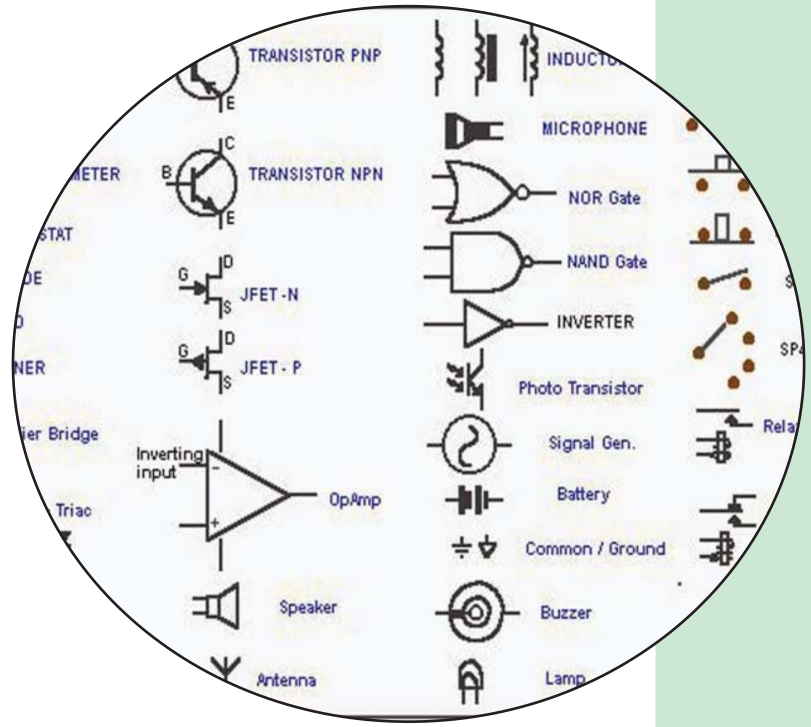
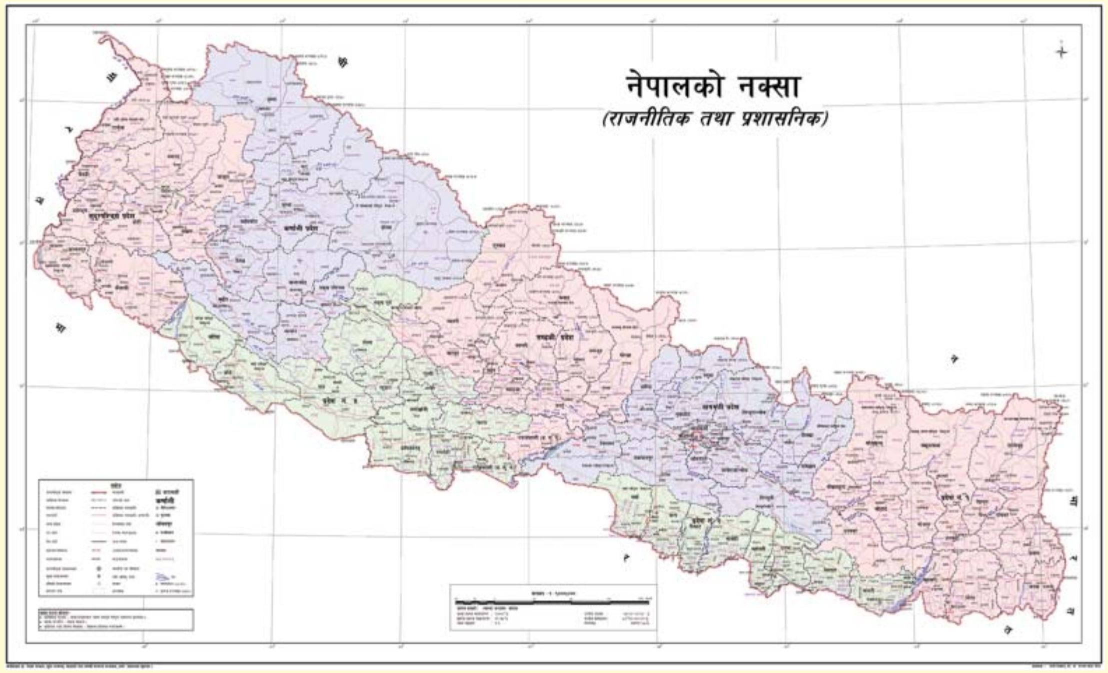
Electrical Engineering

9

Basic Electronics





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Technical and Vocational Stream

Learning Resource Material

Basic Electronics

(Grade 9)

Secondary Level

Electrical Engineering

Government of Nepal

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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Electrical Engineering has been developed in line with the Secondary Level Electrical Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Pro. Dr. Indraman Tamrakar, Harinaryan Yadav, Akhileshwar Mishra, Rupesh Maharjan, Arjun Devkota, Abin Maharjan, Rashna Shrestha, Ananta Dhungana is highly acknowledged. The book is written by Sanju Shrestha and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

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Content

Unit: 1

Introduction

1. Objectives

This chapter mainly focuses on the basics of electricity. The main objectives of this unit are to make the students able;

- To distinguish elements from its symbol, atomic number and atomic weight
- To distinguish conductors, semiconductors and insulators
- To differentiate potential difference and EMF

2. Learning Materials

- Different types of conductor, semiconductor and insulator
- Battery, wires, resistors and voltmeter

3. Course Contents

Matter

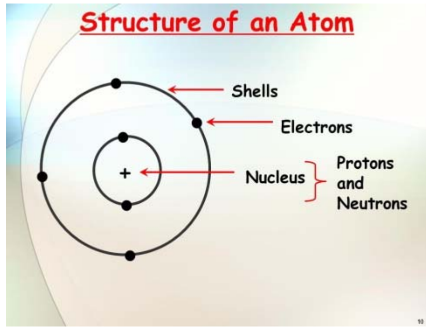
Matter is any substance which has certain mass and occupies space. All physical objects are composed of matter. All matter whether solid, liquid or gas is composed of very small particles called molecules. A molecule is in turn made up of atoms.

Molecule

A molecule is the smallest particle of an element or compound that has chemical properties of that element or compound. It is a particle made up of two or more atoms that are chemically bonded together. For example- HCl is a molecule made of one hydrogen atom bonded to one chlorine atom.

Atom and its structure

Atom is the fundamental particle of matter. All atoms consist of protons, electrons and neutrons. Protons and neutrons are contained within the nucleus whereas electrons revolve around the nucleus in an orbit. There is powerful force of attraction existing between nucleus and its electrons. Proton has positive charge, electron has negative charge and neutron has no electrical charge.The mass of proton is 1837 times that of electron and a neutron has same mass as proton. Under normal conditions, an equal number of protons and electrons exist within an atom. Atom is said to be electrically balanced because the equal number of electrons and protons cancel out each other.



Atomic number, atomic weight and free electrons

- The number of protons or electrons in an atom is called the atomic number of an element.
- The total number of protons and electrons in an atom is called the atomic weight of an element.
- Electrons that move from one atom to another are called free electrons.

Charges and its Electric characteristics

Matter is electrical in nature i.e. it contains particles of electricity- protons and electrons. The relative number of these particles of electricity determines whether a given body exhibits charge or not.

i. If the number of protons is equal to the number of electrons in a body, the resultant charge is zero and the body will be electrically neutral.
ii. If a body loses some electrons, then the body will be positively charged.
iii. If a body gains excess of electrons, then the body will be negatively charged.
iv. One coulomb of charge is equal to charge on $6.25*10^{18}$ electrons.

Electric current

Electric current is the rate of flow of free electrons (charge) in a definite direction. Conventionally, the direction of electric current is taken along the direction of motion of positive charges. When current is caused by flow of electrons (example in metals), the direction of current is opposite to the flow of electron flow. Electric current is measured by the time rate of flow of charge through the conductor. If q is the charge flowing through any cross-section of the conductor in time t, then

Electric current, $I = q/t$

The SI unit of current is ampere.

If q= 1 C and t=1 s, then I= 1/1= 1Ampere

One ampere of current is said to flow through any cross section of the wire if one coulomb of charge flows in 1 second.

Types of materials – conductor, semi-conductor and insulator

Conductors are the materials that can conduct electricity easily. For example- Copper, Aluminum, etc.

Semiconductors are the materials whose conductivity lie between the conductivity of conductors and insulators. For examples- Silicon, Carbon, Germanium etc.

Insulators are the materials that can't conduct electricity. For example- Mica, ceramics, plastics, etc.

Potential difference (pd) and electromotive force (emf)

The electrical potential difference is defined as the amount of work done in carrying a unit charge from a specified point to a reference point in an electric field. In other words, the potential difference is defined as the difference of potential between any two points.

The electromotive force is defined as the difference in the electric potential between two terminals of a source when the circuit is open.

Summary:

Emf is the total voltage in the battery while the potential difference is the work done in moving a charge against the electric field between two specific points in the circuit.

Emf is always greater than the potential difference.

4. Assessment

Very Short Answer Questions

1. What is charge? Write its unit.
2. What is the atomic number of Silicon.
3. Define atom.
4. Define current. Write its unit.
5. Which instrument is used to measure current?

Short Answer Questions

1. Define atomic number and atomic weight. Write the atomic number and atomic weight of Silicon.
2. Why is an atom chargeless?
3. Classify solid materials and explain them.
4. Differentiate pd and emf.

Long Answer Questions

1. Explain in detail about the atom and its structure.

Glossary

Bond: An electrical force linking atoms

Mica: Mineral that is normally used as an insulator

Ceramic: A solid material made up of inorganic materials and heated up at high tempertaures

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http://www.electrical4u.com

http://www.electricaltechnology.org

Unit: 2

Passive Components

1. Objectives

This chapter mainly focuses on the basic components used in electronic circuits. The main objectives of this unit are to make the students able to;

- to make distinguish different types of passive components
- find out the value of the passive components by using color coding or numbering techniques.
- measure the value of the passive components.

2. Learning Materials

i. Different types of resistors, inductors and capacitors

ii. Battery, AC supply, wires, multimeter and LCR meter

3. Course Contents

Passive Components

Electronic components are the materials that make up an electronic circuit. They are the building blocks of electronic circuits. They are broadly classified into two types:- Active components and Passive components.

Active components are those components that are capable of processing or amplifying an electrical signal. Tube devices and semiconductor devices are active components.

Passive components are those components which are not capable of processing or amplifying an electrical signal. These components are required for active components to process or amplify a signal. These components conduct current in both directions.

They are of following types:

i. Resistors

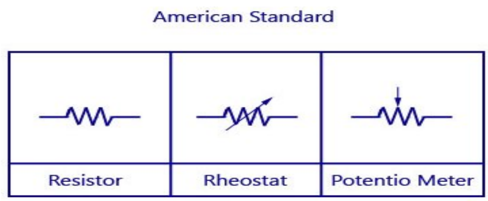
ii. Capacitors

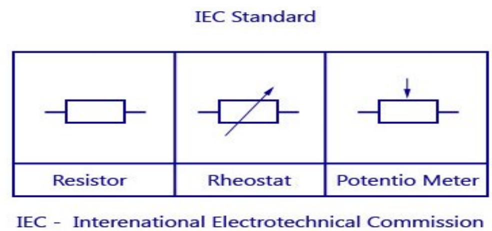
iii. Inductors

Resistor

A resistor is an electronic component which controls the flow of electric current. A resistor conducts current in both directions.

The symbols of resistors as standardized by American standard and IEC Standard are given below:-





Classification of resistors

Resistors are broadly classified into following types:

1. Linear resistors
   a. Fixed resistors
   b. Variable resistors
2. Non-linear resistors

Linear resistors

Those resistors through which the current is directly proportional to the applied voltage are called linear resistors. The resistance of such resistors do not change with the variation in applied voltage or temperature. These resistors are of following types:

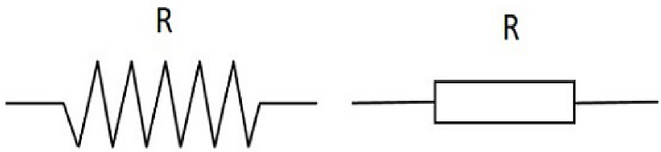
a. Fixed resistors

b. Variable resistors

Fixed resistors

Those resistors whose values do not change with the variation in applied voltage or temperature are called fixed resistors. Carbon composition resistors, thick film resistors, thin film resistors and wire wound resistors are fixed resistors.

The symbol of fixed resistor is given below:



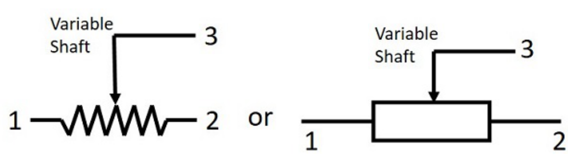
Symbol for a fixed resistor

Carbon composition resistors are made up of carbon powder and insulator binders. The two ends of carbon resistance element are joined with metal leads. These resistors are available in power ratings of 1/8 watts, ¼ watts/1 watt and 2 watts. The size of the resistors varies with the power ratings.

Variable resistors

Those resistors whose values can be varied are called variable resistors. Variable wound resistors, Potentiometer and Trimmer are variable resistors.

The symbol of a variable resistor is given below:



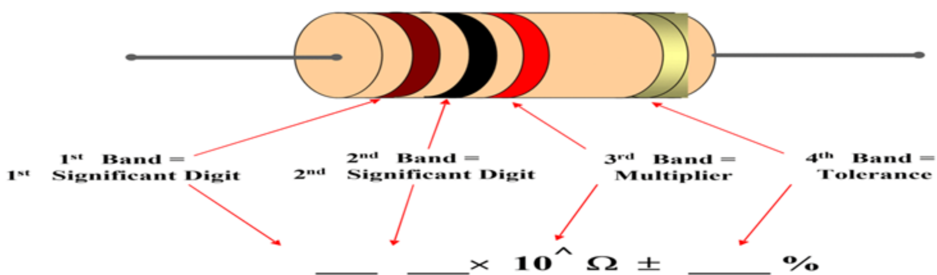
Symbol for a Variable resistor

Non-linear resistors

Those resistors manufactured from semiconductor materials and current passing through them is not of linear quality. The source of energy for these resistors can be voltage, temperature or light. Thermistors, Photoresistors and Varistors are non-linear resistors.

