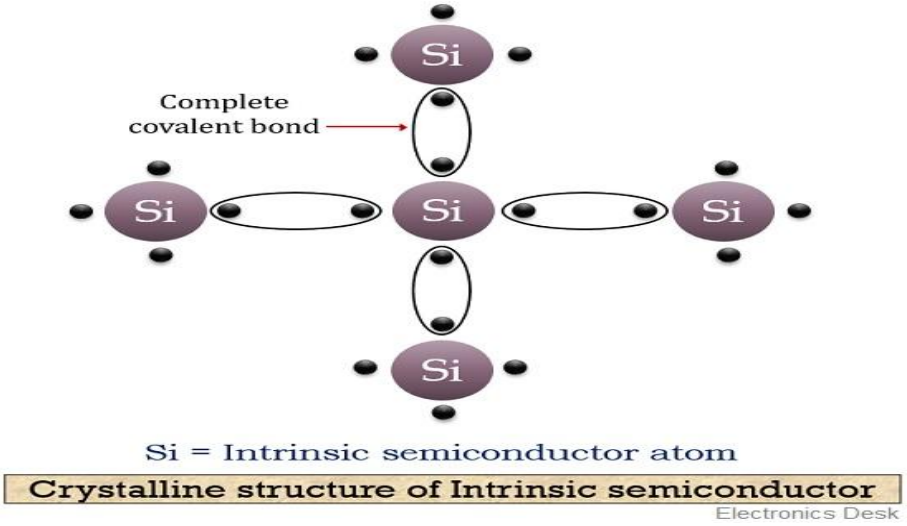
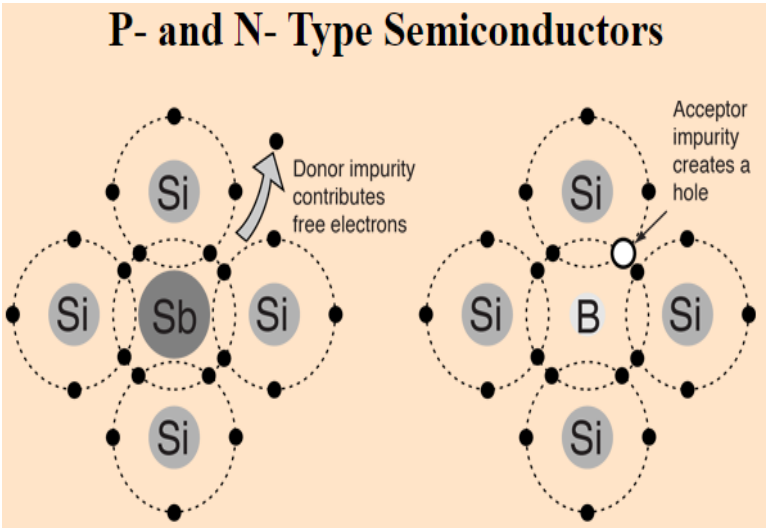
Semiconductor material

- It is a material having the property of both conductor and insulator (eg: Si, Ge (14 th group)).
- They have 4 electrons in valence shell



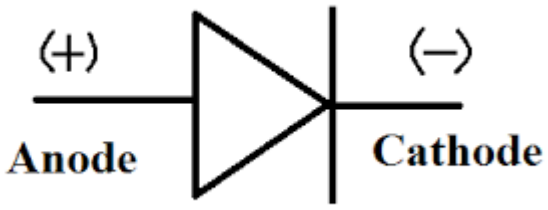
- Doping: The process of adding impurities to a pure semiconductor is called doping
- Intrinsic semiconductor: A semiconductor without any doping (That is no impurities are added) is called intrinsic semi-conductor
- Extrinsic semiconductor: a semiconductor in which impurities are added or a doped intrinsic semiconductor is called extrinsic semiconductor
- P type Semiconductor: When an intrinsic semiconductor is doped with trivalent impurities, such semiconductor is called P type semiconductor. I.e, if silicon is doped with 13th group element aluminum or boron, p type semiconductor is formed. Majority charge carrier in P type semiconductor is Holes
- N type Semiconductor: :When an intrinsic semiconductor is doped with pentavalent impurities, such semiconductor is called N type semiconductor. I.e, if silicon is doped with 15th group element arsenic or antimony, N type semiconductor is formed. Majority charge carrier in N type semiconductor is free electrons



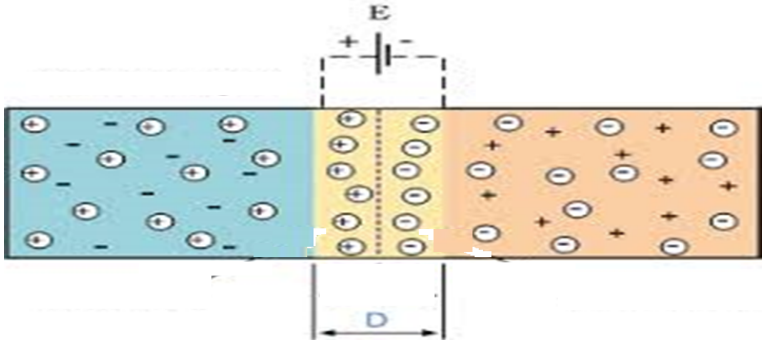
PN junction diode

It is a 2 terminal electronic component. It is a uni-directional device, because it allows only the flow of current in one direction only.it is formed by jointing P type material and N type material.

