LAGOS CITY POLYTECHNIC

LECTURE NOTE

COURSE TITLE: ELECTRONICS 1

COURSE CODE: EEC 124

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LECTURE 1.0

TOPIC: THE CONCEPT OF THERMIONIC EMISSION

Thermionic emission definition

The process by which **free electrons** are emitted from the surface of a metal when external heat energy is applied is called thermionic emission.

Thermionic emission occurs in metals that are heated to a very **high temperature**. In other words, thermionic emission occurs, when large amount of external energy in the form of heat is supplied to the free electrons in the metals.
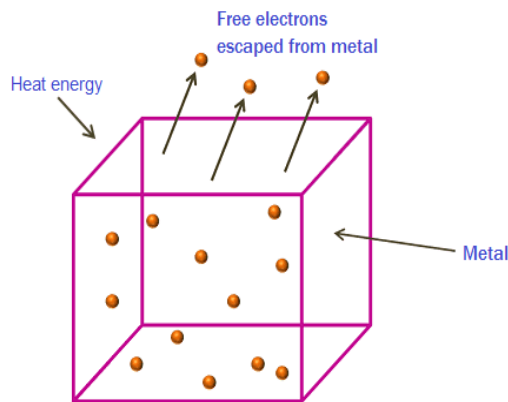

Figure 1.1: Electron Emission

(**For metal** u**nder high temperature**)

When a small amount of heat energy is applied to the metal, the valence electrons gain enough energy and break the bonding with the parent atom. The valence electron, which breaks the bonding with the parent atom, becomes free. This electron, which breaks the bonding with the parent atom, is called the **free electron.**

The **free electrons** in the metal have some kinetic energy. However, they do not have enough energy to escape from the metal. The attractive force of the atomic nuclei opposes the free electrons, which try to escape from the metal.

Free electrons in the metal have less energy compared to the free electrons in vacuum. Hence, free electrons require extra energy from the outside source in order to jump into the vacuum.

Metals under high temperature

When heat energy applied to the metal is increased to a higher value, the free electrons gain

enough energy and overcome the attractive force of the atomic nucleus, which holds the free electrons in the metal. The free electrons, which overcome the attractive force of the nuclei, break the bonding with the metal and jumps into the vacuum.

The free electrons, which are escaped from the surface of a metal when heat energy is supplied, are called **thermions**. Thermionic emission process plays a major role in the operation of electronic devices.

Work function of the metal:

The amount of external heat energy required to remove the free electron from the metal is called **work function** or **threshold energy**. The work function of metals is measured in **<u>electron volts (eV).</u>**

Metals that have low work function will require less amount of heat energy to cause the free electrons to escape from the metal. Hence, the metals with low work function emit large number of free electrons at high temperature.

On the other hand, metals that have high work function will require more amount of heat energy to cause the free electrons to escape from the metal. Hence, the metals with high work function emit less number of free electrons at high temperature.

Thus, the emission of free electrons from the metal is **inversely proportional** to the work function of a metal.

The classical example of thermionic emission is the emission of electrons from a <u>hot cathode</u> into a vacuum (also known as **thermal electron emission** or the **Edison effect**) in a <u>vacuum tube</u>. The hot cathode can be a metal filament, a coated metal filament, or a separate structure of metal or carbides or borides of transition metals. Vacuum emission from metals tends to become significant only for temperatures over 1,000 K (730 °C; 1,340 °F).

Some Basic Terms:

Diode valve :   This is the basic form of thermionic valve / vacuum tube device. It consists of a cathode, anode (and of course the heater or filament). Current can only pass through the diode in one way - electrons flowing from the cathode to the anode - in this way it acts as a rectifier or diode.

Triode valve: The triode valve has a third electrode added. Called the grid, it is able to control the flow of electrons

Tetrode: The tetrode has an fourth electrode added. Called a screen grid, it is normally held at a high potential but lower than that of the anode

Pentode: The pentode had a fifth electrode added. Called the suppressor grid, it was held at a low potential to suppress secondary emission

Applications of thermionic emission

The components, which are made by the process of thermionic emission are used in the electronic devices such as cathode ray tube, radio etc.
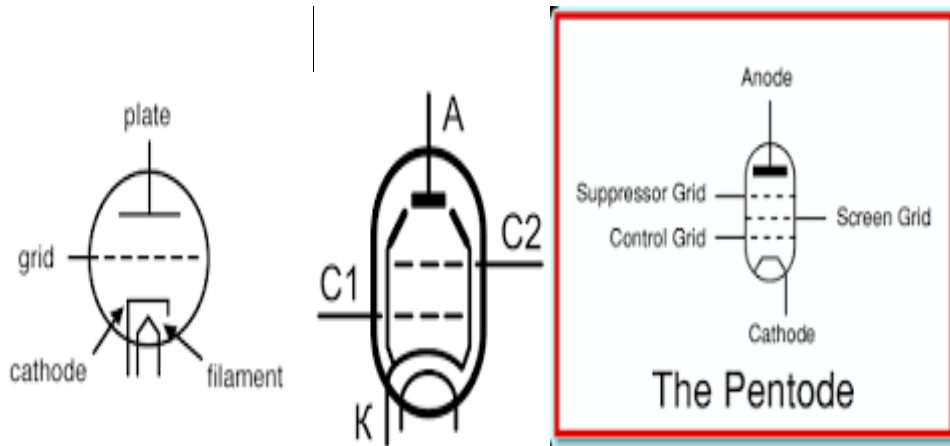
Figures 1.2 (Triode), 1.3 (Tetrode) and 1.4 (Pentode)

ASSIGNMENT 1

(a)State five other applications of thermionic emission in various industries?

(b) Explain what happens to metals under a very high temperature

(c) How does the emission of electron relate to the work function of the metal

QUIZ 1

What do you understand by the following terms:

    i.   Thermionic emission
    ii.   Thermions
    iii.   Work function

LECTURE 2.0

TOPIC: SIMPLE CONCEPTS OF ENERGY LEVEL IN MATERIALS

Energy levels (also called electron shells) are fixed distances from the nucleus of an **atom** where **electrons** may be found. **Electrons** are tiny, negatively charged particles in an **atom** that move around the positive nucleus at the center. **Energy levels** are a little like the steps of a staircase.

Figures 2.1a and 2,1b Internal Structure of a Typical Atom
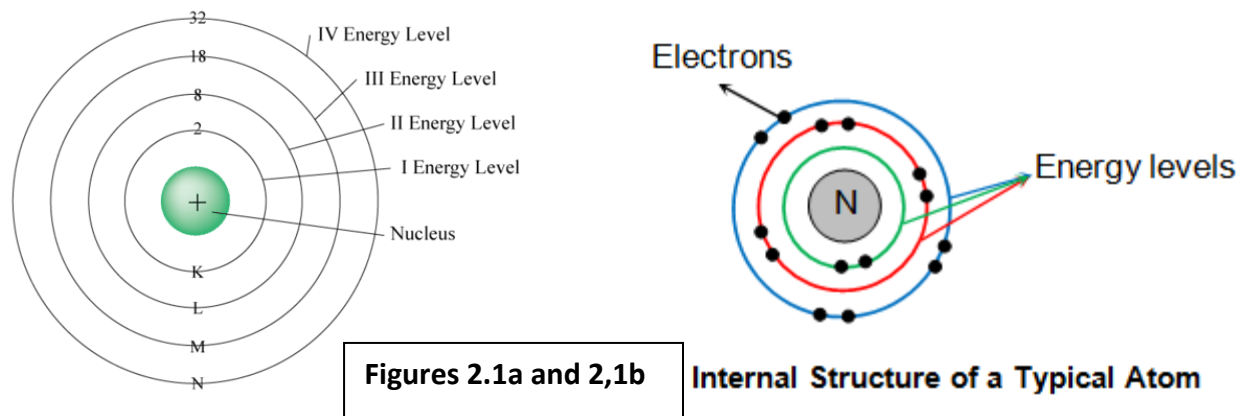
According to the model of atom proposed by **Bohr** in 1913, an atom is composed of a number of electrons moving in circular or elliptical orbits around a relatively heavy nucleus of protons and neutrons.

Electrons in atoms and molecules can change (make _**transitions**_ in) energy levels by emitting or absorbing a **photon** (of electromagnetic radiation), whose energy must be exactly equal to the energy difference between the two levels. Electrons can also be completely removed from a chemical species such as an atom, molecule, or ion. Complete removal of an electron from an atom can be a form of **ionization**, which is effectively moving the electron out to an orbital with an infinite principal quantum number, in effect so far away so as to have practically no more effect on the remaining atom (ion). For various types of atoms, there are 1st, 2nd, 3rd, etc.

To summarize the above, it may be repeated that :

  i.   conduction electrons are found in and freely flow in the *conduction* band ;
 ii.   holes exist in and flow in the valence band ;
iii.   conduction electrons move almost twice as fast as the holes.

Valence and Conduction Bands

The outermost electrons of an atom *i.e.* those in the shell furthermost from the nucleus are called *valence* electrons and have the *highest* energy* or least binding energy. It is these electrons which are most affected when a number of atoms are brought very close together as during the

formation of a solid. The states of lower-energy electrons orbiting in shells nearer to the nucleus are little, if at all, affected by this atomic proximity.

The band of energy occupied by the valence electrons is called the **valence band** and is, obviously, the ***highest occupied band***. It may be completely filled or partially filled with electrons but never empty.

The next higher permitted energy band is called the ***conduction*** band and may either be **empty** or **partially filled** with electrons. In fact, it may be defined as the lowest unfilled energy band.

In conduction band, electrons can move freely and hence are known as ***conduction*** electrons.

The gap between these two bands is known as the ***forbidden energy gap.***

It may be noted that the covalent force of the crystal lattice have their source in the valence band. If a valence electron happens to absorb enough energy, it jumps across the forbidden energy gap and enters the conduction band. An electron in the conduction band can jump to an adjacent conduction band more readily than it can jump back to the valence band from where it had come earlier. However, if a conduction electron happens to radiate too much energy, it will suddenly reappear in the valence band once again.

When an electron is ejected from the valence band, a covalent bond is broken and a positively charged hole is left behind. This hole can travel to an adjacent atom by acquiring an electron from adjacent atom.

