ELECTRONICS MECHANIC

NSQF LEVEL - 5

1st Year (Volume I of II)

TRADE THEORY

SECTOR: ELECTRONICS & HARDWARE

Directorate General of Training

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

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : Electronics and Hardware

Duration : 2 - Years

Trade : Electronics Mechanic 1st Year (Volume I of II) - Trade Theory - NSQF level 5

Developed & Published by

National Instructional Media Institute
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Guindy, Chennai - 32
INDIA
Email: Chennai-nimi@nic.in
Website: www.nimi.gov.in

Printed by
National Instructional Media Institute
Chennai - 600 032

First Edition	: August 2018	Copies : 1,000
Second Edition	: May 2019	Copies : 1,000

Rs.235/-

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, an autonomous body under the Directorate General of Training (DGT), Ministry of Skill Development & Entrepreneurship is entrusted with developing producing and disseminating Instructional Media Packages (IMPs) required for ITIs and other related institutions.

The institute has now come up with instructional material to suit the revised curriculum for **Electronics Mechanic Trade Theory 1st Year (Volume I of II) NSQF Level-5 in Electronics and Hardware Sector** under annual 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 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 the 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.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

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 instructional 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 organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Electronics Mechanic** under Electronics and Hardware Sector for ITIs.

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NIMI records its appreciation for 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 NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

INTRODUCTION

TRADE THEORY

The manual of trade theory consists of theoretical information for the course of the **Electronics Mechanic** Trade NSQF Level - 5. The contents are sequenced according to the practical exercises contained in the manual on Trade Practical. Attempt has been made to relate the theoretical 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 NSQF Level - 5 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 NSQF Level - 5 manual is intented to be used in workshop . It consists of a series of practical exercies to be completed by the trainees during the course of the **Electronics 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 ten modules. The distribution of time for the practical in the ten modules are given below.

Module 1	Basic Workshop Practice	75 Hrs
Module 2	Basic of AC and Electrical cables	50 Hrs
Module 3	Single Range Meters	25 Hrs
Module 4	Cells & Batteries	25 Hrs
Module 5	AC & DC Measuring instruments	50 Hrs
Module 6	Soldering/ De-Soldering and various switches	25 Hrs
Module 7	Active and Passive components	75 Hrs
Module 8	Power supply circuits	50 Hrs
Module 9	Computer hardware, OS, MS Office and Networking	125 Hrs
Module 10	IC Regulators	25 Hrs
	Project work	50 Hrs
	Total	575 Hrs

The skill training in the computer lab is planned through a series of practical exercises centred around some practical project. However, there are few instance 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 traninee. However the development team accept that there if a scope for further improvement. NIMI, looks forward to the suggestions from the experienced training faculty for improving the manual.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

- **Perform basic workshop operations using suitable tools for fitting, riveting,drilling etc. observing suitable care & safety.**
- **Select and perform electrical/electronic measurement of single range meters and calibrate the instrument.**
- **Test & service different batteries used in electronic applications and record the data to estimate repair cost.**
- **Plan and execute soldering & desoldering of various electrical components like switches, PCB & Transformers for electronic circuits.**
- **Test various electronic components using proper measuring instruments and compare the data using standard parameters.**
- **Assemble simple electronic power supply circuit and test for functioning.**
- **Install, configure, interconnect given computer system (S) and demonstrate & utilize application packages for different applications.**

SYLLABUS

Duration: Six Month

Week No.	Ref. Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
1.	• Apply safe working practices	Trade and Orientation 1. Visit to various sections of the institute and identify location of various installations. (5 hrs) 2. Identify safety signs for danger, warning, caution & personal safety message. (3 hrs.) 3. Use of personal protective equipment (PPE). (5 hrs) 4. Practice elementary first aid. (5 hrs) 5. Preventive measures for electrical accidents & steps to be taken in such accidents.(2 hrs) 6. Use of Fire extinguishers. (5 hrs)	Familiarization with the working of Industrial Training Institute system. Importance of safety and precautions to be taken in the industry/shop floor. Introduction to PPEs. Introduction to First Aid. Response to emergencies e.g. power failure, fire, and system failure. Importance of housekeeping & good shop floor practices. Occupational Safety & Health: Health, Safety and Environment guidelines, legislations & regulations as applicable.
2-3	• Perform basic workshop operations using suitable tools for fitting, riveting, drilling etc observing suitable care & safety	Hand tools and their uses 7. Identify the different hand tools. (5 hrs) 8. Selection of proper tools for operation and precautions in operation. (7 hrs) 9. Care & maintenance of trade tools. (8 hrs) 10. Practice safety precautions while working in fitting jobs. (10 hrs) 11. Workshop practice on filing and hacks awing. (5 hrs) 12. Practice simple sheet metal works, fitting and drilling. (5hrs) 13. Make an open box from metal sheet. (10 hrs)	Identification, specifications, uses and maintenance of commonly used hand tools. State the correct shape of files for filing different profiles. Riveting of tags and lugs, cutting and bending of sheet metals,chassis and cabinets.
4-5	• Select and perform electrical/ electronic measurement of single range meters and calibrate the instrument.	Basics of AC and Electrical Cables 14. Identify the Phase, Neutral and Earth on power socket, use a testers to monitor AC power. (6 hrs) 15. Construct a test lamp and use it to check mains healthiness. (7 hrs) 16. Measure the voltage between phase and ground and rectify earthing. (5 hrs) 17. Identify and test different AC mains cables. (7 hrs) 18. Prepare terminations, skin the electrical wires /cables using	Basic terms such as electric charges, Potential difference, Voltage, Current, Resistance. Basics of AC & DC. Various terms such as +ve cycle, -ve cycle, Frequency, Time period, RMS, Peak, Instantaneous value. Single phase and Three phase supply. Terms like Line and Phase voltage/ currents. Insulators, conductors and semiconductor properties. Different type of electrical cables and their Specifications. Types of wires &

		wire stripper and cutter. (7hrs) 19. Measure the gauge of the wire using SWG and outside micrometer. (5 hrs) 20. Refer table and find current carrying capacity of wires. (3 hrs) 21. Crimp the lugs to wire end. (5 hrs) 22. Measure AC and DC voltages using multi meter. (5 hrs)	cables, standard wire gauge (SWG). Classification of cables according to gauge (core size), number of conductors, material, insulation strength, flexibility etc.
6	Select and perform electrical/ electronic measurement of single range meters and calibrate the instrument.	23. Identify the type of meters by dial and scale marking/ symbols. (3 Hrs) 24. Demonstrate various analog measuring Instruments. (3 Hrs) 25. Find the minimum and maximum measurable range of the meter. (3 Hrs) 26. Carryout mechanical zero setting of a meter. (5 Hrs) 27. Check the continuity of wires, meter probes and fuse etc. (5 Hrs) 28. Measure voltage and current using clamp meter. (6 Hrs)	Single range meters Introduction to electrical and electronic measuring instruments. Basic principle and parts of simple meters. Specifications, symbols used in dial and their meaning.
7	Test & service different batteries used in electronic applications and record the data to estimate repair cost.	Cells & Batteries 29. Identify the +ve and -ve terminals of the battery. (2 hrs) 30. Identify the rated output voltage and Ah capacity of given battery. (1 hrs) 31. Measure the voltages of the given cells/battery using analog/ digital multimeter. (3 hrs) 32. Charge and discharge the battery through load resistor. (5 hrs) 33. Maintain the secondary cells. (5 hrs) 34. Measure the specific gravity of the electrolyte using hydrometer. 3 hrs) 35. Test a battery and verify whether the battery is ready for use of needs recharging. (6 hrs)	Cells & Batteries Construction, types of primary and secondary cells. Materials used, Specification of cells and batteries. Charging process, efficiency, lifeof cell/battery. Selection of cells / Batteries etc. Use of Hydrometer. Types of electrolytes used in cells and batteries. Series/ parallel connection of batteries and purpose of such connections.
8-9	Test various electronic components using proper measuring instruments and compare the data using standard parameter.	AC & DC measurements 36. Use the multi meter to measure the various functions (AC V, DC V, DC I, AC I, R) (8 hrs.) 37. Identify the different types of meter for measuring AC & DC parameters (8 hrs.) 38. Identify the different controls on the CRO front panel and observe the function of each control (12hrs.) 39. Measure DC voltage, AC voltage, time period using CRO sine wave parameters (10hrs.) 40. Identify the different controls on the function generator front panel and observe the function of each controls (12 hrs.)	Introduction to electrical measuring instruments. Importance and classification of meters. Forces necessary to work a meter. MC and MI meters. Range extension, need of calibration. Characteristics of meters and errors in meters. Multi meter, use of meters in different circuits. Care and maintenance of meters. Use of CRO, Function generator, LCR meter

10	Plan and execute soldering & desoldering of various electrical components like Switches, PCB & Transformers for electronic circuits.	Soldering/ De-soldering and Various Switches 41. Practice soldering on different electronic components, small transformer and lugs. (5 hrs) 42. Practice soldering on IC bases and PCBs. (5 hrs) 43. Practice de-soldering using pump and wick (2 hrs) 44. Join the broken PCB track and test (3 hrs) 45. Identify and use SPST, SPDT, DPST, DPDT, tumbler, push button, toggle, piano switches used in electronic industries (5 hrs) 46. Make a panel board using different types of switches for a given application (5 hrs)	Different types of soldering guns, related to Temperature and wattages, types of tips. Solder materials and their grading. Use of flux and other materials. Selection of soldering gun for specific requirement. Soldering and De-soldering stations and their specifications. Different switches, their specification and usage.
11-13	• Test various electronic components using proper measuring instruments and compare the data using standard parameter. • Assemble simple electronic power supply circuit and test for functioning.	Active and Passive Components 47. Identify the different types of active electronic components. (3 hrs). 48. Measure the resistor value by colour code and verify the same by measuring with multimeter (3 hrs) 49. Identify resistors by their appearance and check physical defects. (2 hrs) 50. Identify the power rating of carbon resistors by their size. (3 hrs) 51. Practice on measurement of parameters in combinational electrical circuit by applying Ohm's Law for different resistor values and voltage sources. (9 hrs) 52. Measurement of current and voltage in electrical circuits to verify Kirchhoff's Law (5 Hrs) 53. Verify laws of series and parallel circuits with voltage source in different combinations. (5 hrs) 54. Measure the resistance, Voltage, Current through series and parallel connected networks using multi meter (8 hrs) 55. Identify different inductors and measure the values using LCR meter (5 hrs) 56. Identify the different capacitors and measure capacitance of various capacitors using LCR meter (5 hrs) 57. Identify and test the circuit breaker and other protecting devices. (5 hrs)	Ohm's law and Kirchhoff's Law. Resistors; types of resistors, their construction & specific use, colorcoding, power rating. Equivalent Resistance of series parallel circuits. Distribution of V & I in series parallel circuits. Principles of induction, inductive reactance. Types of inductors, construction, specifications, applications and Types of capacitors, construction, specifications and applications. Dielectric constant. Significance of Series parallel connection of capacitors. Capacitor behaviour with AC and DC. Concept of Time constant of a RC circuit. Concept of Resonance and its application in RC, RL & RLC series and parallel circuit. Properties of magnets and their materials, preparation of artificial magnets, significance of electro magnetism, types of cores. Relays, types, construction and specifications etc. energy storage concept. Self and Mutual induction. Behaviour of inductor at low and high frequencies. Series and parallel combination, Q factor. Capacitance and Capacitive Reactance, Impedance. Types of capacitors, construction, specifications and applications. Dielectric constant. Significance of Series parallel connection of capacitors. Capacitor behaviour with AC and DC. Concept of Time constant of a RC circuit. Concept of Resonance and its application in RC, RL & RLC series and parallel circuit.

			Properties of magnets and their materials, preparation of artificial magnets, significance of electro magnetism, types of cores. Relays, types, construction and specifications etc.
14-15	Assemble simple electronic power supply circuit and test for functioning.	Power Supply Circuits 64. Identify different types of diodes, diode modules and their specifications. (5 hrs) 65. Test the given diode using multi meter and determine forward to reverse resistance ratio. (5 hrs) 66. Measure the voltage and current through 67. Identify different types of transformers and test. (3 hrs) 68. Identify the primary and secondary transformer windings and test the polarity (2 hrs) 69. Construct and test a half wave, full wave and Bridge rectifier circuit. (10 hrs) 70. Measure ripple voltage, ripple frequency and ripple factor of rectifiers for different load and filter capacitors. (5 hrs) 71. Identify and test Zener diode. (2 hrs) 72. Construct and test Zener based voltage regulator circuit. (5 hrs) 73. Calculate the percentage regulation of regulated power supply. (5 hrs)	Semiconductor materials, components, number coding for different electronic components such as Diodes and Zeners etc. PN Junction, Forward and Reverse biasing of diodes. Interpretation of diode specifications. Forward current and Reverse voltage. Packing styles of diodes. Different diodes, Rectifier configurations, their efficiencies, Filter components and their role in reducing ripple. Working principles of Zener diode, varactor diode, their specifications and applications. Working principle of a Transformer, construction, Specifications and types of cores used. Step-up, Step down and isolation transformers with applications. Losses in Transformers. Phase angle,phase relations, active and reactive power, power factor and its importance.
16-20	Install, configure, interconnect given computer system(s) and demonstrate & utilize application packages for different application	Computer Hardware, OS, MS office and Networking 74. Identify various indicators, cables, connectors and ports on the computer cabinet. (5 hrs) 75. Demonstrate various parts of the system unit and motherboard components. (5 hrs) 76. Identify various computer peripherals and connect it to the system. (5 hrs) 77. Disable certain functionality by disconnecting the concerned cables SATA/ PATA. (5 hrs) 78. Replace the CMOS battery and extend a memory module. (5 hrs) 79. Test and Replace the SMPS (5 hrs) 80. Replace the given DVD and HDD on the system (5 hrs) 81. Dismantle and assemble the desktop computer system. (10hrs) 82. Boot the system from Different options (5 hrs)	Basic blocks of a computer, Components of desktop and motherboard. Hardware and software, I/O devices, and their working. Different types of printers, HDD, DVD. Various ports in the computer. Windows OS MS widows:Starting windows and its operation, file management using explorer, Display & sound properties, screen savers, font management, installation of program, setting and using of control panel., application of accessories, various IT tools and applications. Concept of word processing,: MS word – Menu bar, standard tool bar, editing, formatting, printing of document etc. Excel – Worksheet basics, data entry and formulae. Moving data in worksheet using tool bars and menu bars, Formatting and calculations, printing worksheet,

		83. Install OS in a desktop computer. (5 hrs) 84. Install a Printer driver software and test for print outs (5 hrs) 85. Install antivirus software, scan the system and explore the options in the antivirus software. (5 hrs) 86. Install MS office software (5 hrs) 87. Create folder and files, draw pictures using paint. (5 hrs) 88. Explore different menu/ tool/ format/ status bars of MS word and practice the options. (8 hrs) 89. Explore different menu/ tool/ format/ status bars of MS excel and practice the options. (7 hrs) 90. Prepare power point presentation on any three known topics with various design, animation and visual effects. (5 hrs) 91. Convert the given PDF File into Word file using suitable software. (5 hrs) 92. Browse search engines, create email accounts, practice sending and	creating multiple work sheets, creating charts. Introduction to power point Basics of preparing slides, different design aspects of slides, animation with slides etc. Concept of Internet, Browsers, Websites, search engines, email, chatting and messenger service.Downloading the Data and program files etc. Computer Networking:- Network features - Network medias Network topologies, protocols- TCP/IP, UDP, FTP models and types. Specification and standards, types of cables, UTP, STP, Coaxial cables. Network components like hub, Ethernet switch, router, NIC Cards, connectors, media and firewall. Difference between PC & Server.
21	Assemble simple electronic power supply circuit and test for functioning.	98. Identify the different types of fixed +ve and – ve regulator ICs and the different current ratings (78/79 series) (5 hrs) 99. Identify different heat sinks for IC based regulators. (2 hrs) 100. Observe the output voltage of different IC 723 metal/ plastic type and IC 78540 regulators by varying the input voltage with fixed load (8 hrs) 101. Construct and test a 1.2V – 30V variable output regulated power supply using IC LM317T. (5 hrs)	Regulated Power supply using 78XX series, 79XX series. Op-amp regulator, 723 regulator, (Transistorized & IC based). Voltage regulation, error correction and amplification etc.
22 - 23	Project work / Industrial visit Broad areas: 1. Full wave Voltage rectifier with indicator. 2. Transformer less 12 V dual power supply 3. Versatile regulated power supply 4. AC/DC voltage tester. 5. Modular rectifiers. 6. Half wave dual power supply with zener diode.		
24-25	**Revision**		

Familiarization of the Industrial Training Institute

Objectives: At the end of this lesson you shall be able to
- **identify the staff structure of the institute**
- **list the available trades in the institute and their functions**
- **describe the ITI training system in India.**

Industrial Training Institutes (ITI) plays a vital role in the economic development of the country, especially in terms of providing skilled manpower requirements by training competent, quality craftsmen.

The Directorate General of Training (DGT) comes under the Ministry of Skill Development and Entrepreneurship (MSDE) offers a range of vocational training under engineering and non engineering trades affiliated with the National Council for Vocational Training (NCVT) NewDelhi. NCVT is the Govt of India body responsible for framing the polices, approving the syllabus for Craftsman Training System (CTS), carrying out the All India Trade Test and issuing the National Trade Certificates (NTC) to the successful candidates.

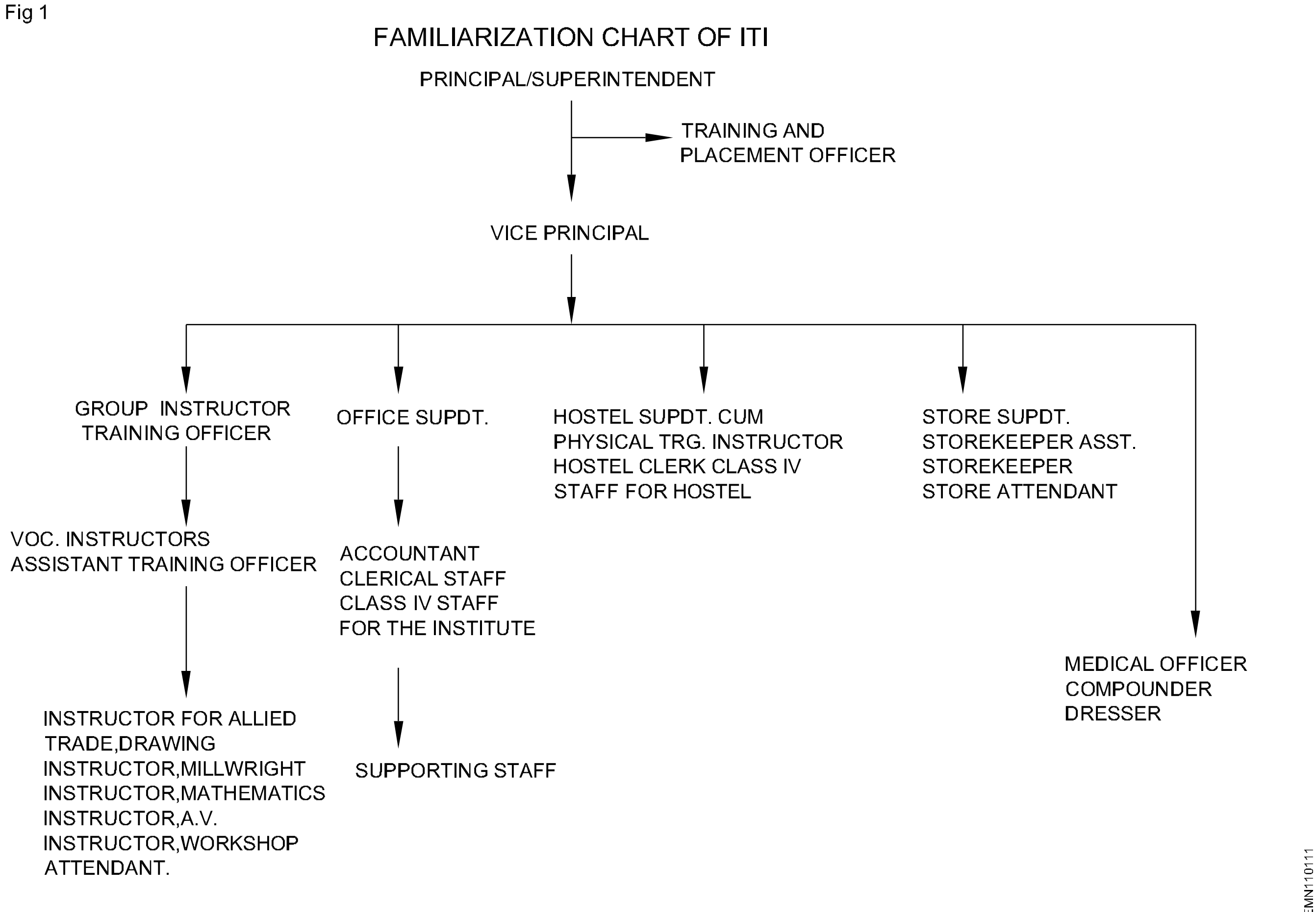
In India there are about 2293 Govt. ITIs and 10872 Private ITIs. (Based on the Govt.of India, Ministry of Labour Annual report of 2016-2017). The Govt. ITIs in each state functioning under the Directorate of Employment and Training Dept (DET) under the state Govts.

The head of the **ITI** is the Principal, under whom there is one Vice-Principal, Group Instructor/ Training officer/ A.T.O and a number of trade instructors as shown in the Organisation chart of ITI.

There are133 trades selected for vocational training and 261 trades identified for Apprentice training, according to the requirement of industrial needs and the duration of the training is from 1 year to 2 years.

At present the Electronic Mechanic trade has been included under National Skill Qualification Frame work (NSQF) with level - 5 competency. The trainees are advised to make a list of othe trades available in their ITI, the type of training and the scope of these trades in getting self employment or job opportunity in the rural and urban areas and also identify the location of the ITI, nearby hospital, fire station and police station ect.

Fig 1



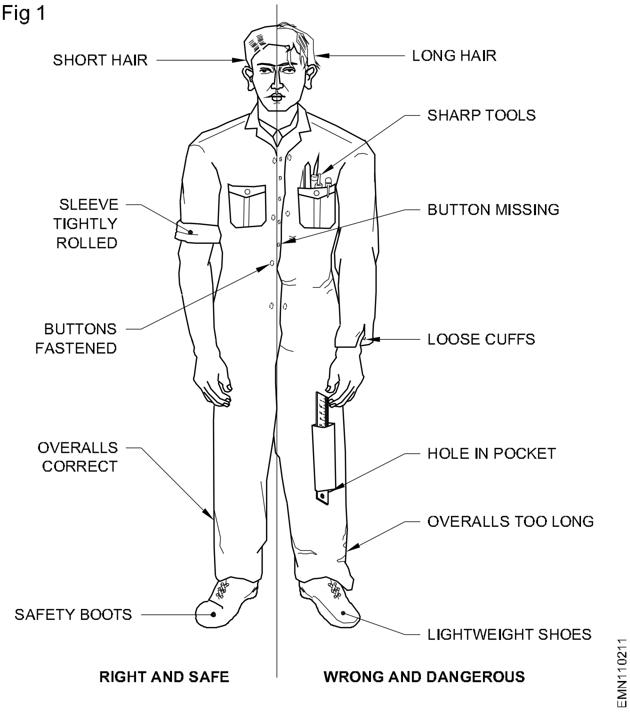
Importance of safety and precautions to be taken in the industry/ shop floor

Objectives: At the end of this lesson you shall be able to
- **state the importance of safety**
- **state the personal safety precautions to be observed**
- **list out the safety precautions to be observed while working on the machines.**

Importance of safety

Generally accidents do not happen; they are caused. Most accidents are avoidable. A Good craftsman, having a knowledge of various safety precautions, can avoid accidents to himself and to his fellow workers and protect the equipment from any damage. To achieve this, it is essential that every person should follow safety procedure. (Fig 1)

Fig 1



Safety in a workshop can be broadly classified into 3 categories.

- General safety
- Personal safety
- Machine safety

General safety

Keep the floor and gangways clean and clear.

Move with care in the worksop, do not run.

Don't leave the machine which is in motion.

Don't touch or handle any equipment/ machine unless authorised to do so.

Don't walk under suspended loads.

Don't cut practical jokes while on work.

Use the correct tools for the job.

Keep the tools at their proper place.

Wipe out split oil immediately.

Replace worn out or damaged tools immediately.

Never direct compressed air at yourself or at your co-worker.

Ensure adequate light in the workshop.

Clean the machine only when it is not in motion.

Sweep away the metal cuttings.

Know everything about the machine before you start it.

Personal safety

Wear a one piece overall or boiler suit.

Keep the overall buttons fastened.

Don't use ties and scarves.

Roll up the sleeves tightly above the elbow.

Wear safety shoes or boots or chain.

Cut the hair short.

Don't wear a ring, watch or chain.

Never lean on the machine.

Don't clean hands in the coolant fluid.

Don't remove guards when the machine is in motion.

Don't use cracked or chipped tools.

Don's start the machine until

- the workpiece is securely mounted
- the feed machinery is in the neutral
- the work area is clear.

Don't adjust clamps or holdig devices while the machine is in motion.

Never touch the electrical equipment with wet hands.

Don't use any faulty electrical equipment.

Ensure that electrical connections are made by an authorised electrician only.

Concentrate on your work.

Have a calm attitude.

Do things in a methodical way.

Don’t engage yourself in conversation with others while concentrating on your job.

Don’t distract the attention of others.

Don’t try to stop a running machine with hands.

Machine safety

Switch off the machine immediately if something goes wrong.

Keep the machine clean.

Replace any worn out or damaged accessories, holding devices, nuts, bolts, etc., as soon as possible.

Do not attempt operating the machine until you know how to operate it properly.

Do not adjust tool or the workpiece unless the power is off.

Stop the machine before changing the speed.

Disengage the automatic feeds before switching off.

Check the oil level before starting the machine.

Never start a machine unless all the safety guards are in position.

Take measurements only after stopping the machine.

Use wooden planks over the bed while loading and unloading heavy jobs.

Safety is a concept, understand it.

Safety is a habit, cultivate it.

Safety Sign Boards

Signboards are a common sight in almost all places such as roadways, railways, hospitals, offices, instituition, industrial units and so on.

Signboards are visual indicators. The signs on the signboards may be just a symbol, a small text, a figure or a combination of these.

Signboards carry a single clear message. These messages are to ensure safety.

Sigboards can be classified into four basic categories.

a) Prohibition signs

Indicating a behaviour which is prohibited (not allowed) in that situation or environment. Refer to chart 1 for examples.

b) Mandatory signs

Indicating a behaviour which is a must, which when not obeyed may cause accidents. Refer to chart 1 for examples.

c) Warning signs

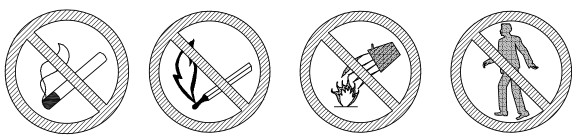
Indicating a warning such tht suitable precatution is taken. Refer to chart 1 for examples.

d) Information signs

Giving information which is very useful and reduces waste of time. Refer to chart 1 for examples.

Chart 1

a) Prohibition signs



SMOKING AND NAKED FLAMES PROHIBITED | DO NOT EXTINGUISH WITH WATER | PEDESTRAINS PROHIBITED

Shape	Circular.
Colour	Red border and crossbar. Black symbol on white background.
Meaning	Shows what must not be done.
Example	No smoking and naked flames

b) Mandatory signs

WEAR HEAD PROTECTION | WEAR EYE PROTECTION | WEAR HEARING PROTECTION | WEAR FOOT PROTECTION | WEAR HAND PROTECTION

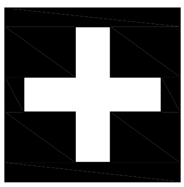
WEAR RESPIRATOR | WEAR SAFETY HARNESS/BELT | USE ADJUSTABLE GUARD | WASH HAND

Shape	Circular.
Colour	White symbol on blue background.
Meaning	Shows what must not be done.
Example	Wear hand protection.

c) Warning signs

Shape	Triangular.
Colour	Yellow background with black border and symbols.
Meaning	Warns of hazard or danger.
Example	Caution, risk of electric shock.

d) Information signs


FIRST AID POINT

Shape	Square or oblong
Colour	White symbols on green background.
Meaning	Indicates or gives information of safety provision/First aid
Example	Caution, risk of electric shock.

Personal Protective Equipment (PPE)

Objectives: At the end of this lesson you shall be able to
- **state the personal protective equipment and its purpose**
- **list the most common type of personal protective equipment**
- **list the conditions for selection of personal protective equipment.**

Personal protective equipment (PPE)

Devices, equipments, or clothing used or worn by the employees, as a last resort, to protect against hazards in the workplace. The primary approach in any safety effort is that the hazard to the workmen should be eliminated or controlled by engineering methods rather than protecting the workmen through the use of personal protective equipment (PPE). Engineering methods could include design change, substitution, ventilation, mechanical handling, automation, etc. In situations where it is not possible to introduce any effective engineering methods for controlling hazards, the workman shall use appropriate types of PPE.

As changing times have modernized the workplace, government and advocacy groups have brought more safety standards to all sorts of work environments. The Factories Act, 1948 and several other labour legislations 1996 have provisions for effective use of appropriate types of PPE. Use of PPE is an important.

Ways to ensure workplace safety and use personal protective equipment (PPE) effectively.

- Workers to get up-to-date safety information from the regulatory agencies that oversees workplace safety in their specific area.
- To use all available text resources that may be in work area and for applicable safety information on how to use PPE best.
- When it comes to the most common types of personal protective equipment, like goggles, gloves or bodysuits, these items are much less effective if they are not worn at all times, or whenever a specific danger exists in a work process. Using PPE consistently will help to avoid some common kinds of industrial accidents.
- Personal protective gear is not always enough to protect workers against workplace dangers. Knowing more about the overall context of your work activity can help to fully protect from anything that might threaten health and safety on the job.
- Inspection of gear thoroughly to make sure that it has the standard of quality and adequately protect the user should be continuously carried out.

Categories of PPEs

Depending upon the nature of hazard, the PPE is broadly divided into the following two categories:

1 **Non-respiratory:** Those used for protection against injury from outside the body, i.e. for protecting the head, eye, face, hand, arm, foot, leg and other body parts

2 **Respiratory:** Those used for protection from harm due to inhalation of contaminated air.

They are to meet the applicable BIS (Bureau of Indian Standards) standards for different types of PPE.

The guidelines on 'Personal Protective Equipment' is issued to facilitate the plant management in maintaining an effective programme with respect to protection of persons against hazards, which cannot be eliminated or controlled by engineering methods listed in table1.

Table1

No.	Title
PPE1	Helmet
PPE2	Safety footwear
PPE3	Respiratory protective equipment
PPE4	Arms and hands protection
PPE5	Eyes and face protection
PPE6	Protective clothing and cover all
PPE7	Ears protection
PPE8	Safety belt and harnesses

Personal protective equipments and their uses and hazards are as follows

Types of protection	Hazards	PPE to be used
Head Protection (Fig 1)	1. Falling objects 2. Striking against objects 3. Spatter	Helmets

Foot protection (Fig 2)	1. Hot spatter 2. Falling objects 3. Working wet area	Leather leg guards Safety shoes Gum boots
Nose (Fig 3)	1. Dust particles 2. Fumes/ gases/ vapours	Nose mask
Hand protecion (Fig 4)	1. Heat burn due to direct contact 2. Blows sparks moderate heat 3. Electric shock	Hand gloves
Eye protection (Fig 5, Fig 6)	1. Flying dust particles 2. UV rays, IR rays heat and High amount of visible radiation	Goggles Face shield Hand shield Head shield
Face Protection (Fig 6, Fig 7)	1. Spark generated during Welding, grinding 2. Welding spatter striking 3. Face protection from UV rays	Face shield Head shield with or without ear muff Helmets with welders screen for welders
Ear protection (Fig 7)	1. High noise level	Ear plug Ear muff
Body protection (Fig 8, Fig 9)	1. Hot particles	Leather aprons

Fig 1

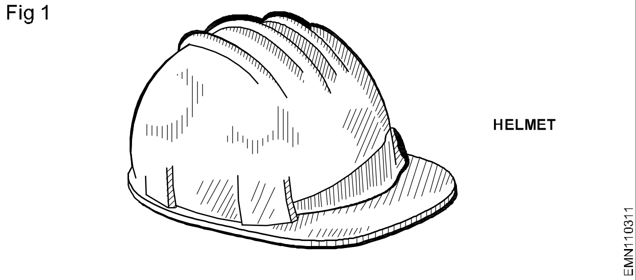


Fig 2

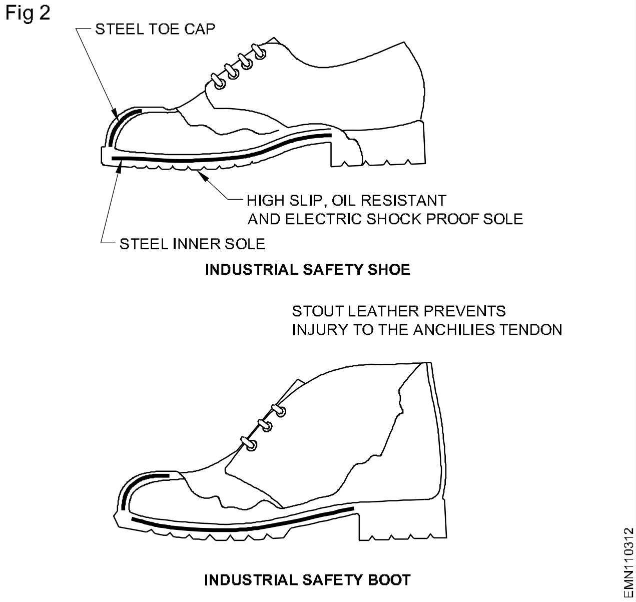


Fig 3

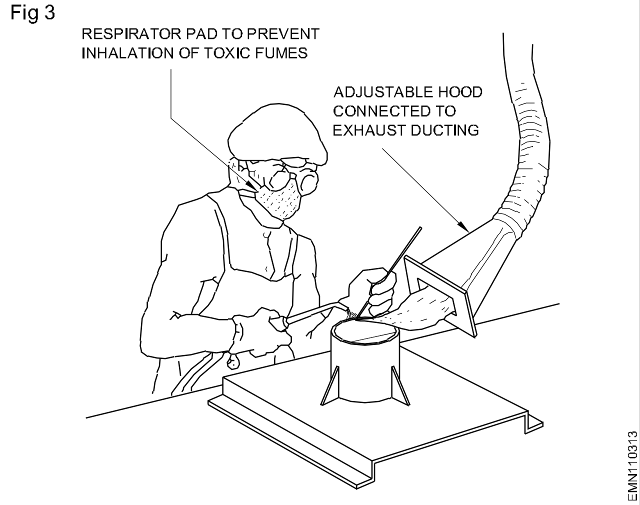


Fig 6

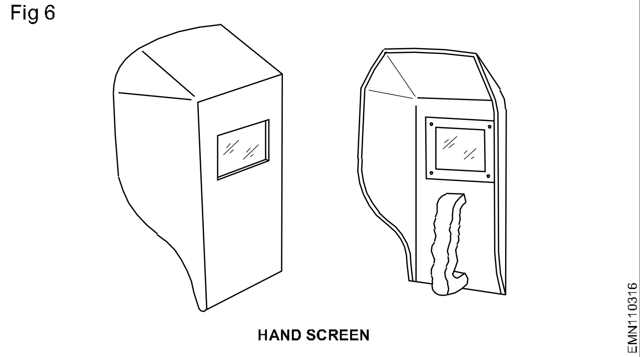
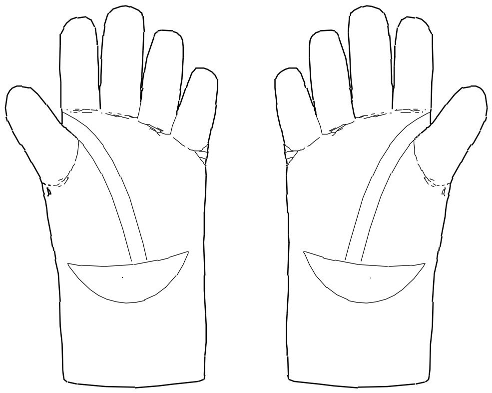


Fig 4



GLOVES

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Fig 5

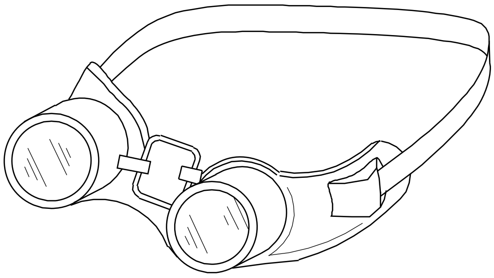

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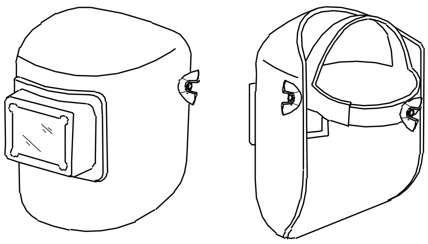
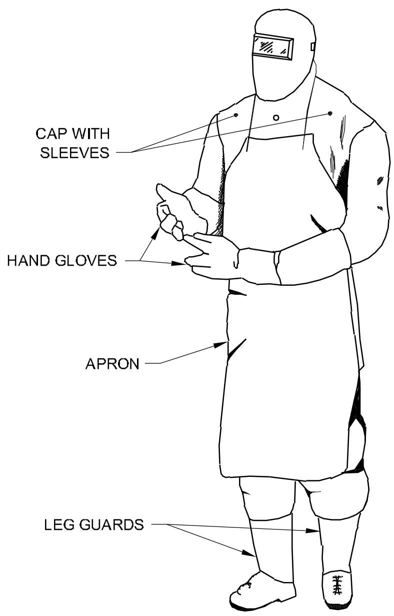
Fig 7



WELDING HELMET

EMN110317

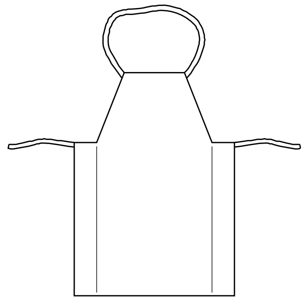
Fig 9



LEG GUARDS

EMN110319

Fig 8



APRON

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Quality of PPE's

PPE must meet the following criteria with regard to its quality-provide absolute and full protection against possible hazard and PPE's be so designed and manufactured out of materials that it can withstand the hazards against which it is intended to be used.

Selection of PPE's requires certain conditions

- Nature and severity of the hazard
- Type of contaminant, its concentration and location of contaminated area with respect to the source of respirable air
- Expected activity of workman and duration of work, comfort of workman when using PPE
- Operating characteristics and limitations of PPE
- Ease of maintenance and cleaning.
- Conformity to Indian/ International standards and availability of test certificate.

Proper use of PPEs

Having selected the proper type of PPE, it is essential that the workman wears it. Often the workman avoids using PPE. The following factors influence the solution to this problem.

- The extent to which the workman understands the necessity of using PPE
- The ease and comfort with which PPE can be worn with least interference in normal work procedures
- The available economic, social and disciplinary sanctions which can be used to influence the attitude of the workman
- The best solution to this problem is to make 'wearing of PPE' mandatory for every employee.
- In other places, education and supervision need to be intensified. When a group of workmen are issued PPE for the first time.

First Aid

Objectives: At the end of this lesson you shall be able to
- **state the first aid**
- **explain the ABC of the first aid**
- **explain the first-aid treatment for a victim**
- **state the importance of house keeping**
- **explain environment, health and safety**
- **state the importance of safety and safety signs.**

First aid is defined as the immediate care and support given to an acutely injured or ill person, primarily to save life, prevent further deterioration or injury, plan to shift the victim to safer place, provide best possible comfort and finally help them to reach the medical centre/ hospital through all available means. It is an immediate life-saving procedure using all resources available within reach.

Imparting knowledge and skill through institutional teaching at younger age group in schools, colleges, entry point at industry level is now given much importance. Inculcating such habits at early age, helps to build good healthcare habits among people.

First aid procedure often consists of simple and basic life saving techniques that an individual performs with proper training and knowledge.

The key aims of first aid can be summarized in three key points:

- **Preserve life:** If the patient was breathing, a first aider would normally then place them in the recovery position, with the patient leant over on their side, which also has the effect of clearing the tongue from the pharynx. It also avoids a common cause of death inunconscious patients, which is choking on regurgitated stomach contents. The airway can also become blocked through a foreign object becoming lodged in the pharynx or larynx, commonly called choking. The first aider will be taught to deal with this through a combination of 'back slaps' and 'abdominal thrusts'. Once the airway has been opened, the first aider would assess to see if the patient is breathing.
- **Prevent further harm:** Also sometimes called prevent the condition from worsening, or danger of further injury, this covers both external factors, such as moving a patient away from any cause of harm, and applying first aid techniques to prevent worsening of the condition, such as applying pressure to stop a bleed becoming dangerous.
- **Promote recovery:** First aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

Training

Basic principles, such as knowing to use an adhesive bandage or applying direct pressure on a bleed, are often acquired passively through life experiences. However, to provide effective, life-saving first aid interventions requires instruction and practical training. This is especially true where it relates to potentially fatal illnesses and injuries, such as those that require cardiopulmonary resuscitation (CPR); these procedures may be invasive, and carry a risk of further injury to the patient and the provider. As with any training, it is more useful if it occurs before an actual emergency, and in many countries, emergency ambulance dispatchers may give basic first aid instructions over the phone while the ambulance is on the way. Training is generally provided by attending a course, typically leading to certification. Due to regular changes in procedures and protocols, based on updated clinical knowledge, and to maintain skill, attendance at regular refresher courses or re-certification is often necessary. First aid training is often available through community organization such as the Red cross and St. John ambulance.

ABC of first aid

ABC stands for airway, breathing and circulation.

- **Airway:** Attention must first be brought to the airway to ensure it is clear. Obstruction (choking) is a life-threatening emergency.
- **Breathing:** Breathing if stops, the victim may die soon. Hence means of providing support for breathing is an important next steps. There are several methods practiced in first aid.
- **Circulation:** Blood circulation is vital to keep person alive. The first aiders now trained to go straight to chest compressions through CPR methods.

When providing first aid one needs to follow some rule. There are certain basic norms in teaching and training students in the approach and administration of first aid to sick and injured.

Not to get panic

Panic is one emotion that can make the situation more worse. People often make mistake because they get panic. Panic clouds thinking may cause mistakes. First aider need calm and collective approach. If the first aider himself is in a state of fear and panic gross mistakes may result.

It's far easier to help the suffering, when they know what they are doing, even if unprepared to encounter a situation. Emotional approach and response always lead to wrong doing and may lead one to do wrong procedures. Hence be calm and focus on the given institution. Quick and confident approach can lessen the effect of injury.

Call medical emergencies

If the situation demands, quickly call for medical assistance. Prompt approach may save the life.

Surroundings play vital role

Different surroundings require different approach. Hence first aider should study the surrounding carefully. In other words, one need to make sure that they are safe and are not in any danger as it would be of no help that the first aider himself get injured.

Do no harm

Most often over enthusiastically practiced first aid viz. administering water when the victim is unconscious, wiping clotted blood (which acts as plug to reduce bleeding), correcting fractures, mishandling injured parts etc., would leads to more complication. Patients often die due to wrong FIRST AID methods, who may otherwise easily survive. Do not move the injured person unless the situation demands. It is best to make him lie wherever he is because if the patient has back, head or neck injury, moving him would causes more harm.

This does not mean do nothing. It means to make sure that to do something the care gives feel confident through training would make matters safe. If the first aider is not confident of correct handling it is better not to intervene of doing it. Hence moving a trauma victim, especially an unconscious one, needs very careful assessment. Removal of an embedded objects (Like a knife, nail) from the wound may precipitate more harm (e.g. increased bleeding). Always it is better to call for help.

Reassurance

Reassure the victim by speaking encouragingly with him.

Stop the bleeding

If the victim is bleeding, try to stop the bleeding by applying pressure over the injured part.

Golden hours

India have best of technology made available in hospitals to treat devastating medical problem viz. head injury, multiple trauma, heart attack, strokes etc, but patients often do poorly because they don't gain access to that technology in time. The risk of dying from these conditions, is greatest in the first 30 minutes, often instantly. This period is referred to as Golden period. By the time the patient reach the hospital, they would have passed that critical period. First aid care come handy to save lives. It helps to get to the nearest emergency room as quickly as possible through safe handling and transportation. The shorter that time, the more likely the best treatment applied.

Maintain the hygiene

Most important, the first aider need to wash hands and dry before giving any first aid treatment to the patient or wear gloves in order to prevent infection.

Cleaning and dressing

Always clean the wound thoroughly before applying the bandage gently wash the wound with clean water.

Not to use local medications on cuts or open wounds

They are more irritating to tissue than it is helpful. Simple dry cleaning or with water and some kind of bandage are best.

CPR (Cardio-Pulmonary Resuscitation) can be life-sustaining

CPR can be life sustaining. If one is trained in PR and the person is suffering from choking or finds difficulty in breathing, immediately begin CPR. However, if one is not trained in CPR, do not attempt as you can cause further injury. But some people do it wrong. This is a difficult procedure to do in a crowded area. Also there are many studies to suggest that no survival advantage when bystanders deliver breaths to victims compared to when they only do chest compressions. Second, it is very difficult to carry right maneuver in wrong places. But CPR, if carefully done by highly skilled first aiders is a bridge that keeps vital organs oxygenated until medical team arrives.

Declaring death

It is not correct to declare the victim's death at the accident site. It has to be done by qualified medical doctors.

How to report an emergency?

Reporting an emergency is one of those things that seems simple enough, until actually when put to use in emergency situations. A sense of shock prevail at the accident sites. Large crowd gather around only with inquisitive nature, but not to extend helping hands to the victims. This is common in road side injuries. No passer-by would like to get involved to assist the victims. Hence first aid management is often very difficult to attend to the injured persons. The first aiders need to adapt multi-task strategy to control the crowd around, communicate

to the rescue team, call ambulance etc., all to be done simultaneously. The mobile phones helps to a greater extent for such emergencies. Few guidelines are given below to approach the problems.

Assess the urgency of the situation. Before you report an emergency, make sure the situation is genuinely urgent. Call for emergency services if you believe that a situation is life-threatening or otherwise extremely critical.

- A crime, especially one that is currently in progress. If you're reporting a crime, give a physical description of the person committing the crime.
- A fire - If you're reporting a fire, describe how the fire started and where exactly it is located. If someone has already been injured or is missing, report that as well.

- A life-threatening medical emergency, explain how the incident occurred and what symptoms the person currently displays.
- A car crash - Location, serious nature of injures, vehicle's details and registration, number of people involved etc.

Call emergency number

The emergency number varies - 100 for Police & Fire, 108 for Ambulance.

Report your location

The first thing the emergency dispatcher will ask is where you are located, so the emergency services can get there as quickly as possible. Give the exact street address, if you're not sure of the exact address, give approximate information.

Give the dispatcher your phone number

This information is also imperative for the dispatcher to have, so that he or she is able to call back if necessary.

Describe the nature of the emergency

Speak in a calm, clear voice and tell the dispatcher why you are calling. Give the most important details first, then answer the dispatcher's follow-up question as best as you can.

Do not hang up the phone until you are instructed to do so. Then follow the instructions you were given.

How to do basic first aid?

Basic first aid refers to the initial process of assessing and addressing the needs of someone who has been injured or is in physiological distress due to choking, a heart attack, allergic reactions, drugs or other medical emergencies. Basic first aid allows one to quickly determine a person's physical condition and the correct course of treatment.

Important guideline for first aiders

Evaluate the situation

Are there things that might put the first aider at risk. When faced with accidents like fire, toxic smoke, gasses, an unstable building, live electrical wires or other dangerous scenario, the first aider should be very careful not to rush into a situation, which may prove to be fatal.

Remember A-B-Cs

The ABCs of first aid refer to the three critical things the first aiders need to look for.

- Airway - Does the person have an unobstructed airway?
- Breathing - Is the person breathing?
- Circulation - Does the person show a pulse at major pulse points (wrist, carotid artery, groin)

Avoid moving the victim

Avoid moving the victim unless they are immediate danger. Moving a victim will often make injuries worse, especially in the case of spinal cord injuries.

Call emergency services

Call for help or tell someone else to call for help as soon as possible. If alone at the accident scene, try to establish breathing before calling for help, and do not leave the victim alone unattended.

Determine responsiveness

If a person is unconscious, try to rouse them by gently shaking and speaking to them.

If the person remains unresponsive, carefully roll them on the side (recovery position) and open his airway.

- Keep head and neck aligned.
- Carefully roll them onto their back while holding his head.
- Open the airway by lifting the chin.

Look, listen and feel for signs of breathing

Look for the victim's chest to raise and fall, listen for sounds of breathing.

If the victim is not breathing, see the section below

- If the victim is breathing, but unconscious, roll them onto their side, keeping the head and neck aligned with the body. This will help drain the mouth and prevent the tongue or vomit from blocking the airway.

Check the victim's circulation

Look at the victim's colour and check their pulse (the carotid artery is a good option; it is located on either side of the neck, below the jaw bone). If the victim does not have a pulse, start CPR.

Treat bleeding, shock and other problems as needed

After establishing that the victim is breathing and has a pulse, next priority should be to control any bleeding. Particularly in the case of trauma, preventing shock is the priority.

- **Stop bleeding:** Control of bleeding is one of the most important things to save a trauma victim. Use direct pressure on a wound before trying any other method of managing bleeding.
- **Treat shock:** Shock may causes loss of blood flow from the body, frequently follows physical and occasionally psychological trauma. A person in shock will frequently have ice cold skin, be agitated or have an altered mental status, and have pale colour to the skin around the face and lips. Untreated, shock can be fatal. Anyone who has suffered a severe injury or life-threatening situation is at risk for shock.
- **Choking victim:** Choking can cause death or permanent brain damage within minutes.
- **Treat a burn:** Treat first and second degree burns by immersing or flushing with cool water. Don't use creams, butter or other ointments, and do not pop blisters. Third degree burns should be covered with a damp cloth. Remove clothing and jewellery from the burn, but do not try to remove charred clothing that is stuck to burns.

- **Treat a concussion:** If the victim has suffered a blow to the head, look for signs of concussion. Common symptoms are: loss of consciousness following the injury, disorientation or memory impairment, vertigo, nausea, and lethargy.
- **Treat a spinal injury victim:** If a spinal injury is suspected, it is especially critical, not move the victim's head, neck or back unless they are in immediate danger.

Stay with the victim until help arrives

Try to be a calming presence for the victim until assistance can arrive.

Unconsciousness (COMA)

Unconscious also referred as Coma, is a serious life threatening condition, when a person lie totally senseless and do not respond to calls, external stimulus. But the basic heart, breathing, blood circulation may be still intact, or they may also be failing. If unattended it may lead to death.

The condition arises due to interruption of normal brain activity. The causes are too many.

The following symptoms may occur after a person has been unconscious:

- Confusion
- Drowsiness
- Headache
- Inability to speak or move parts of his or her body (see stroke symptoms)
- Light headedness
- Loss of bowel or bladder control (incontinence)
- Rapid heartbeat (palpitation)
- Stupor

First aid

- Call EMERGENCY number.
- Check the person's airway, breathing, and pulse frequently. If necessary, begin rescue breathing and CPR.
- If the person is breathing and lying on the back and after ruling out spinal injury, carefully roll the person onto the side, preferably left side. Bend the top leg so both hip and knee are at right angles. Gently tilt the head back to keep the airway open. If breathing or pulse stops at any time, roll the person on to his back and begin CPR.
- If there is a spinal injury, the victims position may have to be carefully assessed. If the person vomits, roll the entire body at one time to the side. Support the neck and back to keep the head and body in the same position while you roll.
- Keep the person warm until medical help arrives.
- If you see a person fainting, try to prevent a fall. Lay the person flat on the floor and raise the level of feet above and support.
- If fainting is likely due to low blood sugar, give the person something sweet to eat or drink when they become conscious.

Do not

- Do not give any food or drink of an unconscious person
- Do not leave the person alone.
- Do not place a pillow under the head of an unconscious person.
- Do not slap an unconscious person's face or splash water on the face and try to revive him.

Loss of consciousness may threaten life if the person is on his back and the tongue has dropped to the back of the throat, blocking the airway. Make certain that the person is breathing before looking for the cause of unconsciousness. If the injuries permit, place the casualty in the recovery position (Fig 2) with the neck extended. Never give any thing by mouth to an unconscious casualty.

How to diagnose an unconscious injured person

- Consider alcohol: look for signs of drinking, like empty bottles or the smell of alcohol.
- Consider epilepsy: are there signs of a violent seizure, such as saliva around the mouth or a generally dishevelled scene?
- Think insulin: might the person be suffering from insulin shock (see 'How to diagnose and treat insulin shock")?
- Think about drugs: was there an overdose? Or might the person have under dosed - that is not taken enough of a prescribed medication?
- Consider trauma: is the person physically injured?
- Look for signs of infection: redness and/ or red streaks around a wound.
- Look around for signs of Poison: an empty bottle of pills or a snakebite wound.
- Consider the possibility of psychological trauma: might the person have a psychological disorder of some sort?
- Consider stroke, particularly for elderly people.
- Treat according to what you diagnose.

Shock

A severe loss of body fluid will lead to a drop in blood pressure. Eventually the blood's circulation will deteriorate and the remaining blood flow will be directed to the vital organs such as the brain. Blood will therefore be directed away from the outer area of the body, so the victim will appear pale and the skin will feel ice cold.

As blood flow slows, so does the amount of oxygen reaching the brain. The victim may appear to be confused, weak, and dizzy and may eventually deteriorate into unconsciousness. Try to compensate for this lack of oxygen, the heart and breathing rates both speed up, gradually becoming weaker, and may eventually cease.

Potential causes of shock include: sever internal or external bleeding; burns; severe vomiting and diarrohea, especially in children and the elderly; problems with the heart.

Symptoms of shock

Victims appear pale, ice cold, pulse appear initially faster and gets slower, breathing becomes shallow. Weakness, dizziness, confusion continue. If unattended the patient may become unconscious and die.

Shock kills, so it is vital that you can recognize these signs and symptoms. With internal bleeding in particular, shock can occur sometime after an accident, so if a person with a history of injury starts to display these symptoms coupled with any of the symptoms of internal bleeding, advise them to seek urgent medical attention. Or take or send them to hospital.

First aid

Keep the patient warm and at mental rest. Assure of good air circulation and comfort. Call for help to shift the patient to safer place/ hospital.

- **Warmth:** Keep the victim warm but do not allow them to get overheated. If you are outside, try to get something underneath her if you can do easily. Wrap blankets and coats around her, paying particular attention to the head, through which much body heat is lost.
- **Air:** Maintain careful eye on the victim's airway and be prepared to turn them into the recovery position if necessary, or even to resuscitate if breathing stops. Try to keep back bystanders and loosen tight clothing to allow maximum air to victim.
- **Rest:** Keep the victim still and preferably sitting or lying down. If the victim is very giddy, lay them down with there legs raised to ensure that maximum blood and therefore maximum oxygen is sent to the brain.

Power Failure

Minor electric shock, fire, or product failure may occasionally occur. Do not disassemble, modify, or repair the product or touch the interior of the product.

Minor injury due to electric shock may occasionally occur. Do not touch the terminals while power is being supplied.

Minor burns may occasionally occur. Do not touch the product while power is beinng supplied or immediately after power is turned OFF.

Fire may occasionally occur. Tighten the terminal screws with the specified torque.

Minor electric shock, fire, or product failure may occasionally occur. Do not allow any pieces of metal or conductors or any clippings or cuttings resulting from installation work to enter the product.

Precautions for Safe Use

Input Voltage

Use a commercial power supply for the power supply voltage input to models with AC inputs.

Inverters with an output frequency of 50/60 Hz are available, but the rise in the internal temperature of the power supply may result in ignition or burning. Do not use an inverter outpur for the power supply of the product.

Grounding

Connect the ground completely. Electric shock occur if te the ground is not connected completely.

Operating Environment

Use each product within the rated range for ambient operating temperature, ambient operating humidity, and storage temperature specified for that product.

Use the power supply within the ranges specifed for vibration and shock reistance.

Do not use the power supply in locations subjects to excessive amount of dust or where liquids, foreign matter, or corrosive gases may enter the interior of the product.

Install the power supply well away from devices that produce strong, high-frequency noise and surge.

Do not use the power supply in locations subject to direct sunlight.

Mounting

The installation screws can be tightened into the power supply only to a limited depth. Make sure that the lengths of the screws protruding into the power supply are within the specified dimensions.

Wiring

Use caution when connecting the input cable to the power supply.

The power supply unit may be destroyed if the input cable is connected to the wrong terminals. Use caution when using a model with a DC input. The power supply unit may be destroyed if the polarity is reversed.

Do not apply more than 75-N force to the terminal block when tightening the terminals.

Wiring materials

Use a wire size that suits the rated ouput current of the power supply to be used in order to prevent smoking or ignition caused by abnormal loads.

Caution is particularly required if the output current from one power supply is distributed to multiple loads. If thin wiring is used to branch wiring, the power supply's overload protection circuit may fail to operate depending on factors such as the impedence of the load wiring even the load is short-circuited.

Therefore insertion of a fuse in the line or other protective measures must be considered.

Precautions against ingress of metal fragments (Fillings)

Drilling on the upper section of an installed power supply may cause drilling fragments to fall onto the PCB, thereby short-circuiting and destroying the internal circuits. Whether the power supply cover is attached or not, cover the power supply with a sheet to prevent ingress of fragments when performing work on the upper sector of the power supply.

Be sure to remove the sheet covering the power supply for machining before power-ON so that it does not interface with heat dissipation.

Load

Internal parts may possibly deteriorate or be damaged if a short-circuited or over current state continues during operation.

Charging a battery

When connection a battery at the load, connect an overcurrent limiting circuit and overvoltage protection circuit.

Output and Ground connections

The power supply output is a floating output (i.e., the primary side and secondary side are separated). so the output line (i.e., +V or -V) can be connected externally directly to a ground. Though the ground, however, the insulation between the primary side and secondary side will be lost. Confirm that no loops are created in which the power supply output is short-circuited through the internal circuits of the load.

Example: When the +V side of the power supply is connected directly to a ground and a load is used for which the internal 0-V line uses the same ground.

Fire safety

Prepare before a fire:

Always familiarize yourself to “where you are” and be sure to know how to reach the two nearest exits.

Remember that in a fire situation, smoke is blinding and will bank down in the rooms and hallways. This condition may force you to crouch or crawl to escape to safety. By always being aware of your surroundings, your knowledge of the nearest exits and having a plan will greatly increase your ability to deal with sudden

If you are notified of, or discover a fire:

- Move quickly to the nearest accessible exit.
- Notify, and assist others to evacuate along the way.
- If the building fire alarm is not yet sounding, manually activate the alarm pull station located near the exit.
- Exit the building and proceed to the “ Area of gathering”

Evacuation procedures for persons with mobility issues:

In the event of an actual emergency incident, persons with mobility issues or who are unable to safely self-evacuate should follow this procedure:

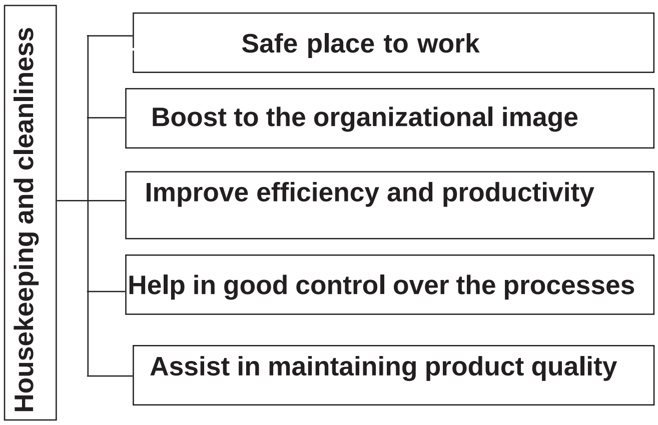
- Relocate to an entry to an evacuation stairwell, marked by a red exit sign.
- Wait near the enclosed exit stairwell if there is no smoke or other threats to your safety. Most fire alarm activations are brief, allowing occupants to return within a few minutes.

If smoke, fire, or other threat is imminent, move into the stairwell:

- After the stairwell crowd has passed below your floor level, enter the stairwell with assistant(s) and wait on the stair landing. Make sure that the door is securely closed.

Housekeeping and cleanliness at workplace

Housekeeping and cleanliness at the workplace are closely linked to the industrial safety. the degree, to which these activities are effectively managed, is an indicator of the safety culture of the organization. House keeping and cleanliness not only make the organization a safer place to work in but also provide a big boost to the image of the organization. These activities also (i) improve efficiency and productivity, (ii) helps in maintaining good control over the processes, and (iii) assist in maintaining the quality of the product. These important aspects of housekeeping and cleanliness are furnished below.



There are several signs which reflect poor housekeeping and cleanliness at the workplace in the organization. Some of these signs are (i) cluttered and poorly arranged work areas, (ii) untidy or dangerous storage of materials (such as materials stuffed in corners and overcrowded shelves etc.), (iii) dusty and dirty floors and work surfaces, (iv) items lying on the shop floor which are in excess or no longer needed, (v) blocked or cluttered aisels and exits, (vi) tools and equipment left in work areas instead of being returned to proper storage places, (vii) broken containers and damaged materials, (viii) overflowing waste bins and containers, and (ix) spills and leaks etc.

Housekeeping and cleanliness is crucial to a safe workplace. It can help prevent injuries and improve productivity and morale, as well as make a good imprint on the people visiting the workplace.

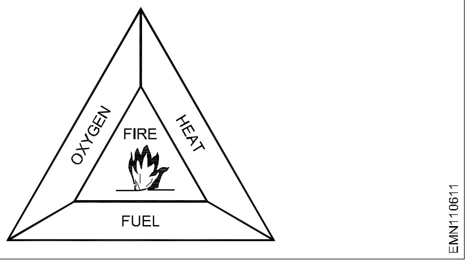
Fire extinguishers

Objectives: At the end of this lesson you shall be able to
- **state the effects of a fire break out**
- **state the conditions required for combustion relevant to fire prevention**
- **state the general precautionary measures to be taken for fire prevention**
- **determine the correct type of fire extinguisher required for a particular function**
- **state environment, health and safety.**

Fire

Fire is nothing but burning of a combustible material. For combustion the three main requirements are shown in Fig 1.

Fig 1



Fuel

Fuel can be any combustible substance in the form of a solid, liquid or gas. Examples; wood, paper, petrol, kerosene, LPG etc., The fuel will catch fire and burn provided a high enough temperature(heat) is brought about and a continuous supply of oxygen is given. It is important to note that without fuel, combustion cannot take place.

Heat

Fuels will begin to burn at a certain temperature. Different types of fuels need different temperatures to catch fire and burn. For example, wood needs a higher temperature to catch fire and burn than paper. Petrol needs much lesser temperature to catch fire and burn than paper. Generally liquid fuels give off vapour when heated. It is this vapour which ignites. Some liquids such as petrol do not have to be heated as they give off vapour at room temperature (15^oC - 25^oC) itself. It is important to note that without heat, fuel cannot get ignited(catch fire) and hence combustion cannot take place.

Oxygen

Oxygen exists in air. The amount of oxygen in air is sufficient to continue the combustion once it occurs. Hence to keep a fire burning, oxygen is a must. It is important to note that without oxygen, combustion cannot continue to take place.

Controlled and uncontrolled fire

Fire is a boon to mankind. Without fire, there would not be cooked food or hot water for bath as and when we want it. At the same time if the fire does not get constrained to a place of requirement, fire can become a bane(curse) to mankind. An uncontrolled fire can cause such a disaster which not only leads to destruction of material but also endanger the life of persons. Hence, the lesson one must never forget is, keep the fire under control. Every effort must be made to prevent uncontrolled fire. When there is a fire outbreak, it must be controlled and extinguished immediately without any delay.

Preventing fire

The majority of fires begin with small outbreaks. If this is not noticed, fire goes out of control and will be on its way of destruction. Hence, most fires could be prevented if suitable care is taken by following some simple common sense rules as given below.

– Do not accumulate combustible refuse such as cotton waste, waste or cloth soaked with oil, scrap wood, paper, etc. in odd corners. These refuse should be in their collection bins or points.

– Do not misuse or neglect electrical equipments or electrical wiring as this may cause electrical fire. Loose connections, low rated fuses, overloaded circuits causes over heating which may in turn lead to fire. Damaged insulation between conductors in cables cause electrical short circuit and cause fire.

– Keep away clothing and other materials which might catch fire from heating appliances. Make sure the soldering iron is disconnected from power supply and is kept safe in its stand at the end of the working day.

– Store highly flammable liquids and petroleum mixtures such as thinner, adhesive solutions, solvents, kerosene, spirit, LPG gas etc. in the storage area exclusively meant for storage of flammable materials.

– Turn off blowlamps and torches when they are not in use.

Controlling and Extinguishing fire

Isolating or removing any of three factors illustrated in Fig1, will control and extinguish fire. There are three basic ways of achieving this.

1 **Starving the fire of fuel**

To remove the fuel which is burning or cut further supply of fuel to the fire.

2 **Smothering**

To stop the supply of oxygen to the fire by blanketing the fire with foam, sand etc.

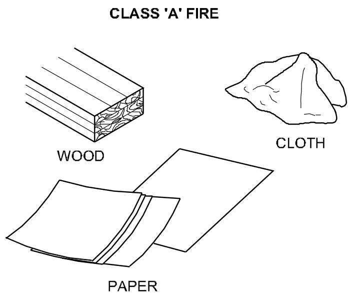
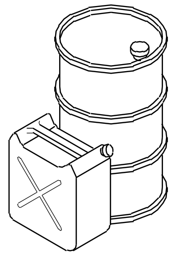
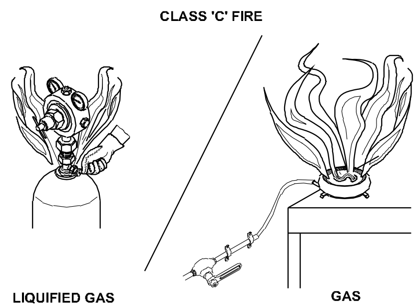
3 **Cooling**

To reduce the temperature of the fire by spraying water and thus cooling the fire.

By any one of the above three methods, fire can be first controlled and then extinguished.

For the purpose of determining the best method of extinguishing different types of fires, fires are classified under four main classes based on the type of fuel as given in Table 1.

TABLE 1

Classification of Fire	Fuel involved	Precautions and extinguishing
Class A Fire	Wood, paper cloth etc. Solid materials 	Most effective method is cooling with water. Jets of water should be sprayed on the base
Class B Fire	Flammable liquids & liquefiable solids 	Should be smothered. The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire. Water should never be used on burning liquids. Foam, dry powder or CO_2 may be used on this type of fire.
Class C Fire	Gas and liquefied gas 	Extreme caution is necessary in dealing withliquefied gases. There is a risk of explosion and sudden outbreak of fire in the entire vicinity. If an appliance fed from a cylinder catches fire -shut off the supply of gas. The safest course is to raise an alarm and leave the fire to be dealt with by trained personnel. Dry powdered extinguishers are used on this type of fire.
Class D Fire	Involving metals 	The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires. **Fire in electrical equipment**: Carbon -di-oxide, dry powder, and vapourising liquid(CTC) extinguishers can be used to deal with fires in electrical equipment. Foam or liquid (eg. water) extinguishers must not be used on electrical equipment at all.

Fire extinguishers

Different fire extinguishing agents should be used for different types of fires as listed in Table 1. Using a wrong type of extinguishing agent can make things worse.

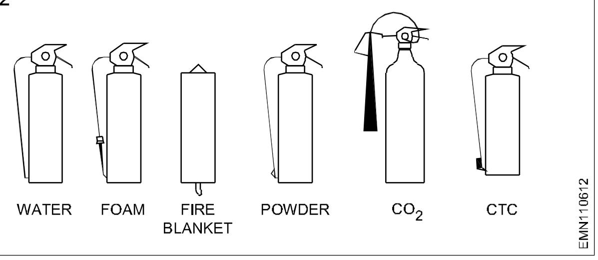
A fire extinguishing agent is the material or substance used to put out the fire. These extinguishing materials are usually (but not always) contained in a container called the 'fire extinguisher' with a mechanism for spraying into the fire when needed.

There is no classification for **electrical fires** as these are only fires in materials where electricity is present. To control electrical fire in a building the electrical supply should be cut off first.

Types of fire extinguishers

Many types of fire extinguishers are available with different extinguishing *agents* to deal with different classes of fires as shown in Fig 2. Always check the operating instructions on the extinguisher before use.

Fig 2



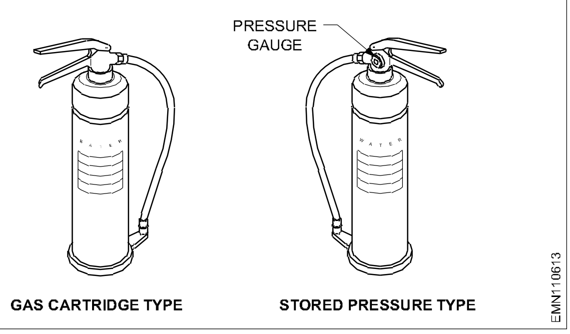
(i) Water-filled extinguishers

In water-filled extinguishers, as shown in Fig 3, there are two types based on the method of operating the extinguisher.

a Cartridge type

b Stored pressure type

Fig 3



In both the methods of operation, the discharge can be interrupted as required. This is to conserve the contact area and to prevent unnecessary damage to the material due to water.

(ii) Foam extinguishers

These may be stored pressure or gas cartridge types as shown in Fig 4.

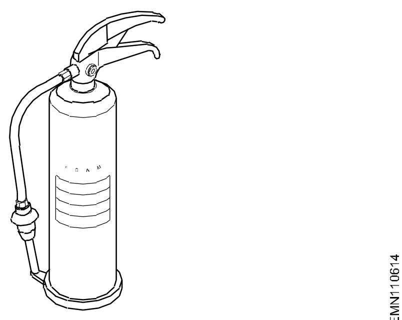
Most suitable for:

– flammable liquid fires

– running liquid fires.

Not to be used in fires where electrical equipment is involved.

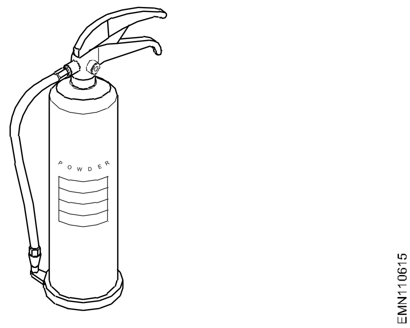
Fig 4



(iii) Dry powder extinguishers

Extinguishers fitted with dry powder may be of the gas cartridge or stored pressure type as shown in Fig 5. Appearance and the method of operation is the same as that of water-filled one. The main distinguishing feature is the fork-shaped nozzle. Powders have been specially developed to deal with Class D fires.

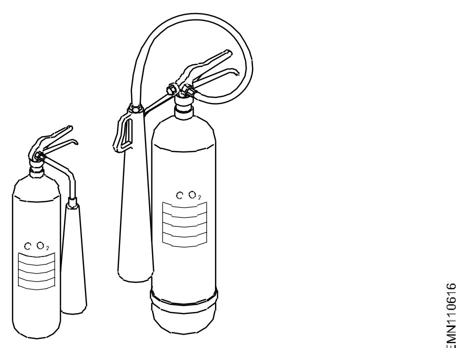
Fig 5



iv) Carbon-di-oxide (CO_2)

This type is easily distinguished by the distinctively shaped discharge horn as shown in Fig 6. These extinguishers are suitable for fires on flammable liquids and liquefiable solids. Best suited where contamination by deposits must be avoided. Not generally effective in the open air.

Fig 6

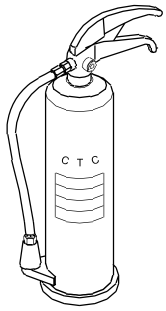


v) Halon Extinguishers (Fig 7)

Carbontetrachloride(CTC) and Bromochlorodifluoro methane (BCF). They may be either gas cartridge or non-conductive.

The fumes given off by these extinguishers are dangerous especially in confined space.

Fig 7



General procedure to be adopted in the event of a fire

1 Raise a loud alarm by using any of the following.

Adopt any one method of giving an alarm signal for fire breaking in your institute/ workshop.

- Raising your voice and shouting Fire! Fire!Fire! .... to call the attention of others.
- Running towards the fire shouting Fire! Fire! and actuate fire alarm/bell/siren. This alarm/bell/siren to be actuated only in case of fire.
- Any other means by which the attention of others can be called and are made to understand there is a fire break out.

2 On receipt of the fire alarm signal, do the following:

- stop the normal work you are doing
- turn OFF the power for all machinery and equipments
- switch OFF fans/air circulators/exhaust fans
- switch OFF the mains if accessible.

3 If you are not involved in fire fighting team, then,

- evacuate the working premises
- close the doors and windows, but do not lock or bolt
- assemble at a safe open place along with the others
- if you are in the room/place where the fire has broken out, leave the place calmly through the emergency exit.

4 If you are involved in the fire fighting team,

- take instructions/give instructions for an organized way of fighting the fire.

If you are taking instructions,

- follow the instructions systematically. Do not be panic. Do not get trapped in fire or smoke in a hurry.

If you are giving instructions,

- assess the class of fire(class A,B,C or D)
- send for sufficient assistance and fire brigade
- judge the magnitude of the fire. Locate locally available suitable means to put-out the fire.
- ensure emergency exit paths are clear of obstructions. Attempt to evacuate the people and explosive materials, substances that can serve as further fuel for fire within the vicinity of the fire break.
- Allot clear activity to persons involved in firefighting by name to avoid confusion.
- Control and extinguish the fire using the right type of fire extinguisher and making use of the available assistance effectively.

5 After fully extinguishing the fire, make a report of the fire accident and the measures taken to put out the fire, to the authorities concerned.

Reporting all fires however small they are, helps in the investigation of the cause of the fire. It helps in preventing the same kind of accident occurring again.

Environment, health and safety (EHS) : is a discipline and specialty that studies and implements practical aspects of environmental protection and safety at work. In simple terms it is what organizations must do to make sure that their activities do not cause harm to anyone.

Regulatory requirements play an important role in EHS discipline and EHS managers must identify and understand relevant EHS regulations, the implications of which must be communicated to executive management so the company can implement suitable measures. Organizations based in the United states are subject to EHS regulations in the code of federal regulations particularly CFR 29,40, and 49. Still, EHS management is not limited to legal compliance and companies should be encouraged to do more than is required by law, if appropriate.

From a health and safety standpoint, it involves creating organized efforts and procedures for identifying workplace hazards and reducing accidents and exposure to harmful situations and substances. It also includes training of personnel in accident prevention, accident response, emergency preparedness, and use of protective clothing and equipment.

From an environmental standpoint, it involves creating a systematic approach to complying with environmental regulations, such as managing waste or air emissions all the way to helping site's reduce the company's carbon footprint.

Sucessful HSE programs also include measures to address ergonomics, air quality, and other aspects of workplace safety that could affect the health and well-being of employees and the overall community.

Basic hand tools

Objectives : At the end of this lesson you shall be able to
- **state the types of screwdrivers**
- **explain the parts of a combination plier and their uses**
- **state the uses of diagonal cutters**
- **state the uses of nose pliers and their types**
- **state the uses of tweezers and their types.**

Basic Hand tools

There are innumerable types of hand tools used for different types of work. Some of the basic tools which are a must for a mechanic electronics are dealing in are :

– screwdrivers

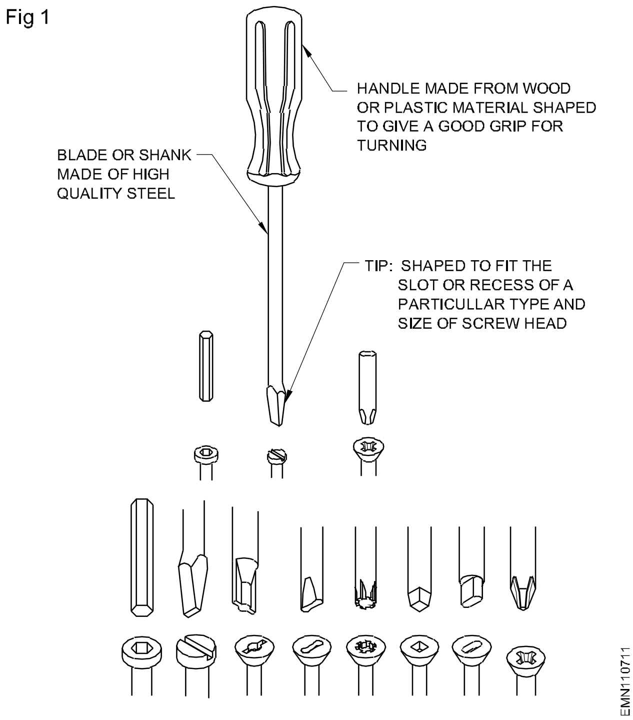
– pliers, and

– tweezers.

Screwdrivers

A screwdriver is a tool used to tighten or loosen screws. A simple screwdriver and its parts are shown in Fig 1.

Fig 1



When a screwdriver is used to tighten or loosen screws. The blade axis of a screwdriver must be linked up with that of the screw axis If this is not taken care of, the screwdriver tip/screw head/threads in the hole will get damaged.

In order not to damage the slot and/or the tip of the screwdriver, it is very important that the tip is correctly shaped and matches the size of the slot the tip to be lifted out of the slot. When turning a screw downward pressure has to be exerted on the screwdriver in order to keep the tip in the slot.

It is important that the width and thickness of a flat screwdriver tip correspond to the dimensions of the slot it is used with. Its width should be slightly less than the length of the slot and its thickness should be almost equal to the width of the slot.

A flat tip which is too wide might cause damage to the workpiece.

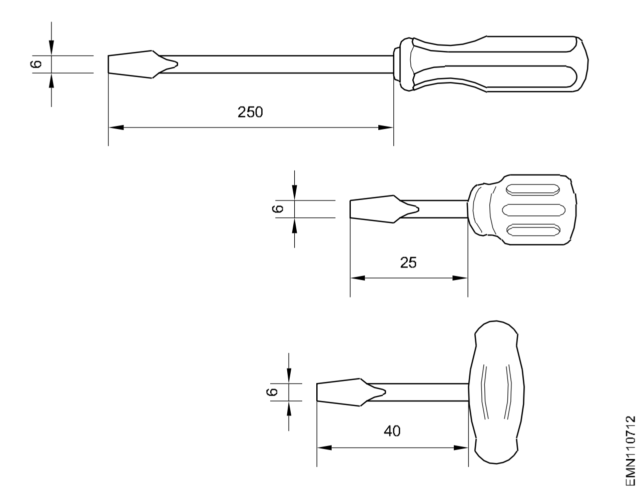
Screwdrivers with flat tips are specified in size by the length of their blade and by the width of their tip. These dimensions are given in millimetres (mm).

Screwdrivers are available in many sizes, ranging from blade lengths from 25 mm to 300 mm and widths of tips ranging from 0,5 mm to 18 mm.

Length of blade L and Length of tip W

Normally there is no relationship between the length of the blade and the width of the tip of a screwdriver. A screwdriver with a 6 mm wide tip can have blade lengths ranging from 25 to 250 mm. It can also have various forms of handles as shown in Fig 2.

Fig 2



There are, however, screwdrivers which are made to an industrial specification such as DIN, ISI etc. These screwdrivers have fixed dimensions and for each size of screwdriver the width of its tip and the length of its blade is specified.

A Phillips cross-type screwdriver tip. It is used to tighten and loosen screws with a Phillips cross-type recess.

Using a screwdriver

The general procedure for using a screwdriver is given below.

– Select a suitable screwdriver having the required blade length, width of tip and thickness of tip.

– Check that the tip of the screwdriver is flat and square.

Worn out tips tend to slip off while turning and may cause injury. Make sure your hands and the screwdriver handle are dry and free from grease. Hold the screwdriver with the axis in line with the axis of the screw. Set the tip of the screwdriver in the screw slot. Be sure of the direction in which the screwdriver is to be twisted. Twist the handle gently and steadily.

Do not apply too much pressure in the axial direction of the screw. This may damage the screw threads.

Never try to use a screwdriver as a lever; this could break the tip or bend the blade and make the screwdriver unusable.

Pliers

Pliers are tools which are used for:

– holding, gripping, pulling and turning small parts and components,

– shaping and bending light sheet metal parts,

– forming, bending, twisting and cutting small diameter wires.

Pliers consist basically of a pair of legs which are joined by a pivot. Each leg consists of a long handle and a short jaw.

If the legs of the pliers are crossed at the pivot, the jaws will close when pressure is applied to the handles. In some pliers the jaws will close when pressure is applied to the handles.

Pliers have serrated or plain jaws. Surrogated jaws offer a better grip on the workpiece. Serrated jaws might, however, damage the surface of the workpiece. In this case protection sleeves or pliers with non-serrated jaws should be used.

Pliers are made from high quality steel. In many cases pliers are chromium plated to protect them against rust. In climates with a high degree of humidity it is advisable to use such pliers as they will last longer and need less maintenance.

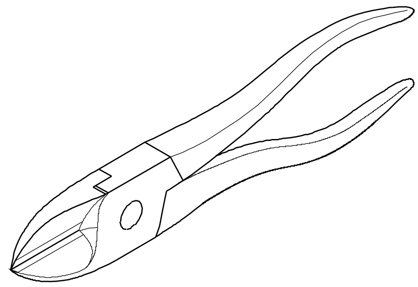
To keep pliers in good working condition, they should be kept clean, the metal parts should be wiped with an oily piece of cloth and, from time to time, a drop of oil should be applied to the pivots and joints.

Diagonal cutter plier

Fig 3 shows diagonal cuttng pliers or side cutting pliers.

They are used for cutting small diameter wires and cables, especially when they are close to terminals.

Fig 3



DIAGONAL CUTTING PLIERS

They are also used to remove the sheath and insulation from cables and cords.

They can also be used for other operations such as splitting and removing cotter pins.

Diagonal cutting pliers are made in the following overall lengths:

100, 125, 140, 160, 180 and 200 mm.

End cutting plier

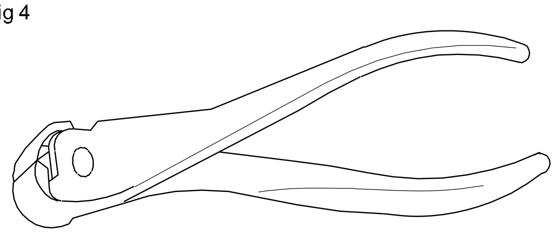
Fig 4 shows end - cutting pliers or end nippers and their applications.

They are used to cut small diameter wires, pins, nails and to remove nails from wood.

End cutting pliers are made in the following overall lengths:

130, 160, 180, 200, 210 and 240 mm.

Fig 4



END CUTTING PLIERS

Flat nose pliers

Fig 5 shows a flat nose pliers and its applications.

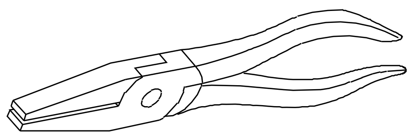
They are used to form and shape wires and small pieces of metal.

They are also used for other operations such as removing the metal sheath from cables, or gripping and holding small parts.

Flat nose pliers are made in the following overall lengths:

100, 120, 140, 160, 180 and 200 mm.

Fig 5



FLAT NOSE PLIERS

Round nose pliers

Fig 6 shows round nose pliers and its applications.

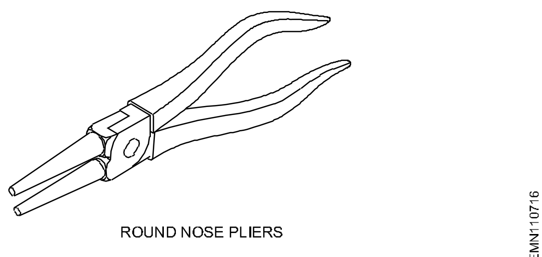
They are used to form curves in wires and light metal strips. The conical shape of the jaws makes it possible to form curves and circles of various dimensions.

They are also used to form eyelets in wires to fit terminal screws, and to hold small parts.

Round nose pliers are made to the following overall lengths:

100, 120, 140, 160, 180 and 200 mm.

Fig 6



Long nose pliers

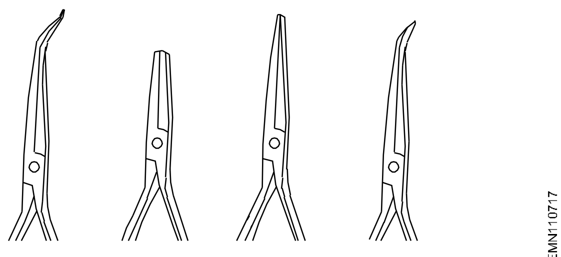
Long nose pliers and its applications. These pliers are made with straight and curved jaws.

They are used to hold small parts, especially in confined areas.

They are also used to adjust fine wires, contacts and other parts.

Long nose pliers are made with many differently shaped jaws as shown in Fig 7. Long nose pliers are available in the following overall lengths:160, 180, 200 and 220 mm.

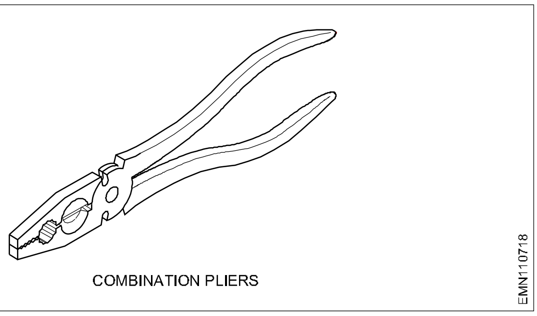
Fig 7



Combination pliers

Fig 8 shows a COMBINATION PLIERS and its application. A number of operations can be performed with these pliers.

Fig 8



The FLAT GRIP can be used to grip and hold parts and components and to twist wires.

Many combination pliers also have a PIPE GRIP which is used to grip and hold cylindrical objects.

They also have a pair of SIDE CUTTERS which are used to cut small diameter wires and cables.

A pair of JOINT CUTTERS are provided for shearing off steel wires.

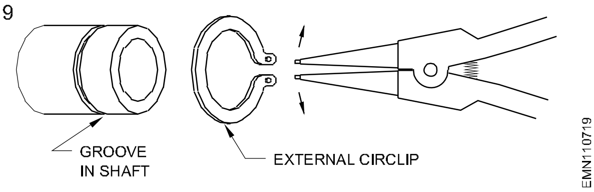
Combination pliers are available in the following overall lengths: 140, 160, 190, 210 and 250 mm.

Circlip pliers for external circlip

Fig 9 shows a CIRCLIP PLIER for EXTERNAL CIRCLIPS. The prongs of the jaws are inserted into the holes of the circlip. By applying pressure to the handles of the pliers, the jaws will expand the circlip which can then be removed or moved onto the workpiece.

These pliers are available with straight and curved jaws in the following dimensions.

Fig 9

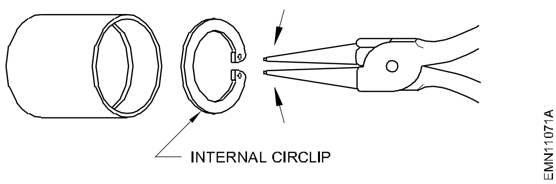


Size	Overall length	Used with circlips shaft diameter of
0	130 mm	3 - 10 mm
1	130 mm	8 - 25 mm
2	170 mm	19 - 60 mm
3	230 mm	40 - 100 mm
4	320 mm	85 - 165 mm

Circlip pliers for internal circlips

Fig 10 shows CIRCLIP PLIERS for INTERNAL CIRCLIPS. By applying pressure to the handles of the pliers, the jaws will compress the circlip which can then be removed from the workpiece.

Fig 10



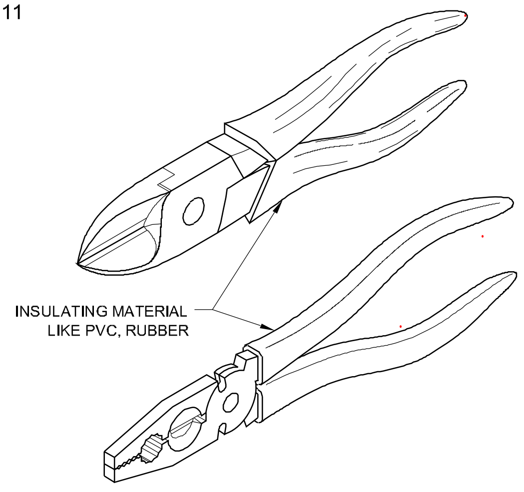
Size	Overall length	Used with circlips shaft diameter of
0	130 mm	3 - 10 mm
0	130 mm	3 - 10 mm
1	130 mm	8 - 25 mm
2	170 mm	19 - 60 mm
3	230 mm	40 - 100 mm
4	320 mm	85 - 165 mm

Pliers used by electrician

A number of pliers, especially diagonal cutting pliers, combination pliers, flat nose pliers, round nose pliers and long nose pliers, are frequently used by electricians.

As an additional safeguard against electric shock, these pliers are available with insulated handles made of high quality rubber or plastic as shown in Fig 11.

Fig 11

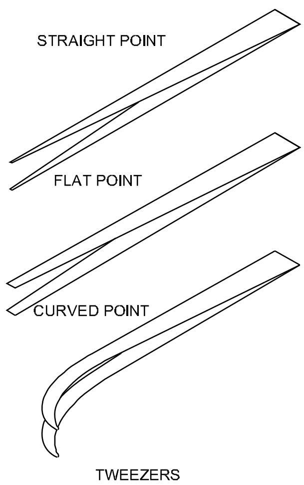


Before you work with electrical installations or electrical appliances, they have to be disconnected from the electrical supply. Working with live parts of an electrical installation or appliance can INJURE or KILL you, and it might seriously damage the installation and equipment.

Tweezers

Tweezers are used to hold light weight and very small components and very thin wires/strands. Tweezers are classified according to the shape of the tip and are specified by their length and shape. Fig 12 shows different types of tweezers.

Fig 12

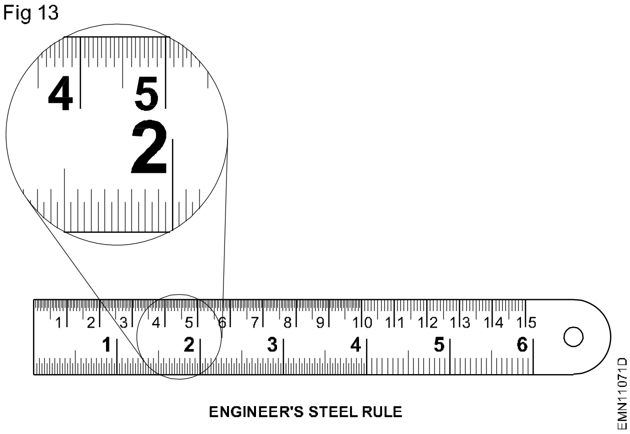


The thin structure of the tweezers permits easy access to places where fingers cannot reach. Tweezers are very useful during soldering of wires, components and placing of small screws in interior places.

Engineer's steel rule

An engineer's steel rule is the basic and most commonly used measuring tool for measuring and drawing the length of straight lines. A typical engineer's steel rule is shown in Fig 13.

Fig 13



Steel rules are made of spring steel or stainless steel. The edges are accurately ground to form a straight line.The surfaces of steel rules are satin-chrome finished to reduce glaring effect while reading, and also to prevent rusting.

Graduation on engineer's steel rule

The engineer's steel rules are generally graduated both in centimetres and inches as can be seen in Fig 13. In centimetre graduations, the smallest graduations are at intervals of 0.5 mm. In inch graduations the smallest graduation is of 1/16 of an inch. Thus the maximum reading accuracy of a steel rule is either 0.5 mm or 1/16 of an inch.

Standard sizes

Steel rules are available in different lengths. The common sizes are 150 mm/6inches, 300 mm/12 inches and 600 mm/24 inches.

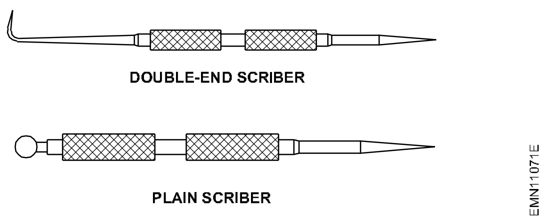
Scriber

A scriber is a pointed, sharp tool made of steel or carbon steel as shown in Fig 14. There are two types of scribers, namely,

– Plain scribers

– Double end scribers

Fig 14



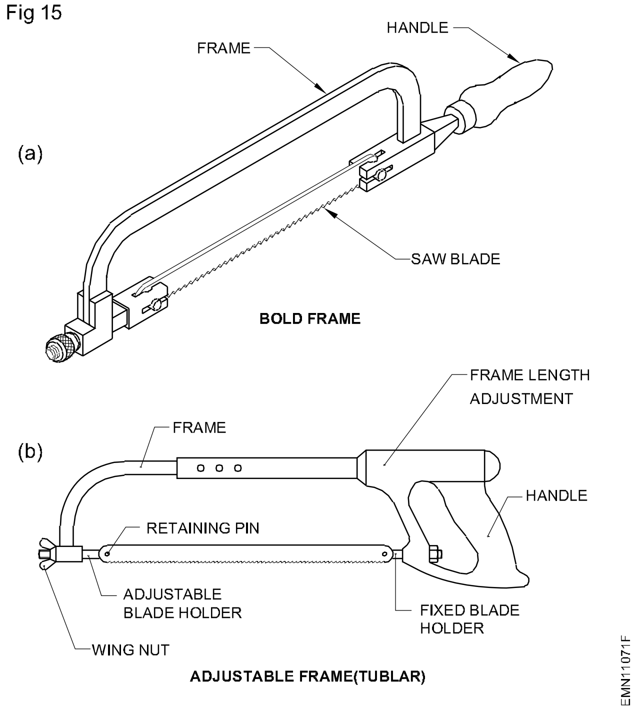
Uses of scribers

Scribers are used for scribing(marking) lines on surfaces prior to cutting. Scribers are generally used for marking on such surfaces on which pencil marking cannot be made or pencil marking is not clearly visible or pencil marking gets erased while handling or pencil marking is too thick. For example pencil marking is not suitable on Hylam or Bakelite sheets. Hence, line markings are done on these boards using scribers.

Hacksaw frame and blade

Fig 15 shows a typical hacksaw frame fitted with a blade. A hacksaw is used to cut metallic sheets or sections. It is also used to cut slots and contours.

Fig 15



Types of hacksaw frames

Bold frame: In this, the frame width is fixed and cannot be altered. Because of this only a particular standard length of hacksaw blade can be fitted with these frames.

Adjustable frame (Flat): In this, the frame is made of flat metal with provision for adjusting the width of the frame. Hence, different standard lengths of blades can be fitted with this frame.

Adjustable frame tubular type: In this, the frame is made of tubular metal with provision for adjusting the width of the frame. Hence, different standard lengths of blades can be fitted with this frame. This is the most commonly used type of hacksaw frame because this frame gives better grip and control while sawing.

Hacksaw blades

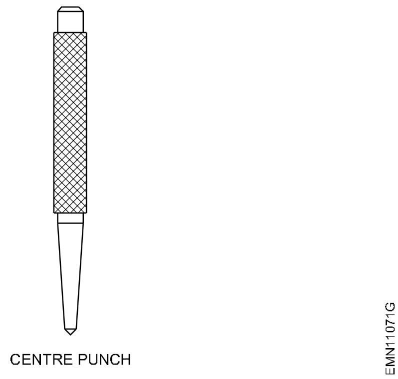
A hacksaw blade is a thin, narrow, steel band with teeth and two pin holes at the ends. These blades are made of either low alloy steel (la) or high speed steel (hs). Hacksaw blades are available in standard lengths of 250 mm and 300 mm.

Punch

A punch is a tool used to make punch marks or light depressions at locations to be drilled or to position dividers or for making permanent dimensional features. A typical punch is shown in Fig 16. Punches are made of hardened steel with a narrow tip on one side.

Centre punch: These punches have an angle of 90^0 at the punch point. The punch mark made by this angle will be wide but not very deep. These punch marks give a good seating for the drill bit at the start of drilling. If one tries to drill at a point without a punch mark, the drill bit will slip away from the point to be drilled and may drill a hole at unwanted points, making the job a waste.

Fig 16



Prick punch: The angle of the prick punch is 30^0 or 60^0. The 30^0 point prick punch is used for marking light punch marks needed to position dividers. The divider leg will get proper seating in this punch mark. The 60^0 punch is used for witness marks.

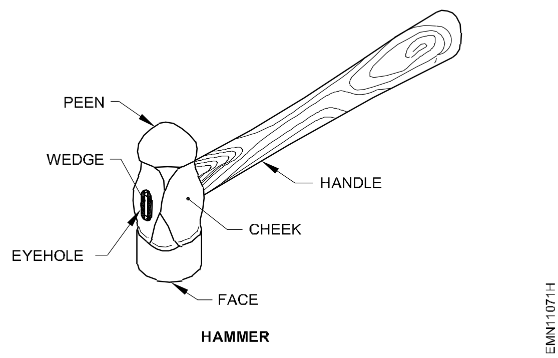
Hammer

An engineer's hammer is a hand tool used for striking purposes like punching, bending, straightening, chipping, forging, riveting etc.,

Parts of a hammer

Fig 17 shows a typical hammer with the parts labeled.

Fig 17



The head is made of drop-forged carbon steel. The handle is generally made of such materials which can absorb the shock while striking. Wood is most popularly used as the material for the handle.

Face: The face of the hammer is that which strikes the objects. Hence, this portion is hardened. Slight convexity is given to the face to avoid digging of the face edges.

Pein: The pein is the other end of the head. It is used for shaping and forming work like riveting and bending. The pein can be of different shapes like ball pein, cross pein and straight pein. The pein of a hammer is also hardened is the face.

Cheek: The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here. This portion of the hammer head will be soft.

Eyehole: The eyehole is meant for fixing the handle. It is shaped to fit the handle rigidly. Wedges are used to fix the handle in the eyehole.

Specification of engineers hammer

Engineer's hammers are specified by their weight and the shape of the pein. Their weight varies from 125 gms to several kilo grams.

Generally, the weight of an engineer's hammer, used for marking purposes is 250 gms.

Using hammers

Before using a hammer,

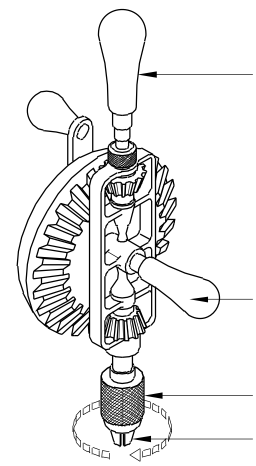
- select a hammer with the correct weight suitable for the job
- make sure the handle is properly fitted
- check the head and handle for any cracks
- ensure that the face of the hammer is free from oil or grease.

Drilling and drilling machines

Drilling is a process of making straight holes in materials. To drill holes, a machine tool known as drilling machine is used. Drilling machines are used with twist drill bits.

These drill bits rotate and penetrate into the material making holes. The drilling machines can be manually driven or electrically driven. A drilling machine can be portable/hand held or mounted on a stand. A typical manually driven, hand held drilling machine most commonly used in small electronics work is shown in Fig 18. Fig 19 illustrates a portable power drilling machine.

Fig 18

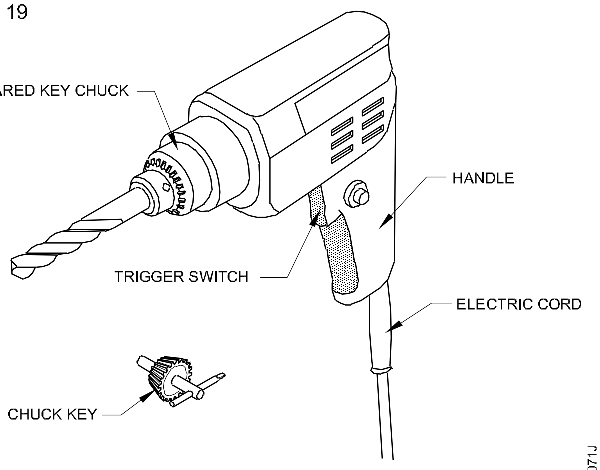


HAND DRILLING MACHINE

The hand drill is used for drilling holes up to 6.5 mm diameter.

Electric drilling machines are used where higher drilling speed and fairly constant speed is required. Holes can be drilled faster and with higher accuracy using electric drilling machines. Portable electric drilling machines are available in 6 mm and 12 mm capacity. These drilling machines generally operate on 230 V, 50 Hz AC mains supply.

Fig 19



ELECTRIC DRILLING MACHINE

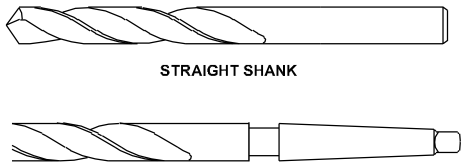
Twist drill/drill bit

Twist drills are used in drilling processes to form round holes in solid materials. When a drill is rotated and the rotating drill is pressed against the material, the drill penetrates and cuts away the material. The rate at which the drill is pressed through the material is called the 'feed'.

Parts of a drill

Shank: Shank is that portion of the drill by which it is held and driven by the drilling machine. Many different types of shanks are available, but two of the most common types of shanks are shown in Fig 20.

Fig 20



Taper shank drills: These are available in sizes from 12 mm to 52 mm in diameter. The shank has a self-holding taper which fits into a sleever or the taper bore of the drilling machine.

Straight shank drills: These types of drills are more commonly used than taper shank drills. The shank has the same diameter as the body of the drill. These drills are available in sizes from 0.35 mm to 16 mm in diameter.

Body: The body extends from the shank to the cutting end(point). Generally, the body shape of most drills is the same, but some special shapes may be necessary for special tasks. It has two helical grooves called flutes which run along its sides. The flutes help:

- to form the cutting edges
- to curl the chips and allow them to come out
- to allow the coolant to flow to the cutting edge.

Drill point: The conical shape of the cutting edge is ground to suit the material to be cut. This is the sharpened end of the drill and has a number of different parts.

Speeds of drills

The outer corner of a drill bit is the most hard-worked part of the cutting lip. For example, in one revolution the outer corner cuts through twice as much metal as the mid-point of the cutting lip.

The cutting speed for a particular material is expressed in feet per minute or in metres per minute.

The recommended speed for a drill is the ideal cutting speed for the outer corners of its lips. Select the revolutions per minute of the drilling machine that will give this cutting speed at the circumference of the drill.

General Rules

If do not have tables of speeds and feeds to guide remember these general rules.

- The smaller the drill, the higher the r.p.m.
- The softer the metal, the greater the feed.
- The harder the metal, the smaller the feed.
- The harder the metal, the lower the r.p.m.
- Soluble oil is a suitable cutting fluid for cooling the drill while drilling for most common metals-other than cast iron, which is best drilled dry.

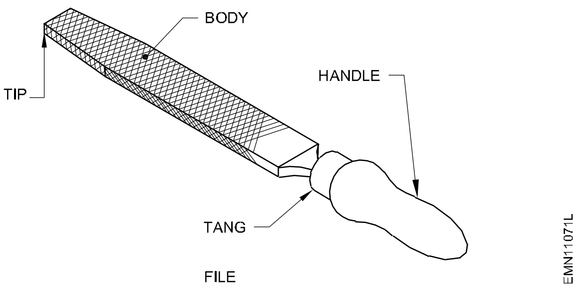
Files

A file is a cutting tool with multiple cutting edges used for filing different materials. Filing in one of the processes used to cut/remove small quantities of materials.

Parts of a file

Fig 21 illustrates the main parts of a typical file.

Fig 21



FILE

File specification

Files are specified according to their:

- length
- grade
- cut
- shape.

Length is the distance from the tip to the heel. It varies form 100mm to 300mm.

Grade: Different grades of files are Rough, bastard, second cut, smooth and dead smooth.

Rough file is used for removing more quantity of metal quickly.

Bastard file is used for ordinary filing purposes.

Second cut file is used for good finishing purposes.

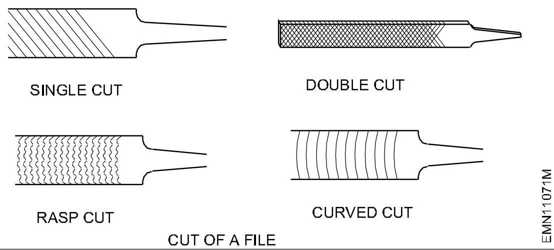
Smooth file is used for removing less metal and for giving good surface finish.

Dead smooth file is used for high degree finishing.

Cut of file

The rows of teeth on the file surface indicate the cut of a file. For example, if there is single row of teeth on the file surface as shown in Fig 22, it is called 'single cut file.'

Fig 22



CUT OF A FILE

Types of cut

The different types of cut of files are:-

- Single cut,
- Double cut,
- Rasp cut, and
- Curved cut.

Single cut: A single cut file has a single row of teeth in one direction on the face of the file at an angle of 60°. These files are used for filing soft materials such as lead, tin, aluminum etc.

Double cut: A double cut file has rows of teeth in two directions across each other at an angle of 50° to 60°, another row at 75°. These files are used to file hard materials such as steel, brass, bronze, etc.

Fitting and sheet metal work

Objectives : At the end of this lesson you shall be able to
- **state the types of sheets**
- **state the names of cutting tools**
- **define riveting and name the types of rivets.**

Cutting And bending of sheet metal

Almost all sheet metal industries use large quantities of steel rolled into sheets of various thicknesses. These sheets are sometimes coated with zinc, tin or other metals for various applications. Other than steel sheets, industries also use sheets made out of zinc, copper, aluminum, stainless steel etc.

The term **sheet metal** generally applies to metals and alloys rolled into sheets of various thicknesses of less than 5 mm. Sheets of thickness over 5 mm are called plates.

Earlier, sheets were specified by standard wire gauge(SWG) numbers. Each gauge is designated with a definite thickness.The larger the gauge number, the lesser is the thickness of the sheet. Nowadays, the sheet thickness is directly specified in millimetres(mm), such as 0.40 mm, 0.50 mm, 0.63 mm, 0.80 mm, 0.90 mm, 1.00 mm, 1.12 mm, 1.25 mm etc.

Types of sheets

Steel sheet: This is an uncoated sheet of mild steel having bluish-black appearance. The use of this metal is limited to articles that are to be painted or enameled.

Galvanized iron sheet: The zinc-coated iron sheets are known as galvanized iron sheets, popularly known as GI sheets. The zinc coating resists rust. These are most commonly used in making water pipes. Articles like pans, buckets, furnaces, cabinets are also made using GI sheet.

Copper sheets: Copper sheets are available either as cold-rolled or hot-rolled sheets. Cold-rolled sheets are worked easily and are used in sheet metal shops. Gutters, roof flashing and hoods are common examples where copper sheet is used.

Aluminium sheets: Aluminium sheets are highly resistive to corrosion, whitish in colour and light in weight. Since aluminium is a ductile material, it can be bent to any shape easily. Aluminium sheets are widely used in manufacturing of a number of articles such as household utensils, light fixtures, windows etc.

Tin sheets: Tin sheet is a sheet of iron coated with tin to protect the iron sheet against rust. The size and thickness of the tin sheets are denoted by special marks, not by gauge numbers.

Tinned sheets are used for food containers, dairy equipment, furnace fitting etc.

Brass sheet: Brass is an alloy of copper and zinc in various proportions. It will not corrode and is extensively used in craft.

Snips - Sheet metal cutting tools

A snip is a cutting tool used for cutting thin sheets of metal. A typical snip looks as shown in Fig 1 and 3.

There are three types of snips.

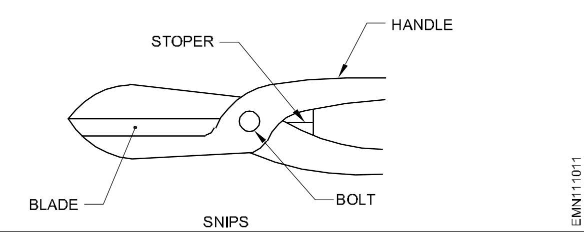
1 Straight snips

2 Bent snips/curved snips

3 Universal snips

Straight snip

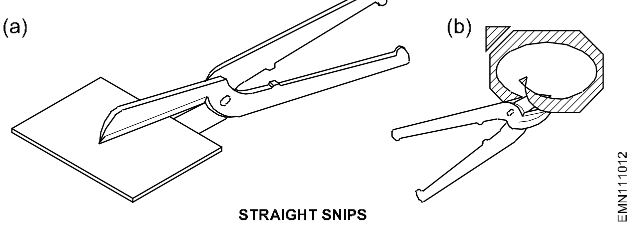
Fig 1



A typical straight snip and its parts are shown in Fig 1.

1 Handle 2 Blade 3 Stopper

Fig 2



Straight snips have straight blades for cutting thin sheets along a straight line as shown in Fig 2a. It can also be used for external curved cuts as shown in Fig 2b.

Bent snips/curved snips

Bent snips have curved blades as shown in Fig 3a. These snips are used for cutting internal curves and for trimming a cylinder on the outside of the cut as shown in Fig 3b.

Fig 4 shows a universal snips. Universal snips are used for most general purpose works. The best size of snip for general use is a pair of 300 mm long.

FOLDING TOOLS

Tools commonly used in the folding of sheet metal are:

– angle steel

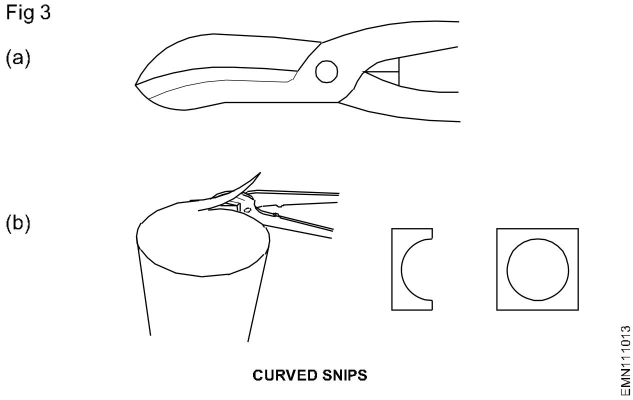
– folding bar

– C clamp

– stakes

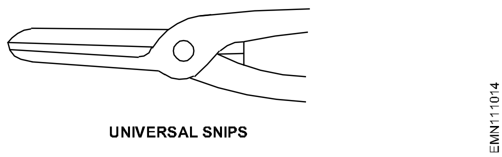
– mallet.

Fig 3



CURVED SNIPS

Fig 4



UNIVERSAL SNIPS

Angle steel: Two pieces of angles are used for folding sheet metal to an angle of 90°. These angles are fitted on a vice with the sheet metal to be bent sandwiched between the angles. For longer sheets, lengthy angles will be used along with a clamp or hand vice.

Folding bars: The sheet metal to be bent is clamped in the folding bars. The sheet metal is bent to the required shape using a mallet (wooden hammer).

C-clamp: A typical C-clamp is used as a holding device. This clamp is used when two pieces has to be securely held or fixed to one another. It is available in different sizes according to the opening width of the jaws.

Stakes: Stakes are tools used for bending, seaming and forming of sheet metal that cannot be done on any regular machine. For the above purposes, different shapes of stakes as listed below. Stakes are made of soft or cast steel.

– Hatchet stake

– Square stake

– Blow-horn square stake

– Bevel-edge square stake

Hatchet stake: It is used for making sharp bends, for bending edges and for folding sheet metal.

Square stake: It is used for general purpose bending works.

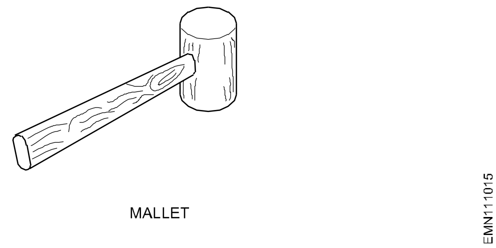
Blow-horn stake: It is used in forming, riveting or seaming tapered, cone-shaped articles, such as funnels etc.

Bevel-edged square stake: It is used to form corners and edges.

Mallet

Fig 5 shows a mallet. A mallet is used for striking while bending sheet metals. Mallets are made of wood, rubber, copper etc. Since these are soft materials, they will not damage the sheet surface while working.

Fig 5



MALLET

NOTCHES

Notches are angular spaces in which the sheet metal is removed. The purpose of making notches is to allow the work to be formed to the required size and shape. Notches prevent excess material from overlapping and causing a bulge at the seam and edges.

Riveting: Riveting is one of the satisfactory methods of making permanent joints of two pieces - metal snips.

It is customary to use rivets of the same metal as that of the parts that are being joined.

Uses: Rivets are used for joining metal sheets and plates in fabrication work, such as bridges, ships, cranes, structural steel work, boilers, aircraft and in various other works.

Material: In riveting, the rivets are secured by deforming the shank to form the head. These are made of ductile materials like low carbon steel, brass, copper and aluminium.

Types of rivets

The four most common types of rivets are:

- tinmen's rivet
- flat head rivet
- round head rivet
- countersunk head rivet.

