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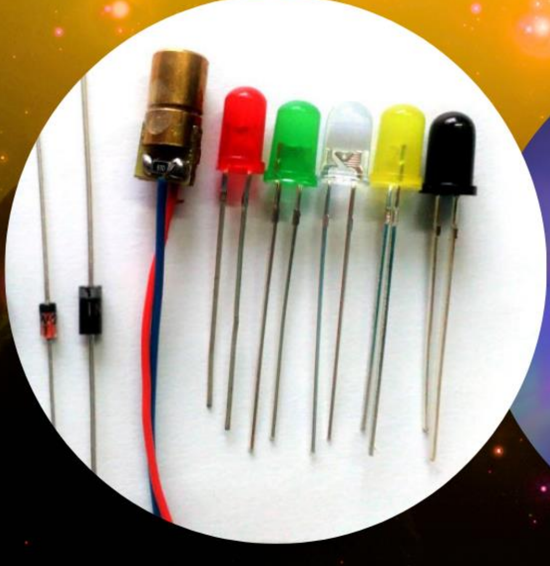
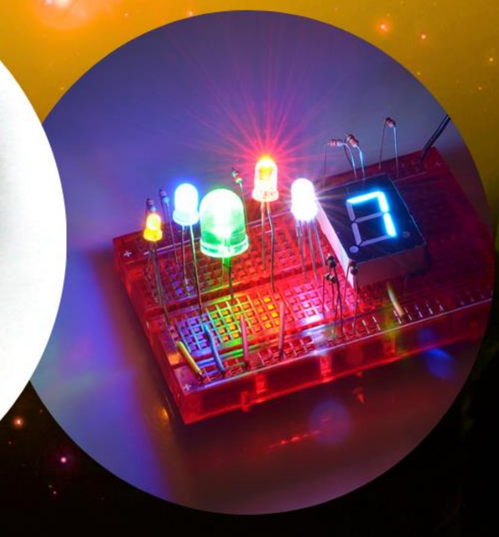
DIODE CHARACTERISTIC AND APPLICATIONS





Ts TAN POH CHUAR

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This eBook is for the purpose basic reference at easy understand and category the types of diode. It is not intended for sale nor is it profitable.

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SYNOPSIS

The eBook is to provide a basic quick reference on the diode characteristic, types of diode and their application. This eBook focuses on material of diode, diode structure and working principle, types of diode and diode application in electronic circuits. It can be used as a supplementary material for Electronic Device and Power Electronic course offered at diploma level in Polytechnics.

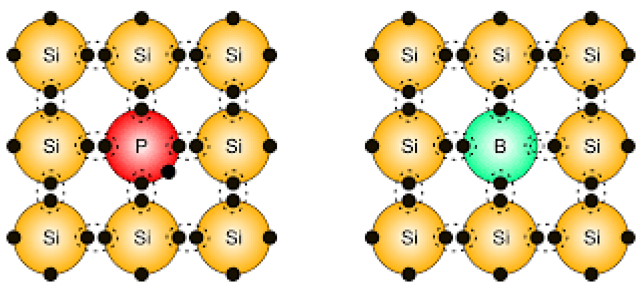
Contents

Chapter 1

Introduction Diode

Upon completion this chapter, you should be able to:

- Explain the basic structure of material and how it is formed with atoms.
- Define doping and name the two types of semiconductor material formed with doping process.
- Name the current carriers in N and P-type material.
- Structure of diode



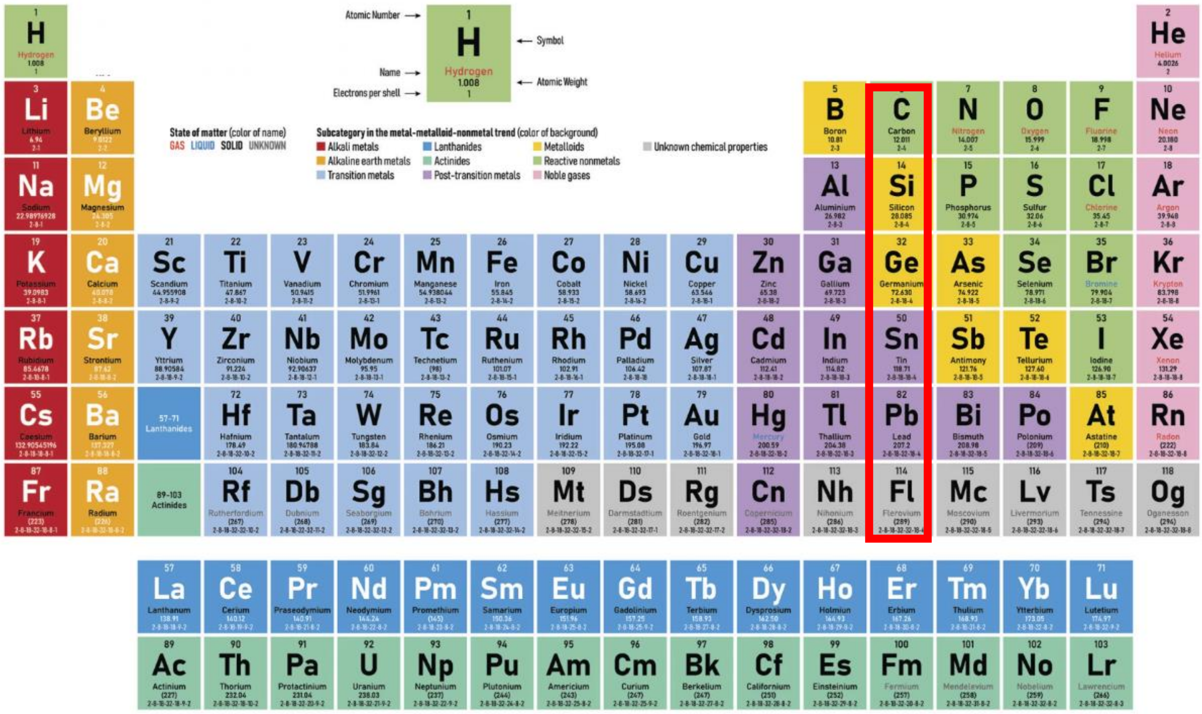
n-type p-type

1.0 Introduction

A **diode** is defined as a two terminal semiconductor component that essentially acts as a one-way switch which allows current to flow easily in one direction but severely restricts current from flowing in the opposite direction. It does not behave linearly with respect to the applied voltage and cannot be described simply by using Ohm's law. In other words, diodes are basic semiconductor devices made from combination semiconductor material which has a P-type and a N-type which are basic unidirectional semiconductor device that will only allow current to flow through in forward bias.

1.1 Basics Semiconductor

Table 1: Periodic Table



When refer the periodic table**, intrinsic (**pure) semiconductors element has four electrons in its outer or valence orbit such as carbon(C), silicon (Si) and germanium (Ge). They have electrical properties between conductor and insulator that essentially can be conditioned to act as good conductors, or good insulators, or anything in between. This means that semiconductors are presented conductors or insulators because semiconductors have very few free electrons are still able to flow but only under special conditions. Silicon (Si) is the best and most widely used semiconductor

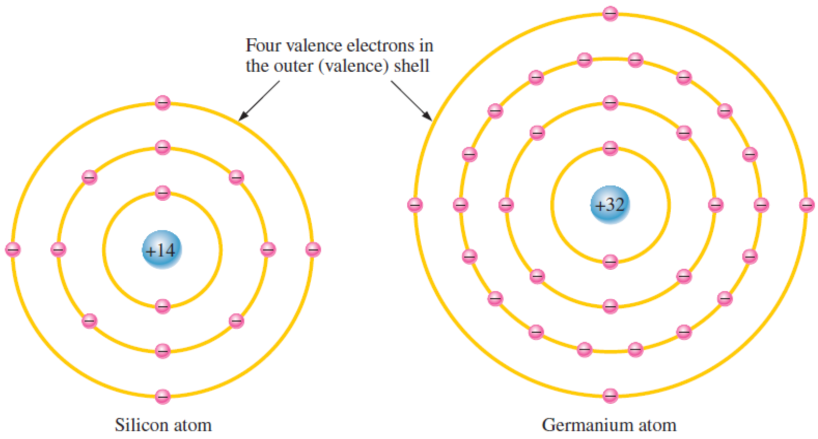


Figure 1.1: Structure atom semiconductor

1.2 Intrinsic Semiconductor

Semiconductor atom has four valence electrons in its outermost shell which it shares with its neighbouring silicon atoms to form full orbitals of eight electrons by covalent bond. This way an atom can have a stable structure with eight valence band electrons.

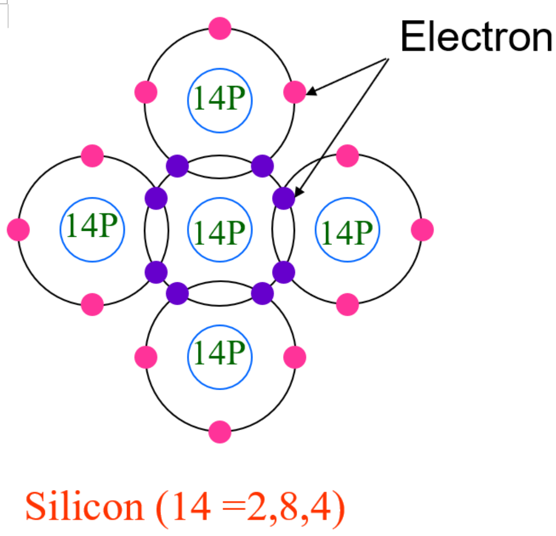


Figure 1.2: Structure material

In generally, a simply connecting a semiconductor material to an electric source is not enough to extract an electric current from it because it in stable structure and no free electron.

1.3 Doping process

The ability of semiconductors to conduct electricity can be improved by adding certain impurity element such as pentavalent elements (donor) or (trivalent elements) acceptor atoms to the material structure thereby, to produce more free electrons than holes or vice versa in increase its electrical conductivity. The process of adding donor or acceptor atoms to semiconductor atoms is called **Doping process** and the produced material is called extrinsic (impure).

Doping process can be done in two ways:

a. Increasing the number of electrons by mixing pentavalent elements (donor) such as phosphorous, arsenic, antimony to produces **N-type** material.

b. Increasing the number of holes by mixing trivalent elements (acceptor) such as aluminum, boron, gallium to produces **P-type** material.

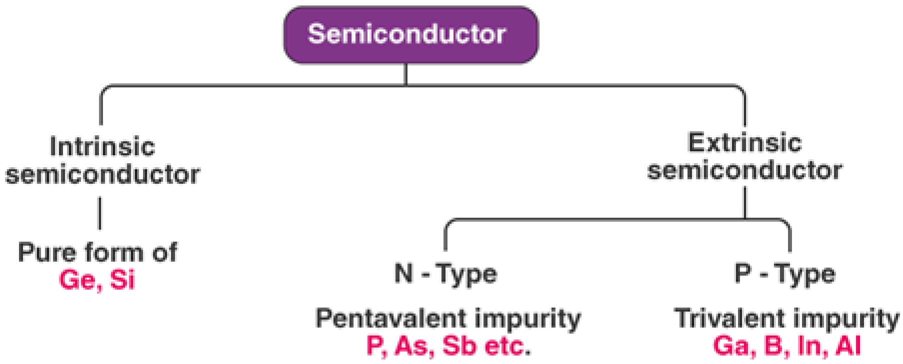


Figure 1.3: semiconductor organization chart

a) N-type Semiconductor

In order to improve the conductivity electricity, an intrinsic semiconductor doped with an impurity element (pentavalent) such as Arsenic (As), Antimony (Sb) or Phosphorus(P) into the material structure making it become extrinsic semiconductor called N-type material. These elements have five outermost electrons (valence electron) in their outer orbital to bond with its neighbouring silicon atoms and get one free electron to become mobile when an electrical voltage is applied. The impurity element (pentavalent) donates one electron is generally known as donors.

