ELECTRONIC MECHANIC

NSQF LEVEL - 5

2nd Year (Volume II of II)

TRADE THEORY

SECTOR: Electronics & Hardware

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Mentor Councils comprising various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Electronic Mechanic, 2nd Year (Volume II of II) Trade Theory NSQF Level - 5 in Electronics & Hardware Sector under Semester Pattern.** The NSQF Level - 5 Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 5 trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 5 the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

RAJESH AGGARWAL
Director General/ Addl.Secretary
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of Federal Republic of Germany. The prime objective of this Institute is to develop and provide instructional materials for various trades as per the prescribed syllabi under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

R. P. DHINGRA
EXECUTIVE DIRECTOR

Chennai - 600 032

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **Electronic Mechanic** under the **Electronics & Hardware** Sector for ITIs.

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NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE THEORY

The manual of trade theory consists of theoretical information for the Fourth Semester course of the Electronic Mechanic Trade. The contents are sequenced according to the practical exercise contained in the manual on Trade practical. Attempt has been made to relate the theortical aspects with the skill covered in each exercise to the extent possible. This co-relation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The Trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indicating about the corresponding practical exercise are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise atleast one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not the purpose of self learning and should be considered as supplementary to class room instruction.

TRADE PRACTICAL

The trade practical manual is intented to be used in workshop . It consists of a series of practical exercises to be completed by the trainees during the Fourth Semester course of the Electronic Mechanic trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 5

The manual is divided into Eight modules. The distribution of time for the practical in the Eight modules are given below.

Module 1	Fiber Optic Communication		25 Hrs
Module 2	Digital Panel Meter		50 Hrs
Module 3	SMPS and Inverter		75 Hrs
Module 4	UPS		75 Hrs
Module 5	Solar Power (Renewable Energy System)		75 Hrs
Module 6	Cell Phones		50 Hrs
Module 6	LED Lights		50 Hrs
Module 7	LCD & LED TV		125 Hrs
	Project work/ Industrial visit	Total	575 Hrs

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI, looks forward to the suggestions from the experienced training faculty for improving the manual.

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LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

- **Prepare fiber optic setup and execute transmission and reception.**
- **Plan and Interface the LCD, LED, DPM panels to various circuits and evaluate performance.**
- **Detect the faults and troubleshoot SMPS, UPS and inverter.**
- **Install a solar panel, execute testing and evaluate performance by connecting the panel to the inverter.**
- **Dismantle, identify the various parts and interface of a cell phone to a PC. Estimate and troubleshoot.**
- **Identify various parts of LED lights & stacks and troubleshoot.**
- **Identify, operate various controls, troubleshoot and replace modules of the LCD/LED TV & its remote control.**

SYLLABUS FOR ELECTRONIC MECHANIC TRADE

2nd Year (Volume II of II) **Duration: 6 Months**

Week No.	Learning Outcome Reference	Professional Skills (Trade Practical) with Indicative hrs.	Professional Knowledge (Trade Practical)
79	• Prepare fibre optic setup and execute transmission and reception.	**Fiber optic communication** 243. Identify the resources and their need on the given fiber optic trainer kit (3 hrs) 244. Make optical fiber setup to transmit and receive analog and digital data (4 hrs) 245. Set up the OFC trainer kit to study AM, FM, PWM modulation and demodulation. (6 hrs) 246. Perform FM modulation and demodulation using OFC trainer kit using audio signal and voice link (4 hrs) 247. Perform PWM modulation and demodulation using OFC trainer kit using audio signal and voice link (4 hrs) 248. Perform PPM modulation and demodulation using OFC trainer kit using audio signal and voice link (4 hrs)	Introduction to optical fiber, optical connection and various types optical amplifier,its advantages, properties of optic fiber, testing, losses, types of fiber optic cables and specifications. Encoding of light. Fiber optic joints, splicing, testing and the related equipment/ measuring tools. Precautions and safety aspects while handling optical cables.
80-81	• Plan and Interface the LCD, LED DPM panels to various circuits and evaluate performance.	**Digital panel Meter** 249. Identify LED Display module and its decoder/driver ICs (6 hrs) 250. Display a word on a two line LED (8 hrs) 251. Measure/current flowing through a resistor and display it on LED Module (10 hrs) 252. Measure/current flowing through a sensor and display it on a LED module(DPM) (10 hrs) 253. Identify LCD Display module and its decoder/driver ICs (8 hrs) 254. Measure/current flowing through a resistor and display it. (8 hrs)	Different types of seven segment displays, decoders and driver ICs. Concept of multiplexing and its advantages. Block diagrams of 7106 and 7107 and their configuration for different measurements. Use of DPM with seven segment display. Principles of working of LCD. Different sizes of LCDs. Decoder/ driver ICs used with LCDs and their pin diagrams. Use of DPM with LCD to display different voltage & current signals.
82-84	• Detect the faults and troubleshoot SMPS, UPS and inverter.	**SMPS and Inverter** 255. Identify the components/ devices and draw their corresponding symbols (4 hrs) 256. Dismantle the given stabilizer and find major sections/ ICs components. (6 hrs)	Concept and block diagram of manual, automatic and servo voltage stabilizer, o/p voltage adjustment. Voltage cut-off systems, relays used in stabilizer. Block Diagram of different types of Switch mode power supplies and their

		257. List the defect and symptom in the faulty SMPS. (5 hrs) 258. Measure / Monitor major test points of computer SMPS. (8 hrs) 259. Troubleshoot the fault in the given SMPS unit. Rectify the defect and verify the output with load. Record your procedure followed for trouble shooting the defects (10 hrs) 260. Use SMPS used in TVs and PCs for Practice. (6 hrs) 261. Install and test the SMPS in PC (6 hrs) 262. Install and test a inverter. (6 hrs) 263. Troubleshoot the fault in the given inverter unit. Rectify the defects and verify the output with load. (6 hrs) 264. Construct and test IC Based DC-DC converter for different voltages (6 hrs) 265. Construct and test a switching step down regulator using LM2576 (6 hrs) 266. Construct and test a switching step up regulator using MC 34063 (6 hrs)	working principles. Various types of chopper circuits. Inverter; principle of operation, block diagram, power rating, change over period. Installation of inverters, protection circuits used in inverters. Battery level, overload, over charging etc. Various faults and its rectification in inverter. Block diagram of DC-DC converters and their working principals.
85-87	• Detect the faults and troubleshoot SMPS, UPS and inverter.	**UPS** 267. Connect battery stack to the UPS. (4 hrs) 268. Identify front panel control & indicators of UPS. (4 hrs) 269. Connect Battery & load to UPS & test on battery mode. (6 hrs) 270. Open top cover of a UPS; identify its isolator transformers, the UPS transformer and various circuit boards in UPS. (10 hrs) 271. Identify the various test point and verify the voltages on these (7 hrs.) 272. Identify various circuit boards in UPS and monitor voltages at various test points (7 hrs) 273. Perform load test to measure backup time. (7 hrs)	Concept of Uninterrupted power supply. Difference between Inverters and UPS. Basic block diagram of UPS & operating principle. Types of UPS : Off line UPS, On line UPS, Line interactive UPS & their comparison UPS specifications. Load power factor & types of indications & protections UPS circuit description and working - controlling circuits, Micro controller circuits, power circuits, charging circuits, alarm circuits, Indicator circuits. Installation of single phase & three phase UPS.
88-90	• Install a solar panel, execute testing and evaluate performance by connecting the panel to the inverter.	274. Perform all above experiment for three phase UPS (30 hrs) Solar Power (Renewable Energy System) 275. Install a solar panel to a roof. (25 hrs) 276. Wire a solar controller to a battery storage station. (5 hrs)	Need for renewable energy sources, Solar energy as a renewable resource. Materials used for solar cells. Principles of conversion of solar light into electricity. Basics of photovoltaic's cell. Module, panel and Arrays. Factors that influence the

		277. Install solar power 500 panel to directly 12 V DC appliances (15 hrs) 278. Connect storage batteries to a power inverter (5 hrs) 279. Connect and test solar panel to the Inverter and run the load. (5 hrs) 280. Install a solar power to charge a rechargeable 12 V DC battery and find out the charging time (15 hrs) 281. Install a Solar Inverter. (5 hrs)	output of a PV module. SPV systems and the key benefits. Difference between SPV and conventional power. Solar charge controller or regulator and its role. Safety precautions while working with solar systems.
91-92	• Dismantle, identify the various parts and interface of a cell phone to a PC. Estimate and troubleshoot.	**Cell phones** 282. Dismantle, identify the parts and assemble different types of smart phones (6 hrs) 283. Dismantle the cell phone/smart phone remove the key pad and clean it, test for the continuity of the matrix/tracks (10 hrs) 284. Interface the cell phone/smart phone to the PC and transfer the data card (6 hrs) 285. Flash the various brands of cell phone/smart phone (at least 3) (5 hrs) 286. Format the cell phone/smart phone for virus (approach the mobile repair shop/service centre) (5 hrs) 287. Unlock the handsets through codes and software (3 hrs) 288. Perform the interfacing of cell phone/smart phone to the PC and dismantle the cell phone and identify the power section and test its healthiness (6 hrs) 289. Find out the fault of basic cell phone system. Rectify the fault in ringer section and check the performance (6 hrs) 290. Replace various faulty parts like mic, speaker, data/ charging/ audio jack etc. (5 hrs)	Introduction to mobile communication. Concept cell site, hand off, frequency reuse, block diagram and working of cell phones, cell phone features. GSM and CDMA technology. Use IEMI number to trace lost/misplaced mobile phone.
93-94	• Identify the various parts of a LED lights & stacks and troubleshoot.	**LED Lights** 291. Dismantle the LED light, identify the connections of LEDs stacks, protection circuits, regulator (12 hrs) 292. Identify the rectifier, controller part of LED lights (8 hrs) 293. Make series string connection of six LED's and connect four Series strings in parallel. (8 hrs)	Types of LED panels used in various lighting applications. Stacking of LEDs. Driving of LED stacks.

		294. Connect to such parallel sets in Series to create a matrix of LED's. (14 hrs.) 295. Apply suitable voltage and check Voltage across series strings. (8 hrs)	
95-99	• Identify, operate various controls, troubleshoot and replace modules of the LCD/LED TV & its remote	**LCD and LED TV** 296. Identify and operate different Controls on LCD, LED TV (10 hrs) 297. Identify components and different sectors of LCD and LED TV. (20 hrs) 298. Dismantle; Identify the parts of the remote control (10 hrs) 299. Dismantle the given LCD/LED TV to find faults with input stages through connectors. (20 hrs) 300. Detect the defect in a LED/LCD TV receiver given to you. Rectify the fault. (25 hrs) 301. Troubleshoot the faults in the given LED/LCD TV receiver. Locate and rectify the faults. (25 hrs) 302. Test LED/LCD TV after troubleshooting the defects (10 hrs) 303. Identify various connectors and connect the cable operators external decoder (set top box) to the TV. (5 hrs.)	Difference between a conventional CTV with LCD & LED TVs. Principle of LCD and LED TV and function of its different section. Basic principle and working of 3D TV. IPS panels and their features. Different types of interfaces like HDMI, USB, RGB etc. TV Remote Control –Types, parts and functions, IR Code transmitter and IR Code Receiver. Working principle, operation of remote control. Different adjustments, general faults in Remote Control.
100-101	**Project work / Industrial visit** **Broad areas:** 1 Remote control for home appliances 2 Solar power inverter 3 Musical light chaser 4 7 segment LED display decoder drive circuit		
102-103	Revision		
104	Examination		

Fiber optic communication

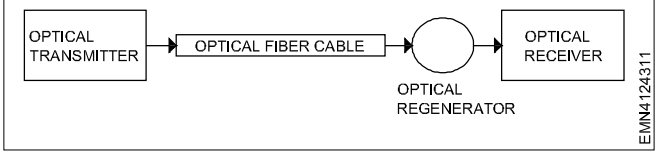
Objectives : At the end of this lesson you shall be able to
- **define the fiber optic communication**
- **explain the block diagram and function of the fiber optic communication**
- **describe the different basic elements of the OFC system**
- **explain the working principle of each element**
- **state the advantages and disadvantages of the optical fiber communication**
- **state the applications of the fiber optic communication.**

Fiber optics is a branch of optics that deals with the study of propagation of light through transparent dielectric wave guides.

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber.

A simple typical optical fiber telecommunication system is as shown in Fig 1.

Fig 1



Fiber-optics have revolutionized the telecommunication industry and have played a major role in this. Because of its advantages over electrical signal transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world. Optical fiber is used by many telecommunication companies to transmit telephone signals, Internet communication, and cable television signals.

A detailed block diagram of optical fiber communication system is shown in Fig 2.

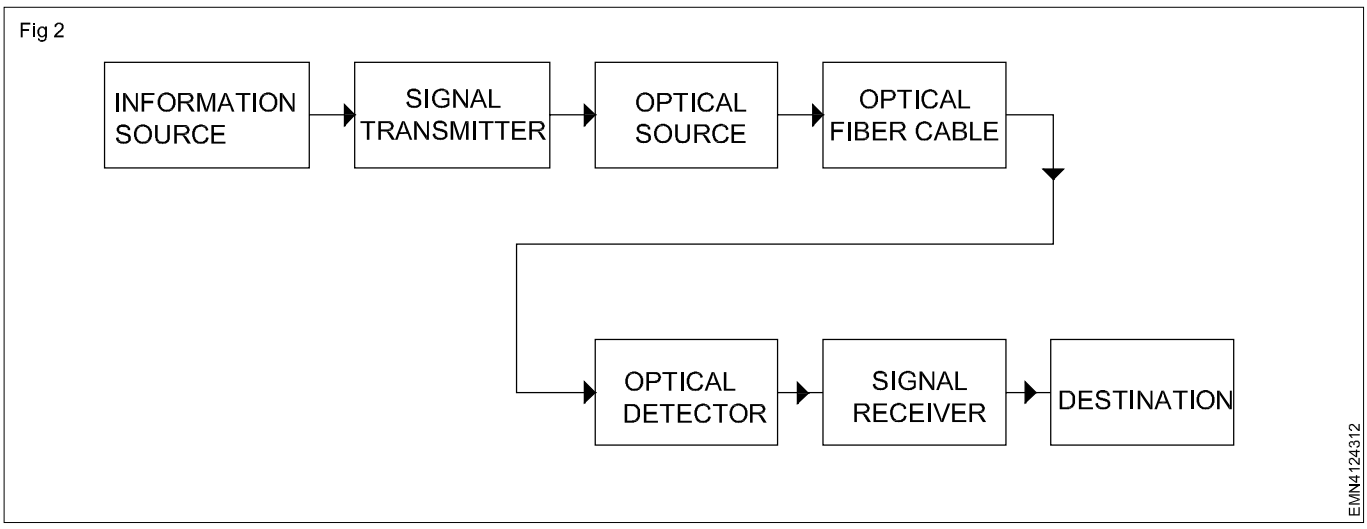
When the input data in the form of electrical signals, is given to the transmitter circuitry; it converts them into light signal with the help of a light source. This source is of LED whose amplitude, frequency and phases must remain stable and free from fluctuations in order to have efficient transmission. The light beam from the source is carried by a fiber optic cable to the destination circuitry wherein the information is transformed or converted back to the electrical signal by a receiver circuit.

The Receiver circuit consists of a photo detector along with an appropriate electronic circuit, which is capable of measuring magnitude, frequency and phase of the optic field. This type of communication uses the wave lengths near to the infrared band that are just above the visible range. Both LED and Laser can be used as light sources based on the application.

Visible light range

Light is an electromagnetic signal like radio wave. It can be modulated by the information signal and sent over the fiber- optic cable. The frequency of light is extremely high; it can be used to accommodate very wide bandwidth of the information and extremely high data rates can be achieved with excellent reliability. Fig 3 shows the frequency spectrum and wavelengths of visible light spectrum.

Fig 2



Basic elements of a fiber optic communication system

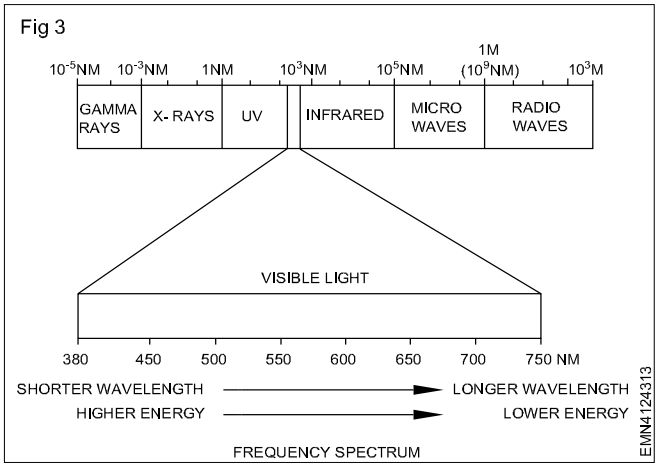
There are three main basic elements of fiber optic communication system. They are

1 Compact light source

2 Low loss optical fiber

3 Photo detector

Fig 3



Accessories like connectors, switches, OFC couplers, multiplexing devices, amplifiers and splicer are also essential elements in this optical fiber communication system.

1 Compact light source

Depending on the applications , the light source requirements may vary. The requirements of the sources including power, speed, spectral line width, noise, ruggedness, cost, temperature, and so on. Two components are used as light sources: light emitting diodes (LEDs) and laser diodes.

The light emitting diodes are used for short distances and low data rate applications due to their low bandwidth and power capabilities. Two such LEDs structures include Surface and Edge Emitting Systems. The surface emitting diodes are simple in design and are reliable, but due to its broader line width and modulation frequency limitation, edge emitting diodes are mostly used. Edge emitting diodes have high power and narrower line width capabilities.

For longer distances and high data rate transmission, Laser Diodes are preferred due to its high power, high speed and narrower spectral line width characteristics. But these are inherently non-linear and more sensitive to temperature variations.

2 Low loss optical fiber

The purpose of optical fiber is to transmit light signal from transmitter to receiver. Optical fiber is a cable, which is also known as cylindrical dielectric waveguide made of low loss material. An optical fiber considers the parameters like the environment in which it is operating, the tensile strength, durability and rigidity. The fiber optic cable is made of high quality extruded glass (si) or plastic, and it is flexible. The diameter of the fiber optic cable is in between 0.25 to 0.5mm (slightly thicker than a human hair).

3 Photo detectors

The purpose of photo detectors is to convert the light signal back to an electrical signal. Two types of photo detectors are mainly used for optical receiver in optical communication system: PN photo diode and avalanche photo diode. Depending on the applications wavelengths, the material composition of these devices may vary. These materials include silicon, germanium, InGaAs, etc.

Advantages

The primary advantages of the Fiber-optic cables over conventional cables and radio waves are:

1 Wider band width

Optical fiber have greater information capacity than metallic cable because of the inherently wider bandwidth upto several thousand GHz available with optical frequencies. It has higher information carrying capacity.

2 Lower loss

With fiber-optic cables, there is less signal attenuation over long distances.

3 Small size and Light weight

Optical fibers are very small diameter in the range from 10 micrometers to 50 micrometers. The space occupied by the fiber cable is negligibly small as compared to the conventional electrical copper cables.

4 Security

Fiber-optic cables cannot be "tapped" as easily as electrical cables.

5 Environmental immunity

OFC cables are more resistant to environment extremes including weather variations than metallic cables. Optic cables also operate over a wide temperature range and are less affected by corrosive liquids and gases.

6 Electrical Isolation

Optical -fibers are fabricated from glass or plastic polymers, they are electrical insulators therefore they do not exhibit earth loop, interference problems, electromagnetic waves or any high current lightning.

7 Potential low cost and maintenance

In comparison with the copper conductors optic-fiber offers low cost line communication. This is because many miles of optical cables are easier and less expensive to install than the same amount of copper wire or cable.

Disadvantages

The cost of interfacing equipments necessary to convert electrical signals to optical signals is more. (Optical transmitters, receivers). Splicing fiber optic cable is also more difficult.

1 Expensive over short distance.

2 Requires highly skilled installers.

3 Adding additional nodes is difficult.

Ruggedness

The main disadvantage of the fiber-optic cable is its small size and brittleness makes more difficult to work with it.

Fiber-Optic Applications

Telecommunication applications are widespread, ranging from global networks to desktop computers. This involves

the transmission of voice, data, or video over distances of less than a meter to hundreds of kilometers using fiber designs.

Optical fiber is used extensively for transmission of data. Multinational firms need secure, reliable systems to transfer data and financial information between buildings to the desktop terminals or computers and to transfer data around the world. Cable television companies also use optical fiber communication system for the delivery of digital video and data services. The high bandwidth provided by fiber makes it perfect choice for transmitting broadband signals, such as high-definition television (HDTV) telecasts.

Intelligent transportation systems, such as smart highways with intelligent traffic lights, automated tollbooths, and changeable message signs, also use fiber-optic-based telemetry systems.

Another important application for optical fiber is the biomedical industry. Fiber-optic systems are used in most modern telemedicine devices for transmission of digital diagnostic images. Other applications for optical fiber include space, military, automotive, and the industrial sector.

Optical fiber

Objectives : At the end of this lesson you shall be able to

- **define optical cable**
- **explain the construction details of an optical cable**
- **define refractive index and total internal deflection**
- **explain the working principle of an optical cable**
- **state the types of fiber**
- **differentiate the single mode and multi mode optical cable.**

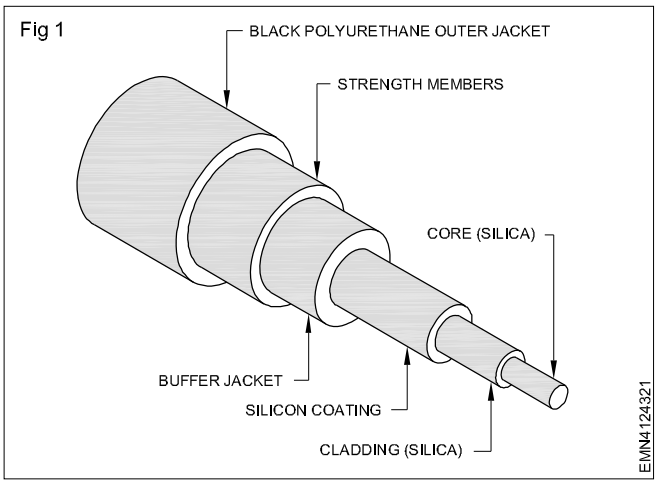
What is an optical fiber?

Typically, fiber optics are long, thin strands of glass (SiO_2) about the diameter of human hair; some can be made out of plastic. Long distance telecommunication systems always use glass because of its lower optical absorption during transmission to maintain the signal strength. When arranged in bundles, they are called optical cables which are used to transmit light signals containing information over long distances.

Construction of optical fiber

The structure of optical fiber is shown in Fig 1.

Fig 1



1 Core

2 Cladding

3 Buffer

4 Jacket

Core

The core of a fiber cable is a cylinder of plastic or silica or glass that runs all along the fiber cable's length, and offers protection by cladding. The diameter of the core depends on the application used. Due to internal reflection, the light travelling within the core reflects from the core and the cladding boundary. The core cross section needs to be a circular one for most of the applications.

Cladding

Cladding is an outer optical material that protects the core. The main function of the cladding is that it reflects the light back into the core. When light enters through the core (dense material) into the cladding(less dense material), it changes its angle, and then reflects back to the core.

Buffer jacket

The main function of the buffer is to protect the fiber from damage while arranged in optical cables. These bundles are protected by the cable's strength members covering.

Outer jacket

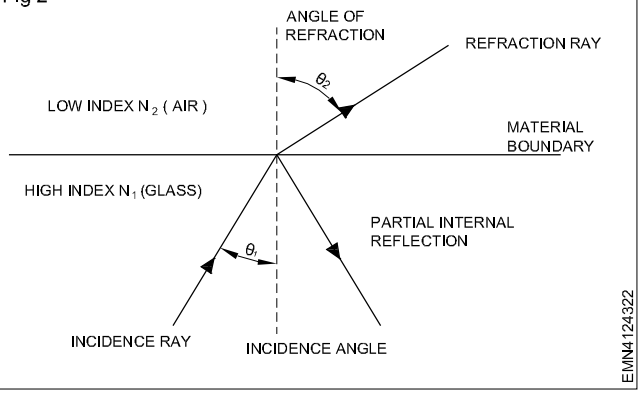
Fiber optic cable's jackets are available in different colours that can easily make us recognize the exact colour of the cable we are dealing with. The colour yellow clearly signifies a single mode cable, and orange colour indicates multimode. It is also given mechanical strength to the optical cables.

Characteristics of light

Reflection: The bouncing back of rays of light from a polished and shiny surface is called reflection of light.

Refraction: It is the bending of light ray that occurs when the light ray passes from one medium to the other.

Fig 2



Angle of incidence: The angle at which light strikes a surface with respect to the normal.

Angle of reflection: The angle at which light is reflected from a surface.

Index of refraction

The index of refraction (or refractive index) is a way of measuring the speed of light in a material. Light travels fastest in vacuum, such as in outer space. The speed of light in a vacuum is about 300,000 kilometers (186,000 miles) per second. The refractive index is the ratio of the speed of light in vacuum to the speed of light in that medium. The refractive index of a vacuum is therefore 1, by definition.

Total internal reflection

The heart of an optical communication system is the optical fiber that acts as the transmission channel carrying the light beam loaded with information.

When the light ray strikes the interface at an angle greater than the critical angle, the light ray does not pass through the interface into the glass. The effect is as if a mirror existed at the interface.

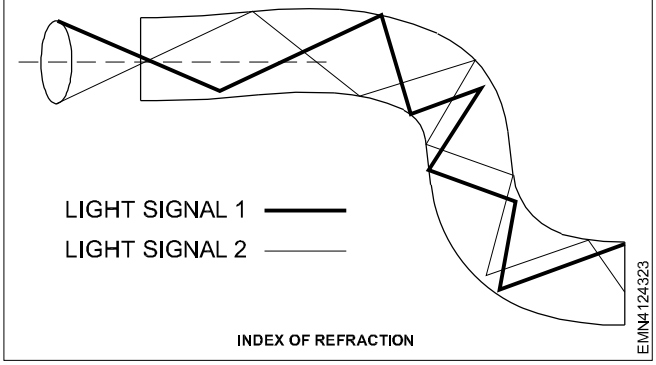
When this occurs the angle of reflection is equal to the angle of incident as if a real mirror were used. This action is known as total internal reflection.

Critical angle is the angle of incidents that causes the refracted light to travel along the interface between two different media. If the angle of incidents is made greater than the critical angle, the reflection occurs instead of refraction.

Working principle of fiber optic cable

The principle of operation of an optical fiber lies in the behaviour of light as shown in Fig 3 that the light always travels in straight line and at constant speed. In this, the light propagates in straight lines, but it is reflected inside the optical Fiber. Million and trillion times of reflected by the clad, it acquires the shape of the optical fiber. So effectively, it is said to have been travelling along the Fiber as shown in the Fig 3. It changes its direction only if there is a change in the dielectric medium . The propagation of light within an optical fiber is necessary to take in to account the refractive index of the dielectric medium.

Fig 3



Refractive index of a medium is defined as the ratio of velocity of light in vacuum to velocity of light in medium.

$$\text{Refractive index} = \frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in medium}}$$

Since, the velocity of light in any solid, transparent material is less than in vacuum, the refractive index of such material is always greater than 1. A ray of light travels slowly in an optical medium than one that is less dense. Now, the direction that the light approaches the boundary between the two materials is very important. When a ray is incident on the interface between two dielectrics of differing refractive indices, refraction occurs. The light is refracted and also partly reflected internally in the same medium; which is referred as Partial Internal Reflection.

Classification of optical fiber

There are two basic ways of classifying fiber

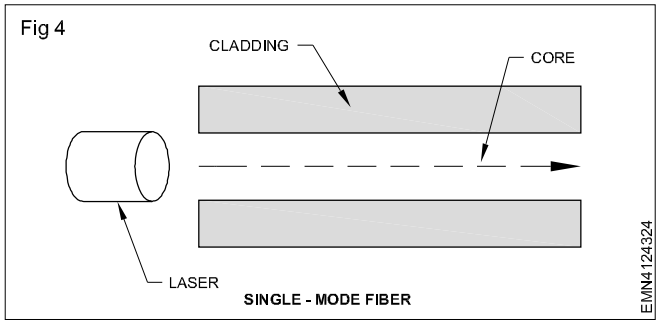
1 Based on the modes
   - i Single mode fiber
   - ii Multi mode fiber

2 Based on index of refraction varies across the cross section of the cable.
   - i Step index fiber
   - ii Graded index fiber

Single mode fibers

The single mode optical fiber SMF (mono mode optical fiber, single mode optical waveguide, or uni mode fiber) type has the smaller core diameter in the order of 3.5×10^{-4} inches or 9 microns and a cladding diameter of 125 mm. These fibers are used in telephone and television due to small cores.

Fig 4

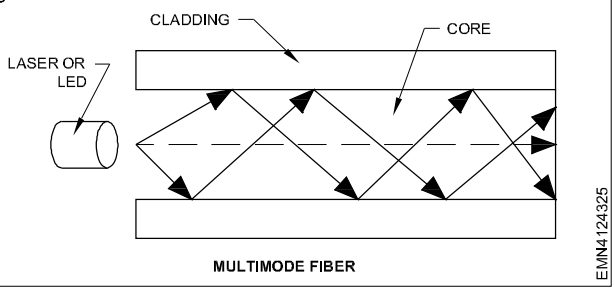


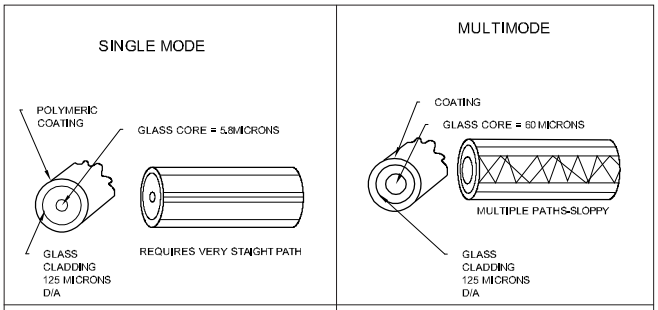
This SMF is designed to carry only a single ray of light (mode). Although the ray travels parallel to the length of the fiber, it is often called transverse mode since its electromagnetic vibrations occur perpendicular (transverse) to the length of the fiber.

Multi mode fibers

The MMF type has larger core diameters on the order of 2.5 x 10^{-3} inches or 62.5 microns as to transmit many signals per fiber. While the number of light reflections increased as the light passes through the core increases. It creates the ability for more data to pass through at a given time. Because of the high dispersion and attenuation rate with this type of fiber, the quality of the signal is reduced over long distances. This application is typically used for short distance, data and audio/video applications in LANs. RF broadband signals commonly used by the cable companies, cannot be transmitted over multimode fiber.

Fig 5





Small core(9 microns)	Larger core than single-mode cable (50 microns or greater)
Less dispersion	Allows greater dispersion and therefore, loss of signal.
Suited for long-distance applications (upto-3 km)	Used for long-distance application, but shorter than single-mode(upto 2 km)
Used lasers as the light source for distances of several thousand meters	Uses LEDs as the light source often within LANs or distances of a couple of hundred meters.

Difference between Single Mode & Multi Mode

Index profile of the optical fiber

Index profile of an optical fiber is the refractive index distribution across the core and the cladding of the fiber. There are two basic ways

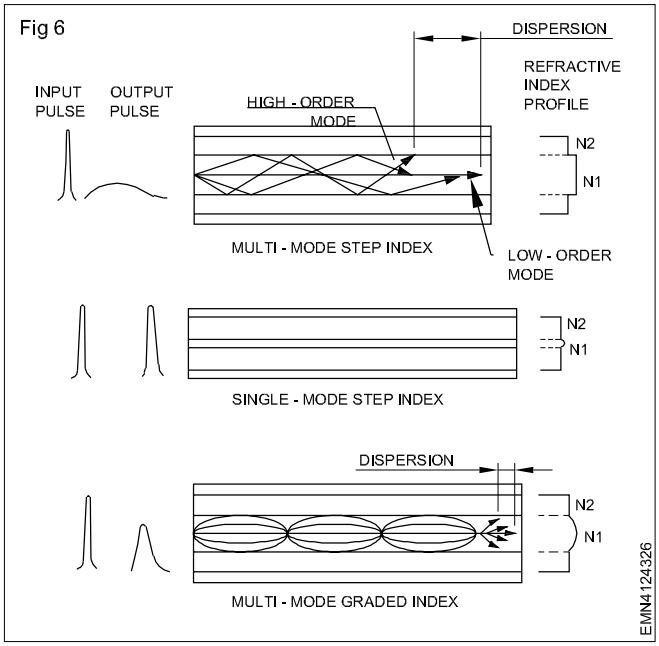
Step index fiber

It has an index of refraction profile that "steps" from low-to-high-to-low as measured from cladding -to-core-to-cladding. Due to its larger core, some of the light rays that may travel a direct route, whereas others zigzag as they bounce off the cladding. These alternate paths cause the different groups of light rays, referred to as modes, to arrive separately at the receiving point. The light rays begins to spread out, losing its well-defined shape. The need to leave spacing between pulses to prevent overlapping limits the amount of information that can be sent. This type of fiber is best suited for transmission over short distances.

Graded index fiber

In which refractive index reduces gradually (smoothly and continuously) as a function of radial distance from the fiber centre. The index of refraction decreases in proportion to the distance away from the center of the fiber core. The higher refractive index at the center makes the light rays moving down the axis advance more slowly than those near the cladding. Due to the graded index, light in the core curves helically rather than zigzag off the cladding, reducing its travel distance. The shortened path and the higher speed allow light at the periphery to arrive at a receiver at about the same time as the slow but straight rays in the core axis. This results digital pulse suffers less dispersion. This type of fiber is best suited for local-area networks.

Fig 6



Specifications

Information Services and Technology (IST) currently specifies the installation of 62.5/125 micron multimode and 8.3/125 micron single mode fiber optic cable to support data communication services.

The following IST specifications for the selection and installation of fiber-optic cable and associated hardware are intended to ensure a reliable and consistent fiber optic media infrastructure

1 Single mode fibers

i Thickness of fiber: 8.3 to 125micro meter

ii Wave length (to be used): 1310 nano meter,1550 nano meter

iii Maximum attenuation: 1.0dB/ kilometer

iv Capable to support tensile load of 180 Kg

v Capable of minimum crush resistance of 152 Kg/cm

vi Cable should be tight buffered, ie., the fiber should not be placed loosely in cladding layer.

2 Multi mode fiber

i Thickness of fiber: 8.3 to 125 micrometer.

ii Wave length (to be used): 850 nano meter,1550 nano meter.

iii Capable to support tensile load of 180 Kg.

iv Capable of minimum crush resistance of 152 Kg/cm.

v Folded core ie., fibers with cladding layer should have been closely bunched together.

Losses in optical fibers

Objectives : At the end of this lesson you shall be able to

- **state the types of losses in the fiber optics**
- **explain the attenuation losses in an optical cable**
- **define dispersion**
- **state the types of dispersion and explain about each type.**

Losses

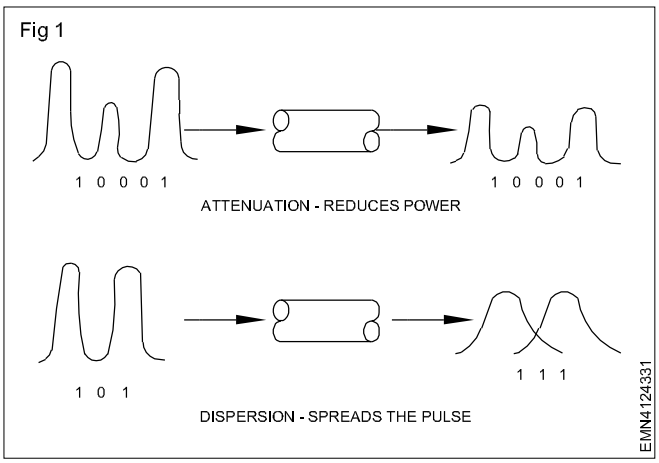
The Signal transmitting through the fiber is degraded by two mechanisms. (Fig 1)

1 Attenuation

2 Dispersion

Both are important to determine the transmission characteristics of the fiber at operating wavelength.

Fig 1



Attenuation

Power loss in a fiber cable is probably the most important characteristics of the cable. Power loss is often called as attenuation.

Attenuation is a measure of decay of signal strength or loss of light power that occurs as light pulses propogate through the length of the fiber.

Attenuation has several adverse effects on performance, including reducing the system bandwidth, information transmission rate, efficiency, and overall system capacity.

Total power loss in an optical fiber cable is

A(dB) = 10 log (Pout/Pin)

Where

A(dB) - Total reduction in power level, attenuation.

Pout - Cable output power (watts) and

Pin - Cable input power (watts)

The basic attenuation mechanisms in a fiber are

1 Absorption

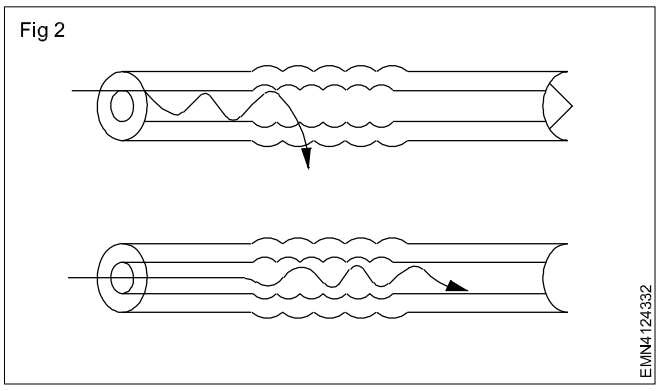
2 Scattering and

3 Radiative losses of the optical energy

Absorption is related to the fiber material and scattering also due to the fiber material and with structural imperfections in the optical waveguide.

Radiative losses occur whenever an optical fiber under goes a bend (both microscopic and macroscopic) of finite radius of curvature as shown in Fig 2.

Fig 2

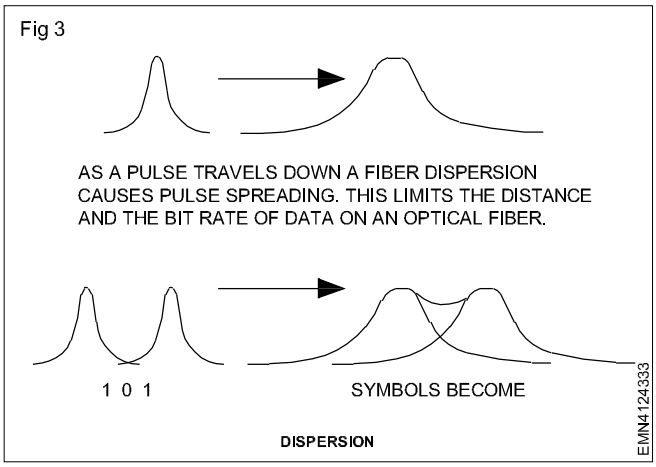


Dispersion

Dispersion means the spreading of light pulse as it propagates through the fiber as shown in Fig 3.

It introduces Intersymbol interference (ISI). It limits the information carrying capacity of fiber.

Fig 3



The dispersion effect can be explained on the basis of behaviour of group velocities of the guided modes in the optical fiber. Group velocity means the velocity at which energy in a pulse travel along the fiber.

Types of dispersion

Dispertion is mainly 2 types

1 Intramodal dispersion

2 Intermodal dispersion

Intramodal dispersion is divided into

i Material or chromatic dispersion

ii Waveguide dispersion

iii Group velocity dispersion (GVD) or Modal dispersion

Intramodal dispersion

Intramodal dispersion is pulse spreading that occurs within a single mode.

It arises due to group velocity being a function of wavelength. The increasing spectral width of the optical source will increase the intramodal dispersion.

Material dispersion (or) Chromatic dispersion

1 This dispersion arises due to the variation of the refractive index of the core material as a function of wavelength or frequency of light.

2 To minimize the material dispersion choosing sources with narrower spectral output width, or by operating at longer wavelengths.

Waveguide dispersion

1 Waveguide dispersion occurs when a single-mode fiber only confines about 80% on the optical power to the core.

2 The amount of waveguide dispersion depends on the fiber design.

Group velocity dispersion

1 Group velocity is the velocity at which the energy in a particular mode travels along the fiber, or it is the velocity of a group of wave length.

2 This type pulse spreading occurs when each mode having different value of the group velocity at single frequency.

Intermodal distortion (or) Multimode dispersion

1 The intermodal distortion arises due to the variation in the group delay for each individual mode at single frequency.

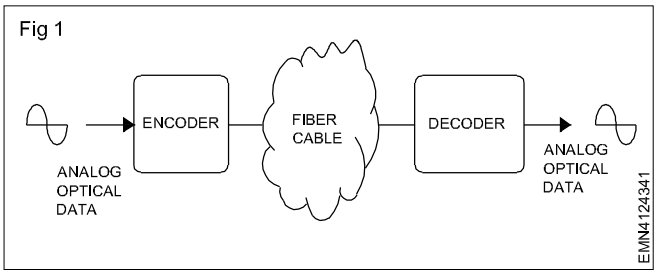
2 This distortion is available in multimode fibers.

Encoding and decoding of light

Objectives : At the end of this lesson you shall be able to

- **define encoding and decoding of light**
- **explain the different types of optical sources**
- **state the requirements of light sources in the fiber optical communication system**
- **explain the principle of operation of LASER diode and different types of optical decoders**
- **state the requirement of photo detectors used in the optical communication system.**

Fig 1



Encoding in optical fiber transmission means the transmission of analog optical information through fiber optics digitally as shown in Fig 1.

This improves the acceptable signal-to-noise ratio (SNR) by 20 to 30 dB over analog transmission.

Transmitter

Fiber optic transmitters are typically composed of a buffer, driver and optical source. The buffer provide both an electrical connection and isolation between the transmitter and the electrical system supplying the data. The driver provides electrical cover to the optical source. Finally the optical source converts the electrical current to the light energy with the same pattern.

Optical source

Optical Sources are active components whose fundamental function is to convert the electrical energy into optical energy(light) in an effective manner. Hence the optical sources are transducers.

Optical source is major component in an optical transmitter.

Popularly used optical sources are Light emitting diode (LED) and semiconductor laser diodes (also referred to as injection laser diodes or ILDs).

Requirements of light sources for communication

i Light output should be highly directional.

ii It must require very small power for its operation.

iii Optical output should be stable irrespective of changes in temperature.

iv The light source should have compact size and high efficiency.

v High optical output power and coupling efficiency.

vi It is essential that the source is comparatively cheap and highly reliable in order to compete with conventional transmission techniques.

Almost all these requirements are satisfied by LASER and LED. Both operate in forward-biased mode.

1 LED-Monochromatic incoherent source.

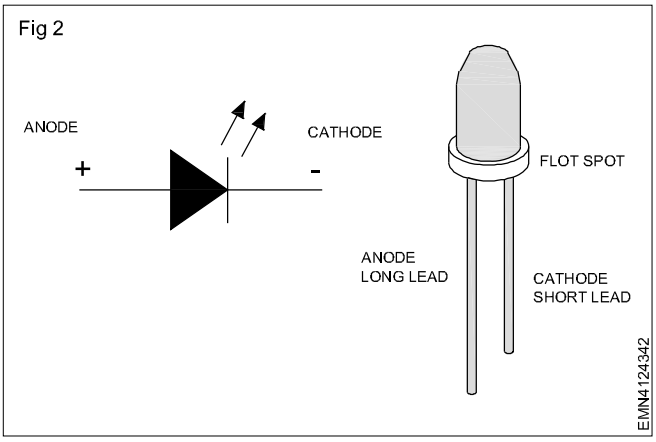
2 LASER-Monochromatic coherent source.

Light Emitting Diode (LED)

LEDs are used in optical communication systems that require bit rate less than approximately 100-200 mbps.It is mostly coupled with multimode fiber.

It covers broad spectrum of wavelengths and the emitted power is proportional to the diode current.

Fig 2



Emission of light from LED

Conduction band of the semiconductor is populated by electrons injected into it. By the forward current through the junction and light is generated when these electrons recombine with holes in valence band to emit a photon.

LED can be used in fiber transmission applications must have

i High Radiance output or brightness.

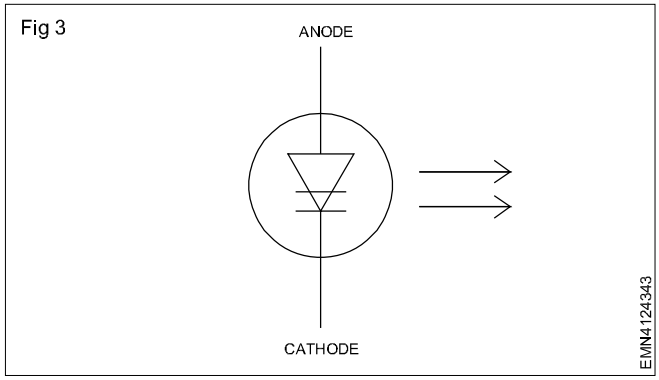
ii Fast transmission response time.

iii High quantum efficiency.

LASER diode

LASER is acronym for Light Amplification by Stimulated Emission of Radiation.

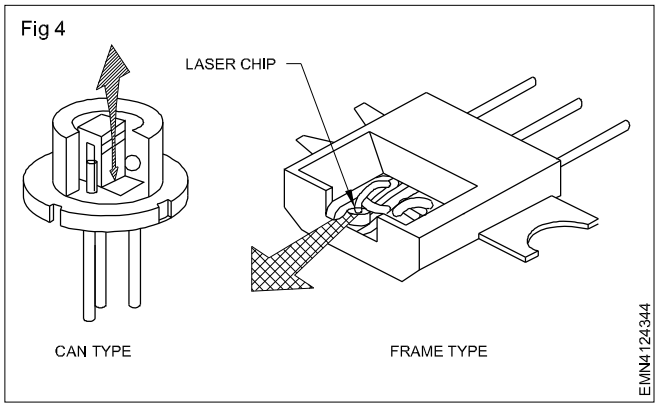
Fig 3



Ideal LASER light is single-wavelength only. This is related to the molecular characteristics of the material being used in the LASER. It is formed in parallel beams and in single phase. That is, it is coherent.

Laser diode is available in two different packages as shown in Fig 4.

Fig 4



1 Can type package

2 Frame type package

The lasing medium can be a gas, a liquid, an insulating crystal, or a semiconductor.

Principle of operation

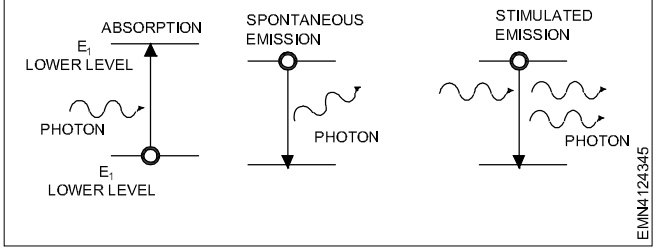
The three different mechanisms are shown in Fig 5 below.

1 **Absorption:** An atom in a lower level absorbs a photon and moves to an upper level.

2 **Spontaneous emission:** An atom in an upper level can decay spontaneously to the lower level and emit a photon if the transition between upper and lower energy level. This photon has a random direction and phase.

3 **Stimulated emission:** An incident photon causes an upper level atom to decay and emitting a "stimulated" photon whose properties are identical to those of the incident photon. The term "stimulated" underlines the fact that this kind of radiation only occurs if an incident photon is present. The amplification arises due to the similarities between the incident and emitted photons.

Fig 5



Comparison of LASER & LED

The differences between LASER and LED for various parameters are listed in the TABLE below.

Sl. No.	Parameter	LASER	LED
1.	Output beam	Coherent	Incoherent
2.	Coupling co efficiency	High	Low
3.	Output power	High	Low
4.	Cost	Expensive	Less
5.	Application	Moderate distance with low data rate	Long distance with high data rate
6.	Circuit complexity	Complex	Simple
7.	Temperature dependent	More	Less

Optical receiver

Optical receiver (photo detector) converts the variation in optical power into a corresponding variation in the electric current. The design of an optical receiver is much more complicated than that of an optical transmitter because the receiver must first detect weak, distorted signals and then make decisions on what type of data was sent based on an amplified version of this distorted signal.

The optical receiver can be broken down into three parts. These consist of:

1 Channel coupler (Output)

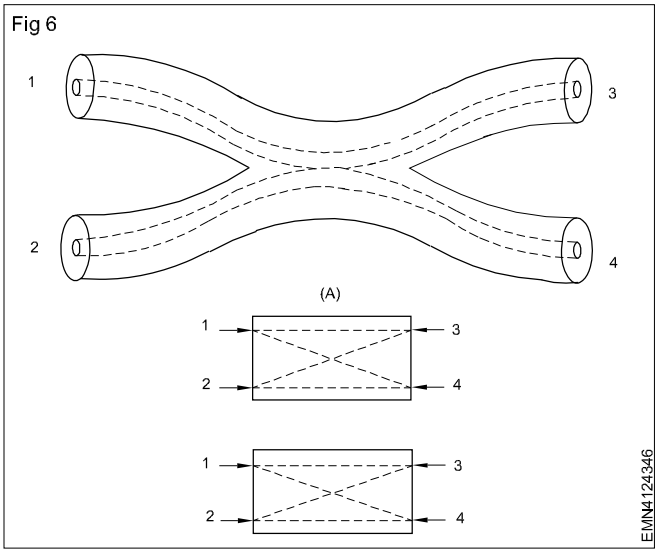
2 Detector

3 Signal processor

Channel coupler (Output)

In a fiber system, the output coupler merely directs the light emerging from the fiber into the light detector. This light is radiated in a pattern identical to the fiber's acceptance cone as shown in Fig 6.

Fig 6



Detector

The detector is an essential component of an optical fiber communication system and is one of the crucial elements which decides the overall system performance.

The information being transmitted must now be taken off the carrier wave. In the fiber system, the optic wave is converted into an electric current by a photo detector.

Signal processor

For analog transmission, the signal processor includes amplification and filtering of the signal.

In addition to filtering of the constant bias, any other undesired frequencies should be blocked from further travel.

An ideal filter passes all frequencies contained in the transmission information and rejects all the others. This improves the clarity of the intended transmission. Proper filtering maximises the signal to noise ratio.

Requirements of photo detectors

1 High sensitivity at operating wavelength

2 **High fidelity:** To reproduce the received signal waveform with fidelity, for analog transmission the response of the photo-detector must be linear with regard to the optical signal over a wide range.

3 High quantum efficiency

4 Short response time to obtain suitable bandwidth

5 A minimum noise introduced by the detector.

6 Small size

7 Stable performance

8 High reliability

9 Low bias voltage

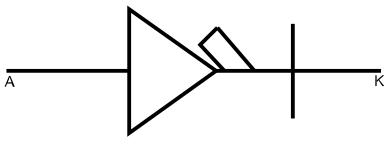
10 Low cost

The two types of photodiodes used are the P-I-N photo-detector and the avalanche photo diode(APD).

P-I-N Photodetector

The circuit symbol of P-I-N diode is shown in Fig 7 below.

Fig 7



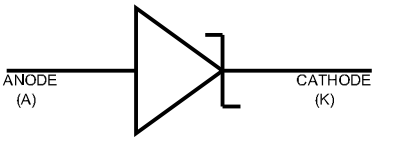
1 The pin photo detector structure consists of p and n regions separated by a very lightly doped intrinsic region.

2 When the photodiode is reverse biased, the intrinsic region of diode is fully depleted of carriers.

Avalanche Photo Diode (APD)

The circuit symbol of the avalanche photo diode is shown in Fig 8.

Fig 8



1 Avalanche photo diodes internally multiply the primary signal photo current before it enters the input circuitry of the following amplifier.

2 It has high internal gain and its responsivity is better than the pin photo diode.

3 Extremely high electric field region is created. Most of the photons are absorbed in the depletion region and the primary electron-hole pairs are generated.

Comparison of PIN diode and APD

The differences between the PIN diode and the Avalanche Photo Diode for various parameters are given below:

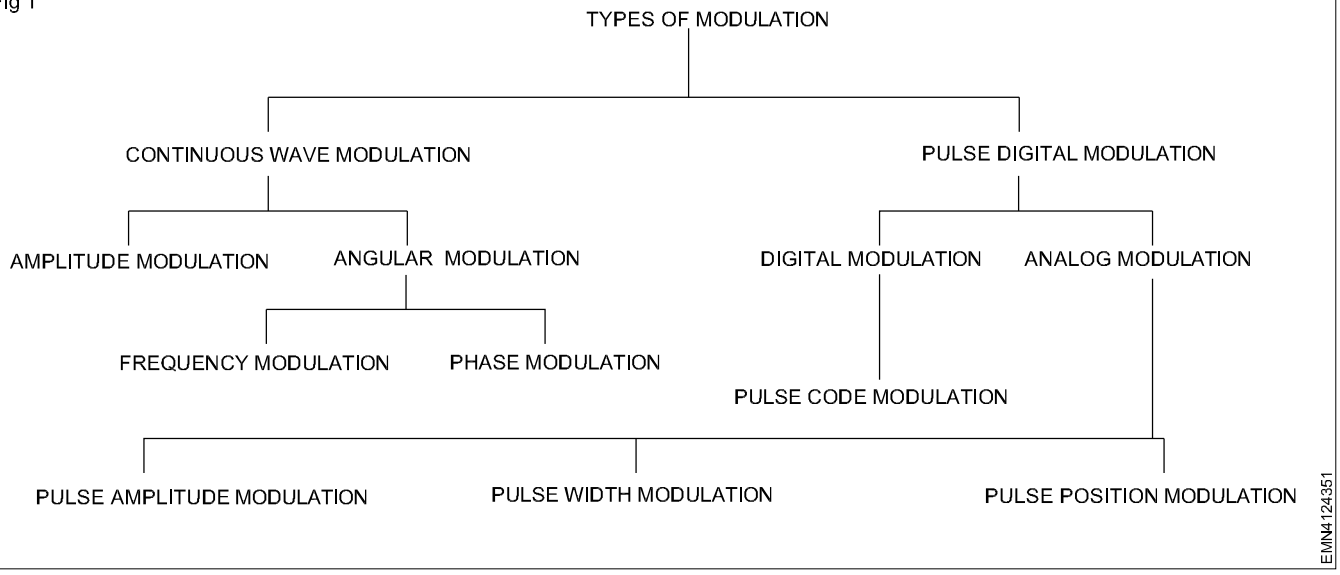
Sl. No.	Parameter	PIN	APD
1	Sensitivity	Less Sensitivity (0-12db)	More sensitivity (5-15db)
2	Biasing	Low reverse biased voltage (5 to 10v)	High reverse biased voltage (20-400v)
3	Wave length region	300- 1100nm	400-1000nm
4	Gain	No internal Gain	internal Gain
5	S N Ratio	Poor	Better
6	Detector circuit	Simple	More complex
7	Cost	cheaper	More expensive

Pulse modulation technique

Objectives : At the end of this lesson you shall be able to
- **define pulse**
- **state the types of pulse modulation**
- **explain PCM,PAM,PWM and PPM**
- **state the advantages, disadvantage and applications of each type of modulation**
- **compare the different types of pulse modulation techniques.**

Types of modulation - Tree Diagram

Fig 1

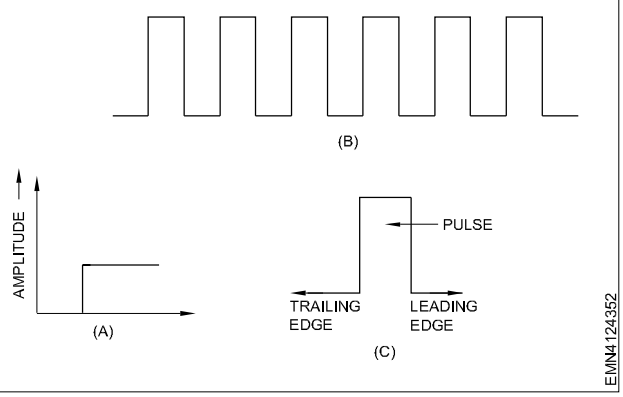


AM, FM modulation & demodulation already we discussed in Semester 3 Communication Electronics topic. Here we can discussed with PWM, PPM.

Pulse

A pulse is an abruptly changing voltage or current wave which may or may not repeat itself as shown in Fig 2. The Fig 2(b) Shows a repetitive pulse train and Fig 2(c) shows a pulse with its trailing and leading edges.

Fig 2



Pulse modulation

It may be defined as a modulation system in which some parameter of a train of pulse is varied in accordance with the instantaneous value of the modulating signal. In this system, waveforms are sampled at regular intervals and the information is transmitted through the sampling rate. The parameters of the pulses which may be varied are : amplitude, width (or duration), position and time etc

In pulse modulation, there are different types of modulation techniques for analog and digital as given below:

PCM : Pulse Code Modulation for Digital Modulation.

PPM : Pulse Position Modulation for Analog Modulation

PWM : Pulse Width Modulation for Analog Modulation.

PAM : Pulse Amplitude Modulation for Analog Modulation.

1 Pulse Code Modulation (PCM)

PCM will transmit the analog in a digital form, whose signal is sampled at regular intervals of time and quantized at same quantum levels to digital code as shown in Fig 3. We know that digital code is nothing but binary code which consists of 1's and 0's that is logic1 and logic0. So we will transmit the digital data in the form of 1's and 0's. When the signal is received by the receiver, demodulator in the receiver will demodulate the binary signal back into pulses with same quantum levels like in modulator and these pulses are again used for regenerating the required analog signal.

Advantages of Pulse Code Modulation

1 Pulse code modulation will have low noise addition and data loss is also very low.

2 The received signal is exact replica of the transmitting signal without any distortion loss.

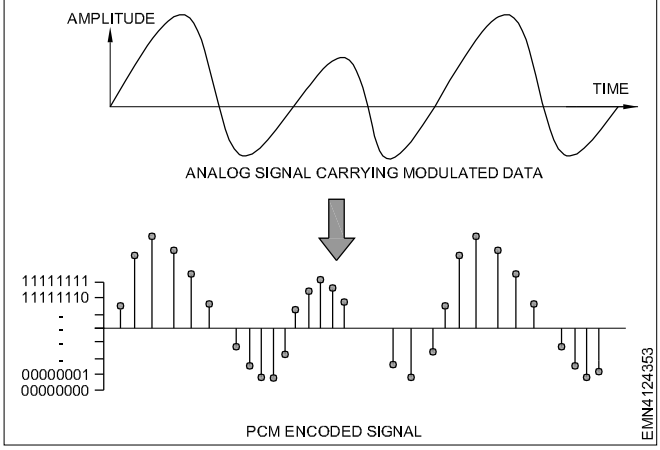
3 PCM can encode the data.

4 Multiplexing of signals can also be done using pulse code modulation. Multiplexing is nothing for adding the different signals and transmitting the signal at same time.

5 Pulse code modulation permits the use of pulse regeneration.

6 PCM can be used in storing data.

Fig 3



Disadvantages of Pulse Code Modulation

1 Specialized complicated complex circuitry is required for transmitting and encoding.

2 Pulse code modulation receivers are costlier than other modulation receivers.

3 Developing pulse code modulation is bit complicated and checking the transmission quality is also difficult and takes more time.

4 It requires larger bandwidth than normal analog signals to transmit message.

5 Channel bandwidth should be more for digital encoding.

6 Decoding also needs special equipments and they are also too complex.

Applications of Pulse Code Modulation (PCM)

i Pulse code modulation is used in telecommunication systems, air traffic control systems etc.

ii Pulse code modulation is used in compressing the data that is why it is used in storing data in optical disks like DVD, CDs etc. PCM is even used in the database management systems.

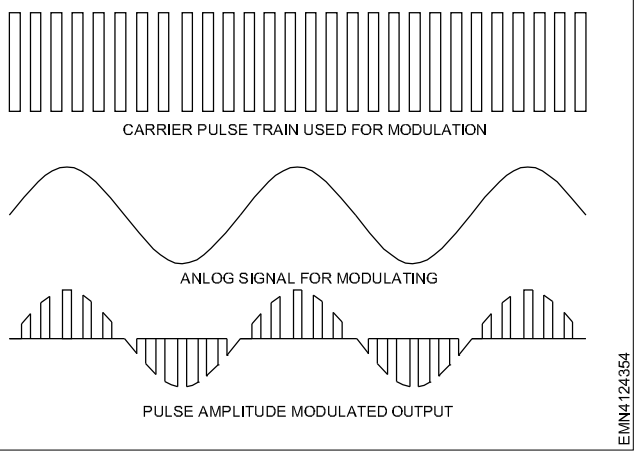
iii Pulse code modulation is used in mobile phones, normal telephones etc.

iv Remote controlled cars, planes, trains use pulse code modulations technique.

2 Pulse Amplitude Modulation (PAM)

In pulse amplitude modulation, the amplitude of regular interval of periodic pulses or electromagnetic pulses are varied in proportion to the sample of modulating signal or

Fig 4



message signal as shown in Fig 4. This is an analog type of modulation. These sample pulses can be transmitted directly using wired media or we can use a carrier signal for transmitting through wireless. It is almost equal to amplitude modulation.

Advantages of Pulse Amplitude Modulation (PAM)

1 It is the base for all digital modulation techniques and it is simple process for both modulation and demodulation technique.

2 No complex circuitry is required for both transmission and reception. Transmitter and receiver circuitry is simple and easy to construct.

3 PAM can generate other pulse modulation signals and can carry the message or information at the same time.

Disadvantages of Pulse Amplitude Modulation (PAM)

1 Bandwidth should be large for transmitting the pulse amplitude modulation signal.

2 The frequency varies according to the modulating signal or message signal. Due to these variations in the signal frequency, interferences will be there. So noise will be great. Pulse amplitude signal varies, so power required for transmission will be more, peak power is also, even at receiving more power is required to receive the pulse amplitude signal.

Applications of Pulse Amplitude Modulation (PAM)

i It is mainly used in Ethernet which is type of computer network communication.

ii It is also used for photo biology which is a study of photosynthesis.

iii Used as electronic driver for LED lighting.

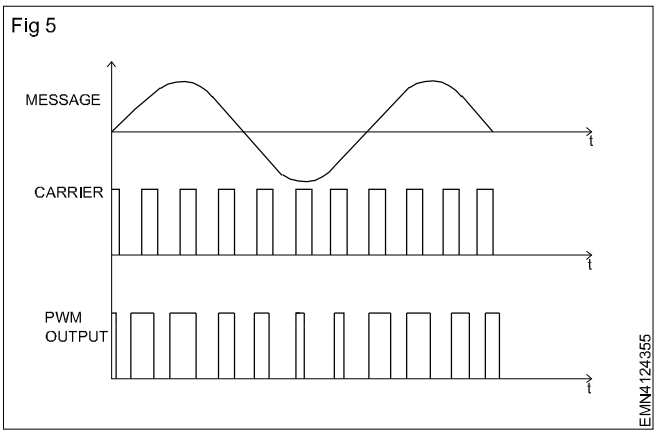
iv Used in many micro controllers for generating the control signals etc.

3 Pulse Width Modulation (PWM) or Pulse Duration Modulation (PDM):

It is a type of analog modulation. In pulse width modulation or pulse duration modulation, the width of the pulse carrier is varied in accordance with the sample values of modulating signal as shown in Fig 5. In this the amplitude

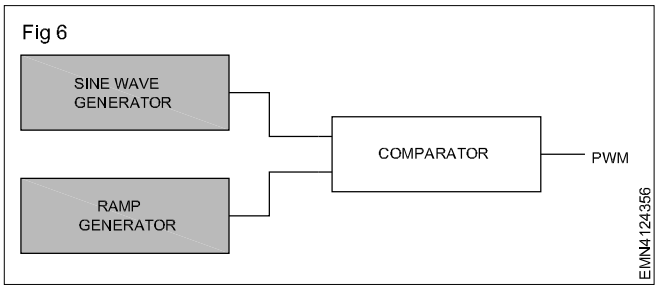
is made constant and width of pulse and position of pulse is made proportional to the amplitude of the signal.

Fig 5



The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown in the Fig 6.

Fig 6



Advantages of Pulse Width Modulation (PWM)

i Noise interference is less due to amplitude has been made constant.

ii Signal can be separated very easily at demodulation and noise can also be separated easily.

iii Synchronization between transmitter and receiver is not required.

Disadvantages of Pulse Width Modulation (PWM)

i Power will be variable because of varying in width of pulse. Transmitter can handle the power even for maximum width of the pulse.

ii Bandwidth should be large to use in communication, should be huge even when compared to the pulse amplitude modulation.

Applications of Pulse Width Modulation (PWM)

i PWM is used in telecommunication systems.

ii PWM can be used to control the amount of power delivered to a load without incurring the losses. So, this can be used in power delivering systems.

iii Audio effects and amplifications purposes also used.

iv PWM signals are used to control the speed of the robot by controlling the motors.

v PWM is also used in robotics.

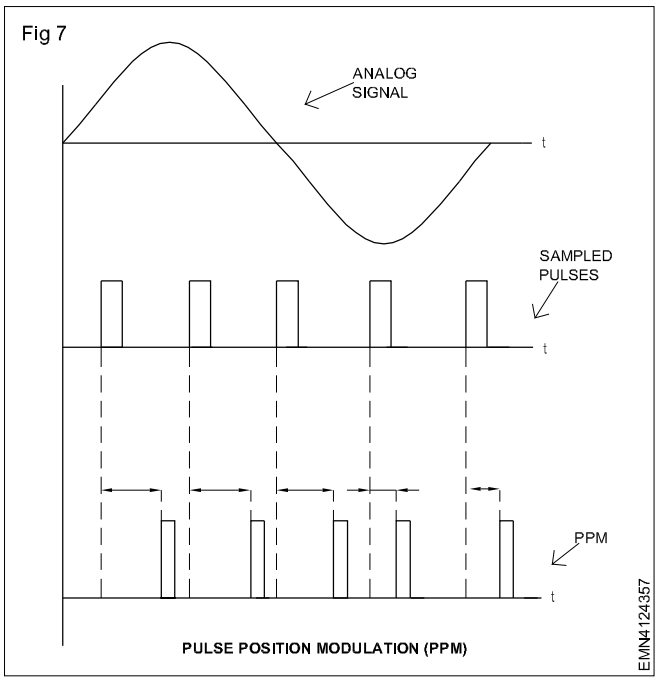
vi Embedded applications.

vii Analog and digital applications etc.

4 Pulse Position Modulation (PPM)

In the pulse position modulation, the position of each pulse in a signal by taking the reference signal is varied according to the sample value of message or modulating signal instantaneously. In the pulse position modulation, width and amplitude is kept constant. It is a technique that uses pulses of the same breadth and height but is displaced in time from some base position according to the amplitude of the signal at the time of sampling. The position of the pulse is 1:1 which is proportional to the width of the pulse and also proportional to the instantaneous amplitude of sampled modulating signal. The position of pulse position modulation is easy when compared to other modulation.

Fig 7



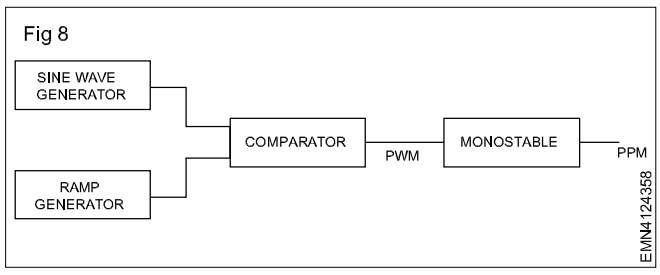
The waveform of the Pulse position modulation is as follows. (Fig 7)

The Pulse Position Modulation (PPM) is a modulation technique designed to achieve the goals like simple transmitter and receiver circuitry, noise performance, constant bandwidth and the power efficiency and constant transmitter power.

In Pulse Position Modulation the amplitude of the pulse is kept constant as in the case of the FM and PWM to avoid noise interference. Unlike the PWM the pulse width is kept constant to achieve constant transmitter power.

Fig 8 shows the block diagram of PPM.

Fig 8



It requires pulse width generator and monostable multivibrator.

Pulse width generator is used for generating pulse width modulation signal which will help to trigger the monostable multivibrator, here trialling edge of the PWM signal is used for triggering the monostable multivibrator. After triggering the monostable multivibrator, PWM signal is converted into pulse position modulation signal.

Advantages of Pulse Position Modulation (PPM):

1 Pulse position modulation has low noise interference when compared to PAM because amplitude and width of the pulses are made constant during modulation.

2 Noise removal and separation is very easy in pulse position modulation.

3 Power usage is also very low when compared to other modulations due to constant pulse amplitude and width.

Disadvantages of Pulse Position Modulation (PPM):

1 The synchronization between transmitter and receiver is required, which is not possible for every time and we need dedicated channel for it.

2 Large bandwidth is required for transmission same as pulse amplitude modulation.

3 Special equipments are required in this type of modulations.

Applications of Pulse Position Modulation (PPM):

1 Used in non coherent detection where a receiver does not need any Phase Locked Loop(PLL) for tracking the phase of the carrier.

2 Used in radio frequency (RF) communication.

3 Also used in contactless smart card, high frequency, RFID (radio frequency ID) tags, etc.

Comparison between PAM,PWM,PPM

The differences between PAM,PWM and PPM are given in the table below:

Sl. No.	PAM	PWM(or PDM, PLM)	PPM
1.	Amplitude of the carrier pulse is proportional to the amplitude of the modulating signal.	The width (or duration or length) of the carrier pulse is proportional to the amplitude of the modulating signal.	The relative position of the carrier pulse is proportional to the amplitude of the modulating signal.
2.	The B.W. of the transmitting channel depends upon the width of the pulse.	The B.W. of the channel depends upon rise time of the pulse B.W. = ½ t Where t is the rise time	The B.W. of the channeldepends upon the rise time of the pulse. B.W. = ½ t
3.	The instantaneous power of the transmitter varies.	The instantaneous power of the transmitter varies.	The instantaneous power of the transmitter remains constant.
4.	Noise interference is high.	Noise interference is low.	Noise interference is low.
5.	Similar to amplitude modulation(AM)	Similar to frequency modulation (AM)	Similar to phase modulation(PM)

1 Fiber optic cable connector

- A fiber - optic cable connector is a mechanical device which is used to terminate the end of a fiber-optic cable and it enables a quicker connection and disconnection with respect to joining which is a permanent, method of joining. The use of fiber-optic cable connectors net result is attenuation in signal strength.
- It consists of an adapter and two connector plugs. Most of the connectors are spring loaded so that the two fiber faces remains pressed together, leaving no air-gap between them, when the connectors are mated.
- Separate connectors are made for glass to glass fibers and teflon to teflon fibers. Different types of fiber optic cable connectors are shown in fig.1 is described as follows:

a Standard connector (SC) - SC connectors use a ceramic ferrule to deliver accurate alignment of the Single Mode Fiber (SMF). The SC connector comes with a locking tab that enables push on /Pull off operation and it is simple, rugged and low cost. SC connectors are in the shape of square or rectangle.

b Ferrule core connector (FC) - FC connectors are widely used in fiber optic networks. This connector used a threaded container and a position locatable notch to achieve exact locating of the Single Mode Fiber (SMF) in relation to the receiver and the optical source.

C Straight Tip (ST) connector - The ST connector's keyboard bayonet design is similar to that of a BNC (Bayonet Nut Connector or Baynot Neill-Concelman) connector. The connector is used widely for multi-meter fiber (MMF) and singlemode fiber (SMF) fiber

optic communication (FOC) and is extremely easy to use. The ST connector is manufactured in two versions - the ST and the ST-II. Both types are keyed and spring loaded, and use a “push-in and twist” mechanism. ST connectors are mainly designed for use with glass, they can also be used with plastic FOC.

d **SMA (Subminiature version-A) connector** - The obsolete SMA connector was the forerunner to the ST connector. This connector was eventually replaced by the ST, and later by SC connectors. SMA connectors are mainly designed for use with glass, they can also be used with plastic FOC.

e **Lucent connector (LC)** - The LC, sometimes referred to as the little connector, is a small form factor FOC that uses a 1.25mm ferrule.

f **Plastic fiber optic cable connectos** - There are relatively fewer plastic connectors available when compared to glass fiber. These connectors are cheaper and are primarily designed for easy application. Polished and epoxy options are generally not available for plastic connectors.

g **Enterprise systems connection connector (ESCON)** - ESCON connectors were developed by IBM for interfacing peripheral storage devices, including tape drives, to their mainframes. ESCON is a half-duplex serial interface that uses FOC.

h **Fiber distributed data interface connector (FDDI)** - FDDI provides data transmisson at 100 Mbps in a dual ring token local area network within a 200-kilometer rang. The FDDI connector connects network equipment to a wall plug.

i **Opti-jack Connector** - The opti-jack duplex connector resembles the universal RJ-45 connector. The package contains two ST type ferrules and is a rugged plug-and-jack (female/male) connector.

j **LX-5 Connector** - The LX-5 provides high density, high performance and reliable connections. This connector uses automatic metal shutter technology in a standardized small form factor package with a 1.25mm ferrule.

k **MT-RJ Connector** - The single polymer ferrule duplex MT-RJ connector includes alignment. It is available in female/male connectors, or a plug-and-jack format.

l **MU Connector** - MU connectors have a reduced footprint and are new generation connectors used mainly in dense applications. The connector is square and employs a push-pull matching mehcanism.

m **MT Connector** - The MT connector is a ribbon cable that has 12 fiber connectors. They are used for factory terminated cable assemblies and cabling systems.

n **E2000 Connector** - Modern day telecommunication networks increasingly make use of E2000 connectors.

Fig 1

The inclusion of an integrated spring loaded shutter is a unique feature of this connector. The E2000 is a latched push-pull locking connector. The major advantages of this connector are the enhanced safety and high performance due to shutter mechanism and the monobloc ferrule.

o **Local connectos (LC)** - which is in the shape of round.

- The most widely used connector for fiber optic cable is SMA (Subminiature version-A).

2 Precautions and safety aspects while handling optical cables

- Optical fibers are made of glass or plastic fibers therefore, following safety precaution should be taken into consideration while using them.

Micro bending: A problem that often occurs in cabling of the optical fiber is the twisting of the fiber core axis an a microscopic scale within the cable form. This phenomenon known as microbending result from small lateral forces exerted on the fiber during the cabling process and it causes losses due to radiation in both multimode and single mode fiber. Do bend the fiber more than 200% of its core diameter.

Example:

- Diameter of bend for optical fiber 125mm will be 25 mm
- Diameter of bend for optical fiber of 400mm will be 80mm.
- Do not keep any heavy load or hand machine on the fiber.
- Protect the fiber from sharp edges otherwise that can damage its protection jacket and harm the cladding and core.
- Fiber should not come in contact of any abrasive or acetone etc.
- Do not throw the pieces of fibers in dustbin etc. and do keep pieces of glass with optical fibers.
- Do not keep eatables or beverages near the ends of optical fibers as they have a high radiation.

Fiber optical splicing

Objectives : At the end of this lesson you shall be able to
- **define splicing**
- **state the related tools used along with splicer**
- **explain cleaving**
- **explain various steps involved in the splicing.**

Introduction

Splicing is the process of joining two ends of optical fiber using electric arc or mechanical means.

In practice, to cover larger distance and as well as to repair the OFC cuts, joints have to be made i.e. OFC has to be joined. This joining is called as splicing.

Fiber splicing is a complicated procedure and requires skilled manpower to achieve. We should completely clean off the gel component when the cable end is stripped for termination.

The necessary tools and accessories for splicing are splicing machine, cleaver, cable cutter, iso-propyl alcohol and tissue paper as shown in Fig 1 and 2.

Fig 1

Fig 2

Splicing machine

A special machine which is used to join the fiber using fusion technique.

Clever (diamond cutter)

It is used to cut optical fiber perpendicular to cable axis exactly by 90 degrees.

Multi purpose cutter (stripper)

It is used to remove primary coating of fiber.

Iso-propyl alcohol, acetone and tissue paper

It is used to clean the dust of fiber before splicing.

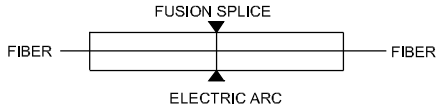
Fusion splicing

The fusion splicers are shown in the Fig 3.

Splicing is the practice of joining two fibers together without using fiber connectors as shown in Fig 4. Two types of fiber splices exist: fusion splicing and mechanical splicing. Splicing may be made during installation or repair.

Fig 3 Fusion splicer Fusion optic cleaver Heat shrink tube

Fig 4



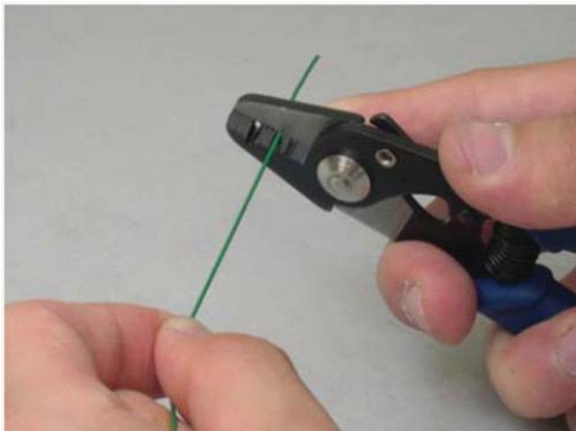
Splices generally have lower loss and better mechanical integrity than connectors, while connectors make system configuration much more flexible. So typically, splices are used to connect fiber cables in outdoor applications and connectors terminate fiber cables inside buildings.

Fusion splicing process has to use high temperature heat generated by electric arc and fuse two glass fibers together (end to end with fiber core aligned precisely). The tips of two fibers are butted together and heated so they melt together. This is normally done with a fusion splicer, which mechanically aligns the two fiber ends, then applies a spark across the fiber tips to fuse them together.

Four basic steps to complete a proper fusion splicing

Step 1

Fig 5



Preparing the fiber - Strip the protective coatings, jackets, tubes, strength members, etc. leaving only the bare fiber showing. The main concern here is cleanliness. (Fig 5)

Step 2

Cleave the fiber - Using a good fiber cleaver, that is essential for a successful fusion splicing. The cleaved end must be mirror-smooth and perpendicular to the fiber axis to obtain a proper splice. These cleavers can consistently producing a cleave angle of 0.5 degree or less.(Fig 6)

Step 3

Fuse the fiber - There are two steps within this step, alignment and heating. Alignment can be manual or automatic depending on what equipment you have. The higher priced equipment you use, the more accurate the alignment becomes. Once properly aligned the fusion splicer unit then uses an electrical arc to melt both the fiber ends joined together permanently as shown in Fig 7.

Step 4

Protect the fiber - Protecting the fiber from bending and tensile forces will ensure the splice not break during normal handling. A typical fusion splice has a tensile strength between 0.5 and 1.5 lbs and will not break during normal handling but it still requires protection from excessive bending and pulling forces. Using heat shrink tubing, silicone gel and/or mechanical crimp protectors will keep the splice protected from outside elements and breakage.

Mechanical splicing method

Mechanical splicing is an optical junction where the fibers are precisely aligned and held in place by a self-contained assembly, not a permanent bond. This method aligns the two fiber ends to a common centerline, aligning

Fig 6

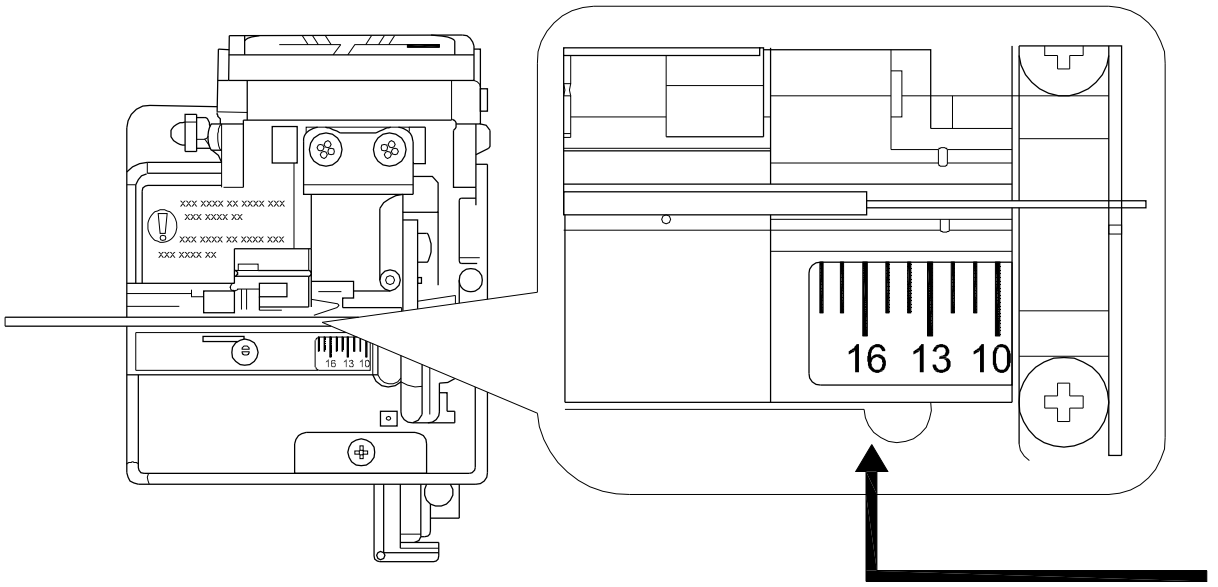
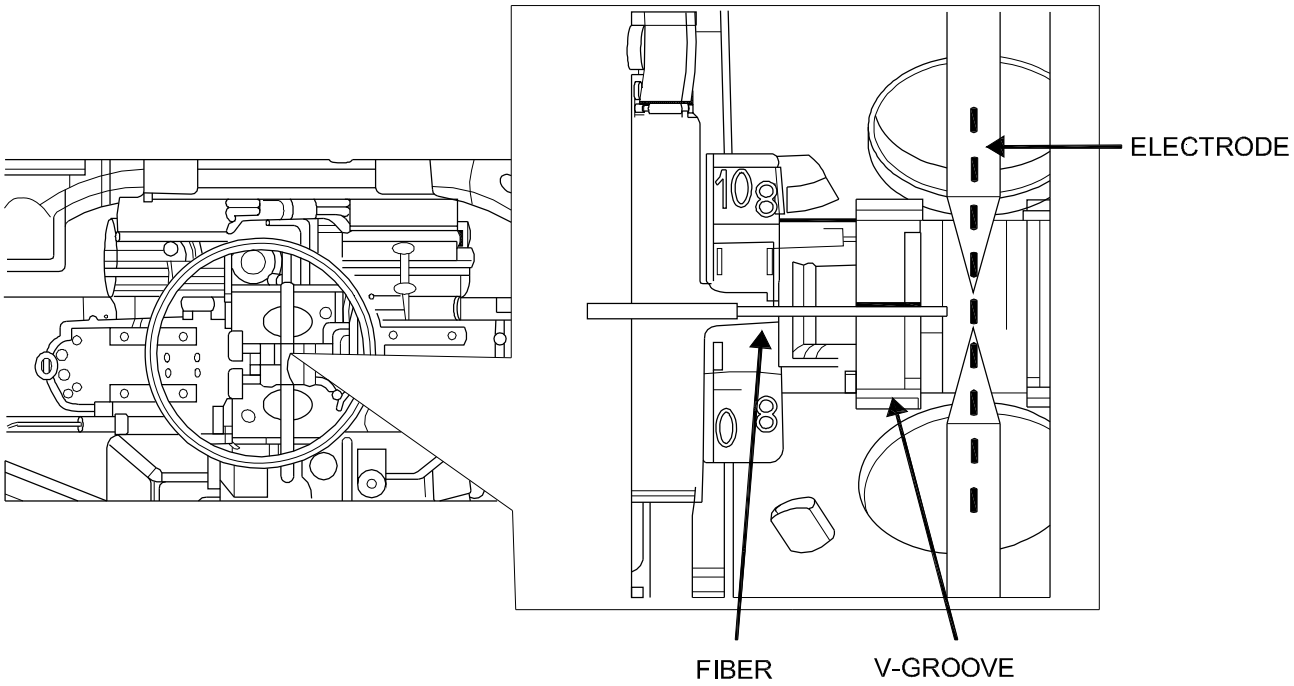
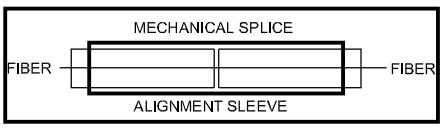


Fig 7



their cores so the lights can pass from one fiber to another. (Fig 8)

Fig 8



Four steps to performing a mechanical splicing

Step 1

Preparing the fiber - strip the protective coatings, jackets, tubes, strength members, etc. leaving only the bare fiber showing. The main concern here is cleanliness.

Step 2

Cleave the fiber - The process is identical to the cleaving for fusion splicing but the cleaving precision is not a critical aspect.

Step 3

Mechanically join the fibers - There is no heat used in this method. Simply position the fiber ends together inside the mechanical splice unit. The index matching gel inside the mechanical splice apparatus will help couple the light from one fiber end to the other. Older apparatus will have an epoxy rather than the index matching gel holding the cores together.

Step 4

Protect the fiber - the completed mechanical splicing provides its own protection for the splice.

Mechanical splicing Vs Fusion splicing

Mechanical splicing

Mechanical splices are simply alignment devices, designed to hold the two fiber ends in a precisely aligned position thus enabling light to pass from one fiber into the other. (Typical loss : 0.3 dB)

Fusion splicing

In fusion splicing a machine is used to precisely align the two fiber ends then the glass ends are "fused" or "welded" together using some type of heat or electric arc. This produces a continuous connection between the fibers enabling very low loss transmission. (typical loss : 0.1 dB)

Which method is better?

The typical reason for choosing one method over the other is economy. Mechanical splicing has a low initial investment but costs more per splice. While the cost per splice for fusing splicing is lower, the initial investment is much higher. The more precise you need the alignment (better alignment results in lower loss) the more you pay for the machine.

Precautions to be taken while laying of cable

1 Before laying the different cable sections, all reels should be visually inspected for possible transportation damage.

2 Before pulling the cable, ensure the stability of the pay-off.

3 To avoid possible damage from a sudden stop, the pay-off must be equipped with a progressive braking system. Under no circumstances should the reel be stopped by hand.

4 The route defined by the design should be accessible and available in accordance with the installation schedule. The users should be advised of all proposed deviations.

5 The installer should establish that the environmental conditions within the routes and the installation methods to be used are suitable for the optical fibre cable to be installed (Check the datasheet of the cable used). If the route contains sections where the optical cable is subject to high temperatures the necessary protection should be provided. Look out for heating tubes, which are not heated all the time.

6 Any measure necessary should be taken to prevent the optical cable experiencing direct stress following installation.

7 The installer should determine the locations at which reels are to be positioned during the installation program.

8 Where necessary, the minimum quantity of ceiling tiles, floor covers should be removed.

9 The installer should ensure that all necessary guards, protective structures and warning signs are used to protect both the optical cable and third parties. Relevant national legislation for safe working practices must be complied with.

Fiber Optic Installation Safety Rules:

1 Keep all food and beverages out of the work area. If fiber particles are ingested they can cause internal hemorrhaging.

2 Wear disposable aprons to minimize fiber particles on your clothing. Fiber particles on your clothing can later get into food, drinks, and/or be ingested by other means.

3 Always wear safety glasses with side shields and protective gloves. Treat fiber optic splinters the sarne as you would glass splinters.

4 Never look directly into the end of fiber cables until you are positive that there is no light source at the other end. Use a fiber optic power meter to make certain the fiber is dark. When using an optical tracer or continuity checker, look at the fiber from an angle at least 6 inches away from your eye to determine if the visible light is present.

5 Only work in well ventilated areas.

6 Contact lens wearers must not handle their lenses until they have thoroughly washed their hands.

7 Do not touch your eyes while working with fiber optic systems until they have been thoroughly washed.

8 Keep all combustible materials safely away from the curing ovens.

9 Put all cut fiber pieces in a safe place.

10 Thoroughly clean the work area.

11 Do not smoke while working with fiber optic systems.

Testing of optical fiber

Objectives : At the end of this lesson you shall be able to
- **define testing**
- **state the different procedures followed for testing**
- **explain different types of testing of fiber optic component**
- **explain the working of OTDR.**

Fiber testing

After the installation of cable, next step is testing. Testing is the process to evaluate the performance of fiber optic components (like fiber, connectors, splices, LED or laser sources, detectors and receivers), cable plants and systems. Testing confirms their performance, specifications and helps understand how they will work together.

Procedures are required under the testing some are listed below

1 Selection of tools

i Source and power meter, optical loss test set or test kit with proper equipment adapters for the cable network are required for testing.

ii Reference test cables that match the cables to be tested and mating adapters, including hybrids if needed.

iii Fiber tracer or Visual fault locator.

iv Cleaning materials - lint free cleaning wipes and pure alcohol.

v OTDR and launch cable for outside plant jobs.

2 Documentation

This is an important part of the testing of fiber. Make sure all cable layouts are available before testing the network. Prepare a spread sheet of all the cables and print a copy for recording each test data.

3 Safety notes

Fiber optic sources, including test equipment, are generally too low in power to cause any eye damage, but it's still a good idea to check connectors with a power meter before looking into it. Some systems like CATV have very high power and they could be harmful.

Types of testing

There are three basic tests

1 Visual inspection for continuity or connector checking

2 Loss testing

3 Network Testing.

Visual inspection

Visual tracing

Continuity checking makes sure that the fibers are not broken and to trace a path of a fiber from one end to another through many connections by using a visible light "fiber optic tracer" or "pocket visual fault locator". It looks like a flashlight or a pen-like instrument with a light bulb or LED source that mates to a fiber optic connector. Attach a cable to test to the visual tracer and look at the other end to see the light transmitted through the core of the fiber. If there is no light at the end, go back to intermediate connections to find the faulty section of the cable.

Visual fault location

A higher power version of the tracer uses a laser that can also find faults. The red laser light is powerful enough to show breaks in fibers or high loss connectors. It also use this gadget to optimize mechanical splices or pre polished-splice type fiber optic connectors.

Visual connector inspection

Fiber optic microscopes are used to inspect connectors to check the quality of the termination procedure and diagnose problems. A well made connector will have a smooth, polished, scratch free finish and the fiber will not show any signs of cracks, chips or areas where the fiber is either extended from the end of the ferrule(connector) or pulling back into it.

The magnification for viewing connectors can be 30 to 400 times but it is best to use a medium magnification. The best microscopes allow you to inspect the connector from several angles, either by tilting the connector or having angle illumination to get the best picture of what's going on. Check to make sure the microscope has an easy-to-use adapter to attach the different types of connectors to the microscope.

Optical power ("Absolute" vs. "Relative")

Fig 1

Practically every measurement in fiber optics refers to optical power. The power output of a transmitter or the input to receiver are "absolute" optical power measurements, that is, it can measure the actual value of

the power. Loss is a "relative" power measurement. A simple method for the power measurement is shown in Fig 1.

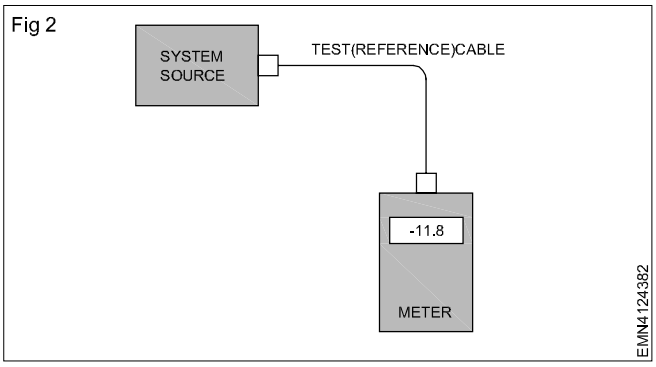
Measuring power

Power in a fiber optic system is like voltage in an electrical circuit - it's what makes things happen! It's important to have enough power, but not too much. Too little power and the receiver may not be able to distinguish the signal from noise; too much power overloads the receiver and causes errors too.

Measuring the power requires a power meter. For that, the meter must be set to the proper range (usually dBm, sometimes microwatts, but never "dB" that's a relative power range used only for testing loss!) and the proper wavelengths matching the source being used.

To measure the receiver power, a reference test cable (tested and known to be good) is attached with the meter to the output side of the cable ., or to a reference test cable (tested and known to be good) that is attached to the transmitter, acting as the "source", to measure transmitter power as shown in Fig 2.

Fig 2



Turn on the transmitter/source and note the power the meter measures. Compare it to the specified power for the system and make sure it's enough power but not too much.

Loss Testing

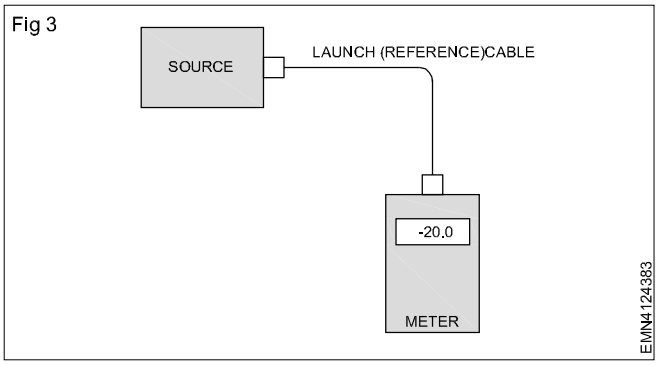
Testing loss is the difference between the power coupled into the cable at the transmitter end and what comes out at the receiver end. Testing for loss requires measuring the optical power lost in a cable (including connectors , splicers, etc.) with a fiber optic source and power meter by using good reference cables.

The accuracy of the measurement is depends on the quality of reference cables used.

Turn on the source and select the wavelength required for the loss test. Turn on the meter, select the "dBm" or "dB" range and select the wavelength value for the loss test. Measure the power at the meter. This is the reference power level for all loss measurements as shown in the Fig 3.

There are two methods that are used to measure loss, "single-ended loss" and "double-ended loss". Single-ended loss uses only the launch cable, while double-ended loss uses a receive cable attached to the meter also. Single-ended loss is measured by connecting

Fig 3



together with the cable has to be tested, to the reference launch cable and measuring the power out the far end with the meter.

In a double-ended loss test, can attach the cable to test between two reference cables, one attached to the source and the other to the meter.

Network Testing

OTDRs were originally designed to test and troubleshoot long haul networks.

OTDR (Fig 4)

Fig 4

An Optical Time-Domain Reflecto meter (OTDR) is an optoelectronic instrument used to characterize an optical fiber. Fig4 shows various types of OTDR normally available. It injects a series of optical pulses into the fiber under test and extracts, from the same end of the fiber, light that is scattered (Rayleigh backscatter) or reflected back from points along the fiber. The scattered or reflected light that is gathered back is used to characterize the optical fiber. The strength of the return pulses is measured and integrated as a function of time, and plotted as a function of fiber length.

Reliability and quality of OTDR equipment

The reliability and quality of an OTDR is based on its accuracy, measurement range, ability to resolve and

measure closely spaced events(Connectors and splices), measurement speed, and ability to perform satisfactorily under various environmental extremes and after various types of physical abuse. The instrument is also judged on the basis of its cost, features provided, size, weight, and ease of use.

