Electronics
B.Tech 1st yr

DIODE…

•A diode is a 2 lead semiconductor that acts as a one way gate to electron flow.

– Diode allows current to pass in only one direction.

•A pn-junction diode is formed by joining together n-type and p-type silicon.

•The p-side is called anode and the n-side is called cathode.

•When the anode and cathode of a pn-junction diode are connected to external voltage such that the potential at anode is higher than the potential at cathode, the diode is said to be forward biased.

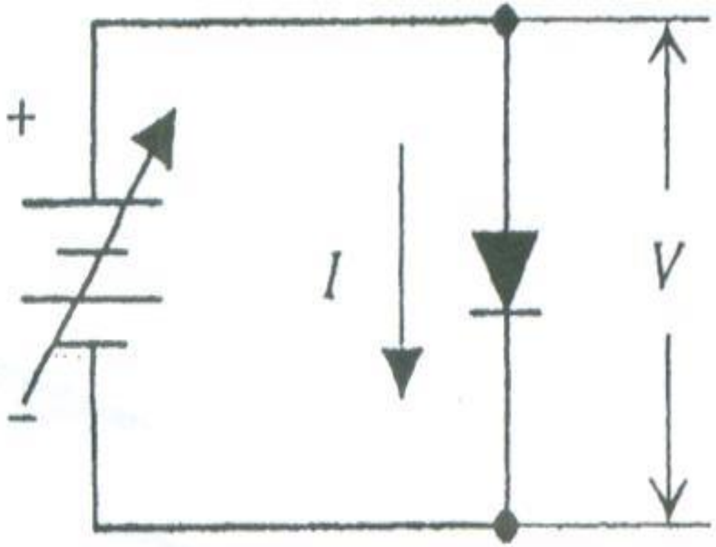
–In a forward-biased diode current is allowed to flow through the device.

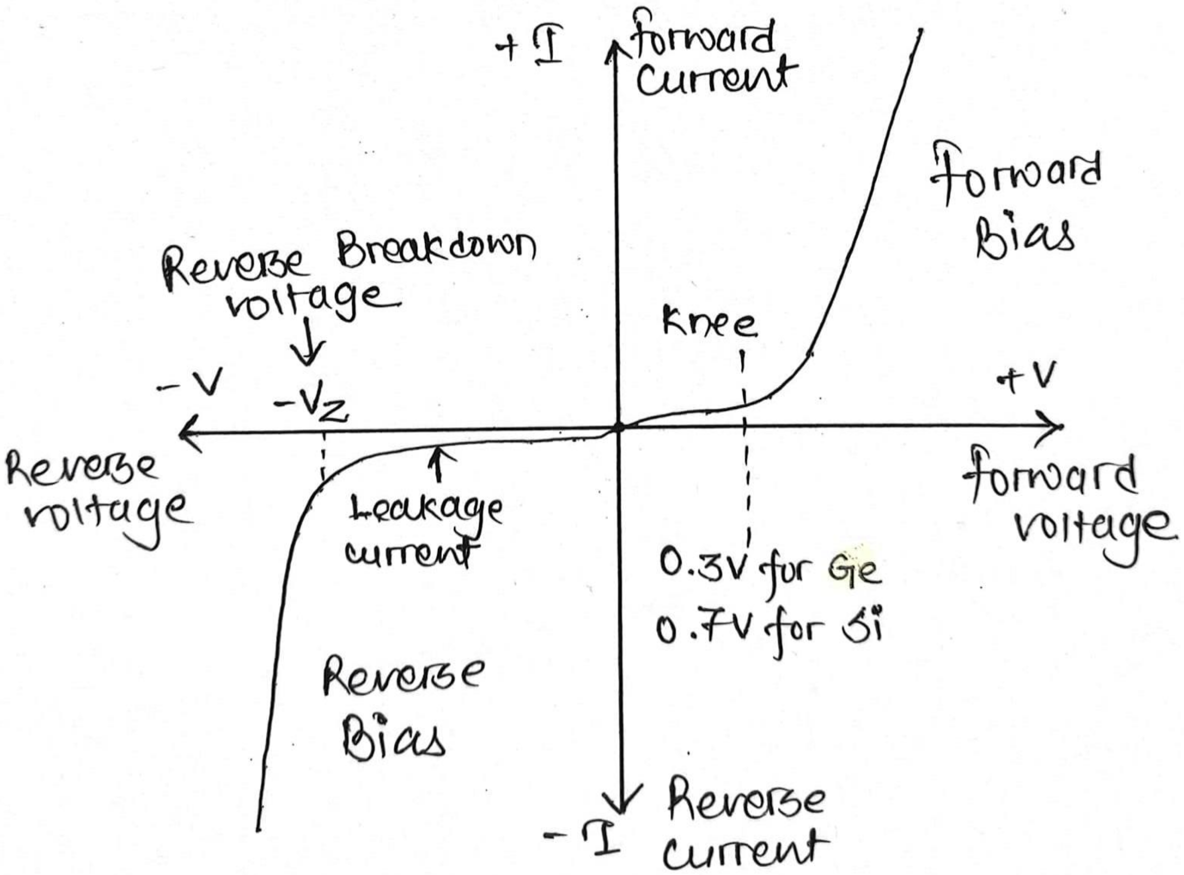
•When potential at anode is smaller than the potential at cathode, the diode is said to be reverse biased. In a reverse-biased diode current is blocked.

DIODE

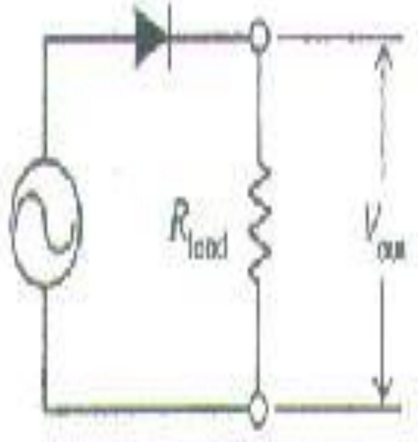
Symbol for DIODE

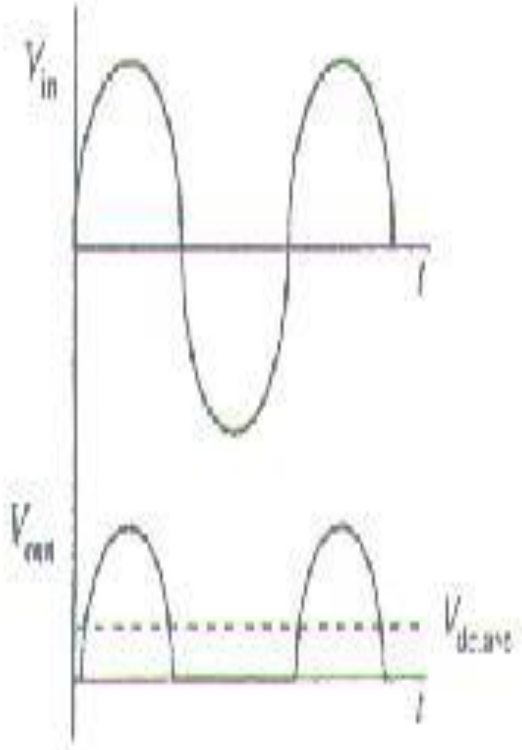
Diodes and i-V characteristics





Half wave rectifier (HWR)





Diode converts ac input voltage to a pulsed dc output voltage.

•Whenever the ac input becomes negative at diode’s anode, the diode blocks current flow.

–o/p voltage become zero.

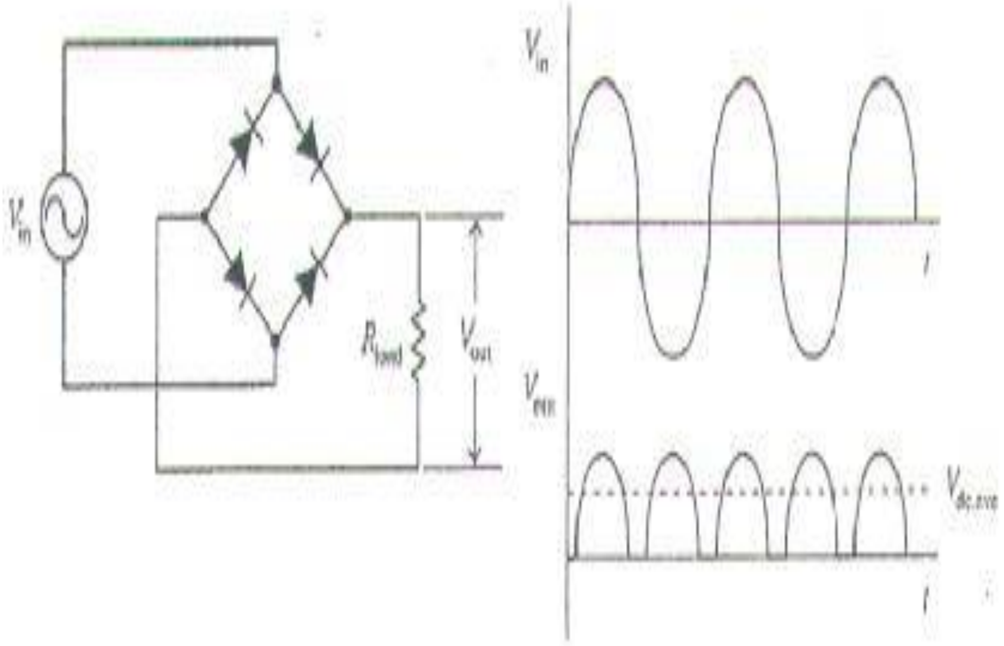
•The o/p frequency is same as the i/p frequency.

Average voltage, $V_{DC} = V_m/2\pi \; {}_0\int^{\pi} \sin\omega t \; d\omega t$

$= V_m/2\pi \; [-\cos\omega t]_0^{\pi} = V_m/2\pi \; [-\cos\pi + \cos 0]$

$= V_m/2\pi \; [1+1] = 2V_m/2\pi = V_m/\pi$

FWR…



A full-wave rectifier does not block negative swings in the i/p voltage, rather it transforms them into positive swings at the o/p.

• To gain an understanding of device operation, follow current flow through pairs of diodes in the bridge circuit.

• It is easily seen that one pair (D3-Rout-D2) allows current flow during the +ve half cycle of Vin while the other pair (D4-Rout-D1) allows current flow during the -ve half cycle of Vin.