Method of riveting: Riveting may be done by hand or by machine.

While riveting by hand, it can be done with a hammer and a rivet set.

Rivet set: The shallow, cup-shaped hole is used to draw the sheet and the rivet together. The outlet on the side allows the slug to drop out.

Electrical terms

Objectives: At the end of this lesson you shall be able to
- **describe electrical charge, potential difference, voltage, current, resistance**
- **explain DC and AC circuit**
- **explain single phase and 3 phase A.C. system.**

Electric charge

Charge is the basic property of elementary particles of matter. Charge is taken as the basic electrical quantity to define other electrical quantities such as voltage, current etc.

According to modern atomic theory, the nucleus of an atom has positive charge because of protons. Generally, when the word charge is used in electricity, it means excess or deficiency of electrons.

Charges may be stationary or in motion. Stationary charges are called static charge. The analysis of static charges and their forces is called electrostatics.

Example: If a hard rubber pen or a comb is rubbed on a sheet of paper, the rubber will attract paper pieces. The work of rubbing, resulted in separating electrons and protons to produce a charge of excess electrons on the surface of the rubber and a charge of excess protons on the paper. The paper and rubber give evidence of a static electric charge having electrons or protons in a static state i.e. not in motion or stationary charges.

The motion of charged particles in any medium is called current. The net transfer of charge per unit time is called current measured in ampere.

Charge of billions of electrons or protons is necessary for common applications of electricity. Therefore, it is convenient to define a practical unit called the coulomb (C) as equal to the charge of 6.25×10^{18} electrons or protons stored in a dielectric.

The symbol for electric charge is Q or q. A charge of 6.25×10^{18} electrons is stated as Q = 1 Coulomb = 1C. This unit is named after Charles A. Coulomb (1736-1806), a French physicist, who measured the force between charges.

Negative and positive polarities

Negative polarity has been assigned to the static charge produced on rubber, amber, and resinous materials in general. Positive polarity refers to the static charge produced on glass and other vitreous materials. On this basis, the electrons in all atoms are the basic particles of negative charge because their polarity is the same as the charge on rubber. Protons have positive charge because the polarity is the same as the charge on glass.

Positive charge is denoted by +Q (deficiency of electrons) and Negative charge is denoted by -Q (excess of electrons). A neutral condition is considered zero charge.

Opposite polarity/charges attract each other

If two small charged bodies of light weight are mounted so that they are free to move easily and are placed close to each other, they get attracted to each other when the two charges have opposite polarity. In terms of electrons and protons, they tend to be attracted to each other by the force of attraction between opposite charges. Furthermore, the weight of an electron is only about 1/1840 of the weight of a proton. As a result, the force of attraction tends to make electrons move towards protons.

Same polarity/charges repel each other

When the two bodies have an equal amount of charge with the same polarity, they repel each other. The two negative charges repel, while two positive charges of the same value also repel each other.

Neutralising a charge

After glass and silk are rubbed together, they become charged with electricity. But, if the glass rod and silk are brought together again, the attraction of the positive charges in the rod pulls the electrons back out of the silk until both materials become electrically neutral.

A wire can also be connected between the charged bodies for discharging. If the charges on both materials are strong enough, they could discharge through an arc, like the lightning.

Electrostatic fields

The attracting and repelling forces on charged materials occur because of the electrostatic lines of force that exist around the charged materials.

In a negatively charged object, the lines of force of the excess electrons add to produce an electrostatic field that has lines of force coming into the object from all directions.

In a positively charged object, the lack of electrons causes the lines of force on the excess protons to add to produce an electrostatic field that has lines of force going out of the object in all directions.

These electrostatic fields either aid or oppose each other.

The strength of attraction or repulsion force depends on two factors,

1) the amount of charge on each object, and
2) the distance between the objects.

The greater the amount electric charges on the objects, the greater will be the electrostatic force. The closer the charged objects are to each other, the greater the electrostatic force.

Static electric charge cannot usually perform any useful function. In order to use electrical charges to do some kind of work, say, to light up an electric bulb, the charges must be set in motion. Thus electric current is said to flow when negative charges/free electrons are moved in the same direction in a medium, for example a copper wire.

Electron movement

In order to produce an electric current, the free electrons in a copper wire must be made to move in the same direction. This can be done by putting electrical charges at the ends of the copper wire more precisely, a negative charge at one end and a positive charge at the other end of a copper wire.

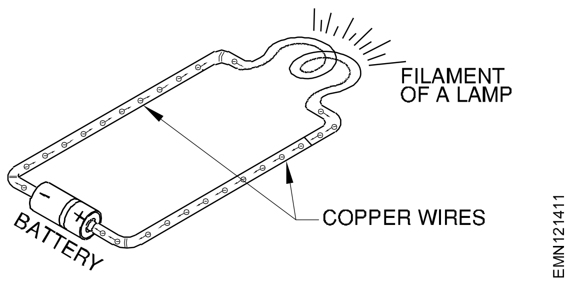
Since the free electrons in copper are negatively charged, they are repelled by the negative charge put at one end of the wire. At the same time these free electrons are attracted by the positive charge, put at the other end of the wire. Hence the free electrons in copper drift towards the positive charge, causing a flow of electric current.

A complete or closed circuit

In order to have continuous electric current, the free electrons must continue to flow. For this to happen, an electrical energy source must be used, to keep applying opposite charges at the ends of the wire. Then, the negative charge would repel the electrons through the wire. At the positive side, electrons would be attracted into the source; but for each electron attracted into the source, an electron would be supplied by the negative side into the wire. Current would, therefore, continue to flow through the wire as long as the energy source continues to apply its electrical charges. This is called a **closed circuit**. Battery is a typical source of electrical charges.

A complete or closed circuit as shown in Fig 1 is needed for current to flow.

Fig 1



Electrical Units of Measurements

Electromotive force (voltage)

The electromotive force (EMF) is a measure of the strength of a source of electrical energy. EMF is not a force in the usual mechanical sense, but it is a convenient term used for the energy which drives current through an electrical circuit.

When two charges have a difference in potential, the electric force that exists between them can be called the electromotive force (EMF). The unit of measure used to indicate the strength of emf is **volt (V)**.

Definition of Volt

When a difference of potential causes 1 coulomb of charge to do 1 joule of work, the emf is 1 volt.

Some typical voltage sources and voltage levels that we come across in day to day life are:

- 1.5 volts from dry cells for pocket torch, digital clocks etc.,
- 9/12/24 volts from batteries for portable radios, emergency lamps motor cycles, automobiles etc.
- 220/240 volts from hydro/hydel or thermal generating stations for lighting and heating of homes
- 440 volts for industrial applications to run motors etc.,

The terms **potential, electromotive force (emf)**, and **voltage** are often interchangeably used.

Quantity of current

The quantity of current flowing through a wire or a circuit is determined by the number of electrons that pass a given point in one second. The unit of measure for the amount of current flowing through a wire or a circuit is **ampere** (A).

Definition of ampere

If 1 coulomb of charge passes a point in 1 second, then a current of 1 ampere is said to be flowing.

NOTE: One coulomb is 6.28×10^{18} electrons.

The term ampere came from the name of a scientist A. M. Ampere(18th century). A quantity of current smaller than one ampere is measured in milliampere and micro-ampere.

1 Milliampere = $\frac{1}{1000}$ of an ampere.

1 Microampere = $\frac{1}{1000000}$ of an ampere.

Types of electricity

Irrespective of how the electricity is generated or produced, electricity can be classified into two types,

1 Alternating current supply, generally known as **AC supply**

2 Direct current supply, generally known as **DC supply**.

AC supply

The term alternating current supply is given to a supply source that makes current to flow through a circuit which reverses or alternates its direction periodically. The number of times that the current alternates in a period of one second is called the **frequency** of alternation. The unit of frequency is **Hertz** denoted as Hz. In India and Europe the frequency is standardised as 50 Hz. In United States and the rest of North America the frequency is standardised to 60 Hz.

In India the electricity generated in hydro/thermal/nuclear power stations is AC.

AC supply has the following advantages over dc supply

1 Reduced transmission loss over very long distances.

2 Voltage levels can be changed using simple devices called transformers.

3 Reduced severity of electrical shock.

4 Generating equipments are simple and cheaper.

5 Can be easily converted to dc supply.

Alternating current is dealt in detail in further lessons.

DC supply

The term direct current supply is given to a supply source that makes current to flow through a circuit in one direction only. This is in contrast to the alternating current supply.

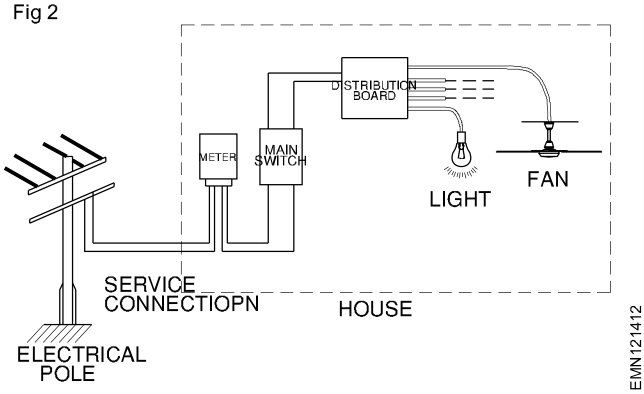
Batteries and some types of generators give DC supply of constant voltage.

DC supply is not distributed by electric supply agencies in India.

Generating stations generate/produce electricity of the order of several hundreds to thousands of mega volts(1 mega = 10^6 volts). This large voltage level is reduced in stages by devices called transformers, and is finally available for the domestic user as a single phase 230 volts, 50Hz, AC. For industrial user three-phase, 440 volts, 50Hz, AC supply is made available.

The domestic voltage of **230 volts AC** is called the **Low tension (LT) voltage**. LT lines enters residential buildings from electricity poles called as service connection as shown in Fig 2.

Fig 2



Electric potential difference

The electrical potential difference is defined as the amount of work done to carrying a unit charge from one point to another in an electric field of the two charged bodies. In otherwords, the potential difference is defined as the difference in the electrica potential.

When a body is charged to a different electric potential as compared to the other charged body, the two bodies are said to be potential difference. Both the bodies are under stress and strain and try to attain minimum potential.

Unit : The unit of potential difference is **volt.**

Resistance

Resistance is the measure of opposition to electric current. A short circuit is an electric circuit offering little or no resistance to the flow of electrons. Short circuits are dangerous with high voltage power sources because the high currents encountered can cause large amounts of heat energy to be released.

A.C. Circuits

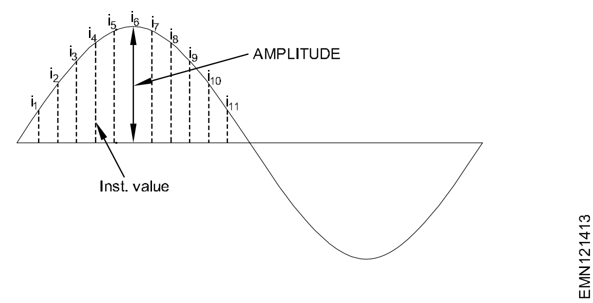
Cycle: A complete change in value and direction of alternating quantity is called cycle.

Period: Time taken to complete one cycle is called period.

Amplitude: It is the highest value attained by the current of voltage in a half cycle.

Instantaneous value: Value at any instant is called instantaneous value. Fig.3 shows this value by i_1, i_2....

Fig 3



Frequency: It is defined as the number of cycles per second. In India 50 c/s frequency is common.

Frequency $= \frac{NF}{120}$ where N is the speed in r.p.m and P is no.of poles of a machine.

R.M.S. Value: Root mean square value of an alternating current is given by that steady d.c. current which produces the same heat as that produced by the alternating current in a given time and given resistance. It is also called the virtual or effective value of A.C.

$$I_{r.m.s.} = 0.707\ I_{max}$$

$$V_{r.m.s} = 0.707\ V_{max}$$

All A.C. voltmeters and ampere meters read r.m.s. value of voltage and current.

Symmetrical Alternating Quantity: The ratio of the value to the mean period

Instantaneous value: The value of a variable quantity at a given instant.

Peak value: The maximum of the values of quantity during a given interval.

Basic of DC circuit

This flow of electrical charge is referred to as electric current. There are two types of current, direct current (DC) and alternating current (AC). DC is current that flows in one direction with a constant voltage polarity (fig.4) while AC is current that changes direction periodically along with its voltage polarity (fig 5). But as societies grew the use of DC over long transmission distances became too inefficient. With AC it is possible to produce the high voltages needed for long transmissions.Therefore today, most portable devices use DC power while power plants produce AC.

Fig 4

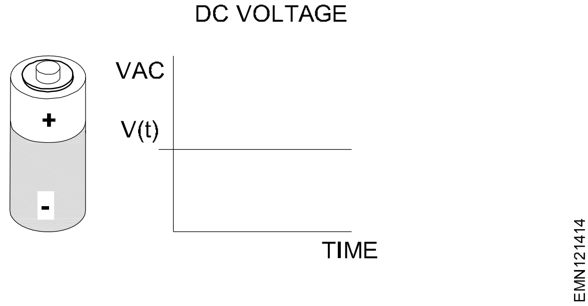
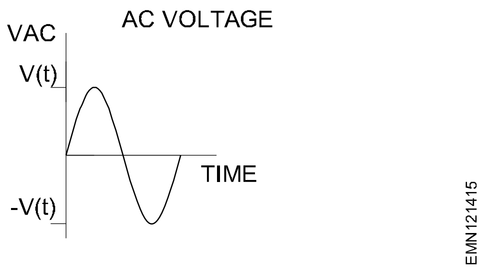


Fig 5



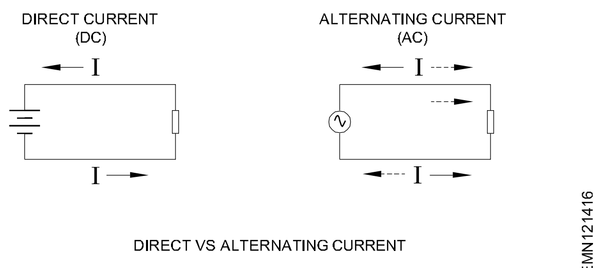
Voltage

We define voltage as the amount of potential energy between two point on a circuit. One point has more charge than another. This difference in charge between the two points is called voltage. It is measured in volts. Techinally, it is the potential energy difference between two points that will impart one joule of energy per coulomb of charge that passes through it. The unit "volt" is named after the Italian physicist Alessandro Volta who invented what is considered the first chemical battery. Voltage is represented in equations and schematics by the letter "V".

Basics of AC circuit

As useful and as easy to understand as DC is, it is not the only "kind" of electricity in use. Certain sources of electricity (most notably, rotary electro-mechanical generators) naturally produce voltages alternating in polarity reversing positive and negative over time. Either as a voltage switching polarity or as a current switching direction back and forth, this "kind" of electricity is known as Alternating Current (AC).

Fig 6



DIRECT VS ALTERNATING CURRENT

Whereas the familiar battery symbol is used as a generic symbol for any DC voltage source, the circle with the wavy line inside is the generic symbol for any AC voltage source.

One might wonder why anyone would bother with such a thing as AC. It is true that in some cases AC holds no practical advantage over DC. In applications where electricity is used to dissipate energy in the form of heat, the polarity or direction of current is irrelevant,so long as there is enough voltage and current to the load to produce the desired heat (power dissipation). However, with AC it is possible to build electric generators, motors, and power distribution systems that are far more efficient than DC, and so we find AC used predominately across the world in high power applications.

General overview of single phase and three phase AC system

Both single phase and three phase systems refer to units using alternating current (AC) electric power. With AC power, the flow of current is constantly in alternating directions. The primary difference between single phase and three phase AC power is the constancy of delivery.

In a single phase AC power system the voltage peaks at 90° and 270°, with a complete cycle at 360°. With these peaks and dips in voltage, power is not delivered at a constant rate. In a single phase system, there is one neutral wire and one power wire with current flowing between them. The cyclical changes in magnitude and direction usually change flow in current and voltage about 60 times per second, depending on the particular needs of a system.

Benefits and uses of a single phase AC power supply

Single phase power supply units have a broad array of applications. Units that have a limited power need up to 1000 watts typically make the most efficient use of a single phase AC power supply. Generally, benefits of selecting a single phase system include:

- Broad array of application uses
- Most efficient AC power supply for up to 1000 watts
- Fewer design costs
- Less complex design

In a 3 phase system there are three power wires, each 120° out of phase with each other. Delta and wye are the two types of circuits use to maintain equal load across a three phase system, each resulting in different wire configurations. In the delta configuration, no neutral wire is used. The wye configuration uses both a neutral and a ground wire. (Note: In high voltage system, the neutral wire is not usually present for a three phase system.) All three phases of power have entered the cycle by 120°. By the time a complete cycle of 360° has completed, three phases of power each peaked in voltage twice as shown in Fig 6. With a three phase power supply, a steady stream of power is delivered at a constant rate, making it possible to carry more load.

Fig 7

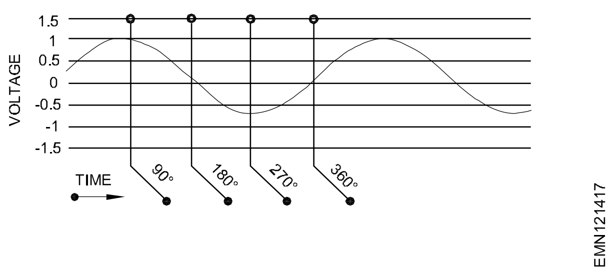
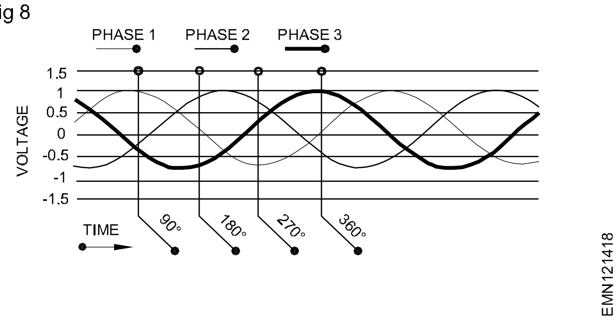


Fig 8



Benefits and uses of a three phase AC power supply

Typical applications for 3 phase systems include data centers, mobile towers, power grids, shipboard and aircraft, unmanned systems, and any other electronic with a load greater than 1000 watts. Three phase power supplies offer a superior carrying capacity for higher load systems. Some of the benefits include:

Reduction of copper consumption

Fewer safety risks for workers

Lower labor handling costs

Greater conductor efficiency

Ability to run higher power loads

Additionally, three phase systems in delta configuration with a 208 volt load requires less circuit breaker pole positions than that of a wye configuration. In these cases, a three phases system yields further savings in installation, maintenance, and cost of production materials due to the reduction of required wires. However, in most cases, the wye configuration is preferable. When is more flexible so that it can power devices that require 3 phase, 2 phase, or 1 phase power. For example, a data center's warehouse of servers may only require three phase power, however the technician monitory the series will likely need single phase power to operate his/her computer, tools and lights.

Line voltage and phase voltage

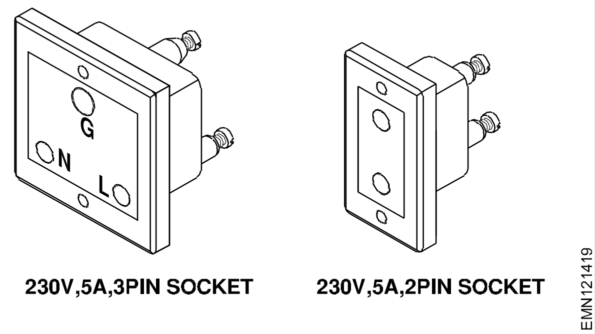
Line voltage is the voltage measured between any two lines in a three-phase circuit. Phase voltage is the voltage measured across a single component in a three-phase source or load.

Line current and Phase current

Line current is the current through any one line between a three- phase source and load. Phase current is the current through any one component comprising a three phase source or load. In balanced "Y" circuits, line voltage is equal to phase voltage times the square root of 3, while line current is equal to phase current.

This 230 volts is used to light up the lamps, fans etc., in homes. To connect electrical appliances at home, 230 V AC is available in either two-pin or three-pin sockets as shown in Fig 9.

Fig 9

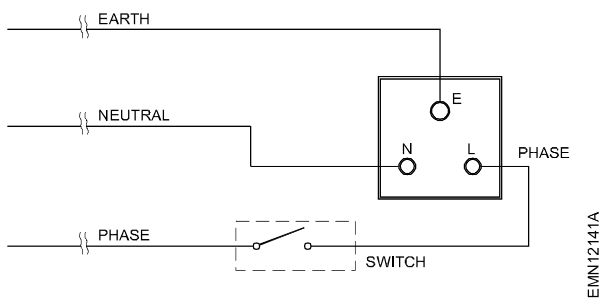


All the 3 pin outlets are generally connected through a single pole ON/OFF switch-as shown in Fig 10. While wiring a 3 pin socket, the following two important points are to be noted,

1 Phase should always be to the RIGHT side of the socket

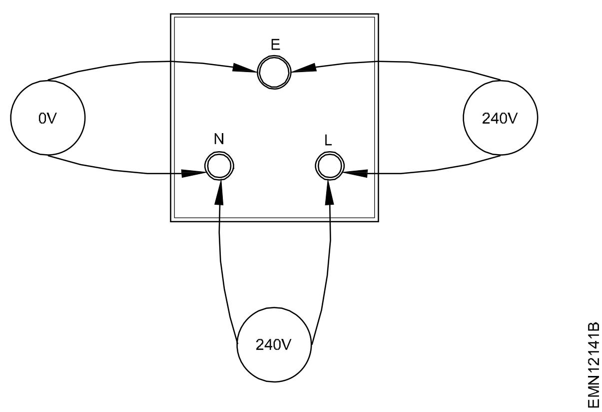
2 Phase should always be wired through the ON/OFF switch as shown in Fig 10. This is as per I.S & I.E rules.

Fig 10



Referring to the Fig 10, when the switch is put ON, the voltages across the three points in a 3 pin socket should be as shown in Fig 11.

Fig 11



Any defect either in mains supply or in the wiring of the socket or in the equipment connected to any other 3 pin sockets in the same building may result in voltages other than that shown in Fig 15.

TESTING A 3 PIN SOCKET OUTLET

On wiring of a new 15 pin socket or if the equipment connected to an existing 3 pin socket is not working or giving a shock, it is necessary to test the socket for voltage across the phase, neutral and ground.

Testing a mains outlet can be done using any one or more of the following test instruments;

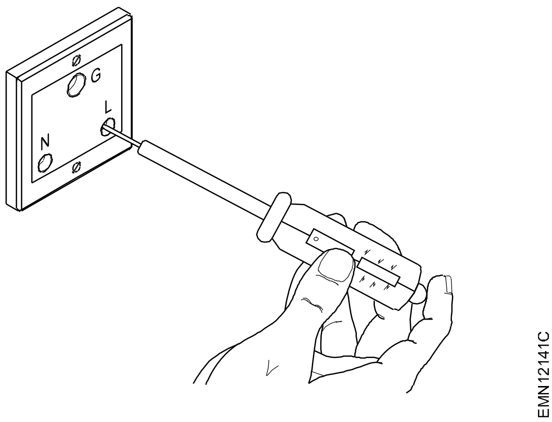
1 Neon tester

A neon tester or neon test lamp is an inexpensive device usually in the form of insulated shank screw driver used to indicate presence of voltage.

When a neon tester is placed at the phase point of a 3 pin socket and the other end of the tester is touched by the finger as shown in Fig 12, if voltage exists at the phase point of the socket, the neon lamp inside the tester glows indicating presence of voltage.

In a correct outlet the lamp should not glow when the neutral and ground points are tested.

Fig 12



2 Test lamp

It is an inexpensive test circuit consisting of an incandescent lamp with two lengthy wires connected across the terminals of the lamp. When the two free ends of the lamp are connected across phase-neutral points of a socket, if voltage exists across the points the lamp glows indicating presence of voltage. The test lamp can be connected across the three outlets of the socket as shown in Fig 11 to confirm condition of the outlet.

3 AC voltmeter/multimeter

Using a voltmeter or a multimeter put to AC 300V range, the voltage across all the 3 terminals of the socket as in Fig 11 is measured to confirm existence of voltage and their correct levels across the outlet points.

Conditions for certifying a 3 pin socket as GOOD or SAFE

1 Voltage across phase-neutral should be equal to mains supply of 230/240 volts. Due to voltage fluctuations, pohase-neutral voltage can sometimes be as low as 210 and as high as 250 V these voltage levels can also be accepted as "tolerable".

2 Voltage across phase - ground should be equal to mains supply of 230/240 V. This indicates that the ground wire to the socket and the local grounding is proper.

3 Voltage across NEUTRAL-GROUND should be zero volts or in the worst case less than 10V. This indicates that the neutral line is safe and there is no excessive leakage in the equipment(s) connected to other 3 pin sockets in the same building.

If the voltage across neutral-ground is higher than 10 volts or very high (of the order of hundreds of volts) the socket is not safe for use, especially when you want to power ON sensitive and delicate equipments/instruments like computers, CRO etc.

Conductor and Insulator

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

- **define conductor and insulator**
- **explain electrical cables**
- **explain the properties of insulating materials.**

Conductors: Materials that contain many free electrons and are capable of carrying an electric current are known as conductors.

Some materials are better conductors of electricity than others. The more free electrons in a material has the better it will conduct. Silver, copper, aluminium and most other metals are good conductors.

Insulators: Materials that have only a few free electrons (if any), and are capable of not allowing the current to pass through them are known as insulators.

Wood, rubber, PVC, porcelain, mica, dry paper, fibre glass are some examples of insulating materials.

Non-conducting materials (insulators) are also called DIELECTRIC.

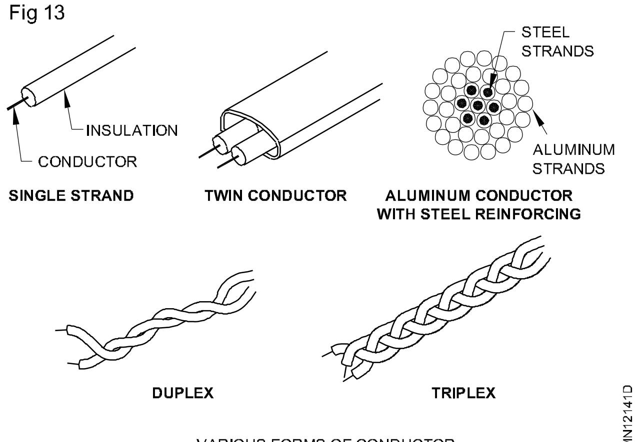
Conductors make up the main conducting path of electric current, and insulating materials prevent current flow through unwanted paths and minimises electrical hazards.

Conductors: The use of conductors and their insulation is regulated by I.E. regulations and I.S.Code of practice.

Regulations and I.S. code cover electrical conductors listing the minimum safety precautions needed to safeguard people, buildings and materials from the hazards of using electricity.

Wires and cables are the most common forms of conductors. They carry electric current through all kinds of circuits and systems. Wires and cables are made in a wide variety of forms suited to many different applications. (Fig.13).

Fig 13



VARIOUS FORMS OF CONDUCTOR

Conductors form an unbroken line carrying electricity from the generating plant to the point where it is used. Conductors are usually made of copper and aluminium.

A conductor is a wire or cable or other form of metal, suitable for carrying current.

All wires are conductors, but all conductors are not wires. For example copper bus bar are conductors but not wires. They are rigid rectangular bars.

Current passing through a conductor generates heat. The amount of heat depends on the value of current and the potential difference between its ends.

The rate of heat production in the conductor equals the amount of power lost by the electricity in passing through the conductor.

The cross-sectional area of the conductor must have a large enough area to give it a low resistance. But the cross-sectional area must also be small enough to keep the cost and weight as low as possible.

The best cross-sectional area depends on how much current the conductor must carry.

The rate of heat production in a conductor increases with the square of the current. As heat is produced the conductor gets hotter and the temperature rises until the rate at which the conductor releases heat to the surroundings equals the rate at which the heat is produced. The temperature of the conductor then remains steady. This steady temperature is called equilibrium temperature.

There is a limit to the temperature each kind of insulation can safely withstand. There is also a limit to the temperature the surroundings can withstand.

I.E. regulations specify the maximum current considered safe for conductors of different sizes, having different insulation and installed in different surroundings.

Size of conductors: The size is specified by the diameter or the cross-sectional area. Typical sizes are 1.5 sq mm, 2.5 sq mm, 6 sq mm etc.

A common measure of wire diameter is the standard wire gauge (SWG), commonly used in our country. The resistance of a material increases as the length of the conductor increases, and the resistance decreases as the cross-sectional area of the conductor increases. We can compare one material with another by measuring the resistance of samples.

Classification of Conductors

Wires and cables can be classified by the type of covering they have.

Bare conductors: They have no covering. The most common use of bare conductor is in overhead electrical transmission and distribution lines.

Insulated conductors: They have a coating of insulation over the metals. The insulation separates the conductor electrically from other conductors and from the surroundings. It allows conductors to be grouped without danger. Additional covering over the insulation adds mechanical strength and protection against weather, moisture and abrasion.

Stranded conductors: They consist of many strands of fine wires. The wires in stranded conductors are usually twisted together. Stranded conductors are more flexible and have better mechanical strength.

Cable: A length of insulated conductor. It may also be of two or more conductors inside a single covering. The conductors in a cable may either be insulated or bare. Cables are available in different types. There are single core, twin core, three core, four core and multi-core cables.

Properties of insulation materials

Two fundamental properties of insulation materials are insulation resistance and dielectric strength. They are entirely different from each other and measured in different ways.

Insulation resistance: It is the electrical resistance of the insulation against the flow of current. Mega-ohmmeter(Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megaohms without causing damage to the insulation. The measurement serves as a guide to evaluate the condition of the insulation.

Dielectric strength: It is the measure of how much potential difference the insulation layer can withstand without breaking down. The potential difference that causes breakdown is called the breakdown voltage of the insulation.

Every electrical device is protected by some kind of insulation. The desirable characteristics of insulation are:

– high dielectric strength

– resistance to temperature

– flexibility

– mechanical strength

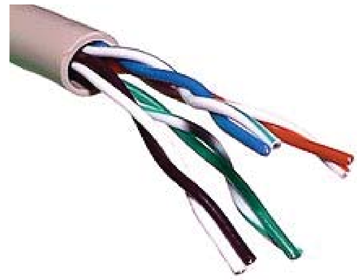
– Non hydroscopic.

No single material has all the characteristics required for every application. Therefore, many kinds of insulating materials have been developed.

Semiconductors: A semiconductor is a material that has some of the characteristics of both the conductor and an insulator. Semiconductors have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

Fig 14



Twisted pair cable

A comparison of the most commonly used metals as conductors in wires is given below:

PROPERTIES	TYPES OF METALS USED AS CONDUCTORS			
	Silver	**Copper**	**Gold**	**Aluminium**
Ability to be drawn into thin wires	Very good	Very good	Very good	Not good
Flexibility (ability to bend without breaking).	Very good	Good	Very good	Not good
Conductivity.	Very good (100%)	Very good (94%)	Good (67%)	Good (56%)
Resistivity in W m at 20°C	$1.6x10^{-8}$	$1.7x10^{-8}$	$2.4x10^{-8}$	$2.85x10^{-8}$
Ability to withstand	Good	Good	Very good	
Cost	Expensive	Cheap	Very expensive	Very cheap

Conductors used in common types of wires are always drawn to thin circular forms (bare wires). A few reasons why the wires are drawn in circular form are given below.

1 Drawing a conductor in the circular shape is cheaper and easier than drawing in any other form.

2 Round shape of the conductor ensures uniform current flow through the conductor.

3 Uniform diameter of wire can be maintained.

4 Insulation can be uniformly covered.

Conductor(s) of wires are covered with insulating material or an insulating coating(enamel). Some of the reasons for covering the conductor of wires with an insulator are given below:

TYPES OF INSULATORS

PROPERTIES	Polyvinyl chloride (PVC)	Vulcanised insulated rubber(VIR)	Teflon
Ability to withstand physical strain	Good (Hard & rough)	Good (Hard & rough)	Good (Hard & rough)
Ability to withstand action of acids	Good	Good	Good

Ability to withstand atmospheric variations	Good	Good	Good
Flexibility	Very good	Not good	Bad
Ease of skinning	Easy	Difficult	Difficult
Ability to withstand high temperature (heat)	Not good	Good	Very good
Cost	Cheap	Expensive	Very expensive

CURRENT CARRYING CAPACITY OF WIRES

A wire is used to carry electric current. The amount of current that can flow through a wire depends on, how good is the conductivity of the conductor used (silver,copper,aluminum etc) physical dimension (diameter) of the conductor(s).

Larger the diameter of the conductor, higher is the current that can flow through it.

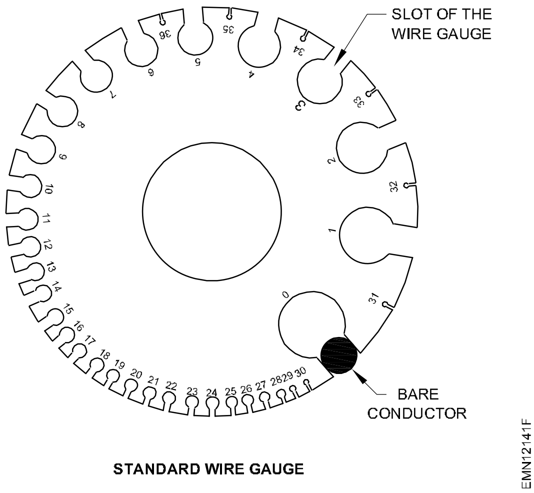
The maximum current that flows through a wire of a particular diameter without heating up the wire is called the maximum current carrying capacity or generally the **current carrying capacity** of a wire. Hence the current carrying capacity of a wire is directly proportional to the conductor's diameter.

STANDARD WIRE GAUGE

Size of a wire means the diameter of the conductor used in that wire. To measure the size of a wire, an instrument called **standard wire gauge (SWG)** is used as shown in Fig 14.

Standard wire gauge is a circular metal disk with varying slot sizes on its circumference. Each slot size corresponds to a gauge number which is written just below the hole. The gauge numbers specify the size of a round wire in terms of its diameter and cross-sectional area. The following points are to be noted while using/reading Standard Wire Gauge:

Fig 15



STANDARD WIRE GAUGE

– As the gauge numbers increase from 0 to 36, the diameter and circular area decrease. Higher gauge numbers indicate thinner wire sizes.

– The circular area doubles for every three gauge sizes. For example, No. 10 SWG has approximately twice the area of No. 13 SWG.

Measuring Instrument Meters

Objectives: At the end of this lesson you shall be able to
- **state the use of meters**
- **list the basic parts of a simple meter**
- **list the minimum specifications of any meter**
- **list the symbols used on meter dial and interpret their meaning.**

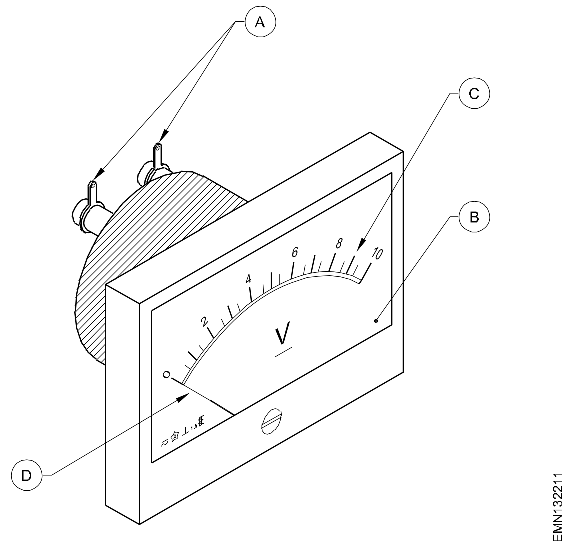
Meters

Meters are instruments used to measure electrical quantities like voltage, current, resistance etc.,

Measurement of electrical quantities is necessary while installing, operating, testing & repairing electrical & electronic equipments and circuits.

A simple meter is shown in Fig 1.

Fig 1



The electrical quantity to be measured is given to the input terminals (A) of the meter. The internal meter movement or mechanism moves the pointer(D) over the graduated scale(C) marked on a plate called the dial plate(B). The pointer stops at a point on the scale which corresponds to the magnitude of the input given at the input terminals(A).

Any simple meter must have the following minimum specifications.

[1] The electrical parameter it can measure.

Example: DC voltage, AC voltage, DC current, AC current, resistance and so on.

[2] The maximum quantity that it can measure.

Example: 10 volts, 100 volts, 1 ampere and so on.

The simple meter shown in Fig 1 can measure DC voltage. This can be found out from the symbol **V** marked on dial plate of the meter. All meters will have such symbols by which the user can identify the electrical parameter that the meter can measure. The different symbols used and their meanings are shown in Charts 1 at the end of this lesson.

Example 1: *A symbol V on a meter dial indicates,*

V for measuring voltage

~ for measuring AC.

This means, a meter with V symbol is for measuring AC voltage.

Example 2: *A symbol V on the meter dial indicates,*

V for measuring voltage

~ for measuring AC

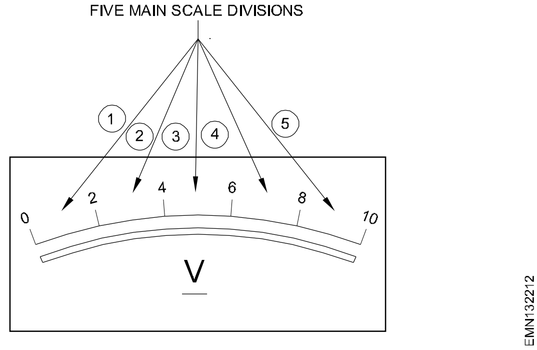
_ for measuring DC.

This means, a meter with V symbol is for measuring AC and DC voltages.

The meter scale as shown in Fig 1, is graduated/marked from 0 to 10. This means that this meter can measure up to a maximum of 10 volts. This is referred to as the maximum measurable value in that meter.

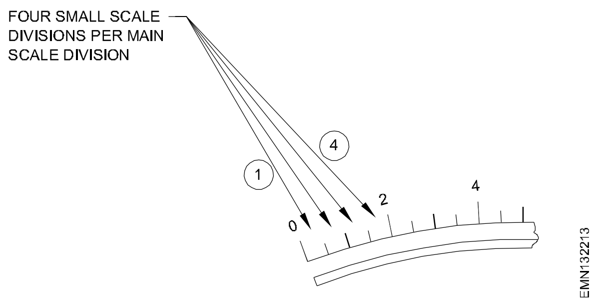
The meter scale of 0 to 10 is divided to 5 parts in steps of 2 volts as shown in Fig 2. Each division is called the Main Scale Division (MSD) of the meter scale.

Fig 2



Each main scale division in Fig 2 corresponds to 2 volts. Further each main scale division (say 0 to 2) is further divided into 4 more divisions as shown in Fig 3. These divisions are called Small Scale Divisions (SSD).

Fig 3



Each small scale division therefore corresponds to,

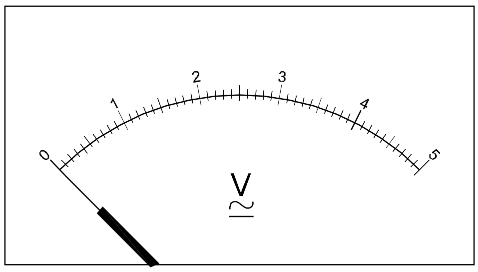
$$\frac{\text{Value of one main scale division}}{\text{Number of small scale division per main scale division}}$$

for fig.1, each SSD is, $\frac{2\text{ volts}}{4} = 0.5$ volts

Hence the smallest voltage that can be accurately measured using this meter is 0.5 volts. This is nothing but the value of one small scale division of the meter.

Example: *To find the maximum and minimum values that can be measured using a meter having a graduated scale as shown in Fig 4.*

Fig 4



Maximum quantity the meter shown in Fig 4 can measure is equal to the full scale deflection value or the highest numeric on the right edge of the of scale = 5 volts.

Minimum quantity the meter can measure is equal to value of one small scale division

$$= \frac{\text{value of one main scale}}{\text{No. of small scale div/main div}}$$

$$= \frac{1\text{ Volt}}{10\text{ div}} = 0.1\text{ volts.}$$

The minimum values that can be measured using the meter in Fig 4 is 0.1 volts and the maximum values that can be measured is 5 volts.

On the dial scale of any meter, in addition to the symbols indicating the electrical parameter (voltage, current etc) it can measure and the type of parameter (AC, DC, AC/DC), there are several other symbols. One of the important symbols to be identified before using the meter is the position symbol.

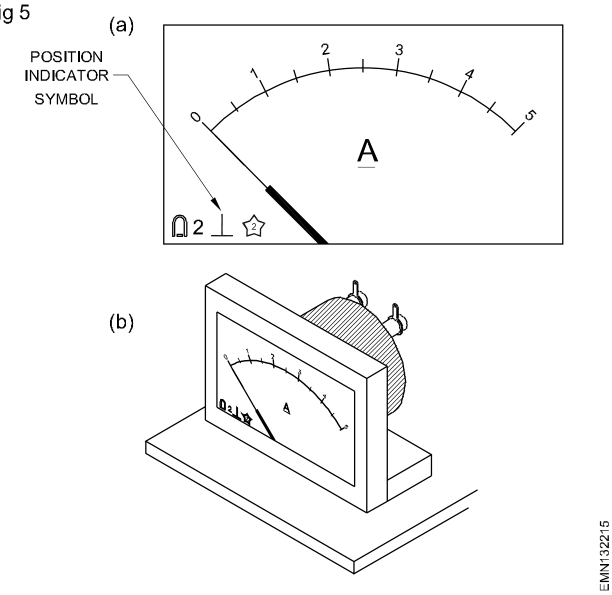
Fig 5(a) indicates a typical position symbol on the dial plate of a meter.

'⊥' symbol on the dial plate indicates that, the meter has to be positioned vertically (at right angle to the Table) as shown in Fig 5(b). If this meter is placed horizontally while taking measurement then, the readings shown by the meter will not be accurate.

Other symbols indicating the position in which a meter is to be kept while taking readings is given in the Chart 1 of this lesson.

[H.I Use Chart 1 and elaborate the meaning of the symbols in the classroom.]

Fig 5



CLASSROOM EXERCISE

For a meter with dial plate markings as shown in Figure 6, referring to Chart 1 of this lesson, find;

i) the nature and type of electrical parameter it can measure

ii) the position in which the meter is to be kept while using

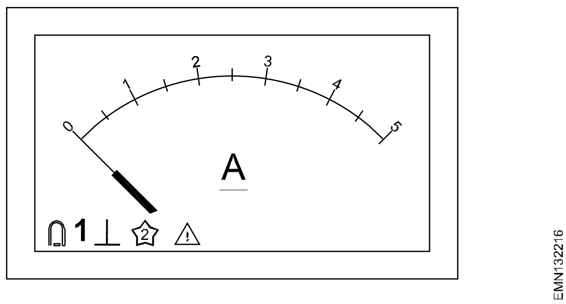
iii) the type of mechanism used for the pointer movement

iv) the percentage of error indicated in the meter reading

v) the maximum test voltage that can be applied

vi) the minimum and maximum quantity the meter can accurately measure.

Fig 6



The meters discussed so far, can measure only one range of values. The meter shown in Fig 1 can measure 0 to 10 volts. The meter shown in Fig 4 can measure 0 to 5 volts. Such meters are called Single range meters. These meters are generally mounted on electrical panels, and on the front panel of power supply units. Hence, these meters are commonly referred to as panel meters.

One of the most common errors in meters is the Mechanical Zero error. This error is caused due to the mechanical movements involved in the meters. This error in meters is correctable. The steps involved to correct this error is called Mechanical zero setting of meters.

All meters will have a screw on it as shown in Fig 6. Keeping the terminals of the meter open, the screw is turned slowly to bring the pointer exactly to 0 position on the meter scale. This means, with no voltage applied, the meter is made to show exactly zero volts.

Care has to be taken while turning this screw as this screw is directly connected with the sensitive and delicate meter movement. Turning the screw in large amounts or in jerks may damage the meter movement permanently making the meter unusable.

Before using a meter for measurements, it is necessary to check if the meter needle is moving freely over the graduated scale. There are possibilities that the meter movement may be sticky due to dust collection on the meter movement or due to the bent pointer needle.

A simple way to check sticky pointer/meter movement is to hold the meter in hand and tilt the meter back and forth gently, checking for the free movement of the pointer. If the pointer is not moving freely, it is advised not to use that meter for making measurements.

Voltmeters used for measuring DC voltages will have their input terminals marks +ve and -ve. For making voltage measurement, the +ve terminal of the meter must be connected to the +ve terminal of the battery and the -ve terminal of the meter to the -ve terminal of battery. If the terminals are reversed, the meter deflects below zero. This may cause temporary or sometimes permanent damage to the meter movement.

Measuring Instruments

a Introduction

- The instruments, which are used to measure any quantity are known as Measuring Instruments.
- Measurement of electrical quantities is necessary while installing, operating, testing & repairing electrical & electronic equipment's and circuits.
- To make electrical measurements the most popular instruments used are called Meters. Meter is a tool used to measure the basic electrical quantities such as Current, Potential difference (Volt) and Resistance.
- Following are the most commonly used electronic instruments.

  i Voltmeter

  ii Ammeter

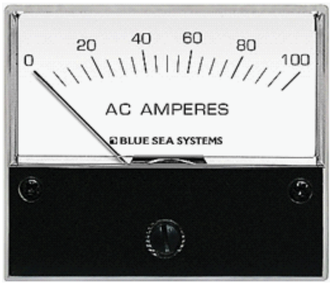
  iii Ohmmeter

  iv Multi-meter

  v Clamp Meter

b Ammeter

- Ammeter is an electronic instruments device used to determine the electric current flowing through a circuit. Ammeters measuring current in milli-ampere range is known as milli-ammeters.
- Ammeters are connected in series to the circuitwhose current is to be measured. Hence this electronic instruments are designed to have as Very Low resistance/ loading as possible.



- There are two types of ammeters: DC ammeter, and AC ammeter.
- DC ammeter measures the DC current that flows through any two points of an electric circuit. Whereas, AC ammeter measures the AC current that flows through any two points of an electric circuit.
- An example of practical AC ammeter is shown in figure which is a (0?100A) AC ammeter. Hence, it can be used to measure the AC currents from zero Amperes to 100 Amperes.

c Voltmeter

- Voltmeter is an electronic instruments used in an electric circuit to determine the potential difference or voltage between two different points.
- Voltmeters are usually connected in parallel (shunt) to the circuit. Hence they are designed to have High resistance as possible to reduce the loading effect.
- There are two types of voltmeters: DC voltmeter, and AC voltmeter i.e RMS value of Voltage.

- DC voltmeter measures the DC voltage across any two points of an electric circuit, whereas AC voltmeter measures the AC voltage across any two points of an electric circuit.
- An example of practical DC voltmeter is shown in figure which is a (0?10V)DC voltmeter. Hence, it can be used to measure the DC voltages from zero volts to 10 volts.

d Ohmmeter

- Ohmmeter is used to measure the value of Resistance between any two points of an electric circuit. It can also be used for finding the value of an unknown resistor.
- There are two types of ohmmeters: series ohmmeter, and shunt ohmmeter.
- In series type ohmmeter, the resistor whose value is unknown and to be measured should be connected in

series with the ohmmeter. It is useful for measuring high values of resistances.

- In shunt type ohmmeter, the resistor whose value is unknown and to be measured should be connected in parallel (shunt) with the ohmmeter. It is useful for measuring low values of resistances.
- An example of practical shunt ohmmeter is shown in the figure, which is a (0?100?)shunt ohmmeter. Hence, it can be used to measure the resistance values from zero ohms to 100 ohms.

e Multimeter

- Multi-meter is an electronic instrument used to measure the quantities such as voltage, current & resistance one at a time.
- This Multi-meter is also Known as Volt-Ohm-Milliammeter (VOM).
- It can be used to measure DC & AC voltages, DC & AC currents and resistances of several ranges.
- A practical multi-meter is shown in the figure, which can be used to measure various high resistances, low resistances, DC voltages, AC voltages, DC currents, & AC currents. Different scales and range of values for each of these quantities are marked in the figure.

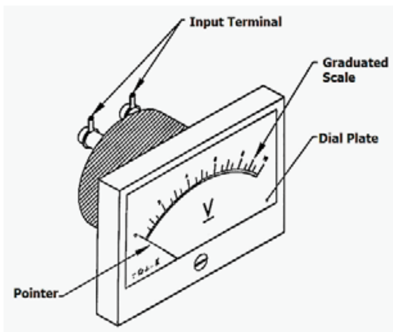
f Clamp meter

- A clamp meter is an electrical test tool that combines a basic digital multi-meter with a current sensor. It is also called a Tong Tester.
- Clamps measure current. Probes measure voltage. Having a hinged jaw integrated into an electrical meter allows technicians to clamp the jaws around a wire, cable or other conductor at any point in an electrical system, then measure current in that circuit without disconnecting/de-energizing it.
- Beneath their plastic mouldings, hard jaws consist of ferrite iron and are engineered to detect, concentrate and measure the magnetic field being generated by current as it flows through a conductor.

Principle and parts of simple meter

a Simple meter

- The electrical quantity to be measured is given to the Input Terminals of the meter. The internal meter movement or mechanism moves the Pointer over the Graduated Scale marked on a plate called Dial Plate.
- The pointer stopes at a point on the scale which corresponds to the magnitude of the input given at the input terminals.
- Any simple meter must have the following minimum specifications.
- The electrical parameter it can measure. Example: DC Voltage, AC Voltage, DC Current, AC Current, Resistance and so on.
- The maximum quantity that it can measure. Example: 10Volts, 100 Volts, 1 Ampere and so on.
- The simple meter shown figure can measure DC voltage. This can be found out from the symbol V marked on dial plate of the meter.
- All meters will have such symbols by which the user can identify the electricl parameter that the meter can measure.



b Graduated scale

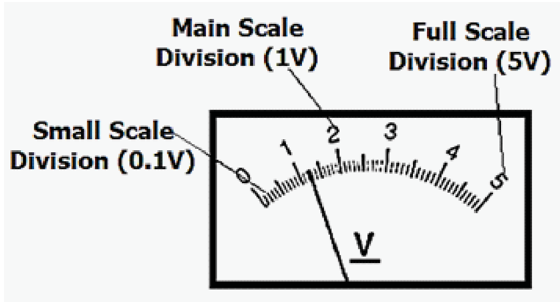
- The meter scale as shown in figure is graduated/ marked from 0 to 5. This means that this meter can measure up to a maximum of 5 Volts. The maximum reading of an analog meter is called Full Scale Deflection (FSD).

- The meter scale of 0 to 5 is divided to parts in steps of 1Volts. Each division is called Main Scale Division (MSD).
- Each Main Scale Division (MSD) is equal to,

$$\frac{\text{Full Scale Deflection}}{\text{Number of Main Scale Division}} = \frac{5}{5} = 1 \text{ Volts}$$

- Each main scale division corresponds to 1 volts. Further each main scale division (say 0 to 1) is further divided into 10 more divisions. These divisions are called Small Scale Divisions (SSD).
- Each Small Scale Division (SSD) therefore corresponds to,

$$\frac{\text{Value of one Main Scale Division}}{\text{Number of Small Scale Division per Main Scale Division}} = \frac{1}{10} = 0.1 \text{ Volts}$$

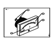
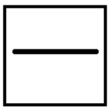


- Hence the smallest voltage that can be accurately measured using this meter is 0.1 Volts.

Symbol on meters

- The different symbols used and their meanings are detailed below:
- The following symbols indicate the reading of AC/DC:

Indicating the reading of AC/DC

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
	DC voltage or Current		AC voltage or current
	DC voltage or Current		AC/DC voltage or current

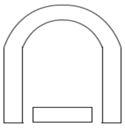
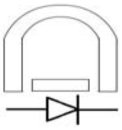
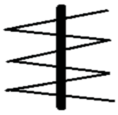
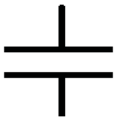
- The following symbols indicate type of meter:

Indicates type of meter

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
V	Voltmeter	**A**	Ammeter
mV	Milli - Voltmeter	**mA**	Milli - Ammeter
µV	Micro - Voltmeter	**µA**	Micro - Ammeter
Ω	Ohmmeter	**OHMS**	Ohmmeter

- The following symbols indicate the type of mechanism/ Principle of the meter pointer movement associated with the meter:

Type of mechanism/principle of the meter pointer movement

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
	Moving coil with permanent magnet		Hot wire
	Moving coil with rectifier		Bimetalic
	Moving iron		Electro static

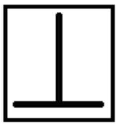
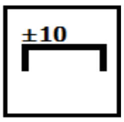
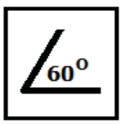
- The following symbols indicate percentage error in the indicated meter reading:

Percentage of Error

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
	± 1% Error expressed as a percentage of the end value of measuring range		±1.5 % Error expressed as a percentage of the end value of measuring range
	±2.5% Error expressed as a percentage of the end value of measuring range		± 1.5 % Error expressed as a percentage of the true value

- The following symbols indicate the placement position of the meter:

Placement position of the meter

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
	Vertical postition		Horizontal position
	Horizontal position with ± 10 error permissible		Inclind position

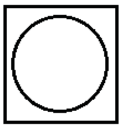
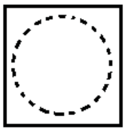
- The following symbols indicate special instructions that go with the meter:

Indicates special instructions that go with the meter

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
	No test voltage		Test voltage 1 Kilo volts
	Test voltage 2Kilo volts		Test voltage 500 volts

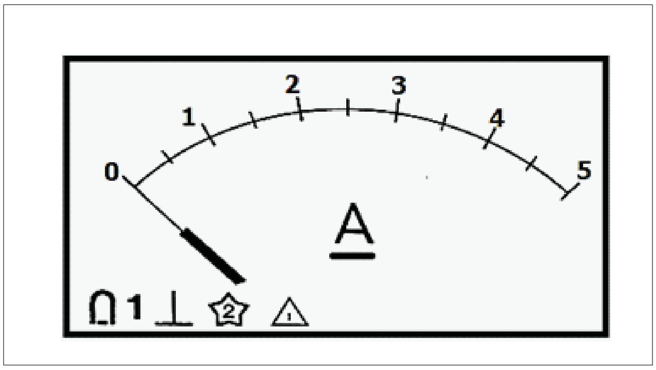
- The following symbols indicate special instructions that go with the meter:

Indicates special instructions that go with meter

Symbol	Meaning of the symbol	Symbol	Meaning of the symbol
	Magnetic shield		Electrostatic shield
	Attention read instructions before use		

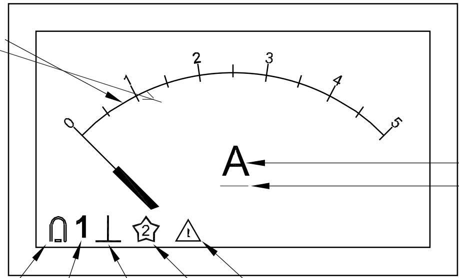
Simple Example:

For a meter with dial plate markings as shown in figure, the following specifications can be identified:



- The nature and type of electrical parameter it can measure - DC Current, 0 - 5 Ampere.
- The position in which the meter is to be kept while using - Vertical Position.
- The type of mechanism used for the pointer movement - Moving Coil with Permanent Magnet.
- The percentage of error indicated in the meter reading - ±1% Error Expressed as a Percentage of the End Value of Measuring Range.
- The maximum test voltage that can be applied - Test Voltage 2 Kilovolts.
- The special instructions of the meter -Attention read instructions before use.
- The minimum and maximum quantity the meter can accurately measure - Minimum Quantity (SSD) - 0.5 A, Maximum Quantity (FSD) - 5 A.

SYMBOLS ON METERS



Scale Marking
Linear / Non Linear

Indicates type of meter

Symbol on meter dial	Meaning of the Symbol
V	VOLTMETER
mV	milli–VOLTMETER
µV	micro–VOLTMETER
A	AMMETER
mA	milli–AMMETER
µA	micro–AMMETER
Ω	OHMMETER
OHMS	OHMMETER

Indicates the reading of AC/DC

Symbol	Meaning of the Symbol
	DC VOLTAGE OR CURRENT
	DC VOLTAGE OR CURRENT
	AC VOLTAGE OR CURRENT
	AC / DC VOLTAGE OR CURRENT

Indicates the type of mechanism / principle of the meter pointer movement associated with the meter.

Symbol	Meaning of the Symbol
MC	MOVING COIL
	MOVING COIL WITH PERMANENT MAGNET
	MOVING COIL WITH RECTIFIER
	MOVING COIL WITH THERMAL CONVERTER / THERMO COUPLE
	MOVING COIL WITH THERMAL CONVERTER ISOLATED
	MOVING COIL QUOTIENT MEASURING
	INDUCTION TYPE
	INDUCTION QUOTIENT MEASURING
	HOT WIRE
	BIMETALL IC
	VIBRATING REED

Symbol	Meaning of the Symbol
M I	MOVING IRON
	MOVING IRON
	MOVING IRON QUOTIENT MEASURING
	MOVING COIL NEEDLE / MAGNET
	MOVING MAGNET QUOTIENT MEASURING
	ELECTRO DYNAMIC CORELESS
	ELECTRO DYNAMIC QUOTIENT MEASURING CORELESS
	ELECTRO DYNAMIC WITH IRON CORE
	ELECTRO DYNAMIC QUOTIENT MEASURING WITH IRON CORE
	ELECTRO STATIC

Indicates percentage error in the indicated meter reading.

Symbol	Meaning of the Symbol
1	±1% error expressed as a percentage of the end value of measuring range
1.5	± 2.5 % error expressed as a percentage of the end value of measuring range
1.5	± 1.5 % error expressed as a percentage of the total scale length of width.
1.5	± 1.5 % error expressed as a percentage of true value.

Indicates the placement position of the meter

Symbol	Meaning of the Symbol
	VERTICAL POSITION
±2°	VERTICAL POSITION PERMISSIBLE DEPARTURE ± 2° FROM VERTICAL POSITION
	HORIZONTAL POSITION
±10°	HORIZONTAL POSITION PERMISSIBLE DEPARTURE ± 10 ° FROM HORIZONTAL POSITION
60°	INCLINED POSITION ANGLE OF INCLINATION 60° FROM HORIZONTAL

Indicates special instructions that go with the meter.

Symbol	Meaning of the Symbol
0	NO TEST VOLTAGE
	TEST VOLTAGE 500VOLTS
	TEST VOLTAGE 1KILOVOLTS
	TEST VOLTAGE 2KILOVOLTS

Indicates special instructions that go with the meter.

Symbol	Meaning of the Symbol
	MAGNETIC SHIELD
	ELECTROSTATIC SHIELD
!	ATTENTION READ INSTRUCTIONS BEFORE USE..

Cells and Batteries

Objectives : At the end of this lesson you shall be able to
- **state the power sources**
- **list the two main classifications of batteries**
- **state the dry and wet cells**
- **state the primary and secondary cells.**

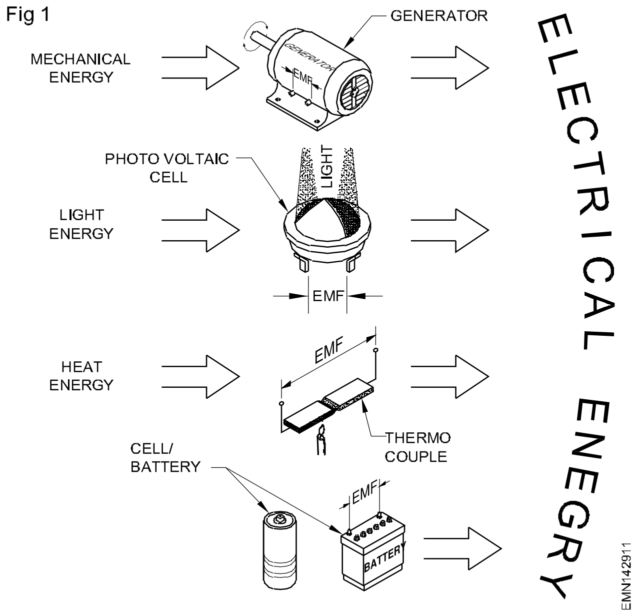
POWER SOURCES

Devices that produce electricity are generally termed as Power sources. These power sources produce electricity by converting some form of energy into electrical energy. As shown in Fig 1, all power sources must first be supplied with external energy such as heat, light or mechanical energy before they can produce electricity with an exception in the case of cell/battery. Batteries are different from the other types of power sources because, energy is provided by chemical reaction in batteries. Therefore, no energy need be supplied from outside for the battery to produce electricity. Hence batteries are one of the most important power sources. In a battery, electrical energy is produced by the chemicals contained within the battery. Cells are the basic units of a battery. Several cells forms to make a battery. Batteries are classified mainly under two categories.

(a) Primary batteries

(b) Secondary batteries

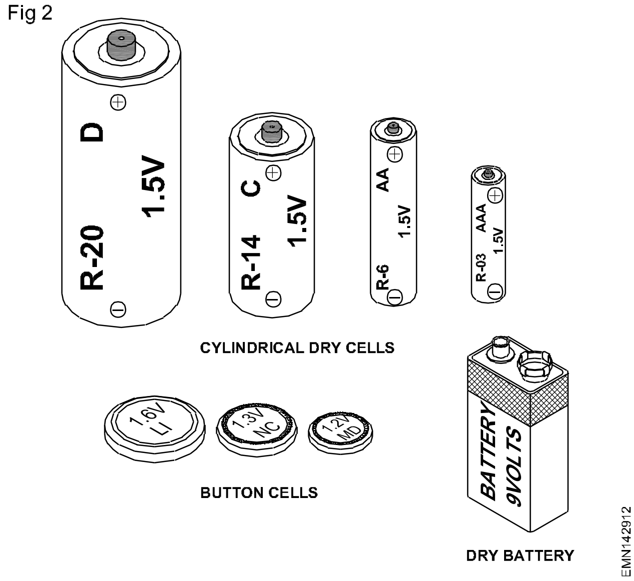
Fig 1



Primary Batteries - Converts chemical energy into electrical energy. This uses the chemicals within it to start the action of energy conversion. The most common types of primary cells and batteries are shown in Fig 2.

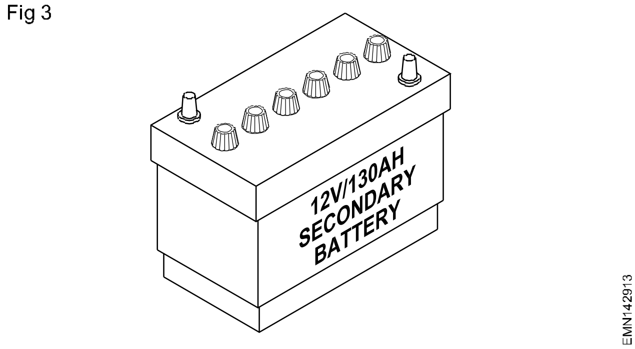
Secondary batteries - These batteries must be first charged with electrical energy. Once the battery is fully charged,it will then convert chemical energy to electrical energy. Secondary batteries first stores electrical energy supplied to it and then supply electrical energy as and when required. Hence secondary batteries are commonly called storage batteries.

Fig 2



A typical secondary storage battery is shown in Fig 3.

Fig 3



A battery may consist of two or more number of cells. The battery shown in Fig 3 has six cells of 2V each. These cells are connected in series to give 12V at battery terminals.

THE CELL

A cell consists of a pair of metal strips called **electrodes** and dipped in a chemical solution called **electrolyte** as shown in Fig 4.

Primary and Secondary cells

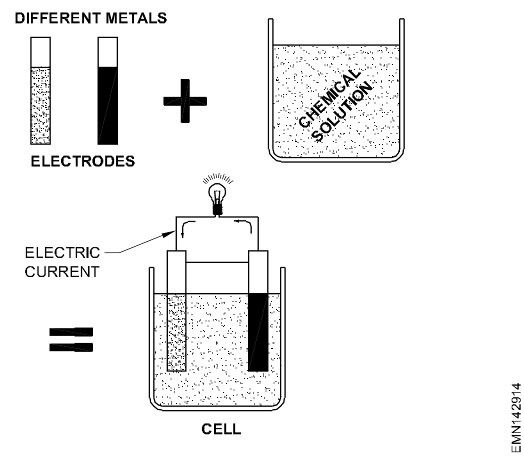
Primary cells are those which once fully used has to be thrown-out or destroyed. This is because the electrodes and electrolyte used in this type of cells cannot be reused.

Hence, primary cells are *non-rechargable* cells. Generally, the electrolyte used in primary cells is of paste form.

Secondary cells are those which once used can be reused by charging them. Hence, secondary cells are rechargable cells. Generally, the electrolyte used in secondary cells is in liquid form. However, there are rechargable cells with paste form electrolyte also.

In this lesson the commercial aspects of primary cells are discussed. Secondary cells are discussed in further lessons.

Fig 4



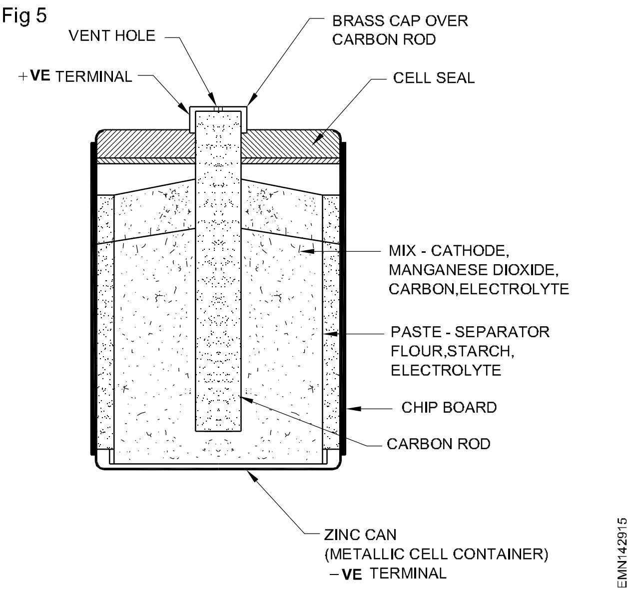
Dry and Wet cells

The electrolyte can be in liquid form or a paste form. Cells with paste form electrolyte are known as DRY cells. Cells with liquid form of electrolyte are called WET cells.

Dry cells and batteries

As the electrolyte used in dry cells is in paste form, it does not spill or leak. Hence, dry cells are used extensively in portable electrical and electronic gadgets. Typical constructional details of a zinc-carbon during cell is shown in Fig 5.

Fig 5



The two electrodes of dry cells are brought out and are available as +ve and -ve terminals of the cell. Usually the metallic cell container serves as the -ve of the cell as shown in Fig 5. The voltage that appears across the terminals depends upon the electrodes and the chemicals used in the cell. The voltage of a cell is so made as to suit the commercial requirement. Generally the voltage across the terminals of a dry cell range between 1.2 to 1.5 volts.

Dry cells and batteries are available in several shapes and sizes to suit commercial requirements. Some popular shapes of dry cells were shown in Fig 2.

Technically, any particular type of cell is defined by the materials used as electrodes and electrolytes in that cell. A dry cell with **zinc** as the -ve electrode, **carbon** as the +ve electrode with **zinc chloride** as the electrolyte is referred to as **zinc-carbon** cell or **zinc chloride** cell.

Similarly a dry cell which uses an alkaline solution as electrolyte is called an **Alkaline cells**.

A Chart on *Types of cells/batteries* given at the end of this lesson lists some popular dry cells along with the names of the materials used for the +ve,-ve electrodes, the electrolyte used, the available sizes, the rated output voltage and their applications.

The use of different materials for their electrodes and electrolytes results in different voltage, current rating discharge characteristics and the shelf life (life of the battery if kept unused).

NOTE: Not all types of cells are suitable for all applications. This is because some appliances draw high initial current or current in pulses which may not suit the discharge characteristics of the cell.

Weak, dead cell

Dry cells are used in various gadgets like flash lights, tape recorders etc, the cells convert the chemical energy built into them into electrical energy. In doing so, the dry cell slowly gets consumed. This means, the voltage across the cell terminals decreases and the current it can supply to the connected load becomes less and less. A stage will reach when the dry cell is no more capable of supplying sufficient voltage/current through the connected load . Then the cell is said to have become **weak** or **dead**.

As a thumb rule, dry cell can be declared unfit for use if, the voltage across its terminals is less than 75% of its rated output voltage.

Example: *A used zinc chloride dry cell with a rated voltage of 1.5 volts has 1.1 volts across its terminals. Find whether the cell is usable or not.*

Rated o/p voltage of the cell is 1.5V.

Measured output of the cell is 1.1V.

% Measured output with respect to rated output is

$$\frac{1.1}{1.5} \times 100 = 73.3\ \%$$

Chart for 1.2.29 &1.2.31

TYPES OF CELLS AND THEIR APPLICATIONS

Usual Name/Types	Classification	Negative Electrode (Anode)	Positive Electrode (Cathode)	Electrolyte	Rated output voltage	Available sizes	Applications
Carbon-Zinc (usually called Leclanche cell)	Primary	Zinc	MnO_2/C	Mixture of NH_4Cl and $ZnCl_2$	1.5V	D, C, B, A, AA, AAA	Flash lights, radio, tape batteries and for general purpose.
Carbon-Zinc (Zinc chloride cell)	Primary	Zinc	MnO_2/C	Zinc chloride	1.5V	D,C, B, A, AA, AAA	Electric shaver, electric knives transmitters, cordless drills, tools etc.
Alkaline-Manganese dioxide cell	Primary & rechargeable	Zinc	Manganese dioxide	Aqueous solution of potassium hydroxide	1.5V	D, C, AA	Camera cranking, radio controlled toys, radios & tape recorders.
Mercuric oxide cell	Primary	Zinc	Mercuric oxide	Aqueous solution of potassium hydroxide or sodium hydroxide	1.35V	C, B, AA and button cells	Cameras, watches, hearing aids, calculators etc.
Silver oxide cell	Primary	Zinc	Ag_2O	Aqueous solution of potassium hydroxide or sodium hydroxide	1.5V	Button cells	Hearing aids, digital wrist watch, micro-lamps, lights, meters etc.
Nickle-Cadmium	Rechargeable (Secondary)	Cadmium	Nickel hydroxide	Aqueous solution of potassium hydroxide	1.2V	All sizes of cyclin-drical, rectangular and buttoncells	Portable equipments like radio, tapes etc., rechargeable flash lights, emergency light etc.
Lithium Manganese	Primary	Lithium	Iodine/metallic oxides, sulphides button cells	Organic, inorganic water	3V to 6 V	Medium to large	Electronic watches, cal-culators, heart pacemaker life support equipments & communication equipments.

Secondary batteries - types of charge, discharge and maintanance

Objectives : At the end of this lesson you shall be able to
- **state the applications of lead-acid batteries**
- **describe the construction of lead acid batteries**
- **explain types of secondary cells, their nominal cell voltage, capacity and applications**
- **explain the effect of temperature on AH capacity**
- **state the care and maintenance of lead acid batteries**
- **describe the hydrometer**
- **connect the cells in series, parallel and series-parallel.**

Secondary batteries

Secondary batteries are made of small units known as cells. The main difference between a primary and a secondary cell is that a secondary cell can be recharged. This is because the type of chemicals used in a secondary cell is such, the chemical reaction is reversible.

When a secondary cell is supplying current to a load, the cell is said to be *discharging*. This discharging current gradually neutralizes the separated positive and negative charges at the electrodes (Anode and Cathode).

On the other hand, when current is supplied to a cell, the charges get re-formed on the electrodes due to reverse chemical reaction. This action is known as *charging* the cell. For charging a cell, the charging current is supplied by an external DC voltage source, with the cell behaving as a load.

The process of discharging and recharging is called *cycling* of the cell. As long as the cell is in good condition the discharge and charge cycles can be repeated several hundred times.

Since a secondary cell can be recharged, in other words the charges restored, these cells are called *storage cells*.

The most common type of secondary cell is the *Lead-acid cell*. A battery consisting of a combination of such cells is called *Lead-acid battery*. Lead-acid batteries are commonly used in automobiles such as cars, buses and lorries etc.,

Lead-acid, wet type cells

Lead-acid secondary batteries made of lead-acid are used in almost every automobile, for starting the engine. These batteries supply load current of 100 to 400A to the starter motor of automobiles.

The nominal voltage of a lead-acid cell is 2.2 V. By connecting three or six cells in series, batteries of 6V or 12V is obtained.

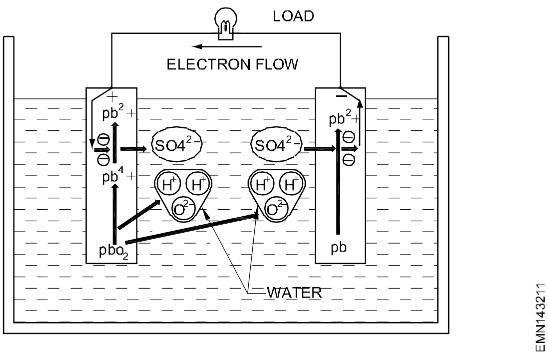
Principle of chemical action

A fully charged lead-acid cell has a lead peroxide (PbO_2) positive electrode, which will be reddish brown in colour and a gray spongy lead (Pb) as the negative electrode. These two electrodes are immersed in an electrolyte which is a diluted solution of sulphuric acid (27% sulphuric acid) having a specific gravity of 1.3. Such a cell produces an output of 2.2 V.

Discharging of lead-acid cells

The chemical action that takes place during the discharging of a lead-acid cell is shown in Fig 1.

Fig 1



During discharge, the lead (Pb) in both the electrodes react with sulphuric acid (H_2So_4) to displace hydrogen and form lead sulphate ($PbSo_4$). This lead sulphate, a whitish material, is somewhat insoluble and hence gets partially coated on both positive and negative plates. Since both plates approach the same material ($PbSo_4$) chemically, the potential difference between these plates begins to decrease. At the same time, the combining of oxygen in the lead peroxide (PbO_2) with the hydrogen atoms of the electrolyte forms water (H_2O) as shown in the equation given below,

$$Pb + PbO_2 + 2H_2So_4 \xrightarrow{\text{Discharge}} 2PbSo_4 + 2H_2O$$

It can be seen from the discharging equation that as the battery discharges (delivers energy to a load), the sulphuric acid solution becomes weaker (more and more diluted) with its specific gravity approaching 1.0.

The coating of whitish lead sulphate on the electrodes and the decrease in specific gravity of the electrolyte makes the voltage of the cell to drop off. Also, the internal resistance of the cell rises due to the sulphate coating on the plates.

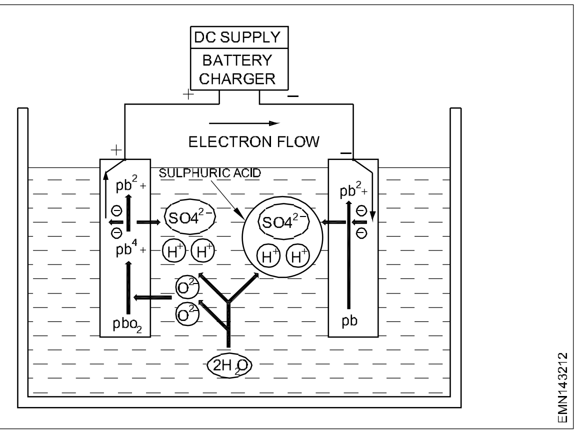
Charging of lead-acid cells

The chemical reaction that takes place during charging of a lead-acid cell is shown in Fig 2.

When a battery charger, having an output voltage (2.5V) which is slightly higher than the nominal voltage of the cell

(2.2V), is connected as shown in Fig 2, the direction of ionic flow gets reversed (refer to Fig 1 for the discharging direction). The electrical energy supplied by the charger causes the recombination of lead sulphate ($PbSo_4$) with hydrogen ions in the electrolyte. Therefore, the excess

Fig 2



water is removed from the electrolyte solution. As the electrolyte returns to its normal strength of sulphuric acid (27%) and the plates return to their original form of lead peroxide and spongy lead, the voltage across the electrodes returns to its nominal value of 2.2 V. The chemical action involved during charging can be represented by the following equation;

At the negative pole:

$$PbSO_4 + 2\text{ electrons} \longrightarrow Pb + SO_4$$

At the positive pole:

$$PbSO_4 - 2\text{ electrons} + 2H_2O \longrightarrow PbO_2 + So_4^{2-} - 4H^+$$

As the above reactions take place simultaneously, the equation can be written as,

$$2PbSO_4 + 2H_2O + \text{Electrical energy} \longrightarrow 2H_2So_4 + Pb + PbO_2.$$

It should be noted that, to charge a lead-acid battery of 12 V (2.2 V x 6 cells), the output voltage of the battery charger used for charging should be between 14.1 V to 15 V, and, its current rating not larger than 30 A. Charging batteries at excessively higher currents can cause boiling of the electrolyte. This reduces the liquid level in the battery and causes buckling and crumbling of the electrodes, thus reducing the life of the cells and hence the battery.

The lead sulphate ($PbSO_4$) which gets coated on the +ve and -ve plates tends to harden into an insoluble salt over a period of time. Hence, it is recommended to fully recharge a battery even if it is not used for quite some time.

Construction of lead-acid batteries

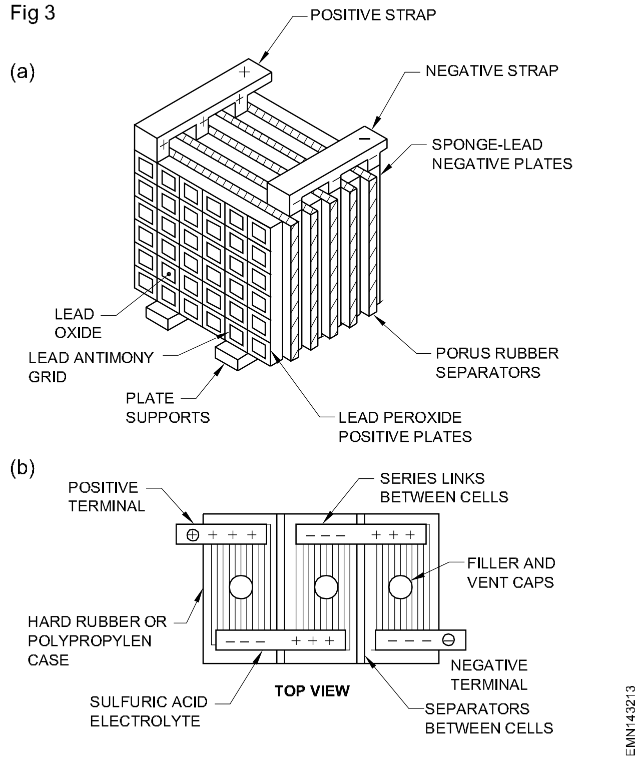
Fig 3 shows the principle behind the construction of commercial lead acid batteries.

Although in Figs 1 and 2, the lead-acid cell electrodes were shown as single plates, in a practical cell, it will not be the case. To increase the surface area and current capacity, a number of positive and negative plates are interleaved and separated by porous rubber sheets as shown in Fig 3a. All the positive plates are electrically connected, and all the negative plates are electrically connected. These parallel connections yield a higher current capacity of the cell with an overall cell output voltage of 2.2V. Several such cells can be connected in series to obtain the required battery voltage. For example, Fig 3b shows three such cells connected in series to produce a 6 volts Lead acid battery.

In lead-acid batteries, since hydrogen gas is produced during recharging, vents (holes) are provided on the battery compartment to let hydrogen and water vapour escape into free air. The vents also help in adding distilled water to the cells to compensate the water evaporated from the electrolyte.

For further details on the construction and manufacturing techniques of lead acid batteries refer reference books listed at the end of this unit.

Fig 3



Current rating of Lead acid batteries

The current rating of a lead acid battery is usually given in ampere-hour (AH) units, based on an 8 hour discharge period. In other words, batteries are rated in terms of how much discharge current they can supply for a specified period of time (often 8 hours). During this time, the cell's output voltage must not drop below 1.7 volts. Typical Ah values of automobile batteries range from 60 Ah to 300 Ah.

For example, A 60-AH battery, used in smaller automobiles, can supply a load current of 60/8 or 7.5 amperes for 8 hours without the cell voltages dropping below 1.7 volts. However this battery can supply less current for longer time (5 amps for 12 hours) or more current for a shorter time (60 amps for 1 hour).

Effect of temperature on AH capacity of Lead-acid batteries

As in the case of primary cells, the capacity of a lead-acid cells also decreases significantly with temperature. These cells lose approximately 0.75% of its rated ampere-hour (Ah) capacity for every 1°F decrease is temperature. At 0°F (–18°C), its capacity is only 60% of the value at 60°F (15.6°C). In cold weather, therefore, it is very important to have an automobile battery always fully charged. In addition, at very cold temperature, the electrolyte freezes more easily as it is diluted by water in the discharged condition.

Keep the batteries always fully charged especially in cold weather conditions.

Specific gravity of electrolyte

Specific gravity is a ratio comparing the weight of a substance with the weight of water. The specific gravity of water is taken as 1 as a reference. For instance, specific gravity of concentrated sulphuric acid is 1.835. This means, sulphuric acid is 1.835 times heavier than water for the same volume.

In a fully charged lead-acid cell, the specific gravity of the electrolyte, which is a mixture of sulphuric acid and water should be 1.28 at room temperature of 70 to 80°F. As the cell discharges, more and more water gets released into the electrolyte, lowering the specific gravity. When the specific gravity of the electrolyte falls down to about 1.150, the cell can be taken as fully discharged. Hence, the state of discharge of a lead-acid cell can be found out by measuring the specific gravity of its electrolyte.

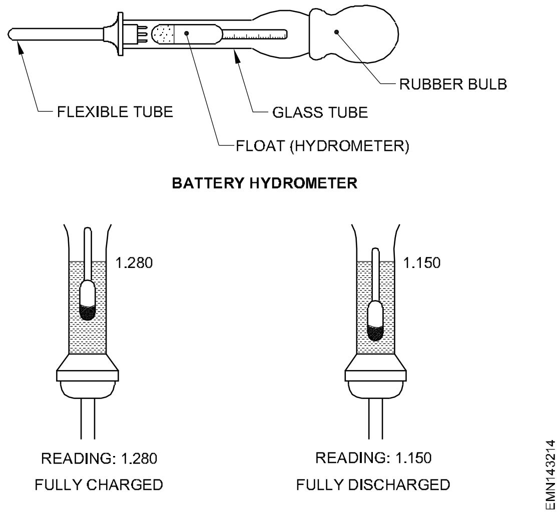
The specific gravity of electrolyte is measured using a instrument known as *Battery hydrometer* as shown in Fig 4 below.

Hydrometer

This meter is used to test the specific gravity of the liquid. It consists of a glass-made tube with bulb. The glass tube is filled with small lead pieces and is fitted with scale on which specific gravity is written as well as the indication of charged to discharged condition of a cell is also written. This hydrometer is kept in another glass-made tube. On one side of this tube a rubber ball is fitted and on the other side, nozal is fitted. When the ball of this meter is pressed and released while keeping this meter in the electrolyte of the cell, the electrolyte comes in the outer glass tube in which hydrometer bulb floats and gives reading with dilute H_2SO_4. The bulb will sink in the electrolyte while with strong H_2SO_4 the bulb will come up Hence, it gives reading. The electrolyte is so filled that the Hydrometer should not stick on the upper head or the bottom of the outer tube.

Reading on the Hydrometer	1280
Full charge	1260
Half charge	1200
Full discharge	1200
or Dead	1180

Fig 4



The importance of specific gravity can be seen from the fact that the open circuit voltage(V) of lead-acid battery is approximately given by,

$$V = \text{Specific gravity} + 0.84.$$

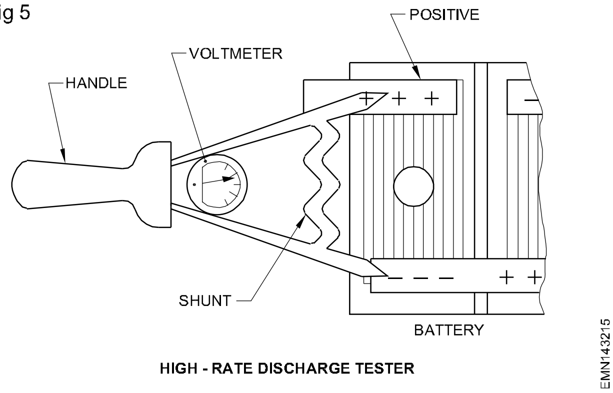
For instance, if the specific gravity is 1.280 then,

$$V=1.280 + 0.84 = 2.12V$$

Instrument for testing condition of cells - High rate discharge tester

The internal condition of a lead-acid battery cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance as shown in Fig 5.

Fig 5



The two terminal prods are pressed on to the terminals of a cell for testing. For fully charged cell the meter pointer points in the range of *full charge* on the meter scale. A sulphated old cell will show the discharge reading. The meter is having three colours red, yellow and green; red for fully discharged, yellow for half charged and green for fully charged condition of the cell respectively.

Topping up of lead-acid battery cells

In normal working condition of a lead-acid battery, the level of the electrolyte solution should be such that all the plates of the cells are fully immersed. If the level of the electrolyte is found to be less, then distilled water should be added to the indicated level of the cell through the vent plugs. This process of maintaining the level of electrolyte in lead-acid battery cell is called topping up.

Do not add tap water or well water for topping up. This will reduce cell life.

When a lead acid battery is being charged, the vent plugs are to be kept open for the gas produced to escape freely into air.

In case of lead-acid batteries used as back-up DC supply in un-interrupted power supplies (UPS), since charging and discharging of batteries is a continuous process, the vent plugs of the batteries will have several holes made on it for the gases produced during charging.

Un-interrupted power supplies are used in Hospitals, Computers etc., where the power failure may prove very costly.

Care and routine maintenance of lead-acid batteries

- DO NOT use battery if it is discharged beyond the minimum value of 1.7V per cell.
- DO NOT leave a discharged battery in that condition for a long time. Even if not in use, keep the battery always fully charged.
- Always maintain the level of the electrolyte 10 to 15 mm above the top of the plates by adding suitable quantity of distilled water (NOT tap water).
- DO NOT add sulphuric acid to maintain specific gravity.
- Keep the vent openings in the filling plug always open to prevent build-up of high pressure due to the gases formed. At least the vent plug should have holes made in it.
- Wash off the acid and corrosion on the battery top using moist cloth, baking soda and water.
- Clean the battery terminals and metal supports up to the bare metal and apply vaseline or petroleum jelly over its surface.
- DO NOT test a discharged battery using a 'High rate discharge tester'.

Some applications of lead-acid batteries

Lead-acid storage battery is the most common type found in commercial market. Lead-acid batteries find a great variety and range of applications. Some common applications are listed below;

- In petrol run motor vehicles like scooters, cars etc.
- In small domestic and industrial private generating plants and in mines.
- Battery run locomotives.
- In emergency lamps for small capacity lighting.
- In uninterrupted power supplies (UPS) for providing reserve supply in the event of mains failure.

Although wet electrolyte lead-acid secondary cells are the most common type, there are other types of secondary cells which find application in certain fields due to their special features. A brief on other types of secondary batteries is given below;

Maintenance free lead-acid batteries

Recent advances in lead-acid cells have resulted in low maintenance and maintenance free batteries. In normal lead-acid batteries, the battery plates contain antimony (4%), as the plates are made of lead antimony. It has been found that the amount of *gassing* i.e. production of hydrogen while charging a cell can be reduced by lowering the amount of antimony in the lead plates. By reducing the antimony in plates to 2%, low maintenance cells can be made. These cells require very little addition of water because very little water is *boiled-off* during charging. Totally maintenance free cells use antimony-free plates allowing complete sealing of battery, since no vents are necessary because gas does not build-up at all. Once sealed, no electrolyte can evaporate from the cell. However in some batteries, a small vent is provided to relieve the pressure arising from altitude changes.

One such maintenance free lead-acid cell is the *Gelled-Electrolyte Lead-acid Cell*. This cell enjoys all the advantages of a wet lead-acid cell but avoids the problems due to liquid electrolyte as it uses a gelled electrolyte. These cells use lead-calcium grids. These cells are completely sealed and can be mounted in any position. A one-way relief valve is provided to release excess pressure if the cell's internal pressure rises too high during charging, and it automatically recloses.

Gelled-electrolyte lead acid batteries are available from 2 V to 12 V with capacities ranging from 0.9 to 20Ah, based on a 20 hour discharge rate. The maximum current for these batteries ranges from 40 to 200 A. These batteries are used in domestic emergency lamps, portable television sets, portable tools and a variety of industrial applications.

Nickel-cadmium (NiCd) cell

Next to lead-acid, these cells are popular because of their ability to deliver high current and can get recycled many times. Also, the cell can be stored for a long time, even when discharged, without any damage. The NiCd cell is available in both sealed and non-sealed designs, but the sealed construction is more common. Nominal output voltage of a nickle-cadmium cell is 1.25 V per cell.

The chemical equation for the NiCd cell can be written as

$$2Ni(OH)_3 + Cd \underset{\text{discharge}}{\overset{\xleftarrow{\text{charge}}}{\longrightarrow}} 2Ni(OH)_2 + Cd(OH)_2.$$

The electrolyte is potassium hydroxide (KOH), but it does not appear in the chemical equation. The reason is that the function of this electrolyte is just to act as a conductor for the transfer of hydroxyl (OH) ions. Therefore, unlike the lead-acid cell, the specific gravity of the electrolyte in the NiCd cell does not change with the state of charge.

The NiCd cell is a true storage cell with a reversible chemical reaction of recharging that can be cycled up to 1000 times. Maximum charging current is equal to the 10-h discharge rate. It should be noted that a new NiCd battery may need charging before use.

Applications include portable power tools, alarm systems, and portable radio or television equipment.

Nickel-iron or Edison cell

This cell was once used extensively in industrial truck and railway applications. However, it has been replaced almost entirely by the lead-acid battery. New methods of construction for less weight, though making this cell a possible alternative in some applications.

The Edison cell has a positive plate of nickel oxide, a negative plate of iron, and an electrolyte of potassium hydroxide in water with a small amount of lithium hydroxide added. The chemical reaction is reversible for recharging. The nominal output is 1.2 V per cell.

Nickel-zinc cell

This type has been used in limited railway applications. There has been renewed interest in it for use in electric cars, because of its high energy density. However, one drawback is its limited cycle life for recharging. The nominal output is 1.6 V per cell.

Alkaline - manganese secondary cells

Alkaline - manganese secondary batteries are maintenance free, hermetically sealed, and will operate in any position. Individual cells use electrodes of zinc and manganese dioxide with an alkaline electrolyte of potassium hydroxide. Each cell has a nominal voltage of 1.5 V. Alkaline-manganese batteries are available in rated Ah capacity of 1 to 4 Ah. The internal resistance of these batteries is appreciably higher than NiCd batteries. Therefore, alkaline manganese batteries are not suitable for large current supplies.

Alkaline manganese batteries have been designed for electronic and electrical appliances where initial cost and low operating cost are of paramount interest. The total number of times the alkaline manganese secondary batteries can be recharged is much less than that of NiCd batteries, but the initial cost is lower.

Charging alkaline manganese batteries is different from that of NiCd batteries. According to the manufacturer's data, the charging should be done at constant current but at a constant voltage. Another difference, when compared with other secondary batteries is that, the alkaline manganese batteries must not be discharged too much; otherwise, the chemical process can be no longer reversed which means they cannot be recharged. It is recommended by the manufacturer not to discharge the cells below 1 volt.

Zinc-chlorine (hydrate) cell

This cell has been under development for use in electric vehicles. It is sometimes considered as a zinc-chloride cell. This type has high energy density with a good cycle life. Nominal output is 2.1 V per cell.

Lithium-iron sulphide cell

This cell is under development for commercial energy applications. Nominal output is 1.6 V per cell. The normal operating temperature is 800 to 900°F which is high compared with the normal operating temperature of the more popular types of cells.

Sodium-sulphur Cell

This is another type of cell being developed for electric vehicle applications. It has the potential of long life at low cost with high efficiency. The cell is designed to operate at temperatures between 550 and 650°F. Its most interesting feature is the use of a ceramic electrolyte.

Lead-acid secondary batteries made of lead-acid are used in almost every automobile, for starting the engine. These batteries supply load current of 100 to 400A to the starter motor of automobiles.

The nominal voltage of a lead-acid cell is 2.2 V. By connecting three or six cells in series, batteries of 6V or 12V is obtained.

Plastic Cells

A recent development in battery technology is the rechargeable plastic cell made from a conductive polymer, which is a combination of organic chemical compounds. These cells could have ten times the power of the lead-acid type with one-tenth the weight and the one-third the volume. In addition, the plastic cell does not require maintenance. One significant application could be for electric vehicles.

A plastic cell consists of an electrolyte between two polymer electrodes. The operation is similar to that of a capacitor. During charge, electrons are transferred from the positive electrode to the negative electrode by a dc source. On discharge, the stored electrons are driven through the external circuit to provide current in the load.

Application of maintenance free Gelled Electrolyte Lead-acid batteries

Since Gelled electrolyte lead-acid batteries are maintenance free and can be placed in any position, these batteries are extensively used in almost all types of portable equipments. The most common application of Gel-batteries can be found in *emergency lamps*. Emergency lamps are nothing but stand-by light sources, used in the event of main's failure. The type of lamp used could be a miniature tube light or a simple filament lamp. Emergency lamps which use miniature tube lights need a special circuit known as *inverter*. The function of the inverter circuit is to convert a low DC voltage into a high AC voltage.

Recharging lead-acid batteries

Recall that lead-acid batteries are rechargeable. Once the cell voltages of a lead-acid battery falls below 1.8 V, the battery needs recharging. This discharged state of battery can be found by measuring the specific gravity of the electrolyte (1.150) or by measuring the voltage across the cells of the battery.

To charge a lead-acid battery, an equipment known as Battery charger is used. A battery charger is nothing but a DC voltage source which can supply the necessary voltage and charging current to the battery.

There are two main methods of charging batteries. They are;

1 Constant current battery charging

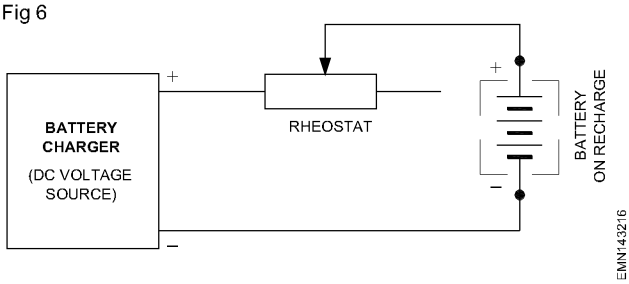
2 Constant voltage battery charging.

1) Constant current battery charging

In this method of charging batteries, the charging current supplied to the battery is kept at a prescribed (by the battery manufacturer) constant value. The amount of this constant current varies depending upon the Ah capacity of the battery. The value of constant charging current should not be excessive as this would cause excessive gassing. Excessive value current rises the cell temperature above the safe limit (generally 40°C) which will reduce the life of the battery.

Fig 6 shows a very simple method of constant current charging system.

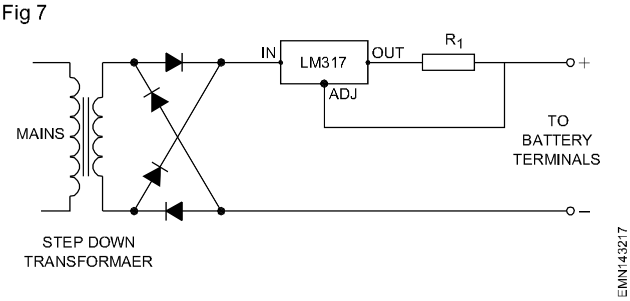
Fig 6



In constant current charging, the output DC voltage of the charger will be generally twice the nominal voltage of the battery to be charged. But, the charging current is controlled by varying the rheostat connected in series with the battery. For example, to charge a 12 V battery, the DC voltage source can be 24 V, but the charging current will be kept controlled say, 1 ampere with the help of the rheostat.

With the introduction of voltage regulator integrated circuits like LM317, it has become very simple and less expensive to make constant current battery chargers. Fig 7 shows a simple constant current battery charger using LM317. This charger can be used for any type of battery charging as long as the charging current is less than 1.5 Amperes.

Fig 7



Current can be set at any value between 10 mA and 1.5 A in the circuit at Fig 7. To have higher currents, suitable external power transistors can be used. In Fig 7, the input voltage to the regulator IC (LM317) should be 1.5 times the battery voltage (to be charged) plus 3 V. LM317 used in Fig 7 is immune to output shorts or reverse battery connections. Hence, the charger will always be safe.

The disadvantage of constant current battery charging is that it takes comparatively long time to fully charge the battery. But, the charge efficiency, which is defined as, is high compared to constant voltage battery charging.

$$\text{Charge efficiency} = \frac{\text{Charge stored by the battery}}{\text{Charge supplied to the battery}}$$

2) Constant voltage battery charging

In this method, the voltage applied across the battery terminals is kept constant, but no control is imposed on the charging current. Therefore, the battery draws large charging current in the beginning and as the cells gets charged, the charging current decreases to a small value.

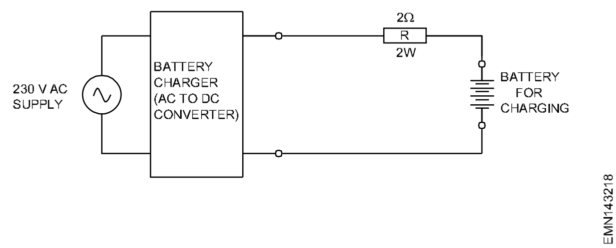
In this method, the time required for charging is reduced to half compared to the constant current charging. But, the charge efficiency gets reduced by approximately 10%.

In constant voltage charging, the voltage applied to the cells for charging should be fixed at about 2.3 to 2.5 volt per cell and not more. For instance, for a 12 volts car battery, the DC voltage output of the charger should be between 14 V to 15 V.

Simple constant voltage battery charging shown in Fig.8. Generally for converting AC into DC. Rectifier circuits are used. For pricision operation, Thyristor based rectifiers also used.

Resistor R is used to limit the initial charging surge current from becoming excessively high. This is because excessive current may damage the diode and transformer of the battery charger unit.

Fig 8



TRICKLE Charging

Whenever a storage battery is used as an emergency reserve, as in the case of un-interrupted power supply (UPS), it is necessary to keep the batteries fully charged and ready for use at any time if the mains supply fails.

A fully charged battery, which is not connected to any load is expected to maintain its terminal voltage. But, due to internal leakage in the battery and other open circuit losses, the battery voltage slowly falls even in idle or open circuit condition. Therefore, to keep it in fully charged condition, the battery should be supplied with a charging current which is small and just sufficient to compensate the idle condition or open circuit losses. This small current charging is known as Trickle charging. Trickle charging keeps the battery always fully charged and in ready to use condition, so that, the battery can be fully made use of in emergency conditions.

Types of measuring instruments, equipments, uses and features

Objectives : At the end of this lesson you shall be able to
- **explain the principle of operation of a PMMC type movement**
- **explain D'Arsonval moving coil meter movement**
- **explain the calibration of instruments**
- **explain the functions of CRO and controls**
- **explain the parts and functions of multimeter.**

To work with electricity and to service electrical appliances, requires accurate measurements. To make electrical measurement the most popular instruments used are called Meters. Meter is a tool used to measure the basic electrical quantities such as current,potential difference(volt) and resistance. Right selection and proper use of meters can only give accurate readings.

All meters have one thing in common. They contain an internal standard to which all measured values are compared. In this respect, an electrical meter is much like a mechanical balance that compares an unknown mass to a standard mass.

Meters discussed in this lesson make use of electric current/voltage to produce a magnetic force , it then compares this force to a counter force exerted by a spring.The resultant of these forces drives a pointer which indicates the value of the electric voltage/current applied to the meter on a graduated scale found on the dial of the meter.

The D'Arsonval Movement

All meters will have some form of indicating device. Those that have a Pointer or needle that moves across a fixed scale are based on a mechanism called D' Arsonval movement.This is named after its invention by D'Arsonval Deprez. The principle of D' Arsonval movement is similar to a motor, it makes use of the force of a magnetic field exerted in a current carrying conductor. The principle of this movement is similar to that of a permanent magnet type electric motor.

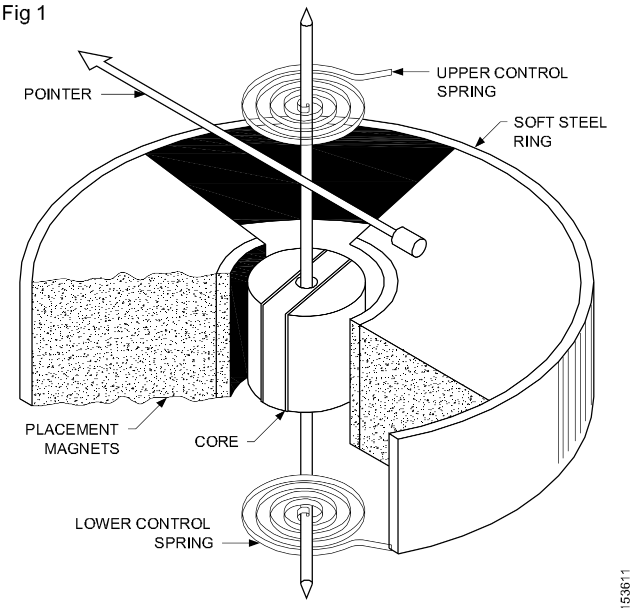
All D'Arsonval meter movements require current and a magnetic field to cause movement of the indicator. Some meters have permanent magnets that work with current to move the pointer. Such type are referred to as permanent magnet moving coil type(PMMC) meters. The other type have no permanent magnets;instead they have current carrying coils to produce the magnetic fields. These are referred to as Moving Iron type (MI) meters.

D'Arsonval meter movements consists of a permanent magnet and a moving coil, also called permenant magnet moving coil galvano meter abbreviated PMMC. The term galvanometer refers to a sensitive current-detecting device.

Fig 1 shows the essential parts of such a galvonometer.

In Fig 1, the coil is mounted on a shaft which rotates between the jewel bearings(not shown in Fig). The Soft steel core reduces the total air gap between the magnetic poles of a permanent magnet. The coil is positioned to turn against precisely made upper and lower control springs. The springs also serve as conductor to carry current to and from the coil. A light weight pointer/indicator attached to the coil indicates how far the coil has rotated. The position of the indicator on the scale tells the amount of current flowing through the coil.

Fig 1



BASIC PARTS OF A D'ARSONAVAL MOVEMENT

Principle of operation of a PMMC type meter movement

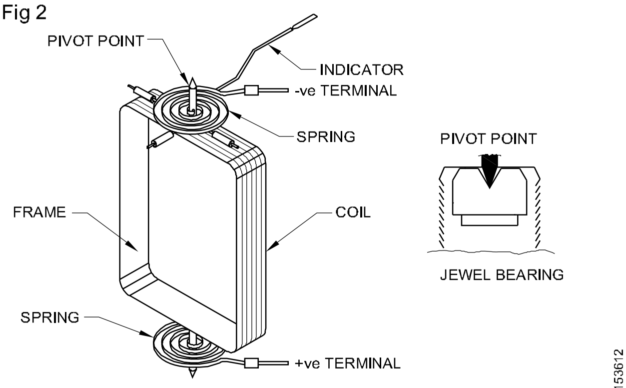
When no current flows through the coil, the control spring's tension hold the coil in a position between the pole faces. This position is defined as "Zero position".

When the coil carries current (whose value is to be measured), the force from the magnetic field due to permanent magnet exerts torque on the current carrying coil and make it rotate(like the motor principle). The indicator moves clock-wise in the direction and the springs controls/resist this motion. The magnetic field exerts a torque on the moveable coil making it to rotate.The indicator then comes to a rest at a non Zero value on the scale where the torque produced by the current and the opposition force of the spring becomes equal.

Because of the permanent magnet, the strength of the magnetic field around the coil is constant. Therefore, the deflecting force is directly proportional to the current through the moveable coil. These conditions makes it possible to calibrate the scale of the instrument to read the measurement value directly.

To allow the moving coil to deflect with bare minimum friction, the shaft of the moving coil is tapered to a point at both ends. The sharp ends rest in a highly polished jewel bearing as shown in Fig 2. The tapered ends hold the shaft precisely in position to maintain the instrument's accuracy. The bearing (usually Sapphire) reduces wear.In addition, the small area of contact keeps the torque caused by friction very low, so that the meter responds rapidly to any changes in current.

Fig 2



BEARING OF A D'ARSONVAL MOVEMENT

Damping in Moving coil type meters

Damping means to control the swing of the coil so that the pointer comes to rest quickly at its final position. Without damping, the pointer attached to the coil swings back and forth before coming to rest. In such case, it is necessary to wait till the swinging stops to take the accurate meter reading.

In permanent magnet moving coil meters, the movable coil is wound on an aluminium frame as shown in Fig 3. This frame, in addition to supporting the coil winding, the bobbin also performs the important function of damping the instrument.

Calibration of Instruments

While the tolerance figures are generally specified, this will not be true if the instrument is in use for a reasonably long time. The main reason for this could be the aging of the instrument. Therfore, to have complete confidence in the instrument used for measurement, it is necessary to "Calibrate" the instrument regularly. If an instrument is left uncalibrated, the same reading taken sometime back will be different not because of the any fault in the manufacturer's specification, but because its calibration might not have been checked within the recommended period.

Calibration is a routine procedure at stated intervals and is performed against preserved and trustworthy standards. The intervals for calibration depends on several factors such as the type of instrument, place of use, accuracy and so on. Hence, most instrument manufacturers specify the interval for calibration and suggest the procedure.

Calibration of Voltmeters and Ammeters

Among the several methods of calibration for volt meters and current meters, the two simple and popular methods are;

– Calibration by potentiometer method

– Calibration by comparison method.

Potentiometer method is the fundamental method of calibration and is necessarily used for the basic standard instrument. But this method is too slow for the general run of calibration and is more precise than needed. Hence the usual portable instruments are calibrated by comparison with a high grade standard instrument of suitable range. At present senario high precision digital instuments can be used as standard instrument while calibrating analog volt/current/ohm meters.

Advantages : The P.M.M.C. instrument

- Consumes less power
- has uniform scale and can cover an arc up to 270^o
- has high torque/weight ratio.
- can be modified as voltmeter or ammeter with suitable resistors
- has efficient damping.
- is not affected by stray magnetic fields, and has no loss due to hysteresis.

Disadvantages : The P.M.M.C. instrument

- can be used only in DC
- is very delicate
- is costly when compared to a moving iron instrument
- may show errors due to loss of magnetism of the permanent magnet.

Moving iron instruments

This instrument derives its name from the fact that a piece of soft iron which is attached to the spindle and needle moves in a magnetic field produced by the current or by a current proportional to the quantity of electricity being measured.

There are two types of this instrument which are used either as voltmeter or ammeter.

They are:

– attraction type

– repulsion type.

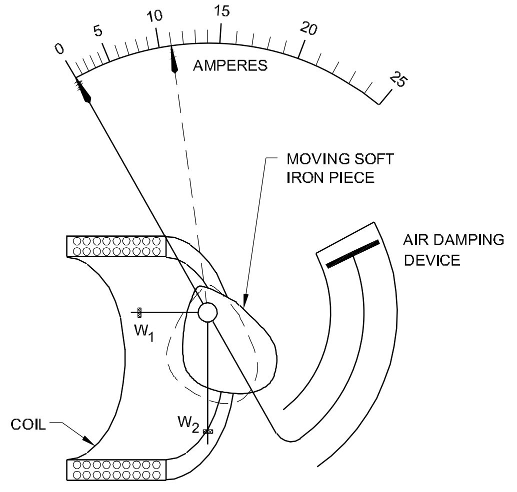
Principle of operation

The attraction type instrument works on the principle of magnetic attraction, and the repulsion type instrument works on the principle of magnetic repulsion between two adjacent pieces of soft iron, magnetised by the same magnetic field.

Construction and working of attraction type moving iron instrument

This instrument consists of an electromagnetic coil having an air core as shown in Fig 3. Just in front of the air core, an oval shaped soft iron piece eccentrically pivoted in a spindle is kept as shown in Fig 3. The spindle is free to move with the help of the jewelled bearings, and the pointer, which is attached to the spindle, could move over the graduated scale. When the electromagnetic coil is not connected to the circuit, the soft iron piece hangs vertically down due to gravitational force and the pointer shows zero reading.

Fig 3

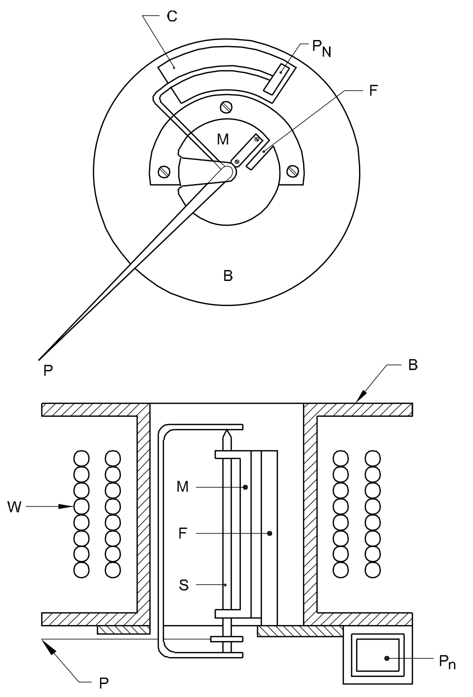


MOVING IRON INSTRUMENT - ATTRACTION TYPE

When the electromagnetic coil is connected to the supply, the magnetic field created in the coil attracts the soft iron piece. (Fig 3) Due to the eccentricity of pivoting of the iron piece, the enlarged portion of the iron piece is pulled towards the coil. This, in turn, moves the spindle and makes the pointer to deflect. The amount of deflection of the pointer will be greater when the current producing the magnetic field is greater. Further, the attraction of the soft iron piece is independent of the current direction in the coil. This characteristic enables the instrument to be used both in DC and AC.

Construction and working of repulsion type moving iron instrument

Fig 4



MOVING IRON INSTRUMENT - REPULSION TYPE

This instrument consists of a coil W wound on a brass bobbin B, inside which two strips of soft iron M and F are set axially as shown in Figs 4a & 4b. Strip F is fixed whereas the iron strip M is attached to the spindle S, which also carries the pointer P.

Spring control is used and the instrument is designed such that when no current is flowing through W, the pointer is at zero position and the soft iron strips M and F are almost touching. (Figs 4a & 4b)

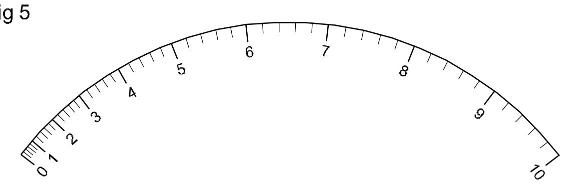
When the instrument is connected to the supply, the coil W carries current which, in turn, produces a magnetic field. This field makes the fixed and moving iron F and M respectively to produce similar poles in the ends. Therefore, the two strips repel each other. The torque set up produces a deflection of the moving system and therefore. brings into play a controlling torque due to torsion. The moving system comes to rest in such a position that the deflecting and controlling torques are equal.

In this type of instrument air damping is used commonly which is provided by the movement of piston P_N in a cylindrical air chamber C as shown in Fig 4a.

Deflecting torque and graduation of scale

However, in the moving iron instruments the deflecting torque is proportional to the square of the magnetic force which, in turn, is proportional to the square of the current passing through the coil. As such the scale of this instrument will be uneven. That is, cramped at the beginning and open at the end as shown in Fig 5.

Fig 5

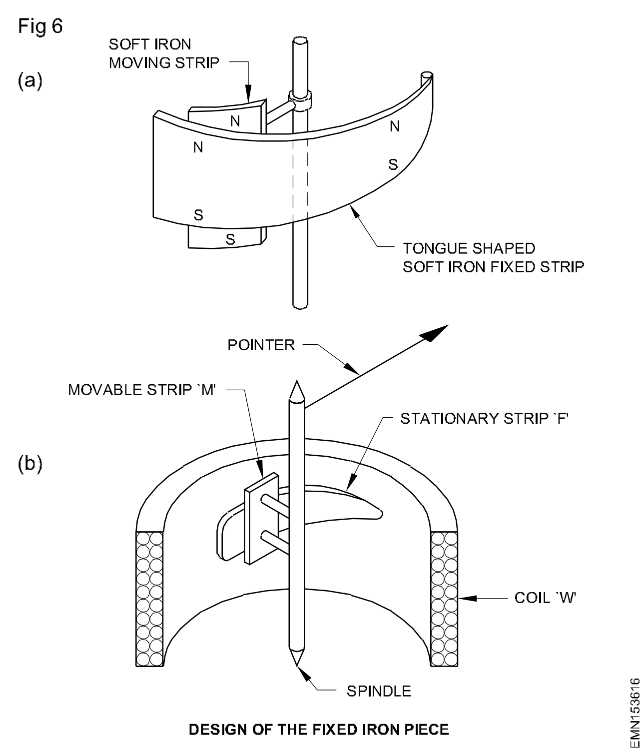


SCALE OF THE MOVING IRON INSTRUMENT (UNEVEN)

In order to achieve uniformity of scale, some manufacturers have designed tongue shaped strips as moving and fixed soft irons as shown in Fig 6a.