Symbol

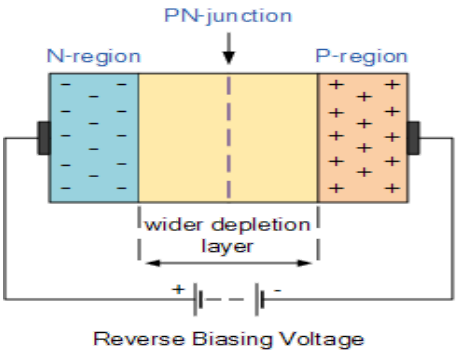


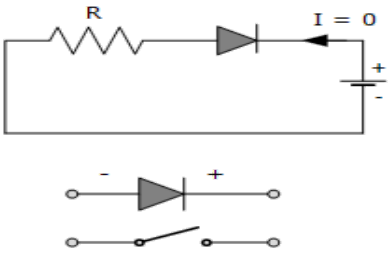
- When a p-type semiconductor is suitably joined to n-type semiconductor, the contact surface is called pn junction.
- When a pn junction is formed, the free electrons near the junction in the n-region begin to diffuse across the junction into the p- region
- As the free electrons diffuse across the junction, they combine with holes and leave a layer of positive charges in the n-region and a layer of negative charges in the p-region. This forms a barrier potential. This action continues until the voltage of the barrier stops further diffusion.
- The barrier potential is also known as cut in voltage or knee voltage.
- For silicon the barrier potential is about 0.7V and for germanium, it is about 0.3V.



Reverse biased PN junction diode

- A diode is said to be Reverse biased when P type semiconductor part of diode(Anode) is connected to negative terminal of the battery and N type semiconductor part (Cathode)of diode is connected to positive terminal of the battery
- In this condition, holes on the P type region are attracted to the negative terminal of the battery and free electrons in the N type region are attracted by the positive terminal of the battery. Due to this, holes in the P type region and free electrons in the N type region are moved away from PN junction. So the width of the depletion layer increases. So majority carriers cannot flow across the junction and hence diode acts as an open switch

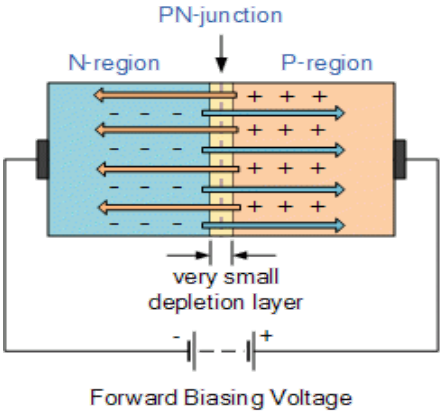


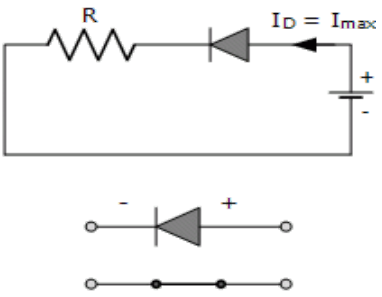


- One final point, if the reverse bias voltage Vr applied to the diode is increased to a sufficiently high enough value, it will cause the diode's PN junction to overheat and fail.
- This may cause the diode to become shorted and will result in the flow of maximum circuit current

