Solid State Devices:

What is a Resistor?

A passive two-terminal electronic component that opposes the flow of electric current.

- Unit of Measurement: Measured in Ohms (Ω)
- Core Law: Operates under Ohm's Law (V = I × R)

Key Functions in a Circuit

1. Current Limiting – Protects sensitive parts
2. Voltage Division – Creates specific reference levels
3. Biasing – Sets proper operating points for transistors

1. Fixed Resistors

Single, unchangeable resistance value determined during manufacturing.

Carbon Composition

Made from carbon dust mixed with ceramic binder. Traditional, inexpensive, but noisy and less stable over temperature shifts.

Carbon Film

Thin carbon layer spiral-cut onto a ceramic rod. Offers enhanced precision and stability over composition types.

Metal Film

Metal layer on ceramic substrate. Celebrated for high accuracy, extremely low noise, and excellent thermal stability.

Metal Oxide Film

Utilizes metal oxide film to survive significantly higher temperatures and power ratings than standard films.

Wirewound

Constructed by winding specialized alloy wire around an insulating core. Built for high-power handling and heavy heat dissipation.

Thin & Thick Film (SMD)

Compact layers designed directly for surface-mount technology (SMD) on modern printed circuit boards.

2. Variable Resistors

Allows manual or mechanical resistance adjustments across a defined range.

Potentiometers

Three-terminal device with a sliding mechanical wiper. Universally used as voltage dividers, volume controls, and dimmers.

Rheostats

Two-terminal variable configuration specifically engineered to handle and control high current flows (e.g., motor regulators).

Trimmer Resistors

Miniature preset variable units adjusted precisely during factory assembly or calibration using a mini screwdriver.

3. Non-Linear Resistors

Resistance dynamically responds to external physical or environmental shifts.

Thermistors (NTC/PTC)

Temperature-dependent resistors. NTC drops resistance as heat rises (sensors); PTC spikes resistance (protection).

Photoresistors (LDR)

Light-dependent components whose resistance plummets when exposed to bright light. Common in streetlights.

Varistors (MOV)

Voltage-clamping devices that suddenly drop resistance during sudden high voltage spikes, protecting sensitive tech.

What is an Inductor?

Definition: A passive two-terminal electrical component that stores electrical energy in a magnetic field when electric current flows through it.

Core Principle: Governed by Faraday's Law of Induction and Lenz's Law. Any variation in current induces an electromotive force (voltage) that opposes that change.

Measurement Unit: Inductance is measured and quantified in Henries (H).

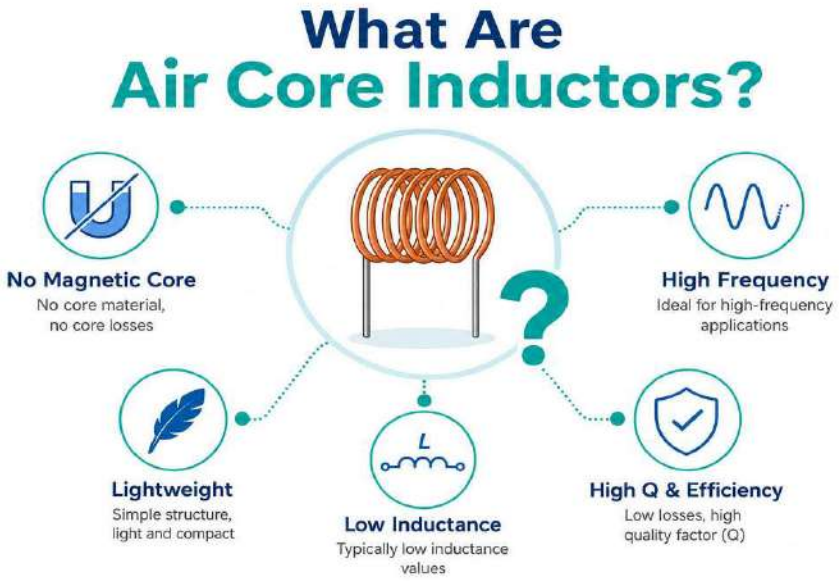
Common Names: Also frequently referred to as a coil, choke, or reactor depending on its application.

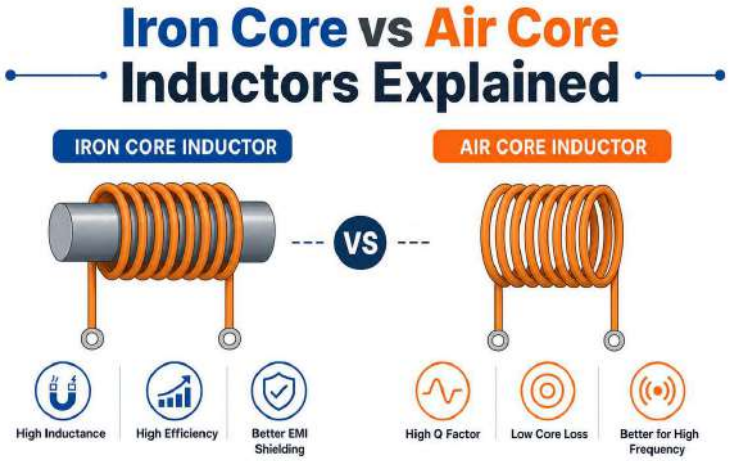
Types of Inductors (Core Material)

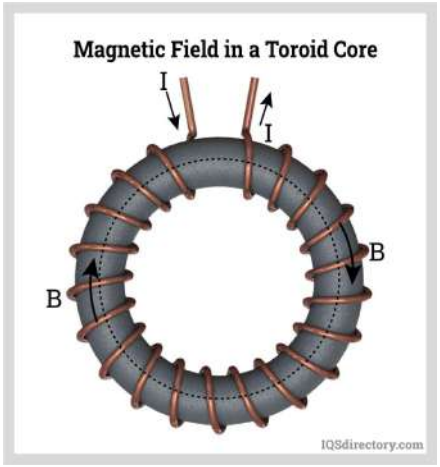
- **Air Core Inductors:** No solid magnetic core. Offers low inductance but excellent high-frequency response with minimal core losses. Perfect for RF circuits.
- **Iron Core Inductors:** Utilizes a solid iron core to achieve high inductance. Ideal for high-power, low-frequency applications like power supplies.
- **Ferrite Core Inductors:** Uses a magnetic ceramic ferrite material. Combines high magnetic permeability with very low energy (eddy current) losses at high frequencies.
- **Laminated Core Inductors:** Constructed using stacked thin sheets of electrical steel. The lamination layers break up electrical paths to dramatically minimize energy-wasting eddy currents.

