NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF MECHATRONICS ENGINEERING

COURSE MATERIALS

EC100 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: 2013
- Course offered: B.Tech Mechatronics Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

To develop professionally ethical and socially responsible Mechatronics engineers to serve the humanity through quality professional education.

DEPARTMENT MISSION

1) The department is committed to impart the right blend of knowledge and quality education to create professionally ethical and socially responsible graduates.

2) The department is committed to impart the awareness to meet the current challenges in technology.

3) Establish state-of-the-art laboratories to promote practical knowledge of mechatronics to meet the needs of the society

PROGRAMME EDUCATIONAL OBJECTIVES

I. Graduates shall have the ability to work in multidisciplinary environment with good professional and commitment.

II. Graduates shall have the ability to solve the complex engineering problems by applying electrical, mechanical, electronics and computer knowledge and engage in lifelong learning in their profession.

III. Graduates shall have the ability to lead and contribute in a team with entrepreneur skills, professional, social and ethical responsibilities.

IV. Graduates shall have ability to acquire scientific and engineering fundamentals necessary for higher studies and research.

PROGRAM OUTCOME (PO’S)

Engineering Graduates will be able to:

PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 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.

PO 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.

PO 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.

PO 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.

PO 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.

PO 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.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 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.

PO 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.

PO 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 OUTCOME(PSO’S)

PSO 1: Design and develop Mechatronics systems to solve the complex engineering problem by integrating electronics, mechanical and control systems.

PSO 2: Apply the engineering knowledge to conduct investigations of complex engineering problem related to instrumentation, control, automation, robotics and provide solutions.

COURSE OUTCOME

After the completion of the course the student will be able to

C110.1	Interpret the basic components of electronics
C110.2	Describe the working and characteristics of different diodes and BJT
C110.3	Recognize the working of rectifiers, power supplies, amplifiers and oscillators
C110.4	Identify analogue IC, Digital IC and Electronic instrumentation system.
C110.5	Explain the concepts in radio communication and satellite communication
C110.6	Define mobile communication,optical communication and entertainment electronics technology.

CO VS PO'S AND PSO'S MAPPING

CO	PO1	PO 2	PO3	PO 4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS0 1	PSO 2
C110. 1	3	2	-	3	-	-	-	-	-	-	-	2	2	1
C110. 2	3	-	-	3	-	-	-	-	-	-	-	2	2	1
C110. 3	3	2		3	-	-	-	-	-	-	-	2	2	1
C110. 4	3	2	3	3	-	-	-	-	-	-	-	2	2	1
C110. 5	3	-	3	3	-	-	-	-	-	-	-	2	2	1
C110. 6	3	-	3	3	-	-	-	-	-	-	-	2	2	1

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

SYLLABUS

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	

	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 I

Q:NO:	QUESTIONS	CO	KL
1	Give a brief description about types of resistors.	CO1	K2
2	Give a brief description about types of capacitors.	CO1	K1
3	Give a brief description about types of inductors.	CO1	K2
4	Explain about different types of transformers.	CO1	K2
5	Discuss about construction and working of relays and contactors.	CO1	K2
6	Explain the colour coding of the resistors.	CO1	K5
7	Differentiate active and passive components.	CO1	K5
8	Explain about step up transformer.	CO1	K5
9	Explain about step down transformer.	CO1	K2
10	Explain the colour coding of the capacitors.	CO1	K1

MODULE II

1	Draw and explain the VI characteristics of a PN junction diode.	CO2	K2
2	What is the working principle of solar cell?	CO2	K1
3	Explain the operation of zener diode.	CO2	K1
4	Draw and explain the input and output characteristics of CE BJT configuration.	CO2	K2
5	Discuss about the structure and operation of	CO2	K2

	PNP transistor.			
6	Discuss about the structure and operation of NPN transistor.	CO2	K3	
7	Differentiate zener and avalanche breakdown.	CO2	K2	
8	What is the working principle of photo diode?	CO2	K2	

MODULE III

1	Give a brief comparison and description about various rectifier circuit.	CO3	K2	
2	What is SMPS?	CO3	K1	
3	How zener diode can be used as a voltage regulator?	CO3	K5	
4	Explain the operation for capacitor filter for full wave and half wave rectifier.	CO3	K5	
5	Explain the block diagram of Public address system.	CO3	K5	
6	With a neat circuit diagram explain the operation of common emitter amplifier.	CO3	K5	
7	With a neat circuit diagram explain the operation of RC phase shift oscillator.	CO3	K4	
8	Discuss about the concept of feedback. What are the various types of feedback circuit.	CO3	K4	

MODULE IV

1	Give block diagram description of op-amp.	CO4	K2	
2	What are the characteristics of ideal op-amp?	CO4	K6	
3	Draw and explain any 3 opamp circuits.	CO4	K2	
4	Give logic symbol and truth table of various logic gates.	CO4	K1	
5	Explain the principle of operation of digital	CO4	K5	

	multimeter with a neat block diagram.			
6	Explain the principle of operation of DSO with a neat block diagram.	CO4	K2	
7	Explain the principle of operation of function generator with a neat block diagram.	CO4	K4	
8	What is Universal logic gates?	CO4	K2	

MODULE V

1	Explain the principle of AM and FM.	CO5	K4	
2	What are the various frequency band used for communication?	CO5	K5	
3	With a neat block diagram explain the operation of super heterodyne receiver.	CO5	K6	
4	What is a pulsed radar. Draw the block diagram.	CO5	K2	
5	Discuss about the operation of satellite transponder.	CO5	K6	
6	How does GPS work?	CO5	K6	
7	Differentiate between AM & FM.	CO5	K6	
8	Give an introduction to communication.	CO5	K6	

MODULE VI

1	Explain the concept of Cell splitting and frequency reuse in mobile communication.	CO6	K5	

2	Give the block diagram description of GSM.	CO6	K6	
3	Give the block diagram description of optical communication system.	CO3	K3	
4	Explain the principle of propagation of light through optical fibre.	CO6	K2	
5	What are the advantages of optical communication system?	CO6	K6	
6	Write short note on cable TV	CO6	K6	
7	Write short note on CCTV	CO6	K6	
8	Write short note on DTH	CO6	K2	
9	Write short note on (a) HDTV (b) Plasma LCD (c) LED TV	CO6	K2	

APPENDIX 1

CONTENT BEYOND THE SYLLABUS

S:NO	TOPIC
1	COUNTERS
2	REGISTERS

CHAPTER 1

INTRODUCTION TO ELECTRONICS

The electronic devices and their usages have influenced our daily life in such a way that it is impossible to spend even a few hours without them. Right from the beginning of the day till the time we go to bed, we use a large number of electronic gadgets to simplify our work and to solve our problems. From small alarm watches to the complex computers, from mobile to the camcorders, from kitchen to toilet, from bedroom to office, everywhere electronic items can be seen. It seems that they are omnipresent.

Why have we become so dependent on electronics? The answer is very simple. They simplify our daily activities and lifestyle. Let us take the example of mobile phone. It has changed the definition of communication. In the beginning of the history of telephone system, no one would have imagined a combination of 'talking and walking.' The invention of mobile phones has made talking while walking possible.

CD drives, DVD players, record players, stereos and tape recorders are the result of the advancement in electronic technology in the last few decades. With the use of headphones, music can be heard without disturbing the people nearby.

The introduction of electronic technology in cameras has completely changed the history of photography. A digital camera is now available at an affordable price. The cell phones now include a fairly sophisticated digital camera that can capture still pictures and even video pictures. The videos and pictures can be easily transferred to a computer, where they can be saved, shared on internet or printed out in hard form. Such pictures taken from a camera can be edited, cropped, enhanced or enlarged easily with the help of electronics.

Even our kitchens are equipped with electronic equipment, from water coolers to microwave ovens. Doctors and scientists have found new uses of electronic systems in the diagnosis and treatment of various diseases. Equipment such as MRI, CT and the X-rays rely on electronics in order to do their work quickly and accurately.

WHAT IS ELECTRONICS?

Electronics can be defined as the branch of science and engineering which deals with the controlled flow of electrons through vacuum, gas or semiconductors.

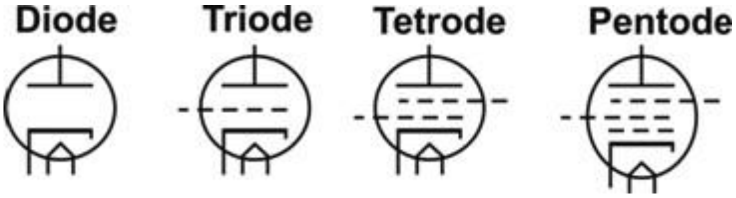
Compared to the more established branches of engineering - civil, mechanical and electrical, electronics is a newcomer. Until around 1960, it was considered as an integral part of electrical engineering. But due to the tremendous advancement over the last few decades, electronics has now gained its own place. The advancement has been so fast that many sub-branches of electronics - such as Computer Science Engineering, Communication Engineering, Control and Instrumentation Engineering and Information Technology - are now full-fledged courses in many universities.

HISTORY OF ELECTRONICS

Invention of Vacuum Tubes

Electronics took birth in 1897 when J.A. Fleming developed a vacuum diode. Useful electronics came in 1906 when vacuum triode was invented by Lee De Forest. This device could amplify electrical signals. Later, around 1925, tetrode and pentode vacuum tubes were developed. These tubes dominated the field of electronics till the end of World War II.

A vacuum tube, electron tube or thermionic valve is a device controlling electric current through a vacuum in a sealed container. The container is often made with thin transparent glass in a roughly cylindrical shape. The simplest vacuum tube, the diode, is similar to an incandescent light bulb with an added electrode inside. When the bulb's filament is heated red-hot, electrons leave its surface
into the vacuum inside the bulb. If the electrode-called a "plate" or "anode"-is made more positive than the hot filament, a direct current flows through the vacuum to the electrode. As the current flows only in one direction, it is possible to convert an alternating current applied to the filament to direct current. As electrodes are added, these devices can be used for various other applications. Tubes with three electrodes are known as triodes, that with four as tetrodes and five as pentodes.



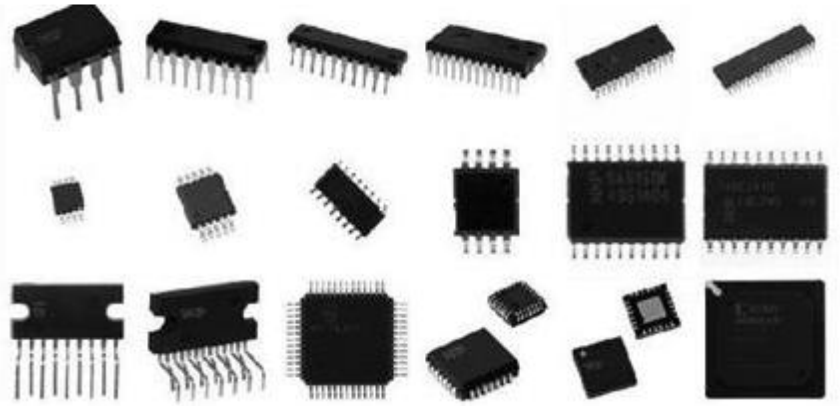
Invention of Transistor

The era of semiconductor electronics began the invention of the junction transistor in 1948 at Bell Laboratories. Soon, the transistors replaced the bulky vacuum tubes in different electronic circuits. The tubes had major limitations: power was consumed even when they were not in use and filaments burnt out, requiring frequent tube replacements. By now, vacuum tubes have become obsolete.
Earlier, the transistors were made of germanium, as it was easier to purify. In 1954, silicon transistors were developed. These afforded operations up to 200°C, whereas germanium device could work well only up to about 75°C. Today, almost all semiconductor devices are fabricated using silicon.

Invention of the Integrated Circuits (IC)

In 1958, Jack Kilby conceived the concept of building an entire electronic circuit on a single semiconductor chip. Later, all active and passive components and their interconnections could be integrated on a single chip. This drastically reduced the size and weight, as well as the cost of electronic equipment

The following approximate data give some indication of the increasing component count per chip of area 3 × 5 mm2 and thickness comparable with human hair.
1951 - Discrete transistors
1960 - Small-Scale Integration (SSI), fewer than 100 transistors.
1966 - Medium-Scale Integration (MSI), 100 to 1000 transistors.
1969 - Large-Scale Integration (LSI), 1000 to 10000 transistors.
1975 - Very-Large-Scale Integration (VLSI), more than 10000 transistors.
1994 - Ultra-large-scale integration (ULSI) more than 1 million transistors.
2012 - INTEL introduced a computer processor chip (62-Core Xeon Phi) containing 5,000,000,000 Transistors.



APPLICATIONS OF ELECTRONICS

Electronics plays an important role in almost every sphere of our life. Electronics has penetrated in every field from an ordinary wrist watch to super computers; from telephone repeaters buried deep under sea to the satellites far out in space; from the control of modern household appliances to the control of super tankers carrying cargo across the sea.

Communication and Entertainment

The progress of a nation depends upon the availability of cheaper and faster means of communication. The main application of electronics in the beginning was in the field of telephony and telegraphy. These utilize a pair of wires as communication channel. Later it was possible to transmit any message from one place to another without wires (wireless communication). Satellite communication has reduced the distance between people and places.

Sir Jagadish Chandra Bose (30 November 1858 - 23 November 1937) was a Bengali physicist, biologist, botanist, archaeologist, as well as an early writer of science fiction. He pioneered the investigation of radio and microwave optics, made very significant contributions to plant science and laid the foundations of experimental science in the Indian subcontinent.

Achievements of Sir J. C. Bose in the field of communication

- He invented the Mercury Coherer (together with the telephone receiver) used by Guglielmo Marconi to receive the radio signal in his first transatlantic radio communication over a distance of 2000 miles from Poldhu, UK to Newfoundland, St. Johns in December 1901.
- In 1895, he gave his first public demonstration of electromagnetic waves, using them to ring a bell remotely and to explode some gunpowder. He sent an electromagnetic wave across 75 feet passing through walls of the room and body of the Chairman, Lieutenant Governor of Bengal.
- He holds the first patent worldwide to detect EM waves using solid-state diode detector.
- He was a pioneer in the field of microwave devices.

Radio and TV broadcasting provide a means of both communication as well as entertainment. Electronic gadgets like tape recorders, music and video players, stereo systems, public address systems, etc. are widely used for entertainment.

Applications in Defence sector

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

One of the most important developments during World War II was the RADAR (Radio Amplification Detection And Ranging). By using RADAR it is possible not only to detect, but also to find the exact location of the enemy aircraft. The anti-aircraft guns can then be accurately directed to shoot down the aircraft. In fact the RADAR and anti-aircraft guns can be linked by an automatic control system to make a complete unit.

Instrumentation

Instrumentation plays a very important role in any industry and research organisation, for precise measurement of various quantities. Very accurate and user-friendly instruments like digital voltmeter (DVM), cathode ray oscilloscope (CRO), frequency counter, signal generator, strain gauge, pH-meter, spectrum analysers, etc. are some of the electronic equipment without which no research laboratory is complete.

Medical Electronics

Electronic equipment are being used extensively in medical field. They not only assist in diagnosis but also help in the researches that provide treatment and cure for illnesses and even genetic anomalies. Examples are Electron microscope, ECG, EEG, X -rays, defibrillator, oscilloscopes, MRI, CT scanner, glucometer, etc.

Applications in Industries

Use of automatic control systems in different industries is increasing day by day. The thickness, quality and weight of a material can be easily controlled by electronic circuits. Electronic circuits are used to control the operations of automatic door openers, lighting systems, power systems, safety devices, etc.

Use of computer has made the ticket reservations in railways and airways simple and convenient. Even the power stations, which generate thousands of megawatts of electricity, are controlled by electronic circuits.

Applications in Automobiles

Several electronic equipment are used in cars for charging battery, enabling power assisting functions, measuring gauges and monitoring and controlling the engine performance. The most important application is electronic ignition, which provides better timing of the ignition spark, especially at high speeds.

Automobile industry is one of the fastest growing sectors in the world. The end users are demanding greater fuel efficiency, security and safety. This is possible because of the rapid development in the technology. Other areas of application in automobile are parking sensors, auto wipers, auto lights, safety (eg. Air bags), security, anti-theft systems, etc.

Consumer Electronics

We use fans in our home, class rooms, library, etc. You are familiar with the electronic regulators used with them. Have you ever thought of the mechanism behind that? Here we use an electronic component known as TRIAC to control the speed of the fan. The speed of the fan is directly proportional to the electric power reaching the motor. The regulator controls the speed by controlling the electric power. The regulator controls electric power according to the position of the knob. Special electronic components like Silicon Controlled Rectifiers (SCRs) are used in the speed-control of motors, power rectifiers and inverters.

ELECTRONIC COMPONENTS - ACTIVE AND PASSIVE

Electronic components can be broadly classified into active and passive components. Active Components are electronic components which are capable of amplifying or processing an electrical signal, e.g.: Diodes, Transistors, etc. Passive Components are electronic components which are not capable of amplifying or processing an electrical signal, e.g.: resistors, capacitors and inductors.

RESISTORS

A resistor is a two terminal component which provides resistance to the flow of current in a circuit. An axial-leaded component, as shown in Fig. 1-1, has leads projecting from each end of the component body aligned with the long axis of the part, while a radial-leaded component, as shown in Fig. 1-2, has parallel leads projecting at right angles from its body. Axial leads must first be bent 90° to insert them into the holes of circuit boards, while radial leads can typically be inserted directly into those holes without bending. However, both axial- and radial-leaded parts can be inserted by automatic machines.

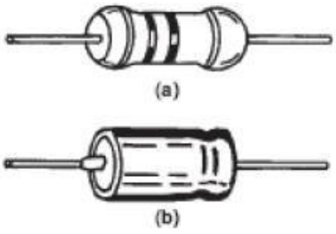


Figure 1-1 Axial-leaded components: (*a*) resistor, and (*b*) electrolytic capacitor.

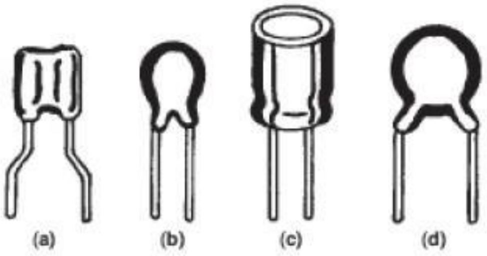


Figure 1-2 Radial-leaded capacitors: (*a*) monolithic ceramic, (*b*) solid tantalum, (*c*) aluminum electrolytic, and (*d*) ceramic disk.

The on going trend toward more surface mounting of electronic components has led to the introduction of more active and passive "leadless" components that can be soldered directly to tinned or plated pads on "hole-less" or surface-mount technology (SMT) circuit boards. Passive SMT components such as capacitors and resistors are leadless rectangular chips or cylinders with metallized end surfaces that are reflow soldered to the circuit boards, but many active components, such as transistors and integrated circuits, are in cases with bent stub or "gull wing" leads that can also be reflow soldered directly to circuit board pads.

Fixed Resistors

A *resistor* is a circuit component that provides a fixed value of resistance in ohms to oppose the flow of electrical current. Resistors can limit the amount of current flowing in a circuit, provide a voltage drop in accordance with Ohm's laws, or dissipate energy as heat.

Fixed resistors are discrete units typically made in cylindrical or planar form. The most common cylindrical style is the axial-leaded resistor, as shown in Fig. 1-1. The resistive element is wound or deposited on a cylindrical core, and a cap with a lead wire is positioned on each end. The resistive elements include *resistive wire* (*wirewound*), *metal film, carbon film, cermet,* and *metal oxide.* Resistor networks and chip resistors are examples of planar resistors. All fixed resistors are rated for a nominal resistance value in ohms over the range of fractions of an ohm to thousands of ohms (kilohms), or millions of ohms (megohms). Other electrical ratings include:

- *Resistive tolerance* as a percentage of nominal value in ohms
- *Power dissipation* in watts (W)
- *Temperature coefficient* (*tempco*) in parts per million per degree Celsius of temperature change (ppm/°C)
- *Maximum working voltage* in volts (V)

Some resistors also have additional ratings for electrical noise, parasitic inductance, and parasitic capacitance. Resistors exhibit unwanted parasitics of inductance and capacitance because of their construction. These effects must be considered by the designer when selecting resistors for unusual or specialized applications such as their use in instrumentation. A resistor's ability to dissipate power is directly related to its size. With the exception of those specified for power supplies, most resistors for electronic circuits are rated under 5 W, usually less than 1 W. A 5-W cylindrical resistor is about 1 in (25.4 mm) long with a diameter of 1⁄4 in (6.4 mm). The 1⁄2-, 1⁄4-, and 1⁄8-W resistors are correspondingly smaller.

CARBON-COMPOSITION RESISTORS

A *carbon-composition resistor,* as shown in Fig. 1-3, is made by mixing powdered carbon with a phenolic binder to form a viscous bulk resistive material, which is placed in a mold with embedded lead ends and fired in a furnace. Because their resistive elements are a bulk material, they can both withstand wider temperature excursions and absorb higher electrical transients than either carbon- or metal-film resistors. These qualities are offset by their typically wider resistive tolerances of _10 to 20 percent and tendency to absorb moisture in humid environments, causing their values to change. However, the benefits of carbon composition resistors are less important in low-voltage transistorized circuits, so demand for them has declined. These resistors have ratings of 1 ohm to 100 megohms, but values in the 10- to 100-ohm range were most popular. Power ratings are 1⁄8 to 2 W

CARBON-FILM RESISTORS

A *carbon-film resistor*, as shown in Fig. 1-4, is made by screening carbon-based resistive ink on long ceramic rods or mandrels and then firing them in a furnace. The rod is then sliced to form individual resistors. After leaded end caps are attached, the resistance values are set precisely in a laser trimming machine that trims away excess resistive film under closed-loop control. The trimmed resistors are then coated with an insulating plastic jacket. Resistive tolerances of carbon-film resistors are typically _10 percent. Standard resistors have power ratings of 1⁄2, 1⁄4, and 1⁄8 W.

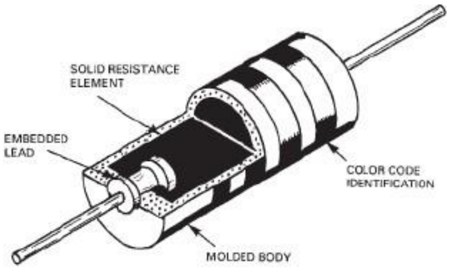


Figure 1-3 Carbon-composition resistor.

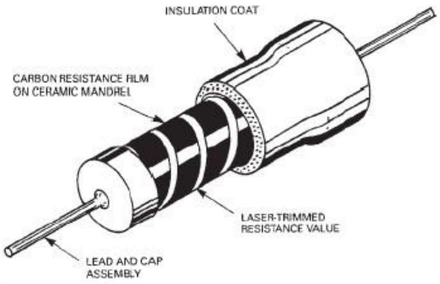


Figure 1-4 Carbon-film resistor.

WIREWOUND RESISTORS

A *wirewound resistor*, as shown in Fig. 1-5, is made by winding fine resistive wire on a plastic or ceramic mandrel. The most commonly used resistance wire is nickel-chromium (nichrome). The axial leads and end caps are attached to the ends of the wire winding and welded to complete the electrical circuit. There are both general-purpose and power wirewound resistors. General-purpose units have resistive values of 10 ohms to 1 megohm, resistance tolerances of _2 percent, and temperature coefficients of _100 ppm/°C. Power units rated for more than 5 W have tolerances that can exceed _10 percent. Wirewound resistors are generally limited to low-frequency applications because each is a solenoid that exhibits inductive reactance in an AC circuit, which adds to its DC resistive value. The inductive reactance can be reduced or eliminated at low or medium frequencies by bifilar winding. This is done by folding the entire length of resistive wire back on itself, hairpin fashion, before winding it on the mandrel. As a result, opposing inductive fields cancel each other, lowering or eliminating inductive reactance.

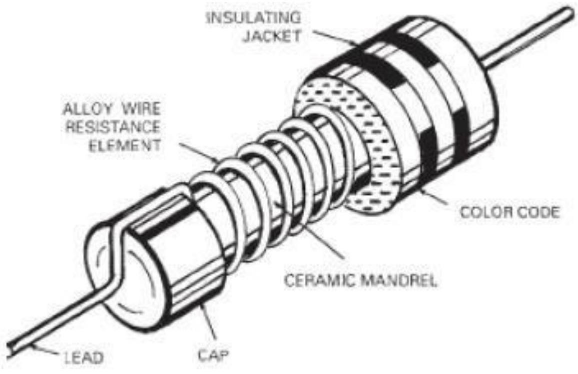


Figure 1-5 Wirewound resistor.

Wirewound resistors are made with both axial and radial leads. Epoxy or silicone insulation is applied to some low-power wirewound resistors, but high-power units are encased in ceramic or placed in heat-dissipating aluminum cases. This reduces the danger of the hot resistor igniting nearby flammable materials or burning fingertips if accidentally touched.

METAL-FILM RESISTORS

A *metal-film resistor*, as shown in Fig. 1-6, is made by the same general method as a carbon-film resistor. A thin metal film is sputtered or vacuum deposited on an alumina (aluminum-oxide) mandrel in a vacuum chamber, or a thick metal film is applied in air. Tin oxide or nickel-chromium are widely used thin films, and a thick film made from powdered precious metal and glass (frit) in a volatile binder is a common cermet resistive ink. These resistors are laser trimmed to precise values under closed-loop control after firing. Metal-film resistors are offered in two grades: (1) those with resistive tolerances of _1 percent and temperature coefficients of 25 to 100 ppm/°C, and (2) those with resistive tolerances of _5 percent and temperature coefficients of 200 ppm/°C. Demand is highest for 1⁄4- and 1⁄8-W units, but 1⁄20-W units are available. Resistive values up to 100 Meg ohms are available as catalog items, but they are generally rated for less than 10 kilohms.

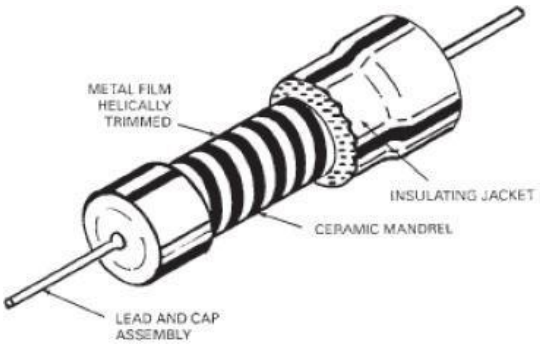


Figure 1-6 Metal-film resistor.

VARIABLE RESISTORS

POTENTIOMETERS

A *potentiometer* is a variable resistor whose resistance value can be changed by moving a sliding contact or wiper along its resistive element to pick off the desired value. A potentiometer has terminals at each end of its fixed resistive element, and the third terminal is connected to a moveable wiper. If the wiper is moved back to the beginning of the resistive element, the potentiometer's resistance value is minimal, but if it is moved across the full length of the element, the value reaches its maximum. There are three different mechanisms for moving the wiper along the resistance element:

1. Sliding the wiper by finger pressure
2. Turning a lead screw on the case to drive the wiper back and forth
3. Rotating a screw or knob attached to the wiper to sweep it around a curved element

Potentiometers for electronic circuits are classified as follows:

- Precision

- Panel or volume-control
- Trimmer

The common abbreviation for potentiometer is *pot*, so there is a *precision pot* and a *panel* or *volume-control pot.* However, a trimmer potentiometer is usually called a *trimmer* (to be distinguished from a trimmer capacitor). These variable resistors share the same schematic symbol and are made from many of the same kinds of materials.

PRECISION POTENTIOMETERS

A *precision pot,* as shown in Fig. 1-11, is an instrument-grade variable resistor. It can provide repeatable resistive accuracy of at least 1 percent. These pots were widely used in analog computers, instruments, and military and aerospace systems, but they now function primarily as sensors. They can provide precise and resettable voltages corresponding to each setting of the control shaft. Vernier dials make it possible to return its shaft to a specific position to obtain a repeatable output voltage within close tolerances. Most precision pots have cylindrical cases and an axial rotating shaft. The resistive material in a single-turn precision pot is cut in a C shape and fastened inside the case. However, the resistive element of a multiturn precision pot is formed as a helix or spiral which is also attached to the inside of the case, as shown in Fig. 1-11. A sliding leadscrew assembly mounted on the control shaft advances and retracts the wiper assembly with shaft motion. This causes the wiper to track around the inside of the helix. Precision pots are identified by their resistive elements. Most are wound resistive wire (wirewound) or resistive plastic.The wirewound element is formed by winding fine resistance wire on a heavier wire form or mandrel. These elements have low temperature coefficients, but they exhibit finite resolution.As the wiper slides along the resistive element, it spans resistance increments equal to the resistive value of an individual turn of fine wire wound around the mandrel. While accuracy improves with helix length, the element always has a tolerance of 1 wire turn. But infinite resolution can be obtained with a hybrid helix, a wirewound element coated with resistive plastic. The coating compensates for the resistive increments. Because bulk resistive plastic resistors made from sheets can have infinite resolution, elements can easily be cut from it to form nonlinear elements. They can be contoured or tapered to produce an output voltage that varies with respect to shaft setting. For example, tapers can be designed to produce output voltages that express sine, cosine, square law, or logarithmic functions.

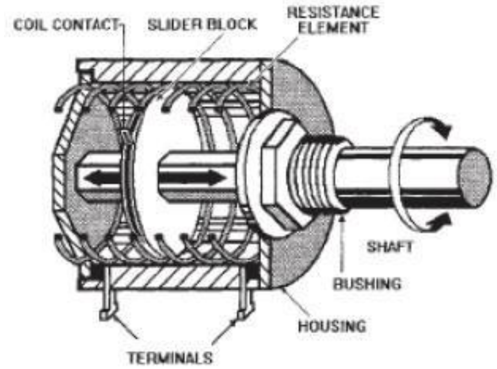


Figure 1-11 Precision potentiometer.

Ceramic-metal (cermet) elements, also capable of infinite resolution, are specified when the precision pot will be operated in a high-temperature environment. Unfortunately, these elements are abrasive and can wear down the wiper, thus limiting the pot's useful life. Precision pots are also classified as single-turn or multiturn. Because of the diversity in resistive materials and the conventions accepted for their manufacture, wirewound and hybrid pots can either be single-turn or multiturn, but all precision pots with conductive plastic or cermet resistive elements are single-turn. The principal specifications for precision potentiometers are:

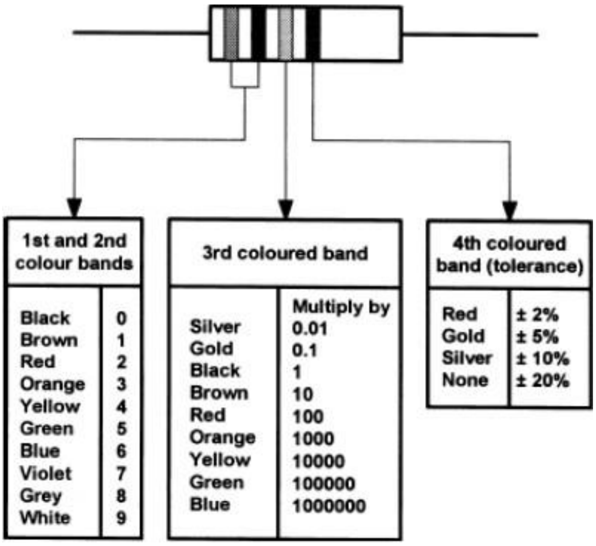
- Starting or running torque
- Resistance range
- Power rating
- Ambient temperature range
- Rotational life

These factors determine the choice of number of turns and resistive element. If a singleturn pot has a resistive element that is too short to give the desired accuracy, a multiturn element is selected. The effective rotation of a single-turn pot is about 320°. The most common multiturn potentiometers are the 3-turn (1080°) and 10-turn (3600°), but 5-, 15-, 25-, and 40-turn units are available. Both single- and multiturn pots with linearities of 0.025 percent or better are standard items. The low-resistance range for single-turn precision pots is about 10 to 150 ohms, and their high-resistance range is about 200 kilohms to 1 megohm. Similarly, the low-resistance range of multiturn precision pots is about 3 ohms to 1 kilohm, and their high-resistance range is about 200 kilohms to more than 5 megohms.

Precision pots are made as panel- or servo-mounted units. Panel-mounted units, like control pots, are positioned behind the panel with their shafts and threaded bushing projecting through a formed hole, and they are fastened with ring nuts and lockwashers. Servomounted units are positioned facedown on metal baseplates and clamped with screw-type lugs secured in the clamping groove that runs around the circumference of the precision pot's case. Precision pots are made as either standard or custom products.

COLOUR CODING OF RESISTORS

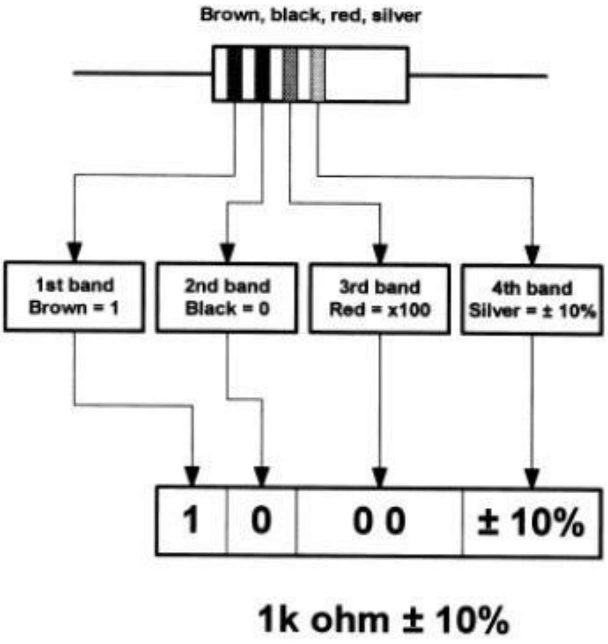
Four colour band method:

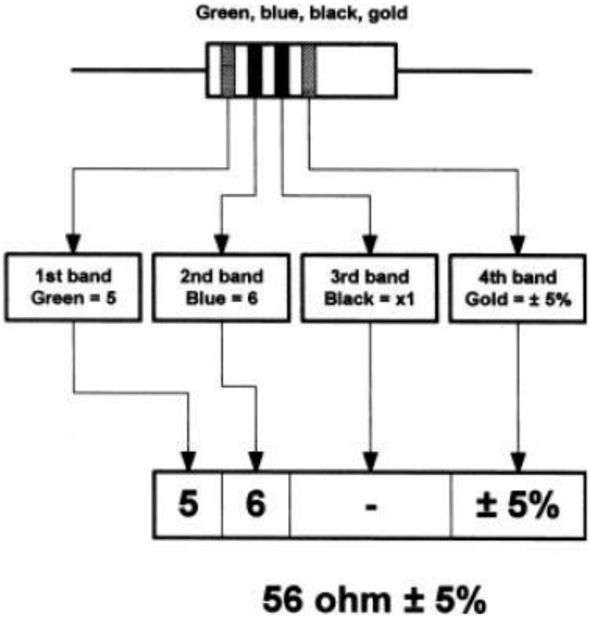


1st and 2nd colour bands	
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

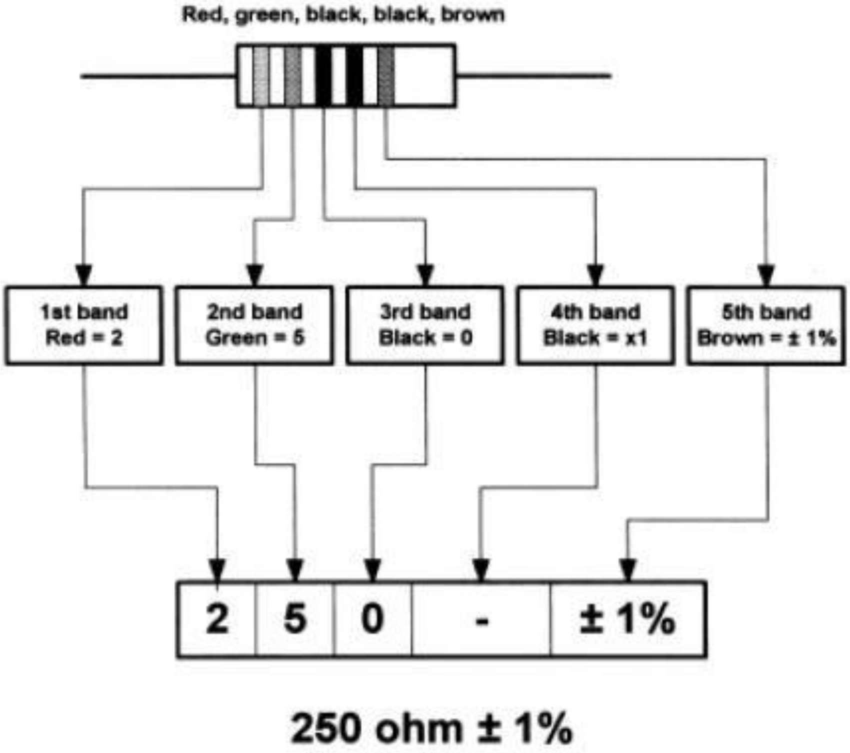
3rd coloured band	Multiply by
Silver	0.01
Gold	0.1
Black	1
Brown	10
Red	100
Orange	1000
Yellow	10000
Green	100000
Blue	1000000

4th coloured band (tolerance)	
Red	± 2%
Gold	± 5%
Silver	± 10%
None	± 20%



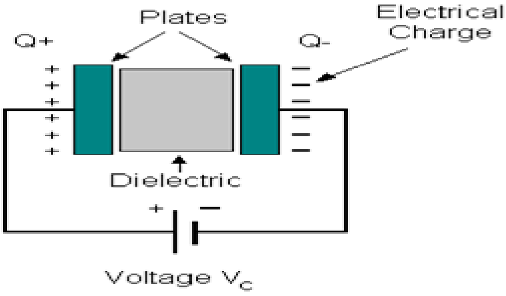


Five colour band method:



CAPACITORS

Capacitors are the most widely used passive components in circuits. Two conducting plates separated by an insulating material (dielectric)forms a capacitor. The basic purpose of a capacitor is to store the charge. The charge on the plates (Q) of a capacitor is directly proportional to the voltage (V) across the plates.



Q α V; Q = CV

Where C is the constant of proportionality and is called capacitance. It is a measure of the energy stored by the capacitor in the form of electrostatic energy. The unit of capacitance is Farad. However the unit of Farad being too large, the capacitors are specified practically in microfarad (μF) or Pico farad(pF)

1 μF =10^{-6} F, 1pF=10^{-12} F, 1 nF=10^{-9}F

A capacitor is a component which offers low impedance to A.C but very high impedance to D.C .The useful function of a capacitor is to block D.C voltage but pass the A.C signal voltage by means of charging and discharging. These applications include coupling, bypassing and filtering for AC signals. Another important application of a capacitor are in starting motors, tuning circuits to specified frequency.

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

Where ϵ_0 absolute permittivity = $8.854*10^{-14}$ F/M
ϵ_r Relative permittivity

Capacitor Specifications

- **Capacitance**
- **Working Voltage**
- **Temp Coefficient**
- **Tolerance**

1.Capacitance

It is a property of a capacitor which opposes the change in voltage by means of energy storage in the form of electrostatic energy.

2. Working Voltage

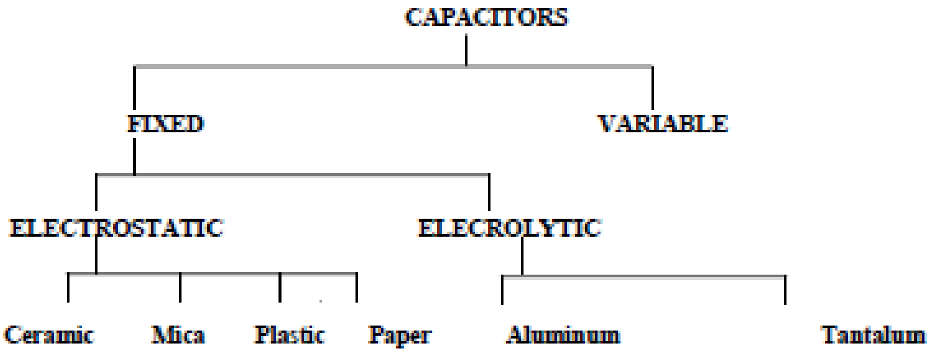
It is defind as the maximum voltage at which the capacitor may be operated continuously at a specified temperature. Working voltage mainly depends upon the dielectric strength of the material used in the capacitor. Capacitor when used in electronic circuits have a working voltage 5v and when us in colour television receivers have more than 50,000v

3. Tolerance

It is expressed in terms of percentage of specified capacitance value.

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

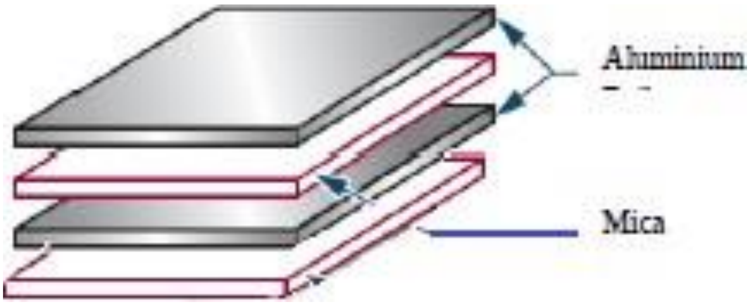
The capacitors' in which the capacitance value cannot be varied by any means(ie either by changing plate separation or area) are called fixed capacitors.

ELECTROSTATIC CAPACITORS

Ceramic Capacitors

These capacitors are made by using various ceramic material as dielectrics. A powdered mixture of barium strontium-titanate is used as a ceramic material. The ceramic capacitors have large capacitance in a small package and can have values from less than 10pf to more than 1 μF .These capacitors have very high dielectric constant and therefore are usually smaller in size than paper or mica capacitors. And it has very high leakage resistance. These capacitors available in both disc and tubular types and are used as bypassing and coupling capacitors in electronic circuits.

Mica Capacitor



These capacitors consists of alternate thin sheets of metal(aluminium or tin)foils separated by thin mica sheets as shown in above figure. Alternate metal sheets are connected together and brought out as one terminal for one set of plates, while the opposite terminal connects to the other set of plates. This unit is generally enclosed in plastic housing. In silver mica capacitors the opposite faces of the mica sheets are silver coated which act as the conducting material. These capacitors are available in capacitance value ranging from 1pF to 10,000pF.These capacitors are expensive but have a stable capacitance value even at a frequency of 200 MHz. These capacitors are able to withstand very high voltages (about 500v) due to high dielectric constant. The mica capacitors are widely used in radio and telecommunication applications.

ELECTROLYTIC CAPACITOR

Electrolytic capacitors normally have the smallest volume and cost for a given capacitance.
These can be Polarised or Non polarised.

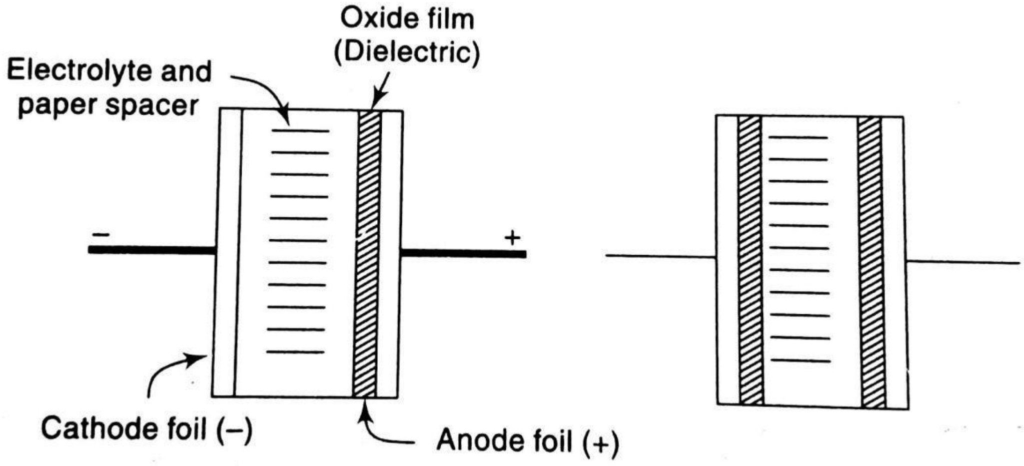


Fig: Elementary electrolytic capacitor, Polarised & Non-polarised

Based on the type of metal used for etching anode and (or) cathode they are classified as

i) Aluminium Type
ii) Tantalum Type

In the case of polarised electrolytic capacitor, a plus or minus sign is printed on the package near one of the two leads . The near the plus sign must be connected to higher DC potential point when the capacitor is put in the circuit . If it connected reverse , then the capacitor may be short circuited and permanently damaged. For a non polarised capacitor there is no such restrictions, when they are connected in the circuits.

1. Polarised Electrolytic Capaitor

The basic structure of polarised electrolytic capacitor is shown in the figure. Certain metals like aluminium, tantalum are used to form anode and cathode foils. Then a very thin layer of aluminium or tantalum oxide is electrochemically formed on the anode foil. The oxide layer becomes the dielectric for the capacitor. Such a very thin film of dielectric results in large capacitance value. The cathode and oxide coated anode is separated by a paper spacer which is soaked in the electrolytic solution. This spacer is required to prevent short circuiting between anode and cathode foils. For high voltage rating capacitors , the spacer is thicker than for low voltage rating capacitors. The most common type of electrolytic capacitor is the roller type, inside which the paper spacer is sandwiched between the anode and cathode foils.

2. Non-polarised Electrolytic Capaitor

The basic structure of this type of capacitor is shown in figure. This has two oxide coated anodes.for an equal size polarised capacitor, the non-polarized type has one half the capacitance for the same voltage rating. They are generally used in applications such as ac motor starting, cross over networks and large pulse signals.

a) Aluminium type:
This type capacitors have high dc leakage and low insulation resistance.The are low in cost and high volumetric efficiency.The dis advantages are their life is limited and capacitance deteriorates with time and usage.

b) Tantalum Type:
Tantalum Capacitors have long life ,suitable operating characteristics,increased operating temperature range and grater volumetric efficiency. The dis advantage of tantalum capacitors are its greater cost and lower voltage rating.

Tantalum electrolytic capacitors can be divided into three types

i) Foil
ii) Wet anode
iii) Solid anode

1. **Foil type:** The tantalum Foil type is similer in construction to aluminium foil electrolytic type.
2. **Wet Anode Type:** The wet anode type capacitor is made by moulding a mixer of tantalum powder and binder into the shape of pellet. Under high temperature and in a vaccum , the pellet mixture is welded together (sintered) and due to this sintering, the binder and impurities are driven off.The result is a porus pellet on which a layer of tantalum oxide is electrochemically formed. The volumetric efficiency of wet anode type is about three times that of foil type.

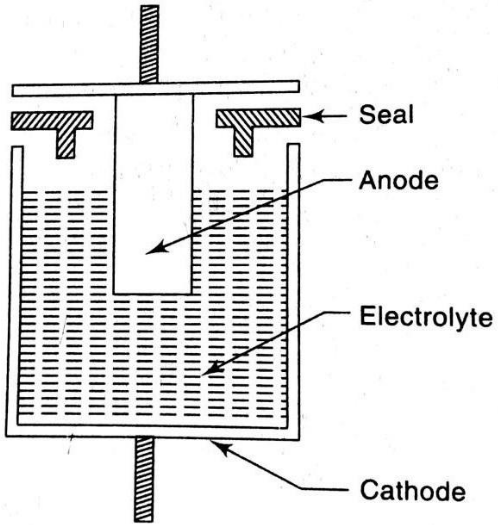


Fig: Wet anode type Tantalum Capacitor

3. **Solid Anode Type**: This type of capacitor is made by sintering an anode pellet on which a layer of tantalum oxide is formed.The pellet is then formed with manganese dioxide layer which serves as solid dielectric. The cathode connection is made by coting this

pellet by carbon and silver paint. The solid anode construction is most widely used. It has the longest life and lowest leakage current of the three types of tantalum capacitors.