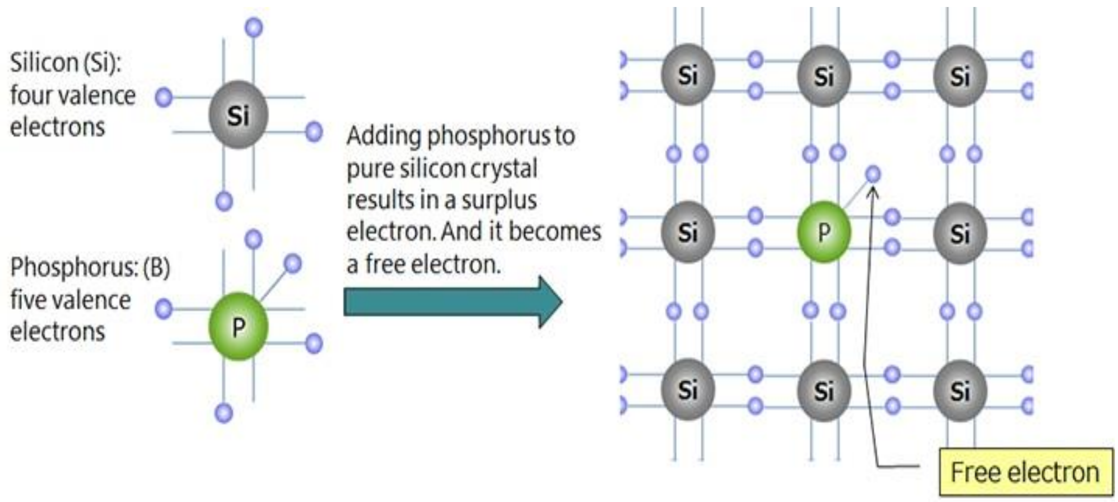
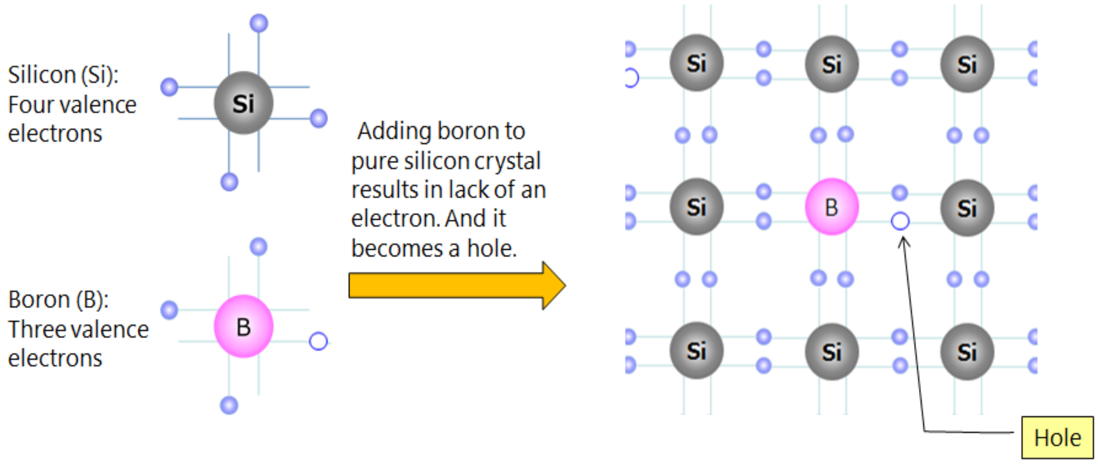


Figure 1.4: Structure N-type

The resulting extrinsic semiconductor has an excess of current-carrying electrons or ion negative charge and is therefore referred the N-type material with the electrons is majority carriers while holes is minority carriers. Antimony (symbol Sb) as well as Phosphorus (symbol P), are frequently used as a pentavalent additive to silicon.

When stimulated by an external power source, the electrons from the silicon atoms by this stimulation are quickly replaced by the free electrons available from the donor. But this migration still leaves an extra electron floating around the doped material making it negatively charged.

b) P-Type Semiconductor



c) Figure 1.5: Structure P-type

In other way, an intrinsic semiconductor doped with an impurity element (trivalent) such as such as Boron (B), gallium (Ga) or Indium (In) which have three (3) valence electrons that there are insufficient number of electrons to complete covalent bonds resulting a hole.

This hole is ready to accept a free electron. Therefore, the semiconductor material an abundance of positively charged carriers known as holes. As there is a hole, a neighbouring electron is attracted to it and will try to move into the hole to fill it. However, the electron filling the hole leaves another hole behind it as it moves and so forth giving the appearance that the holes are moving as a positive charge in material structure. This movement of holes results in a shortage of electrons in the silicon turning the entire doped material into a positive pole. This causes conduction to consist mainly of positive charge carriers resulting in a P-type material with the positive holes are majority carriers while the free electrons are minority carriers. The trivalent elements are generally known as acceptors as they are continually accepting free electrons to become stable with to form full orbitals of eight electrons by covalent bond. Boron (B) is commonly used as a trivalent element

1.4 Majority Carrier and Minority Carrier

- In an n-type material - electron is called majority carrier and hole the minority carrier
- In a p-type material – hole is majority carrier and electron is the minority carrier

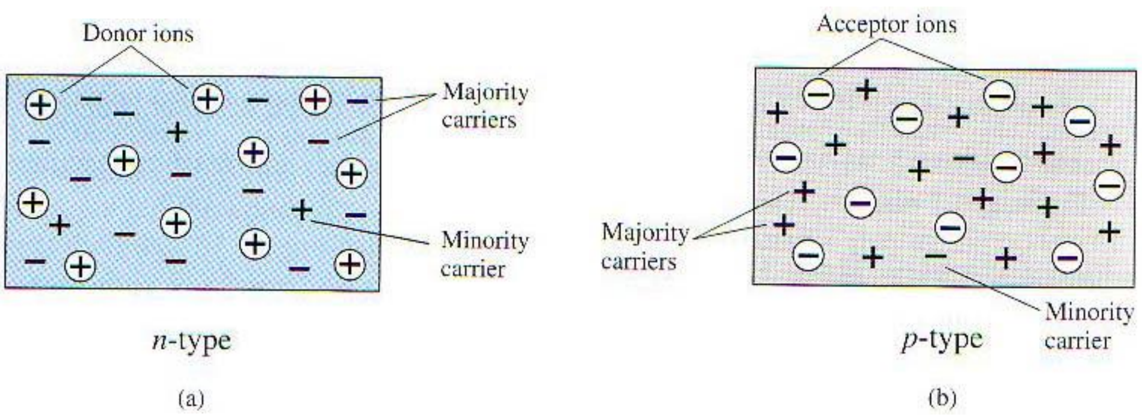


Figure 1.6: Structure material a). N-type b). P-type

1.5 PN Junction

To conduct electricity, P-type and N-type semiconductor material be combined in various pattern to perform the specific function. The contact surface of the combination of a P-type and a N-type semiconductor is called PN junction. In basic structure of the combination, electron that diffuses across the junction and combines with a hole, a positive charge is left in the N-region and a negative charge is created in the P-region, forming a barrier potential as known depletion region. This action continues until the voltage of the barrier repels further diffusion. The blue arrows between the positive and negative charges in the depletion region represent the electric field.

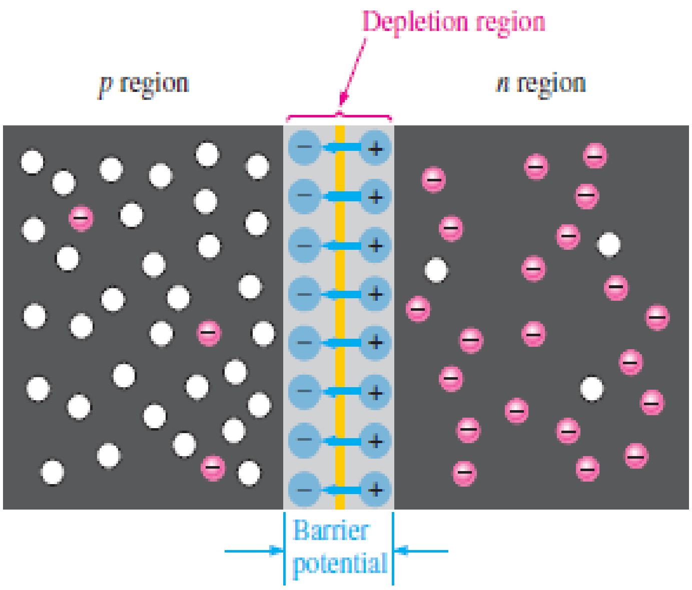


Figure 1.7: combination N-type and P-type

1.6 Construction of Diode

The two semiconductor basics materials, the P-type and the N-type materials is combined to form a PN Junction which is used to produce diodes. That's means that the diode consists of a P-region and N-region separated by a depletion region where charge is stored. The effect is achieved without any external voltage being applied to the actual PN junction resulting in the junction being in a state of equilibrium. However, when the electrical connections at the ends of both the N-type and the P-type materials and then connect them to a power source, an additional energy source now exists to overcome the potential barrier. The effect of appearing of power source results in the free electrons being able to cross or suppress from cross the depletion region from one side to the other. The behavior of the PN junction depends the polarity connection of power source. This will be describing in chapter 2 more clearly.

Normally, the diode is one of the simplest semiconductor devices which has the electrical characteristic of passing current through itself in one direction only. It conducts current in one direction and offers high (ideally infinite) resistance in other direction. The P- region is called anode and N-type region is called cathode. The conductivity characteristic of a diode does not behave linearly with respect to the applied voltage as like a resistor and cannot described its operation by simply using an equation such as Ohm's law.

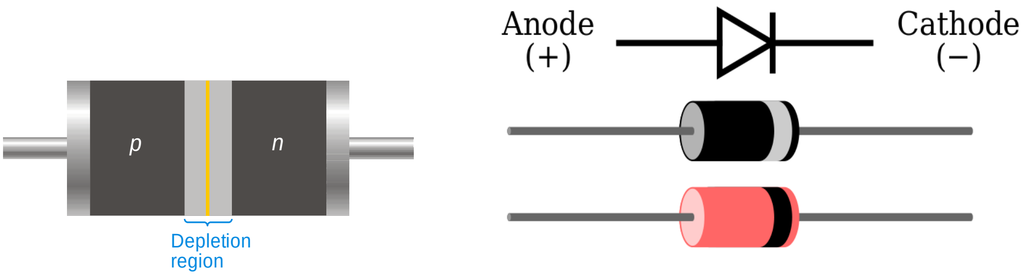


Figure 1.8: Structure Diode and symbol

Activity 1a

1. The holes are positive charged while the electrons ________ charged.
   - a. Neutral
   - b. Negative
   - c. Positive
   - d. All of above

2. A semiconductor may be doped with donor impurities such as Antimony (N-type doping), so that it contains mobile charges which are primarily __________ .
   - a. Proton
   - b. Neutron
   - c. Electron
   - d. Felton

3. semiconductor may be doped with ______ impurities such as Boron (P-type doping), so that it contains mobile charges which are mainly holes.
   - a. Donor
   - b. Acceptor
   - c. Rejector
   - d. Borrower

4. When a junction diode is ________ the thickness of the depletion region reduces and the diode acts like a short circuit allowing full circuit current to flow.
   - a. no bias
   - b. reverse bias
   - c. forward bias
   - d. all in the above

5. The process of adding an impurity to an intrinsic semiconductor is called ______________.
   - a. Ionization
   - b. Recombination
   - c. Atomic modification
   - d. Doping

Answer:
1.b, 2. c, 3. b, 4. c, 5. d

Chapter 2

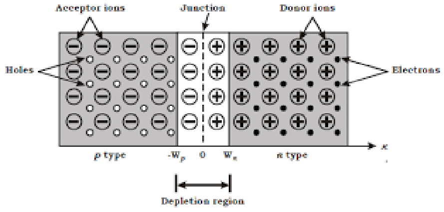
Diode Characteristic

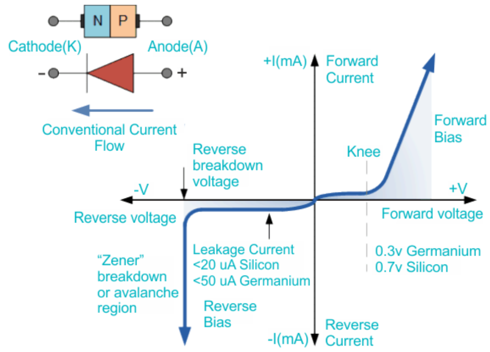
and

Working Principle

Upon completion this chapter, you should be able to:

- Explain Real vs. Ideal diode curve
- Explain diode characteristic
- working principle of diode





2.0 Introduction

A PN junction diode consists of a P-type semiconductor combined with an N-type semiconductor. As study at chapter1 that P-type is semiconductor material doped with impurities element (trivalent) to create positive charge carriers (holes) and N-type is a semiconductor material doped with impurities element (pentavalent) to create negative charged carriers (electron). At PN junction, a depletion region is created when negative charge carriers from the N-type region diffuse into the P-type region, and vice versa.