Types of Inductors (Specialized Designs)

- **Toroidal Inductors:** Wound around a donut-shaped core. The closed-loop geometry tightly confines the magnetic field, significantly reducing electromagnetic interference (EMI).
- **Variable Inductors:** Equipped with an adjustable core (like a threaded ferrite slug). Shifting the core modifies the inductance value dynamically for tuning purposes.
- **SMD / Shielded Inductors:** Miniature variants tailored for surface-mount PCBs. Often encased in protective shields to reject or prevent external electronic noise.
- **Chokes:** A specialized class of inductors designed explicitly to block high-frequency alternating current (AC) while passing direct current (DC).


What Are
Air Core Inductors?
No Magnetic Core
No core material, no core losses
High Frequency
Ideal for high-frequency applications
Lightweight
Simple structure, light and compact
Low Inductance
Typically low inductance values
High Q & Efficiency
Low losses, high quality factor (Q)


Iron Core vs Air Core
Inductors Explained
IRON CORE INDUCTOR
AIR CORE INDUCTOR
VS
High Inductance
High Efficiency
Better EMI Shielding
High Q Factor
Low Core Loss
Better for High Frequency


Magnetic Field in a Toroid Core
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IQSdirectory.com

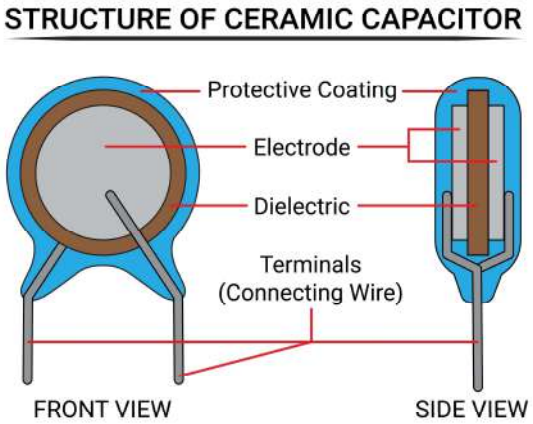


What is a Capacitor?

- **Definition:** A passive, two-terminal electronic component designed to store electrical energy in an electrostatic field.
- **Energy Release:** Unlike a battery (which relies on slow chemical reactions), a capacitor stores electric charge statically and discharges almost instantly.
- **Capacitance (C):** The ability to accumulate electric charge, measured in Farads (F). Expressed mathematically as: $C = Q / V$ (where Q is charge in Coulombs, V is voltage).

Construction & Working Principle

- **Core Structure:** Consists of two parallel conducting metal plates separated by an insulating layer called the dielectric.
- **Charging Process:** When connected to a voltage source, negative charges (electrons) migrate to one plate, leaving the opposite plate positively charged.
- **Electric Field:** This build-up forms an electric field across the dielectric material, holding the static charge securely until it is discharged into a circuit.

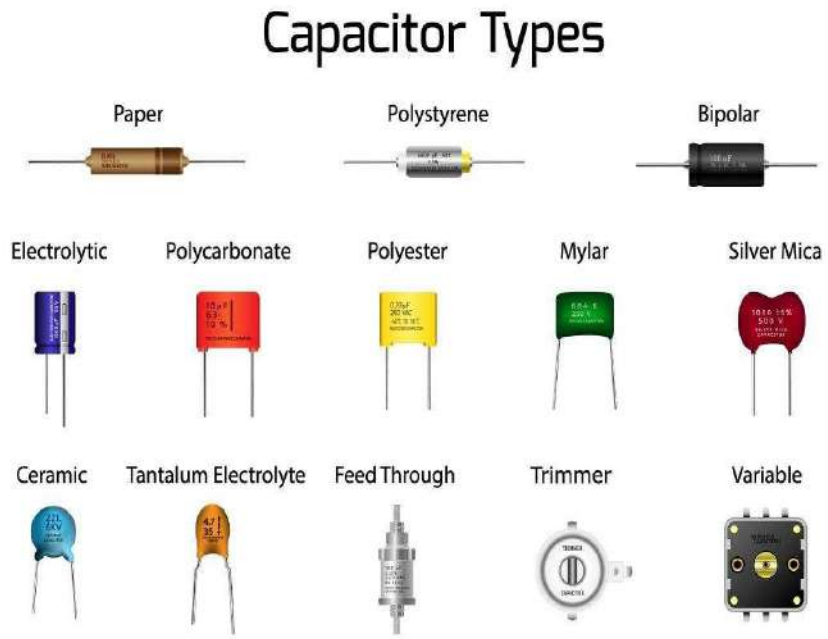


Main Classifications

Capacitors are broadly divided into two structural categories:

- **Fixed Capacitors:** Possess a preset, unchangeable value. Divided into Polarized (strict + and - terminals; risk of bursting if reversed) and Non-polarized (can connect either way; ideal for AC paths).

- **Variable Capacitors:** Feature mechanical or electronic mechanisms to adjust capacitance dynamically. Essential for radio tuning and frequency matching.



Common Types of Capacitors

Type	Polarized?	Key Attributes & Common Uses
Ceramic	Non-polarized	Compact, cost-effective, high frequency limits. Used for noise filtering, coupling, and decoupling signals.
Electrolytic	Polarized	High capacitance density but lower voltage resilience. Deployed for smoothing power supply ripples.
Tantalum	Polarized	High volumetric efficiency, stable, highly reliable. Favored in space-restricted surface-mount circuits.
Film	Non-polarized	Highly stable, highly accurate, low losses. Heavily used in audio systems and precision timing modules.
Variable	Non-polarized	Overlapping plates rotate to alter value. Critical for tuning transmitters and radio receivers.

DIODES: UNDERSTANDING THE ONE-WAY VALVE

A two-terminal electronic component that conducts electric current in only one direction (Anode to Cathode).

OPERATING BIASES

Forward Bias

Anode connected to (+) voltage, Cathode to (-). The internal barrier drops, allowing current to flow easily.

Reverse Bias

Polarity is reversed. The internal barrier widens, blocking almost all current flow up to its specific breakdown limit.

6 MAJOR TYPES OF DIODES

Light-Emitting Diode (LED)

Converts electrical energy directly into visible or infrared light when forward-biased.

Photodiode

Operates in reverse bias to convert incoming light energy (photons) into electrical current.

P-N Junction / Rectifier

Converts alternating current (AC) into steady direct current (DC).

Zener Diode

Operates safely in reverse bias to provide a reliable, steady reference voltage.