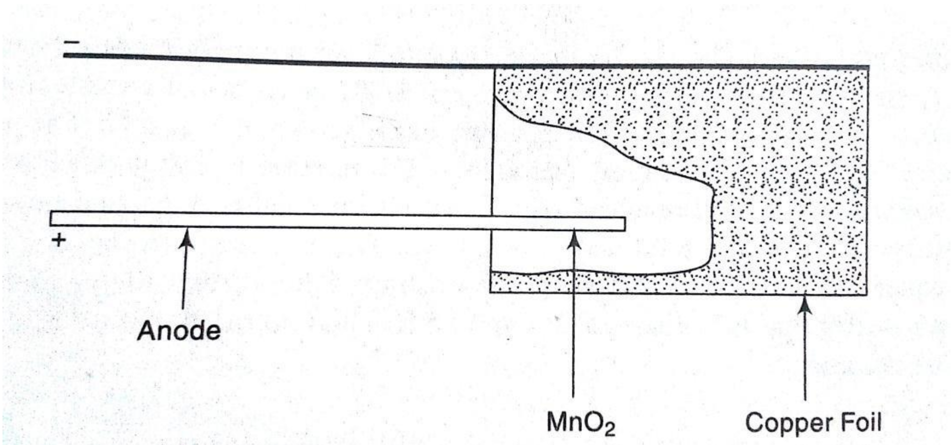
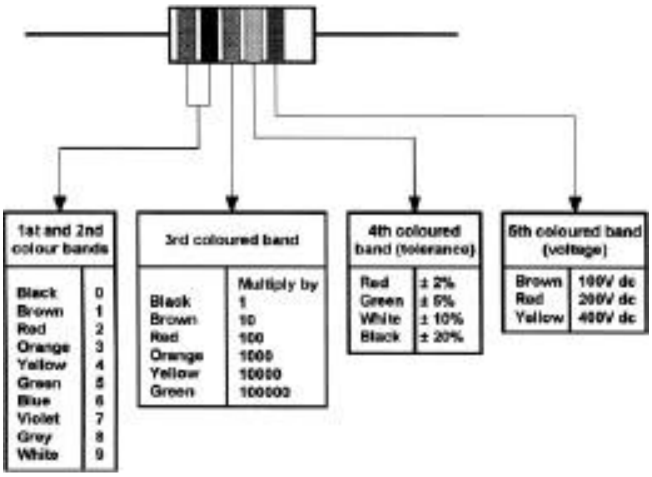


Fig: Solid Anode type Tantalum Capacitor

COLOUR CODING OF CAPACITOR



1st and 2nd colour bands	
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

3rd coloured band	
	Multiply by
Black	1
Brown	10
Red	100
Orange	1000
Yellow	10000
Green	100000

4th coloured band (tolerance)	
Red	± 2%
Green	± 5%
White	± 10%
Black	± 20%

5th coloured band (voltage)	
Brown	100V dc
Red	200V dc
Yellow	400V dc

INDUCTORS

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

$$-$$

Where e = induced emf in volts in any instant
L= Inductance in Henry
−= rate of change of current

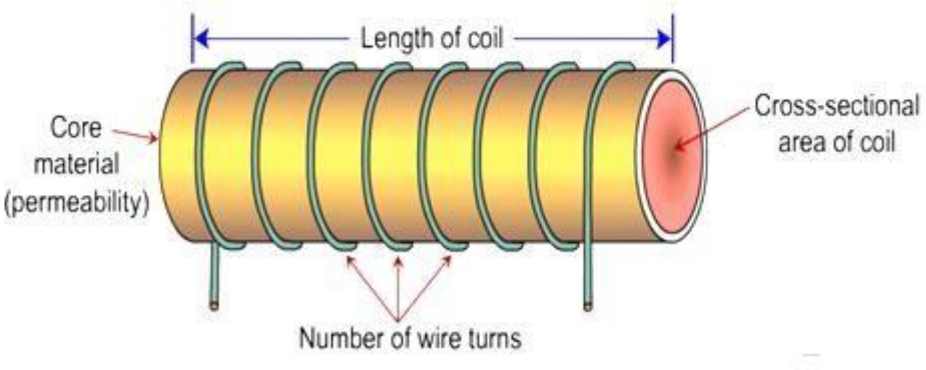
The negative sign indicates that the induced emf opposes the cause for the change in current

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

$$\overline{\qquad\qquad}$$

Where

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

FIXED INDUCTORS

Fixed inductors further divided into three catagories depending on the type of core used. They are

i) Air core inductors

ii) Iron core inductors

iii) Ferrite core inductors

Fixed inductor
(iron-core)

Fixed inductor
(air-core)

Fixed inductor
(powdered-iron or ferrite core)

Air core Inductors

In radio frequency applications where very low values of inductance is required air core inductors are generally used. Air core inductors consists of a few turns of wire wound on a hollow former.

Iron Core Inductors

They have a coil containing a number of turns of copper wire wound on a hollow former and core material passes through a former in such a way that it forms a closed magnetic path for the magnetic flux. The former is made up of paper of plastic material. The core is generally made up of silicon steel (a ferrite material with high permeability) in the form of thin laminated sheets. Laminated sheets are used instead of solid mass to reduce hysteresis and eddy current losses.

Iron core transformers are used in low frequency applications such as filter circuits in power supplies,chocks in fluorescent tubes or as a reactive element in ac circuits. The value of these inductors are generally in the order of few Henries.

Ferrite core Inductors

Iron core inductors are not suitable for high frequency applications (because of enormous increase in hysteresis and eddy current losses). This difficulty is overcome by the use of ferrite materials as the core. A ferrite is basically an insulator having very high permeability.

Ferrite is made up of non- metallic compounds consisting mainly of ferric oxide in combination with one or two bivalent metal oxides. They are hard, dense ceramics and because of their high resistivity they can be used in the form of solid cores. The value of such inductors is in the range of few µH to few mH.

The typical applications of ferrite core inductors are in

i) R F Chokes for supply decoupling purposes
ii) Switching regulated type DC power supplies
iii) Various type of filters used in communication equipment.

Variable Inductors

In certain applications such as tuned circuits ,it is necessary to vary the inductance from a minimum value to maximum value. Ferrite core variable inductors are generally used for this purpose.In such inductors the hollow former on which the coil is wound has screw threads in the inner hollow portion. Similar matching threads are provided on the ferrite core which can be screwed in or out of the former. Because of the change of position of ferrite core the value of inductance changes. It is maximum when the ferrite core is fully in.

Adjustable/variable inductor
(general symbol)

Inductive reactance

The reactance of an inductor of inductance L at frequency *f* is given by

The value of inductance offered by a coil is not constant but depends on frequency of the alternating current passing through it. At higher frequencies, the inductive reactance XL is large and at lower frequencies the inductive reactance is small. For DC i.e at f=0 X_L =0

Therefore the inductor allows very low frequency currents more easily than high frequency currents. Also for a given frequency X_L depends directly on the coil inductance L.

Energy stored in Magnetic Field

In an inductor The strength of magnetic flux is directly proportional to the amount of current flowing through it.If the current flowing through an inductor increases the strength of magnetic flux is also increases. The increase in flux represents energy is taken from the circuit or the applied voltage source. When the current flowing through the inductor decreases the magnetic flux also decreases.The decrease in magnetic flux returns the energy stored in the magnetic flux into the circuit.

The amount of energy stored is

Where L is the inductance of the inductor, I the current flowing through the inductor.

Q Factor of Inductor

Though there is no power loss in an ideal inductor , losses do there in practical inductor. These losses are two types.

i) I^2R Losses(Ohmic loss in the copper wire)

ii) Hysteresis and eddy current losses in the core

An Equivalent circuit of inductor is shown in the figure in which Rs is the effective resistance of the inductor which accounts for the total losses.

The value of impedence Z of practical inductor is given by

√ =√

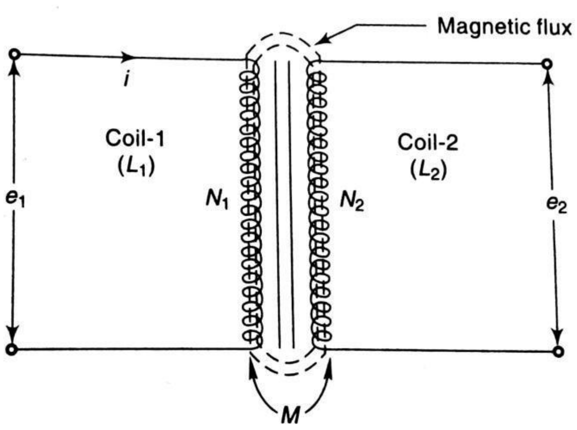
The Quality factor

The ratio of inductive reactance ( ) to the effective resistance is known as Q of an inductor. This is also called Quality factor or figure of merit of an inductor.

Mutually Coupled coils

When two coils are placed very near to each other, the changing magnetic flux of one coil ,linking with the other,produces an induced emf in the other coil.These two coils are then set to have mutual inductance M which is expressed in Henries (H)

Where l is the length of the magnetic Path.



Let the rate of change of currentin the coil be ...... This changing current will produce a changing magnetic flux through it which will link partly of fully with the second coil. Hence an induced emf will be produced in the second coil, which is given by

$$e_2 = M \;\overline{}$$

The mutual inductance of the coil depends up on the self-inductances of the coils and the coefficient of coupling between the coils.The mutual inductance (M) between the two coils is

$$\sqrt{}$$

Where k= coupling coefficient, L1 = Self-inductance of the coil 1, L2 = Self-inductance of the coil 2.

From above relation we get the coupling coefficient

$$\frac{}{\sqrt{}}$$

CONNECTING INDUCTORS

Inductors in Series

The combined inductance of two coils connected in series aiding and having self- inductances L1 & L2 respectively will be given by

But if the coils are connected in series opposing, their combined inductance will be

Inductors in Parallel

If two coils are connected in parallel with fields aiding, then

$$\overline{} \quad \overline{} \quad \overline{}$$

And for coils in parallel with fields opposing, then

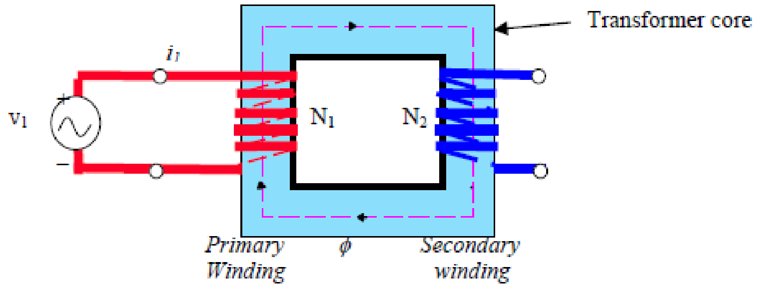
$$\overline{} \quad \overline{} \quad \overline{}$$

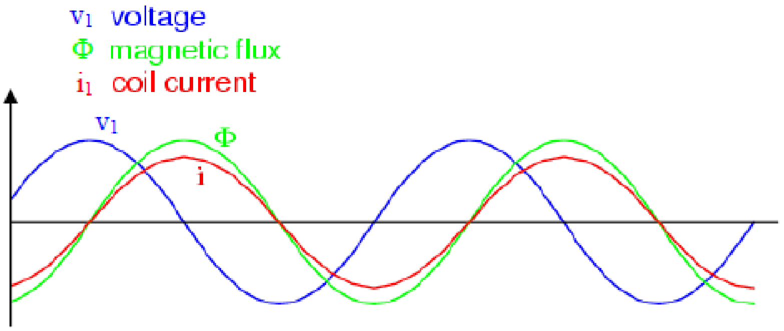
TRANSFORMER

An ideal transformer consists of two conducting coils wound on a common core, made of high grade iron.

- There is no electrical connection between the coils, they are connected to each other through magnetic flux.
- The coil on input side is called the ***primary*** winding (coil) and that on the output side the ***secondary***.

When an AC voltage is applied to the primary winding, a time-varying current flows in the primary winding and causes an AC magnetic flux to appear in the transformer core. The arrangement of primary and secondary windings on the transformer core is shown in figure below. The voltage, current and flux due to the current in the primary winding is also shown.





This flux links with the secondary winding due to the mutual magnetic coupling, and induces a voltage in secondary winding (Faraday's Law).

Depending on the ratio of turns in the primary and secondary winding, the RMS secondary voltage can be greater or less than the RMS primary voltage.

For analyzing an ideal transformer, we make the following assumptions:

- The resistances of the windings can be neglected.
- All the magnetic flux is linked by all the turns of the coil and there is no leakage of flux.
- The reluctance of the core is negligible

We can write the equations for sinusoidal voltage in this ideal transformer as follows.

The primary winding of turns N1 is supplied by a sinusoidal voltage *v1*.

*v1 = V1m cos (*ωt*)*

here, *v1* is the time-varying (also called instantaneous) voltage applied to the primary winding, with the maximum value *V1m* and RMS value of *V1 (=V1m/*√‾).

From Faraday's Law, the voltage across the primary winding terminals can be written as:

v1 =N1 (dϕ/dt)

From these two equations, *N1 (dϕ/dt) = V1m cos (*ωt*)*

Rearranging and integrating, the equation for common flux can be written as:

−sin(ωt)

This common flux passes through both the windings.

Voltage Relationships

This common flux flows through the transformer core and links with the secondary winding. According to Faraday's law, a voltage is induced across the terminals of the secondary winding. Assuming that all of the flux links all of the turns in each coil, when the common flux changes (*d*ϕ */dt*), a sinusoidal voltage *v2* is induced in the secondary winding, the voltages are given by:

— and —

The polarities of the induced voltages are given by *Lenz*'s *law*; i.e. the induced voltages (also called *emf*) produce currents that tend to oppose the flux change.

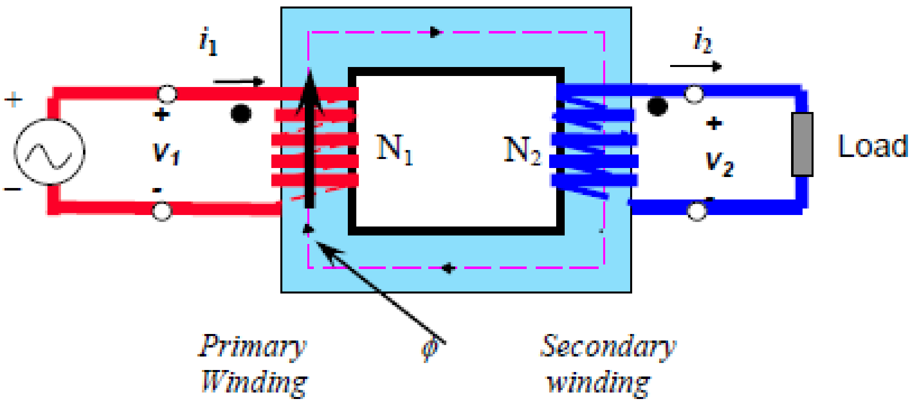
From the above equations, - −

In terms of RMS values , −= a : a is the turns ratio

The "*turns ratio*" determines the amount the voltage is changed

Current Relationships

If we now connect a load across the terminals of the secondary winding , the circuit on the secondary side of the transformer is complete, and a current *i2* starts to flow through it.



The magnetomotive force corresponding to the current in the secondary winding is given by:

$mmf = N_2 i_2$

- The input coil is forced to generate a counter *mmf* to oppose this *mmf*.
- This results in current *i1* such that the total mmf applied to the core is:

$$F = N_1 i_1 - N_2 i_2$$

The mmf is related to the flux and reluctance by:

$$F = R\ \phi$$

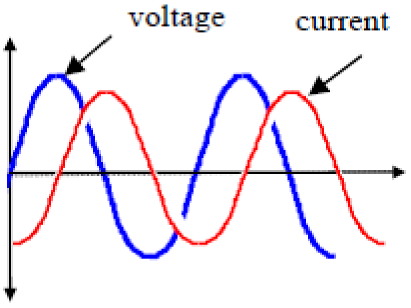
- In a well designed transformer, the core reluctance is very small.
- In the ideal case, this reluctance · is zero, and therefore the mmf required to establish flux in the core is zero.

  Therefore, $F = N_1 i_1 - N_2 i_2 = 0$

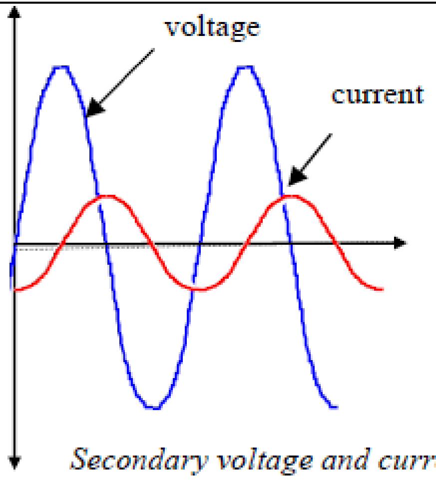
Expressing currents in terms of RMS values

— —

For example, if the transformer has a turns ratio $a = 1/2$, the voltage $V_2 = 2\ V_1$, current $I_2 = 0.5\ I_1$ as shown below.



Primary voltage and current

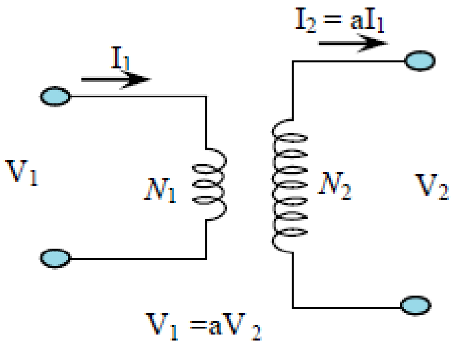


Secondary voltage and current

Ideal Transformer – Equivalent Circuit

The equivalent circuit (i.e., without the magnetic core) of an ideal transformer can be drawn as follows.

The equivalent circuit is used for determining the performance characteristics of the transformer.



Ideal transformer equivalent circuit

If a < 1, i.e. N1 < N2

The output voltage is greater than the input voltage and the transformer is called a **step-up** transformer

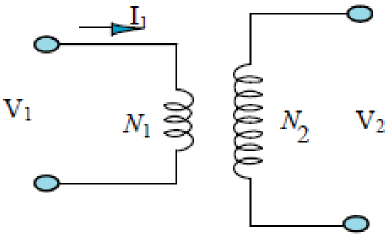
If a > 1, i.e. N1 > N2

The output voltage is smaller than the input voltage and the transformer is called a **step-down** Transformer

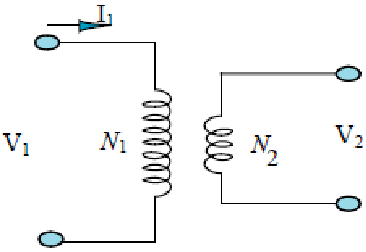
If a = 1, i.e. N1 = N2

The output voltage is the same as the input voltage and the transformer is called an **isolation** Transformer

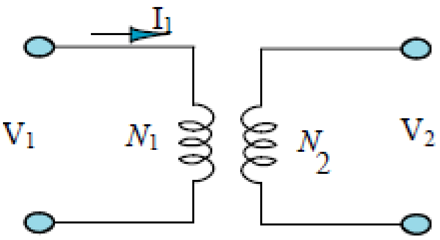
These transformers perform a very useful function for applications where two circuits need to be *electrically* isolated from each other.



Step-up transformer

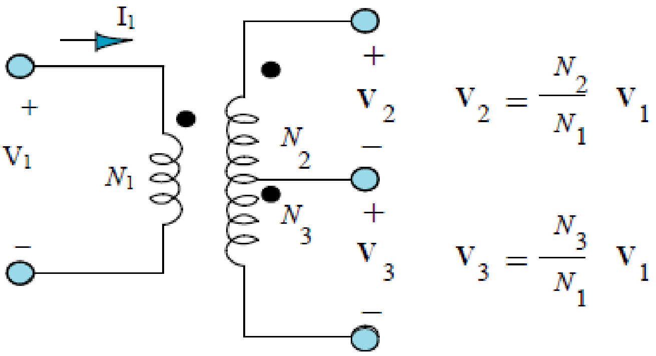


Step-down transformer



Isolation transformer

In many applications, the secondary winding is tapped at two different points, giving rise to two output circuits. The most common configuration is **centre-tapped** transformer which splits the secondary voltage into two equal voltages



Centre-tapped transformer

The power delivered to the load by the secondary winding:

(Note that the lower case letter (e.g. p, v, or i) refers to the time-varying instantaneous value of an ac wave.)
Using equations for *v2* and *i2* and substituting in the above equation,

and

−

However, the power delivered to the primary winding by the source is :

Therefore,

i.e., *Power input = Power output*

TRANSFORMER RATING

The transformer is usually rated in terms of its input and output voltages and apparent power that it is designed to safely deliver.

For example, if a transformer carries the following information on its name-plate:
10kVA, 1100/110volts

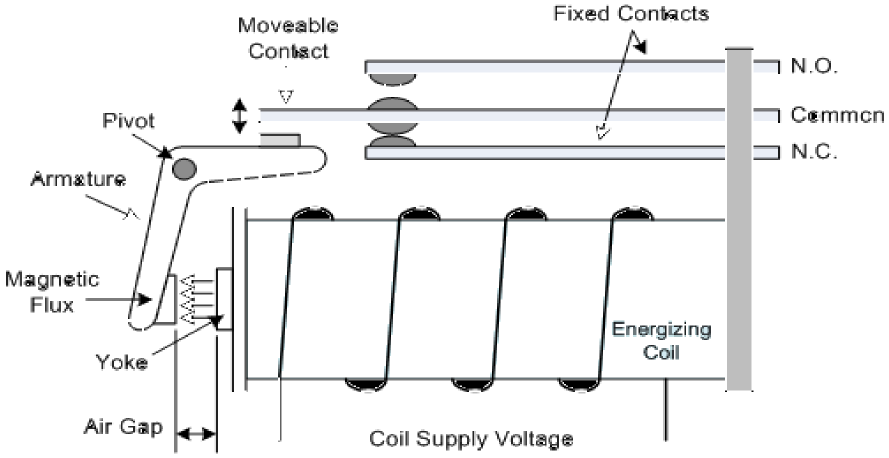
The **voltage ratio** indicates that the transformer has two windings, the *high-voltage* winding is rated for 1100 Volts and the *low-voltage* winding for 110 volts.
These voltages are proportional to their respective number of turns. Therefore, the voltage ratio also represents the turns ratio a. (e.g., $a = 10$ here)
The **kVA rating** (i.e., apparent power) means that each winding is designed for 10 kVA.
Therefore the **current rating** for the high-voltage winding = 10000/1100 = 9.09A
Current rating for low voltage winding = 10000/110 = 90.9 A
The term "**rated load**" for a device refers to the load it is designed to carry for (theoretically) indefinite period of time. **Rated load** for the transformer refers to the apparent power specified as above, and shown in the nameplate information.

ELECTROMECHANICAL COMPONENTS

Relays & Contactors

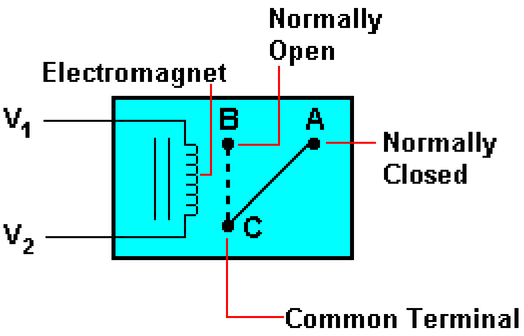
A relay is an **electrically operated switch**. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are **double throw** (**changeover**) switches.

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical



The relay's switch connections are usually labeled COM, NC and NO:

- **COM** = Common, always connect to this, it is the moving part of the switch.
- **NC** = Normally Closed, COM is connected to this when the relay coil is **off**.
- **NO** = Normally Open, COM is connected to this when the relay coil is **on**.
- Connect to COM and NO if you want the switched circuit to be **on when the relay coil is on**.
- Connect to COM and NC if you want the switched circuit to be **on when the relay coil is off**.

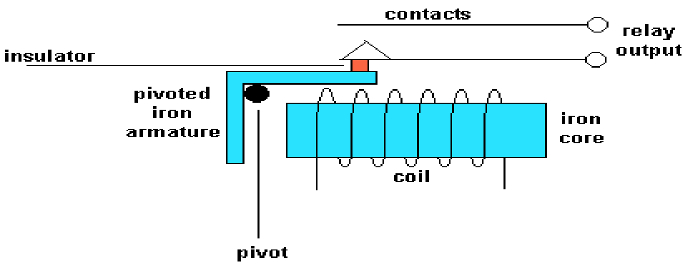


SPDT Relay

Relay consists of

- **Electromagnet**
- **Armature** that can be attracted by the electromagnet
- **Spring**
- **Set of electrical contacts**

The electromagnetic relay consists of a multi-turn coil, wound on an iron core, to form an electromagnet. When the coil is energised, by passing current through it, the core becomes temporarily magnetised.

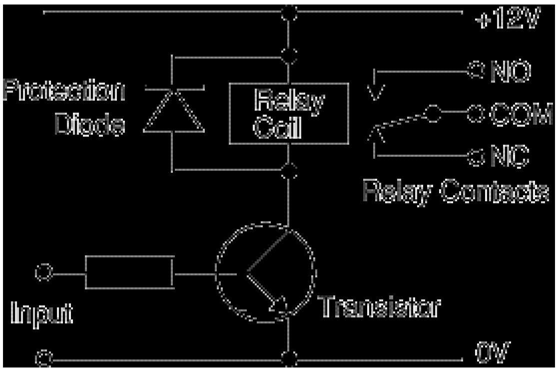


The magnetised core attracts the iron armature. The armature is pivoted which causes it to operate one or more sets of contacts. When the coil is de-energised the armature and contacts are released. The coil can be energised from a low power source such as a transistor while the contacts can switch high powers such as the mains supply. The relay can also be situated remotely from the control source.

Relays can generate a very high voltage across the coil when switched off. This can damage other components in the circuit. To prevent this a diode is connected across the coil. The cathode of the diode is connected to the most positive end of the coil.

The springsets (contacts) can be a mixture of n.o n.c and c.o. Various coil operating voltages (ac and dc) are available. The actual contact points on the springsets are available for high current and low current operation.

PROTECTION DIODES FOR RELAYS



Transistors and ICs must be protected from the brief high voltage produced when a relay coil is switched off. The diagram shows how a signal diode (eg 1N4148) is connected 'backwards' across the relay coil to provide this protection.

Current flowing through a relay coil creates a magnetic field which collapses suddenly when the current is switched off. The sudden collapse of the magnetic field induces a brief high voltage across the relay coil which is very likely to damage transistors and ICs. The protection diode allows the induced voltage to drive a brief current through the coil (and diode) so the magnetic field dies away quickly rather than instantly. This prevents the induced voltage becoming high enough to cause damage to transistors and ICs.

I. PN JUNCTION DIODE

1.1 IDEAL DIODE

The first electronic device to be presented is called the diode. It is the simplest of semiconductor devices but plays a very vital role in electronic systems, having characteristics of a simple switch. It has a number of applications, extending from the simple to the very complex. The term ideal refers to any device or system that has perfect characteristics. It provides a basis for comparison, and it reveals where improvements can still be made. The ideal diode is a two-terminal device having the symbol and characteristics shown in Figs. 1.1a and b, respectively.

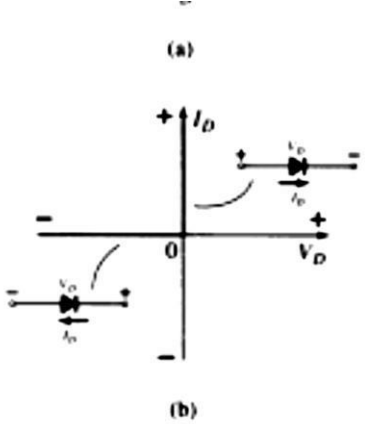


Fig 1.1 : The Ideal diode and its characteristics

Ideally, a diode will conduct current in the direction defined by the arrow in the symbol and act like an open circuit to any attempt to establish current in the opposite direction.

The characteristics of an ideal diode are those of a switch that can conduct current in only one direction. The ideal diode, therefore, is a short circuit for the region of conduction. The ideal diode, therefore, is an open circuit in the region of non-conduction.

In general, it is relatively simple to determine whether a diode is in the region of conduction or non-conduction simply by noting the direction of the current I_D established by an applied voltage. For conventional flow (opposite to that of electron flow), if the resultant diode current has the same direction as the arrowhead of the diode symbol, the diode is operating in the conducting region as depicted in Fig. 1.2a. If the resulting current has the opposite direction, as shown in Fig. 1.2b, the open circuit equivalent is appropriate.

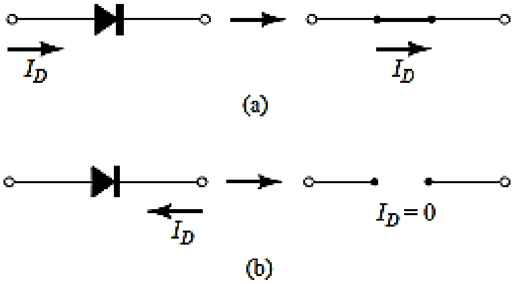


Fig 1.2 : The current flow in diode

1.2 SEMICONDUCTOR MATERIALS

Germanium (Ge) and Silicon (Si) are primarily popular as semiconductor materials. One very important consideration is the fact that they can be manufactured to a very high purity level. In fact, recent advances have reduced impurity levels in the pure material to 1 part in 10 billion. These low impurity levels are really necessary, if one considers that the addition of one part impurity (of the proper type) per million in a wafer of silicon material can change that material from a relatively poor conductor to a good conductor of electricity. The ability to change the characteristics of the material significantly through this process, known as "doping," is yet another reason why Ge and Si have received such wide attention. Further reasons include the fact that their characteristics can be altered significantly through the application of heat or light which is an important consideration in the development of heat-sensitive and light-sensitive devices.

1.2.1 CLASSIFICATION OF SEMICONDUCTORS

Semiconductors are classified into Intrinsic (pure) and Extrinsic (impure) types. The Extrinsic semiconductors are of n- type and p-type.

INTRINSIC SEMICONDUCTOR

Intrinsic materials are those semiconductors that have been carefully refined to reduce the impurities to a very low level that are essentially as pure as can be made available through modern technology.

The free electrons in the material due only to natural causes are referred to as intrinsic carriers. At the same temperature, intrinsic germanium material will have approximately 2.5 x 10^{13} free carriers per cubic centimeter. The ratio of the number of carriers in germanium to that of silicon is greater than 10^3 and would indicate that germanium is a better conductor at room temperature. This may be true, but both are still considered poor conductors in the intrinsic state. It is to be noted that resistivity and conductivity are inversely related. An increase in temperature of a semiconductor can result in a substantial increase in the number of free electrons in the material. Semiconductor materials such as Ge and Si that show a reduction in resistance with increase in temperature are said to have a negative temperature coefficient.

EXTRINSIC SEMICONDUCTOR MATERIALS

The characteristics of semiconductor materials can be altered significantly by the addition of certain impurity atoms into the relatively pure semiconductor material. These impurities, although only added to perhaps 1 part in 10 million, can alter the band structure sufficiently to totally change the electrical properties of the material.

A semiconductor material that has been subjected to the doping process is called an extrinsic material.

There are two extrinsic materials of immeasurable importance to semiconductor device fabrication: n-type and p-type.

n-Type Material

Both the n- and p-type materials are formed by adding a predetermined number of impurity atoms into a germanium or silicon base. The n-type is created by introducing those impurity elements that have five valence electrons (pentavalent), such as antimony, arsenic, and phosphorus. The effect of such impurity elements is indicated in Fig. 1.3 (using antimony as the impurity in a silicon base).

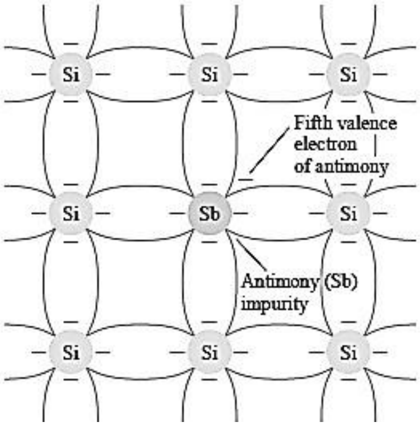


Fig 1.3 : The Covalent bond with antimony impurities

Note that the four covalent bonds are still present. There is, however, an additional fifth electron due to the
impurity atom, which is unassociated with any particular covalent bond. This remaining electron, loosely bound to its parent (antimony) atom, is relatively free to move within the newly formed n-type material. Since the inserted impurity atom has donated a relatively "free" electron to the structure. Diffused impurities with five valence electrons are called donor atoms. It is important to realize that even though a large number of "free" carriers have been established in the n-type material, it is still electrically neutral since ideally the number of positively charged protons in the nuclei is still equal to the number of "free" and orbiting negatively charged electrons in the structure.

p-Type Material

The p-type material is formed by doping a pure germanium or silicon crystal with impurity atoms having three valence electrons. The elements most frequently used for this purpose are boron, gallium, and indium. The effect of one of these elements, boron, on a base of silicon is indicated in Fig. 1.4.

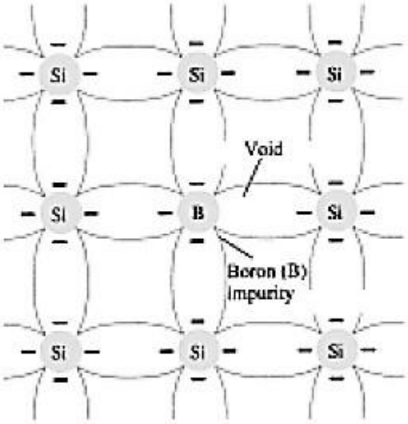


Fig 1.4 : The Covalent bond with boron impurities

Note that there is now an insufficient number of electrons to complete the covalent bonds of the newly formed lattice. The resulting vacancy is called a hole and is represented by a small circle or positive sign due to the absence of a negative charge. Since the resulting vacancy will readily accept a "free" electron. The diffused impurities with three valence electrons are called acceptor atoms. The resulting p-type material is electrically neutral, for the same reasons described for the n-type material.

Electron versus Hole Flow

The effect of the hole on conduction is shown in Fig. 1.5. If a valence electron acquires sufficient kinetic energy to break its covalent bond and fills the void created by a hole, then a vacancy, or hole, will be created in the covalent bond that released the electron. There is, therefore, a transfer of holes to the left and electrons to the right, as shown in Fig. 1.12. The direction to be used in this text is that of conventional flow, which is indicated by the direction of hole flow.

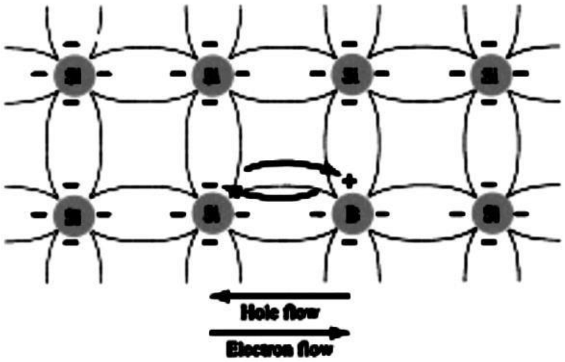


Fig 1.5 : The flow of charge carriers

Majority and Minority Carriers

In the intrinsic state, the number of free electrons in Ge or Si is due only to those few electrons in the valence band that have acquired sufficient energy from thermal or light sources to break the covalent bond or to the few impurities that could not be removed. The vacancies left behind in the covalent bonding structure represent our very limited supply of holes. In an n-type material, the number of holes has not changed significantly from this intrinsic level. The net result, therefore, is that the number of electrons far outweighs the number of holes. For this reason, in an n-type material (Fig. 1.6a) the electron is called the majority carrier and the hole the minority carrier. For the p-type material the number of holes far outweighs the number of electrons, as shown in Fig. 1.6b. Therefore, in a p-type material the hole is the majority carrier and the electron is the minority carrier. When the fifth electron of a donor atom leaves the parent atom, the atom remaining acquires a net positive charge: hence the positive sign in the donor-ion representation. For similar reasons, the negative sign appears in the acceptor ion. The n- and p-type materials represent the basic building blocks of semiconductor devices. It is to be noted that the "joining" of a single n-type material with a p-type material will result in a semiconductor element of considerable importance in electronic systems.

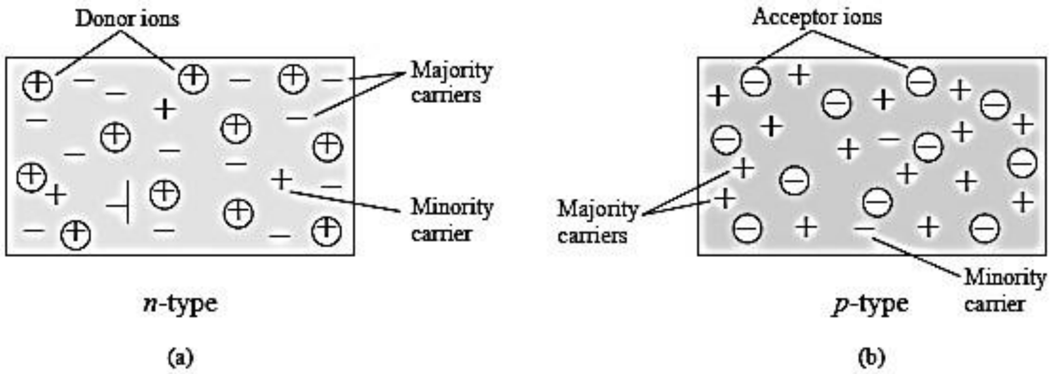


Fig 1.6 : The majority and minority carriers

1.3 SEMICONDUCTOR DIODE

The semiconductor diode is formed by simply bringing these materials together (constructed from the same base—Ge or Si), as shown in Fig. 1.7. At the instant the two materials are "joined" the electrons and holes in the region of the junction will combine, resulting in a lack of carriers in the region near the junction. This region of uncovered positive and negative ions is called the depletion region due to the depletion of carriers in this region. Since the diode is a two-terminal device, the application of a voltage across its terminals leaves three possibilities: *no bias* (V_D = 0 V), *forward bias* (V_D > 0 V), and *reverse bias* (V_D < 0 V). Each is a condition that will result in a response that the user must clearly understand if the device is to be applied effectively.

<u>No Applied Bias (V_D = 0 V)</u>

Under no-bias (no applied voltage) conditions, any minority carriers (holes) in the *n*-type material that find themselves within the depletion region will pass directly into the *p*-type material. The closer the minority carrier is to the junction, the greater the attraction for the layer of negative ions and the less the opposition of the positive ions in the depletion region of the *n*-type material. All the minority carriers of the *n*-type material that find themselves in the depletion region due to their random motion will pass directly into the *p*-type material. Similar assumption can be applied to the minority carriers (electrons) of the *p*-type material. This carrier flow has been indicated in Fig. 1.7 for the minority carriers of each material. The majority carriers (electrons) of the *n*-type material must overcome the attractive forces of the layer of positive ions in the *n*-type material and the shield of negative ions in the *p*-type material to migrate into the area beyond the depletion region of the *p*-type material. However, the number of majority carriers is so large in the *n*-type material that there will invariably be a small number of majority carriers with sufficient kinetic energy to pass through the depletion region into the *p*-type material.

Again, the same type of discussion can be applied to the majority carriers (holes) of the *p*-type material. The resulting flow due to the majority carriers is also shown in Fig. 1.7. The relative magnitudes of the flow vectors are such that the net flow in either direction is zero. This cancellation of vectors has been indicated by crossed lines. The length of the vector representing hole flow has been drawn longer than that for electron flow to demonstrate that the magnitude of each need not be the same for cancellation and that the doping levels for each material may result in an unequal carrier flow of holes and electrons.

In the absence of an applied bias voltage, the net flow of charge in any one direction for a semiconductor diode is zero.

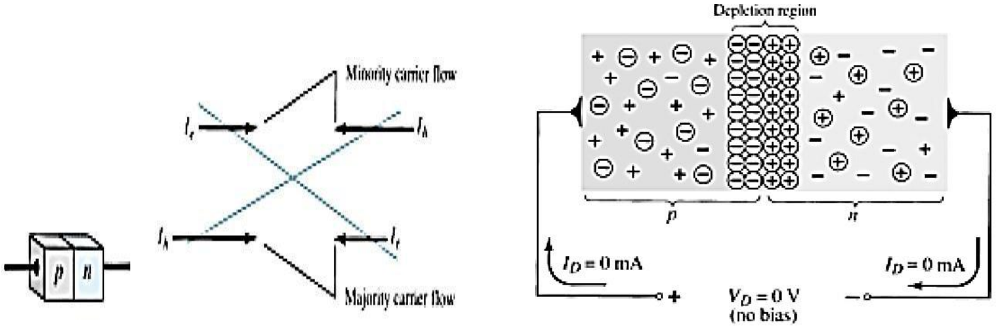


Fig 1.7 : The unbiased PN junction

Reverse-Bias Condition ($V_D < 0$ V)

If an external potential of *V* volts is applied across the *p*-*n* junction such that the positive terminal is connected to the *n*-type material and the negative terminal is connected to the *p*-type material as shown in Fig. 1.16, the number of uncovered positive ions in the depletion region of the *n*-type material will increase due to the large number of “free” electrons drawn to the positive potential of the applied voltage. For similar reasons, the number of uncovered negative ions will increase in the *p*-type material. The net effect, therefore, is a widening of the depletion region. This widening of the depletion region will establish too great a barrier for the majority carriers to overcome, effectively reducing the majority carrier flow to zero as shown in Fig. 1.8.

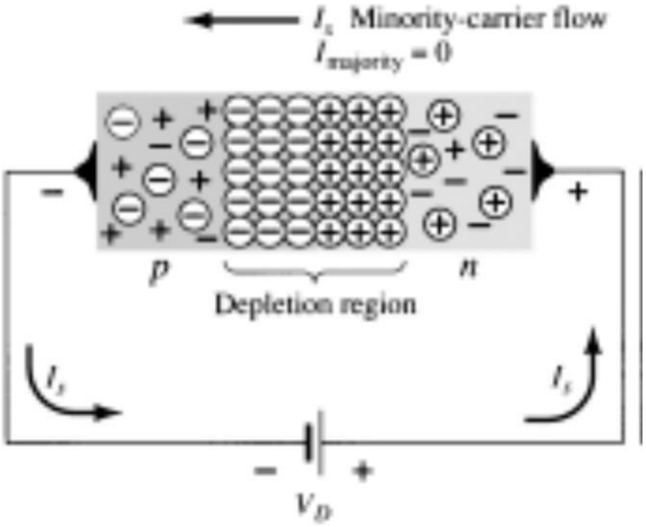


Fig 1.8: Reverse-biased *p-n* junction.

The number of minority carriers, however, that find themselves entering the depletion region will not change, resulting in minority-carrier flow vectors of the same magnitude indicated in Fig. 1.7 with no applied voltage.

The current that exists under reverse-bias conditions is called the reverse saturation current and is represented by I_s. The reverse saturation current is seldom more than a few microamperes except for high-power devices. In fact, in recent years its level is typically in the nanoampere range for silicon devices and in the low-microampere range for germanium. The term *saturation* comes from the fact that it reaches its maximum level quickly and does not change significantly with increase in the reverse-bias potential. The reverse-biased conditions are depicted in Fig. 1.8 for the diode symbol and *p*-*n* junction. Note, in particular, that the direction of *Is* is against the arrow of the symbol. Note also that the *n*egative potential is connected to the *p*-type material and the *p*ositive potential to the *n*-type material—the difference in underlined letters for each region revealing a reverse-bias condition.

Forward-Bias Condition ($V_D > 0$ V)

A *forward-bias* or "on" condition is established by applying the positive potential to the *p*-type material and the negative potential to the *n*-type material as shown in Fig. 1.9.

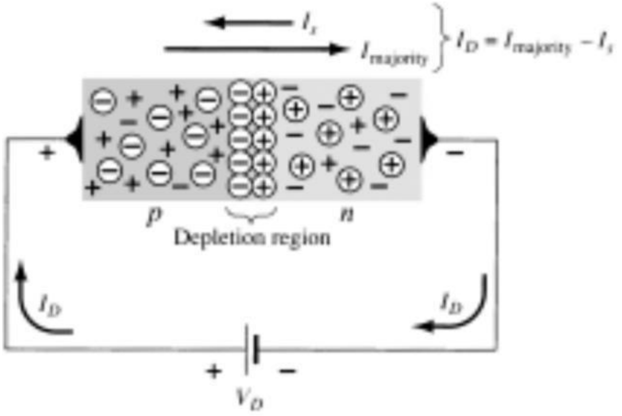


Fig 1.9 : Forward-biased *p-n* junction.

The application of a forward-bias potential will force electrons in the *n*-type material and holes in the *p*-type material to recombine with the ions near the boundary and reduce the width of the depletion region as shown in Fig. 1.9. The resulting minority-carrier flow of electrons from the *p*-type material to the *n*-type material (and of holes from the *n*-type material to the *p*-type material) has not changed in magnitude (since the conduction level is controlled primarily by the limited number of impurities in the material), but the reduction in the width of the depletion region has resulted in a heavy majority flow across the junction. An electron of the *n*-type material now "sees" a reduced barrier at the junction due to the reduced depletion region and a strong attraction for the positive potential applied to the *p*-type material. As the applied bias increases in magnitude the depletion region will continue to decrease in width until a flood of electrons can pass through the junction, resulting in an exponential rise in current as shown in the forward-bias region of the characteristics of Fig. 1.10. Note that the vertical scale of Fig. 1.10 is measured in milliamperes (although some semiconductor diodes will have a vertical scale measured in amperes) and the horizontal scale in the forward-bias region has a maximum of 1 V. Typically, therefore, the voltage across a forward-biased diode will be less than 1 V. Note also, how quickly the current rises beyond the knee of the curve.

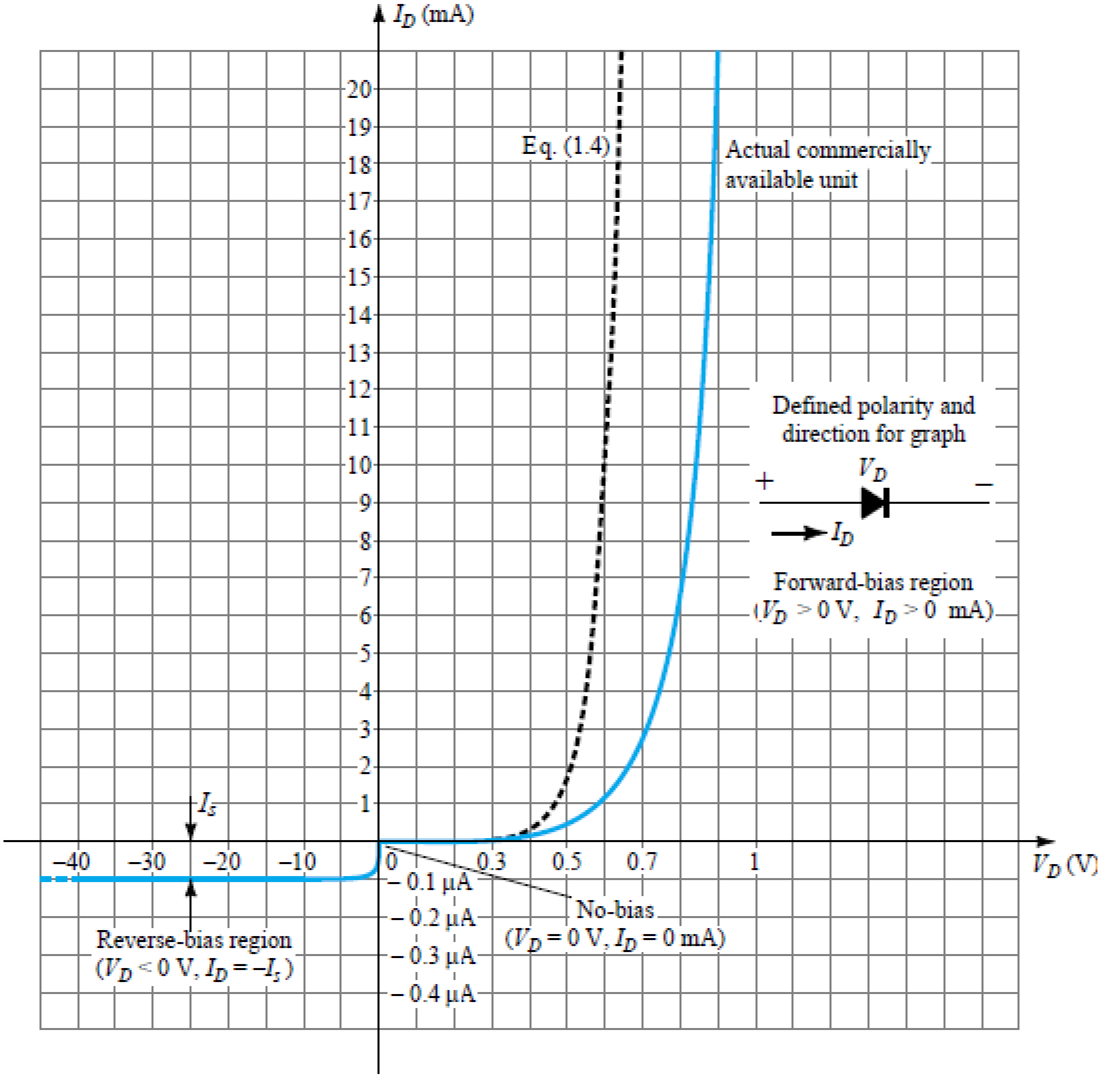


Fig 1.10: Silicon semiconductor diode characteristics.

Zener Region

Even though the scale of Fig. 1.10 is in tens of volts in the negative region, there is a point where the application of too negative a voltage will result in a sharp change in the characteristics, as shown in Fig. 1.11. The current increases at a very rapid rate in a direction opposite to that of the positive voltage region. The reverse-bias potential that results in this dramatic change in characteristics is called the *Zener potential* and is given the symbol V_Z.

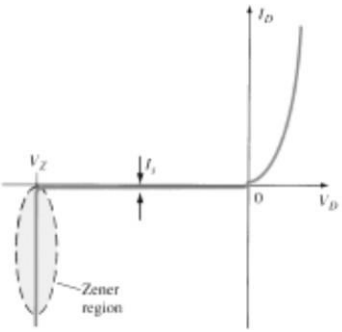


Fig 1.11: Zener region

As the voltage across the diode increases in the reverse-bias region, the velocity of the minority carriers responsible for the reverse saturation current *Is* will also increase. Eventually, their velocity and associated kinetic energy will be sufficient to release additional carriers through collisions with otherwise stable atomic structures. That is, an *ionization* process will result whereby valence electrons absorb sufficient energy to leave the parent atom. These additional carriers can then aid the ionization process to the point where a high *avalanche* current is established and the *avalanche breakdown* region determined.

The avalanche region (V_Z) can be brought closer to the vertical axis by increasing the doping levels in the *p*- and *n*-type materials. However, as V_Z decreases to very low levels, such as -5 V, another mechanism, called *Zener breakdown*, will contribute to the sharp change in the characteristic. It occurs because there is a strong electric field in the region of the junction that can disrupt the bonding forces within the atom and "generate" carriers. Although the Zener breakdown mechanism is a significant contributor only at lower levels of V_Z, this sharp change in the characteristic at any level is called the *Zener region* and diodes employing this unique portion of the characteristic of a *p-n* junction are called *Zener diodes*. The Zener region of the semiconductor diode described must be avoided if the response of a system is not to be completely altered by the sharp change in characteristics in this reverse-voltage region.

The maximum reverse-bias potential that can be applied before entering the Zener region is called the peak inverse voltage (referred to simply as the PIV rating) or the peak reverse voltage (denoted by PRV rating).