The fixed iron consists of a tongue-shaped soft iron sheet bent into a cylindrical form, while the moving iron is also made of another soft iron sheet and is so mounted as to move parallel to the fixed iron and towards its narrower end as shown in Fig 6b. The torque which is proportional to the square of the magnetic force/current is proportionally reduced by the narrow portion of the fixed iron resulting in more or less even torque, and, thereby, getting uniform scale.

These instruments are either gravity or spring controlled and the damping is achieved by the air friction method as shown in Fig 6a.



USES, ADVANTAGES AND DISADVANTAGES

Uses

They are used as voltmeters and ammeters.

They can be used on both AC and DC and, hence, are called unpolarized instruments.

Advantages

They have a small value of friction errors as the torque/ weight ratio is high.

They are less costly when compared to the moving coil instruments.

They are robust owing to their simple construction.

They have satisfactory accuracy levels within the limits of both precision and industrial grades.

They have scales covering 240^{o}.

Disadvantages

They have errors due to hysteresis, frequency changes, wave-form and stray magnetic fields.

They have non-uniform scale usually. However, special manufacturing designs are utilized to get more or less uniform scales.

Moving iron Instrument as an ammeter

It may be constructed for full scale deflection of 1 to 30A without the use of shunts or current transformers. To obtain full scale deflection with currents less than 0.1A, it requires a coil with a large number of fine wire turns, which results in an ammeter with a high impedance.

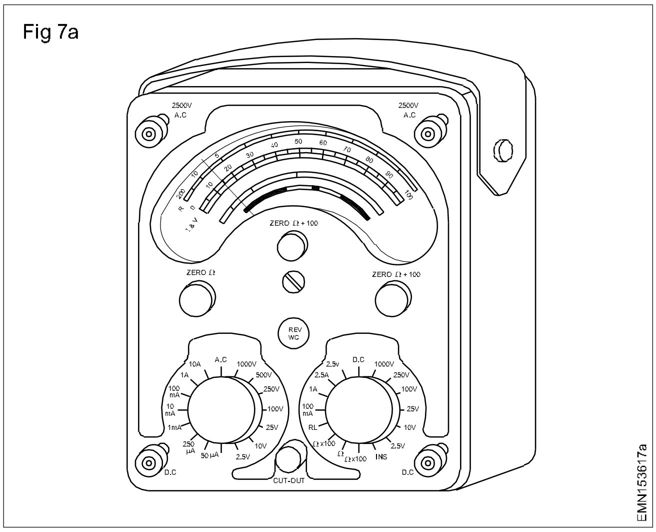
The range of the instrument, when used as an ammeter, can be extended by using a suitable shunt across its terminals. No problem arises during operation with DC but the division of current between instrument and shunt changes with the change in applied frequency while using AC.

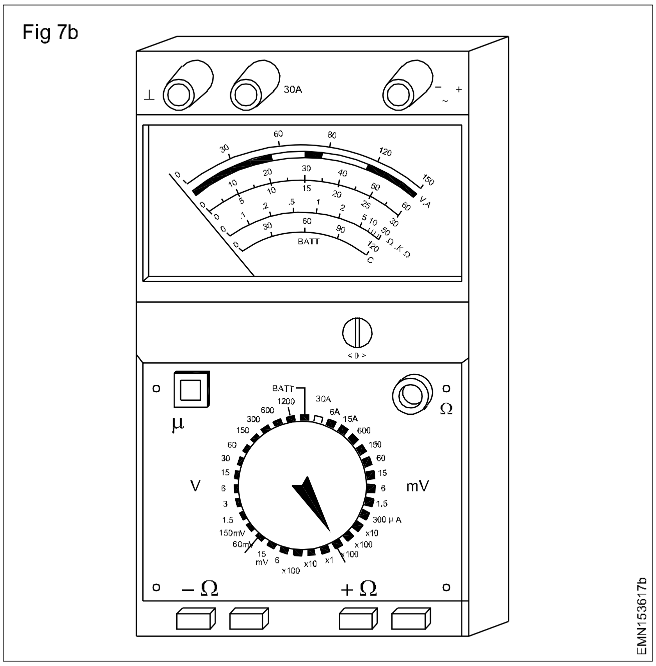
Multimeter

The three most commonly measured electrical quantities are current, voltage and resistance. Current is measured by an ammeter, voltage by a voltmeter and resistance by an ohmmeter.

A single instrument used for measuring all the above three quantities is known as a multimeter. It is a portable, multi range instrument.

It has a full scale deflection accuracy of ±1.5 %. The lowest sensitivity of multimeters for AC voltage range is 5 kΩ/ volts and for the DC voltage range it is 20 kΩ/ volts. The lowest range of DC is more sensitive than the other ranges.





Figs 7a and 7b show typical multimeters.

Construction of a multimeter

A multimeter uses a single meter movement with a scale calibrated in volts, ohms and milliamperes. The necessary multiplier resistors and shunt resistors are all contained within the case. Front panel selector switches are provided to select a particular meter function and a particular range for that function.

On some multimeters, two switches are used, one to select a function, and the other the range. Some multimeters do not have switches for this purpose; instead they have separate jacks for each function and range.

Batteries/cells fixed inside the meter case provide the power supply for the resistance measurement.

The meter movement is that of the moving coil system as used in DC ammeters and voltmeters. (Fig 8)

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Parts of a multimeter

A standard multimeter consists of the main parts and controls, as shown in Fig 9.

Fig 8

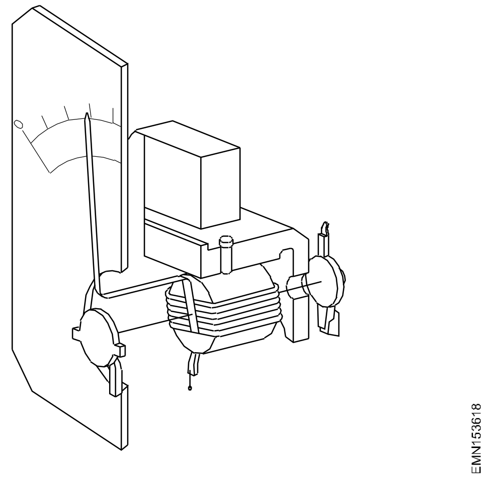
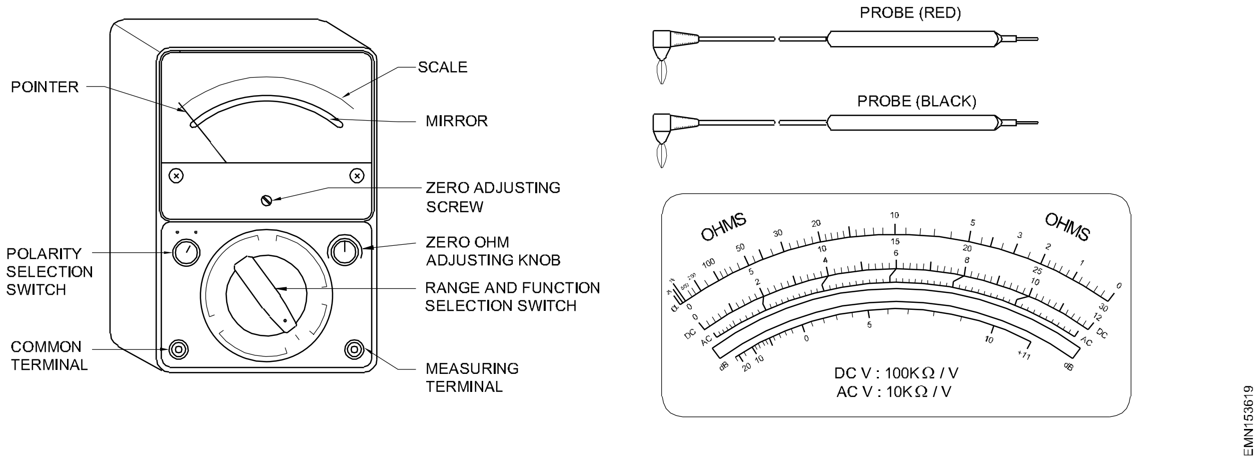


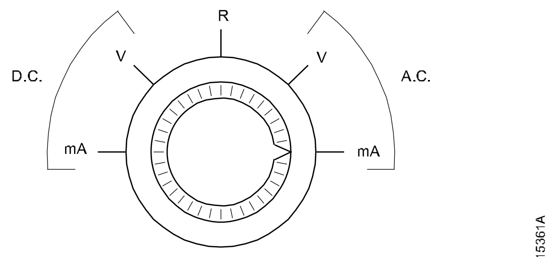
Fig 9



Controls

The meter is set to measure the current, voltage (AC and DC) or resistance by means of the FUNCTION switch. In the example given in Fig 10 the switch is set to mA, AC.

Fig 10



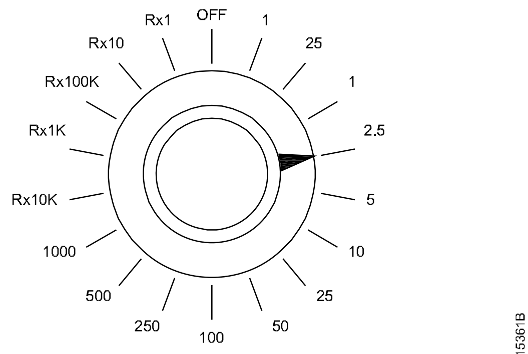
FUNCTION SWITCH

The meter is set to the required current, voltage or resistance range - by means of the RANGE switch. In Fig 11, the switch is set to 2.5 volts or mA, depending on the setting of the FUNCTION switch.

The example in Fig 12 shows the switch set to 25V DC of a meter having the function and the range selected by a single switch.

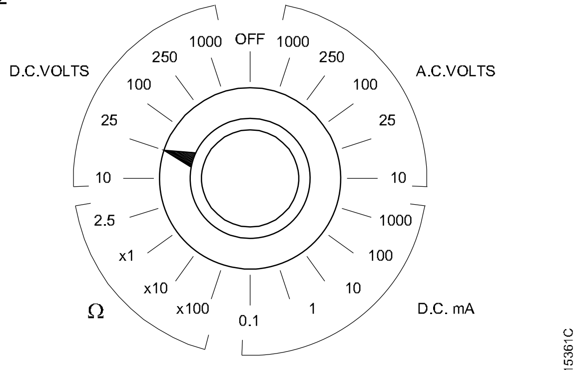
The example in Fig 13 shows the switches set to 250V AC of a meter that uses two function/range switches, one for DC ranges and the other for AC and resistance (ohms) ranges.

Fig 11



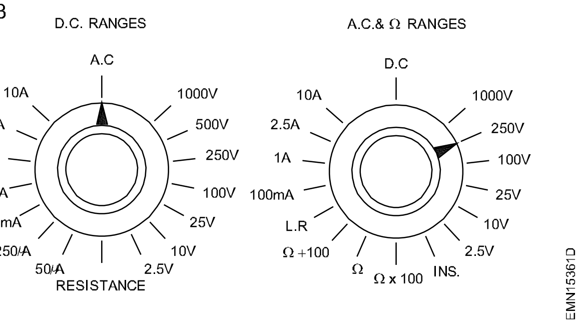
RANGE SWITH

Fig 12



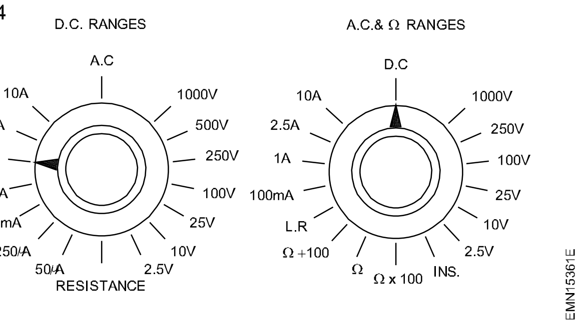
FUNCTION AND RANGE SWITCH

Fig 13



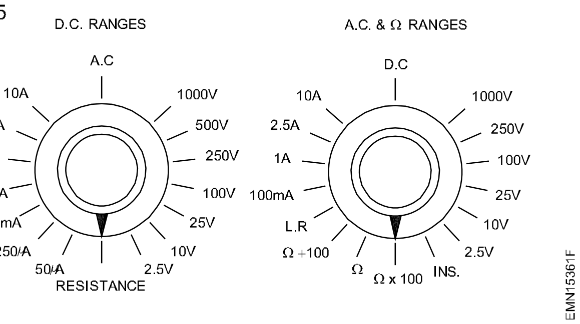
Switches set to 100 mA DC. (Fig 14)

Fig 14



Switches set to resistance, ohms x 100 range. (Fig 15)

Fig 15

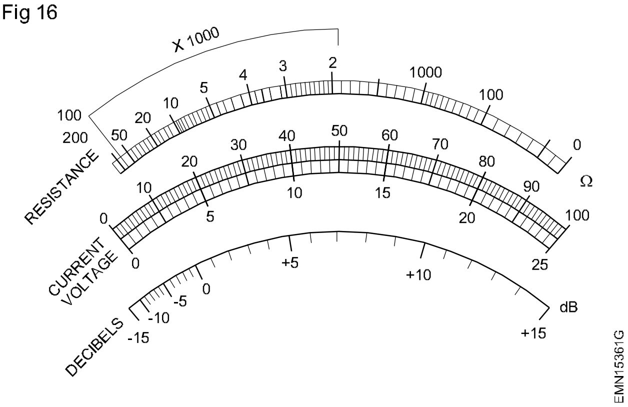


Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 16)

Fig 16



The scale of current and voltage is uniformly graduated.

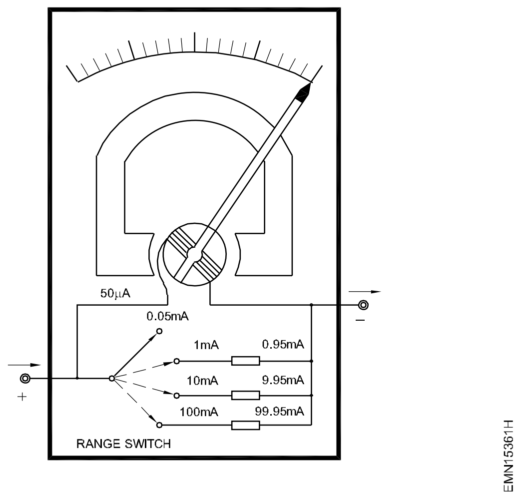
The scale of the ohmmeter is non-linear. That is, the divisions between zero and infinity (∞) are not equally spaced. As you move from zero to the left across the scale, the divisions become closer together.

The scale is usually 'backward', with zero at the right.

Principle of working

A circuitry when working as an ammeter is shown in Fig 17.

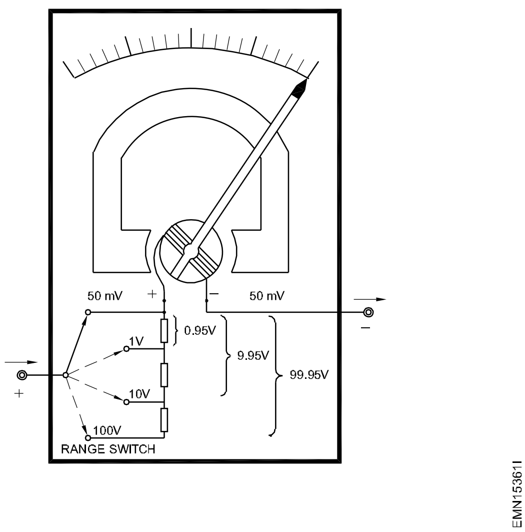
Fig 17



Shunt resistors across the meter movement bypass current in excess of 0.05 mA at FSD. A suitable value of shunt resistor is selected through the range switch for the required range of current measurement.

A circuitry when working as a voltmeter is shown in Fig 18.

Fig 18

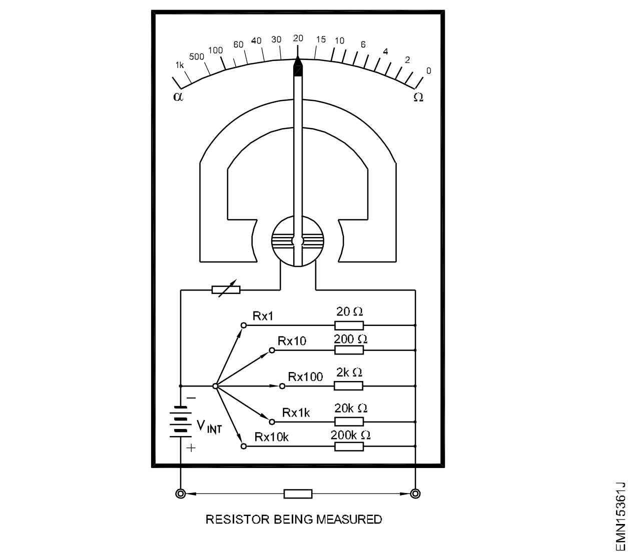


The voltage drop across the meter coil is dependent on the current and the coil resistance. To indicate voltages greater than 50 mV at FSD as per the circuit, multiplier resistances of different values are connected in series with the meter movement through the range switch for the required range of measurement.

A circuitry when working as an ohmmeter is shown in Fig 19.

To measure resistance, the leads are connected across the external resistor to be measured as shown in Fig 19. This connection completes the circuit, allowing the internal battery to produce current through the meter coil, causing deflection of the pointer, proportional to the value of the external resistance being measured.

Fig 19



Zero adjustment

When the ohmmeter leads are open, the pointer is at full left scale, indicating infinite ¥ resistance (open circuit). When the leads are shorted, the pointer is at full right scale, indicating zero resistance.

The purpose of the variable resistor is to adjust the current so that the pointer is at exactly zero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

Multiple range

Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large ones. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the centre scale reading on any range.

Digital Multimeter (Fig 20)

Digital multimeters are high input impedance and better accuracy and resolution. It converts an input analog signal into its digital equivalent and displays it. the analog input signal might be digital voltage, an a.c. voltage, a resistance or an a.c/d.c current. The Figure 20 shows the top view of the digital multimeter

Measurement of resistance using multimeter

A moving coil meter can be used to measure unknown resistance by using a circuit configuration. With the test probes short circuited, the ohms adjust control is turned so that the current through the total circuit resistance deflects the meter to the full scale. Now by connecting the test probes across the unknown resistance, the current is decreased, and the deflection on the scale gives you the resistance value. Ohms law states the output current is proportional to the applied voltage. Unit of resistance is ohms.

Measurement of voltage

The moving coil meter has constant resistance so that the current through the meter is proportional to the voltage across it. so the current meter can be used to measure voltage. To extent, the voltage range of the meter, it is necessary to add resistance in series with the meter circuit. In order to measure a.c. voltage, rectification is required. The principle of generating a.c. is by electromagnetic induction is higher. While measuring unknowing voltage levels with multimeter, always range switch should be set to the highest available range and work down from there Unit of voltage is volts.

Measurement of current:

The moving coil meter is sensitive to the current and is therefore an ammeter. For d.c. measurement, the meter is placed in series with the circuit. So the circuit must be broken to connect the ammeter and it becomes the part of the circuit. For A.C. measurement, rectifier type meters are used which will respond to the average value of the rectified alternating current. Unit of current is amperes.

Electrical instruments may be classified based on the following.

– Manufacturing standards

– Function

– Effects of electric current on the instruments.

Manufacturing standards: The electrical instruments may, in a broad sense, be classified according to the manufacturing standards into absolute instruments and secondary instruments.

Absolute instruments: These instruments give the value of quantity to be measured in terms of deflection and instrument constants. A good example of an absolute instrument is the tangent galvanometer. In this instrument the value of current could be calculated from the tangent of the deflection produced by the current, the radius and number of turns of wire used and the horizontal component of the earth's magnetic field. No previous calibration or comparison is necessary in this type of instruments. These instruments are used only in standard laboratories.

Secondary instruments: In these instruments the value of electrical quantity (voltage, current, power, etc.) to be measured can be determined from the deflection of the instruments on the calibrated dial. These instruments should be calibrated in comparison with either an absolute instrument or with one which has already been caliberated. All the instruments used commercially are secondary instruments.

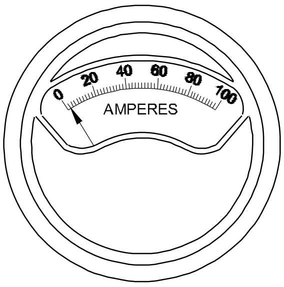
Functions

Secondary instruments are further classified according to their functions, that is, whether the instrument indicates, or records the quantity to be measured. Accordingly, we have indicating, integrating and recording instruments.

Indicating instruments: These instruments, as shown in Fig 2, indicate the value of voltage, current power etc. directly on a graduated dial. Ammeters, voltmeters and wattmeters belong to this class.

Integrating instruments: These instruments measure the total amount, either the quantity of electricity or the electrical energy, supplied to a circuit over a period of time. Ampere hour meters and energy meters belong to this class.

Fig 21



Recording instruments: These instruments register the quantity to be measured in a given time, and are provided with a pen which moves over a graph paper. With this instrument, the quantity can be checked for any particular date and time. Recording voltmeters,ammeters and power factor meters belong to this class. Fig 22 shows such a recording instrument.

Effects of electric current used on electrical instruments: Secondary instruments may also be classified according to the various effects of electricity upon which their operation depends. The effects utilised are as follows.

– Magnetic effect

– Heating effect

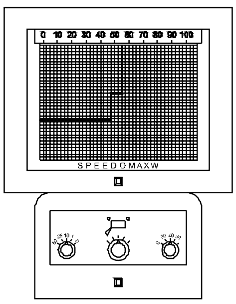
– Chemical effect

– Electrostatic effect

– Electromagnetic induction effect

Essential forces required for an indicating instrument:

Fig 22



The following three forces are essential requirements of an indicating instrument for its satisfactory operation. They are

– deflecting force

– controlling force

– damping force.

Deflecting force or operating force: This causes the moving system of the instrument to move from its `zero' position, when the instrument is connected to the supply. To obtain this force in an instrument, different effects of electric current, such as magnetic effect, heating effect, chemical effect etc. are employed.

Controlling force: This force is essential to control the movement of the moving system and to ensure that the magnitude of the deflction of the pointer is always the same for a given value of the quantity to be measured. As such, the controlling force always acts opposite to the deflecting force, and also brings the pointer to zero position when the instrument is disconnected from the supply.

The controlling force could be produced by any one of the following ways.

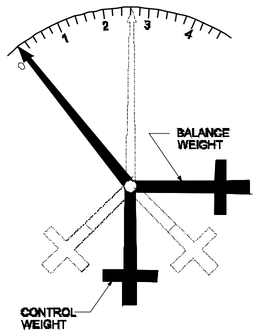
– Gravity control

– Spring control

Gravity control: In this method, small adjustable weights are attached to the opposite extension of the pointer as shown in Fig 23. These weights are attracted by the earth's gravitational pull, and thereby, produce the required controlling force(torque). The instruments with gravity control are to be used in the vertical position only.

When the instrument is not connected to the supply, the control weight and the balance weight attached to the opposite end of the pointer make the pointer to be at zero position as shown in Fig 23. When the instrument is connected to the supply, the pointer moves in a clockwise direction, thereby displacing the weights as shown in dotted lines in the figure. Due to the gravitational pull, the weights will try to come to their original vertical position, thereby exerting a controlling force on the movement of the moving system.

Fig 23



Spring control: The most common arrangement of spring control utilises two phosphor-bronze or beryllium-copper spiral hair-springs A and B, the inner ends of which are attached to the spindle S as shown in Fig 24. The outer end of the spring B is fixed, whereas that of A is attached to the end of a lever `L' pivoted at P, thereby enabling the zero adjustment to be easily effected when needed.

The two springs A and B are wound in opposite directions so that when the moving system is deflected, one spring winds up while the other unwinds, and the controlling force is due to the combined torsions of the springs.

These springs are made from such alloys that they have:

– high resistance to fatigue (can be wound or unwound several times without loosing the tension)

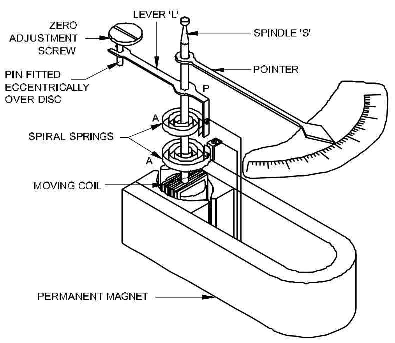
– non-magnetic properties (should not get affected by external magnetism)

– low temperature cofficient (do not elongate due to temperature)

– low specific resistance (can be used for leading current `in' and `out' of the moving system).

Spring controlled instruments have the following advantages over the gravity controlled instruments.

Fig 24



SPRING CONTROL MOVING COIL INSTRUMENT

EMN15361O

Ohm meter

Resistances could be broadly classified according to their values as low, medium and high resistances.

Low resistance: All resistances of the order of 1 ohm and below, may be classified as low resistances.

***Example**:* Armature and series field resistances of large D.C. machines, ammeter shunts, cable resistance, contact resistance, etc.

Medium resistances: Resistances above 1 ohm and upto 100,000 ohms are classified as medium resistances.

***Example**:* Heater resistance, shunt field resistance, relay coil resistance etc.

High resistances: Resistances above 100000 ohms are classified as high resistances.

***Example**:* Insulation resistance of equipment, cables etc.

Medium resistances could be measured by instruments like Kelvin's bridge, Wheatstone bridge, Slide wire bridge, Post Office box and ohmmeter. Also special designs of the above instruments allow measurement of low resistances accurately.

However for measuring high resistances, instruments like megohmmeter or Megger is used.

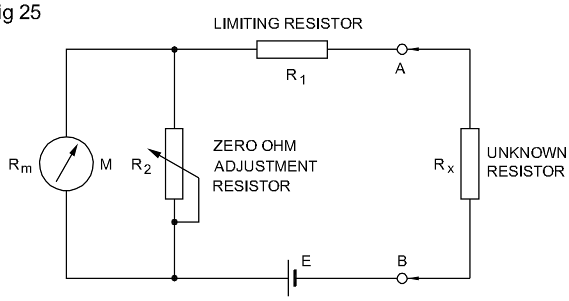
Ohmmeter: The ohmmeter is an instrument that measures resistance. There are two types of ohmmeters, the series ohmmeter, used for measuring medium resistances, and the shunt type ohmmeter, used for measuring low resistances. The ohmmeter, in it basic form, consists of an internal dry cell, a P.M.M.C. meter movement and a current limiting resistance.

Before using an ohmmeter in a circuit for resistance measurement, the current in the circuit must be turned off and also any electrolyte capacitor in the circuit should be discharged, as the ohmmeter has its own source of supply.

Series type ohmmeter

Construction: A series type ohmmeter shown in Fig 25 consists essentially of a P.M.M.C. (`D' Arsonval) movement 'M', a limiting resistance R_1 and a battery 'E' and a pair of terminals of A and B to which the unknown resistance 'R_x' is to be connected and shunt resistance R_2 is connected in parallel to meter 'M' which is used for adjusting the zero position of the pointer.

Fig 25



SERIES TYPE OHMMETER

EMN15361P

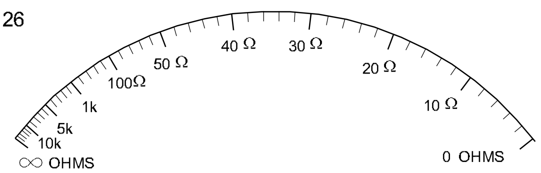
Working: When the terminals A and B are shorted (unknown resistor R_X= zero), maximum current flows in the circuit. Meter is made to read full scale current (I_{fsd})by adjusting the shunt resistance R_2. The full scale current position of the pointer is marked zero(0) ohm on the scale. When the ohmmeter leads (A & B terminals) are open, no current flows through the meter movement. Thereby the meter does not deflect and the pointer remains on the left hand side of the dial. Therefore the left side of the dial is marked infinity (∞) which means that there is infinite resistance (open circuit) between the test leads.

Intermediate marking may be placed in the dial (scale) by connecting different known values of R_x, to the instrument terminals A and B.

The accuracy of the ohmmeter greatly depends upon the condition of the battery. Voltage of the internal battery may decrease gradually due to usage or storage time. As such the full scale current drops, and the meter does not read zero when the terminals A and B are shorted. The variable shunt resistor R_2 in Fig 25 provides an adjustment to counteract the effect of reduced battery voltage within certain limits. If the battery voltage falls beyond a certain value, adjusting the zero adjusting resistance R_2 may not bring the pointer to zero position, and, hence, the battery should be replaced with a good one.

As shown in Fig 26, the meter scale will be marked zero ohms at the right end and infinite ohms at the left end.

Fig 26



SERIES TYPE OHMMETER SCALE

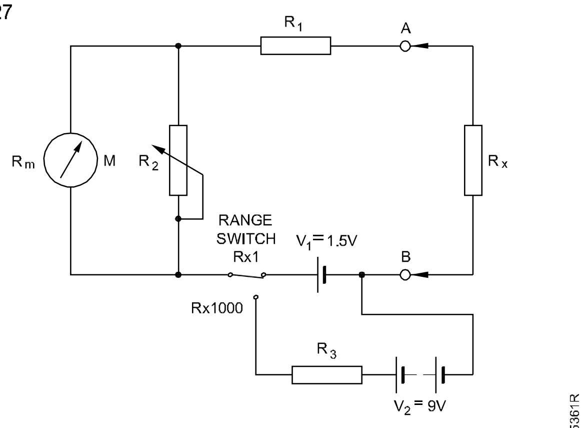
EMN15361Q

This ohmmeter has a non-linear scale because of the inverse relationship between the resistance and current. This results in an expanded scale near the zero end and a crowded scale at the infinity end.

Multiple ohmmeter range: Most of the ohmmeters have a range switch to facilitate measurement of a wide range of resistors, say from 1 ohm up to 100000 ohms. The range switch acts as the multiplying factor for the ohms scale. To get the actual value of measurement,the scale reading needs to be multiplied by the R_x factor of the range switch.

The range switch arrangement is provided either through a network of resistances powered through a cell of 1.5V or through a battery of 9 or 22.5 volts. The latter arrangement is shown in Fig 27. The resistance value of R_3 is so chosen that the full scale current is passed through the meter at the enhanced source voltage.

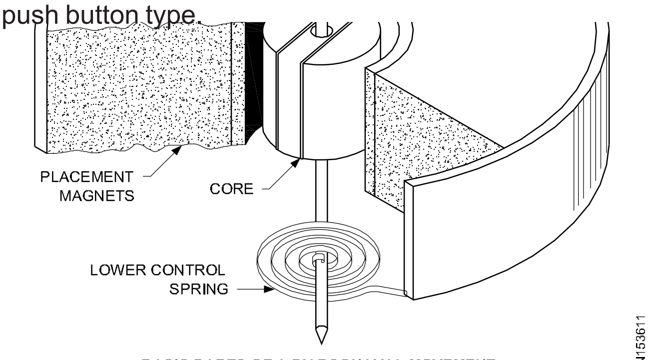
Fig 27



MULTI-RANGE SERIES TYPE OHMMETER

Use: This type of ohmmeter is used for measuring medium resistances only, and the accuracy will be poor in the case of very low and very high resistance measurements.

Shunt type ohmmeter: Fig 28 shows the circuit diagram of a shunt type ohmmeter. In this meter the battery 'E' is in series with the adjustable zero ohm adjust resistor R_1 and the PMMC meter movement. The unknown resistance R_X, which is connected across the terminals A and B, forms a parallel circuit with the meter. To avoid draining of the battery during storage, the switch S is of spring-loaded push button type.



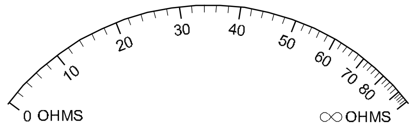
BASIC PARTS OF A D'ARSONAVAL MOVEMENT

Working: When the terminals A and B are shorted (the unknown resistance R_X= zero ohm), the meter current is zero. On the other hand, if the unknown resistance R_X = μ (A and B open) the current flows only through the meter, and by a proper selection of the value R_1, the pointer can be made to read its full scale.

The shunt type ohmmeter, therefore, has the zero mark at the left hand side of the scale (no current) and the infinite mark at the right hand side of the scale (full scale deflection current) as shown in Fig 29. When measuring resistance of intermediate values, the current flow divides in a ratio inversely proportional to the meter resistance and the unknown resistance. Accordingly the pointer takes up an intermediate position.

Use: This type of ohmmeter is particularly suitable for measuring low value resistors.

Fig 29



SHUNT TYPE OHMMETER SCALE

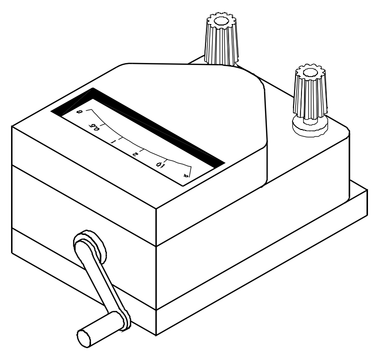
Necessity of megohmmeter: Ordinary ohmmeters and resistance bridges are not generally designed to measure extremely high values of resistance. The instrument designed for this purpose is the megohmmeter. (Fig 30) A megohmmeter is commonly known as MEGGER.

Types of insulation testers: There are two types of insulation testers as stated below.

– Magneto-generator type
– Transistorised type

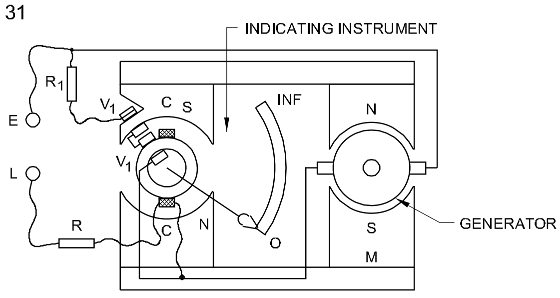
Magneto-generator type Insulation tester: In this tester, the testing voltage is produced by a magneto-generator when the handle is cranked at a speed of 160 r.p.m. approximately, whereas the transistorised insulation tester is incorporated with cells which power the tester. However a testing voltage in the order of 250V to 5000 V DC is produced by internal circuitry

Fig 30



Construction: The megohmmeter consists of (1) a small DC generator, (2) a meter calibrated to measure high resistance, and (3) a cranking system. (Fig 31)

Fig 31



A generator commonly called a magneto is often designed to produce various voltages. The output may be as low as 500 volts or as high as 1 megavolt. The current supplied by the megohmmeter is in the order of 5 to 10 milliamperes. The meter scale is calibrated: either in kilo-ohms (kW) or in megohms(MW).

Working principle: (Fig 31) The permanent magnets supply the flux for both the generator and the metering device. The voltage coils are connected in series across the generator terminals. The current coil is arranged so that it will be in series with the resistance to be measured. The unknown resistance is connected between the terminals L and E.

When the armature of the magnet is rotated, an emf is produced. This causes the current to flow through the current coil and the resistance being measured. The amount of current is determined by the value of the resistance and the output voltage of the generator. The torque exerted on the meter movement is proportional to the value of current flowing through the current coil.

The current through the current coil, which is under the influence of the permanent magnet, develops a clockwise torque. The flux produced by the voltage coils reacts with the main field flux, and the voltage coils develop a counter-clockwise torque. For a given armature speed, the current through the voltage coils is constant, and the strength of the current coil varies inversely with the value of resistance being measured. As the voltage coils deflect counter-clockwise, they move away from the iron core and produce less torque. A point is reached for each value of resistance at which the torques of the current and voltage coils balance, providing an accurate measurement of the resistance. Since the instrument does not have a controlling torque to bring the pointer to zero, when the meter is not in use, the position of the pointer may be anywhere on the scale.

The speed at which the armature rotates does not affect the accuracy of the meter, because the current through both the circuits changes to the same extent for a given change in voltage. However, it is recommended to rotate the handle at the slip speed to obtain steady voltage.

Because megohmmeters are designed to measure very high values of resistance, they are frequently used for insulation tests.

Ranges of magneto-generator type insulation tester: The instrument with the following specification is recommended for testing high tension equipment, transformers, mains etc. and apparatus having a high degree of insulation and considerable capacitance.

Ranges up to 50,000 megohms, 2500 volts.

The instrument with the following specification is recommended for contractors and inspectors for testing power circuits, motors etc. operating on 500 volts and for testing mains having moderate capacitance.

Ranges up to 2,000 megohms, 1000 volts.

The instruments with the following specification is suitable for testing house wiring, small motors etc. operating on voltages not exceeding 250 volts.

Ranges up to 50 megohms, 500 volts.

Electronic insulation tester (transistorised Megger)

This transistorised Megger converts low DC voltage (from dry cell) to high DC voltage by using an oscillator, step up transformer and a converter.

The voltage generated at the test terminals of the insulation tester is in the order of 250V or 500V or 1000 V depending upon the design which is again based on the requirement. A moving coil meter (D. Arsonval instrument) with a high resistance in series forms a series ohmmeter and has a dial graduated in megohms similar to the conventional Megger dial.

A spring loaded push-button switch in the cell circuit connects the battery only during measurement so as to increase the life of the battery. A variable resistance used in the oscillator circuit varies the oscillating amplitude of the wave-form so as to vary the DC test voltage. The instrument provides initial zero adjustment which compensates the voltage variation as the cell discharges. Initially, for every testing, the zero reading must be adjusted by shorting the terminals.

Ratings: The rated resistance in megohms and the rated voltage of the insulation resistance testers having the following ranges are recommended by I.S.2992 of 1980.

Rated voltage (DC volts)	Rated resistance (megohms)
250V	20 megohms 50 megohms
500V	20 megohms 100 megohms 1000 megohms
1000V	200 megohms 2000 megohms 20000 megohms
2500V	5000 megohms 50000 megohms
5000V	100000 megohms

The multi-range insulation testers are also available with rated voltage and rated resistance values selected from the above table. The multi-range insulation tester may be provided with a selector switch to change the range

Connection for measurement: When conducting insulation resistance test between line and earth, the terminal `E' of the insulation tester should be connected to the earth conductor.

Precautions

- A megohmmeter should not be used on a live system.
- The handle of the megohmmeter should be rotated only in a clockwise direction or as specified.
- Do not touch the terminals of a megohmmeter while conducting a test.

- Support the instrument firmly while operating.
- Rotate the handle at slip speed.

Uses of a megohmmeter

- Checking the insulation resistance
- Checking the continuity

Examples

a) Between Earth (metallic body) and winding/element/ conductor.

b) Between two windings/conductor.

Energy meter

Necessity of energy meter: The electrical energy supplied by the electricity board should be billed based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single induction type energy meter:

The opeartion of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils in induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. Torque is porportional to the power as in wattmeter. The watt-hour meter must take both power and time in to consideration. The instantaneous speed is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc in is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counteract any friction produced by the rotating aluminium disc.

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc. The faster the disc rotates, the greater the induced eddy currents, and greater the restraining action. This restraining action is necessary to make the speed of rotation proportional to the current taken by the load and also to stop the disc from further rotation due to inertia when the supply is disconnected.

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diameterically opposite holes are drilled in the disc. The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Meter movement: A basic current meter movement by itself can be used to measure voltage. You know that every meter coil has a fixed resistance, and, therefore, when current flows through the coil, a voltage drop will be developed across this resistance. According to Ohm's Law, the voltage drop (E) will be proportional to the current flowing through the coil of resistance R (E = IR). For example, you have a 0-1 milliampere meter movement with a coil resistance of 1000 ohms. When 1 milliampere is flowing through the meter coil and is causing F.S.D. the voltage developed across the coil resistance will be:

$E = I_M R_M = 0.001 \times 1000 = 1$ volt.

If only half that current (0.5 milliampere) was flowing through the coil, then the voltage across the coil would be:

$E = I_M R_M = 0.0005 \times 1000 = 0.5$ volt.

It can be seen that the voltage developed across the coil is proportional to the current flowing through the coil. Also, the current that flows through the coil is proportional to the voltage applied to the coil. Therefore, by calibrating the meter scale in units of voltage instead of in units of current, the voltage in various parts of a circuit can be measured.

Although a current meter movement inherently can measure voltage, its usefulness is limited because the current that the meter coil can handle, as well as its coil resistance, are very low. For example, the maximum voltage you could measure with the 1 milliampere meter movement in the above example is 1 volt. In actual practice, voltage measurements higher than 1 volt will be required.

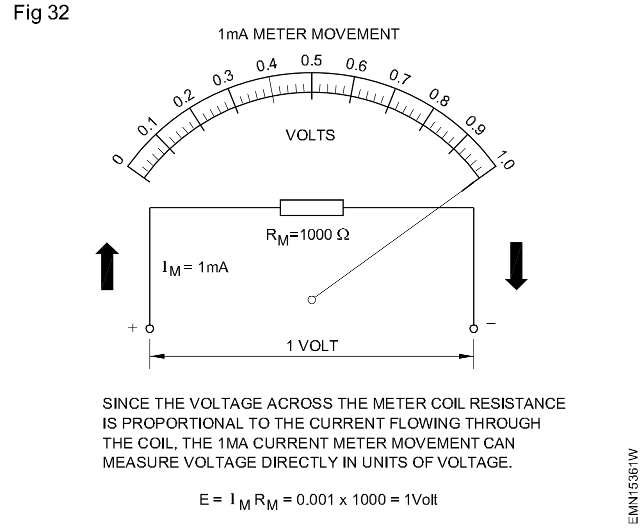
Multiplier resistors: Since a basic current meter movement can only measure very small voltages, how can it measure voltages greater than the $I_M R_M$ drop across the coil resistance? The voltage range of a meter movement can be extended by adding a resistor, in series. The value of this resistor must be such that, when added to the meter coil resistance, the total resistance limits the current to the full-scale current rating of the meter for any applied voltage.

For example, suppose one wanted to use the 1-milliampere, 1000-ohms meter movement to measure voltages up to 10 volts. From Ohm's Law, it can be seen that, if the movement is connected across a 10-volt source, 10 milliamperes would flow through the movement and would probably ruin the meter (I = E/R = 10/1000 = 10 milliamperes). But the meter current can be limited to 1 milliampere if a multiplier resistor (R_{MULT}) is added in series with the meter resistance (R_M). Since a maximum of only 1 milliampere can flow through the meter, the total resistance of the multiplier resistor and the meter ($R_{TOT} = R_{MULT} + R_M$) must limit the meter current to one milliampere. By Ohm's Law, the total resistance is

$$R_{TOT} = E_{MAX}/I_M = 10 \text{ volts}/0.001 \text{ ampere}$$

$$= 10{,}000 \text{ ohms.}$$

Fig 32



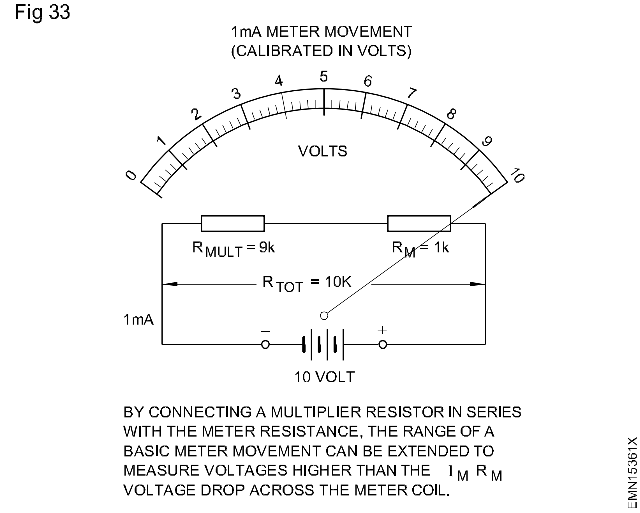
But this is the total resistance needed. Therefore, the multiplier resistance is

$$R_{MULT} = R_{TOT} - R_M = 10000 - 1000 = 9000 \text{ ohms.}$$

The basic 1-milliampere, 1000-ohms meter movement can now measure 0-10 volts, because 10 volts must be applied to cause a full-scale deflection. However, the meter scale must now be re-calibrated from 0-10 volts, or, if the previous scale is used all the reading should be multiplied by 10. (Fig 33)

Multiplying factor (M.F)

Fig 33



$$MF = \frac{\text{Proposed voltmeter range(V)}}{\text{Voltage drop across MC at FSD}} = \frac{V}{V}$$

Calculating the multiplier resistance using M F

$$R_{MULT} = (MF - 1)\, R_M$$

where

R_{MULT} = Multiplier resistance
M F = Multiplying factor
R_M = Meter resistance

A 1 mA meter has a coil resistance of 1000 ohms. What value of multiplier resistor is needed to measure 100V?

$$MF = \frac{V}{v}$$

$$v = I_M \times R_M$$

$$= 1 \times 10^{-3} \times 1000 = 1V$$

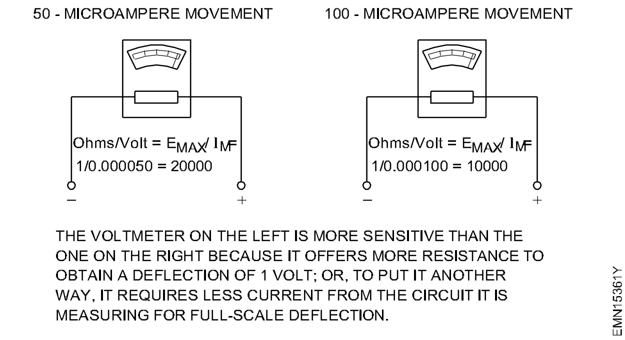
$$MF = \frac{V}{v} = \frac{100}{1} = 100$$

$$R_{MULT} = (MF - 1)R_M = (100 - 1)1000$$

$$= 99{,}000 \text{ ohms.}$$

Sensitivity of voltmeter: An important characteristic of any voltmeter is its impedance or ohms per volt (ohms/volt) rating. Ohms/volt rating is the voltmeter sensitivity. The ohms/volt rating is defined as the resistance required (R_M + R_{MULT}) for full scale deflection. For example, the 1mA 1000 ohms meter movement indicates 1 volt at full scale deflection. Therefore its `ohm/volt' rating is 1000/1 or 1000 ohms/volt (Fig 34) ohms/volt = E_{MAX}/I_M.

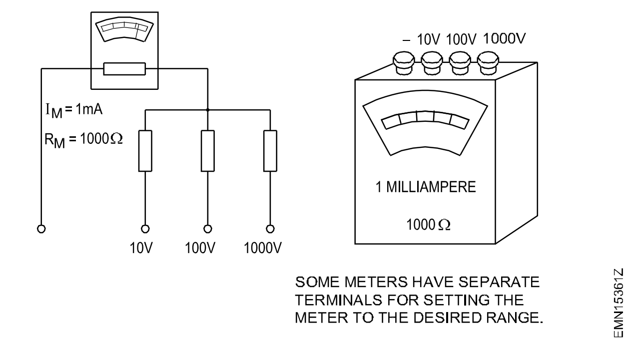
Fig 34



Multi-range voltmeters: In many types of equipment, one encounters voltages from a few tenths of a volt up to hundreds, and even thousands, of volts. To use single-range meters in these cases will be impractical, and costly. Instead, multi-range voltmeters that can measure several ranges of voltage, can be used.

A multi-range voltmeter contains several multiplier resistors that can be connected in series with the meter movement. A range switch is used to connect the proper resistor, or resistors, for the desired range. Also, in some cases, separate terminals for each range are mounted on the meter case. (Fig 35)

Fig 35

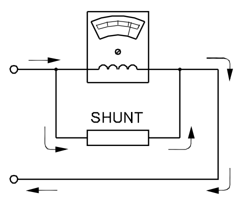


The resistance of the multiplier should not change with temperature. Therefore the material used for multipliers should have very low temperature coefficient of resistance. The temperature co-efficient of resistance of Manganin and constantan are 0.000015 and 0.00001 respectively. Therefore, Maganin and constantan as used for multipliers.

Extension of range of MC ammeters

Shunts: Moving coils of basic meters by themselves cannot carry large currents, since they are made of fine wire. To measure a current greater than that which the moving coil can carry, a low resistance, called a SHUNT, is connected across the instrument terminals as shown in Fig 36.

Fig 36



The shunt, therefore, makes it possible to measure currents much greater than that could be measured by the basic meter alone.

To understand how a shunt can be used to extend the range of a current meter, it is important to understand the behavior of current flow through two resistors connected in parallel. It has already been made clear that current will divide between two resistors in parallel.

It was also made clear that the current through each resistor is inversely proportional to its resistance; that is, if one resistor has twice the resistance of another, the current flowing through the larger resistor will be half the current through the smaller one.

Current flow divides between two resistors parallel in a ratio inversly proportional to their resistance.

Resistor R_2 is twice as large as resistor R_1. Therefore, the current through R_2 will be one-half the current through R_1.

Every meter coil has definite DC resistance. When a shunt is connected in parallel with the coil, the current will divide between the coil and the shunt, just as it does between any two resistors in parallel. By using a shunt of proper resistance, the current through the meter coil will be limited to the value that it can safely handle, and the remainder of the current will flow through the shunt.

Care and Maintenance of meters

Always start by starting the range switch at a value higher than that which you reasonably expect to measure. If not, you could damage the instrument.

Make sure your multi-tester is set in the right mode. Trying to measure voltage with the mode set on “AMPS” could destroy the meter and possibly cause harm to the operator. Also, some meters are destroyed by trying to measure voltage if meter is set to measure resistance.

If you have a choice of finding a fault in a circuit with dangerous voltages on it by either testing voltages or measuring resistance, turn off the power and use the latter.

Keep test leads in good condition-No cracked insulation, keep probes sharp, connectors tight.

Do not place the instrument in a place where it may be pulled off and onto the floor or onto other circuitry.

If using an ammeter that requires that it be inserted in series with the measured circuit, turn OFF the power, make your connections, the turn ON the power and measure. Repeat procedure when disconnecting the meter.

Clamp-on type ammeters do no require the circuit to be opened for insertion of the meter; Safer and faster to use.

When using a HI-POT tester, keep the area clear of these who are not part of the testing.

Always start tests with output control at zero, and the switch in the “OFF” condition. Make sure all equipment grounds are tight, and that the device is connected and used accroding to manufaturer’s instructions .

Controls and functions of Oscilloscope

Objectives : At the end of this lesson you shall be able to
- **explain the use of different controls**
- **explain the use of Alternate and Choped modes for two inputs**
- **explain sweep mode and relevent controls**
- **state the use of different sweep display modes**
- **explain the use of X-Y mode of operation**
- **explain the use of Z -axis input.**

Introduction

In addition to the standard front panel controls of a general purpose oscilloscopes, certain of the controls and functions which are essential while displaying the measurand clearly are discussed in this lesson. Also some tips while using the oscilloscope are also discussed in this lesson.

Focus and Intensity

When the oscilloscope is switched on with the power on switch, the first thing to do is to get a beam trace on the oscilloscope screen. Focus and intensity controls together help to get a sharp, low intensity trace. Lower intensity not only allows to focus the display to a very fine trace, but also increases the life of the CRT of oscilloscope. The trace intensity should never be so bright that it burns a hole in the phosphor coating on the CRT screen.

The damage to the CRT with an extra bright trace is much more severe, particularly when you are working at slower sweep speeds.

Astigmatism

Some oscilloscopes have astigmatism control that should be so adjusted that the focus control is effective on the horizontal and vertical portions of the trace. Simultaneously, astigmatism control should be adjusted with a pulsed waveform displayed on the screen.

Trace rotation

It can be used to make the beam trace perfectly horizontal in the absence of any input signal. It is usually a trimmer whose adjustment screw can be seen on the scope's front panel or on the rear panel.

Beam find

Often we come across a situation where we have switched the oscilloscope ON, increased the intensity level, selected the auto sweep mode and tried to adjust the horizontal and vertical position controls but still have not been able to see the beam trace. Beam find control can be used to locate the beam irrespective of where it is. Pressing this button compresses the range of horizontal and vertical position controls and the result is a dot somewhere on the screen. Keeping the button pressed, adjust the two position controls to bring the dot to the centre of your scope's screen. Release the button and you will see a trace right in the middle of the screen.

Horizontal and Vertical position

Horizontal position (indicated on some scopes as <---> and vertical position (indicated on some scopes as   ) are used to shift the trace horizontally and vertically respectively.

There is usually a common horizontal position control in a dual trace oscilloscope. The position control shifts both the traces in the horizontal direction simultaneously. However, there are two separate vertical position controls for the two channels.

Calibration

All oscilloscopes have a CAL output. The amplitude and the frequency of the calibration signals are indicated on the front panel by the side of the output. The calibration signal can be used to check the amplitude and the time base calibration of the oscilloscope.

Some oscilloscopes provide two calibration signals, both having the same frequency but different amplitudes. Oscilloscope may have two calibration signal outputs i.e. 2Vp-p at 1 kHz and 200mvp-p at 1 kHz should be checked with both the signals. Scope's calibration should be adjusted at regular intervals.

In some oscilloscopes, the output of calibration is indicated by a glowing LED. You will find an LED near the time base setting and LEDs near the vertical deflection factor selector switches of the vertical input channels. Calibration signal is also employed to adjust the probe. The conditions of an under compensated or an overcompensated probe can be easily seen with the calibration signal used as a reference.

Bandwidth limit

Many high sensitivity, high bandwidth oscilloscopes have bandwidth limit control. Though higher bandwidth capability lets you capture high frequency signals, the unwanted high frequency noise also creeps in. It is particularly troublesome when we are viewing a very low level signal (say a few millivolts) of moderate frequency. Due to high bandwidth capability of the scope, the desired signal is often seen accompanied by a lot of hash.

Volts/div and time/div controls

Volts/div and time/div are the controls that need frequent adjustment while viewing and analysing signals. While the former selects vertical sensitivity and is set as per the amplitude of the signal to be viewed, the latter sets sweep speed and its setting is governed by the signal frequency. Both these controls have a selector switch setting and a fine control. The fine adjustment control in both cases should be kept in the calibrated position. The selectable positions in case of these controls are in the decades of 1-2-5.

In most oscilloscopes, there is provision for X5 magnification in the vertical deflection factor control which makes the oscilloscope more sensitive by a factor of 5. That is, 5 mV/

div to 5V/div range becomes 1mV/div to 1V/div. But then we must always remember that this enhancement in vertical sensitivity is at the cost of reduced accuracy. Accuracy specification of typically ±3 percent may deteriorate to ±5 percent. This magnification is usually obtained by pulling the fine adjust control knob in the vertical deflection factor selector switch.

Similarly, a magnification of X10 is usually available in the time base setting, which means that sweep speed at any setting can be increased by a factor of 10 by using this feature. This enhancement is also at the expense of degradations in sweep speed accuracy. The change in accuracy may again be from ±3 percent to ±5 percent. X10 magnification is also achieved by pulling the fine control adjust knob in the base selector switch.

In some oscilloscopes, the time base selector has two switches and a fine adjust. One of the two switches, selectable by bigger of the two knobs, is used to select the main sweep speed. There is another switch concentrically located with a smaller knob. This is used to choose the delayed sweep speed. This second rotary switch is present only in oscilloscopes having delayed sweep facility. Also, the two switches are so internally arranged that the delayed sweep speed can never be set to be slower than the main sweep speed.

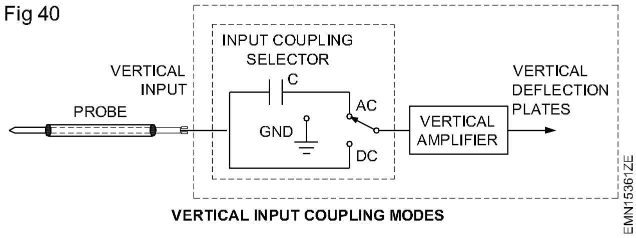
Input coupling

The coupling selector is a three-way switch, to select either DC or AC coupling and ground. In DC coupling, the input signal is fed directly into the amplifier, while AC coupling enables blocking of the DC component of the input signal and passes only the AC component of the signal to the Y amplifier. In the ground position, the input of the Y amplifier is grounded. Hence, care should be taken to ensure that the input signal is not grounded in the ground position and that only the input point of the Y amplifier in the oscilloscope is grounded.

Vertical input coupling modes

All oscilloscopes have two vertical input coupling modes, namely AC coupling and DC coupling as shown in Fig 1. In DC coupling selection, the signal to vertical input BNC receptacle is directly routed to the input of the relevant vertical amplifier as shown in Fig 40 inside the scope. As a result, what you see on the oscilloscope is what you feed into it.

Fig 40



VERTICAL INPUT COUPLING MODES

The DC coupling mode is used in majority of oscilloscope measurements whether it is measuring DC amplitudes or seeing logic low and high levels over analysing transient and repetitive AC waveforms over the specified bandwidth of the oscilloscope. However, when it comes to measuring only the amplitude of a certain DC voltage with no intention of analysing the quality of DC or looking for presence of any noise spikes, the oscilloscope in the DC coupling mode does the job.

In the AC coupling mode, the applied signal is routed to the vertical amplifier input through capacitor (Fig 1) with the result that DC, if any, in the signal gets blocked and only the AC or the time varying part is able to get through and reach the vertical amplifier input. So the displayed waveform is not what you actually feed. For instance, if you want to analyse noise spikes or ripple content riding on a DC you would have no option other than going in for the AC coupling mode.

In the DC coupling mode, the beam would go off the screen as you increase the vertical sensitivity to get an expanded display of comparatively much smaller ripple amplitude. In the AC coupling mode, you could expand the display and make the ripple portion fill the entire screen for detailed analysis.

There is a ground position (designated GND) available on the coupling selector. In this position, the input of the vertical amplifier is grounded and this position can be used to know the position of the beam for zero input.

Input impedance

This is the impedance at the Y input point and is normally specified as 1 M ohms shunted by 25 pF. It is actually the effective resistance and capacitance across the Y input. All oscilloscopes have a standard input impedance of 1M ohm paralleled approximately by 25 pF.

Maximum input voltage

It is the maximum voltage that can be safely applied to the Y input of the oscilloscope. For example, a model specifying the maximum input voltage to be 400V (DC + peak AC) means that the voltage of the signal to the input cannot exceed 400V, which includes both the DC voltage and the peak AC voltage of the signal.

Vertical operating modes and relevant controls

In a dual trace oscilloscope, if the two vertical input channels are designated CH1 and CH2, the available vertical operating modes usually are CH1, CH2, ALT (alternate), CHOP (chopped) and CH1 + CH2. CH1 mode selection implies that the beam traces the waveform applied to the channel-1 vertical input every time it sweeps across the screen.

With CH1 + CH2 mode selected, each sweep across the screen traces channel 2 vertical input waveform. When CH1 + CH2 mode (also referred to as ADD mode) is selected, what we see on the screen is sum of CH1 and CH2 signals as a function of time. Alternate (ALT) or chopped (CHOP) modes are selected when we intend to see two different signals simultaneously.

Alternate or chopped

ALT and CHOP modes are used in two different situations. In the ALT mode, CH1 and CH2 signals are traced on alternate sweeps, i.e if nth sweep traces CH1 signal then (n+1)th sweep would trace the CH2 signal, (n+2)th would trace the CH1 signal again and the process would continue.

If the sweep speed is low, say slower than 10 ms/div or so, we will see a blinking display of the two sweeps. For faster sweep speeds, the two displays appear to be present at the same time. The ALT mode display of two channels thus gives an uncomfortable display when the signal frequencies are low. This mode should preferably be used for viewing high frequency signals.

In the CHOP mode, each sweep across the screen switches the beam between CH1 and CH2 at a very fast rate (the chopping frequency is typically 50 kHz to 100 kHz). In fact, we can see this chopping effect by selecting the CHOP mode and choosing a time base setting faster than the chopping frequency. CHOP mode is not suitable for viewing very high frequency signals as you are likely to miss vital signal information during the time period when the sweep is tracing the other signal. CHOP mode is, however, the right mode to select for viewing signals having frequencies of a few kilohertz or more.

In some oscilloscopes (usually the ones with lower bandwidth) we do not have a separate select button for CHOP and ALT modes. Instead, we have the dual mode in which the oscilloscope has in built circuitry to give a chopped sweep operation for lower frequency signals (or slower time base settings), and an ALT mode for viewing high frequency signals (or faster time base settings). The range of time base setting for which the scope offers a CHOP mode or an ALT mode is usually indicated on the time base selector switch.

In the front panel of a oscilloscope you would notice a light coloured semi-circular band from 0.5 s/div setting to 1 ms/div setting indicating the CHOP mode and another dark semi-circular band from 1 ms/div indicating ALT mode.

LF Rejection

This is a method of coupling the trigger signal with the trigger circuit. The trigger signal is fed to the trigger circuit via a high-pass filter, where the low frequency component (less than 10 kHz) is eliminated. Thus, triggering is effected only by the high frequency component. When the trigger signal contains low frequency noise (particular hum) it is eliminated so that the triggering is estabilished.

HF Rejection

In this method, the trigger signal is fed via a low-pass filter where the high frequency component (more than 30 kHz) is eliminated. Triggering is effected only by the low frequency component.

Triggering modes and relevant controls

All modern oscilloscopes are triggered sweep oscilloscopes, i.e. each sweep across the screen is initiated by a trigger signal either generated inside the scope or supplied externally. The source of trigger signal, the way it is coupled and the controls like ‘trigger slope’, ‘trigger level’ and ‘trigger hold off’ enable you to make full use of the equipment and get a stable display of many a complex waveforms or trigger on the most elusive transient events.

Source of trigger signal

This first relevant control is the one that selects the source of trigger signal. The available options in most of the oscilloscope are internal (INT) line, external (EXT).

When we have selected the INT source of trigger, the trigger signal is generated from the signal to be viewed. A small part of the vertical input signal is taken off, amplified, shaped and then treated as the trigger signal. In a dual channel oscilloscope, where we have two vertical inputs, a separate control decides whether it is a part of CH1 signal or CH2 signal that is to be used for generating the trigger signal. Here, if we select ALT, the trigger signal source is according to the vertical mode displayed. We should also remember that selection of CH1 signal or CH2 signal or ALT trigger arises only when trigger source selection is on INT.

When the trigger source is line, the oscilloscope picks up 50 Hz signal from its power transformer and uses this for producing trigger signal. It is suitable for getting a stable display of signals having power line frequency like ripple on a power supply.

In the EXT mode, the trigger signal is applied externally. The trigger signal amplitude requirements are specified by the manufacturer. Some scopes also have EXT/5 or EXT/10 trigger inputs. The trigger signal applied to this input is alternated by the given factor before it is applied to the trigger circuit. This mode is used when the external trigger signal level is too high.

Trigger source coupling mode

The coupling mode selector determines the way the trigger signal is coupled to the trigger amplifier. The available options on most of the 100 MHz oscilloscopes are DC, AC, Low Freq Rej (low frequency reject), High Freq Rej (high frequency reject) and TV. The Low Freq Rej coupling mode is usually not present in lower band-width oscilloscopes (upto 50 MHz bandwidth).

In DC coupling of trigger source, the trigger signal is directly coupled to the trigger circuitry. This mode is used when triggering is required to be effected including the DC component of the trigger signal. It is suitable for viewing DC and low frequency signals.

In AC coupling, the trigger signal is AC coupled to the trigger circuit. This is the most commonly used trigger source coupling mode as stable triggering can be achieved without being affected by the DC component of the input signal.

In the Low Freq Rej mode any frequency component below a few kilo-hertz present in the trigger signal attenuated. This mode should be used when low frequency components, 50 Hz hum for instance, is present in the trigger signal. High Freq Rej mode is used when any high frequency components present in the triggering signal are creating problems in getting a stable display. In this mode, high frequency components greater than 50 kHz present in the trigger signal are attenuated.

The TV coupling mode is used exclusively for viewing TV video signals. The signal is AC coupled to the TV sync separator circuit. The sync separator picks up the sync signal which is then used as the trigger signal. With this mode we can obtain a stable display of TV video signals.

Trigger slope and level

Trigger slope selection determines the slope of the trigger signal that triggers the sweep. When we select a (+) slope, the sweep is triggered anywhere on positive going or low-to-high transition of the signal. In case of (-) slope, the sweep is triggered anywhere on the negative going or high to low transition of the signal.

The trigger level decides the signal level (positive or negative) where the triggering takes place. If the signal has both positive as well as negative amplitudes, we can trigger on a positive slope and a negative level or a negative slope and a positive level as well. When we select a positive slope, the waveform can be triggered anywhere on the positive slope of this waveform, i.e. from negative peak towards positive peak. The level can be either negative or positive. Similarly, when we select a ($-V_e$) slope, the waveform can be triggered anywhere on the negative slope, i.e. from positive peak towards negative peak. The level can either be positive or negative.

Trigger hold-off control

This control can be used to adjust the pause between initiation of two successive sweeps and is particularly useful for viewing signals that do not repeat symmetrically. In the absence of trigger hold-off feature, it may be difficult to get a stable display of waveform of this kind. The trigger hold-off control can be used to trigger the sweep at the right time.

Sweep modes and relevant controls

The first selection that we have got to do is that of the sweep triggering modes. Usually, three modes are available on almost all oscilloscopes. They are auto (automatic), normal and single sweep modes.

In the auto sweep mode, the sweep generator is a free-running oscillator if there is no triggering signal, internal or external. That is, if the trigger source has been chosen to be INT, we will see a beam trace even in the absence of any vertical input. When a triggering signal is applied, the scope becomes a triggered sweep one and the trigger signal initiates the sweep as per slope and level settings. The auto mode is quite convenient when we are interested in seeing DC voltages or simple waveforms.

In the normal sweep mode, the triggering signal only initiates the sweep. In the absence of any trigger, we do not see any trace on the oscilloscope screen. In the normal mode, we have to carefully select the slope and adjust the level to get a display of the signal. This mode is suitable for viewing complex waveforms and single shot events.

In the single sweep mode, when a triggering signal is applied, the first genuine trigger initiates a sweep and after that all subsequent triggers are ignored. So there is only a single sweep. When the single sweep mode is selected, the oscillosope gets ready to receive the trigger. This mode is very useful for viewing single-shot events.

Sweep display modes

The second selection that needs to be done is that of the sweep display mode. The available choices are the main sweep, delayed sweep, intensified sweep, triggered delayed sweep. These may be designated as A-sweep (mainsweep), B-delayed sweep (delayed sweep), A-intensified (intensified sweep) where the two input channels are referred to as A and B.

The main sweep is what we have been referring to so far. Its speed is set by the main time/div selector switch. It is suitable for most measurements. But what happens when we want to view a small part of a comparatively lower frequency signal on an expanded scale to look for noise glitches? If we try to expand the time base, the desired portion on the waveform is likely to go off the screen and all our efforts to bring it to the centre of the oscilloscope screen with the horizontal position control are rendered unless. One method to overcome this is to use X10 magnifier available with the main sweep. Engaging the magnifier expands the time base by a factor of 10 around the centre of the screen with the result that the desired portion stays on screen. This process is known as magnified sweep.

Magnified sweep too has its own problems. First, the intensity of the sweep diminishes quite a bit on expansion and second, this expansion may not be sufficient to permit a view of very fast glitches, for instance, a few nanoseconds wide glitch sitting somewhere on a waveform with a time period of a few milliseconds.

Delayed sweep is what comes to our rescue in such cases. As mentioned earlier, we have at our disposal two independent time base settings, one for the main sweep and the other for the delayed sweep. To make use of the delayed sweep facility, set the delayed time base at a much faster speed than the main time base. There is also a delay time multiplier (a multiturn potentiometer) control on the panel. Set that to the centre of its range. Engage the intensified sweep button. We would notice a small portion of the waveform being viewed on main sweep getting intensified. This implies that we have engaged the delayed sweep. The width of this intensified portion depends upon the time base setting of the delayed sweep.

The photograph is for a delayed sweep of 5ms/div. The width becomes narrower as we make the sweep faster. Thus, faster the delayed sweep, narrower is the intensified portion and larger is the magnification that we get. The position of this intensified portion is as per the part of the waveform we wish to expand.

After having adjusted the two things, engage the delayed sweep mode. The intensified portion fills the entire screen. In this mode, we can achieve much higher magnification without sacrificing the intensity. In some scopes, there is a provision for viewing the main sweep signal and the intensified delayed signal simultaneously. Most of the 100 MHZ oscilloscopes have this facility. The availability of this feature is indicated by the ALT sweep display mode. To use this facility, depress ALT sweep display instead of main sweep.

B Ends A mode

Sometimes it is observed that when the delayed sweep to main sweep speed ratio is very high, the expanded display in the delayed sweep mode has somewhat reduced intensity. B Ends A mode can be used to increase the intensity of delayed sweep display by ending the main sweep at the minimum required point and increasing the display time for the delayed sweep. This happens because the slow main sweep runs for the full screen and there is very little time for the much faster delayed sweep.

Some oscilloscopes also have triggered delayed sweep facility. Operationally, it is similar to delayed sweep. In the delayed sweep mode, the delay time multiplier can be adjusted to smoothly move the intensified portion on the screen. In the triggered delayed sweep, the intensified portion jumps from one level transition to the next as the adjustment is done. After selecting the desired transition level where you want to trigger the delayed sweep and after selecting a proper slope (+) for positive going and (-) for negative going transition - the delayed sweep is engaged. This mode gives a highly reduced display jitter as the sweep is triggered by a definite trigger signal level.

X-Y operation

In the X-Y mode, the horizontal axis of the oscilloscope also represents a voltage rather than time as is the case in the usual oscilloscope operation. The time base circuitry gets bypassed. The signal to be represented on the horizontal or X-axis is applied to the horizontal deflection input available on the front panel of the oscilloscope having X-Y mode feature.

CH3 input is the horizontal input. It has two selectable horizontal deflection factors of 100mV/div. and 1V/div. i.e. 100mV signal (in case of 100mV/div. selection) and 1V signal (in case of 1V/div. selection) will sweep the beam horizontally by one division. The other signal is applied to the vertical input (one of the two vertical inputs in a dual channel oscilloscope). The result is the desired X-Y display.

A major problem with this kind of X-Y mode of operation is that it offers an uncalibrated fixed sweep speed. This problem is, however, overcome in majority of modern dual channel scopes by letting one of the two vertical inputs to be used as a horizontal input in the X-Y mode. The oscilloscopes having this provision will have the letters ‘X’ and ‘Y’ written near the input connectors of the two channels to indicate X and Y inputs when we select the X-Y mode. Thus, both horizontal and vertical axes have variable calibrated deflection factors.

One can also notice that the vertical position control corresponding to vertical channel being used for X-input in X-Y mode can be used to deflect the X-Y display horizontally. X-Y operational mode has numerous applications like plotting transfer characteristics of devices and circuits, measuring phase difference between two given signals having same frequency, measuring an unknown frequency etc.

Z-axis input

The oscilloscope display has three components: the horizontal component (X-axis component), the vertical component (Y-axis component) and the beam intensity (Z-axis component). The intensity remains constant for a particular setting of the intensity control during normal operation. Most of the scopes have an external Z axis input located on the rear panel. A signal fed to this input can be used to modulate the intensity of the display. Use of this input in conjunction with vertical inputs has many interesting applications.

This class room session is expected to be highly interactive and brainstorming. In this session, the instructor should take-up each of the objective listed above separately and guide the trainees to develope a procedure for carrying out the task. For example, in this classroom session, the instructor should first take-up the first objective “**procedure to calibrate the given CRO using internal calibration signals”** and brief the trainees the nature of task (calibration of CRO).

The instructor should then divide the class into 4 groups and instruct them to draft the procedure to carry out the task in hand (“to calibrate the given CRO using internal calibration signals”). To aid the trainees work, they should be provided with copies of the oscilloscope manuals, related reference books (available in the library) and advised to refer previous lessons on oscilloscope. With these reference materials in hand and the demonstration witnessed by them in the previous exercises, the trainee groups should draft the procedure for carrying out the task in hand (each group should develop one draft).

The draft developed by each group should be discussed with the entire class. During the discussion, the trainees should be motivated to point out procedural errors in the drafts and suitable correction to it. After discussing all the drafts (4 drafts in a class of 16 trainees), the instructor should generate a procedure taking all vital points from the drafts. This shall be used as the final procedure for carrying out the task in the laboratory.

L.C.R. Meter

The LCR meter is an electronic test equipment used to measure among other parameters the impedance of a component (fig 41 and 42)

Fig 41

Usually the device under test (DUT) is subjected to an AC voltage source, then the voltage over and current through device under test are measured. The measured inpedance consists of real and complex components. The phase angle is also an important parameter.

Fig 42

L.C.R. METER

EMN15361ZG

A signal generator with a multimeter and an oscilloscope forms the trio work-horse instrument of an electronic mechanic. The signal generator generate a wide variety of signal waveforms covering broad signals. Therefore, signal generators are classified in two main subdivisions based on waveforms produced and frequency ranges covered. Based on the signal waveforms produced the following main types are popular;

1 The sine-wave generator

It is most common for general-purpose testing. It is widely used in both continuous-wave (CW) and amplitude-modulated (AM) forms.

2 The square-wave generator

It is also commonly found in laboratories and is used for amplifier response testing and in performing other wave-shaping functions.

3 Pulse generator

With a facility for broad selection of pulse duration and repetition rates, these are employed for example for timing and testing electronic circuits both analog and digital.

Square-wave generators

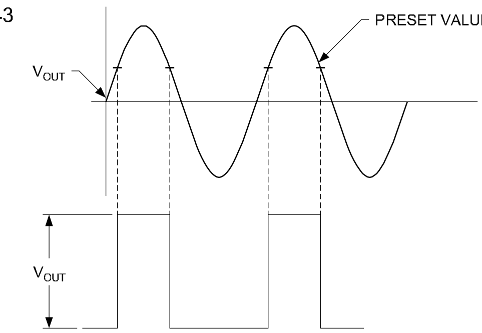
Generators for producing this type of waveform fall into two main groups: the combination sine and square-wave generators and the square-wave generators.

The first group offers a choice of either waveform but does not give the precision of square-wave output of the second group. The square wave generators provides only square waves with high precision. In relatively inexpensive combination generators, a pseudosquare wave is often produced by simply clipping the original sine wave either by diode clipping or overdriven amplifier action. As a result, the products of such action retain the rise and fall portions of the sine wave. In such cases, only an approximate square wave is produced, suitable only for limited wave-shaping observations.

Combination generator

A typical laboratory combination generator generates true square waves as shown in Fig 43 with a Schmitt-trigger circuit. It generally provides frequency ranges of 10 hertz to 100 kilohertz for the square wave section. The rise time of the square wave at full-scale deflection will be generally less than 750 nanoseconds and the tilt is approximately 5 percent at 20 hertz. The peak-to-peak square-wave output will be generally 6 volts, with provision for attenuation in steps of 10 decibels each. Direct output upto 73 volts (p-p) is also provided by-passing the attenuator section.

Fig 43



EMN15361ZH

Square wave generator

A typical laboratory square-wave generator, produces square waves with flat horizontal portions, free of any noticeable overshoot and ringing. The square waves will generally have a rise time of less than 0.02 microsecond (20 nanoseconds) over the frequency range of 25 hertz to 1 megahertz. The frequency, obtained by the setting of a step switch and a continuously variable fine-frequency control can be read directly from the meter provided on the equipment.

Signal generators based on its frequency coverage

The frequency range in a signal generator can affect its operational characteristics markedly. Ranges vary from audio frequency (AF from 20 to 20,000 hertz) to radio frequency. The R-F ranges in telecommunication alone extend well into the gigahertz region, covering ranges where the higher frequencies are millions of times greater than the lower R-F frequencies as given in the Table below.

Table : Regions of the frequency spectrum

Region	Frequency band	ITU Band* No.
(VLF) Very low frequencies	3×10^3 to 3×10^4 (30 kHz)	4
(LF)Low frequencies	3×10^4 to 3×10^5 (300 kHz)	5

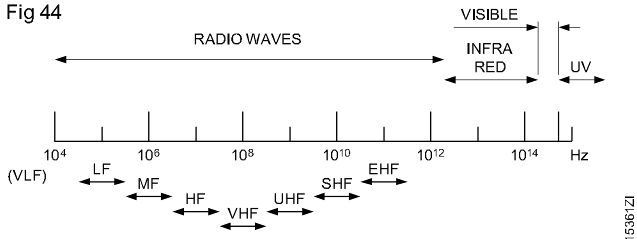
(MF) Medium frequencies	3×10^5 to 3×10^6 (3 MHz)	6
(HF) High frequencies	3×10^6 to 3×10^7 (30 MHz)	7
(VHF) Very high frequencies	3×10^7 to 3×10^8 (300 MHz)	8
(UHF) Ultrahigh frequencies	3×10^8 to 3×10^9 (3 GHz)	9
(SHF) Superhigh frequencies	3×10^9 to 3×10^{10} (30 GHz)	10 (or 1cm)
(EHF) Extremely high frequencies	3×10^{10} to 3×10^{11} (300 GHz)	11 (or 1cm)

***International Telecommunication Band Number**

The more common name microwave frequencies is generally used to span the regions of SHF and EHF. Radar bands in these regions have distinctive names, such as the X-Band at around 10 gigahertz.

Useful frequency regions are being explored at both the lower and upper edges of the electromagnetic spectrum shown graphically in Fig 44.

Fig 44



GRAPHIC VIEW OF ELECTROMAGNETIC SPECTRUM

Audio frequency generators

Signal generation is based on the oscillator. in addition to the common regenerative feed-back amplifier with LC resonant circuit various RC combinations can be used for the oscillating circuit of a signal generator. The one almost universally employed in practical AF generators is the Wien-bridge circuit.

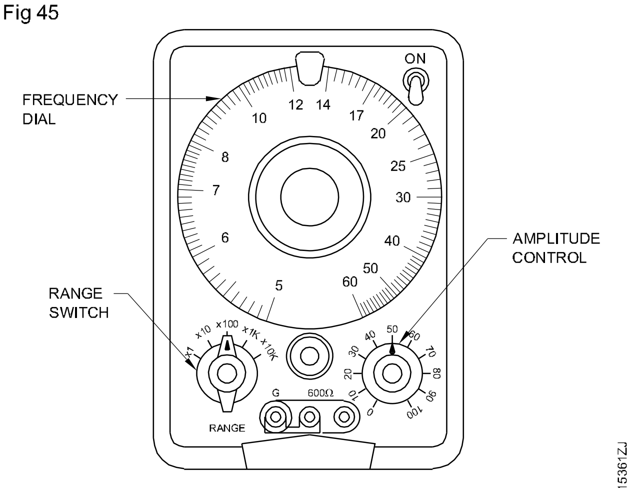
An LC circuit would require bulky nonlinear inductors for changing frequency ranges at lower frequencies. The RC circuit changes range by the use of precision resistors. Moreover, the stability of the RC circuit against changes in load is much better than the stability of an LC circuit, which reacts to load changes with variations in both the frequency and amplitude of the output. Thus even though the RC circuit requires more stages of amplification that required in an LC circuit, the resulting circuit is much more suitable for laboratory purposes and for use in practical instruments.

The AF oscillator shown in Fig 45 generates practically pure sinusoidal waveforms over the range 5 hertz to 600 kilohertz. This range includes signals in the subsonic, audio and ultrasonic bands. There are five overlapping decade bands. The first covers 5 to 60 hertz and the last 50 to 600 kilohertz. At all frequencies, output can be as great as 20 volts runs on open circuit; when delivering a signal to a 600 ohm load, the voltage across the load is one-half the open-circuit voltage, or 10 volts. The power in this matched load is thus E^2/R or

10 x 10 volts/600 ohms = 1/6 watt or 167 milliwatts

Although 167 milliwatts does not look to be large value remember that it represents a comparatively large voltage

Fig 45



AUDIO FREQUENCY GENERATOR

under ordinary test conditions. For any given setting of the amplitude control, the output signal is stable as the frequency is varied and remains undistorted within the tolerances below.

Frequency coverage: 5 hertz to 600 kilohertz (or 1 hertz to 100 kilohertz in alternate model)

Calibration accuracy: ±2 percent under normal conditions

Frequency response: Within ±1 decibel (of a 1000 hertz reference) over entire frequency range.

Frequency stability: Negligible shift in output frequency for ±10 percent line-voltage variations.

Distortion: Less than 1/2 percent below 500 kilohertz (less than 1 percent above 500 kilohertz) independent of load impedance.

Balanced output: May be obtained (at maximum output) with better than 1 percent balance; or may be operated single-ended (with low side grounded), at an internal impedance of 600 ohms, for any portion of output attenuator.

When desired, the output can be obtained ungrounded by using only the high and low output terminals and leaving the ground terminal unconnected. The circuit retains its desirable characteristics throughout a variety of AF and even RF testing conditions where a pure sine-wave signal of constant amplitude over a wide frequency range is required in the laboratory.

Other version of the AF signal generator using the Wien-bridge arrangement, offers some interesting additional features. One such is that it can be synchronized from an external source and extended frequency range of 2 hertz to 2 megahertz.

When an external signal of atleast 1 volt is introduced into the ext sync jack, the oscillator locks in when it is within ±3 percent of the frequency of the introduced signal. This lock-in range can be increased proportionally as the external sync signal becomes greater. If it is a 10 volt sine wave, the frequency of the oscillator may be locked within 30 percent either side of the input signal. Besides the obvious synchronizing application of locking the oscillator output to a crystal-frequency standard, other applications include service as a phase shifter in an amplitude modulation source and an automatic phase-controlled oscillator.

Radio frequency generator

A radio-frequency generator suitable for laboratory applications as a "standard signal generator" must be able to generate frequencies from, around 100 kilohertz upto about 30 megahertz. Also it must have an output signal stable both in frequency and amplitude. It is easy to get an oscillator to oscillate in this range; but difficult to keep the frequency and amplitude constant in spite of slight changes in normal operating conditions.

A ±1 percent change in a nominal output frequency of 1000 hertz (or ±10 hertz) might easily be tolerated for an AF signal; the same change in a 10 megahertz signal would shift the frequency of 100,000 hertz and might easily detune a high-Q tuned circuit. Maintaining and checking the frequency stability of high frequency circuits is greatly simplified by the use of crystal oscillator and crystal calibration circuits. The crystal oscillator is inherently very stable and can provide constant frequencies within much better than 0.01 percent (or 1 part/10,000). When used in a crystal oven it will furnish accuracies of 1 part/1,000,000 (±0.0001 percent). For most laboratory applications, direct reading of the variable-frequency dial to around 1 percent is sufficient, if this dial frequency can be checked against a crystal calibrator whenever greater precision, usually upto ±0.01 percent is desired.

Besides being able to generate a reliably known frequency the standard signal generator must also provide that the signal be accurately calibrated in microvolts of amplitude and be capable of being modulated to a known percentage. The known amplitude calibrated in microvolts is provided by a low-impedance, variable attenuator, monitored by a meter generally labeled carrier microvolts. The low impedance is necessary to maintain constant output as the generator is fed into various loads. The output of the generator is normally provided by a coaxial cable terminated in a low resistance, generally of 50 ohms. The impedance seen by the load, which is this resistor in parallel with the attenuator is usually much lower. This low output impedance is maintained at all settings of the attenuator, which can vary the output from a few microvolts up to calibrated values of 100,000 microvolts and also upto 1 or 2 volts uncalibrated.

Typical specifications of a RF generator

Frequency range: 75 kilohertz to 30 megahertz in different ranges. Each range is push-button selected, and the frequency dial set for any frequency within that range by a reversible motor, which turns the variable capacitors.

Modulation: Continuously variable from 0 to 100 percent either at 400 or 1000 hertz or from an external source.

Output: Continuously variable from 0.1 microvolt to 2.2 volts, at an output impedance of 5 ohms (upto 2 megahertz) rising to 25 ohms (at 30 megahertz). Incidental frequency modulation is less than 0.01 percent at 30 percent amplihertz (or ±10 hertz) might easily be tolerated for an AF signal; the same change in a 10 megahertz signal would shift the frequency of 100,000 hertz and might easily detune a high-Q tuned circuit. Maintaining and checking the frequency stability of high frequency circuits is greatly simplified by the use of crystal oscillator and crystal calibration circuits. The crystal oscillator is inherently very stable and can provide constant frequencies within much better than 0.01 percent (or 1 part/10,000). When used in a crystal oven it will furnish accuracies of 1 part/1,000,000 (±0.0001 percent). For most laboratory applications, direct reading of the variable-frequency dial to around 1 percent is sufficient, if this dial frequency can be checked against a crystal calibrator whenever greater precision, usually upto ±0.01 percent is desired.

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The amplitude and frequency stability of standard-signal RF generator is obtained by careful design of amplifying and isolating circuits, as well as of the primary circuits, whose function is to produce stable oscillations.

Soldering of wires

Objectives : At the end of this lesson you shall be able to
- **explain the purpose of solder and flux and their types**
- **describe the soldering technique**
- **describe the features of soldering iron**
- **explain desoldering and desoldering tools**
- **study the soldering and desoldering station and their specification**
- **explain the desoldering methods using pump and wick.**

Need for soldering

Requirements of an electrical joint

[1] The electrical joint must provide ideally zero resistance or at least a very low resistance path, for the flow of current.

[2] The electrical joint made should be strong enough to withstand vibrations, physical shock, bumps etc, without causing any deterioration to the quality and strength of the joint.

[3] The electrical joint should be able to withstand corrosion and oxidation due to adverse atmospheric conditions.

All the above requirements of an electrical joint can be achieved by making a solder joints.

Solder

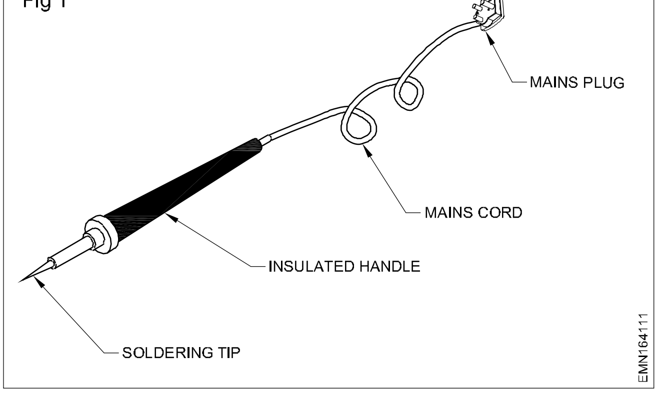
In a soldered joint, the solder is a mixture of metals, generally TIN and LEAD. It is made to melt at a certain temperature. It acts as a filler between the parts of the connection/joint to form a continuous, low resistance metallic path for conduction of electricity.

In soldering, as the metal surface is wetted (free flow of liquid solder over a surface) by the solder, a complex chemical reaction, bonds the solder to the metal surface.

The tin content of the solder diffuses with the metal surface to form a layer of a completely new alloy. The alloy so formed will have the same structure as the constituent metals and retain their metallic properties and strength.

Soldering and soldering irons

Fig 1



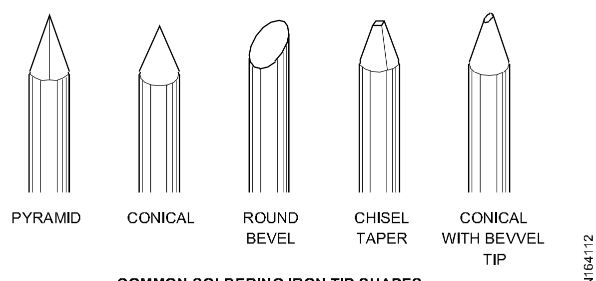
While soldering, the solder is made to melt between the metallic surfaces of the joint, using a soldering iron, as shown in Fig 1. A **soldering iron** is an instrument used to produce the required heat to carry out soldering.

Soldering irons of different wattage ratings starting from 10 watts to more than 150 watts are available commercially. Depending on the type, size and heat sensitivity of the components being soldered, the most suitable wattage soldering iron should be chosen. Most of these soldering iron work on 240V, 50Hz AC mains supply. There are special type irons which work on dc supply also. For soldering delicate components, soldering irons with temperature controlling facility are used. These are known as soldering stations.

Soldering iron tips

Soldering irons are designed to take, a variety of tip sizes and shapes as shown in Fig 2. The choice of the iron and the tip to use depends on, the nature of the joint to be soldered. A proper selection of the soldering iron and tip is important for obtaining good quality soldered joint. To solder effectively, the tip of the soldering iron must be kept clean all times.

Fig 2



COMMON SOLDERING IRON TIP SHAPES

Types of solders

Solders are available in many forms. The type to be chosen depends on, the type of soldering to be carried out. The wire type solder is the most commonly used solder for hand soldering work, using low wattage soldering iron.

Solders available in the market may have different tin-lead proportion in it. For general electronic circuit soldering work, solder with 60% tin and 40% lead is most suited. This solder is commonly called 60/40 solder. This solder has been specially developed to possess superior properties required for electronic circuit work.

Soldering FLUX

A protective oxide layer forms on the exposed surface of most metals. The rate at which the oxide layer is formed varies from metal to metal. The layer forms quickly on newly exposed metal, and over time, the layer slowly become quite thick.

This oxide layer on metals interferes with soldering. Hence, it must be removed before a soldered joint can be made.

The purpose of flux is to first dissolve the thin layer of oxide from the surface of the metals to be joined, and then form a protective blanket over them until the solder can flow over the joint surfaces to form the joint.

However, thick layers of oxide must be removed using an abrasive method as all types of flux are not capable of dissolving their oxide layers.

Types of flux

There are several types of fluxes used in different types of soldering. The type of flux used for soldering electronic components is called **rosin**. Rosin is made from a resin obtained from the sap of trees.

Rosin flux is ideal for soldering electronic components because, it become active at the soldering temperature, but revert to an inactive state when cooled again. An additional advantage is that it is non-conductive.

The rosin has activators or halides added to it. The activators used in rosins are mild acids that become very active at soldering temperatures. These acids dissolve the oxide layer on the metals to be soldered.

Organic and inorganic acid fluxes are available. These fluxes are not suitable for soldering electronic circuits.

Common forms of flux

Flux is available in a variety of forms to suit various types of application. Flux is available as a liquid, paste or a solid block. For most applications flux is often put in the solder itself during manufacture.

Not all flux types are available in all forms. For hand soldering work on electronic circuits, the best form for the flux is either as a liquid or a paste.

Rosin cored solder

Several manufacturers produce solder wire with the flux already included in one or more cores running along its length. This is known as **cored solder**.

The most popular type of cored solder for electronic hand soldering contains rosin type flux. Such solder is known as **rosin cored solder**.

When the solder is heated, the rosin flux melts before the solder. The rosin then flows out over the surface to be soldered ahead of the solder.

The amount of flux contained in the core is carefully controlled by the manufacturer and for most applications it will be sufficient. However, it is a common practice to apply additional liquid flux or flux paste to the joint, just prior to making the joint. This additional flux ensures that, sufficient flux available while the joint is being made. When the soldering has been completed, excess flux if any has to be removed.

Rosin-cored solder is available in different gauges as. It is important to choose a size suitable for the job at hand as given below;

– use 22 gauge for small joints

– use 18 gauge for medium joints

– use 16 gauge for large joints.

Soldering Technique

Soldering a joint

Selection and preparation of the soldering materials is the most time consuming phase of making a solder joint. Heating the joint and applying solder is the least time consuming but, it is the most important part of the soldering process.

Critical factors during soldering

1) Controlling the temperature of the workpiece

2) Limiting of time that a workpiece is held at soldering temperature.These factors are specially critical while soldering electronic components like resistors, capacitors, transistors, ICs etc., Failure to correctly time and coordinate the heating of the joint and add solder, will result in a poor quality joint and may even damage the components.

Stages in soldering

The soldering process can be divided into several distinct stages or phases as given below:

1 Selection and preparation of materials.

2 Heating the joint and adding solder.

3 Cooling the joint.

4 Cleaning the joint.

5 Inspecting the joint.

SELECTION AND PREPARATION OF MATERIALS

Selection of soldering iron wattage

Soldering irons are available in different wattage ratings starting from 10 watts to several 100 watts. The wattage of a soldering iron specifies the amount of heat it can produce. As a thumb rule, higher the physical dimension of the workpiece, higher should be the wattage rating of the soldering iron. Some of the suggested wattage choices are given below:

i) For soldering less temperature sensitive components such as, resistors on lug boards, tag boards, use 25 to 60W iron. For soldering on printed circuit boards, use 10 to 25 W iron.

ii) For soldering highly temperature sensitive components such as, diodes, transistors and integrated circuits, use 10 to 25 watts iron.

Selection of soldering iron tip

To ensure that the joint is heated to the required temperature ideally,

– the area of the tip face should be approximately equal to the area of the joint to be soldered

– the tip should be long enough to allow easy access to the joint.

– the tip should not be too long, as this may result in too low temperature at the tips working face.

In most soldering irons, the tip can be easily removed and replaced.

Selection of tip temperature

Good quality soldering iron tips have numbers punched on them. These numbers indicate the temperature to which the tip can be heated.

Tip No.	Temperature °C	Temperature °F
5	260	500
6	316	600
7	371	700
8	427	800

Selection of tip shape

Suggested soldering tip shapes selection table is given below;

Type of soldering work	Soldering tip shape to choose
Wires, resistors and other passive components on to lug/tag boards	CHISEL TIP
All miniature electronic components except ICs on to lug boards and printed circuit boards (PCB)	BEVEL TIP
Integrated circuits (ICs) on to printed circuit boards (PCBs)	CONICAL TIP

Selection of solder and flux

There are several sizes of the cored solders whose choice depends on the size of the joints to be soldered. Also the tin and lead percentage of the solder should be checked before using the solder. Different tin and lead combinations of solder need different temperatures for it to melt and reach the liquid state.

For electronic soldering applications, solder of tin and lead of 60/40 proportion is used. This solder proportion has a melting point of 200°C which is the required temperature for general purpose soldering irons.

While soldering to make a strong solder joint the flux should melt first, and then the solder. Therefore, while using rosin cored solder, cut off the first 5 to 10mm of the solder using a side cutter,so that any earlier melted portion of the solder blocking the rosin core is removed.

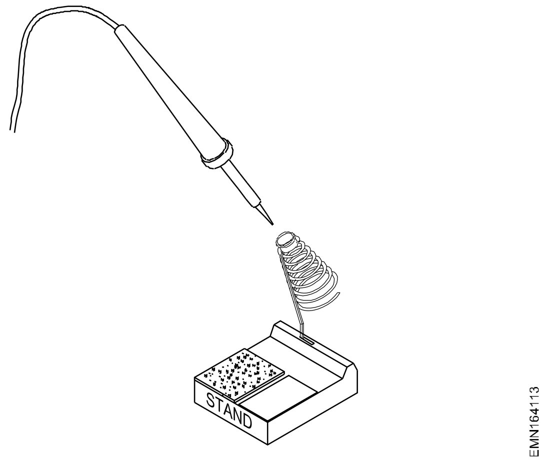
For ease of application, the flux used in addition to the cored flux in solder should be of paste form.

Flux is a chemical substance which has acidic properties. Therefore, it is advised not to touch flux by hand. Use a stick or a thin stiff brush to apply flux on workpieces. Hands should be washed after soldering work.

Soldering stand

Soldering stand plays an important role of retaining the soldering iron tip temperature around the required soldering temperature. The soldering stand should not allow the external temperature to cool the bit. At the same time the stand should not contain all the heat generated.

Fig 3



Soldering stands are specially designed as shown in Fig 3 to fulfill the above requirements. Such a design also prevents accidental burn injuries to the user of the soldering iron.

Another important requirement of a soldering stand is its mechanical stability. When the iron is taken out or placed in the stand frequently, the stand should not topple. An unstable stand is sure to cause burn injuries while carrying out serious soldering work.

Inspection of soldering iron

Most soldering irons are powered by AC mains voltage. This voltage level is high and can give shock if one is careless. Soldering irons will generally have lengthy mains cable. While using the iron, the mains cable gets twisted and will have to bear physical strain. Because of this strain, the insulation of cable may get cut. This may lead to live wires protruding out. The live wires give severe electrical shocks if it touches the user.

Hence, a thorough inspection of the soldering iron is a must before using through it.

Preparation of soldering iron for soldering

HEATING THE JOINT AND ADDING SOLDER

Tips for heating and applying solder to a joint to be soldered are given below:

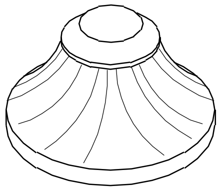
– Do not apply additional flux required for a joint in one place. Apply a small amount of flux around the joint. Do not allow the flux to flow outside the area to be soldered.

– Place the iron tip at the connection such that the tip gets maximum contact with parts to be joined.

– Slowly feed the solder into the joint starting close to the soldering tip and moving towards the edge of the joint.

– Continue applying the solder to the joint until complete wetting of the joint has been achieved and the joint has a concave fillet as shown in Fig 4.

Fig 4



– After enough solder has been applied and solder removed, keep the soldering iron tip on the joint for a moment to ensure that all the flux on the joint has reached the soldering temperature. This will allow majority of the acids within the joint to break down, which otherwise will corrode the joint after a period of time.

Generally the time taken to make a good soldered joint is between 3 to 7 seconds from applying the soldering iron.

COOLING THE JOINT

Tips for cooling a solder joint are given below:

– Allow the joint to cool without assistance. Do not blow air from your mouth or from any other source to cool the joint. Forced cooling, cools the joint much earlier than it has to, resulting in a dry or brittle solder joint which will lead to mechanical and electrical defects of the joint.

– Do not move any part of the joint while it is cooling. This disturbs the chemical bonding taking place. Movement of the joint while it is cooling results in a dry joint.

CLEANING THE JOINT

When a solder joint is made, the amount of flux applied should be just sufficient to make a good joint. But, quite often, there will be a brown waxy substance left on the joint. This is nothing but the flux residue. In its original state this residue is corrosive. Hence, the flux residue or excess flux must be removed from the joint before soldering can be considered as complete.

If the flux residue and excess flux are not properly removed, their corrosive nature of the flux will gradually destroy the component leads and the circuit board. The flux residue is also *tacky* and, if not removed, will collect dust and debris often leading to circuit failure.

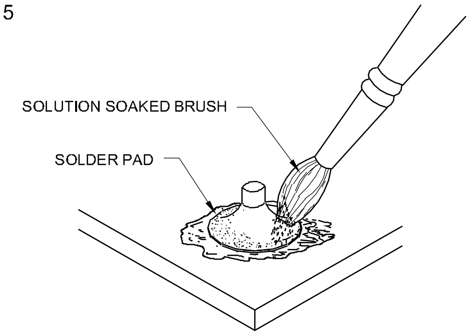
Removal of flux residue requires the use of solvents. The type of solvent depends on the flux used.

IsoPropyl Alcohol (IPA) is one of the solvents used for removing residual flux. It is available either undiluted or pre-mixed with water and can be obtained in pump sprays, aerosols, cans and drums depending on the quantity and style of use.

Cleaning using water/IPA solution

Determine the right method of application. (spray or liquid). Apply the solvent to the soldered joint. Use a clean acid brush, or some other type of stiff brush, to gently scrub the joint as shown in Fig 5, to help dissolve the residue, taking care to avoid splashing the mixture.

Fig 5



When the residue has been dissolved, dry the joint with a lint-free cloth to remove as much of the dissolved residue as possible.

Don't 's While Soldering

- **Do not use a poorly tinned soldering tip.**
- **Do not cool the tip of the iron by wiping it excessively on a damp sponge.**
- **Do not allow the solder to be carried to the joint on the tip of the soldering iron.**
- **Do not attempt to speed up the cooling of the joint by blowing on it.**
- **Do not move the soldered joint until the solder has cooled to solid state.**
- **Do not try and improve a bad solder joint by reheating. All the original solder must be removed and the joint preparation and soldering should be redone.**

Features of soldering iron

There are a number of features that the soldering irons posse need to be examined before a choice of a particular soldering iron is made. These include: size, wattage or power consumption, voltage method of temperature control, anti-static protection, type of stand available, and general maintenance and care issues.

Size: There is a wide variety of sizes of soldering iron available. Obviously those that are smaller will be more suited to fine work, and those that are larger will be more suited to the solder of items that are less delicate. The physical size will also run in parallel with the wattage or power consumption of the iron.

Wattage or power consumption: The power consumption or wattage of a soldering iron is often quoted. The wattage can vary. For basic non-temperature controlled irons, a wattage of 40 watts may be good for general work, and higher if heavy soldering is envisaged. For small PCB work, 15 or 25 watts is good value. For temperature controlled irons slightly higher wattages are common as the temperature control acts more quickly if more heat can be directed to the bit more quickly to compensate for removal of heat via the work item.

Voltage: While most soldering irons on sale in a particular will country have the correct mains voltage, 230V AC and there are also soldering irons that can run from 12 V. Some irons may be made for specialist applications where they need to run from low voltages.

Temperature control: Soldering irons use two main varieties of temperature control. The less expensive irons are regulated by the fact that when they come up to temperature, the loss of heat is the same as the heat generated. In other words they employ no form of electronic regulation. Other, more costly types have thermostatic contol. This naturally regulates the temperature far better.Usually the temperature can be adjusted to the required value.These irons come into their own because when heat is drawn away by a large object being soldered,they will maintain their temperature far better. Those with no regulation may not be able to maintain their temperature sufficiently when soldering a large object,with the result that it is more difficult to melt the solder under these conditions.

Anti-static protection: With the increasing susceptibility of many electronic components,particulary the very advanced integrated circuit chips,static protection is becoming more of an issue. While most components being used by home constructors are often not damaged by static,some are. It is therefore a wise precaution to at least consider whether the soldering iron that is bought is one that has static protection.

Maintenance: When using any soldering iron it is essential that spare parts can be obtained. The soldering iron "bits" used to undertake the actual soldering have a limited life and eventhough the rest of the iron may work for many years,it will be necessary to change the bits at regular intervals. Additionally it is worth ensuring for the more expensive soldering irons,such as those with temperature control,that spare parts are available should they need repair.

Desoldering and desoldering tools

Desoldering

Many a time it may be necessary to disconnect/remove components and wires from a soldered or wired circuit due to the following reasons;

- Component failure(open,short etc).
- Incorrect component installation(polarity,position etc).
- Faulty or defective solder connections(dry solder etc).
- Circuit modifications(replacing,removing components etc).

Disconnecting a component or wire from any soldered circuit involves two separate actions. These are:

1 **DESOLDERING THE CONNECTION** - this action involves removal of the solder from a joint

2 **REMOVAL OF THE COMPONENT** - this action involves removing the component lead from the joint.

De-soldering the connection

De-soldering is a process of heating a soldered joint, to melt the existing solder and removing the molten solder from the joint.

De-soldering makes it easy to separate or pull-out the components,wires from the joint without unnecessary damage to the components and wires.

The heat required to melt the solder is supplied by a soldering iron. But removal of the molten solder from the joint requires the use of one of the following;

– Plunger de-soldering tool or desoldering pump

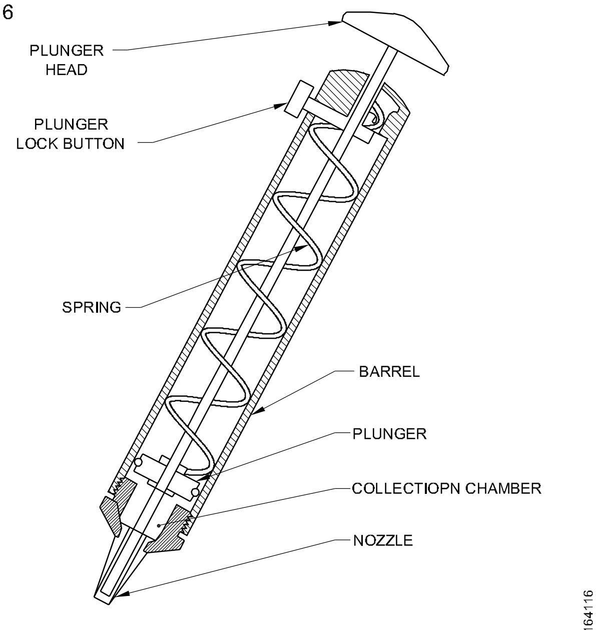
– Wicking braid

But, in many cases, desoldering is done using a nose plier and a soldering iron. First, the joint to be disconnected is heated using the soldering iron. Once the solder at the joint melts, the component lead is pulled away using a nose plier. This method of desoldering can be used for heavy components with strong leads. But this method should not be used for desoldering thin lead delicate components such as transistors, integrated circuits etc., This is because, in this method there is likelyhood of component getting overheated or the leads getting cut or leads getting detached from the body of the component.

PLUNGER DE-SOLDERING TOOL

A typical plunger de-soldering tool is shown in Fig 6.

Fig 6



PLUNGER DESOLDERING TOOL

Plunger type desoldering tool is the most commonly used desoldering tool. This tool works on the principle of air suction. When the plunger head is pushed fully inside gets locked with the help of the plunger button. This is known as cocking tool.

In this condition, the nozzle of the desoldering tool is kept almost touching the joint to be desoldered. If the joint is heated, the solder at the joint melts. If the plunger button of the desoldering pump is pressed, it releases the spring tension and moves the plunger up with a jerk. This causes the air to be sucked-in through the nozzle. Since the nozzle is now in contact with the molten solder, the molten solder is also sucked-in through the nozzle and gets collected in the collection chamber.

When the solder is removed using a plunger de-soldering tool, all the molten solder of a joint may not be sucked by the de-soldering tool at the first attempt, the joint must be reheated and the solder removed in two or three attempts.

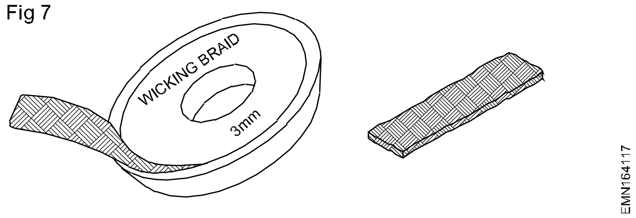
After doing one suction of molten solder, while cocking the tool for second suction, face the nozzle into a dirt collector. This is because, the solder collected at the tip of the nozzle gets pushed out every time the tool is cocked.

After several operations, the waste solder collected within the tool will begin to interfere with its operation. To prevent clogging of nozzle, this solder must be removed periodically and the tool must be cleaned and lubricated.

WICKING BRAID

Wicking braid as shown in Fig 7 is another simple de-soldering aid. This is made of copper and is soaked in flux. Wicking braid is nothing but a tape made of thin strands of copper knitted to form a mesh Fig 7.

Fig 7



A wicking braid relies on the tendency of the hot solder to flow towards the heat source. When a soldered joint is heated via a wicking tape as shown in Fig 23a, the molten solder gets drawn into the wicking braid as shown in Fig 23b. Thus the joint is now free from solder and the component can be removed easily.

The flux content of the wicking braid varies from brand to brand. Generally, the higher the level of flux in the braid, the more efficient it will be at drawing the solder from the joint.

Wicking braids are available in small, hand-held rolls and is supplied in a range of sizes from 0.8 to 6 mm wide so that the correct width of wicking braid can be selected for the joint to be de-soldered.

De-soldering using a wicking braid is commonly used for removing miniature components soldered on printed circuit boards(PCB's).

Removal of component

When solder is removed from the joint, the component can then be removed from the circuit board. If a component was soldered using clinched lead method. it is essential to remove the bridge of solder holding the lead.

To remove the solder bridge, follow the steps.

There are other special tools used for de-soldering such as De-soldering iron and multi-contact de-soldering block.

Soldering and desoldering station

Printed circuit board have changed the face of Electronics industry. Comparing the today's PCBs with the old hardwired, steel chassis devices, they lack the strength making them vulnerable to cracks and related defects. It may sometimes be possible to repair a broken PCB but it is very difficult process. Locating the cracked copper trace on the PCB is the most difficult part of the repair PCBs get damaged very easily. A little rough handing during installation or troubleshoot will invite a crack in the trace. While placing or removing PCBs from their sockets, one needs to put little extra force. This itself might cause a crack in the trace. Similarly when a component on a PCB is removed or inserted a little more heat for a little long period will make copper trace to come off the board's substrate. There may result a microscopic crack in the trace.

Soldering and Desoldering Stations

A typical competitive soldering station with ESD safe by design will comprise of hot air station soldering, LED double digital display. This kind of stations will come with PID controlled closed loop of sensor. The desolder station can give rapid heating, precise and stable temperature, suitable for soldering and de-soldering surface mounted. Such as QFPM PLCC, SOP, BGA etc package of ICs. Hot air station and intelligent cooling system, adopts imported heating wire, for a long life. There are normally light portable handle and suitable for mounting and reworking SMD component by hand for a long time.

Typical specifications of a Solder and Desolder stations:

Hot Soldering Station :

Air Flow	:	0.16 - 1.2 Nm3/h
Pump Consumption	:	45W
Temp. Control	:	150-450°C
Heater	:	250W Metal
Rated Voltage	:	110V/220V 50/60Hz AC
Power Consumption	:	270W
Air Pump	:	Membranous
Solder Equipment	**:**	
Power Consumption	:	60W
Output Voltage	:	24V AC
Temp. Control	:	200-480
Ground Resistance	:	20 ohms

Heater : Ceramic Heating Element

A typical hot soldering station is shown in Fig 8.

Fig 8

Desoldering by using pump and wick

DESOLDERING is the process of removing soldered components from a circuit made on PCB. Desoldering pump along with the soldering iron is used for this purpose. A desoldering pump also known as solder sucker is a small mechanical device which sucks the liquid/molten solder from the joint where the components are mounted. In order to desolder a component from the PCB,we first heat up the solder joint with the soldering iron till the solder liquefies/melts. At the same moment we actuate the soldering pump by pressing the trigger lever and bring the tip over the molten metal and pull the trigger back by pressing a button. At this instant the lever is pulled back and the tip of the pump sucks the molten solder. This process is repeated until all the residue solder is sucked by the pump and the hole on the PCB is clear to solder a fresh component.

To actuate the pump the lever is pressed until there is a click sound which indicates that the lever will remain locked in the same position.

The desoldering pump's buttom head contians a hole through which the molten solder is sucked when the pump is triggered. The head is designed such that the extracted solder does not solidify and block it, consequently the sucked metal can be removed and discarded easily.

Desoldering Wick/ braid

Place the braid over a connection and heat the opposite side with an iron Sometimes adding a small amount of solder to the iron tip can actually speed up the process because that solder will help the iron transfer heat into the braid faster. Cut off and discard tyhe dused wick. The only concern with using desoldering wick/braid is that the components and pads can easily become overheated, especially surface mount pads. As always, try to minimize the time parts are heated. This wick is 1" wide and 5 feet long, which should be satisfactory for most through-hole and many surface mount connections. Width is important because it dictates how much solder a certain length of braid can hold. Too thin, and the solder will quickly fill up the braid and stop it from absorbing. Too thick, and it will be hard not to touch neighboring joints. This particular braid is coated in pure resin - based flux that will leave a non-corrosive, non-conductive, and environmentally friendly residue the residue can be cleaned with alcohol if desired for cosmetic reason, but unless you are making military spec devices, cleaning should not be necessary. The casing is ESD safe.

Switches

Electrical accessories: An electrical accessory is a basic part used in wiring either for protection and adjustment or for the control of the electrical circuits or for a combination of these functions.

Controlling accessories: The accessories which are used to control the circuits or an electrical point like switches are called `controlling accessories'. All the switches are specified in accordance with their function, place of use, type of mounting, current capacity and working voltage. For example - S.P.T. (Single pole tumbler) flush-mounted switch 6 amps 240 volts.

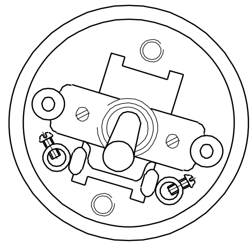
Types of switches according to their function and place of use

1 Single pole, tumbler switch
2 Single pole, two-way switch
3 Intermediate switch
4 Bell-push or push-button switch
5 Pull or ceiling switch
6 Single pole single throw switch (SPST)
7 Single pole double throw switch (SPDT)
8 Double pole single throw switch (DPST)
9 Double pole double throw switch (DPDT)

Of the above 1,2,3,4 and 6 may be either surface mounting type or flush-mounting type.

Single pole, tumbler switch: This is a two terminal device, capable of making and breaking a single circuit only. A knob is provided to make or break the circuit. It is used for controlling light or fan or 6 amps socket circuits. One - way switch is as shown in Fig 9.

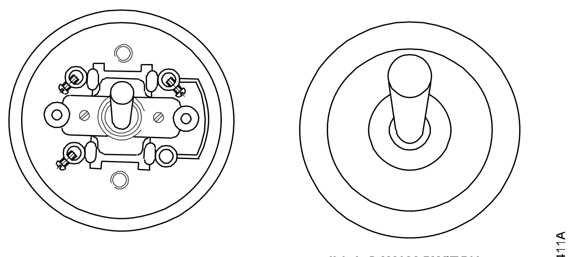
Fig 9



6 AMP SINGLE-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

Single pole, two-way switch: This is a three terminal device capable of making or breaking two connections from a single position as shown in Fig 10. These switches are used in staircase lighting where one lamp is controlled

Fig 10



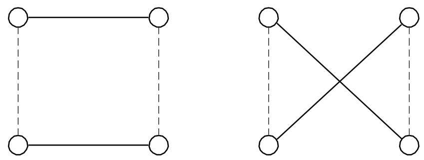
(a) 6 AMP 2-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

(b) A 2-WAY SWITCH WITH A METAL CAP

from two places. Though four terminals could be seen, two are short circuited and only three terminals are available for connection.However, both single way and two-way switches with their cover look alike as shown in Fig 2b but can be differentiated by looking at the bottom. Single way switches will have two terminal posts whereas two-way switches will have four terminal posts.

