G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY
Accredited by NAAC with 'A' Grade of UGC, Approved by AICTE, New Delhi
Permanently Affiliated to JNTUA, Ananthapuramu
(Recognized by UGC under 2(f) and 12(B) & ISO 9001:2008 Certified Institution)
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Department of Electronics and Communication Engineering

Bridge Course
On
Electronic Devices and Circuits

Electronics and its applications:

The world's reliance on electronics is so great that commentators claim people live in an "electronic age." People are surrounded by electronics—televisions, radios, computers, mobiles, Laptop and DVD players, along with products with major electric components, such as microwave ovens, refrigerators, and other kitchen appliances, automatic vehicles, Robotics, as well as hearing aids and medical instruments and numerous applications in industry.

Definition: *The branch of engineering which deals with current conduction through a Vacuum or Gas or Semiconductor is known as* **Electronics.** An *electronic device* is that in which current flows through a vacuum or gas or semiconductor. This control of electrons is accomplished by devices that resist, carry, select, steer, switch, store, manipulate, and exploit the electron or Electronics deals with electrical circuits that involve active electrical components such as vacuum tubes, transistors, diodes and integrated circuits**,** and associated passive interconnection technologies. Commonly, electronic devices contain circuitry consisting primarily or exclusively of active semiconductors supplemented with passive elements; such a circuit is described as an electronic circuit**.**

Passive Components: The passive component is a device, which is basically static in operation. It is not capable of amplification or oscillation. It does not require power for its operation. Typical passive components are resistors, capacitors, inductors.

Resistors: The resistor is an electrical device whose primary function is to introduce resistance to flow of electric current. The magnitude of opposition to flow of current is the resistance of resistor. The resistance is measured in ohms. The various uses of resistor includes setting biases, controlling gains, fixing constants, matching and loading circuits, voltage division, and heat generation. There are two classes of resistors. They are fixed resistors and variable resistors.

Fixed resistor

Variable resistor

Fixed Resistors: A fixed resistor is one in which the value of its resistance cannot change.

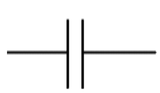
Variable Resistors: A variable resistor is one in which the value of its resistance can change in different ranges.

The different types of variable resistors are:

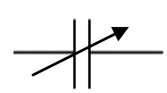
1. Rheostat
2. Potentiometer
3. Preset

Capacitor: Capacitance of a capacitor is the ability of a dielectric to store electric charge. Its unit is Farad. It is named after Michael Faraday. A capacitor is made up of an insulator between two conductors. The capacitors are characterized by two effects namely, charging and discharging.

The symbol of the capacitor is as shown below:



Fixed Capacitor



Variable Capacitor

Characteristics of Capacitor:

- The capacitor is represented by the capacitance value and the voltage.
- Its Capacitance, $C = \frac{Q}{V}$
- Its energy stored $W = \frac{1}{2}CV^2$
- If N capacitors are in series the resultant capacitance is $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_N}$
- If N capacitors are in parallel the resultant capacitance $C = C_1 + C_2 + C_3 + ... + C_N$
- The common problems in capacitors are open or short or leaky.
- They are tested with ohmmeter.
- They can be measured by the capacitance meter.
- Its reactance $X_C = \frac{1}{\omega C}$
- They are classified on the basis of shape of conducting plates and type of dielectrics.
- Its power factor is $\frac{R}{X_C}$.
- Its quality factor is $\frac{X_C}{R}$.
- Capacitance does not depend on Q or V.
- Capacitance depends on dielectric constant, area of the plates and distance between the plates.
- Current in a capacitor leads voltage by 90°.

Inductors: Inductors are used for the storage of magnetic energy. Magnetic energy is stored as long as current keeps flowing through the inductor. Components which are definite value of Inductance are called fixed inductors. A long wire has more Inductance than short wire since conductor length cuts by magnetic flux produces more induced voltage. Similarly a coil has more inductance than equivalent length of straight wire because coil concentrates more fluxes.
The symbol of inductor is shown in figure below.

Characteristics of Inductors:

- The inductor is represented by L, Henrys.
- Its L is given by $\frac{V_i}{\left(\frac{di}{dt}\right)}$.
- Its energy stored $W = \frac{1}{2}LI^2$

- Series inductance of two coils is $L = L_1 + L_2$
- Parallel inductance of two coils is $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$
- The common problem in inductors is open windings.
- They are tested with ohmmeter.
- All inductors have internal resistance.