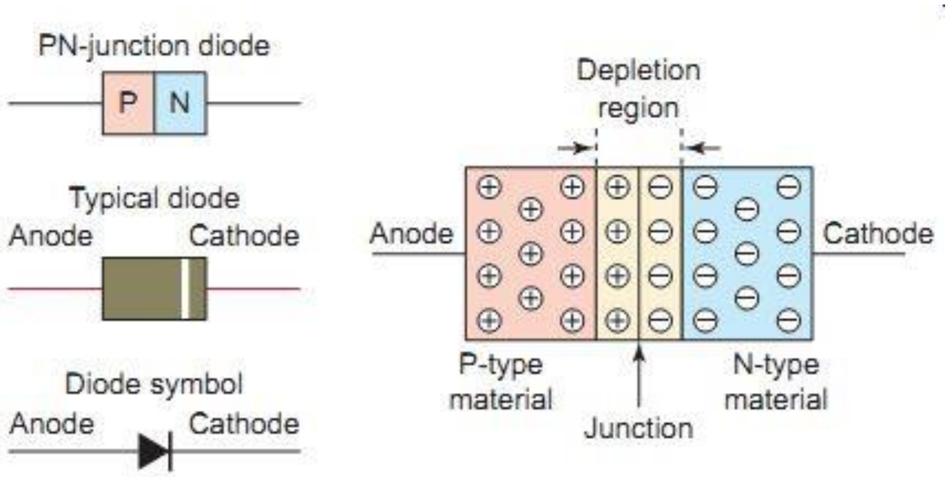


Figure 2.1: Structure Diode and symbol

2.1 Ideal vs. Real diode model

i. Ideal diode

Ideal diodes are diodes as desired that are used to allows the direction of current flow in one direction only called the forward direction whereas the current flowing in the reverse direction is blocked. The desired means that the ideal diodes look like an open circuit in the reverse biased condition, and closed circuit in the forward biased. For resistivity, no resistance to current in forward bias and infinite resistance in reverse bias.

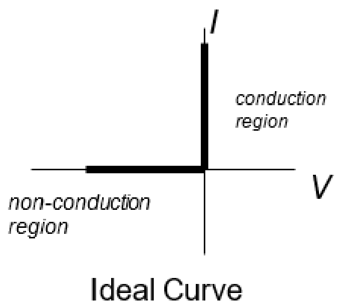


Figure 2.2: ideal diode curve

ii. Real diode

In reality, diode has resistance to current flow in forward bias. It requires a certain voltage to be reached before the depletion region is eliminated and full current flow is allowed though the diode. Likewise, there is a small reverse (leakage) current induced by the flow of minority carriers in reverse bias. At reached a certain voltage (break down voltage) the reverse current will increase significantly. This is called the Avalanche current.

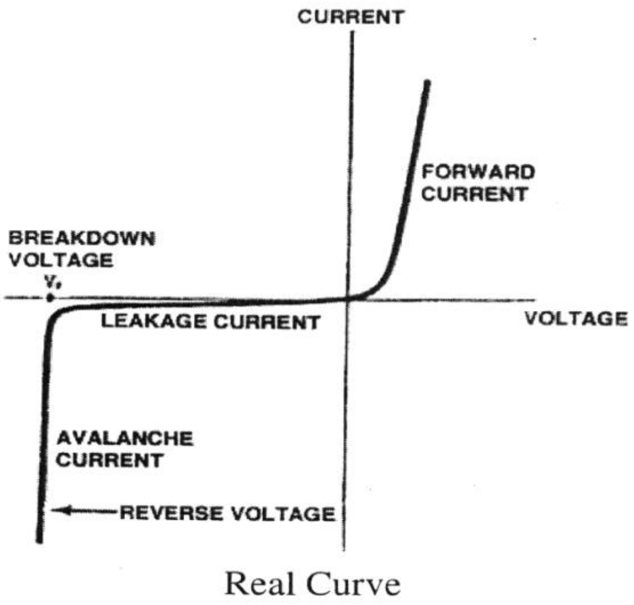


Figure 2.3: Real diode curve

2.2 Construction of Diode

A diode has two material combined as one side is of P-type and the other is of N-type semiconductor. As we know the semiconductor is doped with trivalent impurities in a intrinsic semiconductor (Silicon and germanium) has a majority number of holes are present and it is a positive charge. Therefore, this type of the semiconductor is known as the p-type. For semiconductor doped with pentavalent impurities in semiconductors, due to excess electrons there is a negative charge. Therefore, this type of the semiconductor is known as the N-type.

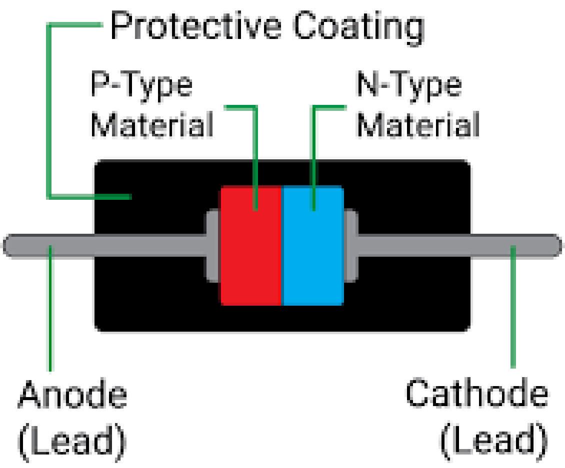


Figure 2.4: Construction of Diode

Diode has 2 (TWO) terminals called anode (positive terminal) and cathode (negative terminal). At P-type called anode and the terminal connect at N-type is called cathode. The current consistently move from anode to cathode in common connection as properly forward current flow.

2.3 Diode Characteristics

The characteristics of the diode can be explained in three condition as below: -

i. No Bias
ii. Forward-Bias
iii. Reverse-Bias

i. No Bias

No bias condition is no power source applied to diode. In this condition, every electron that diffuses across the PN-junction and combines with a hole, a positive charge is left in the N region and a negative charge is created in the P region, this phenomenon forming a barrier potential called depletion region. This phenomenon continues until the voltage of the barrier repels further diffusion in preventing further migration of holes and electrons. In the absence of an applied bias voltage, the net flow of charge in any one direction for semiconductor diode is zero. Figure below shown the electric field in arrows between the positive and negative charges in the depletion region. At normal temperature, a silicon diode has the barrier potential is 0.7V.

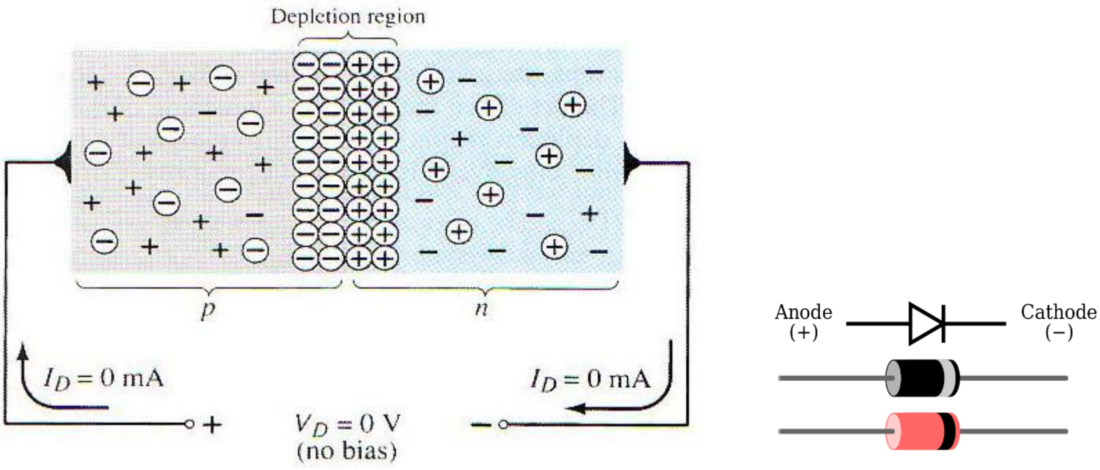


Figure 2.5: no bias diode

ii. Forward-Bias

In forward bias, anode diode is connected to the positive terminal of the source and the negative terminal of the source to the cathode diode.

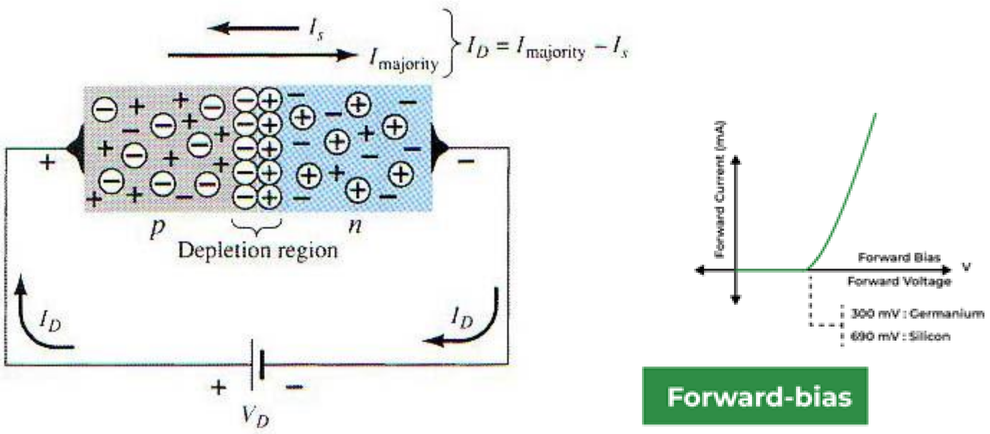


Figure 2.6: Forward bias diode

Actually, forward bias is a condition that allows current through PN junction. This means that diode has low resistivity and high in conductivity. However, the applied voltage (Vbias) must be greater than 'barrier potential' to overcome V_{diode} (forward voltage) in order for the diode to conduct. The forward-bias potential will pressure the electrons in N-type and hole in P-type to recombine with ions near the boundary and the flow of the current during the PN Junction of the diode begins increasing very quickly. The diode behaves like a 'ON' switch in this mode. As more electrons flow into the depletion region reducing the number of positive ions and similarly more holes move in reducing the positive ions. This reduces the width of depletion region.

iii. Reverse-Bias

In reverse biasing, the cathode diode is connected to the positive terminal of source and the anode diode is connected to the negative terminal of the source. In this condition, the applied voltage in reverse polarity with diode.

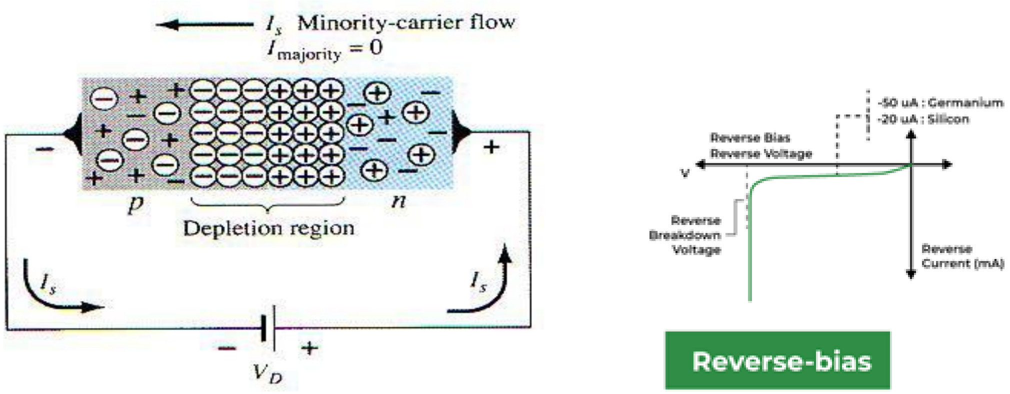


Figure 2.7: Reverse bias bias

The diode behaves like a 'OFF' switch in this mode. If continue to increase reverse voltage V_D breakdown voltage of the diode is reached and diode conducts heavily causing its destruction. This cause the depletion region becomes more widen

2.4 Working Principle of Diode

As study at previous topic, A diode may be act as like a switch either open switch in reverse bias or closed switch in forward bias depend the connection polarities of applied voltage source to diode. The working principle of diode actually concerns the flow of negative charges (electrons) and positive charges (holes) in semiconductor material.

i. When the anode (P-type terminal) of the diode is connected with a positive terminal and cathode ((N-type terminal) is connected with the negative terminal of the source, this type of connection is called a Forward Bias condition. a diode requires a minimum threshold voltage (knee voltage) to surmount the depletion region.

ii. When the anode (P-type terminal) of the diode is connected with a negative terminal and the cathode (N-type terminal) is connected with the positive terminal of a source, this type of connection is called a Reverse Bias condition.

iii. When the reverse voltage across diode reaches breakdown voltage these electrons will get sufficient energy to collide and dislodge other electrons. Diode breakdown is caused by thermally generated electrons in the depletion region. Breakdown Voltage is the characteristic which the minimum voltage level at which an insulator starts behaving as a conductor and conducts electricity. It is also known as the Dielectric Strength of the material. If the reverse voltage is increasing, the number of high energy electrons increases in geometric progression leading to an avalanche effect causing heavy current and ultimately destruction of diode.

