**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING**

# *COURSE MATERIALS*


# *EC 100 BASICS OF ELECTRONICS ENGINEERING*

## VISION OF THE INSTITUTION

To mould true citizens who are millennium leaders and catalysts of change through excellence in education.

## MISSION OF THE INSTITUTION

**NCERC** is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

## ABOUT DEPARTMENT

- Established in: 2002
- Course offered : B.Tech in Computer Science and Engineering

  M.Tech in Computer Science and Engineering

  M.Tech in Cyber Security
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to A P J Abdul Kalam Technological University.

## DEPARTMENT VISION

Producing Highly Competent, Innovative and Ethical Computer Science and Engineering Professionals to facilitate continuous technological advancement.

## DEPARTMENT MISSION

1. To Impart Quality Education by creative Teaching Learning Process
2. To Promote cutting-edge Research and Development Process to solve real world problems with emerging technologies.
3. To Inculcate Entrepreneurship Skills among Students.
4. To cultivate Moral and Ethical Values in their Profession.
5. 

### PROGRAMME EDUCATIONAL OBJECTIVES

**PEO1:** Graduates will be able to Work and Contribute in the domains of Computer Science and Engineering through lifelong learning.
**PEO2:** Graduates will be able to Analyse, design and development of novel Software Packages, Web Services, System Tools and Components as per needs and specifications.
**PEO3:** Graduates will be able to demonstrate their ability to adapt to a rapidly changing environment by learning and applying new technologies.
**PEO4:** Graduates will be able to adopt ethical attitudes, exhibit effective communication skills, Teamworkand leadership qualities.

## PROGRAM OUTCOMES (POS)

**Engineering Graduates will be able to:**

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## PROGRAM SPECIFIC OUTCOMES (PSO)

**PSO1**: Ability to Formulate and Simulate Innovative Ideas to provide software solutions for Real-time Problems and to investigate for its future scope.

**PSO2**: Ability to learn and apply various methodologies for facilitating development of high quality System Software Tools and Efficient Web Design Models with a focus on performance optimization.

**PSO3**: Ability to inculcate the Knowledge for developing Codes and integrating hardware/software products in the domains of Big Data Analytics, Web Applications and Mobile Apps to create innovative career path and for the socially relevant issues.

## COURSE OUTCOMES

| | |
|---|---|
| **CO1** | Demonstrate the knowledge of fundamental concepts in graph theory, including properties and characterization of graphs. |
| **CO2** | Demonstrate the fundamental theorems on Eulerian and Hamiltonian graphs. |
| **CO3** | Demonstrate the properties and characterization of trees. Illustrate the working of Prim's and Kruskal's algorithms for finding minimum cost spanning tree. |
| **CO4** | Explain planar graphs, their properties and an application for planar graphs. |
| **CO5** | Illustrate how one can represent a graph in a computer. |
| **CO6** | Develop the efficient algorithms for graph related problems in different domains of engineering and science. |

## MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES

| CO'S | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C106.1 | 3 | 2 | - | 3 | - | - | - | - | - | - | - | 2 |
| C106.2 | 3 | - | - | 3 | - | - | - | - | - | - | - | 2 |
| C106.3 | 3 | 2 | | 3 | - | - | - | - | - | - | - | 2 |
| C106.4 | 3 | 2 | 3 | 3 | - | - | - | - | - | - | - | 2 |
| C106.5 | 3 | - | 3 | 3 | - | - | - | - | - | - | - | 2 |
| C106.6 | 3 | - | 3 | 3 | - | - | - | - | - | - | - | 2 |
| C106 | 3.00 | 2.00 | 3.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 |

**Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=**

| CO'S | PSO1 | PSO2 | PSO3 |
|---|---|---|---|
| C106.1 | 2 | 2 | |
| C106.2 | 2 | | |
| C106.3 | 2 | 2 | |
| C106.4 | 2 | 2 | 3 |
| C106.5 | 2 | 2 | 2 |
| C106.6 | | | 2 |
| C106 | | | |

| Course No: | Course Name | L-T-P Credits | Year of Introduction |
|---|---|---|---|
| **EC100** | **BASICS OF ELECTRONICS ENGINEERING** | **2-1-0-3** | **2016** |

**Course Objectives**

1) To get basic idea about types, specification and common values of passive and active components.
2) To familiarize the working of diodes, transistors, MOSFETS and integrated circuits.
3) To understand the working of rectifiers, amplifiers and oscillators.
4) To get a basic idea about measuring instruments
5) To get a fundamental idea of basic communication systems and entertainment electronics

**Syllabus**

Evolution and Impact of Electronics in industries and in society, Familiarization of Resistors, Capacitors, Inductors, Transformers and Electro mechanical components, PN Junction diode: Structure, Principle of operation, Zener diode, Photo diode, LED, Solar cell, Bipolar Junction Transistors: Structure, Principle of operation, characteristics, Rectifiers and power supplies: Half wave and full wave rectifier, capacitor filter, zener voltage regulator, Amplifiers and Oscillators: common emitter amplifier, feedback, oscillators, RC phase shift oscillator, Analogue Integrated circuits: operational amplifier, inverting and non-inverting amplifier, Electronic Instrumentation: digital multimeter, digital storage oscilloscope, function generator, Radio communication: principle of AM & FM, Super heterodyne receiver, Satellite communication: geo-stationary satellite system, Mobile communication: cellular communications, Optical communication: system, principle of light transmission through fiber, Entertainment Electronics: Cable TV, CCTV system.

**Expected Outcome**

Student can identify the active and passive electronic components. Student can setup simple circuits using diodes and transistors. Student will get fundamental idea about basic communication systems and entertainment electronics.

**Text Books:**

- Bell, D. A., Electronic Devices and Circuits, Oxford University Press
- Tomasy, W., Advanced Electronic Communication system, PHI Publishers

**References Books**:

- Boylested, R. L. and Nashelsky, L., Electronic Devices and Circuit Theory, Pearson Education
- Frenzel, L. E., Principles of Electronic Communication Systems, Mc Graw Hill
- Kennedy, G. and Davis, B., Electronic Communication Systems, Mc Graw Hill

- Rajendra Prasad, Fundamentals of Electronic Engineering, Cengage Learning

**Course Plan**

| Module | Contents | Hours | Sem. Marks |
|---|---|---|---|
| I | Evolution of Electronics, Impact of Electronics in industry and in society. | 1 | 10% |
| | Resistors, Capacitors: types, specifications. Standard values, marking, colour coding. | 3 | |
| | Inductors and Transformers: types, specifications, Principle of working. | 2 | |
| | Electro mechanical components: relays and contactors. | 1 | |
| II | PN Junction diode: Intrinsic and extrinsic semiconductors, Principle of operation, V-I characteristics, principle of working of Zener diode, Photo diode, LED and Solar cell. | 4 | 20% |
| | Bipolar Junction Transistors: PNP and NPN structures, Principle of operation, input and output characteristics of common emitter configuration (npn only). | 3 | |
| **FIRST INTERNAL EXAM** | | | |
| III | Rectifiers and power supplies: Block diagram description of a dc power supply ,Half wave and full wave (including bridge) rectifier, capacitor filter, working of simple zener voltage regulator. | 4 | 15% |
| | Amplifiers and Oscillators: Circuit diagram and working of common emitter amplifier, Block diagram of Public Address system, concepts of feedback, working principles of oscillators, circuit diagram & working of RC phase shift oscillator. | 4 | |
| IV | Analogue Integrated circuits: Functional block diagram of operational amplifier, ideal operational amplifier, inverting and non-inverting Amplifier. | 3 | 15% |
| | Digital ICs: Logic Gates. | 1 | |
| | Electronic Instrumentation: Principle and block diagram of digital multimeter, digital storage | 2 | |

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| | oscilloscope, and function generator. | | |
| **SECOND INTERNAL EXAM** | | | |
| **V** | Radio communication: principle of AM & FM, frequency bands used for various communication systems, block diagram of super heterodyne receiver. | 3 | 20% |
| | Satellite communication: concept of geo-stationary Satellite system. | 2 | |
| **VI** | Mobile communication: basic principles of cellular communications, concepts of cells, frequency reuse. | 2 | 20% |
| | Optical communication: block diagram of the optical communication system, principle of light transmission through fiber, advantages of optical communication systems. | 2 | |
| | Entertainment Electronics Technology: Basic principles and block diagram of cable TV, CCTV, DTH system. | 2 | |
| **END SEMESTER EXAM** | | | |

Note: Analysis is not required in this course.

# QUESTION BANK

| MODULE 1 | | | | |
|---|---|---|---|---|
| Q.NO | Questions | CO | KL | Page No |
| 1 | Write down the different applications in the field of electronics | CO1 | K3 | 18 |
| 2 | Differentiate between active and passive components | CO1 | K2 | 22 |
| 3 | Write a short note on active components with examples | CO1 | K6 | 22 |
| 4 | Write a short note on passive components with examples | CO1 | K6 | 22 |
| 5 | State the ohm's law | CO1 | K1 | 22 |
| 6 | What is the colour code for a 4.7kΩ resistor with 5% tolerance value? | CO1 | K5 | 30 |
| 7 | What is the nominal resistance of a resistor with colour code orange-white-brown? | CO1 | K4 | 30 |
| 8 | What is the colour code for a 560kΩ resistor with 10% tolerance value? | CO1 | K5 | 30 |
| 9 | What is the colour code for a 22Ω resistor with 20% tolerance value? | CO1 | K5 | 30 |
| 10 | Describe the different types of fixed resistors | CO1 | K1 | 24 |
| 11 | Describe the different types of variable resistors | CO1 | K1 | 27 |
| 12 | How capacitors are classified? | CO1 | K2 | 33 |
| 13 | Write a short note on inductor and its classifications. | CO1 | K3 | 40 |
| 14 | Write a short note on relays. | CO1 | K2 | 42 |

| MODULE 2 | | | | |
|---|---|---|---|---|
| Q.NO | Questions | CO | KL | Page No |
| 1 | Explain about the operation of NPN transistor. | CO2 | K2 | 50 |
| 2 | Explain about the operation of PNP transistor. | CO2 | K2 | 52 |
| 3 | Mention the three regions in which a transistor can operate. | CO2 | K2 | 53 |

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|---|---|---|---|---|
| 4 | Obtain the relationship for the current gain of CE, CB and CC configurations. | CO2 | K3 | 56 |
| 5 | Draw and explain the input output characteristics of CE configuration. | CO2 | K1 | 57 |
| 6 | Describe the working of pn junction diode with I-V characteristics. | CO2 | K4 | 58 |
| 7 | Describe the working of zener junction diode with I-V characteristics. | CO2 | K4 | 62 |
| 8 | Compare avalanche breakdown and zener breakdown | CO2 | K2 | 59 |
| 9 | Write a short note on LED | CO2 | K2 | 61 |
| 10 | Briefly explain the working principle of photo diode | CO2 | K5 | 63 |
| 11 | Write a short note on the working of solar cell | CO2 | K2 | 64 |

| MODULE 3 | | | | |
|---|---|---|---|---|
| Q.NO | Questions | CO | KL | Page No |
| 1 | Give a detailed description about the working of zener voltage regulator. | CO3 | K1 | 65 |
| 2 | Explain the working of a Zener voltage Regulator | CO3 | K4 | 65 |
| 3 | With the help of a block diagram, explain how a digital multimeter can be used to measure voltage and resistance. | CO3 | K5 | 66 |
| 4 | With a neat circuit diagram, explain the working of an RC coupled amplifier. | CO3 | K4 | 68 |
| 5 | Draw the frequency response characteristics of an RC coupled amplifier and state the reasons for the reduction of gain at lower and higher frequencies. | CO3 | K2 | 70 |
| 6 | Explain the concept of voltage divider biasing | CO3 | K1 | 72 |
| 7 | Draw and explain the block diagram of an electronic instrumentation system. | CO3 | K1 | 73 |

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| 8 | Discuss in detail about public addressing system | CO3 | K6 | 66 |
| 9 | Draw and explain the working of a dc power supply. | CO3 | K4 | 59 |
| 10 | With neat sketches explain a cellular communication system | CO3 | K3 | 89 |
| 11 | Differentiate between amplifiers and oscillators. | CO3 | K4 | 75 |
| 12 | Explain the working of RC Phase shift Oscillator. | CO3 | K5 | 89 |
| MODULE 4 | | | | |
| Q.NO | Questions | CO | KL | Page No |
| 1 | Briefly explain the operating principle of Operational amplifier | CO4 | K1 | 92 |
| 2 | Describe in detail about the different parameters of Op amp | CO4 | K4 | 92 |
| 3 | With the help of a circuit diagram explain the working of an inverting amplifier | CO4 | K5 | 97 |
| 4 | With the help of a circuit diagram explain the working of a non inverting amplifier | CO4 | K4 | 99 |
| 5 | Write down the conditions of an ideal op amp | CO4 | K2 | 92 |
| 6 | State the truth tables of basic gates | CO4 | K1 | 100 |
| 7 | Write down the truth table of universal gates | CO4 | K1 | 101 |
| 8 | Write down the truth table of combinational gates | CO4 | K2 | 102 |
| 9 | With the help of a suitable diagram explain the working principle of digital multimeter | CO4 | K5 | 104 |
| 10 | Draw and explain the operation of digital storage oscilloscope | CO4 | K4 | 107 |
| 11 | Explain in detail about the working principle of function generator | CO4 | K4 | 109 |
| | MODULE 5 | | | |
| Q.NO | Questions | CO | KL | Page No |
| 1 | List out the frequency bands used for various communication systems. | CO5 | K1 | 110 |
| 2 | Elaborate in detail about the principle of AM & FM | CO5 | K4 | 112 |
| 3 | With neat block diagram, explain super heterodyne | CO5 | K6 | 118 |

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| | receiver. | | | |
| 4 | With neat block diagram explain the stages of GSM | CO5 | K2 | 121 |
| 5 | Give a brief description about the principle of antenna. | CO5 | K1 | 125 |
| 6 | Explain the principle of GSM. | CO5 | K1 | 127 |
| 7 | Differentiate between Amplitude modulation and Frequency modulation. | CO5 | K5 | 114 |
| 8 | Describe in detail about the working principle behind satellite communication system. | CO5 | K1 | 129 |
| 9 | Discuss the working principle behind Geo stationary satellite system | CO5 | K5 | 130 |
| | MODULE 6 | | | |
| Q.NO | Questions | CO | KL | Page No |
| 1 | With neat sketches explain a cellular communication system | CO6 | K1 | 131 |
| 2 | What do you mean by frequency reuse? | CO6 | K4 | 132 |
| 3 | Write a short note on the concept of cells in cellular communication. | CO6 | K6 | 133 |
| 4 | Discuss in detail about the block diagram of optical communication. | CO6 | K2 | 134 |
| 5 | Mention the advantages of optical communication | CO6 | K1 | 135 |
| 6 | Write a short note on the principle of light emission through optical fiber | CO6 | K1 | 136 |
| 7 | Explain in detail about the working principle behind cable tv operation | CO6 | K5 | 137 |
| 8 | Describe in detail about the operation of CCTV | CO6 | K1 | 138 |

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|---|---|---|---|---|
| 9 | Give a detailed description on the operation of DTH | CO6 | K5 | 139 |
| 10 | Mention the advantages of DTH system | CO6 | K2 | 139 |

**APPENDIX 1**

**CONTENT BEYOND THE SYLLABUS**

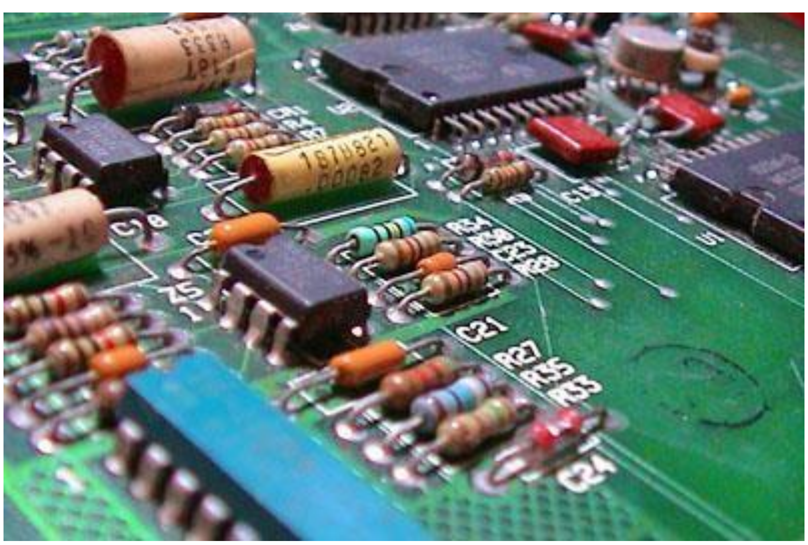
| S:NO; | TOPIC | PAGE NO: |
|---|---|---|
| 1 | Types of Antenna | 140 |
| 2 | Radiation Antenna | 140 |

## MODULE NOTES

### <u>MODULE 1</u>

## <u>Evolution of electronics</u>

The word 'electronics' is derived from electron mechanics, which means the study of the behavior of an electron under different conditions of externally applied fields. The Institution of Radio Engineers (IRE) has given a standard definition of electronics as "that field of science and engineering, which deals with electron devices and their utilization."



Applications of electronics

Electronics play a major role in almost every sphere of our life. The main applications of electronics are as follows.

Communication and Entertainment In communication,

the main application of electronics was in the field of telegraphy and telephony. This utilizes a pair of wires. However, it is now possible with the help of radio waves to transmit any message from one place to another, thousands of kilometers away, without any wires. With such wireless communication (radio broadcasting), people in any part of the world can know what is happening in other parts. Radio and TV broadcasting provide a means of both communication as well as entertainment. With the help of satellites it has become possible to establish instant communication between places very far apart.

Defense Applications
One of the most important developments during World War II was the RADAR. By using radar it is possible to detect and find the exact location of the enemy aircraft.The antiaircraft guns directed to shoot down the aircraft. The radar and antiaircraft guns can be linked by an automatic control system to make a complete unit.

Guided missiles are completely controlled by electronic circuits. In a war, success or defeat for the nation depends on the reliability of its communication system.

Industrial Applications

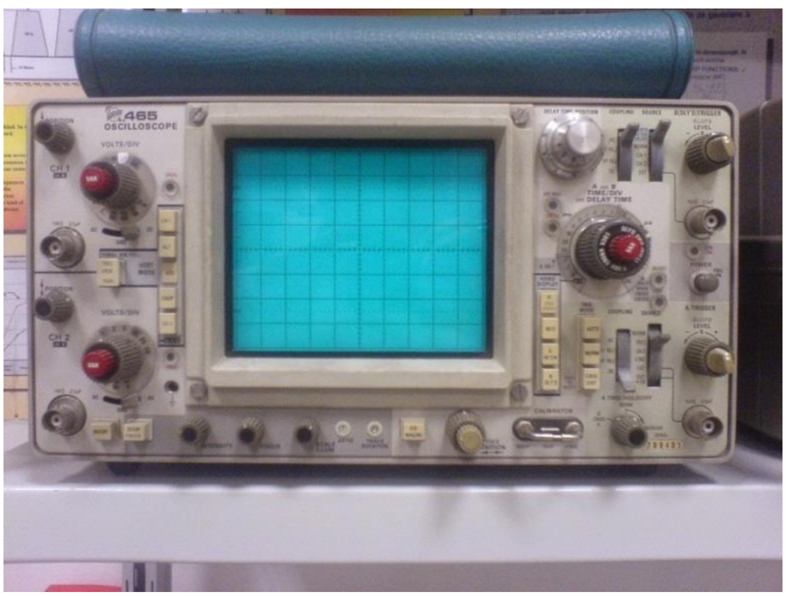
Use of automatic control systems in industries is increasing day by day. Electronic circuits are used in industrial applications like control of thickness, quality, weight and moisture content of a material. It is also used in automatic dooropeners, lightning systems, power systems and safety devices.

Medical Sciences

Doctors and scientists are constantly finding new uses for electronic systems in the diagnosis and treatment of various diseases. Some of the instruments which have been in use are: Xrays, for taking pictures of internal bone structures and also treatment of some diseases Electrocardiographs (ECG), to find the condition of the heart of a patient. Shortwave diathermy units, for healing sprains and fractures. Oscillographs for studying muscle action.

Instrumentation

Instrumentation plays a very important role in any industry and research organization,for precise measurement of various quantities. e,g. VTVM, CRO, frequency counters, pHmeters,straingauges,etc

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Integrated circuit

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An integrated circuit or monolithic integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material that is normally silicon. The integration of large numbers of tiny

MOS transistors into a small chip results in circuits that are orders of magnitude smaller, faster, and less expensive than those constructed of discrete electronic components.

Integrated circuits were made practical by technological advancements in metal–oxide–silicon (MOS) semiconductor device fabrication. Since their origins in the 1960s, the size, speed, and capacity of chips have progressed enormously, driven by technical advances that fit more and more MOS transistors on chips of the same size – a modern chip may have many billions of MOS transistors in an area the size of a human fingernail. These advances, roughly following Moore's law, make computer chips of today possess millions of times the capacity and thousands of times the speed of the computer chips of the early 1970s.

In the early days of simple integrated circuits, the technology's large scale limited each chip to only a few transistors, and the low degree of integration meant the design process was relatively simple. Manufacturing yields were also quite low by today's standards. As the technology progressed, millions, then billions of transistors could be placed on one chip, and good designs required thorough planning, giving rise to the field of electronic design automation, or EDA.

| Scale | Components Count | Year |
|---|---|---|
| SSI (Small Scale Integration) | $< 100$ | 1963 |
| MSI (Medium Scale Integration) | 100-1000 | 1970 |
| LSI (Large Scale Integration) | 1000-10000 | 1975 |
| VLSI (Very Large Scale Integration) | $10000 - 10^9$ | 1980 |
| ULSI (Ultra Large Scale Integration) | $> 10^6$ | 1990 |
| GSI (Giga Scale Integration) | $> 10^{10}$ | 2010 |

# Electronic Components

## The main components used in electronics are of two general types: passive and active.

### (i) Active components

Components required to be powered in some way to make them work i.e. rely on a source of energy

Examples: Active components include amplifying components such as Vacuum Tubes, Transistors, Integrated Circuits, etc

### (ii) Passive components

Doesn't rely on a source of power.

Examples: Passive components include components such as resistors, capacitors, and inductors.

# Resistor

Resistors decrease the intensity of the electric current flowing through a circuit. Resistors do not block electricity. Instead, they convert a percentage of the electric current into heat energy, which is transmitted into an area around the device.

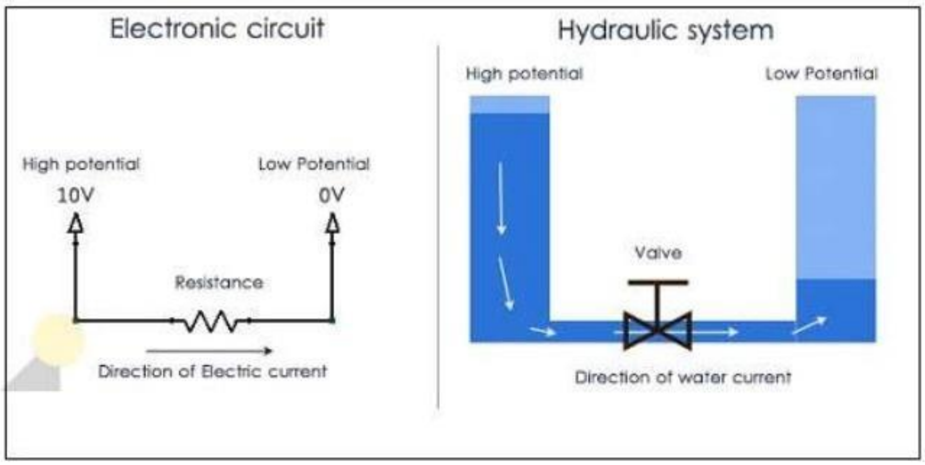
**Resistance: The ability of the material to oppose current.**

The amount of electric current absorbed by a resistor is called "resistance," and is measured in "ohm" units

**Ohm:** an ohm is defined as the electrical resistance between two points of a conductor when a constant potential difference applied between these points produces a current of one ampere

$R = V / I$

A simple analogy with a hydraulic system. Notice that the flow of electricity resembles the flow of water from a point of high potential energy (high voltage) to a point of low potential energy (low voltage). In this simple analogy water is compared to electrical current, the voltage Difference is compared to the head difference between two water reservoirs, and finally the valve resisting the flow of water is compared to the resistor limiting the flow of current.



There won't be any flow of current between 2 points if there is no potential difference between them. In other words, for a flow of current to exist, there must be a voltage difference between two points.

The electric current in a conductor will increase with the decrease of the resistance, exactly as the rate of flow of water will increase with the decrease of the resistance of the valve.

A lot more deductions are based on this simple analogy, but those rules are summarized in the most fundamental equations of electronics: Ohm's law.

Ohm's law states that, at constant temperature the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them.

The mathematical equation that describes this relationship is: $R = V / I$

Where
I is the current through the conductor in unit of ampere,
V is the potential difference measured across the conductor in unit of volt,
R is the resistance of the conductor in unit of ohm.

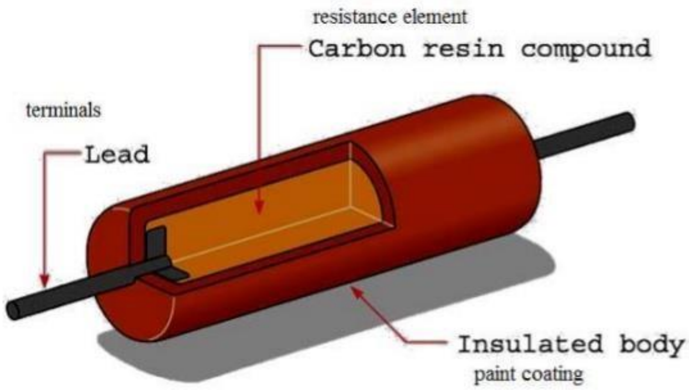
## Fixed value Resistors

The value of resistance remains constant and cannot be varied by the user
The major types of fixed resistors are

(i) Carbon composition resistor
(ii) wire wound resistor
(iii) Carbon film resistor
(iv) Metal film resistor

Choice of resistor for a desired application depends upon the **value of resistance, size, shape, leads, power rating, tolerance, maximum operating voltage ,etc**.

## CARBON COMPOSITION RESISTOR




**Resistance element:** mixture of powdered carbon and powdered insulator.

The resistance element are solidified by a bonding compound and the mixture is extruded into desired shape and size by forcing it through a die.

The process is achieved by sintering in the presence of hydrogen or nitrogen at 1400°C.

**Specifications:**

| | |
|---|---|
| Resistance range: | 2Ω to20MΩ |
| Tolerance: | 5% to 10% |
| Power rating: | 0.125W to 2W |
| Operating Voltage: | 125V to 800V |
| Operating temperature: | -55ºC to150ºC |
| Uses: | General purpose electronic instruments |

## Wire-wound resistors

Wire-wound resistors are fixed resistors that are made by winding a piece of resistive wire around a cylindrical ceramic core. These are used when a high power rating is required.

The wire is preferred according to its resistivity.

The required resistance can be achieved by varying the thickness and length of the resistive wire during winding process.

The resistive wire has to be tightly wound to the ceramic substrate.

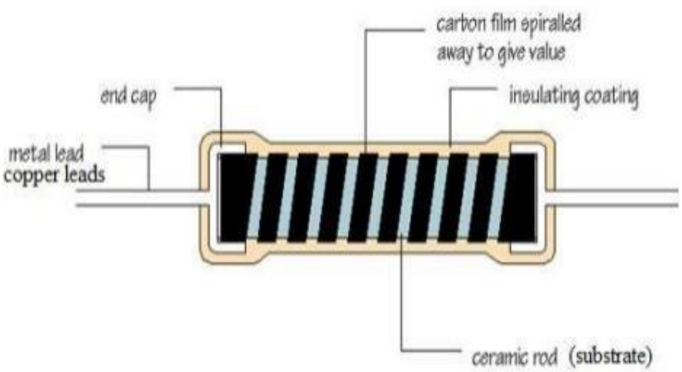
The entire setup is covered by an enamel to prevent it from moisture.

**Specifications:**

| | |
|---|---|
| Resistance range: | 0.1Ω to1MΩ |
| Tolerance: | 0.1% to 5% |
| Power rating: | 10W to 75W |
| Operating Voltage: | <150V |
| Operating temperature: | 55ºC to375ºC |

Applications: Low resistance, low noise, higher power handling capacity in small size.

# Carbon film resistor




➢A thin film of pure carbon is deposited onto a small ceramic rod(substrate) by thermal decomposition at 1000ºC.

➢ The resistive coating is spiralled away in an automatic machine until the resistance between the two ends of the rod is as close as possible to the correct value.

➢Metal leads and end caps are added, the resistor is covered with an insulating coating and finally painted with coloured bands to indicate the resistor value.

**Specifications:**

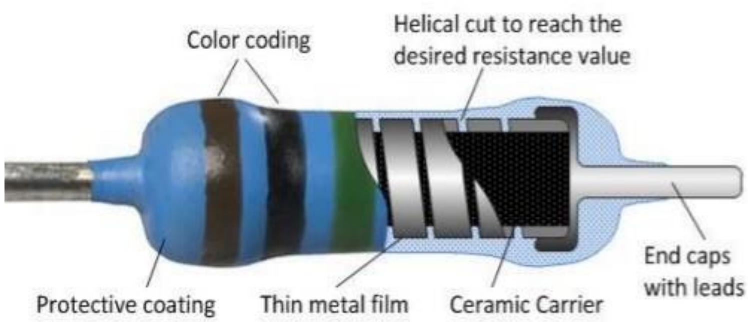
| | |
|---|---|
| Resistance range: | 1Ω to10MΩ |
| Tolerance: | 1% to 5% |
| Power rating: | 5W |
| Operating Voltage: | 500V |

Applications: used in measuring instruments where close tolerances are required.

Carbon film resistors posses better stability than carbon composition resistors, but are of relatively larger size compared to carbon composition resistors . Carbon film resistors cannot withstand electric overloads.

## Metal film resistor

Metal film resistors are axial resistors with a thin metal film(Ni) as resistive element. The thin film is deposited on usually a ceramic body(substrate).




**Specifications:**

| | |
|---|---|
| Resistance range: | 0.5Ω to10KΩ |
| Tolerance: | 2% to 3% |
| Power rating: | 5W |
| Operating Voltage: | 300V |
| Working temperature: | -40 to 150ºC |

Stable, reliable and capable of handling overload for short time.

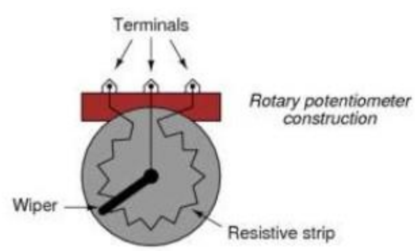
Applications: electronic instruments.

## Variable resistors

Variable resistors can change their value over a specific range. A potentiometer is a variable resistor with three terminals. A rheostat has only two terminals.

A potentiometer is a three terminal variable resistor used to divide voltage

A rheostat is a variable resistor used to control current




**Potentiometers work on the principle that longer lengths of resistance material have greater resistance.**

The closer the wiper is to the end terminal it is connected to, the less resistance there is. This is because the current will not have to travel as far. The further away the wiper moves from the terminal it is wired with, the greater the resistance will be.

Potentiometers usually have three connecting points. Two are connected to the ends of the resistance material and the third is connected to the central sliding contact. The slider can either slide in a straight line or around a curve

## Types of variable resistors

(i) Carbon composition potentiometer
(ii) Wire wound resistor
(iii) Wire wound solenoid
(iv) Helical wound POT

**Characteristics of Variable resistor:**

(i) resistance law: relation between change in R and movement of wiper

(ii) Tolerance

(iii) Insulation resistance(high)

(iv) Speed of operation

(v) Life time

(vi) Ruggedness

# CARBON COMPOSITION POTENTIOMETER(POT)

**(i) Coated film Carbon composition potentiometer**

Resistance element: mixture of carbon, silica and binder

Substrate: ring shaped insulating material

End terminals: brass or phosphor bronze

The resistance element is coated on the ring shaped insulating material.

**Applications:** Preset POT in T.V brightness and contrast control, radio and measuring instruments.

**Specifications:**

Range:100 to $10^7 \Omega$;

power :0.5W to 2.25W;

tolerance: 20% for 1 to $10^6 \Omega$

30% for> $10^6 \Omega$

**(ii) Moulded type Carbon composition potentiometer:** the resistance material is moulded into a cavity in a plastic base(substrate).

Wiper( moving contact): carbon brush.

ON& OFF switch can be incorporated in this type of POT

Applications: Computers, Industrial and defence . Also used in HF applications as associated inductive and capacitive effects are low.

## Wire wound Solenoid

Resistance element: oxidised form of Nickel, copper

Former: ceramic or steel in hexagonal or circular shape

Brush: copper or graphite.

Resistance element is wound on the former.

Range:500 to 10KΩ.

Current :0.1 to 20A

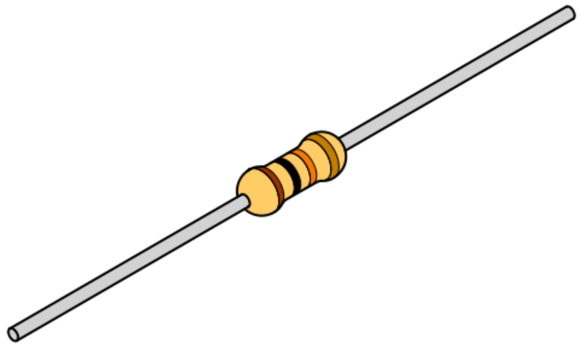
## Helical wound variable resistor

Resistance element is wound on the helical former .

Range: 1 to 125K Ω.

tolerance: 2%

Power rating: 100W to 200W



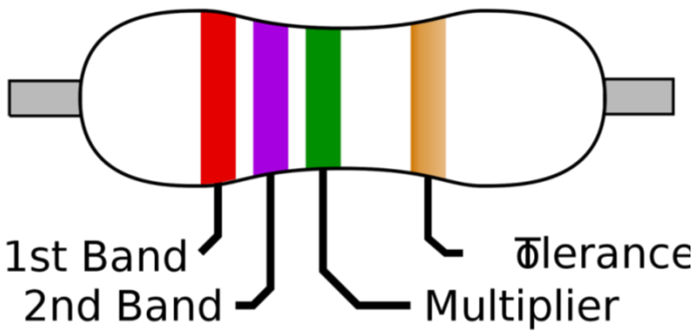
RESISTOR

RESITOR SYMBOL

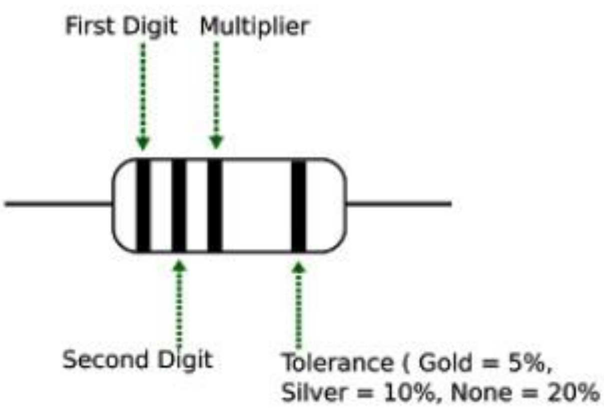
A resistor is a passive electronic component that offers a specific amount of electrical resistance to the flow of current when connected in a circuit. Unit of resistance is ohm ( Symbol Ω ). Ohm is a very small unit. Most practical resistors have resistance in thousands or hundred of thousands of ohm. Therefore resistance is often measured in kilo and megaohms.

Color coding of resistors

Carbon resistors are color coded. Carbon resistors are very small size, it is difficult to write the ohmic values as numbers so color coding is used. Each color has specific numerical values, this help to find the value of the resistor.