Figure 2.2: Energy Band Diagram
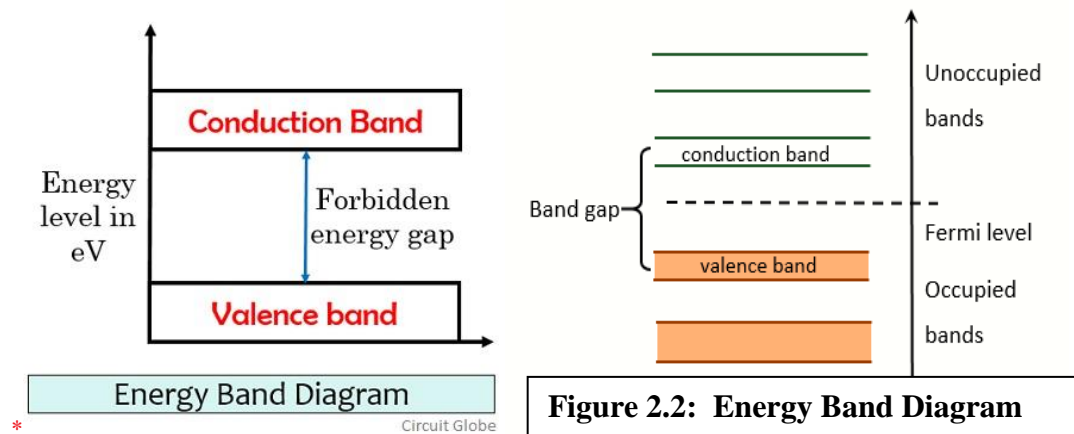
ASSIGNMENT 2

1. Explain the following terms
   (a) Photons (b) Ionization (c) Electrons (d) Fermi level (e) Energy Band
2. Differentiate between valance band and conduction band

QUIZ 2

1. List the first twenty elements
2. Categorize them to metals and non-metals and sketch their internal structure showing their energy levels and valency

LECTURE 3.0

TOPIC: SEMICONDUCTOR DEVICES

Types of materials: (Insulators, Conductors and Semiconductors)

Materials may be classified as **conductors, semiconductors** or **insulators**. The classification depends on the value of resistivity of the material. Good conductors are usually metals and have resistivities in the order of 10^{-7} to 10^{-8} Ωm, **Semiconductors** have resistivities in the order of 10^{-3} to $3 * 10^3$ Ωm and the resistivities of **insulators** are in the order of 10^4 to 10^{14} Ωm.
.
The electrical conduction properties of different elements and compounds can be explained in terms of the electrons having energies in the valence and conduction bands. The electrons lying in the lower energy bands, which are normally filled, play no part in the conduction process.

Examples

Conductors:
Aluminium, Brass, Copper, Steel

Semiconductors:
Silicon, Germanium

Insulators:
Glass, Mica, PVC , Rubber (pure)

In general, over a limited range of temperatures, the resistance of a **conductor** increases with temperature increase, the resistance of **insulators** remains approximately constant with variation of temperature and the resistance of semiconductor materials decreases as the temperature increases.

PROPERTIES OF SEMICONDUCTOR

1. The resistivity of semiconductor is less than that of an insulator but more than that of a conductor
2. They have negative temperature coefficient of resistance, i.e. the resistance of the semiconductor increases with decrease in temperature and vice versa
3. When a suitable metallic material (e.g. arsenic, gallium, antimony etc) is added to the semiconductor, its current conducting properties change appreciably

Silicon and germanium
The most important semiconductors used in the electronics industry are silicon and germanium. As the temperature of these materials is raised above room temperature, the resistivity is reduced and ultimately a point is reached where they effectively become conductors. For this reason,

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silicon should not operate at a working temperature in excess of 150°C to 200°C, depending on its purity, and germanium should not operate at a working temperature in excess of 75°C to 90°C, depending on its purity. As the temperature of a semiconductor is reduced below normal room temperature, the resistivity increases until, at very low temperatures the semiconductor becomes an insulator.

Gallium arsenide (GaAs) is also widely used in high-speed devices but so far, it has been difficult to form large-diameter boules of this material, limiting the wafer diameter to sizes significantly smaller than silicon wafers thus making mass production of GaAs devices significantly more expensive than silicon.

Other less common materials are also in use or under investigation.

Silicon carbide (SiC) has found some application as the raw material for blue light-emitting diodes (LEDs) and is being investigated for use in semiconductor devices that could withstand very high operating temperatures and environments with the presence of significant levels of ionizing radiation. IMPATT diodes have also been fabricated from SiC.

Various indium compounds (indium arsenide, indium antimonide, and indium phosphide) are also being used in LEDs and solid state laser diodes. Selenium sulfide is being studied in the manufacture of photovoltaic solar cells.

The most common use for **organic semiconductors** is **Organic light-emitting diodes**

n-type and p-type materials

Adding extremely small amounts of impurities to pure semiconductors in a controlled manner is called **doping**. Antimony, arsenic and phosphorus **(group 5 elements)** are called **n-type impurities** and form an **n-type material** when any of these impurities are added to silicon or germanium. The amount of impurity added usually varies from 1 part impurity in 105 parts semiconductor material to 1 part impurity to 108 parts semiconductor material, depending on the resistivity required. Indium, aluminium and boron **(group 3 elements)** are called **p-type impurities** and form a **p-type material** when any of these impurities are added to a semiconductor.

In semiconductor materials, there are very few charge carriers per unit volume free to conduct. This is because the **'four electron structure'** in the outer shell of the atoms (called valency electrons), form strong **covalent bonds** with neighbouring atoms, resulting in a tetrahedral structure with the electrons held fairly rigidly in place. A two-dimensional diagram depicting this is shown for germanium
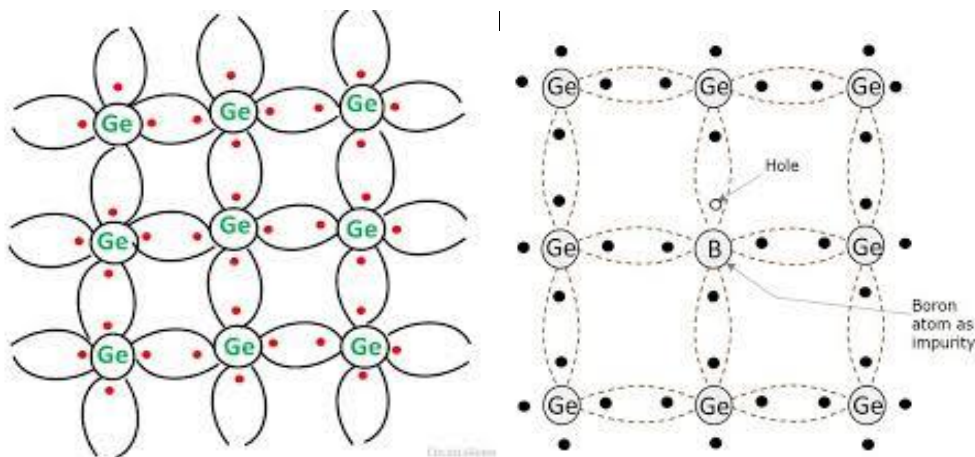
Figures : 3.1a(germanium crystal) and 3.1b (p-type, showing hole)

Arsenic, antimony and phosphorus have five valency electrons and when a semiconductor is doped with one of these substances, some impurity atoms are incorporated in the tetrahedral structure. The **'fifth' valency electron** is not rigidly bonded and is free to conduct, the impurity atom donating a charge carrier. A two-dimensional diagram depicting this is shown in figure 3.2 in which a **arsenic** atom has replaced one of the germanium atoms. The resulting material is called **n-type material**, and contains **free electrons**.

Indium, aluminium and boron have three valency electrons and when a semiconductor is doped with one of these substances, some of the semiconductor atoms are replaced by impurity atoms. One of the four bonds associated with the semiconductor material is deficient by one electron and this deficiency is called a **hole**. Holes give rise to conduction when a potential difference exists across the semiconductor material due to movement of electrons from one hole to another, as shown in **figure 3.1**

In this figure, an electron moves from A to B, giving the appearance that the hole moves from B to A. Then electron C moves to A, giving the appearance that the hole moves to C, and so on. The resulting material is **p-type material** containing **holes**.
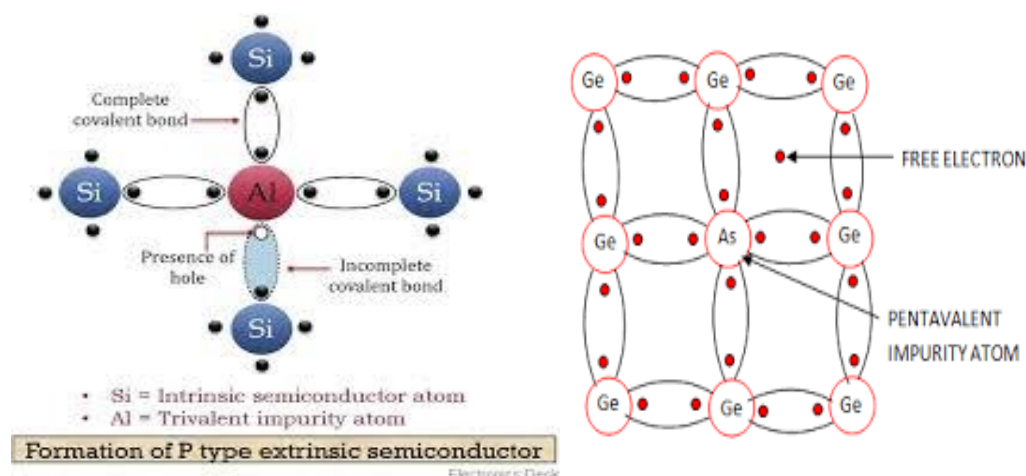
Figures : 3.2a(p-type) and 3.2b (n-type)

ASSIGNMENT 3:

a. State the characteristics of insulators, semiconductors and conductors with examples
b. State five properties of semiconductors
c. Mention the most commonly used semiconductors and state the reasons why they are commonly used?

QUIZ 3:

a. Explain the term "doping"
b. Differentiate between free electrons and holes
c. Show with the aid of 2-D diagrams how semiconductors are doped with n-type and p-type materials with explanations

LECTURE 4.0

 The p-n junction

A **p-n junction** is a piece of semiconductor material in which part of the material is p-type and part is n-type. In order to examine the charge situation, assume that separate blocks of p-type and n-type materials are pushed together. Also assume that a hole is a positive charge carrier and that an electron is a negative charge carrier. At the junction, the donated electrons in the n-type material, called **majority carriers**, diffuse into the p-type material (diffusion is from an area of high density to an area of lower density) and the acceptor holes in the p-type material diffuse into the n-type material as shown by the arrows in Figure 11.5. Because the n-type material has lost electrons, it acquires a positive potential with respect to the p-type material and thus tends to prevent further movement of electrons. The p-type material has gained electrons and becomes negatively charged with respect to the n-type material and hence tends to retain holes. Thus after a short while, the movement of electrons and holes stops due to the potential difference across the junction, called the **contact potential**. The area in the region of the junction becomes depleted of holes and electrons due to electron-hole recombinations, and is called a **depletion layer**.
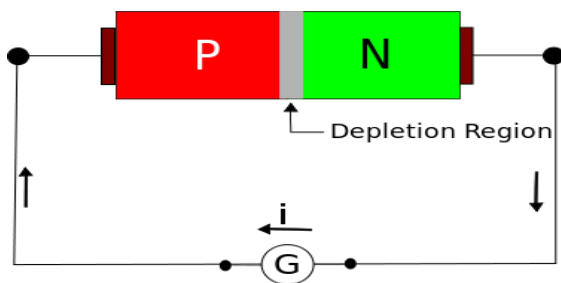
Forward and reverse bias