– The o/p frequency is twice the i/p frequency.

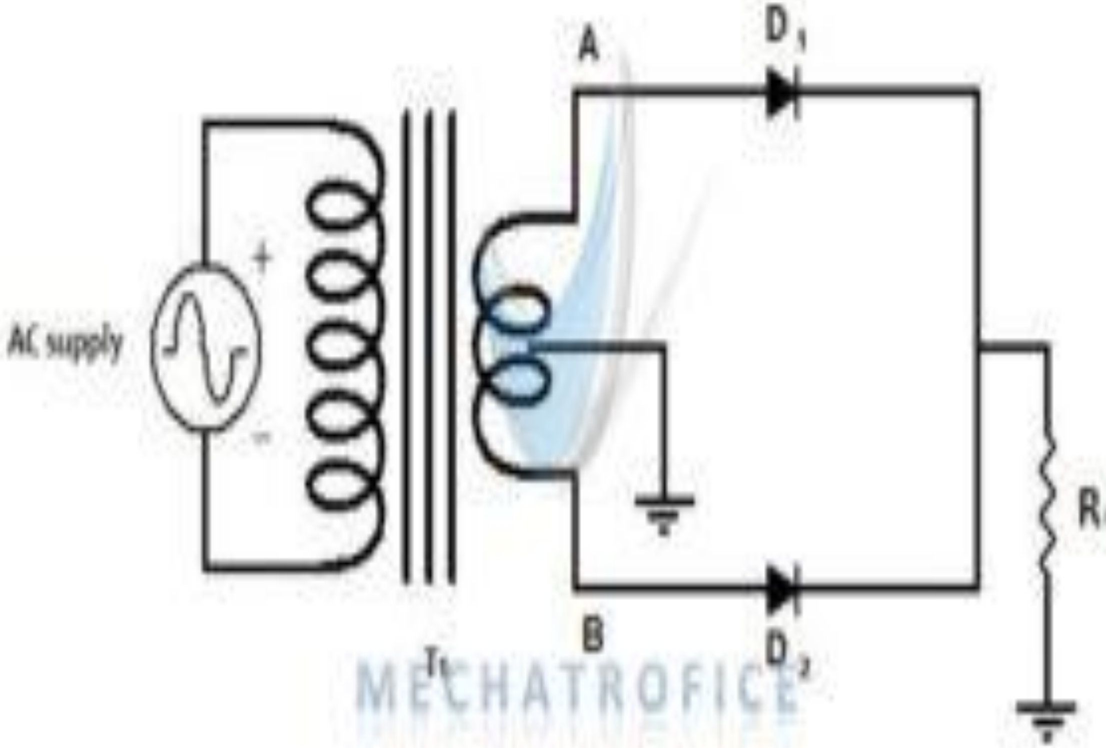
The **average voltage,** $V_{DC} = V_m/\pi \; {}_0\int^{\pi} \sin\omega t \, d\omega t$

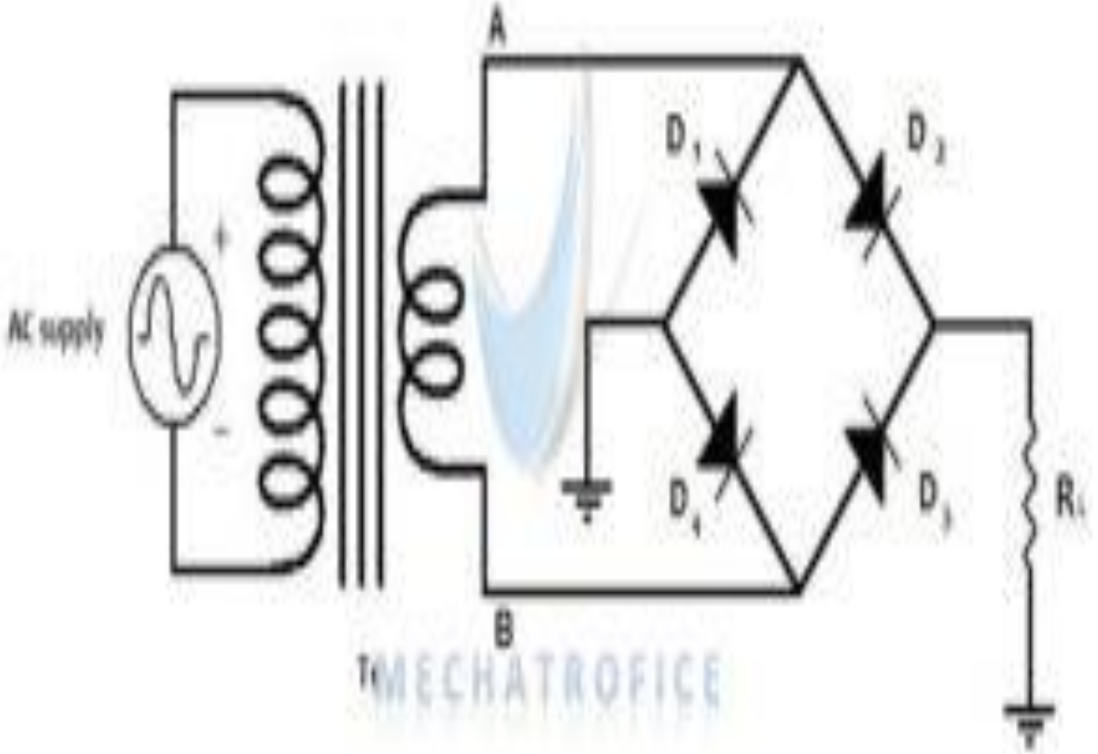
$= V_m/\pi \, [-\cos\omega t]_0^{\pi} = V_m/\pi \, [-\cos\pi + \cos 0]$

$= V_m/\pi \, [1+1] = 2V_m/\pi$

Average voltage equation for a full wave rectifier is $V_{DC} = 2V_m/\pi$.

Centre tapped FWR and Bridge FWR circuit





RMS value of rectifier

RMS (Root mean square) value is the square root of the mean value of the squared values.

The RMS value of an alternating current is the equivalent DC value of an alternating or varying electrical quantity. RMS value of an AC current produces the same amount of heat when an equal value of DC current flows through the same resistance.

RMS value of a signal = √ Area under the curve squared / base length.

For a function f(x) the RMS value for an interval [a, b]

$= \sqrt{(1/b-a) \, {}_a\int^b f^2(x) \, dx}$.

RMS value of Half wave rectifier

In a half wave rectifier, the negative half cycle will be removed from the output. So, the total base length(2π) should be taken from the interval 0 to 2π.

The RMS voltage, VRMS = √ Vm2/2π 0∫π sin2ωt dωt

= √ Vm2/2π 0 ∫π(1 – cos2ωt) / 2) dωt = √ Vm2/4π [ωt – sin2ωt / 2]0π

= √ Vm2/4π [π – (sinπ) / 2 – (0 – (sin0) / 2)] = √ Vm2/4π (π) = √ Vm2/ 4

Therefore the RMS voltage, VRMS = Vm/ 2

RMS value of Full wave rectifier

rms-value-full-wave-rectifierThe RMS voltage, VRMS = √ Vm2/π 0∫π sin2ωt dωt

= √ Vm2/π 0 ∫π(1 – cos2ωt) / 2) dωt = √ Vm2/2π [ωt – sin2ωt / 2]0π

= √ Vm2/2π [π – (sinπ) / 2 – (0 – (sin0) / 2)] = √ Vm2/2π (π) = √ Vm2/ 2

RMS voltage, V_{RMS} = Vm/ √2

Peak factor of rectifier

The peak factor is defined as the ratio of the maximum value to the RMS value of an alternating quantity.

Peak factor = Peak value / RMS value

RMS voltage of a half wave rectifier, $V_{RMS} = V_m/2$. Where V_m is the Maximum or peak voltage.

Then the **Peak factor of half wave rectifier** can be calculated as,

$V_m / V_{RMS} = V_m / (V_m / 2) = 2 V_m / V_m = 2$

Similarly, For a full wave rectifier, the RMS voltage $V_{RMS} = V_m / \sqrt{2}$

Therefore, the **Peak factor value of full wave rectifier =** $V_m / V_m / \sqrt{2}$

$= V_m \sqrt{2} / V_m = \sqrt{2} = 1.414$

Form factor of rectifier

The ratio of RMS value to the average value of an alternating quantity is known as its form factor.

Form factor = RMS value / Average value

RMS voltage of a half wave rectifier, $V_{RMS} = V_m / 2$ and Average Voltage $V_{AVG} = V_m/\pi$, V_m is the peak voltage.

Form factor of half wave rectifier = $V_{RMS} / V_{AVG} = (V_m /2) / (_{Vm} / \pi)$

$= \pi V_m / 2 V_m = 1.57$

For a full wave rectifier, the RMS voltage $V_{RMS} = V_m / \sqrt{2}$ and the average Voltage,

$V_{AVG} = 2 V_m / \pi$

Form factor value of full wave rectifier = $(V_m / \sqrt{2}) / (2V_m / \pi)$

$= \pi V_m / 2\sqrt{2} V_m = 1.11$

Ripple factor of rectifier

The ratio of the RMS value (root mean square) of the AC component to the DC component of the output is defined as the Ripple factor and is denoted by γ.

Ripple factor, $\gamma = V_{AC}/V_{DC}$ | V_{DC} is the average value of the DC output.

$V_{RMS} = \sqrt{V_{DC}^2 + V_{AC}^2}$ or $I_{RMS} = \sqrt{I_{DC}^2 + I_{AC}^2}$

$V_{AC} = \sqrt{V_{RMS}^2 - V_{DC}^2}$

Therefore the ripple factor equation is, $\gamma = \sqrt{(V_{RMS}^2 - V_{DC}^2) / V_{DC}^2}$

$= \sqrt{(V_{RMS} / V_{DC})^2 - 1}$

To calculate the ripple factor of a half wave and full wave rectifier, just substitute the RMS and Average value of the respective rectifier in the above equation.

Efficiency of rectifier

The ratio of DC output power to the AC input power of a rectifier is called as its efficiency. It is denoted by η.