Some of the terms often used in specifying the quality of an OTDR are as follows:

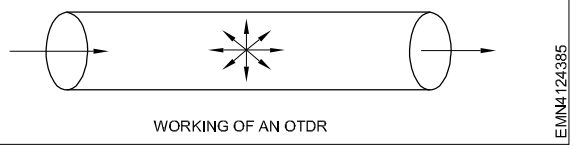
Accuracy: Defined as the correctness of the measurement i.e., the difference between the measured value and the true value of the event being measured.

Measurement range: Defined as the maximum attenuation that can be placed between the instrument and the event being measured, for which the instrument will still be able to measure the event within acceptable accuracy limits.

Instrument resolution: Is a measure of how close two events(Connectors and splices) can be spaced and still be recognized as two separate events.

Working of an OTDR (Fig 5)

Fig 5



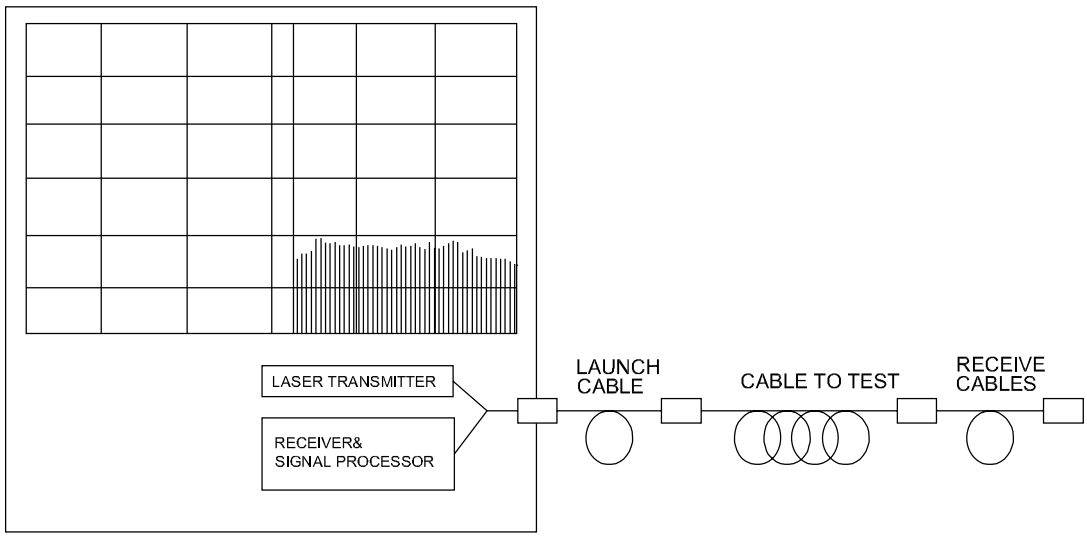
WORKING OF AN OTDR

EMN4124385

Unlike sources and power meters which measure the loss of the fiber optic cable plant directly, the OTDR works indirectly. The source and meter duplicate the transmitter and receiver of the fiber optic transmission link, so the measurement correlates well with actual system loss. (Fig 6)

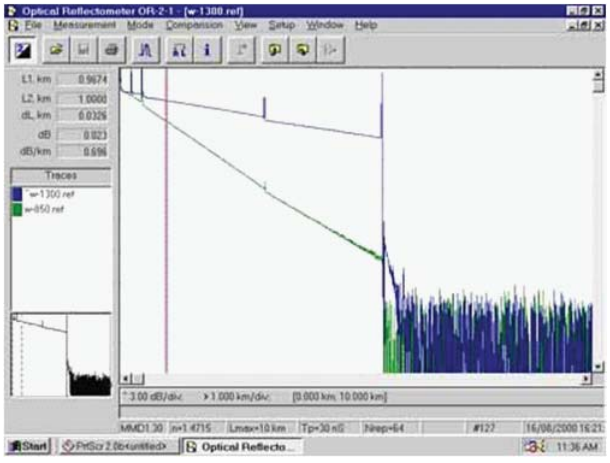
The OTDR, however, uses backscattered light of the fiber to imply loss. The OTDR works as shown in Fig 7and 8 like RADAR, sending a high power laser light pulse down the fiber and looking for return signals from backscattered light in the fiber itself or reflected light from connector or splice interfaces.

Fig 6



EMN4124386

Fig 7



At any point in time, the light the OTDR sees is the light scattered from the pulse passing through a region of the fiber. Only a small amount of light is scattered back toward the OTDR, but with sensitive receivers and signal averaging, it is possible to make measurements over relatively long distances. Since it is possible to calibrate the speed of the pulse as it passes down the fiber, the OTDR can measure time, calculate the pulse position in the fiber and correlate what it sees in backscattered light with an actual location in the fiber. Thus it can create a display of the amount of backscattered light at any point in the fiber.

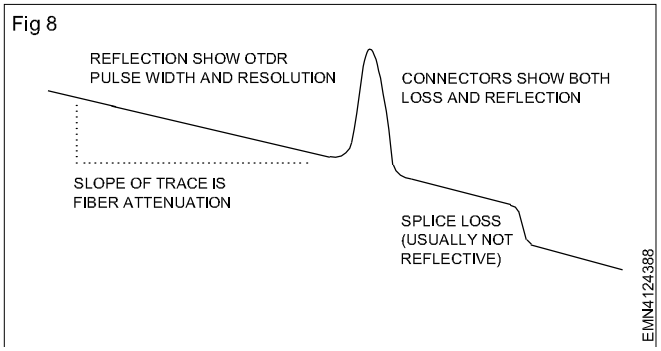
Since the pulse is attenuated in the fiber as it passes along the fiber and suffers loss in connectors and splices, the amount of power in the test pulse decreases as it passes along the fiber in the cable plant under test. Thus the portion of the light being backscattered will be reduced accordingly, producing a picture of the actual loss

occurring in the fiber. Some calculations are necessary to convert this information into a display, since the process occurs twice, once going out from the OTDR and once on the return path from the scattering at the test pulse. (Fig 7)

As shown in fig. can Compare two traces in the same window is useful for confirming data collection and contrasting different test methods on the same fiber. Comparisons are also used to compare fiber traces during troubleshooting with traces take just after installation to see what has changed. All OTDRs offer this feature.

There is a lot of information in an OTDR display. The slope of the fiber trace shows the attenuation coefficient of the fiber and is calibrated in dB/km by the OTDR. In order to measure fiber attenuation, need a fairly long length of fiber with no distortions on either end from the OTDR resolution or overloading due to large reflections. If the fiber looks nonlinear at either end, especially near a reflective event like a connector, avoid that section when measuring loss. (Fig 8)

Fig 8



OTDRs can also detect problems in the cable caused during installation. If a fiber is broken, it will show up as the end of the fiber much shorter than the cable or a high loss splice at the wrong place. If excessive stress is placed on the cable due to kinking or too tight a bend radius, it will look like a splice at the wrong location.

OTDR Limitations

The limited distance resolution of the OTDR makes it very hard to use in a LAN or building environment where cables are usually only a few hundred meters long. The OTDR has a great deal of difficulty resolving features in the short cables of a LAN and is likely to show "ghosts" from reflections at connectors, more often than not simply confusing the user.

Introduction of panel meter

Objectives : At the end of this lesson you shall be able to
- **explain analog panel meter**
- **explain digital panel meter**
- **describe the working of a seven segment display**
- **state the types of seven segment display.**

Introduction

Panel meters are instruments that display an input signal in analog or digital form. These are available in two types as

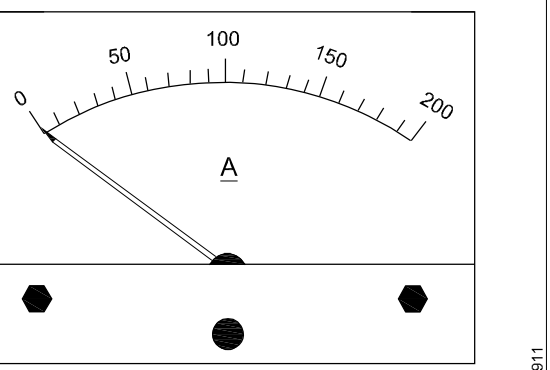
1 Analog panel meter (APM)

2 Digital panel meter (DPM)

Analog Panel Meter (APM)

An analog panel meter uses a moving pointer and a dial to display information, and works on either the band or the jewel and pivot method. A taud band device uses a pointer suspended between two ribbons of metal. Able to withstand high-shock. It generally measures direct current (DC). The less accurate pivot and jewel unit has a coil and pointer supported by polished steel, which fits into two jewel bearings. Better at withstanding vibration, it typically measures alternating current (AC) as shown in Fig 1.

Fig 1



An analog panel meter is more economical than its digital counterpart, but it is less accurate. Non-linear movement can produce errors, and the small meter screen can be difficult to interpret. It typically displays one value, however, so it's considered quicker to read. Analog meters are useful when relative change is more important than absolute accuracy.

Digital Panel Meter (DPM)

A digital panel meter is used to measure and display all types of processes and electrical variables, voltage current, flow, speed, etc. It has a bright LED display that presents information in an alphanumerical format with little or no ambiguity. Many digital panel meters can accept multiple inputs and have adjustable or bar graph displays that allow users to easily switch between these inputs. Displays may also have totalizing, recording, conditioning, or other functional capabilities.

Fig 2

Digital panel meter have two types of displays

1 LED Display

2 LCD display

Digital panel meters are available in LED or LCD display. LED (Light Emitting Diode) display is the easiest to see even in small character heights and is available in colour. LCD (liquid Crystal Display) can be either unlighted "transflective" that depends on ambient lighting or back lighted and can be hard to read at certain angles and lighting. Since Digital Panel Meters actually measure voltages in discrete steps, all inputs must be scaled to match the full count range of the meter. A 3 digit digital panel meter has a count range of 0-999 where a 3½ digit doubles the count to 1999 for very little extra electronics circuits. Scaling for the Digital Panel Meters is accomplished by using a voltage divider usually dividing down the input by a factor of 10, 100, 1000 although there are other factors used.

Visual display of decimal digits (0, 1, 2, ---, 8, 9) is an important task. In 1970's nixie tube were used but now LCD and LED panels are used for this purpose. Decimal digit can be displayed by using Seven Segment Display (SSD) unit. If alphabets are also included with the decimal digits then the same is called Alpha numeric display.

In digital electronics, hexadecimal system is used for expressing large binary numbers. This system is also

known as alphanumeric system. Now-a-days LCD panels are being used in digital wrist watches, mobile phones and many other equipments having display system

Types of DPM and its use

1 **4 digit voltmeter and Ammeter -** it is capable to measure upto 9999 volts or amperes

2 **Three phase voltmeter and Ammeter -** it is capable to measure to 3 phase volts or amperes

3 **3½ digit voltmeter and Ammeter -** it is capable to measure up to 1999 volts or amperes in 3 phase star circuit

4 **4½ digit voltmeter and Ammeter -** it is capable to measure up to 19999 volts or amperes

5 4 and 5 digits frequency meter

6 Digital power factor meter

7 Digital wattmeter.

Seven-segment display

A seven segment display (SSD), or Seven-Segment Indicator (SSI) is the most basic electronic display device that can display digits from 0-9 is shown in Fig 3.

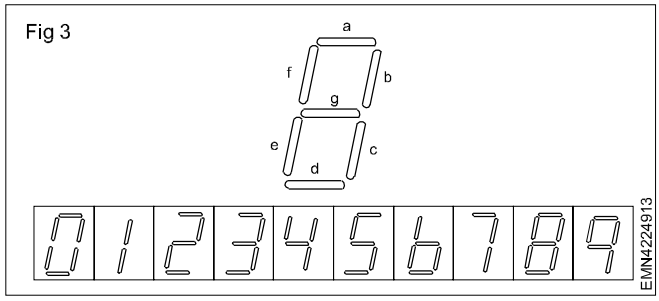
Seven-segment displays are widely used in digital clocks, electronic meters, Radio, Microwave ovens, Basic calculators, and other electronic devices etc.

Concept and visual structure

A seven-segment display consists of seven elements that are made of either LCDs (Liquid Crystal Display) or LEDs (Light-Emitting Diodes). The elements are labelled from a to g as shown in Fig 4.

Depending on which elements are turned ON, the display decimal numerals 0 to 9. In a common cathode display, the cathodes of all the LEDs are joined together and the individual segments are illuminated by HIGH voltages. In a common anode display, the anodes of all the LEDs are joined together and the individual segments are illuminated by connecting to a LOW voltage.

Fig 3



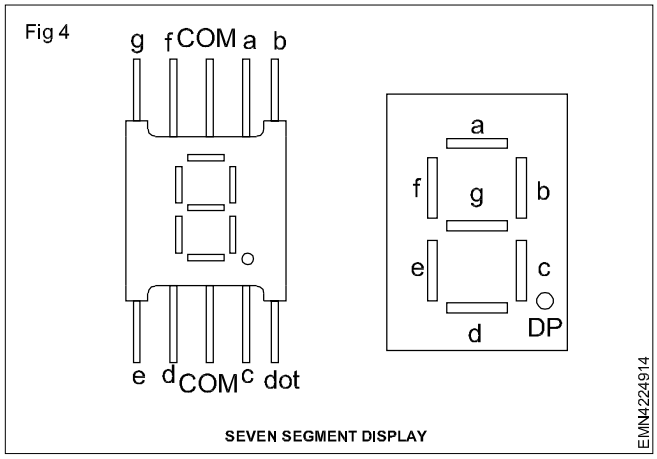
Pin diagram of seven-segment display

Working of seven segment display

Seven segment display works by glowing the respective LEDS in the number. The display is controlled using pins that are left freely. Forward biasing of these pins in a sequence will display the particular number or alphabet. Depending on the type of seven segments the segment pins are applied with logic high or logic zero.

For example to display Number '1' segments b and c are to be switched on and the remaining segments are required to be switched off. In order to display two digits two seven segments are used.

Fig 4



SEVEN SEGMENT DISPLAY

Types of seven-segment display

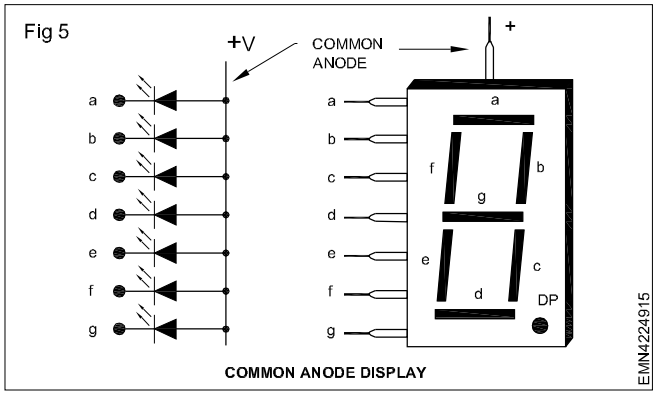
There are two important types of 7-segment LED display.

1 Common Anode (CA) Seven-segment

2 Common Cathode (CC) Seven-segment

1 Common Anode (CA) Seven-segment display

Fig 5

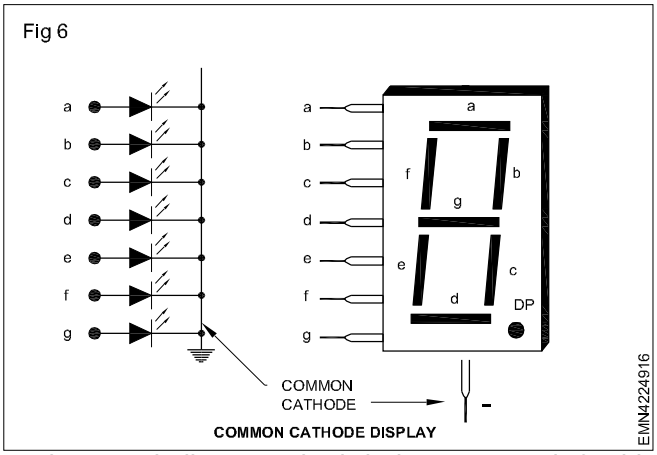


COMMON ANODE DISPLAY

In common anode type, all the anodes of 8 LED's are connected to the common terminal and cathodes are left free. Thus, in order to glow the LED, these cathodes have to be connected to the logic '0' and anode to the logic '1'. as shown in Fig 5.

2 Common Cathode (CC) Seven-segment display

Fig 6



COMMON CATHODE DISPLAY

As the name indicates cathode is the common pin for this type of seven segments and remaining 8 pins are left

free. Here, logic low is applied to the common pin and logic high to the remaining pins as shown in Fig 6.

7-segment display truth table

Truth table shows the data to be applied to the seven segments to display the digits. In order to display digit'0' on seven segment , segments a , b , c , d , e and f are applied with logic high and segment g is applied with logic low.

Fig 7

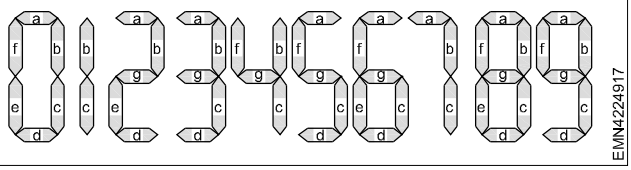


TABLE 1

The TABLE 1 shows the decimal number and respective segments to glow its value on the display.

Decimal number	Individual segments illuminated						
	a	b	c	d	e	f	g
0	On	On	On	On	On	On	Off
1	Off	On	On	Off	Off	Off	Off
2	On	On	Off	On	On	Off	On
3	On	On	On	On	Off	Off	On
4	Off	On	On	Off	Off	On	On
5	On	Off	On	On	Off	On	On
6	On	Off	On	On	On	On	On
7	On	On	On	Off	Off	Off	Off
8	On	On	On	On	On	On	On

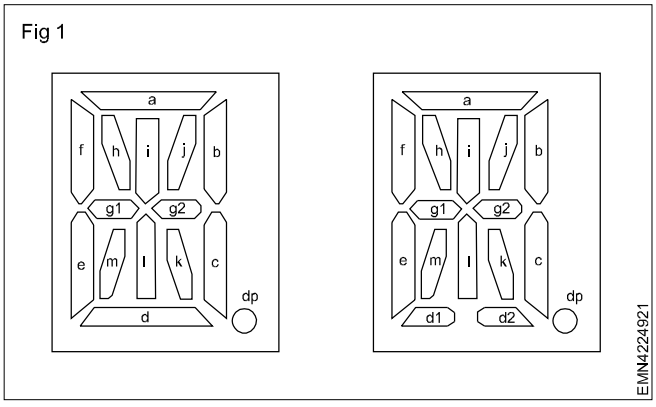
Alphanumeric LED display

Objectives : At the end of this lesson you shall be able to
- **explain the alphanumeric LED display**
- **describe the alphanumeric LED display pinout details.**

1 Alphanumeric LED display:

- Seven-segment displays are capable to display only numbers from 0-9 and few alphabets.
- A 'Starburst' alphanumeric displays with 14-segment and 16-segment (Ignoring the DP) LED displays as shown in fig.1, can able display the alphanumeric characters. Starburst displays provide an economical way of showing the full 26-character roman alphabet in upper case, as well as the numerals 0 to 9.

Fig 1



- Alphanumeric display is an expansion of the common seven segment display, having an additional four diagonal and two vertical segments with the middle horizontal segment broken in half.
- The difference between the 14-segment and the 16-segment digit types is that the top and bottom bar is split on the 16-segment digit, improving the aparance of some charcters.

2 Pinout details:

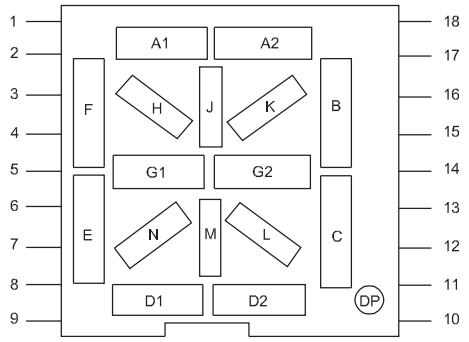
- The pinout details of single alphanumeric display is shwon in fig.2.

Alphanumeric LED - PINOUT details

Pin No.	Segment	Pin No.	Segment
1	A1	10	DP
2	A2	11	M
3	J	12	L
4	H	13	C
5	F	14	G1
6	E	15	G2
7	N	16	B
8	D1	17	K
9	D2	18	+V

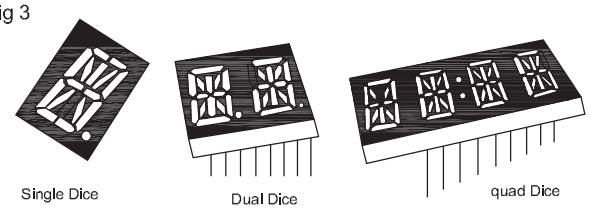
- Small display use one dice per display segment, while large displays may use two or more dice per segment to spread the light effectively and show reasonably uniform intensity across the segment.

Fig 2



Single Dice

Fig 3



Alphanumeric Display

The single and multiple dice displays are shown in fig.2 & 3.

Display decoder/driver

Objectives : At the end of this lesson you shall be able to

- **explain the display decoder/driver**
- **explain the binary to decimal decoder**
- **describe different methods of driving the seven segment display.**

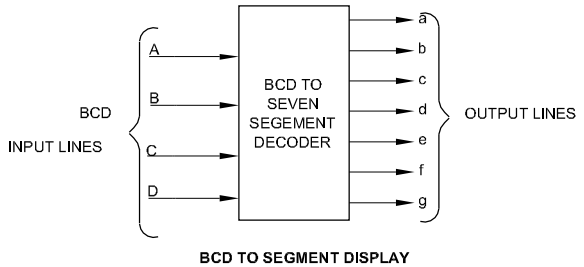
Display decoder

Display decoder is a device which converts one digital format into another digital format. One of the most commonly used devices for doing this is called Binary Coded Decimal (BCD) to Seven- Segment Display (SSD) decoder.

It can be seen that to display any single digit number from 0 to 9 in binary or letters from A to F in hexadecimal, we would require 7 separate segment connections plus one additional connection for the LED's "common" connection. Also as the segments are basically a standard light emitting diode, the driving circuit would need to produce up to 20mA of current to illuminate each individual segment. To display the number 8, all 7 segments would need to be lit resulting a total current of nearly 140mA.

Obviously, the use of so many connections and power consumption is impractical for some electronic or microprocessor based circuits and so in order to reduce the number of signal lines required to drive just one single display, display decoders such as the BCD to 7-segment display decoder and driver IC's are used as shown in Fig 1.

Fig 1



BCD TO SEGMENT DISPLAY

Binary Coded Decimal (BCD)

Binary-coded decimal (BCD) or packet decimal is a class of binary encodings of decimal numbers where each decimal digit is represented by a fixed number of bits, usually four or eight. Special bit patterns are sometimes used as a sign for other indications.

BCD numbers only range from 0 to 9, with the binary number patterns of 1010 through to 1111 (A to F) being invalid inputs for this type of display and so are not used as shown in TABLE 1.

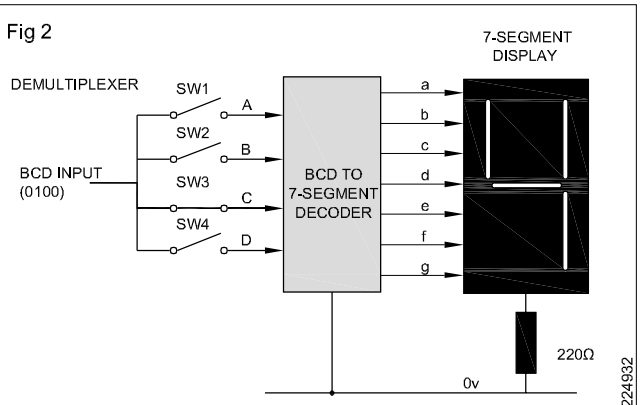
TABLE 1

Decimal	Binary pattern				BCD
	8	4	2	1	
0	0	0	0	0	0
1	0	0	0	1	1
2	0	0	1	0	2
3	0	0	1	1	3
4	0	1	0	0	4
5	0	1	0	1	5
6	0	1	1	0	6
7	0	1	1	1	7
8	1	0	0	0	8
9	1	0	0	1	9
10	1	0	1	0	Invalid
11	1	0	1	1	Invalid
12	1	1	0	0	Invalid
13	1	1	0	1	Invalid
14	1	1	1	0	Invalid
15	1	1	1	1	Invalid

BCD to Seven-segment display decoder

An example of the 4-bit BCD input (0100) representing the number 4 is as shown in Fig 2.

Fig 2



BCD TO SEVEN SEGMENT (DISPLAY)

BCD to seven segment display decoder is a circuit used to convert the input BCD into a form suitable for the display. It has four input lines A, B, C and D and 7 output lines a, b, c, d, e, f and g as shown in Fig 1. Considering common cathode type of arrangement, the truth table for the decoder can be given as in TABLE 2.

Driving a 7-segment display

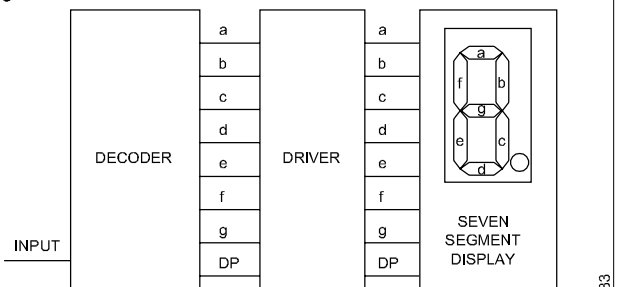
7-segment display can be thought of as a single display, it is still seven individual LEDs within a single package and as such these LEDs need protection from over current. LEDs produce light only when it is forward biased with the amount of light emitted being proportional to the forward current.

TABLE 2

Decimal digit	Input lines				Output lines							Display pattern
	A	B	C	D	a	b	c	d	e	f	g	
0	0	0	0	0	1	1	1	1	1	1	0	
1	0	0	0	1	0	1	1	0	0	0	0	
2	0	0	1	0	1	1	0	1	1	0	1	
3	0	0	1	1	1	1	1	1	0	0	1	
4	0	1	0	0	0	1	1	0	0	1	1	
5	0	1	0	1	1	0	1	1	0	1	1	
6	0	1	1	0	1	0	1	1	1	1	1	
7	0	1	1	1	1	1	1	0	0	0	0	
8	1	0	0	0	1	1	1	1	1	1	1	
9	1	0	0	1	1	1	1	1	0	1	1	

The block diagram of a basic LED seven segment display system that can display a given input in numerical form is shown Fig 3.

Fig 3



BASIC LED 7 SEGMENT DISPLAY DRIVER SYSTEM

Concept of multiplexing

The decoder block converts the given input signal into an 8 line code corresponding to the 'a' to 'g' segments and the decimal point which controls the segments to display the desired number. For example if the line corresponding to 'f 'and 'e' are activated then segments f and e of the display glows indicating a "1". If the input quantity is an analogue signal then it must be converted into digital format using an ADC before applying to the decoder. If the input signal is digital then there is no need for the ADC and the decoder alone will convert the particular input code into the 8 line code compatible to the seven segment LED display. The purpose of the driver stage is to provide the necessary current drive in order to drive the LED seven segment displays. If the decoder stage is powerful enough to drive the display, then the driver stage is not required. A typical 7 segment display driver stage consists of an array (8 nos) transistor or FET based switches. For example consider the line 'a'. The "a" output of the decoder is connected to the input terminal (base/gate) of the corresponding switching element inside the driver stage. The same line is buffered by the switching element and is available as output line 'a' of the driver. This output is connected to the corresponding 'a' element of the display. The driver can be arranged in sinking or sourcing mode.

The following methods are practiced to drive the seven segments.

1 Driving a seven segment display with resistor

2 Driving a seven segment display with transistor

3 Driving a seven segment display with integrated circuit (IC)

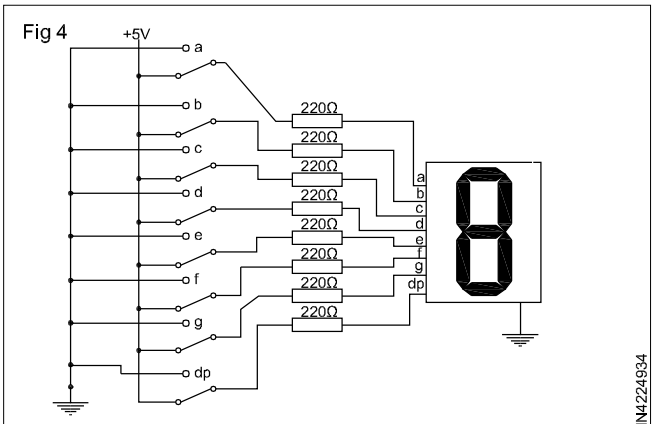
Driving a seven segment display with resistor

Driving a seven segment using resistor is the most common method. In this, generally we use the resistor as the driving element. Generally, LED requires 20 milli Amps of current. Current more than this value may damage the LED. To limit this current a resistor is used .This is called current limiting resistor. Circuit is as shown Fig 4.

Segment pins of the seven segments are connected using a resistor and a switch. The 8 switches are connected to the 8 current limiting resistors and they are connected to a to g segments of display. Let us see how this circuit drives the digital display.

To glow the segment 'a', close the switch 'a'. The current passes through resistor and some drop occurs at current limiting resistor. Thus, the sufficient current passes to the LED. Suppose to display digit 7 switches a, b, c are closed. But the disadvantage here is, illuminating all the LEDs at a time reduces the current.

Fig 4

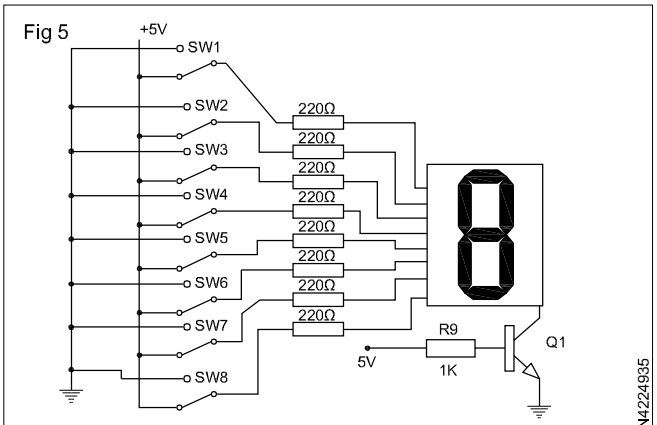


DRIVING SEVEN SEGMENT DISPLAY WITH RASISTOR

Driving a seven segment display with transistor

Another way of driving the seven segments is through transistor. In this, transistor is used for amplifying the input current. The collector of the transistor is connected to the common pin of the seven segment, emitter is connected to the ground and base is connected Vcc. The transistor connected to the common pin amplifies the current in the seven segments as shown in Fig 5.

Fig 5



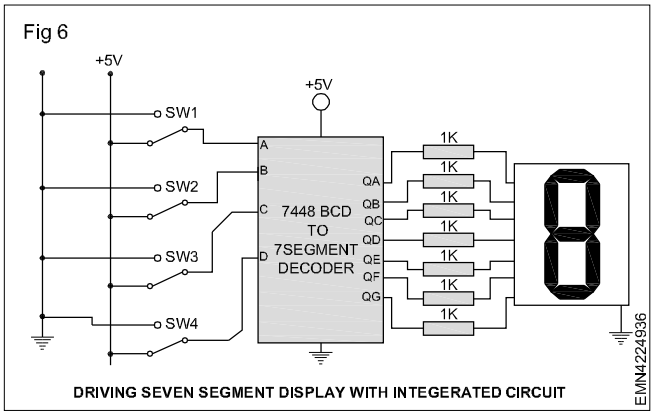
DRIVING SEVEN SEGMENT DISPLAY WITH TRANSISTOR

Driving a seven segment display with integrated circuit

Another way of driving the seven segments is through integrated circuits. This is generally called as seven segment driver or decoder. The most frequently used decoder is 7448. This chip converts 4 bit binary coded decimal to 8 bit seven segment data. This seven segment decoder connected to the seven segments is shown Fig 6.

The below figure shows driving of a seven segment display using BCD to seven segment decoder. Here we have to give BCD data as input to display digits 0 to 9. For example, to display the digit 7 the input to be applied is 0111. The decoder decodes the applied BCD input and sends the appropriate output to the segments. The decoder outputs are connected to the seven segment inputs through the resistors. These resistors are used to limit the current.

Fig 6



DRIVING SEVEN SEGMENT DISPLAY WITH INTEGERATED CIRCUIT

Multiplexing IC 7106/IC 7107

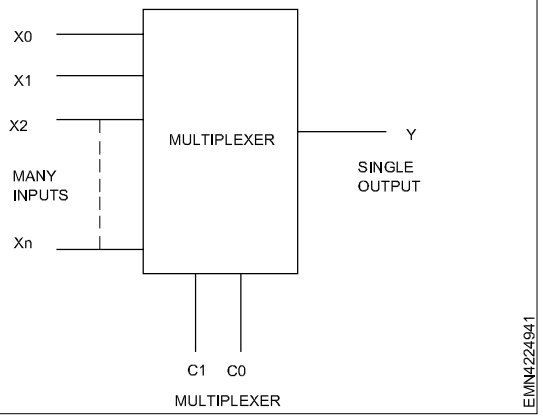
Objectives : At the end of this lesson you shall be able to

- **describe the concept of multiplexing**
- **state the advantages of multiplexing**
- **list out the IC7106/IC7107 pin diagram.**

Multiplexing

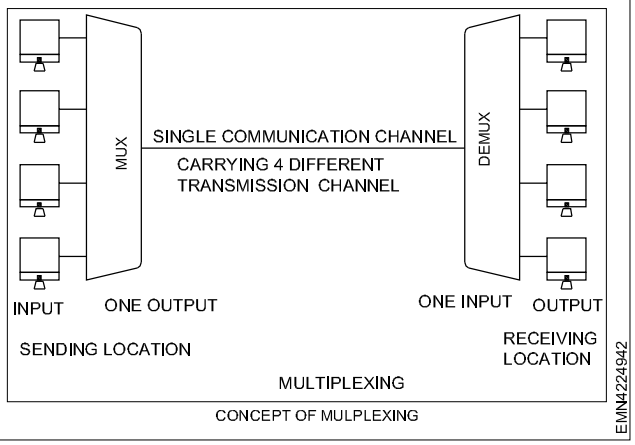
A Multiplexer is a device that allows one of several analog or digital input signals which are to be selected and transmits the input that is selected into a single medium. Multiplexer is also known as data selector. Multiplexer is abbreviated as MUX as show in Fig 1. MUX sends digital or analog signals at higher speed on a single line in one shared device. It recovers the separate signals at the receiving end. The multiplexer boosts or amplifies the information that later transferred over network within a particular bandwidth and time.

Fig 1



Concept of multiplexing

Fig 2



As shown in Fig 2 multiplexer takes 4 input lines and diverts them to single output line. The signal from 4 different devices is combined and carried by this single line. At the receiving side, a demultiplexer takes this signal from a single line and breaks it into the original signals and passes them to the 4 different receivers.

Advantages of multiplexing

1 It reduces number of wires

2 It reduces circuit complexity and cost

3 It simplifies logic design

4 We can implement many combinational circuits using MUX

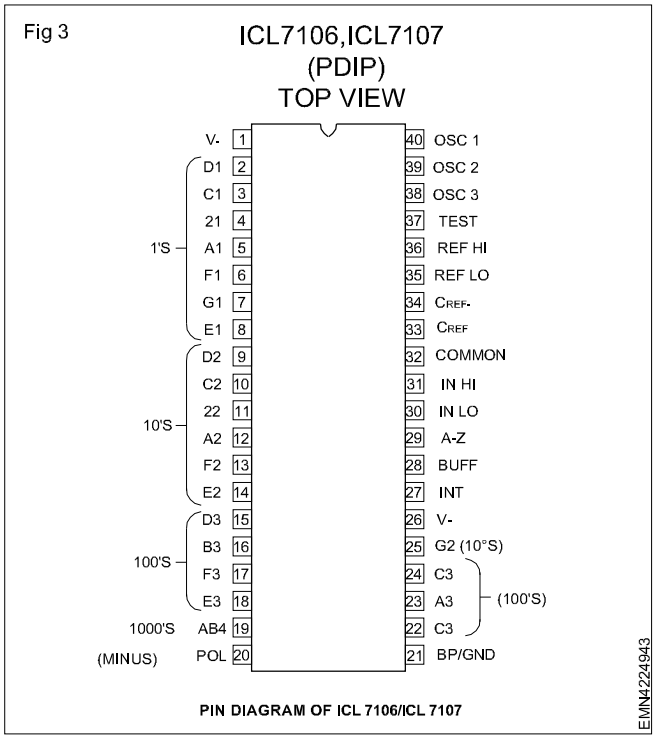
5 It does not need K-maps and simplification.

ICL7106/ICL7107

The ICL7106 /ICL7107 are monolithic analog - to digital converters (ADCs). They have very high input impedances and required no external display drive circuitry. On-board active components include polarity and digits drivers, segment decoders, voltage reference and a clock circuit. The ICL7106 will directly drive a no multiplexed liquid crystal display (LCD), whereas the ICL7107 will directly drive a common Anode Light Emitting Diode (LED) display

PIN diagram of ICL 7106 / ICL 7107

Fig 3



Application

This device can be used in wide range of digital panel meter application such as the measurement of pressure, voltage, resistance, temperature, current, speed, material thickness and conductance.

Fig 4

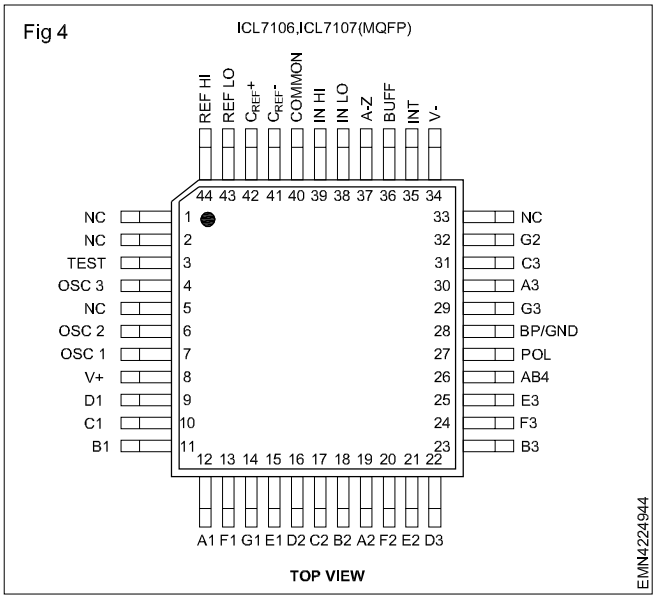
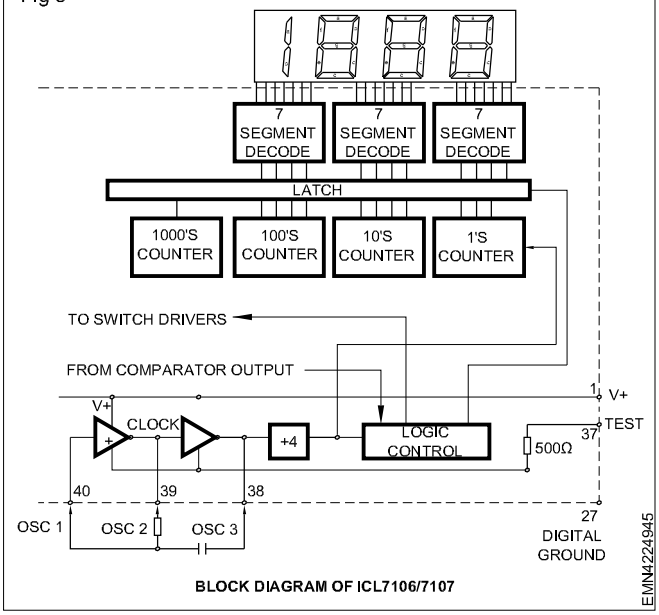


Fig 5



BLOCK DIAGRAM OF ICL7106/7107

Pin Number

Sl. No.	Description
1	V+ - Positive Supply
2	D1 - 1's Digit - D Segment
3	C1 - 1's Digit - C Segment
4	B1 - 1's Digit - B Segment
5	A1 - 1's Digit - A Segment
6	F1 - 1's Digit - F Segment
7	G1 - 1's Digit - G Segment
8	E1 - 1's Digit - E Segment
9	D2 - 10's Digit - D Segment
10	C2 - 10's Digit - C Segment
11	B2 - 10's Digit - B Segment
12	A2 - 10's Digit - A Segment
13	F2 - 10's Digit - F Segment

Pin Number	
Sl. No.	**Description**
14	E2 - 10's Digit - E Segment
15	D3 - 100's Digit - D Segment
16	B3 - 100's Digit - B Segment
17	F3 - 100's Digit - F Segment
18	E3 - 100's Digit - E Segment
19	AB4 - 1000's Digit
20	POL - Polarity Sign
21	BP/GND - Backplane Conn. for LCD/Ground
22	G3 - 100's Digit - G Segment
23	A3 - 100's Digit - A Segment
24	C3 - 100's Digit - C Segment
25	G2 - 10's Digit - G Segment
26	Vneg - Negative Supply
27	INT - Integrator
28	BUFF - Buffer
29	A-Z - Auto Zero
30	IN LO - Input Low
31	IN HI - Input High
32	COMMON - Input Common
33	Cref- - Reference Capacitor
34	Cref+ - Reference Capacitor
35	REF LO - Reference Low
36	REF HI - Reference High
37	TEST - Test
38	OSC3 - Oscillator
39	OSC2 - Oscillator
40	OSC1 - Oscillator

IC 7107/7106 working and configurations

Objectives : At the end of this lesson you shall be able to
- **explain working of IC 7107/ IC 7106 based voltmeter**
- **list out common parameters.**

Application circuits

IC 7106 and IC 7107 are 3½ digit low power consuming A/D converters. Can possible to design panel meter by using about 10 external components and display the result.

Typical test circuit of IC 7106 and IC 7107 are shown in Fig 1 and 2.

Working of circuit

The measuring voltage is applied at pin 31 and 32 through capacitor C_5 and resistor R_5. The resistor R_5 and capacitor C_5 are used to set the internal oscillator (clock) frequency at 48Hz, clock rate at which there will be three readings per second.

The errors due to internal reference voltage can be by using capacitor C_1 connected at pin 33 and 34. It can help to keep display in steady state. The resistor R_2 and

capacitor C_2 are used for integration of input measuring voltage for sampling and prevent division of input voltage and it helps to work circuit faster. It reduces the errors so circuit works more reliable.

If there is no voltage at the input of the circuit, then the capacitor forces the device to display zero using R_1 and R_4. The current through the displays can be controlled to provide sufficient current for brightness without any over current using the resistor R_6. IC 7107 is capable of driving four LED displays in which first three are used to display numbers from 0 to 9 and the most significant LED segment is used only to display number 1 or "-" sign if the voltage is negative. The entire supply to the circuit is given through dual DC supply of +5V at pin 1, 0V at pin 21, and -5V at pin 26 of IC 7107.

Fig 1

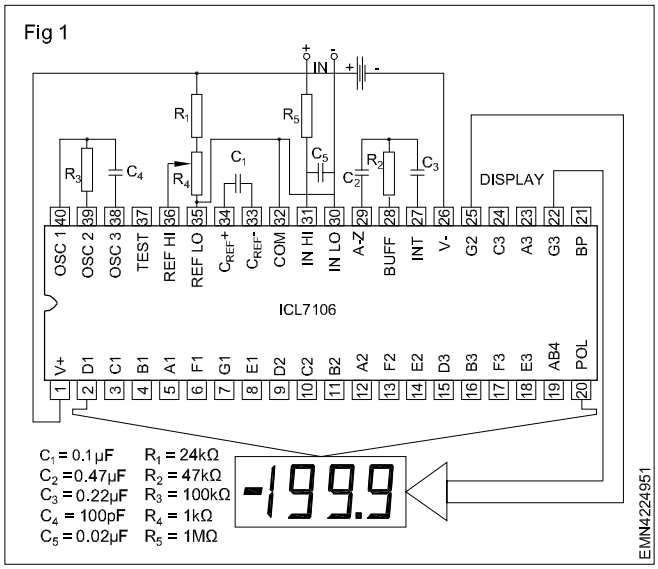
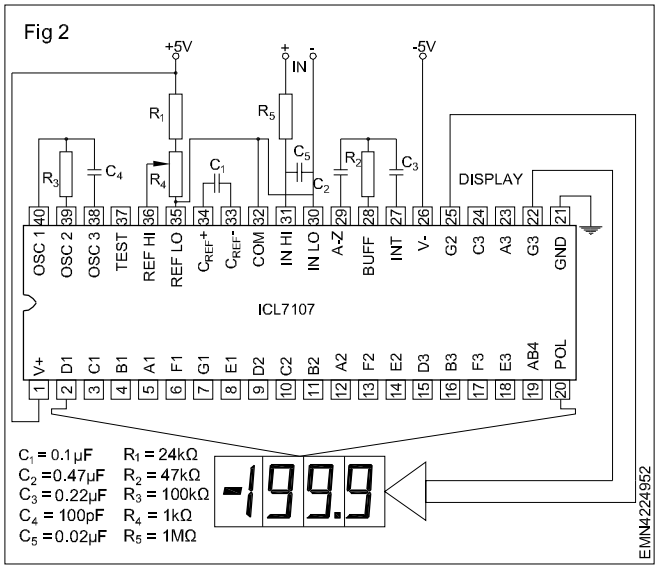


Fig 2



Oscillator frequency

The IC-7106 and IC-7107 require an oscillator clock pulse to operate. So in pin configuration pin 38, pin 39, and pin 40 are used for connecting reference clock signal.

We can provide clock reference by

1 can connect external clock frequency at pin 40.

2 can connect the crystal between 39 and 40.

3 can connect RC oscillator using R and C.

RC oscillator is cost effective. This is shown in Fig 1 resistor R_3 and C_4 connected for generating clock signal. The frequency can be calculated by using formula

$$F_{osc} = 0.45 / (R_3 + C_4)$$

Reference capacitor selection

Reference capacitor connected between 34 and 33. Generally this capacitor is 0.1 micro facrad is suitable in most of the conditions. But, in some cases like when pin no 32 (COMMON) and pin 35 (REF LOW) are not using in some design cases. In that condition capacitor with higher value like 1 micro farad works better for good performance.

Auto zero settings

Pin 29 (A-Z) is refers the auto zero setting. Auto zero setting is indicates the recovery overload speed and level of noise reduction. The value of the auto-zero capacitor has some influence on the noise of the system. For 200mV full scale where noise is very important,a 0.47mF capacitor is recommended. On the 2V scale, a 0.047mF capacitor increases the speed of recovery from overload.

Reference voltage

The analog input required to generate full scale output (2000 counts) is: $V_{IN} = 2V_{REF}$. Thus, for the 200mV and 2V scale, V_{REF} should equal 100mV and 1V, respectively. So, we connect a suitable value of resistor R_4 between pin number 36 and 35 and R_1 with V_{cc} (Fig 1 and 2). For better adjust selecting a R4 as a preset potentiometer to get adjustment.

Removing common mode voltages

This IC has an N-Channel FET and generating 2.8 V. which is below supply of IC voltage that is 2.8 V. This voltage can find at the COMMON pin 32 and can sink up to 25 mA. It is for battery operation and in cases where the input signal floats with respect to the power supply. The voltage at pin 32 can also be utilised as a reference. But it can generate internal heat in IC.

So for removing this voltage can short between pin 32 and 30 and possible to remove common mode voltages for IC. By shorting pin 32 and 35 can possible to remove common mode voltages form reference system also. Refer Fig 1 and Fig 2 at pin 32, 30 and 35 for connections.

Liquid Crystal Display

Objectives : At the end of this lesson you shall be able to
- **explain the working principle of LCD**
- **compare different LCD panel size**
- **list the LCD decoder/driver IC.**

Liquid Crystal Display (LCD)

LCD stands for Liquid Crystal Display, which is used to show status of an application, display values, debugging a program- etc.,

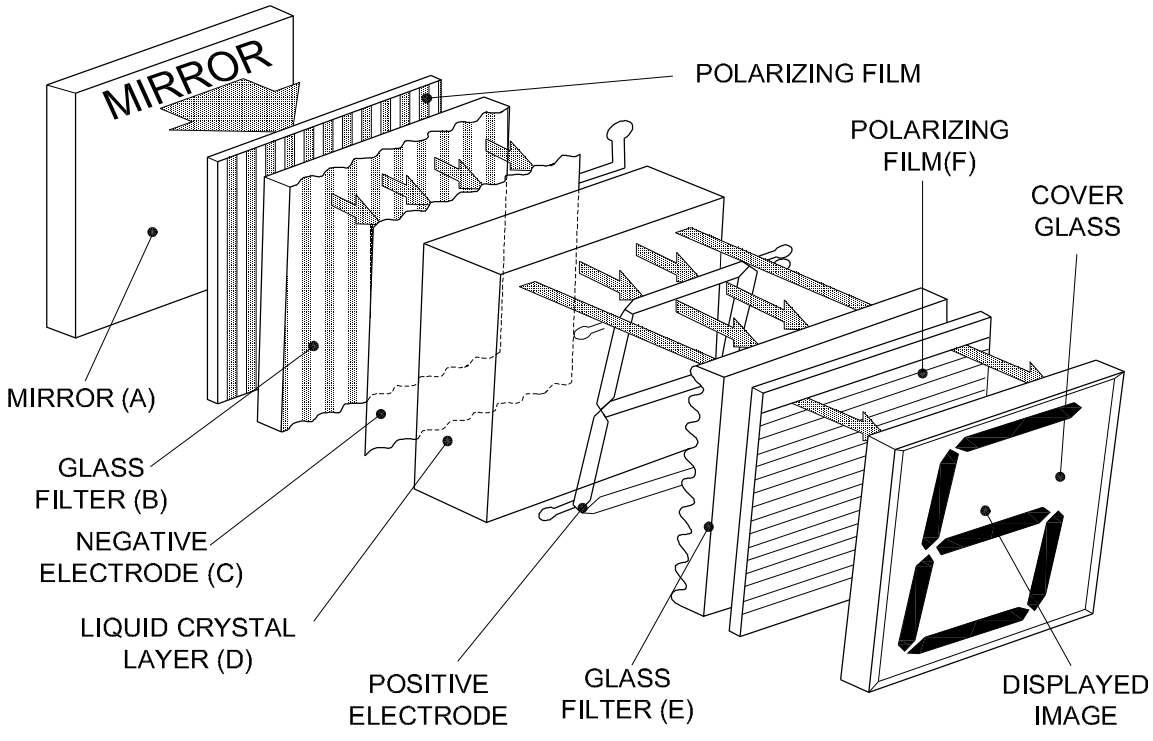
Basics of LCD Displays

The liquid-crystal display has the distinct advantage of having low power consumption than the LED. It is typically of the order of microwatts for the display in comparison to some order of mill watts for LEDs. Low power consumption requirement has made it compatible with MOS integrated logic circuit. Its other advantages are its low cost, and good contrast. The main drawbacks of LCDs are additional requirement of light source, a limited temperature range of operation (between 0 and 60°C), low reliability, short operating life, poor visibility in low ambient lighting, slow speed and the need for an AC drive.

Principles of working of LCD

The main principle behind liquid crystal molecules is that when an electric current is applied to them, they tend to untwist. This causes a change in the light angle passing through them. This causes a change in the angle of the top polarizing filter with respect to it. So little light is allowed to pass through that particular area of LCD, thus that area becomes darker comparing to others For making an LCD screen, a reflective mirror has to be setup in the back. An electrode plane made of indium-tin oxide is kept on top and a glass with a polarizing film is also added on the bottom side. The entire area of the LCD has to be covered by a common electrode and above it should be the liquid crystal substance. Next comes another piece of glass with an electrode in the shape of the rectangle on the bottom and, on top, another polarizing film. It must be noted that both of them are kept at right angles. When there is no current, the light passes through the front of the LCD will be reflected by the mirror and bounced back. As the electrode is connected to a temporary battery the current from it will cause the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle to untwist. Thus the light is blocked from passing through that particular rectangular area appears blank.

Fig 1



Different LCD panel sizes

Alphanumeric LCD Display Sizes

TextLCD::LCD16x2 16x2 LCD panel (default)

TextLCD::LCD16x2B 16x2 LCD panel alternate addressing

TextLCD::LCD20x2 20x2 LCD panel

TextLCD::LCD20x4 20x4 LCD panel

Note: There is now also support for

TextLCD::LCD8x1 8x1 LCD panel

TextLCD::LCD8x2 8x2 LCD panel

TextLCD::LCD16x1 16x1 LCD panel

TextLCD::LCD16x4 16x4 LCD panel

TextLCD::LCD24x2 24x2 LCD panel

TextLCD::LCD24x4 24x4 LCD panel (for KS0078 controller)

TextLCD::LCD40x2 40x2 LCD panel

TextLCD::LCD40x4 40x4 LCD panel (two controllers)

Graphic LCD Display

Graphic LCD Display -122 x 32 Display

Graphic LCD Display -122x64 to 320x240

Decoder / Driver IC used in LCD

A decoder / driver IC is necessary for the conversion of BCD digits into a signal which is capable to energize segments of LCD display unit. The BCD digits are in nipple form, where as LCD display panel required a seven bit signal for seven segment display. A number of decoder /Driver ICs have been developed for this purpose such as M7211AM, MM5483, MM145453 etc.

LCD digital panel display device

Objectives : At the end of this lesson you shall be able to
- **state the pin configurations of the 16 x 2 LCD display**
- **list the commonly used command words in 16 x 2 LCD displays.**

LCD display are used to display the messages for more interactive way to operate the system or displaying error messages etc. Interfacing LCD to microcontroller is very easy if you understand the working of LCD. In order to understand the interfacing, first you have to know about the 16×2 LCD module.

16×2 Liquid Crystal Display which will display the 32 characters at a time in two rows (16 characters in one row). Each character in the display of size 5×7 pixel matrix. Although this matrix differs for different 16×2 LCD modules this matrix will not be same for all the 16×2 LCD modules. There are 16 pins in the LCD module, the pin configuration is given below.

V_{EE} pin is meant for adjusting the contrast of the LCD display and the contrast can be adjusted by varying the voltage at this pin. This is done by connecting one end of a POT to the V_{DD} (5V), other end to the Ground and connecting the center terminal (wiper) of of the POT to the V_{EE} pin.

Sl. No.	Name	Function
1	V_{SS}	This pin must be connected to the ground
2	V_{DD}	Positive supply voltage pin (5V DC)
3	V_{EE}	Contrast adjustment
4	RS	Register selection
5	R/W	Read or write
6	E	Enable
7	DB0	Data
8	DB1	Data
9	DB2	Data
10	DB3	Data
11	DB4	Data
12	DB5	Data
13	DB6	Data
14	DB7	Data
15	LEDA	Back light LED+
16	LEDK	Back light LED-

The JHD162A has two built in registers namely data register and command register. Data register is for placing the data to be displayed , and the command register is to place the commands. The 16×2 LCD module has a set of commands each meant for doing a particular job with the display. We will discuss in detail about the commands later. High logic at the RS pin will select the data register and Low logic at the RS pin will select the command register. If we make the RS pin high and then put a data in the 8 bit data line (DB0 to DB7) , the LCD module will recognize it as a data to be displayed . If we make RS pin low and put a data on the data line, the module will recognize it as a command.

R/W pin is meant for selecting between read and write modes. High level at this pin enables read mode and low level at this pin enables write mode.

E pin is for enabling the module. A high to low transition at this pin will enable the module.

DB0 to DB7 are the data pins. The data to be displayed and the command instructions are placed on these pins.

LED+ is the anode of the back light LED and this pin must be connected to Vcc through a suitable series current limiting resistor. LED- is the cathode of the back light LED and this pin must be connected to ground.

16×2 LCD module commands

16×2 LCD module has a set of preset command instructions. Each command will make the module to do a particular task. The commonly used commands and

their function are given in the table below.

LCD initialization

The steps that has to be done for initializing the LCD display is given below and these steps are common for almost all applications.

1 Send 38H to the 8 bit data line for initialization

2 Send 0FH for making LCD ON, cursor ON and cursor blinking ON.

3 Send 06H for incrementing cursor position.

4 Send 01H for clearing the display and return the cursor.

Sending data to the LCD

The steps for sending data to the LCD module is given below. I have already said that the LCD module has pins namely RS, R/W and E. It is the logic state of these pins that make the module to determine whether a given data input is a command or data to be displayed.

1 Make R/W low.

2 Make RS=0 if data byte is a command and make RS=1 if the data byte is a data to be displayed.

3 Place data byte on the data register.

4 Pulse E from high to low.

5 Repeat above steps for sending another data.

Scrolling display

Objectives : At the end of this lesson you shall be able to
- **explain the functions of dot matrix LED display**
- **describe the operation and application of scrolling display.**

Introduction

- We normally use a simple static LED display screen to convey a message. Earlier, when we want to display large and lengthier data, we used to change message for every few instances. Now scrolling displays are more preferred to static as shown in fig.1.

Fig 1

- Scrolling means a sliding text or image or video across a monitor or display. It may be horizontally or vertically.

DOT matrix display

- It is a display device used to display information on machines, clocks, railway departure indicators and many other devices requiring a simple display device of limited resolution.
- The dot matrix display consists LED lights arranged in rows and coloums of a matrix.
- A dot matrix controller converts instructions from a processor into signals which turns ON or OFF in the matrix so that the required display is produced by the LED display.
- Common sizes of dot matrix displays are as follows

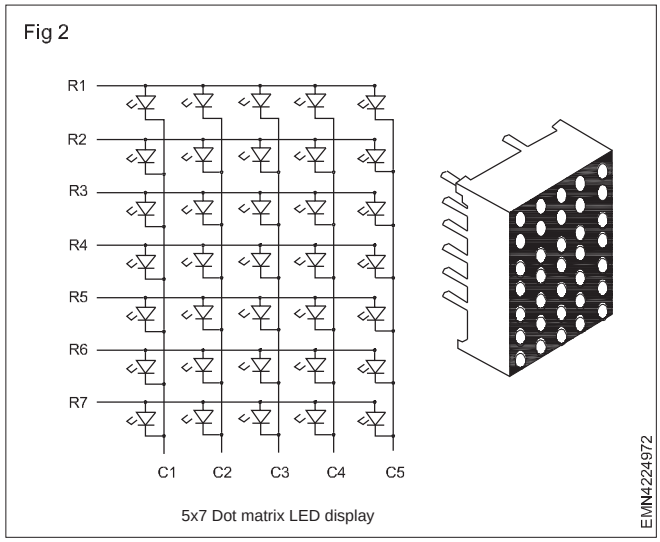
  128 x 16 (Two lined)

  128 x 32 (Four lined)

  192 x 64 (Eight lined)

The 5x7 dot matrix LED display is shown in fig 2. By switching the selected lights ON or OFF any text or graphics can be displayed.

Fig 2



5x7 Dot matrix LED display

Scrolling display

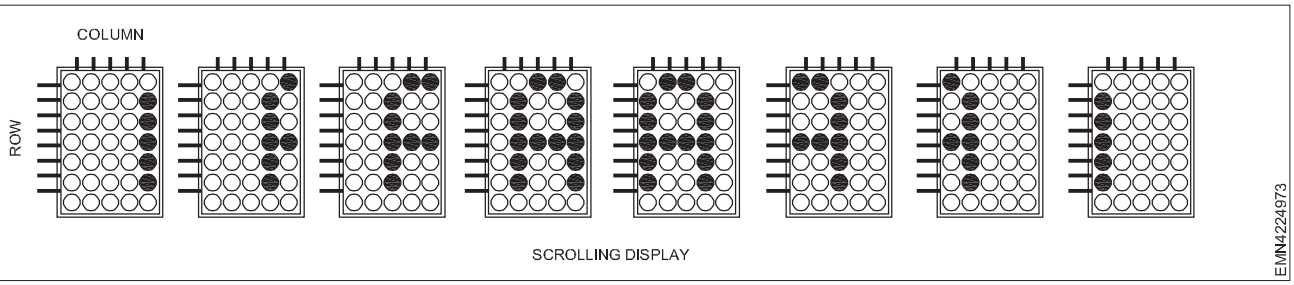
By using a pre-programmed microcontroller, we can make dot matrix LED display in scrolling. We can also make LED display in scrolling. We can also make dot matrix LED to adoptable by using PC controller based system.

- A scrolling message can be used to attract the attention of viewers. For example, TV station has used it to announce the breaking news and companies often use scrolling message on their web site to highlight breaking news, key products, or special promotions.
- Scrolling LED display can be implemented in various methods. Two methods are widely in use,

- Using decade counters and
- Using shift registers.

- The shift register is easy to implement. Scrolling LED display is implemented by using microcontrollers like 8051, AVR (Advanced Virtual RISC - Reduced instruction Set computer) and Peripheral Interface Controller (PIC microcontroller).
- Microcontroller provides the data and clock control signals to the shift register. Microcontroller provides the data sequence to shift register data pin, the first column in LED matrix is connected to ground via relay driver ICULN 2803 and the remaining other columns in the matrix are left unconnected. Hence, LEDs in that column will glow according to port data provided by the microcontroller.
- When the data sequence is provided to shift register, the next column LEDs will glow according to port data provided by the microcontroller unit (MCU). Next column will drive one by one with the corresponding sequence given to the shift register.
- A scrolling is the trick to build one character on the display by scanning the columns very fast, and let say each 20 times (20 frames) scroll it one position to the left, this will give the effect of a walking text across the dot-matrix display.
- So first build one frame, repeat this 20 times, and after that, read the data one address later, if you do this 5 times (5 columns) the character scroll from right to left from the display. (The refersh goes so fast that your brain can't keep up, and what you see is the A scrolling over the display). The scrolling display of a letter is shown in Fig.3.

Fig 3



Application

- Simple outdoor LED message moving or scrolling sign board like, bus route display, Trains/Aeroplane departure and arrival time, etc.
- Electronic projects using LED scroller generator for outdoor digital signs for conveying informations to the public and workers.
- Marketable LED sign board with message scrolling for advertisement purpose.

Voltage and current measurement in DPM

Objectives : At the end of this lesson you shall be able to
- **describe the measurement of AC voltage using DPM**
- **explain the measurement of current using DPM.**

Use a Digital Panel Meter (DPM) to measure AC voltage

Digital Panel Meters (DPMs) are strictly DC meters due to the digital circuitry used. Often it is desired to utilize a DPM to measure AC voltages to take advantage of the improved accuracy and readability of a DPM. This application note will describe the method to accurately display AC voltage values on a DPM. The full scale range of this DPM is 200 mV. To use the DPM to measure AC voltages, the AC voltage must be converted to DC by a rectifier diode. The output from the rectifier diode will be a "pulsed" DC voltage and may produce undesired fluctuations in the reading on the DPM, so we will add a small filter capacitor across the rectified output voltage. The voltage rating of this capacitor and the rectifier diode must be high enough to handle the voltage levels present in the circuit. To be safe, we will use a rectifier diode and capacitor rated at 400V or higher. Since we are using a single rectifier diode to convert the AC into DC, we will have to choose our divider resistors appropriately to compensate for the effects of the half wave rectifier operation. Since the AC power line voltage is rectified by the series diode, the voltage applied to our DPM is the peak value of the 230V line voltage which is 230V multiplied by 1.414

$$V_{out} = V_{in} \times (1.414) = 115 \times (1.414) = 169 \text{ V (DC)}$$

This is the actual DC voltage applied to our voltage divider resistors, so we will use the voltage divider formula to determine the required resistors to produce the correct reading on the DPM.

To keep the calculated values within a range that is readily obtainable, we will use 10 Meg ohms as the maximum series resistor value. We can then calculate the shunt resistor for our voltage divider network using the voltage divider equation

$\frac{V_{out}}{V_{in}} = \frac{R_{shunt}}{R_{series} + R_{shunt}}$ rearranging we can solve for the required.

Use Rseries = 10 Meg Ohms

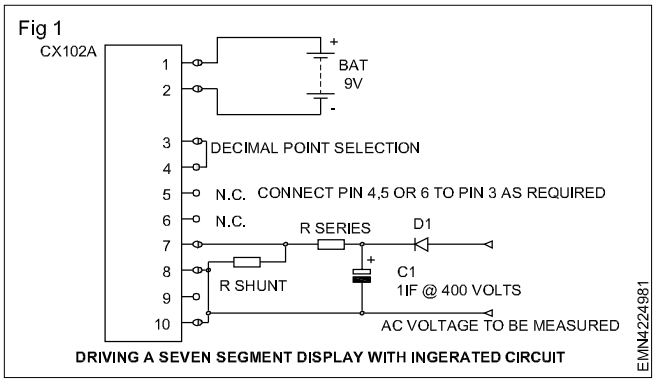
For 0-120 Volts, Rshunt = 7.2 K ohms (use 7.5 K ohm)

We will also need to connect pin 3 to pin 4 (for proper decimal point display).

Note that the voltage value displayed on the meter can be fine-tuned by adjusting the trimmer potentiometer on the back of the DPM.

This application note has shown how a Digital Panel Meter may be used to measure and display AC voltage values. The connection diagram is shown below.

Note that pins 8 & 10 are shorted together and connected to the Neutral connection of the AC voltage that is being measured. Rshunt will be connected across pins 7 & 8 and Rseries will have one end connected to pin 7 and the other end to the voltage that is being measured.



Measuring Current with a Digital Panel Meter (DPM)

When current measurement is required, the current must be converted to a voltage if a digital value is to be displayed. This application note will describe the method will accurately display DC current values on a DPM.

There are several methods that can be used to convert current to voltage such as Hall Effect devices and shunt resistors. Since shunt resistors are the easiest to use and provide the greatest amount of accuracy. The shunt resistor is placed in series with the applied current which causes a voltage drop to occur across the shunt. To minimize the voltage drop in the circuit, the smallest resistance value possible should be chosen. This value depends on the maximum current value that will be encountered. For relatively small current values (below 1 Amp) a 0.1 ohm shunt resistor should perform adequately. This value will minimize any loading on the circuit but will still produce a reasonable reading on the DPM. If higher current levels will be encountered, a 0.01 ohm or lower value should be used.

The CX102A Digital Panel Meter from Circuit Specialists is ideal for this application, as it is designed to use in a system that has the measured signal isolated from the power supply voltage. The application is for a 0-1 Amp DC meter powered by an external 9 volt battery. This application could also be powered by a "wall-wart" type of AC adapter if desired.

Like all Digital Panel Meters, the full scale range of these DPMs is 200 mv. To use the DPM to measure current, we will choose a shunt resistor to assure that not more than 200 mV is developed across it. We will also set the Decimal point jumpers accordingly to indicate the correct Amp reading. For instance, if 1 Amp is the full scale reading desired, we will use the 0.1 ohm resistor and set the decimal point jumper to show three digits to the right of the decimal point. We must also determine the correct power rating of the shunt resistor by using the ohms law power formula P (Power)=E (Voltage) x I (Current).

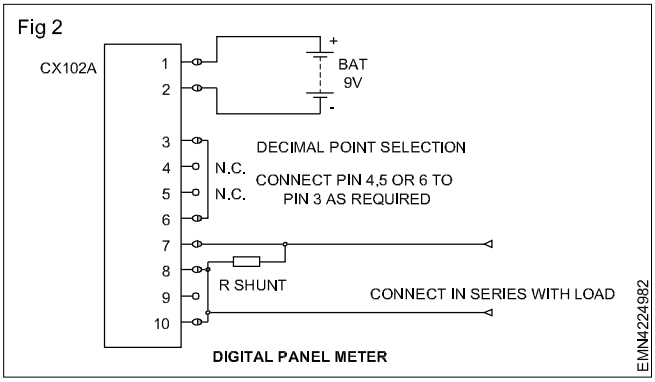
$$P = V_{max} \times I_{max} = (0.200) \times (1.0) = 0.2 \text{ Watt}$$

So we should use a ¼ watt 1% resistor to be safe.

We will also need to connect pin 3 to pin 6 (for proper decimal point display).

Note that the current value displayed on the meter can be fine-tuned by adjusting the trimmer potentiometer on the back of the DPM.

This application note has shown how a Digital Panel Meter may be used to measure and display DC current values. The connection diagram is shown Fig 2.



Note that pins 8 & 10 are shorted together and connected to the Negative end of the shunt resistor. Rshunt will be connected across pins 7 & 8 and will be connected in series with the load.

Measurement of current using DPM

Objectives : At the end of this lesson you shall be able to

- **convert the digital voltmeter to measure the current**
- **calculate the shunt resistance required to measure the current.**

Digital voltmeter using IC7107 has been discussed in this module. It is a high performance, low power, 31/2 digit A/D converters. Included are seven segment decoders, display drivers, a reference, and a clock. The ICL7106 is designed to interface with a liquid crystal display (LCD) and includes a multiplexed backplane drive; the ICL7107 will directly drive an instrument size light emitting diode (LED) display.

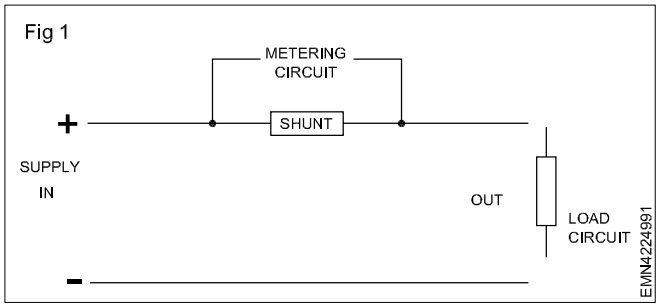
The same PCB of digital voltmeter can be used to display the current too. Please note that the only difference

in the PCB would be to replace the 1Mohm used in the DVM by a 10K and the 1.2 K resistance is removed. Designing of Digital Ammeter is basically a process of converting a voltmeter into a Ammeter.

We know that V=I x R. From this we can say that Voltage is directly proportional to the current (V = I) flowing through resistance. In ammeter this resistance is call Shunt. Shunt resistance have very small value and it will not affect the load voltage. Use low value for shunt resistance.

The formula for measuring the current is quite simple. Refer to the diagram below Fig 1.

Fig 1



To measure the voltage, the voltmeter is connected in parallel and to measure current in a circuit it is connected in series.

By applying Ohms law

V = I x R

Select the Shunt value or the R value to be 1ohm , then the formula above reduces to:

V = I

So, keeping the points above in mind, say that if R = 1 ohm or in orders of 1 milliohm, then measure the voltage it is as good as getting the current reading as V = I.

Hence the selection of the shunt value is quite crucial .

0.01 Ohm resistor should be made out of 1.5 mm thick / 5 cm long copper wire. 0.1 Ohm and 1 Ohm resistors should have 5W ratings.

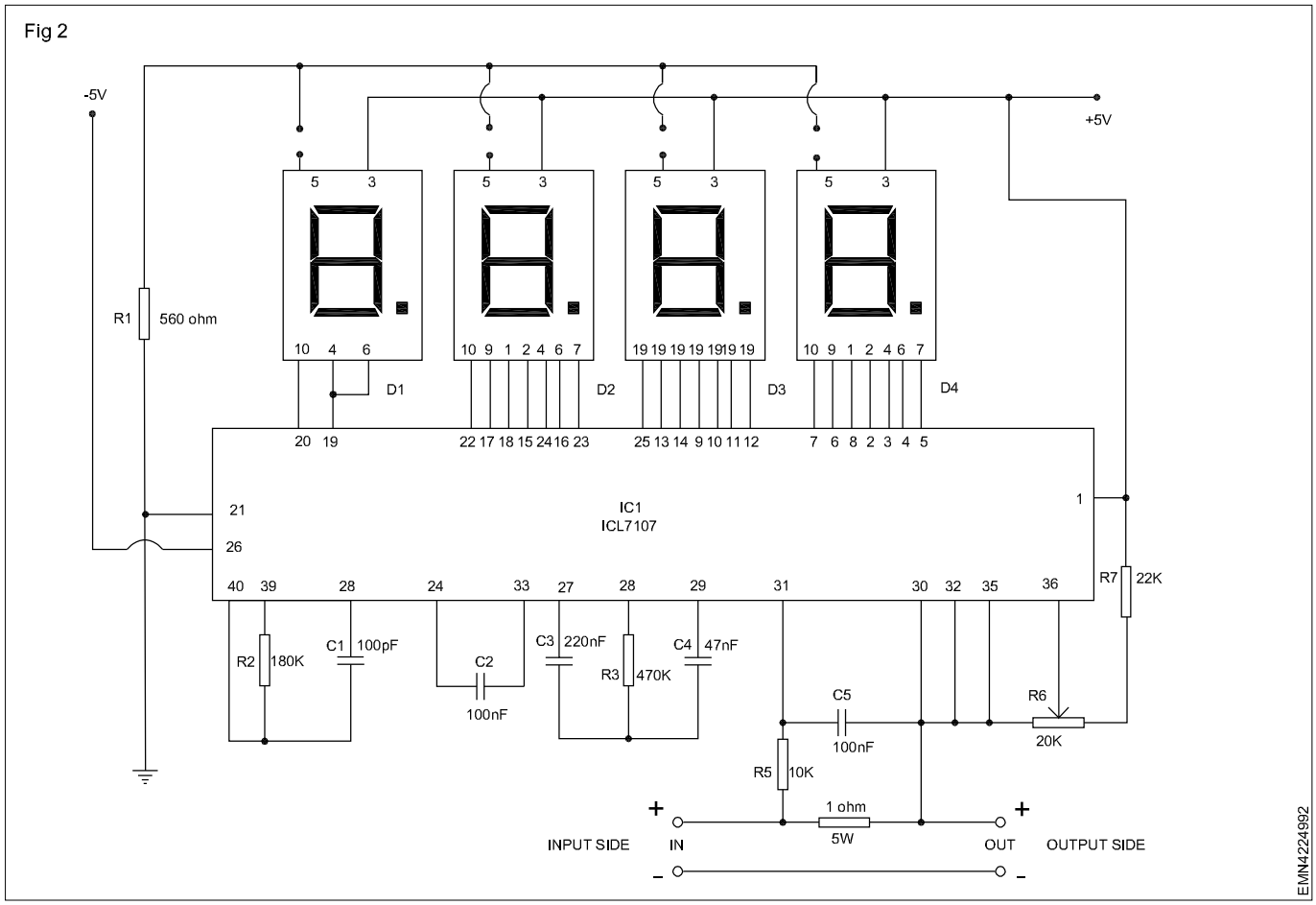
For highest accuracy it is recommended that the ICL7107 Ammeter module should be supplied with its own voltage supply. If measurement of the current of the same supply is needed, ICL7107 Ammeter would have to sample negative not positive voltage supply.

Brightness of the LED displays can be varied by adding or removing 1N4148 small signal diodes that are connected in series. Use two 1N4148 diodes for higher brightness.

Also, the use of 7805 5V voltage regulator is highly recommended to prevent the damage of ICL7107 and 7660 ICs.

Use 10K potentiometer to set the reference voltage between PIN 35 and PIN 36 of the ICL7107 IC to 1V.

Fig 2



Switch Mode Power Supply

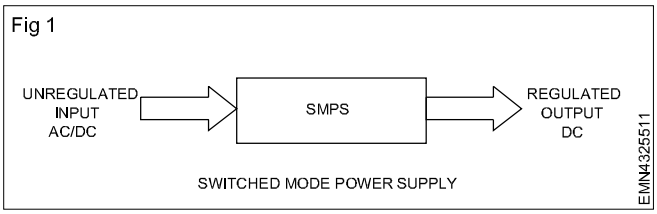
Objectives : At the end of this lesson you shall be able to
- **state the need for SMPS**
- **describe the basic concept of SMPS**
- **compare between linear power supply and SMPS**
- **explain the working principles of different types of SMPS**
- **list out the advantages and disadvantages of SMPS**
- **state the applications and topologies of SMPS.**

Switched-Mode Power Supply(SMPS)

The electronic power supply integrated with the switching regulator for converting the electrical power efficiently from one form to another form with desired characteristics is called as switched mode power supply. This is working on the principle of switching regulation.

It is used to obtain regulated DC output voltage from unregulated AC or DC input voltage.

Fig 1



The SMPS system is highly reliable, efficient, noiseless and compact because the switching is done at very high rate in the order of several KHz to MHz.

Need for switch-mode power supplies

Many household electrical devices require a supply of voltage which is both constant and well regulated, but the voltage which comes from power outlets are noisy AC voltages. The power from such outlet needs to be managed by electronic circuits which are generally referred to as power supplies, even though the power comes from the outlets.

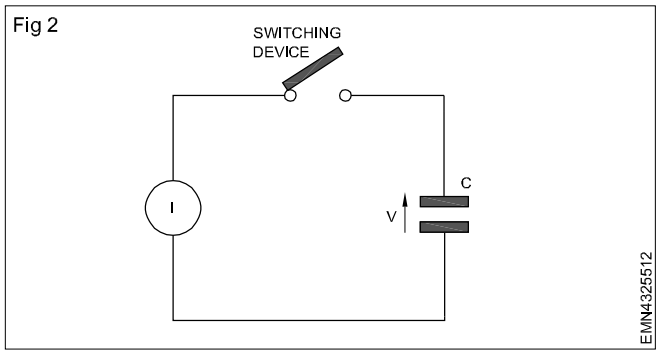
Basically, the AC supply from the outlet has a sinusoidal wave shape, and it is rectified in order to produce a DC voltage. The noisy high voltage need to be converted to a regulated low voltage so that it can be used by low voltage electronic devices such as TV, DVD, Mobile, etc.

Basic concept of SMPS

The basic concept of SMPS is the regulation by using a switching regulator. SMPS uses a series switching element that turns the current supply to a smoothing capacitor on and off.

The switching element is turned on is controlled by the voltage on the capacitor. If it is higher than required, the series switching element is turned off, if it is lower than required, it is turned on. In this way the voltage on the smoothing or reservoir capacitor is maintained at the required level.

Fig 2



Comparison between linear power supply and SMPS

	Linear power supply	SMPS
1) Transformer size and weight	Heatsinks for high power linear regulators add size and weight.	Smaller transformer
2) Operating frequency	50 Hz or 60 Hz	15 KHz to1 MHz
3) Output voltage	Limited voltage available. Voltage varies significantly with load.	Any voltages available. Voltage varies little with load.
4) Efficiency, heat, and power dissipation	If regulated: efficiency largely depends on voltage difference between input and output; output voltage is regulated by dissipating excess power as heat resulting in a typical efficiency of 30–40%. If unregulated,	Output is regulated using duty cycle control; the transistors are switched fully on or fully off, so very little resistive losses between input and the load.

	transformer iron and copper losses may be the only significant sources of inefficiency.	The only heat generated is in the non-ideal aspects of the components and quiescent current in the control circuitry.
5) Circuit complexity	Usually a simpler circuit; unregulated may be simply a diode and capacitor. Regulated has a voltage-regulating circuit and a noise-filtering capacitor.	Consists of a controller IC, one or several power transistors and diodes as well as a pulse transformer, inductors, and filter capacitors. Some design complexities present which are not found in linear regulator circuits.
6) Radio frequency interference	Mild high-frequency interference may be generated by AC rectifier diodes under heavy current loading.	EMI/RFI produced due to the current being switched on and off sharply. Therefore, EMI filters and RF shielding are needed to reduce the disruptive interference.
7) Electronic noise at the output terminals	It can cause audible mains hum in audio equipment, brightness ripples in analog security cameras.	Noisier due to the switching frequency of the SMPS.
8) Electronic noise at the SMPSs	Causes harmonic distortion to the input AC. input terminals	Non power-factor-corrected cause harmonic distortion.
9) Power factor	Low for a regulated supply because current is drawn from the mains at the peaks of the sinusoidal voltage.	Ranging from very low to medium since a simple SMPS without PFC draws current spikes at the peaks of the AC.

Working principles of SMPS

Fig 3 shows the block diagram of SMPS with an AC input and a regulated DC output.

AC input section

Input filter

The AC input from the main supply goes to the input filter to reduce EMI.

Input filter is a protective circuit, which is used to suppress short pulses around the AC voltages. The circuit consists of inductor and high voltage capacitors. A MOV(Metal Oxide Vaistor) is connected across the AC supply to prevent any surge or spikes in the voltages and also PFC circuit is used to correct the power factor.

Rectifier

AC input is converted to DC voltage using a rectifier diodes. The rectifier consisting of a full wave bridge diode or module and large filter capacitors to obtain a smoothed high DC voltage around 300 V DC. The current is drawn from the mains supply.

Power section

The power section consists of high frequency ferrite core transformer and switching power transistors (MOSFETs) to switch D.C Voltage across the transformer winding. This section coverts the rectified high voltage DC into AC at a frequency of 20 KHz - 100 KHz. A current sense circuit is provided to sense overload current and to protect SMPS from overloading. Since the input voltage is chopped into an AC waveform and placed into a magnetic element additional winding can be added to provide for more than one output voltage.

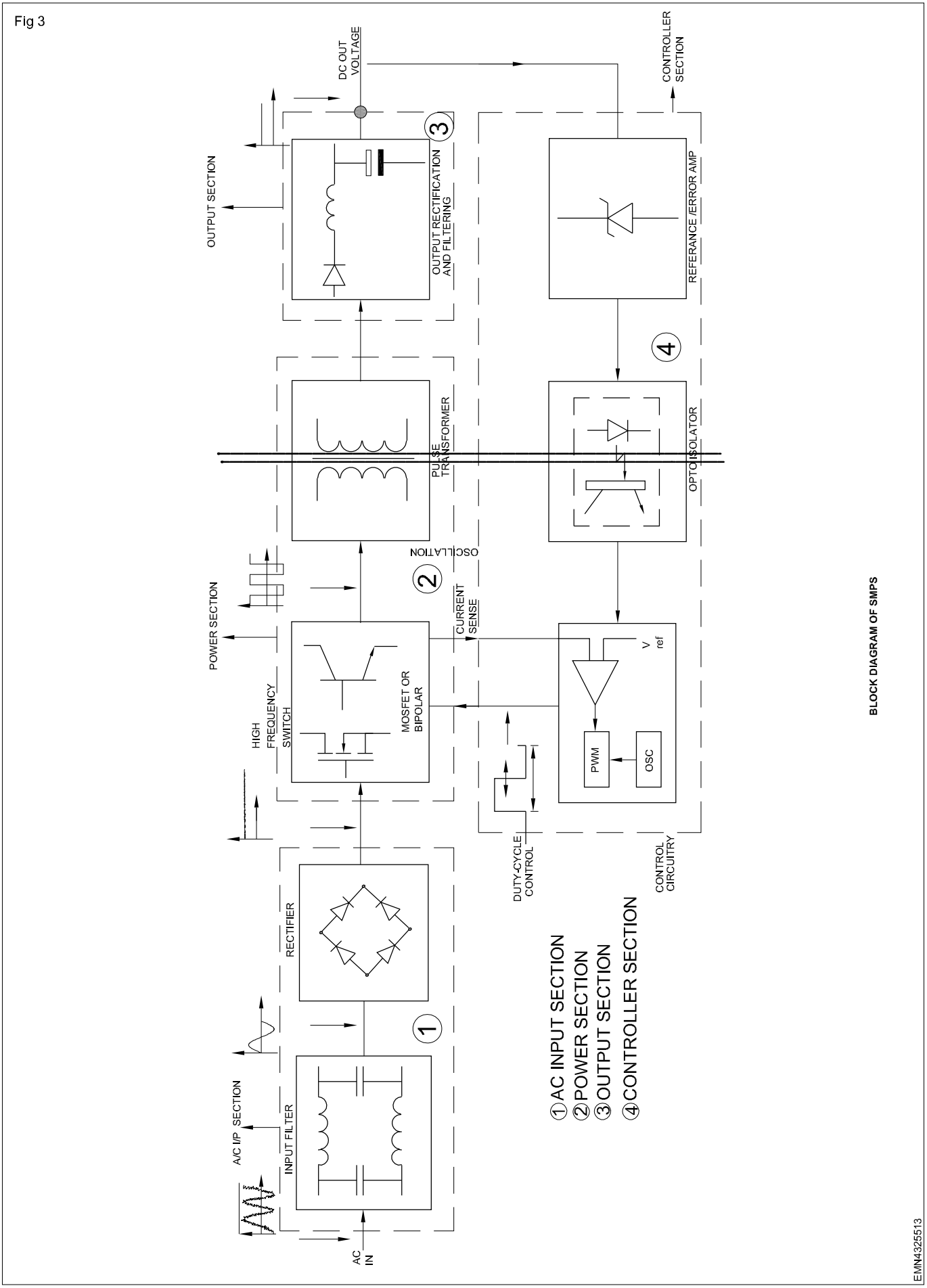
Output section

The output section consists of rectifier and filter circuits for output above the volts ordinary silicon diodes are used. Since the A/C output of the transformer at 20 KHz schottky diodes are used, because of its fast recovery than silicon diodes to get lower voltages. For even lower output voltages MOSFETs may be used as synchronous rectifiers. The filter circuit consists of an inductor and capacitor.

Control section

The controller consists of a feedback circuit PWM circuit and isolation mechanism (opto - coupler). A feedback circuit monitors the output ref voltage of 2.5V and compares it with a reference voltage. Any change in 5V with respect to the load creates an error voltage. This error voltage modifies the pulse width of the output pulses. The output pulses inturn drives the power switching transistor. The output pulses are not directly connected to the power switching transistor. For safety

Fig 3



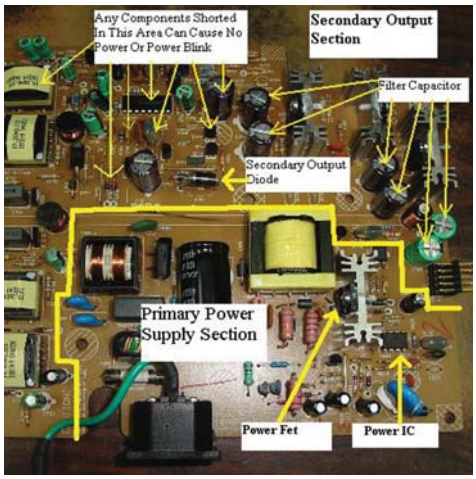
reasons, the output section is isolated by an opto-coupler and transformer. Over current is sensed through a current transformer. The output of current transformer is rectified and used to shut down the power controller when

an excess current is drawn.

Different types of SMPS

Model 1 : SMPS

Fig 4



Model 2 : SMPS used in PC

Fig 5

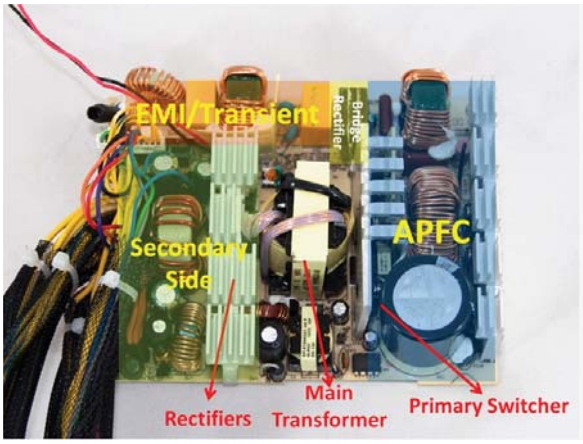
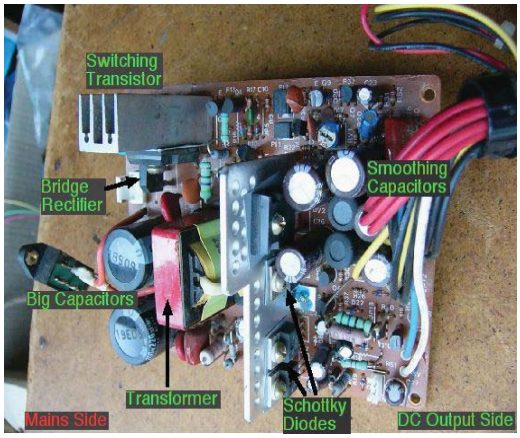
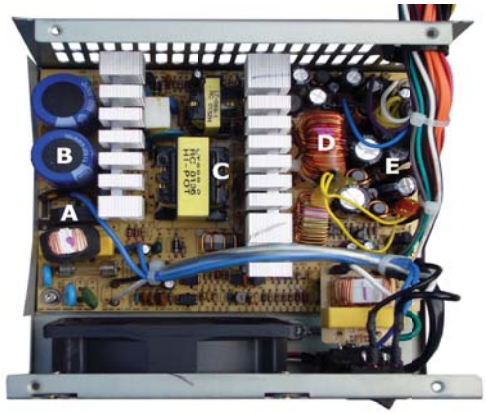


Fig 6



SMPS IN PC

Fig 7



SMPS used in PC(ATX)

ATX SMPS (Fig 7)

below A : input EMI filter and bridge rectifier;

B : input filter capacitors

Between B and C : Primary side heat sink;

C : Pulse transformer

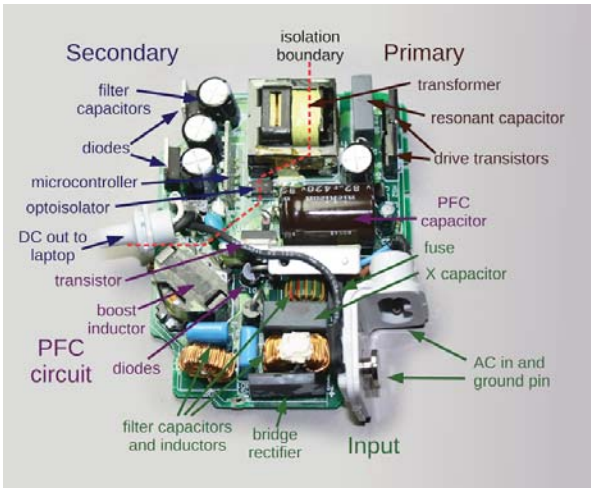
Between C and D : Secondary side heat sink;

D : Output filter coil;

E : Output filter capacitors.

The coil and large yellow capacitor below E are additional input filtering components that are mounted directly on the power input connector and are not part of the main circuit board.

Fig 8



SMPS used in Laptop

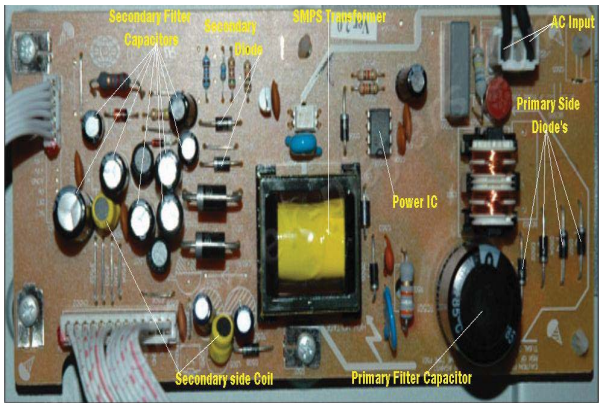
Basic parts and their function

1 **EMI/Transient filter :** Suppress incoming and outcoming EMI/RFI and protects from voltage spikes.

2 **Bridge rectifier :** Rectifies the AC power stream to DC.

3 **APFC :** Controls the current supplied to the PSU so that the current waveform is proportional to the mains voltage waveform.

Fig 9

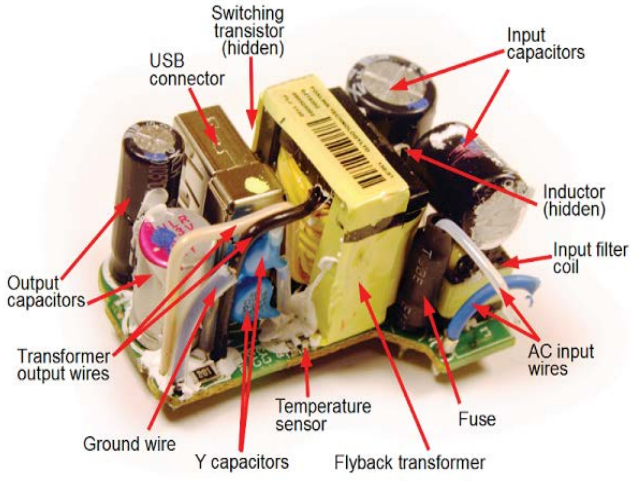


SMPS in DVD player

Fig 10

SMPS in Home theature main board

Fig 11



SMPS in Cell phone charger

4 **Main switches:** Chop the DC signal to very small energy packets, with high frequency.

5 **Transformer :** Isolates primary from secondary side and converts (steps down) the voltage.

6 **Output rectifiers & filters :** Generate the DC outputs and filter them.

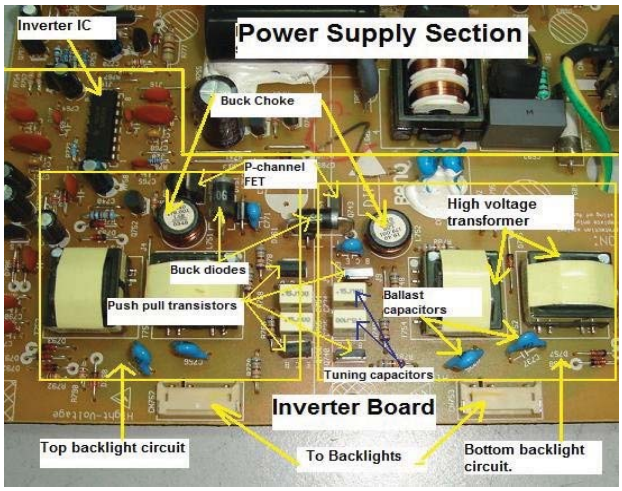
7 **Protection circuits :** Shut down the PSU when something goes wrong.

8 **PWM controller :** Adjusts the duty cycle of the main switches, in order to keep steady output voltage under all loads.

9 **Isolator :** Isolates the voltage feedback that comes from the DC outputs and heads to the PWM controller.

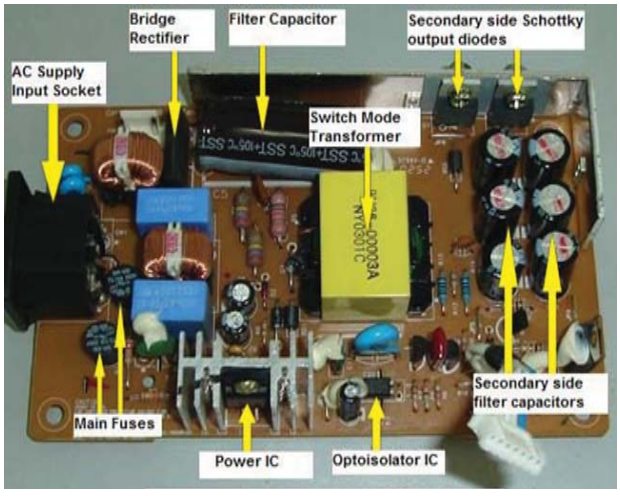
10 The part of the SMPS before the pulse transformer is called "primary" side and the part after it "secondary" side.