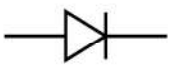
Schottky Diode

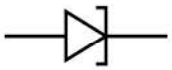
Features ultra-fast switching speeds and a very low forward voltage drop (0.15V-0.45V).

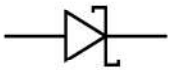
Varactor Diode

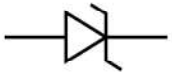
Acts as a voltage-controlled variable capacitor, ideal for tuning RF circuits.

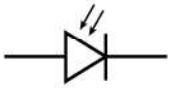
TYPES OF DIODES


Diode


Tunnel Diode


Schottky Diode

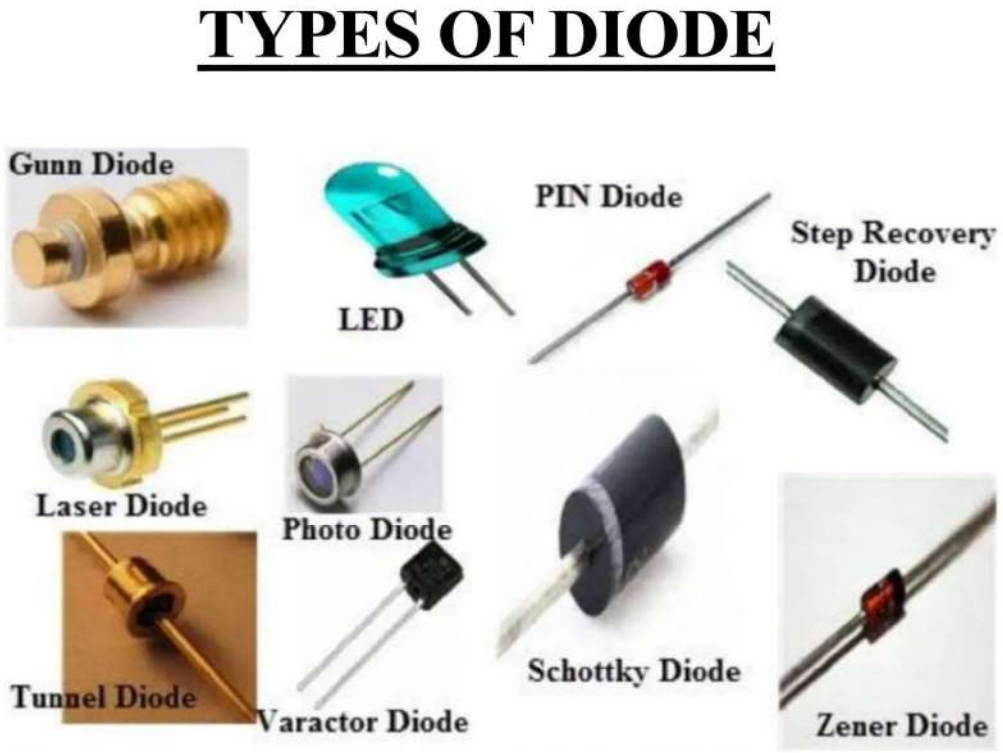

Zener Diode


Photodiode


Laser Diode


Varactor Diode


Current Regulator Diode

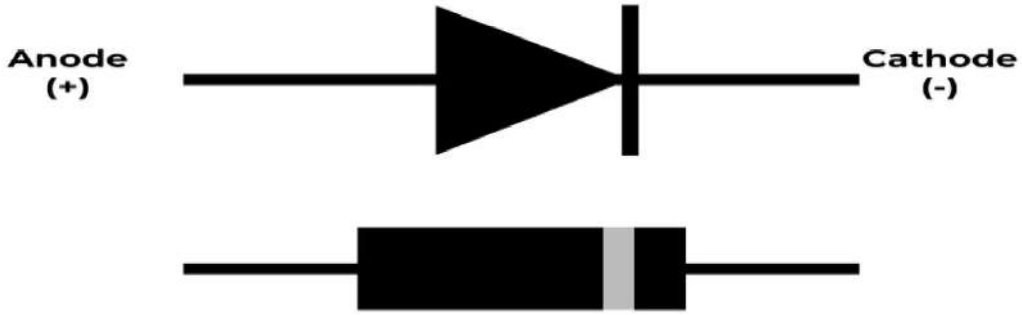


P-N JUNCTION DIODE

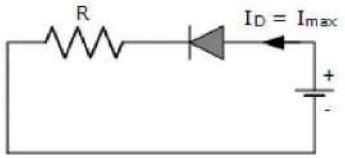
P-N junction diodes also called rectifier diodes are used for the rectification process. In a P-N junction diode, two layers of semiconductors materials are used.

For a P-N junction diode, one layer is made of P-type semiconductor material and the other layer of N-type material. The combination of these two layers forms a junction known as the P-N junction. Thus, the name comes P-N junction diode.

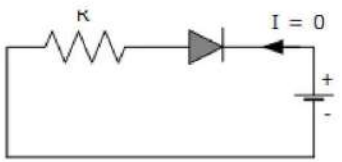
Representation Symbol of a Diode



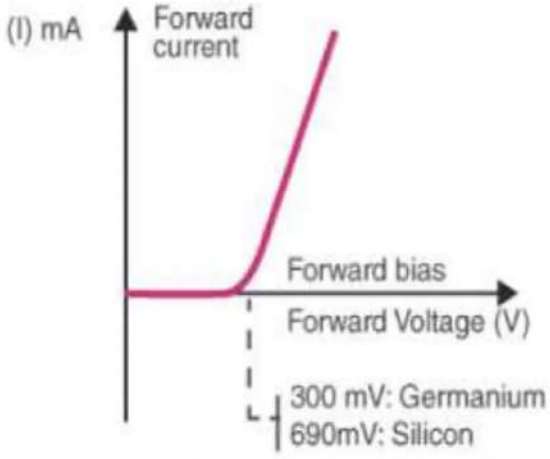
V-I CHARACTERISTICS OF P-N JUNCTION DIODE