Rectifier efficiency, η = DC output power/input AC power = P_{DC} / P_{AC}

Efficiency of Half wave rectifier

$I_{RMS} = I_m / 2$, $P_{AC} = I_{RMS}^2 (r_f + R_L) = (I_m / 2)^2 (r_f + R_L)$

V_m is the peak Current |

$P_{DC} = I_{AVG}^2 R_L = (I_m / \pi)^2 R_L$

For a half wave rectifier,

the Efficiency $\eta = P_{DC} / P_{AC} = ((I_m / \pi)^2 R_L) / ((I_m / 2)^2 (r_f + R_L))$

$= 4 R_L / \pi^2 (r_f + R_L) = 0.405 R_L / (r_f + R_L)$

Therefore the maximum efficiecy = **40.5%**

Efficiency of Full wave rectifier

Similarly for a full wave rectifier,

$I_{RMS} = I_m / \surd 2$, $P_{AC} = (I_m / \surd 2)^2 (r_f + R_L)$

$P_{DC} = (2 I_m / \pi)^2 R_L$

For a half wave rectifier, the Efficiency $\eta = P_{DC} / P_{AC} = ((2 I_m / \pi)^2 R_L) / ((I_m / \surd 2)^2 (r_f + R_L))$

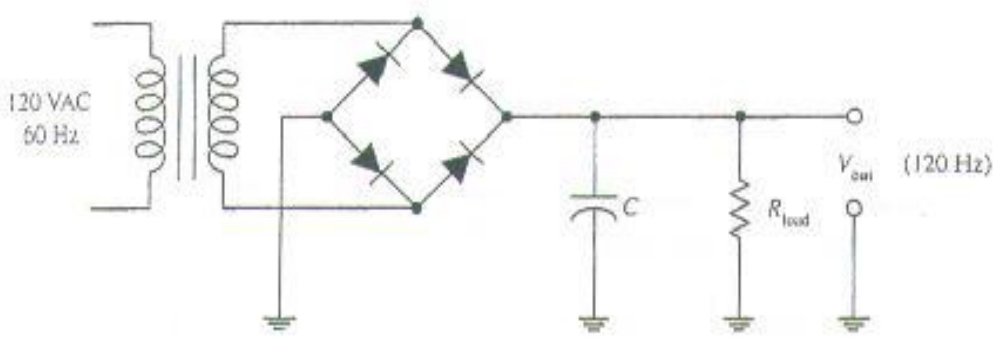
$= 8 R_L / \pi^2 (r_f + R_L) = 0.810 R_L / (r_f + R_L)$

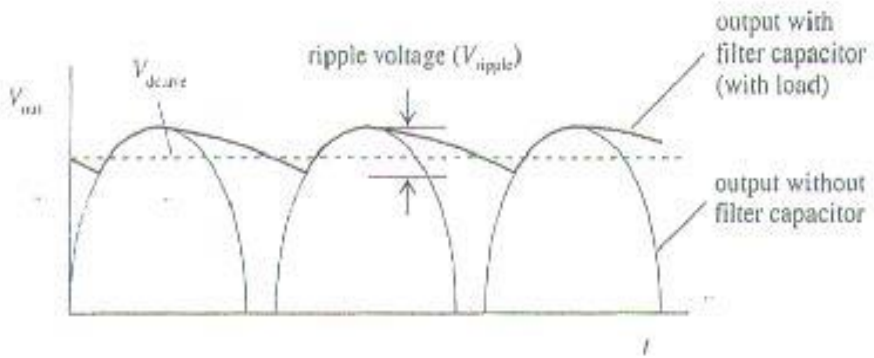
Maximum efficiecy = **81.0%**

Hence we can see that, the efficiency of a full wave rectifier is double than that of a half wave rectifier.

S.No.	Parameter	HW rectifier	FW rectifier
1.	I_{rms}	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$
2.	I_{dc}	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$
3.	V_{dc}	$\frac{I_m R_L}{\pi}$	$\frac{2I_m R_L}{\pi}$
4.	% Rectifier efficiency	$\frac{40.5}{1+(R_f/R_L)}$	$\frac{81.0}{1+(R_f/R_L)}$
5.	Ripple factor	1.21	0.48
6.	Fundamental ripple frequency	f	$2f$
7.	Peak inverse voltage	V_m	$2V_m$

Continued…





Diode Applications —AC2DC Power Supply

•An AC2DC power supply is built using a transformer and a full-wave rectifier.

•Transformer is used to step down the voltage i/p.

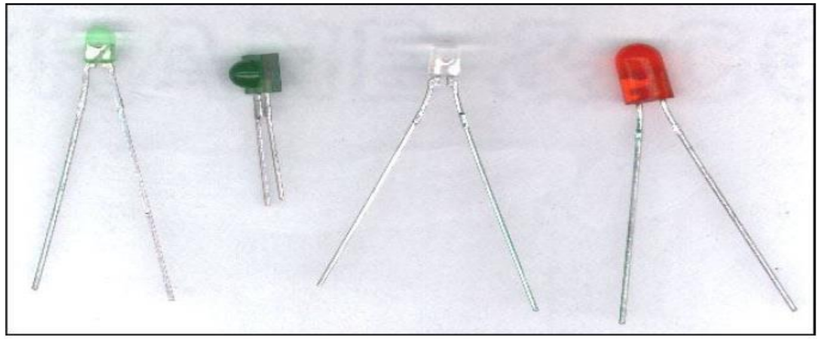
•Rectifier converts AC to pulsed DC.

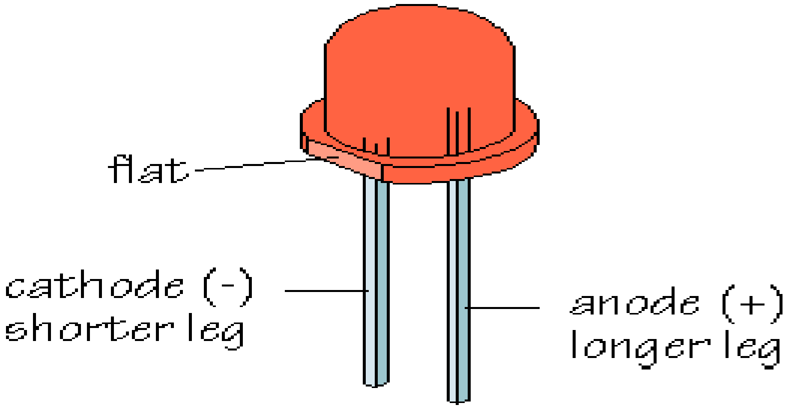
•A filter capacitor is used to smooth out the pulses.

•Capacitor must be large enough to store sufficient charge so as to provide a steady current supply to the load.

Types of diodes

Light-Emitting Diodes (LEDs)





2 lead semiconductor device.

• Light emitting PN-junction diode.

– Visible or infrared light.

• Has polarity.

• Recall diodes act as a one way gate to current flow.

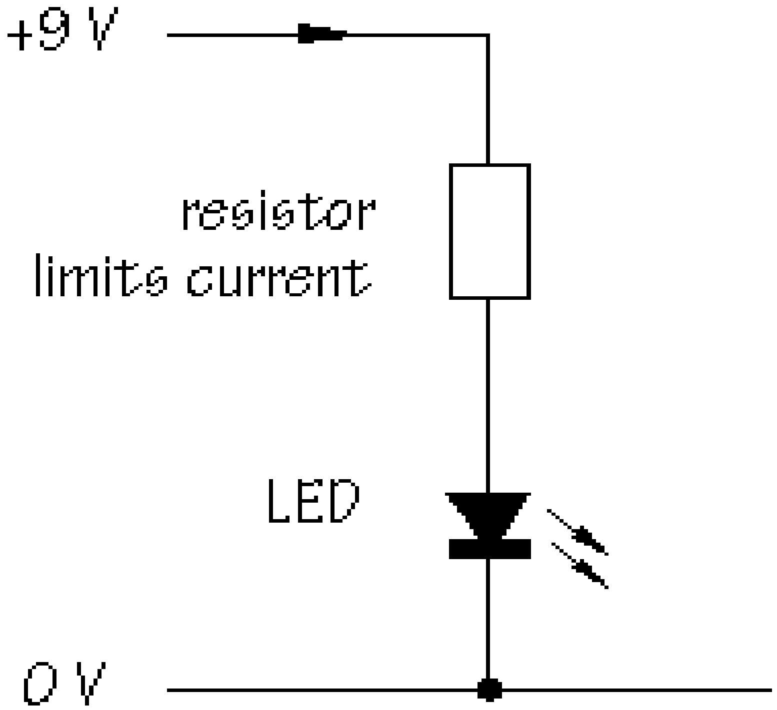
– A forward-biased PN-junction diode allows current flow from anode to cathode.

• An LED conducts and emits light when its anode is made more positive (approx.

1.4V) than its cathode.

– With reverse polarity, LED stops conducting and emitting light.

LEDs continued…



Let Vs be the supply voltage.

• Let Vf be the required forward bias voltage for the LED.

• Let I be the desired current flow through LED.

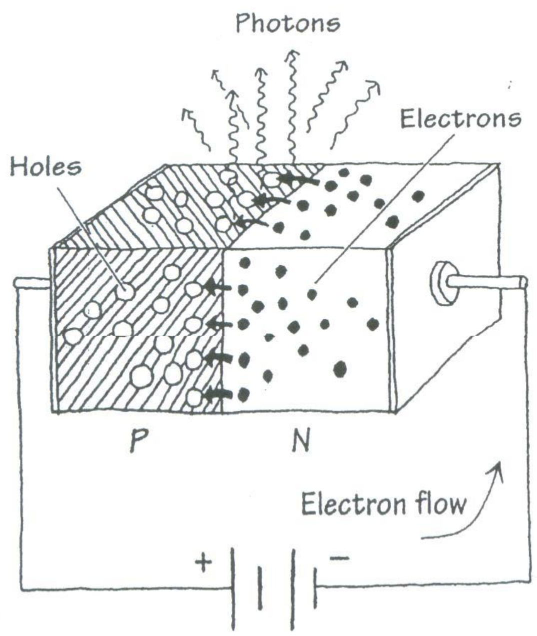
• Then, the current limiting resistance R is sized as follow:

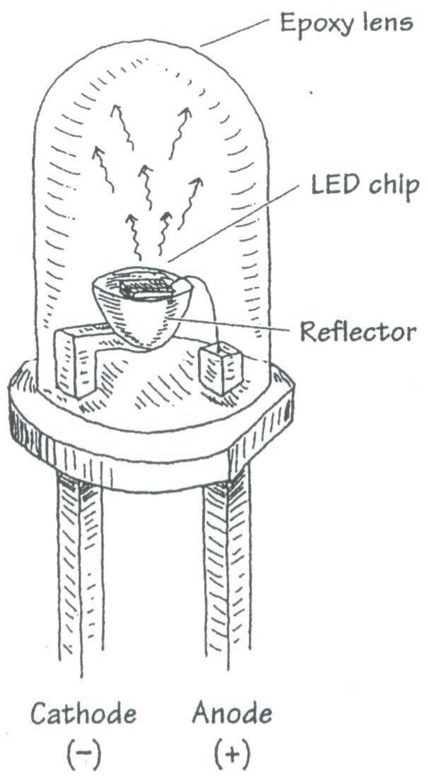
• If R is chosen smaller than the above value, a larger current will flow through the LED.

