BASIC ELECTRONICS

ANANDA CHAITANYA TRAINING ACADEMY

PREFACE

Ananda Chaitanya Foundation, founded by Shri.Thillai Senthil Prabu, is committed to enhancing the well-being of individuals and communities through a range of transformative initiatives. These projects span education, skill development, spiritual growth, and healthcare, creating a holistic approach to societal upliftment.

Under the guidance of Shri. Thillai Senthil Prabu this book is compiled by Ananda Chaitanya Foundation's ACTA team member Shri.Rajamurugan.K .

This handbook on Basics of Electronics is useful for the Students and working professionals to advance their careers and strengthen their foundational understanding of electronics .

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CHAPTER – I BASIC ELECTRONICS

TERMS/ CONCEPT OF BASIC ELECTRONICS

This control of electrons is accomplished by devices (electronic components) that resist, carry, select, steer, switch, store, manipulate, and exploit the electron.

Electronics is the branch of science that deals with the study of flow and control of electrons (electricity) and the study of their behavior and effects in vacuums, gases, and semiconductors, and with devices using such electrons.

FUNDAMENTALS OF BASIC ELECTRONICS

Current, voltage, and resistance are the three basic building blocks of electrical and electronics. They are called electrical quantities.

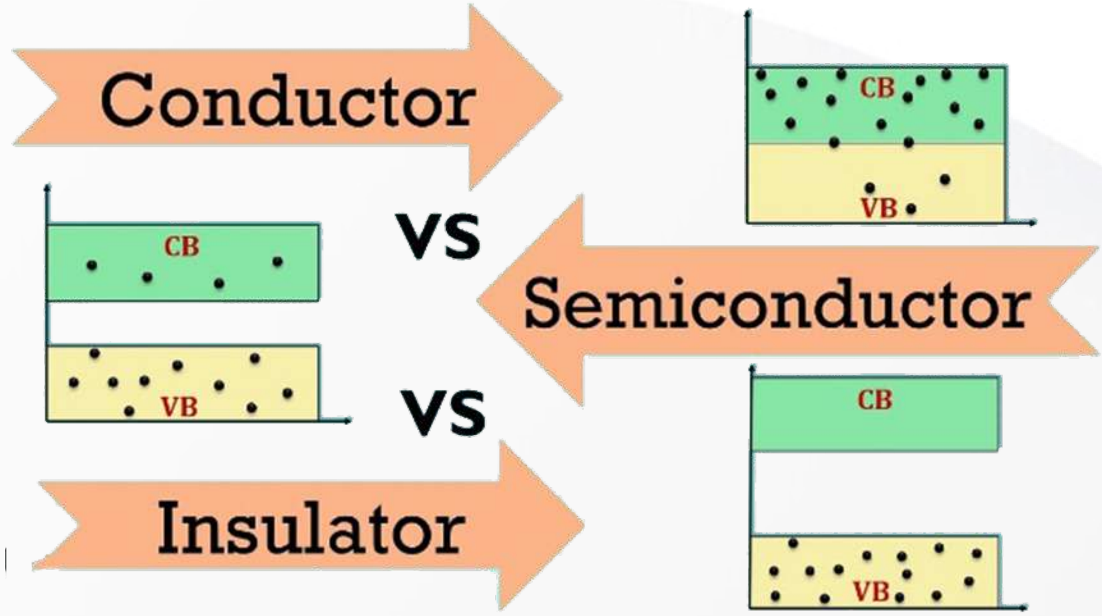
Conductors

The material in which the electrons are loosely held can move very easily. These are called conductors. Metals like copper, aluminum, and steel are good conductors of electricity.

Insulators

The materials which hold their electrons very tightly do not allow the movement of the electrons through them very well. These are called insulators. Rubber, plastic, cloth, glass, and dry air are good insulators and have very high resistance.

The conductors are used to carry electrical current through wires. Insulators are commonly used as coating for the wires.



Semiconductor

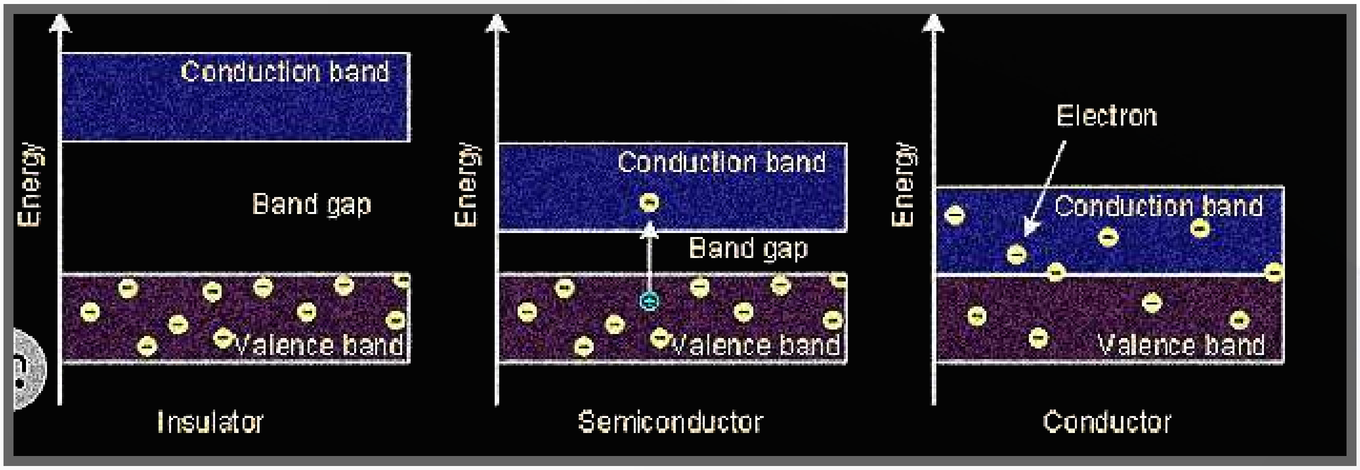
These are materials whose conductivity is between that of conductors and insulators. Electronic devices are made up of semiconductor material. In semiconductor industry, silicon and germanium are used.

Semiconductors are of two types, which are as follows: Intrinsic (pure) It is the pure form of semiconductor. The 'pure' word here represents that this semiconductor does not contain any other impurity atom.

Extrinsic (impure) It is an impure form of semiconductor. When impurity atoms are added in the pure (intrinsic) form of semiconductor, then that semiconductor is known as extrinsic semiconductor. The extrinsic semiconductors are also known as impure semiconductors.

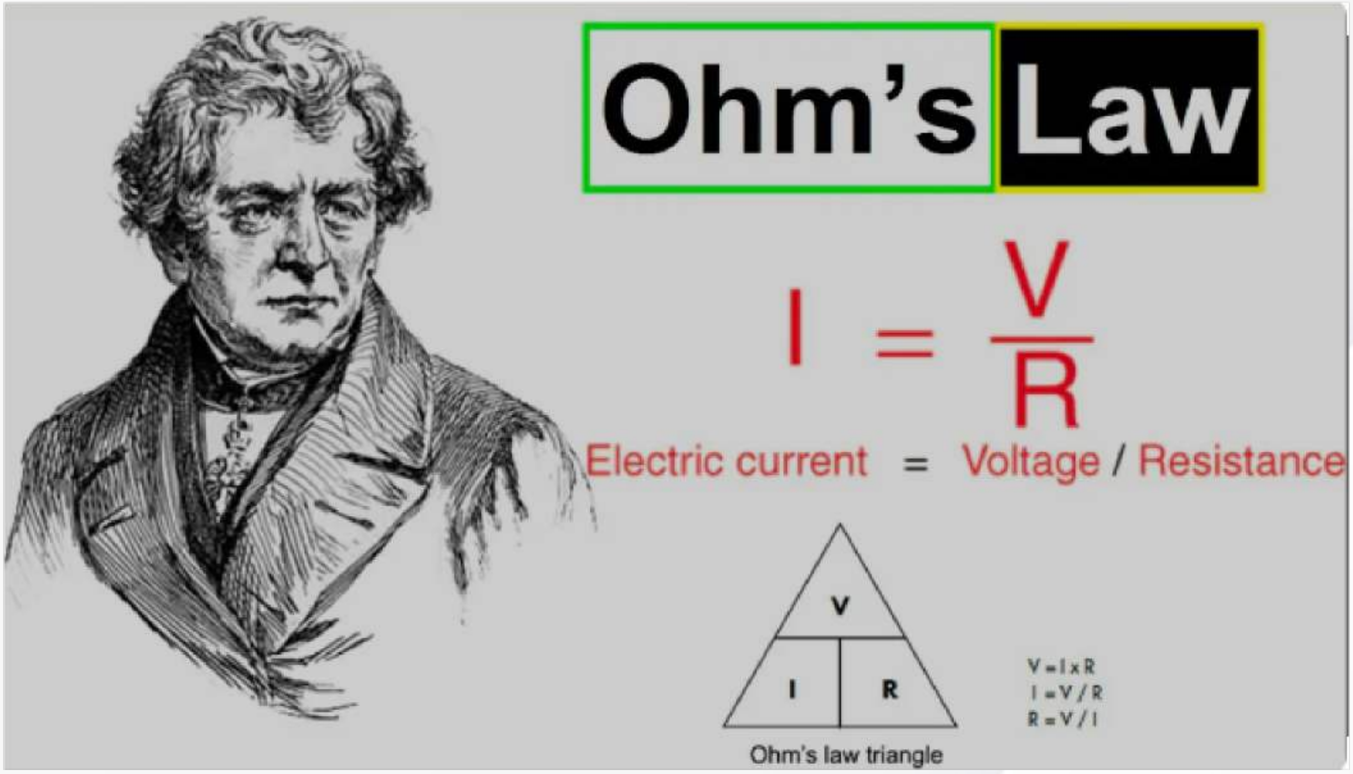
P-type semiconductor: When pentavalent impurity atom is added, an extrinsic semiconductor is formed which is known as P-type semiconductor.

N-type semiconductor: When trivalent impurity atom is added, an extrinsic semiconductor is formed which is known as N-type semiconductor.



PRINCIPLES OF ELECTRONICS

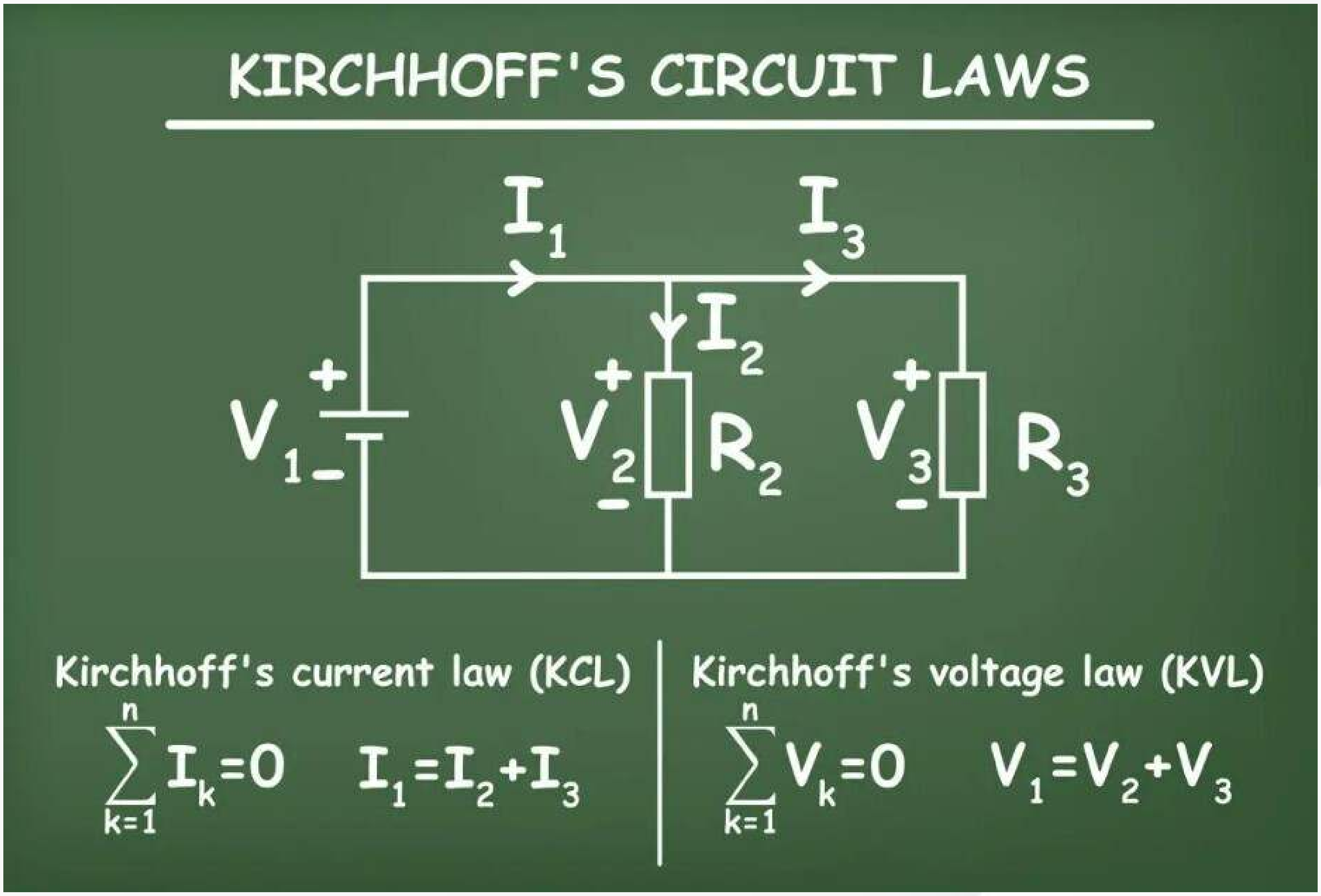
Ohm's Law is a fundamental principle in electronic circuit design. It states that the current through a conductor between two points is directly proportional to the voltage across the two points. Mathematically, this is expressed as I = V/R, where I is the current in amperes, V is the voltage in volts, and R is the resistance in ohms.



Kirchhoff's Laws

Kirchhoff's Laws are two laws that are used to analyse circuits. The first law, known as Kirchhoff's Current Law (KCL), states that the sum of the currents entering a node in a circuit is equal to the sum of the currents leaving the node. The second law, known as Kirchhoff's Voltage Law (KVL), states that the sum of the voltages around any closed loop in a circuit is zero.

Using these laws, it is possible to analyse and solve complex circuits. By applying Ohm's Law, the voltage, current, and resistance of each component can be determined. Then, by applying KCL and KVL, the relationships between the components can be determined and used to solve for any unknown values.

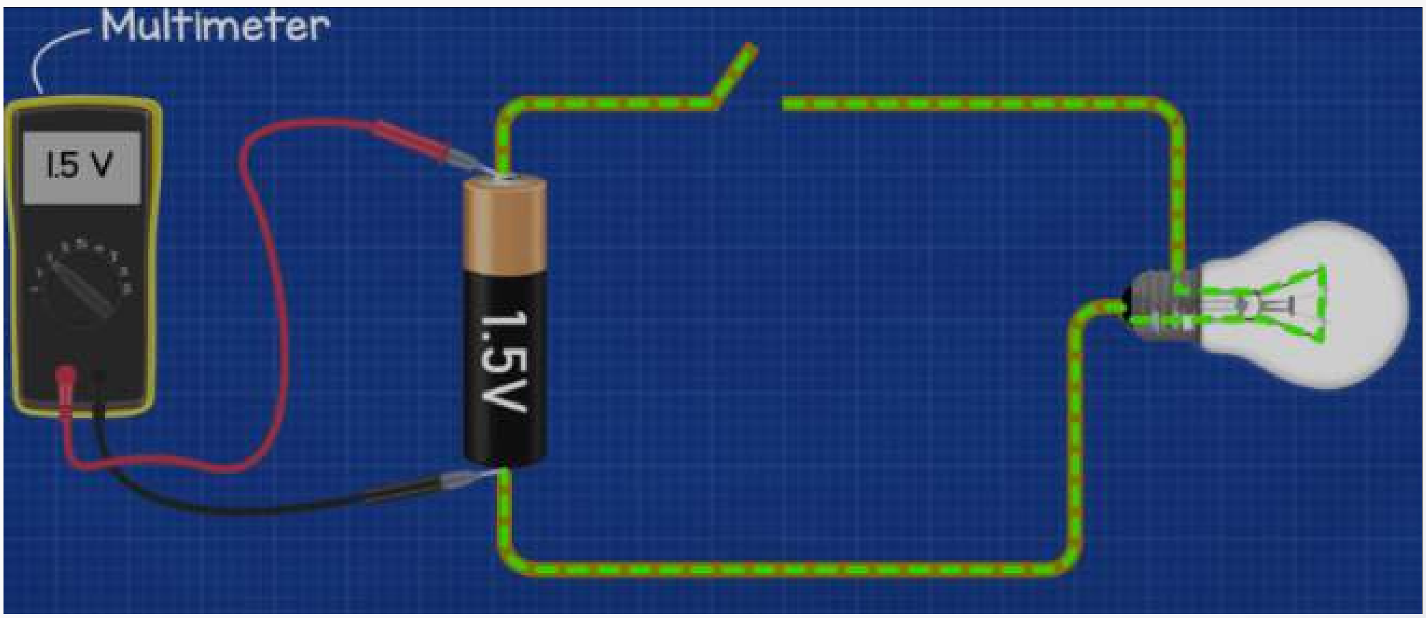


DEFINITION OF CURRENT & VOLTAGE

VOLTAGE

Voltage is the potential difference in charge between two points in an electrical field. Voltage is also known as electromotive force.

The SI unit of voltage is Volts (V). Voltage is denoted by “V”.



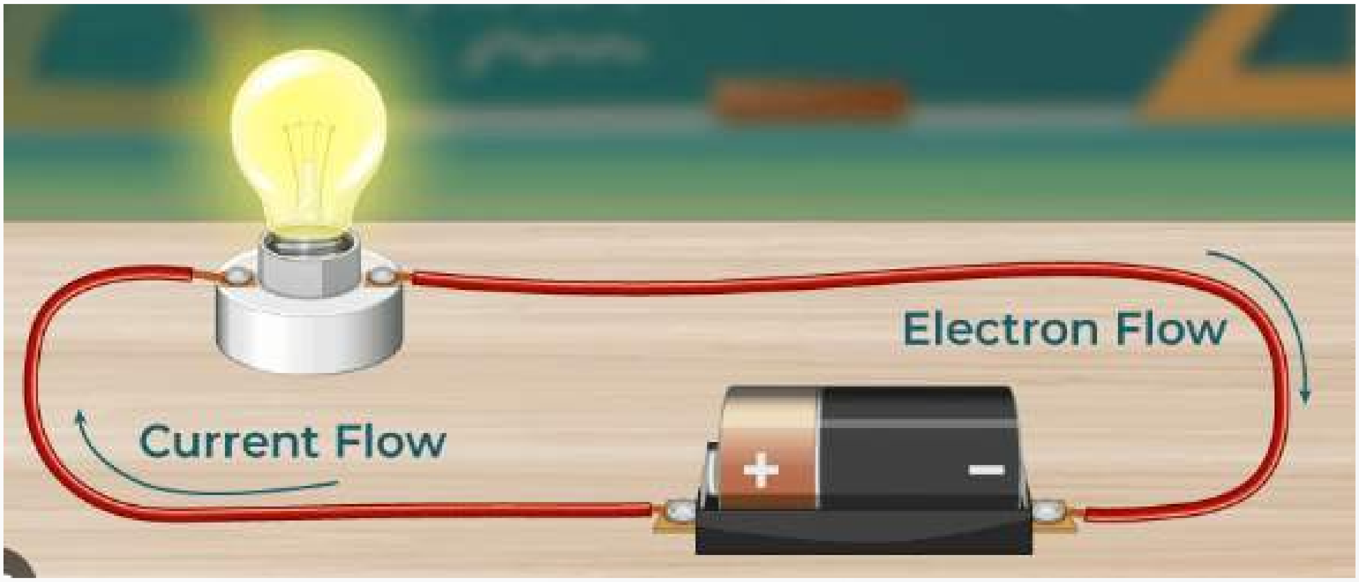
1 Volt= 1 Joule/coulomb (or) V= Work done/Charge

CURRENT

Current is the rate of flow of electric charge. In simple words, the current is the rate at which electric charge flows in a circuit at a particular point.

The SI unit of current is Ampere (A). Current is denoted by “I”.

1 Ampere = 1 coulomb/second or I= Charge/ Time



APPLICATIONS OF ELECTRONICS

Power electronics

This branch of electronics deals with the conversion, control, and conditioning of electric power.

Medical equipment

Electronics are used in the medical industry for control, diagnostics, and treatment systems.

Photovoltaics

Also known as solar cells, these solid-state semiconductor devices convert light into direct-current electricity.

DC-DC converters

These converters provide power to communication backbones, digital devices, and electric cars.

Defence and aerospace

Electronics technology is used in missile launching systems, cockpit controllers, military radars, aircraft systems, and rocket launchers.

Information processing

Electronics are used in information processing, communications, and signal processing.

Mechatronics

This technology combines mechanical, electronics, and software engineering. It is found in many electronic devices, including washing machines and airplanes.

Polymers

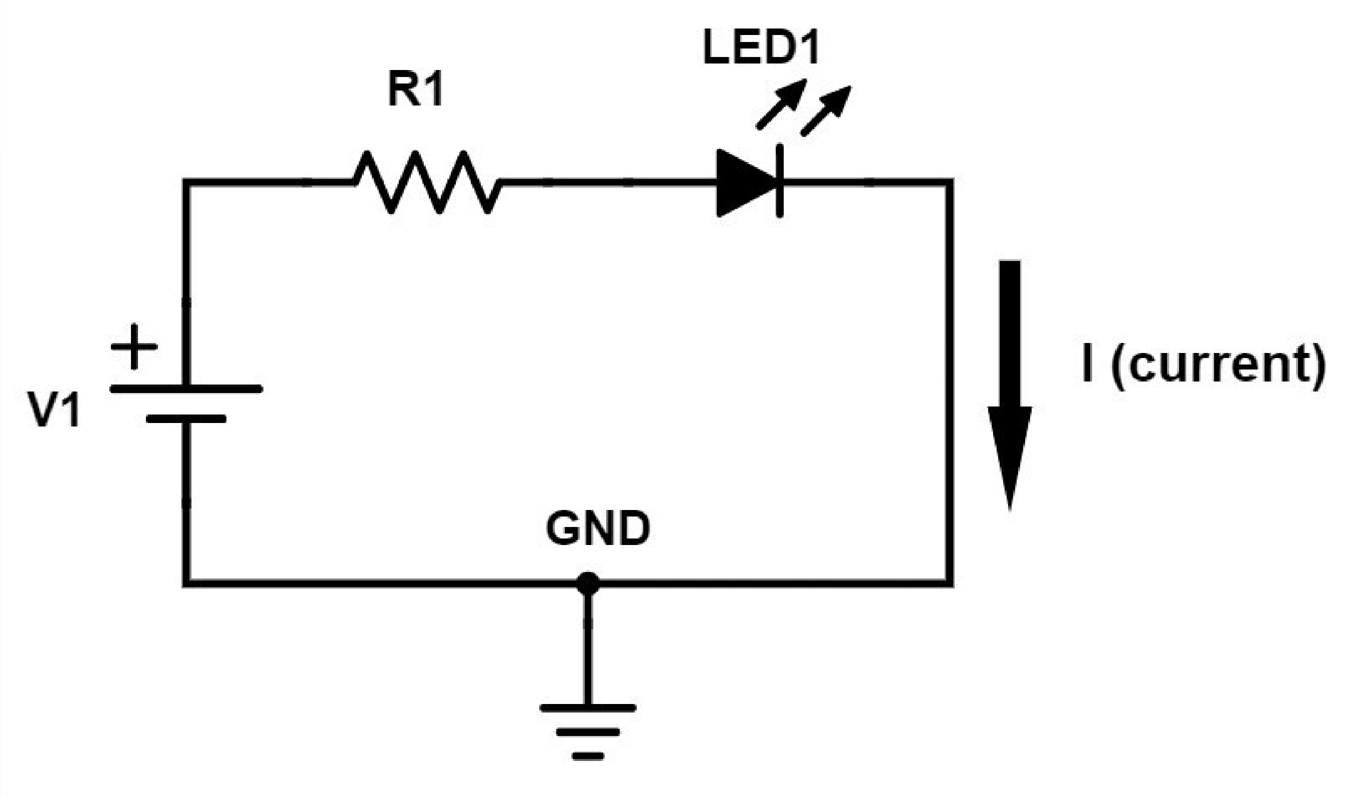
These are used in electronics for insulation, packaging, protection, and bonding.

CHAPTER – II ELECTRONIC CIRCUITS

FUNDAMENTALS OF ELECTRONIC CIRCUITS, COMPONENTS SYMBOLS

An electronic circuit is composed of individual electronic components, such as resistors, transistors, capacitors, inductors and diodes, connected by conductive wires or traces through which electric current can flow.

Electronic circuits are the fundamental building blocks of all electrical and electronic systems. These systems generate, store, and transmit information, process data, perform computations, make measurements, and transfer energy by means of electrical signals.



A Component is a basic element that contributes for the development of an idea into a circuit for execution.

Each component has a few basic properties, and the component behaves accordingly. It depends on the motto of the developer to use them for the construction of the intended circuit. The following image shows a few examples of electronic components that are used in different electronic circuits.

They can either be Active Components or Passive Components.

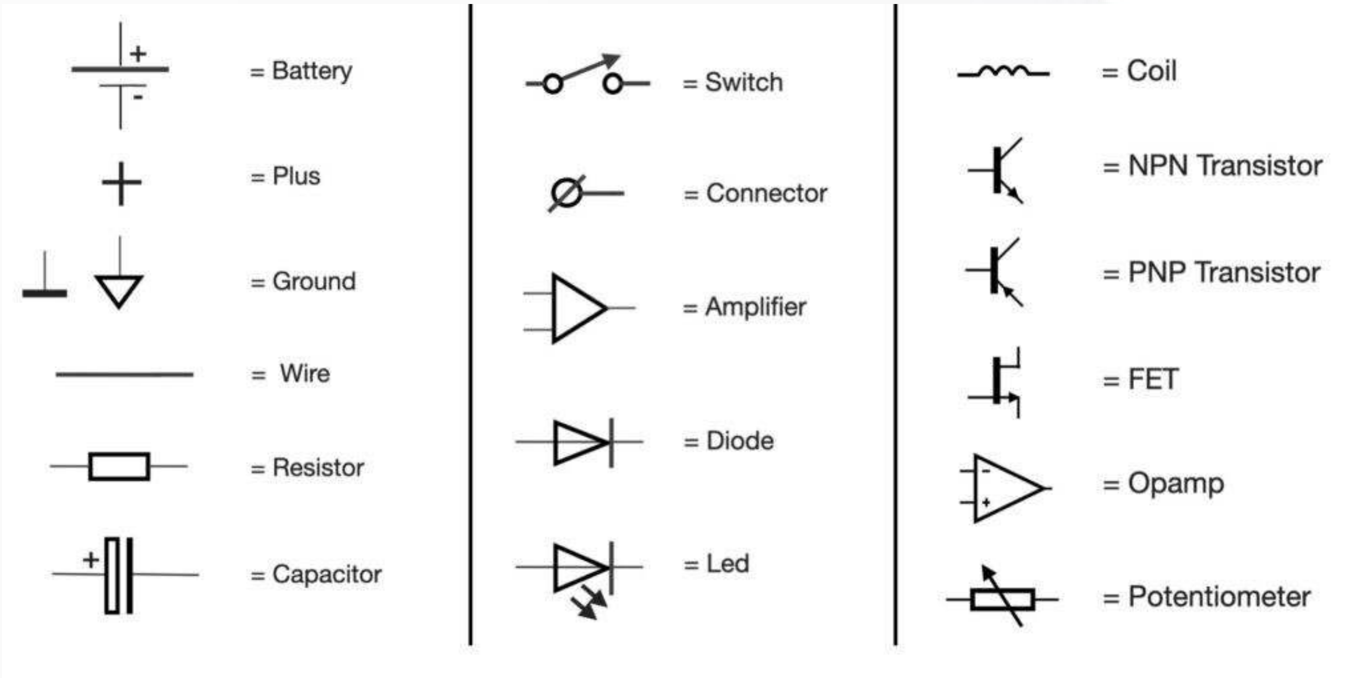
Active Components are those which conduct upon providing some external energy. They produce energy in the form of voltage or current.

Examples – Diodes, Transistors, Transformers, etc.

Passive Components are those which start their operation once they are connected. No external energy is needed for their operation. They store and maintain energy in the form of voltage or current.

Examples – Resistors, Capacitors, Inductors, etc.

Symbols of Electronic Circuits

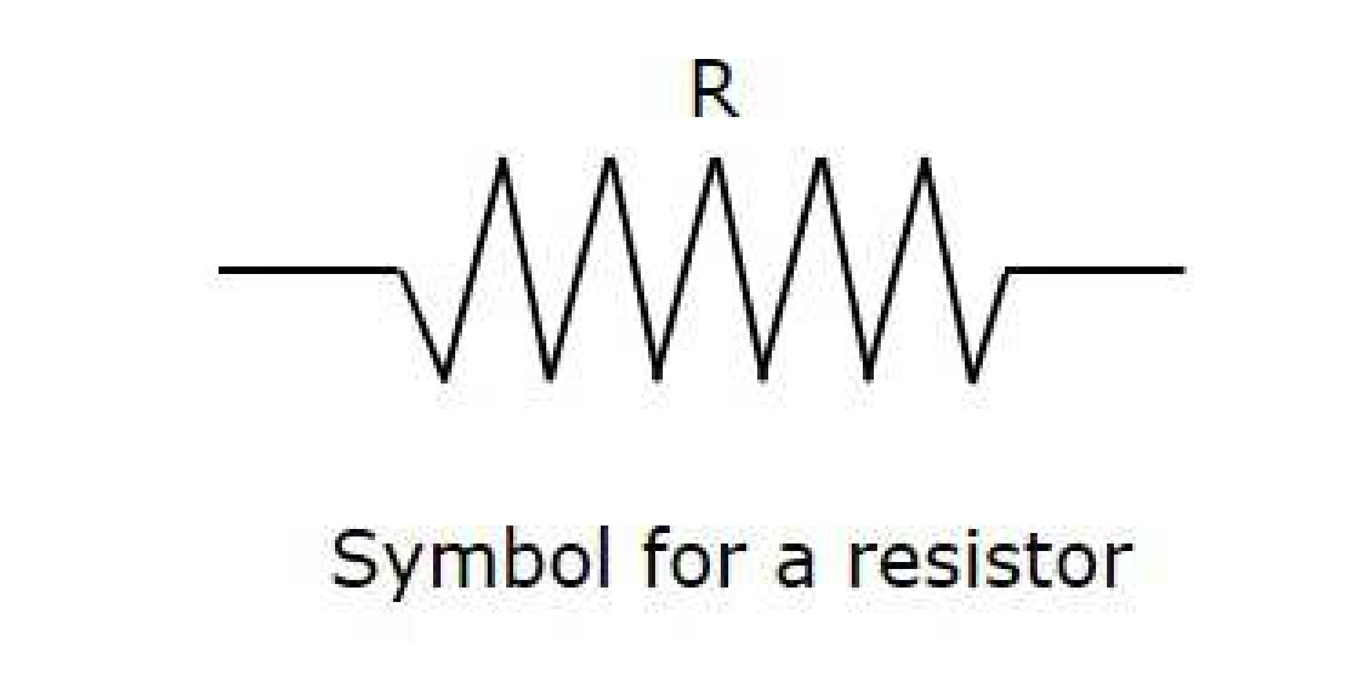


DEFINITION OF RESISTORS, CAPACITORS, AND ITS APPLICATIONS.

Resistors

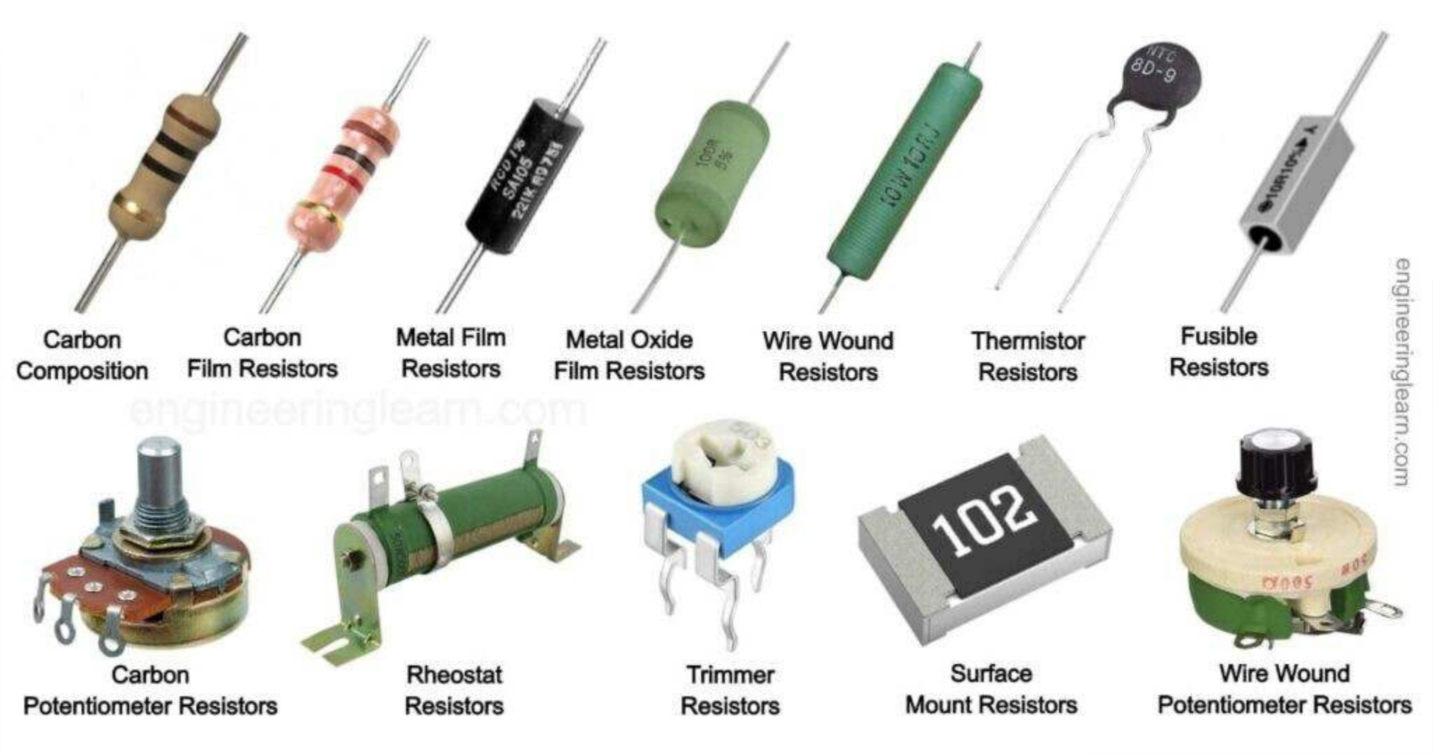
Resistor is defined as a passive electrical component with two terminals that are used for either limiting or regulating the flow of electric current in electrical circuits.

Resistance is the property of opposing the flow of electrons, in a conductor or a semiconductor. A Resistor is an electronic component which has the property of resistance.



The unit of resistance is Ohms, which is indicated by Ω omega.

The formula for resistance is R = V/I Where V is Voltage, and I is Current.



Applications of Resistors:

- Resistors are used in high frequency instrument.
- Resistor is used in power control circuit.
- It is used in DC power supplies.
- Resistors are used in filter circuit networks.
- It is used in amplifiers, oscillators, telecommunication and digital multimeter.
- It is used in wave generators.
- Resistors are used in transmitters, modulators and demodulators.
- It is used in medical instrument.
- It is used in instrumentation applications.
- Resistor is used in voltage regulators.
- It is used in feedback amplifiers.

CAPACITORS:

A capacitor is a two-terminal electrical device that can store energy in the form of an electric charge. It consists of two electrical conductors that are separated by a distance. The space between the conductors may be filled by vacuum or with an insulating material known as a dielectric.

Capacitors are simple passive device that can store an electrical charge on their plates when connected to a voltage source.

- Energy storage.
- Pulsed power and weapons.
- Power conditioning.
- Power factor correction Capacitors.
- Capacitor Safety.
- Hold-up capacitor applications.
- RF coupling and decoupling applications.
- Smoothing capacitor applications.
- Electronic noise filtering.

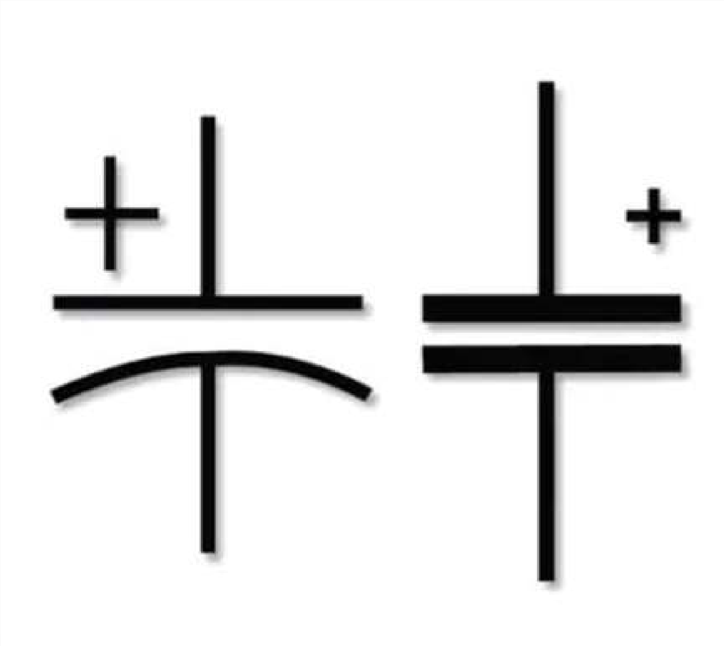
TECHNICAL INTRODUCTION OHM'S LAW AND ITS APPLICATIONS

Voltage, current, and resistance are the three most fundamental components of electricity.

According to Ohm's law, the current flowing through a conductor between two locations is proportional to the voltage across the conductor.

Ohm's law formula is written as.

$$V \propto I$$

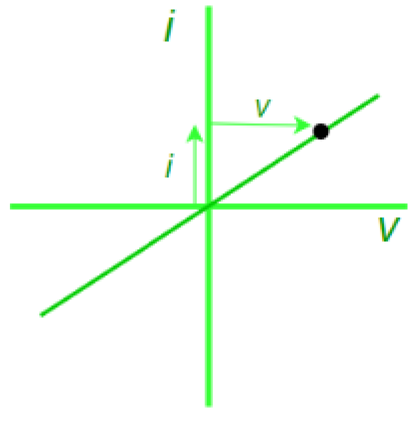


Symbol of Capacitors

The unit of capacitance being the Farad and it is denoted by F.

The Formula for Capacitance is C = Q/V where Q is the Charge Stored in the Capacitor when the Voltage V is applied.

Applications of Capacitor



Voltage-Current Relationship Diagram

There are basically three types of Ohm's law formulas or equations. They are,

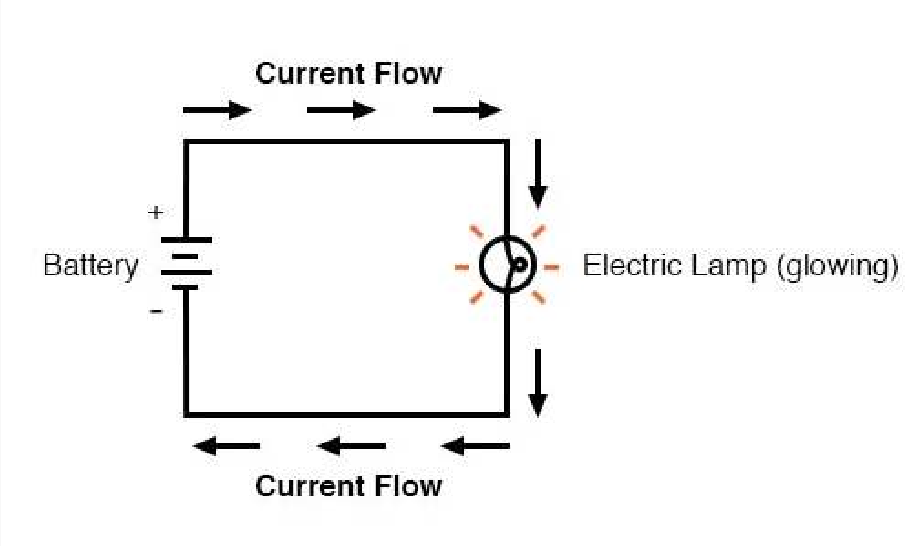
- I = V / R
- V = IR
- R = V / I where V is the voltage, I is the current, and R is the resistance.

Main applications of Ohm's Law:

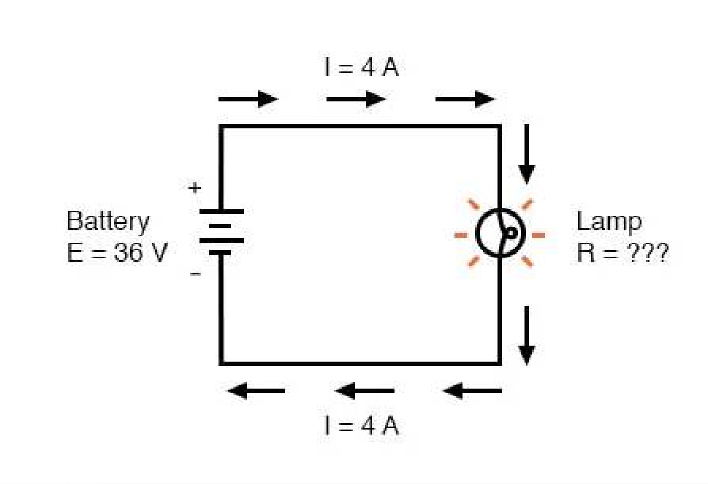
- It also simplifies power calculations.
- To keep the desired voltage, drop between the electrical components, Ohm's law is employed.
- An electric circuit's voltage, resistance, or current must be determined.
- Ohm's law is also utilised to redirect current in DC ammeters and other DC shunts.
- It is used to design resistors.
- It is used to get the desired circuit drop in circuit design.
- Advanced laws such as Kirchhoff's Norton's law, Thevenin's law are based on Ohm's law.
- Electric heaters, kettles and other types of equipment working principle follow Ohm's law.

BASIC CIRCUIT FOR RESISTOR VALUE CALCULATION BY USING OHM'S LAW

Analyzing Simple Circuit with Ohm's Law.