If an application requires a PIV rating greater than that of a single unit, a number of diodes of the same characteristics can be connected in series. Diodes are also connected in parallel to increase the current-carrying capacity.

Silicon versus Germanium

Silicon diodes have, in general, higher PIV and current rating and wider temperature ranges than germanium diodes. PIV ratings for silicon can be in the neighborhood of 1000 V, whereas the maximum value for germanium is closer to 400 V. Silicon can be used for applications in which the temperature may rise to about 200°C (400°F), whereas germanium has a much lower maximum rating (100°C). The disadvantage of silicon, however, as compared to germanium, is the higher forward-bias voltage required to reach the region of upward swing. It is typically of the order of magnitude of 0.7 V for *commercially* available silicon diodes and 0.3 V for germanium diodes when rounded off to the nearest tenths. The potential V_T at which this rise in curve occurs is commonly referred to as the *offset, threshold,* or *firing potential.*

1.4 ZENER DIODES

The Zener region characteristic drops in an almost vertical manner at a reverse-bias potential denoted V_Z. The fact that the curve drops down and away from the horizontal axis rather than up and away for the positive V_D region reveals that the current in the Zener region has a direction opposite to that of a forward-biased diode.

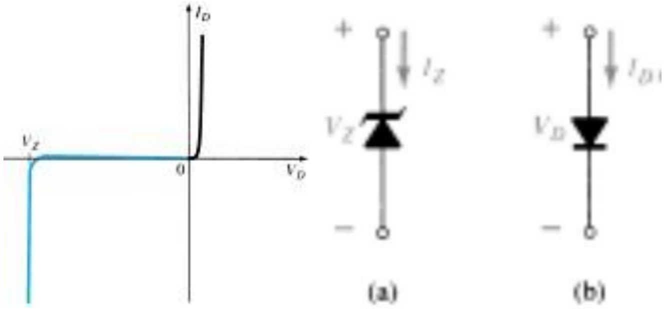


Fig 1.12: Zener diode vs Semiconductor diode

This region of unique characteristics is employed in the design of *Zener diodes,* which have the graphic symbol appearing in Fig. 1.12a with the semiconductor diode in Fig. 1.12b to ensure that the direction of conduction of each is clearly understood together with the required polarity of the applied voltage. For the semiconductor diode the “on” state will support a current in the direction of the arrow in the symbol. For the Zener diode the direction of conduction is opposite to that of the arrow in the symbol. Note also that the polarity of V_D and V_Z are the same as would be obtained if each were a resistive element.

1.5 LIGHT-EMITTING DIODES

The increasing use of digital displays in calculators, watches, and all forms of instrumentation has contributed to the current extensive interest in structures that will emit light when properly biased. The two types in common use today to perform this function are the *light-emitting diode* (LED) and the *liquid-crystal display* (LCD). As the name implies, the light-emitting diode (LED) is a diode that will give off visible light when it is energized. In any forward-biased *p-n* junction there is, within the structure and primarily close to the junction, a recombination of holes and electrons. This recombination requires that the energy possessed by the unbound free electron be transferred to another state. In all semiconductor *p-n* junctions some of this energy will be given off as heat and some in the form of photons. In silicon and germanium the greater percentage is given up in the form of heat and the emitted light is insignificant. In other materials, such as gallium arsenide phosphide (GaAsP) or gallium phosphide (GaP), the number of photons of light energy emitted is sufficient to create a very visible light source. The process of giving off light by applying an electrical source of energy is called Electroluminescence**.**

As shown in Fig. 1.13 with its graphic symbol, the conducting surface connected to the *p*-material is much smaller, to permit the emergence of the maximum number of photons of light energy. Note in the figure that the recombination of the injected carriers due to the forward-biased junction results in emitted light at the site of recombination. There may, of course, be some absorption of the packages of photon energy in the structure itself, but a very large percentage are able to leave.

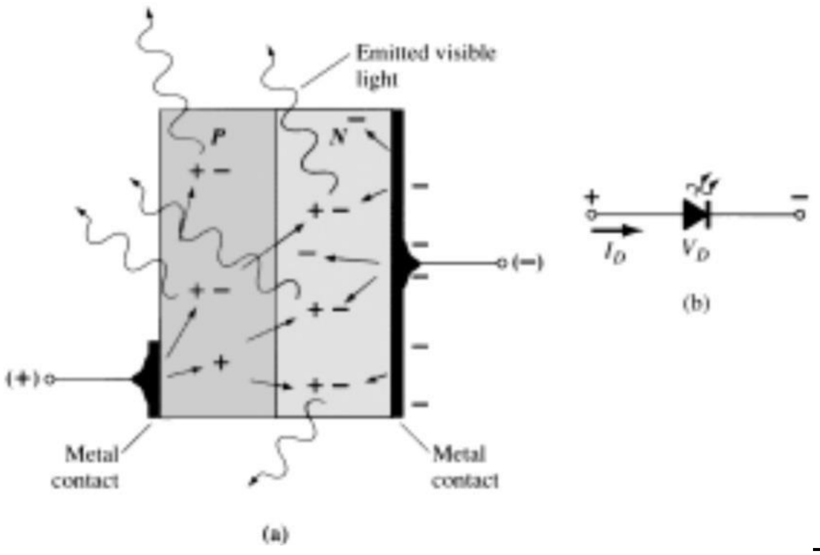


Fig 1.13: LED diode structure

LED displays are available today in many different sizes and shapes. The light emitting region is available in lengths from 0.1 to 1 in. Numbers can be created by segments such as shown in Fig. 1.14. By applying a forward bias to the proper *p*-type material segment, any number from 0 to 9 can be displayed.

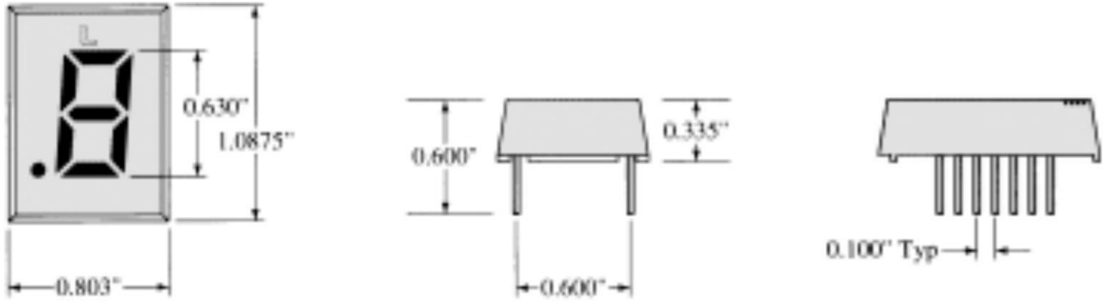


Fig 1.14: LED displays

There are also two-lead LED lamps that contain two LEDs, so that a reversal in biasing will change the color from green to red, or vice versa. LEDs are presently available in red, green, yellow, orange, and white, and white with blue soon to be commercially available. In general, LEDs operate at voltage levels from 1.7 to 3.3 V, which makes them completely compatible with solid-state circuits. They have a fast response time (nanoseconds) and offer good contrast ratios for visibility. The power requirement is typically from 10 to 150 mW with a lifetime of 100,000 hours. Their semiconductor construction adds a significant ruggedness factor.

1.6 THE PHOTODIODE

The photodiode is a device that operates in reverse bias, as shown in Figure 1.15(a), where is the reverse light current. The photodiode has a small transparent window that allows light to strike the *pn* junction. Some typical photodiodes are shown in Figure 1.15(b). An alternate photodiode symbol is shown in Figure 1.15(c).

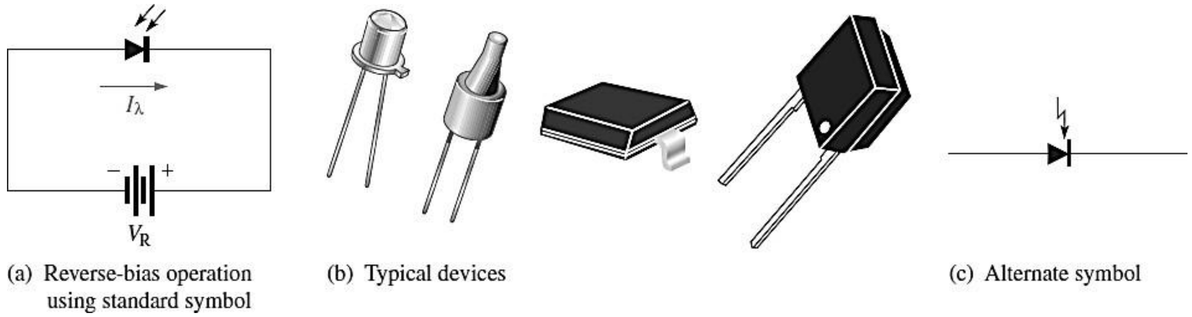


Fig 1.15: Photodiode

When reverse-biased, a rectifier diode has a very small reverse leakage current. The same is true for a photodiode. The reverse-biased current is produced by thermally generated electron-hole pairs in the depletion region, which are swept across the *pn* junction by the electric field created by the reverse voltage. In a rectifier diode, the reverse leakage current increases with temperature due to an increase in the number of electron-hole pairs.

A photodiode differs from a rectifier diode in that when its *pn* junction is exposed to light, the reverse current increases with the light intensity. When there is no incident light, the reverse current, is almost negligible and is called the **dark current.** An increase in the amount of light intensity, expressed as irradiance (mW/cm2), produces an increase in the reverse current, as shown by the graph in Figure 1.16(a).

Technical data specify that the reverse current for this particular device is approximately at a reverse-bias voltage of 10 V with an irradiance of 0.5 mW/cm2. Therefore, the resistance of the device is:

$$R_R = \frac{V_R}{I_\lambda} = \frac{10\text{ V}}{1.4\,\mu\text{A}} = 7.14\,\text{M}\Omega$$

At 20 mW/cm2, the current is approximately 55 mA at V_R = 10 V. The resistance under this condition is

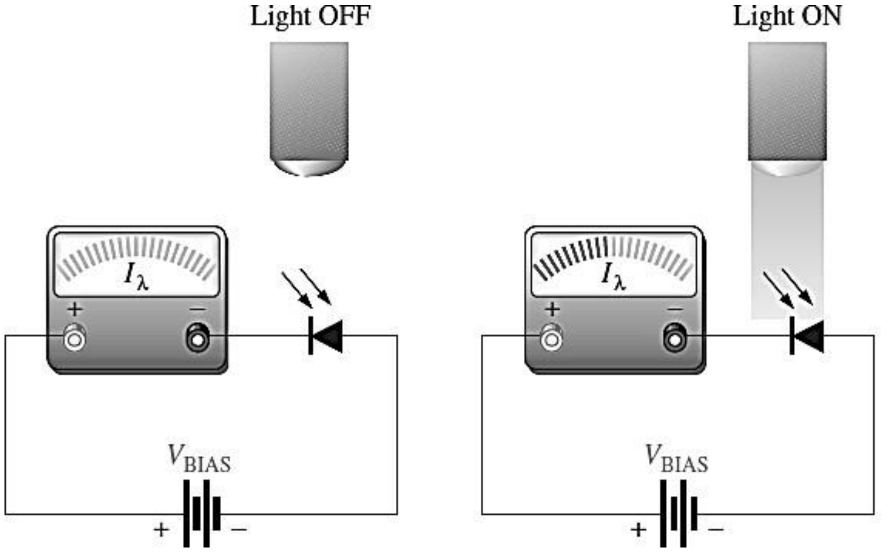
$$R_R = \frac{V_R}{I_\lambda} = \frac{10\text{ V}}{55\,\mu\text{A}} = 182\,\text{k}\Omega$$

These calculations show that the photodiode can be used as a variable-resistance device controlled by light intensity.

(a) General graph of reverse current versus irradiance

Fig 1.16: Photodiode characteristics

Figure 1.17 illustrates that the photodiode allows essentially no reverse current (except for a very small dark current) when there is no incident light. When a light beam strikes the photodiode, it conducts an amount of reverse current that is proportional to the light intensity (irradiance).



(a) No light, no current except negligible dark current

(b) Where there is incident light, resistance decreases and there is reverse current.

Fig 1.17: Photodiode practical operation

1.7 PHOTOVOLTAIC (PV) Cell

The key feature of a PV (solar) cell is the pn junction. The photovoltaic effect is the basic physical process by which a solar cell converts sunlight into electricity. Sunlight contains photons or “packets” of energy sufficient to create electron-hole pairs in the n and p regions. Electrons accumulate in the n-region and holes accumulate in the p region, producing a potential difference (voltage) across the cell. When an external load is connected, the electrons flow through the semiconductor material and provide current to the external load.

The Solar Cell Structure

Although there are other types of solar cells and continuing research promises new developments in the future, the crystalline silicon solar cell is by far the most widely used. A silicon solar cell consists of a thin layer or wafer of silicon that has been doped to create a pn junction. The depth and distribution of impurity atoms can be controlled very precisely during the doping process. The most commonly used process for creating a silicon ingot, from which a silicon wafer is cut, is called the Czochralski method. In this process, a seed crystal of silicon is dipped into melted polycrystalline silicon. As the seed crystal is withdrawn and rotated, a cylindrical ingot of silicon is formed. Thin circular shaped-wafers are sliced from an ingot of ultra-pure silicon and then are polished and trimmed to an octagonal, hexagonal, or rectangular shape for maximum coverage when fitted into an array. The silicon wafer is doped so that the n region is much thinner than the p region to permit light penetration, as shown in Figure 1.18(a). A grid-work of very thin conductive contact strips are deposited on top of the wafer by methods such as photoresist or silk-screen, as shown in part (b). The contact grid must maximize the surface area of the silicon wafer that be exposed to the sunlight in order to collect as much light energy as possible.

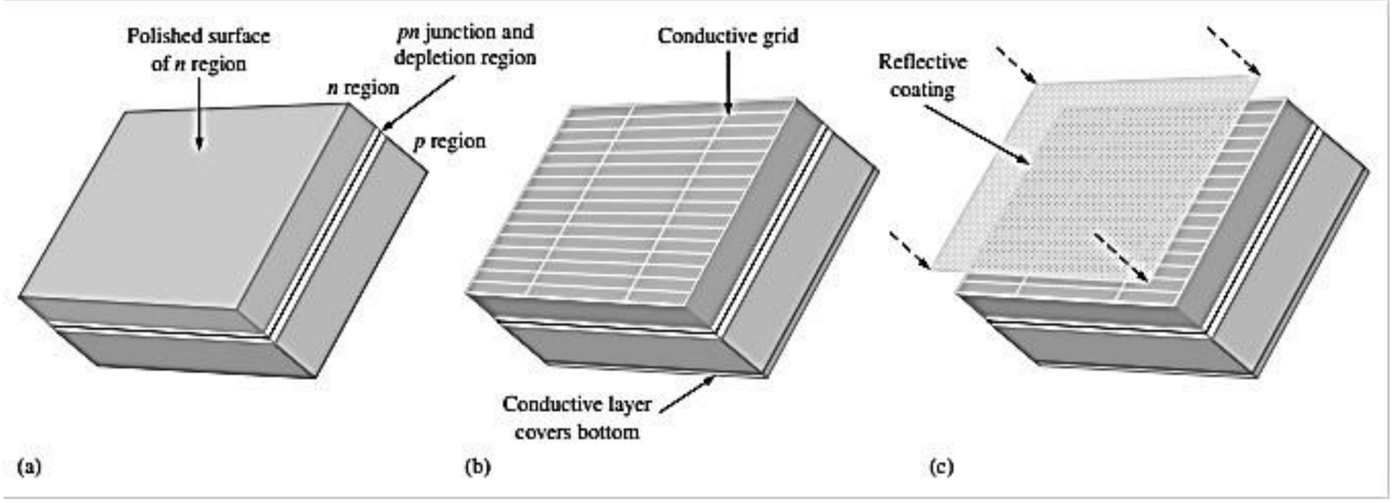


Fig 1.18: Basic construction of a PV Solar Cell

The conductive grid across the top of the cell is necessary so that the electrons have a shorter distance to travel through the silicon when an external load is connected. The farther electrons travel through the silicon material, the greater the energy loss due to resistance. A solid contact covering the entire bottom of the wafer is then added, as indicated in the figure. Thickness of the solar cell compared to the surface area is greatly exaggerated for purposes of illustration.

After the contacts are incorporated, an antireflective coating is placed on top the contact grid and n region, as shown in Figure 1.18(c). This allows the solar cell to absorb as much of the sun's energy as possible by reducing the amount of light energy reflected away from the surface of the cell. Finally, a glass or transparent plastic layer is attached to the top of the cell with transparent adhesive to protect it from the weather. Figure 1.19 shows a completed solar cell.

Fig 1.19: A complete PV Solar Cell

Operation of a Solar Cell

As indicated before, sunlight is composed of photons, or "packets" of energy. The sun produces an astounding amount of energy. The small fraction of the sun's total energy that reaches the earth is enough to meet all of our power needs many times over. There is sufficient solar energy striking the earth each hour to meet worldwide demands for an entire year. The n-type layer is very thin compared to the p region to allow light penetration into the p region. The thickness of the entire cell is actually about the thickness of an eggshell. When a photon penetrates either the n region or the p-type region and strikes a silicon atom near the pn junction with sufficient energy to knock an electron out of the valence band, the electron becomes a free electron and leaves a hole in the valence band, creating an electron-hole pair. The amount of energy required to free an electron from the valence band of a silicon atom is called the band-gap energy and is 1.12 eV (electron volts). In the p region, the free electron is swept across the depletion region by the electric field into the n region. In the n region, the hole is swept across the depletion region by the electric field into the p region. Electrons accumulate in the n region, creating a negative charge; and holes accumulate in the p region, creating a positive charge. A voltage is developed between the n region and p region contacts, as shown in Figure 1.20.

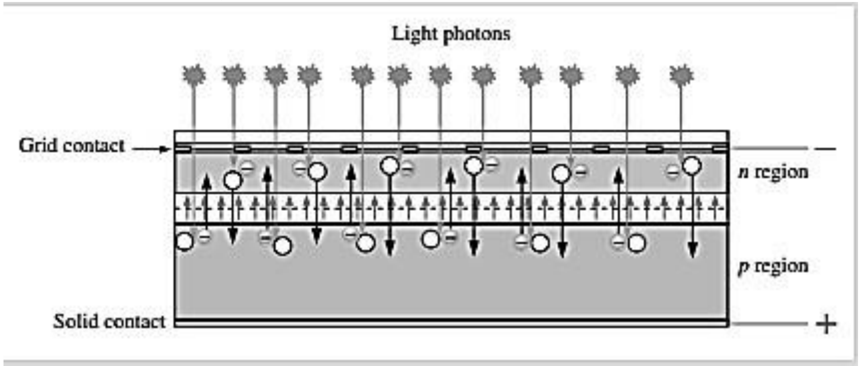


Fig 1.20: Basic operation of a solar cell with incident sunlight.

When a load is connected to a solar cell via the top and bottom contacts, the free electrons flow out of the n region to the grid contacts on the top surface, through the negative contact, through the load and back into the positive contact on the bottom surface, and into the p region where they can recombine with holes. The sunlight energy continues to create new electron-hole pairs and the process goes on, as illustrated in Figure 1.21.

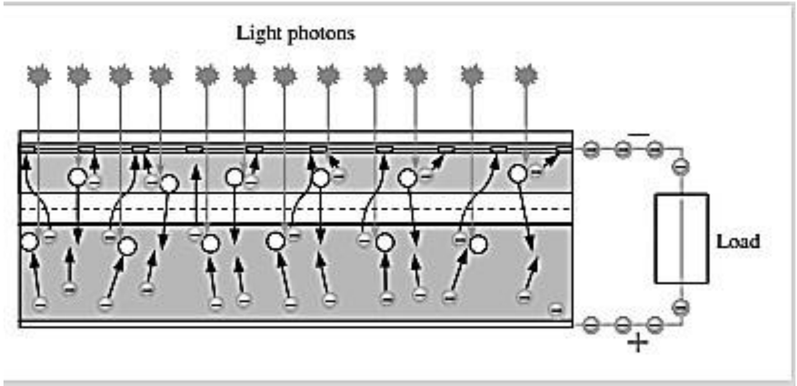


Fig 1.21: A solar cell producing voltage and current through a load under incident sunlight.

Solar Cell Characteristics

Solar cells are typically 100 cm^2 to 225 cm^2 in size. The usable voltage from silicon solar cells is approximately 0.5 V to 0.6 V. Terminal voltage is only slightly dependent on the intensity of light radiation, but the current increases with light intensity. For example, a 100 cm^2 silicon cell reaches a maximum current of approximately 2 A when radiated by 1000 W/m^2 of light. Fig 1.22 shows the V-I characteristic curves for a typical solar cell for various light intensities. Higher light intensity produces more current. The operating point for maximum power output for a given light intensity should be in the "knee" area of the curve, as indicated by the dashed line. The load on the solar cell controls this operating point (R_L = V/ I).

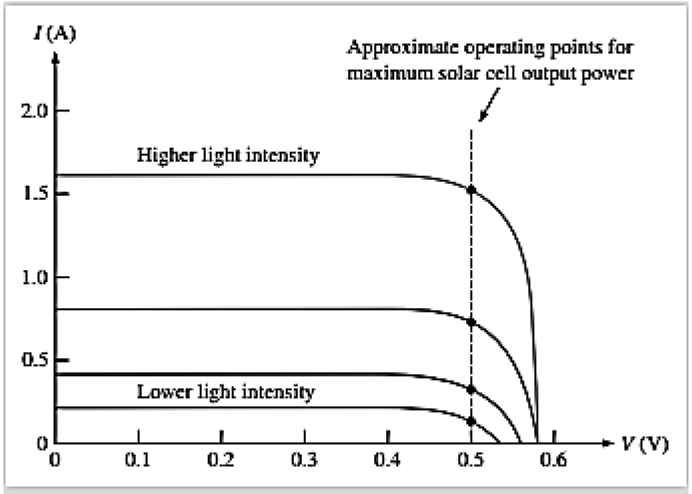
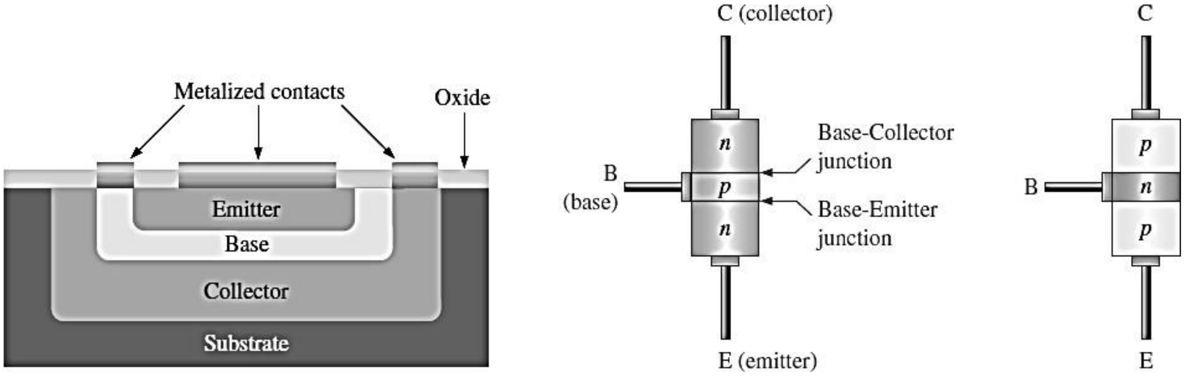


Fig 1.22 : V-I characteristic for a typical single solar cell from increasing light intensities.

II. BIPOLAR JUNCTION TRANSISTORS

The transistor was invented in 1947 by a team of scientists from Bell Laboratories. William Shockley, Walter Brattain, and John Bardeen developed the solid-state device that replaced the vacuum tube. Each received the Nobel prize in 1956. The transistor is arguably the most significant invention of the twentieth century.

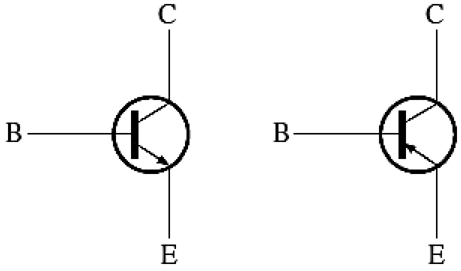
The **BJT** is constructed with three doped semiconductor regions separated by two *pn* junctions, as shown in the epitaxial planar structure in Figure 1.23(a). The three regions are called **emitter**, **base**, and **collector**. Physical representations of the two types of BJTs are shown in Figure 1.23(b) and (c). One type consists of two *n* regions separated by a *p* region (*npn*), and the other type consists of two *p* regions separated by an *n* region (*pnp*). The term **bipolar** refers to the use of both holes and electrons as current carriers in the transistor structure.



(a) Basic epitaxial planar structure (b) *npn* (c) *pnp*

Fig 1.23: Bipolar Junction Transistor

The *pn* junction joining the base region and the emitter region is called the *base-emitter junction*. The *pn* junction joining the base region and the collector region is called the *base-collector junction*. A wire lead connects to each of the three regions, as shown. These leads are labeled E, B, and C for emitter, base, and collector, respectively. The base region is lightly doped and very thin compared to the heavily doped emitter and the moderately doped collector regions. Figure 1.24 shows the schematic symbols for the *npn* and *pnp* bipolar junction transistors.



(a) *npn* (b) *pnp*

Fig 1.24: BJT Symbols

1.8 BASIC BJT OPERATION

In order for a BJT to operate properly as an amplifier, the two *pn* junctions must be correctly biased with external dc voltages. In this section, we mainly use the *npn* transistor for illustration. The operation of the *pnp* is the same as for the *npn* except that the roles of the electrons and holes, the bias voltage polarities, and the current directions are all reversed.

Figure 1.25 shows a bias arrangement for both *npn* and *pnp* BJTs for operation as an **amplifier.** Notice that in both cases the base-emitter (BE) junction is forward-biased and the base-collector (BC) junction is reverse-biased. This condition is called *forward-reverse bias.*

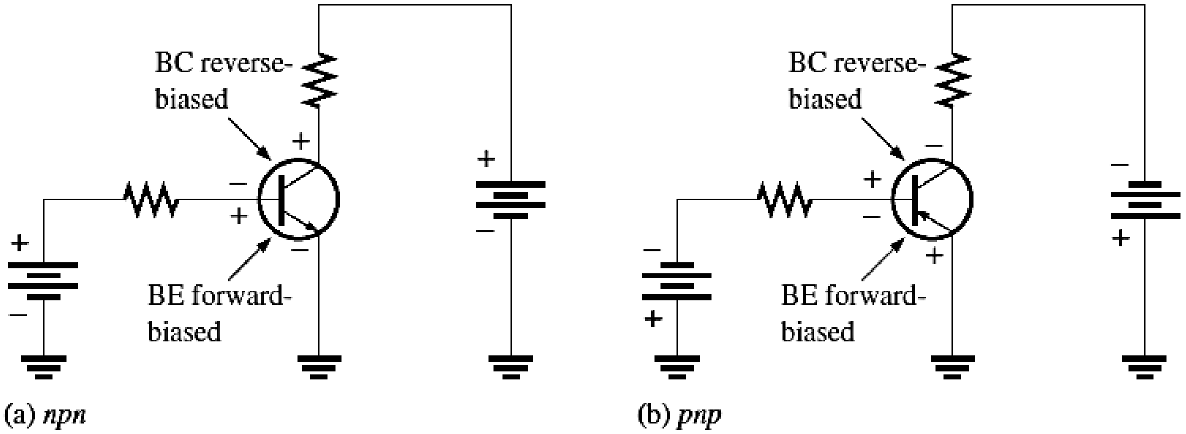


Fig 1.25: BJT Biasing

To understand how a transistor operates, examine what happens inside the *npn* structure.

The heavily doped *n*-type emitter region has a very high density of conduction-band (free) electrons, as indicated in Figure 1.26. These free electrons easily diffuse through the forward biased BE junction into the lightly doped and very thin *p*-type base region, as indicated by the wide arrow. The base has a low density of holes, which are the majority carriers, as represented by the white circles. A small percentage of the total number of free electrons injected into the base region recombine with holes and move as valence electrons through the base region and into the emitter region as hole current, indicated by the red arrows.

When the electrons that have recombined with holes as valence electrons leave the crystalline structure of the base, they become free electrons in the metallic base lead and produce the external base current. Most of the free electrons that have entered the base do not recombine with holes because the base is very thin. As the free electrons move toward the reverse-biased BC junction, they are swept across into the collector region by the attraction of the positive collector supply voltage. The free electrons move through the collector region, into the external circuit, and then return into the emitter region along with the base current, as indicated. The emitter current is slightly greater than the collector current because of the small base current that splits off from the total current injected into the base region from the emitter.

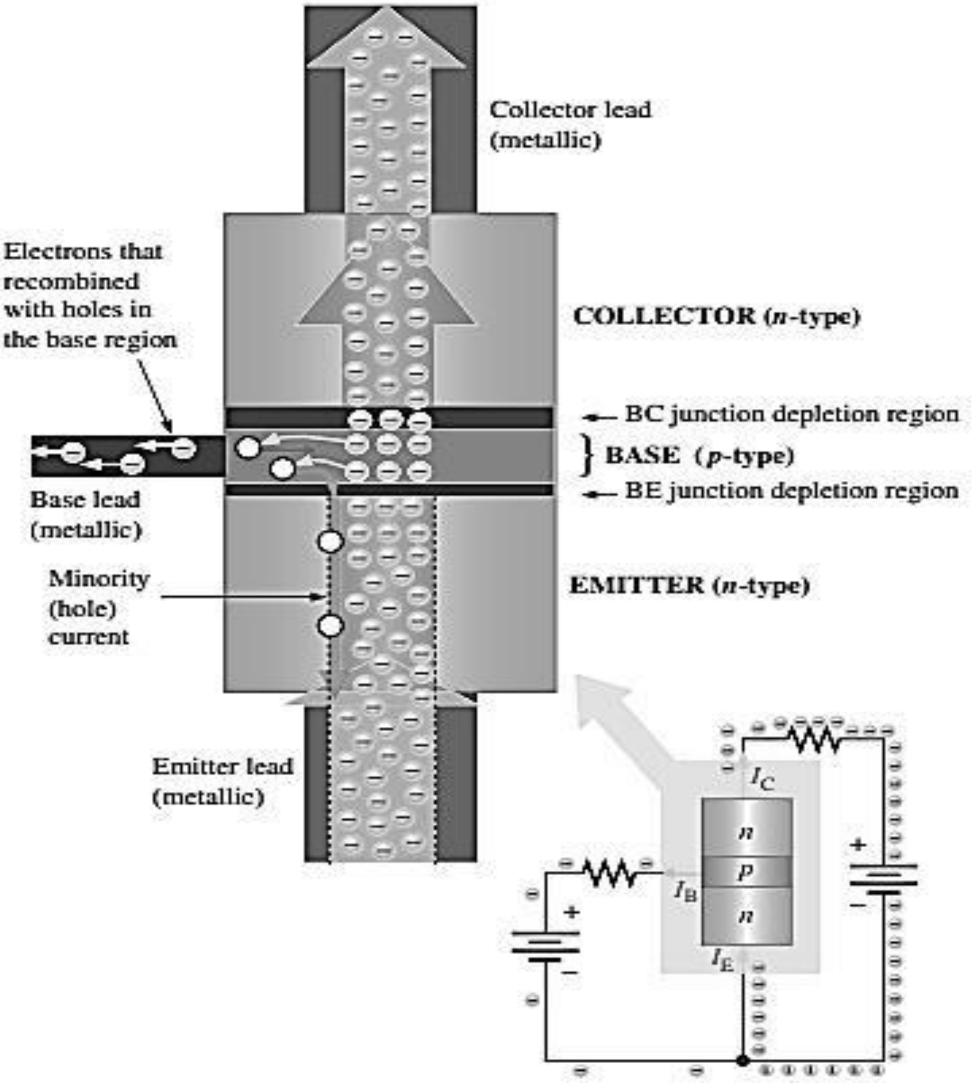


Fig 1.26: NPN Transistor operation

Transistor Currents The directions of the currents in an npn transistor and its schematic symbol are as shown in Figure 1.27(a); those for a pnp transistor are shown in Figure 1.27(b). Notice that the arrow on the emitter inside the transistor symbols points in the direction of conventional current. These diagrams show that the emitter current (I_E) is the sum of the collector current (I_C) and the base current (I_B), expressed as follows:

$I_E = I_C + IB$

I_B is very small compared to I_E or I_C. The capital-letter subscripts indicate dc values.

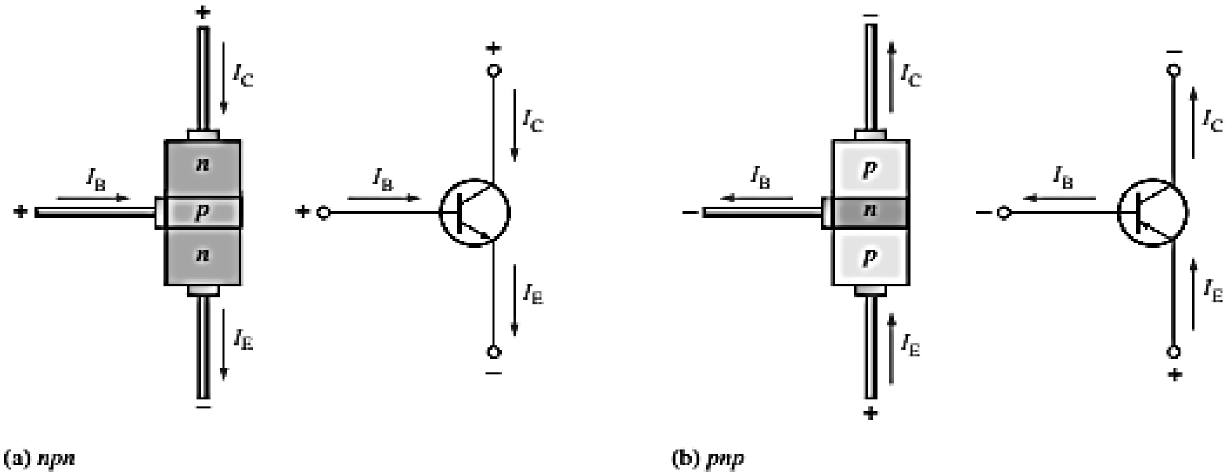


Fig 1.27: Transistor currents

1.18 COMMON-EMITTER CONFIGURATION

The most frequently encountered transistor configuration appears in Fig. 1.28 for the *pnp* and *npn* transistors. It is called the *common-emitter configuration* since the emitter is common or reference to both the input and output terminals (in this case common to both the base and collector terminals). Two sets of characteristics are again necessary to describe fully the behavior of the common-emitter configuration: one for the *input* or *base-emitter* circuit and one for the *output* or *collector-emitter* circuit.

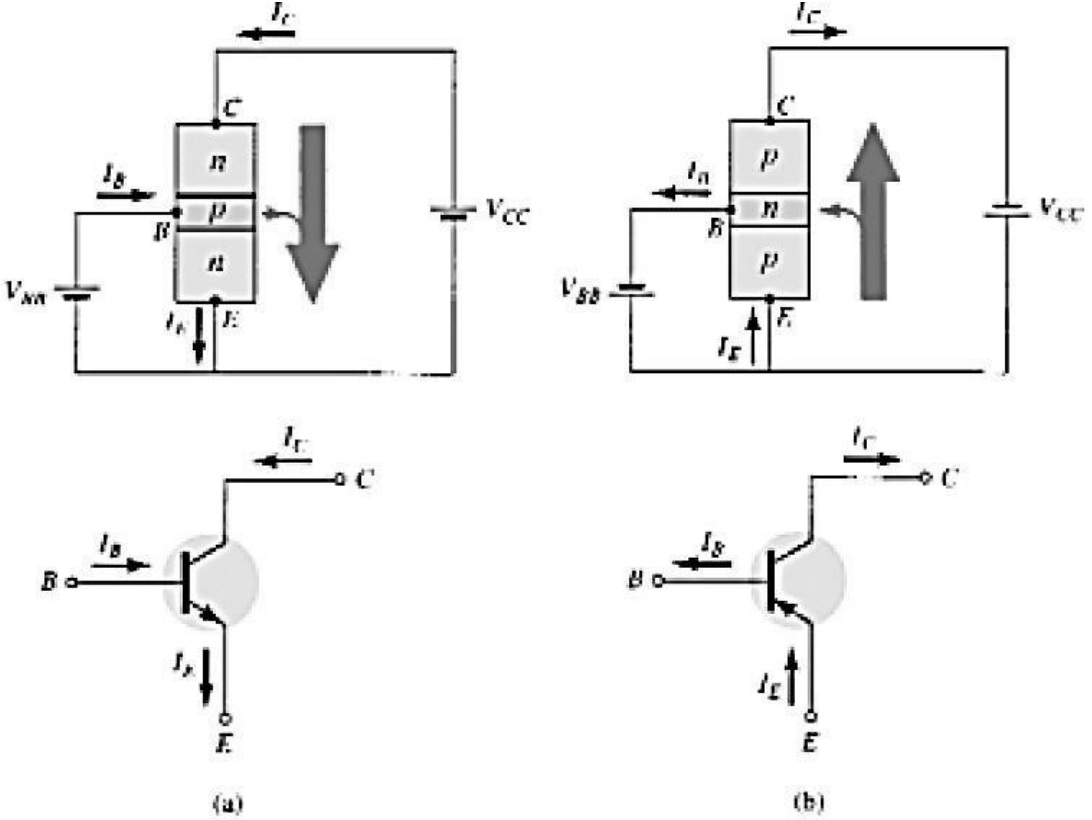


Fig 1.28: CE Transistor Configurations

The emitter, collector, and base currents are shown in their actual conventional current direction. That is, $I_E = I_C + I_B$ and $I_C = \alpha I_E$., where α is the gain factor.

For the common-emitter configuration the output characteristics are a plot of the output current (I_C) versus output voltage (V_{CE}) for a range of values of input current (I_B). The input characteristics are a plot of the input current (I_B) versus the input voltage (V_{BE}) for a range of values of output voltage (V_{CE}).

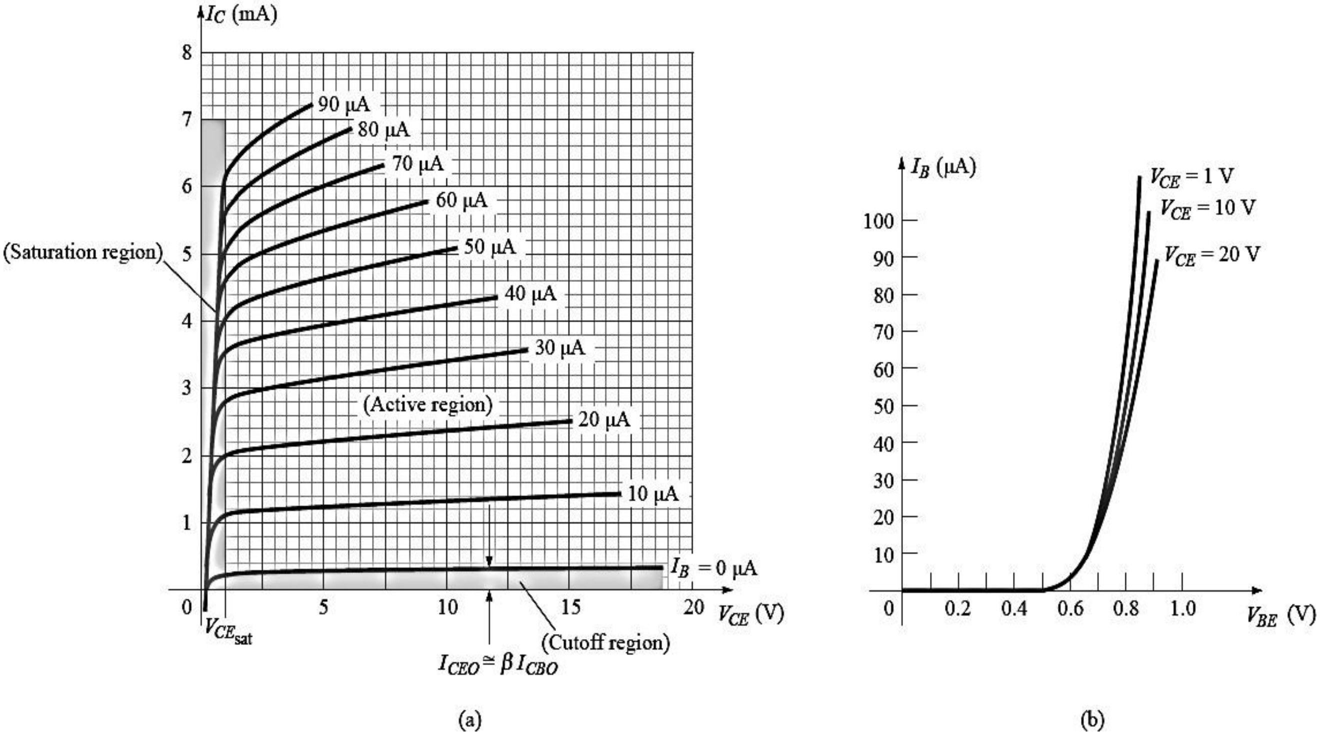


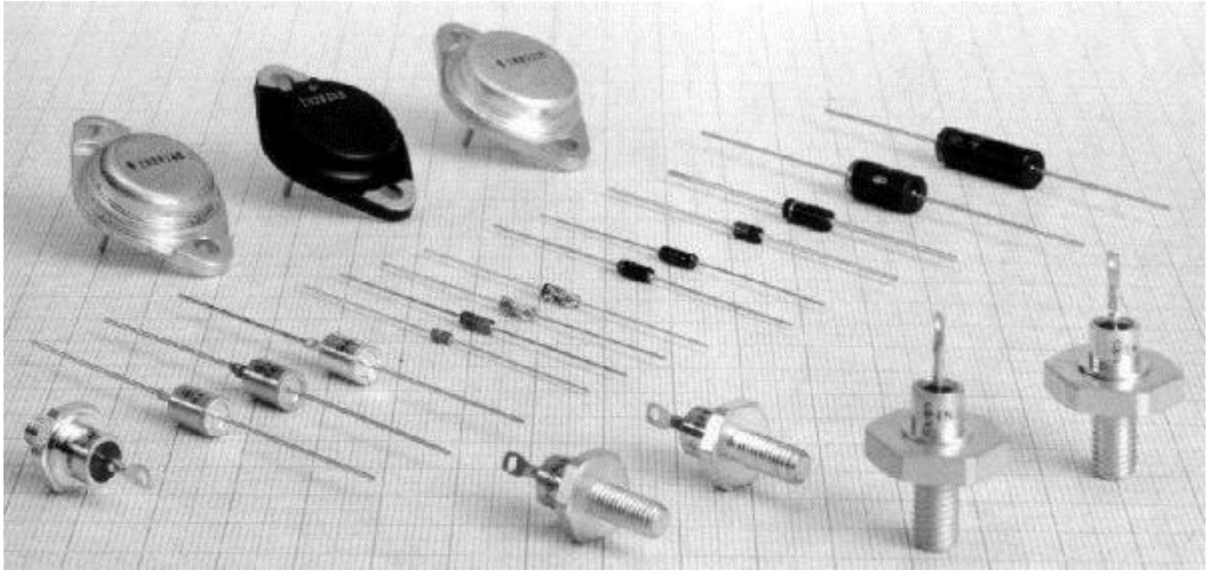
Fig 1.29: CE Transistor Input and Output Characteristics

Note that on the characteristics, the magnitude of I_B is in microamperes, compared to milliamperes of I_C. Consider also that the curves of I_B are not as horizontal as those obtained for I_E in the common-base configuration, indicating that the collector-to-emitter voltage will influence the magnitude of the collector current.

The active region for the common-emitter configuration is that portion of the upper-right quadrant that has the greatest linearity, that is, that region in which the curves for I_B are nearly straight and equally spaced. This region exists to the right of the vertical dashed line at VCE_{sat} and above the curve for I_B equal to zero. The region to the left of VCE_{sat} is called the saturation region.

In the active region of a common-emitter amplifier the collector-base junction is reverse-biased, while the base-emitter junction is forward-biased.

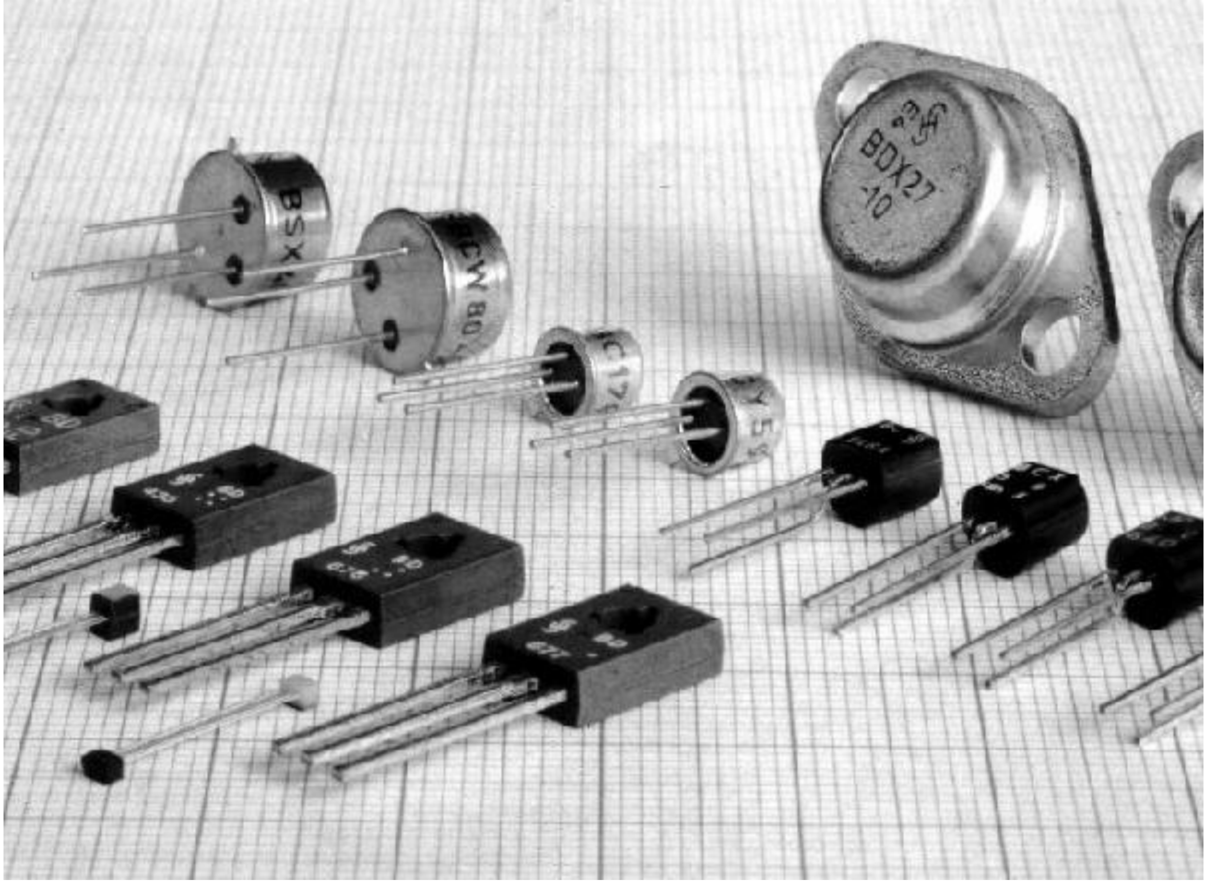
Diode identification rf www.mikroe.com/old/books/keu/04.html



European diodes are marked using two or three letters and a number. The first letter is used to identify the material used in manufacturing the component (A - germanium, B - silicon), or, in case of letter Z, a Zener diode.
The second and third letters specify the type and usage of the diode. Some of the varieties are:
A - low power diode, like the AA111, AA113, AA121, etc. - they are used in the detector of a radio receiver; BA124, BA125 : varicap diodes used instead of variable capacitors in receiving devices, oscillators, etc., BAY80, BAY93, etc. - switching diodes used in devices using logic circuits. BA157, BA158, etc. - these are switching diodes with short recovery time.
B - Two capacitive (varicap) diodes in the same housing, like BB104, BB105, etc.
Y - Regulation diodes, like BY240, BY243, BY244, etc. - these regulation diodes come in a plastic packaging and operate on a maximum current of 0.8A. If there is another Y, the diode is intended for higher current. For example, BYY44 is a diode whose absolute maximum current rating is 1A. When Y is the second letter in a Zener diode mark (ZY10, ZY30, etc.) it means it is intended for higher current.
G, G, PD - different tolerance marks for Zener diodes. Some of these are ZF12 (5% tolerance), ZG18 (10% tolerance), ZPD9.1 (5% tolerance).
The third letter is used to specify a property (high current, for example).
American markings begin with 1N followed by a number, 1N4001, for example (regulating diode), 1N4449 (switching diode), etc.
Japanese style is similar to American, the main difference is that instead of N there is S, 1S241 being one of them.

Transistor specifications

The most common type of transistor is called bipolar and these are divided into NPN and PNP types. Their construction-material is most commonly silicon (their marking has the letter B) or germanium (their marking has the letter A). Original transistor were made from germanium, but they were very temperature-sensitive. Silicon transistors are much more temperature-tolerant and much cheaper to manufacture.



The second letter in transistor’s marking describes its primary use:
C - low and medium power LF transistor,
D - high power LF transistor,
F - low power HF transistor,
G - other transistors,
L - high power HF transistors,
P - photo transistor,
S - switch transistor,
U - high voltage transistor.

Here are few examples:
AC540 - germanium core, LF, low power,

AF125 - germanium core, HF, low power,
BC107 - silicon, LF, low power (0.3W),
BD675 - silicon, LF, high power (40W),
BF199 - silicon, HF (to 550 MHz),
BU208 - silicon (for voltages up to 700V),
BSY54 - silicon, switching transistor.

There is a possibility of a third letter (R and Q - microwave transistors, or X - switch transistor), but these letters vary from manufacturer to manufacturer.