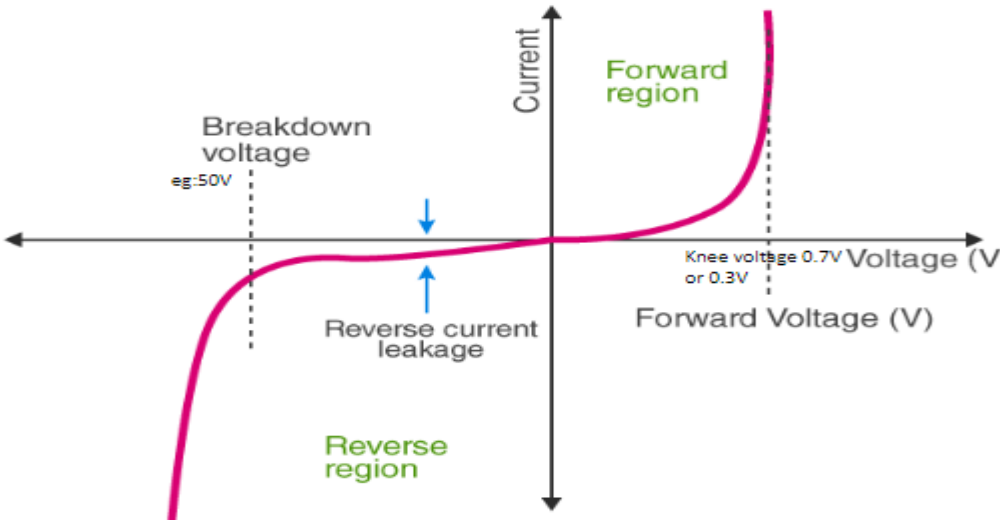
Forward biased PN junction diode

- Diode is said to be forward biased when the anode diode is connected to the positive terminal of the battery and the cathode of the diode is connected to Negative terminal of the battery.
- In this condition, holes on the P type region are attracted to the negative terminal of the battery. So, it moves towards the N type region by crossing the PN junction. Similarly, free electrons in the N type region are attracted by the positive terminal of the battery, so it moves towards the P type region by crossing. Due to the flow of the majority carriers across the junction, the width of the depletion region reduces. So, during forward biased condition, current flow across the junction and diode acts an closed switch
- In other words when the applied voltage is greater than the barrier potential of diode, the PN junction diode will conduct and act like a closed switch





The characteristics of a PN junction diode is shown in the figure below



Applications of diode

1. As rectifier
2. In inverters
3. In logic gates
4. In clippers
5. In clampers
6. In voltage multipliers
7. In SMPS
8. As a switch in digital logic circuits

Rectifier

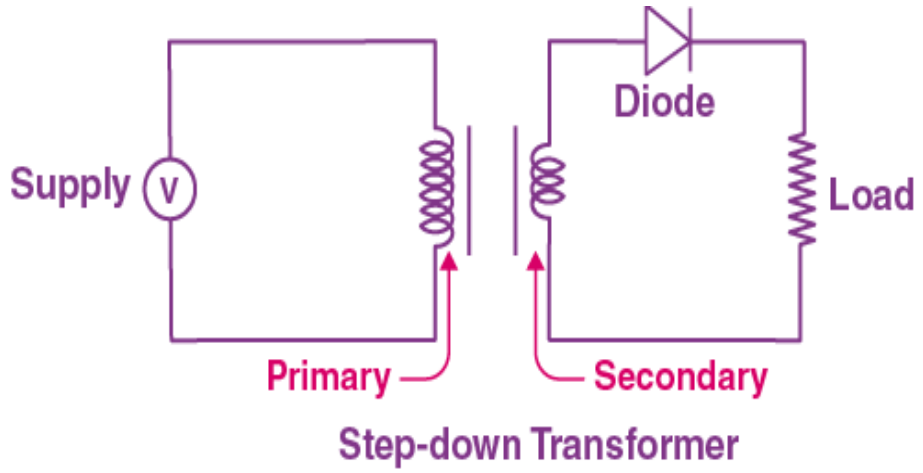
A circuit which convert ac to dc is known as rectifier

Two types

1. Half- wave rectifier
2. Full-wave rectifier
    a. Centre- tapped full wave rectifier
    b. Bridge rectifier

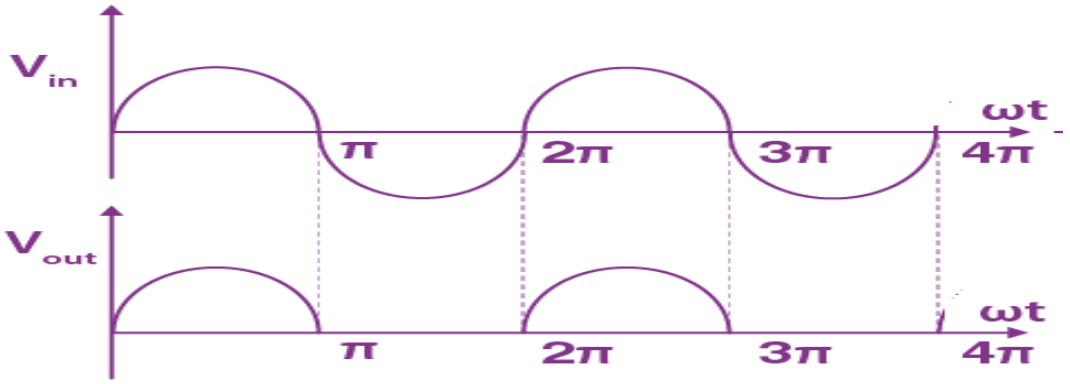
Half wave rectifier

Circuit



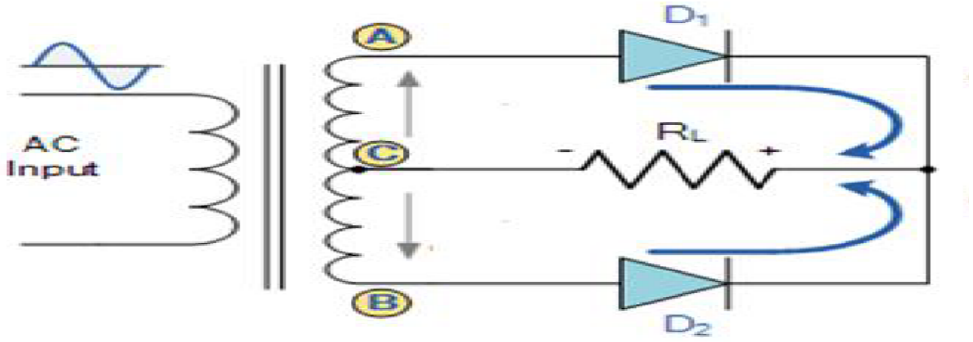
- Step down transformer is used to reduce voltage.
- During the positive half cycle, the diode is forward biased and act as a closed switch , current flows through the load resistor and output voltage appear across the load
- During negative half cycle the diode is reverse biased and act as an open switch, no current flows through the load and no voltage appear across the load