The color bands are read from left to right. The first and second bands represent significant digits respectively of the resistance value. The third band shows the multiplier value. The fourth band gives the tolerance value

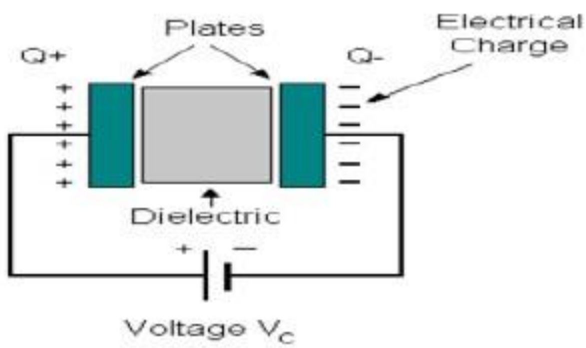



| Color | Digit | Multiplier |
|---|---|---|
| Black | 0 | x 1 |
| Brown | 1 | x 10 |
| Red | 2 | x 100 |
| Orange | 3 | x 1K |
| Yellow | 4 | x 10K |
| Green | 5 | x 100K |
| Blue | 6 | x 1M |
| Violet | 7 | - |
| Grey | 8 | - |
| White | 9 | - |
| Silver | - | x 0.01 |
| Gold | - | x 0.1 |

# CAPACITORS

Capacitor is a physical device which is capable of storing energy by virtue of a voltage existing across it. Capacitor store energy in electrostatic fields. A capacitor consists of two conducting plates separated by an insulating material, The insulating material is known as dielectric. Capacitance is measured by the ability of capacitor to store charge. Capacitance is measured in farads (F). Practical capacitors are measured in microfarads (μF) and picofarads (pF).

$1\ \mu F = 10^{-6} F$, $1 pF = 10^{-12} F$, $1\ nF = 10^{-9} F$




$Q \alpha V;\ Q = CV$

**Factors Affecting Capacitance**

**1 Plate Area:**

It affects capacitance directly ie, capacitance increases with the increase in plate area (A)

**2 Plate Separation:**

It affects the capacitance inversely ie, capacitance decreases with the increase in plate separation

3. **Type of Dielectric:**

It also affects capacitance directly

$$C\ \alpha\ \frac{\varepsilon_r A}{d}$$

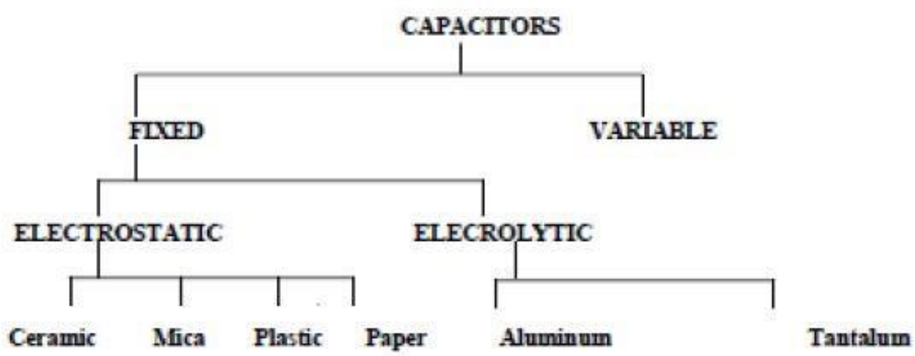
$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

Where $\epsilon_0$ absolute permittivity = $8.854*10^{-14}$ F/M

$\epsilon_r$ Relative permittivity

## *Classification of capacitors*

The capacitors are commonly classified on basis of dielectric material used. The capacitors may be divided in to two classes, namely fixed and variable capacitors. Each type is further sub divided into two types.




### Fixed Capacitors

In fixed capacitors their capacitance value cannot be varied mechanically or by any external means. In fixed capacitors the dielectric is permanently kept in between two fixed plates.

Commonly used fixed capacitors are :

### Paper capacitors

Paper capacitors are one of the earliest types of capacitors. They are made by placing paper soaked with mineral oil between two aluminum foils. The entire assembly is rolled up, wire leads are attached to the aluminum foils, and the assembly is enclosed in a cylindrical cardboard case and sealed with wax.

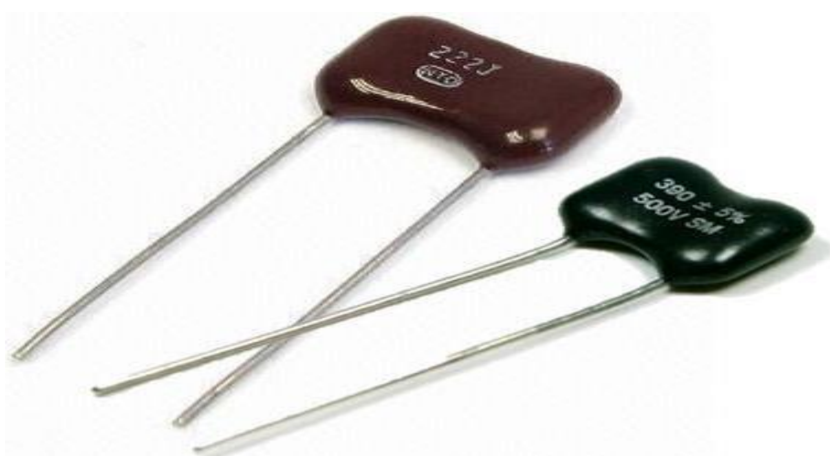
| | |
|---|---|
| Nominal Capacitance | 0.001 uF to 10 uF |
| Working Voltage (at 85°C) | 200V to 1600V |
| Typical Tolerance | 10% |
| Temperature Range | -55°C to 125°C |
| Temperature Coefficient (PPM/°C) | +/-800 |
| Insulation Resistance (Meg Ohms) | $5x10^3$ |
| Polarization | Non-Polarized |
| Dielectric Absorption | 2.5% |
| Dissipation Factor (Operating Losses) | 1% |
| Disadvantage | Size, Hygroscopic and susceptible to moisture |
| Advantage | Low Cost, Stable, High Voltage Rating |
| Applications | Motor Capacitors |
| Cost | Low |

## Mica & Metalized Mica capacitors

Mica capacitors use mica sheets as a dielectric and are usually constructed as multi-plate capacitors. A variation of mica capacitors use silver inked mica sheets as a dielectric for better immunity to moisture and ionization. Mica capacitors are known for low tolerance (as low as 1%), low operating losses (dissipation factor of 0.001%), high-quality factor, and stability at high frequency

Capacitance value vary from 1pF to 10,000pF

These capacitors are able to withstand very high voltage about 500V due to high dielectric constant.




## Plastic film capacitors

Film capacitors include many families of capacitors that use different plastics as a dielectric material. They have nearly replaced the paper capacitors in audio, radio circuits, and circuits operating at low to moderate voltages. Some of the commonly used plastics in film capacitors include Polycarbonate, Polyester (PET), Polypropylene (PP), Polystyrene, Polysulphone, Parylene, Kapton Polyimide, Teflon (PTFE Fluorocarbon), and Metalized Polyester (Metalized Plastic). These capacitors come in a variety of geometries such as oval or round wrap and fill, rectangular epoxy case, round epoxy case, metal hermetically sealed rectangular or round case, and with radial or axial leads.

| | |
|---|---|
| Nominal Capacitance | 1000 pF to 50 uF |
| Working Voltage (at 85°C) | 50V to 600V |
| Typical Tolerance | 5% to 10% |
| Temperature Range | -55°C to 125°C |
| Temperature Coefficient (PPM/°C) | +400 |
| Insulation Resistance (Meg Ohms) | $10^5$ |
| Polarization | Non-Polarized |
| Dielectric Absorption | 0.3% |
| Dissipation Factor (Operating Losses) | 0.75% |
| Disadvantage | High Temperature Coefficient, Frequency Dependence |
| Advantage | Low Cost, Small Size |
| Applications | DC and low power low frequency AC applications |
| Cost | Low |

## Ceramic capacitors

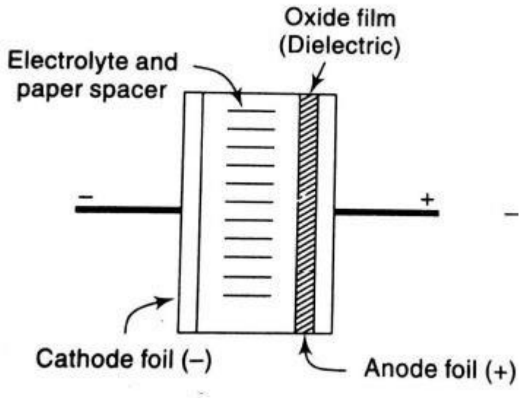
Ceramic capacitors refer to a wide range of capacitors available as disc capacitors, MLC (Multi-Layer Ceramic) capacitors, and SMD capacitors. The composition of these capacitors varies with the manufacturers. Some of the commonly used materials in the construction of ceramic capacitors include strontium titanate, titanium oxide, barium titanate, etc

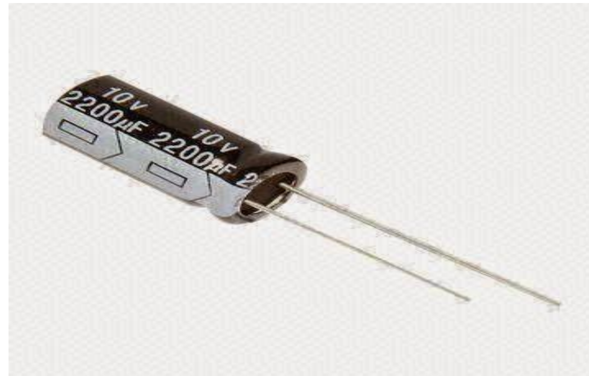
| | |
|---|---|
| Nominal Capacitance | 100 pF to 1 uF |
| Working Voltage (at 85°C) | 50V to 30,000V |
| Typical Tolerance | 1% to 5% |
| Temperature Range | -55°C to 125°C |
| Temperature Coefficient (PPM/°C) | +/-30 to +/-2500 |
| Insulation Resistance (Meg Ohms) | $5x10^3$ |
| Polarization | Non-Polarized |
| Dielectric Absorption | 0.75 |
| Dissipation Factor (Operating Losses) | 0.02% |
| Disadvantage | Cost, Size |
| Advantage | Low Operating Losses, Stability, Low Tolerance |
| Applications | High Frequency Applications |
| Cost | High |

## Electrolytic capacitors

Electrolytic Capacitors are polarized capacitors that offer high capacitance per unit volume. Since these capacitors are polarized, they must be hooked up in a circuit with the right polarity. They have one terminal as the anode, which is a metal plate coated with metal oxide; a liquid or solid electrolytic serves as the cathode. When DC current flows through the electrolytic capacitor, the metal plate starts oxidizing due to an electrolytic and a thin insulating metal oxide layer is deposited on it which serves as a dielectric. As the metal oxide layer is extremely thin, it offers very high capacitance per unit volume. Generally, these capacitors are designed to maximize the surface area of the anode.

When connecting these capacitors in reverse polarity, the electrolyte starts emitting gas which expands in the sealed body of the capacitor and may lead to an explosion. These capacitors have significant leakage current, which makes them unsuitable for many applications.



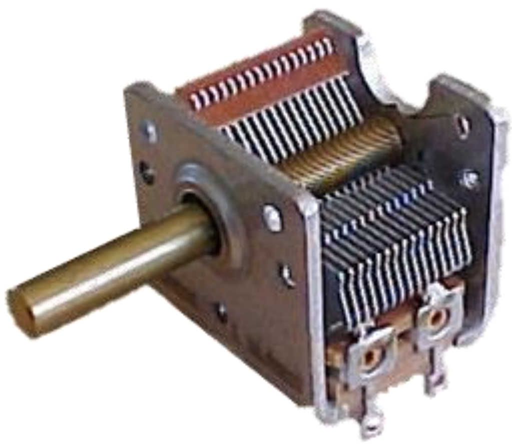




| | |
|---|---|
| Nominal Capacitance | 0.1 uF to 47,000 uF |
| Working Voltage (at 85°C) | 3V to 600V |
| Typical Tolerance | 20% |
| Temperature Range | -40°C to 85°C |
| Temperature Coefficient (PPM/°C) | +2500 |
| Insulation Resistance (Meg Ohms) | 100 |
| Polarization | Polarized |
| Dielectric Absorption | 8 |
| Dissipation Factor (Operating Losses) | 10% |
| Disadvantage | Polarized, High Operating Losses, Leakage Current |
| Advantage | High Volumetric Capacitance |
| Applications | Power Supply Filters, Audio Circuits |
| Cost | High |

## Variable capacitors

The capacitance of the variable capacitors can be varied by changing distance between the conducting plates or by changing the mutual surface area between overlapping plates.

Air Variable (Air-Gap Trimmer) – These variable capacitors have a rotatable set of plates called rotor and a fixed set of plates called stator. The capacitance is varied by rotating a control shaft which varies the distance or surface area between the plates. These capacitors can have a capacitance of a few Picofarad to 1000 Picofarad and voltage rating up to thousands of volts. These non-polarized capacitors were commonly used in RF and audio circuits. Varactor diodes have almost replaced these capacitors.



## Colour coding of capacitor

| Band | Digit | Digit | Multiplier | Tolerance | Tolerance |
|---|---|---|---|---|---|
| Colour | A | B | D | (T) > 10pf | (T) < 10pf |
| Black | 0 | 0 | x1 | ± 20% | ± 2.0pF |
| Brown | 1 | 1 | x10 | ± 1% | ± 0.1pF |
| Red | 2 | 2 | x100 | ± 2% | ± 0.25pF |
| Orange | 3 | 3 | x1,000 | ± 3% | |
| Yellow | 4 | 4 | x10,000 | ± 4% | |
| Green | 5 | 5 | x100,000 | ± 5% | ± 0.5pF |
| Blue | 6 | 6 | x1,000,000 | | |
| Violet | 7 | 7 | | | |
| Grey | 8 | 8 | x0.01 | +80%,-20% | |
| White | 9 | 9 | x0.1 | ± 10% | ± 1.0pF |
| Gold | | | x0.1 | ± 5% | |
| Silver | | | x0.01 | ± 10% | |

## Inductor

This is the third classification of Passive components.It stores the energy in the form of magnetic field and delivers it as and when required

Whenever current pass through a conductor ,lines of magnetic flux are generated around it. Thismagnetic flux opposes any change in current due to the induced emf . This opposition to the change in current is known as inductance and the component producing inductance is known as inductor.

Unit of inductance is Henry (H). The induced emf is actually given by

$$e = -L\frac{d_i}{d_t}$$

Where e = induced emf in volts in any instant

L= Inductance in Henry

$\frac{d_i}{d_t}$ = rate of change of current

The negative sign indicates that the induced emf opposes the cause for the change in current

An inductor is actually a coil of copper wire wound around a core made up of a ferromagnetic material. The inductance L of the coil is given by

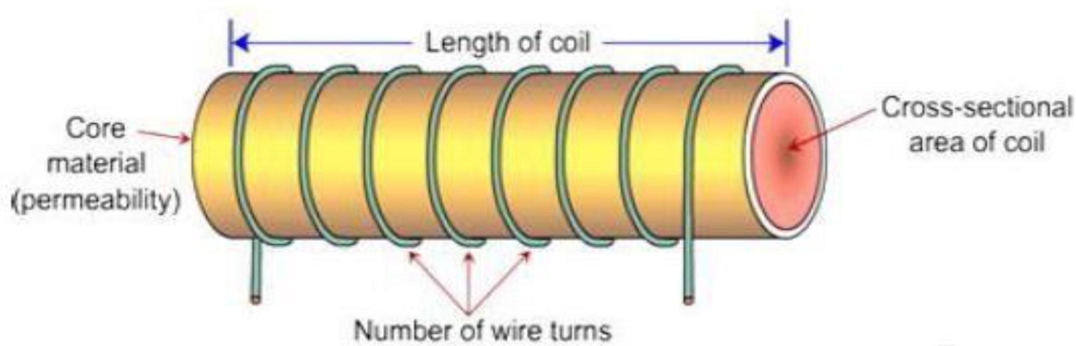
$$L = \frac{\mu_0\, \mu_r A\, N^2}{l}$$

Where $\mu_0 = Permiability\ of\ free\ space = 4\pi\ X\ 10^{-7} H/m = 1.257x\ 10^{-6}\ H/m$

$\mu_r = relative\ permiability\ of\ the\ core$

N= number of turns of the coil

L= length of the core



Hence the value of the inductor depends on the following factors

i) Number of turns

ii) Permeability of the material

iii) Size of the core

Inductors can be further divided into two catagaries

i) Fixed inductors

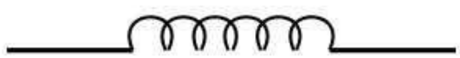
ii) Variable inductors

Inductor Types

There are many differnet types of inductor, each with their own properties - understanding the properties of the different types is essential for selecting the right type for a circuit.

Inductors perform a number of different styles of function within a circuit. Some types can be used for filtering and removing spikes on power lines, others are used within high performance filters. Others may be used within oscillators, and there are many other areas where inductors can be used.

As a result of this, there are many different types of inductor that can be obtained. Size, frequency, current, value, and many other factors means that there is a whole host of different types and forms of inductor.



INDUCTOR SYMBOL

Different inductor core types

Like other types of component such as the capacitor, there are very many different types of inductor. However it can be a little more difficult to exactly define the different types of inductor because the variety of inductor applications is so wide.

Although it is possible to define an inductor by its core material, this is not the only way in which they can be categorised. However for the basic definitions, this approach is used.

- ***Air cored inductor:*** This type of inductor is normally used for RF applications where the level of inductance required is smaller. The fact that no core is used has several advantages: there is no loss within the core as air is lossless, and this results in a high level of Q, assuming the inductor or coil resistance is low. Against this the number of turns on the coil is larger to gain the same level of inductance and this may result in a physical increase in size.
- ***Iron cored inductor:*** Iron cores are normally used for high power and high inductance types of inductor. Some audio coils or chokes may use iron laminate. They are generally not widely used.
- ***Ferrite cored inductor :*** Ferrite is one of the most widely used cores for a variety of types of inductor. Ferrite is a metal oxide ceramic based around a mixture of Ferric Oxide Fe2O3 and either manganese-zinc or nickel-zinc oxides which are extruded or pressed into the required shape.

Inductors on a toroidal ferrite former

- ***Iron power inductor:*** Another core that can be used in a variety of types of inductor is iron oxide. Like ferrite, this provides a considerable increase in the permeability, thereby enabling much higher inductance coils or inductors to be manufactured in a small space

Different mechanical inductor types and applications

Inductors may also be categorised in terms of their mechanical construction. There are a number of different standard types by which inductors may be categorised:

- ***Bobbin based inductor:*** This type of inductor is would on a cylindrical bobbin. They may be designed for printed circuit board mounting, even surface mount of they may be much larger and mounted via some other mechanical means. Some older versions of these inductors may even be in a similar format to normal leaded resistors.
- ***Toroidal inductor:*** This form of inductor is wound on a toroid - a circular former. Ferrite is often used as the former as this increases the permeability of the core. The advantage of a toroid is that the toroid enables the magnetic flux to travel in a circle around the toroid and as a result the flux leakage is very low. The disadvantage with a

toroidal inductor is that it requires a special winding machine is required to perform the manufacture as the wire has to be passed thought the toroid for each turn required.

- ***Multilayer ceramic inductor:*** This type of inductor is widely used for surface mount technology. The inductor is manufactured within a ferrite or more commonly a magnetic ceramic material. The coil is contained within the body of the ceramic and is presented to the external circuit on end caps in the same way as chip capacitors, etc.
- ***Film inductor:*** This form of inductor uses a film of conductor on a base material. The film is then etched or shaped to give the required conductor profile.

A Switch is a device that **makes** or **breaks** a circuit or a contact. As well, it can convert an analog data into digital data. The main requirements of a switch to be efficient are to be quick and to switch without sparking. The essential parts are a switch and its associated circuitry.

There are three **types of Switches**. They are −

- Mechanical switches
- Electromechanical switches or Relays
- Electronic switches

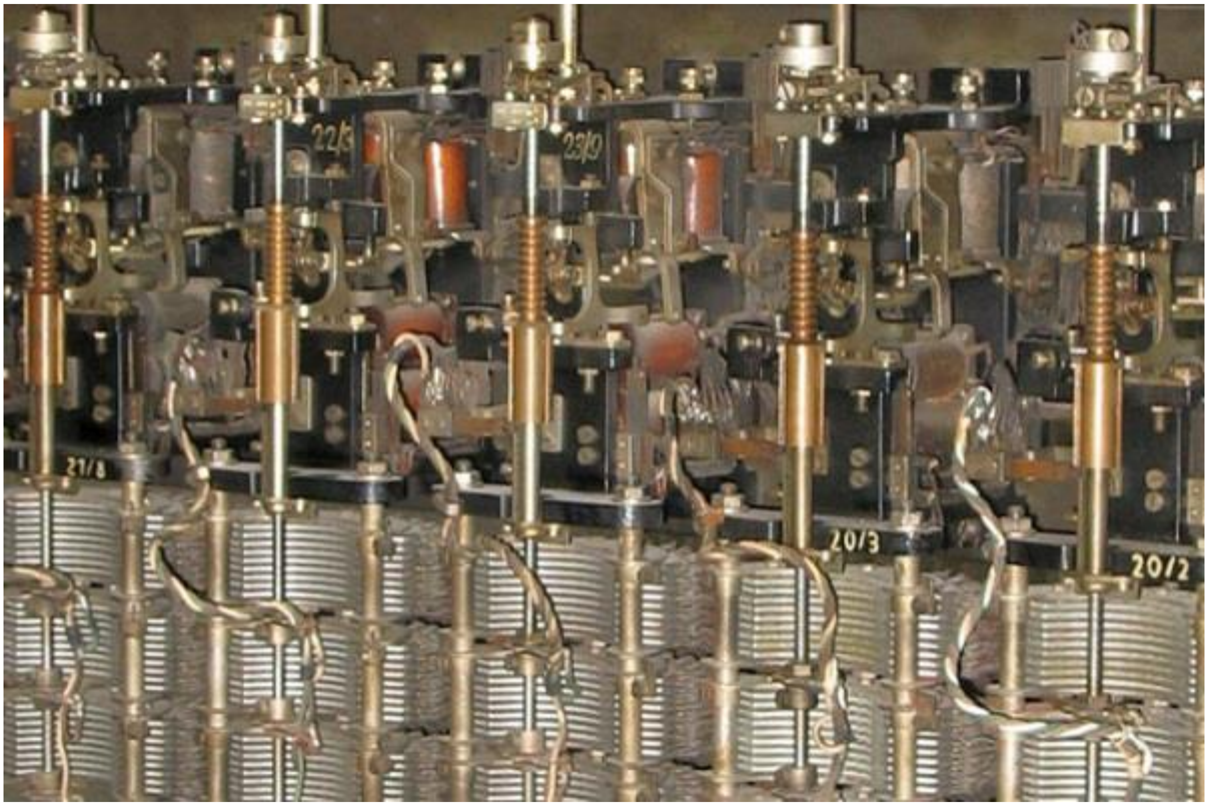
# Mechanical Switches

The Mechanical Switches are the older type switches, which we previously used. But they had been replaced by Electro-mechanical switches and later on by electronic switches also in a few applications, so as to get over the disadvantages of the former.

The drawbacks of Mechanical Switches are as follows −

- They have high inertia which limits the speed of operation.
- They produce sparks while breaking the contact.
- Switch contacts are made heavy to carry larger currents.

The mechanical switches look as in the figure below.



These mechanical switches were replaced by electro-mechanical switches or relays that have good speed of operation and reduce sparking.

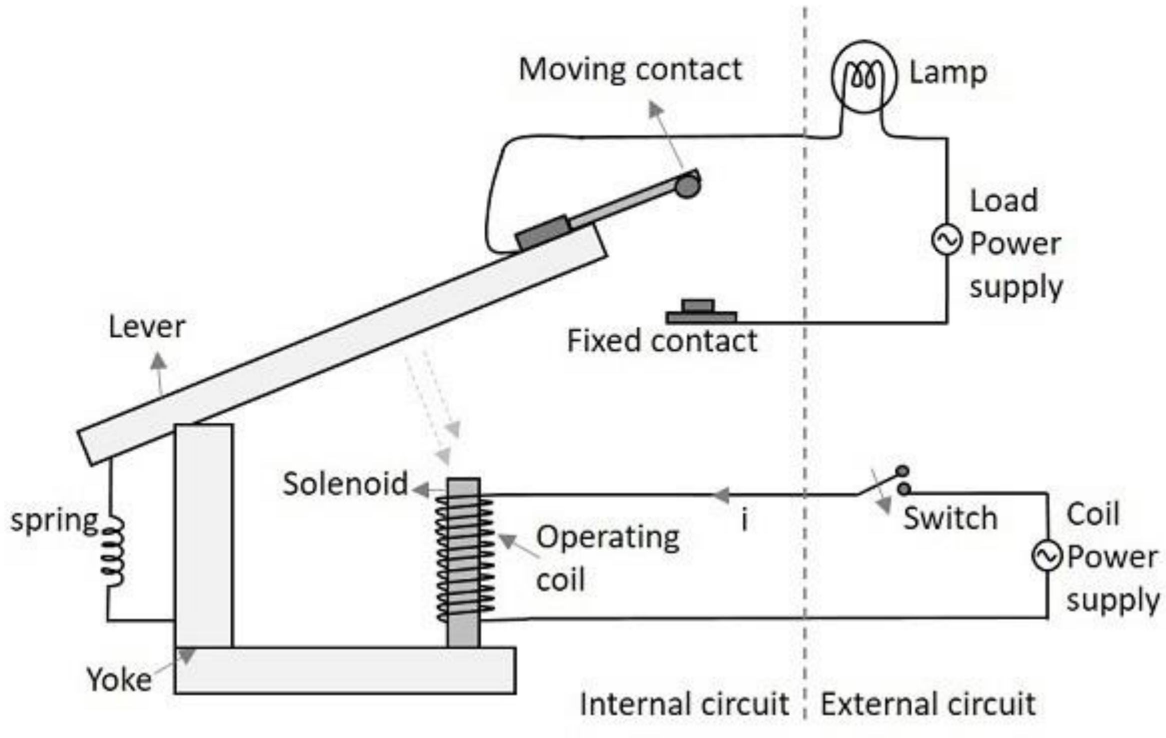
## Relays

Electromechanical switches are also called as **Relays**. These switches are partially mechanical and partially electronic or electrical. These are greater in size than electronic switches and lesser in size than mechanical switches.

### Construction of a Relay

A Relay is made such that the making of contact supplies power to the load. In the external circuit, we have load power supply for the load and coil power supply for controlling the relay operation. Internally, a lever is connected to the iron yoke with a hard spring to hold the lever up. A Solenoid is connected to the yoke with an operating coil wounded around it. This coil is connected with the coil power supply as mentioned.

The figure below explains the construction and working of a Relay.

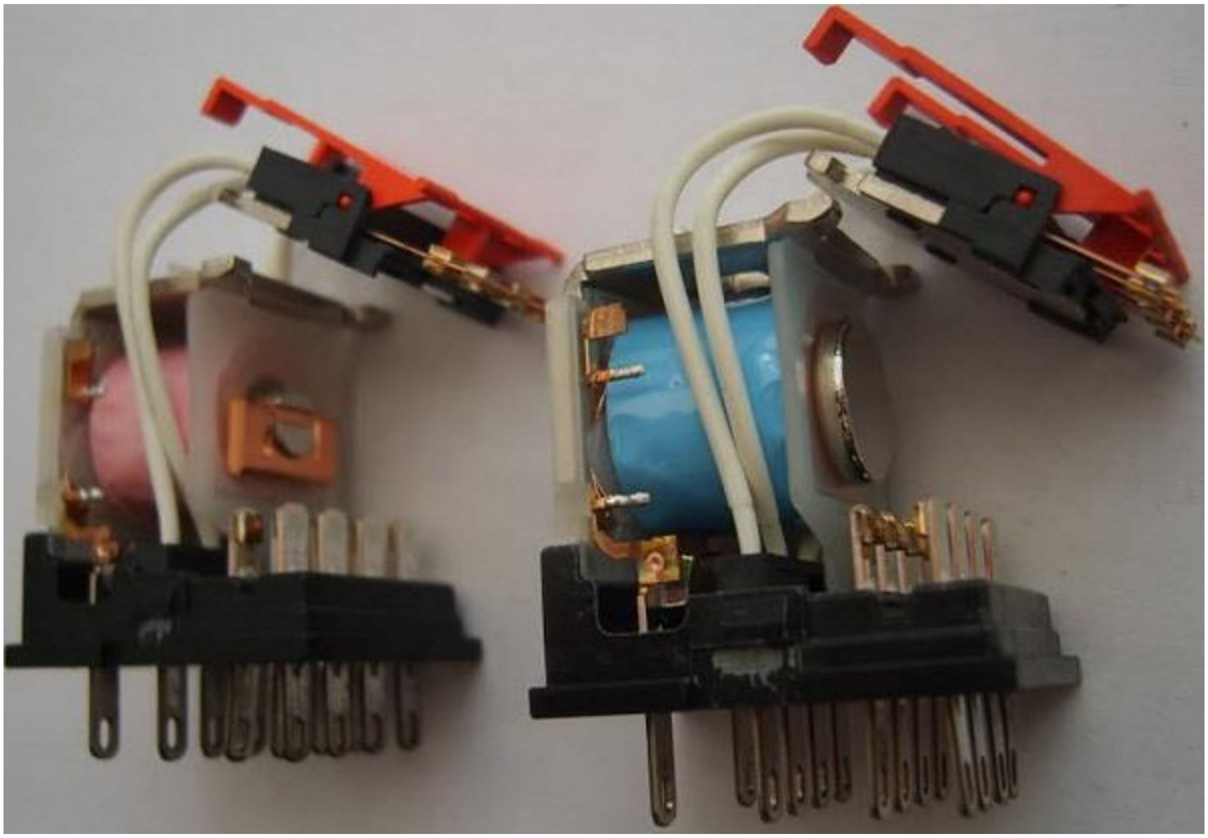



## Working of a Relay

When the Switch is closed, an electrical path is established which energizes the solenoid. The lever is connected by a heavy spring which pulls up the lever and holds. The solenoid when gets energized, pulls the lever towards it, against the pulling force of the spring. When the lever gets pulled, the moving contact meets the fixed contact in order to connect the circuit. Thus the circuit connection is ON or established and the lamp glows indicating this.

When the switch is made OFF, the solenoid doesn't get any current and gets de-energized. This leaves the lever without any attraction towards the solenoid. The spring pulls the lever up, which breaks the contact. Thus the circuit connection gets switched OFF.

The figure below shows how a practical relay looks like.



Let us now have a look at the advantages and disadvantages of an Electro-magnetic switch.

### Advantages

- A relay consumes less energy, even to handle a large power at the load.
- The operator can be at larger distance, even to handle high voltages.
- No Sparking while turning ON or OFF.

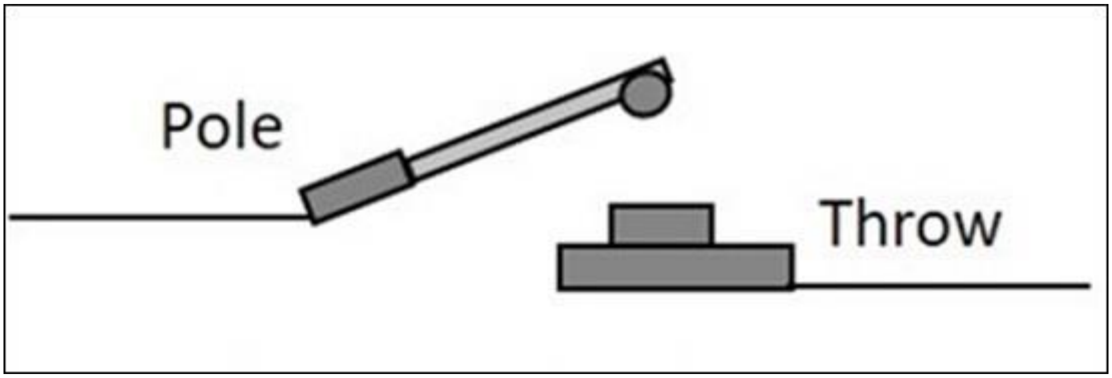
### Disadvantages

- Slow in operation
- Parts are prone to wear and tear

### Types of Latches in Relays

There are many kinds of relays depending upon their mode of operation such as Electromagnetic relay, solid-state relay, thermal relay, hybrid relay, reed relay etc.

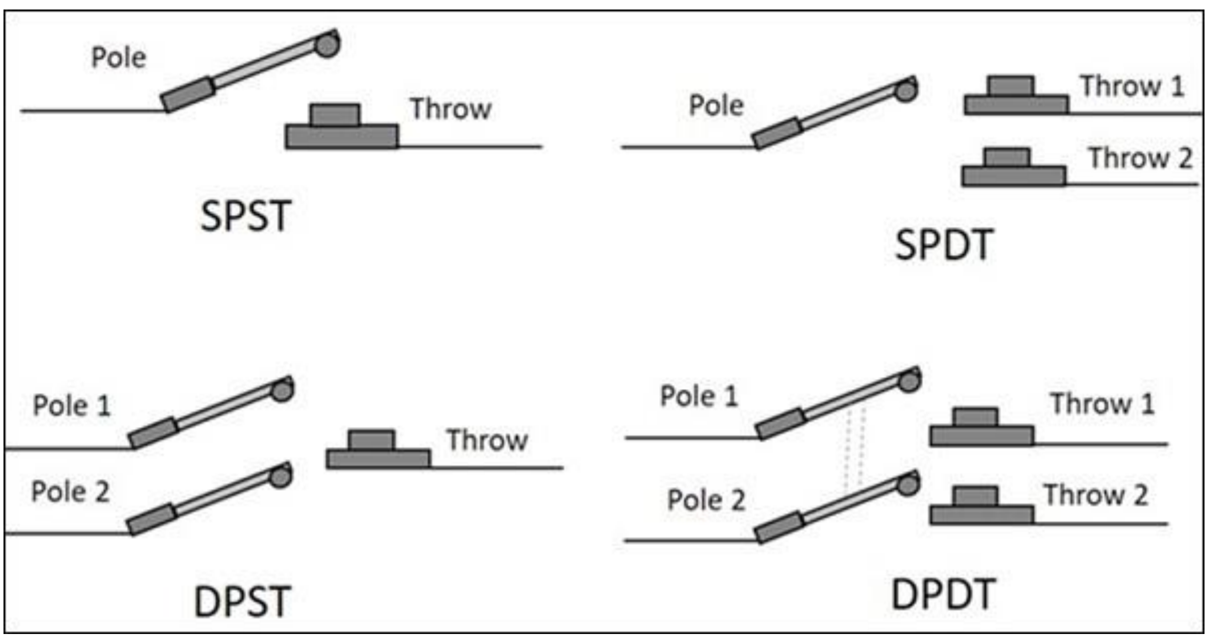
The relay makes the connection with the help of a latch, as shown in the following figure.




There are four types of latch connections in relays. They are −

- **Single Pole Single Throw (SPST) −** This latch has a single pole and is thrown onto a single throw to make a connection.
- **Single Pole Double Throw (SPDT) −** This latch has a single pole and double throw to make a connection. It has a choice to make connection with two different circuits for which two throws were connected.
- **Double Pole Single Throw (DPST) −** This latch has a double pole and single throw to make a connection. Any of the two circuits can choose to make the connection with the circuit available at the single throw.
- **Double Pole Double Throw (DPDT) −** This latch has a double pole and is thrown onto double throw to make two connections at the same time.