When an external voltage is applied to a p-n junction making the p-type material positive with respect to the n-type material, as shown in the Figure, the p-n junction is **forward biased**. The applied voltage opposes the contact potential, and, in effect, closes the depletion layer.
Holes and electrons can now cross the junction and current flows. An increase in the applied voltage above that required to narrow the depletion layer (about 0.2V for germanium and 0.6V for silicon), results in a rapid rise in the current flow. Graphs depicting the current-voltage relationship for forward biased p-n junctions, for both germanium and silicon, called the **forward characteristics**, are shown
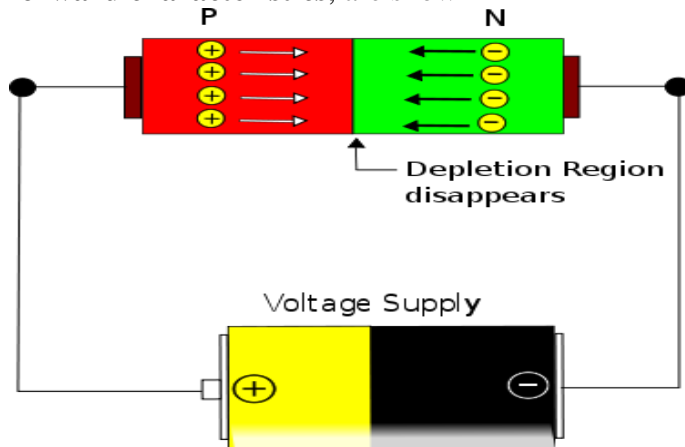

Figure : **Forward bias**

When an external voltage is applied to a p-n junction making the p-type material negative with respect to the n-type material as in shown in Figure 11.9, the p-n junction is **reverse biased**. The applied voltage is now in the same sense as the contact potential and opposes the movement of holes and electrons due to opening up the depletion layer. Thus, in theory, no current flows. However at normal room temperature certain electrons in the covalent bond lattice acquire sufficient energy from the heat available to leave the lattice, generating mobile electrons and holes. This process is called electron-hole generation by thermal excitation. The electrons in the p-type material and holes in the n-type material caused by thermal excitation, are called **minority carriers** and these will be attracted by the applied voltage. Thus, in practice, a small current of a few microamperes for germanium and less than one microampere for silicon, at normal room temperature, flows under reverse bias conditions.
Typical **reverse characteristics** are shown in Figure 11.10 for both germanium and silicon.
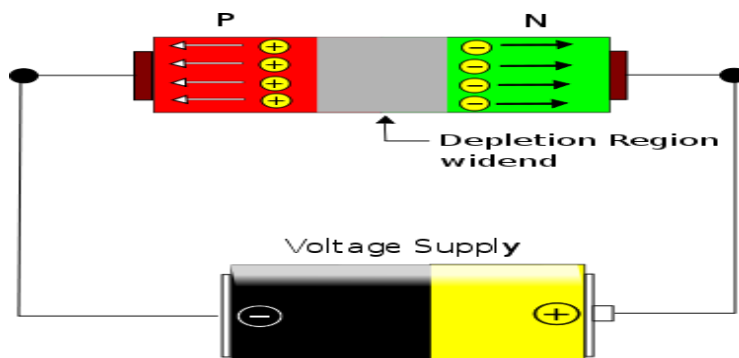

Figure : **Reverse Bias**

Semiconductor diodes

A **diode** is a two-terminal electronic component that conducts __current__ primarily in one direction (asymmetric __conductance__); it has low **(ideally zero)** __resistance__ in one direction, and high **(ideally infinite)** __resistance__ in the other. A diode **__vacuum tube__** or **thermionic diode** is a vacuum tube with two **__electrodes__**, a heated **__cathode__** and a **__plate__ (anode)**, in which electrons can flow in only one direction, from cathode to plate.
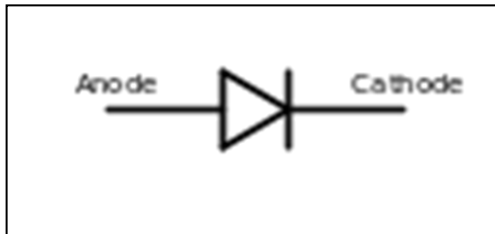

Figure: Symbol of a Diode
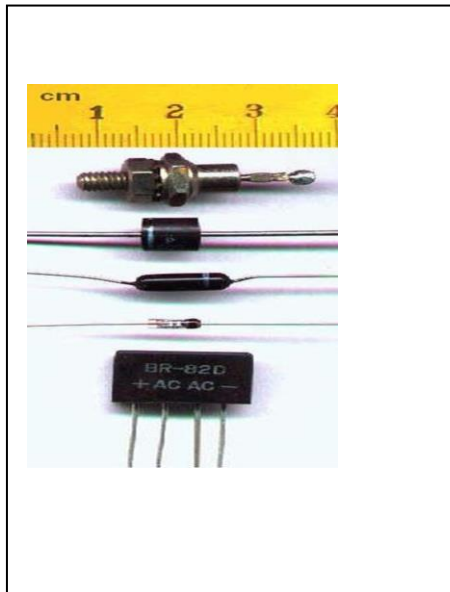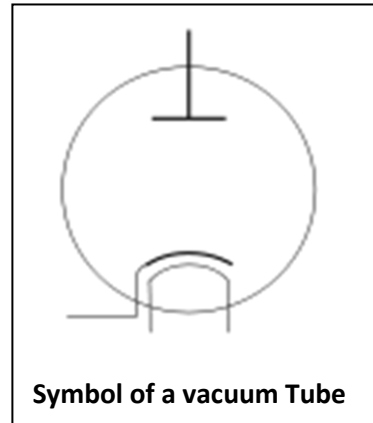

Symbol of a vacuum Tube

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Figure: Picture of various types of diode

Important Terms:

I. **Forward Current**: it is the current flowing through a forward biased diode. Every diode has a maximum value of forward current which it can safely carry. If this value is exceeded, the diode may be destroyed due to excessive heat. For this reason , the manufacturers data sheet specifies the maximum forward current that a diode can handle safely.

II. **Peak Inverse Voltage** : it is the maximum reverse voltage that a diode can withstand without without destroying the junction. If the reverse voltage across a diode exceeds this value, the reverse current increases sharply and breaks down the junction due to

excessive heat. Peak inverse voltage (PIV) is extremely important when diode is used as a rectifier. In rectifier service, it has to be ensured that reverse voltage across the diode does not exceed its PIV during the negative half-cycle of input a.c. voltage. As a matter of fact, PIV consideration is generally the deciding factor in diode rectifier circuits.

III.   **Reverse Current or Leakage Current:** it is the current that flows through a reverse biased diode. This current is due to the minority carriers. Underr normal operating voltages, the reverse current is quite small

A **semiconductor diode**, the most commonly used type today, is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. Semiconductor diodes were the first semiconductor electronic devices. The discovery of asymmetric electrical conduction across the contact between a crystalline mineral and a metal was made by German physicist **Ferdinand Braun** in 1874. Today, most diodes are made of **silicon**, but other materials such as **gallium arsenide** and **germanium** are also used.
A new material called **gallium-arsenide(GaAs)** is found to combine desirable features of both Ge and Si and is finding ever-increasing use in many new applications.
The *P-N* junction may be produced by any one of the following methods :

1. grown junction **2.** alloy junction **3.** diffused junction **4.** epitaxial growth **5.** point contact junction

Semiconductor Diode Construction

Anode   P   N   Cathode

Impurities are added to it to create a region on one side that contains negative **charge carriers** (electrons), called an n-type semiconductor, and a region on the other side that contains positive charge carriers (holes), called a p-type semiconductor. When the n-type and p-type materials are attached together, a momentary flow of electrons occur from the n to the p side resulting in a third region between the two where no charge carriers are present. This region is called the **depletion region (as shown above)** because there are no charge carriers (neither electrons nor holes) in it. The diode's terminals are attached to the n-type and p-type regions. The boundary between these two regions, called a p–n junction, is where the action of the diode takes place. When a sufficiently higher electrical potential is applied to the P side (the anode) than to the N side (the cathode), it allows electrons to flow through the depletion region from the N-type side to the P-type side. The junction does not allow the flow of electrons in the opposite direction when the potential is applied in reverse

Example: *Calculate the current and power dissipated in (a) an ideal diode*
               (b) a 6 Ω resistor, if connected with the ideal diode.

               Solution. The diode is an ideal one and is forward-biased. Hence, it can be
   replaced by a short closed switch. The circuit current, as given by Ohm's law, is
                              $I = 12/6 =$ **2 A**

(*a*) Since there is no voltage drop across the diode, power consumed by it is **zero**. As we know, there is no power when either the voltage or current is zero. In the forward direction, there is current but no voltage drop, hence power dissipated by the ideal diode is zero. In the reverse direction, there is voltage but no current. Hence, power dissipated by the diode is again zero.

In fact, an ideal diode never dissipates any power.

(*b*) power consumed by 6 Ω resistor = 22 × 6 = **24 W.**

Example 2: An a.c voltage of peak value 20V is connected in series with a silicon diode and load resistance of 500Ω. If the forward resistance of diode is 10Ω, find:

(a) Peak current through the diode
(b) Peak output voltage
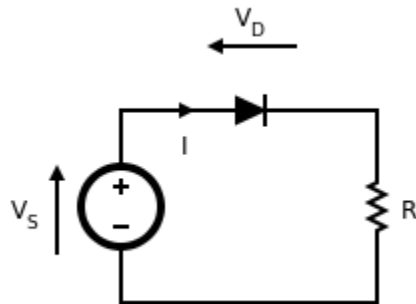
Solutions:

Peak Input Voltage	= 20V
Forward Resistance (r_f)	= 10Ω
Load Resistance (R_L)	= 500Ω
Potential barrier voltage (Vo)	= 0.7V for silicon

The diode will conduct during the positive half-cycles of ac input voltage only. The cicuit is shown above.

(i) The peak current through the diode will occur at the instant when the input voltage reaches positive peak i.e. Vin = Vp = 20V

∴ $$Vf = Vo + (If)peak [(r_f + R_L]$$

Or $$(If)peak = \frac{Vf - Vo}{[(r_f) + R_L} = \frac{20 - 0.7}{10 + 500}$$

$$= \textbf{37.8mA}$$

(ii) Peak Output Voltage = $(I_f)peak$ x R_L
= 37.8mA x 500Ω
= **18.9 V**

LECTURE 5.0:   Rectification through Crystal Diode:

The process of obtaining unidirectional currents and voltages from alternating currents and voltages is called **rectification**. The process of converting the AC current into DC current is called rectification. Rectification can be achieved by using a single diode or group of diodes. These diodes which convert the AC current into DC current are called rectifiers.