The number following the letter is of no importance to users.

American transistor manufacturers have different marks, with a 2N prefix followed by a number (2N3055, for example). This mark is similar to diode marks, which have a 1N prefix (e.g. 1N4004).

Japanese bipolar transistor are prefixed with a: 2SA, 2SB, 2SC or 2SD, and FET-s with 3S:

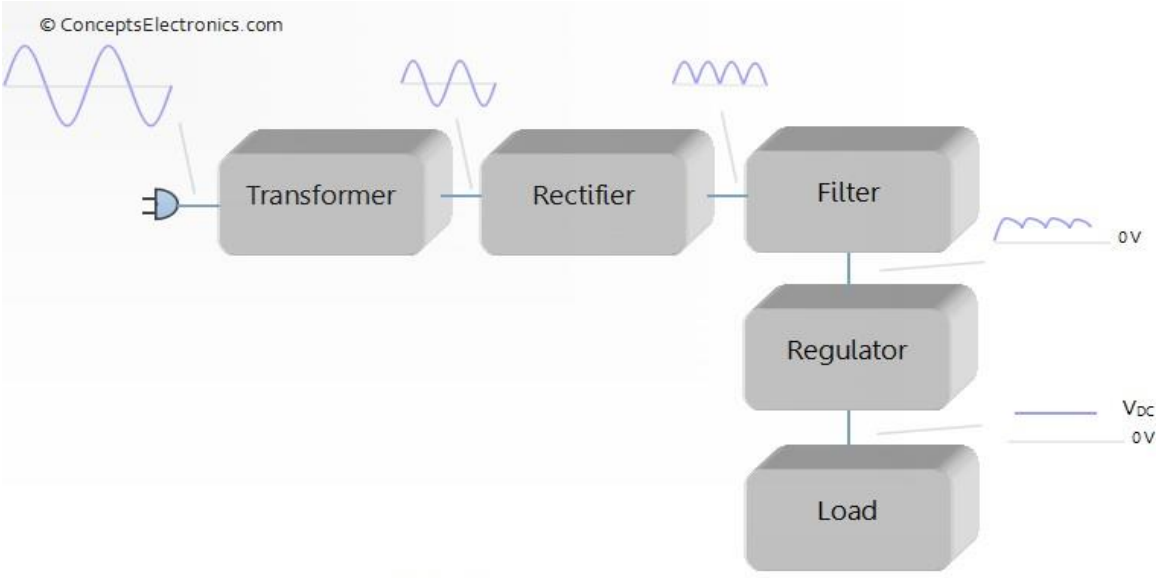
2SA - PNP, HF transistors,
2SB - PNP, LF transistors,
2SC - NPN, HF transistors,
2SD - NPN, HF transistors.

MODULE 3

RECTIFIERS AND POWER SUPPLY

Block diagram of power supply

All electronic devices have one thing in common – they all need power supply. Think of electronic devices like TV, music system, computers, radio, mobile phone etc, they all need some source of power. However the electronic circuitry inside such devices requires low voltage DC power supply. The power that we get from the wall outlet is 230 V 50 Hz (In India). So a need arises to convert high voltage AC into low voltage DC.



Block diagram of power supply

Transformer

A transformer is a device which transforms high voltage AC into low voltage AC or vice versa. Our goal is to convert high voltage AC into low voltage DC. So there is absolutely no reason to use step-up transformer. The transformer that is used in power supply is step-down transformer, which *steps down* the input AC voltage. The magnitude by which transformer steps down the voltage depends on the turns ratio of primary and secondary winding. Observe the magnitude of sinusoidal signal before the transformer block. Its magnitude is quite high as compared to that of the signal after the transformer block diagram. This indicates that that the signal was stepped down by the transformer. There arises an obvious question as to why transformer is used in this system. The main reason why we use transformer in the system are as follows.

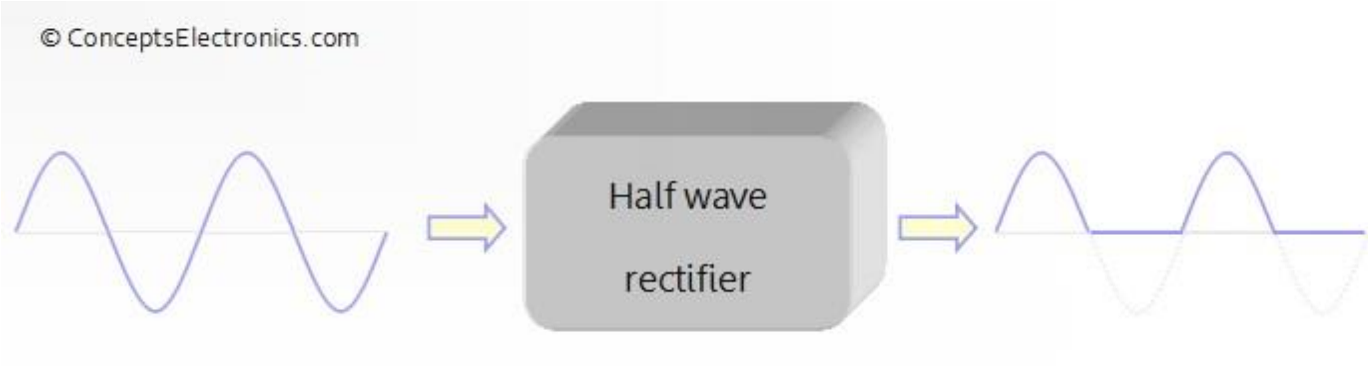
1. We want to reduce the voltage level which we get from the AC mains. Transformer can do the job of reducing the voltage level in a simple and efficient manner.
2. The diodes used in the rectifier block cannot handle such a high level of voltage from the AC mains. So the voltage is first stepped down by the transformer and the reduced voltage is applied to the rectifier section.

Rectifier

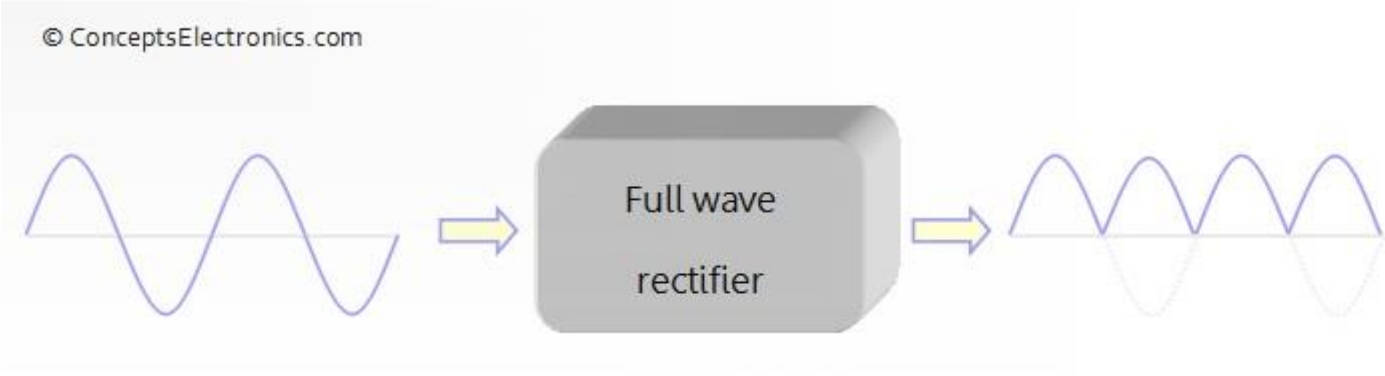
Before understanding what are rectifiers and how they are used in power supplies, let us first understand the meaning of the word “rectification”. Merriam-Webster dictionary defines the word rectification as -“to correct” or “to set right” or “to correct by removing errors”. Let us try to understand why the word “rectifier” or “rectification” is used in the context of electronics. A sinusoidal signal, as we know, has both positive and negative values. Because of the symmetry on both sides, the average value of sinusoidal signal V_{DC} turns out to be zero. We certainly are interested in nonzero average value (or do you want zero average voltage as your final output?). We can get nonzero average voltage by *removing* the negative half cycle of the sinusoidal signal. The circuitry which does this job is called rectifier as *it corrects the signal by removing the negative side of the signal*. Rectifiers are basically of two types

1. Half wave rectifiers
2. Full wave rectifiers

The function of half wave rectifier and full wave rectifier is shown below. Full wave rectifiers are the most commonly used rectifiers in power supply. Speaking of full wave rectifiers in simple language, it simply allows the positive half cycle to pass through and inverts the negative half cycle to positive half cycle. This is shown above in the block diagram of power supply and its function is shown below.



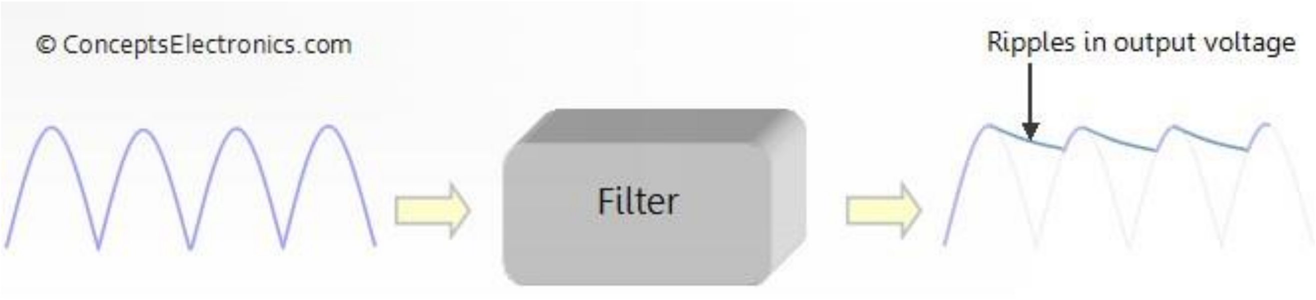
Half wave rectifier



Full wave rectifier

Filters

The output after being processed by full wave rectifier is not a pure DC. The output is a pulsating DC. The output contains large fluctuations in voltages. This is quite apparent from the block of full wave rectifier shown above. The power supply that we intend to design must not have any variation in output voltage. The voltage that we get from full wave rectifier fluctuates between 0 V and V_{peak}, and hence it contains AC components. These AC components needs to be *filtered out* so as to obtain DC voltage. This is where filters come into picture. Filters, as the name suggests, *filters out* any AC component present and provides DC as the output. However, the output from the filter is still not a pure DC but filters removes the AC component in the voltage to a considerable extent. This increases the average DC value of the output voltage. Now a question must arise as to how we can make a filter and which components are required to make a filter. Although it not the goal of this section to study filters in detail, it must suffice to know that filters used in power supplies can be made simply by using capacitors. We leave the design of capacitive filter to some other section. Typical input and output voltage of filters used in power supply is shown below.



Filter along with its input and output voltage

As shown in the figure above, the output voltage from the filter contains voltage ripples. This output is not a pure DC, however considerable amount of AC component is filtered out by the filter. The effectiveness of the filter to remove the AC component is indicated by the ripple factor. Smaller the ripple factor, better the filter.

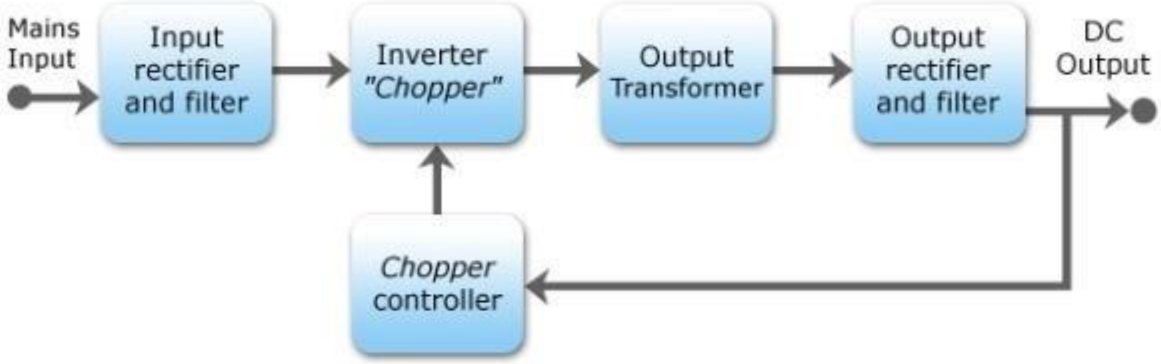
Regulator

Many power supplies which are not intended to power sophisticated equipments contains circuits only upto filter section. Ordinary voltage adapter used to charge small batteries in toys is one such example. The output from the filter is directly applied to power up the circuit. However when there is a need to provide very good quality power supply, a regulator is also added in the circuit.There is at transformer connected with the power supply mains. If there is a fluctuation in AC mains, there will be fluctuation in the output of transformer too. The simple reason for this is that the transformer only steps down whatever is given at its input. It can‟t decide for itself – “Hey, there is a fluctuation in AC mains, I must adjust my output”. The turns ratio which determines the factor by which transformer steps down the voltage is same irrespective of changes in input voltage. The output of transformer is only as good as its input. This output is passed on to rectifier which again rectifies whatever is applied to it. Filter tries to eliminate the AC components as it is designed to do. However the average DC voltage may not be the same as it was intended to be. In such a condition, a voltage regulator comes into picture. Other case where a need of regulator arises is when there is a change in load current. For changes in load current, there is a change in output voltage. In order to maintain constant voltage irrespective of changes in load current, voltage regulator is used.

SWITCH MODE POWER SUPPLY (SMPS)

Switch-mode power supplies are a mostly used in DC-DC power conversion. SMPS offer distinct benefits when compared to alternative methods of converting DC power.

Switch mode regulator is used to overcome the drawbacks of linear regulators. **Switched power supplies are more efficient and they tend to have an efficiency of 80% or more.**They can be packaged in a smaller of the size than linear regulators. switched power supplies can be used for stepping up or steeping down the input voltage.



Block diagram of SMPS

Generally, **switched mode power supply** consists of five standard components:

1. A pulse-width modulating controller,
2. A transistor switch,
3. An inductor ,
4. A capacitor and
5. A diode.

DC-DC converters is also called as choppers earlier, before,SCRs were used but Nowadays, IGBTs and MOSFETs are used mostly for dc-dc conversion and these circuits can be classified as switch mode power supply circuits.

A switch mode power supply circuit can be used to:

- Step up or step down an unregulated dc input voltage to a regulated dc output voltage
- Step up an unregulated dc input voltage to a regulated dc output voltage using a Boost Converter circuit or Step-Up SMPS
- Step down an unregulated dc input voltage to a regulated dc output voltage using a Buck Converter circuit or Step-Down SMPS,

- Invert the input dc voltage using usually a converter circuit , and
- Produce multiple dc outputs using a the fly-back converter circuit.

Switch mode power supply is a widely used in a system such as a computer, television receiver, battery charger etc. The switching frequency above than 20 kHz is used in SMPS, so noise produced is above the audio range.It is used in high-frequency unity-power factor circuit. It is also used to produce a variable dc voltage to a dc motor armature in a variable speed drive.

Advantages of SMPS:

- Greater efficiency because the switching transistor dissipates little power
- Lower heat generation due to higher efficiency
- Smaller in size
- Lighter weight
- Reduced harmonic feedback into the supply main

Disadvantage of SMPS

The most often cited issue in switch-mode converters is **to radiate electromagnetic interference (EMI) and conduct noise**. Electromagnetic radiation is produced by the voltage-switching waveforms and fast transitions of current-that exist in SMPS. .Fortunately, good component placement and PCB layout techniques can successfully used to reduce EMI and noise.

The disadvantages can be managed, and the efficiency and versatility use is very desirable, and often required in the SMPS.

Applications of SMPS:

Most of electronic DC loads are supplied from standard power sources. Sometime, standard source voltages does not match the levels required by microprocessors, motors, LEDs, or other loads, especially when the source voltage is not regulated. Battery-powered devices are prime examples of the problem.

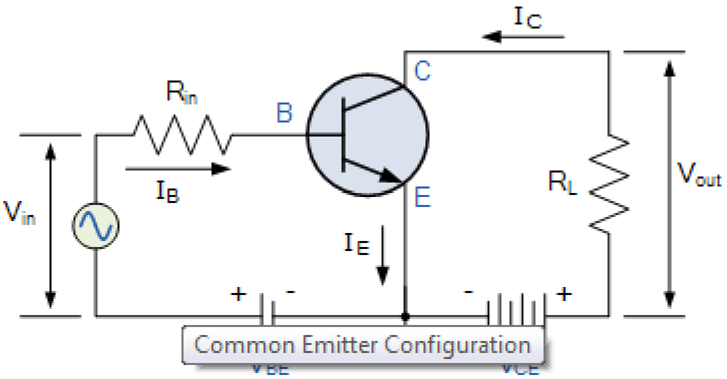
SMPSs are widely used in many applications such as

- Personal computers
- Machine tool industries
- Security systems
- Mobile
- Railways
- HVDC Measurements

AMPLIFIERS AND OSCILLATORS

The common emitter (CE) configuration

In the **Common Emitter** or grounded emitter configuration, the input signal is applied between the base, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor based amplifiers and which represents the "normal" method of bipolar transistor connection. The common emitter amplifier configuration produces the highest current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward biased PN-junction, while the output impedance is HIGH as it is taken from a reverse biased PN-junction.



Common Emitter Configuration

In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as Ie = Ic + Ib.
As the load resistance (RL) is connected in series with the collector, the current gain of the common emitter transistor configuration is quite large as it is the ratio of Ic/Ib. A transistors current gain is given the Greek symbol of Beta, (β).
As the emitter current for a common emitter configuration is defined as Ie = Ic + Ib, the ratio of Ic/Ie is called Alpha, given the Greek symbol of α. Note: that the value of Alpha will always be less than unity.
Since the electrical relationship between these three currents, Ib, Icand Ie is determined by the physical construction of the transistor itself, any small change in the base current (Ib), will result in a much larger change in the collector current (Ic).
Then, small changes in current flowing in the base will thus control the current in the emitter-collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal.

By combining the expressions for both Alpha, α and Beta, β the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:

$$\text{Alpha}, (\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta}, (\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha . I_E = \beta . I_B$$

$$\text{as:} \quad \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

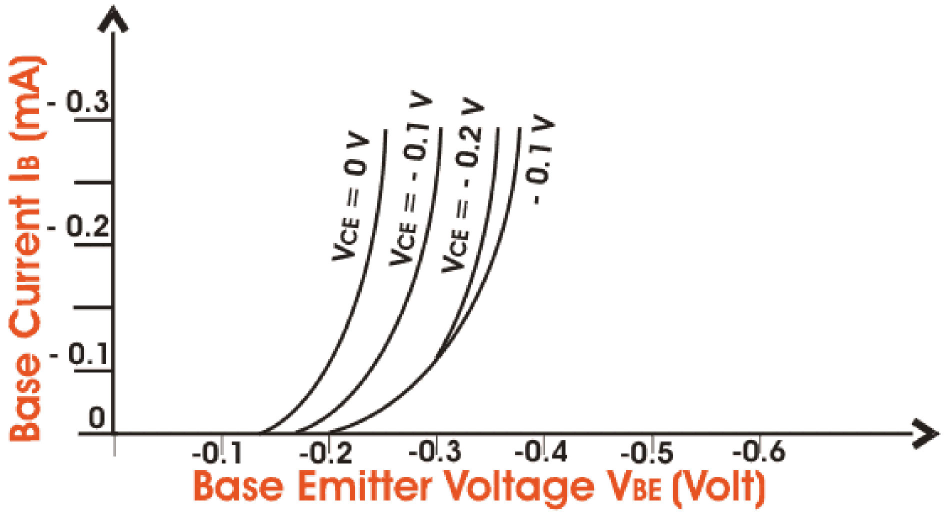
$$I_E = I_C + I_B$$

Where: "Ic" is the current flowing into the collector terminal, "Ib" is the current flowing into the base terminal and "Ie" is the current flowing out of the emitter terminal.

Then to summarise a little. This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is 180^o "out-of-phase" with the input voltage signal.

Input characteristics

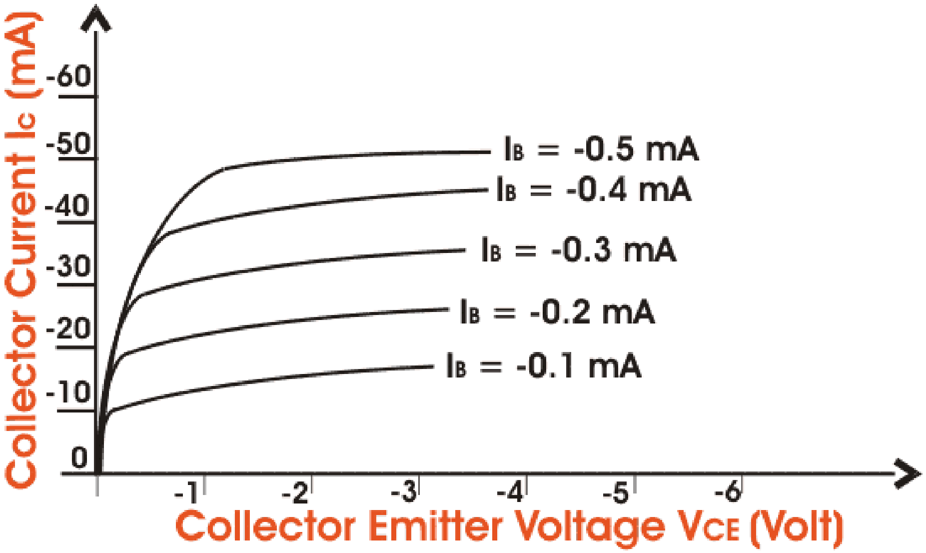
I_B (Base Current) is the input current, V_{BE} (Base - Emitter Voltage) is the input voltage for CE (Common Emitter) mode. So, the input characteristics for CE mode will be the relation between I_B and V_{BE} with V_{CE} as parameter. The characteristics are shown below



The typical CE input characteristics are similar to that of a forward biased of p - n diode. But as V_{CB} increases the base width decreases.

Output characteristics

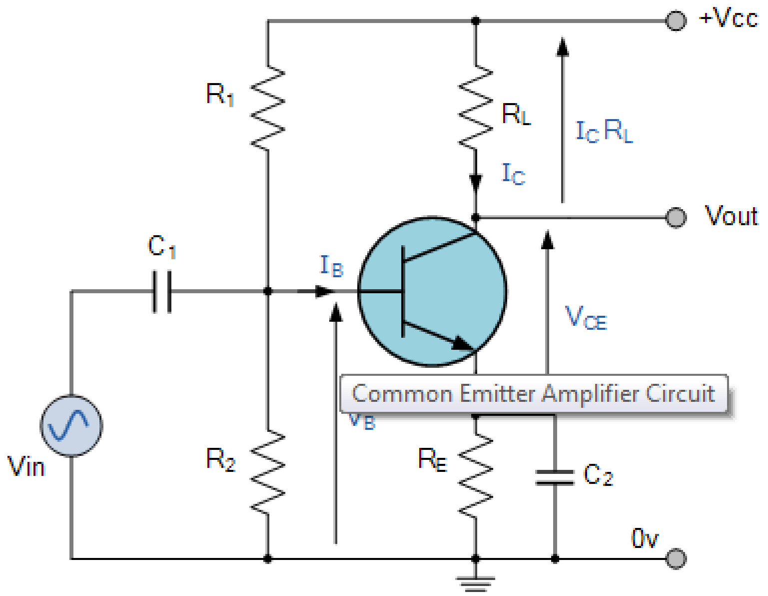
Output characteristics for CE mode is the curve or graph between collector current (I_C) and collector - emitter voltage (V_{CE}) when the base current I_B is the parameter. The characteristics is shown below in the figure.



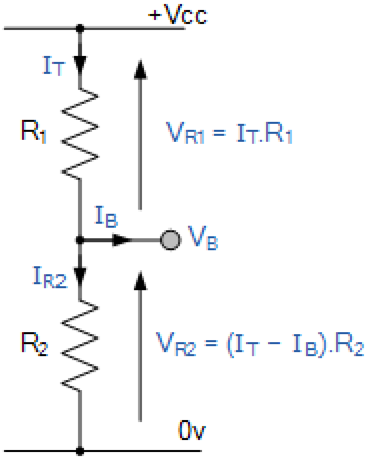
Like the output characteristics of common - base transistor CE mode has also three regions named (i) Active region, (ii) cut-off regions, (iii) saturation region. The active region has collector region reverse biased and the emitter junction forward biased. For cut-off region the emitter junction is slightly reverse biased and the collector current is not totally cut-off. And finally for saturation region both the collector and the emitter junction are forward biased.

THE COMMON EMITTER AMPLIFIER CIRCUIT

The single stage common emitter amplifier circuit shown below uses what is commonly called “Voltage Divider Biasing”. This type of biasing arrangement uses two resistors as a potential divider network across the supply with their center point supplying the required Base bias voltage to the transistor. Voltage divider biasing is commonly used in the design of bipolar transistor amplifier circuits.



Circuit diagram of CE amplifier



Voltage Divider Biasing

This method of biasing the transistor greatly reduces the effects of varying Beta, (β) by holding the Base bias at a constant steady voltage level allowing for best stability. The quiescent Base voltage (Vb) is determined by the potential divider network formed by the two resistors, R1, R2 and the power supply voltage Vcc as shown with the current flowing through both resistors.

Then the total resistance RT will be equal to R1 + R2 giving the current as i = Vcc/RT. The voltage level generated at the junction of resistors R1 and R2 holds the Base voltage (Vb) constant at a value below the supply voltage.

Then the potential divider network used in the common emitter amplifier circuit divides the input signal in proportion to the resistance. This bias reference voltage can be easily calculated using the simple voltage divider formula below:

Bias Voltage

$$V_B = \frac{V_{CC} R_2}{R_1 + R_2}$$

The same supply voltage, (Vcc) also determines the maximum Collector current, Ic when the transistor is switched fully "ON" (saturation), Vce = 0. The Base current Ib for the transistor is found from the Collector current, Ic and the DC current gain Beta, β of the transistor.

Beta Value

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

Beta is sometimes referred to as h_{FE} which is the transistors forward current gain in the common emitter configuration. Beta has no units as it is a fixed ratio of the two currents, Ic and Ib so a small change in the Base current will cause a large change in the Collector current.

One final point about Beta. Transistors of the same type and part number will have large variations in their Beta value for example, the BC107 NPN Bipolar transistor has a DC current gain Beta value of between 110 and 450 (data sheet value) this is because Beta is a characteristic of their construction and not their operation.

As the Base/Emitter junction is forward-biased, the Emitter voltage, Ve will be one junction voltage drop different to the Base voltage. If the voltage across the Emitter resistor is known then the Emitter current, Ie can be easily calculated using Ohm‟s Law. The Collector current, Ic can be approximated, since it is almost the same value as the Emitter current.

Voltage Gain

The Voltage Gain of the common emitter amplifier is equal to the ratio of the change in the input voltage to the change in the amplifiers output voltage. Then ΔV_L is Vout and ΔV_B is Vin. But voltage gain is also equal to the ratio of the signal resistance in the Collector to the signal resistance in the Emitter and is given as:

$$\text{Voltage Gain} = \frac{V_{out}}{V_{in}} = \frac{\Delta V_L}{\Delta V_B} = -\frac{R_L}{R_E}$$

PUBLIC ADDRESS SYSTEM

1. Introduction Public Address System (PA system) is an electronic sound amplification and distribution system with a microphone, amplifier and loudspeakers, used to allow a person to address a large public, for example for announcements of movements at large and noisy air and rail terminals. The simplest PA system consist of a microphone, an amplifier, and one or more loudspeakers is shown in fig 1. A sound source such as compact disc player or radio may be connected to a PA system so that music can be played through the system.

Fig No. 1: Simple PA System

The process begins with a sound source (such as a human voice), which creates waves of sound (acoustical energy). These waves are detected by a microphone, which converts them to electrical energy. This signal is amplified in an amplifier up to a required level. The loudspeaker converts the electrical signal back into sound waves, which are heard by human ears. A block diagram of PA system containing microphone, mixer, limiter, equalizer, amplifier and speaker is shown below in figure No.2:

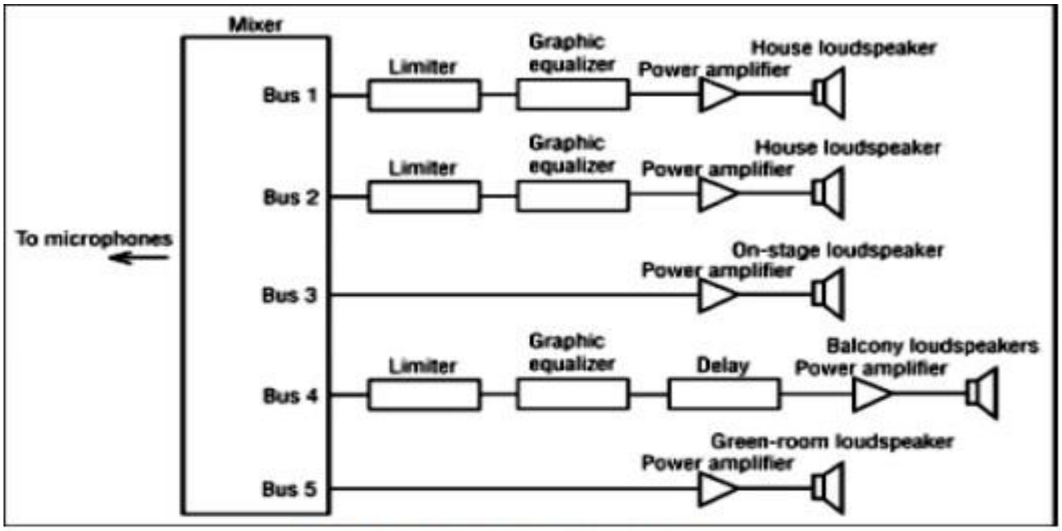


Fig No. 2 Block Diagram of PA system

Application of P.A. system in Railways Passenger Amenity For giving the detailed information about the train arrivals, departures, late running if any, and location of trains and any other important information related to Railway users. Marshalling Yards For communication between Yard Master and Shunting men through paging and talk-back system regarding formation and reception or dispatch of trains. Breakdown train Emergency Equipment The P.A. System in Accident Relief Train must be kept in working condition for guide the passengers and staff in rescue operations at the site of accident. Special functions Local Minister, G.M., etc., officials and VIPs may address some important functions such as Railway Week, felicitations, Scouts and Guides rally, some social work meetings, cultural programmes etc. a quality P.A. System needs to be installed. Railway Workshops Providing announcements to workshops staff when required and also for entertainment music during lunch hours. Conferences For conducting seminars, special lectures, administrative meetings for a limited group of officials in conference halls. In every zone, a G.M. Conference hall is available. In these suitable conference systems were permanently installed.

FEEDBACK CONCEPTS

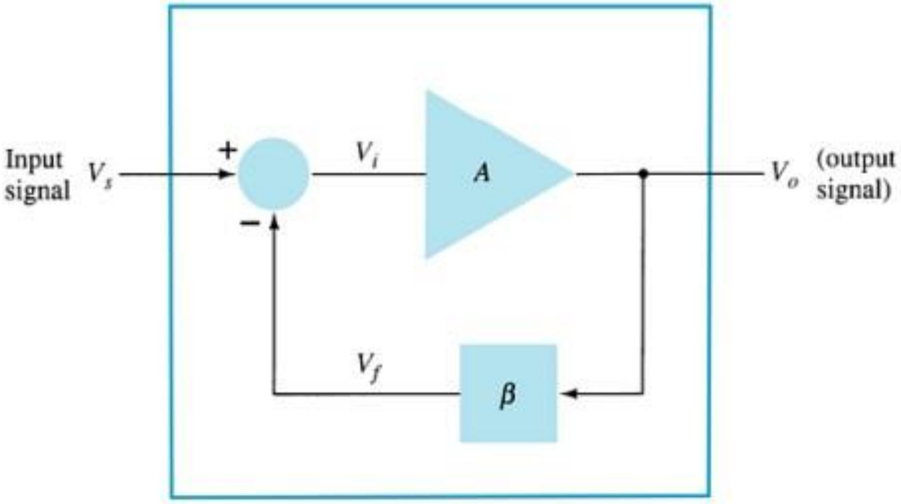
The effects of negative feedback on an amplifier: The effects of negative feedback on an amplifier:

Disadvantage

- Lower gain

Advantages

- Higher input impedance
- More stable gain More stable gain
- Improved frequency response
- Lower output impedance
- Reduced noise
- More linear operation



Feedback amplifier

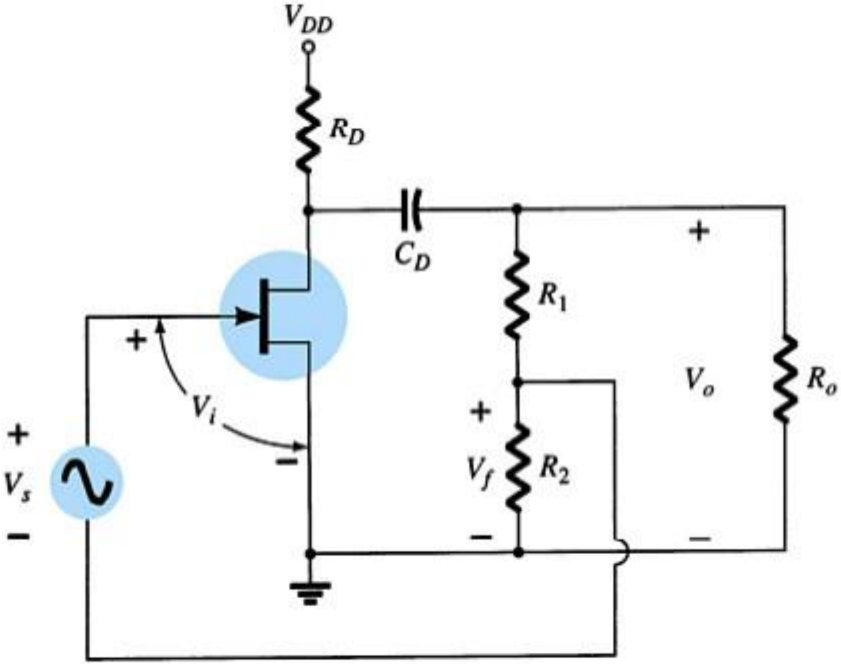
Feedback Connection Types

- Voltage-series feedback
- Voltage -shunt feedback shunt feedback
- Current-series feedback
- Current-shunt feedback

Voltage-Series Feedback

In Voltage Series Feedback, the output voltage is fed back in series to the input. The feedback gain is given by:

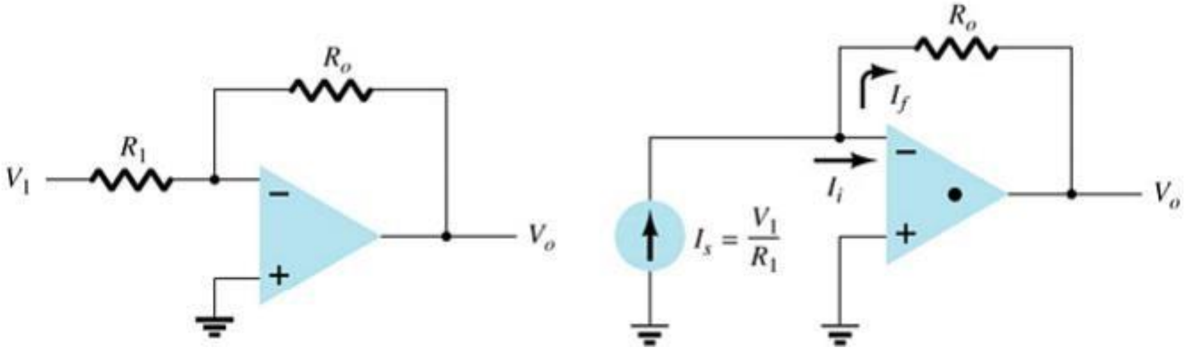
$$\mathbf{A_f \cong \frac{1}{\beta} = \frac{R_1 + R_2}{R_2}}$$



Voltage-Shunt Feedback

For a voltage-shunt feedback amplifier, the output voltage is fed back in parallel with the input. The feedback gain is given by

$$A_f = -\frac{R_o}{R_i}$$

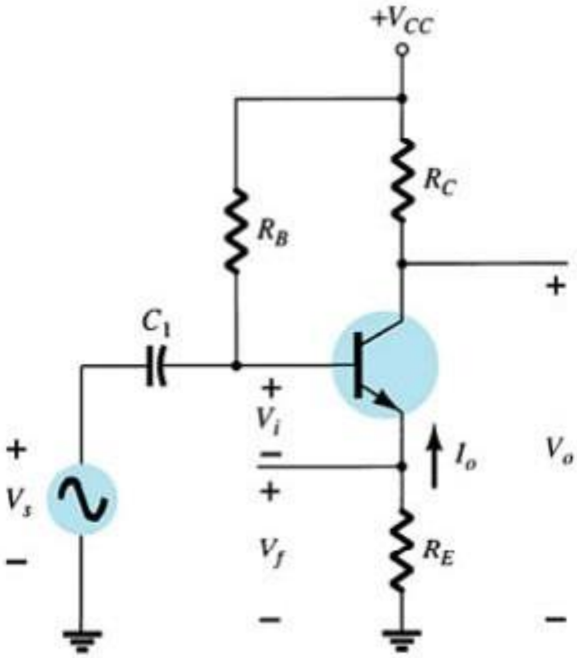


Current-Series Feedback

For a current series feedback amplifier, a portion of the output current is fed back in series with the input.

To determine the feedback gain:

$$A_f = \frac{I_o}{V_s} = \frac{A}{1+\beta A} = \frac{-h_{fe}/h_{ie}}{1+(-R_E)\left(\frac{-h_{fe}}{h_{ie}+R_E}\right)} \cong \frac{-h_{fe}}{h_{ie}+h_{fe}R_E}$$



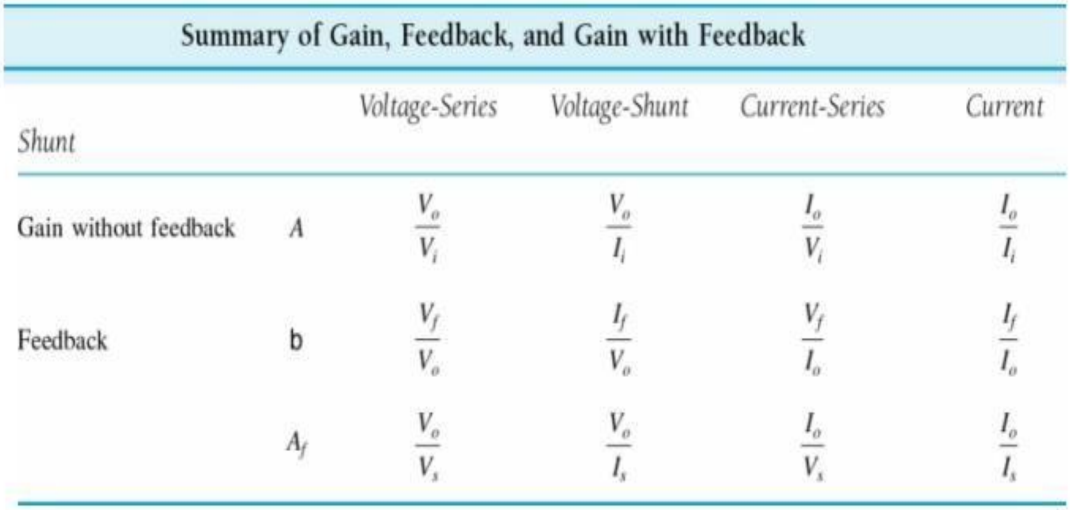
Current Shunt Feedback

For a current-shunt feedback amplifier, a portion of the output current is directed back in parallel with the input.

The feedback gain is given by:

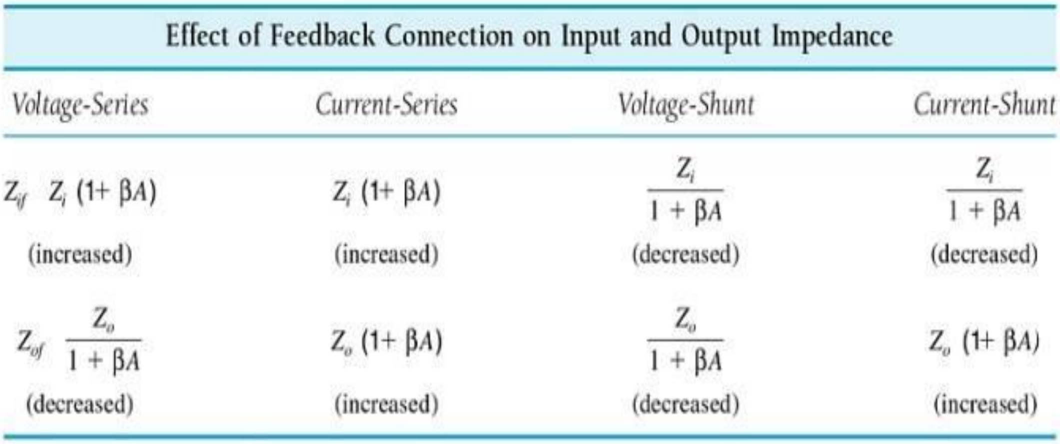
$$A_f = \frac{I_o}{I_s}$$

Summary of Feedback Effects



Summary of Gain, Feedback, and Gain with Feedback

Shunt		Voltage-Series	Voltage-Shunt	Current-Series	Current
Gain without feedback	A	$\frac{V_o}{V_i}$	$\frac{V_o}{I_i}$	$\frac{I_o}{V_i}$	$\frac{I_o}{I_i}$
Feedback	b	$\frac{V_f}{V_o}$	$\frac{I_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$
	A_f	$\frac{V_o}{V_s}$	$\frac{V_o}{I_s}$	$\frac{I_o}{V_s}$	$\frac{I_o}{I_s}$



Effect of Feedback Connection on Input and Output Impedance

	Voltage-Series	Current-Series	Voltage-Shunt	Current-Shunt
Z_{if}	$Z_i\,(1+\beta A)$ (increased)	$Z_i\,(1+\beta A)$ (increased)	$\frac{Z_i}{1+\beta A}$ (decreased)	$\frac{Z_i}{1+\beta A}$ (decreased)
Z_{of}	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o\,(1+\beta A)$ (increased)	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o\,(1+\beta A)$ (increased)

<u>Working Principle of Oscillator</u>

The closed-loop gain G of a feedback system of the form shown in figure is given by the expression:

____

Where A represents the forward gain and B the feedback gain of the arrangement. If the loop gain AB is negative and its magnitude is less than or equal to 1, then the overall gain is greater than the forward gain and we have positive feedback.

If AB = -1, the closed-loop gain is theoretically infinite. Under these circumstances, the system will generally produce an output even in the absence of any input. This situation is used in the production of oscillators and AB = -1 represents the condition needed for oscillation to occur.

A non-inverting amplifier has a positive gain and an inverting amplifier has a negative gain. Thus, the condition AB = -1 can be satisfied if the magnitude of B is equal to 1/A and if either A or B (but not both) is „inverting". The inversion of a sine wave represents a phase shift of 180^o and an alternative way to describe the condition for oscillation is that the product AB must have a magnitude of 1 and a phase angle of 180^o (or radians).

These requirements are expressed by the Barkhausen criterion, which says that the condition needed for oscillation to occur is that:

- The magnitude of the loop gain AB must be equal to 1.
- The phase shift of the loop gain AB must be 180^o or 180^o plus an integer multiple of 360^o.

The second condition is slightly more complicated than our original requirement as it acknowledges that shifting a sine wave by a complete cycle leaves it unchanged. Thus, if a phase shift of 180^o will cause oscillation, then a phase shift of 180^o plus any multiple of 360^0 will have the same effect.

In order to make a useful oscillator, a frequency-selective element is added to ensure that the condition for oscillation is met at only a single frequency. The circuit then oscillates continuously at that frequency.

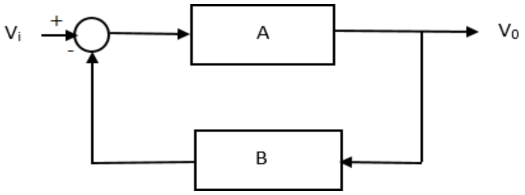


Fig. A generalized feedback arrangement

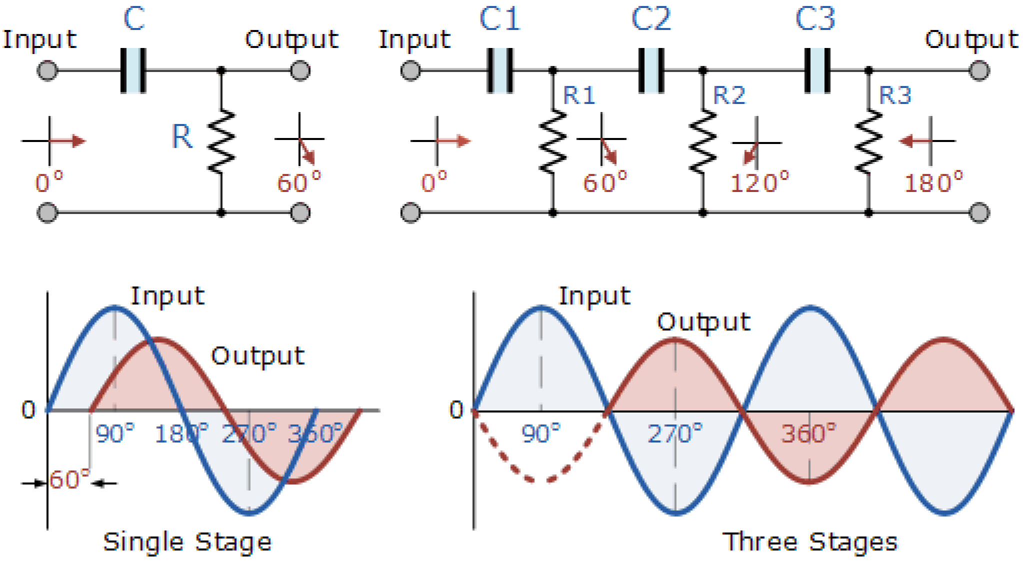
THE RC PHASE SHIFT OSCILLATOR

In our series of tutorials about Amplifiers , we saw that a single stage amplifier will produce 180^o of phase shift between its output and input signals when connected in a class-A type configuration. For an oscillator to sustain oscillations indefinitely, sufficient feedback of the correct phase, ie, "Positive Feedback" must be provided with the amplifier being used as one inverting stage to achieve this.

In an RC Oscillator circuit the input is shifted 180^o through the amplifier stage and 180^o again through a second inverting stage giving us "180^o + 180^o = 360^o" of phase shift which is effectively the same as 0^o thereby giving us the required positive feedback. In other words, the phase shift of the feedback loop should be "0".

In a Resistance-Capacitance Oscillator or simply an RC Oscillator, we make use of the fact that a phase shift occurs between the input to a RC network and the output from the same network by using RC elements in the feedback branch, for example.

RC Phase-Shift Network



The circuit on the left shows a single Resistor-Capacitor Network whose output voltage "leads" the input voltage by some angle less than 90^o. An ideal single-pole RC circuit would produce a phase shift of exactly 90^o, and because 180^o of phase shift is required for oscillation, at least two single-poles must be used in an RC oscillator design.

However in reality it is difficult to obtain exactly 90^o of phase shift so more stages are used. The amount of actual phase shift in the circuit depends upon the values of the resistor and the capacitor, and the chosen frequency of oscillations with the phase angle (Φ) being given as:

RC Phase Angle

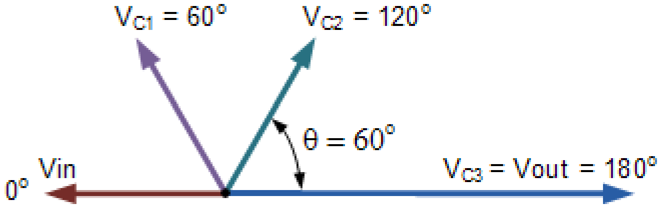
$$X_C = \frac{1}{2\pi f C} \qquad R = R,$$

$$Z = \sqrt{R^2 + (X_C)^2}$$

$$\therefore \quad \phi = \tan^{-1}\frac{X_C}{R}$$

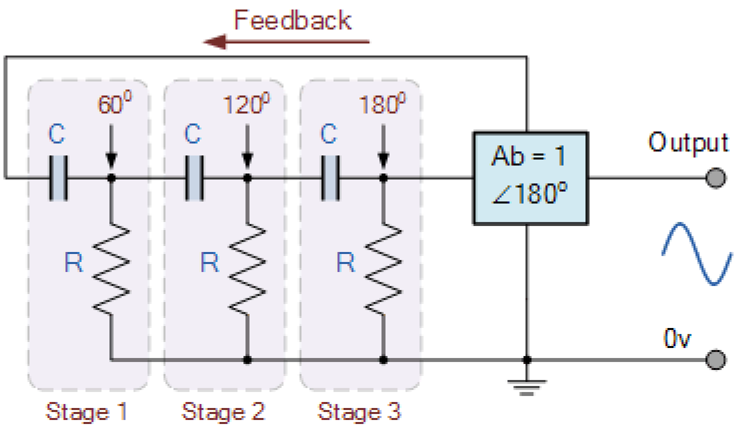
In our simple example above, the values of R and C have been chosen so that at the required frequency the output voltage leads the input voltage by an angle of about 60^o. Then the phase angle between each successive RC section increases by another 60^o giving a phase difference between the input and output of 180^o (3×60^o) as shown by the following vector diagram.