Intermediate switch: This is a four-terminal device capable of making or breaking two connections from two positions as shown in Fig 11. This switch is used along with 2 way switches to control a lamp from three or more positions.

Fig 11



INTERMEDIATE SWITCH CONNECTIONS

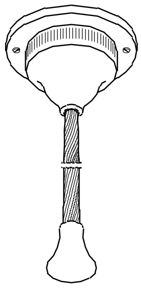
EMN16411B

Bell-push or push-button switch: This is a two-terminal device having a spring-loaded button. When pushed it `makes' the circuit temporarily and attains `break' position when released.

Pull or ceiling switch (Pendent switch): This switch shown in Fig 12 is normally a two-terminal device functioning as a one-way switch to make or break a circuit.

This switch is mounted on ceilings. As the user could operate the switch from a distance through the insulated cord, this could be used safely for operating water heaters in bathrooms or fan or lights in bedrooms.

Fig 12



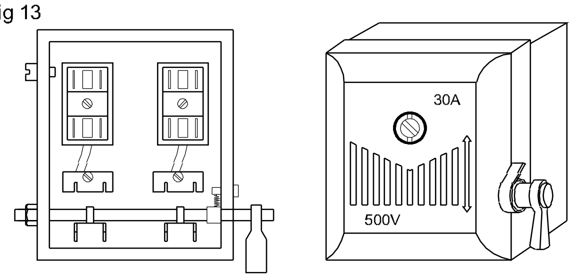
PULL SWITCH

EMN16411C

Double pole switch (D.P.switch): This is a switch with two poles, the two poles being mechanically coupled together. It is operated with a knob. It is also provided with a fuse and a neutral link. These switches are used as main switches to control main or branch circuits in domestic installation.

Double pole iron-clad main switch : This switch shown in Fig 13 is also referred to as D.P.I.C. switch and is mainly used for single phase domestic installations, to control the main supply. It controls phase and neutral of the supply simultaneously. This switch consists of two fuse-carriers. The one in the phase circuit is wired with the fuse and the other in neutral is linked with a brass plate or thick copper wire. These switches should be earthed properly to safeguard the user. The current rating of the switch varies from 16 amps to 200 amperes.

Fig 13



DPIC MAIN SWITCH

EMN16411D

Specification of these switches should have:

– current rating

– voltage rating

– type of enclosure

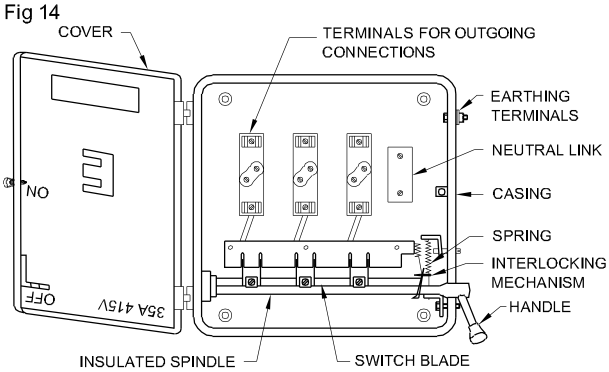
(sheet steel or cast iron).

Triple (three) pole iron-clad main switch: This is shown in Fig 14 and is also referred to as TPIC switch and is used in large domestic installation and also in 3-phase power circuits, the switch consists of 3 fuse carriers, one for each phase. Neutral connection is also possible as some switches are provided with a neutral link inside the casing.

These switches need to be earthed through an earth terminal or screw provided in the outer casing.

The current rating of the switch varies from 16 to 400 amps. Specification of these switches should have

Fig 14



FUSED ICTP `N' SWITCH

EMN16411E

– current rating

– voltage rating

– type of enclosure (sheet steel or cast iron)

– whether with neutral link or otherwise

– rewirable type fuse carriers or HRC type fuse carriers.

Switches used in electric industry

Switching is the most fundamental function in electronics and plays a vital role in every system

Most widely used switch configurations in the industry today are:

1 Single Pole Single Throw (SPST)

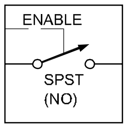
2 Single Pole Double Throw (SPDT)

3 Double Pole Double Throw (DPDT)

Single Pole Single Throw (SPST) is an analog switch used in many industrial instruments and consumer devices to implement test interfaces etc. It consumes very low power with maximum current in the range of 690 nA

Normally open **SPST** switch can isolate multiple peripherals from source and select the required one. (Fig 15)

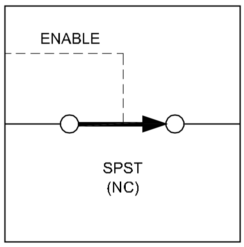
Fig 15



SINGLE POLE SINGLE THROW
NORMALLY

Normally closed **SPST** switch can connect at all times to a peripheral and when not desired the output can be totally stopped by a press of a switch. (Fig 16)

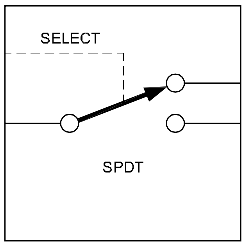
Fig 16



SINGLE POLE SINGLE THROW

Some **SPDT** switches have a select pin and other will have a enable pin. The master in the design for digital control chooses the required trigger action. (Fig 17)

Fig 17



SINGLE POLE DOUBLE THROW

Schmitt trigger action at select and enable control pins results in higher reliability.

Digital bus switches are widely used multiple peripheral and host selection functions, power and clock management, sample and hold circuits, test and debug interfaces etc.

A **dual SPDT** switch in (Fig 18) can be used

1 to route the audio signal from either base band processor to speaker

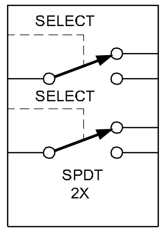
2 to wirelessly route the audio signals between cell phone and an external hands-free device.

The **dual SPDT** and dual SPST switches are available either for simultaneous selection or for simultaneous enable.

Simultaneous select is to connect one of the two signal points or peripherals

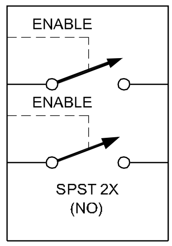
Simultaneous enable is normally open and upon control by master gets enabled remain enabled till disabled.

Fig 18



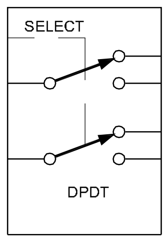
The symbol of dual SPST switch is shown in (Fig 19)

Fig 19



A DPDT switch is a dual SPDT switch into a single select pin as shown in (Fig 20)

Fig 20



DOUBLE POLE DOUBLE THROW

Active electronic components

Objectives: At the end of this lesson you shall be able to
- **state the passive components**
- **explain the active components.**

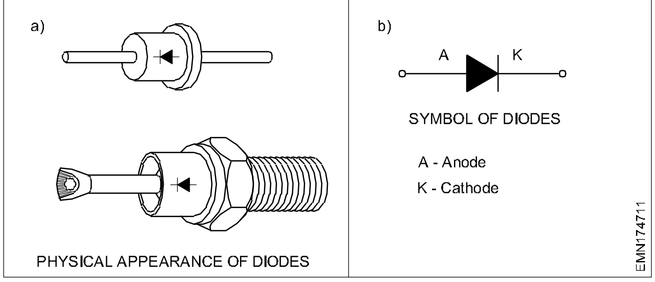
Passive components : Components like resistors, capacitors and inductors used in electronic circuit are called as passive components. These components by themselves are not capable of amplifying or processing an electrical signal. However these components are equally important in electronic circuit as at of active components, Without the aid of passive components, a transistor (active components) cannot be made to amplify electrical signal.

Circuits formed with passive components obey the electrical circuit laws such as Ohm's law, Kirchoff's Laws etc.,

Active components : In electronic circuits, components other than resistors, capacitors and inductors are also used. Namely transistors, diodes, vacuum tubes, SCRs, diacs, zener-diode etc. The application of electrical circuit laws (Ohm's law etc.) in the circuit containing the above components will not give correct results. i.e. these components do not obey Ohm's law, Kirchhoff's law etc. These components are called active components.

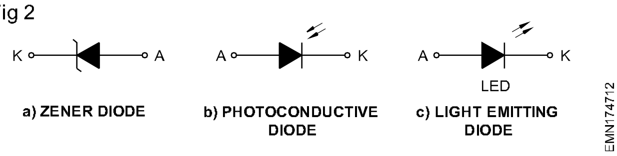
The different active components and the method of representing them by symbols are given in fig 1.

Fig 1



The different types of diodes (Fig 2) used for specific purposes are represented by the symbols given.

Fig 2



Transistor : Figure 3a shows the physical appearance of transistors. There are two symbols to represent a transistor. (Fig 3b). The selection of a symbol is based on either the NPN or the PNP type of transistor.

SCR (Silicon controlled rectifier) : Figure 4a shows the physical appearance of one type of SCR and the symbol is shown in Fig 4 b. SCRs are also called thyristors and used as switching devices.

Fig 3

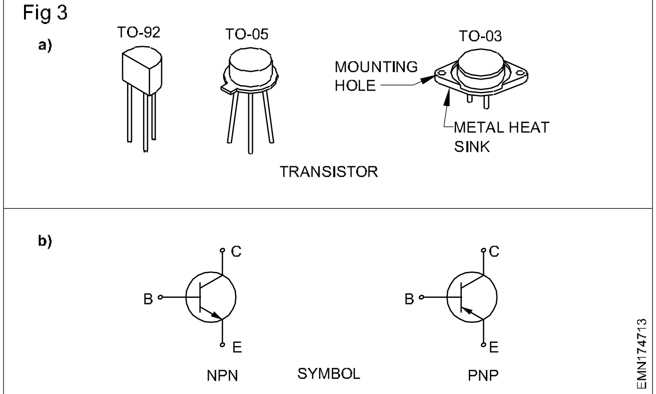
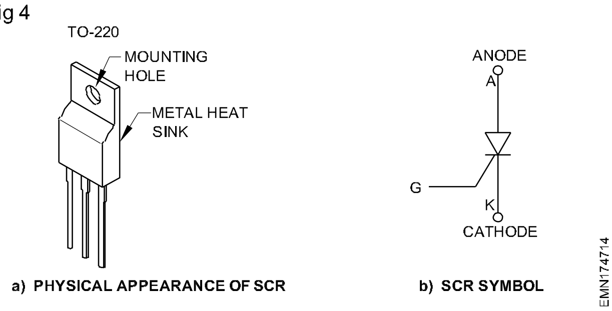
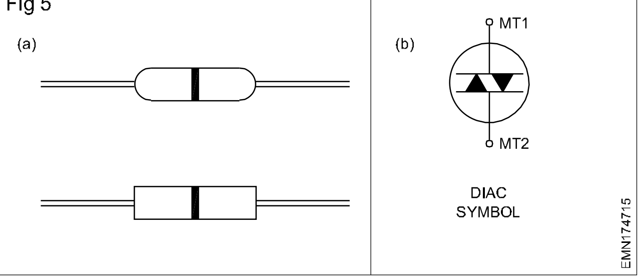


Fig 4



Diac : A diac (Fig 5a) is a two-lead device like a diode. It is a bidirectional switching device. Its symbol is shown in Fig 5b.

Fig 5



Triac : A triac is also a semiconductor device with three leads like two SCRs in parallel. The triac can control the circuit in either direction. (Fig 6)

Bridge rectifier or diode bridge : It is a single package of four semiconductor diodes connected in bridge circuit. The input AC and the output DC leads are marked and terminated as shown in the Figure 7.

UJT (Uni-junction transistor) : It has two doped regions with three leads and has one emitter and two bases.

FET (Field effect transistor) : Fig 9a give a pictorial view of the component, and the related symbol to represent the field effect transistor is shown in Fig 9b. The selection of the symbol is based on whether the FET is a 'N' channel or a 'P' channel one.

Fig 6

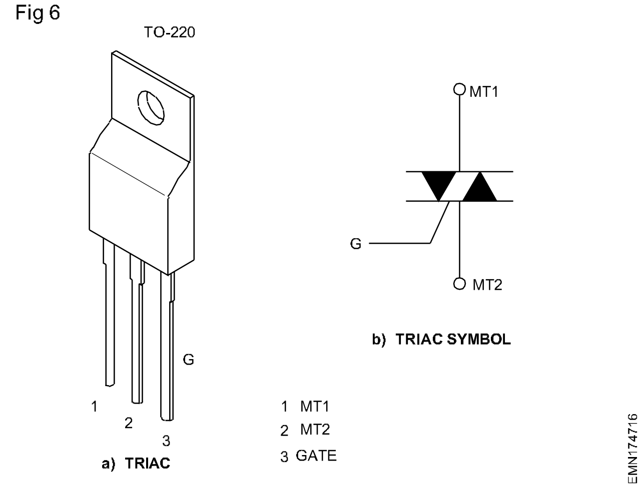


Fig 7

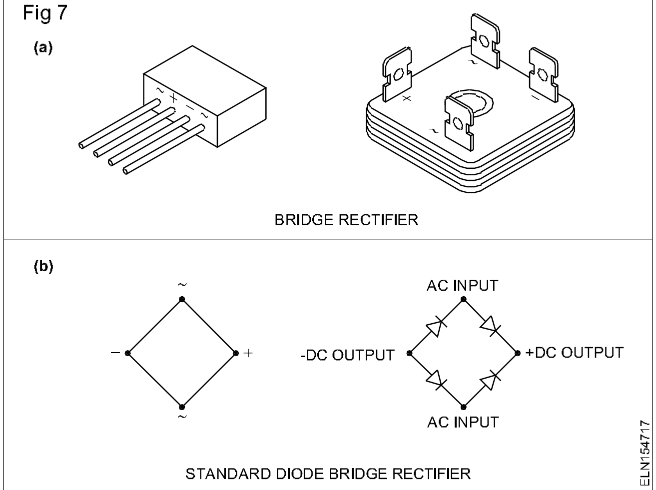


Fig 8

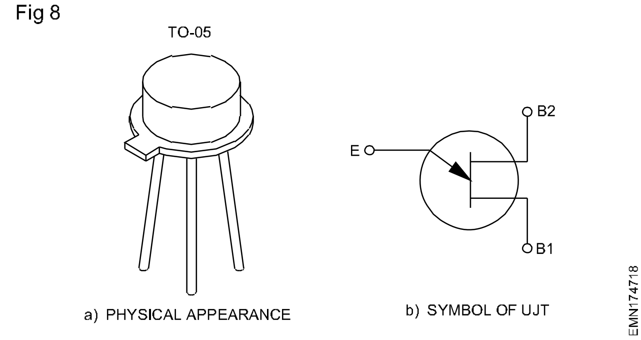
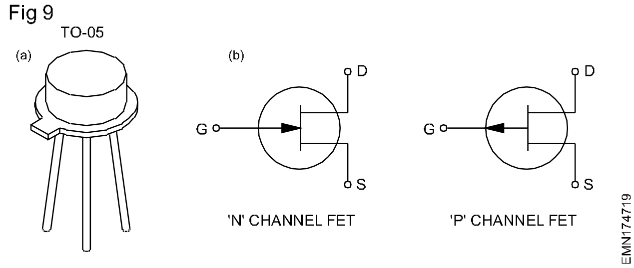


Fig 9



Note:- The devices like transistor, SCR, triac, UJT & FET may look alike due to similarity in encapsulation. They can be identified only by the code numbers and relevant data books.

Passive components - Resistors

Objectives : At the end of this lesson you shall be able to
- **state the function of a resistor in a circuit**
- **explain the classifications of resistors**
- **explain the classifications of fixed value resistors.**
- **state the power rating of resistors**
- **state the tolerance in a resistor**
- **find the value of a resistor using colour code**
- **state the constructional details of fixed and variable resistors.**

Resistors

Resistors are electronic components, used to reduce, or limit, or resist the flow of current in any electrical or electronic circuit. Chart 1 at the end of this lesson shows different types of resistors.

Fig 1 shows a circuit in which the bulb glows brightly. Fig 2 shows the same circuit with a resistor, and the bulb glows dim. This is because, the current in the circuit is reduced by the 1000 ohms resistor. If the value of this resistor is increased, current in the circuit will be further reduced and the light will glow even dimmer.

Fig 1

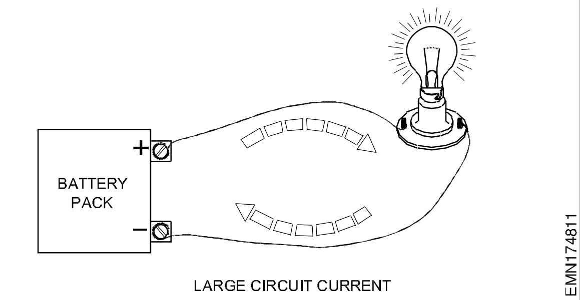
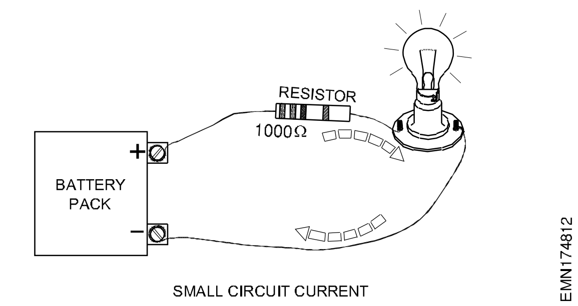


Fig 2



Resistors are made of materials whose conductivity fall in-between that of conductors and insulators. This means, the materials used for making resistors have free electrons, but not as many as in conductors. Carbon is one such material used most commonly for making resistors.

When a large number of electrons are made to flow through a resistor, there is opposition to the free flow of electrons. This opposition results in generation of heat.

Unit of resistance

The property of the resistor to limit the flow of current is known as *resistance*. The value, or quantity of *resistance* is measured in units called **ohms** denoted by the symbol Ω.

Resistors are called *passive devices* because, their resistance value does not change even when the level of applied voltage or current to it is changed. Also, the resistance value remains same when the applied voltage is AC or DC.

Resistors can be made to have very small or very large resistance. Very large values of resistances can be represented as given below;

1000 Ω	= 1 x 1000 Ω	= 1 x kiloΩ	= 1 K Ω
10,000 Ω	= 10 x 1000 Ω	= 10 x kiloΩ	= 10 K Ω
100,000 Ω	= 100 x 1000 Ω	= 100 x kilo Ω	= 100 K Ω
1000,000 Ω	= 1000 x 1000Ω	= 1000 x kiloΩ	= 1000 KΩ
		= 1Mega Ω	= 1MΩ

Classification of Resistors

Resistors are classified into two main categories.

1. Fixed 2. Variable

Fixed value resistors

Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

Fixed resistors are manufactured using different materials and by different methods. Based on the material used and their manufacturing method/process, resistors carry different names.

Fixed value resistors can be classified based on the type of material used and the process of making as follows.

FIXED VALUE RESISTORS

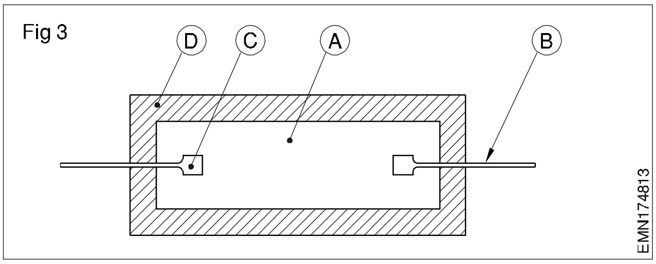
- Carbon composition resistors
- Wire-wound resistors
- Film resistors
  - Carbon - film resistors
  - Metal film resistors
  - Metal oxide film resistors
  - Cermet film resistors
  - Integrated resistors
- Printed resistors

Physical appearance of some types of fixed value resistors is shown in Chart 1 at the end of this lesson.

Carbon Composition Resistors

Construction

These are the simplest and most economical of all other types. Brief constructional detail of the simplest type of carbon composition resistors commonly called *carbon resistor* is shown in Fig 3.



A mixture of finely powdered carbon or graphite(A), filler and binder is made into rods or extruded into desired shapes. Leads(B) made of tinned copper are then attached to the body either by soldering or embedding(C) in the body. A protective layer/tube(D) of phenolic or Bakelite is moulded around the assembly. Finally its resistance value is marked on the body.

Power rating

As already discussed, when current flows through a resistor, heat is generated. The heat generated in a resistor will be proportional to the product of applied voltage (V) across the resistor and the resultant current (I) through the resistor. This product VI is known as *power*. The unit of measurement of power is *watts*.

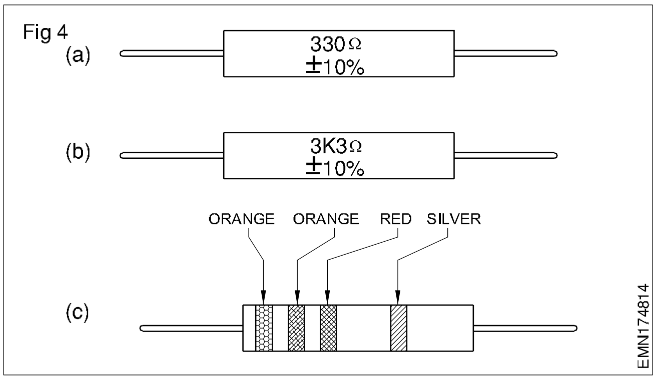
The physical size of a resistor should be sufficiently large to dissipate the heat generated. The higher the physical size, the higher is the heat that a resistor can dissipate. This is referred to as the power rating or wattage of resistors. Resistors are manufacturerd to withstand different power ratings. If the product of V and I exceeds the maximum wattage a resistor can dissipate, the resistor gets charred and loses all its property. For instance, if the applied voltage across a 1 watt resistor is 10 volts resulting in 0.5 Amps of current through the resistor, the power dissipated (VI) by the resistor will be 5 watts. But, the maximum power that can be dissipated by the 1 w resistor is much less. Therefore, the resistor will get overheated and gets charred due to overheat.

Hence, before using a resistor, in addition to its ohmic value, it is important to choose the correct wattage rating. If in doubt, choose a higher wattage resistor but never on the lower side. The power rating of resistors are generally printed on the body of the resistor.

Resistor values - coding schemes

For using resistors in circuits, depending upon the type of circuit in which it is to be used, a particular type, value and wattage of resistor is to be chosen. Hence before using a resistor in any circuit, it is absolutely necessary to identify the resistor's type, value and power rating.

Selection of a particular type of resistor is possible based on its physical appearance. Table 4 at the end of this lesson illustrates the physical appearance of most commonly used fixed value resistors. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms as shown in Fig 4a or using a typographic code as shown in Fig 4b or using a colour code as shown in Fig 4c.



Colour band coding of resistors

Colour band coding as shown in Fig 6c is most commonly used for carbon composition resistors. This is because the physical size of carbon composition resistor is generally small, and hence, printing resistance values directly on the resistor body is difficult.

Tolerance

In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured. This variation will be specified in percentage tolerance. Tolerance is the range(max -to- min) within which the resistance value of the resistor will exist.

Table No.4 of pocket table book gives a list of commercially available standard preferred value of resistors.

Refer to the Pocket Table book, table nos 1, 2 and 3 for methods to read the value of resistors and their tolerance for resistors using 3 band, 4 band and 5 band colour coding schemes.

Typo graphical coding of resistors

In the typographical coding scheme of indicating resistance values, the ohmic value of the resistor is printed on the body of the resistor using a alpha-numeric coding scheme.

Some resistance manufacturers use a coding scheme of their own. In such cases it will be necessary to refer to the manufacturer's guide.

Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

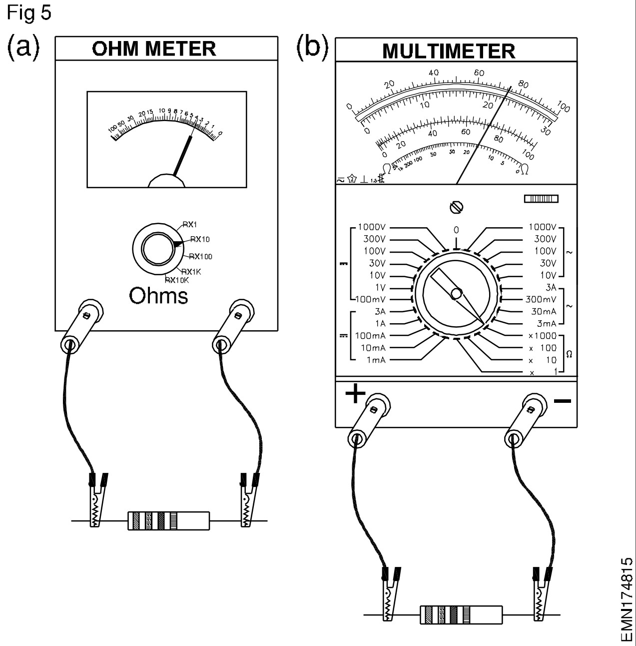
Measuring ohmic value of resistors

It is not possible to read the *exact ohmic value* of a resistor from colour/other coding schemes due to manufacturing tolerance built into the resistors. To find the exact ohmic value of resistors *ohmmeters* are used. When a resistor is placed between the test probes of an ohmmeter as shown in Fig 5a, the meter shows nearest to the exact resistance of the resistor directly on the graduated meter scale. Multimeters are also used to measure the value of resistors as shown in Fig 5b.

When a multimeter is used for resistance measurement, the resistance range switch on the meter should be put to the most suitable resistance range, depending upon the value of resistance being measured.

Table No.11 of Pocket table book suggest the meter ranges for measuring different resistor values accurately.

Fig 5



Wire-wound Resistors

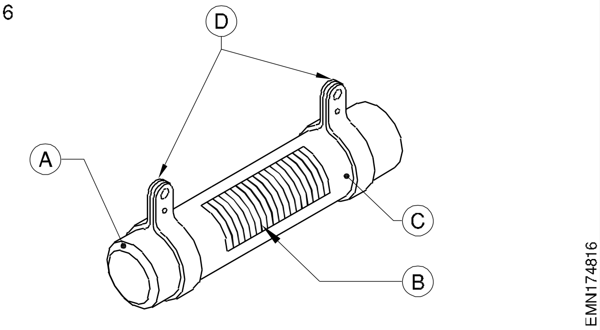
Resistors, in addition to having a required ohmic value, should also be capable of dissipating the heat produced. Carbon by its nature has a limitation in the maximum heat it can dissipate. Carbon resistors become too hot when high current flows through them. This increased heat in carbon resistors changes the ohmic value of the resistors. Sometimes the resistors may even burn open due to excessive heat. Hence carbon resistors are suited only in low power circuits safely up to 2 watts.

This limitation in carbon resistors can be overcome by using wires of resistive materials like Nichrome, Manganin etc., instead of carbon. Resistors made using wires of resistive materials are known as *wire-wound* resistors. These resistors can withstand high temperature, and still maintain the exact ohmic values. In addition, wire-wound resistors can also be made to have fractional ohmic values which is not possible in carbon composition resistors.

Construction

Typical construction of a fixed value wire-wound resistor is shown in Fig 6 . Over a porcelain former (A), resistive wire (B) such as Nichrome, Manganin or Eureka is wound. The number of turns wound depends on the resistance value required. The wire ends are attached to terminals(D).

Fig 6



The entire construction, except the terminals are coated using an insulating binder(C) such as shellac/ceramic paste to protect the wire-wound resistor from corrosion etc. In very high voltage/current application, the resistive wires are coated with vitreous enamel instead of shellac. The vitreous enamel coating protects the wire-wound resistor from extreme heat and inter-winding firing/discharge.

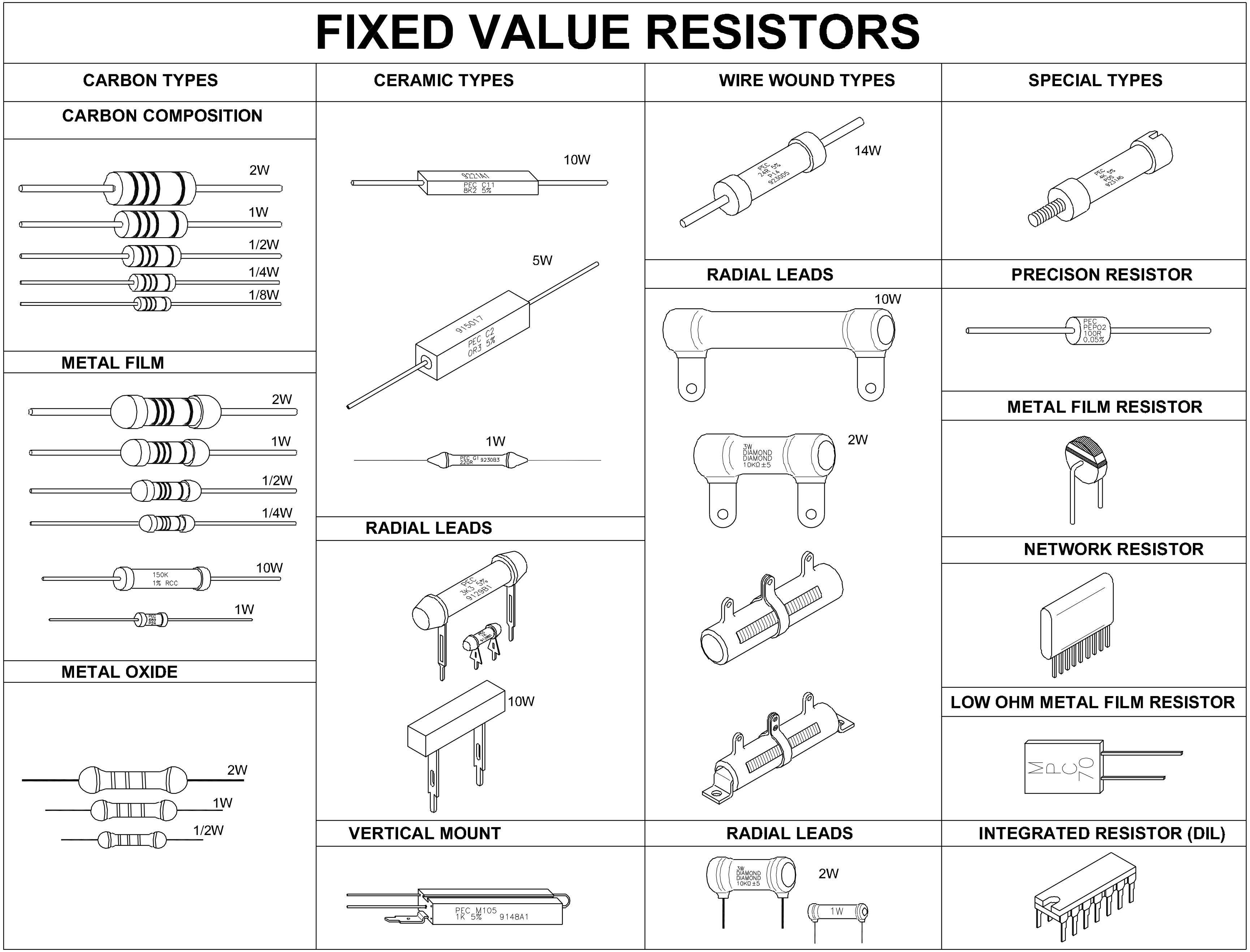
Resistor values

Wire-wound resistors are available from a fraction of an ohm to 100's of Kilo ohms, with a power ratings of 1 watt to several 100s of watts. The higher the power rating, the thicker the resistive wire used, and bigger will be the physical size of the wire-wound resistor.

Applications

Wire-wound resistors are commonly used in electronic circuits where small values, precision values, high wattage ratings are required. A few applications are : regulated power supplies, amplifiers, motor controls, servo control circuits, TV receivers etc.

Chart 1 for lesson 1.7.48 to 1.7.50



Ohm's Law

Objectives : At the end of this lesson you shall be able to
- **state Ohm's law**
- **calculate the total resistance of series resistance circuits**
- **calculate the total resistance of parallel resistance circuits**
- **power dissipation in parallel reistive circuits.**

OHM'S LAW

The quantity of current flowing through a resistor depends on two factors:

1 The ohmic value of the resistor.

2 The voltage applied across the resistor.

If the voltage applied across a resistor is kept constant, higher the resistance of the resistor, lower will be the current flowing through it. In other words current (I) through a resistor is inversely proportional to resistance(R) value of the resistor.

On the otherhand, if the applied voltage (V) across a fixed value resistor is increased, the current flowing through the resistor also increases. In other words current (I) through a resistor is directly proportional to the applied voltage(V) across the resistor.

Combining the above two relationships between resistance(R), current (I) and applied voltage(V), it can be written as,

$$I = \frac{V}{R}$$

This relationship of I = V/R was found by the scientist *George Simon Ohm* and hence this is referred to as *ohm's law.*

The relationship of I = V/R can be expressed mathematically in different forms as

$$I = \frac{V}{R} \text{ or } V = I \times R \text{ or } R = \frac{V}{I}$$

These formulas are used invariably while designing or testing electrical/electronic circuits.

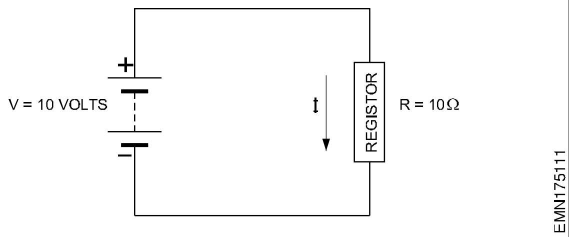
Generalising, ohm's law can be stated as follows:

Under a given constant temperature, the current flowing through a resistor is directly proportional to the voltage across the resistor and inversely proportional to the value of resistance.

This statement holds good not only for a resistor, but in common to all resistive circuits.

Example 1 : Using ohms law, find the current flowing through the resistor in Fig 1.

Fig 1



Solution :

Applied voltage across the resistor is : 10 volts

Resistance value of the resistor is given as 10 ohms.

Therefore current(I) through the resistor by Ohm's law is;

$$I = \frac{V}{R} \text{ Amps.} = \frac{10 \text{ volts}}{10 \text{ ohms}} = 1 \text{ amp.}$$

Current through the resistor is 1 ampere.

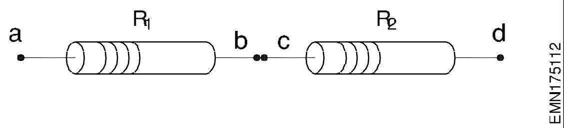
Resistors in series

When resistors are connected end to end as shown in Fig 3, the resistors are said to be in series with each other.

Total resistance of resistors in series

When resistors are connected in series, the total resistance of the series connection will be equal to, the sum of individual resistance values. In Fig 2, total resistance across points a-d will be equal to $R_1 + R_2$.

Fig 2



Example : In Fig 2, if R_1 is 1 K ohms and R_2 is 2.2K ohms. The total or effective resistance between the terminals a and d will be,

(R_1 and R_2 are connected in series).

$= R_1 + R_2$

$= 1.0\ k\Omega + 2.2\ k\Omega = 3.2$ kW.

Current through a series circuit

When resistors are connected in series as shown in Fig 2, the current that flows through R_1 can only flow through R_2. This is because

- there is no other path for any other extra current to flow through R_2

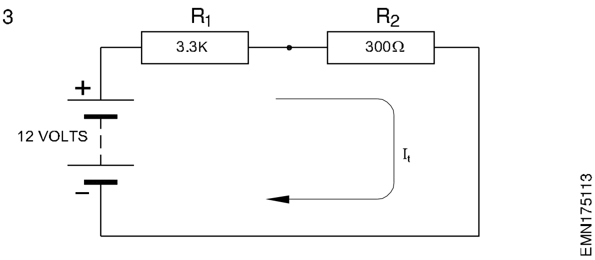
– there is no other path for the current through R_1 to escape from flowing through R_2.

Therefore *in a series circuit, the quantity of current will be the same at all the points (a,b,c,d) of the circuit*.

The quantity of current flowing through the series path is decided by both the resistors put together or the effective resistance of the circuit.

Example : Find the total circuit current(I_t) in the circuit at Fig 3.

Fig 3



Solution :

Resistors R_1 & R_2 are in series. Therefore, the effective resistance of the circuit = $R_1 + R_2$

= 3.3kΩ + 330Ω.

= 3300 + 330 = 3630 ohms.

$$\text{Circuit current } I_t = \frac{V}{R} = \frac{12\text{ V}}{3630\ \Omega} = 0.0033\text{ amps} = 3.3\text{ mA.}$$

Example : Calculate the voltage drops across R_1 and R_2 for the circuit at Fig 3.

Solution :

In the circuit (Fig 3), R_1 and R_2 are in series. Hence the current through both the resistors is the same. This current is 3.3 mA as calculated in the previous example.

From Ohm's Law

Therefore the voltage drop across R_1

= I x R_1 volts

= 3.3 mA x 3.3 kΩ

= $(3.3 \times 10^{-3}) \times (3.3 \times 10^{3})$

= 3.3 x 3.3 = 10.89 volts.

Similarly the voltage drop across R_2

= (3.3×10^{-3}) x 330 ohms

= 1089 milli-volts

= 1.089 volts.

Verification of solution

Since R_1 and R_2 are in series, the sum of the voltage drops across R_1 and R_2 must be equal to the applied battery voltage of 12V. i.e, 10.89 + 1.089 = 11.979 » 12 volts = applied battery voltage.

Power dissipation in resistors

When current flows through a resistor heat is generated. This is because, the voltage driving the current through the resistor is doing some amount of work in overcoming the opposition to the flow of electrons. It is found through experiments and analysis that, the amount of work done by the voltage is directly proportional to the ohmic value(R) of the resistor and square of the current(I^2) flowing through the resistor. This work done is dissipated in the form of heat generated by the resistor. This heat dissipating capacity is known as the power or wattage of a resistor. The unit of power is *Watt*.

Power dissipated by a resistor = I^2 x R Watts.

Where,

I is the current through the resistor

and R is the resistance of the resistor.

Example : If 10 mA flow through a resistor of 10 K ohms, what is the power dissipated by the resistor ?

Power dissipated by the resistor = I^2 x R = (Ix I) x R

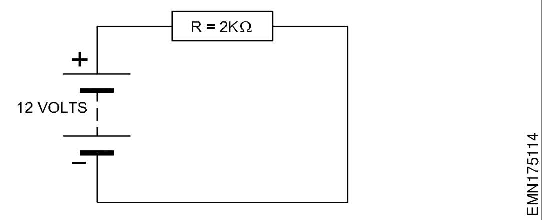
= $(10 \times 10^{-3}) \times (10 \times 10^{-3}) \times (10 \times 10^{3})$

= 1000×10^{-3} = 1000 milli-watts = 1 watt.

The power dissipated by the resistor is 1 watt.

Example : What is the total power dissipated by the circuit given at Fig 4.

Fig 4



Solution :

Current through the circuit is I_t = V/R

= 12V/ 2 kΩ = 6 mA

Power dissipated by the circuit is

= (circuit current)^2 x circuit resistance

= $(36 \times 10^{-6}) \times (2 \times 10^{3})$

= 72×10^{-3} watts

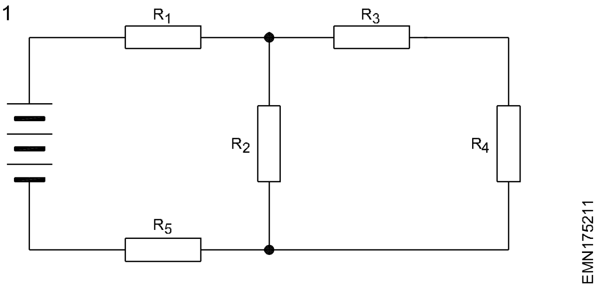
= 72 milli-watts = 0.072 watts.

Kirchhoff's Laws

Objectives: At the end of this lesson you shall be able to
- **state Kirchhoff's current law**
- **state Kirchhoff's voltage law.**

When a circuit consists of several resistors in a complex series - parallel arrangement as in Fig 1, it is difficult to calculate the currents and voltages in the circuit using Ohm's law.

Fig 1



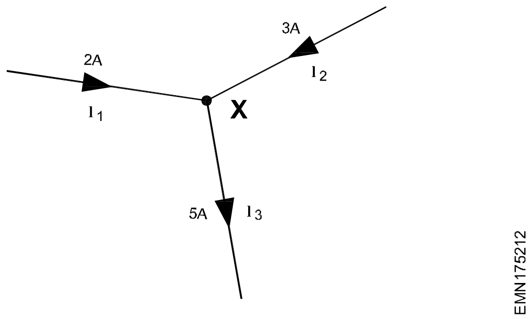
To find current and voltage drops in a complex series - parallel circuit, an easy method was found by a German physicist GUSTAV R. KIRCHHOFF. He formulated two basic laws called,

1. Kirchhoff's Current law
2. Kirchhoff's Voltage law.

1 KIRCHHOFF'S CURRENT LAW:

This law is illustrated in Fig 2.

Fig 2



KIRCHHOFF's Current law states that the sum of currents entering any point in a circuit is equal to the sum of currents leaving that point.

In Fig 2 currents I_1 and I_2 are entering a point X. Current I_3 is leaving the point X.

From Kirchhoff's current law, $I_1 + I_2 = I_3$ ....[1]

This equation can also be written as,

$I_1 + I_2 - I_3 = 0$ ....[2]

From equation 2, Kirchhoff's current can also be stated as The algebraic sum of currents entering and leaving any point in a circuit must be equal to zero .

To determine the algebraic sign of currents,

– consider all currents going into a point as positive and all currents going away from that point as negative.

In Fig 2 , I_1 & I_2 will have positive sign as they are going into point whereas I_3 will have negative sign as it is going out of the point X.

Hence we can also write the Kirchhoff's Current equation as,

At point X,

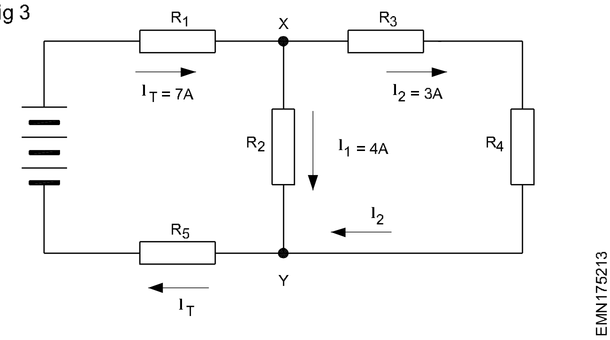
$$(+I_1) + (+I_2) + (-I_3) = 0$$

Simplifying, $I_1 + I_2 - I_3 = 0$

Substituting current values given in Fig 2,
2Amps + 3Amps - 5Amps = 0.

For the circuit shown in Fig 3, Kirchhoff's Current equation at nodes X and Y can be written as follows:

Fig 3



At node X $I_T - I_1 - I_2 = 0$

$7A - 4A - 3A = 0.$

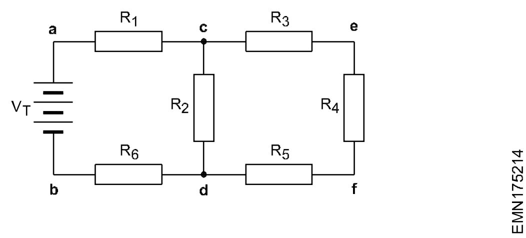
At node Y $I_1 + I_2 - I_T = 0$

$4A + 3A - 7A = 0.$

KIRCHHOFF'S VOLTAGE LAW

In the circuit shown at Fig 4, consider the two closed paths a-c-d-b-a and a-e-f-b-a. These closed paths are called as loops. Each closed path has several resistors and there will be a voltage drop across each resistor. KIRCHHOFF's voltage law states that *The algebraic sum of voltages around any closed path is zero.*

Fig 4



To find the algebraic sum of voltages around a closed path,

– start from any point, go around the path and come back to the same point from where you started.

Example: *Referring to Fig 5, the method of going through a closed path is,*

– start from point **a**, go through points **c,d,b** and return to point **a**.

To determine the signs for voltage drop across the resistors in Fig 5,

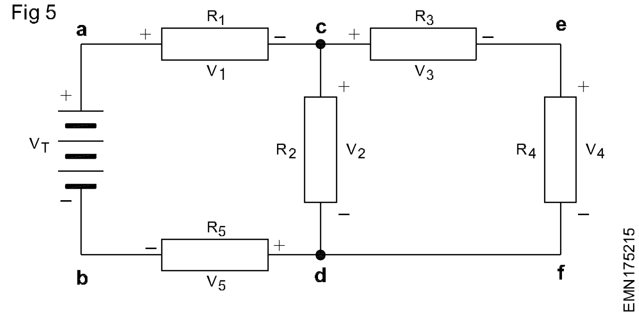
– mark the polarity of each voltage, based on the polarity of source voltage as shown in Fig 5

– go around the path and give +ve sign for the voltage whose +ve terminal is reached first or give -ve sign for the voltage whose -ve terminal is reached first.

Write the loop equation considering the voltage sources also.

To write the loop equation for the closed path a-c-d-b-a of Fig 5, proceed as follows:

Fig 5



Taking clockwise direction for going through the loop, start from point a of Fig 5. Go through the chosen loop a-c-d-b-a and write down the voltage drop across the resistors including their signs and equate it to zero as given below;

$+ V_1 + V_2 + V_5 - V_T = 0$ ......[1]

Rewrite the equation as,

$+ V_1 + V_2 + V_5 = V_T$.

Similarly for the closed path a-e-f-b-a,

considering clockwise direction, start from point a of Fig 6. Go through the chosen loop a-e-f-b-a and write down the voltage drop across the resistors including their signs and equate it to zero as given below;

$+ V_1 + V_3 + V_4 + V_5 - V_T = 0$ ......[2]

Rewriting the equation,

$+ V_1 + V_3 + V_4 + V_5 = V_T$.

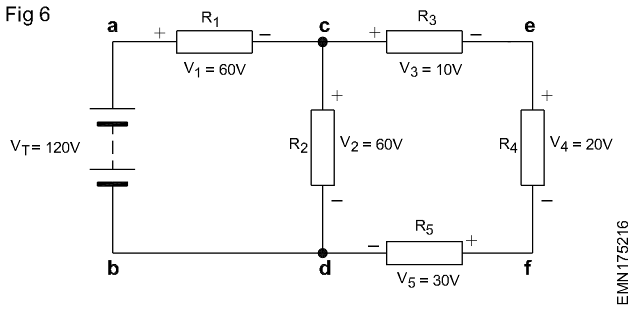
Equations [1] & [2] above state that; In any closed loop, the sum of voltage drops across resistors is equal to the applied voltage. This can be written as:

$S\ V_d = V_T$,

where, $S\ V_d$ is the sum of voltage drops across resistors V_T is the applied voltage.

Example : Write the loop equations for the circuit given at Fig 6.

Fig 6



For the loop a-c-d-b-a, $+V_1 + V_2 - V_T = 0$

or $V_1 + V_2 = V_T$

Verification

60 + 60 = 120

For the loop a-e-f-b-a $+V_1 + V_3 + V_4 + V_5 - V_T = 0$

or $V_1 + V_3 + V_4 + V_5 = V_T$

Verification

60 + 10 + 20 + 30 = 120

For the loop c-e-f-d-c

$+V_3 + V_4 + V_5 - V_2 = 0$

or $V_3 + V_4 + V_5 = V_2$

Verification

10 + 20 + 30 = 60

Circuit with more than one voltage source

Kirchhoff's voltage law is applicable even when, there are more than one voltage source in a circuit. The method of writing loop equations remains the same.

Passive components - Inductors

Objectives : At the end of this lesson you shall be able to
- **state inductor and inductance**
- **state self induction**
- **state the factors determining the value of an inductor**
- **explain mutual inductance**
- **explain the value of inductors in series and parallel**
- **explain Q factor.**

Inductive reactance/DC resistance of Inductance

Inductors are components consisting of coil of wire. The basic function of an inductor is to **store electric energy in the form of magnetic field**, when current flows through the inductor.

Inductance is the electrical property of inductors. Letter 'L' is used as a symbol to represent Inductance. Inductance, is the ability of a device to oppose any change in the current flowing through it. This opposition to change in current, is achieved by the energy stored by it, in the form of magnetic field.

Inductance, and thus an inductor, *chokes off* or restricts sudden changes in current through it. The change may be either increasing or decreasing. Hence inductors are also sometimes called as *Chokes*.

Principle of operation

Recall that, when current begins to flow through a conductor, magnetic flux rings start to expand around the conductor. This expanding flux induces a small voltage in the conductor called *back-emf* or *counter emf*. This induced voltage has a polarity that opposes the source voltage which creates the induced voltage.

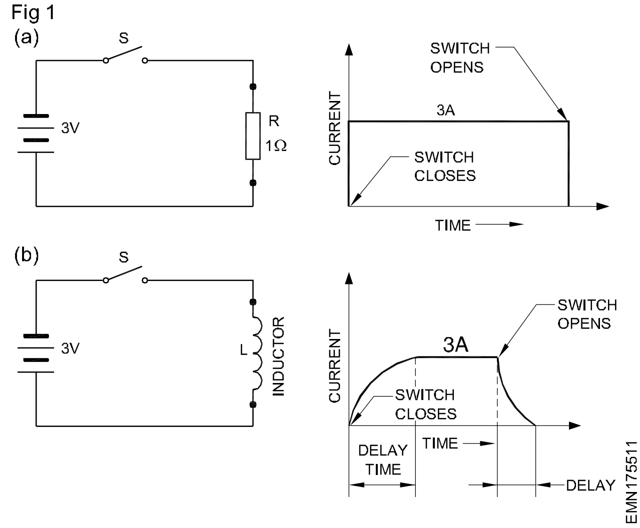
Thus, the inductance in a coil of wire, carrying current, opposes any rise or fall of current through it and tries to keep the current through it constant.

It should be noted that, the inductance cannot completely stop the increase in current because, the induced voltage is caused by the increasing flux, and the increasing flux depends on the increasing current. Therefore, an inductor can restrict only, the rate at which the current can increase or decrease through it.

Example: A Resistor of 1 Ω is connected to a DC source of 3 volts, as shown in Fig 1a. The moment switch S is ON, current will increase from 0 to its steady state value of 3Amps instantaneously, as shown in graph. When the switch is opened, the current drops back to zero just as fast as it raised.

Whereas, when the same DC voltage is applied to an Inductor having a coil resistance of 1Ω as shown in Fig 1b, the current will not increase instantaneously from 0 to its steady value because the inductor in the circuit does not allow it to happen. The current will reach the steady state value after a time delay as shown in graph. The amount of delay depends on the value of inductance and the ohmic resistance of the inductor.

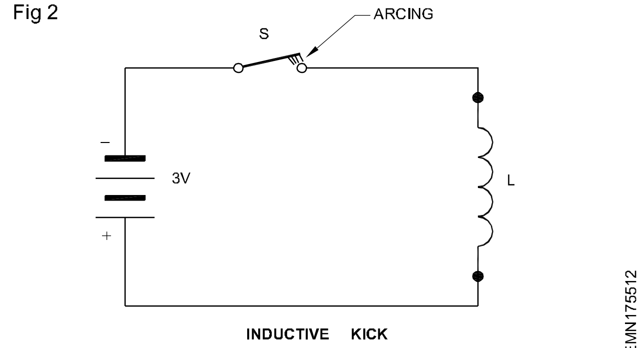
Fig 1



Once the current through the circuit in Fig 1b reaches its steady state value of 3Amps, which is decided by the ohmic value of the inductance, the magnitude of current remains constant and hence the inductive effect stops. At this point, the only opposition the inductor offers is its ohmic/DC resistance.

When the switch S of Fig 1b is opened, the back-emf(bemf) or counter emf(cemf) of the inductor becomes very high, much greater than the source voltage. This high voltage(cemf), prevents the current from instantaneously dropping to zero. It does this by ionizing the air between the switch contacts as the switch opens. This causes the switch contacts to arc and burn as shown in Fig 2. This is known as inductive kick. As the energy stored in the inductors magnetic field gets used up, the switch contacts deionize and current stops.

Fig 2



This property of a coil to induce an emf within the coil due to a changing current through it is termed as **SELF INDUCTANCE**.

Unit of inductance - The Henry

The basic unit of measure of Inductance is Henry abbreviated as H. The unit henry is defined in terms of, the amount of cemf produced when the amplitude of current through the inductor is changing. Based on this , One Henry is that amount of Inductance which develops 1 V of cemf in the coil when the current changes at the rate of 1 Amp/sec.

From the above definition, referring Fig 3,

Inductance, $L = \frac{V_L}{di/dt}$

Where, V_L = Induced voltage

and $\frac{di}{dt}$ = rate of change of current. Refer Fig 3.

Polarity of Induced emf

The induced emf (voltage) in an inductor (cemf) has polarity that always opposes the source voltage (Lenz's law).

Fig 3

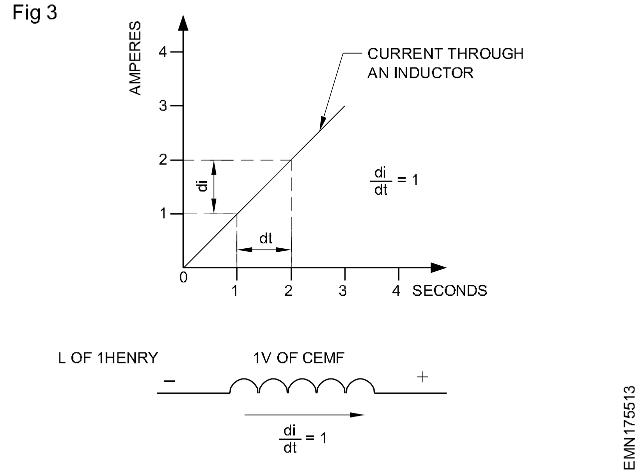


Fig 4 shows an inductor across an AC voltage source. When the applied voltage is increasing from 0 to +ve peak as shown in Fig 4a, the counter emf at end P of inductor will have +ve polarity opposing the increasing source voltage.

In Fig 4b, when the source voltage is decreasing from +ve peak to zero, the cemf at end P of the inductor will have -ve polarity opposing the decreasing source voltage.

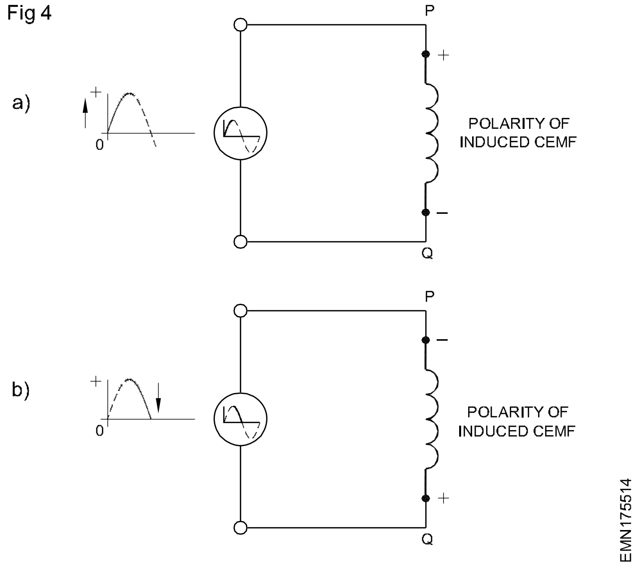
Factors determining value of Inductance

The inductance of an inductor is primarily determined by the following four factors:

1) The number of turns of wire
2) The material on which the coil is wound or the core material
3) The spacing between turns of wire and
4) The diameter of the coil

Fig 5 illustrates the effect of these factors on the inductance value.

Fig 4



Given the parameters listed above, the inductance of a coil can be calculated using the formula,

$$L = \mu \frac{N^2 A}{l} \text{ Henries}$$

where,

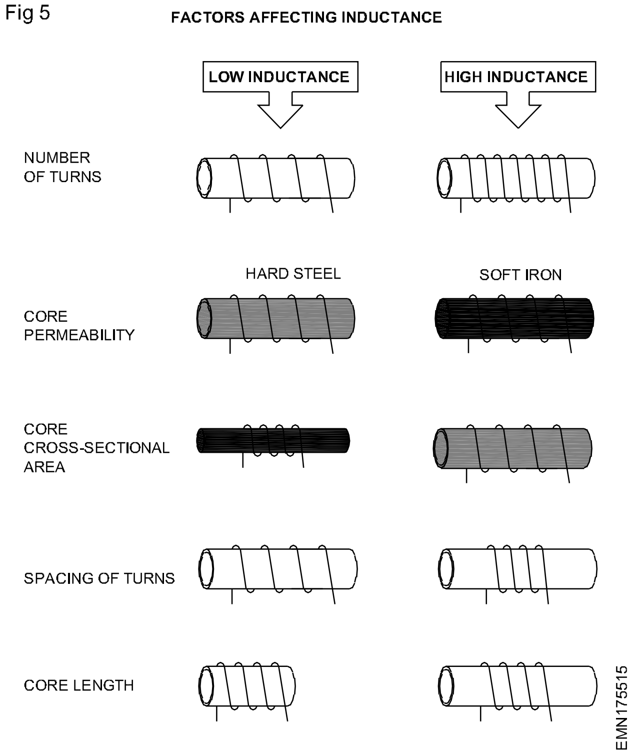
μ = Permeability of the magnetic core around which the coil is wound, in Wb/At-m ($\mu = \mu_o \mu_r$)

N = Number of turns of the coil

A = Area of cross-section of the core in square metres, m^2

l = length of the coil in meters.

Fig 5



Practical inductors and types

For practical applications, inductors are manufactured to give a specified amount of inductance. Value of practical inductors range from a few micro henries for application in high frequency communication circuits upto several henries for power supply ripple filter circuits.

Inductors can be classified under various categories as shown in Chart-1 given at the end of this lesson.

Air core coils have practically no losses from eddy currents or hysteresis. However inductor with air core have their values limited to low values in the range of micro to milli Henries. Air core inductors are used in high frequency applications.

Laminated Iron Core is formed using a group of individual laminations. Each lamination is insulated by a thin coating of iron oxide, silicon steel or varnish. This insulation increases the resistance reducing eddy current losses. These type of inductors are generally used for mains frequency of 50/60 Hz and lower audio frequency range, upto 10 kHz.

Powdered Iron Core is used to reduce the eddy currents in the core when used at radio frequencies. It consists of individual insulated granules pressed into one solid form called *slug*.

Ferrite Core is made from synthetic ceramic material which are ferromagnetic. They provide high value of flux density like iron, but have the advantage of being insulators, thus reducing the eddy current losses to bare minimum. Because of this advantage, inductors with ferrite core are used for high to very high frequency application.

Variable Inductors unlike fixed Inductors, variable inductors have the facility to vary its inductance value either in steps or continuously.

Shielded/Screened inductors will have a metal cover over the inductor. The shield is usually made of copper or aluminum. The reason for shielding is to isolate the coil from external varying magnetic field and to minimize the effect of the coils RF current on external circuits.

While making a shield/screen for an inductor the following points are to be noted;

i) metal used as cover should be a good conductor

ii) clearance between the sides of the coil and the metal should be equal to or greater than the coil radius. If the clearance is less, the shield reduces the inductance value drastically.

Moulded inductors, looks like resistors with their values colour coded. The coding scheme is same as in resistor, except that the value of L are given in microhenry (μH). For example, a coil with yellow, red and black stripes or dots as shown in Fig 10, has inductance value of 42 μH.

Laboratory type variable inductor are available in the form of a **decade box**. In this decade-inductance box precision inductors are switched in-to or out-of circuit by means of rotary switches. Decade variable inductor is used to carryout experiments and in Inductance (L) meters.

Special types of Inductors

Certain electronic circuits use a special type of Inductor called **Thin-film inductors**. These inductors are thin metal films deposited in the form of a spiral on a ceramic or epoxy base. These are tiny sized and have very low value of inductance.

Copper tube Inductors: At high frequencies, current has a tendency to flow in the skin of the conductor, this is known as **skin effect**. Therefore at high frequency & high power applications hollow copper tube coil is used as inductor instead of solid copper wire.

Variometers: If different radio frequencies are to be received using a single antenna, the electrical length of the antenna will have to be varied, to respond to different wave lengths. Variable inductors used to achieve this are called variometers.

INDUCTANCE MEASURING INSTRUMENTS

Instruments that operate on the principle of Wheatstone bridge are used to measure inductance of inductors. These instruments are known as Impedance Bridge, RLC Bridge and so on.

While measuring inductance value using these bridges, an internally generated 1 kHz signal is used for measurement. However an external signal generator may be used to measure the Q of coils at any desired frequency.

These instruments can be used to measure inductance values from 1 μH to 1000 H.

Digital Instruments are also available to measure inductance values ranging from 1 μH to 10 H. These Digital meters are simple to operate and are also highly accurate. The meters are commonly known as Digital LC Meters, Digital RLC meters and so on.

Energy storage in inductors

Energy storage: An inductor stores energy in the magnetic field created by the current. The energy stored is expressed as follows.

$$W = \frac{1}{2} L r^2$$

where I is in amperes,

L is in henries and

W is energy in joules or watt-second

What should we do when correct values of inductors are not available?

To obtain the desired value of inductors, some series and parallel combination of inductors can be used.

Statically induced emf: When the induced emf is produced in a stationery conductor due to changing magnetic field, obeying Faraday's laws of electro magnetism, the induced emf is called as statically induced emf.

There are two types of statically induced emf as stated below:-

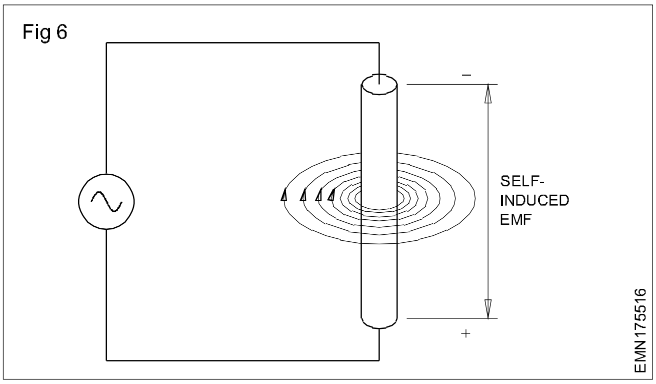
1 **Self induced emf** produced with in the same coil

2 **mutually induced emf** produced in the neighbouring coil

Self-induction: When an alternating current flows in a conductor and the current periodically changes the direction, the magnetic field it produces also reverses the direction. At any instant, the direction of the magnetic field is determined by the direction of the current flow.

With one complete cycle, the magnetic field around the conductor builds up and then collapses. It then builds up in the opposite direction, and collapses again. When the magnetic field begins building up from zero, the lines of force or flux lines expand from the centre of the conductor outward. As they expand outward, they can be thought of as cutting through the conductor.

According to Faraday's Laws, an emf is induced in the conductor. Similarly, when the magnetic field collapses, the flux lines cut through the conductor again, and an emf is induced once again. This is called self-inductance. (Fig 6)



Inductance:Inductance (L) is the electrical property of an electrical circuit or device to oppose any change in the magnitude of current flow in a circuit.

Devices which are used to provide inductance in a circuit are called inductors. Inductors are also known as chokes, coils, and reactors. Inductors are usually coils of wire.

Factors determining inductance: The inductance of an inductor is primarily determined by four factors.

– Type of core permeability of the core m_r

– Number of turns of wire in the coil 'N'

– Spacing between turns of wire (Spacing factor)

– Cross-sectional area (diameter of the coil core) 'a' or 'd'.

The amount of inductance in a coil of wire is affected by the physical make up of the coil.

Core: If soft iron is used as a core material instead of hardened steel, the coil will have more inductance.

If all the factors are equal, an iron core inductor has more inductance than an air core inductor. This is because iron has a higher permeability, that is, it is able to carry more flux. With this higher permeability there is more flux change, and thus more counter induced emf (cemf), for a given change in current.

Number of turns: Adding more turns to an inductor increases its inductance because each turn adds more magnetic field strength to the inductor. Increasing the magnetic field strength results in more flux to cut the conductors (turns) of the inductor.

Spacing between turns of wire: When the distance between the turns of wire in a coil is increased, the inductance of the coil decreases. With widely spaced turns, many of the flux lines from adjacent turns does not link to gether. Those lines that do not link together produce no voltage in other turns. As the turns come closer together only a fewer lines of flux fail to link up.

Cross sectional area:For a given material having same number of turns, the inductance will be high with large cross-sectional area and will be low for smaller cross-sectional area.

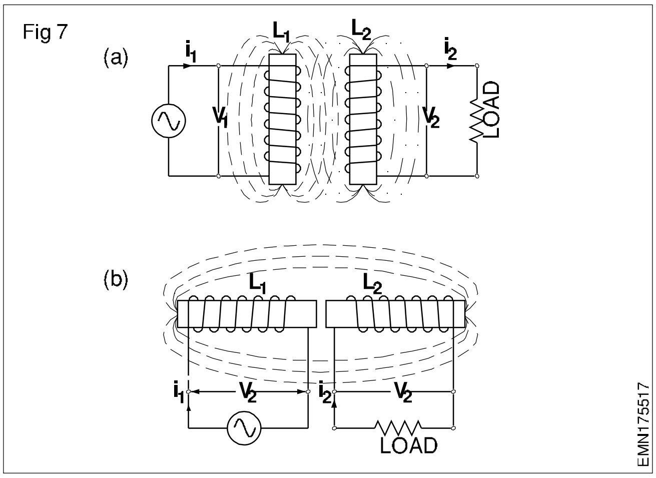
Symbol and unit of Self-inductance: The property of a coil or conductor to self-induce an emf, when the current though it is changing, is called the coil's (conductor's) self-inductance of simply inductance. The letter symbol for inductance is L; its basic unit is henry, H.

Henry: A conductor or coil has an inductance of one henry if a current that changes at the rate of one ampere per second produces a induced voltage (cemf) of 1 volt.

The inductance of straight conductors is usually very low, and for our proposes can be considered zero. The inductance of coiled conductors will be high, and it plays an important role in the analysis of AC circuits.

Mutual Inductance (M)

When two inductors L_1 and L_2 are placed side by side close to each other shown in Fig 7a or Fig 7b, although the two coils are not electrically connected, the two coils are said to be magnetically inter-coupled.



The changing current i_1 in coil L_1 not only self induces an emf (V_1) in L_1, but also causes a voltage (V_2) to be induced in L_2. The voltage V_2 induced in L_2 causes a current i_2 that sets-up its own changing flux around L_2. This in turn, not only self induces a voltage in L_2, but also induces an additional voltage in L_1. That is, a changing current in one coil will induce an emf in other nearby coil. This effect is known as **mutual induction**.

The two coils L_1 and L_2 of Fig 7, are said to have a mutual inductance (M), in addition to their own self-inductances (L).

Mutual inductance, like self-inductance, is also measured in units of Henrys. The definition is given below;

Two coils are said to have a mutual inductance of 1 Henry, when a current changing at the rate of 1 Amp/sec in one coil induces an emf of 1V in the other coil.

Coefficient of coupling

The amount of mutual inductance (M) between two coils depend upon, the self inductance of each coil and the amount of mutual flux between the two coils.

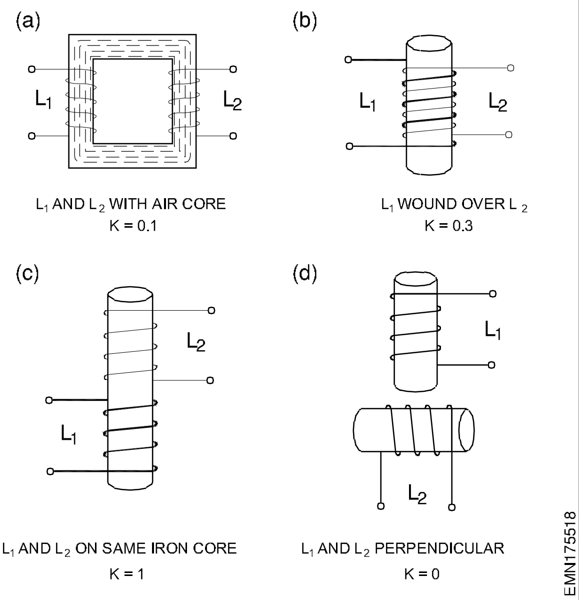
The amount of mutual flux, that links both coils is dependent on the physical placement of the two coils. This is indicated by the term **Coefficient of coupling, k**.

Coefficient of coupling k, between the two coils is given by,

$$k = \frac{\text{Mutual flux between two coils } ø_m \text{, in Webers}}{\text{Total flux set up by one coil, in Webers}}$$

Maximum value of **k** can be 1. This occurs when all the flux (ø) set-up by one coil is linking with the other coil. For example; when both the coils are wound as shown in Fig 15a, almost all the flux set-up in one coil is interacting with the other coil. In other words there is very little or zero leakage of flux. In such cases k is practically equal to 1. This condition of k=1 is also known as **tight coupling**.

Fig 8



In Fig 8b, if only 30% of the flux set-up by coil 1, links with coil 2, the coefficient of coupling is only 0.3.

In Fig 8c and Fig 15d where the coils are placed far apart or when the two coils are placed perpendicular to one another, the coupling is minimum and will be close to zero.

It can be shown that mutual inductance (M) between the given two coils L_1 and L_2 can be found out using the formula,

$$M = k\sqrt{L_1 . L_2} \text{ Henrys.}$$

Where,

k is the coefficient of coupling which has no units

L_1 and L_2 are inductance values, in henrys

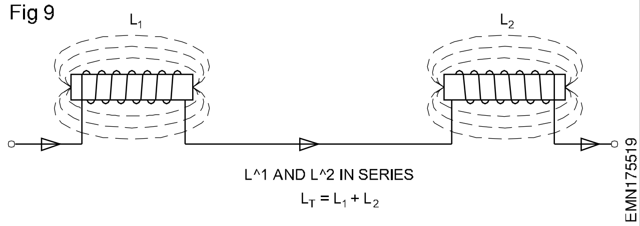
M is the mutual inductance, in henrys

INDUCTORS IN SERIES

In order to obtain a desired value of inductance, inductors can be connected either in series or in parallel.

Fig 9 shows two inductances connected in series. The spacing between the inductors are large enough so that there exists no mutual inductance between the two coils. Hence in Fig 16 k=0. In Fig 9, since the direction of current is same through both coils, the self-induced voltages are additive. Therefore the total inductance of such series connection is given by,

Fig 9



Series coils with mutual inductance

Unlike in Fig 9, when two inductors L_1 and L_2 are connected in series close to each other, the total inductance (L_T) will be larger than just the sum of L_1 and L_2. How much larger will this be depends on the mutual inductance M.

$L_T = L_1 + L_2 + L_3 + ... + L_n$ Henrys (H)

where, L_T is the total inductance across end terminals.

$L_1, L_2 ....L_n$ are individual inductance values.

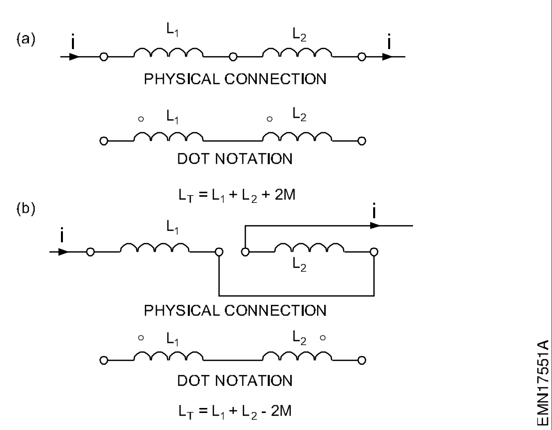
In general, the total inductance of two series-connected coils, with mutual inductance M is given by;

$L_T = L_1 + L_2 \pm 2M$

Dot notation

Whether two coils are connected series-aiding or series-opposing, it is often indicated by using *dot notation* as shown in Fig 10. When current enters both dots or leave both dots as shown in Fig 10a the mutual inductance is additive.

Fig 10



When the current enters one dot and leaves the other dot, as shown in Fig 10b, the mutual inductance is subtractive. In other words the dots indicate the in-phase ends of each other.

CHART - 1 **PHYSICAL APPEARANCE OF DIFFERENT TYPES OF INDUCTORS**

Fig 1 **IRON-CORE INDUCTOR OR CHOKE**

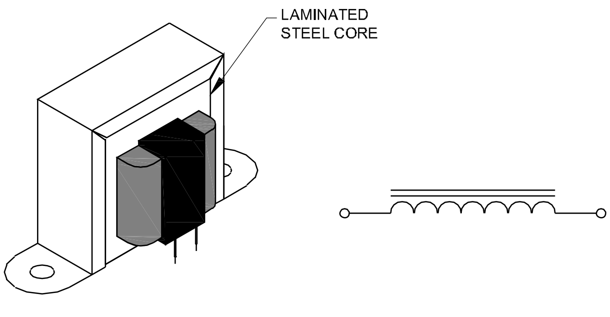


Fig 2 **AIR-CORE INDUCTORs**

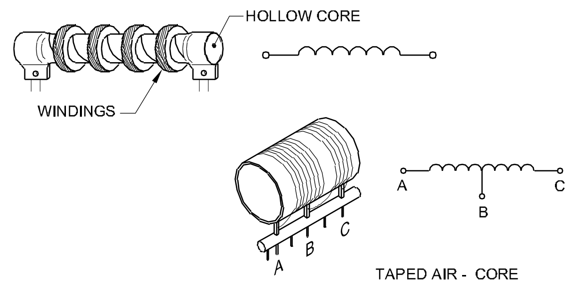


Fig 3 **FERRITE-CORE INDUCTORS**

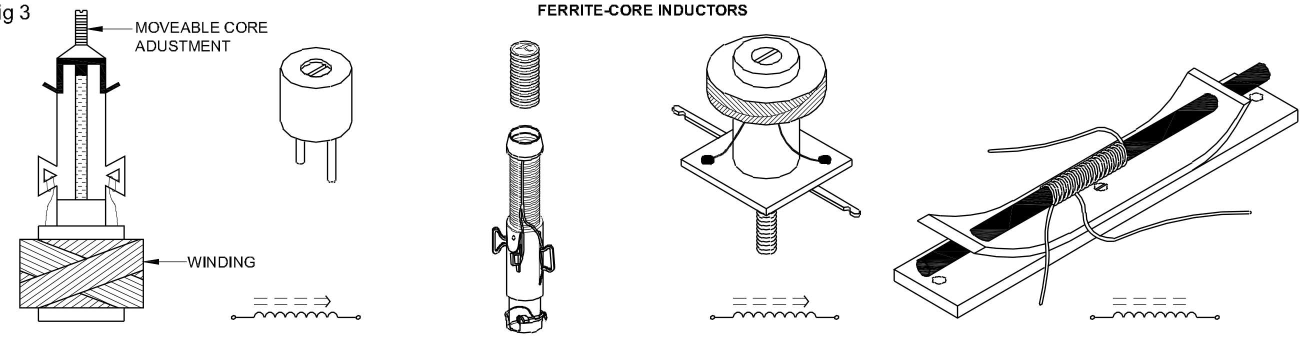


Fig 4 **SHIELDED INDUCTORS**

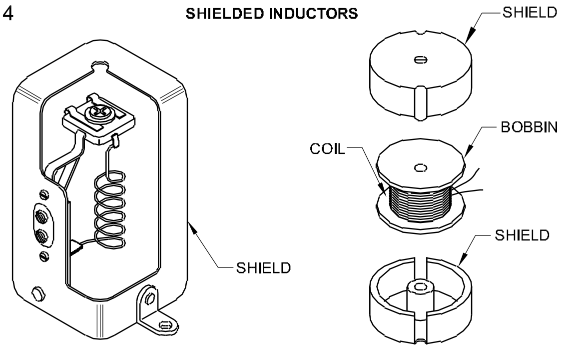


Fig 5 **HIGH FREQUENCY INDUCTORS**

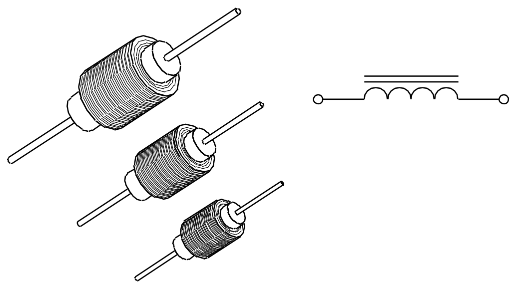


Fig 6 **MOULDED INDUCTORS**

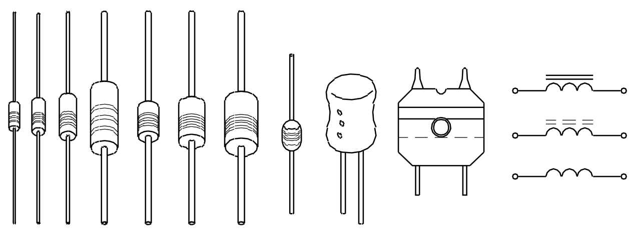
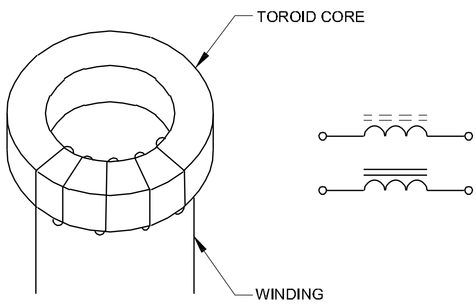


Fig 7 **TOROID FERRITE CORE INDUCTOR**



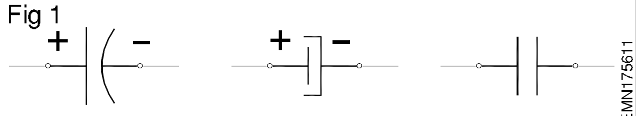
Passive components - Capacitors

Objectives : At the end of this lesson you shall be able to
- **state the function of capacitor.**
- **describe energy storing in capacitor**
- **state the factors that determine capacitance value**
- **state the functions of dielectric in a capacitor**
- **explain the types of fixed value capacitors**
- **explain the constructional details of capacitors**
- **connect the capacitors in series, parallel and series and parallel.**

Capacitors and Capacitance

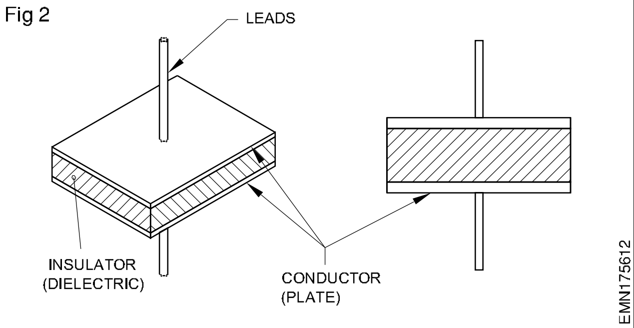
Capacitors are electronic components which can store electric energy in the form of electric charge. The charge storage ability of a capacitor is called the **Capacitance** of a capacitor. Symbols used to represent capacitors are shown in Fig 1. Alphabet 'C' is used to represent the capacitance of a capacitor.

Fig 1



A simple capacitor consists of two pieces of conductors separated by an insulator as shown in Fig 2.

Fig 2



In capacitors the conductors shown in Fig 2 are called **plates** and the insulator is called **dielectric**.

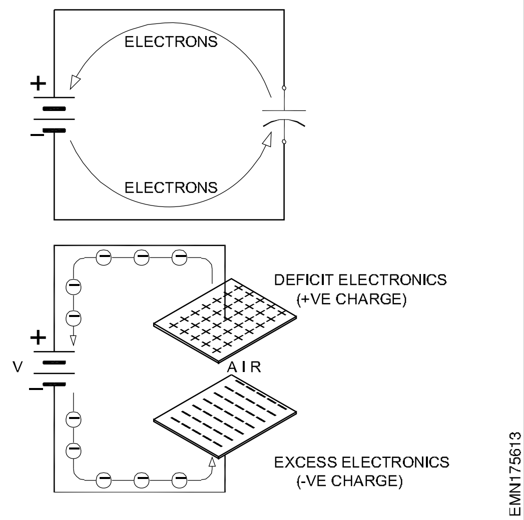
The plates of a capacitor can be of any size and shape and the dielectric may be any one of several insulator materials. Depending on the type of insulator/dielectric used capacitors are called as paper, mica, ceramic, glass, polyester, air electrolyte capacitors etc.,

Capacitor action of storing charge

When electric charge is forced on to the plates of a capacitor by some energy source, such as a battery, the capacitor stores these charges.

When a capacitor is connected to a battery as shown in Fig 3, electrons from the negative terminal of battery move through the connecting leads and pile up on one of the plates of the capacitor. At the same time free electrons from the other plate of the capacitor (remember that plates of a capacitor are conductors having free electrons) move through the connecting lead to the positive terminal of the battery. This process is known as 'charging of capacitor'. As the process of charging continues, the net result is that, one plate of the capacitor ends up with excess of electrons (Negative charge) and the other plate with deficiency of electrons (Positive charge). These charges on the plates of the capacitor represent a voltage source similar to that of the charges on the terminals of a battery/cell. The process of charging stops once the energy stored on the capacitor develops a voltage equal to that of the battery.

Fig 3



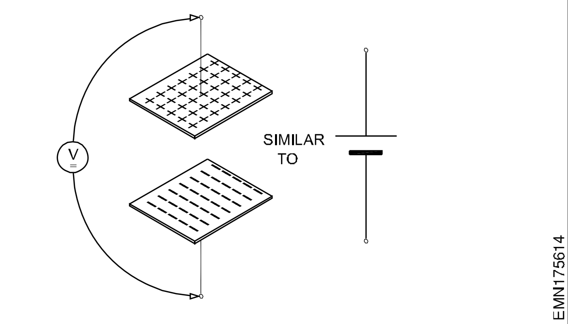
It is important to note that during the process of charging, although electrons were moving from and to the capacitor plates causing current flow in the circuit (you can connect an ammeter to measure it), no electrons moved nor did current flow from one plate through the dielectric to the other plate of the capacitor. The charging current through the circuit stops when the voltage across the capacitor becomes equal to, and in opposition to, the battery voltage. This charged capacitor can be disconnected from the circuit and used as a new energy source as shown in Fig 4.

If a voltmeter is connected across this disconnected charged capacitor, the voltmeter reads the voltage equal to that of the battery which charged it.

If a lamp is connected across this charged capacitor, the bulb glows for a moment indicating current flow through it.

The instructor to demonstrate charging of a capacitor, voltage across a disconnected charged capacitor and discharge of a charged capacitor through a lamp using a suitable demonstration circuit.

Fig 4



The charge stored in the capacitor is sufficient to supply current through the bulb only for a short duration after which the charge filed up on the capacitor plates gets exhausted. A capacitor has limited use as a primary storage device of energy for two reasons:

1 For its weight and size, the amount of energy it can store is very small when compared with that of a battery.

2 The voltage available from the capacitor diminishes rapidly as energy is removed from the capacitor.

Unit of capacitance

The ability of capacitor to store electrical energy in the form of electrostatic field is known *capacitance*. The unit used to measure capacitance is **Farad** abbreviated as **F**.

A capacitor is said to have a capacitance(C) of 1 Farad, if it stores a charge(Q) of 1 coulomb when a voltage(V) of 1V is applied across its plates.

Therefore, capacitance can be mathematically expressed as,

$$\text{Capacitance} = \frac{\text{Charge}}{\text{Voltage}}$$

$$C = \frac{Q}{V}\text{Farads}$$

Farad(F) is a very large quantity of capacitance. As most circuits use capacitance values much lower than one farad (F), smaller quantities of capacitance given below are generally used:

1 Microfarad or 1μF	= 1/1000000 F	or 10^{-6} farads
1 Nanofarad or 1 nF	= $1/10^{9}$ F	or 10^{-9} farads
1 Picofarad or 1pF	= $1/10^{12}$ F	or 10^{-12} farads

Example: ***What is the capacitance (C) of a capacitor that requires a charge (Q) of 0.5 coloumbs to build a voltage(V) of 25 volts across its plates?***

SOLUTION

Given: Charge (Q) = 0.5 Coloumb

Voltage (V) = 25 Volts

Using the formula,

$$\text{Capacitance, } C = \frac{\text{Q Coloumbs}}{\text{V Volts}}\text{Farads}$$

$$\text{Capacitance, } C = \frac{0.5}{25} = 0.02\,\text{Farads}$$

Factors that determine the value of capacitance

The capacitance of a capacitor is determined by the following three main factors;

1 Area of the plates

2 Distance between the plates

3 Type of dielectric material (dielectric constant k)

In addition to the above factors affecting the value of capacitance, the temperature of the capacitor also affects the capacitance although not very significantly. Increase or decrease in temperature affects the characteristics of dielectric material which in-turn increases or decreases the capacitance value. Some dielectrics cause an increase in capacitance as temperature increases. These are called positive temperature coefficients, abbreviated as P. Other dielectric materials have negative temperature coefficient, abbreviated as N, in which case, increase in temperature decreases the capacitance. There are dielectric materials having zero temperature coefficient abbreviated as NPO. The temperature coefficient of a capacitor is specified by the capacitor manufacturer in parts per million per degree Celsius (PPM).

The following expression gives the relation between the three factors that determine the value of capacitance of a capacitor;

$$C = \varepsilon_r \varepsilon_o \frac{A}{d}\text{ Farads}$$

The term e_o is the permittivity of free space (air) = 8.85 x 10^{-12} C^2/Nm^2 and e_r is called the relative permittivity of the dielectric material.

The expression for capacitance (C) of a capacitor can also be written as,

$$C = k\,\varepsilon_o \frac{A}{d}\text{ Farads}$$

The ratio of the capacitance with dielectric to the capacitance with air is called relative permitivity or dielectric constant, k.

Substituting the value of e_o in the above equation, value of a capacitor using any dielectric can be found using the formula;

$$C = (8.85 \times 10^{-12})\,k\,\frac{A}{d}\text{ Farads}$$

where,

C = Capacitance in farads

$(8.85 \times 10^{-12}) = \varepsilon_o$ (permitivity of air)

k = dielectric constant of the insulator used between the plates

A = area of one side of the plate in square meters, m^2

d = distance between the plates in meters, m

Example: ***Two metal plates, each 5 x 6 cms are separated from each other by 1mm. Calculate the capacitance if the dielectric material used between the plates was,***

1) air

2) glass

SOLUTION:

$k_{air} = 1$

$C = (8.85 \times 10^{-12})\ k\ \frac{A}{d}$

$= (8.85 \times 10^{-12}) \times 1 \times (5\times10^{-2}\ m \times 6 \times 10^{-2}\ m)/(1 \times 10^{-3}\ m)$

$= 26.55 \times 10^{-12}$ Farads

= 26.55 pico farads

C = 26.55 pF

2 From PTB table no.18

$k_{Glass} = 5$

$C = (8.85 \times 10^{-12}) \times 5 \times (5\times10^{-2}\ m \times 6 \times 10^{-2}\ m)/(1 \times 10^{-3}\ m)$

= 5 x 26.55pF

C = 132.75 pF

Working voltage or voltage rating of capacitor

The dielectric strength of the insulating material used between the plates of a capacitor gives the capacitor the ability to withstand a potential difference between the plates without causing arcing. Therefore, a specific capacitor using a specific type of dielectric can withstand only up to a specific voltage across it. If the voltage is further increased, the dielectric breaks down or gets punctured. This causes a burn out or a hole in the dielectric material permanently damaging the capacitor.

This maximum voltage that a capacitor can withstand is listed as one of the specifications of capacitors as *direct current working voltage*, DCWV. As an example: if a capacitor has a DCWV of 100 volts, it can be operated at 100 volts for long periods of time without any deterioration in the working of the capacitor. If the capacitor is subjected to 125V or 150V DC, the dielectric may not break down immediately but the life of the capacitor gets greatly reduced and may become permanently defective any time.

Function of a dielectric in a capacitor

1 Solves the mechanical problem of keeping two metal plates separated by a very small distance.

2 Increases the maximum voltage that can be applied before causing a breakdown, compared with air as dielectric.

3 Increases the amount of capacitance, compared with air, for a given dimension of plates and the distance between them.

Types of capacitors

Capacitors can be classified under two main categories:

1 **Fixed value capacitors**

The capacitance value of these capacitors is fixed at the time of manufacture. This value cannot be varied/altered by the user.

2 **Variable capacitors**

The capacitance of such capacitors can be varied between the specified minimum to the specified maximum values by the user.

Amongst fixed value capacitors, many different types of capacitors are manufactured to satisfy the needs of the electronic industry. These different types of capacitors are named according to the

1 Type of dielectric material used in capacitor

Example:

a If paper is used as dielectric, the capacitors are called *paper capacitors.*

b If ceramic is used as dielectric, the capacitors are called *Ceramic capacitors.*

2 Type of construction of the capacitor

Example:

a If the foils of the conductor and dielectric are rolled to form a capacitor, such capacitors are called as *Rolled foil capacitors*.

b If the plates and dielectric are in the form of Discs, such capacitors are called as *Disc capacitors*.

Different types of fixed value capacitors, their sub types, available values, rated voltage and a few applications are given in Chart 1 at the end of this lesson. Also refer to Chart 3 for illustration of some of the popular fixed value capacitors.

Specifications of capacitors

While ordering capacitors, one has to indicate the specifications needed to ensure that the desired capacitor is received. The minimum specifications to be indicated while purchasing/ordering capacitors for general use are;

1 **Type of capacitor**

For example: Ceramic, disc, styroflex, electrolytic and so...on.

2 **Capacitance value**

For example: 100μF, 0.01μF, 10pf and so....on.

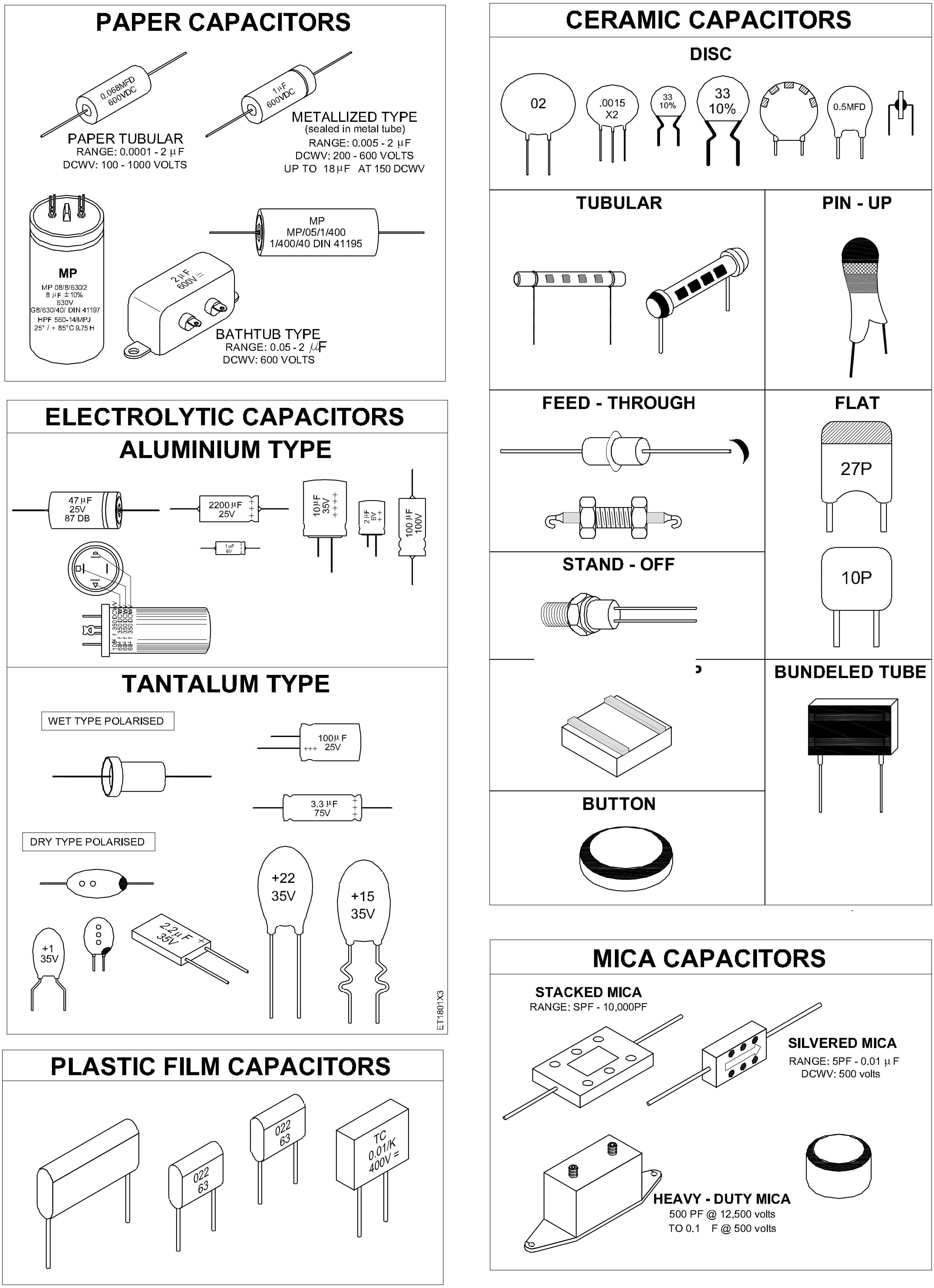
3 **DC working voltage rating (DCWV)**

For example: 100μF-12V, 100μF-100V, 0.01μF-400V and so...on.

4 **Tolerance**

Like resistors, capacitors also have tolerances over its rated value. Tolerance of capacitors may range from ±1% to ±20%. Some capacitors may have tolerance specified as -20%, +80%.

CHART- 1 : Physical appearance of types of fixed value capacitors



the capacitor. During this charging, at the first instance, a reasonably high charging current flows. Since more current through the ohmmeter means less resistance, the meter pointer moves quickly towards zero ohms of the meter scale.

After the initial charging, the charging current to the capacitor slowly decreases (as the voltage across the capacitor increases towards the applied voltage). Since less and less current through the ohmmeter means high and higher resistance, the meter pointer slowly moves towards infinite resistance on the meter scale. Finally, when the capacitor is completely charged to the ohmmeter internal battery voltage, the charging current becomes almost zero and the ohmmeter reads the normal resistance of the capacitor which is a result of just the small leakage current through the dielectric. This charging effect, commonly known as Capacitor action. It indicates, whether the capacitor can store charge, or the capacitor is excessively leaky. Also the capacitor could be fully short-circuited or the capacitor is fully open-circuited.

The capacitor-action test is most suitable for high value capacitors and specially electrolyte capacitors. When small value capacitors such as ceramic disc or paper capacitors are tested for capacitor-action, due to the extremely low charging current the capacitor-action cannot be observed on the meter dial. For such small value capacitors the capacitor-charging-holding test is preferred. However if small capacitors are subjected for capacitor-action test, if the meter shows high resistance the capacitor can be taken as not shorted and hence may be taken as good.

Charging-holding test on capacitors

In this test, a given capacitor is charged to some voltage level using an external battery.

Once the capacitor is charged to the applied voltage level, the battery is disconnected and the voltage across the capacitor is monitored. The voltage is monitored for a period of time to confirm whether the capacitor is able to hold the charge atleast for a small period of time (of the order of a few seconds).

In this test, when the capacitor is tried for charging, if the capacitor does not charge at all even after connecting the battery for a considerable period of time, it can be concluded that the capacitor is either short-circuited or fully open circuited.

If the capacitor is unable to hold the charge even for a considerably small period of time, then it can be concluded that the capacitor is excessively leaky.

The following points are important and are to be noted to get correct results from this test :

1 If the capacitor to be tested is marked with + and - at its terminals (polarised-capacitor) then connect the battery with the same polarity. If a polarised capacitor is tried for charging with opposite polarity, the capacitor may get permanently damaged.

2 Use a FET input voltmeter or high ohm/volt voltmeter to monitor the holding of voltage across the charged capacitor. This is because a low ohm/volt voltmeter will draw current from the charged capacitor resulting in the early discharge of stored charges on capacitor.

The term FET stands for a type of transistor discussed in subsequent units. A FET input voltmeter is a high quality voltmeter having very high ohms/volts. This meter draws almost zero current while measuring voltage across any two terminals. Other average voltmeters draw current in the range of a few hundreds of micro-amps to a few milli-amps while measuring voltage.

Necessity of grouping of capacitors: In certain instances, we may not be able to get a required value of capacitance and a required voltage rating. In such instances, to get the required capacitances from the available capacitors and to give only the safe voltage across capacitor, the capacitors have to be grouped in different fashions. Such grouping of capacitors is very essential.

Methods of grouping: There are two methods of grouping.

- Parallel grouping
- Series grouping

Parallel grouping

Conditions for parallel grouping

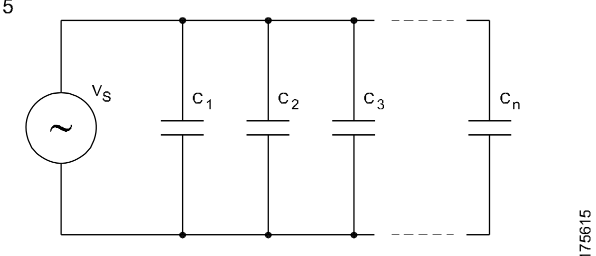
- Voltage rating of capacitors should be higher than the supply voltage Vs.
- Polarity should be maintained in the case of polarised capacitors (electrolytic capacitors).

Necessity of parallel grouping: Capacitors are connected in parallel to achieve a higher capacitance than what is available in one unit.

Connection of parallel grouping: Parallel grouping of capacitors is shown in Fig 5 and is analogous to the connection of resistance in parallel or cells in parallel.

Total capacitance: When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitances, because the effective plate area increases. The calculation of total parallel capacitance is analogous to the calculation of total resistance of a series circuit.

Fig 5

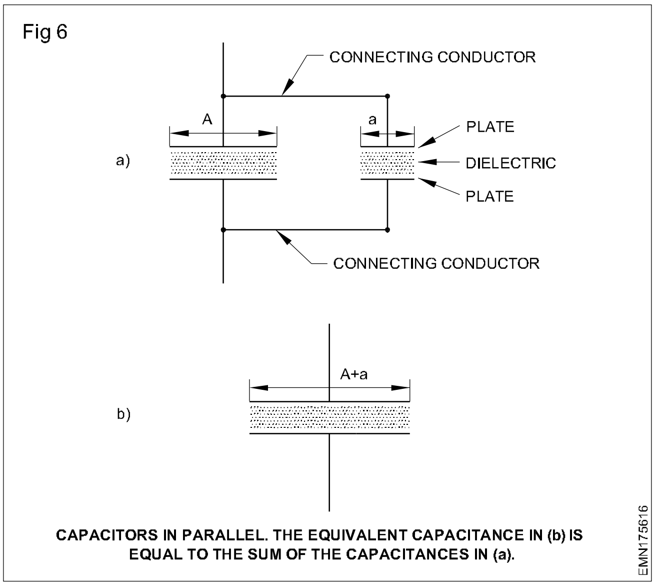


CAPACITORS IN PARALLEL

By comparing Figures 6a and 6b, you can understand that connecting capacitors in parallel effectively increases the plate area.

General formula for parallel capacitance: The total capacitance of parallel capacitors is found by adding the individual capacitances.

Fig 6



CAPACITORS IN PARALLEL. THE EQUIVALENT CAPACITANCE IN (b) IS EQUAL TO THE SUM OF THE CAPACITANCES IN (a).

$C_T = C_1 + C_2 + C_3 + ... + C_n$

where C_T is the total capacitance,

C_1, C_2, C_3 etc. are the parallel capacitors.

The voltage applied to a parallel group must not exceed the lowest breakdown voltage for all the capacitors in the parallel group.

***Example**:* Suppose three capacitors are connected in parallel, where two have a breakdown voltage of 250 V and one has a breakdown voltage of 200 V, then the maximum voltage that can be applied to the parallel group without damaging any capacitor is 200 volts.

The voltage across each capacitor will be equal to the applied voltage.

Charge stored in parallel grouping: Since the voltage across parallel-grouped capacitors is the same, the larger capacitor stores more charge. If the capacitors are equal in value, they store an equal amount of charge. The charge stored by the capacitors together equals the total charge that was delivered from the source.

$Q_T = Q_1 + Q_2 + Q_3 + ... + Q_n$

where Q_T is the total charge

Q_1, Q_2, Q_3.....etc. are the individual charges of the capacitors in parallel.

Using the equation Q = CV,

the total charge $Q_T = C_T V_S$

where V_S is the supply voltage.

Again $C_T V_S = C_1 V_S + C_2 V_S + C_3 V_S$

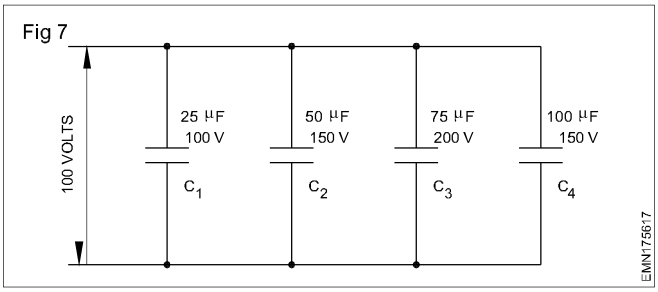
Because all the V_S terms are equal, they can be cancelled.

Therefore, $C_T = C_1 + C_2 + C_3$

Example: Calculate the total capacitance, individual charges and the total charge of the circuit given in Fig 10.

Solution

Fig 7



Total capacitance = C_T

$C_T = C_1 + C_2 + C_3 + C_4$

C_T = 250 micro farads.

Individual charge = Q = CV

Q1 = C1V

$= 25 \times 100 \times 10^{-6}$

$= 2500 \times 10^{-6}$

$= 2.5 \times 10^{-4}$

$= 2.5 \times 10^{-3}$ coulombs.

Q2 = C2V

$= 50 \times 100 \times 10^{-6}$

$= 5000 \times 10^{-6}$

$= 5 \times 10^{-3}$ coulombs.

Q3 = C3V

$= 75 \times 100 \times 10^{-6}$

$= 7500 \times 10^{-6}$

$= 7.5 \times 10^{-3}$ coulombs.

Q4 = C4V

$= 100 \times 100 \times 10^{-6}$

$= 10000 \times 10^{-6}$

$= 10 \times 10^{-3}$ coulombs.

Total charge = Qt= Q1+ Q2 + Q3 + Q4

$= (2.5 \times 10^{-3}) + (5 \times 10^{-3})$

$+ (7.5 \times 10^{-3}) + (10 \times 10^{-3})$

$= (2.5+5+7.5+10) \times 10^{-3}$

$= 25 \times 10^{-3}$ coulombs.

or QT = CTV

$= 250 \times 10^{-6} \times 100$

$= 25 \times 10^{-3}$ coulombs.

Series grouping

Necessity of grouping of capacitors in series: The necessity of grouping capacitors in series is to reduce the total capacitance in the circuit. Another reason is that two or more capacitors in series can withstand a higher potential difference than an individual capacitor can. But, the voltage drop across each capacitor depends upon the individual capacitance. If the capacitances are unequal, you must be careful not to exceed the breakdown voltage of any capacitor.

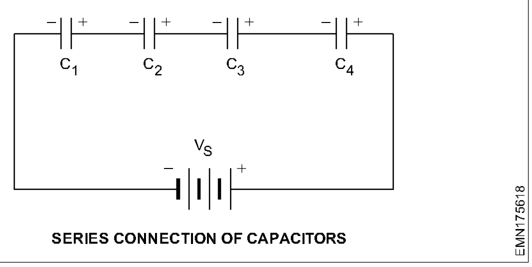
Conditions for series grouping

— If different voltage rating capacitors have to be connected in series, take care to see that the voltage drop across each capacitor is less than its voltage rating.

— Polarity should be maintained in the case of polarised capacitors.

Connection in series grouping: Series grouping of capacitors, as shown in Fig 8 is analogous to the connection of resistances in series or cells in series.

Fig 8



SERIES CONNECTION OF CAPACITORS

Total capacitance: When capacitors are connected in series, the total capacitance is less than the smallest capacitance value, because

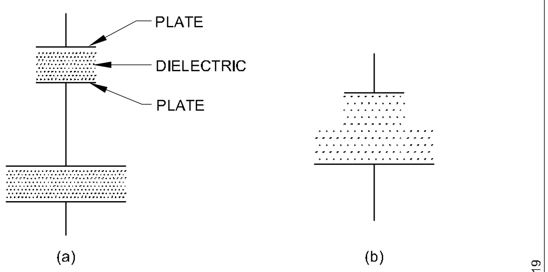
– the effective plate separation thickness increases

– and the effective plate area is limited by the smaller plate.

The calculation of total series capacitance is analogous to the calculation of total resistance of parallel resistors.

By comparing Figs 9 can understand that connecting capacitors in series increases the plate separation thickness, and also limits the effective area so as to equal that of the smaller plate capacitor.

Fig 9



THE EQUIVALENT CAPACITANCE IN (b) IS LESS THAN THE LOWER OF THE TWO CAPACITANCES IN (a).

General formula for series capacitance: The total capacitance of the series capacitors can be calculated by using the formula

If there are two capacitors in series

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ------ + \frac{1}{C_n}}$$

or

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ------ + \frac{1}{C_n}$$

$$C_T = \frac{C1\ C2}{C1 + C2}$$

If there are three capacitors in series

$$C_T = \frac{C_1\ C_2\ C_3}{(C_1\ C_2) + (C_2\ C_3) + (C_3\ C_1)}$$

If there are `n' equal capacitors in series

$$C_T = \frac{C}{n}$$

Maximum voltage across each capacitor: In series grouping, the division of the applied voltage among the capacitors depends on the individual capacitance value according to the formula

$$V = \frac{Q}{C}$$

The largest value capacitor will have the smallest voltage because of the reciprocal relationship.
Likewise, the smallest capacitance value will have the largest voltage.

The voltage across any individual capacitor in a series connection can be determined using the following formula.

$$V_x = \frac{C_T}{C_x} x V_s$$

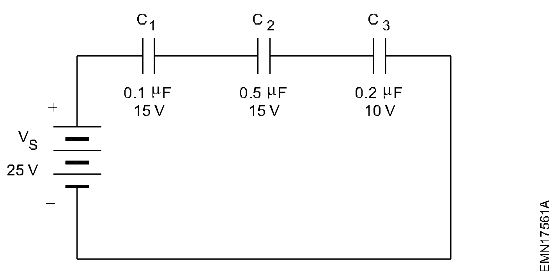
where Vx - individual voltage of each capacitor

Cx - individual capacitance of each capacitor

Vs - supply voltage.

The potential difference does not divide equally if the capacitances are unequal. If the capacitances are unequal you must be careful not to exceed the breakdown voltage of any capacitor.

Fig 10



***Example**:* Find the voltage across each capacitor in Fig 10.

Solution

Total capacitance: CT

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_T} = \frac{1}{0.1} + \frac{1}{0.5} + \frac{1}{0.2} \text{ macro farad}$$

$$\frac{1}{C_T} = \frac{10}{1} + \frac{2}{1} + \frac{5}{1}$$

$$\frac{1}{C_T} = \frac{17}{1}, \text{ and } C_T = 0.0588 \text{ micro farad}$$

$$V_1 = \frac{C_T}{C_1} \times V_s$$

$$V_1 = \frac{0.0588}{0.1} \times 25$$

$$V_1 = 14.71 \text{ Vs}$$

$$V_2 = \frac{C_T}{C_2} \times V_s$$

$$V_2 = \frac{0.0588}{0.5} \times 25$$

$$V_2 = 2.94 \text{ volts}$$

$$V_3 = \frac{C_T}{C_3} \times V_s$$

$$V_2 = \frac{0.0588}{0.2} \times 25$$

$$V_3 = 7.35 \text{ volts}$$

Charge stored in series grouping: Based previous knowledge, we know that

– the current is the same at all points in a series circuit

the current is defined as the rate of flow of charge.

(I = Q/t) or Q = It

The same current is flowing for the same period through the different capacitors of the series circuit. So the charge of each capacitor will be equal (same), and also equal to the total charge QT.

QT= Q1=Q2=Q3=.............=Qn

But the voltage across each one depends on its capacitance value (V = Q/C)

By Kirchhoff's voltage law, which applies to capacitive as well as to resistive circuits, the sum of the capacitor voltages equals the source voltage.

$\frac{V}{1}$ = V1+V2+V3+.........+Vn

Capacitive Reactance

Capacitor oppose changes in voltage with the flow of electrons onto the plates of the capacitor being directly proportional to the rate of voltage change across its plates as the capacitor charges and discharges. Unlike a resistor where the opposition to current flow is its actual resistance, the opposition to current flow in a capacitor is called reactance.

Like resistance, reactance is measured in Ohm's but is given the symbol X to distinguish it from a purely resistive R value and as the component in question is a capacitor, the reactance of a capacitor is called capacitive reactance, (X_c) which is measured in Ohms.

Since capacitors charge and dicharge in proportion to the rate of voltage change across them, the faster the voltage changes the more current will flow.

Likewise, the slower the voltage changes the less current will flow. This means the reactance of an AC capacitor is " inversely proportional " to the frequency of the supply as shown.

Capacitive reactance

Where: X_c is the capacitive reactance in Ohms, f is the frequency in Hertz and C is the AC capacitance in Farads, symbol F.S

$$X_C = \frac{1}{2\pi f} \qquad X_C = \frac{1}{wc} \qquad W = 2\,\Pi f$$

When dealing with AC capacitance, we can also define capacitive reactance in terms of radians, where Omega, w equals $2\Pi f$.

$$X_C = \frac{1}{wc}$$

The impedance of an AC capacitance

Impedance, Z which has the units of Ohms, Ω is the " Total" opposition to current flowing in an AC circuit that contains both resistance, (the real part) and reactance (the imaginary part). A purely resistive impedance will have a phase angle of 0° while a purely capacitive impedance will have a phase angle of -90°.

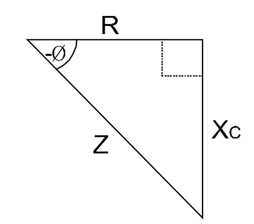
However when resistors and capacitors are connected together in the same circuit, the total impedance will have a phase angle some where between 0° and 90° depending upon the value of the components used. Then the impedance of our simple RC circuit can be found by using the impedance triangle.

The RC impedance triangle

Impedance, $Z=\frac{V}{I}$

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

$\therefore Z^2=R^2+X_C^2$



Then: $(\text{impedance})^2 = (\text{Resistance})^2 + (\text{ j Reactance})^2$ where j represents the 90° phase shift.

By using Pythogoras theorem the negative phase angle, θ between the voltage and current is calculated as.

Phase angle

$\mathbf{Z^2 = R^2 + X_C^{\,2}}$

$$\text{Cos}\varphi = \frac{R}{Z}, \text{Sin}\varphi = \frac{X_C}{Z}, \tan\varphi = \frac{X_C}{R}$$

Circuit breakers

Objectives: At the end of this lesson the trainees shall be able to
- **explain the types of protective devices used in a circuit breaker.**

Circuit breakers are used in electrical installations to make or break the circuit with or without load. They also incorporate protective devices.

Definition: A circuit breaker is a device capable of making and breaking a circuit under normal conditions as well as under abnormal conditions such as those of short circuit.

The following are the different types of breakers in common use in electronic industries

1 Miniature circuit breaker(MCB)

2 Earth leakage circuit breakers (ELCB)

Miniature circuit breakers(MCB)

Construction: The Fig 1 shows the internal construction details and parts of a typical MCB. In these MCB's there is no serviceable part as such when they found defective, the whole unit should be replaced.

Over load trips: The overload trips incorporated in the MCBs may be thermal or of the magnetic type or a combination of these two types.

Advantages of using MCB's over switch fuses

1 MCBs are essentially tamper-proof as they have enclosures of a sealed type.

2 MCBs afford closer protection than the rewireable and HRC fuses in common use, because of the narrowly controlled tripping factor i.e. ratio of minimum trip current/rated current.

3 These are available in plug-in design also, in which case they can be pushed into circuit bus-bars even in energized condition. Thus replacement is easy.

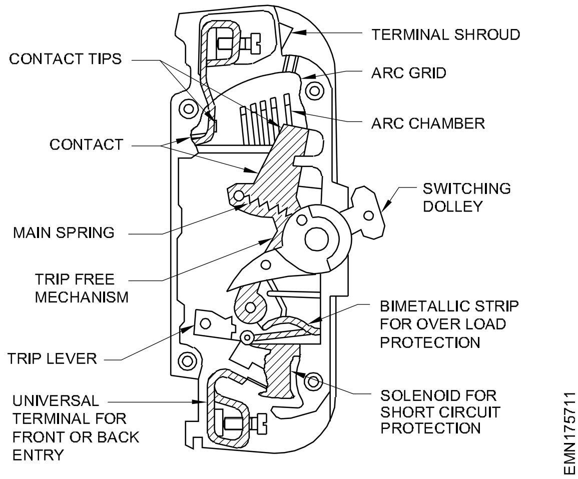
4 These are modular in design which permits their use in various combinations. In the case of triple pole types, since they are gang operated, there is no possibility of single phasing.

5 MCBs can assume the function of a switch as well as a protective device and consequently they may be used to control, as well as protect, the circuits and apparatus.

6 Use in small flats/quarters/rooms. Many large industries and project houses build quarters for their employees/workers wherein fixed light and domestic connections are provided. The electricity bills are not charged as per consumption. A low monthly charge is levied. Sometimes free electricity is provided. In such instances, it is essential that the user does not connect higher load appliances, leading to overheating of wires and burning of supply equipments.