Color Coding of Resistor

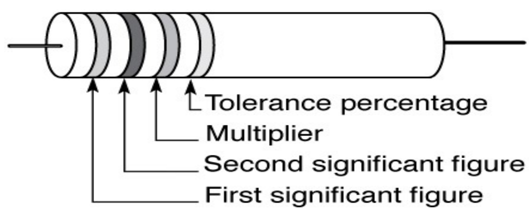
Mostly, carbon composition resistors(fixed resistors) are designed by a color code system. In this system, the bands of different colors are used to identify the values of resistance and tolerance ratings. There are two common systems of color code designation: a four band color code system and five band color code system.



In four band color code system, the first two bands represent the significant figures whereas the third band is the multiplier. The fourth band indicates the tolerance band.

The black band indicates the minimum value 0 and the white band indicates the maximum value 9. The gold band indicates the tolerance of ±5%, silver band ±10% and a plain (colorless band) represents a tolerance of ±20%. The table given below indicates the values of different colors:

Power of 10	Prefix	Abbreviation
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p



Color	Number	% Tolerance
Black	0	
Brown	1	
Red	2	
Orange	3	
Yellow	4	
Green	5	
Blue	6	
Violet	7	
Gray	8	
White	9	
Gold		5%
Silver		10%
No color		20%

Fig: Table showing the significant values of each color of a color coded resistor

Examples:

1. Find the value of a resistor having four band color codes- Red, Blue, Yellow and Silver respectively.

Here,

Significant values of Red and Blue are 2 and 6 respectively and the multiplier is 4 since the color is yellow. The value of tolerance is 10%.

Now,

Value of resistor $= 26X\ 10^4 \pm 10\%\ \Omega$

$= 260 \pm 10\%\ K\Omega$

2. Find the color code of a resistor having a value of $470 \pm 10\%\ \Omega$.

Here,

$470 \pm 10\%\Omega$ can be written as $47X10^1 \pm 10\%\Omega$.

The values of 4, 7 and 1 resemble with Yellow, Violet and Brown respectively. The tolerance value resembles with silver.

Hence the color code is Yellow, Violet, Brown and Silver respectively.

Capacitor

Capacitor is an electronic component manufactured with a specified amount of capacitance. It is a device which

i. has the ability to store charge in the form of electric field
ii. opposes any change of voltage in the circuit in which it is connected
iii. blocks the passage of direct current through it

It consists of two conducting plates separated by an insulating medium (dielectric). The dielectric could be air, mica, paper, polyester, plastics etc.

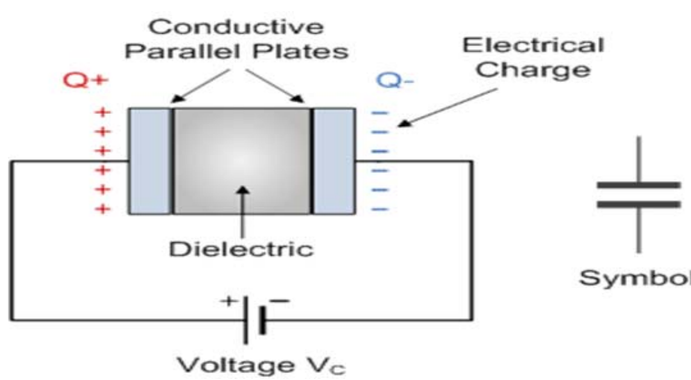


Fig: Schematic diagram of a capacitor

Fig: Different kinds of capacitors

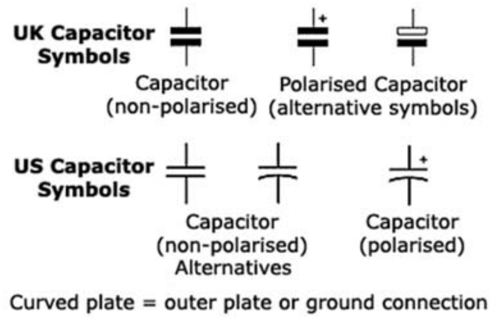


Fig: Different symbols of capacitors

Types of Capacitors

Capacitors are classified into two types

1. Fixed capacitors
    a. Non-electrolytic type
    b. Electrolytic type
2. Variable capacitors

Fixed capacitorsare those capacitors whose values can be changed by any means. They are also further divided into electrolytic and non-electrolytic capacitors.

Non electrolytic type capacitors are those capacitors which have no polarity requirement i.e, they can be connected in either direction in a circuit. Non-electrolytic type capacitors include paper, mica and ceramic capacitors.

Paper capacitor

The capacitor in which two tin foil sheets are separated by waxed paper is called paper capacitor. Paper capacitors have a capacitance range of 0.001 to 2 μF and working voltage range as high as 2000V.

Mica capacitor

The capacitor in which thin metal plates are separated by thin sheets of mica is called mica capacitor. Such capacitors have capacitance range of 50 to 500 pF and working voltage range of 500V and above.

Ceramic capacitor

The capacitor in which dielectric made of ceramic material is used is called ceramic capacitor. Generally, titanium dioxide and barium titrate are used as ceramic material. Such capacitorshave a capacitance range of 10 pF to 1 μF.

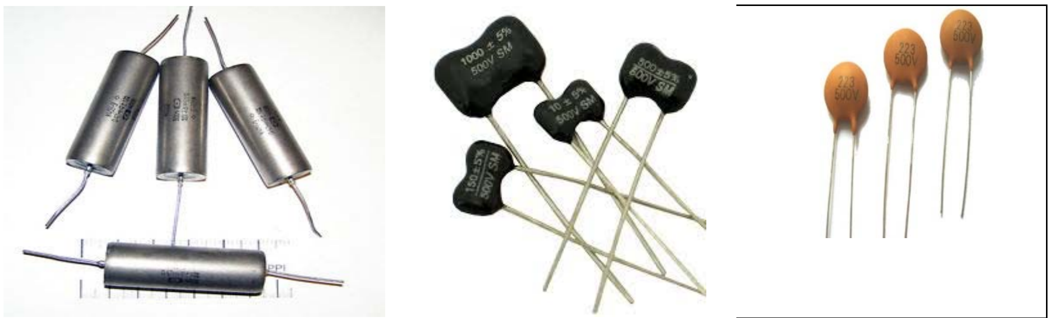


Fig: Paper capacitors, mica capacitors and ceramic capacitors

Variable capacitors are those capacitors whose values can be varied usually by rotating a shaft. They are generally used as tuning capacitors in radio receivers.

Capacitance

Capacitance is defined as the ability of a capacitor to store electrical charge in the form of electric field. Mathematically, it may be defined as the amount of charge required to create a unit potential difference between its plates. If Q coulomb of charge is applied to one of the two plates of a capacitor and if a pdof V volts is established between them, then its capacitance is

$C = Q/V$ farad

If Q=1 C and V=1 V, then C=1 Farad(F)

Hence, one farad is defined as the capacitance of the capacitor which requires a charge of 1 Coulomb to establish a pd of one volt between its plates.

Factors affecting Capacitance

The capacitance of a capacitor depends upon the following factors:

i. Cross section area of the plates (A)

Capacitance increases with the increase in cross section area of the plates.

ii. Distance between the plates (d)

Capacitance is inversely proportional to the distance between the plates. As the distance increases, capacitance decreases.

iii. Nature of the dielectrics

Higher the value of permittivity (ε_r) of the dielectric medium, higher will be the capacitance.

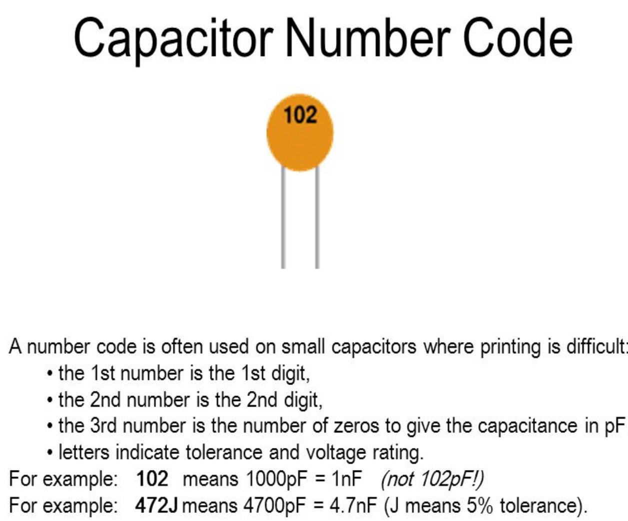
Combining all the factors,

$C=\frac{\varepsilon o \varepsilon r A}{d}$ Farad

whereε_0 is the absolutepermittivity of vacuum i.e 8.854X 10^{-12}F/m.

The relative permittivity of air or vacuum are 1, ceramic is 50-3000, mica is 3-6 and paper is 3-5.

Numeric coding of a ceramic capacitor



If a capacitor has nothing other than a three-digit number printed on it, the third digit represents the number of zeros to add to the end of the first two digits. The

resulting number is the capacitance in pF. For example, *101*represents 100 pF: the digits 10 followed by one additional zero.
If there are only two digits listed, the number is simply the capacitance in pF. Thus, the digits *22* indicate a 22 pF capacitor.

Inductor

Inductor is defined as an electronic component which opposes the change in current by means of electrical storage in the form of magnetic field. It is a coil wound on a core or former of suitable material.

Fig: Different types of inductor

Types of inductors

1. **Fixed Inductor**
    a. Air core inductor
    b. Iron core inductor
    c. Ferrite core inductor
2. **Variable Inductor**

Air core inductor

It is an inductor that is made up of coil wound on a former or cardboard. Since there is air inside the coil, an air core inductor has the least inductance. This inductor is used in Radio frequency applications.

Iron core Inductor

It is an inductor in which a coil of wire is wound on a solid or laminated iron core. Iron core is laminated to reduce eddy current loss. This inductor is generally used for low frequency applications like audio frequency.

Ferrite core inductor

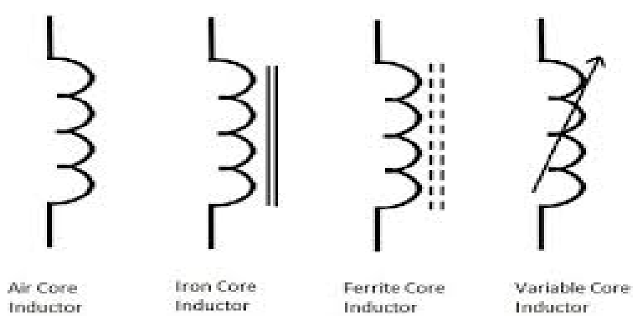
It is an inductor made up of coil of wires wound on a ferrite core. Ferrite is a magnetic material consisting of fine particles of iron, cobalt or nickel embedded in an insulating binder. The ferrite core has a very low eddy current loss. Ferrite core inductors are used at higher frequencies.

Fig: Air core, iron core and ferrite core inductors

Variable inductor

The inductor in which inductance can be varied by any means is called variable inductor. The inductance can be varied by adjusting core or the length of coil. The inductance of a coil can be varied by using tappings or slider contacts. Variable inductors are widely used in tuning and filtering circuits.

The symbols of different inductors are as follows



Inductance

Inductance is defined as the property of a coil due to which it opposes any change of current through it is called inductance(L). Its unit is Henry(H).

Factors affecting Inductance of a coil

i. Inductance is directly proportional to the cross-sectional area of the core(A).

ii. It is square of the number of turns of the coil (N).

iii. It is inversely proportional to the length of the core (l).

iv. It is directly proportional to the permeability of the core material ($\mu_0\mu_r$).

Combining all, we get

$L=\mu_0\mu_r AN^2/l$ Henry

QUANTITY	UNIT	SI Unit	SYMBOL
Capacitance	*C*	Farad	F
Charge	*Q*	Coulomb	C
Conductance	*G*	Siemens	S
Energy	*W*	Joule	J
Frequency	*f*	Hertz	Hz
Impedance	*Z*	Ohm	Ω
Inductance	*L*	Henry	H
Power	*P*	Watt	W
Reactance	*X*	Ohm	Ω
Resistance	*R*	Ohm	Ω
Voltage	*V*	Volt	V

4. Assessment

Very Short Answer Questions

1. What is resistance? Write its symbol.
2. What is a resistor?
3. Define capacitance.
4. Define inductance.
5. What is a capacitor?

Short Answer Questions

1. Explain the construction of a capacitor.
2. Differentiate iron core and air core inductor.
3. Differentiate ceramic and electrolytic capacitance.
4. Classify capacitance on the basis of polarization.
5. Find the value of a resistor having 4-band colors of Red, Red, Blue and Silver.
6. Find the value of a resistor having 4-band colors of Yellow, Violet, Orange and Silver.
7. Find the color code of the resistor having a value 330 ± 10% Ω.
8. Find the color code of the resistor having a value 220 ± 5% KΩ.

Long Answer Questions

1. Explain the types of resistors.
2. Explain the types of inductors. Also draw their symbols.
3. Explain the types of capacitors in detail.
4. Find the range of the resistor having 4-band colors of Red, Red, Blue and Silver respectively.
5. Find the range of the resistor having the colors Yellow, Violet, Blue and Silver respectively.
6. Find the equivalent resistance if two resistors of 20Ω and 50Ω are connected in parallel.
7. Find the equivalent capacitance if two capacitors of 100μF and 200 μF are connected in series.

Glossary

Amplifying: Increase the amplitude

Thermistor: A resistor whose resistance varies with temperature

LDR: Light Dependent Resistor; a resistor whose resistance varies with the intensity of light

Core: A bar of magnetic material that is placed inside a coil

Dielectrics: A material with low conductance

Ceramic: A material made from non metals by firing at high temperatures

Electrolytic: A solution that conducts electricity

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http://www.electricaltechnology.org

Unit: 3

Seminconductor Physics

1. Objectives

This chapter discusses about the physics behind semiconductor devices. The main objectives of this unit are to make the students able to;

- Understand the basics of doping
- Differentiate the types of semiconductor
- Differentiate the dopants used in making extrinsic semiconductor

2. Learning Materials

1. Animated videos of semiconductor

3. Course Contents

Semiconductor

Semiconductor is a material whose electrical properties lie in between those of insulators and conductors. Germanium and Silicon are the widely used semiconductors. The conductivity of semiconductor is lower than that of conductor but higher than that of insulator.