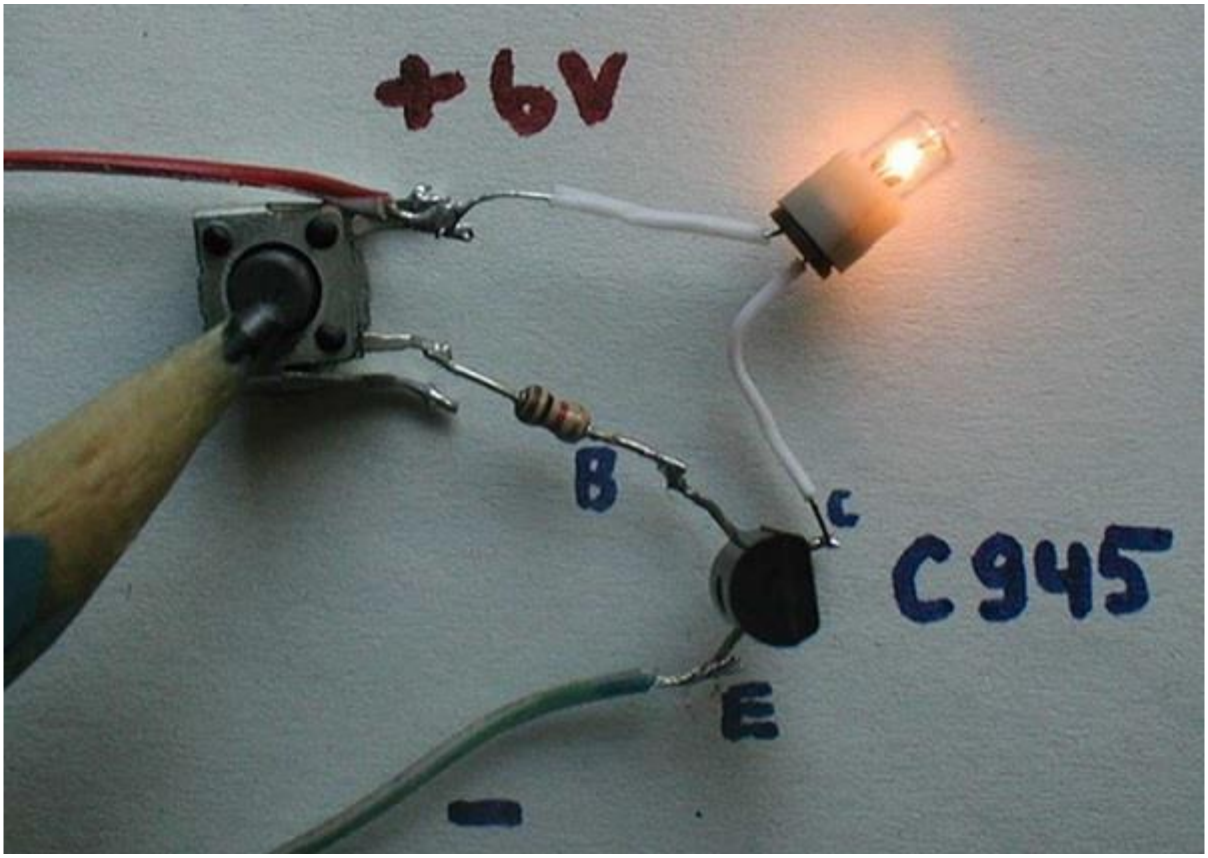
The following figure shows the diagrammatic view of all the four types of latch connections.



## Electronic Switch

The next kind of switch to be discussed is the Electronic Switch. As mentioned earlier, transistor is the mostly used electronic switch for its **high operating speed** and **absence of sparking**.

The following image shows a practical electronic circuit built to make transistor work as a switch.




A Transistor works as a switch in ON condition, when it is operated in saturation region. It works as a switch in OFF condition, when it is operated in cut off region. It works as an amplifier in linear region, which lies between transistor and cut off. To have an idea regarding these regions of operation, refer to the transistors chapter from BASIC ELECTRONICS tutorial.

When the external conditions are so robust and high temperatures prevail, then a simple and normal transistor would not do. A special device named as **Silicon Control Rectifier**, simply **SCR** is used for such purposes. This will be discussed in detail, in the POWER ELECTRONICS tutorial.

### Advantages of an Electronic Switch

There are many advantages of an Electronic switch such as

- Smaller in size
- Lighter in weight
- Sparkles operation
- No moving parts

- Less prone to wear and tear
- Noise less operation
- Faster operation
- Cheaper than other switches
- Less maintenance
- Trouble–free service because of solid-state

A **transistor** is a simple electronic switch that has high operating speed. It is a solid state device and the contacts are all simple and hence the sparking is avoided while in operation. We will discuss the stages of switching operation in a transistor in the next chapter.

# MODULE 2

## PN JUNCTION DIODE

A PN-junction diode is formed when a p-type semiconductor is fused to an n-type semiconductor creating a potential barrier voltage across the diode junction

However, if we were to make electrical connections at the ends of both the N-type and the P-type materials and then connect them to a battery source, an additional energy source now exists to overcome the potential barrier.

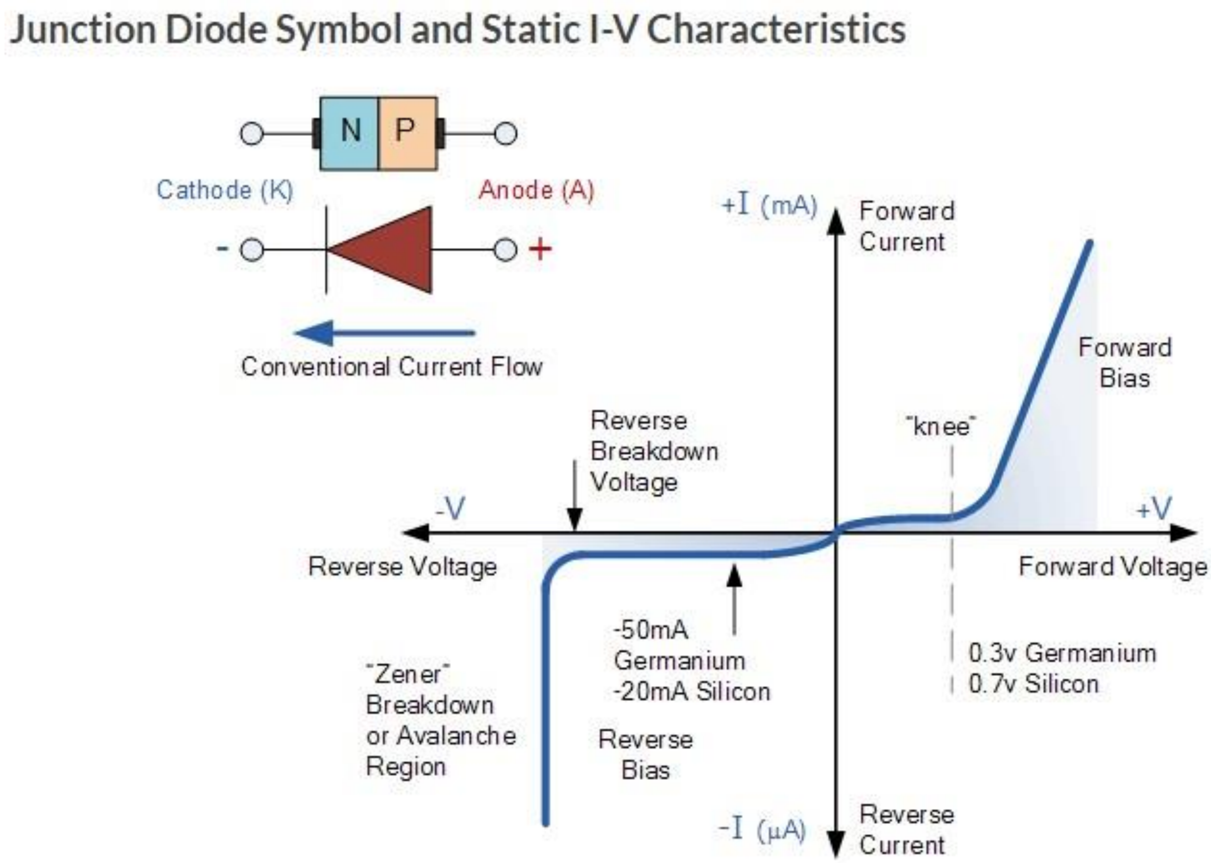
The effect of adding this additional energy source results in the free electrons being able to cross the depletion region from one side to the other. The behaviour of the PN junction with regards to the potential barrier's width produces an asymmetrical conducting two terminal device, better known as the **PN Junction Diode**.

A *PN Junction Diode* is one of the simplest semiconductor devices around, and which has the characteristic of passing current in only one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage ( I-V ) relationship and therefore we can not described its operation by simply using an equation such as Ohm's law.

If a suitable positive voltage (forward bias) is applied between the two ends of the PN junction, it can supply free electrons and holes with the extra energy they require to cross the junction as the width of the depletion layer around the PN junction is decreased.

By applying a negative voltage (reverse bias) results in the free charges being pulled away from the junction resulting in the depletion layer width being increased. This has the effect of increasing or decreasing the effective resistance of the junction itself allowing or blocking current flow through the diode.

Then the depletion layer widens with an increase in the application of a reverse voltage and narrows with an increase in the application of a forward voltage. This is due to the differences in the electrical properties on the two sides of the PN junction resulting in physical changes taking place. One of the results produces rectification as seen in the PN junction diodes static I-V (current-voltage) characteristics. Rectification is shown by an asymmetrical current flow when the polarity of bias voltage is altered as shown below.

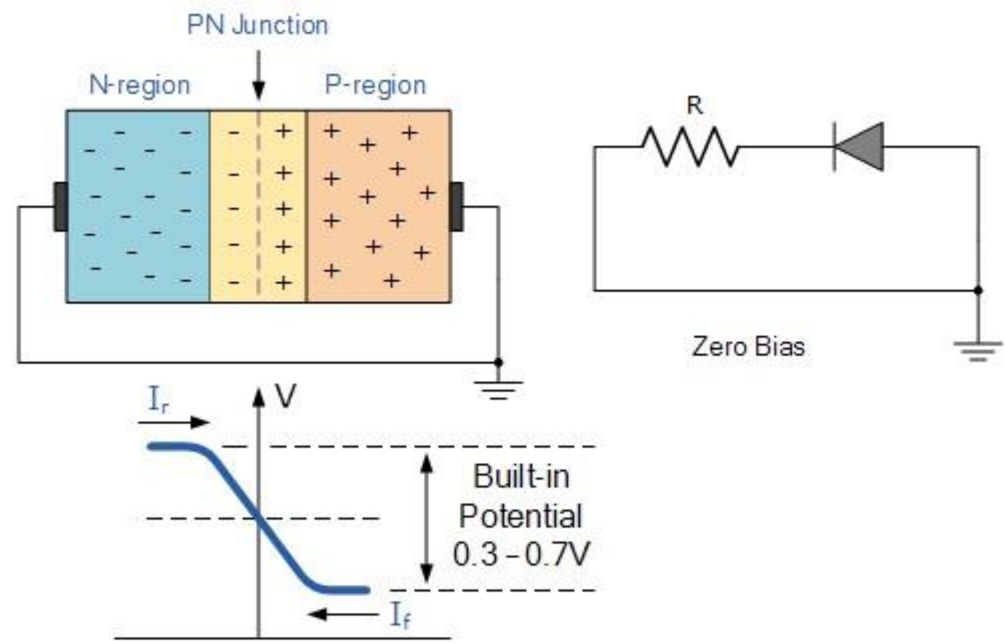



But before we can use the PN junction as a practical device or as a rectifying device we need to firstly **bias** the junction, ie connect a voltage potential across it. On the voltage axis above, "Reverse Bias" refers to an external voltage potential which increases the potential barrier. An external voltage which decreases the potential barrier is said to act in the "Forward Bias" direction.

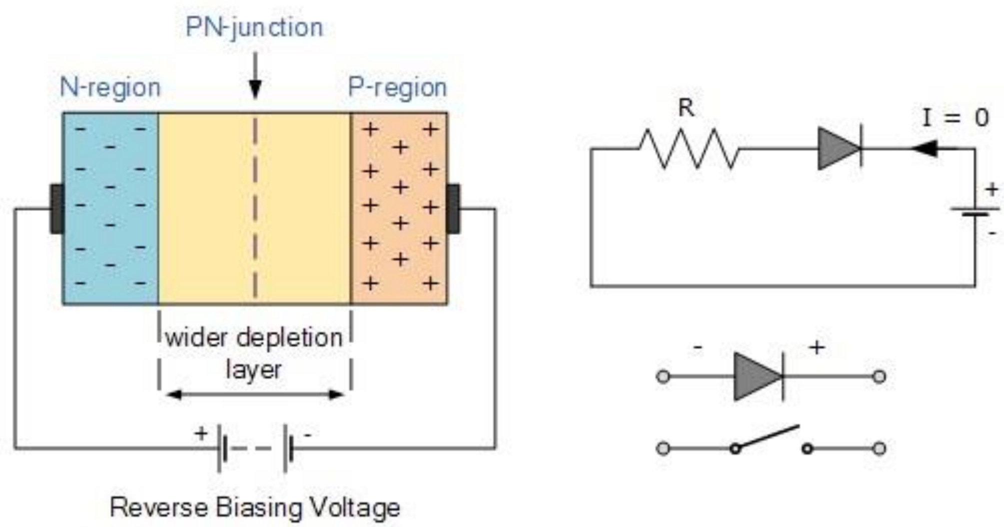
There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

- 1. Zero Bias – No external voltage potential is applied to the PN junction diode.
- 2. Reverse Bias – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.
- 3. Forward Bias – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes width.

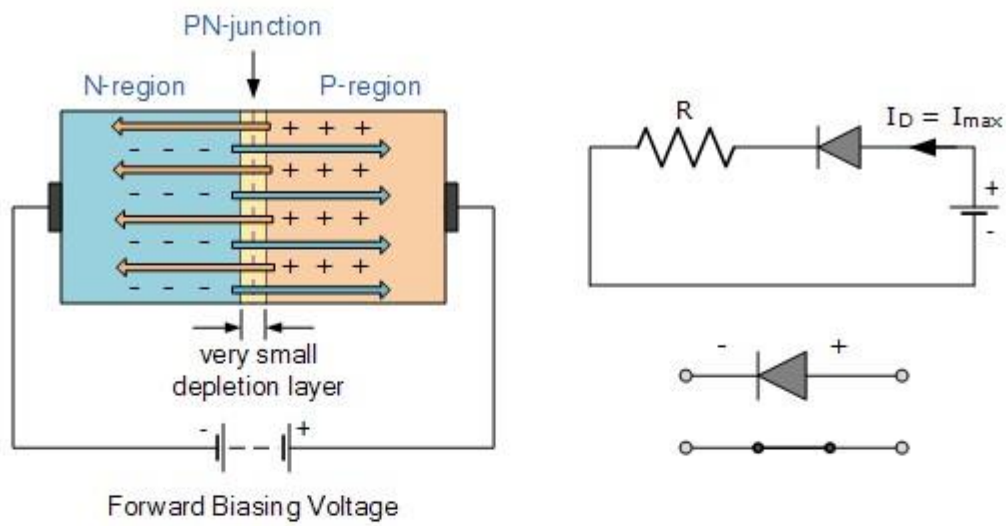
## Zero Biased PN Junction Diode




## Increase in the Depletion Layer due to Reverse Bias



Reduction in the Depletion Layer due to Forward Bias



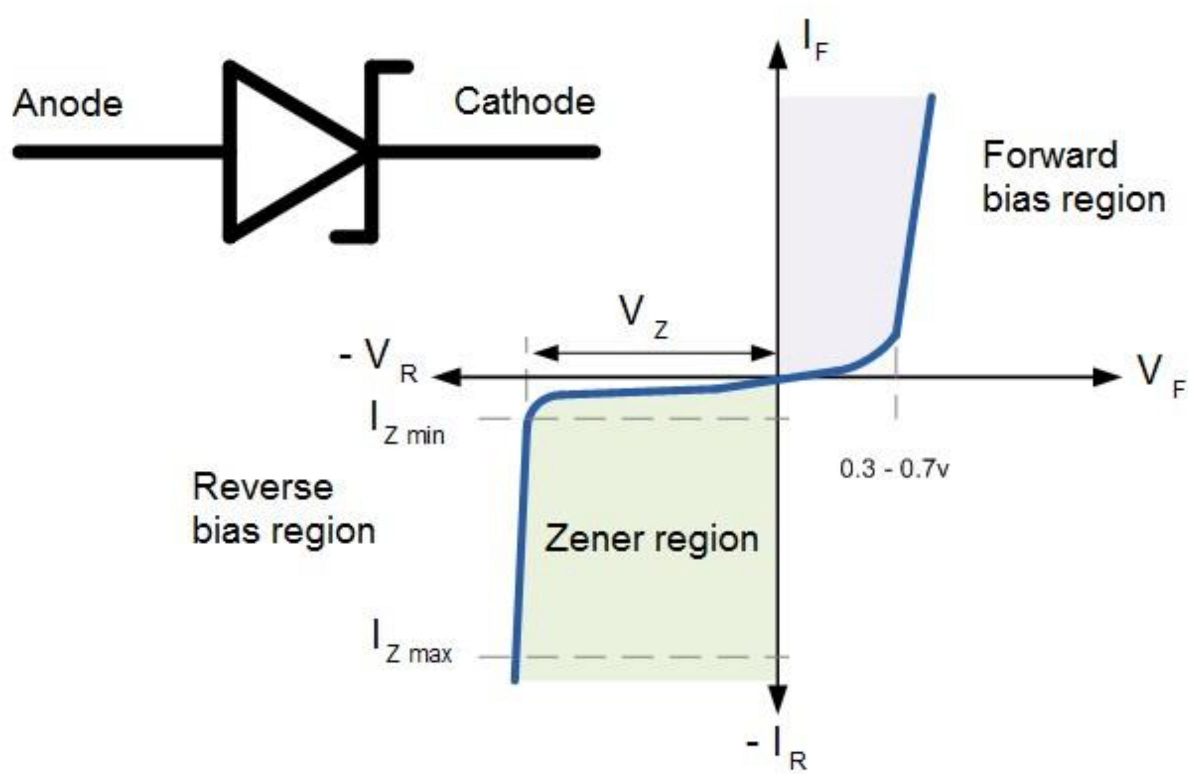

**Junction Diode Summary**

The PN junction region of a **Junction Diode** has the following important characteristics:

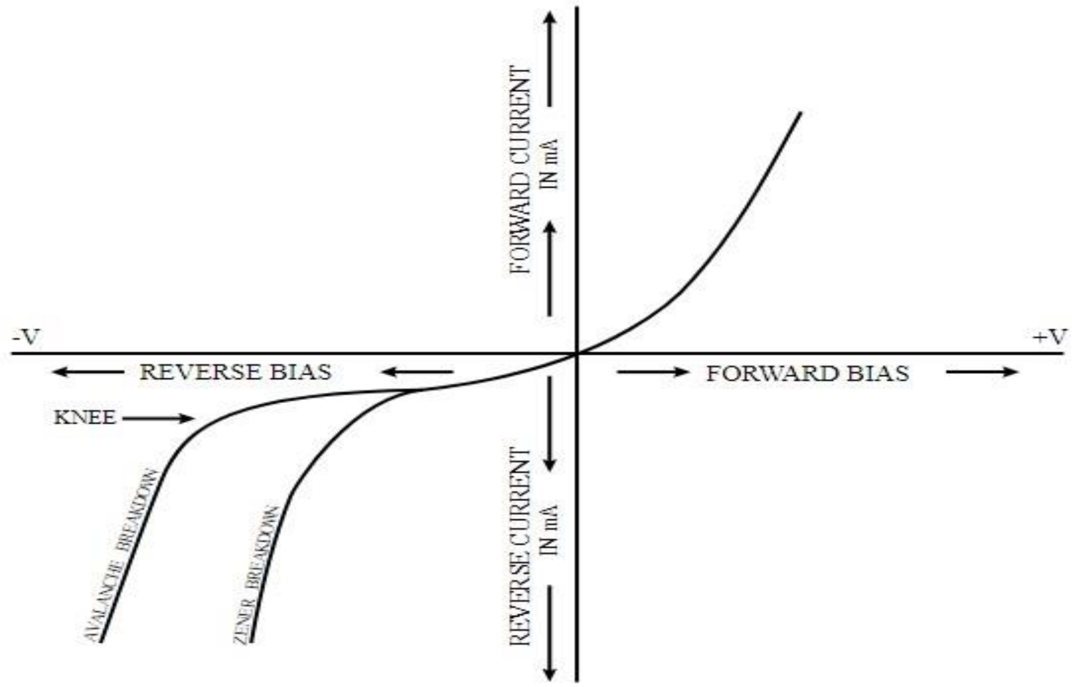
- Semiconductors contain two types of mobile charge carriers, "Holes" and "Electrons".
- The holes are positively charged while the electrons negatively charged.
- A semiconductor may be doped with donor impurities such as Antimony (N-type doping), so that it contains mobile charges which are primarily electrons.
- A semiconductor may be doped with acceptor impurities such as Boron (P-type doping), so that it contains mobile charges which are mainly holes.
- The junction region itself has no charge carriers and is known as the depletion region.
- The junction (depletion) region has a physical thickness that varies with the applied voltage.
- When a diode is **Zero Biased** no external energy source is applied and a natural **Potential Barrier** is developed across a depletion layer which is approximately 0.5 to 0.7v for silicon diodes and approximately 0.3 of a volt for germanium diodes.
- When a junction diode is **Forward Biased** the thickness of the depletion region reduces and the diode acts like a short circuit allowing full current to flow.
- When a junction diode is **Reverse Biased** the thickness of the depletion region increases and the diode acts like an open circuit blocking any current flow, (only a very small leakage current).

## ZENER DIODE

- A **Zener diode** is a type of diode that allows current to flow in the conventional manner - from its anode to its cathode i.e. when the anode is positive with respect to the cathode. When the voltage across the terminals is reversed and the potential reaches the *Zener voltage* (or "knee"), the junction will breakdown and current will flow in the reverse direction - a desired characteristic. This effect is known as the Zener effect, after Clarence Zener, who first described the phenomenon. Zener diodes are manufactured with a great variety of Zener voltages (Vz) and some are even variable.
- Zener diodes have a highly doped p–n junction. A similar break down is observed in general purpose diodes (which might be quite high), but the voltage and sharpness of the knee is not clearly defined as in Zener diodes. Normal diodes are not designed to operate in the breakdown region and it can cause permanent failure of the device. Zener diodes are manufactured to operate reliably and quite precisely in this region, recovering fully from the junction breakdown and not being harmed in proper use.



## AVALANCHE BREAK DOWN AND ZENER BREAK DOWN




**Avalanche breakdown** is a phenomenon that can occur in both insulating and semiconducting materials. It is a form of electric current multiplication that can allow very large currents within materials which are otherwise good insulators. It is a type of electron avalanche. The avalanche process occurs when carriers in the transition region are accelerated by the electric field to energies sufficient to create mobile or free electron-hole pairs via collisions with bound electrons.

Materials conduct electricity if they contain mobile charge carriers. There are two types of charge carriers in a semiconductor: free electrons (mobile electrons) and electron holes (mobile holes which are missing electrons from the normally occupied electron states). A normally bound electron (e.g., in a bond) in a reverse-biased diode may break loose due to a thermal fluctuation or excitation, creating a mobile electron-hole pair. If there is a voltage gradient (electric field) in the semiconductor, the electron will move towards the positive voltage while the hole will move towards the negative voltage. Usually, the electron and hole will simply move to opposite ends of the crystal and enter the appropriate electrodes. When the electric field is strong enough, the mobile electron or hole may be accelerated to high enough speeds to knock other bound electrons free, creating more free charge carriers, increasing the current and leading to further "knocking out" processes and creating an avalanche. In this way, large portions of a normally insulating crystal can begin to conduct.

The large voltage drop and possibly large current during breakdown necessarily leads to the generation of heat. Therefore, a diode placed into a reverse blocking power application will usually be destroyed by breakdown if the external circuit allows a large current. In principle, avalanche breakdown only involves the passage of electrons and need not damage to the crystal. Avalanche diodes (commonly encountered as high voltage Zener diodes) are constructed to break down at a uniform voltage and to avoid current crowding during breakdown. These diodes can indefinitely sustain a moderate level of current during breakdown.

The voltage at which the breakdown occurs is called the breakdown voltage. There is a hysteresis effect; once avalanche breakdown has occurred, the material will continue to conduct even if the voltage across it drops below the breakdown voltage. This is different from a Zener diode, which will stop conducting once the reverse voltage drops below the breakdown voltage.

## DIFFERENCE BETWEEN ZENER AND AVALANCHE BREAKDOWN

| Zener Breakdown | Avalanche breakdown |
|---|---|
| 1.This occurs at junctions which being heavily doped have narrow depletion layers | 1. This occurs at junctions which being lightly doped have wide depletion layers. |
| 2. This breakdown voltage sets a very strong electric field across this narrow layer. | 2. Here electric field is not strong enough to produce Zener breakdown. |
| 3. Here electric field is very strong to rupture the covalent bonds thereby generating electron-hole pairs. So even a small increase in reverse voltage is capable of producing Large number of current carriers. | 3. Her minority carriers collide with semi conductor atoms in the depletion region, which breaks the covalent bonds and electron-hole pairs are generated. Newly generated charge carriers are accelerated by the electric field which results in more collision and generates avalanche of charge carriers. This results in avalanche breakdown. |
| 4. Zener diode exhibits negative temp: coefficient. Ie. breakdown voltage decreases as temperature increases. | 4. Avalanche diodes exhibits positive temp: coefficient. i.e breakdown voltage increases with increase in temperature. |

## BIPOLAR JUNCTION TRANSISTOR

A Bipolar Junction Transistor (BJT) is a three terminal semiconductor device in which the operation depends on the interaction of both majority and minority carriers and hence the name Bipolar. The BJT is analogous to a vacuum triode and is comparatively smaller in size. It is used in amplifier and oscillator circuits, and as a switch in digital circuits. It has wide applications in computers, satellites and other modern communication systems.

## CONSTRUCTION

The BJT consists of a silicon (or germanium) crystal in which a thin layer of N-type Silicon is sandwiched between two layers of P-type silicon. This transistor is referred to as PNP. Alternatively, in a NPN transistor, a layer of P-type material is sandwiched between two layers of N-type material. The two types of the BJT are represented in Fig. 6.1.

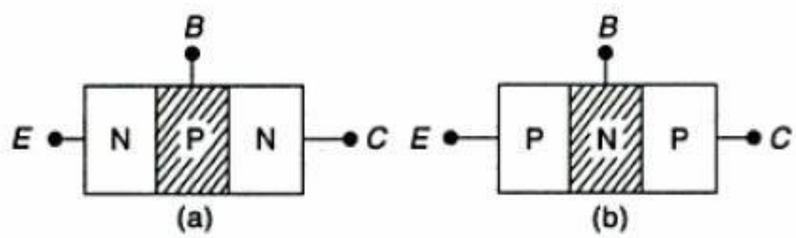



**Fig. 6.1** Transistor (a) NPN and (b) PNP

The symbolic representation of the two types of the BJT is shown in Fig. 6.2. The three portions of the transistor are Emitter, Base and Collector, shown as *E*, *B* and *C*, respectively. The arrow on the emitter specifies the direction of current flow when the *EB* junction is forward biased.

Emitter is heavily doped so that it can inject a large number of charge carriers into the base. Base is lightly doped and very thin. It passes most of the injected charge carriers from the emitter into the collector. Collector is moderately doped.

## TRANSISTOR BIASING

As shown in Fig. 6.3, usually the emitter-base junction is forward biased and collector-base junction is reverse biased. Due to the forward bias on the emitter-base

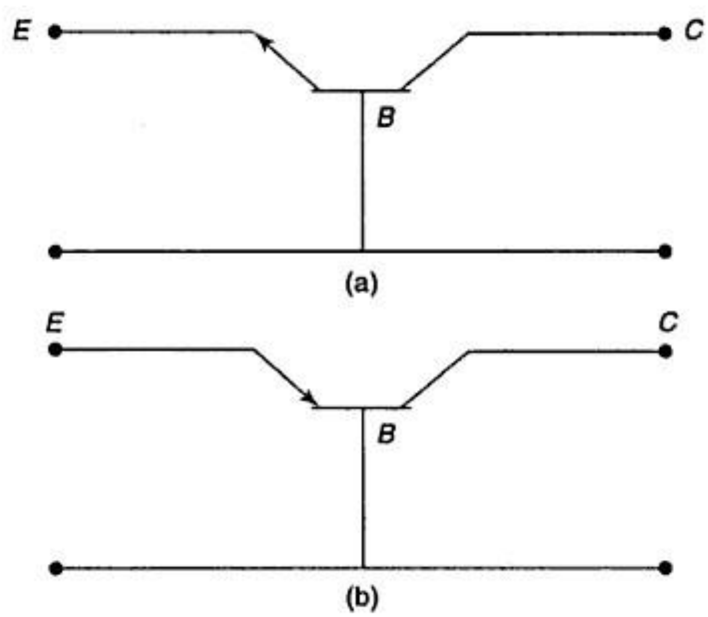



**Fig. 6.2** Circuit symbol. (a) NPN transistor and (b) PNP transistor

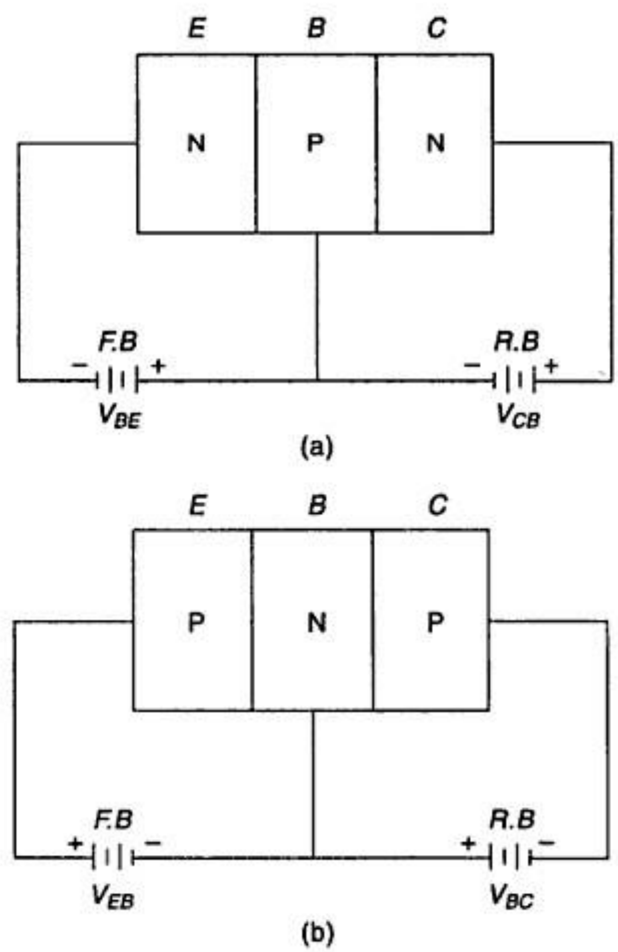



**Fig. 6.3** Transistor biasing (a) NPN transistor and (b) PNP transistor

## OPERATION OF NPN TRANSISTOR

As shown in Fig. 6.4, the forward bias applied to the emitter base junction of an NPN transistor causes a lot of electrons from the emitter region to crossover to the base region. As the base is lightly doped with P-type impurity, the number of holes in the base region is very small and hence the number of electrons that combine with holes in the P-type base region is also very small. Hence a few electrons combine with holes to constitute a base current $I_B$. The remaining electrons (more than 95%) crossover into the collector region to constitute a collector current $I_C$. Thus the base and collector current summed up gives the emitter current, i.e. $I_E = -(I_C + I_B)$.

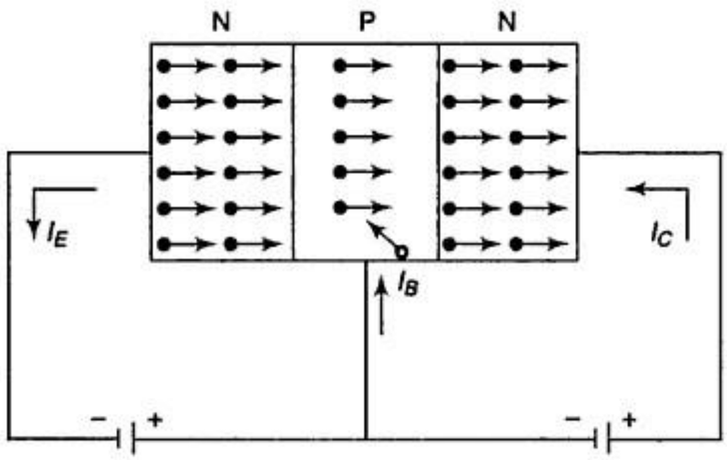



**Fig. 6.4** Current in NPN transistor

In the external circuit of the NPN bipolar junction transistor, the magnitudes of the emitter current $I_E$, the base current $I_B$ and the collector current $I_C$ are related by $I_E = I_C + I_B$.

## OPERATION OF PNP TRANSISTOR

As shown in Fig. 6.5, the forward bias applied to the emitter-base junction of a PNP transistor causes a lot of holes from the emitter region to crossover to the base region as the base is lightly doped with N-types impurity. The number of electrons in the base region is very small and hence the number of holes combined with

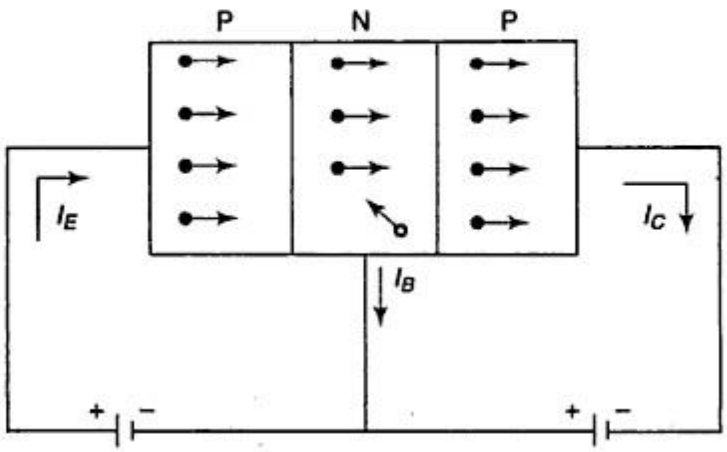



**Fig. 6.5** Current in PNP transistor

electrons in the N-type base region is also very small. Hence a few holes combined with electrons to constitute a base current $I_B$. The remaining holes (more than 95%) crossover into the collector region to constitute a collector current $I_C$. Thus the collector and base current when summed up gives the emitter current, i.e. $I_E = -(I_C + I_B)$.

In the external circuit of the PNP bipolar junction transistor, the magnitudes of the emitter current $I_E$, the base current $I_B$ and the collector current $I_C$ are related by

$$I_E = I_C + I_B \tag{6.1}$$

This equation gives the fundamental relationship between the currents in a bipolar transistor circuit. Also, this fundamental equation shows that there are current amplification factors $\alpha$ and $\beta$ in common base transistor configuration and common emitter transistor configuration respectively for the static (d.c.) currents, and for small changes in the currents.