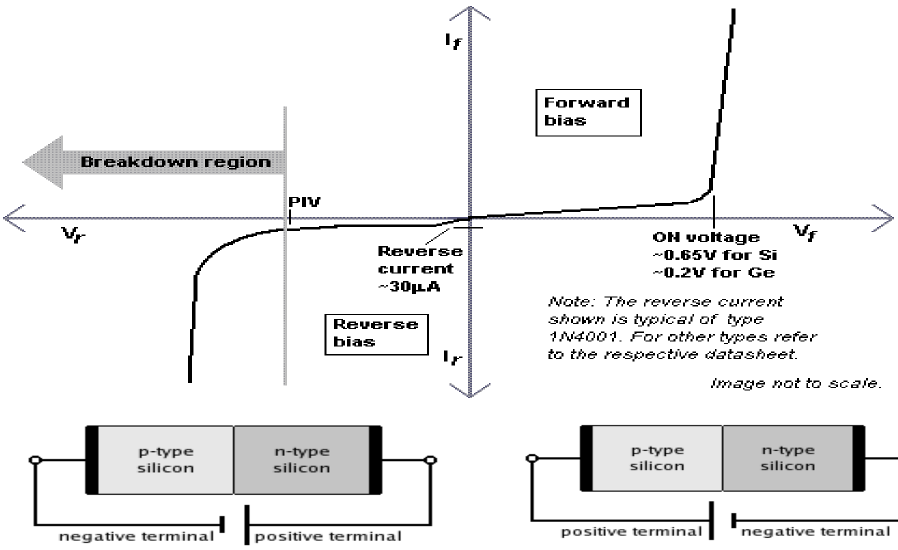


Figure 2.8: I-V characteristic of diode

In summary, a diode act in

- Forward bias as closed switch where allow current to flow and the effect is the depletion region become thinner.
- reverse bias as open switch where suppress current to flow and the effect is the depletion region become widen.

Activity 2a

1. Diodes have _____ terminals.
   a. 2
   b. 3
   c. 4
   d. 5

2. The positive terminal of a diode is known as the ___________.
   a. cathode
   b. anode
   c. base
   d. gate

3. what is an ideal diode?
   a. A two terminal polarity sensitive device that has zero resistance when in forward or when reverse biased.
   b. A two terminal polarity sensitive device that has few resistances when in forward and when reverse biased.
   c. A two terminal polarity sensitive device that has zero resistance when in forward biased and infinite resistance when reverse biased.
   d. A two terminal polarity sensitive device that has infinite resistance when in forward biased and zero resistance when reverse biased.

4. A reverse-biased diode will act as an _________.
   a. open switch
   b. closed switch
   c. short switch
   d. none in the above

5. P-N junction diode allows the current to flow in the ___________
   a. reverse direction
   b. forward direction
   c. both direction
   d. none of the option

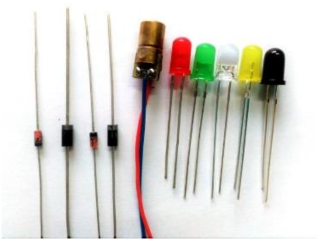
Answer:
1.a, 2.b, 3.a, 4.b, 5.c

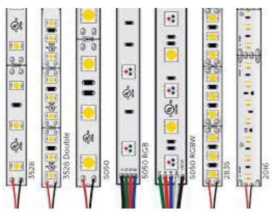
Chapter 3

Types of Diode

Upon completion this chapter, you should be able to:

- Identify the types of diodes
- Explain the function of diodes
- Identify the symbol of diodes





3.0 Introduction

There are different types of diode that are used widely in our daily life and modern electronic products. Let to learn some of common types of diode be used in daily life in structure design, symbol and its specific function.

3.1 Types of diode

1) Zener Diode

Zener diode is a special heavily-doped semiconductors diode that allow current to flow in the opposite direction (reverse bias) when reachs breakdown voltage, unlike the regular diodes. It is specially designed to breakdown voltage in a non-destructive way. Due to the heavily-doped semiconductor material, it allows the depletion region to be very thin to increase the intensity of the electric field.

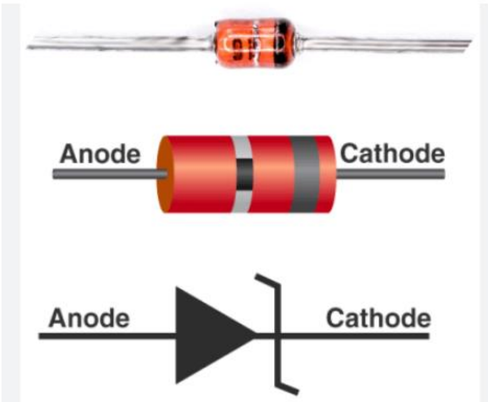


Figure 3.1: structure Zener diode and symbol

Construction:

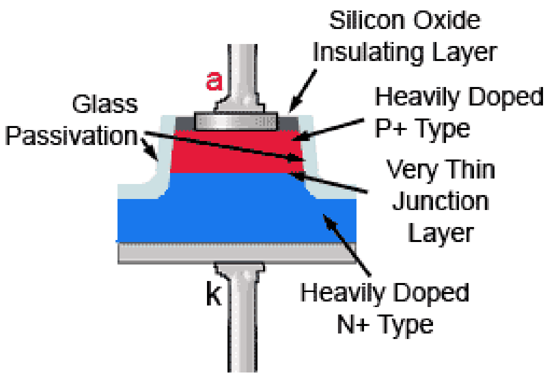


Figure 3.2: construction of Zener diode

2) Rectifier Diode

Rectifier Diode is two-lead semiconductor that as like to other diodes that it only allows current to flow in one direction. They are made out to convert alternating current (AC) to direct current (DC). It process is called rectification.

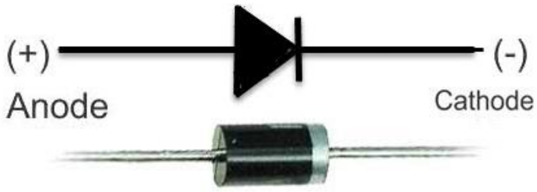


Figure 3.3: structure rectifier diode and symbol

Construction:

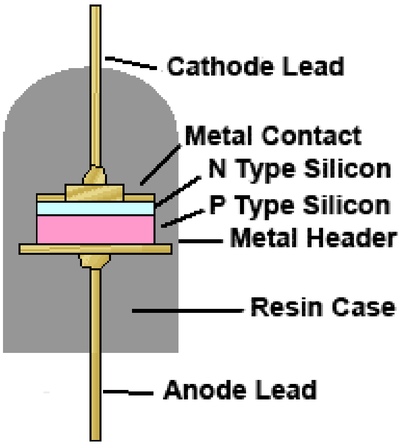


Figure 3.4: construction of diode

Popular Rectifier Diodes:

Table 4: rectifier diodes

Diode	Maximum Current	Maximum Reverse Current
1N4001	1A	50V
1N4002	1A	100V
1N4004	1A	400V
1N4007	1A	1000V
1N5401	3A	100V
1N5408	3A	1000v

3) Schottky Diode

Schottky diode is a semi-metal semiconductor diode formed by the junction of metal with a semiconductor. It is also known as a hot carrier or Schottky barrier diode. It is named after German physicist named Walter H. Schottky. It has a low forward voltage drop. It is used in wave shaping, high-speed switching, RF applications, and in TTL logic gates.

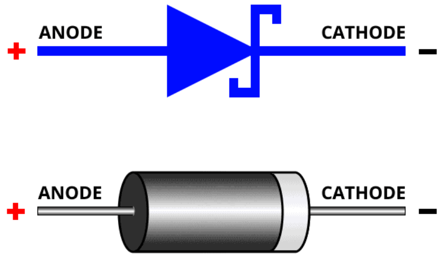


Figure 3.5: structure Schottky diode and symbol

Construction:

Schottky diode is constructed by forming a junction between a metal and a semiconductor called a metal-semiconductor junction or MS junction. It is a unilateral junction. The metals such as gold, platinum, aluminum, and certain silicides are used with n-type silicon semiconductors.

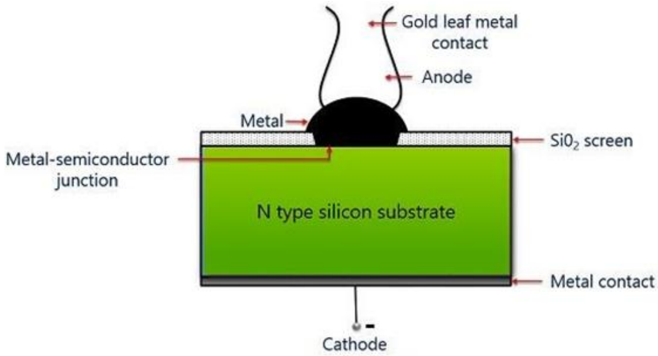


Figure 3.6: construction of Schottky diode

4) Signal diode

Signal Diode is a small non-linear semiconductor device be used in electronic circuits. It has small currents or high frequencies are involved such as in radio, television and digital logic circuits. Signal diodes in the form of the *Point Contact Diode* or the *Glass Passivated Diode*, are physically very small in size.in structure design, the PN junction of a small signal diode is encapsulated in glass to protect the PN junction, and usually have a red or black band at one end of their body to help identify which end is the cathode terminal. The most widely used of the glass encapsulated signal diodes is *1N4148* and its equivalent *1N914* signal diode.

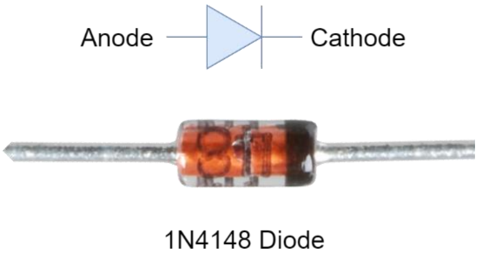


Figure 3.7: structure signal diode and symbol

Construction:

Small-signal diodes are constructed as like PN diodes with a smaller junction area gives the diode a smaller junction capacitance. The structure to reduces the reverse recovery time of the diode to few nanoseconds or less. Small junction capacitance and fast response make the diode suitable for high-frequency applications.

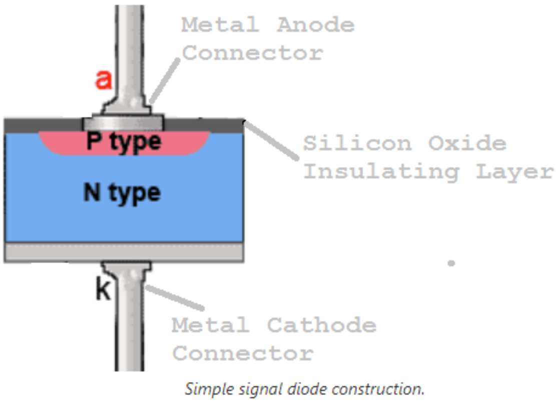


Figure 3.8: construction of signal diode

5) Light Emitter Diode (LED)

Light emitting diode (LED) is a solid-state device that emits light when a current flow from anode to cathode across the PN junction of the PN junction of the device. Basically, a specialized type of PN junction diode that emits either visible light, infrared or laser light at different wavelengths, made from a thin layer of heavily doped semiconductor material. The Light Emitting Diodes I-V Characteristics of LED is non-linear as shown in Figure below, so the LED turns on at a lower voltage and will rapidly draw much higher current as the voltage increases.