Fig 12



SMPS in LED TV

Fig 13



SMPS in LCD monitor

Advantages & Disadvantages of SMPS

Advantages

1 Higher efficiency, smaller size, lighter weight.

2 Heat dissipation is very low.

3 Wide AC input voltage range. (Ex. 90V-270V)

4 High precision voltage regulation.

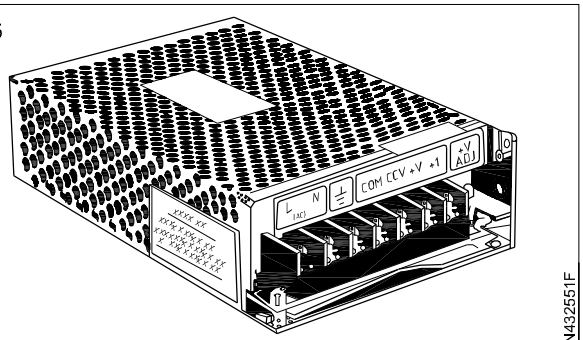
5 Low output noise ripple.

6 Strong protection function. (Ex. Short circuit in output)

Fig 14

Din rail SMPS in control panel

Fig 15



SMPS IN CONTROL PANEL

Disadvantages

1 Complexity of the circuit.

2 Line fitter is necessary to avoid EMI.

3 Non-PFC SMPS cause harmonic distortion.

4 Serving of SMPS is very difficult.

Applications of SMPS

1 Personal computers

2 Battery chargers

3 Central power distribution

4 Vehicles (Electric bike vehicle & space vehicles)

5 Consumer electronics

6 Lighting

7 Space station

Personal computers

Personal computers have parts like Hard disk, Mother board, CPU, CD Rom, etc. In order to run these devices switch mode power supply is used efficiently.

Battery chargers (Mobile phone, Digital camera, Laptop computer)

Due to their high volumes, mobile phone chargers uses effective ringing choke converter (RCC) SMPS topology.

Central power distribution

Where integration of capacitors for stabilization and batteries as an energy storage or AC hum and other interference needs to be avoided in the power distribution, SMPS may be essential for efficient conversion of electric DC energy. For AC applications where frequency and voltage can't be produced by the primary source an SMPS may be essential.

Vehicles

In automobile industry where ordinary trucks use nominal 24V DC but they need 12 V DC & SMPS. Cars use nominal 12V DC and may need to convert this to drive equipment using SMPS. Space vehicles use a lightweight switched-mode power supplies to convert voltages produced by solar panels and fuel cells to the voltages required by equipment.

Consumer electronics

Television receivers, DVD players, Home theatres, Cordless phone, uses a switch-mode power supply. When the A/C voltage reduced to as low as 90 V and as high as 260V, but the image has no alterations.

Lighting

Powering of LED circuits is accomplished with switched-mode power supply setup as a constant current source where efficiency is important.

Space station

The electrical power system on the International Space Station (ISS) uses multiple switch-mode power supplies to convert between the voltage produced by the solar array and battery system, and the voltages required by the different modules. The eight solar panels generate 262 kW at 160 V DC, used to charge nickel-hydrogen batteries that provide power when the solar array is in shadow during earth eclipse. A system voltage of 160 V DC is used for the main power distribution throughout the station.

The space shuttle uses three fuel cells generating 30–36V DC. Some is converted into 400 Hz AC power and 28V DC power using SMPS.

Topologies of Switch Mode Power Supply

There are different types of topologies for SMPS, among those, a few are as follows

1 DC to DC converter

2 AC to DC converter

3 Fly back converter

4 Forward converter

1 Working principle of DC to DC converter SMPS

In a DC-to-DC converter, primarily a high-voltage DC power is directly obtained from a DC power source. This high-voltage DC power is switched at a very high switching speed usually in the range of 15 kHz to 50 kHz.

Then it is fed to a step-down transformer which is comparable to the weight and size characteristics of a transformer unit of 50Hz. The output of the step-down transformer is further fed into the rectifier. This filtered and rectified output DC power is used as a source for loads, and a sample of this output power is used as a feedback for controlling the output voltage.With this feedback voltage, the ON time of the oscillator is controlled, and a closed-loop regulator is formed.

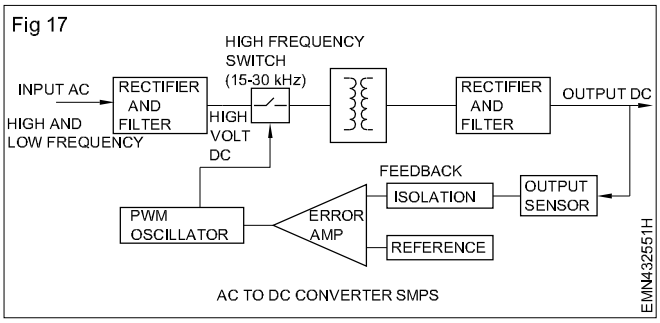
The output of the switching-power supply is regulated by using PWM (Pulse Width Modulation). As shown in the circuit above, the switch is driven by the PWM oscillator, such that the power fed to the step-down transformer is controlled indirectly, and hence, the output is controlled by the PWM, as this pulse width signal and the output voltage are inversely proportional to each other.

If the duty cycle is 50%, then the maximum amount of power is transferred through the step-down transformer, and, if duty cycle decreases, then the amount of power transferred will decrease by decreasing the power dissipation.

2 Working principle of AC to DC converter SMPS

The block diagram of AC to DC converter SMPS is shown in Fig 17. AC input is converted into DC by rectification process using a rectifier and filter. This unregulated DC voltage is fed to the large-filter capacitor or PFC (Power Factor Correction) circuits for correction of power factor as it is affected. This is because around voltage peaks, the rectifier draws short current pulses having significantly high-frequency energy which affects the power factor to reduce.

Fig 17



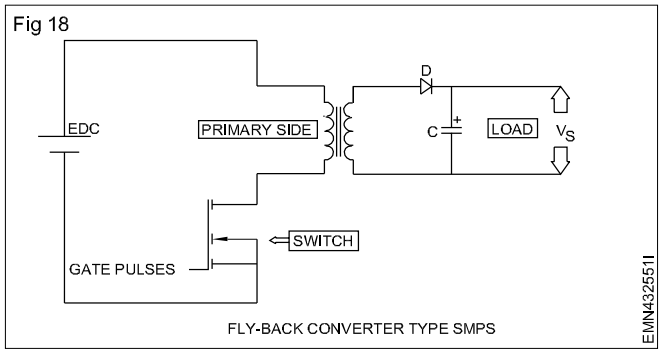
It is almost similar to the above discussed DC to DC converter, but instead of direct DC power supply, here AC input is used. So, the combination of the rectifier and filter, shown in the block diagram is used for converting the AC into DC and switching is done by using a power MOSFET amplifier with which very high gain can be achieved. The MOSFET transistor has low on-resistance and can withstand high currents. The switching frequency is chosen such that it must be kept inaudible to normal human beings (mostly above 20kHz) and switching action is controlled by a feedback utilizing the PWM oscillator.

This AC voltage is again fed to the output transformer shown in the figure to step down or step up the voltage levels. Then, the output of this transformer is rectified and smoothed by using the output rectifier and filter. A feedback circuit is used to control the output voltage by comparing it with the reference voltage.

3 Working principle of Fly-back converter type SMPS

The SMPS circuit with very low output power of less than 100W (watts) is usually of Fly-back converter type SMPS, and it is very simple and low- cost circuit compared to other SMPS circuits. Hence, it is frequently used for low-power applications. The principle of operation is explained using Fig 18.

Fig 18

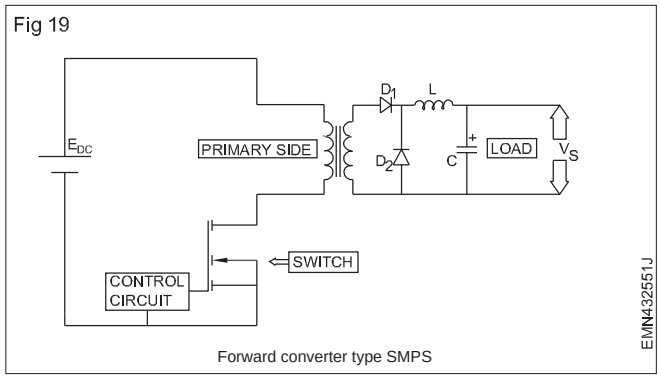


The unregulated input voltage with a constant magnitude is converted into a desired output voltage by fast switching using a MOSFET; the switching frequency is around 100 kHz. The isolation of voltage can be achieved by using a transformer. The switch operation can be controlled by using a PWM control while implementing a practical fly-back converter.

Fly-back transformer exhibits different characteristics compared to general transformer. The two windings of the fly-back transformer act as magnetically coupled inductors. The output of this transformer is passed through a diode and a capacitor for rectification and filtering. As shown in Fig 18, the voltage across this filter capacitor is taken as the output voltage of the SMPS.

4 Working principle of forward converter type SMPS

Fig 19



Forward converter type SMPS is shown in Fig 19. It is almost similar to the Fly-back converter type SMPS, but in the forward converter type, a control is connected for controlling the switch and at the output of the secondary winding of the transformer, and the rectification and filtering circuit is complicated as compared to the fly-back converter.

It can be called as a DC to DC buck converter, along with a transformer used for isolation and scaling. In addition to the diode D1 and capacitor C, a diode D2 and an inductor L are connected at the output end. If switch S gets switched ON, then the input is given to the primary

winding of the transformer, and hence, a scaled voltage is generated at the secondary winding of the transformer.

Thus, the diode D1 gets forward biased and scaled voltage is passed through the low-pass filter preceding the load. If the switch S is turned off, then the currents through the primary and secondary winding reach to zero, but the current through the inductive filter and load can not change abruptly, and a path is provided to this current by the freewheeling diode D2. By using the filter inductor, the required voltage across the diode D2 and to maintain the EMF required for maintaining the continuity of the current at inductive filter.

Even though the current is diminishing against the output voltage, approximately the constant output voltage is maintained with the presence of the large capacitive filter. It is frequently used for switching applications with a power in the range of 100 W to 200 W.

Different types of topologies are there in which SMPS can be realized such as Buck converter, Boost converter, Self Oscillating fly-back converter, Buck-boost converter, Boost-buck, Cuk, Sepic. But only a few are discussed in this article, namely DC to DC converter, AC to DC converter, Fly-back converter and Forward converter.

SMPS used in personal computers

Objectives : At the end of this lesson you shall be able to

- **explain SMPS and different types of SMPS used in PC**
- **explain different types of connectors used in personal computer SMPS**
- **discuss the need of ATX SMPS in PC**
- **explain the functions of SMPS used in PC**
- **explain the working of PWM IC**
- **differentiate between AT and ATX type SMPS.**

SMPS used in PC

Switch Mode Power Supply of a PC is housed in a metal box. It consists of an electronic circuit board, a fan, AC power sockets, power supply interface connectors for motherboard, hard disk drive and floppy disk drive. AC power switch is connected as an optional item to the power cable from the SMPS.

Fig 1

SMPS with its cables or connectors

Basic connectors in PC SMPS

20 + 4 Pin ATX / Motherboard connector

CPU 4 + 4 Pin connector

SATA power connector

Floppy 4 pin connector

Peripheral 4 pin molex connector

PCI-e 6 pin/PCI-e 8 pin connector.

Types of SMPS used in PC

There are 3 types of SMPS

1 AT SMPS

2 ATX SMPS

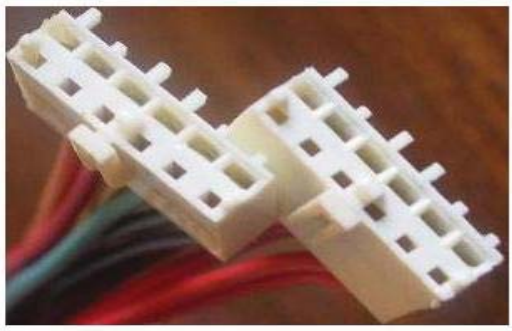
3 BTX SMPS

These three types of SMPS have different connectors and each wire has different voltages.

AT SMPS

AT stands for Advanced Technology. These are all old SMPSs. They had 12pin power connector, this is called as AT power connector. They were used in Pentium-I, Pentium-MMX, Pentium-II and Pentium-III CPUs as shown in Fig 2.

Fig 2



ATX SMPS

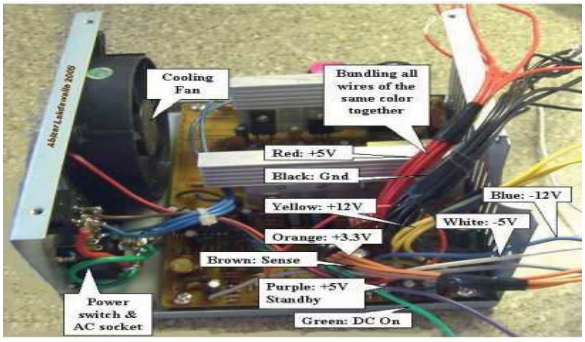
ATX stands for Advanced Technology eXtended. They had 20pin Power connector, this is called as ATX power connector. They were used in Pentium-III, Pentium-IV and AMD CPUs as shown in Fig 3.

BTX SMPS

BTX stands for Balanced Technology eXtended. They have 24pin Power connector, this is also called as ATX power connector. It has 15pin SATA power connectors. They are used in Dual core, core2duo, Quad core, i3, i5, i7 and latest AMD CPUs.

Fig 3

Fig 4



Voltages of power connector

SMPS	AT	ATX	BTX
Red	+5V	+5V	+5V
Yellow	+12V	+12V	+12V
Blue	-12V	-12V	-12V
White	-5V	-5V	-5V
Black	0V	0V	0V
Orange	+5V	+3.3V	+3.3V
Green	---	+5V	+5V
Gray or Brown	---	+5V	+5V
Purple	---	+5V	+5V

Red : It is used to provide stated voltage.

Yellow : It is used for motor running

White &Blue : It is used for backward compatibility

Black : It is used for grounding purpose

Orange : It is used to provide stated voltage

Green : It is used for power supply ON in ATX

Gray or Brown : It is used for power Good(Self-test OK) signal in ATX

Purple : It is used to provide +5V whenever the PSU is powered. Even when the green wire is not connected to ground. (Stand by)

Fig 5

Connectors

20/24 Pin ATX / Mother board connector

This is the connector that goes to the motherboard to provide it with power. The connector has 20 or 24 pins. One of the pins belongs to the PS-ON wire (it is usually green). This connector is the largest of all the connectors. In older AT power supplies, this connector was split in two: P8 and P9. A power supply with a 24-pin connector can be used on a motherboard with a 20-pin connector. In cases where the motherboard has a 24-pin connector, some power supplies come with two connectors (one with 20-pin and other with 4-pin) which can be used together to form the 24-pin connector as shown in Fig 6 and 7.

Fig 6

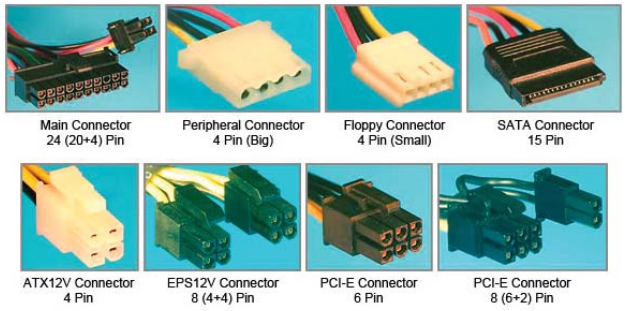
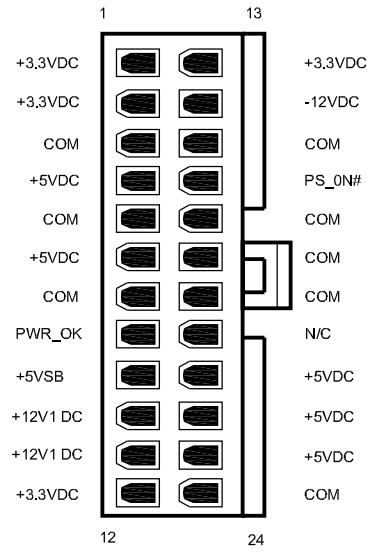


Fig 7

Fig 8

Connected attached (24 pins)

Fig 9

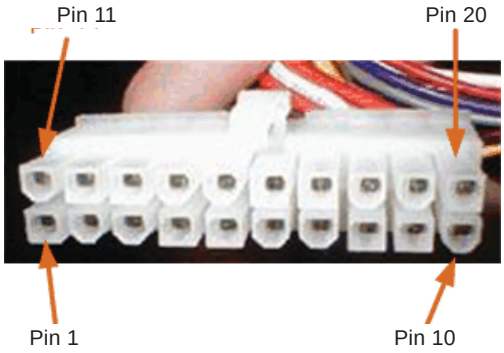


Pin	Name	Color	Description
1	+3.3V	Orange	+3.3 VDC
2	+3.3V	Orange	+3.3 VDC
3	COM	Black	Ground
4	+5V	Red	+5 VDC
5	COM	Black	Ground
6	+5V	Red	+5 VDC
7	COM	Black	Ground
8	PWR_ON	Gray	Power Good
9	+5VSB	Purple	+5 VDC Standby
10	+12V1	Yellow	+12 VDC
11	+12V1	Yellow	+12 VDC
12	+3.3V	Orange	+3.3 VDC
13	+3.3V	Orange	+3.3 VDC
14	-12V	Blue	-12 VDC
15	COM	Black	Ground
16	PS_ON#	Green	Power Supply On
17	COM	Black	Ground
18	COM	Black	Ground
19	COM	Black	Ground
20	NC	White	-5 VDC (Optional - Removed in ATX12V v2.01)
21	+5V	Red	+5 VDC
22	+5V	Red	+5 VDC
23	+5V	Red	+5 VDC
24	COM	Black	Ground

Fig 10

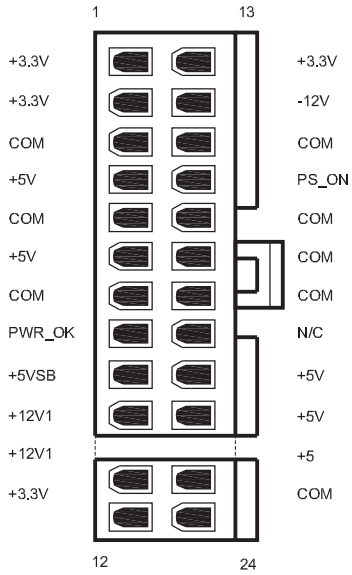
24 Pin detachable connector (20+4)

Fig 11



20 Pin molex connector

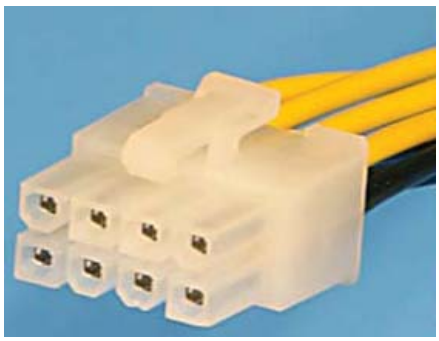
Fig 12



24/20 Pin power supply connector

ATX P4 12V 4-pin power connector (also called the P4 power connector). A second connector that goes to the motherboard (in addition to the main 24-pin connector) to supply dedicated power for the processor. For high-end motherboards and processors, more power is required, therefore EPS12V has an 8-pin connector.

Fig 13



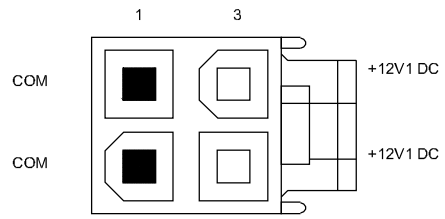
Connector attached (8 Pin)

Some motherboards have 4 pin 12V CPU socket and some have 8 pin 12V socket. Therefore most of the power supply comes with 8 pin (4+4) detachable connector which can be split into two 4 pin connectors.

Fig 14

8 Pin connector detachable

Fig 15



Pin	Name	Color	Description
1	COM	Black	Ground
2	COM	Black	Ground
3	+12VDC	Yellow	+12 VDC
4	+12VDC	Yellow	+12 VDC

4-pin pheripheral power connector (usually called molex)

These are the other smaller connectors that go to the various disk drives cooling fans and other smaller devices of the computer. Most of them have four wires: two black, one red, and one yellow. Unlike the standard mains electrical wire color-coding, each black wire is a ground, the red wire is +5V, and the yellow is +12V. In some cases these are also used to provide additional power to PCI cards such as firewire 800 cards.

Fig 16

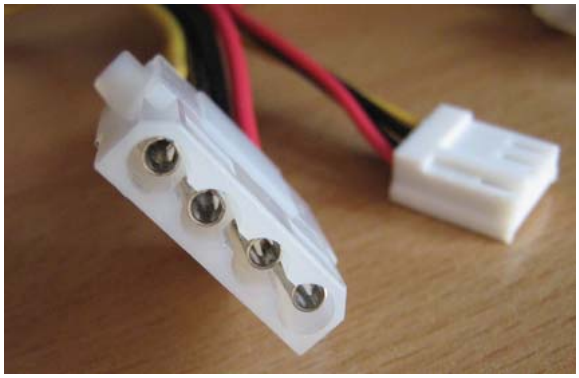
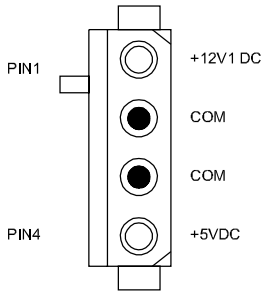


Fig 17



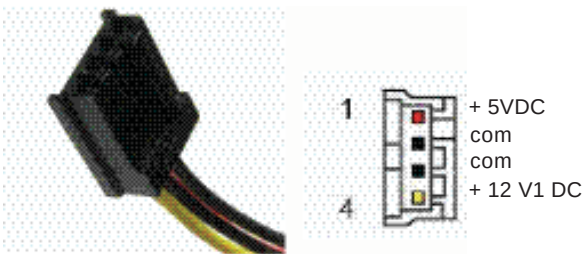
Pin	Name	Color	Description
1	+12VDC	Yellow	+12 VDC
2	COM	Black	Ground
3	COM	Black	Ground
4	+5VDC	Red	+5 VDC

Berg floppy drive 4 pin power connector (Fig 18)

The floppy drive 4 pin power supply connector is the standard floppy drive power connector in computers today.

The power connector itself is a Berg connector, sometimes referred to as a Mini-Molex connector.

Fig 18



Pin	Name	Color	Description
1	+5VDC	Red	+5 VDC
2	COM	Black	Ground
3	COM	Black	Ground
4	+12VDC	Yellow	+12 VDC

15 pin serial ATA power connector

A 15 pin power supply connector which uses SATA power plug is one of the standard pheripheral power connectors in computers. This power connector for all SATA based hard drives and optical drives. This connector supplies power at three different voltages such as +3.3V, +5V and +12V. Modern power supply must have atleast 4 of these, to power up drives at the SATA standard.

4 pin molex connector to SATA power converter cables are also available.

Fig 19

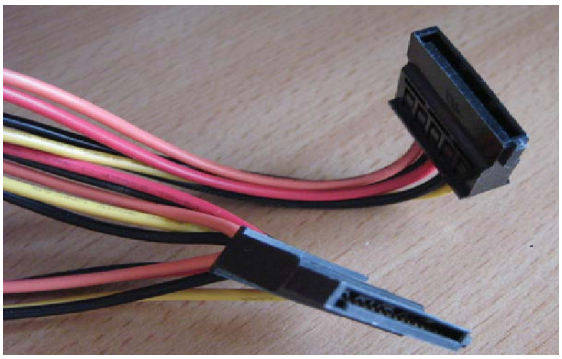
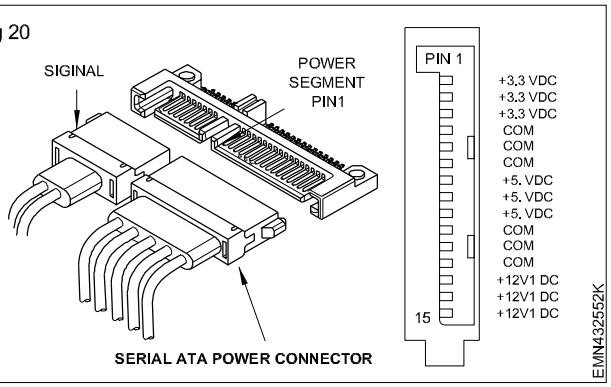


Fig 20



Pin	Name	Color	Description
1	+3.3VDC	Orange	+3.3 VDC
2	+3.3VDC	Orange	+3.3 VDC
3	+3.3VDC	Orange	+3.3 VDC
4	COM	Black	Ground
5	COM	Black	Ground
6	COM	Black	Ground
7	+5VDC	Red	+5 VDC
8	+5VDC	Red	+5 VDC
9	+5VDC	Red	+5 VDC
10	COM	Black	Ground
11	COM	Black	Ground (Optional or other use)
12	COM	Black	Ground
13	+12VDC	Yellow	+12 VDC
14	+12VDC	Yellow	+12 VDC
15	+12VDC	Yellow	+12 VDC

The wire numbers in serial power ATA(SATA) connector are not 1:1. There are three pins for each voltage.

Fig 21

Molex 4 pin connector to SATA power converter cable

The PCI Express connector (PCI - e 6 pin/ PCI - e 8pin)

Most modern computer power supplies include 6-pin connectors which are generally used for PCI express graphics cards, but a newly introduced 8-pin connector should be seen on the latest model power supplies. Each PCI express 6-pin connector can output a maximum of 75W.

6+2 pin for the purpose of backwards compatibility, some connectors designed for this kind of pin configuration to use with PCI express graphics card feature. It allows either a 6-pin card or an 8-pin card to be connected by using two separate connection modules wired into the

Fig 22

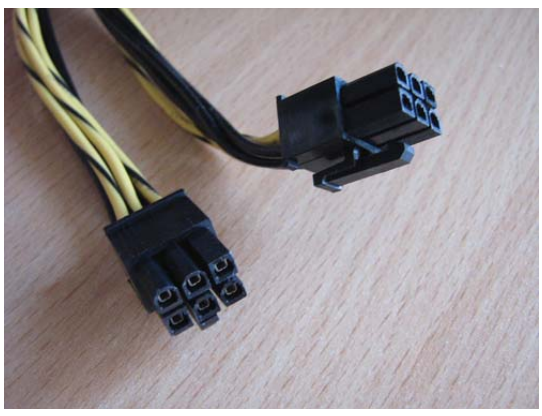
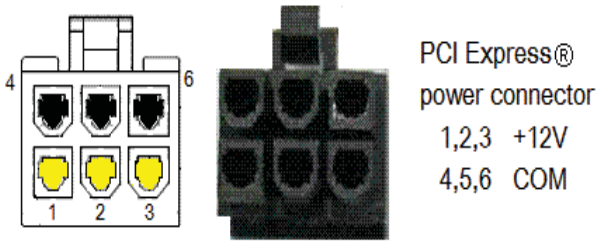


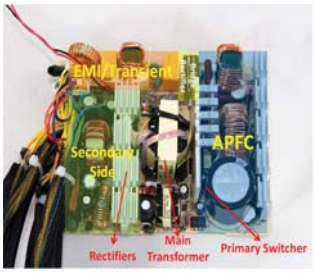
Fig 23



Pin	Name	Color	Description
1	COM	Black	Ground
2	COM	Black	Ground
3	COM	Black	Ground
4	+12VDC	Yellow	+12 VDC
5	+12VDC	Yellow	+12 VDC
6	+12VDC	Yellow	+12 VDC

same sheath: one with 6 pins and another with 2 pins as shown in Fig 24.

Fig 24

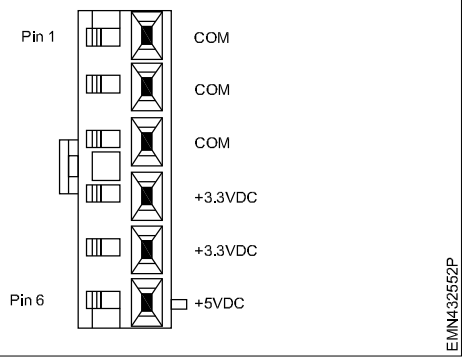


If your power supply doesn't have an 8-pin connector, there are 6-8 adapters.

Auxiliary power connectors

There are several types of auxiliary connectors designed to provide additional power if it is needed.

Fig 25



Power supplies to the PC have the connectors that are vital hardware cables and buses for transferrring power to various components in the computer. PC main is the power connector, also called P1; it connects to the motherboard and powers it. P10 for system monitoring and is responsible for supplying power to the power supply unit's fan. ATX12V 4-pin cable is the second one to connect to the motherboard. The 4-pin connector is used for the powering of disk drives. 4 pin power is used for the accelerated graphics port graphical cards. Auxillary cables are additional power supply units. SATA cable connectors are for the hardware devices that SATA plugs into for power. 6-pin connector powers the computer for PCI express audio-video cards. 6+2 pin is used for the function of reverse compatibility of the PCI express card. An IEC 60320 C14 cable uses a C13 card to connect the PSU to the native power grid.

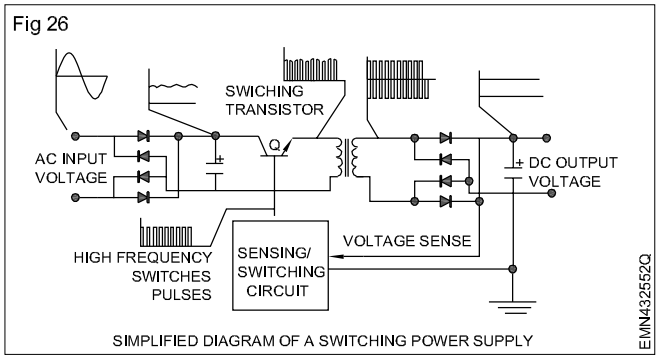
Need of SMPS in PC

On ATX and most of the other later form factors, the motherboard can turn the power supply on or off. This is done through the PS-ON (power supply on) signal that passes between the motherboard and the power supply. If your PC powers off when windows is finished shutting down, you have this feature.

Another indicator that your power supply supports PS-ON is the use of Momentary On or Always On power switches that are connected to the motherboard in place of an exterior switch connected to the power supply. When this signal line is pulled to a low voltage signal, the +12V DC, +5V DC, +3.3V DC, -5V DC and -12V DC power lines are turned on. When it is pulled to a high-voltage signal, or open-circuited, the DC output lines should no longer have current. The +5V DC output is always on as long as the power supply is receiving AC power. Because the ATL, NLX, LTX and other form factor motherboards have some power running to them at all times, you will always want to unplug the PC before working on it.

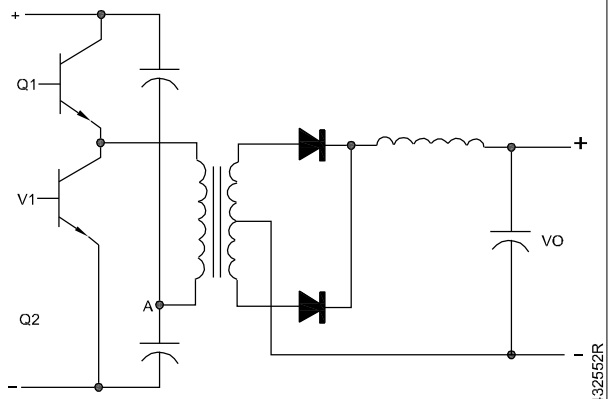
Function of SMPS in PC

Fig 26



AC line input is rectified and converted to DC voltage. The DC voltage is switched at high frequency nearly 20 KHz. The switched voltage is fed to the high frequency step down transformer. The output of the transformer is rectified and energy is stored in an inductor and smoothened by a capacitor. The switching period (pulse width) is controlled by the feed back given to the controller section. Power switching transistors ON time is varied according to the load. When the load increases the output voltage tends to drop. This drop in voltage is fed as the error signal to power controller which increases the ON period of switching pulses. When the load decreases the output goes high. The error voltage is fed to the controller which reduces the ON period of switching pulses. Since there are many outputs in a PC SMPS i.e. 12V, -12V, -5 only the main 5 volts which supplies

Fig 27



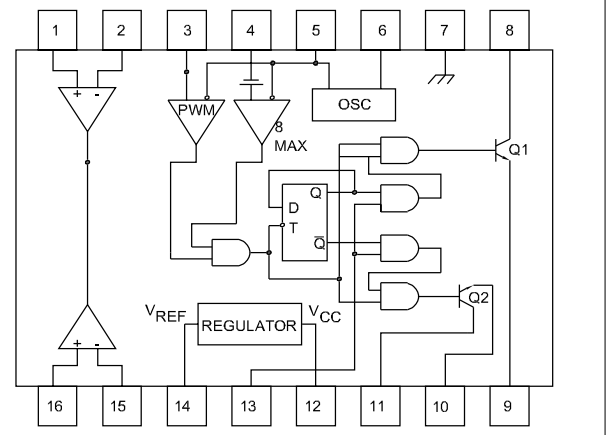
HALF-BRIDGE CONVERTOR CIRCUIT

maximum current is sensed and regulated. The transformer winding is designed taking care of this aspect. A simplified diagram of a switching power supply is shown in Fig 26.

Most widely used configuration in PC SMPS is half bridge converter circuit as shown in Fig 27. Power transistors Q1 and Q2 switch the DC voltage through the windings in a push pull manner.

In most of PC SMPS there is no separate step down transformer used for the power supply of the PWM IC. It is derived from the main ferrite core transformer output. Primary winding of the transformer with a capacitor and resistor along with part of driver transformer form a self oscillating circuit. This oscillation produces secondary output. The 12V winding output is used to power the PWM IC. Once powered the PWM IC takes over the switching operation. Thus the need for separate power supply for the IC is eliminated.

Fig 28



PIN NO;	FUNCTION
1	ERROR AMP.1,NONINVERTING INPUT
2	ERROR AMP.1,INVERTING INPUT
3	COMPENSATION INPUT
4	DEAD TIME CONTROL INPUT
5	OSILLATOR TIMING CAPACITOR
6	OSILLATOR TIMING RESISTER
7	GROUND
8	DRIVE TRANSISTER1,COLLECTOR
9	DRIVE TRANSISTER 1,EMITTER
10	DRIVE TRANSISTER 2,EMITTER
11	DRIVE TRANSISTER 2,CONTROLLER
12	INPUT SUPPLY
13	OUTPUT MODE CONTROL
14	STABILISED REFERANCE VOLTAGE
15	ERROR AMP2,INVERTING INPUT
16	ERROR AMP2,NONINVERTING INPUT

TL94 BLOCK DIAGRAM AND PIN ASSIGNMENTS

Working of PWM (Pulse Width Modulation) IC TL 494 in PC SMPS

Most widely used PWM IC in a PC SMPS is TL 494. Fig 28 shows the pin details and functional details of IC 494. The IC contains an oscillator circuit with external resistor and capacitor. A 5 volt reference is available for feedback control. Two error amplifiers are used to control pulse width and current limit.

The dead time control input is useful in starting the switching operation gradually so that the switching transistors are not loaded suddenly. There are two driver transistors. They are used to drive the power switching transistors. (Fig 29)

Power good signal in SMPS of PC

In addition to providing converted power to the motherboard and the other parts of the PC, the power supply also sends a very important signal to the motherboard called - the Power-Good signal.

When the PC is powered on, the power supply performs a self test and checks to see if the required voltages (in and out) are correct. If so , the Power-Good signal line is set high (on) to indicate that the motherboard can rely on the power being supplied. If the signal is not set, the processor's timing chip (to which this signal line is attached) will send the processor a Reset command that starts the basic input/output (BIOS) initialization code. The effect of the Power-good signal not being set is that the PC is trapped in a loop continuously calling the BIOS. In this situation, the power supply appears to be working and some power is being supplied to the PC and its peripherals. The front panel lights may be on, the disk drives spinning, and the power supply fan running, but the BIOS will never reach the power-on self-test (POST) process and will appear to be hung up on something.

Use of the fan in PC SMPS

A 12V DC fan is used for removing the heat generated inside the power supply. The fan blows out air from the SMPS. The fan also helps in air circulation inside the cabinet. Proper working of fan is ensured by periodic cleaning. Whenever the fan is working intermittently the fan should be cleaned for dust near the motor. A failed fan can result in the failure of the SMPS because of excess heat.

Difference between AT & ATX power supply

AT powersupply does not have soft start option.

AT powersupply does not generate 3.3V DC.

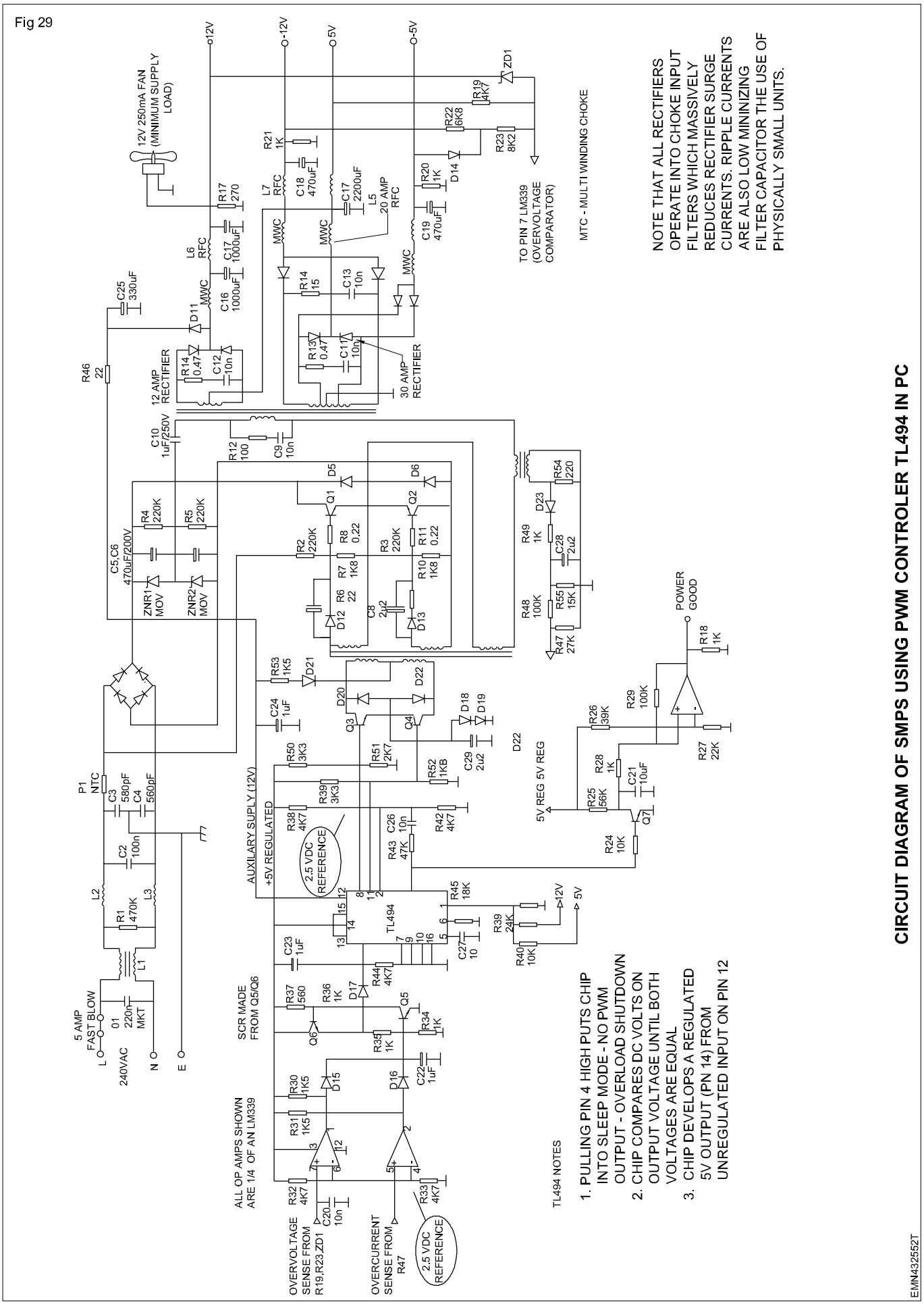
AT motherboard supply connectors come with 2x6 pin connection.

ATX power supply has a soft start.

ATX power supply does not shut down completely. Always the ATX power supply gives 5 volt to the mother board.

ATX power supply generates a 3.3V DC for the processor core voltage.

Fig 29



DC-DC converter

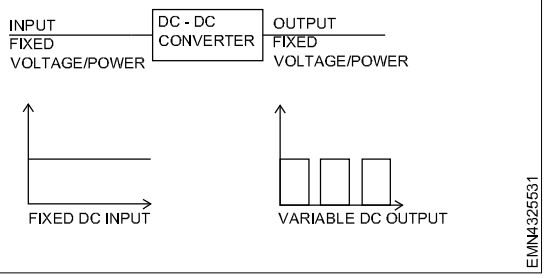
Objectives : At the end of this lesson you shall be able to

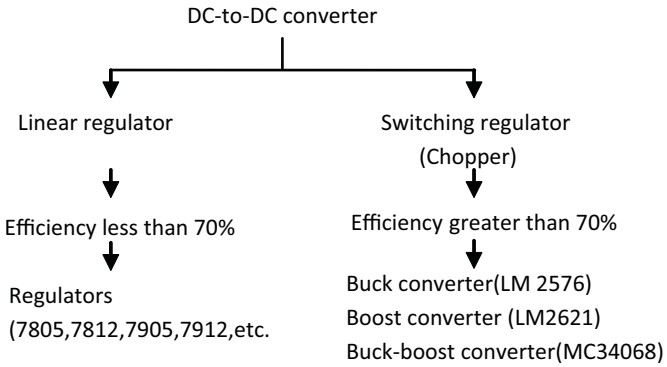
- **state chopper and types of chopper**
- **explain the principle of chopper operation and classifications**
- **compare step-down and step-up chopper**
- **list the application of chopper**
- **explain the working of buck coverter, boost coverter and buck-boost coverter**
- **classify chopper circuit and its quadrant of operation**
- **list out the IC's used in buck converter, buck-boost converter, inverting converter.**

Introduction to DC-to-DC converter

A DC-to-DC converter (chopper) is an electronic circuit that converts one DC voltage level to another, which may be higher or lower by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be either magnetic field storage (Inductors) or electric field storage. (Capacitors)

Fig 1





A linear regulator uses a resistive voltage drop to regulate the voltage, which losses power in the form of heat.

Switching regulator uses an inductive voltage drop, where the energy is stored and can be recovered. This results a much higher efficiency and much less heat.

Choppers

A chopper is basically a dc to dc converter whose main function is to create adjustable dc voltage from fixed dc voltage sources through the use of semiconductors.

Types of choppers

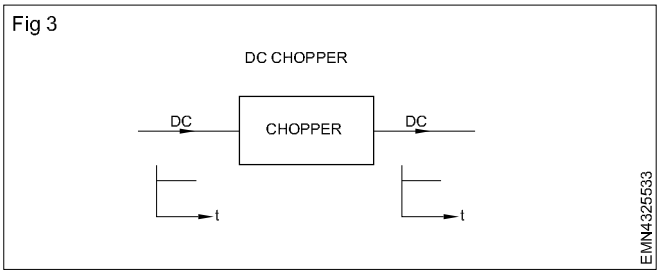
There are two types of choppers - AC and DC.

AC Link Chopper (Fig 2)

In an AC link chopper, DC is converted to AC with the help of an inverter. After that, AC is stepped-up or stepped-down by a transformer, which is then converted back to DC by a diode rectifier. AC link chopper is costly, bulky and less efficient as the conversion is done in two stages.

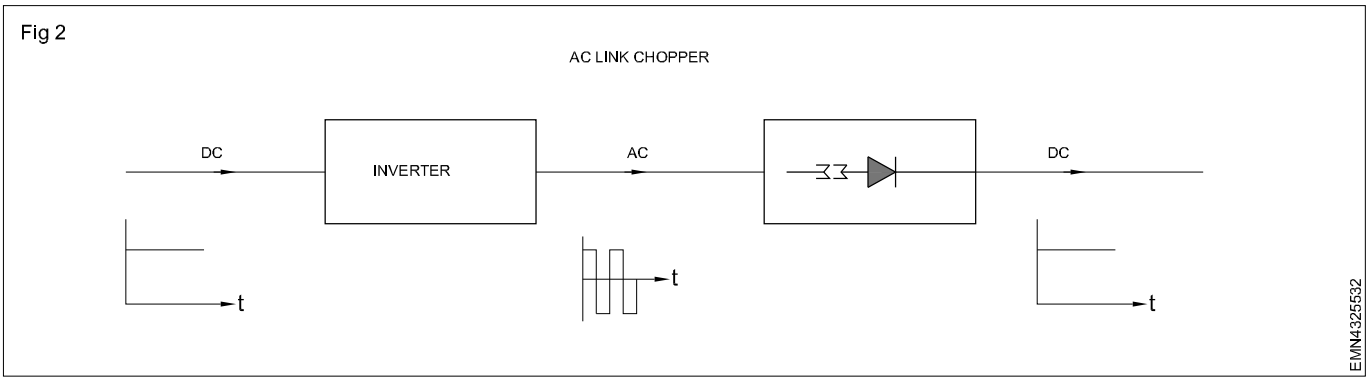
DC Chopper (Fig 3)

Fig 3



A DC chopper is a static device that converts fixed dc input voltage to a variable dc output voltage directly. A chopper can be used to step up or step down the fixed dc output voltage. Choppers are used in many applications in various electronic equipments. A chopper system has a high efficiency, fast response and a smooth control.

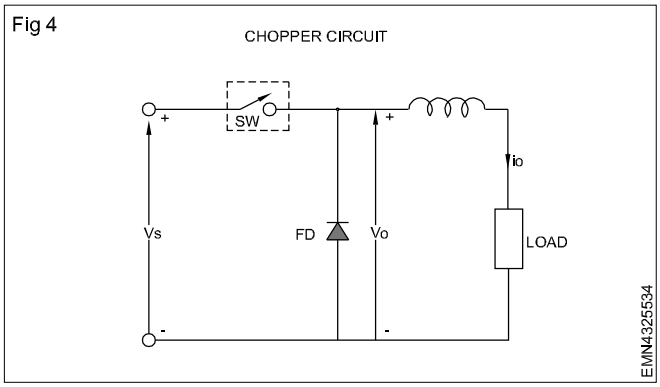
Fig 2



Principle of chopper operation

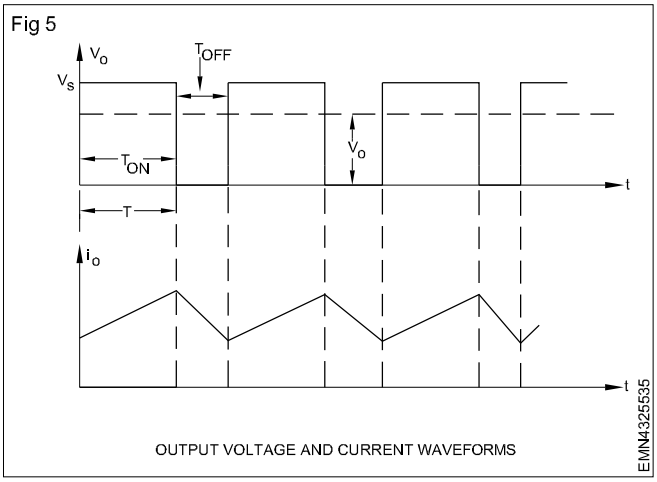
A chopper is a high speed on/off semiconductor switch. Source to load connection and disconnection from load to source happens in a rapid manner. In figure, a chopped load voltage can be obtained from a constant dc supply of voltage, which has a magnitude V_s. Chopper is represented by 'SW' inside a dotted square which can be turned ON or OFF as desired. (Fig 4)

Fig 4



Output voltage and current waveforms (Fig 5)

Fig 5



Devices used in chopper

Low power application : GTO, IGBT, Power BJT, Power MOSFET etc.

High power application : Thyristor like SCR.

Classifications

Chopper may be classified depending upon the direction of O/P current and voltage. ie., step down (Buck converter) Step-up (Boost converter).

1 On the basis of input and output voltage levels

Step-down chopper

Class A

Class B

Class C (Combination of A & B)

Class D

Class E

Step-up chopper

Class B

2 **On the basis of circuit operation**

First quatrant

Two quatrant

Four quatrant

3 On the basis of commutation method

Voltage commutated

Current commutated

Load commutated

Impulse commutated

Comparison between step-up and step-down chopper

Sl.no	Parameters	Step down chopper	Step up chopper
1	Range of output voltage	0 to V volts	V to +0 volts
2	Position of chopper switch	In series with load	In parallel with load
3	Expression for output voltage	V_L dc = D x V volts	V_o = V/(1 - D) volts
4	External inductance	Not required	Required for boosting the output voltage
5	Use	For motoring operation, motor for motor load	For regenerative braking for load.
6	Type of chopper	Single quadrant	Single quadrant
7	Quadrant of operation	1st quadrant	1st quadrant

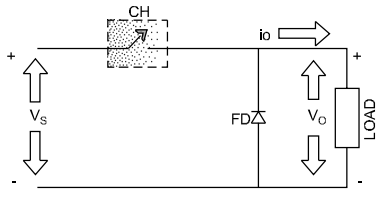
Applications

1 Switched mode power supplies, including DC to DC converters in computers
2 Speed controllers for DC motors
3 Class D Electronic amplifiers
4 Switched capacitor filters
5 Variable-frequency drives
6 D.C. voltage boosting
7 Battery-operated electric cars
8 Battery-operated appliances
9 Battery chargers
10 Subway cars
11 Trolley buses
12 Battery-operated vehicles
13 Solar energy conversion & wind energy conversion
14 Air planes and spaceships
15 On-board regulated DC power supplies
16 Commercial electronics & Electronic instruments.

Step down chopper

Step down chopper as Buck converter is used to reduce the i/p voltage level at the output side. In buck converter, the o/p voltage is lower than the i/p voltage. (Fig 6)

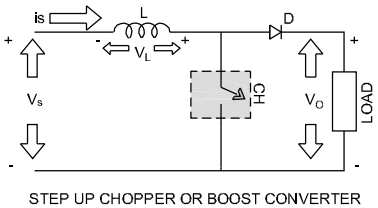
Fig 6



Step up chopper or Boost converter

Step up chopper or boost converter is used to increase the input voltage level of its output side. In boost converter the o/p voltage is higher than the i/p voltage.(Fig 7)

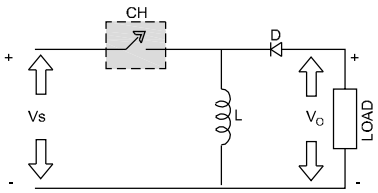
Fig 7



Buck-Boost converter or step up step down converter

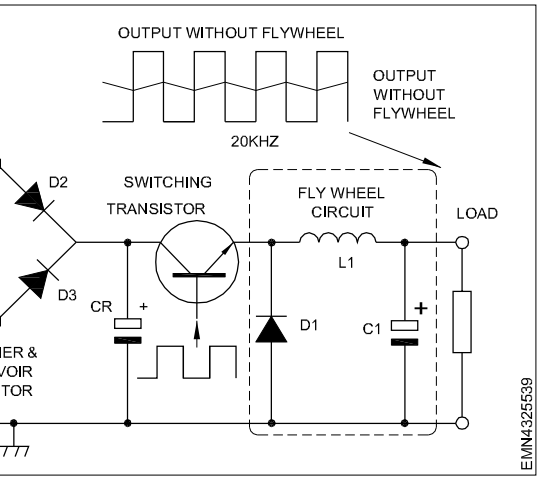
With the help of Buck-Boost converter we can increase or decrease the input voltage level at its output side as per our requirement. This type of converter produces an o/p voltage that is either lower or higher than the i/p voltage. (Fig 8)

Fig 8



Buck converters (Fig 9)

Fig 9



The buck converter

The buck converter is used in SMPS circuits where the DC output voltage needs to be lower than the DC input voltage.

The switching transistor between the input and output of the buck converter continually switches ON and OFF at high frequency. To maintain a continuous output, the circuit uses the energy stored in the inductor L, during the ON periods of the switching transistor, to continue supplying the load during the OFF periods. The circuit operation also called a flywheel circuit.

The buck converter is a form of DC to DC converter that can take an input directly from a DC source, such as a battery. The input could also be DC derived from the AC mains (line) as shown in Fig 10 via a rectifier/reservoir capacitor circuit. The AC input to the rectifier circuit could be AC at high voltage directly from the AC mains supply, or alternatively at a lower voltage via a step down transformer. However the DC applied to the buck converter is obtained; it is then converted to a high frequency AC, using a switching or 'chopper' transistor, driven by a (usually pulse width modulated) square wave.

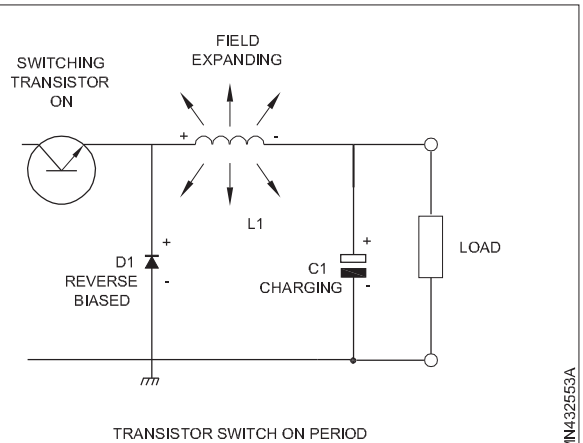
Buck converter operation

As shown in Fig 10 the buck converter circuit consists of the switching transistor, together with the flywheel circuit (DI, L1 and C1). While the transistor is on, current is flowing through the load via the inductor L1. The action of any inductor opposes changes in current flow and also acts as a store of energy. In this case the switching transistor output is prevented from increasing immediately to its peak value as the inductor stores energy taken from the increasing output; this stored energy is later released

back into the circuit as a back e.m.f. as current from the switching transistor is rapidly switched OFF.

Transistor switch ON period

Fig 10



TRANSISTOR SWITCH ON PERIOD

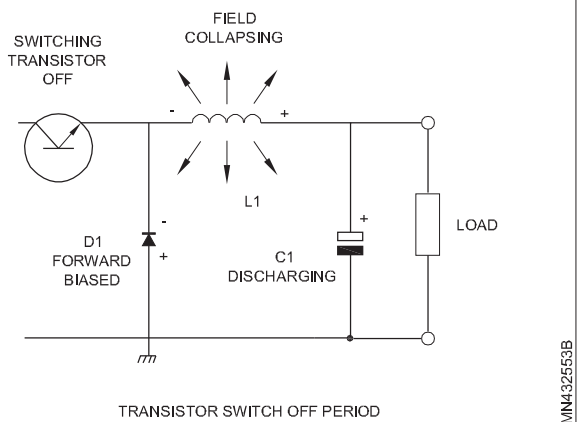
In Fig 10 when the switching transistor is switched ON, it is supplying the load with current. Initially current flow to the load is restricted as energy is also being stored in L1, therefore the current in the load and the charge on C1 builds up gradually during the ON period. Notice that throughout the ON period, there will be a large positive voltage on D1 cathode and so the diode will be reverse biased.

Transistor switch OFF period

When the transistor switches OFF as shown in Fig 11 the energy stored in the magnetic field around L1 is released back into the circuit. The voltage across the inductor (the back e.m.f.) is now in reverse polarity to the voltage across L1 during the ON period, and sufficient stored energy is available in the collapsing magnetic field to keep current flowing for atleast part of the time the transistor switch is open.

The back e.m.f. from L1 now causes current to flow around the circuit via the load and D1, which is now forward biased. Once the inductor has returned a large part of its stored energy to the circuit and the load voltage begins to fall, the charge stored in C1 becomes the main source of current, keeping current flowing through the load until the next ON period begins.

Fig 11

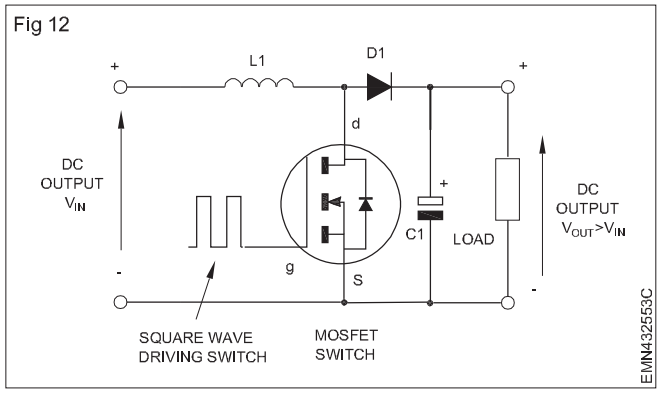


TRANSISTOR SWITCH OFF PERIOD

Boost converter

Fig 12 illustrates the basic circuit of a Boost converter. The switching transistor is a power MOSFET, both Bipolar power transistors and MOSFETs are used in power switching. The rest of the components are the same as those used in the buck converter except that their positions have been re-arranged.

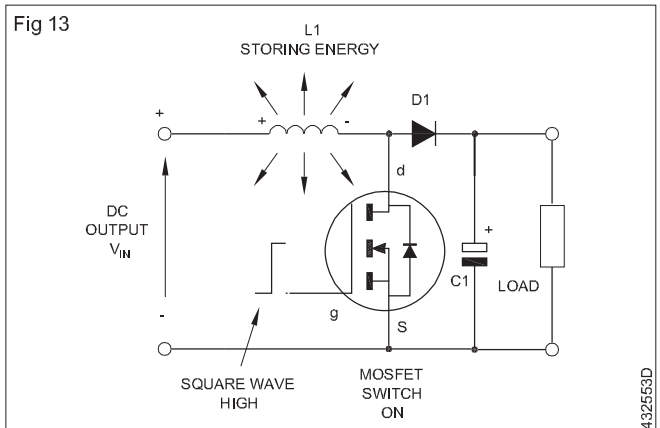
Fig 12



Boost converter operation

Fig 13 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right hand side of L1 to the negative input supply terminal. Therefore, a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent a much higher impedance than the path directly through the heavily conducting MOSFET.

Fig 13



BOOST CONVERTER OPERATION AT SWITCH ON

Fig 14 shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned OFF the sudden drop in current causes L1 to produce a back e.m.f. in the opposite polarity to the voltage across L1 during the on period, to keep current flowing. This results in two voltages, the supply voltage V_{IN} and the back e.m.f.(V_L) across L1 in series with each other.

This higher voltage (V_{IN} +V_L), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to V_{IN} +V_L minus the small forward voltage drop across D1, and also supplies the load.

Fig 14

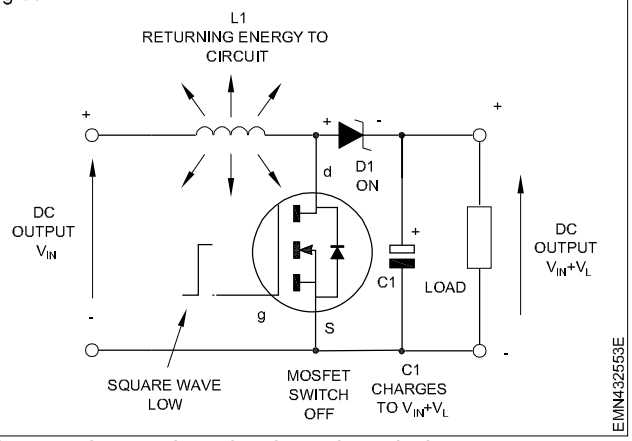
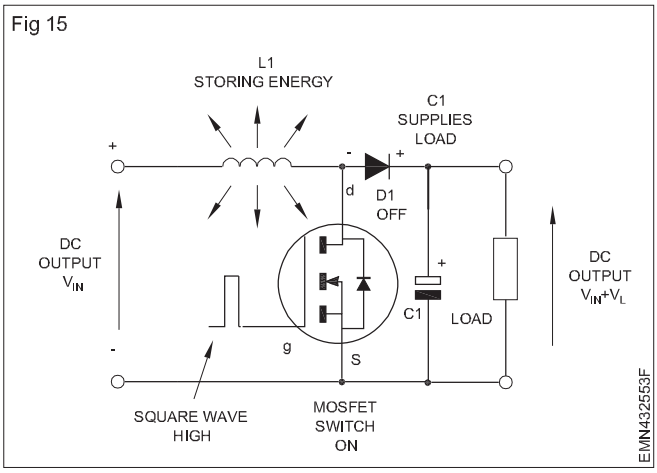


Fig 15 shows the circuit action during MOSFET on periods after the initial start up. Each time the MOSFET conducts, the cathode of D1 is more positive than its anode, due to the charge ON C1. D1 is therefore turned OFF so the output of the circuit is isolated from the input, however the load continues to be supplied with V_{IN} +V_L from the charge ON C1. Although the charge C1 drains away through the load during this period, C1 is recharged each time the MOSFET switches OFF, so maintaining an almost steady output voltage across the load.

Fig 15



Buck-boost converters

A Buck-Boost converter is a type of switched mode power supply that combines the principles of the Buck Converter and the Boost converter in a single circuit.

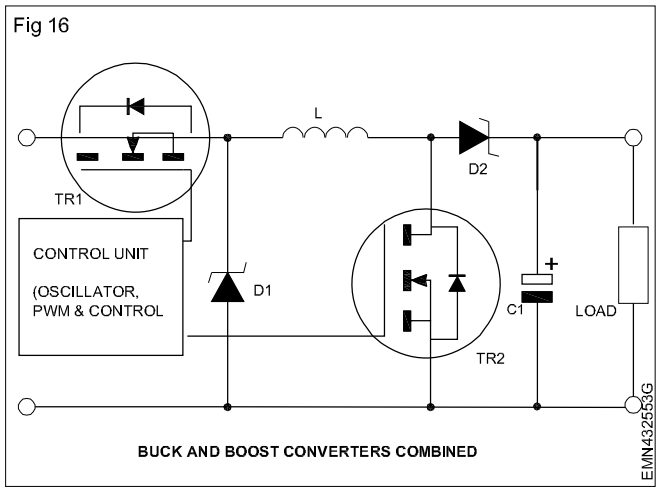
The Buck converter produces a DC output in a range from 0V to just less than the input voltage. The boost converter will produce an output voltage ranging from the same voltage as the input, to a level much higher than the input.

Buck-boost converters are used in Battery-powered systems, where the input voltage can vary widely, starting at full charge and gradually decreasing as the battery charge is used up. At full charge, where the battery voltage may be higher than actually needed by the circuit being powered, a buck regulator would be ideal to keep the supply voltage steady. However as the charge diminishes the input voltage falls below the level required by the circuit, and either the battery must be discarded or re-charged; at this point the ideal alternative would be the boost regulator.

By combining these two regulator designs it is possible to have a regulator circuit that can cope with a wide range of input voltages both higher or lower than that needed by the circuit. Both buck and boost converters use very similar components.

In Fig 16 the common components of the buck and boost circuits are combined. A control unit is added, which senses the level of input voltage, then selects the appropriate circuit action. (Note that in the examples in this section the transistors are shown as MOSFETs, commonly used in high frequency power converters, and the diodes shown as Schottky types. These diodes have a low forward junction voltage when conducting, and are able to switch at high speeds).

Fig 16



Operation as a buck converter

The basic operation of the buck boost converter is illustrated in Fig 16 and 17.

Fig 17 shows the circuit operating as a buck converter. In this mode Tr2 is turned off, and Tr1 is switched on and off by a high frequency square wave from the control unit. When the gate of Tr1 is high, current flows though L, charging its magnetic field, charging C and supplying the load. The schottky diode D1 is turned off due to the positive voltage on its cathode.

Fig 17

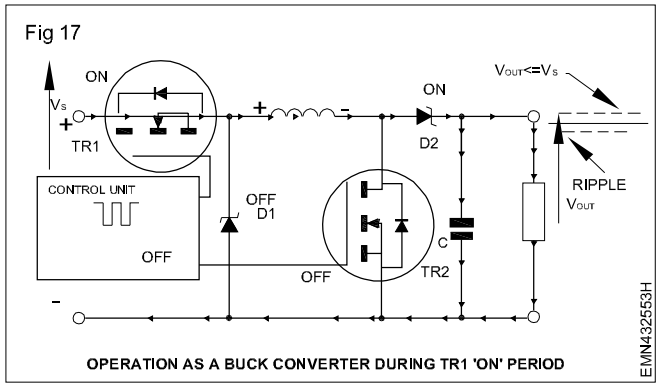
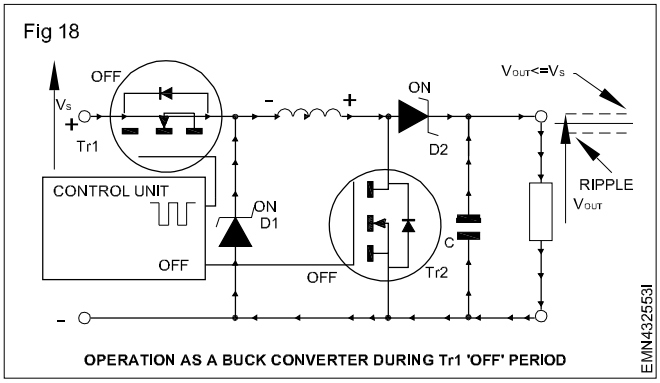


Fig 18 shows the current flow during the buck operation of the circuit when the control unit switches Tr1 off. The initial source of current is now the inductor L. Its magnetic field is collapsing, the back e.m.f. generated by the collapsing field reverses the polarity of the voltage across L, which turns on D1 and current flows through D2 and the load.

As the current due to the discharge of L decreases, the charge accumulated in C during the on period of Tr1 now also adds to the current flowing through the load, keeping V_{OUT} reasonably constant during the OFF period. This helps keep the ripple amplitude to a minimum and V_{OUT} close to the value of V_S.

Fig 18

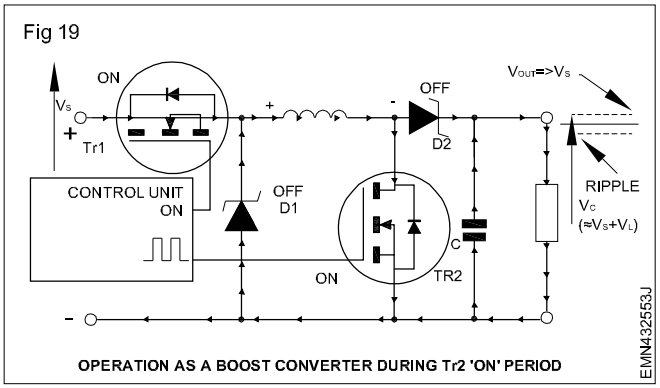


OPERATION AS A BUCK CONVERTER DURING Tr1 'OFF' PERIOD

Operation as a boost converter

In boost converter mode, Tr1 is turned on continually and the high frequency square wave applied to Tr2 gate. During the ON periods when Tr2 is conducting, the input current flows through the inductor L and via Tr2, directly back to the supply negative terminal charging up the

Fig 19



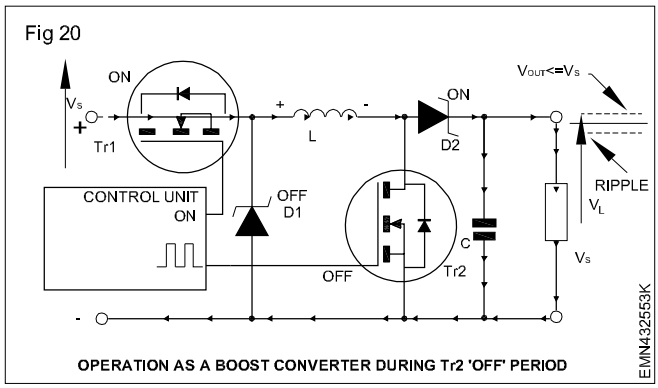
OPERATION AS A BOOST CONVERTER DURING Tr2 'ON' PERIOD

magnetic field around L. Whilst this is happening D2 cannot conduct as its anode is being held at ground potential by the heavily conducting Tr2. For the duration of the ON period, the load is being supplied entirely by the charge on the capacitor C, built up on previous oscillator cycles. The gradual discharge of C during the ON period (and its subsequent recharging) accounts for the amount of high frequency ripple on the output voltage, which is at a potential of approximately $V_S + V_L$.

Transistor OFF period

At the start of the OFF period of Tr2, L is charged and C is partially discharged. The inductor L now generates a back e.m.f. and its value that depends on the rate of change of current as Tr2 switches OFF and ON the amount of inductance the coil possesses; therefore the back e.m.f can be any voltage over a wide range, depending on the design of the circuit. Notice particularly that the polarity of the voltage across L has now reversed, and so adds to the input voltage V_S giving an output voltage that is atleast equal to or greater than the input voltage. D2 is now forward biased and so the circuit current supplies the load current, and at the same time recharges the capacitor to $V_S + V_L$ ready for the next ON period of Tr2.

Fig 20



OPERATION AS A BOOST CONVERTER DURING Tr2 'OFF' PERIOD

Classification of chopper

Depending upon the direction of the output current and voltage, the converters can be classified into five classes namely

1 Class A [One-quadrant operation]

2 Class B [One-quadrant operation]

3 Class C [Two-quadrant operation]

4 Class D Chopper [Two-quadrant operation]

5 Class E Chopper [Four-quadrant operation] (Fig 18)

Class A [One-quadrant operation]

1 Class A Chopper is a first quadrant chopper as shown in Fig 21.

2 When chopper is ON, supply voltage V is connected across the load.

3 When chopper is OFF,V_o = 0 and the load current continues to flow in the same direction through the Fly Wheel Diode(FWD).

4 The average values of output voltage and current are always positive. Class A Chopper is a first quadrant chopper

5 When chopper is ON, supply voltage V is connected across the load.

6 When chopper is OFF, V_o = 0 and the load current continues to flow in the same direction through the Fly Wheel Diode(FWD).

7 The average values of output voltage and current are always positive.

8 Class A chopper is a step-down chopper in which power always flows form source to load.

9 It is used to control the speed of DC motor.

10 The output current equations obtained in step down chopper with R-L load can be used to study the performance of Class A chopper.

Class B [One-quadrant operation]

1 Class B Chopper is a step-up chopper as shown in Fig 22.

Fig 21

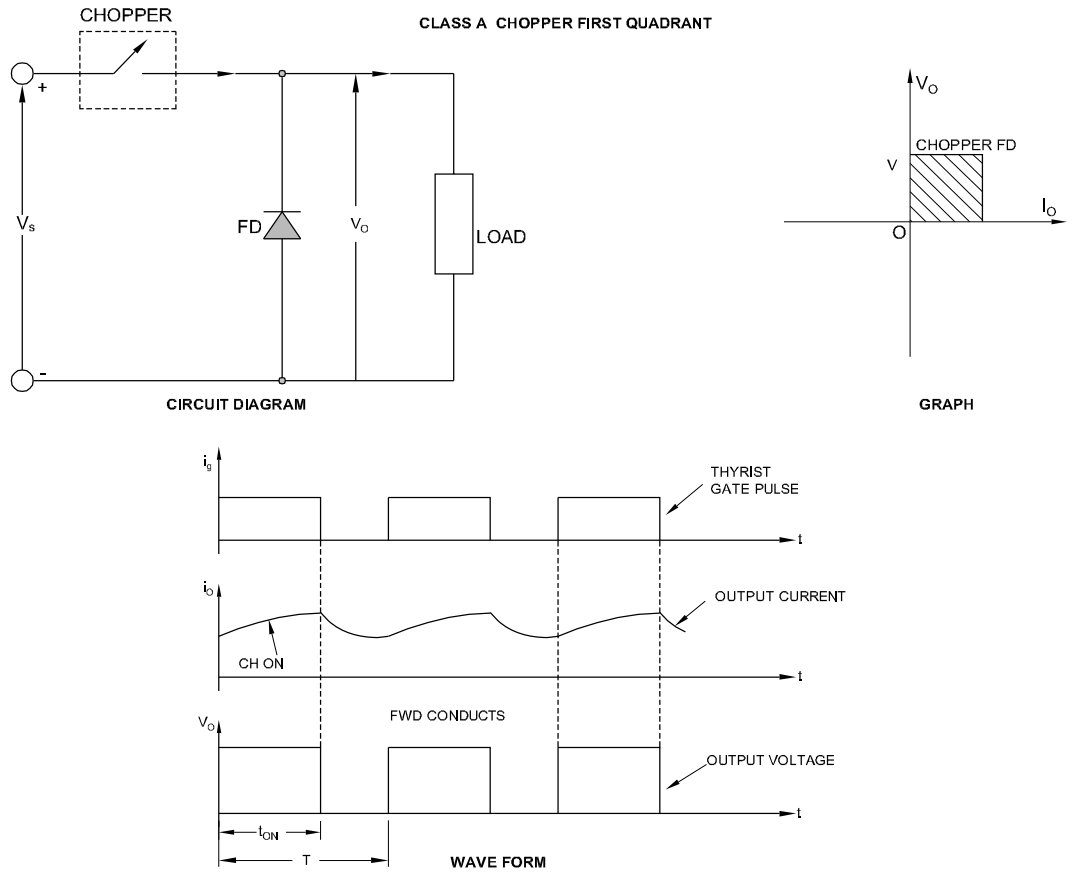
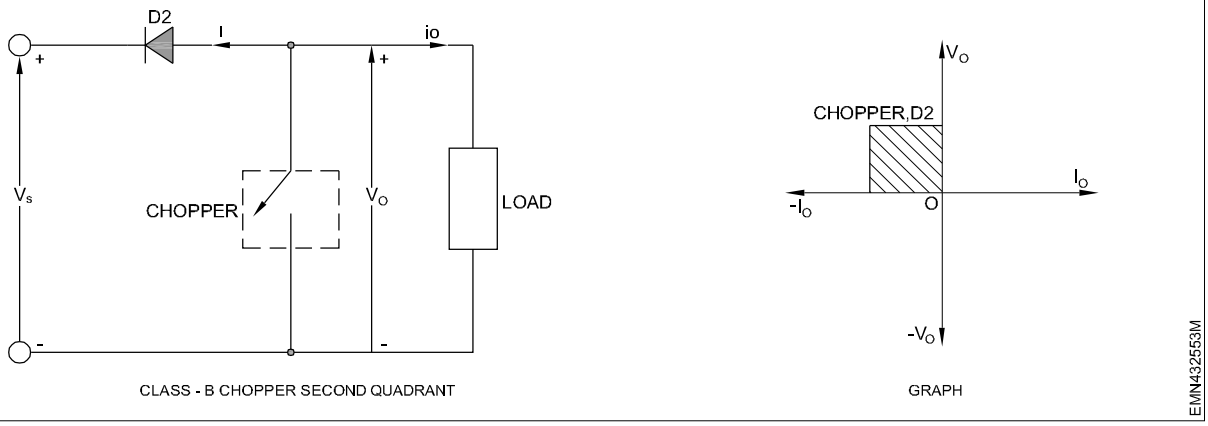


Fig 22



2 When chopper is ON, E drives a current through L and R in a direction opposite to that shown in figure.

3 During the ON period of the chopper, the inductance L stores energy.

4 When Chopper is OFF, diode D conducts, and part of the energy stored in inductor L is returned to the supply.

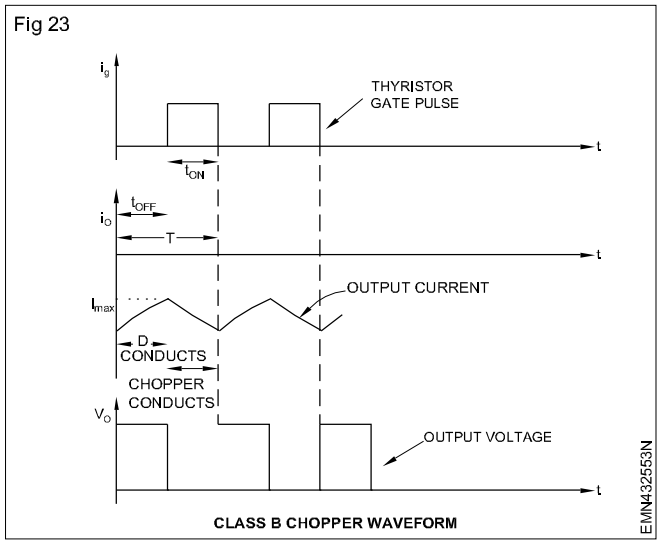
5 Average output voltage is positive. Average output current is negative.

6 Therefore Class B Chopper operates in second quadrant.

7 In this chopper, power flows from load to source.

8 Class B Chopper is used for regenerative braking of DC motor.

Fig 23



Class C [Two-quadrant operation]

1 Class C chopper can be used as a step-up or step-down chopper as shown in Fig 24.

2 Class C chopper is a combination of Class A and Class B Choppers.

3 For first quadrant operation, CH1 is ON or D2 conducts.

4 For second quadrant operation, CH2 is ON or D1 conducts.

5 When CH1 is ON, the load current is positive.

6 The output voltage is equal to 'V' and the load receives power from the source.

7 When CH1 is turned OFF, energy stored in inductance L forces current to flow through the diode D2 and the output voltage is zero.

8 Current continues to flow in positive direction.

9 When CH2 is triggered, the voltage E forces current to flow in opposite direction through L and CH2 .

10 The output voltage is zero.

11 On turning OFF CH2, the energy stored in the inductance drives current through diode D1 and the supply.

12 Output voltage is V, the input current becomes negative and power flows from load to source.

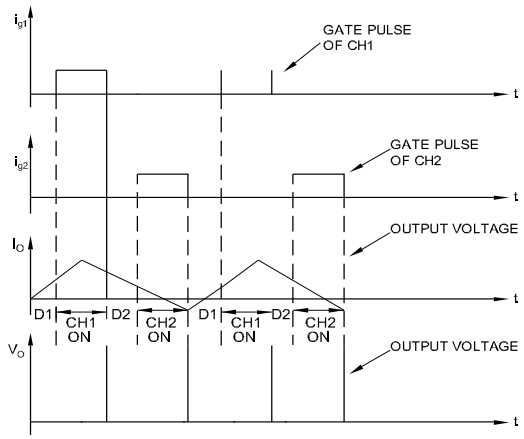
13 Average output voltage is positive.

14 Average output current can take both positive and negative values.

15 Choppers CH1 and CH2 should not be turned ON simultaneously as it would result in short circuiting the supply.

16 Class C Chopper can be used both for dc motor control and regenerative braking of DC motor.

Fig 25



CLASS - C CHOPPER WAVEFORM

EMN432553P

Class D Chopper [Two-quadrant operation]

1 Class D is a two quadrant chopper as shown in Fig 26.

2 When both CH1 and CH2 are triggered simultaneously, the output voltage V_o = V and output current flows through the load.

3 When CH1 and CH2 are turned OFF, the load current continues to flow in the same direction through load, D1 and D2 , due to the energy stored in the inductor L.

4 Output voltage V_o = - V.

5 Average load voltage is positive if chopper ON time is more than the OFF time.

6 Average output voltage becomes negative if $t_{ON} < t_{OFF}$.

7 Hence the direction of load current is always positive but load voltage can be positive or negative.

Class E Chopper [Four-quadrant operation] (Fig 28)

1 Class E is a four quadrant chopper.

2 When CH1 and CH4 are triggered, output current I_o flows in positive direction through CH1 and CH4, and with output voltage V_o = V.

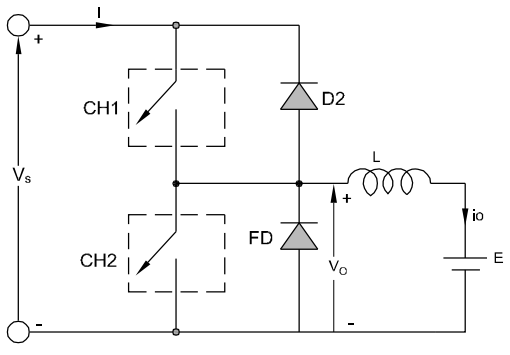
3 This gives the first quadrant operation.

4 When both CH1 and CH4 are OFF, the energy stored in the inductor L drives I_o through D2 and D3 in the same direction, but output voltage V_o = -V.

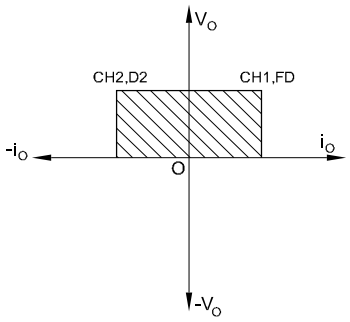
5 Therefore the chopper operates in the fourth quadrant.

6 When CH2 and CH3 are triggered, the load current I_o flows in opposite direction and output voltage V_o = -V.

Fig 24



CIRCUIT DIAGRAM

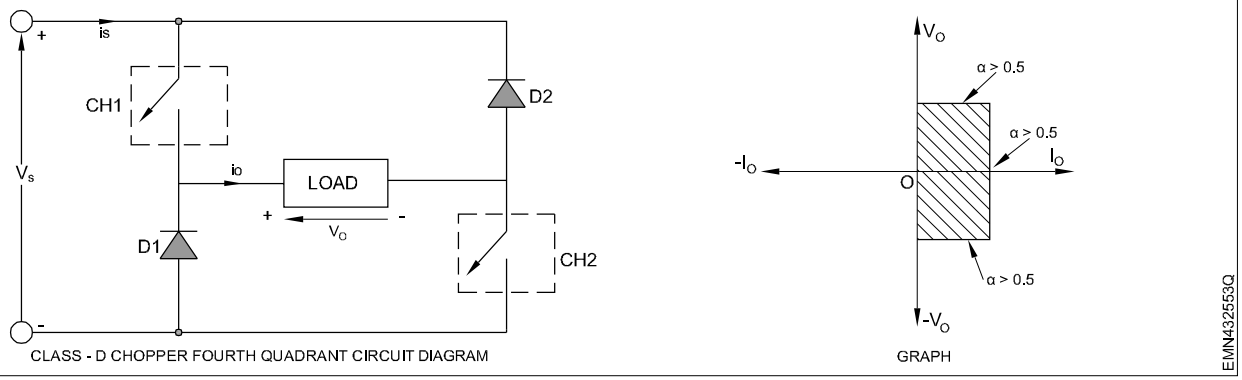


GRAPH

CLASS - C CHOPPER THIRD QUADRANT

EMN432553O

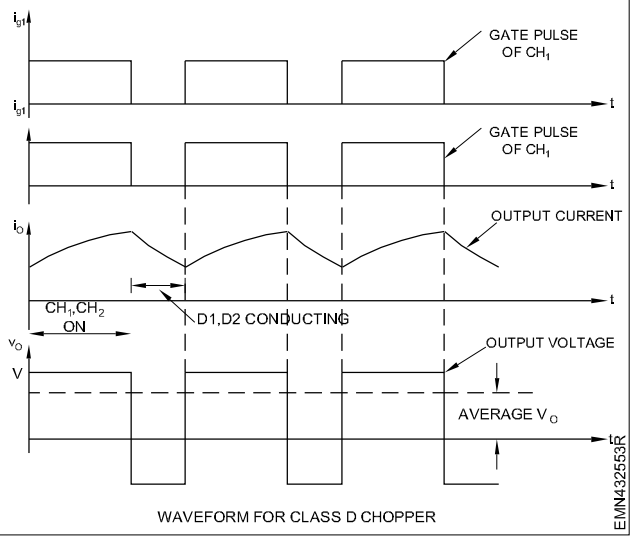
Fig 26



CLASS - D CHOPPER FOURTH QUADRANT CIRCUIT DIAGRAM

GRAPH

Fig 27



WAVEFORM FOR CLASS D CHOPPER

7 Since both I_o and V_o are negative, the chopper operates in third quadrant.

8 When both CH2 and CH3 are OFF, the load current I_o continues to flow in the same direction D1 and D4 and the output voltage I_o = V.

9 Therefore the chopper operates in second quadrant as V_o is positive but I_o is negative.

First quadrant

During the first quadrant operation the chopper CH4 will be ON . Chopper CH3 will be off and CH1 will be operated. AS the CH1 and CH4 is on the load voltage V_o will be equal to the source voltage Vs and the load current I_o will begin to flow . V_o and I_o will be positive as the first quadrant operation is taking place. As soon as the chopper CH1 is turned off, the positive current freewheels through CH4 and the diode D2 . The type E chopper acts as a step- down chopper in the first quadrant.

Second quadrant

In this case the chopper CH2 will be operational and the other three are kept off. As CH2 is on negative current will starts flowing through the inductor L. CH2, E and D4. Energy is stored in the inductor L as the chopper CH2 is on. When CH2 is off the current will be fed back to the source through the diodes D1 and D4. Here (E+L.di/dt) will be more than the source voltage V_s. In second quadrant the chopper will act as a step-up chopper as the power is fed back from load to source.

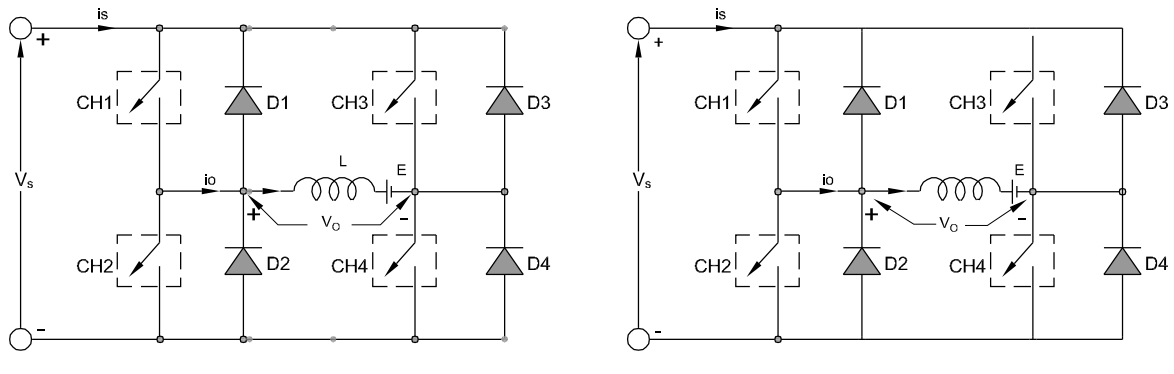
Third quadrant

In third quadrant operation CH1 will be kept off , CH2 will be on and CH3 is operated. For this quadrant working the polarity of the load should be reversed. As the chopper CH3 is ON, the load gets connected to the source V_s and V_o and I_o will be negative and the third quadrant operation will takes place. This chopper acts as a step-down chopper

Fourth quadrant

CH4 will be operated and CH1, CH2 and CH3 will be off. When the chopper CH4 is turned on positive current starts to flow through CH4, D2 ,E and the inductor L will store energy. As the CH4 is turned off the current is feedback to the source through the diodes D2 and D3 , the operation will be in fourth quadrant as the load voltage

Fig 28



is negative but the load current is positive. The chopper acts as a step up chopper as the power is fed back from load to source.

Buck converter (IC LM2576)

1 Features

i 3.3-V, 5-V, 12-V, 15-V, and adjustable output versions

ii Adjustable version output voltage range,1.23 V to 37 V (57 V for HV version) ±4% maximum over line and load conditions

iii Specified 3-A output current

iv Wide input voltage range: 40V upto 60 V for HV version

v Requires only 4 external components

vi 52-kHz fixed-Frequency internal oscillator

vii TTL-shutdown capability, Low-power standby mode

viii High efficiency

ix Uses readily available standard inductors

x Thermal shutdown and current limit protection

2 Applications

i Simple high-efficiency step-down (Buck) regulator

ii Efficient pre-regulator for linear regulators

iii On-card switching regulators

iv Positive-to-Negative converter (Buck-Boost)

3 Description

The LM2576 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, 15 V, and an adjustable output version.

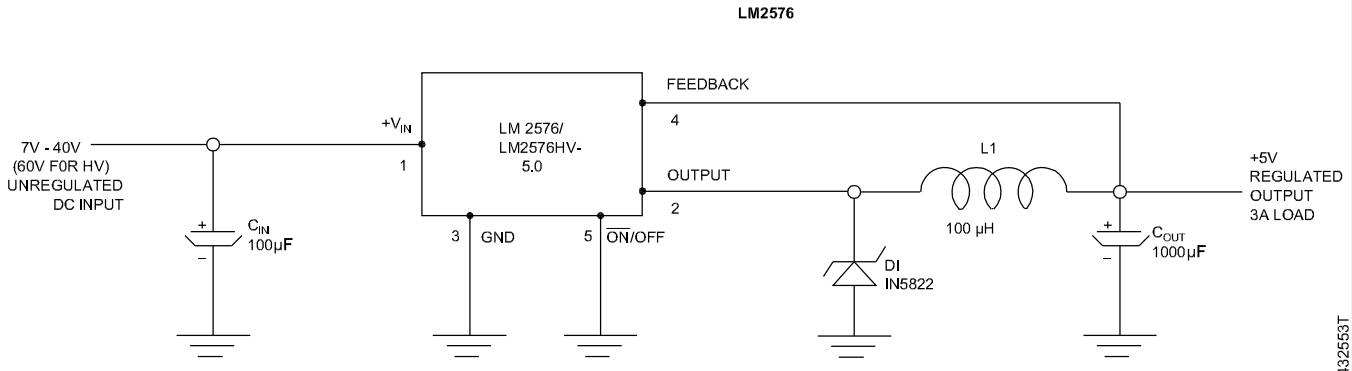
Requiring a minimum number of external components, these regulators are simple to use include fault protection and a fixed-frequency oscillator.

The LM2576 series offers a high-efficiency replacement for popular three-terminal linear regulators. It substantially reduces the size of the heat sink, and in some cases no heat sink is required.

A standard series of inductors optimized for use with the LM2576 are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies.

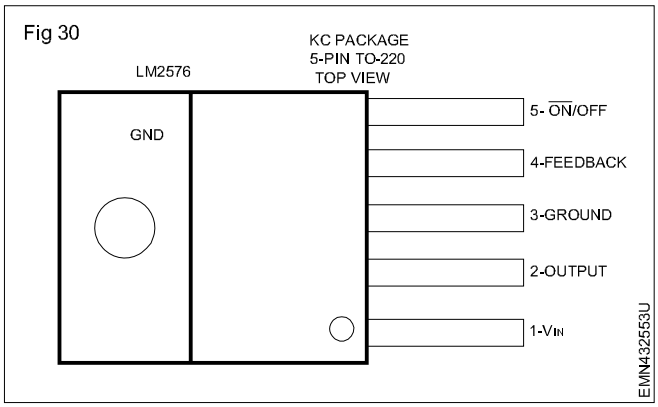
Other features include a ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±10% on the oscillator frequency. External shutdown is included, featuring 50-µA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

Fig 29



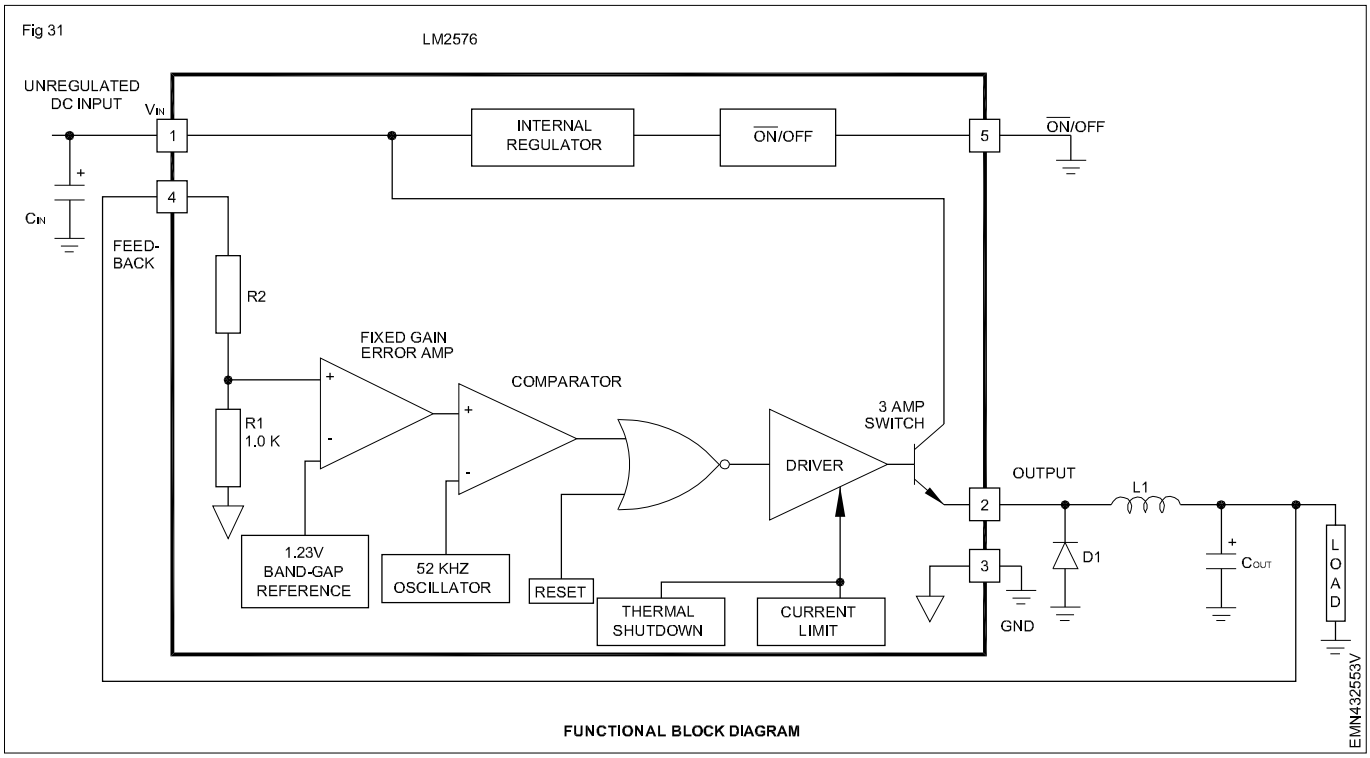
Pin configuration and functions

Fig 30



PIN		I/O	DESCRIPTION
NO.	NAME		
1	V_{in}	I	Supply input pin to collector pin of high-side transistor. Connect to power supply and input bypass capacitors C_{in}. Path from V_{in} pin to high frequency bypass C_{in} and GND must be as short as possible.
2	OUTPUT	O	Emitter pin of the power transistor. This is a switching node. Attached this pin to an inductor and the cathode of the external diode.
3	GROUND	—	Ground pin. Path to C_{in} must be as short as possible.
4	FEEDBACK	I	Feedback sense input pin. Connect to the midpoint of feedback divider to set V_{OUT} for ADJ version or connect this pin directly to the output capacitor for a fixed output version.
5	ON/OFF	I	Enable input to the voltage regulator. High = OFF and low = ON. Connect to GND to enable the voltage regulator. Do not leave this pin float.
—	TAB	—	Connected to GND. Attached to heatsink for thermal relief for TO-220 package or put a copper plane connected to this pin as a thermal relief for DDPAK package.