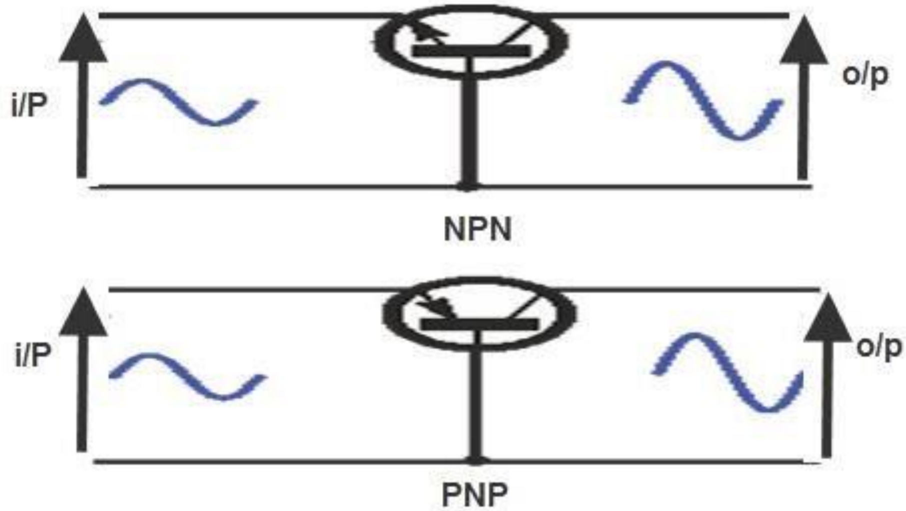
Types of Transistor Configurations

The three different kinds of transistor configurations are

- Common base transistor configuration
- Common emitter transistor configuration
- Common collector transistor configuration

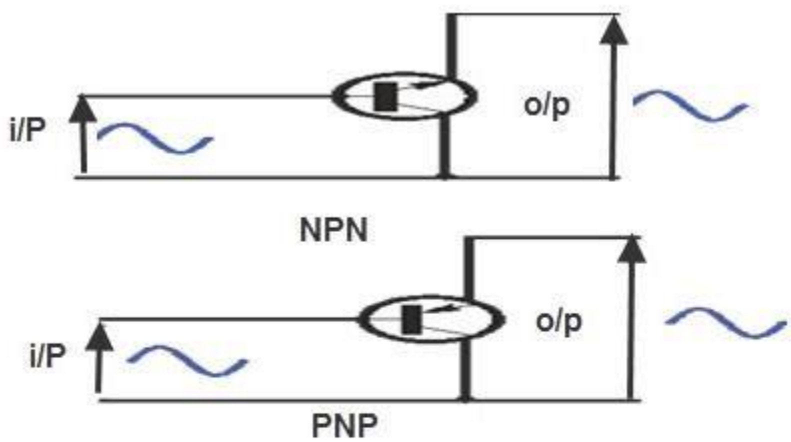
*Common Base Transistor Configuration (CB)*

The common base transistor configuration gives a low i/p while giving a high o/p impedance. When the voltage of the CB transistor is high, the gain of the current and overall gain of the power is also low compared to the other transistor configurations. The main feature of the B transistor is that the i/p and o/p of the transistor are in phase. The following diagram shows the configuration of CB transistor. In this circuit, the base terminal is mutual to both i/p & o/p circuits.




The current gain of the CB circuit is calculated in a method related to that of the CE concept and it is denoted with alpha (α). It is the relationship between collector current and emitter current.The current gain is calculated by using the following formula.

Alpha is the relationship of collector current (output current) to emitter current (input current). Alpha is calculated using the formula:




**$\alpha = (\Delta I_C)/\Delta I_E$**

*Common Collector Transistor Configuration (CC)*

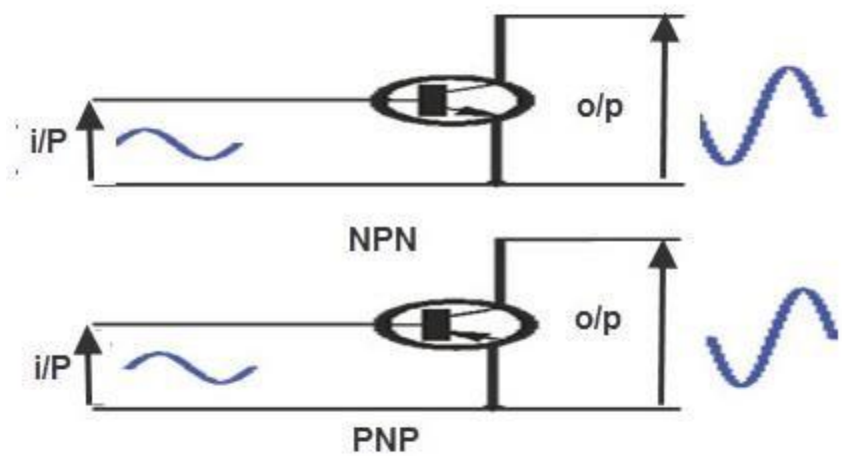
The common collector transistor configuration is also known as the emitter follower because the emitter voltage of this transistor follows the base terminal of the transistor. Offering a high i/p impedance & a low o/p impedance are commonly used as a buffer.The voltage gain of this transistor is unity, the current gain is high and the o/p signals are in phase. The following diagram shows the configuration of CC transistor. The collector terminal is mutual to both i/p and o/p circuits.

The current gain of the CC circuit is denoted with ( $\gamma$ ) and it is calculated by using the following formula.

$$\gamma = \frac{I_E}{I_B}$$

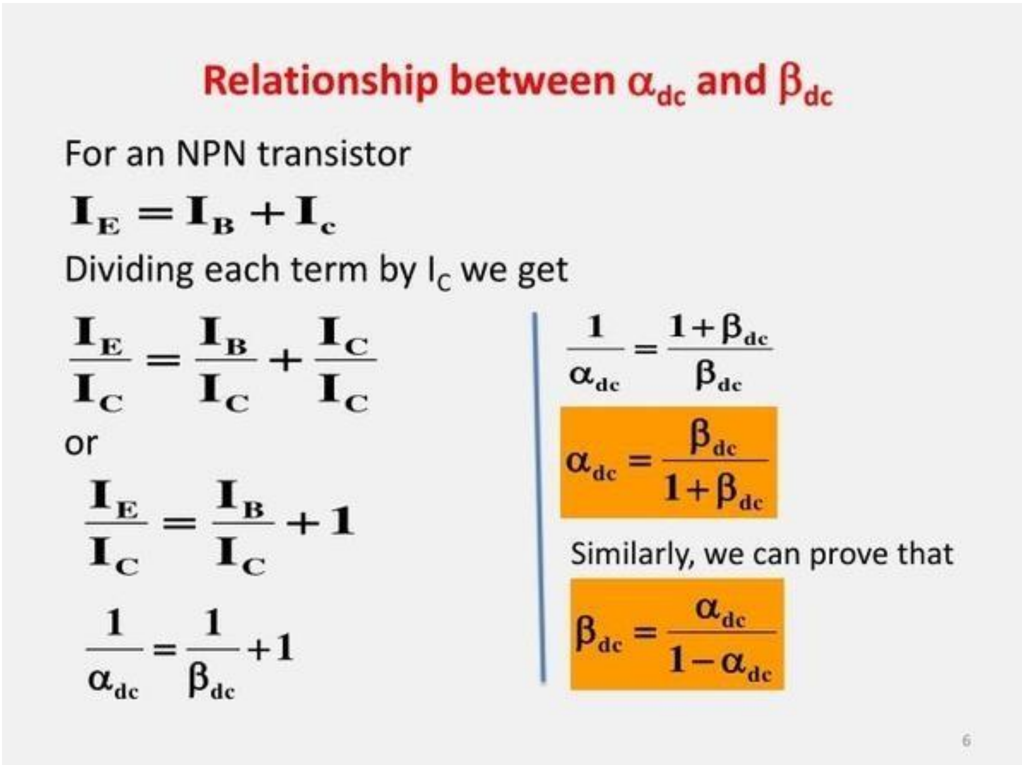
*Common Emitter Transistor Configuration (CE)*

The common emitter transistor configuration is most widely used configuration. The circuit of CE transistor gives a medium i/p and o/p impedance levels. The gain of the both voltage and current can be defined as a medium, but the o/p is opposite to the i/p that is 1800 change in the phase. This gives a good performance and it is frequently thought of as the most commonly used configurations. The following diagram shows the configuration of CE transistor. In this kind of circuit, the emitter terminal is mutual to both i/p & o/p.




The current gain of the common emitter (CE) circuit is denoted with beta (β).It is the relationship between collector current and base current.The following formula is used to calculate the beta (β). Delta is used to specify a small change

$$\beta = \frac{I_C}{I_B}$$




$$\alpha_{dc} = \frac{\beta_{dc}}{\beta_{dc} + 1}$$



$$\beta_{dc} = \frac{\alpha_{dc}}{1 - \alpha_{dc}}$$



Similarly we can prove,

$\gamma = \beta + 1$

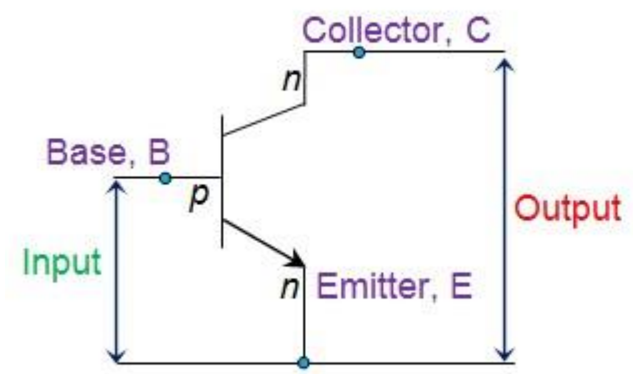
## INPUT AND OUTPUT CHARACTERISTICS OF COMMON EMITTER CONFIGURATION

**Transistor Characteristics** are the plots which represent the relationships between the current and the voltages of a transistor in a particular configuration. By considering the transistor configuration circuits to be analogous to two-port networks, they can be analyzed using the characteristic-curves which can be of the following types

1. Input Characteristics: These describe the changes in input current with the variation in the values of input voltage keeping the output voltage constant.
2. Output Characteristics: This is a plot of output current versus output voltage with constant input current.
3. Current Transfer Characteristics: This characteristic curve shows the variation of output current in accordance with the input current, keeping output voltage constant.

### Common Emitter (CE) Configuration of Transistor

In this configuration, the emitter terminal is common between the input and the output terminals as shown by Figure 9. This configuration offers medium input impedance, medium output impedance, medium current gain and voltage gain.




### Input Characteristics for CE Configuration of Transistor

Figure 10 shows the input characteristics for the CE configuration of transistor which illustrates the variation in $I_B$ in accordance with $V_{BE}$ when $V_{CE}$ is kept constant.

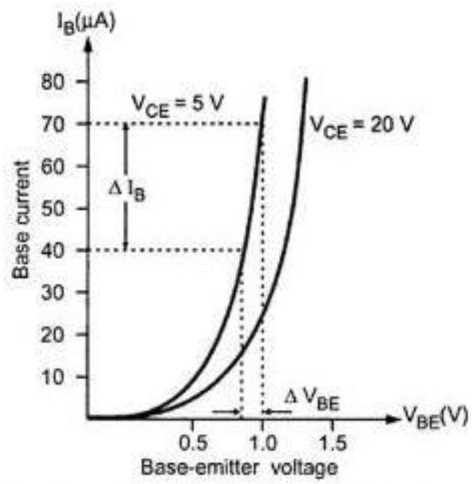



**Fig 3.2: Input characteristics of the transistor in CE configuration**

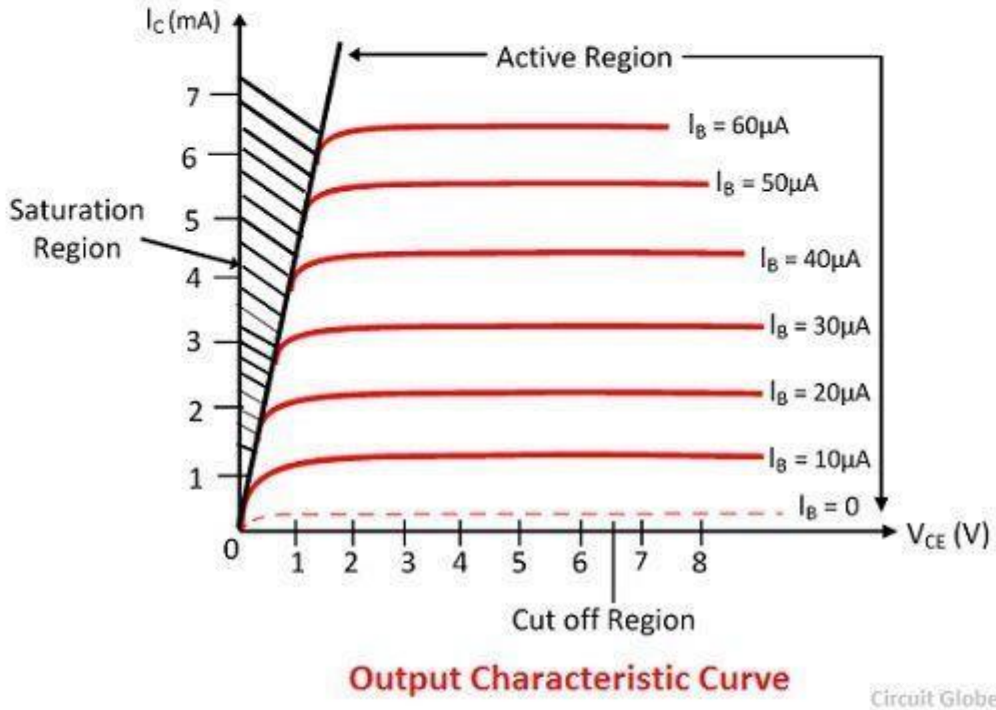
From the graph shown in Figure 10 above, the input resistance of the transistor can be obtained as

$$R_{in} = \frac{\Delta V_{BE}}{\Delta I_B}\bigg|_{V_{CE}=constant}$$

## Output Characteristics for CE Configuration of Transistor

The output characteristics of CE configuration (Figure 11) are also referred to as collector characteristics. This plot shows the variation in $I_C$ with the changes in $V_{CE}$ when $I_B$ is held constant. From the graph shown, the output resistance can be obtained as:

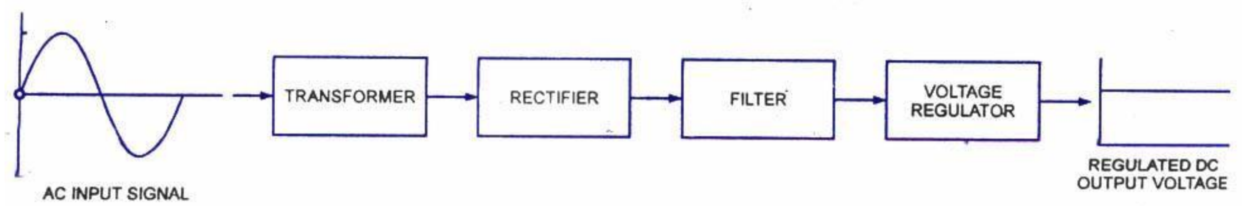
$$R_{out} = \frac{\Delta V_{CB}}{\Delta I_C}\bigg|_{I_E=constant}$$



I_C (mA)
Active Region
I_B = 60μA
I_B = 50μA
I_B = 40μA
I_B = 30μA
I_B = 20μA
I_B = 10μA
I_B = 0
Saturation Region
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8
V_CE (V)
Cut off Region
Output Characteristic Curve
Circuit Globe

## MODULE 3

### BLOCK DIAGRAM DESCRIPTION OF A DC POWER SUPPLY




*Block Diagram of a DC Power Supply*

The electrical power is almost exclusively generated, transmitted and distributed in the form of ac because of economical consideration but for operation of most of the electronic devices and circuits, dc supply is required. Dry cells and batteries can be used for this purpose. No doubt, they have the advantages of being portable and ripple free but their voltages are low, they need frequent replacement and are expensive in comparison to conventional dc power supplies.

Now a days, almost all electronic equipment include a circuit that converts ac supply into dc supply. The part of equipment that converts ac into dc is called DC power supply. In general at the input of the power supply there is a power transformer. It is followed by a rectifier (a diode circuit)a smoothing filter and then by a *voltage* regulator circuit.

From the block diagram, the basic power supply is constituted by four elements viz a *transformer,* a *rectifier,* a *filter,* and a *regulator* put together. The output of the dc power supply is used to provide a constant dc voltage across the load. Let us briefly outline the function of each of the elements of the dc power supply.

*Transformer* is used to step-up or step-down (usually to step-down) the-supply voltage as per need of the solid-state electronic devices and circuits to be supplied by the dc power supply. It can provide isolation from the supply line-an important safety consideration. It may also include internal shielding to prevent unwanted electrical noise signal on the power line from getting into the power supply and possibly disturbing the load.

*Rectifier* is a device which converts the sinusoidal ac voltage into either positive or negative pulsating dc. P-N junction diode, which conducts when forward biased and practically does not conduct when reverse biased, can be used for rectification *i.e.* for conversion of ac into dc. The rectifier typically needs one, two or four diodes. Rectifiers may be either **half-wave rectifiers** or full-wave rectifiers (**centre-tap** or **bridge**) type.

The output voltage from a rectifier circuit has a pulsating character i.e., it contains unwanted ac components (components of supply frequency *f* and its harmonics) along with dc component. For most supply purposes, constant direct voltage is required than that furnished by a rectifier. To reduce ac components from the rectifier output voltage a *filter circuit is required.*

*Thus filter is a device which passes dc component to the load and blocks I ac components of the rectifier output. Filter is typically constructed from reactive circuit I elements such as capacitors and/or inductors and resistors.The magnitude of output dc voltage may vary with the variation of either the input ac voltage or the magnitude of load current. So at the output of a rectifier filter combination a voltage regulator is required, to provide an almost constant dc voltage at the output of the regulator. The voltage regulator may be constructed from a Zener diode, and or discrete transistors, and/or integrated circuits (ICs). Its main function is to maintain a constant dc output voltage. However, it also rejects any ac ripple voltage that is not removed by the filter. The regulator may also include protective devices such as short-circuit protection, current limiting, thermal shutdown, or over-voltage protection.*

## WORKING OF A FULL WAVE BRIDGE RECTIFIER

### FULL-WAVE RECTIFICATION

Bridge Rectifier

The dc level obtained from a sinusoidal input can be improved 100% using a process called full-wave rectification. The most familiar network for performing such a function appears in Fig. 2.52 with its four diodes in a bridge configuration. During the period t = 0 to T/2 the polarity of the input is as shown in Fig. 2.53. The resulting polarities across the ideal diodes are also shown in Fig. 2.53 to reveal that D2 and D3 are conducting while D1 and D4 are in the “off” state. The net result is the configuration of Fig. 2.54, with its indicated current and polarity across R. Since the diodes are ideal the load voltage is Vo = Vi, as shown in the same figure

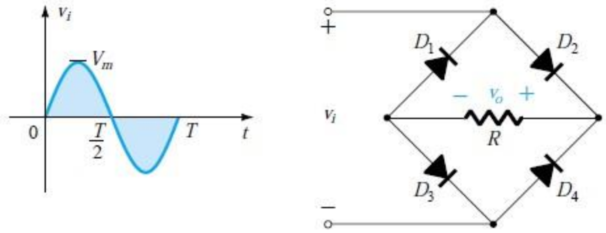



Figure 2.52 Full-wave bridge rectifier.

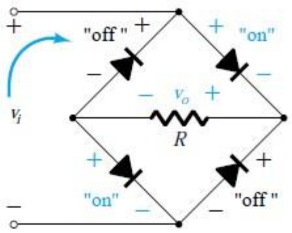



Figure 2.53 Network of Fig. 2.52 for the period $0 \rightarrow T/2$ of the input voltage $v_i$.

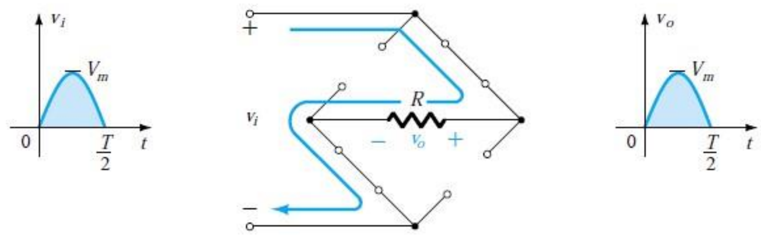



Figure 2.54 Conduction path for the positive region of $v_i$.

For the negative region of the input the conducting diodes are $D_1$ and $D_4$, resulting in the configuration of Fig. 2.55. The important result is that the polarity across the load resistor $R$ is the same as in Fig. 2.53, establishing a second positive pulse, as shown in Fig. 2.55. Over one full cycle the input and output voltages will appear as shown in Fig. 2.56.

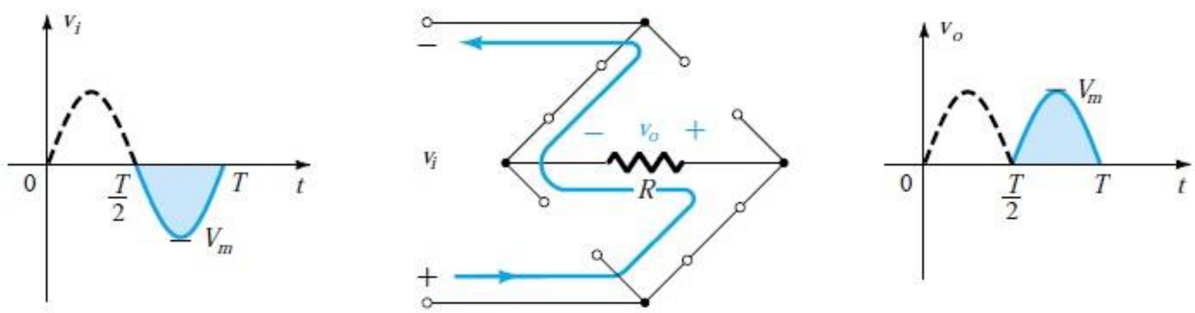



Figure 2.55 Conduction path for the negative region of $v_i$.

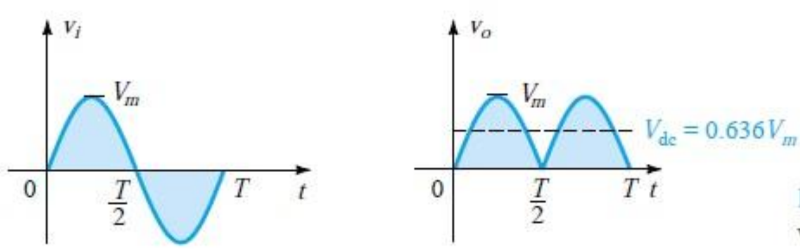
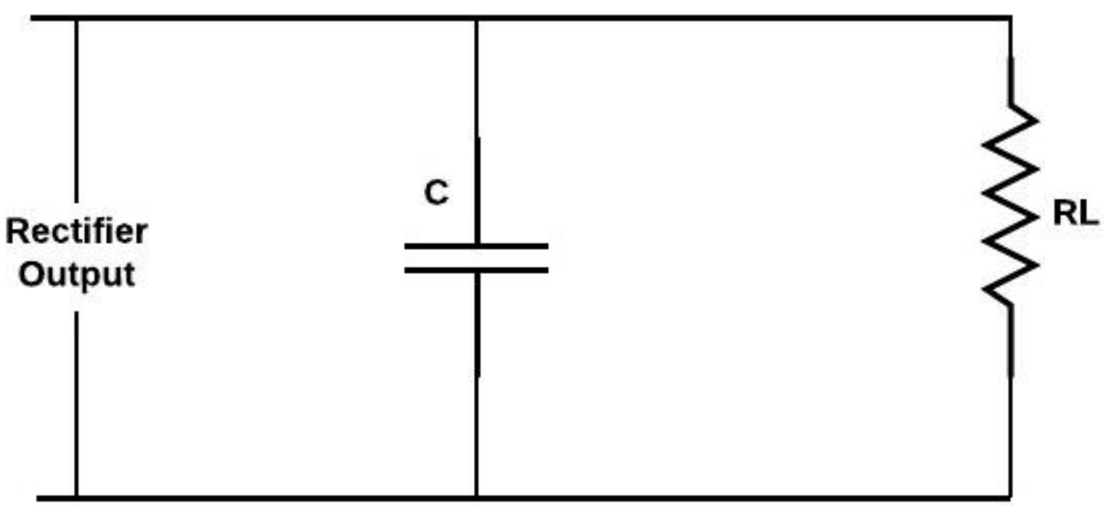



Figure 2.56 Input and output waveforms for a full-wave rectifier.

| Parameters | Center tapped full wave rectifier | Bridge rectifier |
|---|---|---|
| Number of diodes | 2 | 4 |
| Maximum efficiency | 81.2% | 81.2% |
| Peak inverse voltage | $2V_m$ | $V_m$ |
| Vdc(no load) | $2V_m/\pi$ | $2V_m/\pi$ |
| Transformer utilization factor | 0.693 | 0.812 |
| Ripple factor | 0.48 | 0.48 |
| Form factor | 1.11 | 1.11 |
| Peak factor | √2 | √2 |
| Average current | $I_{dc}/2$ | $I_{dc}/2$ |
| Output frequency | 2f | 2f |

## CAPACITOR FILTER

A typical **capacitor filter** circuit diagram is shown below. The designing of this circuit can be done with a capacitor (C) as well as load resistor (RL). The rectifier's exciting voltage is given across the terminals of a capacitor. Whenever the voltage of the rectifier enhances then the capacitor will be charged as well as supplies the current to the load.




At the last part of the quarter phase, the capacitor will be charged to the highest rectifier voltage value that is denoted with Vm, and then the voltage of the rectifier starts to reduce. As this happens, the capacitor starts discharging through the voltage across it and load. The voltage across the load will reduce little only because the next peak voltage occurs instantaneously to charge the capacitor. This procedure will repeat many times and the output waveform will be seen that very slight ripple is missing in the output. Furthermore, the output voltage is superior because it remains significantly close to the highest value of the output voltage of the rectifier.

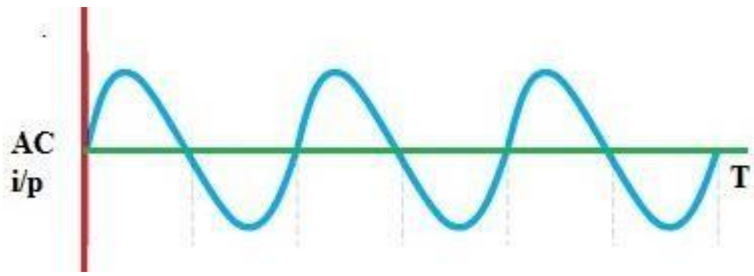



Figure: AC input waveform

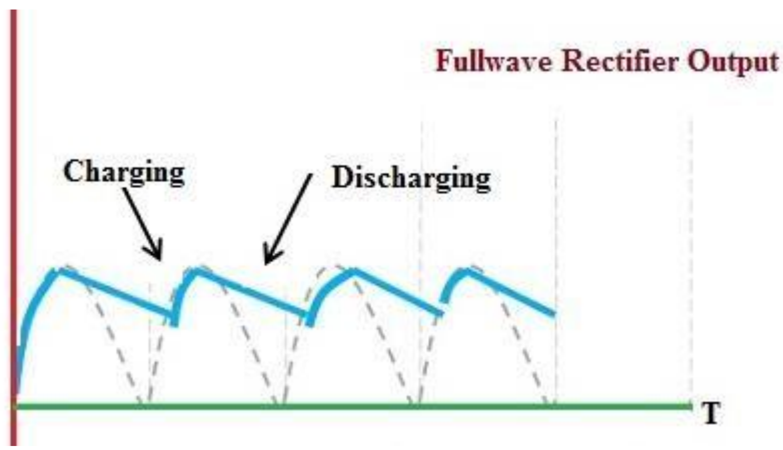


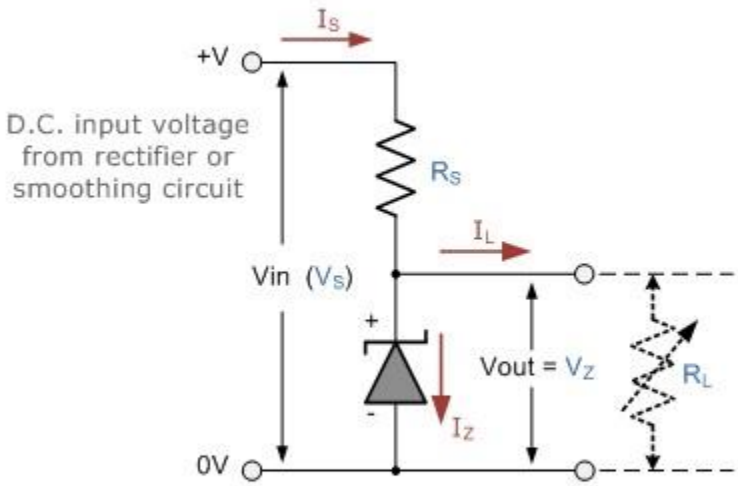

Figure: Output waveform using capacitor filter

A capacitor gives an infinite reactance to DC .For DC, f=0

**Xc = 1/ 2пfc = 1/2п x 0 x C = infinite** Therefore,
a capacitor doesn't permit DC to flow through it.

The capacitor filter circuit is very famous due to its features like low cost, less weight, small size, & good characteristics. The capacitor filter circuit is applicable for small load currents.

## WORKING OF SIMPLE ZENER VOLTAGE REGULATOR




Resistor, $R_S$ is connected in series with the zener diode to limit the current flow through the diode with the voltage source, $V_S$ being connected across the combination. The stabilised output voltage $V_{out}$ is taken from across the zener diode.

The zener diode is connected with its cathode terminal connected to the positive rail of the DC supply so it is reverse biased and will be operating in its breakdown condition. Resistor $R_S$ is selected so to limit the maximum current flowing in the circuit.

With no load connected to the circuit, the load current will be zero, ( $I_L = 0$ ), and all the circuit current passes through the zener diode which in turn dissipates its maximum power. Also a small value of the series resistor $R_S$ will result in a greater diode current when the load resistance $R_L$ is connected and large as this will increase the power dissipation requirement of the diode so care must be taken when selecting the appropriate value of series resistance so that the zener's maximum power rating is not exceeded under this no-load or high-impedance condition.

The load is connected in parallel with the zener diode, so the voltage across $R_L$ is always the same as the zener voltage, ( $V_R = V_Z$ ). There is a minimum zener current for which the stabilisation of the voltage is effective and the zener current must stay above this value operating under load within its breakdown region at all times. The upper limit of current is of course dependant upon the power rating of the device. The supply voltage $V_S$ must be greater than $V_Z$.

One small problem with zener diode stabiliser circuits is that the diode can sometimes generate electrical noise on top of the DC supply as it tries to stabilise the voltage.

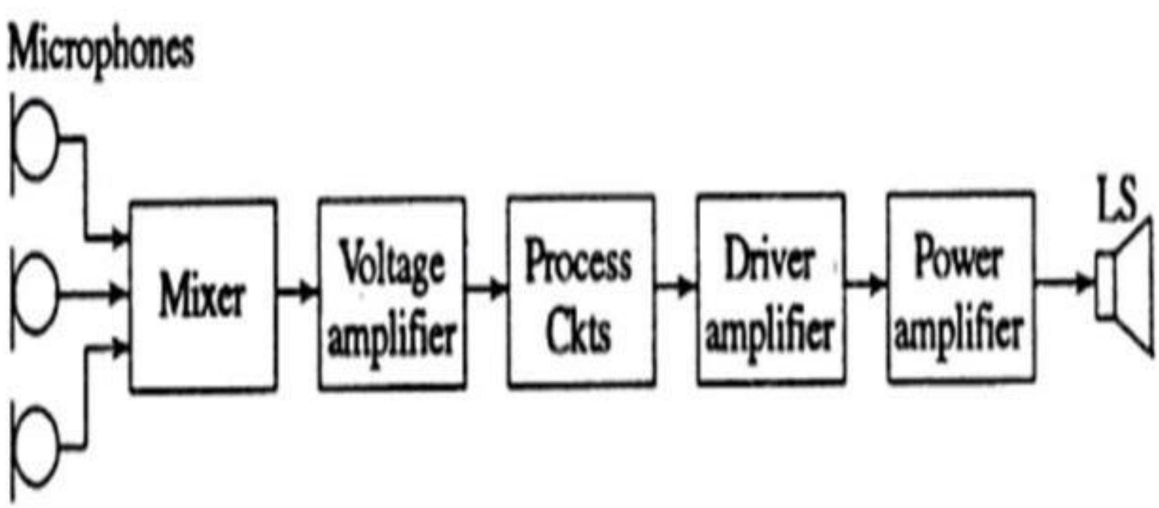
Normally this is not a problem for most applications but the addition of a large value decoupling capacitor across the zener's output may be required to give additional smoothing.

Then to summarise a little. A zener diode is always operated in its reverse biased condition. As such a simple voltage regulator circuit can be designed using a zener diode to maintain a constant DC output voltage across the load in spite of variations in the input voltage or changes in the load current.

The zener voltage regulator consists of a current limiting resistor $R_S$ connected in series with the input voltage $V_S$ with the zener diode connected in parallel with the load $R_L$ in this reverse biased condition. The stabilised output voltage is always selected to be the same as the breakdown voltage $V_Z$ of the diode.

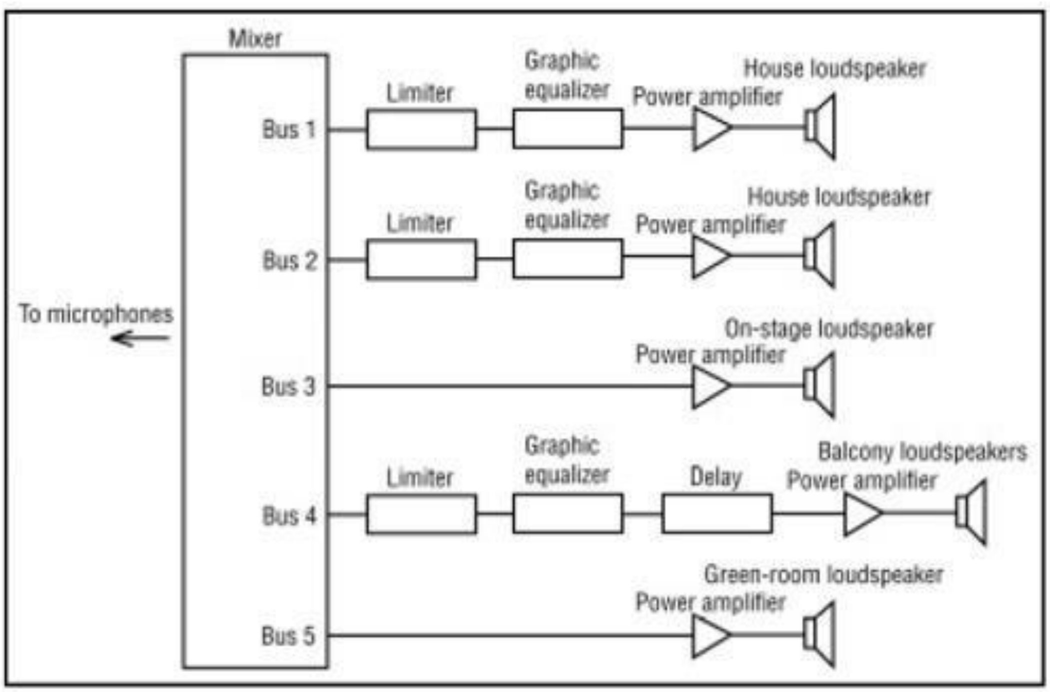
## BLOCK DIAGRAM OF PUBLIC ADDRESS SYSTEM

PA system is an electronic sound amplification and distribution system with a microphone, amplifiers and loudspeakers used in many applications such as addressing a large public,announcements in offices and institutions etc.



- Microphone :- Its pic up a sound wave and convert them into electrical variation, called sound signal.
- Mixer:- It is for effectively isolate different channels from each other before feeding to the main amplifier.
- Voltage amplifier:- Its amplifies the output of the mixer.
- Processing circuit:- This circuit have master gain control and tone control (bass and treble control ).

- Driver amplifier:- It gives voltage amplification to such extent that internal resistance of that stage is reduced. thus, it drives the power amplifier to give more power.
- Power amplifier:- It gives the desire power amplification to the signal.
- Loudspeaker:- It converts electrical audio signal into pressure variation resulting in sound.



- **Equalization** is the process of altering the frequency response of an audio system using filters.
- It adjusts the amplitude of audio signals at particular frequencies.
- Equalization may also be used to eliminate unwanted signals,make certain instruments or voices more prominent.
- **Graphic equalizer:-** allows the user to see graphically and
- control individually a number of different frequency bands.
- Low frequency (popularly called bass) of the signal is amplified
- and converted into audio using low frequency
- speakers(popularly called woofers).
- Similarly high frequency audio signals are amplified and fed to
- high frequency loud speakers.