At room temperature, semiconductors have partially filled conduction band, partially filled valence band and a very narrow energy gap (of the order of 1 eV). At zero Kelvin (0 K), there are no electrons in conduction band of semiconductors and their valence band is completely filled. This means at absolute temperature, semiconductor behaves like a perfect insulator. However, with the increase in temperature, electrons of valence band jumps to the conduction band. Hence, with the increase in temperature, conductivity of semiconductor also increases or resistivity of semiconductor decreases. It means they can negative temperature coefficient of resistance.

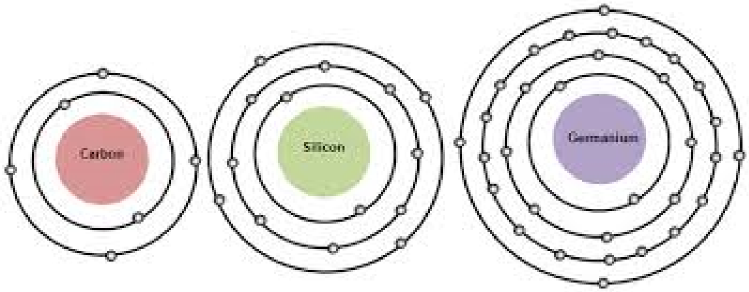


Fig: Atomic structure of Carbon, Silicon and Germanium

Bonds in semi-conductor and its crystal structure

Semiconductorhas covalent bond. In this bond, there is sharing of one or more valence electrons between similar or dissimilar atoms.

In semiconductors like Silicon or Germanium, each tetravalent Si or Ge atom shares one electron each with four surrounding atom making eight electrons in its outermost orbit. Such bonds can be broken by applying sufficient energy. The electron set free by breaking the bond leaves a vacancy called hole. Hence, each bond breakage results in production of two charge carriers- one electron and hole.

Characteristics of Semiconductor

1. Semiconductors have negative temperature coefficient of resistance. This means that with the rise in temperature of semiconductor, its resistance decreases and vice versa.
2. The resistivity of semiconductor is more than that of a conductor but is less than that of insulator.
3. The conductivity of semiconductor varies with temperature.

Definition of energy levels, energy bands, energy gap

Energy levels

The available orbits in an atom represent energy levels for the electrons. Each orbit has fixed amount of energy associated with it and the electrons moving in a particular orbit possess the energy of that orbit. The larger the orbit, the greater is its energy. Hence, the electron in the outer orbit has more energy than the electron in the inner orbit.

Energy bands in solid

In a single isolated atom, the electrons revolving in any orbit possess energy of that orbit. But when atoms form a solid, the orbit of an electron is affected not only by the charges of its own atom but by nucleus and electrons of other atoms in a solid. Hence, the electrons in the same orbits have range of energies which is called energy band. Thus, the range of energies possessed by electrons of the same orbit in a solid is called energy band. The important energy bands in solids are valence band and conduction band.

The energy band which possesses the valence electrons is called valence band. The band which possess the free electrons is called conduction band. It is the higher energy band than valence band. Electrons in this band take part in conduction.

Forbidden Energy gap or Band gap

The energy gap between valence band and conduction band is called forbidden energy gap or band gap. This band gap is called forbidden energy gap because electrons can't stay in this gap. Electrons from valence band can jump to the conduction band if an external energy is applied. This energy should be greater than the energy gap E_G.If the energy is lesser than energy gap then the electrons can't jump because there is no energy level between valence band and conduction band.

The forbidden energy gap is 1.12eV for Silicon and 0.72eV for Germanium.

Classification of materials on the basis of Band gap

On the basis of band gap, materials are classified as follows:-

1. Insulators
2. Conductors
3. Semiconductors

Insulators

In case of insulators, there exists a large forbidden gap between the conduction band and valence band. Thus it is impossible for electrons to jump to the conduction band. The energy gap is about 7eV. Such materials conduct only if huge amount of external supply is applied. Therefore, there is no electrical conductivity of these materials.

Conductors

In case of conductors, conduction band and valence band overlaps with each other i.e. there is not presence of band gap. Thus a small amount of applied external energy provides enough energy for the valence electrons to jump into the conduction band.

In conductors, large number of free electrons are present in the conduction band at room temperature i.e. conduction band is filled with free electrons whereas valence band is partially occupied with electrons. Therefore, the electrical conductivity of these materials is very high.

Semiconductors

In case of semiconductors, the forbidden energy gap is small i.e. about 1eV. At absolute zero, conduction band is completely empty and valence band is filled with electrons. However, at room temperature, some electrons from valence band gains heat energy and jump to the conduction band. Therefore, these materials have electrical conductivity higher than insulators but lower than conductors.

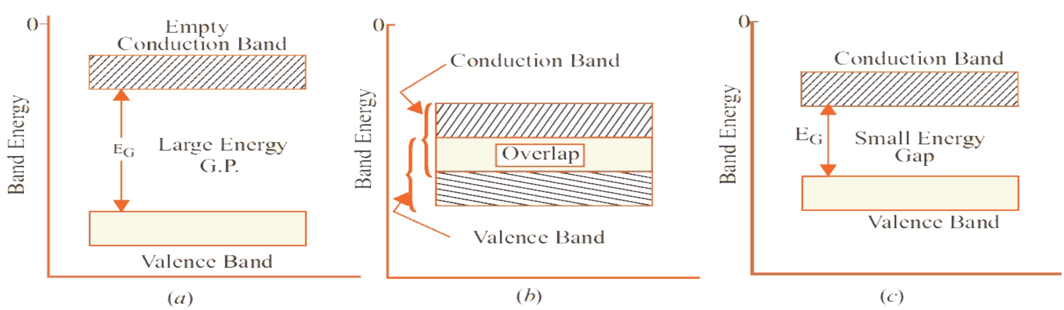


Fig: Energy bands of insulators, Conductors and Semiconductors respectively

Electron and holecurrent

The current due to the movement of electrons is called **electron current.**

The current due to the movement of holes is called **hole current**. Holes move in the direction opposite to that of electrons.

Recombination

In an intrinsic semiconductor, electron hole pairs are generated due to temperature. These electrons and holes move freely throughout the crystal and if they collide with each other, both of them disappear. This process is called recombination.

Types of semiconductor

Semiconductor is mainly of two types:-

1. Intrinsic semiconductor
2. Extrinsic semiconductor

Intrinsic semiconductor

A semiconductor in its extremely pure form is known as intrinsic semiconductor. Some common examples of intrinsic semiconductor are pure Germanium and silicon. A semiconductor is not intrinsic if its impurity content is less than one part impurity in 100 million parts of semiconductor.

In the crystalline structure of Silicon, there are four valence electrons in the outermost orbit or valence shell. Each of the valence electrons takes part in forming covalent bonds with the neighbouring atoms. A covalent bond consists of two electrons, one from its neighbouring atoms. Atoms bond together to form molecules.

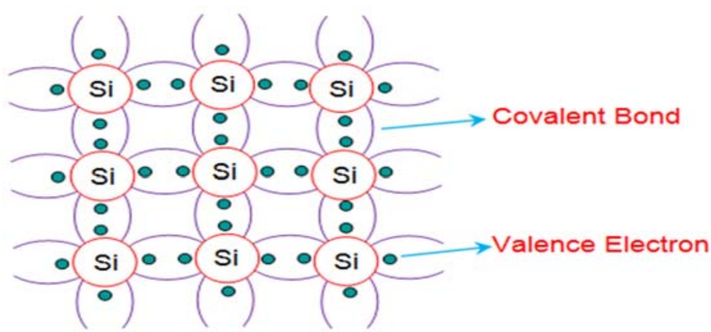


Fig: Crystalline structure of an intrinsic semiconductor

At absolute zero(0 K), all the valence electrons are tightly held by parent atoms and by covalent bonds with other atoms. Hence, no free electrons are available to conduct electricity. Thus, at absolute zero, intrinsic semiconductor behaves like a perfect insulator. But, if the temperature is increased up to room temperature (300 K), some covalent bonds break. When covalent bonds break, the electron becomes free and the vacancy produced is called hole. Since, an electron is negatively charged particle, the vacancy created by this hole will be assumed as positively charged particle. When a free electron is produced, a hole is also produced simultaneously. In intrinsic semiconductors, the concentration of free electrons will be equal to the concentration of holes. Hence, at room temperature, intrinsic semiconductor has some conductivity due to the movement of electrons and holes.

Extrinsic semiconductor

The semiconductor obtained by adding either to increase the number of holes and electrons in a pure semiconductor is called extrinsic semiconductor. The process of adding impurities to a pure semiconductor is called doping. The material which is being used as impurity is called dopant.

Impurities can be of two types: Donor impurity (Pentavalent impurity) and Acceptor impurity (Trivalent impurity).

If the dopant contains five valence electrons then it is called **donor impurity**. Some examples of donor impurity or pentavalent impurity are Arsenic, Phosphorous, Antimony etc.

If the dopant contains three valence electrons then it is called **acceptor impurity**. Some examples of acceptor impurity or trivalent impurity are Boron, Gallium, Indium, Aluminum etc.

Depending upon the types of impurity doped, extrinsic semiconductor is of following types:

1. N-type semiconductor
2. P-type semiconductor

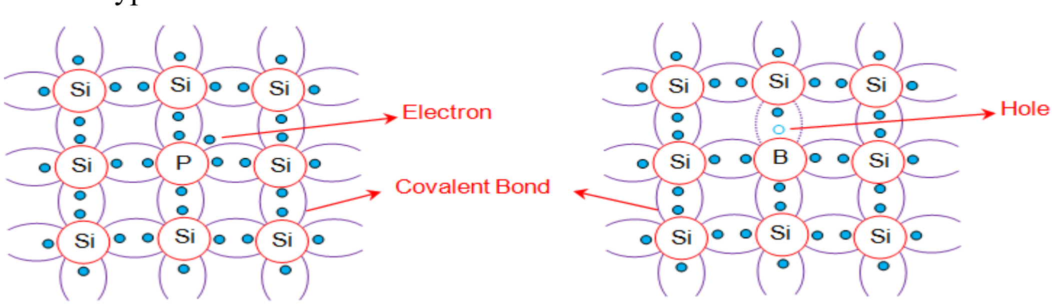


Fig: N type semiconductor and P type semiconductor

N-type semiconductor

The material in which pentavalent or donor impurity is doped with intrinsic semiconductor is called N-type semiconductor.

Pentavalent impurity atoms have five electrons in their valence shell. In P-type semiconductor, each impurity atom is surrounded by intrinsic atoms like Silicon atoms. Each impurity atom consists of five valence electrons and out of these electrons, four form covalent bonds with four Silicon atoms. When the fifth electron of impurity atom gets little amount of energy, it detaches from its parent atom. In this way, each impurity atom donates one electron to the conduction band. Hence, in a N-type semiconductor, there are more number of free electrons in the conduction band.

P-type semiconductor

The material in which trivalent or acceptor impurity is doped with intrinsic semiconductor is called P-type semiconductor.

Trivalent impurities have three electrons in their valence shell. In P-type semiconductor, each impurity atom is surrounded by intrinsic atoms like Silicon atoms. Each impurity atom consists of three valence electrons and these three electrons form covalent bonds with three Silicon atoms. The fourth Silicon atom can't make covalent bond with the impurity atom because the impurity atom has only three valence electrons. The vacancy created in the incomplete covalent bond acts as a hole. An electron from neighbouring atoms can jump into it. Hence, in a P-type semiconductor, there are few electrons in the conduction band but a large number of holes in the valence band.

Majority and minority charge carrier

The charge carrier produced due to thermal or optical action is called minority charge carrier.The charge carrier produced due to doping is called majority charge carrier.

- In P-type semiconductor, holes are majority charge carriers and electrons are minority charge carriers.
- In N-type semiconductor, electrons are majority charge carriers and holes are

minority charge carriers.

4. Assessment

Very Short Answer Questions

1. What is majority charge carrier?
2. Define free electrons and holes.
3. Which is the most commonly used semiconductor?
4. What do you understand by Negative Temperature Coefficient of Resistance?
5. Name the dopants used to make N-type semiconductor.
6. Name the dopants used to make P-type semiconductor.
7. What do you mean by doping?
8. What are dopants?

Short Answer Questions

1. Draw an energy band diagram of a semiconductor and an insulator.
2. What do you mean by minority charge carrier? Which is the minority charge carrier of P type semiconductor?
3. Write any two differences between intrinsic and extrinsic semiconductor.
4. Define recombination.
5. How is N-type semiconductor made?
6. Explain barrier potential.
7. What are the factors affecting the barrier potential?

Long Answer Questions

1. Classify solid materials on the basis of forbidden energy gap.
2. Explain the types of semiconductors in detail.
3. How extrinsic semiconductor is different than that of intrinsic semiconductor. Explain in detail.
4. Explain the construction of a P-type semiconductor.

Glossary

eV: electron Volt

Forbidden: restricted

References

Basic Electronics, Dr. Sanjay Sharma

Electronic Circuit, Sedra and Smith

http://www.electrical4u.com

http://www.electricalbasicprojects.com

https://www.allaboutcircuits.com

http://www.electricaltechnology.org

Unit: 4

Semiconductor Diode

1. Objectives

This chapter introduces the basics of semiconductor diode. The main objectives of this unit are to make the students able to;

- Understand the process of PN junction formation
- Distinguish the two terminals of a diode
- Analyse the IV characteristics of a PN junction diode

2. Learning Materials

i. PN Junction diode, Resistors, Wires, Power supply and a Multimeter

ii. Animated videos

3. Course Contents

PN Junction

The plane dividing the semiconductor material, in which one half is doped with P-type material and the other half with N-type material, into two halves is called PN Junction. In other words, if a piece of P-type semiconductor is joined to a piece of N-type semiconductor by special techniques, then a PN junction is formed.

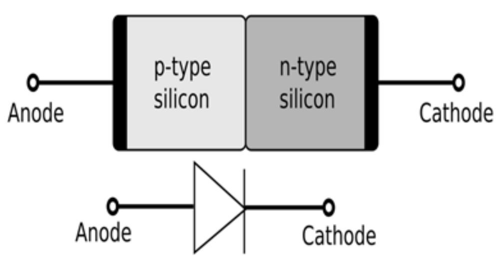


Fig: Structure and symbol of a PN junction

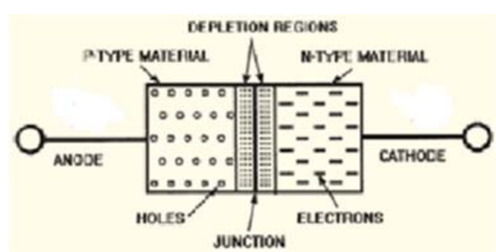


Fig: Structure of a PN junction with depletion layer

As soon as the PN junction is formed, the following actions take place:

1. P-region has more number of holes than electrons and N-region has more number of electrons than holes. Due to the difference of concentration in two regions, diffusion of holes and electrons take place.
2. Holes from P-region diffuse into the N region. In the N-region, they combine

with electrons.