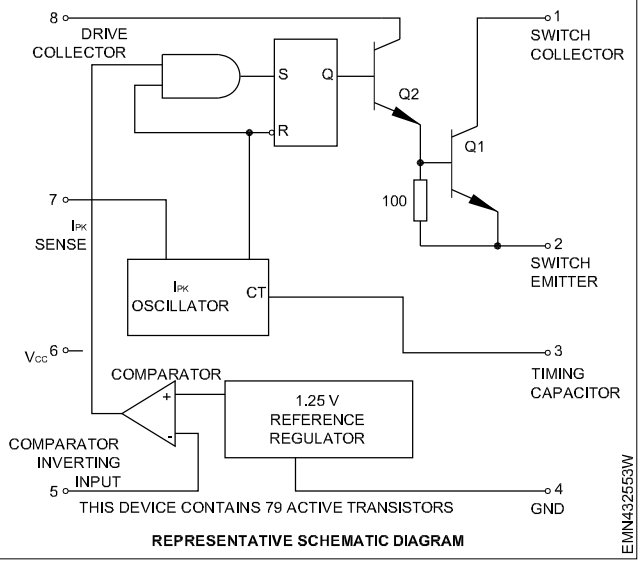
Functional block diagram



FUNCTIONAL BLOCK DIAGRAM

3.3 V R2 = 1.7 k 5 V, R2 = 3.1 k 12 V, R2 = 8.84 k	15 V, R2 = 11.3 k For ADJ. Version R1 = Open, R2 = 0Ω

Fig 32



REPRESENTATIVE SCHEMATIC DIAGRAM

Buck-Boost converter

Features

1 Operation from 3.0 V to 40 V input.

2 Low standby current.

3 Current limiting.

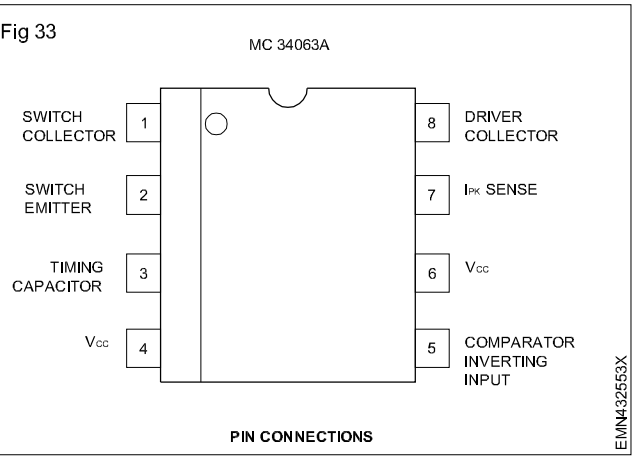
4 Output switch current to 1.5 A.

5 Output voltage adjustable.

6 Frequency operation to 100 kHz.

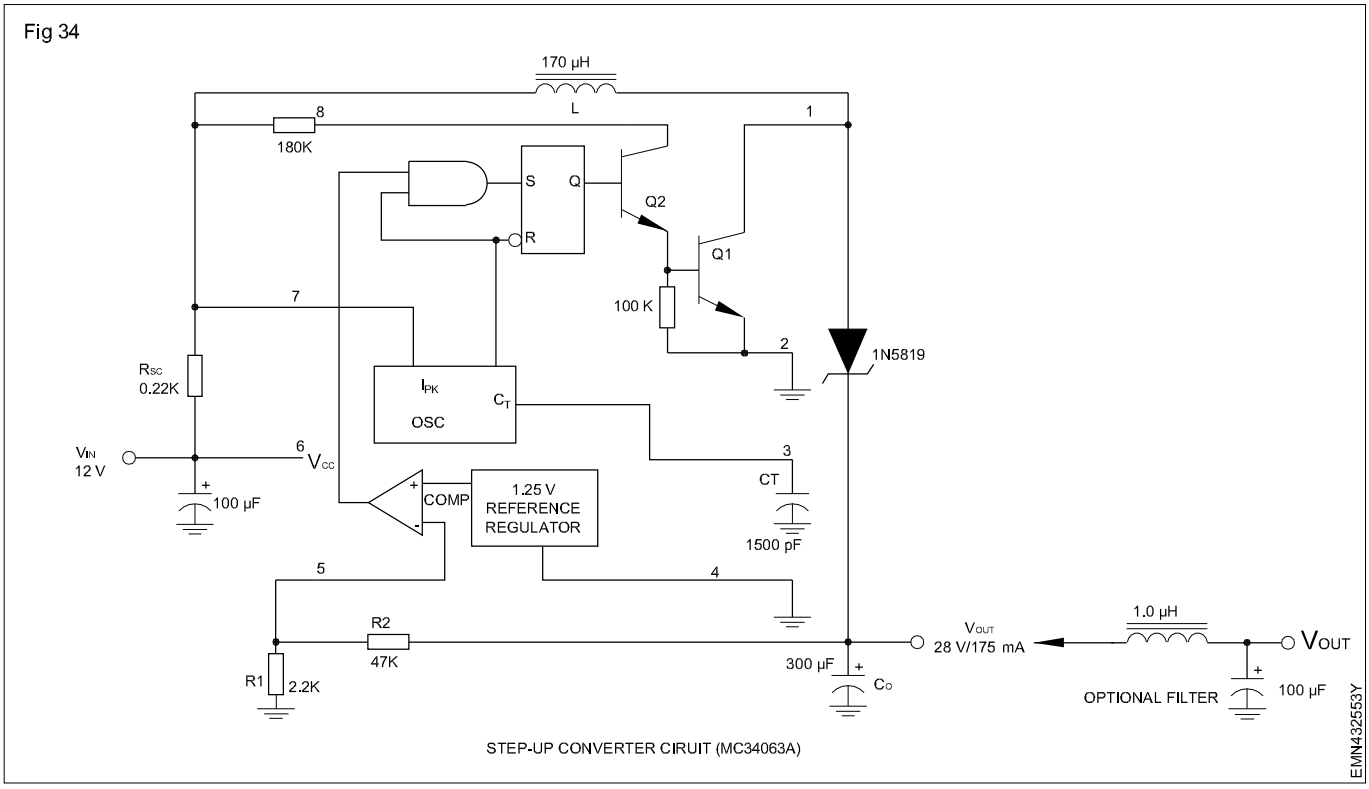
7 Precision 2% reference.

Fig 33



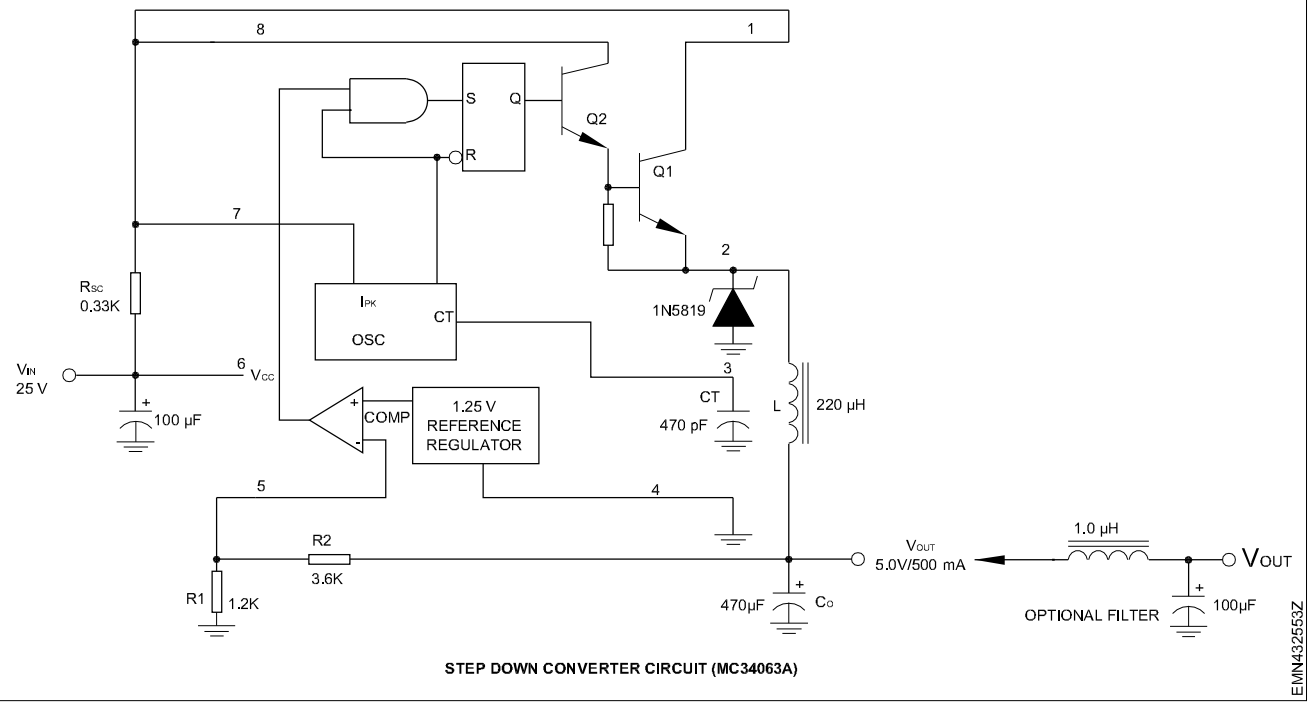
PIN CONNECTIONS

Fig 34



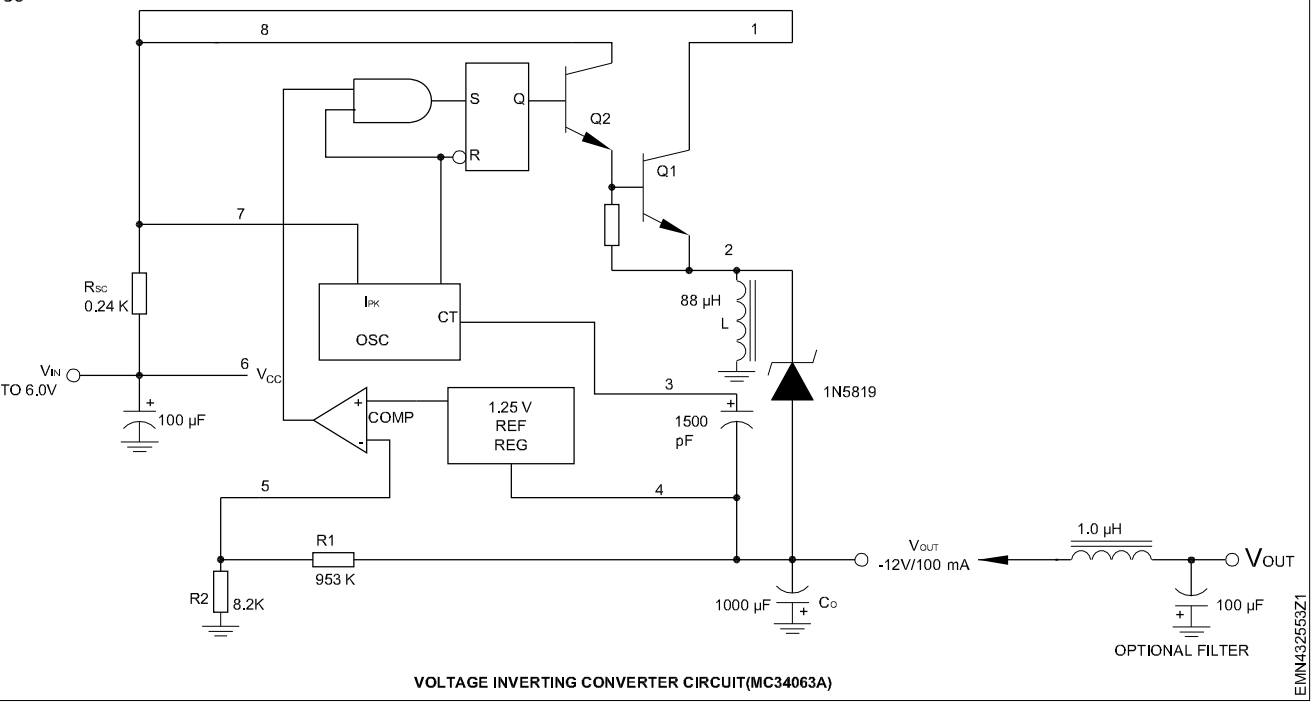
STEP-UP CONVERTER CIRUIT (MC34063A)

Fig 35



STEP DOWN CONVERTER CIRCUIT (MC34063A)

Fig 36



VOLTAGE INVERTING CONVERTER CIRCUIT(MC34063A)

Stabilizers

Objectives : At the end of this lesson you shall be able to
- **discuss about the power conditioning required in electrical appliances**
- **describe about the voltage stabilizer and its types**
- **explain the working principle of voltage stabilizer**
- **explain about constant voltage transformer**
- **describe the working of servo voltage stabilizer.**

Introduction

Electrical appliances and equipment require definite input voltage for their smooth operation. For single phase equipment the magnitude of input voltage is 220 volt and frequency is 50Hz. Six percent variation in voltage and three percent variation in frequency is tolerable. Input voltage should be between 216 and 244 volt and frequency should be between 48.5 Hz and 51.5 Hz. Variation beyond these limits are harmful for equipment. In reality voltage as low as 170 volt or even lower and as high as 280 or even more are observed. Too high or too low input voltage or sudden and abrupt variation in input voltage or sudden switching off can damage equipment. Unwanted and harmful electrical noise, harmonics and surges are also sometimes may be present in the normal electrical power. These are to be filtered out for the safety of equipment and appliances. A power conditioner is an equipment which conditions normal electrical power to clean power by suppressing electrical surge, by filtering noise and by regulating the voltage. A power conditioner is essential for sensitive equipment. Electrical surges also known as spikes are high voltage pulses of very short duration and can damage equipment and appliances. Normal line power is the input and clean power is the output of a power conditioner. Clean power is free from surge, spike and noise. The output from power conditioner is the input to equipment and appliances and is safe.

Voltage stabilizer

A voltage stabilizer stabilises voltage. Mains AC voltage is the input to the voltage stabilizer and nearly constant voltage of 220 volt is the output from the voltage stabilizer. A voltage stabilizer senses the input voltage and compares whether the input voltage is equal to the desired voltage of 220 volt. If the input is different from 220 volt, some action is initiated to adjust the voltage to 220 volt. Loads are connected to the output of the voltage stabilizer. Voltage stabilizer supplies nearly constant voltage even when the input voltage and load varies. The capacity of a voltage stabilizer is expressed in Volt Ampere (VA).

Voltage stabilizers can be classified as

1 Manual voltage stabilizer

2 Automatic voltage stabilizer

3 Constant voltage transformer (CVT)

4 Servo voltage stabilizer

Fig 1

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Manual voltage stabilizer

The essential parts of a basic manual voltage stabilizer are

1 Autotransformer

2 Rotary switch

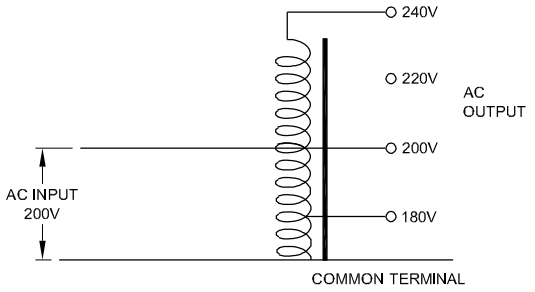
Auto-transformer is the main component of a voltage stabilizer. An auto-transformer is a winding of copper wire wound over magnetic core. There are several tapings. It is basically a transformer with single winding. The same winding acts as primary and also as secondary. A terminal is common to both primary and secondary. AC voltage is applied between the common terminal and a tapping. Then different voltages are available at the autotransformer tappings. These voltages change whenever there is a change in input voltage or input is applied between different tapings. The output voltage is taken between the common terminal and appropriate tapping.

Output voltage is to be monitored manually. When output voltage is not equal to the desired voltage of 220 volt, then by rotating the switch, output voltage is adjusted to the desired value. There are two basic configurations: Without up-down switch and with up-down switch.

Neutral of mains AC is connected to the common terminal of autotransformer. Other terminals of the autotransformer are connected to the rotary switch points. Phase of mains AC is connected to the pole of rotary switch. Output is taken from some point of the rotary switch. Configuration with up-down switch has an additional one pole two way switch and the output is taken from the pole of the up down switch. Step up and step down voltages can be selected by the up down switch and the value of voltage can be adjusted by rotating the rotary switch.

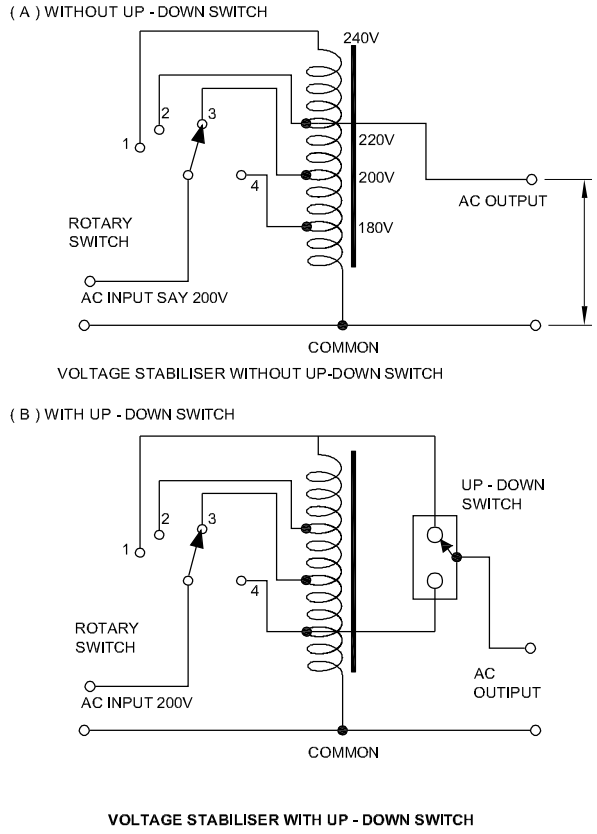
A voltmeter with a switch is connected to show the input and output voltages. The output voltage can be changed

Fig 2



AUTO - TRANSFORMER

Fig 3



VOLTAGE STABILISER WITH UP - DOWN SWITCH

in discrete steps. Continuous adjustment of output voltage is not possible and some delay is involved between the instants the voltage changes till the instant of adjusting the output voltage. This is why manual voltage stabilizers are not capable of providing adequate protection against abrupt variation in voltage and automatic voltage stabilizers are replacing manual voltage stabilizers.

Automatic voltage stabilizer

Automatic voltage stabilizer does not require manual intervention. Relay switches are used which change autotransformer connections. Output voltage adjustment is automatic.

The essential parts of a basic automatic voltage stabilizer are

1 Autotransformer

2 Relay switches

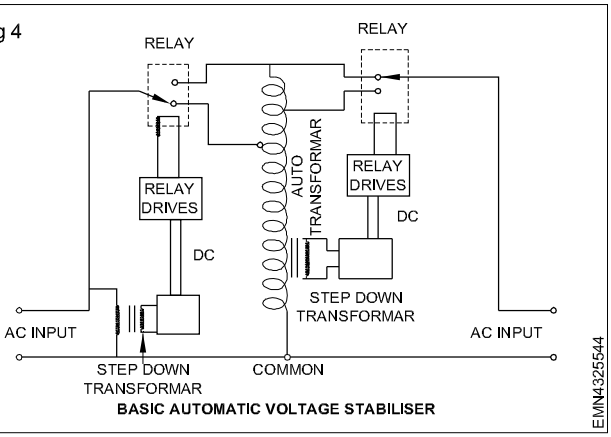
3 Relay driver circuit

4 Control circuit

5 Low voltage power supply

6 Accessories

Fig 4



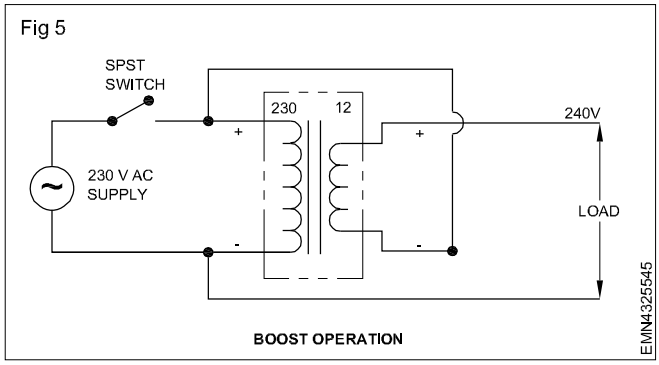
BASIC AUTOMATIC VOLTAGE STABILISER

Basic principle of operation of voltage stabilizer

The voltage regulation is required for two distinct purposes; over voltage and under voltage conditions. The process of increasing voltage from under voltage condition is called as boost operation, whereas reducing the voltage from overvoltage condition is called as buck operations.

Boost operation

Fig 5



BOOST OPERATION

The principle of boost operation of a voltage stabilizer is shown in Fig 5.

Here, the supply voltage is given to a transformer, which is normally a step-down transformer. This transformer is connected in such a way that the secondary output is added to the primary supply voltage.

In case of low voltage condition, the electronic circuit in the stabilizer switches corresponding relay such that this added supply (incoming supply + transformer secondary output) is applied to the load.

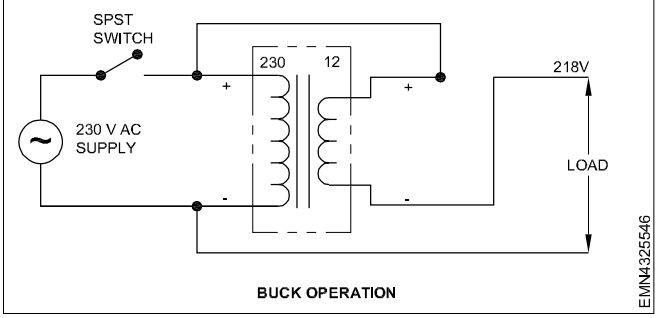
Buck operation

The principle of buck operation of a voltage stabilizer is illustrated in Fig 6.

In buck operation, the secondary of step-down transformer is connected in such a way that secondary output voltage is deducted from incoming voltage.

Therefore, in case of incoming voltage rise, the electronic circuit switches the relay that switches deducted supply voltage (i.e., incoming voltage–transformer secondary voltage) to the load circuit.

Fig 6



BUCK OPERATION

In case of normal voltage operating condition, electronic circuit switches the load entirely to incoming supply without any transformer voltage.

Working of voltage stabilizer

The Fig 7 below shows the working model of a voltage stabilizer that contains a step-down transformer (usually provided with taps on secondary), rectifier, operational amplifier/microcontroller unit and set of relays.

In this, op-amps are tuned in such way that they could sense various set voltages such as lower cut off voltage, boost condition voltage, normal operating voltage, higher cut off voltage and buck operating voltages.

A set of relays are connected in a manner that they trips the load circuit during higher and lower cut off voltages and also they switch buck and boost voltages to the load circuit.

A step-down tap changing transformer has different secondary voltage tapping which are helpful for operating operational amplifier for different voltages and also to add-up and deduct voltages for boost and buck operations respectively.

A rectifier circuit converts AC supply into DC to power-up entire electronic control circuit as well as relay coils.

Let us assume that this is 1 KVA single phase stabilizer that provides stabilization for voltage range of 200 to 245 with a boost-buck voltage of 20-35 V for input voltage of 180 to 270 V.

If the input supply is, say 195 V, then operational amplifier energizes boost relay coil such that 195 + 25 = 220V is supplied to the load. If the input supply is 260 V, corresponding op-amp energizes buck relay coil so that 260-30 = 225 V is supplied to the load.

If the input voltage is below 180 V, corresponding op-amp switches lower cut off relay coil such that load is disconnected from the supply.

And if the supply is beyond 270 V, corresponding op-amp energizes higher cut off relay coil and hence load is terminated from the supply.

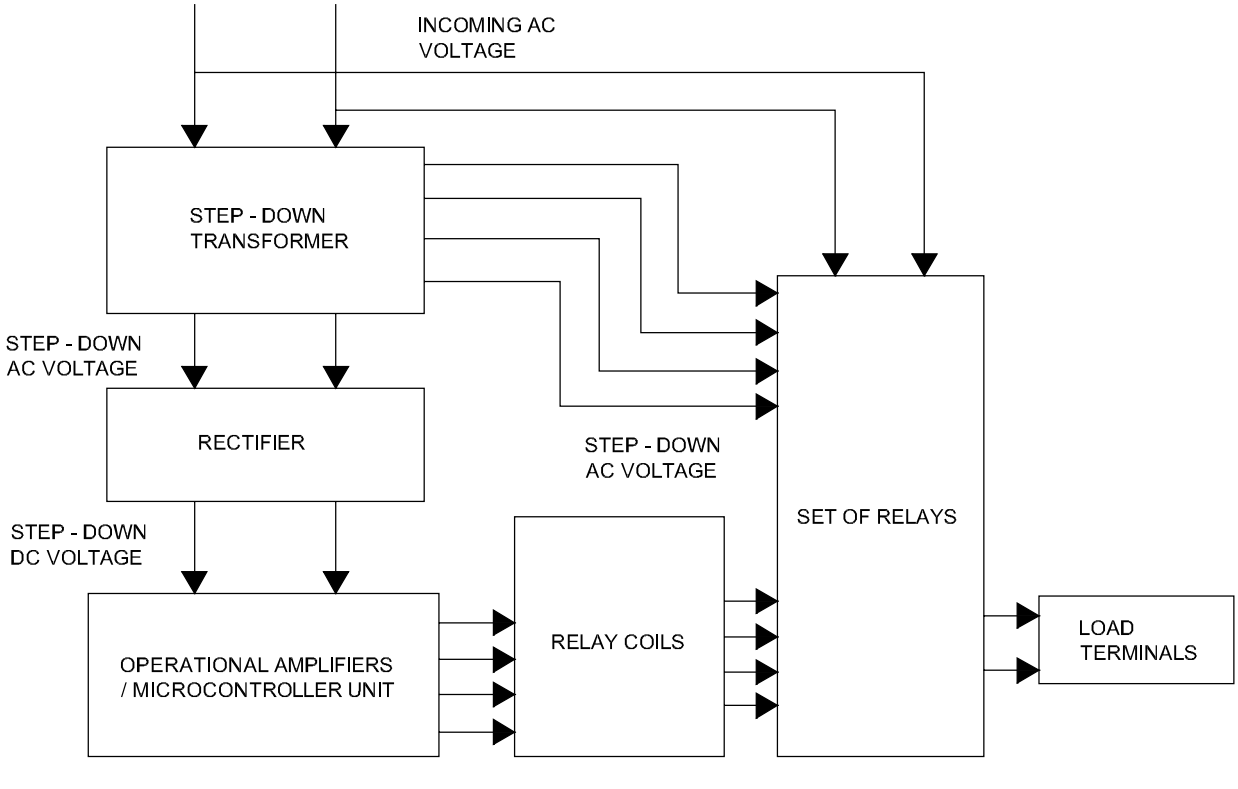
All these values are approximate values; it may vary depending on the application. By this way, a stabilizer operates under different voltage conditions.

Constant Voltage Transformer (CVT)

The parts of a constant voltage transformer are

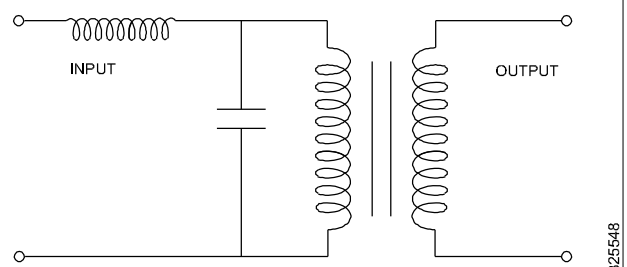
1 Transformer
2 Capacitor
3 Inductor

Fig 7



BLOCK DIAGRAM OF VOLTAGE STABILIZER

Fig 8



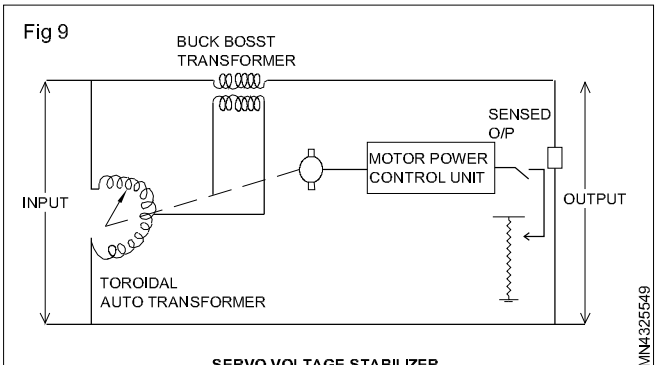
CONSTANT VOLTAGE TRANSFORMER (CVT)

The capacitor is connected in parallel with the primary winding and the inductor is connected in series with the primary winding of the transformer. Output is taken from the secondary. The working of a CVT is based on ferro resonance. Ferroresonance is an interaction between capacitor and iron core inductor and occurs when the capacitive reactance is equal to the inductive reactance. The voltage across capacitor becomes high and high amount of current flows through the primary winding. The transformer core gets saturated. Further change in current in primary does not result in change of magnetic flux in transformer core and hence secondary voltage remains relatively constant. Thus, in spite of variation in the input voltage, the output of a constant voltage transformer remains constant. CVT gives instantaneous adjustment of output voltage, provides isolation between input and output, suppresses spikes and noises and provides instantaneous short circuit and overload protection. CVT requires minimum maintenance as number of components is minimum. Occasionally the capacitor becomes defective and needs replacement.

Servo voltage stabilizer

A servo voltage stabilizer continuously senses and monitors the voltage. Whenever the output voltage differs from the desired voltage of 220 volt, it generates control signal to automatically adjust the output to the desired value of 220 volt. A servo voltage stabilizer uses a servo motor mechanism and continuously adjusts the output voltage. Servo voltage stabilizers are normally available with power rating more than 1KVA.

Fig 9



SERVO VOLTAGE STABILIZER

The essential parts of a servo voltage transformer are -

1 Auto transformer
2 Buck boost transformer
3 Motor
4 Motor driver
5 Control circuit
6 Power supply for control circuit.
7 Set point
8 Accessories

The auto transformer is toroidal in shape and is connected between the phase and neutral of input voltage. The buck boost transformer is connected between input and output of the stabilizer. One end of the primary of buck boost transformer is permanently connected to a suitable tapping of autotransformer. The other end is connected to an arm and brush mechanism attached to the shaft of the motor. The motor is a DC servo motor or an AC synchronous motor and is fitted on top of the autotransformer centre. The motor can rotate in both directions. As the motor rotates the other end of primary of buck boost transformer continuously slides over autotransformer wires and makes contact with different points on the autotransformer winding. The motor driver and the control circuit are solid state circuit with transistors and operational amplifier IC 741. A step down transformer and rectifier unit produces low voltage DC supply for motor driver and control circuit. A stable low DC voltage reference source is obtained and is used for set point. By adjusting the set point, the desired value of output is set usually between 220 to 240 volt. The actual output voltage is continuously sensed and is compared with the desired voltage. The comparator is generally based on operational amplifier 741 IC. When the actual output changes, the motor driver makes the motor in proper direction. The contact of sliding end of primary of buck boost transformer with autotransformer changes and a voltage gets applied to the primary. Voltage in the secondary is induced and because of this voltage the actual output gets adjusted to the desired value.

Servo voltage stabilizer provides continuous adjustment of output as input voltage varies and correction speed is usually between 20 to 40 volt per second. It suppresses voltage surge, spikes and noises that may be present in the input voltage. Features include over voltage and under voltage protection, overload and short circuit protection, auto and manual mode for adjusting output etc. Common problem include oscillatory movement of motor, defects in motor driver and control circuit, jamming or loose contact of arm and brush mechanism attached to the shaft of motor etc.

Fig 10

Inverter and principle - SMPS and inverter

Objectives : At the end of this lesson you shall be able to
- **describe the basic concept of inverter**
- **explain principle of operation of inverter**
- **explain the functional blocks of inverter**
- **state the installation procedure of inverter**
- **classify the types of inverter**
- **state the applications of inverter.**

Definition

Converts DC to AC power by switching the DC input voltage (or current) in a pre-determined sequence so as to generate AC voltage (or current) output.

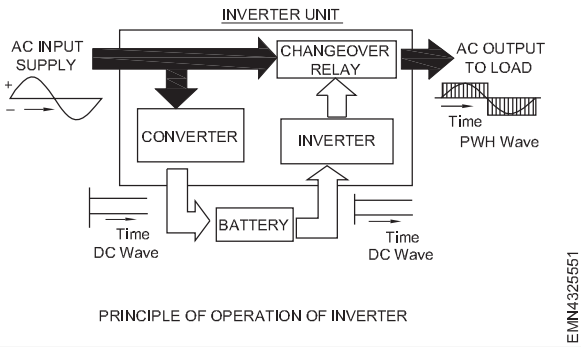
Circuitry that performs the opposite function of rectifier, converting DC to AC, is called an inverter.

The input voltage, output voltage, output frequency, and overall power handling depends on the design of the specific device or circuitry of inverter. The inverter does not produce any power; it only converts the DC battery power into AC power to load.

Principle of operation

Inverter unit converts AC mains supply into DC and stores DC power in the battery. when AC mains present (Mains mode) the input AC power is directly passes to output load through changeover relay. When the absence of AC mains (inverter mode), DC power stored in the battery is converted into AC by the use of electronic circuits, inverter transformer, etc. and is supplied to the load as shown in fig.1.

Fig 1



PRINCIPLE OF OPERATION OF INVERTER

Block diagram representation

The simplified block diagram of the inverter is shown in fig.2. AC mains supply is connected to the sensing section, which senses the presence of AC input voltage and activates the battery charging section through the solid-state relay. During the presence of AC mains, AC supply directly goes to the output socket and to the connected load.

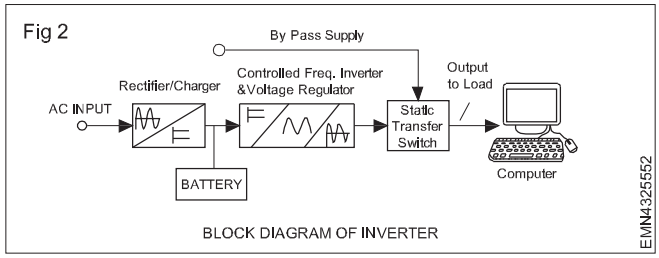
In the absence of AC mains supply, the AC mains sensing section activates the changeover type solid-state relay in milli-seconds time and connects the battery supply to the oscillator, driver and output chopper/ switching sections to produce the 50Hz sine wave.

The oscillator generates trigger pulses and amplified by the driver section, which controls the duty cycle of the semiconductor switches.

Thus, the inverter circuit produces AC supply and the battery supplies the required DC for the standby operation to run the AC load.

Function of an inverter

Fig 2



BLOCK DIAGRAM OF INVERTER

The Function block diagram of the inverter is shown in fig.3. The functioning of an inverter may be understood in the following two situations.

a When the AC mains power supply is available.

b When the AC mains power supply is not available.

When the AC mains power supply is available - Main mode

- When the AC mains supply is available, the AC mains sensing circuit senses it and the supply goes to the changeover relay, which provides,

i Mains supply to the battery charging section and

ii AC mains supply directly to the output socket/load.

- Battery charging section converts AC mains into 12/ 24V DC voltage, then regulated and battery is charged using it.
- There are special circuits for sensing the battery voltage and when the battery is fully charged the charging is stopped.
- In some inverters there will be a trickel charging circuit which keeps the battery constantly at full charge.

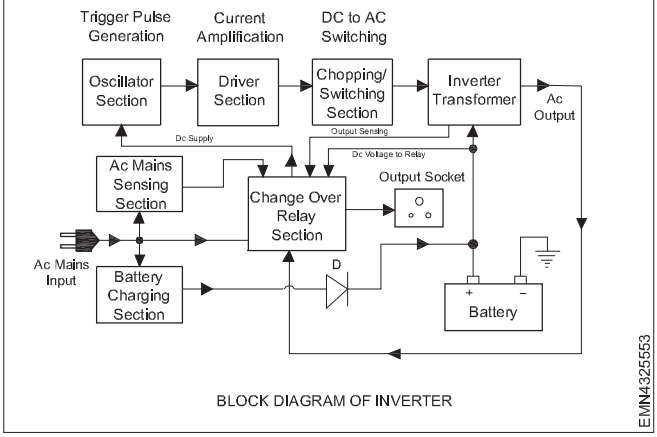
When the AC mains power supply is not available - inverter mode

Under the absence of the AC mains power supply, an oscillator circuit inside the inverter produces a 50Hz trigger signal.

This trigger signal is amplified by the driver section and applied to the chopper/switching section.

The semiconductor switching devices like SCR, TRIAC, MOSFET, IGBT, etc. are connected to the primary winding of the inverter transformer and starts switching/chopping the battery DC supply at a rate of 50 Hz. This switching

Fig 3



BLOCK DIAGRAM OF INVERTER

action of the MOSFETs or transistors produces 50Hz alternating signal at the primary of the inverter transformer.

- Thus a 220V AC supply is available at the secondary of the inverter transformer.
- This secondary voltage is made available at the output socket of the inverter by a changeover solid state realy.

Changeover period

The time required for an inverter to switch from AC mains power to battery power is known as changeover period. This is in the range of 3-8 milli-seconds.

Annuaciation and protection section

Inverter contains various circuits to automatically sense and tackle various situations that may occur when the inverter is running or in standby.

This annunciation section monitor the abnormal situations such as overload, over heat, low battery, over chatge etc. and indicates by means of LED display/indicators and buzzer alarm.

The overload protection circuit is used for the protection of inverter and trips the unit and low battery cut-off circuit is used to cut-off the load from the inverter.

Installation of an inverter

Power rating and calculation: Inverter power is rated in VA or KVA. Before purchasing the inverter, power consumption of load/appliances that is to be connected with inverter is to be calculated as follows;

Power in VA (Volt ampere) = AC volts x Total load current.

Power in KVA (Volt ampere) = (AC volts x Total load current)/1000.

Power in watts = AC voltage x Toatal load cuttent x P.F. where P.F = power factor (If not given assume approximate value of 0.8. which is standard for homes)

Also power in watts = power in VA x P.F.

Example: Connected loads:

3 Nos. of ceiling fans = 2 x 75 watts = 150 watts

3 Nos. of cfl light = 3 x 23 watts = 69 watts

1 No. of television = 1 x150 watts = 150 watts

Total = 369 watts

Therefore the connected load in wattage is 369 W.

Considering approximate power factor of 0.8, the connected load in VA is 369/0.8 = 461.25VA as the connected load capacity comes to 462 VA, the required inverter capacity to be purchased is 500 VA.

Selection of location

The first thing is selection of suitable loaction for placing the inverter. While choosing the loaction the following points are to be considered for better opeartion;

- Make sure the inverter is not placed near any hazardous or flammable materials.
- It must also not be exposed to moisture or water.
- The selected location must be away from direct sunlight and is a dry area.
- It must be placed in an area near the main board of house.

Mouting the inverter

An inverter can be mounted horizontally either on a vertical surface or on or under a horizontal surface as well. Inverter is always placed on the insulation material like wood, foam or hard broad.

Battery installation

There are two main families of batteries used in inverters

- Nickel - cadmium batteries
- Lead - acid batteries

Most commonly liquid or pasted (SMF - Sealed Maintenance Free) Lead-acid batteries are using.

Before connecting the new battery to inverter, battery is to be charged fully, otherwise its life and backup time will be reduced.

While connecting the batteries the polarity of the battery and the inverter terminals should exactly match i.e. positive and negative to negative.

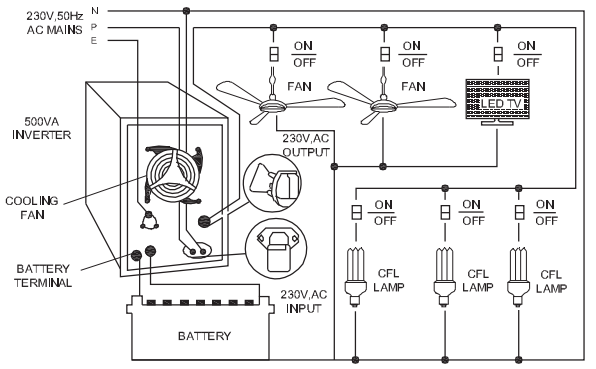
During charging/discharging of batteries, oxygen and hydrogen gas produced due to chemical reactions in the batteries and hence a vent hole will be there in the top up cap.

For liquid type batteries, distilled or demineralised water is to be added periodically with the electrolyte for maintaining the specific gravity of electrolyte between 1.260-1.280 (Fully charged battery).

Inverter wiring

The input connector of the inverter is connected with the AC mains supply and the AC output of the inverter is connected to the electrical/electronics appliances which is called inverter load. Always the connected load should be less than the VA capactiy of the inverter.

Fig 4



INVERTER CONNECTION DIAGRAM

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It is important to note that the neutral connection of the inverter output is directed connected with the neutral wire of AC mains supply as shown in fig.4.

Earthing

In an inverter installation proper earthing is essential because,

It protects the user against electric shock

It protects the inverter incase of an electric short - circuit

It completes the battery's circuit in the cases of vehicles like car, bike, etc.

Classification

a Based on application:

The inverters are classified in two types according to the applications, as

i **Domestic inverters -** The domestic inverter is mainly used for household electrical/electronics appliance.

ii **Industrial inverters** - The industrial inverter system is mainly used with existing plant battery and no need of having separate battery bank. It is used in industries for applications like AC/DC drives for controlling motors, turbine & boiler control, DCS (Distributed control system), and PLC (Programmable logic control), etc.

b **Based on connected load:**

The inverters are classified in two types according to the connected load, as

Single phase inverters - A single-phase inverter converts a DC input into a single - phase AC output. These type of inverters mainly used in domestic purpose to run the loads like ceiling fans, CFL lights, television, etc.

Three phase inverters - A three-phase inverter converts a DC input into a three-phase AC output. The phase angle difference between the three phases are 120° so as to generate a three-phase AC supply. Three phase inverters are used where the connected loads are high and three phase system loads.

Based on the circuit arrangments

According to the circuit arrangement, inverter is classified as

i Voltage source inverters and

ii Current source inverters

Voltage source inverter

A voltage source inverter (VSI or voltage stiff inverter) forms the voltage with required properties: magnitude, frequency, and phase.

It is the most commonly used type of inverter. This inverter has the low internal impedence.

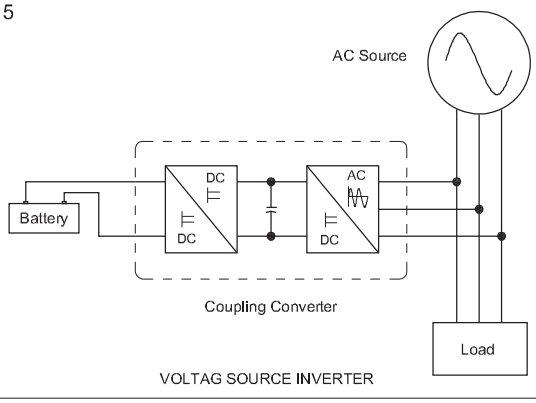
Generally, it has a capacitor of high capacity connected across the supply source that keeps constant input voltage as shown in Fig.5.

The switches of VSI are constructed using full controlled devices like, transistors, tyristors, MOSFET, etc.

If bidirectional current (AC) is required, the freewheeling diodes also called feedback diodes which are connected across the switches.

Current sources inverter

Fig 5



VOLTAG SOURCE INVERTER

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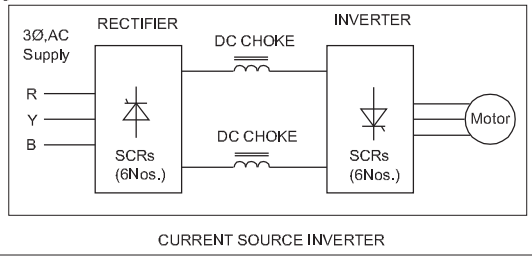
A current source inverter (CSI) is the source of the current with the required properties: magnitude, frequency, and phase.

As a rule, it has an inductor connected in series with the supply source that keeps the current constant as shown in fig.6.

Fig 6



CURRENT SOURCE INVERTER

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d **Based on the input power**

According to the input power used for changing batteries, inverter is classified as:

i AC power inverter - In this case, AC mains supply is converted into DC supply by using rectifier circuit and changes the battery through a battery charger circuit.

ii Solar inverter - In this case, photovoltaic cell (PV cell) converts the solar energy into direct DC supply and charges the battery through a battery charger circuit.

Applications:

Domestic use:

- To provide back-up power to the domestic appliances when power fails.

An inverter is used to control the speed of the compressor motor, so as to continuously regulate the temperature in refrigerator and air-conditioner.

Industrial use:

- AC/DC drives for controlling motors
- Turbine & boiler control
- Industrial motor dirven equipment
- DCS (Distributed Control System)
- PLC (Programmable Logic Control), etc.
- Electric trains

Automotive electronics uses

Application of power electronics in automotive applications plays a major role in controlling automotive electronics. Automative electronics include,

- Modern electric power steering
- HEV main inverter
- Central body control
- Braking system
- Seat control, and so on.

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC) and is also called static inverter.

In rotary type of inverter, the DC motor drives the AC generator (alternator) and supplies AC power to the dynamic loads in industries.

Inverter and principle of operation

Objectives : At the end of this lesson you shall be able to
- **explain the working of the Inverter circuit**
- **explain the working principle of Microcontroller based Inverter**
- **state common inverter problems and solutions.**

Working of Inverter circuit

The simple circuit diagram of DC or AC Inverter is shown in fig.1.

It comprises of the following sections;

- Battery charger section
- Battery
- PWM section
- Inverter switching/chopper
- Section
- Sensing/Feedback section

Battery charger section

The 230V, 50Hz, AC mains supply is applied to the step-down transformer where the step-down transformer where the input AC high voltage is reduced to 15V AC low voltage. The reduced AC voltage is rectified and applied to the battery through SCR TYN616 which controls and regulates the battery charging voltage to 12V DC. The trigger pulse to the SCR comes from the variable voltage regulator IC LM317 which is working here as comparator and the firing angle can be varied by the 4.7K reference pre-set.

Battery

A 12V liquid type or SMF lead-acid battery is connected to the output of charger section and battery gets charged steadily.

PWM section

CA3524 is a 16 pin Pulse Width Modulator (PWM) IC. It generates trigger pulses at pin 11 & 14 which is applied to the gate terminals of semiconductor switch MOSFET 1 & 2 respectively through a bias resistors. The trigger pulse generated by the PWM IC is based on the feedback voltage obtained from the sensing/feedback section at Pin 1.

Inverter switching/Chopping section

The bias DC voltage for MOSFETs are obtained from the battery through the centre tapped primary of the output transformer. The MOSFETs Q1 & Q2 are switched alternativey by the trigger pulses obtained from the PWM IC. The duty cycle of the MOSFET switching controls the AC output voltage. If the connected load of the inverter draws less current, PWM IC generates trigger pulses with reduced duty cycle and thus output decreased. In this manner, the output voltage of the inverter is sensed and duty cycle of the switch PWMs are modified to produce the steady and regulated output voltage. Then a capacitor helps filters the waveform to make a clean 50Hz AC sine wave.

Sensing/feedback section

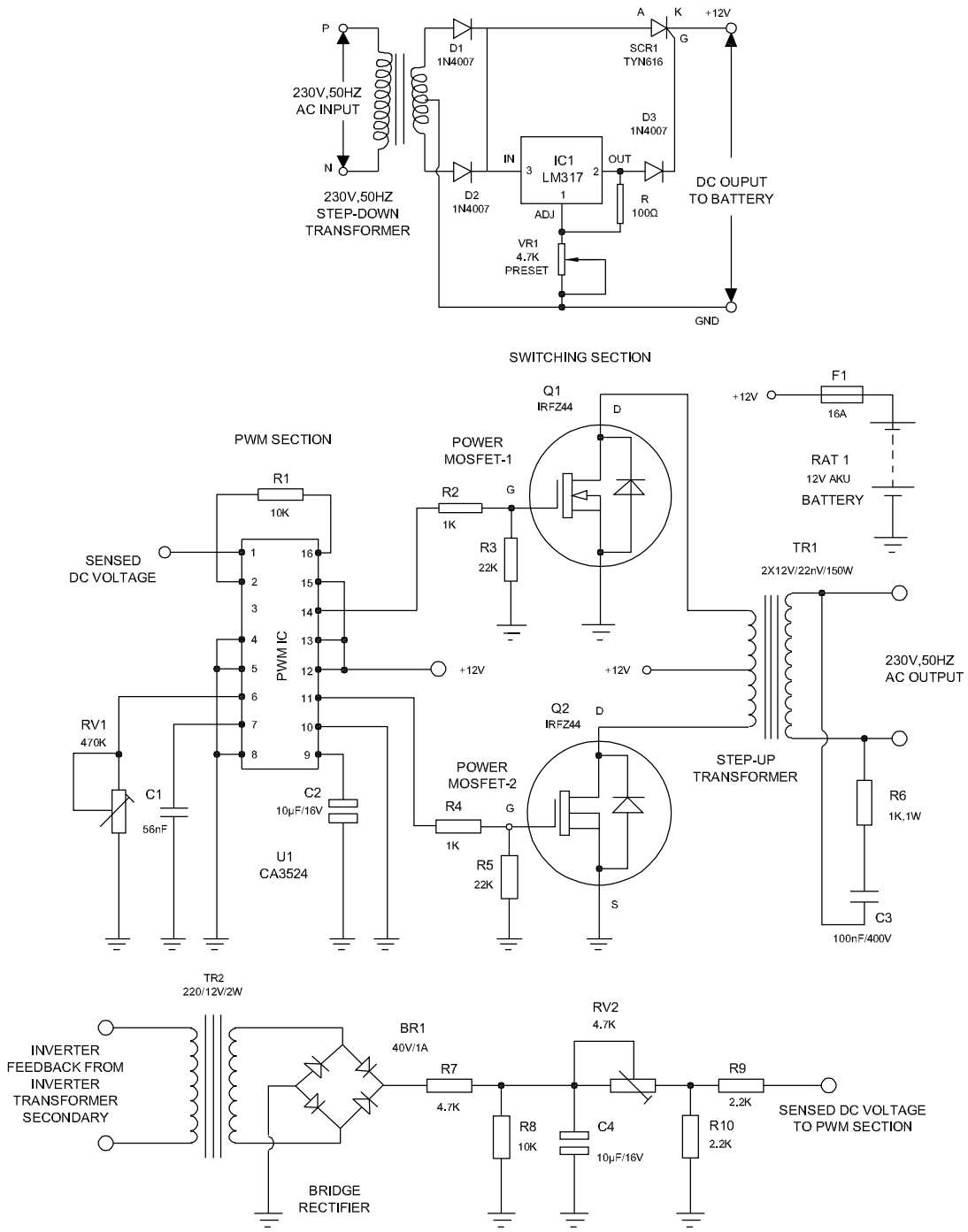
Portion of AC voltage is fed to the sensing section, where it is rectified into DC. This feecback voltage is sent to PWM IC as sensing volage and compared with the reference voltage in order to control the duty cycle.

Microcontroller based inverter

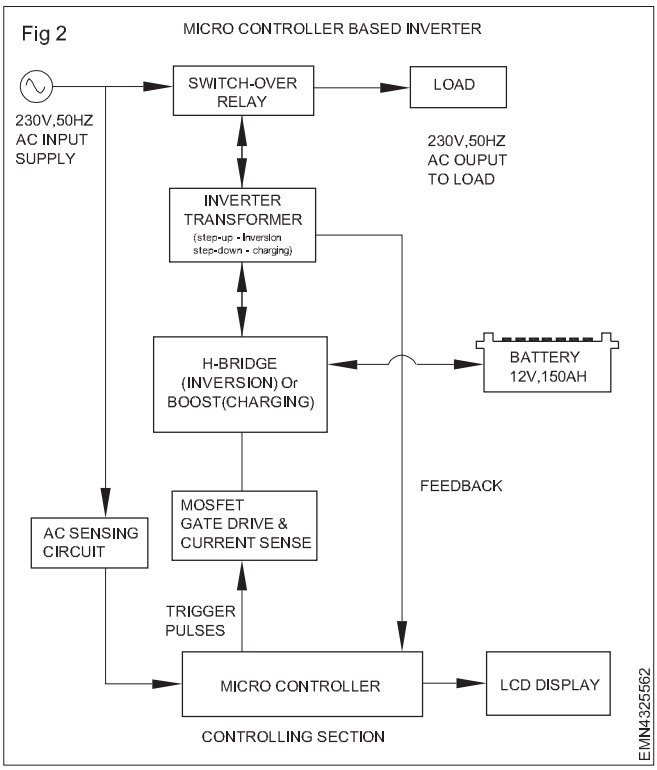
The major sections of a modern inverter producing pure sine wave, designed using the simple electronic devices to the complex embeded microcontrollers is shown in fig.2. It uses pulse width modulation techique, different sensors, actuators, LCD display for status, audible alarm, feather touch switches, etc. for the reliable and user-friendly failsafe operation.

- Under mains mode, the solid-state changeover relay passes the AC input voltage directly to the output and allows charging of the battery.
- Under inverter mode, the absence of AC mains voltage is sensed by the solid-sate realy and microcontroller inverter section is acutated. The micrcontroller, which is a part of the inverter section, generates the trigger pulse to the gate driver input to the MOSFET switching devices.
- The battery voltage is first chopped using high frequency PWM and switching device, (generally 3KHz to 20KHz) to produce an AC waveform. The iron cored step-up transformer boosts the 12V chopped waveform to 220V, 50Hz AC output waveform.

Fig 1



- Then the AC output from the transformer shaped to 50Hz AC sine wave with the helps of capacitor and filter circuits.



- The battery charging current in the “Mains mode” and the battery discharging current in the “Inverter mode” are monitored by the microcontroller continuosly and according trigger pulses are generated. In the inverter mode, the output voltage of the inverter is sensed and duty cycle of the PWM pulses are modified to achieve the regulation in the output voltage.
- In modern microntroller based inverters, the battery voltage and the temperature of the heat sink is continuously monitored. Based on the load variations in the inverter mode or temperature rise of the heat sink, the DC cooling fan is operated. Various LED indicators are used to interface with the user and buzzer and tripping circuits are operated under abnormal/error state in the mains board.

Common inverter problems and solutions

The common faults which occur in the inverter, probable causes and their remedies are listed below

Sl. No.	Common problems	Probable cause	Solutions/remedy
1	Inverter not turning ON	Battery disconnected, terminals loose or rusty & corroded.	If the terminals of the battery are loose, check them for corrosion. Clean the terminals and terminate properly.
		Weak battery	If the battery has gone weak, keep the battery under boost charging for 8 hours and connect with the inverter.
		Discharged battery	In case of fully discharged battery or faulty battery replace the battery with the same rating.
		Defective power switch	Check and replace the power switch.
2	Battery is not getting charged	Dead battery Battery charger section problem	The battery must be replaced. Check the rectifier diodes, input fuses and loose battery connection and set right.
3	Backup time is less	Too much of power Consumption	Remove the extra load connected.

		Battery not properly charged	Charge the battery and top up the electrolyte with distilled water. Remember that the water level must be maintained between the maximum and minimum water limit.
4	Inverter working always in inverter mode	Either input is not connected or fuse may be blown off.	Check the power cable and change the fuse respectively.
		Low or high input voltage	The AC mains supply voltage may be always low or high, hence connect a stabilizer in the input to give input voltage at the prescribed limit.
		Changeover relay problem	Check and replace the relay.
5	Alarm beeping Continuously	Inverter overload	The possible cause could be either overload on the inverter or a stuck cooling fan. Check and set right the cooling fan and disconnect all the extra load in case of overload.
		Low battery	Charge the battery.
6	Inverter cannot boot	Too low battery voltage or damaged	Recharge or replace the battery
		The battery is not connected	Connect the battery
7	No output	Too low battery voltage or damaged	Recharge or replace the battery. Check whether the wire connection is good.
		Too high input voltage	Adjust/reduce the input voltage and switch ON the inverter or use stabilizer at the AC input
8	Inverter works on mains mode but does not operate on inverter mode	Battery fuse is blown Battery is discharged	Check the fuse and polarity of battery. Replace the fuse Recharge or replace the battery with same rating.
9	Battery voltage is good but no output voltage	Problem with PWM IC	Check the input/output voltage PWM IC and if it faulty replace it.
		Fault in switching device	Check the switching device and replacing it if faulty.
10	Inverter output is high	Fault in feed back loop	Check the sensing circuit and feedback transformer wiring and adjust the feedback voltage pre-set.

Uninterruptible Power Supply

Objectives : At the end of this lesson you shall be able to
- **state the need of UPS**
- **differentiate inverter and UPS**
- **explain the block diagram of UPS.**

Uninterruptible Power Supply (UPS)

An uninterruptible power supply (UPS) is a device that allows a computer to keep running for at least a short time when the primary power source is lost. It also provides protection from power surges.

Need of UPS

An Uninterruptible Power Supply (UPS) is used to protect critical loads from mains supply problems, including spikes, voltage drops, fluctuations and complete power failures using a dedicated battery.

A surge protector (or surge suppressor or surge diverter) is an appliance or device designed to protect electrical devices from voltage spikes. A surge protector attempts to limit the voltage supplied to an electric device by either blocking or shorting to ground any unwanted voltages above a safe threshold.

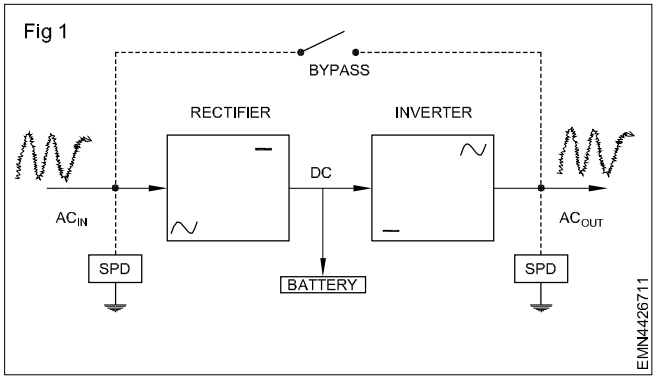
Difference between Inverter and UPS (TABLE 1)

The differences between inverter and UPS under certain important parameters are given in TABLE 1 below.

Block diagram of UPS

The simplified block diagram of UPS is shown in Fig 1.

Fig 1



In UPS, the AC from the mains power is tranformed to DC. This DC is continuously charging the battery. The DC output from the battery is fed to inverter that converts it into AC output and supplies to the equipment.

Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification.

Battery

Battery is a device consisting of one or more electrochemical cells with external connections provided, to power electrical devices.

TABLE 1

Difference between Inverter and UPS

Sl. No.	Parameters	Inverter	UPS
1.	Back-up time	In inverter, the back up time is not rapid. So the computers may break down or data loss.	In UPS, the back up time of power supply is rapid. It will not make any computer crash or loss of data.
2.	Technical variation	The power is consistently drawn from battery.	The AC is changed into DC. This DC helps to charge the battery.
3.	Time delay	500 ms	3 to 8 ms
4.	Connection	The inverter connected to main power supply for providing electricity to different applications such as fan, lights, etc.	UPS directly connected to different application such as computer, printers, etc.
5.	Price	Low	High

Inverter

Inverter is an electronic circuit that converts low voltage DC into high voltage AC power. In solar-electric systems, an inverter may take the 12, 24, or 48 volts DC and convert to 230 volts AC, conventional household power.

The main power AC is supplied to the inverter, and it is transformed into DC simultaneously, which keeps charging the battery continuously. There is a sensor and relay structure that always monitors the ON or OFF status of the main supply.

As soon as there is a power failure, the relayactuator activates the inverter switch. Every other action is similar to the UPS, but because of the sensor and relay process, there is a delay while activating the switch.

Static transfer switch

Static transfer switches (STS) are such electrical devices which are used for very fast switching between electrical power sources. It is used in UPS immediatly switch main power supply, to its stored backup power.

They perform instantaneous switching operations and thus supply immediate power to the load.

Types of UPS

Objectives : At the end of this lesson you shall be able to
- **list different types of UPS**
- **compare ON-line,OFF-line and line interactive types of UPS**
- **state specification of UPS, power factor, calculating battery back-up**
- **explain types of indications and protection.**

Different types of UPS

1 ON line UPS

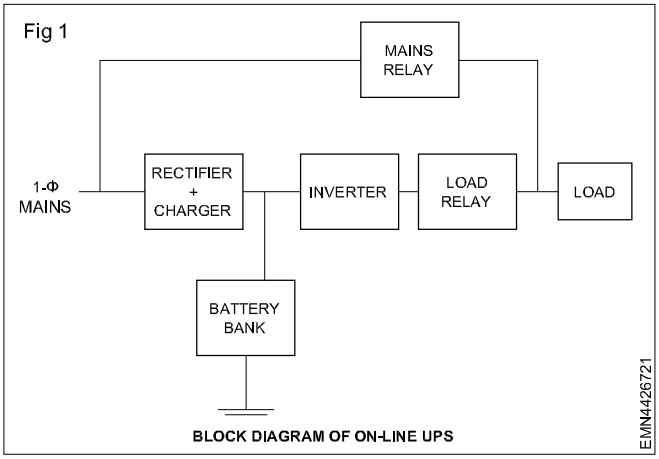
2 OFF line UPS

3 Line interactive UPS

ON line UPS

ON line UPS are also known as double conversion UPS or True ON Line UPS. There are two stages in its operation. In the first stage the mains AC is rectified to DC. There is a DC bus. DC bus can get power from both the DC battery and DC obtained by rectifying the mains AC. In the second stage DC power available from DC bus is converted to AC by the inverter and this AC is connected to the output. In normal operation output comes from mains AC via rectifier and inverter. When mains AC fail, output comes from DC battery via inverter. The changeover is instantaneous. There is no power transfer switch and hence no time delay. When mains AC is available normal operation continues and the rectifier recharges the battery. A bypass switch connects mains AC directly to the output in case there is some problem with the UPS. (Fig 1)

Fig 1



BLOCK DIAGRAM OF ON-LINE UPS

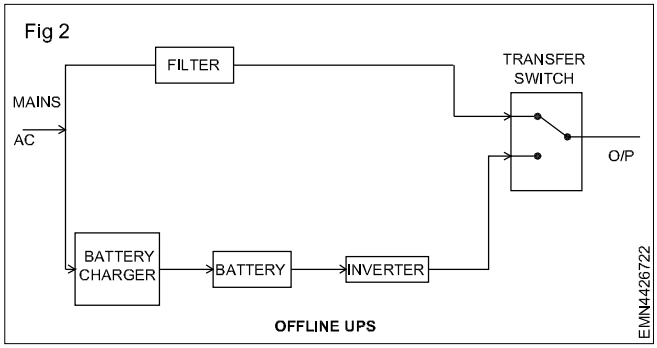
Metal Oxide Semiconductor Field Effect Transistor (MOSFET) power transistors, Insulated Gate Bipolar Transistor (IGBT) devices, microprocessor ICs, Operational amplifier ICs, adjustable voltage regulator ICs, Oscillator and pulse width modulator ICs, GATE ICs, timer etc. are some the important components found in on line UPS.

On line UPS offer the best power protection against all types of disturbances. The output voltage of an On Line UPS is highly stabilized with typical value of tolerance of 1 percent i.e. the output voltage is between 227 and 233 volt and frequency is between 49.95 Hz and 50.05 Hz. The output waveform is purely sinusoidal. A typical modern on line UPS is equipped with protections against short circuit, over-voltage and under-voltage etc, MCB for input, output and battery, and has digital LCD display with facility for displaying input and output voltage and frequency, battery status, output power delivered and error codes and messages.

On line UPS models generally have capacity more than 5kVA. High capacity On Line UPS can be built for all possible requirements and battery backup time can be increased to suit particular need by adding batteries. Sophisticated on Line UPS are available with many advanced features and are highly reliable but are costlier.

OFF line UPS

Fig 2



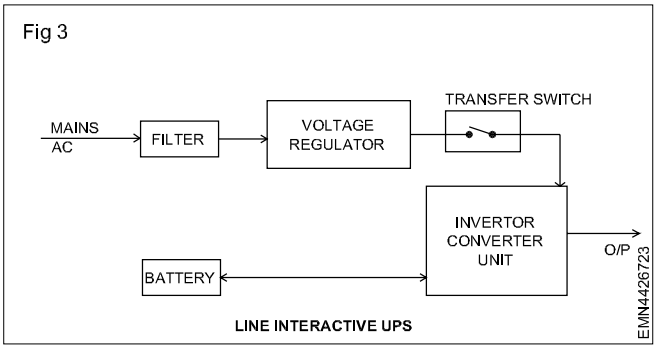
OFFLINE UPS

An OFF line UPS is shown in Fig 2. It is also known as stand by UPS or Backup UPS and supplies emergency power when mains AC fail. The capacity of an off line UPS is generally below 1kVA. A very common application is with PC. In the event of sudden load shedding the off line UPS supplies emergency power to the PC so that work can be continued till normal power is restored or the PC can be safely switched off.

In normal mode mains AC is directly connected to the output through a filter unit. The filter unit filters noise present in the mains AC. When mains AC fails the inverter converts DC power of battery to AC and transfer switch connects this AC to the output. This changeover happens very quickly but is not instantaneous and a time delay of few milliseconds is involved. This time delay normally does not affect ordinary load. Again when mains AC comes, the transfer switch connects mains AC to output. Thus the transfer switch keeps on changing connection of output to between mains AC and AC output of inverter. When mains AC is available, the charger unit recharges the battery. An offline UPS does not have provision for stabilizing the mains AC. Under voltage and over voltage of mains AC activates the power transfer switch and connects AC obtained from inverter to the output. Thus in case of off line UPS under voltage and over voltage of mains AC has similar impact as absence of mains AC.

Line interactive UPS

Fig 3



LINE INTERACTIVE UPS

In a line interactive UPS mains AC is connected to the output through a filter and voltage regulating unit. The voltage regulator usually is an auto transformer with number of tapping and stabilizes the mains input by bucking or boosting as per requirement. A single unit called Inverter converter unit performs the functions of battery charger and inverter. When mains AC is available inverter converter unit charges the battery. When mains AC fails it inverts DC to AC and supplies power to load. The transition is not instantaneous and time delay of few milliseconds is involved. Compared to Off line UPS, line interactive UPS performs better as the mains AC is regulated. Line interactive UPS are generally available with capacity between 750VA and 5KVA and are commonly used for computer network with small group of computers.

Comparison between OFF-line, ON-line and LINE-interactive UPS

OFF-Line UPS

OFF-line UPS passes the input AC to the output sockets if the AC power is available. It always monitor the voltage level in the mains, and if there is a voltage drop or mains failure, it switches ON the inverter to give AC power to the device until the mains supply returns to normal. The switch over time from AC to inverter AC is less than five milli seconds so that the functioning of the equipment is not affected.

ON-Line UPS

ON-Line UPS uses an inverter which always ON to give sine wave AC to the output socket. The incoming AC is first converted into DC to charge the battery as wll as to give power to the inverter. The inverter converts the DC to AC continuously to power the load. If power fails, the battery backup circuit switches ON and takes the load. Online UPS is more efficient than the Offline UPS and uses a "constant duty inverter". It also has a "static bypass" system that transfers the load to the AC power if the inverter system fails. The advantage of the online

Specification of UPS

Sl. No.	Parameter	Details
1.	Type of UPS	TRUE ONLINE
2.	CAPACITY	2 KVA/5 kVA
3.	Technology	The UPS shall be based on IGBT, and microprocessor controlled for providing better sine wave output.
4.	AC input voltage range	175V to 275 V AC, single phase
5.	Input frequency	47-53 Hz, (Suitable for working with generator supply)
6.	UPS power factor	0.9 or better
7.	AC output voltage	230V AC, Single phase
8.	Output frequency	50 Hz
9.	Waveform	Sinusoidal

10.	Efficiency	90% (at rated output voltage and frequency)
11.	Total harmonics distortion	2% maximum
12.	Indications	Standard visual indications for proper function of UPS.
13.	Protections	Over & Under voltage cut-off, overload, and short
14.	Back up time	2kVA = 8 hour at 400 watt load, 5kVA = 8 hr at 1000W load
15.	Type of batteries	Sealed maintenance free (SMF) Lead Acid Battery
16.	Remote monitoring	SNMP based monitoring

UPS is that, it clean up the AC waveform by converting it into DC then reconverting this DC to fresh AC. ON-Line UPS regulate voltage within ± 2-3%.

Line-interactive UPS

Line-interactive UPS system use automatic voltage regulation (AVR) to correct abnormal voltages without switching to battery. The UPS detects when voltag crosses a preset low or high threshold value and uses transformers to boost or lower the voltage by a set amount to return it to the acceptable range. Line-interactive UPS system typically regulate output within ± 8-15% of the nominal voltage.

Power factor

Power factor is a quantity which has important implications when sizing a UPS system and power distribution equipment. Power is a measure of the delivery rate of energy and in DC (direct current). Electrical circuits is expressed as the mathematical product of Volts and Amps (Power = Volts x Amps). However, in AC (alternating current) power system, a complication is introduced; namely that some AC current (Amps) may flow into and back out of the load without delivering energy. This current, called reactive or harmonic current, gives rise to an "apparent" power (Volt x Amps) which is larger than the actual power consumed. This difference between the apparent power and the actual power gives rise to the power factor. The power factor is equal to the ratio of the actual power to the apparent power. The apparent power is expressed as the Volt-Amp or VA rating. Therefore, the actual power in any AC system is the VA rating multiplied by the power factor.

"Watts = volts x amps x power factor". Unfortunately, the PF is rarely stated for most equipment, but it is always a number of 1.0 or less.

A double-conversion UPS gives voltage distortion problem created by the UPS. The input of a double-conversion UPS is essentially a big rectifier. The current drawn by the UPS is non-sinusoidal. This can cause the voltage from the AC mains also to become non-sinusoidal. The voltage distortion can cause problems in all electrical equipment connected to that power source, including the UPS itself. It will also cause more power to be lost in the wiring supplying power to the UPS due to the spikes in current flow. This level of "noise" is measured as a percentage of "total harmonic distortion of the current" (THDI). Classic UPS rectifiers have a THDI level of around 25%-30%.

There are several solutions to reduce the THDI in a double-conversion UPS:

Passive power-factor correction

Classic solutions such as passive filters reduce THDI to 5%-10% at full load. They are reliable, but big and only work at full load.

Active power-factor correction

An alternative solution is an active filter. Through the use of such a device, THDI can drop to 5% over the full power range. The newest technology in double-conversion UPS units is a rectifier that does not use classic rectifier components (thyristors and diodes) but uses high-frequency components instead. A double-conversion UPS with an insulated-gate bipolar transistor rectifier and inductor can have a THDI as small as 2%.

Uninteruptible power supply (UPS) systems are rated in kilowatts (kW) and others in kilo-volt-amperes (kVA).

1 kW and kVA simply mean 1,000 watts or 1,000 volt-amperes - the "kilo" prefix being used for larger numbers.

For large UPS systems have been designed based on a PF of 0.8, which means that a 100 kVA UPS will only support 80 kW of "real" power load. Most UPS systems has power factors of 0.95 - 0.98.

Neither the kW nor the kVA capacity of the UPS can be exceeded, but because of the higher PF numbers, it is usually the kW rating. There are some UPS systems on the market that are PF-corrected so that the kW and kVA ratings are the same.

Calculating UPS/Inverter battery backup

Before calculating the Battery Backup, let us know a few factors that vary battery backup.

For UPS with 875VA we can use a maximum load of 640 watts.

677VA we can use a maximum load of 540 watts.

The main thing is that what ever may be the UPS wattage the battery backup will not vary. The battery backup will only vary depending on the battery Ah and the Usage Load.

To calculate UPS backup, We have a simple formula.

UPS Backup = Battery AH x (Volts/Load) x (1/Powerfactor)

Example : Let us calculate the backup for a system UPS

Load is the usage power, suppose we are running a PC then the load is around 300 watts.

Power factor varies for device to device, the average power factor is 1.4

Voltage is the voltage of the battery.

For a single battery the voltate is 12v.

If the batteries are connected in a series Voltage = 12 x no. of batteries.

Battery AH is the battery ampere used for the ups, system UPS battery AH is 7.

Then battery backup = 7 x (12/300) x (1/1.4)

= 7 x (0.04) x (0.7)

= 0.19 hours

= 19 Minutes

Battery rating calculation

The formula for battery rating calculation is as below :

Formula employed

$$\text{Capacity of Battery(AH)} = \frac{\text{DC current x Duration in Hrs.}}{\text{\%age capacity utilization}}$$

Where, DC Current =

$$\frac{\text{UPS(KVA) x 1000 x Load power factor(PF=1)}}{\text{Inverter efficiency x End voltage}}$$

Hence , VAH = AH x Nominal Voltage

For example : for 3 KVA UPS , 1 hour Backup :

$$\text{DC current} = \frac{3 \times 1000 \times 1}{0.93 \times 10.5 \times 18} = 17.0\text{A}$$

$$\text{Battery "AH"} = \frac{17.0 \times 1.0}{0.62} = 27.4\text{AH}$$

Hence, 18 nos of 12V/28AH batteries are required.

Total VAH = 18 x 12 x 28 = 6048 VAH

The following assumptions have been made in the above calculations:-

1 DC voltage – 216 for 3 KVA

2 End cell voltage / battery of 10.5 V

3 Load Power Factor = 1.0

4 Inverter efficiency = 93%

% Capacity utilization is :

Duration	% Capacity utilization
½ hr (30 mins)	52%
1 hrs	62%
2 hrs	74%
3 hrs	83%
4 hr	85%

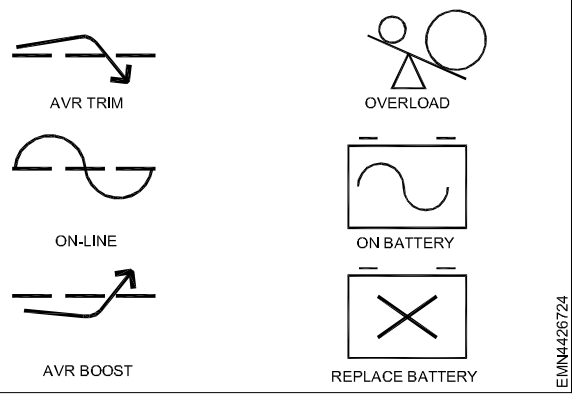
Types of indications and protections

Front panel Indicators (Fig 4)

On-Line

The online LED illuminates when the UPS is supplying utility power to the connected equipment. If the LED is not lit, the UPS is either not turned ON, or is supplying battery power.

Fig 4



AVR Trim

This LED illuminates to indicate the UPS is compensating for a high utility voltage. While the UPS can run in this mode indefinitely without any negative impact on the UPS, the circuit should be checked by a qualified electrician if the utility voltage is consistently high.

AVR boost

This LED illuminates to indicate the UPS is compensating for a low utility voltage. While the UPS can run in this mode indefinitely without any negative impact on the UPS, the circuit should be checked by a qualified electrician if the utility voltage is consistently low.

ON battery

This LED illuminates to indicate the UPS is supplying battery power to the connected equipment.

Overload

This LED illuminates to indicate the equipment plugged into the UPS exceeds the total capacity of the UPS. Some of the equipment (the load) on the UPS should be removed or turned off.

Replace battery

This LED will illuminate when the battery in the UPS has failed.

Some standard UPS incorporates both audio and visual warnings for the user to understand that the power is being consumed from the battery and not from the AC mains.

Visual warning

There are UPS that have ONE LED, TWO LED's and THREE LED's.

1 For UPS with a single LED

The LED glows a green color, indicating the system is working on the main power line. When the power fails, the LED turns either amber or a red with blinking at an interval of thirty seconds indicating that the UPS is working with back up power; power being supplied from the battery that is in the UPS. After for a particular duration of time and if by then the power is not restored by switching on a generator / alternator, the light turns a bright red along with continuous blinking indicating that it has critical two minutes left for the power of the battery to drain out and crash abruptly.

2 For UPS with Two LEDs

If the UPS is having two lights then the green is a solo type indicating mains and the other only one green light is visible. If the green LED is "ON" and the other LED is off indicating main power line consumption. When the main power fails, the other LED either a red or amber turns ON indicating the power is OFF after last two minutes. This is accompanied by continuous blinking of the LED indicator.

3 For UPS that have Three LEDs

The green indicates UPS working from main lines, the amber indicates the UPS working from battery back up and the red LED indicates UPS working from critical backup. As mentioned in the UPS with two LED's the blinking of the UPS is the same here too. For back up it is blinking at the rate of thirty seconds per blink and for critical power it is blinking at the rate of almost one second per blink.

Audio warning

Almost all UPS have an audio warning incorporated into the circuit. The audio warning is a beep sound produced by a piezo buzzer circuit. During critical back up power being consumed the beep is continuous with a frequency that is equal to the blink rate. The audio warning gives an indication to shut down UPS after saving data.

Conditioning and Protection

Sag

A reduction of the AC voltage, at the power frequency, that lasts from a half cycle to a few seconds.

Spike

This is a transient electrical impulse with a duration much less than 1/2 cycle.

Surge / Overvoltage

A voltage that exceeds specified limits either for a short time (seconds) or longer periods.

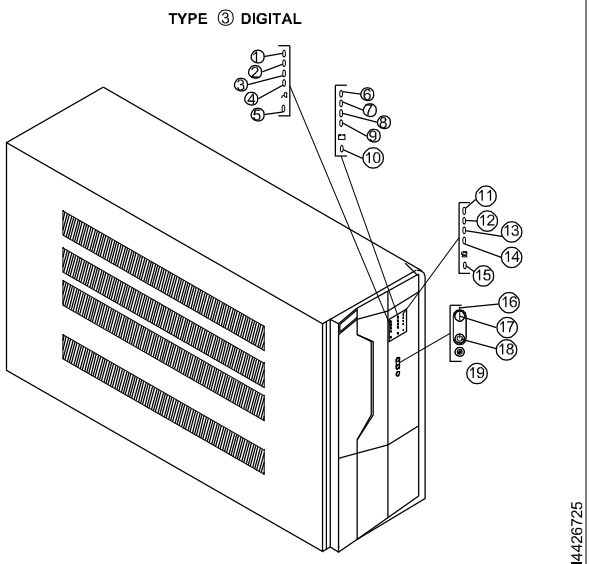
These types of disturbances can occur several times per day throughout most of the country. When a UPS is in a normal mode (not on battery power) these disruptions will not generally cause the UPS to switch to battery mode. Some UPS manufacturers have adjustable threshold settings that can activate the back up at various levels of interference. To avoid excessive switchovers, a conditioning and protection sub-system should be used in the normal mode.

		Symbol
①–④	AC input level	Power cord
⑤	Site wiring fault indicator	
⑥–⑨	Battery charge level	Battery
⑩	Battery service indicator	
⑪–⑭	Load level	Load devices
⑮	Communications	
⑯	ON LED	
⑰	ON button	⏽
⑱	STANDBY button	⏻
⑲	TEST/ALARM RESET button	◉

Indicators on UPS

Type 1 : The front panel LED Display (Digital)

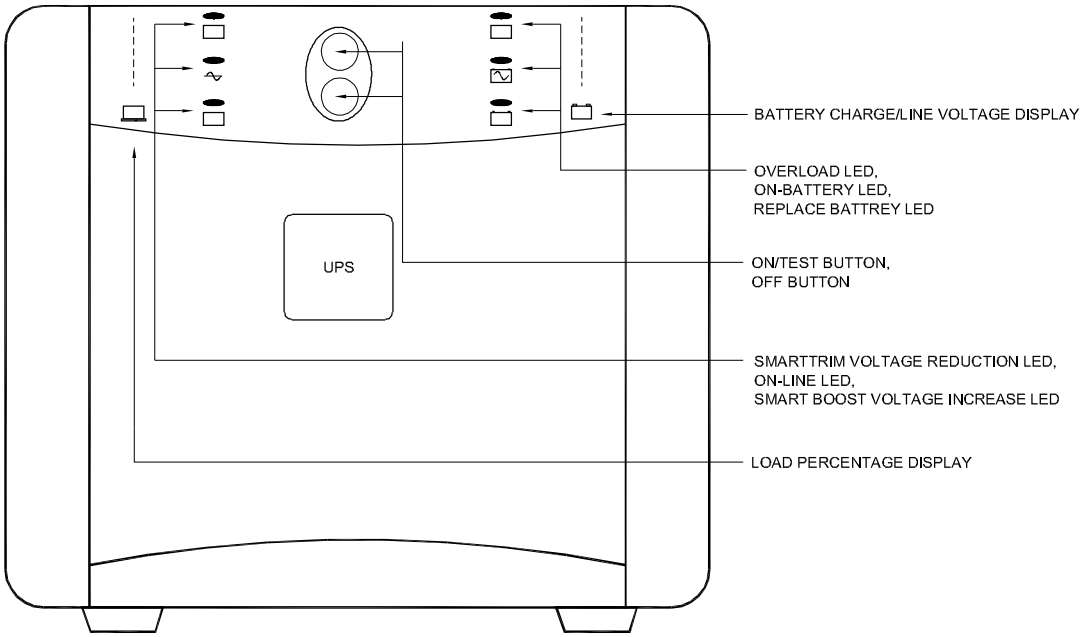
Fig 5



THE FRONT PANEL LED DISPLAY (TOWER MODEL)

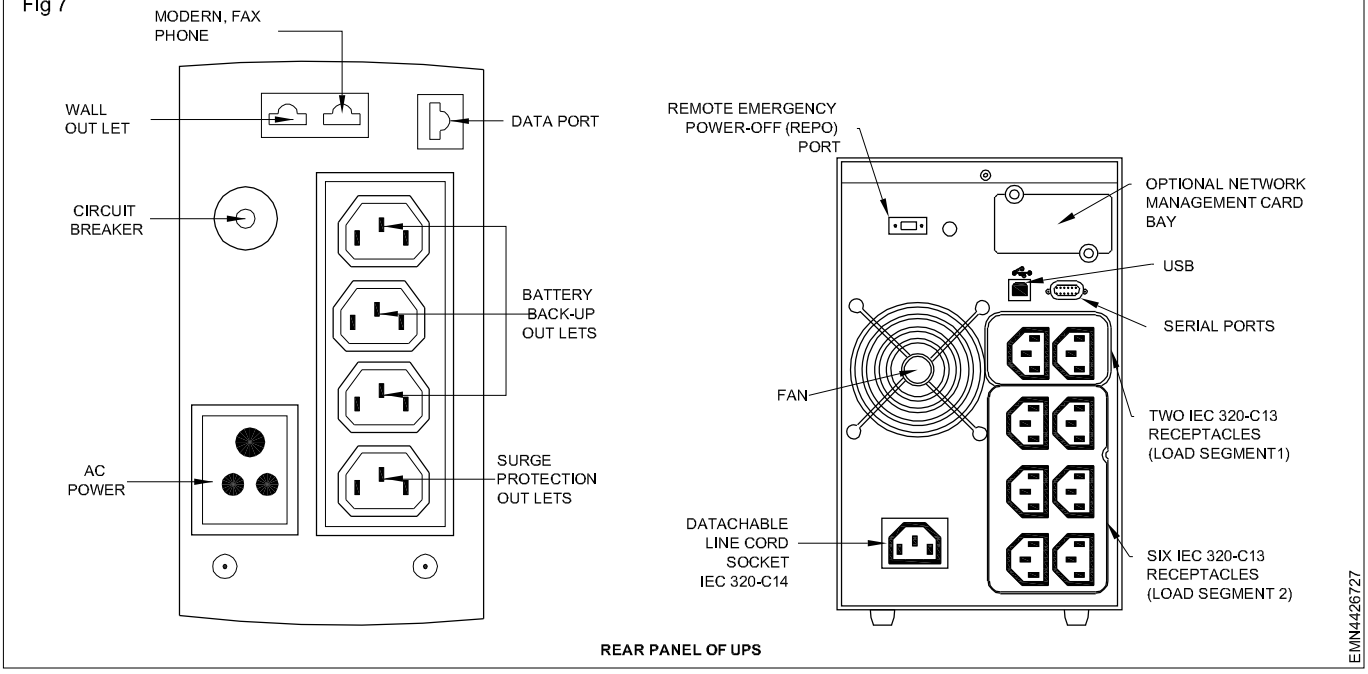
Type 2 :

Fig 6



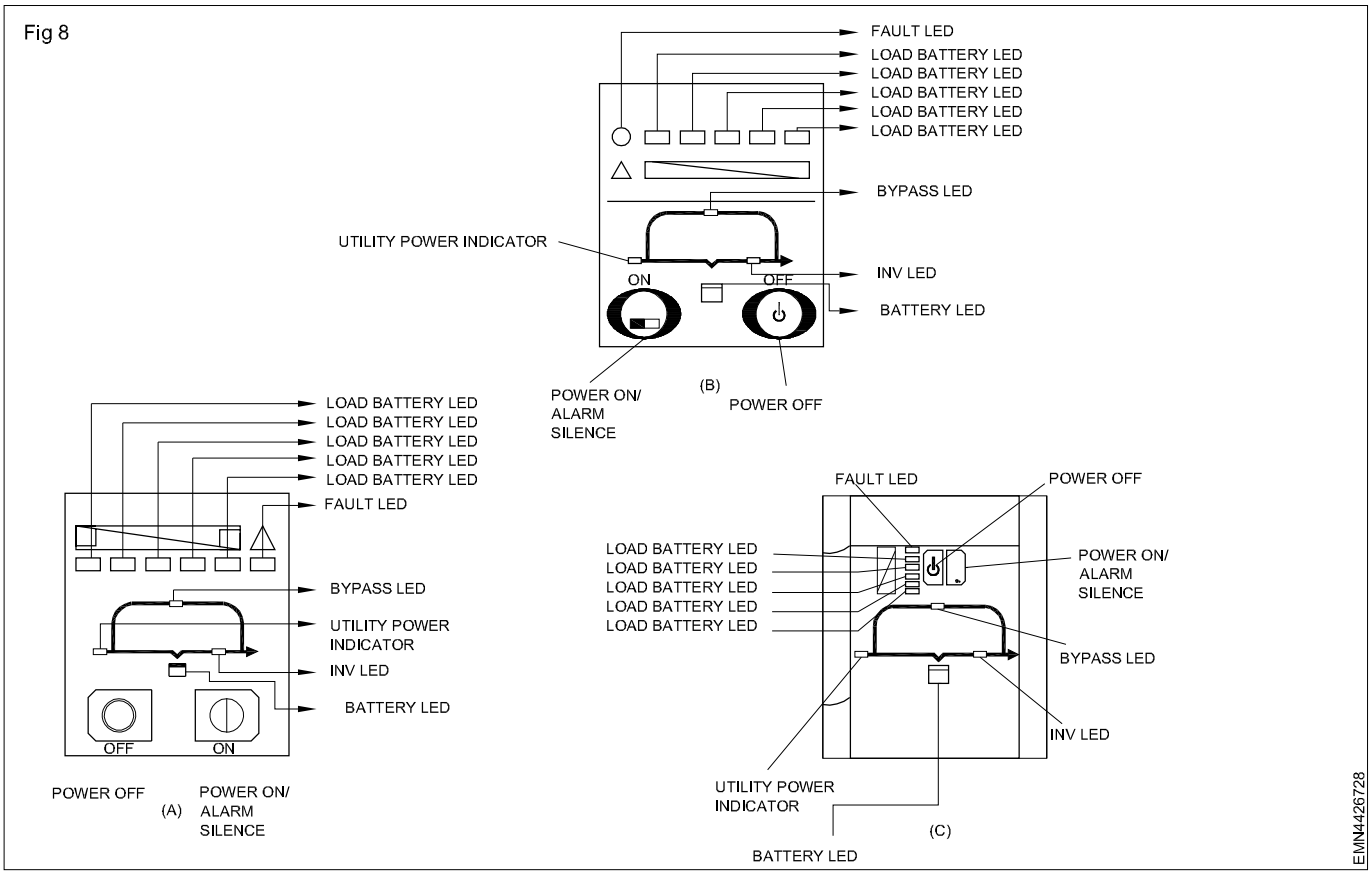
FRONT PANEL OF UPS

Fig 7



REAR PANEL OF UPS

Fig 8



UPS circuit description and working

Objectives : At the end of this lesson you shall be able to

- **describe working of UPS circuit**
- **explain controllor circuit**
- **explain the working of ON-Line UPS using PIC micro controller, charging circuit, alarm circuit and indicator circuit**
- **explain 3∅ UPS, types and specification of 3∅ UPS**
- **compare single phase and three phase UPS**
- **explain different methods of battery installation**
- **explain earthing and types of earthing**
- **describe three point/four point method of measurement of earth resistance**
- **discuss about the maintenance of batteries used in inverter**
- **list out the probable faults and rectification of UPS.**

Uniterruptible power supply (UPS) : Circuit description and working (Fig 1)

The circuit drawn pertains to a regular industrial UPS (Uninterruptible Power Supply), which shows how the batteries take control during an in electrical supply variation beyond the normal limits of the voltage line, without disruption on the operation providing a steady regulated output (5V by LM7805) and an unregulated supply. (12V).

The input to the primary winding of the transformer (TR1) is 240V. The secondary winding can be 15 volts if the value is atleast 12 volts running 2 amp. The fuse(FS1) acts as a mini circuit for protection against short circuits, or a defective battery cell. The presence of electricity will cause the LED 1 to light. The circuit is designed to offer more flexible pattern wherein it can be customized by using different regulators and batteries to produce regulated and unregulated voltages. Utilizing two 12 volt batteries in series and a positive input 7815 regulator, can control a 15V supply.

UPS are generally categorized as:

Standby - battery backup and surge protection

Line interactive - variable - voltage transformer and regulates the output AC voltage.

Online - Supplies all or atleast a part of the output power.

Digital control of an UPS

Uninterruptible power supply systems (UPS) are necessary for all applications where electronic systems have to work also in case of power failure (i.e. computer centers, hospital equipment, communication equipment etc.). Many mainframe computers are fed by UPS systems.

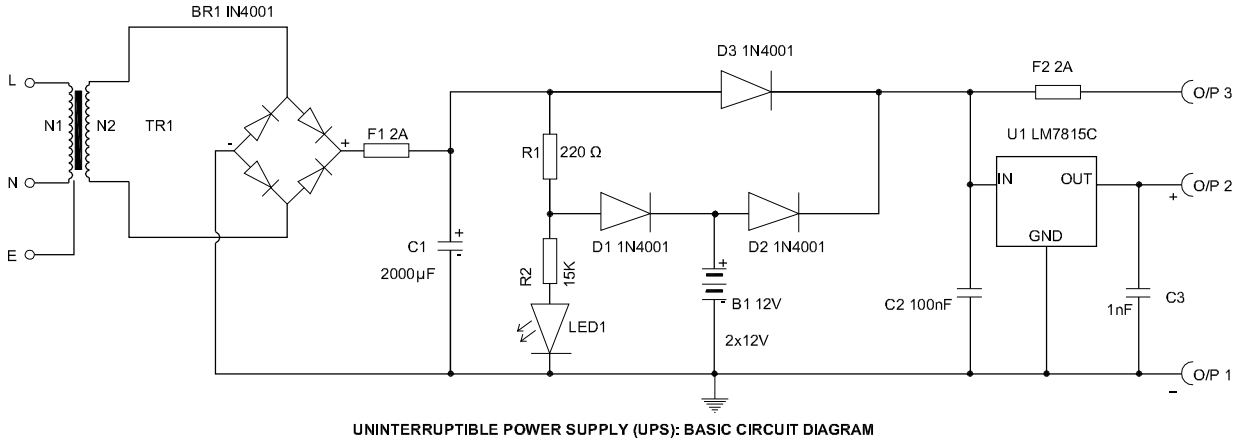
UPS systems conventionally consist of a synchronous generator, a fly-wheel for short-time energy storage and a battery powered motor or diesel engine.

By progress in power electronics static power converters can be realized, especially for mid-range output power (i.e. 5 - 50 kVA). In recent times there is increasing demand for UPS systems with low-distortion output voltages and sinusoidal input currents. Even at non-linear loads producing output currents with high harmonic content, sinusoidal output voltage is required. Due to this, even at unsymmetrical loads a static inverters can be better than rotary converters.

Static UPS system hardware

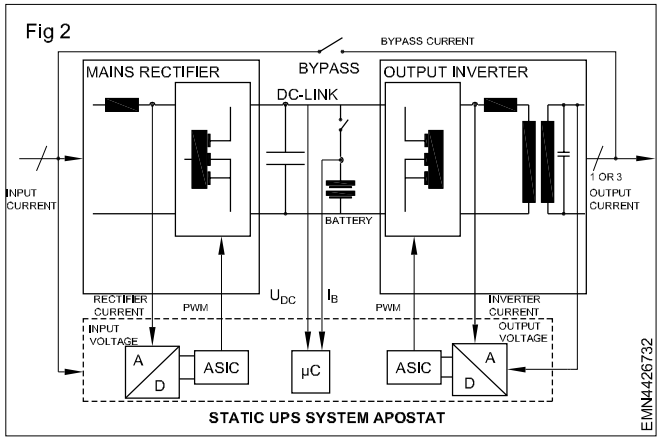
Static UPS systems consist of a rectifier with a single or three-phase mains connection, a DC-link with a battery for power storage and a single- or three-phase output converter. The bypass serves as an energy link in times of system failure or overload situations. (Fig 2)

Fig 1



UNINTERRUPTIBLE POWER SUPPLY (UPS): BASIC CIRCUIT DIAGRAM

Fig 2



STATIC UPS SYSTEM APOSTAT

Static UPS system hardware

Static UPS systems consist of a rectifier with a single or three-phase mains connection, a DC-link with a battery for power storage and a single- or three-phase Output converter. The bypass serves as an energy link in times of system failure or overload situations. (Fig 3)

Output Inverter

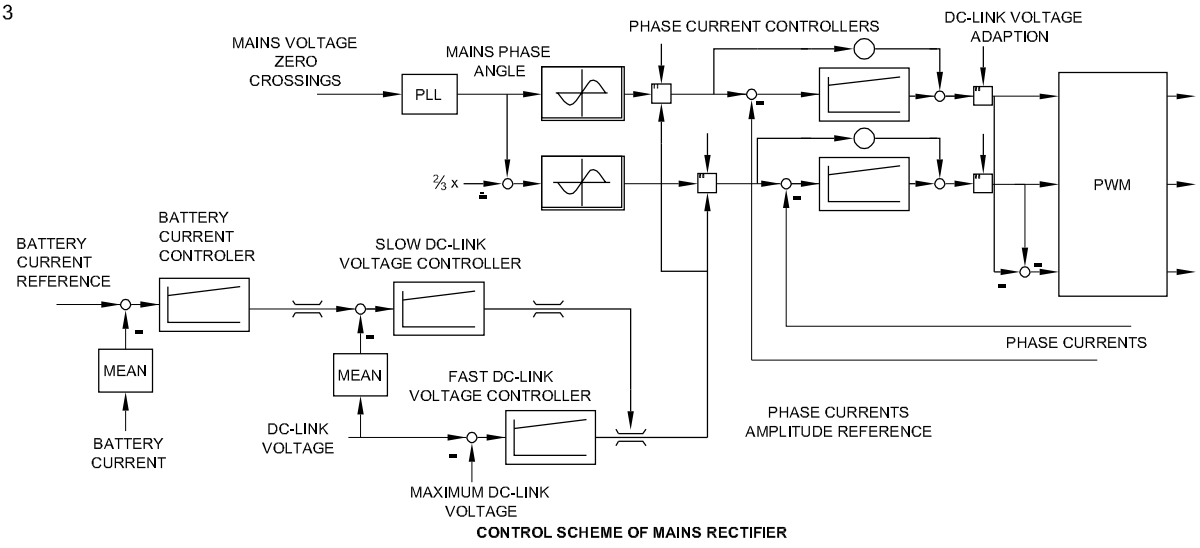
Since output loads are not symmetrical, every output inverter is made up of four power switches building a four-quadrant converter feeding the output transformer. The stray filters the output voltage Inductance of the specially-designed transformer and the output capacitance.