RC Coupled Amplifier

A **Resistance Capacitance (RC) Coupled Amplifier** is basically a multi-stage amplifier circuit extensively used in electronic circuits. Here the individual stages of the amplifier are connected together using a resistor–capacitor combination due to which it bears its name as RC Coupled.

Figure 1 shows such a two-stage amplifier whose individual stages are nothing but the common emitter amplifiers. Hence the design of individual stages of the **RC coupled amplifiers** is similar to that in the case of common emitter amplifiers in which the resistors $R_1$ and $R_2$ form the biasing network while the emitter resistor RE form the stabilization network. Here the $C_E$ is also called bypass capacitor which passes only AC while restricting DC, which causes only DC voltage to drop across $R_E$ while the entire AC voltage will be coupled to the next stage.

Further, the coupling capacitor $C_C$ also increases the stability of the network as it blocks the DC while offers a low resistance path to the AC signals, thereby preventing the DC bias conditions of one stage affecting the other. In addition, in this circuit, the voltage drop across the collector-emitter terminal is chosen to be 50% of the supply voltage $V_{CC}$ inorder to ensure appropriate biasing point.

In this kind of amplifier, the input signal applied at the base of the transistor in stage 1 ($Q_1$) is amplified and appears at its collector terminal with a phase-shift of $180^o$. The AC component of this signal is coupled to the second stage of the **RC coupled amplifier** through the coupling capacitor $C_C$ and thus appears as an input at the base of the second transistor $Q_2$. This is further amplified and is passed-on as an output of the second stage and is available at the collector terminal of $Q_2$ after being shift by $180^o$ in its phase. This means that the output of the second stage will be $360^o$ out-of-phase with respect to the input, which inturn indicates that the phase of the input signal and the phase of the output signal obtained at stage II will be identical.

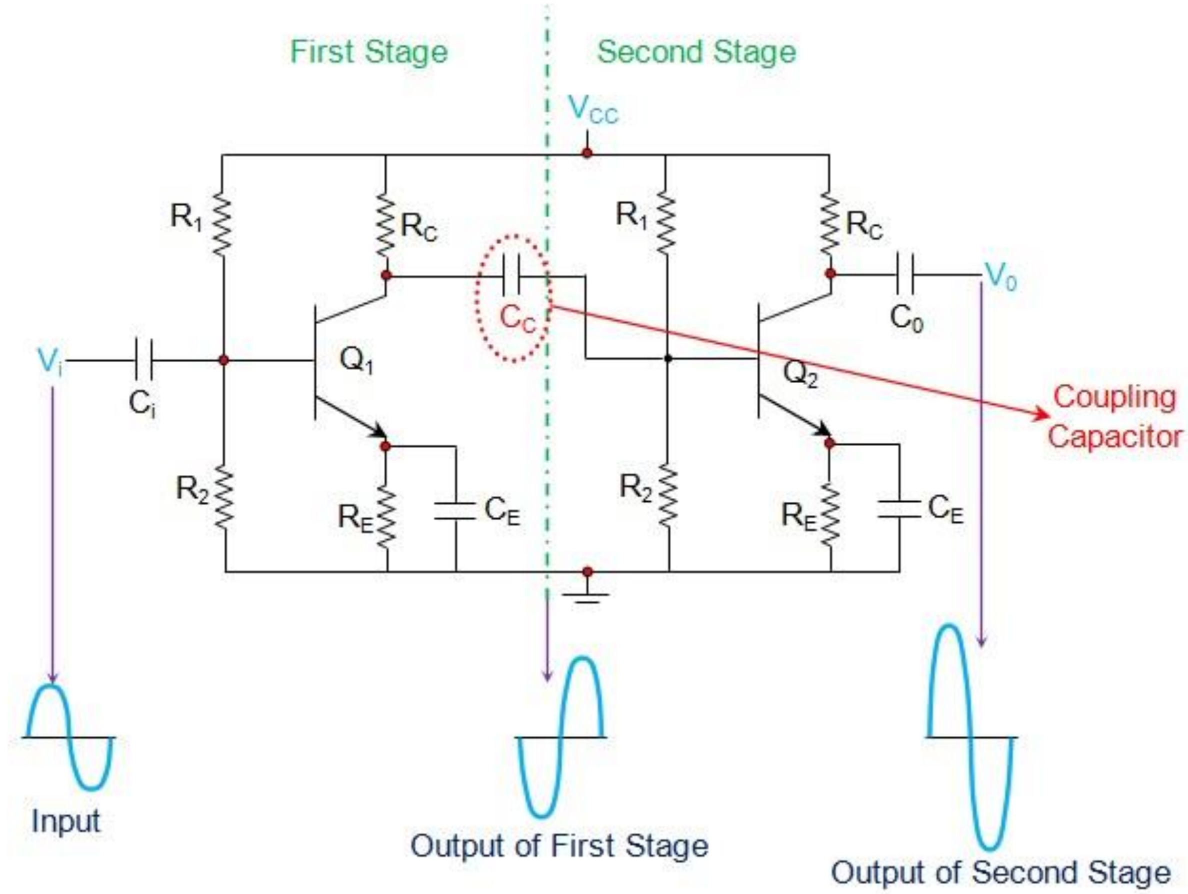
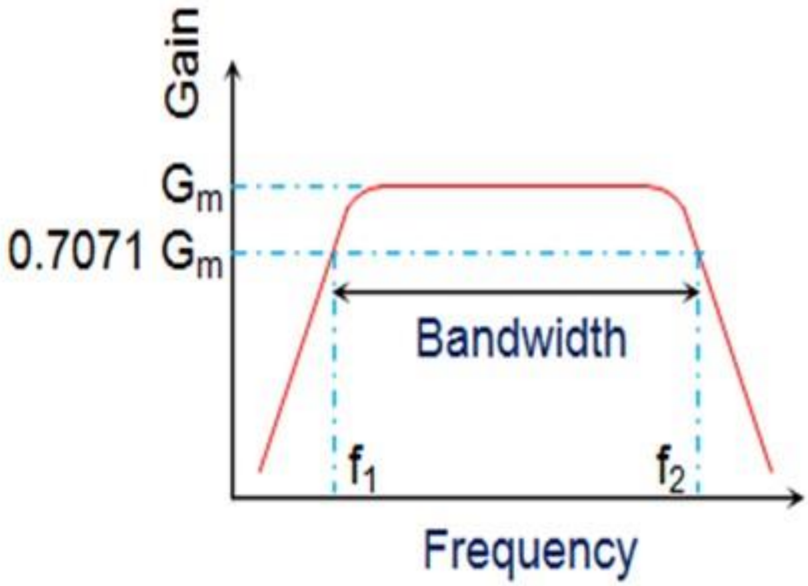



**Figure 1 Two-Stage RC Coupled Amplifier**

Further it is to be noted that the cascading of individual amplifier stages increases the gain of the overall circuit as the net gain will be the product of the gain offered by the individual stages. However in real scenario, the net gain will be slightly less than this, due to the loading effect. In addition, it is important to note that by following the pattern exhibited by Figure 1, one can cascade any number of common emitter amplifiers but by keeping in mind that when the number of stages are even, the output will be in-phase with the input while if the number of stages are odd, then the output and the input will be out-of-phase.

## Frequency Response of RC Coupled Amplifier

Frequency response curve is a graph that indicates the relationship between voltage gain and function of frequency. The frequency response of a RC coupled amplifier is as shown in the following graph.




From the above graph, it is understood that the frequency rolls off or decreases for the frequencies below $F_1$ and for the frequencies above $F_2$. Whereas the voltage gain for the range of frequencies between $F_1$ and $F_2$ is constant.

We know that,

$$XC=1/2\pi fc$$

It means that the capacitive reactance is inversely proportional to the frequency

### At Low frequencies (i.e. below 50 Hz)

The capacitive reactance is inversely proportional to the frequency. At low frequencies, the reactance is quite high. The reactance of input capacitor $C_{in}$ and the coupling capacitor $C_C$ are so high that only small part of the input signal is allowed. The reactance of the emitter by pass capacitor $C_E$ is also very high during low frequencies. Hence it cannot shunt the emitter resistance effectively. With all these factors, the voltage gain rolls off at low frequencies.

### At High frequencies (i.e. above 20 KHz)

Again considering the same point, we know that the capacitive reactance is low at high frequencies. So, a capacitor behaves as a short circuit, at high frequencies. As a result of this, the loading effect of the next stage increases, which reduces the voltage gain. Along with this, as the capacitance of emitter diode decreases, it increases the base current of the transistor due to which the current gain (β) reduces. Hence the voltage gain rolls off at high frequencies.

### At Mid-frequencies (i.e. 50 Hz to 20 KHz)

The voltage gain of the capacitors is maintained constant in this range of frequencies, as shown in figure. If the frequency increases, the reactance of the capacitor $C_C$ decreases which tends to increase the gain. But this lower capacitance reactive increases the loading effect of the next stage by which there is a reduction in gain.

Due to these two factors, the gain is maintained constant.

### Advantages of RC Coupled Amplifier

The following are the advantages of RC coupled amplifier.

- The frequency response of RC amplifier provides constant gain over a wide frequency range, hence most suitable for audio applications.
- The circuit is simple and has lower cost because it employs resistors and capacitors which are cheap.
- It becomes more compact with the upgrading technology.

### Disadvantages of RC Coupled Amplifier

The following are the disadvantages of RC coupled amplifier.

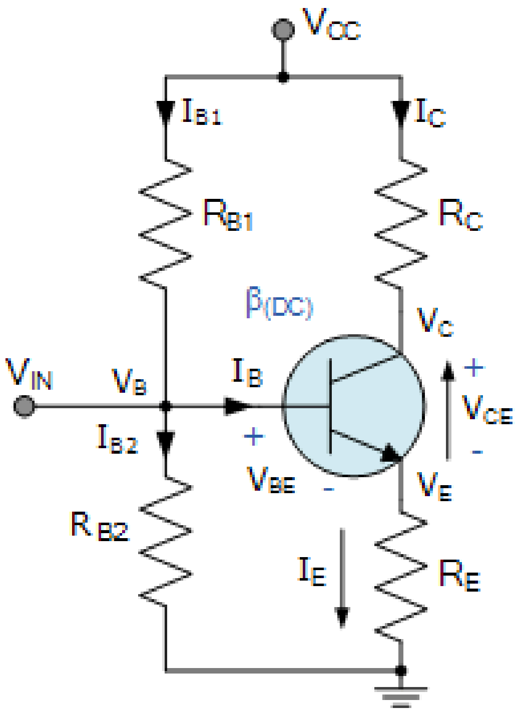
- The voltage and power gain are low because of the effective load resistance.
- They become noisy with age.
- Due to poor impedance matching, power transfer will be low.

### Applications of RC Coupled Amplifier

The following are the applications of RC coupled amplifier.

- They have excellent audio fidelity over a wide range of frequency.
- Widely used as Voltage amplifiers
- Due to poor impedance matching, RC coupling is rarely used in the final stages.

## CONCEPT OF VOLTAGE DIVIDER BIASING




$$V_C = V_{CC} - R_C I_C = (V_E + V_{CE})$$

$$V_E = I_E R_E = V_B - V_{BE}$$

$$V_{CE} = V_C - V_E = V_{CC} - (I_C R_C + I_E R_E)$$

$$V_B = V_{BE} + V_E = V_{RB2} = \left(\frac{R_{B2}}{R_{B1} + R_{B2}}\right) V_{CC}$$

$$I_{B2} = \frac{V_B}{R_{B2}}$$

$$I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$$

$$R_B = \frac{R_{B1} \times R_{B2}}{R_{B1} + R_{B2}} \qquad I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta)R_E}$$

$$I_C = \beta_{(DC)} I_B$$

$$I_E = I_C + I_B = \frac{V_E}{R_E}$$

Here the common emitter transistor configuration is biased using a voltage divider network to increase stability. The name of this biasing configuration comes from the fact that the two resistors $R_{B1}$ and $R_{B2}$ form a voltage or potential divider network across the supply with their center point junction connected the transistors base terminal as shown.

This voltage divider biasing configuration is the most widely used transistor biasing method. The emitter diode of the transistor is forward biased by the voltage value developed across resistor $R_{B2}$. Also, voltage divider network biasing makes the transistor circuit independent of changes in beta as the biasing voltages set at the transistors base, emitter, and collector terminals are not dependant on external circuit values.

To calculate the voltage developed across resistor $R_{B2}$ and therefore the voltage applied to the base terminal we simply use the voltage divider formula for resistors in series.

Generally the voltage drop across resistor $R_{B2}$ is much less than for resistor $R_{B1}$. Clearly the transistors base voltage $V_B$ with respect to ground, will be equal to the voltage across $R_{B2}$.

The amount of biasing current flowing through resistor $R_{B2}$ is generally set to 10 times the value of the required base current $I_B$ so that it is sufficiently high enough to have no effect on the voltage divider current or changes in Beta.

The goal of **Transistor Biasing** is to establish a known quiescent operating point, or Qpoint for the bipolar transistor to work efficiently and produce an undistorted output signal. Correct DC biasing of the transistor also establishes its initial AC operating region with practical biasing circuits using either a two or four-resistor bias network.

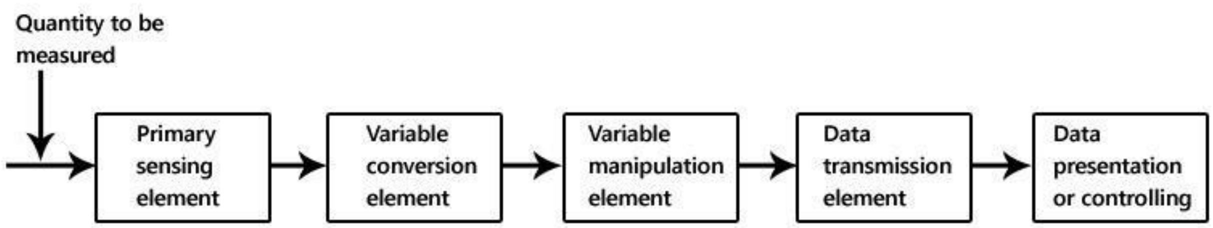
In bipolar transistor circuits, the Q-point is represented by ( $V_{CE}$, $I_C$ ) for the NPN transistors or ( $V_{EC}$, $I_C$ ) for PNP transistors. The stability of the base bias network and therefore the Q-point is generally assessed by considering the collector current as a function of both Beta (β) and temperature.

Here we have looked briefly at five different configurations for "biasing a transistor" using resistive networks. But we can also bias a transistor using either silicon diodes, zener diodes or active networks all connected to the transistors base terminal. We could also correctly bias the transistor from a dual voltage power supply if so wished.

# MODULE 4

## BLOCK DIAGRAM OF INSTRUMENTATION SYSTEM

It is branch of engineering which deals with various types of instrument to record, monitor, indicate and control various physical parameters such as pressure, temperature, etc.




The block diagram shown above is of basic instrumentation system. It consist of primary sensing element, variable manipulation element, data transmission element and data presentation element.

### Primary sensing element

The primary sensing element is also known as sensor. Basically transducers are used as a primary sensing element. Here, the physical quantity (such as temperature, pressure etc.) are sensed and then converted into analogues signal.

### Variable conversion element

It converts the output of primary sensing element into suitable form without changing information. Basically these are secondary transducers.

### Variable manipulation element

The output of transducer may be electrical signal i.e. voltage, current or other electrical parameter. Here, manipulation means change in numerical value of signal. This element is used to convert the signal into suitable range.

### Data transmission element

Sometimes it is not possible to give direct read out of the quality at a particular place (Example – Measurement of temperature in the furnace). In such a case, the data should transfer from one place to another place through channel which is known as data transmission element. Typically transmission path are pneumatic pipe, electrical cable and radio links. When radio link is used, the electronic instrumentation system is called as telemetry system.

Data presentation or controlling element

Finally the output is recorded or given to the controller to perform action. It performs different functions like indicating, recording or controlling.

Logic gates are the basic building blocks of any digital system. It is an electronic circuit having one or more than one input and only one output. The relationship between the input and the output is based on a **certain logic**. Based on this, logic gates are named as AND gate, OR gate, NOT gate etc.

## AND Gate

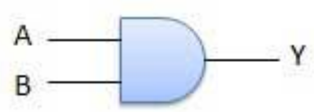
A circuit which performs an AND operation is shown in figure. It has n input (n >= 2) and one output.

Y = A AND B AND C ....... N

Y = A.B.C ....... N

Y = ABC ....... N

### Logic diagram




### Truth Table

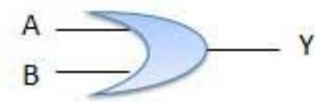
| Inputs | | Output |
|---|---|---|
| A | B | AB |
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

## OR Gate

A circuit which performs an OR operation is shown in figure. It has n input (n >= 2) and one output.

| | | |
|---|---|---|
| Y | = | A OR B OR C ....... N |
| Y | = | A + B + C ....... N |

### Logic diagram




### Truth Table

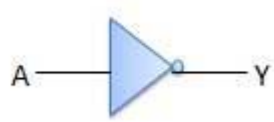
| Inputs | | Output |
|---|---|---|
| A | B | A + B |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

## NOT Gate

NOT gate is also known as **Inverter**. It has one input A and one output Y.

| | | |
|---|---|---|
| Y | = | NOT A |
| Y | = | $\overline{A}$ |

### Logic diagram




### Truth Table

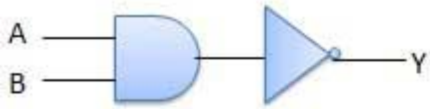
| Inputs | Output |
|---|---|
| A | B |
| 0 | 1 |
| 1 | 0 |

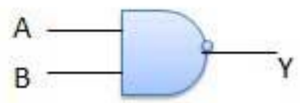
## NAND Gate

A NOT-AND operation is known as NAND operation. It has n input (n >= 2) and one output.

| | | |
|---|---|---|
| Y | = | A NOT AND B NOT AND C ....... N |
| Y | = | A NAND B NAND C ....... N |

### Logic diagram






### Truth Table

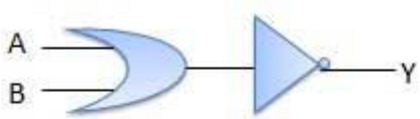
| Inputs | | Output |
|---|---|---|
| A | B | $\overline{AB}$ |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

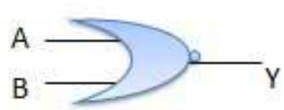
## NOR Gate

A NOT-OR operation is known as NOR operation. It has n input (n >= 2) and one output.

| | | |
|---|---|---|
| Y | = | A NOT OR B NOT OR C ....... N |
| Y | = | A NOR B NOR C ....... N |

### Logic diagram






### Truth Table

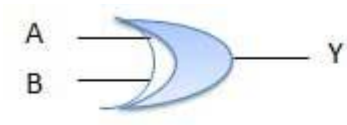
| Inputs | | Output |
|---|---|---|
| A | B | $\overline{A+B}$ |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

# XOR Gate

XOR or Ex-OR gate is a special type of gate. It can be used in the half adder, full adder and subtractor. The exclusive-OR gate is abbreviated as EX-OR gate or sometime as X-OR gate. It has n input (n >= 2) and one output.

| | | |
|---|---|---|
| Y | = | A XOR B XOR C ....... N |
| Y | = | $A \oplus B \oplus C$ ....... N |
| Y | = | $\bar{A}B + A\bar{B}$ |

### Logic diagram




### Truth Table

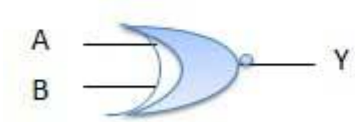
| Inputs | | Output |
|---|---|---|
| A | B | $A \oplus B$ |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

# XNOR Gate

XNOR gate is a special type of gate. It can be used in the half adder, full adder and subtractor. The exclusive-NOR gate is abbreviated as EX-NOR gate or sometime as X-NOR gate. It has n input (n >= 2) and one output.

| | | |
|---|---|---|
| Y | = | A XOR B XOR C ....... N |
| Y | = | $A \odot B \odot C$ ....... N |
| Y | = | $\bar{A}\bar{B} + AB$ |

### Logic diagram



### Truth Table

| Inputs | | Output |
|---|---|---|
| A | B | A ⊖ B |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

### Operational Amplifier

An **Operational Amplifier**, or op-amp for short, 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 basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the **Inverting Input**, marked with a negative or "minus" sign, ( – ). The other input is called the **Non-inverting Input**, marked with a positive or "plus" sign ( + ).

A third terminal represents the operational amplifiers output port which can both sink and source either a voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain ( A ) multiplied by the value of the input signal and depending on the nature of these input and output signals, there can be four different classifications of operational amplifier gain.

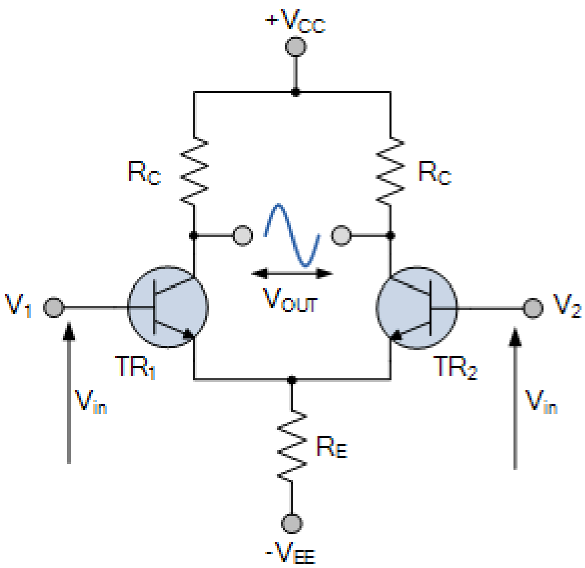
- Voltage – Voltage "in" and Voltage "out"
- Current – Current "in" and Current "out"
- Transconductance – Voltage "in" and Current "out"
- Transresistance – Current "in" and Voltage "out"

Since most of the circuits dealing with operational amplifiers are voltage amplifiers, we will limit the tutorials in this section to voltage amplifiers only, (Vin and Vout).

The output voltage signal from an Operational Amplifier is the difference between the signals being applied to its two individual inputs. In other words, an op-amps output signal is the difference between the two input signals as the input stage of an Operational Amplifier is in fact a differential amplifier as shown below.

## Differential Amplifier

The circuit below shows a generalized form of a differential amplifier with two inputs marked V1 and V2. The two identical transistors TR1 and TR2 are both biased at the same operating point with their emitters connected together and returned to the common rail, -Vee by way of resistor Re.




**Differential Amplifier**

The circuit operates from a dual supply +Vcc and -Vee which ensures a constant supply. The voltage that appears at the output, Vout of the amplifier is the difference between the two input signals as the two base inputs are in *anti-phase* with each other.

So as the forward bias of transistor, TR1 is increased, the forward bias of transistor TR2 is reduced and vice versa. Then if the two transistors are perfectly matched, the current flowing through the common emitter resistor, Re will remain constant.

Like the input signal, the output signal is also balanced and since the collector voltages either swing in opposite directions (anti-phase) or in the same direction (in-phase) the output voltage signal, taken from between the two collectors is, assuming a perfectly balanced circuit the zero difference between the two collector voltages.

This is known as the *Common Mode of Operation* with the **common mode gain** of the amplifier being the output gain when the input is zero.

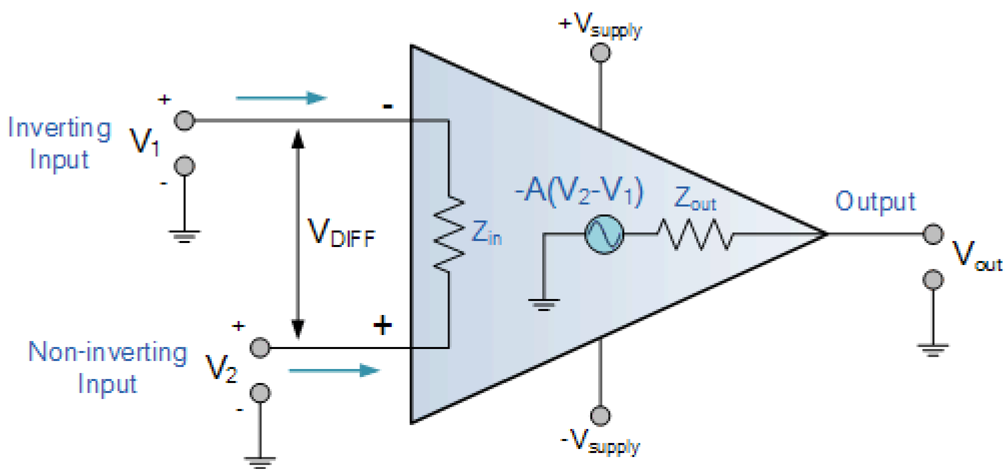
Operational Amplifiers also have one output (although there are ones with an additional differential output) of low impedance that is referenced to a common ground terminal and it should ignore any common mode signals that is, if an identical signal is applied to both the inverting and non-inverting inputs there should no change to the output.

However, in real amplifiers there is always some variation and the ratio of the change to the output voltage with regards to the change in the common mode input voltage is called the **Common Mode Rejection Ratio** or **CMRR** for short.

Operational Amplifiers on their own have a very high open loop DC gain and by applying some form of **Negative Feedback** we can produce an operational amplifier circuit that has a very precise gain characteristic that is dependant only on the feedback used. Note that the term "open loop" means that there are no feedback components used around the amplifier so the feedback path or loop is open.

An operational amplifier only responds to the difference between the voltages on its two input terminals, known commonly as the "*Differential Input Voltage*" and not to their common potential. Then if the same voltage potential is applied to both terminals the resultant output will be zero. An Operational Amplifiers gain is commonly known as the **Open Loop Differential Gain**, and is given the symbol ($A_o$).

## Equivalent Circuit of an Ideal Operational Amplifier




## Op-amp Parameter and Idealised Characteristic

- Open Loop Gain, (Avo)

    - **Infinite** – The main function of an operational amplifier is to amplify the input signal and the more open loop gain it has the better. Open-loop gain is the gain of the op-amp without positive or negative feedback and for such an amplifier the gain will be infinite but typical real values range from about 20,000 to 200,000.

- Input impedance, ($Z_{IN}$)

  - **Infinite –** Input impedance is the ratio of input voltage to input current and is assumed to be infinite to prevent any current flowing from the source supply into the amplifiers input circuitry ( $I_{IN} = 0$ ). Real op-amps have input leakage currents from a few pico-amps to a few milli-amps.

- Output impedance, ($Z_{OUT}$)

  - **Zero** – The output impedance of the ideal operational amplifier is assumed to be zero acting as a perfect internal voltage source with no internal resistance so that it can supply as much current as necessary to the load. This internal resistance is effectively in series with the load thereby reducing the output voltage available to the load. Real op-amps have output impedances in the 100-20kΩ range.

- Bandwidth, (BW)

  - **Infinite** – An ideal operational amplifier has an infinite frequency response and can amplify any frequency signal from DC to the highest AC frequencies so it is therefore assumed to have an infinite bandwidth. With real op-amps, the bandwidth is limited by the Gain-Bandwidth product (GB), which is equal to the frequency where the amplifiers gain becomes unity.

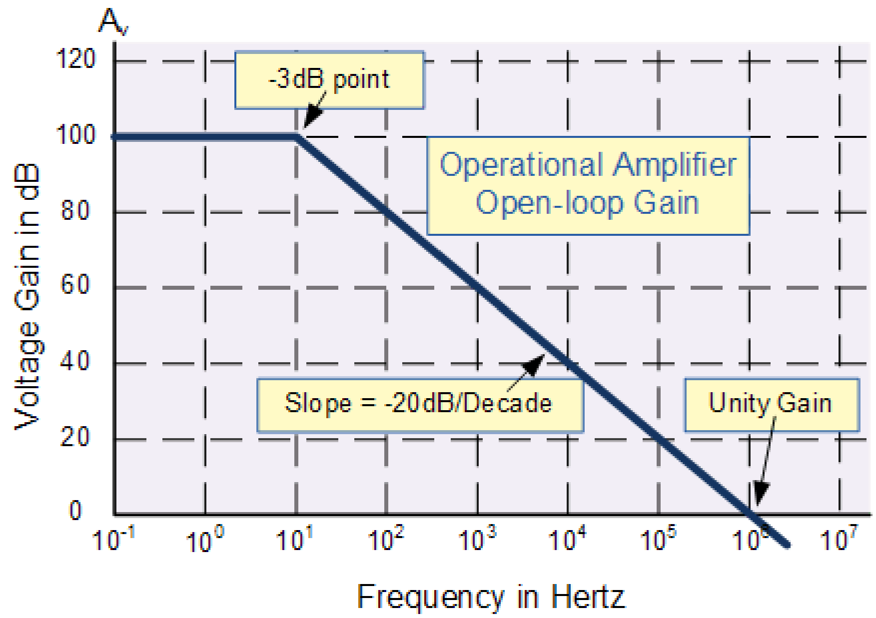
- Offset Voltage, ($V_{IO}$)

  - **Zero** – The amplifiers output will be zero when the voltage difference between the inverting and the non-inverting inputs is zero, the same or when both inputs are grounded. Real op-amps have some amount of output offset voltage.

From these "idealized" characteristics above, we can see that the input resistance is infinite, so **no current flows into either input terminal** (the "current rule") and that the **differential input offset voltage is zero** (the "voltage rule"). It is important to remember these two properties as they will help us understand the workings of the **Operational Amplifier** with regards to the analysis and design of op-amp circuits.

However, real **Operational Amplifiers** such as the commonly available **uA741**, for example do not have infinite gain or bandwidth but have a typical "Open Loop Gain" which is defined as the amplifiers output amplification without any external feedback signals connected to it and for a typical operational amplifier is about 100dB at DC (zero Hz). This output gain decreases linearly with frequency down to "Unity Gain" or 1, at about 1MHz and this is shown in the following open loop gain response curve.

## Open-loop Frequency Response Curve




From this frequency response curve we can see that the product of the gain against frequency is constant at any point along the curve. Also that the unity gain (0dB) frequency also determines the gain of the amplifier at any point along the curve. This constant is generally known as the **Gain Bandwidth Product** or **GBP**. Therefore:

$$GBP = Gain \times Bandwidth = A \times BW$$

For example, from the graph above the gain of the amplifier at 100kHz is given as 20dB or 10, then the gain bandwidth product is calculated as:

$$GBP = A \times BW = 10 \times 100{,}000Hz = 1{,}000{,}000.$$

Similarly, the operational amplifiers gain at 1kHz = 60dB or 1000, therefore the GBP is given as:

$$GBP = A \times BW = 1{,}000 \times 1{,}000Hz = 1{,}000{,}000.$$ **The same!**.

The **Voltage Gain** ($A_v$) of the operational amplifier can be found using the following formula:

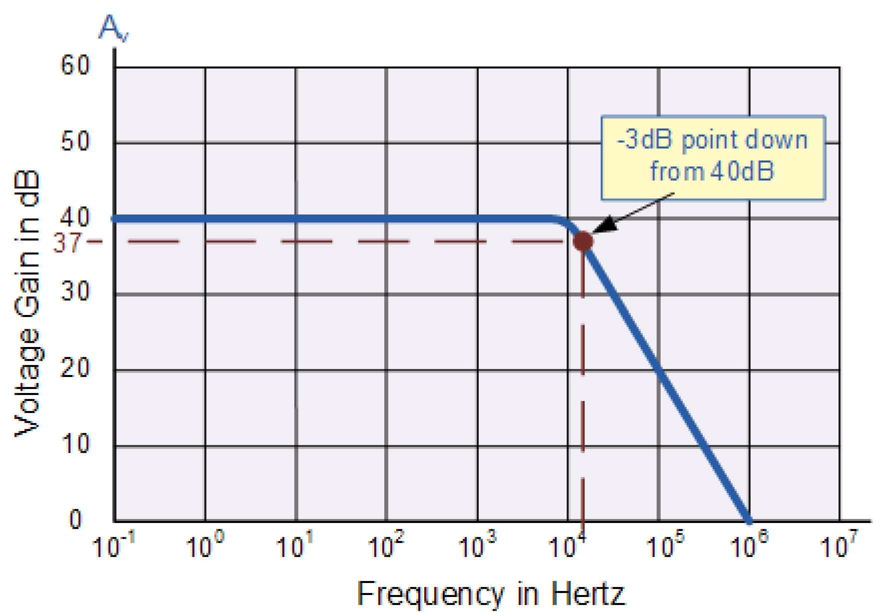
$$\text{Voltage Gain, (A)} = \frac{V_{out}}{V_{in}}$$

and in **Decibels** or (dB) is given as:

$$20\log(A) \text{ or } 20\log\frac{V_{out}}{V_{in}} \text{ in dB}$$

## An Operational Amplifiers Bandwidth

The operational amplifiers bandwidth is the frequency range over which the voltage gain of the amplifier is above **70.7%** or **-3dB** (where 0dB is the maximum) of its maximum output value as shown below.




Here we have used the 40dB line as an example. The -3dB or 70.7% of Vmax down point from the frequency response curve is given as **37dB**. Taking a line across until it intersects with the main GBP curve gives us a frequency point just above the 10kHz line at about 12 to 15kHz. We can now calculate this more accurately as we already know the GBP of the amplifier, in this particular case 1MHz.

## Operational Amplifier Example No1.

Using the formula 20 log (A), we can calculate the bandwidth of the amplifier as:

$$37 = 20 \log (A) \quad \text{therefore, } A = \text{anti-log} (37 \div 20) = 70.8$$

$$GBP \div A = \text{Bandwidth}, \ \text{therefore, } 1{,}000{,}000 \div 70.8 = 14{,}124Hz, \text{ or } 14kHz$$

Then the bandwidth of the amplifier at a gain of 40dB is given as **14kHz** as previously predicted from the graph.

## Operational Amplifier Example No2.

If the gain of the operational amplifier was reduced by half to say **20dB** in the above frequency response curve, the -3dB point would now be at 17dB. This would then give the operational amplifier an overall gain of 7.08, therefore **A = 7.08**.

If we use the same formula as above, this new gain would give us a bandwidth of approximately **141.2kHz**, ten times more than the frequency given at the 40dB point. It can therefore be seen that by reducing the overall "open loop gain" of an operational amplifier its bandwidth is increased and visa versa.

In other words, an operational amplifiers bandwidth is inversely proportional to its gain, ( A 1/∞ BW ). Also, this -3dB corner frequency point is generally known as the "half power point", as the output power of the amplifier is at half its maximum value as shown:

$$\text{Power, } P = \left[\frac{V^2}{R}\right] = \left[I^2 \times R\right]$$

$$\text{At } f_C \ V \text{ or } I = 70.71\% \text{ of maximum}$$

$$\text{If } R = 1 \quad \text{and} \quad V \text{ or } I = 0.7071\text{max}$$

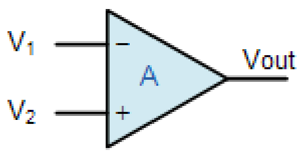
$$\text{Then: } P = \left[\frac{(0.7071 \times V)^2}{1}\right] = \left[(0.7071 \times I)^2 \times 1\right]$$

$$\therefore P = 0.5V \quad \text{or} \quad 0.5I \quad \text{(half power)}$$

## Operational Amplifiers Summary

We know now that an **Operational amplifiers** is a very high gain DC differential amplifier that uses one or more external feedback networks to control its response and characteristics. We can connect external resistors or capacitors to the op-amp in a number of different ways to form basic "building Block" circuits such as, Inverting, Non-

Inverting, Voltage Follower, Summing, Differential, Integrator and Differentiator type amplifiers.