Automatic switching in circuits is carried out by diodes. For methods of half-wave and full wave rectification, see the figures below:

A **half wave rectifier** is defined as a type of **rectifier** that only allows one **half**-cycle of an AC voltage waveform to pass, blocking the other **half**-cycle. **Half-wave** rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct as shown in figure 5.1
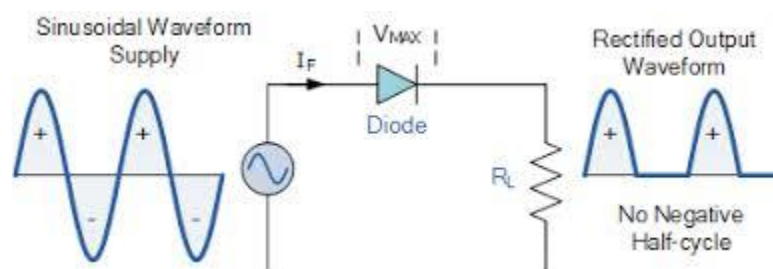

Figure 5.1: Half –wave rectifier

Full wave rectifier definition

A full wave rectifier is a type of rectifier which converts both half cycles of the AC signal into pulsating DC signal.

As shown in the figure below, the full wave rectifier converts both positive and negative half cycles of the input AC signal into output pulsating DC signal.

The full wave rectifier is further classified into two types: center tapped full wave rectifier and full wave bridge rectifier
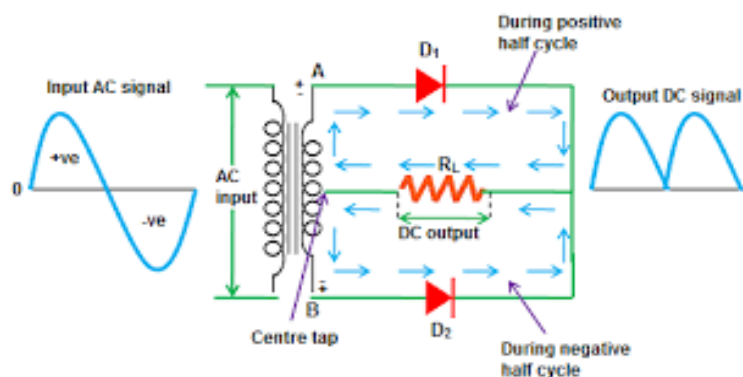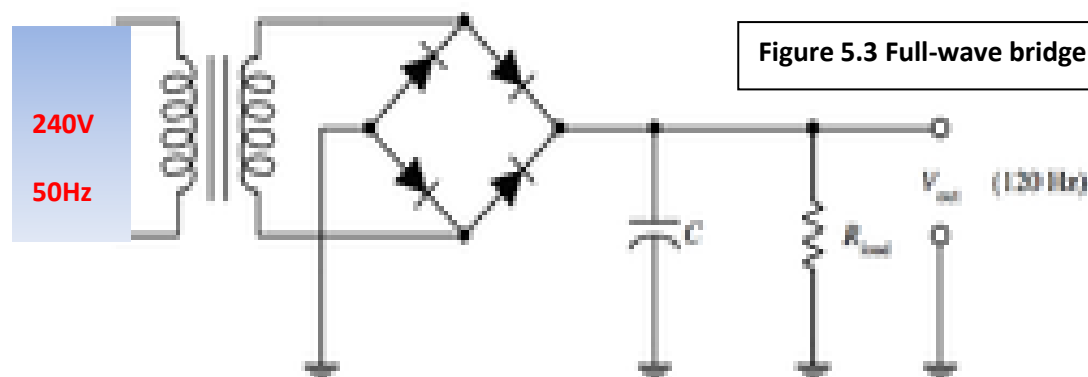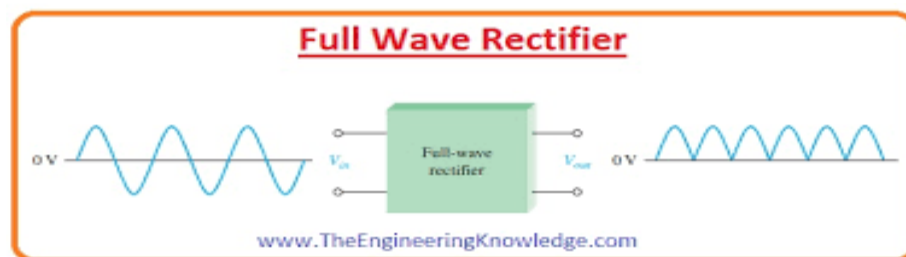
Figure 5.2 Full-wave center-tapped

Figure 5.3 Full-wave bridge rectifier

Characteristics of full wave rectifier

Ripple factor

The ripple factor is used to measure the amount of ripples present in the output DC signal. A high ripple factor indicates a high pulsating DC signal while a low ripple factor indicates a low pulsating DC signal.

Ripple factor is defined as the ratio of ripple voltage to the pure DC voltage

The ripple factor is given by

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

Finally, we get

$$\gamma = 0.48$$

Rectifier efficiency

Rectifier efficiency indicates how efficiently the rectifier converts AC into DC. A high percentage of rectifier efficiency indicates a good rectifier while a low percentage of rectifier efficiency indicates an inefficient rectifier.
Rectifier efficiency is defined as the ratio of DC output power to the AC input power.
It can be mathematically written as

$$\eta = \text{output } P_{DC} / \text{input } P_{AC}$$

The rectifier efficiency of a full wave rectifier is **81.2%.**

The rectifier efficiency of a full wave rectifier is twice that of the half wave rectifier. So the full wave rectifier is more efficient than a half wave rectifier

Peak inverse voltage (PIV)

Peak inverse voltage or peak reverse voltage is the maximum voltage a diode can withstand in

the reverse bias condition. If the applied voltage is greater than the peak inverse voltage, the diode will be permanently destroyed.

The peak inverse voltage **(PIV) = 2V$_{smax}$**

DC output current

At the output load resistor R_L, both the diode D_1 and diode D_2 currents flow in the same direction. So the output current is the sum of D_1 and D_2 currents.
The current produced by D_1 is I_{max} / π and the current produced by D_2 is I_{max} / π.

So the output current $I_{DC} = 2I_{max} / \pi$
            Where,
                  I_{max} = maximum DC load current

DC output voltage

The DC output voltage appeared at the load resistor R_L is given as

            V_{DC} $= 2V_{max} / \pi$
             Where,
                V_{max} = maximum secondary voltage

Root mean square (RMS) value of load current I_{RMS}

The root mean square (RMS) value of load current in a full wave rectifier is

$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

Root mean square (RMS) value of the output load voltage V_{RMS}

The root mean square (RMS) value of output load voltage in a full wave rectifier is

$$V_{RMS} = I_{RMS} R_L = \frac{I_m}{\sqrt{2}} R_L$$

Form factor

Form factor is the ratio of RMS value of current to the DC output current
It can be mathematically written as
                F.F = RMS value of current / DC output current
The form factor of a full wave rectifier is
                F.F = 1.11

Advantages of full wave rectifier with center tapped transformer

High rectifier efficiency

Full wave rectifier has high rectifier efficiency than the half wave rectifier. That means the full wave rectifier converts AC to DC more efficiently than the half wave rectifier.

Low power loss

In a half wave rectifier, only half cycle (positive or negative half cycle) is allowed and the remaining half cycle is blocked. As a result, more than half of the voltage is wasted. But in full wave rectifier, both half cycles (positive and negative half cycles) are allowed at the same time. So no signal is wasted in a full wave rectifier.

Low ripples

The output DC signal in full wave rectifier has fewer ripples than the half wave rectifier.

Disadvantages of full wave rectifier with center tapped transformer

High cost

The center tapped transformers are expensive and occupy a large space.

ASSIGNMENT 5:

1. The applied input a.c. power to a half-wave rectifier is 100 watts. The d.c output power obtained is 40 watts.
    (i)   What is the rectification efficiency?
    (ii)   What happens to remaining 50 watts?
2. Differentiate between fuul wave and half wave rectifier

QUIZ 5:

1. State and explain any three characteristics of full-wave rectifier?
2. Define rectification?
3. Sketch the schematic diagram of a full wave bridge rectifier

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LECTURE 6.0   FILTER CIRCUITS

Generally, a rectifier is required to produce pure d.c supply for using at various places in the electronic circuits. However, the output of a rectifier has pulsating character i.e. it contains a.c. and d.c components. The a.c components is undesirable and must be kept away from the load. Pulsating DC voltage is a DC voltage whose value changes between 0 and a maximum positive value V_max(say). It is most commonly found as output of rectifier, half-wave or full-wave. Only its value changes, not the polarity. In case of Pulsating DC current, only value of current changes between 0 and I_max, not the direction of current. As the ripples are removed by filters, it approaches futher and further to smooth, constant DC
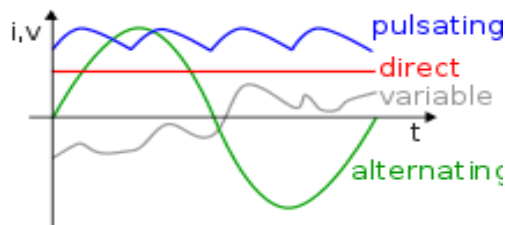

Figure 6.1: Waveforms

A **filter circuit** is a device to remove the A.C components of the rectified output, but allows the D.C components to reach the load. A **filter circuit** is in general a combination of inductor (L) and Capacitor (C) called LC **filter circuit**. A capacitor allows A.C only and inductor allows D.C only to pass. There are two categories of filter, which are:

- Active Filter
- Passive Filter

Active Filters

Filter Circuit which consists of active components like Transistors and Op-amps in addition to Resistors and Capacitors is called **Active Filter**.

Passive Filters

Filter circuit which consists of passive components such as Resistors, Capacitors and Inductors is called as **Passive Filter** (e,g. Capacitor filter, choke input filter and capacitor input filter).

The operating frequency range of the filter banks on the components used to build the circuit. Hence the filter can be further categorized based on the operating frequency of a particular circuit. They are:

- Low Pass Filter
- High Pass Filter
- Band Pass Filter
- Band Stop Filter

- All Pass Filter
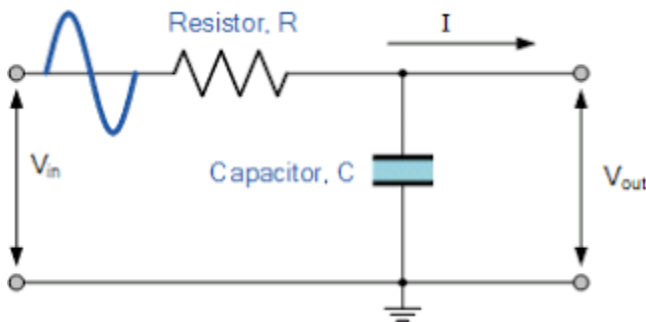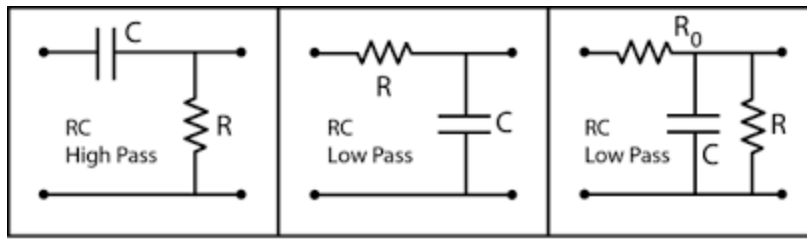
Figures 6.2 and 6.3: Types of Filter circuits

VOLTAGE STABILIZATION

A rectifier with an appropriate filter serves as a good sources of d,c output. However, the major disadvantage of such a power supply is that the output voltage changes with the variations in the input voltage or load. Thus if the input voltage increases, the d,c output voltage of the rectifier also increases. Similarly, if the load current increases, the output voltage falls due to the voltage drop in the rectifying element, filter chokes, transformer windings etc. in many electronic applications, it is desired that the output voltage remain constant regardless of the variations in the input voltage or load. In other to ensure this, a voltage stabilizing device, called **voltage stabilizer** is used. Several stabilizing circuits have been designed but Zener diode will be discussed here.