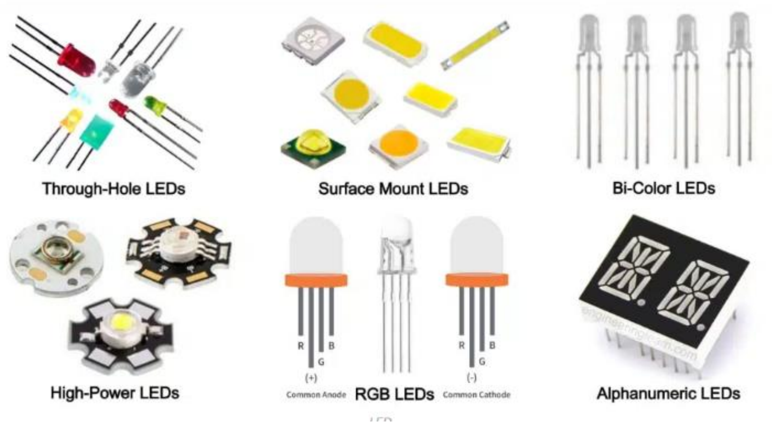


Figure 3.9: types of LED

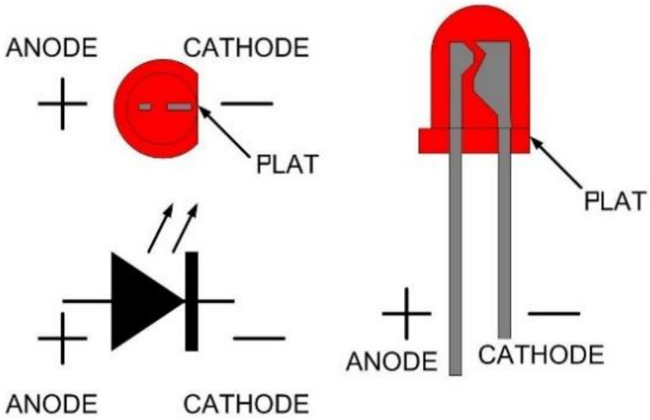


Figure 3.10: structure LED and symbol

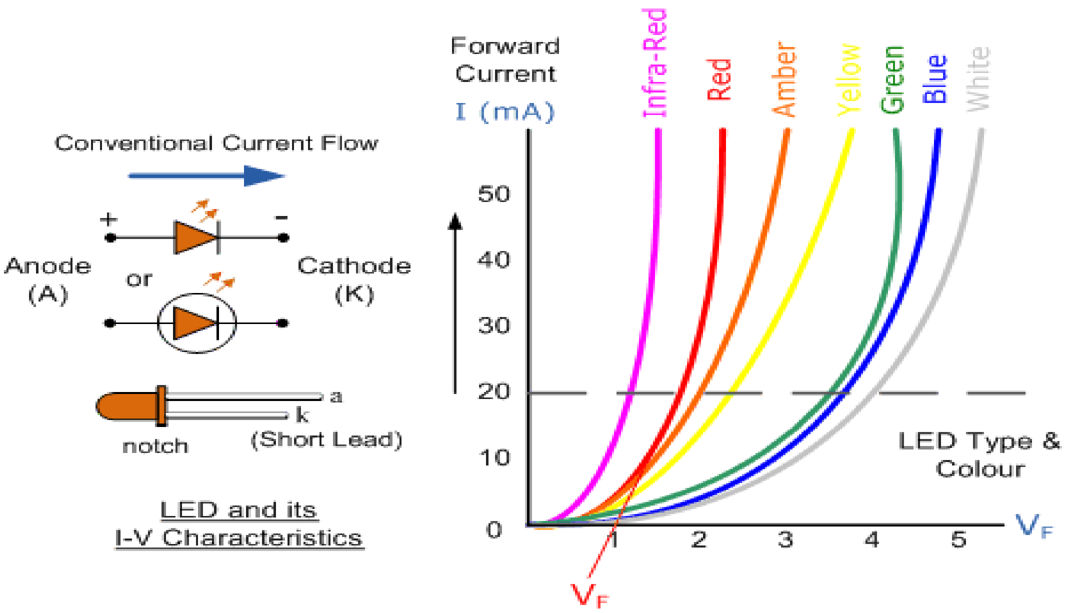


Figure 3.11: Colour LED vs knee voltage

Construction:

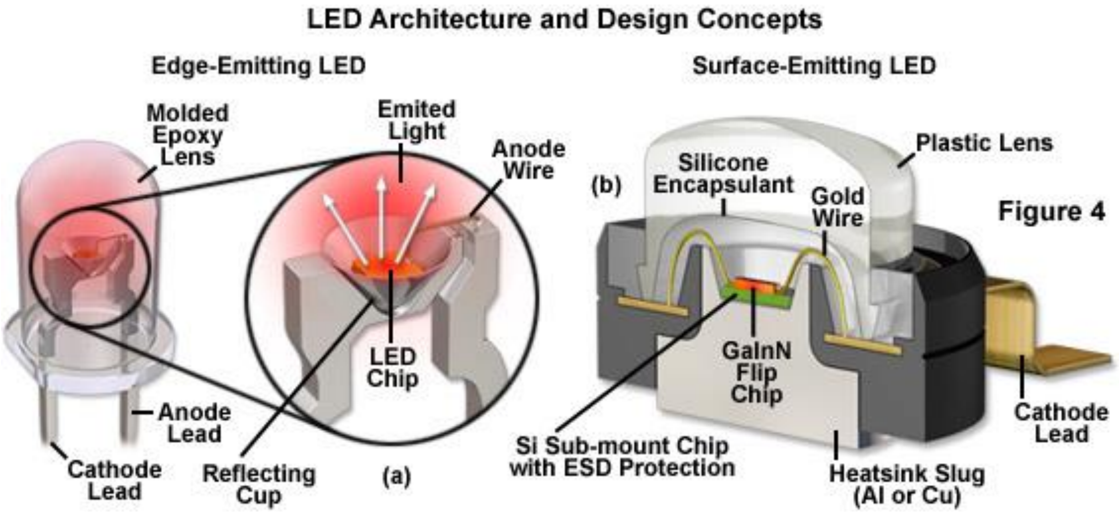


Figure 3.12: construction of LED

3.2 Other types of diode

- **Photodiode** – Exploits the fact that all semiconductors are subject to charged carrier generation when they are exposed to light. Photodiodes are often used to sense light such as in an Opto-isolator.

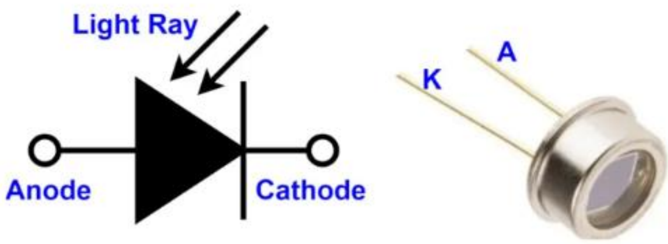


Figure 3.13: photo diode and symbol

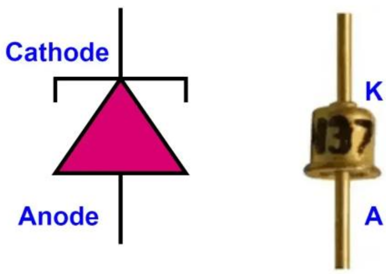
- **Varactor diode** - one kind of semiconductor microwave solid-state device and the applications of this diode mainly involve in where variable capacitance is preferred which can be accomplished by controlling voltage

- **Laser Diode -** It is a different type of diode as it produces coherent light. It is highly used in CD drives, DVDs and laser devices. These are costly when compared to LEDs and are cheaper when compared to other laser generators. Limited life is the only drawback of these diodes.

Figure 3.14: structure laser diode and symbol

- **Avalanche Diode** - This diode belongs to a reverse bias type and operates using the avalanche effect. When voltage drop is constant and is independent of current, the breakdown of avalanche takes place. They exhibit high levels of sensitivity and hence are used for photo detection.

- **Tunnel Diode** -Tunnel diode was invented by **Leo Esaki in 1958** for which he received Nobel prize in 1973, which is why it is also known as **Esaki diode**. A tunnel diode is a **heavily doped** P-N junction diode. It works on the principle of the **tunneling effect**. Due to heavy doping concentration, the junction barrier becomes very thin. This allows the electron to easily escape through the barrier. This phenomenon is known as **tunnelling effect**. The Tunnel diode has a region in its **VI curve** where the current decreases as the voltage increases. This region is known as the **negative resistance region**. The tunnel diode operates in this region in different applications such as an **oscillator** and a **microwave amplifier**.



Tunnel diode

Figure 3.15: structure tunnel diode and symbol

- **PIN Diode** - n the PIN diode, between layers P and N, a pure semiconductor material is known as “I” (Si, or Ge intrinsic material). Layer P and layer N are heavily doped, so they function as an ohmic contact, while the intrinsic “I” layer functions as an insulator, so no current flows through it. As a result, the PIN structure is very useful in RF switching and photodiodes.

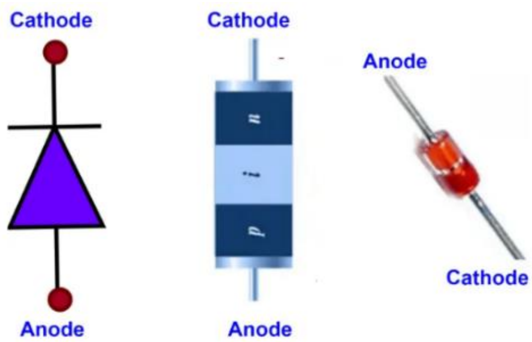


Figure 3.16: structure PIN diode and symbol

- **Backward Diode -** The backward diode functions in a similar way as the tunnel and zener diode functions. Its operating voltage is much lower. It is a type of tunnel diode that has a less doping concentration at one side of the junction in comparison to another side of the junction. A backward diode is essentially a tunnel diode, whose one side of the junction has relatively less doping concentration compared to the other side. In the forward bias, it functions as a tunnel diode and in the reverse bias, it functions as a zener diode.

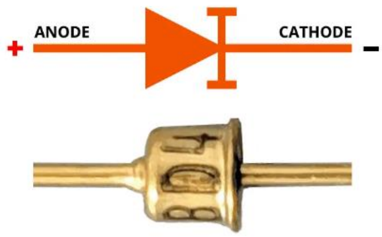


Figure 3.17: structure diode and symbol

- **Transient Voltage Suppression (TVS) Diode -** A TVS diode is a type of avalanche diode that is used to protect the circuit from voltage surges. It can handle higher voltage as compared to an avalanche diode. The unidirectional TVS diode acts as a rectifier in forward boas and it acts as a surge protector in the reverse bias. A bidirectional TVS diode, manufactured as a single component, functions like two avalanche diodes opposing each other in series.

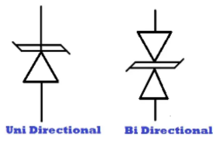


Figure 3.18: Symbol of TVS diode

- **Vacuum Diode -** This type of diode has a vacuum tube and two electrodes-cathode and anode which are enclosed inside the vacuum tube. In forward bias, on heating the cathode, it emits electrons, and the anode which is at positive potential catches these electrons, and current flows between the anode and cathode. In reverse bias, the anode is held at negative potential and it repels the electrons, thus no current flow between the anode and cathode. **Step Recovery Diode - The step** Recovery diode has unusual doping. It has an extremely small doping density near the junction area and, therefore has small numbers of charge carriers near the junction and leading to fast switching of the diode from **ON** state to **OFF** state.