The control scheme of the output inverter is shown in Fig 4. The Controlled quantity is the output voltage. An underlying current control loop is implemented for protection of the power devices. The output value is transformed to switching signals by pulse width modulation (PWM).

PI-controllers for AC quantities normally have phase and amplitude errors, which are not tolerable. On the other hand, PI-controllers provide predictable behavior at all operating modes. To reduce undesired effects feed-forward signals from the reference and output voltage are used. To eliminate the influence of the changing DC link voltage on the gain of the current controller the current control output is multiplied with the reciprocal value of the DC voltage.

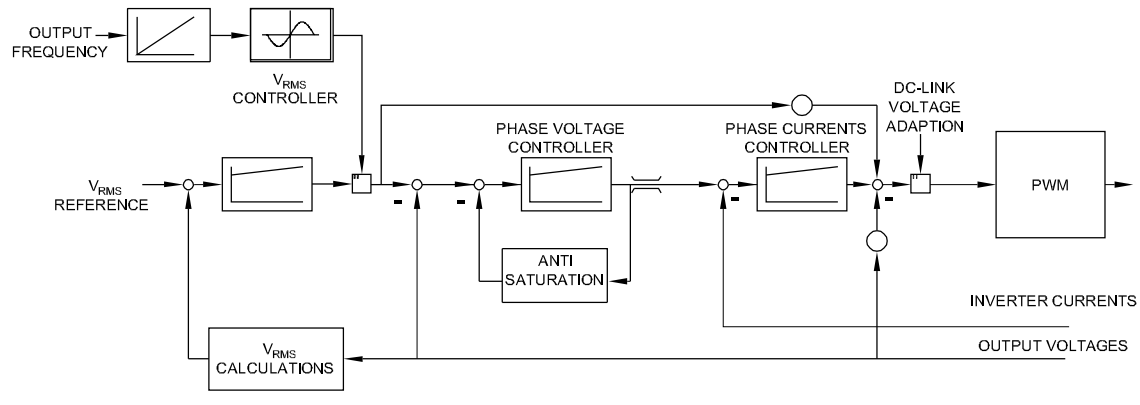
The reference for the current controller is taken from the voltage controller. A modified PI-controller was chosen; special algorithms are implemented to cope with the saturation problem of the output transformer. The output

Fig 3



CONTROL SCHEME OF MAINS RECTIFIER

Fig 4



CONTROL SCHEME OF UPS OUTPUT INVERTER

of the voltage controller is limited to the current capability of the devices.

A sine generator running at a programmable frequency and amplitude produces the reference for the output voltage. An additional voltage controller monitoring the RMS-value of the output voltage during an output cycle calculates the amplitude.

Universal control structure

It was decided to use only digital controllers in order to achieve stability, easy parameter adjustment and additional monitoring features. Some of the controllers have to be very fast to gain best response (current control, output voltage control). For implementing these algorithms fast signal processors and application specific integrated circuits (ASICs) are available. Signal processors do not contain inverter specific peripheral circuitry like pulse width modulation, phase measurement etc. For these functions, an ASIC was the solution with the best price performance ratio. Signalprocessors are optimized for digital filtering and not for control algorithms. Integrating the control algorithms into the ASIC the calculation times could be minimized by developing a processor structure perfectly adapted to the application.

This ASIC containing both peripheral and signal processing hardware is a very cost-effective solution for this UPS system. The disadvantage of having hardware algorithms was acceptable due to the fixed specification of the UPS system and counterbalanced by an universal control structure performed by the ASIC with many switches and load able parameters.

All inner current and voltage control loops are performed with a sampling rate equivalent to the switching frequency of the power devices (10 or 20 kHz).

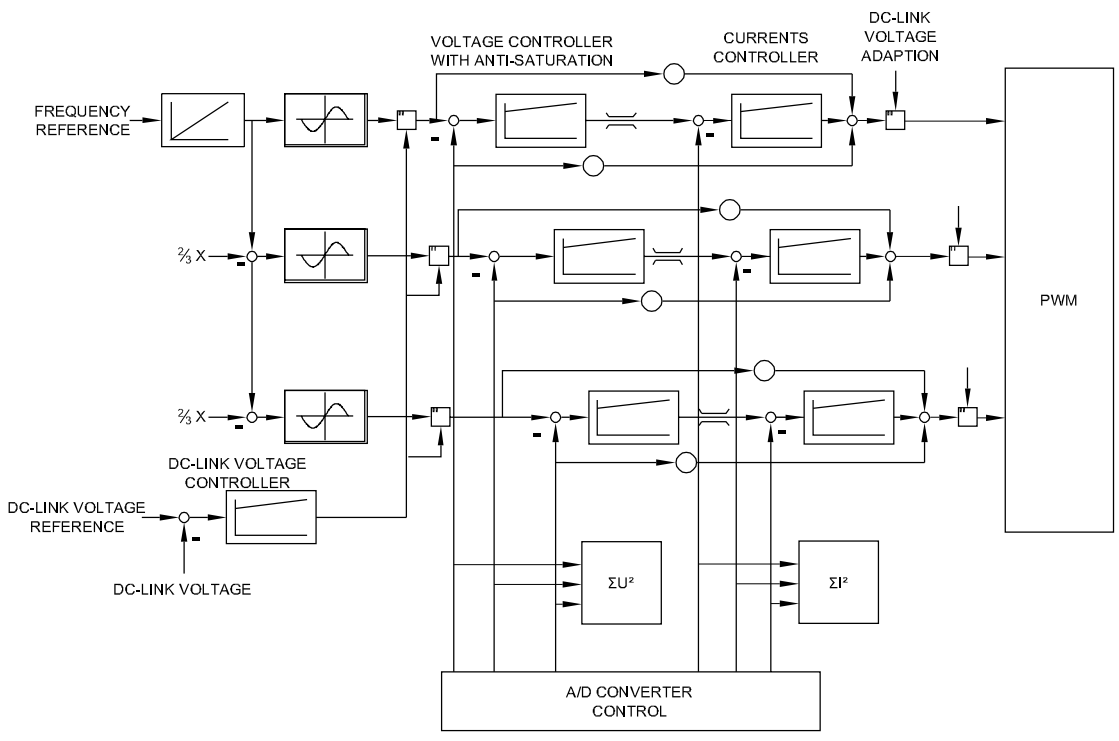
Output inverter and controlled rectifier both contain equivalent circuitry and signal processing pulse width modulator, current control, sine wave generation, DC-link measurement and adaptation. The whole UPS family consists of both one- and three-phase systems. Integrating the total functions for a three-phase rectifier and inverter into one ASIC would be overloaded for single-phase applications.

Therefore, it was decided to put the control of three-phase inverter into one circuit. This can be used for the three-phase output inverter, the three-phase rectifier and also for both a one-phase rectifier and inverter.

Fig. 5 shows the universal control block diagram of the ASIC. It contains seven PI-controllers in total. The pulse width modulation generates the signals for six inverter legs. This allows for three independent four-quadrant DC-inverters being used for a three-phase output inverter. The current controllers operate in two modes: for the output inverter three current controllers are used to control the three phases independently. For the rectifier only two controllers are used; the third phase is calculated at the output voltage level. The voltage controllers are only used for output inverter operation. They can be bypassed at the rectifier mode.

Some additional circuitry was included. The measurement of the phase difference for the PLL-control of the line frequency is supported by the ASIC using phase angle captures functions. To support the microcontroller to determine the effective output voltage and current load the integrated squares of the measured values are calculated during a period of the sine wave frequency.

Fig 5



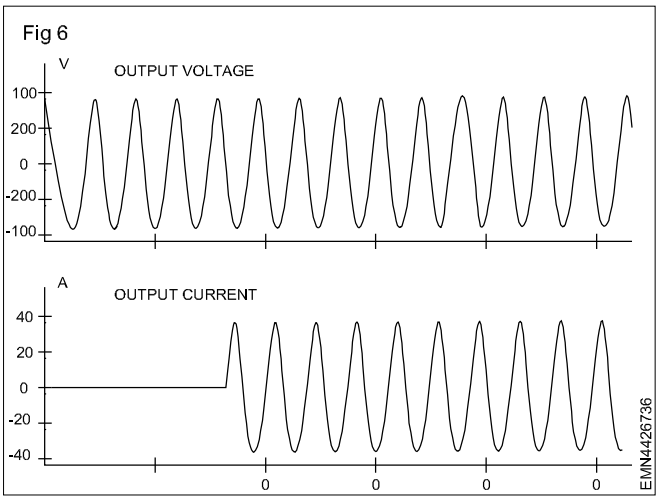
UNIVERSAL CONTROL SCHEME OF ASIC

The repetition cycle of all calculations performed by the The repetition cycle of all calculations performed by the ASIC is the switching frequency of the inverter legs. This frequency normally amounts to 20 kHz. At the beginning of the cycle the A/D-conversion is started. The ASIC calculates the references and the A/D voltage controller. After at most 15 ìs the A/D-conversion is ready and the calculation of the controllers starts being performed in 10 ìs for all six PI-algorithms. New PWM-values are given to the modulator at the middle of the switching cycle. In the remaining second half of the cycle the ASIC performs the calculation of sum of squares of the measured values.

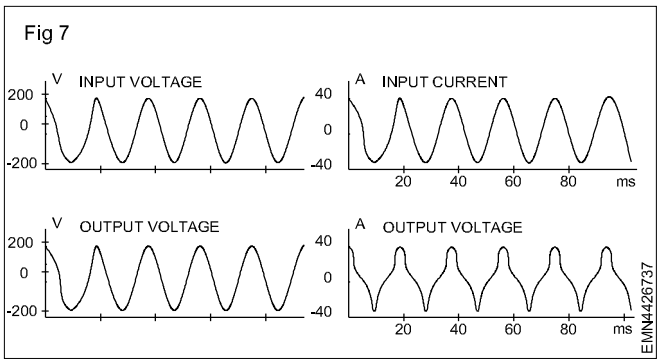
Measured performance results of the UPS system

The inverter controller ASIC is used at the control board of a series of static UPS systems (APOSTAT). This series consists of onephase units with sinusoidal input currents (6.6 kVA and 10 kVA) and three-phase units (10 kVA and 20 kVA).

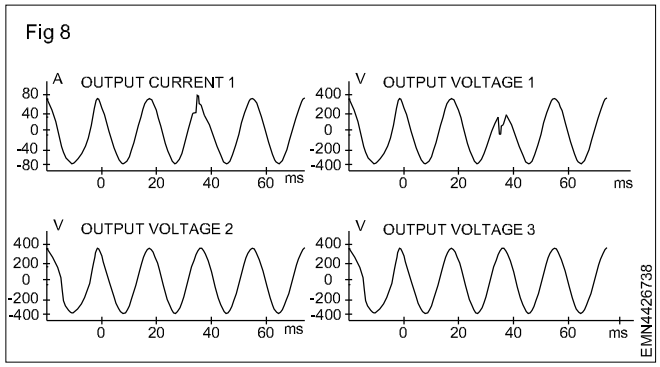
Due to the high sampling rate of the digital control algorithms an excellent dynamic behavior of the UPS-system is achieved. This is important in case of load-steps (Fig. 6) and non-linear loads (Fig. 6). The output inverter and the output filter circuit provide high peak currents (crest factor 3). Harmonic distortions of the output voltages range from 1% to 2% at linear loads and to 5% at non-linear loads.



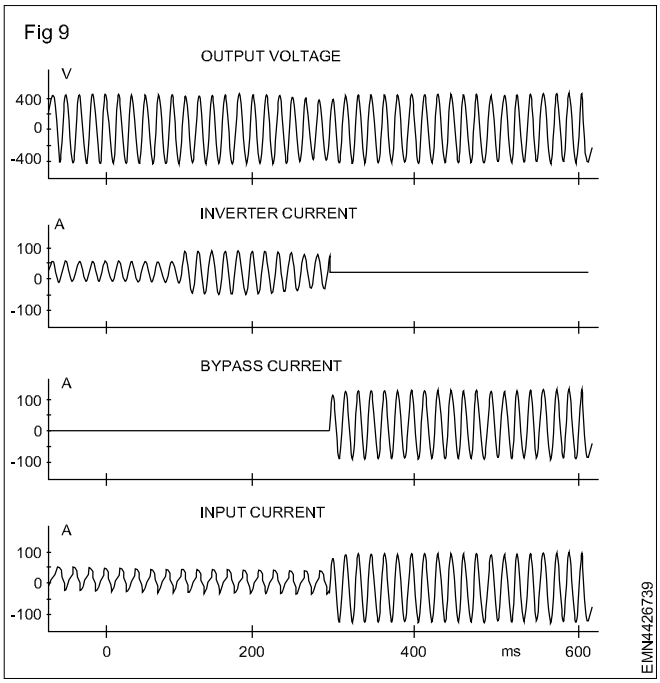
Using a controlled step-up chopper the input currents of the single-phase controlled rectifiers are pure sinusoidal. This transforms nonlinear loads at the output side into linear resistive loads at the line-side. (Fig 7)



The output transformer of the three phase units consists of three individually controlled single-phase transformers. Therefore, voltage distortions of one phase resulting from the load (for example short circuit) do not affect the other phases. Fig. 8 demonstrates the inverter being capable of clearing the short circuit by blowing the fuse without transferring to bypass operation. The maximum peak current available of the inverter during this operation is 300% of RMS-rating. If the output voltage exceeds the allowed voltage range for more than 4 ms the system automatically switches from inverter to bypass operation.



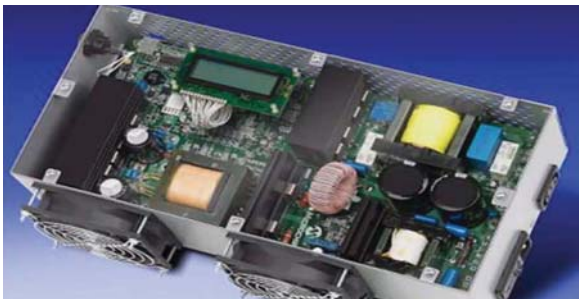
The inverter is able to provide short time overloads (20%/ 100 ms, 1500%/5 sec, 120%/1min). If the load exceeds the current or time limit a current controller reduces output currents and voltages. Fig. 9 shows that the bypass will be activated to supply the output power.



Block diagram of ON-Line UPS using PIC micro controller (Fig 11)

ON-Line uninterruptible power supply (UPS) offers AC voltage regulation with the controllable battery charger. The battery is Lead Acid Type battery. The charge control technique used for battery is constant current charging technique. The constant current is achieved by limiting the duty cycle of charger (or step-down chopper). In protection of battery over charge and battery under discharge is available with relay trip through PIC 16F877A microcontroller by monitoring voltages on continuous

Fig 10



Pictorial diagram of microcontroller UPS

EM430620

basis. The backup of battery takes place the load without spikes or delay when the mains power gets fails or interrupted. Based upon the constant current charging technique, a digital charger is designed and is control through PIC 16F877A microcontroller software. The inverter is simple square wave inverter.

Circuit description of PIC micro controller (Fig 11)

The AC voltages are applied to Rectifier through the step down transformer and power supply. An uncontrolled rectifier converts AC voltages into DC voltages. The fixed DC is fed to the step-down chopper. The PWM control technique keeps switching frequency constant and also regulates duty cycle to ensure the MOSFET to turn on. In constant current charging method current is set at a fixed rate. Constant current is achieved by switching of the chopper. The step-down chopper produces a lower average output voltage than the input voltage. The battery is connected to the variable DC through the relay. Relay gives the trip on the conditions of overcharging and under discharging. The relays will work as static switches. The switching of inverter is controlled through PIC microcontroller. The battery feeds the inverter. The AC output from inverter will fed to load.

230 AC voltages are applied to the step down transformer of 0-18 V/ 8 A. The output of 18 V ac is converted into 12 V dc through rectifier. Rectifier with filter capacitor converts AC into 12 V DC. The capacitors of 2200 mF/ 50 V are used to control the heavy current which may damage the MOSFET switch. The switching frequency of MOSFET switch is 8 kHz. The turn on time and turn off time of MOSFET controlled through the isolated driver which may also regulates the voltage. The turn on time of MOSFET will be different as for constant current charging. Hence, duty ratio will also be different. The inductor used is toroidal type. The variable DC is fed to the battery through the resistors of 12 kW and 3 kW. The voltage sample Vx is taken between 12 kW and 3 kW resistor. Also, other voltage sample Vy is taken across the battery. The voltage samples Vx and Vy are given to the PIC microcontroller for comparing purpose for constant current charging of battery. When the voltage sample Vy is less than 14 V, the load relay will be turns off, and when the voltage sample Vy is more than 12 V, the load relay will be turns on. Also, when voltage sample Vy is more than 14 V it will increases the duty cycle of step down chopper and when voltage sample Vy is less than 14 V it will decreases the duty cycle of step down chopper. The output from pin 17 of port C is given to pin 3 of the level shifter CD4504. At pin 1 of CD4504 the supply of +5 V is fed. Also, the capacitors of 100 uf / 16 V and 0.1 uf are connected for high and low frequency input noise suppression. The level shifter shifts voltages from +5 V to +12 V (low to high). The output from level shifter CD4504 is fed to pin 10 of MOSFET driver IR2110. The output from pin 7 through the current limiting resistor of 100W is given to the gate terminal of MOSFET.

There are four different conditions:

1 Mains available and Battery fully charged at that time

i Charger to battery relay will be OFF and battery to load relay will be ON.

ii Also, Vl to be regulated equal to Vb so that battery will not discharge.

2 Mains available and battery not fully charged

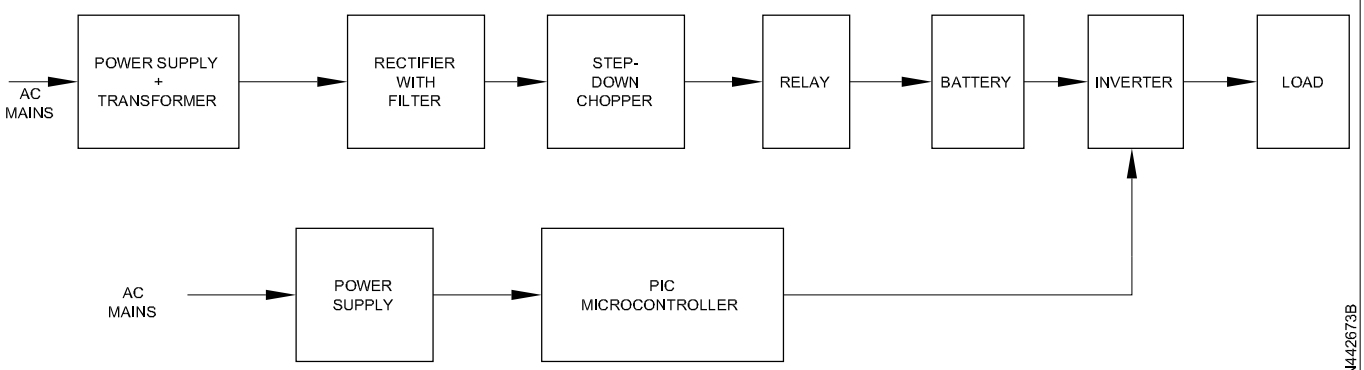
i Charger to battery relay will be ON and battery to load relay will be ON.

ii Charging to be regulated so as to keep Ib < 1 A

3 Mains fail and battery not fully charged but not discharged

i Charger to battery relay will be OFF and battery to load relay will be ON.

Fig 11



BLOCK DIAGRAM OF ON-LINE UPS USING PIC MICRO CONTROLLER

EMN4426738

4 Mains fail and battery discharged

i Charger to battery relay will be OFF and battery to load relay will be OFF.

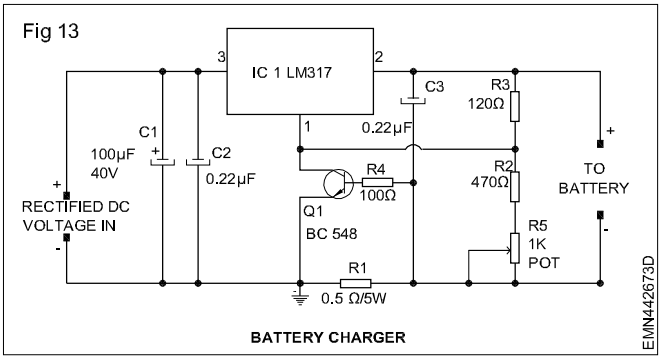
Circuit description for inverter (Fig 12)

The push-pull configuration of inverter is used for designing of inverter for ON-Line UPS. For switching operation MOSFET Switches IRFP150 are used. For that MOSFET switches MOSFET driver IR2110 is used. The output from pin 33 and 34 as PWM waveforms are fed to pin 5 and pin 7 of the level shifter CD4504. The level shifter shifts voltages from +5 V to +12 V (low to high). The 12 V output from level shifter CD4504 is fed to pin 10 and pin 12 of MOSFET driver IR2110. The power supply for MOSFET driver IR2110 is connected at pin 6 which is as shown in Fig 12. When one switch is ON at that time other switch is OFF, therefore dead band circuit is not required for push-pull arrangement of inverter. For MOSFET diver IR2110, isolated power supply is not required because sources of both the MOSFET switches are grounded. The resistor connected at gate of MOSFET is used for current limiting. The capacitors connected across the MOSFET switches are used for snubbing.

Battery charger circuit (Fig 13)

Battery charger circuit using IC LM 317 provides the correct charging voltage for the battery. A battery must be charged with 1/10 its AH value. This charging circuit is designed based on this fact. The charging current for the battery is controlled by Q1, R1, R4 and R5. Potentiometer R5 can be used to set the charging current. As the battery gets charged the current through R1 increases .This changes the conduction of Q1.Since collector of Q1 is

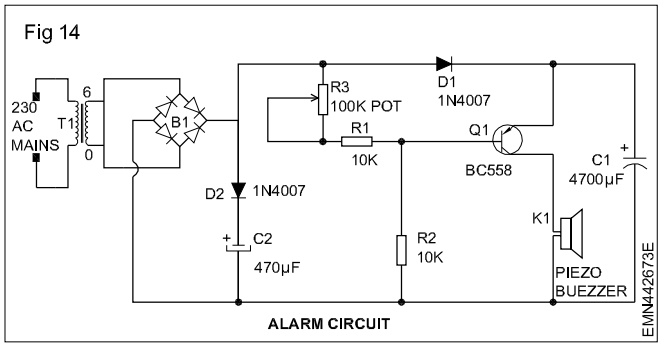
Fig 13



connected to adjust pin of IC LM 317 the voltage at the output of LM 317 increases. When battery is fully charged charger circuit reduces the charging current and this mode is called trickle charging mode.

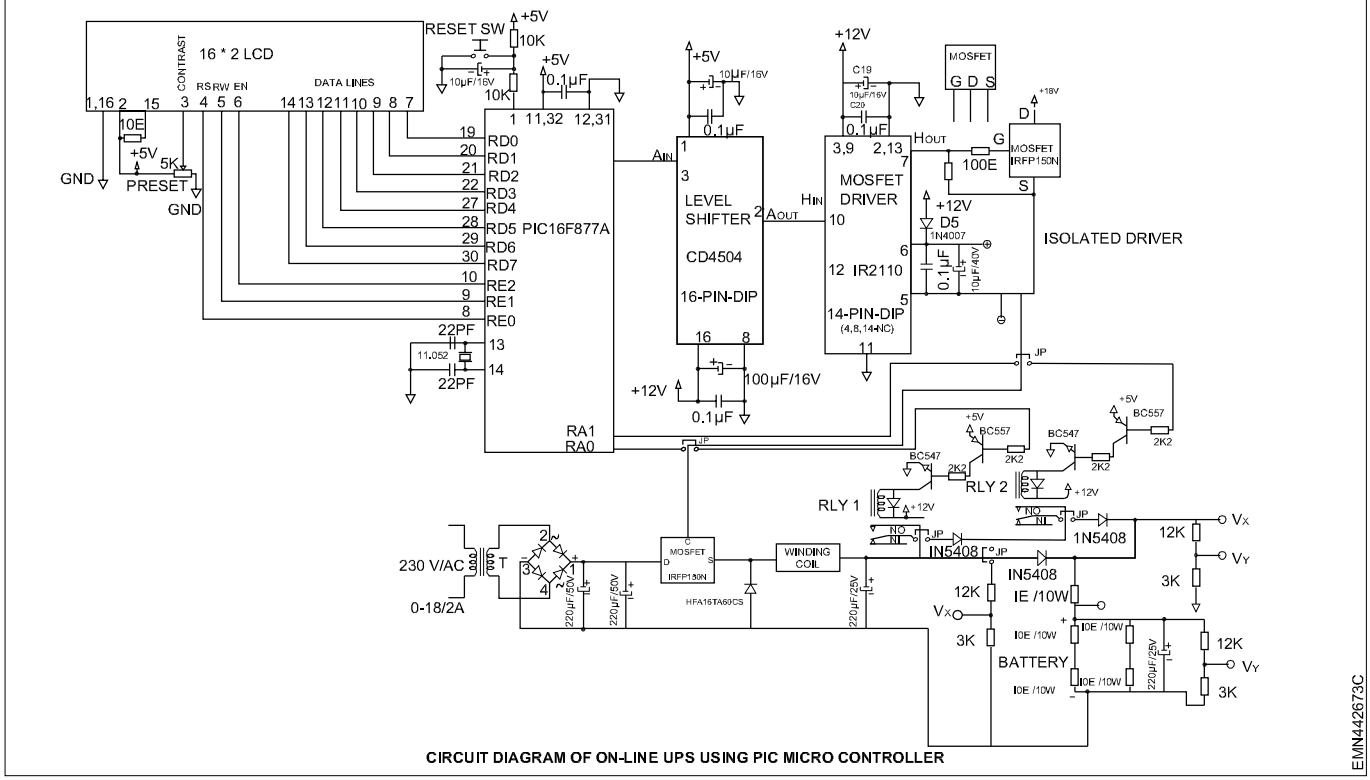
Alarm circuit (Fig 14)

Fig 14



A simple mains power failure alarm/detector circuit that produces an alarm whenever the mains supply fails. Lot of such circuits are available, but the peculiarity of this circuit is that it requires no back up power source like a battery to power the alarm when the mains is absent.

Fig 12



When there is mains supply the transistor Q1(BC558) will be OFF and the capacitor C1 will be charged. When the mains supply fails the transistor Q1 becomes ON and the capacitor C1 discharges through the Q1 to drive the buzzer to produce an alarm. The capacitor C2 is the filter capacitor for the bridge. Diode D2 prevents the discharge of the C2 when mains fails. If D2 is not there, the alarms will remain silent for a time capacitor C2 to fully discharge after the power failure.

Indicator circuit (Battery level indicator) (Fig 15)

This battery level indicator offers five LEDs that light up progressively as the voltage increases: These five LEDs show the approximate charge of the battery in percentage; each LED represents approximately a 25% charge on the battery.

i Red : Power connected (0%)

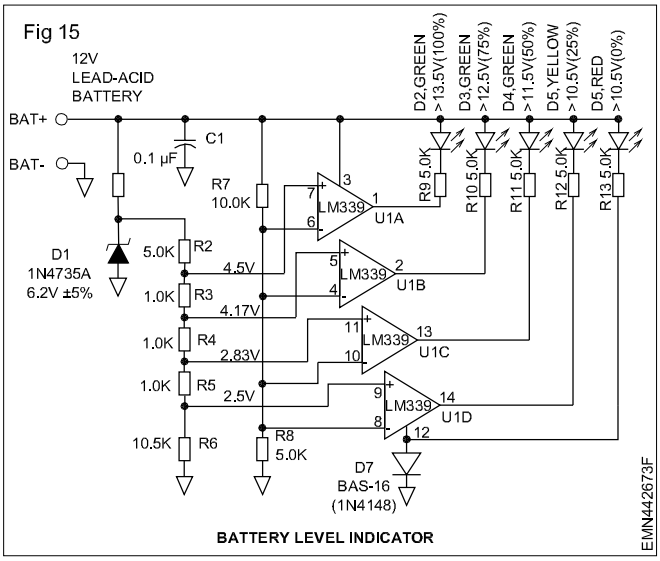
ii Yellow : Greater than 10.5V (25%)

iii Green 1: Greater than 11.5V (50%)

iv Green 2: Greater than 12.5V (75%)

v Green 3: Greater than 13.5V (100%)

Fig 15

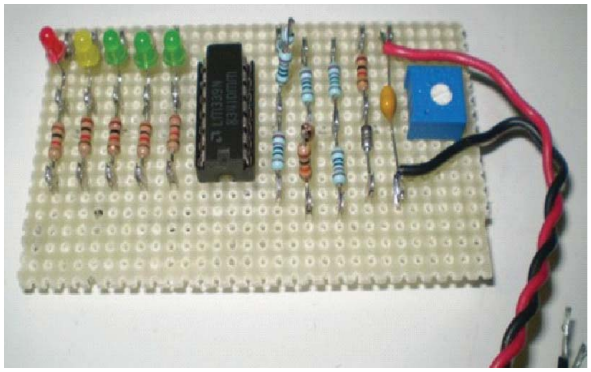


Operation of the battery level indicator

D1 is the voltage reference zener. A string of divider resistors (R2-R6) set the various fixed voltage levels. R7 and R8 form a voltage divider to that reduces the battery voltage by a factor of 3. U1 is an LM339 quad comparator that compares the various voltages from the two dividers. The comparator sections have open collector outputs which function as switches to operate the LEDs. D7 protects against reverse battery connection.

The LEDs are biased to operate at about 4mA which is quite bright. This current can be adjusted by varying the series resistors (R9 through R13).. For energy conservation, connect the battery via a pushbutton switch.

Fig 16



Single phase UPS

A single phase installation consists of a single sine wave input and is typically a single phase of a larger 3 phase supply. A typical example of this would be a local 3 pin socket which uses 230/240 VAC (Single phase) to supply power. Most small power hardware including rack mounted servers, telecoms, network switches, computer systems or any device running from a standard 3 pin plug, operate from a single phase supply.

All single phase UPS up to 3kVA will typically be installed to a standard plug. Sizes above 3kVA would be installed to a single phase distribution board.

Three Phase Uninterruptible Power Supplies (UPS) Introduction

3 phase UPS

A 3 phase installation uses the full 3 phases which is generated from the grid. A 3 phase electrical supply comprises of three individual sine waves, and can be installed as either a 3 wires or 3 wire & neutral configuration. A three phase source would typically come from a local transformer, with the standard three phase voltage being 400/415 VAC.

Three phase uninterruptible power supplies (UPS) operate in conjunction with existing electrical systems to provide power conditioning, back-up protection, and distribution for electronic equipment loads that use three-phase power. A three phase UPS also prevents power disturbances such as outages, sags, surges, spikes, and noise from affecting the performance and life of the electronic device and data. Selecting three phase uninterruptible power supplies (UPS) requires an analysis of technology types, product specifications, and features.

3 phase UPS systems are usually used on larger installations such as data centers, medical equipment / theatres and large industrial applications. All 3 phase UPS need installation to a 3 phase distribution board, which is usually achieved via a bypass switch facility.

Types of three phase uninterruptible power supplies (UPS)

There are three basic types of three phase uninterruptible power supplies (UPS):

1 On-line or double-conversion

2 Line-interactive

3 Off-line or standby

1 On-line or double-conversion

With on-line units, the load is supplied from a continuously-operating power converter that receives its input from a DC supply. This DC supply consists of a battery and a large battery charger, which are connected in parallel.

2 Line-interactive

With line-interactive devices, the inverter works in parallel with conditioned-input AC power to supply power to the load (boosting or bucking), and only handles the full load power when the AC input power fails.

3 OFF-line or standby

With an off-line unit, the power is usually derived directly from the power line, until power fails. After power failure, a battery-powered inverter turns on to continue supplying power.

Capacity specifications

Capacity specifications of three phase uninterruptible power supplies (UPS) are the volt-amp rating, watt rating, and input voltage range. Three phase uninterruptible power supplies (UPS) are rated in volt-amperes (VA) or kilo-VA (kVA).

Note that the VA rating is not the same as the power drain (in watts) of the equipment.

The watt rating is specified only if VA rating is unknown; the watt Rating is less than or equal to VA rating. The input voltage range is the precise identification of the electrical system is critical in the proper selection and application of a three phase UPS.

Performance specifications

Performance specifications for three phase uninterruptible power supplies (UPS) include runtime half load, runtime at full load, and switchover time. Runtimes refer to the length of time the three phase UPS will run at half load, full load, and the amount of time for switchover.

Note that ON-line or double-conversion devices do not have a switchover time.

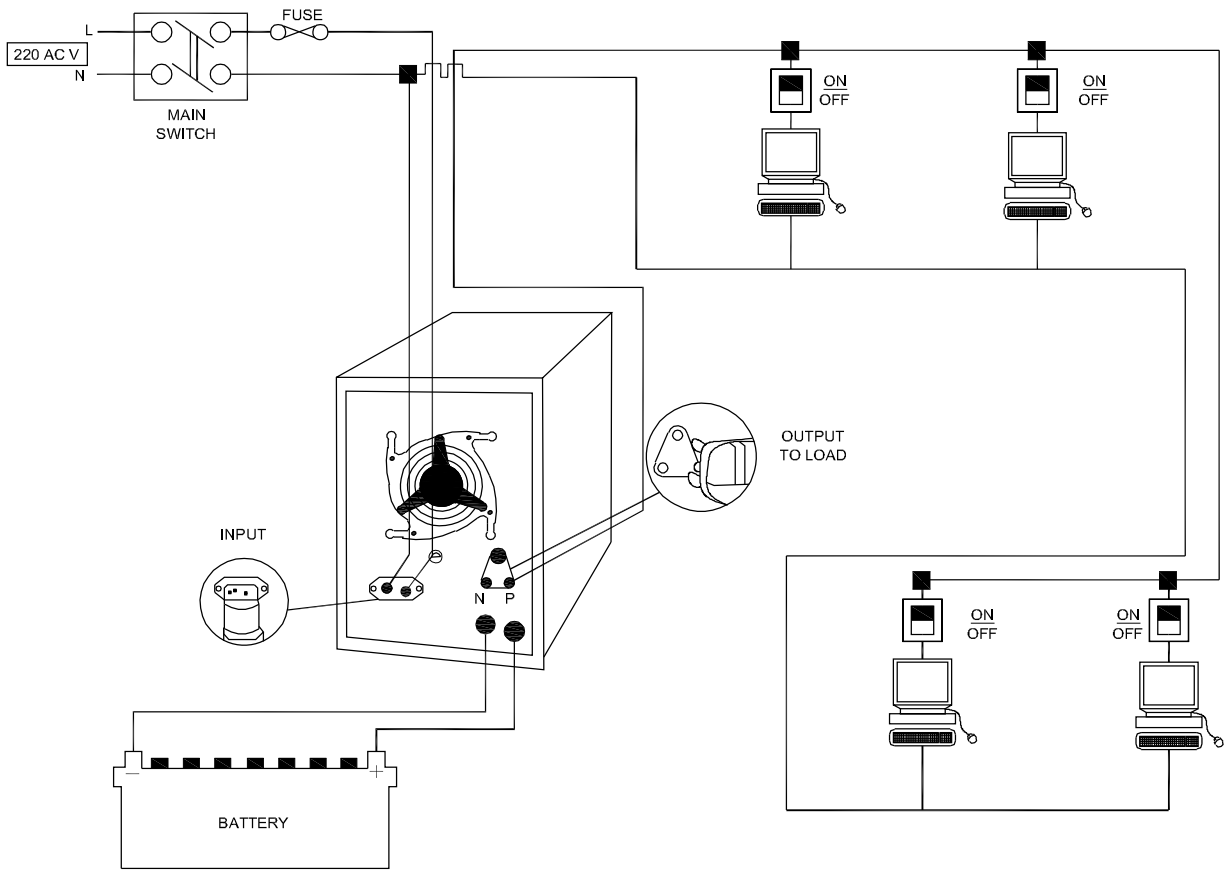
Output specifications

Output specifications for three phase uninterruptible power supplies (UPS) include output voltage in battery mode, number of backed-up outlets, and outlet options. Outlet options include additional electrical outlets, RJ type connectors, and coaxial cable connectors. Mounting options for uninterruptible power supply (UPS), three-phase include tower type, rack or tray, strip type or plug strip, and mounts on or in device protected. In addition to battery backup systems, rotary or battery-free three phase uninterruptible power supplies (UPS) are available that use the energy stored in a rotating member as backup energy.

Electrical wiring of UPS

Single phase UPS system wiring diagram

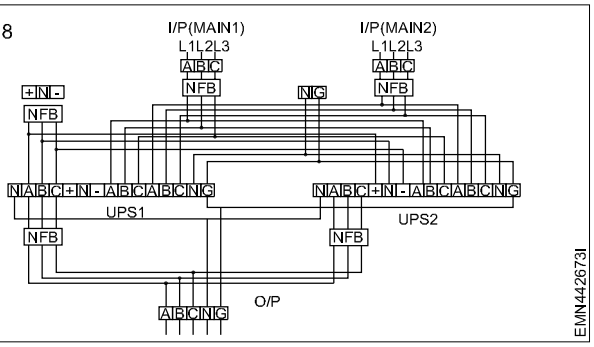
Fig 17



AUTOMATIC UPS SYSTEM WIRING DIAGRAM FOR HOME OR OFFICE (NEW DESIGN WITH ONE LIVE WIRE)

Three phase UPS

Fig 18



Pictorial diagram of Three phase UPS

1

Fig 19

2

Installation of batteries

Fig 20

A battery is made up of interconnected cells which may be vented or of the recombination type.

There are two main types of batteries:

1 Nickel-cadmium batteries

2 Lead-acid batteries

3 Vented cells (lead-antimony): They are equipped with ports to

   i Release to the atmosphere the oxygen and hydrogen produced during the different chemical reactions

   ii Top up the electrolyte by adding distilled or demineralized water

4 Recombination cells (lead, pure lead, lead-tin batteries): The gas recombination rate is at least 95% and they therefore do not require water to be added during service life

Recombination batteries are also often called "sealed" batteries.

Types of batteries used in UPS

1 Sealed lead-acid batteries, used 95% of the time because they are easy to maintain and do not require a special room

2 Vented lead-acid batteries

3 Vented nickel-cadmium batteries

The above three types of batteries may be proposed, depending on economic factors and the operating requirements of the installation, with all the available service-life durations.

Capacity levels and backup times may be adapted to suit the user's needs.

Installation methods

Depending on the UPS range, the battery capacity and backup time, the battery is:

1 Sealed type and housed in the UPS cabinet

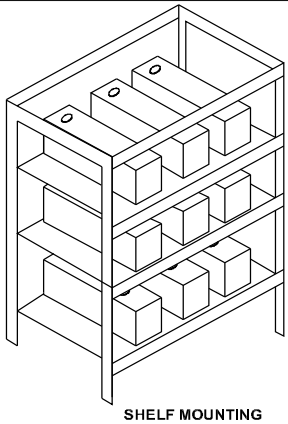
2 Sealed type and housed in one to three cabinets

3 Vented or sealed type and rack-mounted. In this case the installation method may be

On shelves (Fig 21)

1 This installation method is possible for sealed batteries or maintenance-free vented batteries which do not require topping up of their electrolyte.

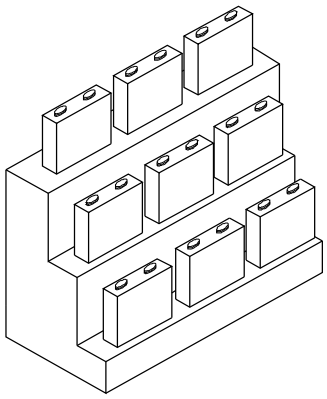
Fig 21



Tier mounting (Fig 22)

1 This installation method is suitable for all types of batteries and for vented batteries in particular, as level checking and filling are made easy.

Fig 22



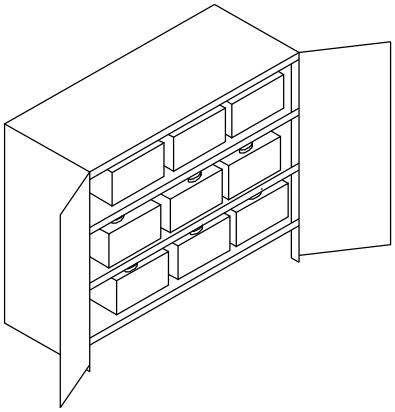
TIER MOUNTING

EMN442673M

In cabinets (Fig 23)

This installation method is suitable for sealed batteries. It is easy to implement and offers maximum safety.

Fig 23



CABINET MOUNTING

EMN442673N

Installation of UPS

The equipment must be installed in upright position. The equipment requires space to front and back to enable cooling airflow, service and maintenance. All cooling air enters at front and exits at unit rear. The required min. clearance from unit rear to an obstruction is 150 mm.

Ventilation space around the equipment

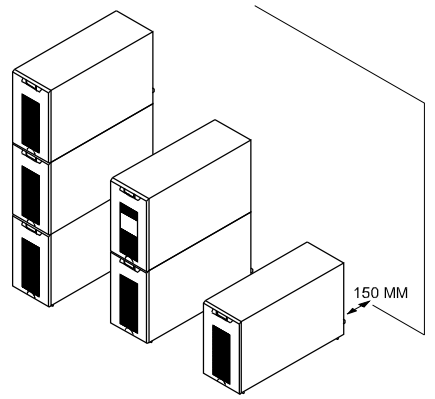
It is required to arrange ventilation of the UPS room. Sufficient amount of air cooling is needed to keep the max. room temperature rise at desired level:

1 Temperature rise of max. +5°C requires the airflow of 600 cubic meter per 1 kW of losses.

2 Temperature rise of max. +10°C requires the airflow of 300 cubic meter per 1 kW of losses.

An ambient temperature of 15 to 25 celsius degrees is recommended to achieve a long life of the UPS and batteries. The cooling air entering the UPS must not exceed +40°C. Avoid high ambient temperature, moisture and humidity.

Fig 24



VENTILATION SPACE AROUND THE EQUIPMENT

EMN442673O

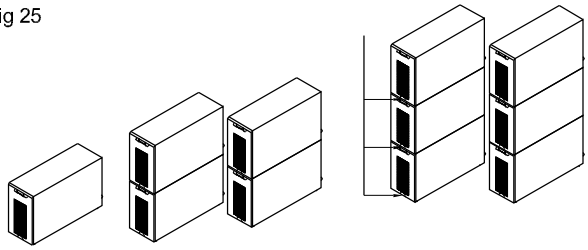
The floor material should be non-flammable and strong enough to support the heavy load. The UPS has (4) leveling feet that should be used when finalising the installation. The diameter of a single leveling foot is 1 inch (25.4 mm).

Cabinet installation

The required distance for UPS units next to each other is ten millimetres. The same applies to the optional battery cabinets that should be installed next to the UPS cabinet.

The UPS family has several alternative battery cabinets and configurations depending on the selected back-up time and quality of batteries.

Fig 25



UPS AND EXTERNAL BATTERY CABINETS

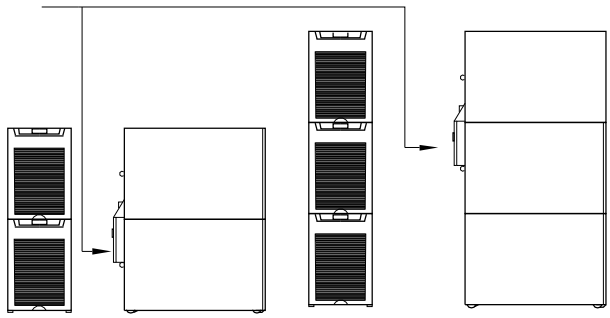
EMN442673P

Maintenance bypass switch (Fig 26)

The maintenance bypass switch (MBS) shall be mounted in back of the UPS battery compartment.

Fix the switch MBS to the wall (din rail) or to the back of the UPS as shown below.

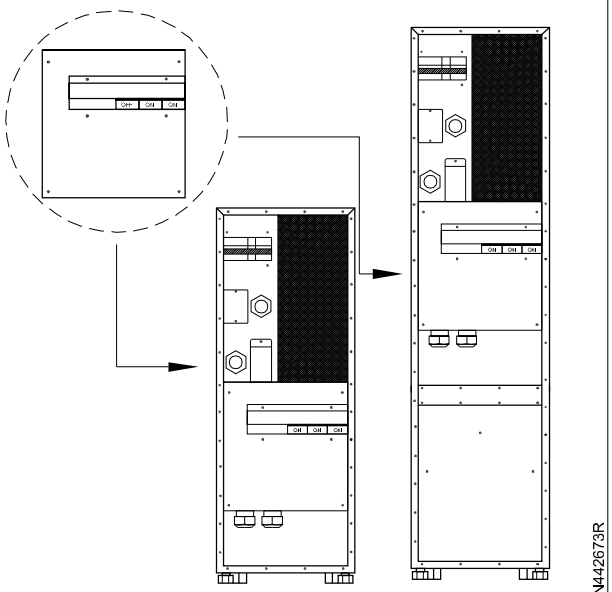
Fig 26



INSTRUCTIONS FOR LOCATING THE MAINTENANCE BYPASS SWITCH

EMN442673Q

Fig 27



THE MAINTENANCE BYPASS SWITCH (MBS) WHEN INSTALLED IN THE BACKSIDE

Relay outputs

Relay outputs can be used for remote alarm indications.

Each relay has four standard pre-programmed settings for alarms:

One of the standard relay settings is "custom" that can be customised by the user. The procedure to select customised alarms:

1 Push any key of the control panel to enable the functions on the LCD screen.

2 First select "SETTINGS", then "USER SETTINGS" and finally "RELAY CONFIG" from the LCD menu.

3 Select the relay what is needed to be configured (ALARM-1 is fixed relay output X57).

4 Select "empty" to clear old settings.

5 Select "custom" and activate needed alarms with the button on the right.

6 After the selection press "OK" button

7 Finally test that UPS alarms correctly

Checking of UPS

Check the mechanical and electrical installation of the UPS before start-up.

1 Read the attached safety manual before work on the unit.

2 The unit is fixed according to mechanical installation

3 The ambient conditions are within specification.

4 The cooling air will flow freely.

5 The UPS is grounded properly.

6 The input and bypass voltages match the UPS nominal voltage.

7 The input, bypass, battery and output terminal connections are OK.

8 Appropriate input and bypass fuses and disconnectors are installed.

9 Appropriate backfeed warning sign for disconnectors are installed.

10 Appropriate cables sizes are used.

11 The external control connections inside the UPS are OK.

12 There are no tools, foreign objects or dust inside the UPS from the installation.

13 Covers are in place.

14 Optional MBS is placed to UPS position as default.

Starting up the UPS

1 Turn the battery and input circuit breakers to ON position.

2 UPS will enter a stand-by mode and starts to charge batteries with a cooling fan operational. Output is without the voltage in the stand-by mode.

3 Push any key of the control panel to enable the functions of the LCD screen

4 Select 'TURN UPS ON' from the LCD menu (see: Display functions)

5 Press and hold button for 2 sec. There shall be no sound during the hold.

The UPS shall check its internal functions, synchronise to bypass and start to supply the load. The green LED is blinking if there occurs an active notice. In normal operation the green LED is constantly lit if no new active notice such as 'unsyncronised' or similar notices present.

The output voltage shall be verified from the output measurements screen of the LCD. If there is voltage in the output then UPS is supplying the load.

Battery start-up

UPS will start on battery if mains is not available.

Shutdown

The procedure to shutdown from LCD is following:

1 Push any key of the control panel to enable the functions of the LCD screen.

2 Select 'TURN UPS OFF' from the LCD menu (see: Display Functions).

3 Press and hold button for 5 sec. There shall be an indication sound during the hold.

4 UPS shall do a shutdown routine.

5 Turn the battery and input circuit breakers to OFF position to finalise the shutdown procedure.

Earthing in electrical network

The main reason for doing earthing in electrical network is for the safety. When all metallic parts in electrical equipments are grounded then if the insulation inside the equipments fails there are no dangerous voltages present in the equipment case.

If the live wire touches the grounded case then the circuit is effectively shorted and fuse will immediately blow. When the fuse is blown then the dangerous voltages are away.

Purpose of earthing

1 Safety for human life/Building/Equipment

To save human life from danger of electrical shock or death by blowing a fuse. It provides an alternative path for the fault current to flow so that it will not give danger to the user.

To protect buildings, machinery and appliances under fault conditions.

To ensure that all exposed conductive parts do not reach a dangerous potential.

To provide safe path to dissipate lightning and short circuit currents.

To provide stable platform for operation of sensitive electronic equipments i.e. to maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.

2 Over voltage protection

Lightning, line surges or unintentional contact with higher voltage lines can cause dangerously high voltages to the electrical distribution system. Earthing provides an alternative path around the electrical system to minimize damages in the System.

3 Voltage stabilization

There are many sources of electricity. Every transformer can be considered as a separate source. If there were not a common reference point for all these voltage sources it would be extremely difficult to calculate their relationships to each other.

The earth is the most important conductive surface, and so it was adopted in the very beginnings of electrical distribution systems as a nearly universal standard for all electric systems.

Conventional methods of earthing

1 Plate type earthing

Generally for plate type earthing normal Practice is to use

Cast iron plate of size 600 mm x 600 mm x12 mm. (or)

Galvanized iron plate of size 600 mm x600 mm x6 mm. (or)

Copper plate of size 600 mm x 600 mm x 3.15 mm

Plate burred at the depth of 8 feet in the vertical position and GI strip of size 50 mmx6 mm bolted with the plate is brought up to the ground level.

These types of earth pit are generally filled with alternate layer of charcoal and salt upto 4 feet from the bottom of the pit.

2 Pipe type earthing

For pipe type earthing normal practice is to use GI pipe of 75 mm diameter, 10 feet long welded with 75 mm diameter GI flange having 6 numbers of holes for the connection of earth wires and inserted in ground by auger method.

These types of earth pit are generally filled with alternate layer of charcoal and salt or earth reactivation compound.

Method for construction of Earthing pit

Excavation on earth for a normal earth pit size is 1.5M x 1.5M x 3.0 M.

Use 500 mm x 500 mm x 10 mm GI plate or bigger size for more contact of earth and reduce earth resistance.

Make a mixture of wood coal powder salt and sand all in equal part.

Wood coal powder use as good conductor of electricity, anti corrosive, rust proves for GI Plate for long life.

The purpose of coal and salt is to keep wet the soil permanently.

The salt percolates and coal absorbs water keeping the soil wet.

Care should always be taken by watering the earth pits in summer so that the pit soil will be wet.

Coal is made of carbon which is good conductor minimizing the earth resistant.

Salt used as electrolyte to form conductivity between GI plate coal and earth with humidity.

Sand has used to form porosity to cycle water and humidity around the mixture.

Put GI Plate (EARTH PLATE) of size 500 mm x 500 mm x 10 mm in the middle of mixture.

Use double GI strip size 30 mm x 10 mm to connect GI plate to system earthing.

It will be better to use GI pipe of size 2.5 diameter with a flange on the top of GI pipe to cover GI strip from EARTH PLATE to top flange.

Cover top of GI pipe with a T joint to avoid jamming of pipe with dust and mud and also use water time to time through this pipe to bottom of earth plate.

Maintain less than one Ohm resistance from EARTH PIT conductor to a distance of 15 Meters around the EARTH PIT with another conductor dip on the Earth at least 500 mm deep.

Check voltage between earth pit conductors to neutral of mains supply 220V AC 50 Hz it should be less than 2.0 volts.

Factors affecting on Earth resistivity

1 Soil resistivity

It is the resistance of soil to the passage of electric current. The earth resistance value (ohmic value) of an earth pit depends on soil resistivity. It is the resistance of

the soil to the passage of electric current.

It varies from soil to soil. It depends on the physical composition of the soil, moisture, dissolved salts, grain size and distribution, seasonal variation, current magnitude etc. In depends on the composition of soil, Moisture content, Dissolved salts, grain size and its distribution, seasonal variation, current magnitude.

2 Soil condition

Different soil conditions give different soil resistivity. Most of the soils are very poor conductors of electricity when they are completely dry. Soil resistivity is measured in ohm-meters or ohm-cm.

Soil plays a significant role in determining the performance of electrode. Soil with low resistivity is highly corrosive. If soil is dry then soil resistivity value will be very high. If soil resistivity is high, earth resistance of electrode will also be high.

3 Moisture

Moisture has a great influence on resistivity value of soil. The resistivity of a soil can be determined by the quantity of water held by the soil and resistivity of the water itself. Conduction of electricity in soil is through water.

The resistance drops quickly to a more or less steady minimum value of about 15% moisture. And further increase of moisture level in soil will have little effect on soil resistivity. In many locations water table goes down in dry weather conditions.

Therefore, it is essential to pour water in and around the earth pit to maintain moisture in dry weather conditions. Moisture significantly influences soil resistivity.

4 Dissolved salts

Pure water is poor conductor of electricity. Resistivity of soil depends on resistivity of water which in turn depends on the amount and nature of salts dissolved in it.

Small quantity of salts in water reduces soil resistivity by 80%. Common salt is most effective in improving conductivity of soil. But it corrodes metal and hence discouraged.

5 Climate condition

Increase or decrease of moisture content determines the increase or decrease of soil resistivity. Thus in dry whether resistivity will be very high and in monsoon months the resistivity will be low.

6 Physical composition

Different soil composition gives different average resistivity. Based on the type of soil, the resistivity of clay soil may be in the range of 4 – 150 ohm-meter, whereas for rocky or gravel soils, the same may be well above 1000 ohm-meter.

7 Location of earth pit

The location also contributes to resistivity to a great extent. In a sloping landscape, or in a land with made up of soil, or areas which are hilly, rocky or sandy, water runs off and in dry weather conditions water table goes down very fast. In such situation back fill compound will not be able to attract moisture, as the soil around the pit would be dry.

The earth pits located in such areas must be watered at frequent intervals, particularly during dry weather conditions.

Though back fill compound retains moisture under normal conditions, it gives off moisture during dry weather to the dry soil around the electrode, and in the process loses moisture over a period of time. Therefore, choose a site that is naturally not well drained.

8 Effect of grain size and its distribution

Grain size, its distribution and closeness of packing are also contributory factors, since they control the manner in which the moisture is held in the soil.

Effect of seasonal variation on soil resistivity: Increase or decrease of moisture content in soil determines decrease or increase of soil resistivity. Thus in dry weather resistivity will be very high and during rainy season the resistivity will be low.

9 Effect of current magnitude

Soil resistivity in the vicinity of ground electrode may be affected by current flowing from the electrode into the surrounding soil. The thermal characteristics and the moisture content of the soil will determine if a current of a given magnitude and duration will cause significant drying and thus increase the effect of soil resistivity.

10 Area available

Single electrode rod or strip or plate will not achieve the desired resistance alone.

If a number of electrodes could be installed and interconnected the desired resistance could be achieved. The distance between the electrodes must be equal to the driven depth to avoid overlapping of area of influence. Each electrode, therefore, must be outside the resistance area of the other.

11 Obstructions

The soil may look good on the surface, but there may be obstructions below a few feet like virgin rock. In that event resistivity will be affected. Obstructions like concrete structure near about the pits will affect resistivity.

If the earth pits are close by, the resistance value will be high.

12 Current magnitude

A current of significant magnitude and duration will cause significant drying condition in soil and thus increase the soil resistivity.

Measurement of earth resistance by use of earth tester

For measuring soil resistivity Earth Tester is used. It is also called the “MEGGER”.

1 It has a voltage source, a meter to measure Resistance in ohms, switches to change instrument range, Wires to connect terminal to Earth Electrode and Spikes.

2 It is measured by using Four Terminal Earth Tester Instrument. The terminals are connected by wires.

3 P=Potential Spike and C=Current Spike. The distance between the spikes may be 1M, 2M, 5M, 10M, 35M, and 50M.

4 All spikes are equal distance and in straight line to maintain electrical continuity. Take measurement in different directions.

5 Soil resistivity =2pLR.

6 R = Value of Earth resistance in ohm.

7 L = Distance between the spikes in cm.

8 p = 3.14

9 P = Earth resistivity ohm-cm.

10 Earth resistance value is directly proportional to soil resistivity value

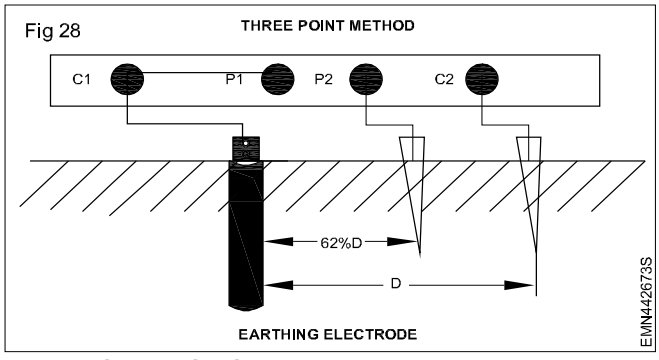
Measurement of earth resistance (Three point method)

In this method earth tester terminal C1 and P1 are shorted to each other and connected to the earth electrode (pipe) under test. Terminals P2 and C2 are connected to the two separate spikes driven in earth. These two spikes are kept in same line at the distance of 25 meters and 50 meters due to which there will not be mutual interference in the field of individual spikes.

If we rotate generator handle with specific speed we get directly earth resistance on scale. Spike length in the earth should not be more than 1/20th distance between two spikes. Resistance must be verified by increasing or decreasing the distance between the tester electrode and the spikes by 5 meter.

Normally, the length of wires should be 10 and 15 meters or in proportion of 62% of 'D'.

Suppose, the distance of Current Spike from Earth Electrode D = 60 ft, Then, distance of Potential Spike would be 62 % of D = 0.62D i.e. 0.62 x 60 ft = 37 ft.



Four point method

In this method 4 spikes are driven in earth in same line at the equal distance. Outer two spikes are connected to C1 and C2 terminals of earth tester. Similarly inner two spikes are connected to P1 and P2 terminals. Now if we rotate generator handle with specific speed, we get earth resistance value of that place.

In this method error due to polarization effect is eliminated and earth tester can be operated directly on AC.

GI earthing Vs Copper earthing

1 As per IS 3043, the resistance of Plate electrode to earth (R) = (r/A) x under root(P/A).

2 Where r = Resistivity of soil Ohm-meter.

3 A = Area of earthing plate m3.

4 The resistance of pipe electrode to earth (R) = (100r/2pL) x loge (4L/d).

5 Where L = Length of pipe/rod in cm

6 d = Diameter of pipe/rod in cm.

7 The resistivity of the soil and the physical dimensions of the electrode play important role of resistance of rod with earth.

8 The material resistivity is not considered important role in earth resistivity.

9 Any material of given dimensions would offer the same resistance to earth. Except the sizing and number of the earthing conductor or the protective conductor.

Pipe earthing Vs Plate earthing

1 Suppose copper plate having of size 1.2m x 1.2m x 3.15 mm thick. soil resistivity of 100 ohm-m,

2 The resistance of plate electrode to earth (R)=(r/A) x under root(p/A) = (100/2.88) x (3.14/2.88)=36.27 ohm

3 Now, consider a GI pipe electrode of 50 mm diameter and 3 m Long. soil resistivity of 100 Ohm-m,

4 The resistance of pipe electrode to earth (R) = (100r/2pL) x loge (4L/d) = (100x100/2x3.14x300) x loge (4x300/5) = 29.09 Ohm.

5 From the above calculation the GI pipe electrode offers a much lesser resistance than even a copper plate electrode.

6 As per IS 3043 pipe, rod or strip has a much lower resistance than a plate of equal surface area.

Length of pipe electrode and Earthing pit

The resistance to earth of a pipe or plate electrode reduces rapidly within the first few feet from ground (mostly 2 to 3 meter) but after that soil resistivity is mostly uniform.

After about 4 meter depth, there is no appreciable change in resistance to earth of the electrode. Except a number of rods in parallel are to be preferred to a single long rod.

Amount of salt and charcoal (more than 8 Kg)

To reduce soil resistivity, it is necessary to dissolve in the moisture particle in the Soil. Some substance like Salt/ Charcoal is highly conductive in water solution but the

additive substance would reduce the resistivity of the soil, only when it is dissolved in the moisture in the soil after that additional quantity does not serve the Purpose.

5% moisture in salt reduces earth resistivity rapidly and further increase in salt content will give a very little decrease in soil resistivity.

The salt content is expressed in percent by weight of the moisture content in the soil. Considering 1M3 of Soil, the moisture content at 10 percent will be about 144 kg. (10 percent of 1440 kg). The salt content shall be 5% of this (i.e.) 5% of 144kg, that is, about 7.2kg.

Amount of water porring

Moisture content is one of the controlling factors of earth resistivity. Above 20 % of moisture content, the resistivity is very little affected. But below 20% the resistivity increases rapidly with the decrease in moisture content.

If the moisture content is already above 20% there is no point in adding quantity of water into the earth pit, except perhaps wasting an important and scarce national resource like water.

Length Vs Diameter of earth electrode

Apart from considerations of mechanical strength, there is little advantage to be gained from increasing the earth electrode diameter with the object in mind of increasing surface area in contact with the soil.

Select a diameter of earth electrode, which will have enough strength to enable it to be driven into the particular soil conditions without bending or splitting. Large diameter electrode may be more difficult to drive than smaller diameter electrode.

The depth to which an earth electrode is driven has much more influence on its electrical resistance characteristics than has its diameter.

Maximum allowable Earth resistance

1 Major power station = 0.5 Ohm

2 Major Sub-stations = 1.0 Ohm

3 Minor Sub-station = 2 Ohm

4 Neutral Bushing = 2 Ohm

5 Service connection = 4 Ohm

6 Medium Voltage Network = 2 Ohm

7 L.T.Lightening Arrestor = 4 Ohm

8 L.T.Pole = 5 Ohm

9 H.T.Pole = 10 Ohm

10 Tower = 20-30 Ohm

Treatments for minimizing earth resistance

1 Remove oxidation on joints and joints should be tightened.

2 Pour sufficient water in earth electrode.

3 Use bigger size of earth electrode.

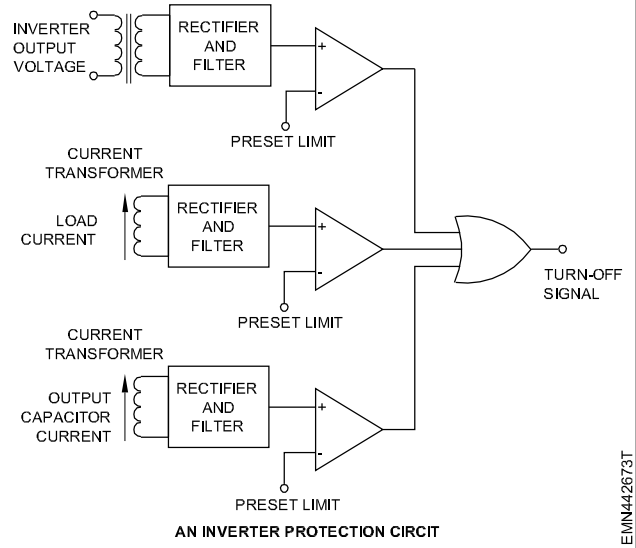
4 Electrodes should be connected in parallel.

5 Earth pit of more depth and width- breadth should be made.

Protection circuit used in inverters

The most common form of overcurrent protection in Inverter is fusing, but this method is not always effective because fuses have relatively slow response-time, so additional protective equipment is required, such as crowbar circuits or a di/dt limiting inductance. The DC supply and load-side transients can be suppressed with filters, which have the disadvantage of increasing the inverter power losses, cost and weight. Current source inverters (CSI) have an inherent overcurrent protection capability, since proper design of the DC link inductance can provide protection against overload conditions. Voltage source inverters (VSI) include an LC filter at the output stage thus, in case of an output shortcircuit condition, the filter inductance limits the output current rising rate. In both preceding cases, the high inductance value leads to inverter size and power losses increase. A commonly used protection circuit is shown in Fig 29. The inverter output current, load voltage and filter capacitor current are sensed and compared to preset limits. If any of the above quantities exceeds the preset limits, an inhibit signal shuts off the DC power supply. In motor drive applications, the inverters are usually protected only from overloading conditions, using either intrusive current sensing techniques, which measure the DC input current or the load current or special motor control algorithm techniques. However, the above methods do not fully detect all possible fault conditions, e.g. a DC link capacitor short circuit. The advancement of the microcontroller technology has led to the implementation of digital control techniques for controlling and monitoring inverters.

Fig 29



AN INVERTER PROTECTION CIRCIT

Battery level

Maintenance of battery in inverters

Batteries are expensive items to replace. They should be serviced regularly as recommended by the manufacturer.

If maintained properly, they can be used for longer periods. The following aspects are to be checked to maintain the battery in good condition.

Check and top up electrolyte level every week. Electrolyte should be 10 mm to 15 mm above the plates.

If the voltage of each cell is less than specified, then the battery should be recharged.

While charging do not overcharge the battery.

Keep the battery terminals always tight and clean.

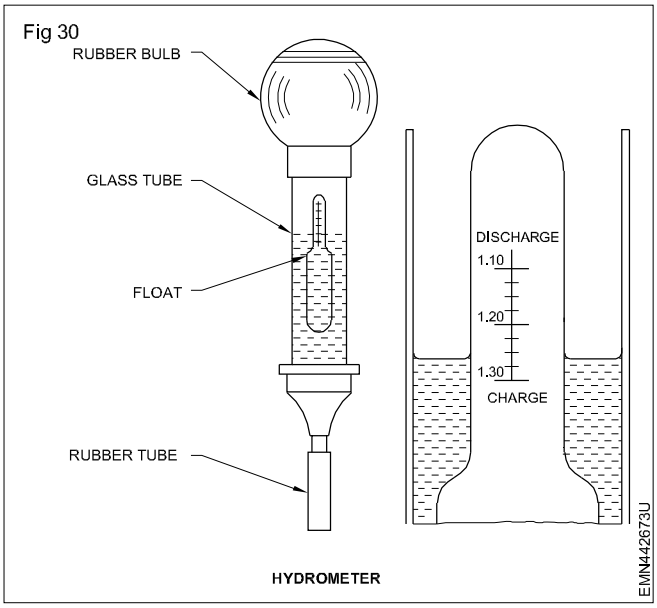
To prevent formation of corrosion on the terminals smear petroleum jelly on it.

Hydrometer

Hydrometer is a device used to check the specific gravity of the battery as shown in fig 30.

Check the specific gravity of the battery with a hydrometer. If the specific gravity falls below 1.180 then add a few drops of sulphuric acid.

Fig 30



HYDROMETER

Specific gravity readings and the state of charge of the battery are as follows.

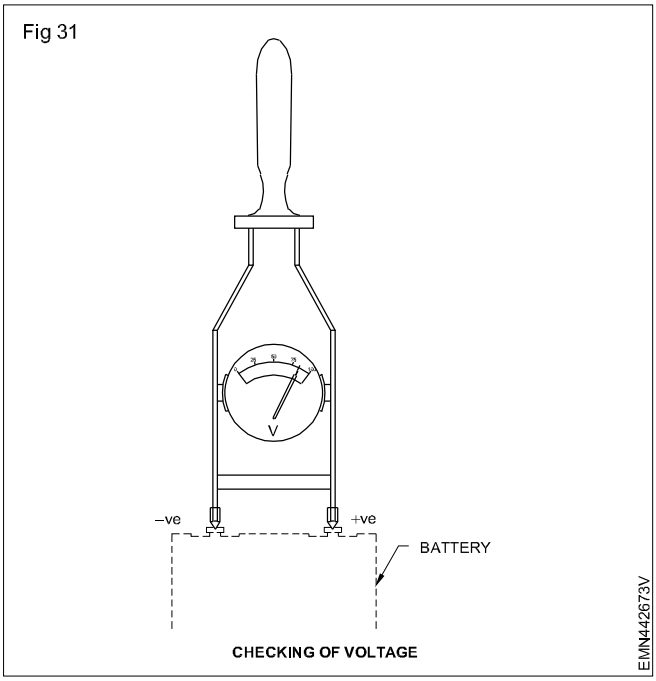
Sl. No.	Specific gravity	State of charge of the battery
1.	1.260 - 1.280	Fully charged
2.	1.230 - 1.260	3/4 charged
3.	1.200 - 1.230	1/2 charged
4.	1.170 - 1.200	1/4 charged
5.	1.140 - 1.170	About run down
6.	1.110 - 1.140	Discharged

High rate discharge tester

The two legs of the cell tester are alternatively pressed against each of the battery terminals for a period of 5 to 10 seconds as shown in Fig 31 below.

The needle must be in the green area (voltage reading between 1.75 to 1.80 volts). There should not be any sudden drop of the needle within 5 to 10 seconds. If the needle drops suddenly battery should be recharged.

Fig 31

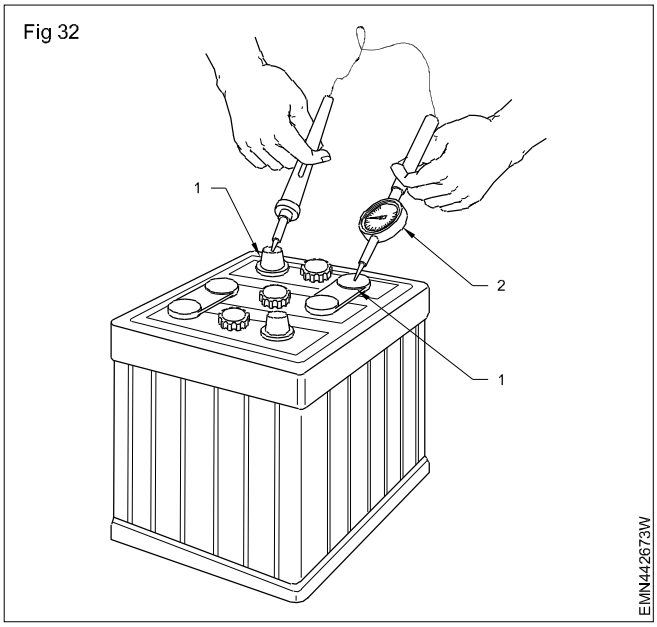


CHECKING OF VOLTAGE

Voltage check of battery

With the help of a voltmeter the voltage of each cell is tested as shown in Fig 32. This will commonly vary from 2.0V to 2.15V and 2.3 volts per cell for fully charged condition. The difference of voltage between the cells in one battery should not exceed 0.1 volt. If the difference is more than 0.1 volt then the battery should be recharged.

Fig 32

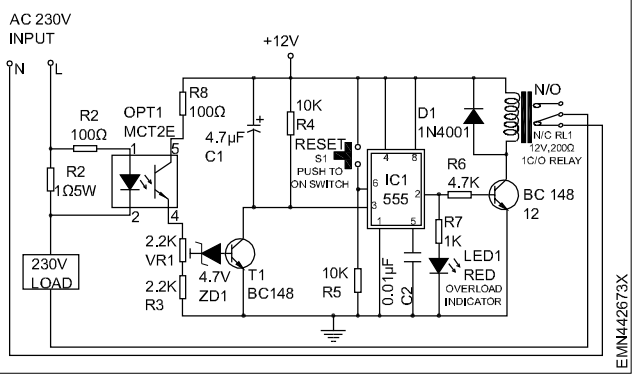


Overload protection circuit using 555 timer

Overload protection circuits are required in inverters to make sure that the loads connected to them do not exceed the maximum power ratings. This project describes a simple overload protection circuit based on a 555 timer IC is given in Fig 33. The current drawn by a load is sensed through a 5W 1 Ohm resistor. The voltage

drop across this resistor is proportional to the current drawn and hence can be used to sense any short circuit or excess load current. An optocoupler is used to isolate the mains AC part from the rest of the circuit.

Fig 33



Overload current threshold can be varied through the potentiometer VR1. The mains AC supply to the load is connected through the N/C (normally closed) connection of relay RL1. When an overload is detected, the relay is energized to disconnect the load from the mains supply. The bypass capacitor C1 avoids any false trigger of the circuit because of fluctuations in the mains supply.

Overcharging

Overcharging is the most destructive element in battery service. During overcharging, excessive current causes the oxides on the plates of the battery to "shed" and precipitate to the bottom of the cell and also heat the battery, thus removing water from the electrolyte. Once removed the charge is no longer active in the battery. In addition, the loss of water from the electrolyte may expose portions of the plates and cause the exposed areas to oxidize and become inactive, thus reducing additional capacity. Sealed batteries are not affect from the same internal results when overcharged. Batteries sealed and gel batteries are particularly sensitive to overcharging. Once moisture is removed from the battery, it cannot be replaced. Portions of the battery damaged due to overcharging are irretrievable. However, if detected early, corrective adjustments to the charging device will save the undamaged portion of the battery. Initial signs of overcharging are excessive usage of water in the battery, continuously warm batteries, or higher than normal battery voltages while under the influence of the charger. If overcharging is suspected, correct immediately.

Trouble shooting / Fault finding methods

Problem	Probable cause	Solution/Remedy
No LED display on the front panel	Low battery	Charge the UPS at least 8 hours
	Battery fault	Replace the battery with the same type of battery.
	The UPS is not turned on	Press the power switch again to turn on the UPS
Alarm continuously sounds when the mains is normal.	The UPS is overloaded.	Remove some loads first. Before reconnecting equipment, please verify that the load matches the UPS capability specified in the specs.
	UPS fault	Send/Return the unit to service center
Alarm sounds every 2 seconds when the mains is normal.	Battery defective	Replace the battery with the same type of battery.
	Charging circuit is damaged.	Send/Return the unit to service center.
When power fails, backup time is shortened.	The UPS is overload Battery voltage is too low.	Remove some critical load Charge the UPS at least 8 hours
	Battery defective.	Replace the battery with the same type of battery.
The mains is normal but green LED is flashing	Power cord is loose	Reconnect the power cord properly.

Trouble shooting chart

Sl.No	Fault	Possible reason	Trouble shooting
1.	UPS works on 220 VAC mains, but does not operate on battery.	1. Battery fuse is blown 2. Battery is discharged	1. Check the fuse and polarity of battery. If the fuse is blown, replace it, if it is loose, tighten. 2. Recharge the battery
2.	When UPS is switched on, charger does not turn on.	1. Mains input fuse may be blown 2. Charger input fuse may blown	1. Change mains fuse 2. Check the battery polarity and conditions, correct it if wrong replace the fuse. 3. Check the supply from mains. If OK then check relay wiring, check relay coil.
3.	220VAC mains supply NOT available.	1. Input AC mains is very high 2. Capacity of i/p cable is low 3. Loose connection of i/p wiring	1. Check the supply of mains 2. Change cable 3. Tight the connection of wiring coming from distribution board.
4.	DC voltage is OK, but UPS shows DC under voltage and trips.	Inverter fuse is blown	Replace fuse
5.	When the UPS is switched ON with out load, DC under voltage indicator turns ON and inverter turns/trips OFF.	1. Capacity of mains input cable is low 2. Loose connection of input side	1. Use cable with proper rating 2. Tight the connections of input cable
6.	When the UPS is switched on with load, overload indicator turn ON.	Surge in the load	When the output voltage is 230V, add loads one by one.
7.	Where there is no AC mains supply, and the UPS is operating on battery, DC under voltage indicator turns ON.	Battery is discharged state	Recharge the battery use cable with proper current capacity with the battery.
8.	DC fuse blows OFF	1. Skin effect due to long use 2. Overload or short circuit	1. Change DC fuse 2. Reduce the overload. If power transistors are short of leaky replace them.
9.	UPS does not switch ON	1. Supply is stopped due to blown fuse or some break in cable. 2. No DC supply in the control card due to dry soldering loose connection or de soldering	1. Check correct dry soldering loose connection and replace the fuse. 2. Check control card wiring
10.	UPS trips when full load is connected.	Overload cut setting is wrong	Adjust the overload cut setting check the power consumption of the load. When 220v o/p is available, slowly increase the load.

11.	UPS output is high	1. Some connection is broken in the feed back loop 2. Control card is not functioning properly. 3. Over voltage sensing is faulty	1. Check feedback transformer wiring and adjust feed back voltage preset. 2. Check /Replace control card 3. Check overload sensing circuit
12.	When the mains or inverter section turn on, UPS does NOT work.	Output fuse is blown.	Check/Replace output fuse/fuse holder.
13.	Mains switch trips frequently	This could happen when the UPS is operating on generator	Check/set output frequency.
14.	Low battery indication glows	This could be due to the DC capacitor is not getting properly charged	Check/Replace capacitors.
15.	UPS does not switch on in battery mode	Mains earthing is not proper	Check battery, MOSFET, oscillator section, driver section, output section. Check and correct the earthing properly
16.	Battery wire getting burned	This happens if the relay points are joined together.	Check/Replace relays.
17.	Change over time high, computer connected to the UPS reboots during change over.	Check oscillator circuit	Check/Replace ICS and other components of oscillator section
18.	Low backup time	Main filter capacitor	Check battery
19.	MOSFETs getting burned	Battery short	High current from battery

Energy sources

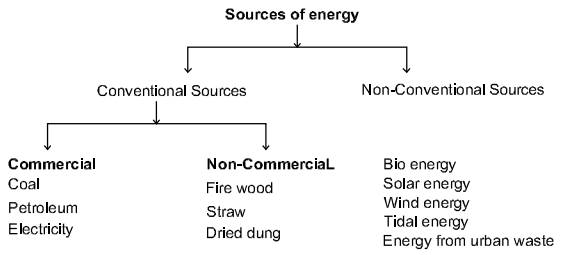
Objectives : At the end of this lesson you shall be able to
- **define energy**
- **list out the types of energy**
- **discuss about conventional energy and its types**
- **state renewable energy and its types**
- **differentiate conventional and non conventional sources of energy.**

Energy

Energy is one of the most important components of economic infrastructure.

Main sources of energy

The source of energy is following two types.



Conventional sources of energy

The conventional sources of energy is also called Non renewable energy source. These sources of energy are in limited quantity.

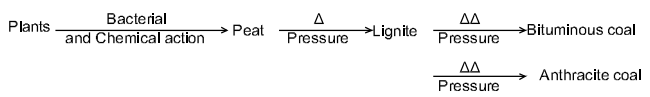
The conventional energy sources are classified in two types like Commercial and non-commercial.

Commercial conventional energy

Coal, petroleum and electricity, these are called commercial energy because they have a price and consumer has to pay the price to purchase them.

Coal

Coal is a major conventional energy sources. It was formed from the remains of the trees and ferns grew in swamps around 500 millions year ago. The bacterial and chemical decomposition of such plant debris (which remained buried under water or clay) produced an intermediate product known as peat which is mainly cellulose $(C_6H_{10}O_5)n$.



Coal deposits in India are 148790 million tonnes. Total lignite reserves found at Neyveli are 3300 million tonnes. In 1950-51, annual production of coal was 32 million tonnes. In 2005-06, annual production of coal was 343 million tonnes.

Coal deposits are mainly found in Orissa, Bihar, Bengal and Madhya Pradesh.

Petroleum or oil and natural gases

Oil is considered as the most important source of energy in India and the world. It is widely used in automobiles, trains, planes and ships etc.

Petroleum is a complex mixture of hydrocarbons, mostly alkanes and cycloalkanes. It occurs below the earth crust entrapped under rocky strata. In its crude form, the viscous black liquid is known as petroleum and a gas in contact with petroleum layer which flows naturally from oil wells is termed as natural gases. The composition of natural gas is a mixture of mainly methane, (95.0%), small amounts of ethane, propane and butane (3.6%) and traces of CO_2 (0.48%) and N_2 (1.92%).

A liquid mixture of propane and butane can be obtained from natural gas or refinery gases at room temperature under a pressure of 3-5 atmospheres. This is stored and distributed in 40-100 litre capacity steel cylinders.

Natural gas has been the most important source of energy since last two decades. It can be produced in two ways:

(i) With petroleum products as associated gas.

(ii) Free gas obtained from gas fields in Assam, Gujarat and Andhra Pradesh.

Electricity

Electricity is the common and popular source of energy. It is used in commercial and domestic purposes. It is used for lighting, cooking, air conditioning and working of electrical appliances like T.V., fridge and washing machine.

Fuel woods

The rural peoples require fuel wood or fire Wood for their day to day cooking which are obtained from natural forests and plantations. Due to rapid deforestation, the availability of fire wood or fuel wood becomes difficult. This problem can be avoided by massive afforestation (plantation) on degraded forest land, culturable waste land, barren land grazing land etc.

Hydropower

Energy obtainable from water flow or water falling from a higher potential to lower potential, is known is hydro-

power. It is a conventional and renewable form of energy which can be transmitted to long distance through cables and wires.

Nuclear energy

A small amount of radioactive substance (U^{235}) can produce a lot of energy through the process of nuclear fission. For example, one ton of uranium can provide energy which is much higher than three million tons of coal or 12 million barrels of oil. In order to obtain nuclear energy, nuclear reactors are required. There are around 300 nuclear reactors all over the world. India has only four nuclear power stations (reactors).

Non- conventional Energy or Renewable Energy

Renewable energy is energy that is generated from natural processes that are continuously replenished. This includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This energy cannot be exhausted and is constantly renewed.

Renewable energy source types

1 Solar power

Fig 3

Solar Power

2 Wind power

Fig 4

Wind Power

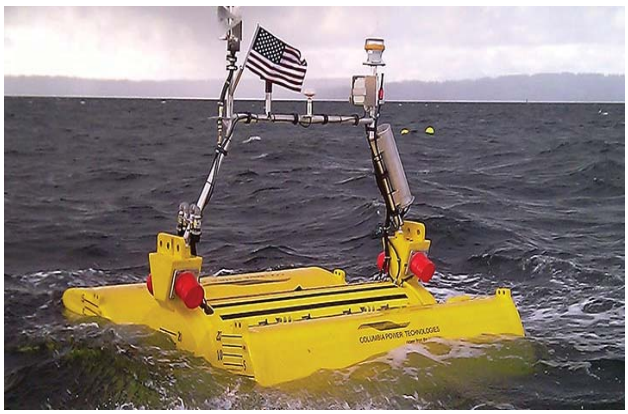
3 Tidal Energy

4 Geothermal

5 Hydroelectricity/micro hydro

6 Biomass and bio-fuels

Fig 5



Tidal Energy

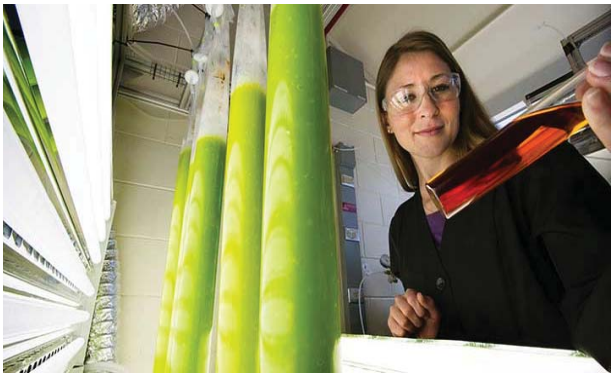
Fig 6

Geothermal

Fig 7

Hydroelectricity/micro hydro

Fig 8



BIOMASS

Difference between conventional energy and non conventional energy

S.No	Conventional energy	Non conventional energy
1.	Conventional energy, such as thermal powers (from coal, petroleum, and natural gas), hydel power (from high velocity of running water) are tapped and used abundantly at present.	Non-conventional sources of energy (solar energy, tidal energy, geo-thermal energy, wind energy etc) are not used frequently and in large scale (commercially).
2.	Their uses are practiced for a long time.	Their uses are comparatively more recent.
3.	Except hydel power, the sources of thermal power i.e. other conventional energies are non renewable in nature.	But the sources of non-conventional energy are flow-resources. There is no anxiety for their exhaustion.
4.	Except hydel power, the generation of other conventional energy produces air pollution.	But the generation of non-conventional energy does not produce air pollution.
5.	Except hydel power, the other conventional energy is costly.	But comparatively, the non-conventional energy is much cheaper.

Solar cells (photovoltaic cell)

Objectives : At the end of this lesson you shall be able to
- **define solar cells**
- **describe working of photovoltaic's cell**
- **explain photovoltaic cell basics**
- **list the types of solar cells**
- **differentiate monocrystalline and polycrystalline solar panels.**

Solar cells or photovoltaic cell

Photovoltaic: Photovoltaic (PV) materials and devices convert sunlight into electrical energy, and PV cells are commonly known as solar cells.

Photovoltaic cells

Photovoltaic (PV) cells, or solar cells, take advantage of the photoelectric effect to produce electricity. PV cells are the building blocks of all PV systems because they are the devices that convert sunlight to electricity.

PV cells come in many sizes and shapes, from smaller than a postage stamp to several inches across.

Crystalline silicon cells

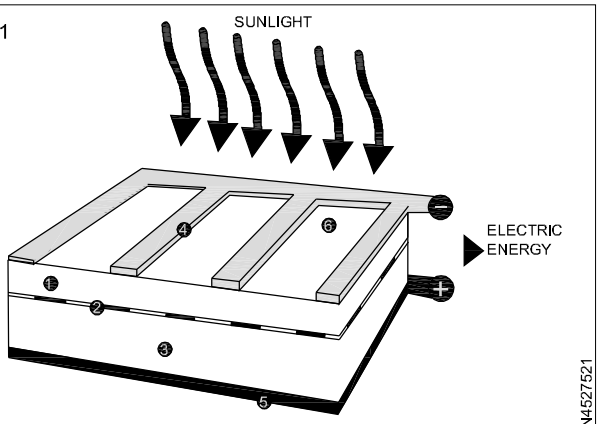
Crystalline silicon PV cells are the most common photovoltaic cells in use today. They are also the earliest successful PV devices. Therefore, crystalline silicon solar cells provide a good example of typical PV cell functionality.

Working principle of photovoltaic cell or solar cell

Photovoltaic cell consists of high-purity silicon. On the silicon, a PN (positive-negative) junction was formed as a potential barrier. Photons falling on the PN junction cause the rise of pairs of opposite electrical charge carriers (electron - hole), which as a result of the presence

of PN junction are separated into two different directions. Electrons go to the semiconductor N and holes go to the semiconductor P. The voltage will arise on the junction. Because the separated electrical charges are redundant carriers, having so called, infinite life and a PN junction voltage is constant, the junction, on which the light falls acts as a stable electric cell.

Fig 1



CONSTRUCTION OF PHOTOVOLTAIC CELL

1 Semiconductor n

2 p-n junction

3 Semiconductor p

4 Metallic connection

5 Anti-glare material

Cell coating

Silicon is a shiny grey material that can act as a mirror by reflecting more than 30% of the light that impinges on it. To improve the conversion efficiency of a solar cell, the amount of light reflected must be minimized. Two techniques are commonly used to reduce reflection.

The first technique is to coat the top surface with a thin layer of: silicon monoxide (SiO). A single layer reduces surface reflection to about 10%, and a second layer can lower the reflection to less than 4%.

The second technique is to texture the top surface. Chemical etching creates a pattern of cones and pyramids, which captures light rays that might otherwise be deflected away from the cell. Reflected light is redirected into the cell, where it has another chance to be absorbed.

Solar cell materials

Silicon (Si) - including single - crystalline Si, multicrystalline Si, and amorphous Si

Polycrystalline thin films - including copper indium diselenide (CIS), cadmium telluride (CdTe), and thin-film silicon

Single-Crystalline thin films - including high-efficiency material such as gallium arsenide (GaAs).

Photovoltaic cell basics

Crystalline silicon cells are the most common type, photovoltaic (PV), or solar cells, can be made of many semiconductor materials. Each material has unique strengths and characteristics that influence its suitability for specific applications. For example, PV cell materials may differ based on the crystallinity, bandgap, absorption, and manufacturing complexity.

Crystallinity

The crystallinity of a material indicates how perfectly ordered the atoms are in the crystal structure. Silicon, as well as other solar cell semiconductor materials, comes in various forms, including:

1 Single-crystalline,

2 Multicrystalline,

3 Polycrystalline, and

4 Amorphous

In a single-crystal material, the atoms that make up the framework of the crystal are repeated in a very regular, orderly manner from layer to layer. In contrast, in a material composed of numerous smaller crystals, the orderly arrangement is disrupted moving from one crystal to another.

Bandgap

The bandgap of a semiconductor material is the minimum energy needed to move an electron from its bound state within an atom to a free state.

This free state is where the electron can be involved in conduction.

The lower energy level of a semiconductor is called the valence band. The higher energy level where an electron is free to roam is called the conduction band.

The bandgap (often symbolized by Eg) is the energy difference between the conduction and valence bands.

Absorption

The absorption coefficient of a material indicates how far light with a specific wavelength (or energy) can penetrate the material before being absorbed. A small absorption coefficient means that light is not readily absorbed by the material.

The absorption coefficient of a solar cell depends on two factors:

1 The material of the cell and the

2 Wavelength or energy of the light being absorbed

Solar cell material has an abrupt edge in its absorption coefficient because light with energy below the material's bandgap cannot free an electron.

Manufacturing complexity

The most important parts of a solar cell are the semiconductor layers because this is where electrons are freed and electric current is created.

Several semiconductor materials can be used to make the layers in solar cells, and each material has its benefits and drawbacks. The cost and complexity of manufacturing varies across materials and device structures based on many factors, including deposition in a vacuum

environment, amount and type of material used, number of steps

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3 Semiconductor p

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5 Anti-glare material

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Types of solar cells

There are four types solar cells

1. Monocrystalline silicon solar cell
2. Polycrystalline (or multi-crystalline) solar cell
3. Amorphous/thin film solar cell
4. Hybrid silicon solar cell

Monocrystalline silicon solar cell

Monocrystalline solar cells are made out of silicon ingots, which are cylindrical in shape. To optimize performance and lower costs of a single monocrystalline solar cell, four sides are cut out of the cylindrical ingots to make silicon wafers, which give monocrystalline solar panels their characteristic look.

Polycrystalline silicon solar cells

Solar panels based on polycrystalline silicon, which also is known as polysilicon (p-Si) and multi-crystalline silicon (mc-Si), unlike monocrystalline-based solar panels, polycrystalline solar panels do not require the Czochralski process. Raw silicon is melted and poured into a square mold, which is cooled and cut into perfectly square wafers.

Thin-Film solar cells (TFSC)

Depositing one or several thin layers of photovoltaic material onto a substrate is the basic gist of how thin-film solar cells are manufactured. They are also known as thin-film photovoltaic cells (TFPV). The different types of thin-film solar cells can be categorized by which photovoltaic material is deposited onto the substrate:

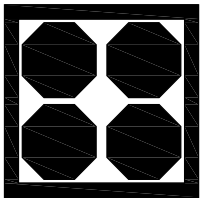
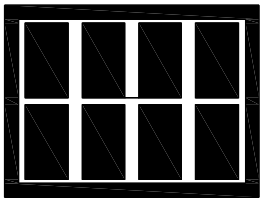
1. Amorphous silicon (a-Si)
2. Cadmium telluride (CdTe)
3. Copper indium gallium selenide (CIS/CIGS)
4. Organic photovoltaic cells (OPC)

Depending on the technology, thin-film module prototypes have reached efficiencies between 7-13% and production modules operate at about 9%. Future module efficiencies are expected to climb close to the about 10-16%.

Hybrid silicon solar cell

Hybrid solar panels are made from a mix of amorphous and monocrystalline cells to generate maximum efficiency. There are a variety of types of hybrid cells and they are still very much at the research and development stage.

Difference between monocrystalline and polycrystalline solar panels

Sl.No.		Monocrystalline solar panels	Polycrystalline solar panels
1.	Shape	Square with missing corners	square shaped
2.	Colour	Black	Blue / metal shard
3.	Efficiency	high	low
4.	Sensitive	high	low
5.	Cost	high	Low
6.	Panel type		
7.	Cell arrangement	One direction	Made up of several bits
8.	Angle	Correct angle	All angle

Photovoltaic systems materials

Objectives : At the end of this lesson you shall be able to
- **discuss about the photovoltaic system**
- **explain the photovoltaic module or panel**
- **describe the working of solar panel and photovoltatic array**
- **differentiate solar cell and module array.**

Photovoltaic system

Photovoltaic (PV), or solar electric system, is made up of several photovoltaic solar cells.

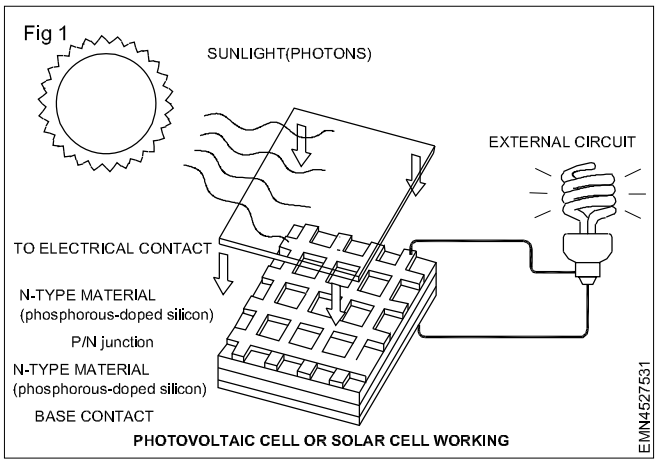
An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output number of PV cells are connected together to form larger units called modules. Modules, in turn, can be connected to form even larger units called arrays, which can be interconnected to produce more power, and so on. In this way, PV systems can be built to meet almost any electric power need, small or large

Photovoltaic cells or solar cell

Photovoltaic (PV) cells, or solar cells, take advantage of the photoelectric effect to produce electricity. PV cells are the building blocks of all PV systems because they are the devices that convert sunlight to electricity.

PV cells come in many sizes and shapes, from smaller than a postage stamp to several inches across.

Photovoltaic cell or solar cell working



A PV / Solar cell is a semiconductor device that can convert solar energy into DC electricity through the "Photovoltaic Effect" (conversion of solar light energy into electrical rays energy) as shown in Fig 1. When light rays impinges on a PV/solar cell, it may be reflected, absorbed, or passes right through. But only the absorbed light generates electricity.

Photovoltaic Module or solar panel

A solar module is an individual solar panel - consisting of multiple solar cells, wiring, a frame, and glass. PV or solar modules are manufactured in standard sizes such as 36-cell, 60-cell and 72-cell modules. The term solar panel is sometimes used interchangeably with solar module

Photovoltaic or solar panel working

Solar panels work through photovoltaic process - where radiation energy (photo) is absorbed and generates electricity (voltaic).

Radiation energy is absorbed by semi conductor cells - normally silicon - and transformed from photo energy (light) into voltaic (electrical current).

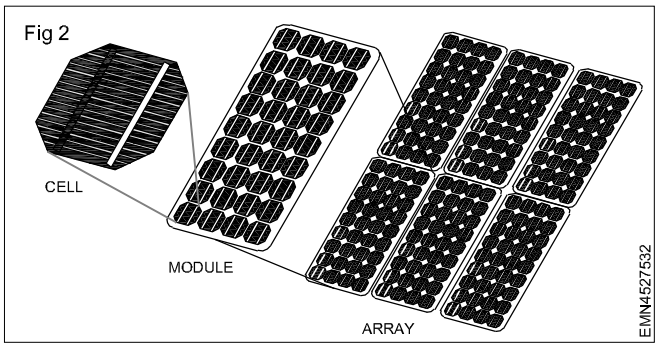
The sun's radiation hits a silicon atom; a photon of light energy is absorbed and released electrons to create an electric current.