In the above circuit, there is only one source of voltage (the battery, on the left) and only one source of resistance to current (the lamp, on the right). This makes it very easy to apply Ohm's Law. If we know the values of any two of the three quantities (voltage, current, and resistance) in this circuit, we can use Ohm's Law to determine the third.



In this circuit, we will calculate the amount of resistance (R) in a circuit, given values of voltage (E) and current (I):

What is the amount of resistance (R) offered by the lamp?

$$R = \frac{E}{I} = \frac{36\ V}{4\ A} = 9\ \Omega$$

DEFINITION AND CONFIGURATION

TRANSISTOR, MOSFET, IGBT, BJT, FET AND ITS APPLICATIONS

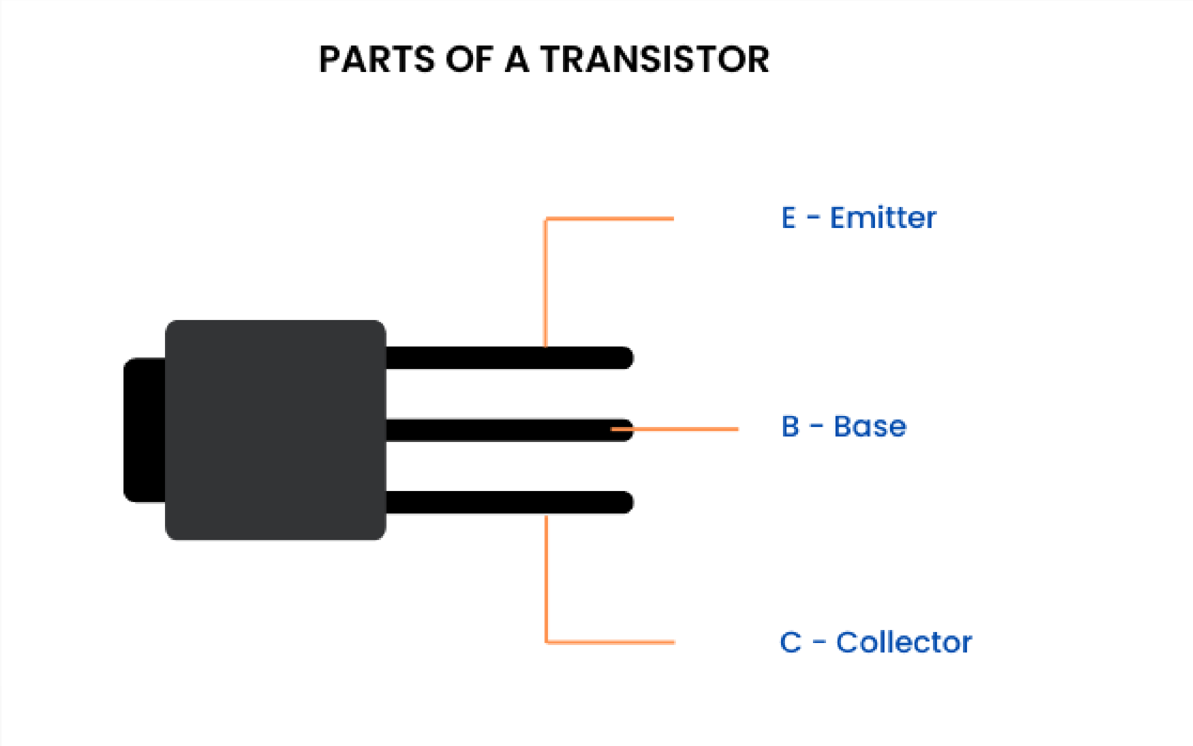
TRANSISTOR

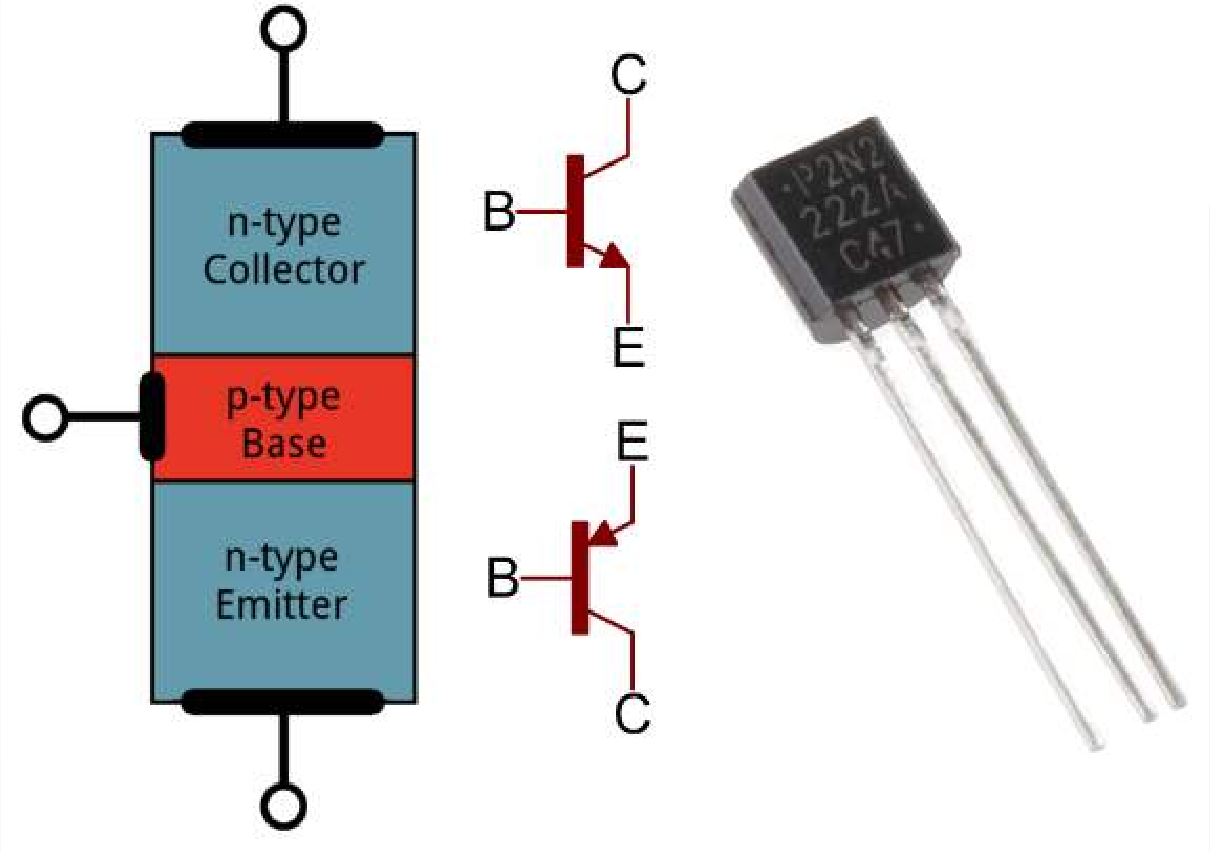
A Transistor is a three terminal semiconductor device that regulates current or voltage flow and acts as a switch or gate for signals.

The Transistor is a three terminal solid-state device which is formed by connecting two diodes back-to-back. Hence it has got two PN junctions. Three terminals are drawn out of the three semiconductor materials present in it.

The three terminals drawn from the transistor indicate Emitter, Base and Collector terminals.

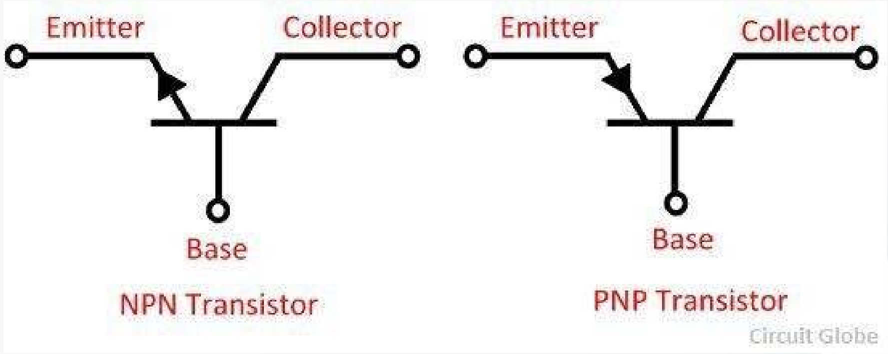
The two main types of transistors are the Bipolar Junction Transistor (BJT) and the Field-Effect Transistor (FET). The fundamental difference between the two types of transistors is the fact that the BJT is a current-controlled device, while the FET is a voltage-controlled device.





NPN and PNP transistors are BJT-type transistors. Type NPN consists of two N Regions separated by a P Region. The PNP type consists of two P regions separated by an N region.

Both types amplify the weak signal entering the transistor's base and produce strong amplified signals at its collector's end.

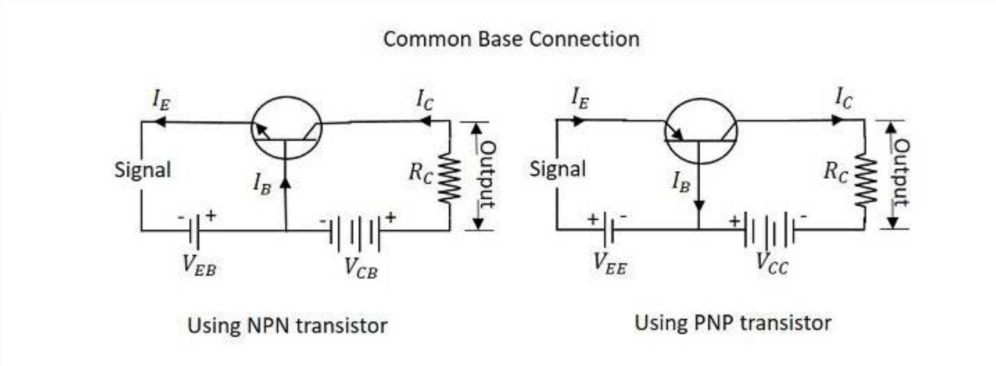


Configuration of Transistor:

The three types of configurations are Common Base, Common Emitter and Common Collector configurations. In every configuration, the emitter junction is forward biased, and the collector junction is reverse biased.

Common Base - CB Configuration.

The name itself implies that the Base terminal is taken as common terminal for both input and output of the transistor. The common base connection for both NPN and PNP transistors is as shown in the following figure.



Let us consider NPN transistor in CB configuration. When the emitter voltage is applied, as it is forward biased, the electrons from the negative terminal repel the emitter electrons and current flows through the emitter and base to the collector to contribute collector current. The collector voltage VCB is kept constant throughout this.

In the CB configuration, the input current is the emitter current IE and the output current is the collector current IC.

Current Amplification Factor α

The ratio of change in collector current ΔI_C to the change in emitter current ΔI_E when collector voltage **V_{CB}** is kept constant, is called as **Current amplification factor**. It is denoted by α.

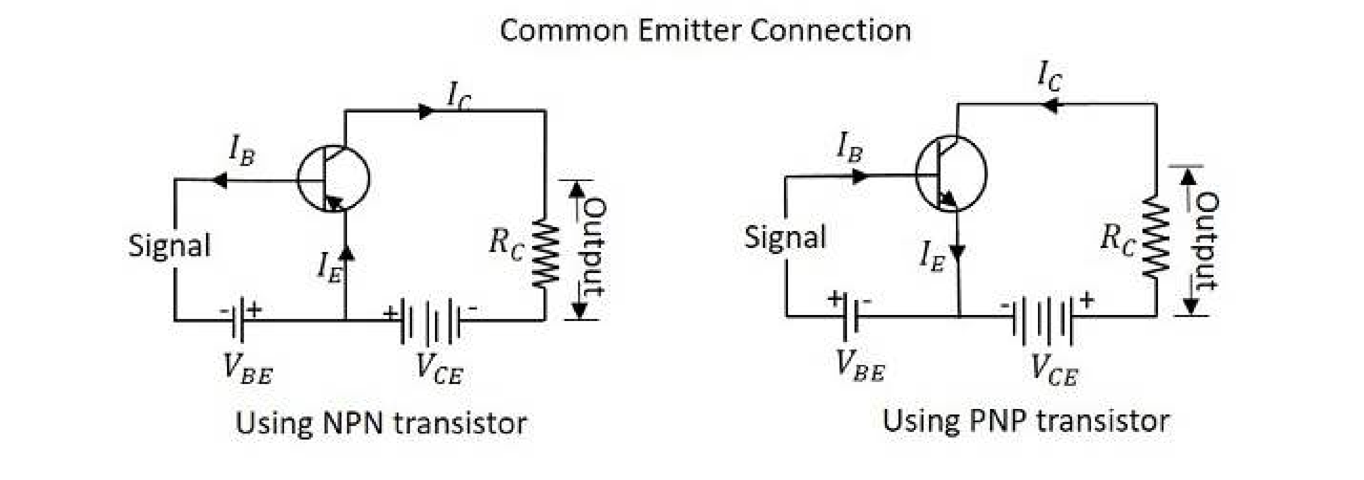
$$\alpha = \frac{\Delta I_C}{\Delta I_E} \; at\ constant\ V_{CB}$$

Characteristics of CB configuration

- This configuration provides voltage gain but no current gain.
- This Configuration provides good stability against increase in temperature.
- The CB configuration is used for high frequency applications.
- Being V_{CB} constant, with a small increase in the Emitter-base voltage V_{EB}, Emitter current I_E gets increased.
- Emitter Current I_E is independent of Collector voltage V_{CB}.
- As the output resistance is of very high value, a large change in V_{CB} produces a very little change in collector current I_C.

Common Emitter - CE Configuration

The name itself implies that the Emitter terminal is taken as common terminal for both input and output of the transistor. The common emitter connection for both NPN and PNP transistors is as shown in the following figure.



Just as in CB configuration, the emitter junction is forward biased, and the collector junction is reverse biased. The flow of electrons is controlled in the same manner.

The input current is the base current I_B and the output current is the collector current IC here.

Base Current Amplification factor β

The ratio of change in collector current ΔIC to the change in base current ΔIB is known as Base Current Amplification Factor. It is denoted by β

$\beta = \Delta IC / \Delta IB$

The current gain in Common Emitter connection is very high. This is the reason this circuit connection is mostly used in all transistor applications.

In the Common Emitter configuration, I_B is the input current and I_C is the output current.

$I_E = I_B + I_C$

Knee Voltage

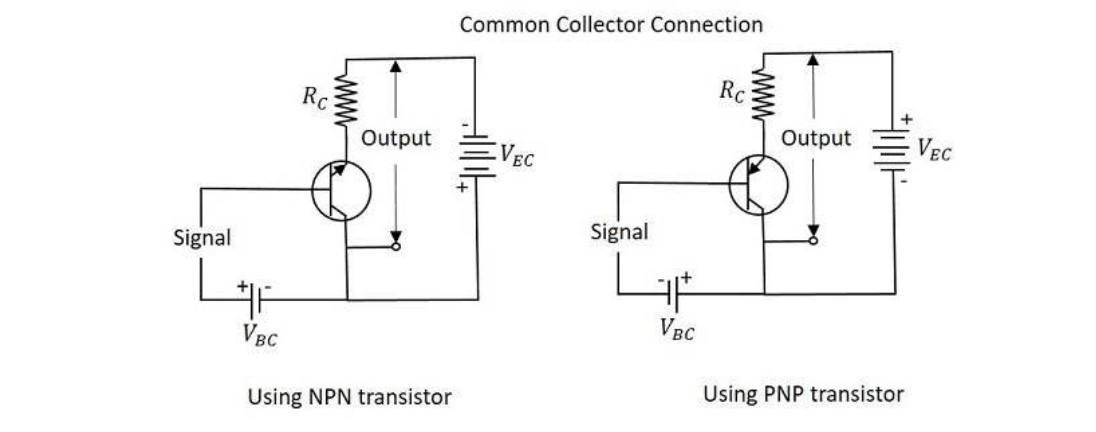
In CE configuration, by keeping the base current I_B constant, if V_{CE} is varied, I_C increases nearly to 1v of V_{CE} and stays constant thereafter. This value of V_{CE} up to which collector current I_C changes with V_{CE} is called the Knee Voltage. The transistors while operating in CE configuration, they are operated above this knee voltage.

Characteristics of CE Configuration

- This configuration provides good current gain and voltage gain.
- Keeping VCE constant, with a small increase in VBE the base current IB increases rapidly than in CB configurations.
- For any value of VCE above knee voltage, IC is approximately equal to βIB.
- As the output resistance of CE circuit is less than that of CB circuit.
- This configuration is usually used for bias stabilization methods and audio frequency applications.

Common Collector CC Configuration

The name itself implies that the Collector terminal is taken as common terminal for both input and output of the transistor. The common collector connection for both NPN and PNP transistors is as shown in the following figure.



Just as in CB and CE configurations, the emitter junction is forward biased, and the collector junction is reverse biased. The flow of electrons is controlled in the same manner. The input current is the base current I_B and the output current is the emitter current IE here.

Current Amplification Factor γ

The ratio of change in emitter current $ΔIE$ to the change in base current $ΔIB$ is known as Current Amplification factor in common collector CC configuration. It is denoted by γ.

$γ=ΔIE/ΔIB$.

Characteristics of CC Configuration

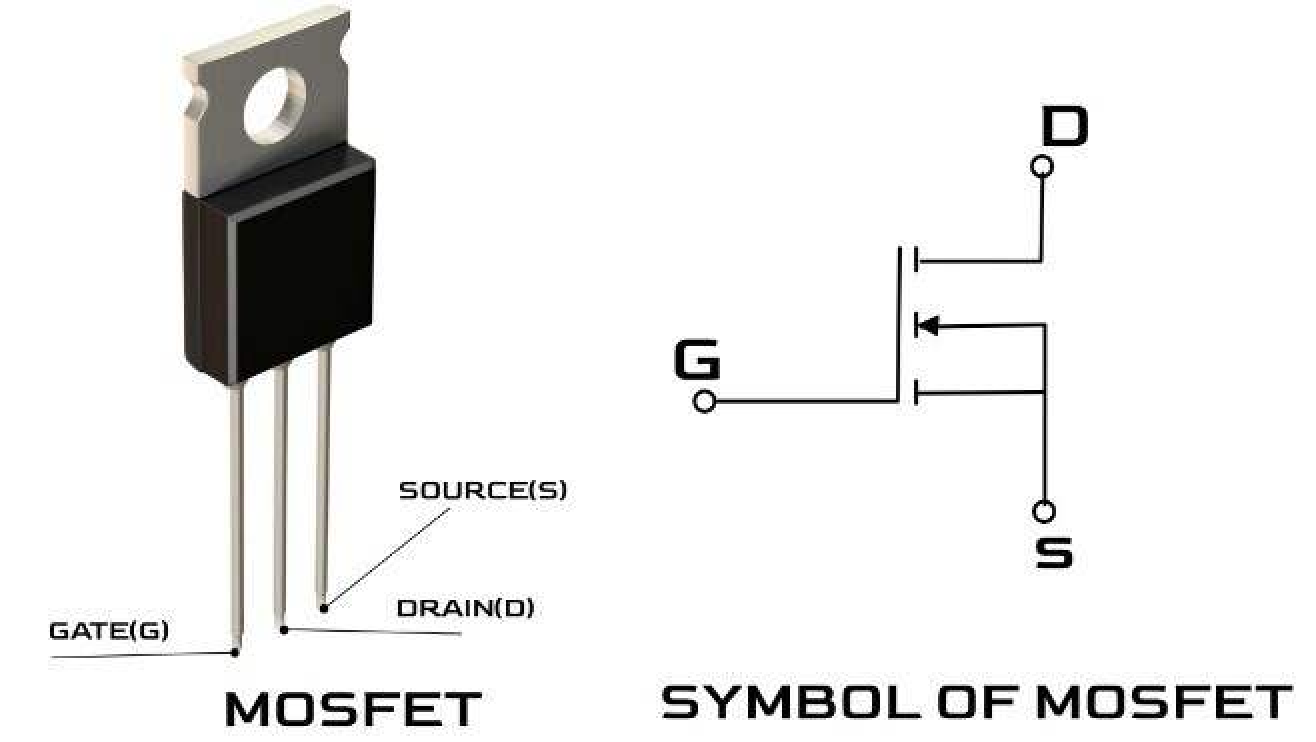
- This configuration provides current gain but no voltage gain.
- In CC configuration, the input resistance is high, and the output resistance is low.
- The voltage gain provided by this circuit is less than 1.
- The sum of collector current and base current equals emitter current.
- The input and output signals are in phase.
- This configuration works as non-inverting amplifier output.
- This circuit is mostly used for impedance matching. That means, to drive a low impedance load from a high impedance source.

Applications of Transistors:

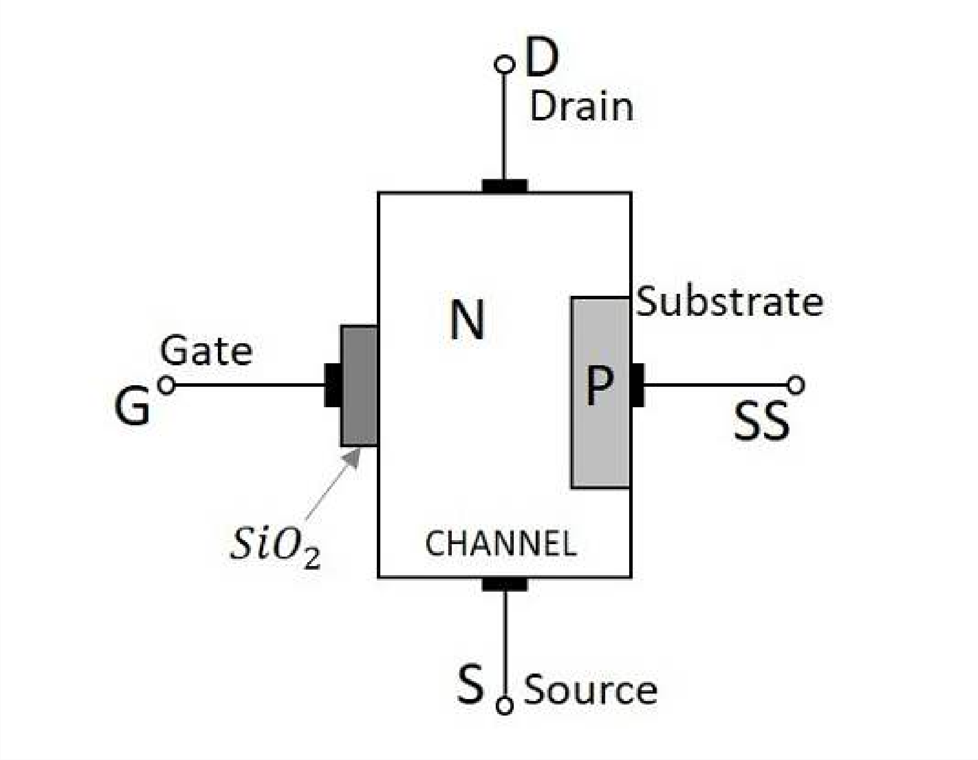
1. As Amplifier Circuit
2. Microphone
3. Oscillator Circuit
4. Computers
5. Space and Defence Applications.

Definition and Configuration of MOSFET

MOSFET stands for Metal Oxide Silicon Field Effect Transistor or Metal Oxide Semiconductor Field Effect Transistor. The FET is operated in both depletion and enhancement modes of operation. The following figure shows how a practical MOSFET looks like.

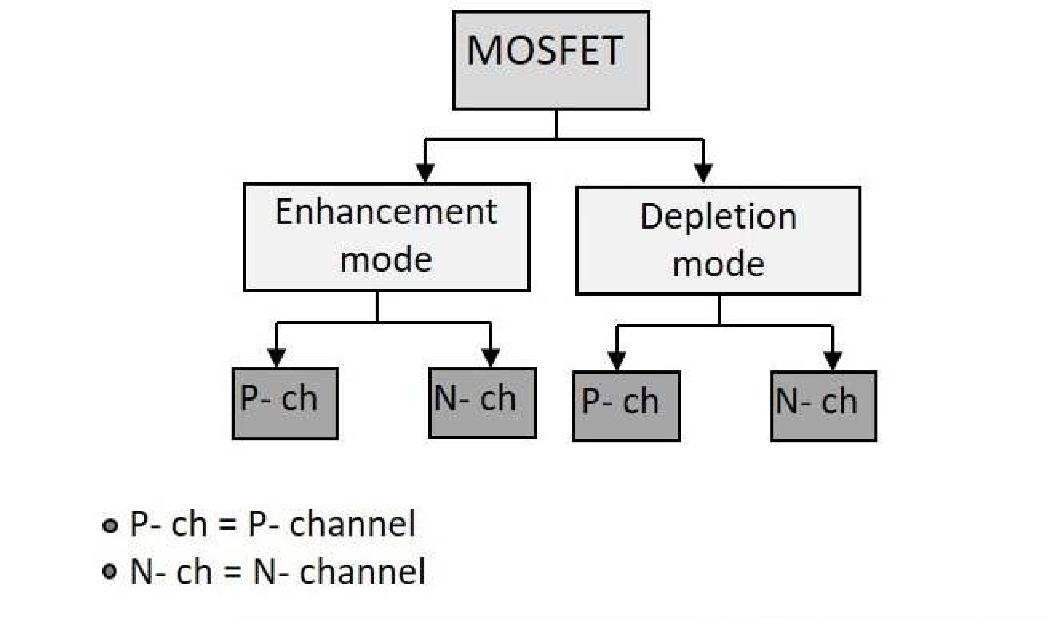


An oxide layer is deposited on the substrate to which the gate terminal is connected. This oxide layer acts as an insulator (sio2 insulates from the substrate), and hence the MOSFET has another name as IGFET - Insulated Gate Field Effect Transistor. In the construction of MOSFET, a lightly doped substrate, is diffused with a heavily doped region. Depending upon the substrate used, they are called as P-type and N-type MOSFETs.

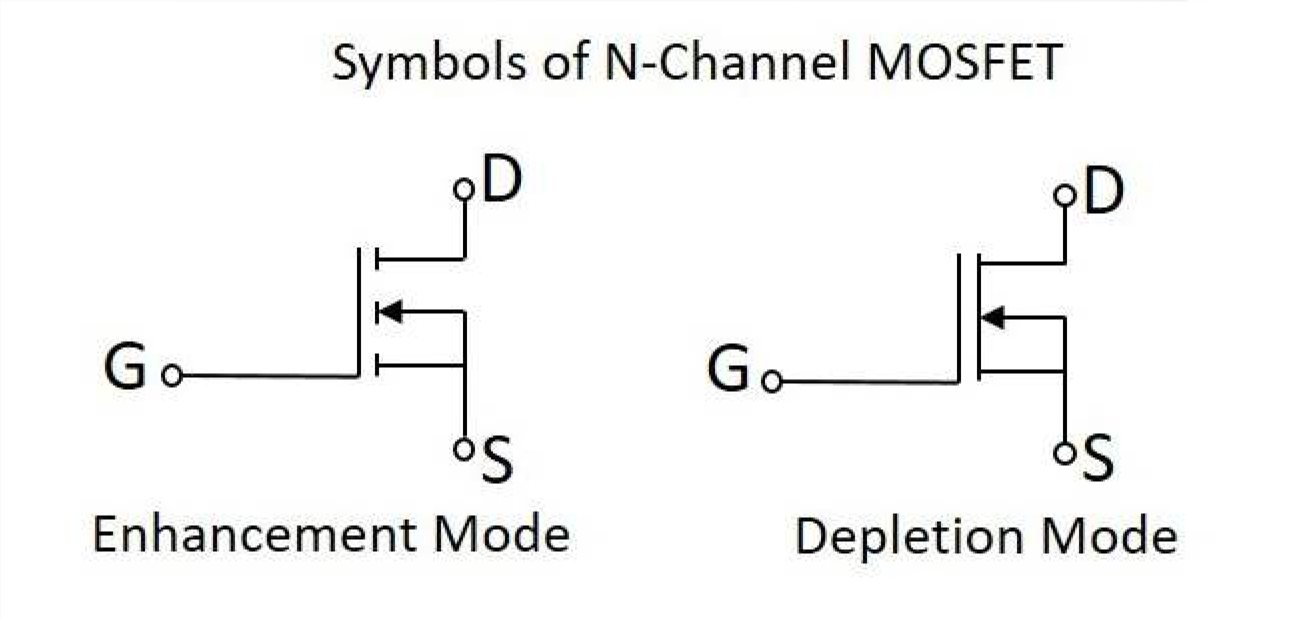


Classification of MOSFETs

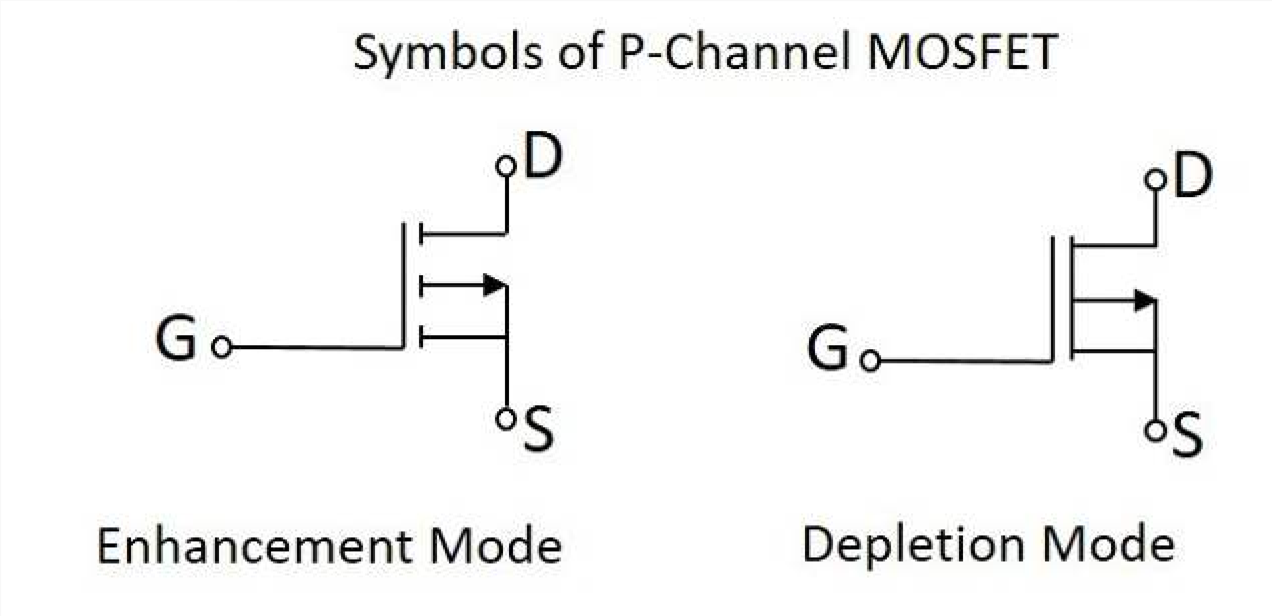
Depending upon the type of materials used in the construction, and the type of operation, the MOSFETs are classified as in the following figure.



The N-channel MOSFETs are simply called as NMOS. The symbols for N-channel MOSFET are as given below.



The P-channel MOSFETs are simply called as PMOS. The symbols for P-channel MOSFET are as given below.



DEPLETION TYPE MOSFET

A depletion-type MOSFET typically turns on at zero gate to source voltage. There will be a threshold voltage required to turn the MOSFET off if it is an N-Channel Depletion-type MOSFET. For instance, to turn off an N-Channel Depletion MOSFET with a -3V or -5V threshold voltage, the gate of the MOSFET must be brought down to a negative -3V or -5V potential. For the N channel, this threshold voltage will be negative, and for the P channel, it will be positive. In logic circuits, this type of MOSFET is frequently employed.

Enhancement Type MOSFET

When the gate voltage is zero, the device is still off in the enhancement type. We need to supply a minimum Gate to Source voltage to switch on the MOSFET (Vgs Threshold voltage). However, the drain current is very dependent on this gate-to-source voltage; when the Vgs rises, the drain current follows suit. The best MOSFETs to use when building an amplifier circuit are of the enhancement type. It also has the NMOS and PMOS subtypes, just like a depletion MOSFET.

There are three main configurations of MOSFET amplifiers:

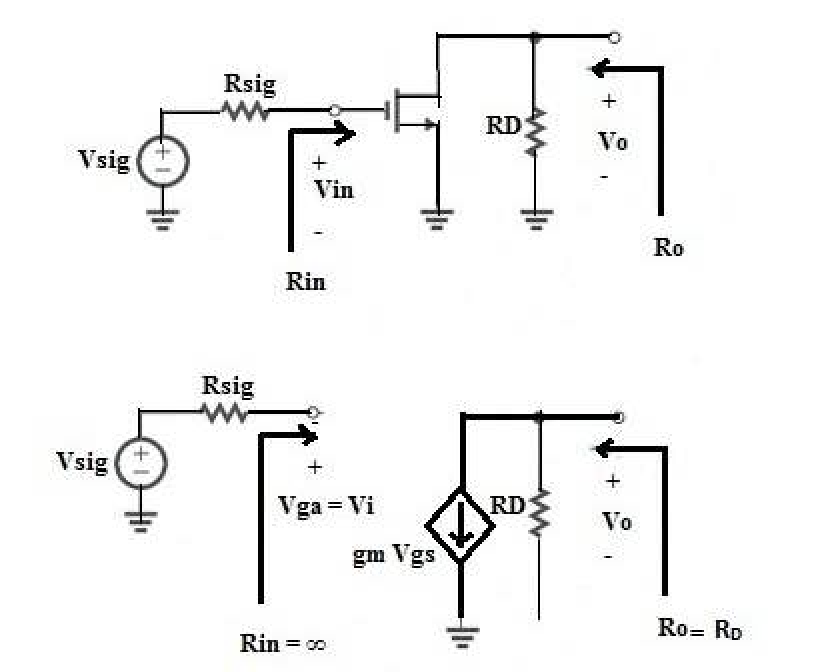
1. Common-Source configuration
2. Common-Gate configuration
3. Common-Drain configuration.

Common Source MOSFET Amplifier

Common source amplifier can be defined as when the i/p signal is given at both the terminals of the gate (G) & source (S), the o/p voltage can be amplified & attained across the resistor at the load within the drain (D) terminal. In this configuration, the source terminal acts as a common terminal in between the i/p and o/p.

The small-signal and hybrid π model of a common source MOSFET amplifier is shown below.

The common-source MOSFET amplifier is related to the CE (common-emitter) amplifier of BJT. This is very popular due to high gain and larger signal amplification can be achieved.



The current induced within the o/p port is $I = -g_m v_{gs}$ as specified through the current source. Therefore,

$Vo = -g_m v_{gs} R_D$

The voltage gain of open-circuit is

$A_{vo} = Vo/vi = -g_m R_D$

From the information that Rin = ∞, after that vi = vsig. So, the voltage gain (Gv) is the similar as the voltage gain accurate (Av),

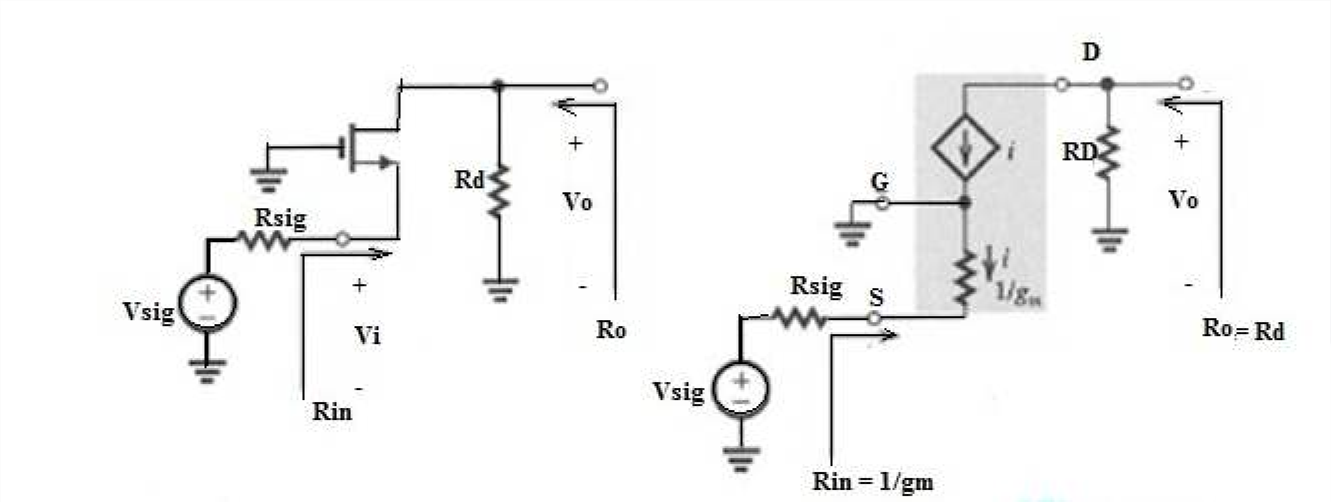
$Gv = Vo/Vsig = -gm(RD||\ RL)$

Thus, the CS MOSFET amplifiers have infinite i/p impedance, high o/p resistance & high voltage gain. The output resistance can be reduced by decreasing the RD but also the voltage gain can also be decreased. A CS MOSFET amplifier suffers from a poor high-frequency performance like most of the transistor amplifiers do.

Common-Gate (CG) Amplifier

A common-gate (CG) amplifier is normally used as a voltage amplifier or current buffer. In the CG configuration, the source terminal (S) of the transistor works like the input whereas the drain terminal works like the output & the gate terminal is connected to the ground (G). The common gate amplifier configuration is mainly used to provide high isolation in between i/p & o/p to prevent oscillation or less input impedance.

The small-signal model and T model of a common-gate amplifier equivalent circuit are shown below. Here in the 'T' model, the gate current is always zero.



The o/p voltage can be given as Vo = $-iR_D$

The open-circuit voltage can be given as Avo = Vo/vi = $g_m R_D$

The voltage gain is expressed as Gv = (1/gm/Rsig + 1/gm) gm(RD||RL)

Gv = RD||RL/Rsig + 1/gm

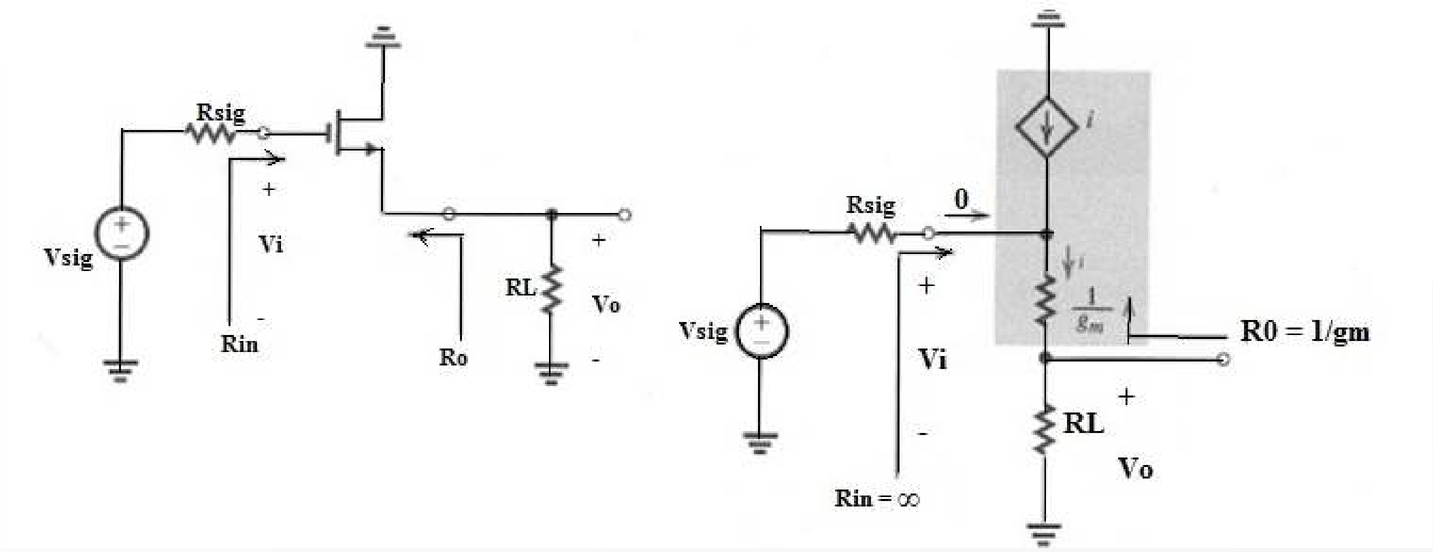
Thus, the common gate MOSFET amplifier has less i/p resistance '1/gm'. So, this is undesirable because it will draw a huge current once it is driven through an input voltage. The CG amplifier's voltage gain can be made related in magnitude to that of the common source amplifier once RD||RL can be made large as compared to Rsig + 1/gm. The o/p resistance can be made high as Ro = RD. The frequency performance of this amplifier is high.

Common Drain Amplifier or Source MOSFET Follower

A common-drain (CD) amplifier is one where the input signal is given to the gate terminal & the output is obtained from the source terminal, making the drain (D) terminal common to both. The CD amplifier is frequently used as a voltage buffer to drive small o/p loads. This configuration provides extremely high i/p impedance & low o/p impedance.

This common drain amplifier circuit is similar to the emitter follower circuit of the BJT. So, it is used as a voltage buffer. This amplifier is a unit-gain amplifier including very huge input impedance although a smaller o/p impedance. So it is excellent for high-impedance circuit matching to a less -impedance circuit otherwise to a circuit that works with a larger supply current.

The small-signal & T-model equivalent circuit of the common drain amplifier is shown below. In this circuit, the i/p input source can be signified through an equivalent voltage of Thevenin (vsig) & resistor (Rsig). A load resistor (RL) can be connected to the o/p in between the source (S) & ground (G).