– LEDs can handle only limited current (varies from 20mA to 100mA).

– If current through LED is larger than the maximum allowed value, than the LED will be damaged.

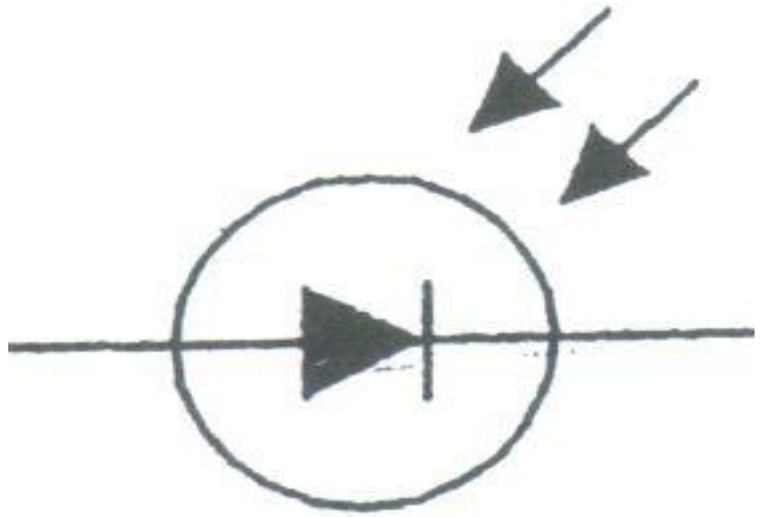
Working of LED





- The light-emitting section of an LED is made by joining n-type and p-type semiconductors together to form a pn junction.
- When the pn junction is forward-biased, electrons in the n side are excited across the pn junction and into the p side, where they combine with holes.
- As the electrons combine with the holes, photons are emitted.
- The pn-junction section of an LED is encased in an epoxy shell that is doped with light scattering particles to diffuse light and make the LED appear brighter.
- Often a reflector placed beneath the semiconductor is used to direct the light upward.

PHOTODIODE



Photodiode Symbol

• Photodiode is a 2 lead semiconductor device that transforms light energy to electric

current.

• Suppose anode and cathode of a photodiode are wired to a current meter.

– When photodiode is placed in dark, the current meter displays zero current flow.

– When the photodiode is expose to light, it acts a a current source, causing current flow

from cathode to anode of photodiode through the current meter.

• Photodiodes have very linear light v/s current characteristics.

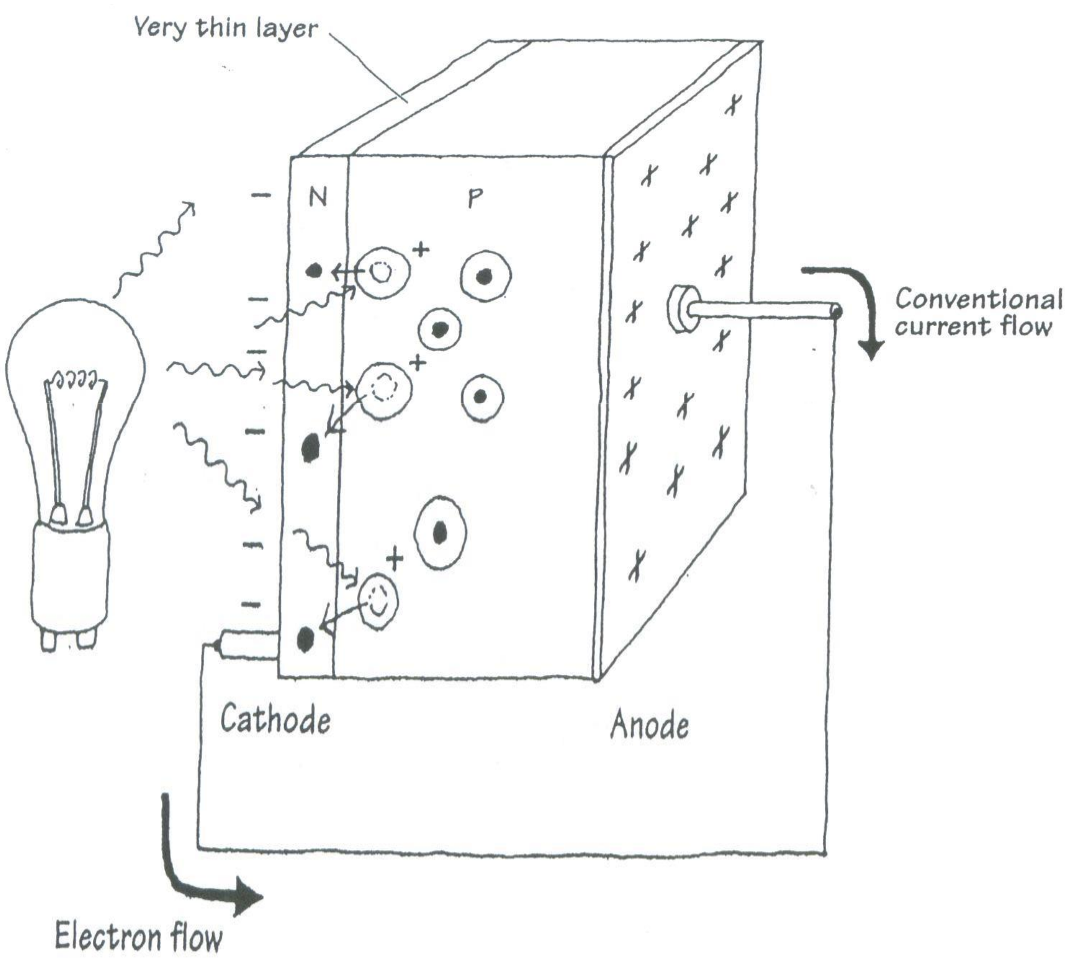
– Commonly used as light meters in cameras.

• Photodiodes often have built-in lenses and optical filters.

• Response time of a photodiode slows with increasing surface area.

• Photodiodes are more sensitive than photoresistor.

Working…



- Photodiode: A thin n-type semiconductor sandwiched with a thicker p-type semiconductor. N-side is cathode, p-side is anode.
- Upon illumination, a # of photons pass from the n-side and into the p-side of photodiode.

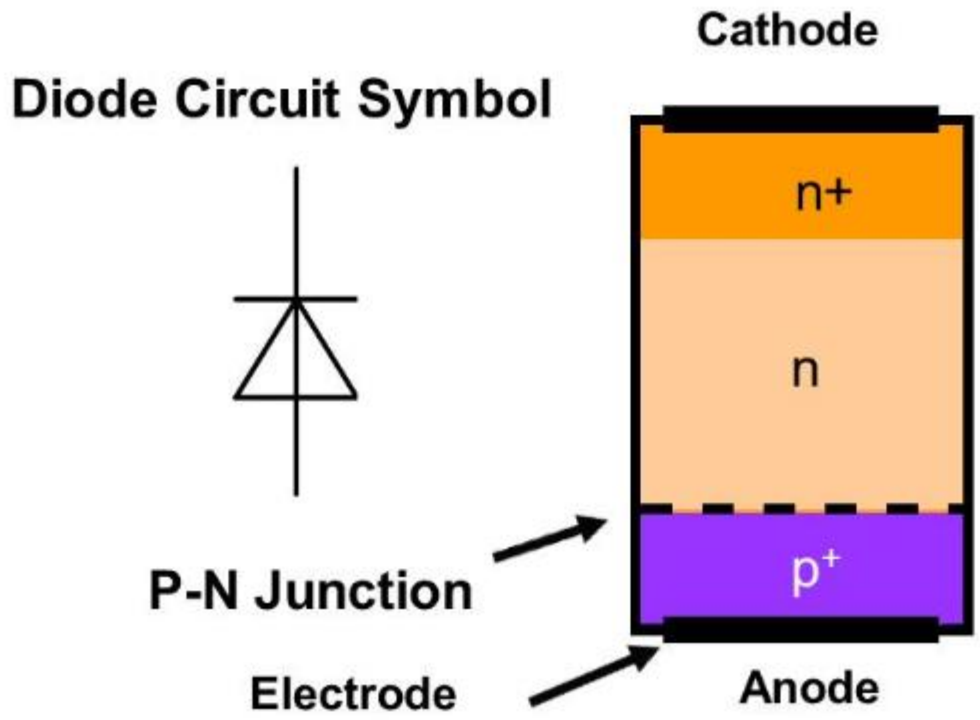
– Some photons making it into p-side collide with bound electrons within p semiconductor, ejecting them and creating holes.

– If these collisions are close to the p-n interface, the ejected electrons cross the junction, yielding extra electrons on the n-side and extra holes on the p-side.

– Segregation of +ve and -ve charges leads to a potential difference across the pn-junction.

– When a wire is connected between the cathode and anode, a conventionally positive current flow from the anode to cathode

PIN diode…



- The PIN diode is a one type of photo detector, used to convert optical signal into an electrical signal. The PIN diode comprises of three regions, namely P-region, I-region and N-region. Typically, both the P and N regions are heavily doped due to they are utilized for Ohmic contacts.
- The intrinsic region in the diode is in contrast to a PN junction diode. This region makes the PIN diode an lower rectifier, but it makes it appropriate for fast switches, attenuators, photo detectors and applications of high voltage power electronics.

Characteristics..

- This obeys the typical diode equation for small frequency signals. At higher frequencies, PIN diode appears like an approximately perfect resistor. There is a set of stored charge in the intrinsic region. At small frequencies, the charge can be detached and the diode switched OFF.
- At higher frequencies, there is not sufficient time to eliminate the charge, so the PIN diode never switched OFF. The diode has a reduced reverse recovery time. A PIN diode properly biased, therefore performs as a variable resistor. This high-frequency resistance may differ over a broad range (from 0.1 Ω-10 kΩ in some cases; the practical range is slighter, though).