The electric current then goes to an inverter unit, which converts the current from DC (direct current) to AC (alternating current).

The system is then connected to the mains power or electricity grid.

Photovoltaic array

Photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels, as shown in Fig 2.

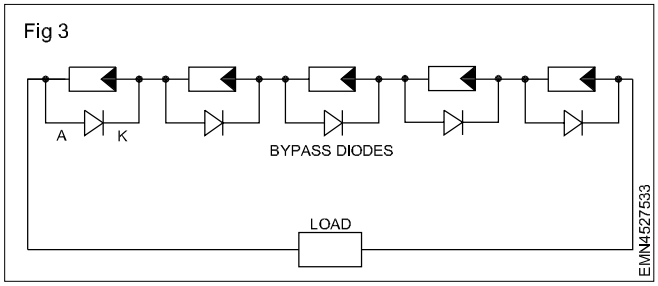


Photovoltaic array working

The Sun generates photons that stream down to earth as visible light. Solar cells convert the energy of light directly into electricity. Assemblies of solar cells are used to make solar modules (or panels). One or more solar panels are typically put together on a rack that faces the sun called an array. Some racks have motors that keep them pointed directly at the sun as it moves across the sky. The DPU-NEDO racks are fixed and do not move to track the sun.

Many racks of solar panels are typically lined up into long columns and those columns form a large scale Photovoltaic Array, "Solar Array," or Grid. The array generates direct current (DC) electrical power. The DC power (480 volts) must be converted to Alternating Current (AC) by inverters in order for the power to be fed into transformers that setup the power to Electrical Grid after passing through a Vista power switch.

By pass diode



PV / Solar cells are wired in series and in parallel to form a PV / Solar Panel (Module). The number of series cells indicates the voltage of the Panel (Module), whereas the number of parallel cells indicates the current. If many cells are connected in series, shading of individual cells can lead to the destruction of the shaded cell or of the lamination material, so the Panel (Module) may blister and burst. To avoid such an operational condition, Bypass Diodes are connected anti-parallel to the solar cells as in Fig.3 As a consequence, larger voltage differences cannot arise in the reverse-current direction of the solar cells. In practice, it is sufficient to connect one bypass diode for every 15-20 cells. Bypass diodes also allow current to flow through the PV module when it is partially shaded, even if at a reduced voltage and power. Bypass diodes do

not cause any losses, because under normal operation, current does not flow through them.

Battery

Battery can be defined as direct current (DC) electrical energy storage. Even PV system that is connected to a grid can often benefit from a battery backup system where outages are a concern.

Inverter

The DC-AC inverter converts direct current (DC) power into alternating current (AC) for use in appliances, electronics and other devices.

Charge controller

A charge controller regulates, charges, and maintains battery voltage.

Electrical load

Electrical load includes the appliances and other device that use of energy generated by the PV system. Electrical load can be either DC or AC; it is possible to have both kinds of electrical load on the same PV system.

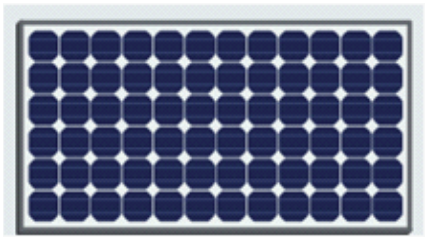
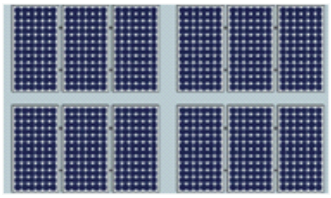
Wiring

The wiring includes the wires also known as conductors that connect the system components to complete circuit.

Surge protector

A surge protector is device that safeguards against electrical shock from short circuit and damaging power fluctuations.

Difference between solar cell, module & array

Sl.No	Solar cell	Solar module	Solar array
1			
2	The basic elecment of a PV system is photovoltaic (PV) cell, also called solar cell.	A number of individual PV series cells are interconnected together in a sealed, weatherproof package called a Panel (Module)	Modules are wired in parallel is called a PV Array

Solar electric system

Objectives : At the end of this lesson you shall be able to

- **define solar power**
- **describe the block diagram of solar electric system**
- **explain briefly about the components of solar electric system**
- **discuss about types of solar electric system**
- **discuss about sizing of solar electric system**
- **list out the advantages and disadvantages of solar electric system.**

Solar power

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic's (PV), or indirectly using concentrated solar power.

Solar power working principles

Solar heating principles

Solar heating systems perform the following three basic functions.

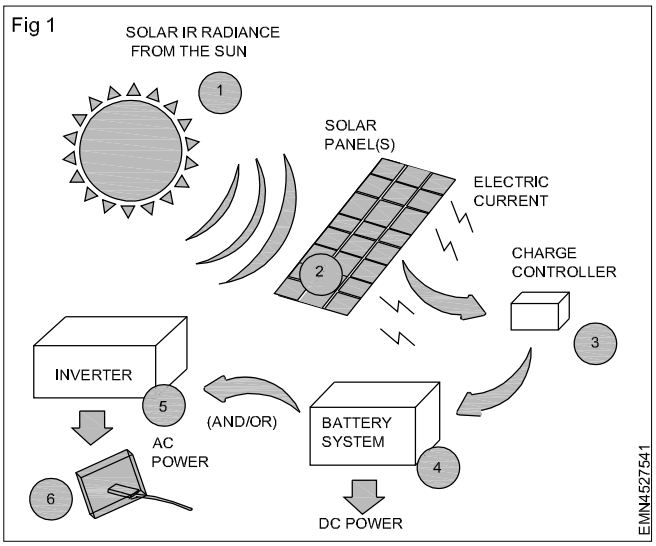
Collection: Radiant energy from the Sun is captured and converted to solar thermal energy using solar collectors.

Storage: The solar thermal energy is stored using thermal mass, water tanks, or rock bins.

Distribution: Distribution of the heat can be done with both active solar energy and passive solar energy methods. Example: Solar space heating, solar water heating, and solar pool heating systems.

Solar electricity principles

Solar electric systems use solar cells to convert the Sun's radiant energy into electricity. This is done using a principle known as the photovoltaic effect.



Solar energy block diagram

Solar panels convert sunlight into DC electricity, which is stored via a charge controller into batteries; DC loads can be run directly off these batteries. Cables from the batteries go to an inverter, which changes the DC to AC to run the conventional household loads.

Components of Solar Electric System

Photovoltaic module

Photovoltaic module consists of solar cells which convert light into electricity. When light photons are absorbed by the atomic electrons in the semiconductor material from which the solar cells are made. Each photon absorbed causes an electron to be freed from its atom and drift through the semiconductor material in an electric field created by p-n junction formed just below the surface of the solar cell. The free electrons and the resultant positive changes are collected by metallic contacts applied to the front and back surfaces of the solar cells thereby setting up an electron current which is made to flow through an electrical circuit to deliver power just like a storage battery. The current produced by a solar cell is proportional to its surface area and the light intensity, whereas the voltage is limited by the forward potential drop across the p-n junction.

In order to get higher voltages and currents, the cells are arranged in series and parallel strings and packed into modules for mechanical protection. The support structure for PV modules should be corrosion resistant (galvanized or stainless steel or aluminium) and electrolytically compatible with materials used in the module frame, fasteners, nuts, and bolts. The design of the support structure should allow for proper orientation of the module and tilt.

Charge controller

As PV cell costs continue to fall, the battery in a stand-alone PV system becomes an increasingly large part of the system cost. Battery's life now has the greatest impact on the economic viability of solar electric system. The controller must manage a rapid, yet safe, recharge under a very diverse range of system conditions. The charge controller in small stand-alone systems is the primary driver of system reliability and battery life. An advanced controller will affect the system performance more than any other component, and an improved controller will on the long run reduce the system's cost as the battery won't need to be replaced often.

Battery

The most commonly used battery in solar electric systems is a lead-acid battery of the type used in automobiles, sized to operate for desired hours or days. Automotive batteries are often used because they are relatively inexpensive and readily available. Ideally, solar electric systems should use deep cycle lead-acid batteries that have thicker plates and more electrolyte reserves than automotive batteries and allow for deep discharge without seriously reducing the life of the battery or causing damage. In a well designed solar electric system, such batteries can last for more than ten years.

Inverter

An inverter is a basic component of any independent power system that produces AC power. Inverters convert DC power from PV module or stored in batteries into AC power to run conventional appliances. Another application of inverter is in the case of uninterruptible power supply where the inverter with the aid of 12V DC battery is able to generate up to 220V AC that can be used to power most house and office appliances depending of their power rating. While one needs to buy PV module and battery, a hobbyist who likes putting things together may personally love to build an inverter for his solar electric project by himself. Ofcourse I do for personal uses. Why the waste of time and resources when there are cheap and neatly packaged inverters in the market.

Types of solar electric system:

Solar electric system can be classified into two major types.

1 Off-grid systems

2 Grid-tied systems

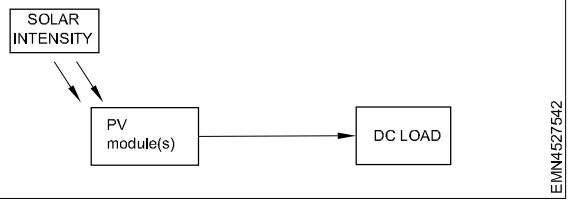
Off - grid systems

Off- grid system also called stand-alone systems. Although they are most common in remote locations without utility grid service, off-grid solar-electric systems can work anywhere. These systems operate independently from the grid to provide household's electricity. That means no electric bills and no blackouts-at least none caused by grid failures. They are generally designed and sized to supply DC and/or AC electrical load. People choose to live off-grid for different reasons, including the prohibitive cost of bringing utility lines to remote home sites, the

appeal of an independent lifestyle, or the general reliability a solar-electric system provide. Those who choose to live off-grid often need to make adjustments to when and how they use electricity, so they can live within the limitations of the systems design.

The simplest type is the direct-coupled system, where the DC output of a PV module is directly connected to a DC load. The critical part of designing a well performing direct-coupled system is the matching of impedance of the electrical load to the maximum power output of the PV module. It can be used to operate pumping machine where water is pumped in the day to reservoir for used in the night. The drawbacks in this type of off-grid are:

Fig 2



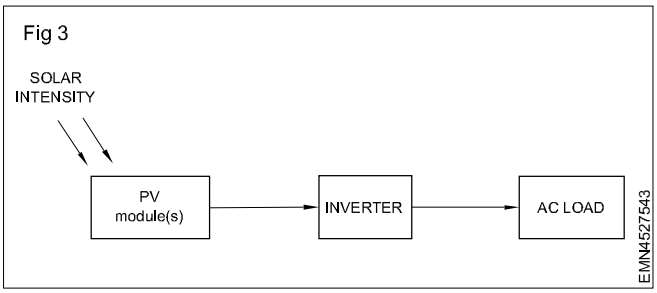
1 It can only be used in the day to supply load as there is no battery for storing energy.

2 It cannot be used with AC load.

Direct-coupled system

Another type of off-grid system is the type that incorporate inverter unit for conversion of DC voltage to AC at appropriate voltage level. The only drawback of this system is the lack of storage unit, so it will not supply load at night. The block diagram is shown in Fig 3.

Fig 3



System with inverter

The problem of no electricity generation in the night is eliminated with the inclusion of storage unit (batteries) as backup energy in the night. The block diagrams of this type is shown in Fig 4.

Off grid systems can also be sized to provide electricity during cloudy periods when the sun doesn't shine. Sizing a system to cover a worst-case, like several clouds days can result in a very large expensive system that rarely get used to its capacity. To reduce cost, it is sized moderately, but includes a back-up engine generator to get through occasional sunless stretches. The generator produces AC electricity that a battery charger (either stand-alone or incorporated into the system) converts to DC energy, which is stored in batteries. Below is the block diagram of this type of stand-alone system with generator back-up.

Fig 4

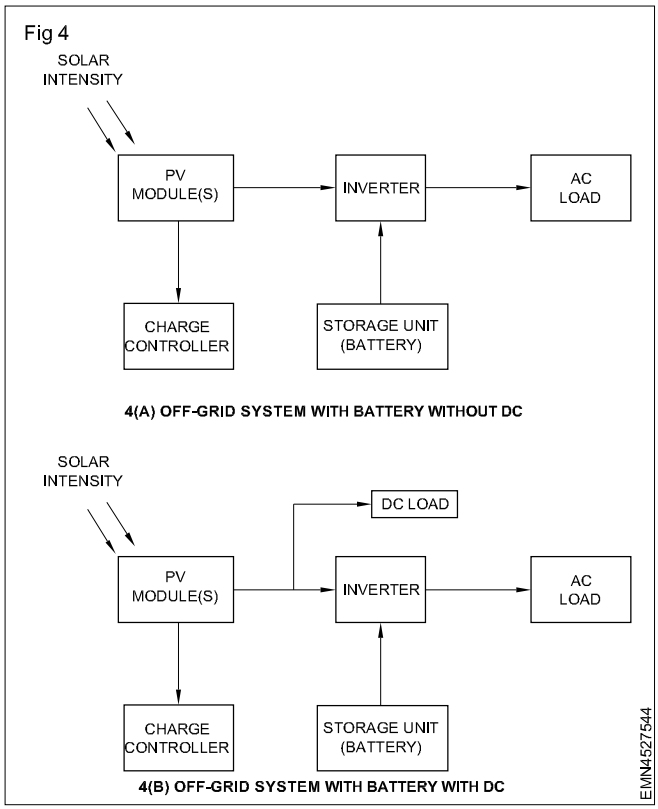
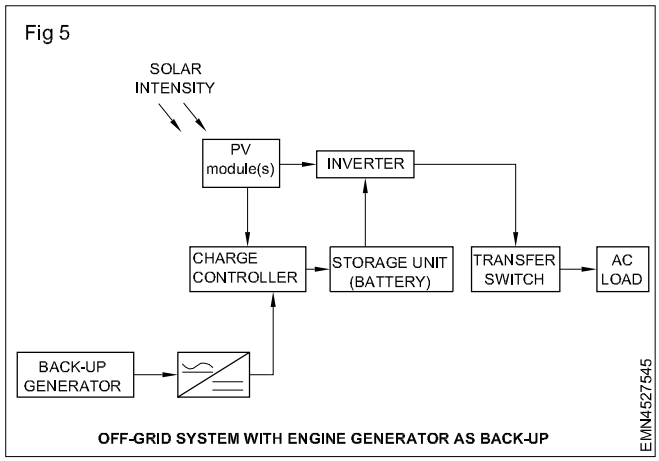


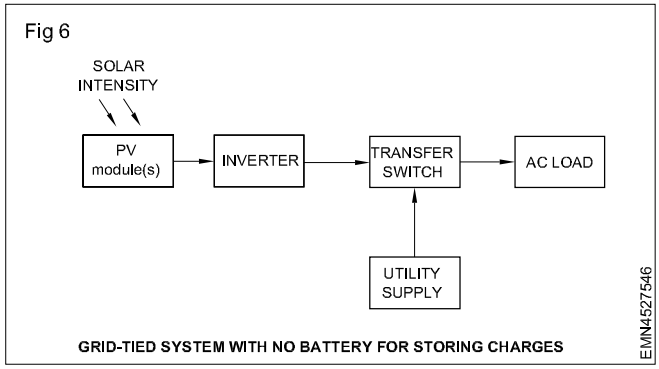
Fig 5



Grid-tied systems

Gird- tied system also called on-grid or utility interactive. Grid-tied systems are designed to operate in parallel with and interconnected with the electric utility grid. Below are the block diagrams of grid-tied systems.

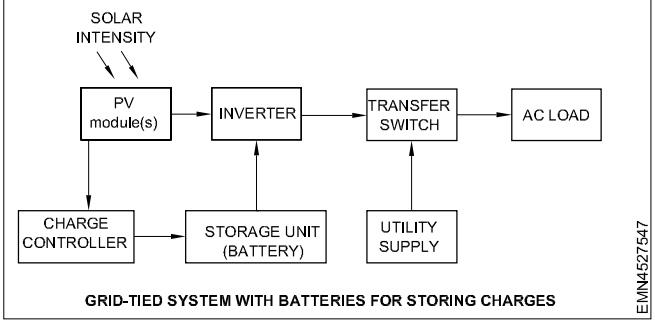
Fig 6



Grid-tied system can also be connected in a way that utility supply will be charging battery in the period of low light intensity. It has the same features as off-grid system

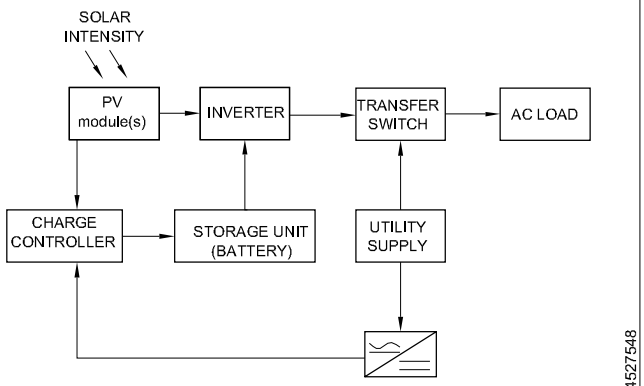
with engine generator back-up. In the case of long cloudy days and utility outage, there is likely to be blackout.

Fig 7



GRID-TIED SYSTEM WITH BATTERIES FOR STORING CHARGES

Fig 8



GRID-TIED SYSTEM WITH UTILITY CONNECTED TO CHARGE BATTERY

Sizing solar electric system

Before sizing various components of solar electric system, need to find out what average energy usage is.. Dividing this by the number of days of the month gives you an average daily energy usage.

It is also important to estimate various losses associated with installation. Some of these include losses due to orientation of PV module, shade, dust, temperature effect, name plate mismatch, cable loss, semiconductor loss (in inverter), running power of charge controller etc.

Sizing of PV module

The capacity of modules is given in watt-peak. This allows for calculation of electricity generated under different levels of sunshine. To standardize the capacity of solar PV modules, the capacities are given at an illumination at exactly 1000 watts per square meter. One watt-peak generate one watt of electricity under the standard test conditions of 1000 watts per square meter and temperature of 25ºC.

Again, one needs to know the amount of sun that is available. Meteorological tables show the solar insulation (usually in KWh/m^2/day). This is different from day to day and shows a seasonal variation over the year. It is safe to design the system based on the average daily insulation in the month with lowest insulation. The easiest way to know the average daily insulation of area is to search the internet: someone must have published something on that.

Having done that, you can now slot in all the information into the formula below to get the required PV module size in watt-peak (W_p)

$$\frac{\text{Daily energy consumpton}}{\text{Insolation x efficiency}}$$

Sizing of battery bank

Batteries are rated in ampere-hour (AH) and the sizing depends on the household energy consumption.

Due to low voltage disconnect, one does not use the complete battery capacity. Only certain percentage (discharge capacity) of the battery would be used. A deep-cycle battery can be discharged up to 80% (actual value depends critically on the low voltage setting) of its capacity. Now battery is sized with the formula below.

$$\text{Battery size(AH)} = \frac{\text{Daily energy consumpton}}{\text{battery voltage x discharge capacity}}$$

If the system is being designed to power ac load and inverter is needed, one has to put into consideration the inverter efficiency. The formula above can be modified to

Battery size (AH) =

$$\frac{\text{Daily energy consumpton}}{\text{battery voltage x discharge capacity x inverter efficiency}}$$

Advantages of solar electric system

1 Renewable energy source

2 Reduces electricity bills

3 Diverse application

4 Low maintenance cost

5 Technology development

Disadvantages of solar electric system

1 Initial installation cost is very high.

2 Affected due to weather condition.

3 Battery storage is expensive.

4 Uses a lot of space.

SPV system and solar charge controller

Objectives : At the end of this lesson you shall be able to
- **describe SPV system**
- **list the types of SPV system**
- **differentiate SPV system and conventional power**
- **define charger control**
- **list types of solar charger control**
- **explain working of solar charger control**
- **state the application of solar charger control.**

SPV system

Solar photoVoltaic means generation of voltage from sunlight. Photovoltaic cells are also called solar cells and these cells converts light energy in to electric energy.

Though the Photovoltaic cells can produce electric energy in the presence of light but cannot store it. As soon as the source of light is removed, they stop generating electric energy. It is a known fact that full sunlight is not available throughout the day. It is therefore essential that there should be some device which can store the energy produced by SPV cells so that it may be utilised whenever required. The storage batteries are mainly used for this purpose. These batteries convert the electric energy generated by the SPV cells into chemical energy and deliver back for the use of converting the chemical energy back to electric energy. Thus the SPV Power Source is a non-conventional energy source, comprised of a SPV Modules, which convert Solar Energy (Sun light) directly into DC electricity to charge the battery, through a charge controller. The Charge Controller is used to control the charging process

There are three types of SPV system

1 Stand alone system

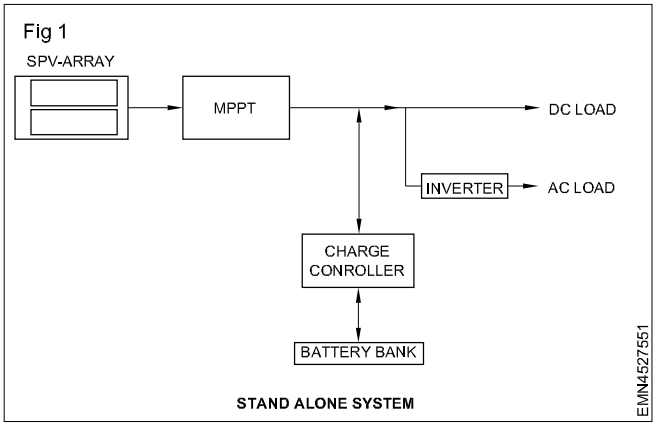
2 Hybrid system

3 Grid-connected system

Stand alone system

The entire power is generated by an SPV array and stored in a battery to be provided in response to demand.

Fig 1

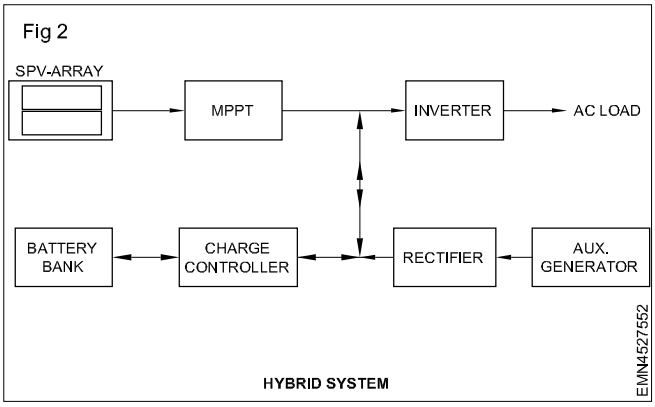


STAND ALONE SYSTEM

Hybrid system

In addition to an SPV array, other means such as AC mains, wind and diesel generators are also used to supply power.

Fig 2

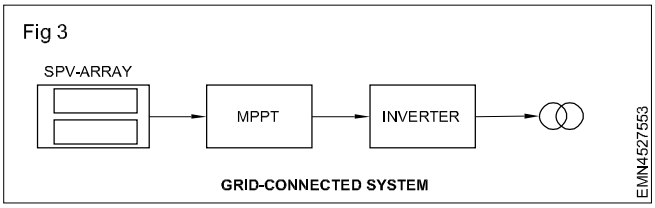


HYBRID SYSTEM

Grid-Connected system

In such system the output of SPV planes is connected to the grid and there is no storage battery; metering is used to keep account of imported and exported power by the user.

Fig 3



GRID-CONNECTED SYSTEM

Solar charge controller

A solar charge controller is fundamentally a voltage or current controller to charge the battery and electric cells from overcharging. It limits the rate at which the voltage/ current is charged or discharged from batteries. It is also charge regulator or battery regulator.

Types of solar charger controller

There are three different types of solar charge controllers,

1 Simple 1 or 2 stage controls

2 PWM (pulse width modulated)

3 Maximum power point tracking (MPPT)

Simple 1 or 2 stage controls: It has shunt transistors to control the voltage in one or two steps. This controller basically just shorts the solar panel when a certain voltage is arrived at.

PWM (Pulse Width Modulated): This is the traditional type charge controller, for instance anthrax, Blue Sky and so on. These are essentially the industry standard now.

Maximum power point tracking (MPPT): The MPPT solar charge controller is the sparkling star of today's

solar systems. These controllers truly identify the best working voltage and amperage of the solar panel exhibit and match that with the electric cell bank. The outcome is extra 10-30% more power out of your sun oriented cluster versus a PWM controller. It is usually worth the speculation for any solar electric systems over 200 watts.

Working of solar charge controller

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices.

Generally solar power systems utilize 12V of batteries. Solar panels can convey much more voltage than is obliged to charge the battery. The charge voltage could be kept at a best level while the time needed to completely charge the electric storage devices is lessened. This permits the solar systems to work optimally constant. By running higher voltage in the wires from the solar panels to the charge controller, power dissipation in the wires is diminished fundamentally.

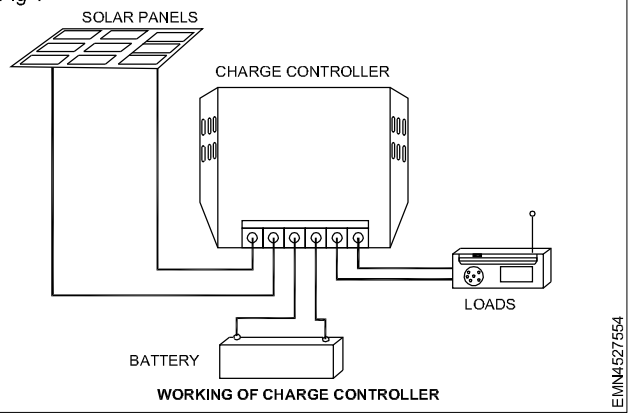
The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.

TABLE 1

Difference between SPV and conventional power

Sl.No.	Item	Power plant configuration	
		Solar PV	Conventional power
1	Operation	Decentralised	Centralised
2	Dependency on external fuel source	Very low	Completely
3	Design	Load specific	Capacity -specific
4	Suitability	Lower capacity	Higher capacity
5	Gestation period	Short	Long
6	Transmission losses	Low	High
7	O&M costs	Low	High
8	Capital cost	High	Low
9	Running cost	Low	High
10	Environmental pollution	None	Add gaseous and particulate toxins which causes pollution and ecological imbalance

Fig 4



WORKING OF CHARGE CONTROLLER

This unit performs 4 major functions

1 Charges the battery.

2 Gives an indication when battery is fully charged.

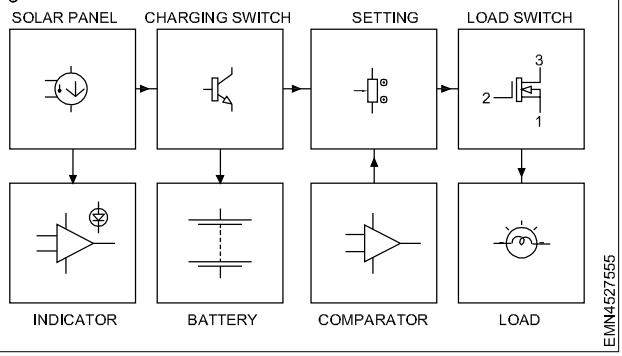
3 Monitors the battery voltage and when it is minimum, cuts off the supply to the load switch to remove the load connection.

4 In case of overload, the load switch is in OFF condition ensuring the load is cut off from the battery supply.

A solar panel is a collection of solar cells. The solar panel converts the solar energy into electrical energy. The solar panel uses Ohmic material for interconnections as well as the external terminals. So the electrons created in the N-type material passes through the electrode to the wire connected to the battery. Through the battery, the electrons reach the P-type material. Here the electrons combine with the holes. When the solar panel is connected to the battery, it behaves like other battery, and both the systems are in series just like two batteries connected serially. The solar panel has totally consisted of four process steps overload, under charge, low battery and

deep discharge condition. The output from the solar panel is connected to the switch and from there the output is fed to the battery and setting from there it goes to the load switch and finally at the output load. This system consists of 4 different parts-over voltage indication and detection, over charge detection, over charge indication, low battery indication and detection. In case of the over charge, the power from the solar panel is bypassed through a diode to the MOSFET switch. In case of low charge, the supply to MOSFET switch is cut OFF to make it in OFF condition and thus switch OFF the power supply to the load.

Fig 5



Solar energy is the cleanest and most available renewable energy source. The Modern technology can harness this energy for a variety of uses, including producing electricity, providing light and heating water for domestic, commercial or industrial application.

MPPT Solar charger controller parts and working

1 Charging LED indicator.

2 Battery status LED indicator.

3 Local temperature sensor-acquires ambient temperature to perform temperature compensation for charging and discharging.

4 Setting LED Indicators-work mode, timers, and battery selection.

5 LCD display-load and work mode status is displayed.

6 Set button-Adjust parameters, cycle through settings, or turn load ON/OFF.

7 RJ45 port for MT-5 Tracer (optional accessory)-connects remotely to temperature sensor in order to acquire ambient temperature.

LED indicators in MPPT solar charger controller

Applications

The process of generating electricity from sunlight is having more popularity than other alternative sources and the photovoltaic panels are absolutely pollution free and they don't require high maintenance. The following are some examples where solar energy is being utilized.

1 Street lights use photovoltaic cells to convert sunlight into DC electric charge. This system uses solar charge controller to store DC in the batteries and uses in many areas.

2 Home systems use PV module for house-hold applications/appliances.

3 Hybrid solar system uses for multiple energy sources for providing full time backup supply to other sources.

Fig 6

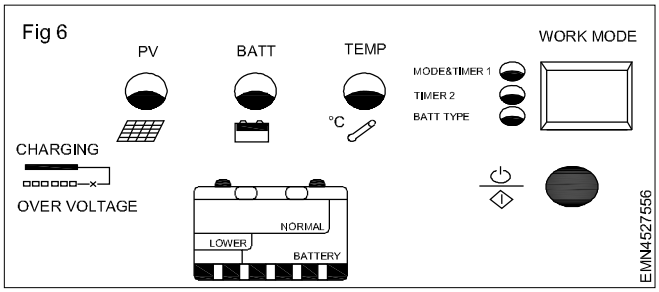


Fig 7

Charge Indicator	
Solid. Battery is charging	
No light. Not charging.	
Flashing. Battery is over-voltage.	
Battery Indicator	
Solid. Battery Normal.	
Flashing. Battery is Full.	
Solid. Battery is under-voltage.	
Solid. Battery is over-discharged.	
Flashing. The load is either over-current or short-circuited.	
Work Mode	
P	The PV's open circuit voltage (V_{oc}) is exceeding the maximum rating of the charge controller. The array will remain disconnected until the V_{oc} is at a safe rating.
C	The PV's input current is exceeding the maximum rating of the charge controller. The array will remain as is until solution is implemented.

Safety precaution in solar electric system

Objectives : At the end of this lesson you shall be able to
- **state general safety precautions in solar electric system**
- **safety while working on solar panel**
- **safety on solar installation.**

General safety precautions

The safety basics

Solar system is fully automatic and comes with built-in safety features. Do not attempt to work on, alter, or repair the system; doing so could expose you to dangerous electrical currents and void manufacturer warranties.

Do not attempt to service any portion of the system. Only a trained and certified professional should service the system.

It's not necessary to go on the roof for panel cleaning or inspection. If choose to go on roof, take all safety precautions and do not touch or disturb the panels or wiring. It is important to remember that only an authorized person should repair or touch system components.

Always, remind anyone going on roof that they should not disturb the panels or wiring.

Do not step on the panels or allow objects to fall on the panels.

Do not disassemble or remove any part of the system. This will void manufacturer warranties.

Small children and pets should be kept away from the inverter.

Safety precautions for installing a solar photovoltaic system

1 Solar modules produce electrical energy when exposed to sunlight. DC voltages may exceed 30V on a single exposed module.

2 Connect modules with the same rated output current only in series. If modules are connected in series, the total voltage is equal to the sum of the individual module voltages.

3 Connect modules or series combinations of modules with the same voltage in parallel. If modules are connected in parallel, the total current is equal to the sum of individual module or series combination currents.

4 Bypass diodes are pre-assembled in each module. Do not remove these diodes.

5 Keep children well away from the system while transporting and installing mechanical and electrical components.

6 Completely cover all modules with an opaque material during installation to prevent electricity from being generated.

7 Do not wear metallic rings, watchbands, ear, nose, or lip rings or other metallic devices while installing or troubleshooting photovoltaic systems.

8 Use appropriate safety equipment (insulated tools, insulating gloves, etc) approved for use on electrical installations.

9 Observe the instructions and safety precautions for all other components used in the system, including wiring and cables, connectors, DC-breakers, mounting hardware, inverters, etc.

10 Use only equipment, connectors, wiring and mounting hardware suitable for use in a photovoltaic system.

11 Always use the same type of module within a particular photovoltaic system.

12 Under normal operating conditions, PV modules will produce currents and voltages that are different than those listed in the data sheet. Data sheet values are applicable at standard test data.

13 Short-circuit current and open-circuit voltages should be multiplied by a factor of 1.25 when determining component voltage ratings, conductor ampacity, fuse sizes and size of controls connected to the module or system output. An additional multiplying factor of 125 percent (80 percent de-rating) may be applicable.

Safety while working on solar panel

1 Never work on a PV system alone.

2 Know the system before start to work on it.

3 Study electrical diagrams of the system.

4 Discuss the test objectives and techniques with partner.

5 Keep test equipment in top operating condition.

6 Check test equipment before go to the system site.

7 Wear appropriate clothing.

8 Wear only approved electrical safety hat.

9 Wear eye protection, particularly if working on batteries. Remove any jewellery.

10 Wear dry leather gloves to reduce the probability of getting shocked.

11 Measure the conductivity from exposed metal frames and junction boxes to ground.

12 Measure voltage from all conductors (on the PV output circuit) to ground.

13 Measure the operating voltage and current. Work with one hand whenever possible.

Solar safety

Follow these solar power safety rules to minimize the risk

The first safety rule to keep in mind when working with photovoltaic panels or other PV components is, always stop working in bad weather. PV panels can be blown around by the wind or a storm which can result in falling or damage to the PV system.

Do not apply pressure on PV photovoltaic panels by sitting or stepping on them or they might break and cause bodily injury, electrical shock or damage to the solar panels. Also never drop anything on the PV panels.

Through the entire process of photovoltaic solar installation, make sure don't get the home's sheathing wet or roof may leak thereafter. This is usually an issue with roofs that are just being built, but it can happen to older roofs too.

Do not install a PV system in any location within 0.3 miles of an ocean or salty water. Vapours and mist could interfere with photovoltaic equipment and cause damage or electrical shock.

Also do not install photovoltaic equipment in locations that are corrosive area.

Make sure that the roof where mounting solar panels is strong enough to support the weight.

This next PV safety rule could save life. Make sure entire PV system is properly and safely earth grounded to prevent electrical shock and injury.

Never work when it's raining, immediately after rain or in wet or slippery conditions or with wet tools.

Never install a PV system near flammable gases or could cause a fire or explosion.

Cover photovoltaic solar panels with an opaque material during wiring to stop or prevent electricity production.

Make sure the area underneath your solar panels is clean, clear and free of foreign objects.

Another solar safety rule is do not wear metallic jewellery when working on PV system, or it could cause electric shock. Also never touch any electrical contacts or wiring without proper protection and safety gear.

When working on roof tops. Always insure that extreme safety precaution (including harnesses, lifelines and safety nets) are taken to prevent slipping, falling and causing injury or death.

Inspect all power tools to ensure that they are working safely prior to starting the installation of PV system. Also, use insulated tools when working on a photovoltaic system.

Another solar safety rule you should always follow is never work in conditions of snow or high wind or when these conditions are expected due to increased chance of slipping or losing your balance.

Always get a second person to securely hold ladders as climb and use rubber lattex mats to prevent the ladder from slipping.

Wear all necessary protective safety clothing including work clothes that fit well and allow to move easily and freely, non-slip shoes, insulating gloves and a helmet. When installing a PV system, use scaffolds (not ladders) at height 6 foot and higher. Be very careful of falling objects and do not ever throw objects up or down when installing a PV system.

Always protect wires or cables with flexible metal conduit when wiring through walls, for wires exposed to sunlight, rain or anywhere outdoors. Failure to follow this photovoltaic solar safety rule can result in electrical shock or short circuit

Use waterproof fitting or duct seal to prevent water from entering the conduit and damaging photovoltaic system.

Always connect a grounding wire from the mounting hardware to the earth to prevent shock.

Maintenance and troubleshooting of solar electric system

Objectives : At the end of this lesson you shall be able to
- **explain the maintenance of solar electric system**
- **maintenance of solar charge control**
- **troubleshooting of solar electric system**
- **troubleshooting of solar charge control.**

Maintenance of solar panel

Solar panel maintenance is important because insufficient care for solar panels can reduce the amount of energy. Since a solar panel system needs to absorb energy from the sun the most vital component of solar panel care is to keep the panels clean. Usually maintain a solar panel using the same equipment that uses to wash residential and automobile windows, as long as provide regular care and don't allow dirt and other environmental elements from settling on the panels for too long.

Solar panel cleaning

1 Solar panels cleaning kit should contain a liquid soap, a wiper, a small brush and in some cases another brush with a longer handle. In many ways, these items are similar to clean the car, so if you cannot purchase a cleaning kit that is specifically designed for cleaning

solar panels then you can substitute it with your car cleaning equipment instead.

2 Mix the soap with water in a bucket. The amount that needs to be mixed should be mentioned on the bottle of liquid soap as shown in Fig 1.

Fig 1

3 Dip the brush into the soap and water mixture and gently rub it over the solar panels; solar panels divided into smaller arrangements with a small handheld brush. However, for larger arrangements it can be difficult to reach the panels in the middle so need to use the brush with the longer handle as shown in Fig 2.

4 Wipe the solar panels with the wiper while the panels are still wet. At times, the wiper is attached at the back of the brush. It is important that you don't allow the soap to dry on the solar panels since this will block the amount of sunlight that they can absorb and make them inefficient as shown in Fig 3.

Fig 2

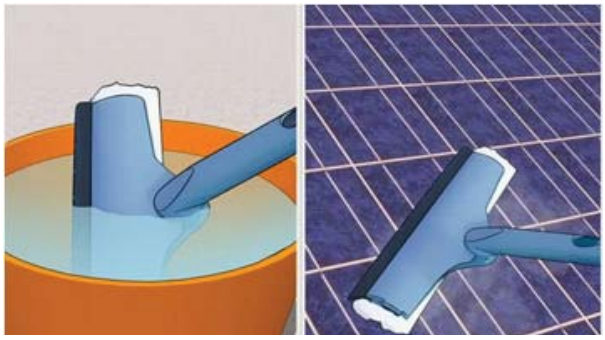
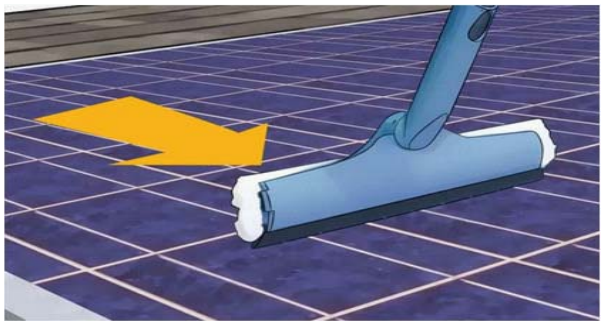


Fig 3



Maintenance of solar charge controller

1 Check that controller is mounted in a clean, dry, and ventilated area.

2 Check wiring going into the charge controller and make sure there is no wire damage or wear.

3 Tighten all terminals and inspect any loose, broken, or burnt up connections.

4 Make sure readings in the LCD and LED are consistent. Take necessary corrective action.

5 Check to make sure none of the terminals has any corrosion, insulation damage, high temperature, or any burnt/discoloration marks.

Troubleshooting of solar electric system

Problem	Possible causes	Solution/Remedy
The light does not turn on at all.	The batteries are discharged	Charge the batteries
	The batteries are bad.	Replace the batteries
	The LED fixture is bad	Replace the LED fixture
	A fuse is blown	Replace the fuse
	Controller is bad.	Check the controller
The light does not stay on for the	The run time is incorrectly set. expected period of time.	Contact authorised sevice personelfor assistance
The light turns on at dusk but does not turn on again at dawn (split run time)	The run time exceeds the maximum run time for your model and location.	Contact authorised sevice personelfor assistance

	Low battery voltage caused by inclement weather.	Allow for two to three days of consecutive sunny weather to charge the battery pack.
	Low battery voltage caused by shading of the PV panel.	Clear tree branches and other obstructions from the vicinity of the PV panel.
	The batteries are bad.	Replace the batteries
The red LED on the controller remains illuminated The light does not operate every day.	Low battery voltage caused by inclement weather	Allow for two to three days of consecutive sunny weather to charge the battery pack.
	Low battery voltage caused by shading of the PV panel.	Clear tree branches and other obstructions from the vicinity of the PV panel.
	The batteries are bad.	Replace the batteries
The fuse blows repeatedly.	There is a short circuit in the wiring	Check all system wiring for a short circuit.
The battery voltage is less than 9.0 volts	One (or both, if there are two) controller is bad.	Check the controller(s)
	The batteries are bad.	Replace the batteries

Troubleshooting of solar charge control:

Sl.No	Trouble symptom/Fault	Remedy
1.	OFF during day light	**Charge indicator**
		Ensure that the PV wires are correctly and tightly secured inside the charge controller PV terminals. Use a multi-meter to make sure the poles are correctly connected to the charge controller.
2.	Flashing green light	Use a multi-meter to check the battery voltage and make sure it is within specification for the charge controller. NEVER disconnect battery without disconnecting the solar panels first.
3.	Solid orange light	**Battery Indicator** Disconnect loads, if any, and let the PV modules charge the battery bank. Use a multi-meter to frequently check on any change in battery voltage to see if condition improves. This should ensure a fast charge. Otherwise, monitor the system and check to see if system improves.
4.	Solid Red	The controller will have cutoff the output of the battery to ensure that it charges. Make sure there are no excessive loads and give the system appropriate time and sunlight to charge. Monitor readings with a multi-meter to see if they system improves
5.	Flashing Red light	**Overload:** Use a multi-meter to check load drawn and limit loads if possible. If no progress, disconnect all loads and gradually reconnect loads to see if the condition improves.
		Short-circuit: Upon experiencing its first short circuit, the controller will cut off for 10 seconds, and then resume normal operation. Upon the second short-circuit, the controller will not automatically reboot and the user must press the orange button to resume controller working.

Mobile communication

Objectives : At the end of this lesson you shall be able to
- **state mobile communication**
- **state mobile phone function**
- **explain the generation of cellphones**
- **explain the concept of cell site, hand off and frequency reuse.**

Mobile communication

Mobile communication is wireless form of communication in which voice and data information is emitted, transmitted and received via microwaves. This type of communication allows individuals to converse with one another and /or transmit and receive data while moving from place to place. Example - cellular and digital cordless telephones, pagers, telephone answering devices, air-to-ground telecommunications and satellite-based communications.

A cellular phone is a portable telephone that does not use a wired connection. It connects to a wireless carrier network using radio waves.

Mobile phone

The mobile phone or cell phone is a portable electronic device used for mobile communication through wireless network using radio waves. In addition to the standard voice function of a telephone, current mobile phones can support many additional services such as SMS for text messaging, email, packet switching for access to the Internet, and MMS for sending and receiving photos and video. Most current mobile phones connect to a cellular network of base stations (cell sites), which is in turn interconnected to the public switched telephone network (PSTN) Mobile Communications.

Generation of cellphones

When wireless generation started, it was analog communication. That generation is 1G. They used various analog modulation for data transfer. Now when the communication migrated from analog to digital, the foundation of latest communication were lead. Hence came 2G.

1G technology mobile phones

1 1G refers to the first generation of wireless telephone technology in mobile telecommunications which was introduced in 1980s and completed in early 1990s.

2 It's speed was upto 2.4kbps, allowed the voice calls within the country.

3 It used analog signal and Advance Mobile Phone System (AMPS) was first launched in USA in 1G mobile systems shown in Fig 1.

Drawbacks

1 Poor voice quality

Fig 1

2 Poor battery life

3 Large phone size

4 No security

5 Limited capacity

6 Poor handoff reliability

2G technology mobile phones

1 2G technology refers to the 2nd generation which is based on GSM as shown in Fig 2.

2 It was launched in Finland in the year 1991 and used digital signals.

3 It's data speed was upto 64 kbps.

Features

1 It enables services such as text messages, picture messages and MMS (multi media message service).

2 It provides better quality and capacity.

Drawbacks

1 2G requires strong digital signals for mobile phones work. If there is no network coverage in any specific area, signals will weak.

2 These systems are unable to handle complex data such as videos.

Fig 2

2G technology phones

2.5G technology

1 2.5G is a technology between the second (2G) and third (3G) generation of mobile telephony shown in Fig 3.

2 It is sometimes described as 2G Cellular Technology combined with GPRS.

Fig 3

Features includes

1 Phone calls

2 Send/Receive E-mail messages

3 Web browsing

4 Speed : 64-144 kbps

5 Camera phones

3G Technology

1 3G technology refer to third generation which was introduced in the year of 2000s.

2 Data transmission speed is 144kbps- 2Mbps.

3 Typically called smart phones as shown in Fig 4 and features increased its bandwidth and data transfer rates to accommodate web-based applications and audio and video files.

Fig 4

Features include

1 Providing faster communication

2 Send/Receive large email messages

3 High speed web / more security

4 Video conferencing / 3D gaming

5 TV streaming / mobile TV/ Phone calls

6 Large capacities and broadband capabilities

7 11 sec - 1.5 min. time to download a 3 min Mp3 song.

Drawbacks

1 Expensive fees for 3G licenses services

2 It was challenge to build the infrastructure for 3G

3 High bandwidth requirement

4 Expensive 3G phones.

5 Large cell phones

4G technology

1 4G technology refer to fourth generation which was started from late 2000s.

2 Capable of providing 100Mbps - 1Gbps speed.

3 One of the basic term used to describe 4G is MAGIC. 4G mobile phones are shown in Fig 5.

Fig 5

Magic

1 Mobile multimedia

2 Anytime anywhere (Universal)

3 Global mobility support

4 Integrated wireless solution

5 Customized personal services.

6 Also known as mobile broadband everywhere.

7 The next generations of wireless technology that promises higher data rates and expanded multimedia services.

8 Capable to provide speed of 100Mbps-1Gbps.

9 High quality of services(QOS) and High security.

10 Provide any kind of service at any time at anywhere as per user requirements.

Features include

1 More security

2 High speed

3 High capacity

4 Low cost per-bit

Drawbacks

1 Battery usage is more.

2 Need complicated hardware.

3 Expensive equipment required to implement next generation network.

Comparison of 1G, 2G, 3G, 4G, 5G

Comparison of all generation of mobile technologies (1G-5G)

Generation	1G	2G	2.5G	3G	3.5G	4G	5G
Start	1970 -1980	1990 -2000	2001 - 2004	2004 - 2005	2006 - 2010	2011- Now	Soon (2020)
Data Bandwidth	2 kbps	64 kbps	144 kbps	2 Mbps	More than 2 Mbps	1 Gbps	More than 1 Gbps
Technology	Analog cellular	Digital cellular	GPRS, CDMA	CDMA 2000 (1×RT, EVDO) UMTS, EDGE	EDGE, Wi-Fi	WiMAX LTE Wi-Fi	WWWW
Service	Voice	Digital voice, SMS, Higher capacity packet size Data	SMS, MMS	Integrated high Quality Audio, Video & Data	Integrated High Quality Audio, Video & Data	Dynamic information access, wearable Devices	Dynamic information access, wearable devices with all capabilities
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	TDMA, CDMA	TDMA, CDMA	TDMA, CDMA	TDMA, CDMA
Switching	Circuit	Circuit, packet	Packet	Packet	All Packet	All packet	All Packet
Core Network	PSTN	PSTN	PSTN	Packet N/W	Internet	Internet	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal & Vertical	Horizontal & Vertical

Concept of cell

1 Cell refers to the geographical area under one base station with a single transmitter and receiver.

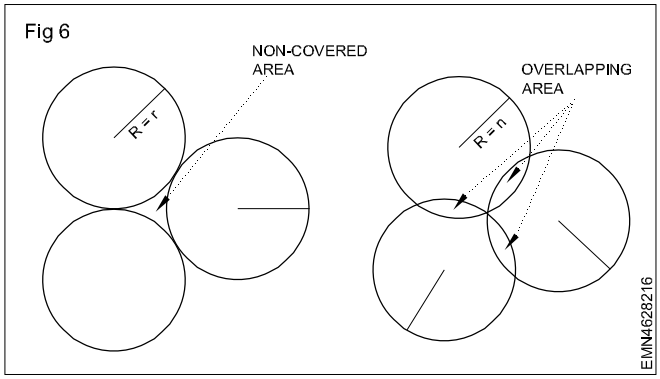
- The size of a cell depends upon the density (number) of users in a given area.
- For a heavily populated city area, many small cells are used to ensure service.
- In less populated rural areas, fewer cells are used.
- A group of cells are called a cluster. Each cell in a cluster will be having different frequencies to avoid interference.
- The cell will be in hexagonal shape in a honeycomb pattern.

The geographical area or cellular service is divided into small hexagonal region called cells. It is the basic unit of a cellular system. These cells collectively provide coverage over larger geographical areas.

Hexagonal cell shape as shown in Fig 8 is perfect over square or triangular cell shapes in cellular architecture because it cover an entire area without overlapping i.e. they can cover the entire geographical region without any gaps. If cell is in circular shape, there may be overlapping of areas or some geographical area may not be covered as shown in Fig 6.

Frequency reuse and cell splitting is the process of dividing a larger congested cell into smaller cells. Each cell has its own base station.

Fig 6



When the traffic in an area increases, larger cells are split into smaller cells so that frequency can be reused. By splitting the cell, the capacity of the system will be increased because availability of additional number of channels per unit service area is also increased.

Cell site

The cell site is used to refer to the physical location of the radio equipment that provides coverage within the cell. A list of hardware located at a cell site include power source interface equipment, radio frequency transmitter, receiver and antenna system as shown in Fig 7.

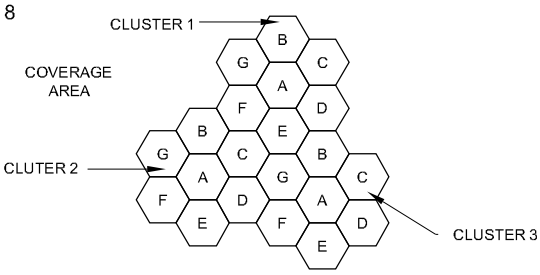
Fig 7

Frequency reuse concept

- Since the frequencies available for mobile communication are limited compared to the user demand of these systems, the concept of frequency reuse is employed.
- Frequency reuse is the process in which the same set of frequencies (channel) can be allocated to more than one cell, provided the cells are separated by sufficient distance (to avoid mutual interference).
- The figure 8 shows a geographic cellular coverage area with 3 clusters. There are seven cells in each cluster, each cells having a different frequencies (denoted by the letters A, B C, D, E, F, and G)
- Cells with the same letter uses the same set of channel frequencies.
- Here the same set of frequencies are used 3 times, which increases the number of usable channels by threefold.

Structure of cells for frequency reuse

Fig 8

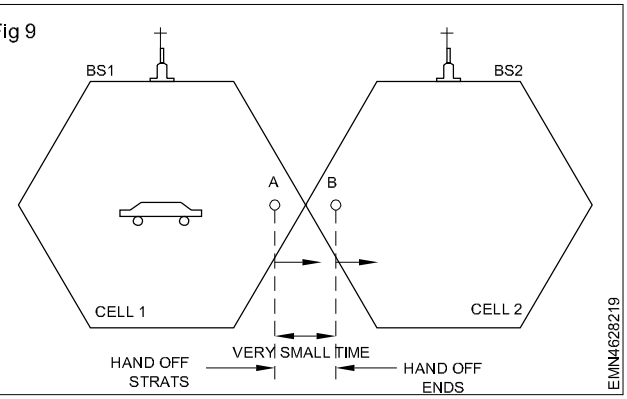


Concept of handoff

- A handoff refers to the process of transferring an active call or data session from one cell in a cellular network to another.
- Handoff is often initiated either by crossing a cell boundary or by deterioration in quality of signal in current channel.
- For instance, if a subscriber moves out of the coverage area from a particular cell while entering to another, a handoff takes place between the two cells as shown in Fig 9. The cell that served the call prior to the handoff is relieved of its duties, which are then transferred to the second cell.

- A handoff may also be triggered when the number of subscribers using a particular cell has already reached the cells maximum limit (capacity). Such a handoff is possible because the reach of the cell sites serving these cells can sometimes overlap.

Fig 9



Cellular network

Objectives : At the end of this lesson you shall be able to
- **explain the cellular system infrastructure**
- **state GSM network**
- **describe CDMA network**
- **compare GSM & CDMA**
- **explain GPRS network.**

Cellular system infrastructure

1 Cellular system infrastructure was developed to increase the capacity for mobile radio telephone service.

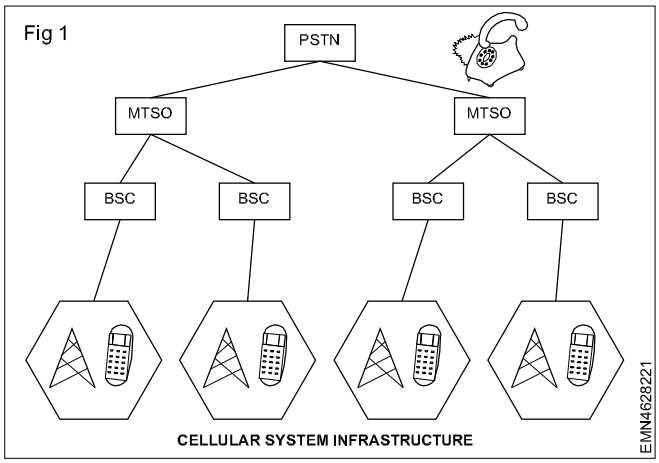
2 A basic cellular system consists of 3 layers as shown in Fig 1.

i **Mobile unit -** It is the mobile which is in the hands of users.

ii **Base Station Controller (BSC) -** The mobile unit is normally connected to the base station. The base stations are considered as cells. The base station includes an antenna, a controller and a number of transceivers for communicating on channel assigned to that cell.

iii **Mobile Telephone Switching Office (MTSO)** - Each BSC is connected to an MTSO, with one MTSO serving with multiple base stations. MTSO is also connected to PSTN (Public Switched Telephone Network) or the conventional landline.

Fig 1



CELLULAR SYSTEM INFRASTRUCTURE

The MTSO assigns voice channels to each call, performs hand off, and monitors the call for billing information.

Global System for Mobile Communication (GSM)

1 Earlier cellular telephone systems in European countries were working at different frequencies, they were incompatible with other systems.

2 To improve the inter operatability among various cellular communication systems the European telecommunication Standardization Institute (ETSI) has formulated a global standard called GSM.

3 It is world's first cellular system to specify digital modulation and level architecture and service, and it is the most popular 2G technology.

GSM Services

1 GSM services are classified into three groups

i **Teleservices -** Tele services includes the voice communication via mobile phones.

ii **Data services -** Data services include various data services for information transfer between GSM and other networks like PSTN, ISDN etc. Data services also include short message service (SMS).

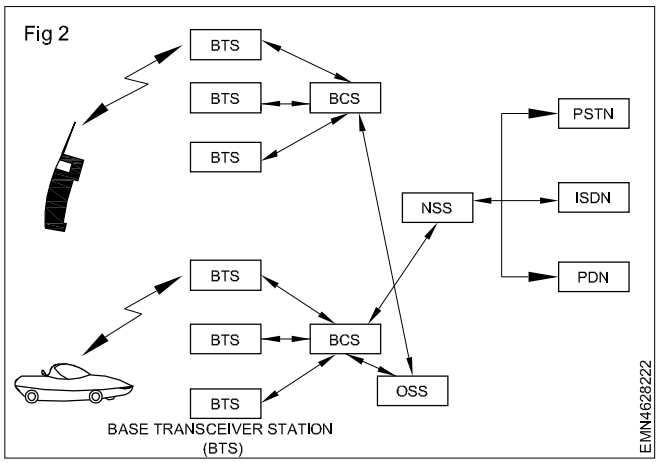
iii **Supplementary services -** Supplemantary services such as call forwarding, call barring etc are also offered with GSM.

GSM architecture

GSM architecture components

1 GSM architecture has three major interconnected subsystems that interact among one another and with subscribers through specified network interfaces as shown in Fig 2.

Fig 2



i **Base Station Subsystem (BSS) -** BSS is also known as radio subsystem as it provides and manages radio-frequency transmission paths between mobile unit and the mobile switching center (MSC). Mobile Unit is also considered as a part of BSS.

ii **Network Switching Subsystem (NSS) -** NSS manages the switching function of the system and allows MSC to communicate with other telephone network like PSTN (Public Switched Telephone Network), ISDN (Integrated Services Digital Network) and PDN (Public Data Network).

iii **Operational Support Subsystem (OSS) -** The OSS supports operation and maintenance, of the system and allows engineers to monitor, diagonise, and troubleshoot every aspect of the GSM network.

Advantages of GSM over earlier Analog systems

1 Capacity increases.

2 Reduced RF transmission power, thus longer battery life.

3 International roaming capability.

4 Better security

5 Encryption capability for information security and privacy.

6 Compatibility with ISDN, leading to wider range of services.

Code Division Multiple Access (CDMA)

1 CDMA is a digital cellular technology based on spread spectrum technique, where the entire bandwidth of frequencies is available to each user at the same time.

2 CDMA operates by coding to discriminate between users.

There are two types of CDMA

1 **Direct Sequence Spread Spectrum (DSSS) CDMA** Here a narrowband input from a user is coded (spread) by a unique broadband code (Pseudorandom Noise) and then transmitted. All the receivers get this coded broadband signal. But only the receiver who knows this unique broadband code can recover the user data.

2 **Frequency Hopping Spread Spectrum (FHSS) CDMA -** Here each user narrowband signal varies among discrete frequencies based on a code. Only the receiver who knows this code for frequency variation can recover the data. Frequency hopping technique is used by the military since it gives very high data security.

Block diagram of CDMA system

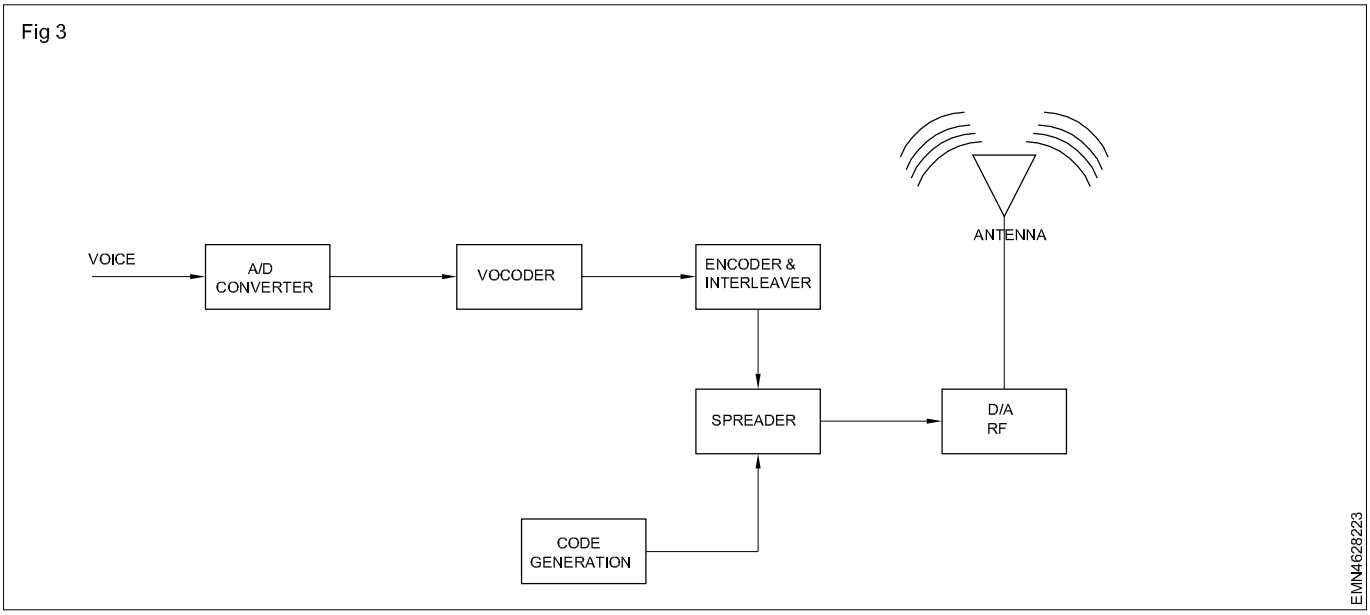
Fig 3 shows the block diagram of a CDMA system. It consists of

1 **A/D converter -** It converts analog voice signal to digital signal.

2 **Vocoder-** Digitalized voice is vocoded. Here the digital voice is variably compressed to make more efficient use of the air link and system resources.

3 **Encoder and Interleaver -** The purpose of encoder is to build redundancy into the signal. Interleaving is

Fig 3



a method of reducing the effects of burst errors and recovering bits when burst errors occur.

4 **Spreader -** the encoded signals are spread (channelized) using spreader. The spreader converts the narrowband signal into a wideband signal using spreading code such as walsh code or pseudo- noise codes.

5 **Code generator -** The code generator generates the spreading code. Orthogonal (Walsh) codes are used on the forward link (base station to mobile station) to channelize the users. A Pseudorandom Noise (PN) code is used on the reverse link (mobile station to base station).

6 **D/A converter -** It converts digitally coded signal to analog RF signal for transmission.

7 **Antenna -** It transmits the RF signal which can be received by uses with mobile handsets.

8 Only the users who knows the pseudorandom noise code (or the frequency variation code in FHSS CDMA) can recover the original data.

Advantages of CDMA

1 Capacity increases 4 to 5 times that of GSM systems.

2 Improved call quality.

3 Simplified system planning through the use of same frequency in every sector of every cell.

4 Enhanced privacy.

5 Improved coverage characteristics, allowing the possibility of fewer cell sites.

6 Extra bandwidth can be made available on demand.

General Packet Radio Services (GPRS)

1 GPRS is a non voice value added service that allows data information to be sent and received across a mobile telephone network.

2 It uses existing GSM networks to transmit and receive TCP/IP (Transmission Control Protocol/ Internet Protocol) based data to and from mobile devices.

3 GPRS involves overlaying a packet based air interface on the existing GSM network. Thus network architecture of GPRS is similar to that of GSM.

4 GPRS facilitates instant connection whereby information can be sent or received immediately as the need arises, subject to radio coverage. No dial-up modem connection is necessary.

Advantages of GPRS

Speed - GPRS can achieve speed up to 171.2 kilobits per second (KBPS) using all eight timeslots at the same time. This is thrice as fast as older data transmission systems.

Immediacy - GPRS facilitates instant connections whereby information can be sent or received immediately as the need arises, subject to radio coverage. No dial up modem connection is necessary.

New and better applications - GPRS facilitates several new applications that have not previously been available on GSM network due to the limitations in speeds and lengths. GPRS fully enable the internet applications normally used on desktop computers (from web browsing to chat) over the mobile networks.

Difference between CDMA & GSM

	CDMA	GSM
Stands for	Code Division Multiple Access.	Global system for mobile communication.
Storage Type	Internal memory.	SIM (subscriber identity module) card.
Network	There is one physical channel and a special code for every device in the coverage network. Using this code, the signal of the device is multiplexed, and the same physical channel is used to send the signal.	Every cell has a corresponding network tower, which serves the mobile phones in that cellular area.
International roaming	Less Accessible.	Most Accessible.
Frequency band	Single (850 MHZ).	Multiple (850/900/1800/1900 MHZ).
Network service	Handset specific.	SIM specific. User has option to select handset of this choice.
Dominance	Dominant standard in the U.S.	Dominant standard worldwide except the U.S.
Secrecy	More	Less

Block diagram and features of cell phones

Objectives : At the end of this lesson you shall be able to
- **explain the block diagram of cell phone**
- **state the feature and application of cell phone**
- **list the features of smartphone**
- **state the uses of cell phone.**

Block diagram of the cell phone

Now-a-days cell phone become more popular for SMS/ MMS and internet applications due to GPRS feature. After the introduction of Smartphone many applications such as face book, Orkut, Twitter, Various games comes built-in the phone. Now mobile phone has slowly taken the place of laptop for many of the applications.

Fig 1 shows the block diagram of a cell phone with respect to GSM standard.

RF Part

As shown in the figure 1, every mobile phone will have RF part which consists of RF frequency up converter and RF frequency down converter. There are two approaches employed in GSM Mobile phone receiver, i.e. heterodyne or homodyne. The basic component used for frequency conversion is RF mixer.

Antenna

Antenna is the metallic object which converts electro-magnetic signal to electric signal and vice versa. Commonly used antennas in the mobile phone are helix type, planar inverted F type, and whip or patch type. Micro strip based patch type of antennas are popular among mobile phones due to its size, easy integration on the PCB and multi frequency band of operation and supports various GSM bands and also various technologies such as CDMA, LTE, WiMAX (Worldwide Interoperability for Microwave Access) and also WLAN, Bluetooth and so on.

Tx/Rx Switch

As there is only one antenna used for both transmit and receive at different times, Tx/Rx Switch is used to connect both Tx path and Rx path with antenna. Tx/Rx Switch is controlled automatically by DSP (digital signal processor) based on GSM. For FDD (Frequency Division Duplexing) systems diplexer is used in place of switch which acts as filter to separate various frequency bands.

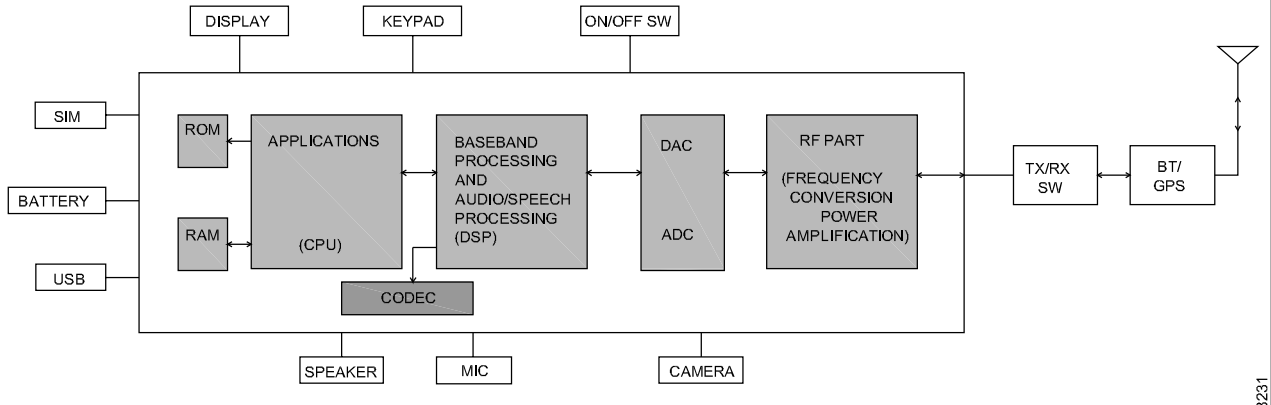
Baseband Part

This part is used to convert voice/data to be carried over GSM air interface to baseband signal. This is the core part which changes for various air interface standards viz. CDMA, Wimax, LT E, and more. For speech/audio, codec is used to compress and decompress the signal to match the rate to the frame it has to fit in. CODEC converts speech at 8 KHz sampling rate to kbps rate for full rate speech traffic channel.

ADC and DAC

ADC (Analog to Digital Converter) and DAC (digital to analog converter) is used to convert analog speech signal to digital signal and vice versa in the mobile handset. At transmit path, ADC converted digital signal is given to speech coder. AGC (Automatic Gain Control) and AFC (Automatic Frequency Control) is used in the receiver path to control gain and frequency. AGC helps maintain working of DAC satisfactorily, as it keeps signal within the dynamic range of DAC. AFC keeps frequency error within limit to achieve better receiver performance.

Fig 1



GSM CELL PHONE BLOCK DIAGRAM

Application layer

It also runs on CPU. Various applications run in GSM mobile phone. It includes audio, video and image/ graphics applications. It supports various audio formats such as MP3, MP4, WAV, RM, JPEG image formats are usually available. It supports video formats e.g. MPEG-1 to MPEG-5.

Operating system

Various operating systems are supported in mobile phone such as Symbian, java, android, RT-Linux, Palm. It runs on CPU of different manufacturers. For time critical application RTOS (real -time operating system) is used.

Battery

It is the major source of power to make/to keep mobile phone functional. There are various types of batteries made of Nickel Cadmium (NiCd), Nickel Metal Hydride (NiMH), based on lithium, Li-ion and so on. Battery comes usually with 3.6 or 3.7 voltage and 600 mAH or 960 mAH ratings. Li-ion is long lasting and lighter, but more expensive.

Connectivity (WLAN, Bluetooth, USB, GPS)

To make data transfer fast enough between mobile phone and other computing devices (laptop, desktop, tablet) or between mobile and mobile various technologies are evolved which include WLAN, Bluetooth, USB, GPS (global positioning system) is used for location assistance and will enable google map to work efficiently.

Bluetooth and wi-fi uses 2.4 GHz frequency band. This band is the most favourite and it is license free band.

Microphone

Microphone or mic converts sound signal variations to electrical signal to couple on the PCB for further processing. Usually in mobile phone mics having different types such as condenser, dynamic, carbon or ribbon.

Speaker

It converts electrical signal to sound signal (pressure vibrations) for human being to hear. This is often coupled with audio amplifier to get required amplification of audio signal. It also tied with volume control circuit to change the amplitude of the audio signal.

Camera

The mobile phone camera feature is available for one to click pictures at various occasions. It is the major specifications in increasing cost of mobile phone. There are various mega pixel cameras for mobile phones are available such as 12 mega pixel, 14 mega pixel and even 41 mega pixel available in smart phones. This has become evident because of advancement in sensor technology.

Display

Displays are used to viewing the various informations. There are various display devices used in mobile phone such as LCD (liquid crystal display), TFT (Thin-film transistor) screen, OLED (organic light emitting diode), TFD (thin film diode), touch screen of capacitive and resistive type.

Keypad

Earlier days keypad was simple matrix type keypad which contains numeric digits (0 to 9), alphabets (a to z), special characters and specific function keys. These has been designed for various applications such as accepting call, rejecting call, cursor movement (left, right, up, down) dialing number, typing name/sms/mms and so on. Now-a days keypad has been removed from the phone design and it has become part of mobile phone software. It loops on the display screen itself which can be operated by user using touch of a finger tip.

Features

1 **Accessories -** Manufacturers offer a number of accessories that can make phones even more convenient to use, such as hands-free options (headsets, ear buds, bluetooth hands free devices), extra batteries, and portable charging adapters.

2 **Bluetooth -** This wireless communications technology links compatible for mobile phone datas to transfer.

3 **Caller ID -** A feature that displays the name or number of the calling party on the phone's display when an incoming call is received.

4 **Digital Camera -** Allows to take digital photos and transmit the images wirelessly.

5 **Display -** Prices increase along with display sizes. However, a larger display is a virtual requirement for wireless internet users. Wireless web use should consider a smartphone of larger and color screen for viewing images or web-surfing then.

6 **GPS -** Some selected phones offer GPS, or global positioning and navigation functions. This feature can be especially useful to those who often travel.

7 **International Support -** Travellers may want to investigate a world phone, compatible with the respective frequencies (GSM or CDMA) most commonly used in Europe, Asia, and North America. Users want international access to make sure to research which networks are used in areas they will be travelling, as GSM and CDMA are not compatible.

8 **Multimedia -** To download digital ringtones to download and play MP3s, and stream video.

9 **Organizer Applications -** Even basic cell phones often have organizer applications, such as calendaring.

10 **SIM Card -** Number of SIM slots are available with new generation cell phone.

11 **Smartphone (Palm or Pocket PC) -** Devices, with computing, Internet, and networking features, are often referred to as smart phones.

12 **Speakerphone -** Persons such as drivers who want to keep their hands free can buy phones with built-in speakerphone capability.

13 **Text Messaging -** Text messaging allows short text messages to be received and displayed on the phone.

14 **Video Recording**

15 **Voice Dialing -** This feature lets users speak a name to dial a number.

16 **Voice Mail -** A feature that supports audio messages from callers. Users can leave spoken messages for

one another and listen to the messages by executing the appropriate command. This is often a standard feature that comes with a mobile phone service.

17 **Weight -** Mobile phone manufactures consistently streamline their products; however, some phones are heavier and more awkward than others.

18 **Wi-Fi -** Wireless fidelity is technology for providing a local area network that allows compatible devices to access data on the network or other networks such as the internet.

19 **Infrared (IR) PORT -** A wireless data communications connection between 2 devices that uses an Infrared signal. The 2 devices must have line- of - sight position.

Smart phone

A cell phone having advanced computing ability through the use of an application software is called a smart phone. It contains the following additional stages.

1 Digital camera module

2 Internal and external memory cards

3 Radio tuner

4 CPU and Computer OS software

5 Appointment calendar (Outlook synchronization for faculty and staff through ActiveSync)

6 Address book

7 MP3 player

8 Web browser

9 E-mail access, in addition to text messaging

10 Mini-keyboards or onscreen keyboards

11 Voice dialing

12 Bluetooth

13 Character recognition (allowing for handwritten input)

14 Synchronization of information with desktop or laptop computers

15 Voice recording

16 Digital camera

17 Video recording

18 GPS

19 Microsoft Office (MS) compatible applications (Native with Pocket PC operating systems; Palm operating systems may require third-party software)

Main uses of cell phones

The most popular uses and applications of mobile phones are:

1 Voice calling - Talking on the telephone.

2 Voice mail - Callers can leave a message if your phone is busy or turned off.

3 E-mail - Send and receive e-mails with other e-mail addresses.

4 Messaging - Send and receive text, picture and instant (chat) messages with other mobile phone users and e-mail addresses.

5 Mobile content - Get news, weather, sports, financial and other information.

6 Gaming - Play games that are downloaded to your handset or played online on the Internet.

7 Personalize your phone - to your own style by adding custom ringtones, ringback tones, face-plates, themes, background images, icons, voice greetings and screen-savers.

8 Play music - using an audio (MP3) player to play downloaded tracks or listen to radio.

9 Take photos or videos - with a built-in camera. Then send the image files to others.

10 Download and view images - with a photo (JPEG) viewer or video (MPEG) player.

11 Organize personal information - using a calendar, clock, alarm, address book, task manager or memo pad.

12 Shop - Make retail purchases from Web-based stores (e-commerce).

13 Bank - Manage your money using an e-wallet.

14 Location-based services - Maps & directions. Retail store directory. Track persons, cars, pets, etc.

15 Business Uses for Mobile Phones

16 For the Mobile Professional

17 Mobile Business Applications

18 Small Business

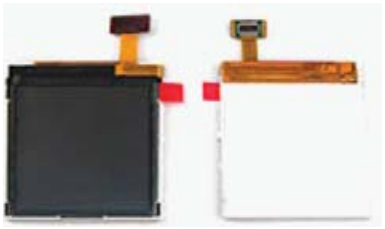
Parts of mobile/cell phones and their functions

Objectives : At the end of this lesson you shall be able to
- **state the different parts used in a cell phone**
- **state the purpose of different components in cell phone**
- **explain the faults occur in different parts of cell phones.**

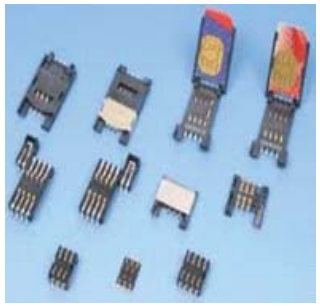
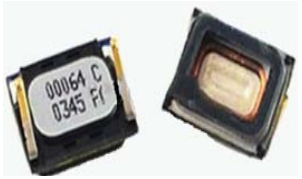
Parts of a cell phone and their function

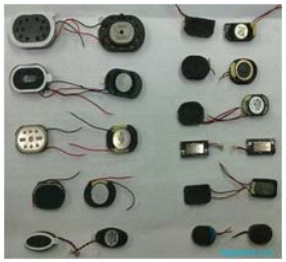
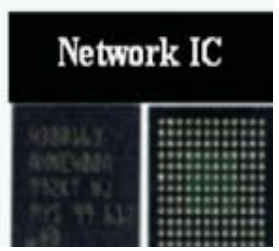
There are all kinds of parts and electronic components in a mobile cell phone. These parts and components can be divided into Big Parts and Small Parts. This lesson explains all about big parts and components in a mobile cell phone and their function.

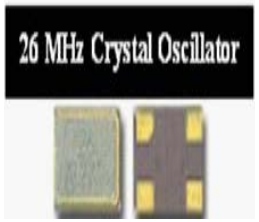
When learning how to repair a mobile cell phone, it is important to identify its parts and understand their function. PCB of a mobile phone is divided into 2 sections namely: Network Section; and Power Section.

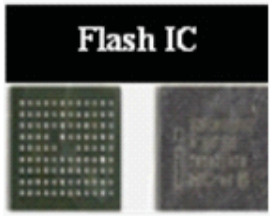
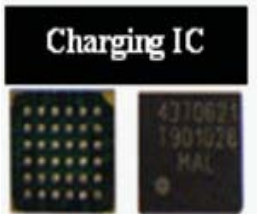
Sl.No.	Parts Name	Function	Parts	Fault
1.	Display (LCD) Liquid Crystal Display	This component that visualize the operation of a mobile phone. It is made of glass with tiny crystal pixel. That imitate the light source of certain information such as text and images. Display picture will be made and LCD screen and for lighting using backlight or edge LED.		Ink display, Line display, Half display, Mirror display, Blink display, Blank Cracked Display Screen
2.	Touch Screen (Touch pad)	Touch screen are made of flat thin glass which is designed with high capacitance or resistive. It navigates everywhere on LCD screen by using a finger or a stylus pen to switch through certain feature on a mobile phone handset.		No touch working, crack of such bounce of touching portion.
3.	Keypad	A keypad is a set of buttons or keys bearing digits, symbols and/or alphabetical letters placed in order on a pad, which can be used as an efficient input device. In smart phone, keypad will display graphically on the screen. It can have option for selecting numeric or aphanumeric etc. keyboards. We can also select language based keyboard.		

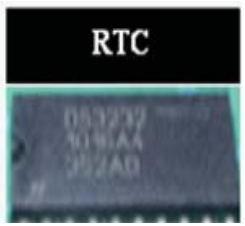
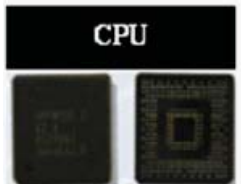
4.	Keypad Tips	It is used to switch between the numbers and the directional functions of the keypad, when press the Num Lock key on the keyboard.		Text are not able to typing, Randomly buttons are not working. Even able tomake a call.
5.	Battery connectors	Battery terminals are the electrical contacts used to connect a load or charger to a single cell or multiple-cell battery.		Not charging. In between charging.
6.	Charging connector	Charging connectors are interfaces used in charging while charger plugging, USB and data cabels. Various mobile products also have different charging connector designs.		Not charging. In between charging.
7.	Battery	A battery is used to provide power supply to the PCB circuits and components.		Battery backup is not good. Cell phone not getting ON.

8.	Sim Slot	This is an interface that acts as a holder and connects the sim card to PCB circuit available in different sizes like micro, nano sim slots.		No insertion of sim Network not available Invallid sim
9.	Memory card slot	This is interface that acts as a holder and connects the memory card to PCB circuit.		Insert memory card No space
10.	Speaker	The speaker converts electrical signal into voice. It is also called an earpiece.		Not able to hear the voice of the calling person during a call.
11.	Mic	A mic converts voice into electrical signal. It is also called microphone and mouthpiece.		Voice will not be heard by the person you are talking to. Not able to record voice.

12.	Ringer / Buzzer	A ringer, also called a loud speaker through which you hear ringtone and music. During a call, when you activate the loud speaker, the louder voice which you start hearing also comes from the ringer. It is also called a buzzer in basic low-end mobile phones.		No ring tone music or loud speaker's voice during a call
13.	Antenna Switch	It is found in the Network Section of a mobile phone. In GSM sets it is found in white color and in CDMA sets it is found in golden metal. It searches network and passes forward after tuning.		If the Antenna Switch is faulty then there will be no network in the mobile phone.
14.	P.F.O	It is found near the Antenna Switch in the Network Section of the PCB of Mobile Phone. It is also called P.A (Power Amplifier) and Band Pass Filter. It filters and amplifies network frequency and selects the home network.		If the PFO is faulty then there will be no network in the mobile phone. If it gets short then the mobile phone will get dead.
15.	RF IC / Hagar / Network IC	This electronic component found near the PFO in the Network Section of a Mobile Phone. It is also called RF signal processor. It works as transmitter and receiver of audio and radio waves according to the instruction from the CPU.		If the RF IC is faulty then there will be problem with network in the mobile phone. Sometimes the mobile phone can even get dead.

16.	26 MHz Crystal Oscillator	It is found near the PFO in the Network Section of a Mobile Phone. It is also called Network Crystal. It creates frequency during outgoing calls.		If this crystal is faulty then there will be no outgoing call and no network in the mobile phone.
17.	VCO	It is found near the Network IC in the Network Section of a Mobile. It sends time, date and voltage to the RF IC / Hager and the CPU. It also creates frequency after taking command from the CPU.		If it is faulty then there will be no network in the mobile phone and it will display “Call End” or “Call Failed”.
18.	RX Filter	It is found in the Network Section of a Mobile Phone. It filters frequency during incoming calls.		If it is faulty then there will network problem during outgoing calls.
19.	ROM	It is found in the Power Section of a Mobile Phone. It loads current operating program in a Mobile Phone.		If ROM is faulty then there will software problem in the mobile phone and the set will get dead.

20.	RAM phone program	It is found in the power section of a mobile phone. It sends and receives commands of the operating in a mobile phone.		If RAM is faulty then there will be software problem in the mobile and it will get frequently get hanged and the set can even get dead.
21.	Flash IC	It is found in the Power Section of a Mobile Phone. It is also called EEPROM IC, Memory IC, RAM IC and ROM IC. Software of the mobile phone is installed in the Flash IC.		If Flash IC is faulty then the mobile phone will not work properly and it can even get dead.
22.	Power IC	It is found in the power section of a mobile Phone. It takes power from the battery and supplies to all other parts of a mobile phone.		If Power IC is faulty then the set will get dead.
23.	Charging IC	It is found in the power section It takes current from the charger and charges the battery.		If Charging IC is faulty then the set will not get charged. If the Charging IC is short-circuited then the set will get dead.

24.	RTC (Simple Silicon Crystal)	It is Real Time Clock and is found in the Power Section near Power IC. It is of long shape. It helps to run the date and time in a mobile phone.		If RTC is faulty then there will be no date or time in the mobile phone and the set can even get dead.
25.	CPU	It is found in the Power Section. It is also called MAD IC, RAP IC and UPP. It is the largest IC on the PCB of a Mobile Phone and it looks different from all other ICs.		It controls all sections of a mobile phone.
26.	Logic IC / UI IC	It is found in any section of a mobile phone. It has 20 pins or legs. It is also called UI IC and Interface IC. It controls Ringer, Vibrator and LED of a mobile phone		If Logic IC / UI IC is faulty then Ringer, Vibrator and LED of mobile phone will not work properly.
27.	Audio IC	It is found in Power Section of a mobile phone. It is also called Cobba IC and Melody IC. It controls Speaker and Microphone of a mobile phone.		If Audio IC is faulty then Speaker and Microphone of a mobile phone will not work and the set can even get dead.

Data transfer among phone, internal and external

Objectives : At the end of this lesson you shall be able to
- **differentiate between internal and phone memory**
- **describe SD card memory**
- **explain the data transfer between phone memory and S.D card meory**
- **explain how to interface the cell phone/smart to the PC and transfer data.**

Internal Storage

There are three types of memory capacities in our smart phones these days: Internal, Phone and External. The first two are often confused for each other while the third is still understood as SD card storage.

Internal memory used for installing the applications (the operating system) and data. Applications are installed in this storage and the personal data such as text messages, contact lists, email settings and the likes are stored on this. This is considered to be quite sensitive information and this is not accessible to user. Whenever the phone is reset to factory settings, all this storage gets erased. This memory is reserved for the operating system and personal data. It will never show up whenever phone is connected to computer.

Phone Storage

This is the storage that is available to user. This is the storage that user get from the phone itself. Games and applications are installed in this one and it is the default memory for storing pictures, movies, songs and so on. User can access it when the phone is connected to computer.

When use most of internal storage, user will get a notification for low storage, asking to delete some files, even when user have most of phone storage empty. This message will be triggered by a system file which stores its data on Internal Storage. If user attempt to download more apps, they will be housed on phone storage. So user can store apps on phone storage as well. It can also disable apps which prompt low storage message due to lack of storage space to refresh their app data.

External Storage

It is the external storage capacity of phone. It depends on the compatibility of the memory card slot and to what extent is it supported. In simpler terms, it is the storage which can be removed easily by user (memory card) and can be used for storing pictures, music, videos and many more. It may or may not be able to install applications on it. This is because some manufacturers allow for it while some don't. To an extent, even user's cloud storage can be categorized as external storage.

Data transferring

The data in the cell phone is possible to transfer from phone to SD memory or PC and vice versa. Even we can transfers the same application (Apps) stored in phone to SD card for improving performance. Data transferring to/ from cell phone.

1 Phone to SD card

2 Phone to PC

- i Using data cable
- ii Using card reader
- iii Using wi-fi syncing
- iv Using bluetooth
- v Using e-mail
- vi Using cloud storage

Application (App) transfer

Apps are transferable from phone memory to SD and vice versa for improving performance and using memory efficiently. This is possible in Android base phones mostly. This option is available at settings and application manager. In application manager, consisting a tab for moving data. We can also delete the application by uninstalling the app.

Data transfer between phone and SD memory

The data or file in phone or SD card can inter-transferable in the cell phone. This can be achieved by simply selecting and copying the data and pasting folder view options are need to get by installing apps. The new folder can create by simply selecting options.

Data transfer between phone and PC (Using data cable)

There are so many methods and techniques for transferring data. In those, using data cable is the easiest method.

In this, data cable is connected between PC and phone. Most of the cases PC will detect the phone as a memory devices. In some cases need to download the supporting file from internet. It need to permit the PC to access phone for accessing data. This can be automatically asks when the phone is connected to PC.

The data can copy or clag from phone to PC and vice versa, as like memory card (Pen drive).

Data transfer using card reader

The phone data can also be transferred by using card reader. For this we need to ensure the data of phone is available in SD card memory. For this transfer data from phone to SD card by copy and paste. Need to switch OFF the phone before removing SD card. SD card can also be removed by unmounting the external memory in phone setting at memory section. The data in the memory is transferable by using card reader as pen drive in PC.

Data transfer using wi-fi

If the PC can support wi-fi (in built), phone can transfer data simply by enabling wi-fi network. For this, some softwares for PC and apps like "SHARE IT" for phone must be available in internet. For connecting wi-fi to the PC, external wi-fi cards are available in the market. This is faster than bluetooth method.

In this method, there is no need of any physical connection between PC and phone. It is suitable for large files like video, audio, etc.

Data transfer using bluetooth

It is also similar to the wi-fi method. But for this method there is no special software or apps are needed to install. Most of the phones and PCs are supporting bluetooth. In some cases PC needs bluetooth connecting device for enabling. It is slower than wi-fi method. But it is cost effective. It is suitable for small size of files like photos, text, etc.

Data transferring using e-mail

This is a technique used for transferring data. This method mostly used for long distance data transfer. In this simply mailing the required data file to self address or some one address and this can be downloaded by opening email from PC or phone. But this method requires internet connection. It is having limitations of file size due to email support. This can overcome by cloud storage method.

Data transferring using cloud storage

This method is similar to e-mail method. But, here instead of email account, using cloud storage account. For this, so many third party cloud store operators are available in internet. They are offering large amount of data space for file storage. For data transfer, need to install cloud storage software in PC and App in phone. We can simply transfer data by upload method and downloading. This method also required internet connection.

Formatting and the need for formatting of cell phones

Objectives : At the end of this lesson you shall be able to

- **explain meaning of formatting of cell phone and the need for formatting**
- **define virus**
- **explain the signs of a phone infected by virus**
- **protect the cell phone from virus**
- **list the various steps to be followed to keep the handset secure from different malwares.**

Formatting of mobile phone

Formatting a cell phone means erasing or deleting all the stored data and information like contacts, images, multimedia files, etc from the phone memory. Data stored in the memory card is not deleted, it will remain safe during formatting.

In formatting the cell phone the operating system like iOS, symbian, Windows or Android are not at all to be reinstalled unlike in computers. The OS is not affected and it remains intact.

The procedure where we have to reinstall the OS is called flashing in cell phone repair jargon. Which is very much different from formatting. So let us go ahead with formatting a phone and not get confused with flashing.

In general the process of formatting is usually done when there is any problem due to infection by a virus.

Virus

A mobile virus is nothing but a small software code written by some one to corrupt or damage the information stored in the mobile system.

The signs that the phone is infected by virus are:

1 **Slow Functioning :** The entire handset will become very slow. If you open the menu, it will load after 2-5 seconds. Also all the software's and apps will take double the time to open. In short, the handset will stuck!

2 **Frequent Freezing :** The device will freeze very frequently. It will get stuck all of a sudden and hang. Sometimes the handset will not even switch OFF. It has to restarted or remove the battery and insert again.

3 **Switching Off Automatically :** Many times, the device will switch off automatically without informing. This will happen for more than 3-5 times a day!

4 **Restarting:** Sometimes instead of switching off automatically, it will restart frequently.

5 **Not Booting Properly :** Sometimes, the virus can corrupt the OS very badly, so that the cell phone will not boot properly i.e. it will display a blank screen or it will get stuck at the logo when switched on. It will not proceed further.

6 **Failure of some apps :** Some of the applications will not function properly.

Protect a mobile phone from virus

A virus can infect your mobile phone the same way that it infects computer. It will do the same damage like what a computer virus can do! It becomes very difficult to operate when it gets infected with any malware, spyware, trojan or any other virus whether it is an android, Apple iphone, Blackberry or any other smartphone or a tablet. It is important to clean the infected phone from all badware before it spreads. Protecting cell phone from virus is shown in Fig 1.

Fig 1

Before knowing how to protect one should know the sources from which viruses can come and also take precautions so that it does not infect the gadget again. The best precaution against viruses is to install a reputed and updated antivirus program. If not, then one may end up getting the phone infected very soon.

The sources from which viruses can come in to the device are: (Fig 2)

Fig 2

1 **Internet surfing:** This is the most common source, especially if the user is visiting unknown and untrusted sites. The phone may most likely to get infected, if the user visit untrusted websites.

2 **MMC card:** If you insert your memory card into a virus infected gadget and then insert it back into your phone, your handset will most likely get infected. Also do not put any other MMC card into your device, because if the other MMC has virus, it will spread into your device as well.

3 **Bluetooth / Wi-Fi / Hotspot:** While transferring files to and from one phone to the other via bluetooth, WI-Fi or hotspot, when accept files from other phones, ensure that the user antivirus scans the incoming files before opening them.

It is easy to keep your handset safe and secure from different malwares, if you follow these simple steps:

1 **Install antivirus program and keep it updated:** Always keep the bluetooth switched-off unless required. Or it is preferable to keep the handset to hidden mode unless it needs to be visible.

2 **Keep your bluetooth switched-off:** Always keep the bluetooth switched-off. If by fluke, the phone has kept on, do not accept any files from unknown sources. Still if the user have got any file by mistake NEVER OPEN SUCH FILE AS IT IS MOST LIKELY A VIRUS. Just delete the file.

3 **Don't visit untrusted websites:** While surfing the internet, only visit the most trusted and reputed websites. Also if you have visited any unknown website, it's ok until you find it to be a suspicious one.

4 **Don't download from untrusted sources:** Surfing unknown websites is not as risky as downloading content from them. Be careful of downloading any file especially if you find the website to be a suspicious one. If you have downloaded anything, please do not open that file and just delete it.

5 **Be careful of the memory card:** The MMC have to be used carefully. So do not put your MMC in another handset or anybody's MMC into your handset. It might get infected easily and spread very fast.

Setting-up flashing files

Objectives : At the end of this lesson you shall be able to
- **define flashing of a cell phone and effects of cellphone after flashing**
- **define flashing files**
- **explain the availability of flashing files.**

Flashing

Inside the cell phone handset, software is used to run and control its different functions. Software makes the mobile handset to function in a good and proper manner.

During the normal day to day operation, this software could become corrupt and the phone will start to function in some unpredictable manner.

Phone could completely stop working or will start to show some errors.

In this type of situation Universal Flash Storage (UFS) device can be used to reload the mobile phone with the correct software, so that the phone will once again start working properly.

This process of loading the mobile phone with correct software using the UFS device is called “Flashing”.

This process is also known as “Software Repairing” of the mobile phones.

During the flashing process the UFS device sends some files to the cell phone. These files replace the corrupted/ damaged file on the mobile phone and the phone will return to its proper state. This process is similar to the way operating system is reinstalled on a computer system when it becomes corrupt.

Flashing files

Files sent by the UFS device to the mobile phone are called flashing files. These files contain the software required for proper operation of the mobile phone. Different functions provided by the mobile phone depend on these software. These files could also contain ringtones, wallpapers and various operating commands.

When the flashing is done, the UFS device first removes existing data and files from the mobile phone and then the new data and files are written.

Flashing files supported by some mobile are:

1 Nokia - MCU, PM, PMM, WUG, SLD, FBI, EEP, PP, MLF, RPL.
2 Samsung - MCU, AXF, OGM, MEL, S3, TFS, CLA, SRE.
3 Ericsson - MCU, MOD, GDF, PDA, LANG.
4 Sony Ericsson - MCU, CUST/FS, GDF.
5 Motorola-Acer - FLX, MCU, LP.

Availability of flashing files

When one buys UFS package, with the UFS box set of flashing cables and flashing software CDs are also provided. The number of flashing cables and software received with the UFS package depends on the make/ brand of the UFS package and also on how latest is the package being purchased.

For example, sometimes back one used to get 38 to 55 flashing cables with the UFS package, but currently around 60 flashing cables are provided with the latest UFS-3 package.

One also gets around 25 CD with the latest UFS-3 package. These CDs contain driver for UFS package, flashing software and flashing files for different make/ model of mobile handsets.

Current UFS-3 device can be used to flash/repair more than 400 models of Nokia, Samsung, Sony Ericsson, LG, Sharp, Motorola etc., make of handsets.

Flashing files required to flash/repair these mobile handsets are provided on the CDs provided with the UFS package. Many of these flashing files are provided in compressed ZIP format on the CD.

Compressed files are files with file names ending with ZIP, LZH, ARJ, or ARC, depending on how they were created. One need to decompress/extract these files before using them, this decompression process is commonly known as “Unzipping the file”.