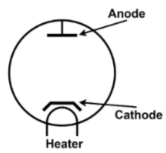


Figure3.19 vacuum diode symbol

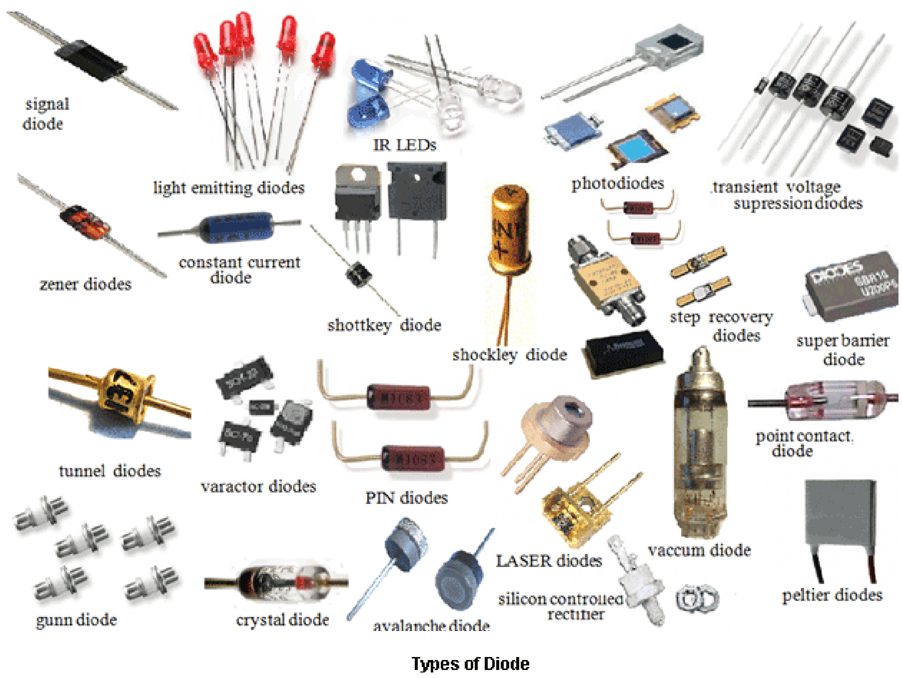


Figure 3.19 Diodes

3.3 Diodes Symbol

After knowing a bit more about the diodes and its background info, let's look at the symbols .

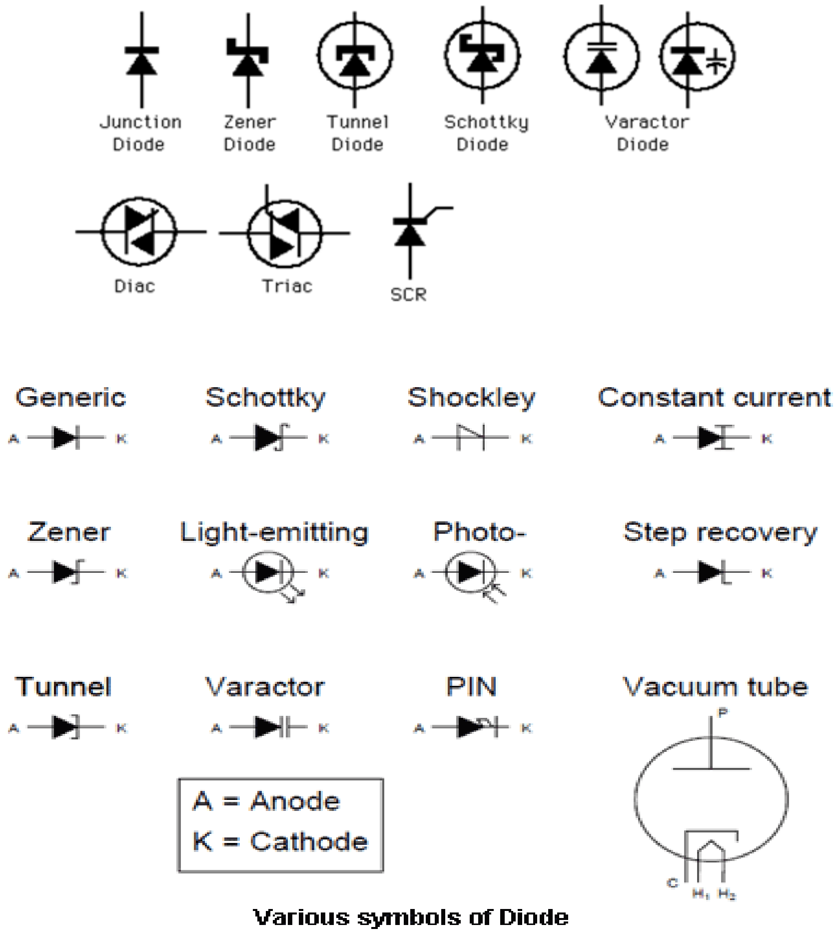


Figure 3.20: Symbol of diodes

Activity 3a

1. Do you know the diode?

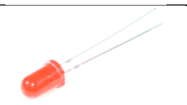
a). Diode produces coherent light is ________________.
b). Diode emits visible light is called ________________.
c). Diode is used to rectify the AC voltage to DC voltage called_________________
d). Diode will receive the light to functions is
e). Diode functions as voltage regulator is _

Zener diode
regular diode
Light Emitter Diode (LED)
Laser Diode
photo diode

2. match the real component with its name.

a). photo diode
b). laser diode
c). LED
d). Zener diode
e). varactor diode



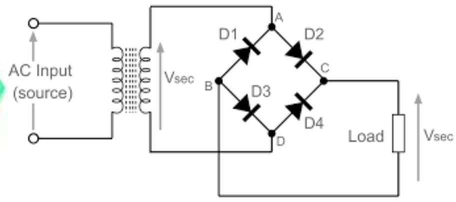


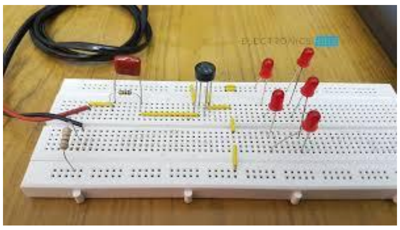
Chapter 4

Diode Applications

Upon completion this chapter, you should be able to:

- Define the name of application of diode
- Explain the working principle of the circuit using diode.
- Understand the application of diode in electronic circuit.





4.0 Introduction

Diode as simplest semiconductor component has a wide variety of applications in modern electronic systems. Various electronic and electrical circuits/systems use this component as an essential device to produce the required outcome.

Diode made from combination P-type material and N-type material which allows the current flow in one direction only in forward bias and suppose the current flow at other direction in reverse bias. Th other words, diode works as one-way switch in electronic circuit where as a closed switch in forward bias and an open switch in reverse bias. Most diodes allow current to flow only when positive voltage is applied to the anode in forward bias.

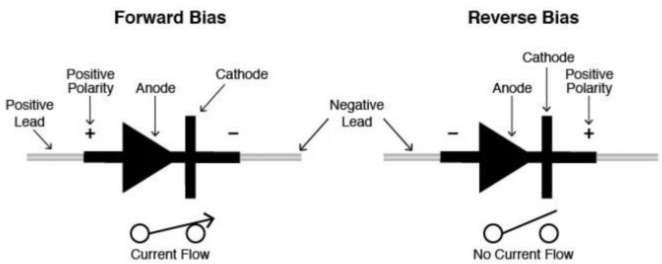


Figure 4.1: diode working condition

Diode has two terminals namely anode ((positive lead)) and cathode (-). This device can be operated by controlling the voltage applied to these terminals. When the voltage applied to the anode is positive with respect to the cathode, the diode is said to be in Forward Bias. If the voltage applied to the diode is greater than the threshold level (generally, it is of ≈0.7V for Silicon Diodes), then diode acts as a short circuit and allows the current flow. If the polarity of the supply voltage is changed be opposite, the cathode is become positive with respect to anode, then it is in Reverse Bias and acts as open circuit. It is no current flows through it.

The application of diodes in wide include power supply systems as rectifiers and inverters, communication systems as limiters, clippers, gates; computer systems as logic gates, clampers;; television systems as phase detectors, limiters, clampers; radar circuits as gain control circuits, parameter amplifiers, etc. The following description describes some applications of diodes briefly.

4.1 Diode Applications

Diodes become a important component in daily life. Some Common Applications of Diodes as

a) Rectifiers
b) Voltage regulators.
c) Clipper Circuits
d) Clamping Circuits
e) Reverse Current Protection Circuits
f) In Logic Gates

4.1.a. RECTIFIER

As we know rrectification is the process of turning an alternating current (AC) waveform into a direct current (DC) waveform. So, rectifier is an electronic device which converts an AC waveform(Usually a Bi-directional waveform with Zero Average value) to a Pulsating DC waveform (Uni-directional waveform with Nonzero Average value). Using diodes, we can construct different types of rectifier circuits.

The basic types of these rectifier circuits are half wave, full wave center-tapped and full bridge rectifiers. If a Rectifier does it's operation only in one half of the cycles, it is known as Half Wave Rectifier. If a Rectifier does it's operation in both the half cycles, it is known as Full Wave Rectifier.

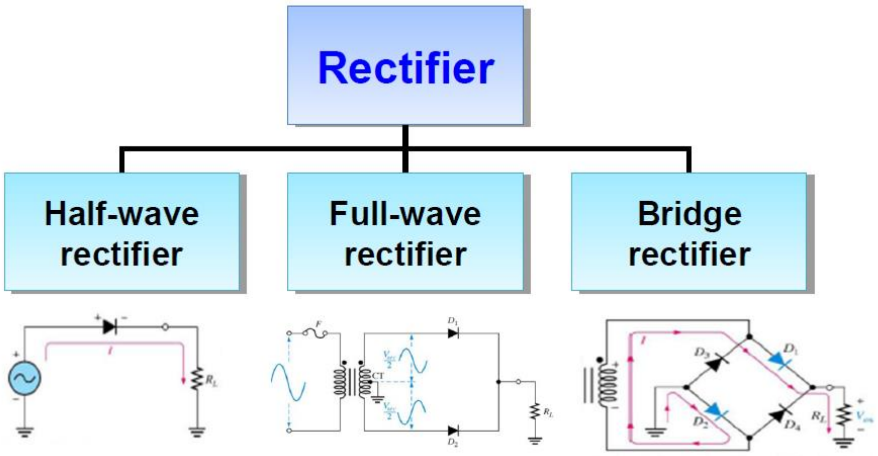


Figure 4.2: Types of rectifier

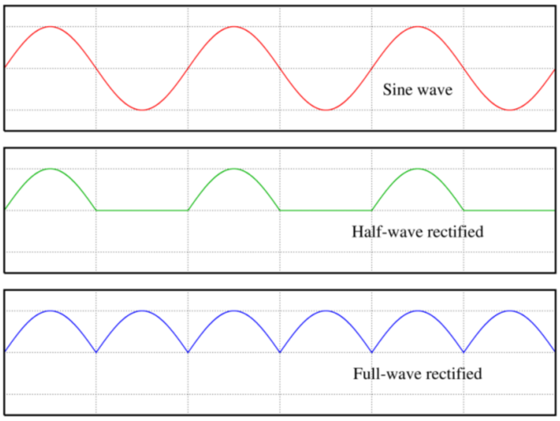


Figure 4.3: Input and output waveform of rectifier

Half-wave rectifier

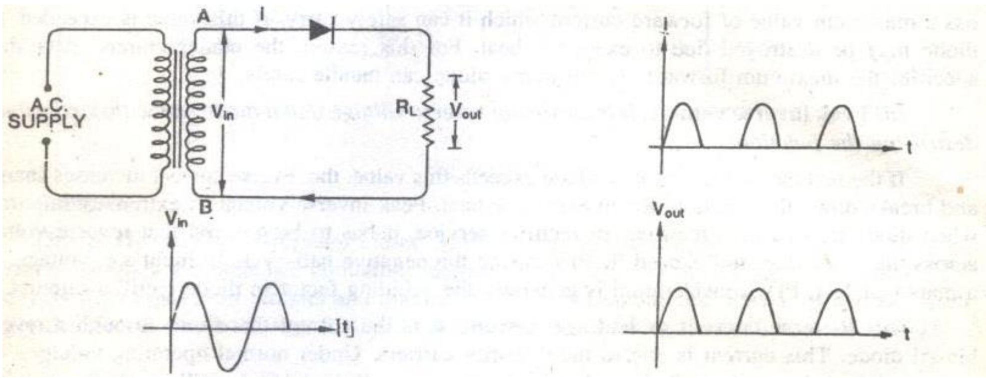


Figure 4.4: half wave rectifier

- During the positive half-cycle of the input sinusoidal wave, anode is positive with respect to cathode where the diode in forward biased. This results current is allowing to flow to the load. The voltage waveform across the load resistor will be same as the supply voltage in sinusoidal voltage and load current flow is proportional to the voltage applied.
- During the negative half-cycle of the input sinusoidal wave, anode is negative with respect to cathode where the diode in reverse biased. So , no current flows to the load. The circuit becomes open circuit.
- Both voltage and current at the load side are of one polarity means the output voltage is pulsating DC. The rectification is continuing by a filter circuit that is connected across the load to produce steady and continuous DC currents without any ripples.