Vector Diagram



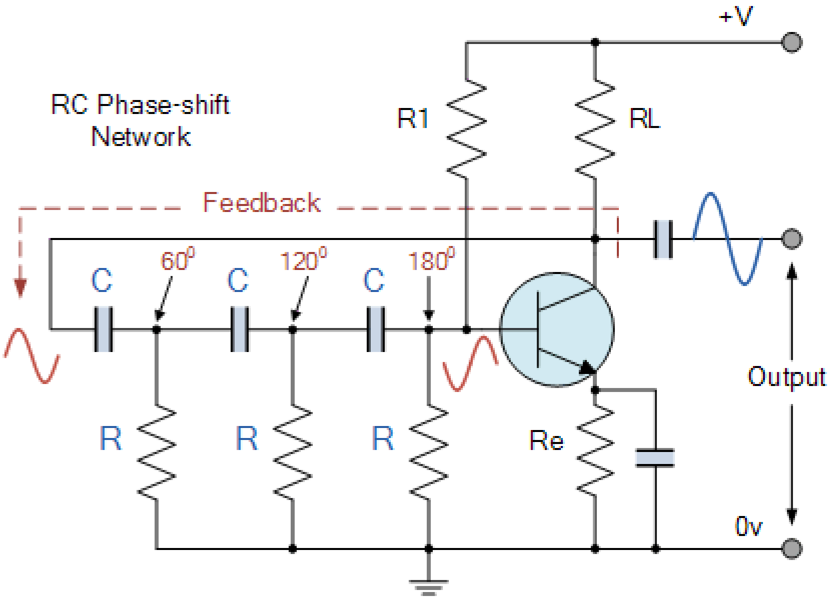
Then by connecting together three such RC networks in series we can produce a total phase shift in the circuit of 180^o at the chosen frequency and this forms the bases of a “phase shift oscillator” otherwise known as a RC Oscillator circuit.

We know that in an amplifier circuit either using a Bipolar Transistor or an Operational Amplifier, it will produce a phase-shift of 180^o between its input and output. If a three-stage RC phase-shift network is connected between this input and output of the amplifier, the total phase shift necessary for regenerative feedback will become $3 \times 60^o + 180^o = 360^o$ as shown.



The three RC stages are cascaded together to get the required slope for a stable oscillation frequency. The feedback loop phase shift is -180^o when the phase shift of each stage is -60^o. This occurs when $\omega = 2\pi f = 1.732/RC$ as ($\tan 60^o = 1.732$). Then to achieve the required phase shift in an RC oscillator circuit is to use multiple RC phase-shifting networks such as the circuit below.

Basic RC Oscillator Circuit



The basic RC Oscillator which is also known as a Phase-shift Oscillator, produces a sine wave output signal using regenerative feedback obtained from the resistor-capacitor combination. This regenerative feedback from the RC network is due to the ability of the capacitor to store an electric charge, (similar to the LC tank circuit).

This resistor-capacitor feedback network can be connected as shown above to produce a leading phase shift (phase advance network) or interchanged to produce a lagging phase shift (phase retard network) the outcome is still the same as the sine wave oscillations only occur at the frequency at which the overall phase-shift is 360^o.

By varying one or more of the resistors or capacitors in the phase-shift network, the frequency can be varied and generally this is done by keeping the resistors the same and using a 3-ganged variable capacitor.

If all the resistors, R and the capacitors, C in the phase shift network are equal in value, then the frequency of oscillations produced by the RC oscillator is given as:

$$f_r = \frac{1}{2\pi RC\sqrt{2N}}$$

Where,

f_r is the Output Frequency in Hertz

R is the Resistance in Ohms

C is the Capacitance in Farads

N is the number of RC stages. (N = 3)

Since the resistor-capacitor combination in the RC Oscillator circuit also acts as an attenuator producing an attenuation of -1/29th ($Vo/Vi = \beta$) per stage, the gain of the amplifier must be sufficient to overcome the circuit losses. Therefore, in our three stage RC network above the amplifier gain must be greater than 29.

The loading effect of the amplifier on the feedback network has an effect on the frequency of oscillations and can cause the oscillator frequency to be up to 25% higher than calculated. Then the feedback network should be driven from a high impedance output source and fed into a low impedance load such as a common emitter transistor amplifier but better still is to use an Operational Amplifier as it satisfies these conditions perfectly.

MODULE 4

OPERATION AMPLIFIER

An operational amplifier is a direct coupled high gain amplifier consisting of one or more differential amplifiers, followed by a level translator and an output stage. It is a versatile device that can be used to amplify ac as well as dc input signals & designed for computing mathematical functions such as addition, subtraction ,multiplication,

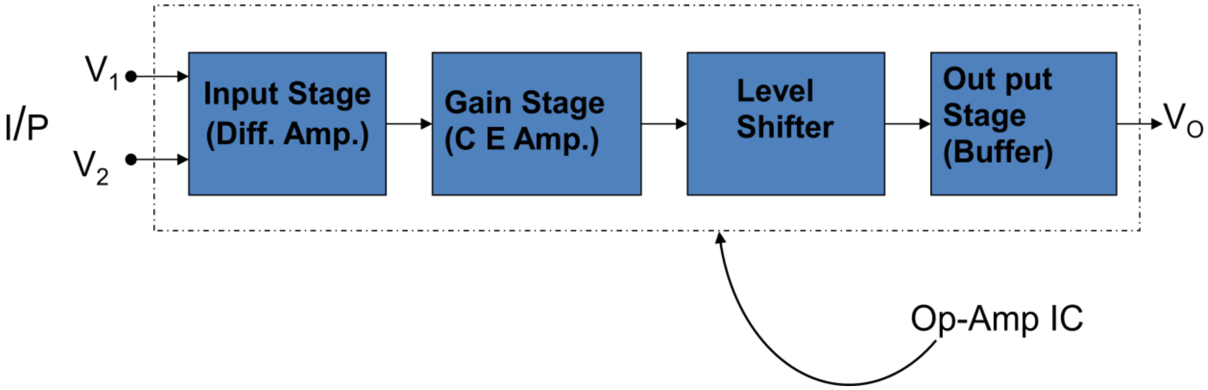
integration & differentiation

FUNCTIONAL BLOCK DIAGRAM OF OPERATIONAL AMPLIFIER

An Op-Amp can be conveniently divided in to four main blocks

1. An Input Stage or Input Diff. Amp.
2. The Gain Stage
3. The Level Translator
4. An Output Stage

It can be used to perform various mathematical operations such as Addition, Subtraction, Integration, Differentiation, log etc.



Differential amplifier

The different amplifier provides the inverting and non-inverting inputs the high common mode rejection ration and the high input resistance as well as voltage gain.

Gain stage

The interior stage of the OP-AMP is required to have a large voltage gain. Often high-B composite transistor such as Darlington pair and common collector emitter cascade are used in the stage

Lever Shifter

Since no coupling capacitors can be used (if the OP-AMP is to operate down to D.C), it may be necessary to shift the quiescent voltage of one stage before applying is output to t he following stage. Level shifting is also required in order for the output to be close to zero in the quiescent state (no input signal). The input resistance of the level shifting stage should be high to prevent loading of the gains stage. Similarly it is desirable that the output resistance be low to effectively drive the output stage.

Output Stage (Emitter Follower)

The output stage of an OP-AMP must be capable of supplying the external load current and must have a low output resistance. This stage must also provide a large output voltage swing. A common configuration for the output stage that possesses these features is the compliment emitter follower

Bias Network

The function of bias network is to provide stable biasing voltage to the active devices in OP-AMP

AN IDEAL OP AMP

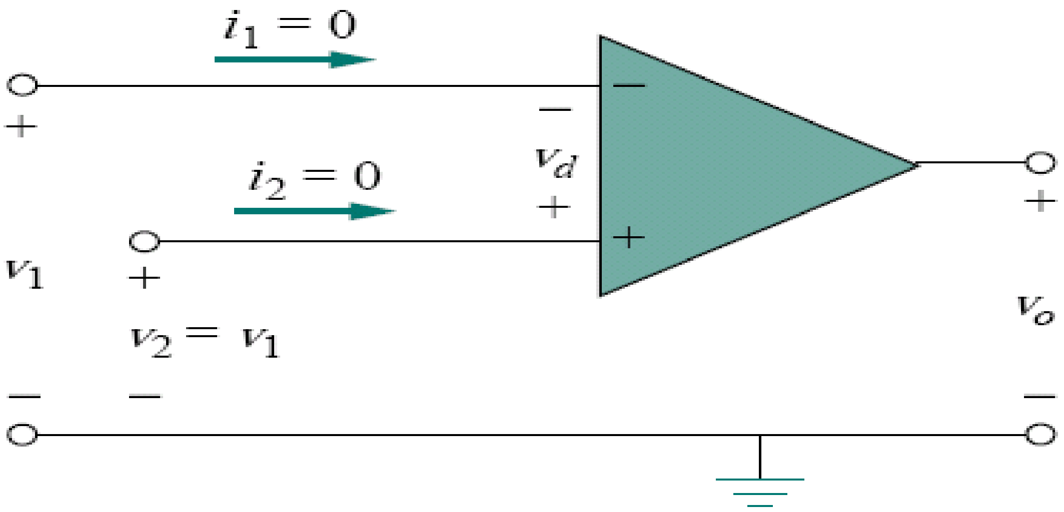
An ideal op amp has the following characteristics:

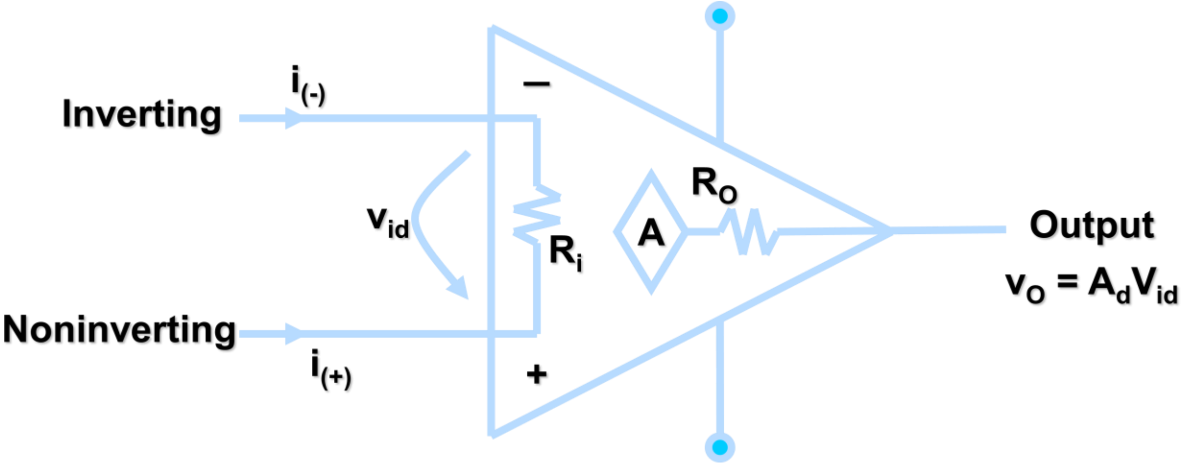
1. Infinite open-loop voltage gain, $A_V \approx \infty$.
2. Infinite input resistance, $R_i \approx \infty$.
3. Zero output resistance, $R_o \approx 0$.
4. Infinite CMRR, $\rho = \infty$
5. The output voltage Vo=0; when $V_d = V_2 - V_1 = 0$

6. Change of output with respect to input, slew rate = ∞

7. Change in output voltage with Temp., $\partial V_o/\partial V_i=0$

An Electrical Representation of Op Amp





- $i_{(+)}$, $i_{(-)}$: Currents into the amplifier on the inverting and non-inverting lines respectively

- v_{id} : The input voltage from inverting to non-inverting inputs

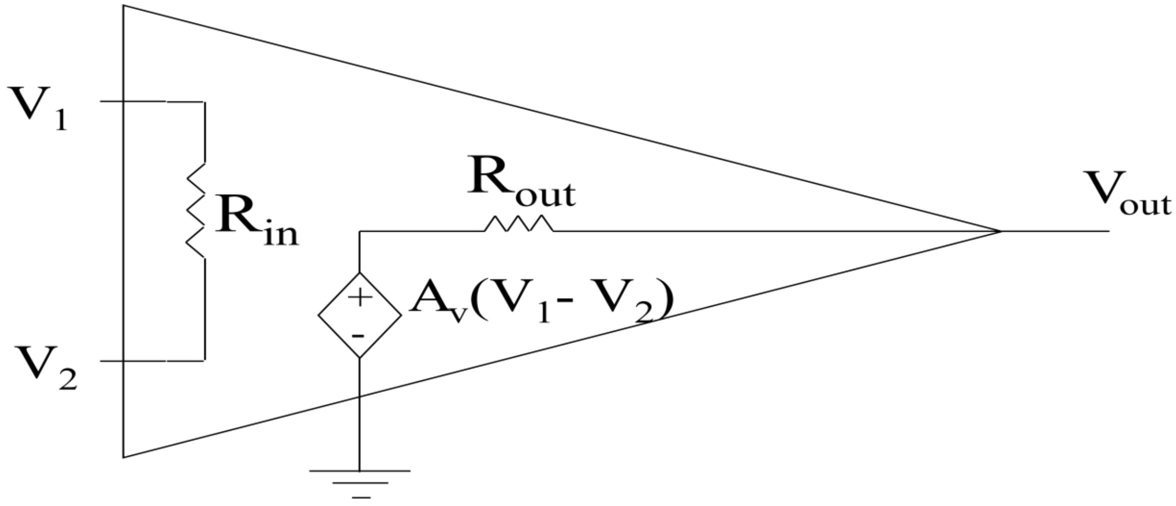
- $+V_S$, $-V_S$: DC source voltages, usually +15V and –15V

- R_i : The input resistance, ideally infinity
- A : The gain of the amplifier. Ideally very high, in the $1x10^{10}$ range.
- R_O: The output resistance, ideally zero
- v_O: The output voltage; $v_O = A_{OL}v_{id}$ where A_{OL} is the open-loop voltage gain

Operational Amplifier Model

- An operational amplifier circuit is designed so that
    1) $V_{out} = A_v (V_1-V_2)$ (**A_v** is a very large gain)
    2) Input resistance (**R_{in}**) is very large

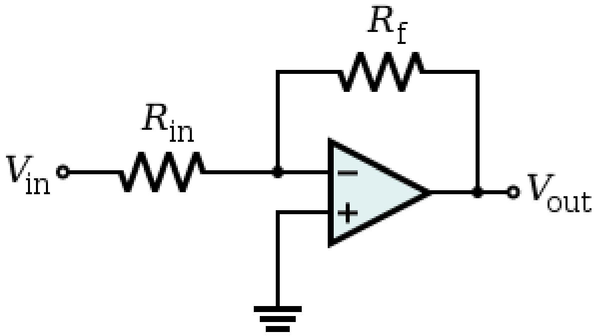
Output resistance (**R_{out}**) is very low



Ideal characteristics of OPAMP

1. Open loop gain infinite
2. Input impedance infinite
3. Output impedance low
4. Bandwidth infinite
5. Zero offset, ie, Vo=0 when V1=V2=0

INVERTING AMPLIFIER



An inverting amplifier is a special case of the differential amplifier in which that circuit's non-inverting input V_2 is grounded and inverting input V_1 is identified with V_{in} above. The closed-loop gain is R_f / R_{in}, hence

$$V_{\mathrm{out}} = -\frac{R_{\mathrm{f}}}{R_{\mathrm{in}}} V_{\mathrm{in}}.$$

The simplified circuit above is like the differential amplifier in the limit of R_2 and R_g very small. In this case, though, the circuit will be susceptible to input bias current drift because of the mismatch between R_f and R_{in}.

To intuitively see the gain equation above, calculate the current in R_{in}:

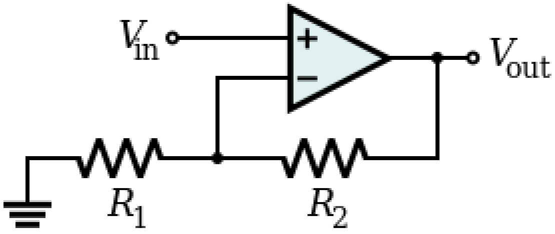
$$i_{\mathrm{in}} = \frac{V_{\mathrm{in}}}{R_{\mathrm{in}}}$$

then recall that this same current must be passing through R_f, therefore (because $V_- = V_+ = 0$):

$$V_{\mathrm{out}} = -i_{\mathrm{in}} R_{\mathrm{f}} = -V_{\mathrm{in}} \frac{R_{\mathrm{f}}}{R_{\mathrm{in}}}$$

A mechanical analogy is a seesaw, with the V_- node (between R_{in} and R_f) as the fulcrum, at ground potential. V_{in} is at a length R_{in} from the fulcrum; V_{out} is at a length R_f. When V_{in} descends "below ground", the output V_{out} rises proportionately to balance the seesaw, and vice versa.

NON-INVERTING AMPLIFIER



A non-inverting amplifier is a special case of the differential amplifier in which that circuit's inverting input V_1 is grounded, and non-inverting input V_2 is identified with V_{in} above, with $R_g \gg R_2$. Referring to the circuit immediately above,

$$V_{\text{out}} = \left(1 + \frac{R_2}{R_1}\right) V_{\text{in}}.$$

To intuitively see this gain equation, use the virtual ground technique to calculate the current in resistor R_1:

$$i_1 = \frac{V_{\text{in}}}{R_1},$$

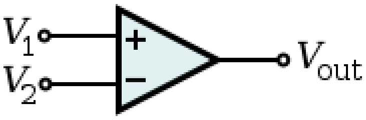
then recall that this same current must be passing through R_2, therefore:

$$V_{\text{out}} = V_{\text{in}} + i_{\text{in}} R_2 = V_{\text{in}} \left(1 + \frac{R_2}{R_1}\right)$$

A mechanical analogy is a class-2 lever, with one terminal of R_1 as the fulcrum, at ground potential. V_{in} is at a length R_1 from the fulcrum; V_{out} is at a length R_2 further along. When V_{in} ascends "above ground", the output V_{out} rises proportionately with the lever.

The input impedance of the simplified non-inverting amplifier is high, of order $R_{dif} \times A_{OL}$ times the closed-loop gain, where R_{dif} is the op amp's input impedance to differential signals, and A_{OL} is the open-loop voltage gain of the op amp; in the case of the ideal op amp, with A_{OL} infinite and R_{dif} infinite, the input impedance is infinite. In this case, though, the circuit will be susceptible to input bias current drift because of the mismatch between the impedances driving the V_+ and V_- op amp inputs.

Op-amp voltage comparator



An operational amplifier (op-amp) has a well balanced difference input and a very high gain. This parallels the characteristics of comparators and can be substituted in applications with low-performance requirements.

In theory, a standard op-amp operating in open-loop configuration (without negative feedback) may be used as a low-performance comparator. When the non-inverting input (V+) is at a higher voltage than the inverting input (V-), the high gain of the op-amp causes the output to saturate at the highest positive voltage it can output. When the non-inverting input (V+) drops below the inverting input (V-), the output saturates at the most negative voltage it can output. The op-amp's output voltage is limited by the supply voltage. An op-amp operating in a linear mode with negative feedback, using a balanced, split-voltage power supply, (powered by ± V_S) has its transfer function typically written as: $V_{out} = A_o(V_1 - V_2)$. However, this equation may not be applicable to a comparator circuit which is non-linear and operates open-loop (no negative feedback)

In practice, using an operational amplifier as a comparator presents several disadvantages as compared to using a dedicated comparator:

1. Op-amps are designed to operate in the linear mode with negative feedback. Hence, an op-amp typically has a lengthy recovery time from saturation. Almost all op-amps have an internal compensation capacitor which imposes slew rate limitations for high frequency signals. Consequently an op-amp makes a sloppy comparator with propagation delays that can be as long as tens of microseconds.
2. Since op-amps do not have any internal hysteresis, an external hysteresis network is always necessary for slow moving input signals.

3. The quiescent current specification of an op-amp is valid only when the feedback is active. Some op-amps show an increased quiescent current when the inputs are not equal.
4. A comparator is designed to produce well limited output voltages that easily interface with digital logic. Compatibility with digital logic must be verified while using an op-amp as a comparator.
5. Some multiple-section op-amps may exhibit extreme channel-channel interaction when used as comparators.
6. Many op-amps have back to back diodes between their inputs. Op-amp inputs usually follow each other so this is fine. But comparator inputs are not usually the same. The diodes can cause unexpected current through inputs.

Working

A dedicated voltage comparator will generally be faster than a general-purpose operational amplifier pressed into service as a comparator. A dedicated voltage comparator may also contain additional features such as an accurate, internal voltage reference, an adjustable hysteresis and a clock gated input.

A dedicated voltage comparator chip such as LM339 is designed to interface with a digital logic interface (to a TTL or a CMOS). The output is a binary state often used to interface real world signals to digital circuitry (see analog to digital converter). If there is a fixed voltage source from, for example, a DC adjustable device in the signal path, a comparator is just the equivalent of a cascade of amplifiers. When the voltages are nearly equal, the output voltage will not fall into one of the logic levels, thus analog signals will enter the digital domain with unpredictable results. To make this range as small as possible, the amplifier cascade is high gain. The circuit consists of mainly Bipolar transistors. For very high frequencies, the input impedance of the stages is low. This reduces the saturation of the slow, large P-N junction bipolar transistors that would otherwise lead to long recovery times. Fast small Schottky diodes, like those found in binary logic designs, improve the performance significantly though the performance still lags that of circuits with amplifiers using analog signals. Slew rate has no meaning for these devices. For applications in flash ADCs the distributed signal across eight ports matches the voltage and current gain after each amplifier, and resistors then behave as level-shifters.

The LM339 accomplishes this with an open collector output. When the inverting input is at a higher voltage than the non inverting input, the output of the comparator connects to the negative power supply. When the non inverting input is higher than the inverting input, the output is 'floating' (has a very high impedance to ground). The gain of op amp as comparator is given by this equation V(out)=V(in)

LOGIC GATES

Boolean functions may be practically implemented by using electronic gates. The following points are important to understand.

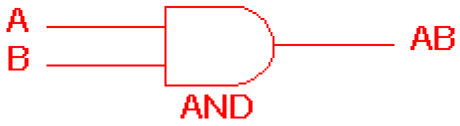
- Electronic gates requ34ire a power supply.
- Gate **INPUTS** are driven by voltages having two nominal values, e.g. 0V and 5V representing logic 0 and logic 1 respectively.
- The **OUTPUT** of a gate provides two nominal values of voltage only, e.g. 0V and 5V representing logic 0 and logic 1 respectively. In general, there is only one output to a logic gate except in some special cases.
- There is always a time delay between an input being applied and the output responding.

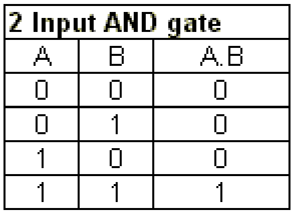
Truth tables are used to help show the function of a logic gate.

Basic Logic gates

Digital systems are said to be constructed by using logic gates. These gates are the AND, OR, NOT, NAND, NOR, EXOR and EXNOR gates. The basic operations are described below with the aid of truth tables.

AND gate

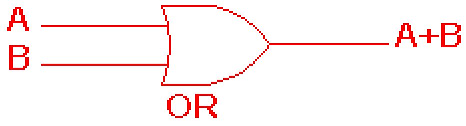


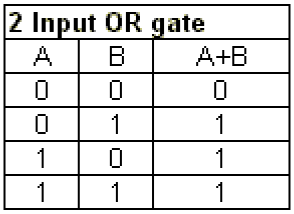


2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

The AND gate is an electronic circuit that gives a **high** output (1) only if **all** its inputs are high. A dot (.) is used to show the AND operation i.e. A.B. Bear in mind that this dot is sometimes omitted i.e. AB

OR gate

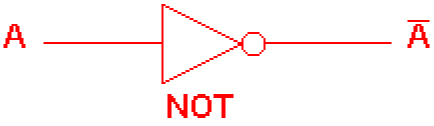


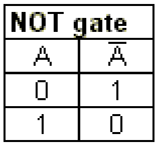


2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

The OR gate is an electronic circuit that gives a high output (1) if **one or more** of its inputs are high. A plus (+) is used to show the OR operation.

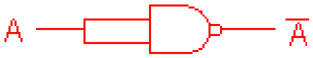
NOT gate

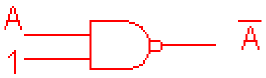




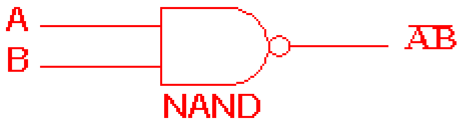
NOT gate	
A	$\overline{A}$
0	1
1	0

The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an inverter. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs. The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.





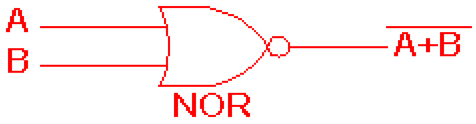
NAND gate



2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

This is a NOT-AND gate which is equal to an AND gate followed by a NOT gate. The outputs of all NAND gates are high if **any** of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion.

NOR gate

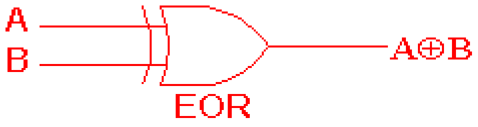


2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

This is a NOT-OR gate which is equal to an OR gate followed by a NOT gate. The outputs of all NOR gates are low if **any** of the inputs are high.

The symbol is an OR gate with a small circle on the output. The small circle represents inversion.

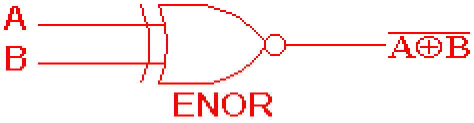
EXOR gate

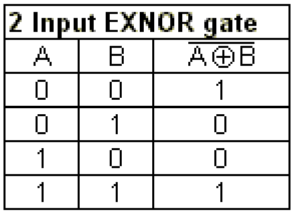


2 Input EXOR gate		
A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

The '**Exclusive-OR**' gate is a circuit which will give a high output if either, but not both, of its two inputs are high. An encircled plus sign (⊕) is used to show the EOR operation.

EXNOR gate





2 Input EXNOR gate		
A	B	$\overline{A\oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

The '**Exclusive-NOR'** gate circuit does the opposite to the EOR gate. It will give a low output if either, but not both, of its two inputs are high. The symbol is an EXOR gate with a small circle on the output. The small circle represents inversion.

The NAND and NOR gates are called *universal functions* since with either one the AND and OR functions and NOT can be generated.

A function in *sum of products* form can be implemented using NAND gates by replacing all AND and OR gates by NAND gates.

A function in *product of sums* form can be implemented using NOR gates by replacing all AND and OR gates by NOR gates.

Table 1: Logic gate symbols

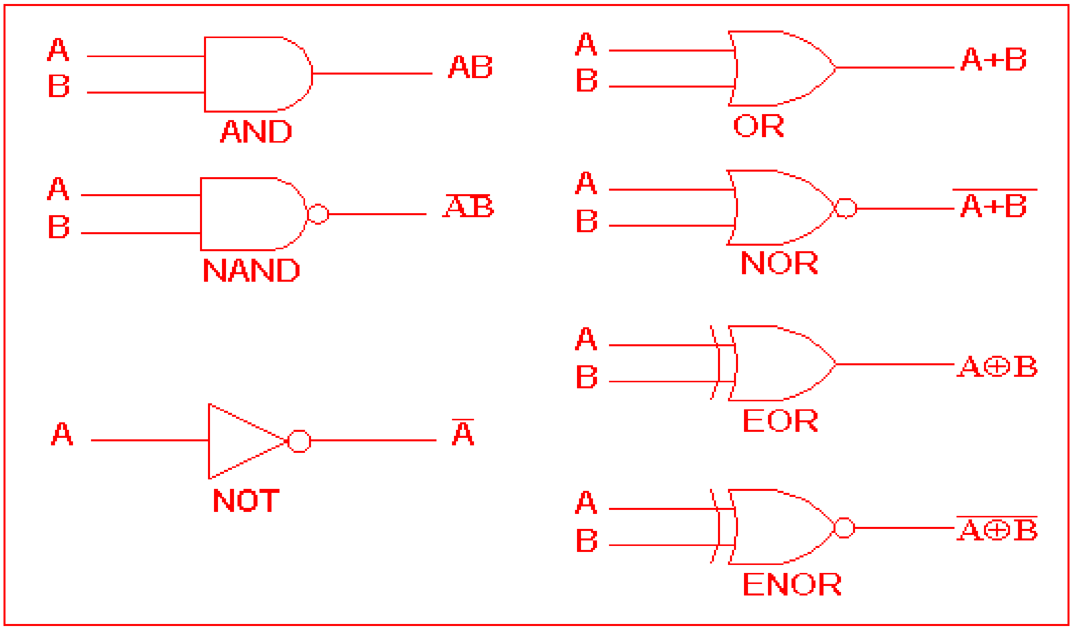
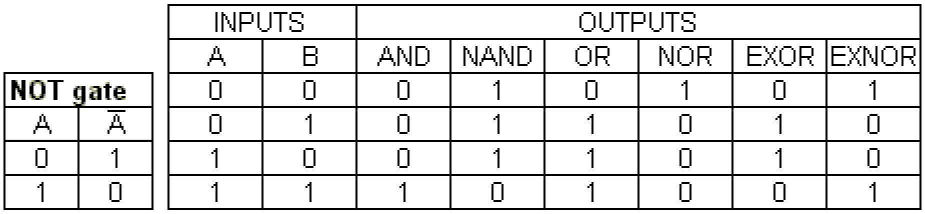


Table 2 is a summary truth table of the input/output combinations for the NOT gate together with all possible input/output combinations for the other gate functions. Also note that a truth table with 'n' inputs has 2^n rows. You can compare the outputs of different gates.

Table 2: Logic gates representation using the Truth table

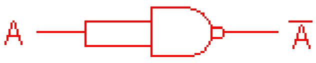


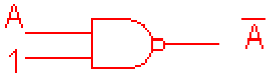
NOT gate	
A	$\bar{A}$
0	1
1	0

INPUTS		OUTPUTS					
A	B	AND	NAND	OR	NOR	EXOR	EXNOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

Example

A NAND gate can be used as a NOT gate using either of the following wiring configurations.





Universal Gates:

A universal gate is a gate which can implement any Boolean function without need to use any other gate type.

The NAND and NOR gates are universal gates.

In practice, this is advantageous since NAND and NOR gates are economical and easier to fabricate and are the basic gates used in all IC digital logic families.

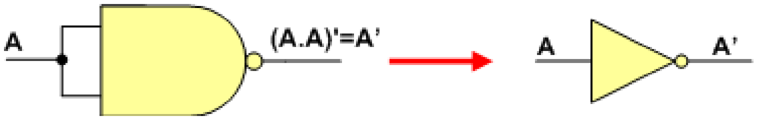
In fact, an AND gate is typically implemented as a NAND gate followed by an inverter not the other way around

Likewise, an OR gate is typically implemented as a NOR gate followed by an inverter not the other way around

NAND Gate is a Universal Gate:

To prove that any Boolean function can be implemented using only NAND gates, we will show that the AND, OR, and NOT operations can be performed using only these gates.

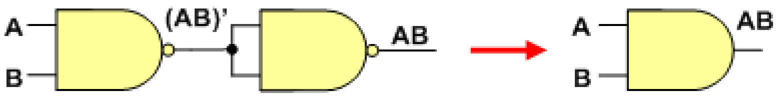
1. All NAND input pins connect to the input signal **A** gives an output **A‟**.



2. One NAND input pin is connected to the input signal **A** while all other input pins are connected to logic **1**. The output will be **A'**.

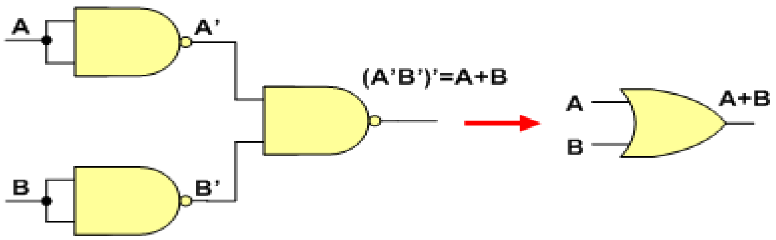
Implementing AND Using only NAND Gates

An AND gate can be replaced by NAND gates as shown in the figure (The AND is replaced by a NAND gate with its output complemented by a NAND gate inverter).



Implementing OR Using only NAND Gates

An OR gate can be replaced by NAND gates as shown in the figure (The OR gate is replaced by a NAND gate with all its inputs complemented by NAND gate inverters).



Thus, the NAND gate is a universal gate since it can implement the AND, OR and NOT functions.

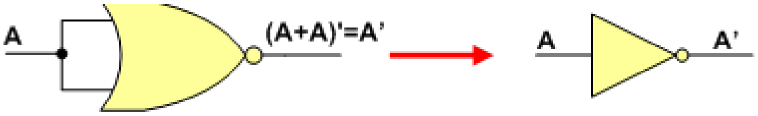
NAND Gate is a Universal Gate:

To prove that any Boolean function can be implemented using only NOR gates, we will show that the AND, OR, and NOT operations can be performed using only these gates.

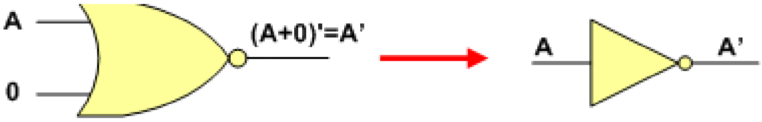
Implementing an Inverter Using only NOR Gate

The figure shows two ways in which a NOR gate can be used as **an inverter (NOT gate)**.

1. All NOR input pins connect to the input signal **A** gives an output **A’**.

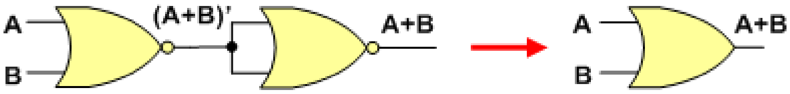


2. One NOR input pin is connected to the input signal **A** while all other input pins are connected to logic **0**. The output will be **A’**.



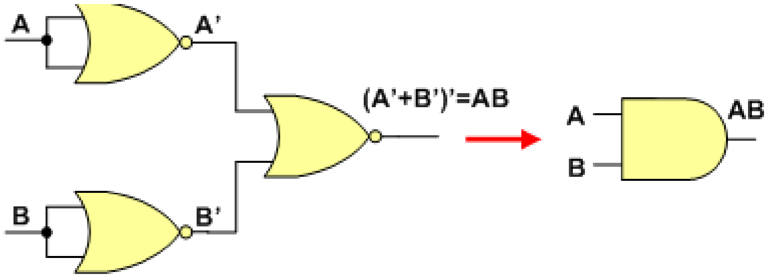
Implementing OR Using only NOR Gates

An OR gate can be replaced by NOR gates as shown in the figure (The OR is replaced by a NOR gate with its output complemented by a NOR gate inverter)



Implementing AND Using only NOR Gates

An AND gate can be replaced by NOR gates as shown in the figure (The AND gate is replaced by a NOR gate with all its inputs complemented by NOR gate inverters)



Thus, the NOR gate is a universal gate since it can implement the AND, OR and NOT functions.

ELECTRONIC INSTRUMENTATION

1) DIGITAL MULTIMETER

While most analog meters require no power supply, give a better visual indication of trends and changes, suffer less from electric noise and isolation problems, and, are simple and inexpensive, digital meters offer higher accuracy and input impedance, unambiguous readings at greater viewing distances, smaller size, and a digital electrical output (for interfacing with external equipment) in addition to visual readout. The main part of most of the digital multimeter (DMMs) is the analog to digital converter (A/D) which converts an analog input signal to a digital output. While specifications may vary, virtually such multimeters are developed around the same block diagram of Figure 13.

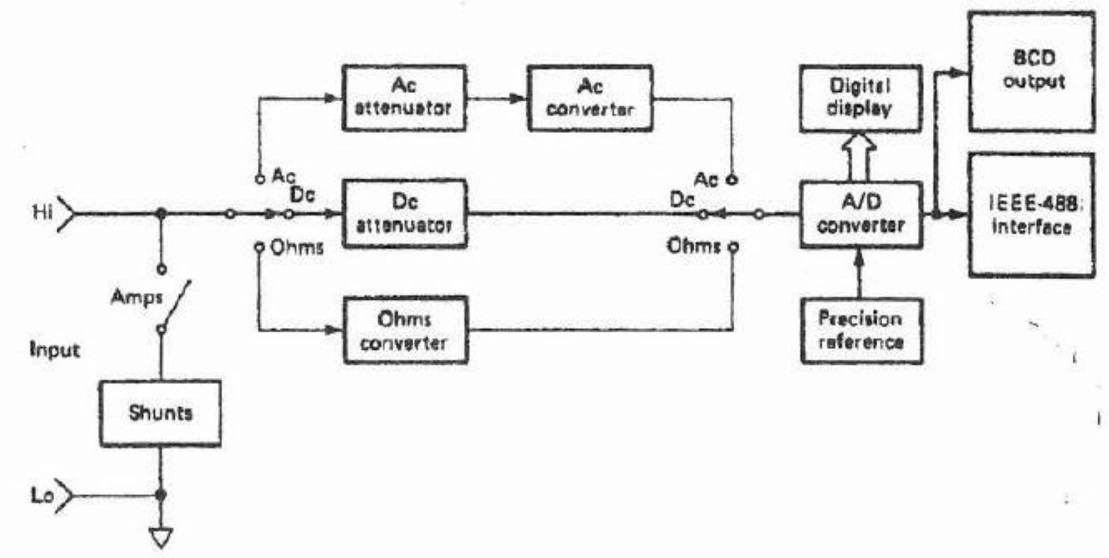


Figure 13.

Since the DMM is a voltage sensing meter; current is converted to volts by passing it through a precision low resistance shunt while ac is converted to dc at the AC converter by employing rectifiers and filters. Most of the AC converters detect the peak value of the signal and are calibrated to give the rms value of a sine wave. However, some measures the mean of the rectified signal such as the digital multimeter Agilent 34401A. Finally, this dc level is applied to the A/D converter to obtain the digital information. For resistance measurement, the meter includes a precision low current source that is applied across the unknown resistor. Then the dc voltage drop across the resistor, which is proportional to the value of the unknown resistor, is measured. For AC measurements, the digital multimeter is a true rms instrument that it measures true rms value of any periodic signal

Figure 14. The digital multimeter used in this laboratory.

A) VOLTAGE MEASUREMENT

To measure voltage, the instrument should be set to a A.C. or D.C. range (the buttons of “DC V” and “AC V”). The red probe should be connected to upper-right socket and black one to middle-right socket as indicated in Figure 14. The digital multimeter is an auto-range device that it is not needed to arrange the range of voltage.

B) CURRENT MEASUREMENT

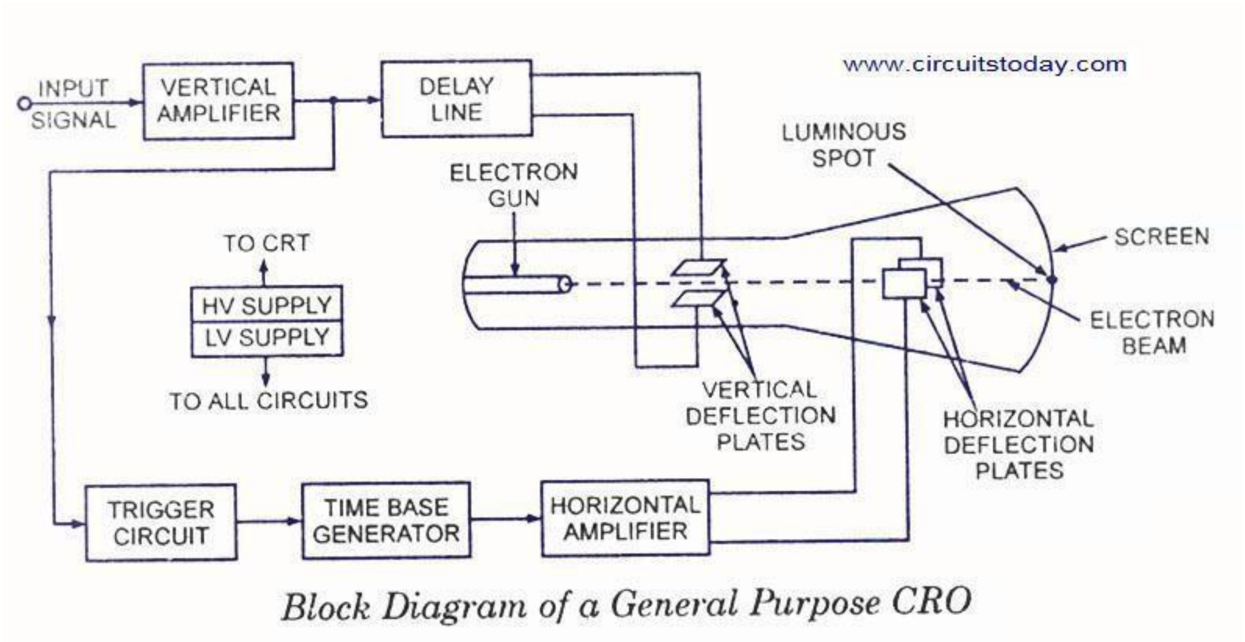
To measure current, the instrument should be set to a suitable A.C. or D.C. range. For this purpose, firstly, blue “Shift” button is depressed then “DC V” or “AC V” button is depressed. The red probe should be connected to lower-right socket and black one tmiddle-right socket.

C) RESISTANCE MEASUREMENT

To measure resistance, the “2W” button should be depressed without selecting blue “Shift” button. The red probe should be connected to upper-right socket and black one to middle-right socket as in voltage measurement.

BLOCK DIAGRAM OF CRO

The cathode ray oscilloscope (CRO) is a very useful and versatile laboratory instrument used for display, measurement and analysis of waveforms and other phenomenon in electrical and electronics circuits. A CRO consists of the following parts.



Block Diagram of a General Purpose CRO

1 **. Cathode Ray Tube:**

Cathode Ray Tube is the heart of the oscilloscope. When the electrons emitted by the electron gun strikes the phosphor screen of the CRT, a visual signal is displayed on the CRT.

2. Vertical Amplifier

In Vertical Amplifier**,**The input signals are amplified by the vertical amplifier. Usually, the vertical amplifier is a wide band amplifier which passes the entire band of frequencies.

3. Delay Line

Delay Line as the name suggests that, this circuit is used to, delay the signal for a period of time in the vertical section of CRT. The input signal is not applied directly to the vertical plates because the

part of the signal gets lost, when the delay Time not used. Therefore, the input signal is delayed by a period of time.

4. Time Base Circuit

Time base circuit uses a uni junction transistor, which is used to produce the sweep. The sawtooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section. The spot is deflected by the saw tooth voltage at a constant time dependent rate.

5. Horizontal Amplifier

In Horizontal Amplifier,The saw tooth voltage produce by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates

6. Trigger Circuit

In the Trigger Circuit the signals which are used to activate the trigger circuit are converted to trigger pulses for the precision sweep operation whose amplitude is uniform. Hence input signal and the sweep frequency can be synchronized.

7. Power supply:

The Power supply voltages require by CRT, horizontal amplifier and vertical amplifier are provided by the power supply block.

Power supply block of oscilloscope is classified in to two types

(1) Negative high voltage supply

(2) Positive low voltage supply

The voltages of negative high voltage supply is from -1000V to -1500V and the range of positive voltage supply is from 300V to 400V approx.

The instrument employs a **cathode ray tube** (CRT), which is the heart of the oscilloscope. It generates the electron beam, accelerates the beam to a high velocity, deflects the beam to create the image, and contains a phosphor screen where the electron beam eventually becomes visible. For accomplishing these tasks various electrical signals and voltages are required, which are provided by the power supply circuit of the oscilloscope. Low voltage supply is required for the heater of the electron gun for generation of electron beam and high voltage, of the order of few thousand volts, is required for cathode ray tube to accelerate the beam. Normal voltage supply, say a few hundred volts, is required for other control circuits of the oscilloscope.

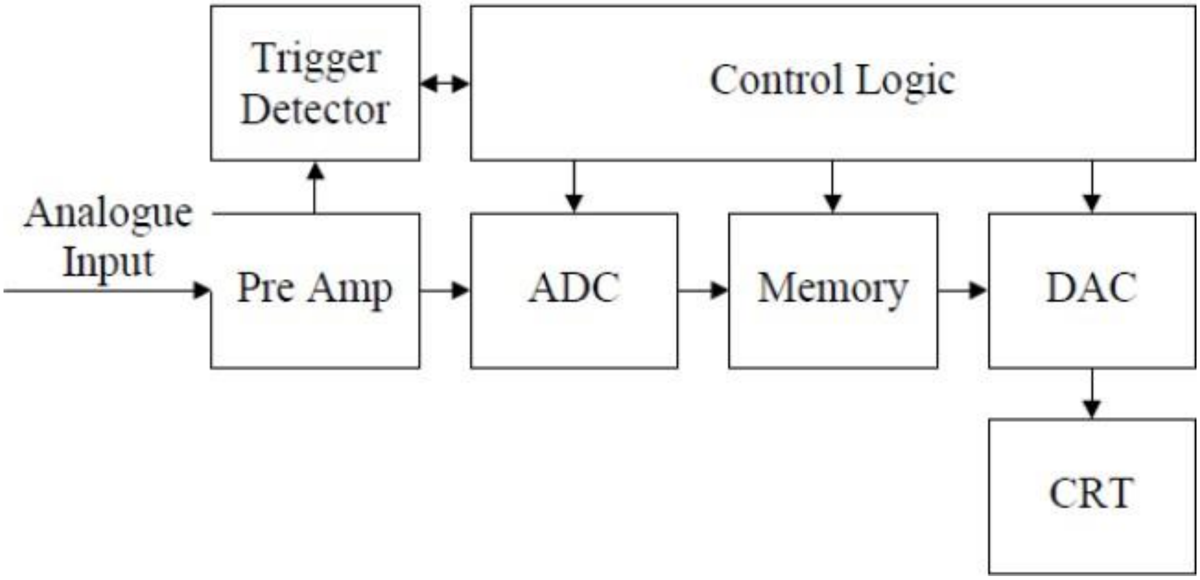
Horizontal and vertical deflection plates are fitted between electron gun and screen to deflect the beam according to input signal. Electron beam strikes the screen and creates a visible spot. This spot is deflected on the screen in horizontal direction (X-axis) with constant time dependent rate. This is accomplished by a time base circuit provided in the oscilloscope. The signal to be viewed is supplied to the vertical deflection plates through the vertical amplifier, which raises the potential of the input signal to a level that will provide usable deflection of the electron beam.

Now electron beam deflects in two directions, horizontal on X-axis and vertical on Y-axis. A triggering circuit is provided for synchronizing two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps

PRINCIPLE AND BLOCK DIAGRAM OF DSO

A storage scope is more useful as it captures and stores the signal. Which can then be displayed to the user. Because the screen is not continuously refreshed with the current state of the signal the scope can be used to analyze non-repeating signals and signal glitches. Both analogue storage and digital storage scopes are available, with digital scopes being by far the most common. Normal oscilloscopes use an electron beam, which is swept across a phosphorscreen, the vertical deflection of the beam being proportional to input voltage. Areas of the screen that are bombarded by the electron beam will emit light, resulting in animage that shows the waveform of the input signal. Analogue storage scopes use a specially modified cathode ray tube (CRT) to store the signal. Unlike a conventional scope an analogue storage scope only sweeps the electron beam (the write beam) across the screen once. Then by exposing the entire screen with a low level electron beam. Unfortunately the faster the write beam is swept across the screen the shorter the residence time of the image. This results in fast recording only being visible for a few ten"s of milliseconds. To solve this problem the write beam is scanned onto an intermediate target at high speed, then before the image decays it is transferred to the phosphor screen by a read gun. As the image is transferred to the screen at a relatively low speed it will have a high residence timeA Digital Storage Oscilloscope (DSO) uses digital memory to store a waveform. Inorder to do this the incoming signal must first be digitized, once this is complete the data in the memory can be continuously replayed through a digital to analogue converter and displayed on a CRT. Unlike analogue storage scopes the captured waveform does not decay over time. The speed and length of the recording are parameters that limit the type of signals that can be analysed by a DSO. Most commercially available DSO"s allow the user to increase the length of the recording only by reducing the sampling frequency. This is not always desirable as it can lead to aliasing of the signal and the loss of small details like signal glitches that can seriously restrict the usefulness of a DSO, as engineers are often interested in these very glitches. The memory capacity of a DSO determines the maximum length of a recording for a given sample rate. Therefore increasing the storage capacity of a DSO enables the recording to be lengthened without reducing the sample rate.

