Unit Five

Basics of Electronics

- Electronics is a part of physics that study and design of system that uses the flow of electronics through semiconductors, resistors, and capacitors.
- Some of the electronics devices that we use everyday life activities: calculators, digital watches, mobile phones, televisions, and computers.
- Electronics also plays an important role in aerospace industry, automobile industries, medicine, including MRI, CT and X-rays.

Semiconductors

Conductors are materials which allow electricity to flow through them. Metals are good conductors of electricity. This is due to they have free electrons that allow the easy flow of electric current.

Some materials do not allow electricity to pass through them. These materials are known as insulators. Plastic, wood, glass and rubber are good electrical insulators.

Semiconductors:

@ are materials which have a conductivity between conductors and insulators;

@ can be pure elements, such as silicon or germanium, or compounds such as gallium arsenide or cadmium selenide.

@ act as insulators at absolute zero temperature (zero kelvin) and conductors at higher temperatures.

In a process called doping, small amounts of impurities are added to pure semiconductors causing large changes in the conductivity of the material.

Lattice structure of semiconductors

- Semiconductors, such as silicon (Si) are made up of individual atoms bonded together in a
- regular and periodic structure to form an arrangement whereby each atom is surrounded by eight electrons.
- The electrons in the outer most shell of each atom in a semiconductor are part of a covalent bond.
- Hole in a semiconductor means the absence of electron in an atom
- Hole behaves like a positive charge.
- Holes and electrons are two types of charge carriers responsible for current in semiconductor materials.

Types of Semiconductors

Semiconductors are divided into two categories: Intrinsic semiconductor and extrinsic semiconductor.

Intrinsic semiconductors are:

@ composed of only one kind of material; silicon and germanium are two examples;

@ semiconductor materials which has not had impurities added to them in order to change the carrier concentrations;

@ also called undoped semiconductors.

Extrinsic semiconductors:

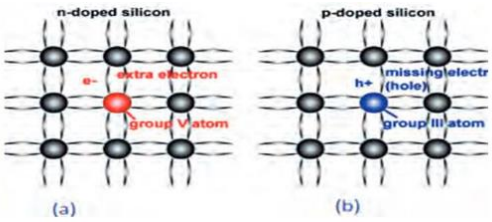
- have impurities added to their lattice structure.
- The addition of small amounts of selected impurities to a pure semiconductor considerably improves its conductivity.
- The process of adding impurity to a pure semiconductor crystal to improve its conductivity is called doping. Sometimes the impurity is called a dopant.
- The extrinsic semiconductors are further classified as N-type and P-type semiconductors,based on the type of atomic impurity added to the semiconductors.

N-type semiconductor:

- an extra electron is created by adding a pentavalent atom in the pure structure; The electron carries a negative charge, so the material is called an N-type semiconductor and conduction is due to a large number of electrons.
- Since N-type dopants donate their free electrons to the semiconductor, they are known as donor atoms.
- In this type of semiconductor, electrons are majority and holes are minority.

P-type semiconductor:

- when Group III element such as aluminum, boron, gallium, or indium is added to a pure semiconductor.
- The absence of an electron creates a hole. Boron needs one more electron to complete its covalent bond. So, Boron is an acceptor of electrons.
- In this type of semiconductor, the holes are majority and the electrons are minority.



Diodes and their Functions

• A diode is a two-terminal electronic component that only conducts current in one direction and blocks current in the reverse direction.

• Diodes are made from a large variety of materials including silicon, germanium and gallium arsenide, etc.

