across the amplifier. The amplifier is in Inverting configuration.

Op-amp gain is Infinite; therefore, the Inverting input of the amplifier is a virtual ground. When a voltage is applied across the R1, the current start to flow through the resistor as the capacitor has very low resistance. The capacitor is connected in the feedback position and the resistance of the capacitor is insignificant.

At this situation, if the amplifier gain ratio is calculated, the result will be less than the unity. This is because the gain ratio, XC/R1 is too small. Practically, the capacitor has very low resistance between the plates and whatever the value R1 holds, the output result of XC/R1 will be very low.

The capacitor begins to charge up by the input voltage and in the same ratio, the capacitor impedance also starts to increase. The charging rate is determined by the RC - time constant of R1 and C1. The op-amp virtual earth now hampered and the negative feedback will produce an output voltage across the op-amp to maintain the virtual earth condition across the input.

The Op-amp produce a ramp output till the capacitor gets fully charged. The capacitor charges current decreases by the influence of the potential difference between the Virtual earth and the negative output.

Q-9:Discuss the operation of an OP-amp differentiator.

Answer:’

OP-amp differentiator: An op-amp differentiator is a circuit that performs the mathematical operation of differentiation on an input signal. The output of the differentiator is proportional to the rate of change of the input signal.

The basic circuit of an op-amp differentiator consists of an operational amplifier, a resistor, and a capacitor. The resistor is connected between the inverting input of the operational amplifier and ground, and the capacitor is connected between the non-inverting input of the operational amplifier and the input signal.

The operation of the differentiator can be understood by considering the transfer function of the circuit. The transfer function of the differentiator is given by:

$$\mathbf{V_{out} = - RC * V_{in}/t}$$

where:

V_{out} is the output voltage of the differentiator

V_{in} is the input voltage of the differentiator

RC is the time constant of the differentiator

V_{in}/t is the rate of change of the input voltage

The transfer function shows that the output voltage of the differentiator is proportional to the rate of change of the input voltage. The larger the value of RC, the slower the differentiator will respond to changes in the input voltage.

The differentiator can be used to measure the frequency components of a signal. The output of the differentiator will be high for frequencies that are close to the cutoff frequency of the differentiator. The cutoff frequency of the differentiator is given by:

$$fC = 1/(2 * pi * RC)$$

where:

fC is the cutoff frequency of the differentiator

RC is the time constant of the differentiator

The differentiator can also be used to generate sawtooth waves. A sawtooth wave is a waveform that has a constant slope. The differentiator can be used to generate a sawtooth wave by applying a square wave to the input of the differentiator.

The differentiator is a versatile circuit that can be used for a variety of applications. It is often used in signal processing, where it can be used to measure the frequency components of a signal or to generate sawtooth waves.

Here are some of the applications of op-amp differentiator:

- Measuring the frequency components of a signal
- Generating sawtooth waves
- Detecting edges in signals
- Suppressing low-frequency noise
- Enhancing high-frequency signals

Set-7: Power Electronics and Oscillators

Q-1: What is Power Electronics? Discuss the importance of Power Electronics.

Answer:

Power Electronics: The branch of electronics which deals with the control of power at 50 Hz (i.e supply frequency) is known as power electronics.

The importance of Power Electronics: Power electronics is used in a wide variety of applications, including:

- **Power supplies:** Power supplies are used to convert AC power from the mains to DC power for use in electronic devices. Power electronics is used to design efficient and reliable power supplies.
- **Motor drives:** Motor drives are used to control the speed and torque of electric motors. Power electronics is used to design efficient and powerful motor drives.
- **Lighting:** Power electronics is used to control the brightness and color of light sources. This is used in LED lighting and fluorescent lighting.
- **Uninterruptible power supplies:** Uninterruptible power supplies (UPSs) are used to provide backup power in case of a power outage. Power electronics is used to design efficient and reliable UPSs.
- **Solar and wind power:** Power electronics is used to convert the power from solar and wind sources into AC power that can be used in the grid.

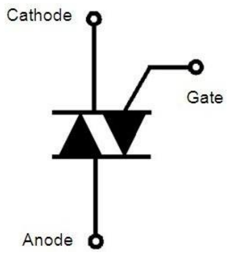
Here are some of the benefits of power electronics:

- Efficiency: Power electronics can help to improve the efficiency of power converters, which can lead to significant savings in energy costs.
- Reliability: Power electronics can help to improve the reliability of power converters, which can help to reduce the number of power outages.
- Control: Power electronics can be used to control the power output of devices, which can be used to improve the performance of devices or to meet specific requirements.
- Compactness: Power electronics can be used to design smaller and more compact power converters, which can be used in a wider range of applications.