Zener Diode

A **zener diode** is used for voltage reference purposes or for voltage stabilization.

A **Zener diode** is a particular type of diode that, unlike a normal one, allows current to flow not only from its anode to its cathode, but also in the reverse direction, when the so-called "**Zener voltage**" is reached. Zener diodes have a highly doped p-n junction. Normal diodes will also break down with a reverse voltage but the voltage and sharpness of the **knee** are not as well defined as for a Zener diode. Also normal diodes are not designed to operate in the **breakdown region,** but Zener diodes can reliably operate in this region.

The device was named after **Clarence Melvin Zener,** who discovered the **Zener effect**. Zener reverse breakdown is due to electron **quantum tunnelling** caused by a high strength electric field. However, many diodes described as "Zener" diodes rely instead on **avalanche**

breakdown. Both breakdown types are used in Zener diodes with the Zener effect predominating under **5.6 V** and avalanche breakdown above.

Zener diodes are widely used in electronic equipment of all kinds and are one of the basic building blocks of electronic circuits. They are used to generate low power stabilized supply rails from a higher voltage and to provide reference voltages for circuits, especially stabilized power supplies. They are also used to protect circuits from over-voltage, especially electrostatic discharge (ESD
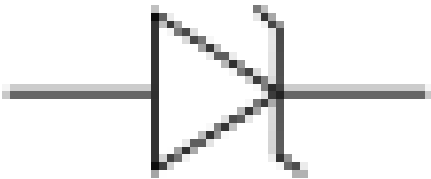

Figure 6.4: Symbol of a Zener Diode   Figure 6.5: Graphical Picture of a Zener Diode
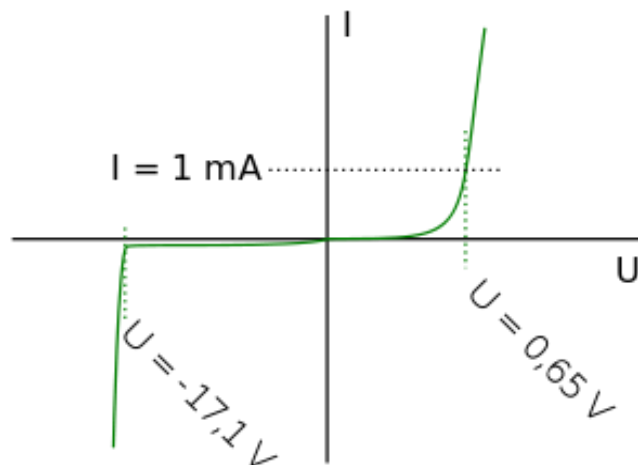

Figure 6.6 Current-voltage characteristic of a Zener diode with a breakdown voltage of 17 volts. Notice the change of voltage scale between the forward biased (positive) direction and the reverse biased (negative) direction.
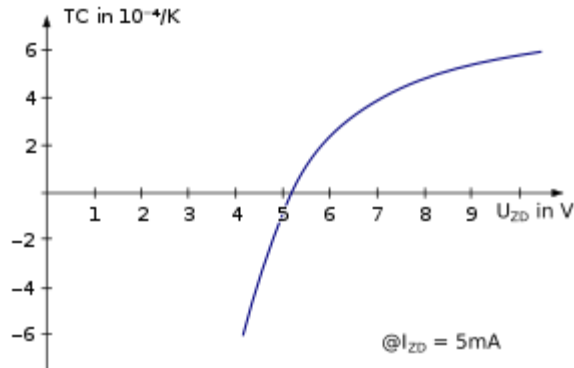
Figure 6.7: Graphical form

The **Zener diode** specially made to have a reverse **voltage** breakdown at a specific **voltage**. Its characteristics are otherwise very similar to common **diodes**. In breakdown the **voltage** across the **Zener diode** is close to constant over a wide range of currents thus making it useful as a shunt **voltage regulator**

Example 6.1:
For the circuit shown:

Find the maximum and minimum value of zener diode current, given that the variable voltage ranges are 80v-120v, with zener voltage of 50v, input resistance of 5kΩ and output resistance of 10kΩ

Zener Diode & Zener Voltage Regulator Calculator
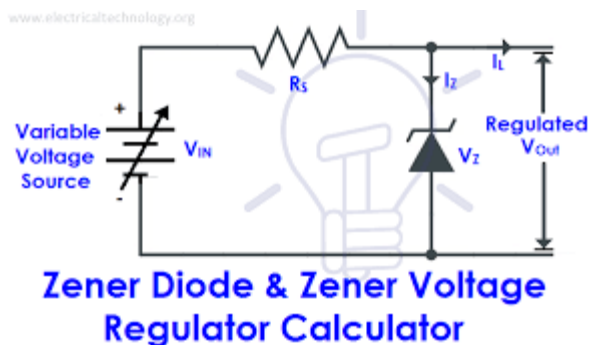
Solution:

(i)   Maximum Zener current: The sener diode will conduct maximum current when the input voltage is maximum i.e. 120V. Under such conditions:

Voltage across 5kΩ = 120v – 50v = 70v
Current through 5kΩ,
$$I = \frac{70v}{5k\Omega} = \textbf{14mA}$$

Load Current $I_L = \dfrac{50v}{10k\Omega} = \mathbf{5mA}$

Applying Kirchhoff;s first law

$$I = I_L + Iz$$

Zener Current $Iz = I - I_L = 14mA - 5mA$
$= \mathbf{9mA}$

(ii)   Minimum Zener Current . The zener diode will conduct minimum current when the input voltage is at minimum i.e. 80v
Under such conditions :
Voltage across $5k\Omega = 80v - 50v = 30v$
Current through $5k\Omega$, $I = \dfrac{30v}{5k\Omega} = 6mA$

Load Current $I_L = 5mA$
Zener Current $Iz = I - I_L = 6mA - 5mA$
$= \mathbf{1mA}$

Thyristor Switch

A thyristor is a solid-state semiconductor device with four layers of alternating P- and N-type materials. It acts exclusively as a bistable switch, conducting when the gate receives a current trigger, and continuing to conduct until the voltage across the device is reversed biased, or until the voltage is removed
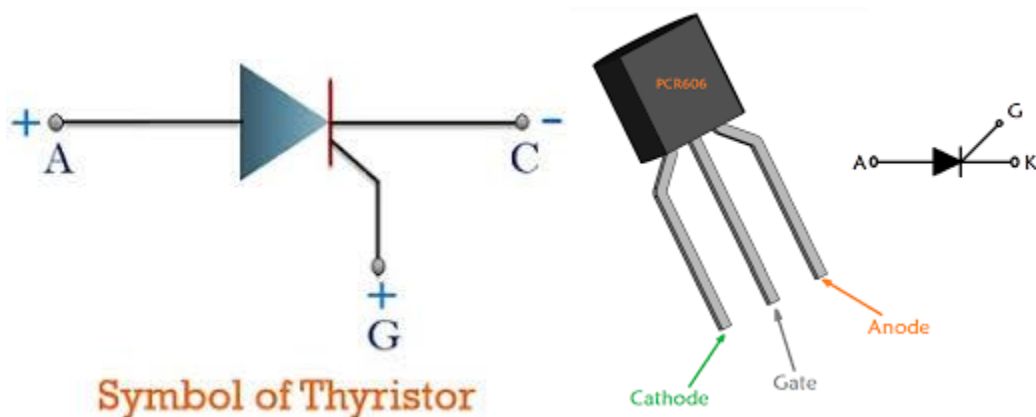
Figures 6.8a, 6.8b : Symbol and picture of thyristor
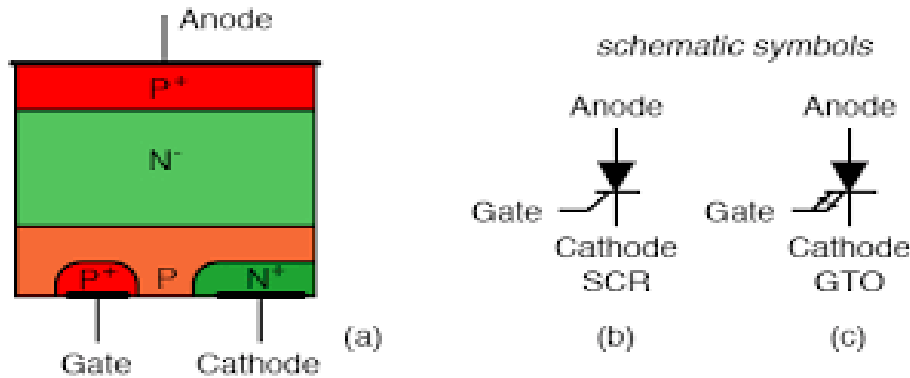
Figures 6.9a and 6.9b Schematic symbols of a thyristor

Thyristors are **high-speed** solid-state devices which can be used to control motors, heaters and lamps. The amount of power delivered to a load can be controlled using a **thyristor**, which is a semi-conductor device
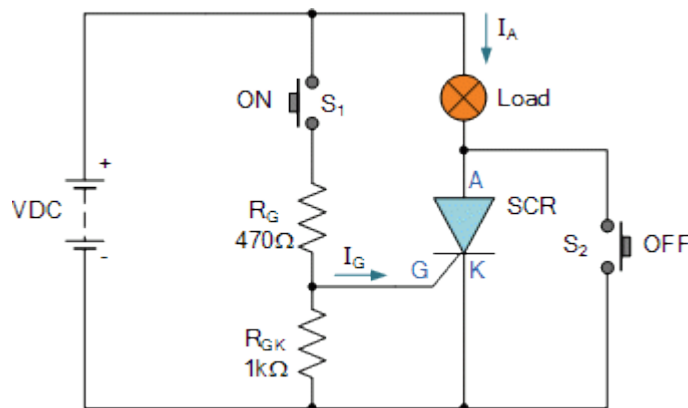
Figure 6.10 : Thyristor firing circuit

This simple "on-off" thyristor firing circuit uses the thyristor as a switch to control a lamp, but it could also be used as an on-off control circuit for a motor, heater or some other such DC load. The thyristor is forward biased and is triggered into conduction by briefly closing the normally-open "ON" push button, S_1 which connects the Gate terminal to the DC supply via the Gate resistor, R_G thus allowing current to flow into the Gate. If the value of R_G is set too high with respect to the supply voltage, the thyristor may not trigger.