By using the formula of the voltage divider, it is noticed that voltage gain correct or gain of terminal voltage is Av = vo/vi = RL/RL + 1/gm

The voltage gain of an open-circuit (RL = ∞) & Avo = 1

Because of the endless input impedance (Rin), vi = vsig, & the overall voltage gain, Gv is similar when the voltage gain proper Av

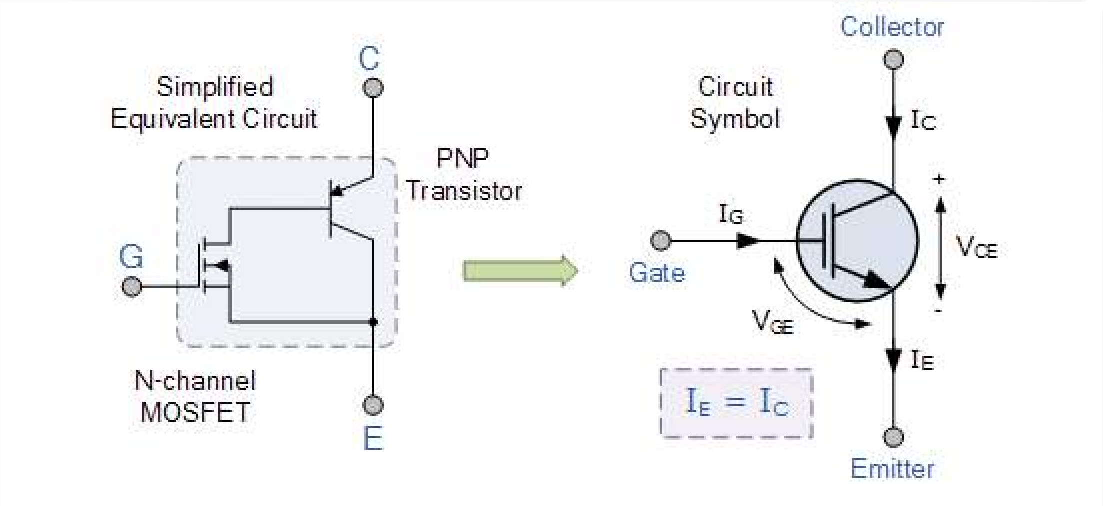
Gv = Av = RL/RL + 1/gm

Since Ro = 1/gm is normally small through large load resistor 'RL', the gain is low than unity, however is near to unity. Therefore, this is a source follower, as the source voltage tracks the i/p voltage, however, it can supply a larger current toward the o/p than the i/p current.

Definition and Configuration of IGBT

The Insulated Gate Bipolar Transistor also called an IGBT for short, is something of a cross between a conventional Bipolar Junction Transistor, (BJT) and a Field Effect Transistor, (MOSFET) making it ideal as a semiconductor switching device.

The Insulated Gate Bipolar Transistor, (IGBT) combines the insulated gate technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor.



We can see that the insulated gate bipolar transistor is a three terminal, transconductance device that combines an insulated gate N-channel MOSFET input with a PNP bipolar transistor output connected in a type of Darlington configuration.

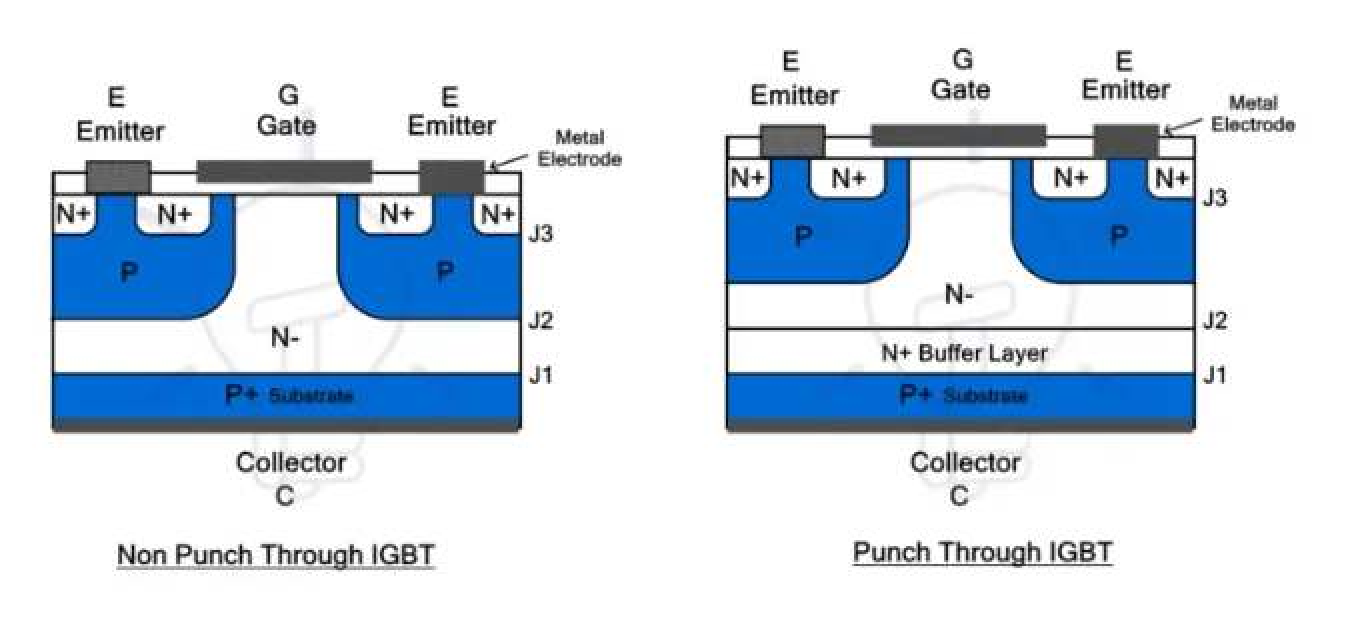
As a result, the terminals are labelled as: Collector, Emitter and Gate. Two of its terminals (C-E) are associated with the conductance path which passes current, while its third terminal (G) controls the device.

Types of IGBT

There are two types of IGBT based on the inclusion of N+ buffer layer. The inclusion of this extra layer divides them into symmetrical and asymmetrical IGBT.

Punch through IGBT

The Punch through IGBT includes N+ buffer layer due to which it is also known as an asymmetrical IGBT. They have asymmetric voltage blocking capabilities i.e. their forward and reverse breakdown voltages are different. Their reverse breakdown voltage is less than its forward breakdown voltage. It has faster switching speed. Punch through IGBTs is unidirectional and cannot handle reverse voltages. Therefore, they are used in DC circuits such as inverters and chopper circuits.



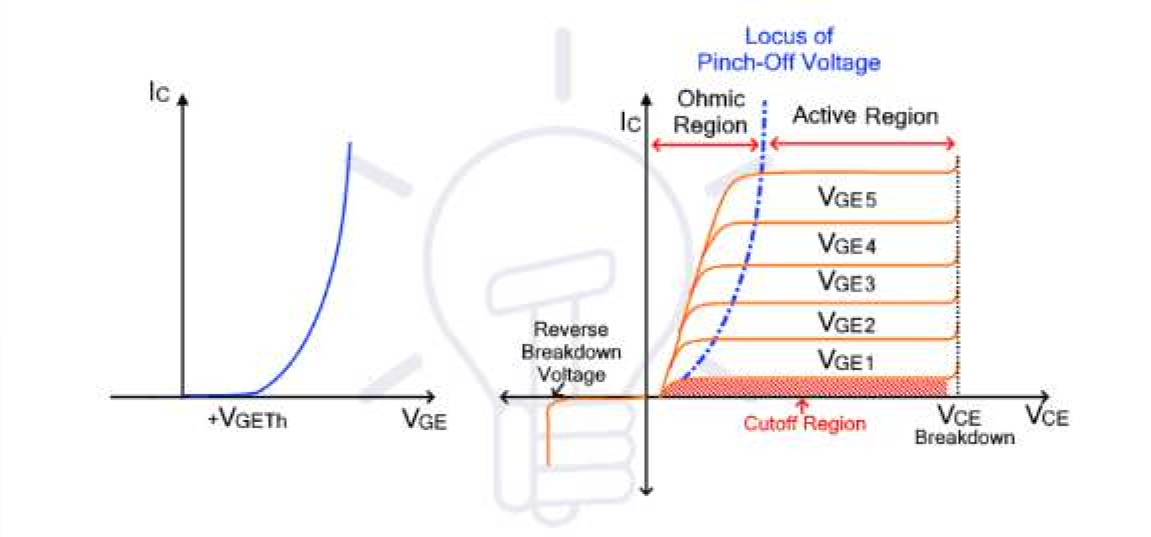
Non-Punch through IGBT

They are also known as symmetrical IGBT due to the absence of extra N+ buffer layer. The symmetry in structure provides symmetrical breakdown voltage characteristics i.e. the forward and reverse breakdown voltages are equal. Due to this reason, they are used in AC circuits.

V-I Characteristics of IGBT

Unlike BJT, IGBT is a voltage-controlled device that requires only a small voltage at its gate to control the collector current. However, the gate-emitter voltage VGE needs to be greater than the threshold voltage.

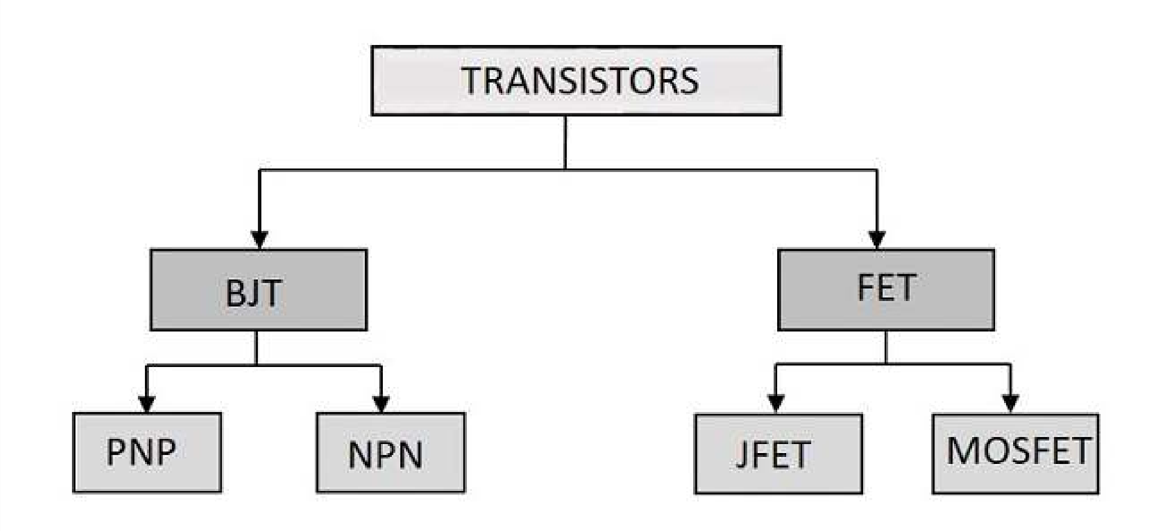
Transfer characteristics of the IGBT show the relation of input voltage VGE to output collector current IC. When the VGE is 0v, there is no IC and the device remains switched off. When the VGE is slightly increased but remains below threshold voltage VGET, the device remains switched off but there is a leakage current. When the VGE exceeds the threshold limit, the IC starts to increase and the device switches ON. Since it is a unidirectional device, the current only flows in one direction.



I-V Characteristics of IGBT

The given graph shows the relation between the collector current IC and collector-emitter voltage VCE at different levels of VGE. At VGE < VGET the IGBT is in cutoff mode and the IC = 0 at any VCE. At VGE > VGET, the IGBT goes into active mode, where the IC increases with an increase in VCE. Furthermore, for each VGE where VGE1 < VGE2 < VGE3, the IC is different.

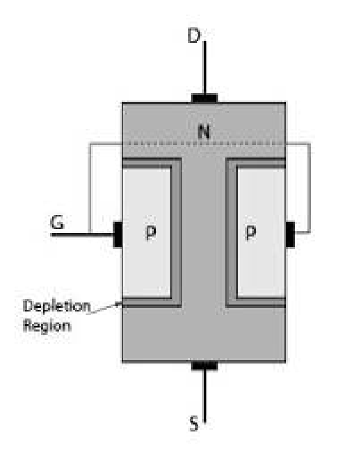
The reverse voltage should not exceed the reverse breakdown limit. So does the forward voltage. If they exceed their respective breakdown limit, uncontrolled current starts passing through it.



Definition and Configuration of FET

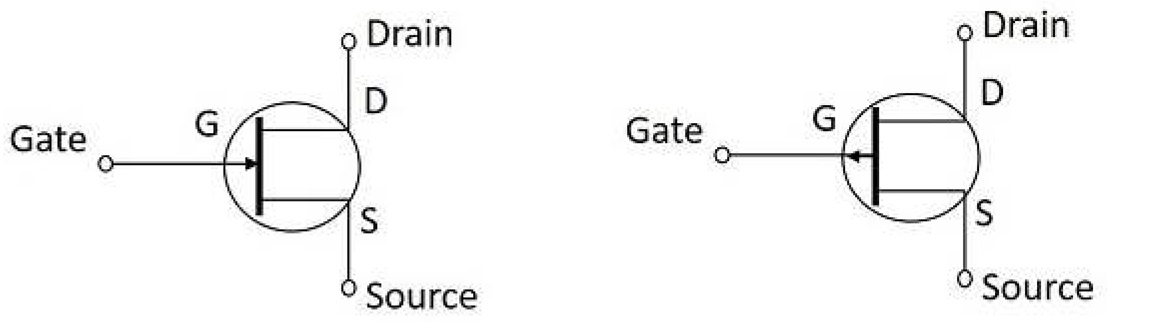
An FET is a three-terminal unipolar semiconductor device. It is a voltage-controlled device.

The FET is a unipolar device, which means that it is made using either p-type or n-type material as main substrate. Hence the current conduction of a FET is done by either electrons or holes.



The three terminals of FET are Gate, Source and Drain. The Source terminal in FET is analogous to the Emitter in BJT, while Gate is analogous to Base and Drain to Collector.

The symbols of a FET for both NPN and PNP types are as shown below



Symbol of n-channel FET   Symbol of p-channel FET

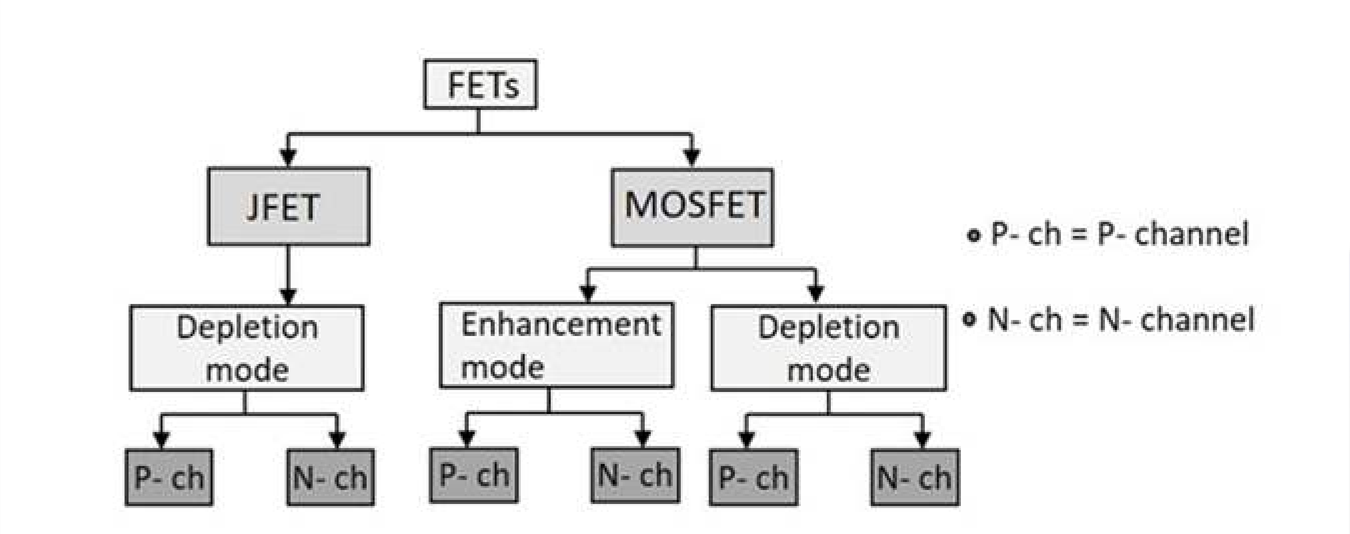
The main advantage of FET is that it has a very high input impedance, which is in the order of Mega Ohms. It has many advantages like low power consumption, low heat dissipation and FETs are highly efficient devices.

JFET	BJT
It is an unipolar device	It is a bipolar device
Voltage driven device	Current driven device
High input impedance	Low input impedance
Low noise level	High noise level
Better thermal stability	Less thermal stability
Gain is characterized by transconductance	Gain is characterized by voltage gain

Applications of FET

- FET is used in circuits to reduce the loading effect.
- FETs are used in many circuits such as Buffer Amplifier, Phase shift Oscillators and Voltmeters.

Types of FET



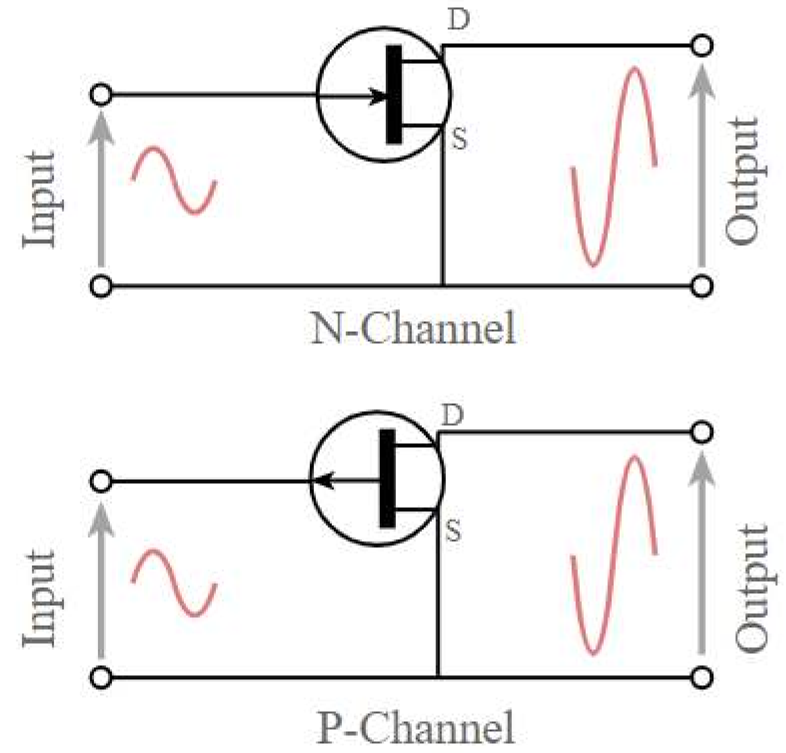
FET CONFIGURATION BASICS

The terminology used for denoting the three basic FET configurations indicates the FET electrode that is common to both input and output circuits. This gives rise to the three terms: common gate, common drain and common source.

The three different FET circuit configurations are:

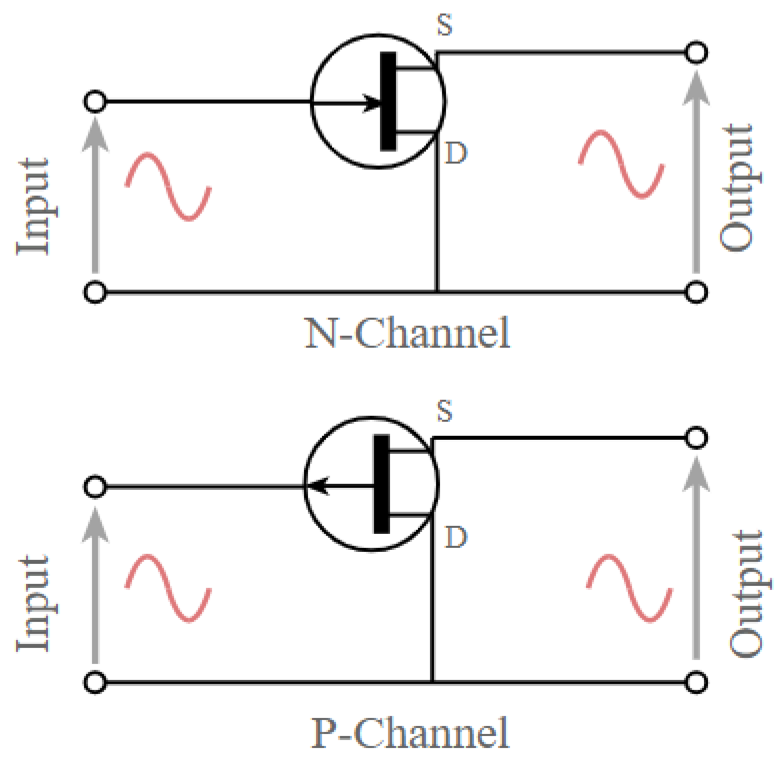
1. Common-Source configuration
2. Common-Gate configuration
3. Common-Drain configuration.

Common source: This FET configuration is probably the most widely used. The common source circuit provides a medium input and output impedance levels. Both current and voltage gain can be described as medium, but the output is the inverse of the input, i.e. 180° phase change. This provides a good overall performance and as such it is often thought of as the most widely used configuration.



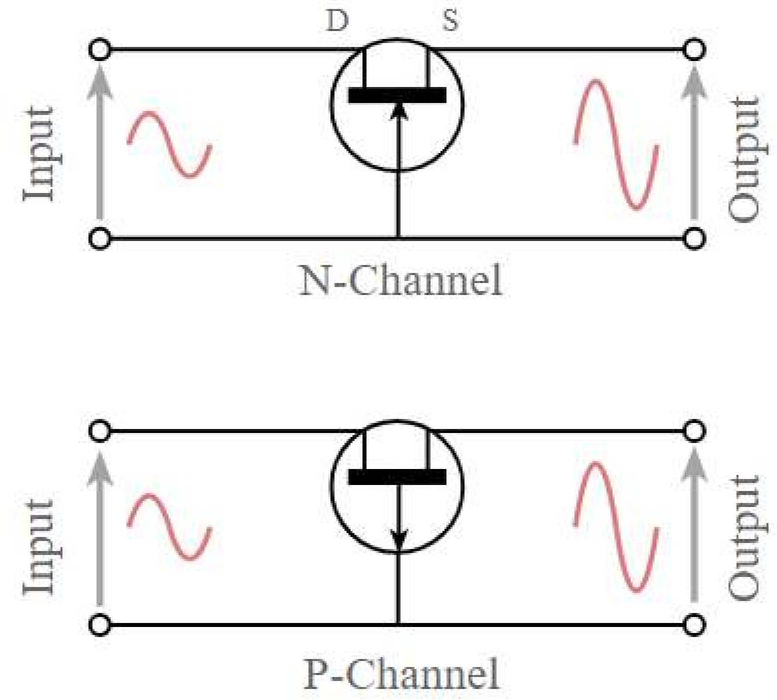
Common source FET circuit configuration

Common drain: This FET configuration is also known as the source follower. The reason for this is that the source voltage follows that of the gate. Offering a high input impedance and a low output impedance it is widely used as a buffer. The voltage gain is unity, although current gain is high. The input and output signals are in phase.



Common drain (source follower) FET circuit configuration

Common gate: This transistor configuration provides a low input impedance while offering a high output impedance. Although the voltage is high, the current gain is low and the overall power gain is also low when compared to the other FET circuit configurations available. The other salient feature of this configuration is that the input and output are in phase.



Common gate FET circuit configuration

FET CONFIGURATION SUMMARY TABLE

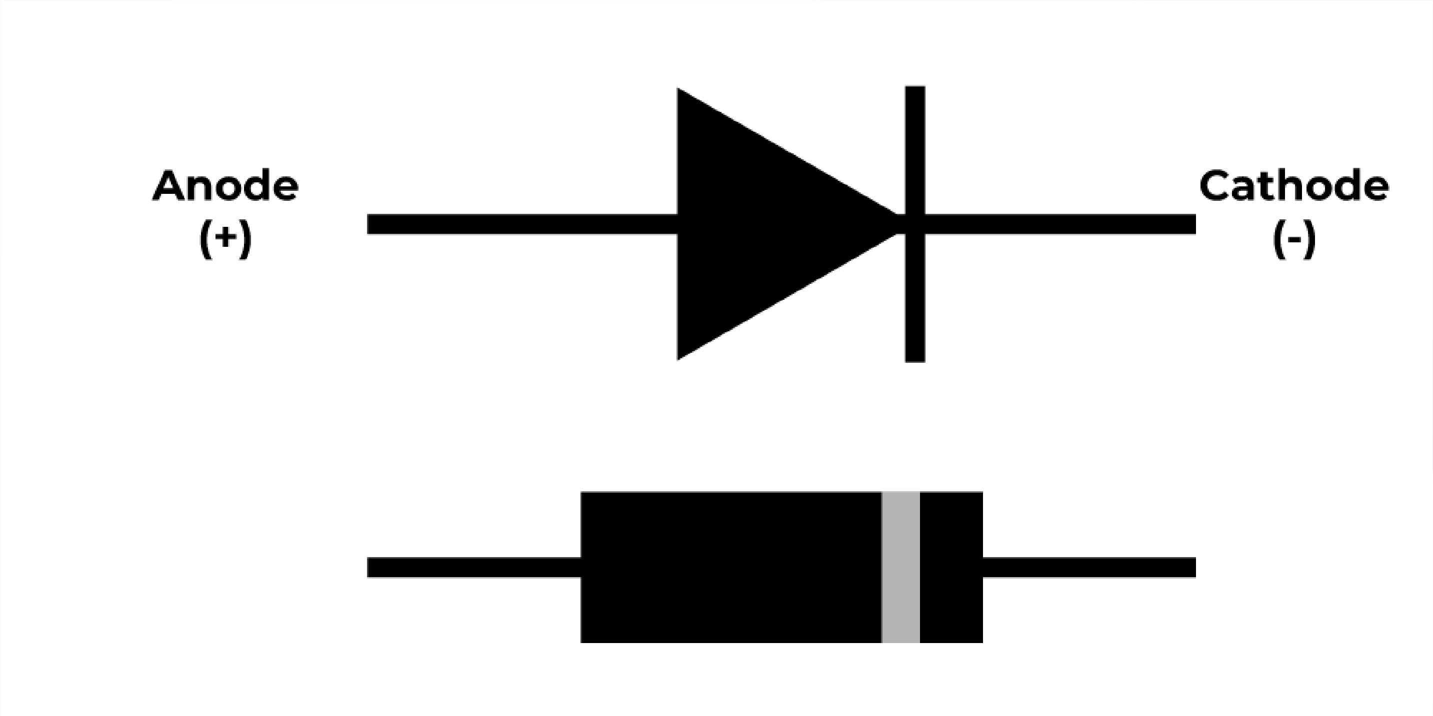
FET CONFIGURATION	COMMON GATE	COMMON DRAIN (SOURCE FOLLOWER)	COMMON SOURCE
Voltage gain	High	Low	Medium
Current gain	Low	High	Medium
Power gain	Low	Medium	High
Input resistance	Low	High	Medium
Output resistance	High	Low	Medium
Input / output phase relationship	0°	0°	180°

The common source is the most widely used FET circuit configuration and it equates to the common emitter transistor amplifier. The FET common drain or source follower is used as a buffer amplifier, and it equates to the transistor common emitter amplifier.

DIODE, ZENER DIODE, LIGHT EMITTING DIODE (LED)

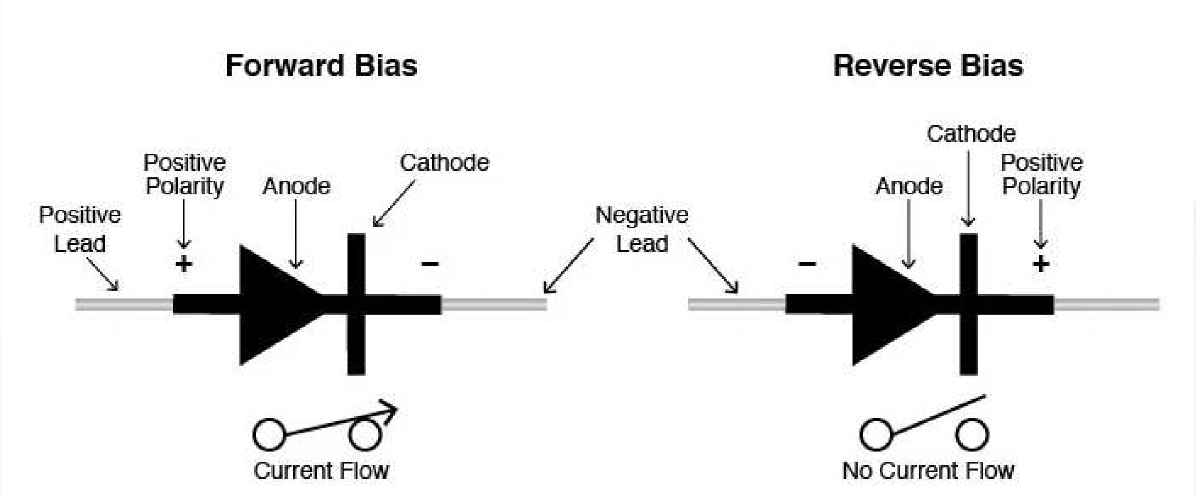
DIODE:

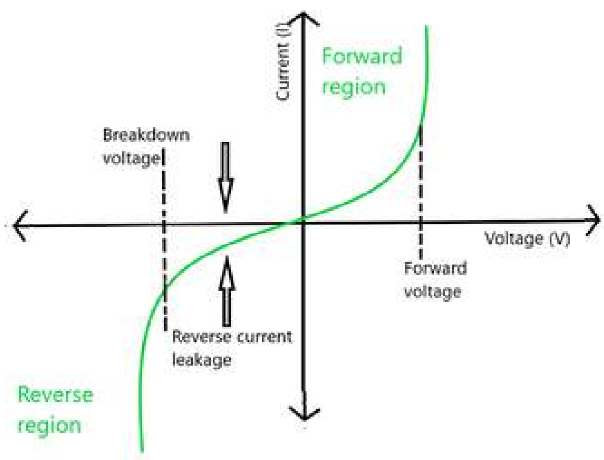
A diode is an electronic device having a two-terminal unidirectional power supply i.e it has two terminals and allows the current to flow only in one direction. Diodes are widely used in modern-day circuits to secure circuits from over-voltage and they are also used to change AC current to DC current. The arrowhead symbol represents the anode and the other end represents the cathode. The current flow from cathode to anode in the forward bias condition. The general representation of a Diode is given below,



Characteristics of Diode

- Forward-Biased Diode
- Reverse-Biased Diode
- Zero Biased Diode OR Unbiased Diode





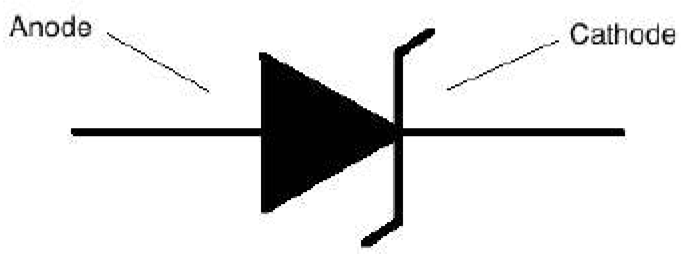
VI Characteristics of Diode

Applications of Semiconductor Diode

- Rectifier Diode: A rectifier diode is a kind of diode that is used for the rectification of alternating current (A.C).
- LED: LEDs are diodes used for providing light.
- Zener Diode: Zener diode is used for the stabilization of current and voltage in electronic systems.
- Photodiode: Photodiodes are used to detect light.
- Switching Diode: Switching diodes are used for providing fast switching in circuits.
- Tunnel Diode: A tunnel diode is a special type used in the negative resistance region.

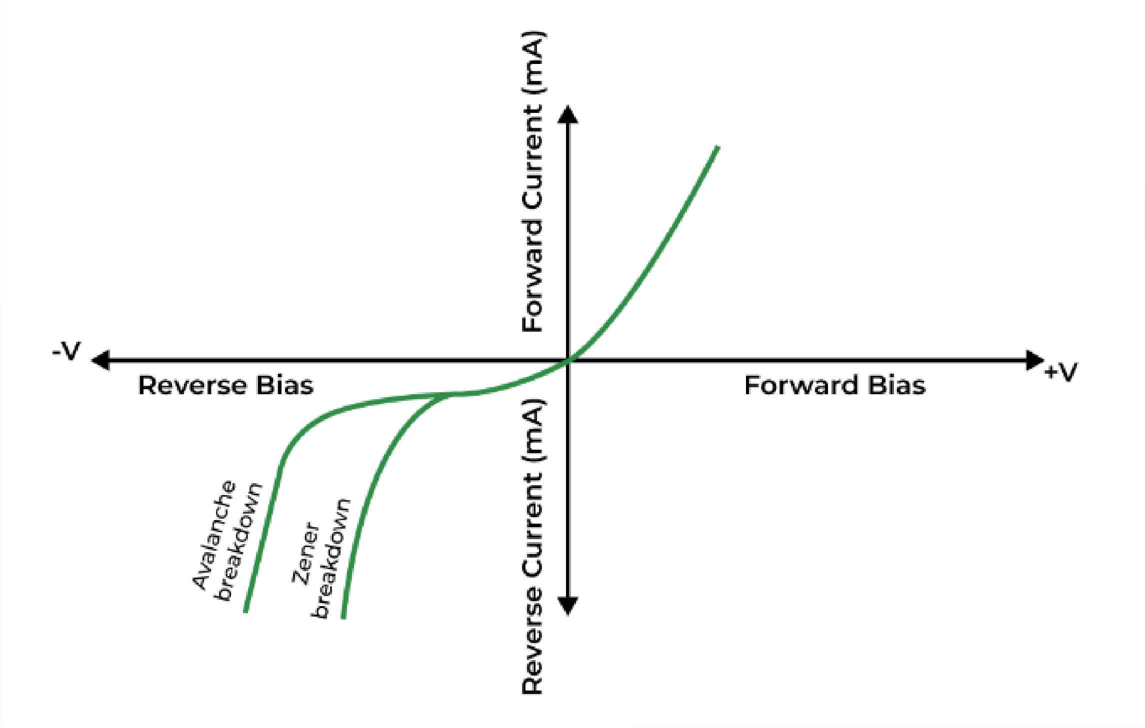
ZENER DIODE:

A heavily doped p-n junction diode that works in reverse bias conditions is called a Zener Diode. They are special semiconductor devices that allow the current to flow in both forward and backward directions. For the Zener diode, the voltage drop across the diode is always constant irrespective of the applied voltage. Thus, Zener diodes are used as a voltage regulator.



A Zener diode which is also called a Breakdown diode works in reverse bias conditions. An electrical breakdown occurring in the reverse-biased condition of the PN junction diode is called the Zener effect. In this condition when the electric field increases to a high value it enables the tunnelling of electrons from the valence band to the conduction band of a semiconductor, which suddenly increases the reverse current.

VI Characteristics of Zener Diode.



In reverse bias condition, two kinds of breakdowns occur for Zener Diode which are,

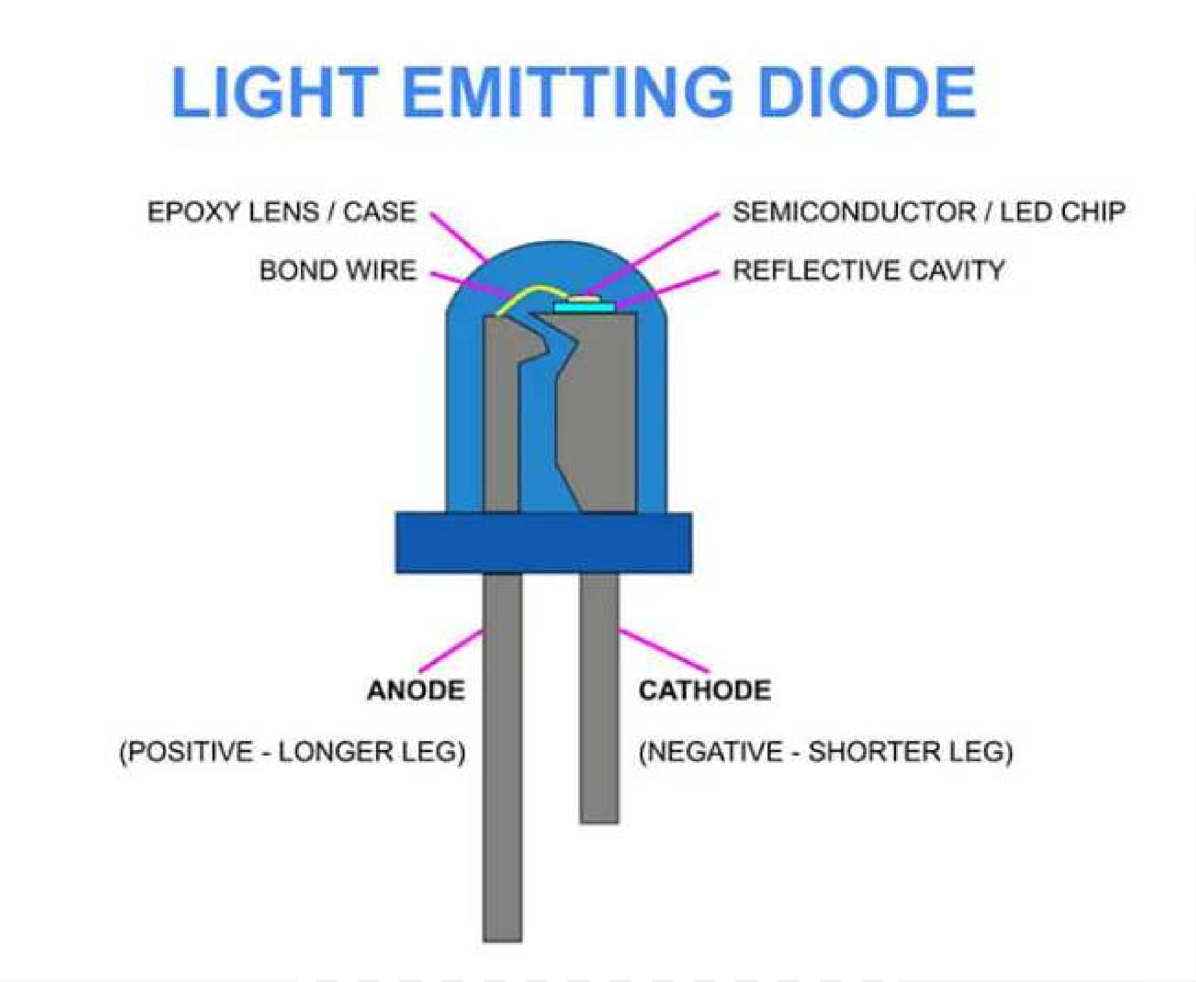
- Avalanche Breakdown
- Zener Breakdown

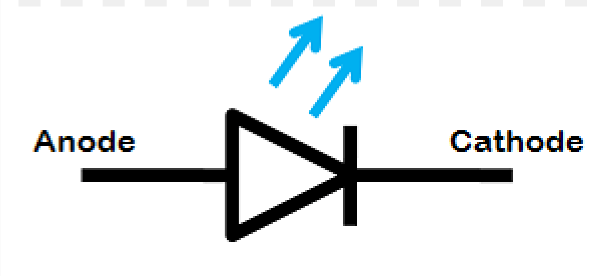
Applications of Zener Diode:

- Voltage Regulator
- Over-Voltage Protection
- Clipping Circuits.

LIGHT EMITTING DIODES - LED

Like a normal PN junction diode, this is connected in forward bias condition so that the diode conducts. The conduction takes place in a LED when the free electrons in the conduction band combine with the holes in the valence band. This process of recombination emits light. This process is called as Electroluminescence. The color of the light emitted depends upon the gap between the energy bands.

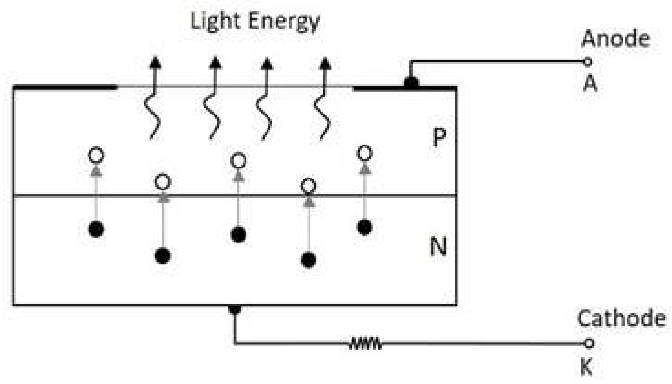




LED symbol

The materials used also effect the colors like, gallium arsenide phosphide emits either red or yellow, gallium phosphide emits either red or green and gallium nitrate emits blue light. Whereas gallium arsenide emits infrared light. The LEDs for non-visible Infrared light are used mostly in remote controls.

The basic structure of LED is as shown in the figure below.



Basic Structure of LED

As shown in the above figure, as the electrons jump into the holes, the energy is dissipated spontaneously in the form of light. LED is a current dependent device. The output light intensity depends upon the current through the diode.

Applications of LEDs

In Displays

- Especially used for seven segment display
- Digital clocks
- Microwave ovens
- Traffic signalling
- Display boards in railways and public places
- Toys

In Electronic Appliances

- Stereo tuners
- Calculators
- DC power supplies
- On/Off indicators in amplifiers
- Power indicators

Commercial Use

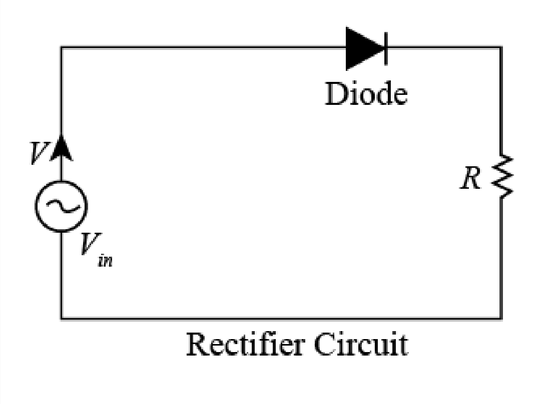
- Infrared readable machines
- Barcode readers
- Solid state video displays

Optical Communications

- In Optical switching applications
- For Optical coupling where manual help is unavailable
- Information transfer through FOC
- Image sensing circuits
- Burglar alarms
- In Railway signalling techniques
- Door and other security control systems.

PRINCIPLES OF RECTIFIERS, WORKING, TYPES AND ITS APPLICATIONS

A rectifier is a device that converts an oscillating two-directional alternating current (AC) into a single-directional direct current (DC). A simple PN junction diode acts as a rectifier. The forward biasing and reverse biasing conditions of the diode makes the rectification.