Centre-tapped rectifier

- During the positive half-cycle of the input sinusoidal wave, the source voltage polarity is positive (+) on top and negative (-) on bottom.
    - Only top diode is conducting; bottom diode is blocking current, and load "sees" first half of sinusoidal wave.
    - Only top half of transformer's secondary winding carries current during this half-cycle.

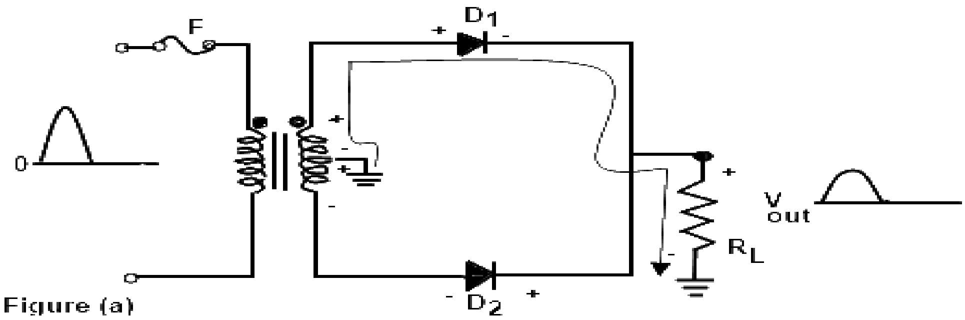


Figure 4.5: Centre-tapped rectifier during positive cycle

- During the negative half-cycle of the input sinusoidal wave, other diode and other half of transformer's secondary winding carry current while portions of circuit formerly carrying current during last half-cycle sit idle.
- The load still "display" half of sine wave, of same polarity as before.

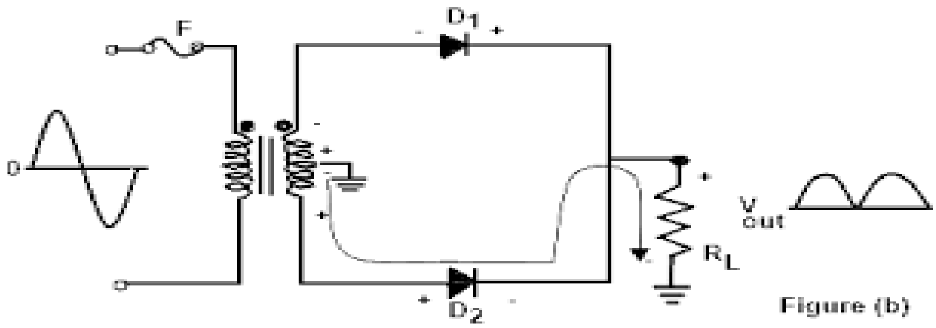
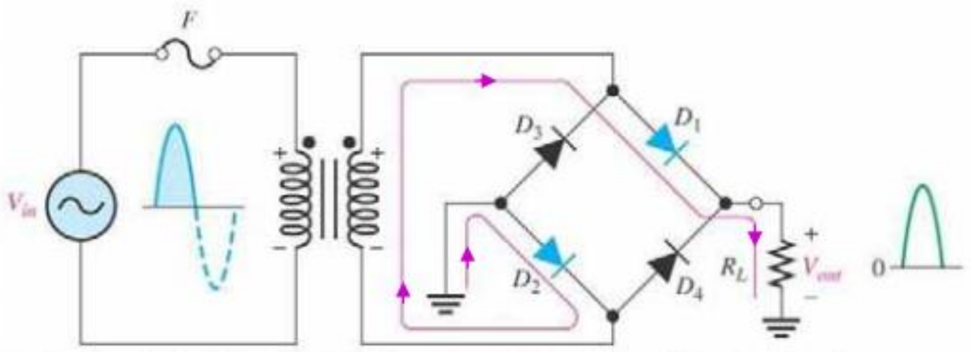


Figure 4.6: Centre-tapped rectifier during negative cycle

Full-wave bridge rectifier

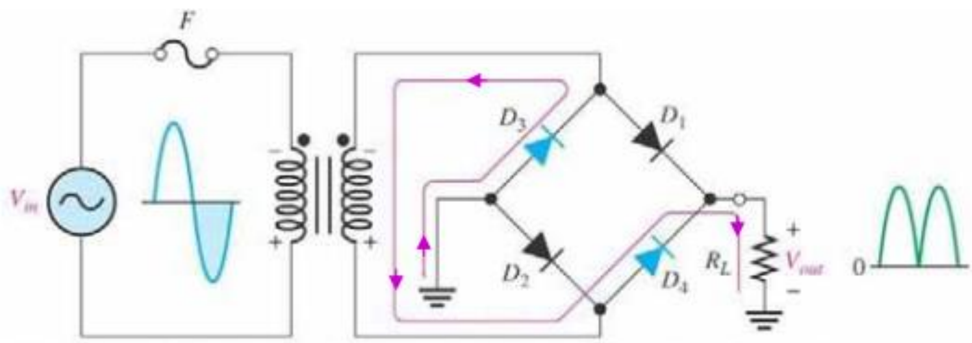
- The output of a full-wave rectifier is driven by both the positive and negative cycles of the sinusoidal input, unlike the half-wave rectifier which uses only one cycle.
- it is built around four-diode bridge configuration.
    - Negative components are inverted
- positive half-cycle of source is positive half-cycle at load.



(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

Figure 4.7: Bridge rectifier during positive cycle

- negative half-cycle of source also is positive half-cycle at load.



(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

Figure 4.8: Bridge rectifier during negative cycle

Current flow is through two diodes in series for both polarities. The polarity of input, current flows in same direction through load. Thus, two diode drops of source voltage are lost (0.7·2 = 1.4 V for Si) in diodes.

4.1.b. VOLTAGE REGULATORS.

A voltage regulator is designed to provide a very steady or well-regulated dc output which is a component that helps to maintain a fixed or constant output voltage. The output level is maintained regardless of the variation of the input voltage. To meet the function, voltage regulator diodes (Zener diode) utilize the reverse characteristics at PN junction. When raising reverse voltage of diodes, high current starts flowing at a certain voltage, and constant voltage can be obtained. This phenomenon is called breakdown and this voltage is called breakdown voltage.

The commonly used voltage regulators are

i. Zener diode
ii. the series voltage regulator
iii. the shunt voltage regulator.

i. Zener diode

For low current power supplies, a simple voltage regulator can be made with a resistor and a Zener diode connected in reverse. The resistor, RS is connected in series with the Zener diode to limit the current flow through the diode with the voltage source, VS being connected across the combination. The stabilized output voltage Vout is taken from across the Zener diode. The Zener diode is connected with its cathode terminal connected to the positive rail of the DC supply so it is reverse biased and will be operating in its breakdown condition. The voltage point at which the voltage across the Zener diode becomes stable is called the “Zener voltage”, (Vz) and for Zener diodes this voltage can range from less than one volt to a few hundred volts.

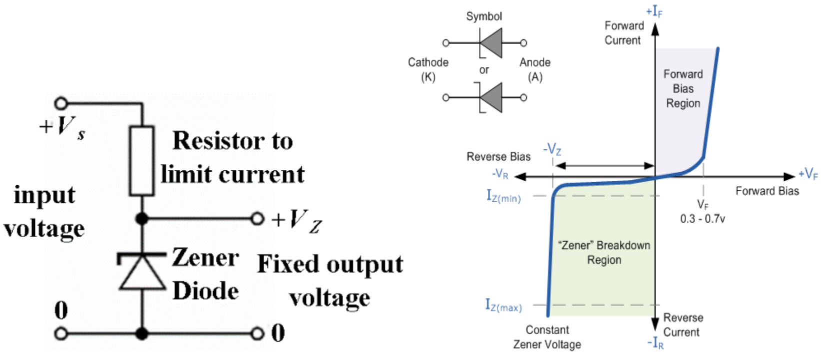


Figure 4.9: Zener voltage regulator

ii. Zener Controlled Transistor Series Voltage Regulator

Zener Controlled Transistor Series Voltage Regulator also named an emitter follower voltage regulator because the transistor used is connected in an emitter follower configuration. The circuit consists of an N-P-N transistor and a zener diode. The collector and emitter terminals of the transistor are in series with the load. The transistor used is a series pass transistor. With series regulation the control element is in series with the input and output.

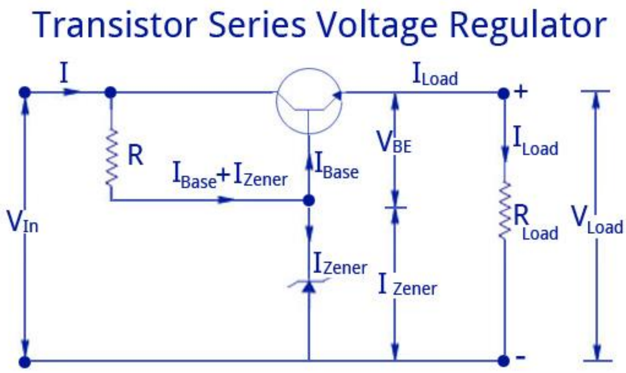


Figure 4.10: Zener Controlled Transistor Series Voltage Regulator

iii. Zener Controlled Transistor Shunt Voltage Regulator

The circuit consists of an NPN transistor and a zener diode along with a series resistor Rseries that is connected in series with the input supply. The zener diode is connected across the base and the collector of the transistor which is connected across the output. In shunt regulation the control element is in parallel with the load.

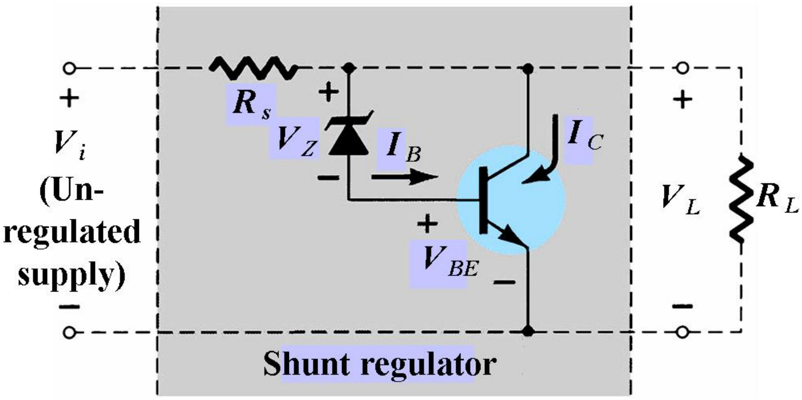


Figure 4.11: Zener Controlled Transistor Shunt Voltage Regulator

4.1.c. CLIPPING CIRCUITS

In generally, clipping Circuits are used in Frequency Modulation (FM) transmitters, where signal peaks are limited to a certain value so that excessive peaks are filtered from signal source. The clipper circuit is used to take out the voltage beyond the pre-set value without disturbing the remaining part of the input waveform.

The clipper circuits are of the following types.

i. Series positive clipper
ii. Series negative clipper
iii. Shunt or parallel clipper

i). Series Positive Clipper

The figure below shows the positive series and output waveform. For positive series clipper, during the half positive cycle of the input, the diode in reverse-biased so the voltage at the output is zero. result is input waveform clipped off at the output. During the half negative half cycle of the input, the diode is forward-biased and result is input waveform appears across the output.