- Its reactance $X_L = \omega L$.
- Its quality factor is $\frac{X_L}{R}$.
- Current in an inductor lags the voltage by 90°.

Active components: Requiring a source of power to operate. Includes transistors (all types), integrated circuits (all types), TRIACs, SCRs, LEDs, etc.

Applications of electronics:

Consumer electronics: include products like – Audio Systems, Video Systems, TV (Television), Computer, Laptop, Digital Camera, DVD Players, Home and Kitchen Appliances, GPS, Mobiles Phones etc.

Communication: Electronic communication systems connect people around the world. Using telephones, Internet and computers, people in different countries communicate almost instantly. Radios transmit sounds and televisions transmit sounds and pictures great distances. Cellular telephones enable a person to call another person. Within seconds, fax machines send and receive copies of documents over telephone lines/Satellite.

Information processing: Scientists, artists, students, government and business workers, and hobbyists at home all rely on computers, Internet to handle huge amounts of information quickly and accurately. Computers solve difficult mathematical problems, maintain vast amounts of data, create complex simulations, and perform a multitude of other tasks that help people in their everyday lives.

Medicine and research: Include product like X-ray machines ECG (Electrocardiogram) use radiation to take images of bones and internal organs. Radiation therapy, or radiotherapy, uses X-rays and other forms of radiation to fight cancer. Many hearing-impaired people depend on hearing aids to electrically amplify sound waves.

Computers: and other electronic instruments provide scientists and other researchers with powerful tools to better understand their area of study. Computers, for example, help scientists design new drug molecules, track weather systems, and test theories about how galaxies and stars develop. Electron microscopes use electrons rather than visible light to magnify specimens 1 million times or more.

Automation: Electronic components enable many common home appliances, such as refrigerators, washing machines, and toasters, to function smoothly and efficiently. People can electronically program coffeemakers, lawn sprinklers, and many other products to turn on and off automatically. Microwave ovens heat food quickly by penetrating it with short radio waves produced by a vacuum tube.

Instrumentation: Measuring Instruments like CRO, Multimeter, ph-meter, strain gauge, VTVM, Frequency Counter are used in different Laboratory/organizations.

Many automobiles have electronic controls in their engines and fuel systems. Electronic devices also control air bags, which inflate to protect a driver and passengers in a collision.

Atom: An **atom** is the smallest form of a chemical particle that retains the properties of the particle.

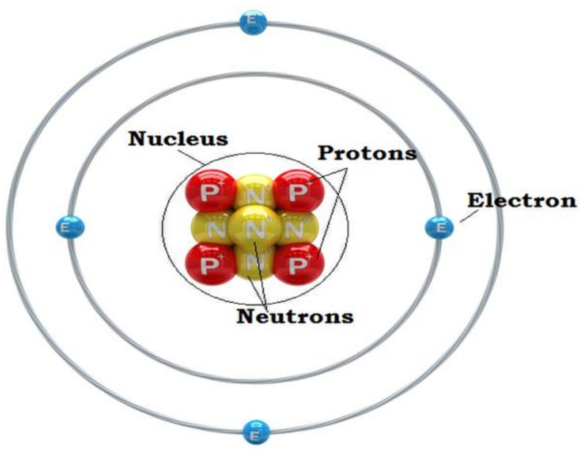
The word 'atom' comes from the Greek word 'atomos', meaning 'unable to be cut'. The original meaning of atom was the smallest, indivisible form of a chemical particle. Now that we know how to divide atoms into sub-atomic particles, the definition of an atom includes the concept that the particle must retain its chemical properties.

Structure of an atom:

An atom contains three sub-atomic particles. At the centre is a **nucleus**, which contains **protons**, positively charged particles, and **neutrons**, which are particles with no charge. Surrounding the nucleus are moving **electrons**, which are negatively charged particles. Electrons are revolving around the nucleus in different shells or orbits. Each shell has energy level associated with it. Closer the shell to the nucleus, more it is bound to the nucleus and possesses lower energy level.

The outermost shell is called as valence shell. And electrons in this shell are called as valence electron. The valence electron is having highest energy level. An electron which is not subjected to the force of attraction of nucleus and come out of the valence shell is called a free electron. Such a free electron is responsible to flow of current.