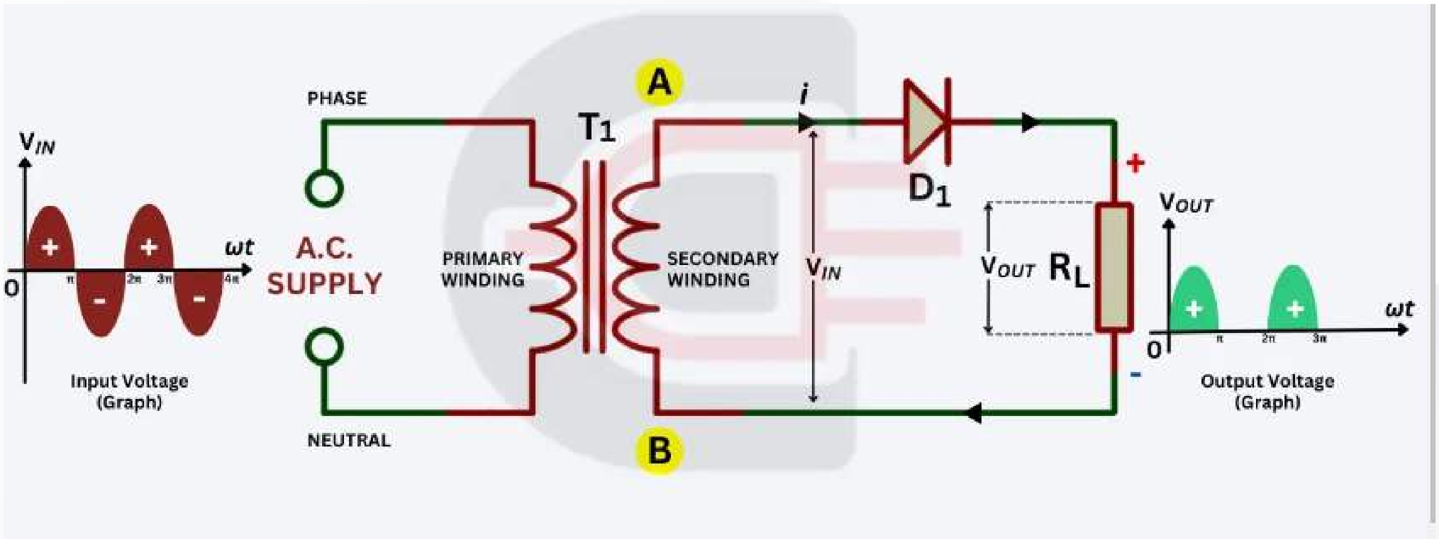
There are two main types of rectifier circuits, depending upon their output.

- Half-wave Rectifier
- Full-wave Rectifier

HALF WAVE RECTIFIER

The simplest rectifiers, called half-wave rectifiers, work by eliminating one side of the AC, thereby only allowing one direction of current to pass through. The AC signal is given through an input transformer which steps up or down according to the usage. Mostly a step-down transformer is used in rectifier circuits, so as to reduce the input voltage.

The input signal given to the transformer is passed through a PN junction diode which acts as a rectifier. This diode converts the AC voltage into pulsating dc for only the positive half cycles of the input. A load resistor is connected at the end of the circuit. The figure below shows the circuit of a half wave rectifier.



WORKING OF A HWR

The input signal is given to the transformer which reduces the voltage levels. The output from the transformer is given to the diode which acts as a rectifier. This diode gets ON conducts for positive half cycles of input signal. Hence current flows in the circuit and there will be a voltage drop across the load resistor. The diode gets OFF doesn't conduct for negative half cycles and hence the output for negative half cycles will be, iD=0 and Vo=0.

Hence the output is present for positive half cycles of the input voltage only neglecting the reverse leakage current. This output will be pulsating which is taken across the load resistor. Applications of Half-Wave Rectifiers:

- In firing circuits and pulse generating circuits.
- Small power supplies.
- Battery chargers.
- Soldering irons.
- Mosquito repellent.
- Step up and step-down transformers.

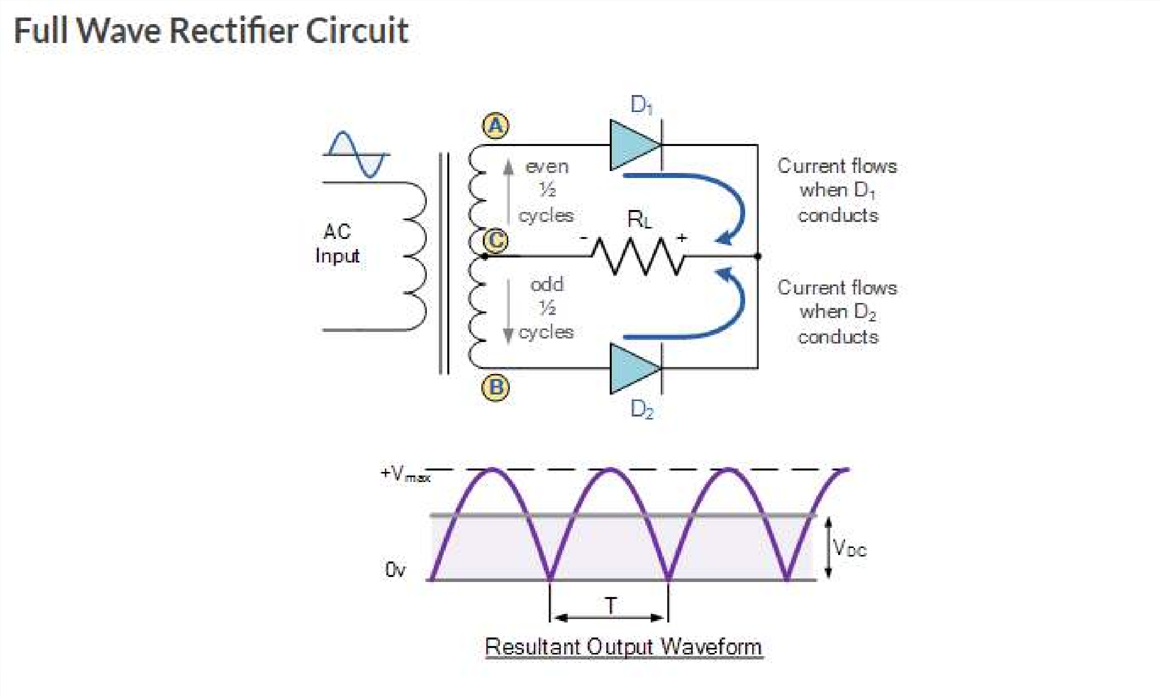
FULL WAVE RECTIFIER

A Rectifier circuit that rectifies both the positive and negative half cycles can be termed as a full wave rectifier as it rectifies the complete cycle. The construction of a full wave rectifier can be made in two types.

1. Center-tapped Full wave rectifier
2. Bridge full wave rectifier

Center-tapped Full wave rectifier

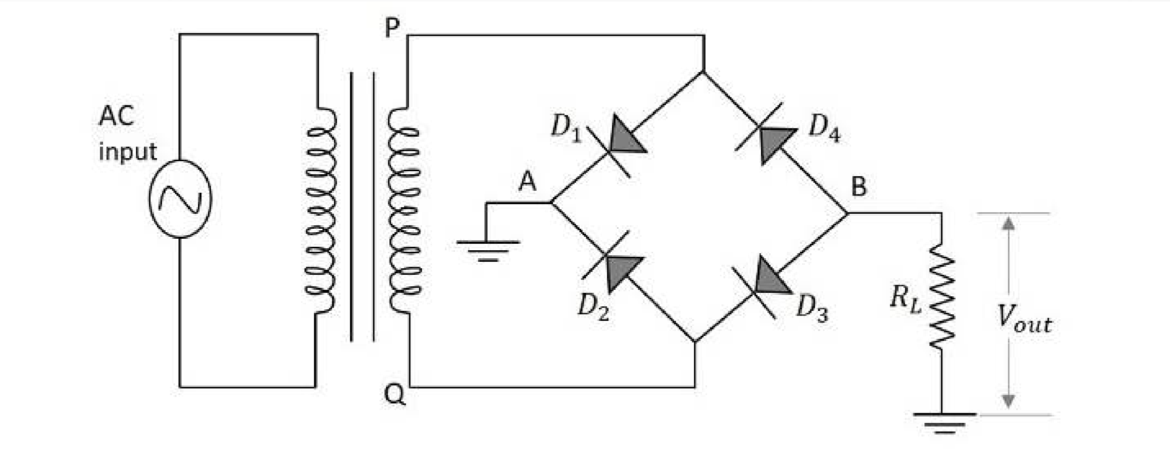
In a Full Wave Rectifier circuit two diodes are now used, one for each half of the cycle. A multiple winding transformer is used whose secondary winding is split equally into two halves with a common centre tapped connection, (C). This configuration results in each diode conducting in turn when its anode terminal is positive with respect to the transformer centre point C producing an output during both half-cycles, twice that for the half wave rectifier so it is 100% efficient as shown below.



Bridge Full-Wave Rectifier

This is such a full wave rectifier circuit which utilizes four diodes connected in bridge form to produce the output during the full cycle of input. Four diodes called D1, D2, D3 and D4 are used in constructing a bridge type network so that two of the diodes conduct for one half cycle and two conduct for the other half cycle of the input supply.

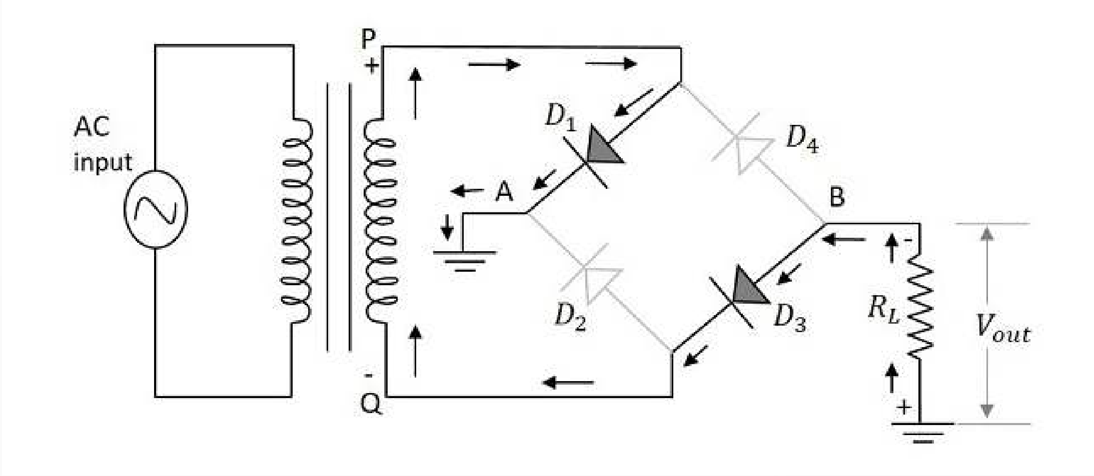
The circuit of a bridge full wave rectifier is as shown in the following figure.



Working of a Bridge Full-Wave Rectifier

The full wave rectifier with four diodes connected in bridge circuit is employed to get a better full wave output response. When the positive half cycle of the input supply is given, point P becomes positive with respect to the point Q. This makes the diode D1and D3 forward biased while D2 and D4 reverse biased. These two diodes will now be in series with the load resistor.

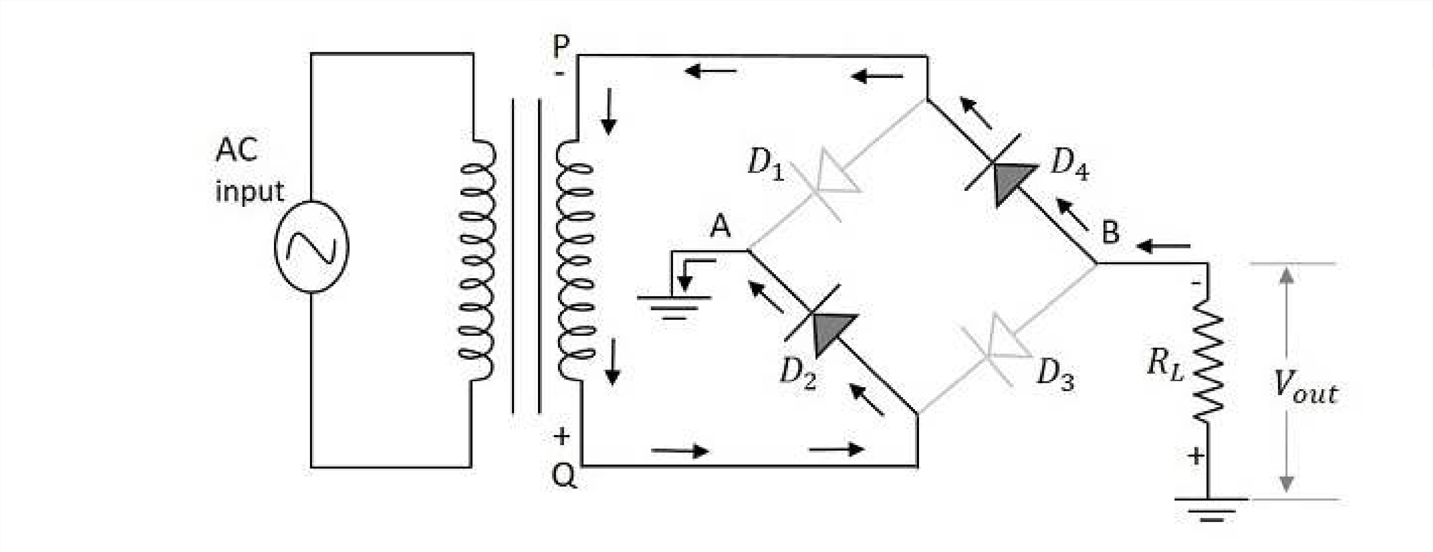
The following figure indicates this along with the conventional current flow in the circuit during the positive half cycle.



Hence the diodes D1 and D3 conduct during the positive half cycle of the input supply to produce the output along the load resistor. As two diodes work in order to produce the output, the voltage will be twice the output voltage of the center tapped full wave rectifier.

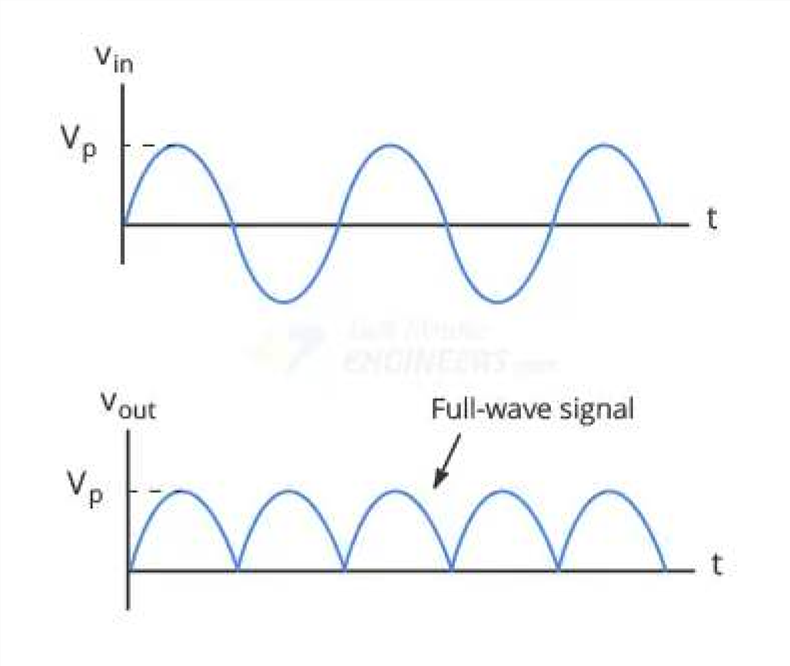
When the negative half cycle of the input supply is given, point P becomes negative with respect to the point Q. This makes the diode D1 and D3 reverse biased while D2 and D4 forward biased. These two diodes will now be in series with the load resistor.

The following figure indicates this along with the conventional current flow in the circuit during the negative half cycle.



Hence the diodes D2 and D4 conduct during the negative half cycle of the input supply to produce the output along the load resistor. Here also two diodes work to produce the output voltage. The current flows in the same direction as during the positive half cycle of the input.

The Waveform of the Bridge Full-Wave Rectifier Circuit:

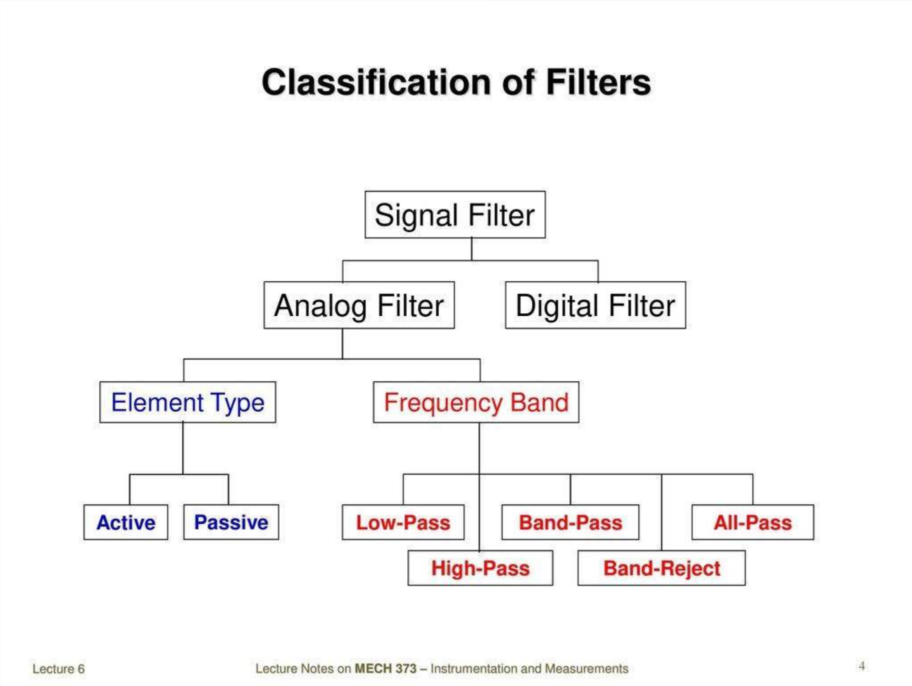


Applications of Full Wave Rectifier:

- Battery charging
- Signal processing
- Uninterrupted Power supply
- Welding
- Radio signals
- LED Driver Circuits.
- Audio Amplifier.
- Radios

CLASSIFICATION OF FILTERS

A filter is a circuit capable of passing (or amplifying) certain frequencies while attenuating other frequencies. Thus, a filter can extract important frequencies from signals that also contain undesirable or irrelevant frequencies.



Filters can be placed in one of two categories: Passive or Active.

Passive filters include only passive components—resistors, capacitors, and inductors. In contrast, active filters use active components, such as op-amps, in addition to resistors and capacitors, but not inductors.

The four primary types of filters include the low-pass filter, the high-pass filter, the band-pass filter, and the notch filter (or the band-reject or band-stop filter).

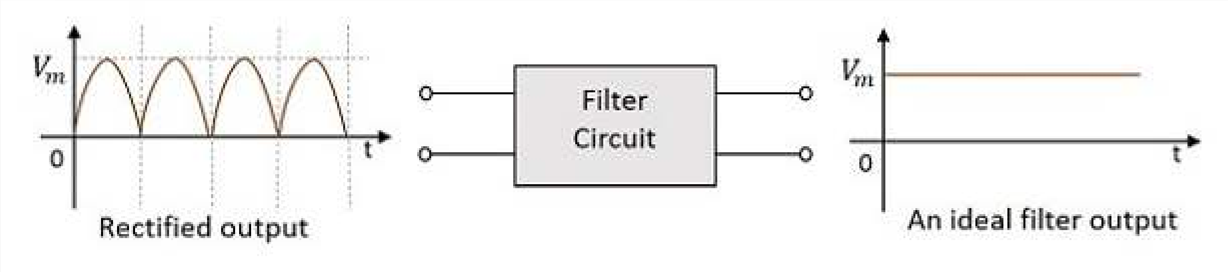
Low Pass Filter: The low pass filter only allows low frequency signals from 0 Hz to its cut-off frequency, ƒc point to pass while blocking any higher frequency signals.

High Pass Filter: The high pass filter only allows high frequency signals from its cut-off frequency, ƒc point and higher to infinity to pass through while blocking those any lower.

Band Pass Filter: The band pass filter allows signals falling within a certain frequency band set up between two points to pass through while blocking both the lower and higher frequencies either side of this frequency band.

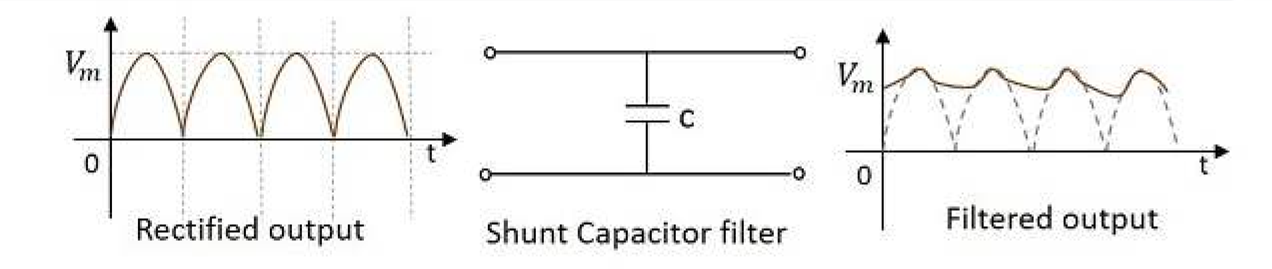
Band Stop Filter: The band stop filter blocks signals falling within a certain frequency band set up between two points while allowing both the lower and higher frequencies either side of this frequency band.

The following figure shows the functionality of a filter circuit.



Shunt Capacitor Filter

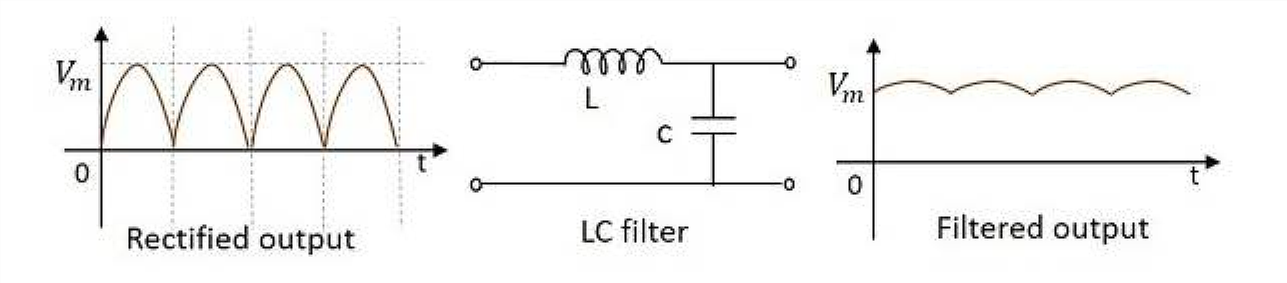
As a capacitor allows ac through it and blocks dc, a filter called Shunt Capacitor Filter can be constructed using a capacitor, connected in shunt, as shown in the following figure.



The rectified output when passed through this filter, the ac components present in the signal are grounded through the capacitor which allows ac components. The remaining dc components present in the signal are collected at the output.

Choke Input Filter

A filter circuit can be constructed using both inductor and capacitor in order to obtain a better output where the efficiencies of both inductor and capacitor can be used. The figure below shows the circuit diagram of a LC filter.



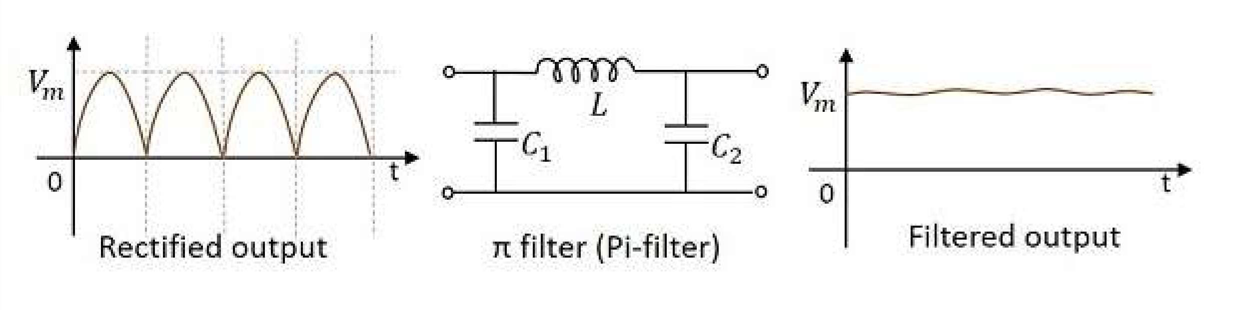
The rectified output when given to this circuit, the inductor allows dc components to pass through it, blocking the ac components in the signal. Now, from that signal, few more ac components if any present are grounded so that we get a pure dc output.

This filter is also called as a LC filter as both the Inductor & Capacitor is used in the circuit.

Capacitor Input Filter

This is another type of filter circuit which is very commonly used. It has capacitor at its input and hence it is called as a Capacitor Input Filter. Here, two capacitors and one inductor are connected in the form of π shaped network which gives the circuit another name called Pi-filter. A capacitor in parallel, then an inductor in series, followed by another capacitor in parallel makes this circuit.

If needed, several identical sections can also be added to this, according to the requirement. The figure below shows a circuit for π filter or Pi–filter.



Working of a Pi filter

In this circuit, we have a capacitor in parallel, then an inductor in series, followed by another capacitor in parallel.

Capacitor C1 – This filter capacitor offers high reactance to dc and low reactance to ac signal. After grounding the ac components present in the signal, the signal passes to the inductor for further filtration.

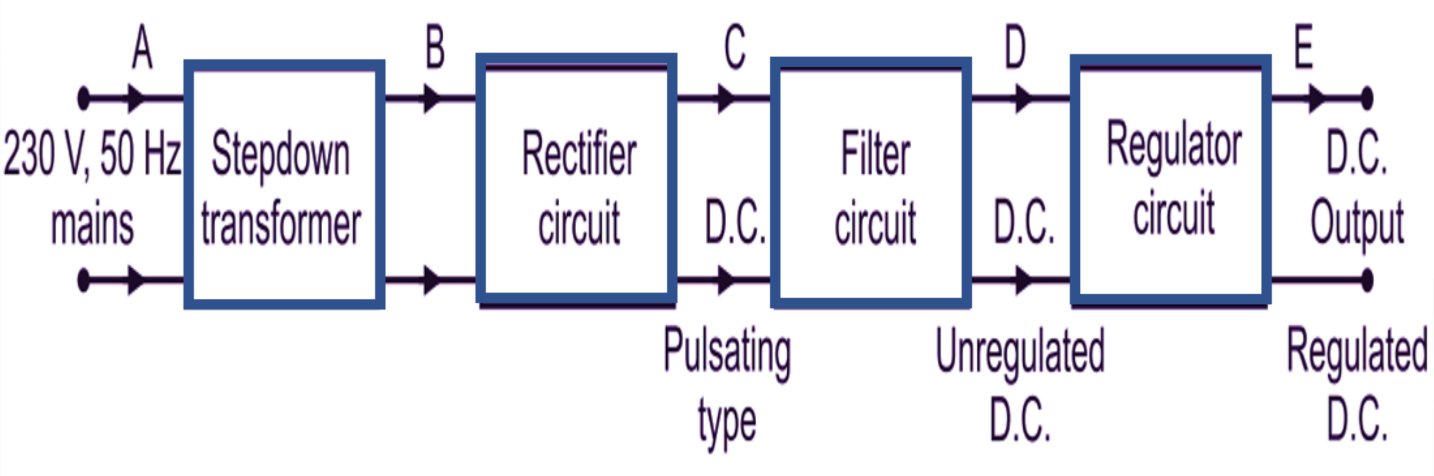
Inductor L – This inductor offers low reactance to dc components, while blocking the ac components if any got managed to pass, through the capacitor C1.

Capacitor C2 – Now the signal is further smoothened using this capacitor so that it allows any ac component present in the signal, which the inductor has failed to block.

Thus we, get the desired pure dc output at the load.

DEFINITION OF DC POWER SUPPLY SYSTEM

A DC power supply is a device that converts alternating current (AC) to direct current (DC), or from one voltage to another. DC power supplies are used as a power source to run electronic circuits or to check electronic devices. They are also known as bench power supplies.



DC power supplies are also used in industrial and scientific applications where voltage and current must be properly controlled. In these instances, DC power supplies are frequently used in conjunction with electrical devices known as power regulators to ensure that the DC voltage or current remains constant.

VOLTAGE REGULATOR AND ITS APPLICATIONS

A voltage regulator is a circuit which is connected between the power source and a load, which provides a constant voltage despite variations in input voltage or output load. Voltage regulators (VRs) keep the voltages from a power supply within a range that is compatible with the other electrical components.

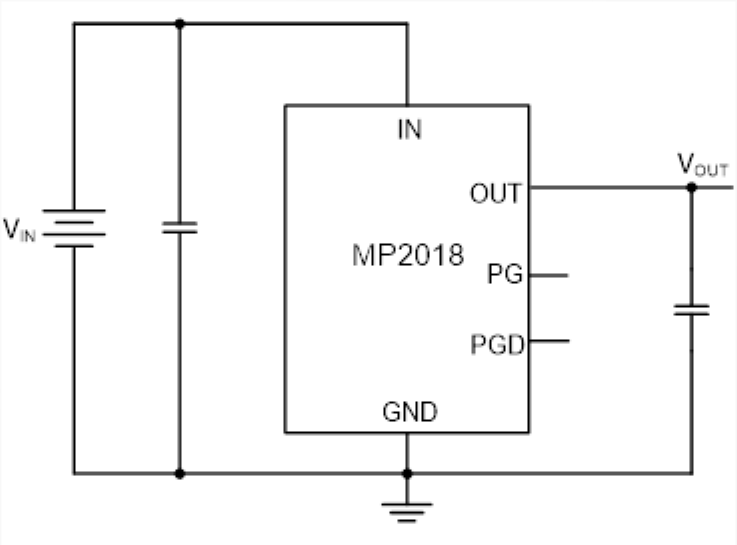
There are two main types of voltage regulators: Linear and Switching.

Linear Regulators:

A linear voltage regulator utilizes an active pass device (such as a BJT or MOSFET), which is controlled by a high-gain operational amplifier. To maintain a constant output voltage, the linear regulator adjusts the pass device resistance by comparing the internal voltage reference to the sampled output voltage, and then driving the error to zero.

Linear regulators are step-down converters, so by definition the output voltage is always below the input voltage. However, these regulators offer a few advantages: they are generally easy to design, dependable, cost-efficient, and offer low noise as well as a low output voltage ripple.

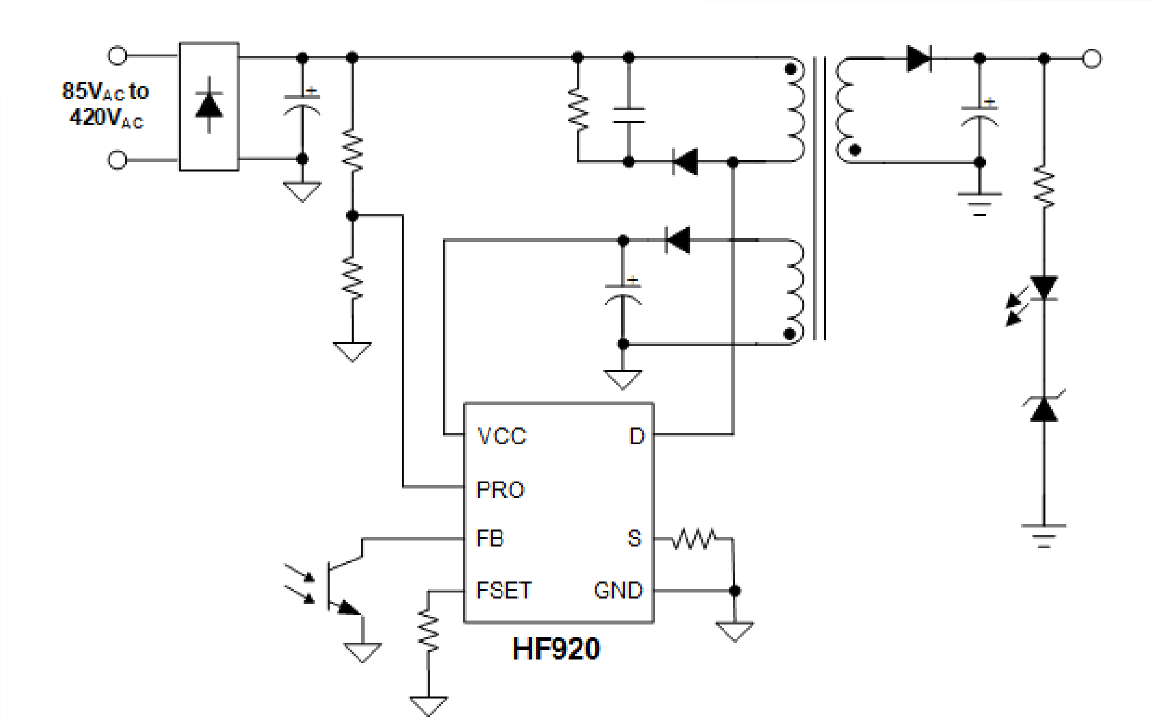
Linear regulators, such as the MP2018, only require an input and output capacitor to operate. Their simplicity and reliability make them intuitive and simple devices for engineers and are often highly cost-effective.



Switching Regulators

A switching regulator circuit is generally more complicated to design than a linear regulator, and requires selecting external component values, tuning control loops for stability, and careful layout design. Switching regulators can be step-down converters, step-up converters, or a combination of the two, which makes them more versatile than a linear regulator. Advantages of switching regulators include that they are highly efficient, have better thermal performance, and can support higher current and wider VIN / VOUT applications. They can achieve greater than 95% efficiency depending on the application requirements.

Unlike linear regulators, a switching power supply system may require additional external components, such as inductors, capacitors, FETs, or feedback resistors. The HF920 is an example of a switching regulator that offers high reliability and efficient power regulation.



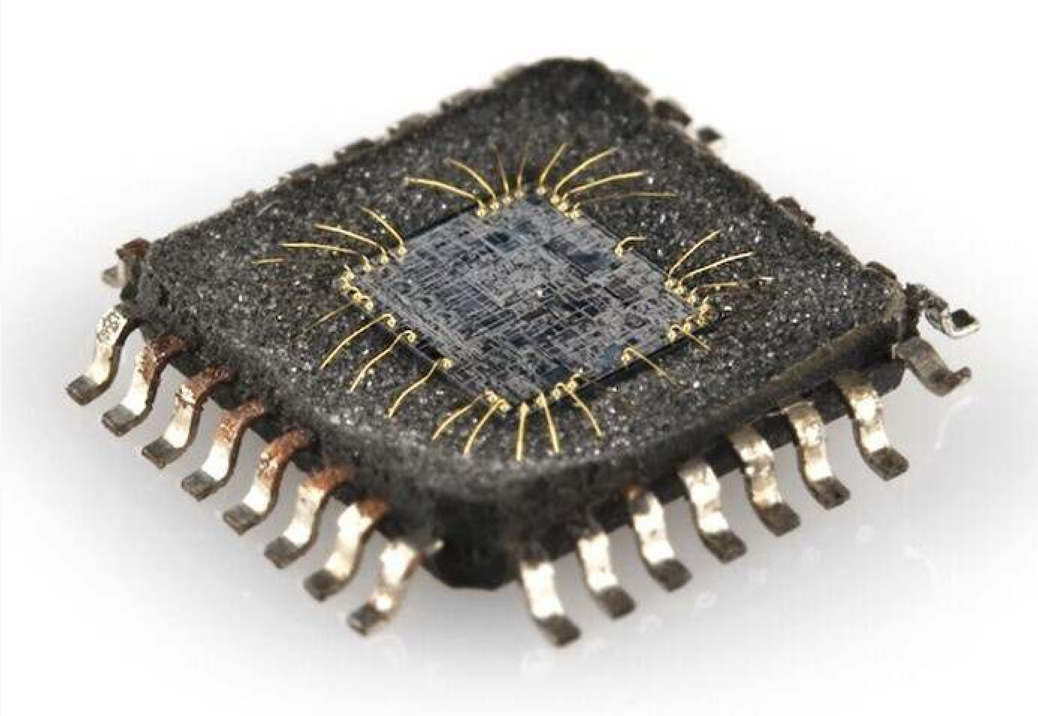
Applications of Voltage Regulators:

- Power supplies
- Battery charging
- Automotive electronics
- Communication devices
- Consumer electronics
- Medical equipment
- Renewable energy systems
- Industrial control systems

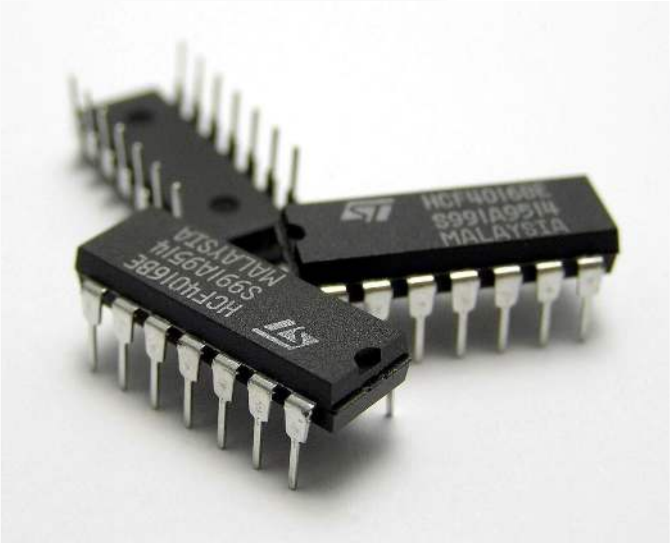
CHAPTER III -LINEAR INTEGRATED CIRCUITS

INTEGRATED CIRCUITS (IC) DEFINITION AND ITS APPLICATIONS

An integrated circuit (IC), sometimes called a chip, microchip, or microelectronic circuit, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, diodes, and transistors are fabricated. Integrated circuits are the building blocks for most electronic devices and equipment.



An integrated circuit (IC) can be used as an amplifier, oscillator, timer, counter, logic gate, computer memory, microcontroller, or processor.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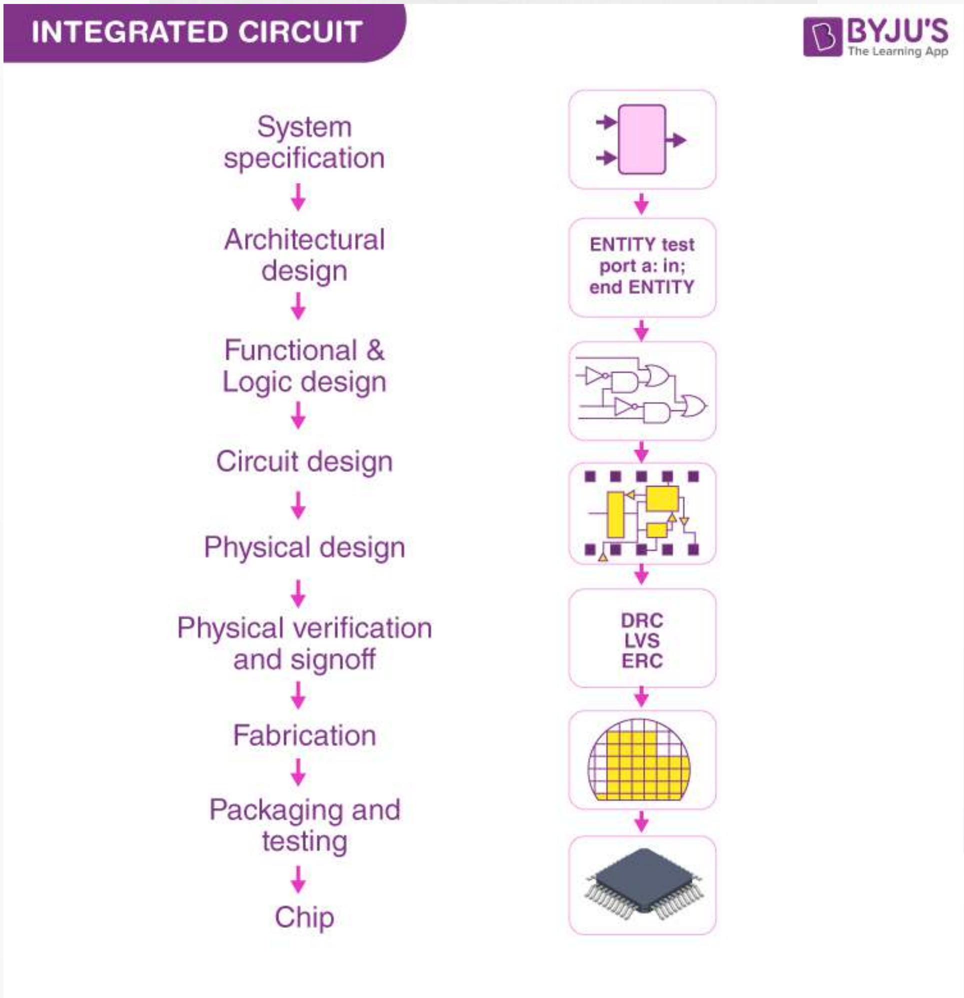

INTEGRATED CIRCUIT
BYJU'S
The Learning App
System specification
Architectural design
Functional & Logic design
Circuit design
Physical design
Physical verification and signoff
Fabrication
Packaging and testing
Chip
ENTITY test
port a: in;
end ENTITY
DRC
LVS
ERC

Types of Integrated Circuits

Integrated circuits are of two types – Analog Integrated Circuits and Digital Integrated Circuits.

1. Analog Integrated Circuits

Integrated circuits that operate over an entire range of continuous values of the signal amplitude are called as Analog Integrated Circuits.

1. Digital Integrated Circuits

If the integrated circuits operate only at a few pre-defined levels instead of operating for an entire range of continuous values of the signal amplitude, then those are called as Digital Integrated Circuits.

Advantages of IC's

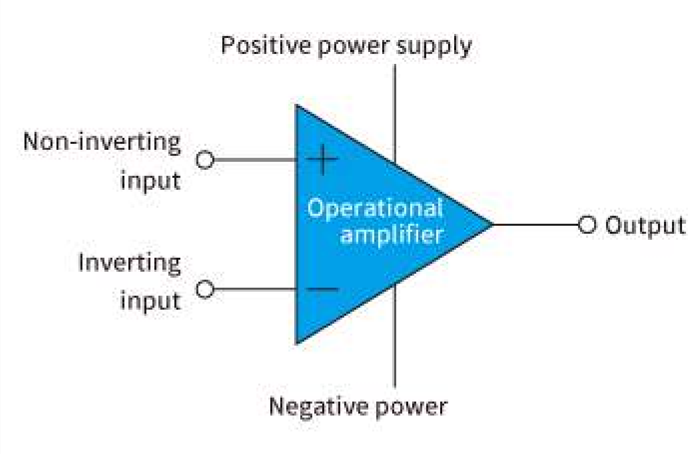
1. Compact size
2. Lesser weight
3. Low power consumption
4. Reduced cost
5. Increased reliability
6. Improved operating speeds.

Some applications of ICs include:

- Computer systems
- Radars for navigation and tracking
- Logic devices
- Video processors
- Memory devices
- Audio amplifiers
- Calculator chips
- Radiofrequency decoders and encoders
- Voltage regulators
- Timers
- Clock chips
- Calculators
- Flip flops
- Memory chips
- Counters
- Temperature sensors
- Microcontrollers

BASIC OF OPERATIONAL AMPLIFIERS

An operational amplifier (op amp) is an analog circuit block that takes a differential voltage input and produces a single-ended voltage output. Op amps usually have three terminals: two high-impedance inputs and a low-impedance output port.