Applications of PIN Diode

- PIN Diode has a wide range of applications coming in various fields of physics like radio frequency switch, microwave switch, radiofrequency attenuator, microwave attenuator, photodetector, etc. Some applications are given below:
- These diodes are used in the RF and also for microwave switches and microwave variable attenuators since they are said to have low capacitance.
- They are used in Photodetectors and photovoltaic cells, and the PIN photodiodes are used for fibre optic network cards and switches.
- These diodes are effectively used for RF protection circuits, and they can also be utilized as an RF switch.
- The PIN photodiode is also used to detect X-rays and gamma rays photons.

Zener diode (working and symbol)

In forward-biased conditions, the Zener Diode works like any normal diode but in the reverse-bias condition, a small leak current flows through the diode. As we keep increasing the reverse voltage it reaches a point where the reverse voltage equals the breakdown voltage. The breakdown voltage is represented as V_z and in this condition the current start flowing in the diode. After the breakdown voltage the current increase drastically unit it reaches a stable value.

In reverse bias condition, two kinds of breakdowns occur for Zener Diode which are,

Avalanche Breakdown and Zener Breakdown

Avalanche Breakdown

The phenomenon of Avalanche breakdown occurs both in the ordinary diode and Zener Diode at high reverse voltage. For a high value of reverse voltage, the free electron in the PN junction diode gains energy and acquires high velocity and these high-velocity electrons collide with other atoms and knock electrons from that atoms. This collision continues and new electrons are available for conducting current thus the current increase rapidly in the diode.

This phenomenon of a sudden increase in the current is called the Avalanche breakdown. This phenomenon damages the diode permanently whereas the Zener diode is a specific diode that is made to operate in this reverse voltage area.

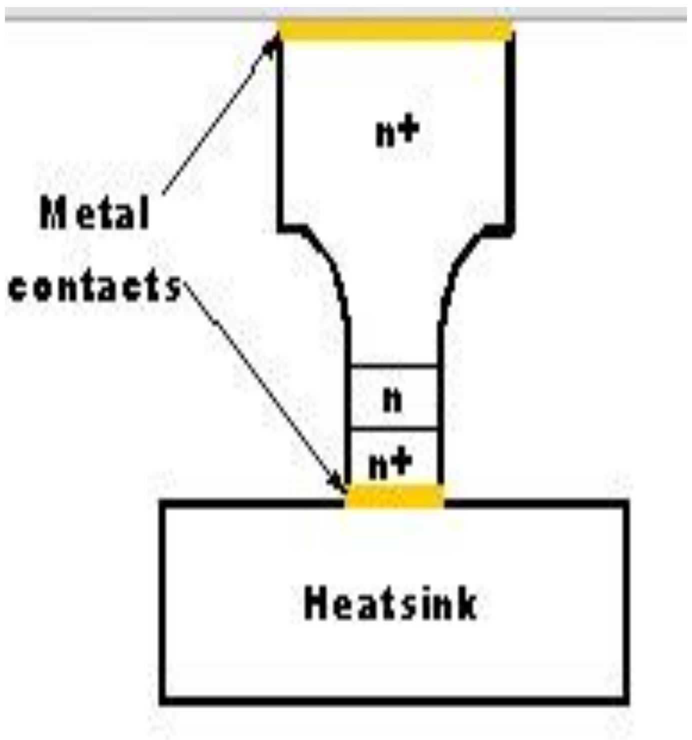
If the reverse voltage is greater than 6V the avalanche breakdown happens in the Zener diode.

Zener Breakdown

Zener breakdown happens in heavily doped PN junction diodes. In these diodes, if the reverse bias voltages reach closer to Zener Voltage, the electric field gets stronger and is sufficient enough to pull electrons from the valance band. These electrons then gain energy from the electric field and break free from the atom. Thus, for these diodes in the Zener breakdown region, a slight increase in the voltage causes a sudden increase in the current.

Zener Diode Symbol

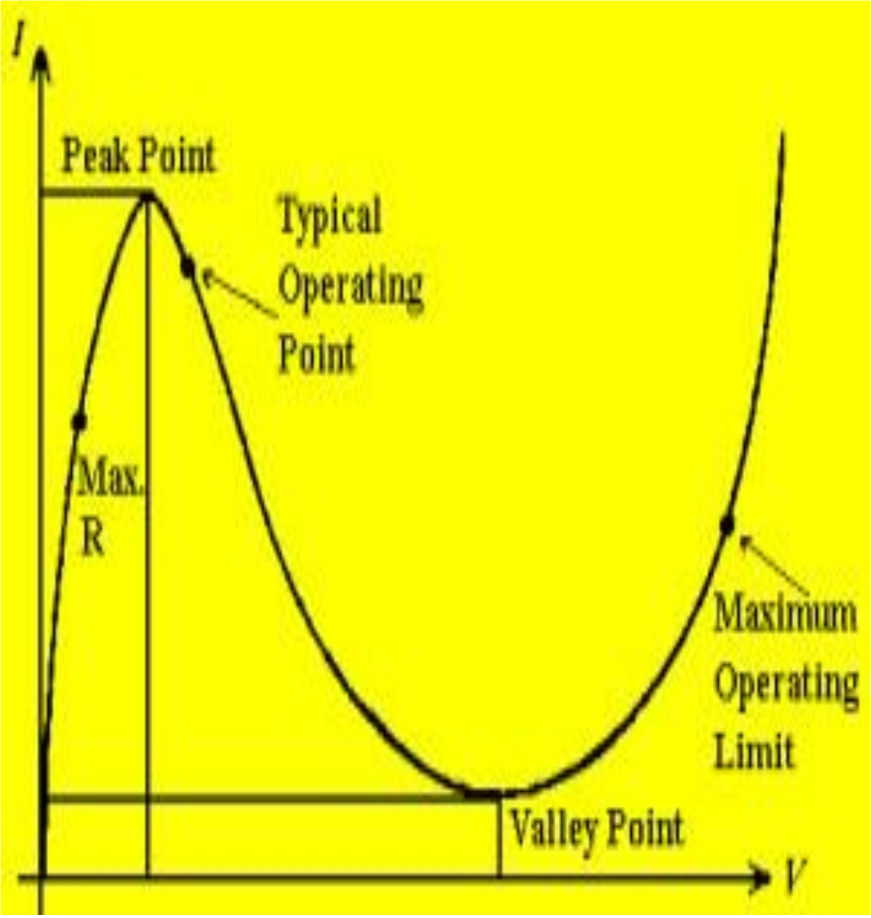
Gunn diode



A Gunn Diode is considered as a type of diode even though it does not contain any typical PN diode junction like the other diodes, but it consists of two electrodes. This diode is also called as a Transferred Electronic Device. This diode is a negative differential resistance device, which is frequently used as a low-power oscillator to generate microwaves. It consists of only N-type semiconductor in which electrons are the majority charge carriers. **To generate short radio waves such as microwaves, it utilizes the Gunn Effect.**

The Gunn Effect can be defined as generation of microwave power (power with microwave frequencies of around a few GHz) whenever the voltage applied to a semiconductor device exceeds the critical voltage value or threshold voltage value.

Characteristics….

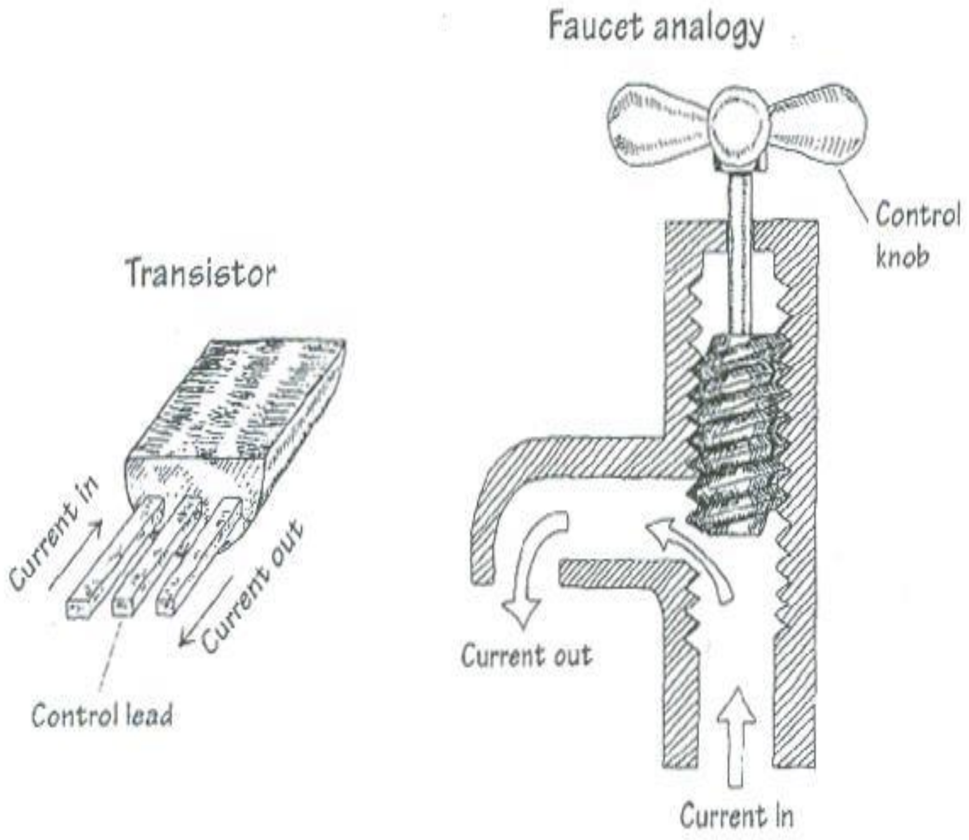


- The current-voltage relationship characteristics of a Gunn diode are shown in the above graph with its negative resistance region. These characteristics are similar to the characteristics of the tunnel diode.
- As shown in the above graph, initially the current starts increasing in this diode, but after reaching a certain voltage level (at a specified voltage value called as threshold voltage value), the current decreases before increasing again. The region where the current falls is termed as a negative resistance region, and due to this it oscillates. In this negative resistance region, this diode acts as both oscillator and amplifier, as in this region, the diode is enabled to amplify signals.

Applications…

- Used as Gunn oscillators to generate frequencies ranging from 100mW 5GHz to 1W 35GHz outputs. These Gunn oscillators are used for radio communications, military and commercial radar sources.
- Used as sensors for detecting trespassers, to avoid derailment of trains.
- Used as efficient microwave generators with a frequency range of up to hundreds of GHz.
- Used for remote vibration detectors and rotational speed measuring tachometers.