In such cases load rated MCBs can be used as the main incoming circuit breakers. In the event of extra load being connected /drawn, the circuit breaker will trip and cut off supply.

Fig 1



For such applications, the MCBs can be provided in enclosures, with padlocking devices so that only the authorised persons has to be approached for re-switching on the supply. Some manufacturers produce such enclosures with MCBs as well.

For other general small flats/rooms, it is advantageous to install a circuit breaker of 10 amps or 15 amps for over-all protection.

Availability of MCBs: MCBs are available indegeneous in the various combinations of poles and current ratings.

i) Single pole MCB. Current rating 5 to 60 amps.

ii) Double pole MCB (i.e. two MCBs with common trip bar) 5 to 60 amps.

iii) Triple pole MCB (i.e. three MCBs, with common trip bar) current rating 5 to 60 amps.

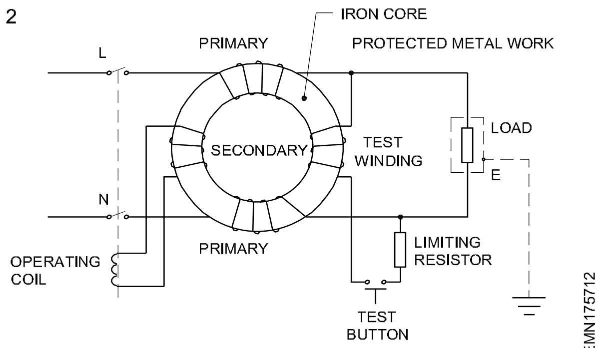
iv) Four pole MCB (i.e. four MCBs with common trip bar) current rating 5 to 60 amps.

Earth leakage circuit breaker (ELCB): Earth leakage circuit breakers are the devices designed to provide protection against accidents by rapidly interrupting dangerous contact voltages which may be present in the faulty electrical equipment as a result of ground faults, insufficient insulation, insulation failure or misuse and sabotage. Basically the ELCBs are of two types, voltage operated ELCBs and current operated ELCBs.

Over the years, it has been established that current operated ELCBs are much more reliable in operation, easier to install and maintain. Besides, there is no dangerous ageing of the protective system components involved, as in the voltage operated ELCBs, where the earth electrode resistance changes with time and hence the earth loop impedance does not remain constant over a period. This leads to dangerous touch voltages on the metal enclosures without being sensed by the voltage operated ELCBs, whereas current operated devices are safer as they operate on the principle of the vector sum of the line currents and the neutral current. Any current even in milliamperes which is not returning to the source through the neutral is assumed to be flowing through the earth or through any insulating body. This differential current is immediately sensed by the current operated ELCB which switches off the electricity supply, protecting the people from dangerous electrical shocks and the insulations from failing and inviting dangerous fires.

They also provide a high degree of protection against earth faults and fires. Fig 2 shows the circuit diagram of a residual - current earth leakage circuit breaker. The essential part of the ELCB is a toroid type core transformer with two opposed windings called primary. One is connected in series with the line and the other in series with the neutral. As far as there is no leakage current, the line current is equal to the neutral current and the magnetic flux produced by the two primary windings oppose and cancel each other. Thus the secondary winding which is connected to the trip (operating) coil does not induce any voltage.

Fig 2



However, when there is any leakage in the circuit, the line current differs from neutral current, thus inducing a voltage in the secondary and the trip coil opens the circuit. Working of the ELCB could be checked by the test button at intervals. Specification for ELCB should contain normal rated current, leakage current and the time duration within which the ELCB should trip. Some state electricity authorities in India insist on the use of ELCB in each of the domestic installation as a safety measure.

Types of closing mechanism in circuit breakers: Various mechanisms are devised to close the circuit breaker contacts. The main types are :

1) spring-operated closing mechanism

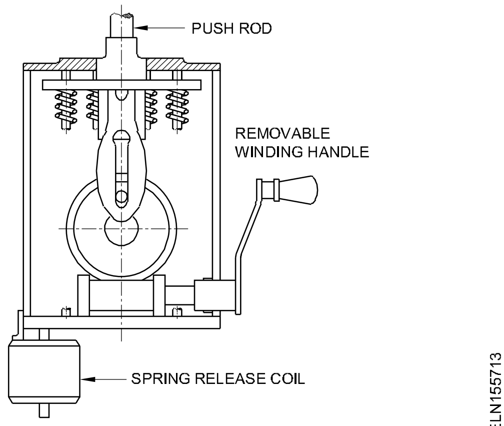
2) solenoid-operated closing mechanism

3) air-pressure operated closing mechanism.

Spring-operated closing mechanism: It can be of three types as explained below.

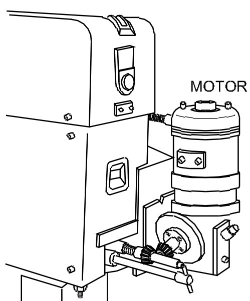
Manually operated spring press mechanism: This normally consist of a handle as shown in Fig 3 which has to be pushed by a downward stroke to close the circuit. As the handle is brought down, the springs are compressed as shown in Fig. The final part of the stroke releases the springs and closes the breaker.

Fig 3



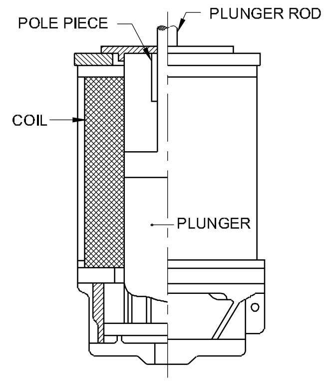
Spring press: The spring press consists of a rotatable handle as shown in Fig 4. This spring press provides a means of closing the circuit breaker without the use of auxiliary electrical supplies. A number of springs are slowly compressed by winding the handle. At the end of the winding, the springs are released by a catch and the circuit breaker closes.

Fig 4



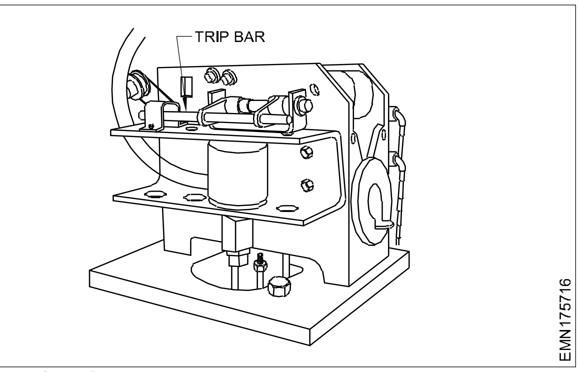
Motor driven spring press: Either an AC or DC motor could be used to automatically charge the springs. The springs can be released electrically by a small spring release solenoid or manually. This type of circuit breaker is shown in Fig 5.

Fig 5



Solenoid-operated closing mechanism: Fig 6 shows the circuit breaker having a solenoid operated closing mechanism. In this mechanism a plunger is free to move inside a solenoid. When the solenoid is energised, the plunger is attracted to the pole piece, lifting the plunger rod. The plunger rod operates the circuit breaker closing mechanism.

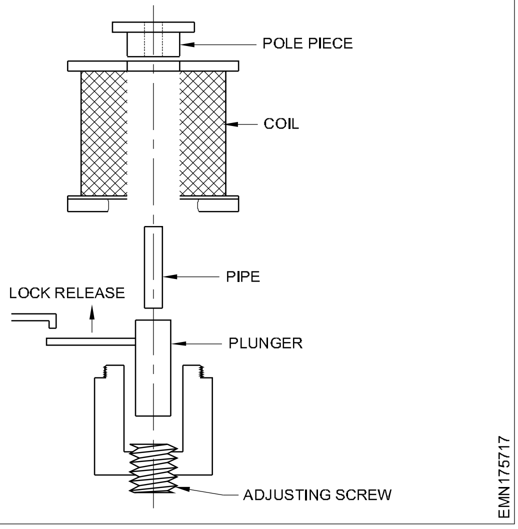
Fig 6



Trip mechanism: Trip mechanism is incorporated in the circuit breaker to switch off the circuit breaker at faulty condition either automatically or manually at the desired time.

Fig 7 shows the arrangement. When the circuit breaker is closed, the mechanism is locked in position by a system of linkages. This lock can be released by lifting the trip bar. Trip bar is attached to the tripping lever which in turn can be operated manually. The tripping lever is generally kept locked. When the trip bar is lifted the mechanism opens the breaker contacts.

Fig 7



Trip coils: When remote operation is desired, trip coils are used. The trip coils are small solenoids either operated by AC or DC supplies. Fig 8 shows the general arrangement of the trip coil mechanism. A plunger moves freely inside the solenoid. When the solenoid is energised by the trip switch the plunger moves up and releases the lock which holds the trip bar. Further the trip coils are also actuated by short circuit/overload and under-voltage relays as described in the following paragraphs.

Shunt trip coils: The shunt trip coil requires an auxiliary supply, a C.T. and a relay. The relay can be set to give time-graded protection. The relay closes the trip coil circuit when the load current exceeds the stipulated value. This relay is shown in Fig 9.

Series trip coil: The series trip coil mechanism shown in Fig 10 consists of a series solenoid with a plunger controlled by a spring. When current in the load become excessive the plunger rises and trips the mechanism.

The current necessary to trip the circuit breaker is regulated by a screw which adjusts the tension of the spring controlling the plunger. Time-lag can be adjusted by the position of the dash pot which holds the piston of the plunger in the oil bath.

In three-phase circuit breakers, there are three series trip coils, three dash pots, three plungers. They can operate the trip mechanism together or independently.

Fig 8

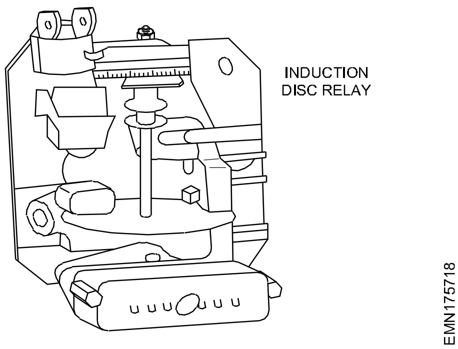


Fig 9

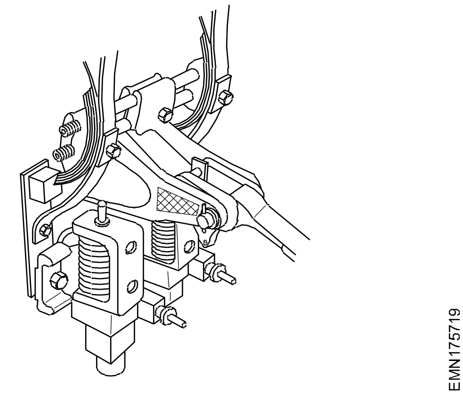
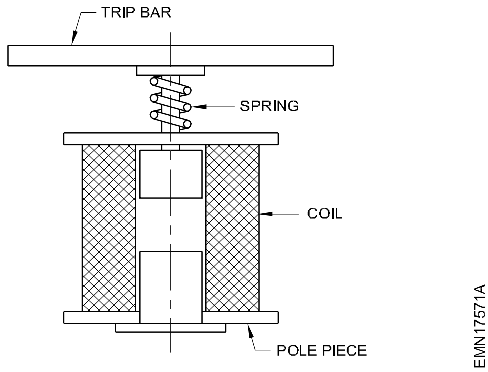


Fig 10



Under voltage release coils: The under-voltage release coil is used in installations where detection and isolation of abnormally low voltage is required. The construction of the under-voltage trip coil shown in Fig 11 is similar to the trip coils discussed above except that the plunger is held away from the pole piece by a coiled spring. Under normal operating conditions, the solenoid is energised and the plunger is held down against the force of the spring. When the supply voltage falls, the under-voltage release coil will not be in a position to hold the plunger down against the spring tension. Thus the plunger moves up and pushes the trip bar to trip the circuit breaker.

Magnetism, Relays

Objectives : At the end of this lesson you shall be able to
- **state magnetism**
- **explain the properties of magnets**
- **state flux and flux density.**
- **state the magnetic materials**
- **state the type of magnetic field around a current carrying conductor**
- **explain relay types, construction and specification.**

Magnets and magnetism

Magnets are those which have the power to attract iron or alloys of iron (ferrous materials). Magnets available in nature are called *natural magnets* or lodestones.

The property of a material to attract pieces of ferrous materials is called **magnetism.**

Natural magnets are of very little practical use these days because it is possible to produce much better magnets by artificial means.

Magnetic and non-magnetic materials

All materials cannot be made magnets artificially. Materials which are attracted by magnets are called *magnetic materials* and only such magnetic materials can be made as artificial magnets. All other materials are called *non-magnetic materials*. A list of a few magnetic and non-magnetic materials is given below:

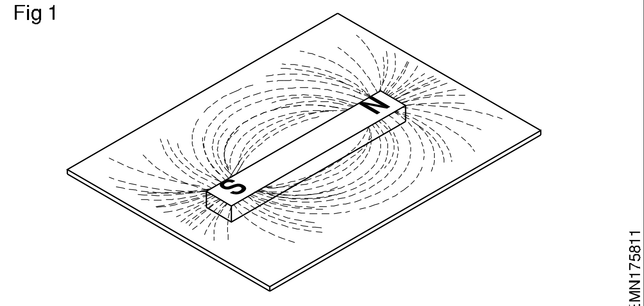
Magnetic materials	Non-magnetic materials
IRON	ALUMINIUM
STEEL	COPPER
COBALT	BRASS
NICKEL	LEAD

Poles of a magnet

The magnetic strength of a magnet is concentrated at two points on the magnet. These points are called the *poles* of a magnet.

MAGNETIC FIELD AND MAGNETIC FLUX (Ø)

Fig 1



The property of magnetism in any magnet is because of an invisible field of force between the two poles at the opposite ends of the magnet as shown in Fig 1. It can be seen that the *magnetic field is strongest at the poles*. Magnetic field exists in all directions, but decreases in strength, as you go away from the poles(decreases inversely as the square of the distance from the poles). The magnetic lines can be considered to flow outward from the north pole and enter the magnet at the south pole. The entire group of magnetic lines, which can be considered to flow outward from the north pole of a magnet, is called the *magnetic flux.* The magnetic flux is symbolically represented by the Greek letter *ø (phi).* The more the magnetic flux ø, the stronger is the magnetic field, and hence, the magnet.

PROPERTIES OF MAGNETS

- **Unlike poles attract each other.**

When the north pole of a freely movable permanent magnet is brought near the south pole of a second permanent magnet, an invisible force causes the two poles to be attracted to each other. The two unlike poles actually stick to one another. The force of attraction between unlike poles increases as the distance between the poles decreases. Actually, the force of attraction varies inversely as the square of the distance between poles.

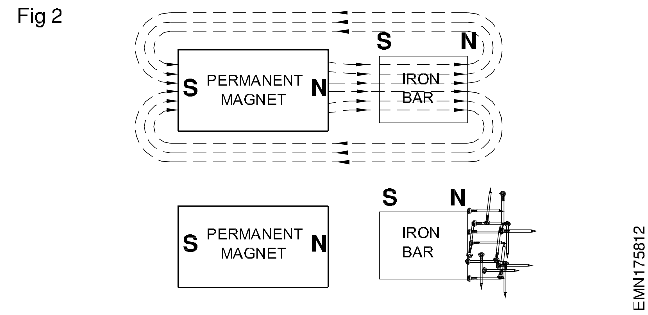
- **Like poles repel each other.**

When the north pole of a freely movable permanent magnet is brought near the north pole of a second permanent magnet, an invisible force causes the two poles to repel each other. The two unlike poles actually move away with a jerk. This force of repulsion increases as the distance between the poles decreases. Actually, the force of repulsion varies inversely as the square of the distance between poles.

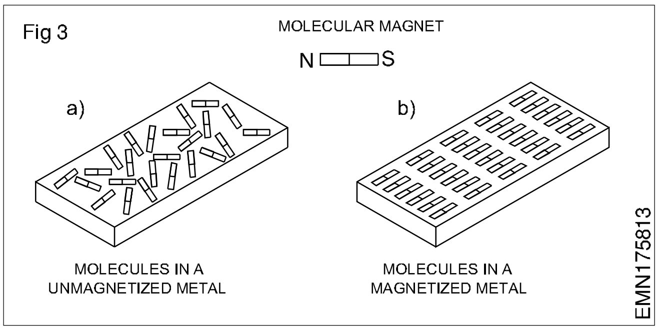
- **Induces magnetic properties to magnetic materials.**

A permanent magnet can induce magnetism to an unmagnetised iron bar such that the iron bar become a magnet. To induce magnetism, it is enough if the permanent magnet comes close to the iron bar as shown in Fig 2.

Fig 2



What is happening in Fig 2 is that, the magnetic lines of force generated by the permanent magnet, make the internal molecular magnets in the iron bar line up in the same direction as shown in Fig 3b. An unmagnetised iron as shown Fig 3a, the molecules will be in random directions. Note from Fig 2 that, the induced poles in the iron bar have opposite polarity from that of the poles of the permanent magnet.



It should be noted that inducing magnetism was possible only because the unmagnetised material was a magnetic material. In Fig 3 instead of iron, a copper bar is used, the permanent magnet will not induce magnetism in copper as copper is a non-magnetic material. The magnetic field lines will be unaffected by the non-magnetic materials when placed in the magnetic field of a magnet.

TYPES OF MAGNETS

Magnets are available naturally, and can also be made artificially. When magnets are made artificially, depending on the type of material magnetism is retained for different durations. For example, if a piece of soft iron and a piece of steel are magnetized. The magnetism in steel remains for a much longer duration than in soft iron. This ability of a material to retain its magnetism is called *retentivity* of the material. Depending upon the retentivity of the material, artificial magnets can be classified as *temporary magnets* and *permanent magnets*. Temporary magnets lose their magnetic power or magnetism once the magnetizing force is removed.

The magnetism that remains in a magnetic material, once the magnetizing force is removed, is called *residual magnetism.* This term is usually only applicable to temporary magnets.

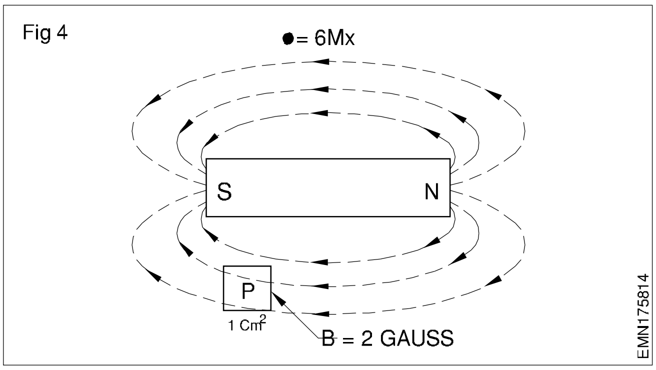
Permanent magnets retain magnetism for a long period of time.

Classification of magnets, popularly used types of magnets and their applications are given in Chart 1 at the end of this lesson.

Units of magnetic flux ø

Maxwell

One *Maxwell (Mx)* unit equals one magnetic field line. In Fig 4, for example, the flux illustrated is 6 Mx because, there are six field lines flowing in or out of each pole. A one pound magnet can provide a magnetic flux ø of about 5000 Mx.



Maxwell is a unit of magnetic field in CGS system of units.

This is a larger unit of magnetic flux. One *weber (Wb)* equals 1×10^8 lines or maxwells. Since weber is a large unit for typical fields, microweber (μWb) unit can be used.

$1\mu Wb = 10^{-6} Wb.$

For a one lb magnet producing the magnetic flux of 5000 Mx, corresponds to 50 μWb.

Weber is a unit of magnetic field in SI system of units.

FLUX DENSITY (B)

The flux density is the number of magnetic field lines per unit area of a section perpendicular to the direction of flux as shown in Fig 4.

As a formula,

$$B = \frac{ø}{A} = \frac{\text{flux}}{\text{Area}}$$

In magnets, the flux density will be higher close to the poles because flux lines are more crowded near the poles.

Units of flux density

Gauss: One Gauss is equal to one flux line per square centimeter, or 1 Mx/cm^2.

Gauss is a unit of flux density in CGS system of units.

As for example in Fig 4,

total flux ø is 6 lines, or 6 Mx

At point P in this field, the flux density B is 2 Gauss because there are 2 lines per cm^2.

As an example the flux density B for a 1 lb magnet will be 1000 G at the poles.

Example : With a flux of 10,000 Mx through a perpendicular area of 5 cm^2, what is the flux density in gauss?

$$B = \frac{ø}{A} = \frac{10.000Mx}{5\ cm^2} = 2000Mx\ cm^2$$

B = 2000 G.

Typical values of flux densities are ,

Earth's magnetic flux density is about 0.2 G.

A large laboratory magnet produces flux density of 50,000 G.

Since gauss is a small unit, flux density if often measured in kilogauss

1 kilogauss = 10^3 Gauss.

In SI units of measurement, the unit of flux density B, is webers per square metre (Wb/m^2). One weber per square metre is called a tesla, abbreviated as T.

Tesla is a unit of flux density in SI system of units.

Example : A flux of 400 μWb passes through an area of 0.0005 m^2, What is the flux density in tesla units?

$$B = \frac{ø}{A} = \frac{400 \times 10^{-6} \quad Wb}{5 \times 10^{-4} \quad m^2}$$

$$= \frac{400}{5} \times 10^{-2} = 80 \times 10^{-2} \quad Wb/m^2$$

B = 0.80 Tesla

Tesla is a larger unit than gauss 1 T = 1 x 10^4 G. For example, the flux density of 20,000 G is equal to 2 T.

CLASSIFICATION OF MAGNETIC MATERIALS

Based on the strong magnetic property of iron, other materials are classified as either magnetic or non-magnetic materials. However, a more detailed classification is given below;

1 Ferromagnetic materials

2 Paramagnetic materials

3 Diamagnetic materials

These are materials which become strongly magnetized. These materials gets magnetised in the same direction as the magnetizing field. These materials have high values of permeability in the range of 50 to 5000. Examples of ferromagnetic materials are iron, steel, nickel, cobalt, and commercial alloys such as alnico and permalloy. Permalloy has a μr of 100,000 but gets saturated at relatively low values of flux density.

Paramagnetic materials

These are materials which become weakly magnetized. These materials gets magnetised in the same direction as the magnetizing field. The permeability of paramagnetic materials is slightly more than 1. Examples of paramagnetic materials are aluminum, platinum, manganese, and chromium.

Diamagnetic materials

These are materials which become weakly magnetized. These materials gets magnetised in the opposite direction of the magnetizing field. The permeability of diamagnetic materials is less than 1. Examples of diamagnetic materials are bismuth, antimony, copper, zinc, mercury, gold and silver.

The basis of the above three classifications is the motion of orbital electrons in atoms.

There are two kinds of electron motion in the atom;

1 The electron revolving in its orbit: This motion provides a diamagnetic effect. However, this magnetic effect is weak because of the thermal agitation at normal room temperature. This results in random directions of motion that neutralizes the magnetic effect of each other.

2 The magnetic effect from the motion of each electron spinning on its own axis: The spinning electrons works as a tiny permanent magnets. Opposite spins provide opposite polarities. Two electrons spinning in opposite directions form a pair, neutralizing the magnetic fields. In the atoms of ferromagnetic materials, however, there are many unpaired electrons with spins in the same direction, resulting in a strong magnetic effect.

Iron, cobalt and nickel are said to be very good magnetic materials. Alloys of these three metals make up almost the entire range of magnetic materials used by the electrical, electronic and communication industries.

Temporary and permanent magnets

Another classification of magnetic materials based on their application are:

1 Temporary magnets

2 Permanent magnets

Soft and hard magnetic materials

Magnetic materials can be classified as:

1 Hard magnetic materials

2 Soft magnetic materials

Hard magnetic is a term is used to cover the range of materials used for making permanent magnets.

Some of the hard magnetic materials commonly used and a brief of their magnetic properties are given below;

Carbon steel

This was the only material used for permanent magnets in olden days. It has poor magnetic materials and not in much use today.

Carbon steel is now used only for applications where low cost is more important than magnetic performance.

Carbon steel is used in making compass needles, thin sheet magnets and magnets for toys.

Tungsten and chromium steels

The addition of tungsten and chromium to carbon steel gives a group of alloys having better magnetic properties than carbon steel. These materials can be rolled or forged to different shape and are machinable.

Large quantities of instrument magnets are produced from steel containing approximately 6% tungsten.

Chromium steel is cheaper to produce but slightly less effective than tungsten steel as a permanent magnet. Instrument magnets are made by punching out the shape required from steel strips containing 3% chromium.

Cobalt steel

The addition of cobalt to chromium steel considerably increases the magnetic strength of the material.

To meet all reasonable industrial requirements, a range of five cobalt steel alloys, each having a different cobalt composition are produced. These alloys can be rolled or cast and machined before hardening.

Cobalt steel alloys are used for making rotating magnets, telephone receivers, speedometer magnets, multi-pole rotors used in electric clocks and hysteresis motors.

Iron-aluminimum-nickel

In 1931 an alloy of iron, aluminum and nickel was discovered. This alloy gives a better magnetic performance as a permanent magnet when compared to all the other commercially produced permanent magnetic materials.

Most permanent magnets produced today are made from Alnico and Alcomax group of alloys. These have iron-nickel and aluminium with additions of cobalt and copper.

Magnets made from these alloys can only be produced by the processes of casting and sintering. They are very brittle and cannot be machined except by grinding.

Soft magnetic is a term which covers the range of materials which are easy to magnetize and demagnetize. They are used for the cores of electromagnets or temporary magnets.

Soft magnetic materials used for making electromagnets are easy to magnetize and demagnetize. They have low hysteresis loss, higher saturation value (B), higher permeability and low coercivity values when compared with hard magnetic materials.

Soft magnetic materials are generally used for making laminated, transformer cores, motor & generator armatures and other electrical equipments which are subject to continual reversal of magnetization.

Some of the soft magnetic materials commonly used and their magnetic properties are given below;

Mild steel

It is an inexpensive material to produce, and, therefore, an ideal material to use where cost is important and the magnetic properties required not so stringent. As the carbon content in mild steel is increased, the effect is to lower the magnetic properties.

Iron-silicon alloys

A range of iron-silicon alloys, containing silicon between 0.3% to 4% is produced as sheets or strips and used for making laminations. Iron with a small amount of silicon has better magnetic properties than pure iron.

These alloys have low hysteresis loss, high saturation and are used for the magnetic circuits of electrical equipment operated at power frequencies of 50 Hz such as power transformers, alternators and electric motors of all sizes.

Due to the brittleness of the higher silicon alloys, it is not possible to make it into very thin sheets or strips.

Magnetic field around a current-carrying conductor

When current is passed through a conductor, a magnetic field is produced around it. It is important to note the following two factors about the magnetic lines of force around a current carrying conductor.

1 The magnetic lines are circular and the field is symmetrical with respect to the current carrying wire in the centre.

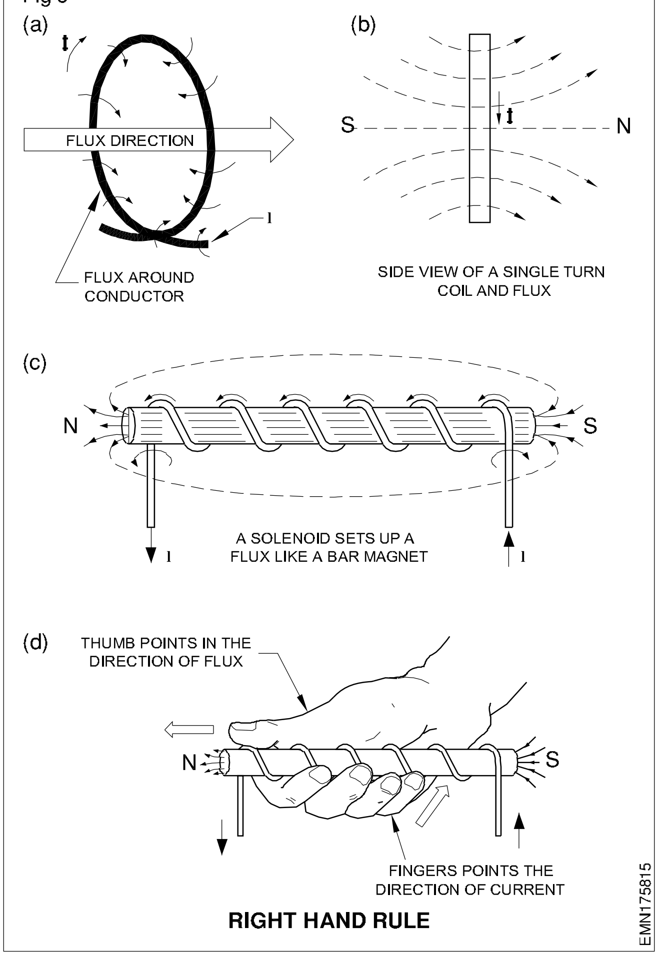
2 The magnetic field with circular lines of forces is in a plane perpendicular to the current in the wire.

The direction of the magnetic lines around the conductor can be determined by the right hand screw rule. The direction of magnetic lines reverses, if the direction of current through the conductor is reversed. This magnetic field around a single conductor is too weak to make the wire behave as a useful magnet.

Magnetic field around a coil

Consider the effect of passing a current through a one-turn coil of wire as shown in Fig 5a.

Fig 5



RIGHT HAND RULE

Fig 5a and 5b shows the magnetic flux generated by the electric current passing through the centre of the coil. Therefore, a one-turn coil acts as a little magnet. It has a magnetic field with an identifiable N pole and S pole. Instead of a single turn, a coil may have many turns as shown in Fig 5c. In this case, the flux generated by each of the individual current-carrying turns, tends to link-up and pass out-of one end of the coil and back into the other end as shown in Fig 5c. This type of coil, also known as a solenoid has a magnetic field pattern very similar to that of a bar magnet.

The *right hand rule* for determining the direction of flux from a solenoid is illustrated in Fig 5d. When the solenoid is gripped with the right hand such that, the fingers are pointed in the direction of current flow in the coils, the thumb points in the direction of the flux as shown in Fig 5d. The coil now behaves like an electromagnet.

The solenoid acts like a bar magnet whether it has an iron core or not. Adding an iron core in a solenoid increases the flux density inside the coil. In addition, the field strength will then be uniform for the entire length of the core. It should be noted that, adding an iron core into a solenoid does not change the N and S pole positions of the solenoid.

When the direction of the current through the coil is changed, it changes the direction of magnetic lines, thereby changing the poles of the solenoid.

Applications of electromagnet

Electromagnets are used in various applications such as electrical circuit breakers, relays, door bells etc.

Faraday's law

Whenever a conductor cuts magnetic lines of force, an *emf* is induced in the conductor. This is known as Faraday's law of *Electromagnetic Induction.*

Lenz's Law

The basic principle used to determine the direction of induced voltage or current is given by *Lenz's Law*.

Lenz' law states that the direction of induced current is such that the magnetic field set-up due to the induced current opposes the action that produced the induced current.

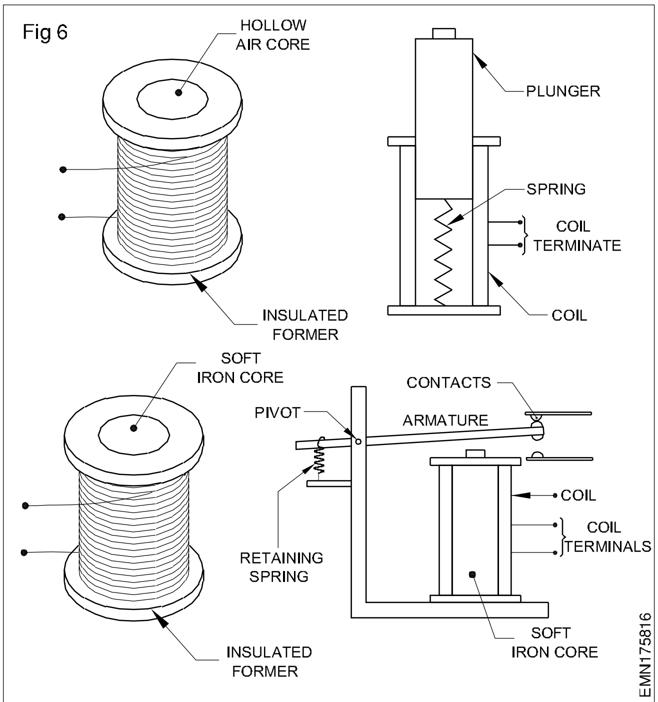
Relays:

Introduction

In addition to solenoids, one other most popular application of electromagnets is in what are called electromagnetic relays.

Important similarities and differences between a solenoid and a relay is illustrated in Fig 6.

Fig 6



Electromagnetic relays

The term relay was used for the first time, to describe an invention made by Samuel Morse in 1836. The device invented by *Morse* was a *Telegraph Amplifying Electromagnetic Device.* 'This device enabled a small current flowing in a coil to switch-ON a large current in another circuit, and thus helped in relaying of telegraph signals.

In any application, the object of a relay is generally to act as a remote switch or as a electrical multiplier switch. This means, a relay enables a comparatively weak current to bring into operation a much stronger current or currents.

Construction and operation of a simple relay

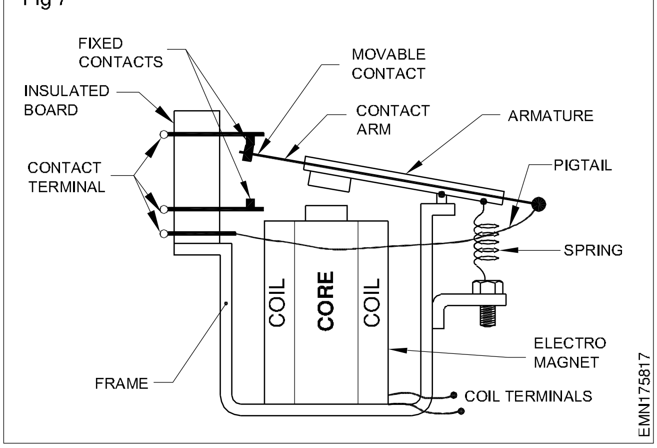
Electromagnetic relay is basically a switch or a combination of switches operated by magnetic force generated by a current flowing through a coil.

Essentially, a typical relay shown in Fig 7 consists of the following parts;

- an electromagnet comprising of a core and coil
- a movable armature,pivoted and held in tension by a spring
- a set of contacts
- a frame to mount all these components.

As shown in Fig 7, a typical relay consists of a core surrounded by a coil of wire. This is mounted on a metal frame. The movable part of the relay is the armature. One end of the armature is hinged and connected to a spring. On the armature is mounted a contact arm carrying movable contacts. The fixed relay contacts and its terminals are mounted on an insulated terminal board.

Fig 7



When the relay is OFF or not energized, the contact arm touches the top contact. When the relay is energized by applying voltage to the coil terminals, the metallic armature is attracted. The armature and contact arm assembly move downward so that the contact arm mounted on the armature touches the bottom contact. Thus, the relay is doing the function of a single pole, double throw (SPDT) switch.

On removing the voltage applied to the coil, the spring attached to one end of the armature returns the armature to its original position and the contact arm touches the top contact.

Operating delay of relays

When an energizing voltage is applied to a relay coil, the relay does not work instantaneously. It takes some time, usually a few milliseconds to operate. Reasons for this delay are given below:

– Due to inductance of the relay coil, current grows slowly and takes some time to reach the required current value.

– Due to inertia, the armature takes sometime to move from one position to another.

When rated voltage is applied to terminals of a relay coil, the gradual build up of current in the coil is due to the initial opposition to the current flow by the self-inductance of the coil. After some delay, when sufficient magnetization is built up and when the force of attraction is sufficient to overcome the opposition of the tension due to return spring plus, tension of contact springs, the armature is attracted and it closes the relay contacts. The relay is then said to be energized or pulled-in or picked.

Once the relay is energised then, only a small amount of energy is required to maintain it in energized condition. The rest of the electrical energy is wasted as heat.

When the current through the coils falls below a certain value, the relay gets de-energised and the return spring pulls the armature back. This is called as relay drop-out.

From above it can be seen that, very little amount of electrical power is consumed for the switching of relay whereas most of the power is consumed while holding.

Parts of a Relay

Each part of a relay is as important as the other in the overall performance of the relay. Details of the parts of a relay and their purpose are given below:

Frame and core : One of the main function of the relay frame is to provide a base for mounting other relay parts. But, the most important function is, the frame forms a part of the complete magnetic path between the armature and core. The core, frame and armature are made of an easily magnetizable material such as iron.

Hinges : The hinges connect the armature to the frame. A good hinge must be as free from friction as possible. They must also be strong enough to support the weight of the armature and contacts. The hinges must provide low reluctance to the magnetic flux in its path from the core through the frame and the armature.

Return springs : The springs are usually very thin and cannot concentrate any large amount of flux. Spring steel, which has a lower reluctance than other materials acts to retain its magnetism and remain attracted to the core after the relay is de-energised. Springs also have a disadvantage of being stiff and are likely to break after a few operations.

Relay coil : The coil is usually wound on a former and slipped over the magnetic core in the relay frame. This permits easy replacement of damaged coils by new ones.

Coil Specifications

Generally relays are made to operate at different voltages such as, 6, 12, 18, 24, 48, 100 or 240 volts AC or DC. A coil resistance chart is usually given with relays which helps in calculating the coil current and power dissipation. Maximum wattage, maximum permissible temperature and the wattage for satisfactory operation, are specified along with relays.

Operate current – is the minimum current required to energize a relay.

Hold current – is the minimum coil current required to continue to hold the relay energized.

Release current – is the maximum current which releases the relay.

Relay coils are always insulated from the frame of the relay. The electrical resistance between the coil and the body is a measure of the isolation of energising voltage from the ground. Similarly, the electrical resistance between the coil and the contacts is a measure of the electrical isolation between the energising driving and the driven circuits. These resistances will be of the order of hundreds or thousands of megohms.

Relay contacts

The contacts on a relay are the parts that actually perform the electrical switching of the controlled circuits. Also, these contacts are the ones that cause most trouble and require frequent maintenance as compared to any other part of a relay.

Contact materials and design

The relay contacts are made of material which are very good conductors as well as corrosion-resistant.

An arc is created when the contacts open and close. This arc burns and oxidises the contacts. An oxide coating make the contacts either poor conductors or non-conductors. For this reason, contacts are made of silver, palladium and palladium-iridium alloys, gold alloys, gold plated silver, tungsten and alloys of other highly corrosion-resistant materials that do not oxidize easily.

Even with these materials, some oxidation still takes place. To get rid of the oxide, the contacts are designed to have a wiping action. As the contacts close and open, the surfaces rub together. This action rubs off any oxide or dirt which might cause poor contact.

Contacts come in many shapes and sizes, and in a variety of contact arms. These contact arms are generally called contact springs because they maintain good contact pressure.

Size of the contacts determines the current handling capability. The larger the contacts, the more current they can switch without excessive deterioration.

The contact arms or springs are made thick and wide enough to carry the current for which the contacts are rated. They are also made spongy enough to ensure good contact. If the springs are too soft they may vibrate when the relay opens, causing contact bounce when the contacts open and close repeatedly. This bounce can also occur on closing. The bouncing of contacts is always undesirable. Contact debouncing circuits are used to overcome the undesirable effects of contact bouncing in sensitive circuits such as digital electronic circuits.

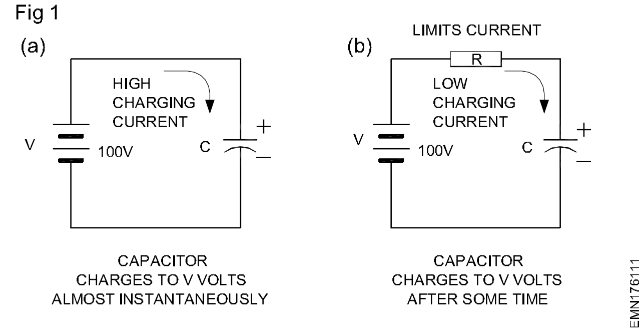
Time constant for RC circuit

Objectives: At the end of this lesson you shall be able to
- **explain the importance of RC time constant**
- **state the need of universal time constant curve**
- **list a few applications of RC time delay circuits**
- **explain the use of oscilloscope in measuring time delay.**

RC time constant τ while charging

When a capacitor is connected across a battery or a source of dc voltage as shown in Fig 1a, it charges almost instantaneously. This is because there is no resistance in the charging circuit to limit the charging current. On the other hand, if a resistor is connected in series with the capacitor, as shown in Fig 1b, the resistance limits the maximum current that can flow in the series circuit. This limiting of charging current causes delay in the time required for the capacitor to charge up-to the source voltage.

Fig 1



Even if a resistor were not connected in the circuit , the resistance due to connecting wires, leads internal resistance of the supply source acts as a lumped resistance to delay the charging. The exact time required for the capacitor to charge depends on both the resistance (R) in the charging circuit, and the capacitance (C) of the capacitor(recall higher capacitance value allows higher current in the circuit, $I = CV/\tau$).

This relationship between resistance, capacitance and the charging time is expressed by the equation,

$$\tau = RC$$

where t (spelled as tau) is the capacitive time constant or *RC time constant*, representing the time required for the capacitor to charge to 63.2% of its full charge voltage.

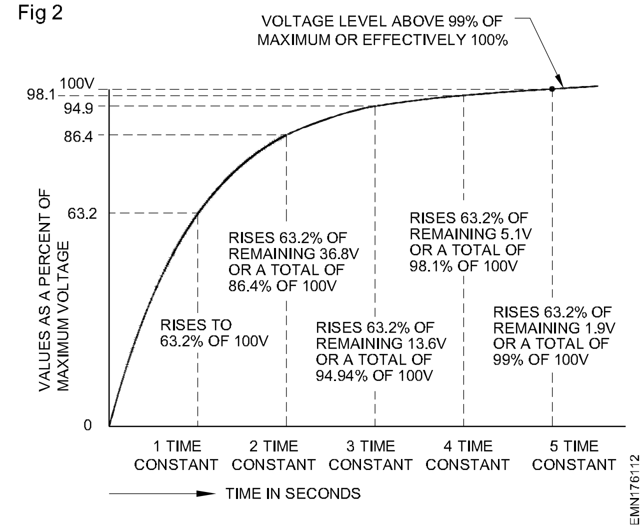
It is interesting to note that, in each succeeding time constant τ, the voltage across the capacitor increases by an additional 63.2 % of the remaining voltage. Thus, after the second time constant (2τ) the capacitor would have charged to 86.4 % of its maximum voltage,

- after 3τ, 94.9 percent, of its maximum voltage,
- after 4τ, 98.1 percent, of its maximum voltage

and – after 5τ, more than 99 percent of its maximum voltage.

Fig 2 shows the charging curve of the resistor - capacitor (RC) circuit shown in Fig 1 and its relationship with RC time constant, τ.

Fig 2

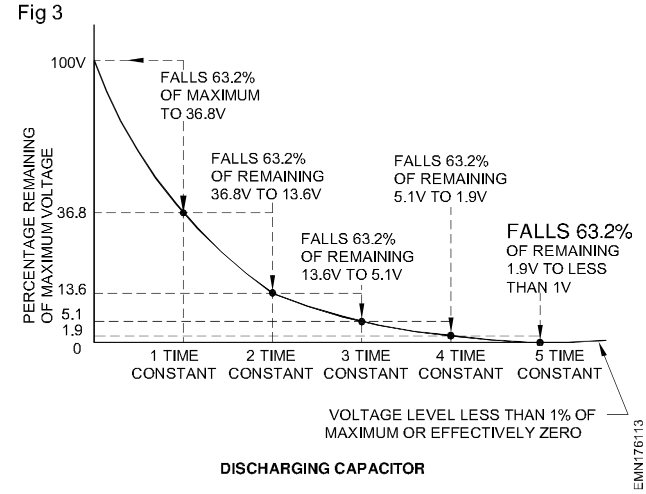


Hence, the capacitor is considered to be fully charged only after a period of more than five time constants or atleast five time constants.

RC time constant while discharging

As in charging, while a capacitor is discharging, there is time delay in discharging the stored charges depending upon the value of resistance and capacitance. This discharge time constant τ, is also given by RC. This time constant gives the time required for the voltage across a discharging capacitor to drop to various percentages of its maximum value as shown in graph at Fig 3.

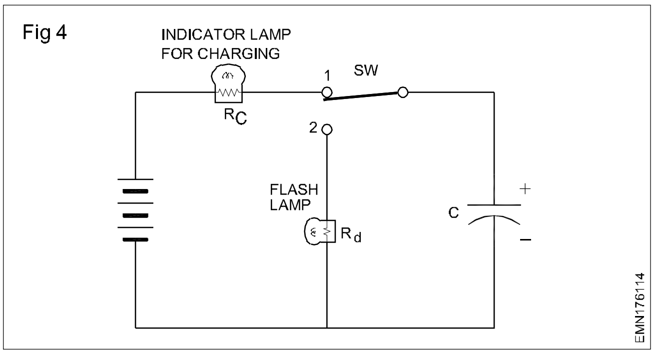
Fig 3



Notice the similarity between the capacitive time constant and the inductive time constant, discussed in previous lessons. The similarity is that, *the voltage across a capacitor* and *the current through an inductor* builds up/ rises and drops off/falls exactly in the same way.

Application of capacitor in camera flash units

A typical circuit of a flash unit is shown in Fig 4. A flash unit produces a short duration, high current pulse without drawing a large current from the supply.



When the flash unit is charging, switch SW is in position 1. The lamp resistance R_C will be large. This high resistance limits the peak charging current I_C to a low value such that the capacitor charges gradually with a large time constant $\tau_1 = R_C C$.

When the switch is thrown to position 2, the low resistance R_d of the flash lamp allows a high discharge current through it. Hence the bulb glows very brightly for a very small duration. The duration of this current is determined by the time constant $\tau_2 = R_d C$.

All similar system of obtaining high surge current is used in applications like, electric spot welding, radar transmitter tubes etc.

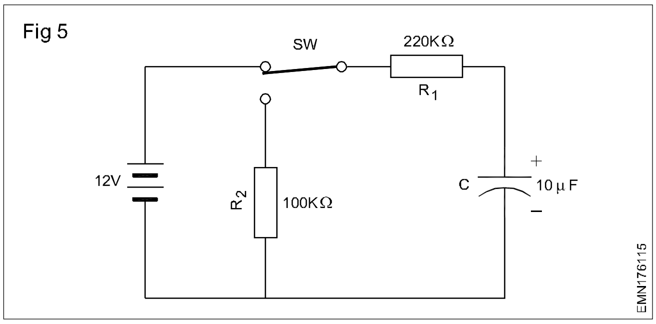
Universal time-constant curves

To determine the voltage and current in a capacitor at times other than 1τ, 2τ,....5τ time constants, the *universal time-constant curves* are used. Refer pocket table book, table no.14 for the universal time-constant curve.

The universal time-constant curves give the instantaneous voltage across the capacitor as a percentage of the initial or final values, with time given in time constants τ. From the graph, note that at one time constant τ, the capacitor would have charged to 63% of its final steady-state voltage. Also at this point the charging current has dropped to only 37% of its initial maximum value current. Note that, in either case, a change of 63% occurs in one time constant.

From these curves it can also be confirmed that, the *Charging or discharging of a capacitor is complete after five time constants*.

For the circuit at Fig 5, using the universal time constant curves, determine the capacitor voltage after 3.5 seconds.



SOLUTION

$\tau = R_1 C$

$= 220 \times 10^3 W \times 10 \times 10^{-6} F$

$= 2.2$ seconds.

Allowed charge time $\tau = 3.5s$

Equivalent number of time constants is equal to

$$= \frac{3.5s}{2.2s/\tau} = 1.59\tau \approx 1.6\tau$$

From the universal graph

where $\tau = 1.6\ \tau$, V_C is almost = 80% of V (the final value).

Therefore,

V_C = 80% of 12 volts

= 0.8 x 12 V = 9.6 volts.

While calculating the discharge time constant, the total series resistance R_1+R_2 must be considered.

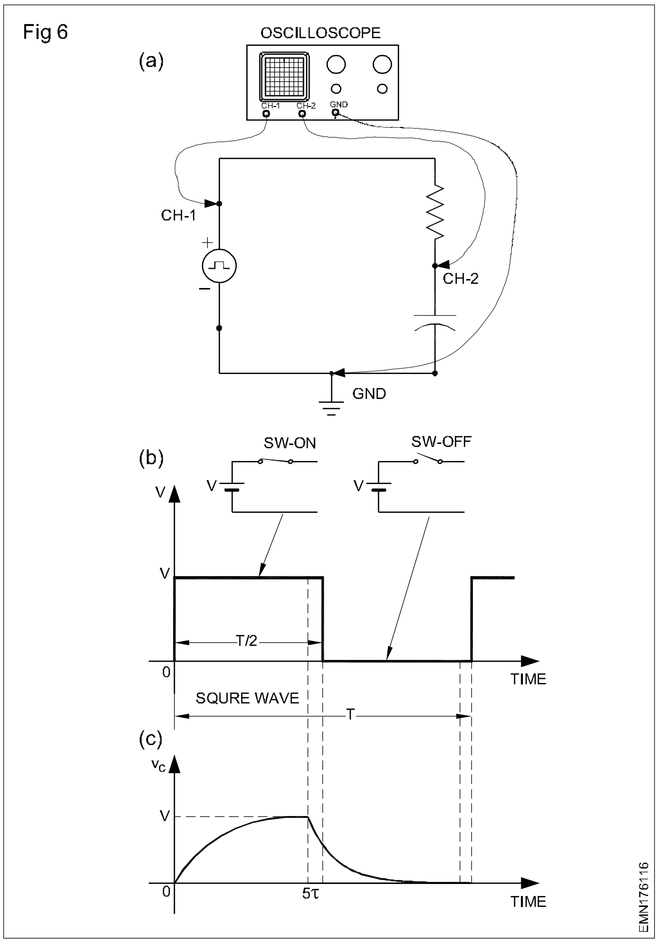
Measurement of voltage levels and capacitance using oscilloscope

A charging and discharging wave-form of a R-C circuit can be seen using an oscilloscope. However, it is difficult to view the charging and discharging of a R-C circuit having a switch similar to the one shown in Fig 5. This is because, the wave-forms appear and disappear on the screen. Hence, instead of a switch, a square wave signal as shown in Fig 6b, whose voltage level changes between 0 and V, just as a switch repeatedly switched ON and OFF, can be more conveniently used.

The advantage of using a square waveform is that, the rate of switching (ON/OFF) can be increased or decreased by increasing or decreasing the frequency of the wave-form (more optly known as pulse repetation rate, PRF).

The output of a square wave signal generator is connected to the capacitive circuit as shown in Fig 6a. The frequency of the waveform (rate of switching ON/OFF of circuit) is adjusted until the voltage wave-form across the capacitor is similar to that as in Fig 6c. Here, half-period of the square wave output ($\tau/2$) is equal to or greater than five time constants, that is $\tau/2$ ³ 5 RC(τ).

With the oscilloscope connected across the capacitor, as shown in Fig 6a, the time required to reach 63% of the final voltage is the time constant, τ. The voltage levels at 1τ, 2τ etc can be easily measured if the Time/Div of the CRO is made equal to the time constant τ.

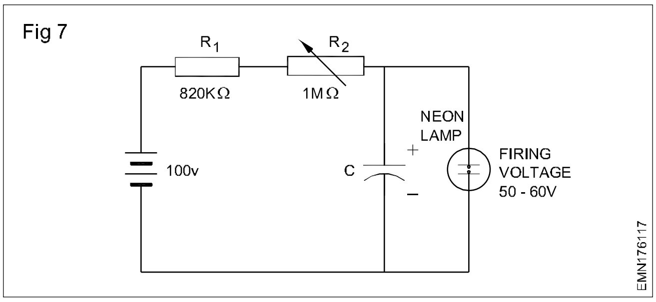


If the total resistance of the circuit is known, the capacitance of the capacitor, if unknown, can be calculated using the formula,

$$C = \frac{\tau}{R} \left(\text{Derived from the formula}, \tau = RC\right)$$

Application of R-C delay circuits

An RC circuit with a large time constant can be used to introduce delay in a circuit as shown in Fig 7.



Here, the neon lamp acts as an open circuit until a firing voltage of the lamp is reached(50-60V). When the circuit is switched ON, the voltage across the capacitor charges toward the final value of 100V, with a time constant of (R_1 + R_2)C. When the charge across the capacitor reaches a value between 50 to 60 volts, the firing voltage of the neon lamp is reached and the lamp fires. The capacitor, hence, discharges through the neon lamp, lighting it up. Because of the low resistance of the neon lamp, the capacitor voltage drops quickly and the lamp gets extinguished after being lighted for a brief period of time(flashing). The lamp once again becomes an open circuit and the capacitor starts recharging, providing a controlled delay time before the lamp one again fires. The rate of flashing can be varied by adjusting R_2.

The delay introduced by the R-C in circuit in Fig 7 can be used for several other useful purposes. For example, if it is required to delay the switching ON of a DC relay following the application of voltage to the relay coil, the circuit at Fig.7 can be used.

R.C. Differentiator

Objectives : At the end of this lesson you shall be able to
- **define R.C. differentiator**
- **connect capacitor and resistance in series**
- **explain about single pulse R.C. differentiator.**

RC Differentiator

The passive RC differentiator is a series connected RC network that produces an output signal which corresponds to the mathematical process of differentiation.

For a passive RC differentiator circuit, the input is connected to a capacitor while the output voltage is taken across a resistance being the exact opposite to the RC integrator circuit.

A passive RC differentiatior is nothing more than a capacitance in series with a resistance. It is a frequency dependant device which has reactance in series with a fixed resistance. Just like the integrator circuit, the output voltage depends on the circuits RC time constant and input frequency.

Thus at low input frequencies the reactance, XC of the capacitor is high blocking any d.c. voltage or slowly varying input signals. While at high input frequencies the capacitors reactance is low allowing rapidly varying pulses to pass directly from the input to the output.

This is because the ratio of the capacitive reactance (X_c) to resistance (R) is different for different frequencies and the lower the frequency the less output. So for a given time constant, as the frequency of the input pulses increases, the output pulses more and more resemble the input pulses in shape.

The effect of passive high pass filters and if the input signal is a wave, an **RC differentiator** will simply act as a simple high pass filter (HPF) with a cut off or corner frequency that corresponds to the RC time constant (tau, τ) of the series network.

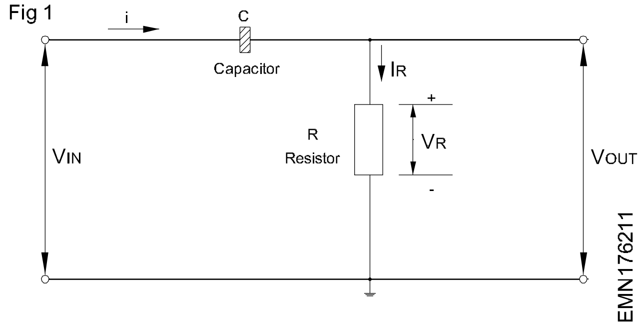
Thus when fed with a pure sine wave an RC differentiator circuit acts as a simple passive high pass filter due to the standard capacitive reactance formula of $X_C = 1/(2\Pi fc)$.

But a simple RC network can also be performed differentiation of the input signal. The rate at which the capacitor charges (or discharges) is directly proportional to the amount of resistance and capacitance giving the time constant of the circuit. Thus the time constant of a RC differentiator circuit is the time interval that equals the product of R and C. Consider the basic RC series circuit is shown in fig 1.

RC differentiator circuit

For an RC differentiator circuit, the input signal is applied to one side of the capacitor with the output taken across the resistor, then V_{out} equals V_R. As the capacitor is a frequency

Fig 1



dependent element the amout of charge it takes a time for across the plates is equal to the time integral of the current capacitor to fully charge as the capacitor can not charge instantaneously only charge exponentially.

Resistor voltage

We said previously that for the RC differentiator the output is equal to the voltage across the resistor , that is V_{out} equals VR and being a resistance, the output voltage can change instantaneous only.

However, the voltage across the capacitor cannot change instantly but depends on the value of the capacitance, C as it tries to store an electrical charge, Q across its plates. Then the current flowing into the capacitor, that is i_t depends on the rate of change of the charge across its plates. Thus the capacitor current is not proportional to the voltage but to its time variation giving: i = dQ/dt.

As V_{OUT} equals V_R where V_R according to ohms law is equal too: i_R x R. The current that flows through the capacitor must also flow through the resistance as they are both connected together in series. Thus :

$V_{OUT} = V_R = R \times i_R$

As $i_R = i_C$, therefore:

$$V_{out} = RC\frac{dv_{IN}}{dt}$$

Thus the standard equation given for an RC differentiator circuit is :

RC Differentiator Formula

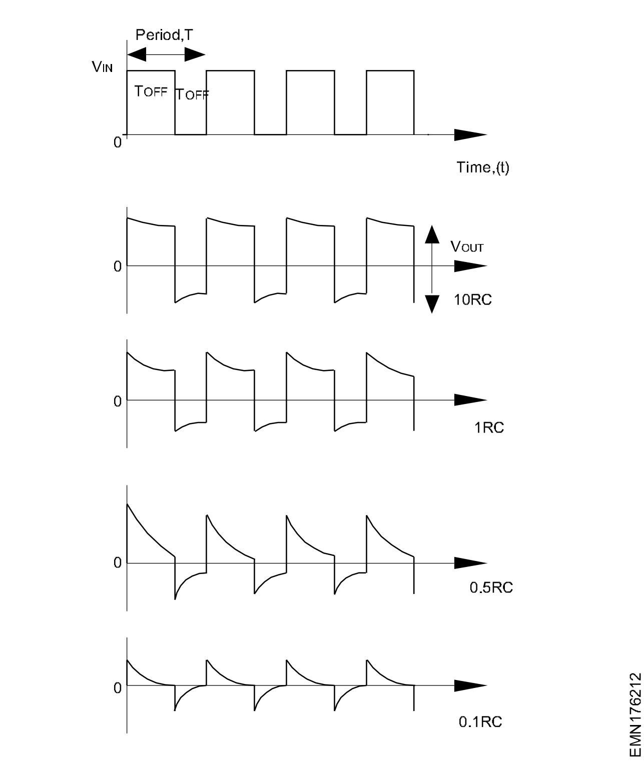
$$V_{out} = RC\frac{dv_{IN}}{dt}$$

We can see that the output voltage, V_{OUT} is the derivative of the input voltage, V_{IN} which is weighted by the constant of RC. Where RC represents the time constant, T of the series circuit.

Single pulse RC differentiator

When a signle step voltage pulse is first applied to the input of an RC differentiator, the capacitor " appears" initially as a short circuit to the fast changing signal. This is because the slope dv/dt of the positive-going edge of a square wave is very large (ideally infinite), thus at the instant signal appears, all the input voltage passes thorugh to the output appearing across the resistor.

Fig 2



RC Differentiator Output Waveforms

We can see that the shape of the output wave form depends on the ratio of the pulse width to the RC time constant. When RC is much larger (Greater than 10RC) than the pulse width the output waveform resembles the square wave of the input signal.When RC is much smaller (less than 0.1 RC) than the pulse width, the output waveform takes the form of very sharp and narrow spikes as shown above

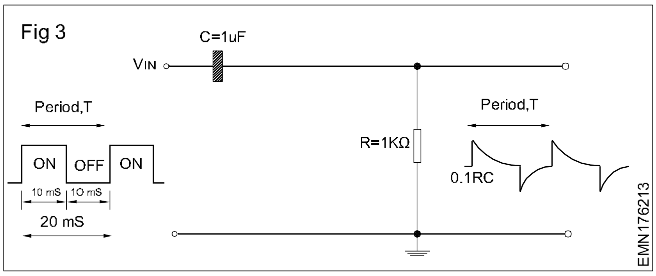
So by varying the time constant of the circuit from 10RC to 0.1 RC we can produce a range of different wave shapes. Generally a smaller time constant is always used in RC differentiator circuits to provide good sharp pulses at the output across R. Thus the differential of a square wave pulse (high dv/dt step input) is an infinitly short spike resulting in an RC differentiator circuit.

Lets assume a square wave waveform has a period, T of 20 mS giving a pulse width of 10mS (20mS divided by 2). For the spike to discharge down to 37% of its initial value, the pulse width must equal the RC time constant, that is RC = 10mS. If we choose a value for the capacitor, C of 1 uF, then R equals 10kΩ.

For the output to resemble the input, we need RC to be ten times (10RC) the value of the pulse width, so for a capacitor value of say, 1uF, this would give a resistor value of : 100kΩ. Likewise, for the output to resemble a sharpe pulse, we need RC to be one tenth (0.1 RC) of the pulse width, so for the same capacitor value of 1 uF, this would give a resistor value of: 1kΩ, and so on.

Example for RC differentiator

Fig 3



So by having an RC value of one tenth the pulse width (and in our example above this is 0.1 x 10mS = 1mS) or lower we can produce the required spikes at the output, and the lower the RC time constant for a given pulse width, the sharper the spikes. Thus the exact shap of the output waveform depends on the value of the RC time constant.

R.L.C. Series and parallel circuit

Objectives : At the end of this lesson you shall be able to
- **define inductive reactance**
- **define resistance and inductance in AC series circuit**
- **describe resistance and capacitance in AC series circuit**
- **explain resistance inductance and capacitance in AC series circuit**
- **describe resistance and inductance in AC parallel circuit**
- **explain resistance and capacitance in AC parallel circuit**
- **describe resistance, inductance and capacitance in AC parallel circuit**
- **explain series and parallel resonance circuit.**

Inductive reactance (X_L)

When a DC voltage is applied to an inductor, the inductor has its effect only during switching ON and switching OFF of the circuit . With steady current in circuit, inductance has no effect. Instead of DC, if a sinusoidal AC current is made to flow through an inductor, as shown in Fig 1a, since the magnitude of sinusoidal current is continuously varying, as shown in Fig 1b, the inductor continuously keep opposing these changes. This continuous opposition is entirely dependent on the induced emf in the coil and has nothing to do with opposition due to the DC resistance of the coil. The effective opposition to the flow of alternating current, due to the self induced emf. The inductive reactance can be calculated by the equation $X_L = 2\pi fL$ generated by an inductor (L) and the frequency (f) of the current.

As in a resistive circuit, where opposition to current is given by,

$R = V_R / I_R$

where, V_R = Voltage across the resistor

and I_R = Current through the resistor

similarly, the opposition to current by a pure inductance is given by,

$X_L = V_L / I_L$

where,

X_L is the inductive reactance in ohms, W

V_L is the voltage across the pure inductor in volts, V

I_L is the current through the inductor in amperes, A

Power consumed by a pure inductor

The power consumed by a pure resistor is given by;

$P = I^2R = I.V$ (V=I.R)

The power consumed by a components having both resistive and reactive component is given by $P = V.I.Cos\theta$

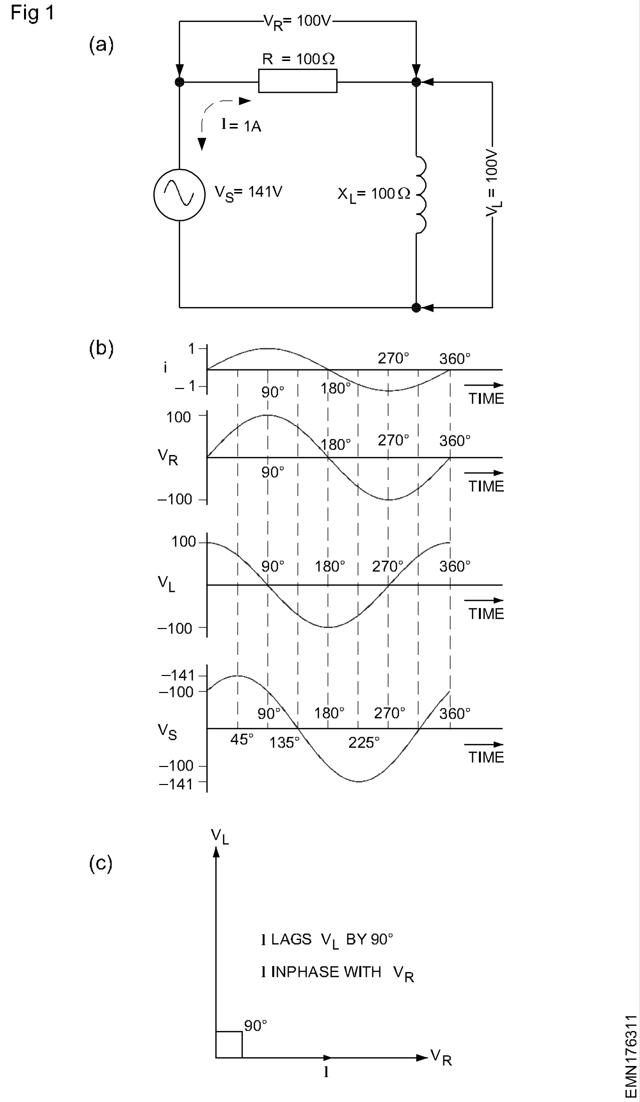
where,

V = Voltage applied across the component

I = Current through the component

and ø = Phase angle difference between V and I

Fig 1



In a pure inductor, as shown in Fig 3b, phase difference between V and I is 90°. Therefore, the power consumed by a pure inductor is $P_{inductor}$ = V.I.Cos90°

Cos 90° = 0 (Refer trigonometric tables)

Therefore $P_{inductor}$ = V.I.0 = 0.

R-L series circuit

Referring to Fig 1a, the circuit current(I) is limited by both the ohmic resistance R and inductive reactance X_L. Each has its own series voltage drops IR and IX_L. Here the circuit current is labeled as I, instead of I_L, because current I flows through both the series components R and L.

In this way, the total inductance (L_t) is equal to the sum of individual inducatance (L_1, L_2, L_3, ...)

Graph at Fig 1b shows the instantaneous values of i, V_R, V_L and the source voltage V_S. A vector diagram of V_R, V_L and I is shown in Fig 1c. The vector diagram at Fig 1c, shows that the current I lags behind the voltage V_L by 90°. But the current I is in phase with V_R.

From the graph at Fig 1b, V_R is maximum(100V) when V_L is minimum and vice versa. This is again because of the phase difference. Because of this the series voltage drops V_R and V_L cannot be added arithmetically to get the applied source voltage V_S. The method of adding V_R and V_L is shown in Fig 2.

Fig 2a shows the vectorial addition method to get V_S knowing V_R and V_L.

Fig 2c gives the total resultant opposition to current flow due to R and X_L. This total resultant opposition due to resistance R and inductive reactance X_L is called Impedance in ohms with the symbol Z. The impedance Z, takes into account the phase relationship between R and X_L.

The impedance Z of the circuit given at Fig 2c is,

$$Z = \sqrt{R^2 + X_L{}^2} \quad ...[4]$$

$$= \sqrt{100^2 - 100^2} = 141\Omega$$

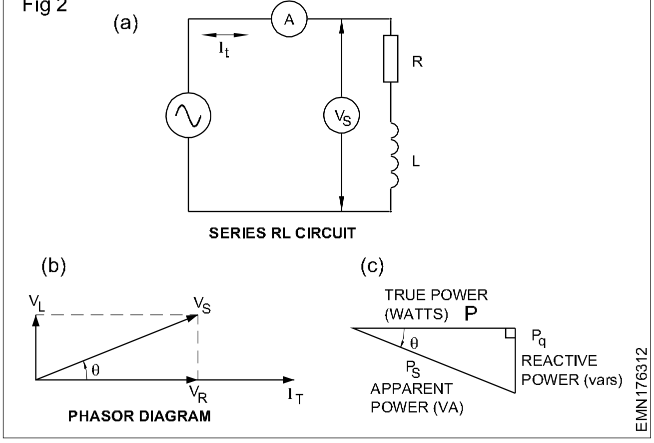
Power consumed in a Resistance - Inductance Circuit (R-L circuit)

The total power consumed in a R-L circuit will contain the True power due to the pure resistive component and the Reactive power due to the reactive component.

The power consumed by a reactive component is referred to as reactive power.

In the series R-L circuit at Fig 2a, Apparent power P_s is the vectorial sum of True power (P) and the reactive power (P_q) as shown in Fig 2c.

Fig 2



Apparent power (P_s) is also given by the product of source voltage V_S and total circuit current I_t.

Apparent power = $V_s \times I_t$ in volt-ampers, VA ...[5]

To distinguish from reactive power and apparent power, the power dissipated in a resistor in the form of heat (or in any other form), the term Real power or True power is used.

True power = $V_R \times I_R$ watts, W

Quality factor - Q of coil

At high frequencies, how useful is a coil is not only judged by its inductance, but also by the ratio of its inductive reactance to its internal DC resistance of the coil. This ratio is called the Quality factor or merit or Q of the coil.

Q of a coil is given by, $Q = \frac{X_L}{R_i}$

where,

X_L is the reactance of the coil in ohms

R_i is the internal Resistance of the coil in ohms

Since X_L and R_i have the same units of measure, Q has no unit.

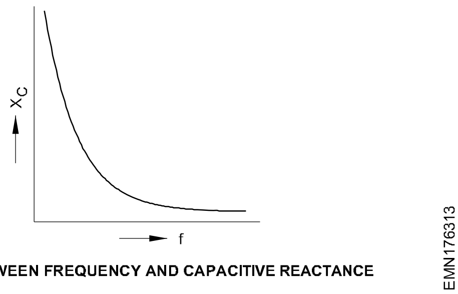
The Q of a coil can be defined as the ability of a coil to produce self-induced voltage. The Q factor of a coil can also be defined as the capability of the coil to store energy. Hence the Q factor of a coil is also known as the storage factor.

If Q of a coil is 200, it means, that the X_L of the coil is 200 times more than it's R_i. Q of coils range from less than 10 for a low Q coil up-to 1000 for a high Q coils. R.F coils have Q in the range from 30 to 300.

R-C series circuit:

In a circuit with capacitance, the capacitive reactance (X_C) decreases when the supply frequency (f) increases as shown in Fig 3.

Fig 3



RELATION BETWEEN FREQUENCY AND CAPACITIVE REACTANCE

$$X_c \alpha \frac{1}{f}$$

When the capacitive reactance X_C increases the circuit current decreases.

$$I \alpha \frac{1}{X_c}$$

Therefore the increase in frequency (f) results in the increase of the circuit current in the capacitive circuit. When resistance (R), capacitance (C) and frequency f are known in a circuit, the power factor cos θ can be determined as follows.

$$X_c = \frac{1}{2\pi f c}$$

$$Z = \sqrt{R^2 + X_c^2}$$

Power factor, $\cos\theta = \frac{R}{Z}$

Power consumed in a R-C series circuit can be determined using the formula.

P= VI Cosθ where P = Power in watts, I = Current in ampere Cosθ = Power factor

Example 1: In RC series circuit shown in the diagram (Fig 4) obtain the following.

– Impedance in ohms

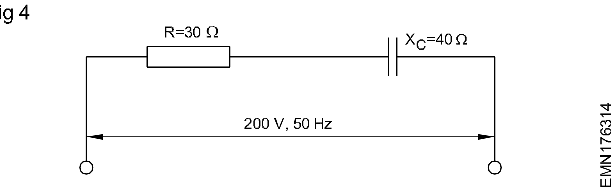


Fig 4

– Current in amps

– True power in watts

– Reactive power in VAR

– Apparent power in volt amp.

– Power factor

Solution

1. Impedence Z

$$= \sqrt{R^2 + X_C^2} = \sqrt{30^2 + 40^2} = \sqrt{2500} = 50\Omega.$$

2. Current $I = \frac{V}{Z} = \frac{200}{50} = 4A$

3. True power W = $I^2R = 4^2 \times 30 = 480W$
(Power consumed by capacitoir = zero)
$V_C = IX_C = 4 \times 40 = 160$ V

4. Reactive power VAR = $V_C I = 160 \times 4 = 640$ VAR
Apparent power $VI = 200 \times 4 = 800$ VA

PF $\cos\theta = \frac{R}{Z} = \frac{30}{50} = 0.6$

RLC Series circuit

Assume an AC single phase circuit consisting a resistance, inductor and capacitor in series. Various parameters could be calculated as shown in the example.

Example : The value of the components shown in Fig 5 is R = 40 ohms L = 0.3 H and C = 50µ. The supply voltage is 240V 50 Hz. Calculate the inductive reactance, capacitance reactance, net reactance, impedance, current in the circuit, voltage drops across the R, L and C power factor, active power, reactive power and apparent power. Also draw the impedance triangle, voltage triangle and power triangle.

Calculate the resulting reactance in RLC circuit : Inductance and capacitance have directly opposite effects in an AC circuit. The voltage drop caused by the inductive reactance of the coil leads the line current by 90°. The voltage drop across the inductor coil and the capacitor are 180 degrees apart and oppose each other. To calculate the net reactance in the above example:

Inductive reactance

$X_L = 2\pi fL = 314 \times 0.3 = 94.2\ \Omega$

Capactive reactance

$$X_c = \frac{1}{2\pi fC} = \frac{1}{314 \times 0.00005} = \frac{1}{0.0157} = 63.69\ \Omega$$

Net reactance = $X_L - X_C = 94.2 - 63.69 = 30.51\ \Omega$

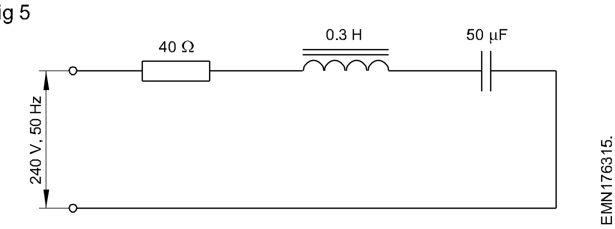


Fig 5

Measurement of current and voltage drop in RLC circuit. The voltage drop across R = E_R across L = E_L and drop across C = E_C and the formula for finding their values and given below. (Fig 6)

$E_R = IR$

$E_L = IX_L$

$E_C = IX_C$

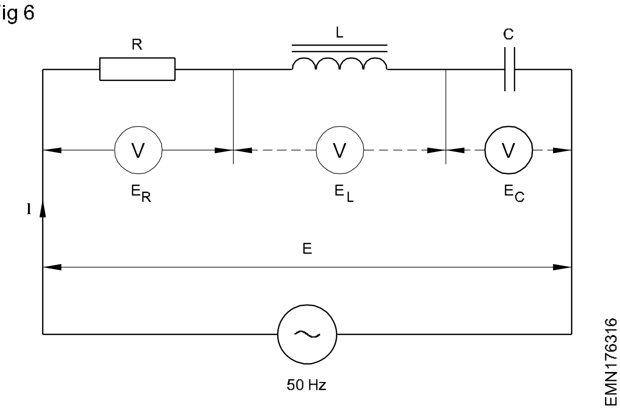


Fig 6

Current in given RLC series circuit: Current in this series circuit is I = E/Z = 240/50.3 = 4.77 amps.

Identifying whether the current flow is leading or lagging the voltage in a RLC series circuit: As this is a series circuit, the current is the same in all parts of the circuit, but the voltage drop across the resistor, the inductor coil and capacitor are

$E_R = IR = 4.77 \times 40 = 190.8$ volts

$E_L = IX_L = 4.77 \times 94.2$ W = 449.33 volts

$E_C = IX_C = 4.77 \times 63.69 = 303.80$ volts.

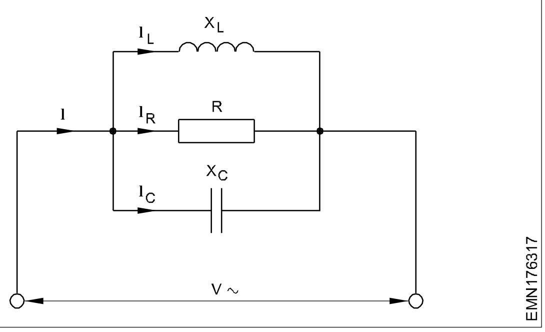
Resonance circuit: When the value of X_L and X_C are equal, the voltage drop across them will be equal and hence they cancel each other. The value of voltage drops V_L and V_C may be much higher than the applied voltage. The impedance of the circuit will be equal to the resistance value. Full value of applied voltage appears across R and the current in the circuit is limited by the value of resistance only. Such circuits are used in electronic circuits like radio/ TV turning circuits. When $X_L = X_C$ the circuit is said to be in resonance. As current will be maximum in series resonant circuits it is also called acceptor circuits. For a known value of L and C the frequency at which this occurs is called as resonant frequency. This value can be calculated as follows when $X_C = X_L$

$$2\pi fL = \frac{1}{2\pi fC}$$

Hence resonant frequency $f = \dfrac{1}{2\pi\sqrt{LC}}$

Parallel connection of R, X_L and X_C: X_L and X_C oppose each other, that is to say, I_L and I_C are in opposition, and partly annul one another. (Fig 7)

Fig 7



$I_X = I_C - I_L$ or $I_L - I_C$, depending on whether the capacitive or inductive current dominates.

Graphic solution: when $I_L > I_C$

1 V as common value

2 I_R in phase with V

3 I_C leads by 90^o

4 I_L lags by 90^o

5 $I_X = I_L - I_C$

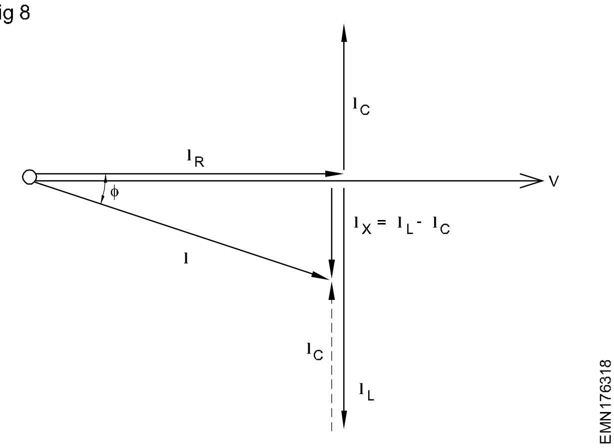
6 I as resultant

7 <) φ (in this case inductive, I lags)

Particular case*:* X_L and X_C are equally large - I_L and I_C cancel each other. Z = R; parallel resonance occurs.

Currents in the reactances may be greater than the total current.

Fig 8



The calculation of the resonant frequency is the same as for the series connection.

Example*:* Calculate the value of I_T Z power factor and power for the circuit in Fig 9.

Given

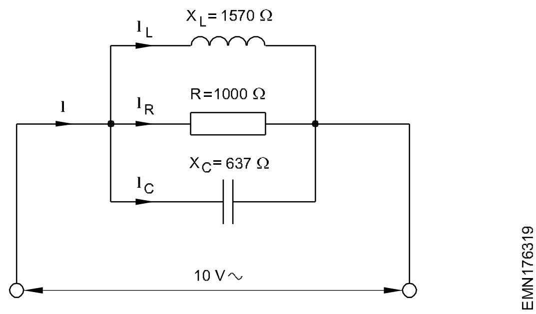
$V_T = 10V$

$R = 1000\ \Omega$

$X_L = 1570\ \Omega$

$X_C = 637\ \Omega$

Fig 9



Known: Ohm's Law

$$I_T = \sqrt{(I_C - I_L)^2 + I_R^2}$$

Solution

$$I_C = \frac{10\ V}{637\ \Omega} = 0.0157\ A = 15.7\ mA$$

$$I_L = \frac{10\ V}{1570\ \Omega} = 0.0064\ A = 6.4\ mA$$

$$I_R = \frac{10\ V}{1000\ \Omega} = 0.01 = 10\ mA$$

$$I_T = \sqrt{(0.0157 - 0.0064)^2 + 0.01^2}$$

$$= 0.0137\ A = 13.7\ mA$$

$$Z = \frac{10V}{0.0137\ A} = 730\ \Omega$$

$$P.F = \frac{Z}{R} \qquad Y = \frac{1}{Z} \text{ and } g = \frac{1}{R}$$

$$= \frac{730}{1000} = 0.73$$

$$\text{PF in admittance triangle} = \frac{g}{Y} = \frac{1}{R} \times \frac{1}{1/Z} = \frac{Z}{R}$$

$$\text{Power} = V I \cos\theta$$

$$= 10 \times 0.0137 \times 0.73$$

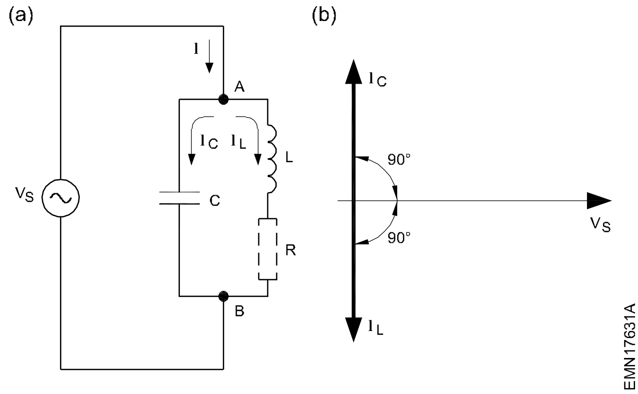
$$= 0.1 \text{ Watt or } 100 \text{ mw.}$$

PARALLEL RESONANCE

The circuit at Fig 10, having an inductor and a capacitor connected in parallel is called parallel LC circuit or parallel resonance circuit. The resistor R, shown in dotted lines indicate the internal DC resistance of the coil L. The value of R will be so small compared to the inductive reactance, that it can be neglected.

From Fig 10a, it can be seen that the voltage across L and C is same and is equal to the input voltage V_S.

Fig 10



By Kirchhoff's law, at junction A,

$$I = I_L + I_C.$$

The current through the inductance I_L (neglecting resistance R), lags V_S by 90°. The current through the capacitor I_C, leads the voltage V_S by 90°. Thus, as can be seen from the phasor diagram at Fig 10b, the two currents are out of phase with each other. Depending on their magnitudes, they cancel each other either completely or partially.

If $X_C < X_L$, then $I_C > I_L$, and the circuit acts capacitively.

If $X_L < X_C$, then $I_L > I_C$, and the circuit acts inductively.

If $X_L = X_C$, then $I_L = I_C$, and hence, the circuit acts as a purely resistive.

Zero current in the circuit means that the impedance of the parallel LC is infinite. This condition at which, for a particular frequency, f_r, the value of $X_C = X_L$, the parallel LC circuit is said to be in parallel resonance.

Summarizing, for a parallel resonant circuit, at resonance,

$$X_L = X_C,$$

$$Z_p = ¥$$

$$I_L = I_C$$

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$I = \frac{v}{Z_p} \approx 0$$

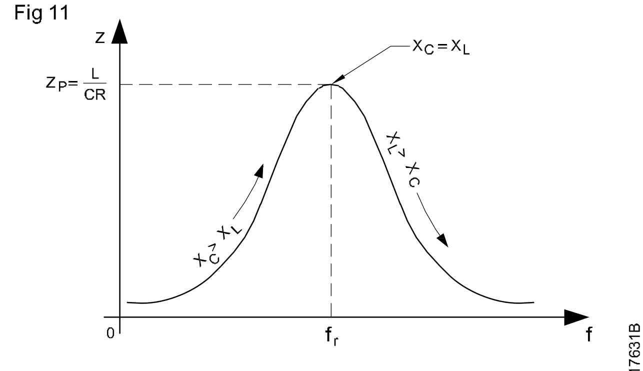
In a parallel resonance circuit, with a pure L(no resistance) and a pure C(loss-less), at resonance the impedance will be infinite. In practical circuits, however small, the inductor will have some resistance. Because of this, at resonance, the phasor sum of the branch currents will not be zero but will have a small value I. This small current I will be in phase with the applied voltage and the impedance of the circuit will be very high although not infinite.

Summarizing, the three main characteristics of parallel resonance circuit at resonance are,

- phase difference between the circuit current and the applied voltage is zero
- maximum impedance
- minimum line current.

The variation of impedance of a parallel resonance circuit with frequency is shown in Fig 11.

Fig 11



FREQUENCY VERSES IMPEDENCE OF A PARALLEL RESONANT CIRCUIT

In Fig 11, when the input signal frequency to the parallel resonance circuit is moved away from resonant frequency f_r, the impedance of the circuit decreases. At resonance the impedance Z_p is given by,

$$Z_p = \frac{L}{CR}$$

At resonance, although the circuit current is minimum, the magnitudes of I_L & I_C will be much greater than the line current. Hence, a parallel resonance circuit is also called current magnification circuit.

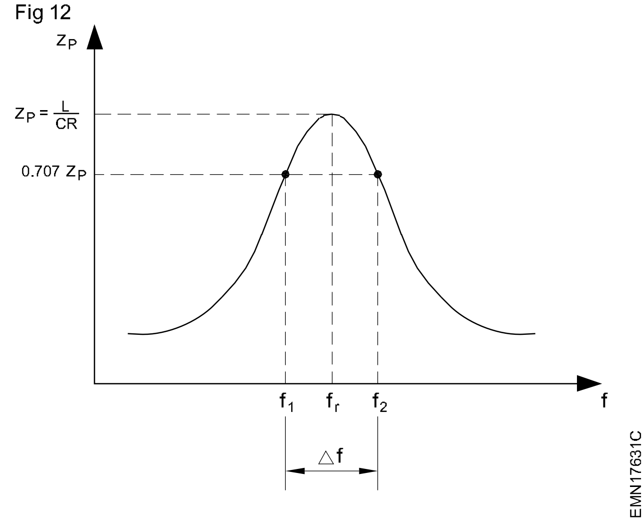
Bandwidth of parallel resonant circuits

As discussed in series resonance, all resonant circuits have the property of discriminating between the frequency at resonance(f_r), and those not at resonance. This discriminating property of the resonant circuit is expressed in terms of its **bandwidth(BW).** In the case of series resonant circuits the response of the circuit at resonance frequency(f_r) is in terms of the line current(which is maximum), and in a parallel resonant circuit, it is in terms of the impedance(which is maximum).

The bandwidth of a parallel resonant circuit is also defined by the two points on either side of the resonant frequency at which the value of impedance Z_p drops to 0.707 or $1/\sqrt{2}$ of its maximum value at resonance, as shown in Fig 12.

From Fig 12, the bandwidth of the parallel resonance circuit is,

Fig 12



Bandwidth, BW = Df = $f_2 – f_1$

As can be seen in Fig 43, the value of Z_p is dependent on the resistance R of the coil (Z_p = L/CR). If R is less Z_p will be larger and vice versa. Since the bandwidth depends on Z_p and Z_p depends on R, we can say that the bandwidth of a resonant circuit depends upon the resistance associated with the coil. The resistance of the coil in turn decides the Q of the circuit. Thus, the Q of the coil decides the band width of the resonant circuit and is expressed as,

$$\text{Bandwidth(BW)} = (f_2 - f_1) = \frac{f_r}{Q}$$

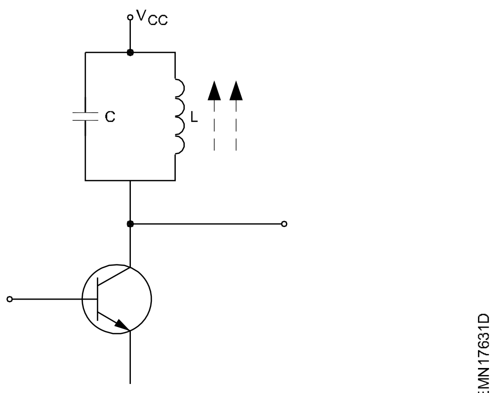
Storage action of parallel resonance circuit

At parallel resonance, though the circuit current is minimum(ideally zero), I_L and I_C will still be there. This I_L and I_C will be a circulating current in the closed loop formed by L and C. This circulating current will be very high at resonance. This circulating current flip-flops between the capacitor and inductor, alternately charging and discharging each. When a capacitor or an inductor is charged, it stores energy. When it is discharged it gives up the energy stored in it. The current inside the LC circuit switches the stored energy back and forth between L and C. If the inductor had no resistance and if the capacitor was loss-free, then, no more external energy would be required to retain this flip-flop or oscillation of charging and discharging. But, in a practical circuit, since ideal L and C cannot be obtained, some amount of the circulating energy is lost due to the resistance of the coil and the loss due to capacitor. This lost energy is the only energy the power supply source(V_S) must supply in the form of circuit current,I. This current, therefore, is called as **make-up current.** It is this storage action of the parallel-resonant circuit which gives rise to the term **tank circuit**, often used with parallel resonant circuits. Hence, parallel resonant circuits are also called tank circuits.

Application of parallel resonant circuits

Parallel resonance circuits or tank circuits are commonly used in almost all high frequency circuits. Tank circuits are used as collector load in class-C amplifiers instead of a resistor load as shown in Fig 13.

Fig 13



Tank circuits are used in circuits known as oscillators which are designed to generate AC signals using DC supply.

Table below gives a comparison between *series resonant* and *parallel resonant* circuit at frequencies above and below their resonant frequency f_r.

Semiconductor diodes

Objectives : At the end of this lesson you shall be able to
- **define semiconductors**
- **state the types of semiconductors**
- **state the unique property of a PN junction**
- **explain the classifications of diodes**
- **list out type numbers/code numbers of diodes.**

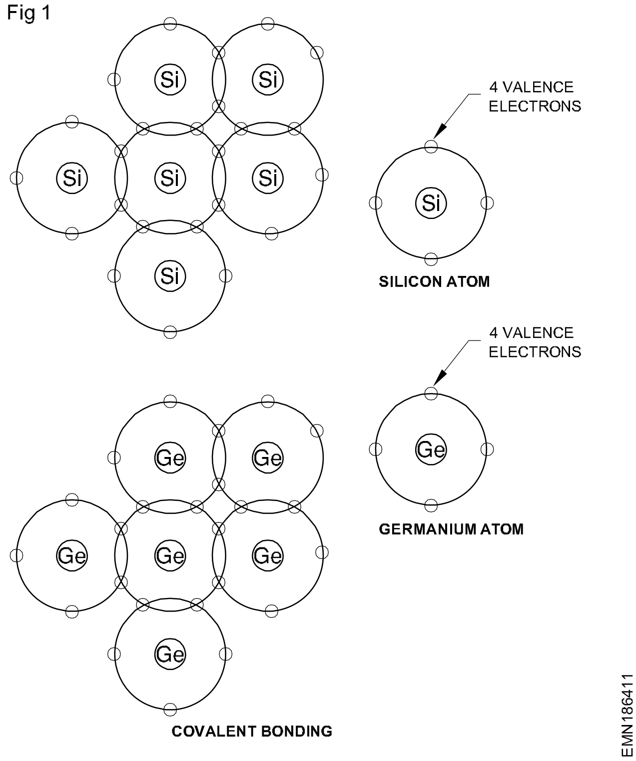
Semiconductors

Semiconductors are materials whose electrical property lies between that of Conductors and Insulators. Because of this fact, these materials are termed as semiconductors. In conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in a semiconductor the valence electrons are normally bound but can be set free by supplying a small amount of energy. Several electronic devices are made using semiconductor materials. One such device is known as Diode.

Semiconductor theory

Basic semiconductor materials like other materials have crystal structure. The atoms of this structure, are bonded to each other as shown in Fig 1. This bonding is known as covalent bonding. In such a bonding, the valence electrons of the atoms are shared to form a stable structure as shown in Fig 1.

Fig 1

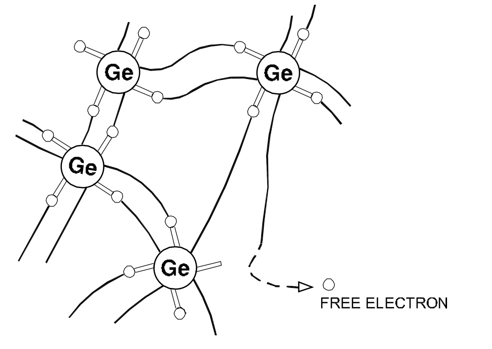


Intrinsic semiconductors

The most important of the several semiconductor materials are Silicon (Si) and Germanium (Ge). Both these semiconductor materials have four valence electrons per atom as shown in Fig 1. These valence electrons, unlike in conductors, are not normally free to move. Hence, semiconductors in their pure form, known as Intrinsic semiconductors, behave as insulators.

However, the valence electrons of a semiconductor can be set free by applying external energy. This energy will tear-off the bound electrons from their bond and make them available as free electrons as shown in Fig 2. The simplest method of turning bonded valence electrons into free electrons is by heating the semiconductor.

Fig 2



The higher the temperature to which the semiconductor is heated, more the bound electrons becoming free and will be able to conduct electric current. This type of conduction in an intrinsic semiconductor (pure semiconductor) as a result of heating is called intrinsic conduction.

From the above said phenomena, it is important to note that semiconductors are temperature-sensitive materials.

Extrinsic semiconductor

The number of free electrons set free by heating a pure semiconductor is comparatively small to be used for any useful purpose. It is found experimentally that, when a small quantity of some other materials such as Arsenic, Indium, Gallium etc. is added to pure semi conductor material, more number of electrons become free in the mixed material. This enables the semiconductor to have higher conductivity.

These foreign materials added to the pure semiconductor are referred to as impurity materials.

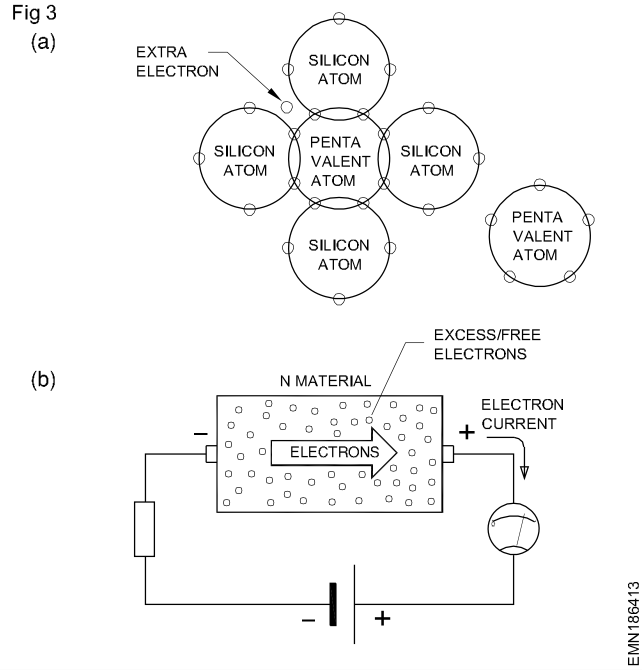
The process of adding impurity to an Intrinsic semiconductor material is known as Doping. Since the doped semiconductor materials are no longer pure, they are called impure or **extrinsic semiconductors.**

Depending upon the type of impurity used, extrinsic semiconductors can be classified into two types;

1 N-type semiconductors

When a pentavalent material like Arsenic (As) is added to a pure Germanium or pure Silicon crystal, one free electron results per bond as shown in Fig 3a. As every arsenic atom donates one free electron, arsenic is called the donor impurity. Since a free electron is available and since the electron is of a Negative charge, the material so formed by mixing is known as **N type material.**

Fig 3



When a N-type material is connected across a battery, as shown in Fig 3b, current flows due to the availability of free electrons. As this current is due to the flow of free electrons, the current is called electron current.

In N type semi conductor the current is due to electrons, therefore the electrons are the majority charge carriers.

The semi conductor materials are temperature sensitive, heating causes the covalent bonds to break down by creating electron-hole pair. The holes are minority charge carriers - in N type semi-conductors.

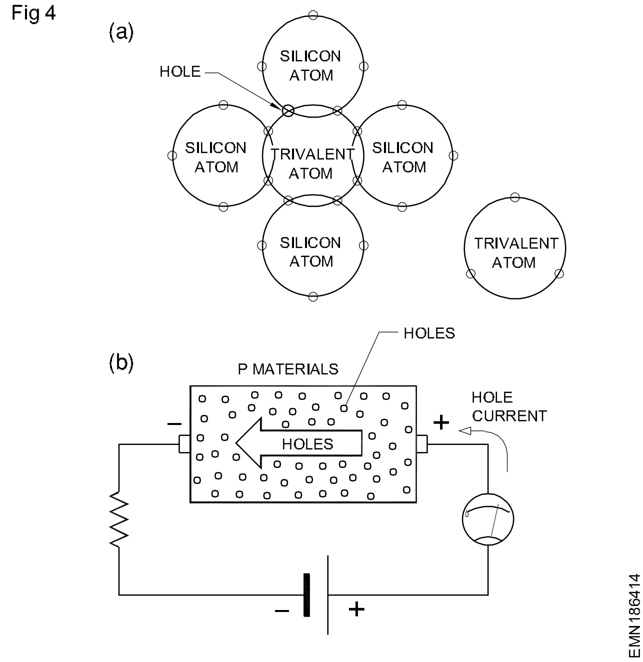
2 P-type semiconductors

When a trivalent material like Gallium(Ga) is added to a pure Germanium or pure Silicon crystal, one vacancy or deficit of electron results per bond as shown in Fig 4a. As every gallium atom creates one deficit of electron or hole, the material is ready to accept electrons when supplied. Hence gallium is called acceptor impurity. Since vacancy for an electron is available, and as this vacancy is a hole which is of Positive charge, the material so formed is known as **P-type material**.

When a P-type material is connected across a battery as shown in Fig 4b, current flows due to the availability of free holes. As this current is due to flow of holes, the current is called hole current.

The holes are the majority charge carriers in P type semi conductor and the electrons are the minority charge carriers.

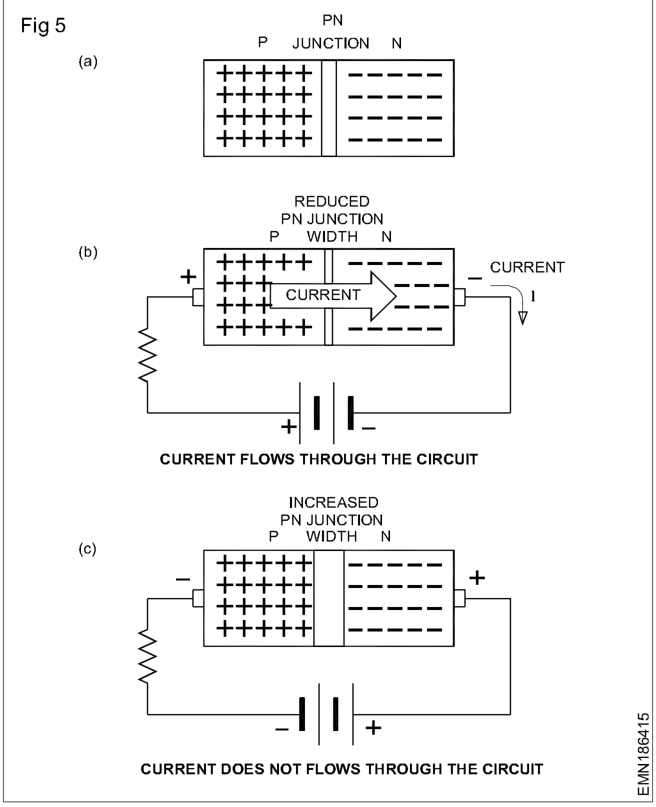
Fig 4



P-N junction

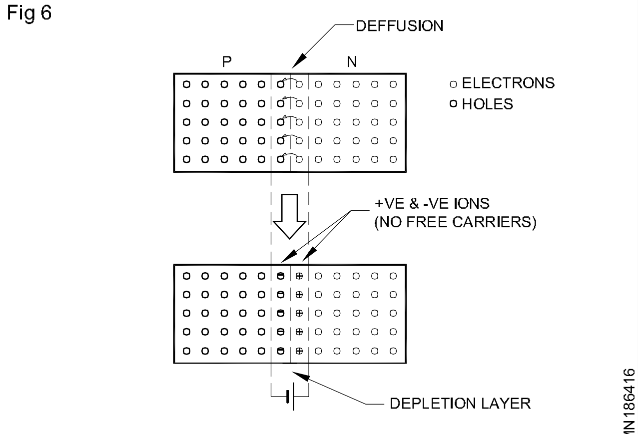
When a P-type and a N-type semiconductors are joined, a contact surface between the two materials called PN-junction is formed. This junction has a unique characteristic. This junction, has the ability to pass current in one direction and stop current flow in the other direction. To make use of this unique property of the PN junction, two terminals one on the P side and the other on the N side are attached. Such a PN junction with terminals attached is called a **Diode.**

Fig 5



When a P and N material is put together, at the junction of P and N materials, as shown in Fig 6, some electrons from the N-material jump across the boundary and recombine with the hole near the boundary of the P-material. This process is called diffusion. This recombination makes atoms near the junction of the P-material gaining electrons and become negative ions, and the atoms near the junction of the N-material, after losing electrons, become

Fig 6



BATTERY EQUIVALENT OF JUNCTION

positive ions. The layers of negative and positive ions so formed behave like a small battery. This layer is called the depletion layer because there are neither free electrons nor holes present (depleted of free carriers). This depletion region prevents further the movement of electrons from the N-material to the P material, and thus an equilibrium is reached.

The internal voltage set up due to +ve and -ve ions at the junction is called barrier potential. If any more electrons have to go over from the N side to the P side, they have to overcome this barrier potential. This means, only when the electrons on the N side are supplied with energy to overcome the barrier potential, they can go over to the P side.

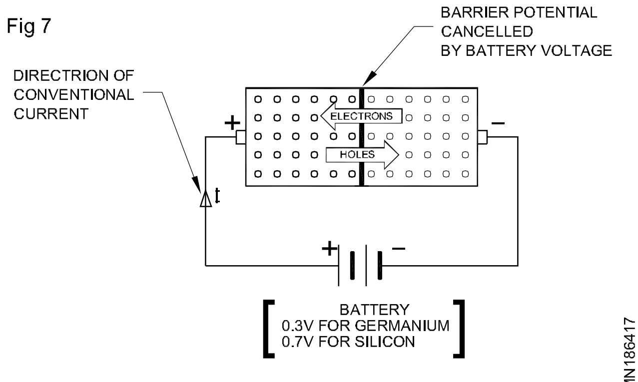
In terms of voltage applied across the terminals of the PN junction diode, a potential difference of 0.7V is required across the terminals in the case of silicon diode and 0.3V in the case of Germanium diode for the electrons, in order to cancel off the barrier potential and cross over the barrier as shown in Fig 7. Once the barrier potential gets canceled due to external voltage application, current flows through the junction freely. In this condition the diode is said to be forward biased.

When the applied external battery polarity is as shown in Fig 8, instead of canceling the barrier potential, the external battery voltage adds up to the barrier potential, and, hence, no current flows through the junction. In this condition the diode is said to be reverse biased.

Since current flows through a PN junction diode when it is forward biased and does not when reverse biased, the diode can be thought of to be a unidirectional current switch.

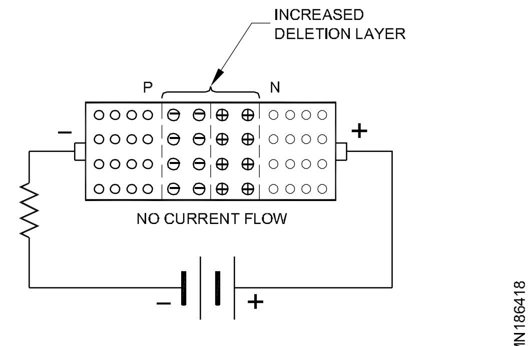
The two leads connected to the P and N terminals are known as Cathode and Anode.

Fig 7



FORWARD BIASED P N JUNCTION

Fig 8



REVERSE BIASED P N JUNCTION

To forward-bias a diode, the Anode should be connected to the +ve terminal of the battery and the Cathode to the -ve terminal of the battery. When a diode is in the forward biased condition, the resistance between the terminals will be of the order of a few ohms to a few tens of ohms. Hence, current flows freely when a diode is forward biased.

On the other hand, when a diode is reverse biased, the resistance between the terminals will be very high, of the order of several tens of megohms. Hence, current does not flow when a diode is reverse biased. As a rule, the ratio of resistance in forward to reverse bias should be of at the minimum order of 1:1000.

Types of diodes

The PN junction diodes discussed so far are commonly referred to as rectifier diodes. This is because these diodes are used mostly in the application of rectifying AC to DC.

Classification of Diodes

1 Based on their current carrying capacity/power handling capacity, diodes can be classified as

- **low power diodes:** can handle power of the order of several milliwatts only
- **medium power diodes:** can handle power of the order of several watts only
- **high power diodes:** can handle power of the order of several hundreds of watts.

2 Based on their principal application, diodes can be classified as,

- **Signal diodes:** low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing

- **Switching diodes:** low power diodes used in switching circuits such as digital electronics etc. for fast switching ON/OFF of circuits
- **Rectifier diodes:** medium to high power used in power supplies for electronic circuits for converting AC voltage to DC.

3 **Based on the manufacturing techniques used, diodes can be classified as,**

- **Point contact diodes:** a metal needle connected with pressure on to a small germanium(Ge) or silicon(Si) tip.
- **Junction diodes:** made by alloying or growing or diffusing P and N materials on a semiconductor substrate.

Types of diode packaging

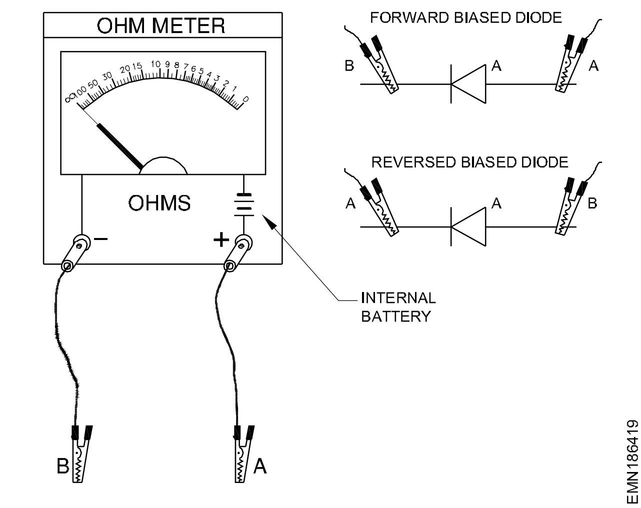
The type of packaging given to diodes is mainly based on the current carrying capacity of the diode. Low power diodes have either glass or plastic packaging. Medium power diodes have either plastic or metal packaging. High power diodes will invariably have either metal can or ceramic packaging. High power diodes are generally of stud-mounting type.

Testing rectifier diodes using ohmmeter

A simple ohmmeter can be used to quickly test the condition of diodes. In this testing method, the resistance of the diode in forward and reverse bias conditions is checked to confirm its condition.

Recall that there will be a battery inside an ohmmeter or a multimeter in the resistance range. This battery voltage comes in series with the leads of the meter terminals as shown in Fig 9 and lead A is positive, lead B negative.

Fig 9



If the positive lead of the ohmmeter, lead A in the Fig 10, is connected to the anode of a diode, and the negative (lead B) to the cathode, the diode will be forward-biased. Current will flow, and the meter will indicate low resistance.

On the other hand, if the meter leads are reversed, the diode will be reverse-biased. Very little current will flow because a good diode will have very high resistance when reverse biased, and the meter will indicate a very high resistance.

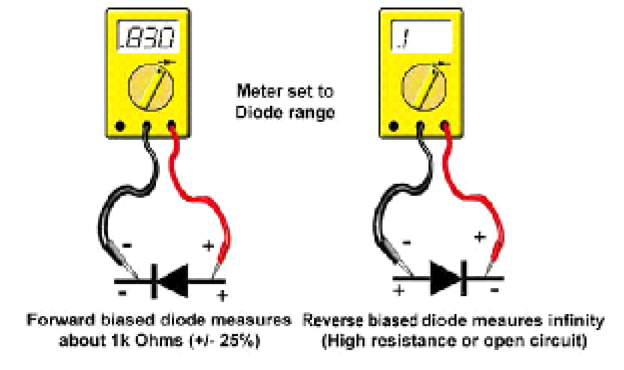
While doing the above test, if a diode shows a very low resistance in both the forward and reverse biased conditions, then, the diode under test must have got damaged or more specifically shorted. On the other hand, a diode is said to be open if the meter shows very high resistance both in the forward and reverse biased conditions.

Testing of diodes using digital Multimeter

If the digital multimeters are used for testing the diodes, first the selector switch must be kept at diode testing position. The +ve terminal of the MM (lead A as in the fig 10 must be connected to the anode of a diode and the negative terminal (lead) to the cathode, the diode is forward biased the MM will display the barrier voltage of the diode in the forward biased condition.

On the other hand, if the meter leads are reversed, the diode will be reverse biased and MM will display 1.

Fig 10



BYxxx,	xxx- from 100 onwards,	examples: BY127, BY128 etc.
DRxxx,	xxx- from 25 onwards.	examples: DR25, DR150 etc.,
1Nxxxx	examples: 1N917	1N4001, 1N4007 etc.

Behaviour of diode when FORWARD BIASED

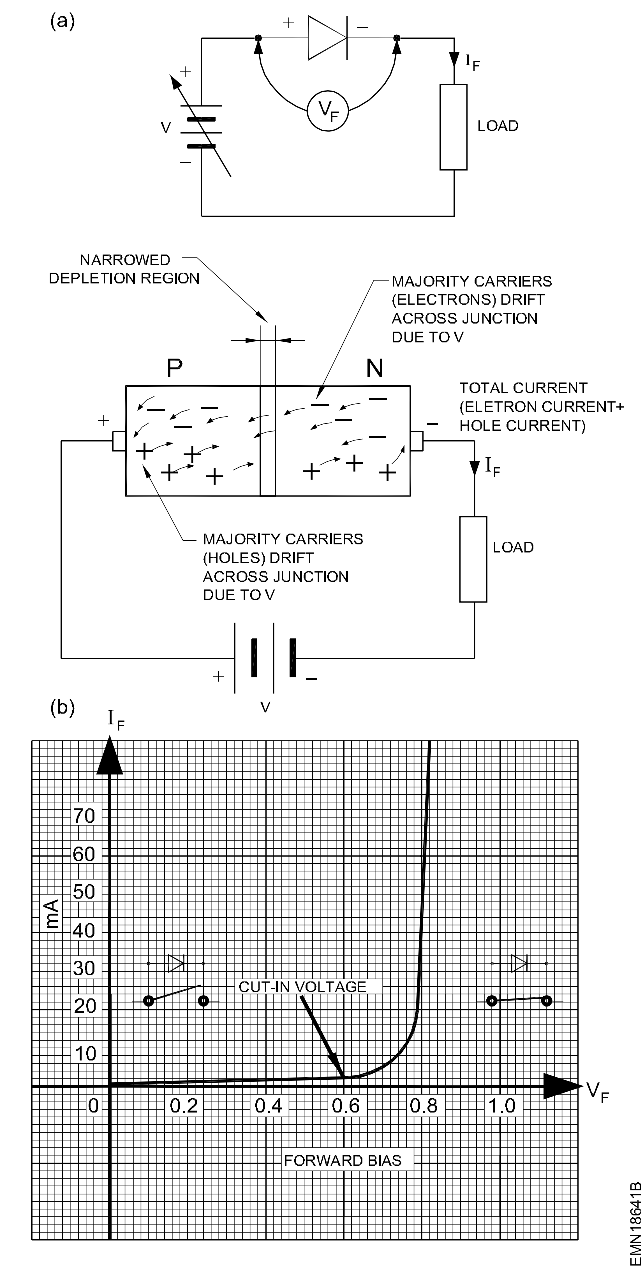
Fig 11a shows a forward biased silicon PN junction diode using a variable DC supply. When the applied voltage is slowly increased starting from 0 volts as long as the voltage across the diode V_F is less than that of the depletion barrier potential (0.7 volts for Si diodes), no current or a negligible current flows through the diode, and, hence, through the circuit. This is shown in the graph at Fig 11b.

But once the voltage V_F across the diode becomes equal to or greater than the barrier potential 0.6 to 0.7V, there will be a canceling effect of the barrier potential. Hence, the free electrons from the N region get pushed away by the -ve battery terminal(remember like charges repel) and cross over the junction, pass through the P region and get attracted by the + terminal of the battery. This results in the *electron current* passing through the diode, and, hence, through the Load.

In a similar way, the holes in the P region are pushed away by the +ve battery terminal, cross over the junction, pass through the N region and get attracted by the -ve terminal of the battery. This results in *hole current* through the diode, and, hence, through the Load.

Thus current flows through the diode when the forward bias potential is higher than the barrier potential. This current flow through the diode is because of both electrons and holes. The total current in the circuit is the sum of the hole current and the electron current. Hence, diodes are called *bipolar devices* in which both hole current and electron current flows.