.

ASSIGNMENT 6:

1. For the circuit shown in example 6.1 above:
    Find the maximum and minimum value of zener diode current, given that the variable voltage ranges are 60v-100v, with zener voltage of 40v, input resistance of 5kΩ and output resistance of 15kΩ
2. Sketch and explain any two types passive filters

QUIZ 6

1. State four applications of thyristor switch
2. Explain the following terms:
    (a) pulsating dc
    (b) breakdown region
    (c) filter circuit

LECTURE 7.0:   TRANSISTORS

There are basically two types of transistors, the Bipolar Junction Transistor **(BJT)** and the Field Effect Transistor **(FET).**

BIPOLAR JUNCTION TRANSISITORS

A bipolar transistor - properly known as a bipolar junction transistor or BJT - is a versatile **discrete semiconductor** device. Discrete semiconductors are designed primarily to perform one function as a single semiconductor, as opposed to having to build multiple semiconductor components into an **integrated circuit** on a printed circuit board (PCB). **Bipolar junction transistors** are solid state, three-pin (base, collector and emitter) components, constructed from three layers of silicon. There are two main types of **BJT transistor**, namely **PNP** (positive-negative-positive) and **NPN** (negative-positive-negative). As with all transistors, the basic function of a BJT is typically to **amplify power**.

Bipolar junction transistors are **'current operated devices'**, meaning a much smaller base current causes a larger current to flow from emitter to collector. Whereas transformers can amplify either current or voltage, transistors can **amplify both current and voltage**. In its raw configuration, a BJT will naturally amplify current, but when integrated into a circuit it can easily be made to amplify voltage - and so a bipolar transistor is thus frequently used as a method of signal amplification across a broad spectrum of circuits, systems and product types.

Transistors are used in a great many different types of electrical and electronic applications; indeed, they're often seen as one of the fundamental building blocks of modern circuitry.

When used as discrete components or in smaller quantities, bipolar transistor devices can be used to amplify signals on circuits, or to create simple electronic logic switches. Transistors can also be combined into much larger quantities and arrays, providing a far more powerful and flexible range of functions for use in modern computing and other complex electronics processes.

A bipolar junction transistor **comprises three terminals**, or pins, known respectively as **a base, a collector, and an emitter**. As with any transistor, the core working concept of a BJT is that a small amount of current flowing between the base and collector pins causes a larger current to flow between the collector and emitter pins.

The BJT can be driven into **'cutoff' (off)** and **'saturation' (on) modes**, as well as its standard **'active' (amplification) mode**.

- **'Active' mode**
  - In this mode, the transistor can function as an amplifier for the current flowing from base pin to collector, and proportionally increase that current flow from the collector pin to the emitter
  - This is among the most versatile and powerful modes a transistor can operate in, and is arguably the most common application for transistors used in circuits

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- **'On' or saturation mode**

  o In this mode, the transistor effectively acts as a short circuit between the collector and the emitter, with current flow between the two essentially unrestricted (the transistor operates as a closed or complete circuit)

- **'Off' or cutoff mode**

  o In this mode, which is the opposite of saturation, the transistor essentially resembles a broken or open circuit; no collector current is allowed to flow, and so there is no emitter current output

As stated in the bullet points above, when driven into either cutoff or saturation modes, the BJT effectively functions more like a binary (on/off) circuit switch. In addition to amplification, this is another of the most powerful and versatile uses of transistors, as we'll discuss in the following section

How a BJT works as a switch

Controlling the flow of power from one part of an electronic circuit to another is one of the key functions a transistor exists to fulfill - and, in this role, the transistor is effectively acting as an electronic switch rather than an amplifier per se. When pushed into either saturation or cutoff modes, a BJT essentially replicates the binary on/off functionality of a regular circuit switch, and can thus be used to create logic gates.
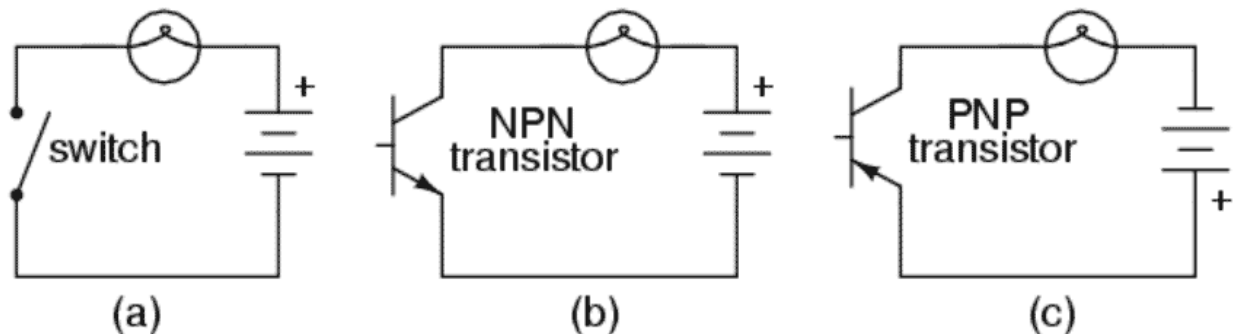
Figures 7.1a, 7.1b and 7.1c:

(a) Mechanical switch **(b)** NPN transistor switch **(c)** PNP transistor switch

Transistor Configurations: circuit configurations

Transistor circuits use one of three transistor configurations: **common base**, **common collector (emitter follower)** and **common emitter** - one is selected during the electronic circuit design process.

Each of the different transistor topologies has the inputs and outputs applied to different points, with one terminal common to both input and output.

In addition to selecting the right circuit configuration or topology in the electronic circuit design stage, to provide the required basic performance, additional electronic components are placed around the transistor: typically resistors and capacitors, and the values are calculated to give the exact performance needed

Common base transistor configuration

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

This transistor configuration is probably the least used, but it does provide advantages that the base which is common to input and output is grounded and this has advantages in reducing unwanted feedback between output and input for various RF circuit design applications. This occurs because the base, which is the electrode physically between the emitter and collector is grounded, thereby providing a barrier between the two.

As a result, the common base configuration tends to be used for RF amplifiers where the increased isolation between input and output gives a greater level of stability and reduces the likelihood of unwanted oscillation. As anyone involved in RF design will attest, this is a very useful attribute.

Also the low input impedance can often able this to provide a good match to 50Ω, a useful attribute for many RF design scenarios.

Common collector (emitter follower)

The common collector circuit configuration is possibly more widely known as the emitter follower because the emitter voltage follows that of the base, although lower in voltage by an amount equal tot he turn on voltage of the base emitter junction.

The common collector, emitter follower offers a high input impedance and a low output impedance. The voltage gain is unity, although current gain is high. The input and output signals are in phase.

In view of these characteristics, the emitter follower configuration is widely used as a buffer circuit providing a high input impedance to prevent loading of the previous stage, and a low output impedance to drive following stages.

Common emitter transistor configuration

This transistor configuration is probably the most widely used. The circuit provides a medium input and output impedance levels. Both current and voltage gain can be described as medium, but the output is the inverse of the input, i.e. 180° phase change. This provides a good overall performance and as such it is often the most widely used configuration.

INPUT Characteristics of CE

In a **Common Emitter configuration** of a Junction Transistor, the **emitter** is the **common** terminal. **Input** is between the base and **emitter**. The output is between the collector and **emitter**. **Input characteristics** are the variation of base current (I_B) with the base-**emitter** voltage (V_{BE}).

The **input characteristics** describe the relationship between **input** current or base current (IB) and **input** voltage or base-**emitter** voltage (VBE)
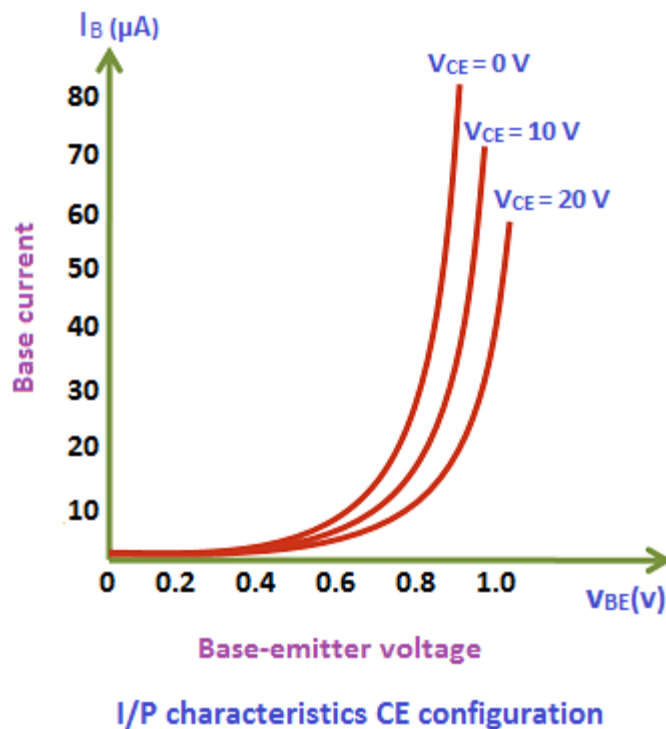

Figure 7.2

I/P characteristics CE configuration

Output Characteristics

In a **Common Emitter configuration** of a Junction Transistor, the **emitter** is the **common** terminal. Input is between the base and **emitter**. The **output** is between the collector and **emitter**. ... **Output characteristics** are the variation of collector current (I_C) with the collector-**emitter** voltage (V_{CE}).
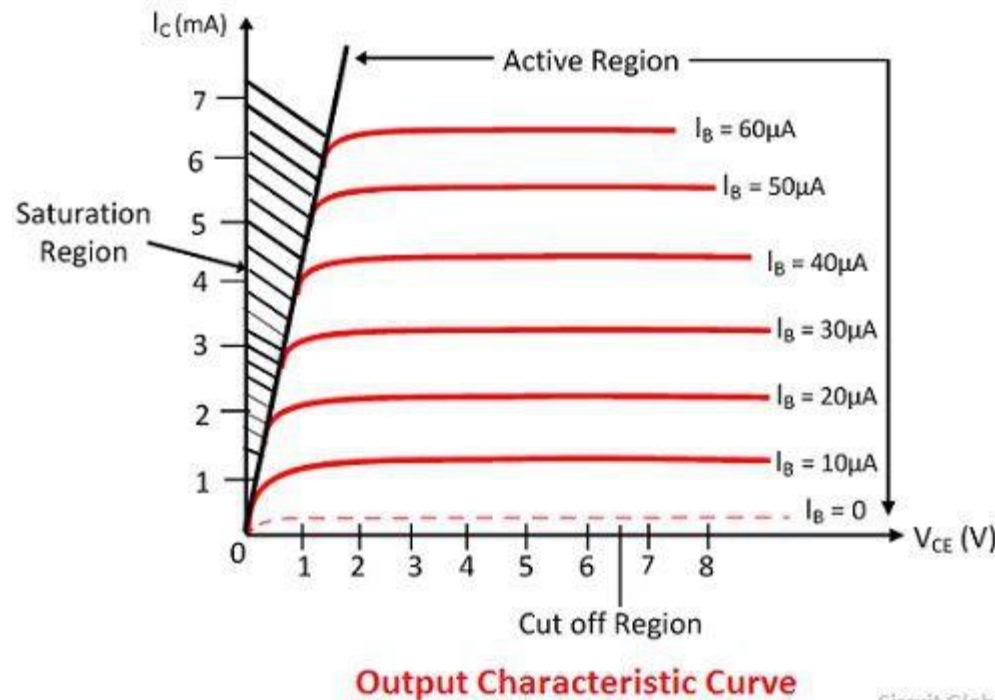

Figure 7.3

Transistor Biasing

Whatever form of transistor confirmation is chosen in the electronic circuit design stage, additional components will be needed around the transistor: resistors to set the bias points and capacitors to provide the coupling and decoupling.