Wave forms



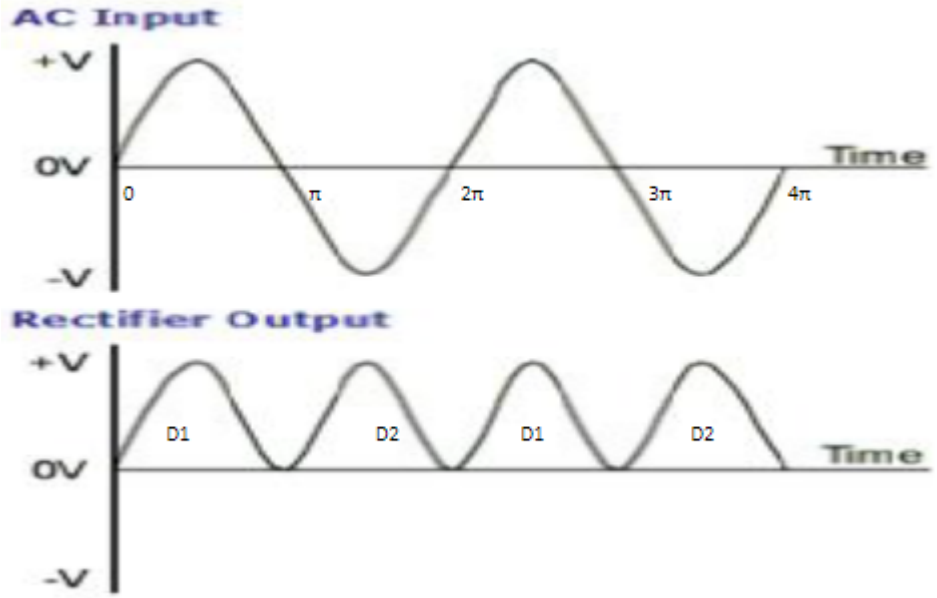
Centre tapped full wave rectifier

Circuit

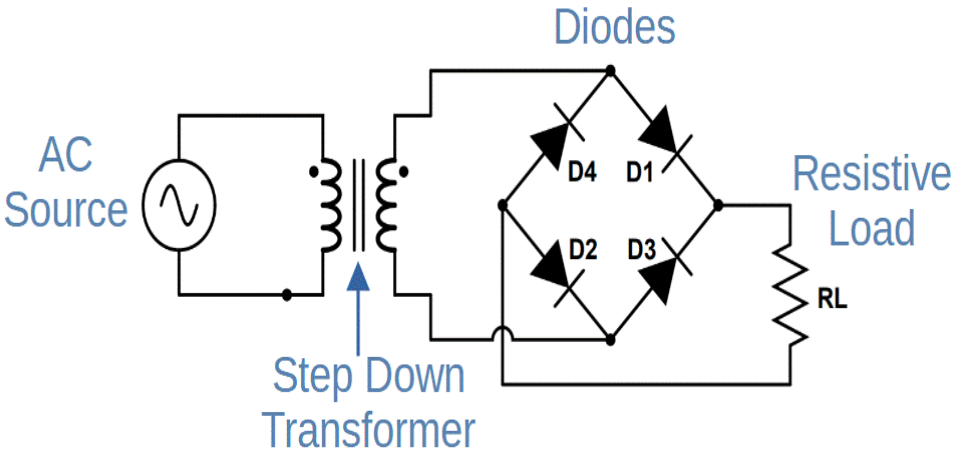


- Here a special type of transformer called center tapped transformer and two diodes are used
- During positive half cycle of input terminal A is positive and diode D_1 is forward biased and conducts the current flows through load resistor
- During negative half cycle , Diode D2 is forward biased and conducts and current flows through load resistor
- During both positive and negative half cycle the current flow through load is in same direction
- The voltage appearing across load resistor R_L is unidirectional (DC)