Fig 11



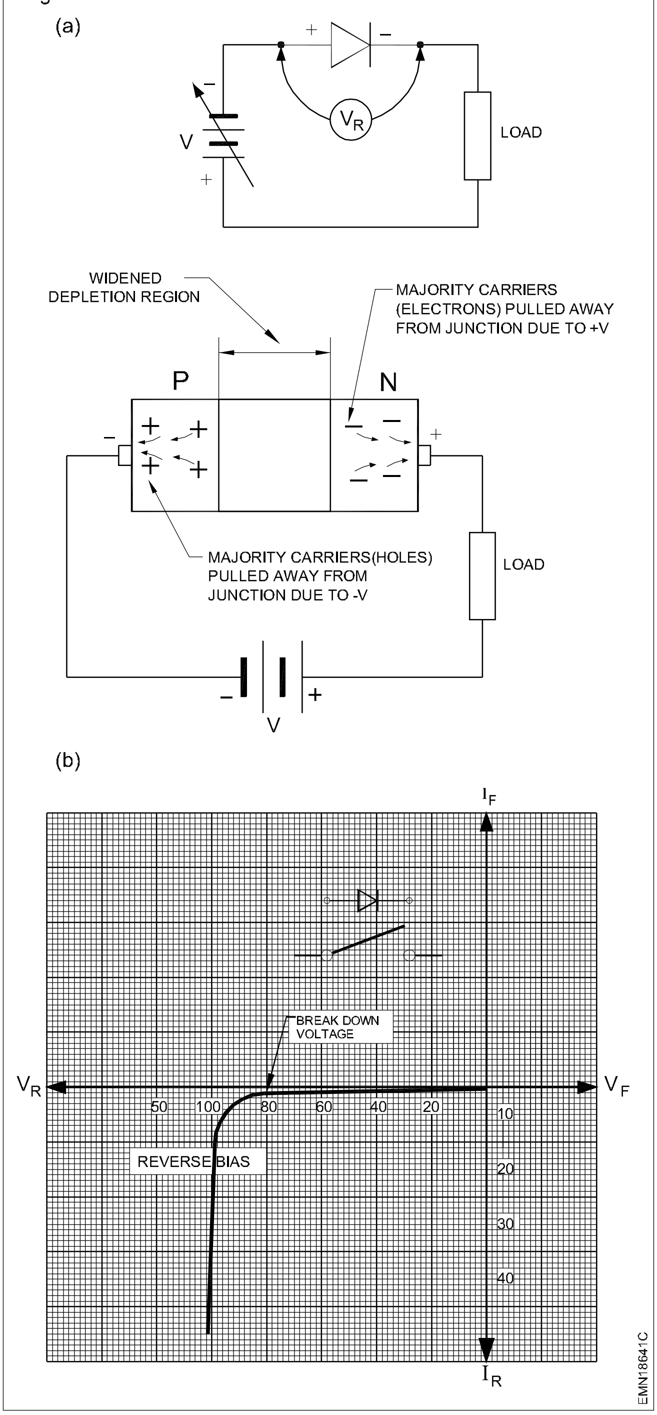
From the graph at Fig 11b, it can be seen that, once the forward voltage goes above 0.6V the diode starts conducting, resulting in considerable current through the circuit. This voltage level across the diode is referred to as *cut-in* or *knee or threshold voltage.*

If the applied forward voltage is further increased beyond the cut-in voltage, the depletion layer further narrows down allowing more and more current to flow through the diode. It can be seen from the graph at Fig 11b, that beyond the cut-in voltage, the current increases sharply for very small voltage increase across the diode. In this region, above the cut-in voltage, the forward biased diode behaves almost like a closed switch. The only limiting factor for the current at this stage is the maximum current the diode can handle without getting burnt or the junction getting punctured permanently. This current limit is given in diode data books as *maximum forward current,* $I_{f max.}$

Behaviour of diode when reverse biased

When an external DC voltage is connected across the diode with the polarity as shown in Fig 12, the diode is said to be reverse biased.

Fig 12



In this condition, when the battery voltage is increased from 0 to several tens of volts, the polarity of the applied voltage instead of canceling the barrier potential, aids the barrier potential. This, instead of narrowing the depletion layer, widens the depletion layer. The widening of the depletion layer results in, not allowing the current to flow through the junction, and, hence, the load. In other words, the polarity of the applied voltage is such that the holes and electrons are pulled away from the junction resulting in a widened depletion region.

Referring to the graph shown in Fig 12b, it can be seen that there is no current even when the voltage V_R across the diode is several tens of volts.

It the applied reverse voltage is kept on increased, say to hundred volts (this depends from diode to diode), at one stage the applied voltage V_R across the junction is so large that it punctures the junction damaging the diode. This results in shorting of the diode. This short results in uncontrolled heavy current flow through the diode as shown in graph at Fig 12b. This voltage at which the diode breaks down is referred to as *reverse break-down or avalanche breakdown.*

The maximum reverse voltage that a diode can withstand varies from diode to diode. This reverse voltage withstanding capability of a diode is referred to as the *peak-inverse-voltage* or PIV of the diode. This value for diodes is given in the diode data manual. The PIV of diodes varies from a minimum of 50 volts in small signal diodes to several thousands of volts in high power diodes.

Minority current in Diodes

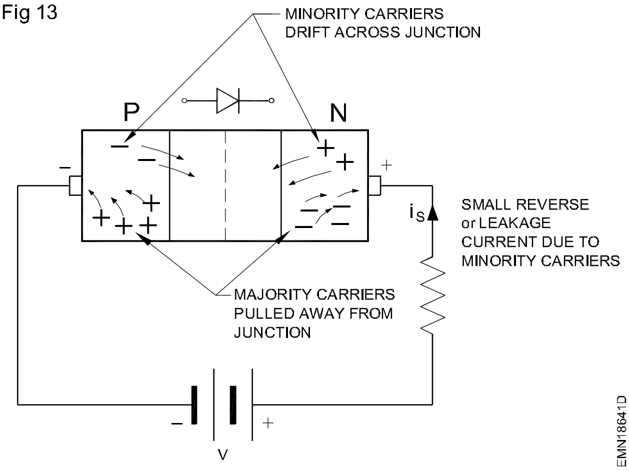
When a PN junction is reverse biased, due to the increased width of the depletion layer, there can be no current through the diode. But, in practice there will be a small current of the order of a few nano-amperes or a few micro-amperes through the diode as shown in Fig 13.

The reason for this small current is due to the creation of a very limited number of free electrons and holes on both sides of the junction due to thermal energy. Semiconductors are highly sensitive to temperature. Even a temperature of 25°C is sufficient to create a small number of electrons and holes resulting in a current of the order of a few nano-amperes. These current carriers created are referred to as *minority current carriers*. This current, due to minority current carriers, which flows through the diode when reverse biased, is known as reverse current or *leakage current* or *saturation current,* i_s. Based on experiments, for all silicon diodes, this reverse current doubles for each 10°C rise in temperature. For example, if it is 5nA at 25°C, it will be approximately 10nA at 35°C and so on.

Effect of temperature on barrier voltage

It is known that semiconductors are highly sensitive to temperature. Since the functioning of a diode is basically due to the unique property of its junction and its barrier voltage, the barrier voltage also depends on the junction temperature. If the temperature of the junction is increased beyond a limit (25°C), electrons are produced due to thermal agitation in the semi-conductor crystal structure. These electrons, having sufficient energy, drift across the junction. This decreases the barrier voltage. It is experimentally found that the barrier voltage decreases by 2 mV/°C increase in temperature. This reduced barrier voltage allows more current through the junction. More current heats up the junction further, reducing the barrier voltage further. If this cumulative effect continues, the junction will get damaged making the junction no more useful. Therefore, diodes should not be allowed to go above a specified temperature. This maximum limit a diode junction can withstand safely is given in the diode manual as *junction temperature,* $T_{j\,max}$.

Fig 13



Diode specification

Introduction

Semiconductor diodes are used for various applications. Some of the major areas of application are listed below.

- Modulation and demodulation in communication receivers.
- Switching high speed and digital circuits.
- Low power and high power rectification.
- As surge protectors in EM relay and other circuits.
- For clipping, clamping wave-forms.

For different applications, diodes of different current carrying capacity, different PIV capacity and so on are required. Therefore, manufacturers of diodes make diodes to cater to varied applications with different specifications. Before using a diode for a particular application, it is a must to find out whether the voltage, current, and temperature characteristics of the given diode match the requirement or not.

Important specifications of a diodes

- The material the diode is made-of: This could be Silicon or Germanium or Selenium or any other semiconductor materials. This is important because the cut-in voltage depends upon the material the diode is made-of. For example, in Ge diodes the cut-in voltage is around 0.3 V, whereas in Si diodes the cut-in voltage is around 0.7V.
- Maximum safe reverse voltage denoted as V_R or V_r that can be applied across the diode. This is also known as peak-inverse-voltage or PIV. If a higher reverse voltage

than the rated PIV is applied across the diode, it will become defective permanently.

- Maximum average forward current, I_F or I_f that a diode can allow to flow through it without getting damaged.
- Forward voltage drop, V_F or V_f that appears across the diode when the maximum average current, I_F flows through it continuously.
- Maximum reverse current, I_{vr} that flows through the diode when the Maximum reverse voltage, PIV is applied.
- Maximum forward surge current, I_S that can flow through the diode for a defined short period of time.
- The maximum junction temperature in degree centigrade the diode junction can withstand without malfunctioning or getting damaged.
- Suggested application indicates application for which the diode is designed and produced.

The above listed specifications go with all rectifier diodes. As all these specifications cannot be printed on the physically small size diodes, the diodes are printed with a type number instead. When this type number is referred to in the manufacturer's manual, the detailed specifications for a particular type number of the diode can be obtained.

There are hundreds and thousands of diode manufacturers all over the world. To bring standardization for the diodes and other components manufactured by different manufacturers, the manufacturers and standards associations have set certain international standards for the benefit of users of the components. The principal industry standard numbering systems are dealt with here:

a The JEDEC type code

The EIA in USA maintains a register of **1N, 2N** types familiarly known as Jedec types, which have world wide acceptance.

1N is used as a prefix for semiconductors with one junction. For example all 1N components refer to diodes because diodes have one junction. Prefix 2N is used with components having two junctions.

b The PRO-ELECTRON type code.

The Association International Pro-electron in Europe maintains a register of Pro-electron types which have wide acceptance in Europe.

Components in the Pro-electron system have,

i two letter and numeral code for consumer devices (Example, BY127 and so on).

ii three letter and numeral code for industrial devices. (Example, ACY17 and so on).

The first letter in the pro-electron type code indicates the type of semiconductor material used in making the device. Example, device numbers starting with A are made of germanium.

The second and third letter indicate the applications of the component. Example, in the type code BY127, the second letter Y indicates that it is a rectifier diode.

The numeral after the second or third letter is the code number of its detailed voltage, current and temperature specifications.

c The JIS type code

In Japan, the JIS, (Japanese Industrial Standards) code is used. This system of component numbering is almost universal. In this system, all component numbers start with 2S, followed by a letter and several numbers. Example. 2SB364. The letters after the S has the following significance:

A = pnp hf

B = pnp lf

C = npn hf

D = npn lf

Some components will have type numbers which does not match with any of the above said international standards. Then, these type numbers are particular to the individual manufacturers. These codes are generally referred to as manufacturer's house code. However, these type numbers may conform to one or more of the international standards. Almost all standard diode data books lists popular manufacturers house codes.

Diode equivalents

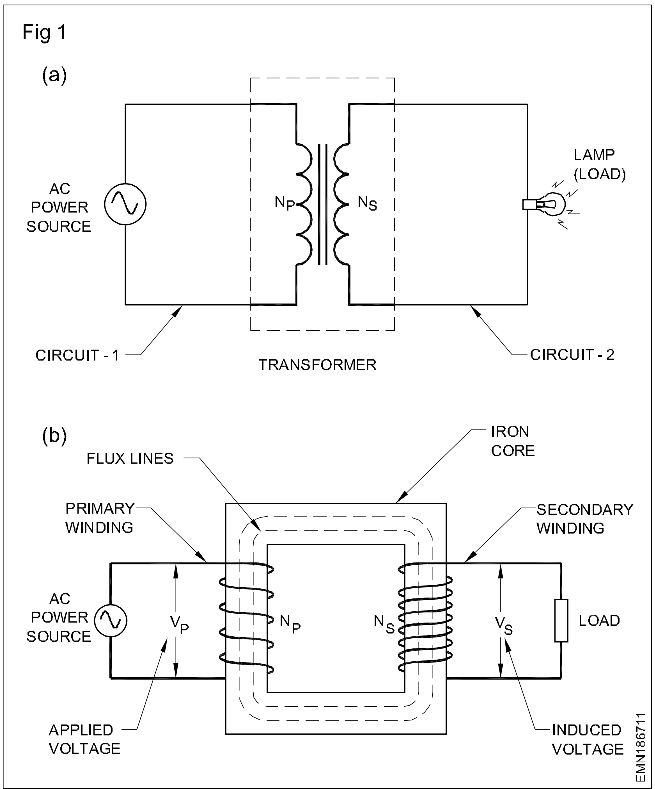
There are several occasions, especially while servicing electronic circuits, it may not be possible to get a replacement for a diode of a particular type number. In such cases one can obtain a diode having specification closest to the one to be replaced. Such diodes are referred to as equivalents.

Example: In a circuit, diode 1N 4007 is found to be defective. If 1N4007 is not available in stock, then, instead of 1N4007, BY127 can be used because BY127 is the equivalent for 1N4007.

Transformer

Objectives : At the end of this lesson you shall be able to
- **state the basic function of a transformer**
- **state the classifications of transformers**
- **describe the phase relationship in transformer**
- **explain losses and efficiency of transformer**
- **explain the method to determine the efficiency of transformer.**

Transformer is an electrical device used to transfer electric energy from one AC circuit to another circuit by magnetic coupling as shown in Fig 1a.



A transformer essentially consists of two coils of insulated conducting material, generally copper. These coils are wound on a core made of iron or ferrite as shown in Fig 1b. These coils are so arranged that magnetic flux developed in one coil will link with the other coil. Hence, mutual inductance exists between the two coils with tight-coupling (k=1). A change in current through one coil (say N_p) induces a voltage in the other coil (say N_s). The magnitude of induced voltage in the secondary winding depends on the number of turns of the coils and on how tight the magnetic coupling(k) is, between the two coils.

In a transformer, as shown in Fig 1b, the coil or the winding to which electrical energy is given from an ac power source is called the **primary winding**. In Fig 1 this coil is marked N_p. The second coil to which, energy from the primary winding is coupled magnetically is called the secondary winding (N_s in Fig 1b). If a load, say a lamp or a resistor, is connected across the secondary winding, current flows through the load although there is no direct AC power source connected to it.

Hence, transformers can be defined as devices that make use of the principle of mutual induction, in transferring electrical energy from one ac circuit to another circuit with out direct electrical connection.

It is important to note that transformers cannot transfer DC energy from primary winding to secondary winding, because, a DC current cannot produce changing magnetic field and hence cannot develop induced voltage.

Important terms used with iron-core transformers are explained below;

1. Turns Ratio of a transformer

The ratio of the number of turns of coil in the primary (N_p) to the number of turns of coil in the secondary (N_s) is called the *turns ratio of the transformer*.

$$\text{Turns ratio} = \frac{N_p}{N_s}$$

For example, 1000 turns in the primary and 100 turns in the secondary gives a turns ratio of 1000/100, or 10:1 which is stated as* ten-to-one *turns ratio.

2. Voltage Ratio of a transformer

The ratio of voltage across the primary winding(V_p) to the voltage available across the secondary winding(V_s) is called the *voltage ratio of the transformer*.

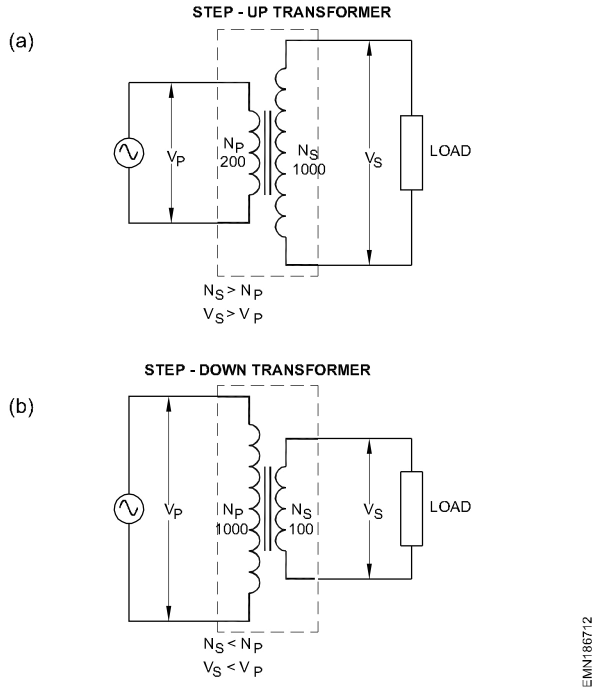
$$\text{Voltage ratio} = \frac{V_p}{V_s}$$

When coefficient of mutual coupling(k) between primary and secondary winding is 1, the voltage induced per turn of the secondary winding is the same as the self-induced voltage per turn in the primary winding. The total voltage appearing across the secondary winding depends on the number of turns of secondary winding. Therefore, the voltage ratio is in the same proportion as the turn ratio:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

This means, if the secondary winding has more turns than the primary winding ($N_s > N_p$) then, the secondary voltage will be higher than the primary voltage. In other words, in such a condition the primary voltage is said to be raised or stepped-up. Such transformers are called STEP-UP transformer as shown in Fig 2a.

Fig 2



Example: As shown in Fig 2a, a tranformer has 200 turns of N_p and 1000 turns of N_s, its turns ratio will be,

$$\text{Turns ratio} = \frac{N_p}{N_s} = \frac{200}{1000} = 1:5$$

For this transformer, if the applied AC primary voltage (V_p) is 110 V_{rms}, the secondary voltage will be stepped up in the same ratio as that of turns ratio. Hence, the secondary voltage will be twice the primary voltage, i.e, 5 x 110 = 550 V_{rms}.

On the other hand, when the secondary winding has less number of turns than the primary winding, the primary voltage is said to be lowered or stepped - down. Such transformers are called Step - down tranformers as shown in Fig 2b.

Example: **As shown in Fig 2b a power transformer has 1000 turns of N_P and 100 turns of N_s, What is the turns ratio? How much is the secondary voltage V_s when a primary voltage is 240V?**

SOLUTION:

The turns ratio is 1000/100, or 10:1. Hence, secondary voltage will be stepped down by a factor of 1/10, making V_s equal to 240/10 or 24 Volts.

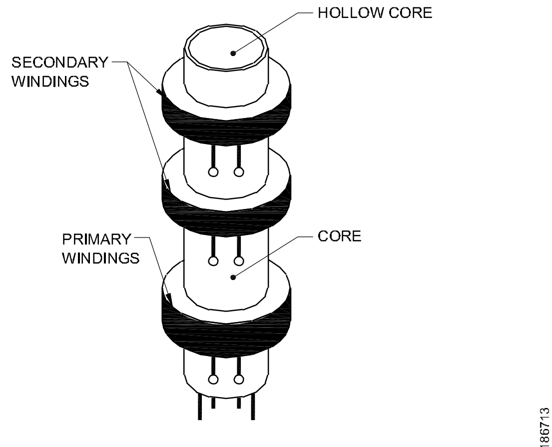
Classification of Transformers

1. Classification based on the type of Core Material used

Transformers can be classified according to the type of material used for the core as;

(a) **Air core transformers** : As shown in Fig 3, air core transformers consists of a hollow non magnetic core, made of paper or plastic over which the primary and secondary windings are wound. These transformers will have values of k less than 1. Air core transformers are generally used in high frequency applications because these will have no *iron-loss* as there is no magnetic core material.

Fig 3

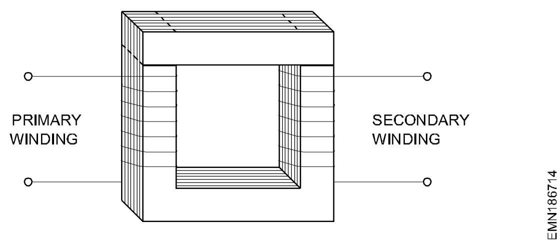


AIR CORE TRANSFORMER

Iron-loss is a type of transformer loss due to core material. Transformer losses are discussed in detail in further lessons.

(b) **Iron core transformers**: Fig 4 shows a laminated iron-core transformer. These transformers have stacked laminated sheets of silicon steel over which the windings are wound. This is the most common type of transformer used with mains power supply(240V,50Hz). In these transformers, since the core is a magnetic material and due to the shape of the core, the value of k is almost equal to 1.

Fig 4



(c) **Ferrite core transformers**: These transformers have Ferrite material as its core. In most cases, the primary and secondary windings are wound on a hollow plastic core and the ferrite material is then inserted into the hollow core. These transformers are used in high frequency to very high frequency applications as they have the advantage of introducing minimum losses. In these transformer, the position of core can be changed, thus changing the value of M.

2 Classification based on the shape of core and relative position of primary and secondary windings:

(a) **Core type transformers**: In Core type of transformer, the primary and secondary windings are on two separate sections/limb of core. Core type transformers are less frequently used as their efficiency is low because the magnetic flux spreads out reducing the number of useful flux lines.

(b) **Shell type transformers**: In this type, both the primary and the secondary windings are wound on the same section/limb of the core. As the portion of the core surrounds the two windings, almost all the flux is confined to the core of the transformer. Shell type transformers have a higher efficiency as compared to core type transformers. These are widely used as voltage and power transformers.

(c) **Ring type transformers**: In this, the core is made up of circular or semicircular laminations. These are stacked and clamped together to form a ring. The primary and secondary windings are then wound on the ring. The disadvantage of this type of construction is the difficulty involved in winding the primary and secondary coils. Ring type transformers are generally used as instrument transformers for measurement of high voltage and current.

3 Classification based on the Transformation ratio:

a **Step-up Transformers**: Transformers in which, the induced secondary voltage is higher than the source voltage given at primary are called *step-up transformers*.

b **Step-down Transformers**: Transformers in which, the induced secondary voltage is lower than the source voltage given at primary are called *step-down transformers*.

c **Isolation transformers**: Transformers in which, the induced secondary voltage is same as that of the source voltage given at primary are called *one-to-one* or *isolation transformers*. In these transformers the number of turns in the secondary will be equal to the number of turns in the primary making the turns ratio equal to 1.

4 Classification based on the operating frequency:

a **Audio frequency (AF) transformers**: These AF transformers look similar to a mains voltage tranformer but they are very small in size comparatively. Most AF transformers are of PCB mounting type. These transformers are designed to operate over the audio frequency range of 20 Hz to 20 kHz. Audio transformers are used in,

– coupling the output of one stage of audio amplifier to the input of the next stage (interstage coupling)

– the amplified audio signal from an amplifier to the speaker of a sound system.

These transformers are said to have *flat frequency response* over the entire audio range. This means that the transformer behaves equally well over the entire range of audio frequencies.

The transformation ratio of audio transformers will be generally less than unity.

These transformers also use a colour coding scheme to identify those used as driver transformers (for inter-stage coupling) or out-put transformers (for amplifier to speaker).

(b) High frequency transformers: The core of high frequency transformers are made of powdered iron or ferrite or brass or air core(hollow core). These transformers are called Radio frequency transformers (RFTs) and Intermediate frequency transformers (IFTs). These transformers are used for coupling any two stages of high frequency circuits such as radio receivers. The upper frequency limit of these transformers is 30 MHz.

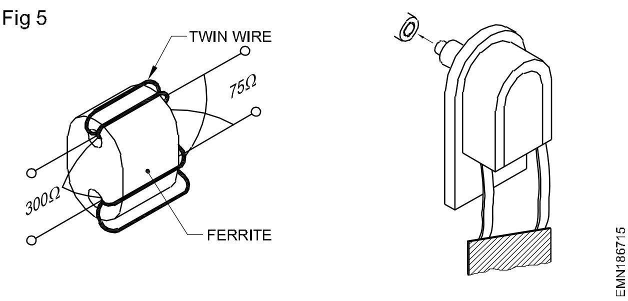
Another speciality of these transformers is that the position of the core can be altered, which results in varied coupling and energy transfer. These transformers also have another electronic component called capacitor connected across the windings in parallel. This results in a different behavior of the transformer at different frequencies. Hence these transformer types are also called Tuned transformers.

These transformers are smaller than even audio frequency (AF) transformers. These transformers will generally be shielded/screened using a good conductor(recall lesson on inductors for need of screening).

RFTs and IFTs also have a colour coding scheme to identify their different places of application.

(c) **Very high frequency transformers**: These transformers also have air or ferrite or brass as core material. These transformers are constructed specially to minimize energy losses at very high frequencies. Very high frequency transformers are available in several shapes and designs. Some of these find wide application in Television receivers. Fig 5 illustrates a high frequency transformers used in TV receivers.

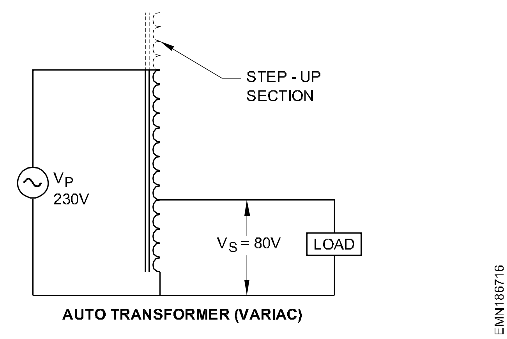
Fig 5



5 Auto-transformers:

Auto-transformer as shown in Fig 6 is a special variety of transformers which have only a single winding. Because of single winding, there is no isolation between primary and secondary side. Auto-transformers are used when isolation between input and output is not important. Auto-transformers can be used for variable voltage operation by using a sliding contact like a potentiometer. But, it is important to note that an auto-transformer does not function as a simple voltage divider.

Fig 6



AUTO TRANSFORMER (VARIAC)

Auto-transformers are smaller in size and uses less iron than a conventional two winding transformer of the same rating.

Auto-transformers used for variable voltage operation are referred to the trade name of VARIAC.

As shown in Fig 6, auto-transformers has a step-up section (shown in dotted lines) which enables the transformer to develop a variable voltage output from 0 to 270V from a 240V input AC supply.

Auto-transformers are mostly used in laboratories for conducting experiments.

6 Single phase and three phase transformers:

Transformers are designed for use with single phase AC mains supply. Hence these transformers will have a single primary winding. Such transformers are known as single phase transformers. Transformers are also available for 3 phase AC mains supply. These are known as poly-phase transformers. In a 3-phase transformer, there will be three primary windings. Three phase transformers are used in electrical distribution and for industrial applications.

7. Classification based on application:

Transformers can also be classified depending upon their application for a specialized work. Since there are innumerable number of applications, the types are also innumerable. However a few of these are listed below:

Current Transformers - used in clip - on current meters, overload trip circuits etc.,

Constant voltage transformers - used to obtain stabilized voltage supply for sensitive equipments

Ignition transformers - used in automobiles

Welding transformers - used in welding equipments

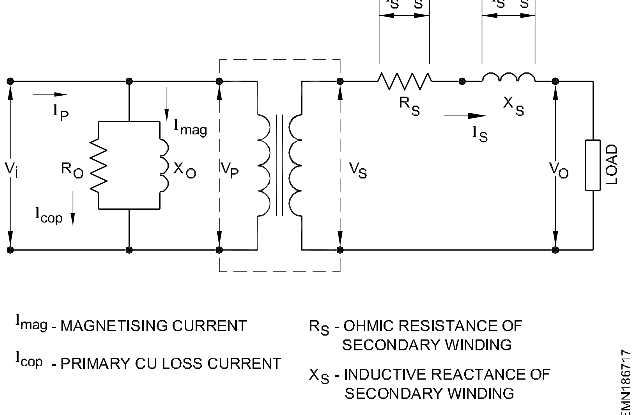
Pulse transformers - used in electronic circuits

Voltage Regulation

For simplicity in understanding, in all the previous lessons on transformers, the resistive and inductive effect of the primary and secondary windings were neglected. Also, the effect of load current on the magnitude of secondary voltage was neglected. In a practical situation, the secondary voltage of a transformer decreases as the load/load-current is increased.

Consider the equivalent circuit of a transformer shown in Fig 7.

Fig 7



From the circuit in Fig 8, the secondary current I_s produces voltage drops I_sR_s and I_sX_s across the resistive and reactive components of the secondary winding. Consequently, the output voltage V_o is less than V_s.

When load is not connected at the output terminals of the transformer, no secondary current flows, and hence, no voltage drops occur across R_s and X_s. Hence, V_o equals V_s. Thus, the transformer secondary voltage is greatest on no-load.

Under loaded condition, the voltage drops across the resistive and reactive components of the secondary winding, reducing V_o. The larger the load current, larger will be the drop across the resistive and reactive components of the secondary and hence, smaller will be the value of V_o.

The percentage change in output voltage V_o, from no-load to full load is termed the voltage regulation of the transformer.

% Voltage regulation =

$$\frac{V_o\,(\text{No - load}) - V_o\,(\text{Full - load})}{V_o\,(\text{Full - load})} \times 100\%$$

Ideally, there should be no change in V_o from no-load to full-load, (i.e., regulation = 0%). For best possible performance, the transformer should have the lowest possible percentage regulation.

In some text books, the regulation discussed above is termed as "% Regulation-Up" some books also use, the term "% Regulation-Down" given by,

% voltage regulation down = $$\frac{V_{o\,(NL)} - V_{o\,(FL)}}{V_{o\,(NL)}}$$

For example, if a transformer has an output of 13 V when on no-load and has an output of 11.8 V when on its rated resistive load, the regulation of the transformer is,

$$\%\ \text{Voltage regulation} = \frac{V_{o(NL)} - V_{o(FL)}}{V_{o(FL)}} \times 100\%$$

$$= \frac{13 - 11.8}{11.8} \times 100\% = 10\%$$

Finding regulation from OC and SC test results

$$\text{Voltage regulation} = \frac{V_{o(NL)} - V_{o(FL)}}{V_{o(FL)}} \times 100\ \%$$

$V_{o(NL)}$ is the secondary voltage in test obtained from OC test.

$V_{o(FL)}$ is the secondary voltage under rated full load.

$V_{o(FL)}$ can be calculated knowing turns ratios and the data obtained in SC test as follows;

$$V_{o(FL)} = V_{o(FL)} \times \frac{N_s}{N_p}$$

where, $V_{p(FL)} = V_{p(NL)} - V_{i(SC)}$

where, $V_{i(SC)}$ is the voltage applied to primary at full load in SC test.

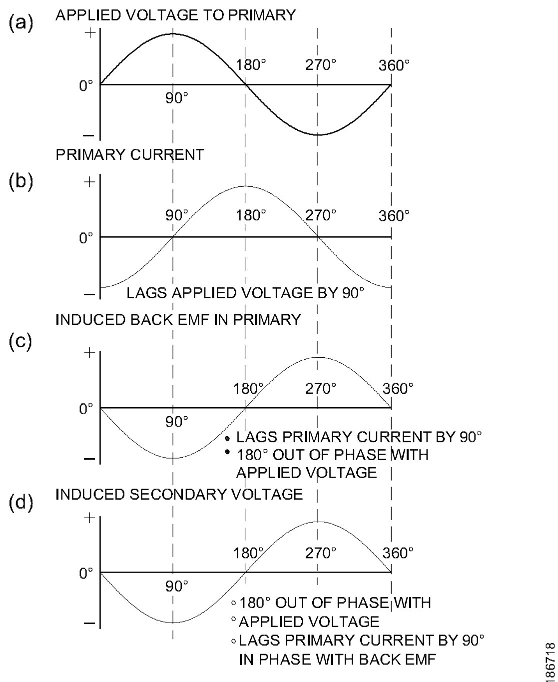
Phase relationship between primary and secondary

With Open secondary winding

For ease of understanding the phase relation ship between voltages and currents in primary and secondary of a transformer, consider a transformer having an open secondary. Referring to Fig 8, with open secondary, the primary winding works similar to that of an inductor.

This means that,

Fig 8



PHASE RELATIONSHIPS IN TRANSFORMER WITH OPEN SECONDARY

– **the primary current lags behind the applied voltage V_i by 90°** as shown in Fig 8b.

– From Lenzs' law the back-emf produced in the primary, which opposes the cause, therefore lags behind the primary current by 90° as shown in Fig 8c.

The voltage induced in secondary is maximum when the primary back-emf is maximum. That means,

– the secondary voltage lags behind the primary current by 90 degrees and hence **the secondary voltage(V_s) is 180° out of phase with the primary voltage.**

Fig 9 shows a combined illustration of the phase relationship between primary and secondary.

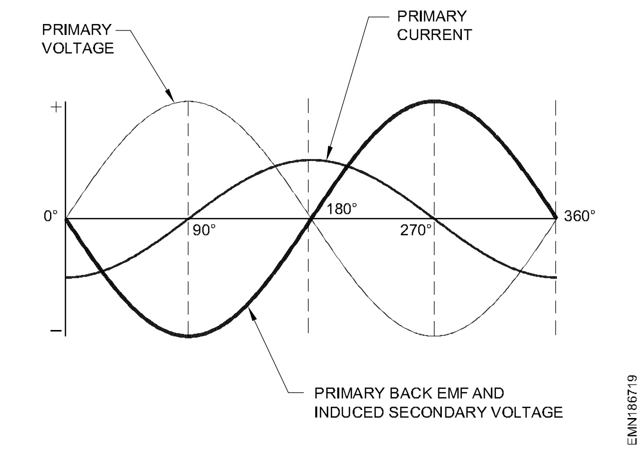
With loaded secondary

When a load is connected to the secondary of a transformer, current flows in the secondary. As in any inductance,

– **the current through the secondary winding lags behind the secondary voltage** that produces it **by 90 degrees**.

Since the secondary voltage lags behind the primary current by 90°, and since the secondary current lags behind the secondary voltage by 90°,

Fig 9



– **the secondary current is 180° out of phase with primary current**.

As the secondary current changes, it generates its own magnetic field, whose flux lines oppose those of the magnetic field created by the primary current. This reduces the strength of the primary magnetic field. As a result, less back-emf is generated in the primary. With less back-emf to oppose the applied voltage, the primary current increases. The amount of increase in primary current is directly proportional to the amount of increase in secondary current. Thus, **when secondary current in a transformer increases, the primary current automatically also increases.** And when secondary current decreases, the primary current also decreases.

Applying rated primary voltage, if the secondary of a transformer is shorted, excessive current will flow in the primary as well as in the secondary. This excessive current will not only burn out the transformer, but there is a possibility that the source supplying power to the primary would also be damaged.

The power in a DC circuit can be calculated by using the formula.

- $P = E \times I$ watts

- $P = E^2/R$ watts.

The use of the above formulae in AC circuits will give true power only if the circuit contains pure resistance. Note that the effect of reactance is present in AC circuits.

Power in AC circuit: There are three types of power in AC circuits.

- Active power (True power)
- Reactive power
- Apparent power

Active power (true power): The calculation of active power in an AC circuit differs from that in a direct current circuit. The active power to be measured is the product of $V \times I \times \cos\theta$ where $\cos\theta$ is the power factor (cosine of the phase angle between current and voltage). This indicates that with a load which is not purely resistive and where the current and voltage are not in phase, only that part of the current which is in phase with the voltage will produce power. This can be measured with a wattmeter.

Reactive power: With the reactive power (wattless power)

$P_q = V \times I \times \sin\theta$

only that part of the current which is 90° out of phase (90° phase shift) with the voltage is used in this case. Capacitors and inductors, on the other hand, alternatively store energy and return it to the source. Such transferred power is called reactive power measured in volt/ampere reactive or vars. Unlike true power, reactive power can do no useful work.

Apparent power: The apparent power, $P_a = V \times I$.

The measurement can be made in the same way as for direct current with a voltmeter and ammeter.

It is simply the product of the total applied voltage and the total circuit current and until it is volt-ampere (VA).

The power triangle: A power triangle identifies three different types of power in AC circuits.

- True power in watts (P)
- Reactive power in vars (P_q)
- Apparent power VA (P_a)

The relationship among the three types of power can be obtained by refferring to the power triangle. (Fig 12)

Therefore

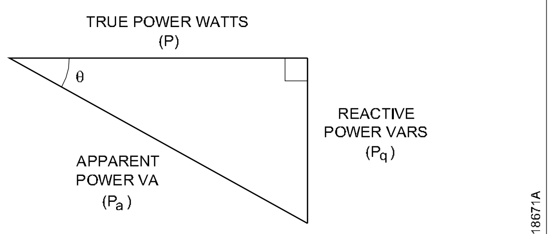
$P_a^2 = P^2 + P_q^2$ Volt- amperes (VA)

where 'P_a' is the apparent power in volt-ampere (VA)

'P' is the true power in watts (W)

P_q is the reative power in volt-amperes reactive. (VAR)

Fig 10



POWER TRIANGLE

Power factor : The ratio of the true power delivered to an AC circuit compared to the apparent power that the source must supply is called the power factor of the load. If we examine any power triangle (Fig 10), the ratio of the true power to the apparent power is the cosine of the angle q.

$$\text{Power Factor} = V \times \frac{P}{Pa} = \cos\theta$$

From the equation, you can observe that the three powers are related and can be represented in a right angled power triangle, from which the power factor can be obtained as the ratio of true power to apparent power. For inductive loads, the power factor is called lagging to distinguish it from the leading power factor in a capactive load.

sA circuit's power factor determines how much current is necessary from the source to deliver a given true power.

A circuit with a low power factor require a magnet current than a unity power factor circuit.

Efficiency of transformers

In practice, ideal transformers cannot be made. This is because some amount of power is always wasted in transferring the power from primary to secondary. Hence, the power consumed in primary will always be higher than that available in secondary. This difference in the power between primary and secondary is lost or wasted as a result of transformer losses.

Transformers can be designed and made so that the transformer losses are minimum. *The degree to which any transformer approaches the ideal condition is called the efficiency of the transformer.* Efficiency of a transformer is generally expressed in percentage as,

$$\text{Efficiency } \eta \text{ (in \%)} = \frac{\text{Output power}}{\text{Input power}} \times 100$$

LOSSES IN TRANSFORMERS

The losses in the transformer convert some of the electrical energy into heat energy. As a thumb rule, if a transformer is heating-up while in operation, the losses in the transformer is high.

Most common types of transformer losses which always exist with almost all iron-core transformers are explained below;

1. Copper losses

Transformer windings are made of many turns of copper wire. Copper wire although a very good conductor, still has some resistance. The value of this resistance depends upon the type of material and the length of wire. As the number of turns in windings increase, the longer is the length of wire, and greater will be the resistance. When primary and secondary currents flow through the windings, due to the ohmic resistance of the windings, power(I^2R) is dissipated in the form of heat.

These I^2R losses are called *Copper losses*. Copper losses increase if the currents through primary and secondary increases. Total copper loss in a transformer is equal to;

Copper loss = $I_p^2.r_p + I_s^2 r_s$

Copper losses can be minimised by using a thicker gauge copper wire, but this increases the size, weight and cost of the transformer.

2 Core losses or Iron losses

Core/Iron losses in transformer are due to two different types of losses namely;

i Hysteresis loss

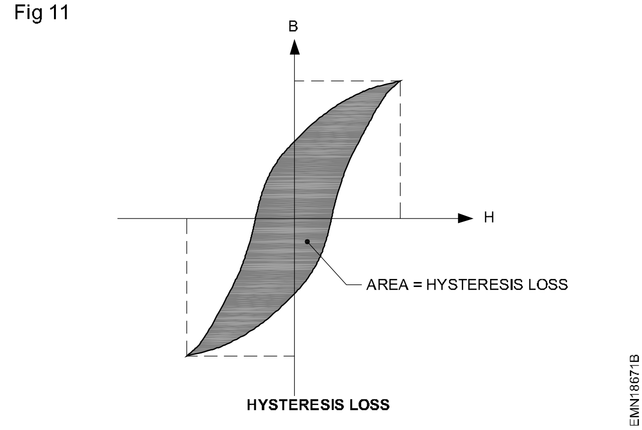
ii Eddy current loss

i Hysteresis loss

The magnetic field in the iron-core of a transformer undergoes a complete reversal 50 times each second for a mains-supply frequency of 50Hz. Every time the polarity of the supply reverses, the molecules of iron with its N-S poles change its direction, such that the direction of magnetic field reverses.

Energy has to be supplied to the molecules of the iron core to make them catch-up with the new direction of magnetic field. This turning around of molecules, or reversing the magnetism of iron core, consumes energy in the form of heat. This loss of energy, appearing in the form of heat, is proportional to the area of the B-H curve or Hysteresis loop of the core material as shown in Fig 11.

Fig 11



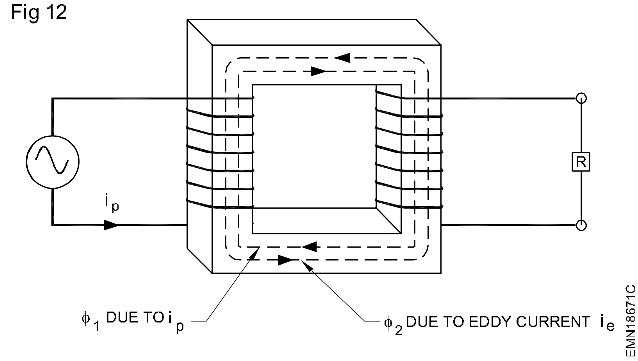
This loss of energy in the primary of the transformer in reversing the magnetism of the iron core is called *hysteresis loss* of the transformer.

It should be noted that air core transformer will not have hysteresis loss as air core transformers do not use magnetic core material.

ii) Eddy current loss

In iron-core transformers, the core material is a conducting material. So, the changing magnetic field of transformer induces a voltage in the core. This induced voltage in the core cause small current to circulate within the core. This current is called *eddy current*.

Fig 12



The induced eddy current is large if the resistance of the core material is small. Due to this circulating eddy currents and the resistance of the core material, power loss occurs in the form of heat as shown in Fig 12.

In addition, the induced eddy currents set-up an opposing flux ($ø_2$) in the core as shown in Fig 12. This results in more primary current trying to maintain the magnetic field in the core. This further increases the eddy current and hence the losses due to it.

This loss of power in a transformer due to eddy current in the transformer core is referred to as *eddy current loss*.

Eddy current loss in a transformer core can be reduced by making the core, into thin flat sections. These thin flat sections are called *laminations*.

Since these laminations have very small cross-sectional areas, the resistance offered to the setting up eddy current is greatly increased and hence the loss due to it is also reduced.

Such laminations, are stacked together.These laminations are insulated from each other by means of an insulation coating, generally shellac. Due to the insulation between laminations, the eddy currents can only flow in individual laminations. Hence the overall eddy current loss of the transformer is greatly reduced.

The power loss due to eddy currents is directly proportional to,

a the frequency of current.

b the magnitude of current.

If iron-core transformers are used at high frequencies, the eddy current losses become high. Hence iron-core transformers are not preferred in high frequency applications.

It should be noted that air core transformer will not have any eddy current loss as they do not have core material in which the eddy current can flow.

Other losses in transformers

In addition to *copper losses* and *iron losses*, transformers have two more types of losses. They are:

1 Loss due to flux leakage

2 Core saturation loss

Loss due to flux leakage

All the flux lines produced by the primary and secondary windings does not travel through the iron core. Some of the magnetic lines leak from the windings and go out into space. These leaked magnetic lines cannot do useful work. This leakage of the flux lines represents wasted energy, reducing the efficiency of the transformer.

Loss due to core saturation

When the current in the primary winding of an iron-core transformer increases, the flux lines generated follow a path through the core to the secondary winding, and back through the core to the primary winding, As the primary current first begins to increase, the number of flux lines in the core increases rapidly. Additional increases in primary current will produce only a few additional flux lines less than what it should have produced. The core is then said to be saturated. Any further increase in primary current after core saturation, results in wasted power.

Summing the different types of losses in a transformer, the total loss is given by,

Total transformer loss = Copper losses(primary + secondary) + Iron losses

(Hysteresis + eddy current) +

Flux leakage loss + Core satu ration loss.

Compared with the other two losses, the flux leakage loss and the core saturation loss are negligible. Also these two losses can be greatly reduced by good transformer design and safe current level operation. Hence, the total losses that occur in a transformer can be found after knowing its copper losses and iron losses.

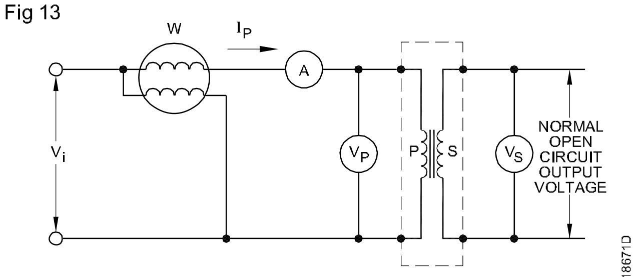
Measuring transformer losses

To determine losses in a transformer, its turns ratio and efficiency, two simple tests are conducted. These tests are, the *no-load test* and the *full-load test*.

No-load test or open circuit test (O-C test)

Fig 13 shows the circuit arrangement for O-C test on a transformer.

Fig 13



OPEN - CIRCUIT TEST ON A TRANSFORMER

The AC input voltage (V_i) is set at a rated primary voltage. The input power (P_i) is measured by the wattmeter (W). The input current (I_p) is measured by ammeter.

The open-circuit secondary voltage (V_s) is measured by voltmeter.

Since the secondary is open there is no current in secondary.

As the transformer secondary is open-circuited(I_s=0), the primary current (I_p) is very small. Since I_p is very small, the voltage drops across the ammeter and wattmeter can be neglected. So the input voltage (V_i) can be taken as primary voltage (V_p). Therefore, the ratio of the two voltmeter readings gives turns ratio of the transformer.

$$\text{Turns ratio of transformer} = \frac{N_p}{N_s} = \frac{V_p}{V_s}.$$

The input power (P_i) measured by the wattmeter (W) gives the total transformer *core losses* because with very small primary current and zero secondary current the copper losses in the windings are negligible and hence can be taken as zero.

Total losses in a transformer = Copper loss + Iron loss

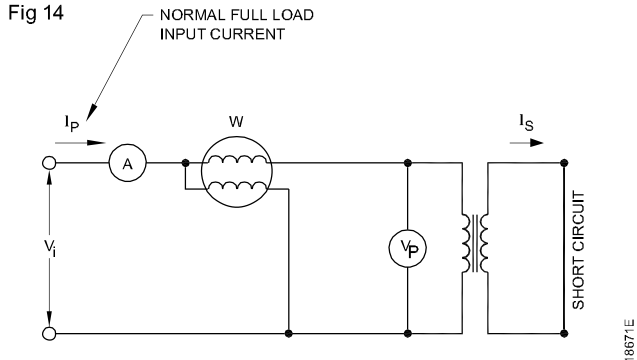
= 0 + Iron loss

With copper loss being zero, the input power measured on the wattmeter(W) is the total transformer Core loss or Iron loss (W_i).

Full load test or short circuit test (S-C test)

Fig 14 shows the circuit arrangement for S-C test on a given transformer.

Fig 14



SHORT - CIRCUIT TEST ON A TRANSFORMER

With the secondary terminals shorted, the input voltage (V_i) is increased slowly from zero till the ammeter in the primary circuit indicates rated full-load primary current, I_p. When this occurs, the rated full load secondary current I_s will be circulating in the secondary winding.

Because the secondary terminals are shorted, the voltage required at primary, V_p to produce full-load primary and secondary current is just around 3% of the rated input voltage (V_i).

In this condition, the wattmeter measuring input power (P_i) indicates the full-load copper losses for the reasons given below;

- With a low level of input voltage (3% of rated), core flux is minimum. Hence the core losses are so small that they can be neglected and taken as zero.
- Since the winding, both primary and secondary are carrying rated full-load currents, the input is supplying the rated full-load copper losses only.

Total losses = Copper loss + Iron loss

Total losses = Copper loss + 0 + Iron loss

With Iron loss being zero, the input power measured(W_c) on the wattmeter is the total transformer copper loss at rated full-load current.

Using the results of the SC test, the phase angle difference (ø) between the current and the voltage can be determined as given below;

$$\text{Power factor}, \cos\theta = \frac{\text{True power}}{\text{Apparent power}}$$

Working principle of zener diodes

Objectives : At the end of this lesson you shall be able to
- **state the need of regulators in power supplies**
- **state the formula to calculate the % load regulation factor**
- **explain the important specifications of a zener diode**
- **explain working characteristic, application and specification of varactor diode**
- **describe working of a half wave full wave and rectfier**
- **describe ripple filters, R.C filters, inductor input filters L.C. filters.**

Voltage regulators

The DC output voltage level of power supplies such as, full-wave and bridge rectifiers, tend to decrease or increase,

- when the load current increases or decreases
- when the AC input voltage level decreases or increases.

Such variations in the output DC voltage level of power supply is not acceptable for most of the electronic circuits. Hence, it is required to regulate the DC output of power supplies so as to keep the DC output level constant, inspite of variations in the DC load current or the AC input voltage. Circuits or components used to keep the DC output voltage of a power supply constant are called voltage regulators.

Regulation factor

The ability of a power supply to maintain a constant DC output voltage for variations in the load current is referred to as load regulation. Load regulation of a power supply is generally given as a percentage.

$$\text{Load regulation factor \%} = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100$$

where,

V_{NL} = DC output at no load or open circuit

and $V_{FL}\leftrightarrow$ = DC output at rated full load.

It should be noted that lower the percentage of load regulation factor, better is the voltage regulation.

Example: The DC output of a power supply is 12 volts at no-load and 11 volts at full load.

$$\text{\% Load regulation} = \frac{12 - 11}{12} \times 100 = 8.33\%$$

In practice the load regulation of a good power supply should be less than 0.1 %.

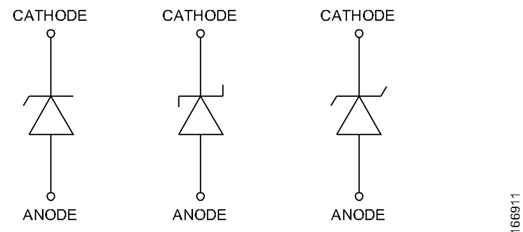
Regulating the DC output voltage for variations in the input AC level is termed as line regulation. This is discussed in further units.

The zener diode

In a power supply one of the simplest ways of regulating the DC output voltage (keeping the output voltage constant) is by using a zener diode. With zener in reverse breakdown condition, the voltage across the zener diode remains constant for a wide range of input and load variations.

Because of this property, zener diodes are also known as voltage regulators or voltage reference diodes. Fig 1 shows the symbol used for zener diodes.

Fig 1



ZENER DIODE SYMBOLS

The difference between a rectifier diode and a zener diode are listed below;

- Compared to normal rectifier diodes, zener diodes are heavily doped.
- Unlike ordinary diodes which do not work in the break-down region, zener diodes work only in the breakdown region.
- Generally rectifier diodes are used in forward-biased condition, whereas zeners are always used in reverse-biased condition.
- The reverse breakdown voltage of zener diodes is very much less (3 to 18V) compared to rectifier diodes (minimum 50V).

The similarities of a zener diode with those of general purpose rectifier diodes are listed below;

- Zener diodes are also PN junction diodes, which are also generally made of silicon.
- Zener diodes also have two terminals (anode and cathode).
- In physical appearance, the zener diodes and ordinary diodes look alike.
- Like rectifier diodes, zener diodes are also available with glass, plastic and metal casing.

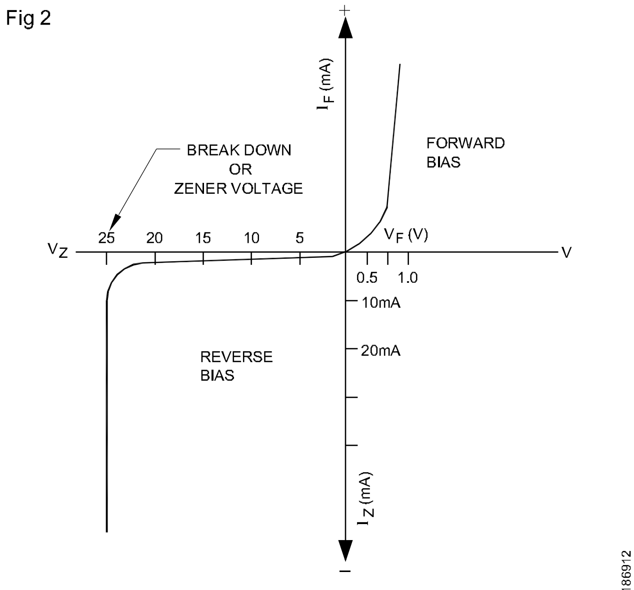
– The anode and cathode marking technique on the body is same for both zener and rectifier diodes.

– The zener can be tested with an ohmmeter in the same way as in rectifier diodes.

– Zener requires approximately the same voltage for it to be forward-biased into conduction as that of an ordinary diode.

Fig 2 shows the conduction characteristics of a typical zener diode. Because of the nature and heavy doping in a zener, its characteristics are different compared to a rectifier diode.

Fig 2



ZENER DIODE CONDUCTION CHARACTERISTICS

Note that, the zener diode acts as a rectifier diode when forward biased. It also behaves as a rectifier diode when reverse-biased, till the voltage across it reaches the breakdown voltage. As can be seen from Fig 2, even the reverse or leakage current remains almost negligible and constant despite the increase in the reverse-biased voltage till the break down voltage, also called zener voltage is reached. But, Once the zener breakdown voltage is reached, the diode current begins to increase rapidly and the zener suddenly begins to conduct. In the case of a normal rectifier diode, once the break down voltage is reached the diode gets punctured and starts conducting heavily whereas, in a zener diode, the diode does not get punctured even though it conducts current in the reverse biased condition.

The cause for this reverse conduction is referred to as the avalanche effect. The avalanche effect cause, the electrons to be knocked loose from their bonds in the crystal structure. As more electrons are loosened, they in turn knock others and current builds quickly. This action causes the voltage drop across the zener to remain constant regardless of the zener current. As shown in Fig 2, once the zener voltage is reached, very small voltage changes create much greater current changes. It is this characteristic, which makes the zener useful as a constant voltage source or as a voltage regulator.

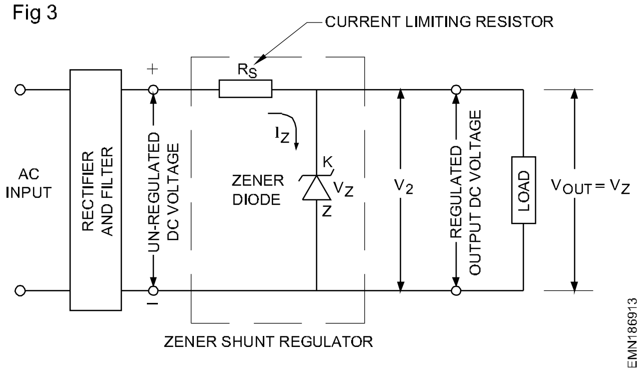
Unlike in a rectifier diode, the reverse current through the zener is not destructive. If the current is kept within the specified limits depending upon the wattage rating of the zener, using a suitable series resistance, no harm is done to the zener diode.

Because the zener diode is designed to operate as a breakdown device, the zener can be brought out of condition easily. A zener is brought out of its zener conduction by lowering the reverse-biased voltage below the zener voltage or by reversing the polarity of the applied voltage.

Application of zener diodes

The most popular use of zener diodes is as voltage regulators in DC power supplies. Fig 3 illustrates a simple zener regulated power supply.

Fig 3



In the circuit at Fig 3, the zener diode is in parallel with the output or load of the power supply. It is very important to note that the zener is connected in the reverse-biased condition. Such a parallel circuit connection is often called a shunt. When used in this way, the zener is said to be a shunt regulator.

In Fig 3, the zener begins to conduct in the reverse-biased condition as the voltage across it reaches the zener voltage V_Z. The voltage across the zener remains constant immaterial of the input DC voltage. Since the load is in parallel with the zener, the voltage across the load V_{OUT} will be same as the voltage across the zener V_Z ($V_{OUT} = V_Z$).

If the input DC voltage to the zener increases, as can be seen from its characteristics in Fig 2, the current I_Z through the zener increases but the voltage across the zener remains the same due to avalanche effect. Because the zener voltage, V_Z does not change, the output voltage V_{OUT}, does not change and so the voltage across the load is constant. Thus, the output is said to be regulated.

Referring to Fig 4, the zener can be looked at as an automatically changing resistance. Total current through the resistance R_S is given by,

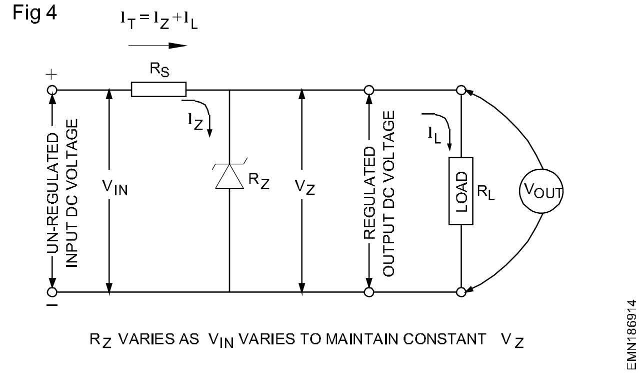
$$I_T = I_Z + I_L$$

Thus the voltage across R_S is,

$$V_R = (I_Z + I_L)\, R_S$$

If the input DC voltage V_{IN} increases, output voltage V_{OUT}, tends to increase. In the meantime, the zener conducts more heavily, causing more current (more I_Z) to flow through R_S. Hence, more voltage drop occurs across R_S. This increase in drop across R_S offsets the increase in the output voltage V_{OUT}, thus retaining the voltage across load R_L at its original value. Likewise, if the value of R_L is decreased (increased I_L), current through the zener I_z decreases, retaining the value of I_T through R_S. This ensures sufficient load current through the load R_L without decrease in the level of V_{OUT}.

Fig 4



Zener specifications

Like in rectifier diodes, the type-code number is marked generally on the body of the zener. From the type-code marked, detailed specifications of the zener can be found referring to any standard diode data manual.

Important zener diode specifications are listed below;

- **Nominal Zener voltage, $V_{z:}$**: This is the reverse biased voltage at which the diode begins to conduct in reverse bias.
- **Zener voltage tolerance**: Like the tolerance of a resistor, this indicates the percentage above or below V_z. For example, 6.3 V ± 5 percent.
- **Maximum zener current, I_z,max**: This is the maximum current that the zener can safely withstand while in its reverse-biased conduction (zener) mode.
- **Maximum power dissipation, P_z** is the maximum power the zener can dissipate without getting damaged.
- **Impedance (Z_z)**: The impedance of the zener while conducting in zener mode.
- **Maximum operating temperature** : The highest temperature at which the device will operate reliably.

These specifications of zener diodes are given in diode data books.

The example given below enables to interpret the specifications of certain types of zener diodes without the need to refer diode data book:

Example 1: The type-code printed on a zener is BZ C9V1.

BZ C9V1

B	Z	C	9V1
silicon	zener	5% tolerance	9.1V

Example 2: The type-code printed on a zener is 1Z 12.

1Z 12

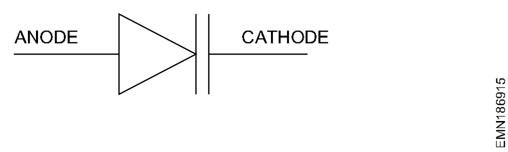
1	Z		12
Means a semiconductor with one PN junction	zener	No tolerance code means, 10% tolerance	12V

Other popular zener diode type-codes are, 1N750, 1N4000, ZF27, ZP30, DZ12, BZ148, Z6, etc.

Varactor diode or varicap diode

Varactor diode is a one kind of semiconductor microwave solid-state device and the applications of this diode mainly involve in where variable capacitance is preferred which can be accomplished by controlling voltage. These diodes are also named as varicap diodes. Even though the outcome of the variable capacitance can be showed by the normal P-N junction diodes, but these diodes are chosen for giving the desired capacitance changes as they are special types of diodes (Fig 5). Varactor diodes are specifically fabricated and optimized such that they permits a high range of changes in capacitance.

Fig 5



The different types of varactor diodes are available in the market such as hyperabrupt, abrupt and gallium - arsenide varactor diodes. The symbol of the varactor diode is shown in the above figure that includes a capacitor symbol at one end of the diode that signifies the characteristics of the variable capacitor of the varactor diodes.

The symbol of the varactor diodes looks like a common PN-junction diode that includes two terminals namely the cathode and the anode. And at one end this diode is inbuilt with two lines that specifies the capacitor symbol.

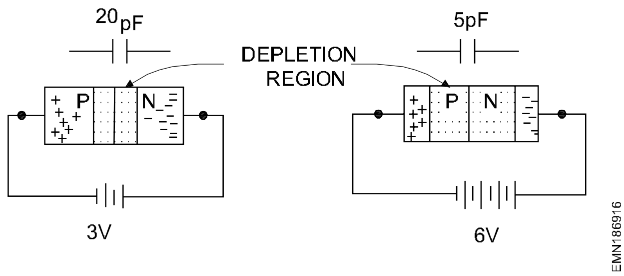
Working of a Varactor diode

To know the varactor diode working principle, we must know the function of capacitor and capacitance. Let us consider the capacitor that comprises of two plates aliented by an insulator as shown in the figure 6.

We know that, the capacitance of a capacitor is directly proportional to the region of the terminals, as the region of the terminals increases the capacitance of the capacitor increases. When the diode is in the revers biased mode, where the two regions of P-type and N-type are able to conduct and thus can be treated as two terminals. The depletion area between the P-type & N-type regions can be considered as insulating dielectric. Therefore, it is similar to the capacitor shown above.

The volume of the depletion region of the diode varies with change in reverse bias. If the reverse voltage of the diode is increased, then the size of the depletion region increases. Likewise, if the reverse voltage of the Varactor diode is decreased, then the size of the depletion region decreases.

Fig 6

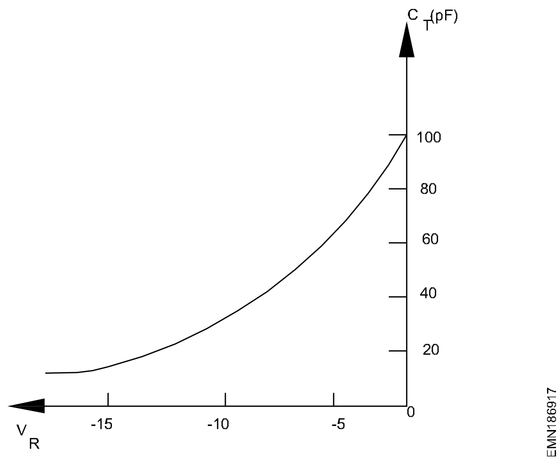


Characteristics of varactor diode

The characteristic of varactor diode have the following:

- These diodes significantly generate less noise com pare to other diodes.
- The cost of these diodes is available at lower and more reliable also.
- These diodes are very small in size and very light weight.
- There is no useful when it is operated in forward bias.
- In reverse bias mode, varactor diode enhances the capacitance as shown in the Fig 7.

Fig 7



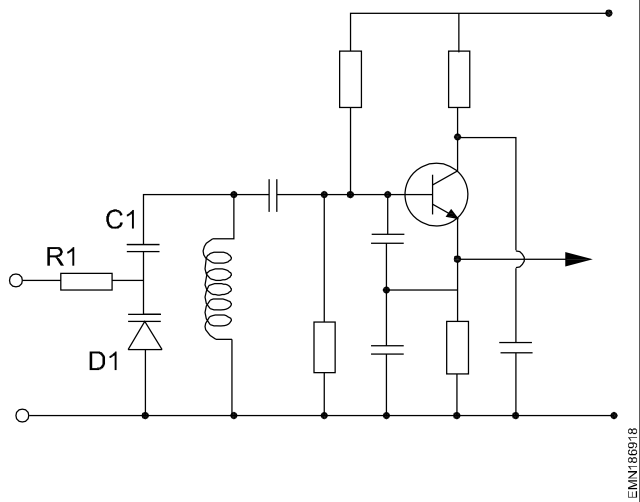
Applications of varactor diode

The applications of varactor diode mainly involve within the RF design area however, in this article, we are discussing about the couple of applications of varactor diodes, to illustrate how these diodes can be used in practical. The capacitor in a practical circuit can be changed with the varactor diode, but it is necessary to make sure the tune voltage necessary to set the diode capacitance. And to ensure that this diode is not influenced by the bias voltage in the circuit. By using voltage control technique in the diode ciruit, changing capacitanc can be offered.

Voltage contolled oscillators

Consider the circuit of VCO designed by using varactor diode 'D_1' as symbolized in the figure (8). The oscillator can be allowed by changing the 'D_1' diode. The capacitor C_1 is used to stop the reverse bias for the varactor diode, also neglects the diode getting short circuited through the indicator. The diode can be adjusted by applying bias through an R_1 resistor (isolating series resistor).

Fig 8



RF filters

The varactor diodes can be used in th RF filters to tune. In the receive front to follow the frequency of the incoming received signal which can be restricted using a control voltage. Usually, the is offered by microporcessor control through the DAC. A few of the main applications of varactor diodes can be listed below:

- These diodes can be used as frequency modulators and RF phase shifters.
- These diodes can be used as freqency multipliers in microwave receive.
- These diodes are used to change the capacitance in tank LC circuits.

Specifications of varactor diode

When choosing a varactor diode, the varactor specifications need to be carefully determined to asses whether it will meet the circuit requirements.

While there will be many varactor diode specifications that are the same as those applied to other types of diode, including signal diode, etc, there are many other varactor specifications that are crucial to the perfornance of the varactor in any variable capacitance role.

Many of the difference varactor parameters will be detailed in the varactor specification sheet that may be accessed in the manufactures literature.

Reverse breakdown

The reverse breakdown voltage of a varactor diode is importance. The capacitance decrease with increasing reverse bias, although as voltages becomes higher the decreases in capacitance becomes smaller. However the minimum capacitance level will be determined by the maximum voltage that the device can withstand. It is also wise to choose a varactor diode that has a margin between the maximum voltage it is likely to expect, i.e. the rail voltage of the driver circuit, and the reverse breakdown voltage of the diode. By ensuring there is sufficient margin, the circuit is less likely to fail.

It is also necessary to ensure that the minimum capacitance required is achieved within the rail voltage of the driver circuit, again with a good margin as there is always some variation between devices.

Diodes typically operate with reverse bias ranging from around a couple of volts up to 20 volts or possibly higher. Some may even operate up to as much as 60 volts, although at the top end of the range comparatively little change in capacitance is seen. Also as the voltage on the diode increases. It is likely that specific supplies for the circuits driving the varactor diodes will be required.

Maximum frequency of operation

There are a number of items that limit the frequency of operation of any varactor diode. Th minimum capacitance of the diode is obviously one limiting factor. If large levels of capacitance are used in a resonant circuit, this will reduce the Q.A further factor is any parasitic responses, as well as stray capacitance and inductance that may be exhibited by the device package. This means that device with low capacitance levels that may be more suitable for high frequencies will be placed in microwave type package. These and other considerations need to be taken into account when choosing a varactor diode for a new design.

As a particular varactor diode type may be available in a number of packages, it is necessary to choose the variant with the package that is most suitable for the application in view

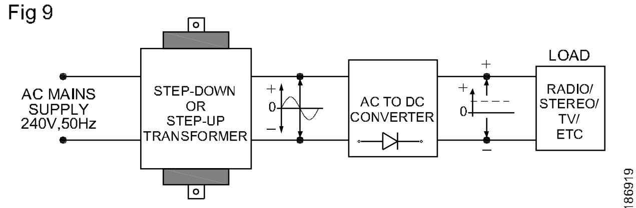
Rectifier

Almost all electronic circuits need DC voltage for their working. This DC voltage can be obtained by dry cells and batteries. Use of a dry cell is practicable only in portable electronic circuits such as transistor radio, tape recorders etc. But in circuits requiring large voltages and currents, like high power audio amplifiers, television sets etc. batteries will not only be very expensive but also be voluminous.

An alternative method of obtaining DC voltage is by converting the AC mains supply of 240V, 50Hz into DC voltage. This technique is not only convenient but also takes very small space compared to battery packs. This process of converting AC to DC is known as rectification. Fig 9 shows the principle of converting AC to DC of required voltage level.

The transformer will step-down or step-up the mains AC to the required level. The stepped-up or stepped-down AC from the output of the transformer is then converted to DC using diodes making use of their unique unidirectional property.

Fig 9



Half wave rectifier

The simplest form of AC to DC converter is obtained by using one diode. such an AC to DC converter is known as half-wave rectifier as shown in Fig 10.

At the secondary of the transformer, across terminals P & Q, when seen on a CRO, the electric signal is a sinusoidal wave with its peak value of V_P and a frequency determined by the rate at which the alternations (+ve to –ve) are taking place. In Fig 10, the frequency is 50Hz as this voltage is taken from 50Hz AC mains supply.

If the voltage across P and Q is measured using an AC voltmeter, the voltmeter shows the rms (root mean square) value, V_{rms} of the sinusoidal wave which will be less than the peak value. The relationship between V_{Peak} and V_{rms} is given by,

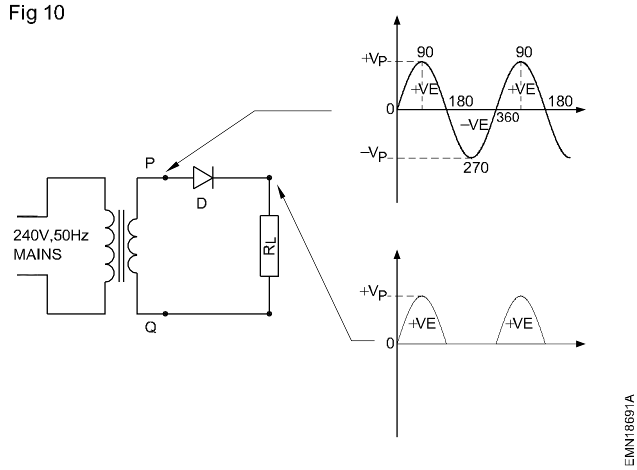
$V_{rms} = 0.707\ V_{peak}$ ....[1]

conversely,

$$V_{peak} = \frac{V_{rms}}{0.707} = \sqrt{2}\ V_{rms}$$

When this sinusoidal signal is applied across the diode D as shown in Fig 10, the diode conducts (behaves as a closed switch) only during the +ve half cycle of the input sinusoidal voltage and does not conduct (behaves as a open switch) during the -ve half of the input sinusoidal voltage. This process repeats again and again thus producing a pulsating +ve wave form at the output across the load, R_L as shown in Fig 10.

Fig 10



The operation of a half-wave rectifier circuit can be summarised with the help of Fig 11 as follows:

1 During the positive half cycle of AC input, the diode is forward biased as the anode of diode is positive as shown in Fig 11a.

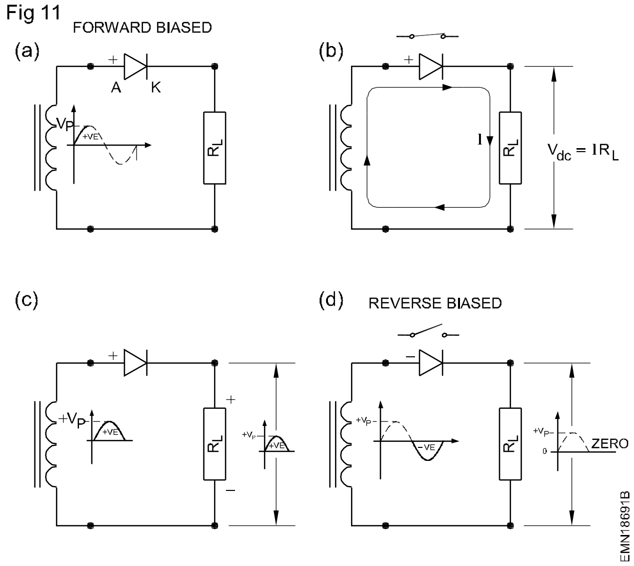
2 Hence current flows from anode to cathode, through load R_L to secondary of transformer as shown in Fig 11b. The IR_L drop across load resistor R_L is the DC voltage V_{dc} with the polarity as shown in Fig 11b.

3 When the +ve half cycle of the input sinusoidal is completed, the voltage across the R_L will be a positive half sinewave as shown in Fig 11c. The peak of rectified voltage is also equal to the peak of the input AC voltage.

4 During the negative half cycle of the input AC, the diode is reverse biased as the anode of diode is negative as shown in Fig 11d.

5 Hence, the diode behaves as an open switch and no current flows through the load and hence there is no voltage output across load R_L as shown in Fig 11d.

Fig 11



6 After completing the –ve half cycle, when the input signal goes positive again, the whole operation repeats starting from step 1.

As can be seen from Fig 10, the output of the half-wave rectifier is always a +ve voltage (DC) although it is pulsating. In other words, the output is either positive (during +ve half cycle of the AC input) or zero (during -ve half cycle of AC input) but never negative. Hence, the output of a rectifier is a pulsating +ve DC voltage.

The circuit at Fig 10 is known as a half-wave rectifier as the rectification is done by the circuit only during one half cycle of the input AC signal.

Calculating output DC level in half-wave rectifiers

Two important points to note for calculating the output DC level of a halfwave rectifier are;

– the output of a halfwave(HW) rectifier across the load resistor is a pulsating DC whose peak voltage is equal to the peak value of the +ve half cycle of the AC input as shown in Fig 12. This can be checked using an oscilloscope.

  The small forward voltage drop of the diode (0.7 for Si) when forward biased is ignored for simplicity in understanding.

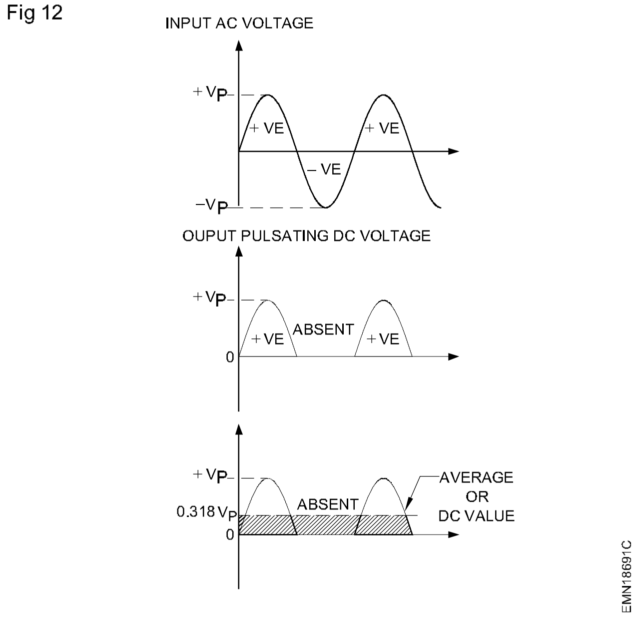
– the pulsating signal level is zero when the input AC is in the –ve half cycle as shown in Fig 12.

Hence, when a DC voltmeter is connected across the load resistor R_L, the meter reads the average DC value of the pulsating signal. Ignoring the diode drop, the average DC value of the pulsating output in a half wave rectifier is given by,

$V_{average}$ or $V_{dc} = 0.318\ V_P$ ....[2]

Example: If the total secondary voltage of the transformer (V_S) in Fig 10 is 24 V_{rms} (measured by AC meter), the output V_{dc} will be,

Fig 12



From ...1, $V_p = \sqrt{2}\ V_{rms}$

From ...2, $V_{dc} = (0.318)\ V_p = 0.45\ V_{S(rms)}$

Therefore, for a half-wave rectifier the level of output DC is given by,

$V_{dc} = 0.45\ V_{S(rms)}$ .....[3]

Where $V_{S(rms)}$ is the input rms AC voltage.

In the example considered above, the output DC voltage at Fig 10 will be,

$V_{dc} = 0.45 \times V_{S(rms)} = 0.45 \times 24 = 10.8$ volts.

Ripple frequency

From Fig 12 it is evident that the frequency of the rectified pulsating DC is same as the frequency of the input AC signal. This is true for all half-wave rectifiers.

Peak inverse voltage

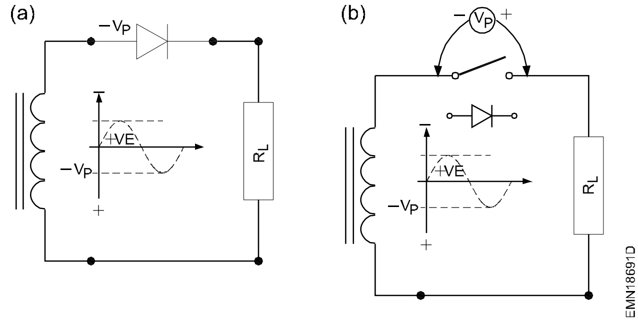
Fig 13a shows the half-wave rectifier at the instant the secondary voltage is at its maximum negative peak.

In this condition, since the diode is reverse biased, it behaves as an open switch as shown in Fig 13b. Since the diode is reverse biased, there is no voltage across the load R_L. Therefore, From Kirchhoff's voltage law, all the secondary voltage appears across the diode as shown in Fig 13b. This is the maximum reverse voltage that appears across the diode in the reverse biased condition. This voltage is called the peak reverse voltage or more commonly as the **peak inverse voltage (PIV).** Therefore, in a half-wave rectifier the peak inverse voltage across the diode is equal to the -ve peak value of the secondary voltage $V_{S(peak)}$. Since, the -ve peak voltage and +ve peak voltage in a sinusoidal wave is same in magnitude, the peak inverse voltage (PIV) across the diode in a halfwave rectifier can be taken as a $V_{S(peak)}$.

In the example considered earlier, the PIV across the diode will be,

$$V_{s(peak)} = \frac{V_{s(rms)}}{0.707} = \frac{24}{0.707} = 33.9 \approx 34 \text{ volts.}$$

Fig 13



To avoid break down of the diode used, the PIV appearing across the diode of the designed HW rectifier must be less than the PIV rating of the diode. For instance, in the above example to avoid break down of the diode, the PIV rating of the diode should be greater than 34 volts.

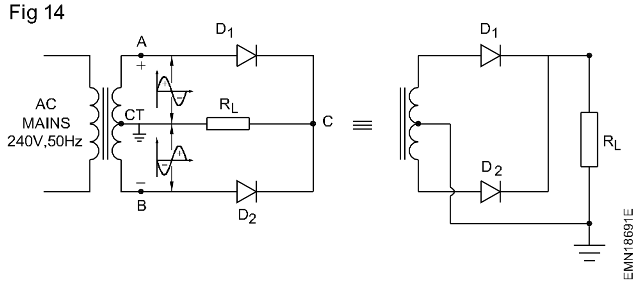
Two diode full wave rectifier

In a half-wave rectifier there is no rectification action during the -ve half cycle of the input AC voltage. Because of this the output DC level is low (0.318 $V_{S(peak)}$). This limitation of a half-wave rectifier can be overcome by using two diodes and a centre-tap-transformer as shown in Fig 14.

In Fig 14, each diode and the common load resistor R_L form two independent half-wave rectifiers. Because of the centre-tapped secondary winding, each diode receives only half of the total secondary voltage.

The opposite ends of the transformer secondary windings always have opposite polarities with respect to the centre tap. As shown in Fig 14, when end A of the secondary winding is positive, the bottom end B will be negative.

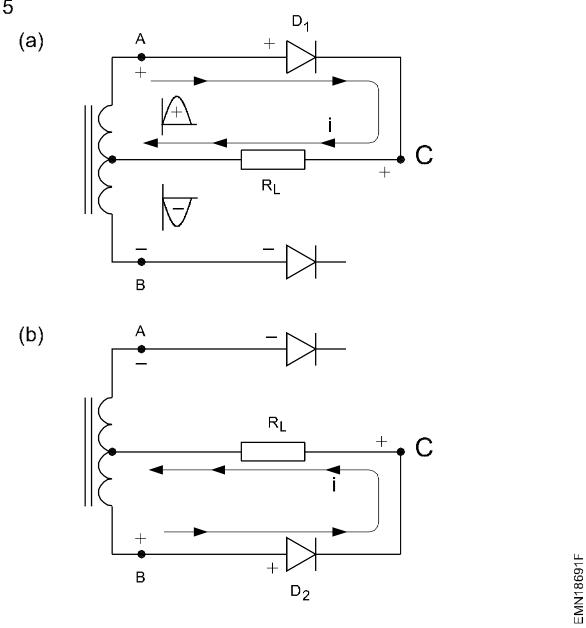
Fig 14



For the polarity shown in Fig 15a, the anode of D_1 is positive and, hence, forward biased. Whereas, the anode of D_2 is negative, and, hence, does not conduct. Current flows from the transformer(end A) → D_1 → R_L → back to the transformer centre-tap. This direction makes point C across the load R_L as the +ve terminal of the output DC voltage.

During the next half cycle, end B of transformer is +ve and A is –ve as shown in Fig 15b. Hence the anode of D_2 is +ve and this diode conducts whereas D_1 does not. Current flows from the transformer(end B) → D_2 → R_L → back to the transformer centre-tap. This direction of current again makes point C across the load R_L as the +ve terminal of the output DC voltage.

Fig 15



Regulated power supply

Objectives: At the end of this lesson you shall be able to
- **explain the regulated and unregulated power supply.**

DC regulated power supply : The main purpose of a DC regulated power supply is to get a constant DC supply for electrical and electronic circuits for conducting experiments in laboratories and also to provide testing voltage for equipments like radio, TV, tape recorders, computers etc.

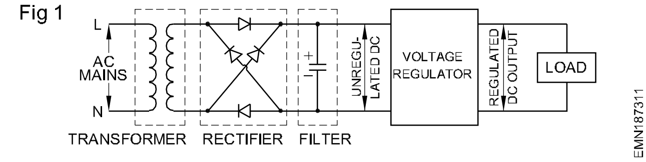
DC unregulated power supply : The most common method of obtaining DC from AC supply is to use a transformer for stepping down/up of the AC voltage and to use a rectifier circuit for converting AC supply into DC. Often capacitors/inductors are used to filter the DC output. In this type of circuits the DC output voltage changes with a change in load and is generally used in a circuit where load current is constant eg. battery charging, electroplating, communication system etc.

Types of regulated power supply : There are two basic ways of deriving a stable DC supply from an AC supply. They are the conventional way and a system using switch mode technique.

Most of the electronic equipment uses the conventional type of power supply. In this type, voltage and current regulation are used combinely.

Voltage regulated power supply: The voltage regulated power supply consists of a step down transformer, rectifier and a storage capacitor to generate an unregulated DC supply that is electrically isolated from the AC mains supply. Then this DC output voltage which is not regulated is passed through voltage regulator circuitory to get the regulated DC voltage. (Fig 1).

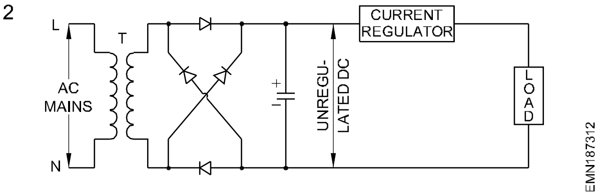
Fig 1



The regulator circuit parameter may consist of zener diodes, transistors or integrated circuits as discussed in Ex. 812 of 2nd year. A transistor version of a fixed voltage regulator is shown in Fig 1 of Ex.812 and a transistor version of a variable voltage regulator is shown in Fig 2 of Ex.812 of 2nd year. Please refer to them.

Current-regulated power supply : A current regulated power supply consist of an unregulated power supply simillar to voltage-regulated power supply and a current limiting circuit. (Fig 2)

Fig 2



By suitably designing the current regulator circuit it is possible to get current regulation for a single range or a multi-range of currents.

Voltage and current regulation combined : Commercially available DC regulated power suppliers provide both voltage and current regulation combined in the supply unit. (Figs 3 and Fig 4)

Fig 3

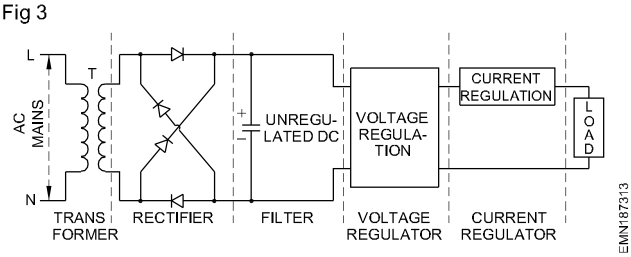
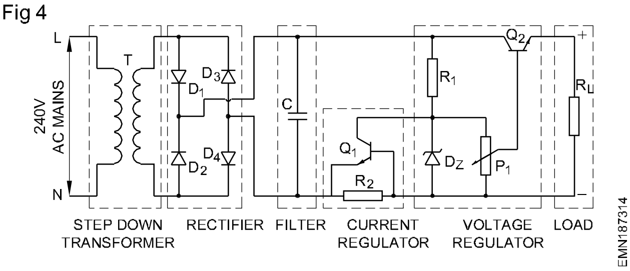


Fig 4



Circuit description : Fig 4 shows a circuit diagram of a simple voltage and current regulated power supply. The functions of circuit elements are as follows. Transformer 'T' is used for stepping down AC voltage to the required AC voltage. Full wave bridge rectifier 'D_1 to D_4' is used to rectify AC to DC voltage. A capacitor 'C' is used for filtering. The voltage across zener diode 'D_z' is used as a reference voltage source which is constant. The potentiometer 'P_1' is used for controlling the DC output voltage. Transistor Q_2 works as a voltage regulator. For a set voltage by potentiometer 'P_1' that is when there is no load, transistor Q_2 conducts less and voltage drop across collector and emitter is maximum. When the load current increases transistor 'Q_2' conducts more and the voltage drop across collector and the emitter decreases almost compensating the drop in unregulated DC output, thereby keeping the regulated output voltage constant. Transistor 'Q_2' also works as a current regulator. The conduction of transistor 'Q_1' depends upon the voltage drop across resistor 'R_2'. In turn the voltage drop across 'R_2' depends upon the resistance value of R_2 and load current (I_L x R_2). When the load current increases the voltage drop across 'R_2' also increases and for a set current transistor 'Q_1' conducts resulting the base of transistor 'Q_2' to almost at negative potential reducing the output voltage. The ultimate result is the current will not increase above the set value of current but the voltage goes on decreasing for any reduction of load resistance "R_L".

TERMS USED IN SPECIFYING REGULATED POWER SUPPLIES

The regulation requirement of a regulated power supply is often associated with its application. Hence the following terms are considered while selecting a regulated power supply.

Line regulation (Source regulation) : The line regulation is also called a source regulation specifying the change in DC output voltage due to the variation in the line voltage.

$$\% \text{ Source regulation} = \frac{\begin{array}{l}\% \text{ of variation of DC output}\\ \text{voltage for a given constant load}\end{array}}{\begin{array}{l}\% \text{ of variation of AC input}\\ \text{line voltage}\end{array}} \times 100$$

Load regulation : The load regulation is also called load effect which is defined as the change in the regulated output voltage when the load current changes from minimum to maximum.

Load regulation = No load voltage E_{NL} – Full load voltage E_{FL}

Load regulation = $E_{NL} - E_{FL}$

Load regulation is often expressed as a percentage by dividing the change in the load voltage by the no load voltage.

$$\% \text{ Load regulation} = \frac{E_{NL} - E_{FL}}{E_{NL}} \times 100$$

Ripple : The term ripple implies that the residue of AC delivered to the load as a result of imperfect rectification and filtering.

The ripple may be mentioned as AC voltage available for a given or nominal DC output voltage. In general the 'Ripple factor' is defined as the percentage ratio of the AC voltage available in the DC output.

$$\% \text{ Ripple factor} = \frac{\text{AC voltage available in DC output}}{\text{Normal DC voltage at the output}} \times 100$$

The size of the power supply unit depends upon the maximum DC output power required ie. DC voltage and DC amperes. The circuit of the regulated power supply becomes more and more sophisticated depending upon the high precision in regulation and a number of protection circuits incorporated in the equipment. The circuit may use a number of ICs transistors, controls and other components depending on the accuracy required.

Computer, parts and their working

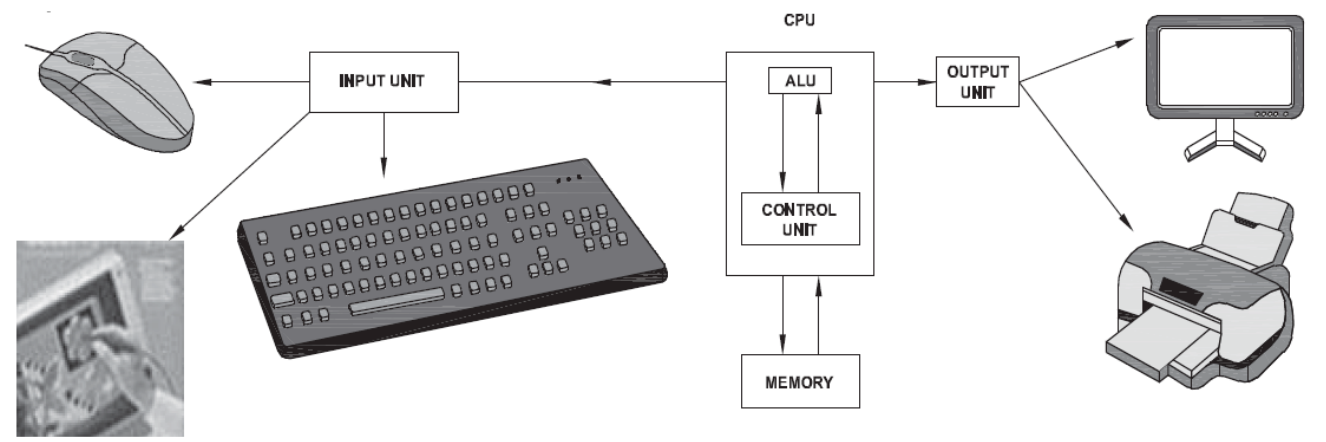
Objectives : At the end of this lesson you shall be able to
- **explain the basics of computer**
- **identify various peripheral devices.**
- **identify and explain computer connection and ports**
- **explain the main components on the mother board**
- **explain the types of cables used in computer**
- **explain the CPU and memory.**

What is a computer?

The term computer is used to describe a device made up of electronic and electro mechanical components. The computer itself cannot perform any task and is referred to as hardware.

A computer system consists of three elements.

Fig 1



1 Hardware

2 Software

3 People

Hardware : The physical components which you can see, touch and feel in the computer system are called hardware Eg monitor, keyboard, mouse etc.

Software : Software is used to describe the instructions that tells the computer how to perform a task. Software is categorized as

1 System softwares (eg . operating systems, compilers, editors, etc)

2 Application softwares (MS-word, excel, accounting packages, etc)

People : People who operate the computer and also create computer software instructions.

Computer hardware

Basic components in a computer system are central processing unit (CPU), memory, the input device and output device.

Computer systems – Micros, Minis and Mainframes.

Micro computer : Micro computer is also called as personal computer or PC. It has a processor based on a single silicon chip. Personal computers come in three different physical sizes, pocket pc's, lap pc's and desktop pc's. Pocket pc's and lap pc's belong to portable category. Microcomputer is used in small businesses.

Ex : IBM compatible or IBM clone and Apple Macintosh systems.

Multiuser microcomputers. Until recently microcomputers were personal

computers for individual use only. But now days several microcomputers can be networked together for simultaneous use by several people.

Mini computers: Mini computer is simply a small mainframe computer. It is a reduced version of mainframe. Attached printers are not so fast. So it has less storage capacity less processing speed of that of mainframe computers. They are usually used by small businesses. For example research groups, engineering firms, colleges etc. use mini computers.

Mainframe computers: A mainframe computer is a large expensive machine whose processing speed is very high and has large amount of secondary storage and fast printers. A large mainframe computer may be used to meet the data processing requirements of the entire organization.

Examples: airline booking systems, Railway booking systems , weather forecast etc.

System types

We can classify systems into the following categories :

8-bit, example : 8085 microprocessor

16-bit, example : 8086, 286, 386 processor

32-bit , example : 486

64-bit, example : Pentium - II

This gives us two basic system types or classes of hardware.

8-bit (PC/XT) class systems

16/32/64 (AT) class systems

PC stands for personal computers, XT stands for eXTended PC, and AT stands for an advance technology PC.

The XT basically was a PC system that included a hard disk for storage in addition to the floppy drive found in the basic PC system. These systems has an 8-bit processor and an 8-bit INDUSTRY STANDARD ARCHITECTURE

(ISA) bus for system expansion. Bus is the name given to expansion slots in which additional plug in circuit board can be installed.

16-bit and greater systems are said to be AT class. 16-bit (and latter 32 and 64 bit) processors and expansion slots are included. The first AT class systems had a 16-bit version of the ISA bus which is an extension of the original 8-bit ISA bus found in the PC/XT class systems. Afterwards several expansion slots were developed for AT class systems.

Example

16/32 bit PS/2 microchannel architecture (MCA) bus.

16-bit PC card (PCMCIA) bus

16 bit ISA bus

16/32 bit Extended ISA(EISA) bus

32/64 - bit card Peripheral Component Interconnect (PCI) bus.

The easiest way to identify a PC/XT system is by the 8-bit ISA expansion slots regardless of the processor present in the system. AT systems can be similarly identified by having 16-bit of greater slots of any type (ISA, EISA, PCI) slots.

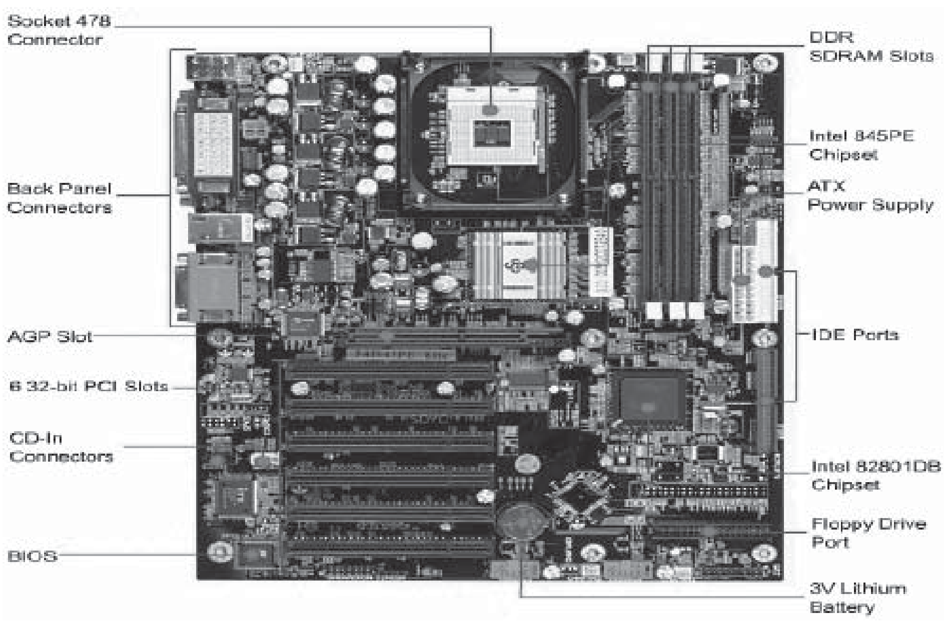
System components

Component needed to assemble a basic modern PC system.

- Motherboard
- Processor
- Memory (Primary)
- Hard disk
- CD-ROM
- Floppy Drive
- Keyboard
- Mouse
- Monitor
- Power Supply
- Cabinet

Motherboard : Motherboard is the important component of the computer as everything else is connected to it. And it controls everything in the system. Motherboard are available in several different shapes. Motherboard usually contain the following individual components shown in Fig 2.

Fig 2



1 Processor slot

2 Processor voltage regulators

3 Motherboard chipset

4 Level 2 cache

5 Memory SIMM or DIMM sockets

6 Bus slots

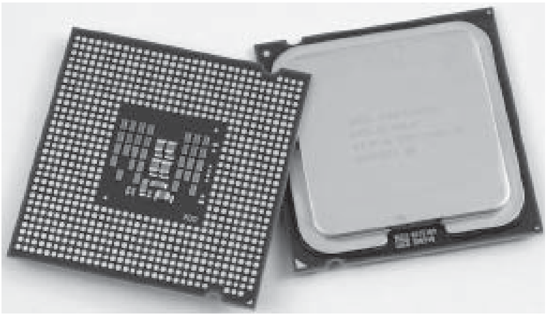
7 ROM BIOS

8 Clock / CMOS battery

9 Super I/O chips

Processor (Fig 3)

Fig 3



The processor is often thought as the engine of the computer shown in Fig 3. Then the processor reads the commands from the memory and then executes them. The processor is one of the most expensive parts of the computers and is also one of the smallest parts.

Primary Memory

Memory: Is used to hold programs and data during execution.

Primary memory is often called as RAM(Random Access Memory). It holds all the programs and data the processor is using at a given time. RAM is volatile because its contents are erased when power is switched off. The other type of system memory is ROM(Read only Memory)which is permanent because it contents are not erased even when power is switched off. It is usually used to load an operating system.

Hard disk drive (Fig 4)

Fig 4

A hard drive consists of spinning platters made up of aluminum or ceramic that is coated with magnetic media shown in Fig 4. The platters come in various sizes. The hard drive with many different storage capacities can be created depending upon the density, size and number of platters. This is also called as Secondary memory. There can be several programs in the system, which cannot be stored in RAM, so we need a very huge non-volatile memory, which can be used for storing all the programs, and data when the system is not in use are called as Hard disks.

CD-ROM drive

CD-ROM stands for compact disk read only memory. It consists of small disks similar to the gramophone records to hold digital information. As the name applies they are read only medium. With the advancement in technology writable CD's are also available.

Floppy Disk Drive

Floppy disks are the slowest and the smallest form of secondary storage. They provide a simple way to carry information from one place to another, and backup small amount of files. In modern days floppy drive component is not as important as it was years ago. All PC's made in the last 10 years use a standard 3 ½ inch, 1.44 MB capacity floppy drive.

Keyboard

The keyboard is the main input device for most computers. It is used to input text or enter commands into the PC. Nowadays keyboards with additional features are available like multimedia keyboard, wireless keyboard.

Mouse

With the invention of graphical user interface mouse is used to input information into the computer. Users simply point and click to enter information. The main advantage of mouse over keyboard is simplicity. And there are many operations that are much easier to perform with a mouse than a keyboard.

Monitor

The monitor is the specialized high-resolution screen similar to a television. The video card sends the contents of its video memory to the monitor at a rate of 60 or more time per second. The actual display screen is made up of red, green and blue dots that are illuminated by electron beam from behind. The video card DAC chip controls the movement of the electron beam, which then controls what dots are turned on and how bright they are. Which then determines the picture you see on the screen.

Power supply

SMPS(Switch Mode Power Supply): The power supply provides power to every part in the PC. The main function of the power supply is to convert the 230 V AC into 3.3 V, 5 V and 12 V DC power that the system requires for the operations. In addition to supplying power to run the system, the power supply also ensures that the system does not run unless the power supplied is sufficient to operate the system properly. The power supply completes internal checks and tests before allowing the system to start. If the tests are successful, the power supply sends a special signal to the motherboard called **Power Good.**

If this signal is not present continuously, the computer does not run. Therefore, when the AC voltage dips and the power supply becomes stressed or overheated, the **Power Good** signal goes down and forces a system reset or complete shutdown.

Cabinet

The box or outer shell that houses most of the computers. The cabinet actually performs several important functions for your PC including protection to the system components, directing cooling airflow, and allowing installation access to the system components. The cabinet often includes a matching power supply and must also be designed with shape of the motherboard and other system components in mind.

Peripheral Devices

Any external device, which is not necessary to perform the basic operation of computer, is called as peripherals. They provide additional computing capabilities. For ex : Printers, Modems, Speakers etc.

Modem

Modem (Modulator and Demodulator) is typically used to send digital data over a phone line . The sending modem converts digital data into analog data, which can be transmitted over telephone lines, and the receiving modem converts the analog data back into digital form. This is used to connect to Internet.

Modems are available in different capacities.

- 300 bps - 1960s through 1983 or so
- 1200 bps - Gained popularity in 1984 and 1985
- 2400 bps
- 9600 bps - First appeared in late 1990 and early 1991
- 19.2 kilobits per second (Kbps)
- 28.8 Kbps
- 33.6 Kbps
- 56 Kbps - Became the standard in 1998
- ADSL, with theoretical maximum of up to 8 megabits per second (Mbps)

  Gained popularity in 1999

Printers

The capability to produce a printed version often called a hard copy of a document is the primary function of a printer. Different types of printers are 1) Laser 2) Inkjet 3) Dot-Matrix.

Network Connector

The Network Connector, also referred to as a NIC card, is how your CPU talks to the network. A network cable is plugged into the back of the computer in this location . The other end of the network cable is plugged into a network jack in the wall. If the wall jack is "live", meaning it has been wired to talk to the network, then your computer will connect to the network

USB Ports

The USB ports are present on newer machines and most often require Windows 98 or higher. If you have Windows95, the USB ports may not work. USB ports allow you to connect an external device, such as a printer, camera, scanner, or other device to your computer.

USB ports transfer information from the connected device to your computer.

Monitor Connector

The monitor connector is a 15 pin female connector. This is how the monitor is connected to the computer. On the back of the monitor, there is a 15 pin male connector. The monitor cable gets plugged into the back of the computer in this location.

Keyboard Connector

The PS/2 Keyboard connector is where the keyboard gets connected to the computer. The keyboard cable, has a round connection with one flat side.

Mouse Connector

The PS/2 Mouse connector is where the mouse gets connected to the computer. Although the keyboard connector and the mouse connector look the same, they are not interchangeable. In newer PC's, the components are color coded and it is clear where the mouse and keyboard go. In older models, the keyboard connector comes first.

Com Port 1 & 2

Com Port 1

Com Port 2

Com Ports are usually have 9 pins and are male connectors. Com Port stands for communication port and is how your computer talks to external devices such as modems, scanners or digital cameras.

Parallel Port

The parallel port is sometimes referred to as a printer port (or LPT1) because that is the typical device that is attached to this port. The parallel port is a 25 pin female connector. If you have a direct connect printer, the male end of the printer cable (pictured later in this manual) is connected here.

Game Stick Port

The game stick port is where you would connect an external device like a game stick or joystick. It is a 15 pin female connector.

Sound Card

Sound Card – Speaker Connector

Sound Card – Audio Out Connector

Sound Card – Microphone Connector

A sound card allows you to hear sounds from a CDROM or audio file. The connectors allow you to attach speakers, microphones or headphones. If your computer does not have these connectors, you will not be able to hear sound.

CPU Power Cord

The CPU power cord connects the CPU to the electrical supply.

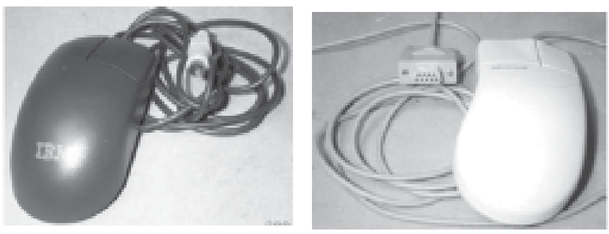
Keyboard

The illustration above shows two examples of keyboard connectors – the left is the larger connector and the right is the smaller. On the larger connector, there is an arrow that should face up when you are connecting it to the CPU. On the smaller connector, there is a flat side that should face up when connecting it to the CPU.

Mouse (Fig 5)

The illustrations above (Fig 5) show two examples of mouse connectors. The left is a PS/2 mouse connector (circle) and the right is a serial connector that would plug into one of your com ports

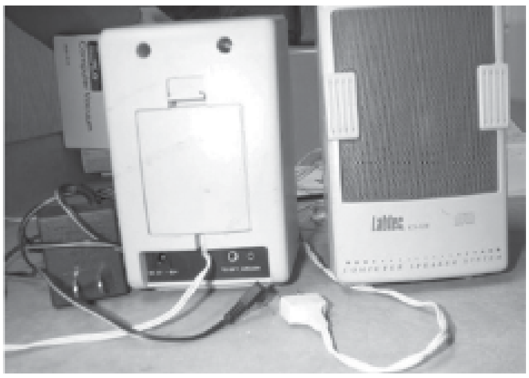
Fig 5



Speakers (Fig 6)

The following cords are connected to a set of speakers

Fig 6



The following cords are connected to a set of speakers shown in Fig 6

- Power cord – connecting one speaker to the power source
- Left to Right speaker connector – connecting one speaker to the other
- Speaker to CPU connector – connecting speakers to the CPU

Monitor

There are two cords attached to the back of the monitor. The first is a power cord that connects the monitor to the power source. The second is a monitor cable.

The monitor cable is a 9 pin male connector that gets connected to the monitor connector on the back of the CPU

Network Cable and Network Jack

The network cable can be blue, purple or off-white. One end is connected to the back of the computer (in location A) and the other end is plugged into the network jack on the wall.

Parallel Printer Cable

The parallel printer cable has one connector on each end. The 25 pin male connector gets connected to the back of the CPU in location G and the other end is connected to the local printer.

USB Printer Cable

Newer computers and printers will support the use of a USB printer cable. A USB cable will transfer information more quickly than a parallel cable. The flat end of the USB cable gets connected to the back of the CPU in location B. The square end is connected to the local printer.

The following should help you put the pieces together.

1 Position the CPU in the desired location

2 Connect one end of the **network cable** to the back of the CPU (location A**)** and the other to the wall jack.

3 Connect the **keyboard** to the back of the CPU (location D)

4 Connect the **mouse** to the back of the CPU (location E)

5 Connect the **monitor cable** to the back of the CPU (location C)

6 Connect the monitor power cable to the power source

7 If you have speakers, connect the speaker power cord to the power source, connect the left and right speaker and connect the speaker to the sound card on the back of the CPU (location J) – note, some speakers are color coded to assist in the set-up, if yours are, follow the color codes.

8 If you have a local printer, connect one end of the parallel printer cable or USB Printer Cable to the back of the CPU (location G or location B) and the other end to the printer

9 Connect one end of the power cord to the back of the CPU and the other end to the power source.

Mother board and CPU

1 **Memory**: This is the area used by the processor to store raw data and instructions

2 **Microprocessor**: This is the CPU, which is the main component in a computer that does all the processing work of the data fed into the computer.

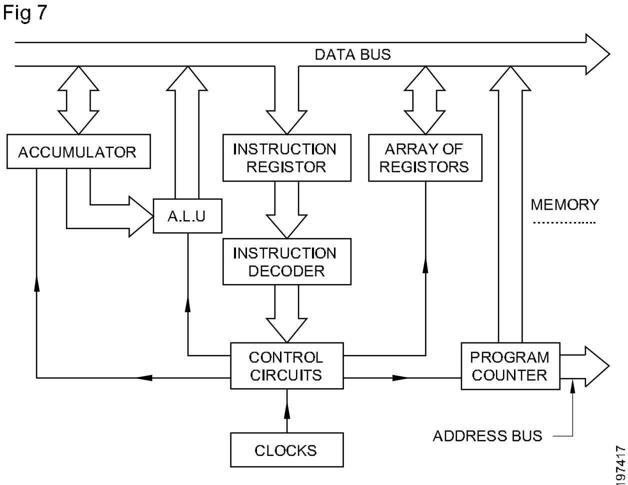
It contains three units viz.,

1 Memory units (internal , called as registers)

2 Arithmetic Logic Unit (ALU)

3 Control Unit

Fig 7



BLOCK DIAGRAM OF A MICROPROCESSOR CHIP

Memory Unit: It is the nervous system of the computer. It controls arithmetic operations to be performed. These unit co-ordinates the activities of all other units in the system. It has two main functions. They are:

1 To control the transfer of data and information between various units

2 To indicate appropriate functions by the arithmetic unit

3 Bus: These are the pathways through which data and instructions pass from one area to another within the computer. The bus carries the signals to various devices that are attached to the computer. There are three buses: Address bus, Control Bus and Data bus.

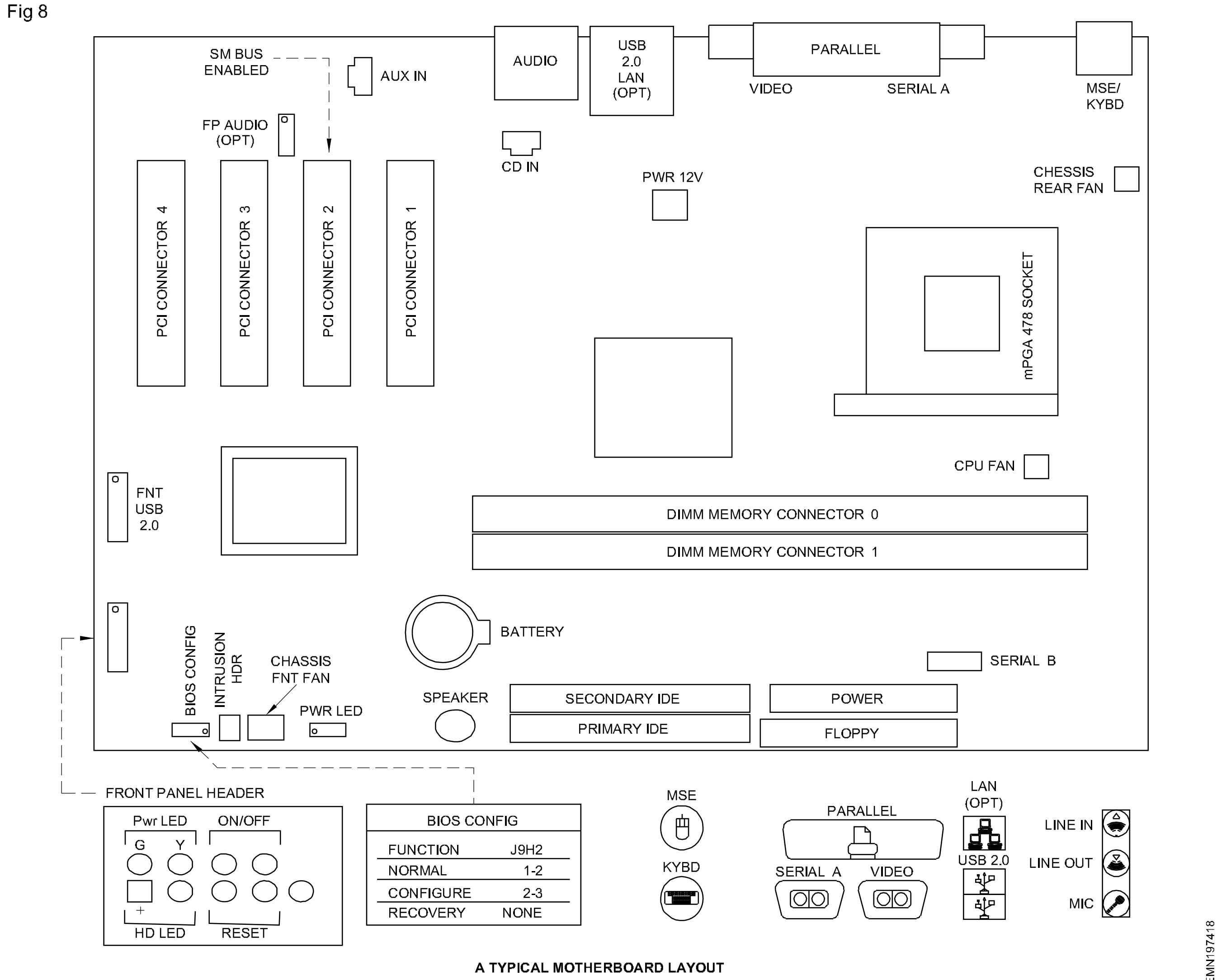
Arithmetic Logic Unit (ALU): This unit does arithmetic calculations and logical operations involved in the program, such as addition, multiplication, comparison etc.,

The CPU uses the address bus to select the memory address of the device in order to read and write data. The actual data is sent using the data bus. Control bus carries the control information like instructing the ALU which operation to perform. Out of these buses the address and control buses are unidirectional whereas the data bus is bidirectional.

4 **Storage Devices**: These are the floppy drives and hard disk drives, both of which we would discuss in detail in the lesson on secondary memory devices.

5 **Motherboard**: The motherboard is the primary component of the entire system. Without the support

Fig 8



A TYPICAL MOTHERBOARD LAYOUT

circuitry and functions that this device provides, even the CPU is unable to function. The detailed diagram of a mother – board is given below.

The various slots are provided to mount add- on cards like display cards, sound card, internal modem, hard disk controller cards etc. However, now- a –days most of these cards come in built within the motherboard itself.

Tips for removing add- on cards from the mother board

1 Put on anti- static wrist strap.

2 Ensure that all the cables from the add- on card connected on to the mother board is removed. Label the removed cable with suitable information. Before removing, record to which slot on the motherboard it was plugged.

3 Remove the boards mounting screw which fixes the metal mounting bracket of the add- on card.

4 Hold the board along it's edges and rock it up gently using equal force at both holding ends and remove the card.

After removing the card, avoid touching the edge connector of the card.

5 Place the card preferably in an antistatic mat such that the components on the card are visible to you.

6 Identify and record the jumper settings on the card.

7 Identify and record the switch setting if any on the mother board.

8 Place the add-on card safely in anti-static pouch and keep it safely in the drawer of your working table or in a shelf.

Tips for removing the Mother board from the cabinet

When all the cables and add- on board are taken out from the processor unit of PC, than it looks quite easy to work further 1
Ensure that all the cables from, the mother board is removed

2 Ensure that all the add-on cards connected on to the mother board is removed.

3 Plan/determine your most likely exit route for the mother board.

4 Remove the two screws holding motherboard on the chassis of the cabinet.

5 Locate the plastic pinch spacers holding the motherboard on to the chassis of the cabinet.

6 slide the motherboard until the plastic pinch spacers feel free of the motherboard using nose pliers

Make sure that you don't accidentally remove any jumper switches with rough handling. Correct jumper settings are crucial for proper operation of the motherboard.

Most CPU's of both types will generate have micro fan mounted right on the chip.

RAM Modules: These memory modules can be seen as small PCB strips(much smaller than add –on cards) plugged into lengthy slots(DIMM-168-pin) (SIMM-72 pin) (SIMM-30 pin) perpendicularly on the motherboard as shown in Fig 8.You may see only one RAM module strip or more than one. Each RAM module strip may have capacity ranging from 4 MB to more than 128 MB .