In other words, it is described as “It is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals”.

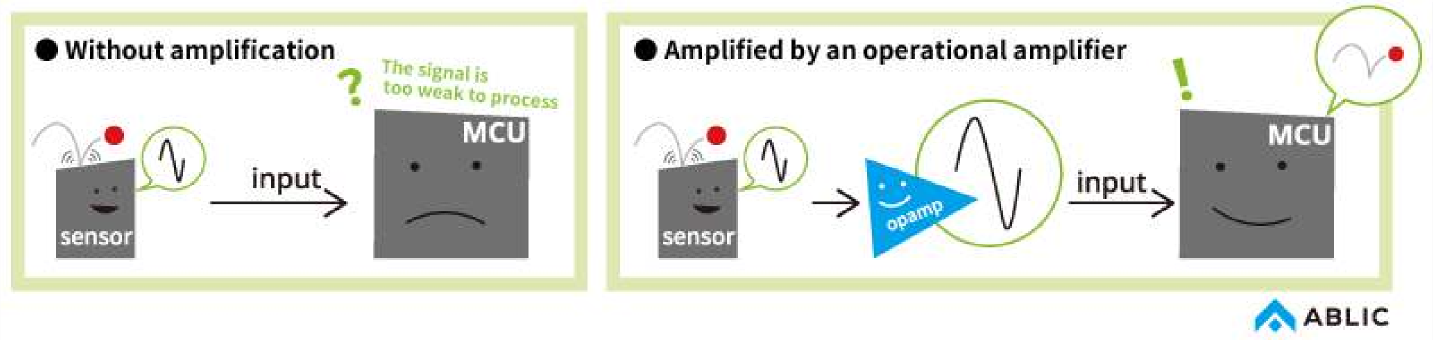
These feedback components determine the resulting function or “operation” of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of “Operational Amplifier”.

An operational amplifier is not used alone but is designed to be connected to other circuits to perform a great variety of operations.

Some of the operations are given below:

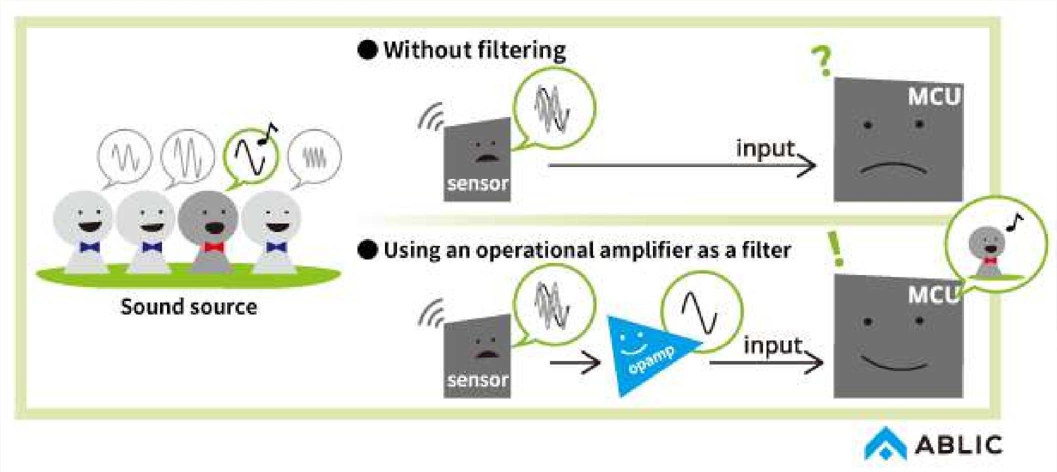
- Enables substantial amplification of an input signal

When an operational amplifier is combined with an amplification circuit, it can amplify weak signals to strong signals. It behaves like a megaphone where the input signal is a person's voice, and the megaphone is the operational amplifier circuit. For example, such a circuit can be used to amplify minute sensor signals.



●Enables elimination of noise from an input signal

By operating as a filter of input signals, the operational amplifier circuit can extract the signal with the target frequency. For example, when an operational amplifier circuit is used for voice recognition or in a voice recorder, it can extract frequencies close to the targeted sound while shutting out all other frequencies as noise.



Operational amplifiers work to amplify the voltage differential between the inputs, which is useful for a variety of analog functions including signal chain, power, and control applications.

The three most important characteristics of an operational amplifier are:

- Very high gain.
- Very high input impedance.
- Very low output impedance.

Operational Amplifier Classifications

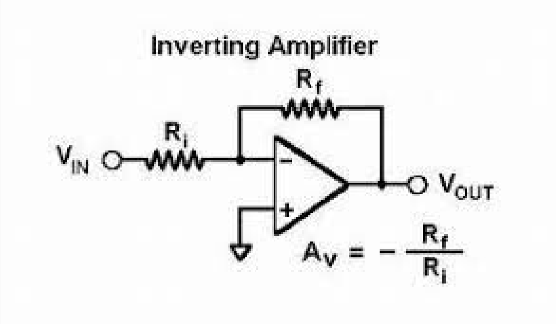
There are four ways to classify operational amplifiers:

- Voltage amplifiers take voltage in and produce a voltage at the output.
- Current amplifiers receive a current input and produce a current output.
- Transconductance amplifiers convert a voltage input to a current output.
- Trans resistance amplifiers convert a current input and produces a voltage output.

INVERTING AND NON-INVERTING AMPLIFIER

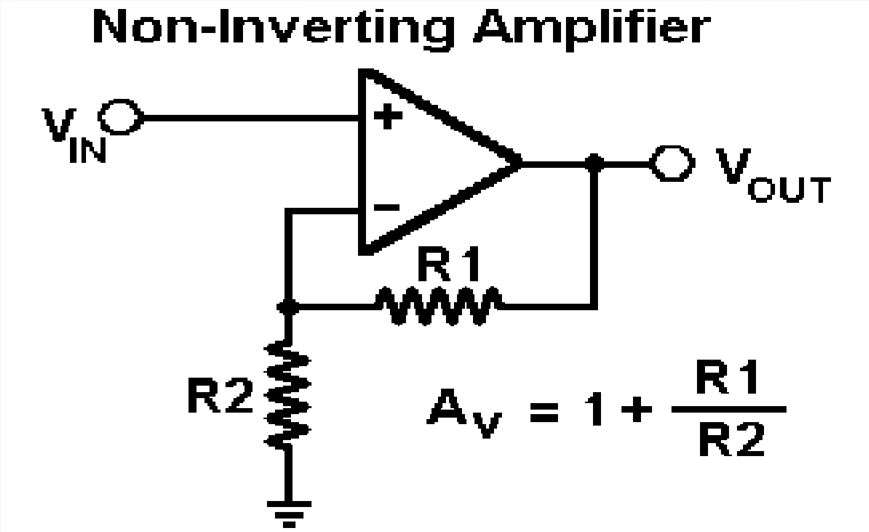
Inverting Amplifier

An inverting amplifier (also known as an inverting operational amplifier or an inverting op-amp) is a type of operational amplifier circuit which produces an output which is out of phase with respect to its input by 180o.This means that if the input pulse is positive, then the output pulse will be negative and vice versa.



$$A_v = -\frac{R_f}{R_i}$$

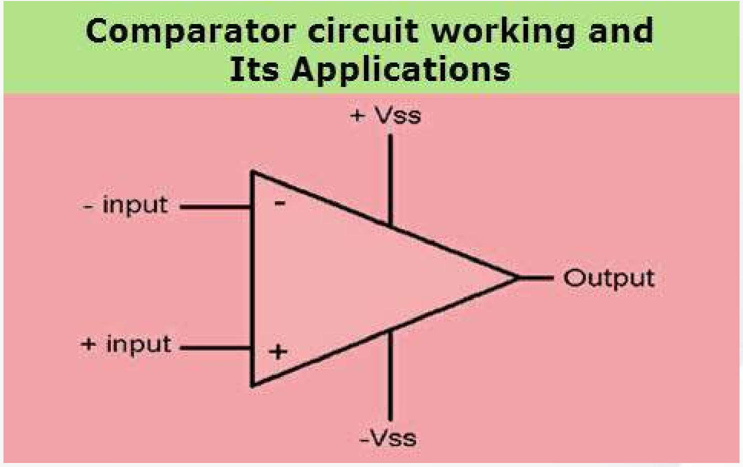
Non-Inverting Amplifier



A non-inverting op amp is an operational amplifier circuit with an output voltage that is in phase with the input voltage. Its complement is the inverting op amp, which produces an output signal that is 180o out of phase.

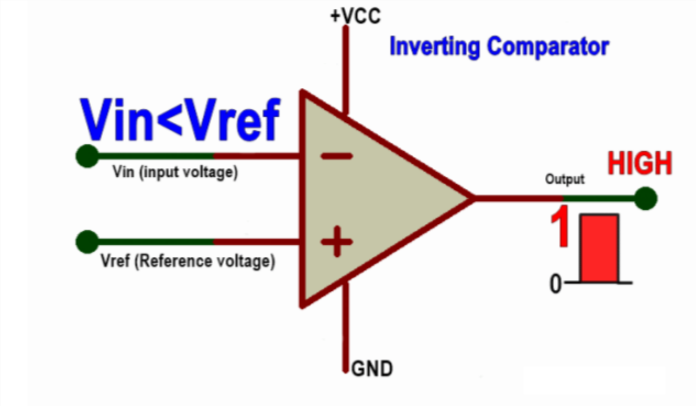
COMPARATOR AND ITS WORKING

A comparator compares two input voltages and outputs a binary signal indicating which is larger. If the non-inverting (+) input is greater than the inverting (-) input, the output goes high. If the inverting input is greater than the non-inverting, the output goes low.



The most frequent application for comparators is the comparison between a voltage and a stable reference.

Comparators have many applications, including threshold detectors/discriminators, zero-crossing detectors, and oscillators.

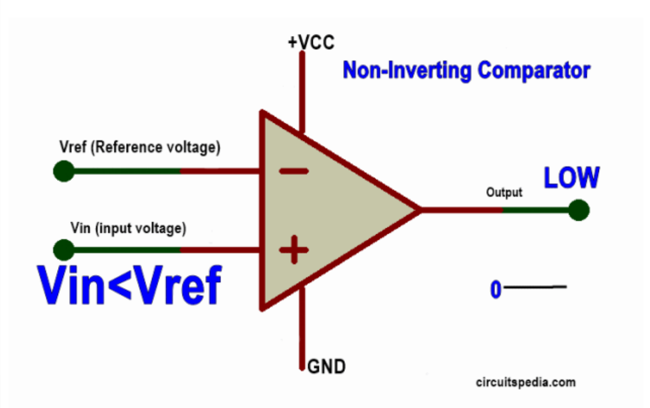


Types of Comparators

The two basic types of voltage comparator are inverting and non-inverting, depending on which terminal the input signal is applied to.

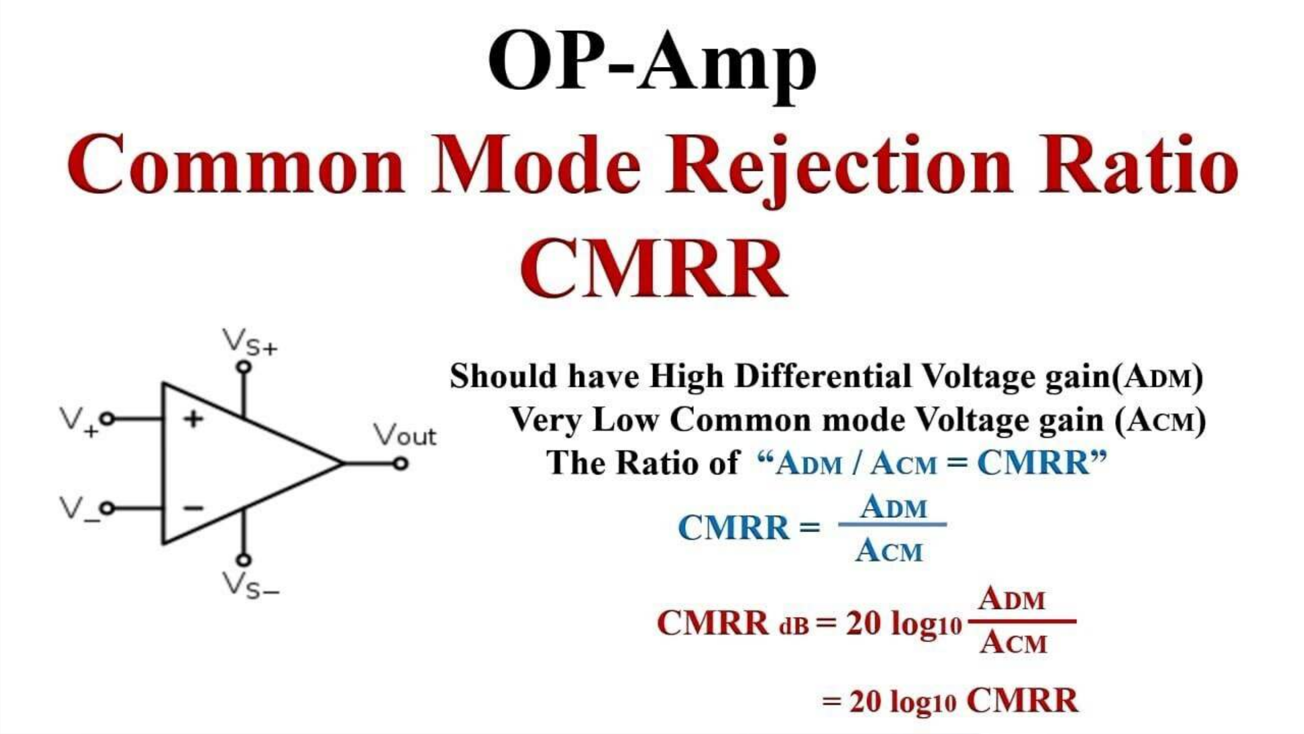
In an inverting comparator (or negative voltage comparator), the input signal is applied to the inverting terminal and the reference voltage is at the non-inverting terminal. This creates a positive voltage output if the input voltage is less than the reference voltage.

In a non-inverting comparator, the input signal is applied to the non-inverting terminal and the reference voltage is at the inverting terminal. This creates a positive voltage output if the input voltage is greater than the reference voltage.



COMMON MODE REJECTION RATIO (CMRR) AND ITS DEFINITION

Common mode rejection ratio (CMRR) is a metric that measures how well a device can reject common-mode signals. Common-mode signals are signals that appear simultaneously and in-phase on both inputs. CMRR is a crucial parameter in electronic circuits that helps to reduce noise and preserve signal integrity.



CMRR is defined as the ratio of the differential voltage gain to the common mode voltage gain. For a good-quality differential amplifier, the CMRR should be very large.

For practical operational amplifiers, The Common Mode Rejection Ratio (CMRR) should be 85 to 105 db. For Ideal operational amplifiers, The Common Mode Rejection Ratio (CMMR) should be infinity.

A higher CMRR indicates better rejection of common mode signals, leading to improved signal integrity and accuracy. It ensures that the device focuses on amplifying the desired signal while minimizing any interference that may degrade the quality of the measurement.

When a differential amplifier receives two input signals, it amplifies the voltage difference between them, known as the differential voltage. At the same time, it suppresses any signal that is present in both inputs, known as the common mode voltage. This rejection of common mode signals is crucial for accurate signal processing and noise reduction.

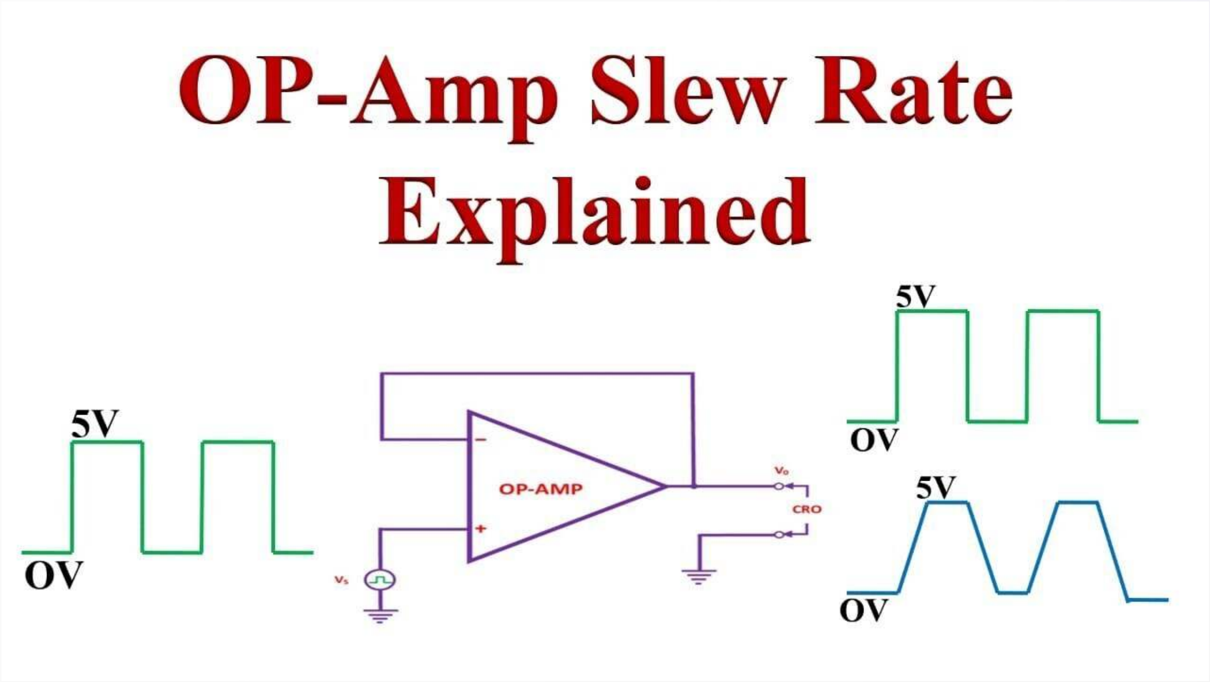
The differential output from the amplifier is then filtered to remove any remaining common mode components, effectively isolating the desired signal. This filtering stage further enhances the rejection of common mode noise, ensuring that only the differential signal is passed through for further processing.

SLEW RATE AND ITS FORMULA

Slew rate is defined as the maximum rate of change of an op amps output voltage and is given in units of volts per microsecond. Slew rate is measured by applying a large signal step, such as one volt, to the input of the op amp, and measuring the rate of change from 10% to 90% of the output signal's amplitude.

It plays a key role in op-amp to help in identifying the highest input frequency & amplitude suitable such that the output of the op-amp is not much distorted.

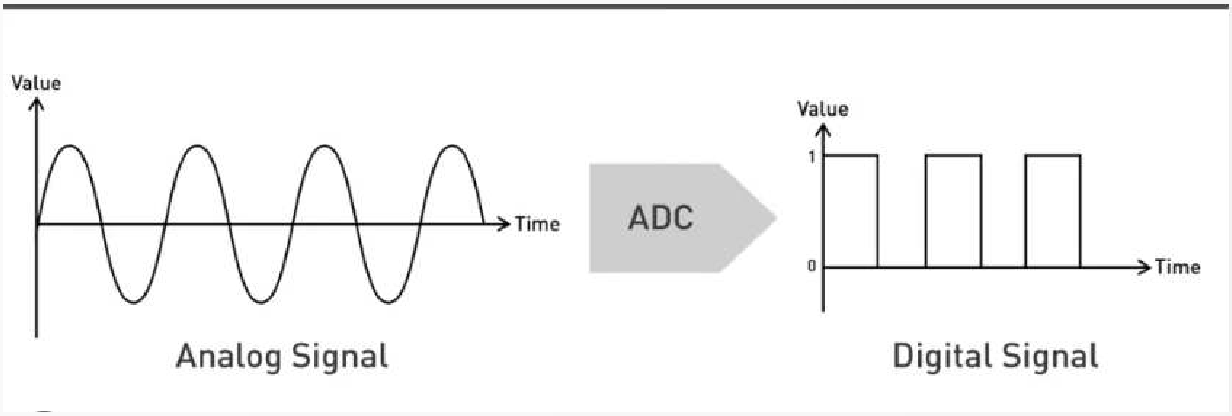
So, the slew rate must be high to ensure the highest undistorted o/p voltage swing. It is used to verify whether an operational amplifier can deliver a reliable output to the input or not. This factor will be changed once the voltage gain is changed.



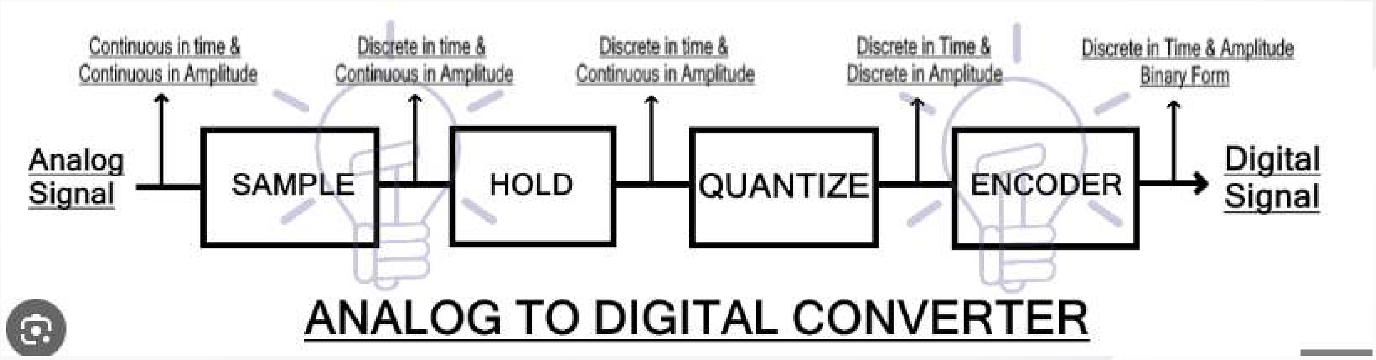
The slew rate formula is (S) = ΔVout/Δt. The units of slew rate are V/μs or Volts per second.

ADC (ANALOG TO DIGITAL CONVERTERS) AND DAC (DIGITAL TO ANALOG CONVERTERS) ADC - (ANALOG TO DIGITAL CONVERTERS)

An analog-to-digital converter (also known as an ADC or an A/D converter) is an electronic circuit that measures a real-world signal (such as temperature, pressure, acceleration, and speed) and converts it to a digital representation of the signal.



An ADC compares samples of the analog input voltage (produced using a Sample and Hold circuit) to a known reference voltage and then produces a digital representation of this analog input. The output of an ADC is a digital binary code

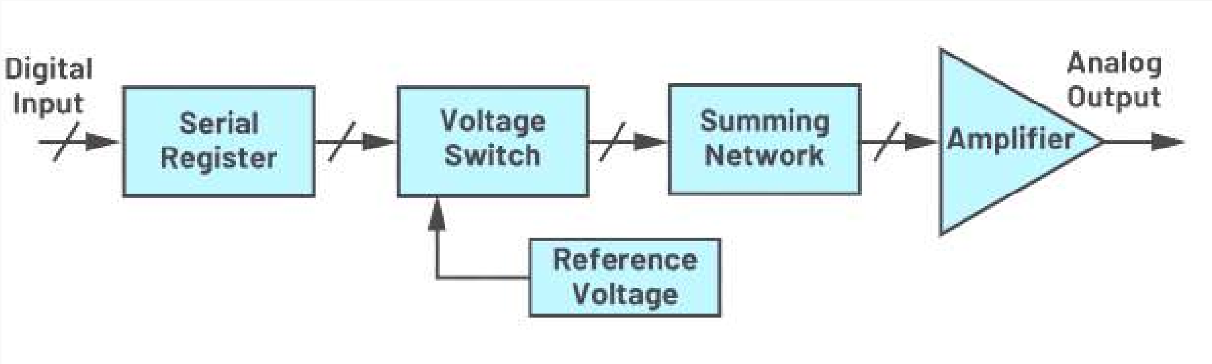


The Analogue-to-Digital Converter, (ADCs) allow micro-processor controlled circuits, Arduinos, Raspberry Pi, and other such digital logic circuits to communicate with the real world. In the real world, analogue signals have continuously changing values which come from various sources and sensors which can measure sound, light, temperature or movement, and many digital systems interact with their environment by measuring the analogue signals from such transducers.

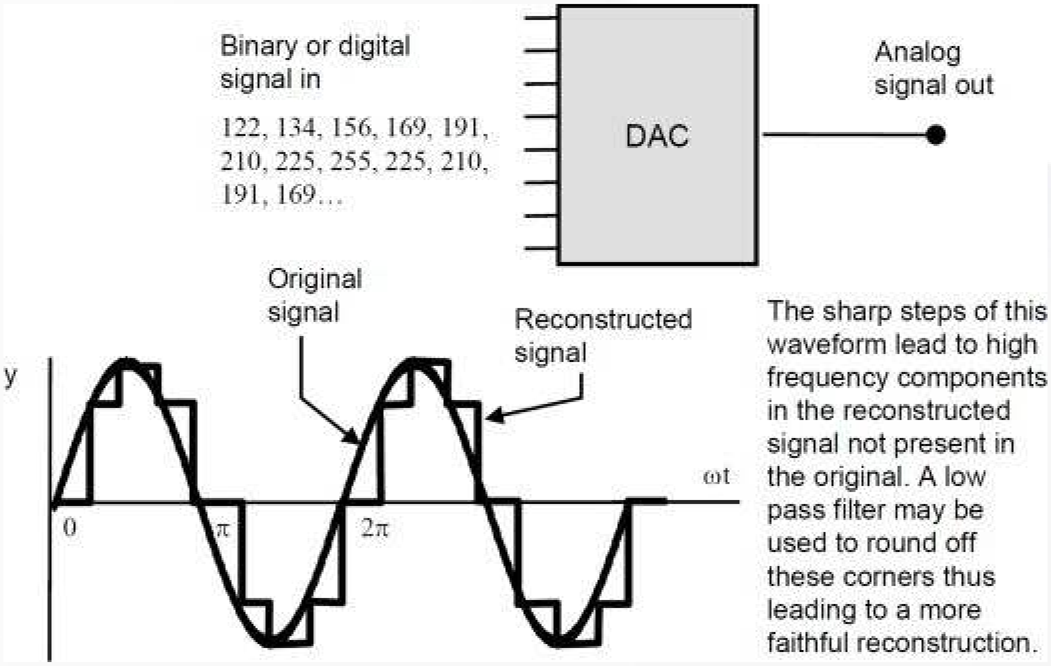
DAC - (Digital to Analog Converters)

A digital-to-analog converter (DAC), as the name implies, is a data converter which generates an analog output from a digital input. A DAC converts a limited number of discrete digital codes to a corresponding number of discrete analog output values.

Digital-to-Analog Converters (DACs) are used to transform digital data into an analog signal.



DACs are commonly used in music players to convert digital data streams into analog audio signals. They are also used in televisions and mobile phones to convert digital video data into analog video signals. These two applications use DACs at opposite ends of the frequency/resolution trade-off. The audio DAC is a low-frequency, high-resolution type while the video DAC is a high-frequency low- to medium-resolution type.



SCHMITT TRIGGER, PRECISION RECTIFIER, PEAK DETECTOR DEFINITIONS

Schmitt trigger

A Schmitt trigger is a comparator circuit that uses positive feedback to create hysteresis. Hysteresis is the ability to have different threshold voltage levels for signal rise and fall.

What does a Schmitt trigger do?

Schmitt triggers can be used to change a sine wave into a square wave, clean up noisy signals, and convert slow edges to fast edges.

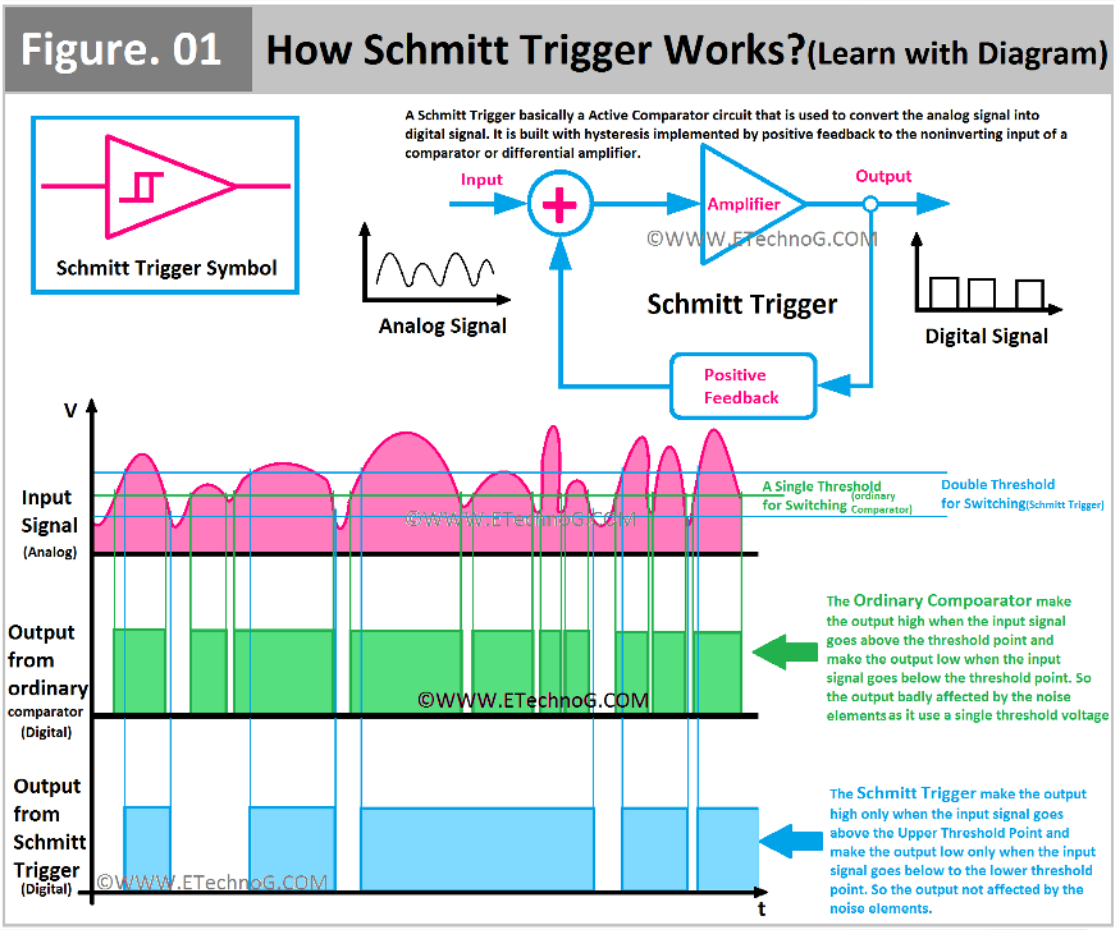
Schmitt Trigger Circuit

The Schmitt trigger circuit uses positive feedback. Therefore, this circuit is also known as the regenerative comparator circuit. The Schmitt Trigger circuit can be designed with the help of Op-Amp and Transistor. And it classified as.

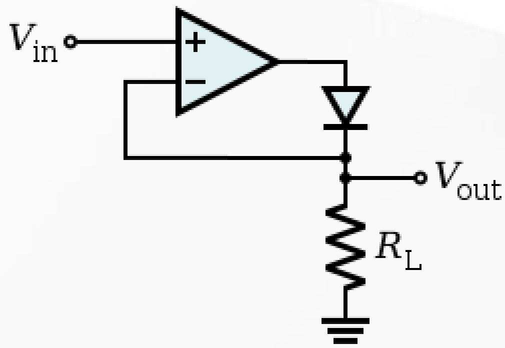
- Op-amp based Schmitt trigger.
- Transistor based Schmitt trigger.

Precision Rectifier

A precision rectifier is a circuit that acts like a perfect diode. It's useful for high-precision signal processing. It is also known as "Super Diode"



The precision rectifier is a configuration obtained with an operational amplifier in order to have a circuit behave like an ideal diode and rectifier.[1] It is very useful for high-precision signal processing. With the help of a precision rectifier the high-precision signal processing can be done very easily.



Here are some characteristics of a precision rectifier:

- Conducts perfectly when forward-biased
- Blocks perfectly when reverse biased
- Converts AC signal to DC without any loss of signal voltage
- Rectifies voltages below the level of cut-in voltage of the diode
- Rectifies very small voltages

Precision rectifiers use op amp based circuits. Some advantages of precision rectifiers include:

- No diode voltage drop between input and output
- Ability to rectify very small voltages

Precision rectifiers are used in:

- Half wave rectifiers
- Full wave rectifiers
- Peak value detector
- Clippers
- Clampers
- AM detectors

Peak Detector

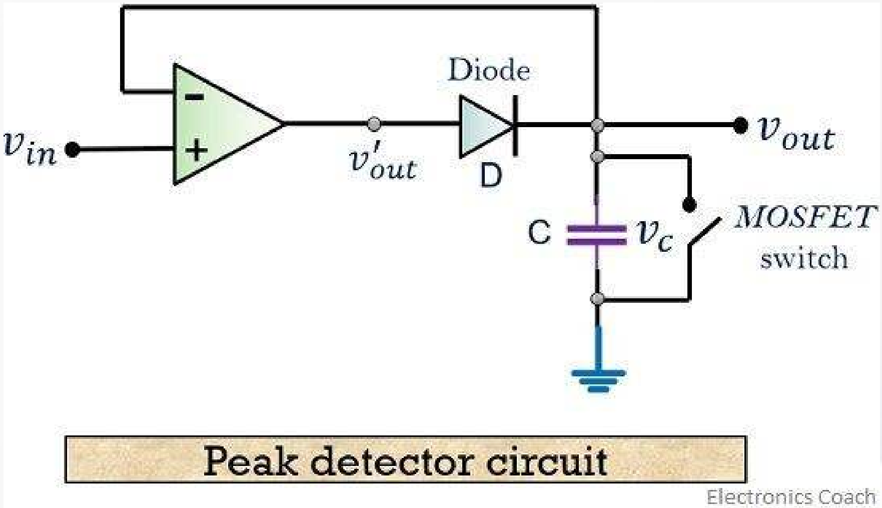
Definition: Peak detector circuits are used to determine the peak (maximum) value of an input signal. It stores the peak value of input voltages for infinite time duration until it comes to reset condition. The peak detector circuit utilizes its property of following the highest value of an input signal and storing it.

Rectifier circuits usually provide an output in proportion to the average value of the input. However, some application requires measurement of the peak value of the signal. Thus, peak detectors are used.

Usually, the peak of non-sinusoidal waveforms is measured using a peak detector. As traditional ac voltmeter cannot measure the peak of such signals.

Circuit Working of Peak detector

The figure below shows the circuit of a basic positive peak detector-



It consists of a diode and capacitor along with an op-amp as shown above. The circuit does not require any complex component in order to determine the peak of the input waveform.

Working Principle

The working principle of the circuit is such that, the peak of the input waveform is followed and stored in terms of voltage in the capacitor.

By the time on moving further, if the circuit detects a higher peak, the new peak value is stored in the capacitor until it is discharged.

The capacitor employed in the circuit is charged through the diode by the applied input signal. The small voltage drop across the diode is ignored and the capacitor is charged up to the highest peak of the applied input signal.

Applications of Peak detector

1. It is used in the analysis of spectral and mass spectrometer.
2. Peak detector finds its application in destructive testing.
3. It is used for instrumentation measurement, mostly in amplitude modulated wave communication.
4. It widely finds applications in sound measuring instruments.

TIMER IC AND ITS CONCEPTS

The 555 timer IC is an integrated circuit (chip) used in a variety of timer, delay, pulse generation, and oscillator applications.

The main function of this IC is to generate an accurate timing pulse for operating various devices and electronic components.

The 555 Timer is designed using 25 transistors, 2 diodes and 15 resistors. The functional parts of the 555 timer IC include a flip-flop, voltage divider & a comparator altogether.

Operating modes of the 555 Timers

There are three operating modes of the 555 timers: Monostable, Bistable and Astable. Various combinations of capacitors and resistors are connected to the input pins of the 555 timers to switch between these modes. This allows us to create different applications with the 555 timers, just by rearranging the externally connected components.

MONOSTABLE

This is also known as the "one-shot" mode. When triggered, the timer generates only a single output pulse and returns to its stable state. Uses include time delay generation, touch switches, pulse width modulation, and many more.

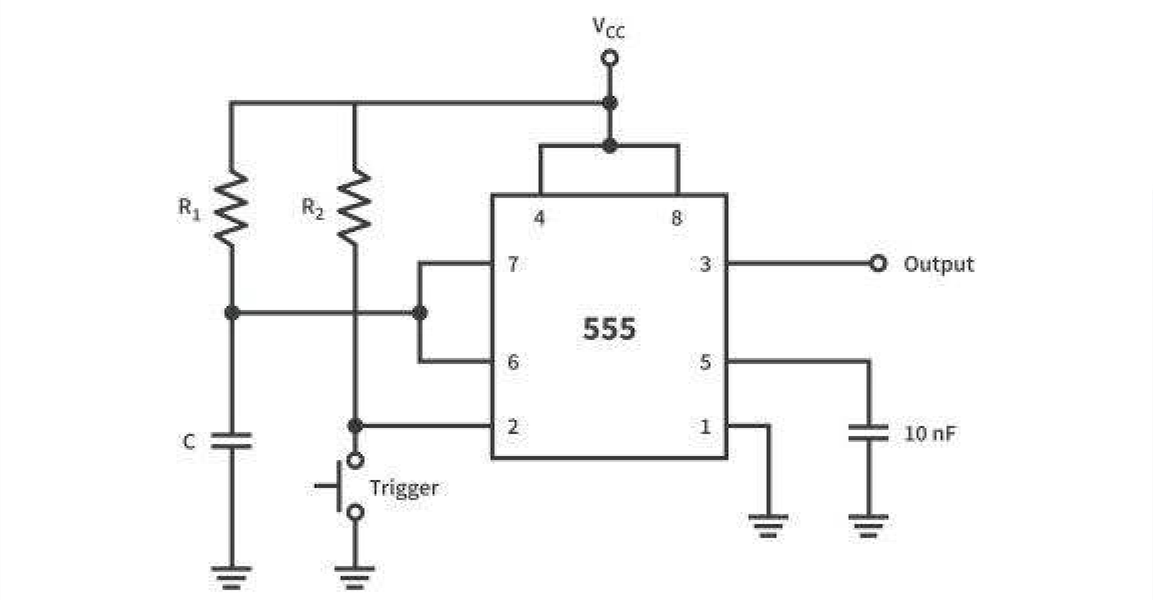


Figure 1: Monostable mode schematic

BISTABLE

In this mode, the timer acts as a flip flop as it has two stable modes. We can store 1 bit of data using the timer. However, this is not a preferred method for storing data.

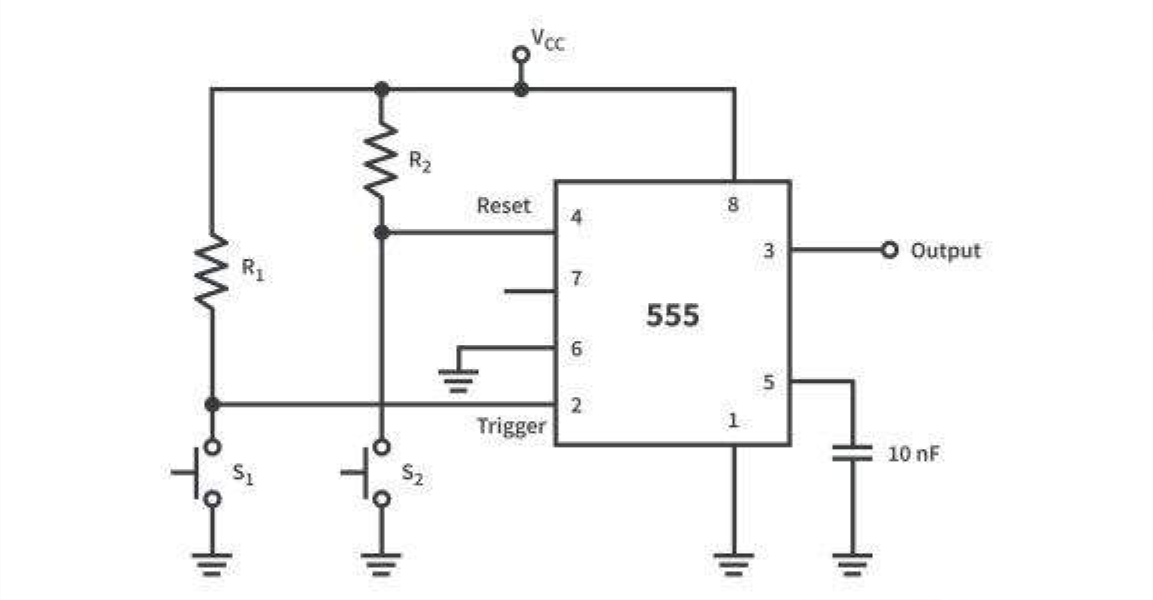


Figure 2: Bistable mode schematic

ASTABLE

In this mode, 555 acts as an electronic oscillator. The output continuously switches from logic high to logic low as per the configured period. This mode is used for pulse generation, logic clock generation, LED, and lamp flashers.

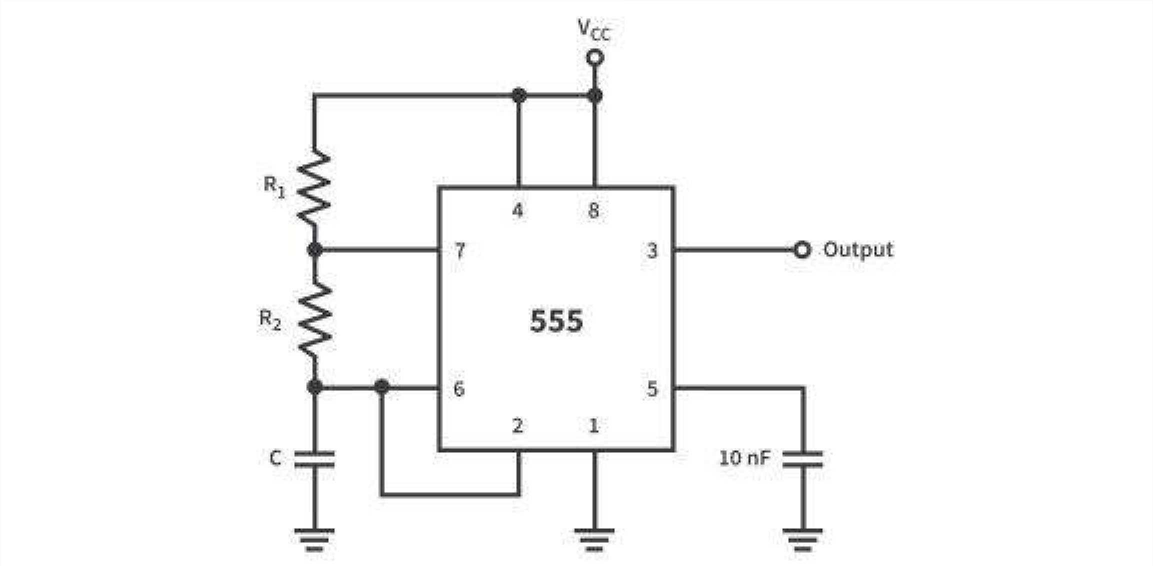


Figure 8: Astable mode schematic

CHAPTER IV- POWER ELECTRONICS

BASIC

What is power electronics?