Waveform



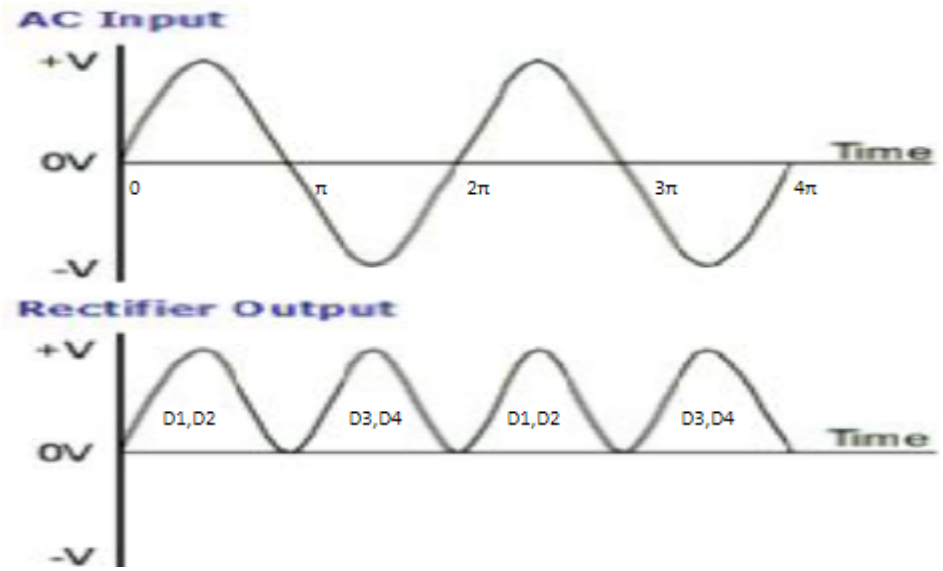
Full wave bridge rectifier



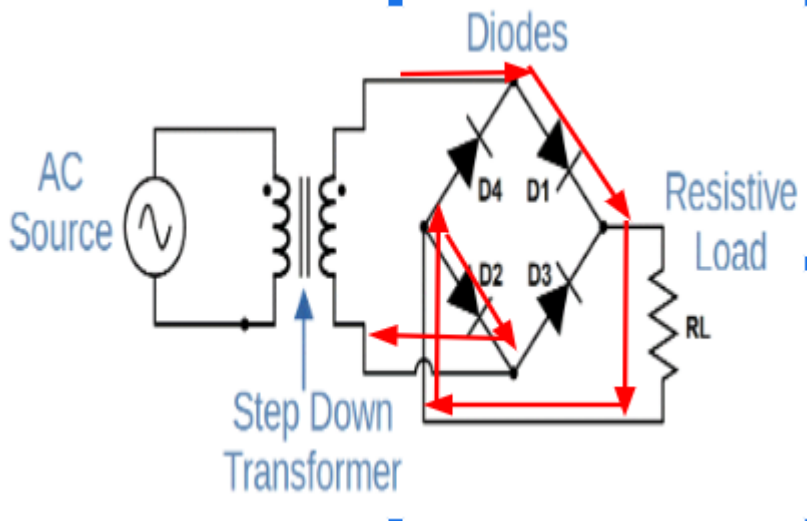
In this rectifier four diodes are used.
➢ During positive half cycle diode D1 and D2 are forward biased and conduct, current flows through load resistor and output voltage is obtained across the load resistor.
➢ During negative half cycle only diode D3&D4 are forward biased and conduct, current flows through load resistor and output voltage is obtained across the load resistor.
➢ During both positive and negative half cycle current flows through load resistor in the same direction.