In this circuit of the common emitter amplifier, the basic configuration sets the basic circuit conditions of medium input impedance, medium output impedance, reasonable voltage gain and the like. The additional electronic components are then calculated to give the required operating conditions beyond this.

Each of the electronic components needs to be calculated during the electronic circuit design stage to give the required performance.

Although the common emitter will probably be seen most often with electronic components like resistors and capacitors, when used for RF circuit design, components like inductors, and transformers may also be incorporated into the circuit. The same is true for the other transistor circuit configurations as well.
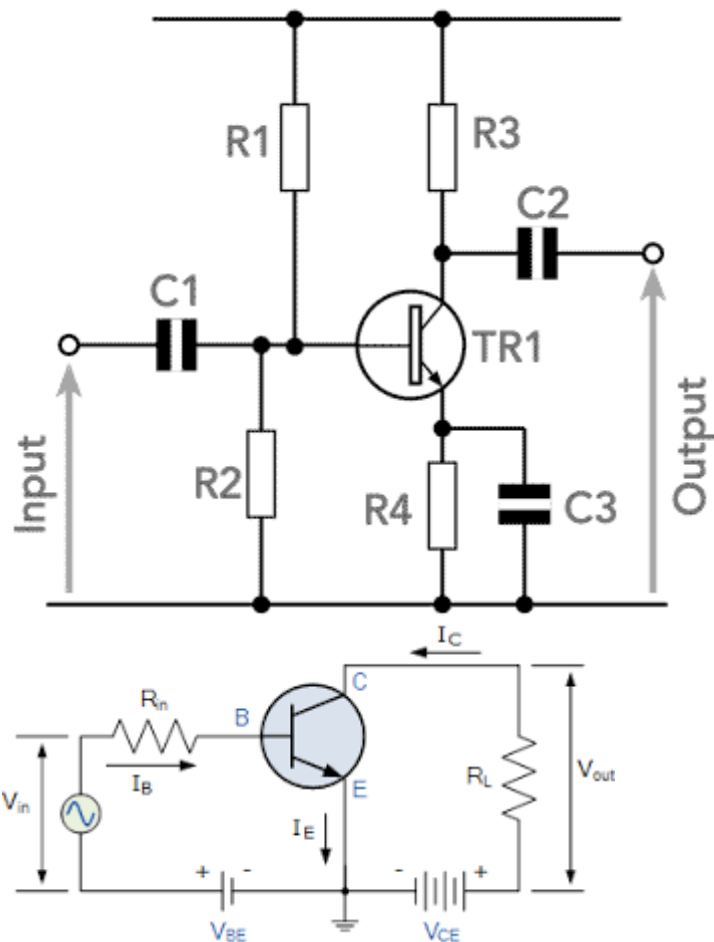
Figure 7.4: Biasing circuits of CE

Thermal runaway:

When a transistor is used as an amplifier it is necessary to ensure that it does not overheat. Overheating can arise from causes outside of the transistor itself, such as the proximity of radiators or hot resistors, or within the transistor as the result of dissipation by the passage of current through it. Power dissipated within the transistor, which is given approximately by the product ICVCE, is wasted power; it contributes nothing to the signal output power and merely raises the temperature of the transistor. Such overheating can lead to very undesirable results. The increase in the temperature of a transistor will give rise to the production of hole electron pairs, hence an increase in leakage current represented by the additional minority carriers. In turn, this leakage current leads to an increase in collector current and this increases the product ICVCE. The whole effect thus becomes self-perpetuating and results in **thermal runaway**. This rapidly leads to the destruction of the transistor.

LECTURE 8.0

Field-effect transistor (FET)

The **field-effect transistor** (**FET**) is a type of transistor which uses an electric field to control the flow of current. FETs are devices with three terminals: *source*, *gate*, and *drain*. FETs control the flow of current by the application of a voltage to the gate, which in turn alters the conductivity between the drain and source.

FETs are also known as **unipolar transistors** since they involve single-carrier-type operation. That is, FETs use electrons or holes as charge carriers in their operation, but not both. Many different types of field effect transistors exist. Field effect transistors generally display very high input impedance at low frequencies. The most widely used field-effect transistor is the MOSFET (metal-oxide-semiconductor field-effect transistor).

The field-effect transistor is also used as a controlled switch in high-voltage and high-frequency power circuits. The three terminals, **drain**, **gate**, and **source**, in an **n-channel** device bear the same relationship as the **collector**, **base**, and **emitter** in an NPN bipolar transistor. That is, a positive signal from gate to source causes the device to conduct a positive drain current.
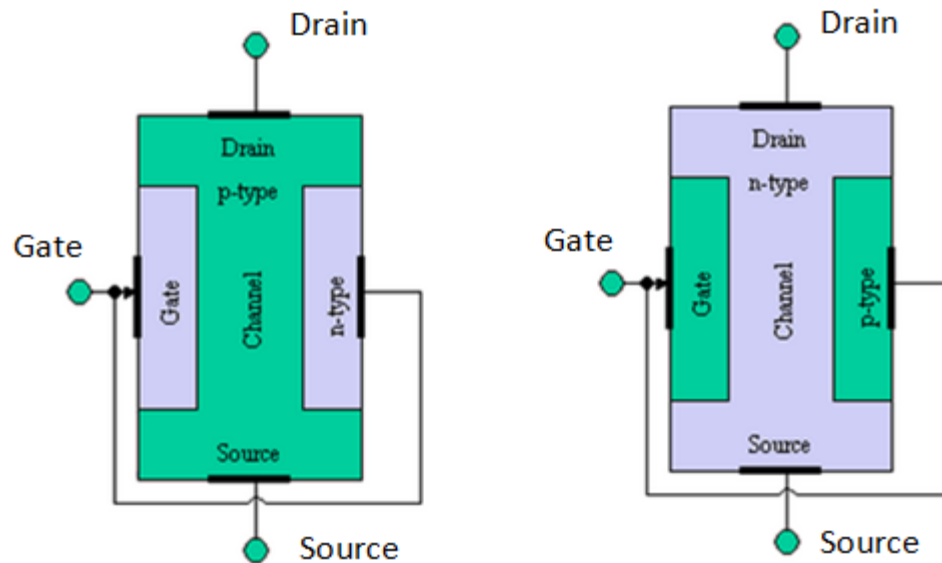
Figures 8.1a and 8.1b :　　**Field-Effect Transistors**

The **advantages** of power field-effect transistors over bipolar transistors are:

1. Field-effect transistors have faster switching speeds with reduced delay, rise, storage, and fall times.

2. Devices are voltage controlled rather than current controlled and can be driven from logic-level signals.

3. The second-breakdown failure mechanism of bipolar transistors is absent in field-effect transistors.

4. Field-effect transistors, because of the conduction voltage drop versus temperature characteristic, tend to share current when operated directly in parallel.

5. The device does not block reverse voltage but has a "built-in" rectifier that has a current rating equivalent to the drain current rating.

A **disadvantage** of present field-effect transistors is the higher conduction voltage drop when compared with a bipolar transistor of the same current rating. The value of "on" resistance is a function of the drain-source voltage rating of the device. Higher-voltage devices have higher on resistances and therefore lower drain currents for the same temperature rise. The voltage drop can be comparable with the voltage drop of a Darlington transistor.

At present, the voltage and current ratings of field-effect transistors are not as high as those available in bipolar transistors. Field-effect transistors have replaced some bipolar transistors in switching power supplies at generally higher operating frequencies, typically over 50 kHz.

Field-effect transistors (FETs) or thin-film transistor (TFTs) have gained considerable attention over the last few years because of their steadily increasing performance level and amenability for several different applications. TFTs are a wider class of gated devices that do not necessarily involve the field-effect mechanism. Their wide range of applications includes, digital display, electronic paper, radiofrequency identification, humidity control, pH measurement, detection of chemical and biologic species, monitoring of cell's growth, and drug delivery. Furthermore, they can also facilitate cell signaling and tissue regeneration.

The use of organic bioelectronics holds much promise as a platform to create novel investigation tools to study biochemical interactions and detect and transduce signals transmitted by biologic systems, such as, tissues and neuronal cells. Organic electrochemical transistors, whose operation mechanism is based on electrochemical doping of organic semiconductor (OSC), have attracted particular interest for chemical and biosensing applications due to the possibility of implementing biocompatible and water-stable OSCs.

n - Channel JFET   p - Channel JFET
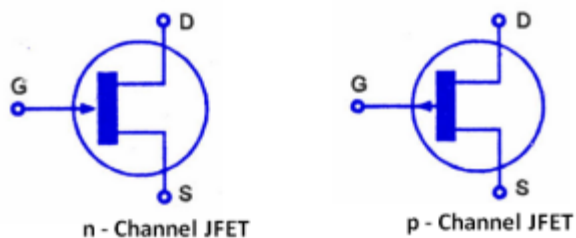
Figures 8.2a and 8.2b: Schematic Symbol of JFET

FETs are widely used as input amplifiers in oscilloscopes, electronic voltmeters and other measuring and testing equipment because of their high input impedance. As a **FET** chip occupies very small space as compared to **BJT** chip, **FETs** are widely used in ICs.
o Field effects transistors (FETs) are used in mixer circuits to control low inter modulation distortions.
o FETs are used in low frequency amplifiers due to its small coupling capacitors.
o It is a voltage controlled device due to this it is used in operational amplifier as voltage variable resistors.
o It is commonly used as input amplifiers in devices i.e. voltmeters, oscilloscopes, and other measuring devices, due to their high input Impedance.
o It is also used in radio frequency amplifiers for FM devices.
o It is used for mixer operation of FM and TV receiver.
o It is used in **large scale integration** (LSI) and computer memories because of its small size

BJTs vs FETs

	BJTs	FETs
How it operates	BJTs are current-controlled. They require a biasing current to the base terminal for operation.	FETs are voltage-controlled. They only require voltage applied to the gate to turn the FET either on or off. They do not require a biasing current for operation.
Input Impedance	BJTs offer smaller input impedances, meaning they draw more current from the power circuit feeding it, which can cause loading of the circuit.	FETs offer greater input impedance than BJTs. This means that they practically draw no current and therefore do not load down the power circuit that's feeding it.
Gain (Transconductance)	BJTs offer greater gain at the output than FETs.	The gain (or transconductance) of FETs are smaller than for BJTs.
Size	BJTs are larger in size and therefore take up more physical space than FETs normally.	FETs can be manufactured much smaller than BJTs. This is especially important for integrated circuits that are composed up of many transistors.
Popularity	BJTs are less popular and less widely used	FETS are definitely more popular and widely used in commercial circuits today than BJTs
Cost	BJTs are cheaper to manufacture	FETs, especially MOSFETs, are more expensive to manufacture

ASSIGNMENT 8:

1. What type of transistor is FET?
2. Differentiate between FET and BJT

QUIZ 8:

1. State five applications of FET
2. What are the advantages of FET over BJT

LECTURE 9.0   Single Stage Transistor Amplifier

When in an amplifier circuit only one transistor is used for amplifying a weak signal, the circuit is known as single stage amplifier.