Power Electronics refers to the process of controlling the flow of current and voltage and converting it to a form that is suitable for user loads. The most desirable power electronic system is one whose efficiency and reliability is 100%.

Power electronics is a sub field of electrical engineering that deals with the design, control, and conversion of electrical power from one form to another. It involves the use of solid-state electronics, such as transistors and diodes, to control and manipulate high-power electrical energy.

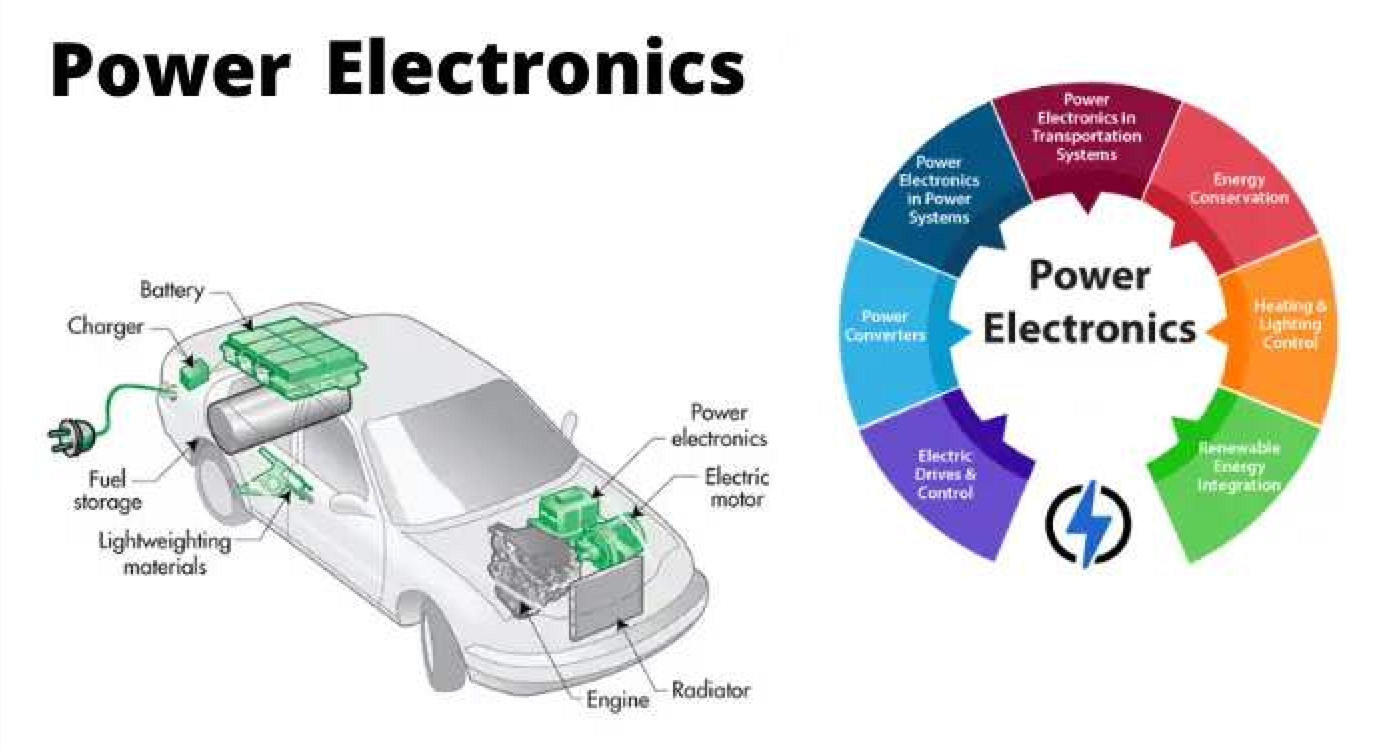
What are the basic application of power electronics?

A whole lot of power electronics applications that we use in our daily life, such as a fan regulator, air-conditioning, induction cooking, light dimmer, emergency lights, vacuum cleaners, personal computers, UPS, battery charges, etc., are the major applications of power electronics.

What are the basic concepts of basic electronics?

The basics of electronics refer to the concepts that include inductance, capacitance, resistance, voltage and electrical currents.

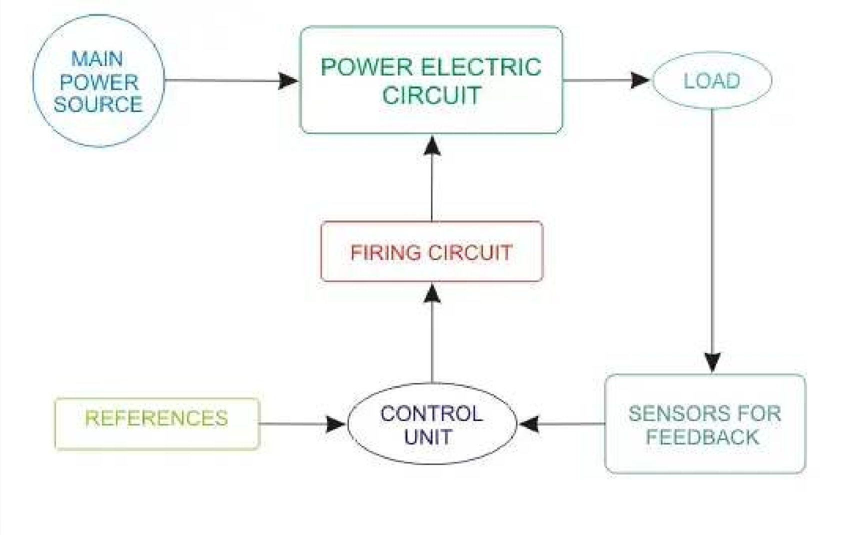
Professionals who know the basics of electronics understand how devices control electrons via manipulating, storing, switching, selecting, steering, carrying or resisting them.



FUNDAMENTALS

What are the major Fundamentals of power electronics?

In summary, the research area of Power Electronics and Power Systems aims to improve the efficiency and sustainability of electrical power conversion. Researchers focus on developing efficient technologies and optimizing power systems to reduce energy waste and enhance overall performance.



Power electronics engineering is a field of electrical engineering that deals with the design, development, and implementation of power electronic systems. It involves the study of the conversion, regulation, and control of electrical power, with a focus on high-power and high-frequency applications.

Power electronics engineers use a combination of electrical, electronic, and computer engineering principles to design, develop, and test power electronics components and systems. They work with a range of technologies, including power semiconductors, power supplies, energy storage systems, and power conversion systems.

Key skills for power electronics engineers include:

- Circuit design and analysis
- Power electronics theory and application
- Semiconductor devices and materials
- Power system design and analysis
- Analog and digital electronics
- Control theory and design
- Computer-aided design (CAD)
- Testing and measurement techniques

Power electronics engineers may work in a variety of industries, including renewable energy, electric transportation, consumer electronics, industrial automation, and power distribution and transmission. They may also work in academia, conducting research and developing new technologies in the field.

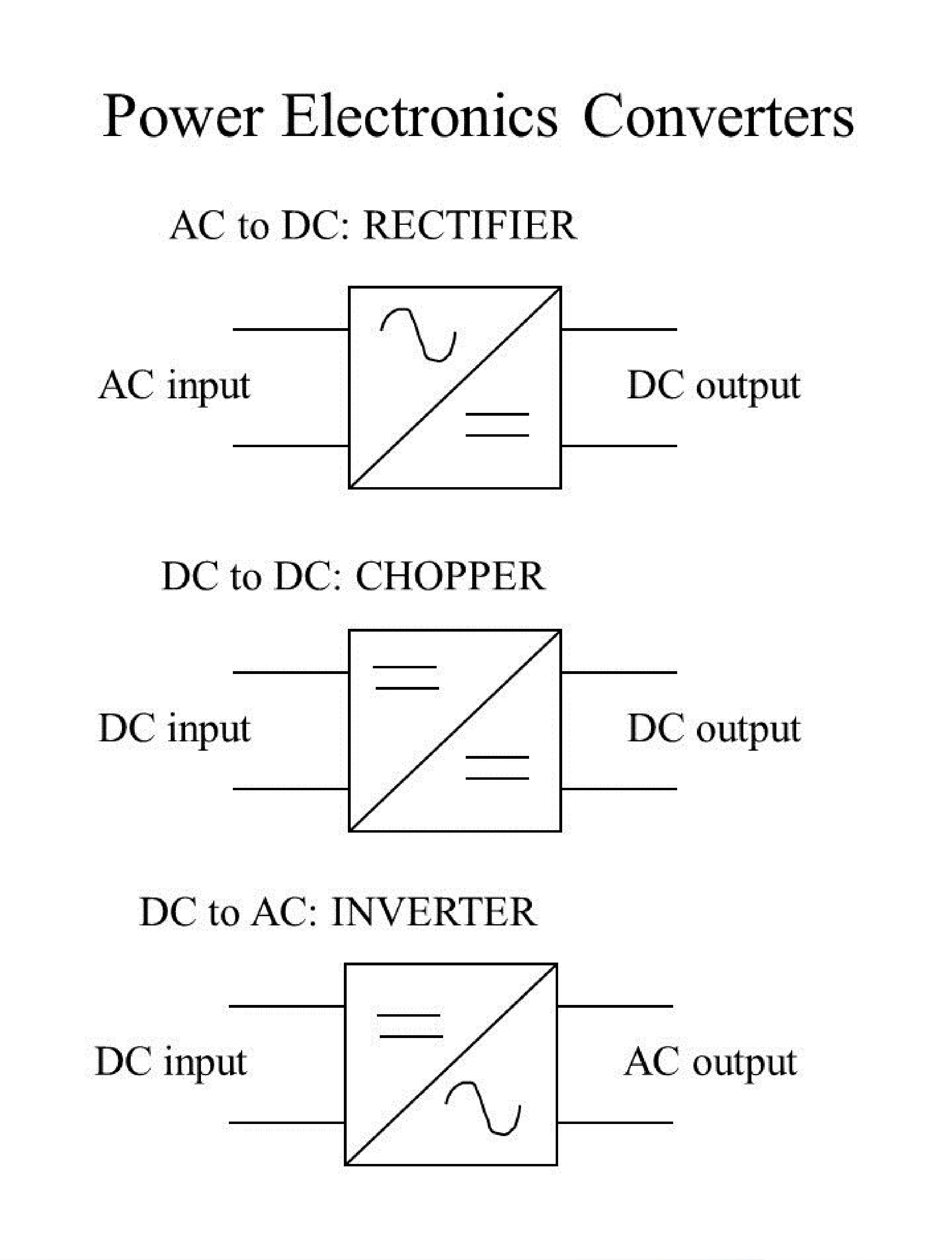
What is the use of power electronics?

Power electronics are widely used in motor control systems such as industrial automation, robotics, and power generation systems. They are utilized to regulate the speed and torque of electric motors, resulting in enhanced efficiency and reduced energy consumption.

SEMICONDUCTOR DEVICES

Power Electronics Devices/Components

The main components of power electronics systems include:


Power Electronics Converters
AC to DC: RECTIFIER
AC input
DC output
DC to DC: CHOPPER
DC input
DC output
DC to AC: INVERTER
DC input
AC output

They include diodes, thyristors, transistors, and MOSFETs. These devices are essential for power electronics because they provide a fast and efficient way to switch electrical power on and off. Inductors and capacitors: Inductors and capacitors are used to store and release energy in power electronic circuits.

Rectifiers:

Rectifiers are used to convert AC power to DC power. They are often used in applications such as battery charging, DC power supply, and AC-to-DC power conversion.

Inverters:

Inverters convert DC power to AC power. They are used in applications such as AC power supply, renewable energy integration, and uninterruptible power supplies.

DC-DC converters:

DC-DC converters are used to regulate voltage levels between different DC sources. They are used in applications such as voltage regulation, battery management, and load matching.

AC-DC converters:

AC-DC converters are used to regulate voltage levels between AC and DC sources. They are used in applications such as AC-to-DC power conversion, renewable energy integration, and battery charging.

Power semiconductor devices:

These are used to control the flow of electrical power. They include diodes, thyristors, transistors, and MOSFETs. These devices are essential for power electronics because they provide a fast and efficient way to switch electrical power on and off.

Inductors and capacitors:

Inductors and capacitors are used to store and release energy in power electronic circuits. They help smooth out the voltage and current waveforms in the circuit, which is essential for stable and efficient power conversion.

Transformers:

Transformers are used to step up or step down voltage levels in power electronic circuits. They are essential for adapting the voltage level of the electrical power to the requirements of the load.

Control circuits:

Control circuits are used to regulate the operation of power electronic components and to ensure stable and efficient power conversion. They are used to control the switching of power semiconductors, regulate voltage and current levels, and perform other control functions.

Protection circuits:

Protection circuits are used to prevent damage to the power electronic components and to ensure the safe operation of the system. They are used to detect and respond to over-current, over-voltage, and over-temperature conditions in the circuit, which can cause damage to the components or cause safety hazards.

These components work together in a power electronics system to control and convert electrical power from one form to another. The design and selection of these components are crucial for achieving the desired performance and efficiency of the system.

- Power electronics has a wide range of applications, including:
- Renewable energy integration:
- Power electronics is used in solar panels, wind turbines, and other renewable energy sources to convert the generated power into usable AC power that can be integrated into the power grid.
- Electric transportation:
- It is used in electric vehicles to manage the charging and discharging of the battery, control the electric motor, and regulate the power flow in the vehicle.
- Consumer electronics:
- It is used in consumer electronics devices, such as laptops, smartphones, and televisions, to regulate the voltage levels and manage the power supply.
- Industrial drives and control systems:
- It is used in industrial drives and control systems to control the speed and torque of electric motors, regulate the power supply, and improve system performance.
- Energy storage:
- It is used in energy storage systems, such as batteries and flywheels, to regulate the charging and discharging of the energy storage device and to ensure efficient and stable power conversion.
- Lighting and lighting control:
- It is used in lighting and lighting control systems to regulate the voltage levels, control the brightness, and manage the power supply of lighting systems.
- Power distribution and transmission:
- It is used in power distribution and transmission systems to regulate voltage levels, improve system efficiency, and prevent power losses.
- Medical equipment:
- It is used in medical equipment, such as imaging systems, life support systems, and therapeutic devices, to regulate the voltage levels, manage the power supply, and improve system performance.

- These are just a few of the many applications of power electronics. The field is constantly evolving, and new applications are being developed all the time as technology advances and new challenges arise.

Advantages

- Power electronics has several advantages, including:
- Energy efficiency:
- Power electronics improves energy efficiency by converting AC power to DC power with minimal losses, and by regulating the voltage levels to match the requirements of the load.
- Increased reliability:
- It increases reliability by providing stable and consistent power conversion, and by preventing damage to the electrical components from over-current, over-voltage, and over-temperature conditions.
- Improved control:
- It provides improved control over the flow of electrical power, allowing for precise regulation of voltage levels, current levels, and power quality.
- Increased safety:
- Power electronics improve safety by preventing electrical hazards and by providing protection for the electrical components from damage.
- Cost savings:
- It can provide cost savings by reducing energy consumption, increasing system efficiency, and reducing the need for maintenance and repairs.
- Versatility:
- It is versatile and can be used in a wide range of applications, from renewable energy integration to electric vehicles to consumer electronics.

- Compact design:
- Power electronics components are typically smaller and lighter than traditional electrical components, allowing for more compact and streamlined designs in electrical systems.
- High-speed switching:
- It provides high-speed switching, allowing for fast and efficient control of the electrical power flow.
- These advantages have contributed to the widespread adoption of power electronics in a variety of industries and applications, and have driven the development of new and innovative solutions in the field.
- Challenges in Power Electronics Design
- Despite its many advantages, power electronics also have some disadvantages.
- Thermal Management:
- Power electronic devices generate heat during operation, which can reduce their efficiency and shorten their lifespan. Effective thermal management is crucial to maintaining the performance and reliability of power electronic systems.
- Power Density:
- As power electronic systems become more compact, the challenge of achieving high power density increases. This requires the use of high-performance materials and innovative design techniques to manage heat and increase efficiency.
- Efficiency:
- Power electronic systems must be highly efficient to minimize energy losses and reduce the size and cost of cooling systems. Designers must also consider the overall system efficiency, including the power conversion efficiency, the efficiency of passive components, and the efficiency of control systems.
- Reliability:

Power electronic systems must be highly reliable to ensure that they can operate for extended periods of time without failure. Designers must consider factors such as the reliability of components, the effects of temperature and humidity, and the impact of over-voltage and over-current conditions.

Electromagnetic Compatibility (EMC):

Power electronic systems must meet stringent electromagnetic compatibility (EMC) requirements to ensure that they do not generate harmful electromagnetic interference (EMI) that can affect other electronic systems.

Cost:

Power electronics systems must be cost-effective while meeting the technical requirements and performance goals of the application. Designers must balance the cost of components, manufacturing, and testing with the desired performance and reliability goals.

Despite these disadvantages, power electronics has proven to be a critical technology in many applications, and efforts are ongoing to address these challenges and improve the performance, efficiency, and reliability of power electronics components and systems.

What are semiconductor devices?

Semiconductor device, electronic circuit component made from a material that is neither a good conductor nor a good insulator (hence semiconductor). Such devices have found wide applications because of their compactness, reliability, and low cost.

Which device is used as semiconductor?

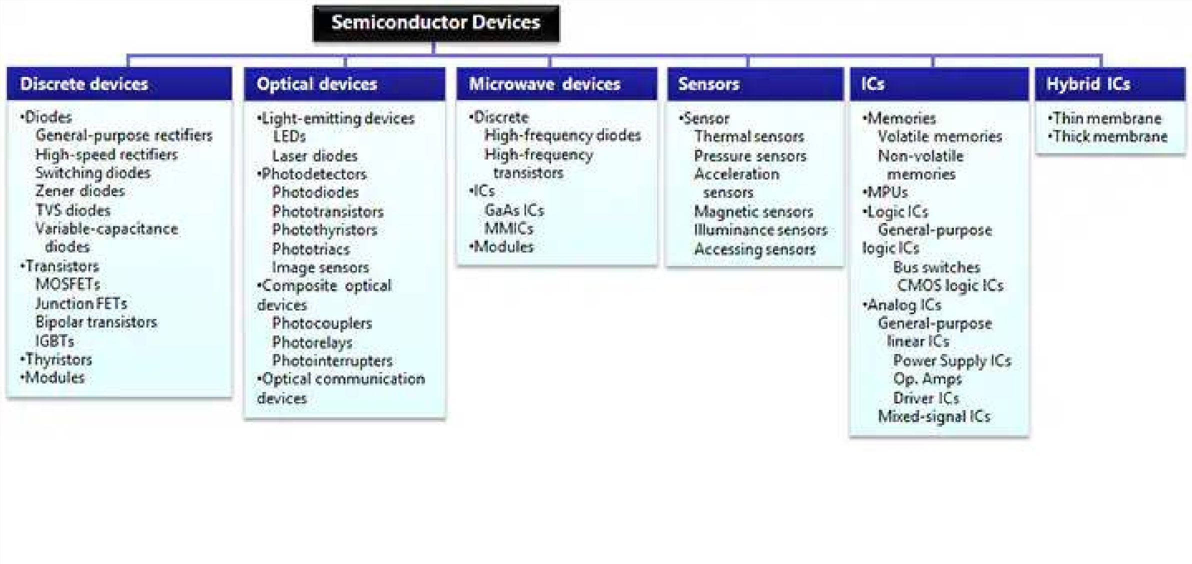
A diode is a semiconductor device that comprises a single p-n junction. P-n junctions are usually formed by joining up of p-type and n-type semiconductor materials.

What are 5 applications of semiconductors?

CPUs that operate personal computers are also made with semiconductors. Many digital consumer products in everyday life such as mobile phones / smartphones, digital cameras, televisions, washing machines, refrigerators and LED bulbs also use semiconductors.

Why are semiconductors used?

It controls and manages the flow of electric current in electronic equipment and devices. As a result, it is a popular component of electronic chips made for computing components and a variety of electronic devices, including solid-state storage.



FORMULAS POWER, UNITS, ENERGY

What is the formula unit ?

Noun Chemistry. (of an ionic compound that does not form molecules, as most salts) the chemical formula with the least number of elements out of the set of empirical formulas having the same proportion of ions as elements: NaCl is the formula unit for the ionic compound sodium chloride.

What is SI formula of power?

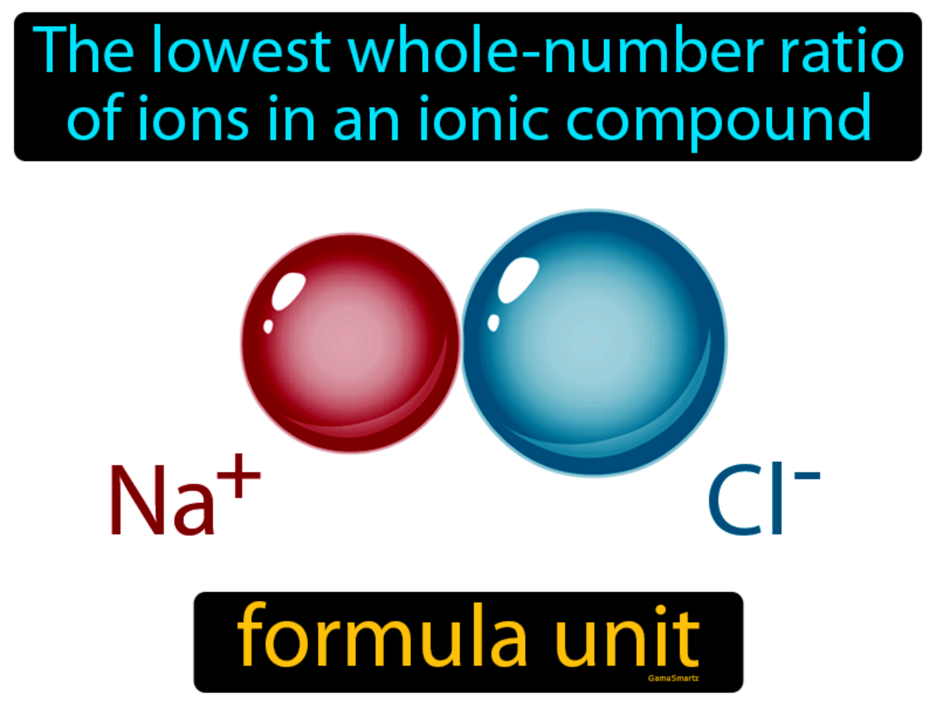
The SI unit of power is Watt (W) which is joules per second (J/s).

What is current formula and power?

The equation for electrical power is P=IV. Where P is electrical Power, I is current, and V is voltage. If you multiply power by time this will give you the total energy, which is generally given in kilowatt-hours. The power equation and the Ohm's law can be combined to produce P=V^2/R and P=I^2R.

What is basic power formula?

The formula for power in watts is given by the work and the time. The formula is P = W/t, where W is the work done in some time t



What is unit of power?

Unit of Power is Watt (W). In other terms, we spent one Watt of Power while completing one Joule of Work in one second. 1 Watt = 1 Joule / 1 second. Other units of Power are Kilowatt (kW), Megawatt (MW) and Gigawatt (GW).

Power

Power is the rate at which energy is transferred or the rate at which work is done.

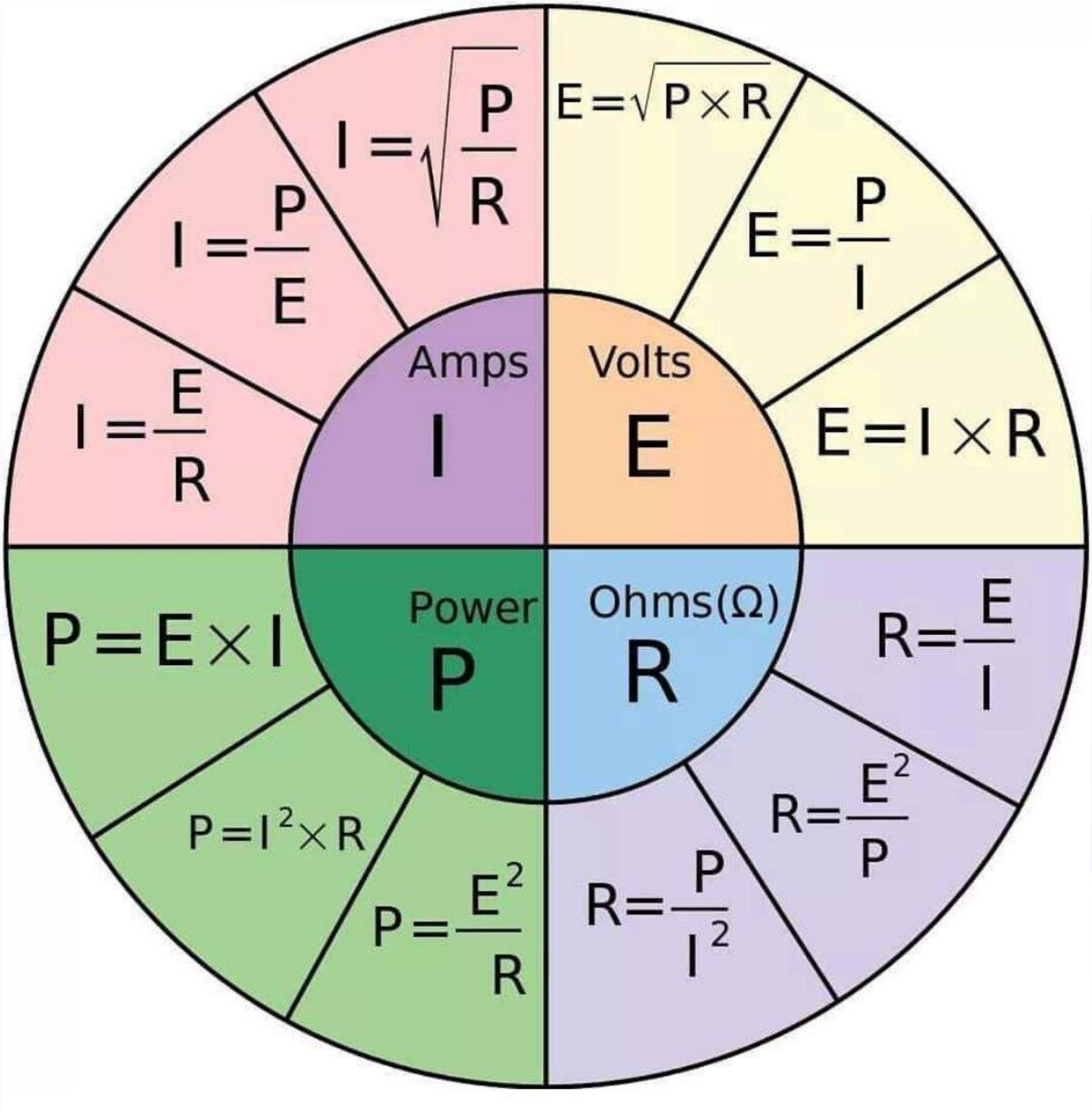
$$P = \frac{W}{t}$$

$$P = \frac{\Delta E}{t}$$

P = power (Watt)
W = work done (J)
ΔE = energy transferred (J)
t = time (s)

- How are energy calculated?
- Energy = Power × Time.
- The formula for electrical energy is E = VIt joules,
- where:
- V: is the potential difference
- I: is the current
- t: is the time
- The formula for electrical power is Power (P) = V*I watts.
- The formula for energy is Energy = Power x Time, or E = P t.
- Power is typically given in Watts, time is usually given in seconds, and energy is usually measured in joules.
- What is the energy formula?

The equation developed by Albert Einstein, which is usually given as E = mc2, showing that, when the energy of a body changes by an amount E (no matter what form the energy takes), the mass (m) of the body will change by an amount equal to E/c2.


Amps
I
Volts
E
Power
P
Ohms(Ω)
R
I = √(P/R)
I = P/E
I = E/R
E = √(P×R)
E = P/I
E = I × R
R = E/I
R = E²/P
R = P/I²
P = E²/R
P = I² × R
P = E × I

INVERTERS

An inverter is a power electronics device that converts direct current (DC) voltage into alternating current (AC) voltage. Inverters are a type of power electronics device that regulates the flow of electrical power

Inverters are used to convert DC power from sources such as batteries or fuel cells to AC electricity. The electricity can be at any required voltage.

Inverters are also called AC Drives, or VFD (variable frequency drive). They are electronic devices that can turn DC (Direct Current) to AC (Alternating Current). It is also responsible for controlling speed and torque for electric motors.

An inverter can be defined as it is a compact and rectangular shaped electrical equipment used to convert direct current (DC) voltage to alternating current (AC) voltage in common appliances. The applications of DC involves several small types of equipment like solar power systems.

The basics function of inverter is to convert DC power into AC power, while at the same time regulating the voltage, current and frequency of the signal. Basically, Inverter is a kind of oscillator.

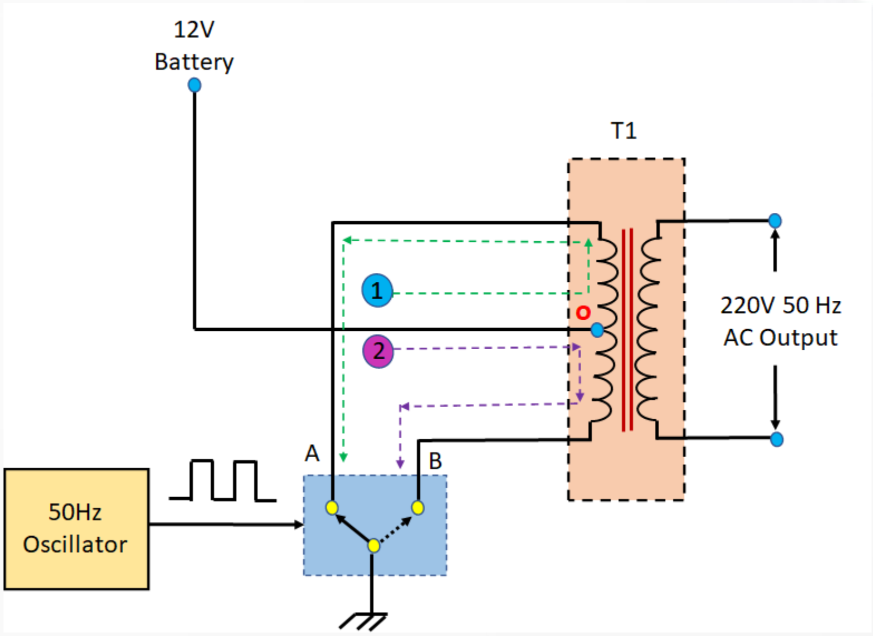
Transistors are the key components of inverter, which convert DC power into AC power. IGBT, MOSFET are the most commonly used switches in inverter.

How many numbers of switches we use depends on the type of inverter?

The transistor is used to change the steady voltage and one-way current flow of DC to the constantly changing voltage and oscillating current of AC.

The key feature of the transistor in the generation of AC power is that it can rapidly switched on or off.

Let's see the working:



Here we see in the circuit diagram here we use 12V battery, one transformer (Primary winding of transformer is Center tapped), One two-way switch and 50 Hz oscillator.

Here 12V battery generate DC supply and inverter will change it into, AC supply of 220V, 50Hz to use to operate any appliances.

The 12V DC supply from the positive terminal of the battery comes to the primary winding of transformer which is center tapped. The two ends of the primary winding of transformer (A and B point) are connected to the two-ways switch to the ground. If the switch connects to A point of the primary winding.

The current flows from the battery into upper half of primary winding (o) through A contact of the switch to the ground. If switch turn from A point into B point. This time the current number 1 stops flowing. Then, the current 2 flows to the ground through o and contact B of the switch.

Here, 2 ways switch is controlled with the square wave oscillator it generates a frequency of 50 Hz. It causes the switch to selects between A and B point with speed about 50 times per second. Also, the current 1 and 2 flows to the transformer alternately at a rate of 50 times per second. So, the current flows into the transformer alternately look like AC voltage.

We know that transformers work on the principle of Electromagnetic induction. When current flow in primary winding EMF induced and a current will be induced into the secondary winding of transformer. Which it causes AC voltage 220V 50Hz. Now, the voltage is use to be supplied to the various types of electrical equipment that operate in 220 Volt AC supply.

Applications Of Inverter

When the AC main power supply is not available, an uninterruptible power supply (UPS) uses battery and inverter.

Power inverters are basically, used in the HVDC transmission line. It also used to connect two asynchronous AC systems.

The output of the solar panel is DC power. The solar inverter used to convert DC power into AC power.

What is power inverter?

A power inverter convert bulk DC power into AC power and used in the power system network. For example power inverters are used at the receiving end of HVDC transmission lines. This inverter is known as a grid-tie inverter.

What is kVA inverter?

UPS systems are often "sized" by a kW (kilowatts) and/or a kVA (kilo-volt-amperes) rating. For example, a 1 kVA UPS means its circuitry can handle 1,000 volt-amperes. For example, 1kVA UPS from N1C has the capacity to power 900 watts of connected equipment. This means the UPS has a "power factor" of 0.9.

CONVERTERS

Power electronic converters are a key part of power electronics, a field of electrical and electronics engineering that converts power from one form to another. Power electronic converters are used in industries and homes as power controllers.

The field of power electronics mainly deals with the conversion of power from one form to another and the change from one voltage level to another by using different power electronic converters. There are many control strategies used in the converters to aid this conversion. Another important aspect of using power converters is conditioning.

The conditioning of signals helps us to ensure clean and pure, i.e. free from harmonics, input and output signals. It is not possible to obtain absolutely clean signals, but there are ways and means to reduce the harmonic content, the simplest of which is the use of a simple low-pass LC filter.

Power electronics converters mainly comprise of solid-state switches, such as Power MOSFET, Power BJT, IGBT, Thyristors etc., and lossless components, namely inductors and capacitors. Inductors and capacitors are ideally suited for use in power converters as the power loss in these components are zero as compared to resistances.

Resistances lead to a loss of power, and thus a loss in efficiency and power converters are required to be highly efficient as power loss during conversion leads to lowering of the efficiency of the whole system. If you're looking to study some technical questions on power electronics, check out our basic electronics questions.

What is kVA inverter?

In power electronics, the solid state devices are used as switches. They can be either on or off. They are never used for amplification. The frequency with which the solid state devices are switched on and off is called the switching frequency. The inductor and capacitors used can lead to an increase in weight and also an increase in the volume of the power converters which leads to a decrease in the power density of the converters. This can be remedied by using a higher switching frequency which reduces the size of the components used in the converter. But higher switching frequency leads to higher switching losses.

However, switching losses are small compared to conduction losses. Higher switching losses will lead to higher temperatures across the junctions, and a temperature difference of more than a 100oC between the body and junction can lead to damage to the solid-state device. We can take care of this with a suitably sized heat sink.

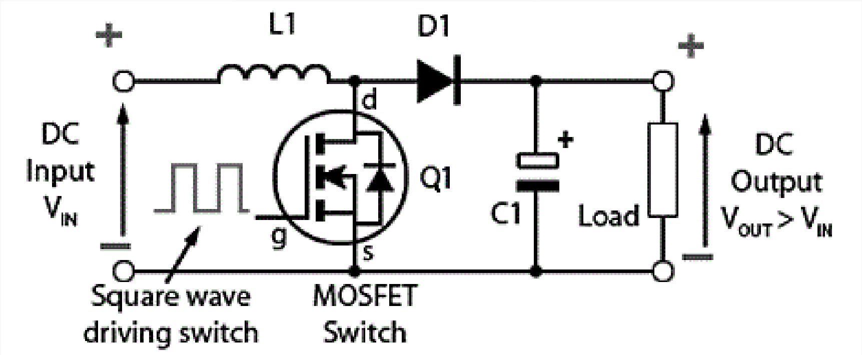
The main types of conversion are DC to DC, AC to DC, DC to AC and AC to AC. The use of DC to DC converters to step-up or step-down a DC voltage is a great boon because AC voltages can be stepped up or stepped down easily using a transformer but using a transformer with DC leads to saturation of the core and will ultimately damage the transformer. The conversion of AC to DC is known as rectification which is used to supply DC loads, such as DC motors, using AC power supply.

DC to AC conversion is known as inversion and is a very useful important part of our daily lives nowadays where we are trying to remove our dependency on fossil fuels. Inverters can take power from DC sources, such as batteries, and convert them to AC power for use in AC motors as can be seen in to, etc. AC to AC conversion is done using either Cyclo converters or Matrix Cyclo converters. These converters are very powerful in a sense they can be used for a wide range of industrial uses, such as cement and ball mill drives, Rolling mill drives etc. converters can even convert a single-phase AC supply to a three-phase supply and vice-versa.

Control of converters deals with the logic implemented, either with analog electronics or digital based micro-controllers, DSP processors or FPGA's, to switch on and off the solid-state devices. The simplest is the Pulse Width Modulation (PWM) scheme. Control of the converters becomes complicated when the converters use feedback loops.

Working Principle of DC-DC converter

The working principle of the DC-to-DC converter is very simple. The inductor in the input resistance has an unexpected variation in the input current. If the switch is kept as high (on), then the inductor feeds the energy from the input and stores the energy in the form of magnetic energy.



DC-to-DC Converters Working Principle

If the switch is kept as low (off), it discharges the energy. Here, the output of the capacitor is assumed as high that is sufficient for the time constant of an RC circuit on the output side. The huge time constant is compared with the switching period and made sure that the steady-state is a constant output voltage. It should be Vo(t) = Vo(constant) and present at the load terminal.

- Types of DC-to-DC Converters
- 1: Magnetic Converters

In these DC-to-DC Converters, energy is periodically stored and released from a magnetic field in an inductor or a transformer. The frequency ranges from 300 kHz to 10MHz. By maintaining the duty cycle of the charging voltage the amount of power that needs to be transferred continuously to a load can be more easily controlled.

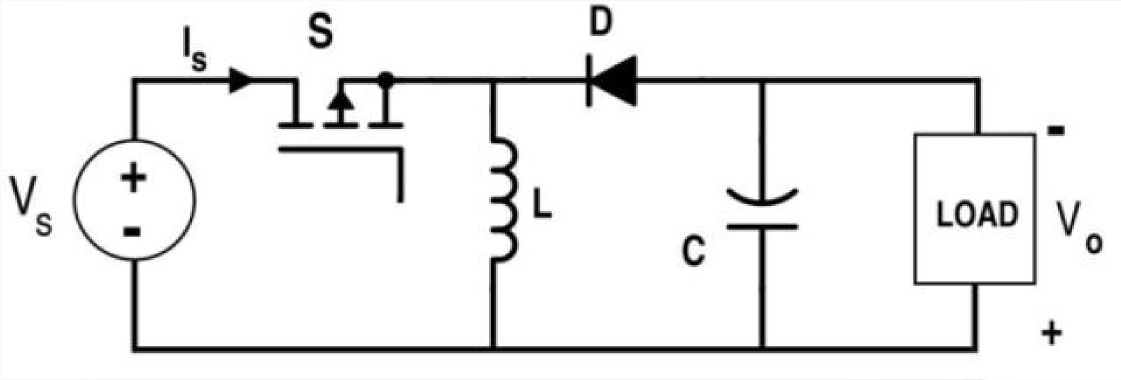
Moreover, the control can also be applied to the input current, the output current or to maintain constant power through the circuit. The transformer-based converter can easily provide the isolation between input and output.

2: Non-Isolated Converters

Non-isolated converters are mostly used when the change in the voltage is comparatively small. It posses the input and output terminal to a common ground. The major disadvantage is that it cannot provide protection from high electrical voltages and it poses more noise.

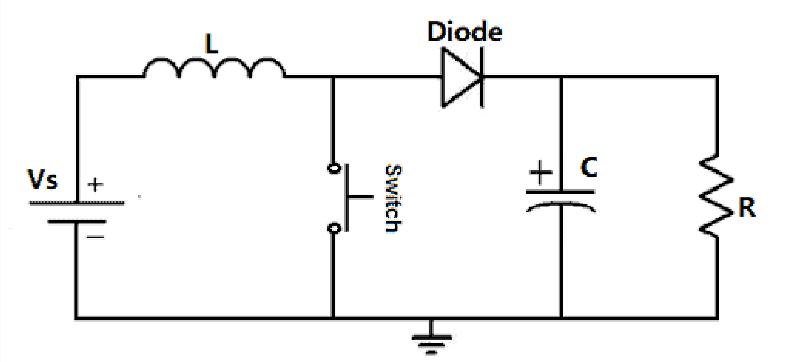
3: Step-down/Buck Converters

In a typical non-isolated step-down or buck converter the output voltage VOUT depends on the input voltage VIN and the switching duty cycle D of the power switch.



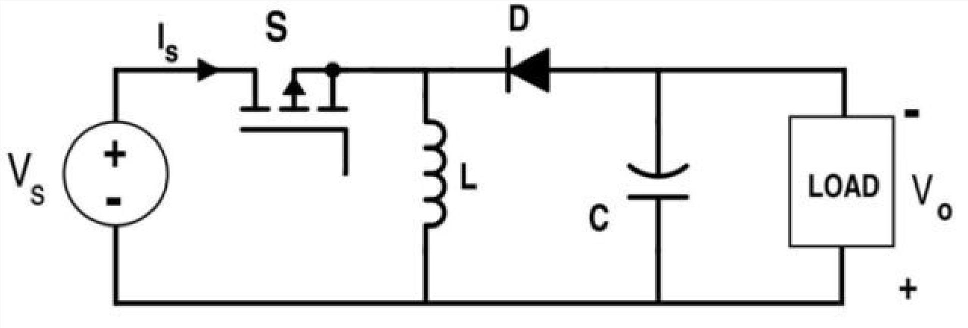
4: Step-up/Boost Converters

It is used to boost DC to DC converter voltage and it uses the same number of passive components but arranged to step up the input voltage so that the output is higher than that of the input.



5: Buck-Boost Converters

This converter allows the input DC voltage to be either stepped-up or stepped-down, depending on the duty cycle.