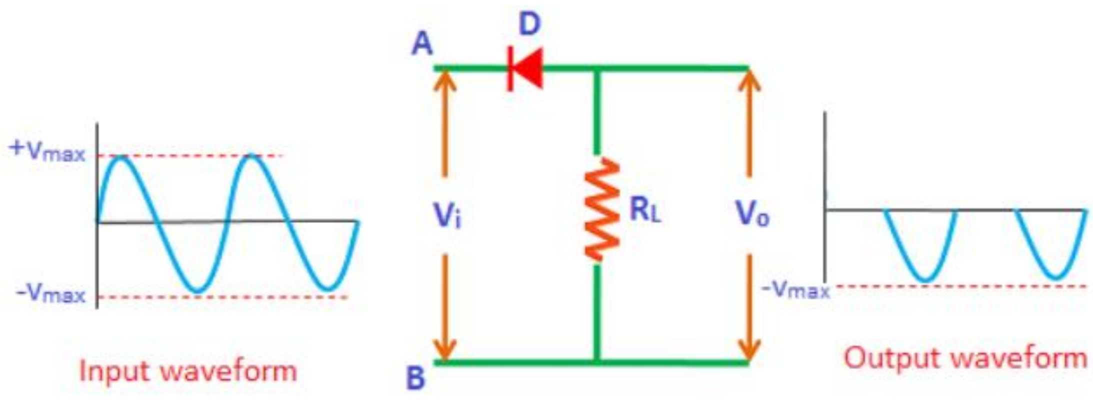


Figure 4.12: Series Positive Clipper

ii). Series Negative Clipper

For negative series clipper, during the half positive cycle of the input or forward biased condition, electric current flows through the diode so the positive half cycle is allowed appears at the output. During negative half cycle, diode is said to be reverse biased. Therefore, the negative half cycle is completely blocked or removed at the output. In other words, a series of negative half cycles are removed at the output.

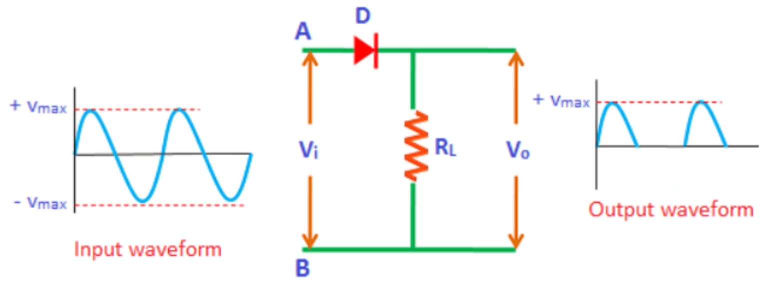


Figure 4.13: Series Negative Clipper

iii). Shunt or Parallel Clipper

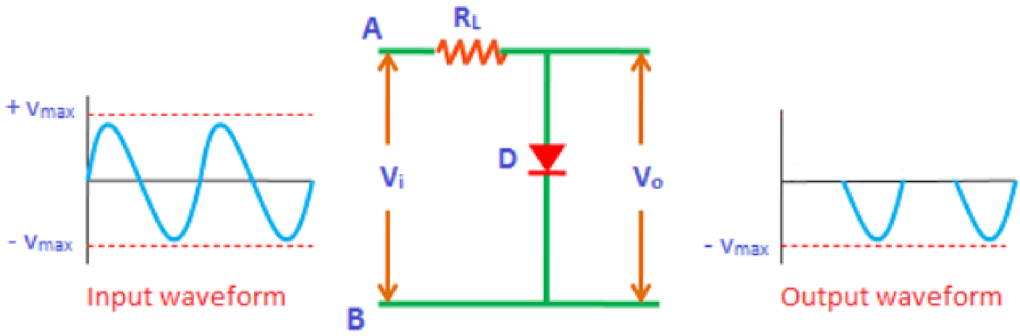


Figure 4.14: Shunt or parallel Positive Clipper

For positive shunt clipper, , the diode is forward-biased during the positive half cycle and as diode acts as a closed switch so output voltage is zero. The diode is reverse-biased during the negative half cycle and acts as open switch so the full input voltage appears across the output.

Some applications for Clippers such as

Clippers

- Used for the generation and shaping of waveforms
- Used for the protection of circuits from spikes
- Used for amplitude restorers
- Used as voltage limiters
- Used in television circuits
- Used in FM transmitters

4.1.d. CLAMPING CIRCUITS

A clamper circuit or called as Level Shifter or DC restorer is used to shift or alter either positive or negative peak of an input signal to a desired level. The clamping circuit can be positive or negative depending on the configuration of diode in the circuit.

i). Positive Clamper circuit

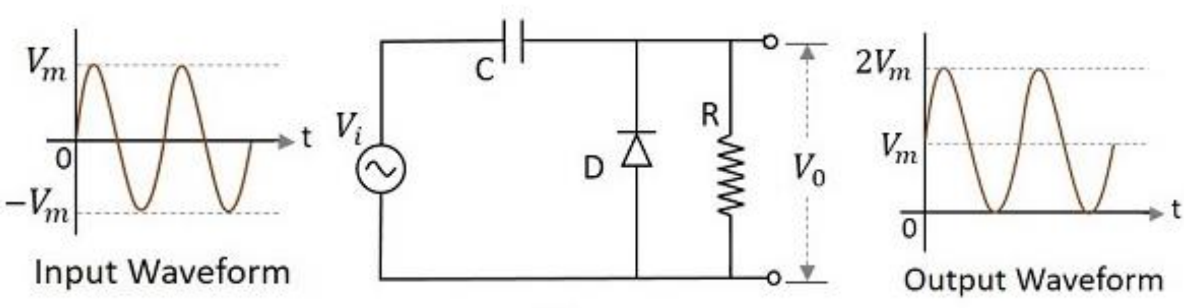


Figure 4.15: Positive Clamper circuit

In positive clamping circuit, negative peaks are raised upwards so the negative peaks fall on the zero level. In case of the negative clamping circuit, positive peaks are clamped so that it pushes downwards such that the positive peaks fall on the zero level.

During the positive half-cycle of the input, diode is reverse-biased so the output voltage is equal to the sum of input voltage and capacitor voltage (considering the capacitor is initially charged).

During the negative half-cycle of the input, diode is forward-biased and behaves as a closed switch so the capacitor charges to a peak value of the input signal.

i). Negative Clamper circuit

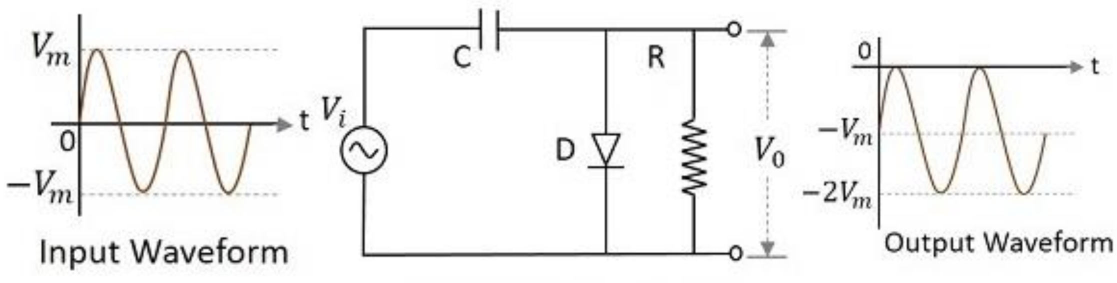


Figure 4.16: Negative Clamper circuit

During the positive half cycle, the diode is forward biased and the capacitor gets charged to its peak value. During the negative half cycle, the diode gets reverse biased and as open circuit. The output of the circuit id clamped as shown in the above figure. The output signal changes according to the changes in the input, but shifts the level according to the charge on the capacitor, as it adds the input voltage.

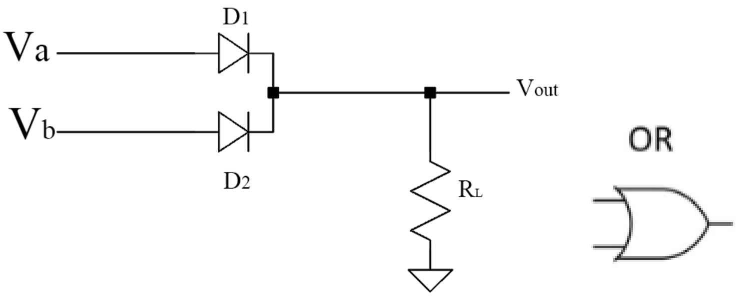
Some applications for Clampers such as

- Used as direct current restorers
- Used to remove distortions
- Used as voltage multipliers
- Used for the protection of amplifiers
- Used as test equipment
- Used as base-line stabilizer

4.1.e. LOGIC GATES

Diodes also be used to perform digital logic gate operations such as AND, OR, etc.

i. OR Gate Using Diode



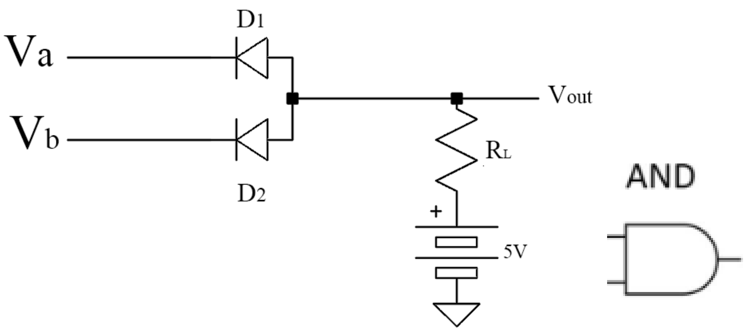
A	B	Output
0	0	0
1	0	1
0	1	1
1	1	1

Figure 4.17: OR gate and truth table

If all inputs are in LOW, both the diode becomes in reverse biased hence acts as an open switch. Hence the output voltage is LOW.

If Va is HIGH and Vb is LOW, the diode D1 becomes in forward biased hence act as the closed switch. (Neglecting diode forward resistance and voltage drop across the diode) Hence the output is HIGH.

ii. AND gate using diodes



A	B	Output
0	0	0
1	0	0
0	1	0
1	1	1

Figure 4.18: gate and truth table

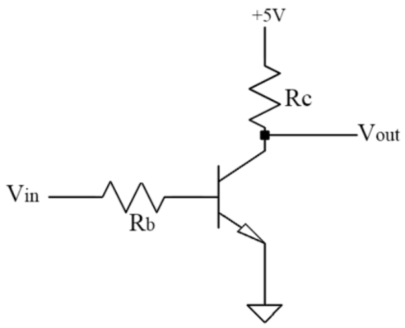
If Va is HIGN and Vb is LOW, the diode D1 becomes in reversed biased hence act as an open switch. Also, diode D2 becomes in forward biased hence act as the closed switch. Hence the output is LOW.

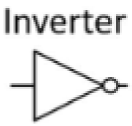
If Va is LOW and Vb is HIGH, the diode D1 becomes in forward biased hence act as the closed switch. Also, diode D2 becomes in reversed biased hence act as an open switch. The output is LOW.

If all inputs are LOW then all diode becomes in forward biased and act as an open switch. Hence the output is LOW.

When all inputs are HIGH, all diodes become in the reversed biased hence act as an open switch. Hence the output is HIGH.

iii. NOT gate using a transistor





Input	Output
0	1
1	0

Figure 4.19: NOT gate and truth table

If the input is LOW, the parameter is chosen so that the output is V(sat). Also, if the input is HIGH, the parameter is chosen so that the output is LOW.

If the input is LOW, the transistor act as an open switch. Hence the output is HIGH.

If the input is HIGH, the transistor act as the closed switch. Hence the output is LOW (Neglecting voltage drop).

Activity 4a

1. Component that convert AC to DC and allow current to flow in one Direction.
   a. Diode
   b. Capacitor
   c. Inverter
   d. Resistor

2. Which of the following is not a necessary component in a clamper circuit?
   a. Independent DC Supply
   b. Diode
   c. Resistor
   d. Capacitor

3. Types of diodes used in lighting system and display
   a. Zener diodes
   b. LED
   c. rectifier diodes
   d. photo diodes

4. what is the meaning of rectification?
   a. a process of smoothing using a capacitor
   b. a process of adding impurities to pure materials
   c. a process of converting *a*n alternating current into a direct current by using a diode.
   d. a process of shift or alter either positive or negative peak of an input signal to a desired level.

5. Which of the following is a common application for Zener diodes?
   a. Voltage regulation
   b. Demodulation.
   c. AC rectification.
   d. Input protection.

Answer:
1.a, 2.d, 3.b, 4.c, 5.a

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