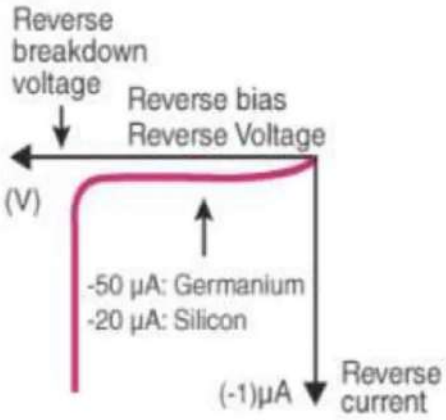
Forward Biased Diode



Reversed Biased Diode

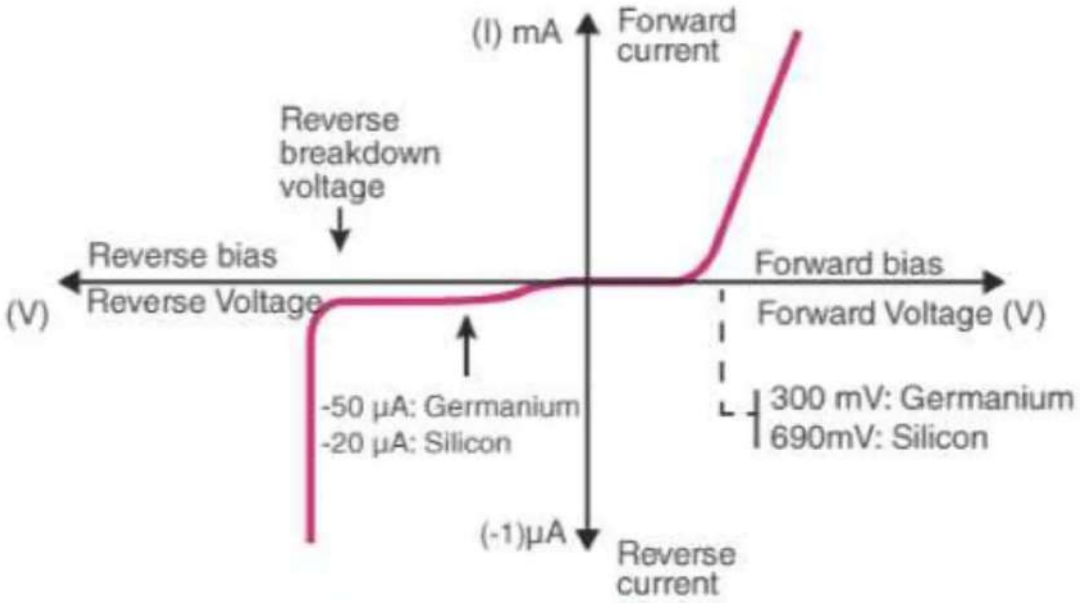


Forward-biased diode



Reverse-biased diode

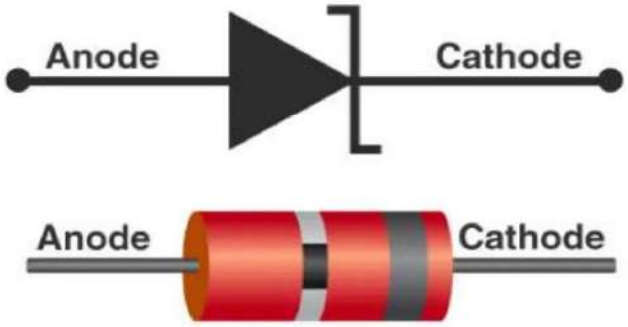
V-I CHARACTERISTICS OF P-N JUNCTION DIODE



VI characteristics of Diode

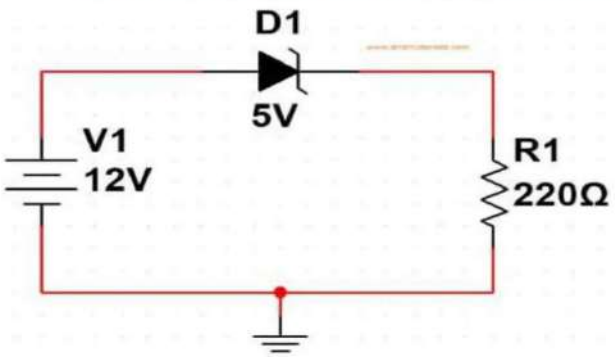
ZENER DIODE

- **Zener Diode is recognized as a semiconductor device which allows the flow of current in both directions (forward and reverse).**
- **It is a diode which works in reverse bias conditions.**
- **A Zener diode which is also called a Breakdown diode works in reverse bias conditions.**

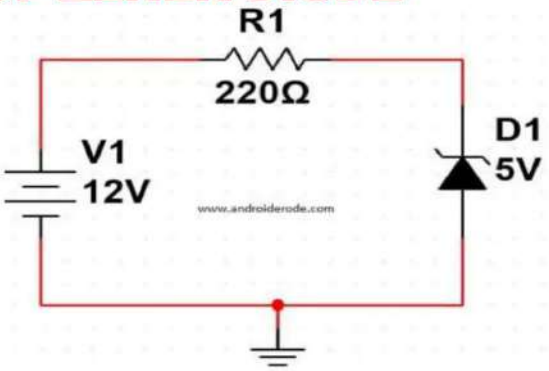


(Zener diode)

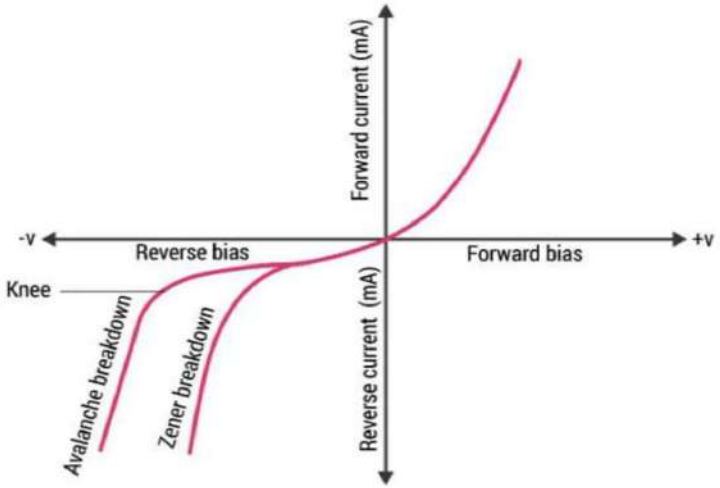
V-I CHARACTERISTICS OF ZENER DIODE



Forward Biased Diode



Reverse Biased Diode



BREAKDOWNS OCCUR FOR ZENER DIODE

- Avalanche Breakdown
- Zener Breakdown

Avalanche Breakdown

- The phenomenon of Avalanche breakdown occurs both in the ordinary diode and Zener Diode at high reverse voltage.
- If the reverse voltage is greater than 8V the avalanche breakdown happens in the Zener diode.
- For a high value of reverse voltage, the free electron in the PN junction diode gains energy and acquires high velocity and these high-velocity electrons collide with other atoms and knock electrons from that atoms.
- This collision continues and new electrons are available for conducting current thus the current increase rapidly in the diode.
- This phenomenon of a sudden increase in the current is called the **Avalanche breakdown.**

Zener Breakdown

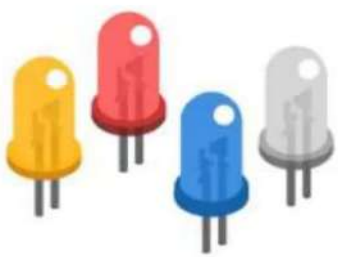
- Zener breakdown happens in heavily doped PN junction diodes.
- Zener breakdown is observed in Zener diode having Vz less than 5v or between 5 to 8V.
- In these diodes, if the reverse bias voltages reach closer to Zener Voltage, the electric field gets stronger and is sufficient enough to pull electrons from the valance band.
- These electrons then gain energy from the electric field and break free from the atom.
- Thus, for these diodes in the Zener breakdown region, a slight increase in the voltage causes a sudden increase in the current.