The output voltage is given by the relation as mentioned below:

VOUT = -VIN *D/ (1-D)

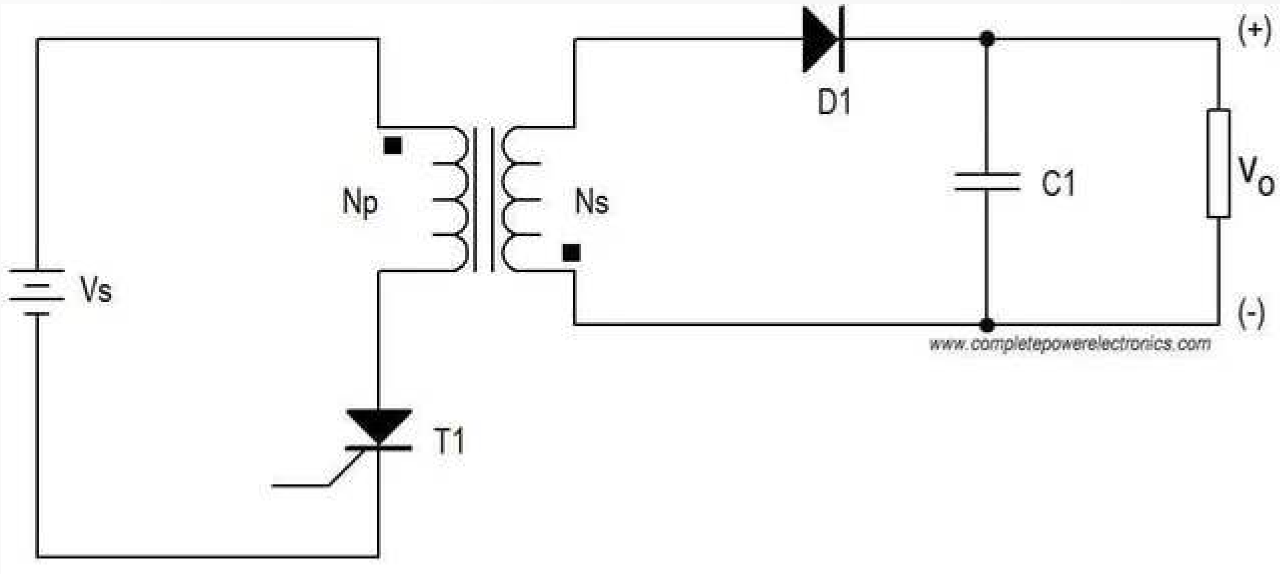
From the above expression, we can notice that the output voltage is always reversed in polarity with respect to the input. Therefore, a buck-boost converter is also known as a voltage inverter.

6: Isolated Converters

The Isolated converter has a separation between its input and output terminals. They have high isolation voltage properties. They can block the noise and interference. With this, they are able to produce a cleaner and desired DC output voltage. They are further categorized into two types.

7: Fly back converters

The working of this converter is similar to the buck-boost converter of the non-isolating category. The only difference is that it uses a transformer to store energy instead of an inductor in the circuit.



CALCULATION OF TIME PERIOD, FREQUENCY, POWER, RMS VALUE, PEAK TO PEAK

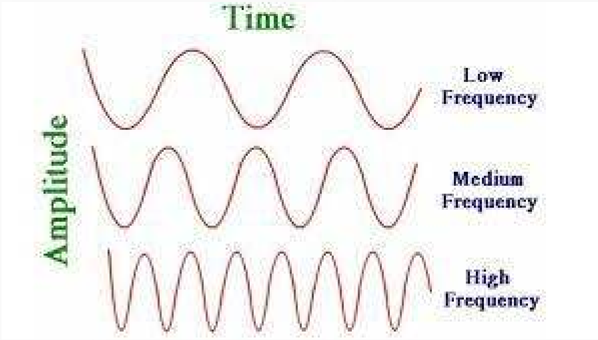
What is the time formula for frequency?

Frequency and time period have a mathematical relationship that can be expressed as T = 1/f or f = 1/T.

What is the formula for time constant in electronics?

t = RC

Use the time constant formulas t = RC for RC circuits and t = L/R for RL circuits. Plug in the values for R, C, or L, ensuring they are in the correct units (ohms for R, farads for C, henrys for L). Calculate the time constant, which will be in seconds.



Frequency in power electronics is the number of waves that occur in electricity in one second. It is typically represented in Hertz (Hz).

The two main power frequencies used globally are 50Hz or 60Hz. Most countries use a 50Hz frequency for their mains supply, but a significant number of countries use a 60Hz supply.

In much of the world, a voltage of 230 volts and a frequency of 50 Hz is used. In North America, the most common combination is 120 V and a frequency of 60 Hz.

Japan is a rare exception because the frequency of its power is either 50 Hz or 60 Hz depending on the region.

What is frequency in electronics?

Frequency is the rate at which current changes direction per second. It is measured in hertz (Hz), an international unit of measure where 1 hertz is equal to 1 cycle per second.

What is the frequency of the power source?

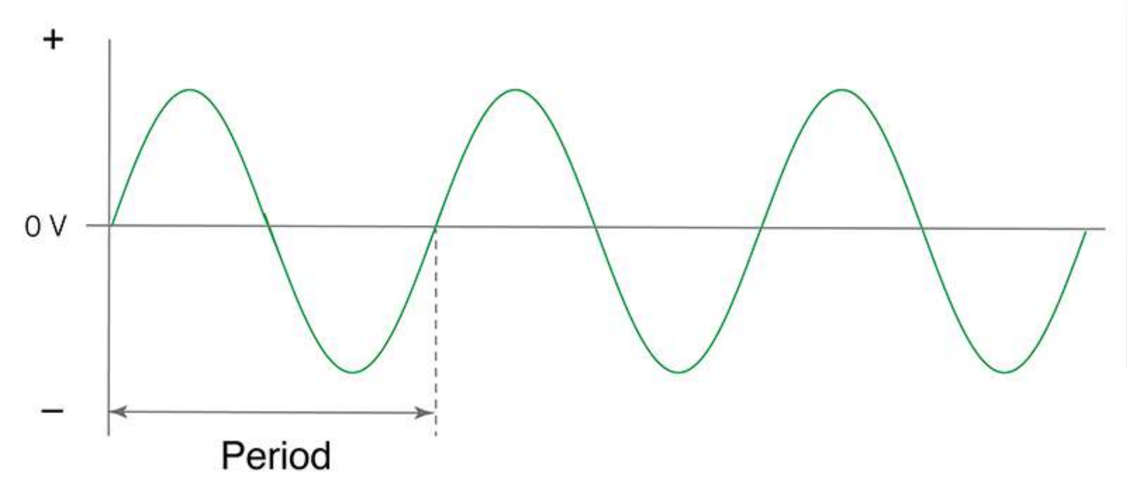
The two main power frequencies used across the globe are 50Hz or 60Hz (Hertz), and the majority of countries favour a 50Hz frequency for their mains supply, though there are still a significant number of countries using a 60Hz supply.

Why 50Hz frequency is used?

The difference in frequency has implications for the design and operation of electrical equipment. 60Hz systems tend to be more efficient for longer distance transmission and are better suited for high-power applications, while 50Hz systems are more suited for low-power, local distribution.

What is DC frequency?

The frequency of DC is zero (0 Hz). This is because of the flow of electric charge in one direction. As there is no way for any reverse in the direction, the frequency of DC always remains zero



$$f = \frac{1}{T}\ [\text{Hz}] \qquad f\text{: frequency} \qquad T\text{: period}$$

What is unit power?

Unit of Power is Watt (W). In other terms, we spent one Watt of Power while completing one Joule of Work in one second. 1 Watt = 1 Joule / 1 second. Other units of Power are Kilowatt (kW), Megawatt (MW) and Gigawatt (GW)

What are the 3 formulas for power?

Power Formula for Different Relations

P = VI. This formula is the mathematical expression of Ohm's law.

P=RI2, with regard to current and resistance. P=V2R, with regard to voltage and resistance. The above formulas are variants of Ohm's law.

P=Et - Power equation.

RMS

Root mean square (RMS) value is the square root of the arithmetic mean of the squares of a set of values. It can also be defined as the square of the function that defines a continuous waveform.

The RMS value for voltage is the effective voltage. For current, the RMS value is also known as alternating current (AC).

The RMS value can be calculated by taking the square root of the arithmetic mean of squared observations. It can be evaluated using either a graphical or analytical method.

For sinusoidal oscillations, the RMS value is equal to the peak value divided by the square root of 2.

The RMS value is applicable to all waves, including sinusoidal, non-sinusoidal, symmetrical, and asymmetrical. It is denoted by Irms or Iv.

What is RMS value of AC supply?

RMS stands for Root-Mean-Square of instantaneous current values. The RMS value of alternating current is given by direct current which flows through a resistance. The RMS value of AC is greater than the average value. The RMS value of sine current wave can be determined by the area covered in half-cycle.

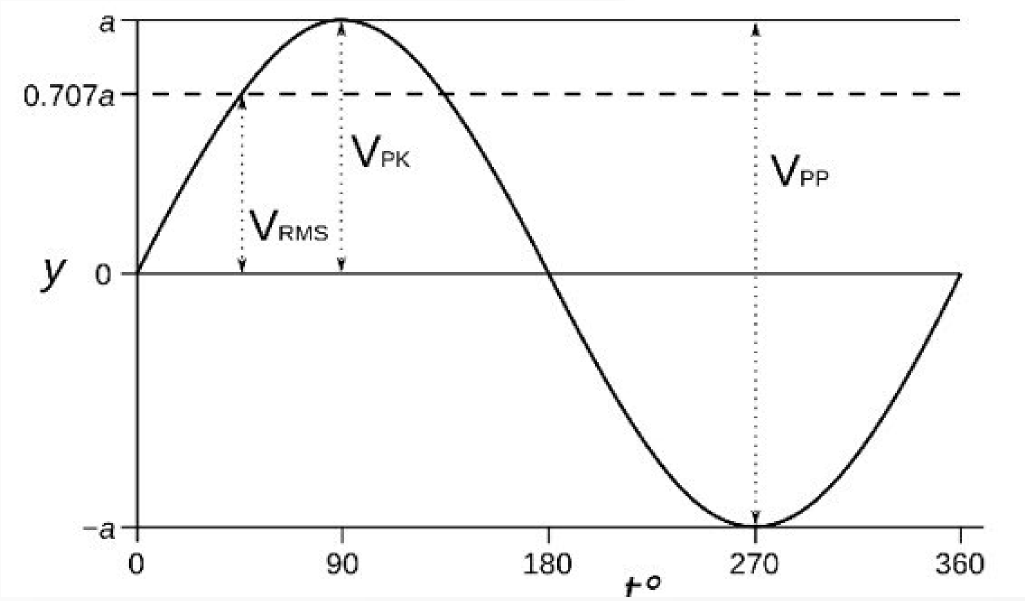
Why do we calculate RMS?

In everyday use, AC voltages (and currents) are always given as RMS values because this allows a sensible comparison to be made with steady DC voltages (and currents), such as from a battery. For example, a 6V AC supply means 6V RMS with the peak voltage about 8.6V.

$$RMS = \sqrt{\frac{1}{n} \sum_i x_i^2}$$

What is peak voltage?

Peak voltage is the highest point or highest value of voltage for any voltage waveform. It is a power quality issue that occurs when devices that use Pulse Width Modulation, such as a variable frequency drive, is added to a power system.



What is peak voltage formula?

Simply Vrms * square root of (2) = V-peak.

What is the peak voltage in 3 phase?

Peak voltage is the maximum voltage that a sinusoidal voltage swings between. For a 120V 3 phase system, the voltage of a single phase swings from around -170 V to 170 V, thus the peak is 170 V

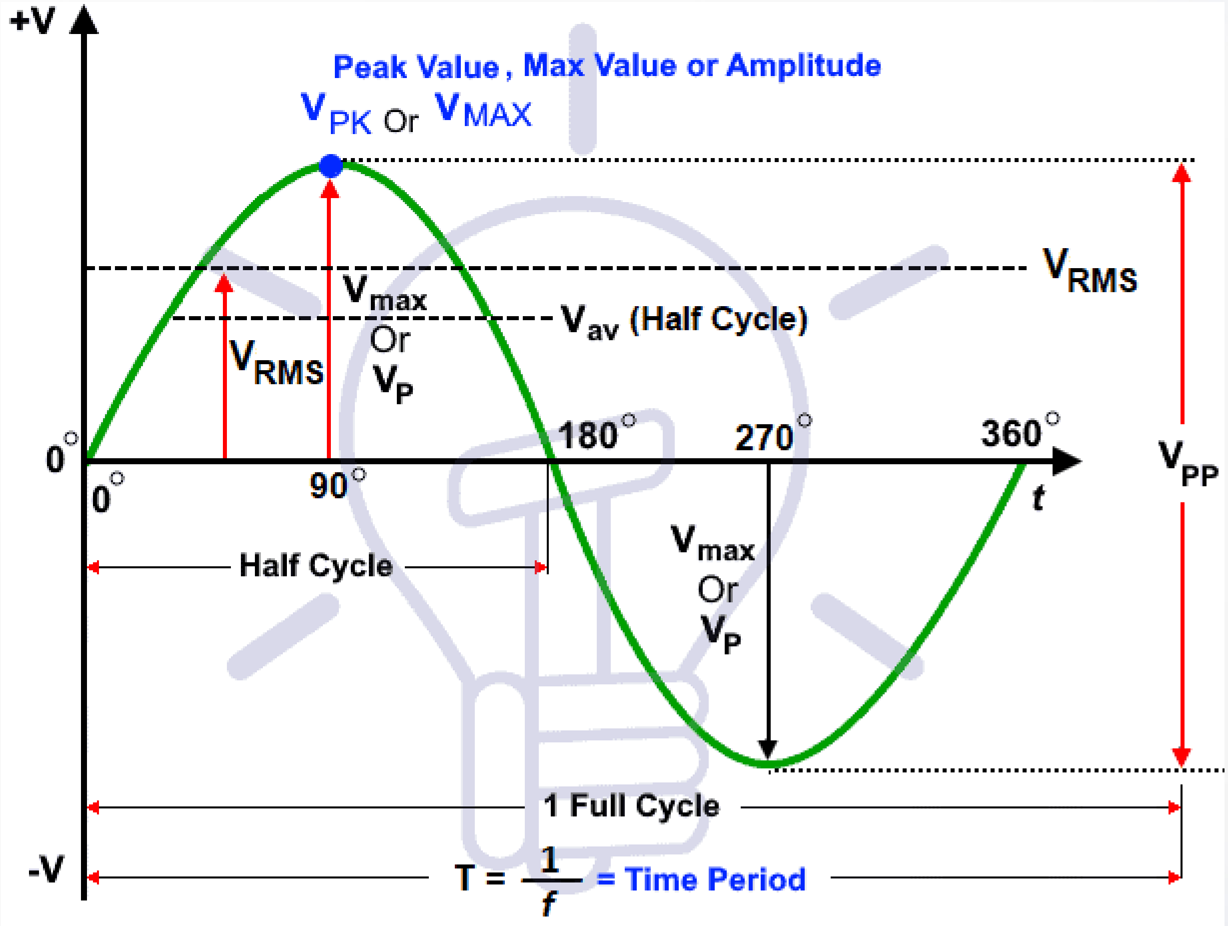
Peak to Peak Voltage

Peak-to-peak voltage (Vpp) is the difference between the highest and lowest voltage values in alternating current (AC). It's a parameter measured over a single period

In AC applications, the peak-to-peak value is two times the peak value. It's more commonly used in waveform analysis or amplifier design, and less often with AC electrical work.

For example, if the maximum value is 5 V and the minimum value is -5 V, the peak-to-peak voltage is 10 V.

Peak-to-peak voltage is not interchangeable with peak voltage.



PHASE DIFFERENCE AND PHASE SHIFT

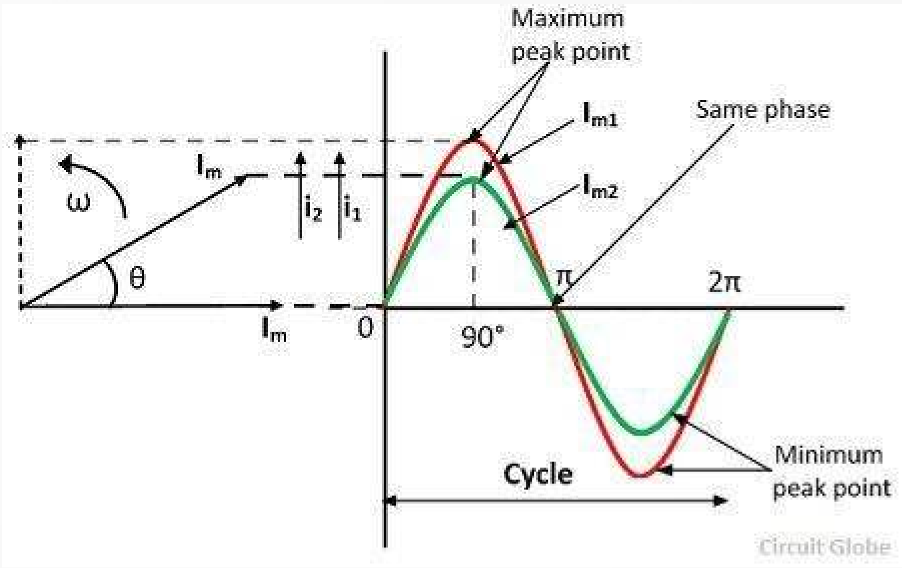
Phase difference is the difference in position between two waves traveling in the same direction. It can also be defined as the angular difference or displacement between two waveforms, oscillations, or periodic events.

Phase difference is expressed in degrees or radians. It is a characteristic of a single wave and the relative characteristic of two or more waves.

Phase difference is commonly encountered in various fields, including physics, engineering, and signal processing. It is used in fission and fusion, medical tracers, nuclear reactors, radiotherapy, the random nature of radioactive decay, and thickness monitoring.

To calculate phase difference, one must know the value of path difference. The formula is phase difference = 2px path difference.

A phase comparison can be made by connecting two signals to a two-channel oscilloscope.

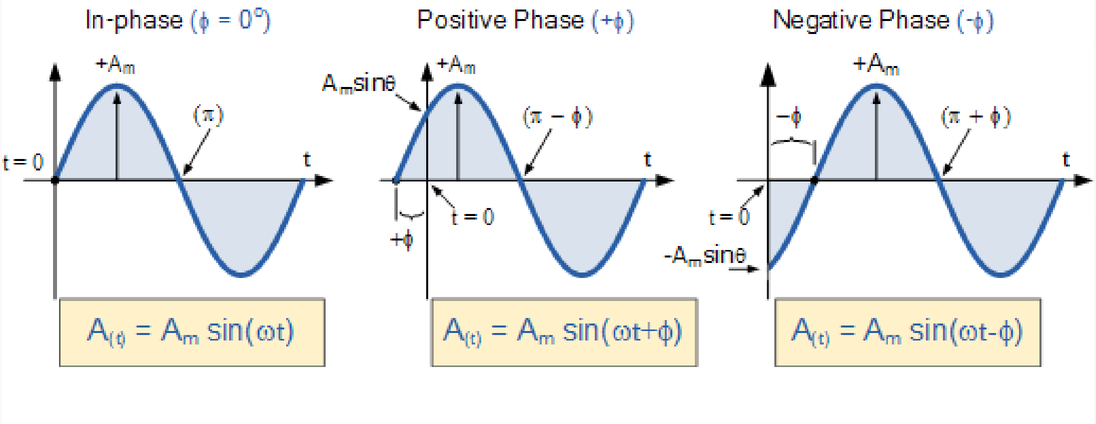


What is phase difference in AC circuit?

Phase Relationships in AC Circuits, When capacitors or inductors are involved in an AC circuit, the current and voltage do not peak at the same time. The fraction of a period difference between the peaks expressed in degrees is said to be the phase difference.

What is phase difference in DC circuit?

When more than one quantity of same frequency are not going through zero in the same direction simultaneously it is said a phase difference exist. If they go to zero in the same direction together they are of same phase, or phase difference is zero. Obviously no phase can be defined for DC quantities



What is phase differencing method?

Basically, the method consists of subtracting two sinusoidal signals with same frequencies and measuring the resulting signal amplitude: this amplitude being a minimum whenever there is a coincidence between both signal phases.

Phase Shift

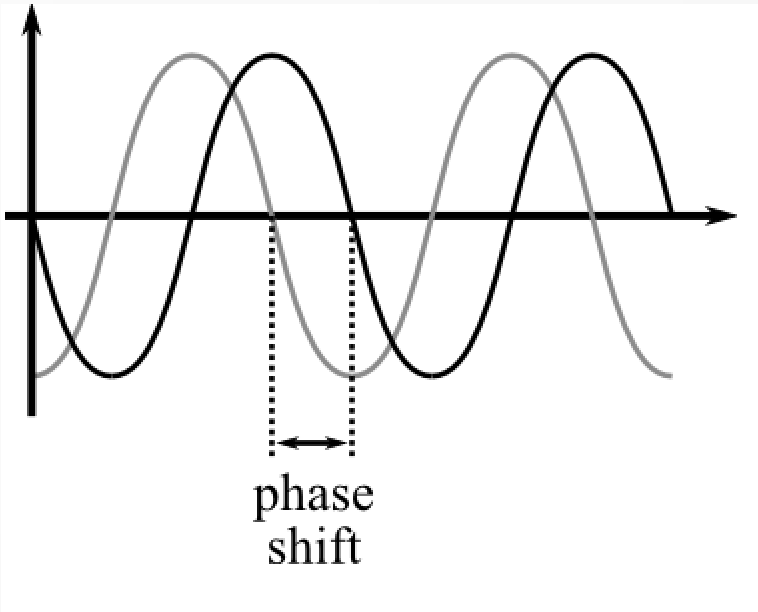
A phase shift is the difference in the position of a wave at a given point in time compared to the position of the same wave at the same point in time in another location.

In electronics and mathematics, a phase shift is the delay present between two waveforms that share the same frequency or period.

In AC circuits, the voltage and current may not reach the same amplitude peaks at the same time. This timing difference is called phase shift, and is measured in angular degrees.

Phase shift is measured as the angle (in degrees or radians) between two points on a circle at the same time. For example, if a waveform is displaced by a complete wavelength, it is described as having a phase-shift of 360°. If it is displaced by half a wavelength (180°), one wave will peak where the other is in a trough state and complete cancellation will result.

What causes phase shift?

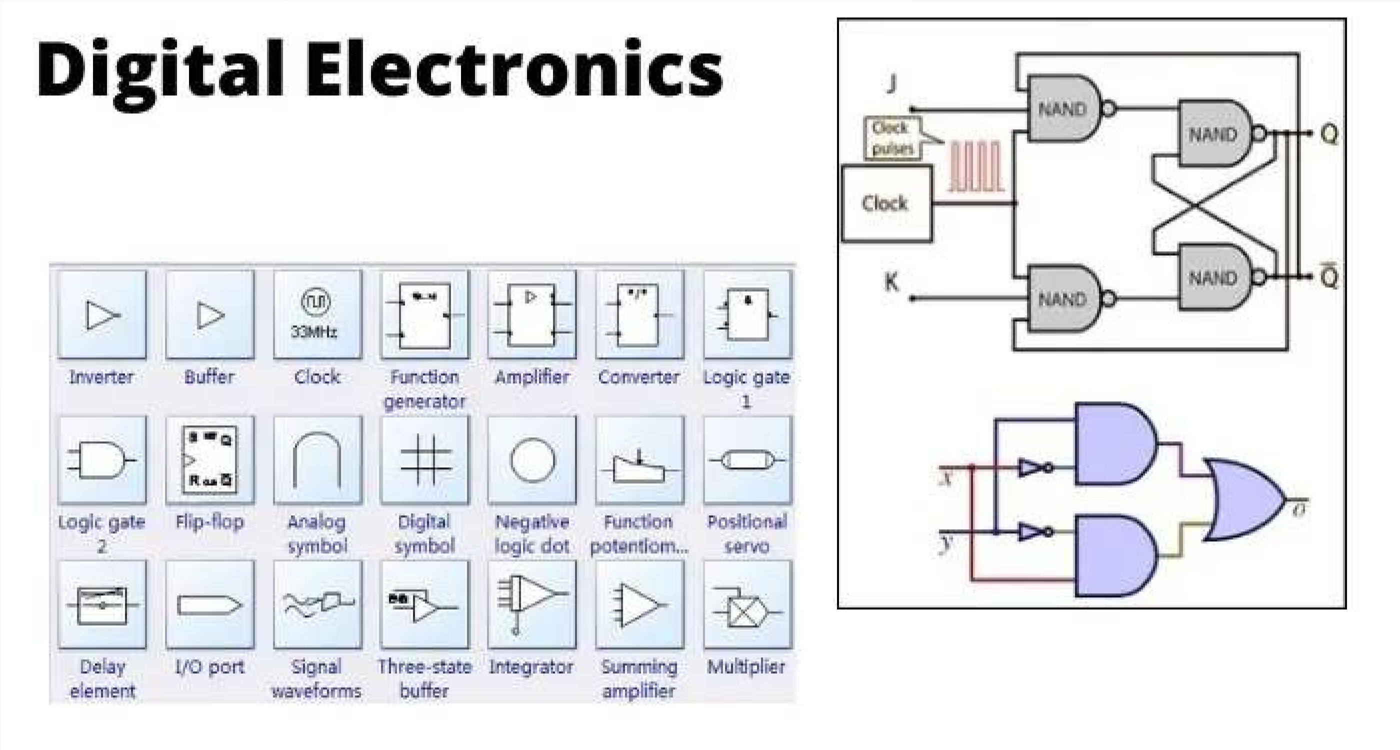


Phase shifts can be caused by a variety of factors, including changes in the medium through which the wave is traveling, changes in the frequency of the wave, and changes in the distance the wave has travelled.

CHAPTER V - DIGITAL ELECTRONICS

FUNDAMENTALS OF DIGITAL ELECTRONICS

Digital electronics is the branch of electronics that deals with the representation and manipulation of data in digital form. It involves the use of devices such as transistors, diodes, and microcontrollers to process and transmit digital signals.



Some of the Fundamental concepts in digital electronics includes,

- Boolean algebra,
- Logic gates,
- Digital filters,
- Flip-flops.

Boolean algebra

Boolean algebra is a mathematical system that is used to represent and manipulate logical statements. It is used in digital electronics to represent and manipulate logical statements such as AND, OR, and NOT.

LOGIC GATES

A logic gate is a device that acts as a building block for digital circuits. They perform basic logical functions that are fundamental to digital circuits. For example, logic gates can be used in technologies such as smartphones, tablets or within memory devices.

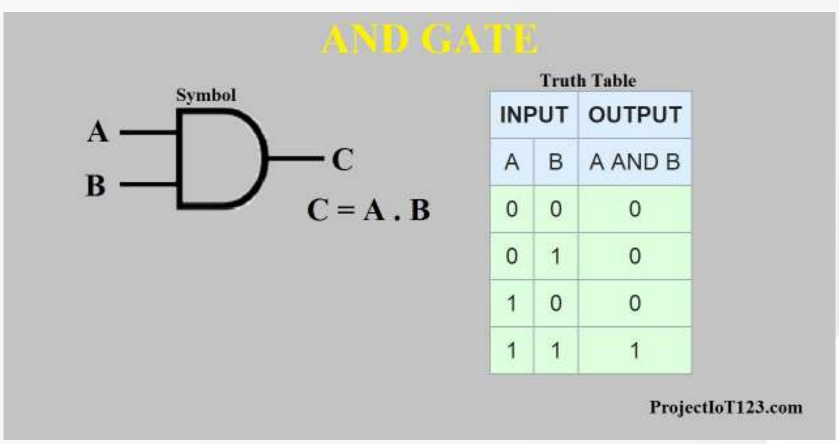
Basic Logic Gates:

There are seven basic logic gates which are also called as Universal Gates.

AND, OR, NOT, NAND, NOR, XOR and XNOR.

AND GATE:

The Logic AND Gate is a type of digital logic circuit whose output goes HIGH to a logic level 1 only when all its inputs are HIGH and if any one of the inputs is LOW, then the output is also LOW. The below picture shows the Symbol, Truth table and Boolean expression of AND Gate,



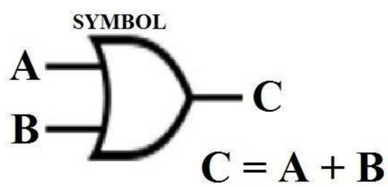
The logic or Boolean expression given for a digital AND gate is that for Logical Multiplication which is denoted by a single dot or full stop symbol, (.) giving us the

Boolean expression of AND Gate: A.B = C.

OR GATE:

The Logic OR Gate is a type of digital logic circuit whose output goes HIGH to a logic level 1 only when one or more of its inputs are HIGH. The below picture shows the Symbol, Truth table and Boolean expression of OR Gate,

OR Gate



TRUTH TABLE

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

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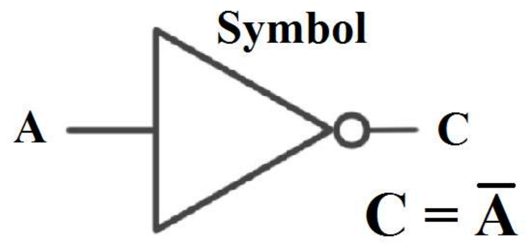
The logic or Boolean expression given for a digital logic OR gate is that for Logical Addition, which is denoted by a plus sign, (+) giving us the

Boolean expression of OR Gate: A+B = C.

NOT GATE:

The Logic NOT Gate is the most basic of all the logical gates and is often referred to as an Inverting Buffer or simply an Inverter.

NOT Gate



Truth Table

INPUT	OUTPUT
A	NOT A
0	1
1	0

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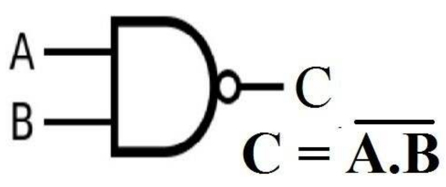
The logic or Boolean expression given for a digital logic AND gate is denoted by an inverse sign of the output.

The Boolean Expression of NOT Gate: of: A =.

NAND GATE:

The Logic NAND Gate is a combination of a digital logic AND gate and a NOT gate connected in series. The Logic NAND Gate is the reverse or “Complementary” form of the AND gate we have seen previously.

NAND GATE



Truth Table

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

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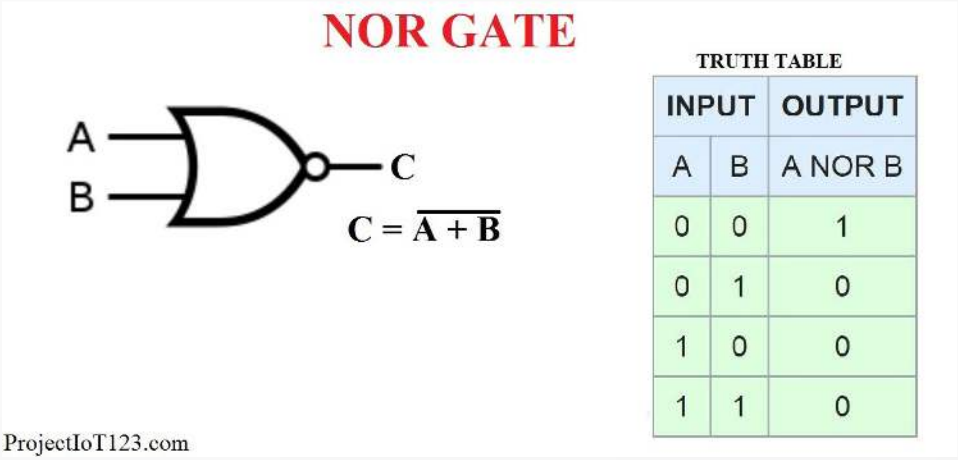
Its Boolean expression is denoted by a single dot or full stop symbol, (.) with a line or *Overline*, (‾) over the expression to signify the NOT or logical negation of the NAND gate giving us the

Boolean expression of NAND Gate: = C

NOR GATE:

The Logic NOR Gate is a combination of the digital logic OR gate and an inverter or NOT gate connected in series. The Logic NOR Gate is the reverse or "*Complementary*" form of the inclusive OR gate we have seen previously.



TRUTH TABLE

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

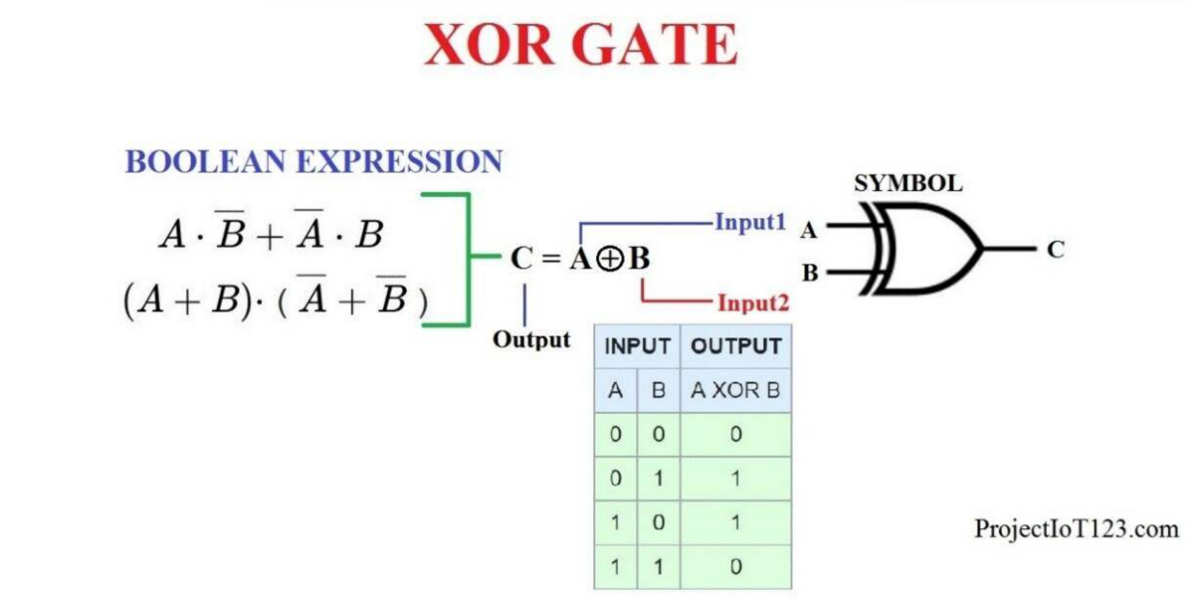
Its Boolean expression is denoted by a plus sign, (+) with a line or *Overline*, (‾) over the expression to signify the NOT or logical negation of the NOR gate giving us the

Boolean expression of NOR Gate: = C.

XOR GATE:

The "Exclusive OR Gate" is another type of digital logic gate commonly used in arithmetic operations since it can be used to give the sum of two binary numbers as well as error-detection and correction circuits. In other words, the output of an Exclusive-OR gate ONLY goes "HIGH" when its two input terminals are at "DIFFERENT" logic levels with respect to each other.

The Boolean expression of XOR Gate: C = B

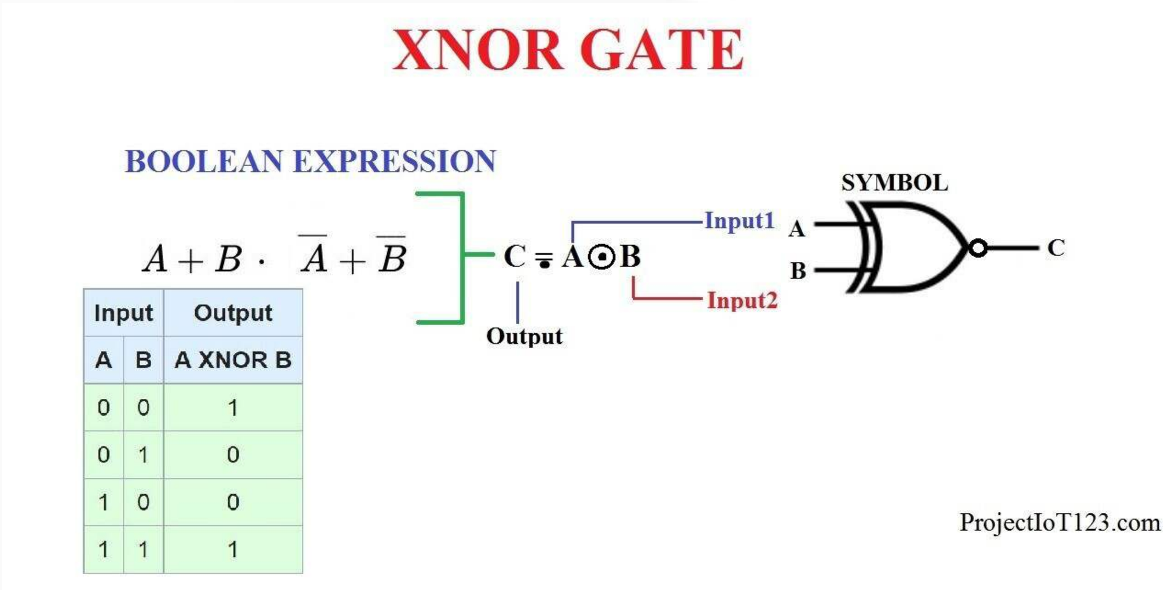


INPUT		OUTPUT
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

X-NOR GATE:

The Exclusive-NOR Gate function is a digital logic gate that is the reverse or complementary form of the Exclusive-OR function.

The output of a digital logic Exclusive-NOR gate ONLY goes "HIGH" when its two input terminals, A and B are at the "SAME" logic level which can be either at a logic level "1" or at a logic level "0". Hence, this type of gate gives an output "1" when its inputs are "*logically equal*" or "*equivalent*" to each other, which is why an Exclusive-NOR gate is sometimes called an Equivalence Gate.



The logic symbol for an Exclusive-NOR gate is simply an Exclusive-OR gate with a circle or "inversion bubble", (o) at its output to represent the NOT function. Then the Logic Exclusive-NOR Gate is the reverse or "Complementary" form of the Exclusive-OR gate, (A ⊕ B) we have seen previously.

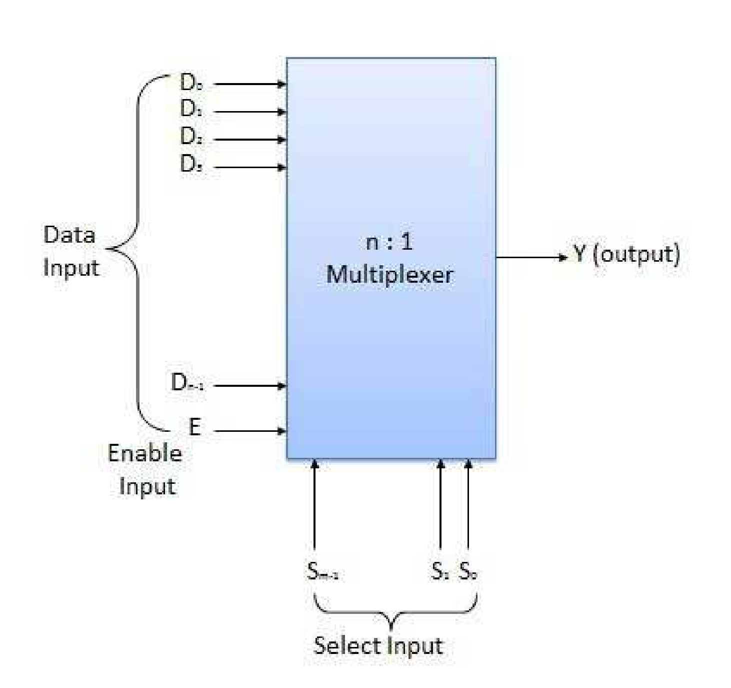
Boolean Expression of XNOR Gate is C =

MULTIPLEXER AND DE-MULTIPLEXER, ENCODER, DECODER, BCD

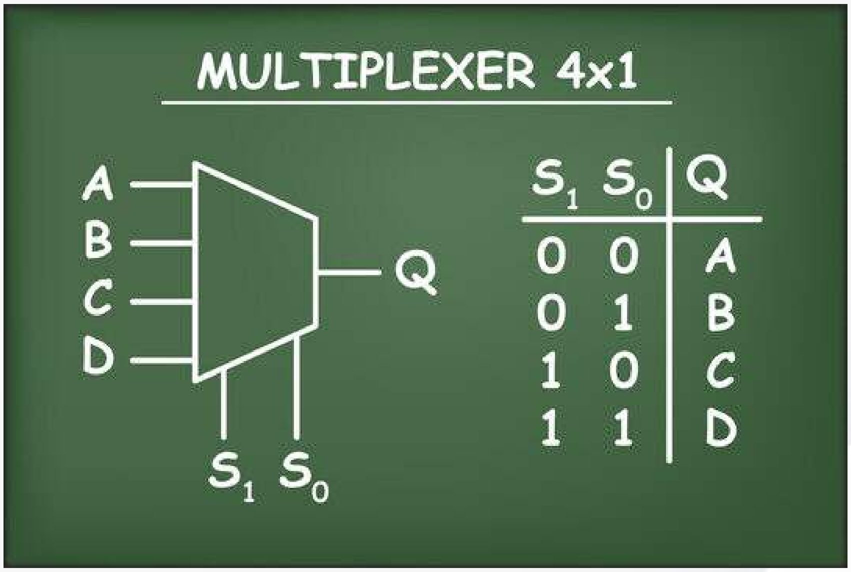
MULTIPLEXER or MUX

The multiplexer, often referred as "MUX" or "MPX", is a combinational logic circuit designed to switch one of several input lines through to a single common output line by the application of a control signal. Multiplexers operate like very fast acting multiple position rotary switches connecting or controlling multiple input lines called "channels" one at a time to the output.

Multiplexers are also known as DATA SELECTORS.



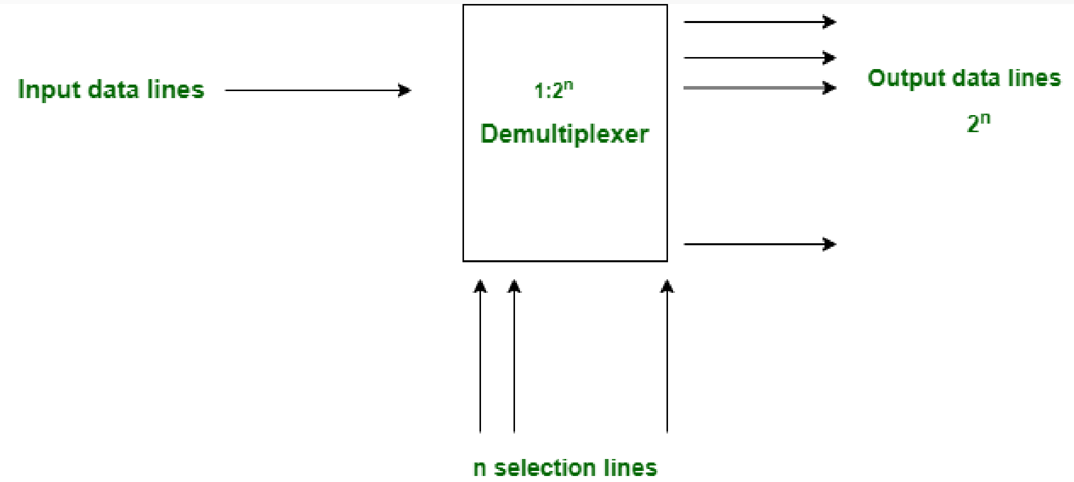
Generally, the selection of each input line in a multiplexer is controlled by an additional set of inputs called *control lines* and according to the binary condition of these control inputs, either "HIGH" or "LOW" the appropriate data input is connected directly to the output. Normally, a multiplexer has an even number of 2n data input lines and a few "control" inputs that correspond with the number of data inputs.