Fig 1. Conventional DSO Block Diagram

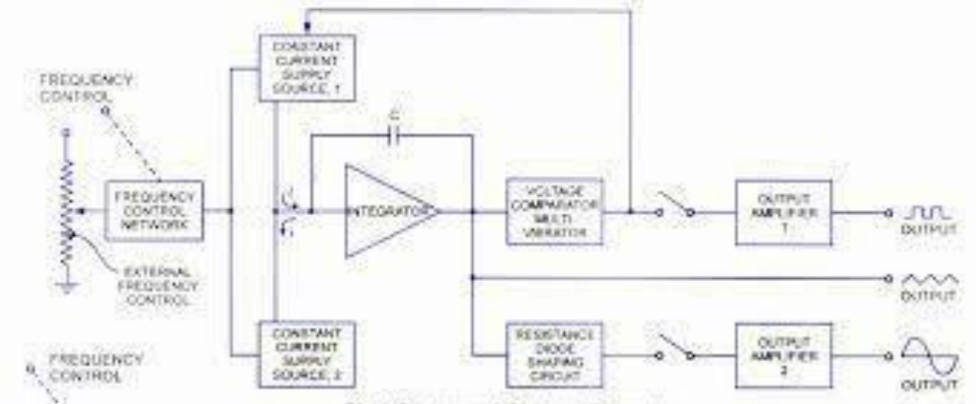


The analogue signal being monitored is fed into a pre amp, which changes it‟s amplitude so that it falls within the input range of the Analogue to Digital Converter (ADC) and the trigger detector. When the resulting voltage crosses a threshold set by the user the trigger unit signals the device to start recording. The ADC samples the output of the pre amp at regular intervals and the digital output from the ADC is then stored in consecutive locations in the memory. When the memory is full the recording is stopped. The Digital to Analogue Converter (DAC) continuously scans through the recording producing a repeating analogue signal representing the contents of the memory, which is sent to the Cathode Ray Tube (CRT) for display. This is required because the CRT image will fade away if not continuously refreshed. If changes in the input voltage re-triggers the DSO then the memory is overwritten with a new recording unless the user puts the system into HOLD mode, Hold mode allows the user to analyse the signal trace for as long

Function generator

Function or signal generator is one of the most important component used in designing electronics circuits especially for practical or experimental applications. I think you are already aware of the importance of a function generator. However, here we are going to discuss about Signal generators .A function generator is a signal source that has the capability of producing different types of waveforms as its output signal. The most common out of them are the frequencies of all these waveforms can be adjusted from a fraction of a hertz to megahertz range. Actually the function generators are very versatile instruments as they are capable of producing a wide variety of waveforms and frequencies. In fact each of these waveforms are suitable for specific applications. All the function generators are capable of producing two different waveforms simultaneously from two different outputs. This may find helpful for certain application which requires more than one output waveforms at a time. For instance, by providing a square wave for linearity measurements in an audio system, a simultaneous sawtooth output may be used to drive the horizontal deflection amplifier of an oscilloscope, providing visual display of the measurement result. Another important feature of some function generator is their capability of phase locking to an external signal source. One function generator may be used to phase lock a second function generator, and the two output signals can be displaced in phase by an adjustable amount. In addition, one function generator may be phase locked to a harmonic of the sine wave of another function generator. By adjusting the phase and amplitude of the harmonics almost any waveform may be produced by the summation of the fundamental frequency generated by one signal generator and the harmonic generated by the other. The signal generator can also be phase locked to an accurate frequency standard, and all its output waveforms will have the same frequency, stability, and accuracy as the standard

BLOCK DIAGRAM OF FUNCTION GENERATOR



Block Diagram of Function Generator

Working of Signal generator

Here in this instrument the frequency is controlled by varying the magnitude of current that drives the integrator. It provides different types of waveforms at its output with a frequency range of 0.01 Hz to 100 kHz. The frequency controlled voltage regulates two current supply sources. Current supply source one supplies constant current to the integrator whose output

voltage rises linearly with time according to the output signal voltage. An increase or decrease in the current increase or reduce the slope of the output voltage and thus controls the frequency. The voltage comparator multivibrator changes state at a predetermined maximum level, of the integrator output voltage. This change cuts off the current supply from source 1 and switches to supply source 2. The current supply 2 supplies a reverse current to the integrator so that its output drops linearly with time. When the output attains a predetermined level the voltage comparator again changes its state and switches on to the current supply source 1.

The output of the integrator is a triangular wave whose frequency depends on the current supplied by the constant current supply sources. The comparator output provides a square wave of the same frequency as output. The resistance diode network changes the slope of the triangular wave as its amplitude changes and produces a sinusoidal wave with less than 1% distortion.

LISSAJOUS PATTERNS

An oscilloscope can be used to observe and measure ac waveforms. It may also be used to observe a voltage-versus-voltage pattern by eliminating the time parameter. The resulting pattern is referred to as a *Lissajous pattern*. It is the purpose of this experiment to acquaint you with the uses of such patterns and the methods by which they may be observed. By disconnecting the sweep generator of the oscilloscope and applying two ac waveforms to both the horizontal and vertical amplifiers, you can observe a Lissajous pattern on the screen. If one of the input waveforms is completely known, the frequency, phase, and magnitude relationships between the two waveforms may be measured from the pattern, and the unknown waveform parameters may be calculated as described below. When both applied waveforms are sinusoidal, the resulting Lissajous pattern may take many forms depending upon the frequency ratio and phase difference between the waveforms. Figure 7.1 shows Lissajous patterns for sinusoids of the same frequency, but varying phase relationships.

Fig. 7.1

The Lissajous patterns shown in Fig. 7.2 are from sinusoids of varying frequency and phase relationships. To determine the frequency ratio, draw horizontal and vertical lines through the center of the pattern as shown in Fig. 7.3. The ratio of the number of horizontal axis crossings to the number of vertical axis crossings determines the frequency ratio. The ratio is given as

$$\frac{f_y}{f_x} = \frac{\text{number of horizontal crossings}}{\text{number of vertical crossings}}$$

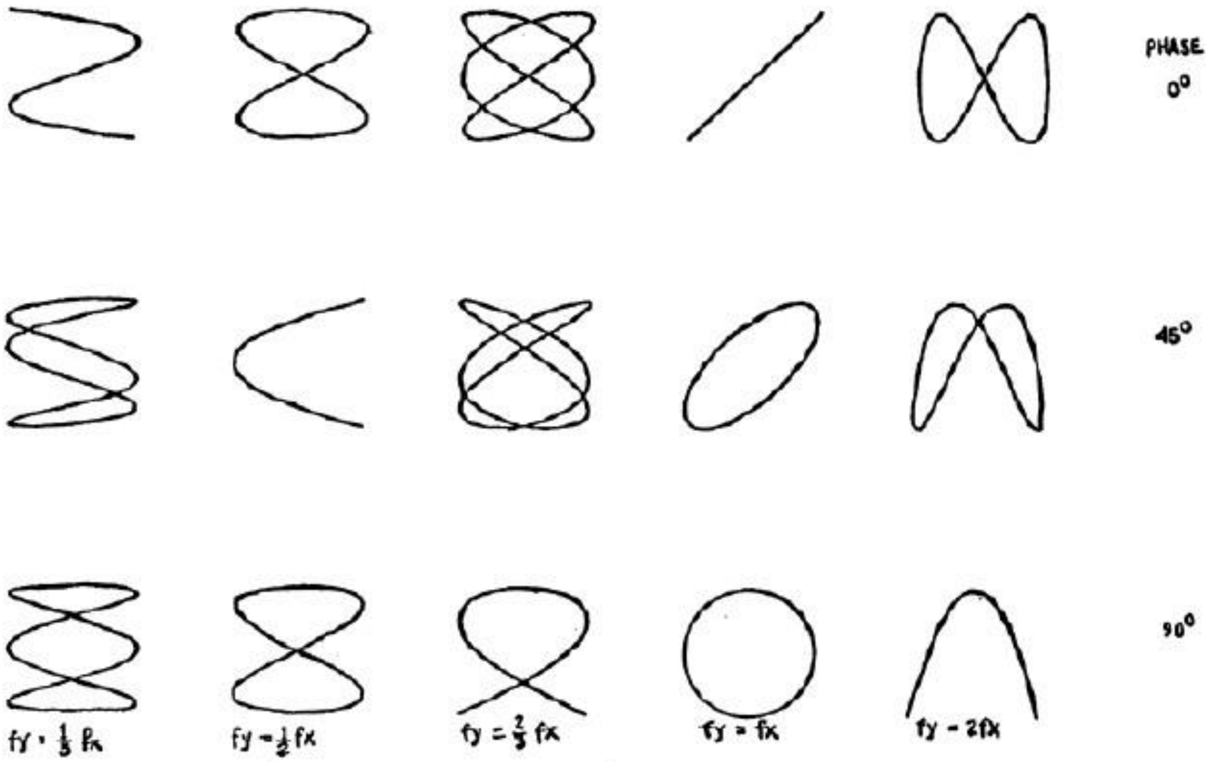


Fig. 7.2 Sine-vs-sine plots (Lissajous figures) for several frequency ratios

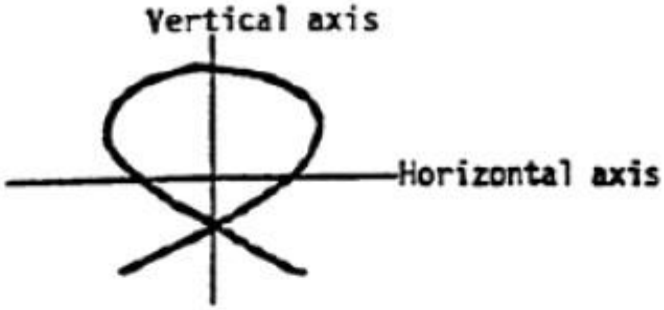


Fig. 7.3

For example, in Fig. 7.3 the frequency ratio would be

$$\frac{f_y}{f_x} = \frac{\text{number of horizontal crossings}}{\text{number of vertical crossings}} = \frac{2}{3}$$

$$f_y = 2/3\, f_x \,.$$

We can obtain the phase angle and magnitude relationships for two sinusoids of the same frequency by using their Lissajous pattern, as shown in Fig. 7.4. The ratio of peak voltages is $V_x / V_y = M / A$

The phase difference is $\theta = \sin^{-1}[B/A]$, and the sinusoids are

$v_x = V_x \sin(\omega t)$ and $v_y = V_y \sin(\omega t + \theta)$. (Remember, this is valid only for signals for which $f_y = f_x$.)

The Zener Diode

In the previous Signal Diode tutorial, we saw that a “reverse biased” diode blocks current in the reverse direction, but will suffer from premature breakdown or damage if the reverse voltage applied across it is too high.

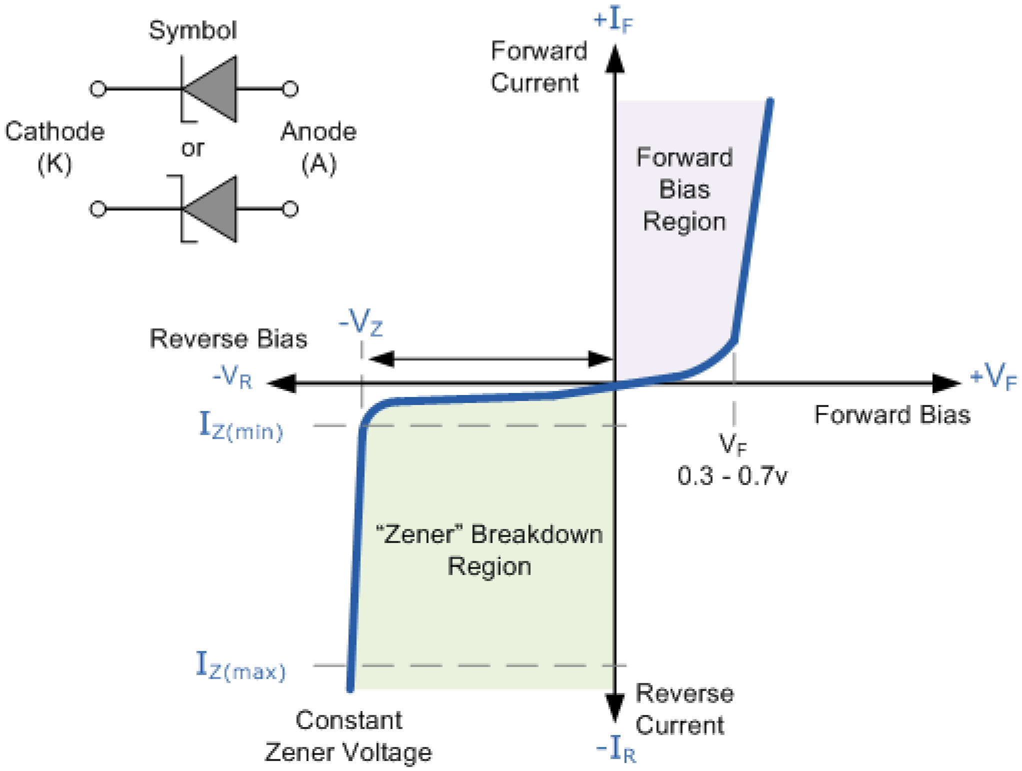
However, the Zener Diode or “Breakdown Diode” as they are sometimes called, are basically the same as the standard PN junction diode but are specially designed to have a low pre-determined Reverse Breakdown Voltage that takes advantage of this high reverse voltage. The zener diode is the simplest types of voltage regulator and the point at which a zener diode breaks down or conducts is called the “Zener Voltage” (Vz).

The Zener diode is like a general-purpose signal diode consisting of a silicon PN junction. When biased in the forward direction it behaves just like a normal signal diode passing the rated current, but as soon as a reverse voltage applied across the Zener Diode exceeds the rated voltage of the device, the diodes breakdown voltage is reached at which point a process called Avalanche Breakdown occurs in the semiconductor depletion layer and a current starts to flow through the diode to limit this increase in voltage.

The current now flowing through the zener diode increases dramatically to the maximum circuit value (which is usually limited by a series resistor) and once achieved this reverse saturation current remains fairly constant over a wide range of applied voltages. The voltage point at which the voltage across the zener diode becomes stable is called the “zener voltage” for zener diodes this voltage can range from less than one volt to hundreds of volts.

The point at which the zener voltage triggers the current to flow through the diode can be very accurately controlled (to less than 1% tolerance) in the doping stage of the diodes semiconductor construction giving the diode a specific zener breakdown voltage, (Vz) for example, 4.3V or 7.5V. This zener breakdown voltage on the I-V curve is almost a vertical straight line.

Zener Diode I-V Characteristics



The Zener Diode is used in its "reverse bias" or reverse breakdown mode, i.e. the diodes anode connects to the negative supply. From the I-V characteristics curve above, we can see that the zener diode has a region in its reverse bias characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current $I_{Z(min)}$ and the maximum current rating $I_{Z(max)}$.

This ability to control itself can be used to great effect to regulate or stabilize a voltage source against supply or load variations. The fact that the voltage across the diode in the breakdown region is almost constant turns out to be an important application of the zener diode as a voltage regulator.

The function of a regulator is to provide a constant output voltage to a load connected in parallel with it in spite of the ripples in the supply voltage or the variation in the load current and the zener diode will continue to regulate the voltage until the diodes current falls below the minimum $I_{Z(min)}$value in the reverse breakdown region.

The Zener Diode Regulator

Zener Diodes can be used to produce a stabilised voltage output with low ripple under varying load current conditions. By passing a small current through the diode from a voltage source, via a suitable current limiting resistor (R_S), the zener diode will conduct sufficient current to maintain a voltage drop of Vout.

We remember from the previous tutorials that the DC output voltage from the half or full-wave rectifiers contains ripple superimposed onto the DC voltage and that as the load value changes so to does the average output voltage. By connecting a simple zener stabiliser circuit as shown below across the output of the rectifier, a more stable output voltage can be produced.

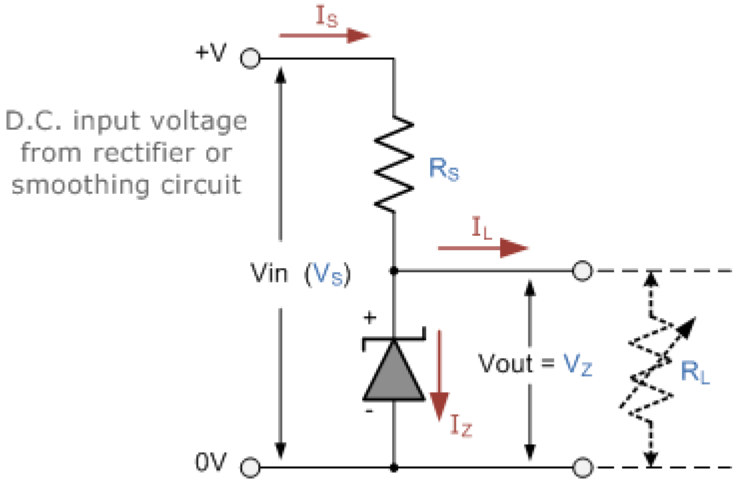


Fig: Zener Diode Regulator

The 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 stabilized 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 stabilization 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 dependent upon the power rating of the device. The supply voltage V_S must be greater than V_Z.

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

A zener diode is always operated in its reverse biased condition. A 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 stabilized output voltage is always selected to be the same as the breakdown voltageV_Z of the diode.

Zener Diode Example No1

A 5.0V stabilised power supply is required to be produced from a 12V DC power supply input source. The maximum power rating P_Z of the zener diode is 2W. Using the zener regulator circuit above calculate:

a). The maximum current flowing through the zener diode.

$$\text{Maximum Current} = \frac{\text{Watts}}{\text{Voltage}} = \frac{2\text{w}}{5\text{v}} = 400\text{mA}$$

b). The minimum value of the series resistor, R_S

$$R_S = \frac{V_S - V_Z}{I_Z} = \frac{12 - 5}{400mA} = 17.5\Omega$$

c). The load current I_L if a load resistor of 1kΩ is connected across the zener diode.

$$I_L = \frac{V_Z}{R_L} = \frac{5v}{1000\Omega} = 5mA$$

d). The zener current I_Z at full load.

$$I_Z = I_S - I_L = 400mA - 5mA = 395mA$$

Zener Diode Voltages

As well as producing a single stabilised voltage output, zener diodes can also be connected together in series along with normal silicon signal diodes to produce a variety of different reference voltage output values as shown below.

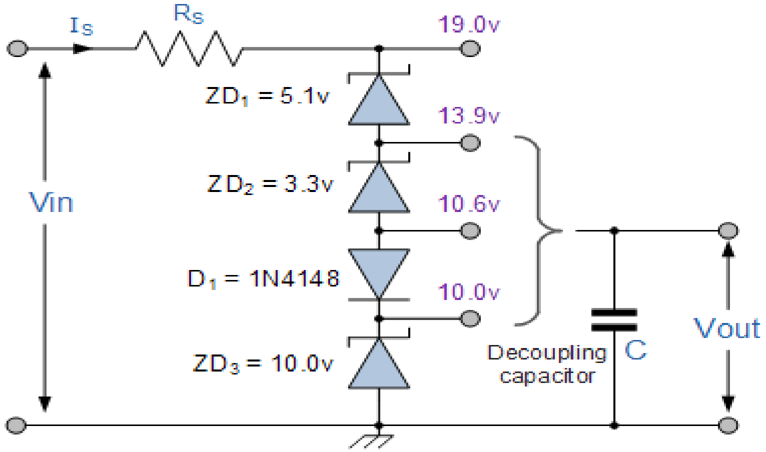


Fig: **Zener Diodes Connected in Series**

The values of the individual Zener diodes can be chosen to suit the application while the silicon diode will always drop about 0.6 – 0.7V in the forward bias condition. The supply voltage, Vin must of course be higher than the largest output reference voltage and in our example above this is 19v.

A typical zener diode for general electronic circuits is the 500mW, BZX55 series or the larger 1.3W,BZX85 series were the zener voltage is given as, for example, C7V5 for a 7.5V diode giving a diode reference number of BZX55C7V5.

The 500mW series of zener diodes are available from about 2.4 up to about 100 volts and typically have the same sequence of values as used for the 5% (E24) resistor series with the individual voltage ratings for these small but very useful diodes are given in the table below.

Zener Diode Standard Zener Voltages

BZX55 Zener Diode Power Rating 500mW							
2.4V	2.7V	3.0V	3.3V	3.6V	3.9V	4.3V	4.7V
5.1V	5.6V	6.2V	6.8V	7.5V	8.2V	9.1V	10V
11V	12V	13V	15V	16V	18V	20V	22V
24V	27V	30V	33V	36V	39V	43V	47V
BZX85 Zener Diode Power Rating 1.3W							
3.3V	3.6V	3.9V	4.3V	4.7V	5.1V	5.6	6.2V
6.8V	7.5V	8.2V	9.1V	10V	11V	12V	13V
15V	16V	18V	20V	22V	24V	27V	30V
33V	36V	39V	43V	47V	51V	56V	62V

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PUBLIC ADDRESS SYSTEM

2. Introduction Public Address System (PA system) is an electronic sound amplification and distribution system with a microphone, amplifier and loudspeakers, used to allow a person to address a large public, for example for announcements of movements at large and noisy air and rail terminals. The simplest PA system consist of a microphone, an amplifier, and one or more loudspeakers is shown in fig 1. A sound source such as compact disc player or radio may be connected to a PA system so that music can be played through the system.

Fig No. 1: Simple PA System

The process begins with a sound source (such as a human voice), which creates waves of sound (acoustical energy). These waves are detected by a microphone, which converts them to electrical energy. This signal is amplified in an amplifier up to a required level. The loudspeaker converts the electrical signal back into sound waves, which are heard by human ears. A block diagram of PA system containing microphone, mixer, limiter, equalizer, amplifier and speaker is shown below in figure No.2:

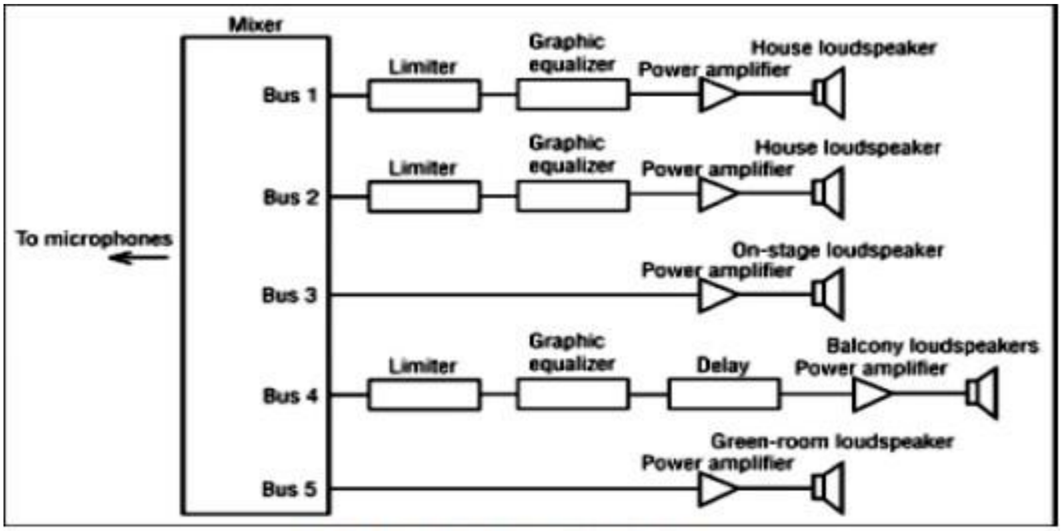


Fig No. 2 Block Diagram of PA system

Application of P.A. system in Railways Passenger Amenity For giving the detailed information about the train arrivals, departures, late running if any, and location of trains and any other important information related to Railway users. Marshalling Yards For communication between Yard Master and Shunting men through paging and talk-back system regarding formation and reception or dispatch of trains. Breakdown train Emergency Equipment The P.A. System in Accident Relief Train must be kept in working condition for guide the passengers and staff in rescue operations at the site of accident. Special functions Local Minister, G.M., etc., officials and VIPs may address some important functions such as Railway Week, felicitations, Scouts and Guides rally, some social work meetings, cultural programmes etc. a quality P.A. System needs to be installed. Railway Workshops Providing announcements to workshops staff when required and also for entertainment music during lunch hours. Conferences For conducting seminars, special lectures, administrative meetings for a limited group of officials in conference halls. In every zone, a G.M. Conference hall is available. In these suitable conference systems were permanently installed.

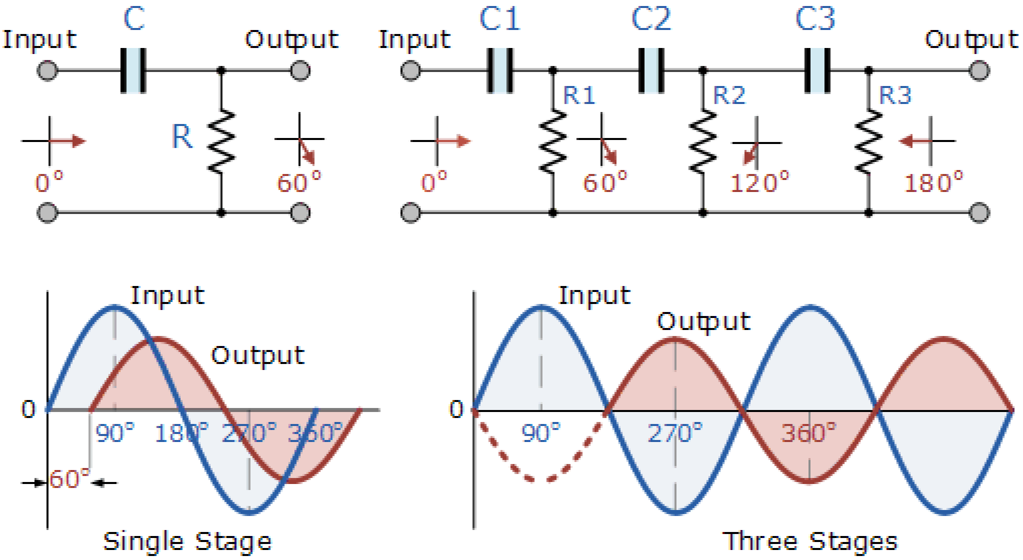
THE RC PHASE SHIFT OSCILLATOR

In our series of tutorials about Amplifiers , we saw that a single stage amplifier will produce 180^o of phase shift between its output and input signals when connected in a class-A type configuration. For an oscillator to sustain oscillations indefinitely, sufficient feedback of the correct phase, ie, “Positive Feedback” must be provided with the amplifier being used as one inverting stage to achieve this.

In an RC Oscillator circuit the input is shifted 180^o through the amplifier stage and 180^o again through a second inverting stage giving us “$180^o + 180^o = 360^o$” of phase shift which is effectively the same as 0^o thereby giving us the required positive feedback. In other words, the phase shift of the feedback loop should be “0”.

In a Resistance-Capacitance Oscillator or simply an RC Oscillator, we make use of the fact that a phase shift occurs between the input to a RC network and the output from the same network by using RC elements in the feedback branch, for example.

RC Phase-Shift Network



The circuit on the left shows a single Resistor-Capacitor Network whose output voltage “leads” the input voltage by some angle less than 90^o. An ideal single-pole RC circuit would produce a phase shift of exactly 90^o, and because 180^o of phase shift is required for oscillation, at least two single-poles must be used in an RC oscillator design.

However in reality it is difficult to obtain exactly 90^o of phase shift so more stages are used. The amount of actual phase shift in the circuit depends upon the values of the resistor and the capacitor, and the chosen frequency of oscillations with the phase angle (Φ) being given as:

RC Phase Angle

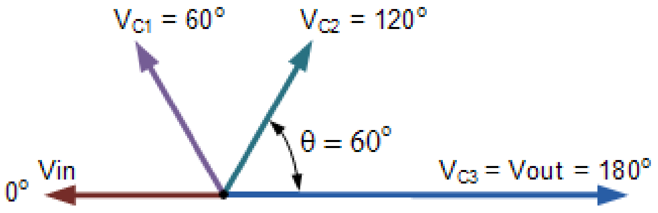
$$X_C = \frac{1}{2\pi f C} \qquad R = R,$$

$$Z = \sqrt{R^2 + (X_C)^2}$$

$$\therefore \quad \phi = \tan^{-1} \frac{X_C}{R}$$

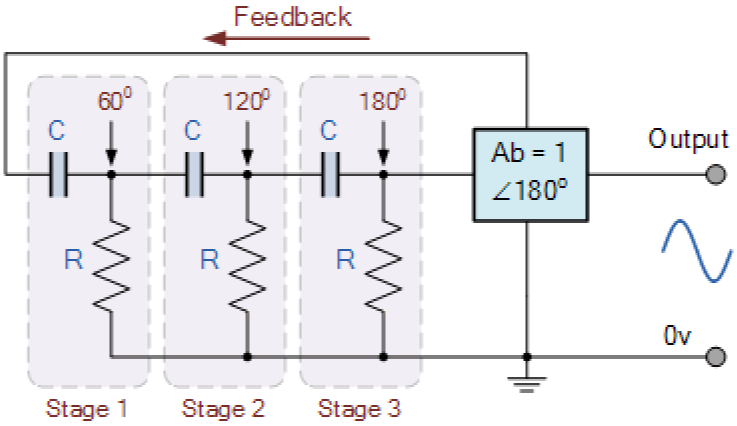
In our simple example above, the values of R and C have been chosen so that at the required frequency the output voltage leads the input voltage by an angle of about 60^o. Then the phase angle between each successive RC section increases by another 60^o giving a phase difference between the input and output of 180^o (3×60^o) as shown by the following vector diagram.

Vector Diagram



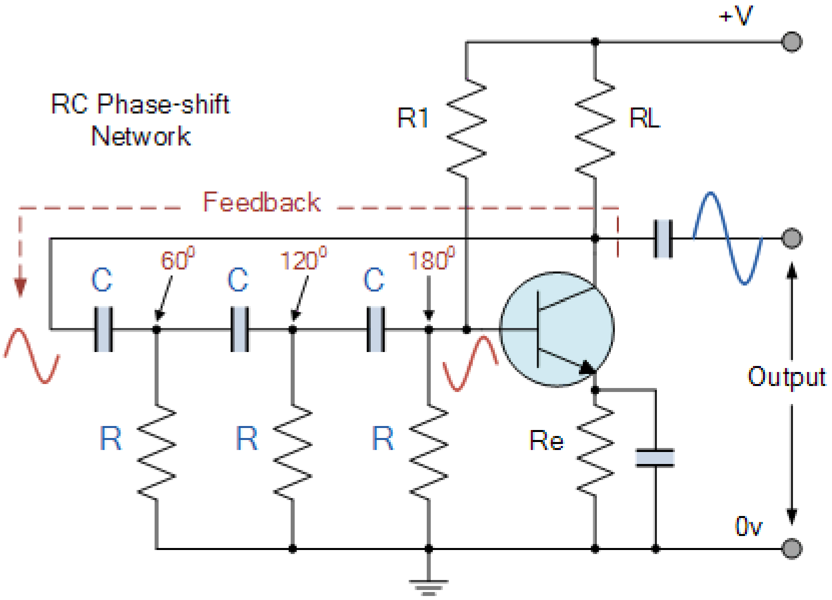
Then by connecting together three such RC networks in series we can produce a total phase shift in the circuit of 180^o at the chosen frequency and this forms the bases of a "phase shift oscillator" otherwise known as a RC Oscillator circuit.

We know that in an amplifier circuit either using a Bipolar Transistor or an Operational Amplifier, it will produce a phase-shift of 180^o between its input and output. If a three-stage RC phase-shift network is connected between this input and output of the amplifier, the total phase shift necessary for regenerative feedback will become $3 \times 60^o + 180^o = 360^o$ as shown.



The three RC stages are cascaded together to get the required slope for a stable oscillation frequency. The feedback loop phase shift is -180^o when the phase shift of each stage is -60^o. This occurs when $\omega = 2\pi f = 1.732/RC$ as ($\tan 60^o = 1.732$). Then to achieve the required phase shift in an RC oscillator circuit is to use multiple RC phase-shifting networks such as the circuit below.

Basic RC Oscillator Circuit



The basic RC Oscillator which is also known as a Phase-shift Oscillator, produces a sine wave output signal using regenerative feedback obtained from the resistor-capacitor combination. This regenerative feedback from the RC network is due to the ability of the capacitor to store an electric charge, (similar to the LC tank circuit).

This resistor-capacitor feedback network can be connected as shown above to produce a leading phase shift (phase advance network) or interchanged to produce a lagging phase shift (phase retard network) the outcome is still the same as the sine wave oscillations only occur at the frequency at which the overall phase-shift is 360°.

By varying one or more of the resistors or capacitors in the phase-shift network, the frequency can be varied and generally this is done by keeping the resistors the same and using a 3-ganged variable capacitor.

If all the resistors, R and the capacitors, C in the phase shift network are equal in value, then the frequency of oscillations produced by the RC oscillator is given as:

$$f_r = \frac{1}{2\pi RC\sqrt{2N}}$$

Where,

f_r is the Output Frequency in Hertz

R is the Resistance in Ohms

C is the Capacitance in Farads

N is the number of RC stages. (N = 3)

Since the resistor-capacitor combination in the RC Oscillator circuit also acts as an attenuator producing an attenuation of -1/29th (Vo/Vi = β) per stage, the gain of the amplifier must be sufficient to overcome the circuit losses. Therefore, in our three stage RC network above the amplifier gain must be greater than 29.

The loading effect of the amplifier on the feedback network has an effect on the frequency of oscillations and can cause the oscillator frequency to be up to 25% higher than calculated. Then the feedback network should be driven from a high impedance output source and fed into a low impedance load such as a common emitter transistor amplifier but better still is to use an Operational Amplifier as it satisfies these conditions perfectly.

FEEDBACK CONCEPTS

The effects of negative feedback on an amplifier: The effects of negative feedback on an amplifier:

Disadvantage

- Lower gain

Advantages

Higher input impedance

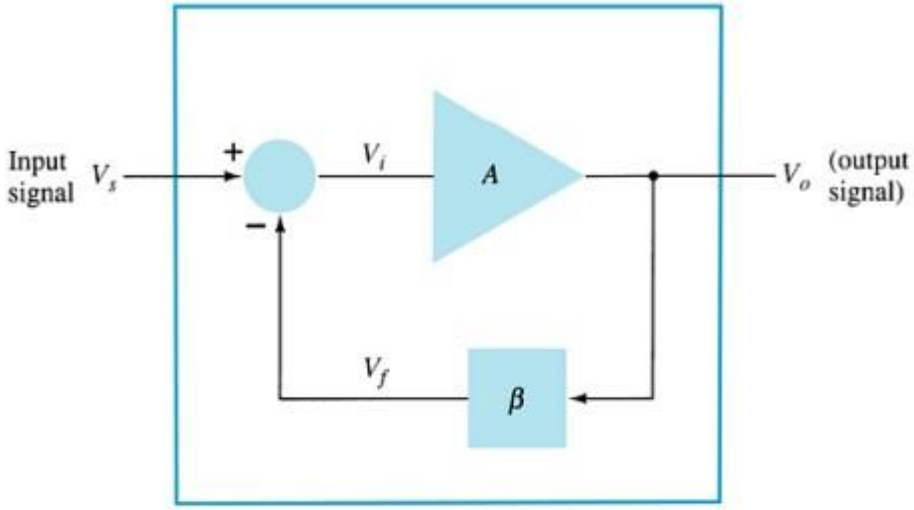
More stable gain More stable gain

Improved frequency response

Lower output impedance

Reduced noise

More linear operation



Feedback amplifier

Feedback Connection Types

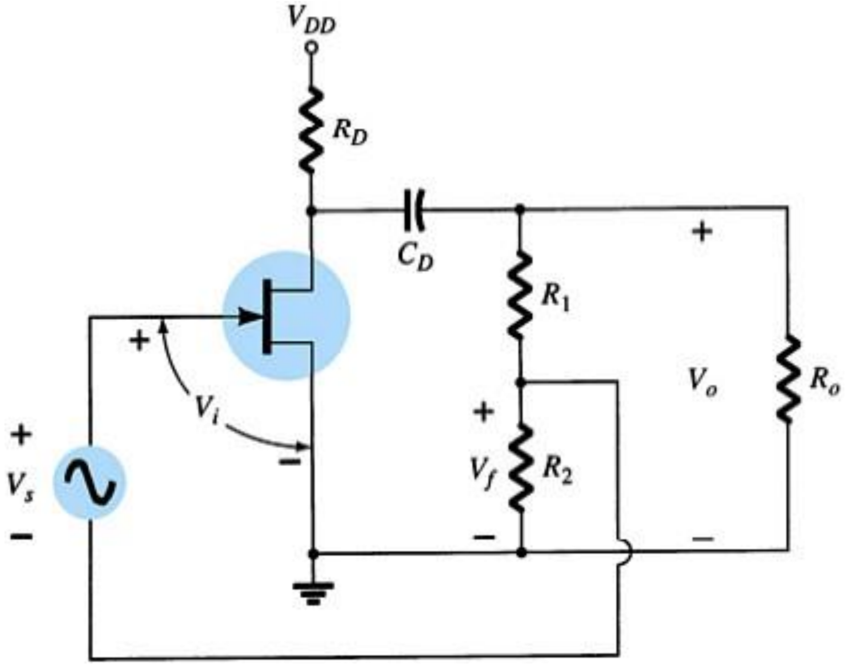
- Voltage-series feedback
- Voltage -shunt feedback shunt feedback

- Current-series feedback
- Current-shunt feedback

Voltage-Series Feedback

In Voltage Series Feedback, the output voltage is fed back in series to the input. The feedback gain is given by:

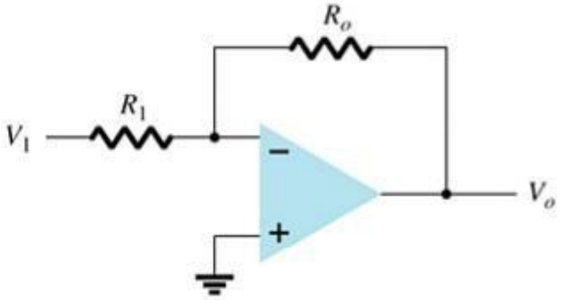
$$A_f \cong \frac{1}{\beta} = \frac{R_1 + R_2}{R_2}$$

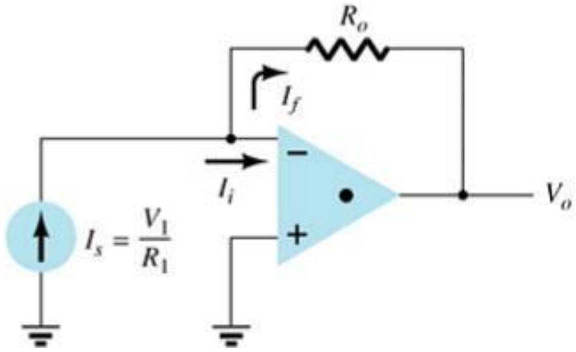


Voltage-Shunt Feedback

For a voltage-shunt feedback amplifier, the output voltage is fed back in parallel with the input. The feedback gain is given by

$$A_f = -\frac{R_o}{R_i}$$


R_o
R_1
V_1
−
+
V_o

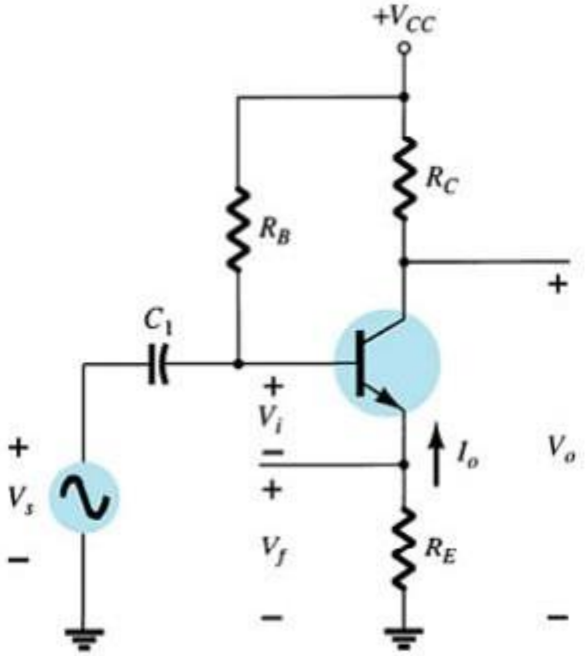

R_o
I_f
I_i
−
+
V_o
$I_s = \frac{V_1}{R_1}$

Current-Series Feedback

For a current series feedback amplifier, a portion of the output current is fed back in series with the input.

To determine the feedback gain:

$$A_f = \frac{I_o}{V_s} = \frac{A}{1+\beta A} = \frac{-h_{fe}/h_{ie}}{1+(-R_E)\left(\dfrac{-h_{fe}}{h_{ie}+R_E}\right)} \cong \frac{-h_{fe}}{h_{ie}+h_{fe}R_E}$$

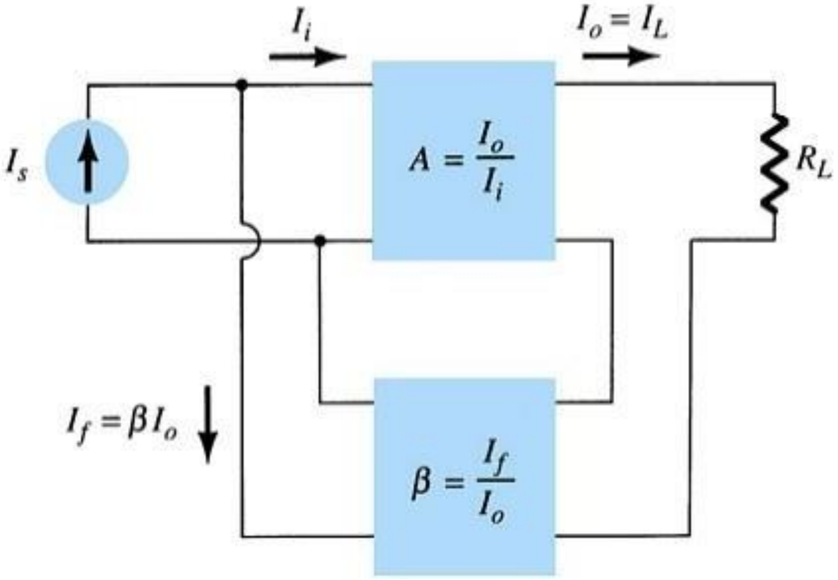


Current Shunt Feedback

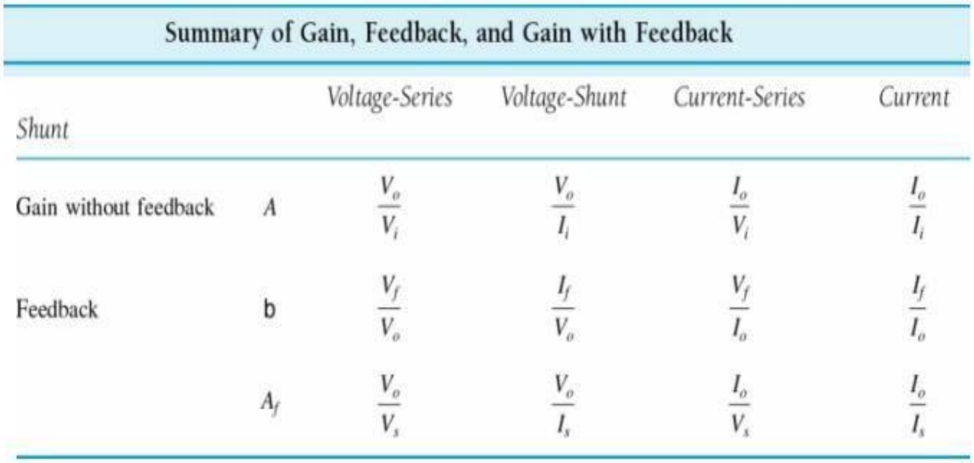
For a current-shunt feedback amplifier, a portion of the output current is directed back in parallel with the input.

The feedback gain is given by:

$$A_f = \frac{I_o}{I_s}$$

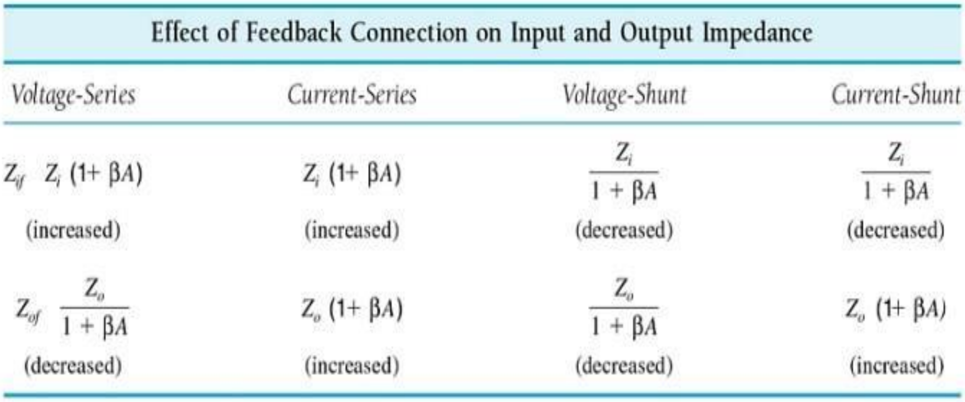


Summary of Feedback Effects



Summary of Gain, Feedback, and Gain with Feedback

Shunt		Voltage-Series	Voltage-Shunt	Current-Series	Current
Gain without feedback	A	$\frac{V_o}{V_i}$	$\frac{V_o}{I_i}$	$\frac{I_o}{V_i}$	$\frac{I_o}{I_i}$
Feedback	b	$\frac{V_f}{V_o}$	$\frac{I_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$
	A_f	$\frac{V_o}{V_s}$	$\frac{V_o}{I_s}$	$\frac{I_o}{V_s}$	$\frac{I_o}{I_s}$



Effect of Feedback Connection on Input and Output Impedance

Voltage-Series	Current-Series	Voltage-Shunt	Current-Shunt
Z_{if} $Z_i\,(1+\beta A)$ (increased)	$Z_i\,(1+\beta A)$ (increased)	$\frac{Z_i}{1+\beta A}$ (decreased)	$\frac{Z_i}{1+\beta A}$ (decreased)
Z_{of} $\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o\,(1+\beta A)$ (increased)	$\frac{Z_o}{1+\beta A}$ (decreased)	$Z_o\,(1+\beta A)$ (increased)

MODULE 5

RADIO COMMUNICATION

The purpose of a communication system is to transmit information signals through a communication channel. The figure below depicts the elements of a communication system.

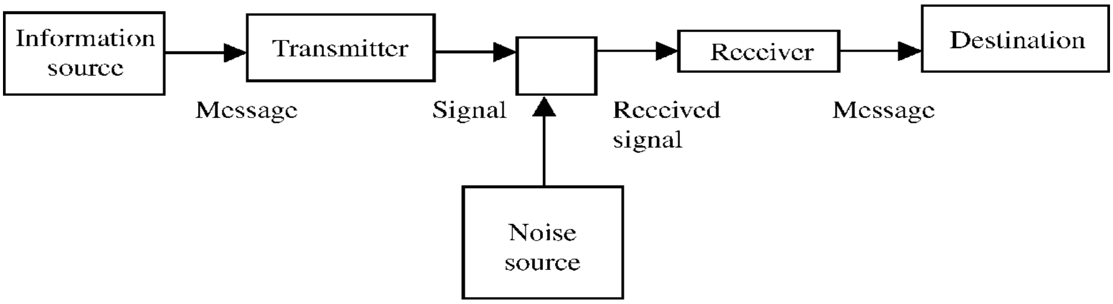


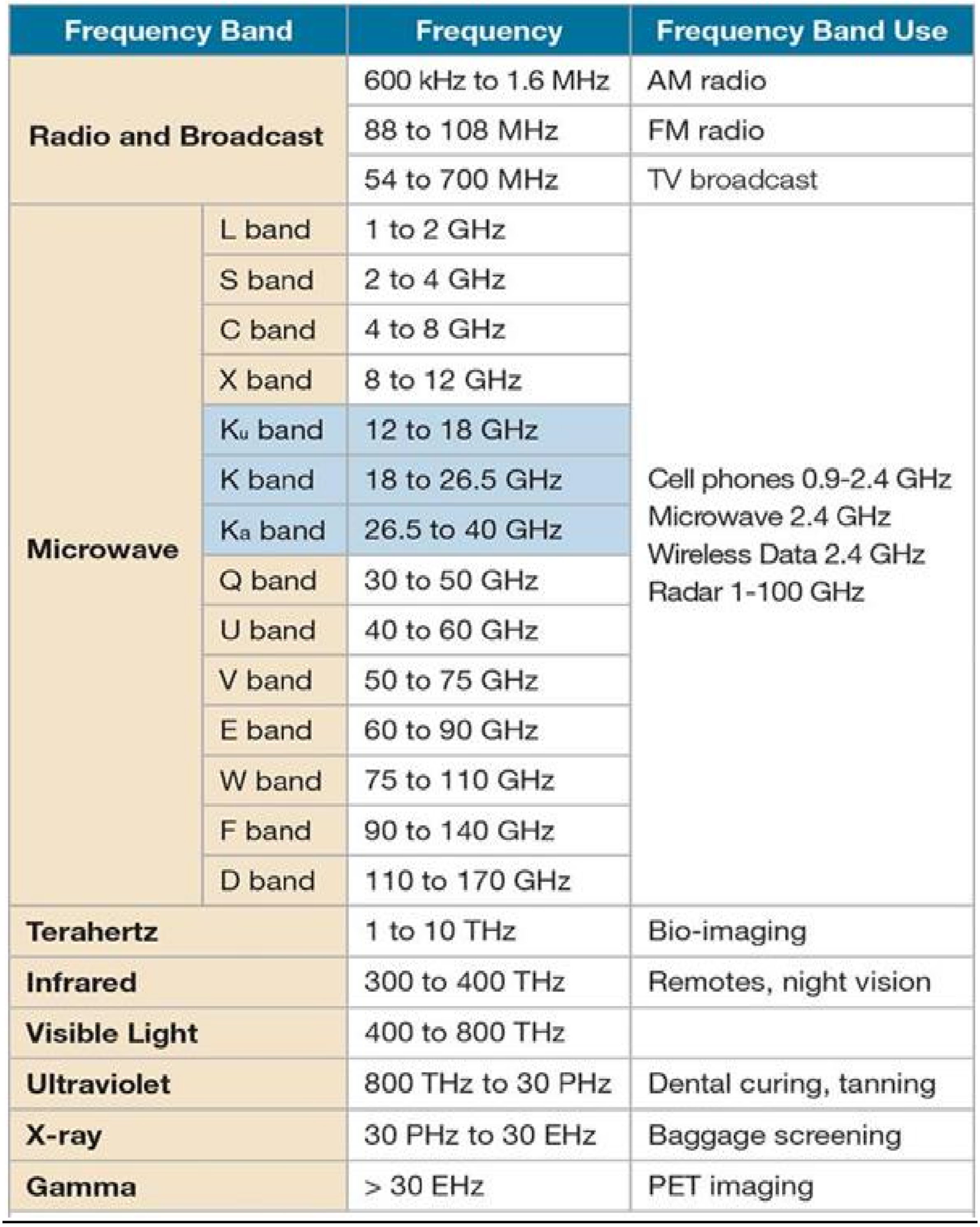
Fig: General block diagram for a communication system

The transmitter puts the information from the source onto the channel.The channel is the medium connecting the transmitter and the receiver and the transmitted information travels through this channel.The original message signal usually contain frequencies in the low frequency or audio frequency range.Therefore some form of frequency band shifting is necessary in order to make the signals suitable for transmission.This is achieved by the process known as modulation.