3. Electrons from N-region diffuse into the P region. In the P-region, they combine with holes.
4. The process of diffusion continues only for a short period of time. After a few recombination, a restraining force is set up which is called barrier. As a result, further diffusion can't take place.
5. Due to the diffusion of electrons and holes, a depletion layer is formed.This region is called depletion region because the mobile charge carriers are depleted. Hence this region contains only immobile or fixed ions.The width of depletion region depends upon the doping level of impurity in N-type or P-type semiconductor. For higher doping level, the depletion layer becomes thinner.

Depletion region

The region having the acceptor and donor ions is called depletion region. This region contains only fixed and immobile positive and negative ions.

Energy barrier potential

The electric potential established across the junction due to the presence of charged ions is called energy barrier potential. This region is known as barrier potential because it stops the further flow of charge carriers across the junction unless an external voltage is applied.

The barrier potential of Silicon is 0.7V whereas the barrier potential of Germanium is 0.3V.

PN junction biasing

The process of applying potential difference across the ends of PN junction is called PN junction biasing. It can also be said that the process of supplying external power supply to the PN junction is called PN junction biasing.

Biasing can be done in two ways

- **Forward biasing**
- **Reverse biasing**

Forward biasing

The process of connecting battery across the PN junction in which positive terminal of the battery is connected to the P-region and negative terminal of the battery is connected to the N-region is called forward biasing.

In this method of biasing, holes are repelled from the positive terminal of the battery and forced towards the junction. Similarly, electrons are repelled from the negative terminal of the battery and forced towards the junction. Because of the energy, some electrons and holes are driven towards the junction where they recombine. This reduces the barrier potential and decreases the width of depletion layer. The movement of electrons and holes cause large current to flow towards the junction. Both electrons and holes move inside the crystal but only free electrons move in the external circuit.

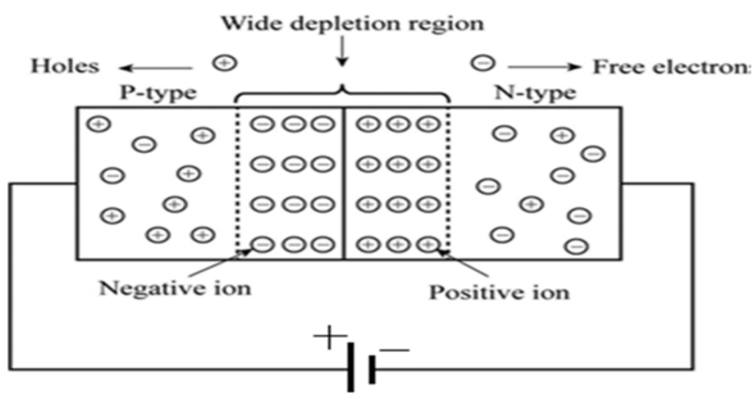


Fig: Forward biasing of a PN junction diode

Reverse biasing

The process of connecting battery across the PN junction in which positive terminal of the battery is connected to the N-region and negative terminal of the battery is connected to the P-region is called reverse biasing.

In this method of biasing, holes are attracted towards the negative terminal of the battery whereas electrons are attracted towards the positive terminal of the battery. Since both electrons and holes move away from the junction, the width of depletion layer increases. Hence, no current flows and the junction offer high resistance.

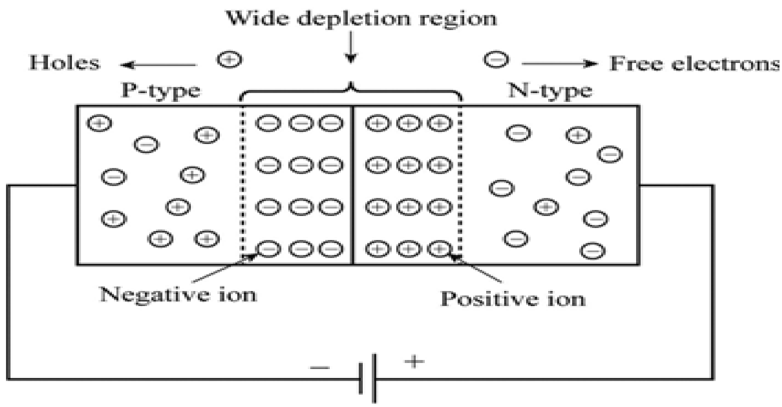


Fig: Reverse biasing of a PN junction diode

PN Junction diode

A PN junction diode is a unidirectional two terminal semiconductor device. This diode is made up of PN junction. It conducts current in only one direction but offers high resistance in other direction.

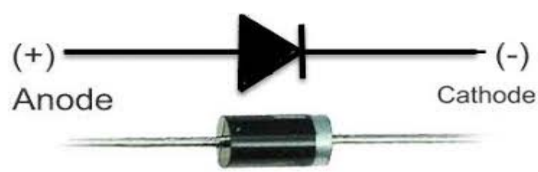
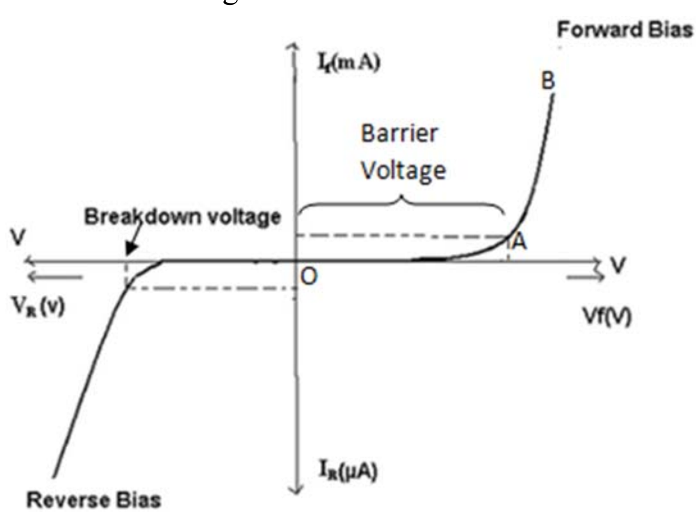


Fig: PN Junction diode



The graph plotted between the voltage applied across the diode (V) and the amount of current flowing through it (I) is called I-V characteristics of a PN Junction diode.

The graph plotted for forward biased mode is called forward bias characteristics. Similarly, the graph plotted for reverse biased mode is called reverse bias characteristic. The forward characteristic lies on the first quadrant of the graph whereas the reverse characteristic lies on the third quadrant of the graph.

When a PN Junction diode is forward biased, current flows through the diode when the applied voltage is greater than the barrier potential. The barrier potential of Silicon PN junction diode is about 0.7V and that of Germanium PN Junction diode is about 0.3V. When the applied voltage is less than barrier potential, current does not flow through the diode but the current sharply increases when it reaches the knee voltage. The knee voltage is marked above with the letter 'A'.

When the diode is reverse biased, current do not flow through the diode until a point called avalanche breakdown is reached. When the applied reverse voltage is equal to the avalanche breakdown, excessive current flows through the diode. This excessive current permanently damages the diode.

Applications of PN Junction diode

i. They are used in rectifiers.

ii. They are used in clipping and clamping circuits.

iii. They are used in voltage multipliers.

iv. They are used as freewheeling diodes.

4. Assessment

Very Short Answer Questions

1. What is a PN Junction diode?
2. Name the terminals of a PN junction diode. Draw a symbol of a PN Junction diode.
3. What is the function of a diode?
4. What do you mean by biasing of a diode?

Short Answer Questions

1. Write any two applications of a diode.
2. Define forward biasing of a PN junction.

3. Write any two differences between forward and reverse biasing of a PN junction.
4. Draw I-V characteristics of PN junction diode.

Long Answer Questions

1. Explain the types of biasing methods of PN junction in detail.
2. Explain in detail about PN junction.
3. Explain IV Characteristics of a PN junction diode.

Glossary

Barrier: A structure that restricts free movement

Diffusion: The property of being dispersed

Biasing: Connection of battery across the ends of diode.

References

Basic Electronics, Dr. Sanjay Sharma

Electronic Circuit, Sedra and Smith

http://www.electrical4u.com

http://www.electricalbasicprojects.com

https://www.allaboutcircuits.com

http://www.electricaltechnology.org

Unit: 5
Special Purpose Diodes

1. Objectives

This chapter introduces various kinds of diodes. The main objectives of this unit are to make the students able to;

- Use the required diode as per necessity
- Distinguish one type of diode from other diode
- Apply proper diodes in electronic circuits

2. Learning Materials

i. Zener diodes, Photodiodes, LEDs, Power diodes and Varactor diode

ii. Power supply, wires, resistors and multimeter

2. Course Contents

Zener Diode

Zener diode is a heavily doped PN junction diode which is operated at breakdown region of reverse biased mode.

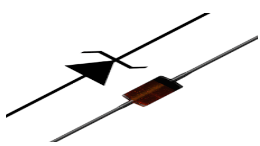


Fig: Zener diode

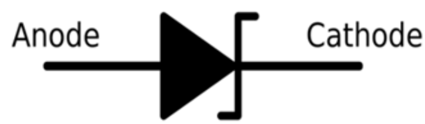


Fig: Symbol of a Zener diode

The reverse breakdown of a PN junction may occur due to one of the effects-Avalanche or zener effect. The avalanche breakdown occurs when the free electrons acquire sufficient energy to ionize a lattice atom. The additional free electrons are accelerated by the reverse field causing more and more ionization. The Zener breakdown occurs when the electric field across the junction, produced due to reverse voltage, is sufficiently high. This force is so strong that the covalent bonds break and it produces large number of charge carriers.

Characteristics of a Zener diode

The forward characteristics of a Zener diode are similar to that of normal PN Junction diode. When reverse voltage is applied to a Zener diode, the reverse current remains negligible upto the breakdown point. At this point, the breakdown voltage(Zener breakdown voltage) remains constant. The diode maintains constant voltage across its terminals from minimum value of zener current to the maximum value of zener current. The diode may be damaged if the current through the diode is greater than the maximum value of zener current.

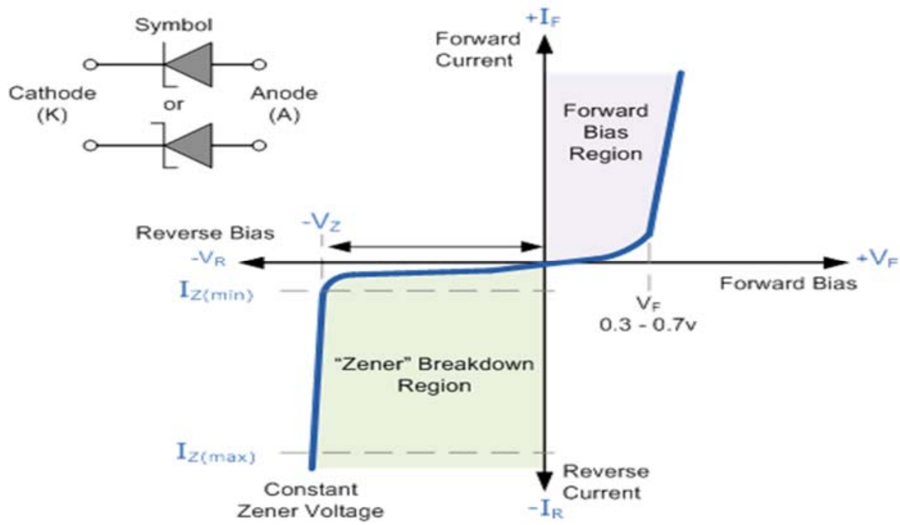


Fig: IV Characteristics of a Zener diode

Applications of Zener diode

i. It is used in voltage regulation.

ii. It is used as peak clippers.

iii. It is used for protecting meters against burn –out from accidental overloads.

iv. It is used as fixed reference voltage in a network for comparing or biasing purposes.

LED (Light Emitting Diode)

LED is a semiconductor device (PN Junction diode) which emits light when it is forward biased. The emitted light may be of any color-green, yellow, red, blue, infrared etc. The color of the emitted light depends upon the type of semiconductor used. For instance- gallium arsenide emits infrared, gallium arsenide phosphide emits yellow or red light, gallium phosphide emits red or green, gallium nitride emits blue etc.

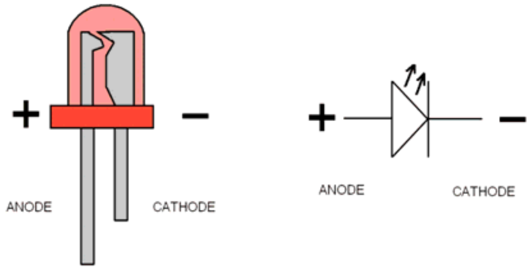


Fig: Structure and symbol of a LED

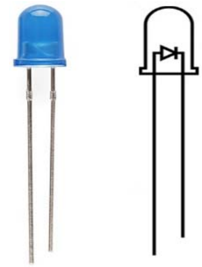


Fig: Leads of a Light Emitting Diode

When LED is forward biased, the electrons and holes move towards the junction and recombination takes place. During recombination, the electrons lying in the conduction band of N-region fall into the holes lying in the valence band of P-region. The light is emitted as a result of recombination.

The amount of light emitted by the LED is directly proportional to the forward current. Higher the forward current, higher is the light output.

Applications of LED

1. LEDs are used to make lamps.
2. They are used to make seven segment, sixteen segments and dot matrix displays. Such displays are used in digital clocks, calculators, advertisement boards etc.
3. They are used to make indicators.
4. They are used as video displays in cell phones, computers etc.
5. They are used to make traffic light signals.
6. They are used in optical switching devices.

Power diode

The diode with higher forward current rating and reverse blocking voltage is called power diode. This diode is mainly used in high power applications. It has large PN junction in order to pass large amount of current and dissipate large amount of heat.