Protons and neutrons have about the same mass. Although smaller and of very little mass, electrons occupy the bulk of the space with their movement around the nucleus is shown in below figure.



Energy band theory: A material can be placed in to insulators, conductors and semiconductors depending up to energy band structure. The energy band diagram consists of three bands.

1. Valence band
2. Conduction band
3. Forbidden band

Valence band: The valence electrons possess highest energy level. The energy associated with valence electrons formed as a energy band which is called as Valence band.

Conduction band: The energy level formed due to merging of energy levels associated the free electrons is called conduction band.

Forbidden band: While jumping from valence band to conduction band the electrons have to cross an energy gap. The energy gap which is present separating the conduction band and valence band is called forbidden band.

Insulators: The valence band is fully filled and conduction band is almost empty and forbidden gap is more. The conductivity of insulators is almost zero. Examples of the insulators are Glass, Wood, Diamond, Mica etc. The energy band diagram for Insulators is shown in below figure.

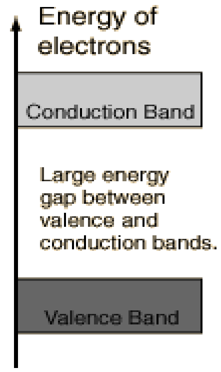


Fig: Energy band diagram of an insulator

Conductors: In this valence band and conduction band are fully filled and there is no forbidden band. As a result the electrons in the valence band can easily move in to the conduction band. The conductivity of conductors is more. Examples for conductors copper, aluminium etc. The energy band diagram for conductors is shown in below figure.

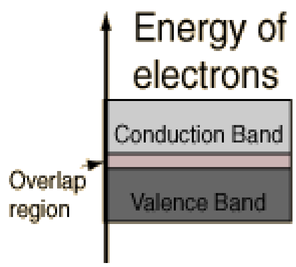


Fig: Energy band diagram for Conductor

Semiconductors: In this the valence band is fully filled and conduction band is almost empty and forbidden band is very small. Semiconductors are materials whose conductivity lies between conductors and insulators. The examples of semiconductors are Germanium, Silicon. The energy band diagram for semiconductors is shown in below figure.

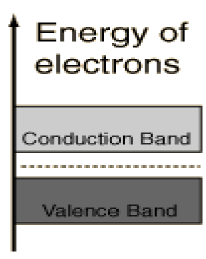


Fig: Energy band diagram for Semiconductors

Semiconductors are divided in to two types intrinsic semiconductors and extrinsic semiconductors. These materials have four valence electrons each and it is referred as tetravalent elements.

Intrinsic semiconductor: Pure semiconductors are known as intrinsic semiconductor.

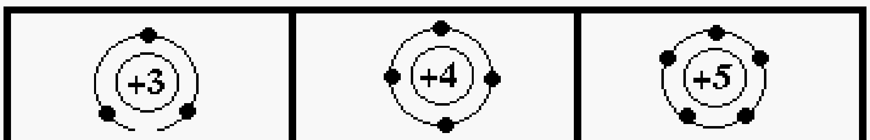
Ex: Ge, Si

Extrinsic semiconductor: when impurities are added to intrinsic semiconductor then it becomes extrinsic semiconductor. The conductivity of intrinsic semiconductors is very less. Therefore to improve the conductivity of semiconductors some impurities are added which is called as Extrinsic semiconductor materials.

Doping: The process of adding impurities to semi conductors to achieve desired characteristics, generally to increase its conductivity.

Depending upon type impurity added to intrinsic semiconductor, extrinsic semiconductors are of two types

1. N – Type semiconductor-Majority charge carriers are electrons and minority charge carriers are holes.
2. P – Type semiconductor- Majority charge carriers are holes and minority charge carriers are electrons.



Trivalent	Tetravalent	Pentavalent
5 B BORON	6 C CARBON	7 N NITROGEN
13 Al ALUMINUM	14 Si SILICON	15 P PHOSPHORUS
31 Ga GALLIUM	32 Ge GERMANIUM	33 As ABSENIC
49 In INDIUM	50 Sn TIN	51 Sb ANTIMONY

When trivalent impurities are added to the pure semiconductor, P type semiconductor is formed.

When pentavalent impurities are added to the pure semiconductor, N type material is formed.

List of band gaps: Table below is the band gap values for some selected materials.