Modulation can be defined as the process of combining a low frequency signal with a very high frequency carrier wave.Thus some characteristics of the carrier signal is varied in accordance with the amplitude of message signal. The message signal or the baseband signal is called the modulating signal.The resultant wave of the modulation process is known as the modulated wave.Modulation is performed at the transmitting end of the communication system.At the receiving end of the system,the original message signal is restored by a process known as demodulation.Need for modulation is as follows:

1) to reduce the antenna height
2) to multiplex the more number of signals
3) to reduce the noise & distortions
4) to narrow banding the signal
5) to reduce equipment complexity

Frequency Bands used for various communication systems



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 Microwave 2.4 GHz Wireless Data 2.4 GHz 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

Principle of AM

Amplitude modulation is the process of changing the amplitude of a relatively high frequency carrier signal in proportion with the instantaneous value of modulating signal (information).It is process of translating information signal from low band frequency to high band frequency. Amplitude of the carrier signal varies with the information signal. The modulated signal consist of carrier signal, upper sideband and lower sideband signals.

AM double-sideband full carrier (AM DSBFC) is the most commonly used and the oldest and simplest form of AM modulation. Sometimes called conventional AM or simply AM. The outline of the positive and negative peaks of the carrier frequency re-create the exact shape of the modulating signal known as envelope.Note that the repetition rate of the envelope is equal to the frequency of the modulating signal. Modulation index is used to describe the amount of amplitude change (modulation) present in an AM waveform.Percentage modulation (%m) is simply the modulation index (m) stated as a percentage.More specifically percent modulation gives the percentage change in the amplitude of the output wave when the carrier is acted on by a modulating signal.

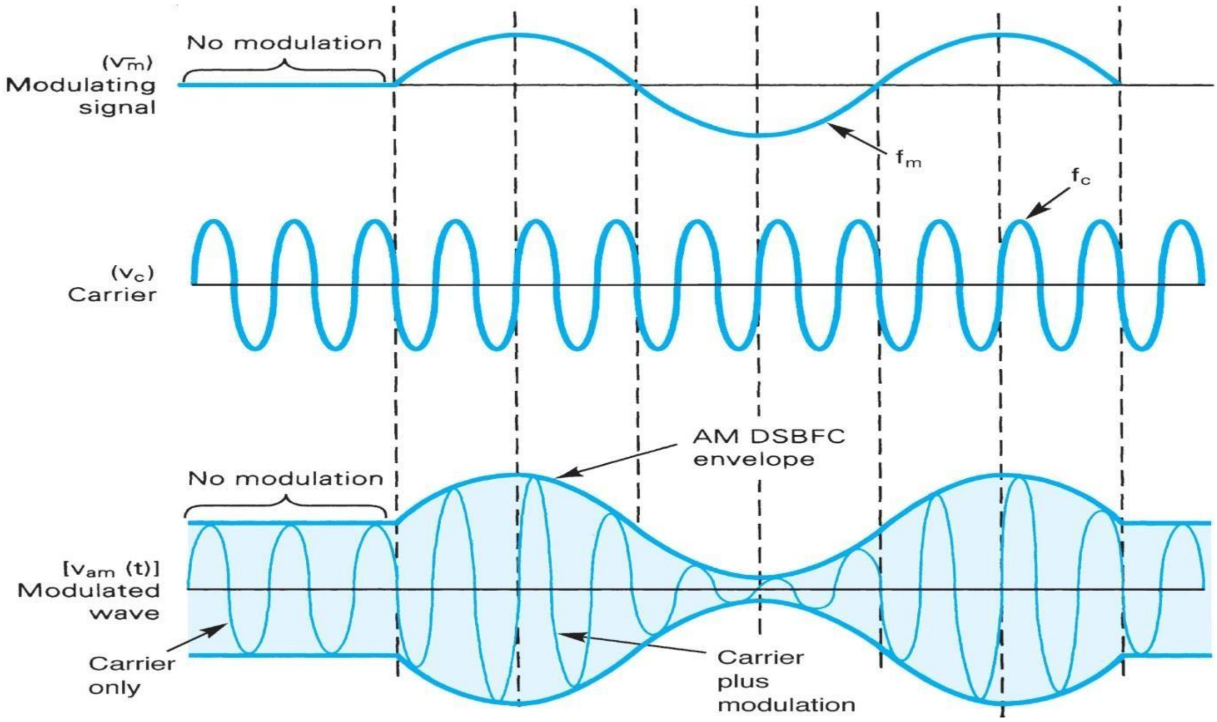


Fig: Generation of AM wave

A carrier is described by

$$v = V_c \text{ Sin } (\omega_c t + \theta)$$

To amplitude modulate the carrier its amplitude is changed in accordance with the level of the audio signal, which is described by

$$v = V_m \text{ Sin } (\omega_m t)$$

The amplitude of the carrier varies sinusoidally about a mean of V_c. When the carrier is modulated its amplitude is varied with the instantaneous value of the modulating signal. The amplitude of the variation of the carrier amplitude is V_m and the angular frequency of the rate at which the amplitude varies is ω_m. The amplitude of the carrier is then:

Carrier amplitude = $V_c + V_m \text{ Sin } (\omega_m t)$

and the instantaneous value (value at any instant in time) is

$$\begin{aligned} v &= \{V_c + V_m \text{ Sin } (\omega_m t)\} * \text{Sin } (\omega_c t) \\ &= V_c \text{ Sin } (\omega_c t) + V_m \text{ Sin } (\omega_m t) * \text{Sin } (\omega_c t) \end{aligned}$$

Using Sin A * Sin B = ½ Cos (A - B) - ½ Cos (A + B) this becomes

$$v = V_c \text{ Sin } (\omega_c t) + ½ V_m \text{ Cos } ((\omega_c - \omega_m) t) - ½ V_m \text{ Cos } ((\omega_c + \omega_m)t)$$

This is a signal made up of 3 signal components

- carrier at ω_c (rad/s) Frequency is $f_c = \omega_c/2\pi$ Hz
- upper side frequency $\omega_c + \omega_m$ (rad/s) Frequency is $(\omega_c + \omega_m)/2\pi = f_m + f_c$ Hz
- lower side frequency $\omega_c - \omega_m$(rad/s) Frequency is $(\omega_c - \omega_m)/2\pi = f_m - f_c$ Hz

Principle 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.As the amplitude of the information signal varies, the carrier frequency shifts proportionately.As the modulating signal amplitude increases, the carrier frequency increases.With no modulation the carrier is at its normal center or resting frequency. It is generally preferred over AM because it is less sensitive to noise, and it is in fact possible to trade bandwidth for noise performance. The advantages of FM come at the expense of increased complexity in the transmitter and in the receiver. This having been said, we will see a simple FM receiver is actually no more complicated (to build) than its AM counterpart.

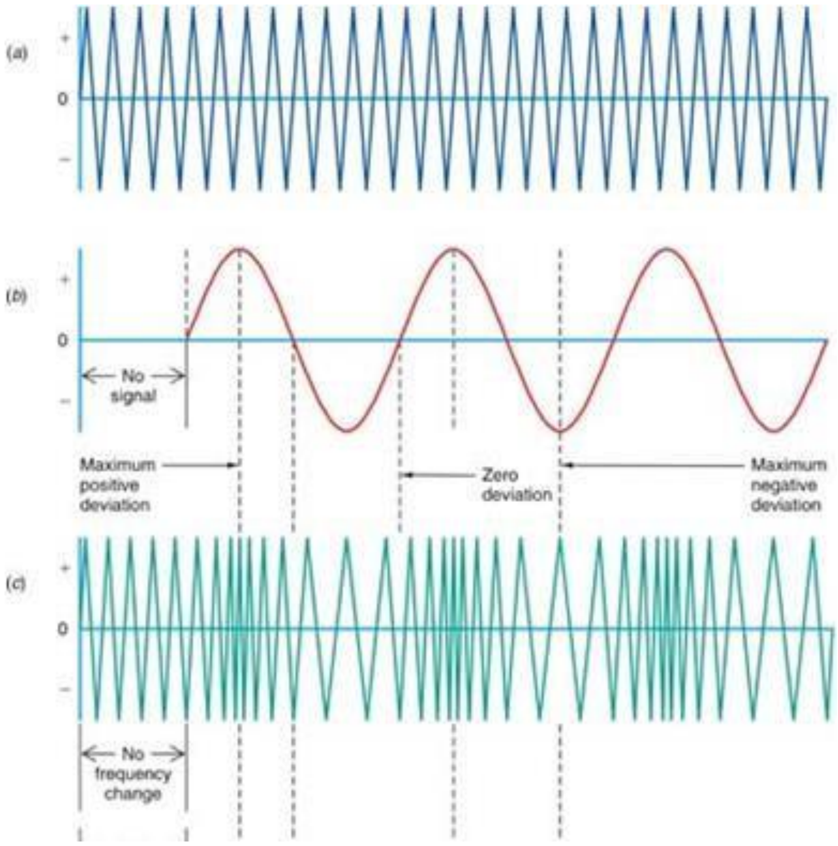


Fig: FM wave generation

If the information to be transmitted (i.e., the baseband signal) is $x_m(t)$ and the sinusoidal carrier is $x_c(t) = A_c \cos(2\pi f_c t)$, where f_c is the carrier's base frequency, and $A_c$is the carrier's amplitude, the modulator combines the carrier with the baseband data signal to get the transmitted signal:

$$y(t) = A_c \cos\left(2\pi \int_0^t f(\tau)d\tau\right)$$

$$= A_c \cos\left(2\pi \int_0^t \left[f_c + f_\Delta x_m(\tau)\right] d\tau\right)$$

$$= A_c \cos\left(2\pi f_c t + 2\pi f_\Delta \int_0^t x_m(\tau)d\tau\right)$$

In this equation, $f(\tau)$ is the instantaneous frequency of the oscillator and f_Δ is the frequency deviation, which represents the maximum shift away from f_c in one direction, assuming $x_m(t)$ is limited to the range ±1.

While most of the energy of the signal is contained within $f_c \pm f_\Delta$, it can be shown by Fourier analysis that a wider range of frequencies is required to precisely represent an FM signal. The frequency spectrum of an actual FM signal has components extending infinitely, although their amplitude decreases and higher-order components are often neglected in practical design problems.

Superheterodyne 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.

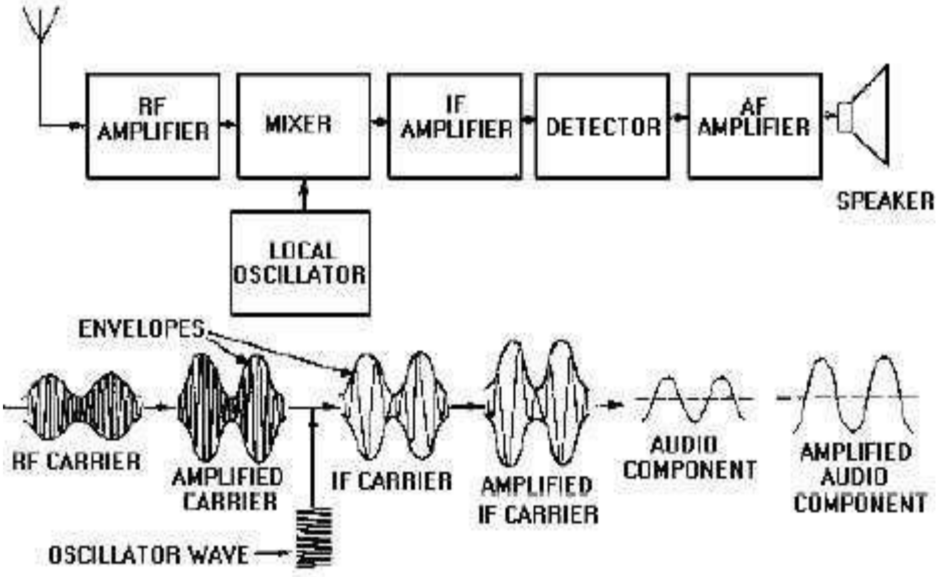


Fig: Block diagram of Superheterodyne Receiver

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.

SATELLITE COMMUNICATION

Satellite communication is the most recent and fastest growing communication method.A communication satellite is a special man made vehicle placed in orbit around the earth that carries receiverand transmitter equipmentcapable of transferring signals.It can receive the waves transmitted from the ground based stations called earth stations and retransmit the same back to other earth stations.Atransmission from an arth station to the satellite is referred to ad uplink while the transmission from the satellite to the earth station is called downlink.Basic elements in a satellite communication system is depicted in the figure below.

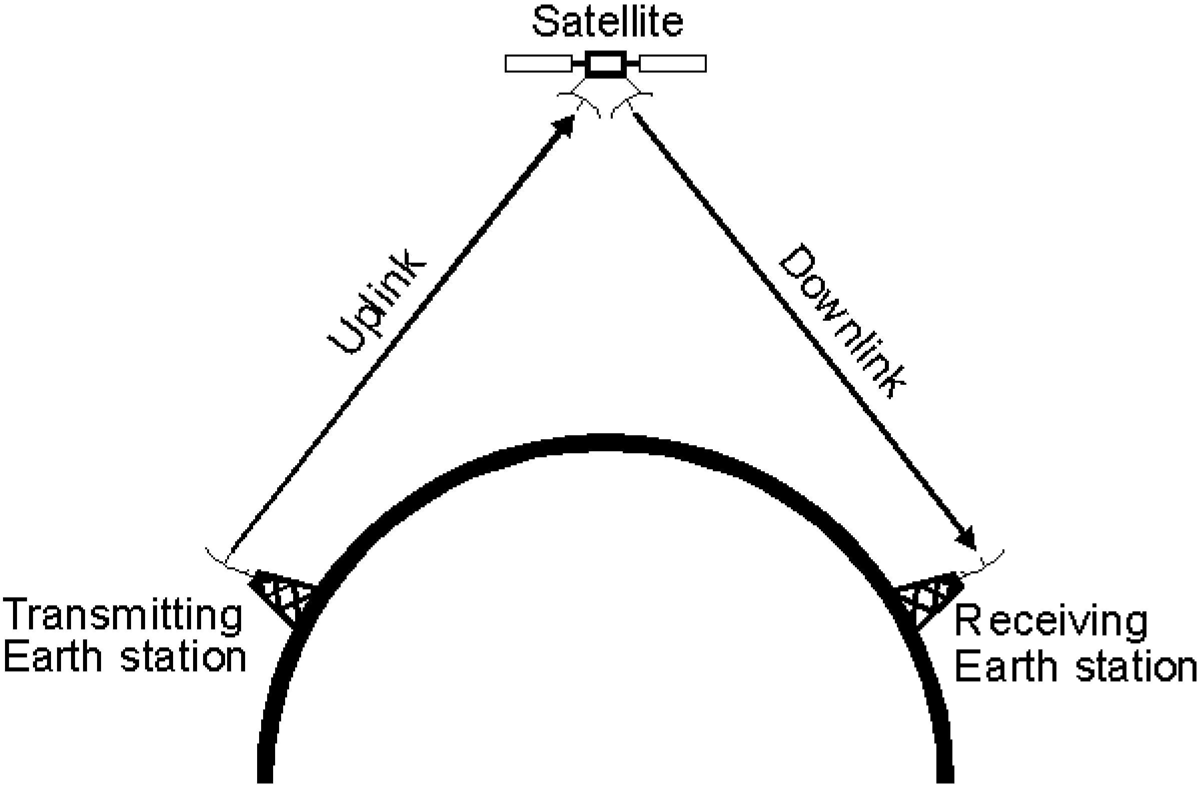


Fig: Satellite communication system

Satellites offer a number of features not readily available with other means of communications. Because very large areas of the earth are visible from a satellite, the satellite can form the star point of a communications net, simultaneously linking many users who may be widely separated geographically. The same feature enables satellites to provide communications links to remote communities in sparsely populated areas that are difficult to access by other means. Of course, satellite signals ignore political boundaries as well as geographic ones, which may or may not be a desirable feature.

Satellite Transponder

The electronic system that converts an uplink to a downlink is called a transponder.A transponder is a combination of receiver, amplifier and transmitter. Receiver in the transponder amplifies the uplink signal and converts it into another frequency downlink frequency.It is mainly used in satellite communication to transfer the received signals.

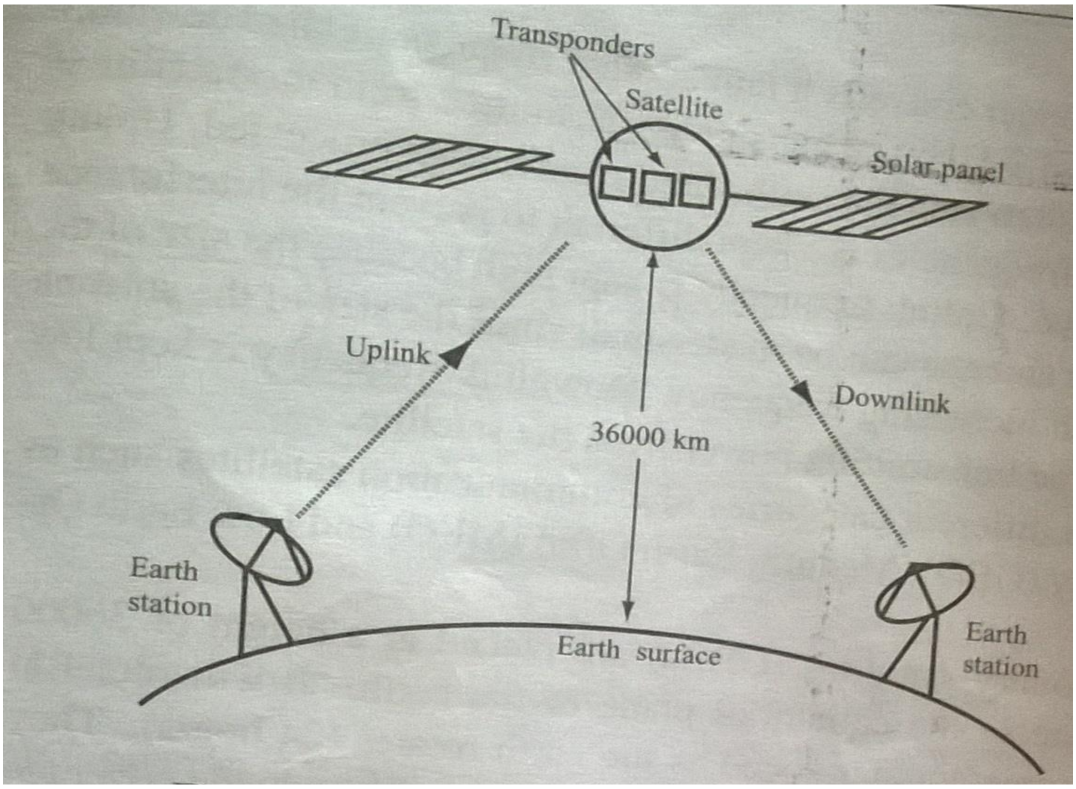


Fig: Block diagram for Transponder

Most transponders operate on abent pipe principle, sending back to earth of what goes into the conduit with only amplification and a shift from uplink to downlink frequency. However, some modern satellites use on-board processing, where the signal is demodulated, decoded, re-encoded and modulated aboard the satellite. This type, called a "regenerative" transponder, has many advantages, but is much more complex. With data compression and multiplexing, several video (including digital video) and audio channels may travel through a single transponder on a single wideband carrier.

Geo-stationery satellites

There are different categories of communication satellites such as Geo stationary(GEO),Medium earth orbit(MEO) and Lower earth orbit(LEO).Geo stationary satellites are placed at a height of 36000km and rotate in equatorial plane of the earth.

A geosynchronous satellite is a satellite in geosynchronous orbit, with an orbital period the same as the Earth's rotation period. Such a satellite returns to the same position in the sky after each sidereal day, and over the course of a day traces out a path in the sky that is typically some form of analemma. A special case of geosynchronous satellite is the geostationary satellite, which has a geostationary orbit – a circular geosynchronous orbit directly above the Earth's equator.Disc in the center of the Earth. The term "geosynchronous" refers to the satellite's orbital period being exactly one sidereal day which enables it to be synchronized with the rotation of the Earth ("geo"). Along with this orbital period requirement, to be geostationary as well, the satellite must be placed in an orbit that puts it in the vicinity over the equator. These two requirements make the satellite appear in an unchanging area of visibility when viewed from the Earth's surface, enabling continuous operation from one point on the ground. The special case of a geostationary orbit is the most common type of orbit for communications satellites.

If a geosynchronous satellite's orbit is not exactly aligned with the Earth's equator, the orbit is known as an inclined orbit. It will appear (when viewed by someone on the ground) to oscillate daily around a fixed point. As the angle between the orbit and the equator decreases, the magnitude of this oscillation becomes smaller; when the orbit lies entirely over the equator in a circular orbit, the satellite remains stationary relative to the Earth's surface – it is said to be geostationary.

Geostationary satellites appear to be fixed over one spot above the equator. Receiving and transmitting antennas on the earth do not need to track such a satellite. These antennas can be fixed in place and are much less expensive than tracking antennas. These satellites have revolutionized global communications, television broadcasting and weather forecasting, and have a number of importantdefense and intelligence applications.

Global Positioning System

The Global Positioning System (GPS) is a space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites.[1] The system provides critical capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver. The GPS concept is based on time. The satellites carry very stable atomic clocks that are synchronized to each other and to ground clocks. Any drift from true time maintained on the ground is corrected daily. Likewise, the satellite locations are monitored precisely. GPS receivers have clocks as well—however, they are not synchronized with true time, and are less stable. GPS satellites continuously transmit their current time and position. A GPS receiver monitors multiple satellites and solves equations to determine the exact position of the receiver and its deviation from true time. At a minimum, four satellites must be in view of the receiver for it to compute four unknown quantities (three position coordinates and clock deviation from satellite time).Each GPS satellite continually broadcasts a signal (carrier frequency with modulation) that includes:

- A pseudorandom code (sequence of ones and zeros) that is known to the receiver. By time-aligning a receiver-generated version and the receiver-measured version of the code, the time of arrival (TOA) of a defined point in the code sequence, called an epoch, can be found in the receiver clock time scale
- A message that includes the time of transmission (TOT) of the code epoch (in GPS system time scale) and the satellite position at that time.

The current GPS consists of three major segments. These are the space segment (SS), a control segment (CS), and a user segment (US).[53] The U.S. Air Force develops, maintains, and operates the space and control segments. GPS satellites broadcast signals from space, and each GPS receiver uses these signals to calculate its three-dimensional location (latitude, longitude, and altitude) and the current time.

1) Space Segment:

The space segment consists of 29 satellites circling the earth every 12 hours at 12,000 miles in altitude. This high altitude allows the signals to cover a greater area. The satellites are arranged in their orbits so a GPS receiver on earth can receive a signal from at least four satellites at any given time. Each satellite contains several atomic clocks. The satellites transmit low radio signals with a unique code on different frequencies, allowing the GPS receiver to identify the signals. The main purpose of these coded signals is to allow the GPS receiver to calculate travel time of the radio signal from the satellite to the receiver. The travel time multiplied by the speed of light equals the distance from the satellite to the GPS receiver.

2) Control Segment:

The control segment tracks the satellites and then provides them with corrected orbital and time information. The control segment consists of five unmanned monitor stations and one Master Control Station. The five unmanned stations monitor GPS satellite signals and then send that information to the Master Control Station where anomalies are corrected and sent back to the GPS satellites through ground antennas.

3) User Segment:

The user segment consists of the users and their GPS receivers. The number of simultaneous users is limitless.

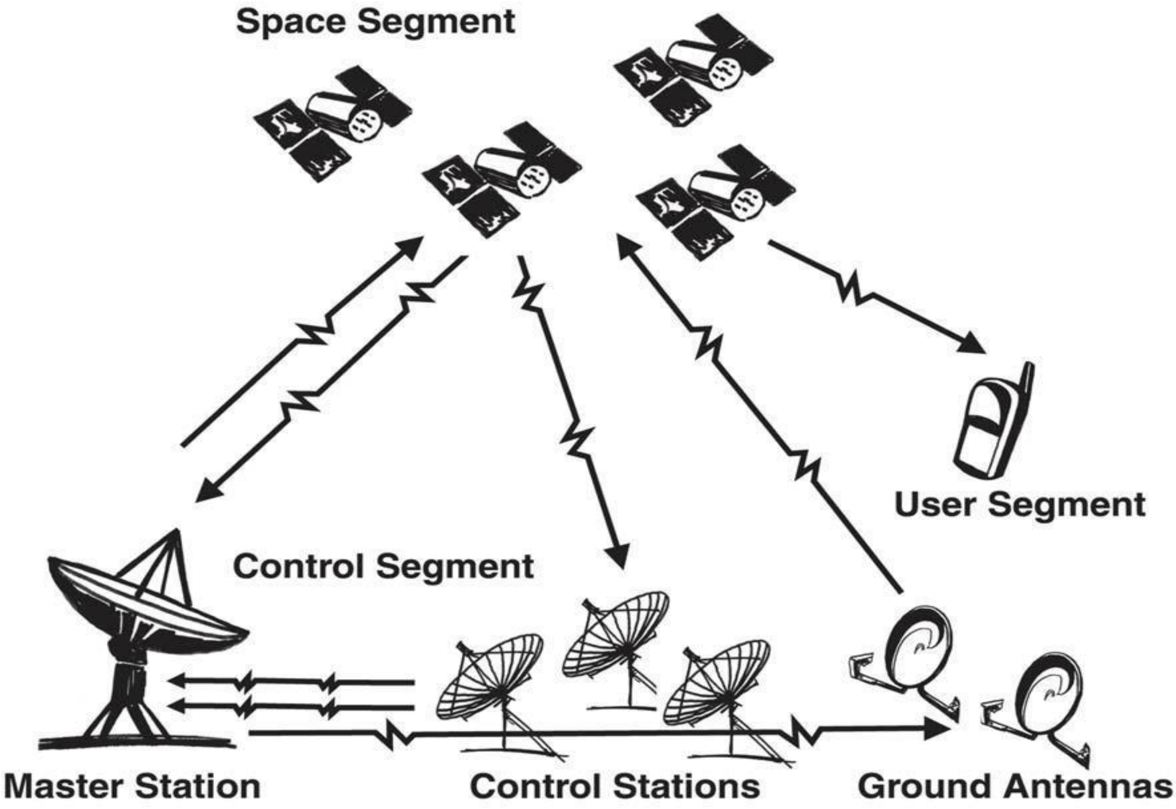


Fig: Three segments of GPS

RADAR SYSTEM

Radar is an acronym for Radio Detection and Ranging. It is an electronicsystem used to detect, locate or measure the velocity of targets.It collects information about distant objects or targets by sending electromagneticwaves to them and thereafter analyzing reflected waves orthe echo signals from the objects. Radar can detect static or mobileobjects in various conditions such as darkness, rain, fog and snow. Thefrequencies used by radar lies in the upper UHF and microwave range.The basic principle of radar can be explained with the help of theblock diagram as shown in the figure . It consists of a transmitter and areceiver, each connected to a directional antenna. The transmitter generateshigh power modulated signal and transmits through the antenna.The duplexer allows the use of a single antenna for transmission andreception and also separates transmitter and receiver from each other.During transmission, the duplexer disconnects the receiver and connectsthe transmitter to the antenna.

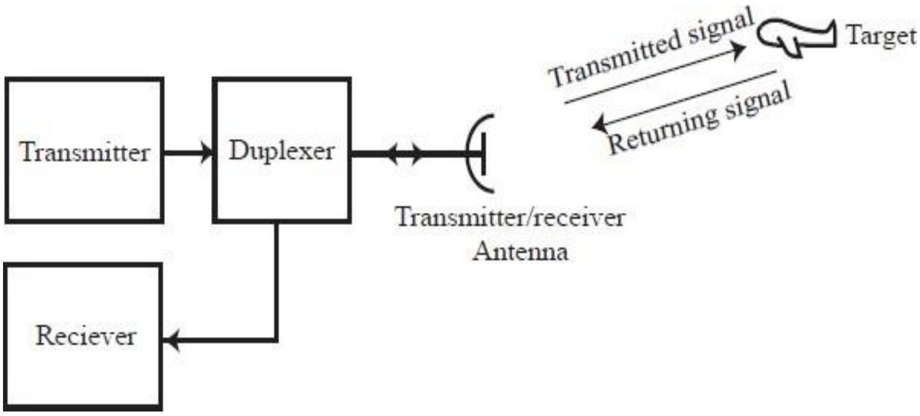


Fig: Basic block diagram for radar

The antenna radiates electromagnetic waves and these waves strike on a distant target which can reflect (echo) some of energy back to the same antenna. After transmission, the duplexer connects the antenna with the receiver and disconnects the transmitter. Then echo signals from the target are received by the receiver and processed to extract the required information. By noting the time taken for the signal to reach the target and echo signal to return back, the distance of the target canbe calculated. The direction of the received echo signal gives an ideaabout the angular position of the target. It is also possible to detect theheight, speed and direction of a moving target.

Pulsed Radar

The operation of a typical pulse radar may be described with the aid of the block diagram shown in the figure. The transtnitter may be an oscillator, such as a magnetron, that is " pulsed" (turned on and on) by the rnodulator to generate a repetitive train of pulses. The magnetron has probably been the most widely used of the various microwave generators for radar. A typical radar for the detection of aircraft at ranges of 100 or 200 nmi might employ a peak power of the order of a megawatt, an average power of several kilowatts, a pulse width of several microseconds, and a pulse repetition frequency of several hundred pulses per second. The waveform generated by the transmitter travels via a transmission line to the antenna, where it is radiated into space. A single antenna is generally used for both transmitting and receiving. The receiver must be protected from damage caused by the high power of the transmitter. This is the function of the duplexer. The duplexer also serves to channel the returned echo signals to the receiver and not to the transmitter. The duplexer might consist of two gas-discharge devices, one known as a TR (transmit-receive) and the other an ATR (anti-transmit-receive). The TR protects the receiver during transmission and the ATR directs the echo signal to the receiver during reception. Solid-state ferrite circulators and receiver protectors with gas-plasma TR devices and/or diode limiters are also employed as duplexers. The receiver is usually of the superheterodyne type.

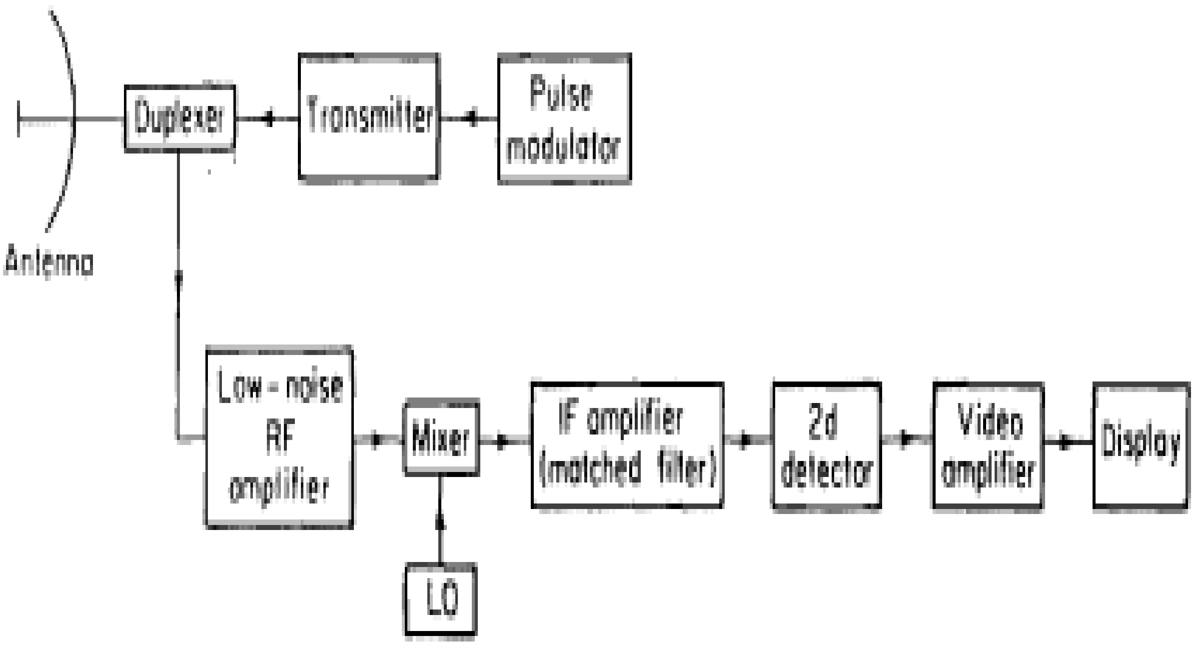


Fig: Block diagram of Pulsed Radar

The first stage might be a low-noise RF amplifier, such as a parametric amplifier or a low-noise transistor. However, it is not always desirable to employ a low-noise first stage in radar. The receiver input can simply be the mixer stage, especially in military radars that must operate in a noisy environment. Although a receiver with a low-noise front-end will be more sensitive, the mixer input can have greater dynamic range, less susceptibility to overload, and less vulnerability to electronic interference.

The mixer and local oscillator (LO) convert the RF signal to an intermediate frequency **(IF).**A typical" IF amplifier for an air-surveillance radar might have a center frequency of 30 or 60 MHz and a bandwidth of the order of one megahertz. In a radar whose signal waveform approximates a rectangular pulse, the conventional IF filter bandpass characteristic approximates a matched filter when the product of the IF bandwidth B and the pulse width is of the order of unity. After maximizing the signal-to-noise ratio in the IF amplifier, the pulse modulation is extracted by the second detector and amplified by the video amplifier to a level where it can be properly displayed, usually on a cathode-ray tube (CRT). Timing signals are also supplied to the indicator to provide the range zero. Angle information is obtained from the pointing direction of the antenna. A common form of radar antenna is a reflector with a parabolic shape, fed (illuminated) from a point source at its focus. The parabolic reflector focuses the energy into a narrow beam, just as does a searchlight or an automobile headlamp. The beam may be scanned in space by mechanical pointing of the antenna. Phased-array antennas have also been used for radar. In a phased array.the beam is scanned by electronically varying the phase of the currents across the aperture.

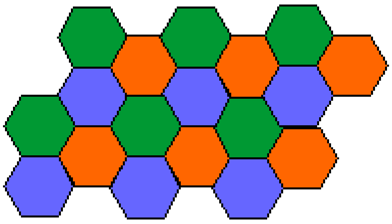
MODULE 6

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.

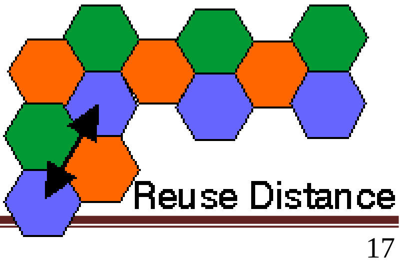


Real-World Cells

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

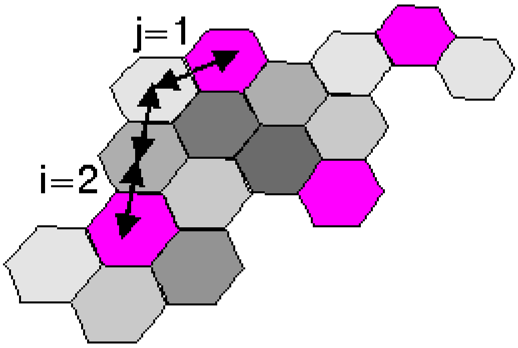
Reuse Distance

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 = 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.

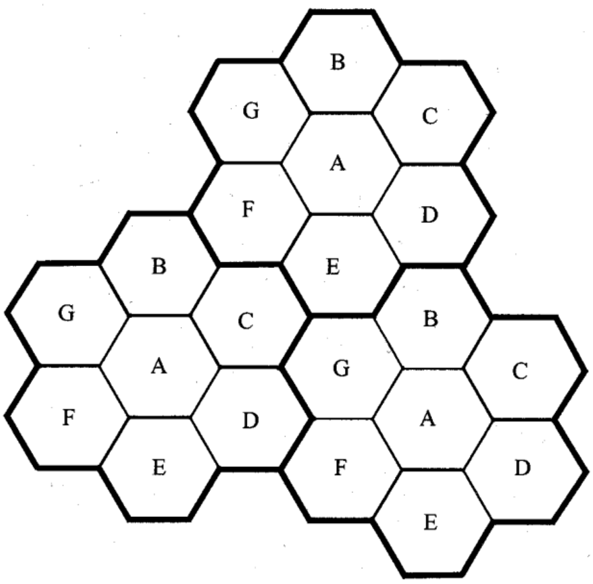


Cells

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.



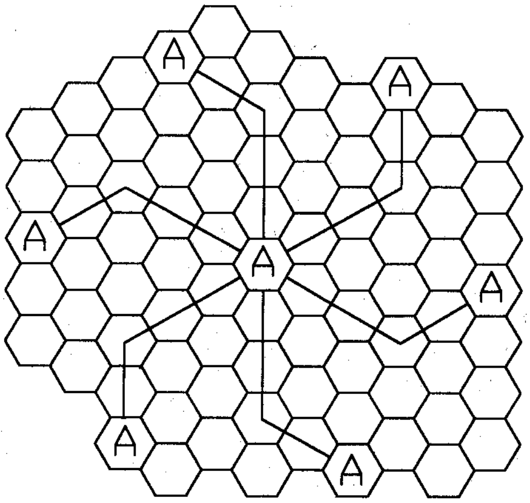
- seven groups of channel from A to G
- footprint of a cell - actual radio coverage
- omni-directional antenna v.s. directional antenna

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*.



Channel Assignment Strategies

- Frequency reuse scheme
  - increases capacity
  - minimize interference
- Channel assignment strategy
  - fixed channel assignment
  - dynamic channel assignment
- Fixed channel assignment
  - each cell is allocated a predetermined set of voice channel
  - any new call attempt can only be served by the unused channels
  - the call will be *blocked* if all channels in that cell are occupied
- Dynamic channel assignment

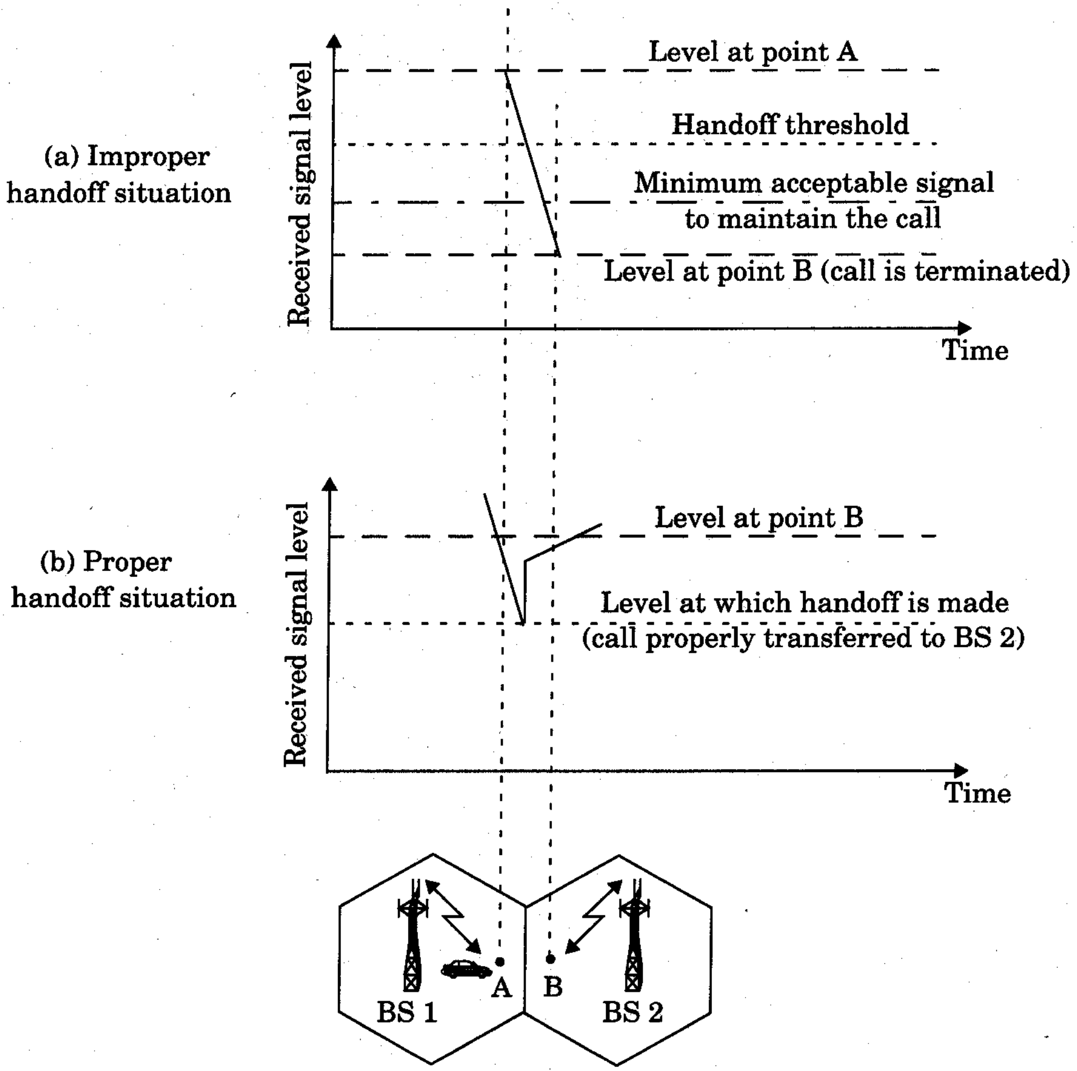
  - channels are not allocated to cells permanently.
  - allocate channels based on request.
  - reduce the likelihood of blocking, increase capacity.

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.

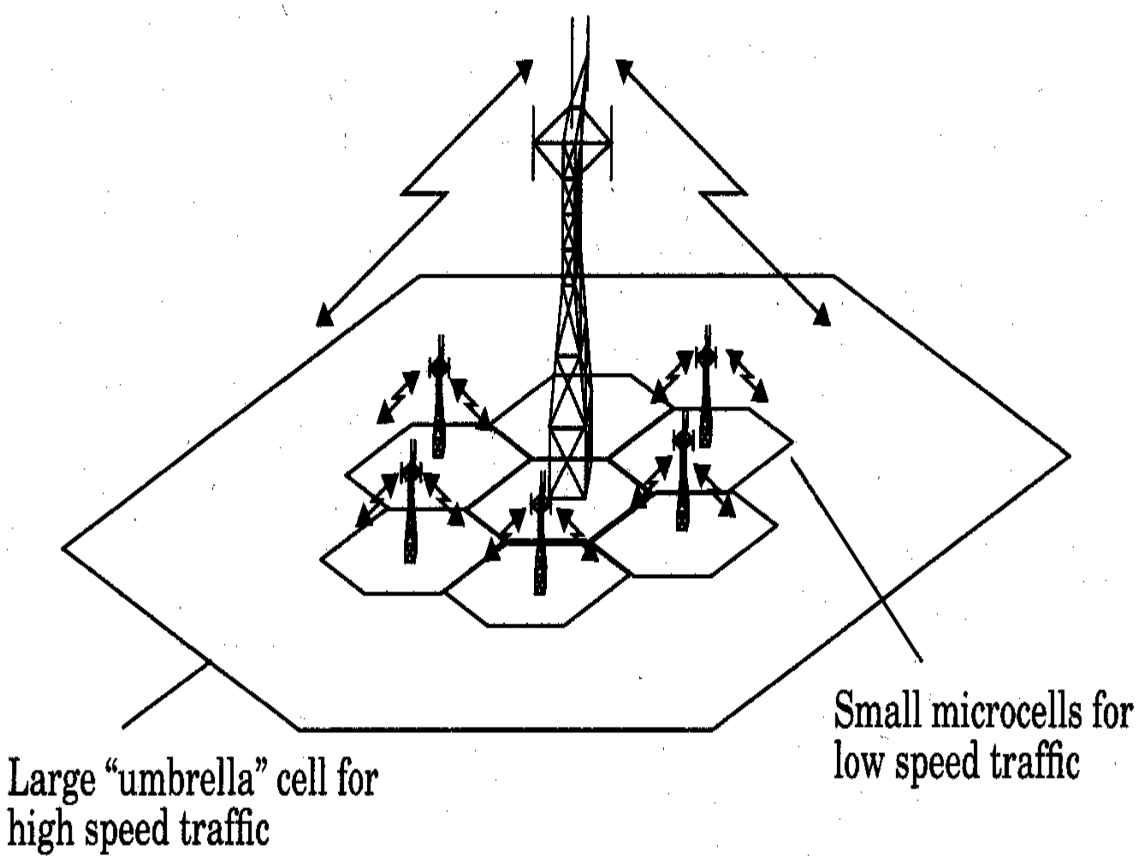


- Handoff must ensure that the drop in the measured signal is not due to momentary fading and that the mobile is actually moving away from the serving base station.
- Running average measurement of signal strength should be optimized so that unnecessary handoffs are avoided.
  - Depends on the speed 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.