You will generally see two small plastic card extractors on the edges of the connector.

7 Store the PC cabinet in a safe place.

8 Keep the working table clean and place the mother board for studying.

9 Record the jumper and switch setting on the motherboard.

Tips for identifying the major components on the mother board

CPU: The Central Processing Unit or CPU ,is an integrated Circuit(IC).This will be biggest IC which you can easily identify. This IC can be of two basic types:

1 A super socket-7 or socket 370 types.

2 A socket -1 type.

3 **ROM BIOS Chip:** This means Read Only Memory Basic input-output System. These Chips contain permanent code that the PC uses when the PC is first turned-On.

Most ROM Bios Chips will have a glass window at its center. Some times this window is closed using a adhesive glossy paper slip on which it would be marked the marker of this Bios such as AWARD or AMI or PHOENIX and like. On this glossy paper slip ,a few other details including the year will be printed. This is an important data to be recorded.

4 **Battery:** A round shining big coin like thing ,held in a plastic enclosure with a '+' mark can be seen on the mother board. This is technically called as a button cell. This is actually a Lithium ion battery. This provides power supply to the CMOSRAM for maintenance of Real Time Clock(RTC) and BIOS settings.

Also shows a connector with lot of pins, generally in pairs. These provide necessary signal for the LED's and switches mounted on the front panel of the PC. Right by the sides of this connectors, markings can be seen as to which it should be connected, such as, LED,SPK, RST, etc.

5 ADD-ON Cards/Expansion Card SLOTS: There will generally be three different types of slot female edge connectors.

ISA slots: ISA means Industry Standard Architecture. This type of connector will be Black in color and is the longest of the three types. This slot is called as the ISA slots. These are the old versions and hence your PC mother board may have just one slot of this type or more. Note that your mother board may not have this type of slot also. If so, don't be worried as ISA is an old type and not very essential.

PCI slots: PCI means Peripheral Component Interconnect. These are more recent type compared to ISA and are very popular. These slots are generally white in color and smaller in size compared to ISA slots. A PC Motherboard will definitely have one PCI slot but generally more than one.

AGP slots: AGP means Accelerated Graphics Port. This slot is much more recent than the PCI slot and this slot holds the add-on graphic card to enhance the graphic capabilities of your PC. This slot is generally brown in color and there will be only one such slot on the mother board. If the AGP control circuit is integrated on the mother board itself, then you may not find an AGP on the mother board.

L2 Cache Slot: Some mother board will have small slots for placing cache memory chip modules. These slots are generally white in color . Not all mother boards will have this slot.

IDE/EIDE Connectors: Most motherboards will have two such connectors, one slot marked as IDE1 or Primary and other as IDE2 or Secondary. Through these connectors IDE/EIDE devices such as HDD's and CD ROM drives are connected to the motherboard.

Floppy Diskette Drive Connector: This is a 34 pin mate black plastic connector. On most motherboards there will be only one such connector. The cable used with connector will have facility to connect two floppy diskette drivers.

Power supply connector on the Motherboards: This will generally be a plastic male Molex connector will be one connector strip of 12 pins in single line .In case of ATX models, there will two rows of 10 pin connectors.

Keyboard port, Mouse Port, On Board Serial and Parallel Port: Keyboard Port is one which is always on the Mother. The key board port can be of these types listed below.

1 The olden type-5 pin –DIN connector

2 The more recent type -6 pin P/S -2 connector.

3 The most modern USB port

These motherboards having only the 5-pin DIN port can also use P/S 2-keyboards using a cross adapter cable.

Those motherboard not having USB(Universal Serial Bus) circuitry on board can place a USB adapter card in one of the PCI slots. Then use the USB connector for connecting a USB keyboard.

Serial ports are generally a 9 pin male mini D shell type(DB- 9) connector. Generally any motherboard will have at least two serial ports. All motherboard may not have the serial port connectors mounted right on the motherboard at its edge as shown in figure above. But there will be a two 9 pin connector on the motherboard some where, using which, you have to run 9 wire flat cables to the ports mounted on a metal plate and fixed at one of the metal slots found at the rear of the cabinet.

Some devices need a 25 pin serial port(DB-25). However there will be only 9 pin connections at it. These DB-25 serial port can be easily identified because, this 25 pin slot is a male connector(Whereas a DB-25 pin female is a parallel port).

Mouse is connected to any one of the DB-9 serial port or a P/S-2.6 pin mini DIN connector or a USB port. Where is the mouse to be connected depends upon the type of connector your mouse has. However, you can use cross adapter cable to connect a mouse to a P/S-2 port or vice versa.

CPU Architecture: The basic function performed by a computer is execution of a program, which is a set of instructions stored in memory. The processor does the actual work by executing instructions specified in the program. The instruction execution takes place in the CPU registers, which are:

Memory Address Register (MAR): It specifies the address of memory location from which data or instruction is to be accesses (for read operation) or to which the data is to be stored (for write operation).

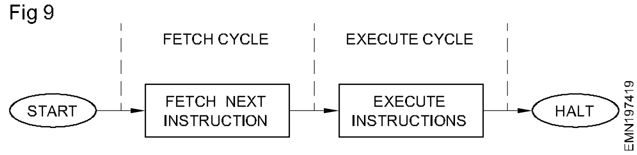
Program Counter (PC): It keeps track of the instruction which is to be executed next, after the execution of an on-going instruction.

Instruction Register(IR): Here the instructions are loaded before their execution.

Instruction Execution: The simplest model of instruction processing can be a two step process. The CPU reads (fetches) instructions (codes) from the memory one at a time, and executes or performs the operation specified by the instruction. Instruction fetches involves reading of an instruction from a memory location to the CPU register. The execution of this instruction may involve several operations depending on the nature of the instruction.

The processing needed for a single instruction (fetch and execution) is referred to as **instruction cycle.** The instruction cycle consist of the fetch cycle and the execute cycle.Program execution terminates if the electric power supply is discontinued or some sort of unrecoverable error occurs, or by a program itself.

Fig 9



Fetch Cycle: For fetch cycle, typically the program counter is used. Program counter keeps track of the instructions which is to be fetched next. The fetched instructions is in the form of binary code and is loaded into an instruction register in the CPU.

Execute Cycle: The CPU interprets the instructions in the instruction register and does the required action. In general, these action can be divided into the following categories.

1 Data may be transferred from processor to memory or from memory to processor.

2 Data may be transferred to or from a peripheral device and an I/O module.

Following are few of the important output devices, which are used in Computer Systems

Computer - Memory

A memory is just like a human brain. It is used to store data and instruction. Computer memory is the storage space in computer where data to be processed and instructions required for processing are stored.

The memory is divided into large number of small parts. Each part is called cell. Each location or cell has a unique address, which varies from zero to memory size minus one.

For example, if computer has 64k words, then this memory unit has 64* 1024 = 65536 memory locations.

Memory is primarily of three types:

1 Cache Memory

2 Primary Memory/Main Memory

3 Secondary Memory

Computer - RAM

A RAM consitutes the internal memory of the CPU for storing data, program result. It is read/write memory. It is called random access memory (RAM).

Since access time in RAM is independent of the address to the world that is, each storage location inside the memory is as easy to reach as other location & takes the same amount of time. We can reach into the memory at random & extremely fast but can also be quite expensive.

RAM is volatile i.e. data stored in it is lost when we switch off the computer or if there is a power failure. Hence, a backup uninterruptible power system (UPS) is often used with computers. RAM is small, both in terms of its physical size and in the amount of data it can hold.

RAM is of two types

1 Static RAM (SRAM)

2 Dynamic RAM (DRAM)

Computer - ROM

ROM stands for Read Only Memory. The memory from which we can only read but cannot write on it. This type of memory is non-volatile. The information is stored permanently in such memories during manufacture.

A ROM stores such instructions as are required to start computer when electricity is first turned on, this operation is referred to as bootstrap. ROM chip are not only used in the computer but also in other electronic items like washing machine and microwave oven.

Computer - Motherboard

The motherboard serves as a single platform to connect all of the parts of a computer together. A mother board connects CPU, memory, hard drives, optical drives, video card, sound card and other ports and expansion cards directly or via cables. It can be considered as the backbone of a computer

Features

1 Motherboard varies greatly in supporting various types of components

2 Normally, a motherboard supports a single type of CPU and few types of memories

3 Video Cards, Hard disks, Sound Cards have to compatible with motherboard to function properly

4 Mother boards, cases and power supplies must be compatible to work properly together

Computer - Memory Units

1 It is the amount of data that can be stored in the storage unit.

2 The storage capacity are expressed in terms of Bytes

Computer - Ports

1 A computer port is a physical docking point using which an external device can be connected to the computer

2 A computer port can also be programmatic docking point through which information flows from a program to computer or over the internet.

CMOS setup and Install the windows OS.

Objectives : At the end of this lesson you shall be able to
- **state the purpose of CMOS**
- **state the CMOS battery's life**
- **describe the functions of BIOS.**

CMOS may refer to any of the following:

Alternatively referred to a real-time clock (RTC), Non-Volatile RAM (NVRAM) or CMOS RAM, CMOS is short for complementary metal-oxide semiconductor. CMOS is an on-board, battery powered semiconductor chip inside computers that stores information. This information ranges from the system time and date to system hardware settings for your computer. The fig shows an example of the most common CMOS coin cell battery (Panasonic CR 2032 3V) used to power the CMOS memory.

The Motorola 146818 chip was the first RTC and CMOS RAM chip to be used in early IBM computers; capable of storing a total of 64 bytes of data.Since the system clock used 14 bytes of RAM, this left an additional 50 bytes for storing system settings. Today, most computers have moved the settings from CMOS and integrated them into the southbridge or super I/O chips.

LIfe of battery

The standard lifetime of a CMOS battery is around 10 years. However, this can vary depending on the use and environment in which the computer resides.

CMOS are used in the following

- Digital logic circuits
- Static RAM (SRAM)
- Micro processors
- Micro controllers

The Basic Input/Output System (BIOS), also known as System BIOS, ROM BIOS or PC BIOS is a generally accepted standard defining a firmware interface.

The fundamental purpose of the BIOS is to initialize and test the system hardware components and load an operating system from a mass memory device. The BIOS is special software that interfaces the major hardware components of the computer with the operating system. It is usually stored on a Flash memory chip on the motherboard, but sometimes the chip is another type of ROM. The BIOS is a firmware (software instructions permanently recorded on a chip located on your motherboard).

Functions of BIOS

The BIOS software has a number of different roles, but its most important role is to load the operating system. The BIOS checks and initializes the PC hardware each time the system powers up or restarts before handing over control to the operating system. Some of the other common tasks that the BIOS performs include:

- A power-on self-test (POST) for all of the different hardware components in the system to make sure everything is working properly
- Activating other BIOS chips on different cards installed in the computer - For example the graphics cards often have their own BIOS chips.
- Providing a set of low-level routines that the operating system uses to interface to different hardware devices. They manage things like the keyboard, the screen, and the ports, especially when the computer is booting.
- Managing a collection of settings for the hard disks, clock, etc.

CMOS Setup

The first thing the BIOS will do is check the information stored in a tiny (64 bytes) amount of RAM located on a complementary metal oxide semiconductor (CMOS) chip. The CMOS Setup provides detailed information particular to your system and can be altered as your system changes. The BIOS uses this information to modify or supplement its default programming as needed.

Configuring BIOS

The BIOS checks the CMOS Setup for custom settings. To change the CMOS settings we need to enter the CMOS setup. To enter the CMOS Setup, a certain key or combination of keys must be pressed during the initial startup sequence. Most systems use "Esc," "Del," "F1," "F2," "Ctrl-Esc" or "Ctrl-Alt-Esc" to enter setup. There is usually a line of text at the bottom of the display that tells "Press ___ to Enter Setup."

The BIOS setup shows a set of text screens with a number of options. Some of these are standard, while others vary according to the BIOS manufacturer. Common options include:

- System Time/Date - Set the system time and date
- Boot Sequence - The order that BIOS will try to load the operating system
- Plug and Play - A standard for auto-detecting connected devices; should be set to "Yes" if your computer and operating system both support it
- Mouse/Keyboard - "Enable Num Lock," "Enable the Keyboard," "Auto-Detect Mouse"...

- Drive Configuration - Configure hard drives, CD-ROM and floppy drives
- Memory - Direct the BIOS to shadow to a specific memory address
- Security - Set a password for accessing the computer
- Power Management - Select whether to use power management, as well as set the amount of time for "standby" and "suspend"
- Exit - Save your changes, discard your changes or restore default settings

The BIOS uses CMOS technology to save any changes made to the computer's settings. With this technology, a small lithium or Ni-Cad battery can supply enough power to keep the data for years. Major BIOS manufacturers include American Megatrends Inc. (AMI), Phoenix Technologies, Winbond etc.

Installing the Windows operating System

A hard disk needs to be partitioned (though not mandatory) and formatted before you can store data on it.

Partitioning

A partition, sometimes also called a volume, is an area on a hard disk that can be formatted with a file system and identified with a letter of the alphabet. For example, drive C on most Windows computers is a partition. the first three partitions you create are primary partitions. These can be used to start an operating system. If you want to create more than three partitions, the fourth partition is created as an extended partition.

An extended partition is a container that can hold one or more logical drives. Logical drives function like primary partitions except that they cannot be used to start an operating system.

Many computers are partitioned as a single partition that equals the size of the hard disk. Partitioning a hard disk into several smaller partitions is not required, but it can be useful for organizing data on your hard disk.

Creating more than one partition has the following advantages:

- Separation of the operating system (OS) and program files from user files.
- Having a separate area for operating system virtual memory swapping/paging.
- Keeping frequently used programs and data near each other.
- Use of multi-boot setups, which allow users to have more than one operating system on a single computer. For example, one could install Linux and Microsoft Windows or other operating systems on different partitions of the same HDD and have a choice of booting into any operating system at power-up.
- Protecting or isolating files, to make it easier to recover a corrupted file system or operating system installation. If one partition is corrupted, other file systems may not be affected.
- Raising overall computer performance on systems where smaller file systems are more efficient.
- Partitioning for significantly less than the full size available can reduce the time for diagnostic tools such as checkdisk to run.

Formatting

Disk formatting is the process of preparing a data storage device such as a hard disk drive, solid-state drive or USB flash drive for initial use. It is the act of creating a file system on a volume, so that the operating system can store and retrieve data on that volume.

Formatting a disk is of two categories:

1 Low-level formatting (i.e., closest to the hardware) marks the surfaces of the disks with markers indicating the start of a recording block. It also provides information about block checks done for future use by the disk controller to read or write data. This is intended to be the permanent foundation of the disk, and is often completed at the factory. A hard disk needs to be partitioned and formatted before you can store data on it

2 High-level formatting creates the file system format within a disk partition or a logical volume. This formatting includes the data structures used by the OS to identify the logical drive or partition's contents. This may occur during operating system installation, or when adding a new disk.

Installing the Windows operating System

The three basic types of windows installation procedures are as follows:

- Install on a brand new diskorcomputesystem
- Erase the disk, format it, and install.
- Install into a new directory for dual-booting

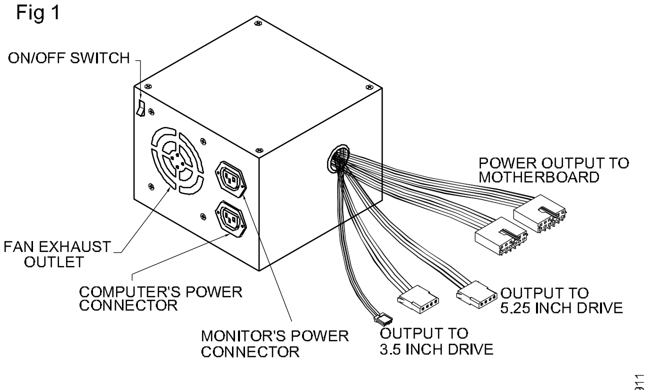
For the first two methods, it must be ensured that the computer can boot from a DVD or any other removable drive. To do this the drive boot order needs to be changed in the BIOS. The latest Windows DVDs are bootable and run the Setup program automatically. Then the installation can be done by following the procedure step by step as indicated on the subsequent screens

Switch Mode Power Supply for PC

Objectives: At the end of this lesson you shall be able to
- **explain the parts of SMPS**
- **explain with block diagram and working principle of an SMPS**
- **explain the working of TL494 PWM IC**
- **explain the precautions to be taken while testing and troubleshooting of different SMPS.**

Switch Mode Power Supply of a PC is housed in a metal box. SMPS 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 connected to the power cable from the SMPS. The connectors are polarised and standards are followed so that any PC SMPS can be interchanged. A typical SMPS is shown in Fig 1.

Fig 1



COMMON COMPUTER SMPS

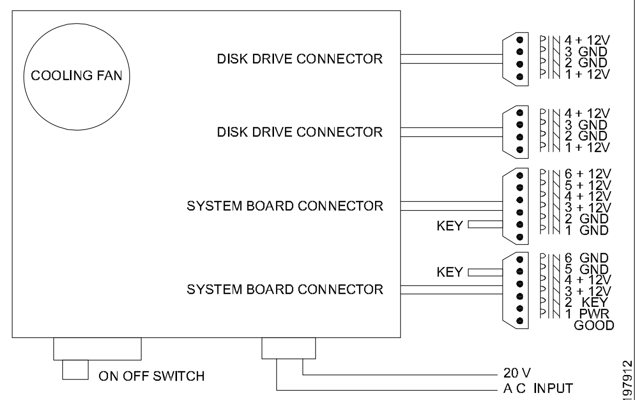
The SMPS comes in various capacities for PCs. The capacities are 80W, 150W, 200W, 230W, 250W and 280W. For PC nodes/ unix terminals 80W supply is used. The connector details are printed on the cover of the SMPS as shown in Fig 2. Table 1 gives the colour of wire for different voltages and the current ratings.

Table 1

DC outputs				
Red	+5V	20A max	Total power	200W
Yellow	+12V	8A max	AC Input	220-240V
White	-5V	0.5A max		
Orange	PG			

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.

Fig 2

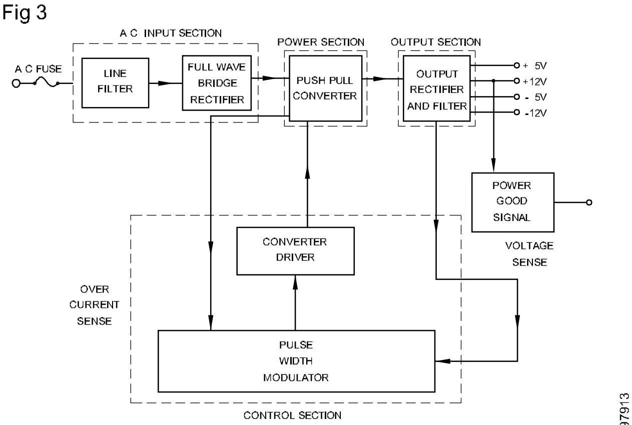


INTERFACE CONNECTION

Block diagram of SMPS

The block diagram in Fig 3 shows the various functional sections in SMPS.

Fig 3



BLOCK DIAGRAM OF SMPS

The AC input section consists of a line filter and current limiting resistors/thermistors. Line filter is a protective circuit. Any variations in main supply is suppressed by the filter area. Line filter circuit consists of inductor and high voltage capacitors. A MOV (Metal Oxide Varistors) is connected across the AC supply to prevent any over voltages.

AC input is converted to DC voltage by a bridge rectifier and filter capacitors. Around 300 volt DC is developed across the capacitors. The power section consists of high frequency ferrite core transformer and switching power transistors to switch DC voltage across the transformer winding. A current sense circuit is provided to sense overload current and to protect the SMPS from over loading.

The output section consists of output rectifiers and filter circuits. A voltage sense circuit is used for feedback to the control section. The 5 volt is sensed for regulating the pulse width of the controller. The diodes used for rectification are schottky diodes. Since the AC outputs of the transformer are at 20kHz, normal silicon diodes cannot be used. Special fast recovery diodes are used. Example of schottky diode are BA157. The filter circuit consists of an inductor and capacitor.

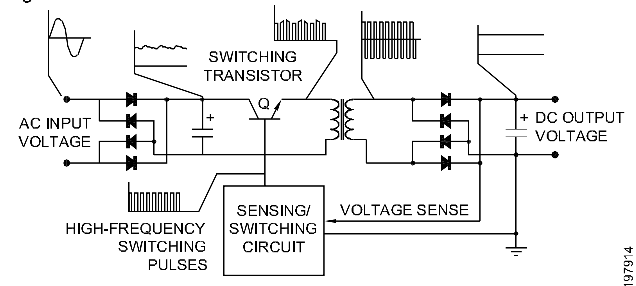
Power good signal section checks for the correct level of DC voltages and gives a power good signal to the motherboard. Power good signal is connected to the reset pin of the processor. Power good signal is given to reset pin after a delay when the voltage levels are correct and satisfactory.

The controller section consists of a pulsewidth modulator circuit. The output voltage of 5V is sensed and compared with a reference voltage. Any change in 5V with respect to load creates an error voltage. This error voltage modifies the pulse width of output pulses. The output pulses in turn drives the power switching transistor. The output pulses are not directly connected to the power switching transistors. Isolation is provided by a driver transformer. Over current is sensed through a current transformer. The output of current transformer is rectified and used to shutdown the power controller when an excess current is drawn.

Working principle of SMPS

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 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 4.

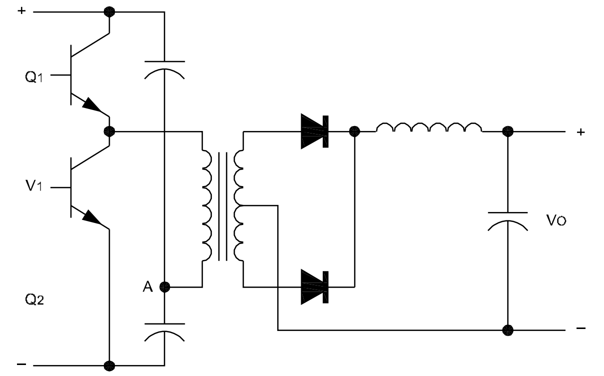
Fig 4



SIMPLIFIED DIAGRAM OF A SWITCHING POWER SUPPLY

Most widely used configuration in PC SMPS is half bridge converter circuit as shown in Fig 5. Power transistors Q1 and Q2 switch the DC voltage through the windings in a push pull manner.

Fig 5

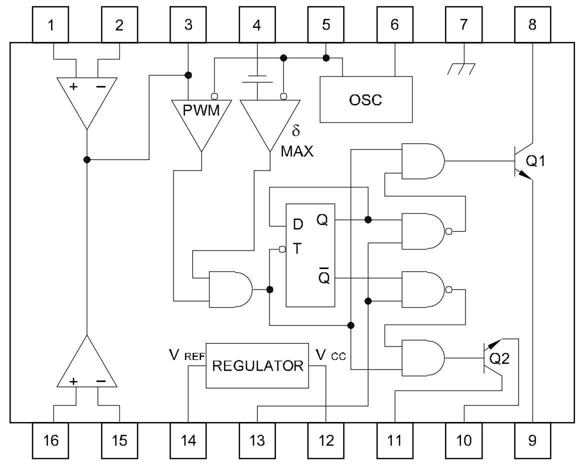


MOST WIDELY USED HALF-BRIDGE CONVERTER CIRCUIT

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.

Pulse width modulation control IC 494

Fig 6



PIN NO.	FUNCTION
1.	ERROR AMP. 1, NONINVERTING INPUT
2.	ERROR AMP. 1, INVERTING INPUT
3.	COMPENSATION INPUT
4.	DEAD TIME CONTROL INPUT
5.	OSCILLATOR TIMING CAPACITOR
6.	OSCILLATOR TIMING RESISTOR
7.	GROUND
8.	DRIVE TRANSISTOR 1, COLLECTOR
9.	DRIVE TRANSISTOR 1, EMITTER
10.	DRIVE TRANSISTOR 2, EMITTER
11.	DRIVE TRANSISTOR 2, COLLECTOR
12.	INPUT SUPPLY
13.	OUTPUT MODE CONTROL
14.	STABILIZED REFERENCE VOLTAGE
15.	ERROR AMP2, INVERTING INPUT
16.	ERROR AMP2, NONINVERTING INPUT

EMN197916

TL494 BLOCK DIAGRAM AND PIN ASSIGNMENTS

Most widely used PWM IC in a PC SMPS is TL 494. Fig 6 show 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.

Good power

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.

Power ON and OFF

On ATX and most of the other later from 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.

Advantages and disadvantages of SMPS

SMPS for the power rating is smaller in size. A conventional power supply for similar power rating will be heavy and big in size.

SMPS efficiency is very high so heat dissipation is low. A conventional power supply efficiency is less and heat generated is more.

SMPS output has high frequency noise. So cannot be used for critical applications. In conventional power supply the noise is very minimal

Servicing of SMPS is difficult because of interdependance of circuits and components.

Servicing of linear power supply is relatively straight forward.

Difference between AT and 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.

Precaution to be taken while testing and servicing an SMPS

Since the SMPS is operating directly from rectified 220V AC, potentially hazardous DC voltage exist inside. So care should be taken while opening and testing.

High voltage capacitors must be discharged safely using a resistor.

When using any AC powered instrument to test an SMPS the instrument must be isolated. To isolate use isolation transformer.

Some SMPS start with sufficient load only.

Hard disk drives

Objectives: At the end of this lesson you shall be able to
- **explain the basic components of a hard disk**
- **explain boot process**
- **explain Windows OS desk top shortcuts and various options.**

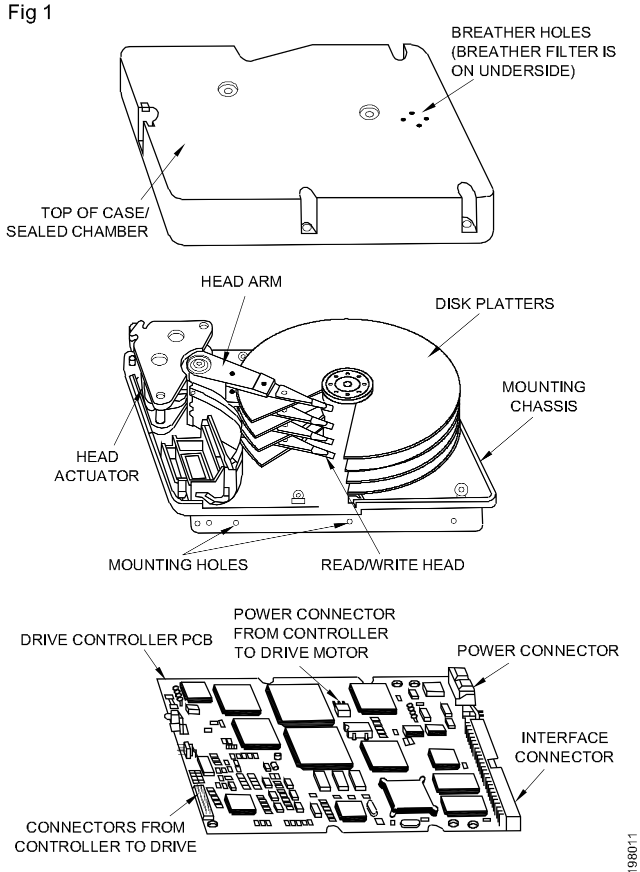
INTRODUCTION

Magnetic disks are the most common form of permanent data storage. Their capacities may range from a few kilobytes to several Gigabytes. An aspect common to all magnetic drives is the scheme that determines how the data on the disk is organised. The operating system determines this scheme before any information can be stored on a magnetic disk, provided the disk is formatted. Formatting allows the drive to store and retrieve data in an orderly manner.

The basic parts of Hard disk

The basic hard disk drive components are as shown in the Fig 1.

Fig 1



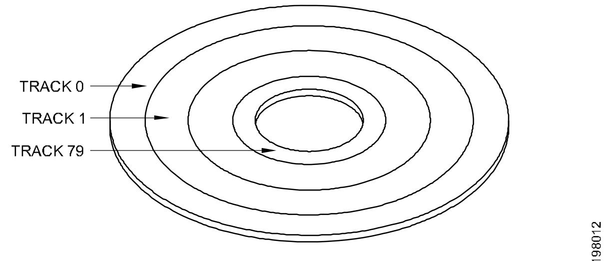
HARD DISK DRIVE COMPONENTS

Disk platters, Logic board, Read/write head, Head - actuate mechanism, connectors, Spindle motor, spindle, platter motor, heads and Actuator are assembled inside a sealed chamber. Drive electronics (PCB) is located outside the chamber.

Hard Disk has one or more platters. Platter is made of aluminium or glass, coated with magnetic media to store information. A read/write head is placed on a spring loaded arm. The arm is moved along the radius by actuator mechanism. Motor that spins the platter is called spindle motor. It rotates at 3600 to 7200 rpm. Logic board controls the drive motor and head actuator mechanism. Data is transferred to and from the platter in a standard format. Hard disk has a FRC connector for data cable and molex connector for power. Power supply requirements are +12V 1 amp, +5V, 500 mA

Hard disk platter is divided into tracks of a particular width as shown in Fig 2. Each track is dived into sectors. Outermost track is numbered '0 '. Similar numbered track on each platter is combined to form a cylinder. Capacity of the hard disk is determined by number of cylinders, number of heads, sectors and data storage mode.

Fig 2



TRACKS ON A PLATTER

Boot process

Computer initialisation is a process from the time a PC is switched on until the PC displays A>:\C:> or windows Desk top, is called boot process. Number of steps are involved in this process.

When power is applied, the power good signal (PG) resets the CPU into its process. Program starts by fetching an instruction from ROM BIOS. The BIOS programme as explained earlier does the POST and looks for the operating system from drive A. If booting programme is not found in drive A, automatically it looks for a boot program in C:. In BIOS setup one can alter the sequence C to A or A to C.

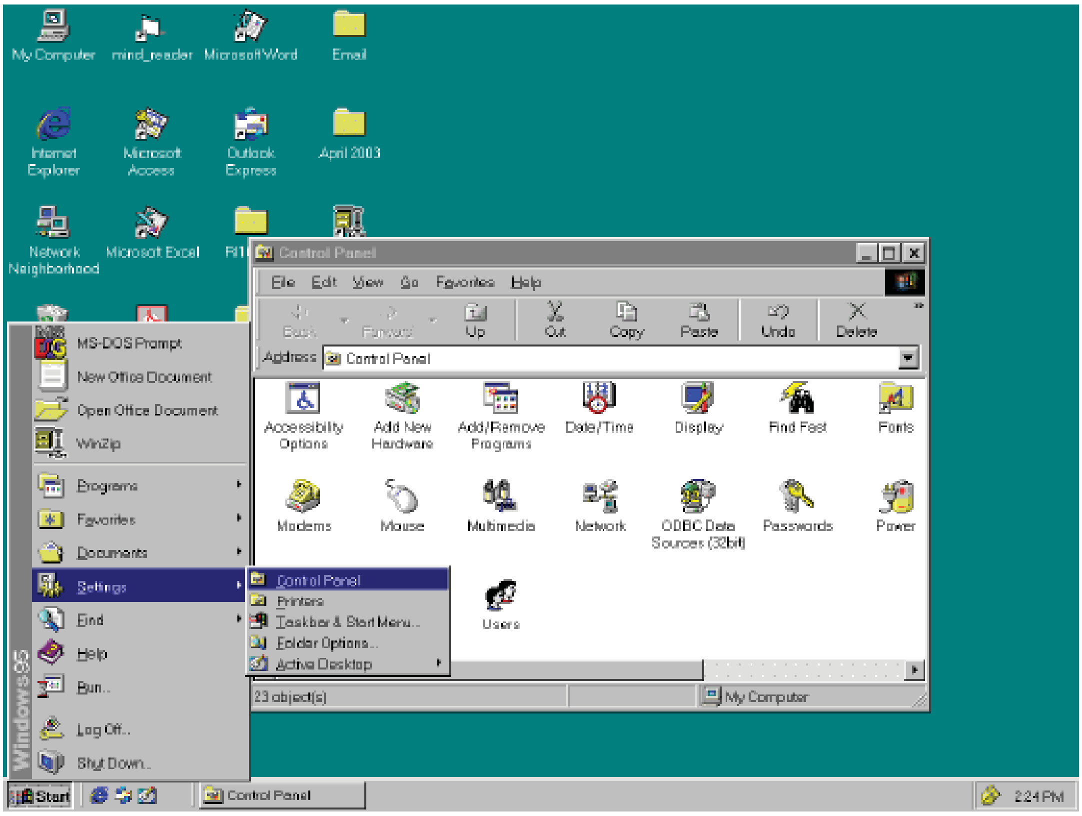
Once operating system is found, the boots trap loader programme loads the operating system components into the memory and hands over the control to the operating system. When the process is complete, the monitor displays A>:/,C:> or windows desktop.

Handling hard disk

Hard disk should not be dropped. It will permanently damage the platter. Hard disk electronics should not be handled with bare hands as it is more sensitive to static charges. Hard disk interface cable and power supply should be connected/removed only after switching off mains power. No magnetic material should be placed near HDD.

Control Panel: It is presented as a folder full of icons. To view Control panel, click the Start button, point the settings and then click Control panel (Fig 3) shows the contents of Control panel.

Fig 3



Accessibility options: Change your computer screen, mouse, keyboard, features, and sound to make windows more accessible for people with disablities.

Add / Remove programs: Install and remove software automatically, and add or remove installed components in windows NT.

Console: Change the appearance of your MS-DOS screen by changing screen colors, screen size and position, fonts, cursor size and more.

Date / Time: Change the system date, time, and time zone.

Devices: Start, stop and configure the start up type for device drivers.

Display: Change the appearance of your screen by changing screen, colors, fonts, the appearance and size of windows, background design, icons and other visuals.

Fonts: Add or remove screen, vector, True type, and Type1 fonts, some printer fonts are installed automatically when you install a printer. Other printer fonts must be installed using a font installation program provided by the font manufacturer.

Keyboard: Adjust the keyboard delay and repeat rate, and add keyboard symbols that are exclusive to other languages.

Modems: Add modems using the Add modem wizard, a step-by-step modem set up program.

Multimedia: Adjust audio, video, CD (music), and MIDI, and add or remove multimedia devices.

Network: Configure network adapter cards, network services and protocols, and join a workgroup or a domain.

PC Card (PCMCIA): Display resources used by any PC cards, if you have these devices.

Ports: Set parameters for, and add and remove serial communications ports.

Printers: Add and remove printers and remove, control and create share access to printers using the Add printer wizard, a step-by-step printer set up program.

Regional Settings: Change sort dates, time currency and numbers to reflect regional standards.

SCSI Adapters: Display adapters and devices connected to your computer.

Server: Display user and share information.

Services: Start, Stop, Pause, or continue the services available on the computer, and configure start up options.

Sounds: Assign sounds to system and application events, and turn on or off the warning beep and system sounds.

System: Specify the default operating system for startup, change user environment variables and define paging file size.

Tape Devices: Display, add and remove tape devices.

Telephony: Display, add, and remove telephony drivers change telephony properties. Adjust telephony conditions depending on whether the computer is docked or undocked.

UPS: Create settings for uninterrupted power supply.

The control panel is thus the place where most of the system working can be controlled. The following are the various settings that can be done:

Date and Time properties: The date and time properties dialog is used to change the systems date and time which is shown in the system tray at the right end corner of the task bar.

Changing the date.

– Day

– Month

– Year

Changing the time

– Hour

– Time

– Seconds

The spinner button  is used to change the meridians , i.e. AM. and PM.

There is one more tab in the Date & Time properties i.e. Time Zone that is used to set the local time in tune with the Greenwich Meridian Time (GMT) as shown in Fig 5.

Click on the down arrows button in the box indicated in above figure and change it to Colombo GMT+6:00. Watch how the World map shifts itself towards left.

Also observe time now in the system tray. It will be changed now.

Changing the Wall Paper and screen savers: Wallpapers are the screen patterns that can be set as the background of the desktop. There are built in wallpapers available that can be selected in the Background tab of the Display property dialog.

A HTML document (called the Hyper Text Markup Language used as Web pages) or a picture (called Windows Bitmap pictures i.e. BMP created using Paint Brush application) are the two types of images that can be set as background image.

1 To set the Windows picture created by the user himself using Paintbrush click on the Browse button.

2 Select the file created in the open dialog.

3 Observe the preview in the screen within the dialog (as shown)

4 Then click on the apply button and observe the desktop background now.

There is one more display option called the Display type.

It is used to display the wallpapers in 2 different styles

1 Centered in which the picture is centered in the desktop

2 Tile in which the same copy of the picture is shown as a number of tiles scattered on the desktop.

Screen Saver Settings : Screen saver is a program that gets invoked when the system is idle .i.e. not pressing any key and moving the mouse.

There are a lot of programs that can be selected for the display during the system's idle state. Each program is having its own type of settings by which its behavior can be controlled. This is invoked by clicking on the Settings buttons.

The Wait minute box represents how much of time the system can wait until the screen saver can be invoked.

The screen program that is used to display any message in the form of text is the 3D text.

– Click on Ok button to effect the settings. This will return to the previous tab.

– Clicks on Preview button to see the screen saver running (do not move the mouse or press any key). Once you move the mouse or hit any key the screen saver automatically stops.

Appearance of Window : The look and feel of windows can be changed using the Appearance Tab of the Display property dialog. This tab can be used to change the whole appearance of windows like the color, size of icons, fonts that are used in the menus and title bars etc. each type of these appearance is presented as a set of schemes.

Click in the Scheme list box and select the Windows standard as the type of the appearance for the windows.

– Watch how immediately the window in the top box appears.

– Clicking on the respective items individually can change the appearance of each individual item. For instance clicking on the active window in the box can change the appearance of the active.

The Save as button is used to save your own scheme of colors, fonts, size etc under a different name. Delete button is used to remove the schemes.

Regional Settings: The Regional settings properties sheet controls a variety of features that can be used by your programs to adjust the way they behave. Double clicking on the Regional Settings icon allows you to examine these regional settings.

If you are going to change this setting, we suggest changing the region first. The map changes to highlight the region of the world that you have selected, and the choices available on the other four pages are changed to ones appropriate to that region.

The Number card includes settings for what should be used for the Decimal Symbol, the No. of digits after decimal, the symbol that should be used to group digits (in the U.S. this is referred to as the “thousands separator”), and the Number of digits in group.

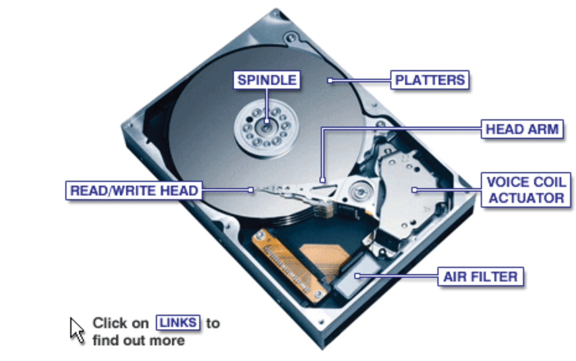
The Currency pages allows you to set some characteristics specific to currency such as the Currency symbol, the Position of currency symbol, the Negative number format, as well as the features just mentioned for use in the Number pages.

The formats for time and date information allow you to select from a drop-down list of features. The choices for time include the Time style; the Time separator between hours, minutes, and seconds; and the choice for AM symbols and for PM symbols.

Hard drives

A Hard drive is a data storage device used for storing and retrieving digital information using one or more rigid "hard" rapidly rotating disks (platters) coated with magnetic material. The platters are paired with magnetic heads arranged on a moving actuator arm, which read and write data to the platter surfaces. Data is accessed in a random-access manner, meaning that individual blocks of data can be stored or retrieved in any order rather than sequentially.A typical hard disk drive consists of a motor, spindle, platters, read/write heads, actuator and electronics as shown in Fig 4.

Fig 4



The primary characteristics of an HDD are its capacity and performance. Capacity is specified in powers of 1000: a 1-terabyte (TB) drive has a capacity of 1,000 gigabytes (GB; where 1 gigabyte = 1 billion bytes). Performance is specified by the time required to move the heads to a track or cylinder (average access time) plus the time it takes for the desired sector to move under the head (average latency, which is a function of the physical rotational speed in revolutions per minute), and finally the speed at which the data is transmitted (data rate).

A HDD records data by magnetizing a thin film of ferromagnetic material on a disk. Sequential changes in the direction of magnetization represent binary data bits. The data is read from the disk by detecting the transitions in magnetization. User data is encoded using an encoding scheme, such as run-length limited encoding, which determines how the data is represented by the magnetic transitions.

Illustration of Read/Write Heads:

The data is of course written and read by the heads.

1 Electrical connections to platter motor.

2 Microprocessor chip.

3 Programmable flash memory chip.

4 Platter motor controller chip.

5 S-ATA data connector (the connection between the hard drive and the motherboard).

6 S-ATA power connector (provides the drive with DC power).

Drives

A drive is a medium that is capable of storing and reading information that is not easily removed like a disk.

C: is the hard disk drive, D: and E: partitions of the hard drive, and F: is the CD-ROM drive. Typically the CD-ROM drive is the last drive. In most situations the hard drive is the C: drive and a CD-ROM or other disc drive is the D: drive. Every hard drive in use has at least one partition.

The hard disk drive is the most important part of a computer system. A hard disk drive is a sealed unit that a PC uses for non-volatile data storage.

Non-volatile, or semi permanent, storage means that the storage device retains the data even when no power is supplied to the computer. Because the hard disk drive is expected to retain data until deliberately erased or overwritten, the hard drive is used to store crucial programming and data. As a result, when the hard disk fails, the consequences are usually very serious.

A hard disk drive contains rigid, disk-shaped platters, unlike floppy disks, the platters can't bend or flex hence the term hard disk. In most hard disk drives, you can't remove the platters, which is why they are sometimes called fixed disk drives. Removable hard disk drives are also available. Usually, this term refers to a device in which the entire drive unit is removable.

Hard Disk Drive Operation

The basic physical construction of a hard disk drive consists of spinning disks with heads that move over the disks and store data in tracks and sectors. The heads read and write data in concentric rings called tracks, which are divided into segments called sectors, which typically store 512 bytes each.

Hard disk drives usually have multiple disks, called platters, that are stacked on top of each other and spin in unison, each with two sides on which the drive stores data. Most drives have two or three platters, resulting in four or six sides, but some PC hard disks have up to 12 platters and 24 sides with 24 heads to read them (Seagate Barracuda 180). The identically aligned tracks on each side of every platter together make up a cylinder. A hard disk drive usually has one head per platter side, with all the heads mounted on a common carrier device or rack. The heads move radially across the disk in unison, they can't move independently because they are mounted on the same carrier or rack, called an actuator.

Originally, most hard disks spin at 3,600rpm approximately, now; however, most drives spin even faster. Although speeds can vary, modern drives typically spin the platters at either 4,200rpm; 5,400rpm; 7,200rpm; 10,000rpm; or 15,000rpm.

IDE Interface

The interface used to connect hard disk and optical drives to a PC is typically called IDE (Integrated Drive Electronics). Although ATA (Advance Technology Attachment) is the official name of the interface, IDE is a marketing term originated by some of the drive manufacturers to describe the drive/controller combination used in drives with the ATA interface.

ATA was originally a 16-bit parallel interface, meaning that 16 bits are transmitted simultaneously down the interface cable. A newer interface, called Serial ATA, was officially introduced in late 2000 and was adopted in desktop systems starting in 2003 and in laptops starting in late 2005. Serial ATA (SATA) sends 1 bit down the cable at a time, enabling thinner and smaller cables to be used, as well as providing higher performance due to the higher cycling speeds it enables. SATA is a completely new and updated physical interface design, while remaining compatible on the software level with Parallel ATA. Throughout this book, ATA refers to either just the parallel or both the parallel and serial versions, whereas Parallel ATA (PATA) refers specifically to the parallel version and Serial ATA (SATA) refers specifically to the serial version.

Parallel ATA (IDE)

Parallel ATA has unique specifications and requirements regarding the physical interface, cabling, and connectors as compared to Serial ATA. The following sections detail the unique features of parallel ATA.

Parallel ATA I/O Connector

The parallel ATA(IDE) interface connector is normally a 40-pin header-type connector with pins spaced 0.1" (2.54mm) apart, and generally it is keyed to prevent the possibility of installing it upside down. To create a keyed connector, the manufacturer usually removes pin 20 from the male connector and blocks pin 20 on the female cable connector, which prevents the user from installing the cable backward. Some cables also incorporate a protrusion on the top of the female cable connector that fits into a notch in the shroud surrounding the mating male connector on the device. The use of keyed connectors and cables is highly recommended. Plugging an ATA cable in backward normally doesn't cause any permanent damage; however, it can lock up the system and prevent it from running.

Parallel ATA PIO Transfer Modes

ATA-2 and ATA-3 defined the first of several higher-performance modes for transferring data over the parallel ATA interface, to and from the drive. These faster modes were the main part of the newer specifications and were the main reason they were initially developed. The following section discusses these modes.

The PIO (programmed I/O) mode determines how fast data is transferred to and from the drive using PIO transfers. In the slowest possible mode PIO Mode 0the data cycle time can't exceed 600 nanoseconds (ns). In a single cycle, 16 bits are transferred into or out of the drive, making the theoretical transfer rate of PIO Mode 0 (600ns cycle time) 3.3MBps, whereas PIO Mode 4 (120ns cycle time) achieves a 16.6MBps transfer rate.

Parallel ATA DMA Transfer Modes

ATA drives also support direct memory access (DMA) transfers. DMA means that the data is transferred directly between drive and memory without using the CPU as an intermediary, as opposed to PIO. This has the effect of offloading much of the work of transferring data from the processor, in effect allowing the processor to do other things while the transfer is taking place.

There are two distinct types of direct memory access: singleword (8-bit) and multiword (16-bit) DMA. Singleword DMA modes were removed from the ATA-3 and later specifications and are obsolete. DMA modes are also sometimes called bus master ATA modes because they use a host adapter that supports bus-mastering. Ordinary DMA relies on the legacy DMA controller on the motherboard to perform the complex task of arbitration, grabbing the system bus and transferring the data. In the case of bus mastering DMA, all this is done by a higher-speed logic chip in the host adapter interface (which is also on the motherboard).

PATA is a common interface used in many personal computers before the emergence of SATA. It is the least expensive of the interfaces.

Advantages

- Low costs
- Large capacity

Disadvantages

- Older ATA adapters will limit transfer rates according to the slower attached device (debatable)
- Only ONE device on the ATA cable is able to read/ write at one time
- Limited standard for cable length (up to 18inches/ 46cm)

Serial ATA (SATA)

SATA is basically an advancement of PATA.With the development of ATA-8, it seems that the parallel ATA standard that has been in use for more than 10 years has finally reached the end of the line. Sending data at rates faster than 133MBps down a parallel ribbon cable is fraught with all kinds of problems because of signal timing, electromagnetic interference (EMI), and other integrity problems. The solution is called Serial ATA, which is an evolutionary replacement for the venerable parallel ATA (PATA) physical storage interface. Serial ATA is software-compatible with parallel ATA, which means it fully emulates all the commands, registers, and controls so existing software will run on the new architecture without any changes. In other words, the existing BIOSs, operating systems, and utilities that work on parallel ATA also work on Serial ATA.

Of course, they do differ physically that is, it can't plug parallel ATA drives into Serial ATA host adapters and vice versa, although signal converters make that possible. The physical changes are all for the better because Serial ATA uses much smaller and thinner cables with only seven conductors that are easier to route inside the PC and easier to plug in with smaller, redesigned cable connectors. The interface chip designs also are improved with far fewer pins and lower voltages. These improvements are all designed to eliminate the design problems inherent in parallel ATA.

Serial ATA Transfer Modes

Serial ATA transfers data in a completely different manner from parallel ATA. As indicated previously, the transfer rates are 1.5Gbps (150MBps), 3.0GBps (300MBps), and 6.0GBps (600MBps), with most drives today supporting either the 1.5GBps or 3.0GBps rate. Note that speeds are backward-compatible for example, all drives supporting the 3.0GBps rate also work at 1.5GBps. Note that because SATA is designed to be backward-compatible with parallel ATA, some confusion can result because SATA drives can report speeds and modes that emulate parallel ATA settings for backward compatibility. This means the drive is merely lying for backward compatibility with existing software.

Parallel and Serial ATA are completely different electrical and physical specifications, but Serial ATA does emulate parallel ATA in a way that makes it completely software transparent.

Advantages

- Low costs.
- Large capacity.
- Faster transfer rates compared to ATA (difference is marginal at times though).
- Smaller cables for better heat dissipation.

Disadvantages

- Slower transfer rates compared to SCSI.
- Not supported in older systems without the use of additional components.

SCSI Disk Drives

Small Computer System Interface (SCSI) disk drives used to be among the fastest drives available, although newer computers may no longer provide SCSI ports. Although no longer highly popular, SCSI technology has been implemented in various ways over the years, with each successive generation achieving better performance. SCSI is commonly used in servers, and more in industrial applications than home uses.

Advantages

- Faster
- Wide range of applications
- Better scalability and flexibility in Arrays (RAID)
- Backward compatible with older SCSI devices
- Better for storing and moving large amounts of data
- Tailor made for 24/7 operations
- Reliability

Disadvantages

- Costs
- Not widely supported
- Many, many different kinds of SCSI interfaces
- SCSI drives have a higher RPM, creating more noise and heat

SAS(Serial Attached SCSI Drive)

SAS is a point-to-point serial protocol that moves data to and from computer storage devices such as hard drives and tape drives.

SAS replaces the older Parallel SCSI (Small Computer System Interface, pronounced "scuzzy") bus technology that first appeared in the mid-1980s. SAS, like its predecessor, uses the standard SCSI command set. SAS offers backward compatibility with SATA, versions 2 and later. This allows for SATA drives to be connected to SAS backplanes. The reverse, connecting SAS drives to SATA backplanes, is not possible.

SAS Drives generally offers 805 MB/sec transfer rate. SAS Cables are used to connect SAS Drives. Maximum of 128 drives can be connected in a single SAS cable.

Solid State Drives (SSD)

These hard disksdoes not consist of moving components. SSDs use semiconductors for data storage. Since there are no moving components, these hard disks are much faster and less likely to break down than other drives. However, their price is a bit more than other hard disks. These type of hard drive are generally incorporated in desktop computers and laptops

Internal - Replacing the hard drive is one of the easiest upgrades inside the computer.

An internal hard drive is your cheapest and most popular option, when replacing the existing harddrive in the computer

External - With an external hard drive, you can leave your computer's case intact and just plug your new drive into an available USB, Fire wire, or Thunderbolt port on the front or back of the computer.

Different types of printers

Objectives : At the end of this lesson you shall be able to
- **state different types of print technologies and printers**
- **explain the impact printers/dot matrix printers**
- **state non-impact printers, inkjet printers & laserjet printers.**

Printers are electro-mechanical devices that enable a user to print whatever is displayed by the monitor - letters, contracts, business documents, images.

Print Technologies

A printer outputs data that is seen on the computer screen on to a paper. Most printers are used through a parallel port, but some newer ones use USB connections. The most crucial printer measurement is dots per inch rating. Printers are best chosen by actually seeing the quality of the printer output. There are many types of print technologies like Daisy wheel, Laser, Inkjet etc. Printers are normally categorized into impact and non-impact types.

Printers can be divided into two categories (Fig 1)

- **Impact**
- **Non-Impact**

Impact: The impact printers incorporate a built-in mechanism to print images on paper using a series of pins or hammers which strike on an inked ribbon to create the image. For Example: Dot matrix, Daisy Wheel, etc.

Non-Impact: The non-impact printers include those printers that do not have any kind of contact with the paper while printing either text or image. For Example: Inkjet, Laser, Bubble Jet, etc.

These printers use different technology to print an image. For Example, a laser printer uses heat to attach microscopic particles of dry toner to specific parts of the page. An Inkjet printer has tiny nozzles through which it sprays droplets of ink on to the page.

Impact Printers: In this hammers or pins strike against a ribbon and paper to print the text. This mechanism is known as electro-mechanical mechanism. They are of two types.

1 Character Printer

2 Line Printer

Character Printer: It prints only one character at a time. It has relatively slower speed. Eg. Dot Matrix Printers

Dot Matrix Printer: It prints characters as combination of dots. Dot matrix printers are the most popular among serial printers. These have a matrix of pins on the print head of the printer which form the character. The computer memory sends one character at a time to be printed by the printer. There is a carbon between the pins & the paper. The words get printed on the paper when the pin strikes the carbon. There are generally 24 pins.

Non-Impact Printers: These printers use non-Impact technology such as ink-jet or laser technology. These printers provide better quality of O/P at higher speed. These printers are of two types :

Ink-Jet Printer: It prints characters by spraying patterns of ink on the paper from a nozzle or jet. It prints from nozzles having very fine holes, from which a specially made ink is pumped out to create various letters and shapes. The ink comes out of the nozzle in a form of vapors. After passing through a reflecting plate, it forms the desired letter/shape at the desired place.

Laser Printer is a type of printer that utilizes a laser beam to produce an image on a drum. The light of the laser alters the electrical charge on the drum wherever it hits. The drum is then rolled through a reservoir of toner, which is picked up by the charged portions of the drum. Finally, the toner is transferred to the paper through a combination of heat and pressure.

This is also the way copy machines work. Because an entire page is transmitted to a drum before the toner is applied, laser printers are sometimes called page printers. There are two other types of page printers that fall under the category of laser printers even though they do not use lasers at all. One uses an array of LEDs to expose the drum and the other uses LCDs. Once the drum is charged, however, they both operate like a real laser printer. One of the chief characteristics of laser printers is their resolution - how many dots per inch (dpi) they lay down.

The available resolutions range from 300 dpi at the low end to 1,200 dpi at the high end. In addition to text, laser printers are very adopt at printing graphics, so you need significant amounts of memory in the printer to print high-resolution graphics. To print a full-page graphic at 300 dpi, for example, you need at least 1 MB (megabyte) of printer RAM. For a 600 dpi graphic, you need at least 4 MB RAM.

Because laser printers are non-impact printers, they are much quieter than dot-matrix or daisy-wheel printers. They are also relatively fast, although not as fast as some dot-matrix or daisy-wheel printers. The speed of laser printers ranges from about 4 to 20 pages of text per minute (ppm). A typical rate of 6ppm is equivalent to about 40 characters per second (cps).

Computer Viruses and protection

Objectives : At the end of this lesson you shall be able to
- **describe the computer virus**
- **explain how viruses spread in computer**
- **protect the computer from viruses**
- **explain the Anti-Virus software.**

What is a Virus?

A computer virus is one of thousands of programs that can invade computer systems (both IBM PC and Macintosh) and perform a variety of functions ranging from annoying (e.g., popping up messages as a joke) to dangerous (e.g., deleting files or destroying your hard disk). Trojan horses or worms are specific types of clandestine programs (loosely categorized as viruses) and can be just as dangerous. For simplicity's sake, future mention of viruses in this document will refer to viruses, Trojan horses, and worms taken as a whole.

How Do Viruses Spread?

Computer viruses are programs that must be triggered or somehow executed before they can infect your computer system and spread to others. Examples include opening a document infected with a "macro virus," booting with a diskette infected with a "boot sector" virus, or double-clicking on an infected program file. Viruses can then be spread by sharing infected files on a diskette, network drive, or other media, by exchanging infected files over the Internet via e-mail attachments, or by downloading questionable files from the Internet.

How Can Protect computer

With dangerous viruses on the network, what can computer users do to protect their systems? Here are just a few hints:

- Be sure to install an anti-virus software program to guard against virus attacks. Also, be sure you turn on the scanning features. It can't protect if it's not enabled.
- Practice caution when working with files from unknown or questionable sources.
- Do not open e-mail attachments if do not recognize the sender. Scan the attachments with anti-virus software before opening them.
- Download files only from reputable Internet sites, and be wary when exchanging diskettes or other media with friends.
- Scan the hard drive for viruses monthly. Even with these precautions, new viruses may find ways to enter the computer system.

Getting Anti-virus Software

Anti-virus software are programs that are installed onto your computer and can scan and remove known viruses which you may have contracted. The software can also be set to automatically scan diskettes when inserted into the disk drive, scan files, downloaded from the Internet, or scan e-mail when received.

Be sure to have only one anti-virus program running on your system. Multiple programs may cause conflicts and system instability. Keeping it Current

Even with active monitoring of computer systems, anti-virus software can only protect against viruses that it knows about. For this reason, update files (generally called Definition Files) for anti-virus software are needed every time there is a new virus release. On the Windows platform, this means an update roughly every week; the Macintosh has fewer new viruses to worry about so updates are usually done monthly. The software that ITS distributes has an "Auto Update" feature to automatically connect to a Web site and download the latest Definition Files. Refer to the documentation to turn this feature on and receive the maximum protection against viruses on computer. Be sure to keep the Definition Files current!

How to remove virus?

If computer becomes infected with a virus, don't panic! For most viruses, can simply use anti-virus program to scan and remove the virus. If your Definition Files are up-to-date, the program should be able to clean off all but the most recent viruses. In the case of rather nasty viruses, some damaged files that cannot be fixed. Restore these from backups.

MS Office and its Installation, creating a basic document in MS Word

Objectives : At the end of this lesson you shall be able to
- **define Micro Soft word**
- **describe document, formating, spacing and headers.**

Introduction:

Microsoft Word is an essential tool for the creation of documents. Its ease of use has made Word one of the most widely used word processing applications currently on the market. Therefore, it's important to become familiar with the various facets of this software, since it allows for compatibility across multiple computers as well as collaborative features. Word is a fairly simple program to use for completing simple tasks. However, it may be more difficult to learn how to explore the more advanced possibilities of Word.

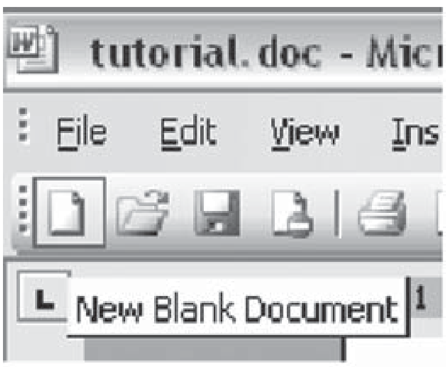
Opening Microsoft Word:

To run Word on the computer: "Start" >> "Programs" >> "Microsoft Office" >> "Microsoft Office Word 2003." If there is an icon of Microsoft Word available on your desktop (shaped like a square with a "W" in the middle), can open up the program by double-clicking it, as well.

Making a New Blank Document:

When Word is opened, a new blank document should automatically open. If not, then can begin a new blank document in a variety of ways. First, find the "New Blank Document" icon, which looks like a blank sheet of paper, located underneath the menu bar in Word in what is called the "standard toolbar." shown in Fig 1 Click on the icon to bring up a new blank document.

Fig 1



Go to the menu bar and select File >> New… (shortcut: Ctrl+N).

To begin typing, just click the cursor anywhere within the new blank document.

Opening a Document:

To open to view, edit, or print a document, must first open up that file in Word.

You can open a file by clicking on the "Open" folder icon (with a picture of a folder)

located in the standard toolbar. Or, you can use the menu bar and navigate to File >> Open… (shortcut: Ctrl+O).

Saving a Document:

When working with any sort of media in any software, sure to save work often. In Word, there are numerous options for saving documents in a variety of file types. To save a new, unsaved document, you can click on the Save icon, shaped like a disk located on the standard toolbar. Or, you can go to the menu bar and select File >> Save… (shortcut: Ctrl+S).

A dialogue box should appear, offering a number of options. To save the document in the desired location on computer, locate and select the folder on the computer. Give the document a name in the file name text box. While give document long names, make sure save it with a name remember. Please note that it's good practice not to use spaces or special characters in file names. For example, long file name may look like this: expos_sample_paper1.doc To save a completely new document using previously existing (and opened) text, use the Save As option. Open the document that wish to save as an entirely new file, go to the menu bar, and click on File >> Save as. In the file name text box, give your document a new name. Using this option allows you to save multiple versions (with different file names) of a document based on one original file.

Formatting Text/Paragraphs Using Toolbars:

In a word processing program such as Word, there are numerous options available for presenting your text. This part of the tutorial will guide through several of the important features in Word that will allow to edit, modify, and display text (and non-text) components.

The Standard Toolbar:

Word allows all toolbars to be customized, so you may not find all options listed here. There are several buttons that may or may not appear immediately in the version of Word. Use the following graphic as a guide to the Standard Toolbar.

1.**New Blank Document:**

To begin a new document, click on the New Blank Document icon, shaped like a blank sheet of paper.

2.**Open:**

Clicking on this icon opens up a previously saved document on computer.

3.**Save:**

Clicking on the Save icon saves the document you are currently working on. If saving a document for the first time, click on this button. However, if want to save a new file from a preexisting document, then you must go to the menu bar and select "File" >> "Save As" and give the file a new name. When working on any document, sure to save frequently, so that do not lose any work.

4.**Permission:**

Microsoft has enabled Information Rights Management (IRM) within the new version of Word, which can help protect sensitive documents from being copied or forwarded. Click this for more information and options.

5.**Print:**

Clicking on the Print icon automatically prints the document currently active in Word. If wish to explore more print options, then go to the menu bar and select "File" >> "Print."

6.**Print Preview:**

To get an idea of the appearance of document in print before actually print it out, click on this icon to view document from a zoom-out distance.

7.**Spelling and Grammar:**

Clicking begins a review of document in search of spelling and grammatical errors that may need to be corrected.

8.**Copy:**

Copy the current selection to the clipboard, which can then be pasted elsewhere in the document, or into a completely separate program/document.

9.**Paste:**

Clicking on the Paste button inserts the text that has been most recently added to the Clipboard (the text would have been added there by Cutting or Copying). With Paste, can either insert the copied text into a document or replace selected text.

10.**Undo Typing:**

The Undo Typing button goes back and removes the last addition or change made to document.

11.**Insert Hyperlink:**

To make links to a particular web site, web page, or some other kind of online file in Word document. Using the Insert Hyperlink button, you can turn selected text into hyperlinks. When the icon is clicked, a window will appear that will allow to insert the URL (web address) of the web page want to link to. Can type in the URL or insert a preexisting bookmark. Once the link is inserted, the link in Word document can be clicked and the web page will open up in a web browser.

12.**Insert Table:**

When this icon is clicked, a small window will appear in the form of a grid of squares. Use this window as a guide to indicate how many rows and columns table to contain. Once selected, a table will automatically appear in Word. Clicking the Tables and Borders button will allow to modify the table. To modify an aspect of the table, select, or place the cursor in, the area and apply changes such as borders and colors.

The Formatting Toolbar:

Word allows all toolbars to be customized, so you may not find all options listed here. There are several buttons that may or may not appear immediately in version of Word. Use the following graphic as a guide to the Formatting Toolbar.

1 **Style:** Styles in Word are used to quickly format portions of text. For example, could use the "Normal" or "Default Paragraph Font" for the body text in a document. There are also three preset styles made for headings.

2 **Font:** Font is a simple but important factor in Word documents. The choice of font (the style of the text itself) can influence the way others view documents, either on the screen or in print. For example, Arial font looks better on screen, while Times New Roman is clearer in print. To apply a font to text, select desired text with your cursor, and choose a font from the font drop down menu.

3 **Font Size:** You may encounter times in which you need to display some text larger or smaller than other text. Selecting desired text with the cursor and choosing a font size from the drop down menu changes the size of text.

4 **Bold:** Places the text in **bold**.

5 **Italic:** Places the text in italics.

6 **Underline:** Underlines the text.

7 **Align Left:** Aligns the selection to the left of the screen/ paper.

8 **Center:** Aligns the selection to the center of the screen/ paper.

9 **Align Right:** Aligns the selection to the right of the screen/paper.

10 **Justify:** Aligns the selection to both the left and right of the screen/paper.

11 **Line Spacing:** Adjust the line spacing (single-spaced, double-spaced, etc.)

12 **Numbering:** Create a numbered list.

13 **Bullets:** Create an unordered, bulleted list.

14 **Decrease Indent:** Decreases the indentation of the current selection (to the left).

15 **Increase Indent:** Increases the indentation of the current selection (to the right).

16 **Outside Border:** Places a border around the current selection; click the drop-down for a wide selection of bordering options.

17 **Highlight:** Highlight the current selection; default color is yellow.

Paint tools in Windows

Objectives : At the end of this lesson you shall be able to
- **explain the MS paint tools**
- **state different tools used in Microsoft paint.**

What is Paint?

Microsoft Paint is a graphics development tool that comes packaged with Microsoft's Windows operating system. As such, it is free and is functional on all Windows machines.

The Toolbar (Fig 1)

Tools (Fig 1) can be chosen by clicking on them one at a time. Choosing a tool deselects the previous tool selected. A more detailed explanation of each of the tools follows:

Fig 1

Selection Tools

The selection tools are used to highlight objects on the canvas to be moved, deleted, or changed. The "Star-shaped" tool. allows the user to create a "freehand" selection area while the "Square-shaped" tool mandates that the user drag a rectangle shaped selection area.

The Eraser

While left-clicking and dragging the eraser over any object on the canvas, that portion of the object is erased. The size of the eraser can be adjusted by using the size selector at the bottom of the toolbar. This selector is only visible when the eraser is selected.

Fill Tool

Choose this tool to fill any **completely enclosed object or area** on the canvas. The color can be chosen via the **Color Box** located at the bottom/left of the Paint screen.

Color Box

Colors can be chosen from this color box in conjunction with the fill tool as well as other object tools in the toolbar

Additional Colors

Additional colors (over and above those in the color box) can be accessed by using the **Colors – Edit Colors** menu options. Then, the **Edit Colors Pane** will open allowing the user to choose different shades.

Edit Colors Pane

By choosing the **Define Custom Colors** button, additional shades can be chosen. Here, the user can choose a basic color and its pallet will appear to the right. Clicking in the pallet will choose a color, the shade of which can be adjusted via the color slide all the way to the right. In addition, the RGB color code is available .

Pick Color Tool

This tool allows the user to click on any color in any object on the canvas and it will be chosen as the current color for filling or drawing additional objects.

Magnifier Tool

Choosing this tool enables the **Magnification Option Pane** to open, allowing the user to choose the amount of magnification he/she desires in order to accomplish a task. Many times, intricate shading and finishing work needs to be done in a magnified mode.

Pencil Tool

This tool in conjunction with the color pallet allows the user to create free-hand lines.

Brush Tool

The brush tool allows the user to draw freehand "brush-stroke-like" lines where, depending upon the brush chosen, the effect of a true brush stroke with differing widths can be achieved. The brush stroke choices appear at the bottom of the toolbar when the brush is chosen. The brush stroke selections consist of 2-dimensional strokes (constant width) and true brush strokes (diagonal lines). Magnification Option Pane

Air Brush Tool

This tool allows the user to "spray" color onto the canvas in concentrations designated by the air brush selector pane, which appears at the bottom of the toolbar when the air brush is chosen. By choosing wider spray patterns, the user can diffuse the color chosen a bit more when applying it to the canvas.

MS word file, folder, editting, formatting text & labels

Objectives : At the end of this lesson you shall be able to
- **how to open microsoft word**
- **make a new blank document**
- **format text/paragraphs using toolbars.**

Introduction:

Microsoft Word is an essential tool for the creation of documents. Its ease of use has made Word one of the most widely used word processing applications currently on the market. Therefore, it's important to become familiar with the various facets of this software, since it allows for compatibility across multiple computers as well as collaborative features. Word is a fairly simple program to use for completing simple tasks. However, it may be more difficult to learn how to explore the more advanced possibilities of Word.

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Making a New Blank Document:

When Word is opened, a new blank document should automatically open. If not, then

you can begin a new blank document in a variety of ways. First, find the "New Blank Document" icon, which looks like a blank sheet of paper, located underneath the menu bar in Word in what is called the "standard toolbar." Click on the icon to bring up a new blank document.

Also, go to the menu bar and select File >> New… (shortcut: Ctrl+N).

To begin typing, just click the cursor anywhere within the new blank document.

1 **Center:** Aligns the selection to the center of the screen/ paper.

2 **Align Right:** Aligns the selection to the right of the screen/paper.

3 **Justify:** Aligns the selection to both the left and right of the screen/paper.

4 **Line Spacing:** Adjust the line spacing (single-spaced, double-spaced, etc.)

5 **Numbering:** Create a numbered list.

6 **Bullets:** Create an unordered, bulleted list.

7 **Decrease Indent:** Decreases the indentation of the current selection (to the left).

8 **Increase Indent:** Increases the indentation of the current selection (to the right).

9 **Outside Border:** Places a border around the current selection; click the drop-down for a wide selection of bordering options.

10 **Highlight:** Highlight the current selection; default color is yellow.

11 **Font Color:** Change the font color; the default/automatic color is black.

More Formatting: Besides the toolbars, Word provides a great deal of ways to customize and format your text and documents.

Paragraph Spacing:

To access the Paragraph formatting options, navigate to the menu bar, and select "Format" >> "Paragraph," or right-click within a paragraph.

A window will appear with options for modifying spacing and indenting. Here, you can choose to make the text in your document single or double spaced, as well as edit the margins for the document.

MS Word

Creating a basic document

1 Open the microsoft word application. Do this by double-clicking the microsoft word icon.

2 Review the available templates. On the right side of the screen, you'll see several templates of interest.

- Blank document - A blank document with default formatting.
- Creative Resume/Cover Letter - A clean, pre-formatted resume (and accompanying cover letter) document.
- Student Report with Cover Photo - A document format geared toward an academic demographic.
- Fax Cover Sheet - A document to preface fax reports.
- Search for specific templates online from within Word by using the search bar at the top of this screen.

3 Choose a template. Doing so will open the template in Word with whatever pre-determined formatting applies to it. Now that your document is open, and ready to review Toolbar options.

- When in doubt, open a blank document.

4 Click the File tab. It's in the top left side of the screen.From here, several useful options on the far left side of screen.

- Info (PC only) - Click this to review the documents statistics, such as when it was last modified, as well as any potential issues with the document.
- New - Click this to bring up the "New Document" page that lists all of the pre-formatted templates. Opening a new document will prompt to save your old one.
- Open - Click this to review a list of recently-opened documents. Select a directory (e.g., "This PC") in which to search.
- Save - Click this to save your document. If this is first time saving this particular document, prompted to enter a name, save location, and preferred file format as well.
- Save As - Click to save the document "as" something (e.g., a different name or file format).
- Print - Click this to bring up printer settings.
- Share - Click this to view sharing options for this document, including email and cloud options.
- Export - Click to quickly create a PDF or change the file type.

5 Click in the top left corner of screen. If using a Mac, --simply click your document to exit the "File" menu.

6 Review the Home tab to see your formatting options. At the top of the screen--from left to right--are five subsections of this tab.

- Clipboard - Whenever copy text, it is saved on the clipboard. View copied text by clicking the Clipboard option here.
- Font - From this section, change the font style, size, color, formatting (e.g., bold or italic), and highlighting.
- Paragraph - Change aspects of the paragraph formatting--such as line spacing, indentation, and bullet formatting--from this section.
- Styles - This section covers different types of text for various situations (e.g., headings, titles, and subtitles). You'll also see the popular "No Spacing" option here, which removes excess spaces between lines of text.
- Editing - A couple of commonly-used tools--such as "Find and Replace", which allows you to quickly replace all appearances of one word with another--live here.

7 Click the Insert tab to review the types of media can place in document. Insert is to the right of the Home tab. The Insert tab allows to add things like graphics and page numbers to document.

- Table - Clicking this option will allow you to create an Excel-style table right in the document.
- Pictures - Use this feature to insert a picture into document.
- Header, Footer, and Page Number - These options are all essential for writing in MLA- or APA-style formatting. The Header places a space at the top of the document for comment, while the Footer goes at the bottom--page numbers are customizable.
- Equation/Symbol - These options use special formatting to accurately display simple equations. Select these equations or symbols from the pertinent drop-down menu.

8 Click the Design tab to create the template. It's to the right of the Insert tab.

- The Design tab contains pre-designed themes and formats listed across the top of the page.

9 Click the Layout tab to customize your page's formatting. This tab contains options for changing the following aspects of your document.

- Margins
- Page orientation (vertical or horizontal)
- Page size
- Number of columns (defaults to one)
- Location of page breaks
- Indentation

10 Click the References to manage your citations. If you have a bibliography page, you can also manage it from here.

- For quick bibliography formatting, click the Bibliography drop-down menu and select a template.
- In the "Citations & Bibliography" group of options, can change bibliography formatting from APA to MLA (or other citation styles).
- The "Captions" group has an option to insert a table of figures. This is useful for scientific review papers or similar documents in which statistical data is prioritized over quotations

11 Click the Mailings tab to review document sharing options. Review email settings and share documents from within this sections.

- Print an envelope or label template by clicking the pertinent option in the top left corner of the screen.
- The Select Recipients drop-down menu allows you to choose Outlook contacts as well as an existing contact list within Word.

12 Click the Review tab. The Review section is geared towards editing, so it includes options for marking up documents and proofreading.

- Spelling & Grammar - Click this option (far left corner) to underline any spelling or grammatical errors.
- The "Changes" section - This is to the far right of the toolbar. From here, you can enable the "Track Changes" feature which automatically formats any additions or deletions make in a document to appear in red pri

MS Excel

Objectives : At the end of this lesson you shall be able to
- **explain the spread sheet**
- **explain cell and its contents**
- **explain the data types**
- **align cells contents and text**
- **create and print charts**
- **insert rows and columns.**

Spread sheet : A Spread sheet is simply a paper with rows and columns in which one can enter data which may be text or numbers. For instance, Balance sheet of company is a spread sheet. An Electronic spread sheet Excel is like a paper spread sheet spread on the screen of a computer monitor. Electronic spread sheet has the following advantages;

– Making modification to the content of the sheet is much faster and easier.

– Taking copies of the sheet is easier

– Has the facility to view only a part of the whole sheet which gives better clarity and is like seeing the spread sheet through a window.

– Allows formulae to be entered into the work sheet resulting in rapid calculation.

The popular Electronic spread sheet programs are;

LOTUS 123	- this has become relatively old.
Microsoft EXCEL	- most popular as on day.

The rows and columns are numbered as 1,2,3, ... and A,B,C,.... The electronic spread sheet is also called as worksheet.

A few popular applications of Spread sheet are listed below;

1 Pay roll - where pay details of employee in a big organisation can be stored in a single spread sheet. The details could be Employee Name, Employee Identity No., Basic Salary, HRA, DA, etc. which will be helpful to the employee as well as employer to keep a track of the record.

2 Human Resource Development of a company where the Personal details of individual Employee like Name, Address, Date of Birth, Date of Joining the Present Company, Personnel Details. This data will be useful to get the details of an employee.

3 Accounting - This is the area where the spread sheet is widely used. The companies ledger, trial balances, balance sheet for determining the profit and loss of the company.

Some of other areas where the spread sheets are widely used are

a Tax assessment

b Stores Maintenance (Ordering / Invoicing)

c Quality control, etc.

The Microsoft Excel provides three basic component that perform different tasks.

1 Spread Sheet component is used to display and anaslyse text and numbers in grids i.e. rows and columns.

2 Database component is used to manipulate lists of information of particular company.

3 Chart component is used to produce the charts to present data graphically.

The Application package Excel has a capability of transferring and manipulate data easily with all the three above components.

Opening of Excel Worksheet : A Microsoft Excel is invoked using the sequence.

Start ⇨ **Programs** ⇨ **Microsoft Excel,** two windows appears as shown in the Fig 1. One is Application window which is an interface between the Excel and the outer world and the other one is Document window which is used as Excel worksheet and charts.

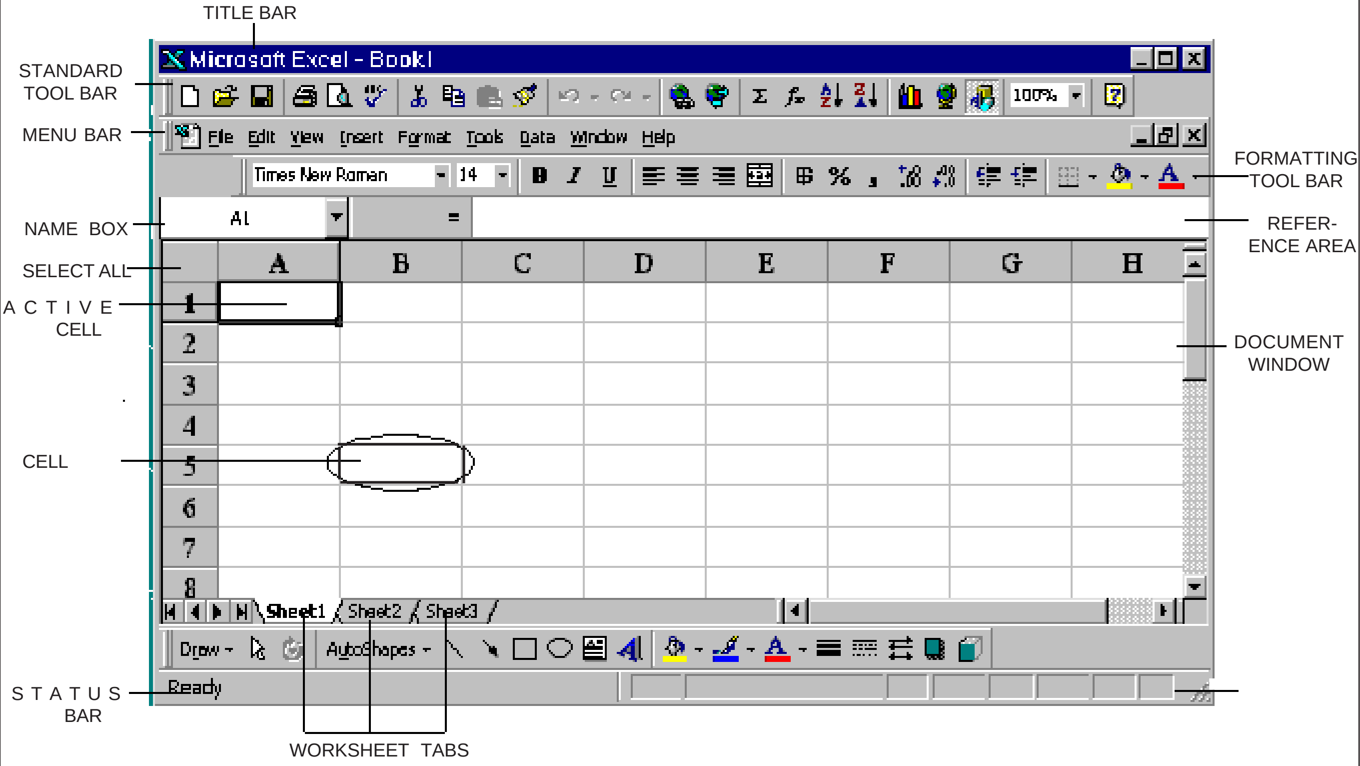
The basic component of Excel Window are explained below:

Title bar : Appears on the top of Excel Window. This consists of Application control menu at the left and minimize and restore button at right.

Menu Bar : Below the title bar is the menu bar which is similar to any other Microsoft Window for example Microsoft Word, lists the menus like File, Edit, View... etc. which contains commands to Excel.

Standard Tool Bar : Contains tool buttons which are used to carry out standard operations like Autosum, Spell Check, etc.

Fig 1



Formatting Toolbar : Contains tools to choose frequently used formatting commands; example Bold, Italics, Left, Centre, Right, Alignment, etc...

Formula Bar : Contains the Name box at the left end which will display the active cell address. The right area is called reference area/formula bar and is used to display data present in the cells.

Status Bar : Contains the messages and prompts. The message **Ready** in Status bar indicates Excel is ready to accept data. The Edit indicates that Excel is in Edit mode. The status bar appears at the bottom of the window.

Excel document window displays the present active worksheet. Similar to application window the document window consists of the following.

Title bar : displays the name of the work book.

Control menu : contains the maximise / restore button.

Sheet tabs : Contains the different worksheets within the current work book.

Scroll bars : Used to scroll through the worksheet.

Column / Row : The letter at the top of the column A,B, C,D... denotes the column heading. The number at the left of each work sheet 1,2,3,.... denotes the row heading.

Excel stores the data in a worksheet by location. The worksheet is a grid of 65,536 rows and 256 columns. The columns are numbered A to Z, AA to AZ, BA & BZ... etc., the rows are numbered 1 to 256. The worksheets are numbered automatically as sheet 1, sheet 2, sheet 3, etc.

Worksheets are organised in workbook. Each new work-book opened contains three worksheets by default. User can add worksheets upto a maximum of 255 worksheets.

Cell : The intersection of row and column is called a cell. Each cell is surrounded by a grey lines called gridlines.

Each Cell is addressed by a cell address. With row and column element. For example the cell address of 3rd row and 3rd column is C3. Similarly cell address of 7th row and 2nd column is B7. The first cell address is A1.

To Enter the text / number into cell, first it should be made active i.e. selected. Any cell can be selected / made active by clicking on the cell. Selected cell is indicated by a dark border.

The selected cell address will be displayed on the name box.

Entering data : To Enter Data in the active cell user can type the text directly. You can also use Cut, Copy command to Paste the data from another file in the active cell. As the text is typed, the typed text will appear in both the cell and the reference area.

As the first character is entered the cancel button, Enter button and the Edit formula button appear in the reference area.

Once the data is entered user can either press Enter key or press one of the arrow keys to move to the next cell. Excel will move the active cell to the cell in the direction of the arrow key. Alternatively user can just click the desired cell to select and type the data.

User can select the cell by Entering the cell address inside the name box. For example user wants to Enter the data in A6 Cell. By typing the address A6 in Name box, Excel will display the A6 cell as active cell.

The entered information will be displayed in the active cell as well as in the reference area / formula bar. User can

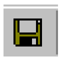
Enter / Edit the information in the reference area also.

If the text entered is too long for the cell, the text entered will be displayed in the cells to the right if they are empty; other wise only the part that fits will be displayed.

Printing the Worksheet : The information entered in the Worksheet need to be Printed in order to allow user to share the information with others. Excel provides number of options to print the way user wants. The options for both setting parameters and printing the worksheet are contained in several dialog boxes.

By default Excel select every thing for printing that is entered on the present worksheet in case where only a portion of the worksheet is to be printed, the user has to highlight the required range. User have an option of Print Preview where preview of the selected worksheet will appear in a print preview window.

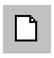
Saving Work Book : After entering required data in the worksheet, the worksheet need to be saved so that it can be used after a period of time.

Worksheet can be saved by **choosing File ⇨ Save** from the main menu or save file tool bar button . On invoking Excel opens up a Save as dialog.

User can Choose the folder of their choice and the file name. Once the file name and the folder is specified Excel gives the extension **.xls** automatically and the file is saved.

Creating Work Sheet / Work Book : On invoking the Microsoft Excel Application package a Workbook with a label "Book1" is displayed on title bar of the Excel window.

By default the Excel opens a new unsaved workbook. A workbook is an Excel file where the user data is stored. The default work book 'Book1' consists of three blank worksheets with label Sheet1, Sheet2, Sheet3. Each work book consists of several worksheet. The workbook can be thought of as a folder, each worksheet as a page in the folder.

To create a workbook user can click on the New button  on the standard tool bar. On clicking ,the new dialog box appears on the screen with options. User can choose one of the options available on the dialog box. To open a workbook based on a spread sheet template user need to choose **File ⇨ New** to display the New dialog box. On clicking on the spread sheet solution tab the Excel template will be displayed. The previous Window displays the selected template first. User can choose the appropriate template and click on OK button to open the same.

Page Setup : The Screen gives the required information which user needs, for example, mark sheet, budget, sales details are to be distributed among people as well as to have a hard copy to the institution, company, etc. To have a hard copy some Parameters should be set before the actual printing is done.

By default Microsoft Excel selects every thing entered on the current worksheet. Where only a portion of the worksheet is required to be printed, the user need to highlight the Print range.

To setup the required parameters user should choose **File ⇨ Page Setup**. On choosing **Page Setup** dialog box appears.

The Page Setup dialog box provides option for setting up Page Margins, Header / Footer and Sheet width.

Page tab provides the option to setup the

Page Orientation	:	User can choose Portrait or Landscape orientation.
Scaling	:	This option provides to adjust the size of printing. By selecting the Adjust to radio button user can enter the percentage of normal size. By default 100% is selected. By selecting the Fit to radio button user can specify the number of pages wide by the number of Pages tall.
Paper Size	:	The paper size drop down list provides the different paper size.
Print Quality	:	User can select the resolution of Printer from the drop-down list.

The Margins tab provides the option to Setup the distances in inches from the edge of the page to the printed data on four sides. The four margin top, bottom, left and right preview can be viewed in the center of the dialog box.

Microsoft Excel can automatically Center the contents using the center on Page check box available in the dialog box.

Header / Footer tab provides the user to add a text at the top of the worksheet as Header and at the bottom of page called Footer. The header normally contains the description of company, filename, etc. The footer contains the Page number.

The default header is the sheet name and the default footer is the "Page" and the Page Number. Header / Footer tab is explained in detail in future exercises.

The sheet tab provides the option to printing of grid between each cell, printing of cell notes, row and column heading on and off.

User can select the draft quality print and take only black and white printout.

Most useful option in the sheet tab is that the user can determine how a multipage workbook is to be printed. This is very useful in printing reports, budgets, etc.

Range : Range is a group of rectangular cells. The smallest range is a single cell. Range can contain cells from single sheet or cells from adjacent sheets. Excel allows only rectangular ranges .Angular ranges are not allowed.

Use of ranges helps in performing a single operation on selected data at once. Ranges are defined by the cell address of two opposite corner. For example A4 : B6 or B10

: H12. The pairs of cells are separated by [:] or [..] to denote it is a range.

To select a range of cells with the mouse move the mouse pointer to one corner of the range eg. A4 and drag the mouse to opposite corner of the range say H10. The cells covering the A4 to H10 get highlighted.

Selecting the range of cells with the Key board select the cell in A4 cell and hold shift key pressed. Use Arrow keys to move the cursor and bring it to H10. The selected range gets highlighted.

By selecting the range, the cells can be merged by a single click of mouse. Excel provides a merge and center button in the formatting tool bar which merges the cells and centers the text to the selected range of cells.

User can select the whole worksheet with a single click on the select all button available on the intersection point of row and column.

Increasing / Decreasing the cell width : Excel provides two methods to increase or decrease the cell width and height. User can increase the width of the cell by placing the cursor on the intersection cell column label, the cursor changes to . This denotes that the width can be increased dragging the mouse right and decreased dragging the mouse left. While dragging a rectangle yellow box prompts the cell width value.

Another method is to enter the value of the width directly in the column width dialog box. Column width dialog box can be invoked by choosing **Format** **Column** **Width**. The dialog box appears.

User can select the entire worksheet and change the column width at once or select the columns to which the width to be changed choose the above sequence to invoke the column width dialog box.

Auto sum : The Autosum tool available on the main menu automatically builds a sum formula. For example by selecting the range B6 to G6 and clicking on Autosum tool button the formula = Sum (B6:G6) is formed automatically. The sum will be placed on the H6. The formula can be viewed on the reference area / Edit area by selecting the H6 in this case or any where, where the value of sum is placed.

Entering Text : On Excel Work Sheet the text / Numerals can be entered by selecting the desired cell. User can type the text directly. The text is terminated by entering Enter key or choosing the check button on the formula bar.

After entering the text, some text may not appear properly, since the column width of cell may not be enough to contain the text.To view the text in a cell fully, increase the width of the cell.

Moving around worksheet : Microsoft Excel organizes worksheets by work book.

As discussed earlier each worksheet contains 65, 536 rows and 256 columns. The worksheets are numbered automatically as Sheet 1, Sheet 2, ... Sheet 256. The name of the worksheet can be changed by user to suit the information entered in the worksheet, for example Income Tax, Budget, etc. Work sheet name can be upto 31 characters. It is advisable to have a label with short name so that number of sheet label can be viewed on the monitor. The sheet tabs are available at the bottom of the Excel windows.

Data Types : Excel handles data in five different types.

1 Numbers are values that are numerals 0 through 9, with a decimal point (.) as a separator for decimal and comma (,) as a separator for thousands.

   Numbers can start from the currency symbol $,Rs, or with a + (Positive)or - (Negative)sign. They can end with a % sign.

2 Dates are handled as serial numbers in Excel which represent the number of days elapsed since 1-1-1900. Excel will recognise the dates in the following format.

1.	DD - MMM - yy	-	04-Dec - 99
2.	MM/DD./YY	-	10/4/00
			Where 00 -> 2000
3.	DD-MMM	-	04 - Jan
4.	MMM - YY	-	Feb -99.

3 Time is also represented as serial numbers. Excel represents 24 hours of the day as values between 0 and 24. Time can be entered in the following format

HH : MM : SS		12:12:15
HH : MM AM/PM		12:30 PM
HH : MM : SS AM/PM		12:12:15 PM
HH : MM	-	12 :15

4 Formulas are Mathematical formulas which perform calculation on data should be entered into cell. For example to sum the values in cell B2, B3 and B4 user would enter the formula = B2 + B3 + B4 in cell B5.

5 Text

   Excel recognises data as text which is not number, time, date or formula. Excel will treat the numeric value that are outside of its accepted number, date and time formats as text. For example 10:52AM will be treated as text because it does not fit in the time format.

User have an option to select to entered data as Number or Text by choosing **Format** **Cells. Select** the Number tab from the Format Cells dialog box. Text or Number can be selected from the category box.

Adding Worksheet : As discussed earlier the new work book opens with three worksheet by default. User can insert worksheet as many as 255 worksheets.

To add a new worksheet choose **Insert Worksheet** from the main menu. Excel will add new worksheet to the left of the worksheet selected.

Alignment : Excel aligns the text and numbers entered in the cell automatically. By default numbers are right aligned and Text are left aligned. User can overwrite this by selecting the cell and selecting the one of the button on the formatting tool bar. Merge and Center button allows user to center the contents of cell across a number of columns.

The text can be aligned Horizontal, Vertical and Orientation to the text can be given with the help of format cells dialog box. The format cell dialog box can be invoked by choosing **Format** ⇨ **Cell**. Selecting Alignment tab in the format cell dialog box the option of alignment of text, text orientation appears. User will also have the option of wrapping the text, shrink the text to fit in the cell.

To change the orientation of the text user can either enter the value directly in the Degree box or use the Up/Down arrow to increase or decreases the value. Another way is to use the protractor shown in the orientation box.

Applying Border : User can apply the border to the active cell or range of cells by clicking the border button on the formatting tool bar. On clicking the preset border drop down list appears.

User can apply the border to the active cell by Choosing **Format** ⇨ **Cell** to display the format cells dialog box. **Border** tab gives more option of border and style.

Applying Colors to borders : The Border Tab in Format dialog box provides an option to user to apply a color to the border. This will help in highlighting the contents of the cell.

The Color window under the style opens up a color palette.

By selecting the choice color from the palette, the selected color is applied to the border.

Excel provides graphical component which allows to represent data in the worksheet graphically. Graphically represented data helps in understanding, analysing easier.

Chart:- A chart is graphical representation of entered data in the worksheet. Graphical representation of data makes the data more clearer and easier to read. Chart can be viewed, edited and can be embedded in the worksheet.

Chart can be either two dimensional (2D) or three dimensional (3D). The basic elements of the charts are

AXIS	Charts have X-axis (horizontal) and Y- axis (Vertical). The 3-D charts will have Z axis (depth).
Title	Each axis will have chart titles.
Legend	This identifies each data series (Color, Pattern, etc.)
Data Series	This is set of data from which the chart is drawn. Most of charts can have two or more data series. Except Pie chart has only one data series.
Categories	Is the data by which the data series is separated. If data series in years 1900 to 2000, each year is a category.
Gridlines	These are the lines drawn across the chart from the axis for visual reference.

Types of Charts: Excel offers different types of charts. Some of them discussed below are very often used to represent the data.

1 **Area Charts :** Shows the magnitude of change over time. It is used where several components are changing and the user needs sum of the components. It is a stacked line chart with the area between the lines filled with color or shading.

2 **Bar Charts :** Are very frequently used charts which consists of a series of horizontal bars that allow comparison of the relative size of two or more item at single point of time.

Bar chart are of three types.

a Stacked bar chart

b 3D bar chart

c 100% stacked bar chart

3 **Column Charts :** Consists of a series of Vertical columns that allow comparison of the relative size of two or more data items. Here also each column represent single data point.

4 **Line chart :** Is used to show the trends over time. Each data series is used to produce a line on the chart.

5 **Pie Chart :** Is very widely used to compare the percentage of sum that several numbers represent.

Each number can be represented by a slice. One of the slices can be separated from the other slices.

The major difference between all other charts and pie chart is that it has only one data series.

Chart Wizard : Excel allows user to create chart either on a separate sheet as a chart sheet or it can be embedded on the current worksheet. The easiest way and the best way to create a chart is using the chart wizard.

The chart wizard button is available on the standard tool bar.

The chart wizard guides the user step by step in creating the chart.

It also gives the option to user to

1 Suppress the axis.

2 Choosing the gridlines to display

3 To display legend and placing the legend

4 To display data labels or not.

5 To display the data table which is very useful in chart sheet.

Excel allows user to move, resize, delete and edit the chart.On clicking the chart size handles appears around the chart.Using the handles user can resize the charts.

Changing chart types : User is also allowed to change the chart from one type to another. The chart tool bar provides the quick access to important parts of a chart.

Chart objects is used to pick the object user wants from the drop down list.

Format element displays the format dialog box for the element chosen.

Chart type button applies the indicated chart type to the chart .On clicking the drop down list displays which user can change the chart type.

Legend button toggles the display of the legend.

Data table button toggles the display of the data table.

Angle text downward and Angle text upward tilts the selected text at a 45 degree angle. By clicking the respective buttons that are present in the chart tool bar we can add legend, title and gridlines for a chart. Alternatively, these can also be added using the Insert menu.

Printing of Charts : Since charts are stored with worksheet pages, the tasks of saving and printing charts are so different from saving and printing worksheets. If it is an embedded chart, you can size and place it on the worksheet and view it in print preview. If it is a chart sheet, you can size and scale it in your required manner.

Inserting Rows & Columns : It is easy to insert rows or columns in Excel Work Sheet. One method is to select the entire row below the place where you want to insert new blank row. Choose **Insert** ⇨ **Rows** from the main menu.

For example, click on the row number 5 in your worksheet to select the full row.

The new blank row 5 gets inserted. The contents of the previous row 5 will be now content of row 6. All other rows are pushed down and re-numbered.

The new blank row 5 gets inserted. The contents of the previous row 5 will be now content of row 6. All other rows are pushed down and re-numbered.

User can insert multiple rows by selecting multiple rows before issuing the insert rows command.

Another method to insert rows is to select the row below the place where you want to insert new blank row. Click on the right mouse button. Choose Insert from the context menu, the row gets inserted.

To Delete the unwanted rows click on the row number label which is to be deleted. Click on the right mouse button. From the context menu choose Delete. The selected row gets deleted.

Similarly to insert a column select the label of the column where you want the new column to appear.

For example if you want a blank column at column C. Select Column C and use any one method used to insert the rows and select column instead of rows. The column gets inserted with label C. The contents of C becomes the contents of D. The columns that follow will also be pushed right and renamed.

To delete the column follow the same method as deleting rows.

Inserting Cells : You can insert empty cell into an existing worksheet, by pushing existing cell either to the right of the insertion point or down from the insertion point.

For example to insert a cell at C6, Activate cell C6 and choose **Insert** ⇨ **Cells..**. from the main menu. The insert dialog box appears.

The dialog box gives an option to shift cells right or down. You also have an option to insert an entire row or entire column. If you select the Shift cells down radio button a cell gets inserted and the contents of the earlier cell get pushed down.

A range of cells can be deleted or inserted. The insert and Delete commands in case of a range of cells work only with rectangular selections. Non contiguous range of cells cannot be inserted or deleted with a single command. When the selected cell or cells are deleted, they are removed from the worksheet and the adjacent cells shift to fill in the space.

Hiding Rows and Columns : Some times you may wish to hide some information which is already entered in the worksheet.Excel provides an option to hide the rows or column without displaying their contents. It can be revealed later when it is required.

To hide rows, select the row by clicking on the row label choose **Format** ⇨ **Row** ⇨ **Hide** from the main menu.

Observe that you will not see the continuous row numbers, when hide is performed. You can also hide numbers of rows. To do this select the rows to be hidden and choose hide command.

To unhide the rows at the later stage select the rows where the row is hidden.

Choose **Format** ⇨ **Row** ⇨ **Unhide** from the main menu. The hidden row will appears.

Similarly if you want to hide column C. Select the column label C and repeat the procedure you have done to hide the rows. Choose column instead of rows.

Microsoft power point

Objectives : At the end of this lesson you shall be able to
- **state the MS power point**
- **explain the normal view and slide view**
- **start, navigate, and exit the slide show.**

Microsoft powerpoint 2010

Microsoft powerpoint is part of the microsoft office suite of programs. It can be one of the most powerful tools for communicating ideas and information during presentations. In powerpoint, able to place the content into a series of "slides" which can be projected for audiences, printed and distributedas handouts, or published online using different file formats.

Microsoft office file tab, quick Access Tool bar title bar

Ribbon

In powerpoint 2010, the ribbon to issue commands. The ribbon is located near the top of the powerpoint window, below the quick access toolbar . At the top of the ribbon are several tabs; clicking a tab displays several related command groups. Within each group are related command buttons. Click the buttons to issue commands or to access menus and dialog boxes. And may also find a dialog box launcher in the bottom-right corner of a group. When click the dialog box launcher, a dialog box makes additional commands available.

Zoom sider

On the bottom right of the window you will find the zoom slider. Clicking or dragging the slider arrow or + /- icons with the mouse will enlarge or shrink the size of the slide in the window.

Viewing pane

Also notice the four icons to the left of the slider. These are shortcuts to the normal, sorter, slideshow, or reading pane view of the presentation.

Inserting animated images

In powerpoint 2010 can add images that move. These are called animated images. You can insert an animated Clip Art image on any slide and move and size the image as desire. To do this need to click - on insert in the ribbon, and then click- on Clip Art. A new task pane will open up on the right of the screen.

Transitions

Now we'll add some effects to our presentation. Click on the transitions tab at the top of the page.

This slide transition tab will allow us to choose the type of transitions from one slide to the next. Transitions can be neat, visual movements from slide-to-slide.

Notice that can see more transition choices by clicking on the dropdown arrow next to the row of slide images.

Go ahead and click-on one of the choices. Each time you make another selection, see that transition effect on the selected slide.

Build

Building is a team indicating how content on a slide will enter the screen. The lines, words, letters, pictures and charts can move in or appear from almost any direction. To build the content on each slide, follow these directions. Go back to slide 1 and click on the first line of text. The box shows first typed text in this box will appear.

Slide sorter view

When reviewing presentation, the slide sorter view is a great place to arrange, hide, or delete the slides. Click on the icon. After selecting a slide, drag, copy or delete it.

You can also hide or unhide the slides if want to use them at another time. Right click on the mouse to see the menu of options.

Printing

You can also print the slideshow, which is often helpful for the notes when presenting. From the file tab, choose print. You have many options to choose from. From the drop down under slides you can see the various types of prints you can make from the presentation. Most often to choose the slide handout.

Normal View or Slide View

Normal View or Slide View, as it is often called, is the view when, start the program. It is the view that most people use most of the time in PowerPoint. Working on a large version of a slide is helpful when you are designing presentation.

Normal View displays thumbnails on the left, a large screen where you enter your text and images, and an area at the bottom where you can type presenter notes.

To return to Normal view at any time, click the View menu and select Normal.

Outline View

Outline view shows only the text on the PowerPoint slide.

In the Outline view, your presentation is displayed in outline form. The outline is made up of the titles and main text from each slide.

Internet websites text/images & use of E- mails

Internet

The internet is a world wide collection of network, servers, gateways and computers using a common set of telecommunication protocol to link and inter operate them together.

The internet provides world wide access to information and resources. It is possible to find information about almost any subject imaginable from universities, government organisations, the military or libraries which may be in any part of the world.

The internet evolved from a US department of defence project. The advanced Research Projects Agency (ARPA) of the department funded a project to connect university computer scientists and engineers together via their computers and telephone lines. This project called ARPANET, allowed researchers to share each others computer facilities over long distances. It was also used to exchange electronic mail (e-mail) with other users. The network protocol used by the project was TCP/IP which continues to be used on the Internet today. With the combination of electronic mail, file transfers and mailing lists this network of networks called internet began to take shape.

The simplest definition of internet is that its the longest computer network in the world. A study in 1997 estimated that the internet has 16.1 million hosts or computers connected to it.

Technically, the internet is actually a network which is made up of many smaller networks that exist all over the world, but this is as invisible to the user as the telephone network which provides national to international calls (STD/ ISD). There is no particular person or company who controls the internet. It can be considered as a vast and growing online library in which anyone can publish anything they want.

Services of the internet

Over the last few years the primary users of the internet have shifted from research based activity and business use of the internet is increasing. All types of software and hardware companies are finding new ways to promote and sell their products on the internet. Lot of business applications like stock market trading, shopping on line, ordering of parts, booking of tickets, train accommodation and reservations etc. have been developed and already in use. An engineer can use the internet as a resource for current topic relating to products, technologies, tools and troubleshooting. One can also find latest news update, weather, sports and other information like travel advice, listen to music etc. Even internet telephony has come into place and at the expense of local call charges long distance and international calls can be established through the internet.

Some of the best known services available on the internet are

– WWW or World Wide Web
– FTP or File Transfer Protocol
– E-mail or Electronic mail
– Mailing lists
– Newsgroups
– Search engines
– Telnet
– Telephony
– VPN

World Wide Web

It is the internets multimedia service. It is also the widely used part of internet. It is a vast storehouse of documents known as hyper text documents. These documents are written using the hypertext markup language (HTML). Hypertext is a method for presenting text, images, sound and videos that are linked together in a document. It allows a user to browse through topics in any order. It also includes dynamic links or connections which will take you to access those pages. Using WWW, you have access to millions of pages of information.

The sum of all the hyper text and connecting links connected via the internet form is known as the world web wide or WWW or the web. The web allows you to move among linked documents stored on host computers that may be physically very distant from one another.

You can read a hyper text file, look at its illustrations and even listen any audio in it and also follow its links. Certain words or phrases appear in text of a different colour than the text and is also underlined. When you move the cursor and point it on these words a small hand appears which indicates that it is a link. You click this word and a new hypertext document gets opened.

Website

A website is a collection of hypertext documents. A document on the site is called a web page. The first page in a series of related documents or a site is called a home page. The first document you access at any site is called the home page. Many individuals on the internet have their own home page - a document about them and their interests - that anyone on the internet can access. This is a very useful way to represent a company or individual.

The web combines TCP/IP, the protocol for sending documents across network, with an entirely new method of locating and accessing documents on different networks. It involves a simple coding mechanism around a string of characters called a URL or a Universal Resource Locator. The URL identifies the name and address of each document available to the web.

The URLs specify the server to access as well as the access method and the location. Each website on the internet has its own URL.

An URL consists of

1 The server protocol to be used where the document is located. A server setup specifically for web documents uses hypertext transfer protocol (HTTP).

2 A colon

3 The type of site generally world wide web (WWW), file transfer protocol (FTP), a protocol used specifically to transfer files from one computer to another or Gopher, a client server application that organizes the files on a server, so users need not know or enter the exact file name.

4 The address of the host computer. Also known as domain address. The address begins with two forward slashes. It consists of the name of server or site, the network, university or computer name and the domain (two or three letter designation of the type of institution). The specific location of the document on that computers network

Example:

1. http://www.microsoft.com/home.htm

http	- Server protocol
www	- Type of site
microsoft	- Company name
com	- Domain name
home.htm	- Location of the document

2. ftp://ftp.microsoft.com

3. gopher://gopher.microsoft.com

Domain name system

In addition to URLs every computer on the internet has a unique IP address. The IP address is four sets of digits separated by dots. (198.64.3.20)

Because these numbers are hard to remember and difficult to type, the domain name system was created. Domain names enable short, alphabetical names to be assigned to IP addresses to describe where a computer is located. In the e.g. http://www.microsoft.com, www.microsoft.com is the domain name.

The last three characters of DNS or URL address indicate the type of domain. Some common domain names used in US are

com	- commercial organisations
edu	- educational institutions
gov	- government organisations
mil	- military
net	- network, companies and groups who ad minister the internet
org	- organisation

Countries outside the US use a two letter country code as their domain name.

au - australia

in - india

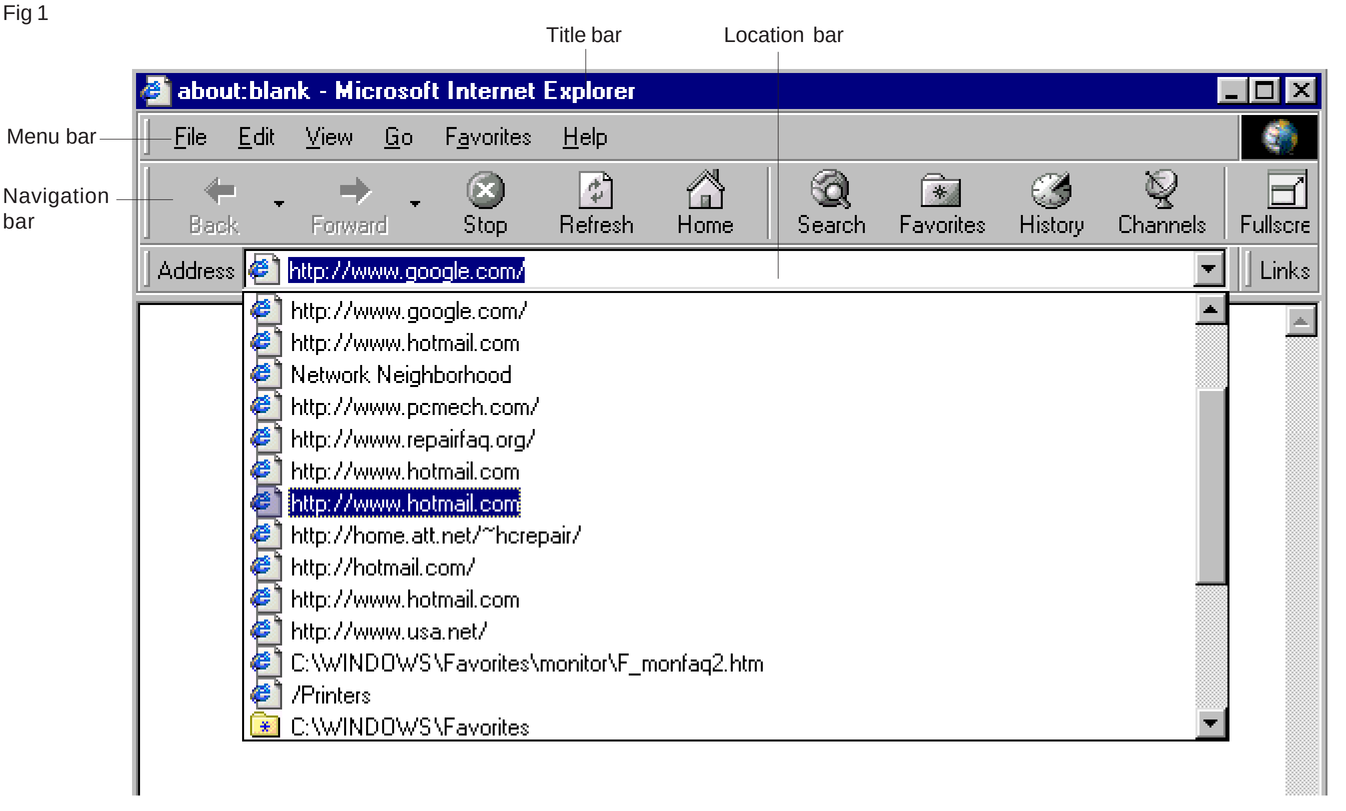
fr - france

uk - united kingdom

Browser

To view the web sites/pages you need a graphical user interface, called a web browser. It is a piece of software, that lets you visit different web sites on the internet and display their pages on your own computer. You can visit the site by supplying the browser with an address or URL.

Fig 1



A browser displays a document from the internet on the computer screen. Like any windows based program, a browser has a number of features - buttons, menus, scroll bars, toolbars etc, that let you control its operation. The latest version of the browser is recommended, since the technologies involved in publishing information on the internet are constantly changing.

Once you have your browser and a internet connection, accessing the internet is fairly straight forward. Commonly used browsers are Netscape Navigator and Microsoft Internet Explorer.

Page 1 gives the home page of Microsoft internet explorer.

Title bar: Shows the name of the page you are currently viewing on the documents file name if it is not a web page.

Menu bar: Provides with drop down menus contains almost all the commands you will need in the browser.

Navigation toolbar: Provides command action buttons. Click the icon for the specified action to occur. If you point at a button for a few seconds, without clicking, a tool tip will appear describing the action of the button.

Location tool bar: Type the URL you want to connect in the "document URL" area of the location toolbar. On the right side of the window a small arrow appears. Click the arrow and the URLs most recently visited will pop up as a list.

Internet options: Select view on the menu bar and select internet options to edit internet explorers default settings.

Search Engines

A search engine is an application on the web that allows you to search for particular web pages on sites based on key words or concepts. There are growing number of search engines found on the world wide web and each one produces different results.

Some of the popular search engines are www.msn.com, www.rediff.com, www.google.com etc.

In the window provided, type the text to be searched for and click 'submit'. You will be returned with the matching documents and related websites. Point the mouse cursor over the URL and a hand appears and click to open the document.

Chat: When send email or post news, have to wait till the mail is sent, read by the recipient and he has to reply the mail and receive the answer. Instead chat allows people to converse more in the way, as it happens in person or on the phone. You talk something, people hear it and respond on the spot. In case of chat, this exchange happens on computer screen. The communication happens in real time without delay.

E mail: Electronic mail, the sending and receiving of electronic messages, is currently one of the most popular activities on the internet. E-mail is used on most commercial online services, and for many people, is the primary reason for getting onto the internet or an online service.

To send e-mail, you must know the recipients e-mail address. These addresses are composed of the user's identification, followed by the @ sign, followed by the location of the receipients computer. For example, the email address of an individual will be name @hotmail.com

When access the internet through a local service provider or one of the large commercial online services, can exchange email without incurring the long distance charges of a telephone call. Email has the added advantage of allowing you to access messages at your convenience. Can send an identical message to any number of people at one time.

FTP: File transfer protocol is the internet's standard method for moving/downloading text files, data files and binary program files from one computer to another. A browser can be used for some FTP transfers. Its often faster and easier to use a dedicated FTP client software to download.

The procedure is essentially the same for all.

1 Connect your client program/browser to an FTP server

2 Log on as 'anonymous' and give email address as the password

3 Move to the directory on the server that contains the file

4 Specify the directory on computer to store downloaded files

5 Transfer the file from the FTP server to computer

6 Disconnect the server.

Telnet: Telnet makes the computer as a remote terminal that sends commands and receives data from the remote server through internet. When type on your own keyboard, the data goes directly to the remote computer, as if directly connected to it. Have an account and connection to the remote computer.

To make a telnet connection, one has to use the terminal emulation program such as hyper terminal in windows.

Making an internet connection

In order to access servers on the internet, your computer needs to be connected to the internet service provider.

It can be achieved through

a PSTN dial up lines

b ISDN dial up

c Dedicated leased line

Dial up link: Requires a telephone line, a dial up modem and dial up account with the ISP. Whenever IE needs access to internet, it has to establish the dial up connection first. Use dial up networking which makes the call and gets connected. But only 33kbps speed is achieved typically, can be used to connected only one computer to the ISP.

ISDN: This service connects networks through digital lines. It provides a faster connection and can be more economical than dial up service. A special ISDN modem can be used to access the ISP. An ISDN dial up account should also be taken from the ISP.

ISDN can be used from a LAN, which connects multiple users at a specific location to the internet. To enable this, a special type of computer called proxy server is required to act as a gateway between their local network and the internet. The proxy server filters the requests from internet and makes it more difficult for unauthorised requests to reach local network.

Leased line connection: For users demanding more bandwidth and internet availability for 24 hrs all days, leased lines are recommended. The typical speeds which can be used are 64 kbps, 128 kbps and 2.048 Mbps. It requires a router attached with a leased line modem to be interfaced with the leased line. A leased line account is also required from the ISP.

Web server

A Web server is a program that, using the client/server model and the World Wide Web's HyperText Transfer Protocol (HTTP), serves the files that form Web pages to Web users.

Every computer on the Internet that contains a Web site must have a Web server program. The most popular Web servers are; The Microsoft's Internet Information Server which comes with the Windows NT server; Netscape FastTrack and Enterprise servers; and Apache, a Web server for UNIX-based operating systems. Other Web servers include Novell's Web Server for users of its NetWare operating system and IBM's family of Lotus Domino servers, primarily for IBM's OS/390 and AS/400 customers.

Web servers often come as part of a larger package of Internet related programs for serving e-mail, downloading requests for File Transfer Protocol(FTP) files and building and publishing Web pages. Considerations in choosing a Web server include how well it works with the operating system and other servers, its ability to handle server-side programming, and publishing, search engine, and site building tools that may come with it.

Internet Service Provider (ISP)

An ISP (Internet service provider) is a company that provides individuals and other companies access to the Internet and other related services such as Web site building and virtual hosting.