Group	Material	Symbol	Band gap (eV) @ 302K
IV	Diamond	C	5.5
IV	Silicon	Si	1.11
IV	Germanium	Ge	0.67
III–V	Gallium nitride	GaN	3.4
III–V	Gallium phosphide	GaP	2.26
III–V	Gallium arsenide	GaAs	1.43
IV–V	Silicon nitride	Si_3N_4	5
IV–VI	Lead sulfide	PbS	0.37
IV–VI	Silicon dioxide	SiO_2	9

EXTRINSIC MATERIALS-*n*-and *p*-type:

The characteristics of semiconductor materials can be altered significantly by the addition of certain impurity atoms into their relatively pure semiconductor material .These impurities, although only added to perhaps 1part in 10million, can alter the band structure sufficiently to totally change the electrical properties of the material. A semiconductor material that has been subjected to the doping process is called an extrinsic material. There are two extrinsic materials of immeasurable importance to semiconductor device fabrication: *n*-type and *p*-type.

N-Type Material:

Both the *n*-and *p* type materials are formed by adding a predetermined number of impurity atoms in to a germanium or silicon base. The *n*-type is created by introducing those impurity elements that have *five* valence electrons (*pentavalent*), such as *antimony*, *arsenic*, and *phosphorus.* The effect of such impurity elements is indicated in

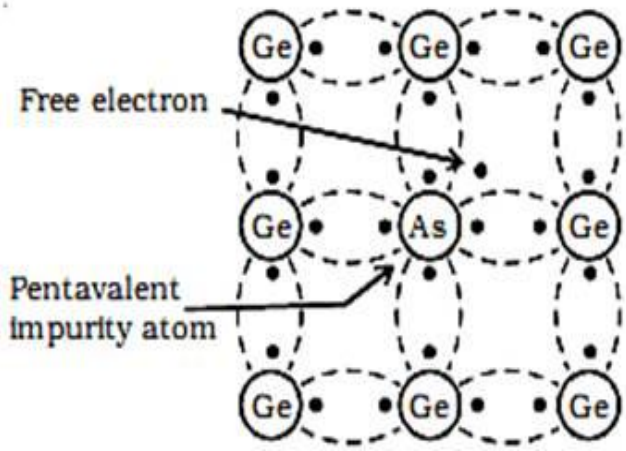
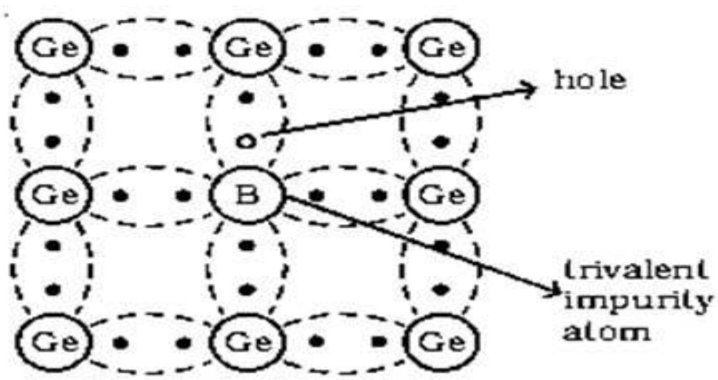


Fig above (using arsenic as the impurity in a germanium base). Note that the four covalent bonds are still present. There is, however, an additional fifth electron due to the impurity atom, which is *unassociated* with any particular covalent bond. This remaining electron, loosely bound to its parent (antimony) atom, is relatively free to move within the newly formed *n*-type material. Since the inserted impurity atom has donated a relatively-free electron to the structure: Diffused impurities with five valence electrons are called donor atoms***.***

P-Type Material: The p-type material is formed by doping a pure germanium or silicon crystal with impurity atoms having three valence electrons. The elements most frequently used for this purpose are boron, gallium, and indium. The effect of one of these elements, boron, on a base of silicon.

Note that there is now an insufficient number of electrons to complete the covalent bonds of the newly formed lattice. The resulting vacancy is called a *hole* and is represented by a small circle or positive sign due to the absence of a negative charge. Since the resulting vacancy will readily. *Accept* a— free electron: The diffuse impurities with three valence electrons are called acceptor atoms.