Before using the ZIP files on the CD, you need to extract them to some folder on the hard disk drive. For this you need WinZip or WinRar program installed on your computer.

Extracting these files on the hard disk drive will consume a lot of hard disk space, so you will require a computer with large hard disk drive for mobile flashing purpose. If you have limited hard disk space then you can extract files of only those mobile handsets which you require frequently. Other files can be extracted as and when the need arises.

Flashing files of some of the mobile sets needs to be installed before using them. When looking at the folder on flashing CD, if you see application files, instead of ZIP files then that file needs to be installed.

Process to extract or install these files are explained later in this book.

One can also copy all the CDs received with the UFS device to some folder on the hard disk drive, and install/ unzip them as and when required. This will be helpful if you misplace the CDs or CDs become corrupt due to any reason (scratch etc.).

Various locks of cell phone

Objectives : At the end of this lesson you shall be able to
- **state the need of cell phone locks**
- **explain different types of lock and unlock functions**
- **describe lock and unlock functions in your cell phone.**

Cell phone locks

Following are some of the locks which can be used in cell phone. The various lock of the mobile handset is used for safety purpose.

1 Keypad Lock
2 Phone Lock
3 Security Lock
4 SIM Lock

Keypad Lock

As the name suggests, this lock will locks the handset’s keypad, one will not be able to use the keypad for any type of number or text entry.

Even when the keypad lock is active one can answer incoming call by pressing the keypad keys.

Different handsets use different method to enter into keypad lock mode and to remove the lock. When the phone is in keypad lock mode, pressing of any key on the keypad will display a message on the screen, explaining the process to unlock the keypad.

Phone Lock

In this mode the handset cannot be used to make/receive any call, even though the keypad stays active during this lock.

In this mode, when the handset is switched on, it asks for an unlocking code known as PIN or Personal Identity Number". If this PIN is entered only it will work.

Security lock

Security lock is used to lock all the functions of the mobile handset. When the security lock is on, the phone asks for the PIN code when it is switched on.

Some handset may ask for the PIN number even when the SIM card of the phone is changed.

This facility is not provided on all handsets.

SIM Lock

When one buys a mobile handset from mobile service provider under some scheme, the provider may lock the handset with the SIM card in the phone.

This prevents the user from using the handset with SIM card from some other service provider.

Currently, phones can be locked to accept only SIM cards from one or more of the following:

1 Countries (your phone will work in one country, but not another)

2 Network/Service providers (e.g. T-Mobile, Movistar,Vodafone etc)

3 SIM types (i.e. only specific SIM cards can be used with the phone).

Unlocking technology

A handset can be unlocked by entering a special code, or in some cases, over-the-air by the carrier.

Typically, a locked phone will display a message if a restricted SIM is used, requesting the unlock code.

For example, in some mobile phone, "Insert correct SIM card" will appear on the phone's display if the wrong SIM is used. Once a valid unlocking code is entered, the phone will display "Network unlocked". In some cases, the phone will simply display a message explaining that it is locked.

The code required to remove all SIM locks from a phone is called the master code or network code key.

The unlock code is verified by the phone itself, and is either stored in a database or calculated using an obscure mathematical formula by the provider.

In some other mobiles embed a random number in the handset's firmware that is only retained by the network on whose behalf the lock was applied. Such phones can often still be unlocked, but need to be connected to special test equipment that will rewrite that part of its firmware where the lock status is kept.

Most phones have security measures built in its software that prevent users from entering the unlock code too many times, usually four. After that the phone becomes "hard-locked" and special unlocking equipment has to be used in order to unlock it.

The main reason to unlock a phone is to be able to use it with a different SIM card. For example, when travelling abroad it is usually cheaper to temporarily use a foreign network, for example with a prepaid subscription. Contrary to some beliefs, an unlocked phone can't access extra cell phone towers or give free phone service. All it can do is accept other SIMs.

Unlocking via computer

One of the most popular way of phones are unlocked is using the USB, RS-232 or LPT port of a computer using software usually written specifically for the model of phone being unlocked. In some cases, special "unlocking clips" or "unlocking boxes" are used which re-program the software that controls the phone, removing the SIM lock. However, such clips are usually very expensive.

Unlocking via Mail

Some companies have begun to offer a "mail-in" service, such as travelinsider.com. These services allow the user to send their phone in and have it sent back in an unlocked condition.

Regulations on unlocking

Unlocking a phone without the permission or unlocking code from the provider is usually in breach of the agreement with the provider, though most countries do not make specific laws prohibiting the removal of SIM locks.

Security lock

A security code is for the safety and security of your mobile phone. If you activate it in the security settings, the phone will ask it while booting it every time or when you lock the keypad and want to unlock the keypad.

The default security codes of major brands of cell phones are as follows:

Samsung : 0000 / 00 00 00 / 00 00 00 00

Nokia : 12345

All other brands of cell phones : 0000 / 1234

Chinese brands : 1122 / 0000 / 1234 / 4321

So it is advisable to change the security code for safety. So if you change the security code, you should never forget it. If you forget and put the wrong security code, the handset will not accept it. So if you forget it and are unable to put the right code, your phone will be considered as locked. You will have to get it unlocked by special software.

Internet on cell phone and IMEI number

Objectives : At the end of this lesson you shall be able to
- **define internet and working of internet**
- **define to acces the internet**
- **explain some applications of internet from cell phone**
- **define the IMEI NO and its importance**
- **list the precaution to maintain the cell phone.**

Internet

The Internet is a decentralised, international network of networks.

Devices such as computers, mobile phones can connect each other and form a network. The networks are connected to each other through electronic, wireless and optical networking technologies.

Multiple interconnected networks form the Internet.

Working of Internet

The Internet works based on protocols which handle chunks of data, known as "packets".

Various types of hardware, such as an ethernet network card or a modem, convert our device's binary packet data into network signals and then back into packet data.

Internet Protocols(IP) are used to direct packets to a specific computer or server.

Transmission Control Protocols (TCP) are used to direct packets to specific applications on a computer using a port number.

Accessing the Internet

We access the Internet because our router connects our device to an Internet Service Provider (ISP).

Internet Service Providers (ISPs), such as Verizon, AT&T and Comcast, give us access to the Internet through a range of technologies.

A single device is assigned an address when it connects to the Internet: an Internet Protocol (IP) address. This address distinguishes our device in the network from all other devices.

However, our national ISP can only connect us directly to servers located in our country. If we want to connect to servers located in a different country, then we need that country's ISP to connect us to those servers.

Protocols translate the text of our message into electronic signals, transmit it through the network and translate it back into text once it reaches another device.

Data plan

Phones today have lots of features through the accessing of internet. You can check email, get directions, and even chat over video. Ultimately, you can stay connected at all times. But in order to do so, your device needs to be able to connect to the Internet to send and receive data.

If you're somewhere that offers Wi-Fi (like your house), staying connected is as simple as logging on to the server. However, if you want to stay connected on the go, you're going to need a data plan to give you access to your provider's data network.

Navigation

GPS is a wonderful way to get around town. However, those map apps definitely use data. In order to find your destination, note your current location, and give you turn-by-turn directions, your GPS app needs to be connected to the Internet.

Uploads

In order to upload and post a picture or video to social media, you need to first be able to access it, which requires an Internet connection. While you can draft posts offline on some channels (like Facebook), your device needs to be connected to the Internet through Wi-Fi or your cellular data network in order to actually publish.

Downloads

This is the process of receiving data over the internet. It is the opposite of uploaders.

IMEI number

IMEI is short for International Mobile Equipment Identity and is a unique number given to every single mobile phone, typically found behind the battery. The IMEI is only used for identifying the device and has no permanent or semi-permanent relation to the subscriber. Instead, the subscriber is identified by transmission of an IMEI number, which is stored on a SIM card that can be transferred to any handset. However, many network and security features are enabled by knowing the current device being used by a subscriber

IMEI numbers of cellular phones connected to a GSM network are stored in a database (EIR - Equipment Identity Register) containing all valid mobile phone equipment.

When a phone is reported stolen or is not type approved, the number is marked invalid.

The number consists of four groups that look similar to this:

AA-BBBBBB-CCCCCC-D

AA - BBBBBB - CCCCCC - D

TAC Serial # Checksum

The Type Allocation Code (TAC) is the initial eight-digit portion of the 15-digit IMEI code used to uniquely identify wireless devices. The first two digits represent the country

code. The second group of numbers identifies the manufacturer. The third set is the serial number and the last single digit is an additional number (usually 0).

For example 99-000033-792410-8:

- 99 is country
- 000033 is manufacturer
- 792410 is the serial number
- 8 is the checksum value

How to check IMEI Number for your mobile: *06#

Mobile phone maintenance

Mobile phone is delicate device and needs care for its proper functioning. Here are the common measures to keep the mobile phone in good condition.

- Do not keep mobile phone in wet area or use it with wet hands. Moisture can cause non-repairable internal corrosion of parts.
- Do not drop the phone or damage the connection points.
- Do not over stress the phone. It may damage the display.
- Do not keep the phone near heat generating devices. High temperature in a car can damage its electronics.
- Do not over charge the battery. Charge the battery only its charge status goes below 50 percent.
- Prevent cloning.

Current technology of cell phones

Cell phone has the follwing special features;

a The fingerprinrt or iris scanners.

b New facial recognition technology which scans the contours the person face and head.

c Unbreakable and foldable phones - The display screens are flexiable and hence it is foldable.

d Improved power backup - using nanobatteries, hydrogen fuel cells and solar power the power backup time to the cell phones can be improved. The future phones battery can also be charged improved. The future phones battery can also be charged faster by wi-fi with the help of wireless signals and no need of conventional power source/power bank.

e Contextual intelligence(also known as practical intelligence) - The phones will use sensors to get data about your physical surroundings and conditions, use saved information about you along with the contextual intelligence technology to make decisions for you even before you thought of the question.

f Depth-sensing cameras-It provides 3D printing and 3D scanning facility as shown in Fig.1.

Fig 1

g Multi-screen capabilities or screen casting - To connect and share the screen of the smartphone with the tablet, television or projector with no limitations imposed by different platforms or OS, and irrespective of make or form as shown in Fig.2.

Fig 2

Fig 3

h Infrared support - Turn the smartphone into universal to operate the electronic and electrical gadget using remote control as shown in fig.3. When this remote control goes missing, we can give phone call and find out the remote/Cell phone.

i Dual recording - Existing smartphones come with front and rear cameras but only one of them works at a time. Future smartphones may have better camera support to allow simultaneous recording using both cameras.

j Besides the above features, there are numerous user friendly apps with encriped security & hardware are

developed to use the smartphone to function like & special device for a dedicated purpose also.

Advanced features in cell phones

Current technology cell phones has the following special features:

a The fingerprint or iris scanning.

b New facial recognition technology which scans the contours the persons face and head.

c Unbreakable and foldable phones - The display screens are flexiable and hence it is foldable.

d Improved power backup - using nanobatteries, hydrogen fuel cell phones can be improved. The up time to the cell phones can be improved. The future phones battery can also be charged faster by wi-fi with the help of wireless signals and no need of conventional power source/power bank.

e Contextual intelligence (also known as practical intelligence) - The phones will use sensors to get data saved information about you along with the contextual intelligence technology to make decisions for you even before you thought of the question.

f IoT Technology - The smart phone can be used as control device for IoT (internet of things) platforms like, to enable remote health monitoring and emergency notification systems, industrial controls, house hold appliances/gadgets/security monitoring and controlling, etc.

g Depth - sensing cameras - It provides 3D printing and 3D scanning facility as shown in fig.1.

Fig 1

h Multi-screen capabilities or screen casting - To connect and share the screen of the smartphone with the tablet, television or projector with no limitations imposed by different platforms or OS, and irrespective of make or form as shown in fig.2.

Fig 2

i Infrared support - Turn the smartphone into universal remote controlto operate all the electronic and electrical gadgets using remote control as shown in fig.3. When this remote control goes missing, we can give a phone call and find out the remote/cell phone.

j Dual recording - Existing smartphones come with front and rear cameras support to allow simultaneous recording using both cameras.

Besides the above technical features, there are numerous user friendly apps with encrypted security and hardware are develped to use the smart phome accordigly to function like a special device for a dedicated purpose also.

Fig 3

ANNEXTURE

Mobile Phone Related Abbreviations

In this article we expand common, and not so common, Mobile and Mobile Telephony abbreviations.

AC = Authentication Center;

ACRE = Authorisation and Call Routing Equipment;

A - GPS (also: AGPS) = Assisted - Global Positioning System;

AMOLED = Active Matrix Organic Light Emitting Diode;

AMPS = Analogue (Also: Advanced) Mobile Phone System;

ANS = Advanced Network Services;

App(s) = Application(s);

BS = Base Station;

BSC = Base Station Controller;

BSS = Base Station System;

CAMEL = Customised Applications (for) Mobile-network

Enhanced Logic (GSM / ETSI);

CDMA = Code Division Multiple Access;

(C)EIR = (Central) Equipment Identity Register; Blocked and Blocking and IMEI And Phone Identity.

CMAS - Commercial Mobile Alert Service;

CSIM = CDMA Subscriber Identity Module;

D-AMPS = Digital Advanced Mobile Phone Service;

EDGE = Enhanced Data (for) GSM Evolution;

EE = Everything Everywhere (Merger between T-Mobile and Orange);

EGSM = Extended Global System (for) Mobile;

EIR = Equipment Identity Register;

EMS = Enhanced Message Service;

ESN = Electronic Serial Number;

ETSI = European Telecommunications Standards Institute;

EUIMID = Expanded User Identity Module Identifier;

FAC = Final Assembly Code; IMEI And Phone Identity

GMSC = Gateway Mobile Switching Center;

GPS = Global Positioning System;

GPRS = General Packet Radio Services;

GPU = Graphics Processing Unit;

GSM = Global System (for) Mobile Communication;

GSMA = Global System (for) Mobile Association;

GSMS = GPRS Short Message Service;

GTP = GPRS Tunnelling Protocol;

ICCID = Integrated Circuit Card Identifier;

IMEI = International Mobile Equipment Identity;

IMEISV = International Mobile Equipment Identity Software Version;

IMSI = International Mobile Subscriber Identity;

IMT2000 = International Mobile Telecommunications 2000;

LAI = Local Area Identity;

LTE = Long Term Evolution;

MAG = Mobile Access Gateway;

MAP = Mobile Application Part;

ME = Mobile Equipment;

MEID = Mobile Equipment Identifier;

MCC = Mobile Country Code;

MIM = Mobile Instant Messaging;

MIN = Mobile Identification Number;

MMS = Multimedia Message Service;

MNC = Mobile Network Code;

MNO = Mobile Network Operator;

MNP = Mobile Number Portability;

MP3 = MPEG-1 Audio Layer-3 (Moving / Motion Picture Expert Group 3);

MP4 = MPEG-4 Part - 4 (Moving / Motion Picture Expert Group 4);

MPEG = Moving (Also: Motion) Picture Experts Group;

MS = Mobile Station;

MSC = Mobile Switching Centre(s);

MSE = Mobile Station Equipment;

MSIN = Mobile Station Identification Number;

MT = Mobile Terminated;

MTSO = Mobile Telephone Switching Office;

MVNA = Mobile Virtual Network Aggregators;

MVNE = Mobile Virtual Network Enabler;

MVNO = Mobile Virtual Network Operator;

N-AMPS = Narrowband - Advanced Mobile Phone Service;

NUC = Network Unlocking Code;

OMA = Open Mobile Alliance;

PAC = Port Authorisation Code;

PAYG = Pay As You Go;

PAYM =Pay Monthly;

PDA = Personal Digital Assistant; Also: Portable Digital Assistant;

PIM = Personal Information Manager;

PIN = Personal Identification Number;

PLMN = Public Land Mobile Network;

PSTN = Public Switched Telephone Network;

GSM = Global System for Mobile Communication;

PUK = Pin Unlock Key;

RAM = Random Access Memory;

RIM = Research In Motion (The company behind Blackberry);

ROM = Read Only Memory;

R-UIM = Removable - User Identity Module;

SAP = SIM Access Profile;

S - GPS (Also: SGPS) = Simultaneous - Global Positioning System;

SIC = System Identification Code;

SIM = Subscriber Identity Module; SIM Card Facts

SMS = Small Message Service; Also: Short Message Service;

SMSC = Small Message Service Center; Also: Short Message Service Center;

SMC-CS = Small (Also: Short) Message Control - Circuit Switched;

SMC-GP = Small (Also: Short) Message Control - GPRS Protocol;

SMSMM = Small (Also: Short) Message Service Mobility Management;

SMS - MO = Small (Also: Short) Message Service - Mobile Originated;

SMS - MT = Small (Also: Short) Message Service - Mobile Terminated;

SM-RL = Small (Also: short) Message - Relay Layer;

SM-TL = Small (Also: Short) Message - Transfer Layer;

SNS = Social Network Service (Also: Social Network Server)

TAC = Type Approval Code; or Type Allocation Code; IMEI And Phone Identity

TMSI = Temporary Mobile Subscriber Identity;

UI = User Interface;

UIMID = User Identity Module Identifier;

UMA = Unlicensed Mobile Access;

UMTS = Universal Mobile Telecommunications System (ETSI);

USIM = Universal Subscriber Identity Module;

USB = Universal Serial Bus;

VLR = Visitor Location Register;

VoIP = Voice over Internet Protocol;

WAP = Wireless Application Protocol;

Wi-Fi = Wireless Fidelity;

2G = 2nd Generation;

3G = 3rd Generation;

3G-MSC / VLR = 3rd Generation Mobile Switching Centre Visitor Location Register;

3GPP = 3rd Generation Partnership Project;

3G-SGSN = 3rd Generation Serving GPRS Support Node;

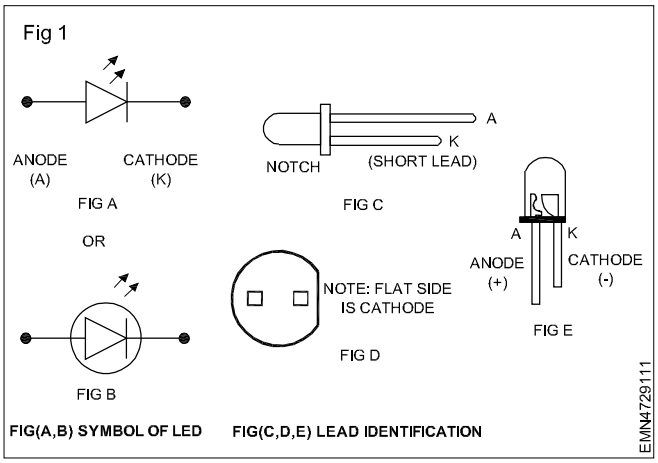
4G = Fourth (4th) Generation;

Introduction of LED lights

Objectives : At the end of this lesson you shall be able to
- **define LED and the advantages of LED lights over other lighting systems**
- **state the difference between LED lights and traditional lights**
- **explain the parts and working of LED lights**
- **describe the different colour generation in LED lights.**

Introduction

The LED is used as a light source in our day to day applications. LED is the short form of "Light Emitting Diode". LEDs are basically electronic devices, made with semiconducting material, which that emits light when it is connected in forward bias mode. LED's properties are similar to general purpose diodes consisting of two leads called as anode and cathode. LED lights are energy efficient and having long life making them ideal replacements for traditional power halogen and standard incandescent lights.LED lights can save up to 90% of household lighting costs. Fig 1 shows LED symbol and lead identification.

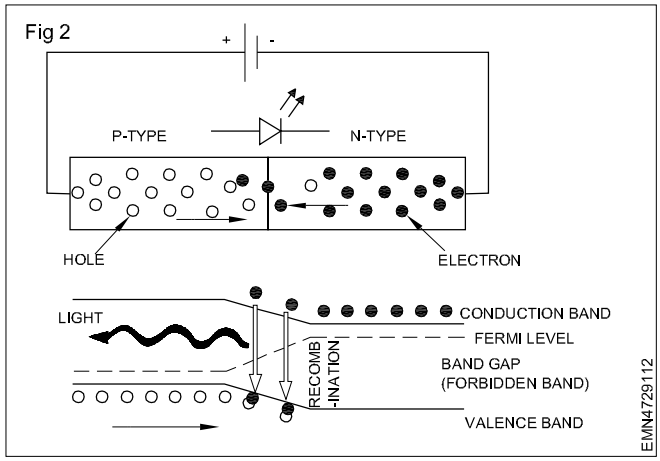


Difference between traditional lights and LED lights

LED lighting differs from incandescent lamp and compact fluorescent lamp in several ways. When designed well, LED lighting can be more efficient, durable, versatile and long lasting. Incandescent lamp produces light by use of a filament. When current passing through a bulb, bulb will dissipate the power in the form of heat, thus producing light. CFLs (compact fluorescent Lamps) are producing light by exciting the mercury vapour held inside the lamp with electricity. LEDs produce light through a "cold process" when current flowing through the semiconducting material (usually gallium, arsenic and phosphorus), electrons are able to recombine with holes within the device, releasing energy in the form of photons (i.e. light). This effect is called "electroluminescence".

LED working

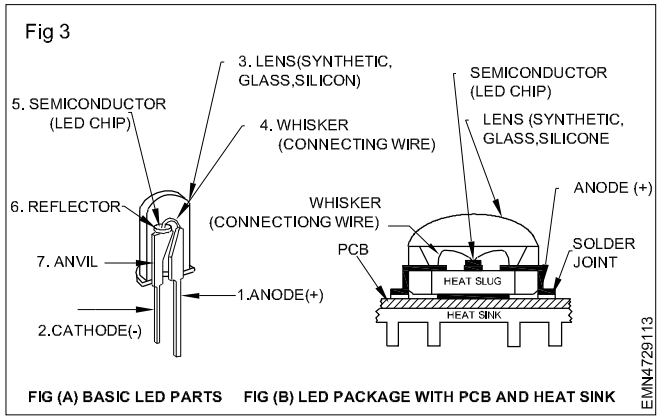
Basically LED is a semiconductor device which is made with P N junction. LED is used to convert current into light when it is in forward biased condition. When LED is forward biased, the electrons in N region are crossing the junction and recombine with the holes in P region. In energy band diagram electrons are in conduction band whereas holes are in valance band as shown in Fig 2. At the time of electron hole recombination electrons are moving from higher energy band(conduction band) to lower energy band (valancy band). So dissipate some amount of energy. This emitted energy will be in the form of light.



Parts of LED

The Fig 3(A) shows basic parts of LED and Fig 3(B) shows a power LED with heat sink.

When a LED connected to supply, current flows to semiconductor chip through anode lead(1) and a whisker (4). The other side of the semiconductor is attached to the top of the anvil (7) and cathode (2). The colour of LED light depends on the material used for making LED chip(5). There are no loose or moving parts within the solid epoxy enclosure.



The LED package will protect the LED chip from the outside environment. The dissipated heat can be transferred by using a heat sink. The epoxy resin enclosure lens (3) has the following three functions.

1 It is designed to allow more light from the semiconductor.

2 It focuses the light (viewing angle).

3 It protects the semiconducting material from the other elements.

Colours of LEDs

LEDs are used to generate a monochromatic colour of particular wave length. The generated colour of LED is depends upon the material used to make the LED chip. Unlike normal signal diodes, Light Emitting Diodes are made from exotic semiconductor compounds such as Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN) all mixed together at different ratios to produce a distinct wavelength of colour.

The semiconductor material used will determine the wavelength of the photon light emission and the resulting colour of the emitted light as shown in TABLE 1.

1 Gallium Arsenide (GaAs) - infra-red

2 Gallium Arsenide Phosphide (GaAsP) - red to infra-red, orange

3 Aluminium Gallium Arsenide Phosphide (AlGaAsP) - high-brightness red, orange-red, orange, and yellow

4 Gallium Phosphide (GaP) - red, yellow and green

5 Aluminium Gallium Phosphide (AlGaP) - green

6 Gallium Nitride (GaN) - green, emerald green

7 Gallium Indium Nitride (GaInN) - near ultraviolet, bluish-green and blue.

8 Silicon Carbide (SiC) - blue as a substrate

9 Zinc Selenide (ZnSe) - blue

10 Aluminium Gallium Nitride (AlGaN) - ultraviolet.

White light from LED

Unlike incandescent lamps, LEDs are not inherently white light sources. LEDs emit highly efficient coloured light for the applications such as traffic lights and exit signs. General light source needs white light. In LED white light can be achieved in three ways:

1 Phosphor conversion : In which a phosphor is used on or near the LED is used to convert the coloured light to white light as shown in Fig 4.

2 RGB systems: In which light from multiple monochromatic LEDs (e.g., red, green, and blue) are mixed, resulting in white light as shown in Fig 4.

3 A hybrid method : In which uses both phosphor-converted (PC) and monochromatic LEDs.

Phosphor white light is more efficient than RGB white.

In the phosphor conversion method white light can be produced by a single LED combining with a short wavelength LED such as blue or UV, and a yellow phosphor coating. The blue or UV photons generated in the LED either travels through the phosphor layer without alteration, or they are converted into yellow photons in the phosphor layer. The combinations of the blue and yellow photons combine to generate white light.

Fig 4

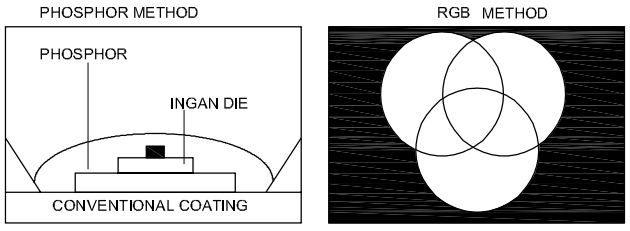
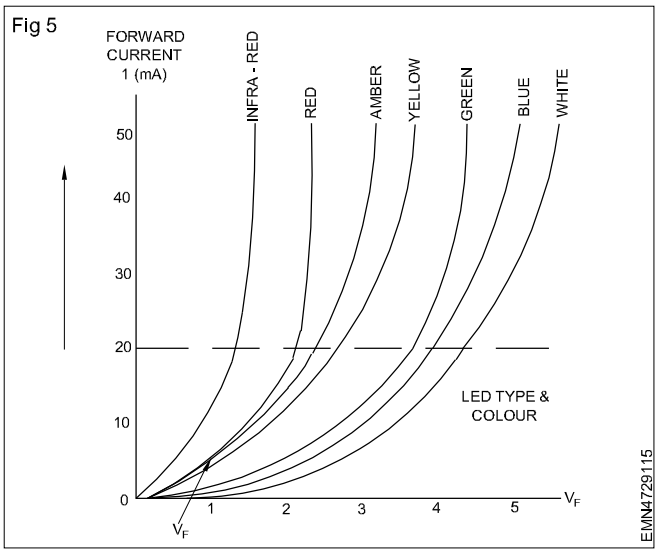


TABLE 1

Typical LED characteristics

Sl.No.	Semiconductor material	Wavelength	Colour	VF @ 20mA
1.	GaAs	850-940nm	Infra-Red	1.2v
2.	GaAsP	630-660nm	Red	1.8v
3.	GaAsP	605-620nm	Amber	2.0v
4.	GaAsPN	585-595nm	Yellow	2.2v
5.	AlGaP	550-570nm	Green	3.5v
6.	SiC	430-505nm	Blue	3.6v
7.	GaInN	450nm	White	4.0v

Fig 5



VI characteristics of LED

VI characteristics curve of a LED is shown in Fig 5.

To emit light in a LED needs a current flow through it, as it is a current dependant device with their light output intensity being directly proportional to the forward current flowing through the LED.

As the LED is to be connected in a forward bias condition across a power supply it should be a current limiter (using a series resistor) to protect it from excessive current flow, it will destroy instantly because of too much current will pass through and burn it out. Generally 5mA is the maximum forward current for a simple LED and 30 mA for a high bright light output LED.

From the TABLE 1 the characteristics of each LED has its own forward voltage drop across the PN junction and this parameter which is determined by the semiconductor material used for a forward current of 20mA.

LED Color guide

LED P/N Suffix	Description	Chemistry	# of elements	peak wavelength (χ/x-coord)	Dominant wavelength (χ/y-coord)	Forward voltage (Vf type)	(Vf Max)
H	High efficiency red	Gap	2	700	660	2.0	2.5
SR	Super red	GaAIAs	3	660	640	1.7	2.2
SR	Super red	AInGap	4	660	640	2.1	2.5
SI	Super high intensity red	AInGap	4	636	628	2.0	2.6
I	High intensity red	GaASP	3	635	625	2.0	2.5
Zi	TS AllnGap red	AInGap	4	640	630	2.2	2.8
SO	Super orange	AInGap	4	610	602	2.0	2.5
A	Amber	GaAsP	3	605	610	2.0	2.5
SY	Super yellow	AllnGap	4	590	588	2.3	2.8
ZY	TS AllnGap yellow	AllnGap	4	590	589	2.1	2.5
Y	Yellow	GaAsP	3	590	588	2.2	2.6
SUG	Super ultra green	AllnGap	4	574	568	2.2	2.6
G	Green	Gap	2	565	568	2.2	2.6
SG	Super green	Gap	2	565	568	2.2	2.5
G	Pure green	Gap	2	555	555	2.1	4.0
UPG	Ultra pure green	InGaN	3	525	520	3.5	4.0
UEG	Ultra emerald blue	InGaN	3	500	505	3.5	4.0
USB	Ultra super blue	InGaN	3	470	470	3.5	4.0
UV	Ultra voilet	InGaN	3	410	-	3.5	4.0
SUV	Super voilet	InGaN	3	380	-	3.4	3.9

T	Turquoise	InGaN	3	0.19	0.41	3.2	4.0
V	Voilet/Purple	InGaN	3	0.22	0.11	3.2	4.0
P	Pink	InGaN	3	0.33	0.21	3.2	4.0
MW(Warm)	Warm white	InGaN	3	-	-	3.2	4.0
NW(Neutral)	Neutral white	InGaN	3	-	-	3.3	4.0
UW (Cool)	Cool white	InGaN	3	-	-	3.3	4.0

LED efficiency, comparision with CFL and incandescent lamps

Objectives : At the end of this lesson you shall be able to
- **compare LED lights and traditional lighting system**
- **state the characteristics for the LED lighting system**
- **list the advantages of LED lighting system**
- **state the limitations of LED lighting system.**

LED efficiency, comparison with CFL and Incandescent lamps

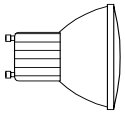
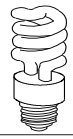
Many types of lighting systems are available such as incandescent lamps , fluorescent lamps and LED lamps. Incandescent lamps are traditional and available from long back. These are bulky in size, more power consuming than others and having less life span. The compact florescent lamps are popular due to more efficient , high illumination, more life span, less power consumption than incandescent lamps.

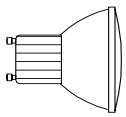
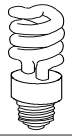
Now a day's LED lights are more popular and emerging technology in lighting systems. TABLE 1 gives the comparison between these three lighting systems by various aspects.

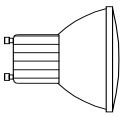
TABLE 1

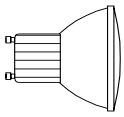
Comparison chart

LED lights vs Incandescent light bulbs vs. CFLs

Sl. No.	Particulars	LED light	Incandescent lamp	Compact Flourescent Lamp(CFL)
	I. Energy efficiency & Energy costs			
1.	Life span (Average)	50,000 hours	1,200 hours	8,000 hours
2.	Watts of electricity used (equivalent to 60 watt bulb)	6 - 8 watts LEDs use less power (watts) per per unit of light generated(lumens). LEDs help to reduce green house gas emissions from power plants and lower electric bills.	60 watts	13 - 15 watts
3.	Kilo-watts of electricity used (Equivalent to 30 Incandescent bulbs per year)	329 KWh/yr.	3285 KWh/yr.	767 KWh/yr.

Sl. No.	Particulars	LED light	Incandescent lamp	Compact Flourescent Lamp(CFL)
	II. Environmental impact			
1.	Contains the TOXIC Mercury (equivalent to 60 watt bulb)	No	No	Yes - Mercury is very toxic to health and the environment.
2.	RoHS complaint	Yes	Yes	No - Contains 1 mg - 5 mg of mercury and is major risk to the environment.
3.	Carbon-di-oxide emissions (30 bulbs per year) Lower energy consumption decreases: CO_2 emissions, sulphur oxide and high-level nuclear waste.	451 pounds/year	4500 pounds/year	1051 pounds/year

Sl. No.	Particulars	LED light	Incandescent lamp	Compact Flourescent Lamp(CFL)
	III. Important facts			
1.	Sensitivity to low temperatures	None	Some	Yes - may not work under negative 10 degrees fahrenheit or over 120 degrees fahrenheit.
2.	Sensitive to humidity	No	Some	Yes
3.	Turns on instantly	Yes	Yes	No - takes time to warm up
4.	Durability	Very durable	Not very durable glass or filament can break easily.	Not very durable - glass can break easily.
5.	Heat emitted	3.4 btu's / hour	85 btu's / hour	30 btu's / hour
6.	Failure modes	Not typical	Some	Yes - may catch on fire, smoke, or emit an odor.

Sl. No.	Particulars	LED light	Incandescent lamp	Compact Flourescent Lamp(CFL)
	IV. Light output			
1.	Lumens	Watts	Watts	Watts
2.	450	4 - 5	40	9 - 13
3.	800	6 - 8	60	13 - 15
4.	1100	9 - 13	75	18 - 25
5.	1600	16 - 20	100	23 - 30
6.	2600	25 - 28	150	30 - 55

Characteristics of LED lights

1 Colour quality
2 Light output
3 Less power consumption
4 High efficiency
5 Long lifetime
6 Smallest in size
7 High resistance to switching cycles
8 Immediate light at switching on
9 Wide operating temperature range
10 High impact and vibration resistance
11 No UV or IR radiation
12 High colour saturation level without filtering
13 Mercury-free

Lifespan of LED Lighting

All the lighting sources having different expected lifespan under various laboratory test conditions. Manufacturers will provide these information on their product packages on hours basis. In TABLE 2 shows the expected lifespan of various lights.

The life of LED is about 10 to 25 times higher than incandescent lamp and 2 to 5 times than CFL's. So, LED bulbs are good for long time considerations. TABLE 3 shows some calculation regarding operational cost of various lighting systems.

TABLE 2

Types of bulbs	Expected lifetime
Incandescent Bulbs	Between 750 and 2,000 hrs.
Compact Fluorescent Lamp (CFL)	Between 6,000 and 10,000hrs.
LED Lights	Between 20,000 and 50,000 hrs.

TABLE 3

Aspect	Incandes-cent	CFL	LED
Approximate cost per bulb	Rs. 20/-	Rs.100/-	Rs 250/-
Average lifespan	1,200 hrs	8,000 hrs	25,000 hrs
Watts used	60 W	15 W	10 W
No. of bulbs needed for 25,000 hrs of use	20	3	1
Total purchase price of bulbs (25,000 Hrs.)	Rs.1200/-	Rs.300/-	Rs. 250/-
Total cost of electricity used (25,000 hours at Rs.3 per kWh)	Rs.4500/-	Rs.1125/-	Rs. 750/-
Total operational cost over (25,000 Hrs.)	Rs. 5700/-	Rs.1425/-	Rs. 1000/-

Advantages of LED Lighting:

LEDs are having a number of advantages when compared to traditional lighting systems.

Durability of LED lights

Incandescent bulbs and fluorescent lamps will break easily when shaken or dropped. The incandescent bulb has a filament that is likely to break in such a situation. The LED lights are made in robust design. They are suffering considerably less degradation over time. A typical LED light would be expected to lose only 2 per cent of its total efficiency after a period of 10,000 hours.

The useful lifespan of LED lighting products is defined differently than that of other light sources, such as incandescent or CFL. This is because LEDs typically do not "burn out" or fail. Instead, they experience lumen depreciation, where the amount of light produced decreases and light colour appearance can shift over time.

LED lighting efficiency

Incandescent bulb and fluorescent lamp dissipate more amount of energy, so that heat produced, because they distribute light in many directions. By comparison, LED lights operate at low temperature and produce more focused form of light. A typical incandescent lamp operates at an efficiency level of around 9 percent. LED light can achieve efficiency levels which is closer to 40 per cent. The LED lights can be manufactured in smaller sizes and can be placed in spaces that would not be suitable for other forms of lighting.

Light output

Modern LED lights have the appropriate light output and colour characteristics to exceed the performance levels of incandescent bulbs. LED lighting can also be used in connection with standard household dimmer switches, or with more flexible control systems, allowing colour settings to be manipulated quickly.

Disposing of LED Lights

Unlike fluorescent bulbs, LED lights does not release mercury into the air. Some studies have shown that, they include a number of other toxic materials. When dealing with a broken LED light, it is advisable to make use of gloves and to be aware of the toxic nature of the materials that have been used in the manufacture of the lights. However, LED lights can be disposed at landfill sites.

Range of uses

LED Lights do not release out an Ultra Violet (UV) rays, which means that they can safely be used in situations where precious items need to be exhibited. An example of this might be in the case of lighting the paintings or other artifacts.The lack of UV rays means that insects are not attracted to these light sources. This is particularly useful for the food industry and also for external installations. It is also possible to create lighting in a wide range of colours, without the need of different coloured bulbs or filters. As a result, interesting effects can be created using LED lighting, allowing for an element of creativity within domestic and commercial purposes.

Instant lighting

One of the drawback of traditional lighing is they does not light up immediately. With LED lighting, there is no such delay. When switched on, they reach full brightness up to 100 times faster than other alternatives. This feature ensures that they are well suited to use in vehicles.

Less wiring required

LED lights operate with low voltage and current. So the size (Gauge) of wire used for house wiring will be less. So the cost of wire bundle will be lesser in all aspects.

Health benefits

Fluorescent lamp can be replaced by the LED lights due to flickering effect. Such an effect can be annoying, it can also have more serious health implications. Migraine sufferers and epileptics may find that the use of LED tubes more comfortable.

Lower maintenance costs

LED lights never needed to be replaced and maintenance costs tend to be extremely low. It is rare for an individual LED to fail, if such a situation occurs, it does not mean that the entire lamp will fail.

Directional light source

LEDs are "directional" light sources, which means they emit light in a specific direction, unlike incandescent and compact fluorescent bulbs, (which emit light and heat in all directions). For this reason, LED lighting is able to use light and energy more efficiently in many applications. However, sophisticated engineering is needed to produce an LED light bulb that emit light in all directions like an incandescent lamp.

A general purpose LED may not distribute light in all directions if used in a table lamp.

Heat dissipation by LED

The LED lighting systems are not radiate heat as much as an incandescent lamp or halogen bulb. This is usually done with the help of a heat sink, which is a passive device that absorbs the heat produced and dissipates it into the surrounding environment. This keeps LEDs from over heating and burning out. Thermal management is one of the most important factor for the successful performance of an LED product. Because the higher the operating temperature of a LED more quickly the light will degrade, and the shorter the useful lifespan will be.

Limitations of LED bulbs

1 The initial cost of LED bulbs are more. The price per lumen is very high than other types.

2 LED bulbs need a definite voltage and constant current for good results.

3 LED drivers are more costlier.

4 LED bulb colours are changing due to age and ambient temperature.

5 Two different white LEDs are not having same colour characteristics.

6 LED performance mostly depends on the correct engineering to manage the heat generated by the LED. Which causes deterioration of the LED chip itself. Otherwise overheating the LED package, eventually leading to device failure. Adequate heat-sink is required to maintain long life.

Types of LED lights

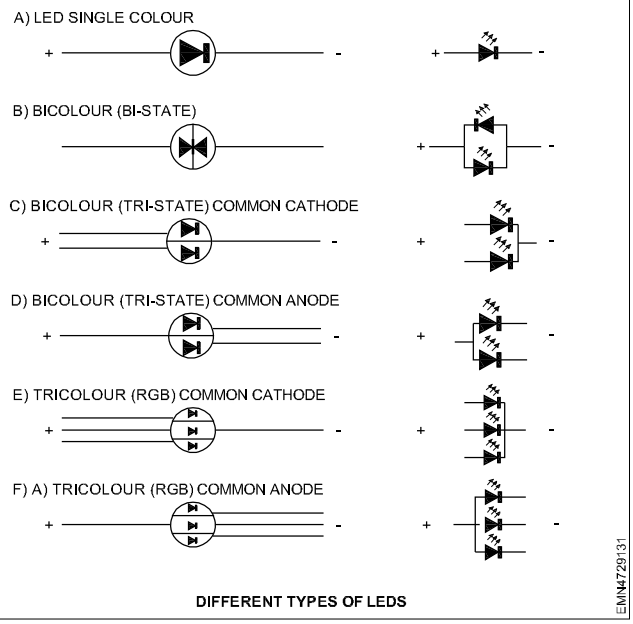
Objectives : At the end of this lesson you shall be able to
- **list out the type of LED lights**
- **explain the classification of low power LEDs**
- **explain the classification of high power LEDs**
- **list out the specification of LED lights.**

Introduction

LED lights are mostly used for white colours in domestic and industrial applications. But in some other applications we need different colour LED lights in - red, orange, green, blue, etc.

Some LED lights are available in single colour, dual colurs and multi-colour types. These multicolour lights consist of 2 or more colour LEDs in a board. By operating external switches or by remote we can select the colour of LED lights . By selecting 2 or more colours we can generate various combinations of colours. Fig 1 shows the symbols of different type of LEDs

Fig 1



DIFFERENT TYPES OF LEDS

2-Pin LED

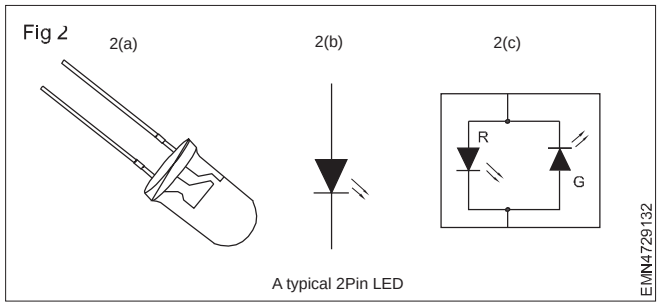
The most common type of LED is the 2-pin, 5 mm, round lens type. Generally these are a single LED. Polarity is indicated by the long lead (+/anode) or the flat on one side of the base (-/cathode).

The two-pin package can contain a single or two back-back LEDs.

Be aware that bi-colour LEDs are also sold in this package. Some are dual-colour so that reversing the current through them changes the colour. Others may have both LEDs the same colour and this can be useful in AC applications as it can conduct on both cycles of the mains and eliminates the need for a rectifier.

The data sheet of the bi-colour LED provides the terminal connection for the colours

Fig 2



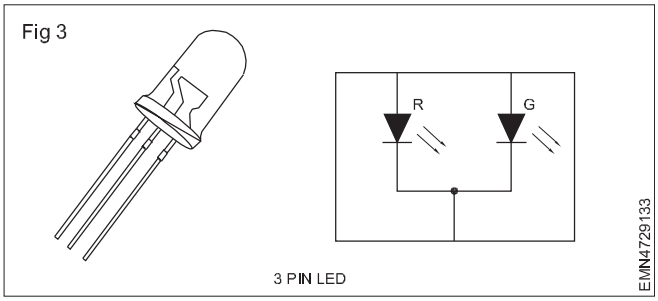
A typical 2Pin LED

3-Pin LED

The three-pin LED is usually a pair of LEDs of different colours sharing a common anode or common cathode. Either LED can be turned on independently or blended to create a combination.

A bi-colour, 3-pin, common-cathode LED is shown in Fig 3

Fig 3



3 PIN LED

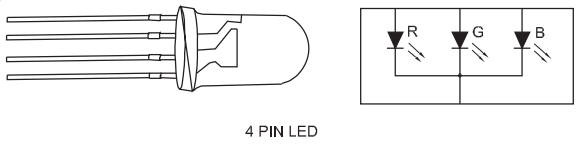
4-Pin LED

The 4-pin LED package is most commonly seen on RGB (Red-green-blue) LEDs. Common cathode and common anode versions are available. It produces the red, green and blue colours acros the visible spectrum, common cathode type. The RED LED in a 4 pin package is shown in Fig.4

6-Pin

RGB with individual pinouts allows common anode, common cathode configuration as well as series connection of the LEDs is shown in Fig 5

Fig 4



When the number of Pins reaches six all sorts of strange variations are possible to bring out each LED anode and cathode on individual pins. This allows a single part to be used to common anode, common cathode and series LED configurations.

A slightly modified 6-pin, RB-GB, LED, has two separate 3-pin LEDs in one package as shown in Fig.6

LF5WAEMBGMDW, 6-pin, RB-GB LED has two 3-pin LEDs in one package. Both have a blue LED. Note the pin length orientation clue.

Fig 5

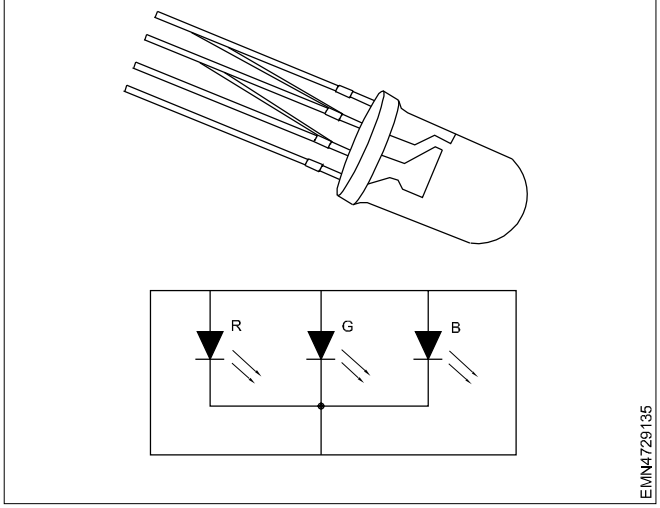
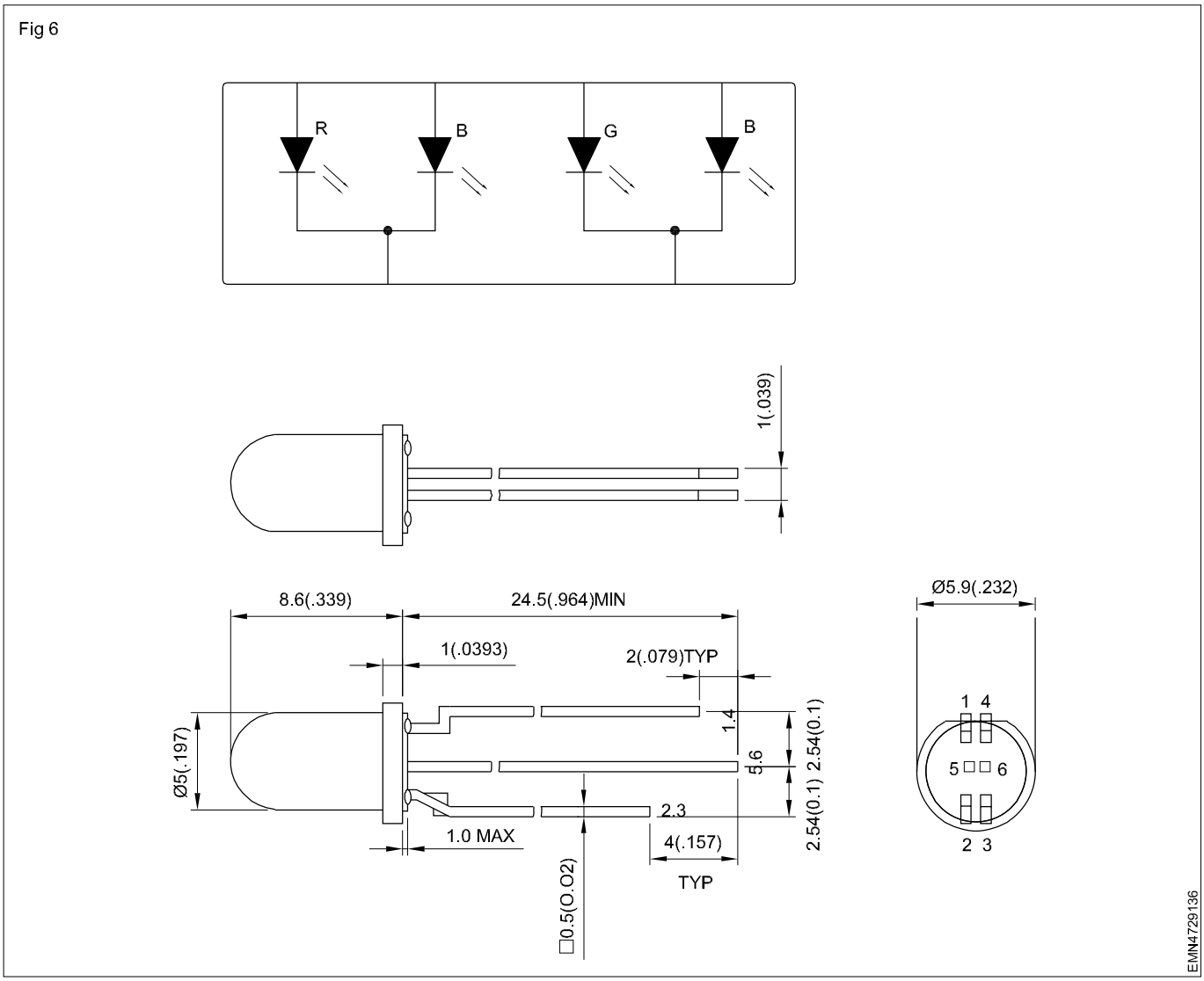


Fig 6



Classification of LED lights

A. According to the power level

LED lights are classified in to two categories. Those are

I. Low power LEDs or miniature LEDs

II. High power LEDs

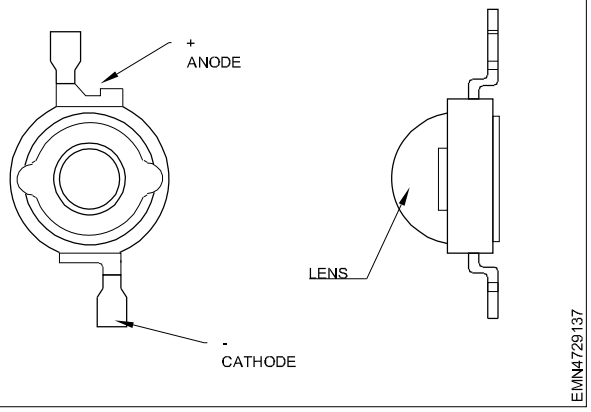
I. Low power LEDs or miniature LEDs

These LEDs are more familiar as indicators in mobile phones, in television sets and in different types of digital devices. They are usually available in standard size & shape from 2 mm to 10 mm in hole and surface mount packages. There is no need of separate heat sink. So it is compatible to different circuit boards. Different

companies are manufacturing these LEDs in 5V and 12V ranges. Generally current rating about 1 mA to 20 mA. They are available in a "ready to fit" mode.

Common package shapes include round, with a domed or flat top, rectangular with a flat top, and triangular or square with a flat top as shown in Fig 2.

Fig 7



There are three main categories

1 Low-current

Typically rated for 2 mA at around 2 V (approximately 4 mW consumption)

2 Standard

20 mA LEDs (ranging from approximately 40 mW to 90 mW) at around:

i 1.9 to 2.1 V for red, orange, yellow, and traditional green

ii 3.0 to 3.4 V for pure green and blue

iii 2.9 to 4.2 V for violet, pink, purple and white

3 Ultra-high-output

II. High power LEDs

These LEDs are the result of advanced semiconductor technology. As the name indicates, these LEDs are known by its high output. High-power LEDs (HP-LEDs) or high-output LEDs (HO-LEDs) can be driven at currents from hundreds of mA to more than an ampere, compared with the other LEDs. LED power density up to 300 W/cm^2 has been achieved. They are capable of producing light output with higher luminous intensity. The HP-LEDs must be mounted on a heat sink for heat dissipation. If the heat from a HP-LED is not removed, the device will fail in seconds.

High power LED's come in different shapes & sizes. A common example of high power LED in daily use is "LED strips" that are used for walls & room interiors.

Different types of LED lights are shown in Fig 3.

LED lights are made of arrays of SMD modules. Such lights are made with standard shapes and fittings like Edison screw base, MR16 shape with a bi-pin base, or a GU5.3 (bi-pin cap) or GU10 (bayonet fitting)etc. are as shown in Fig 4.(Refer page 167) They are compatible with the supply sockets. They included driver circuitry.

B. According to the shape LED lights are divided in to 3 categories.

1 Spherical lights,

2 Tapered lights

3 Cup-shaped lights

C. LED tube lights

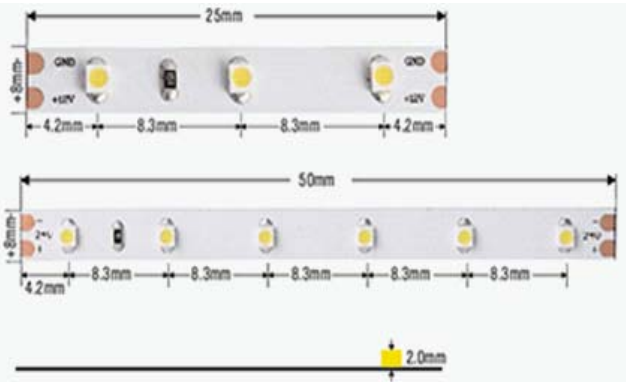
LED tube lights are designed to physically fit in fixtures instead of fluorescent tubes. Some LED tube are suitable for existing fixtures if appropriate ballast is used. An LED tube light generally uses many individual Surface-Mounted LEDs which are directional and require proper orientation to emit light in all directions around the tube. Most LED tube lights can be used in place of T8, T10, or T12 tube designations, T8 is D26mm, T10 is D30mm, in lengths of 590 mm (23 inch), 1,200 mm (47 inch) and 1,500 mm (59 inch).

D. LED strip lights

An LED Strip Light also known as an LED tape or ribbon light. LED strip light is a flexible circuit made by surface mounted light-emitting diodes (SMD LEDs) on a flexible type PCB layers. These strips are usually comes with an adhesive agent in back. Previously, strip lights had been used solely in accent lighting, backlighting, task lighting, and decorative lighting applications. Now a days due to the increased luminous efficacy and longer life-spans LED strip lights are used in applications such as high brightness task lighting, fluorescent and halogen lighting replacements, indirect lighting applications, Ultra Violet inspection during manufacturing processes, costume design, etc.

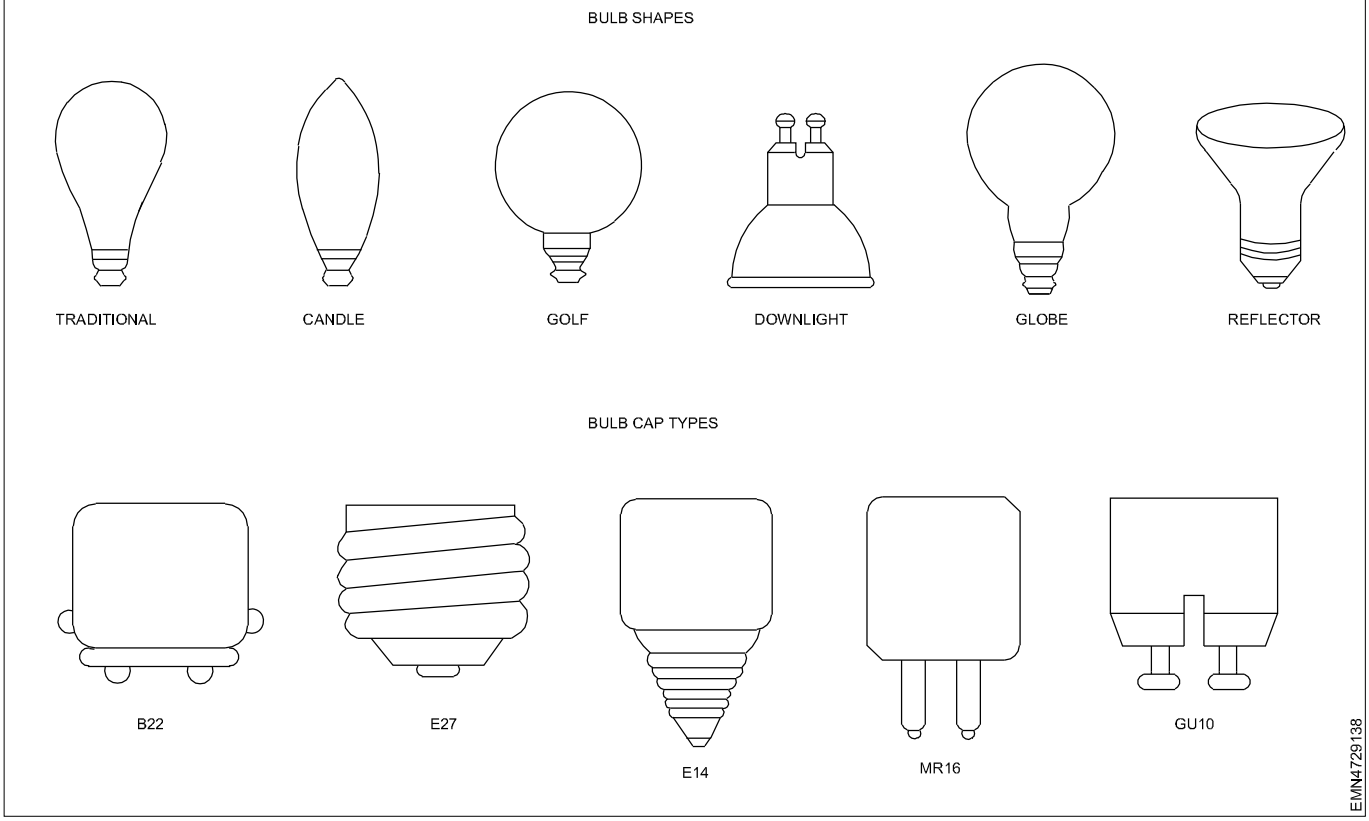
E. SMD LEDs

Fig 5



SMD is short form of "Surface Mount Device", describes LED packages that can be mounted on a surface or a PCB by soldering method as shown in Fig 5. SMDs come in all shapes and sizes, and are typically described with a four digit number. 3528 SMDs and 5050 SMDs are presently some of the most commonly used SMDs. The four digit numbers refer to the length and width dimensions of the SMD, in this case, 3.5 x 2.8 mm and 5.0 x 5.0 mm, respectively.

Fig 8



F. COB (chip on board) LED modules

These are LED lighting system have multiple LED chips mounted on a single PCB, encapsulated in a phosphor epoxy mix. These modules can reach many hundreds watts, delivering over 10000 lumens. They can often be used in high-bay or exterior lighting.

LED light can be described in a number of ways

1 LED bulb shape

2 LED bulb diameter

3 LED bulb length

4 LED bulb base type

LED light bulb shape

It's shapes describe the general physical characteristics of the LED light. LED light bulbs vary in shape from tube shaped bulbs to funnel or pear shaped light bulbs. These LED light bulb shapes each have a code. For example: T designates a 'tube', PAR signifies a 'parabolic aluminium reflector' and MR is used for ‘multifaceted reflector’.

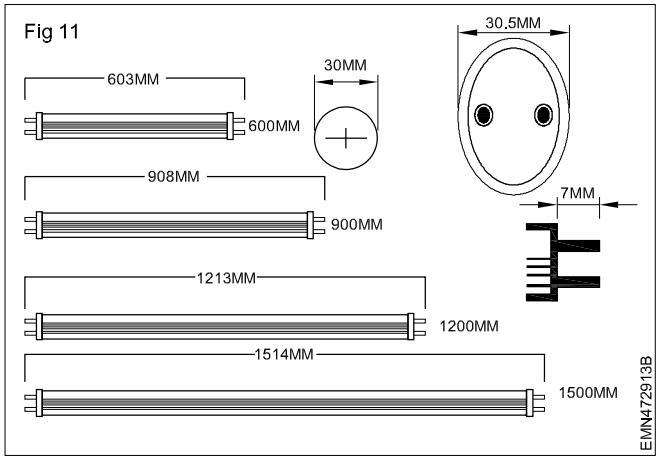
LED bulb diameter

The diameter of a light bulb is measured in two ways, in millimetres and in 1/8th of an inch. The diameter for light bulb shape is measured at the point of maximum size. Examples are: T12 is 12 eights of an inch or 12/8 = 1.5 inches in diameter, PAR20 is 20 eighths of an inch in diameter or 2.5 inches, MR16 is 16 eighths = 16/8 = two inches in diameter.

LED light bulb length

LED light bulb length is the overall length measured, typically in electrical connection, from base to the tip of the bulb. Or in the case of Tube from end to end. This can be in metric or in inches or feet as shown in Fig 5.

Fig 11



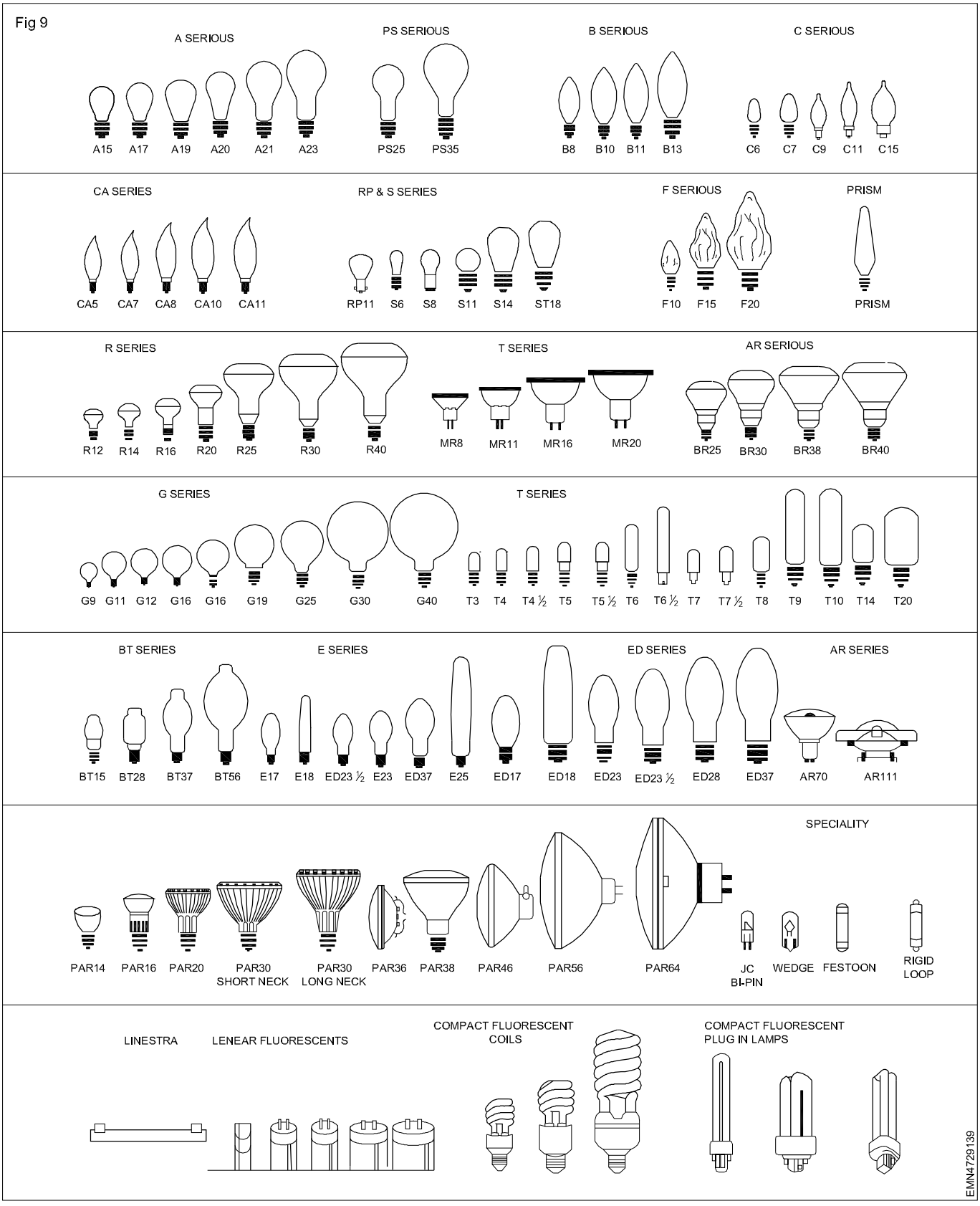
Bulb base types

LED light bulb base types are typically measured by type and diameter in millimetres. For example a typical Edison medium screw-in base like E27 is 27 millimetres in diameter. LED bi-pin bases, like a fluorescent tube replacement or a bi-pin MR16, are measured between the centres of each pin.

Size of LED on strip

The light output (lumen output) and light patterns are depending on the size of LEDs on strips. Integral LED strips are available with two sizes

Fig 9



1 35:28 - this indicating LED size as 3.5mm x 2.8mm LED. These are suitable for domestic applications like cabinet decoration, stairs , windows , photos, celing coves etc.

2 50:50 - this is indicating LED size as 5.0mm x 5.0mm LED. These are bright LED strips and the size will be about 40% bigger than 35:28 LEDs. These producing high light output. These can use for both commercial and domestic applications such as outdoor lighting, ambient lighting for commercial areas, wall washers etc.

Number of LEDs per meter

The number of LEDs per metre affects the brightness (lumens) and light pattern of a strip. Integral LED strips are available in three variations:

1 30 LEDs/m - generally using domestic decorations like kitchen kick plates, etc.

2 60 LEDs/m - task lighting, under kitchen cabinets, bar tops, steps/staircase edging, doorway frames.

3 120 LEDs/m - high ceiling coves, exterior edge lighting, path ways, signage.

LED cut marks are normally 3 LEDs apart. The distance between cut marks will depend on the number of LEDs per metre.

Thermal management of high-power LEDs

High power light-emitting diodes (LEDs) can use 350 milliwatts or more in a single LED. Most of the electricity in an LED becomes heat rather than light (about 70% heat and 30% light). If the dissipated heat is not removed, the LEDs operates at high temperatures will causes to lowers their efficiency, and reliability. So it is necessary to keep the temperature with in safe limit and remove excess heat form the light for improving its lifespan and accuracy.

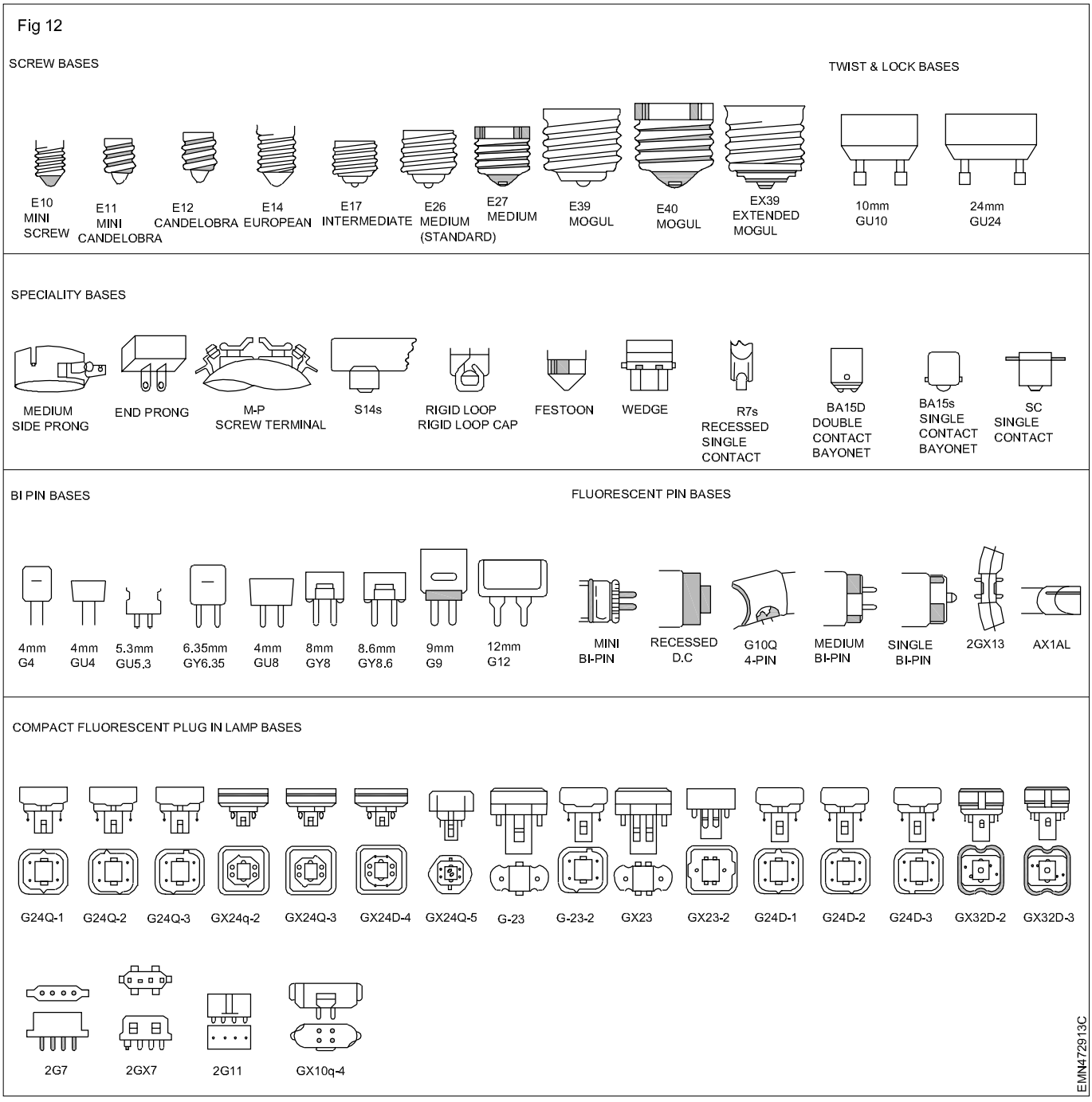
The excess temperature of LED light can be eliminated by

1 Using heat adhesive with boards and heat sinks.

2 **Heat sinks :** The thermal conductive type materials (eg. aluminium) are using with LEDs which are dissipating heat by conduction methods. The shape and size of heat sink also effects the speed of heat dissipation.

   i Surface finishing of a heat sinks effecting the heat dissipation. A painted surface having more heat emmition than unpainted and unfinished one.

Fig 12



ii Mounting methods also effect the cooling system. Heat-sink mountings with screws or springs are often better than regular clips, thermal conductive glue or sticky tape.

LED lamp specifications

It is important to know the specifications of LED lights for its selection . LED lights having so many specifications in those more important specifications are as given below.

1 Power rating

2 Equivalent incandescent lamp rating

3 Operating voltage and frequency

4 The light colour emitted

5 Its colour rendering index (CRI)

6 Luminous flux

7 Operating life time

8 Fitting type and whether the lamp is dimmable

9 In the case of directional lamps, the luminous intensity and beam angle may also need to known.

LED stacks - Connections, Driver circuits

Objectives : At the end of this lesson you shall be able to
- **describe the LED panel materials**
- **explain the stacking of LED**
- **explain the working of LED driver circuits.**

The main materials of LED panel light structure are as follows

1 Aluminum frame

AL6063, aluminum extrusion mold is used due to low initial investment cost, good surface appearance, good heat dissipation.

2 Diffuser plate

Installation of diffusion plate is used to invisible the screen dot. Diffuser plate generally uses acrylic diffuser plate or PC 2.0 materials. Acrylic diffuser plate is low cost, higher light transmission than PC 2.0 and is poor in anti-aging. The price of PC 2.0 is slightly higher, but it is good at anti-aging. Acrylic diffuser plate light transmission rate is 92% and that of PC 2.0 is 88%. We can choose the materials of diffuser plate according to different requirement and usually use the acrylic materials.

3 Light guide plate

To emit the uniform light, light guide plate plays an important roll in blocking the screen dot. The side LED light changes the angle of light ray by light refraction of screen dot. Light guide plate is the heart of the LED panel light and its screen dot design is very important. If the screen dot design is not good, the overall lighting effect will be bad like 1. Bright in the middle and dark in both sides. 2. Bright in the bright side and dark in the middle.

4 Rear cover

Sealing lamp body usually uses aluminum. It plays a role of dissipating heat and protecting the light.

5 LED lighting source

3528 is the usual light source. Besides, there are 5630 and 5050. The luminous efficiency of 5630 and 5050 is not high and the design of their screen dot is difficult but their cost is lower. The lighting effect of 3528 is high and the screen dot is in acceptable range.

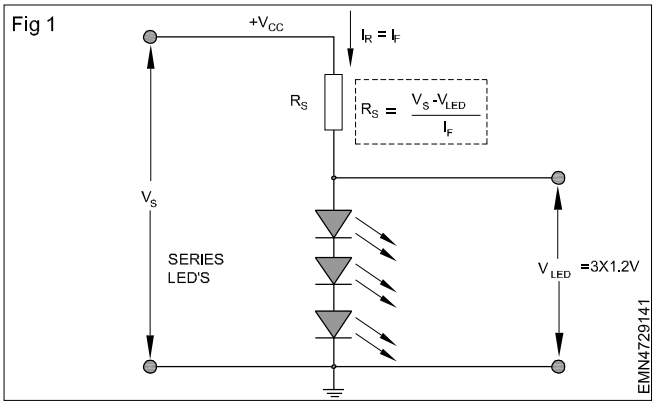
6 Drive power

There are two kinds of power modes: first, directly using cross-flow power (this mode has high efficiency and PF value is up to 0.95, so it is cost-effective);second, constant pressure with cross-flow mode (this mode is stable, but with low efficiency and high cost).

LEDs in series

We can connect LED's together in series to increase the light level. If LED's are connected in series all have the same forward current flow as shown in Fig 1.

Fig 1



Although, the series voltage drop across them needs to be considered when calculating the required value of the current limiting resistor, Rs. If we assume that each LED has a voltage drop of 1.2V across its when it is illuminated then the voltage drop across three will be 3x1.2v =3.6 volts. Consider that the supply voltage is 5 volt with a forward current of about 10mA. The value of series resistance Rs. will be calculated as:

V_{LED} = 3 x 1.2 volts = 3 x 1.2 V = 3.6 V

$R_S = V_S - V_{LED}$ = 5 - 3.6 = 1.4 volts

$$R_S = \frac{1.4v}{10mA} = 140\ W$$

Stacking of LEDs

Stacking means grouping of LEDs. LEDs may be connected in series, parallel or series - parallel combinations. It is necessary in each stacking that a LED is operated at its rated DC voltage and the current passed throgh a LED does not exceed to its rated value. The voltage rating of LEDs ranges from 1.6V to 4.2V and the current rating ranges from 2mA to 20mA.

1 Parallel stacking

In this stack, all the LED are connected in parallel to a single source of supply with a current limiting resistor for each LED. Decorative lighting strip may contain any number of LEDs that are connected in parallel with a current limiting resistor for each LED.

2 Series-parallel stacking

LED light panels generally contain a parallel group of some series groups. Each series group usually contains 3 to 4 LEDs. These panels may be of built-in type or mounted type.

3 Series stacking

In this stack, LEDs are connected in series, but usually more than 3-4 LEDs are not connected in series. Of course, some series groups of 3-4 LEDs may be connected in parallel. The reason behind it is different voltage distribution and current limiting of LEDs.

Driving of LED stacks

Here, driving means to apply DC supply to a stack (group) of LEDs. In general, a current limiting resistor is used with each LED.

1 Driving a single LED

For driving (operating) a single 3 resistors. In the given Fig 3, only two groups of 3 LEDs each are shown, but there are 24 such groups. IC 555 is used to limit the, circuit current at 10mA.

2 Driving a stack of 72 LEDs

For driving a stack of 72 LEDs, IC 555 may be used. 72 LEDs are divided into 24 groups of 3 LEDs connected in series and all the 24 groups are connected in parallel across an IC 555 and 12 volts DC source. A current limiting and voltage dropping resistor of 82 ohms is used in each group of 3 resistors. In the given figure, only two groups of 3 LEDs each are shown, but there are 24 such groups. IC 555 is used to limit the, circuit current at 10mA.

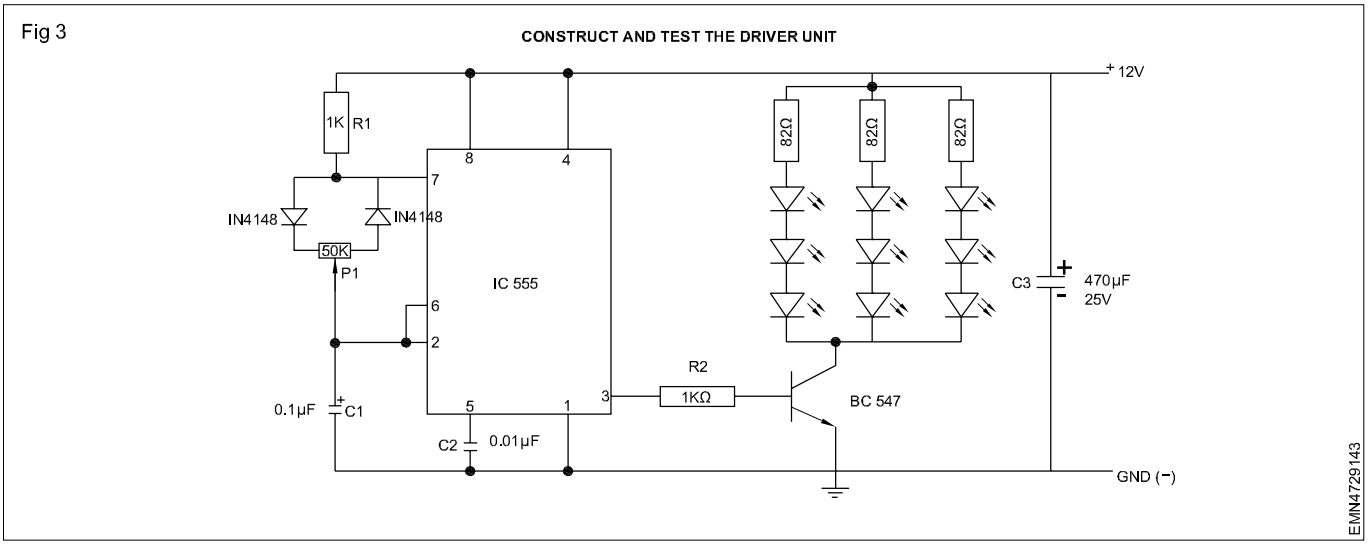
3 Other driving circuits

A number of LEDs stack driving circuits have been developed which employ different ICs. A current limiting resistor is necessarily connected in series of a single LED or a series group of 3-4 LEDs.

Driver circuit

Fig 2

Fig 3



LED drivers and its types

Objectives : At the end of this lesson you shall be able to
- **explain the need for a LED driver**
- **list out the types of LED drivers**
- **explain the factors to be considered to choose a LED driver**
- **describe the working of LED driver circuit.**

Need for a LED Driver

LED light sources require specialized devices called LED drivers to operate. LED drivers (also known as LED power supplies) are similar to ballasts for fluorescent lamps or transformers for low voltage bulbs: they provide LEDs with the electricity they require to function and perform at their best.

LEDs require drivers for two purposes:

1. LEDs are designed to run on low voltage (12-24V), direct current electricity. However, most places supply higher voltage (120-270V), alternating current electricity. An LED driver rectifies higher voltage, alternating current to low voltage, direct current.
2. LED drivers also protect LEDs from voltage or current fluctuations. A change in voltage could cause a change in the current being supplied to the LEDs. LED light output is proportional to its current supply, and LEDs are rated to operate within a certain current range (measured in amps). Therefore, too much or too little current can cause light output to vary or degrade faster due to higher temperatures within the LED.

In brief, LED drivers convert higher voltage, alternating current to low voltage, direct current. They also keep the voltage and current flowing through an LED circuit at its rated level.

Internal vs. External drivers (Fig 1)

For the aforementioned reasons, every LED light source requires a driver. However, some LEDs, particularly those designed for household use, contain internal drivers rather than separate, external drivers. Household bulbs usually include an internal driver because it makes replacing old incandescent or CFL bulbs easier. The figure 1 shows the external and internal drivers.

Choosing an LED Driver

There are two main types of external LED drivers, constant-current and constant-voltage, as well as a third type of driver called an AC LED driver. Each type of driver is designed to operate LEDs with a different set of electrical requirements. When replacing a driver, the old driver's input/output requirements must be matched as closely as possible.

Constant-Current drivers

Constant-current drivers power LEDs that require a fixed output current and a range of output voltages. There will be only one output current specified, labeled in amps or milliamps (350mA, 700mA or 1A), along with a range of voltages that will vary depending on the load (wattage) of the LED.

Constant-Voltage Drivers

Constant-voltage drivers power LEDs that require a fixed output voltage with a maximum output current. In these LEDs, the current is already regulated, either by simple resistors or an internal constant-current driver, within the LED module. These LEDs require one stable voltage, usually 10 V, 12V DC or 24V DC.

AC LED Drivers

LEDs have such a small electrical load that regular transformers do not register that they're wired to a bulb at all. AC LED drivers are typically used with bulbs that already contain an internal driver that converts the current from AC to DC, so an AC LED driver's job is to register the low wattage of LEDs and step down the voltage to meet the bulb's voltage requirements, usually 12 or 24 volts. AC LED drivers are typically used to power 12-24V AC input LED MR16 bulbs.

Fig 1

Factors to be considered to choose a LED driver

Max Wattage

According to the NEC (National Electrical Code), LED drivers should be paired with LEDs that use 20% less than their maximum rated wattage (with the exception of AC LED drivers). Drivers should not be paired with an LED that is at or exceeds the driver's maximum wattage to avoid overstressing the driver components. For example, if you have a driver that can operate a maximum of 96 watts, it should only operate LEDs that use 77 watts at most (96 x 0.8 = 76.8).

Dimming

Dimming functions are desirable to optimize illumination as ambient light levels may change due to artificial or natural variations in the lighting variations both indoors and outdoors.

Both constant-current and constant-voltage LEDs and drivers can be made with a dimming capability. Dimmable external drivers often require an external dimmer, or other dimming control devices to work. Since technologies are improving rapidly, it's best to test specific LED/ dimmable driver combinations for acceptable dimming performance.

Power Factor

Power factor describes how efficiently an LED driver uses electricity. The closer to 1 the power factor is, the more efficient the driver is. A good power factor is 0.9 or above.

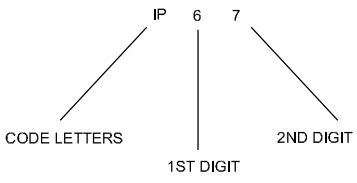
Ingress Protection (IP) Rating

IP ratings tell users the environmental protection that a driver's outer casing provides. The first number specifies protection against solid objects, and the second number specifies protection against water elements. For example, according to the chart below, a driver with an IP67 rating is protected against dust and temporary immersion in water.

Physical size and shape

Consider the physical dimensions of the driver. Make sure it will fit in the area you will place it.

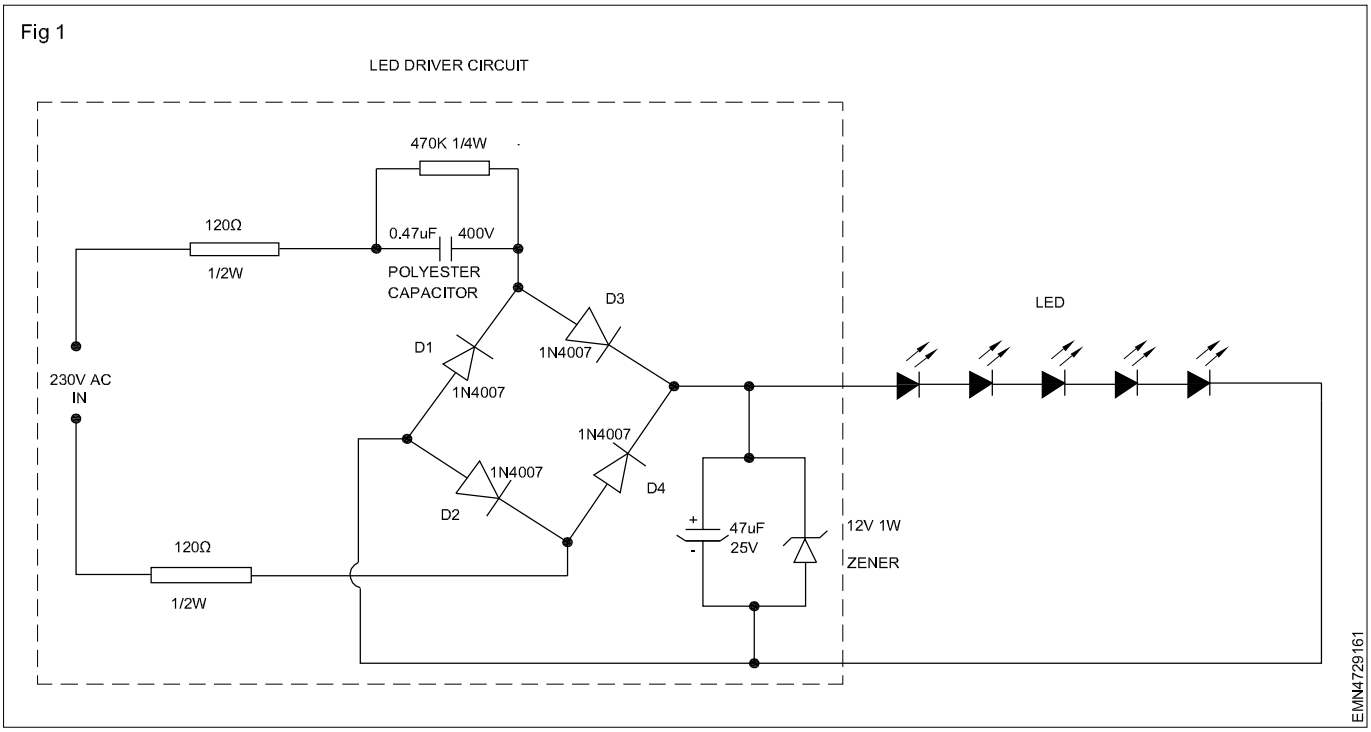
IP Rating Chart

1st Digit	Solid Object Protection	2nd Digit	Water Protection
0	Not protected	0	Not Protected
1	Protected against solid objects greater than 50mm (e.g. accidental bump of hand)	1	Protected against vertically dripping water
2	Protected against solid objects greater than 12.5mm (e.g. fingers)	2	Protected against sprays of water when tilted up to 15 degrees vertically
3	Protected against solid objects greater than 2.5mm (e.g. tools and wires)	3	Protected against sprays of water when tilted up to 60 degrees vertically
4	Protected against solid objects greater than 1mm (e.g. small wires)	4	Protected against water sprayed in all directions
5	Protected against dust	5	Protected against low-pressure jetting water from all directions
6	Dust tight (total protection)	6	Protected against powerfully jetting water from all directions
		7	Protected against temporary immersion in water (under 30 minutes)
		8	Protected against continuous immersion in water

Different schematics of drivers

Objective : At the end of this lesson you shall be able to
- **explain the working of a 230V led driver circuit.**

Fig 1



A 230V LED Driver circuit without using a transformer is shown in Fig 2. 5 led's are used here, the count it can be increased at your convineance. Due to the absence of Transformers we can reduce the cost and size of the circuit considerably. LED's are Cheap, efficient and cool device with low power consumption, so our electricity bills will be reduced to a great extent.

The circuit is powered by 230V 50Hz ac supply, so be careful while troubleshooting this circuit.

LED's commonly works only in DC, so we have to convert the alternating current to direct current and step down to a safe value before applying to the led sequence.

The circuit mainly consisting of 5 LED bulbs, a bridge rectifier and a filtering network with voltage regulator.

The bridge rectifier is used to convert alternating current (AC) to pulsating DC. It is made possible by means of rectifying diodes (D1 to D4 1N4007)

The filtering is made possible by means of a capacitor (47uF). It is used to eliminate the ripples coming from rectifier circuit.

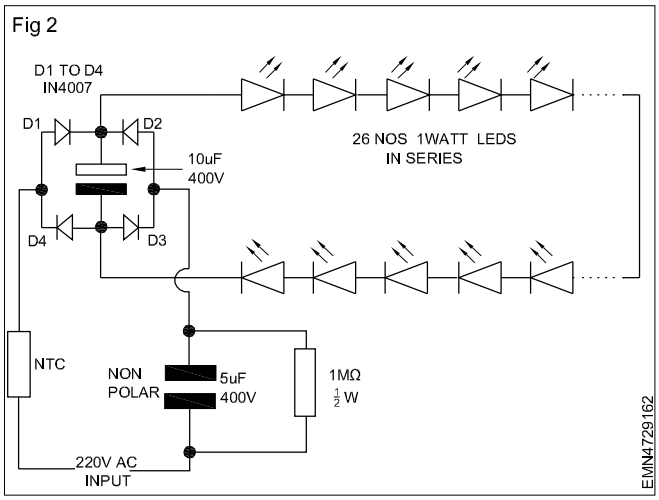
After regulating the filtered voltage using a zener diode, we get an almost direct current suitable for LED's.

A simple one more LED light driver circuit diagram is shown in Fig 3. In the above circuit diagram there is no protection for surge current. In this circuit a surge protection device a NTC has been included. There is in-rush surge currents flow in the circuit during power switch ON in any circuit.

An NTC is attributed with a special property through which it is able to raise its resistance significantly during power switch ON. When used in electronic circuits this property helps blocking the initial surge currents in to the connected circuit. However in the process, the NTC becomes relatively warmer, which brings down its resistance to lower levels such that the normalized safe power subsequently is allowed to pass over to the adjacent circuits.

Normally in an electronic circuit an NTC component is connected with one of the mains supply line as shown in the circuit diagram given below in series.

Fig 2



Design a emergency light using LEDs

Objectives : At the end of this lesson you shall be able to
- **state the brief idea about the emergency light**
- **explain the working of the emergency light with charging circuit.**

A simple LED emergency light circuit that can be implemented for home lighting during power failures is given in the figure below. This LED lighting circuit design is intended to light automatically during main power failures. This circuit is a simple and low cost emergency light. The main part of this LED light schematic is a relay, which automatically connects DC voltage to the battery when main power is present and connect LEDs to the battery in the absence of mains AC power supply.

Working of Emergency light charger circuit

The step down transformer and the diode bridge rectifier steps down and convert the high AC(in the range 230V) voltage to low (12V) DC voltage. The diode D5 prevents the battery charge from flowing back, it acts as a free wheeling diode too.

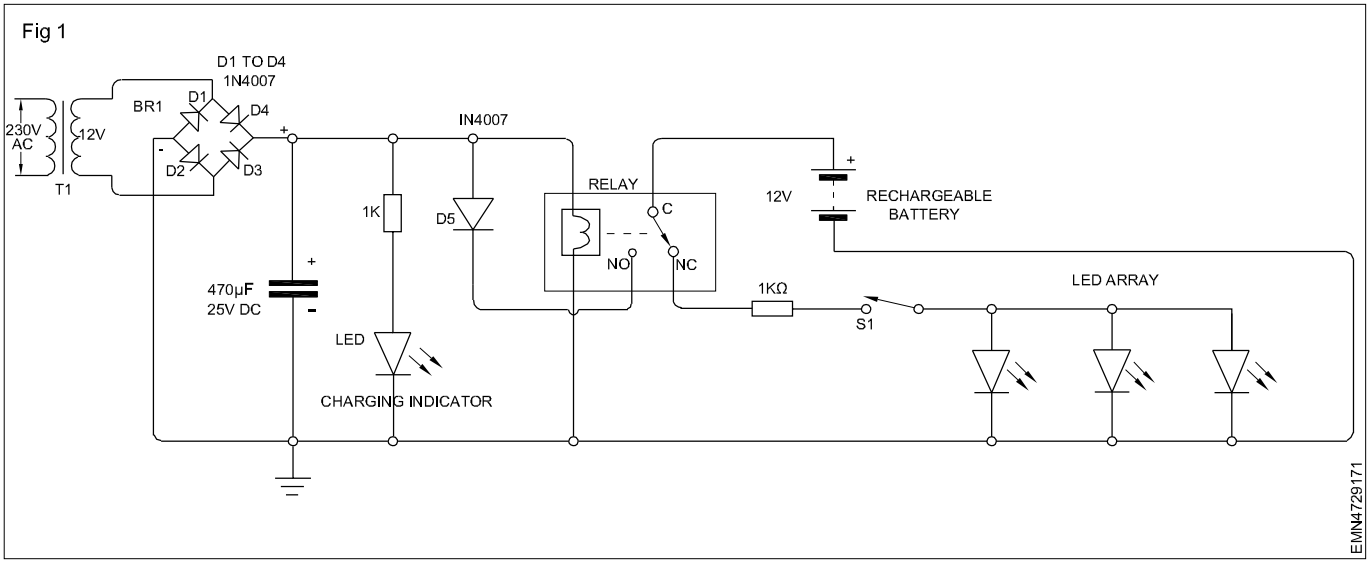
In the presence of electricity, the relay contact connects the NO (Normally Open) terminal to battery. Thus battery charges during this time. A red LED is used in the circuit as the charging indicator which glows when the emergency light battery is charging.

When AC mains supply failure occurs, relay connects the NC (Normally Closed) terminal to the battery. If the switch S1 is closed, the LED arrays are connected to NC terminal, thus they glow by using the charge stored in the battery.

Whenever the emergency light is not used or not required to light, the switch S1 may be released, so that the LEDs will not glow.

To increase the brightness or light few more LEDs may be connected in series and parallel.(series and parallel combination)

Fig 1



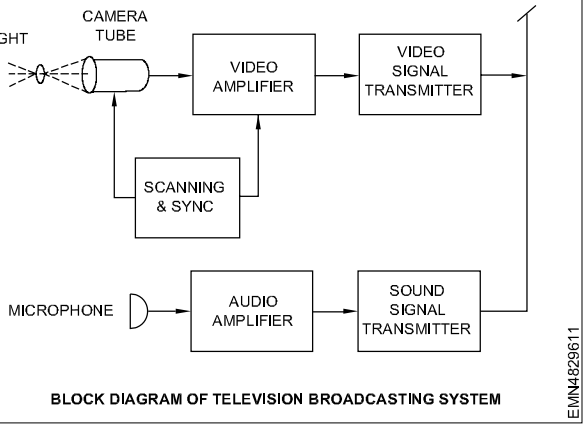
Television transmitter and receiver

Objectives : At the end of this lesson you shall be able to
- **explain the television broadcasting system**
- **explain the television broadcast channel**
- **state the three television systems used across/around the world.**

Television broadcasting

The meaning of the word television "Tele" means at a distance, "vision" means to see the scene or a picture is focused through a TV camera which converts the scene or picture into images to electrical signal. The camera's output signal is modulated and transmitted as electromagnetic waves along with respective sound as in Fig 1.