Fig: Power diodes

It also has two terminals (Anode and Cathode) like a signal diode. It allows forward current to flow from anode to cathode when forward biased and doesn't conduct current when reverse biased.Its symbol is similar to that of signal diode.

Applications of Power diode

1. It is used to make rectifiers.
2. It is used as a voltage multiplier.
3. It is used as a freewheeling diode

Varactor diode

The diode which uses the inherent capacitance of the depletion layer when it is reverse biased is called varactor diode. It is also known as Varicap, Voltcap or tunning diode. It is used as a voltage variable capacitor.

Fig: Varactor diodes

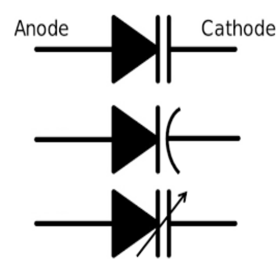


Fig: Symbols of varactor diodes

When the reverse biasing voltage is increased, the width of the depletion layer increases. This increases the dielectric thickness which in turn decreases the capacitance. When the reverse biasing voltage is decreased, the width of the depletion layer decreases. This decreases the dielectric thickness which in turn increases the capacitance.

Applications of varactor diode

1. It is used as electronic tuners in radio, television and other receivers.
2. It is used in automatic frequency control devices.
3. It is used in adjustable band pass filter.

Photo diode

Photodiode is a semiconductor material which converts light energy into an electrical signal. The working function of a photodiode is just opposite to that of LED. This diode is always reverse biased. The amount of current generated is directly proportional to the intensity of the light. It is also termed as photo detector, photo sensor or light detector.

Dark current is the leakage current that flows in the photodiode in the absence of light. The dark current in the photodiode increases when temperature increases.

Fig: Photodiodes

Fig: Symbol of a Photodiode

Applications of Photodiodes

1. It is used in smoke detectors.
2. It is used in opto-coupler circuits..
3. It is used in optical communication devices.
4. It is used in medical application like CT scan, pulse oximeters etc.

4. Assessment

Very Short Answer Questions

1. List the names of special diodes.
2. What is the function of a LED?
3. Draw the symbols of LED, photodiode and zener diode.
4. What is the application of zener diode?

Short Answer Questions

1. Write in short about Zener diode.
2. Write any two applications of a varactor diode.
3. Write any two applications of a LED.

Long Answer Questions

1. Explain in detail about different types of special diodes.
2. Write the applications of different special diodes.

Glossary

Avalanche: A sudden appearance of huge amount of current

Lattice: An arrangement of particles in a regular pattern

Clippers: A nonlinear electronic circuit whose output is limited

Opto-coupler: A pair of light emitting and light sensing components but with no electrical connection between them

References

Basic Electronics, Dr. Sanjay Sharma

Electronic Circuit, Sedra and Smith

http://www.electrical4u.com

http://www.electricalbasicprojects.com

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Unit: 6
Cell and Battery

1. Objectives

This chapter mainly focuses on the basics of electricity. The main objectives of this unit are to make the students able to;

- Differentiate primary and secondary cells
- Understand the importance of combination of cells
- Understand the physical meaning of capacity of a battery

2. Learning Materials

i. Primary cells and secondary cells

i. Battery, wires, resistors, voltaic cell arrangement and voltmeter

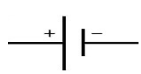
i Dry cells

3. Course Contents

Cell

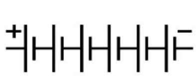
The electro-chemical device which can convert stored chemical energy into electrical energy is called a cell. It is the basic unit of battery. Also, it can be defined as the device in which potential difference is created between the two electrodes. The two electrodes are called Anode and Cathode and the electrodes are immersed in an electrolyte.

The rate of chemical reaction in the cell depends upon the surface area of the electrodes, temperature and the load connected across the cell.

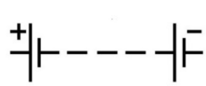
The symbol of a cell  is .

Battery

The combination of two or more cells in series or parallel combination is known as battery. The number of cells in a battery is related to the desired voltage and required current. The symbol of a battery is



or



Classification of cells

The cells may be classified into two general classes:

1. Primary cell
2. Secondary cell

Primary cell

The cell in which chemical substances produce electromagnetic force (emf) by chemical reaction is known as primary cell. The chemical action in this cell is not reversible. Since this cell cannot be revived, this cell is called non-rechargeable cell.After the cell is used, the substances in it become useless.

Commonly used primary cell is as follows:-

1. Voltaic cell
2. Daniel cell
3. Leclanche cell

Voltaic cell

It consists of a glass container, in which conducting materials (copper and zinc plates), are immersed in an electrolyte (dilute sulphuric acid (i.e. H_2SO_4 + H_20)). The chemical action results in the voltage difference between the two materials. This method is called Voltaic cell, after the name of its inventor Alessandro Volta.

The charged conductors in the electrolyte of a cell are called the electrodes or plates of the cell. The zinc plate acts as a positive electrode while the copper plate acts as a negative electrode. When a volt meter is connected across these electrodes, it indicates the presence of emf. When a load is connected across the electrodes, the conventional direction of the current outside the cell is from the positive terminal to the negative terminal of the cell. Inside the cell, the direction of the current is in the opposite direction, that is, from negative terminal to positive terminal.

Working principle of Voltaic cell

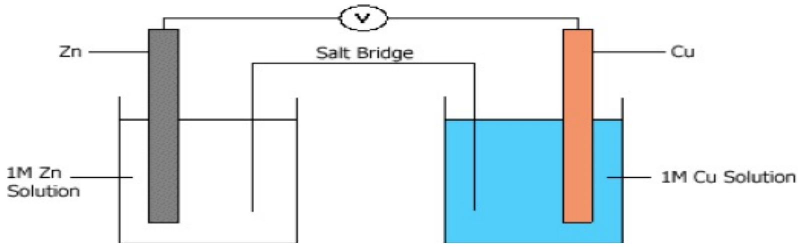


Fig: voltaic cell

Whenever two dissimilar metals are immersed inside an electrolyte solution, the more reactive metal plate will be negativity charged and the less reactive metal will be positively charged. In case of simple voltaic cell, the two dissimilar metals are zinc plate and copper plate and the electrolyte is sulphuric acid. Since the copper is less reactive metal than zinc, zinc plate will get negatively charged and copper plate will get positively charged. However, this action stops when the potential difference (PD) developed in the cell is 1.08V.

Draw backs of Voltaic cell

1. Polarization
2. Local Action

Polarization

When current is drawn from the cell, hydrogen gas in given off in the form of small bubbles from the copper plate. Therefore there is formation of thin layer on the plate surface this layer acts as insulation and hence increases the internal resistance of the cell. This reduces the emf of the cell and the cell becomes inactive. This effect is called polarization.

This effect is prevented by rubbing the copper plate with a brush. In some primary cells, a chemical substance, known as depolarizer, is used. The chemical substance which gives oxygen to mixed hydrogen during chemical reaction is called depolarizer.

Local Action

This defect is due to impurities in the zinc i.e., usually particles of iron, copper, tin, etc. When a commercial Zinc electrode is used in the cell, small cells are formed between these impurities and zinc and thus local current circulates between them inside the cell. This defect is known as local action. Due to this effect, the terminal voltage of the cell is reduced.

To avoid the cell from local action, the zinc electrode is coated mercury amalgam.

Daniel cell

It is a two fluid cell and is a modification of the simple voltaic cell. This cell consists of an outer copper vessel. The vessel consists of concentrated solution of copper sulphate ($CuSO_4$) which acts as a depolarizer.

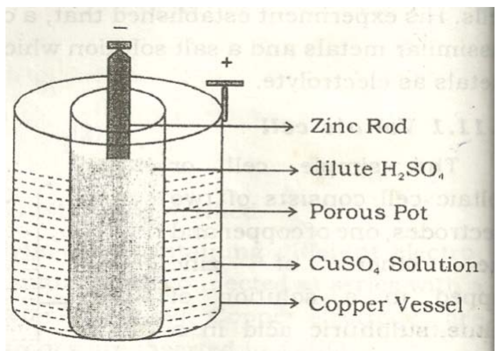


Fig: Daniel Cell

Secondary cell

The cell in which chemical action is reversible; the electrolytes and electrodes can be restored to the previous state once it is used up is secondary cell. This cell is first charged from the external source and then it gives electric current storing electric energy in the form of chemical. It is also called a storage cell because this cell is rechargeable. For example: Lead Acid Cell, nickel, cadmium cell, etc.

Differences between Primary Cell and Secondary Cell

S.N.	Primary Cell	S.N.	Secondary Cell
1	It is a non-rechargeable cell.	1	It is a rechargeable cell.
2	It cannot be recharged once it is discharged.	2	It can be recharged once it is discharged.
3	It has shorter life.	3	It has comparatively longer life.

4	It has lighter weight.	4	It has heavier weight than primary cell.
5	It is used for intermittent work with low current rating.	5	It is used for conditions with high current rating.
6	For e.g.: Daniel cell, Voltaic cell, Leclanche cell etc.	6	For e.g. Lead acid cell, nickel cadmium cell.

Electromotive force (emf) of a cell

The potential difference between the positive and negative plates of a cell in an open circuit is called emf of a cell. It is represented by ‘E’. Its unit is Volt (V).

Terminal voltage or potential difference of a cell

The potential difference between the plates of a cell when delivering current to the external circuit is called the terminal voltage or potential difference of a cell. It is represented by ‘V’. Its unit is also Volt.

Methods of charging

There are two methods of charging a lead acid battery:

- Constant voltage charging method.
- Constant current charging method.

Constant voltage charging method

In this method of charging,the charging voltage is held constant throughout the charging process. Charging current is high in the beginning but reduces as the back emf of the battery increases.

Constant current charging method

In this method of charging, the charging current is kept constant by adjusting the external resistance. This method is usually adopted for charging new batteries initially. It is also used for charging fully discharged batteries.

Internal resistance of a cell

The opposition offered to the flow of current in a cell is called internal resistance of a cell. It is represented by ‘r’. The internal resistance of a cell is due to the resistance of

a. Electrodes

b. Terminal of the cell

c. Electrolyte

It depends upon size and spacing of plates. It is independent of the current supplied by cell.

Grouping of cells

1. Series connection
2. Parallel connection

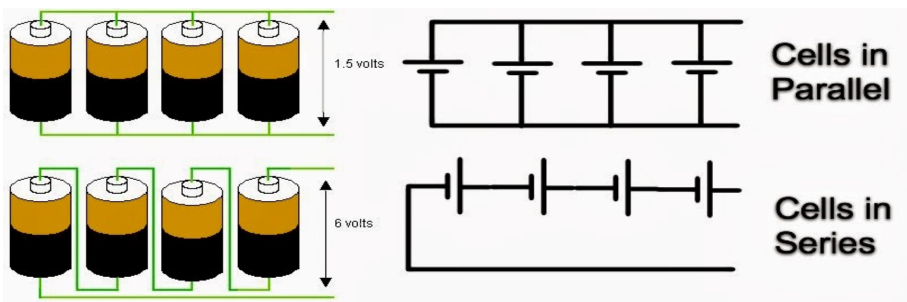


Fig: Parallel and Series combination of cells

Series connection

Cells are said to be connected in series when the negative terminal of a first cell is connected to the positive terminal of a second cell, the negative terminal of second is connected to the positive terminal of a third cell and so on. In a series connection, the individual voltages of the cells add up, but the current capacity of a battery remains same as for one cell because same current flows through all the cells.

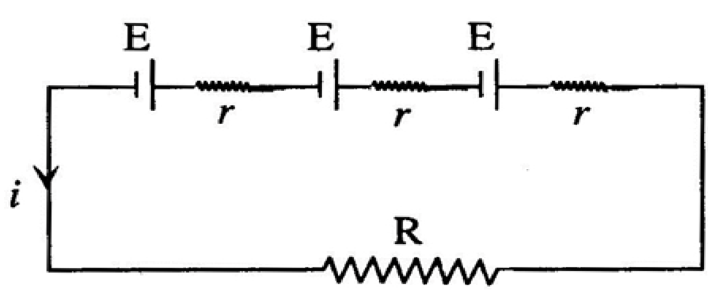


Fig: Series combination of cells

When cells are connected in series, total emf is given by the sum of their individual emf and sum of their individual internal resistances.

Total EMF (E)= E1+E2+E3………..En

Total internal resistance(r)= $r_1+r_2+r_3$——r_n

If similar cells of emf ‘E’ and internal resistance ‘r’ are connected in series, then Total emf(E_t)=nE

Total internal resistance (r_T)= nr

Cells are connected to an external resistance ‘R’ then current flowing through the current(I)= nE/nr

=E/r

Cells in a parallel connection

Cells are said to be in parallel when all the positive terminals are connected at one point and all the negative terminals are connected at another point. When cells are connected in parallel, the available voltage is same as the voltage supplied by each cell when all of the cells have the same voltage rating. If all of the cells do not have same voltage rating, the cells of lower voltage will drain current from the cells of higher voltage. In parallel combination, the cells can have different current ratings if they all supply the same voltage.

When similar cells are connected in parallel then

Total Emf(E)= Emf of one cell

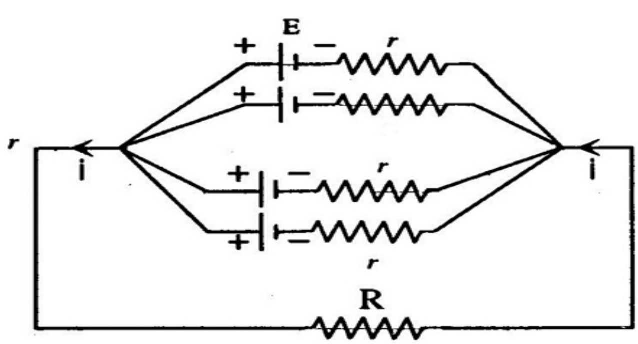


Fig. Parallel connection of cell

The combined internal resistance of the circuit = r/m

If ‘R’ is the external resistance in the circuit then the current(I) through the circuit is given by

I=E/ (R+r/m)

For maximum current, external resistance should be small as compared to the total resistance.

Capacity of a battery

The useful quantity of electricity that can be taken from a battery at the specified rate of discharge is called capacity of a battery.It is expressed in Ampere-hour (Ah) or milli-Ampere hour (mAh) which is the product of the specific discharge current in Ampere or milli-Ampere and time in hours.