Transistor



A three lead semiconductor device that acts as:

– an electrically controlled switch, or

– a current amplifier.

• Transistor is analogous to a faucet.

– Turning faucet’s control knob alters the flow rate of water coming out from the faucet.

– A small voltage/current applied at transistor’s control lead controls a larger current flow through its other two leads.

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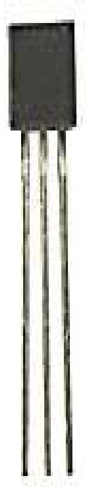
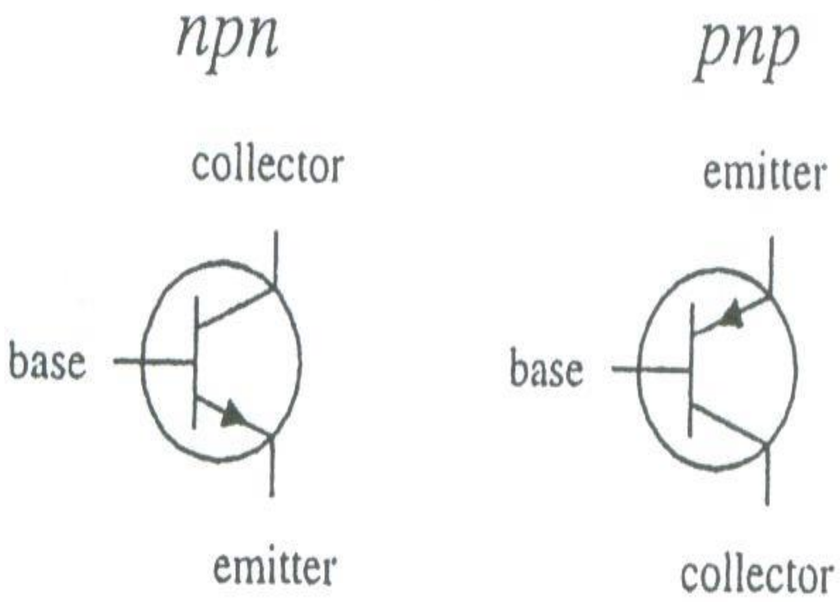


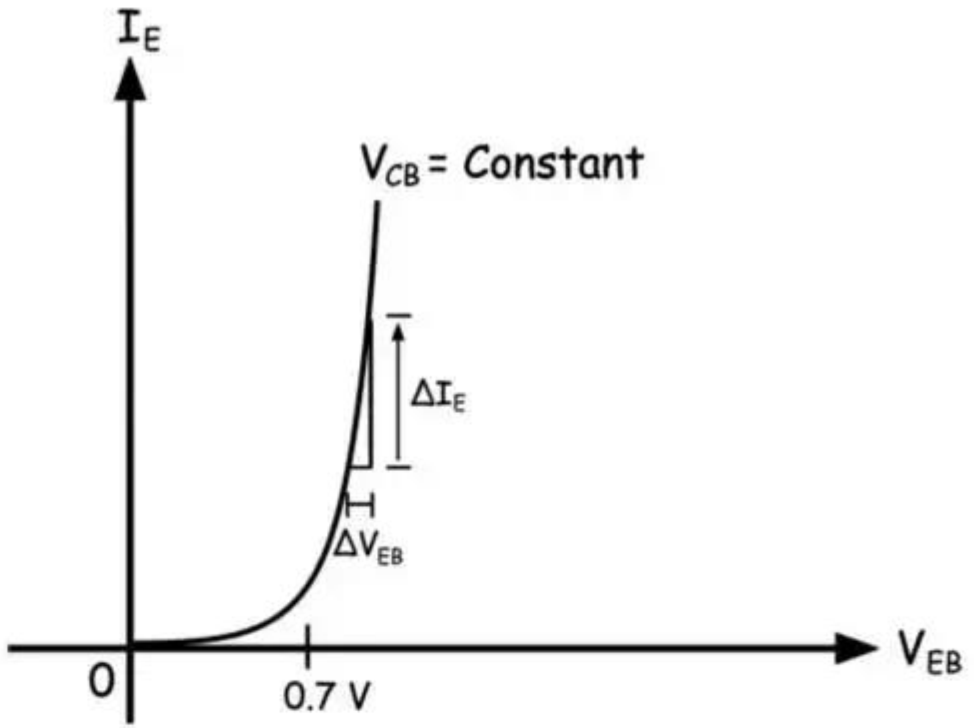


NPN and PNP.

– NPN: a small input current and a positive voltage applied @ its base (with VB>VE) allows a large current to flow from collector to emitter.

– PNP: a small output current and a negative voltage @ its base (with VB<VE) allows a much larger current to flow from emitter to collector.

i/p Characteristics..

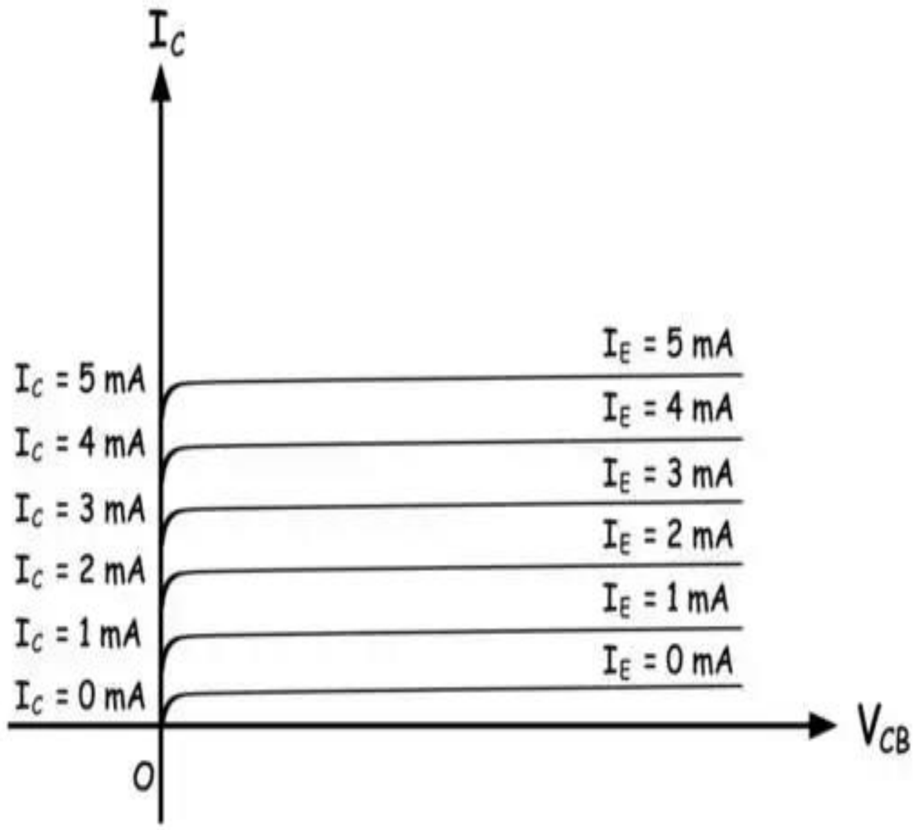


Input Characteristic of Common Base PNP BJT

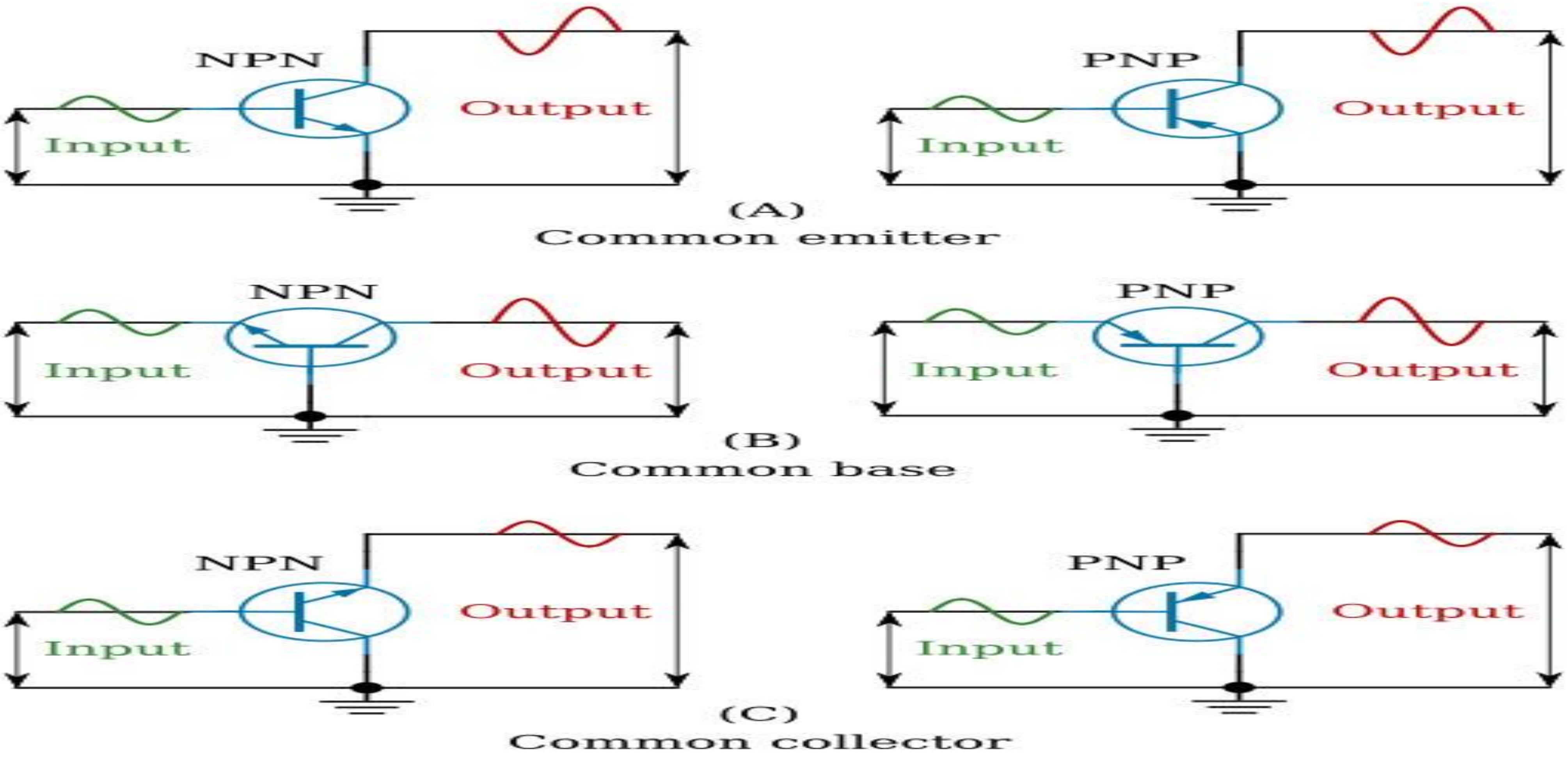
The characteristic curve drawn against variations of base current and base-emitter voltage is input characteristic of a common emitter transistor. The pn junction between base and emitter is forward biased hence the characteristic would be similar to that of a forward biased pn junction diode. Here also the base current does not get any value before the base-emitter voltage crosses the forward barrier potential of the junction but after that, the base current rises significantly with the increase of base-emitter voltage. The rate of rising of base current with respect to the base-emitter voltage is high here but not as high as in the case of common base mode.