Practical Handoff Consideration

- Different type of users
  - High speed users need frequent handoff during a call.
  - Low speed users may never need a handoff during a call.
- Microcells to provide capacity, the MSC can become burdened if high speed users are constantly being passed between very small cells.
- Minimize handoff intervention
  - handle the simultaneous traffic of high speed and low speed users.
- Large and small cells can be located at a single location (umbrella cell)
  - different antenna height
  - different power level
- Cell dragging problem: pedestrian users provide a very strong signal to the base station
  - The user may travel deep within a neighboring cell



Cellular System Components

The cellular system offers mobile and portable telephone stations the same service provided fixed stations over conventional wired loops. It has the capacity to serve tens of thousands of subscribers in a major metropolitan area. The cellular communications system consists of the following four major components that work together to provide mobile service to subscribers (see Figure 8):

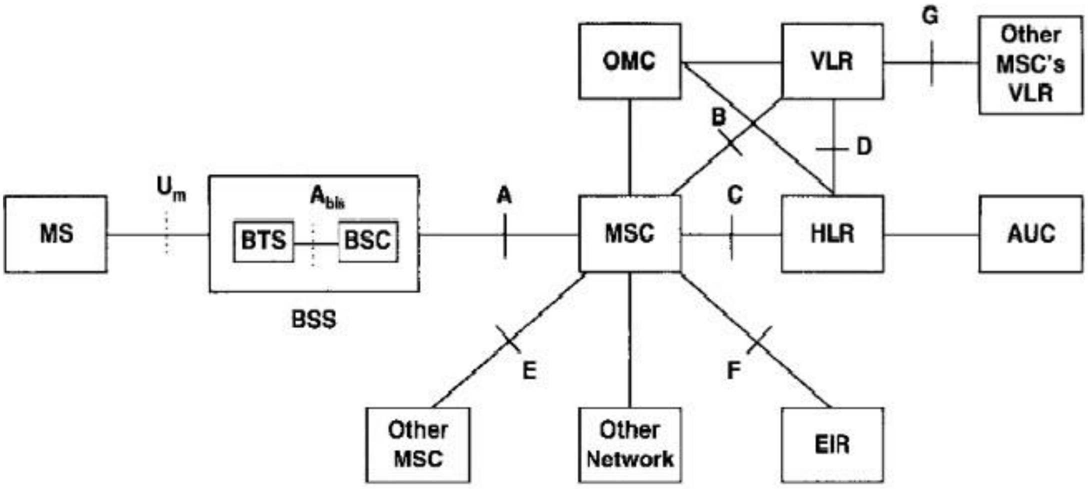
1.public switched telephone network (PSTN)

2.mobile telephone switching office (MTSO)

3.cell site with antenna system

4.mobile subscriber unit (MSU)

Block diagram of GSM

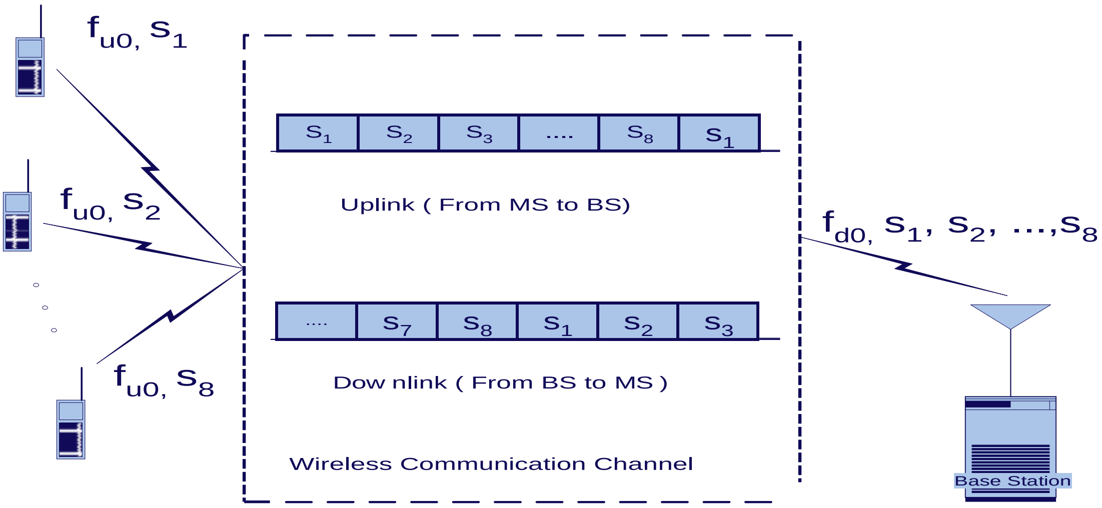


- **MS:** Mobile Station
- **BSS:** Base Station Subsystem
- **BTS:** Base Transceiver Station
- **BSC:** Base Station Controller
- **MSC:** Mobile Service Switching Center
- **OMC:** Operations and Maintenance Center
- **HLR:** Home Location Register
- **VLR:** Visitor Location Register

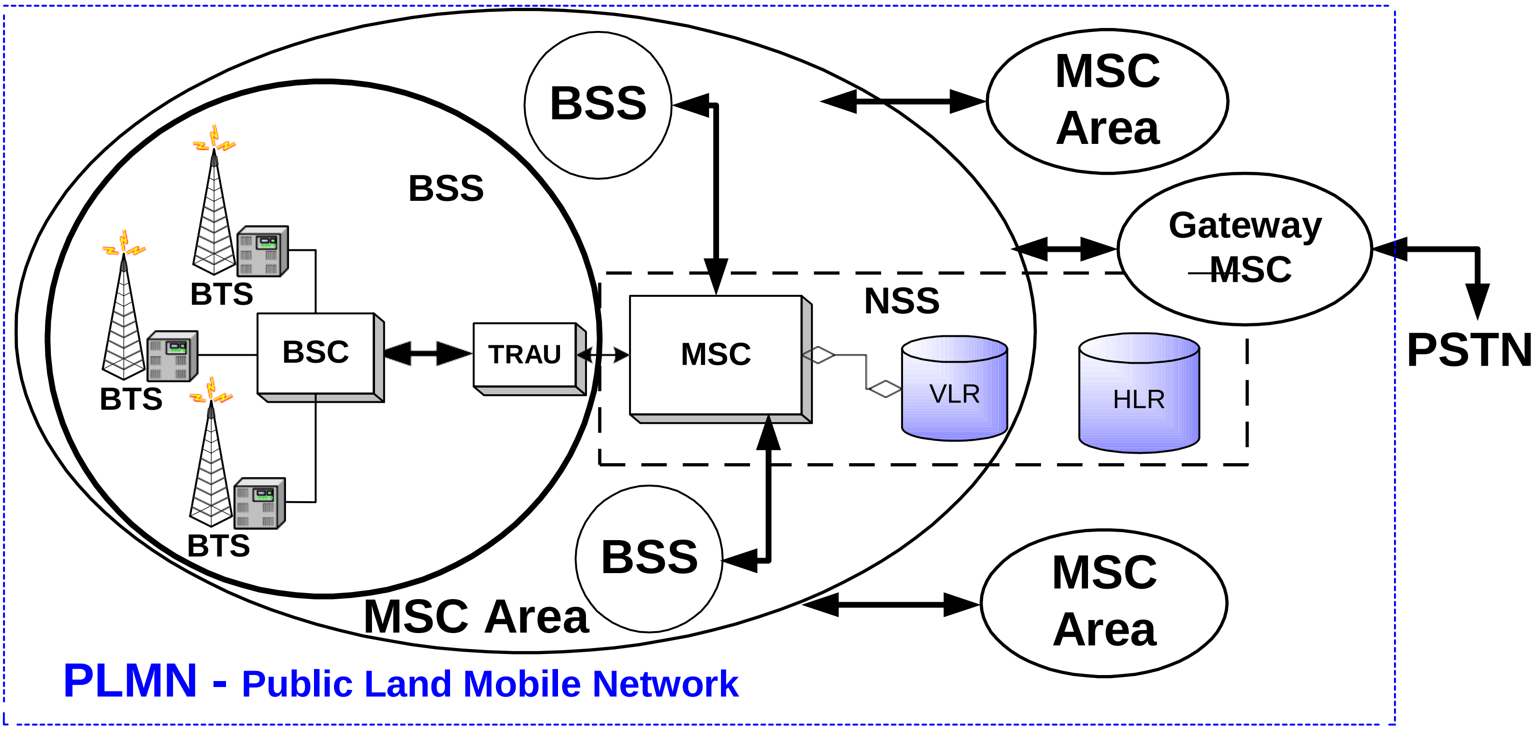
- GSM system layout is standardized
    - Standardization involves:
        - Elements of the network
        - Communication Interfaces
    - Standard layout allows for the use of equipment from different suppliers
    - Two functional parts
    - HW and SW specific for GSM radio interface
    - Subscriber 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



OPTICAL COMMUNICATION

A communication system transmits information from one place to another, whether separated by a few kilometers or by transoceanic distances. Information is often carried by an electromagnetic carrier wave whose frequency can vary from a few megahertz to several hundred terahertz. Optical communication systems use high carrier frequencies (~100 THz) in the visible or near-infrared region of the electromagnetic spectrum. They are sometimes called lightwave systems to distinguish them from microwave systems, whose carrier frequency is typically smaller by five orders of magnitude (~1 GHz). Fiber-optic communication systems are lightwave systems that employ optical fibers for information transmission. Such systems have been deployed worldwide since 1980 and have indeed revolutionized the technology behind telecommunications. Indeed, the lightwave technology, together with microelectronics, is believed to be a major factor in the advent of the ‒information age.‖

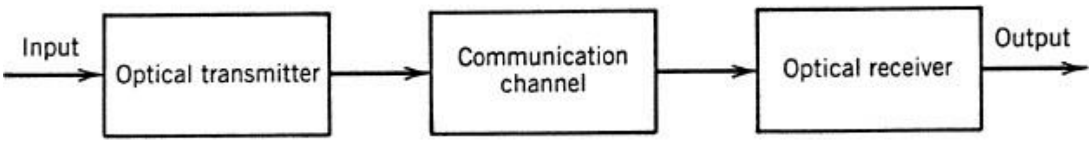


Fig: General block diagram of Optical communication system

Figure shows a generic block diagram of an optical communication system. It consists of a transmitter, a communication channel, and a receiver, the three elements common to all communication systems. Optical communication systems can be classified into two broad categories: guided and unguided. As the name implies, in the case of guided lightwave systems, the optical beam emitted by the transmitter remains spatially confined. Since all guided optical communication systems currently use optical fibers, the commonly used term for them is fiber-optic communication systems. The term lightwave system is also sometimes used for fiber-optic communication systems, although it should generally include both guided and unguided systems. In the case of unguided optical communication systems, the optical beam emitted by the transmitter spreads in space, similar to the spreading of microwaves. However, unguided optical systems are less suitable for broadcasting applications than microwave systems because optical beams spread mainly in the forward direction (as a result of their short wavelength).

Propagation of light through Fibres

Light energy can be modelled in three different forms which relate the particular model of light to the context in which it is talked about. Light can be characterized in any one of the following models:

1)Ray Model

2)Wave Model

3)Quantum Model

In the simplest possible context, light is treated as a ray and the different phenomena exhibited by light are explained in terms of the ray-model of light. Constructionally, an optical fiber is a solid cylindrical glass rod called the core, through which light in the form of optical signals propagates. This rod is surrounded by another coaxial cylindrical shell made of glass of lower refractive index called the cladding. This basic arrangement that guides light over long distances is shown in the figure.

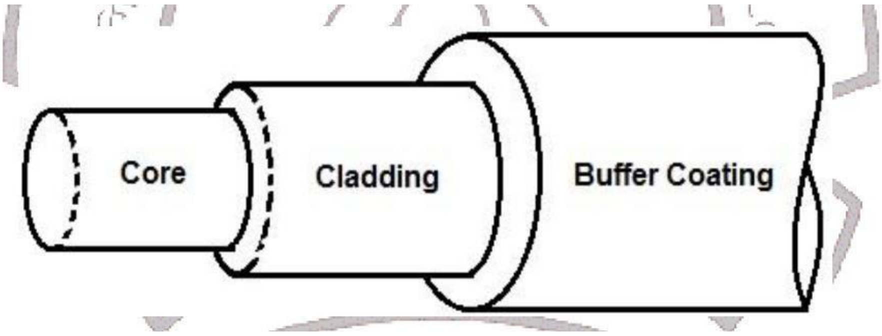


Fig: constructional details of an optical fibre

The diameter of the cladding is of the order of 125 µm and the diameter of the core is even smaller than that. Thus it is a very fine and brittle glass rod that we are dealing with. In order to provide mechanical strength to this core-cladding arrangement, other coaxial surrounding called the buffer coating and jacketing layers are provided. They do not play any role in the propagation of light through the optical fiber, but are present solely for providing mechanical strength and support to the fiber. The light energy in the form of optical signals propagates inside the corecladding arrangement and throughout the length of the fiber by a phenomenon called the Total Internal Reflection (TIR) of light. This phenomenon occurs only when the refractive index of core is greater than the refractive index of cladding and so the cladding is made from glass of lower refractive index. By multiple total internal reflections at the corecladding interface the light propagates throughout the fiber over very long distances with low attenuation. We shall now discuss the essential requirements of the propagation of light through an optical fiber, over long distances with minimum loss, in detail.

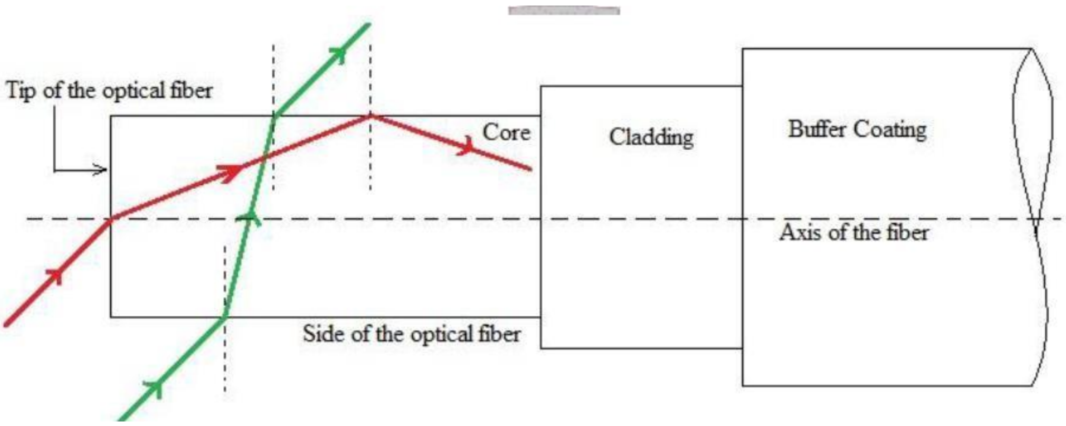


Fig: Launching of light into a fibre

Figure above shows a section of the core of an optical fibre. If a ray of light is incident on the core of an optical fibre from the side, the ray of light simply refracts out from the fibre on the other side. The ray shown in figure demonstrates the situation. No matter what the angle of incidence of the light is, any light that enters the fiber from the side does not propagate along the fiber. The only option thus available with us is to launch the light through the tip of the fiber. That is, in order to guide light along the fiber, the light must be incident from the tip of the optical fiber. The second ray of light in figure explains this situation. In other words, if the tip of the optical fiber is not exposed to light, no light will enter the fiber. Although there may be ambient light, as long as the tip is protected, no light from the sides propagates along the fiber. Equivalently, if there was propagation of light through the fiber, no light would emerge from the sides of the fiber. This characteristic of the optical fiber imparts the advantage of information security to the Optical Fiber Communication Technology.

We have already stated that for explaining propagation of light in an optical fiber, the Ray-Model of light shall be used. The Ray-Model of light obeys the Snell‘s laws. Following figure depicts a situation of a typical refraction phenomenon taking place at the interface of two optically different media having refractive indices n1 and n2. The angles measured in the expression for Snell‘s law are measured with respect to the normal to the media interface at the point of incidence. If n2 > n1 , then the angle of refraction is greater than the angle of incidence and the refracted ray is said to have moved away from the normal. If the angle of incidence (θ1) is increased further, the angle of refraction (θ2) also increases in accordance with the Snell‘s law and at a particular angle of incidence the angle of refraction becomes 90o and the refracted ray grazes along the media interface. This angle of incidence is called the critical angle of incidence (θc) of medium 2 with respect to medium 1.

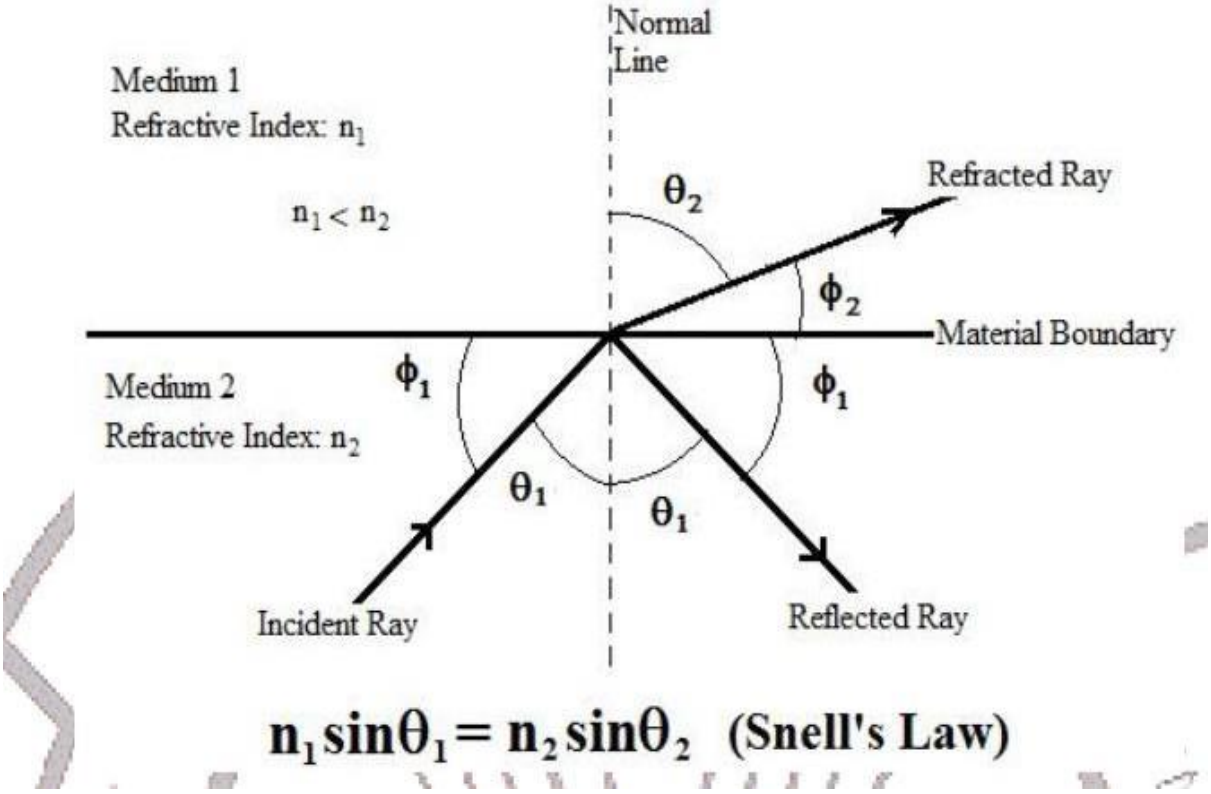


Fig: Refraction of light

Note that here critical angle is media-relative. That means, the same optically denser medium may have different critical angles with respect to different optically rarer media. If θ1 is increased beyond the critical angle, there exists no refracted ray and the incident light ray is then reflected back into the same medium. This phenomenon is called the total internal reflection of light. The word _total‘ signifies that the entire light energy that was incident on the media interface is reflected back into the same medium. Total Internal Reflection (TIR) obeys the laws of reflection of light. This phenomenon shows that light energy can be made to remain confined in the same medium when the angle of incidence is greater than the angle of reflection. Thus we can see that there are two basic requirements for a TIR to occur: 1. The medium from which light is incident, must be optically denser than the medium to which it is incident. In figure n2 > n1. 2. The angle of incidence in the denser medium must be greater than the critical angle of the denser medium with respect to the rarer medium.

Advantages of Optical Communication

Fiber-optic systems have a large number of advantages over copper wire cables. Among the most important are the following:

- Because fiber-optic cables are both lighter and smaller in diameter than copper lines, they can be more easily produced and installed.
- Fiber-optic systems use significantly less energy than copper lines and are thus immune to many dangers associated with the electrical current used in copper lines.
- Fiber-optic communication systems can be used to transmit more information than copper cables and are well-suited for use with digital communications.
- When compared to copper cables, fiber-optic cables are both immune to electromagnetic interference and produce no interference when operating.
- Finally, fiber-optic lines are less expensive than copper cables, which can drastically reduce the cost of installing new lines or maintaining older ones.

ENTERTAINMENT AND SECURITY ELECTRONICS TECHNOLOGY

Cable TV Principles

Cable television brings us more channels and generally better reception than off-air reception of broadcast television since TV signals travel to your home through a combination of fiber optics and cable - rather than through the air.

Cable television brings television stations from your local area, across the country and around the world into your home through miles of high-technology fiber optics and cable, uninterrupted by trees, buildings and other surface obstacles.

Cable television lets us receive many additional channels from communications satellites.

1. Individual television programs are produced in many locations around the world.
2. These programs are transmitted to communications satellites that orbit the earth. These satellites stay in a fixed position 22,300 miles above the earth, allowing them to transmit to your community.
3. Our local receiving dishes pick up these signals.
4. The cable television "head-end" - the control center - processes these satellite signals - along with the signals from your local TV stations and other sources - so they can be transmitted over our cable system (consisting of state of the art fiberoptics and coaxial cable) to your home.
5. These quality television programs are brought to your home via hundreds of miles fiber optics and cable, either strung on the same poles that carry your telephone or electric service or buried underground

CC TV

As the name implies, Closed Circuit Television (CCTV) is a system in which the circuit is closed and all the elements are directly connected. This is unlike broadcast television where any receiver that is correctly tuned can pick up the signal from the airwaves. Directly connected in this context includes systems linked by microwave, infrared beams, etc. This article introduces the main components that can go to make up CCTV systems of varying complexity.

The applications of CCTV

Probably the most widely known use of CCTV is in security systems and such applications as retail shops, banks, government establishments, etc. The true scope for applications is almost unlimited. Some examples are listed below.

- Monitoring traffic on a bridge.
- Recording the inside of a baking oven to find the cause of problems.
- A temporary system to carry out a traffic survey in a town centre.
- Time lapse recording for the animation of plasticine puppets.
- Used by the stage manager of a show to see obscured parts of a set.
- The well-publicised use at football stadiums.
- Hidden in buses to control vandalism.
- Recording the birth of a gorilla at a zoo.
- Making a wildlife program using a large model helicopter.
- Reproducing the infrared vision of a goldfish!
- Aerial photography from a hot air balloon.
- Production control in a factory.

DTH or Direct –To- Home System

As the name indicates, DTH services enable the delivery of video, and other content, directly to a user‘s home via a satellite link. A simplified example of a DTH system architecture is shown in Figure below. The basic function of the DTH headend is to aggregate content into a format suitable for broadcasting directly to the homes of customers who have signed up and are authorized to receive the service. The source content, as available to the DTH headend, may not be in format suitable for reception at the home. The source content may arrive from multiple sources, such as downlinks from existing satellite feeds, terrestrial links, local broadcasters, or be locally stored at the headend for play-out. The required content conditioning varies, based on the format of the respective sources.

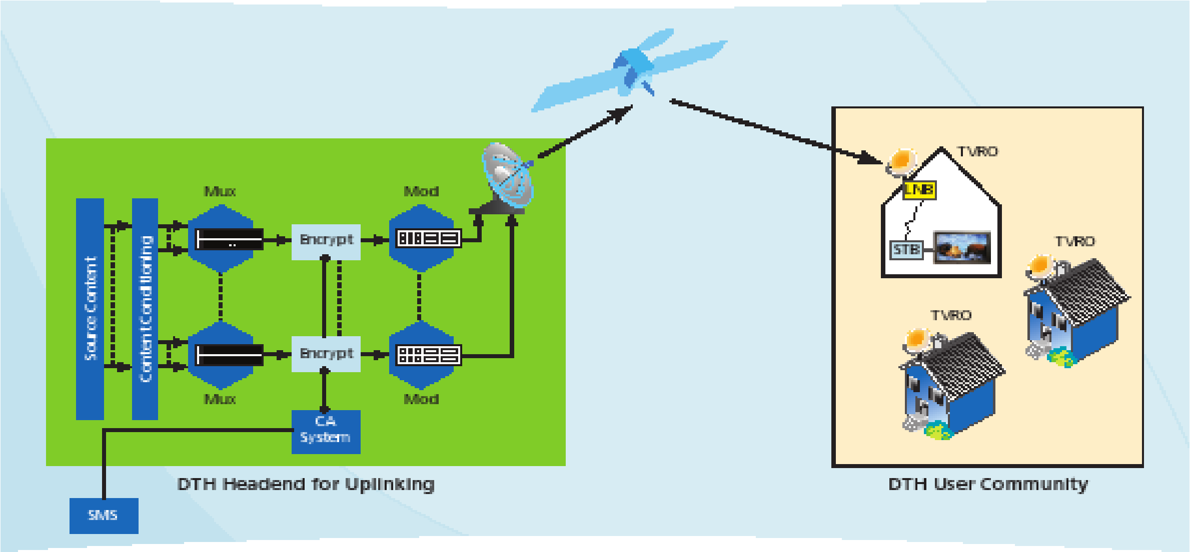


Fig: Overview of DTH system

In most cases the content is available in an encoded (compressed) format, such as MPEG2 at certain data rate. If a format other than MPEG2 is required, such as MPEG4, the video needs to be transcoded (decoded and re-encoded). If the format is correct, but the data rate is too high, transrating (rate reduction) equipment is required. If the video is in an uncompressed format, Once in the correct format, the content is aggregated using multiplexers. There is one multiplexer corresponding to each satellite transponder. The content is aggregated to a data rate fully utilizing the transponder bandwidth and power. Content is encrypted (scrambled) to preclude unauthorized viewing. For a given DTH service provider, the user community is managed with a SMS (subscriber management system), which interacts with the encryption system via a conditional access (CA) system. The content is then modulated and transmitted from the DTH headend to the satellite for downlinking to customers. To view the content, a customer requires a TVRO (Television Receive Only) antenna, a LNB (low noise block downconverter), and an authorized STB (set top box). The STB outputs the video in a format compatible for TVs and/or monitors.MPEG2 or MPEG4 encoders are required.

<u>LED TV</u>

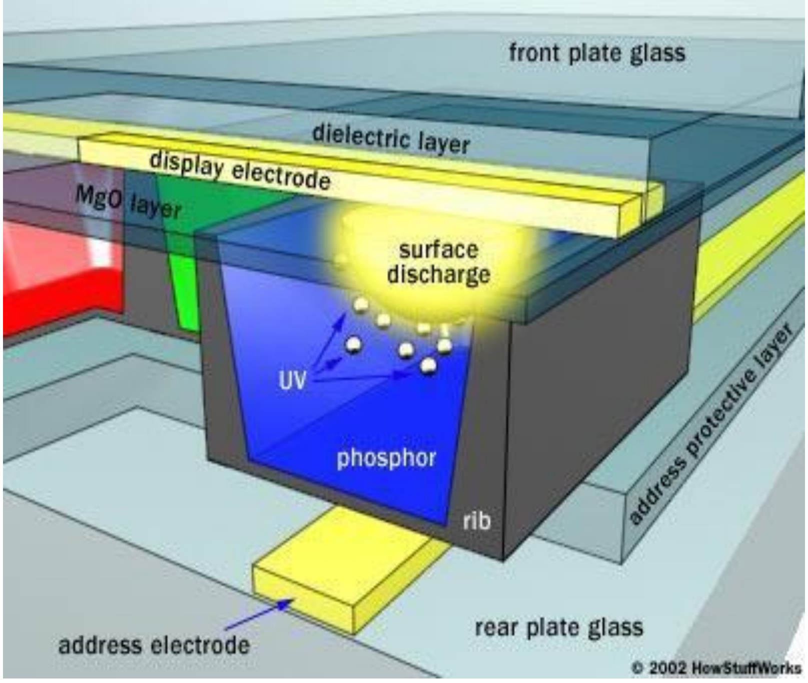
The LED has become a pivotal illumination technology with a wide variety of applications. Since their initial invention, LEDs have been used in many diverse applications such as TV,watches, calculators, remote controls, indicator lights, and backlights for many common gadgets and household devices. The technology is advancing at a rapid pace and new applications continue to emerge as the brightness and efficiency of LEDs increase.

As the name implies, an LED is a diode that emits light. The diode is the most basic semiconductor whose purpose is to conduct electrical current with some form of controlled variability. The diode in its simplest form is comprised of poor conducting materials that have been modified (or ―doped‖) to increase the amount of free electrons that are available. High electron materials (referred to as N-type materials) are combined with low electron materials (referred to as P-type materials) to form a junction for these free electrons to flow. This junction is often referred to as the PN junction. An LED is a PN junction diode semiconductor that emits photons when voltage is applied. This process of photon emission is called injection electroluminescence and occurs when electrons move from the N-type material to fill the lower energy holes that exist in the P-type material. When the high energy electrons fall into these holes, they lose some of their energy which results in the generation of photons. The materials used for the P-type and N-type layers along with the size of the gap between them determine the wavelength and overall energy level of the light that is produced. Many materials have been developed for manufacturing LEDs. AluminumGallium-Arsenide (AlGaAs), Aluminum-Indium-Gallium-Phosphide (AlInGaP), and Indium-Gallium-Nitride (InGaN) are commonly used for present LED architectures. ―AlInGaP‖ is typically used for Red and Yellow dies while ―InGaN‖ is used for Blue and Green. These materials efficiently produce photons that have wavelengths in the visible spectrum. These materials in combination with new manufacturing architectures have enabled the production of very bright LEDs that are beginning to find their way into general lighting and automotive applications. Some architectures have begun utilizing additional phosphor compounds to generate white light and are now beginning to compete with common incandescent and fluorescent lighting - with much lower power and much longer lifetimes.

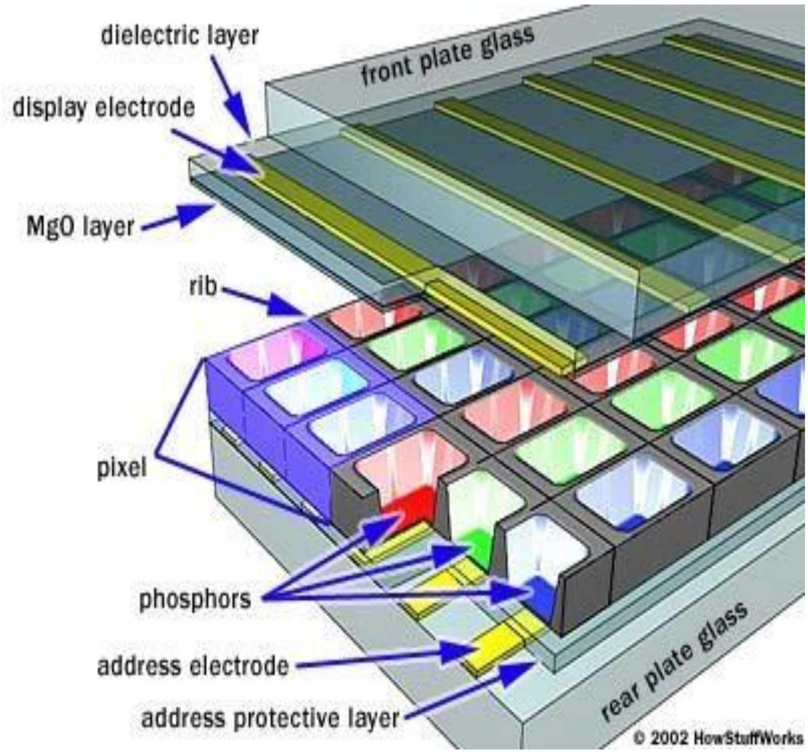
Plasma TV

The basic idea of a plasma display is to illuminate tiny, coloredfluorescent lights to form an image. Each pixel is made up of three fluorescent lights -- a red light, a green light and a blue light. Just like a CRT television, the plasma display varies the intensities of the different lights to produce a full range of colors.

The central element in a fluorescent light is a **plasma**, a gas made up of free-flowing **ions**(electrically charged atoms) and **electrons** (negatively charged particles). Under normal conditions, a gas is mainly made up of uncharged particles. That is, the individual gas atoms include equal numbers of protons (positively charged particles in the atom's nucleus) and electrons. The negatively charged electrons perfectly balance the positively charged protons, so the atom has a net charge of zero. If you introduce many free electrons into the gas by establishing an electrical voltage across it, the situation changes very quickly. The free electrons collide with the atoms, knocking loose other electrons. With a missing electron, an atom loses its balance. It has a net positive charge, making it an ion.



In a plasma with an electrical current running through it, negatively charged particles are rushing toward the positively charged area of the plasma, and positively charged particles are rushing toward the negatively charged area. In this mad rush, particles are constantly bumping into each other. These collisions excite the gas atoms in the plasma, causing them to release **photons** of energy. Xenon and neon atoms, the atoms used in plasma screens, release **light photons** when they are excited. Mostly, these atoms release **ultraviolet** light photons, which are invisible to the human eye. But ultraviolet photons can be used to excite visible light photons. The xenon and neon gas in a plasma television is contained in hundreds of thousands of tiny **cells** positioned between two plates of glass. Long electrodes are also sandwiched between the glass plates, on both sides of the cells. The **address electrodes** sit behind the cells, along the rear glass plate. The transparent **display electrodes**, which are surrounded by an insulating **dielectric material** and covered by a **magnesium oxide protective layer**, are mounted above the cell, along the front glass plate.



Both sets of electrodes extend across the entire screen. The display electrodes are arranged in horizontal rows along the screen and the address electrodes are arranged in vertical columns. As you can see in the diagram below, the vertical and horizontal electrodes form a basic grid. To ionize the gas in a particular cell, the plasma display's computer charges the electrodes that intersect at that cell. It does this thousands of times in a small fraction of a second, charging each cell in turn. When the intersecting electrodes are charged (with a voltagedifference between them), an electric current flows through the gas in the cell. As we saw in the last section, the current creates a rapid flow of charged particles, which stimulates the gas atoms to release ultraviolet photons. The released ultraviolet photons interact with phosphor material coated on the inside wall of the cell. Phosphors are substances that give off light when they are exposed to other light. When an ultraviolet photon hits a phosphor atom in the cell, one of the phosphor's electrons jumps to a higher energy level and the atom heats up. When the electron falls back to its normal level, it releases energy in the form of a **visible light photon**. The phosphors in a plasma display give off colored light when they are excited. Every **pixel** is made up of three separate **subpixel** cells, each with different colored phosphors. One subpixel has a red light phosphor, one subpixel has a green light phosphor and one subpixel has a blue light phosphor. These colors blend together to create the overall color of the pixel. By varying the pulses of current flowing through the different cells, the control system can increase or decrease the intensity of each subpixel color to create hundreds of different combinations of red, green and blue. In this way, the control system can produce colors across the entire spectrum.

The main advantage of plasma display technology is that you can produce a very wide screen using extremely thin materials. And because each pixel is lit individually, the image is very bright and looks good from almost every angle. The image quality isn't quite up to the standards of the best cathode ray tube sets, but it certainly meets most people's expectations.

CONTENT BEYOND SYLLABUS

Registers & Counters

- ☐ Objectives

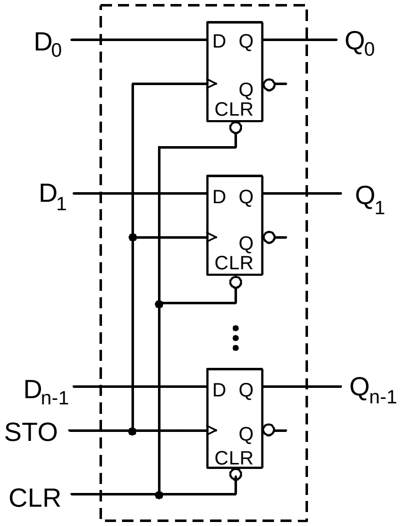
  This section deals with some simple and useful sequential circuits. Its objectives are to:
  - Introduce registers as multi-bit storage devices.
  - Introduce counters by adding logic to registers implementing the functional capability to increment and/or decrement their contents.
  - Define shift registers and show how they can be used to implement counters that use the one-hot code.
- ☐ Reading Assignment
  - Sections 4.4 and 5.4

---

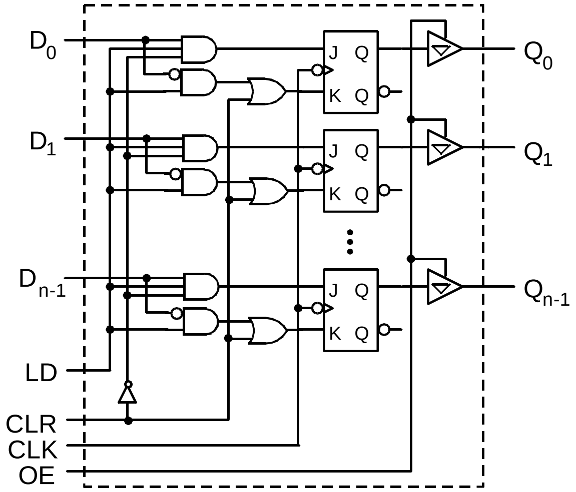
1. Registers

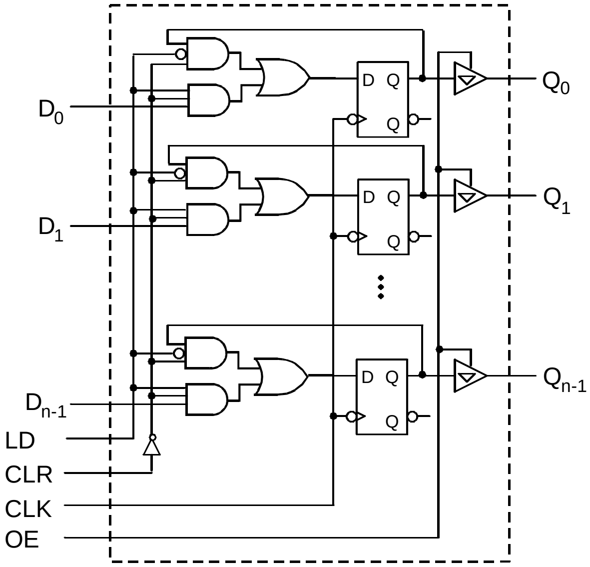
- ☐ A register is a memory device that can be used to store more than one bit of information.
- ☐ A register is usually realized as several flip-flops with common control signals that control the movement of data to and from the register.
  - Common refers to the property that the control signals apply to all flip-flops in the same way
  - A register is a generalization of a flip-flop. Where a flip-flop stores one bit, a register stores several bits
  - The main operations on a register are the same as for any storage devices, namely
    - ◆Load or Store: Put new data into the register
    - ◆Read: Retrieve the data stored in the register (usually without changing the stored data

- Control Signals
  - When they are asserted, they initiate an action in the register
  - *Asynchronous Control Signals* cause the action to take place immediately
  - *Synchronous Control Signals* must be asserted during a clock assertion to have an effect
- Examples
  - On the following three registers, which control signals are asynchronous and which are synchronous? How are the control signals asserted?



```
module reg1 (STO, CLR, D, Q);
   parameter n = 16;
   input STO, CLR;
   input [n-1:0] D;
   output [n-1:0] Q;
   reg [n-1:0] Q;

   always @(posedge STO or negedge CLR)
            if (CLR ==0) Q <= 0;
            else Q <= D;

endmodule
```


D_0
D_1
D_{n-1}
LD
CLR
CLK
OE
J
Q
K
Q
Q_0
Q_1
Q_{n-1}


D_0
D_1
D_{n-1}
LD
CLR
CLK
OE
D
Q
Q
Q_0
Q_1
Q_{n-1}

- Verilog description of previous two registers

```
module reg2 (CLK, CLR, LD, OE, D, Q);
  parameter n = 4;
  input CLK, CLR, LD, OE;
  input [n-1:0] D;
  output [n-1:0] Q;
  reg [n-1:0] IQ, Q;
  integer k;

  always @(posedge CLK)
    if (CLR) IQ <= 0;
    else if (LD) IQ <= D;

  always @(OE)
    if (OE) Q = IQ;
    else Q = 'bz;

endmodule
```

---

2. Counters

- A counter is a register capable of incrementing and/or decrementing its contents

$$Q \leftarrow Q \text{ plus } n$$
$$Q \leftarrow Q \text{ minus } n$$

  - The definition of "plus" and "minus" depend on the way the register contents encode the integers
  - Binary Counters: Encode the integers with the binary number code

☐Example: 3-bit binary counter:

000
001
010
plus ↓ 011
100
101 ↑ minus
110
111
000
⋮

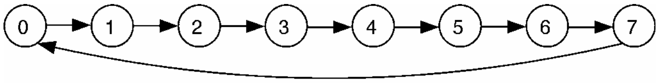
Count Sequence

000	001
001	010
010	011
011	100
100	101
101	110
110	111
111	000

Transistion Table

0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	0

State Table



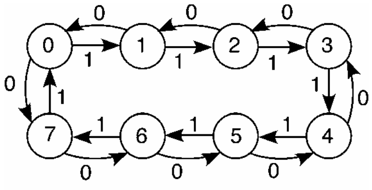
State Diagram

- What does the counter count?
- The output signals are just the state variables

☐Example: 3-bit binary up/down counter

	0	1
000	111	001
001	000	010
010	001	011
011	010	100
100	011	101
101	100	110
110	101	111
111	110	000

TransitionTable

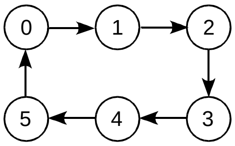


StateDiagram

☐Example: Binary mod 6 counter

000	001
001	010
010	011
011	100
100	101
101	000
110	x x x
111	x x x

Transistion Table



State Diagram

☐ Design of a Binary Up Counter

Q2	Q1	Q0
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1
0	0	0
	•	
	•	
	•	

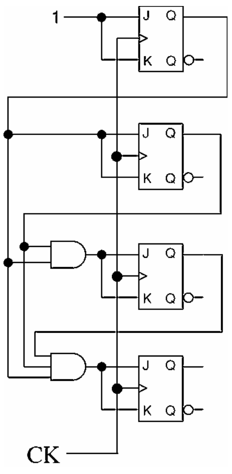
Count Sequence

Q0 Toggles every clock cycle

Q1 toggles on those clock cycles where Q0=1

Q2 toggles on those clock cycles where Q0=Q1=1

- Qi toggles on every clock cycle where Qj = 1, for i > j ≥ 0



Binary Up Counter

☐Design of a Binary Down Counter

Q2	Q1	Q0
1	1	1
1	1	0
1	0	1
1	0	0
0	1	1
0	1	0
0	0	1
0	0	0
1	1	1
•	•	•

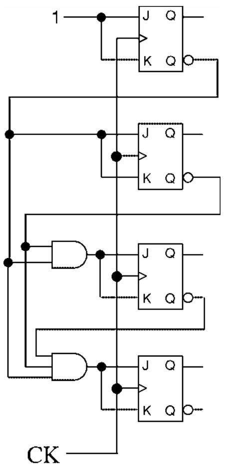
Count Sequence

Q0 Toggles every clock cycle

Q1 toggles on those clock cycles where Q0=0

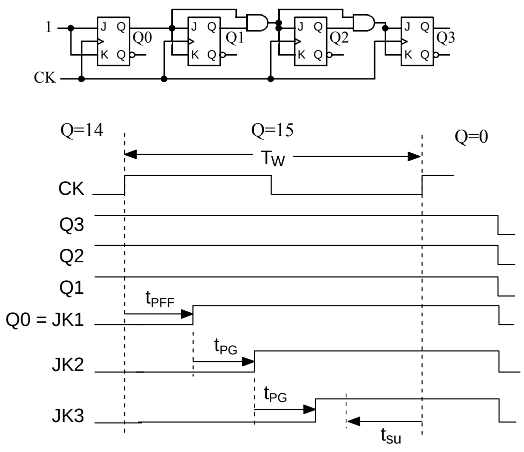
Q2 toggles on those clock cycles where Q0=Q1=0

- Qi toggles on every clock cycle where Qj = 0, for i > j ≥ 0



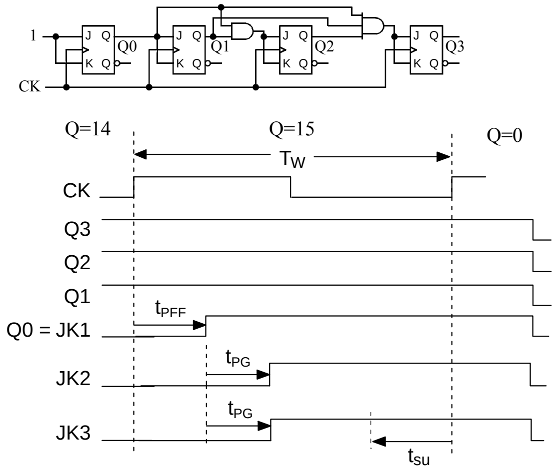
Binary Down Counter

☐ Synchronous, Series-Carry Binary Counter



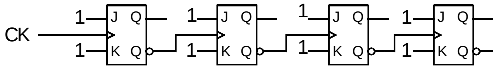
$$T_W \geq \quad t_{PFF} + (n-2)t_{PG} + t_{su} \text{ (for } n \geq 2\text{)}$$

☐ Synchronous, Parallel-Carry Binary Counter

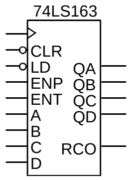


$$T_W \geq \quad t_{PFF} + t_{PG} + t_{su} \text{ (for } n \geq 3\text{)}$$

Asynchronous Counters



Typical MSI counter chip



- LD and CLR are synchronous
- LD asserted during the rising edge of the clock loads the register from ABCD.
- CLR asserted during the rising edge of the clock clears the counter
- CLR overrides LD
- LD overrides EN
- $R_{CO} = Q_D \bullet Q_C \bullet Q_B \bullet Q_A \bullet ENT$, used for cascading chips

Verilog description of the 74x163

```
module  V74x163 (CLK, CLR_L, LD_L, ENP, ENT, D, Q, RCO);
  input CLK, CLR_L, LD_L, ENP, ENT;
  input [3:0] D;
  output RCO;
  output [3:0] Q;
  reg [3:0] Q;
  reg RCO;

  always @(posedge CLK)
    if (CLR_L == 0) Q <= 4'b0000;
    else if (LD_L == 0) Q <= D;
    else if (ENT & ENP) Q <= Q +1;

  always @(Q or ENT)
    if (Q == 15 && ENT == 1) RCO = 1;
    else RCO = 0;

endmodule
```

☐ Verilog description of an up/down counter

```
module updowncount (R, Clock, L, E, up_down, Q);
   parameter n = 8;
   input [n-1:0] R;
   input Clock, L, E, up_down;
   output [n-1:0] Q;
   reg [n-1:0] Q;
   integer direction;

   always @(posedge Clock)
   begin
      if (up_down)  direction = 1;
      else  direction = -1;
      if (L)  Q <= R;
      else if (E) Q <-= Q + direction;
      end

endmodule
```

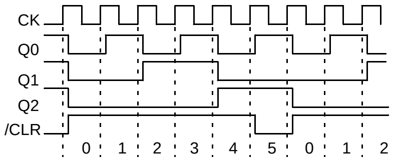
☐ Verilog description of mod-n counters

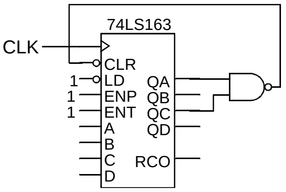
```
module upmodn (Ck, Q);
  parameter n = 6;
  input Ck;
  output [3:0] Q;
  reg [3:0] Q;

  always @(posedge Ck)
    if (Q == n)
      Q <= 0;
    else
      Q <= Q + 1;

endmodule
```

```
module dwnmodn (Ck, Q);
  parameter n = 5;
  input Ck;
  output [3:0] Q;
  reg [3:0] Q;

  always @(posedge Ck)
    if (Q == 0)
      Q <= n;
    else
      Q <= Q -1;
endmodule
```

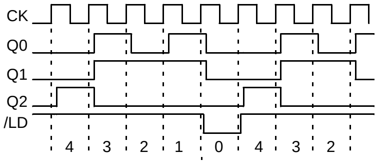
Design of Mod n Counters

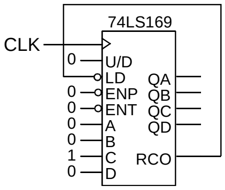
- Mod 6 Up Counter



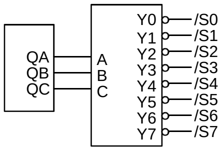


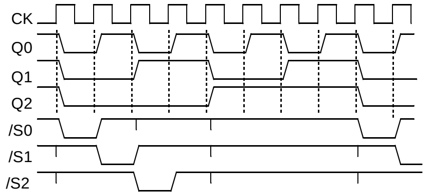
  - Mod 5 Down Counter



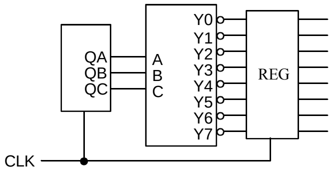


Decoding Binary Counter States

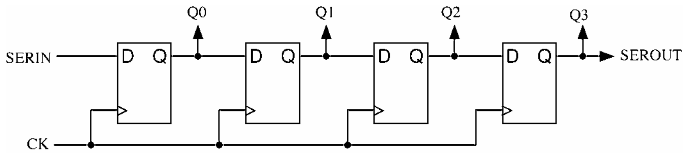




- The decoding spikes are hazzards that can not be designed out
- The following circuit will mask the decoding spikes, at the cost of delaying the outputs one clock cycle.

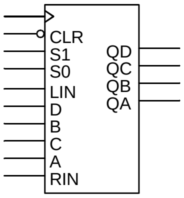


3. Shift Registers



- How would you add a control signal to control when the shift register shifted?
- How would you add parallel input capability and why would you want to?
  - What kind of control signals are needed?
- Is the shift register drawn above a left shifter or a right shifter?
- How would you make a shift register that could shift either left or right and what control signals would you need?

☐ Example: 74LS194



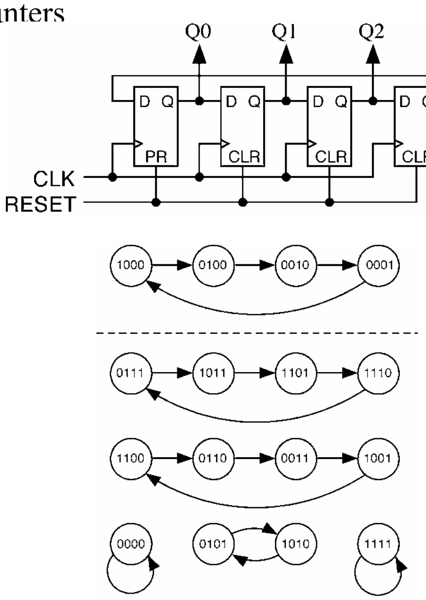
S1	S0	Action	QA*	QB*	QC*	QD*
0	0	hold	QA	QB	QC	QD
0	1	shift right	RIN	QA	QB	QC
1	0	shift left	QB	QC	QD	LIN
1	1	load	A	B	C	D

- Shift left is from A to D
- Shift right is from D to A
- CLR is asynchronous

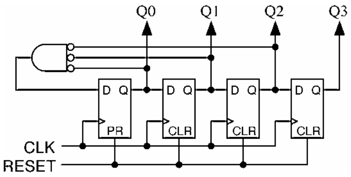
☐ Verilog Description Of A Shift Register

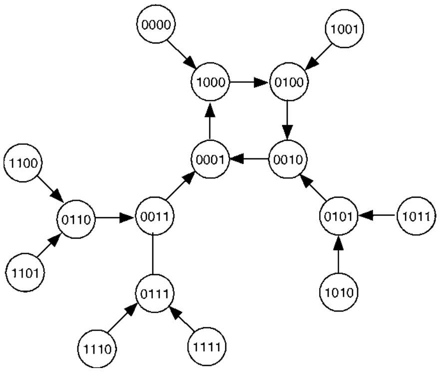
```
module shift4 (D, LD, LI, Ck, Q);
    input [3:0] D;
    input LD, LI, Ck;
    output [3:0] Q;
    reg [3:0] Q;

    always @(posedge Ck)
        if (LD)
            Q <= D;
        else
        begin
            Q[0] <= Q[1];
            Q[1] <= Q[2];
            Q[2] <= Q[3];
            Q[3] <= LI;
        end

endmodule
```

☐ Ring Counters

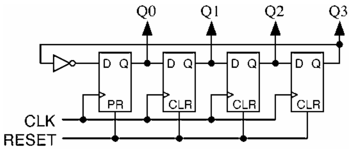


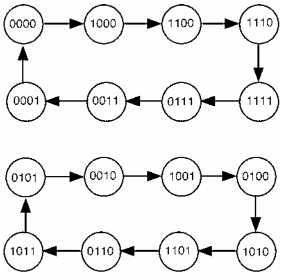
☐ Self-Correcting Ring Counter



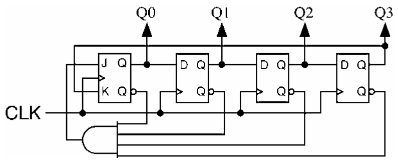


☐ Johnson counter, switch-tail counter, moebius counter

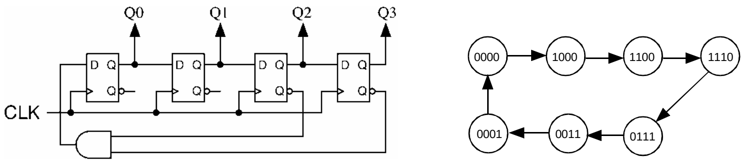




- Self-Correcting Johnson Counter



- Odd Length Johnson Counter



  - This counter is also self-correcting

4. Review

- Register control signals and assertions.
- Binary counters and their operations.
  - Reset, Load, Output Enable.
  - Counter timing; maximum clock frequency.
- Mod-n counters
  - Synchronous vs. asynchronous load and reset signals.
- Shift registers and shift register counters.
  - Ring counters, Johnson counters, etc
  - Self-correcting counters
- Counter realization of sequential circuits