However, a practical amplifier consists of a number of single stage amplifiers and hence a complex circuit. Therefore, such a complex circuit can be conveniently split into several single stages and can be effectively analysed.
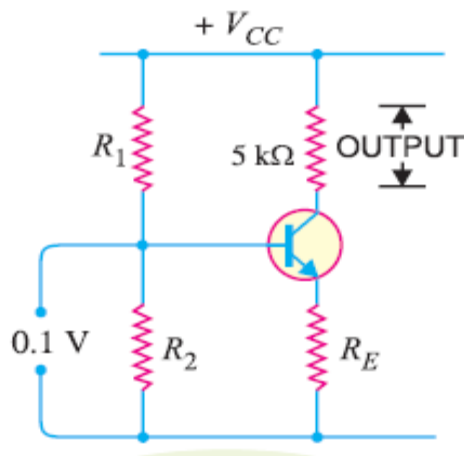

Figure 9.1   The above fig. shows a single stage transistor amplifier.

When a weak a.c. signal is applied to the base of the transistor, a small base current starts flowing in the input circuit.

Due to transistor action, a much larger (β times the base current) a.c. current flows through the the load Rc in the output circuit.

Since the value of load resistance Rc is very high, a large voltage will drop across it.

Thus, a weak signal applied in the base circuit appears in amplified form in the collector circuit. In this way the transistor acts as an amplifier.

A practical single stage transistor amplifier circuit is shown in fig. below.
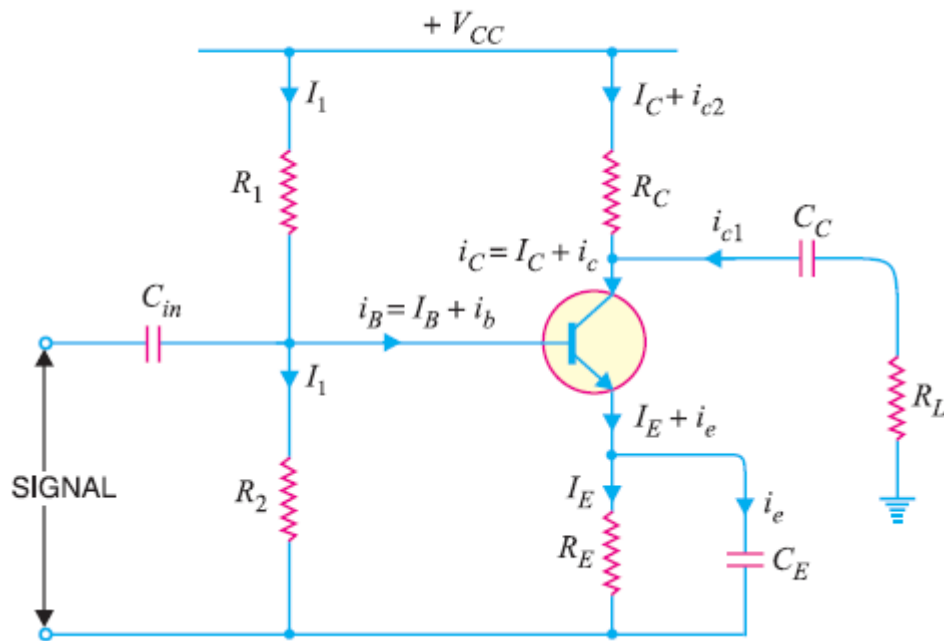
To achieve <u>faithful amplification</u> in a transistor amplifier, we must use proper associated circuitry with the transistor

(i) Biasing Circuit

The resistances R_1 , R_2 and R_E provide <u>biasing</u> and stabilisation.
The biasing circuit must establish a proper operating point otherwise a part of the negative half cycle of the signal may be cut off in the output and you will get faithful amplification.

(ii) Input Capacitor (C_{in})
An electrolytic capacitor of value 10 μF is used to couple the signal to the base of the transistor.

Otherwise, the signal source resistance will come across R_2 and thus can change the bias.

iii) Emitter Bypass Capacitor (C_E)
An emitter bypass capacitor of value 100 μF is used in parallel with R_E to provide a low reactance path to the amplified a.c. signal.
If this capacitor is not connected in the output circuit then the amplified a.c. signal will flow through R_E and cause a voltage drop across it, thereby reducing the output voltage

(iv) Coupling Capacitor (C_C)
The coupling capacitor of value 10 μF is used to couple one stage of amplification to the next stage.

If it is not used, the bias condition of the next stage will be drastically changed due to the shunting effect of R_C . This is because R_C will come in parallel with the resistance R_1 of the

biasing circuit of the next stage amplifier circuit and hence, alter the biasing condition of the next stage.

Therefore, the coupling capacitor is used to isolates the d.c. of one stage from the next stage and allows the a.c. signal only.

ASSIGNMENT 9:

1. What is an amplifier
2. Draw the circuit and explain how a triode can be used as a single stage amplifier

QUIZ 9:

1. What is the need for biasing a transistor
2. List three different biasing arrangements in BJT and explain any one, using diagram to support your answer

LECTURE 10.0   Integrated Circuits

An **Integrated circuit** (IC, microchip, or chip) is an electronic circuit made up of small semiconductor devices and other electronic components that are manufactured on a semiconductor material. The integration of a large number of transistors into a single chip was a great achievement. It was only made possible after conducting a great number of experiments, and then it was discovered that semiconductor devices could perform the functions of vacuum tubes. The first integerated chip was designed by **Jack S Kilby at Texas Instruments in 1958**. The discovery of integrated circuits was a huge breakthrough in the field of electronics due to the fact that ICs were a lot more reliable, capable, and cheaper than discrete circuits. Also the space occupied by the electronic components is minimized as all the components are printed as a unit and much less material is required. Power consumption is another advantage of ICs because the components are very small in size and are working as a unit.

Figure 10.1: Samples of some ICs

Designing

There are certain circuit design and logic techniques that are used to design an integrated circuit. There are two categories of IC design which are:

1. Digital design
2. Analog Design

Microprocessors, memories (RAM, ROM) and FPGA's are designed by Digital IC design method. Digital designing ensures that the circuits are correct and the circuit density is at maximum. The overall efficiency of the circuit is very high. On the other hand, Analog design method is used to design oscillators, filters, line regulators, operational amplifiers and phase locked loops. Analog designing is used where gain, power dissipation and resistance are required to be perfect.

Construction and Manufacturing

There are two main steps in the manufacturing process:

1. Fabrication
2. Packaging

1. Fabrication

The process of creating integrated circuits is called Fabrication. It is a sequence of chemical and photographic steps in which the circuits are constructed on a semiconductor material known as "wafer". The steps are described below:

- **Lithography**

In this step, a layer of photo-resisting liquid is applied on the surface of semiconductor or wafer. It is then backed and hardened.

- **Etching**

In etching process, unwanted material is removed from the wafer. Then the pattern of the photo-resist is transferred to the wafer.

- **Deposition**

In this step, films of different materials are applied on the wafer. It is done by either "Physical Vapor Deposition" or "Chemical Vapor Deposition".

- **Oxidation**

In the oxidation process, the silicon layers on the top are converted to silicon dioxide by oxygen or water molecules.

- **Diffusion**

Diffusion is carried out to anneal the lattice defects.

2. Packaging

Packaging is also called "encapsulation" or "assembly". It is the final stage of IC manufacturing. In the beginning, ICs were packaged in ceramic flat packs. This technique was used for some years then the "Dual in-line package"(DIP) was introduced. With the passage of time other techniques were introduced such as "Pin Grid Array" and "Surface mount." Intel and AMD have moved to "land Grid array" packages. The packaging process also has some steps that have to be followed which are given below:

1. Die attaching
2. IC Bonding
3. Flip Chip
4. Quilt Packaging
5. Film Attaching
6. IC encapsulation

- **Diffusion**

Diffusion is carried out to anneal the lattice defects.

Integrated circuits are mostly packaged in opaque plastic or ceramic insulation. There are metal pins in the packaging which are used to connect to the outside world.

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circuit, **microchip**, or **chip**, an assembly of electronic components, fabricated as a single unit, in which miniaturized active devices (e.g., transistors and diodes) and passive devices (e.g., capacitors and resistors) and their interconnections are built up on a thin substrate of semiconductor material (typically silicon). The resulting circuit is thus a small monolithic "chip," which may be as small as a few square centimetres or only a few square millimetres. The individual circuit components are generally microscopic in size

Classification of ICs (Integrated Circuits)

- SSI: Small scale integration. 3 – 30 gates per chip.
- MSI: Medium scale integration. 30 – 300 gates per chip.
- LSI: Large scale integration. 300 – 3,000 gates per chip.
- VLSI: Very large scale integration. More than 3,000 gates per chip.

Advantages of IC

1. The entire physical size of IC is extremely small than that of discrete circuit.
2. The weight of an IC is very less as compared entire discrete circuits.
3. It's more reliable.
4. Because of their smaller size it has lower power consumption.
5. It can easily replace but it can hardly repair, in case of failure.
6. Because of an absence of parasitic and capacitance effect it has increased operating speed.

7. Temperature differences between components of a circuit are small.
8. It has suitable for small signal operation.
9. The reduction in power consumption is achieved due to extremely small size of IC.

Dis-advantages of IC

1. Coils or indicators cannot be fabricated.
2. It can be handle only limited amount of power.
3. High grade P-N-P assembly is not possible.
4. It is difficult to be achieved low temperature coefficient.
5. The power dissipation is limited to 10 watts.
6. Low noise and high voltage operation are not easily obtained.
7. Inductors and transformers are needed connecting to exterior to the semiconductor chip as it is not possible to fabricate inductor and transformers on the semiconductor chip surface.
8. Inductors cannot be fabricated directly.
9. Low noise and high voltage operation are not easily obtained.

ASSIGNMENT 10

1. Differentiate between the two categories of IC designs
2. Explain the followings and state their application areas:
    (a) LSI   (b) VLSI   (c) MSI   (d) AI

QUIZ 10:

1. State five advantages and disadvantages of ICs over the discrete components
2. Differentiate between` CMOS and TTL logic families of ICs

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