LIGHT EMITTING DIODE (LED)

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it.

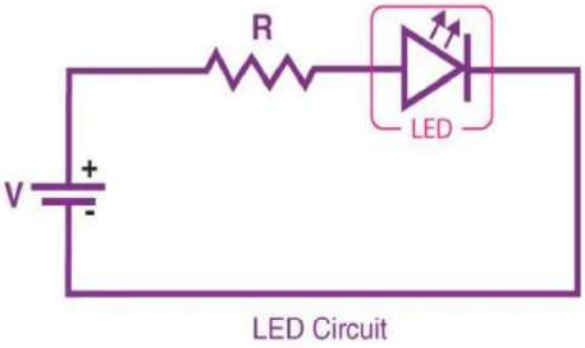
When current passes through an LED, the electrons recombine with holes emitting light in the process.

LEDs allow the current to flow in the forward direction and blocks the current in the reverse direction.

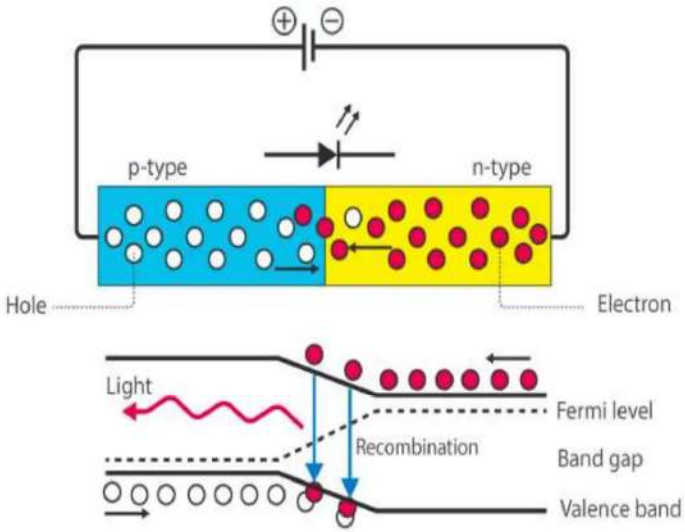




How does an LED work?



LED Circuit



WHAT DETERMINES THE COLOUR OF AN LED?

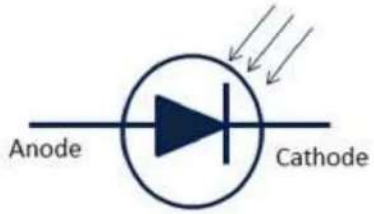
- The colour of an LED is determined by the material used in the semiconducting element.
- Aluminium alloys are used to obtain red, orange and yellow light, and indium alloys are used to get green, blue and white light.

Uses of LED

- Used for TV back-lighting
- Used in displays
- Used in Automotives
- LEDs used in the dimming of lights

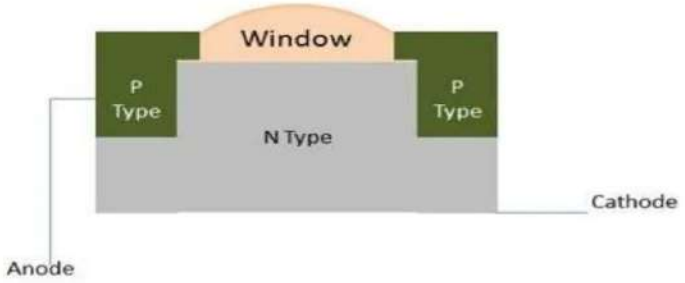
PHOTODIODE

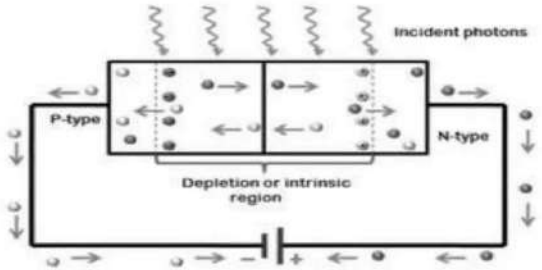
- **A photodiode is a PN-junction diode that consumes light energy to produce an electric current. it is also called a photo-detector, a light detector, and photo-sensor.**
- **Photodiodes are designed to work in reverse bias condition.**
- **This diode is very sensitive to light so when light falls on the diode it easily changes light into an electric current.**



Symbol of Photo Diode

WORKING OF PHOTODIODE





Photodiode Working Principle

- It is a **reverse-biased diode**. Reverse current increases as the intensity of incident light increases.
- It consists of a PN junction mounted on a P-type substrate and sealed in a metallic case. The junction point is made of transparent lens and it is the window where the light is supposed to fall.
- when PN junction diode is reverse biased, a very small amount of reverse current flows. The reverse current is generated thermally by electron-hole pairs in the depletion region of the diode.
- When light falls on PN junction, it is absorbed by the junction. This will generate more electron-hole pairs.

TYPES OF PHOTODIODE

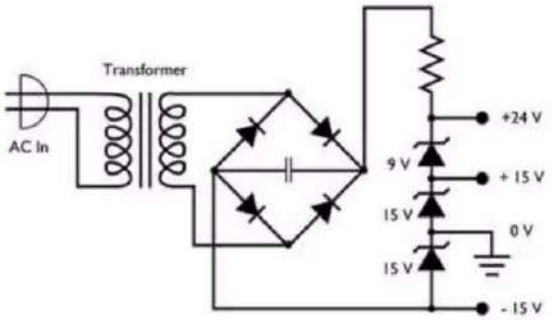
- **PN Photodiode**
- **Schottky Photo Diode**
- **PIN Photodiode**
- **Avalanche Photodiode**

APPLICATIONS OF PHOTODIODE

- Photodiodes are used in solar cell panels.
- Photodiodes are faster and more complex than normal PN junction diodes and hence are frequently used for lighting regulation and optical communication.
- Photodiodes are used in safety electronics such as fire and smoke detectors.
- Photodiodes are used in numerous medical applications.