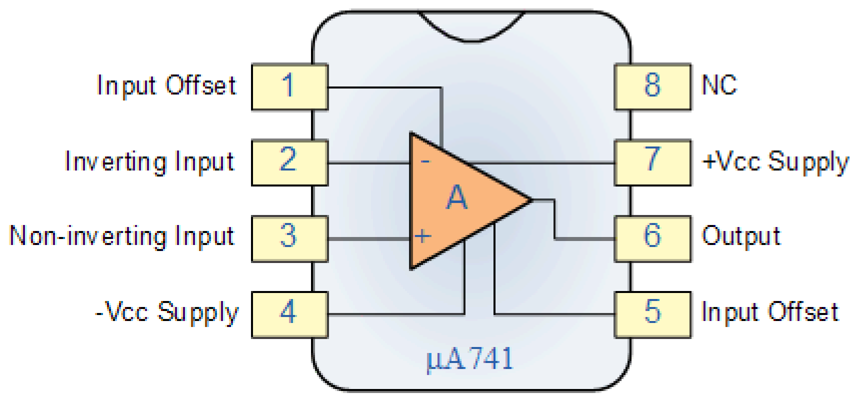



**Op-amp Symbol**

An “ideal” or perfect operational amplifier is a device with certain special characteristics such as infinite open-loop gain $A_O$, infinite input resistance $R_{IN}$, zero output resistance $R_{OUT}$, infinite bandwidth 0 to ∞ and zero offset (the output is exactly zero when the input is zero).

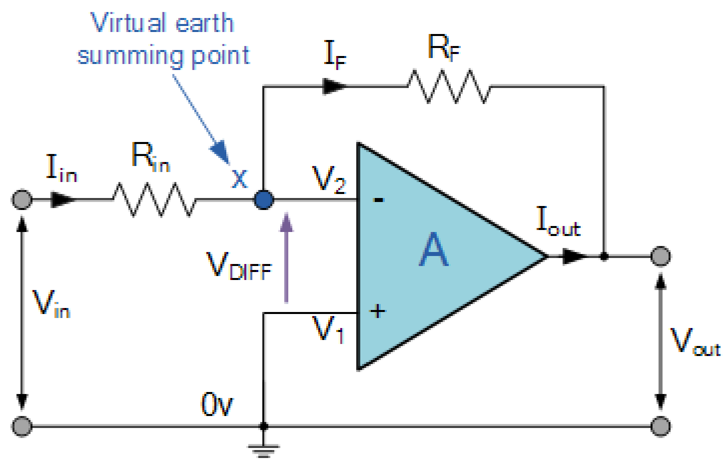
There are a very large number of operational amplifier IC’s available to suit every possible application from standard bipolar, precision, high-speed, low-noise, high-voltage, etc, in either standard configuration or with internal Junction FET transistors.

Operational amplifiers are available in IC packages of either single, dual or quad op-amps within one single device. The most commonly available and used of all operational amplifiers in basic electronic kits and projects is the industry standard **µA-741**.




In the next tutorial about Operational Amplifiers, we will use negative feedback connected around the op-amp to produce a standard closed-loop amplifier circuit called an Inverting Amplifier circuit that produces an output signal which is 180° “out-of-phase” with the input.

## Inverting Operational Amplifier Configuration




In this **Inverting Amplifier** circuit the operational amplifier is connected with feedback to produce a closed loop operation. When dealing with operational amplifiers there are two very important rules to remember about inverting amplifiers, these are: "No current flows into the input terminal" and that "V1 always equals V2". However, in real world op-amp circuits both of these rules are slightly broken.

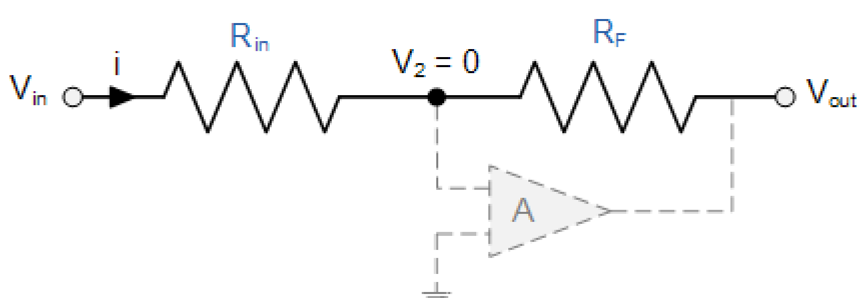
This is because the junction of the input and feedback signal ( X ) is at the same potential as the positive ( + ) input which is at zero volts or ground then, the junction is a **"Virtual Earth"**. Because of this virtual earth node the input resistance of the amplifier is equal to the value of the input resistor, Rin and the closed loop gain of the inverting amplifier can be set by the ratio of the two external resistors.

We said above that there are two very important rules to remember about **Inverting Amplifiers** or any operational amplifier for that matter and these are.

- No Current Flows into the Input Terminals
- The Differential Input Voltage is Zero as V1 = V2 = 0 (Virtual Earth)

Then by using these two rules we can derive the equation for calculating the closed-loop gain of an inverting amplifier, using first principles.

Current ( i ) flows through the resistor network as shown.



$$i = \frac{Vin - Vout}{Rin + Rf}$$

$$\text{therefore, } i = \frac{Vin - V2}{Rin} = \frac{V2 - Vout}{Rf}$$

$$i = \frac{Vin}{Rin} - \frac{V2}{Rin} = \frac{V2}{Rf} - \frac{Vout}{Rf}$$

$$\text{so, } \frac{Vin}{Rin} = V2\left[\frac{1}{Rin} + \frac{1}{Rf}\right] - \frac{Vout}{Rf}$$

$$\text{and as, } i = \frac{Vin - 0}{Rin} = \frac{0 - Vout}{Rf} \qquad \frac{Rf}{Rin} = \frac{0 - Vout}{Vin - 0}$$

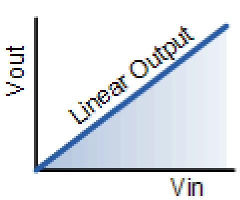
$$\text{the Closed Loop Gain (Av) is given as, } \frac{Vout}{Vin} = -\frac{Rf}{Rin}$$

Then, the **Closed-Loop Voltage Gain** of an Inverting Amplifier is given as.

$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

and this can be transposed to give Vout as:

$$Vout = -\frac{Rf}{Rin} \times Vin$$



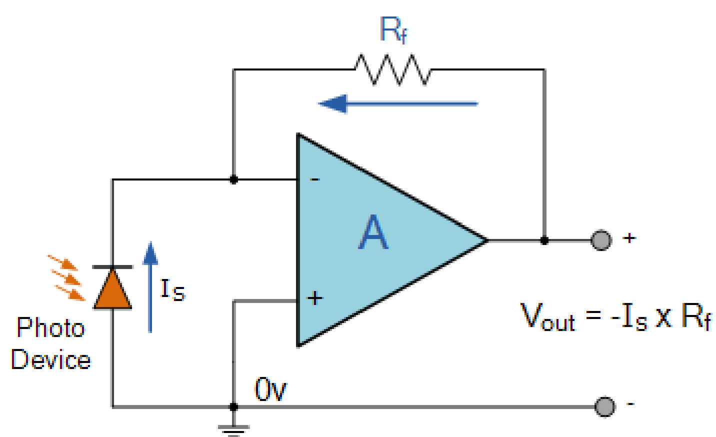
## Linear Output

The negative sign in the equation indicates an inversion of the output signal with respect to the input as it is 180° out of phase. This is due to the feedback being negative in value.

The equation for the output voltage Vout also shows that the circuit is linear in nature for a fixed amplifier gain as Vout = Vin x Gain. This property can be very useful for converting a smaller sensor signal to a much larger voltage.

Another useful application of an inverting amplifier is that of a “transresistance amplifier” circuit. A **Transresistance Amplifier** also known as a “transimpedance amplifier”, is basically a current-to-voltage converter (Current “in” and Voltage “out”). They can be used in low-power applications to convert a very small current generated by a photo-diode or photo-detecting device etc, into a usable output voltage which is proportional to the input current as shown.

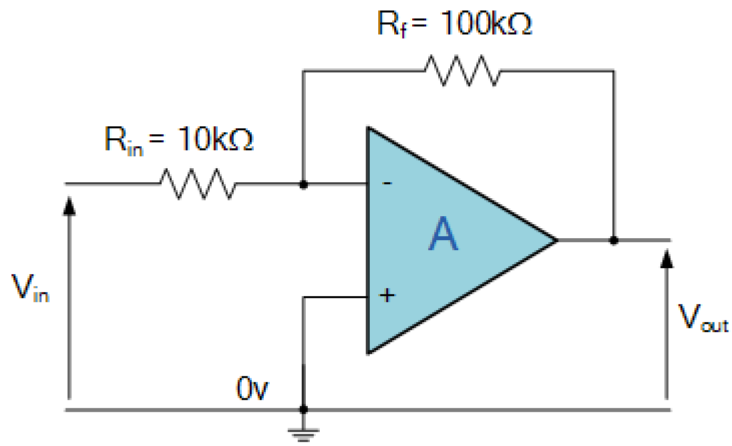
## Transresistance Amplifier Circuit




The simple light-activated circuit above, converts a current generated by the photo-diode into a voltage. The feedback resistor R*f* sets the operating voltage point at the inverting input and controls the amount of output. The output voltage is given as Vout = $I_s$ x R*f*. Therefore, the output voltage is proportional to the amount of input current generated by the photo-diode.

## Inverting Op-amp Example No1

Find the closed loop gain of the following inverting amplifier circuit.




Using the previously found formula for the gain of the circuit

$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

we can now substitute the values of the resistors in the circuit as follows,

Rin = 10kΩ and Rƒ = 100kΩ

and the gain of the circuit is calculated as: -Rƒ/Rin = 100k/10k = -10

Therefore, the closed loop gain of the inverting amplifier circuit above is given **-10** or **20dB** (20log(10)).

## Inverting Op-amp Example No2

The gain of the original circuit is to be increased to **40** (32dB), find the new values of the resistors required.

Assuming that the input resistor is to remain at the same value of 10KΩ, then by re-arranging the closed loop voltage gain formula we can find the new value required for the feedback resistor Rƒ.

Gain = Rƒ/Rin

therefore, Rƒ = Gain x Rin

Rƒ = 40 x 10,000

Rƒ = 400,000 or 400KΩ

The new values of resistors required for the circuit to have a gain of **40** would be:

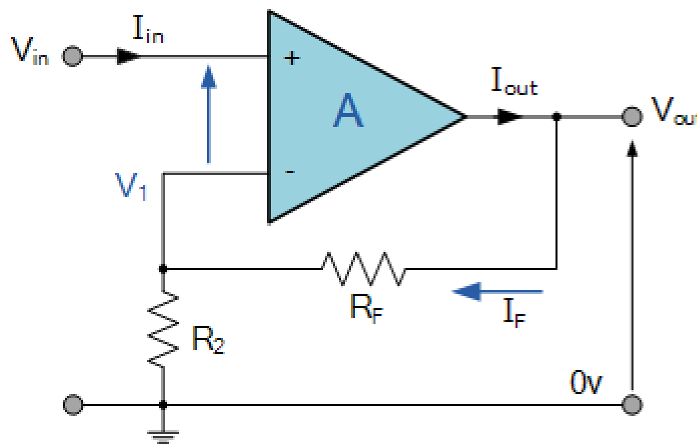
Rin = 10KΩ and Rƒ = 400KΩ

The formula could also be rearranged to give a new value of Rin, keeping the same value of R$f$.

One final point to note about the **Inverting Amplifier** configuration for an operational amplifier, if the two resistors are of equal value, Rin = R$f$ then the gain of the amplifier will be **-1** producing a complementary form of the input voltage at its output as Vout = -Vin. This type of inverting amplifier configuration is generally called a **Unity Gain Inverter** of simply an *Inverting Buffer*.

In the next tutorial about Operational Amplifiers, we will analyse the complement of the **Inverting Amplifier** operational amplifier circuit called the Non-inverting Amplifier that produces an output signal which is "in-phase" with the input.

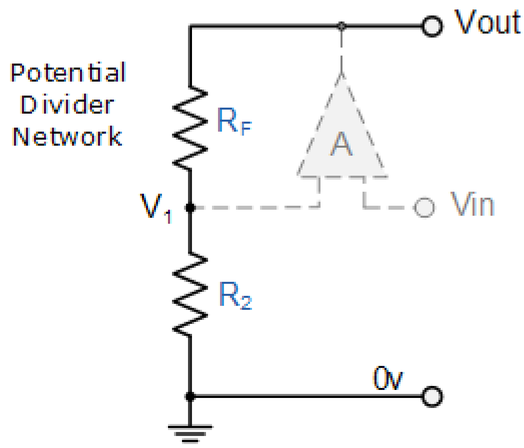
## Non-inverting Operational Amplifier Configuration




In the previous Inverting Amplifier tutorial, we said that for an ideal op-amp "No current flows into the input terminal" of the amplifier and that "V1 always equals V2". This was because the junction of the input and feedback signal ( V1 ) are at the same potential.

In other words the junction is a "virtual earth" summing point. Because of this virtual earth node the resistors, R$f$ and R2 form a simple potential divider network across the non-inverting amplifier with the voltage gain of the circuit being determined by the ratios of R2 and R$f$ as shown below.

Equivalent Potential Divider Network




Then using the formula to calculate the output voltage of a potential divider network, we can calculate the closed-loop voltage gain ( $A_V$ ) of the **Non-inverting Amplifier** as follows:

$$V_1 = \frac{R_2}{R_2 + R_F} \times V_{OUT}$$

$$\text{Ideal Summing Point: } V_1 = V_{IN}$$

$$\text{Voltage Gain, } A_{(V)} \text{ is equal to: } \frac{V_{OUT}}{V_{IN}}$$

$$\text{Then, } A_{(V)} = \frac{V_{OUT}}{V_{IN}} = \frac{R_2 + R_F}{R_2}$$

$$\text{Transpose to give: } A_{(V)} = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_2}$$

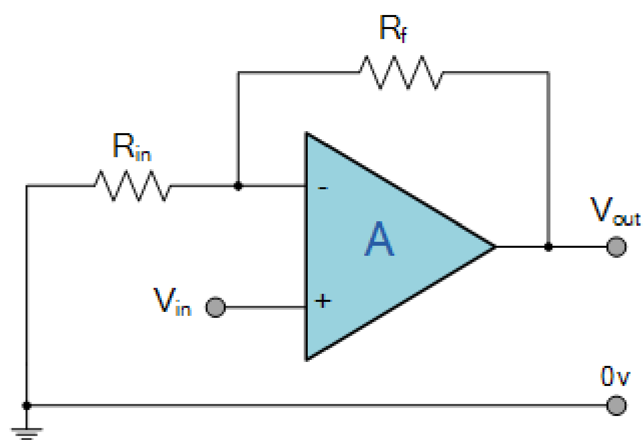
Then the closed loop voltage gain of a **Non-inverting Operational Amplifier** will be given as:

$$A_{(v)} = 1 + \frac{R_F}{R_2}$$

We can see from the equation above, that the overall closed-loop gain of a non-inverting amplifier will always be greater but never less than one (unity), it is positive in nature and is determined by the ratio of the values of $Rƒ$ and R2.

If the value of the feedback resistor $Rƒ$ is zero, the gain of the amplifier will be exactly equal to one (unity). If resistor R2 is zero the gain will approach infinity, but in practice it will be limited to the operational amplifiers open-loop differential gain, ( $A_o$ ).

We can easily convert an inverting operational amplifier configuration into a non-inverting amplifier configuration by simply changing the input connections as shown.



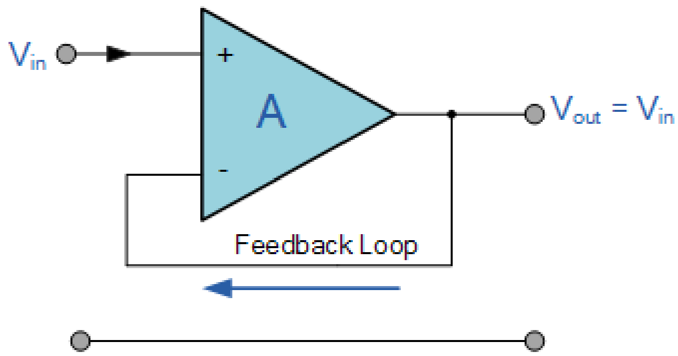

## Voltage Follower (Unity Gain Buffer)

If we made the feedback resistor, $Rƒ$ equal to zero, ($Rƒ = 0$), and resistor R2 equal to infinity, ($R2 = \infty$), then the resulting circuit would have a fixed gain of "1" (unity) as all the output voltage is fed back to the inverting input terminal (negative feedback). This configuration would produce a special type of the non-inverting amplifier circuit called a **Voltage Follower**, also known as a "unity gain buffer".

As the input signal is connected directly to the non-inverting input of the amplifier the output signal is not inverted resulting in the output voltage being equal to the input voltage, thus Vout = Vin. This then makes the **voltage follower** circuit ideal as a constant voltage source or voltage regulator because of its input to output isolation properties.

The advantage of the unity gain voltage follower configuration is that it can be used when impedance matching or circuit isolation is more important than voltage or current amplification as it maintains the input signal voltage at its output terminal. Also, the input impedance of the voltage follower circuit is extremely high, typically above 1MΩ as it is equal to that of the operational amplifiers input resistance times its gain ( Rin x $A_o$ ). The op-amps output impedance is very low since an ideal op-amp condition is assumed so is unaffected by changes in load.

## Non-inverting Voltage Follower




In this non-inverting circuit configuration, the input impedance Rin has increased to infinity and the feedback impedance R*ƒ* reduced to zero. The output is connected directly back to the negative inverting input so the feedback is 100% and Vin is exactly equal to Vout giving it a fixed gain of 1 or unity. As the input voltage Vin is applied to the non-inverting input, the voltage gain of the amplifier is therefore given as:

$$V_{out} = A(V_{in})$$

$$(V_{in} = V+) \text{ and } (V_{out} = V-)$$

$$\text{therefore Gain, } (A_V) = \frac{V_{out}}{V_{in}} = +1$$

Since no current flows into the non-inverting input terminal the input impedance is infinite (ideal conditions) so zero current will flow through the feedback loop. Thus any value of resistance may be placed in the feedback loop without affecting the characteristics of the circuit as no current flows through it so there is zero voltage drop across it resulting in zero power loss.

As the input impedance is extremely high, the unity gain buffer (voltage follower) can be used to provide a large power gain as the extra power comes from the op-amps supply rails and through the op-amps output to the load and not directly from the input. However in most real unity gain buffer circuits there are leakage currents and parasitic capacitances present so a low value (typically 1kΩ) resistor is required in the feedback loop to help reduce the effects of these leakage currents providing stability especially if the operational amplifier is of a current feedback type.

The voltage follower or unity gain buffer is a special and very useful type of **Non-inverting amplifier** circuit that is commonly used in electronics to isolated circuits from each other especially in High-order state variable or Sallen-Key type active filters to separate one filter stage from the other. Typical digital buffer IC's available are the 74LS125 Quad 3-state buffer or the more common 74LS244 Octal buffer.

One final thought, the closed loop voltage gain of a voltage follower circuit is "1" or **Unity**. The open loop voltage gain of an operational amplifier with no feedback is **Infinite**. Then by carefully selecting the feedback components we can control the amount of gain produced by a non-inverting operational amplifier anywhere from one to infinity.

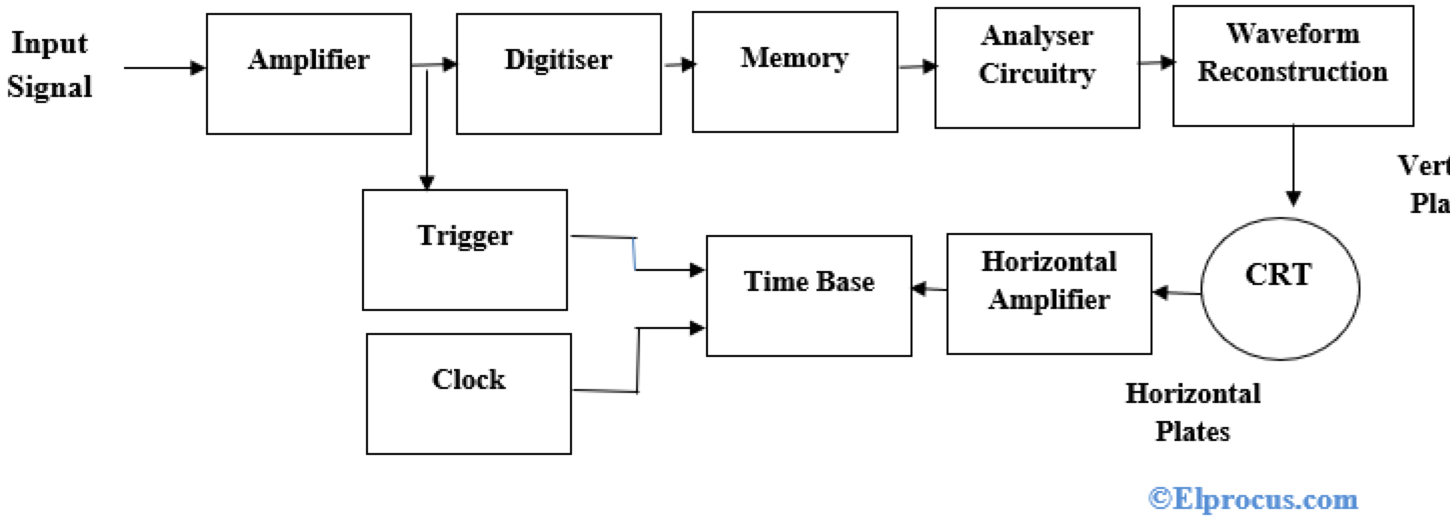
Thus far we have analysed an inverting and non-inverting amplifier circuit that has just one input signal, Vin. In the next tutorial about Operational Amplifiers, we will examine the effect of the output voltage, Vout by connecting more inputs to the amplifier. This then produces another common type of operational amplifier circuit called a Summing Amplifier which can be used to "add" together the voltages present on its inputs.

### Digital Storage Oscilloscope

The digital storage oscilloscope is an instrument which gives the storage of a digital waveform or the digital copy of the waveform. It allows us to store the signal or the waveform in the digital format, and in the digital memory also it allows us to do the digital signal processing techniques over that signal. The maximum frequency measured on the digital signal oscilloscope depends upon two things they are: sampling rate of the scope and the nature of the converter. The traces in DSO are bright, highly defined, and displayed within seconds.

## Block Diagram of Digital Storage Oscilloscope

The block diagram of the digital storage oscilloscope consists of an amplifier, digitizer, memory, analyzer circuitry. Waveform reconstruction, vertical plates, horizontal plates, cathode ray tube (CRT), horizontal amplifier, time base circuitry, trigger, and clock. The block diagram of the digital storage oscilloscope is shown in the below figure.




Digital Storage Oscilloscope Block Diagram

As seen in the above figure, at first digital storage oscilloscope digitizes the analog input signal, then the analog input signal is amplified by amplifier if it has any weak signal. After amplification, the signal is digitized by the digitizer and that digitized signal stores in memory. The analyzer circuit process the digital signal after that the waveform is reconstructed (again the digital signal is converted into an analog form) and then that signal is applied to vertical plates of the cathode ray tube (CRT).

The cathode ray tube has two inputs they are vertical input and horizontal input. The vertical input signal is the 'Y' axis and the horizontal input signal is the 'X' axis. The time base circuit is triggered by the trigger and clock input signal, so it is going to generate the time base signal which is a ramp signal. Then the ramp signal is amplified by the horizontal amplifier, and this horizontal amplifier will provide input to the horizontal plate. On the CRT screen, we will get the waveform of the input signal versus time.

The digitizing occurs by taking a sample of the input waveform at periodic intervals. At the periodic time interval means, when half of the time cycle is completed then we are taking the samples of the signal. The process of digitizing or sampling should follow the sampling theorem. The sampling theorem says that the rate at which the samples are taken should be greater than twice the highest frequency present in the input signal. When the analog signal is not properly converted into digital then there occurs an aliasing effect.

When the analog signal is properly converted into digital then the resolution of the A/D converter will be decreased. When the input signals stored in analog store registers can be read out at a much slower rate by the A/D converter, then the digital output of the A/D converter stored in the digital store, and it allows operation up to 100 mega samples per second. This is the working principle of a digital storage oscilloscope.

## DSO Operation Modes

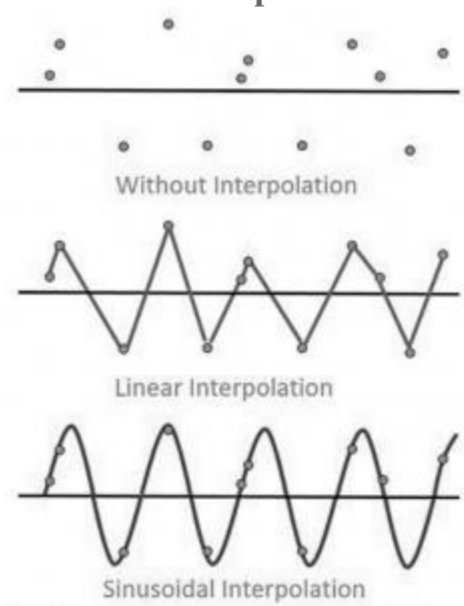
The digital storage oscilloscope works in three modes of operations they are roll mode, store mode, and hold or save mode.

**Roll Mode:** In roll mode, very fast varying signals are displayed on the display screen.
**Store Mode:** In the store mode the signals stores in memory.
**Hold or Save Mode:** In hold or save mode, some part of the signal will hold for some time and then they will be stored in memory.
These are the three modes of digital storage oscilloscope operation.

## Waveform Reconstruction

There are two types of waveform reconstructions they are linear interpolation and sinusoidal interpolation.

**Linear Interpolation:** In linear interpolation, the dots are joined by a straight line.
**Sinusoidal Interpolation:** In sinusoidal interpolation, the dots are joined by a sine wave.




Waveform Reconstruction of Digital Storage Oscilloscope

The difference between DSO and the conventional storage oscilloscope or analog storage oscilloscope (ASO) is shown in the below table.

| S.NO | Digital Storage Oscilloscope | Conventional Storage Oscilloscope |
|---|---|---|
| 1 | The digital storage oscilloscope collects data always | After triggering only, the conventional storage oscilloscope data |
| 2 | The cost of the tube is cheap | The cost of the tube is costlier |
| 3 | For higher frequency signals the DSO produce bright images | For higher frequency signals the ASO cannot produce bright in |
| 4 | The resolution is higher in digital storage oscilloscope | The resolution is lower in conventional storage oscillosco |
| 5 | In DSO an operating speed is less | In ASO an operating speed is less |

**Function Generator**

A function generator is a specific form of signal generator that is able to generate waveforms with common shapes. Unlike RF generators and some others that only create sine waves, the function generator is able to create repetitive waveforms with a number of common shapes.

In particular it can be made to become a sine wave generator, square wave generator, and triangular wave generator.

Also a function generator may be able to vary the characteristics of the waveforms, changing the length of the pulse, i.e. the mark space ratio, or the ramps of the different edges of triangular or sawtooth waveforms, but it is only be able to create the waveforms that are built in to the function generator. It cannot be programmed to create additional waveforms - an arbitrary waveform generator, AWG is required for this.

Apart from just generating the waveforms themselves, this type of test instrument has the capability to add a DC offset to the signal. This can be very useful in a number of testing applications.

Typically function generators are only able to operate at relatively low frequencies, some only operating to frequencies of around 100kHz, although more costly test instruments can operate at higher frequencies, up to 20 or 30MHz.

# Function generator capabilities

Function generators are capable of producing a variety of repetitive waveforms, generally from the list below:

- ***Sine wave:*** A function generator will normally be able to act as a sine wave generator. This is the standard waveform that oscillates between two levels with a standard sinusoidal shape. Using the function generator as a sine wave generator is one of the more commonly used applications. Sine waves are widely used in testing applications.

- ***Square wave:*** Another very widely used waveform is the square wave. It consists of a signal moving directly between high and low levels. Used as a square wave generator, this test instrument provides a very useful source of a basic digital waveform.

- ***Pulse:*** A pulse waveform is another type that can be produced by a function generator. It is effectively the same as a square wave, but with the mark space ratio very different to 1:1. This form of waveform is again often used within digital applications.

- ***Triangular wave:*** This form of signal produced by the function generator linearly moves between a high and low point. This form of waveform is often generated using an operational amplifier acting as an integrator. The triangular waveform generator typically also has a square wave output as well, and it is used as the basis for generating all the waveforms in a function generator test instrument.

  The triangular waveform is often used in testing amplifiers - it is far easier to see distortion and clipping on a triangular waveform than it is on a sine waveform.

- ***Sawtooth wave:*** Again, this is a triangular waveform, but with the rise edge of the waveform faster or slower than the fall, making a form of shape similar to a sawtooth. It is generated by the same circuit as the triangular waveform, but with the different rise and fall times created by changing the charge rate for the rise and fall elements of the integrator.

These are the basic waveforms that are produced within a function generator test instrument. These waveforms satisfy most of the needs for testing a number of items. Where specialised waveforms are required, then an arbitrary waveform generator is required.

# Function generator controls

In addition to a selection of the basic waveforms that are available, other controls on the function generator may include:

- ***Frequency:*** As would be expected, this control alters the basic frequency at which the waveform repeats. It is independent of the waveform type.
- ***Waveform type :*** This enables the different basic waveform types to be selected:
    - Sine wave
    - Square wave
    - Triangular wave
- ***DC offset:*** This alters the average voltage of a signal relative to 0V or ground.
- ***Duty cycle:*** This control on the function generator changes the ratio of high voltage to low voltage time in a square wave signal, i.e. changing the waveform from a square wave with a 1:1 duty cycle to a pulse waveform, or a triangular waveform with equal rise and fall times to a sawtooth.

# Function generator usage

Function generators are normally used within electronics development, manufacturing test and service departments. They provide a flexible form of waveform generation that can be used in many tests.

These test instruments are very flexible and not thought of as specialist instruments. Although they can often generate signals into the low end of the RF spectrum, normally a specific RF generator would be used, unless none were available.

Also they are generally not used for performance audio testing as the levels of distortion on the sine aves that would normally be used would have higher levels of distortion than these tests sometimes require. A typical figure for the sine wave distortion might be about 1%.

If very high frequency stability is required, ten some of these test instruments allow for the output signal to be phase locked to another source.

# MODULE 5

In general terms, a **satellite** is a smaller object that revolves around a larger object in space. For example, moon is a natural satellite of earth.

We know that **Communication** refers to the exchange (sharing) of information between two or more entities, through any medium or channel. In other words, it is nothing but sending, receiving and processing of information.

If the communication takes place between any two earth stations through a satellite, then it is called as **satellite communication**. In this communication, electromagnetic waves are used as carrier signals. These signals carry the information such as voice, audio, video or any other data between ground and space and vice-versa.

Soviet Union had launched the world's first artificial satellite named, Sputnik 1 in 1957. Nearly after 18 years, India also launched the artificial satellite named, Aryabhata in 1975.

## Need of Satellite Communication

The following two kinds of propagation are used earlier for communication up to some distance.

- **Ground wave propagation** − Ground wave propagation is suitable for frequencies up to 30MHz. This method of communication makes use of the troposphere conditions of the earth.
- **Sky wave propagation** − The suitable bandwidth for this type of communication is broadly between 30–40 MHz and it makes use of the ionosphere properties of the earth.

The maximum hop or the station distance is limited to 1500KM only in both ground wave propagation and sky wave propagation. Satellite communication overcomes this limitation. In this method, satellites provide **communication for long distances**, which is well beyond the line of sight.

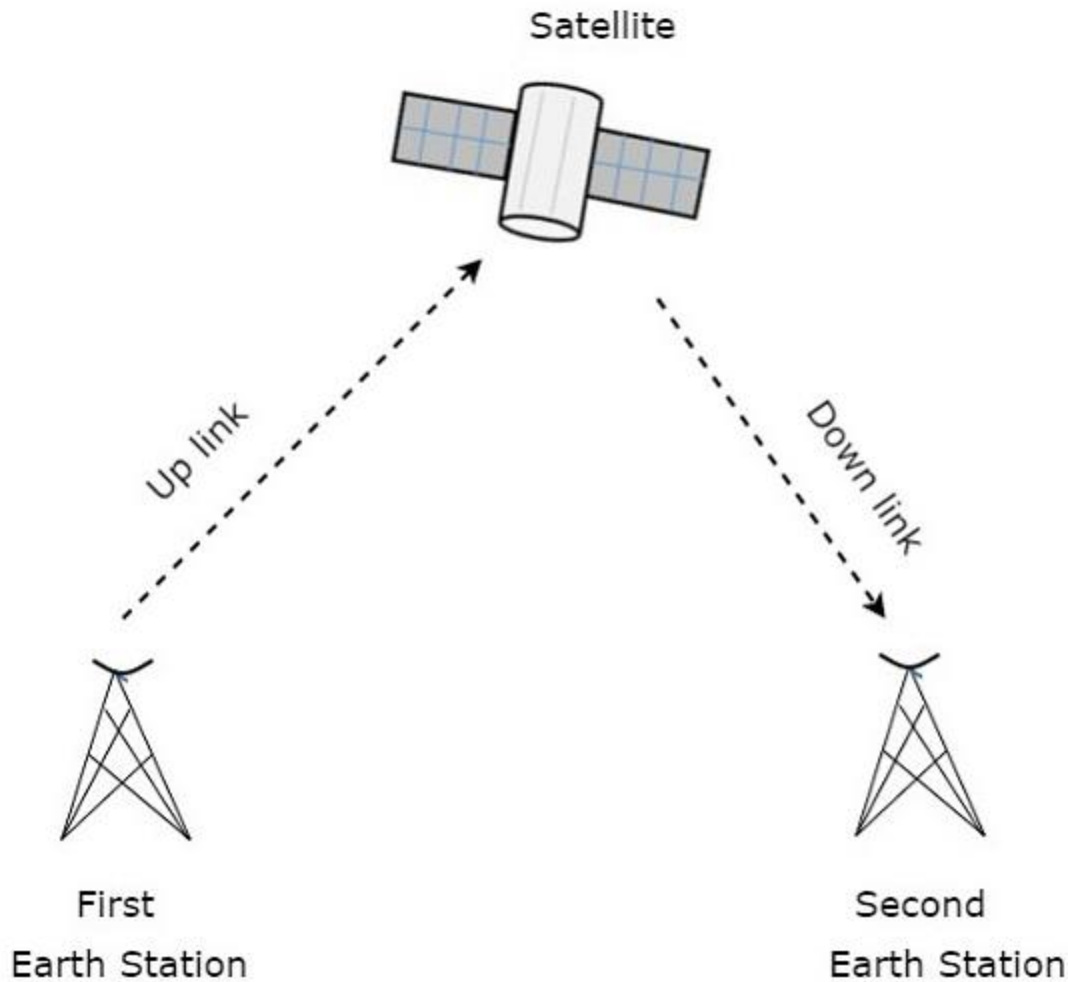
Since the satellites locate at certain height above earth, the communication takes place between any two earth stations easily via satellite. So, it overcomes the limitation of communication between two earth stations due to earth's curvature.

## How a Satellite Works

A **satellite** is a body that moves around another body in a particular path. A communication satellite is nothing but a microwave repeater station in space. It is helpful in telecommunications, radio and television along with internet applications.

A **repeater** is a circuit, which increases the strength of the received signal and then transmits it. But, this repeater works as a **transponder**. That means, it changes the frequency band of the transmitted signal from the received one.

The frequency with which, the signal is sent into the space is called as **Uplink frequency**. Similarly, the frequency with which, the signal is sent by the transponder is called as **Downlink frequency**. The following figure illustrates this concept clearly.




The transmission of signal from first earth station to satellite through a channel is called as **uplink**. Similarly, the transmission of signal from satellite to second earth station through a channel is called as **downlink**.

**Uplink frequency** is the frequency at which, the first earth station is communicating with satellite. The satellite transponder converts this signal into another frequency and sends it down to the second earth station. This frequency is called as **Downlink frequency**. In similar way, second earth station can also communicate with the first one.

The process of satellite communication begins at an earth station. Here, an installation is designed to transmit and receive signals from a satellite in an orbit around the earth. Earth stations send the information to satellites in the form of high powered, high frequency (GHz range) signals.

The satellites receive and retransmit the signals back to earth where they are received by other earth stations in the coverage area of the satellite. Satellite's **footprint** is the area which receives a signal of useful strength from the satellite.