Fig: Batteries with their capacities imprinted on it

The capacity of battery depends upon the following factors:-

1. Size and number of plates
2. Quantity of acid
3. Rate of discharge
4. Operating temperature

Applications of Batteries

Batteries are widely used in residential to industrial applications. They are used in tiny watches to large satellites. Some of the common applications of batteries are as follows:

1. Miniature batteries are used in watches, calculators, medical devices etc.
2. Batteries are used in portable devices like flash lights, cell phones, radios, camcorders etc.
3. They are used in vehicles like trucks, buses, etc. for Starting, Lighting and Ignition (SLI) purposes.

4. They are used in UPS, Emergency power, local energy storage, communication base stations etc.
5. They are used in military and aerospace like satellites, communication, robots, emergency power etc.

4. Assessment

Very Short Answer Questions

1. What do you mean by an electric cell?
2. What do you understand by secondary cell?
3. How can secondary cell be revived back?
4. List out the types of primary cell.
5. Draw a symbol of a cell and a battery.

Short Answer Questions

1. What are the components of a cell?
2. Differentiate primary and secondary cell.
3. What is a Daniel cell?
4. Define capacity of a battery. Write the unit of capacity of a battery.
5. Explain the methods of charging of cells.

Long Answer Questions

1. Define Voltaic cell in detail.
2. Explain the parallel combination of cells.
3. Explain the series connection of cells.

Glossary

Discharge: The act of giving off energy

References

http://www.electrical4u.com

http://www.electricalbasicprojects.com

http://www.electricaltechnology.org

Unit: 7

Rectifier

1. Objectives

This chapter deals with the construction of rectifiers. The main objectives of this unit are to make the students able to;

- Construct different types of rectifiers
- Understand the use of diodes in rectifiers
- Compare the input and output waveforms of rectifier

2. Learning Materials

i. IN4007 Diodes, Center tapped Transformer(6-0-6), wires and resistors

ii. Multimeter, Breadboard, Stripper and Cutter, Jumper wires etc.

iii. Oscilloscope

3. Course Contents

Rectifier

A rectifier is an electrical circuit which converts alternating current (AC) into direct current (DC). AC reverses its direction periodically whereas DC is unidirectional. The process of conversion from AC to DC is known as rectification. Diodes are involved in rectification unit.

The rectification system can be done in two ways:-

- Half wave rectification
- Full wave rectification

Based on the method of rectification, rectifiers are of two types:

1. Half wave rectifier
2. Full wave rectifier
    - Center tapped type full wave rectifier
    - Bridge type full wave rectifier

Half wave rectifier

The half wave rectifier is a type of rectifier which converts half of the AC input signal (positive half cycle) into pulsating DC output signal and the remaining half signal (negative half cycle) is blocked or lost.

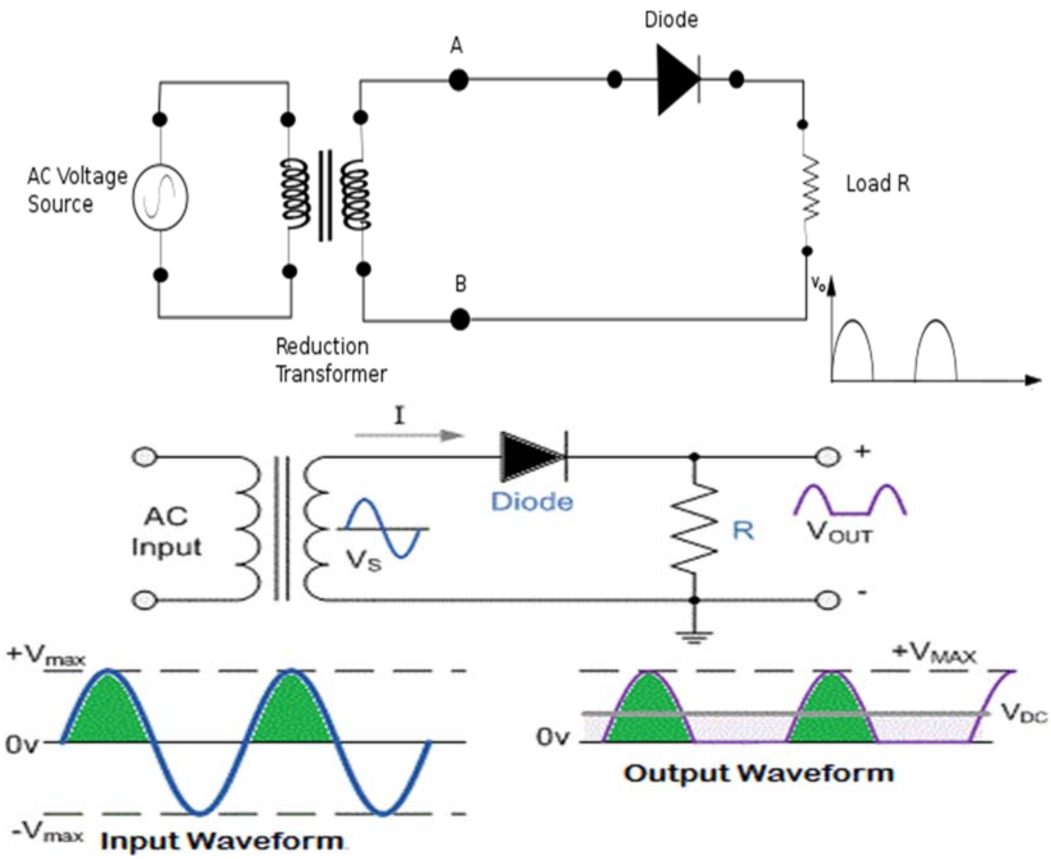


Fig: Half Wave Rectification

Full wave rectifier

A full-wave bridge rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. It is a type of rectifier which converts the full AC input signal (positive half cycle and negative half cycle) to pulsating DC output signal. Unlike the half wave rectifier, the input signal is not wasted in full wave rectifier. There are two types of full wave rectifier:-

- Center tapped type full wave rectifier
- Bridge type Full wave rectifier

Center tapped type full wave rectifier

The center-tapped full-wave rectifier circuit uses two diodes D_1 and D_2 which are connected to the center-tapped secondary winding of the transformer. The center-tapped on the secondary is taken at zero voltage reference point. If the secondary voltage is V_2 then the voltage between one end of secondary and center tapped is equal to $V_2/2$.

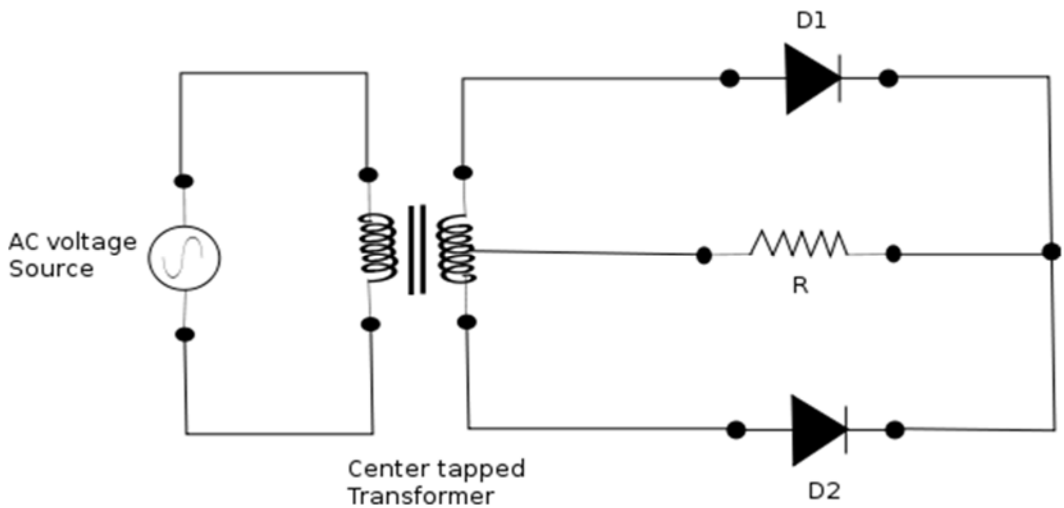


Fig:-Circuit of a Center Tapped Full wave rectifier

Working

During positive half cycle, diode D_1 is forward biased whereas diode D_2 is reverse biased. Hence, diode D_1 onlyconducts but diode D_2 does not for positive half cycle. Thus, current I flows through the load resister R.

During negative half cycle, diode D_2 is forward biased whereas diode D_1 is reverse biased. Hence diode D_2 onlyconducts but diode D_1 does not for negative half cycle. Thus, current I flows through the load resistor R in the direction same as above.

It is clear that one diode conducts for positive half cycle and another diode conducts for negative half cycle. Hence, an unidirectional current flows continuously in a full wave rectifier.

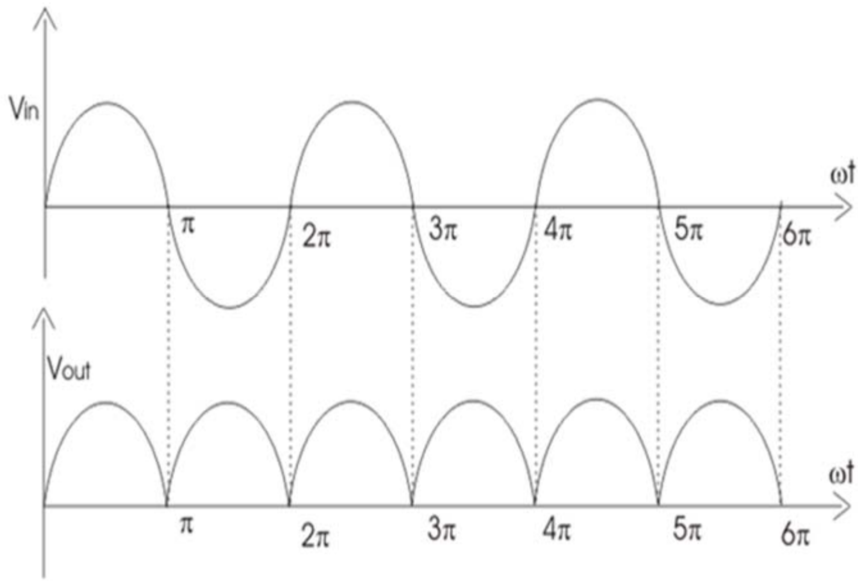


Fig: Input and output waveforms of a center tapped full wave rectifier

Bridge type Full wave rectifier

The full wave bridge rectifier uses four diodes arranged in a bridge circuit which are connected across the secondary of a transformer. This circuit gives full wave rectification without the need of a centre-tapped transformer.

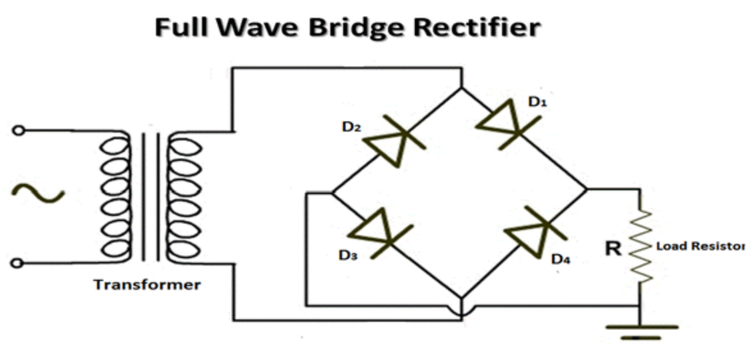


Fig: Construction of a bridge type full wave rectifier

Working

During positive half cycle, the diodes D_1 and D_3 are forward biased whereas diodes D_2 and D_4 are reverse biased. Hence diodes D_1 andD_3 onlyconduct but diodes D_2 andD_4 do not. Thus, the current will flow through diode D_1, load resistor R and diode D_3.

During negative half cycle, the diodes D_2 and D_4 are forward biased whereas diodes D_1 and D_3 are reverse biased. Hence diodes D_2 andD_4 onlyconduct but diodes D_1 andD_3 do not. Thus, the current will flow through diode D_4, load resistor R and diode D_2.

It is clear that the output voltage is unidirectional across the load continuously in a bridge type full wave rectifier. The input and output voltage waveform for a bridge type full wave rectifier is shown below:

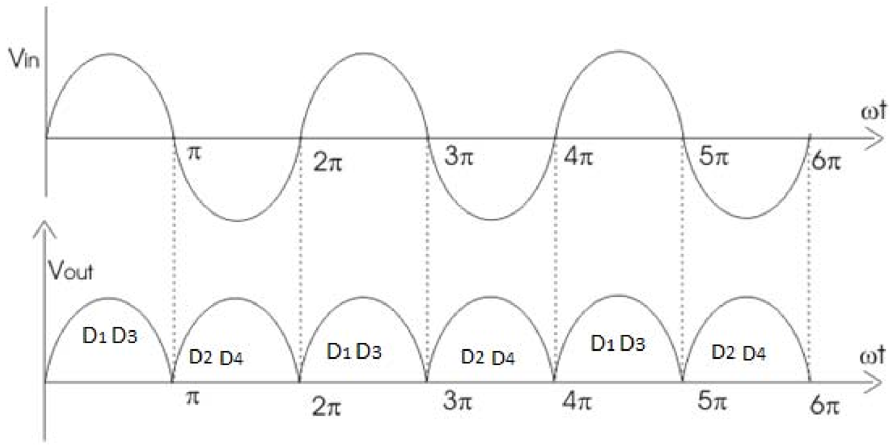


Fig: Input and Output Waveforms of Bridge Type full wave Rectifier

4. Assessment

Very Short Answer Questions

1. What do you mean by power supply?
2. What are the main components of a power supply?
3. Which component is used in rectification?
4. How many diode/s are there in half wave rectifier?
4. What do you mean by center tapped transformer?

Short Answer Questions

1. Define hall wave rectifier.
2. What is a rectifier? Which component is used to convert AC into DC?
3. Draw the output waveform of full wave rectifier with proper labelling when pure sine wave is given input.

Long Answer Questions

1. List out the main parts of a DC power supply unit. Explain each of them in detail.
2. Explain the construction and working of a half wave rectifier.
3. Explain the construction and working of a center tapped full wave rectifier.
4. Explain the construction and working of a bridge type full wave rectifier.

Glossary

Fabricate: put together/ construct

Tapping: Tapping of a transformer means the connection point along the transformer winding to select the suitable number of turns.