Hence output voltage across load resistor is unidirectional

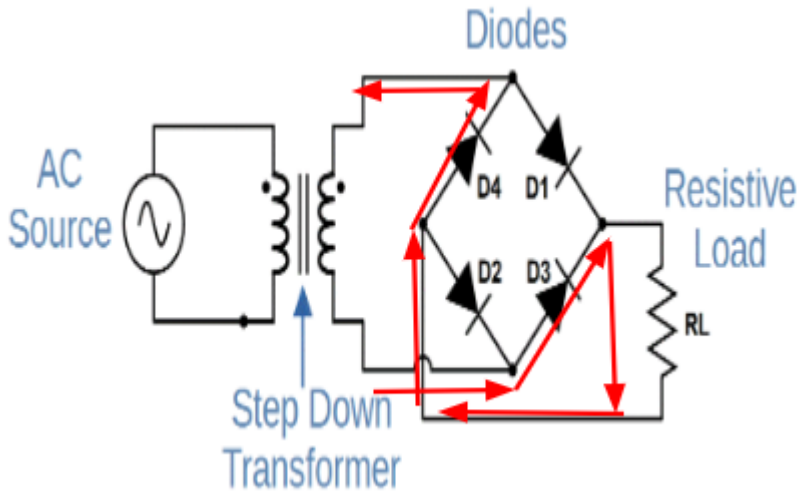
Waveform



The direction of current flow during positive half cycle is as shown below



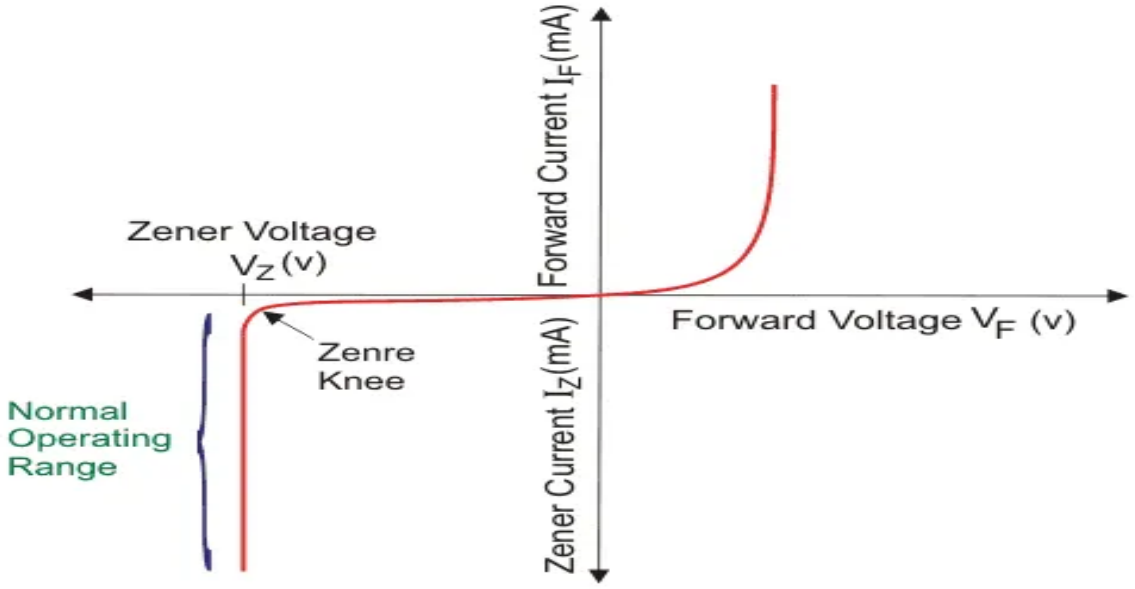
The direction of current flow during negative half cycle is as shown below



Zener diode

Symbol

A Zener Diode, also known as a breakdown diode, is a heavily doped semiconductor device that is designed to operate in the reverse direction. When the voltage across the terminals of a Zener diode is reversed and the potential reaches the Zener Voltage (knee voltage), the junction breaks down and the current flows in the reverse direction. This effect is known as the Zener Effect.
A Zener diode operates just like a normal diode when it is forward-biased



The characteristic of zener diode is just like a normal diode during forward biased condition.

In reverse biased condition, if the voltage is increased , a small but constant leakage current flows through the diode. This current remains constant until a certain voltage known as zener voltage or break down voltage is reached. Beyond this voltage, the reverse current increases rapidly, but the voltage across it remains constant .
This property (**Voltage remaining constant over a wide range of current**) is used in voltage regulator circuit using zener diode.

Applications

Voltage regulator
Fixed reference voltage source
Peak clipper
Over voltage protection circuit
Wave shaping circuits

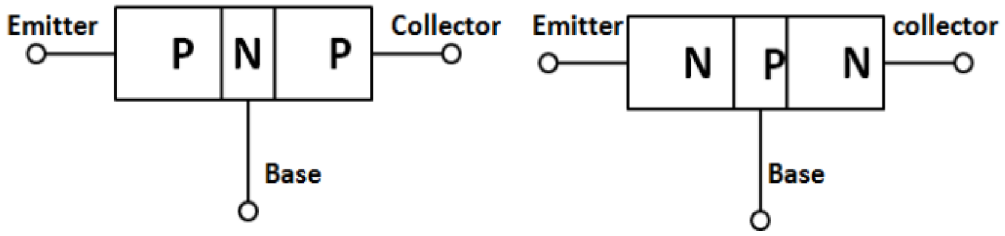
Transistor (Bipolar Junction Transistor(BJT))

A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.

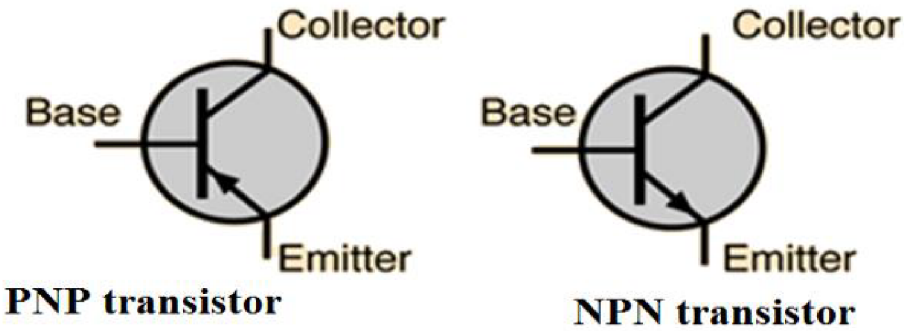
➢ A transistor has three terminal emitter , base and collector.