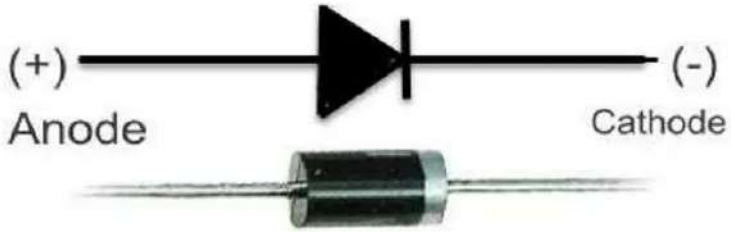
Basic of Rectifiers

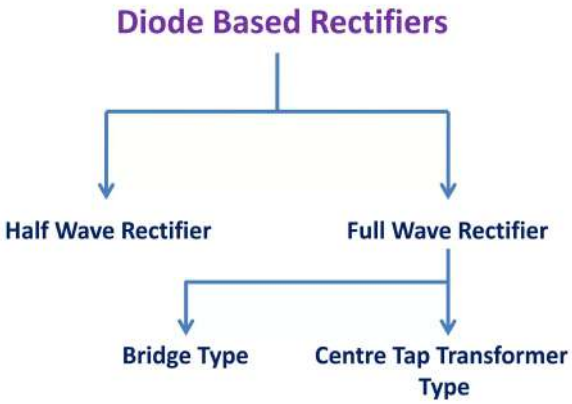
The presentation focus on the basics of rectifier.



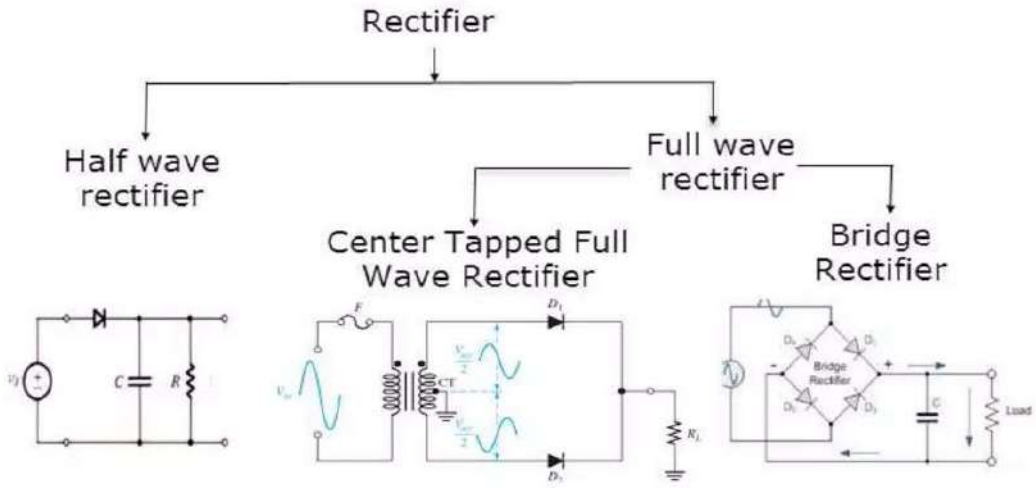
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Weber State University.
EMT212/4 - Analogue Electronic II
Courtesy : Google images



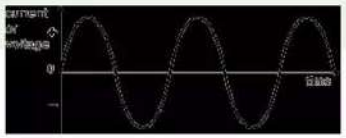
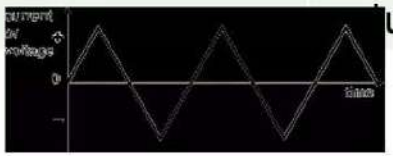


- A rectifier is a circuit which converts the Alternating Current (AC) input power into a Direct Current (DC) output power.
- Diode and SCR are primarily used in rectifier circuits.



Difference between AC and DC signals.

AC (Alternating current)	DC (Direct Current)
AC signal Flows one way, then the other way, continually reversing direction.	Direct Current signal always flows in the same direction, but it may increase and decrease.
Continually changing between positive (+) and negative (-).	A DC signal is always positive (or always negative), but it may increase and decrease.
Rate of changing direction is called the **frequency** of the AC and it is measured in **hertz (Hz)**.	Frequency is zero.
Average value of signal is zero.	It will always have average value.

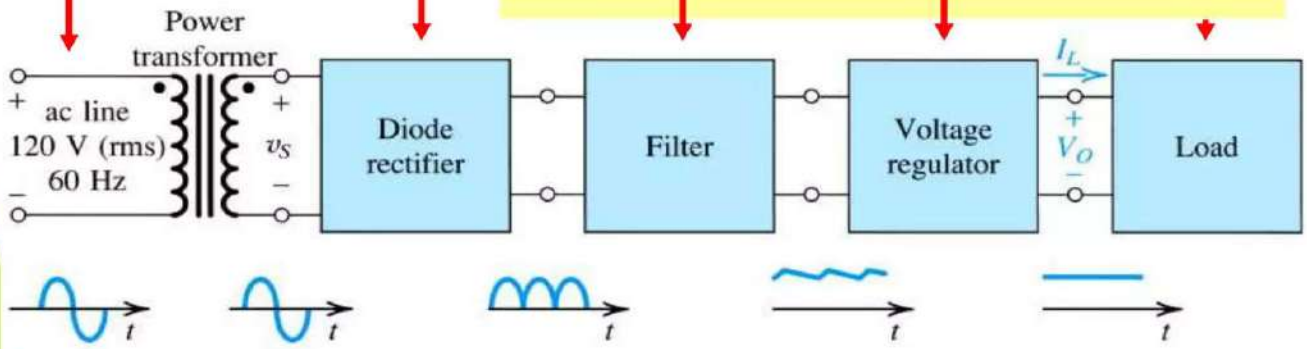

step #1: increase / decrease rms magnitude of AC wave using transformer

step #2: convert full-wave AC to half-wave DC (still time-varying and periodic)

step #3: employ low-pass filter to reduce ripple component by > 90%

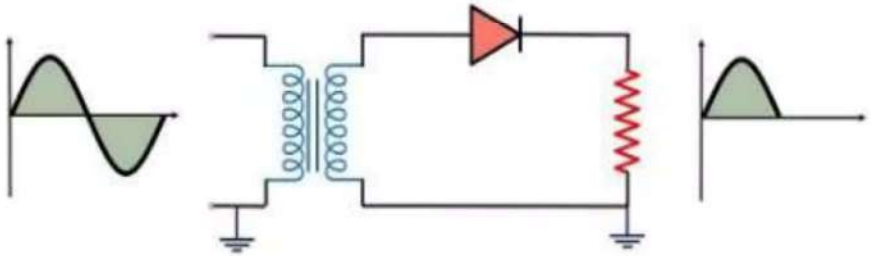
step #4: employ voltage regulator to eliminate ripple