o/p Characteristics

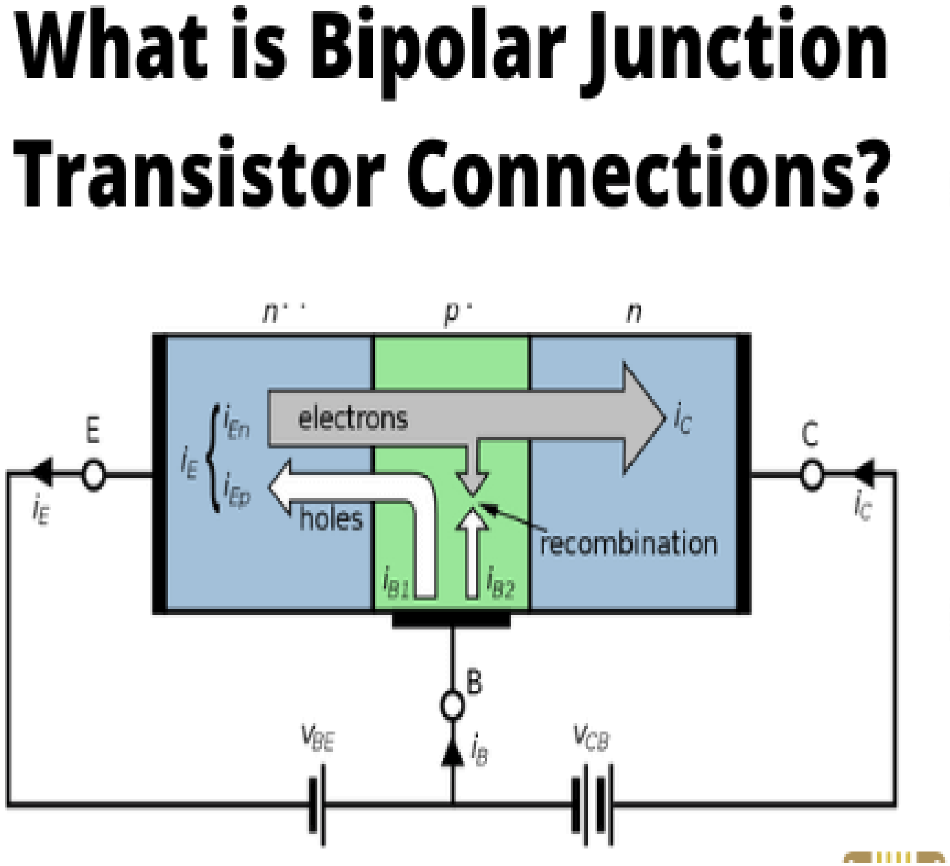
- Here the variation of collector current for different values of collector-base voltage is plotted against a fixed value of base current. It is found that at the beginning the collector current proportionately gets increased with increasing collector-emitter voltage but after certain voltage level, the collector current becomes almost constant. This is because at the beginning the base-collector junction does not get sufficient reverse biasing but after a certain voltage it becomes sufficiently reverse biased and then the major portion of charge carriers coming from emitter region to base region would migrate to collector region to contribute collector current.

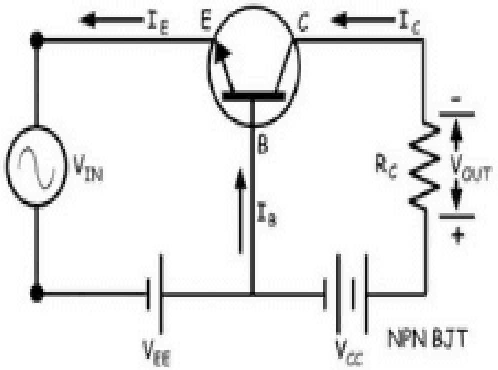


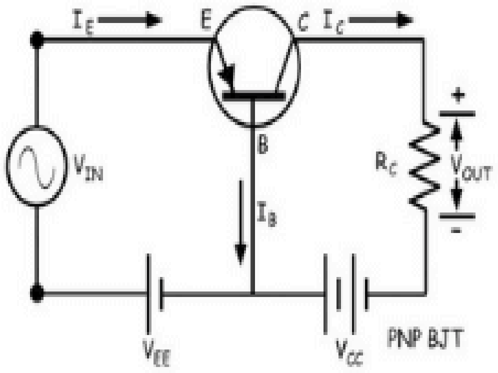
Transistor Configurations…



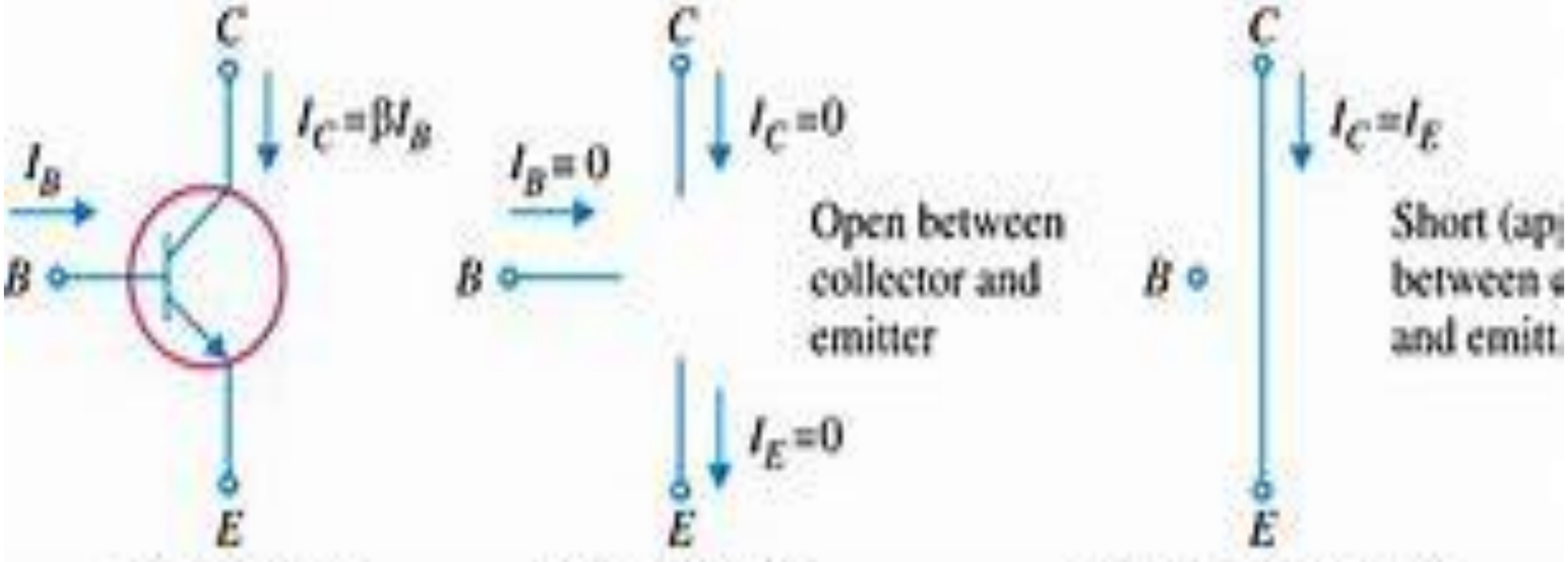
Biasing and region of operation…





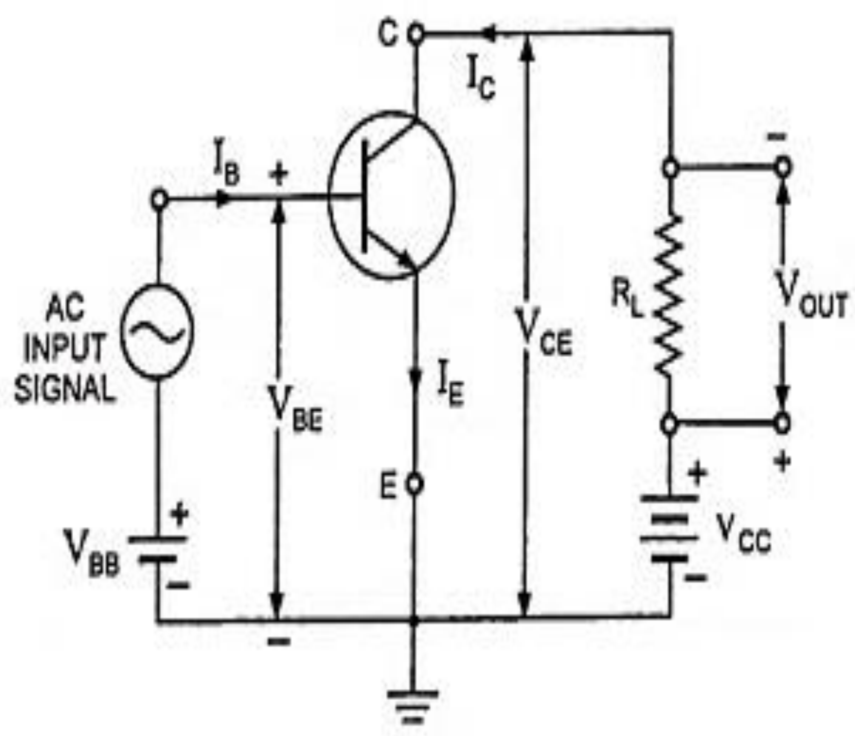


- Active
- Saturation
- Reverse active
- cutoff



(*i*) ACTIVE (*ii*) CUT-OFF (*iii*) SATURATED

Load line and Q point



In the circuit shown in Fig., V_{CC} is the supply voltage to collector, R_C (or R_L) is the collector resistance (or load resistance) and V_{CE} is the collector-to-emitter voltage. Applying Kirchhoff's second law to the output or collector circuit we have,

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

$$\text{or } I_C = \frac{V_{CC} - V_{CE}}{R_C}$$

$$\text{or } I_C = \frac{-V_{CE}}{R_C} + \frac{V_{CC}}{R_C}$$

This equation is to be plotted on the output characteristic of the transistor, V_{CE} and I_C are variables.