Waveform: A graphical representation which shows the changes in amplitude over a certain amount of time.

AC Mains: Alternating Current power supply delivered to homes and offices for general purpose

References

Basic Electronics, Dr. Sanjay Sharma

Electronic Circuit, Sedra and Smith

http://www.electrical4u.com

http://www.electricalbasicprojects.com

https://www.allaboutcircuits.com

http://www.electricaltechnology.org

Unit: 8
Transistor

1. Objectives

This chapter explains the basics of transistor and its types. The main objectives of this unit are to make the students able to;

- Understand the construction and working of transistors
- Differentiate the varieties of transistors
- Distinguish the terminals of given transistors

2. Learning Materials:

i. PNP Transistors (BC 557), NPN Transistors (BC 547)

ii. N-channel JFET and P-channel JFET

iii. E-MOSFET and D-MOSFET

iv. Multimeter

3. Course Contents

Transistor

Transistor is a basic building block of modern electronic systems. It is a three terminal device. It consists of two pn junctions. There, a transistor may be regarded as a combination of two diodes connected back to back.

Generally, one junction of transistor is forward biased and the other junction is reverse biased. The forward biased junction has a low resistance path whereas the reverse biased junction has a high resistance path. The weak signal is introduced in the low resistance circuit whereas the output is taken from the high resistance circuit. Therefore a transistor transfers a signal from low resistance to high resistance. The prefix ‘trans’ means the signal transfer property of the device while the ‘istor’ classifies it as an element in the same family with the resistor. Hence, this device is named as TRANSISTOR.

Classification of transistor

Transistors are broadly classified as follows:

1. Bipolar Junction Transistor (BJT)
ii. Field Effect Transistor (FET)

BJT (Bipolar Junction Transistor)

It is a three terminal semiconductor device which is often used in electronic circuits. This device is named as BJT because the transistor operation is carried out by two types of charge carriers- majority charge carriers and minority charge carriers. The output voltage, current or power is controlled by the input current in a BJT. Hence this device is called a current controlled device.

Construction of a BJT

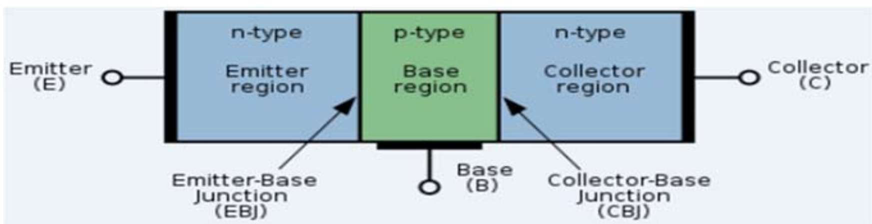


Fig: Construction of NPN and PNP transistors

A transistor has three regions. They are emitter, base and collector. These regions are connected to each terminals hence they are also called terminals of a BJT. They are introduced as follows:-

Emitter

The region which emits charge carriers (electron or holes) is called emitter. This region is the most highly doped region. It is an outer region situated in one side of transistor.

Base

The region which allows the passage of charge carriers is called base. This is the least doped region. Charge carriers emitted by the emitter pass towards the collector through the base. It is situated in between the emitter and the collector. This region is the smallest region in size.

Collector

The region which collects charge carriers is called collector. This region is moderately doped region. It is an outer region situated in the other side of transistor.

This region is physically larger than the emitter region and the base region so as to dissipate the heat generated.

Note:

i. The size of the base is the smallest whereas the size of the collector is the largest. The size of the emitter is greater than base but smaller than the collector.

ii. Emitter is highly doped, base is lightly doped and collector is moderately doped.

A BJT has two junctions J_1 and J_2- Emitter-Base (EB) junction and Collector-Base (CB) junction. The junction formed between the emitter and the base is called EB junction (J_1) and the junction formed between the collector and the base is called the CB junction (J_2).

Region	**Doping**	**Area**
Emitter	Highly doped	Smaller than C and larger than B
Base	Lightly doped	Smallest region
Collector	Moderately doped	Larger than E and B

Types of BJT

There are two types of transistors: NPN and PNP.

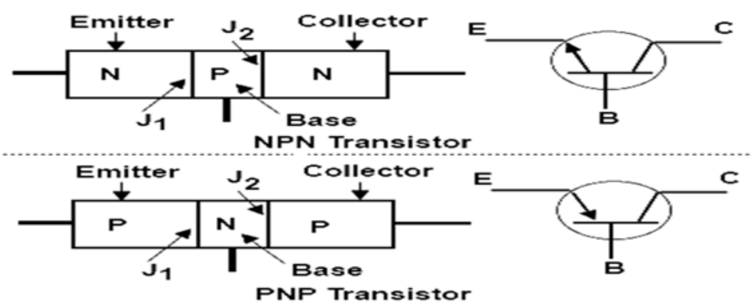


Fig: Structures and symbols of NPN and PNP transistors

In a NPN transistor, the arrowhead in an emitter indicates the direction of a conventional current flow. The arrowhead points from the P-region towards the N-region. Therefore, in a NPN transistor, the conventional current will flow from the base to the emitter.

In a PNP transistor, the arrowhead in an emitter points from the P-region towards the N-region. Therefore, in a PNP transistor, the conventional current will flow from the emitter to the base.

Out of these two types of transistors, the NPN transistor is mostly used. In NPN transistors, the current conduction is mainly by electrons whereas in PNP transistors, the current conduction is mainly by holes. The conduction in NPN transistors is higher than in PNP transistors because electrons are more mobile than holes.

Two diodes model of a BJT

In this model of a BJT, two diodes are connected back to back to make a NPN or PNP transistor. The base region is a combination of two anodes or two cathodes. If two anodes are made common, then NPN transistor is formed whereas if two cathodes are made common, the PNP transistor is formed.

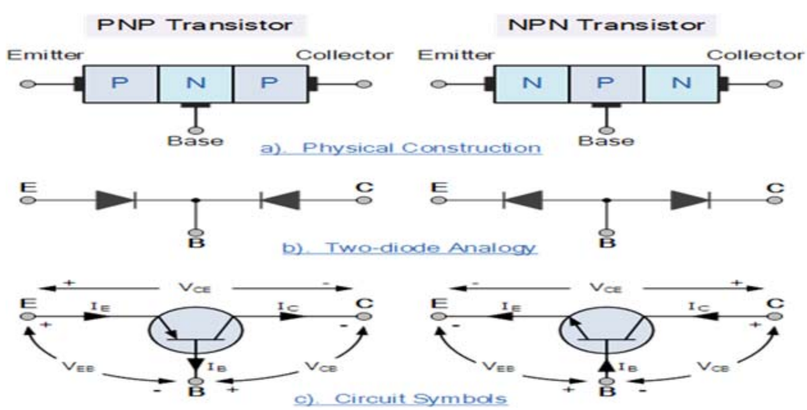


Fig: Two diode model of a transistor

Working principle of NPN transistor

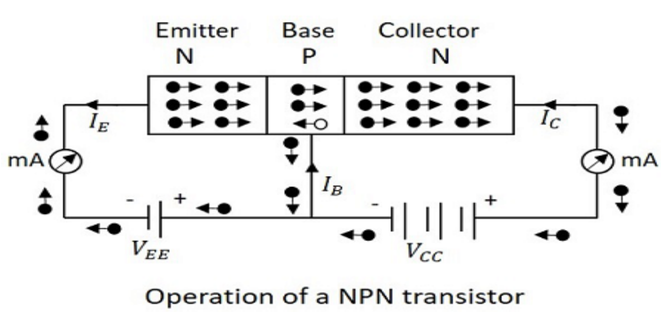


Fig. : Working of an NPN Transistor

Let us consider a NPN transistor which is biased for active operation i.e., emitter base junction is forward biased and collector base junction is reverse biased. The forward biased voltage is small and the reversed biased voltage is quite larger.

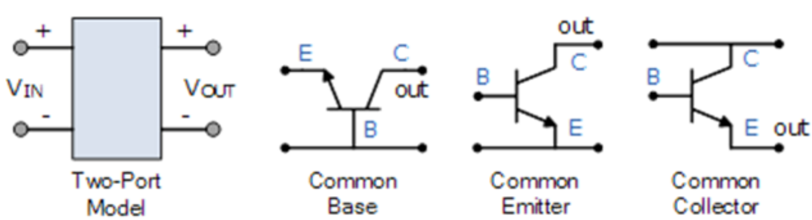
When emitter is forward biased, a large number of free electrons of N-type emitter region are pushed towards the base. A few numbers of holes also pass from base to the emitter. This flow of electrons and holes constitute emitter current, I_E. Since the base is thin and lightly doped region, only a very small amount of electrons combines with holes to constitute the base current, I_B. The remaining electrons pass towards the collector. These electrons in the collector region constitute collector current, I_C.

The emitter current of a transistor consists of base current and collector current. Base current is only about 2% of the emitter current whereas the collector current is about 98% of the emitter current. Thus emitter current is almost equal to the collector current.

Different Configurations of BJT

Any of the terminals of a BJT can be made common to input and output. This common terminal is generally grounded or connected to the chassis. Depending upon the common terminals, there are three transistor configurations. They are:

1. Common base configuration
2. Common emitter configuration
3. Common collector configuration



Common base configuration

The arrangement in which base of a BJT is made common to both emitter and collector is called common base configuration. The input is applied between the emitter and base and the output is taken between the collector and base.

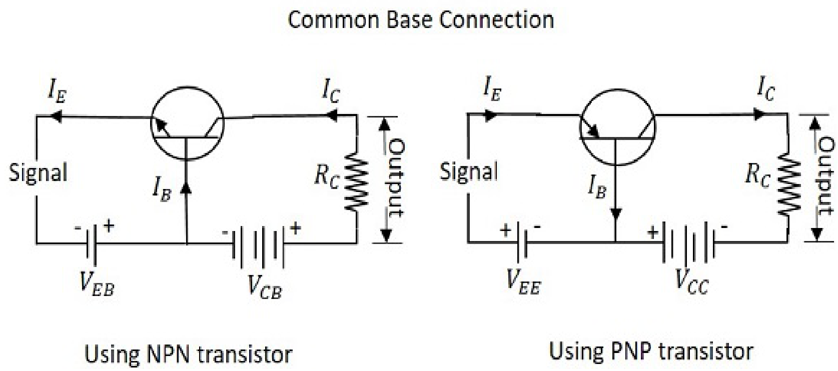


Fig: Common base configuration of NPN and PNP Transistor

In this configuration, emitter base junction is considered as input whereas collector base junction is considered as output.

Common emitter configuration

The arrangement in which the emitterof a BJT is made common to both base and collector is called common emitter configuration.

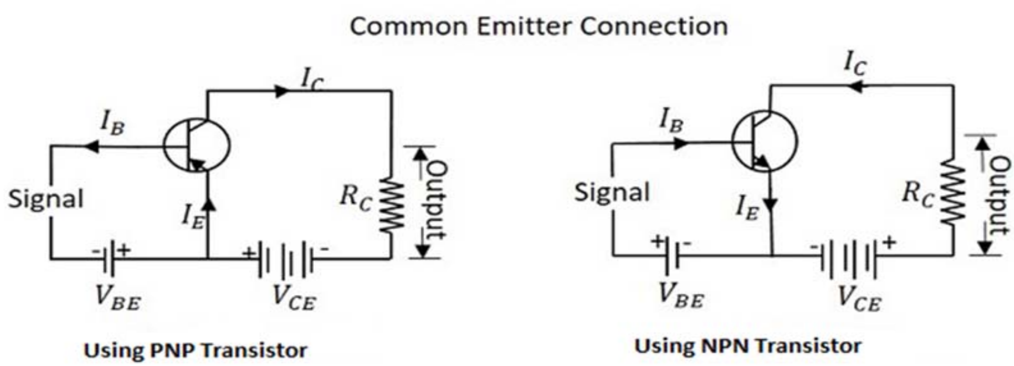


Fig: Common emitter configuration of NPN and PNP transistors

In this configuration, emitter and base are taken as input terminals whereas emitter and collector are taken as output terminals.

3. Common collector configuration

The arrangement in which the collector of a BJT is made common to both emitter and base is known as collector configuration.

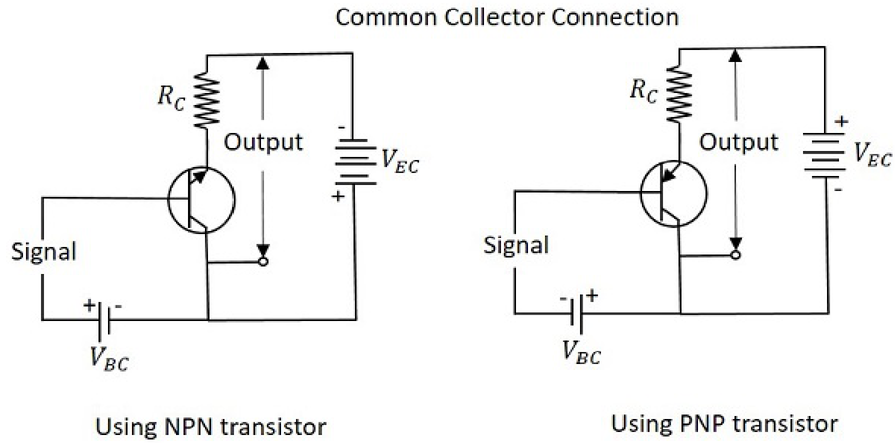
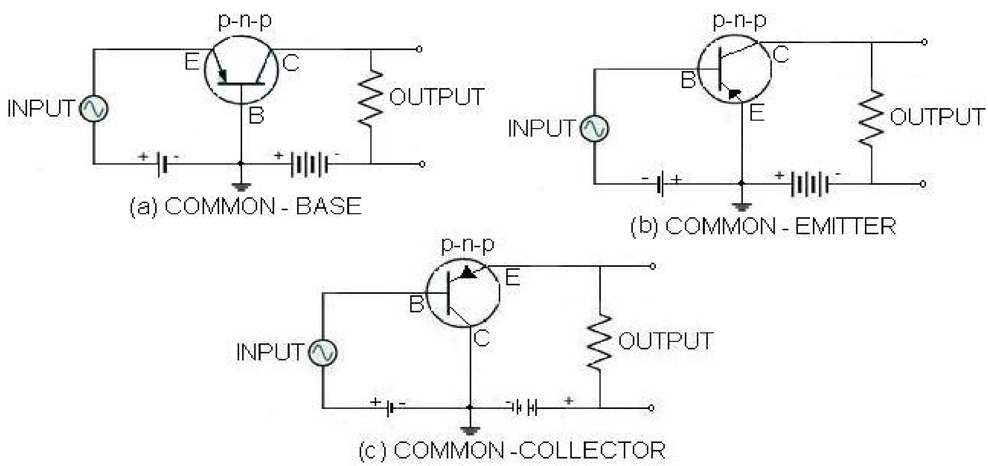


Fig: Common collector configuration of NPN and PNP transistors

Note: Commonemitter configuration is the mostly used configuration of a BJT.