➢ There are two types of transistors

- P-N-P transistor
- N-P-N transistor

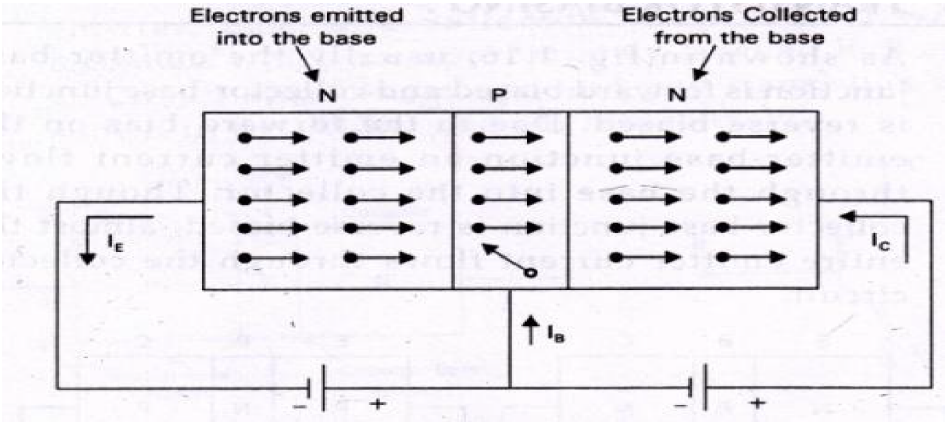


Symbol of a transistor



Working of NPN transistor

- Doping concentration Emitter>Collector>Base
- Width of regions Collector>Emitter>Base



- Consider an NPN transistor
- In an NPN transistor P type base is sandwiched between N type emitter and collector
- For normal operation the emitter-base junction is always forward biased while the collector-base junction is always reverse biased.

- Electrons are injected into the emitter region by the emitter bias supply (-ve voltage connected to emitter will repel electrons) . The electrons injected to the emitter enter to the base and only few electrons recombine with the holes in the base region and contributes base current

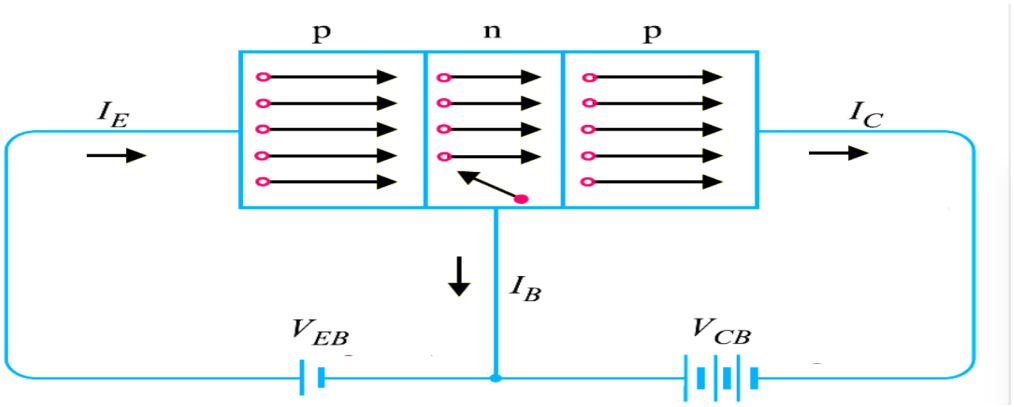
- Due to extremely small thickness and low doping concentration of base and most of the electrons cross into the collector region and contributes collector current. (The positive voltage connected to collector will attract majority of electrons)

- $I_E=I_B+I_C$

Working of PNP transistor

- Doping concentration Emitter>Collector>Base

- Width of regions Collector>Emitter>Base



- Consider an PNP transistor
- In an PNP transistor N type base is sandwiched between P type emitter and collector

- For normal operation the emitter-base junction is always forward biased while the collector-base junction is always reverse biased.

- Holes are injected into the emitter region by the emitter bias supply.(Positive voltage connected to emitter will repel holes) The holes injected to the emitter enter to the base and only few holes recombine with the electrons in the base region and contributes base current
- Due to extremely small thickness and low doping concentration of base , most of the holes cross into the collector region and contributes collector current. (The negative voltage connected to collector will attract majority of the holes)
- $I_E=I_B+I_C$