- Identify this equation as y = mx + c where m = $-1/R_C$ as the slope of the line and $I_C = V_{CC}/R_C$ as intercept of the line on vertical current axis (Fig. 10.33).
- **Consider the following two particular situations:**

(i) When $V_{CE} = 0$, $I_C = \frac{V_{CC}}{R_C}$ ...saturation point A

(ii) When $I_C = 0$, $V_{CE} = V_{CC}$ ...cut-off point B

By joining these two points A and B, dc load line is obtained. The dc load line represents the dynamic characteristic of the device. The dc load line provides the values of collector current IC and collector-emitter voltage VCE corresponding to zero signal conditions.

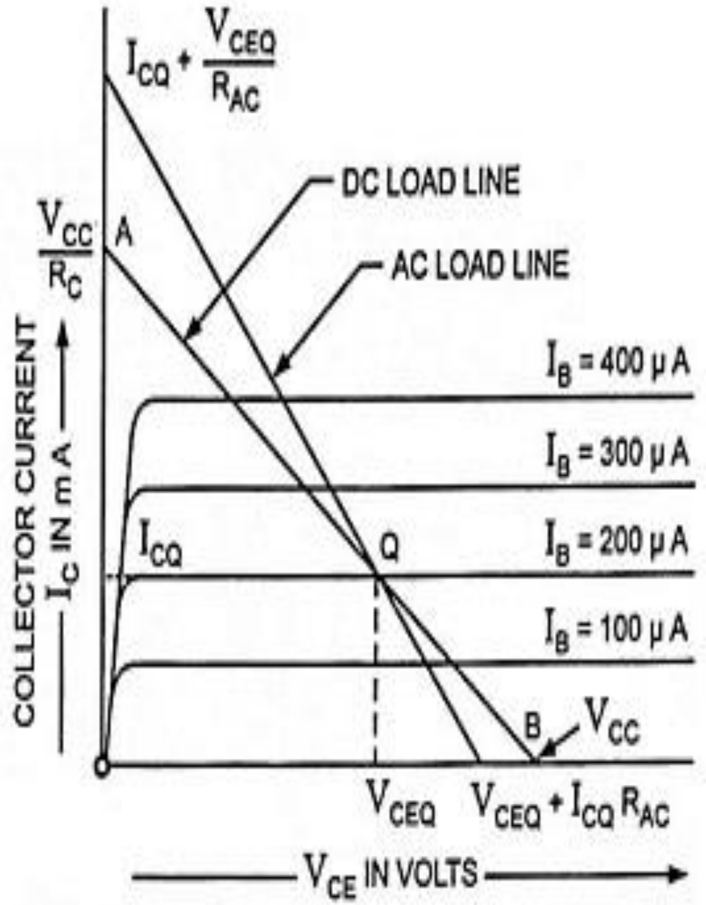


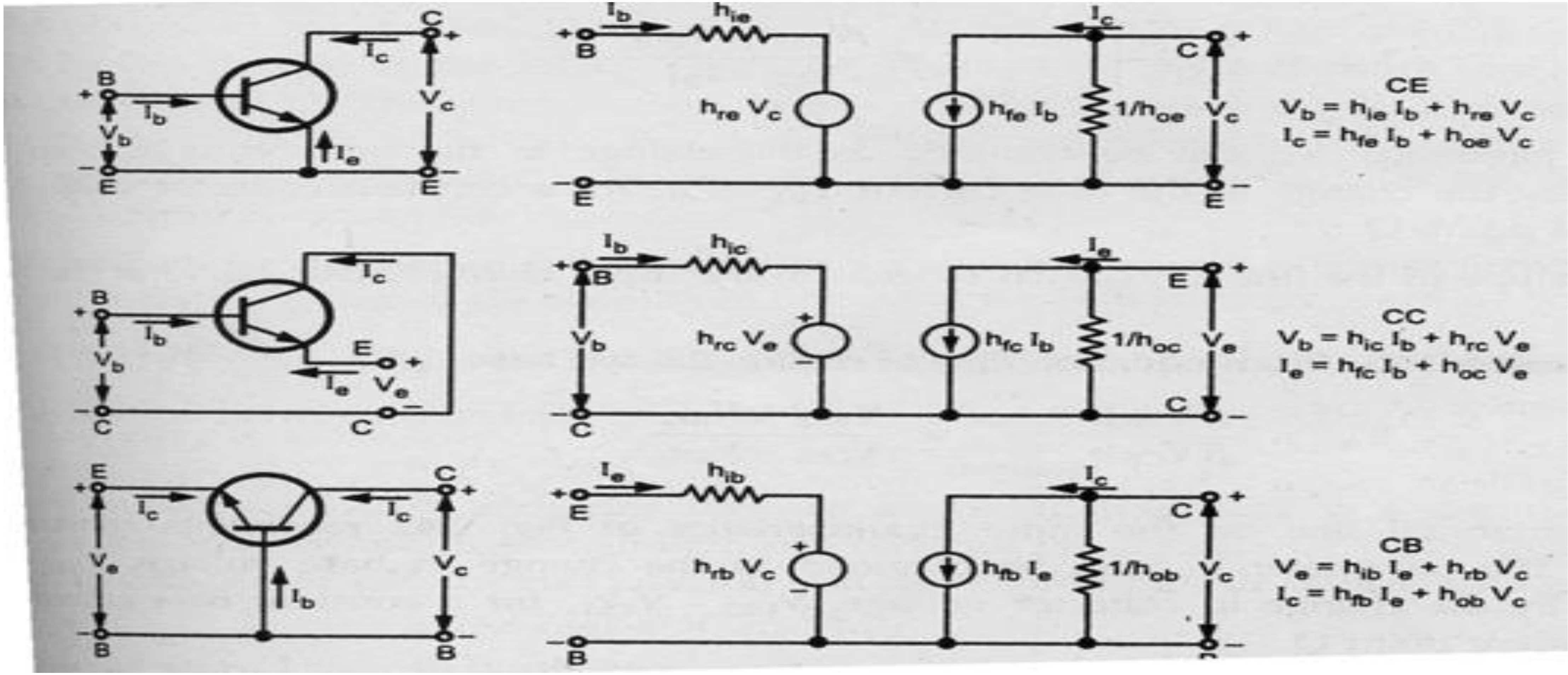
Fig. 10.33 *Common Emitter Transistor Output Characteristics With DC and AC Load Lines*

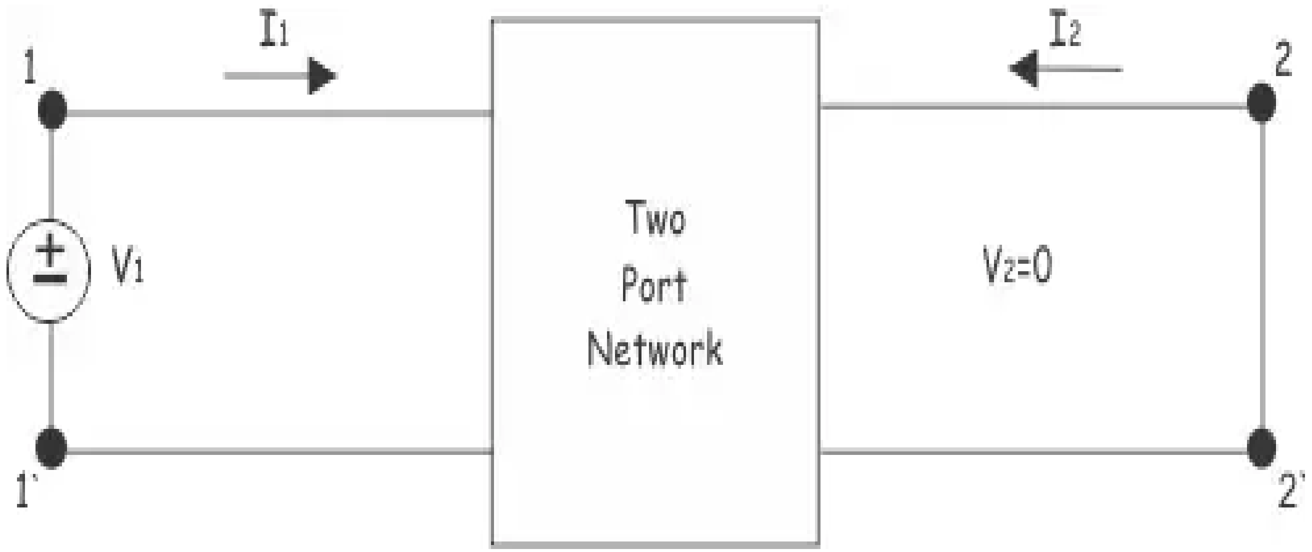
Quiescent Point:

It is a point on the dc load line which represents dc collector-emitter voltage V_{CE} and collector current I_C in the absence of ac signal. It is also called the **operating point** because the variations in V_{CE} and I_C take place about this point when signal is applied. The best position for this point is midway between cutoff and saturation points where $V_{CE} = 1/2\ V_{CC}$. Point Q is quiescent point marked on the output characteristics shown in Fig.

Selection of the operating point is done as per application for which the device is to be used.

Transistor H parameter model





$$\left.\frac{V_1}{I_1}\right|_{V_2=0} = h_{11}$$ = short circuit input impedance

$$\left.\frac{I_2}{I_1}\right|_{V_2=0} = h_{21}$$ = short-circuit current gain

$$\left.\frac{V_1}{V_2}\right|_{I_1=0} = h_{12}$$ = reverse voltage gain

$$\left.\frac{I_2}{V_2}\right|_{I_1=0} = h_{21}$$ = open circuit output admittance.