Applications of BJTs

1. It can be used as an electric switch.
2. It can be used as an amplifier.
3. It can be used to make digital circuits.

Field Effect Transistor (FET)

FET is a voltage controlled device. This means output characteristics of FET are controlled by the input voltage and not by the input current. In addition to this, FET is a unipolar device. This means that the current flowing through it is due to only one type of charge carriers i.e., either holes or electrons.

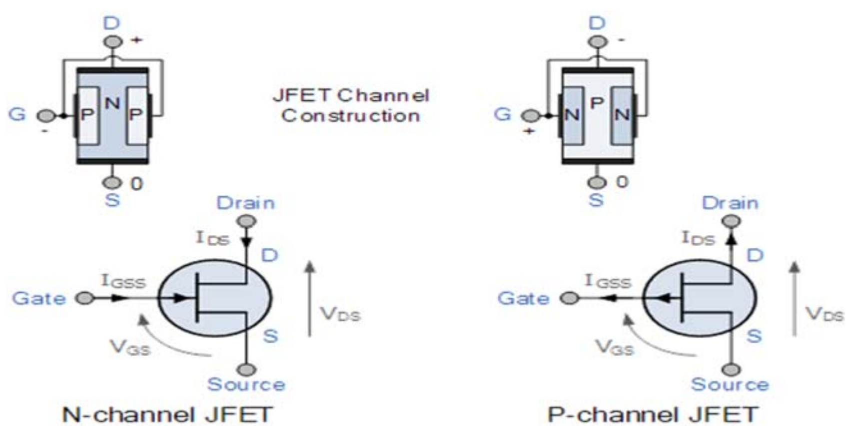
Classification of field effect transistors

There are mainly two types of FET:-

1. Junction Field Effect Transistor (JFET)
    a. N-channel JFET
    b. P-channel JFET
2. Metal Oxide Semiconductor Field Effect Transistor (MOSFET)
    a. Depletion Metal Oxide Semiconductor Field Effect Transistor (DMOSFET)
        a. N-channel DMOSFET
        b. P-channel DMOSFET
3. Enhancement Metal Oxide Semiconductor Field Effect Transistor (E-MOSFET)
    a. N-channel EMOSFET
    b. P-channel EMOSFET

Junction Field Effect Transistor (JFET)

It is a three terminal semiconductor device. The terminals are Gate (G), Drain (D) and Source (S). The gate is a terminal that regulates the flow of charge carriers. The source is a terminal through which charge carriers enter the semiconductor. The drain is a terminal through which the charge carriers leave the semiconductor.



Classification of JFET

Depending upon their structure, JFET are mainly of two types:

a. N-channel JFET

b. P-channel JFET

N-channel JFET

It consists of an N-type semiconductor bar with two heavily doped P-type regions on the opposite sides of its middle part. The P-type regions form two PN junctions. The space between the two junctions is known as a channel. Both the P-type regions are connected internally and a single wire is taken out in the form of a terminal known as the gate (G). The electrical connections made to the both ends of the N-type semiconductor are known as Drain and Source.

Whenever a voltage is applied across the drain and source terminals, a current flows through the N-channel. The current consists of only electrons.

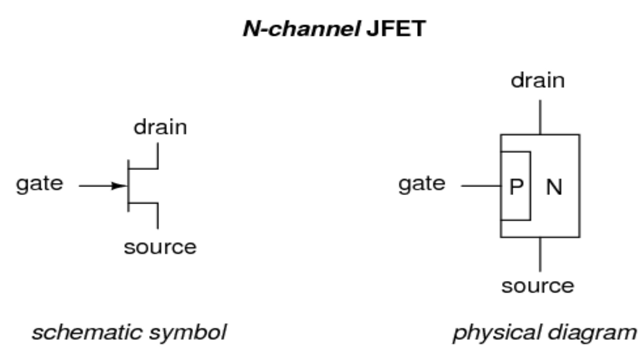
P-channel JFET

It consists of an P-type semiconductor bar with two heavily doped N-type regions on the opposite sides of its middle part. The N-type regions form two PN junctions. The space between the two junctions is known as a channel. Both the N-type regions are connected internally and a single wire is taken out in the form of a terminal known as the gate (G). The electrical connections made to the both ends of the P-type semiconductor are known as Drain and Source.

Whenever a voltage is applied across the drain and source terminals, a current flows through the P-channel. The current consists of only holes.

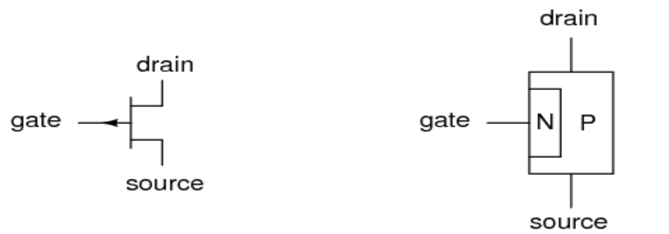
Symbol of JFET

In an N-channel JFET, the arrow points towards the N-channel.

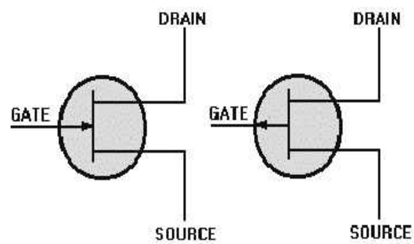


In a P-channel JFET, the arrow points away from the P-channel.

P-channel **JFET**



schematic symbol *physical diagram*



N CHANNEL P CHANNEL

Applications of JFET

1. It can be used as a low noise amplifier.
2. It can be used as a switch in ADC/DAC circuits.
3. It can be used as a Voltage Variable Resistor (VVR).
4. It can be used as phase shift oscillator.

MOSFET

It is an abbreviation of Metal Oxide Semiconductor Field Effect Transistor. Like JFET, it has a source, drain and gate. However, unlike JFET, the gate of a MOSFET is insulated from the channel. So, MOSFET is also called IGFET which stands for Insulated Gate Field Effect Transistor.

The IGFET or MOSFET is a voltage controlled field effect transistor that has a "Metal Oxide" Gate electrode which is electrically insulated from the main semiconductor n-channel or p-channel by a very thin layer of insulating material usually silicon dioxide, commonly known as glass.

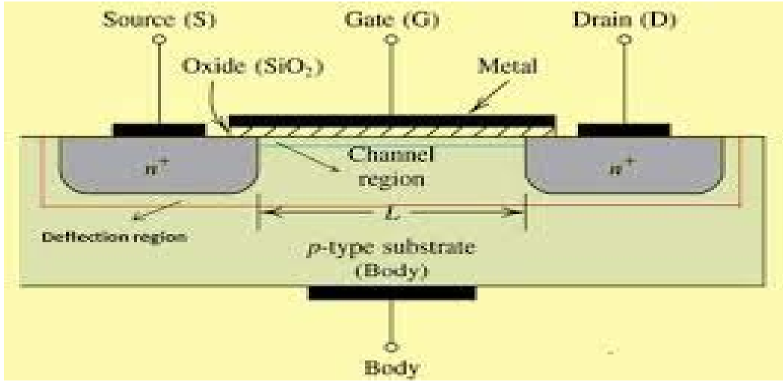


Fig: Construction of a MOSFET

Classification of MOSFET

MOSFET are mainly of two types :

1. Depletion type Metal Oxide Semiconductor Field Effect Transistor (DMOSFET)
2. Enhancement type Metal Oxide Semiconductor Field Effect Transistor (E-MOSFET)

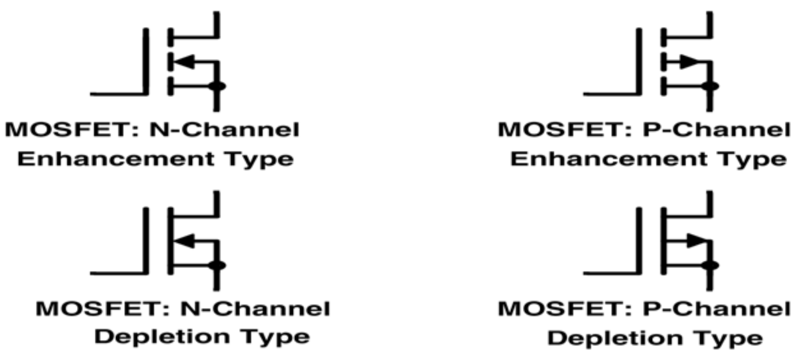
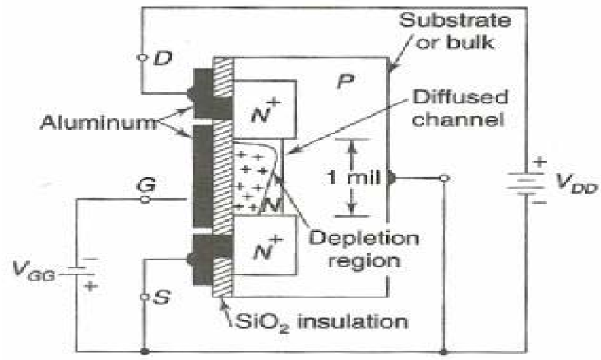
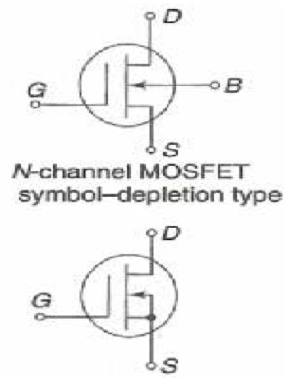


Fig: Symbols of Enhancement type and Depletion type MOSFET

Depletion type Metal Oxide Semiconductor Field Effect Transistor (DMOSFET)

Depletion type MOSFET may be N-channel DMOSFET or P-channel DMOSFET. This device requires the gate to Source Voltage (V_{GS}) to switch OFF the device. The depletion mode MOSFET is also called "Normally Closed" switch.





Depletion MOSFET

The channel conducts when $V_{GS} = 0$ making it a “normally-closed” device. For the n-channel depletion MOSFET, a negative gate-source voltage, $-V_{GS}$ will deplete the conductive channel of its free electrons switching the transistor “OFF”. Likewise for a p-channel depletion MOSFET, a positive gate-source voltage, $+V_{GS}$ will deplete the channel of its free holes turning it “OFF”.

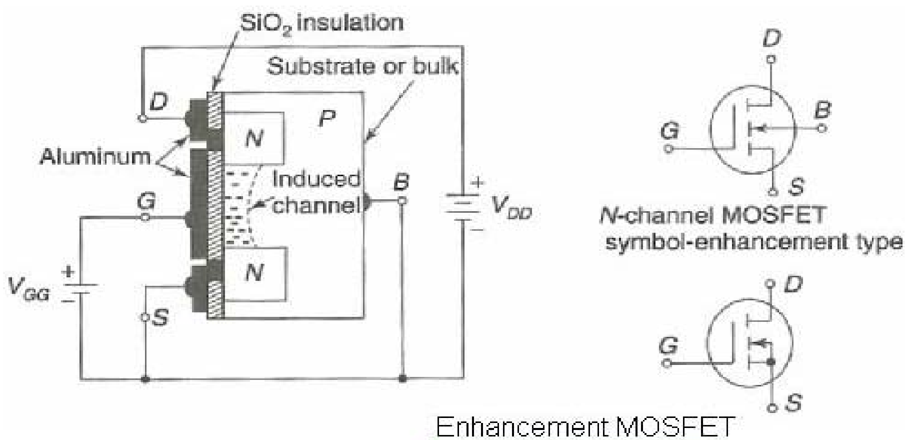
In other words, for an n-channel depletion mode MOSFET: $+V_{GS}$ means more electrons and more current. While a $-V_{GS}$ means less electrons and less current. The opposite is also true for the p-channel types. Then the depletion mode MOSFET is equivalent to a “normally-closed” switch.

Enhancement Metal Oxide Semiconductor Field Effect Transistor (E-MOSFET)

Enhancement type MOSFET may be N-channel E-MOSFET or P-channel E-MOSFET. This device requires the Gate to Source Voltage (V_{GS}) to switch ON the device. The enhancement mode MOSFET is also called “Normally Open” switch.

Here the conducting channel is lightly doped or even undoped making it non-conductive. This results in the device being normally “OFF” (non-conducting) when the gate bias voltage, V_{GS} is equal to zero.For the n-channel enhancement MOSFET, a drain current will only flow when a gate voltage (V_{GS}) applied to the gate terminal is greater than the threshold voltage (V_{TH}) level.

The reverse is true for the p-channel enhancement MOSFET. When $V_{GS} = 0$ the device is “OFF” and the channel is open. The application of a negative (-ve) gate voltage to the p-type EMOSFET enhances the channels conductivity turning it "ON". Then for a p-channel enhancement mode MOSFET: $+V_{GS}$ turns the transistor "OFF", while $-V_{GS}$ turns the transistor "ON".



Enhancement MOSFET

Applications of MOSFET

1. It can be used as a switching device in inverters, choppers etc.
2. It can be used as an amplifier.
3. It can be used in linear voltage regulators.

4. Assessment

Very Short Answer Questions

1. What is a transistor?
2. Draw the symbols of the types of JFET.
3. Write the full forms of JFET and MOSFET.
4. Write the types of MOSFET.

Short Answer Questions

1. Write the functions of a transistor.
2. Write the applications of a MOSFET.
3. Draw the symbols of all types of MOSFET.

Long Answer Questions

1. Write the types of transistors in detail.
2. Explain the construction and working of aN-channel BJT.
3. Explain the different configurations of a BJT.
4. Explain the types of JFET.

Glossary

Configuration: Arrangement of different parts

Oscillator: A circuit that generates AC waves

References

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