Applications of transistor

1.Used as amplifier in audio and video systems

2. Used in tuning circuits

3. Used in oscillator circuits

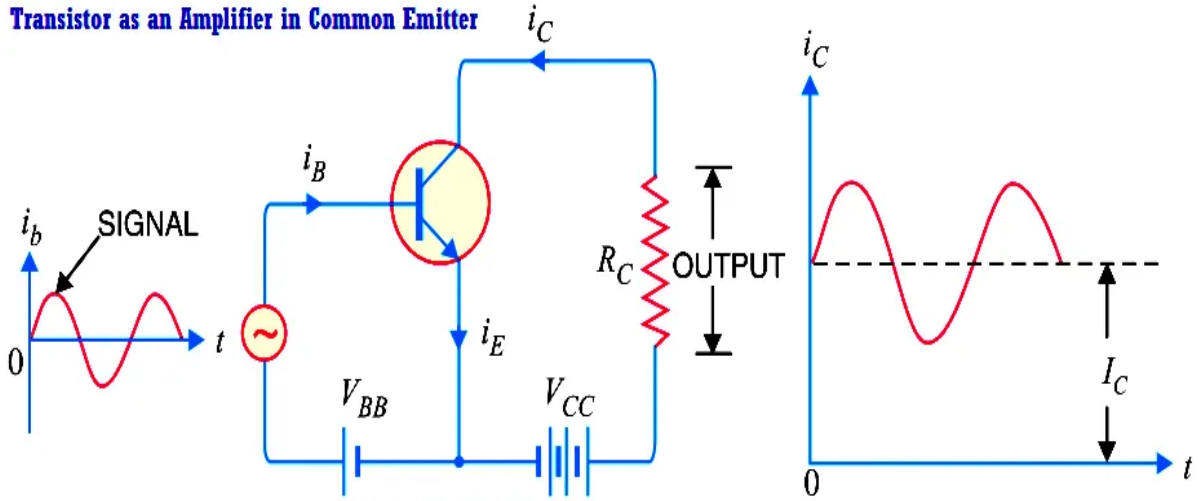
4. Used as a switch

5. Used in regulated power supply

6. Sensors in transducer

7. Voltage limiter, Clamping, Clipping etc

Transistor as amplifier



- Figure shows basic amplifier circuit with common emitter configuration with NPN transistor
- In the circuit battery VBB provides forward bias to emitter base junction and battery Vcc provides reverse bias to collector base junction
- This biasing is provided to make the transistor work in active region(to work as amplifier)
- Here base is input terminal and collector is output terminal
- This typical common emitter configuration has a current gain β usually in the range of 50

- ie; the collector current is β times base current
- ie; if i_B is 1 mA, i_C is 50mA
- ie;If we give a signal in input at base amplified form of input can be obtained at output(collector resistor)

Logic gates

A logic gate is an idealized or physical device implementing a Boolean function, a logical operation performed on one or more binary inputs that produces a single binary output.

The symbol and truth table of logic gates are as shown below

OR gate

➢ The OR gate performs logical addition.

➢ An OR gate has two or more input signals with only one output signal.

➢ In OR gate ,output voltage is high if any or all of the input voltages are high.

Symbol

Truth table

INPUT		OUTPUT
A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

AND gate

- The AND gate performs logical multiplication.
- An AND gate has two or more input signals with only one output signal.
- In AND gate ,output voltage is high only when all the input voltages are high.

• Symbol

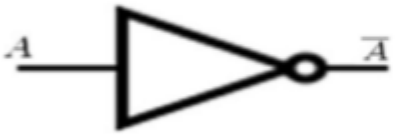
Truth table

INPUT		OUTPUT
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

NOT gate

- The NOT gate performs a basic logical function called inversion or complementation.
- The purpose of NOT gate is to change one logical level to the opposite level.
- This gate has only one input and one output
- It changes a 1 to 0 and vice-versa.

Symbol



Truth table

INPUT	OUTPUT
A	NOT A
0	1
1	0

NAND gate

- NAND = AND + NOT
- The NAND gate performs AND function with inverted output.
- In NAND gate , output voltage is low only when all the input voltages are high.

• Symbol

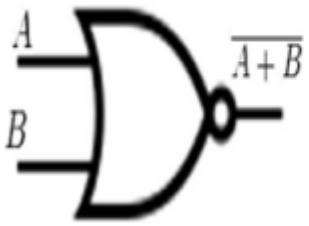
Truth table

INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

NOR gate

- NOR = OR + NOT
- The NOR gate performs OR function with inverted output.
- In NOR gate ,output voltage is high only when all the input voltages are low.

Symbol



Truth table

INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

XOR gate

XOR gate provides output when both inputs are different

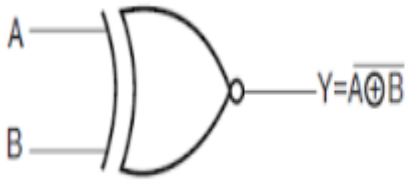
Symbol

Truth table

INPUT		OUTPUT
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

XNOR gate

XNOR gate provides output when both inputs are same



INPUT		OUTPUT
A	B	A XNOR B
0	0	1
0	1	0
1	0	0
1	1	1

- NAND and NOR gates are known as universal gates
- We can realise all logic functions such as AND,OR,NOT etc. using universal gates only

Applications of logic gates

- Logic gates are used in microprocessor microcontroller etc
- Most of the digital IC s use logic gate as fundamental component

- Logic gates are used in disc read write IC, Printer IC etc
- In digital control circuits logic gates are used for creating commands
- Smartphones and calculators use logic gate for their operation
- Computer, digital stopwatch etc uses digital ICs
- NAND Gates are used in Burglar alarms and buzzers
- They are also used in push button switches. E.g. Door Bell.
- They are used in the functioning of street lights.
- AND Gates are used to enable/inhibit the data transfer function.
- They are also used in TTL (Transistor Transistor Logic) and CMOS circuitry.