An Internet service provider (ISP) has the equipment and the telecommunication line access required to have POP on the Internet for the geographic area served. Larger ISPs have their own high-speed leased lines so that they are less dependent on the telecommunication providers and can provide better service to their customers. Among the largest ISPs are AT&T WorldNet, IBM Global Network, MCI, Netcom, UUNet, PSINet, etc.

ISPs also include regional providers such as VSNL, NEARNet, BARNet etc. They also include thousands of local providers. In addition, Internet users can also get access through online service providers (online service provider) such as America Online and Compuserve.

An ISP is also sometimes referred to as an IAP (Internet Access Provider). ISP is sometimes used as an abbreviation for independent service provider to distinguish a service provider that is an independent, separate company from a telephone company.

Internet Access Provider

The basic service that any Internet Service Provider (ISP) offers is the means to provide a dial-up link via a public telecommunication service such as telephone or ISDN, which supports an IP(Internet Protocol) packets coming from and going to that link.

In order to support the IP link across the telephone system, an additional protocol is required, which an ISP must also be able to support. This will either be the Point-to-Point Protocol (PPP) or Serial Line Internet Protocol (SLIP). PPP has largely replaced SLIP access now a days, hence in the following discussions will assume PPP.

The ISP must also provide a means of resolving what are known as 'Domain Name' address queries. This process will be supplied by the ISP's Domain Name Server. The IP protocol provides a means of converting Domain Names which people can understand, into IP addresses (e.g., 012.345.678.9) which computers can understand. Thus when you type a URL into your web browser, the Domain Name part of the URL must first be converted into its IP address before the web page can be located and delivered to the browser. Each Domain Name is assigned its specific IP address when it is created, and so the process of converting one to the other is simply a matter of looking up its entry in a database. Finding where that particular Domain Name/IP address relationship is recorded and then using this information to make the correct conversion is the job of the 'Domain Name Server' (DNS).

The minimum basic services that an ISP must provide can be summarized as follows:

- Dial-up access for either analogue (public telephone) or digital (ISDN) telecom links.
- Support for handling IP packets
- Support for the PPP protocol
- Access to a Domain Name Server

As these are the basic minimum, most ISPs will provide these as a matter of course and will not necessarily advertise these capabilities.

Cc: stands for "carbon copy". Anyone listed in the Cc: field of a message receives a copy of that message when you send it. All other recipients of that message can see that the person you designated as a Cc: recipient has received a copy of the message.

Bcc: stands for "blind carbon copy". This is similar to the Cc: feature, except that Bcc: recipients are invisible to all the other recipients of the message (including other Bcc: recipients). For example, if you send a mesagge To: suryaamehta@yahoo.co.in and Bcc: jayashrimehta@yahoo.co.in, then suryaamehta sees himself as the message's only recipient. Jayashrimehta, on the other hand, is "in the know" - she can see that you sent the message To: suryaamehta, and that you blind-copied her. To add an entry in the Bcc: field, click the "Show BCC" link to the right of the "To:" field.

Note: To send a message, you must always specify atleast one recipient in the "To:" field. If you don't an error message appears when you attempt to send the message.

The maximum attachment size using Yahoo! Mail account for sending and receiving messages upto 10MB.

A subject gateway can be defined as a facility that allows easier access to network-based resources in a defined subject area. The simplest types of subject gateways are sets of Web pages containing lists of links to resources. The resources accessible through these gateways are reviewed, selected, evaluated and catalogued by information professionals or subject experts.

What is a search engine?

A search engine is a searchable database which collects information on web pages from the Internet, and indexes the information and then stores the result in a huge database where it can be quickly searched. The search engine then provides an interface to search the database.

Examples : Google, Alta Vista, Exite

A Search engine has **three** parts.

- **Spider:** Deploys a robot program called a spider or robot designed to track down web pages. It follows the links these pages contain, and add information to search engines' database. Example: **Googlebot** (Google's robot program)
- **Index:** Database containing a copy of each Web page gathered by the spider.
- **Search engine software :** Technology that enables users to query the index and that returns results in a schematic order.

How does a search engine work?

Types of search engines

In broad sense, search engines can be divided into two categories.

1. Individual search engines

An individual search engine uses a spider to collect its information regarding websites for own searchable index. There are two types of individual search engines.

i . General search engines

Examples: Google, AltaVista, HotBot, Lycos

ii. Subject specific search engines

Examples: MetaPhys, Chritech, ReligionExplorer, Chordie, ChemFinder

2. Meta search engines

A Meta search engine searches multiple individual engines simultaneously. It does not have its own index, but uses the indexes collected by the spiders of other search engines.

Example: metacrawler, Ixquick, mamma

Advantages of using search engines

Search engines are best at finding unique keywords, phrases, quotes, and information buried in the full-text of web pages since they normally index WWW documents word by word. Search engines allow the user to enter keywords, and then they are searched against its database. Users can use advanced search techniques such as phrase searching, truncation/wildcard searching, as well as for Boolean operators (AND, OR, NOT combinations). With comparison to web directories, search engines are huge databases and contain a large amount of materials. Also, the database is updated at a variable rate.

Download content

Downloading content from internet has become a commonplace activity for all internet users – in the home, in business and in schools. All internet users download content from time to time – typically programs, games, pictures, music, video and documents. Downloading content can be troublesome. Downloads can fail. Downloads can take excessive time. Downloads can be password-protected. Some content cannot be downloaded using your web browser. A download manager is a utility designed to fix all the problems you may be having downloading content from the internet. They have quickly become a must-have utility for all internet users. Download managers can accelerate your downloads, allow you to resume broken downloads and contain numerous features that allow to you get hard-to-get files from the internet.

Key terms

URL

A URL (or Uniform Resource Locator) is the location of a resource on the internet. The format of a URL includes the protocol (e.g. http://, https://, ftp://, mms://, etc.), the domain name (or IP address), and additional path information (or folder & file name). A URL may address a web page file, a program file, an image file, a CGI file, or any other type of file, folder or program. Download managers use URLs to find the location of files, web sites and FTP sites that you want to download. You input URLs when download content from the internet.

Examples of URLs are:

- http://www.conceiva.com/downloads/downloadstudio2200.exe
- ftp://ftp.microsoft.com/pub/msoffice.zip
- http://www.google.com
- http://www.itunes.com/hiphop/newtrack.mp3

Servers, Domains and Groups

A server name represents a single web server. For example, "www.conceiva.com" and "www.google.com" are examples of server names. Even "google.com" counts as a different server name since it is not the same as "www.google.com"

– even though if you visit "http://www.google.com" and "http://google.com" in your web browser you may see the same content. A domain name is the most general part of a server name. For example, "conceiva.com", "google.com" and "zdnet.co.uk" are examples of domain names. When downloading files, if you set the download job to span across Domains, it will download files from any servers that share the same domain name. For example, "www.conceiva.com", "images.conceiva.com" and "downloads.conceiva.com" all belong to the same domain "conceiva.com".

A group name refers to any number of servers that share the same name regardless of the country-specific part of the name. For example, "www.conceiva.net", "ftp.conceiva.org.au" and "images.conceiva.co.jp" would all be part of the same group, because they all contain the word "conceiva" directly before the country specific part of the name.

Using the URL "http://www.conceiva.com/images/logo.gif" as an example:

- "www.conceiva.com/images" is the folder name
- "www.conceiva.com" is the server name
- "conceiva.com" is the domain name
- "conceiva" is the group name

Data files.
An increasing number of businesses download data files from the internet on a daily basis – often as a regular scheduled backup of their online data or to simply get the latest up-to-date data for their business. Data files can be any type of file and can be large in size, requiring significant bandwidth and time to download.

Email

Most people will be familiar with the term email (electronic mail) in this day and age. It basically covers all messages sent over the Internet, normally between computer users, but also is now used with other internet-connected devices such as mobile phones. Email messages can be just text based or can also contain graphical or other multimedia information. One common misconception with email is that messages will always arrive immediately or at least very quickly (within minutes). Whilst this is often the case, any email relies on many computers and networks to be working, therefore emails are at risk of delays at any stage. However, sending messages within one system (such as the SHU First Class email service) should be immediate. To send email messages all you need to know is a valid address of the recipient - see addressing below. Messages can either be like formal letters or increasingly they are much more "conversational" where the emotions of the writer are expressed as emoticons (also called "smilies").

Internal and External Email Addresses

To send an email to someone else, you need to know their email address. Users can have internal and external email addresses.

Internal Email Addresses

Internal email addresses are listed in the directory of the email system you are using. At Sheffield Hallam University this is on First Class which is the email system used by all students. Staff use another system, Exchange, but are also listed in the First Class directory. All you need to know when you are searching for someone in the internal directory is usually their real name and the faculty they belong to. Using the directory to find the internal address of users depends a little on whether you are using the First Class client or the web interface. You can normally find the name you want by just typing part of the first and last names of a particular user.

Example: Open a New Message in First Class.

Typing in: **Vir Woo** into the To: field will match to a fictitious student user called "Virginia Woolf". If you are using First-Class client software you will need to press **Enter** to complete the name; if you are logging into your mailbox using the web interface via the Portal you will need to click on the **Add** button.

External Email Addresses

External email addresses are required for sending or receiving email outside the university. An external email address is also often known as an Internet email address. External email addresses have a very specific format - please see the example below. When using them you must type them exactly as specified. And if you quote your address for others to use it must be exactly right. External email addresses are made up of two parts separated by an @ (pronounced "at") sign: - the first part is the email name - the second part is the Internet address of an Internet "post box". The post box address is the address of a central server within the organisation in which the mailbox is located which handles all email before relaying on to personal mailboxes.

Example: Below is the external email address of our example student Virginia Woolf at Sheffield Hallam University.

virginia.woolf@student.shu.ac.uk is Internet email name and student postbox address. This address would be pronounced as:

" **virginia** dot **woolf** at **student** dot **S H U** dot **A C** dot **U K** ".

You can try sending test messages to Virginia Woolf to try out the different address formats.

Other Email Features

Other features you will commonly find when using email:

Cc: This stands for "carbon copy" or "courtesy copy" and is the field where you can put extra addresses in to send to other mailboxes if not the main recipient.

Bcc: Like c:, but the mailbox address entered in this field is not visible to the main recipient of the mail.

Attachment: Any file being sent along with the main message; eg a Word file, a picture etc.

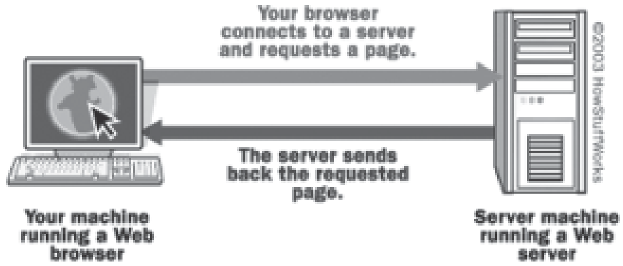
SPAM: Any unwanted and often malicious unsolicited emails. At SHU we try and detect these and mark them appropriately so that they can be deleted by the user without needing to open them.

How E-mail Works

A Simple E-mail Server

Given that you have an e-mail client on your machine, you are ready to send and receive e-mail. All that you need is an **e-mail server** for the client to connect to. Let's imagine what the simplest possible e-mail server would look like in order to get a basic understanding of the process shown in Fig 2. Then we will look at the real thing.

Fig 2



If you've read How Web Servers Work, then you know that machines on the Internet can run software applications that act as **servers**. There are Web servers, FTP servers, telnet servers and e-mail servers running on millions of machines on the Internet right now. These applications run all the time on the server machine and they listen to specific **ports**, waiting for people or programs to attach to the port. The simplest possible e-mail server would work something like this:

1. It would have a list of e-mail accounts, with one account for each person who can receive e-mail on the server. My account name might be **mbrain**, John Smith's might be **jsmith**, and so on.
2. It would have a text file for each account in the list. So, the server would have a text file in its directory named MBRAIN.TXT, another named JSMITH.TXT, and so on.
3. If someone wanted to send me a message, the person would compose a text message ("Marshall, Can we have lunch Monday? John") in an e-mail client, and indicate that the message should go to mbrain. When the person presses the Send button, the e-mail client would connect to the e-mail server and pass to the server the name of the recipient (mbrain), the name of the sender (jsmith) and the body of the message.
4. The server would format those pieces of information and append them to the bottom of the MBRAIN.TXT file. The entry in the file might look like this:

From: jsmith

To: mbrain

Marshall,

Can we have lunch Monday?

John

There are several other pieces of information that the server might save into the file, like the time and date of receipt and a subject line; but this is an extremely simple process.

The SMTP Server

Whenever you send a piece of e-mail, your e-mail client interacts with the SMTP (Simple Mail Transfer Protocol) server to handle the sending. The SMTP server on your host may have conversations with other SMTP servers to deliver the e-mail.

Let's assume that you want to send a piece of e-mail. your e-mail ID is brain, and you have account on howstuffworks.com. You want to send e-mail to jsmith@mindspring.com. You are using a stand-alone e-mail client like Outlook Express.

When you set up account at howstuffworks, Outlook Express the name of the mail server — mail.howstuffworks.com. When you compose a message and press the Send button, here's what happens:

1. Outlook Express connects to the SMTP server at mail.howstuffworks.com using port 25.
2. Outlook Express has a conversation with the SMTP server, telling the SMTP server the address of the sender and the address of the recipient, as well as the body of the message.

Computer networking, Network Cable Components, and Servers

Objectives : At the end of this lesson you shall be able to
- **explain the network**
- **state the components of a network**
- **explain the type of network topology**
- **state the types of cables and connectors used in nework**
- **explain P.C. server and webserver.**

Introduction

If there is one concept that facilitates a global community, it is networking. A network by definition is a collection of two or more computers connected together. Through these networked computers, people can share almost anything that include:

– **Data files:** Word processing, electronic spread sheet or presentation documents.

– **Peripheral devices:** Printers, monitors, scanners etc.

– **Software applications:** Bundled PC software such as MS-Office or Lotus Smart suite, Financial accounting software, database software etc.

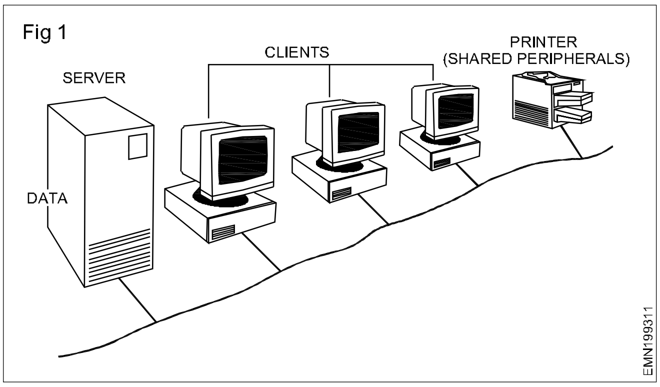
– **An internet connection:** Going On line to connect to another network or to send e-mail to another person.

In essence a network is a group of computers, printers and other devices that are connected together with cables. Information travels over the cables, allowing network users to share any hardware or software that is connected to the network.

Components of a network: All networks have certain components in common. They are:

Servers - computers that provides shared resources. Fig 1

Fig 1



Shared resources: Files, directories, applications, printers, CD rom drives, and other peripherals which are accessed by the users on the network.

Clients: Computers that access or use shared resources from server

Media: The physical cable that connects the computers in a network.

Network interface card: To convert a standalone computer to be connected to a network, first a network interface card has to be plugged into the PCs expansion slot and configured.

Network topology

The term network topology refers to the arrangement or physical layout of computers, cables and other components on the network. The term Topology is also commonly used to refer to the network's basic design. Topology is an important issue when you plan for a network. It depends on the type of cable and protocol to be used in the network.

The most common topologies are:

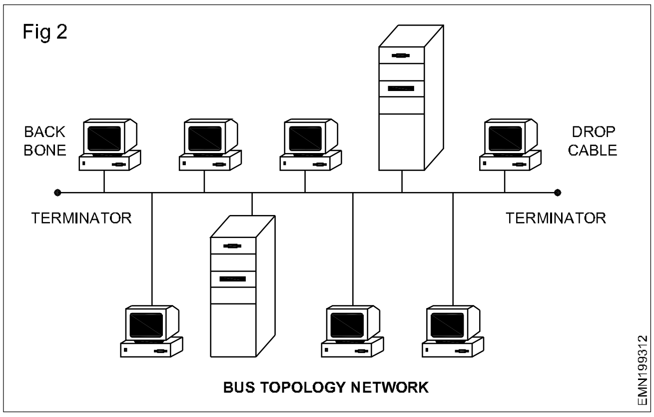
1 Bus

2 Star

3 Ring

Bus Topology:

Fig 2



In this type of arrangement as shown in Fig 2, computers are connected in a row. This is the simplest and most common method of networking computers. The cable that is used to connect all the computers is also called as backbone. Bus topology networks use coaxial cable. They use BNC connectors to connect all the individual cables. Each computer is connected to the network through the use of a BNC. This connection allows the backbone cable to be continued to the next computer. To make a longer piece of cable, a component called a barrel connector is used.

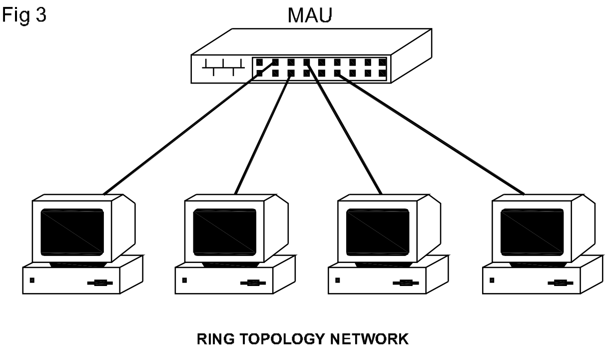
In this topology, the network data is sent in the form of an electronic signal along with the MAC (Manufacturer address code) address of the machine to which data has to be sent. All the computers on the network receive this data. But only the computer whose address matches the address in the data sent over the network will accept the information. Only one computer at a time can send messages over the network.

Because the data, or electronic signal, is sent to the entire network, it will travel from one end of the cable to the other. If the signal were allowed to continue uninterrupted, it would keep bouncing back and forth along the cable and prevent other computers from sending signals. Therefore, the signal must be stopped after it has reached the proper computer. To stop the signal from bouncing, a component called Terminator is placed at each end of the cable to absorb free signals. Absorbing the signal clears the cable so that other computers can send data. The protocol that is used in bus topology is Ethernet.

If the cable is physically cut or if any one end of the cable gets disconnected from the terminator or T-connector, the entire network is down. Then the computers will not be able to communicate with each other.

Ring Topology: The ring topology connects computers on a single circle of cable. There are no terminators at the end of cable like in bus topology. Refer to the Fig 3 shown below.

Fig 3



he signals travel around the loop in one direction and pass through each computer. Each computer boosts the signal and sends it to next computer. Because the signal passes through each computer in the ring, the failure on one computer effect the entire network.

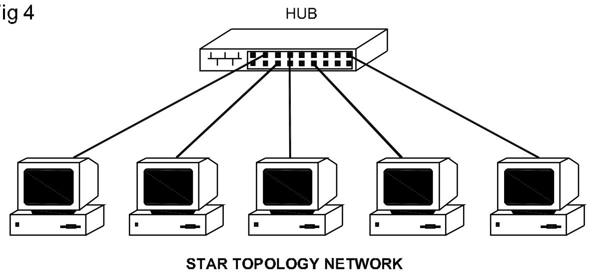
Though the computers are logically connected in a ring fashion, the actual cables from the NIC of the computer gets connected to the MAU or Multistation Access Unit centrally. The function of the MAU is to accept signals transmitted from one computer and direct the signals to the computer to which it is addressed.

One method of transmitting data around a ring is called token passing. A token is passed from one computer to the next and so on. When a station wants to transmit on the ring, it waits for a free token to pass by. The sending computer takes the token. It modifies by putting an electronic address of the computer to which it has to transmit. Then it sends the token out on the rings. As the busy token passes by, each computer on the ring checks the token's address. If the address does not match with its own address, it sends the token to the next computer. If the address matches, the computer copies the data from the token. It also returns a message on the token to the sending computer indicating that the data has been received. After verification, the sending computer creates a new token and releases it on the network.

Token ring topology uses category 3/4/5 UTP or fibre optic cable. Though originally 4 Mbps speed was used, the typical speed used now is 16Mbps. A newer version of fast token ring standard also exists that enhances the speed to 100 Mbps.

Star Topology: In this type, computers are connected by cables to a centralised component, called a hub. Signals are transmitted from the sending computer through the Hub to all the computers on the network as shown in Fig 4.

Fig 4



Star topology is easy to install. You must install a separate cable from the Hub to the computer. So it may require more cabling than other topologies. Shifting, adding and removal of nodes are very simple. Even if one cable breaks down, only that computer gets affected on the network and the rest is operational. UTP or FTP cables Cat5 or Ecat5 may be used for achieving speeds upto 100/1000 Mbps. They are limited to a length of 100 meters (328 feet) for each node connection.

There is no limitation in the number of nodes in a segment. Uses RJ-45 connectors for all connections.

Network Architecture

Network architecture combines standards, topologies and protocols to produce a working network. Ethernet is currently the most popular network architecture. It uses a bus topology, it follows the IEEE's 802.3 specification.

The Ethernet media draws power from the computer and this will not fail unless the media is physically cut or improperly terminated. The transfer speed is 10/100 Mbps. It supports Thin, Thick coaxial cables and UTP.

Cables or Transmission media

Network computers must have a pathway to contact other computers. The physical path through which the electrical signals travel is called transmission media or cables.

Cable media are wires or fibres that conduct electricity or light. The following types of cables are used in LAN.

1 Twisted pair cable

2 Co-axial cable

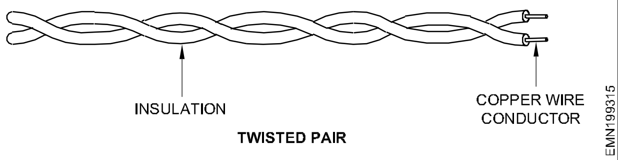
3 Fiber optical cable

1 Twisted pair cable

Twisted pair is a common scheme for using copper wire as telecommunication cable because copper is a good conductor of electrons. Twisted copper wires reduces cross talk and signal emissions.

Twisted pairs are formed by two insulated 22 to 26 gauge copper wires that are twisted about each other as in Fig 5. These twisted cables are available in two types.

Fig 5



The two types of cables are:

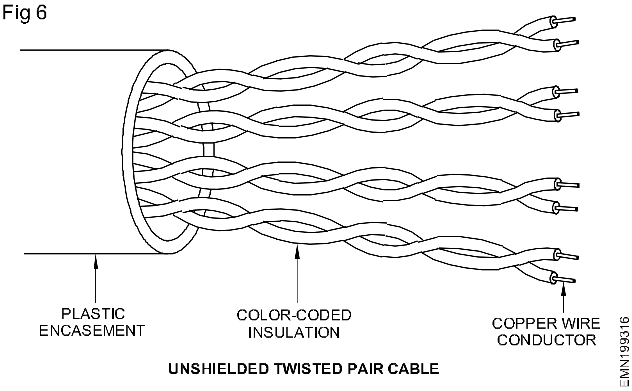
– Unshielded twisted pair cable.(UTP)

– Shielded twisted pair cable. (STP)

Unshielded twisted pair cable (UTP)

Unshielded twisted pair cable is composed of a set of twisted pairs with a simple plastic encasement as in Fig 6.

Fig 6



It is commonly used in telephone systems and has been largely standardized.

Twisted pair network cables are rated in terms of their capability to carry network traffic. They are referred as category 3, 4 and 5.

Category 3/Cat 3	-	10 Mbps	-	used for voice grade telephone or 10 mbps ethernet
Category 4/Cat 4	-	16 Mbps	-	Token ring network
Category 5/Cat 5	-	100 Mbps	-	For 100 Mbps Ethernet
/ECat 5	-	100/1000 Mbps		

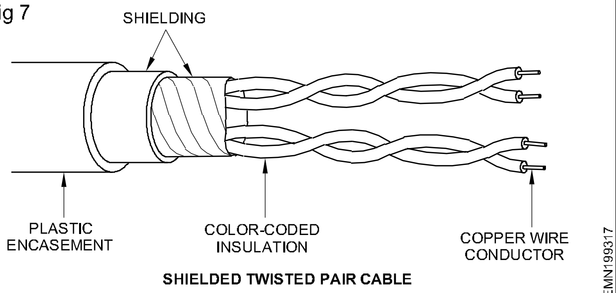
ECategory 5 and category 5 UTP are commonly used in computer networking.

UTP cables are limited to a length of 100 meters (328 feet) for each node to Hub connection.

Shielded twisted pair cable

Today, the mostly used cable is UTP. But some forms of shielded twisted pair (STP) still exist. The below Fig 7 shows the STP cable. It is used in places where electromagnetic interference caused by electric motors, power lines and other sources.

Fig 7



The STP is insulated cable which includes bundled pair wrapped in a foil shielding.

UTP

UTP is a popular choice for structured cabling systems used widely in office network environments. Structured cabling system is a network cabling pattern which follows strict engineering design rules. It allows voice, data and video to be transmitted/received on the same cabling system. It allows shifting, adding and replacing the nodes easily.

The cabling starts from the Hub or switch which is placed in a Rack centrally. A patch cable (usually 6-10 feet long) connects a port on the hub to a patch panel which is also in the Rack using RJ-45 connectors on each end. On the back side of the patch panel, the UTP cable is hard-wired or crimped to the panel connector. From the patch panel, theUTP cable runs continuously to a wall jack or information outlet (I/O). The information outlet contains a RJ-45 jack called I/O jack in it.

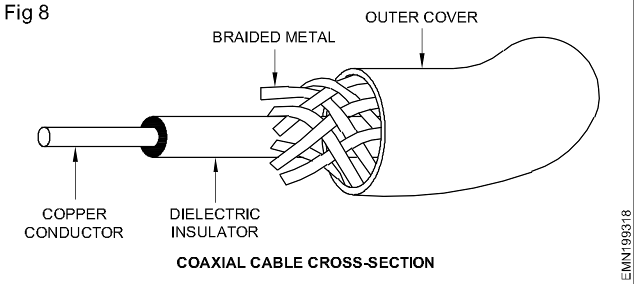
The UTP cable is crimped to the information outlet. Another patch cable connects to the RJ-45 jack in the information outlet and the other end gets connected to the NIC of the computer. Note that the distance from the connector on the hub to the connector on the computer's NIC cannot exceed 100 metres of cable length.

2 Co-axial cable

Co-axial cable commonly called ("Coax") is made of two conductors that share a common axis, hence the name ("co", "axis"). typically, the centre of the cable is relatively stiff solid copper wire or stranded wire surrounded by an insulating plastic foam. The foam is surrounded by the second conductor, a wire mesh tube as in Fig 8.

Several co-axial cable standards are in comon use for computer networking. The most common types meet one of the following ohm and size stanards.

Fig 8



COAXIAL CABLE CROSS-SECTION

– 50 ohm RG-8 and RG-11 (used in thick Ethernet specifications.)

– 50 ohm RG-58 (used in thin Ethernet specifications).

– 75 ohm RG-62 (used for ARC net specifications)

The co-axial cable can handle a speed of only 10 Mbps maximum and the distance it can drive is only 185 m maximum.

Types of Co-axial cable

There are two types of co-axial cable

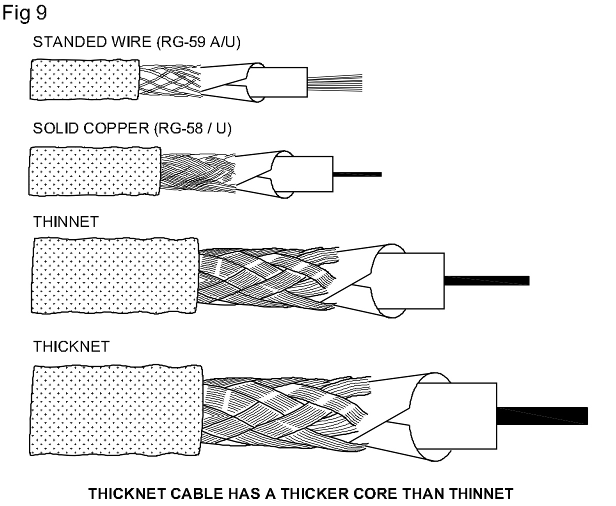
– Thin (Thinnet)

– Thick (Thicknet)

Thinnet: Thinnet is a flexible coaxial cable about 0 .25 inch thickness. Because this type of coaxial is flexible and easy to work with, it can be used in almost any type of network installation. Networks that use a thinnet have the cable connected directly to a computer's network interface card.

Thinnet is included in a group referred to as the RG-58 family and has a 50-ohm impedance. The main difference in the RG-58 family is the center core of copper. It can be a either stranded wire or solid copper core.

Fig 9



THICKNET CABLE HAS A THICKER CORE THAN THINNET

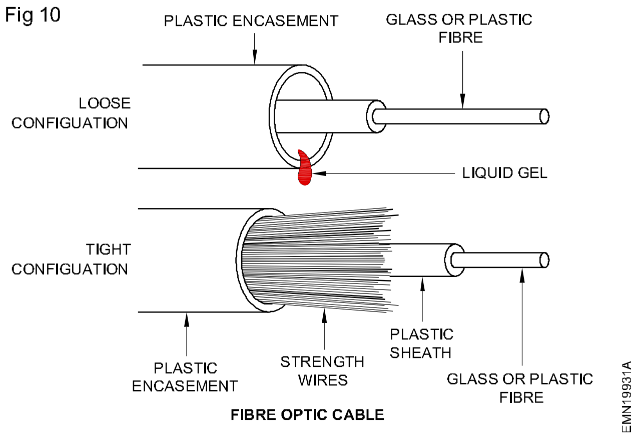
Thicknet: Thicknet is relatively rigid co-axial cable about 0.405 inches in diameter. The copper core is thicker than a thinnet core as shown in Fig 9. This cable is typically installed along the floor of the site. They are usually yellow in colour and is marked every 2.5 metres for the taps to which the computers connect. To connect a computer to the cable, you apply a vampire tap. A vampire tap is a clamp that you connect to the cable after drilling a hole in the sheath. The Vampire tap includes a component called transceiver which connects to the NIC with an AVI cable that has 15 pin shell connectors at both ends. The thick Ethernet segment can have max. cable distance upto 500 metres and a speed of 10 Mbps.

3 Fiber Optic Cable

Fiber optic cable is made of light-conducting glass or plastic core surrounded by more glass and a tough outer sheath as in Fig 10.The center core provide the light path or wave guide while the glass or cladding is composed of varying layers of reflective glass. The glass cladding is designed to refract light back into the core. Each core and cladding strand is surrounded by a tight or loose sheath in tight configurations, the strand is completely surrounded by the outer plastic sheath. Loose configuration use a liquid gel or other material between the strand and the protective sheath.

The optical fibers may be multimode or single mode in nature. Single mode fiber has been optimized to allow only one light path while multimode fiber allows various paths. Single mode fiber cable can be used for distances upto 10 kms. and multimode cable for upto 2.5 km. The typical speeds are 100/1000 Mbps. The types of optic cable are differentiated by mode, composition (glass or plastic) and core/cladding size.

Fig 10



FIBRE OPTIC CABLE

Common types of fiber optical cables:

– 8.3 micron core/125 micron cladding single mode

– 62.5 mciron core/125 micron cladding multimode

– 50 micron core/125 micron cladding multimode

– 100 micron core/140 micron cladding multimode

The signal carried by a single mode cable is generated by a laser source and that of a multimode by light emitting diode (LED). Together, these qualities allow single mode cable to operate at higher bandwidths than multimode and traverse distances upto 50 times longer. Single mode cable is cheaper than multimode and has a relatively high bend radius, which makes it more difficult to work with. MMF is most commonly used.

Fiber optic connectors

The connector used on fiber optic cables is called an ST (straight tip) connection.

One more connector type is SC (subscriber connector) is coming up popularly. It has a square body and locks by simply pushing it into the socket.

The MTRJ is a new fiber optic connector being used widely. It can operate at Gigabit ethernet speeds (1000 Mbps) easily. The MT-RJ has a latching mechanism similar to the RJ-45 UTP connector. A standard MT-RJ connection consists of 3 components: a male connector (with pins), a female MT-RJ (with guide holes) and as MTRJ adapter. It is easy to install and maintain and should be considered for any new installation.

Fiber-optic connectors can attach to the cable in several ways, using either a crimped compresion fitting or an epoxy glue.

Fiber cables are mainly used for backbone connectivity across the floors or when the distance cannot be covered by UTP cable limitation or when the network path to be connected is exposed to sky.

Fiber cables come in three varieties depending on the place of usage.

1 Indoor cable - for in-house usage within buildings.

2 Outdoor cable/Armoured cable - to be used in areas which are exposed to sky. Has an additional hard shield to prevent any occassional damage.

3 Indoor/outdoor cable can be used inside and outside buildings. Does not carry heavy shield as in outdoor cable, but better than indoor cable.

Different types of network connectivity hardware

In a network number of hardware devices are used to connect each computer to a media segment. These devices are:

1 Transmission media connectors

2 Network interface boards

3 Modems

We can also connect multiple separate segments of transmission media to form one large network. For this purpose, use the following networking devices.

1 Repeaters

2 Hubs

3 Bridges

4 Multiplexers

5 Transceiver

6 Routers

1 Transmission media connectors:

Every medium has one or more physical connectors to which can attach various devices.

BNC (Bayonet nut connector)

It is a connector for co-axial cable that locks when one connector is inserted into another and is rotated 90 degrees.

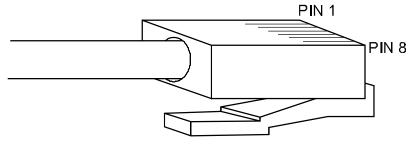
T-connector: A T-shaped co-axial connector that connects two thinnet co-axial cables while supplying an additional connector for a network interface card.

Terminators: A resistor used at each end of a co-axial cable to ensure that signals do not reflect back and cause errors. The terminators should be of 50 ohm resistance.

Barrel connector: Barrel connector is used to connect two pieces of cable together to make a longer piece of cable.

RJ-45: An eight wire modular connector used to join a network cable to a wall plate or some other device. It is similar to an RJ-11 telephone conenctor but has twice the number of conductors. The number of pins are explained in below table. Fig 11.

Fig 11



PIN NUMBER	WIRE COLOR
1	WHITE - ORANGE
2	ORANGE
3	WHITE - GREEN
4	BLUE
5	WHITE - BLUE
6	GREEN
7	WHITE - BROWN
8	BROWN

MODULAR CONNECTOR

EMN19931B

RS 232: (Reference Standard 232) An industry standard for serial communication connections. Adopted by the Electrical Industries Association (EIA). This recommended standard (RS) defines the specific lines and signal characteristics used by serial communications controllers to standardise the transmission of serial data between devices. RS 232 pin assignments details are given in the following Fig 12 and 13.

Transceiver: A device that connects a computer to the network. The term transceiver is derived from transmitter/ receiver, so a transceiver is a device that receives and transmitts the signals. It switches the parallel data stream used in the cables connecting the computers.

Network interface cards

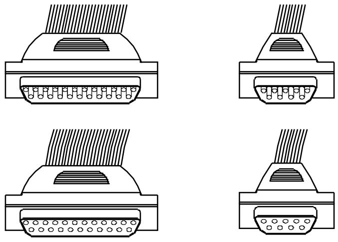
Network interface cards act as the physical interface or connection between the computer and the network cable.The cards are installed in an expansion slot in each computer and server on the network.

After the card has been installed, the network cable is attached to the card's port to make the actual physical connection between the computer and the rest of the network.

Modems (Modulator/Demodulators) converts your computers digital signals to an analog transmission signal to use with telephone lines or microwave transceivers. The Fig 14 shows modem.

Suppose that one of your computers was located across the city. You can use a modem to connect to that computer using telephone line or microwave transceivers.

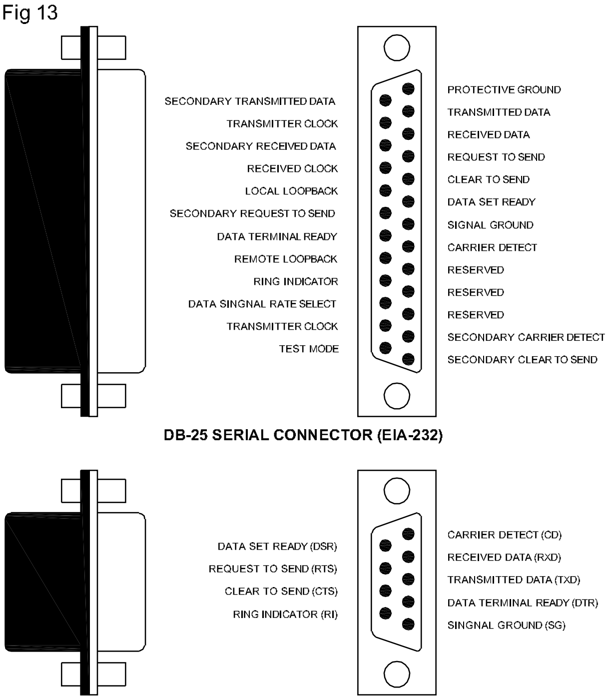
Fig 12



INDUSTRY STANDARD FOR SERIAL COMMUNICATION

EMN19931C

Fig 13

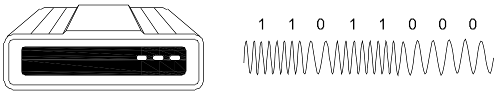


DB-9 SERIAL CONNECTOR (EIA-574)

RS-232 PIN ASSIGNMENTS

EMN19931D

Fig 14

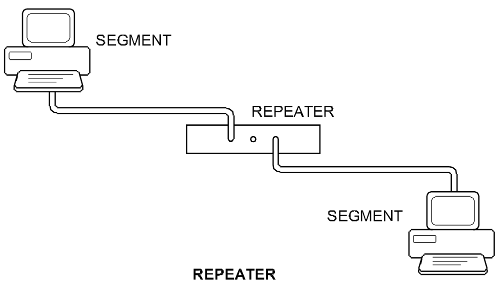


MODEM

EMN19931E

Repeaters: Electro magnetic waves become weaker as they pass through transmission medium. Each transmission medium can only be used for a certain distance. One can exceed the physical mediums maximum effective distance by using an amplification device called repeater. Repeater is shown in Fig 15.

Fig 15

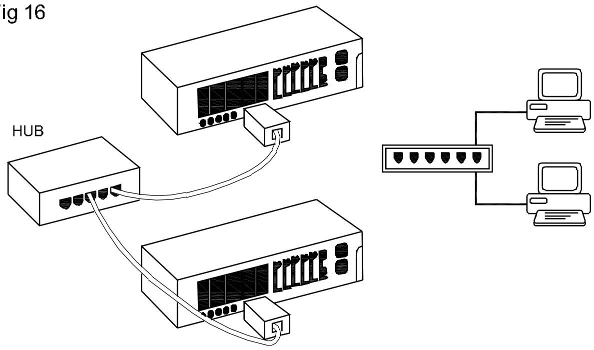


REPEATER

EMN19931F

Hubs: Some networks require a central point of connection between media segments. These central points are referred to as hubs is shown in Fig 16.

Fig 16



HUBS

EMN19931G

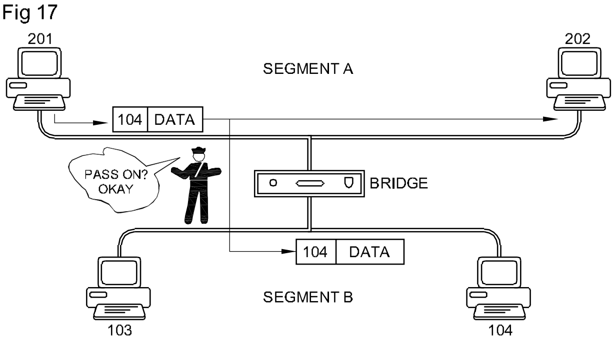
Bridges: A bridge extends the maximum distance of your network by connecting separate network segments. Bridges selectively pass signals from one medium segment to another as in below Fig 17.

The above figure explains that

– Receive all signals sent on segment A.

– Discard signals addressed to other nodes on segment A.

Fig 17



RS-232 PIN ASSIGNMENTS

EMN19931H

– Retransmit all other signals out of the appropriate ports

– Perform the same functions for data on other connected segments.

Multi plexers: A multiplexer combines two or more separate signals on a single transmission media segments i.e. to efficiently use the entire transmission media band width, we can use multiplexers.

Routers: Routers connect two or more logically separate networks (consisting of several network segments with different protocols and architectures) is called router.

PC-Server: The term client-server can describe hardware, in which case it is referring to network servers and client computers, or it can refer to a way of organising software applications and services on a network. Client server computing is a powerful way of constructing programs on a network. In order to describe its advantage and how it works, we will first describe two alternatives to client-server computing:

– Centralised computing

– Client computing with central file storage

Centralized computing : Centralized computing originated with mainframe computers and time-sharing. The principle behind centralized computing is that a central computer executes a program, such as a database or a transaction-processing program (for instance, an airline reservations system or a bank records program) and remote terminals merely display data on a screen and convey keyboard data back to the central computer.

In modern networks, personal computers can perform the role of dumb terminals. With Windows software, the PC can appear to the central computer as many terminals, each virtual terminal accessing different data or performing a separate transaction on the mainframe.

In centralized computing it is the central computer that does all the work. The data resides on the central computer and the program executes on the central computer. The personal computer or dumb terminal only display screen data and accepts keystrokes for the central computer to process. Centralized computing does not fully use the capabilities of today's powerful network clients.

Client computing with Central file storage : At the opposite end of the spectrum from centralized computing is client computing with central file storage (see Fig 40). In this way of organizing an application, the client computer does all the work. A central file server stores, but that is all.

Client computers cooperate to ensure that central files are not corrupted by attempts by several computers to access them at the same time. When a client computer needs to perform an operation, the file is transferred to the client computer to perform the operation. Two examples of this type of application are networked database programs that do not use a SQL. (Structured Query Language) server and any network-aware application that does not communicate with a special program executing on the server, such as network scheduling programs and groupware.

While it is fully exploits the capabilities of client computers and provides a richer and more customizable environment for the user, this type of program can place heavy demands on the network if the data files in which program works with are large. It also takes time to transmit data from the server to the client, process the data, and transfer it back to the server so other network programs can access the data.

The Client-Server Model : The Client-server model combines the advantages of both the centralized computing model and the client model of computing. It does this by performing the operations that are best executed by a central computer on the file server and performing those operations that are best done close to the user on the client computer. The client-server model works best when many people need access to large amounts of data. Simply stated, a client-server system is any system in which the client computer makes a request over a network to a server computer that then satisfies the request.

The Client : When you use a client-server system, what you see is the client, or front end. It presents the interface to manipulate or search for data. The request you make by manipulating windows, menu, check boxes and so on, is translated into a compact form that the client transmits over the network for the server to perform.

One example of a front end is Microsoft Access when it is used with a SQL back end. Access displays tables in windows or in forms you can browse. It allows you to modify and search the tables in an easy-to-use graphical environment. All the actual data manipulation, however, occurs on the SQL server. Access translates all the data-base operations into SQL for the server to perform. The results of the operations are transmitted back to Access to display in an intuitive, graphical form.

SQL is not limited to database programs such as Microsoft Access. User programs such as Microsoft Excel can use SQL to query the back-end data-base server for values to use in spreadsheet calculations. Program tools allow custom programs to store and retrieve data in server-based databases. Query tools provide direct access to the SQL data.

The Server : The server is where data operations in a client-server system occur. The central computer can service many client requests quickly and efficiently, which is the traditional advantage of centralized computing. The central computer can also provide enhanced security by performing only authorized operations on the data.

Back-end database software is optimized to perform searches and sorts and the back-end computer is often more powerful than the front-end computer.

Web server : A web server is a program using the client/server model and the World Wide Web's Hyper Text Transfer Protocol (HTTP) serves the files that form web pages to web users.

Every computer on the internet that contains a web site must have a web server program. The most popular web servers are: The Microsoft's Internet Information Server (IIS) which comes with the Microsoft's Windows NT Server; Netscape Fast Track and Enterprises Servers and Apache, a web server for Unix-based operating systems. Other web servers include Novell's Web Server for users of its Netware Operating System and IBM's family of Lotus Domino Servers. Primarily for IBM's OS/390 and AS/400 customers.

Web servers often come as a part of a larger package of Internet related programs for serving e-mail, downloading requests for File Transfer Protocol (FTP) files and building and publishing web pages. Consideration in choosing a web server include how well it works with the operating system and other servers, its ability to handle server side programming and publishing, search engine and site building tools that may come with it.

WiFi Network

Objective: At the end of this lesson you shall be able to
- **explain the bluetooth device**
- **explain wifi and network protocols.**

Wireless network

Connecting to a network using wires has become nowadays outdated as most times availability of wireless networks is there in public places.

Wireless network uses the connections through wifi devices and bluetooth devices.

Bluetooth device

Bluetooth device are installed inside devices like mobile phones laptops and on a seperate adapters in desktops. It connects devices by identification using machine id and one-to-one basic paired connections. The date shared between paired devices are about Mbps in normal USB mode. Sharing internet is also availabe in bluetooth networks. The only restriction is its connecting area and speed of transmission.

WiFi device

Compared to bluetooth the wifi devices are very fast in transmitting data and area of coverage and connecting devices are also more. Wifi also used to connect a LAN using TCP/IP settings. Unlike bluetooth, wifi is secured with connection. Key as passwords, which restricts unauthorised accessing of network and sharing internet connections. Configuring wifi network using a mobile phone is very easy as just select '"wifi hotspot" to share its internet connectivity and access from other devices by providing pass key. Also when dhcp mode is enabled in a wifi modem, systems can easily be connected to the network as configured.

Wi-Fi

Wi-Fi or WiFi (/'waifai/') is technology for radio wireless local area networking of devices based on th IEEE 802.11 standards. Wi-Fi is a trademark of the Wi-Fi Alliance, which complete interoperability certification testing.

Devices that can be Wi-Fi technology include personal computers, video-game consoles, smartphones and tablets, digital cameras, smart TVs, digital audio players and modern printers. Wi-Fi compatible devicescan connect to the internet via a WLAN and a wireless access point.Such an acceass point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometers achieved by using multiple overlapping access points.

Depiction of a device sending information wirelessly to another device, both connected to the local network, in order to print a document.

Wi-Fi most commonly uses the 2.4 gigahertz (12 cm) UHF and 5.8 gigahertz (5cm) SHF ISM radio bands, these bands are subdivided into multiple channels. Each channel can be time-shared by multiple networks. These wavelengths work best for line-of sight. Many common materials absorb or reflect them, which further restricts range, but can tend to help minimise interference between different networks in crowded environments. At close range, some versions of Wi-Fi, running on suitable hardware can achieve speeds of over 1 Gbps.

Anyone within range with a wireless network interface controller can attempt to access a network; because of this, Wi-Fi is more vulnerable to attack (called eavesdropping) than wired networks. Wi-Fi protected access is a family of technologies created to protect information moving across Wi-Fi networks and includes solutions for personal and enterprise networks. Security features of Wi-Fi protected Access have included stronger protections and new security practices as the security landscape has changed over time.

Network Protocol

Rules of Network Protocol include guidelines that regulate the following characteristics of a network: access method, allowed physical topologies, types of cabling, and speed of data transfer.

Types of Network Protocols

The most common network protocols are:

- Ethernet
- Local Talk
- Token Ring
- FDDI

ATM

The followings are some commonly used network symbols to draw different kinds of network protocols.

Ethernet

The Ethernet protocol is by far the most widely used one. Ethernet uses an access method called CSMA/CD (Carrier Sense Multiple Access/Collision Detection). This is a system where each computer listens to the cable before sending anything through the network. If the network is clear, the computer will transmit. If some other nodes have already transmitted on the cable, the computer will wait and try again when the line is clear. Sometimes, two computers attempt to transmit at the same instant. A collision occurs when this happens. Each computer then backs off and waits a random amount of time before attempting to retransmit. With this access method, it is normal to have collisions. However, the delay caused by collisions and retransmitting is very small and does not normally effect the speed of transmission on the network.

The Ethernet protocol allows for linear bus, star, or tree topologies. Data can be transmitted over wireless access points, twisted pair, coaxial, or fiber optic cable at a speed of 10 Mbps up to 1000 Mbps.

Fast Ethernet

To allow for an increased speed of transmission, the Ethernet protocol has developed a new standard that supports 100 Mbps. This is commonly called Fast Ethernet. Fast Ethernet requires the application of different, more expensive network concentrators/hubs and network interface cards. In addition, category 5 twisted pair or fiber optic cable is necessary. Fast Ethernet is becoming common in schools that have been recently wired.

Local Talk

Local Talk is a network protocol that was developed by Apple Computer, Inc. for Macintosh computers. The method used by Local Talk is called CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). It is similar to CSMA/CD except that a computer signals its intent to transmit before it actually does so. Local Talk adapters and special twisted pair cable can be used to connect a series of computers through the serial port. The Macintosh operating system allows the establishment of a peer-to-peer network without the need for additional software. With the addition of the server version of AppleShare software, a client/server network can be established.

The Local Talk protocol allows for linear bus, star, or tree topologies using twisted pair cable. A primary disadvantage of Local Talk is low speed. Its speed of transmission is only 230 Kbps.

Token Ring

The Token Ring protocol was developed by IBM in the mid-1980s. The access method used involves token-passing. In Token Ring, the computers are connected so that the signal travels around the network from one computer to another in a logical ring. A single electronic token moves around the ring from one computer to the next. If a computer does not have information to transmit, it simply passes the token on to the next workstation. If a computer wishes to transmit and receives an empty token, it attaches data to the token. The token then proceeds around the ring until it comes to the computer for which the data is meant. At this point, the data is captured by the receiving computer. The Token Ring protocol requires a star-wired ring using twisted pair or fiber optic cable. It can operate at transmission speeds of 4 Mbps or 16 Mbps. Due to the increasing popularity of Ethernet, the use of Token Ring in school environments has decreased.

FDDI

Fiber Distributed Data Interface (FDDI) is a network protocol that is used primarily to interconnect two or more local area networks, often over large distances. The access method used by FDDI involves token-passing. FDDI uses a dual ring physical topology. Transmission normally occurs on one of the rings; however, if a break occurs, the system keeps information moving by automatically using portions of the second ring to create a new complete ring. A major advantage of FDDI is high speed. It operates over fiber optic cable at 100 Mbps.

ATM

Asynchronous Transfer Mode (ATM) is a network protocol that transmits data at a speed of 155 Mbps and higher. ATM works by transmitting all data in small packets of a fixed size; whereas, other protocols transfer variable length packets. ATM supports a variety of media such as video, CD-quality audio, and imaging. ATM employs a star topology, which can work with fiber optic as well as twisted pair cable.

ATM is most often used to interconnect two or more local area networks. It is also frequently used by Internet Service Providers to utilize high-speed access to the Internet for their clients. As ATM technology becomes more cost-effective, it will provide another solution for constructing faster local area networks.

Internet Protocol (TCP/IP)

Definition

Transmission Control Protocol/Internet Protocol (TCP/IP)

Transmission Control Protocol/Internet Protocol (TCP/IP) is the language a computer uses to access the internet. It consists of a suite of protocols designed to establish a network of networks to provide a host with access to the internet.

TCP/IP is responsible for full-fledged data connectivity and transmitting the data end to end by providing other functions, including addressing, mapping and acknowledgment. TCP/IP contains four layers, which differ slightly from the OSI model.

The technology is so common that one would rarely use the full name. In other words, in common usage the acronym is now the term itself.

Techopedia explains Transmission Control Protocol/ Internet Protocol (TCP/IP)

Nearly all computers today support TCP/IP. TCP/IP is not a single networking protocol - it is a suite of protocols named after the two most important protocols or layers within it - TCP and IP.

As with any form of communication, two things are needed: a message to transmit and the means to reliably transmit the message. The TCP layer handles the message part. The message is broken down into smaller units, called packets, which are then transmitted over the network. The packets are received by the corresponding TCP layer in the receiver and reassembled into the original message.

The IP layer is primarily concerned with the transmission portion. This is done by means of a unique IP address assigned to each and every active recipient on the network.

TCP/IP is considered a stateless protocol suite because each client connection is newly made without regard to whether a previous connection had been established.

File Transfer Protocol (FTP)

File Transfer Protocol(FTP) is an application layer protocol which moves files between local and remote file systems. It runs on the top of TCP, like HTTP. To transfer a file, 2 TCP connections are used by FTP in parallel: control connection and data connection

Control connection

For sending control information like user identification, password, commands to change the remote directory, commands to retrieve and store files etc., FTP makes use of control connection. Control connection is initiated on port number 21.

Data connection

For sending the actual file, FTP makes use of data connection. Data connection is initiated on port number 20.

FTP sends the control information out-of-band as it uses a separate control connection. Some protocols send their request and response header lines and the data in the same TCP connection. For this reason, they are said to send their control information in-band. HTTP and SMTP are such examples.

FTP Session

When a FTP session is started between a client and a server, the client initiates a control TCP connection with the server side. The client sends the control information over this. When the server receives this, it initiates a data connection to the client side. Only one file can be sent over one data connection. But the control connection remains active throughout the user session. As we know HTTP is stateless i.e. it does not have to keep track of any user state. But FTP needs to maintain a state about its user throughout the session.

Data Structures

FTP allows three types of data structures

1 File Structure - In file-structure there is no internal structure and the file is considered to be a continuous sequence of data bytes.

2 Record Structure - In record-structure the file is made up of sequential records.

3 Page Structure - In page-structure the file is made up of independent indexed pages.

Integrated circuit voltage regulators

Objectives : At the end of this lesson you shall be able to
- **state the classification of integrated circuits**
- **state the specification of I.C**
- **state the types of IC voltage regulators.**

Introduction

Electronic circuits invariably consist of a number of discrete components connected to each other in a specific way. For instance, the series regulator circuit discussed in earlier lessons, consisted of transistors, zener diodes, resistors and so on, connected in a defined way for it to function as a regulator. If all these components instead of building on a board, if they are built on a single wafer of a semiconductor crystal, then, the physical size of the circuit becomes very very small. Although small, this will do the same job as that of the circuit wired using discrete components. Such miniaturised electronic circuits produced within and upon a single crystal, usually silicon, are known as **integrated circuits** or **IC**s. Integrated circuits (ICs) can consist of thousands of active components like transistor, diodes and passive components like resistors and capacitors in some specific order such that they function in a defined way, say as voltage regulators or amplifiers or oscillators and so on.

Classification of integrated circuits

Integrated circuits may be classified in several ways. However the most popular classifications is as follows:

1 **Based on its type of circuitry**

(a) Analog ICs - Example: amplifier ICs, voltage regulator ICs etc.

(b) Digital ICs - Example: Digital gates, flip-flops, adders etc.

2 **Based on the number of transistors built into IC**

(a) Small scale integration (SSI) - consists of 1 to 10 transistors.

(b) Medium scale integration (MSI) - consists of 10 to 100 transistors.

(c) Large scale integration (LSI) - 100 to 1000 transistors.

(d) Very large scale integration (VLSI) - 1000 and above.

3 **Based on the type of transistors used**

(a) Bipolar - carries both electron and hole current.

(b) Metal oxide semiconductor (MOS) - electron or hole current.

(c) Complementary metal oxide semiconductor (CMOS) - electron or hole current.

Integrated circuit (IC) voltage regulators

The series voltage regulators discussed in earlier lessons are available in the form of integrated circuits (ICs). They are known as voltage regulator ICs.

There are two types of voltage regulator ICs. They are,

1 Fixed output voltage regulator ICs

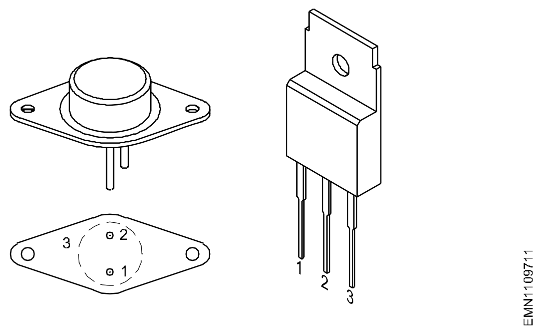
2 Adjustable output voltage regulator ICs.

Fixed output voltage regulator ICs

The latest generation of fixed output voltage regulator ICs have only three pins as shown in Fig 1. They are designed to provide either positive or negative regulated DC output voltage.

These ICs consists of all those components and even more in the small packages shown in Fig 1. These ICs, when used as voltage regulators, do not need extra components other than two small value capacitors as shown in Fig 2.

Fig 1

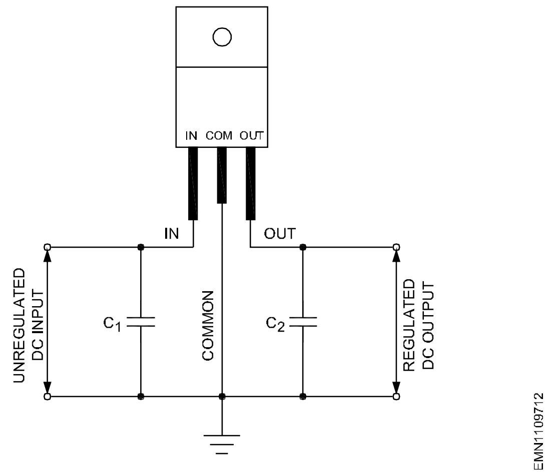


The reason behind using capacitor C_1 is, when the voltage regulator IC is more than a few inches from the filter capacitors of the unregulated power supply, the lead inductance may produce oscillations within the IC. Capacitor C_1 prevents setting up of such oscillations. Typical value of bypass capacitor C_1 range from 0.220μF to 1μF. It is important to note that C_1 should be connected as close to the IC as possible.

The capacitor C_2 is used to improve the transient response of the regulated output voltage. C_2 bypasses these transients produced during the ON/OFF time. Typical values of C_2 range from 0.1μF to 10 μF.

Fixed voltage three terminal regulators are available from different IC manufacturers for different output voltages (such as 5V, 9V, 12V, 24V) with maximum load current rating ranging from 100mA to more than three amps.

Fig 2



The most popular three terminal IC regulators are,

1 LMXXX-X series

Example: LM320-5, LM320-24 etc.

2 78XX and 79XX series

Example: 7805, 7812, 7912 etc.

A list of popular three terminal regulators is given in Pocket Table Book, Table No.30.

Specifications of three terminal IC regulators

For simplicity in understanding, let us consider the specification of a three terminal IC µA7812. The table given below lists the specifications of µA7812.

Parameter	Min.	Typ.	Max.	Units
Output voltage	11.5	12	12.5	V
Output regulation		4	120	mV
Short-circuit output current		350		mA
Drop out voltage		2.0		V
Ripple rejection	55	71		dB
Peak output current		2.2		A

– **Output voltage:**

This specification indicates the regulated DC output voltage that can be obtained from the IC. As can be seen from the sample specification table given above, the manufacturer specifies minimum, typical and maximum output voltages. While using this IC take the typical value as this value corresponds to the output voltage at IC under normal input and load conditions.

– **Output regulation**

This indicates the amount by which the output voltage may vary at rated maximum load condition. For example, in µA7812 IC, the output voltage may vary by 4 mV from its rated 12 V DC when the rated typical load current is 2.2A.

– **Short circuit output current**

This indicates the shorted current I_{SC} if the output gets shorted. In µA 7812 the output current is limited to 350mA when the output terminals are shorted.

– **Drop out voltage**

For instance, in µA7812 in which the output voltage is +12 V, the input unregulated DC voltage to the regulator must be higher than the output voltage. The specification drop out voltage indicates, the minimum positive difference between the input and output voltages for the IC to operate as a regulator. For example, in, µA7812 the unregulated input voltage should be atleast 2 volts more than the regulated DC output of 12V. This means for µA7812 the input must be atleast 14V.

The difference between the voltage across the input and output of the IC should also not to be very high as this causes unwanted dissipation. As a thumb rule, the input voltage to the regulator shall be restricted to a maximum of twice the output voltage of the regulator. For example, for µA7812, the unregulated input voltage should be more than 14V, but less than 24V.

– **Ripple rejection**

This indicates the ratio of ripple rejection between the output to input, expressed in decibels.

– **Peak output current**

This indicates the highest output or load current that can be drawn. Above this rated maximum current the safety of the IC is not guaranteed.

Identification of output voltage and rated maximum load current from IC type number

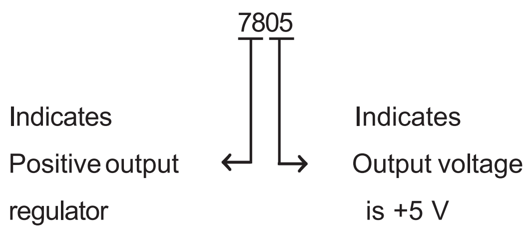
– 78XX and 79XX series are **3 Terminal voltage regulators.**

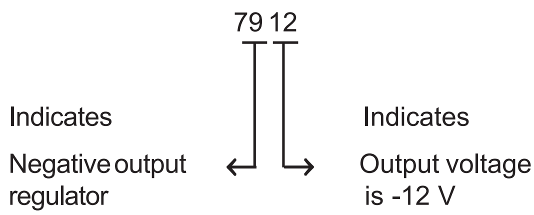
– All 78XX series are **positive output voltage regulators.**

– All 79XX series are **negative output voltage regulators.**

The term XX indicates the rated output regulated voltage.

Example:





It is important to note that, different manufacturers of 78XX/79XX series such as Fair Child (µA/µpc), Motorola, Signetics (SS) adopt slightly different coding schemes to indicate the rated maximum current of the three pin regulated ICs. One such scheme is given below.

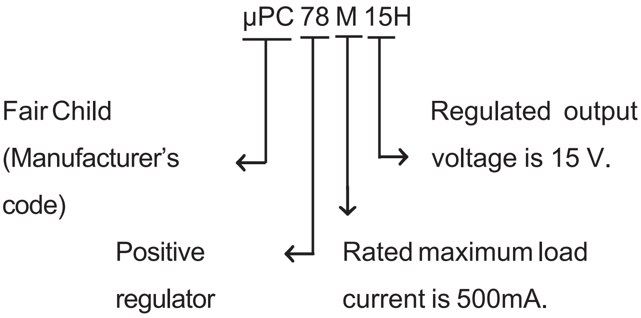
78LXX - L indicates rated maximum load current as 100mA.

78MXX- M indicates rated maximum load current as 500mA

78XX - Absence of an alphabet between 78 and XX indicates that the rated maximum load current is 1A.

78SXX - S indicates rated maximum load current is 2 amps.

Example:



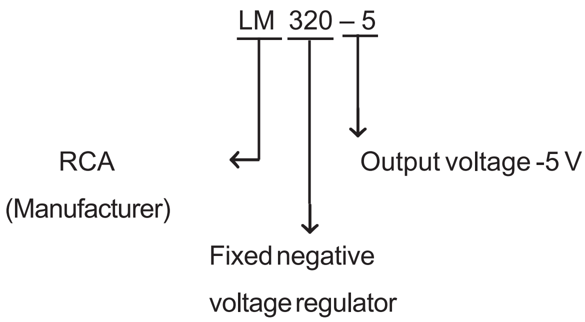
LM 3XX series of 3 terminal voltage regulators

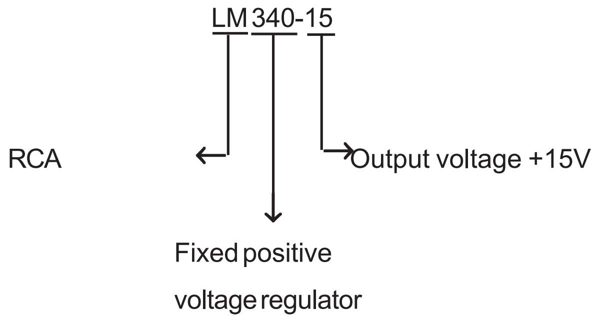
In LM series of three terminal regulators, to find the specifications, it is suggested to refer to its data manual. However, the following tips will help in identifying whether the IC is a fixed positive or fixed negative regulator.

LM320-X and LM320-XX ⟶ Fixed -ve voltage regulators.

LM340-X or LM340-XX Fixed +ve voltage regulators.

Examples:

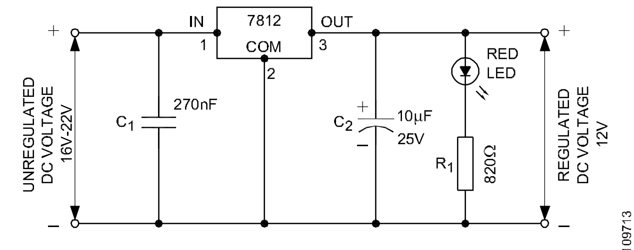




Practical 78XX and 79XX voltage regulator circuits

Fig 3 shows the circuit connections of a 12 V, 1 A regulated power supply using 7812.

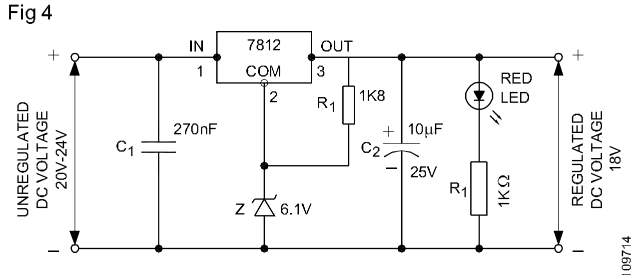
Fig 3



+12V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

The output voltage of a 3-terminal regulator IC is with reference to the IC's common terminal (COM). When the COM terminal is grounded, the output voltage of the regulator will be the specified output voltage of the IC as shown in Fig 3. But the output voltage of the IC can be increased above the specified value by raising the voltage at the COM terminal as shown in Fig 4. Because of 6.1V zener, the output voltage will be 6.1V + 12V = 18.1V or approximately 18V as shown in Fig 4.

Fig 4



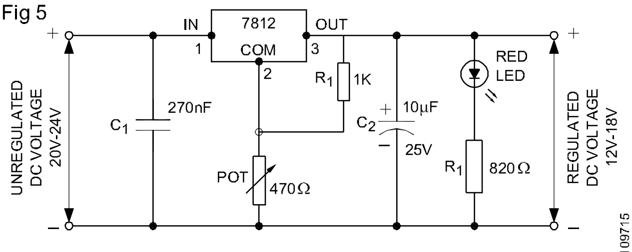
+18V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

When the COM terminal of the IC is grounded as shown in Fig 3, the quiescent current flowing from the COM terminal to ground in 78 series is around 8 µA. This current decreases as the load current increases. When a zener is connected at COM terminal as shown in Fig 4, to ensure that the zener is always in the reverse ON condition, resistor R_1 is used. If R_1 = 1.8K, I_Z will be 7mA which is sufficient to keep the zener ON always.

Fig 5 shows a variable output voltage regulator using a fixed voltage regulator. The variable reference voltage at COM terminal is obtained using a POT.

Since the quiescent current through the pot is very low (around 8µA) and it decreases with load resistor R_1 is used to compensate the changes in the quiescent current due to loading. Therefore, the bias voltage is determined by the sum of the quiescent current I_Q and the bias current set by R_1. In Fig 5, when the resistance of the POT is set to 0, COM is grounded and hence output will be 12V. As the set value of pot increases the output voltage also increases.

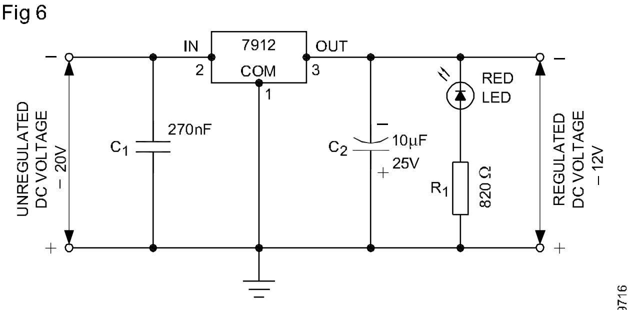
Fig 5



VARIABLE OUTPUT VOLTAGE REGULATOR CIRCUIT

Fig 6 shows a negative voltage regulator using 7912. The working of this circuit is similar to that of Fig 7 except that it is a negative voltage regulator and hence the voltage at pin no.3 of the IC will be -12volts.

Fig 6

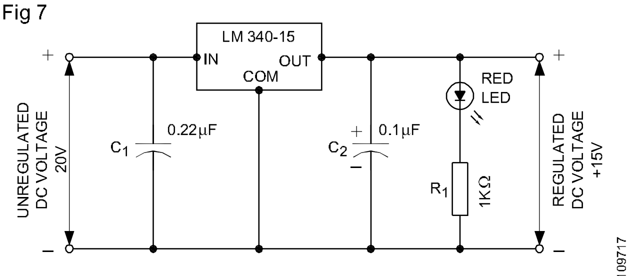


– 12V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

NOTE: PIN NUMBERS ARE DIFFERENT FROM 7812

Fig 7 shows a +15 volts regulator using LM340. This circuit connection is very much similar to that of the 78XX series regulator.

Fig 7



+12V FIXED OUTPUT VOLTAGE REGULATOR CIRCUIT

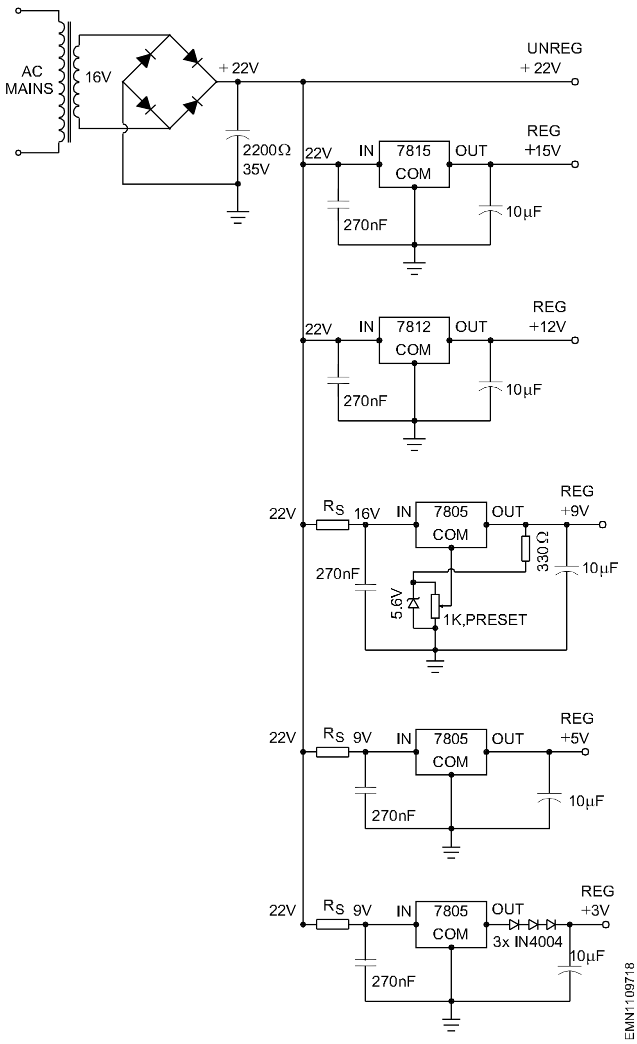
Multiple voltage using three-terminal fixed voltage regulator

Fig 8 shows how a three-terminal IC can be used to obtain multiple voltages. Such economical and elegant circuits are very useful for electronic circuits and for service technicians.

Recall, than the value input unregulated DC to a regulator should always be less than twice the output of the regulator. As shown in the third regulator (7805) of Fig 8, when it is necessary to operate with a large input voltage, a series resistance R_S can be added in series to drop required voltage.

The scheme shown in Fig 8 is one of the several schemes that can be adopted to get multiple voltage output.

Fig 8



Heat Sinks for I.C. based Regulators

Objectives : At the end of this lesson you shall be able to
- **explain the IC 79XX voltage regulator**
- **explain heat sink.**

IC 79XX voltage regulator

79XX voltage regulators are very commonly used in electronic circuits. The main purpose of this IC is to supply required regulated negative voltage to the circuits. IC 79XX can supply a constant negative voltage output. In spite of any voltage fluctuations in its input voltage. It can be mainly found in the circuits in which integrated circuits that require +Vcc and -Vcc are used.

IC79xx is a three pin negative voltage controller IC as shown in Fig 1. It is a small integrated ciruit used in a circuit to supply a constant negative input voltage. The number 79 indicates that it is a negative voltage regulator and xx indicates the output voltage of the IC. 'xx' can be replaced by the controlled output voltage provided by the regulator, for example, if it is 7905, then the output voltage of the IC is -5 V. Similarly if it is 7912, then output voltage of the IC is -12 volts and so on. The name of the IC may vary based on the manufacturer as LM79xx, L79xx, MC79xx etc.

Heat sink

IC 79xx requires heat sink for its safe operation. Heat sink boosts heat dissipation therefore the life of the device can be extended

79xx ICs and output voltages

IC Number	Output Voltage
7905	-05 Volts
7912	-12 Volts
7915	-15 Volts
7918	- 18 Volts

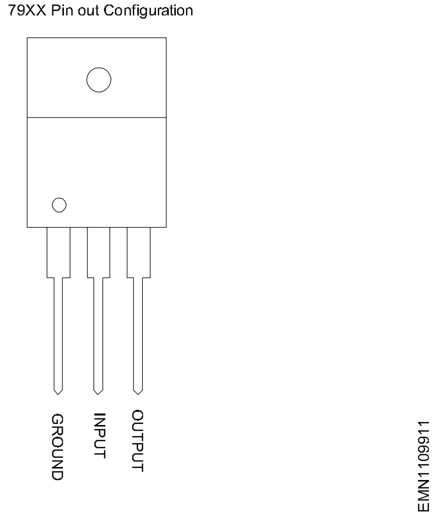
The pin 1 acts as the ground terminal (0V). The pin 2 acts as the input terminal (5V to 24 V). The pin 3 acts as the output terminal (constant regulated 5V).

Pin out configuration of IC 79xx.

The pin out configuration of IC 79xx is shown in the diagram below

- The pin 1 acts as the ground terminal (0V).
- The pin 2 acts as the input terminal (5V to 24V)
- The pin 3 acts as the output terminal (constant regulated 5V)

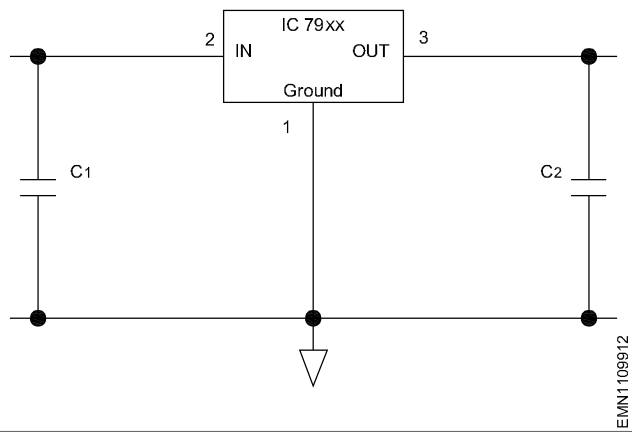
Fig 1



Connection diagram

IC 78xx is used in circuit as shown in the (Fig 2). In order to improve stability two capacitors C_1 and C_2 are used. The capacitor C_1 is used only if the regulator is seperated from filter capacitor by more than 3". It must be a 2.2µF solid tantalum capacitor or 25µF aluminium electrolytic capacitor. The capacitor C_2 is required for stability. Usually 1µF solid tantalum capacitor is used. One can also use 25µF aluminium electrolytic capacitor. Values given may be increased without limit.

Fig 2 79xx Connection diagram



IC 78xx

Similar to IC 79xx, IC 78xx is a three pin IC that gives a constant output voltage of +5V irrespective of the varying input voltages. The maximum value of input voltage that the IC can withstand is 24 volts.

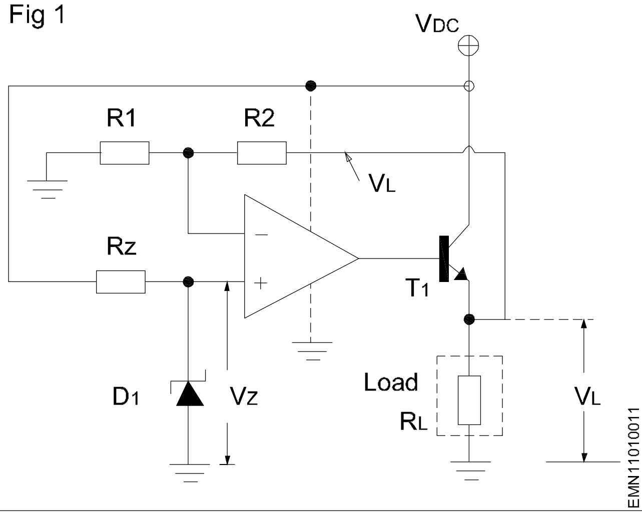
Op-Amp Voltage regulator

Objectives : At the end of this lesson you shall be able to
- **explain the concept of using an operational amplifier**
- **explain the circuit diagram of a IC723 voltage regulator**
- **explain the circuit diagram of a positive voltage regulator.**

Concept of Op-amp voltage regulator

Here, we explain the general concept of using an operational amplifier for voltage regulation. By utilizing an op-amp and few other external components, we can easily build a linear voltage regulator. Apart for being a regulator, the same circuit is also a voltage stabilizer, able to stabilize voltage at a grade better than 0.01%. The circuit as shown in Fig 1 from a non-stabilized DC-power source, and uses a transistor (T1) inside a feedback loop. The transistor is used to supply the load with much more current than the op-amp itself could possibly supply. The D1 diode is a Zener-type diode and it is used for voltage reference.

Fig 1



D1 is biased through Rz. When correctly reverse biased, the zener diode keeps the voltage across its leads close to the zener breakdown voltage. The op-amp is used as a linear voltage amplifier. Due to the high open loop voltage gain of the op-amp, and as far as the op-amp remains in its linear region, the voltage difference between its inverting (V_-) and non-inverting input (V_+) is almost equal to zero. In other words, the voltage at its non-inverting input, in respect to the ground, equals the voltage at its inverting input:

$V_- = V_+$ (1)

Equation (1) holds true for any op-amp working at its linear region (as an amplifier).

R1 and R2 form a voltage divider, and the voltage (V_-) at their connection point is also given by the well known voltage-divider formula:

$V_- = V_L \cdot R1/(R1+R2)$ (2)

However, V+ is also equal to the zener breakdown voltage (Vz), because the non-inverting input of the op-amp is directly connected to the cathode of the zener diode

$V_+ = V_Z$ (3)

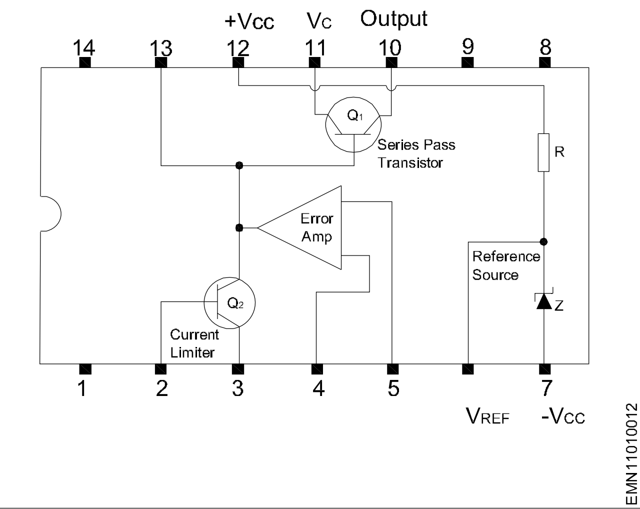
After solving (1),(2) and (3), we get: $V_L = V_Z \cdot (1+R_2/R_1)$ (4)

From equation (4), we conclude that V_L voltage (which is the voltage applied to the load) is directly proportional to the Zener voltage. As far as the Zener voltage remains stable, V_L also remains stable. Additionally, the voltage applied to the load, can be easily adjusted by adjusting R1, R2 or both of them. For continues voltage adjustment, R1 and R2 should be replaced by a potentiometer, having its wiper at the non-inverting input of the op-amp, and its other leads at the ground and the V_L line, respectively. VL_Z is not possible to exceed V_{DC}. It can be almost as much high as V_{DC} when T_1 saturates, but no more than this. V_L (the voltage at the load) could not also be lower than V_Z. That's why $V_Z<V_L<V_{DC.}$

As in any linear regulator, heat losses on T1 increase when the output voltage decreases. In fact, the power loss due to heating is the current times the voltage dropped across T1. Besides heating losses, a linear regulator is often preferred over a switching one because it does not require any inductors which can be relatively expensive or bulky.

Fig 2

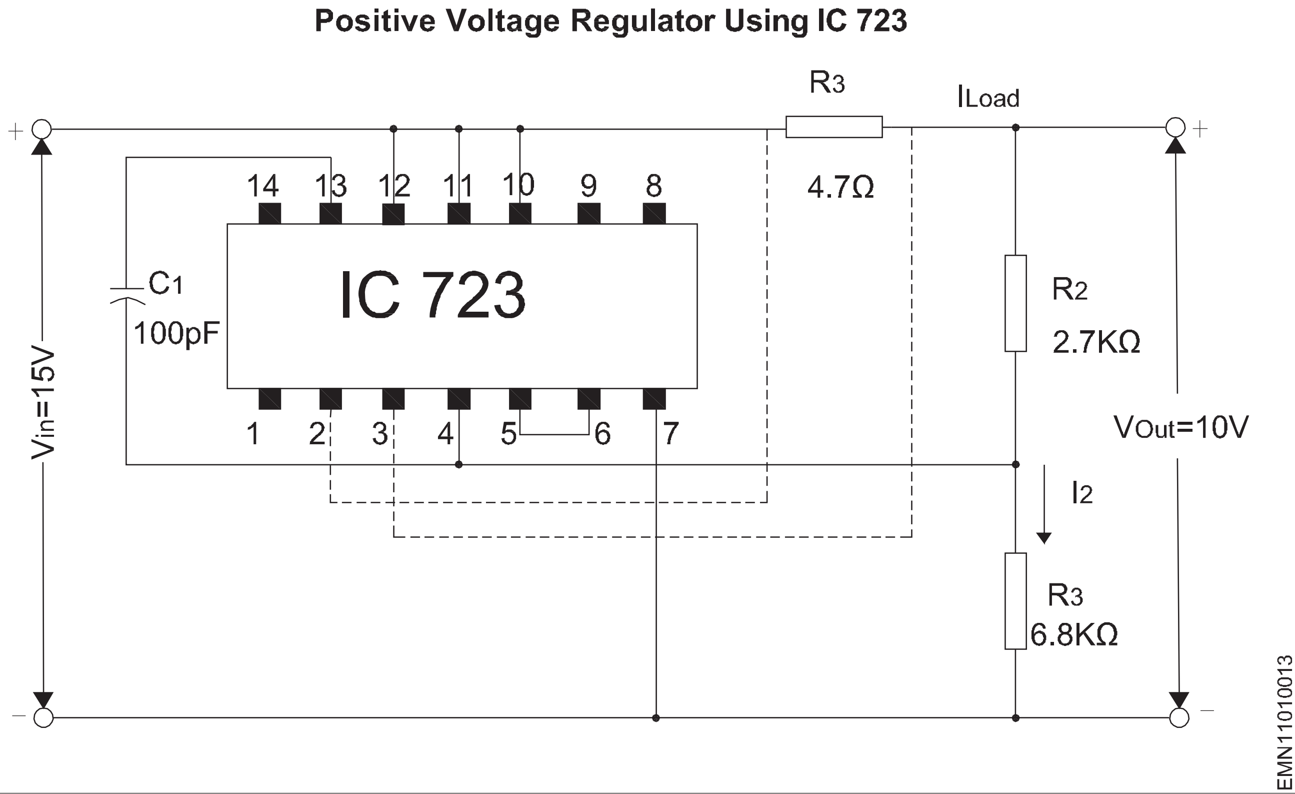
IC 723 Voltage Regulator Circuit



We have already explained in detail about the basics of voltage regulators and IC voltage regulators. Let us take a look at one of the most popular IC voltage regulators, the 723 voltage regulator IC. The functional diagram of the voltage regulator is shown in fig 2. It consists of a voltage reference source (pin 6), an error amplifier with its inverting input on pin 4 and non-inverting input on pin 5, a series pass transistor (pin 10 and 11) and a current limiting transistor on as pins 2 and 3. The device can be set to work as both positive and negative voltage regulations with an output voltage ranging from 2V to 37V, and output current levels upto 150m A. The maximum supply voltage is 40V, and the line and load regulations are each specified as 0.01%.

The figure shown in Fig 3 is a positive voltage regulator with an IC 723. The output voltage can be set to any desired positive voltage between (7-37) volts. 7 volts is the reference

Fig 3



starting voltage. All these variations are brought with the change of values in resistors R1 and R2 with the help of a potentiometer. A darlington connection is made by the transistor to Q1 to handle large load current. The broken lines in the image indicate the internal connections for current limiting. Even foldback current limiting is possible in this IC. A regulator output voltage less than the 7V reference level can be obtained by using a voltage divider across the reference source. The potentially divided reference voltage is then connected to terminal 5.

Another important point to note about this IC is that the supply voltage at the lowest point on the ripple waveform, should be at least 3 V greater than the output of the regulator and greater than Vref. If it is not so a high-amplitude output ripple is possible to occur.

IC voltage regulators - variable output

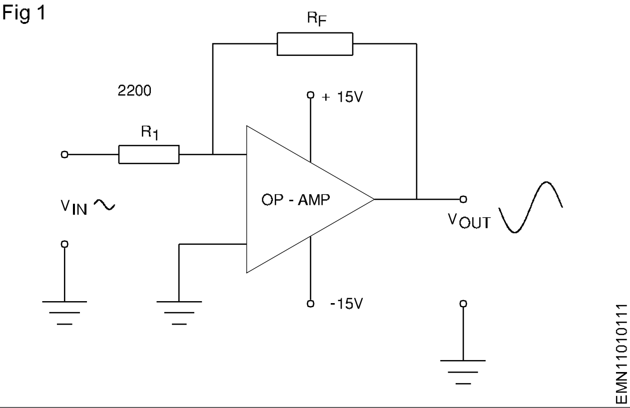
Objectives: At the end of this lesson you shall be able to
- **explain the dual power supply**
- **list a few variable regulator 3-pin ICs**
- **explain feedback and error amplification.**

Dual power supply

Most electronic circuits generally need either a +ve DC supply or a -ve DC supply for its working. However, there are circuits which are designed to work using both +ve and -V_e supplies. An example of circuits which require both +ve and -ve supply are the OP-AMPs. OP-AMPs are integrated circuit amplifiers which need, +ve supply, -ve supply and ground. A typical OP-AMP circuit is shown in Fig 1.

Therefore, for circuits which require both +ve and -ve DC supplies, a single power supply which can deliver both ± DC is required to be designed. Power supplies which can deliver both ± DC are generally referred to as Dual Power Supply.

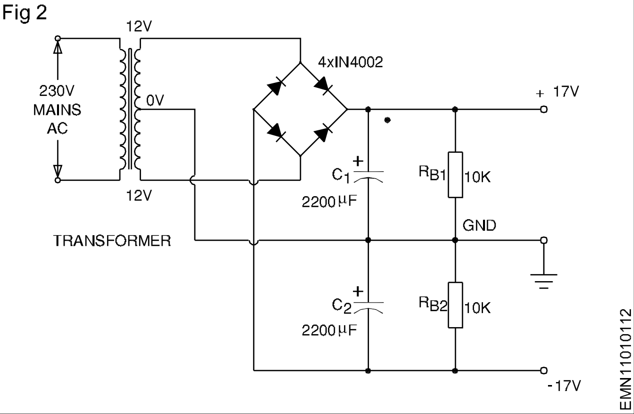
Fig 1



To design a ± or dual regulated power supply, as a first step it is required to design a ± unregulated DC supply. Fig 2 shows a simple method of obtaining ± unregulated DC supply.

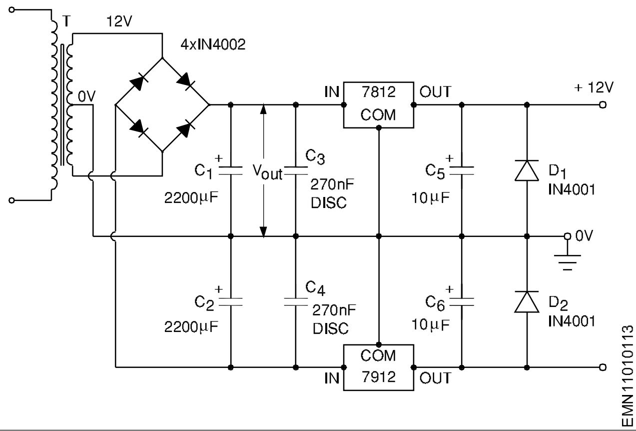
Once, a ± unregulated DC supply is available, one each of +ve regulator 3-terminal IC and a -ve regulator 3-terminal IC

Fig 2



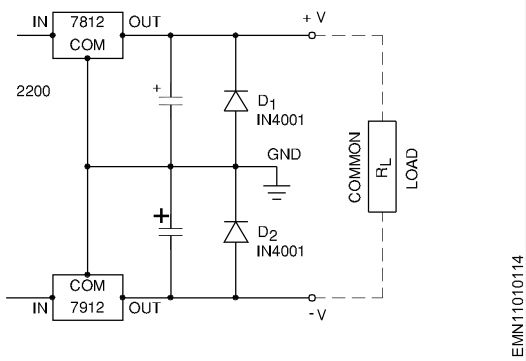
can be attached, to obtain a ± regulated DC supply. One such ± regulated DC supply using 7812 (+ve regulator) and 7912 (-ve regulator) is shown in Fig 3.

Fig 3



The +ve and -ve regulator circuits shown in Fig 3. The function of diodes is very important. If these diodes D_1 and D_2 are not used, the regulator ICs may get damaged due to common load problems. The term common load means, a load connected across the +ve and -ve outputs of the regulator as shown in Fig 4. Because of the fact that these common leads does not make use of the ground (GND) several problems occur when the supply is switch ON, in case of over loads and so on. Hence to avoid the common load problem in dual power supplies diodes D_1 and D_2 are very essential.

Fig 4



Variable/adjustable output voltage regulators

A number of IC voltage regulators are available using which an adjustable output voltage of 1.2V to 32 volts can be obtained. Amongst these adjustable output voltage regulators, there are two types:

3-Terminal variable output voltage regulators ICs

Multi-terminal variable output voltage regulator ICs

3-Terminal variable output regulators ICs

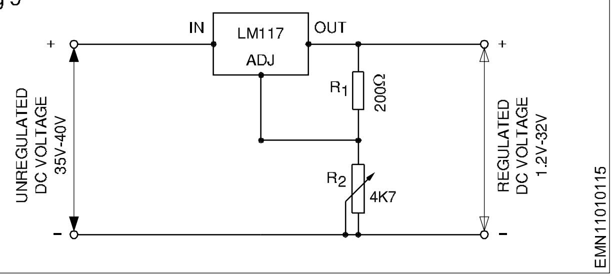
These ICs look like 3-terminal fixed output voltage regulators as shown in Fig 3. A few examples of 3-terminal adjusted output voltage regulator ICs are,

- LM117 Output adjustable from 1.2 V to 37 V
- LM317 Output adjustable from 1.2 V to 32 V
- LM338 Output adjustable from 1.2 V to 32 V
- LM350 Output adjustable from 1.2 V to 33 V

These variable output voltage regulator ICs are designed for adjustable output voltage, unlike the fixed output 3-pin regulators such as 7812, LM 340-5 etc which can be modified to get variable output voltage.

Fig 5 shows a basic variable output voltage regulator.

Fig 5

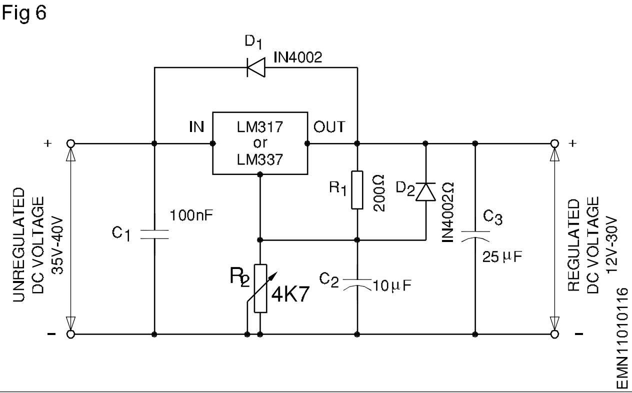


In the circuit at Fig 3, if the adjustment terminal (ADJ) is grounded, the output of the regulator will be 1.2 volts. To obtain a higher output voltage a small reference voltage is given at ADJ using a voltage divider circuit consisting of R_1 and R_2 as shown in Fig 5. With this the regulated output voltage is approximately given by

$$V_{out} = 1.2\ V \times (1 + (R_2 / R_1)) \qquad ....\{1\}$$

A practical version of the circuit at Fig 3 is shown in Fig 6. This circuit uses a few bypass capacitors and protection diodes.

Fig 6



In Fig 6, capacitor C_1 is used to prevent setting up of the oscillations and should be connected as close to IC as possible. Capacitor C_2 is used to improve the ripple in the output voltage. Note that the value of C_3 should not be very high (recall, surge current). Capacitor C_2 is used to avoid excess ringing.

When external capacitors are used with any IC regulator, it is necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Hence, diodes D_1 and D_2 are used. D_1 protects the IC against shorts due to C_3 and D_2 protects against shorts due to C_2.

The ICs LM317 and 338 have built in fold back current limiting and thermal protection. These ICs are available in both plastic and metal packages with current ratings from 0.1A (LM317L) to 5A (LM338K).

> ***LM117, LM317 and LM338 are of the same family ICs, and hence, are interchangeable.***

Multiple-pin-Variable voltage regulator ICs

Unlike 3-pin fixed output voltage regulators and 3-pin variable output voltage regulators, voltage regulator ICs having multiple pins are designed for versatility. These multiple pin IC regulators can be used as a linear regulator (all the regulators discussed so far), or as a switching regulator (to be discussed), or as a shunt regulator (to be discussed) or as a current regulator (to be discussed).

Generally in multiple pin types of regulators, dissipation limitation of the IC packages restrict the output current to a few tens of milliamps. However, external transistors can be added to obtain currents in excess of 5A.

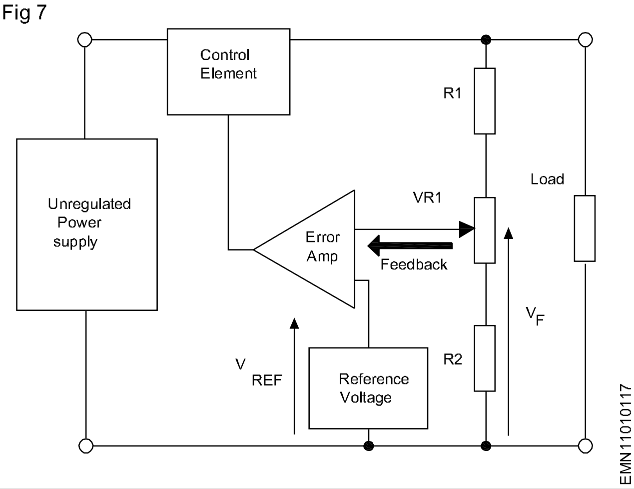
Some of the multiple pin, versatile IC regulators are, LM100, LM105, LM205, LM305, µA723, CA3085 and so on.

Feedback and Error Amplification

To improve on the simple series regulator a feedback circuit and error amplifier can be added to the basic series circuit.

Fig 7 shows a block diagram of a series regulator circuit with error amplification. In this system the reference voltage Vz is compared with a feedback voltage V_F, which is a portion of the actual output voltage. The difference between the two inputs produces an error voltage that is used to vary the conduction of the control element, correcting any error in the output voltage.

Fig 7



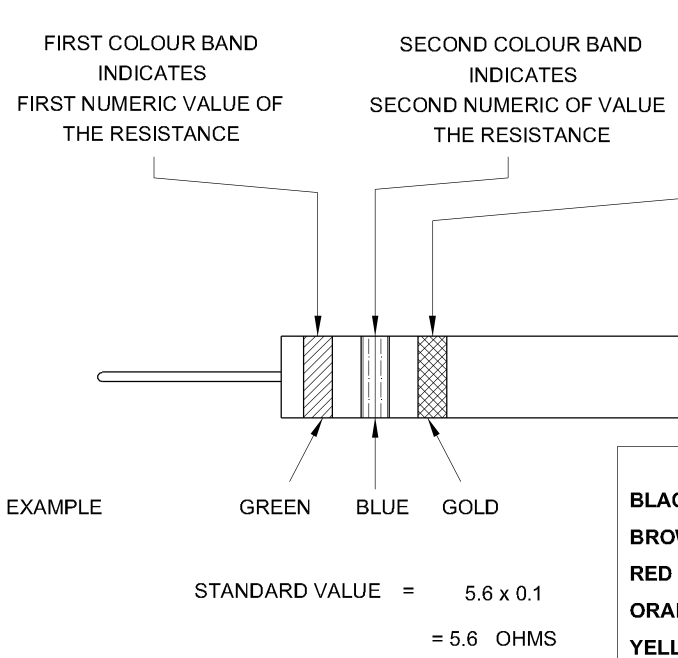
Error-correction power amp

Error correction looks at the difference between the amp output and the amp input (taking into account of course the amp gain). Any difference is returned to the input and added to that input, in precisely the right amount to make the output identical to the input. Because the output is now identical to the input, distortion becomes ideally not just smaller, but zero. In practice, this will not happen, as the precision with which you can return the error and add it at the input is always less than perfect. Also, whatever the load, the output stays correct, so it looks as if the output impedence is really zero (or close to it) This technique does not require that the amp (open loop) gain is very, very high. It is enough if the amp has a gain close to the final required gain, and then the ec fills in the missing fraction in the signal.

Appendix

Table - 1

THREE COLOUR BAND



COLOUR VALUE TABLE

BLACK	**0**	**BLUE**	**6**
BROWN	**1**	**VIOLET**	**7**
RED	**2**	**GRAY**	**8**
ORANGE	**3**	**WHITE**	**9**
YELLOW	**4**	**GOLD**	**0.1**
GREEN	**5**	**SILVER**	**0.01**

Table - 2

FOUR COLOUR BAND

TOLERANCE VALUE TABLE	
NO COLOUR	± 20%
SILVER	± 10%
GOLD	± 5%
BROWN	± 1%
RED	± 2%
GREEN	± 0.5%
BLUE	± 0.25%
VIOLET	± 0.1%

COLOUR VALUE TABLE

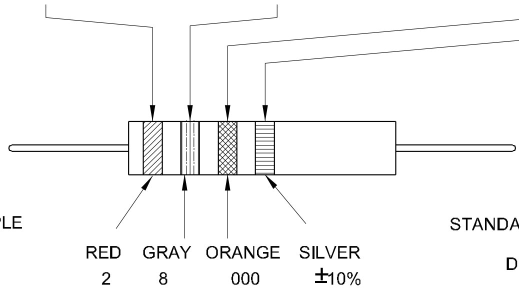
BLACK	0	ORANGE	3	BLUE	6	WHITE	9
BROWN	1	YELLOW	4	VIOLET	7		
RED	2	GREEN	5	GRAY	8		

FIRST COLOUR BAND INDICATES FIRST NUMERIC VALUE OF THE RESISTANCE

SECOND COLOUR BAND INDICATES SECOND NUMERIC OF THE RESISTANCE

THIRD COLOUR BAND INDICATES NUMBER OF ZERO'S TO FOLLOW

FOURTH COLOUR BAND INDICATES % DEVIATIONS FROM STANDARD VALUE (TOLERANCE)



EXAMPLE

STANDARD VALUE = 2 8 000 OHMS OR 28K

DEVIATION : 10% OF 28000

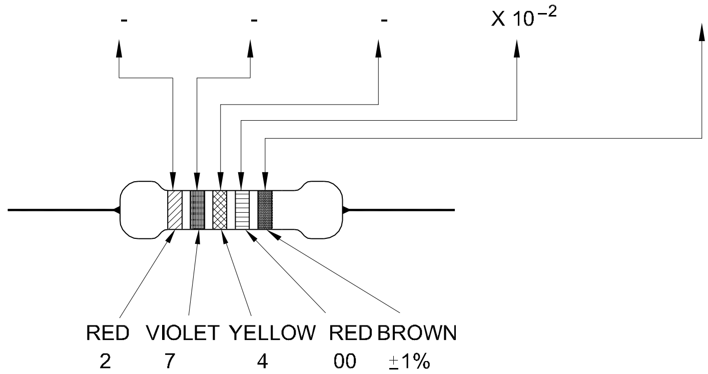
i.e $\frac{28000 \times 10}{100} = 2800\ \Omega$

MAX & MIN VALUES : MAX: 28000 + 2800 = 30800 Ω OR 30.8K

MIN : 28000 - 2800 = 25200 Ω OR 25.2K

Table - 3
Coding scheme for five colour band resistors

COLOUR	RING - 1	RING - 2	RING - 3	RING - 4	5.RING
BLACK	0	0	0	.0	
BROWN	1	1	1	0	1 %
RED	2	2	2	00	2 %
ORANGE	3	3	3	000	
YELLOW	4	4	4	0 000	
GREEN	5	5	5	00 000	0.5 %
BLUE	6	6	6	0 00 000	
VIOLET	7	7	7	00 00 000	0.1 %
GREY	8	8	8	0 00 00 000	
WHITE	9	9	9	00 00 00 000	
GOLD	-	-	-	X 10^{-1}	
SILVER	-	-	-	X 10^{-2}	



RED-VIOLET-YELLOW-RED-BROWN = 27.4K Ω ±1%

27400Ω ±1%
27.4K Ω ±1%

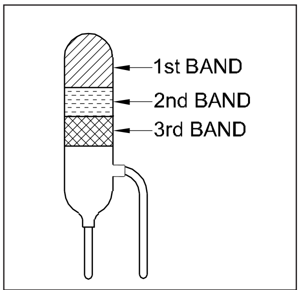
Table - 4

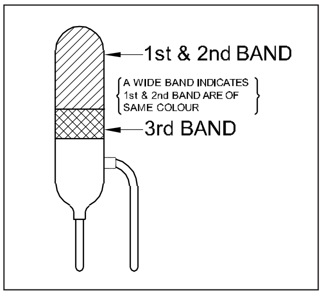
Standard/ Preferred values of carbon composition resistors

Resistance in Ohms 10%						
1.0	10	100	1K	10K	1M	10M
1.1	11	110	1.1K	11K	1.1M	11M
1.2	12	120	1.2K	12K	1.2M	12M
1.3	13	130	1.3K	13K	1.3M	13M
1.5	15	150	1.5K	15K	1.5M	15M
1.6	16	160	1.6K	16K	1.5M	16M
1.8	18	180	1.8K	18K	1.8M	18M
2.0	20	200	2K	20K	2.0M	20M
2.2	22	220	2.2K	22K	2.2M	22M
2.4	24	240	2.4K	24K	2.4M	
2.7	27	270	2.7K	27K	2.7M	
3.0	30	300	3K	30K	3.0M	
3.3	33	330	3.3K	33K	3.3M	
3.6	36	360	3.6K	36K	3.6M	
3.9	39	390	3.9K	39K	3.9M	
4.3	43	430	4.3K	43K	4.3M	
4.7	47	470	4.7K	47K	5.1M	
5.6	56	560	5.6K	56K	5.6M	
6.2	62	620	6.2K	62K	6.2M	
6.8	68	680	6.8K	68K	6.8M	
7.5	75	750	7.5K	75K	7.5M	
8.2	82	820	8.2K	82K	8.2M	
9.1	91	910	9.1K	91K	9.1M	

Table - 5

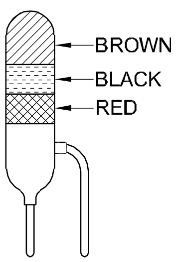
Coding scheme for capacitors with 2 or 3 bands





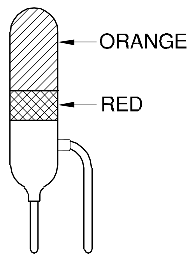
NOTE: Capacitance values formed using colour code is always in PF (Picofarads)

Example:



1st Band	2nd Band	3rd Band
Brown	Black	Red
1	0	10^2

Capacitance = 1000 pf = 1 kpf

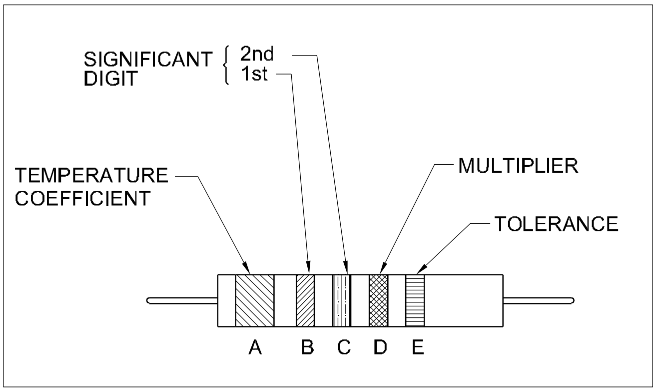


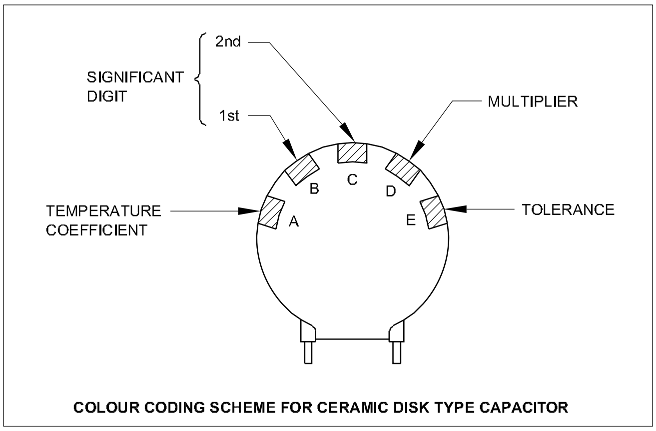
1st Band	2nd Band	3rd Band
Brown	Black	Red
3	3	10^2

Capacitance = 3300 pf = 3K3 kpf

Table - 6

Coding scheme for ceramic capacitors





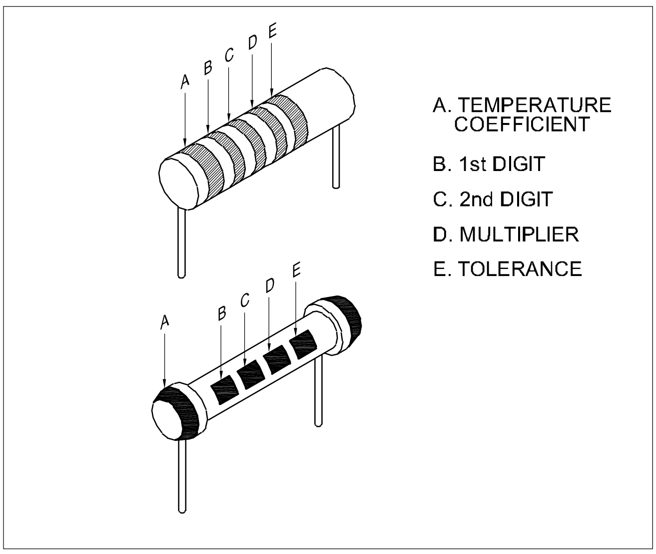


Table - 7

Proelectron type code for diodes

Semiconductor material (First letter)	**Main function (second letter)**
A Germanium B Silicon C Gallium arsenid D Indium antimonids R Materials for photo conductors and hall generators	A Signal diode B Varactor diode E Tunnel diode G Oscillator diode H Magnetic field diode K Hall generator M Hall generator P Photo diode Q Lumiescence diode T Controllable power rectifier X Multiplier Y Rectifier/ power diode Z Z-diode and reference diode

Examples for identifying types of semiconductor diodes

Type Number	**Semiconductor material and nature of semiconductor diode**
AA 143	Germanium - Signal diode
AEY 30A	Germanium - Tunnel diode for **industrial/professional applications**
BA 157	Germanium - Magnetic field diode for **industrial/professional applications**
BA 157	Silicon - Signal diode
BAT 43	Silicon - Schottky-diode
BY 103	Silicon - Rectifier diode
BY 121A	Silicon - Varactor diode
BZX 84/C9V1	Silicon - Z-diode
BPW 50	Silicon - Photo diode
CQY 65	GaAS - LED

Table - 8

Diode Equivalents

Diode type-number	**Possible equivalent type - numbers (s)**
OA79	1N34, 1N54, 1N60
OA85	1N478
OA90	1N87A
DR25	OA10
DR300	BA148
BY125	1N4003......1N4007
BY126	1N4005......1N4007
BY127	1N4006......1N4007
1N36	AA113, 1N34, 1N60
1N38	AA117, AA118
1N914	1N4148...49,1N4151
1N915	1N4148...49,1N4151
1N4001, 1N4002	BY126....127, BY133...135,1N5614..22
1N4004	BY126....127, BY133...135,1N5616
1N4007	BY127, BY133...135,1N5616
1N4148	BAW62, BAX95, 1N4446

Table - 9

Fixed voltage 3-terminal IC regulators

Test	**Short description**
L7805 C(CT)	+5V,1.5A
L7806 C(CT)	+6V,1.5A
L7807	+7V,1.5A, 5%
L7808 C(CT)	+8V,1.5A
L7809(C)T	+9V,1.5A
L7810CV,ACV	+10V,1.5A, 5%
L7812 C(CT)	+12V,1.5A
L7815 C(CT)	+15V,1.5A
L7818 C(CT)	+18V,1.5A
L7820 CV	+20V,1.5A
L7824 C(CT)	+24V,1.5A
L7875 (C)T	+7.5V,1.5A
L7905 CT	-5V,1.5A
L7908 CT	-8C,1.5A
L7912 CT	-12V,1.5A
L7915 CT	-15V,1.5A

Table - 9 Continues......

Test	**Short description**
L7918 CT	-18V,1.5A
L7920 CT	-20V,1.5A
L7924 CT	-24V,1.5A
L7952 CT	-5,2V,1.5A
LM7805 CK	+5V,1A
LM7806 CT, CU	+6V,1A
LM7808 CT, CU	+8V,1A
LM7812 CK	+12V,1A
LM7812 CK	+15V,1A
LM7818 CT, CU	+18V,1A
LM7824 CT, CU	+24V,1A
LM7905 CT, CU	-5V,1A
LM7912 CT, CU	-12V,1A
LM7915 CT, CU	-12V,1A

Table - 10

Adjustable voltage regulators

Type		Package	Output min (V)	Output max (V)	Output $I_{max(A)}$ Voltage	Input voltage V_{in} - V_{out} mod (V)	Drop typical
LM317L	+	TO-92	+1.2	+37	0.1	40	2.5
LM337L	-	TO-92	-1.2	-37	0.1	40	2.5
LM317H	+	TO-39	+1.2	+37	0.5	40	2
LM337H	-	TO-39	-1.2	-37	0.5	40	2
LM317T	+	TO-220	+1.2	+37	1.5	40	2.5
LM337T	-	TO-220	-1.2	-37	1.5	40	2.5
LM350K	+	T-3	+1.2	+32	3	35	2.5
LM333T	-	TO-220	-1.2	-32	3	35	2.5
LM338K	+	TO-220	+1.2	+32	5	35	2.5
LM396K	+	TO-3	+1.2	+15	10	20	2.1
mA78GU1C	+	TO-220	+5	+30	1	40	2.5
mA79GU1C	-	TO-220	-2.5	-30	1	-40	2
LAS15U	+	TO-3	+4	+30	1.5	40	2.4
LAS18U	-	TO-3	-2.6	-30	1.5	-40	2.1
LM376N	+	DIP-8	+5	+37	0.03	40	3
NE550N	+	DIP-14	+2	+40	0.15	40	3
mA723PC	+	DIP-14	-12	+37	0.15	40	3
LAS1000	+	TO-5	+3	+38	0.15	40	2
LAS1100	+	TO-5	+3	+48	0.15	50	2
MC1466L	-	DIP-4	0	+1000	-	-	2
LAS3700	+	TO-5	0	+1000	-	-	-

Table - 11

Commonly used primary and secondary cells

Sl. No.	Cell Name	Type	Nominal voltage	Typical capacity
1	Carbon-zinc	Primary	1.5V	60m Ah to 30Ah
2	Zinc chloride	Primary	1.5V	100mAh to 9Ah
3	Alkaline manganese	Primary	1.5V	1000mAh to 28Ah
4	Mercuric-oxide (Mercury cell)	Primary	1.35V	16mAh to 28Ah
5	Silver oxide	Primary	1.5V	35mAh to 200m Ah
6	Lithium	Primary	3V	1Ah to 10Ah
7	Lead acid (wet and dry type)	Primary	6V, 12V	3Am to 10,000Am
8	Nickel-cadmium	Secondary	1.25V	50mAh to 20Ah
9	Nickel-iron (Edison Cell)	Secondary	1.2V	
10	Silver-zinc	Primary & secondary	1.5V	0.5Ah to 350Ah
11	Silver-cadmium	Secondary	1.1V	0.5Ah to 1.75Ah