P-N junction diode

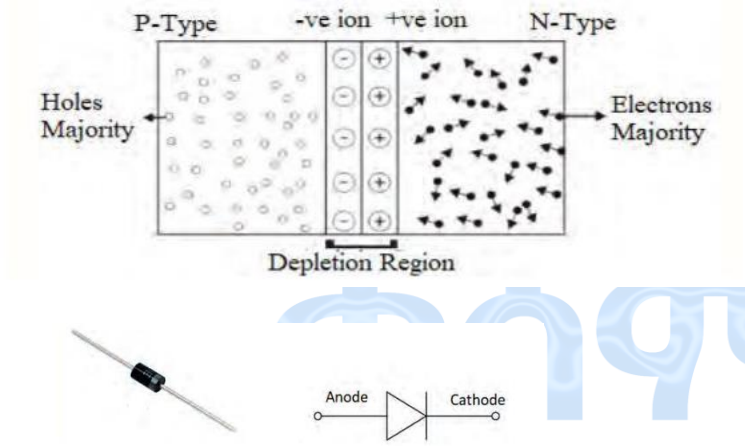
• Semiconductor diodes are the most common type of diode.

• When an N-type semiconductor is joined with the P-type semiconductor, a P-N junction diode is formed

- When a P-N junction is formed, some of the electrons in the N-region diffuse across the junction and combine with holes to form negative ions on the P-side. In so doing they leave behind positive ions in the N-region.
- The combination of electrons and holes near the junction creates a narrow region in the vicinity of the junction called the depletion region, where there are very few mobile electrons and holes.

• The electric field created by the ions in the depletion region prevents any further diffusion across the junction by establishing a barrier potential across the junction.

• The barrier potential is the potential difference required to move the electrons through the electric field. It depends on the type of semiconductor material, which is approximately 0.7V for silicon and 0.3V for germanium. •.



Biasing of P-N junction diode

• Applying a suitable DC voltage to a diode is known as biasing.

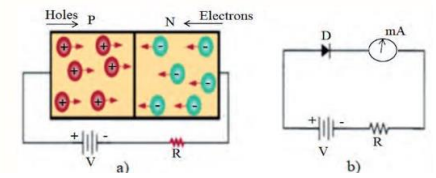
• It can be done in two ways: forward and reverse biasing.

• Diodes in both forward and reverse bias are useful for computer chips, solar cells, and other electronic devices.

• Zero biasing condition is when no external voltage is applied to the P-N junction diode.

Forward biased

• the positive terminal of the battery is connected to the P-type semiconductor and the negative terminal to the N-type semiconductor

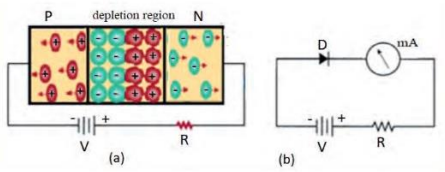


When a forward biasing voltage is applied to a junction diode, the depletion region becomes very thin and narrow. This represents a low resistance path through the junction, allowing high currents to flow.

Reverse biased

• the negative terminal of the battery is connected to the P-type semiconductor and the positive terminal to the N-type semiconductor.

- This increases the width of the depletion region, which blocks the majority charge carrier current.
- This condition represents a high resistance path through the P-N junction and almost zero current flows through the junction diode.



Current-voltage (I-V) characteristics of the semiconductor diode

• From the I-V curve we can see that the current is very low if the forward voltage is lower than the cut-in voltage.

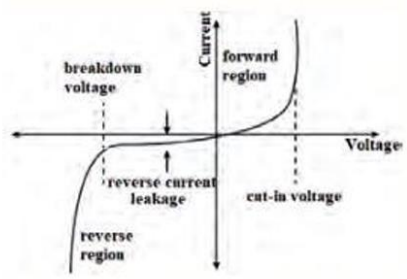
• The cut-in voltage is the voltage at which the forward diode current starts increasing rapidly.

• Once the forward bias exceeds the cut-in voltage, the current will be dramatically increased.

• Since the diode can conduct very high current above the cut-in voltage, resistors are used in series with the diode to limit its current flow.

• In the reverse bias, a very small current called a reverse bias current or leakage current flows through the junction due to the minority charge carriers.