## Pros and Cons of Satellite Communication

In this section, let us have a look at the advantages and disadvantages of satellite communication.

Following are the **advantages** of using satellite communication:

- Area of coverage is more than that of terrestrial systems
- Each and every corner of the earth can be covered
- Transmission cost is independent of coverage area
- More bandwidth and broadcasting possibilites

Following are the **disadvantages** of using satellite communication −

- Launching of satellites into orbits is a costly process.
- Propagation delay of satellite systems is more than that of conventional terrestrial systems.
- Difficult to provide repairing activities if any problem occurs in a satellite system.
- Free space loss is more
- There can be congestion of frequencies.

## Applications of Satellite Communication

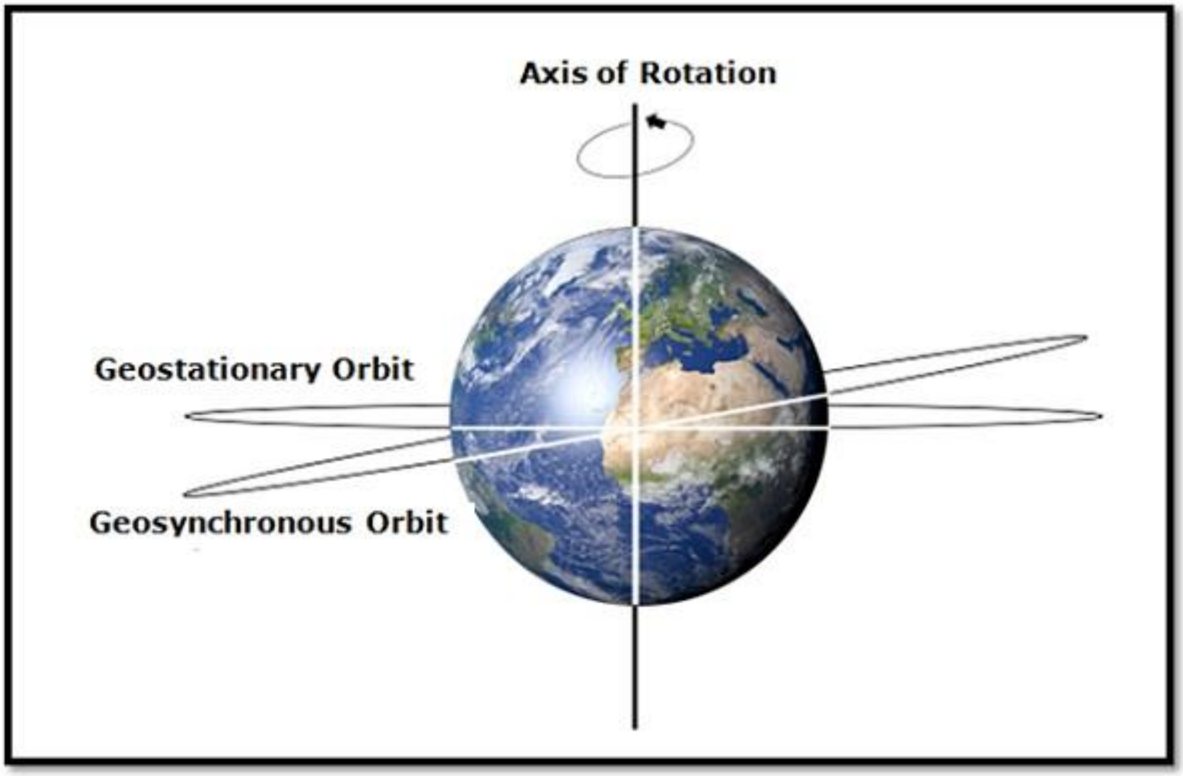
Satellite communication plays a vital role in our daily life. Following are the applications of satellite communication −

- Radio broadcasting and voice communications
- TV broadcasting such as Direct To Home (DTH)
- Internet applications such as providing Internet connection for data transfer, GPS applications, Internet surfing, etc.
- Military applications and navigations
- Remote sensing applications
- Weather condition monitoring & Forecasting

### Geostationary Satellite and Geostationary Orbit (GEO)

A circular geosynchronous satellite which is placed at $0^{o}$ angle to the equatorial plane is called a geostationary satellite. It appears to be stationary at a fixed position of the sky throughout the day by a ground observer.

The orbit in which a geostationary satellite is placed is called a geostationary orbit (GEO). It is placed 35, 800 km above the earth’s equator and has an orbital period equal to the sidereal day.




## Uses and Examples of Geosynchronous Satellites

### Uses

- Voice and data communication
- Internet
- Broadcasting cable TV and radio signals

### Examples

- Raduga 29 of Russia
- Astra 1C of India
- MEASAT 2 of Malaysia

## Uses and Examples of Geostationary Satellites

### Uses

- Weather reports about a particular region
- Weather forecasting
- Terrestrial reports of a geographical area
- Spy networks

### Examples

- Geostationary Operational Environmental Satellite (GEOS) of USA

- INSAT of India
- Himawari of Japan
- Fengyun of China
- Meteostat of Europe

## RADIO COMMUNICATION:

# NEED FOR MODULATION

- It is because modulation makes the information **signal more compatible** with the medium.
- **Modulation =** Imposing information at low frequency onto a higher frequency signal.
- A technique for transmitting information efficiently from one place to another.
- Simplest form of modulation is the amplitude modulation.

# PRINCIPLES OF AM

- AM is defined as:
  - Amplitude of carrier frequency change proportionately to the value of the modulation signal.
- Advantages:
  - Simple modulator circuits
  - Cheap :low-quality form of modulation used for commercial broadcasting of audio & video signal.
- Disadvantages:
  - Poor performance due to noise
  - Inefficient use of transmitter power.
- Application:
  - 2 way radio communications, broadcasting, aircraft comm. & citizen band (CB) radio.

- AM modulators are nonlinear devices
  - 2 input and 1 output: modulating signal and carrier signal.
- Several types of amplitude modulation
  - AM DSBFC
  - DSB-SC
  - SSB
- AM generation is shown in Figure 2.1
- Modulated wave = AM envelope as shown in Figure 2.2

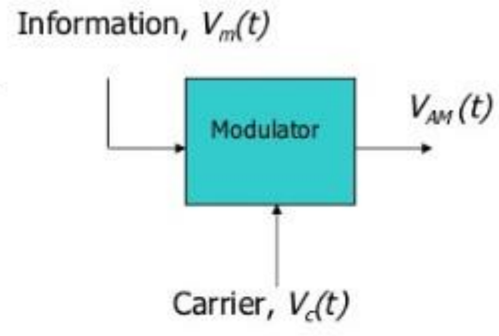
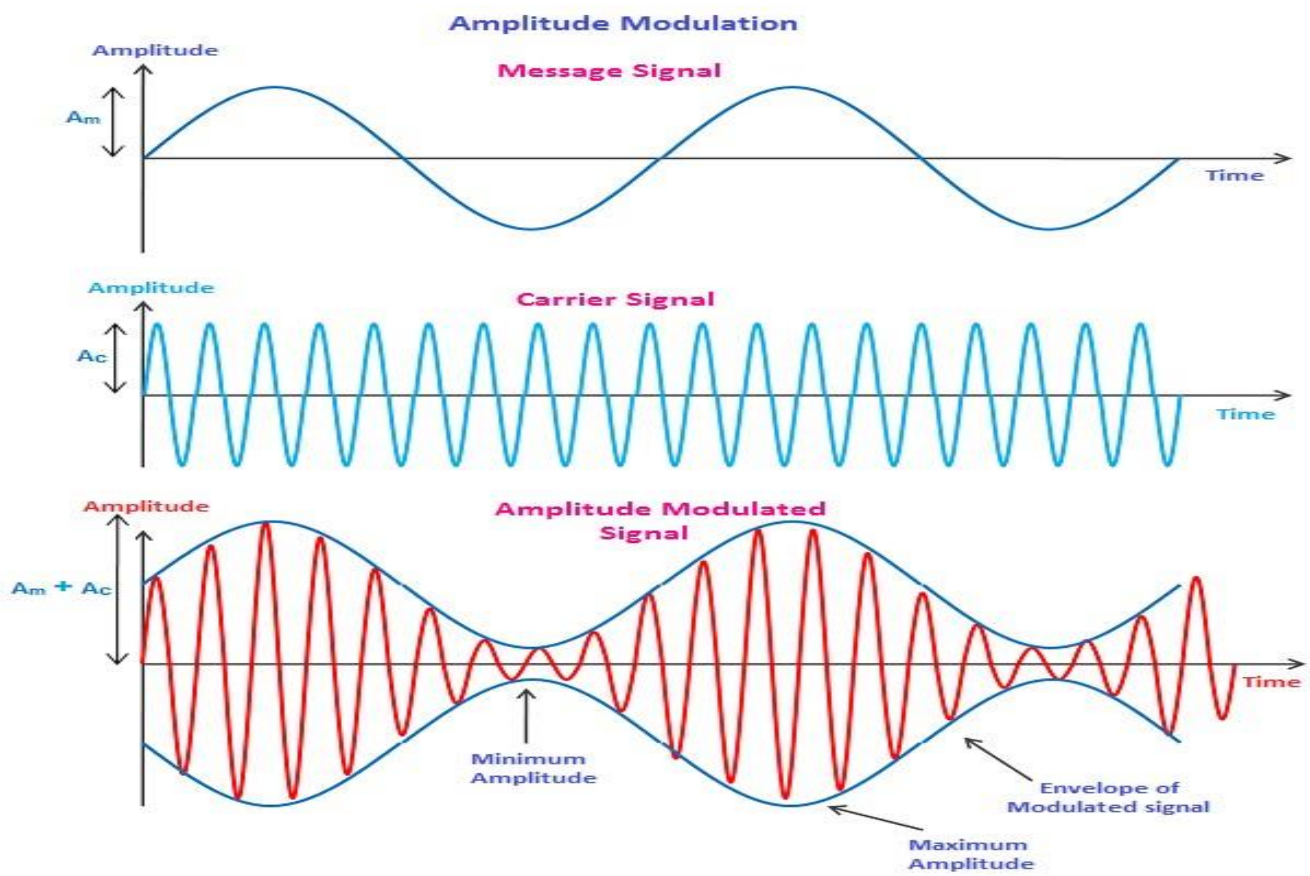



Figure 2.1: Block diagram of Amplitude Modulation



# DERIVATION OF AM EQUATION

- AM begins with carrier $v_c$, → a sine wave with frequency $f_c$ & amplitude $V_c$:

  $$v_c = V_c \sin 2\pi f_c t$$

- Modulating signal:

  $$v_m = V_m \sin 2\pi f_m t$$

- Then AM is:

$$V_{env} = V_c + v_m$$

$$V_{env} = V_c + V_m \sin 2\pi f_m t \qquad [m = V_m / V_c]$$

$$V_{env} = V_c + m V_c \sin 2\pi f_m t$$

- Where *m (modulation index)* is defined as $V_m/V_c$, hence:

  $$V_{env} = V_c (1 + m \sin 2\pi f_m t)$$

- The voltage resulting AM wave envelope at any instant is:

  $$v = V_{env} \sin 2\pi f_c t$$
  $$= V_c (1 + m \sin 2\pi f_m t) \bullet \sin 2\pi f_c t$$

## Using Trigo ID

$$(\sin a)(\sin b) = 1/2[\cos(a-b) - \cos(a+b)]$$

$$v = V_c \sin 2\pi f_c t + \frac{m}{2} V_c \cos 2\pi (f_c - f_m) t - \frac{m}{2} V_c \cos 2\pi (f_c + f_m) t$$

$$v_{AM} = V_c \sin 2\pi f_c t + \frac{V_m}{2} \cos 2\pi (f_c - f_m) t - \frac{V_m}{2} \cos 2\pi (f_c + f_m) t$$

Carrier — LSB — USB

- This yield, the upper and lower sidebands – frequency & amplitude.

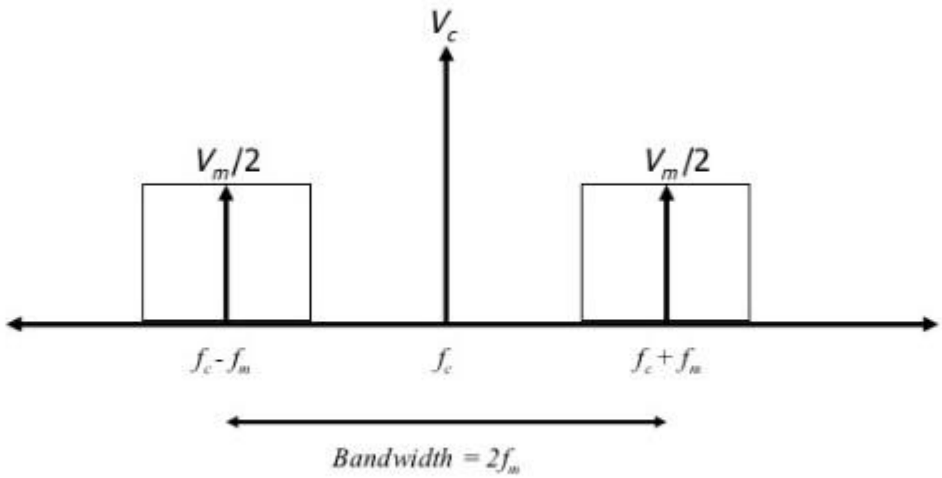
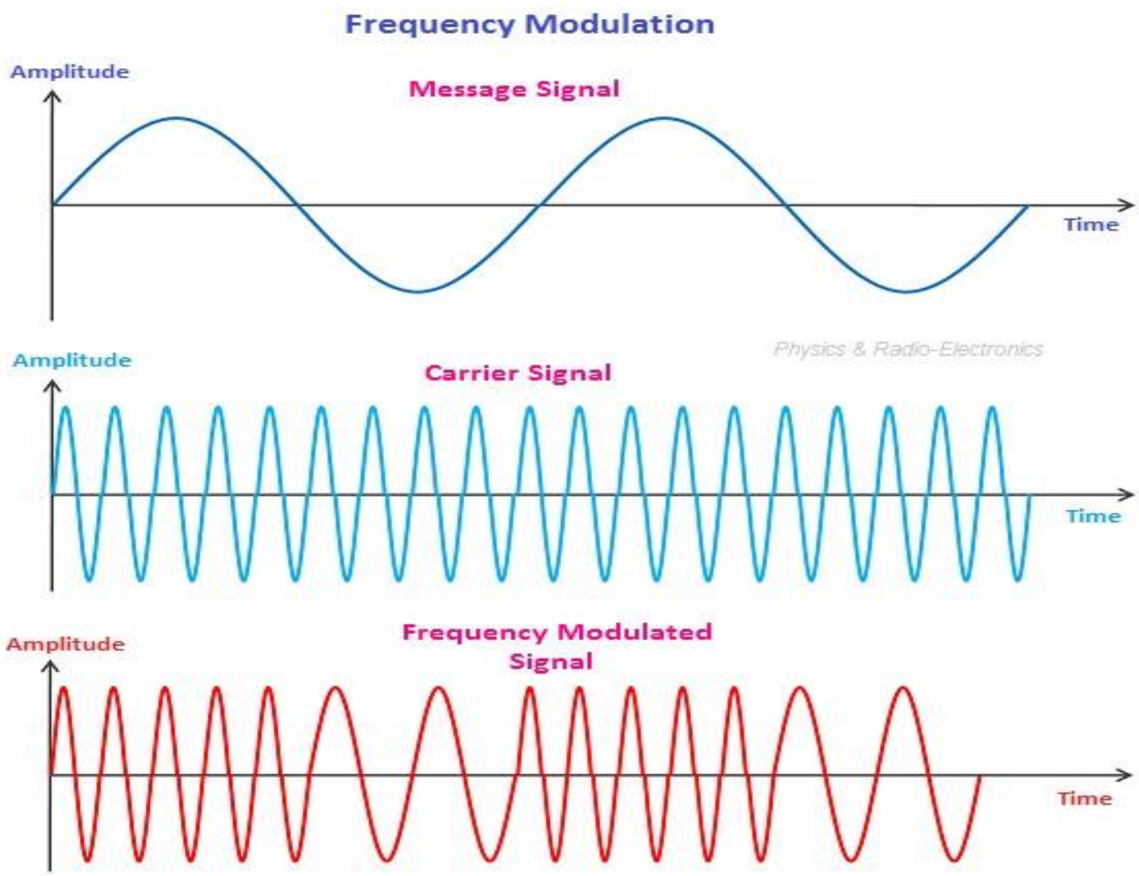



Figure 2.3: Frequency spectrum for AM wave

# Principles of FM

- A sine wave carrier can be modified for the purpose of transmitting information from one place to another by varying its frequency. This is known as**frequency modulation (FM).**
- In FM, the carrier amplitude remains constant and the carrier frequency is changed by the modulating signal

- **Frequency deviation ($f_d$)** is the amount of change in carrier frequency produced by the modulating signal.
- The **frequency deviation rate** is how many times per second the carrier frequency deviates above or below its center frequency.
- The frequency of the modulating signal determines the frequency deviation rate.
- A type of modulation called **frequency-shift keying (FSK)** is used in transmission of binary data in digital cell phones and low-speed computer modems.



# Mathematical analysis of FM

- Mathematical analysis:
- Let message signal:

$$v_m(t) = V_m \cos \varpi_m t$$

- And carrier signal:

$$v_c(t) = V_c \cos[\varpi_c t + \theta]$$

- During the process of frequency modulations the frequency of carrier signal is changed in accordance with the instantaneous amplitude of message signal. Therefore the frequency of carrier after modulation is written as

$$\omega_i = \omega_c + K_1 v_m(t) = \omega_C + K_1 V_m \cos\omega_m t$$

- To find the instantaneous phase angle of modulated signal, integrate equation above w.r.t. ***t***

$$\phi_i = \int \omega_i dt = \int (\omega_C + K_1 V_m \cos\omega_m t) dt = \omega_C t + \frac{K_1 V_m}{\omega_m} \sin\omega_m t$$

- Thus, we get the FM wave as:

$$v_{FM}(t) = Vc\cos\phi_1 = V_C\cos(\omega_C t + \frac{K_1 V_m}{\omega_m}\sin\omega_m t)$$

$$v_{FM}(t) = V_C\cos(\omega_C t + m_f \sin\omega_m t)$$

- Where modulation index for FM is given by

$$m_f = \frac{K_1 V_m}{\omega_m}$$

  - Therefore:

$$\Delta f = K_1 V_m;$$

$$m_f = \frac{\Delta f}{f_m}$$

  - $K_l$ – deviation sensitivities Hz/V

FREQUENCY BAND USED FOR VARIOUS COMMUNICATION

| Frequency Band | | Frequency | Frequency Band Use |
|---|---|---|---|
| **Radio and Broadcast** | | 600 kHz to 1.6 MHz | AM radio |
| | | 88 to 108 MHz | FM radio |
| | | 54 to 700 MHz | TV broadcast |
| **Microwave** | L band | 1 to 2 GHz | Cell phones 0.9-2.4 GHz<br>Microwave 2.4 GHz<br>Wireless Data 2.4 GHz<br>Radar 1-100 GHz |
| | S band | 2 to 4 GHz | |
| | C band | 4 to 8 GHz | |
| | X band | 8 to 12 GHz | |
| | $K_u$ band | 12 to 18 GHz | |
| | K band | 18 to 26.5 GHz | |
| | $K_a$ band | 26.5 to 40 GHz | |
| | Q band | 30 to 50 GHz | |
| | U band | 40 to 60 GHz | |
| | V band | 50 to 75 GHz | |
| | E band | 60 to 90 GHz | |
| | W band | 75 to 110 GHz | |
| | F band | 90 to 140 GHz | |
| | D band | 110 to 170 GHz | |
| **Terahertz** | | 1 to 10 THz | Bio-imaging |
| **Infrared** | | 300 to 400 THz | Remotes, night vision |
| **Visible Light** | | 400 to 800 THz | |
| **Ultraviolet** | | 800 THz to 30 PHz | Dental curing, tanning |
| **X-ray** | | 30 PHz to 30 EHz | Baggage screening |
| **Gamma** | | > 30 EHz | PET imaging |

## SUPER HETERODYNE RECEIVER

A superheterodyne receiver usesfrequency mixing to convert a received signal to a fixedintermediate frequency (IF) which can be more conveniently processed than the original radio carrier frequency. The word "super" referrers to "super-sonic" (ultra-sonic today) meaning the IF frequency was superior to or above human hearing. Heterodyne means to mix two frequencies in a non linear device or translate one frequency to another. The name "Superheterodyne" receiver is sometimes shortened to "superhet".

The basic block diagram of a superheterodyne receiver is shown in the following figure.The way in which the receiver works can be seen by following the signal as is passes through the receiver.

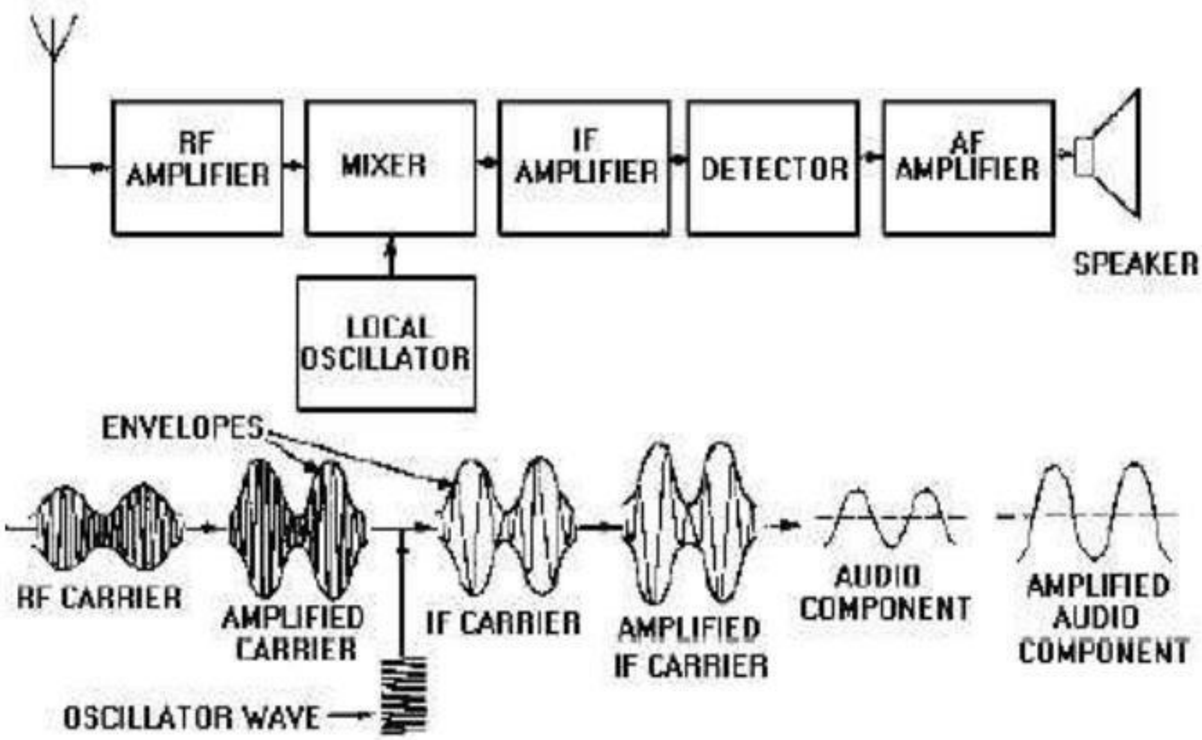



**Fig:** Block diagram of Superheterodyne Receiver

**Front end amplifier and tuning block:** Signals enter the front end circuitry from the antenna. This circuit block performs two main functions:

Tuning:- Broadband tuning is applied to the RF stage. The purpose of this is to reject the signals on the image frequency and accept those on the wanted frequency. It must also be able to track the local oscillator so that as the receiver is tuned, so the RF tuning remains on the required frequency. Typically the selectivity provided at this stage is not high. Its main purpose is to reject signals on the image frequency which is at a frequency equal to twice that of the IF away from the wanted frequency. As the tuning within this block provides all the rejection for the image response, it must be at a sufficiently sharp to reduce the image to an acceptable level. However the RF tuning may also help in preventing strong off-channel signals from entering the receiver and overloading elements of the receiver, in particular the mixer or possibly even the RF amplifier.

Amplification:- In terms of amplification, the level is carefully chosen so that it does not overload the mixer when strong signals are present, but enables the signals to be amplified sufficiently to ensure a good signal to noise ratio is achieved. The amplifier must also be a low noise design. Any noise introduced in this block will be amplified later in the receiver.

**Mixer / frequency translator block:** The tuned and amplified signal then enters one port of the mixer. The local oscillator signal enters the other port. The performance of the mixer is crucial to many elements of the overall receiver performance. It should be as linear as possible. If not, then spurious signals will be generated and these may appear as 'phantom' received signals.

**Local oscillator:** The local oscillator may consist of a variable frequency oscillator that can be tuned by altering the setting on a variable capacitor. Alternatively it may be a frequency synthesizer that will enable greater levels of stability and setting accuracy.

**Intermediate frequency amplifier, IF block :** Once the signals leave the mixer they enter the IF stages. These stages contain most of the amplification in the receiver as well as the filtering that enables signals on one frequency to be separated from those on the next. Filters may consist simply of LC tuned transformers providing inter-stage coupling, or they may be much higher performance ceramic or even crystal filters, dependent upon what is required.

**Detector / demodulator stage:** Once the signals have passed through the IF stages of the superheterodyne receiver, they need to be demodulated. Different demodulators are required for different types of transmission, and as a result some receivers may have a variety of demodulators that can be switched in to accommodate the different types of transmission that are to be encountered.

**Audio amplifier:** The output from the demodulator is the recovered audio. This is passed into the audio stages where they are amplified and presented to the headphones or loudspeaker.

## PRINCIPLE OF ANTENNA – RADIATION FROM ACCELERATED CHARGE

Antenna is a source or radiator of Electromagnetic waves or a sensor of Electromagnetic waves. It is a transition device or transducer between a guided wave and a free space wave or vice versa. It is also an electrical conductor or system of conductors that radiates EM energy into or collects EM energy from free space. Antennas function by transmitting or receiving electromagnetic (EM) waves. Examples of these electromagnetic waves include the light from the sun and the waves received by your cell phone or radio. Your eyes are basically "receiving antennas" that pick up electromagnetic waves that are of a particular frequency. The colors that you see (red, green, blue) are each waves of different frequencies that your eyes can detect. All electromagnetic waves propagate at the same speed in air or in space. This speed (the speed of light) is roughly 671 million miles per hour (1 billion kilometers per hour). This is roughly a million times faster than the speed of sound (which is about 761 miles per hour at sea level). The speed of light will be denoted as c in the equations that follow. We like to use "SI" units in science (length measured in meters, time in seconds, mass in kilograms):

$$c = 3 \times 10^8 \text{ meter/second}$$

Under time varying conditions, Maxwell’s equations predict the radiation of EM energy from current source (or accelerated charge). This happens at all frequencies, but is insignificant as long as the size of the source region is not comparable to the wavelength. While transmission lines are designed to minimize this radiation loss, radiation into free space becomes main purpose in case ofAntennas. The basic principle of radiation is produced by accelerated charge. The basic equation of radiation is

$$I L = Q V \, (Ams^{-1})$$

where,

I = Time changing current in Amps/sec

L = Length of the current element in meters

Q = Charge in Coulombs

V = Time changing velocity

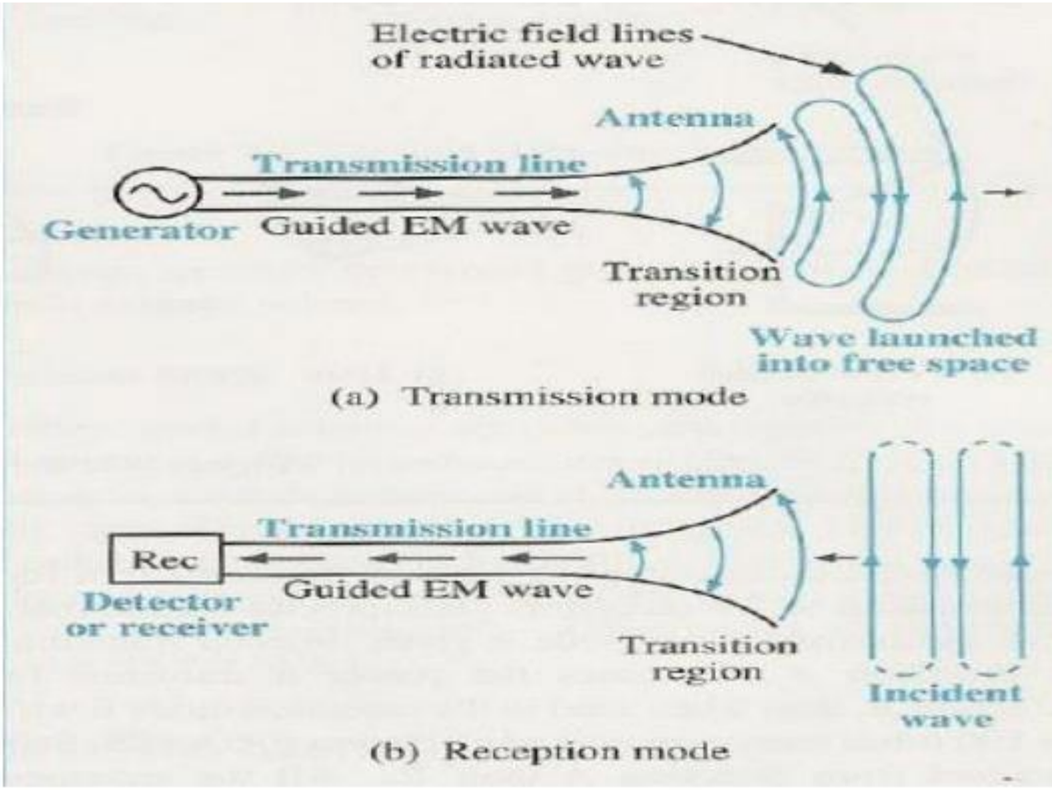
Thus time changing current radiates and accelerated charge radiates. For steady state harmonic variation, usually we focus on time changing current. For transients or pulses, we focus on accelerated charge. The radiation is perpendicular to the acceleration and the radiated power is proportional to the square of IL or QV.

**Transmission line opened out in a Tapered fashion as Antenna:** a).

**As Transmitting Antenna:**

Here the Transmission Line is connected to source or generator at one end. Along the uniform part of the line energy is guided as Plane TEM wave with little loss. Spacing between line is a small fraction of λ. As the line is opened out and the separation between the two lines becomes comparable to λ, it acts like an antenna and launches a free space wave since currents on the transmission line flow out on the antenna but fields associated with them keep on going. From the circuit point of view the antennas appear to the transmission lines as a resistance Rr , called Radiation resistance. b) **As Receiving Antenna:**

Active radiation by other Antenna or Passive radiation from distant objects raises the apparent temperature of Rr .This has nothing to do with the physical temperature of the antenna itself but is related to the temperature of distant objects that the antenna is looking at. Rr may be thought of as virtual resistance that does not exist physically but is a quantity coupling the antenna to distant regions of space via a virtual transmission line.



(a) Transmission mode

(b) Reception mode

Thus, an antenna is a transition device, or transducer, between a guided wave and a free space wave or vice versa. The antenna is a device which interfaces a circuit and space.

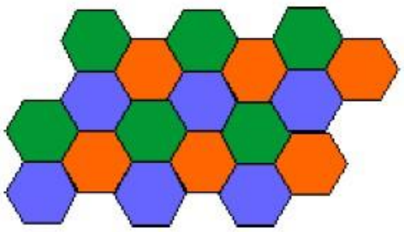
# MODULE 6

## MOBILE COMMUNICATION

### Concepts of cells and Frequency reuse

In the cellular concept, frequencies allocated to the service are re-used in a regular pattern of areas, called 'cells', each covered by one base station. In mobile-telephone nets these cells are usually hexagonal. In radio broadcasting, a similar concept has been developed based on rhombic cells.

To ensure that the mutual interference between users remains below a harmful level, adjacent cells use different frequencies. In fact, a set of $C$ different frequencies $\{f_1, ..., f_C\}$ are used for each cluster of $C$ adjacent cells. Cluster patterns and the corresponding frequencies are re-used in a regular pattern over the entire service area.

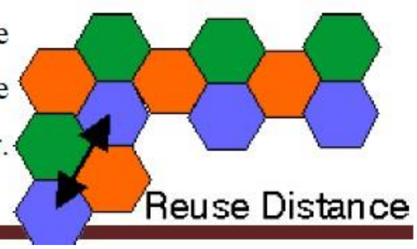


**Real-World Cells**

In the practice of cell planning, cells are not hexagonal as in the theoretical studies. Computer methods are being used for optimised planning of base station location and cell frequencies. Pathloss and link budgets are computed from the terrain features and antenna data. This determines to coverage of each base station and interference to other cells

**Reuse Distance**

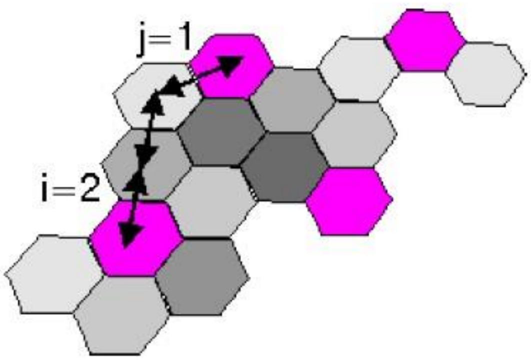
The closest distance between the centres of two cells using the same frequency (in different clusters) is determined by the choice of the cluster size $C$ and the lay-out of the cell cluster.




This distance is called the frequency 're-use' distance. It can be shown that the reuse distance $r_u$, normalised to the size of each hexagon, is

$r_u = \text{SQRT}\{3\ C\}$

For hexagonal cells, i.e., with 'honeycomb' cell lay-outs commonly used in mobile radio, possible cluster sizes are $C = i^2 + ij + j^2$, with integer $i$ and $j$ ($C$ = 1, 3, 4, 7, 9, ...). Integers $i$ and $j$ determine the relative location of co-channel cells.

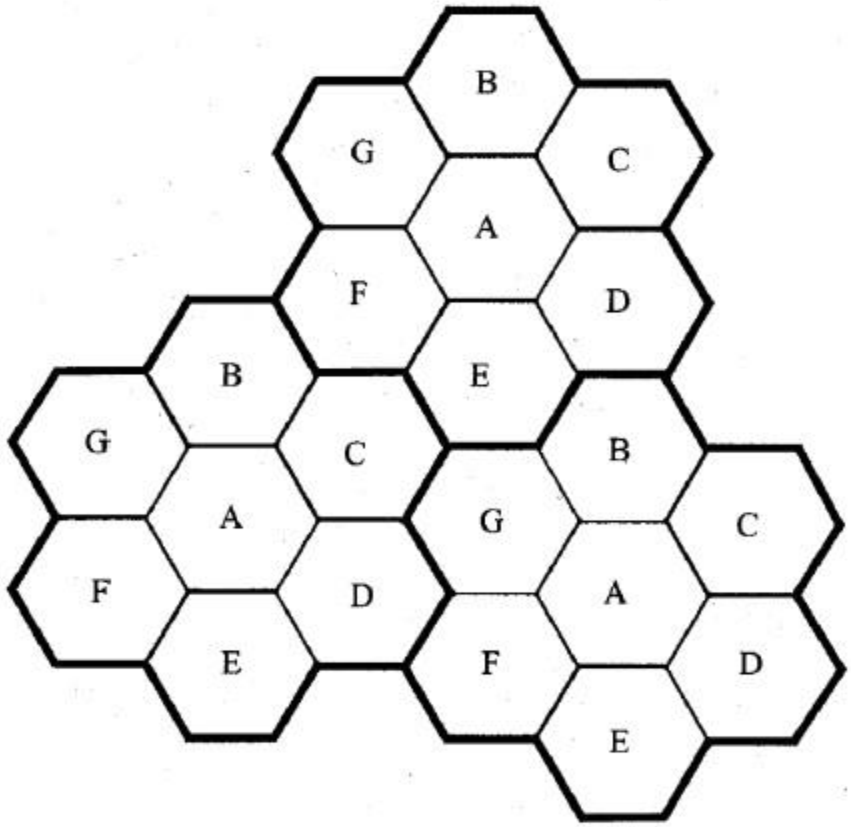



**Cells**

A cell is the basic geographic unit of a cellular system The term  cellular comes from the honeycomb shape of the areas into which a coverage region is divided. Cells are base stations transmitting over small geographic areas that are represented as hexagons. Each cell size varies depending on the landscape. Because of constraints imposed by natural terrain and man-made structures, the true shape of cells is not a perfect hexagon.