Fig 1

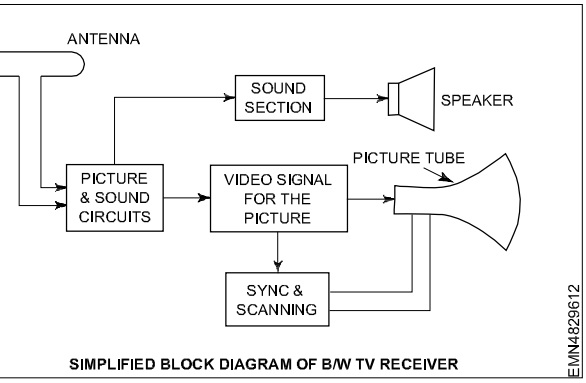


BLOCK DIAGRAM OF TELEVISION BROADCASTING SYSTEM

The term broadcast means to send out in all directions. The transmitting antenna radiates electromagnetic waves which can be picked up by the receiving antenna. The TV transmitter has two functions visual and sound transmission. Both picture signal and the sound signal are emitted from the common radiating antenna.

The receiving antenna intercepts both the picture and the sound carrier signals. The signals are amplified and then detected to recover the original modulation. Then the detected video signal is amplified enough to drive the picture tube.

Fig 2



SIMPLIFIED BLOCK DIAGRAM OF B/W TV RECEIVER

There are three major television systems which are followed in different parts of the world. India and many of the "European" countries follows a system of "PAL" (Phase Alternate Line) which is based on 625 lines 7 MHz channel width with a line frequency of 50Hz. In "America" a system known as "NTSC" (National Television Systems Committee) is followed which is based on 525 lines, 6MHz channel width operating on line frequency of 60 Hz. "France" and some "European" countries follows a system called "SECAM" (Sequential a memory) based on 625 lines with 9 MHz band width.

A television based on one particular system cannot be used in other countries following a different system. For example a television used in America cannot be used in India. The present day Televisions have provision to select one of the three systems so that the same TV could be used with different system in different countries.

Television broadcast channels

The band of frequencies used for video and audio signal transmission is called a television channel.

TV signals are radiated at frequencies above 40 MHz. The VHF and UHF frequency bands that have been assigned for the use of the TV stations are as follows.

Television channel

TABLE 1

Band I	41 MHz to 68 MHz channel 1 to 4
Band II	88 MHz to 108 MHz used for FM Radio broadcast
S-Band	104 MHz to 174 MHz
Band III	174 MHz to 230 MHz Channel 5 - 12 known as VHF band
Hyper Band	230 MHz to 470 MHz and 2 to 20 known as UHF
Band IV	470 to 582 MHz channel 21 to 36
Band V	606 to 870 MHz channel 37 to 69

Only band I and III are used for TV transmission in India. Each band is divided in to a number of channels. According to the standards adopted in India each channel width is 7 MHz.

TV transmitters are provided in different places to cater the needs of the local population. Depending upon the area to be covered either a low-power transmitter (LPT) or high power transmitter (HPT) is installed. A high power transmitter can service an area of around 120Km and a low power transmitter around 20Km radius only.

Scanning bandwidth composite video signal

Objectives : At the end of this lesson you shall be able to
- **define scanning**
- **explain different types of scanning**
- **explain USB transmission and band width of TV signal.**

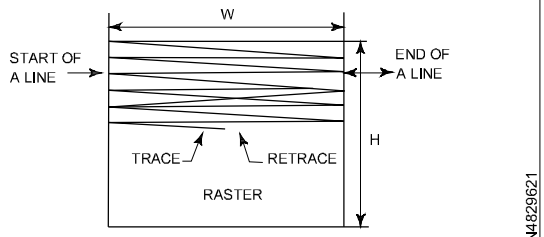
Scanning

Scanning is the process of reading the scene rapidly both in the horizontal and vertical directions simultaneously to provide sufficient number of complete pictures or frames per second to give the illusion of continuous uniform motion. Instead of 24 frames as is the practice in commercial motion pictures, the frame repetition rate is 25 per second in most television systems.

Horizontal scanning

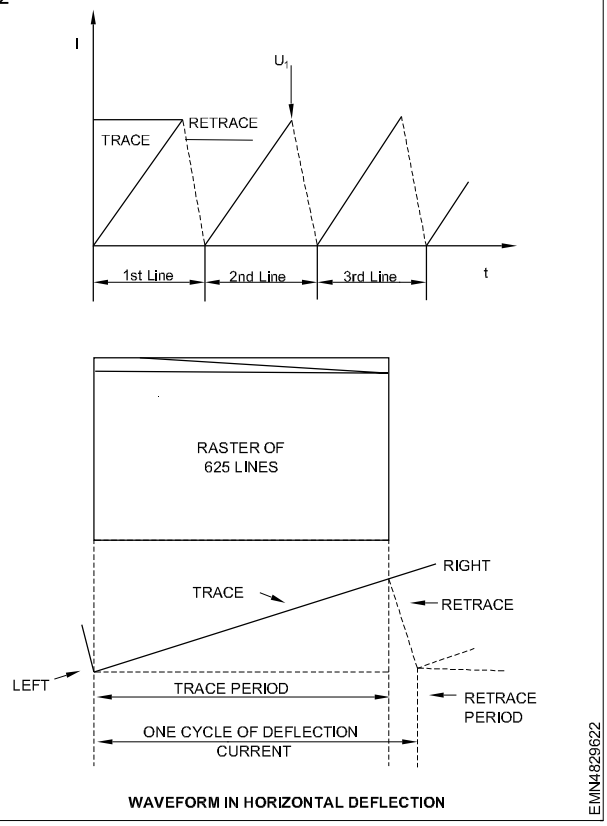
Fig 1 shows the trace and retrace of several horizontal lines. The linear rise of current in the horizontal line deflection coils as shown in Fig 2 deflects the beam across the screen with a continuous, uniform motion for the trace from left to right.

Fig 1



HORIZONTAL TRACE & RETRACE LINES

Fig 2



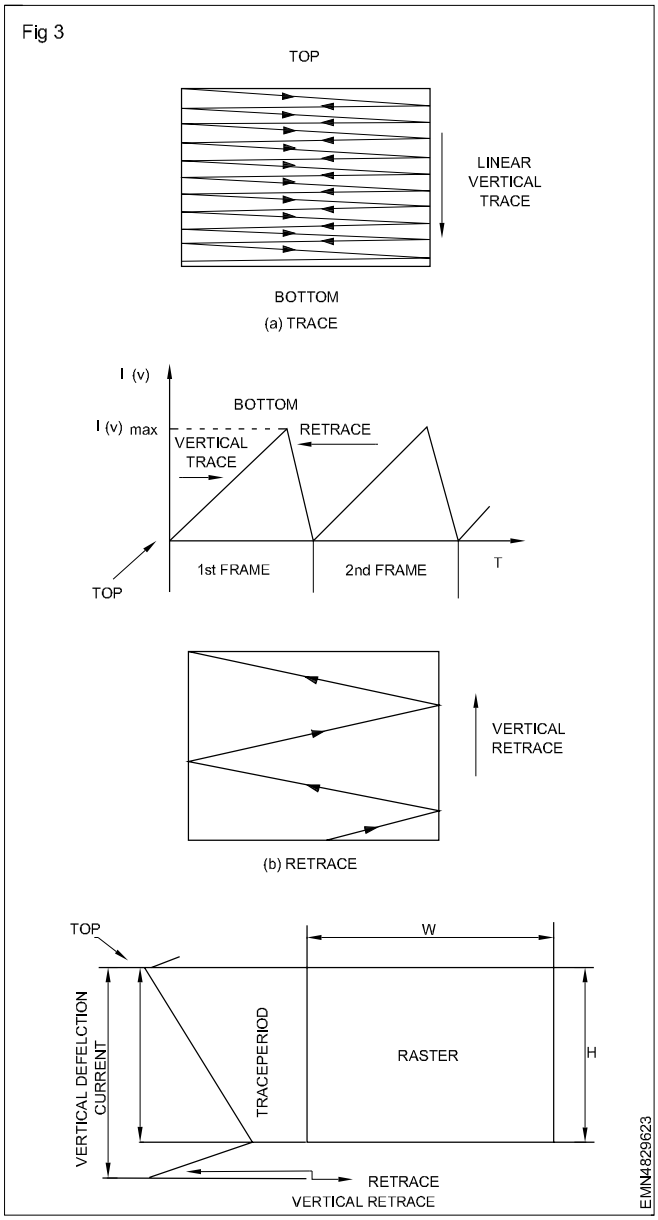
WAVEFORM IN HORIZONTAL DEFLECTION

At the peak of its rise the saw tooth wave-reverses direction and decreases rapidly to its initial value. This fast reversal produces the retrace or fiy back. The start of horizontal trace is at the left edge of raster. The finish is at the right edge and then the fly back produces retrace back to the left edge.

The heavy lines indicate useful scanning time and dashed lines correspond to the retrace time.

Vertical scanning

Fig 3



The saw tooth current in the vertical deflection coils as shown in Fig 3 moves the electron beam from top to bottom.

As shown in Fig 3 the trace part of the saw tooth wave for vertical scanning deflects the beam to the bottom of

raster. Then the rapid vertical retrace returns the beam to the top.

During vertical retrace, horizontal scanning continues and several lines get scanned during this period. Because of motion in the scene being televised, the information at the top of the picture tube screen normally changes by the time the beam returns to the top to recommence the whole process. This information is picked up during the next scanning cycle and the whole process is repeated 25 times per second to cause an illusion of continuity".

It must be noted that both during horizontal and vertical retrace intervals the scanning beams at the camera tube and picture tube are blanked and no picture information is either picked up or reproduced. These short retrace intervals are utilized for transmitting distinct narrow pulses to keep sweep oscillators of the picture tube deflection circuits of the receiver in synchronization with those of the camera at the transmitter. This ensures exact correspondence in scanning at the two ends and results in distortion less reproduction of picture details.

Interlaced scanning

Although the rate of 24 pictures per second in motion pictures and that of scanning 25 frames per second in television pictures is enough to cause an illusion of continuity, they are not rapid enough to allow the brightness of one picture or frame to blend smoothly into the next through the time when the screen is blanked between successive frames. This results in definite flicker of light that is very annoying to the observer when the screen becomes alternately bright and dark.

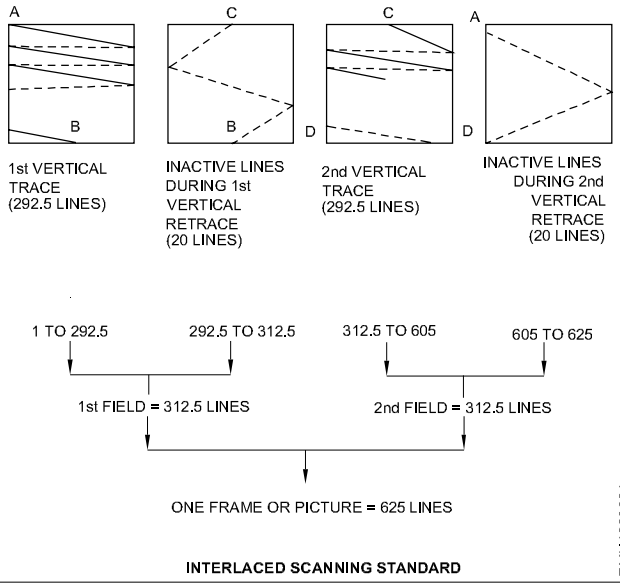
This problem is solved in motion picture by showing each picture twice so that 48 views of the scene are shown per second although there are still the same 24 picture frames per second. As a result of the increased blanking rate, flicker is eliminated.

In television pictures an effective rate of 50 vertical scans per second is utilized to reduce flicker, by making every alternate line to get scanned instead of every successive line. Then when the beam reaches the bottom of picture frame at the end of the first scan, it quickly returns to the top to scan those lines that were missed in the first scanning. Thus the total number of lines are divided into two groups called as "Odd" field and "Even" field. Each field is scanned alternately. This method of scanning is known as 'Interlaced scanning.

In the 625 line TV system each frame or picture is divided into sets of 312.5 lines and each set is scanned alternately to cover the entire picture area. To achieve this the horizontal sweep oscillator is made to work at a frequency of 15625 Hz (312.5 x 50 = 15625), to scan the same number of lines per frame (15625/25 = 625 lines), but the vertical sweep circuit is run at a frequency of 50 Hz.

Note that since the beam is now deflected from top to bottom in half the time and the horizontal oscillator is still operating at 15625 Hz. The first field ends in a half line and the second field commences at middle of the line on top of the screen. The complete geometry of the standard interlaced scanning pattern is shown in Fig 4.

Fig 4



INTERLACED SCANNING STANDARD

The function of video amplifier is to provide sufficient gain to the video signal such that it can drive the picture tube from cut-off for blanking, to zero grid cathode voltage for peak white. The peak to peak value of the video signal required to drive the picture tube vary depending on its size. The video signal with range of video frequencies from 25Hz to over 4 MHz has to be uniformly amplified by the video amplifier. So a wide band amplifier is used with a high amplification factor.

The three basic requirements of a video amplifier are

1 The entire band of video frequencies should be uniformly amplified.

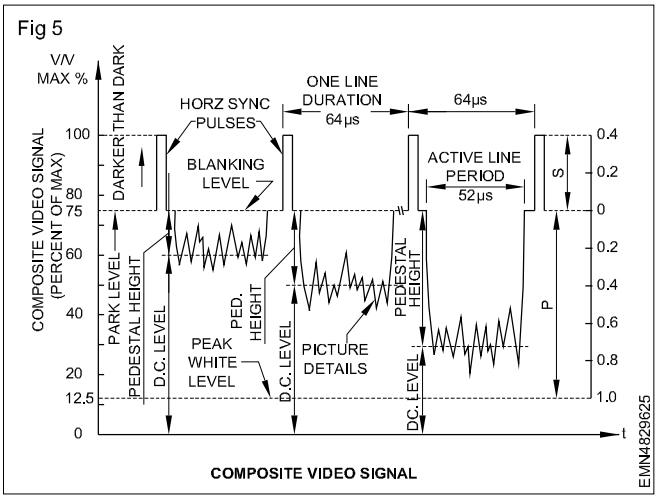
2 As the amplitude of the video signal determines the contrast of the picture, the peak-to-peak value of the video signal is to be sufficient enough to produce a range from bright to dark picture elements on the screen. If the peak-to-peak value is low then the picture on the screen will be very dim.

3 Composite video signal with negative polarity is to be applied at the cathode of the picture tube. Hence the video amplifier should produce such signal from the output of video detector. The Fig 5 shows such type of composite video signal.

VSB or Vestigial side-band transmission

Vestigial sideband transmission system is employed in telecasting. Since, the bandwidth of a Television channel width is 7 MHz and if double sideband transmission is employed then the total telecasting bandwidth will be equal to 14 MHz. Hence, it will be necessary to keep a minimum difference of 14 MHz between two telecasting stations and thus the number of total telecasting stations in the V.H.F and U.H.F. Bands will be reduced. Therefore, V.S.B. transmission system is suitable for telecasting. The width of a T.V. channel is kept 7 MHz for the reason that sound signal is also transmitted along with the video signal. Secondly, a small portion of lower and full upper sidebands is also included in the telecast, see Fig 6.

Fig 5



The system of transmitting video and audio carriers together by employing a single unit is known as inter carrier system. Here, the video carrier frequency is kept 1.25 MHz higher than the channel's lower frequency. Similarly, the sound carrier frequency is kept 0.25 MHz lower than the channel's higher frequency. In this way, the sound carrier frequency rests 5.5 MHz higher than the video carrier frequency. The sound signal is modulated in F.M. mode, therefore, the sound carrier frequency has a sideband of ±100 KHz only.

For example the video carrier frequency and sound carrier frequency of TV channel - 4 under VHF band-I is given below:

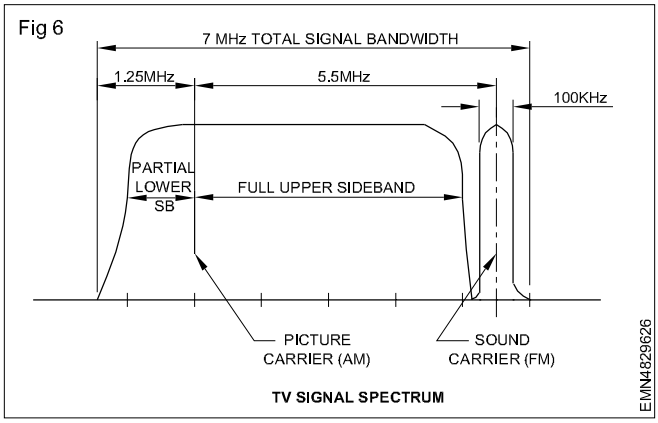
Frequency band allocated - 61 MHz to 68 MHz.

Video carrier frequency is 62.25 MHz (61 + 1.25 MHz = 62.25 MHz)

Sound carrier frequency is 67.75 MHz (68 - 0.25 MHz = 67.75 MHz)

Inter carrier frequency is 67.75 - 62.25 MHz = 5.5 MHz

Fig 6



Principles of colour TV system

Objectives : At the end of this lesson you shall be able to
- **list the primary colours used in colour TV system**
- **define additive and subtractive mixing**
- **describe the production of luminance and chrominance signals**
- **explain QAM signals.**

Primary colours and their mixing

There are three primary colours RED, BLUE and GREEN (RGB) which are used in colour Television system. These three primary colours are capable to produce all the seven rainbow colours - VIOLET, INDIGO, BLUE, GREEN, YELLOW, ORANGE and RED (VIBGYOR).

a) Additive Mixing

Red + Green = Yellow

Red + Blue = Magenta

Blue +Green = Cyan

b) Subtractive Mixing

Yellow = White - Blue

Magenta = White - Green

Cyan = White - Red

So, by additive and subtractive mixing of colours, many other colours are produced.

c) Colour specification

A colour can be specified by three characteristics known as HUE (TINT), SATURATION and LUMINANCE.

i Hue represents the actual colour as seen by the eye. The seven colours of rainbow have different wavelengths and they produce different hue.

ii Saturation represents the purity of a colour. A fully 'saturated' colour will have no white colour mixed in it.

iii Luminance or brightness is the amount of light intensity.

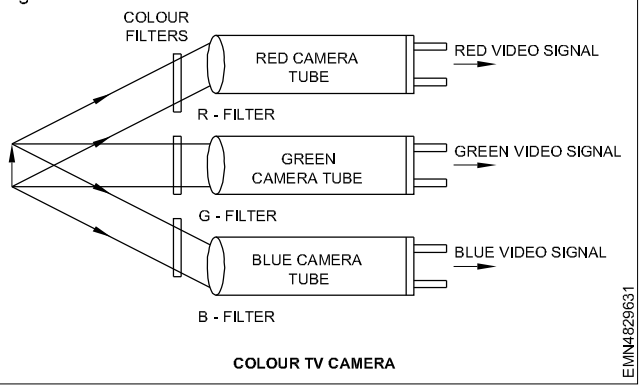
d) Chrominance

The term used to describe the information about hue and saturation of a colour. Different colours represent waves of different frequencies in the visible spectrum. These are electromagnetic waves of frequencies ranging from 4×10^{14} Hz to 8×10^{14} Hz (red to violet) corresponding to 780×10^{-9}m to 380×10^{-9} m wavelengths. Each colour will have a frequency (i.e., hue) and amplitude (i.e., luminance).

Colour TV Camera

For televising a scene in colour, the light originating from a scene is first separated into three primary colours with the help of special filters. Each filter allows only one colour to pass through. Then, the three primary colours (RGB) are converted into three video signals by three camera tubes, see Fig 1. The three video signals called R, G and B signals are then 'encoded' (combined in specific proportions) to produce following two main signals.

Fig 1



COLOUR TV CAMERA

i Luminance signal (Y-signal)

It is also known as y signal. It is obtained by mixing red, green and blue colours in the following ratio:

Y=30% Red + 59% Green + 11% Blue

The above percentage is chosen with a view to the colour sensitivity of human eye. Luminance signal is modulated to the video carrier frequency to provide compatibility by reproducing a black and white picture on a monochrome TV receiver. In colour TV this signal helps in decoding the three primary colours at the colour picture tube.

ii Chrominance signal (C-signal)

It contains all the colour information regarding 'hue' and 'saturation' of a colour. This information is then produced in the form of V(R-y) and U(B-y) signals, for LCD and LED TV Receivers.

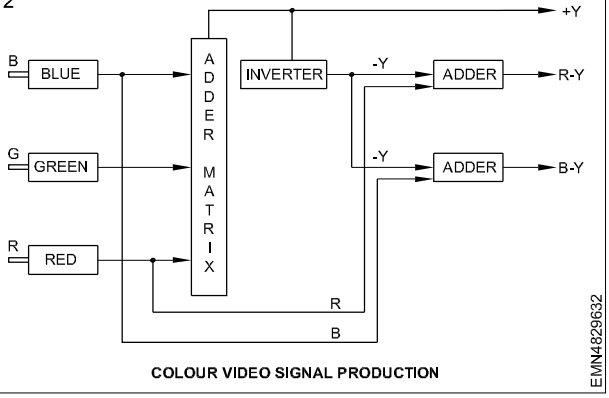
For this purpose. The Y signal is inverted into (-Y) by an inverter stage and then added to R and B signals in the following manner:

R + (-Y) = R - Y (V-signal)

B + (-Y) = B - Y (U-signal)

G-Y signal is not required because the G-information is already contained in the Y-signal. The two colour-difference signals (R-Y and B-Y) are modulated with a subcarrier frequency of 4.43 MHz (Fig 2)

Fig 2



COLOUR VIDEO SIGNAL PRODUCTION

Matrix

The circuit in which, the video signals are mixed in a given proportion and modulated with a sub-carrier frequency for telecasting, is called matrix unit.

A special type of amplifier stage is used which produces Quadrature Amplitude Modulated (QAM) signal. The chrominance signal is obtained by employing amplitude modulation. The two colour difference signals (R-Y and B-Y) are modulated with a sub carrier frequency (4.43 MHz) in amplitude modulation mode so that they have a phase difference of 90°, i.e., they are in 'quadrature'.

At any instance, the amplitude and phase of the chrominance signal depends on the relative amplitudes and phases of the colour-difference-signals. The amplitude of chrominance signal represents the 'saturation; and its phase represents the 'hue' in the modulated signal. Since, R-Y and B-Y signals are mutually at right angles, therefore, the modulated signal is called 'quadrature amplitude modulated' signal.

Difference between CTV with LCD/LED TV and CRT screen

	LCD & LED	CRT
Slim Factor	Slim	Bulky
Viewable screen	Full or very close to its size	Usually 0.9 inches or less than actual size
Screen Flatness	True Flat	Fake Flat (unless aperture grille)
Radiation	Little or none	More Radiation
Weight	Light	Heavy
Power Requirements	Low Power requirement	250% or more power compared to LCD/LED TV
Glare	No Glare	Reduced Glare
Image Sharpness	Sharp	Slightly less sharp images

Automatic Resize	Perfect	Imperfect
Burn-In	None	Suffers from burn-in problem
Refresh Rate	No refresh rate (60hz fixed)	Needs refresh rate (minimum 72hz)
Warmness	Little	CRT cathode gets warm after sometime
Dead / Stuck Pixel	No such problem	May have dead / stuck pixel
Response Rate	No issue with response rate	Slow
Price	Cheap	Expensive
Native Resolution	None	Has a native resolution
Max Colours	32 bit	8-Bit max, 16.7 million colours.
Viewing Angle	Wide viewing angle	Narrow viewing angle
Video	Ideal for any video viewing including HD	Not ideal for videos, unless HD
Blackness	True Black	Between Dark Grey to Grey

Block diagram of colour Television

Objectives : At the end of this lesson you shall be able to
- **state various stages of a colour TV receiver**
- **describe the broad functions of the individual stages**
- **state the names of important components in the stages.**

The block diagram of a CTV receiver is shown at the end of this lesson. As a reference will help in understanding the concepts of CTV. It stages and flow of signals easy for the beginners. It uses PAL standard.

The basic functions of each stage/blocks are as follows.

Antenna

Antenna receives the electromagnetic waves and converts them into corresponding RF signals which is fed to the television set.

Yagi antenna is commonly used in VHF/UHF range for its simple construction and low air resistance. (Now-a-days cable TV and DTH set-top box is used)

Tuner

The main functions of the tuner are

1 to select the desired channel signal and rejects others.
2 to convert the RF signal into intermediate frequency (IF) by mixing it with local oscillator frequency.
3 to provide gain to the weak input signal picked up by the antenna.
4 to isolate the local oscillator from the feeder circuit to prevent undesired radiation through the antenna.
5 to match the antenna with input circuits of the receiver, and to prevent the appearance of ghost image.
6 to reject the image frequency which also causes the ghost image along with the picture.

The main blocks of the tuner are RF amplifier, oscillator and mixer stage.

Television receiver controls

Most televisions especially B/W TV have the basic controls like brightness, contrast, channel selector and fine tuning, volume control and ON OFF switch. In colour televisions in addition to the above there will be a control for colour.

There are two types of tuning mechanisms available in television which are as follows.

1 Mechanical tuner (Turret type or wafer type)
2 Electronic tuner.

Turret type tuners are used mainly in B/W TVs where a channel is selected by rotating the selector switch and then adjusting the clarity by rotating the fine tuning ring . In electronic tuners there are 8 to 12 switches called as program selectors. Each selector switch has a separate band selector and tuning facility, individual selectors can be tuned to different channels, and subsequently any pre tuned program can be seen in the TV just by pressing the required selector switch.

The brightness control varies the brightness level of the picture and contrast control helps to get the desired gray tone and variations on the picture.

VIF stage

Pre-Amplifier

It amplifies the IF signal obtained from the tuner. IC 203 (SL 1430) is used in this stage.

This stage of amplification is necessary because the gain of receiver is reduced by the use of SAW filter.

VIF Amplifier

This stage has the blocks of video IF amplifier, video detector, Automatic gain control (AGC) and Automatic

frequency tuning (AFT) circuit. This stage has been constructed around IC201 (TDA4420).

Sound section

IC 202(TDA1701) performs the function of complete sound section accommodating sound IF amplifier (SIF), FM detector, Audio driver and audio output.

Luminance and delay line (Y delay)

From buffer amplifier, Y-signal passes through a delay line to Y-amplifier stage. The delay line delays the Y-signal by approximately 60 micro seconds time.

The delay line is a very thin metallic coil with very high value of inductance and distributed capacitance, so that the speed of the signal through the delay line is greatly reduced.

If this delay is not introduced, luminance signal will reach to the picture tube earlier than chrominance signal.

The two main reasons required for delay in Y-signal are as follows

1 Chrominance signal has to pass through relatively complex circuit of the decoder and for this reason it is functionally delayed as compared to Y-signal.

2 The bandwidth of Y-signal is more than that of Chrominance signal. The narrower bandwidth signals take longer time to travel a particular distance.

The main luminance (Y) amplifier

After the delay line the Y-signal is fed to the main Y-amplifier. The circuit used is also called emitter follower which acts as buffer amplifier to prevent any mutual interference between contrast control and black level clamp circuits.

The output signal voltage from Y amplifier is fed to the matrix where it is added with colour difference signals to produce original red, green and blue colour signals.

The horizontal and vertical blanking pulses derived from horizontal and vertical output stages are also fed to Y-amplifier stage.

These pulses ensure that the Y-signal fed to the matrix is held at black level during retrace periods. The average value of luminance signal fed to the matrix unit determines the mean brightness of the picture appearing on the screen.

The contrast control is used for adjusting the amplitude of the luminance signal obtained from the amplifier.

Chrominance signal

IC8707TDA3561 is used in this section (PAL decoder)

Composite colour video signal obtained from video IF section is given to this amplifier. It isolates the video IF section from the other sections, composite video signal output is taken from the emitter circuit which contains.

1 The luminance or Y-signal

2 The colour sub-carrier carrying red and blue chroma signals.

3 The horizontal and vertical sync pulses and

4 The colour burst signal.

Here the division of the luminance and chroma separation takes place. From here composite colour video signal is coupled to chroma band-pass amplifiers through chroma filter, sync separator and the luminance delay line.

U and V signal demodulators

The function of U and V demodulators is to detect U (B-Y) and V (R-Y) modulating signals from the U and V chroma signals.

Each demodulator has two input signals

1 Chroma signal, which is to be demodulated and

2 A constant amplitude output from the sub-carrier oscillator.

After modulation U (B-Y) and V (R-Y) modulating colour difference signals are fed to the matrix from where separated R, G and B colour video signals are available. Y-signal (luminance) is also fed to the matrix.

Video output

The colour video signals R, G and B are fed to respective cathodes of the picture tube after one stage of amplification. Video output circuits for each colour signal are identical. Transistors 92 PU393 is used for all the three video output circuits.

Horizontal section

This section includes sync separator, AFC .horizontal oscillator driver and output stage. This stage has been constructed around IC 601 (TDA1940F)

Horizontal driver stage

The signal obtained from horizontal oscillator is very weak; in this stage voltage amplification is provided and sent to the horizontal output stage through the horizontal driver transformer. Transistor T714 (BF393) is used in this circuit as horizontal driver.

Horizontal output stage

This stage consists of a transistor T716 (BU 508) and Extra high tension transformer (E HT) / line output transformer (LOT).

Power amplification is provided to the horizontal scanning signal by this stage. The 15625Hz signal is sent to the horizontal deflection yoke (HDC) and EHT/ horizontal output transformer.

Other functions of horizontal output stage

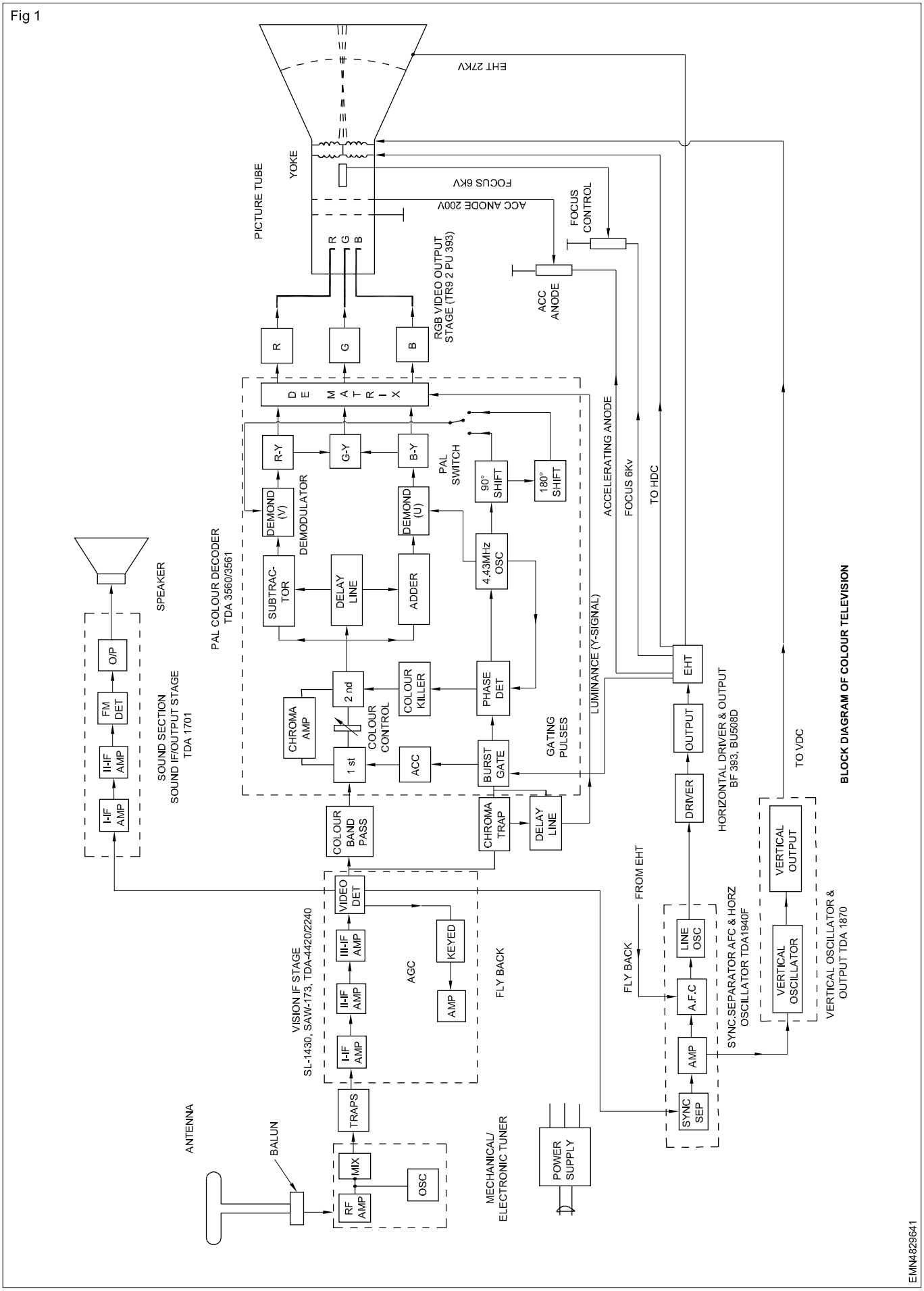
Vertical section

IC401 (TDA1870) is used in vertical section. This section consists of vertical trigger cum vertical oscillator or saw tooth generator, vertical driver and output.

Vertical output

It provides the sufficient power amplification to the vertical deflection signal and then it is sent to the vertical deflection yoke (VDC). Vertical blanking signal is also achieved from this stage and is fed to the video output section.

Fig 1



Principles and working of LCD

Objectives : At the end of this lesson you shall be able to
- **explain the construction of LCD display**
- **describe the working principle of LCD display**
- **list the advantages and disadvantages of LCD displays.**

Introduction

LCD stands for Liquid Crystal Display used to show status of an application, display values, debugging a program, etc.

LCD TV is a television display technolgy based on LCD. By the development of LCD, conventional TVs are changed by the LCD TV. LCD TV consumes much less power and utilize less space. They work on the principle of blocking light rather than emitting, etc.

Construction and working of LCD

Construction of LCD is rather simple, there are certain facts that should be noted while making it.

1 The basic structure of an LCD should be controlled by changing the applied electric current.

2 The light that is used on the LCD can be polarized.

3 Liquid crystals should be able to control both transmit and change the polarized light.

4 There are transparent substances that can conduct electricity.

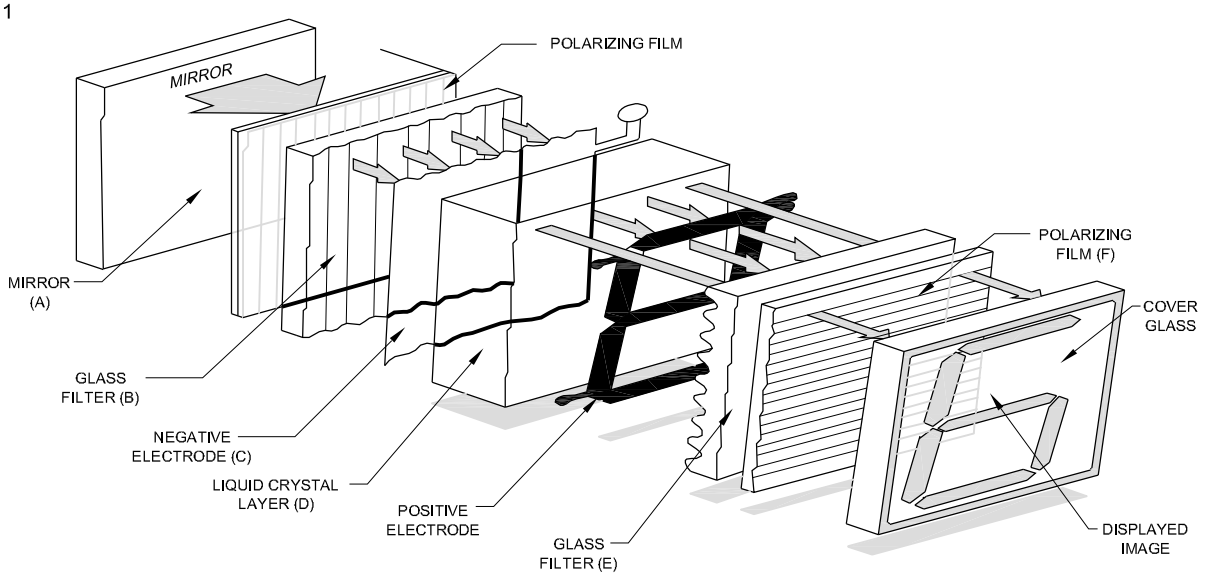
The constructional details of LCD is shown in Fig 1. Two polarized glass filter pieces are required to construct the LCD. The glass which does not have a polarized film on the surface. It must be rubbed with a special polymer which creates microscopic grooves in the surface of the polarized glass filter and the grooves must be in the same direction of the polarized film. Then added a coating of nematic liquid crystals to one of the polarized filters of the polarized glass. The microscopic channel will cause the first layer of molecules to align with the filter's orientation.

When the right angle appears at the first layer piece places a second piece of glass with the polarized film. The first filter will be naturally polarized as the lights strikes it at the starting sleek. Thus the light passes through each layer and is guided on to the next with the help of molecules. The molecules tend to change the plane of vibration of the light in order to match their angle. When the light reaches the far end of the liquid crystal substance, it vibrates at the same angle as the final layer of molecules vibrates. The light is only allowed to enter into the device only if the second layer of the polarized glass matches with the final layer of the molecule.

Working principle

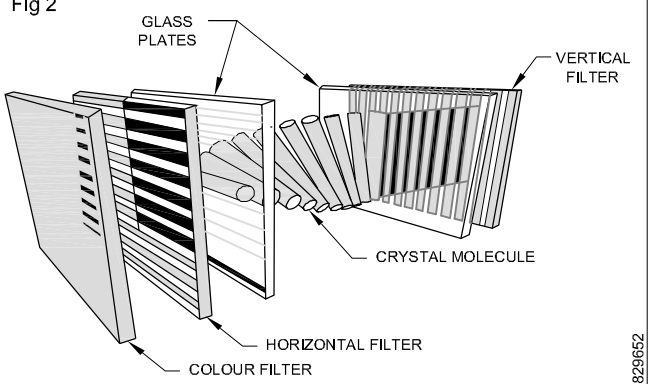
LCD displays consists of two sheets of polarized glass plates seperated by a thin layer of liquid crystal molecule as shown in Fig 2. The type of liquid crystal used in LCD panels have very specific properties. That serves as effective 'shutters' to open and close to block or permit light through in response to an electric current. The current through the liquid crystal is controlled by a voltage applied between the glass plates via transparent electrodes that form a grid with rows on one side of the panel and columns on the other. As the electric current passes through these liquid crystals, they untwist to change the angle of the molecules depending on the applied voltage. This untwisting effect will change the polarization of the light passing through the LCD panel. As the polarization changes with respect to the applied voltage across the glass plates, more or less light is able to pass through the particular area of the polarized filter on the face of the LCD.

Fig 1



HOW LCDs WORK

Fig 2

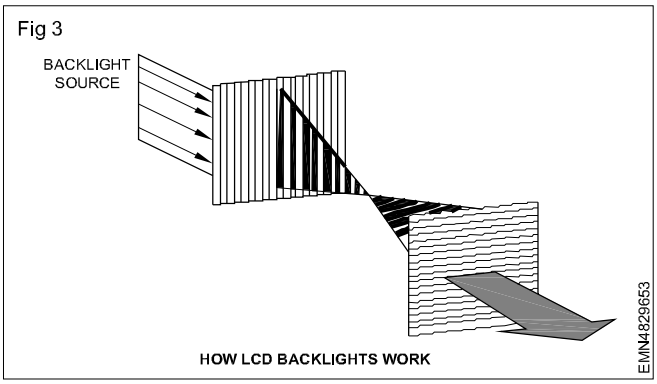


WORKING OF LCD MONITOR

How LCD TV backlights work (Fig 3)

There are too many different types of LCD TV backlight. This hasn't always been the case, though. Initially, the only option was a cold-cathode-fluorescent-lamp system, which essentially comprises of fluorescent tubes behind an LCD panel, providing the light that makes the picture visible.

Fig 3



HOW LCD BACKLIGHTS WORK

Advantages of an LCD's

1 LCD's consumes less amount of power compared to CRT due to the emission of less amount of heat.

2 LCDs are of low cost.

3 Provides excellent contrast.

4 LCD screen is very compact and light weight.

5 Very little emission of electromagnetic radiation.

Disadvantages of an LCD's

1 Limited viewing angle

2 Require additional light sources

3 Range of temperature is limited for operation

4 Low reliability

5 Speed is very low

6 LCD's need an AC drive

7 Some times black level will be unacceptable bright.

Applications of Liquid Crystal Display

Liquid crystal technology has major applications in the field of science and engineering as well on electronic devices.

1 Liquid crystal thermometer

2 Sometimes black level will be unacceptable bright with direct sunlight LCD shows a poor display.

3 Optical imaging

4 The liquid crystal display technique is also applicable in visualization of the radio frequency waves in the waveguide

5 Used in the medical applications

6 Used as TV monitor.

Types of LCD panels

Objectives : At the end of this lesson you shall be able to
- **explain the types of LCD panels**
- **explain twisted nematic display**
- **explain IPS display technology**
- **compare the advantages and disadvantages of IPS screen over the TN display.**

LCD display

LCD displays are mainly two types

1 Twisted Nematic display (TN display)

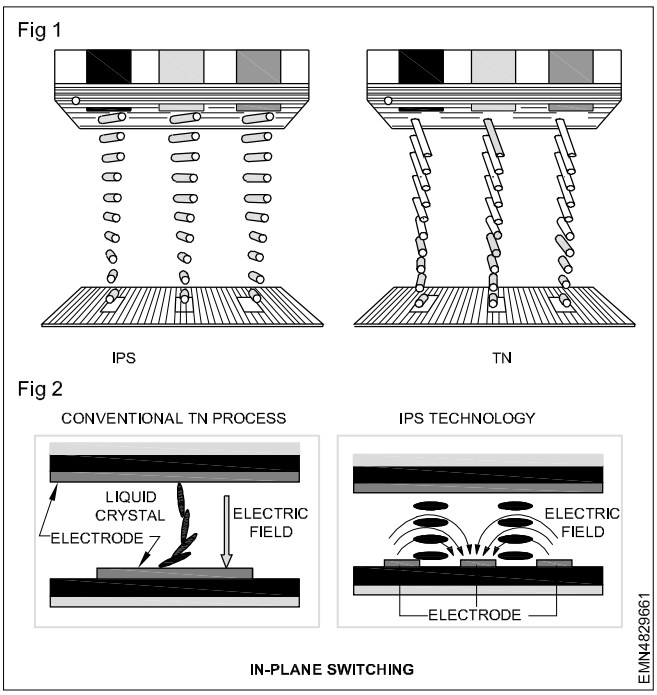
2 In-plane switching or IPS screen technology

Twisted Nematic display (TN display)

A twisted nematic (TN) display is a common type of liquid-crystal display (LCD) that consists of a substance called a nematic liquid crystal that is confined between two plates of polarized glass as shown in Fig 1.

The TN display takes advantage of the ability of the nematic substance to rotate the polarization of light beams passing through it. Two polarizing filters, parallel planes of glass with their polarizing lines oriented at right angles with respect to each other, are positioned on either side of the liquid crystal. When light enters the display, it is polarized by the input filter. In the absence of an electric field, all the incoming light is transmitted. This is because the light polarization is rotated 90 degrees by the nematic liquid crystal, and the light therefore passes easily through the output filter, which is oriented to match the 90-degree shift.

With the application of a voltage, an electric field is produced in the nematic liquid crystal . Under these conditions the polarization effect is reduced. If the voltage is large enough, the polarization effect disappears altogether, and the light is blocked by the output polarizing filter.



Most TN displays have a characteristic black-on-gray or black-on-silver appearance, and are suitable for use in alphanumeric readouts such as those found in wristwatches, cell phone displays, and some calculator displays.

Disadvantages

1 In this particularly poor viewing angle and

2 Low-quality colour reproduction, as well as

3 Poor off-axis image quality and moving picture quality.

4 The application of LCD would be limited to small-display devices, suitable for use in alphanumeric readouts such as calculator displays, digital wristwatches, and earlier models of mobile phones.

In-plane switching or IPS screen technology

IPS, also known as In-Plane Switching, is a type of monitor display and screen technology. More specifically, an IPS panel is a type of TFT LCD (or "active matrix" LCD). The light modulating properties from unlit liquid crystals are used for providing a flat panel or electronic visual display. TFT, which stands for Thin Film Transistor, is an LCD display used for enhanced colour, as well as contrast and black levels.

The active matrix IPS TFT LCD was developed by Hitachi in 1996 as a solution to the display limitations of TN TFT LCDs (Twisted Nematic). The TN display is known for its flawed viewing angles, such as inverting colours at extreme angles, and poor colour quality. By contrast, IPS displays provide wider viewing angles and higher quality colour reproduction by altering pixels to be parallel, rather than perpendicular as shown in Fig 1,2. In an IPS screen, the liquid crystals run parallel with the panels when energized. In a TN display, the crystals turn perpendicular to the top of the panel. High-performance tablets and smart phones deploy IPS display technology used to watch movies, video chat and store photos. The improved angle and colour technology features provide an overall better experience.

Other IPS versions include the following technologies:

1 Super TFT (IPS) for a wide viewing angle.

2 Super-IPS (S-IPS) for colour shift free and an improvement on pixel refresh timing.

3 Advanced Super-IPS (AS-IPS) for high transmittance.

4 Enhanced IPS (E-IPS) for an enhanced diagonal viewing angle and reductions in response time.

5 Horizontal IPS (H-IPS) for an improved contrast ratio and an Advanced True White polarizing film that creates a more natural colour of white.

6 Professional IPS (P-IPS) for truer colour depth.

Advantages of IPS screen technology over TN

1 IPS screen technology is the wide viewing angle.

2 This also results in better colour reproduction.

3 It becomes very popular in displays for television, computers, and laptops, in consumer electronic devices, particularly smartphones and tablets.

4 Under bright outdoor lights or direct sunlight, an IPS screen is more viewable or readable.

Disadvantages of IPS as compared to TN

1 More power consumption. A typical IPS screen requires 15 percent more power than TN.

2 Faster battery drainage.

3 Producing IPS screen displays is more expensive than producing a TN LCD because of the involved engineering complexity. Thus, this screen technology is commonly featured in high-end devices.

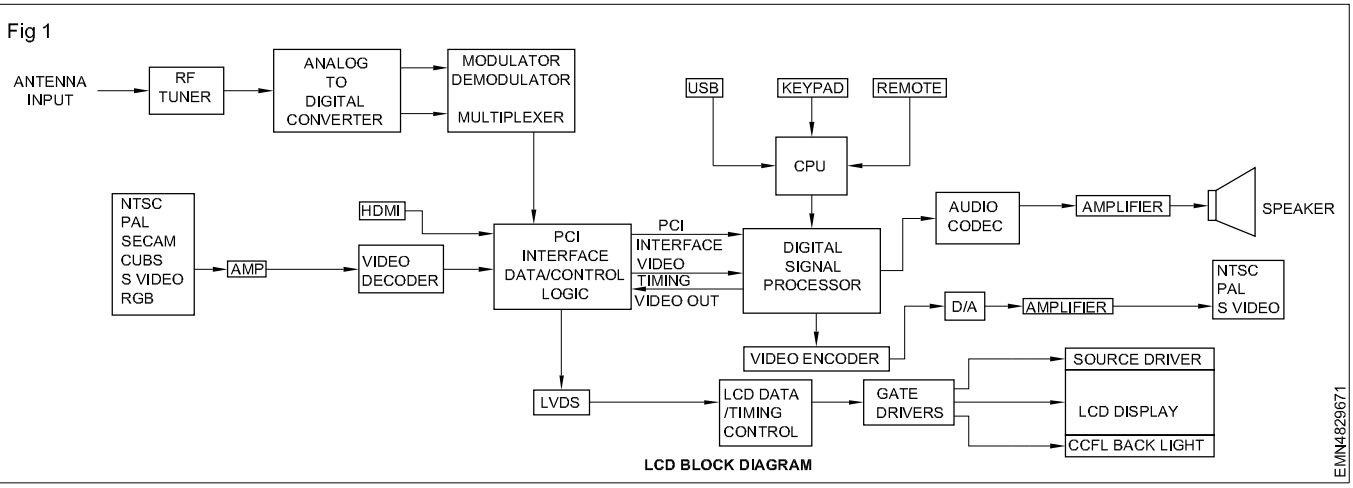
4 The refresh rate of IPS is also slower than TN. This disadvantage makes a conventional IPS screen unsuitable for watching high definition movies or playing fast-paced video games due to ghosting effects.

Block diagram of LCD TV

Objectives : At the end of this lesson you shall be able to
- **explain the block diagram of LCD TV**
- **illustrate block diagram of LCD television**
- **state the features of LCD television.**

Block diagram of LCD TV (Fig 1)

Fig 1



LCD TV block diagram explanation

1 RF Tuner

RF tuner receives the analog signal and converting into VIF & SIF. This signal is demodulated to get video signal. This CVBS(Composite Video Baseband Signal) is processed, and decoded video signal is given to a LCD display panel. The sound signal is demodulated, amplified, and sent to drive the speaker.

2 Digital broadcast

Digital tuner receives the digital signal and demodulate it. The MPEG decoder and composite video encoder-decodes the MPEG compressed data and also encodes video into NTSC/PAL/SECAM signal as an output.

3 HDMI (High Definition Multimedia Interface)

HDMI video signal is processed by video decoder video processor and LVDs(Low Voltage Differential Signal). This signal goto drive the display panel. HDMI audio signal is sent to processor, audio decoder, preamplifier and finally goes to the loud speaker.

All input signals whether it is coming from antenna, audio video, video graphics, HDMI and USB are fed to corresponding processing circuit. Processed converts all the signals into digital signal and fed to PCI (Pheripheral Component Interconnect) interface.

4 PCI interface (Data and control logic)

With the help of CPU all the signals from previous section (audio/video signals) are processed, and sent to output section which is controlled by a front panel control and also by a remote control.

5 Front panel controls

The controls in the TV front panel are used to adjust/ control the overall performance of the TV.

6 Digital signal processor

The signal that comes from the PCI section is processed by the DSP section. The sound signal converted into analog signal (DAC) and fed to audio amplifier stage and digital video signal processed and feeding to video encoder section.

7 Image signal processing

The signal that comes from the PCI interface section is processed (Amplification error correction, colour signal separation) and sent to LCD screen and colour processor.

8 Colour processor

The signal from the image signal processor is processed (Horizontal timing colour correction) and fed to LCD screen.

9 LCD screen

LCD display receive both the signals from LCD data/ timing control and colour processor. According to both the signals the LCD screen produce the picture or image.

10 Colour balance in LCD screen

In a TV displays, colour is achieved by a continuous flow of light waves at pixel, and also by an amount of light passed by a mosaic filter (Red, Green, Blue). Colour balance is extremely difficult in LCD monitor, because colour trial must remain constant for any change in light. This is difficult for black, because all colour wavelength is different, so some light passes and produce other colour rather than black. One way to block light of all wavelength by maintaining a liquid crystal cell gap at a particular distance to the wavelength of light going from same location. The practical way is only by a multiple gap technology. The thickness of the red, green and blue mosaic filters are arranged in the cell gap is 6.4 µm, 5.8 µm and 4.8 µm respectively.

11 Power section

Power section including the AC to DC conversion to create the main power for the entire unit. Most of the functional block in the LCD TV requires a particular voltage and current especially for the main processor, DDR memory, the tuner and video/audio signal chains.

12 LCD

The LCD screen brightness is not enough to view with bare eyes. So some backlight is needed to light the image, which is done by Cold Cathode Fluorescent Lamp (CCFL) in LCD TV.

Working principle of LED TV

Objectives : At the end of this lesson you shall be able to
- **describe LED TV technology**
- **explain the type of LED lighting technology**
- **explain the difference between LED and LCD TV.**

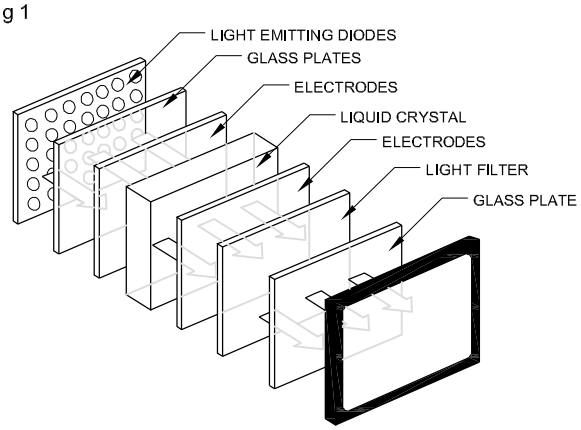
The LED has become a pivotal illumination technology with a wide variety of applications. The rapid advancement of semiconductor technology together with new concepts in packaging design has led to a significant increase in LED brightness, so that the use of light emitting diodes in backlighting applications has gained increasing importance. Due to their increased efficiency, LEDs are being used in many new application areas ranging from larger display panels to television screens.

LED TV technology

LED, which stands for "Light Emitting Diodes", differs from general LCD TVs in that LCDs use fluorescent lights as backlight while LED TVs use those light emitting diodes.

An LED TV illuminates its LCD panel with light-emitting diodes as shown in Fig 1. LEDs consist of small semiconductors, which glow during exposure to electric current. Specifically, this current flow between LED anodes and LED cathodes as shown in Fig 2.

Fig 1

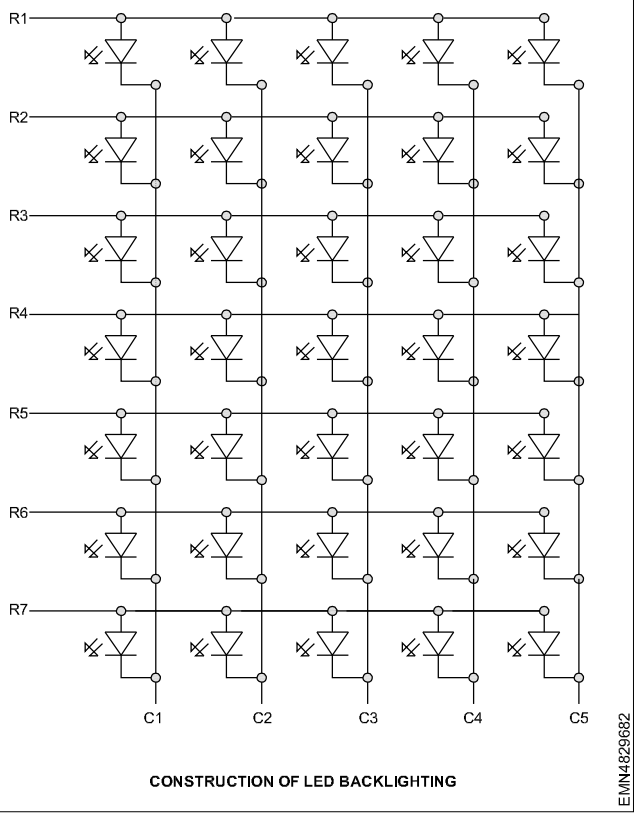


LED TV TECHNOLOGY PROCESS

The fluorescent lamps function in LED TV by using mercury vapour to create ultraviolet rays, which in turn cause the phosphor coating of the lamps to glow.

LEDs have several advantages over fluorescent lamps, including requiring less energy and being able to produce brighter on-screen colours.

Fig 2



CONSTRUCTION OF LED BACKLIGHTING

Types of LED lighting technology

There are two primary forms of LED lighting technology that LED TVs can utilize full-array LED backlighting and edge-lit LED backlighting. Also known as local-dimming technology, full-array technology employs arrays or banks of LEDs that cover the entire back surfaces of LED TV screens.

In contrast, edge-lit technology employs LEDs only around the edges of LED TV screens. Unlike an edge-lit LED TV, an LED TV with full-array technology can selectively dim specific groups of LEDs, allowing for superior contrast ratio and superior overall picture quality.

Energy consumption

As with any TV, an LED TV needs energy in order for its components to function. Specifically, an LED TV needs electric current for stimulating the liquid crystals in its LCD panel and for activating its LED backlighting.

In comparison to standard LCD TVs, LED TVs consume less energy. An LED TV will typically consume between 20 and 30 percent less energy than an LCD TV with the same screen size.

Difference between LCD and LED

1 LCD stands for "Liquid Crystal Display" and technically, both LED and LCD TVs are liquid crystal displays. The basic technology is the same in that both television types have two layers of polarized glass through which the liquid crystals both block and pass light. So really, LED TVs are a subset of LCD TVs.

2 LED, which stands for "Light Emitting Diodes", differs from general LCD TVs in that LCDs use fluorescent lights as backlight while LEDs use those light emitting diodes.

3 The fluorescent lights in an LCD TV are always behind the screen. On an LED TV, the light emitting diodes can be placed either behind the screen or around its edges.

4 The difference in lights and in lighting placement has generally meant that LED TVs can be thinner than LCDs. It has also meant that LED TVs run with greater energy efficiency and can provide a clearer, better picture than the general LCD TVs.

5 LED TVs provide a better picture for two basic reasons, first, LED TVs work with a colour wheel or distinct RGB-coloured lights (red, green, blue) to produce more realistic and sharper colours, second, light emitting diodes can be dimmed. The dimming capability on the back lighting in an LED TV allows the picture to display with a truer black by darkening the lights and blocking more light from passing through the panel. This capability is not present on edge-lit LED TVs. However, edge-lit LED TVs can display a truer white than the fluorescent LED TVs.

6 All the LCD TVs are thin-screen, each has particular viewing angle and anti-glare issues. The backlit TVs provide better, cleaner viewing angle than the edge-lit LED TV. However, the backlit LED TV will usually have better viewing angle than the standard LCD TV.

Block diagram of LED TV

Objectives : At the end of this lesson you shall be able to
- **explain the block diagram of LED TV**
- **describe the back light in an LED TV**
- **explain the driver circuit used in an LED TV.**

Introduction

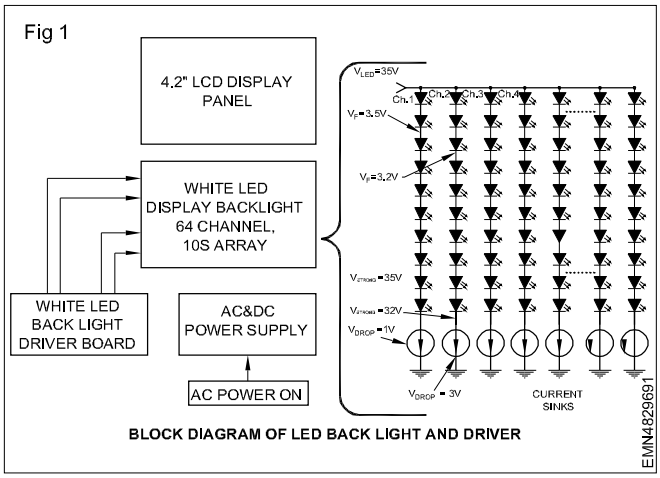
The functional block diagram of LED TV is similar to that of a LCD TV. The only difference is in its display screen technolgy.

LED Driver and back light in LED TV

There are large arrays of LEDs located behind the LCD panel in a typical LCD TV LED backlighting system as shown in Fig 1. In this array are a large number of parallel channels of LEDs connected in series depending on the size of the TV and the type of backlighting, for example edge backlighting (less LEDs but more in series) or direct backlighting (more LEDs in parallel).The LED voltage (VLED) is provided by the White LED Backlight Driver Board to each LED channel and is regulated to a level needed by the highest voltage required to maximize the light output of each LED string.

Depending upon the power supply requirements determined by the number of LEDs in the string or grouping of parallel LED strings, the up-stream power

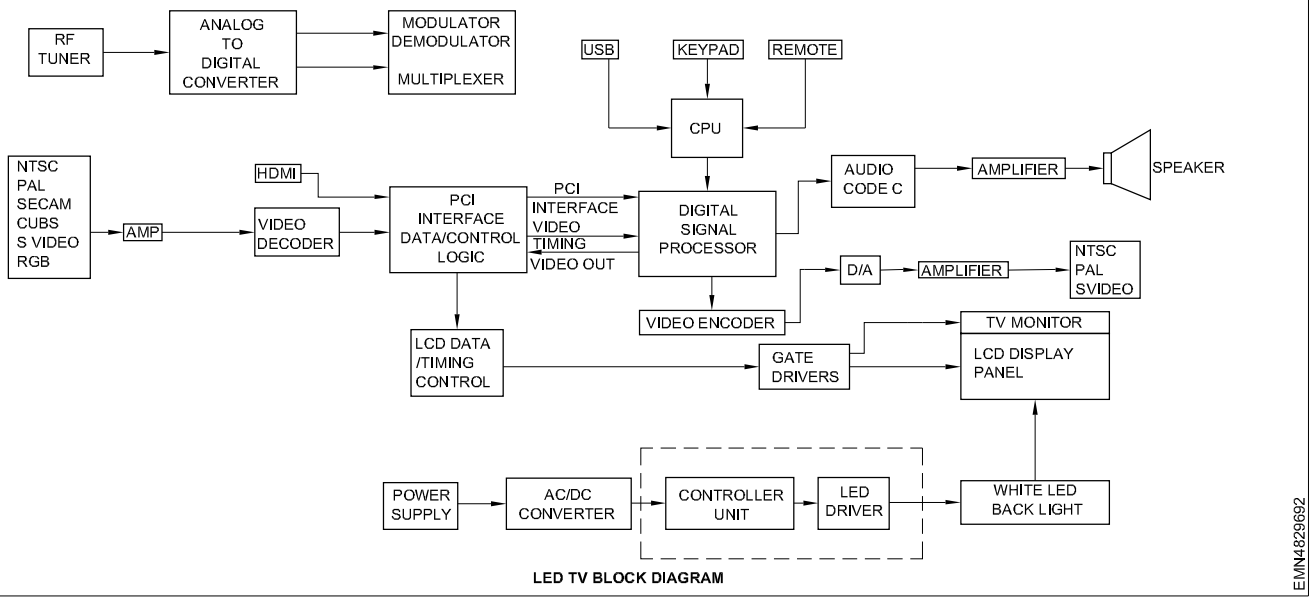
Fig 1



BLOCK DIAGRAM OF LED BACK LIGHT AND DRIVER

source for the LED backlight driver board may be a DC/DC step-up boost converter, a DC/DC step-down converter or more commonly an AC/DC converter. In the case where supply voltage is lower than the required VLED, a step-up boost converter will be used.

Fig 2



LED TV BLOCK DIAGRAM

Introduction of OLED TV

Objectives : At the end of this lesson you shall be able to

- **define OLED TV**
- **working of OLED TV**
- **types of OLED TV**
- **OLED advantages and disadvantages**
- **application, of OLEDs**

OLED TV

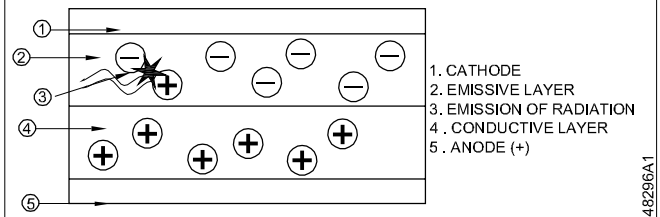
An OLED TV is a television display technology based on the characteristics of organic light-emitting diodes (OLED). An organic light-emitting diode (OLED) is a light-emitting diode (LED) in which an emissive electroluminescent layer as a film of organic compound is sandwiched between two conductors, which emits light in response to an electric current. A typical OLED is composed of an emissive layer, a conductive layer, a substrate, and anode and cathode terminals. The layers have conductivity levels ranging from insulators to conductors, so OLEDs are considered as organic semiconductors. OLED TV is a different technology than LED TV.

The OLED displays do not require backlighting. They can be thinner and weigh less than other display technologies like LCD. OLED displays also have a wide viewing angle - up to 160 degrees even in bright light and use only two to ten volts to operate. An OLED display works without a backlight; thus, it can display deep black levels.

Working of OLED TV

The first most basic OLEDs consisted of a single organic layer, light-emitting polymer device synthesised by Burroughs et al from USA , involved a single layer of poly(p-phenylene vinylene). Multilayer OLEDs can have more than two layers to improve device efficiency. As well as conductive properties, layers may be chosen to aid charge injection at electrodes by providing a more gradual electronic profile, or block a charge from reaching the opposite electrode and being wasted.

Fig 1



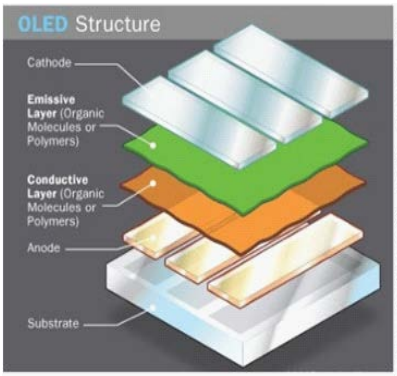
SCHEMATIC OF A 2-LAYER OLED

A voltage is applied across the OLED such that the anode is positive with respect to the cathode. This causes a current of electrons to flow through the device from cathode to anode. Thus, the cathode gives electrons to the emissive layer and the anode with draws electrons from the conductive layer; in other words, the anode gives electron holes to the conductive layer.

Soon, the emissive layer becomes negatively charged, while the conductive layer becomes rich in positively charged holes. Electrostatic forces bring the electrons and the holes towards each other and they recombine. This happens closer to the emissive layer, because in organic semiconductors holes are more mobile than electrons. The recombination causes a drop in the energy levels of electrons, accompanied by an emission of radiation whose frequency is in the visible region. That is why this layer is called emissive.

Indium tin oxide is commonly used as the anode material. It is transparent to visible light and has a high work function which promotes injection of holes into the polymer

Fig 2



layer. Metals such as aluminum and calcium are often used for the cathode as they have low work functions which promote injection of electrons into the polymer layer.

OLED types

OLEDs can be categorized into passive-matrix and active-matrix displays.

AMOLED

Active-matrix OLEDs (AMOLED) require a thin-film transistor backplane to switch each individual pixel ON or OFF, but allow for higher resolution and larger display sizes.

PMOLED

PMOLED stands for Passive-Matrix OLED, which relates to the way to control (or drive) the display. A PMOLED display uses a simple control scheme in which to control each row (or line) in the display sequentially (one at a time). PMOLED do not contain a storage capacitor and so the pixels in each line are actually off most of the time. To compensate for this you need to use more voltage to make them brighter.

OLED advantages

1 Flexible
2 Very thin
3 Colour capability
4 Power consumption
5 Bright images
6 Wide viewing angle
7 Fast response time

OLED disadvantages

1 Moisture sensitive
2 Limited life
3 **Lifespan:** The lifespan of the OLED displays is a major problem. Currently they are around half that of an LCD, being around 15 000 hours.
4 **UV sensitivity:** OLED displays can be damaged by prolonged exposure to UV light. To avoid this UV blocking filter is often installed over the main display, but this increases the cost.

Applications

OLEDs are being used in many applications from television set screens, and computer monitors, along with other small, portable system screens such as mobile smart phones to watches, advertising, information, and indication. OLEDs are also used in large-area light-emitting elements for general illumination.

Currently OLEDs emit less light than their in-organic counterparts, but their flexibility means that they can be used in a much greater number of applications.

Concept of 3D TV

Objectives : At the end of this lesson you shall be able to
- **define 3D TV technology**
- **concept of 3D TV**
- **different 3D TV standards.**

Definition of 3D TV technology

3D TV is a television display technology that enables a "three dimensional effect", so that viewers perceive that an image has depth as well as height and width, similar to objects in the real world.

The principles of 3D TV and how it works

The viewer perceives depth because the right eye and the left eye are in different locations and each eye captures even so slightly different image. The brain processes the two different images into a single image enabling us to focus and perceive the world around us with a sense of depth.

The central principle behind 3D TV is exactly the same - two different images are displayed and then shown to the left eye and right eye. The footage shown to the eyes is recorded from two slightly different perspectives, either from two different cameras, or a camera with two lenses.

This footage is then interlaced into one image and broadcast to 3D-ready TVs which are then able to polarise (separate) the original 3D broadcast back into separate images. They appear on the screen as not clear images - but when viewed through 3D glasses, the separate images are directed to either the right eye or left eye, creating the impression of depth.

Different 3D TV standards

Anaglyphic 3D

Many people associate 3D with a pair of cardboard red/ cyan (a kind of greenish colour) tinted glasses and legendary

movies like "jaws 3D". This format is called anaglyphic 3D and till quite recently this was the most popular way to create 3D content.

Anaglyphic 3D is created by filming in two different coloured layers. Usually red and cyan, these images are filmed slightly offset from the actual image focused on. The viewer when wearing the filtered glasses sees a differently coloured image in each eye. However, the viewers brain is tricked into thinking the coloured layers are as one, thus creating an added sense of depth and creating the 3D image.

This form of 3D viewing is now largely obsolete. Common problems with the format included poor image quality, blurring and even motion sickness in extreme cases.

Polarisation 3D

The polarisation format will be instantly familiar to anyone who has been to see a 3D movie at the cinema of lately. These grey tinted, plastic glasses are much more substantial.

The general principles are the same as for the anaglyphic 3D format as two slightly different images are seen by each eye, assembled by the brain into one image creating a sense of depth. The way of achieving this though is very different. These glasses work by allowing each eye to see differently polarised light. For example, light polarised in one direction will be seen by the left eye and light polarised in the other by the right.

Alternate frame sequencing

The frame sequential format is already the accepted standard for 3D blu-ray. This format requires a pair of active shutter glasses to deliver its 3D content.

In this format the footage is recorded by two cameras (or a single dual lensed camera) and is then placed next to each other on a strip of film, following this it is displayed frame-by-frame in an alternating order. The active shutter glasses are synchronised with the television through an infra-red signal and rapidly blink on and off to play to back images alternatively to the viewers eyes at a rate of 50 frames per second.

The majority of new 3D TVs come with one or two pairs of active shutter glasses. These glasses are typically designed to be brand specific although Panasonic and Samsung are interchangeable. These glasses are primarily designed for watching 3D blu-ray content. These glasses are also quite a lot more expensive and require a power source to drive the LCD shutters, usually via a USB port on the television. Some viewers have complained of warm eyes after prolonged use from these early models.

Comparison of CRT and LCD/LED TV

Objective : At the end of this lesson you shall be able to
- **list out the differences between CRT, LED and LCD TV.**

Comparison between CRT with LCD and LED TV

	LCD & LED	CRT
Slim Factor	Slim	Bulky
Viewable screen	Full or very close to its size	Usually 0.9 inches or less than actual size
Screen Flatness	True Flat	Fake Flat (unless aperture grille)
Radiation	Little or none	More Radiation
Weight	Light	Heavy
Power Requirements	Low Power requirement	250% or more power
Glare	No Glare	Reduced Glare
Image Sharpness	Sharp	Slightly less sharp images
Automatic Resize	Perfect	Imperfect
Burn-In	None	Suffers from burn-in problem
Refresh Rate	No refresh rate (60Hz fixed)	Needs refresh rate (minimum 72 Hz)
Warmness	Little	Cathode gun gets warm after some time
Dead / Stuck Pixel	No such problem	May have dead / stuck pixel
Response Rate	No issue with response rate	Slow
Price	Cheap	Expensive

Native Resolution	None	Has a native resolution
Max Colours	32 bit	8-Bit max, 16.7 million colours.
Viewing Angle	Wide viewing angle	Narrow viewing angle
Video	Ideal for any video viewing including HD	Not ideal for videos, unless HD
Blackness	True Black	Between Dark Grey to Grey

Types of cables used in LCD/LED TV

Objectives : At the end of this lesson you shall be able to
- **differentiate types of input/output sockets provided on the LCD/LED TV**
- **explain the different types of cables used in LED and LCD TV.**

Types of cables used in LCD/LED TV

The modern television technology has paved the way for using the TV as a versatile display device for various audio visual equipments as well as computer.

The following types of connectors are provided on the side/rear or on the front panel of the latest television sets.

1 R.F. socket

2 A.V. input/output

3 HDMI socket

4 USB socket

5 DVI cable

6 Optical input/output

7 VGA input

8 3.5 mm stereo jack

1 R.F. socket

Fig 1a

R.F. Flyer cable

Fig 1b

R.F. Extension cable

It is used to connect the antenna signal to the TV. An aerial fly lead as shown in Fig 1a is used to connect from a TV aerial socket on the wall to an aerial input socket on a TV or set-top box. It will have a male aerial plug at both ends. Co-axial aerial extension lead has both male and female plug at each end. (Fig 1b). They are also used to connect set-top box and recorders to TV sets.

2 A.V. input/output (RCA cables)

Fig 2a

RCA Socket

Fig 2b

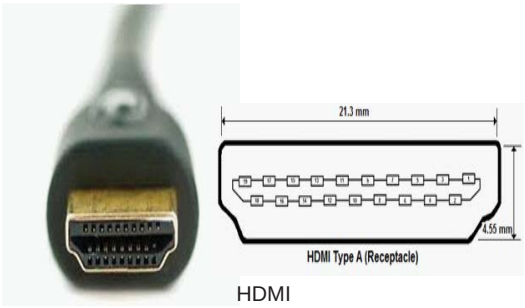
3RCA to 3RCA cable

For audio and video signals RCA cables are used to connect the VCR, CD/DVD players, set-top box, video camera, etc to TV sets. These RCA cables are available as 2RCA to 2RCA as well as 3RCA to 3RCA cable pairs to connect stereo audio red for right channel, white for left channel and yellow for video signal. Seperate set of AV input and output sockets are provided to play or record signals.

3 HDMI socket (High Definition Multimedia Interface)

This socket is a common digital interface for audio and video signals from DVD /Blue ray/ Home theatre system, set-top box, etc. HDMI is a digital interface for audio and video that provides a single cable solution for consumer electronics equipments like TVs, home theatre, blue-ray/

Fig 3



HDMI

DVD, set-top box, etc. This replace long running analog interfaces like VGA, S-Video and RGB.

4 USB socket (Universal Serial Bus)

Fig 4

USB - Flash drive

USB 2.0 terminal for connecting USB flash drive/mass storage devices MP3 music/songs and movies playing directly on LCD/LED TV set. Stored programs can be selected by the remote control of the TV set.

5 DVI cable (Digital Visual Interface cable)

Fig 5a

DVI to HDMI adapter

Fig 5b

DVI to VGA/D-sub adapter

This is also known as Digital Versatile Interface cable. It is used to connect video signals to the display devices of desktop computers and LCD/LED monitors. It is similar to VGA connectors with upto 24 pins and supports for analog as well as digital video. DVI can stream upto 1320 x 1200 HD video or with dual link DVI connectors can support upto 2500 x 1600 pixels.

6 Optical input/output

Fig 6a

AV input/output

Fig 6b

This cable is also known as SPDIF connector. This is used to connect the home theatre/DVD player/Blue ray disc player into LCD/LED TV for playback. It is also used to play the audio/music from LCD/LED TV through the home theatre system.

7 VGA input(15 pin D-type)

This terminal is used to connect computer output using VGA cable for functioning the LCD/LED TV as video monitor. Even the laptop output can be displayed on the wide LCD/LED screen of the TV set.

Fig 7

VGA - Cable

8 3.5 mm stereo jack

This socket is provided to connect stereo head phone for TV program sound/audio. It can be used for recording the audio signal thro external equipment or play the sound/audio using public address amplifier system.

Fig 8

3.5 mm stereo to RCA cable

Remote control

Objectives : At the end of this lesson you shall be able to

- **define remote control**
- **describe different types of remote controls**
- **list out parts of a remote control**
- **explain the block diagram of IR transmitter and IR receiver**
- **explain the working principle of a IR remote control.**

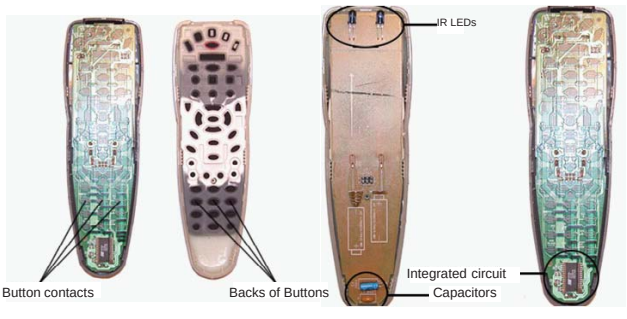
Introduction

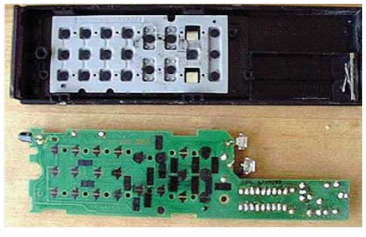
Remote control is an electronic device, used to control the functions of another device wirelessly from a short distance.

A remote control (RC) is a small, usually hand-held, electronic device for controlling another device, such as a television, radio or audio/video recording device, gaming console, set-top box etc. Remote controls commonly operate via infrared(IR) signals but sometimes by radio frequency signals also. The remote control may control a variety of functions such as volume, channel, track number and other functions. Modern remote control devices often have more controlling functions, which may have only a few primary essential controls.

A remote control may also be called a clicker, flipper, tuner, changer or converter.

Fig 1





Types of Remotes

There are three basic types of remote controls in common usage:

1 Infrared (IR) Remote

2 RF Remote

3 Bluetooth Remote

Infrared Remote (IR)

IR remote control works on a pretty simple principle of "Photo electric effect".

Infra Red remote control is wireless device used to operate audio, video and other electronic equipment within a room using light signals in the infrared (IR) range. Infrared light requires line of sight to its destination. Low-end remotes use only one transmitter at the end of the unit and have to be aimed directly pointing to the receiving sensor on the other equipment. High-quality remotes have three or four powerful IR transmitters set at different angles to shower the room with signals.

Radio Frequency Remote control (RF)

Radio frequency remote control also is a wireless device used to operate audio, video and other electronic equipment using Radio Frequency (RF) transmission. Unlike the common infrared (IR) remotes, RF remotes do not have to be aimed at the equipment.

Bluetooth remote control

A subset of RF remotes, these rely on the Bluetooth protocol to communicate. Most commonly used for video game controllers and some newer set-top boxes

Parts of a IR remote control

The internal parts of IR type remote control is shown in Fig 1. The basic parts involved in sending IR signal include

1 Buttons/Keypads

2 Integrated circuit

3 Button contacts

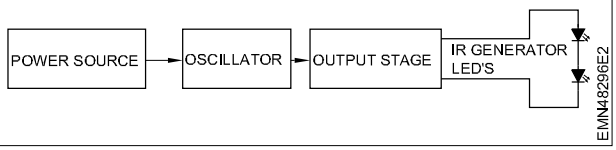
4 IRLED

5 Battery

IR code Transmitter

The block diagram of the remote control transmitter is shown in Fig 2.

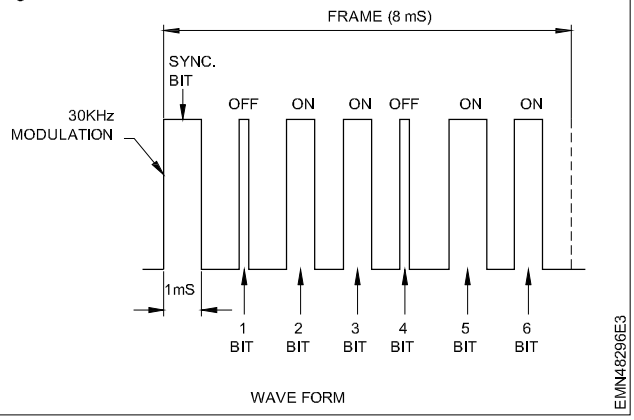
Fig 2



The transmitter section consist of power supply, an oscillator and an output stage including IR LEDS in the transmitter section. Oscillator IC 555 is wired as an astable multivibrator with a centre frequency of about 36 KHZ. The transmitter is powered from 2 nos of 'AA' or 'AAA' size battery.

Signalling from remote

Fig 3



Channel number	Six-bit code	Decoded function
1	000 000	Switch A on
2	000 001	Switch A off
3	000 010	Switch B on
4	000 011	Switch B off
-	----------	----------
-	----------	----------
61	111 100	Volume increase
62	111 101	Volume decrease
63	111 110	Brilliance increase
64	111 111	Brilliance decrease

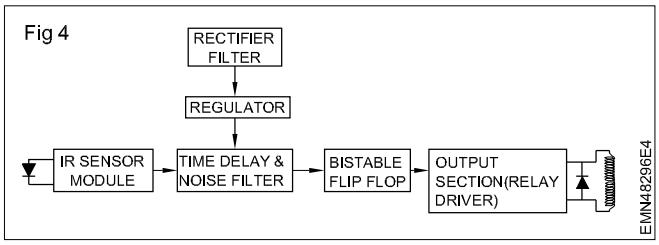
The modern infra-red remote control system works on multi channel system. Each channel gives a digital control signal for each independent work like ON, OFF, volume, channel selection etc. A sample output wave form is shown in Fig 3.

It is basic 6 bit multi channel output, the first bit is of 1 mS duration provides frame synchronization signal to the decoder the subsequent 6 bits provides logic code depending on the duration of pulse. If the pulse duration is less than 0.25 mS then it is taken as logic 0 and if it is more than 0.25 mS it is taken as logic 1. With this type of six bit coding it is possible to generate 64 independent functions as shown below.

IR code Receiver

The block diagram of the IR receiver is shown in Fig 4.

Fig 4



The receiver section comprises of power supply, an infrared detector module, time delay circuit with noise filter, bi-stable flip flop.

This signal is received via our receiver circuit's phototransistor. The high pass amplifier allows us to preserve only the high frequency components of our received signal. The band pass filter is tuned to our modulation frequency, thus removing more noise at higher and lower frequencies. The signal at this point is a high frequency AC signal. The rectifier and low pass filter convert the signal from AC to DC, and the comparator allows us to adjust the sensitivity threshold so that we do not detect spurious noise signals. Finally, the flip-flop toggles the output on and off with each subsequent press of the transmission button.

Infrared is a part of electromagnetic spectrum and these IR waves moves in the form of pulse train. When any one of the button/key on the remote is pressed, this circuit translate the action into a beam of IR waves which moves to the receiver circuit. It sends out different codes for different way commands. The sensor in the TV receives this signal and the microchip reads, amplifies and controls the functions like volume up/down or changing channels, etc. If any obstruction/blocking between the remote control and TV receiver, the command is not working because the IR waves always travels in a straight line only.

General faults in remote controls

Since the remote control is a small hand held device, sometimes it slips from our hand and falls down resulting in malfunctioning. The most probable troubles with the remote control operation is that the batteries are dead or it has not been programmed properly. It is often easy to

fix the problems with the remote control.

i) Problems with remote control

1 Dead batteries or batteries inserted wrongly.

2 Corroded battery contacts.

3 Broken or intermittent contacts on the circuit board.

4 Dry soldered/broken ceramic resonator/transistor.

5 Dirt, spills, oily build-up inside the contacts.

6 Worn or corroded pods on circuit board.

7 Worn conductive material on rubber button.

8 Cracked circuit board.

9 Bad IR LED.

10 Bad IC.

11 Dead memory capacitor.

ii) Problems with the other device/equipment

1 Increased range of remote path.

2 Wrong positioning of device.

3 Dust covered on the receiver sensor.

4 Program mode done wrongly.

Satellite transmitter and receiver

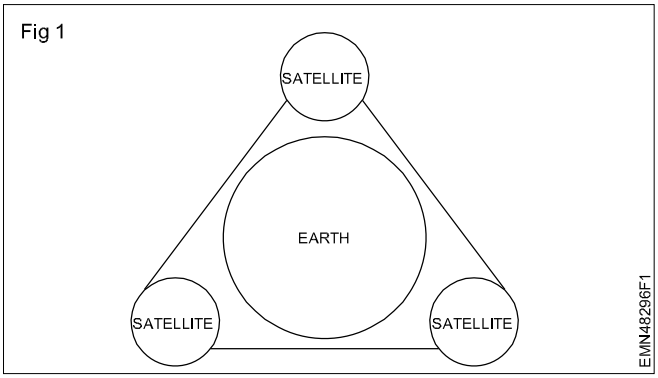
Objectives : At the end of this lesson you shall be able to

- **explain elements in satellite communication system**
- **explain components in satellite link**
- **describe the function of sections in set-top box(STB)**
- **explain the working principle of set-top box.**

Satellite communication

With the advancement of satellite communication system the electronic signals in the microwave range are transmitted around the world instantaneously. The satellite is a microwave repeater placed in the geo-stationary and placed at an altitude of 22300 miles or 35900 km above the ground level. The satellite travels at the same speed at which the earth rotates around the sun. The rotation of satellite is synchronized with the rotation of the earth as a result satellite appears to be stationary in the sky with respect to the earth station is constant. There are 3 satellites placed at an angle of 120º in geo-stationary orbit; they provide 100% coverage from one earth station to anywhere on the earth as shown in Fig 1.

Fig 1



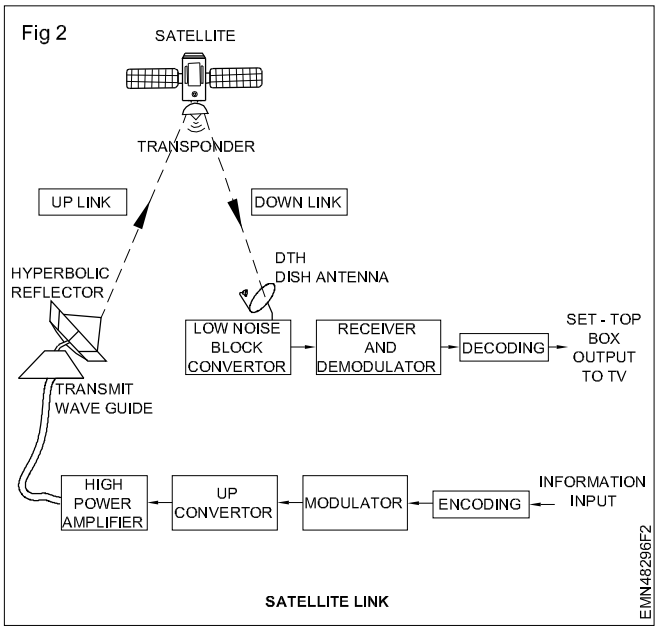
The simplified diagram of satellite link is shown in Fig 2.

The basic elements of satellite communication are

1) Earth station, 2) Satellite, 3) Terrestrial system, and 4) User.

The satellite communication system consists of many earth stations on the ground and they are linked with a satellite in space. The users are connected to the earth station through a terrestrial station and this network may be a telephonic switch or well established link to the earth station.

Fig 2



1 Earth station

The broadcast centre is the central hub of the earth station. At the broadcast centre, the television provider receives signals from various programming sources and beams a broadcast signal to satellites in geostationary orbit. The satellites receive the signals from the broadcast station and rebroadcast them to the ground. The dish picks up the signal from the satellite (or multiple satellites in the same part of the sky) and passes it on to the receiver. The receiver processes the signal and passes it on to a standard television.

Multiplexer

The multiplexer is a device used in the broadcasting centre compresses all the frequency signals into one single channel & transmits it to the Geo- Stationary satellite. It sends this single channel to the modulator.

Modulator

Modulation is a process in which the information signal is imposed on a carrier signal which is of high strength and greater frequency. This process is done in the modulator. The modulator modulates the signals and sends to the encoder.

Encoder

The encoder encodes the signals to transmit the signals. The satellite sends this signal to the dish antenna. The antenna process the signals to the set-top box.

2 Satellite

The satellite consists of a large number of transponders and repeaters in the space that perform the reception of modulated RF carrier in its uplink frequency spectrum from all the earth stations in the present networks, amplifies these carriers and re-transmits them back to the Earth station in the down link frequency spectrum. In order to avoid the interference, downlinks frequency spectrum should be different from uplink frequency spectrum.

3 Terrestrial network

The signal at the earth stations is transmitted and received to get back the base band signal, is sent to the user through a terrestrial network.

4 User

The user can receive the signal either through telephone network cable provided by the PSTN or cable TV connection by the cable operator and also DTH (Direct to home)service by the use of set-top Box (STB). A Geo-stationary satellite plays an important role in STB systems.

Satellite receiver

Components of satellite receiver are

1 Dish antenna

2 LNB

3 Set-top box

Dish Antenna

A dish antenna, also known simply as a dish, is common in microwave systems. This type of antenna can be used for satellite communication and broadcast reception, space communications, radio astronomy, and radar. The standard dish consists of a parabolic (bowl-shaped) surface and a central feed horn. The signal captured by the dish reflected to the central feed horn and send to the LNB.

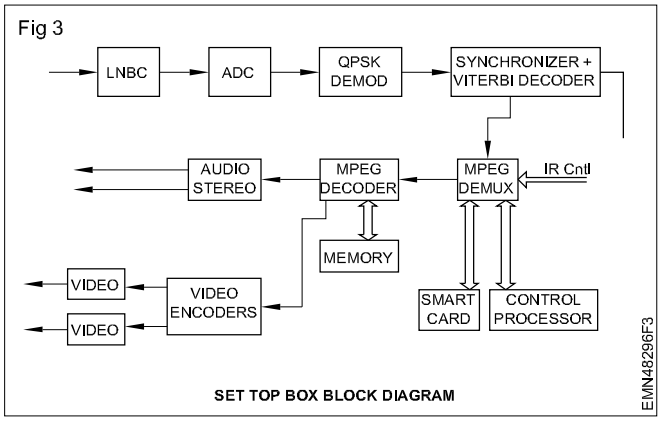
LNB (Low Noise Block down converter)

The incoming satellite signal propagates down the waveguide of the feed horn and exits into a rectangular chamber mounted at the front of the low-noise block down converter (LNB), in which a tiny resonant probe is located. This pickup probe, which has a wavelength that resonates with the incoming microwave frequencies, conducts the signal onto the first stage of electronic amplification. LNB In addition to amplifying the incoming signal, the first stage of electronic amplification also generates thermal noise internally. The internal noise contribution of the LNB is amplified along with the incoming signal and passed on to succeeding amplifier stages.

Set-top box

A set- top Box is a consumer electronics device connected between a television and a content provider such as Direct Broadcast Satellite operator, Cable operator or Terrestrial operator. This device converts and provides digital audio and video sources after decoding the incoming digital signals. It then separates audio and video data streams for presenting them to respective displays. The function of set-top box is to provide more TV channels on the same limited number of frequencies. The block diagram of set-top box is shown in Fig 3.

Fig 3



SET TOP BOX BLOCK DIAGRAM

The basic features of set-top box are to receive, demodulate, demultiplex, and decode the incoming digital signal and convert it into analog format. Input digital stream to STB may be from satellite, cable or terrestrial medium. It can also descramble the received signal and thus provide the conditional access to the STB. Conditional Access is key feature for pay TV system. Input digital signal contains audio, video and high speed and low speed data contents, which is reproduced by the set-top box. In future the STB will have features like Internet on cable, interactive TV, VOD (Video On Demand), music on demand etc.

Working of set-top box

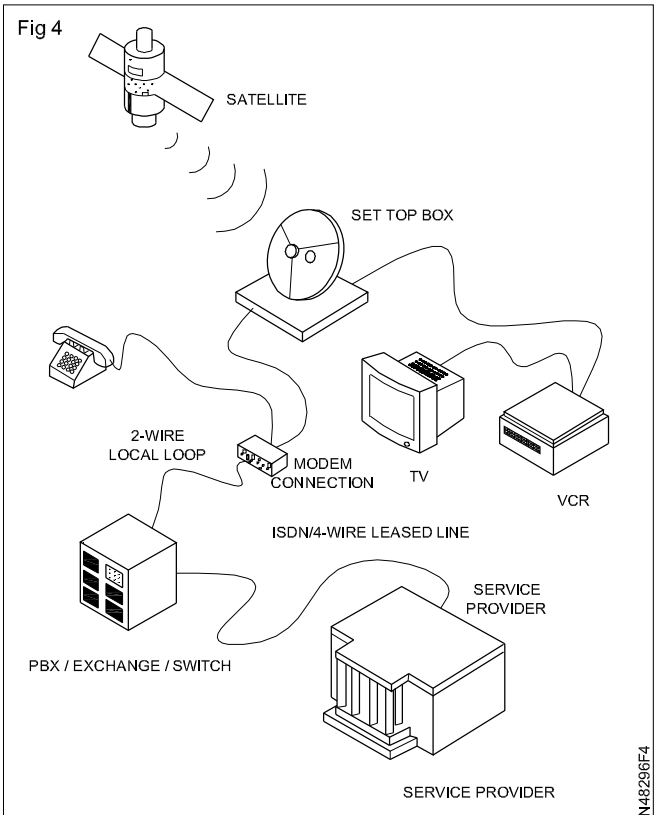
The set-top box accepts the entire down converted band and separates out the individual transponder frequency. Then signals are first converted to fixed IF and then QPSK demodulated. After the QPSK (Quadrature Phase-Shift Keying) demodulation, the digital bit stream obtained contains several multiplexed channels as well as error control bits. The bit stream is processed to correct and detect errors, de-interleaved, and decrypted. A digital de-multiplexer then extracts the bits for wanted channel, and sends them to MPEG decoder, and finally generates stereo audio and video signals with DIA converters to drive TV set. Connection of set-top box to TV is shown in Fig 4.

Basic operation of STB

Set-top box can be operated using either by front panel switches or using Remote control as shown in Fig 5 and

Fig 6. The various functions which can be operated, using front panel control or remote control are tuning of particular channel, feeding frequency, symbol rate and other useful data, generating test patterns. All the functions available in the set-top box are displayed on the TV screen using On Screen Display (OSD). It is Graphical User Interface (GUI) for ease of operation. Remote control and front panel switches are the main input console for set-top box.

Fig 4



CONNECTION OF SET TOP BOX TO TV

Input to the set-top box is RF signal and its range and type of Modulation depends upon its application. If set-top box is used for satellite application then Input frequency range is 950 to 2150 MHz and modulation technique used is QPSK. For Set Top Box for cable application the input frequency range is 110 to 862 MHz and type of modulation is QAM. While frequency range for set-top box for terrestrial is 47 to 860 MHz and type of modulation use for it is COFDM.

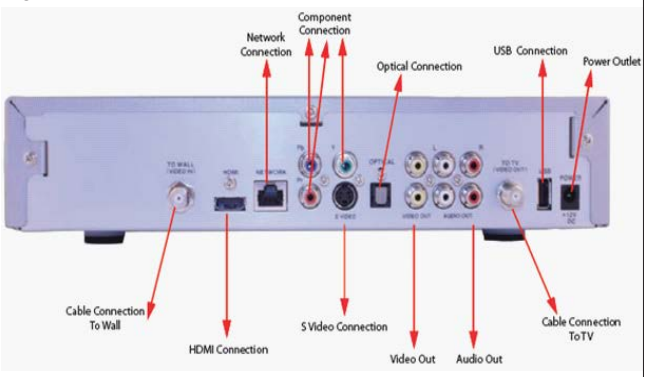
The basic technology used in Set Top Box is DVB (Digital Video Broadcasting) and MPEG (Moving Picture Expert Group). Modern compression technique allows a TV signal to be compressed and transmitted at rate 1.5 to 15 Mbps. The standardization process initiated in 1988 and almost completed in 1994 - which develop MPEG 1, MPEG 2 up to MPEG 7. DVB is recently created DTV transmission standard, which allows Inter- operability between different systems and manufactures. DVB group establishes a set of transmission parameters for compression, error correction and channel coding. DVB technology leads to transformation of basic analog transmission system into digital, which is used for all transmission and communication applications.

Fig 5 and 6 shows front and rear view of a set-top box.

Fig 5

Set-top box front panel indicators

Fig 6



Set-top box rear panel