• If the reverse bias voltage is too high, a sharp change in the reverse bias characteristics occurs. At a certain voltage, called the breakdown voltage, the current in the reverse direction increases rapidly.



Rectification

is the process in which an AC voltage supply is converted into a unidirectional (DC) voltage;

@ The electric circuit used for the conversion is called a rectifier.

@ There are two basic types of rectifier circuit used with power supplies: half-wave rectifiers and full-wave rectifiers.

Half wave rectification

• Only allows one half-cycle of an AC voltage waveform to pass by blocking the other half-cycle. Therefore, the current in the circuit flows in only one direction.

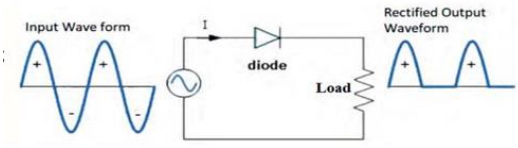
• A half-wave rectifier consists of a diode and a load resistor connected in series to the cathode end of the diode.

In a half-wave rectifier circuit during the positive half-cycle of the input, the diode is forward biased. During the negative half-cycle, the diode is reverse biased and does not conduct.

• Thus, the DC voltage across the load is sinusoidal for the first half-cycle only and a pure AC input signal is converted into a DC pulsating output signal.

• To have a smooth DC, you can connect capacitor in the rectifier.

• The fact that the current flows only during half of each cycle in a half-wave rectifier is a disadvantage.

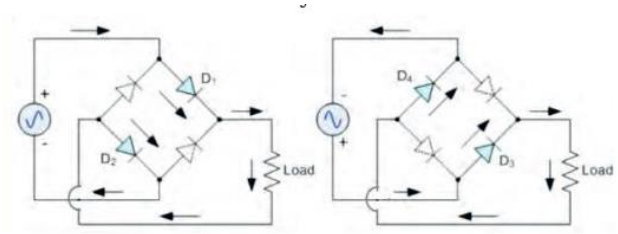


Full-wave Rectification

• We can use either two or four diodes arranged in a particular way.

• During the positive half-cycle of the supply, diodes D1 and D2 are forward bias. However, diodes D3 and D4 are reverse biased;

• During the negative half-cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch off as they are now reverse biased.

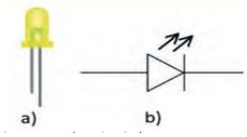


Practical uses of diodes

a) Light emitting diodes (LED)

• is a P-N junction diode which can emit light when an electrical current flows through it.

• The frequency(color) of the light emitted is determined by the type of semiconductor material used in construction of the diode.



b) Photodiode

• is a semiconductor device with a P-N junction that converts photons (or light) into electrical current.

• Photons absorbed in the depletion region will create electron-hole pairs which will move to opposite ends of the diode due to the electric field. These moving charge carriers form the current (photocurrent) in the photodiode.

• A light sensitive diode which is used to measure the intensity of light



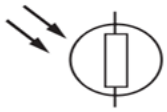
c) LDR (Light dependent resistor)

• In the dark region, it has high resistance, while in the light region it has less resistance.

• Shining light on it appears to 'unjam' it, because its resistance falls

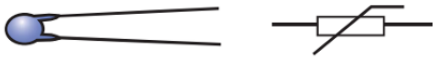
• The brighter the light, the better it conducts





d) Thermistor (Heat dependent resistor)

• It has high resistance in cold, while its resistance drops as it becomes warmer



e) Photovoltaic cell

• a cell that converts solar energy into electrical energy

• when light strikes the junction between N and P types, electrons flow through the structure of the cell.





f) Logic gates

• Diodes and resistors can be combined with other components to construct AND and OR

logic gates. This is referred to as diode resistor logic.

d) Over-voltage protection

• Excess voltage can damage our electronic devices. Sensitive electronic devices need to be

protected from fluctuations in voltage; the diode is perfect for this.