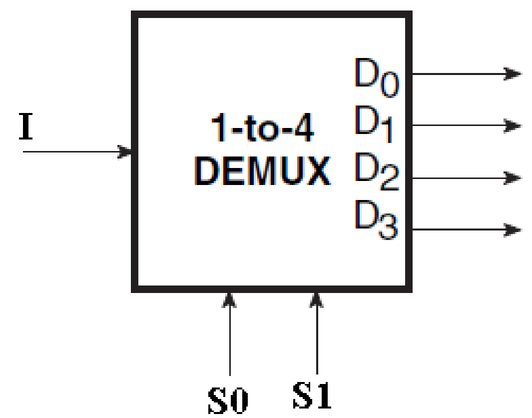
DE-MULTIPLEXER OR DEMUX

The demultiplexer takes one single input data line and then switches it to any one of individual output lines one at a time. It is also known as DATA DISTRIBUTORS.

A Demultiplexer is a combinational logic circuit that receives the information on a single input line and transmits the same information over one of 'n' possible output lines.



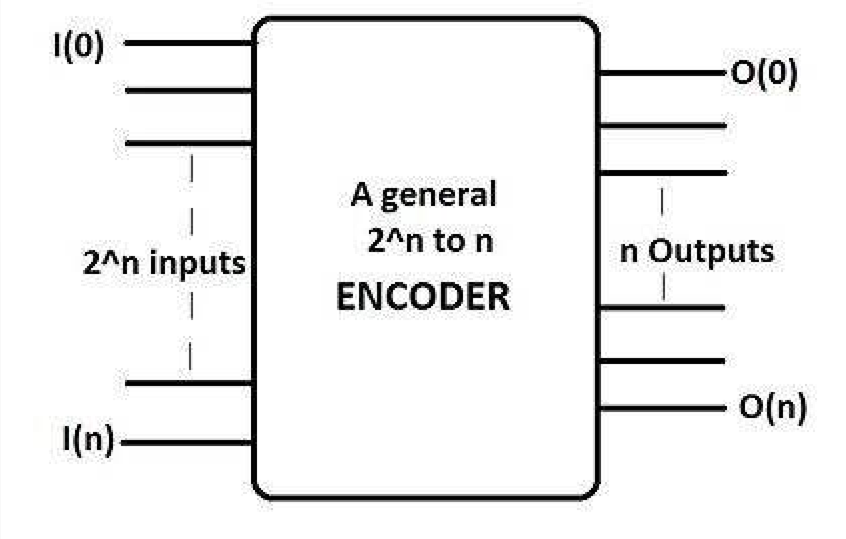
To select a particular output, we have to use a set of Select Lines and the bit combinations of these select lines control the selection of specific output line to be connected to the input at a given instant.



I	Select		O/P			
	S0	S1	D_0	D_1	D_2	D_3
1	0	0	1	0	0	0
1	0	1	0	1	0	0
1	1	0	0	0	1	0
1	1	1	0	0	0	1

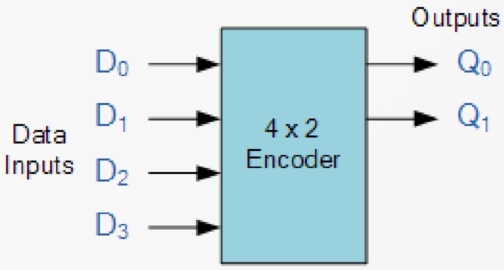
ENCODER

The Digital Encoder more commonly called a Binary Encoder takes ALL its data inputs one at a time and then converts them into a single encoded output. Thus, a binary encoder, is a multi-input combinational logic circuit that converts the logic level "1" data at its inputs into an equivalent binary code at its output.



Generally, digital encoders produce outputs of 2-bit, 3-bit or 4-bit codes depending upon the number of data input lines. An "n-bit" binary encoder has 2n input lines and n-bit output lines with common types that include 4-to-2, 8-to-3 and 16-to-4-line configurations.

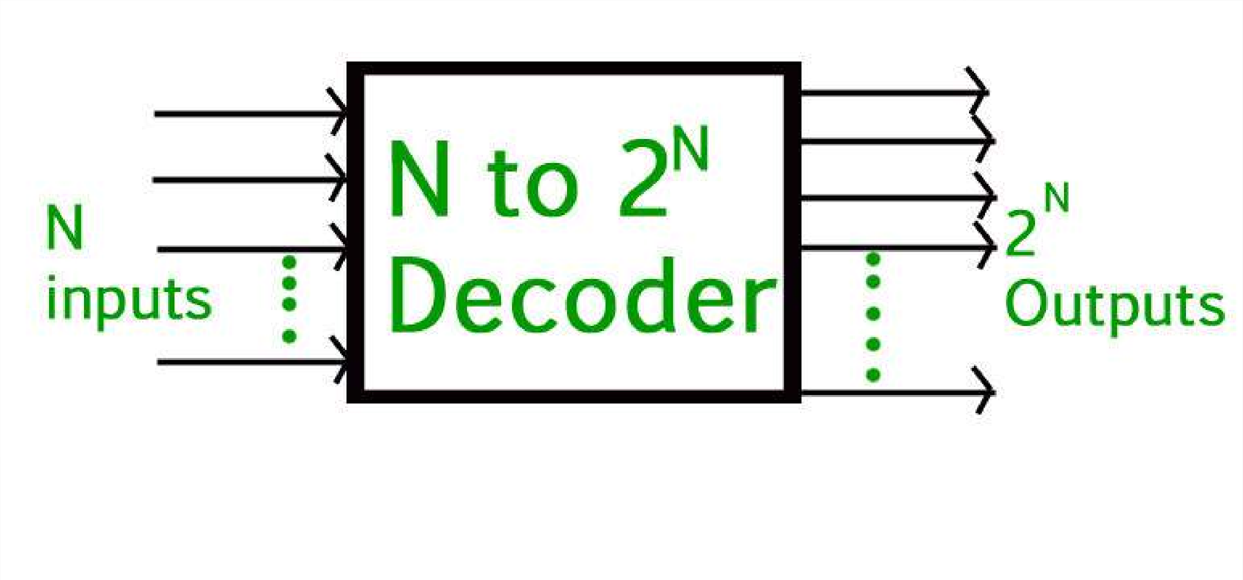
The output lines of a digital encoder generate the binary equivalent of the input line whose value is equal to "1" and are available to encode either a decimal or hexadecimal input pattern to typically a binary or "B.C.D" (binary coded decimal) output code.



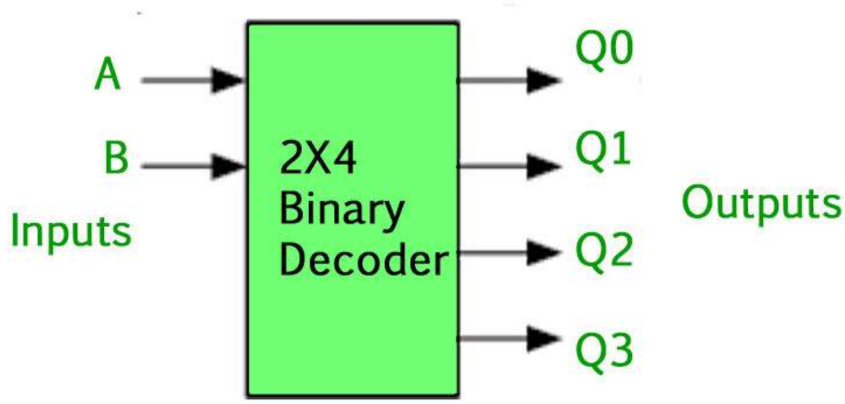
Inputs				Outputs	
D_3	D_2	D_1	D_0	Q_1	Q_0
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1
0	0	0	0	x	x

DECODER

The term "Decoder" means to translate or decode coded information from one format into another, so a binary decoder transforms "n" binary input signals into an equivalent code using 2^n outputs.



Binary Decoders are another type of digital logic device that has inputs of 2-bit, 3-bit or 4-bit codes depending upon the number of data input lines, so a decoder that has a set of two or more bits will be defined as having an *n*-bit code, and therefore it will be possible to represent 2^n possible values.



A	B	Q0	Q1	Q2	Q3
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1

BCD – Binary Coded Decimal

Binary Coded Decimal, or BCD, is another process for converting decimal numbers into their binary equivalents.

An n-bit binary code is a group of "n" bits that assume up to 2n distinct combinations of 1's and 0's. The advantage of the Binary Coded Decimal system is that each decimal digit is represented by a group of 4 binary digits or bits in much the same way as Hexadecimal. So, for the 10 decimal digits (0-to-9) we need a 4-bit binary code.

Decimal	BCD
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1

The main advantage of binary coded decimal is that it allows easy conversion between decimal (base-10) and binary (base-2) form.

So, for example, 357_{10} (Three Hundred and Fifty-Seven) in decimal would be presented in Binary Coded Decimal as:

357_{10} = 0011 0101 0111 (BCD)

In other words, the BCD is a weighted code and the weights used in binary coded decimal code are 8, 4, 2, 1, commonly called the 8421 codes as it forms the 4-bit binary representation of the relevant decimal digit.

Binary Coded Decimal Representation of a Decimal Number

Binary Power	2^3	2^2	2^1	2^0
Binary Weight:	8	4	2	1

FLIP FLOP

A flip-flop is a sequential digital electronic circuit having two stable states that can be used to store one bit of binary data. Flip-flops are the fundamental building blocks of all memory devices.

Types of Flip-Flops

The flip-flops are of the following types:

1. S-R Flip Flop

2. J-K Flip Flop

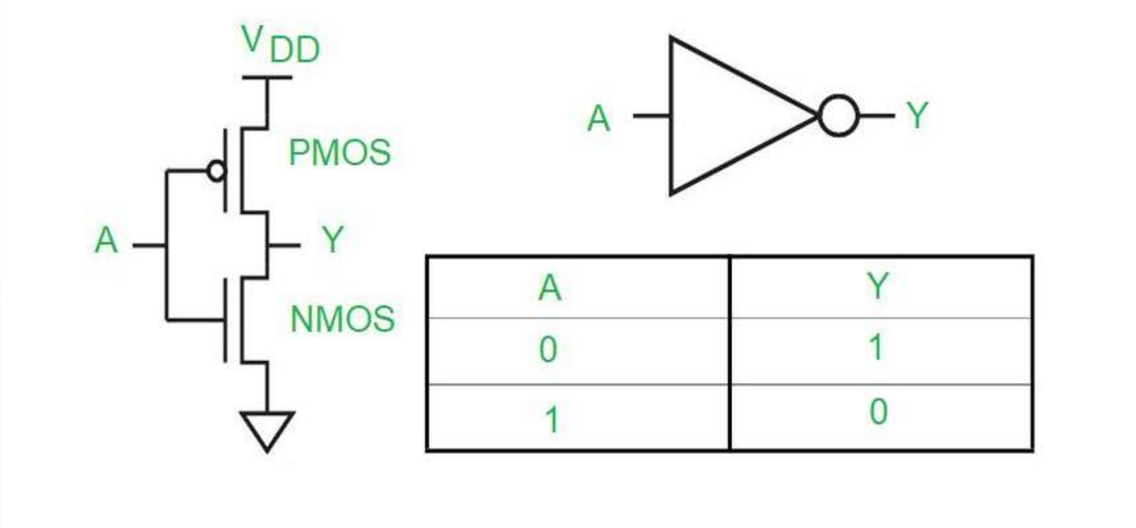
3. T Flip Flop

4. D Flip Flop

CMOS, TTL, Registers, Counters

CMOS - Complementary Metal-Oxide-Semiconductor

A circuit that uses complementary pairs of p-channel and n-channel MOSFETs is called CMOS (Complementary MOS). CMOS logic ICs combine MOSFETs in various ways to implement logic functions. A logic gate composed of a single pair of p-channel and n-channel MOSFETs is called an inverter.



CMOS Inverter

A MOSFET transistor is a voltage-controlled switch. The MOSFET acts as a switch and turns on or off depending on whether the voltage on it is either high or low. There are two types of MOSFETs: NMOS and PMOS. The NMOS turns on when the voltage is high and off when the voltage is low. The PMOS, on the other hand, turns on whenever the voltage is low and goes off as the voltage goes high. When the two are used together to realize the logic gates, they are called CMOS (Complementary MOS).

CMOS circuit has the advantages of simple structure, low power consumption, large noise tolerance and strong temperature stability, which is conducive to high integration.

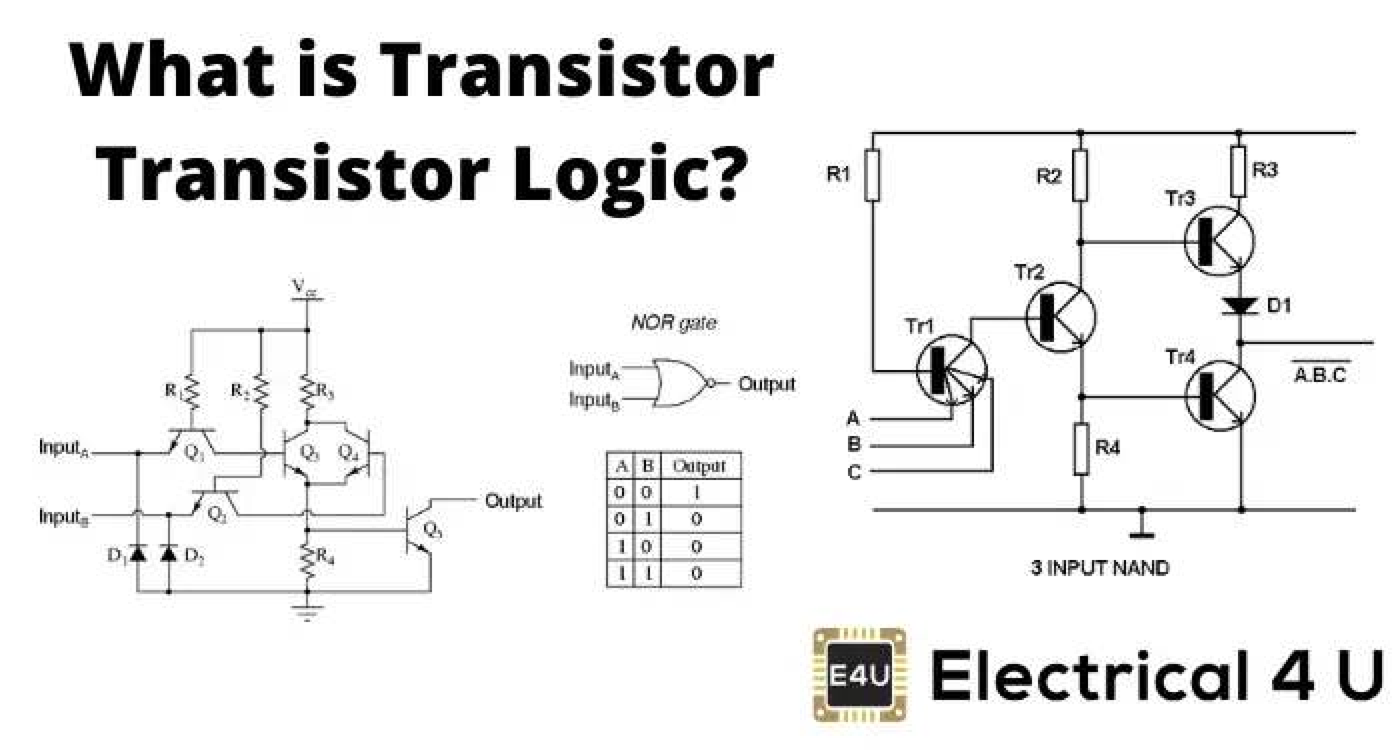
Applications of CMOS

- Microcontrollers
- Static RAM
- Microprocessor
- Digital logic circuits
- Image sensor

TTL – Transistor-transistor logic

Transistor-transistor logic (TTL) is a type of digital circuit that uses bipolar transistors to maintain logic states and achieve switching. TTL circuits are built from transistors and resistors.

TTL is named for the fact that transistors perform two functions: logic and amplification.



Some examples of TTL logic gates include the 7402 NOR Gate and the 7400 NAND gate.

Features of TTL:

Logic states: TTL maintains logic states.

Switching: TTL achieves switching

Input rise: TTL gate inputs rise to a logical “1” if left unconnected.

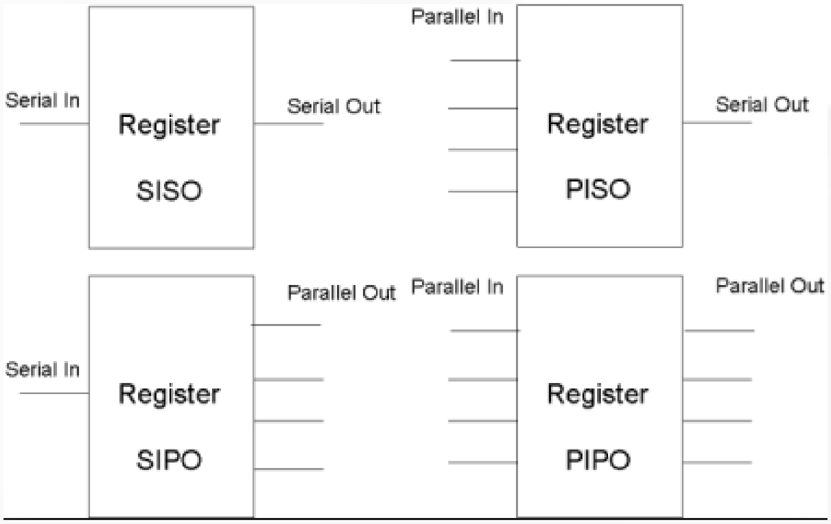
Registers

Register in digital electronics are the basic element of a computer and can hold arbitrary numbers of bits. This can range from one bit to millions of bits. Typically, it stores information for small amounts of time until it is sent on to another device or location.

A register is made up of multiple flip-flops. Each flip-flop can store one bit of information. By combining multiple flip-flops, registers can store larger binary values, such as bytes or words.

The registers that allow data transfers between flip flops are called as shift registers. There are four modes of operations of a shift register.

- Serial Input Serial Output
- Serial Input Parallel Output
- Parallel Input Serial Output
- Parallel Input Parallel Output



Counters

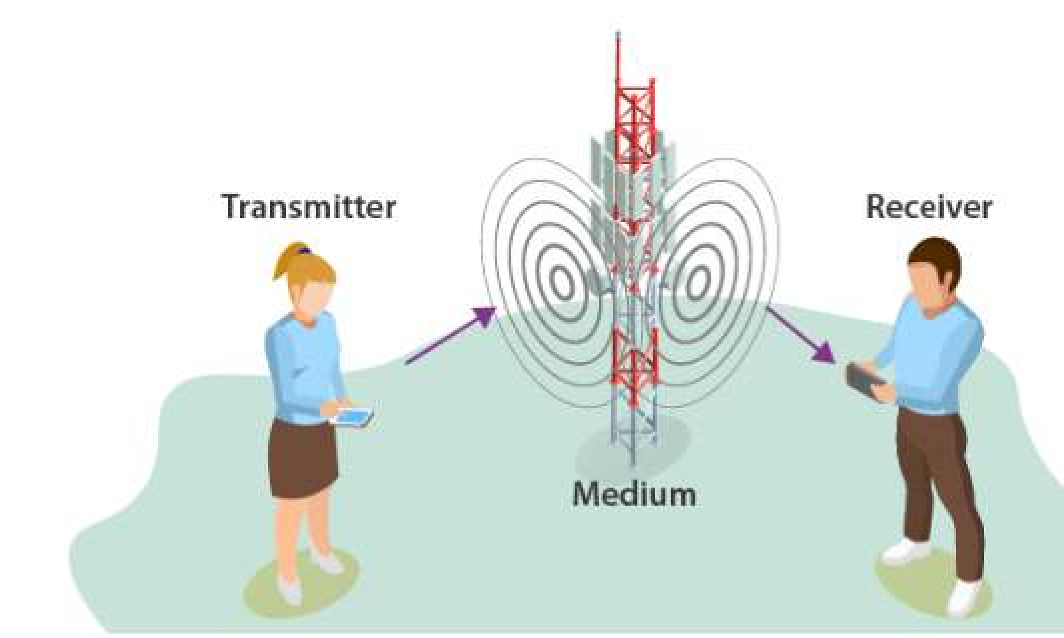
A Counter is a device which stores (and sometimes displays) the number of times a particular event or process has occurred, often in relationship to a clock signal. Counters are used in digital electronics for counting purpose, they can count specific event happening in the circuit.

Counters are sequential circuit that count the number of pulses can be either in binary code or BCD form. The main properties of a counter are timing, sequencing, and counting. Counter works in two modes.

- Up counter
- Down counter

CHAPTER VI - COMMUNICATION SYSTEMSBASICS OF COMMUNICATION SYSTEMS

The communication system is a system which describes the information exchange between two points. The process of transmission and reception of information is called communication. The major elements of communication are the Transmitter of information, the Channel or medium of communication and the Receiver of information.

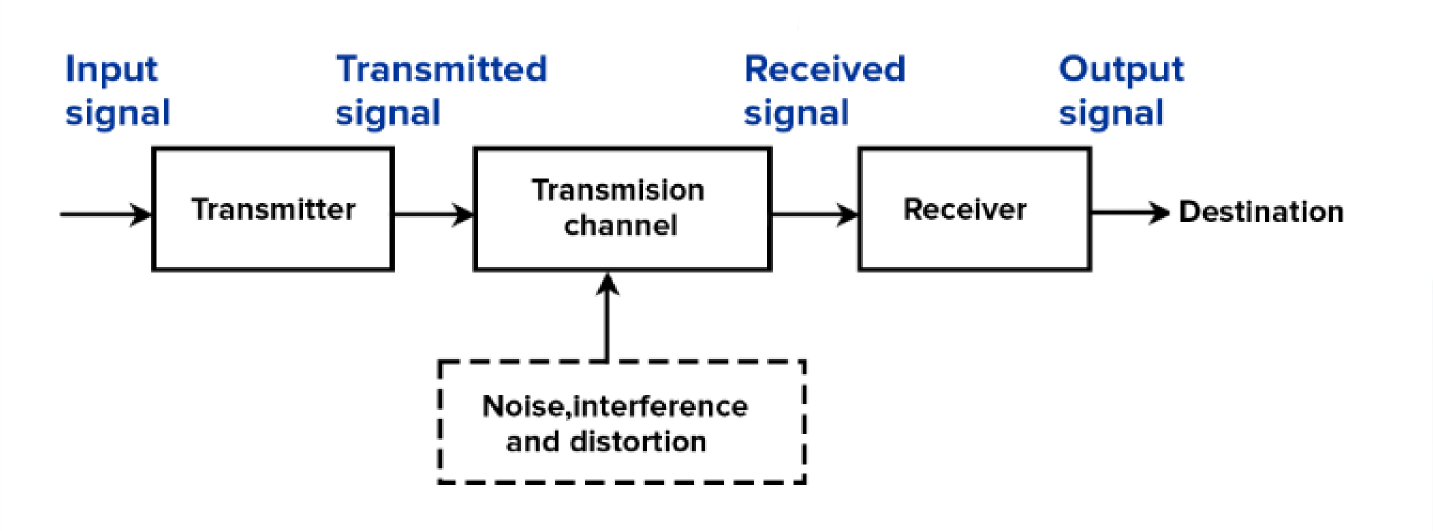


Types of Communication Systems

1. Analog Communication Systems & 2. Digital Communication Systems

Analog technology communicates data as electronic signals of varying frequency or amplitude. Broadcast and telephone transmission are common examples of analogue technology.

In digital technology, the data is generated and processed in two states: High (represented as 1) and low (represented as 0). Digital technology stores and transmits data in the form of 1s and 0s.



The four basic elements of any communication system include sending and receiving devices, communication channels, connection devices, and data transmission specifications.

SERIAL AND PARALLEL COMMUNICATIONS

Serial communication is a communication method that uses one or two transmission lines to send and receive data, and that data is continuously sent and received one bit at a time. Since it allows for connections with few signal wires, one of its merits is its ability to hold down on wiring material and relaying equipment costs.

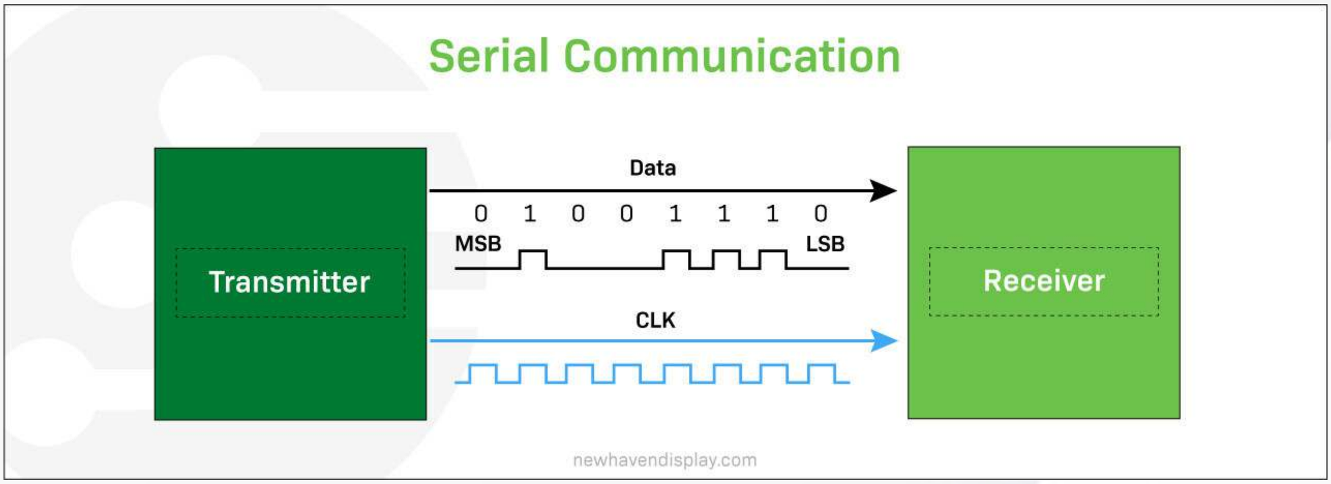


Diagram of serial communication: a transmitter sends one bit at a time to the receiver for every clock pulse (CLK). The receiver interprets the bits as the binary number 01001110.

In simple terms, serial data transmission is like a single-lane road where cars can only travel one after the other, not side by side. Here is a simple breakdown of how serial data is transmitted:

- Start of communication: The device sending the data, called the transmitter, sends a start bit to the device receiving the data, known as the receiver. The start bit is like a heads-up, signaling, "Hey, I'm about to send some data."
- Data transmission: Next, the transmitter sends the data bit by bit in a specific order. It's like sending a long message, one letter at a time.
- End of communication: When all the data bits have been sent, the transmitter sends a stop bit, saying, "That's it, I've sent everything I had to send."
- Error checking (optional): The receiver then checks if it has received the data correctly. This is done through a process known as parity checking. If the data isn't correct, the receiver can ask the transmitter to resend the data.

The telegraph was one of the first devices for long-distance serial communication, using a single wire to transmit data. Serial communication protocols and standards began to develop in the 1960s. These protocols, such as RS-232, SPI, I²C, RS485, USB, and MIPI, are widely used in electronic circuits, LCDs, OLEDs, computer systems, embedded systems, and telecommunications.

Parallel Communication

Parallel communication is a method of transmitting data in which multiple bits are sent simultaneously over multiple channels or cables. These bits are generally sent in data groups of 8 bits, known as bytes, in a single clock pulse. This means each bit is transmitted over a dedicated cable. This technique is like a multi-lane highway, with each 'bit' having its own lane, allowing for simultaneous data transmission.

Here is a simple breakdown of how parallel data is transmitted:

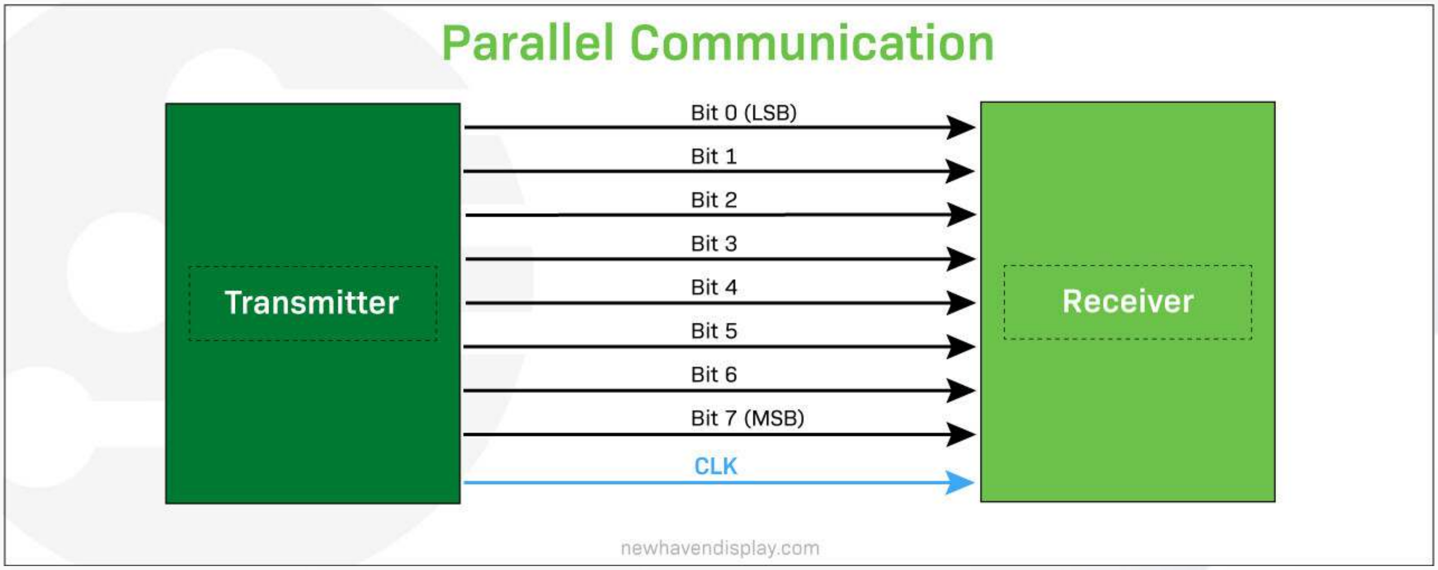
Start of communication: The transmitter signals the receiver about data transmission readiness.

Data transmission: The data is divided into multiple bit groups, and the transmitter sends all the bits simultaneously over separate communication lines or cables.

Data reception: The receiver gets all the data streams and arranges them in the correct order to reconstruct the original data.

End of communication: Once all parallel bits are received, and data is reconstructed, the communication is complete.

Error checking (optional): Some systems may use error-checking mechanisms to verify data accuracy.

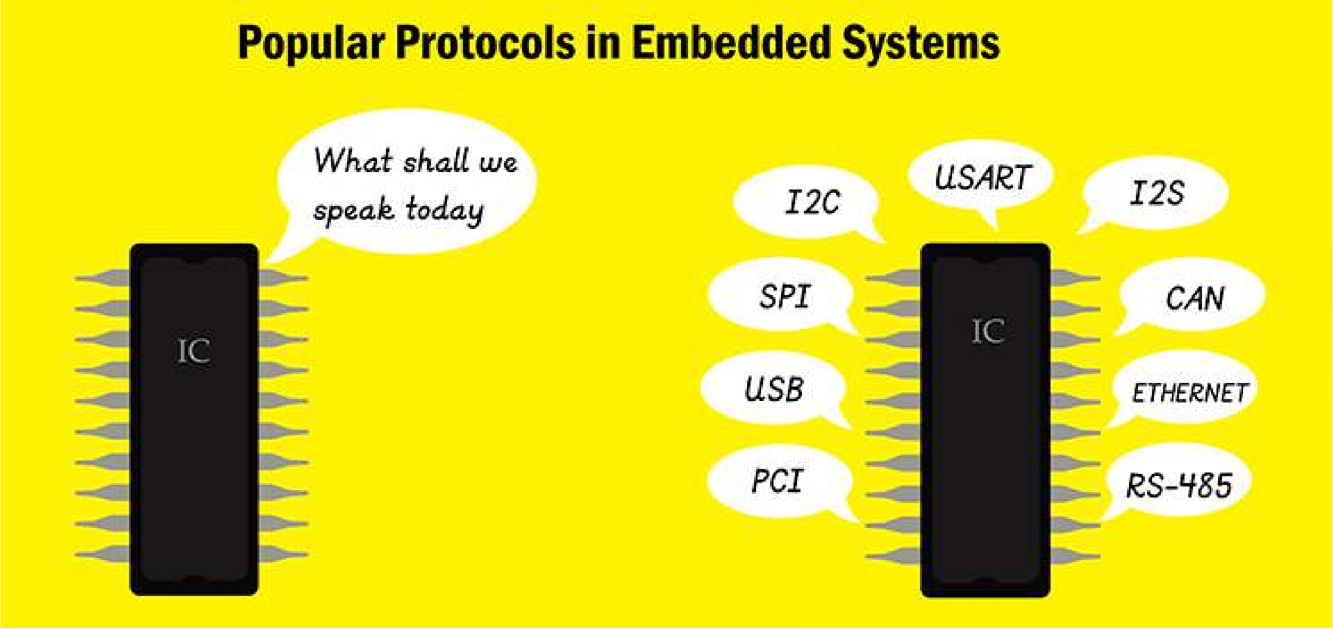


Parallel communication simultaneously sends multiple bits to the receiver for every clock pulse (CLK). The receiver interprets the data as the binary number 01001110.

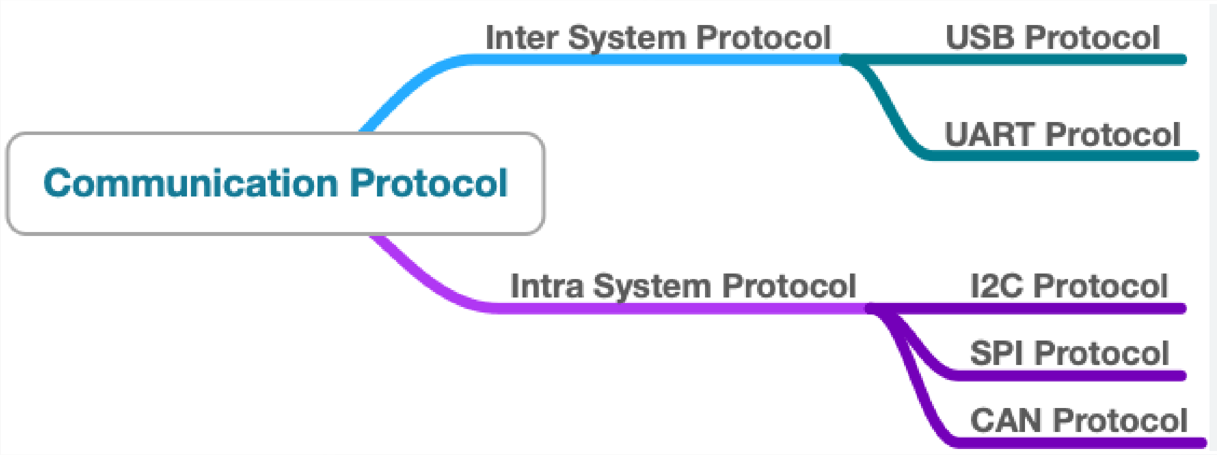
	Serial	Parallel
Speed	Typically slower for short distances than parallel communication.	Typically faster as multiple bits are sent at once
Complexity	Simple for long distances	Simple for short distances
Cost	Typically cheaper for long distances	Typically more expensive for long connections
Reliability	Reliable over long distances	May suffer signal degradation over long distances
Interference	Less prone to crosstalk	More prone to crosstalk in longer connections
Synchronization	Complex at very high speeds	Easier to synchronize at short distances
Scalability	High-speed scalability can be challenging	Can be easily scaled for short distances
Wiring	Requires fewer wires, reducing bulk	Requires more wires, increasing bulk
Bandwidth	Bandwidth limited by channel characteristics	High bandwidth potential

PROTOCOLS AND ITS APPLICATIONS

Communication Protocols are a system of rules and digital message formats enabling the transmission of information between devices. In short, two-way communication exchange is controlled by a set of rules that enable data to be transferred between devices to send and receive messages.



APPLICATIONS OF PROTOCOLS.

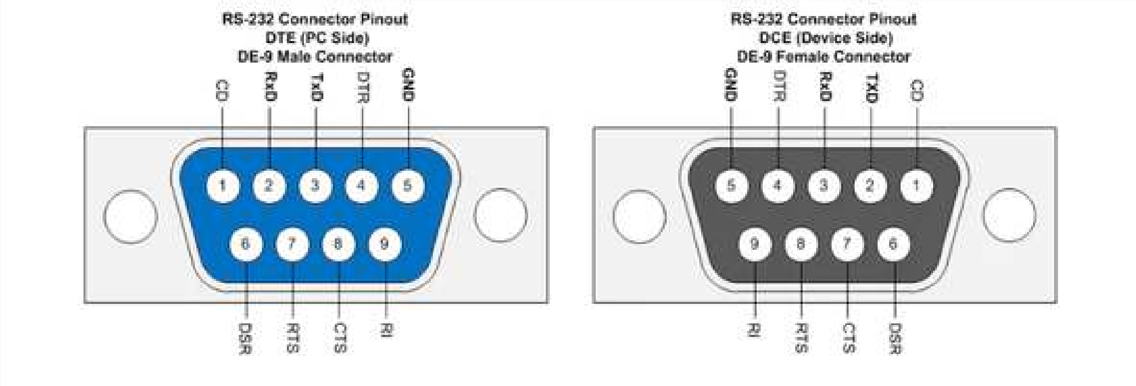


- Authentication,
- Error detection and correction,
- Signalling,
- Emails, SMS, Walkie-talkie,
- Telecommunications,
- Mouse, Keyboard, Hubs, switches, pen drive.

RS232, RS485, WIFI, CAN, ETHERNET, MODBUS

RS232 Protocol

RS232 is a standard communication protocol that defines the physical and electrical characteristics of a serial communication system. It is used for data transfer between two devices and is typically used for short distance communications.



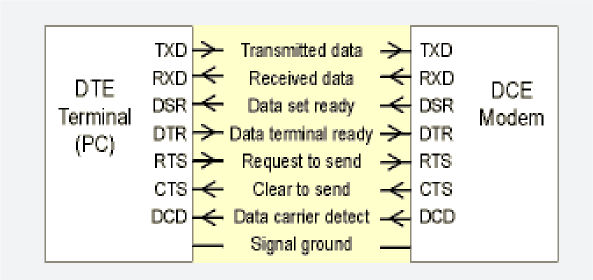
RS232 represents the signals connecting between DTE and DCE. Therefore, DTE represents Data Terminal Equipment and an example for DTE is a computer. DCE represents Data Communication Equipment or Data Circuit Terminating Equipment and an example for DCE is a modem.

The pins in DE-9 connector, their names and description are given in the following table.

Pin Number	Name	Direction
1	CD (Carrier Detect)	Incoming signal from DCE
2	RD (Receive Data)	Incoming Data from DCE
3	TD (Transmit Data)	Outgoing Data to DCE
4	DTR (Data Terminal Ready)	Outgoing handshaking signal
5	GND (Signal Ground)	Common reference voltage
6	DSR (Data Set Ready)	Incoming handshaking signal
7	RTS (Request to Send)	Outgoing flow control signal
8	CTS (Clear to Send)	Incoming flow control signal
9	RI (Ring Indicator)	Incoming signal from DCE

In RS232, the data is transmitted serially in one direction over a single data line. In order to establish two way communication, we need at least three wires (RX, TX and GND) apart from the control signals. A byte of data can transmitted at any time provided the previous byte has already been transmitted.

RS232 follows asynchronous communication protocol i.e. there is no clock signal to synchronize transmitter and receiver. Hence, it uses start and stop bits to inform the receiver when to check for data.



Applications

- Though RS232 is a very famous serial communication protocol, it is now has been replaced with advanced protocols like USB.
- Previously they we used for serial terminals like Mouse, Modem etc.
- But RS232 is still being used in some Servo Controllers, CNC Machines, PLC machines and some microcontroller boards use RS232 Protocol.

RS485 Protocol

RS-485 is an industrial specification that defines the electrical interface and physical layer for point-to-point communication of electrical devices. The RS-485 standard allows for long cabling distances in electrically noisy environments and can support multiple devices on the same bus.

In RS485 standard, data is transmitted via two wires twisted together also referred to as "Twisted Pair Cable". The twisted pairs in RS485 give immunity against electrical noise, making RS485 viable in electrically noisy environments.

வையத்தலைமை கொள் - Lead the World

Ananda Chaitanya Foundation's Skill Development Initiative

About the Initiative:

Vaiya Thalamai Kol (Lead the World) is a skill development initiative by the Ananda Chaitanya Foundation, aimed at empowering individuals with essential technical and soft skills. Conducted under ACTA (Ananda Chaitanya Training Academy), this program bridges the gap between academic knowledge and industry requirements, providing hands-on training in cutting-edge technologies and professional development.

Industry Collaboration:

These programs are conducted in association with top industries like MAK Controls, Suntech, FX Multi-tech, etc., as part of their CSR activities.

Unique aspects:

- Training sessions led by industry experts with 15-20 years of experience.
- Professionals volunteer their time to mentor and guide participants.
- This ensures high-quality, practical learning directly from professionals who have deep domain expertise.

We offer expert-led programs in:

- **Embedded Systems**
- **Automation - PLC, SCADA & LabVIEW**
- **Electrical Systems Design**
- **CADD & Engineering Design**
- **Soft Skills & Leadership Training**
- **Smart Management**
- **Communication & Professional Development**

Please visit **https://acta.anandachaitanya.org** for all the courses, E-Books and Self learning Training materials.

Our Mission: This initiative nurtures talent, enhance employability, and create a future-ready workforce through industry-relevant skill development.

SUMMARY

This book contains the information of basics of electronics with various applications. The basics of electronics refer to the concepts that include inductance, capacitance, resistance, voltage and electrical currents. Professionals who know the basics of electronics understand how devices control electrons via manipulating, storing, switching, selecting, steering, carrying or resisting them.

Note: This e-book has been compiled from various resources of Internet and by the personal knowledge of the team involved. It covers the basic topics as required by the Industries.

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Ananda Chaitanya Training Academy is a skill development initiative of Ananda Chaitanya Foundation's "Vaiya Thalaimai Kol" Project.

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