**Clusters**

A cluster is a group of cells. No channels are reused within a cluster.

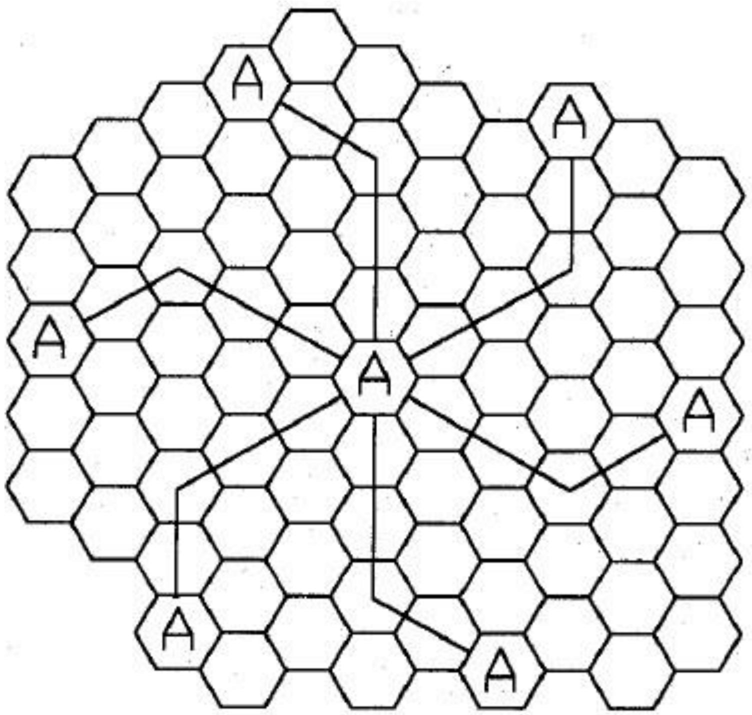



- seven groups of channel from A to G
- footprint of a cell - actual radio coverage
- omni-directional antenna v.s. directional antenna

**Frequency Reuse**

Because only a small number of radio channel frequencies were available for mobile systems, engineers had to find a way to reuse radio channels in order to carry more than one conversation at a time. The solution the industry adopted was called frequency planning or frequency reuse. Frequency reuse was implemented by restructuring the mobile telephone system architecture into the cellular concept The concept of frequency reuse is based on assigning to each cell a group of radio channels used within a small geographic area. Cells are assigned a group of channels that is completely different from neighboring cells. The coverage area of cells are called the footprint. This footprint is limited by a boundary so that the same group of channels can be used in different cells that are far enough away from each other so that their frequencies do not interfere.

- Consider a cellular system which has a total of *S* duplex channels.
- Each cell is allocated a group of *k* channels,
- The *S* channels are divided among *N* cells.
- The total number of available radio channels
- The *N* cells which use the complete set of channels is called *cluster*.
- The cluster can be repeated *M* times within the system. The total number of channels, *C*, is used as a measure of capacity
- The capacity is directly proportional to the number of replication *M*.
- The cluster size, *N*, is typically equal to 4, 7, or 12.
- Small *N* is desirable to maximize capacity.
- The frequency reuse factor is given by
- Hexagonal geometry has
    - exactly six equidistance neighbors
    - the lines joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees.
- Only certain cluster sizes and cell layout are possible.
- The number of cells per cluster, *N*, can only have values which satisfy
- Co-channel neighbors of a particular cell, ex, $i=3$ and $j=2$.

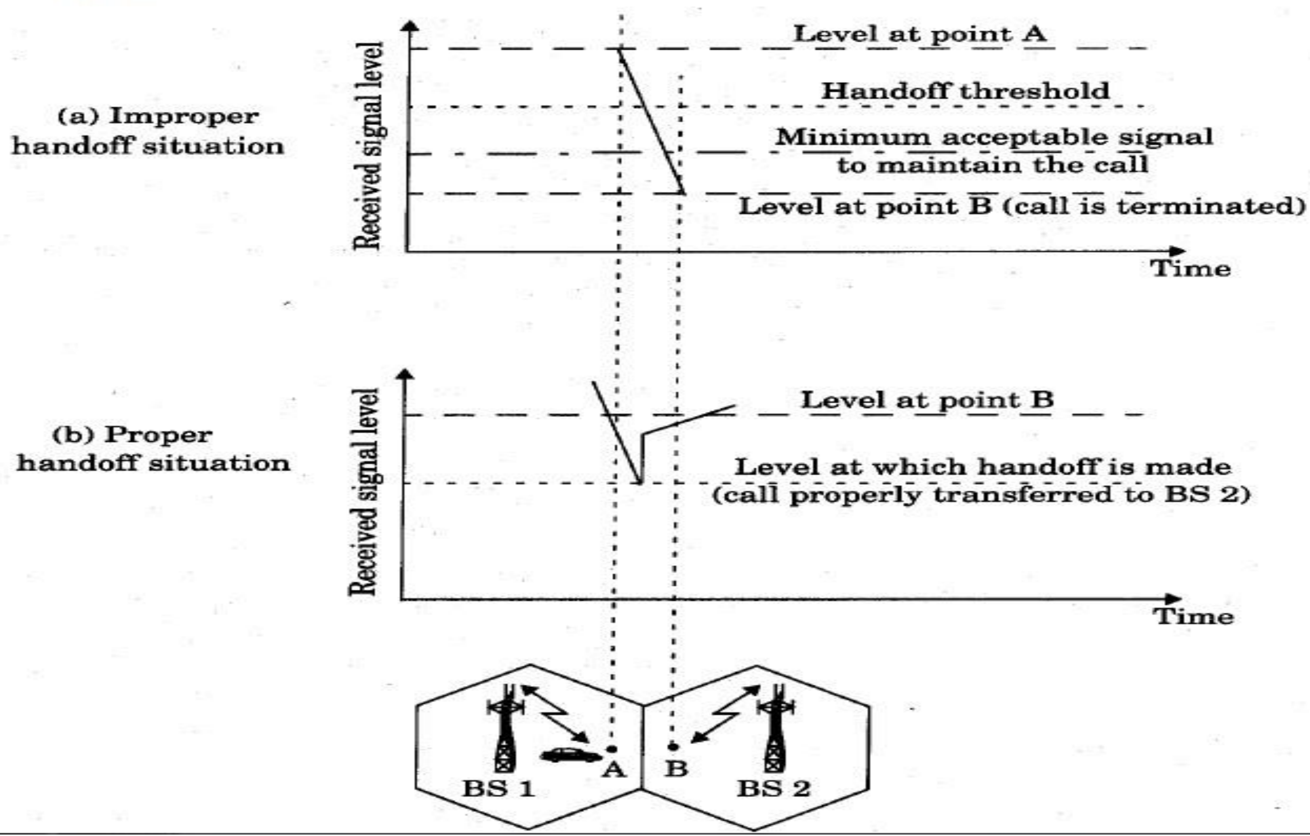



**Cell Splitting**

Unfortunately, economic considerations made the concept of creating full systems with many small areas impractical. To overcome this difficulty, system operators developed the idea of cell splitting. As a service area becomes full of users, this approach is used to split a single area into smaller ones. In this way, urban centers can be split into as many areas as necessary in order to provide acceptable service levels in heavy-traffic regions, while larger, less expensive cells can be used to cover remote rural regions Handoff The final obstacle in the development of the cellular network involved the problem created when a mobile subscriber traveled from one cell to another during a call. As adjacent areas do not use the same radio channels, a call must either be dropped or transferred from one radio channel to another when a user crosses the line between adjacent cells. Because dropping the call is unacceptable, the process of handoff was created. Handoff occurs when the mobile telephone network automatically transfers a call from radio channel to radio channel as A mobile crosses adjacent cells During a call, two parties are on one voice channel. When the mobile unit moves out of the coverage area of a given cell site, the reception becomes weak. At this point, the cell site in use requests a handoff. The system switches the call to a stronger-frequency channel in a new site without interrupting the call or alerting the user. The call continues as long as the user is talking, and the user does not notice the handoff at all

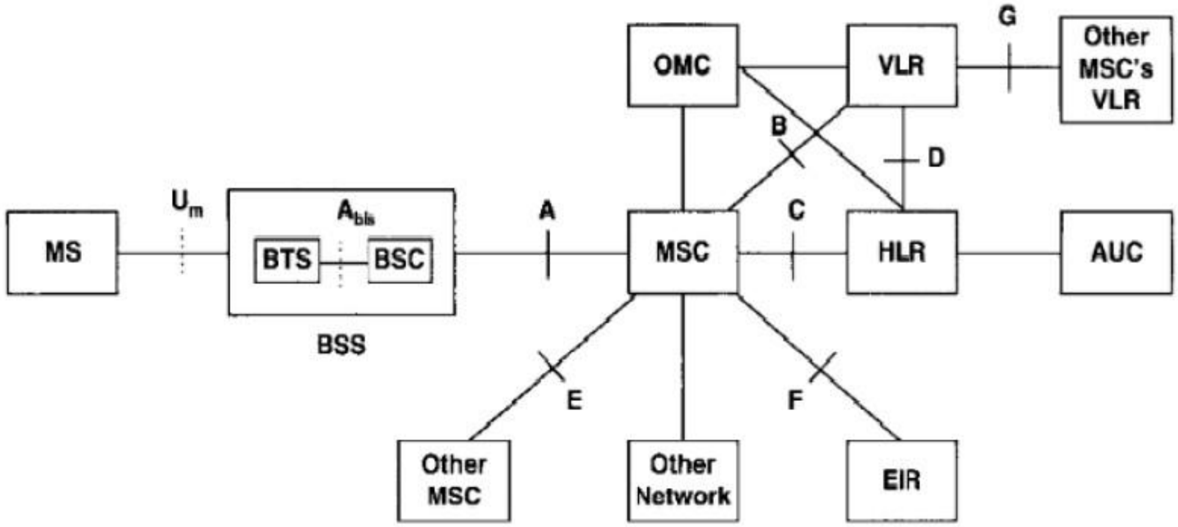
- When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.
- Handoff operation
  - identifying a new base station
  - re-allocating the voice and control channels with the new base station.
- Handoff Threshold
  - Minimum usable signal for acceptable voice quality (-90dBm to -100dBm)
  - Handoff margin cannot be too large or too small.
  - If is too large, unnecessary handoffs burden the MSC

– If too small, there may be insufficient time to complete handoff before a call is lost.



- Handoff must ensure that the drop in the measured signal is not due to momentary fading and that the mobile is actually moving away from the serving base station.
- Running average measurement of signal strength should be optimized so that unnecessary handoffs are avoided.
  - Depends on the speed at which the vehicle is moving.
  - Steep short term average -> the hand off should be made quickly
  - The speed can be estimated from the statistics of the received short-term fading signal at the base station
- Dwell time: the time over which a call may be maintained within a cell without handoff.
- Dwell time depends on
  - propagation
  - interference
  - distance
  - speed
- Handoff measurement
  - In first generation analog cellular systems, signal strength measurements are made by the base station and supervised by the MSC.
  - In second generation systems (TDMA), handoff decisions are mobile assisted, called mobile assisted handoff (MAHO)
- Intersystem handoff: If a mobile moves from one cellular system to a different cellular system controlled by a different MSC.
- Handoff requests is much important than handling a new call.

## Block diagram of GSM

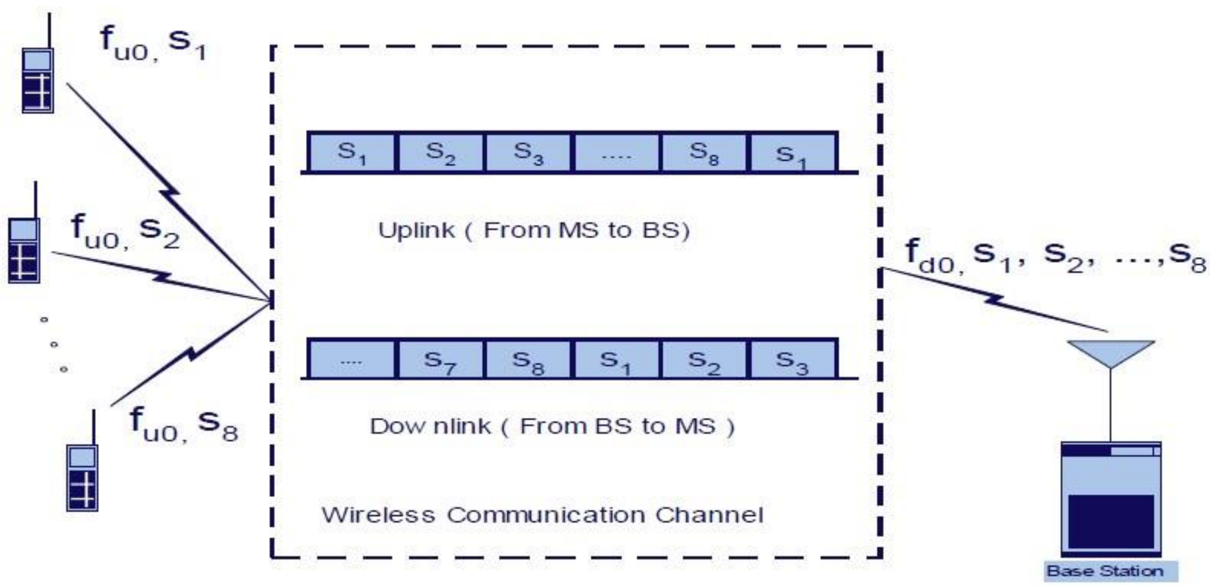



- MS: Mobile Station
- BSS: Base Station Subsystem
- BTS: Base Transceiver Station
- BSC: Base Station Controller
- MSC: Mobile Service Switching Center
- OMC: Operations and Maintenance Center
- HLR: Home Location Register
- VLR: Visitor Location Register

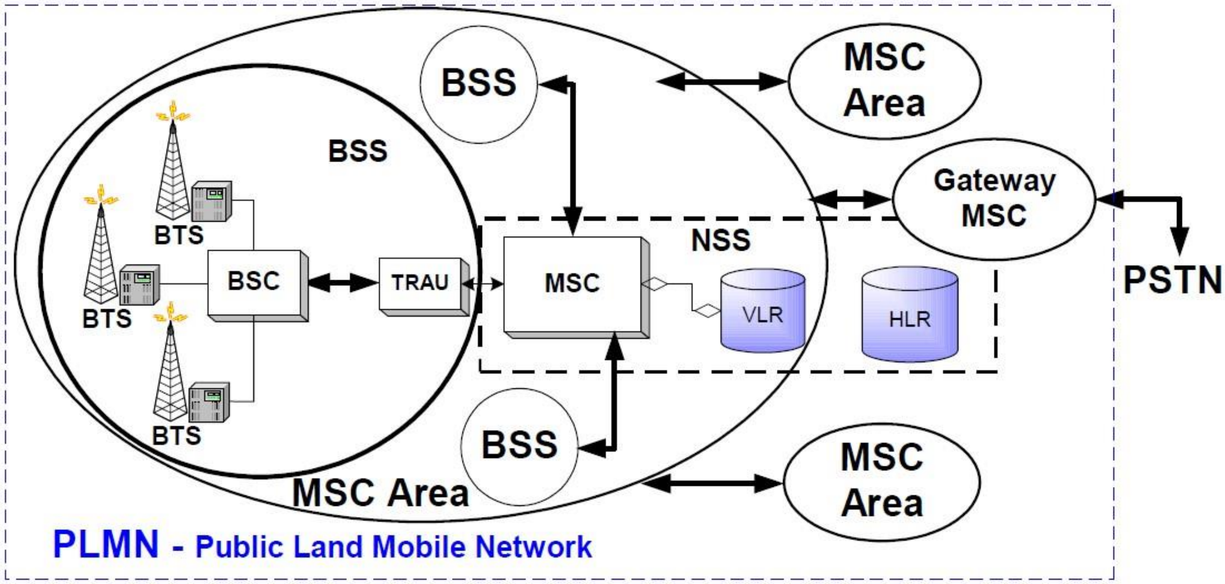
- GSM system layout is standardized
    - Standardization involves:
        - Elements of the network
        - Communication Interfaces
    - Standard layout allows for the use of equipment from different suppliers
    - Two functional parts
    - HW and SW specific for GSM radio interface
    - Subscriber Identity Module (SIM)
    - SIM – detaches user identity from the mobile
    - Stores user information
    - Without SIM – only emergency calls
- BSC plays a role of a small digital exchange.
- It can be connected to many BTSs and it offloads a great deal of processing from MSC
- One BSC connects to several tens to couple of hundred BTS
- Some of BSC responsibilities:
    - Handoff management
    - MAHO management
    - Power control
    - Clock distribution
    - Operation and maintenance
- TRAU is responsible for transcoding the user data from 16Kb/sec to standard ISDN rates of 64Kb/sec.
- It can physically reside on either BSC side or MSC side.
- If it resides on the MSC side, it provides substantial changes in the backhaul – 4 users over a single T-1/E-1 TDMA channel.
- TRAU, BSC and BTSs form Base Station Subsystem (BSS

- Responsible for connecting the mobile to the landline side
- GSM MSC is commonly designed as a regular ISDN switch with some added functionality for mobility support
- GSM Network can have more than one MSC
- One of the MSC has an added functionality for communication with public network – Gateway MSC (GMSC)
- All calls from the "outside networks" are routed through GMSC

**TDMA Access Scheme**




- Multiple users operate on the same frequency, but not at the same time.
- Advantages of TDMA:
  - Relatively low complexity
  - MAHO
  - Different user rates can be accommodated
  - Easier integration with the landline
- Disadvantages:
  - High sync overhead
  - Guard times
  - Heavily affected by the multipath propagation



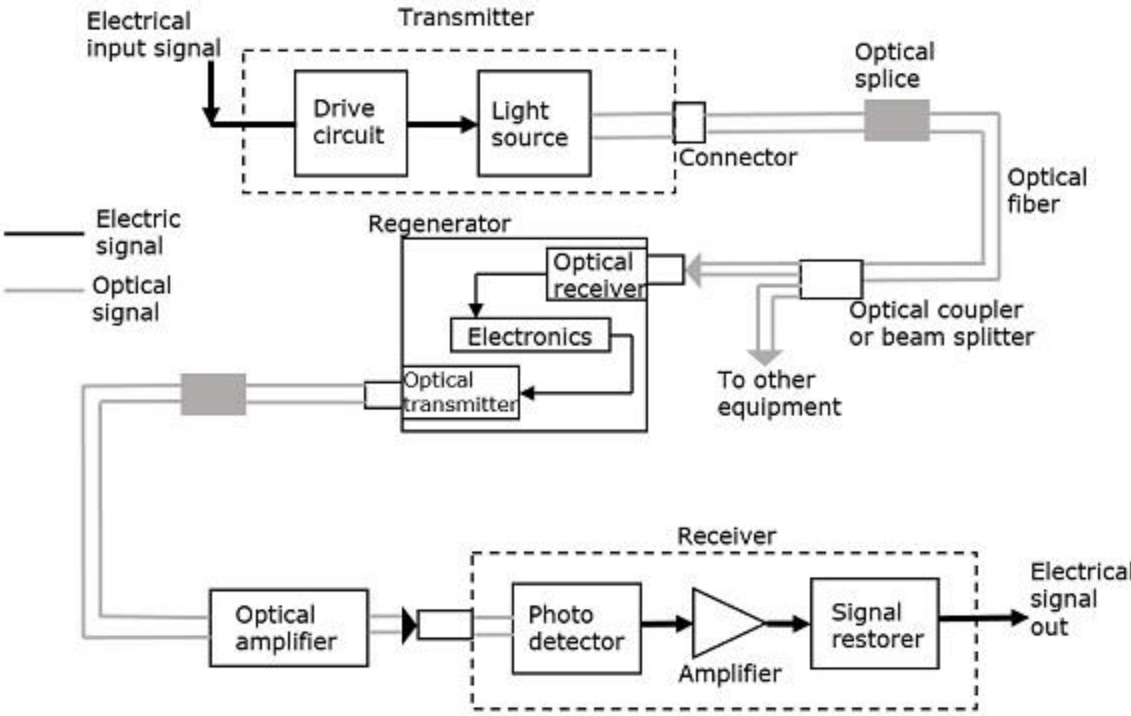

**CONTENT BEYOND THE SYLLABUS**

**Types of Antenna**

Some Antenna Types:
Wire Antennas- dipoles, loops and Helical
Aperture Antennas-Horns and reflectors
Array Antennas-Yagi, Log
periodic Patch Antennas-
Microstrips, PIFAs Basic
Antenna Parameters:
A **radio antenna** may be defined as the structure associated with the region of transition between a guided wave and a free space wave or vice versa.

## Optical Fiber Communications

The communication system of fiber optics is well understood by studying the parts and sections of it. The major elements of an optical fiber communication system are shown in the following figure.




The basic components are light signal transmitter, the optical fiber, and the photo detecting receiver. The additional elements such as fiber and cable splicers and connectors, regenerators, beam splitters, and optical amplifiers are employed to improve the performance of the communication system.

### Functional Advantages

The functional advantages of optical fibers are −

- The transmission bandwidth of the fiber optic cables is higher than the metal cables.
- The amount of data transmission is higher in fiber optic cables.
- The power loss is very low and hence helpful in long-distance transmissions.
- Fiber optic cables provide high security and cannot be tapped.
- Fiber optic cables are the most secure way for data transmission.
- Fiber optic cables are immune to electromagnetic interference.
- These are not affected by electrical noise.

### Physical Advantages

The physical advantages of fiber optic cables are −

- The capacity of these cables is much higher than copper wire cables.

- Though the capacity is higher, the size of the cable doesn’t increase like it does in copper wire cabling system.
- The space occupied by these cables is much less.
- The weight of these FOC cables is much lighter than the copper ones.
- Since these cables are di-electric, no spark hazards are present.
- These cables are more corrosion resistant than copper cables, as they are bent easily and are flexible.
- The raw material for the manufacture of fiber optic cables is glass, which is cheaper than copper.
- Fiber optic cables last longer than copper cables.

### Disadvantages

Although fiber optics offer many advantages, they have the following drawbacks −

- Though fiber optic cables last longer, the installation cost is high.
- The number of repeaters are to be increased with distance.
- They are fragile if not enclosed in a plastic sheath. Hence, more protection is needed than copper ones.

### Applications of Fiber Optics

The optical fibers have many applications. Some of them are as follows −

- Used in telephone systems
- Used in sub-marine cable networks
- Used in data link for computer networks, CATV Systems
- Used in CCTV surveillance cameras
- Used for connecting fire, police, and other emergency services.
- Used in hospitals, schools, and traffic management systems.
- They have many industrial uses and also used for in heavy duty constructions.

Cable television is a popular television system that delivers television programming services through cables. This is different from terrestrial television (where radio waves are transmitted over air and received by antennas) and satellite television (where signals are sent by communication satellites and received by satellite dish).

## Types of cables used in cable TV

- coaxial cables through which radio-frequency signals are transmitted
- fiber optic cables through which light pulses are sent

## Services offered by Cable TV

Originally used for broadcasting television services, the functionalities of cable TV has now been extended for providing different services of computer networks as well.

Some of the most predominant services of cable TV are −

- Standard television services
- FM programming
- Cable Internet
- Telephone services
- **Closed-circuit television** (**CCTV**), also known as **video surveillance**,[1][2] is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted, though it may employ point-to-point (P2P), point-to-multipoint (P2MP), or mesh wired or wireless links. Even though almost all video cameras fit this definition, the term is most often applied to those used for surveillance in areas that require additional security or ongoing monitoring. On another note, videotelephony is seldom called "CCTV" which is one exception to the use of video in distance education, where it is an important tool.[3][4]
- Surveillance of the public using CCTV is common in many areas around the world. In recent years, the use of body worn video cameras has been introduced as a new form of surveillance, often used in law enforcement, with cameras located on a police officer's chest or head.[5] Video surveillance has generated significant debate about balancing its use with individuals' right to privacy even when in public.[6][7][8]
- In industrial plants, CCTV equipment may be used to observe parts of a process from a central control room, for example when the environment is not suitable for humans. CCTV systems may operate continuously or only as required to monitor a particular event. A more advanced form of CCTV, using digital video recorders (DVRs), provides recording for possibly many years, with a variety of quality and performance options and extra features (such as motion detection and email alerts). More recently, decentralized IP cameras, perhaps equipped with megapixel sensors, support recording directly to network-attached storage devices, or internal flash for completely stand-alone operation.
- By one estimate, there will be approximately 1 billion surveillance cameras in use worldwide by 2021.[9] About 65% of these cameras are installed in Asia. The growth of CCTV has been slowing in recent years.[10] The deployment of this technology has facilitated significant growth in state surveillance, a substantial rise in the methods of advanced social monitoring and control, and a host of crime prevention measures throughout the world.[11]

DTH Technology or (Direct To Home) Technology has acquired a key position in TV broadcasting industry in the last decade. This article will discuss DTH (Direct To Home) Technology, its architecture, components, how it works and its advantages over conventional cable TV services.

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## What is DTH Technology

DTH stands for **D**irect-**T**o-**H**ome. Direct-To-Home service is a digital satellite service that provides television services direct to home with a personal dish. Local cable operators are not required in DTH and puts the broadcaster directly in touch with the consumer.

Direct to Home Technology provides better picture and sound quality. It also offers services like internet access, video conferencing and email. HDTV (High Definition TV) and 3D TV are the enhanced features of this Technology. It also has options to record/rewind/pause live TV.


**Fig. 1 – Introduction to DTH (Direct To Home) Technology**

## Components of DTH Technology

DTH (Direct to Home) System consists of the following components:

- Dish Antenna
- LNBF (Low Noise Block Down Converter plus Feedhorn)
- Coaxial Cable
- Set Top Box

## Dish Antenna

It is a Parabolic Reflector. It receives the signal and redirects it to the LNBF which works as receiver for signal transmitted by satellite Parabolic Reflector.

## LNBF (Low Noise Block Down Converter Feedhorn)

Small metal horn antenna on the Dish is called as Feedhorn. It collects the signal from dish and amplifies the signal bouncing off the dish and filters out the noise (signals not carrying programming).

## Coaxial Cable

It is the Cable that connects mini Dish and Set Top Box.

## DTH Set Top Box

DTH Set Top Box, unlike the regular cable connection, decodes the encrypted transmission data and converts these signals into audio & video signal.

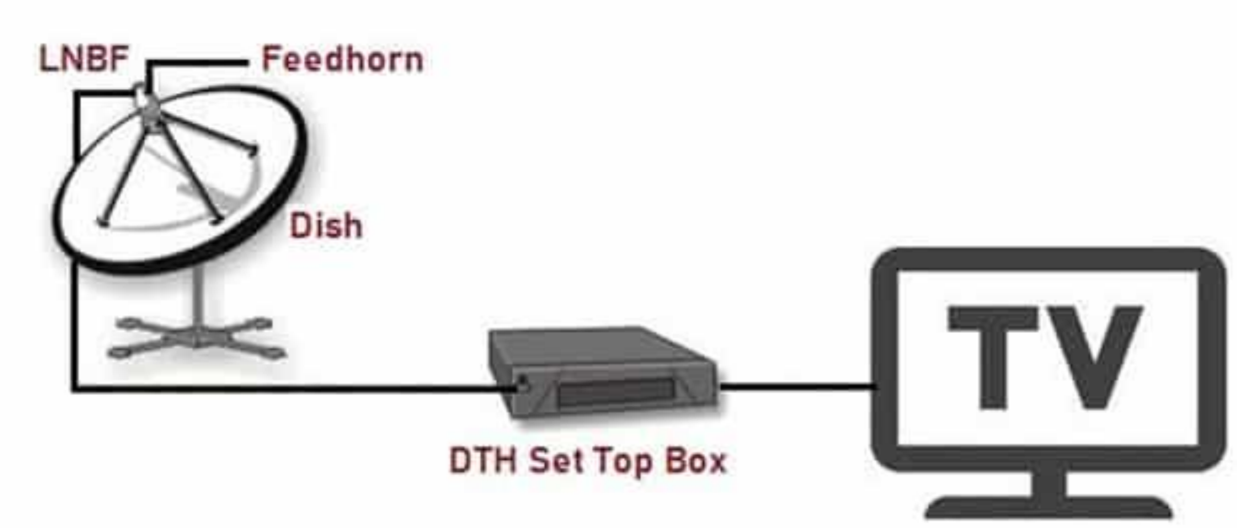


**Fig. 2 – Components of DTH System**

### Architecture of Direct To Home Technology

The architecture of Direct to Home System includes:

- Satellite
- Broadcasting Centre
- Multiplexer
- Modulator
- Encoder
- DTH Receiver

## Satellite

A Geo-Stationary Satellite plays an important role in Direct To Home system. Satellites have a much larger “line of sight” range as they are higher in the sky than TV antennas. It transmits the signals to the DTH Antenna.

## Broadcasting Centre

The Broadcast Centre is the central hub of the system. The television provider receives signals here from various programming sources and then beams a broadcast signal to satellites which are in Geostationary orbit. The satellites receive the signals from the broadcasting station and rebroadcast them to the ground.

## Multiplexer

Multiplexer is a device which transmits the information of many channels in one channel. It is a part of the broadcasting centre. In the Broadcasting Centre, the Multiplexer compresses all the frequency signals into one single channel & transmits it to the Geo-Stationary satellite. It sends the single channel to the Modulator.

## Modulator

Modulation is a process in which the information signal is imposed on a carrier signal which is of high strength. The Modulator modulates the signals and sends to the Encoder.

## Encoder

The Encoder encodes the signals to transmit the signals. The satellite sends the signals to the DTH Antenna which further transmits them to the Set Top Box.

## DTH Receiver

Receiver is the end component in the entire DTH System. It decodes or descrambles the encrypted signal. For unlocking signal, it needs the proper decoder chip for that programming package. The service provider can communicate with that chip with the help of satellite signal to make required operations to its decoding program.

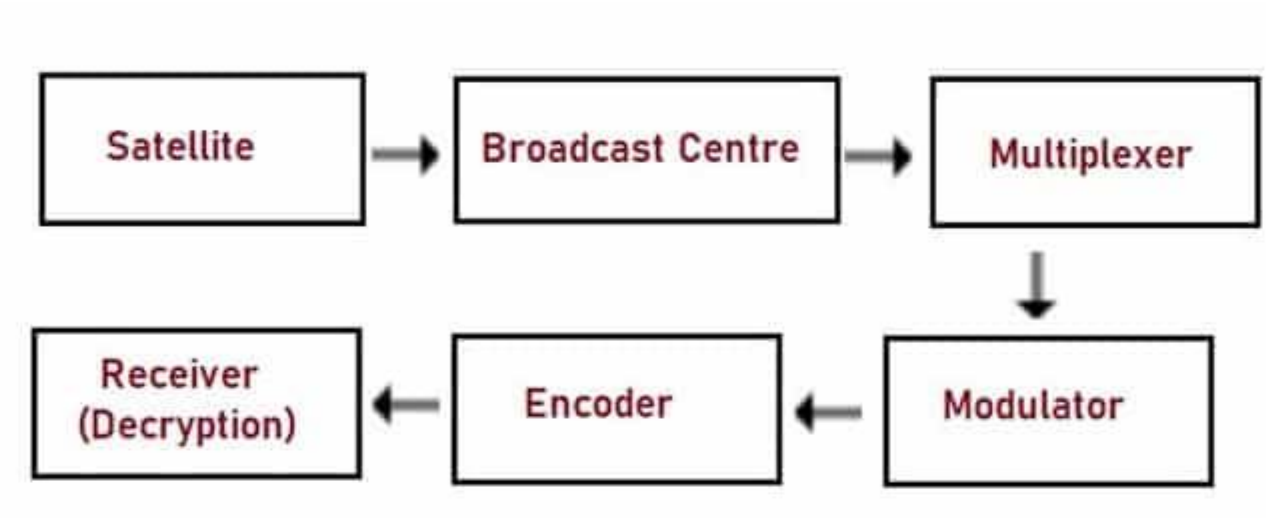


**Fig. 3 – Basic Architecture of DTH Technology System**

## How does Direct To Home (DTH) Technology Work

The Satellites which are located approximately 35700 km above the Earth's surface transmits signals to the Broadcast stations on the Earth's Surface. The Broadcast Centre receives the signals and Transponder on the satellite helps in establishing Communication channel between Transmitting and Receiving Units. Satellite rebroadcasts the signals which are encoded.

The Encoder converts the data, audio and video signals into the digital format and these signals are muxed or combined by the multiplexer. There will be a small Dish Antenna and Set Top Box at the user end to Receive, Decode and view numerous channels.

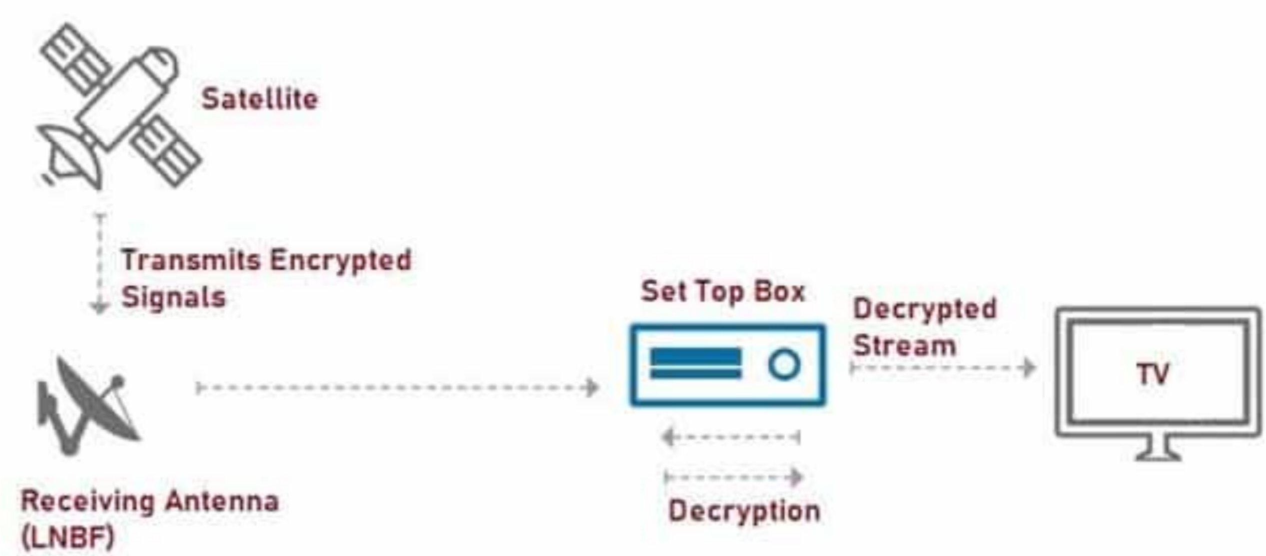


**Fig. 4 – Schematic Representation of Working Principle**

### Advantages of DTH Technology

The advantages of DTH Technology include:

- Greater service coverage.
- More channels.
- Better signal quality.
- Multiple language options.
- Pay only for the channels and services that the user wants.
- Applications such as Parental Lock, Pre-booked Pay-Per-View and Impulse Pay-Per-View.

### Disadvantages of DTH Technology

The disadvantages of DTH Technology include:

- One of the major problems for the subscribers of Direct To Home service is unable to view any channel during heavy rains due to weak signals.
- Changing service provider is not easy as the user has to pay additional cost to buy new Set Top Box from new service provider.

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