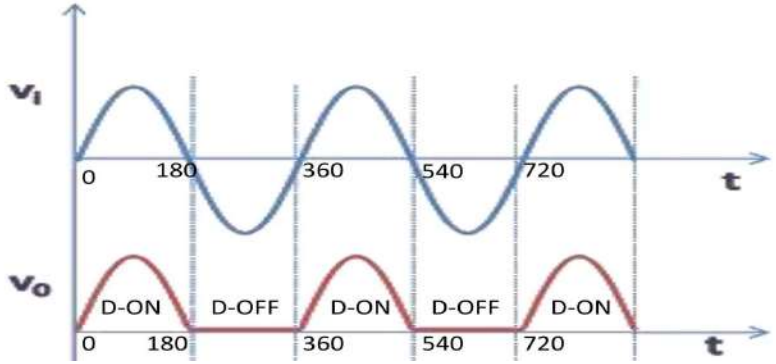
step #5: supply dc load



Half Wave Rectifier (HWR)

- Half-wave rectifiers are used to c**onvert AC voltage to DC voltage,** and it required a single diode to construct the circuit.
- The diode only conducts when the anode is positive with respect to cathode, the current will flows only during the positive half cycle of the inpu voltage i.e., **current flow in one direction.**





Working of half wave rectifier

- AC voltage is applied to the primary winding of the **step-down transformer** which step-down to low voltage at the secondary winding which will be applied to the diode.
- During the positive half cycle of the AC voltage, **the diode will be forward biased** and the **current flows through the diode**.
- During the negative half cycle of the AC voltage, the **diode will be reverse biased** and the **flow of current will be blocked**.

Half wave rectifier

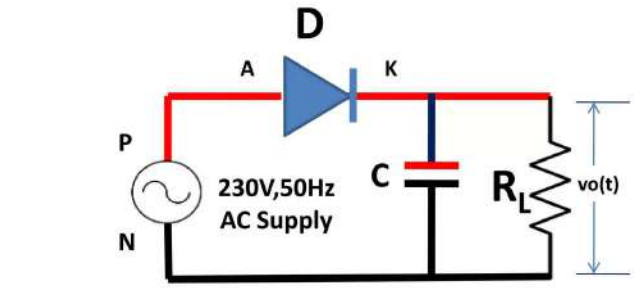
Advantage:

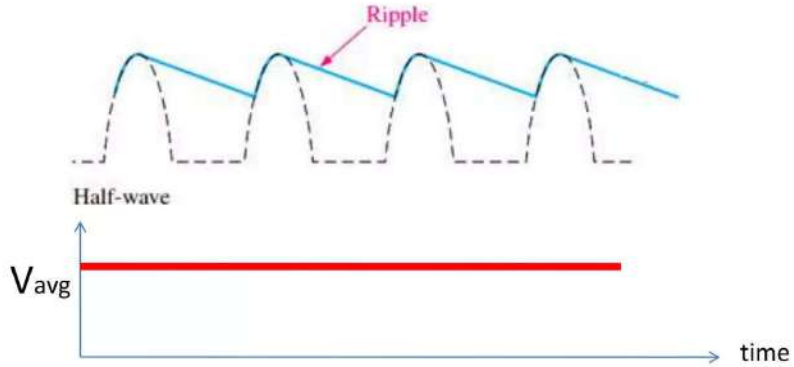
- Simple in circuit construction.
- Cost efficient.

Disadvantage:

- Filters are required to get pure DC.
- AC supply delivers power during half cycle only. So output is low.
- Ripple factor is quite high (RF=1.21) than full wave rectifier
- Efficiency is 40.6% only.

Half Wave Rectifier With Filter





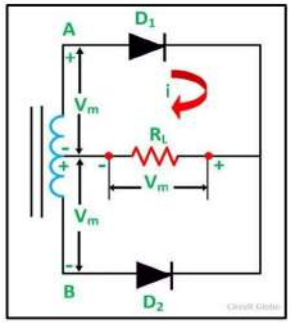
Full wave rectifier

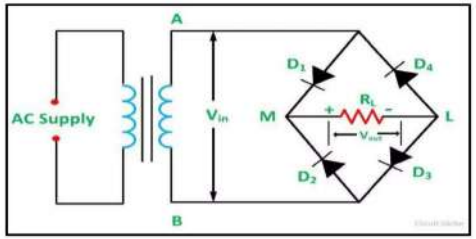
- A **Full Wave Rectifier** is a circuit, which converts an ac voltage into a pulsating dc voltage using both half cycles of the applied ac voltage.
- It uses two diodes of which one conducts during one half cycle while the other conducts during the other half cycle of the applied ac voltage.

Full wave rectifier

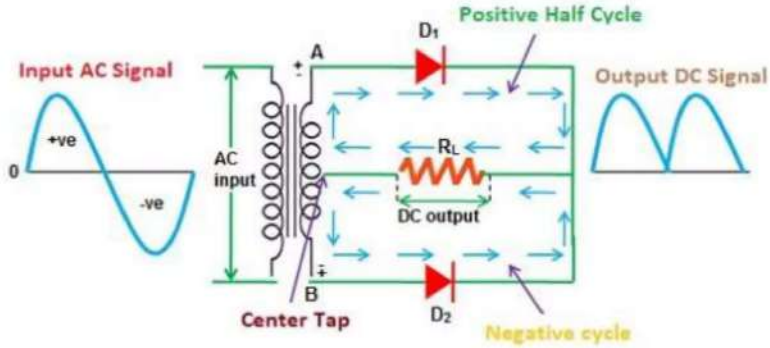
Classification **full wave rectifiers** into,

- Centre-tapped Full Wave Rectifier
- Full Wave Bridge Rectifier





Full wave rectifier with center-tapped transformer



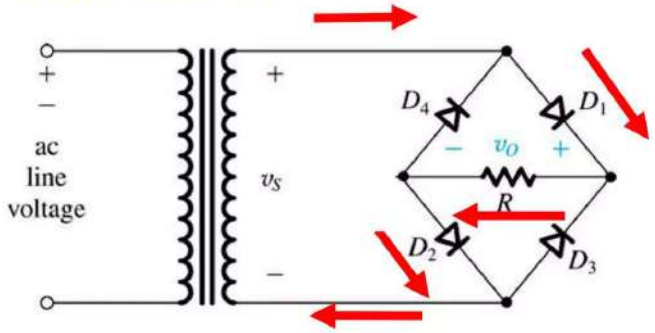
Full wave rectifier with center-tapped transformer