Majority and Minority Carriers: In the intrinsic state, the number of free electrons in Ge or Si is due only to those few electrons in the valence band that has acquired sufficient energy from thermal or light sources to break the covalent bond or to the few impurities that could not be removed. The vacancies left behind in the covalent bonding structure represent our very limited supply of holes. In an *n*-type material, the number of holes as not changed significantly from this intrinsic level. Then result, therefore, is that the number of electrons far outweighs the number of holes. In an n-type material the electron is called the majority carrier and the hole the minority carrier .For the *p*-type material the number of holes far outweighs the number of electrons ,as shown in Fig.1.13b. Therefore: In a p-type material the hole is the majority carrier and the electron is the minority carrier. When the fifth electron of a donor atom leaves the parent atom, the atom remaining acquires a positive charge: hence the positive sign in the donor-ion representation.

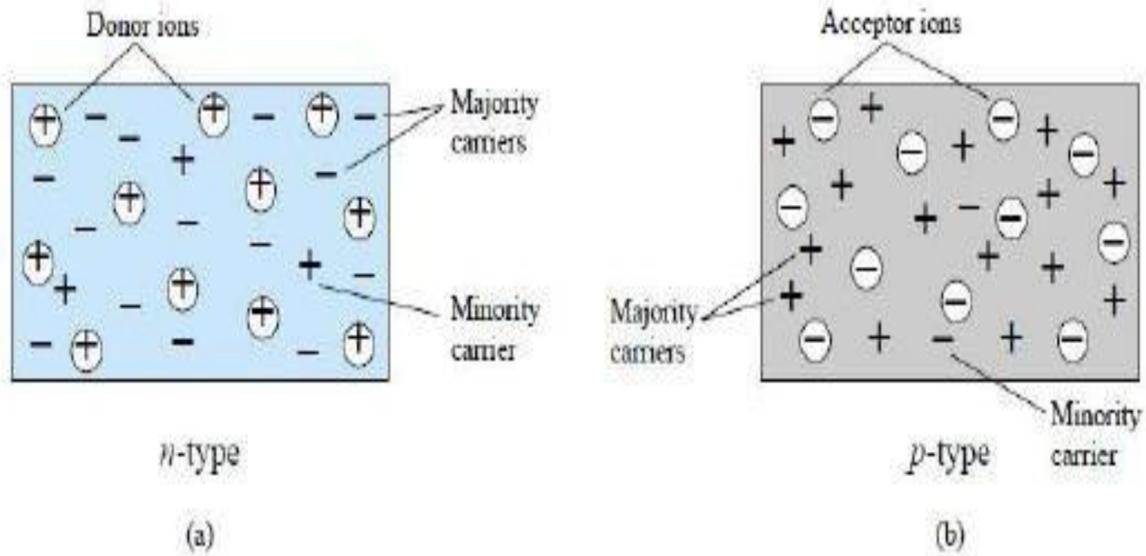


Figure 1.13 (a) n-type material; (b) p-type material.

Fermi Level in N & P type materials is shown in below Fig:

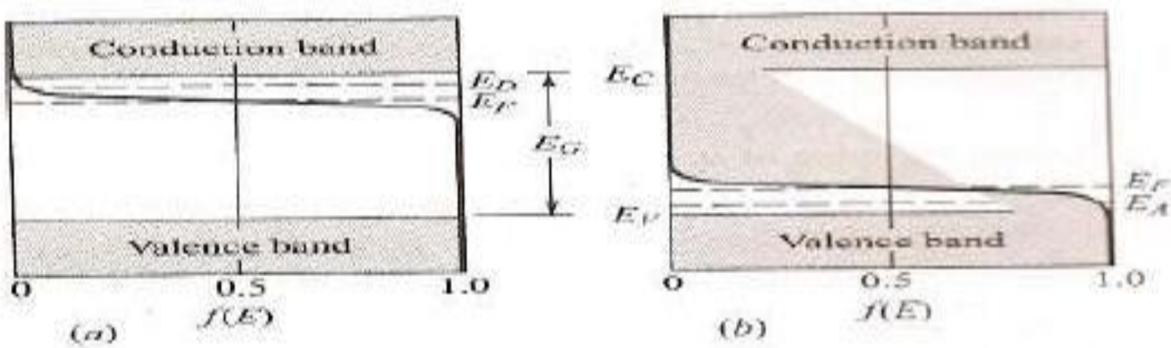


Fig. Positions of Fermi level in (a) n-type and (b) p-type semiconductors.

In N type material Fermi level is just below the conduction band. In P type material Fermi level is just above the valence band.