Q-2: What is a Triac & Diac?

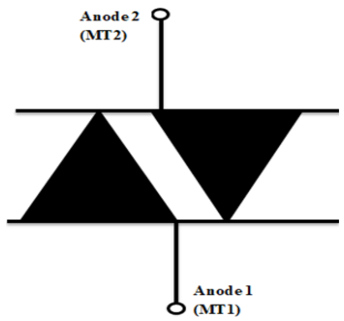
Answer:

Triac: Triac is an abbreviation for triode a.c. switch. **"Tri"** indicates that the device has three terminals and **"a.c."** means that the device controls alternating current or can conduct in either direction. A Triac is a three-terminal



semiconductor switching device which can control alternative current in a load.

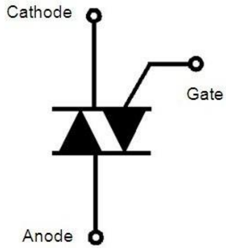
Diac: A Diac is two terminals, three-layer bidirectional device which can be switched from is OFF state to ON state for either polarity of applied voltage. DIAC stands for **"Diode for Alternating Current".**



Q-3: Describe, in your own words, the basic behaviour of the SCR using the two-transistor equivalent circuit.

Answer:

Triac: Triac is an abbreviation for triode a.c. switch. **“Tri”** indicates that the device has three terminals and **“a.c.”** means that the device controls alternating current or can conduct in either direction. A Triac is a three-terminal



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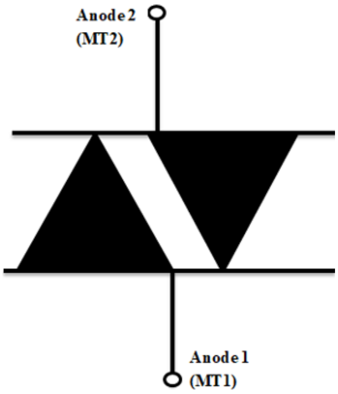
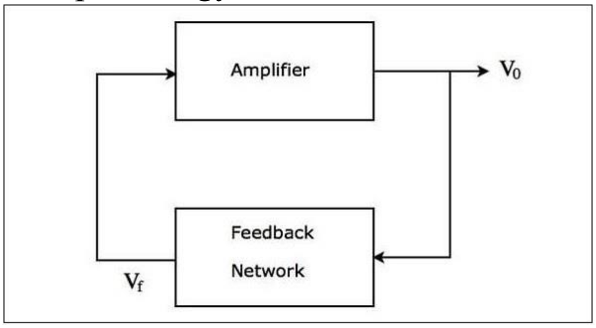


Q-4: What is a Sinusoidal Oscillator? Types of Sinusoidal Oscillations? Describe the oscillator circuits.

Answer:

Sinusoidal Oscillator: An **oscillator** is an electronic circuit that produces a periodic signal. If the oscillator produces **sinusoidal oscillations**, it is called as a sinusoidal oscillator. It converts the input energy from a DC source into an AC output energy of a periodic signal.



There are two types Sinusoidal Oscillations: -

1. **Damped Oscillations:** The electrical oscillations whose amplitude goes on decreasing with time are called dumped oscillation.
2. **Undamped Oscillations:** The electrical whose Songs amplitude remains constant with time are called undamped oscillation.

Oscillatory circuits: A circuit which produce electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit.

The basic principle behind the working of oscillators is positive feedback. Positive feedback is when a portion of the output signal is fed back to the input in such a way that it reinforces the input signal. This reinforcement can cause the input signal to grow exponentially, leading to the generation of an oscillating signal.

The most common type of oscillator is the LC oscillator. An LC oscillator consists of an **inductor** (L) and a **capacitor** (C) connected in parallel. The LC circuit forms a resonant circuit, which means that it has a natural frequency of oscillation. When the **oscillator** is turned on, the input signal is amplified by the amplifier circuit. The amplified signal is then fed back to the input in such a way that it reinforces the input signal. This reinforcement causes the input signal to grow exponentially, leading to the generation of an oscillating signal at the natural frequency of the LC circuit.

Other types of oscillators include crystal oscillators, relaxation oscillators, and multivibrators. Crystal oscillators use a piezoelectric crystal to generate a very precise frequency of oscillation. Relaxation oscillators use a bistable device, such as a flip-flop, to generate an oscillating signal. Multivibrators are a type of relaxation oscillator that can be used to generate square waves, triangle waves, or sawtooth waves.

Oscillators are used in a wide variety of applications, including radios, televisions, computers, and clocks. They are also used in many other electronic devices, such as synthesizers, amplifiers, and test equipment.

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