Centre-tapped Transformer:

- It is a normal transformer with slight modification.
- It has an addition wire connected to the exact centre of the secondary winding.
- This type of construction divides the AC voltage into two equal and opposite voltages namely **+Ve** voltage **(V_a)** and **-Ve** voltage **(V_b).**
- The total output voltage is,

$$V = V_a + V_b$$

Bridge Rectifier

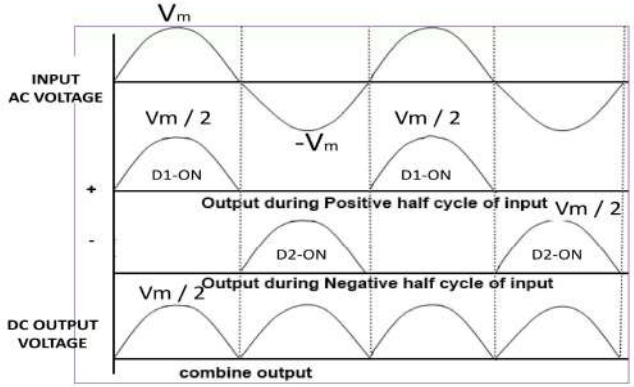


PIV = Vm
Ripple frequency = 100 Hz

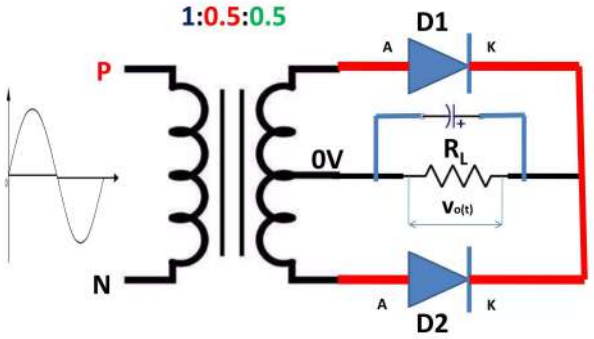
- An alternative implementation of the full-wave rectifier is **bridge rectifier**
- Does not require center-tapped transformer
- Four diodes instead of two

when source voltage is positive, D_1 and D_2 conduct while D_3 *and* D_4 block
when source voltage is negative, D_3 and D_4 conduct while D_1 *and* D_2 block

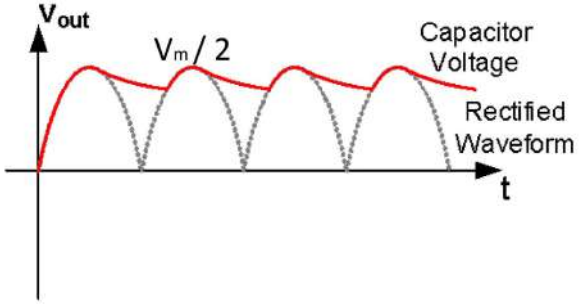
Waveforms



FWR with Filter



FWR Output with Filter



Full wave rectifier

Advantages:

- Efficiency is higher (η =81.2%)
- Low power loss because no voltage signal is wasted in the rectification process.
- Produces large DC power output
- Ripple factor is less.

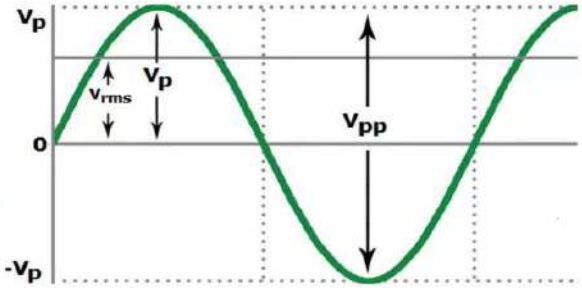
Disadvantages:

- The centre-tapped rectifier is more expensive than half-wave rectifier and tends to occupy a lot of space.
- Peak Inverse Voltage(PIV) rating of diode is higher.

Comparison of Rectifiers

Properties	Half Wave Rectifier	Full Wave Center Tap Rectifier	Full Wave Bridge Rectifier
Number of Diodes	1	2	4
D.C Current	Im / π	2 Im / π	2 Im / π
Transformer Necessary	No	Yes	No
Max Value of Current	Vm / (rf + RL)	Vm / (rf + RL)	Vm / (2rf + RL)
Ripple Factor	1.21	0.482	0.482
O/P Frequency	fin	2 fin	2 fin
Max Efficiency	40.6%	81.2%	81.2%
Peak Inverse Voltage	Vm	2 Vm	Vm

Relationship between Peak-to-peak and rms value.



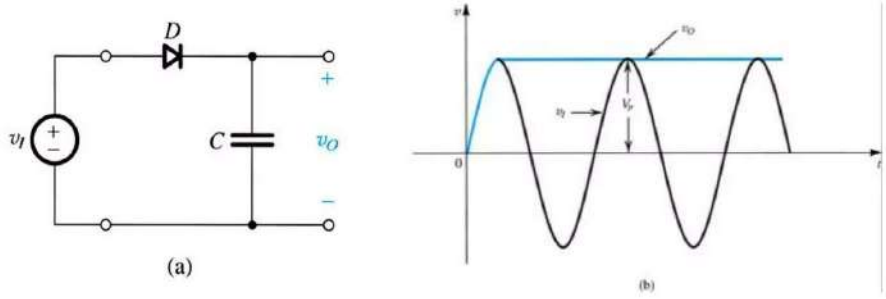
$$V_{rms} = \frac{1}{\sqrt{2}} * V_p = 0.7071 * V_p$$

$$V_{rms} = \frac{1}{2\sqrt{2}} * V_{pp} = 0.35355 * V_{pp}$$

$$V_{rms} = \frac{\pi}{2\sqrt{2}} * V_{avg} = 1.1107 * V_{avg}$$

The Rectifier with a Filter Capacitor

- Filters are required to remove the ripple components so as to get regulated dc output voltage free from unwanted ac components.
  - Mainly passive components like Capacitors, Inductors and their combination are used in filter circuits.



- Why is this example unrealistic?
- Because for any practical application, the converter would supply a load (which in turn provides a path for capacitor discharging)

The PIV for the above capacitor filter is $2Vm$.

